2016

Jo Daviess County Soil and Water Conservation District

APPLE CANYON LAKE WATERSHED BASED MANAGEMENT PLAN

Apple Canyon Lake Watershed Based Management Plan

Prepared for:

Apple Canyon Lake Property Owners Association
Apple River, IL

Illinois Environmental Protection Agency
Springfield, IL

Prepared by:
Mike Malon
Megan Hederman
Chris Hinze
Virginia van Vianen

Jo Daviess County Soil & Water Conservation District
Elizabeth, IL

2016

Funding for this project provided, in part, by the Illinois Environmental Protection Agency through Section 319 of the Clean Water Act (#3191405). This work was also supported in part through an internship to Chris Hinze provided by the National Great Rivers Research & Education Center through grant #NGRREC-IP2015-20, and an internship to Virginia van Vianen provided by the National Great Rivers Research & Education Center through grant #NGRREC-IP2016-19.

Cover photo: Apple Canyon Lake Property Owners Association

TABLE OF CONTENTS

Section **Page**

LIST OF FIGURES

Figure **Page**

LIST OF TABLES

Table **Page**

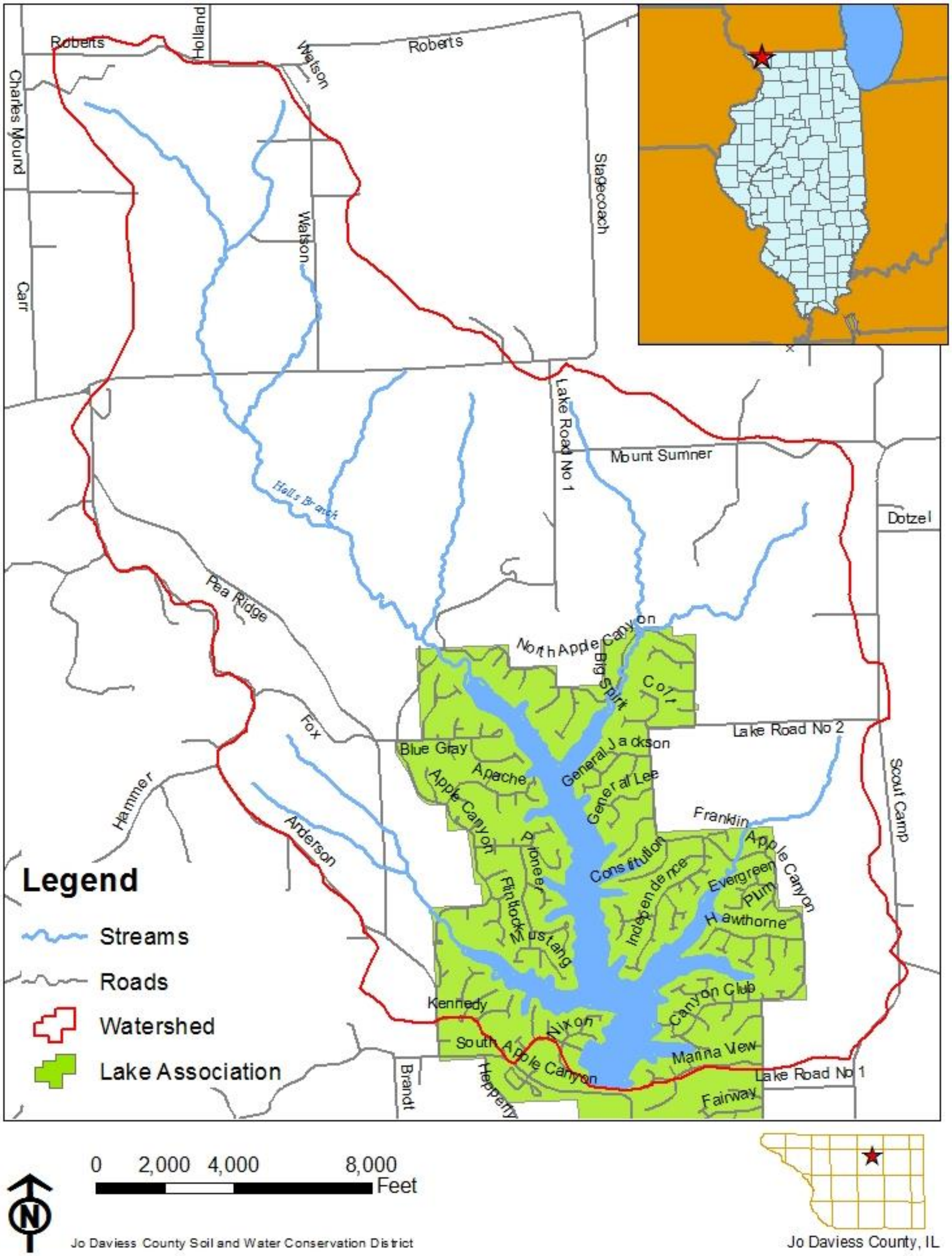


Figure 1-1. Apple Canyon Lake Watershed

1.0 EXECUTIVE SUMMARY

This plan has been created to identify environmental concerns in the Apple Canyon Lake watershed and develop an adaptive management approach to address these concerns. A diverse group of stakeholders formed in 2014 to reach consensus about how to reverse the downward trend in water quality. The stakeholders group is composed of farm owners, farm operators, property owner association homeowners, government agency representatives, and property owner association personnel. Planning group information, reference materials, meeting minutes, and plan drafts are available at www.applecanyonlake.org.

The Apple Canyon Lake watershed lies in the northwest corner of Illinois, in Jo Daviess County. The watershed drains approximately 9,776 acres (15.27 mi.^{2}) flowing south through Hell's Branch Stream (IL-MNEA), a tributary of the Apple River (IL-MN), which flows directly into the Mississippi River (IL-M). The topography of the watershed is rugged, characteristic of the Driftless Area landscape, with over 400 feet of elevation change in the watershed. At the terminus of the watershed lies Apple Canyon Lake (IL-RMJ), a 418.88 acre impoundment built in 1969 by the Branigar Corporation.

Soil erosion and associated phosphorus are the primary concerns for the watershed. Land use in the watershed is primarily rural agricultural with the exception of Apple Canyon Lake. Approximately 75% of the land in the watershed is in agricultural production. This land is split evenly between row crops and hay/pasture. The lake itself is surrounded by the Apple Canyon Lake Property Owners Association, a privately owned homeowner's association, which comprises 2,366.1 acres (3.70 mi^2), 24.2 % of the watershed. Development in the watershed is fairly slow, averaging approximately 18 homes per year until 2010 when growth slowed further to approximately 3 homes per year.

This action plan outlines clear and measurable objectives, identifies responsible parties, and provides a timeline for implementation. Through the planning process, four goals were set: (1) monitor and improve surface water quality, (2) reduce algal blooms and excessive aquatic plant growth, (3) educate watershed community, and (4) mitigate existing flood problems. Along with these goals, physical load reduction needs have been set. These parameters shall be analyzed annually to determine efficacy of plan implementation.

The planning group intends to see 25% achievement of these load reductions by the year 2021, with full achievement of the load reduction goals by 2036. Load reduction goals are based on physical conditions of surface waters in the watershed and vary based on annual rainfall patterns. Illinois EPA guidelines are used for surface water quality standards. In order to meet these goals the following action items have been made high priority.

- The streams and shorelines have been prioritized for stabilization.
- New policies are being created on the property owner's association properties to (1) create a zero-runoff stormwater policy for new construction, and (2) enforce the 50 ft. buffer requirement around the lakeshore.
- Hells Branch, the largest subwatershed in the area and primary tributary to Apple Canyon Lake, contributes approximately 67% of the loading in the watershed. Further study will be performed on this subwatershed first.
- An assessment of the septic systems around the lake will be performed.
- Ongoing education efforts and quarterly meetings will continue throughout the process to keep the public informed about current watershed events and increase awareness about water quality issues.

2.0 INTRODUCTION

The Apple Canyon Lake watershed lies in the northwest corner of Illinois, in Jo Daviess County. The watershed drains approximately 9,776 acres (15.27 mi.^{2}) flowing south through Hell's Branch Stream (IL-MNEA). The area of land that drains to a specific body of water is a watershed. Landscape features such as hills or valleys determine the watershed boundaries. Imagine pouring water over a mountain range; water will either run down one side of the mountains or the other. The Apple Canyon Lake Watershed's boundaries are defined by landscape features that are higher than the surrounding landscape. Any rain that falls at or below the high landscape features will eventually end up at the bottom of the watershed (imagine an upside-down umbrella in the rain; water that hits the umbrella will run to the lowest point in the center). But where does the water from Apple Canyon Lake go? It will first travel to the Apple River (IL-MN), then to the Mississippi River (IL-M), and finally to the Gulf of Mexico. With each addition of a water body, the watershed scale becomes larger and larger. We are therefore always within the boundaries of a watershed, whether it's the small hill that drains to a pond or the Upper Mississippi River Basin.

Because we are always in a watershed, our choices and behaviors are always influencing the quality of water that is flowing into water bodies within and beyond our watershed. Excess fertilizer applied to a lawn will only stay on the lawn until the next rainfall; salts used on our roads will run off with the melted ice; oil leaking from a car will travel through stormwater systems, out of a spillway, and into a water body. In a watershed, individual actions have an impact on the quality of water for recreation, drinking, and wildlife, both locally and on a larger scale.

Many watershed communities have recognized the importance of having a healthy watershed and have organized to form watershed planning groups. Groups, made up of land owners, government agencies, non-government organizations, special interest groups, academia, and tribal nations collaborate and come up with ways that the watershed community can change their behavior, practices, and landscape to improve the water quality and overall health of the watershed. Some of the changes could include adding vegetative buffers around waterways to filter out excessive nutrients, applying less fertilizer to crops and lawns by increasing application precision, and holding watershed education events to engage and inform the public. It is important to understand each individual's role in a watershed and consider what travels downstream to the areas that we use for recreation, land on which we grow our food, or areas our native wildlife uses for habitat. The Apple Canyon Lake watershed is 9,775.6 acres (15.27 mi.^{2}) and is primarily fed by Hells Branch stream. The lowest drainage area of the watershed contains Apple Canyon Lake, an impoundment of Hells Branch stream. Of this area, 2,366.1 acres (3.70 mi^2, 24.2 % of the watershed) is part of the Apple Canyon Lake Property Owners Association, a private residential recreational community developed around the lake area. The entire watershed is still today largely rural, with the exception of the development around Apple Canyon Lake, and contains no municipalities. Most accounts of pre-European settlement conditions in the Midwest describe abundant fisheries and wildlife utilizing large tracts of un-fragmented habitat. This was likely the case within the Apple Canyon Lake watershed. Sprawling oak-hickory forests and oak savannah likely dominated the region until Native American peoples started to manipulate the landscape through burning vegetation which promoted the spread of prairies. Alterations to the landscape made by creation of Apple Canyon Lake, extensive agricultural activity, and urban development around the lake have altered the water quality in Hells Branch, both above and below Apple Canyon Lake. Historic aerial imagery shows that prior to the lake's construction in 1969 the watershed was primarily used for rural agriculture and sparsely populated (*see figure 2-1*). At this time, Hells Branch flowed freely back and forth across the valley floor. Comparing to more recent aerial imagery, streams in much of the lower watershed meander much like they always have, except where cleared and drained by tile, however the upper Hell's Branch which feeds 67% of Apple Canyon Lake has been altered, straightened, or constricted, as land has been developed for its current land use. In addition, it is well known that historically beavers had a major presence in the area and provided a great deal of storm water detention through the ponds created by dam building (Johnson and Naiman, 1987).

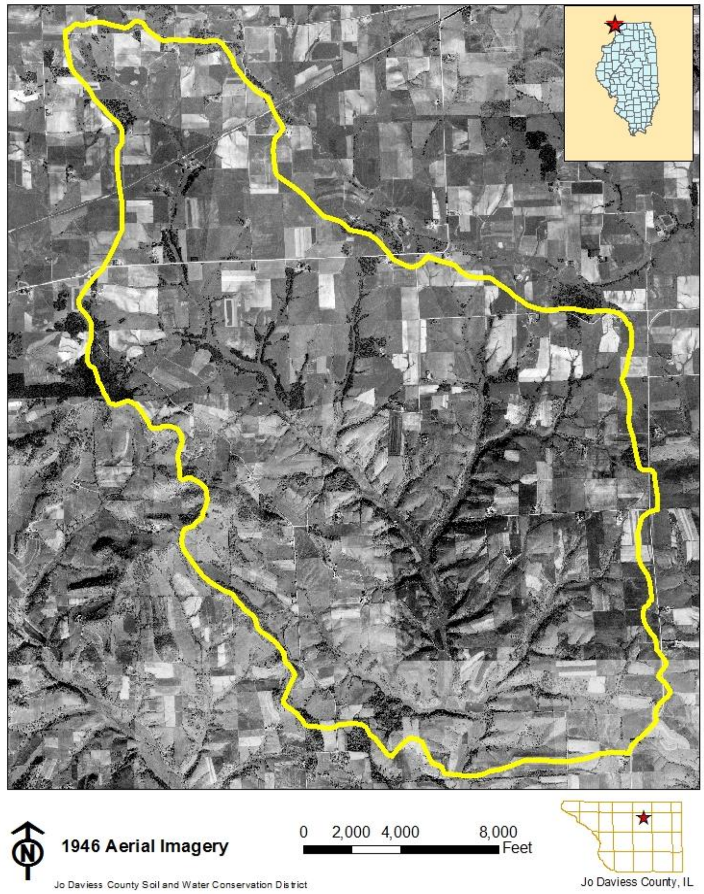


Figure 2-1. Historic imagery of the Apple Canyon Lake watershed in 1946.

Water quality monitoring began in Apple Canyon Lake in the 1990s as part of the Illinois EPA's Volunteer Lake Monitoring Program. Through annual results of this program a downward trend in water quality has been observed since approximately 2000. These changes are a combined result of the aforementioned factors as well as weather induced impacts which are both natural and resulting from climate change. Monitoring has increased to include sampling in the streams which feed Apple Canyon Lake,

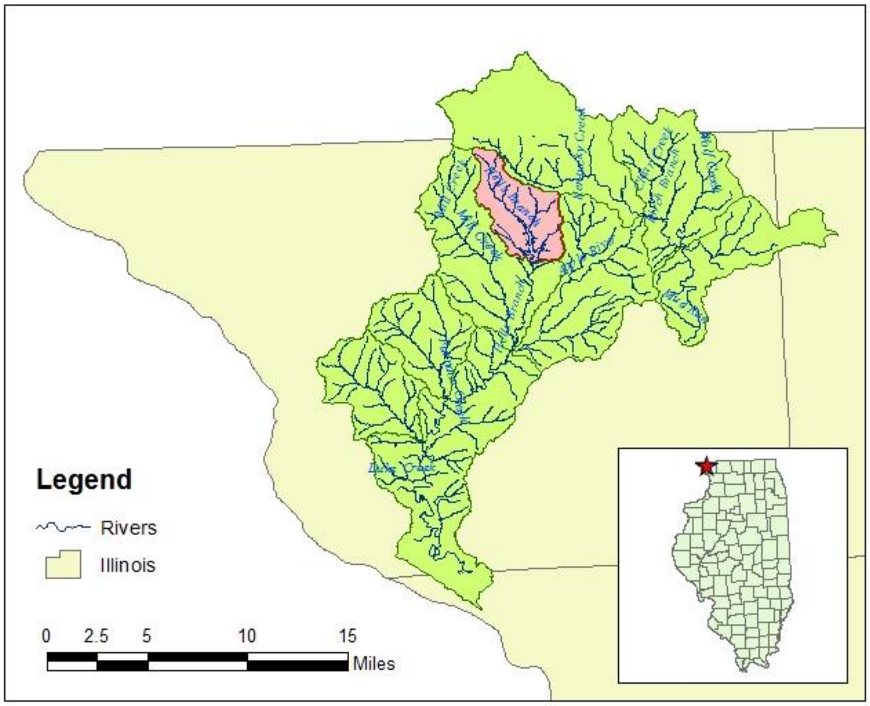


Figure 2-2. Apple Canyon Lake watershed (pink) and the larger Apple River watershed (green) in Jo Daviess County, IL.

in addition to the in-lake sampling begun in the 1990's. This monitoring is the basis for the recommendations made in this plan.

A variety of student projects have also been incorporated into management activities at Apple Canyon Lake (*see appendices*). These projects began as partnerships between the University of Dubuque and the University of Wisconsin, Platteville. These collaborations have added further to our understanding of the watershed's natural and induced processes. These partnerships also provide real-world educational experiences to the students. Together, the data collection, student projects, and a complete inventory of the watershed's resources have coalesced to create this comprehensive watershed-based plan to attain water quality improvements throughout the watershed.

2.1 Apple Canyon Lake (IL-RMJ)

Apple Canyon Lake is a private three mile long impoundment of the Hell's Branch Creek, a tributary of the Apple River, located between the villages of Scales Mound, Apple River, Elizabeth and Stockton, in Northwest IL. The lake was constructed in 1969 by the Branigar Organization, Inc. It has an approximate maximum depth of 82 feet and an approximate lake surface area of 418.88 acres. The Lake is filled by a 15.4 mi^2 (9,775.6 acre) watershed. (*See Appendix 1 for the History of Apple Canyon Lake*).

The Lake has approximately 15 miles of shoreline and is surrounded by a semi-residential community. The property owners association encompasses approximately 2,366.1 acres (3.70 mi^2), 24.2% of the watershed. There are 2,746 lots in the Association which had a total of 910 homes as of 2015, of which 219 are full time residents. Many of these homes are second homes, retirement residences, or rental homes.

Apple Canyon Lake has formed a community of residents who actively support and participate in the care and maintenance of the lake. Led by a nine-member board of directors, Apple Canyon Lake Property Owners Association oversees the management of the lake. Community involvement is encouraged through participation in volunteer committees. Residents actively oversee lake monitoring, watershed conservation, architectural control, maintenance of common properties, and lakeside events. To stay abreast of Apple Canyon Lake's news and calendar of activities "The Apple Core" newspaper is published monthly.

Open to residents and guests only, this planned community offers a club house, swimming pool, beach and bath house, tennis courts, and a 13-mile trail system used for hiking, all-terrain vehicles (ATVs), and cross-country skiing. Swimming is permitted at the pool and in the lake in no-wake zones and the main body of water within 75 feet of the shoreline. Nixon Beach is the center of many community events. Apple Canyon Lake Campground, with 59 seasonal RV sites, nine rental RV sites, and 14 primitive (tent) sites, provides showers, restrooms, and laundry facilities. In addition to a full-service marina, the Property Owners Association offers boat rentals and boat slip rentals. There are 732 boat slips owned by the Association, 168 private boat slips, and five rental boat slips. A 190 acre nine-hole golf course and lakefront restaurant are open to the public.

Figure 2-3. Apple Canyon Lake 2014 aerial photography.

Recreational cruising, waterskiing, tubing, canoeing, and kayaking are popular boating activities. A large number of bays, coves, and no-wake zones provide habitat and wildlife viewing areas to observe deer, squirrels, rabbits, raccoons, beavers, otters, and other small wildlife. Power boats are restricted to a 40 mile per hour limit on the lake and five miles per hour in no-wake zones. The lake is stocked for fishing. Among the species found in Apple Canyon Lake are largemouth bass, walleye, channel catfish, crappie, and bluegill.

Results of a 2013 survey (Apple Canyon Lake website, 2015) report that 45% of the Property Owners Association membership have their primary residence in the Chicago suburbs, and 18% have a home at the Lake as a primary residence. Approximately 11% live in surrounding northwest Illinois and the remainder have their primary residence in other areas of Illinois or the surrounding states.

Apple Canyon Lake is monitored through the open water season under the Illinois EPA's Volunteer Lake Monitoring Program (VLMP). Some records from the VLMP at Apple Canyon Lake date back to 1984. Although some years are missing data due to State of Illinois funding problems, there has been an overall downward trend in water quality observed since approximately 2000. This trend has been observed in the total phosphorus levels in the lake, which exceeded the Illinois EPA's water quality criteria of 0.05 mg/L in 2003, and has averaged above this level, annually, to date (*see figure 2-4*). Algal growth has been noted to start to stimulate at approximately 0.03 mg/L (Holdren, Jones, & Taggart, 2001).

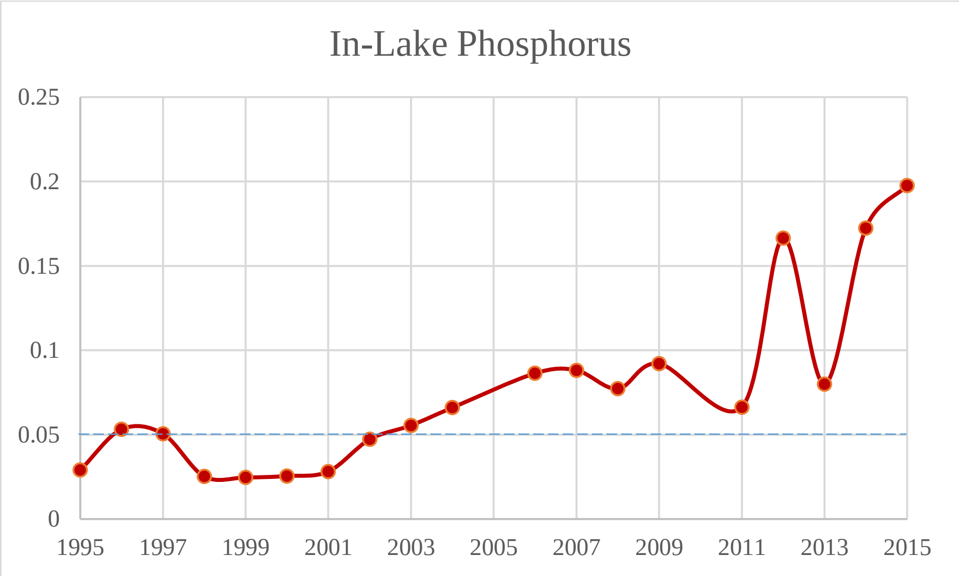


Figure 2-4. Annual average total phosphorus trend in Apple Canyon Lake.

2.2 USEPA Watershed-Based Plan Requirements

The United States Environmental Protection Agency (USEPA) provides guidance for watershed planning through the "Nonpoint Source Program and Grant Guidelines for States and Territories" (USEPA, 2013), and through development of the "Handbook for Developing Watershed Plans to Restore and Protect Our Waters" (USEPA 2008).

The following elements are required:

Element A: Identification of the causes and sources or groups of similar sources of pollution that will need to be controlled to achieve the pollutant load reductions estimated in the watershed-based plan;

Element B: Estimate of the pollutant load reductions expected following implementation of the management measures described under Element C, below;

Element C: Description of the nonpoint source management measures that will need to be implemented to achieve the load reductions estimated under Element B, above, and an identification of the critical areas in which those measures will be needed to implement the plan.

Element D: Estimate of the amounts of technical and financial assistance needed, associated costs, and / or the sources and authorities that will be relied upon to implement the plan;

Element E: Public information / education component that is designed to enhance public understanding and to change social behavior;

Element F: Plan implementation schedule;

Element G: Description of interim, measurable milestones;

Element H: Set of criteria that can be used to determine whether pollutant loading reductions are being achieved over time;

Element I: Monitoring component to evaluate the effectiveness of the implementation efforts over time.

This comprehensive watershed-based plan has incorporated all of these elements with the purpose of improving water quality in the Apple Canyon Lake Watershed.

2.3 Watershed Planning Meetings

Public watershed meetings began in September 2014, and were held quarterly through the watershed planning process. The Jo Daviess County Soil and Water Conservation District coordinated the meetings with assistance from the Apple Canyon Lake Property Owners Association. At the start of the planning process, a mailing list was created to identify landowners in the watershed. This mailing list was utilized to reach out to the watershed community, and invite participants directly. This mailing list was expanded throughout the planning process by including additional meeting attendees not already on the list. Direct mailings were made to each household for each meeting. Additionally, notices were published in the local Apple Canyon Lake (ACL) newspaper, the Apple Core, and press releases were issued to all local news sources. Meeting agendas, minutes, and presentations were all published on the ACL website (www.applecanyonlake.org). The planning group was formed through collaboration with the following stakeholders: ACL Property Owners Association (POA), Apple River Township board, Illinois Department of Agriculture, Illinois Department of Natural Resources, Illinois Environmental Protection Agency, Jo Daviess County Apple Plum Watershed Planning Committee, Jo Daviess County Farm Bureau, Jo Daviess County Health Department, Jo Daviess County Soil and Water Conservation District, residents in the watershed, residents of the ACL-POA, Scales Mound Township, Thompson Township, and United States Department of Agriculture (Farm Service Agency, and Natural Resources Conservation Service). Table 2-1 includes meeting dates and associated topics.

All meetings were held on Thursday nights, and replicated the following Saturday morning, for convenience to both local residents as well as weekend visitors to the lake. Combined, each set of meetings averaged approximately 30 attendees. The meetings had heavy participation by the ACL-POA Conservation Committee Members, and by the farming community in the watershed.

Table 2-1. Scheduled watershed planning meetings.

Date	Agenda	Topic
September 2014	Watershed Planning Summary	Jo Daviess County Soil and Water Conservation District (JDSWCD) describes the watershed planning process and background decisions are made regarding the formation of the watershed group and meeting times.
December 2014	Available Data, Watershed Characteristics	Available data on the watershed and its characteristics are presented. This information includes area, soils, volume of the lake, geology and lake volume.
March 2015	Water Quality, Data Collection, preliminary load reduction estimates.	Monitoring data from 2014 is presented along with load estimates. Areas to prioritize efforts are selected from this information.
July 2015	Agriculture in the Watershed	Dan Jaynes, soil scientist, Agricultural Research Service, gives a presentation on nutrient management.
September 2015	Best Management Practices, existing and proposed	JDSWCD summarizes existing best management practices (BMP) in the watershed and proposed BMPs to meet the objectives of the watershed planning group and water quality standards.
December 2015	Prioritization of Goals, Objectives, Milestones, Strategies & Projects	Strategies, goals, objectives, and milestones to reach these targets are set.
March 2016	Review Draft Plan	Draft plan is brought before the watershed group for public input and adjustments.
September 2016	Public Meeting for Plan Approval	Updated draft is brought before the watershed group for final approval before submission to the Illinois EPA.

3.0 APPLE CANYON LAKE (IL-RMJ) AND ITS WATERSHED (070600050601)

3.1 Watershed Boundaries and Jurisdictions

The Apple Canyon Lake watershed is 9,775.6 acres (15.27 mi.^{2}) located entirely in Jo Daviess County, Illinois. Of this area, 2,366.1 acres (3.70 mi^2, 24.2%), is the Apple Canyon Lake Property Owners Association (*see figure 3-1*). There are no municipalities located in the watershed, though the watershed spreads across three townships (*see figure 3-2*). Thompson Township encompasses all of the lake and property owners association, 5,836 acres (59.7% of the watershed). Scales Mound Township covers 2,062 acres (21.1% of the watershed), and Apple River Township covers 1,877 acres (19.2%). The Apple Canyon Lake watershed is part of the larger Apple River watershed, which contributes directly to the Mississippi River (*see figure 3-3*). Jo Daviess County governs zoning and health department authority over the entire watershed area, and maintains approximately 2.6 miles of county roads in the watershed.

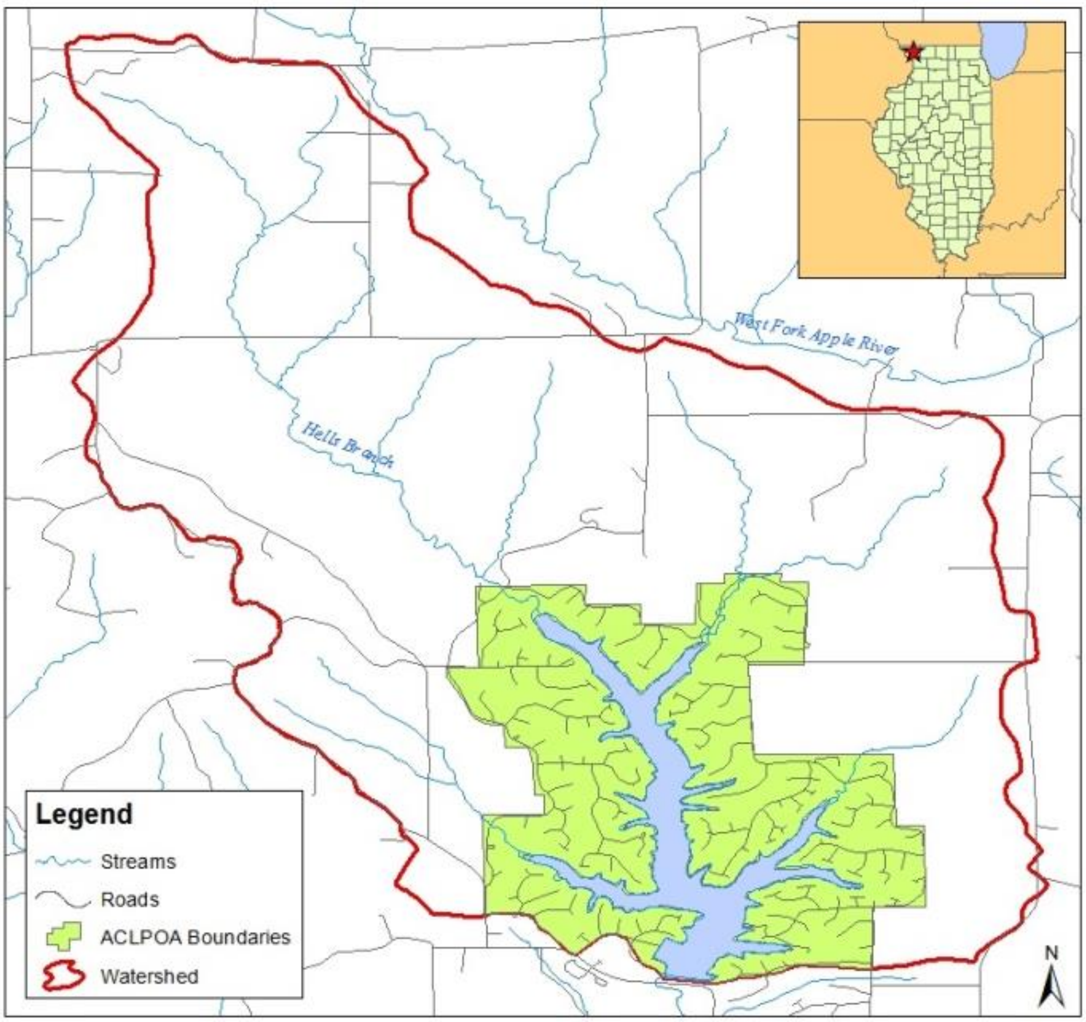


Figure 3-1. The boundaries of the Apple Canyon Lake Property Owners Association.

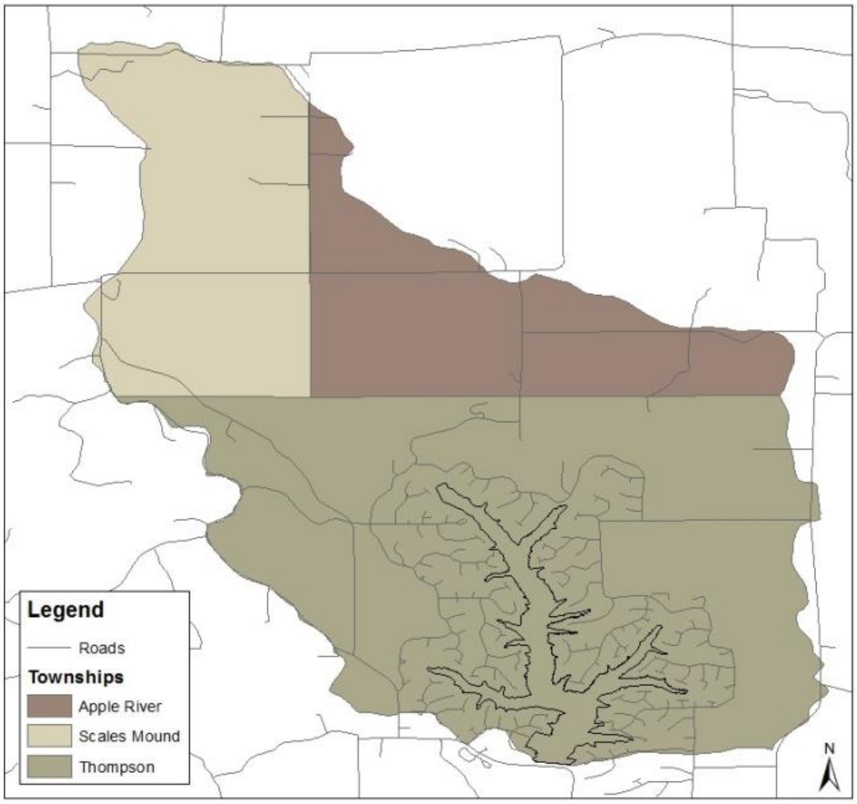


Figure 3-2. The watershed spans across three townships; Thompson, Scales Mound, and Apple River, but does not encompass any municipalities.

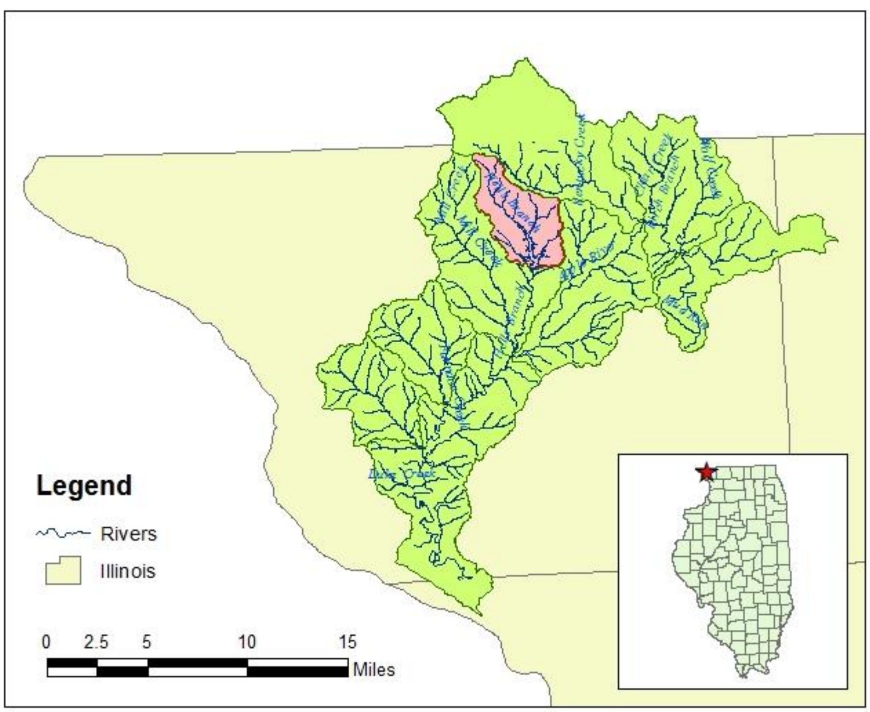


Figure 3-3. The Apple Canyon Lake watershed (pink) and receiving Apple River watershed (green) in Jo Daviess County, Illinois.

Table 3-1. Jurisdictions in the Apple Canyon Lake watershed.

Entity	Watershed Acres	Percent of Watershed	Authority
Jo Daviess County	9,776	100%	Zoning, County Roads and Bridges
Scales Mound Township	2,062	21.1%	Township roads and bridges.
Apple River Township	1,877	19.2%	Township roads and bridges.
Thompson Township	5,836	59.7%	Township roads and bridges.
Apple Canyon Lake P.O.A.	2,366	24.2%	Ownership

3.2 Topography

The topography of the watershed is rugged, characteristic of the Driftless Area landscape, with over 400 feet of elevation change in the watershed. At the terminus of the watershed lies Apple Canyon Lake (IL-RMJ), a 418.88 acre impoundment built in 1969 by the Branigar Corporation.

Due to its location in the Driftless Region, a great deal of topographic relief exists, which geologically formed the canyon which was impounded to form Apple Canyon Lake. The elevation at the spillway is approximately 800 ft. above sea-level, with the highest points in the watershed topping 1,240 feet. This gives over 400 feet of elevation change in the watershed, with a distance of approximately 14,900 from highest elevation to the lowest (142 feet per mile). From the farthest point in the headwaters to the bottom of the spillway, a distance of approximately 7.4 miles is covered. The lake bed at the deepest point contains a few pockets another 80 feet below the surface, corresponding with the elevation of Hell’s Branch at the bottom of the spillway (MNEA-02). Topographical elevations are shown below in figure 3-4.

The implications of this topography mean that water runs off the surface at an increased rate, infiltration of storm water is less, and concern for erosion is magnified. The average slope in Illinois is 1.22 %. Jo Daviess County averages the highest average slope in the state, at 4.25%. The Apple Canyon Lake watershed is 14.8%.

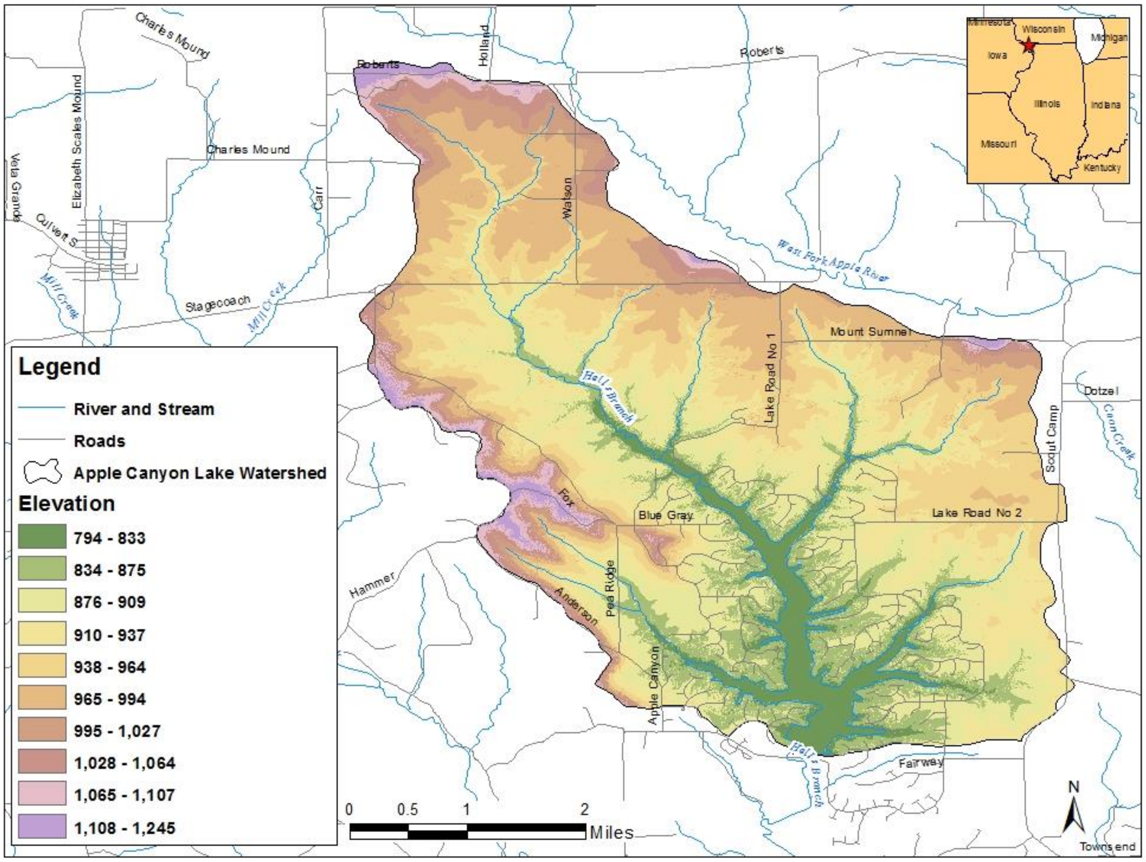


Figure 3-4. Topographic features of the Apple Canyon Watershed. There is over 400 feet of elevation change within the area.

3.3 Demographics

U.S. Census Bureau data from 2010 was accessed to determine population and demographic data for the watershed. Using this dataset, approximately 728 people live in the Apple Canyon Lake watershed as full-time residents (U.S. Department of Commerce, 2010). Because the property owners association consists of a recreational community, there is a large in-flux of part-time residents and guests which can surge to 10,000 during peak season (June – August), especially weekends.

Population in Jo Daviess County has remained fairly constant since 1900. Census data shows populations in the county as shown in Table 3-2. Using this information, future forecasts for population growth are expected to change very little. From 1990 to 2000, the population grew by 2%. From 2000 to 2010, the population again grew by 2%. Projecting future growth for 2020 using this growth rate we may determine the population of the county to increase to 23, 132, and for the Apple Canyon Lake watershed, 743 people.

Table 3-2. Census population data for Jo Daviess County (U.S. Census Bureau Website, 2014).

YEAR	JO DAVIESS Co.
1900	24,533
1910	22,657
1920	21,917
1930	20,235
1940	19,989
1950	21,459
1960	21,821
1970	21,766
1980	23,520
1990	21,821
2000	22,289
2010	22,678

The median per capita income for Jo Daviess County for 2008-2012 was shown to be $28,529 while the median household income was reported to be $50,817, and was below the Illinois State average of $56,797 (U.S. Census Bureau Website, 2014). In 2010, there were 37.7 people per square mile in the county, and the median age was 47.

Age statistics for Jo Daviess County are shown in Table 3-3. Statistics are not available for the watershed, and due to demographic differences in the property owners at Apple Canyon Lake, may only correspond loosely to these statistics. Individual data for Apple Canyon Lake is not available.

Table 3-3. Age statistics for Jo Daviess County (U.S. Census Bureau Website, 2014).

Population By Age		
0-4 years	1,194	5.27%
5-17 years	3,521	15.53%
18-64 years	13,131	57.90%
64 years and over	4,832	21.31%
Total	22,678	100%

According to the U.S. Census Bureau, 91.7% of Jo Daviess County residents are high school graduates. This is above the U.S. average of 86.3%. However, the county average of those persons aged 25 or older who have completed a bachelor's degree or higher is 23.5%, below the U.S. average of 29.3%.

Employment statistics in Jo Daviess County are shown in Table 3-3. Management and professional occupations lead in Jo Daviess County with 27.8% of jobs falling into this category. Sales and office occupations are 21.1% and production, transportation, and material moving are 19.5%. The service industry also is a strong component of employment in the county with 17.9% of the jobs. Construction and maintenance account for 11.4% of jobs. Despite the large area of land dedicated to farming in Jo Daviess County, farming jobs only account for 2.3% of the county's reported occupations. This number is slightly higher by industry, at 6.9%.

Table 3-4. Employment statistics for Jo Daviess County (U.S. Census Bureau Website, 2014).

OCCUPATION	Number	%
Management, professional, and related occupations	3,200	27.8
Sales and office occupations	2,436	21.1
Production, transportation, and material moving occupations	2,253	19.5
Service occupations	2,060	17.9
Construction, extraction, and maintenance occupations	1,317	11.4
Farming, fishing, and forestry occupations	262	2.3
Total	11,528	100
INDUSTRY		
Manufacturing	2,023	17.5
Educational, health and social services	1,994	17.3
Arts, entertainment, recreation, accommodation and food services	1,383	12.0
Retail trade	1,264	11.0
Construction	990	8.6
Agriculture, forestry, fishing and hunting, and mining	798	6.9
Professional, scientific, management, administrative, and waste management services	700	6.1
Finance, insurance, real estate, and rental and leasing	584	5.1
Transportation and warehousing, and utilities	537	4.7
Other services (except public administration)	537	4.7
Wholesale trade	280	2.4
Public administration	280	2.4
Information	158	1.4
Total	11,528	100

3.4 Land Use, Land Cover, and Development

The Apple Canyon Lake watershed is primarily rural with the exception of the development surrounding the lake, which is still relatively sparse by design compared with urbanized areas. The development that exists in the watershed is limited primarily to the southeast portion of the lake which contains the marina, pool, clubhouse, golf course, beach, campground, and maintenance area. The remaining portion of homes surrounding the lake is still heavily wooded and contains many open fields, many used for hay production.

Primary land use in a majority of the watershed is comprised of cropland, grassland, wetlands, woodlands, waterways, and developed land combined to make up a total of approximately 9,775 acres (*see figure 3-5*). Of that total, almost three quarters of the land is used agriculturally, with cropland making up 73% of the watershed (*see table 3-5*). The 8,000 acres of land used agriculturally is divided almost evenly between cultivated crops (41% of total watershed) and hay/pasture production (32% of total). The second largest portion of land is forested, with approximately 15% of the watershed in woodland areas. Grassland makes up around 1%, wetlands 0.1% and 4% of the watershed is water (majorly perennial streams). Approximately 8% of the 9,785-acre watershed is developed, which includes parks, golf courses, lawns, housing units, condominium and apartment complexes, commercial/industrial space, roads, parking lots, etc., with 1% of the total watershed being made of impervious surfaces, such as roads and parking lots. There are 941 homes in the watershed. Businesses are limited to an agricultural retailer at the North end of the watershed, Rick's Sales and Service, and property owner's association businesses, The Cove Restaurant, The Apple Canyon Lake Marina, and the Golf Course Clubhouse.

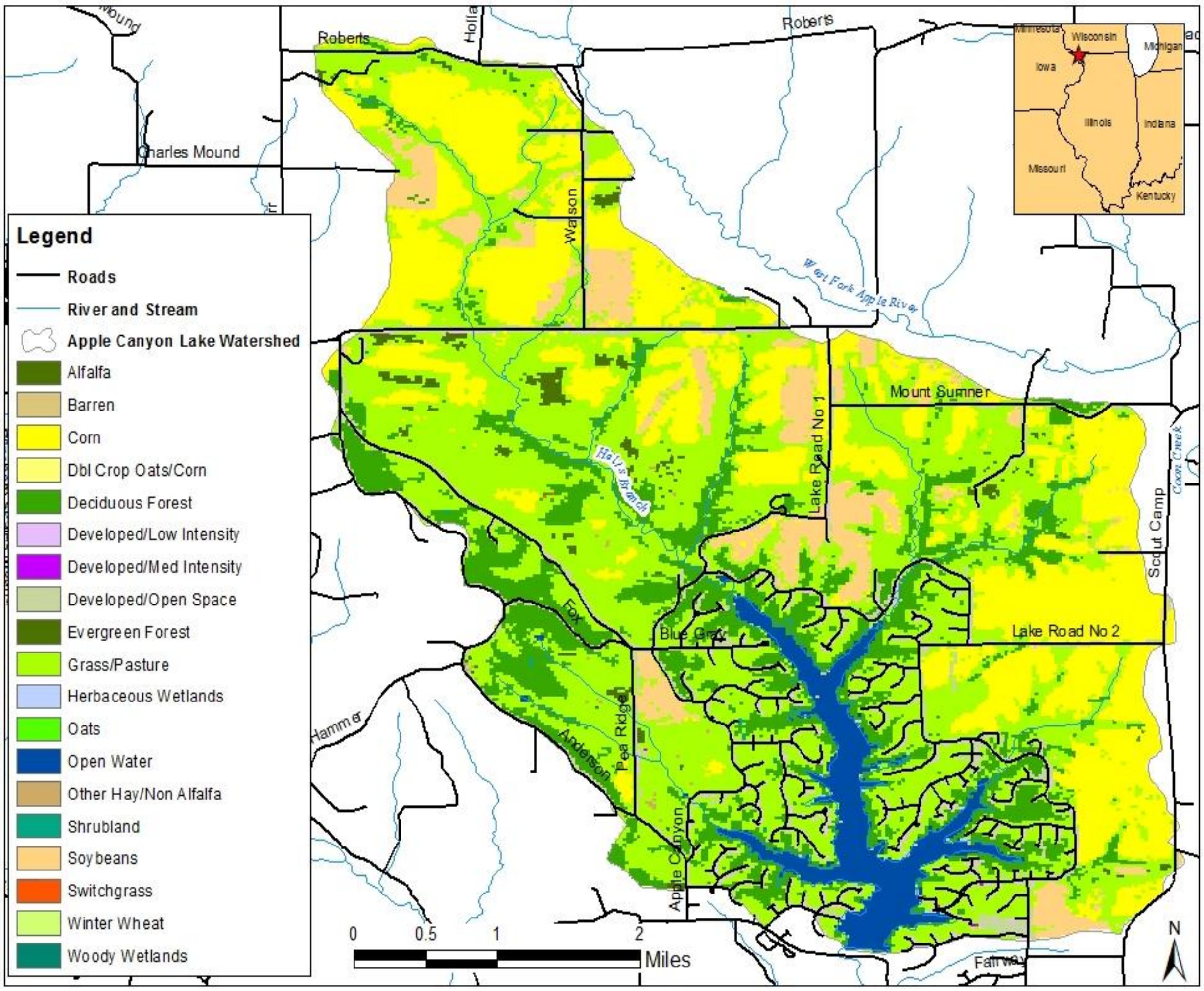


Figure 3-5. The land composition in the Apple Canyon Lake watershed. The majority is used for agricultural purposes, with the second largest area being forest.

Row cropped fields in the watershed are primarily in the upland areas (for more information on row cropping practices see Section 3.5). While still significantly sloped, the rugged drainages are extremely sloped and primarily left unused as forested land. The forested land is historically oak-hickory hardwood forest. These areas are still heavily dominated by oaks and hickories today, interspersed with black walnut, black cherry, and basswood, as well as some other species to a lesser extent. The emerald ash borer was first discovered in Jo Daviess County at Apple Canyon Lake in 2014. Few ash trees exist in the watershed, with a majority of the ash population being centered at intentional plantings in the resort area. A 2015 survey of the ash trees documented a primary infestation area in the most highly developed area at the lake, with infection spreading out slightly from there (*See figure 3-6*). The larger issue in the watershed on forested land appears to be bush honeysuckle (*Lonicera sp.*) and autumn olive (*Elaeangus sp.*). These species form dense canopies which provide so much shade that little growth occurs underneath these species. This factor, along with their shallow root system, cause a condition

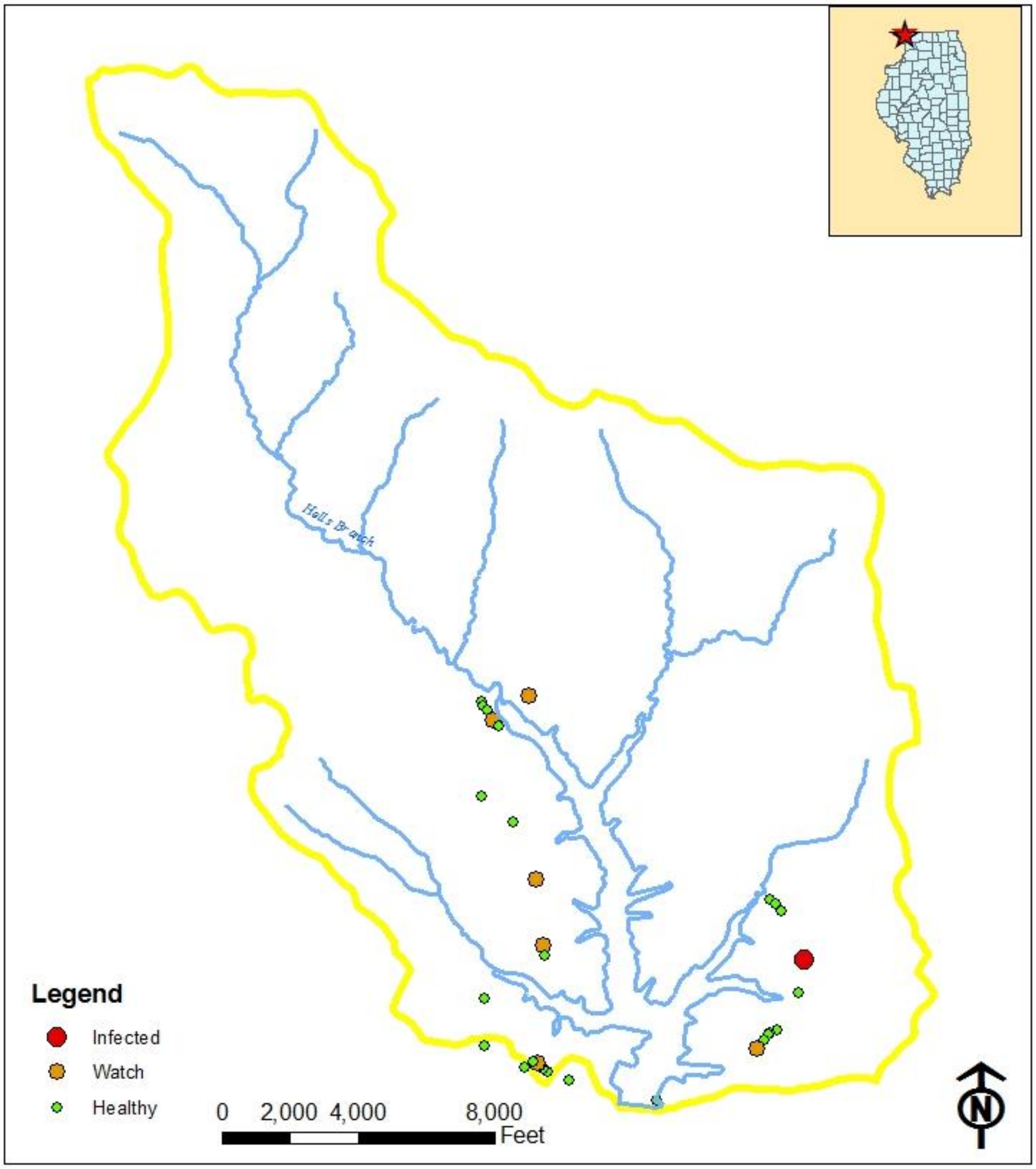


Figure 3-6. Ash trees identified in a 2014 survey for Emerald Ash Borer infestation. For trees designated "watch" infection could not be determined.

where soils are extremely prone to erosion once infested with these invasive species. The facts that most of the woodland in the watershed exists on the most highly sloping ground which cannot be cropped, and that many of the wooded stream corridors border drainages to the streams and lake, make invasive species control a major issue which needs to be addressed in the watershed. Due to funding priorities, many landowners have taken advantage of the USDA-NRCS Environmental Quality Incentives Program (EQIP) for forest management plans, however the Apple Canyon Lake Property Owners Association owns the most significant portion of forested lands in the watershed and is not yet in the program. Much of the lower stream corridors are grasslands, and predominantly grazed by cattle.

Table 3-5. Land categories within Apple Canyon Lake watershed calculated as percentages (USDA-NASS, 2014).

Category	Acreage	% of Total
Corn	2,430.3	24.86%
Soybeans	582.5	5.96%
Winter Wheat	0.4	0.00%
Oats	0.9	0.01%
Alfalfa	102.1	1.04%
Other Hay/Non Alfalfa	5.8	0.06%
Switchgrass	0.4	0.00%
Open Water	418.1	4.28%
Developed/Open Space	468.8	4.80%
Developed/Low Intensity	185.3	1.90%
Developed/Medium Intensity	2.0	0.02%
Barren	3.1	0.03%
Deciduous Forest	1,392.4	14.24%
Evergreen Forest	2.7	0.03%
Shrubland	6.2	0.06%
Grass/Pasture	4,163.5	42.59%
Woody Wetlands	4.0	0.04%
Herbaceous Wetlands	6.7	0.07%
Dbl Crop Oats/Corn	0.4	0.00%
TOTAL ACREAGE	**9,775.6**	

Land use has changed very little since Apple Canyon Lake was created in 1969. There was an initial impact created by the infrastructure formed by the property owner's association, however, land-use data available from the National Agricultural Statistics Service has shown little change for the period of data collection. The available data shows more change in land use / land cover due to errors in data collection (cloud cover) than with changes in development. Due to this, little change is expected in development or impervious surface growth. The rate of building development has stayed fairly constant in Jo Daviess County, with a small rise in construction between 2001 and 2007. It is assumed to be similar for Apple Canyon Lake watershed. Jo Daviess County development statistics are summarized in Table 3-6 and Figure 3-7. Land use on agricultural lands varies from year to year based on beef markets, corn prices, crop rotation practices, and availability of Farm Bill subsidy dollars. Remote sensing using 2015 aerial imagery estimates approximately 31 farms in watershed. There are an estimated 30 row cropping operations and 11 livestock operations. Data is not available to verify if these are separate operations or combined, or whether they are owned or rented operations. Due to this lack of data, it is more appropriate to look at land use acres in the watershed directly. However, through the watershed planning process, the planning group was made aware of producers that are located outside of the watershed area that rent and operate some of the land in the watershed.

Table 3-6. Development statistics for Jo Daviess County from 1995 – 2014.

Year	New Homes	Mobile Homes	Accessory Buildings	Additions	Decks	Towers	Commercial	Total Value
1995	187	12	47	21	2	1	7	$29,496,322
1996	145	5	46	24	1	0	0	$22,001,055
1997	148	2	33	17	1	0	0	$26,508,801
1998	131	9	28	36	1	2	2	$22,525,951
1999	137	2	42	30	1	0	0	$20,276,768
2000	130	3	48	38	1	1	0	$27,068,805
2001	135	5	88	40	9	4	4	$28,149,735
2002	182	4	69	45	6	0	1	$32,826,025
2003	178	1	81	32	11	0	3	$36,634,355
2004	172	3	78	39	5	0	4	$47,563,900
2005	184	6	80	40	3	5	0	$57,158,300
2006	125	4	84	46	6	2	3	$36,687,543
2007	115	1	68	52	12	13	5	$36,037,489
2008	62	0	74	51	7	3	10	$23,150,854
2009	37	0	60	35	15	12	12	$18,050,528
2010	33	0	52	26	14	10	0	$12,305,627
2011	31	0	47	22	18	6	0	$18,142,819
2012	43	1	67	44	17	16	0	$17,469,360
2013	37	0	84	52	13	14	22	$16,128,444
2014	27	0	72	58	15	3	38	$14,723,028

Figure 3-7. Development in Jo Daviess County by value of construction.

3.5 Tillage Practices

Corn and soybeans are the primary crops in the watershed. In many operations these crops are rotated from year to year, with soybeans providing a nitrogen source for future corn crops. Due to the high slope of the watershed these crops experience a much greater increase in erosion than in many parts of the US which grow these crops. The producers in the watershed have been extremely proactive over the years at adopting best management practices (BMPs, *see figure 3*.9). Due to changes in weather patterns and increased intensity of rainfall events many of these BMPs have not been effective and will likely affect future participation by producers.

A tillage transect survey was conducted in 2015 using Illinois Department of Agriculture methods to assess the cropland practices in the watershed. Out of the total of 68 fields which were assessed in the transect survey, 57 were in active crop production, and 28% showed erosion. Corn was the dominant crop, planted on 42 of the 68 fields. Soybeans were planted on 14 fields, and wheat was planted on one field. Hay also made up a significant portion of the survey (9 fields). A significant number of points on Association property have historically been cut for hay but do not currently show signs of activity. Because of this, these sites were not included in the survey.

Approximately 12% of the fields are in a no-till cropping system, while 88% of the fields show signs of some tillage, though in most cases tillage is significantly reduced. No conventional tillage was observed in the survey and residue levels in most cases were high. Despite the high residue, the high level of ephemeral erosion indicates that a true no-till system would benefit the cropland in the watershed, as well as increasing the use of buffers, waterways, and removing some steep fields from production. Under high rainfall events, a no-till system will allow greater infiltration through enhanced soil structure created by worm and micro-organism activity, reducing runoff (Edwards, et al., 1988; others). The erosion also shows the need for field buffers to reduce sediment loading into streams.

3.6 Subwatersheds

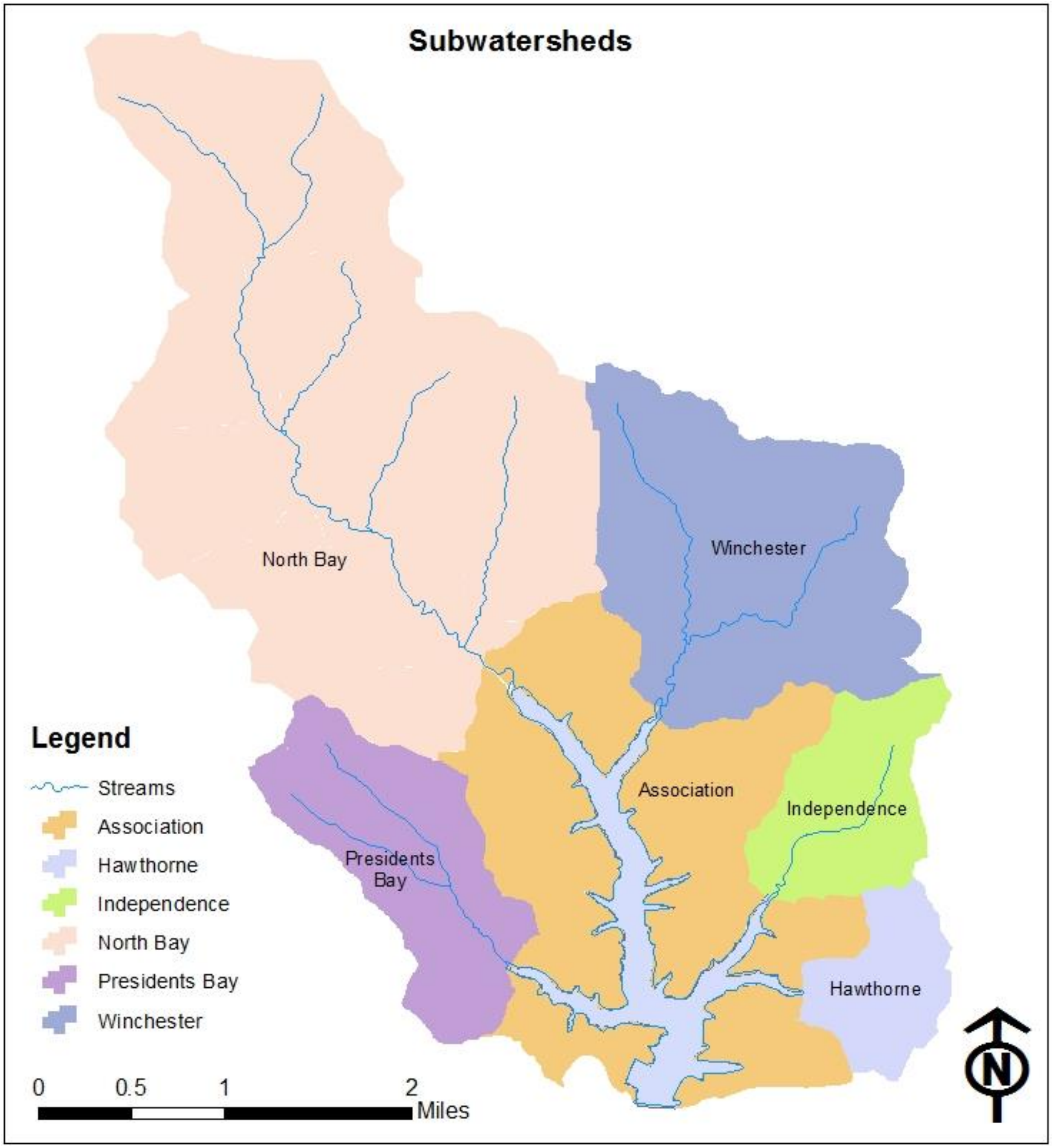


Figure 3-8. Subwatersheds within the Apple Canyon Lake Watershed.

The planning group identified six sub-watersheds within the larger Apple Canyon Lake Watershed planning area. All of these subwatersheds are predominantly agriculture land uses, dominated by cultivated crops (corn and soybeans), pasture, and hay. Primarily, 10-20% of the subwatersheds are forested, with the exception of President's Bay, which is 27% forested. The subwatershed labeled "Association" is part of the lake basin and directly contributes into the lake with no major stream with continuous flow. Subwatershed boundaries are shown below in figure 3-7. Table 3-7 describes land use for each of the subwatersheds. For more information about the subwatersheds, see section 4.3.

Table 3-7. The land use within each subwatershed in acres and in percentage acreage to total land use.

Subwatershed ID	Total Acres	Open Water	Developed Open Space	Developed, Low Intensity	Deciduous Forest	Mixed Forest	Shrub / Scrub	Grassland Herbaceous	Pasture / Hay	Cultivated Crops	Wetlands
North Bay	4,331.3	0.0	154.8	47.6	580.0	2.7	18.8	31.1	1,197.9	2,297.3	0.8
Association	2,026.9	395.3	149.6	84.7	416.0	1.6	27.4	6.1	625.5	316.5	4.2
Winchester	1,554.5	0.0	69.0	7.2	183.8	1.7	2.2	1.8	611.2	676.2	1.4
Presidents	827.2	0.0	49.8	5.7	226.5	0.0	14.0	4.2	338.2	188.9	0.0
Independence	530.9	0.0	25.3	2.7	57.7	0.0	5.6	0.0	139.1	300.4	0.0
Hawthorne	346.2	0.0	9.5	6.3	31.4	0.0	0.0	3.1	227.3	68.2	0.4
Total (Acres)	9,617.0	395.3	458.0	154.2	1,495.4	6.0	68.0	46.3	3,139.2	3,847.5	6.8

Subwatershed ID	Total Acres	Open Water	Developed Open Space	Developed, Low Intensity	Deciduous Forest	Mixed Forest	Shrub / Scrub	Grassland Herbaceous	Pasture / Hay	Cultivated Crops	Wetlands
North Bay	4,331.3	0.0%	3.6%	1.1%	13.4%	0.1%	0.4%	0.7%	27.7%	53.0%	0.0%
Association	2,026.9	19.5%	7.4%	4.2%	20.5%	0.1%	1.4%	0.3%	30.9%	15.6%	0.2%
Winchester	1,554.5	0.0%	4.4%	0.5%	11.8%	0.1%	0.1%	0.1%	39.3%	43.5%	0.1%
Presidents	827.2	0.0%	6.0%	0.7%	27.4%	0.0%	1.7%	0.5%	40.9%	22.8%	0.0%
Independence	530.9	0.0%	4.8%	0.5%	10.9%	0.0%	1.1%	0.0%	26.2%	56.6%	0.0%
Hawthorne	346.2	0.0%	2.7%	1.8%	9.1%	0.0%	0.0%	0.9%	65.7%	19.7%	0.1%
Total	9,617.0	3.3%	4.8%	1.5%	15.5%	0.0%	0.8%	0.4%	38.4%	35.2%	0.1%

3.7 Animal Operations

Information on commercial animal operations is available from the National Agricultural Statistics Service. Detailed livestock data for the 12-digit hydrologic unit code is not available. Data for Jo Daviess County is presented in Table 3-8. Remote sensing using 2015 aerial imagery estimates approximately 11 livestock operations in the watershed. These operations are primarily cattle on pasture, with winter feeding taking place in the pasture. There was one sheep operation identified.

Table 3-8. Commercial animal operations in Jo Daviess County, number of animals. (USDA-NASS, 2014)

Livestock Type	2002	2007	2012
Cattle and Calves	57,276	57,254	53,057
Hogs and Pigs	18,983	18,860	14,146
Poultry	510	1,273	*no data*
Sheep and Lambs	1,998	796	1,312
Horses and Ponies	838	2,214	926

3.8 Septic Systems

Septic systems were originally used to serve individual homes in rural areas where population densities were too low to economically justify sanitary sewers. Septic systems also have been used to serve more densely settled areas where, at least originally, occupancy was seasonal. Households in the Apple Canyon Lake watershed are not connected to a municipal sewer system. The entirety of this watershed is served by individual onsite sewage disposal systems, or septic systems. Septic systems are a household feature that is often forgotten unless obvious failure has occurred.

A properly functioning septic system will remove most disease-causing organisms and some nutrients and chemicals from wastewater. However, it will not remove or treat many water soluble pollutants such as solvents, drain cleaners, and many household chemicals. Consequently, the proper location, design, construction, operation, and maintenance of septic systems are critical in areas close to lakes and streams, as well as in shallow groundwater zones. Lake community homeowners have a special responsibility to ensure that their septic systems are not polluting the lake. Septic systems can be safe and effective so long as installers design, locate, and construct systems correctly, ***and*** homeowners actively monitor and maintain them.

Septic systems that are not functioning properly can pose a health threat by allowing sewage to contaminate drinking water. The ecology of nearby waterways can be harmed as well. Septic systems have been found to be a significant source of phosphorus pollution (Jones and Lee, 1979), which usually is the nutrient limiting algae and rooted aquatic plant growth in Illinois lakes (IEPA, 1995). Discharge of septic tank effluent to a lake or tributary stream, either through overland flow or groundwater seepage, can contribute to localized increases in algae or aquatic plant growth. In extreme cases, the oxygen depletion associated with untreated sewage can even kill fish. Widespread discharge to a lake over a period of time can significantly accelerate the lake's eutrophication rate. Because phosphorus is very slow to leave a lake system, sewage inputs often have lingering effects long after they have been discontinued. Bacterial contamination can be a concern if the lake is used as a source of drinking water or for body contact recreation such as swimming.

The most common type of septic system consists of two primary components: 1) a septic tank for collecting waste and settling out solids, and 2) a soil absorption field for filtering the liquid waste. Older, and much less efficient, septic systems often utilize drywells instead of an absorption field or combine the functions of both the septic tank and absorption field into a cesspool. Where soil composition or depth is not suitable for a conventional septic tank/absorption field, alternative systems may be required. Mound systems create a suitable area for an absorption field by piling up "good" soils to an approved depth and placing the absorption field within the resulting mound. Often this requires pumping the liquid waste up to the elevation of the new field, adding additional mechanical complexities. Other more intricate and expensive designs must be used when conditions dictate. These include aerobic treatment units, sand filters, lagoons, electro-osmosis systems, leeching chambers, and holding tank/truck collection systems.

Phosphorus loading in lakes from seasonally high water tables is well known (Gilliom and Patmont, 1983). Failing or leaking septic systems also contribute to fecal coliform pollution. Animal waste, urban runoff, and permitted point sources can also contribute to fecal coliform pollution. The septic tank serves three functions: storage, settling, and digestion. However, the degree of nutrient removal is limited by soils and system upkeep and maintenance. Properly designed, installed, and maintained septic systems have an expected lifespan of 15 -20 years (McGauhey & Winneberger, 1964). Many of the septic systems in the watershed, and especially within the Property Owners Association, are this age and much older. Additionally, ownership change can significantly impact the proper operation of septic systems. A septic system is designed based specific attributes, such as number of occupants and frequency of use. Changes to these attributes, such changes in household size, addition of in-drain garbage disposal systems, conversion to rental units, and frequency of use, can greatly impact the ability of a septic system to properly function. In some cases, systems are designed such that septic drainfields must be manually switched by control valve year-to-year. If a change in ownership occurs and this information is not passed on, a system may be extremely limited in function. Jet aeration units, modified sand filters, and conventional drain fields are often inappropriate for the soils and specific household conditions which feed the septic systems. Changes in landscaping and land use also affect the proper operation of the septic system for a residence.

Soil limitations for septic drainage fields are shown in Table 3-9. Over 95% of the soils in the watershed have limitations for nutrient removal. Additionally, the underlying bedrock in the watershed is known to be frequently fractured. In the event of septic system failure, effluent can seep into bedrock fractures and into the aquifer instead of appearing at the soils surface. Due to the development period of the Property Owners Association properties, many of the septic systems were installed prior to 1985 and significant changes have taken place in state, county, and Property Owners Association codes, as well as changes in septic design, and septic technology.

The property owners association has existing rules regarding septic systems on the association property, including the requirement to have systems pumped and inspected with conventional systems inspected no less than every six years, and mechanical systems inspected twice a year, at six month intervals. Dwellings used for rental purposes are required to be inspected every three years. These rules can be found in the Amended and Restated Covenants & Restrictions, Article III, §11, and in the Apple Canyon Lake Building and Environmental Code, §108.

The Jo Daviess County Health Department reports 901 septic systems in the property owner's association. These systems are combinations of tank systems with drainfields, sand filters, and pumps. Due to the number and age of homes in close proximity to Apple Canyon Lake, a detailed study is needed to identify critical areas with septic systems which may not be properly functioning. This study is outside of the scope of this plan but has been identified as an action item in Section 6.0. In addition to this study, field sampling is recommended to determine the impact on water quality from residential septic areas. Smaller coves and bays around Apple Canyon Lake which have their entirety in the "Association" subwatershed (*see section 4.3*), such as Blackhawk, Colony, and Concord Cove, should be used.

Table 3-9. Nutrient removal occurs in septic fields. The degree of nutrient removal is limited by soils and system upkeep and maintenance. Watershed soil limitations for septic drainage fields are displayed in this table.

Rating	**Acres**	**Percent**
Very limited	6,288.4	64.3%
Somewhat limited	3,069.6	31.4%
Null or Not Rated	418.3	4.3%
Total	9,776.3	100.0%

3.9 Existing Best Management Practices

Best Management Practices are *non-structural* practices such as site planning and design aimed to reduce stormwater runoff and avoid adverse development impacts - or *structural* practices that are designed to store or treat stormwater runoff to mitigate flood damage and reduce pollution. Some BMPs used in urban areas may include stormwater detention ponds, restored wetlands, vegetative filter strips, porous pavement, silt fences and biotechnical streambank stabilization. The watershed was surveyed using high-resolution aerial imagery, flown in 2014, and existing best management practices (BMP) were identified in the landscape. These practices include terracing in fields, grassed waterways, retention ponds and basins, dry-dams, rain gardens, and stream stabilization practices. Figure 3-8 identifies points where existing BMPs were identified. Table 3-9 provides corresponding identification for the points labeled in figure 3-8. A majority of these BMPs were installed in the 1990s and early 2000s when the Illinois Department of Agriculture's

C-2000 program was heavily funded. These BMPs were designed with a 10-year lifespan and are now beyond the design lifespan and in need of maintenance.

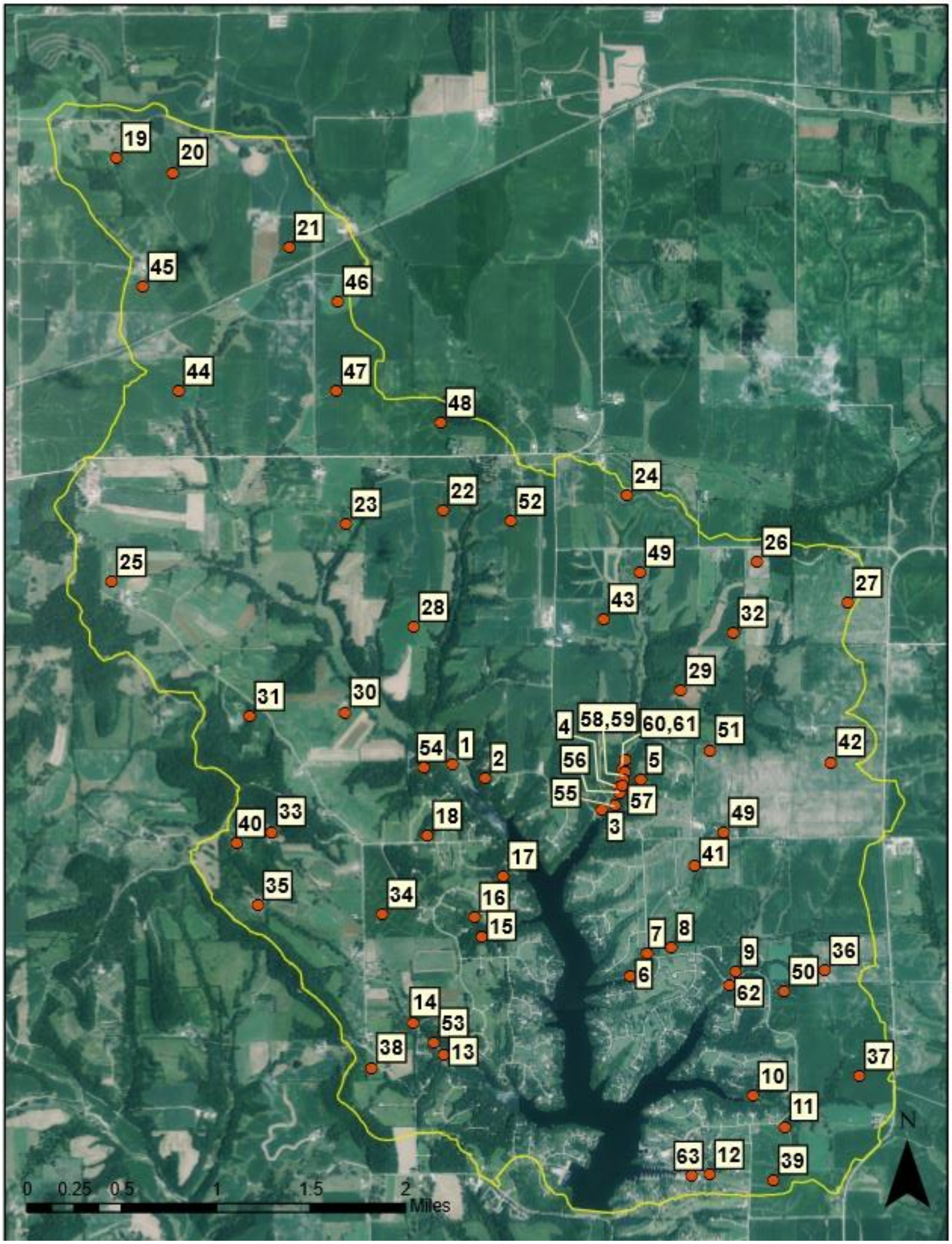


Figure 3-9. Points in Apple Canyon Lake Watershed where best management practices are being used.

Table 3-10. Points shown in *Figure 3-8* with corresponding best management practice.

Point Number	BMP Practice
1	Dredge Pond
2	Dry Dam
3	Dredge Pond
4	Restored Wetland
5	Dry Dam
6	Dredge Pond
7	Culvert
8	Dry Dam
9	Dredge Pond
10	Dry Dam
11	Dredge Pond
12	Dry Dam (4)
13	Dredge Pond
14	Retention Pond
15	Dry Dam
16	Dry Dam
17	Dry Dam
18	Dry Dam
19	Retention Pond
20	Grass Waterway
21	Grass Waterway
22	Grass Waterway
23	Terracing
24	Terracing
25	Grass Waterway
26	Grass Waterway
27	Grass Waterway
28	Terracing
29	Terracing
30	Grass Waterway
31	Grass Waterway
32	Grass Waterway

Point Number	BMP Practice
33	Retention Pond
34	Grass Waterway
35	Retention Pond
36	Grass Waterway
37	Terracing
38	Terracing
39	Grass Waterway
40	Grass Waterway
41	Grass Waterway
42	Grass Waterway
43	Grass Waterway
44	Grass Waterway
45	Terracing
46	Terracing
47	Grass Waterway
48	Terracing
49	Terracing
50	Grass Waterway
51	Grass Waterway
52	Grass Waterway
53	Rock Riffles
54	Rock Riffles, LPSTP
55	Rock Riffles
56	Rock Riffles
57	Rock Riffles
58	Rock Riffles
59	Rock Riffles
60	Rock Riffles
61	Rock Riffles
62	Rock Riffles, LPSTP
63	Rain Garden

4.0 PHYSICAL CHARACTERISTICS

4.1 Watershed Drainage System

Active stream flow for the Apple Canyon Lake watershed was measured on the USGS Sinsinawa River Gauge (05414820), located 4.4 miles northwest of Galena, IL, which records real-time data from the Sinsinawa River watershed (*see figure 4.2*). The discharge data is available from 1967 – present. Average monthly flows in the Sinsinawa River range from 21 cubic feet per second (cfs) in November to 42 cfs in March. The gauge drains 40.1 square miles. This data was used to estimate flow values for Hells Branch (IL-MNEA) at the lowest-most point in the watershed using the drainage area ratio method:

$$\mathbf{Q_{gaged}\left(\frac{Area_{ungaged}}{Area_{gaged}}\right) = Q_{un-gaged}}$$

Where Q_{gaged} = Streamflow of the gaged basin
$Q_{un\text{-}gaged}$ = Streamflow of the ungaged basin
$Area_{gaged}$ = Area of the gaged basin
$Area_{ungaged}$ = Area of the un-gaged basin

This assumes that the flow per unit area is equivalent in watersheds with similar characteristics, and the flow per unit area in the gaged watershed multiplied by the area of the un-gaged watershed estimates the flow for the un-gaged watershed. This calculation estimates an average of 11.09 cfs flowing over the spillway at ACL.

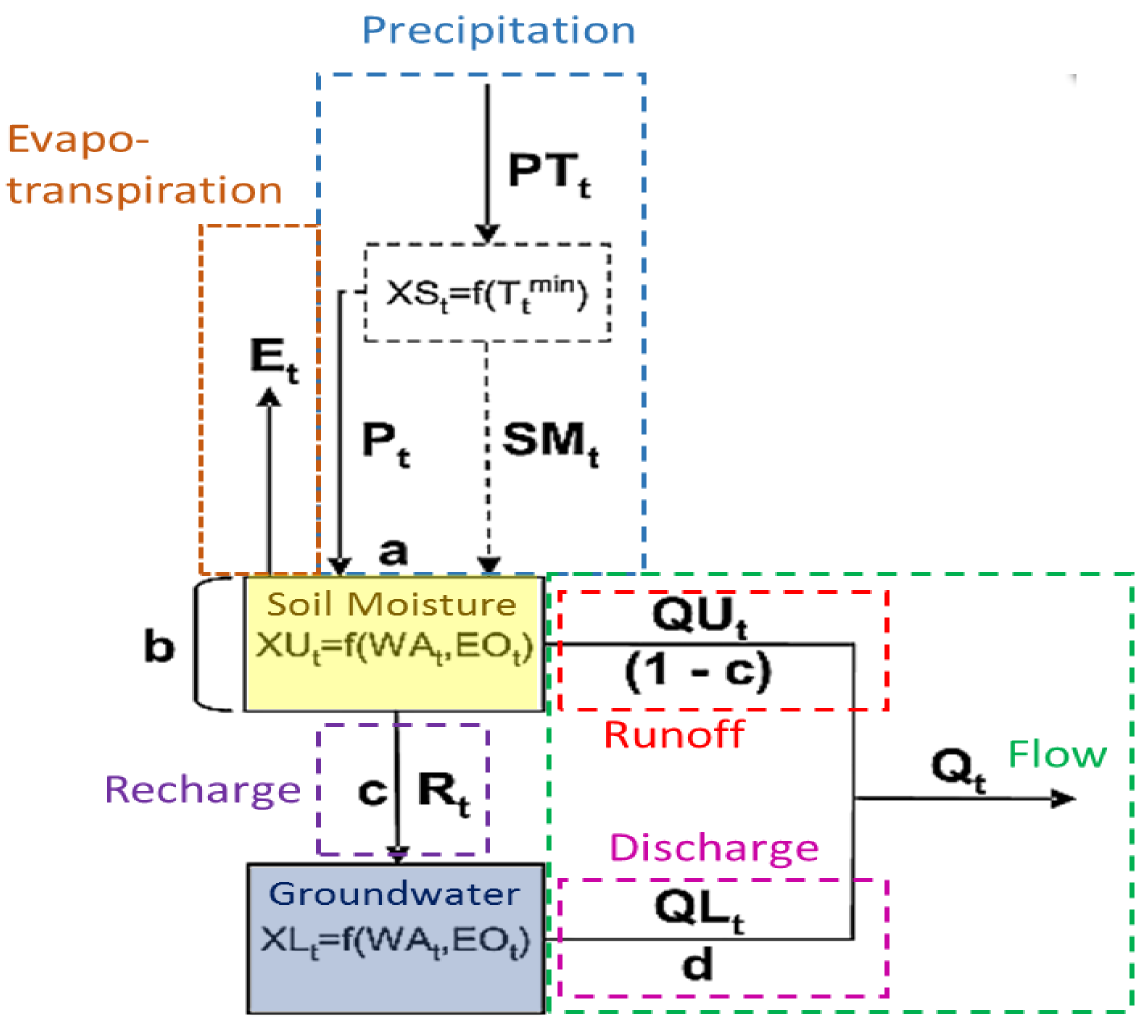
For a comparison, discharge was measured on the USGS Apple River Gauge (05419000), located 0.3 miles south of Hanover, IL, which records real-time data from the larger Apple River watershed. The discharge data is available from 1935 – present. Average monthly flows in Apple River range from 116 cubic feet per second (cfs) in October to 348 cfs in March. This gauge drains 246.28 square miles and using the above equation estimates an average discharge for Apple Canyon Lake as 11.88 fps. The USGS estimated slope of the larger Apple River watershed is 10.49 feet per mile, while the Sinsinawa's USGS estimated slope is 19.60 feet per mile, much closer to the Apple Canyon Lake's watershed which is estimated by USGS as 23.87 feet per mile. The two estimated discharge calculations are very similar. The Sinsinawa River's gauge was chosen for discharge estimates because the watershed size and slope are much closer to Apple Canyon Lake's, and the data range is closer to the span of time since the reservoir was constructed.

This flow data was then used as input into the ABCD water balance model (Thomas, 1981). The ABCD water balance model was created to quantify the volume of runoff for the watershed over a two-decade time period (1998 – 2014). The entire water balance was based on two smaller water balances of (1.) the water balance determining the soil moisture and (2.) the water balance determining the volume of groundwater (*see figure 4-1*). Equations 1 and 2 show the soil moisture and groundwater water balances, respectively. The variable "t" signifies the current time step, while "t-1" represents the value of the previous time step.

The ABCD model uses precipitation and temperature data from National Climatic Data Center station in Apple River Canyon State Park, IL from December 1998 to March 2015. From the temperature data, averages were used in congruence with the empirical Hargreaves model (Hargreaves, Hargreaves & Riley, 1985) to find potential evapotranspiration (PET, Equation 3).

R_a is the total incoming extraterrestrial solar radiation, C_t is a temperature reduction based on the amount of relative humidity, $\delta_t^{1/2}$ is the difference between mean low and high monthly temperatures, and $T_{avg.d}$ is the mean temperature at a point in time. Equations 4 – 9 consist of the components of the Hargreaves model that derive the values in the PET calculation.

Figure 4-1. ABCD water balance model.



Equation 1:

Soil Moisture (t) + ET(t) + Runoff f(t) + Recharge (t) = Soil Moisture (t-1) + Precipitation (t)

Equation 2:

Groundwater (t) + Discharge (t) = Groundwater (t-1) + Recharge (t)

Equation 3:

$$PET = 0.0075 \times R_\alpha \times C_t \times \delta_t^{1/2} \times T_{avg.d}$$

Equation 4:

$R_a = 15.392 \times d_r\,(W_s \times \sin\varnothing \times \sin\delta + \cos\delta \times \sin W_s)$

Equation 5:

$C_t = 0.035(100 - W_\alpha)^{1/3}$ where $W_\alpha \geq 54\%$

Equation 6:

$C_t = 0.125$ where $W_\alpha < 54\%$

Equation 7:

$d_r = 1 + 0.033 \times \cos\left(\frac{2\pi \times J}{365}\right)$

Equation 8:

$\boldsymbol{\delta = 0.4093} \times \sin\left(\frac{2\pi \times J}{365} - 1405\right)$

Equation 9:

$W_s = \arccos\,(-\tan\varnothing \times \tan\delta)$

In the ABCD model, snow melt, effective precipitation and effective evapotranspiration were found using the "A", "B", "C", and "D" components. The parameter "A" quantifies the volume of runoff and recharge in terms of precipitation from rain and snow melt. The parameter "B" identifies the soil saturation level after taking into account precipitation, runoff, recharge, and evapotranspiration. The parameter "C" gives the groundwater recharge to surface runoff ration. The parameter "D" determines the rate of groundwater discharge.

Data found in the ABCD model was compared to actual runoff amounts recorded from the Sinsinawa River USGS gauge and physical discharge readings recording during routine field sampling. The ABCD model was calibrated by multiple methods to check its accuracy and find the best fit to the observed Sinsinawa River data. Figure 4-3 shows monthly flows generated from the ABCD model for the Apple Canyon Lake watershed.

Using this data, a flow duration curve was developed for the Apple Canyon Lake watershed (*see figure 4-4*). These flow predictions are observed to be much closer to the recordings made during routine field sampling and are believed to be the most accurate available. This information is valuable in assessing water chemistry data by comparing sample chemistry with discharge readings taken at the time of sampling.

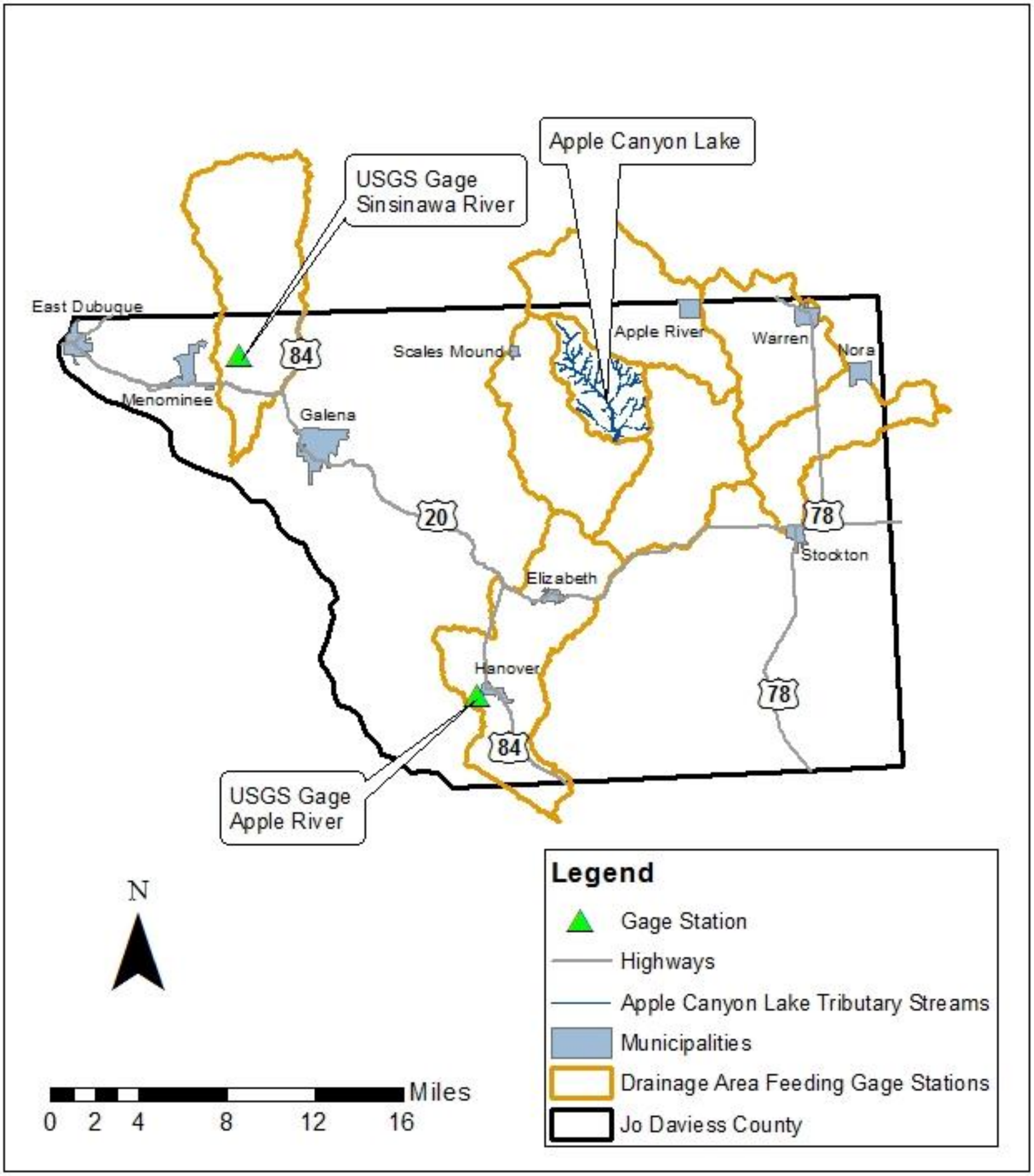


Figure 4-2. Geographic size and location comparison of drainage areas feeding USGS gage sites.

.

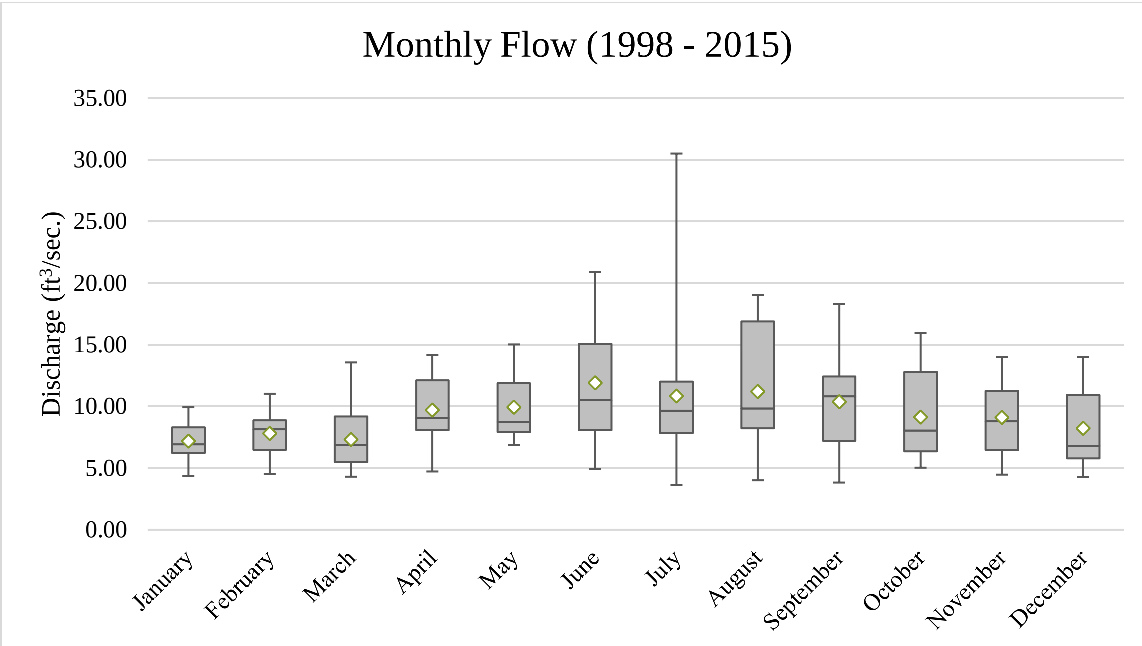


Figure 4-3. Estimated discharge calculations for Apple Canyon Lake watershed based on USGS flow data for the Sinsinawa River (05414820) from 1998-2013. Whiskers show the range of flows on record while boxes indicate 25%, median, and 75% flow values. Diamonds indicate mean flow.

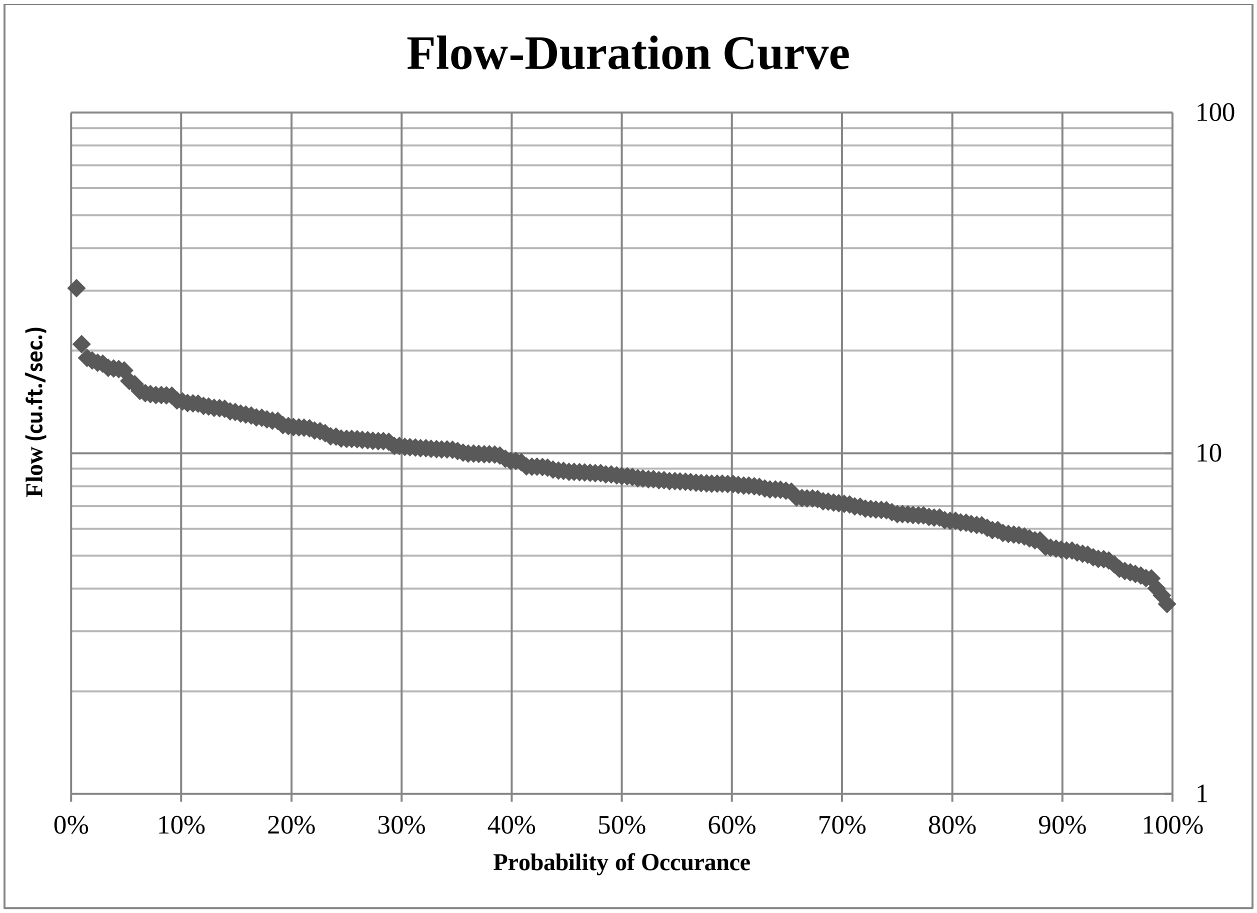


Figure 4-4. Flow duration curve developed for the Apple Canyon Lake watershed shows estimated probability of occurrence of a given flow.

4.2 Water Flow

The streams in the watershed flow into Apple Canyon Lake and exit Hell's Branch at the southern end of the lake (*see figure 4-5*). Flow generally starts in the north of the subwatersheds and flows in a generally southerly direction into Apple Canyon Lake. Water leaves the reservoir via the spillway at the far south end of the lake.

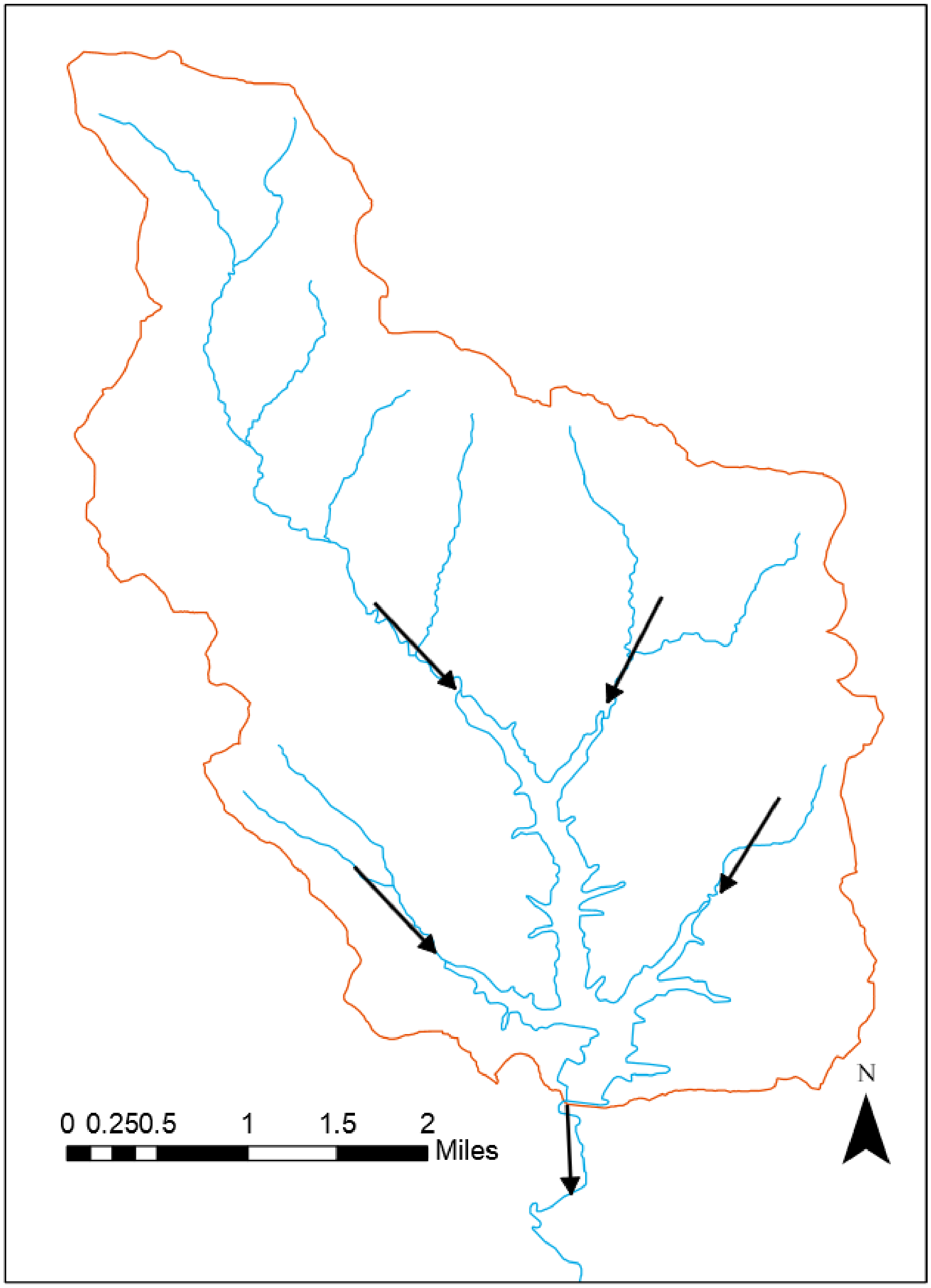


Figure 4-5. The direction of stream flow through the Apple Canyon Lake Watershed.

4.3 Floodzone

Flood zones are geographic areas that the Federal Emergency Management Agency (FEMA) has defined according to varying levels of flood risk. These zones are depicted on a community's Flood Insurance Rate Map (FIRM) or Flood Hazard Boundary Map. A 100-year flood is a flood event that has a 1% probability of occurring in any given year. The 100-year flood is also referred to as the 1% flood, since its annual exceedance probability is 1%. Based on the expected 100-year flood flow rate, the flood water level can be mapped as an area of inundation. The resulting floodplain map is referred to as the 100-year floodplain. FEMA floodplain designations are limited to larger watersheds, although bottomland areas of smaller creeks are still subject to flooding, so local knowledge and common sense apply. The 100-year floodplain is shown in figure 4-6 for the Apple Canyon Lake Watershed.

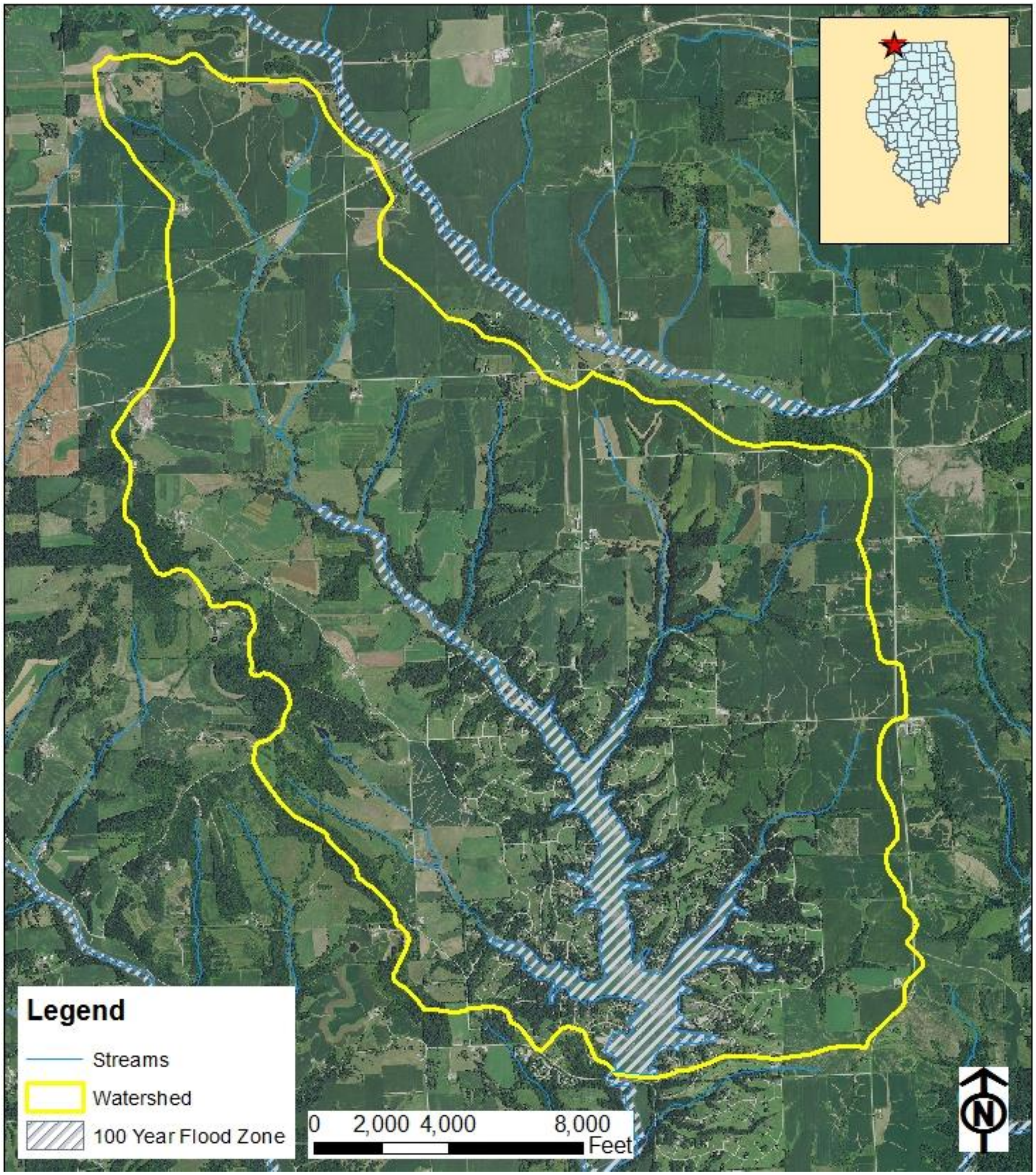


Figure 4-6. FEMA 100-year floodmap for the Apple Canyon Lake watershed.

4.4 Subwatersheds

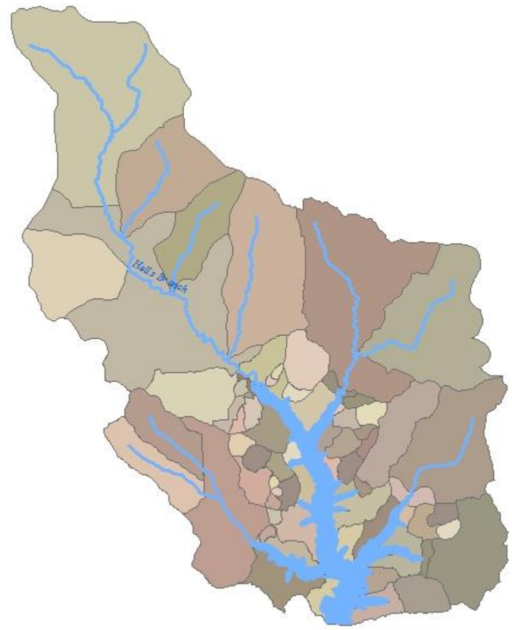


Figure 4-7. Individual drainages identified in the watershed.

Using lidar imagery and GIS, individual drainages within the watershed were extracted. Using this method, 71 individual drainages were identified (*see figure 4-6*). These drainages were grouped into five major corridors which feed the lake, and a sixth area immediately adjacent to the lake, for the purpose of planning (*see figure 4-7*). These subwatersheds are North Bay, Winchester, Independence, Hawthorne, Presidents Bay, and Association. The *Association* subwatershed is composed of 50 small drainages which are directly adjacent to the lake, feed directly into the lake during runoff events but contain no constant or significant flow of water, and are all located entirely on Property Owners Association land.

Of the six subwatersheds, North Bay is the largest with an area of just over 4000 acres (42%, *see table 4-1*). Winchester Bay is the next largest area which feeds a single tributary of the lake (16%). President's Bay (9%), Independence (5%) and Hawthorne (4%) are much smaller contributions, but still contain perennial streams. The Association subwatershed covers a significant area (2,427 acres, 24% of the total watershed) but is a collective of many smaller ravines surrounding Apple Canyon Lake, with only intermittent and ephemeral streams. While contributing significantly less flow, these areas are still important for controlling erosion and nutrient loading issues.

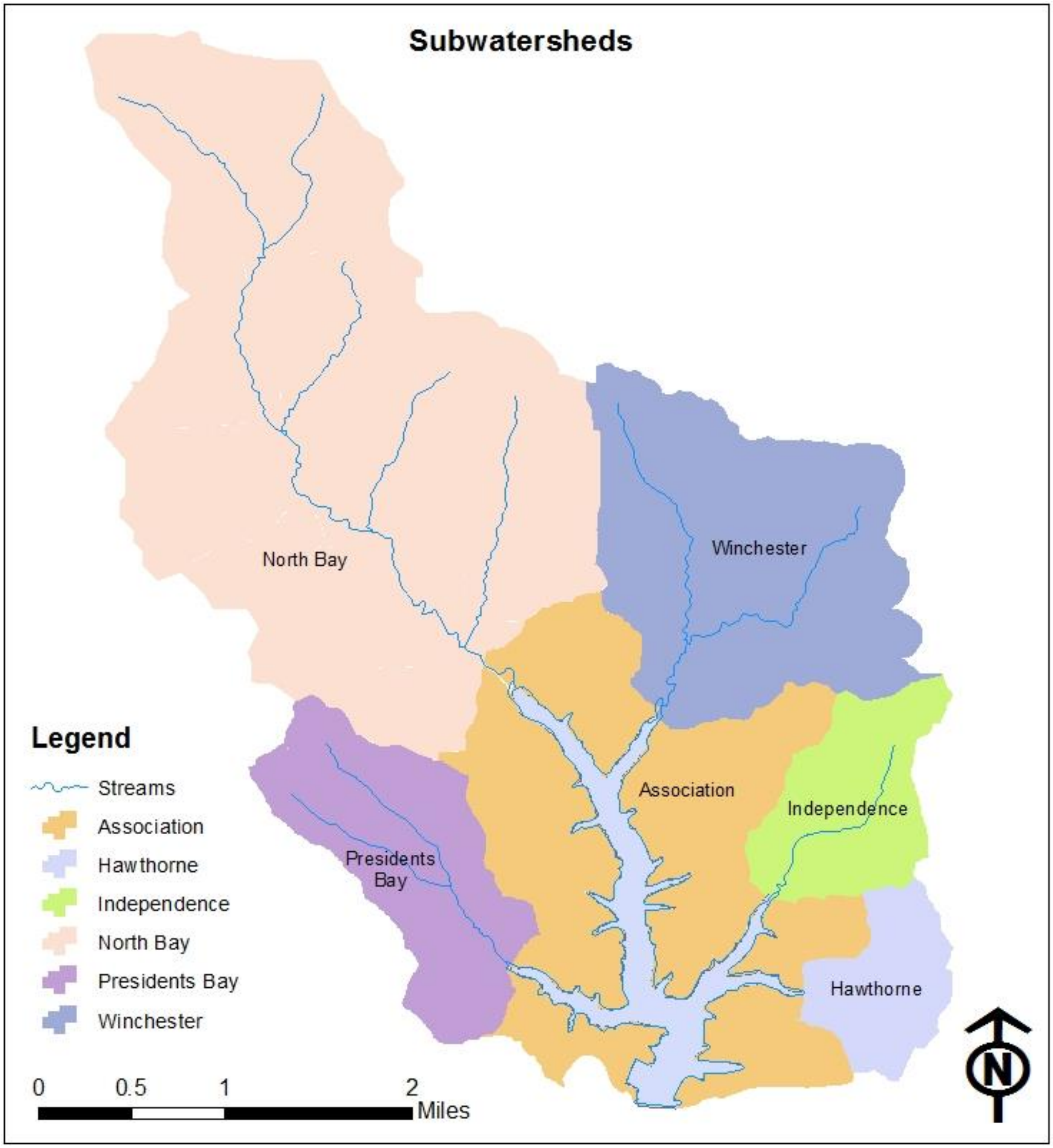

Subwatersheds
North Bay
Winchester
Association
Independence
Presidents Bay
Hawthorne
Legend
Streams
Association
Hawthorne
Independence
North Bay
Presidents Bay
Winchester
0 0.5 1 2
Miles
N

Table 4-1. Subwatershed area (acres), percentage of total watershed area, and number of perennial stream miles.

Location	Acreage	% of Watershed	Stream Miles
Hells Brach / North Bay	**4,072**	**41.77%**	**1.02**
Association	**2,427**	**24.90%**	**0**
Winchester	**1,555**	**15.95%**	**1.58**
Presidents	**827**	**8.48%**	**0.72**
Independence	**521**	**5.34%**	**0.62**
Hawthorne	**346**	**3.55%**	**0.42**

4.5 Bathymetry

A bathymetric map of Apple Canyon Lake was created to determine average depth and total volume of the lake (*see figure 4-7*). A sonar unit was linked to a GPS receiver and depth measurements were taken every 3 meters over the entire surface of the lake, with depths accurate to 0.1 foot. Corrections were made to account for lake level and quality control determinations found accuracy within 3%. Using this data set, average depth of the lake was determined to be 22.04 ft., maximum depth 82.7 feet, and surface area 414.88 acres. Volume of the lake was then calculated using a numerical approximation algorithm to be 2,979,551,277.88 gallons (11,278,916.14 m^3). Using flow data from Section 4.1, water in the lake has an estimated average residence time of 536 days or 1.47 years.

Figure 4-8. Subwatersheds in Apple Canyon Lake Watershed used for planning.

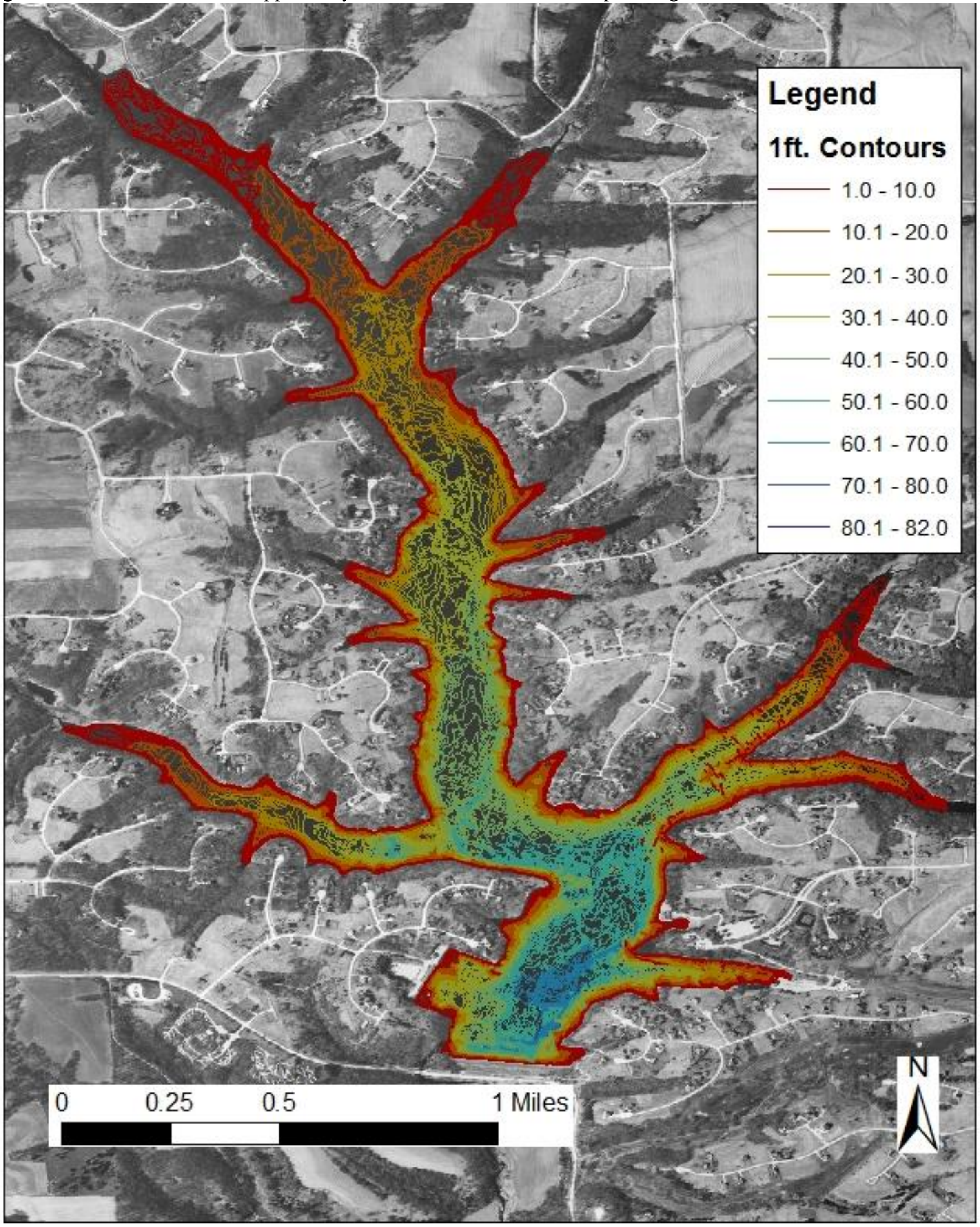


Figure 4-9. A bathymetric map of Apple Canyon Lake. Average depth of the lake was determined to be 22.04 ft., maximum depth 82.7 feet, and surface area of 414.88 acres. Total volume was calculated to be 2,979,551,277.88 gallons.

4.6 Stream Corridor Assessments

Figure 4-10. Surveying North Bay subwatershed.

Stream corridors were assessed during the summer of 2014. A total of 21 streams were identified and assessed, with a total of 95,810 ft. (18.15 miles). Assessments took place using U.S. Forest Service stream inventory protocol (U.S. Forest Service, 2008). The assessed streams shown in figure 4-9 were walked from the pool of the lake through the top of the watershed where visible surface water started to appear. Along the way, cross sections of the streams were taken at stable pool crests. The length of pools and riffles was recorded as well as average depth, maximum depth, and width. Streambank erosion extent was also recorded. Riparian conditions were noted, in addition to aquatic organisms observed, and any resource concerns noted. This information was tabulated to create tables 4-2 through 4-4.

Streambank erosion was measured for length and height. Linear regression rate (LRR) was estimated. Length, height, and LRR was input into a spreadsheet which estimates nutrient and sediment erosion rates, developed by the Illinois Department of Agriculture. This spreadsheet's calculation methods are based on Steffen (1982). Results from this assessment are shown in Tables 4-2 through 4-4.

Channel erosion and channelization were classified as none or low if no or very minor erosion or channelization were visible. Moderate was classified when erosion or channelization were noted as being recent or minor events, with the assumption that this situation is only starting to occur. High erosion and channelization were designated when the channelization was physically manipulated (straightened streams with dug channels), or is evident that it has been occurring regularly, and sediment is actively being delivered to the stream under regular flows. Similarly, riparian areas were classified as "good", "fair", or "poor". Good condition was scored when vegetation was entirely native trees and plants and a functioning riparian buffer was observed. Fair conditions were identified when non-native or invasive plants were evident, or when the riparian area was showing some signs of being affected by cropping, livestock, or lawn being mowed. Poor conditions were identified when the riparian area was thick with non-native and invasive species, vegetative cover was removed by more than 30% by livestock or agriculture, or when lawns were kept mowed to less than three inches in length. The average width of 50 feet was considered for the riparian buffer area.

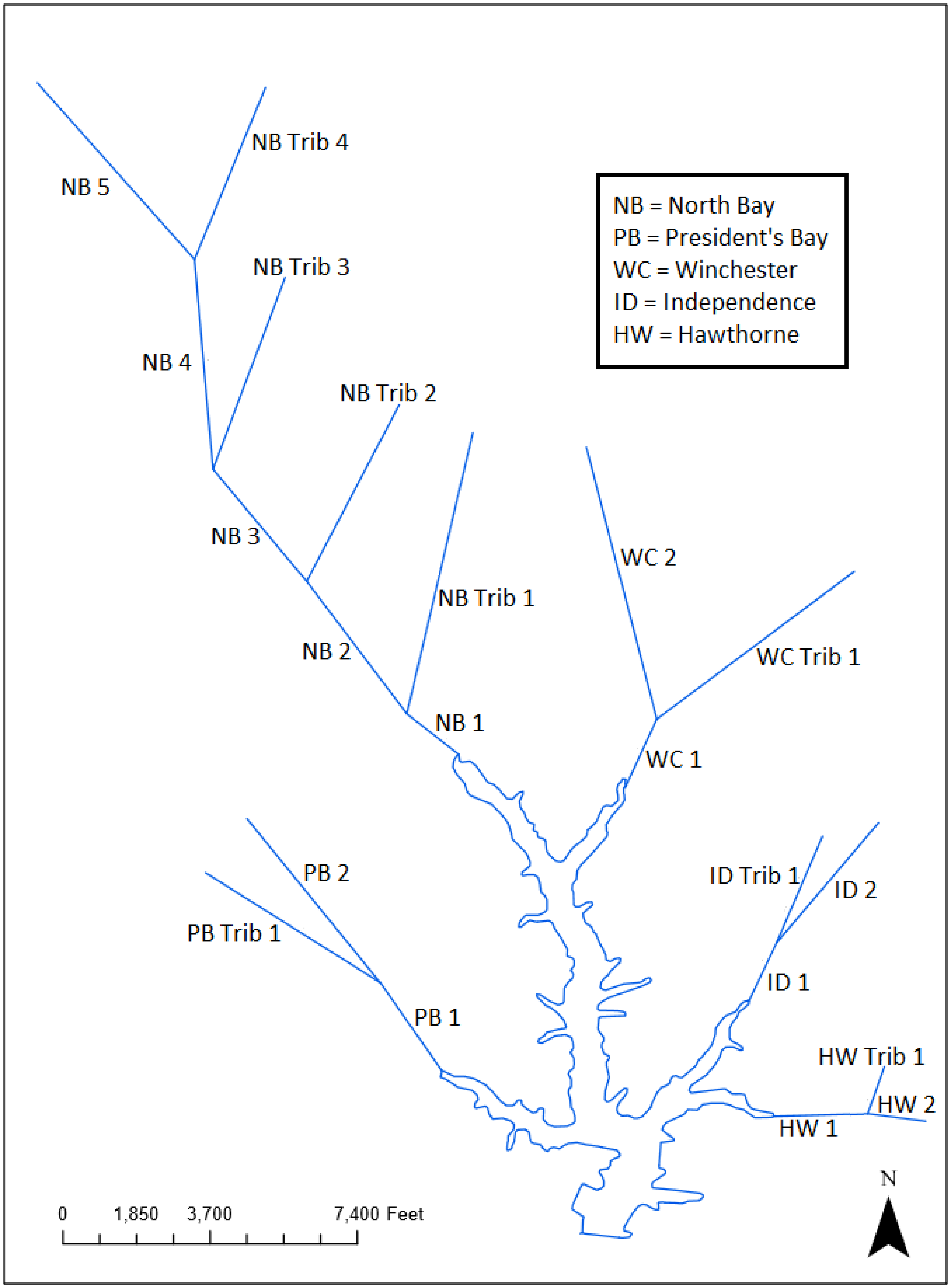


Figure 4-11. Delineation of watershed streams flowing into Apple Canyon Lake.

Table 4-2. Summary of stream and tributary channelization.

Stream or Tributary Name	Reach Code	Stream Length Assessed (ft)	None or Low Channelization (ft/%)		Moderate Channelization (ft/%)		High Channelization (ft/%)	
North Bay	NB 1	1,838	328	18%	325	18%	1,185	64%
North Bay	NB 2	5,479	3,481	64%	1,289	24%	709	13%
North Bay	NB 3	4,773	3,888	81%	885	19%	0	0%
North Bay	NB 4	6,550	5,592	85%	472	7%	486	7%
North Bay	NB 5	6,470	6,470	100%	0	0%	0	0%
North Bay	NB Trib 1	7,857	7,857	100%	0	0%	0	0%
North Bay	NB Trib 2	5,656	5,656	100%	0	0%	0	0%
North Bay	NB Trib 3	5,374	4,381	82%	0	0%	993	18%
North Bay	NB Trib 4	5,538	4,534	82%	1,004	18%	0	0%
North Bay Totals		**49,535**	**42,187**		**3,975**		**3,373**	
Presidents Bay	PB 1	2,936	1,381	47%	320	11%	1,235	42%
Presidents Bay	PB 2	5,560	2,792	50%	2,051	37%	717	13%
Presidents Bay	PB Trib 1	5,431	4,703	87%	0	0%	728	13%
Presidents Bay Totals		**13,927**	**8,876**		**2,371**		**2,680**	
Winchester	WC 1	2,471	433	18%	560	%	1,478	60%
Winchester	WC 2	8,285	4,842	58%	2,204	27%	1,239	15%
Winchester	WC Trib 1	7,688	6,713	87%	357	5%	618	8%
Winchester Totals		**18,444**	**11,988**		**3,121**		**3,335**	
Independence	IN 1	2,119	0	0%	0	0%	2,119	100%
Independence	IN 2	4,431	2,639	60%	532	12%	1,260	28%
Independence	IN Trib 1	1,823	1,750	96%	73	4%	0	0%
Independence Totals		**8,373**	**4,389**		**605**		**3,379**	
Hawthorne	HW 1	2,501	842	34%	0	0%	1,659	66%
Hawthorne	HW 2	1,755	1,505	86%	250	14%	0	0%
Hawthorne	HW Trib 1	1,275	1,093	86%	75	6%	107	8%
Hawthorne Totals		**5,531**	**3,440**		**325**		**1,766**	
Totals		**95,810**	**70,880**		**10,397**		**14,533**	

Table 4-3. Summary of stream and tributary riparian area condition.

Stream or Tributary Name	Reach Code	Stream Length Assessed (ft)	Good Condition (ft/%)		Fair Condition (ft/%)		Poor Condition (ft/%)	
North Bay	NB 1	1,838	0	0%	1,838	100%	0	0%
North Bay	NB 2	5,479	0	0%	5,479	100%	0	0%
North Bay	NB 3	4,773	0	0%	4,773	100%	0	0%
North Bay	NB 4	6,550	0	0%	6,550	100%	0	0%
North Bay	NB 5	6,470	6,470	100%	0	0%	0	0%
North Bay	NB Trib 1	7,857	7,857	100%	0	0%	0	0%
North Bay	NB Trib 2	5,656	5,656	100%	0	0%	0	0%
North Bay	NB Trib 3	5,374	5,374	100%	0	0%	0	0%
North Bay	NB Trib 4	5,538	5,538	100%	0	0%	0	0%
North Bay Totals		**49,535**	**30,895**		**18,640**		**0**	
Presidents Bay	PB 1	2,936	0	0%	2,936	100%	0	0%
Presidents Bay	PB 2	5,560	3,733	67%	1,827	33%	0	0%
Presidents Bay	PB Trib 1	5,431	4,703	87%	728	13%	0	0%
Presidents Bay Totals		**13,927**	**8,436**		**5,491**		**0**	
Winchester	WC 1	2,471	0	0%	0	%	2,471	100%
Winchester	WC 2	8,285	2,862	35%	5,423	65%	0	0%
Winchester	WC Trib 1	7,688	4,365	57%	2,273	30%	1,050	14%
Winchester Totals		**18,444**	**7,227**		**7,696**		**3,521**	
Independence	IN 1	2,119	1,262	60%	757	36%	100	5%
Independence	IN 2	4,431	4,431	100%	0	0%	0	0%
Independence	IN Trib 1	1,823	1,823	100%	0	0%	0	0%
Independence Totals		**8,373**	**7,516**		**757**		**100**	
Hawthorne	HW 1	2,501	0	0%	1,500	60%	1,001	40%
Hawthorne	HW 2	1,755	0	0%	1,755	100%	0	0%
Hawthorne	HW Trib 1	1,275	0	0%	1,275	100%	0	0%
Hawthorne Totals		**5,531**	**0**		**4,530**		**1,001**	
Totals		**95,810**	**54,074**		**37,114**		**4,622**	

Table 4-4. Summary of stream and tributary bank erosion.

Stream or Tributary Name	Reach Code	Stream Length Assessed (ft)	None or Low Erosion (ft/%)		Moderate Erosion (ft/%)		High Erosion (ft/%)	
North Bay	NB 1	1,838	1,384	75%	0	0%	454	25%
North Bay	NB 2	5,479	4,532	83%	0	0%	947	17%
North Bay	NB 3	4,773	3,646	76%	0	0%	1127	24%
North Bay	NB 4	6,550	5,075	77%	0	0%	1475	23%
North Bay	NB 5	6,470	6,470	100%	**0**	0%	**0**	0%
North Bay	NB Trib 1	7,857	7,857	100%	**0**	0%	**0**	0%
North Bay	NB Trib 2	5,656	5,656	100%	**0**	0%	**0**	0%
North Bay	NB Trib 3	5,374	4,926	92%	**0**	0%	**448**	8%
North Bay	NB Trib 4	5,538	5,538	100%	**0**	0%	**0**	0%
North Bay Totals		**49,535**	**4464**		**0**		**4003**	
Presidents Bay	PB 1	2,936	1,765	60%	**15**	1%	**1156.5**	39%
Presidents Bay	PB 2	5,560	4,318	78%	**0**	0%	**1242**	22%
Presidents Bay	PB Trib 1	5,431	5,034	93%	**0**	0%	**397**	7%
Presidents Bay Totals		**13,927**	**2372**		**15**		**2795.5**	
Winchester	WC 1	2,471	302	12%	**0**	%	**2169**	88%
Winchester	WC 2	8,285	4,721	57%	**30**	0%	**3534**	43%
Winchester	WC Trib 1	7,688	**17**	0%	**0**	0%	**464**	6%
Winchester Totals		**18,444**	**4090**		**144**		**6167**	
Independence	IN 1	2,119	1,072	51%	**0**	0%	**1047**	49%
Independence	IN 2	4,431	3,874	87%	**0**	0%	**557**	13%
Independence	IN Trib 1	1,823	999	55%	**0**	0%	**824**	45%
Independence Totals		**8,373**	**2247**		**0**		**2428**	
Hawthorne	HW 1	2,501	1,411	56%	**0**	0%	**1090**	44%
Hawthorne	HW 2	1,755	1,263	72%	**25**	1%	**467.5**	27%
Hawthorne	HW Trib 1	1,275	1,244	98%	**0**	0%	**31**	2%
Hawthorne Totals		**5,531**	**681.1**	**2968%**	**25**	**1.0895**	**1588.5**	**69.2277**
Totals		**95,810**	**13,854**		**184**		**16,982**	

4.7 Lake Shoreline Assessment

Apple Canyon Lake contains 14.83 miles of shoreline. Of this area, 8.90 miles are owned by the property owners association, and 5.93 miles are privately owned by members. The lake shoreline was assessed similarly to the streams in the watershed. Erosion was physically measured along the shoreline and classified as high, medium or low erosion (*see section 4.5 for a definition of classifications*). Each section was georeferenced using GPS and plotted on high-resolution maps. The distinction was further made whether the section was Association property or private property. The 50 ft. riparian area (buffer) around the shoreline was also assessed for high, medium, or low integrity using the same classification system as the riparian areas from the stream corridor assessments (*Section 4.5*). The Property Owners Association covenants require a 50 foot buffer on the lakeshore, however, this covenant has not been enforced. Figures and tables showing the results of these assessments follow.

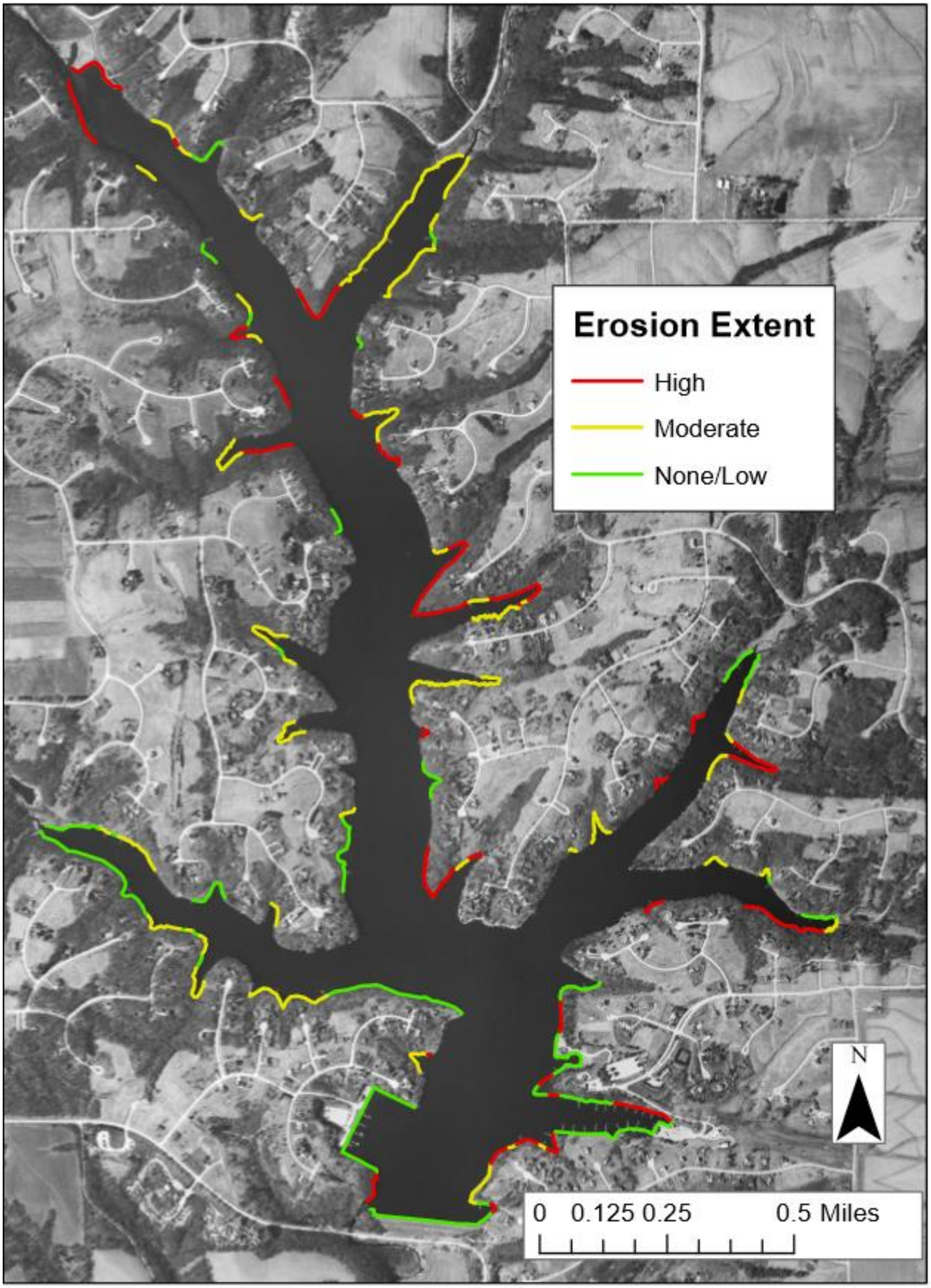


Figure 4-12. Erosion extent assessment of shoreline belonging to Apple Canyon Lake Association (common property).

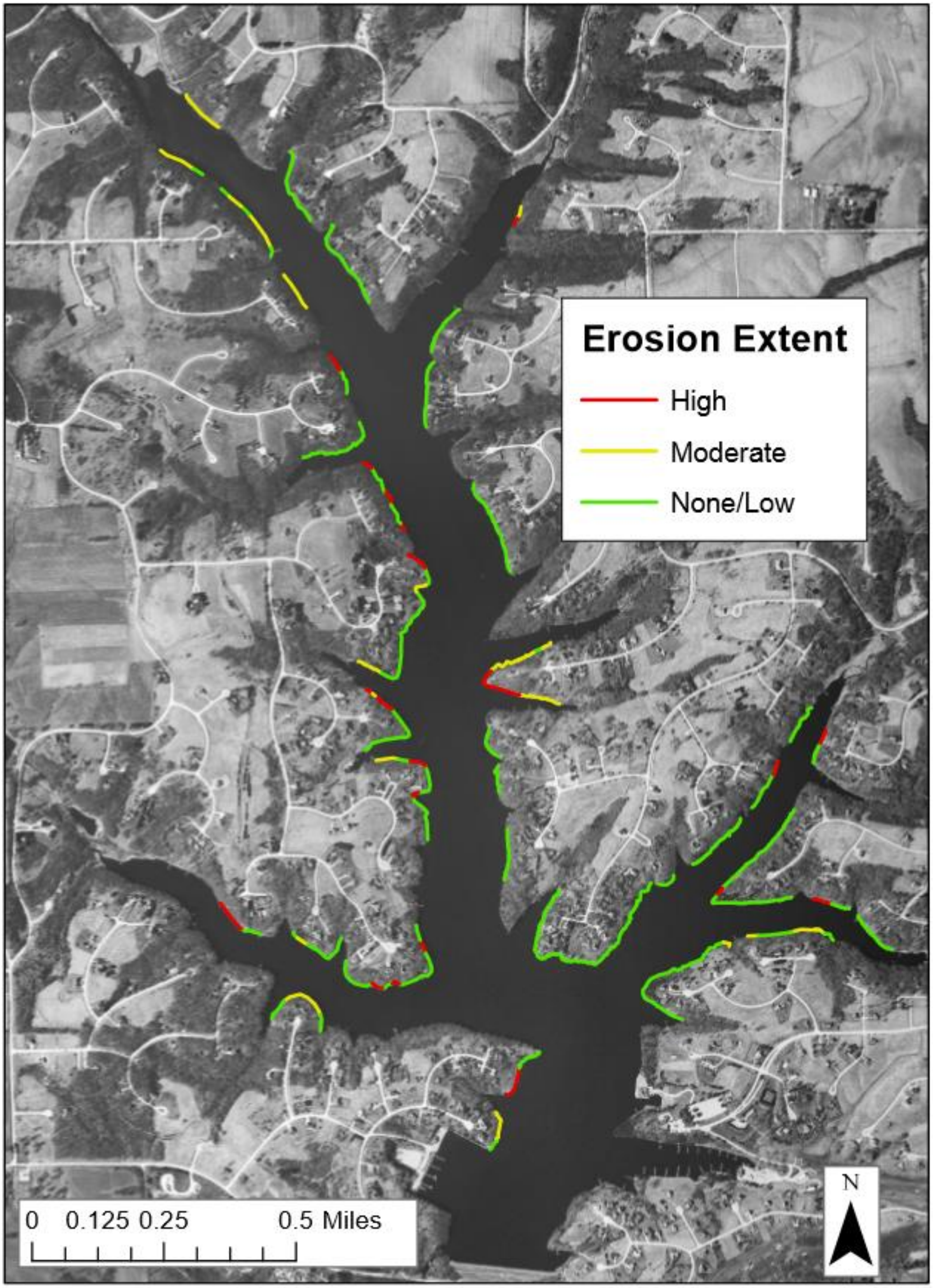


Figure 4-13. Erosion extent assessment of shoreline belonging to Private Landowners.

Table 4-5. Summary of shoreline erosion.

Lake Name	Reach Code	Shoreline Length Assessed (ft)	None or Low Erosion (ft/%)		Moderate Erosion (ft/%)		High Erosion (ft/%)	
Apple Canyon Lake	Association Shore	47,010	15,654	33.30	17,752	37.76	13,604	28.94
Apple Canyon Lake	Private Shore	31,258	22,733	72.73	5,196	16.62	3,330	10.65
Totals		**78,268**	**38,387**	**49.04**	**22,948**	**29.32**	**16,934**	**21.64**

Table 4-6. Shoreline loading reduction estimates if eroded banks are stabilized.

Shoreline Erosion Extent	Shoreline Length (ft)	Soil Saved (tons/yr)	Sediment Load Reduction (tons/yr)	Nitrogen Load Reduction (lb/yr)	Phosphorous Load Reduction (lb/yr)
None/Low Erosion	38387	171	171	343	171
Moderate Erosion	22948	683	683	1365	683
High Erosion	16934	1259	1259	2519	1259
Totals	**78269**	**2113**	**2113**	**4227**	**2113**

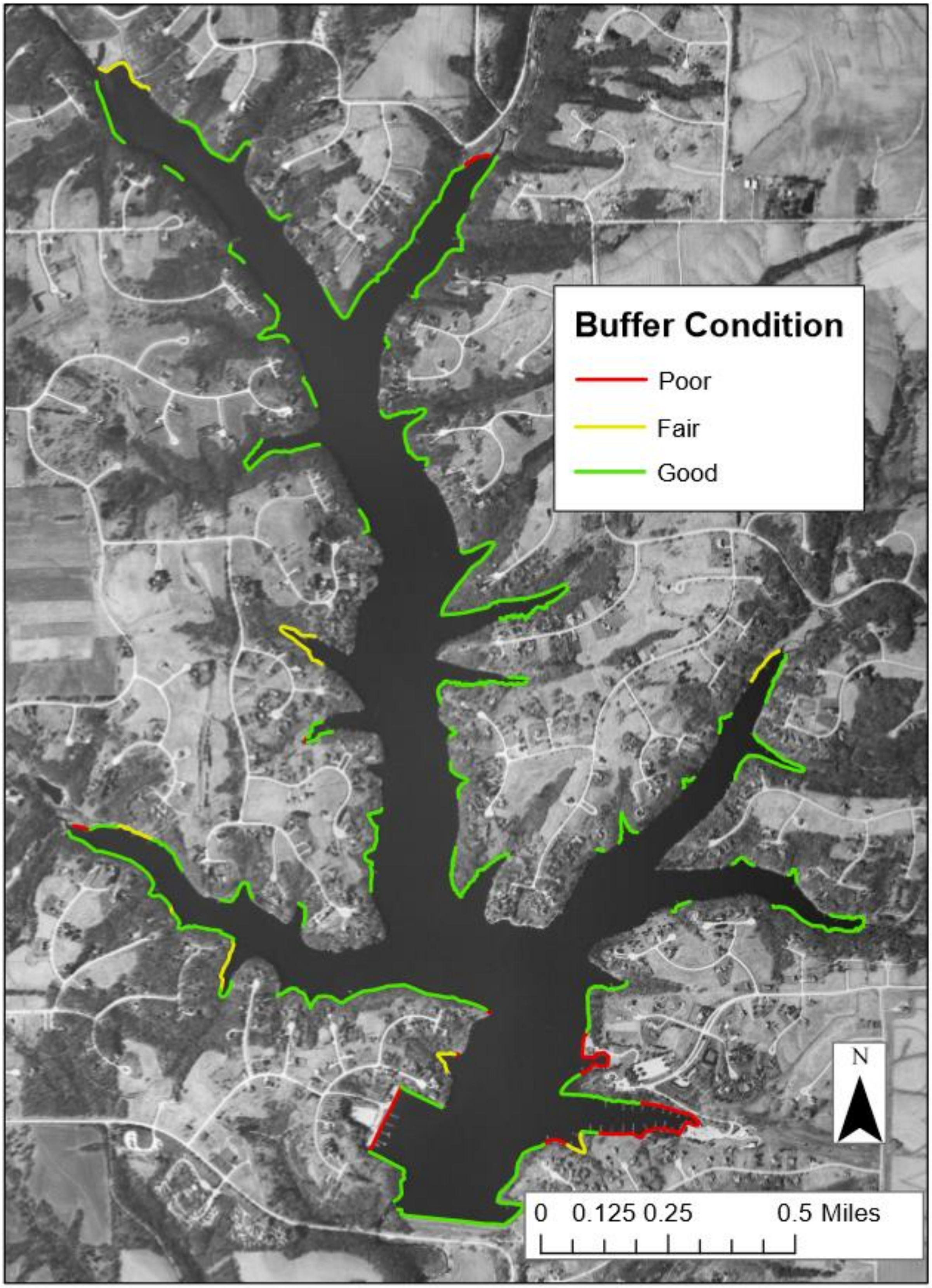


Figure 4-14. Shoreline buffer condition assessment of shoreline belonging to Apple Canyon Lake Association (common property).

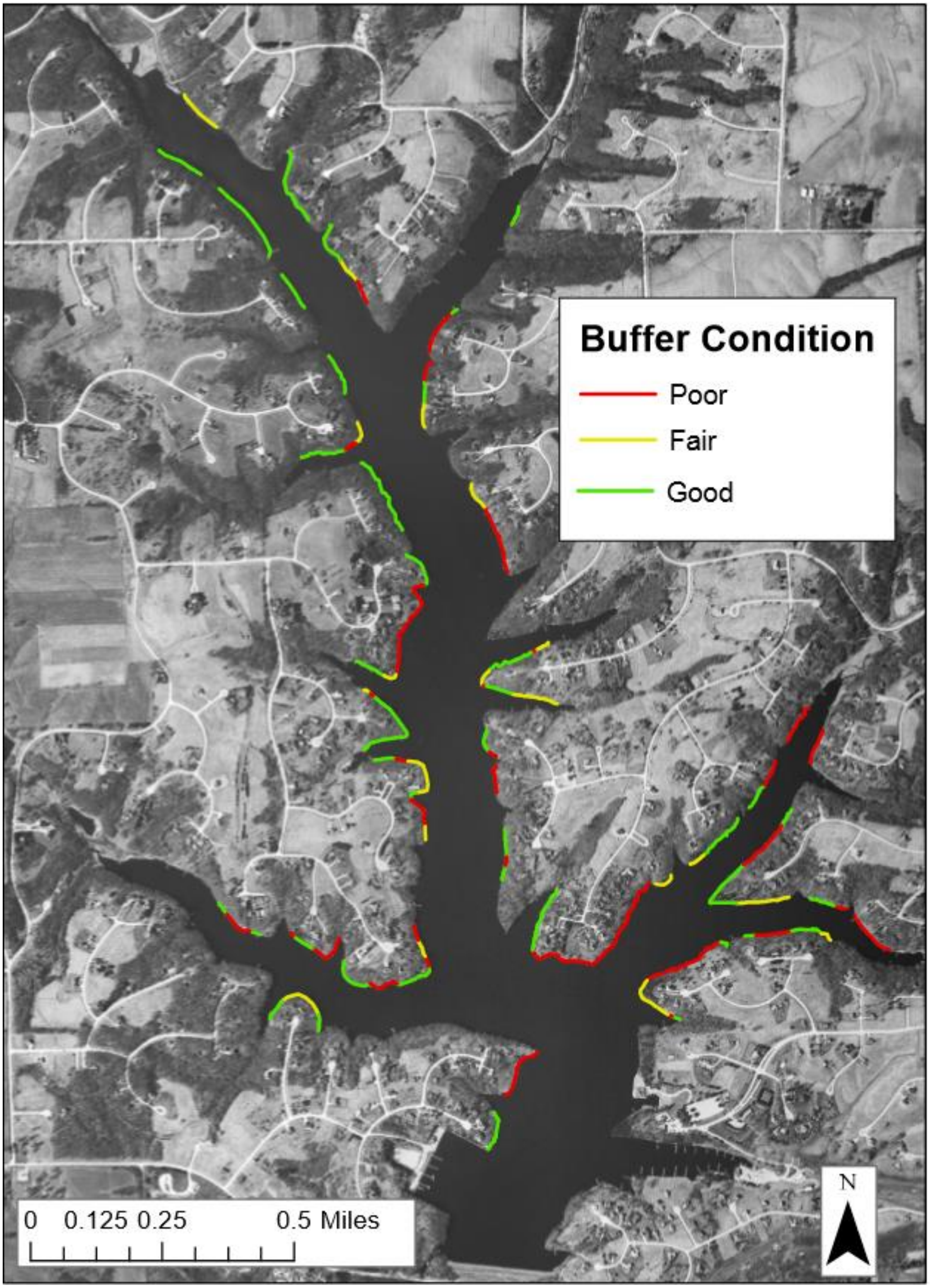


Figure 4-15. Shoreline buffer condition assessment of shoreline belonging to Private Landowners.

Table 4-7. Summary of shoreline buffer zones.

Lake Name	Reach Code	Shoreline Length Assessed (ft)	Good Condition (ft/%)		Fair Condition (ft/%)		Poor Condition (ft/%)	
Apple Canyon Lake	Association Shore	47,010	38,360	81.60	4,050	8.62	4,600	9.78
Apple Canyon Lake	Private Shore	31,258	13,981	44.73	5,389	17.24	11,888	38.03
Totals		**78,268**	**52,341**	**66.87**	**9,439**	**12.06**	**16,488**	**21.07**

4.8 Geology

The watershed is predominantly underlain with bedrock of the Ordovician Galena-Platteville formation (5,993.0 acres or 61.3%, *see figure 4-14*). Ordovician age Maquoketa shale underlays much of the uplands (3,603.2 acres or 36.8%). A small percentage of the highest points in the watershed are undifferentiated Silurian dolomite (185.2 acres or 1.9%).

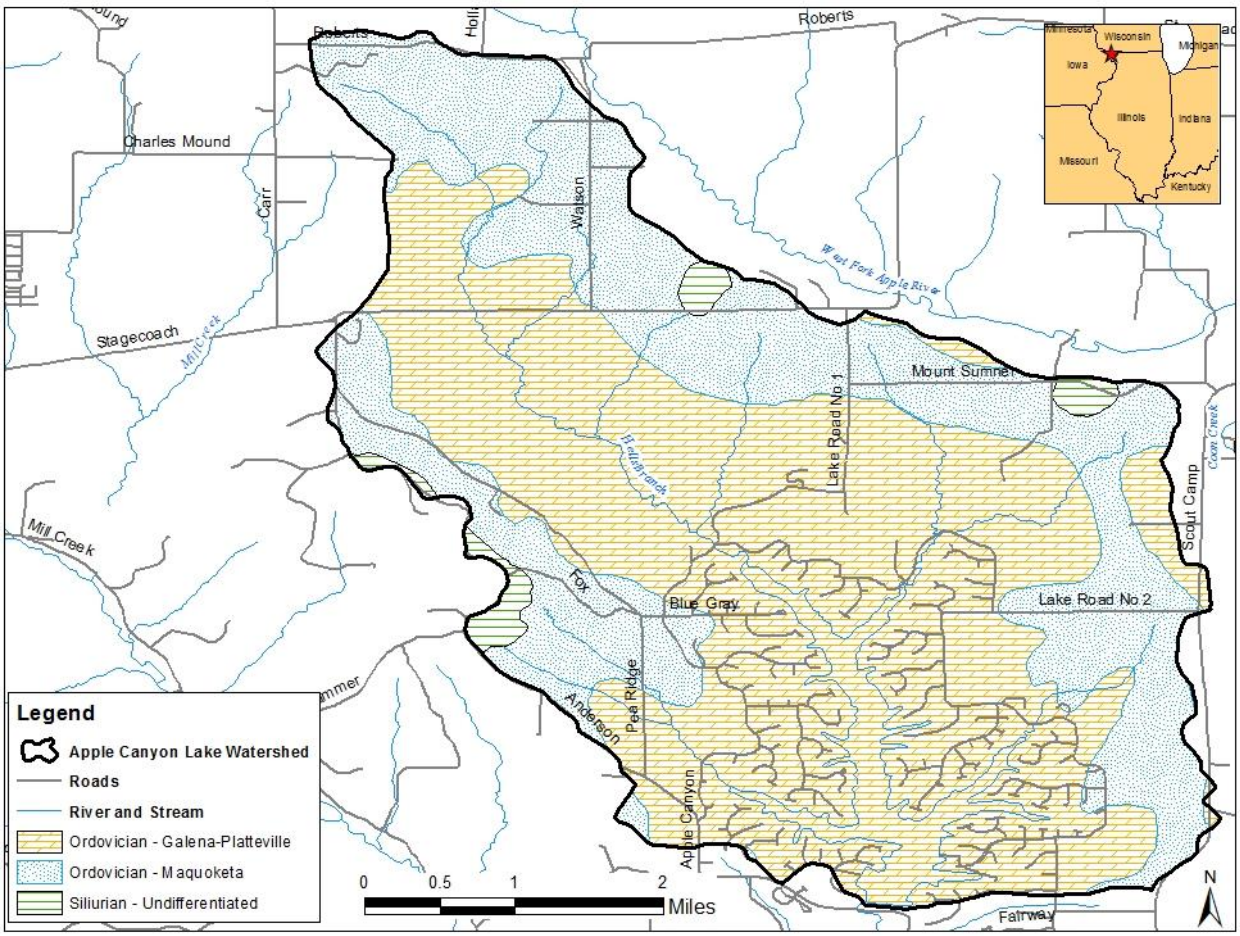


Figure 4-16. Bedrock geology of the Apple Canyon Lake Watershed.

The Galena-Platteville Unit, consisting of the Ordovician Platteville and Galena Groups, is predominantly pure limestone and dolomite, while the Maquoketa Unit consists of dolomitic shale, argillaceous dolomite, and limestone assigned to the Ordovician Maquoketa Group.

Where present within about 25-125 ft. of the bedrock surface, weathering and dissolution of the carbonate rocks (limestone and dolomite) of the Galena-Platteville and Maquoketa Units has resulted in enough secondary porosity and permeability that part or all of the units may be included in the shallow bedrock aquifer. The combined thickness of the Galena-Platteville and Maquoketa Units ranges from 100-610 ft., increasing eastward. A map referencing the geology for the area is attached.

The Maquoketa Group is composed of silty, dolomitic shale to silty, argillaceous dolomite. This uppermost Ordovician unit ranges in thickness from 0 (where eroded) to about 225feet (0 to 69 m). The Maquoketa Group has been differentiated into four formations in northeastern Illinois; however, lithologic distinctions are not readily identifiable or mappable in northwestern Illinois. Shale is compacted or cemented silt and/or clay with fine laminations along which rock easily splits.

Silurian dolomite is of limited areal extent in Jo Daviess County and forms in the highlands, and is rarely used as a groundwater source. It is possible that for large blocks of Silurian-age dolomite on ridges to separate along crevices and migrate downhill on the underlying shale, which causes linear collapse features. Carbonate rocks deposited during the Silurian and Lower to Middle Devonian Periods are included in the Silurian-Devonian Carbonate Unit. The Silurian System consists largely of dolomite, but lesser amounts of shale are present, and the dolomites may be argillaceous, silty, or clean. Within about 25 to 125 ft of the bedrock surface, the Silurian Unit incorporates secondary porosity and permeability and is included in the Shallow Bedrock Aquifer. Silurian and Devonian rocks consist mainly of dolomite and limestone. Although the Silurian and Devonian rocks overlap some Ordovician rocks, they are more closely in accord with Ordovician than with Mississippian rocks. Silurian rocks disconformably overlie Ordovician rocks (Maquoketa Shale). A disconformity separates Silurian and Devonian rocks. Devonian carbonate rocks are separated from undifferentiated Devonian-Mississippian rocks by an unconformity. These rocks are subsurface only.

4.9 Climate

Apple Canyon Lake's watershed experiences a common upper-Midwestern temperate climate with four distinct seasons, and consistent variability in temperature, precipitation, and wind (*see table 4-8).* Local residents have reported a change in weather patterns (temperatures and rainfall) since the lake was created in 1969. Research has shown that large artificial basins can affect weather patterns (Degu, et al., 2011). Surges of air moving southward from Polar Regions and tropical air moving northward from the Gulf of Mexico cause daily and seasonal temperature fluctuations. Low pressure centers form at the confluence of these two systems and result in rainfall, generally moving west to east. Where these pressure centers meet open water bodies, evaporation and thermal storage affect the weather systems differently than normal transpiration from vegetated areas. More moisture is available from large water bodies to the weather system, which can both increase precipitation events downwind, and act to dissipate storms that approach. The implications of this effect result in increased rain events surrounding large water bodies. This increased rain can synonymously lead to increases in erosion, especially in dramatically sloping areas such as Apple Canyon Lake watershed.

Accessing weather station data from Elizabeth, IL (NCDC, 2015), average annual temperatures in the watershed are 48°F. Average winters see highs in the 30s and lows in the teens, with an average of 142 days at or below 32°F and 16 days at or below 0°F. The coldest day on record is -28°F. Average summers have highs in the 80s and lows in the 60s with 24 days at or above 90°F and one day over 100°F occurring about every other year. The hottest day on record is 100.5°F. Spring and fall have moderate temperatures, with spring highs around 57°F and lows of 36°F and fall highs of 60°F and lows of 40°F. The average length of the frost-free growing season is 165 days. The last occurrence of 32°F in the spring is on average April 28 and the first occurrence of this temperature in the fall is on average October 7. April, May and June are typically the wettest months and January and February are the driest months. Average annual precipitation is 36.00”. Once per year on average, the area may experience a snowfall of six inches or more. Average annual snowfall is 35.00”.

Table 4-8. Climate summary for Elizabeth, IL, Illinois, and the United States.

Summary	Elizabeth, IL	Illinois	United States
Weather Index	33	90	100
Hail Index	75	139	100
Hurricane Index	2	14	100
Tornado Index	58	172	100
Wind Index	103	143	100
Annual Maximum Avg. Temperature	58.0° F	61.0° F	N/A
Annual Minimum Avg. Temperature	38.0° F	42.0° F	N/A
Annual Avg. Temperature	47.7° F	51.1° F	N/A
Percent of Possible Sunshine	52	57	N/A
Mean Sky Cover (Sunrise to Sunset - Out of 10)	6	6	N/A
Mean Number of Days Clear (Out of 365 Days)	93	99	N/A
Mean Number of Days Rain (Out of 365 Days)	118	115	N/A
Mean Number of Days Snow (Out of 365 Days)	11	8	N/A
Avg. Annual Precipitation (Total Inches)	36.00"	36.00"	N/A
Avg. Annual Snowfall (Total Inches)	35.00"	27.00"	N/A

4.10 Soils

Soil conditions were referenced from the USDA-NRCS Soil Survey or Jo Daviess County, last updated 12/06/2013.   Erosion factor indicates the susceptibility of a soil to sheet and rill erosion by water. K-Factor is one of six factors used in the Universal Soil Loss Equation (USLE) and the Revised Universal Soil Loss Equation (RUSLE) to predict the average annual rate of soil loss by sheet and rill erosion in tons per acre per year. The estimates are based primarily on percentage of silt, sand, and organic matter and on soil structure and saturated hydraulic conductivity (sat). Values range from 0.02 to 0.9. Other factors being equal, the bigger the value, the more susceptible the soil is to sheet and rill erosion by water. Soil slope groups are shown in figure 4-15 and aggregated in Table 4-9. Class A soils are 0-2% slope, B are 3-6%

slope, C are 7-12% slope, D are 13-18% slope, E are 19-25% slope, F are 26-35% slope, and G are greater than 35% slope.

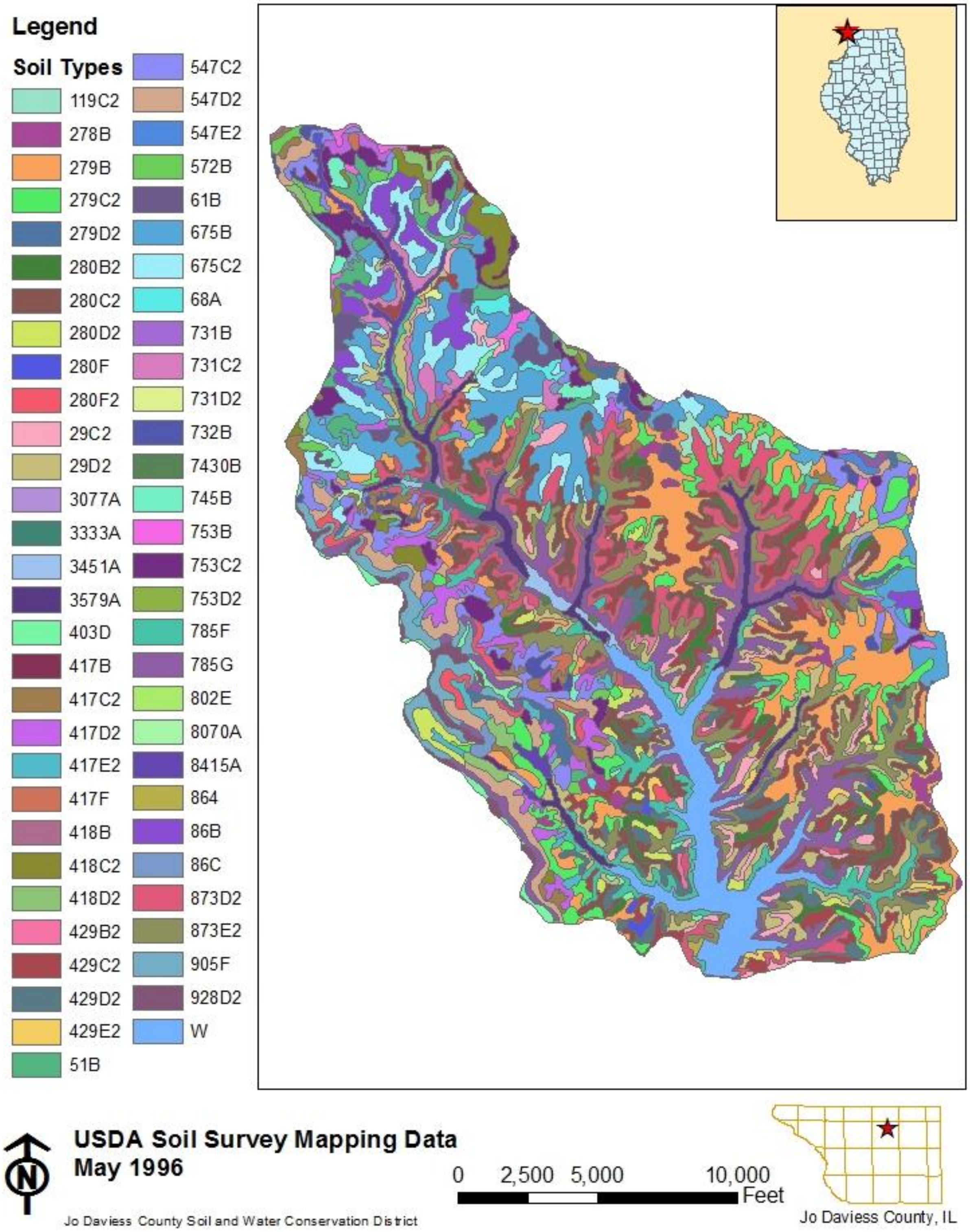


Figure 4-17. Soils map for the Apple Canyon Lake Watershed.

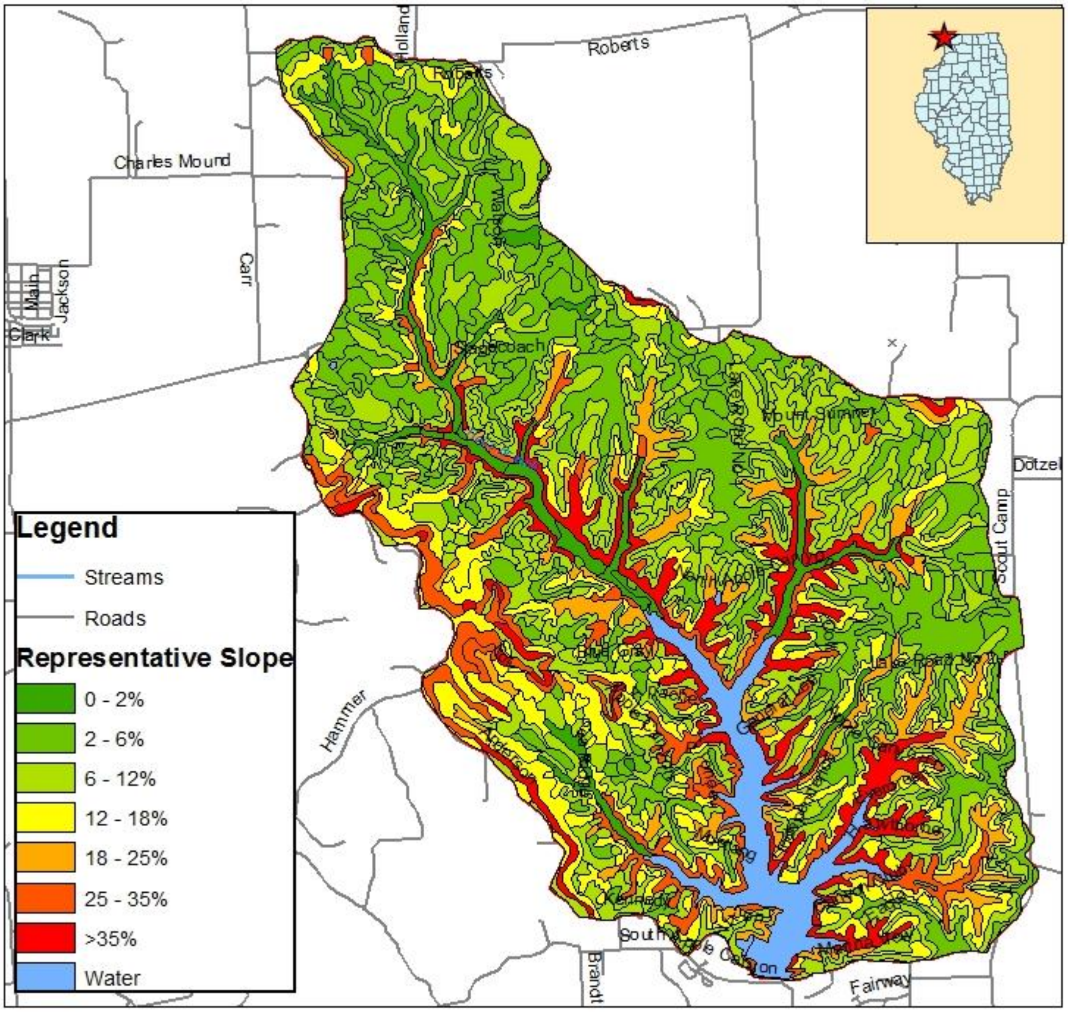


Figure 4-18. Geographic locations of soil slopes in Apple Canyon Lake watershed.

Table 4-9. Area coverage of soil slopes within Apple Canyon Lake watershed.

Soil Slopes	Acres	% of Watershed
A (0 - 2%)	391.7	4.0%
B (2 - 6%)	2,275.6	23.3%
C (6 – 12%)	2,819.7	28.8%
D (12 – 18%)	2,013.2	20.6%
E (18 – 25%)	665.0	6.8%
F (25 – 35%)	568.4	5.8%
G (>35%)	629.2	6.4%
Water	412.0	4.2%
Total	**9774.8**	**99.9%**

4.10.1 K Factor

K factor is soil erodibility factor which represents both susceptibility of soil to erosion and the rate of runoff, as measured under the standard unit plot condition. Soils high in clay have low K values, about 0.05 to 0.15, because they are resistant to detachment. Coarse textured soils, such as sandy soils, have low K values, about 0.05 to 0.2, because of low runoff even though these soils are easily detached. Medium textured soils, such as the silt loam soils, have a moderate K values, about 0.25 to 0.4, because they are moderately susceptible to detachment and they produce moderate runoff. Soils having a high silt content are most erodible of all soils. They are easily detached; tend to crust and produce high rates of runoff. Values of K for these soils tend to be greater than 0.4.

Organic matter reduces erodibility because it reduces the susceptibility of the soil to detachment, and it increases infiltration, which reduce runoff and thus erosion. Addition or accumulation of increased organic matter through management such as incorporation of manure is represented in the C factor rather than the K Factor. Extrapolation of the K factor nomograph beyond an organic matter of 4% is not recommended or allowed in RUSLE. In RUSLE, factor K considers the whole soil and factor Kf considers only the fine-earth fraction, the material of <2.00mm equivalent diameter. For most soils, Kf = K.

Soil structures affects both susceptibility to detachment and infiltration. Permeability of the soil profile affects K because it affects runoff.

Although a K factor was selected to represent a soil in its natural condition, past management or misuse of a soil by intensive cropping can increase a soil's erodibility. The K factor may need to be increased if the subsoil is exposed or where the organic matter has been depleted, the soil's structure destroyed or soil compaction has reduced permeability. A qualified soil scientist can assist in making this interpretation.

Table 4-10. K-factor by area and percentage within the Apple Canyon Lake watershed area, 16.5% is water.

k-Factor	Acres	% of Watershed
0.2	77.3	0.9%
0.24	1.7	0.0%
0.28	21.3	0.2%
0.32	1,823.2	21.3%
0.37	5,656.1	66.0%
0.43	576.5	6.7%
Water	414.88	4.8%
Total	**8,570.98**	**100%**

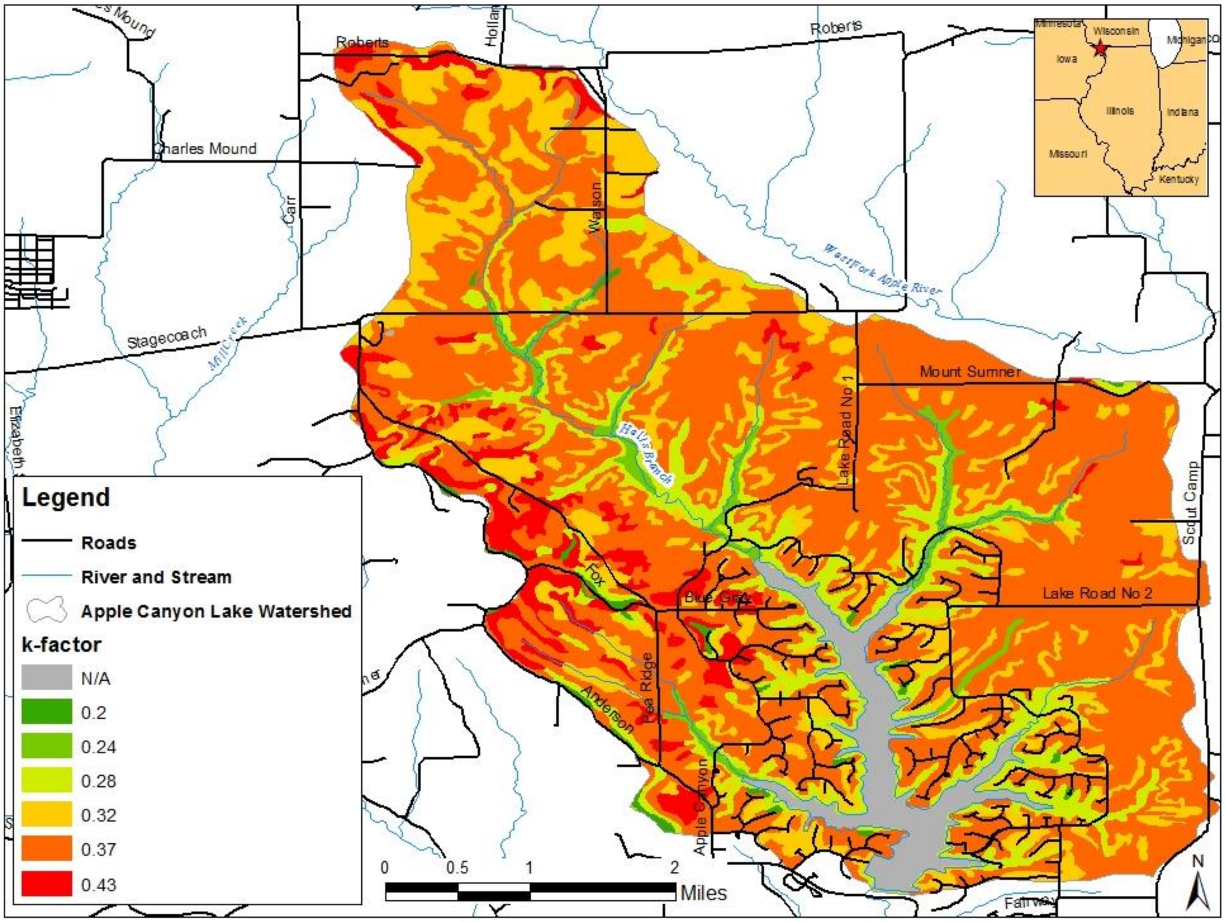


Figure 4-19. K-factor geographic dispersion within the Apple Canyon Lake watershed area.

4.10.2 Highly Erodible Soils

In the United States agriculture policy, highly erodible land (HEL) refers to land that is very susceptible to erosion, including fields that have at least 1/3 or 50 acres of soils with a natural erosion potential of at least eight times their tolerable soil loss value. Natural Resources Conservation Service soil scientists and soil conservationists determine if a soil, or soil map unit, is "highly erodible" or "potentially highly erodible" due to sheet and rill erosion. This determination is done by using the Universal Soil Loss Equation (USLE). The USLE relates the effects of rainfall, soil characteristics, and the length and steepness of slope to the soil's tolerable sheet and rill erosion rate. The maximum erosion potential is calculated without consideration to crop management or conservation practices, which can markedly lower the actual erosion rate on a given field. Highly erodible land comprises approximately 68.5% (6,694 acres) of the watershed while non-highly erodible land comprises approximately 25.7% (2,512 acres). An additional approximately 1.6% (154.9 acres) of the watershed is not classified or needs further investigation (*see figure 4-17, denoted as *NHEL*). Table 4.11 displays HEL soils in Jo Daviess County. These soils are related to conservation compliance and tied to the 1985 Farm Bill.

Table 4-11. HEL Soils in Jo Daviess County.

Mapsymbol	Soil Name	Slope (%)
27D2	Miami silt loam	10-15
29C2	Dubuque silt loam	4-10
29D2	Dubuque silt loam	10-15
36C	Tama silt loam	5-10
119C2	Elco silt loam	5-10
274C2	Seaton silt loam	5-10
274D2	Seaton silt loam	10-15
274E2	Seaton silt loam	15-25
274F	Seaton silt loam	25-45
279C2	Rozetta silt loam	5-10
279D2	Rozetta silt loam	10-15
280C2	Fayette silt loam	5-10
280D2	Fayette silt loam	10-15
280E2	Fayette silt loam	15-25
280F	Fayette silt loam	25-45
286C2	Downs silt loam	5-10
417C2	Derinda silt loam	5-10
417D2	Derinda silt loam	10-15
417E2	Derinda silt loam	15-25
417F	Derinda silt loam	25-45
418C2	Schapville silt loam	5-10
418D2	Schapville silt loam	10-15
419C2	Flagg silt loam	5-10
429C2	Palsgrove silt loam	5-10
429D2	Palsgrove silt loam	10-15
429E2	Palsgrove silt loam	15-25
504D	Elizabeth silt loam	7-15
540C2	Frankville silt loam	4-10
547C2	Eleroy silt loam	5-10
547D2	Eleroy silt loam	10-15
547E2	Eleroy silt loam	15-25
565C2	Tell silt loam	5-10
569F2	Medary silty clay loam	15-45
680C	Fayette-Orthents complex	4-12
681E	Dubuque-Orthents-Fayette complex	12-25
731C2	Nasset silt loam	5-10
731D2	Nasset silt loam	10-15
753C2	Massbach silt loam	5-10
753D2	Massbach silt loam	10-15
755F2	Massbach silt loam	15-30
779F	Lamoille silt loam	20-45
785F	Chelsea loamy fine sand	15-30
785G	Lacrescent silt loam	30-50
873D2	Dunbarton-Dubuque silt loams	7-15
873E2	Dunbarton-Dubuque siltloams	15-25
905F	Newglarus-Lamoille silt loams	15-35
928D2	Newglarus-Palsgrove silt loams	7-15

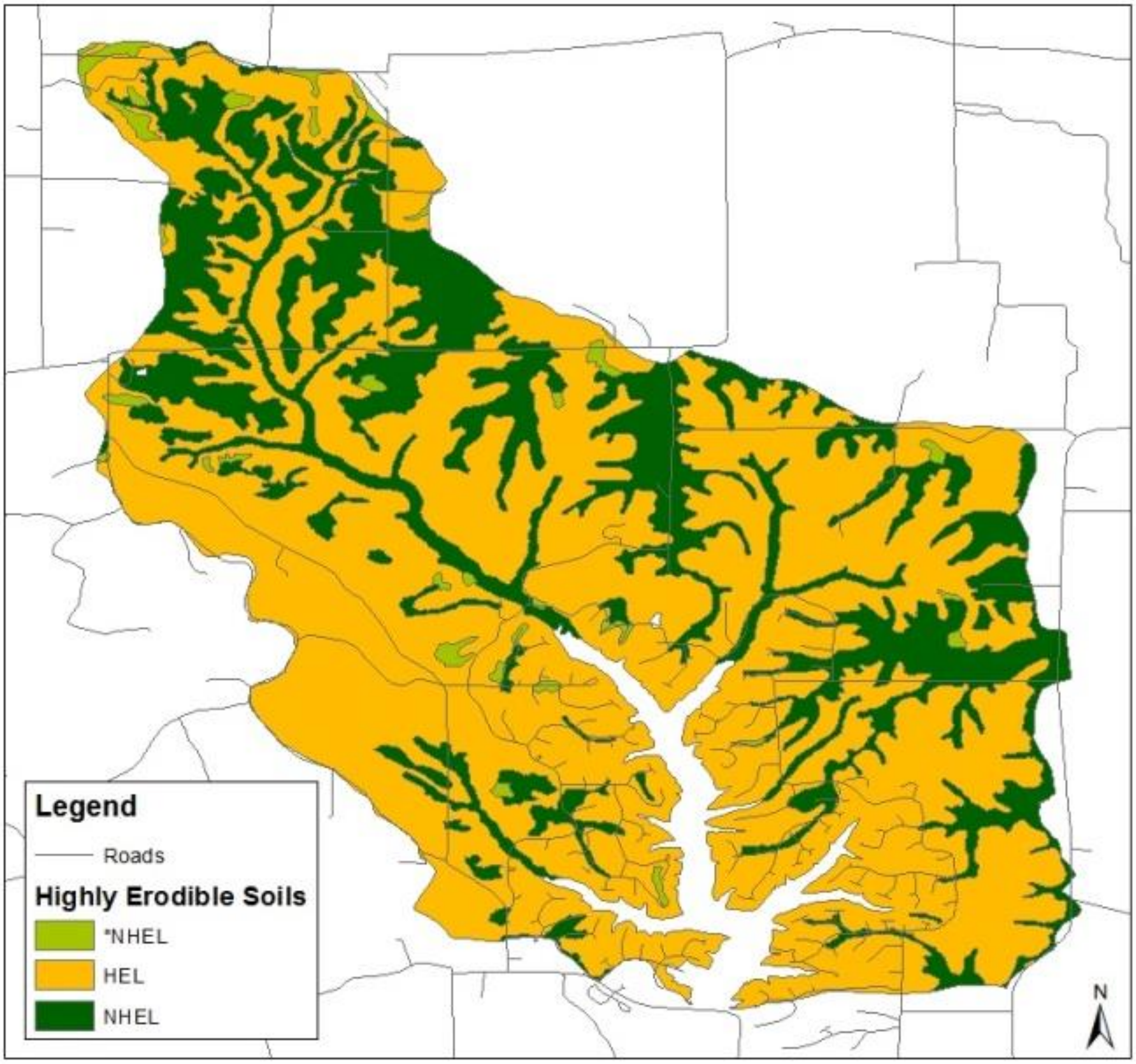


Figure 4-20. Highly erodible soils within Apple Canyon Lake watershed.

4.10.3 Hydrologic Soil Groups

Hydrologic soil groups are based on estimates of runoff potential. Soils are assigned to one of four groups according to the rate of water infiltration when the soils are not protected by vegetation, are thoroughly wet, and receive precipitation from long-duration storms.

The soils in the United States are assigned to four groups (A, B, C, and D) and three dual classes (A/D, B/D, and C/D). The groups are defined as follows:

Group A. Soils having a high infiltration rate (low runoff potential) when thoroughly wet. These consist mainly of deep, well drained to excessively drained sands or gravelly sands. These soils have a high rate of water transmission.

Group B. Soils having a moderate infiltration rate when thoroughly wet. These consist chiefly of moderately deep or deep, moderately well drained or well drained soils that have moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

Group C. Soils having a slow infiltration rate when thoroughly wet. These consist chiefly of soils having a layer that impedes the downward movement of water or soils of moderately fine texture or fine texture. These soils have a slow rate of water transmission.

Group D. Soils having a very slow infiltration rate (high runoff potential) when thoroughly wet. These consist chiefly of clays that have a high shrink-swell potential, soils that have a high water table, soils that have a claypan or clay layer at or near the surface, and soils that are shallow over nearly impervious material. These soils have a very slow rate of water transmission.

If a soil is assigned to a dual hydrologic group (A/D, B/D, or C/D), the first letter is for drained areas and the second is for undrained areas. Only the soils that, in their natural condition are in group D, are assigned to dual classes. Hydrologic soil groups are summarized in Table 4-12.

Table 4-12. Hydrologic soil groups and the area of coverage in the watershed.

Hydrologic Group	Acres	Percent of Watershed
A	206.4	2.12%
B	5004.6	51.33%
C	1981.4	20.32%
D	1619.5	16.61%
B/D	460.9	4.73%
C/D	58.0	0.59%
Pits/Quarries	6.5	0.07%
Water	411.7	4.22%
Total	**9749.0**	**99.99%**

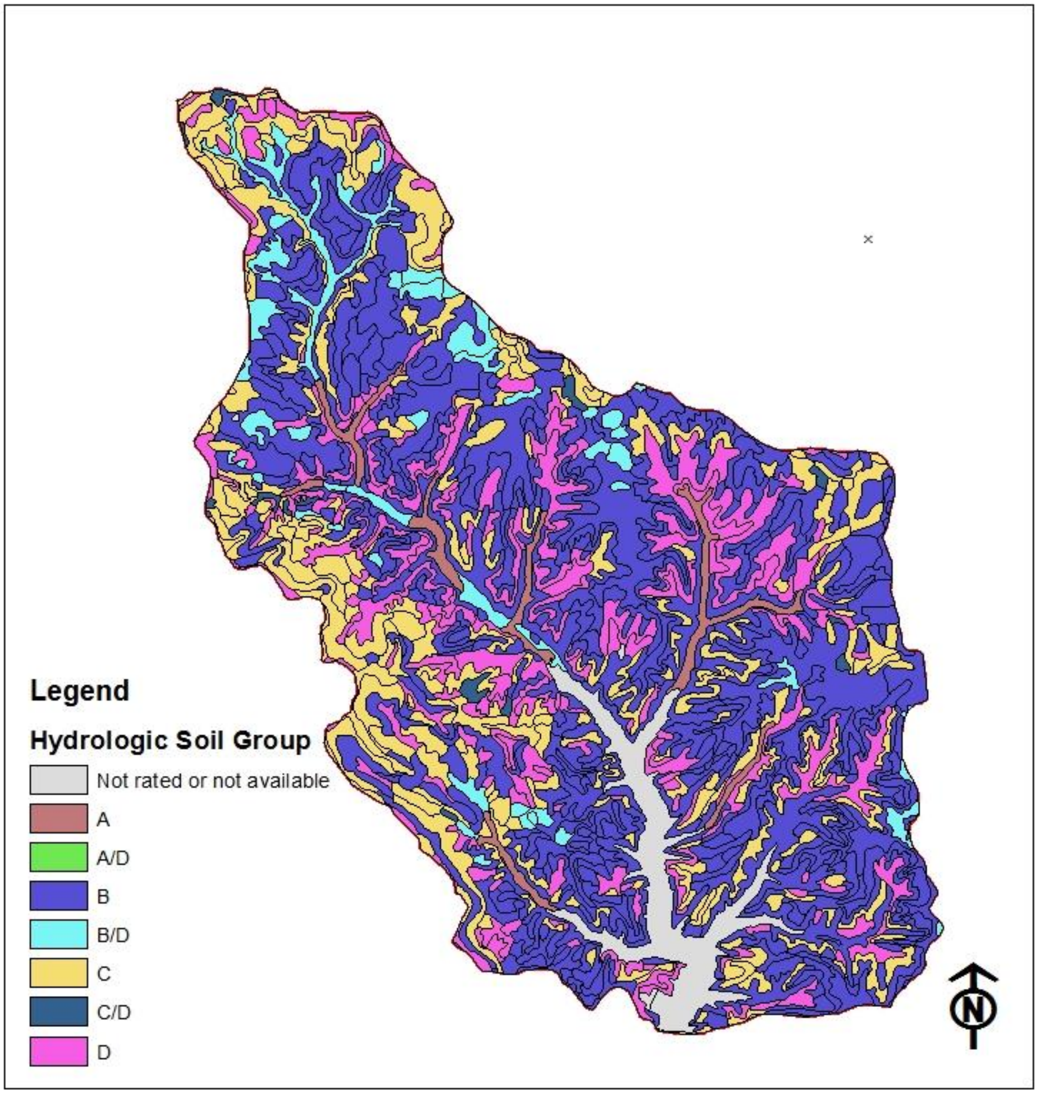


Figure 4-21. Hydrologic soil groups in the watershed.

4.10.4 Texture

Texture is given in the standard terms used by the U.S. Department of Agriculture. These terms are defined according to percentages of sand, silt, and clay in the fraction of the soil that is less than 2 millimeters in diameter. "Loam," for example, is soil that is 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand. If the content of particles coarser than sand is 15 percent or more, an appropriate modifier is added, for example, "gravelly." The Apple Canyon Lake watershed is primarily silt-loam, with some areas of cobbly silt-loam in low lying floodplains through stream corridors. Silty clay loam is common on shale bedrock on some of the ridges and hill slopes in the watershed. Figure 4-22 depicts soil texture and Table 4-13 shows these values for the watershed.

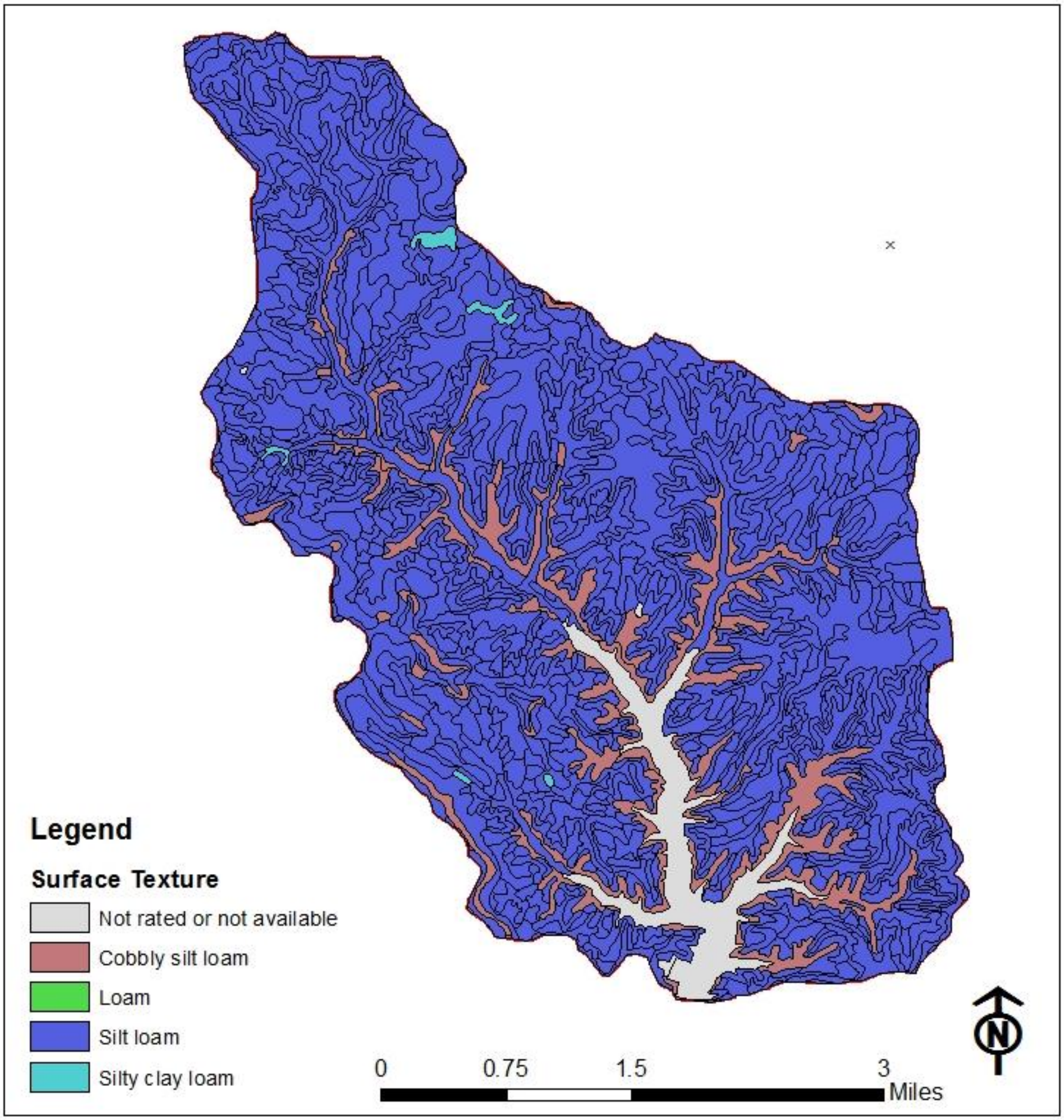


Figure 4-22. Representative texture class of the surface horizon.

Table 4-13. Summary of textures for the soils in the watershed and their corresponding acreages and percentage of the total watershed.

Texture	Acres	Percent of Watershed
Loam	0.9	0.01%
Silt Loam	8348.1	85.63%
Silty Clay Loam	38.0	0.39%
Cobbly Silt Loam	943.8	9.68%
Pits/Quarries	6.5	0.07%
Water	411.70	0.04%
Total	**9749.0**	**95.82%**

4.10.5 Drainage Class

"Drainage class" refers to the frequency and duration of wet periods under conditions similar to those under which the soil formed. Alterations of the water regime by human activities, either through drainage or irrigation, are not a consideration unless they have significantly changed the morphology of the soil. Seven classes of natural soil drainage are recognized-excessively drained, somewhat excessively drained, well drained, moderately well drained, somewhat poorly drained, poorly drained, and very poorly drained. These classes are defined in the "Soil Survey Manual." Soils in the Apple Canyon Lake watershed are primarily well drained (77.6%) and moderately well drained (11.0%). Drainage is listed and table 4-14 and depicted in figure 4-23.

Table 4-14. Summary of the drainage ratings for the soils in the watershed.

Drainage	Acres	Percent of Watershed
Poorly drained	38.0	0.4%
Somewhat poorly drained	579.1	5.9%
Moderately well drained	1069.1	11.0%
Well drained	7566.7	77.6%
Somewhat excessively drained	77.9	0.8%
Pits/Quarries	6.5	0.1%
Water	411.7	4.2%
Total	**9749.0**	**100%**

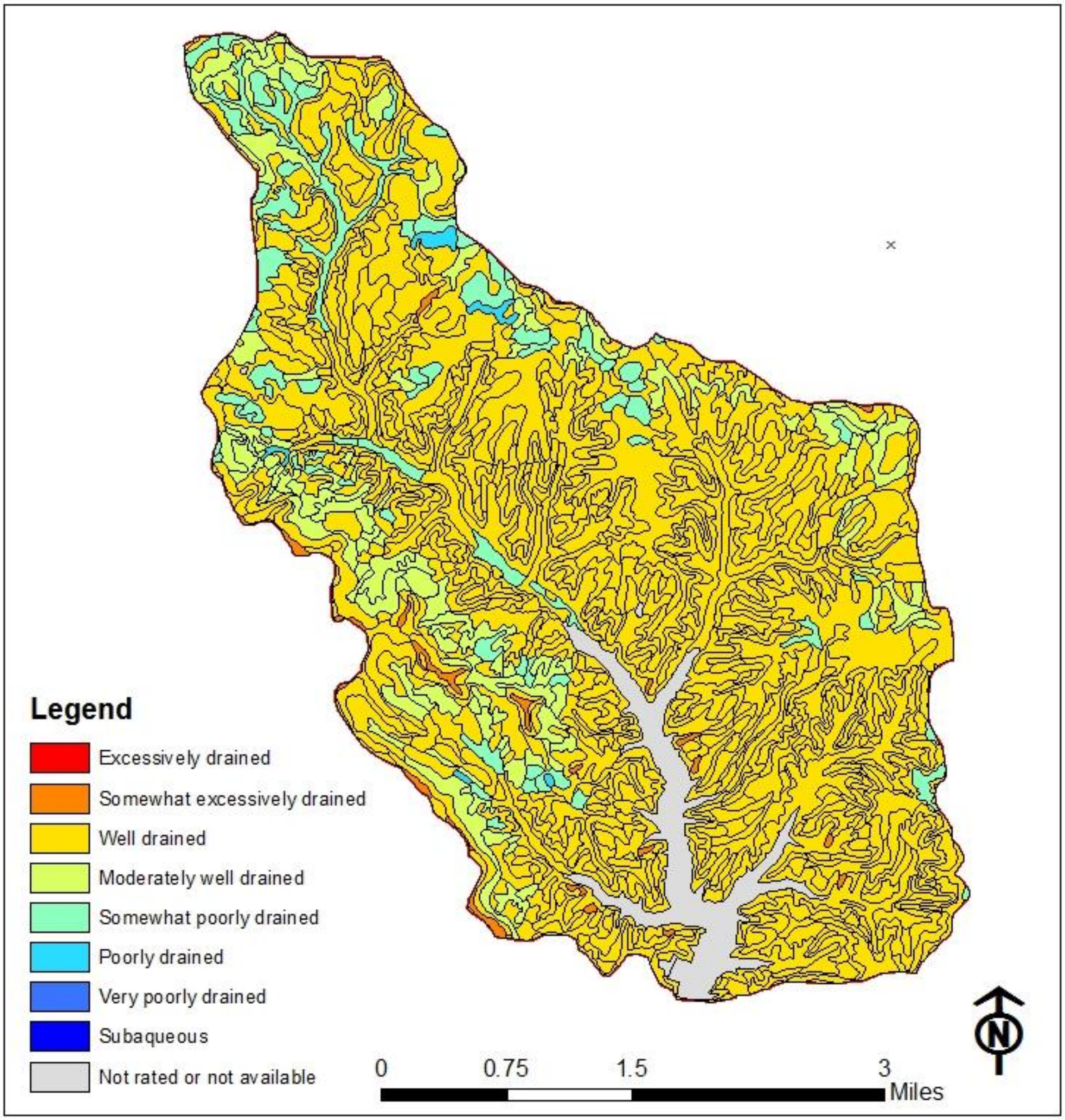


Figure 4-23. Drainage classes in the watershed.

4.10.6 Hydraulic Conductivity

Saturated hydraulic conductivity (Ksat) refers to the ease with which pores in a saturated soil transmit water. The estimates are expressed in terms of micrometers per second. They are based on soil characteristics observed in the field, particularly structure, porosity, and texture. Saturated hydraulic conductivity is considered in the design of soil drainage systems and septic tank absorption fields.

For each soil layer, this attribute is actually recorded as three separate values in the database. A low value and a high value indicate the range of this attribute for the soil component. A "representative" value indicates the expected value of this attribute for the component. For this soil property, only the representative value is used. The soils in the watershed primarily fall into the average range of greater than 2.82 and less than or equal to 9.17. Variances from this occur only in bottom drainage areas.Ksat values for the Apple Canyon Lake watershed are shown in figure 4-24.

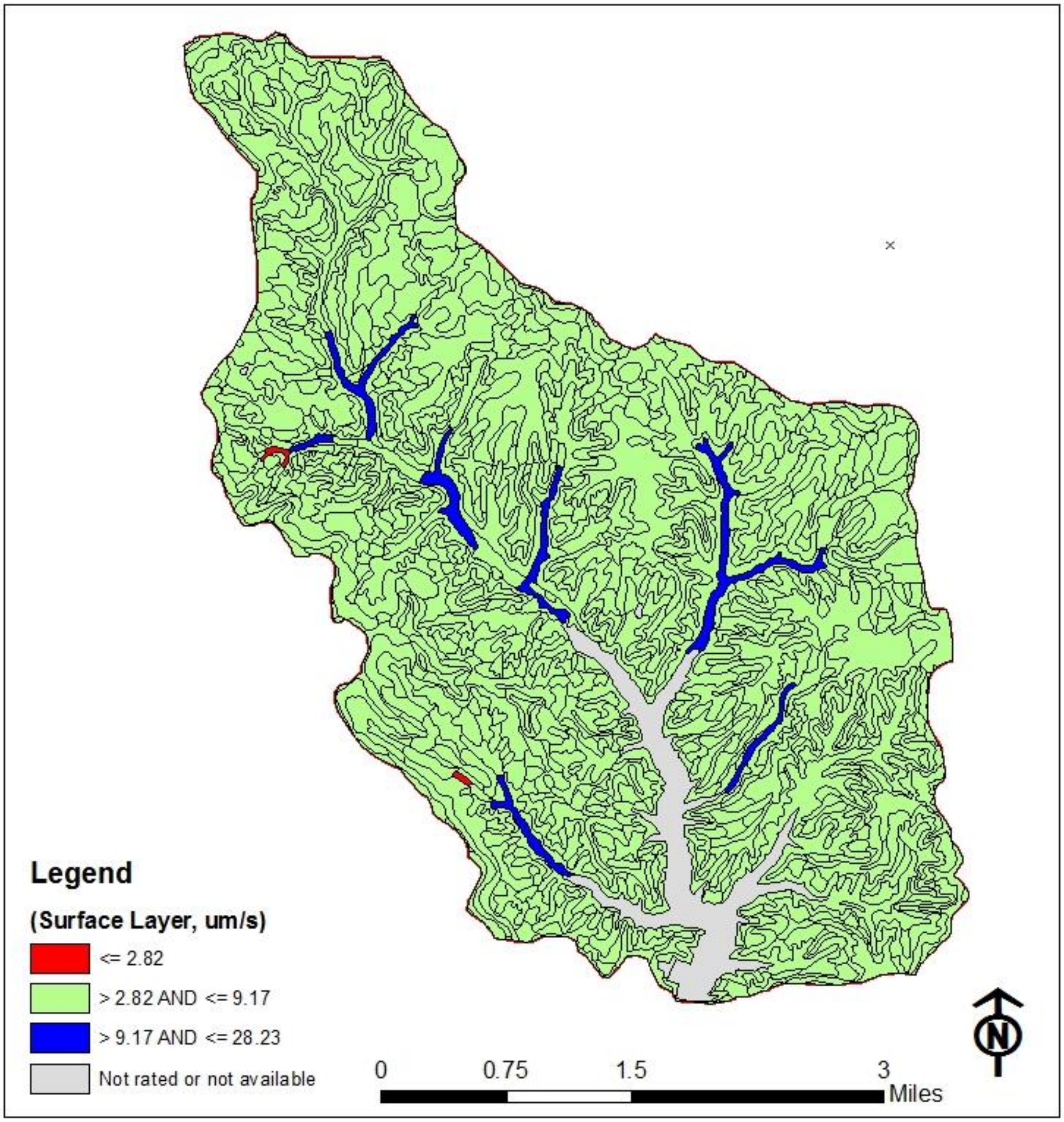


Figure 4-24. The numeric saturated hydraulic conductivity (Ksat) values have been grouped according to standard Ksat class limits.

4.10.7 Hydric Soils

Apple Canyon Lake's watershed has very few delineated wetlands. Many soil types within the watershed have hydric inclusions requiring field investigation to make the final determination. While field visits were not made to these sites to make wetland determinations, the hydric inclusion category is broad for soils in the county and state and most are unlikely to be wetlands in the topography existing in Apple Canyon Lake's watershed. Figure 4-25 shows the extent of hydric soils and inclusions as mapped and depicts many inclusions on ridgetops which are unlikely locations for hydric soils. Approximately 0.4% (37.97 acres) of the watershed is a hydric soil type with 26.5% (2,586.9 acres) containing potential hydric inclusions (USDA) (*see figure 4-25*.

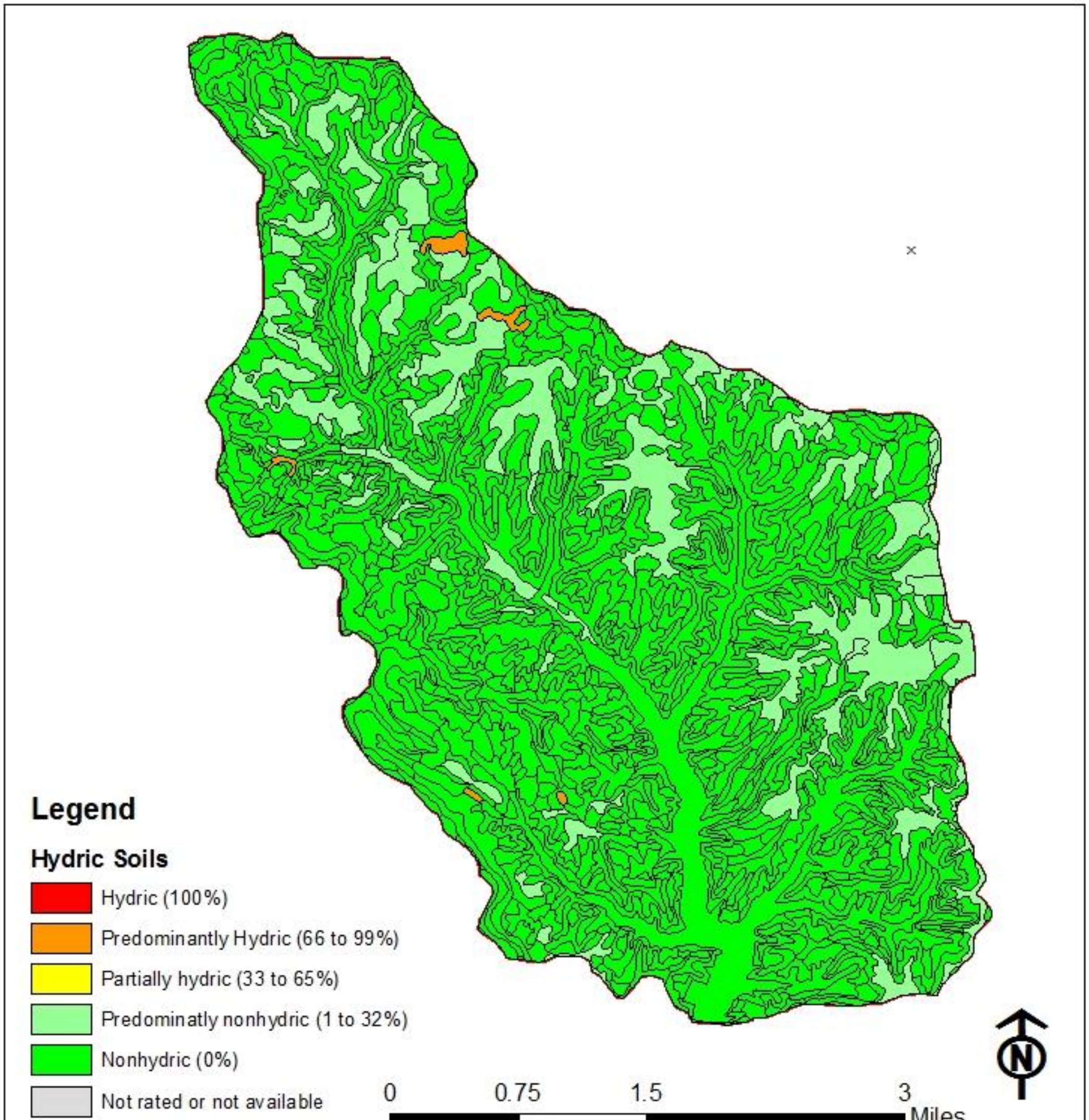


Figure 4-25. Hydric soils and hydric inclusions in the watershed.

5.0 WATER QUALITY ASSESSMENT

Apple Canyon Lake (IL_RMJ, 0706000506) is assessed by the Illinois Environmental Protection Agency (IEPA) for aquatic life, fish consumption, primary contact, secondary contact, and aesthetic quality. Neither Apple Canyon Lake nor its tributaries (AUID: IL_MNEAG-01, IL_MNEA-03, IL_MNEAE-01, IL_MNEAC-01, IL_MNEACA-01, IL_MNEAB-01) are currently listed as impaired by IEPA. Analysis of water quality data shows total phosphorus levels as the primary nutrient of concern for aesthetic quality. It is well known that phosphorus is the limiting nutrient for eutrophication in lakes (Bennett, Carpenter, & Caraco, 2001; Schindler, et al., 2008; others). Phosphorus is known to reside on the sediments of the lake. As the lake has been accumulating phosphorus for more than 40 years, this legacy sediment is expected to remain for years, even after phosphorus inputs are reduced, and can be expected to affect water quality results after BMPs are implemented.

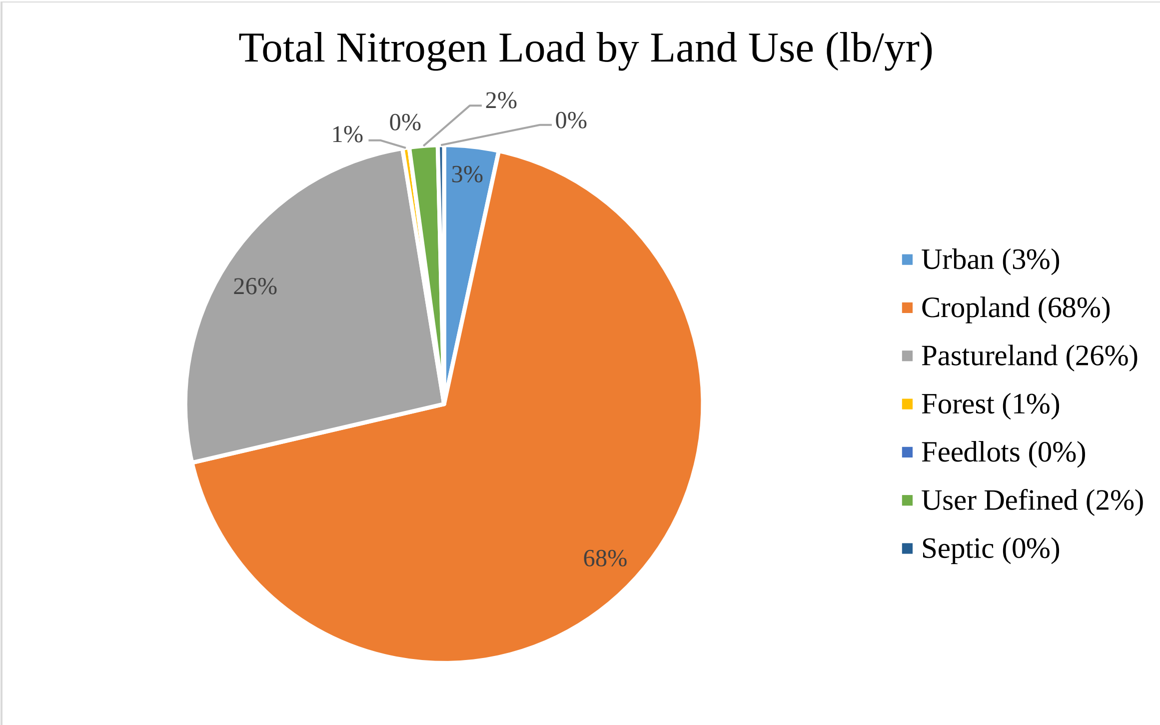
Using the STEP-L model and land-use statistics from the National Agricultural Statistics Service (NASS), annual loading estimates by land use were generated (*see figures 5-1 and 5-2, and table 5-1*). Nutrient samples are taken bi-monthly at three locations in the lake through the Illinois EPA Volunteer Lake Monitoring Program (AUID IL_RMJ-01, IL_RMJ-02, IL_RMJ-03). Tributary stream samples are taken monthly and at storm events greater than 1” rainfall. See figure 5-3 for sample site locations.

By physically measuring the chemistry and volume of water coming into the lake, in the lake, and leaving the lake, the design model accounted for an accurate balance of loading conditions in the watershed. Data from 2014 and 2015 were utilized to calculate loads for each year. Annual changes in loading can be expected based on weather conditions, such as specific rainfall events, and annual weather related trends. Modeling estimates were checked against physical samples and found to be highly accurate (+/- 0.04%). Results for each of the sampling years follows in sections 5.1 and 5.2.

Estimated pollutant loads are calculated by source using estimates from the spreadsheet tool for estimating pollutant loads (STEP-L) and shown in table 5-4. This tool estimates that cropland and pastureland are the largest contributors of nutrients in the watershed. Resource inventories in the watershed also document that gulley erosion throughout the watershed is a large contributor of sediment, and consequently phosphorus. Land use practices which reduce the overland flow of water will have the greatest impact on the reduction of gulley erosion.

Table 5-1. Total load percentages in watershed by land use type. “User Defined” category represents low-developed areas within property owners association.

Sources	N Load (%)	P Load (%)	BOD Load (%)	Sediment Load (%)
Urban	3%	2%	6%	1%
Cropland	69%	78%	56%	73%
Pastureland	25%	15%	34%	19%
Forest	0%	1%	0%	1%
Feedlots	0%	0%	0%	0%
User Defined	3%	4%	3%	7%
Septic	0%	1%	1%	0%
Total	100%	100%	100%	100%



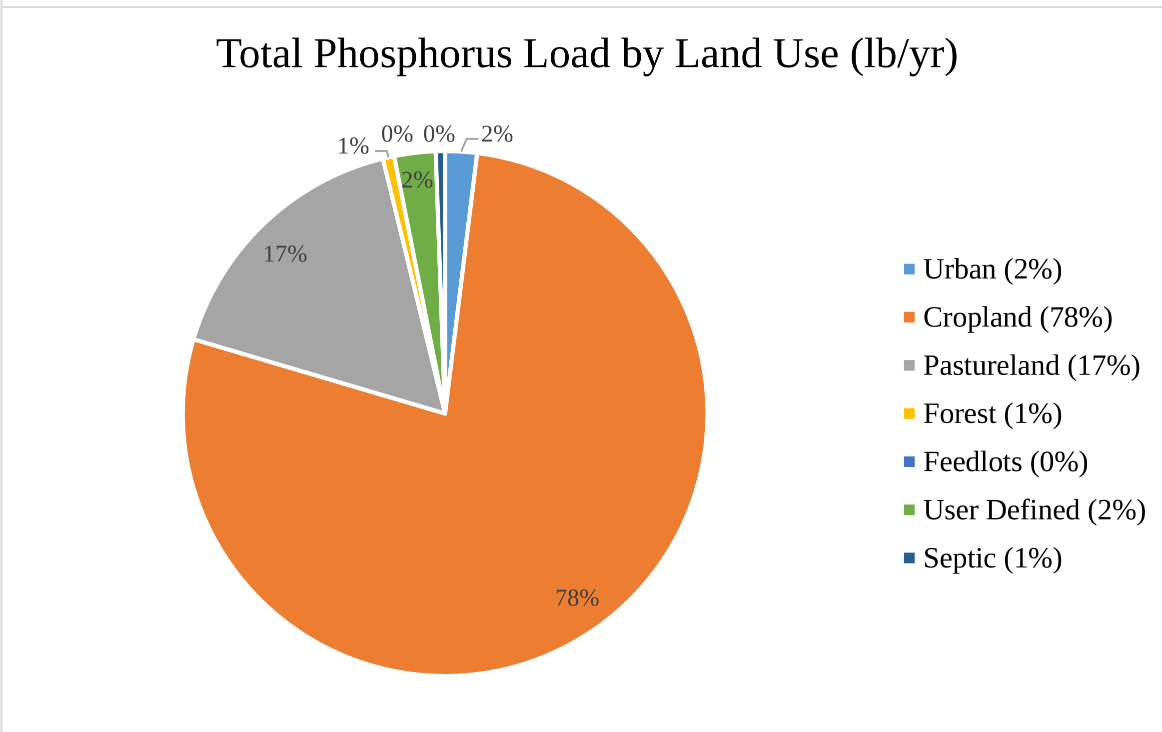
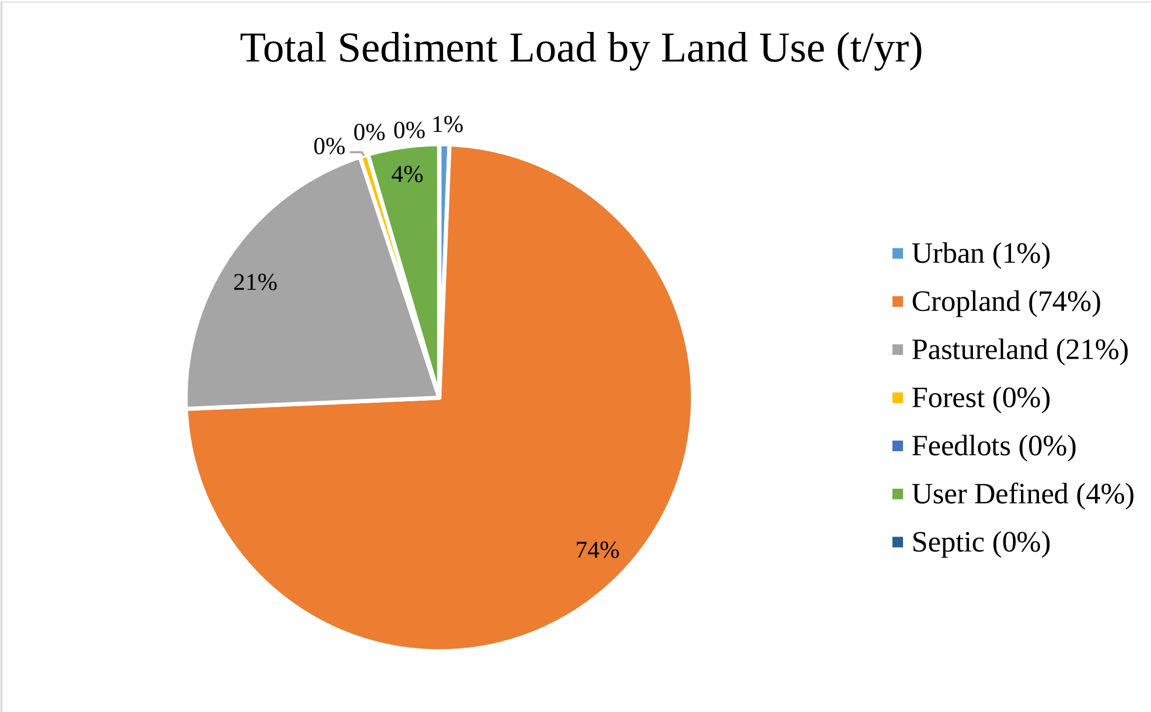


Figure 5-1. Annual loading estimates of nitrogen and phosphorous by land use, generated using the STEP-L model and land-use statistics from the NASS (2014). "User Defined" category represents low-developed areas within property owners association.



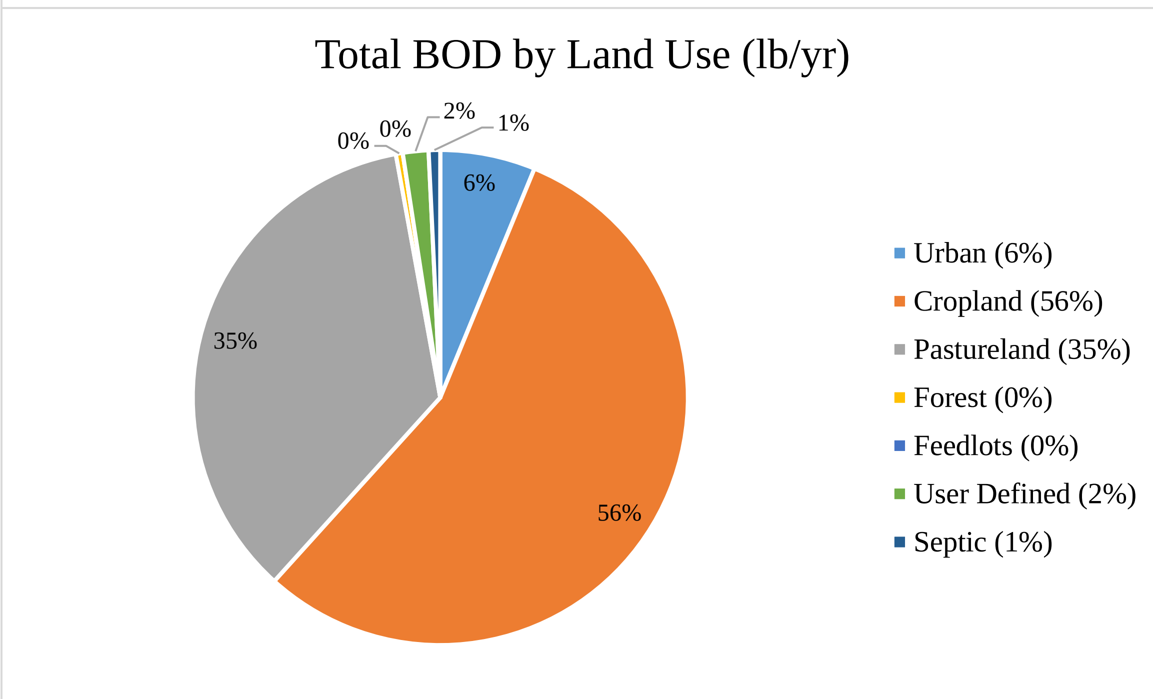


Figure 5-2. Annual loading estimates of sediment and biological oxygen demand by land use, generated using the STEP-L model and land-use statistics from the NASS (2014). “User Defined” category represents low-developed areas within property owners association.

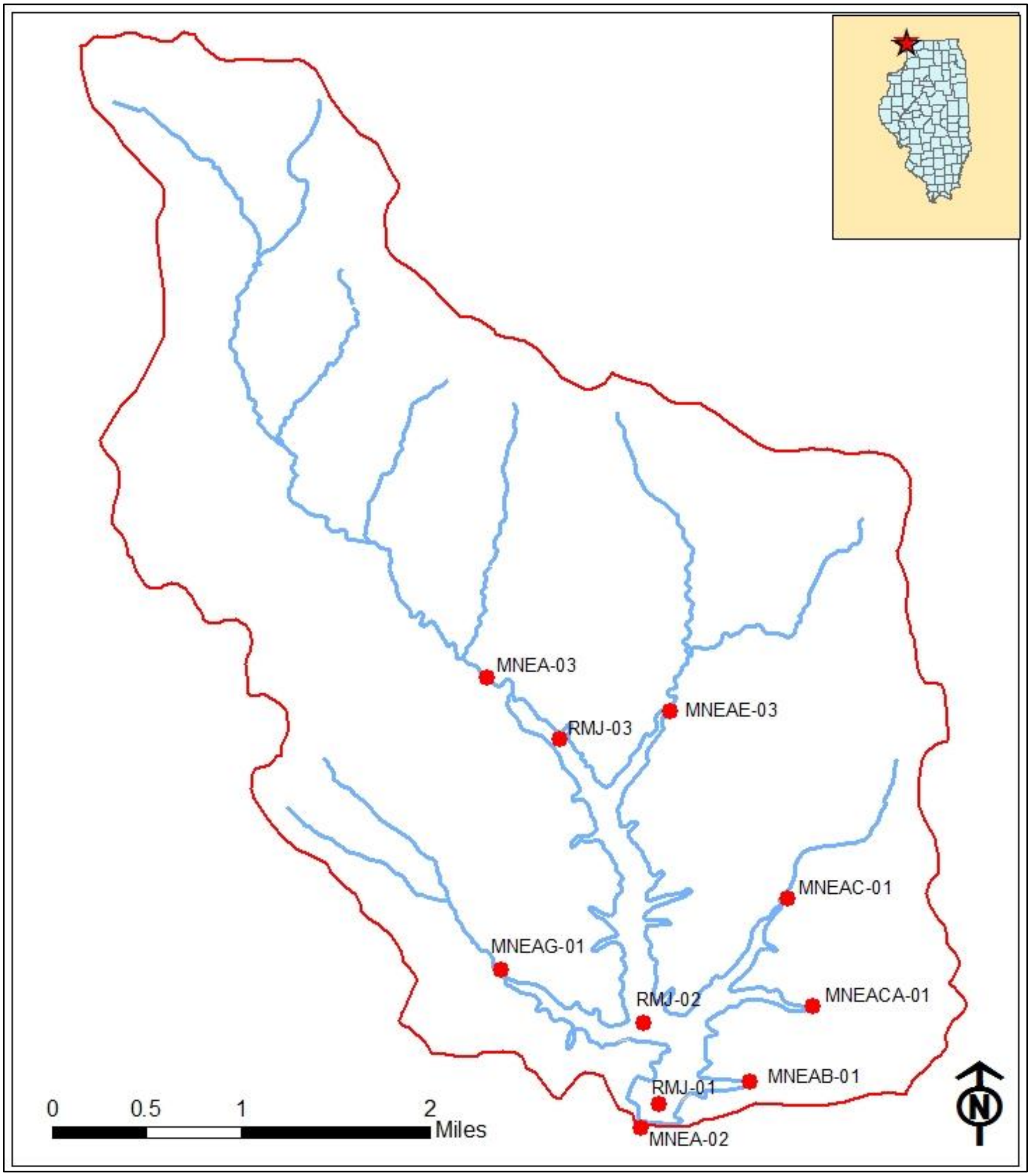


Figure 5-3. Sample locations and associated codes.

Table 5-2. Summary of stream sampling codes from above figure.

Stream Code	Subwatershed	Stream Name
MNEA-02	Association	Spillway
MNEAG-01	Presidents	President's Bay
MNEA-03	North Bay	North Bay
MNEAC-01	Independence	Independence Bay
MNEACA-01	Hawthorne	Hawthorne Bay
MNEAE-01	Winchester	Winchester Bay
MNEAB-01	Association	Marina

5.1 2014 Sampling Year

Water monitoring is completed under the guidance of the EPA approved Quality Assurance Project Plan: Apple Canyon Lake Watershed Management Plan, Version 5 (QAPP). This QAPP describes sampling sites at the major tributaries feeding Apple Canyon Lake. Sampling sites were chosen at the farthest downstream end of each tributary before entering the lake in order to provide a snapshot of each sub-watershed with each sampling event. At each sampling site for each sampling event, water samples were taken and analyzed for total phosphorus, dissolved phosphorus, nitrate/nitrite, total Kjeldahl nitrogen, ammonia, and total suspended solids. At the time of sampling a Hach Quanta water quality meter was used to determine dissolved oxygen levels, pH, temperature, and specific conductance. Additionally, velocities were recorded to across the stream's cross section in order to quantify the amount of water and constituents flowing at that site. Samples were taken monthly through the open-water season, and at the three largest flowing sites (North Bay, President's Bay, and Winchester Bay) during storm events greater than 1" rainfall.

Data for the lake was compiled from the IEPA's Volunteer Lake Monitoring Program. In this program, water temperature, secchi depth, and dissolved oxygen measurements are recorded, and water samples are analyzed for total Kjeldahl nitrogen, total phosphorus, total suspended solids, volatile suspended solids, and chlorophyll concentration. Three sites are monitored in the lake, twice a month, from May through September. These sites are located at the north, central, and southern portions of the lake, and take into account the variability in conditions found in the lake.

Total phosphorus levels observed at in-lake sites for 2014 are shown in Table 5-2. All samples exceed the total phosphorus standard of 0.05 mg/L (IL Administrative code, 1979). Four of the twelve samples (33%) are twice the applicable phosphorus standard and two of the twelve samples (17%) are three times the phosphorus standard. The average value for all surface samples taken in 2014 is 0.081 mg/L. Because phosphorus typically binds to soil particles and precipitates out in solution, deep water chemical samples were also used to calculate nutrient reductions. When deep water samples were included in the 2014 data, the average phosphorus levels rose to 0.172 mg/L.

Although Nitrogen standards do not currently exist for lakes and reservoirs or for surface waters and streams, it is well known that the nitrogen to phosphorus ratio (N:P) in a lake can be very important in changes in stable states which may favor harmful blue-green algae instead of grazing micro-invertebrates (Schindler, 2006). With this factor in mind, it is important that nitrogen reductions be proportional to phosphorus reductions to prevent harmful algal blooms from occurring. Load reduction calculations were set by combining lake load information from 2014 (*Table 5-2*) and stream load information from 2014 (*Table 5-3*), and extrapolated based on the volume of the lake and runoff estimates based on discharge recordings made at sampling time. Once total phosphorus reductions were calculated, nitrogen reduction estimates were created using the nitrogen to phosphorus (N:P) ratio of 7.2 (Jung, 2010).

Table 5-3 shows discharge readings averaged from physical discharge observations recorded at the time of chemical sampling. N:P ratios were calculated based on lab sample results and are included in the table, as well. Approximately 28% of the incoming phosphorus loads passed over the spillway of the lake and traveled downstream while 72% remained in the lake. The lake acts as a beneficial sediment trap preventing a large amount of phosphorus (approximately 2,000 pounds in 2014 and 4,858 pounds in 2015) from contributing to downstream waters. However, this sediment loading in the lake detracts from water quality and the designated uses in Apple Canyon Lake.

Table 5-3. Total phosphorus levels from Apple Canyon Lake, 2014 (IEPA, VLMP program, 2015). Deep water samples are included to provide a consistent picture of stratification impacts on loading presence.

Sample Site	Sample Depth (ft)	Collection Date	Result (mg/l)
RMJ-1	1	5/19/2014	0.068
RMJ-1	45	5/19/2014	0.199
RMJ-1	1	6/9/2014	0.07
RMJ-1	49	6/9/2014	0.372
RMJ-1	1	7/7/2014	0.149
RMJ-1	42	7/7/2014	0.42
RMJ-1	1	8/5/2014	0.061
RMJ-1	46	8/5/2014	0.47
RMJ-2	1	5/19/2014	0.079
RMJ-2	1	6/9/2014	0.057
RMJ-2	1	7/7/2014	0.184
RMJ-2	1	8/5/2014	0.064
RMJ-3	1	5/19/2014	0.076
RMJ-3	1	6/9/2014	0.081
RMJ-3	1	7/7/2014	0.269
RMJ-3	1	8/5/2014	0.138
		Average	**0.172**

Table 5-4. Average metered discharge at sampling locations, total phosphorus, and total nitrogen results from 2014 monitoring. Nitrogen/phosphorus ratio and the percentage of the phosphorus load are also included in this table.

Location (AUID)	Ave Discharge ($ft.^3/sec$)	Ave Total Phosphorus (mg/L)	Ave Total Nitrogen (mg/L)	N:P Ratio	% P Load
Spillway (MNEA-02)	3.86	0.1	0.93	9.3	28.23%
Presidents Bay (MNEAG-01)	0.21	0.31	1.02	3.3	4.77%
North Bay (MNEA-03)	1.11	0.84	3.44	4.1	66.79%
Winchester (MNEAE-01)	0.53	0.54	2.04	3.8	20.40%
Independence (MNEAC-01)	0.35	0.23	1.05	4.6	5.73%
Hawthorne (MNEACA-01)	0.08	0.32	2.03	6.3	1.74%
Marina (MNEAB-01)	0.05	0.17	0.9	5.3	0.57%

Table 5-5. Estimated 2014 nutrient load by source at the watershed scale.

Source	N Load (lb/yr)	P Load (lb/yr)
Urban	460	65
Cropland	9,525	2,682
Pastureland	3,409	535
Forest	58	24
Feedlots	0	0
Shoreline	374	133
Septic	53	19
Total	**13,878**	**3,458**

Table 5-6. Annual nutrient loads for 2014 by sub-watershed.

Sub-watershed (AUID)	N Load (lb/yr)	P Load (lb/yr)	Sediment Load (tons/yr.)
President’s Bay	433	131	131
North Bay	7,540	1,832	1,832
Winchester Bay	2,117	560	560
Independence Bay	723	157	157
Hawthorne Bay	305	48	48
Lakeside	2,760	730	730
Total	**13,878**	**3,458**	**3,458**

Table 5-7. Nutrient load reductions needed for 2014*.

Sub-watershed	N Load (lb/yr)	P Load (lb/yr)	Sediment Load (tons/yr)
President's Bay	160	93	93
North Bay	3711	1301	1301
Winchester Bay	948	397	397
Independence Bay	395	112	112
Hawthorne Bay	205	34	34
Lakeside	1235	518	518
Total	**6,654**	**2,454**	**2,454**

***-** Loads estimated based on average flow. Individual loads will depend on natural fluctuations in flow regime.

The guideline for 303d listing for total suspended solids (TSS) impairment for aquatic life in lakes is a non-volatile suspended solids (NVSS, total suspended solids minus volatile suspended solids) level greater than 12 mg/L. Aesthetic quality in lakes is considered impaired by the IEPA when NVSS is greater than 3 mg/L. Using 2014 data from the Volunteer Lake Monitoring Program, no samples have an NVSS value near 3mg/L (see table 5-7). Additionally, the residence time for water in the lake is estimated to be approximately 16.12 months. This general factor indicates that any changes in lake water quality can be profoundly delayed from the time of BMP implementation in the watershed.

Table 5-8. Non-Volatile Suspended Solids (NVSS) values for Apple Canyon Lake in 2014.

Date	Site 1 (RMJ-01)	Site 2 (RMJ-02)	Site 3 (RMJ-03)	Lake Average
5/19/2014	No Data	1	No Data	1
6/9/2014	No Data	0	3	1.5
7/7/2014	0	1	0	0.3
8/5/2014	0	1	0	0.3

RiverWatch monitoring was performed on the tributaries sampling sites in the watershed. The Illinois RiverWatch Network is a volunteer stream monitoring program that seeks to engage Illinois citizens by training them as Citizen Scientists. Each year at adopted stream sites in their communities, Citizen Scientists conduct habitat and biological surveys, including the collection and identification of small stream organisms called macroinvertebrates that serve as bioindicators of water quality. The program strives to collect consistent, high-quality data on the conditions of local streams and provide citizens with a hands-on opportunity to be better stewards of our watersheds. The RiverWatch program is headed by the National Great Rivers Research and Education Center. This program assesses streams for macroinvertebrate taxa richness, EPT taxa richness, and the macroinvertebrate biotic index. Taxa richness is the total number of taxa identified in the sample. This index measures the variety of organisms in a sample. Generally, tax richness increases as water quality, habitat diversity, and habitat suitability increase. However, some pristine headwater streams naturally harbor few taxa, while the number of taxa can actually increase in polluted streams. The EPT taxa richness is the total number of Ephemeroptera (mayfly), Plecoptera (stonefly), and Trichoptera (caddisfly) taxa present in a sample. Higher index values indicate less organic pollution. EPT are most diverse in natural streams and decline with increaseing watershed disturbance. The macroinvertebrate biotic index (MBI) was developed by the Illinois EPA to detect organic pollution such as sewage. It provides a weighted average of the pollution tolerance of indicator organisms in a sample. These assessements are combined to rank streams as very poor, poor, fair, good, or excellent. Four sites in the Apple Canyon Lake watershed ranked “very poor”, one site ranked “poor”, while the remaining three sites ranked “fair” (*see table 5.9*).

Table 5-9. RiverWatch monitoring performed on streams entering Apple Canyon Lake, and one stream exiting the lake (Below Dam site).

Site	Station Code	Organisms Sampled	Taxa Richness	EPT Taxa	MBI	Rating
North Bay (MNEA-03)	R0117091	141	17	3	5.63	Fair
Winchester (MNEAE-01)	R0128902	63	16	4	5.3	Fair
Presidents Bay (MNEAG-01)	R0129001	66	15	2	7.03	Very Poor
Independence (MNEAC-01)	R0129101	68	13	1	6.63	Very Poor
Hawthorne (MNEACA-01)	R0128801	15	8	0	6.07	Poor
Marina (MNEAB-01)	R0129201	68	9	0	6.26	Very Poor
Spillway (MNEA-02)	R0117902	160	19	2	7.03	Very Poor

5.2 2015 Sampling Year

The sampling year 2015 saw a great deal more rainfall than the 2014 sampling year. Additionally, samples were taken April – October adding two extra months to the database from the previous year, and also gathered discharge data at every sample. As expected with the high rainfall, nutrient loading was also higher. Because the reduction strategy is tied to rainfall and discharge in the watershed, reduction goals are also modified based on sampling year data.

Table 5-10 shows total phosphorus levels from surface samples taken by the Illinois EPA’s VLMP program. This table also includes depth samples which were included in modeling estimates to achieve a total average of 0.198 mg/L in the lake. Depth measurements are included in modeling because of the nature of phosphorus which tends to precipitate out in solution and collect on the bottom.

Table 5-11 shows loading rates averaged for the 2015 sampling year along with average discharge, nitrogen: phosphorus ratio, and percentage of total loads. With the higher rainfall amounts, significantly more loading is attributed to North Bay subwatershed (82% of the total load). Table 5-12 shows estimated pollutant loads by source. Cropland and pastureland are the largest contributors. High rainfall in 2015 mobilized more nutrients than observed in the previous year. Cropland and pastureland is especially vulnerable to nutrient transport during rain events. For 2015, the input estimate for loads totaled 6,977 pounds of phosphorus. The phosphorus exiting the lake was estimated to be 2,119 pounds, leaving an estimated amount left in the lake of 4,858 pounds. The estimate based on in-lake sampling was 6,974 pounds. This is a difference of 3 pounds, or less than 1% error (0.04%).

Table 5-10. Total phosphorus levels from Apple Canyon Lake, 2015 (IEPA, VLMP program, 2016).

Sample Site	Sample Depth (ft)	Collection Date	Result (mg/l)
RMJ-1	1	6/8/2015	0.033
RMJ-1	50	6/8/2015	0.356
RMJ-1	1	7/14/2015	0.025
RMJ-1	52	7/14/2015	0.409
RMJ-1	1	8/24/2015	0.052
RMJ-1	52	8/24/2015	0.575
RMJ-1	1	9/15/2015	0.054
RMJ-1	48	9/15/2015	0.629
RMJ-1	1	10/26/2015	0.12
RMJ-1	50	10/26/2015	0.914
RMJ-2	1	6/8/2015	0.038
RMJ-2	1	7/14/2015	0.034
RMJ-2	1	8/24/2015	0.072
RMJ-2	1	9/15/2015	0.057
RMJ-2	1	10/26/2015	0.12
RMJ-3	1	6/8/2015	0.094
RMJ-3	1	7/14/2015	0.053
RMJ-3	1	8/24/2015	0.116
RMJ-3	1	9/15/2015	0.098
RMJ-3	1	10/26/2015	0.104
		Average	**0.198**

Table 5-11. Average metered discharge at sampling locations, total phosphorus, and total nitrogen results from 2015 monitoring. Nitrogen/phosphorus ratio and the percentage of the phosphorus load are included in this table.

Location (AUID)	Ave Discharge (ft^3/sec.)	Ave Phosphorus (mg/L)	Ave Total Nitrogen (mg/L)	N:P Ratio	% P Load
Spillway (MNEA-02)	10.84	0.099	0.83	8.4	30.37%
Presidents Bay (MNEAG-01)	0.79	0.16	0.491	3.1	7.24%
North Bay (MNEA-03)	4.14	0.216	0.902	4.2	56.82%
Winchester (MNEAE-01)	1.29	0.208	0.844	4.1	14.95%
Independence (MNEAC-01)	0.43	0.09	0.375	4.2	1.10%
Hawthorne (MNEACA-01)	0.13	0.089	0.314	3.5	0.32%
Marina (MNEAB-01)	0.4	0.043	0.477	11.1	0.48%

Table 5-12. Estimated 2015 pollutant load by source at the watershed scale, reported by STEP-L model.

Source	N Load (lb/yr)	P Load (lb/yr)
Urban	960	132
Cropland	19,884	5,413
Pastureland	7,116	1,080
Forest	121	48
Feedlots	0	0
Shoreline	780	268
Septic	110	39
Total	**28,971**	**6,974**

Table 5-13. Annual pollutant loads for 2015 by sub-watershed.

Sub-watershed (AUID)	N Load (lb/yr)	P Load (lb/yr)	Sediment Load (tons/yr.)
President's Bay	1,547	505	505
North Bay	16,542	3,966	3,966
Winchester Bay	4,245	1,044	1,044
Independence Bay	318	76	76
Hawthorne Bay	78	22	22
Lakeside	5,533	1,361	1,361
Total	**28,263**	**6,974**	**6,974**

Table 5-12 shows the total pollutant loads by sub-watershed for the 2015 sample year. Total pollutants were higher than observed in 2014. As soils become saturated there is much more likelihood of nutrients to move across the soil surface and less ability for nutrients to infiltrate into the soil. Table 5-13 shows the 2015 reduction estimates. Not surprisingly, reduction needs are much higher based on the amount of rainfall mobilizing nutrients in the watershed. However, in a wet year BMPs are also less effective at reducing nutrient passport, yet even more necessary for reducing movement as much as possible. Nitrogen to Phosphorus ratio was used as described in Section 5.1 to determine nitrogen reductions in order to prevent harmful algal blooms.

Table 5-14. Nutrient load reductions needed for 2015.

Sub-watershed	N Load (lb/yr)	P Load (lb/yr)	Sediment Load (tons/yr)
President's Bay	492	358	358
North Bay	8,256	2,815	2,815
Winchester Bay	2,064	741	741
Independence Bay	159	54	54
Hawthorne Bay	32	16	16
Lakeside	2,690	966	966
Total	**13,693**	**4,950**	**4,950**

The guideline for 303d listing total suspended solids (TSS) impairment for aquatic life in lakes is a Non-volatile suspended solids (NVSS) result (TSS-VSS) greater than 12 mg/L. Aesthetic quality in lakes is considered impaired when NVSS is greater than 3. Using 2015 data from the Volunteer Lake Monitoring Program, no samples have an NVSS value near 3 when averaged for the lake (see table 5-15). However, negative results are not valid, and indicate that there is an unknown error in data reporting from the laboratory or NVSS methodology. Because data is averaged across sites, and some sites do not have some data available from the lab for each month, the negative numbers occur.

Table 5-15. NVSS values for Apple Canyon Lake in 2015.

Date	Site 1	Site 2	Site 3	Lake Average
6/8/2015	No Data	-1	-1	-1
7/14/2015	No Data	No Data	-2	-2
8/24/2015	No Data	-2	3	0.5
9/15/2015	0	-2	5	1
10/26/2015	No Data	-2	No Data	-2

5.3 2016 Aquatic Plant Survey

In 2016, an aquatic plant survey was undertaken to assess the current condition of plants in the lake (see Appendix 8 for the complete report from the survey). The only prior data available is from a 2012 preliminary survey that focused on parts of the lake, but not all. The 2016 survey was performed twice, in early June and mid-July. The entire littoral zone of the lake (depth $\leq$ 4.88m) was travelled to identify all plants, including invasive species. Coverage maps and data are shown below.

Overall, diversity was higher in 2012 than in 2016, with two species observed in 2012 that were not observed in 2016 and no new species observed. However, diversity was higher in July 2016 than June 2016 following the seasonal die-off of invasive Curly Leaf Pondweed (which was notably found in much higher quantities in 2016 than 2012). Compared to similar eutrophic lakes, Apple Canyon Lake has fairly low aquatic plant coverage. Invasive species present are Curly Leaf Pondweed and Eurasian Water Milfoil. Lake residents report that concentrations of Curly Leaf Pondweed were much higher in 2016 than in previous years, which is likely a result of the mild 2015-2016 winter.

Total coverage of plants overall in the lake in June 2016 was 9.00% surface cover, and 29.33% of the littoral zone. Invasive plants covered 6.00% and native plants 5.56% (plants often overlapped in coverage, hence why the two numbers add to greater than 9.00%). In July, total plant cover decreased to 2.96% overall and 9.64% of the littoral zone, a 67.12% decrease. Invasive species declined by 96.02% to 0.28% coverage, and native plants decreased by 49.82% to 2.79% cover.

Decreased plant cover in July 2016 is likely due to use of broad-spectrum herbicides for management. Future management recommendations focus on early-season or fall herbicide applications to control Curly-Leaf Pondweed, along with the use of Renovate® (triclopyr), a species-specific herbicide that only affects Eurasian Water Milfoil. The POA also maintains a weed harvester used for the purpose of cutting channels through plants to docks.

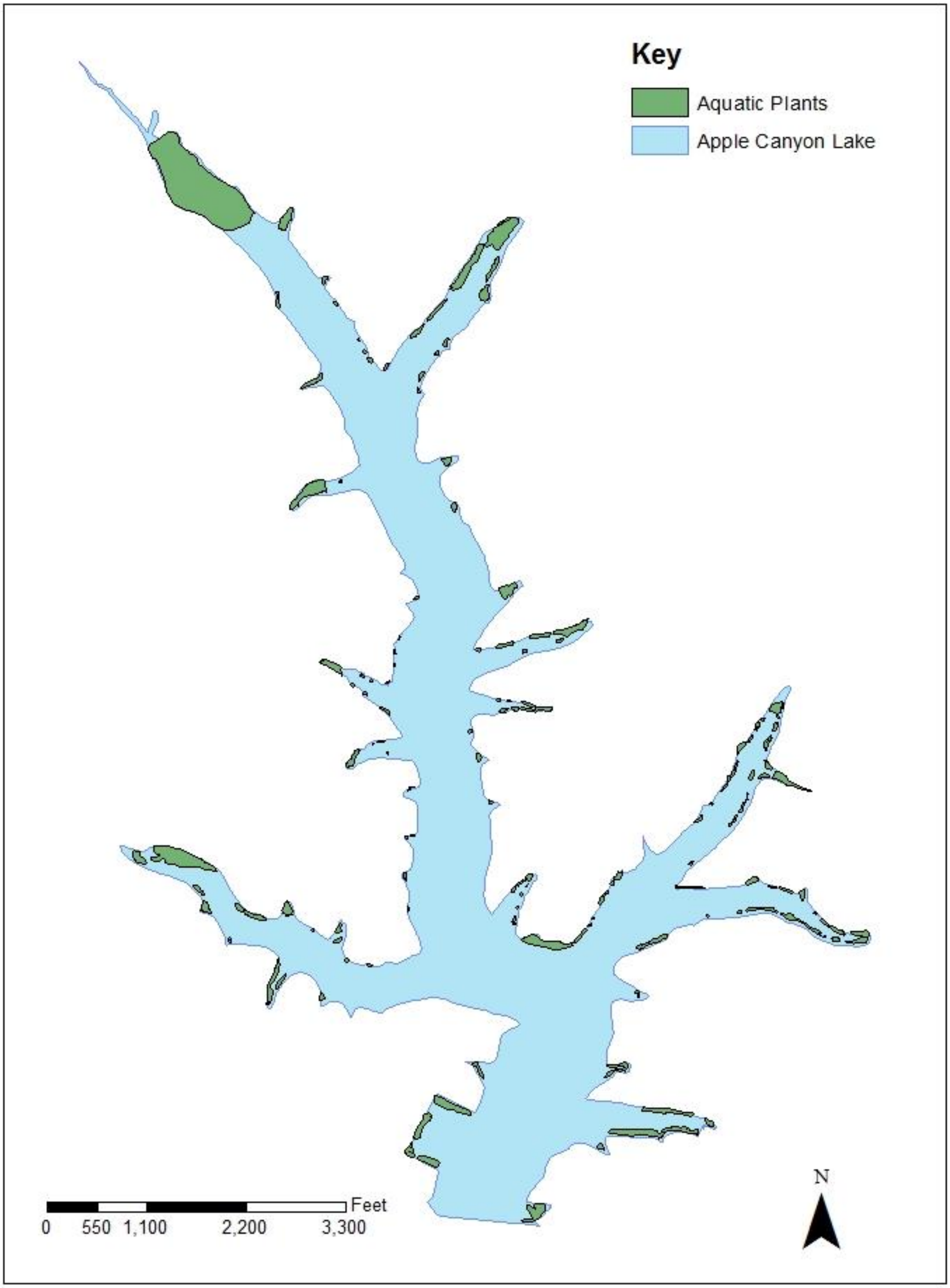


Figure 5-4. Locations of aquatic plants in June 2016.

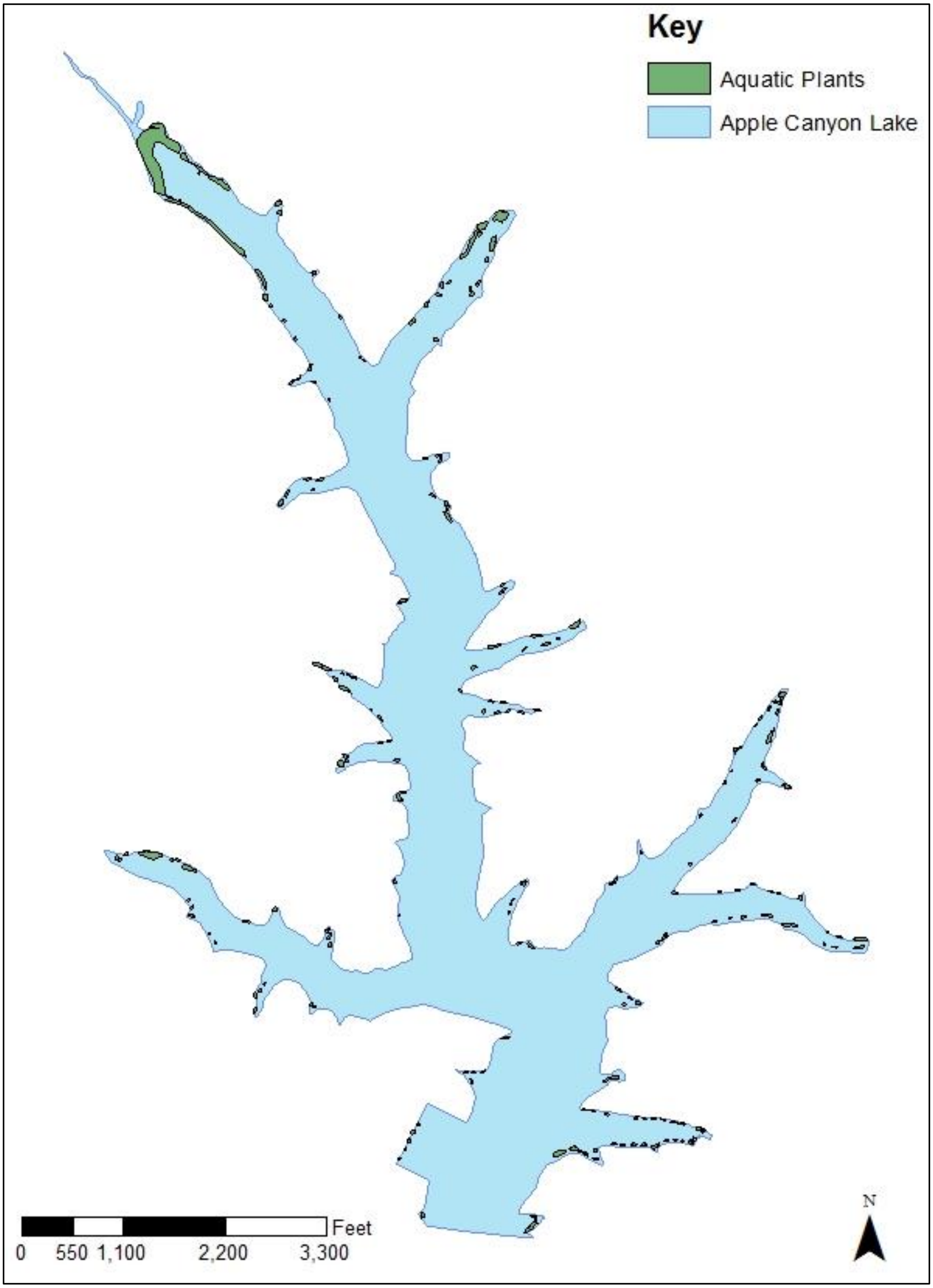


Figure 5-5. Locations of aquatic plants in July 2016.

Table 5-16. Aquatic plant coverage data for Apple Canyon Lake

Common Name	Scientific Name	June Coverage (acres)	June Coverage (percent)	July Coverage (acres)	July Coverage (percent)
Curly Leaf Pondweed	***Potamogeton crispus***	**25.02**	**6.06**	0.77	0.18
Coontail	*Ceratophyllum demersum*	14.89	3.61	6.87	1.66
Elodea	*Elodea canadensis*	11.29	2.73	0.77	0.19
Eurasian Water Milfoil	***Myriophyllum spicatum***	**7.27**	**1.76**	0.31	0.08
White Water Lily	*Nymphae odorata*	6.16	1.49	2.98	0.72
Duckweed	*Lemna sp.*	2.99	0.72	2.29	0.55
Fries Pondweed	*Potamogeton friesii*	2.52	0.61	0.66	0.16
Bulrush	*Scirpus sp.*	0.33	0.08	0.12	0.03
Reeds Canary Grass	***Phalaris arundinacea***	**0.21**	**0.05**	0.06	0.01
American Pondweed	*Potamogeton nodosus*	0.06	0.01	0.02	<0.01
Water Celery	*Vallisneria americana*	0	0	1.09	0.26
Cattail	*Typha sp.*	0	0	0.29	0.07
Arrowhead	*Sagittaria sp.*	0	0	0.20	0.05
Sago Pondweed	*Potamogeton pectinatus*	0	0	<0.01	<0.01

Invasive species indicated in bold.

Table 5-17. Aquatic plants observed in 2012 that were not seen in 2016

Common Name	Scientific Name
Southern Naiad	*Najas guadalupensis*
Water Star Grass	*Heteranthera dubia*

Table 5-18. Change in aquatic plant cover from June 2016 to July 2016.

Cover	**Change (percent)**	**Change (acres)**
All plants	-67.12%	-24.94
All invasive plants	-96.02%	-27.38
All native plants	-49.82%	-11.44
Curly Leaf Pondweed	**-96.92%**	**-24.25**
Eurasian Water Milfoil	**-95.74%**	**-6.96**
Elodea	-93.18%	-10.52
Fries Pondweed	-73.80%	-1.86
Reeds Canary Grass	**-71.43%**	**-0.15**
American Pondweed	-66.67%	-0.04
Bulrush	-63.64%	-0.21
Coontail	-53.86%	-8.02
White Water Lily	-52.11%	-3.12
Duckweed	-23.41%	-0.70

Invasive species indicated in bold.

6.0 MANAGEMENT GOALS

The collaborative Apple Canyon lake watershed planning group set several management goals which support the overarching target of improving water quality in Apple Canyon Lake and its watershed to meet established water quality standards for lakes and surface water as identified by the Federal and Illinois EPA. The underlying management goals provide a road map to reach the target. The underlying management goals were identified as follows:

(1) Improve water quality.
(2) Reduce algal blooms and excessive aquatic plant growth.
(3) Mitigate existing flood problems.
(4) Educate the watershed community.

Each of these goals was given a set of objective achievements in order to reach these goals.

6.1 Goal 1: Improve Water Quality.

Objectives:

a) Prioritize and stabilize stream banks in the watershed.
b) Stabilize eroded shoreline on the lake.
c) Improve the riparian buffer throughout the watershed.
d) Expand water quality database through continued monitoring.
e) Continue RiverWatch monitoring.
f) Develop cost-sharing program for BMP implementation in the watershed.
g) Improve the septic inspection policy at the property owners association.

6.2 Goal 2: Reduce algal blooms and excessive aquatic plant growth.

Objectives:

a) Map current extent of plant coverage.
b) Develop a management plan for controlling aquatic plants.
c) Identify critical areas in the watershed.
d) Perform a study to reduce nutrient loading in North Bay.

6.3 Goal 3: Mitigate existing flooding problems.

Objectives:

a) Increase connectivity between streams and floodplains.
b) Create green infrastructure plan for developed areas.
c) Create a zero-runoff policy for new construction in the property owners association.
d) Encourage zero-runoff adherence for existing properties.

6.4 Goal 4: Educate watershed community.

Objectives:

a) Increase public participation in the watershed planning and implementation process.
b) Continue quarterly watershed meetings.
c) Demarcate watershed boundaries on major roads.
d) Publish educational articles in local news sources and online resources.
e) Host educational events.
f) Increase participation in the RiverWatch program.

6.5 Management Action Plan

The resource inventory and water quality analysis identify watershed impairments based on cause and source. This plan identifies potential areas of redress in order to reverse the downward trend in water quality. This section includes a Management Action Plan developed through stakeholder meetings which specifically address objectives directly related to plan goals. These management measures are first presented at a general scale and shall be implemented as opportunity and funding are available. For each action item, the classification of “High”, “Medium”, and “Low” is assigned based on feasibility, cost, and impact on goals. High priority action items should be carried out in the near future (1-5 years). Medium and Low action items will have a lower impact on overall plan success and are encouraged to be achieved during a longer time frame 6-10 years for Medium priority action items and 11-25 years for Low priority action items. Table 6-1 identifies the key stakeholders and partners in the watershed. To address these management goals, the subwatersheds were prioritized based on size and loading rates. For Association dollars spent, projects will be focused on these prioritized areas to achieve maximum benefit from implementation efforts. See the following sections 6.5.1 – 6.5.4 for management measures corresponding to each goal.

Table 6-1. Apple Canyon Lake Watershed stakeholders and partners.

Apple Canyon Lake Watershed Stakeholder/Partner	Acronym/Abbreviation
ACL-POA Architectural Committee	AC
ACL-POA Conservation Committee	CC
Apple Canyon Lake Property Owners Association	ACL-POA
Consultant	Consultant
Illinois Department of Natural Resources	IDNR
Illinois Environmental Protection Agency	IEPA
Illinois Farm Bureau	IFB
Jo Daviess County Soil and Water Conservation District	SWCD
Land owners in the watershed	Landowners
Members of the Apple Canyon Lake Property Owners Association	PO
National Great Rivers Research and Education Center	NGRREC
Townships	TWP
University of Illinois Extension	UIE
University of Wisconsin Platteville, Dept. of Environmental Engineering	UWP
U.S. Fish and Wildlife Service	FWS
U.S. Forest Service	USFS
USDA Natural Resources Conservation Service	NRCS

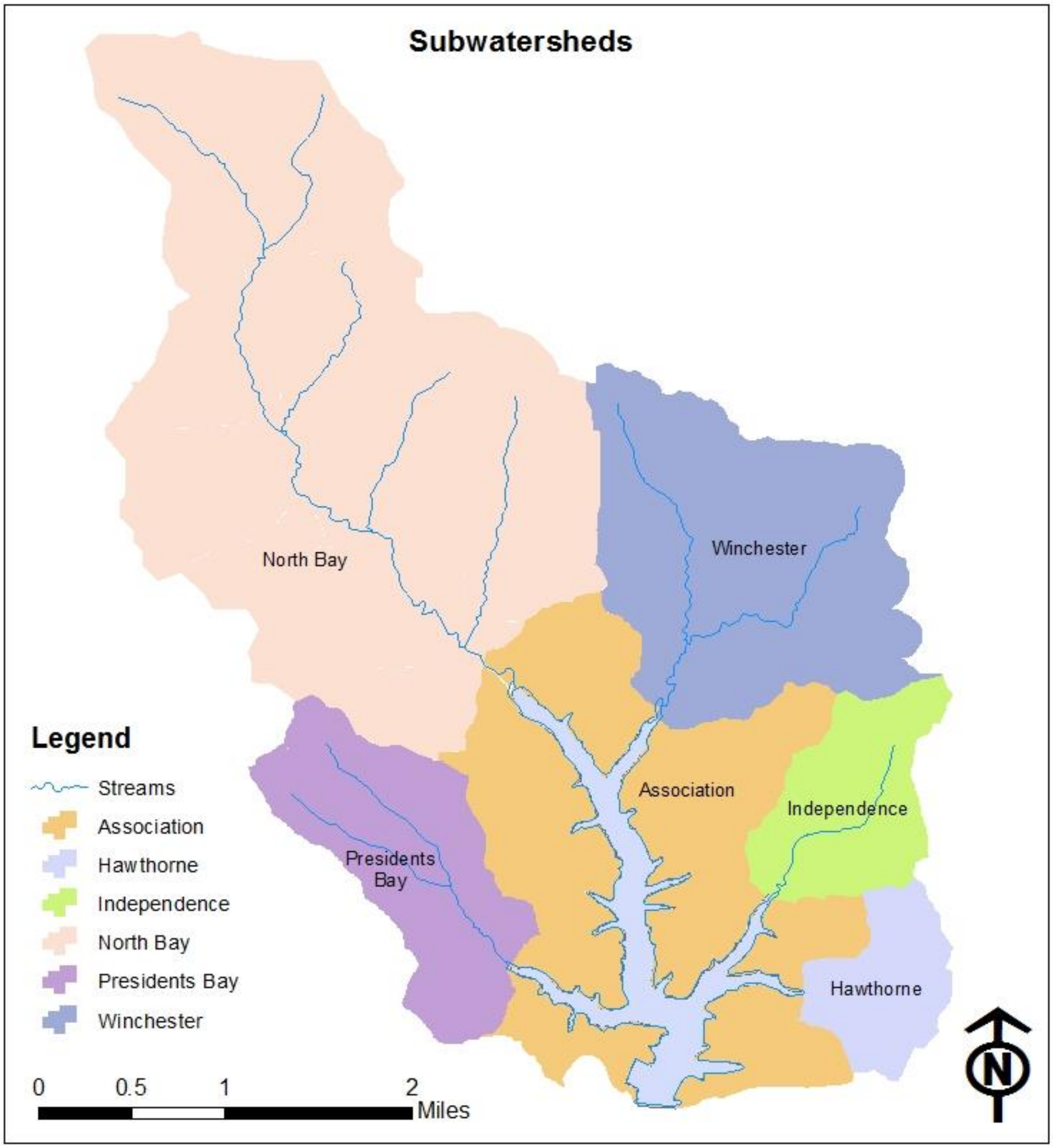


Table 6-2. Subwatershed area (acres) and percentage of total watershed area.

Figure 6-1. Subwatersheds within Apple Canyon Lake Watershed.

Location	Acreage	% of Watershed
North Bay	**4,331**	**41.77%**
Association	**2,027**	**24.90%**
Winchester	**1,555**	**15.95%**
Presidents	**827**	**8.48%**
Independence	**531**	**5.34%**
Hawthorne	**346**	**3.55%**
Total	**9,617**	**99.99%**

6.5.1 Goal 1: Improve Water Quality.

	Management Measures	Priority	Primary Objective	Responsible Stakeholder	Technical Assistance
1	Stabilize stream reaches with high levels of erosion.	High	1a	All Stakeholders	Consultant
2	Stabilize high erosion areas around lakeshore.	High	1b	ACL-POA, PO	Consultant
3	Improve the riparian buffer around the lake.	High	1c	Landowners	ACL-POA SWCD/NRCS
4	Identify critical areas affecting water quality in the watershed.	High	1c	ACL-POA, SWCD	SWCD, UWP
5	Improve riparian buffer in the watershed.	High	1c	ACL-POA, Landowners	Consultant
6	Continue water quality monitoring for tributary streams.	High	1d	ACL-POA	Consultant, Volunteers, IEPA
7	Continue Tier III VLMP monitoring.	High	1d	ACL-POA	Volunteers, IEPA
8	Develop cost-sharing program for BMP implementation on private lands in the watershed.	High	1f	ACL-POA	SWCD, Consultant
9	Improve septic system operation at Apple Canyon Lake.	High	1g	ACL-POA, Conservation Committee	Conservation Committee
10	Provide annual analysis of water quality data.	High	1d	ACL-POA	Consultant
11	Apply gypsum to cropland in watershed.	High	1f	Landowners, ACL-POA	SWCD
12	Apply cover crops to cropland in watershed.	High	1f	Landowners, ACL-POA	SWCD
13	Install a demonstration tile gate on a tiled crop field.	High	1f	Landowners, ACL-POA	SWCD
14	Stabilize stream reaches with medium levels of erosion.	Medium	1a	All Stakeholders	Consultant
15	Stabilize medium erosion areas around lakeshore.	Medium	1b	ACL-POA, PO	Consultant
16	Continue to develop RiverWatch database.	Medium	1e	Volunteers	NGRREC, SWCD
17	Stabilize stream reaches with low levels of erosion.	Low	1a	All Stakeholders	Consultant
18	Stabilize low erosion areas around lakeshore.	Low	1b	ACL-POA, PO	Consultant

6.5.2 Goal 2: Reduce algal blooms and excessive aquatic plant growth.

	Management Measures	Priority	Primary Objective	Responsible Stakeholder	Technical Assistance
1	Map current extent of aquatic plant species coverage.	High	2a	ACL-POA	Consultant
2	Develop a management plan for aquatic plants.	High	2b	ACL-POA	Consultant
3	Identify critical areas in the watershed where restoration has the greatest impact on water quality improvement.	High	2c	ACL-POA	Consultant, UWP
4	Perform feasibility study for storm retention in North Bay.	High	2d	ACL-POA	Consultant, UWP
5	Reduce nutrient and sediment loading in lake (refer to Goal 1).	High	Goal 1	All Stakeholders	All Stakeholders

6.5.3 Goal 3: Mitigate existing flooding problems.

	Management Measures	Priority	Primary Objective	Responsible Stakeholder	Technical Assistance
1	Increase connectivity between streams and floodplains.	High	3a	All Stakeholders	SWCD
2	Create green infrastructure plan for developed areas.	High	3b	ACL-POA	Consultant
3	Create a zero-runoff policy for new construction in the property owners association.	High	3c	ACL-POA	AC
4	Encourage zero-runoff adherence for existing properties.	Medium	3d	ACL-POA	AC, CC

6.5.4 Goal 4: Educate watershed community.

	Management Measures	Priority	Primary Objective	Responsible Stakeholder	Technical Assistance
1	Increase public participation in watershed planning and implementation process.	High	4a	All Stakeholders	All Stakeholders
2	Continue quarterly watershed meetings.	High	4b	All Stakeholders	All Stakeholders
3	Publish educational articles in local news sources and online resources.	High	4d	CC	SWCD, Consultant
4	Host educational events.	High	4e	CC	SWCD, Consultant
5	Increase participation in the RiverWatch program.	High	4f	CC	NGRREC, SWCD
6	Demarcate watershed boundaries on major roads.	Medium	4c	ACL-POA	Consultant

6.6 Management Measures to Achieve Goals

Through stakeholder meetings in the watershed planning process as well as through the resource inventory portion of plan development multiple best management practices (BMP) were identified to reach the goals of this plan. These BMPs were analyzed to estimate individual load reductions expected from BMP implementation as well as cost. These BMPs are in the form of stream stabilization, riparian buffers, shoreline stabilization, agricultural BMPs (cover crops, saturated buffers, gypsum application, tile discharge control, etc.), and policy recommendations.

6.6.1 Cover Crops

Cover crops have come to the forefront in the effort to reduce nutrient loads in agricultural watersheds. Cover crops are included in the Illinois Nutrient Load Reduction Strategy (NLRS) as an important practice that farmers can use to reduce nonpoint source pollution. Historically, producers have been reluctant to plant cover crops because of the time and money involved.

Producers typically grow cover crops to provide living cover on farm fields during times when cash crops are not grown, usually during late fall and early spring. While farmers usually do not harvest cover crops for profit, they provide many economic and environmental benefits. First, cover crops recycle nutrients and help prevent them from entering waterways. They help water infiltrate soil, preventing nutrient-heavy runoff from entering waterways. This increased soil infiltration also provides some flood mitigation. Additionally, cover crops absorb excess nitrogen, reducing nitrogen leaching into the groundwater or drainage systems. In one field study, a cereal rye cover crop reduced nitrate concentration in drainage water by 48 percent, and oats reduced nitrate concentration by 25 percent. Although results will vary depending how much the cover grows, this means that widespread use of cover crops can significantly improve water quality and recycle valuable nutrients back to our soil.

Second, cover crops help to retain topsoil. When farmland is left without any living cover topsoil is lost through erosion. An Iowa study found that using rye cover crop following no-tillage soybeans reduced sheet erosion by 54 percent and rill erosion by 90 percent compared to no-tillage fields without cover crops. An oat cover crop produced about one-half the benefit of a rye cover crop. In addition to providing soil cover, the cover crops also helped to anchor residues and prevented them from moving with flowing water. This is especially important with the frequent high intensity rainfall events observed in the last decade.

Not only do cover crops help retain soil, but they also improve soil health. Cover crops recycle nutrients that would otherwise end up in waterways and redeposit those nutrients into the soil where they will eventually be available for future crops. Legume cover crops can also fix atmospheric nitrogen and deposit it into the soil. Cover crops can also improve soil health by increasing soil organic matter and increasing earthworm populations. They can help to control weeds and increase plant diversity by improving habitat for beneficial microbes, insects, and wildlife. While cover crops require additional financial input, labor, and crop management, they are an important long-term investment for securing the future success on farms.

Recent farmer surveys have reported that effectively managed cover crops do not significantly affect cash crop yields and recent reports find that cover crops increase cash crop yields during periods of weather volatility. In drought-stricken areas, farmers reported that corn yields were 11 percent higher and soybean yields were 14 percent higher than yields for corn and soybeans not planted after cover crops.

The Illinois Department of Agriculture’s cover crop cost-share assistance program, the Conservation Practices Program, has set a state-wide maximum average cost of $40 per acre to purchase seed and apply cover crops. Based on land-use statistics identified in the resource inventory, there are approximately 3014.1 acres of cropland in the watershed (30.8%) which could benefit from cover crop implementation. This equates to a maximum cost of seed purchase and establishment of approximately $120,564 annually to establish cover crops in the watershed.

6.6.2 Education Activities

Numerous educational activities have been identified through the planning process. Many of these activities have since been implemented during plan development. Monthly educational articles are published in the Apple Core and local area newspapers circulated in the watershed. At the onset of the planning process the Conservation Committee began printing a Conservation Page in the ACLPOA newspaper, the Apple Core. This page is conservation focused, though not always directly watershed related. The Conservation Page contains a number of articles, some contributed by the Conservation Committee, some by residents, and some by the Jo Daviess County SWCD. The objective is to have at least one article that is watershed related each month. Further education is needed to educate private property owners, land managers, agricultural producers, septic system owners, streamside land owners, lake management, and youth.

The Conservation Committee has planned two educational field days each year, as well as a lake clean-up event on earth day. Topics for the educational field days are watershed oriented and intended to increase watershed awareness and stewardship. Although these events target members of the property owners association, all events are open to the public.

The National Great Rivers Research and Education Center (NGRREC) hosts the RiverWatch program. The Illinois RiverWatch Network is a volunteer stream monitoring program that seeks to engage Illinois citizens by training them as Citizen Scientists. Each year at adopted stream sites in their communities, Citizen Scientists conduct habitat and biological surveys, including the collection and identification of small stream organisms called macroinvertebrates that serve as bioindicators of water quality. The program strives to collect consistent, high-quality data on the conditions of local streams and provides citizens with a hands-on opportunity to be better stewards of our watersheds. RiverWatch was initiated in 1995 as part of the Critical Trends Assessment Project (CTAP), and Illinois Department of Natural Resources (IDNR) project designed to conduct a long-term comprehensive assessment of the environment in Illinois. In 2006, responsibility for RiverWatch was officially transferred to NGRREC. Two stream sites were adopted under the RiverWatch Program in 2001 (Hells Branch above Apple Canyon Lake R0117901, and Hells Branch below the Apple Canyon Lake Spillway, R0117902). In 2014, four additional sites were adopted to correspond to water monitoring data collected as part of this watershed planning effort. A RiverWatch training was held at the Property Owners Club at Apple Canyon Lake in 2015 to educate, garner more volunteers, and expand the RiverWatch mission. This program will continue to monitor the Apple Canyon Lake streams in perpetuity.

Additionally, a Kids Camp is held for three days every summer. This camp is open to all people regardless of property ownership and targets children aged 6-11. Kids Camp has been conducted during the planning process and shall continue on in perpetuity. Activities range from demonstrating a watershed model, describing nutrients and water pollution, visiting streams and taking water samples, and learning some of the RiverWatch curriculum.

Finally, quarterly watershed planning meetings will continue once the watershed plan is completed. The quarterly watershed meetings are necessary to review plan implementation, continue to induct participants into stakeholder discussions, address milestones and fallacies in planning as well as updating the watershed plan as necessary. Watershed planning meetings may be changed to a single meeting quarterly or to a different time and/or location as deemed necessary. The planning meetings will also develop future presenters, topics, issues to be addressed at the meetings. Partnerships will enrich these events, such as presentations by University of Illinois Extension staff, and USDA staff.

6.6.3 Gypsum Application

During the watershed planning process the application of gypsum to cropland acres was embraced by the agricultural community. Gypsum application to crop fields has been shown to reduce phosphorus transport as well as benefit crop yields making this best management practice attractive to producers to benefit production and help achieve nutrient reduction goals.

Gypsum is a relatively common mineral that is widely available in agricultural areas and has a number of specialized agronomic uses, principally as a calcium source on legumes and as a soil conditioner on sodic soils (Shainberg et al., 1989). Research by Stout et al. (1999) showed the reduction of water soluble phosphorus as much as 60% with the use of a 10 g/kg gypsum treatment. Applying this research to the Apple Canyon Lake watershed, approximately 3000 acres of cropland exists which could be treated with gypsum. Gypsum is typically applied in the fall after crops are out of the fields. There are no apparent restrictions on field application, and no detriment to streams or waters systems if it is transported prior to incorporation into soil systems. Quotes from local agriculture service companies result in the cost of approximately $40 per acre to purchase and apply gypsum to a field. Using this information the derived annual cost to treat crop fields in the watershed with gypsum is $120,000. This treatment could produce as much as a 30% reduction in aquatic phosphorus levels (Sharpley et al., 1994).

6.6.4 Policy

During the watershed planning process the stakeholder group identified a number of policy changes that are desired to be implemented into the covenants of the Apple Canyon Lake Property Owners Association. Policy initiatives include (1) a zero-runoff policy for new construction, (2) zero-runoff best management practice encouragement for existing construction, (3) the inclusion of a septic drainfield inspection in addition to the existing septic tank inspections, (4) the inclusion of a green-infrastructure component for Association property improvements, such as pervious pavement for parking lots, and (5) allocating funding into next year's budget for plan implementation. These policies will only be applicable to Association properties, which contain the density of development in the watershed. Prior to implementing a septic drainfield inspection policy, a study should be performed on the existing septic practices. Results from this study will dictate septic policy needs in the property owners association. Due to the varied nature of these policies, estimating actual nutrient reductions expected from these policies is not possible.

6.6.5 Riparian Buffer Improvements

This plan is calling for 4,622 linear feet of riparian area improvement. North Bay, Association, Winchester, President's Bay, Independence, and Hawthorne were all assessed to determine areas next to streams on existing cropland flowing into Apple Canyon Lake could be improved by converting cropland to a buffer zone. This was done using methodology developed by Storm et al. (2006). Installation of these buffers could be beneficial for preventing nutrients and sediment from entering the water and also help with erosion control. A total of 16.63 acres of potential buffer areas were identified; areas that were 0.1 acre or smaller were not considered. Nutrient load and erosion reduction predictions were made based on if buffers were installed in these areas (*see Table 6-3*). These 16.63 acres equate to approximately 14,488 linear feet of riparian stream area. Many of these areas are eligible for the USDA's Conservation Reserve Program where landowners could receive a rental payment on these areas if they implement the buffer area. It has also been identified that a student project could be associated with this to develop a more sophisticated identification of key areas in the watershed which would strategically protect water quality in the watershed. This project will be solicited through the University of Wisconsin, Platteville, and environmental engineering department as available. Detailed listings for areas currently identified follow by sub-watershed.

During the water quality assessment a variety of modeling techniques were used and checked with known data for accuracy. The STEP-L model was particularly beneficial in identifying efficacy of best management practice implementation techniques. Of these, riparian buffers and vegetated field borders were most effective at reducing loading rates. These practices apply primarily to agricultural land higher in the watershed and off of ACLPOA properties. Incentives will likely be necessary for these practices to be implemented. However, studies of tile drained agricultural lands in Illinois have shown that buffers alone are not adequate to override nutrient export from subsurface tile drainage (Lemke et al., 2011) and therefore will not be a high priority for implementation.

Table 6-3. Consolidated totals of identified potential buffer plots in North Bay, Association, Winchester Bay, President's Bay, and Independence Bay Subwatersheds (Data from Tables 6-4 thru 6-8).

Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen Reduction (lb/yr)	Phosphorous Reduction (lb/yr)	Sheet & Rill Erosion (t/ac/yr)
16.63	**567.32**	**453.9**	**1358**	**730**	**291.2**

6.6.5.1 North Bay Subwatershed

Areas in the North Bay sub-watershed which have been identified as key areas for implementation of a riparian buffer using protocol developed by Storm et al. (2006) are listed in the following table.

Table 6-4. Identified potential buffer plots in North Bay and the acreage of each plot. The 'Buffer ID Number' corresponds with the plot labels in Figure 6-2.

Buffer Number	Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen reduction (lb/yr)	Phosphorous reduction (lb/yr)	Sheet & Rill (t/ac/yr)
2	0.09	1.4	0.3	1	0	16.2
3	0.1	2.4	3.7	11	6	7.9
4	0.1	0.9	2.5	6	3	14.2
8	0.11	19	19.7	62	33	5.3
10	0.11	1.3	2.5	7	4	9.8
11	0.12	3.2	3.3	10	6	5.3
12	0.12	1.3	1.3	4	2	5.3
13	0.13	2.8	2.9	9	5	5.3
14	0.14	1.6	2.5	7	4	8.1
15	2	20.32	11.9	42	22	3
19	1.24	3	4.4	15	8	3
20	1.1	164	4.6	19	10	1.4
21	0.27	9.26	17.6	49	26	9.8
22	0.18	1.4	1.7	5	3	6.1
23	0.9	8.27	11	33	18	6.9
24	0.2	13.07	13.6	43	23	5.3
25	0.23	1.3	2.6	7	4	10.2
26	0.23	1.5	0.9	3	2	3
29	0.28	0.6	2	5	3	17.6
30	0.29	5	9.5	26	14	9.8
32	0.29	3.6	2.2	8	4	3.1
33	0.3	68	26.3	100	54	2
34	0.32	3	7.8	20	11	13.3
37	0.35	6.2	40.1	87	47	33.3
38	0.41	3.2	4.9	14	8	7.9
39	0.55	12.6	13.1	41	22	5.3
40	4.26	83	143.6	406	218	8.9
Total	14.42	441.22	356.5	1040	560	227.3

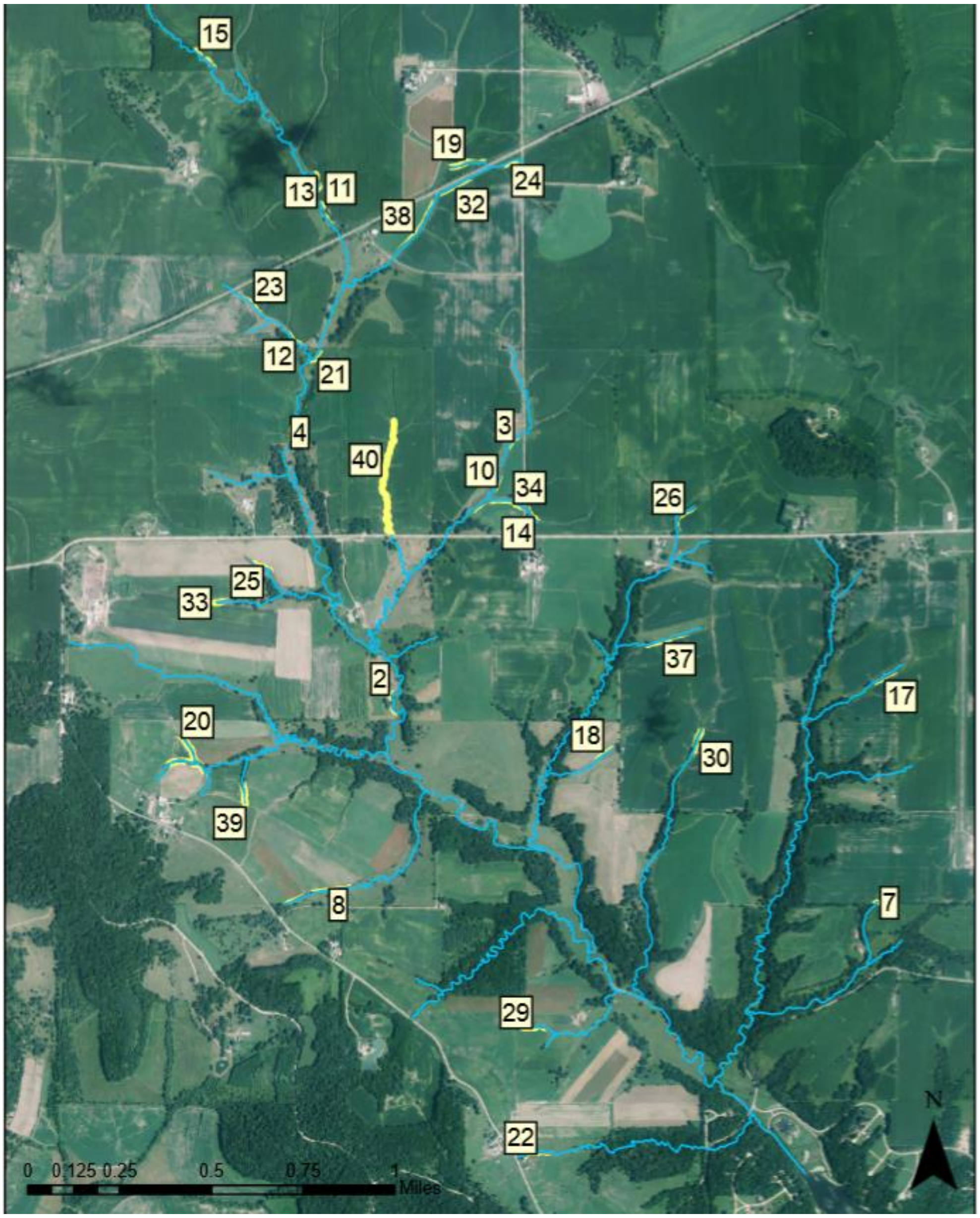


Figure 6-2. Areas in North Bay subwatershed within a 50ft buffer zone of stream that are currently used for cropland and have been identified as potential plots to convert to buffer.

6.6.5.2 Association Subwatershd

Areas in the Association sub-watershed which have been identified as key areas for implementation of a riparian buffer are listed in the following table.

Table 6-5. Identified potential buffer plots in Association and the acreage of each plot. The 'Buffer ID Number' corresponds with the plot labels in Figure 6-3.

Buffer Number	Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen reduction (lb/yr)	Phosphorous reduction (lb/yr)	Sheet & Rill
9	0.11	1	1.6	5	2	8.3
Total	**0.11**	**1**	**1.6**	**5**	**2**	**8.3**

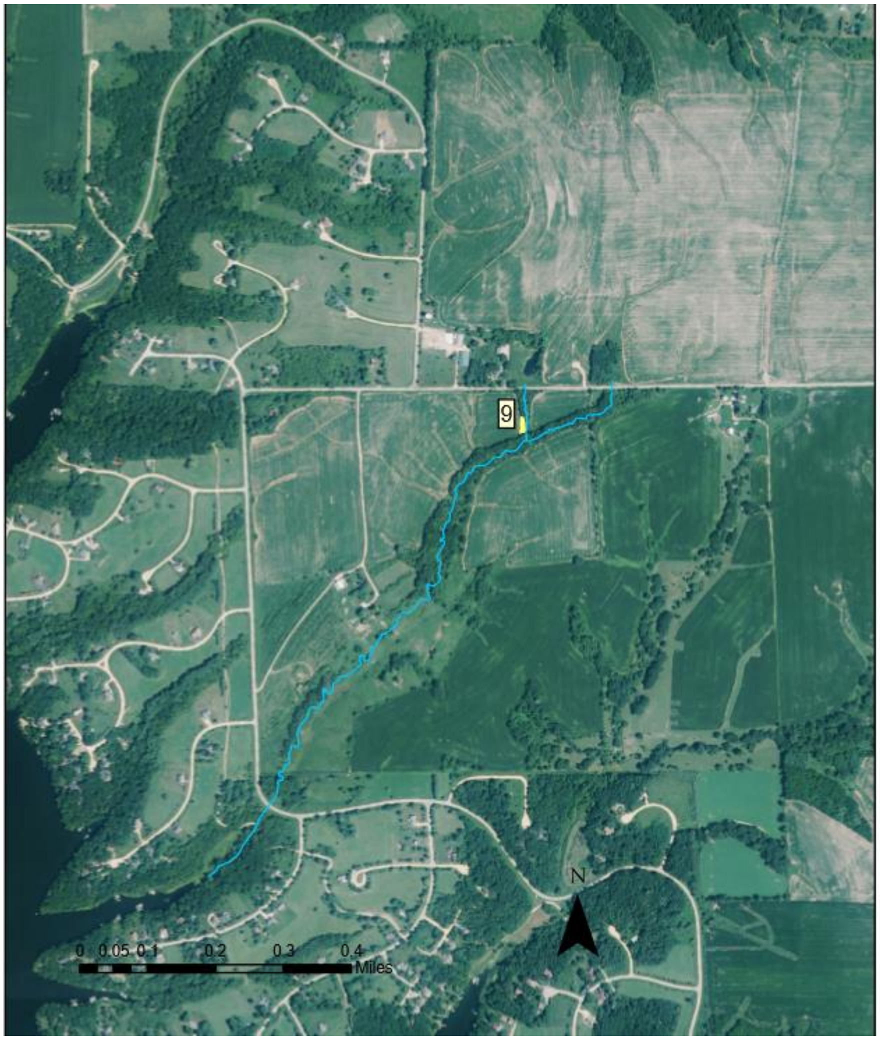


Figure 6-3. Identified buffer areas in the NE portion of the Association sub-watershed.

6.6.5.3 Winchester Bay Subwatershed

Areas in the Winchester Bay sub-watershed which have been identified as key areas for implementation of a riparian buffer are listed in the following table.

Table 6-6. Identified potential buffer plots in Winchester and the acreage of each plot. The 'Buffer ID Number' corresponds with the plot labels in Figure 6-4.

Buffer Number	Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen reduction (lb/yr)	Phosphorous reduction (lb/yr)	Sheet & Rill
1	0.09	0.7	1.6	4	2	11.7
6	0.11	7.6	12	34	18	8.1
28	0.26	9.9	7.8	26	14	4.0
Total	**0.79**	**18.8**	**21.4**	**64**	**34**	**23.8**

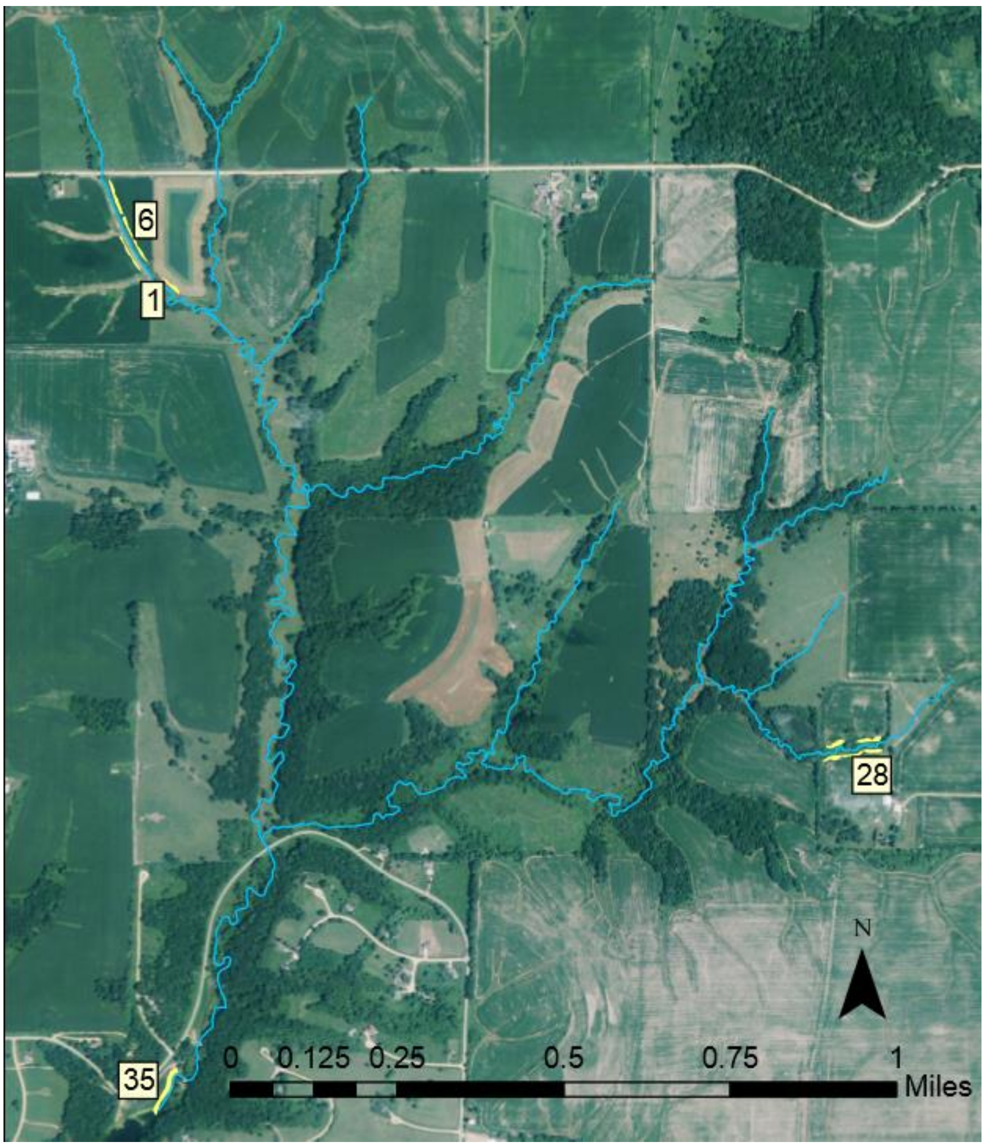


Figure 6-4. Greater than .1 acre areas within a 50ft buffer zone of stream that are currently used for cropland and have been identified as potential plots to convert to buffer.

6.6.5.4 Presidents Bay Subwatershed

Areas in the Presidents Bay sub-watershed which have been identified as key areas for implementation of a riparian buffer are listed in the following table.

Table 6-7. Identified potential buffer plots in Presidents Bay and the acreage of each plot. The 'Buffer ID Number' corresponds with the plot labels in Figure 38.Greater than .1 acre areas within a 50ft buffer zone of stream that are currently used for cropland.

Buffer Number	Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen reduction (lb/yr)	Phosphorous reduction (lb/yr)	Sheet & Rill (t/ac/yr)
16	0.15	3.2	7.1	19	10	11.4
27	0.25	4	4.2	13	7	5.3
36	0.33	0.7	1.1	3	2	8
Total	**0.73**	**7.9**	**12.4**	**35**	**19**	**24.7**

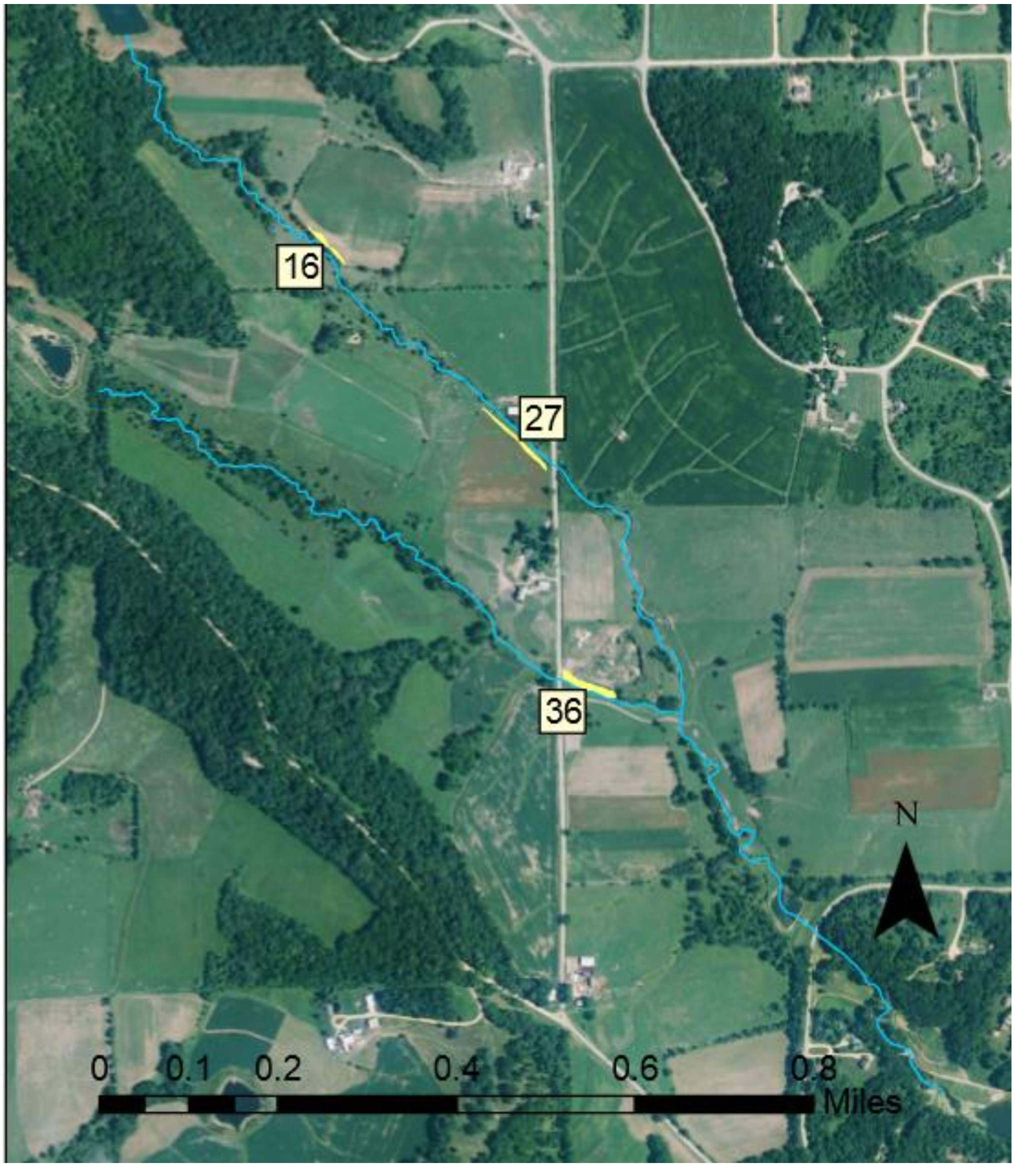


Figure 6-5. Greater than .1 acre areas within a 50ft buffer zone of stream that are currently used for cropland and have been identified as potential plots to convert to buffer.

6.6.5.5 Independence Bay Subwatershed

Areas in the Independence Bay sub-watershed which have been identified as key areas for implementation of a riparian buffer are listed in the Table 6.8, and graphically depicted in Figure 6.6.

Table 6-8. Identified potential buffer plots in Independence and the acreage of each plot. The 'Buffer ID Number' corresponds with the plot labels in Figure 6-6.

Buffer Number	Acres	Drainage Acres	Sediment Reduction (t/yr)	Nitrogen reduction (lb/yr)	Phosphorous reduction (lb/yr)	Sheet & Rill (t/ac/yr)
31	0.29	32	27.2	89	48	4.4
5	0.62	67	34.8	125	67	2.7
Total	**0.91**	**99**	**62**	**214**	**115**	**7.1**

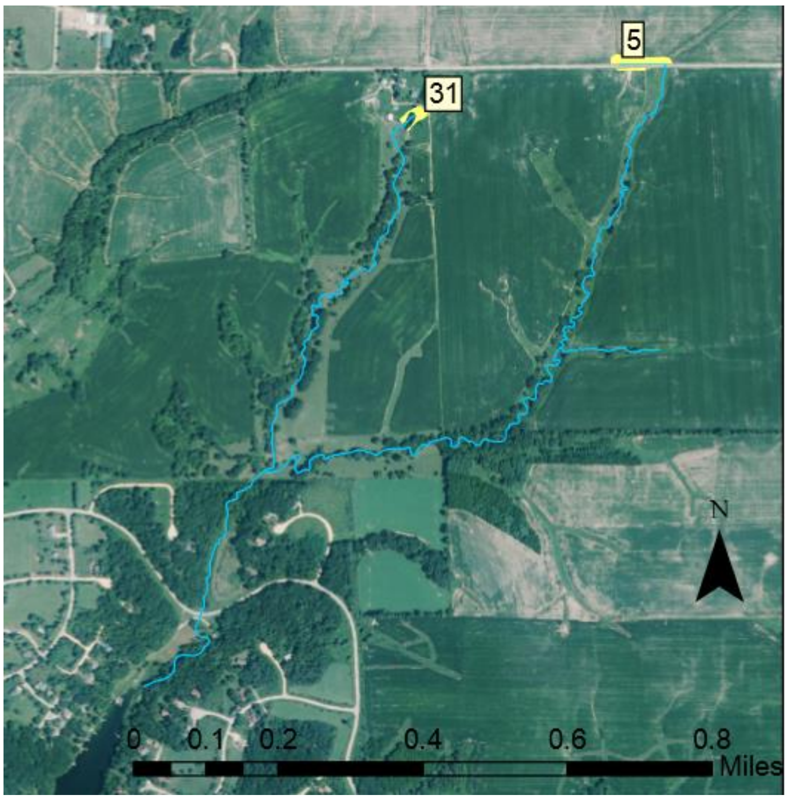


Figure 6-6. Greater than .1 acre areas within a 50ft buffer zone of stream that are currently used for cropland and have been identified as potential plots to convert to buffer.

6.6.6 Saturated Buffer

Agricultural tile drainage systems provide a direct conduit for agricultural nutrients to enter waterways (Mitsch et al., 2001). Due to the cost of nutrient applications, it is at the producer's advantage to conserve nutrients on the field for personal gain as well as environmental benefit. Several opportunities exist for controlling subsurface drainage on agricultural lands, such as treatment wetlands, bio-reactors, saturated buffers, blind inlets, improved waterways, tile outlet terraces, dry dams and diversions, and drainage water management. It is at the producer's discretion which practices are appropriate for a specific property. These Best Management Practices (BMP) are known as "edge of field" practices.

The total number of acres drained by tile in the watershed is unknown. The shale soils of the watershed are known to be actively tile drained to facilitate agricultural production. This ranges from pre-1900 clay tile that was hand dug to new plastic perforated tile that can be laid mechanically. Given the high number of acres in row crop production in the watershed there is likely a high degree of tile drainage, but no data exists to provide an educated guess. Water quality impairment due to Tile drainage has historically been focused on nitrogen loss, although recent research has hinted that more phosphorus can be present in tile drainage water than was previously anticipated (Dils & Heathwaite, 1999; Gentry, et al., 2007; Schelde, et al., 2006). The Illinois Nutrient Loss Reduction Strategy (IEPA, 2015) identifies that in-field BMPs can achieve 10 – 30% nitrogen reductions and 10 – 50% phosphorus reductions. Edge-of-field BMPs can achieve 40 – 90% nitrogen reductions and 25 – 50% phosphorus reductions. Once the nutrients make it to the field edge they are no longer available to the crops, making application of in-field practices more desirable to producers. Jaynes, et al. (2008) have found drainage water management, denitrification bioreactors, and saturated buffers to be most effective edge of field practices for nitrogen loss, and blind inlets for phosphorus loss. Due to average slope on agricultural fields in the watershed, there are few places where these practices are possible. However, there are suitable locations available in the watershed on some fields in the northernmost headlands of the watershed and their adoption is encouraged. In-field nutrient management is the best place to start, and working in-field and edge-of-field practices together can reduce runoff by 50 – 100%.

6.6.7 Shoreline Stabilization

As identified in the resource inventory (*see section 4.6*), shoreline stabilization has been identified as an area to improve erosion extent. Apple Canyon Lake contains 14.83 miles of shoreline. Of this area, 8.90 miles are owned by the property owners association, and 5.93 miles are privately owned by members. Stabilization of the lakeshore has a large potential for load reductions. Table 6-9 summarizes the cost and load reduction potential covered in Section 4.6.

Shoreline can be stabilized using rock rip rap corresponding to NRCS shoreline and streambank stabilization practice standards.

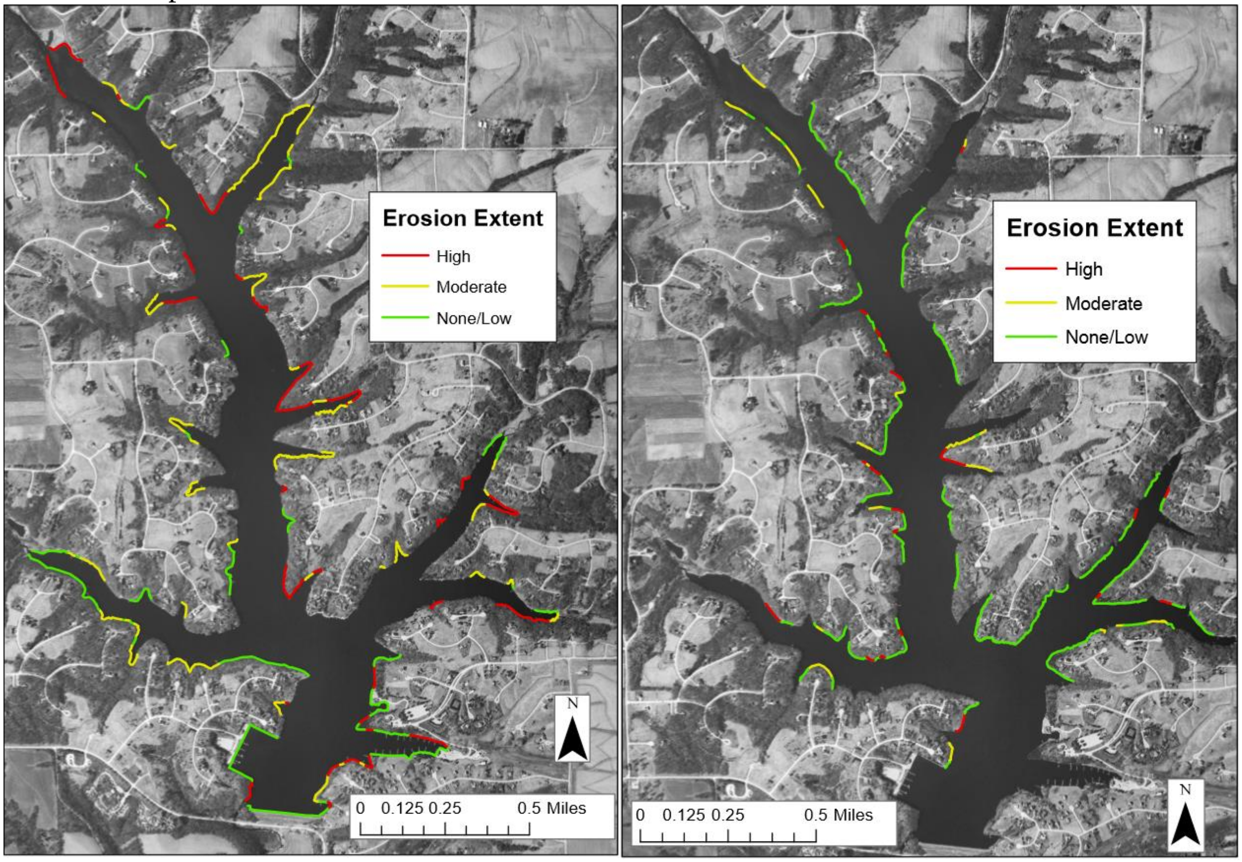


Figure 6-7. Shoreline classifications along Apple Canyon Lake. The map on the left shows shoreline owned by ACL-POA and the map on the right shows shoreline owned by private landowners.

Table 6-9. Shoreline stabilization needs and associated costs.

Lake Name	Shoreline Length Assessed (ft)	Total Erosion (ft.)	Estimated Cost ($40/ft.)
POA Shoreline	47,010	31,356	$1,254,240
Private Shoreline	31,258	8,526	$341,040
Totals	**78,268**	**39,882**	**$1,595,280**

Table 6-10. Shoreline erosion designations and load reduction estimates.

Shoreline Erosion Extent	Shoreline Length (ft)	Soil Saved (tons/yr)	Sediment Load Reduction (tons/yr)	Nitrogen Load Reduction (lb/yr)	Phosphorous Load Reduction (lb/yr)
None/Low Erosion	38,387	171	171	343	171
Moderate Erosion	22,948	683	683	1,365	683
High Erosion	16,934	1,259	1,259	2,519	1,259
Total	**78,269**	**2,113**	**2,113**	**4,227**	**2,113**

6.6.8 Stream Restoration

The stream assessment identifies 22,945 linear feet (4.35 miles) of streams contributing to loading in the watersheds. The estimated cost of this restoration is $997,800 using traditional estimation methods used by the NRCS. The cause of much of this degradation is top soil which has migrated from hill tops in the watershed and down into the floodplain. This has created a situation where the floodplain has become elevated and stormwater no longer has access to spread over the floodplain and dissipate energy. BMPs necessary to address this will primarily be creating secondary benches or rock riffles to connect streams with flood control. Armoring of stream bends will be necessary in some situations to protect sinuous corners. The topography of the watershed is such that vegetative bank protection does not work, and past implementation of rock bank protection also has not worked if flood capacity is not increased. Table 6-11 outlines the anticipated costs of stream stabilization needs in the watershed identified through field surveys conducted in 2014. Costs include survey and design, construction costs, and construction oversight and certification. These costs were based on Jo Daviess County SWCD standard rates. Engineering fees from outside entities could be considerably higher. Also included in table 6-11 are load reduction estimates which correspond to the individual projects. These loading rates were estimated using Illinois Department of Agriculture standards (Steffen, 1982).

Additionally, an analysis of the drainages on the Association Subwatershed area needs to be completed. While major stream corridors were assessed in the resource inventory, numerous contributing drainages were identified which accommodate very small drainages but collectively contribute an estimated 2,690 pounds of nitrogen and 966 pounds of phosphorus into Apple Canyon Lake each year. Individually, none of these sites are a high priority, but a study is needed to investigate these sites and develop a prioritization schedule for fixing the deteriorating conditions in each.

Table 6-11. Stream reaches, associated load contributions, and estimated restoration costs.

TRIBUTARY/STREAM	REACH	Estimated Cost	Stream Bank Length Protected (ft)	Soil Saved (tons/yr)	Sediment Load Reduction (tons/yr)	N load Reduction (lb/yr)	P load Reduction (lb/yr)
Hell's Branch/North Bay	NB1	$40,320	908	47.29	47.29	94.58	47.29
Hell's Branch/North Bay	NB1	$61,240	1431	96.87	96.87	193.74	96.87
Hell's Branch/North Bay	NB2	$56,480	1312	65.56	65.56	131.11	65.56
Hell's Branch/North Bay	NB3	$73,160	1729	157.95	157.95	315.89	157.95
Hell's Branch/North Bay TOTAL		**$231,200**	**5380**	**367.66**	**367.66**	**735.32**	**367.66**
Winchester	WC1	$133,160	3229	201.19	201.19	402.38	201.19
Winchester	WC Trib 1	$36,200	805	50.80	50.80	101.61	50.80
Winchester	WC2	$129,520	3138	178.32	178.32	356.64	178.32
Winchester	WC2	$50,520	1163	49.93	49.93	99.86	49.93
Winchester TOTAL		**$349,400**	**8335**	**480.24**	**480.24**	**960.49**	**480.24**
President's	PB1	$46,480	1062	63.67	63.67	127.33	63.67
President's	PB1	$27,920	598	34.52	34.52	69.03	34.52
President's	PB Trib 1	$25,840	546	26.00	26.00	52.01	26.00
President's	PB Trib 2	$67,240	1581	90.25	90.25	180.51	90.25
President's TOTAL		**$167,480**	**3787**	**214.44**	**214.44**	**428.88**	**214.44**
Independence	ID 1	$27,680	592	33.34	33.34	66.67	33.34
Independence	ID 1	$34,760	769	37.53	37.53	75.06	37.53
Independence	ID 1	$15,360	284	13.16	13.16	26.31	13.16
Independence	ID Trib 1	$27,640	591	36.82	36.82	73.64	36.82
Independence	ID 2	$44,600	1015	44.95	44.95	89.91	44.95
Independence TOTAL		**$150,040**	**3251**	**165.79**	**165.79**	**331.59**	**165.79**
Hawthorne	HW1	$55,600	1290	83.39	83.39	166.78	83.39
Hawthorne	HW2	$37,600	840	57.36	57.36	114.72	57.36
Hawthorne	HW Trib 1	$6,480	62	5.27	5.27	10.54	5.27
Hawthorne TOTAL		**$99,680**	**2192**	**146.02**	**146.02**	**292.05**	**146.02**
	Total	**$997,800**	**22,945**	**1,374**	**1,374**	**2,748**	**1,374**

Multiple intermittent and perennial drainages exist in the Association subwatershed and are beyond the scope of this analysis; subsequently not included in Table 6-11. These areas are the lowest in priority only because when considered for remediation it was determined by the SWCD that these areas would require the highest dollar amount to complete, with the lowest amount of sediment reduction.

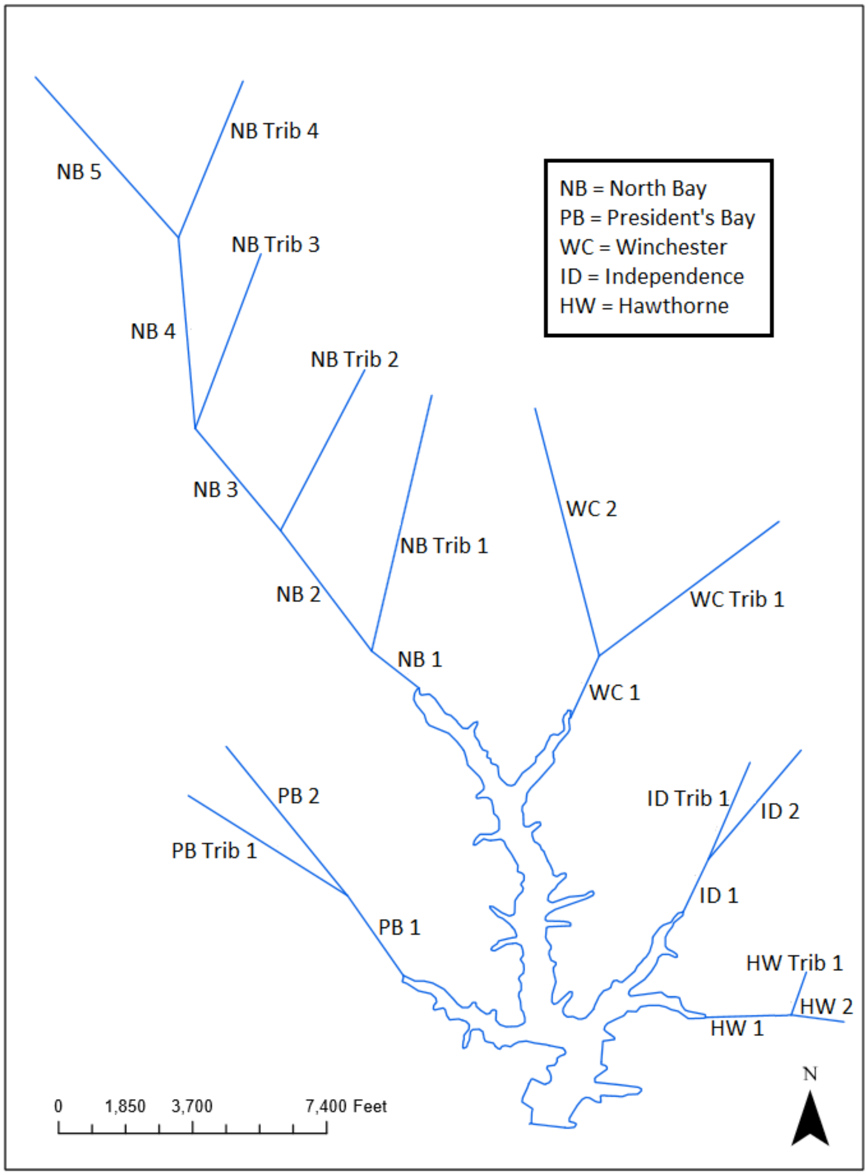


Figure 6-8. Designated stream reaches in the Apple Canyon Lake watershed.

6.6.8.1 Stream Reach NB 1

For the section of stream on ACLPOA property where Hells Branch feeds Apple Canyon Lake, 908 feet of stream needs to be stabilized. This stabilization should occur across the property boundary and encompass approximately 2300 ft. A detailed analysis will need to take place in order to take the best approach to restoration. A feasibility study should be performed in order to assess the possibility of installing a retention structure or constructed wetland in the area upstream from the lake. This may require purchase of land by ACLPOA and will require funding allocations in addition to current allocations to create a reserve for funding land acquisitions.

Figure 6-9. Downcutting and bank erosion in Stream Reach NB1

6.6.8.2 Stream Reach WC 1

Approximately 3200 ft. of stream at Winchester Bay feeding Apple Canyon Lake on Association property is extremely eroded. This erosion process continues up stream into WC 1 and WC Tributary 1. A significant cause of this erosion through this section is channelization of the stream caused by the road and incorrect installation of the road culvert where the stream crosses. A detailed study will be required to determine the needs and costs associated with a bridge to replace this culvert.

Figure 6-10. Elevated floodplain in WC1 leads to increased flow velocities.

6.6.8.3 Stream Reach PB 1

This section of stream has had a great deal of work installed on it in the past with only minor areas needing some repair. Through the Illinois Dept. of Agriculture's Stream Stabilization and Restoration Program three rock riffles have been installed along with several sections of streambank protection. There are still some minor sections of exposed soil where installed practices have been damaged by high storm flows as well as a heavily scoured area at the outlet of the culvert under Northwest Apple Canyon Rd. The upstream side of the culvert receives a regulated flow from a retention pond which already acts as a barrier to fish passage and culvert replacement is not likely to be necessary. In most cases, fish passage barriers are a concern. However, in this watershed migration of lacustrine species such as largemouth bass can impact native smallmouth bass fisheries in the streams of the watershed. Barriers preventing lacustrine species spread is a benefit in the Apple Canyon Lake watershed.

6.6.8.4 Stream Reach ID 1

Independence Bay has received significant stabilization work in the past with minor touch-ups being needed on existing projects as well as improvements in riparian vegetation. Significant scouring has occurred around the outlet of the culvert under East Apple Canyon Road. The stream is extensively channelized throughout this area and needs to be reconnected with a floodplain (*a culvert and dry dam inventory and report was completed by the University of Wisconsin, Platteville, Environmental Engineering Department in December 2015).*

Figure 6-11. Erosion and bank condition in ID 1. Former bank is evident in these photos, however, spot treatment has not remedied larger issues.

6.6.8.5 Stream Reach HW 1

The stream segment directly feeding Hawthorne Bay is highly channelized with the primary cause being the culvert which supports the recreational trail. The grade of the stream needs to be raised and the culvert design must accommodate more capacity. Similarly, the culvert under East Apple Canyon Road causes similar channelization. In the restored prairie segment between the two culverts the stream condition is improved and the stream is able to access the floodplain under storm conditions (*a culvert and dry dam inventory and report was completed by the University of Wisconsin, Platteville, Environmental Engineering Department in December 2015. See Appendix 7).*

6.6.9 Other Best Management Practices

In addition to the tasks outlined in Sections 6.6.1 – 6.6.8, it has been noted throughout this planning process that some additional studies are still needed. These studies include an inventory of the culverts and bridges in the watershed, a study of septic system functionality, an assessment and remediation prioritization of drainages in the Association subwatershed, and an analysis to determine whether road salt has any impact on the watershed. These studies were beyond the scope of this watershed plan, and/or determined to have a minimal or lower priority than the larger projects addressed in this plan to meet the goals and objectives. Still, these tasks are important and can benefit some of the higher priority tasks.

Other upland best management practices (BMP) identified as beneficial for the watershed but not specifically allocated for implementation or quantified for nutrient benefits at this time are listed below:

- Nutrient management (rate, timing, placement, and form).
- Residue & Tillage management; no-till/strip-till.
- Grassed waterways.
- Water and sediment control basins.
- Grade stabilization structures.
- Terraces.
- Pasture/grassland management; prescribed grazing.
- Anaerobic digester.
- Wetland restoration.
- Pond development.
- Fencing livestock from streams.
- Additional individual stream stabilization projects not listed in 6.6.8.1 – 6.6.8.5.
- Stream crossings.

These BMPs are encouraged to improve water quality throughout the watershed, however they were not identified in the resource inventory as high priority projects due to cost, potential benefit, and/or stakeholder willingness to participate. There are many references available for identifying and evaluating practices. The following list is taken from the Jo Daviess County Water Resource Management Workbook (LWV, 2016). This list is not complete, and efforts to identify and evaluate additional practices should be ongoing. It should also be noted that some stormwater management problems may require multiple practices to create an effective solution. Where available, technical job sheets relating these practices have been included in Appendix 4.

The following definitions have been created primarily by referencing the following resources:

- Natural Resource Conservation Service (NRCS) Field Office Technical Guide (FOTG) as applicable in Illinois (https://efotg.sc.egov.usda.gov/treemenuFS.aspx), http://www.nrcs.usda.gov/wps/portal/nrcs/detail/il/home/?cid=nrcs141p2_031327
- Association of Illinois Soil Water Conservation Districts' "Illinois Urban Manual" (www.aiswcd.org/illinois-urban-manual),
- The "Illinois Nutrient Loss Reduction Strategy" (http://www.epa.illinois.gove/Assests/iepa/water-quality/watershed-management/nlrs/nlrs-final-revised-083115.pdf),

- The Illinois Council on Best Management Practices (http://illinoiscbmp.org/), and
- The U.S. Green Building Council's Leadership in Energy and Environmental Design certification program (LEED) (www.usgbs.org/leed)
- University Extension (Illinois: http://extension.illinois.edu/lcr/stormwater.cfm, Wisconsin: http://www4.uwm.edu/swec/publications/cabinet/p2/Wisconsin%20Storm%20Water%20and%20Run-Off%20Information%20and%20Resources.pdf)

Bioswales
"Grassed Waterway": A shaped or graded channel that is established with suitable vegetation to convey surface water at a non-erosive velocity using a broad and shallow cross section to a stable outlet (NRCS Conservation Standard 412).

"Grass-Lined Channels": Natural or constructed channel vegetated to convey water (AISWCD Code 840).

"Infiltration Trench": Pits or trenches designed to hold water to increase infiltration (AISWCD Code 847).

"Vegetated Treatment Area": An area of permanent vegetation used for agricultural wastewater treatment (NRCS Conservation Standard 635).

Cisterns/tanks/rain barrels
A rain barrel is a system that collects and stores rainwater from your roof that would otherwise be lost to runoff and diverted to storm drains and streams (Jo Daviess County SWCD).

Larger tanks and underground cisterns can also be used to store greater quantities of rainwater.

Composting
A mixture of decayed or decaying organic matter used to fertilize soil. Compost enhanced and amended soils reduce runoff, soil erosion, and unwanted transport or chemicals and residues. University of Wisconsin offers a master composter resource guide: http://www4.uwm.edu/shwec/publications/cabinet/composting/Master%20Composter%20Resource%20Guide.pdf

Conservation Tillage
"Reside and Tillage Management, No-Till": Limiting soil disturbance to manage the amount, orientation, and distribution of crop and plant residue on the soil surface year round (NRCS Conservation Standard 329).

Cover Crops
"Cover Crop": Grasses, legumes, and forbs planted for seasonal vegetative cover (NRCS Conservation Standard 340).
Farmer and Landowner Greg Thoren, working with John Musser (Stephenson Farm Service), Mike Malon (Jo Daviess Count Soil & Water Conservation District), Jay Solomon (University of Illinois Extension), and Art Scheele (Agnetic, LLC), is conducting a five-year experiment with

10 cover crop mixes on acreage on Rte. 78 immediately south of Stockton. The study is investigating cover crop implementation strategies that are successful in northern Illinois to improve soil health, nutrient management, fertility, and water quality. The Farm Bureau has awarded an $8,000 grant to support soil sampling being done by the Stephenson FS. Field days are being offered to showcase and share the information gathered during the experiment. Those wishing to be notified of field days at the cover crop plot should contact the Jo Daviess County Farm Bureau Manager at jdcfbmgr@blkhawk.net

Detention/Retention Basins

"Sediment Basin": A basin constructed with an engineered outlet, formed by an embankment or excavation or a combination of the two (NRCS Conservation Standard 350).

"Shallow Water Development and Management": The inundation of lands to provide habitat for fish and or/wildlife (NRCS Conservation Standard 646).

"Structure for Water Control": A structure in a water management system that conveys water, controls the direction or rate of flow, maintains a desired water surface elevation, or measures water (NRCS Conservation Standard 587).

"Water and Sediment Control Basin": An earth embankment or a combination ridge and channel constructed across the slope of minor watercourses to form a sediment trap and water detention basin with a stable outlet.

The University of Wisconsin, Platteville, Environmental Engineering students designed detention basins for the City of Galena.

Filter/Buffer Strips

"Filter Strips": A strip or area of permanent herbaceous vegetation situated between cropland, grazing land, or disturbed land and environmentally sensitive areas (NRCS Conservation Standard 393).

"Filter Strips": Vegetated filter zone to remove pollutants (AISWCD Code 835).

"Contour Buffer Strips": Narrow strips of permanent, herbaceous vegetative cover established around the hill slope, and alternated down the slope with wider cropped strips that are farmed on the contour (NRCS Conservation Standard 332).

"Conservation Buffers": Conservation buffers are strips of permanent vegetation that are meant to capture nutrients and sediment carried by surface water. They do that by slowing down surface water and allowing plants to take up and use the water and nutrients (C-BMP).

"Riparian Buffers": Riparian buffers are vegetated areas next to water resources that protect water resources from nonpoint pollution and provide bank stabilization and aquatic and wildlife habitat.
http://www.soil/ncsu.edu/publications/BMPs/buffers.html

Green Roofs
A green roof, or "living roof" is a roof of a building that is partially or completely covered with vegetation and a growing medium, planted over a waterproofing membrane. It may also include additional layers such as a root barrier and drainage or irrigation systems.

Native Perennial Plantings
Perennial crops are crops that live for years and can be harvested many times before they die. Plants such as apples and alfalfa are perennials that are commercially grown and harvested, as are biofuel crops such as miscanthus and switchgrass. Perennial crops have been shown to reduce nutrient losses (C-BMP).

"Conservation Cover": Establishing and maintaining permanent vegetative cover (NRCS Conservation Standard 327).

"Critical Area Planting": The establishment of permanent vegetation on sites with high erosion rates and on sites that have physical, chemical, or biological conditions that prevent the establishment of vegetation with normal practices (NRCS Conservation Standard 342).

Nutrient Management
In the Science Assessment portion of the "Illinois Nutrient Loss Reduction Strategy", the Northern Mississippi Valley Area (USDA Major Land Resource Area 105) is assumed to be primarily non-tiled land, and using available information, 31.3 lbs. of Nitrate-N is estimated to be lost per row crop acre per year. This is the highest rate of loss shown in the state for non-tiled areas (the next highest is 11.8 lbs. lost). The Science Assessment also notes that "The largest manure phosphorous rate was . . . in northwestern Illinois, where there was a high density of livestock." (INLRS p. 3-22)

The agricultural community in Illinois is actively pursuing best practices to reduce the loss of nutrients from the field to reduce input costs, maximize yields, and improve water quality. Efforts have focused on the "4 Rs" of Nutrient Stewardship: Right Source, Right Rate, Right Time, and Right Place.

"Nutrient Management": Managing the amount (rate), source, placement (Method of application), and timing of plant nutrients and soil amendments (NRCS Conservation Standard 590).

"Drainage Water Management": Drainage water management is the practice of using a water control structure in a main, submain, or lateral drain to vary the depth of the drainage outlet. *http://www.extension.umn.edu/agriculture/water/publications/pds/highreswq44rev.pdf*

"Denitrifying Bioreactor": A structure containing a carbon source, installed to reduce the concentration of nitrate nitrogen in subsurface agricultural drainage via enhanced denitrification (NRCS Conservation Standard 747).

"Saturated Buffer": A saturated buffer is a riparian buffer in which the water table is artificially raised by diverting subsurface drainage along the buffer, accomplished by installing a water

control structure in the main drainage outlet.
https://efotg.sc.egov.usda.gov/references/public/IA/Saturated_Buffer_739_FS_2015_01.pdf

Permeable Surfaces
"Permeable Pavement": Pavement having interspersed sod, gravel, or sand areas (AISWCD Code 890).

The City of Dubuque has been implementing a permeable paver program:
http://cityofdubuque.org/1818/Green-Ally-Reconstruction

Rain Gardens
Small, shallow, flat-bottomed, depressions constructed to temporarily hold and infiltrate stormwater close to where the stormwater is generated (Under NRCS "Stormwater Runoff Control, Code 570).

Streambank Stabilization
"Streambank and Shoreline Protection": Treatment(s) used to stabilize and protect banks of streams or constructed channels, and shorelines or lakes, reservoirs, or estuaries (NRCS Conservation Standard 580).

"Vegetative Streambank Stabilization": Vegetation to control streambank erosion (AISWCD Code 995).

"Structural Streambank Stabilization": Structure to control streambank erosion (AISWCD Code 940).

Terraces
"Terrace": An earth embankment, or a combination ridge and channel, constructed across the field slope (NRCS Conservation Standard 600).

Wetland Protection/Restoration/Creation
A wetland is a marsh-type area with saturated soils and water-loving plants. Wetlands can be constructed for the purpose of removing nutrients because they filter nutrients, chemicals, and sediment from runoff or tile water before water moves . . . into streams and rivers. Because wetlands slow overland flow and store runoff water, they reduce both soil erosion and flooding downstream. Many wetlands release water slowly into the ground which recharges groundwater supplies (C-BMP).

"Constructed Wetland": An artificial ecosystem with hydrophytic vegetation for water treatment (NRCS Conservation Standard 656).

"Wetland Creation": The creation of a wetland on a site location that was historically non-wetland (NRCS Conservation Standard 658).

"Wetland Enhancement": The augmentation of wetland functions beyond the original natural conditions on a former, degraded, or naturally functioning wetland site: sometimes at the expense of other functions (NRCS Conservation Standard 659).

"Wetland Restoration": The return of a wetland and its functions to a close approximation of its original condition as it existed prior to disturbance on a former or degraded wetland site (NRCS Conservation Standard 657).

"Bioretention": Constructed wetland to improve stormwater quality (AISWCD Code 800).

6.6.10 Woodland Management

Throughout the resource inventory invasive species were frequently encountered. Section 3.4 documents the Emerald Ash Borer's impact as well as the impact of invasive plant species such as bush honeysuckle (*Lonicera sp.*), autumn olive (*Elaeangus sp.*), multiflora rose (*Rosa multiflora*), and garlic mustard (*Alliaria petiolata*). These species form dense canopies which provide so much shade that little growth occurs underneath these species. This factor, along with their shallow root system, cause a condition which leads to rapid erosion beneath the plants, as well as undermining plant diversity.

Improved woodland management is inherently necessary. Woodland accounts for 1405.3 acres (14.4% of the watershed), and has the potential to have a notable improvement in stormwater runoff, if managed correctly. There are many public programs available to manage woodlands, such as programs created through the NRCS, IDNR, and not-for-profit conservation groups. A majority of the forestland in the watershed can be enrolled in these programs to provide management plans and implementation to profitably manage these forests. For assessment of these activities, percentage of plans created can be divided by total number of forested acres to determine achievement level.

7.0 OVERALL WATERSHED MANAGEMENT

7.1 Plan Logistics

The planning committee represents those parties who are affected or have vested interest in the outcome of the watershed planning process. At the first watershed meeting it was decided by the attendance that in order to keep a democratic planning process everyone's comments would be heard and all participants would have an equal share in arriving at goals and strategies for the planning process. The Jo Daviess County Soil and Water Conservation District has led the planning meetings and has performed most organizational, survey, and analysis work. The Apple Canyon Lake Property Owners Association (ACLPOA) management and residents were heavily involved in the planning process and devising goals for the watershed. The ACLPOA Conservation Committee has been instrumental with making budget recommendations to the ACLPOA board of directors. The agricultural community, which owns or operates a majority of land in the watershed, has been extremely active in the planning process and was well represented. Additional planning assistance was received by the Jo Daviess County Health Department and the Jo Daviess County Building and Zoning Office. The townships of Scales Mound, Thompson, and Apple River represent interest in road projects.

The Jo Daviess County SWCD will continue to lead the implementation of the plan as outlined in this document. The Apple Canyon Lake Watershed Plan is written using an adaptive management approach. Adaptive management is a systematic process for continually improving management policies and practices by learning from the outcomes of implemented management strategies. For this reason, monitoring is highly important to the success of the implementation practices advocated in this plan. Monitoring results are evaluated and adjustments can be made to ensure that all actions are effective. At five year intervals this entire plan will be assessed to assure adherence to the planning framework, outline additional funding needs, and to make revisions to the plan, as needed. The monitoring component will be utilized annually to identify shortcomings in planning estimates.

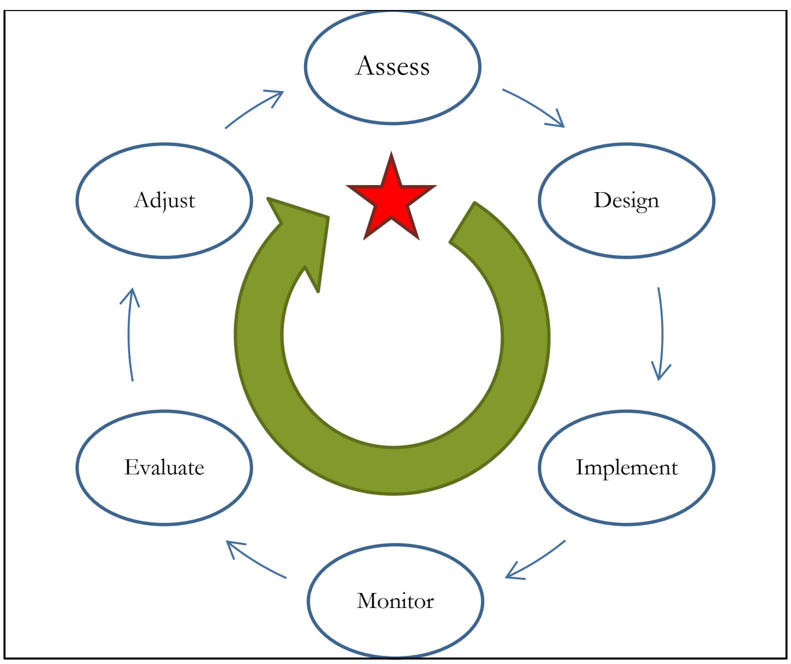


Figure 7-1. Graphic of the adaptive management process.

7.2 Apple Canyon Lake Property Owners Association

Apple Canyon Lake Property Owners Association (ACLPOA) has been the leading entity in the watershed planning process. ACLPOA initiated watershed planning and has provided the backing funds to complete the watershed plan. ACLPOA oversees enforcement of the covenants on their property, creates rules and regulations, and provides the organizational framework for the Conservation Committee, Architectural Committee, volunteers, and educational events. Within the governing board of ACLPOA, the annual budget allocates significant funding towards the implementation of the planning strategy contained in this document. Finally, the ACLPOA oversees the implementation of their budget and ensures that projects are completed in a timely manner, as designed, and in accordance with all necessary state and federal regulations.

7.3 Agricultural Areas

During the planning process the agricultural community which owns and operates a majority of the land outside of the property owners association has been extremely involved in participating in plan creation. These individuals know their lands better than anyone and also know what will work on their specific conditions. Although experts can make recommendations for projects to implement on these private farm lands, the individuals are the final decision makers when it comes to BMP implementation. While BMP practices may be optimized for water quality, the planning group understands that land owners have to justify expenses within their own business and land constraints, often requiring compromises on both parts. While this plan recommends the adoption of many BMPs on private agricultural lands the landowner is ultimately responsible for specific practices on their own land.

8.0 IMPLEMENTATION FRAMEWORK

Plan implementation is primarily led through the Property Owners Association, as the largest control of land in the watershed is under their ownership. Implementation is based on priority with milestones identified to track steps towards completion and identification of critical control points.

Project priority is given towards the largest subwatersheds first, with smaller areas receiving lower priority. For ACLPOA properties and projects, implementation begins with a stream corridor restoration approach to the largest subwatershed, North Bay, followed by Winchester Bay, Presidents Bay, Independence Bay, and Hawthorne Bay. Allocated ACLPOA funding will address restoration to the stream sections on ACLPOA property before it enters the lake.

The Association subwatershed surrounding the lake comprises nearly 25% of the total watershed size, though 4% of the watershed area is the lake. This area contains little to no perennial streams but is composed of many steep, highly eroded drainage ditches with only ephemeral flow. During dry years these areas have very little contribution to nutrient and sediment loading but may become significant during periods of flash storm events and heavy rainfall. These areas were not prioritized directly, but funding will be shifted to address these areas after the priority implementation schedule has been completed. The methods to address these areas will be assessed at that time. Minor spot treatment within these areas will be addressed on an individual basis as needed and as funding becomes available.

Because the water in Apple Canyon Lake is the lowest point in the watershed, it becomes one of the best areas for assessing the success of water quality improvement projects and best management practice implementation. However, the water in Apple Canyon Lake has an estimated residence time of 16 months. Given this time period, results from practice implementation will not be immediately evident. Stream water quality monitoring is more useful to track specific loading contributions. The following sections outline the implementation framework which will lead to the success of the identified goals and objectives.

8.1 Measuring Plan Implementation Progress

8.1.1 Monitoring

A monitoring strategy is essential for the success of a comprehensive watershed management plan. The monitoring strategy provides the ability to evaluate plan implementation progress and success over time. Monitoring the implementation of this plan involves reviewing all of the activities associated with the goals and objectives, and can be grouped into (1) water quality monitoring, (2) BMP implementation monitoring, and (3) education monitoring.

Further monitoring will take place in revisions made to the watershed plan made at five-year intervals. At this time, land-use statistics will be re-evaluated to document fluctuations. Flow data and weather statistics will also be evaluated to consider environmental changes which affect the efficacy of planning efforts. Using the checklists at the end of this plan (*see section 8.4*), will provide a feedback loop for determining monitoring success.

8.1.1.1 Water Quality Monitoring

Monitoring the tributaries which feed Apple Canyon Lake began in 2014 under an Illinois Environmental Protection Agency (IEPA) approved Quality Assurance Project Plan (QAPP). This adds to baseline data dating back to 1999 collected under the IEPA's Volunteer Lake Monitoring Program. Used together, this data provides a basis for trend identification and efficacy of implementation of best management practices installed as part of this plan. The water in Apple Canyon Lake has an estimated residence time of 16.1 months. Given this figure, reliance on periodic data from the VLMP program is not enough. VLMP program data is extremely important, however, for overall analysis of lake water quality and must be continued. Individual tributary monitoring gives more precise data for particular loading factors from the subwatersheds. The dataset for this information is currently very small as opposed to the VLMP dataset. Ongoing tributary monitoring will help to establish this expanded dataset which will provide more detailed information on changes in water quality relating to plan implementation as opposed to changes caused by physical conditions.

8.1.1.1.1 Tributary Stream Monitoring

Tributary streams began being monitored in 2011 by private homeowners at Apple Canyon Lake. In 2012, monitoring was done on tributaries through a partnership with the University of Dubuque. A student tested nine sites and an improved testing regimen was conducted. Unfortunately, quality assurance procedures were not in place and samples were held well past allowable holding times. The samples were eventually processed in the fall of the year but were not able to be used for sampling. A sampling protocol was started at the onset of the watershed planning process and follows a quality assurance project plan (QAPP) approved by the Illinois Environmental Protection Agency (*see Appendix 5*). Under this QAPP, nine sites were selected to monitor water around the watershed (*see figure 8-1*). One site (MNEAA-01) is not located in the watershed but was selected to monitor the water coming off of the Apple Canyon Lake golf course. MNEA-02 monitors the water flowing out of Apple Canyon Lake, and is assumed to be the final outflow of surface waters from the watershed. MNEAG-02 monitors the water coming in to Koester's pond in President Bay subwatershed. This site was selected to compare the efficacy of the retention pond for improving water quality in that subwatershed. The remaining sites were all selected to sample waters at the terminus of their respective subwatershed and as they enter Apple Canyon Lake. After two years of monitoring, MNEAA-01 and MNEAB-01 have been removed due to very low flow making testing and discharge measurements physically impossible in many months, resulting in inconsistent results. MNEAG-02 is also removed for cost savings to the Property Owners Association because the Presidents Bay subwatershed is also monitored at a MNEAG-01 which is consistent with the other subwatershed testing sites.

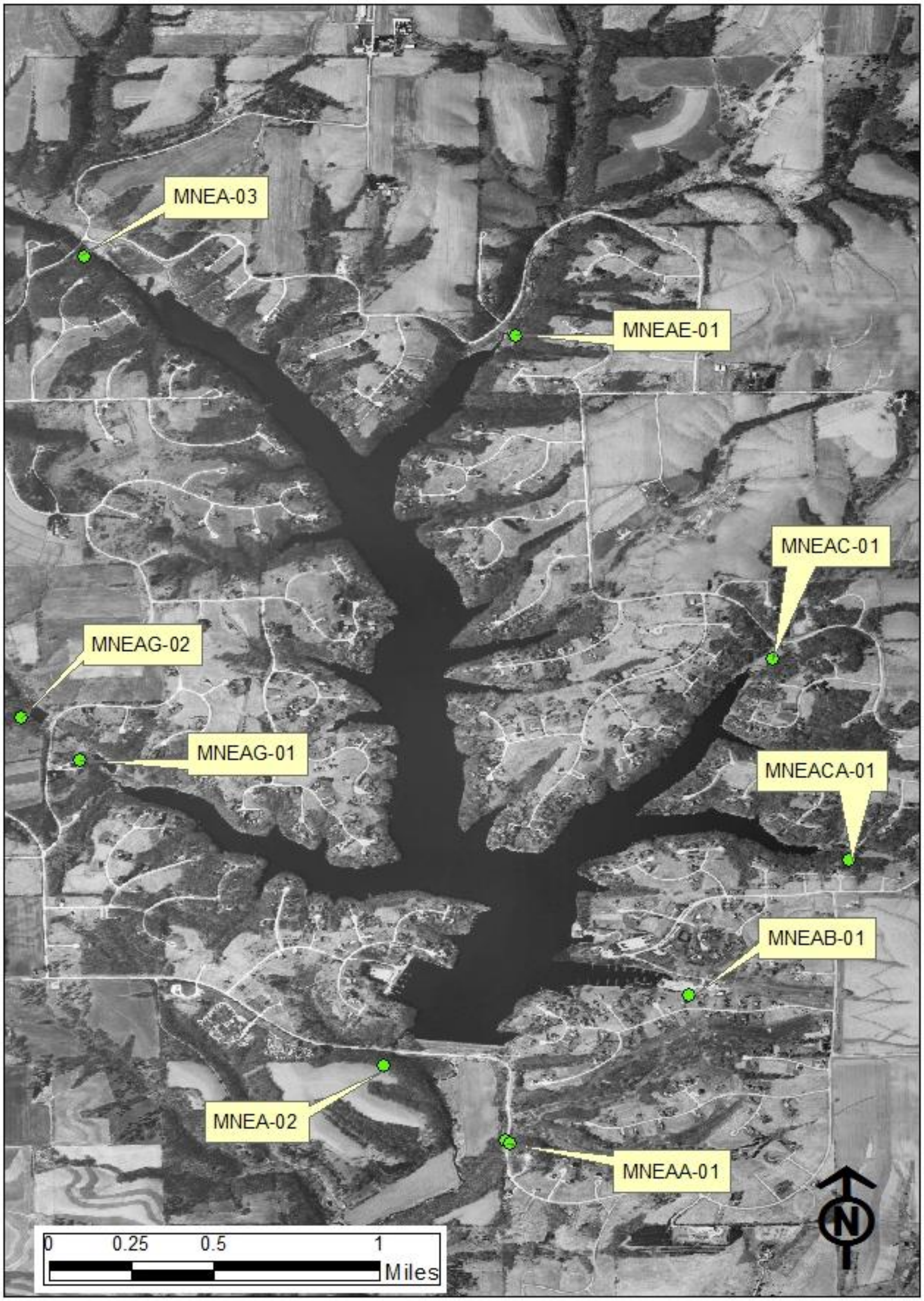


Figure 8-1. Sampling locations for tributary water sampling and discharge measurements.

8.1.1.1.2 Volunteer Lake Monitoring Program Monitoring

In 1981, the Illinois Environmental Protection Agency established the Volunteer Lake Monitoring Program (VLMP). The program provides a service to the Agency by harnessing the time and talent of citizen volunteers to help gather fundamental information on more Illinois' inland lakes than could otherwise be possible with existing staff. This program also serves its volunteers and the general public by opening a path for citizen involvement with the environment and providing environmental education and outreach opportunities for Illinois citizens to learn about lake ecosystems. This program also serves as a cost-effective method for gathering fundamental information on inland lakes, which ultimately leads to making better lake management decisions.

VLMP data is available for Apple Canyon Lake as far back as 1994. Although levels of testing have varied over the years with funding, a basic consistent database is available for most of this time period. Testing at the Tier III level, which includes chemical lab analysis, has been performed alongside stream monitoring which creates consistency between both testing programs and allows correlation between stream and lake water quality. It would be beneficial if VLMP testing would remain at Tier III to continue with the Property Owners Association efforts to continue stream monitoring. Figure 8 – 2 shows locations for the samples taken for the VLMP program.

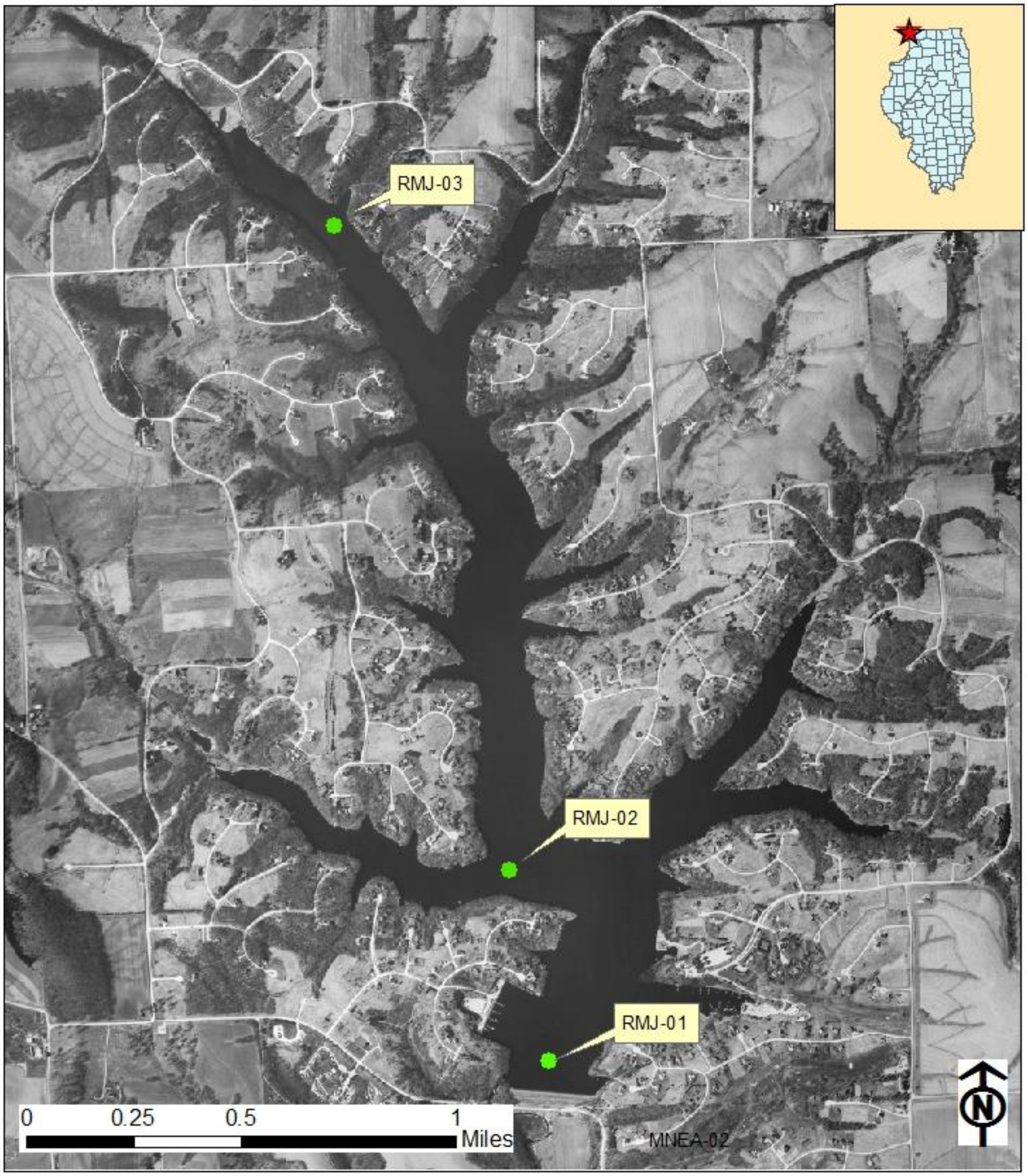


Figure 8-2. In-lake testing sites used for the VLMP program.

8.1.1.1.3 RiverWatch Monitoring

RiverWatch monitoring (*described in section 6.6.2*) will continue to be performed at the same monitoring sites as used for chemical and discharge monitoring, described in section 8.3.1 and shown in figure 8 – 1. This program adds to both our monitoring database, the statewide database, and part of the education strategy of the watershed planning effort.

8.1.1.2 BMP Implementation Monitoring

BMP implementation monitoring will take place on a regular basis. Formally, at five year intervals the plan will be reviewed and updated. Less formally, the plan will be reviewed annually using the checklists in Section 8.4. There is a wide variety of BMP practices and applicable entities recommended to complete the implementation plan in this document. These tasks can easily be lost if management is not active. The overall scope of these tasks is also large, requiring multi-year coordination among multiple entities. In order to stay on track with the timeline a frequent review of the implementation schedule is necessary.

8.1.1.3 Education Monitoring

Tracking educational events is an important part of the monitoring process. Conducting the educational activities is not enough to ensure that the events are themselves effective. By monitoring readership numbers and attendees at events and meetings the efficacy of educational activities can be reviewed and future events can be tailored to ensure that activities continue to engage and educate the target groups.

8.2 Implementation Schedule

Goal 1 - Improve Water Quality		Phase 1			Phase 2			Phase 3			Phase 4 & 5		
		Years 1 - 4			Years 5 - 8			Years 9 - 12			Years 13 - 20		
Task	**Objective**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**
Stabilize erosive stream reaches.	1a	5,791 ft.	690	345	4,124 ft.	531	266	6,059 ft.	677	338	6,971 ft.	849	424
Stabilize erosive lakeshore.	1b	7,976 ft.	1,186	593	7,976 ft.	1,186	593	7,976 ft.	562	281	15,953 ft.	1,292	646
Improve the riparian buffer around the lake.	1c	3.79 ac. / 3,298 ft.	451	242	3.79 ac. / 3,298 ft.	451	242	3.79 ac. / 3,298 ft.	451	242	7.57 ac. / 6,595 ft.	1,726	925
Identify critical areas affecting water quality in the watershed.	1c	Perform Study.	*	*	As study indicates.	*	*	As study indicates.	*	*	As study indicates.	*	*
Improve riparian buffer in the watershed.	1c	3.3 ac.	272	146	3.3 ac.	272	146	3.3 ac.	272	146	6.7 ac.	543	292
Continue water quality monitoring for tributary streams.	1d	28	0	0	28	0	0	28	0	0	56	0	0
Continue Tier III VLMP monitoring.	1d	12	0	0	12	0	0	12	0	0	24	0	0
Develop cost-sharing program for BMP implementation on private lands in the watershed.	1f	1	0	0	0	0	0	0	0	0	0	0	0
Perform study on septic systems at ACL.	1g	Perform Study.	*	*	As study indicates.	*	*	As study indicates.	*	*	As study indicates.	*	*
Improve septic inspection policy at the Property Owners Association.	1g	1	0	0	0	0	0	0	0	0	0	0	0
Provide annual analysis of water quality data.	1d	4	0	0	4	0	0	4	0	0	8	0	0
Apply gypsum to cropland in watershed.	1f	6,000 ac.	0	215	6,000 ac.	0	215	6,000 ac.	0	215	11,000 ac.	0	394
Apply cover crops to cropland in watershed.	1f	6,000 ac.	22,885 lb.	11,446 lb.	6,000 ac.	22,885 lb.	11,446 lb.	6,000 ac.	22,885 lb.	11,446 lb.	11,000 ac.	275,086 lb.	137,369 lb.
Install a demonstration tile gate on a tiled crop field.	1f	1	100	25	0	0	0	0	0	0	0	0	0
Continue to develop RiverWatch database.	1e	4	0	0	4	0	0	4	0	0	8	0	0
Review watershed plan annually and amend as necessary.		4	*	*	4	*	*	4	*	*	8	*	*

Goal 2 - Reduce algal blooms and excessive aquatic plant growth.		Phase 1			Phase 2			Phase 3			Phase 4 & 5		
		Years 1 - 4			Years 5 - 8			Years 9 - 12			Years 13 - 20		
Task	**Objective**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**
Map current extent of plant coverage.	2a	1	NA	NA	1	NA	NA	1	NA	NA	2	NA	NA
Develop a management plan for aquatic plants.	2b	1	NA	NA	1	NA	NA	1	NA	NA	2	NA	NA
Identify critical areas in the watershed.	2c	1	NA	NA	1	NA	NA	1	NA	NA	2	NA	NA
Perform feasibility study for storm retention in North Bay.	2d	1	NA	NA	1	NA	NA	1	NA	NA	1	NA	NA

Goal 3 - Mitigate existing flooding problems.		Phase 1			Phase 2			Phase 3			Phase 4 & 5		
		Years 1 - 4			Years 5 - 8			Years 9 - 12			Years 13 - 20		
Task	**Objective**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**	**Units**	**N Reduction (lbs)**	**P Reduction (lbs)**
Increase connectivity between streams and floodplains.	3a	Accomplished through stream stabilization (see Goal 1)	*	*	*	*	*	*	*	*	*	*	*
Create green infrastructure plan for developed areas.	3b	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Create a zero-runoff policy for new construction in the property owners association.	3c	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Encourage zero-runoff adherence for existing properties.	3d	1	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Goal 4 - Educate watershed community.		Phase 1			Phase 2			Phase 3			Phase 4 & 5		
		Years 1 - 4			Years 5 - 8			Years 9 - 12			Years 13 - 20		
Task	**Objective**	**Meetings**	**Articles**	**Events**	**Meetings**	**Articles**	**Events**	**Meetings**	**Articles**	**Events**	**Meetings**	**Articles**	**Events**
Continue quarterly watershed meetings.	4a, 4b	16	*	*	16	*	*	16	*	*	32	*	*
Publish educational articles in local news sources and online resources.	4a, 4d	*	48	*	*	48	*	*	48	*	*	96	*
Host educational events.	4a, 4e	*	*	8	*	*	8	*	*	8	*	*	16
Increase participation in the RiverWatch program.	4a, 4f	*	*	4	*	*	4	*	*	4	*	*	8
Demarcate watershed boundaries on major roads.	4a, 4c	NA	NA	5	NA	NA	Maintain as needed	NA	NA	Maintain as needed	NA	NA	Maintain as needed

8.2.1 Milestones

This comprehensive watershed management plan has been written to cover a 20-year timeframe and is broken down into five phases. Total water quality improvements for each phase are shown in Table 8-2 and can be used to track progress towards reaching the overall project goals. The water quality milestones are specifically for total nitrogen, total phosphorus, and total sediment delivery into the lake. The anticipated reductions are largest (25%) during the Phase 1 (2017-2021) and equally spaced afterwards. Specific implementation of practices may occur during different phases of the watershed plan timeframe. A higher proportion of identified practices will be targeted for implementation in Phases 1 and 2 (2017-2024). Due to the 16 month residence time in the lake, surface water monitoring results may not be apparent in the lake monitoring immediately. As phosphorus primarily moves with sediment delivery, it is assumed that phosphorus reduction would be the result of a reduction of sediment. Due to the large reserve of phosphorus in the lake bottom sediments lake water quality may require a significantly longer period to clear. These reduction goals are based on flow conditions in the 2015 sample year. Actual anticipated results will be analyzed based on flow and the flow duration curve created in this plan. High rain events and high rainfall years are expected to deliver more nutrient runoff than low seasonal events and low rainfall years.

Table 8-1. Milestones for total nitrogen, total phosphorus and sediment delivery in the watershed.

Apple Canyon Lake Watershed Load Reduction Scenarios*			
Scenario	**Total Nitrogen Load (lb/yr)**	**Total Phosphorus Load (lb/yr)**	**Total Sediment Load (ton/yr)**
2015 Estimates	28,263	6,974	6,974
Phase 1 Reduction	24,840	5,737	5,737
Phase 2 Reduction	22,272	4,808	4,808
Phase 3 Reduction	19,705	3,880	3,880
Phase 4 Reduction	17,137	2,952	2,952
Phase 5 Reduction	14,570	2,024	2,024
Target	14,570	2,024	2,024

* Reduction scenarios are based on 2015 rainfall. Actual reduction goals will correspond to conditions.

8.3 Potential Funding Sources

Funding for implementation of the watershed plan will come from many sources. In order to accommodate plan implementation, the Apple Canyon Lake Property Owners Association (ACLPOA) will need to reserve in its annual budget the following items:

(1) **$50,000 per year for shoreline stabilization.** This amount will be used annually to address shoreline stabilization needs until all Association property shoreline is stabilized. Prioritization will be given to areas of high wave action or high erosion (*see section 6.6.7*). Prior to annual implementation, private lake property owners will be notified and given the opportunity to pay for private lots to be stabilized while the stabilization contractor is on site. This reduces private landowner costs as mobilization fees associated with stabilization work will be absorbed by ACLPOA.

(2) **$50,000 per year for stream stabilization.** The annual budget shall address stream stabilization needs on ACLPOA property. Stream stabilization needs are outlined in Table 6-11 and Figure 6-8, and subwatersheds have been prioritized from top to bottom in the table based on order of decreasing discharge. Once all outlined Association properties have been treated, allocations will address new areas identified in revisions to the watershed plan made at five year intervals.

(3) **$10,000 per year for watershed erosion control projects**. ACLPOA shall establish a cost-sharing program available to landowners and tenants in the watershed to assist with costs of implementation of best management practices (BMPs) in the watershed. This funding will be available annually until the funds are depleted. ACLPOA shall determine the rate of reimbursement for projects to make the best use of the funding. Funding shall be available to all applicants at the same reimbursement percentage rate.

(4) **$12,000 per year for monitoring.** ACLPOA will continue to fund the existing QAPP approved monitoring program to facilitate assessment of plan implementation as well as successes and shortcomings.

These amounts correspond to the prioritization and implementation schedule identifying priority projects to implementation, as well as correspond to milestone reduction goals set by the planning group.

Further funding sources have been identified by the stakeholder group, including cost-sharing assistance and technical assistance available from the USDA-NRCS, Illinois Department of Agriculture, Illinois EPA, and U.S. Fish and Wildlife Service. Table 8-1 lists programs which were identified and will be utilized to partially fund identified projects.

Table 8-2. Overview of potential funding sources.

Funding Program	Funding Agency	Payment Type	Payment Cap	Project Types (not exhaustive)
C-2000/Conservation Practices Program (CSP)	Soil and Water Conservation District (SWCD)	Cost-share	60%	Well sealing, tile outlet control, cover crops
Streambank Stabilization and Restoration Program (SSRP)	Soil and Water Conservation District (SWCD)	Cost-share	75%	Riprap, bendway weirs, rock riffles
319 Grant	Illinois Environmental Protection Agency (IEPA)	Cost-share	60%	Non-point source pollution reduction practices identified in watershed plan
Environmental Quality Incentives Program (EQIP)	Natural Resources Conservation Service (NRCS)	Flat payment	$450,000/contract	Nutrient management plans, composters, tile outlet control, manure storage, erosion control
Conservation Reserve Program (CRP)	Farm Service Agency (FSA)	Cost-share Yearly rental rate	50% $50,000/year	Takes marginal cropland out of production for conservation
Conservation Stewardship Program (CSP)	Natural Resources Conservation Service (NRCS)	Yearly rental rate	$200,000/contract through 2018	Energy savings, drift reduction, innovative conservation techniques
Fishers & Farmers	Fishers & Farmers Partnership; US Fish & Wildlife Service	Cost-share	60%	Fish habitat creation and restoration, monitoring

8.4 Goal Checklists

A successful watershed plan involves volunteer stakeholder participation to get projects completed, and must include a feedback mechanism to measure progress toward meeting goals. Watershed "Checklists", developed specifically for each goal in this plan, provide this information. Each checklist provides:

1. Summaries of current conditions for each goal to better understand what efforts are needed.
2. Most important performance criteria related to goal objectives.
3. Milestones to be met for various time frames.
4. Monitoring needs and efforts required to evaluate milestones.
5. Remedial actions to take if milestones are not met.
6. A "notes" section.

Goal checklists were developed for each of the four plan goals. The milestones are based on "Critical Term" (1 - 5 years, 2017 – 2021), "Short Term" (1 - 10 years, 2017 – 2026), and "Long Term" (10 – 20 years, 2027 – 2036) objectives. Grades for each milestone term should be calculated using the following scale: 80% - 100% of milestones met = A; 60% – 79% of milestones met = B; 40% - 59% of milestones met = C; and < 40% of milestones met = failed. These grades are calculated quantitatively in all possible cases where the percentage is calculated by dividing the amount completed by the amount listed in the goals and objectives (ex. 2,000 feet of stream stabilization completed ÷ 2,200 feet goal = 91%).

Goal checklists are meant to be used for the watershed as a whole, and should be used annually by the planning group to identify and track plan implementation to ensure that progress is being made towards achieving the plan goals and to make corrections as necessary. In addition to annual use, a final grade shall be determined at the end of each planning phase (1-5 years, 5-10 years, etc.). Lack of progress could be demonstrated in factors such as monitoring that shows no improvement, new environmental problems, lack of technical assistance, or lack of funds. In these cases the check lists user should explain why other factors resulted in milestones not being met in the notes section of the check list. Adaptive management should be implemented accordingly by referencing the adaptive management recommendations on each check list then developing a strategy to either change the milestone(s) or decide how to implement projects or actions to achieve the milestone(s).

Goal 1 Checklist: Improve Water Quality

Historic and Current Condition:

• Historic watershed conditions contained prairies, wetlands, and savannas prior to European settlement.
• Water quality in Apple Canyon Lake watershed is generally fair based on collected data. All parameters tested meet recommended standards during base flow conditions. However, total phosphorus and total suspended solids exceed recommended standards following significant storm events just upstream of Apple Canyon Lake; streambank erosion is a major contributor.
• Apple Canyon Lake is not listed as impaired but shows a negative trend in water quality.

Criteria to Meet Goal Objectives:

• Linear feet of restored streambank and lake shoreline.
• Acres of riparian buffer restored around ACL.
• Water quality monitoring taking place; chemical water quality standards: <12 mg/L TSS, <0.05 mg/L TP in ACL.
• Cost sharing program developed for BMPs in the watershed.
• Implement septic field inspection policy at ACLPOA.
• Reduced labor and expenses operating hydraulic dredge, weed harvestor, and maintaining dredge ponds.
• Acres of forest land with management plans created and management plans implemented.

Goal Milestones:		**Score**
1-5 Yrs. (*Critical*)	1) Construction plans developed for high priority streambank and shoreline stabilization (§6.6.7 & §6.6.8). 2) Annual monitoring completed at the six primary monitoring sites (§5.0 & §8.1.1.1). 3) Funding secured to implement projects (§8.3). 4) Septic study and Association Subwatershed stream analysis completed (§6.6.4 & §6.6.8). 5) Water quality results analyzed (§8.1.1.1). 6) Cropland acres treated with gypsum and cover crops (§6.6.3). 7) Water quality results indicate 25% reduction in phosphorus loading (§8.2.1). 8) Enroll Property Owners Association greenspace into forest management programs (§6.6.10).	
5-10 Yrs. (*Short*)	1) All critical and high priority areas stabilized (§6.6.7, §6.6.8). 2) Construction plans developed for medium priority streambank and shoreline stabilization (§6.6..7, §6.6.8). 3) Demonstration tile gate installed (§6.5.1, §6.6.6). 4) ACL policy adjusted to address results of study (§6.6.4, §7.1). 5) Water quality monitoring results indicate phosphorus reduction to 4,808 lbs./yr. (§8.2.1). 6) ≥33% reduction in aquatic plant and algae management expenses (§8.2). 7) Forest management plans created and implemented (§6.6.10).	
10-20 Yrs. (*Long*)	1) Construction plans developed for lower priority streambank and shoreline stabilization (§6.6.7, §6.6.8). 2) All medium priority areas stabilized (§6.6.7, §6.6.8). 3) Funding secured for remaining BMPs (§8.3). 4) Water quality monitoring results indicate phosphorus reduction to 2,024 lbs./yr. (§8.2.1). 5) ≥70% reduction aquatic plant and algae management expenses (§8.2). 6) Forest management plans created and implemented (§6.6.10).	

Monitoring Needs/Efforts:

• Water chemistry will need to continue indefinitely to track changes in water quality.
• RiverWatch monitoring will continue indifinitely to track changes in water quality.
• Track number of streambank, shoreline, wetland and detention projects implemented.

Remedial Actions:

• Quantify number of projects and actions that have been implemented versus waterquality changes and determine if projects are effectively removing pollutants.
• Review watershed plan and update for necessary changes.
• Review policy changes for consistency with watershed plan.
• Re-evaluate goals and BMP options to determine feasibility.

Notes:

Grade Evaluation: 80%-100% met = A; 60%-79% met = B; 40-59% met = C; and < 40% = failed.

Goal 2 Checklist: Reduce Algal Blooms and Excessive Plant Growth		
Historic and Current Condition: • The historic watershed landscape consisted of prairies, savannas, and wetlands prior to European settlement in the 1800s. • Historic land use limited nutrient production and encouraged storage and filtration of nutrients. • VLMP data indicates a downward trend in water quality and secchi depth clarity. • Aquatic plant coverage is heavily treated making nutrients available to algal growth. • Harmful algal blooms (HAB) are monitored in Apple Canyon Lake. Only one HAB has been detected, occuring in 2013.		
Criteria to Meet Goal Objectives: · Number of new prairies, savannas, wetlands, and retention basins implemented. · Number of critical areas treated with riparian buffer. · Meeting water quality goals and objectives (Goal 1). · Number of years in database monitoring aquatic plant, invertebrate, and algal population. · Reduced labor and expenses operating weed harvestor. · Reduced incidence of harmful algal blooms.		
Goal Milestones:		**Grade**
1-5 Yrs. (*Critical*)	1) Map coverage and diversity of aquatic plants in Apple Canyon Lake (§6.5.2). 2) Create management plan for aquatic plants in Apple Canyon Lake (§6.5.2). 3) ≥ 4 acres of the 16.6 acres of critical areas converted to riparian buffer (§6.6.5). 4) Perform feasibility study for North Bay subwatershed (§6.6.8.1). 5) ≥33% reduction in aquatic plant and algae management expense (§8.2). 6) No incidence of harmful algal blooms (§5.0).	
5-10 Yrs. (*Short*)	1) Reduced complaints about excessive plant growth in lake (Yes/No) 2) ≥ 50% reduction in aquatic plant and algae management expense (§8.2). 3) ≥ 4 additional acres of the 16.6 acres of critical areas converted to riparian buffer (§6.6.5). 4) Monitor invertebrate population to determine trends with lower food chain ecology (§6.6.2).	
10-20 Yrs. (*Long*)	1) Aquatic plant and algae stable, providing recreational opportunities and fish habitat (Yes/No). 2) ≥70% reduction in aquatic plant and algae management expense (§8.2). 3) ≥ 4 additional acres of the 16.6 acres of critical areas converted to riparian buffer (§6.6.5). 4) Monitor invertebrate population to determine trends with lower food chain ecology and	
Monitoring Needs/Efforts: • Assess aquatic plant coverage and secchi depths and adjust implementation plan to meet objectives. · Monitor invertebrate population determine trends with lower food chain ecology. · Monitor for harmful algal blooms.		
Remedial Actions: • Review aquatic management plan and adjust to meet management goals. · Allocate funds and submit grant proposals to implement goal objectives. · Reevaluate goals and BMP options to determine feasibility.		
Notes:		

Grade Evaluation: 80%-100% met = A; 60%-79% met = B; 40-59% met = C; and < 40% = failed.

Goal 3 Checklist: Mitigate Existing Flooding Problems.

Historic and Current Condition:

- The historic watershed landscape consisted of prairies, savannas, and wetlands prior to European settlement in the 1800s.
- Channelization has increased stream velocity and down cutting prevents streams access to the flood plain.
- Increased storm variability causes erosion and channelization throughout the watershed.

Criteria to Meet Goal Objectives:

- Number of feet/stream miles of stream restoration projects that reconnect the stream channel to the adjacent flood plain.
- Number of retention basins installed in the watershed.
- % of new and redevelopment that incorporates high infiltration best management practices.
- Number of existing homes retrofitted with high infiltration best management practices.
- Number of restored wetlands.

Goal Milestones:		Grade
1-5 Yrs. (*Critical*)	1) Stream reaches NB1 and WC 1 are evaluated for potential to reconnect hydrologically to adjacent flood plain (§6.6.7 & §6.6.8). 2) ACLPOA adopts zero runoff policy for new development (§6.6.4). 3) Implement project at NB1 (§6.6.7 & §6.6.8). 4) Assess culverts and bridges in watershed to allow greater stream capacity and connectivity (§6.6.9). 5) Retrofit ≥ 5 homes with high infiltration best management practices (§6.6.4).	
5-10 Yrs. (*Short*)	1) Stream reaches PB 1, ID 1, and HW 1 are evaluated for potential to reconnect hydrologically to adjacent flood plain (§6.6.7 & §6.6.8). 2) Work with stakeholders outside of the POA to reconnect problem stream areas (§6.6.7). 3) Implement projects at WC1, PB1, ID1, and HW1 (§6.6.7 & §6.6.8). 4) Replace ≥ 1 road bridge and ≥ 50% of identified problem culverts in watershed (§6.6.9). 5) Retrofit ≥ 10 homes with high infiltration best management practices (§6.6.4)	
10-20 Yrs. (*Long*)	1) Reconnect minor drainages on Association property leading to lake (§6.6.9). 2) Replace ≥ 1 road bridge and ≥50% of identified problem culverts in watershed (§6.6.9). 3) Retrofit ≥ 10 homes with high infiltration best management practices (§6.6.4).	

Monitoring Needs/Efforts:

- Annually survey stream corridors to determine efficacy of actions and note changes in hydrologic systems.
- Monitor sediment delivery to Apple Canyon Lake.
- Review green infrastructure policy and certify that it is being enforced.

Remedial Actions:

- Increase budgeting to implement more critical projects.
- Seek larger funding pools to fund project implementation.
- Investigate student and volunteer opportunities to achieve objectives.
- Re-evaluate goals and BMP options to determine feasibility.

Notes:

Grade Evaluation: 80% -100% met = A; 60% -79% met = B; 40-59% met = C; and < 40% = failed.

Goal 4 Checklist: Educate Watershed Community.		
Historic and Current Condition: · Apple Canyon Lake Property Owners Association, along with the Jo Daviess SWCD, is leading the watershed planning process. Watershed residents and various other stakeholders are involved. · The watershed stakeholders currently promote appreciation and stewardship of the watershed through many education and volunteer activities. Meetings typically have approximately 20 attendees and volunteer events average 10 attendees.		
Criteria to Meet Goal Objectives: · Number of ways taken to inform the general public that a watershed plan has been developed. · Number of people that attend watershed education campaigns. · Number of participants in Kids Camp. · Number of demonstration projects implemented. · Number of Boy/Girl Scout service projects. · Number of Earth Day volunteers.		
Goal Milestones:		**Grade**
1-5 Yrs. (*Critical*)	1) Watershed partners inform public about the watershed plan via media and watershed activity campaigns and track the engagement of audience (§6.6.2). 2) ≥2 demonstration projects are implemented (§6.5.1 & §6.6.6). 3) A watershed tour is conducted focused on agricultural BMPs (§6.6.2). 4) ≥ 30 children attend each Kid's Camp (§6.6.2). 5) ≥ 25 people attend each watershed meeting (§6.6.2).	
5-10 Yrs. (*Short*)	1) ≥ 20 people attend each educational event (§6.6.2). 2) ≥ 50 people volunteer for the Earth Day event each year (§6.6.2). 3) ≥ 10 school or youth projects are supported by watershed partners per year (§6.6.2). 4) ≥ 4 demonstration projects are implemented (§6.5.1 & §6.6.6). 5) ≥ 25 people attend each watershed meeting (§6.6.2).	
10-20 Yrs. (*Long*)	1) ≥ 20 people attend each educational event (§6.6.2). 2) ≥ 50 people volunteer for each Earth Day event (§6.6.2). 3) ≥ 10 school or youth projects are supported by watershed partners each year (§6.6.2). 4) ≥ 4 demonstration projects are implemented (§6.6.2). 5) ≥ 25 people attend each watershed meetings (§6.6.2).	
Monitoring Needs/Efforts: · Track number of ways taken to inform general public that a watershed plan has been developed. · Track number of people attending each educational event. · Track number of agencies participating in educational presentations. · Track number of school or Boy/Girl Scout projects supported and completed by watershed partners. · Track number of demonstration projects implemented. · Track number of watershed meeting attendees. · Survey engagement or changes in practices as a result of efforts.		
Remedial Actions: · Seek program guidance and increased participation from state, county, and government agencies. · Reevaluate education strategy. · Gain new partners to assist in education campaign strategies. · Increase access and signage for watershed improvement projects to promote them as demonstrations.		
Notes:		

Grade Evaluation: 80% -100% met = A; 60% -79% met = B; 40-59% met = C; and < 40% = failed.

9.0 CONCLUSION

The Apple Canyon Lake watershed has experienced a great deal of change from European settlement to the creation of the lake in 1969. Since the creation of the lake and the Apple Canyon Lake Property Owners Association, land use in the watershed has remained fairly consistent. The area feeding Apple Canyon Lake is dominated by agriculture and forest, with the area immediately surrounding the lake classified as low-density urban development. The rugged topography typical of the driftless region amplifies storm water runoff, carrying pollutants typical of these land uses downstream through the watershed.

The lake acts as a large sediment retention basin, collecting a majority of the phosphorus which is transported through the watershed. Although Apple Canyon Lake and its watershed are not impaired there has been a consistent decline in water quality since approximately 2001. The Illinois EPA’s Volunteer Lake Monitoring Program has large database on water quality information taken over the years from the lake, and stream monitoring beginning in 2014 has been added to complement the existing database. This information, along with a resource inventory of the watershed, has been presented to the watershed stakeholder planning group over a two year planning process. This process has taken input from multiple sources and perspectives in the watershed and collaboratively developed the comprehensive watershed plan contents. Through this collaboration it has been recognized that the farmlands, forests, streams, and lake are all valuable resources which provide the variety of benefits to the residents and users of the watershed.

As creation of this plan comes to a close, the planning process is just beginning. The creation of a plan is the start of the much larger task of implementation which will ultimately determine if the plan is a success. The planning group is now tasked with putting this plan into action and achieving the goals and objectives set forth. The watershed planning group has determined to see a 25% attainment of their water quality goals in five years. This is a realistic achievement but will be only be half determined by plan implementation and half determined by weather related factors. The residence time of water in the lake can delay water quality impacts by as much as a year and a half. As the plan is completed the real work now begins. This is not the time to relax but instead the time to get moving! Within the Apple Canyon Lake Property Owners Association there is policy to be created, mandating green infrastructure, septic drain, zero-storm water runoff, and enforcing the existing buffer area policy around the lake. A study must be completed on the existing septic systems and small water drainages at the lake. In the whole watershed there are numerous best management practices which can be implemented to help with the overall goals and objectives of this plan while simultaneously improving crop production and economic returns. Cover crops can have a tremendous impact on water quality. Terminating field drain tile outlets into a vegetated retention basin is also useful in meeting nutrient reduction goals. Stabilizing field soils with gypsum applications is another option, in addition to overall good nutrient management. Ultimately, meeting reduction goals in the watershed cannot be achieved by any one practice, but rather must be a combination of many practices which are right for each landowner and will collectively add up to meet the goals.

CONCLUSION

A major part of the ultimate success of this endeavor is engaging and educating the public. Through newspaper articles, field days, public meetings, and public participation in watershed monitoring, watershed residents and users will learn more about and better understand the functions of a watershed, and make more informed decisions in their day-to-day lives which affect water quality. The success of this education relies just as heavily on recruiting participants as it does in programming.

It is believed by the individuals involved with drafting this plan that the contents of this comprehensive watershed based plan have the potential to meet the planning group's goals and objectives as expressed through the planning meetings. This belief comes not just on faith but rather on sound science. By the nature of watershed function, the attainment of the planning group's goals will not only improve the water quality in Apple Canyon Lake and the surrounding watershed, but also in the Apple River, the Mississippi River, and the Gulf of Mexico. Let's get started!

10.0 REFERENCES

Apple Canyon Lake website. (2015). Long Range Planning Committee shares 2013 ACL Survey results. Retrieved from: http://applecanyonlake.org/announcements/category-cid-1-p-2

Bennett, E. M., Carpenter, S. R., & Caraco, N. F. (2001). Human impact on erodable phosphorus and eutrophication: a global perspective increasing accumulation of phosphorus in soil threatens rivers, lakes, and coastal oceans with eutrophication. BioScience, 51(3), 227-234.

Degu, A. M., Hossain, F., Niyogi, D., Pielke, R., Shepherd, J. M., Voisin, N., & Chronis, T. (2011). The influence of large dams on surrounding climate and precipitation patterns. *Geophysical Research Letters*, *38*(4).

Dils, R. M., & Heathwaite, A. L. (1999). The controversial role of tile drainage in phosphorus export from agricultural land. *Water science and technology*, *39*(12), 55-61.

Gentry, L. E., David, M. B., Royer, T. V., Mitchell, C. A., & Starks, K. M. (2007). Phosphorus transport pathways to streams in tile-drained agricultural watersheds. *Journal of Environmental Quality*, *36*(2), 408-415.

Gilliom, R. J., & Patmont, C. R. (1983). Lake phosphorus loading from septic systems by seasonally perched groundwater. Journal (Water Pollution Control Federation), 1297-1305.

Hargreaves, G. L., Hargreaves, G. H., & Riley, J. P. (1985). Irrigation water requirements for Senegal River basin. Journal of Irrigation and Drainage Engineering, 111(3), 265-275.

Holdren, C., Jones, W, & Taggart, J. (2001). Managing lakes and reservoirs. North American Lake Management Society and Terrene Institute, in cooperation with Office of Water Assessment, Watershed Protection Division, U.S. Environmental Protection Agency. Madison, Wisconsin.

Johnston, C. A., & Naiman, R. J. (1987). Boundary dynamics at the aquatic-terrestrial interface: the influence of beaver and geomorphology. *Landscape Ecology*, *1*(1), 47-57.

Jung, N. C. (2010). Eco-hydraulic modelling of eutrophication for reservoir management. CRC Press. P. 137.

IEPA. (1995). Lake Notes. Retrieved from http://www.epa.state.il.us/water/conservation/lake-notes/septic-systems.pdf

IEPA. (2014). Illinois Nutrient Loss Reduction Strategy. Retrieved from: http://www.epa.illinois.gov/topics/water-quality/watershed-management/excess-nutrients/nutrient-loss-reduction-strategy/index

Ill. Admin. Code tit. 35, § 302.205 (1979). Retrieved from: http://www.ilga.gov/commission/jcar/admincode/035/035003020B02050R.html

REFERENCES

Jones, R. A., & Lee, G. F. (1979). Septic tank wastewater disposal systems as phosphorus sources for surface waters. Journal (Water Pollution Control Federation), 2764-2775.

Lemke, A. M., Kirkham, K. G., Lindenbaum, T. T., Herbert, M. E., Tear, T. H., Perry, W. L., & Herkert, J. R. (2011). Evaluating agricultural best management practices in tile-drained subwatersheds of the Mackinaw River, Illinois. *Journal of environmental quality*, *40*(4), 1215-1228.

LWV. (2016). Jo Daviess County Water Resource Management Workbook. League of Women Voters.

McGauhey, P. H., & Winneberger, J. H. (1964). Studies of the failure of septic tank percolation systems. *Journal (Water Pollution Control Federation)*, 593-606.

Mitsch, W. J., Day, J. W., Gilliam, J. W., Groffman, P. M., Hey, D. L., Randall, G. W., & Wang, N. (2001). Reducing nitrogen loading to the Gulf of Mexico from the Mississippi River Basin: strategies to counter a persistent ecological problem ecotechnology—the use of natural ecosystems to solve environmental problems—should be a part of efforts to shrink the zone of hypoxia in the Gulf of Mexico. *BioScience*, *51*(5), 373-388.

Schelde, K., de Jonge, L. W., Kjaergaard, C., Laegdsmand, M., & Rubæk, G. H. (2006). Effects of manure application and plowing on transport of colloids and phosphorus to tile drains. *Vadose Zone Journal*, *5*(1), 445-458.

Schindler, D. W. (2006). Recent advances in the understanding and management of eutrophication. Limnology and Oceanography, 51(1part2), 356-363.

Schindler, D. W., Hecky, R. E., Findlay, D. L., Stainton, M. P., Parker, B. R., Paterson, M. J., ... & Kasian, S. E. M. (2008). Eutrophication of lakes cannot be controlled by reducing nitrogen input: results of a 37-year whole-ecosystem experiment. *Proceedings of the National Academy of Sciences*, *105*(32), 11254-11258.

Shainberg, I., Sumner, M. E., Miller, W. P., Farina, M. P. W., Pavan, M. A., & Fey, M. V. (1989). *Use of gypsum on soils: A review*. Springer US, 9:1-111.

Sharpley, A. N., Chapra, S. C., Wedepohl, R., Sims, J. T., Daniel, T. C., & Reddy, K. R. (1994). Managing agricultural phosphorus for protection of surface waters: Issues and options. Journal of Environmental Quality, 23(3), 437-451.

Steffen, L.J. (1982). Channel Erosion (personal communication), as printed in "Pollutants Controlled Calculation and Documentation for Section 319 Watersheds Training Manual," June 1999 Revision; Michigan Dept. of Environmental Quality, Surface Water Quality Division, Nonpoint Source Unit. EQP 5841 (6/99).

Storm, D.E., White, M.J., Brown, G.O., Smolen, M.D., & Kang, R.S. (2006). Protocol to determine the optimal placement of riparian/buffer strips in watersheds. Oklahoma State University.

Stout, W. L., Sharpley, A. N., Gburek, W. J., & Pionke, H. B. (1999). Reducing phosphorus export from croplands with FBC fly ash and FGD gypsum. Fuel, 78(2), 175-178.

Thomas, H. A. (1981), Improved methods for national water assessment: Final report, U.S. Geological Survey. Water Resources Contract WR15249270, 44 pp.

USDA-NASS. (2014, January 31). USDA, National Agricultural Statistics Service, 2013 Illinois Cropland Data Layer (2013 Edition). Raster digital data. USDA, NASS Marketing and Information Services Office, Washington, D.C.: USDA, NASS.

USDA website. (2014). Web soil survey. Data retrieved from: http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx

USEPA. (2008, March). Handbook for developing watershed plans to restore and protect our waters. EPA 841-B-08-002.

USEPA. (2013, April 12). Nonpoint Source Program and Grants Guidelines for States and Territories.

U.S. Census Bureau. (2014). State and County Quick-Facts: Jo Daviess County, Illinois. Retrieved from: http://quickfacts.census.gov/qfd/states/17/17085.html

U.S. Department of Commerce, U.S. Census Bureau, Geography Division. (2010). TIGER/Line 2010 Census, Census Tract national-based.

U.S. Forest Service. (2008). Region 6 stream inventory training: reference materials for NR9. United States Forest Service. Bend, OR.

USGS. (2014, March 31). NLCD 2011 Land Cover (2011 Edition): None, U.S. Geological Survey, Sioux Falls, SD.

USGS. (2014, November 18). USGS 05419000 Apple River near Hanover, IL. Retrieved from: http://waterdata.usgs.gov/nwis/uv?site_no=05419000

11.0 APPENDICES

11.1 Appendix 1. Glossary

100-year floodplain: A 100-year flood is a flood that has a 1-percent chance of being equaled or exceeded in any given year. A base flood may also be referred to as a 100-year storm and the area inundated during the base flood is called the 100-year floodplain.

303(d): The Federal Clean Water Act requires states to submit a list of impaired waters to the USEPA for review and approval using water quality assessment data from the Section 305(b) Water Quality Report. States are then required to develop total maximum daily load analyses (TMDLs) for waterbodies on the 303(d) list.

305(b): The Illinois 305(b) report is a water quality assessment of the state's surface and groundwater resources that is compiled by the Illinois EPA as a report to the USEPA as required under Section 305(b) of the Clean Water Act.

Aquatic habitat: Structures such as stream substrate, woody debris, aquatic vegetation, and overhanging vegetation that is important to the survival of fish and macroinvertebrates.

Base Flood Elevation (BFE): The elevation delineating the level of flooding resulting from the 100-year flood frequency elevation. (See also Floodplain.)

Base flow: The flow that a perennially flowing stream reduces to during the dry season. It is often supported by groundwater seepage into the channel.

Bedrock: The solid rock that underlies loose material, such as soil, sand, clay, or gravel.

Best Management Practices (BMPs): See *Management Measure*

Biodiversity: The variety of organisms (plants, animals and other life forms) that includes the totality of genes, species and ecosystems in a region.

Bio-infiltration (rain gardens): Excavated depressional areas where stormwater runoff is directed and allowed to infiltrate back into groundwater rather than allowing to runoff. Infiltration areas are planted with appropriate vegetation.

Biological Oxygen Demand (BOD): The amount of dissolved oxygen that is required by microscopic organism (e.g. bacteria) to decompose organic matter in waterbodies.

Bioengineering (or Soil Bioengineering): Techniques for stabilizing eroding or slumping stream banks that rely on the use of plants and plant materials such as live willow posts, brush layering, coconut logs and other "greener" or "softer" techniques. This is in contrast to techniques that rely on creating "hard" edges with riprap, concrete and sheet piling (metal and plastic).

Center for Watershed Protection (CWP): Non-profit 501(c)3 corporation founded in 1992 that provides local governments, activists, and watershed organizations around the country with the technical tools for protecting some of the nation's most precious natural resources such as streams, lakes and rivers.

Certified Municipalities: A municipality that is certified to enforce the provisions of local stormwater ordinances. The municipality's designated Enforcement Officer enforces the provisions in the Ordinance.

Channelized stream: A stream that has been artificially straightened, deepened, or widened to accommodate increased stormwater flows, to increase the amount of adjacent land that can be developed or used for urban development, agriculture or for navigation purposes. In addition to being unsightly, channelized streams have a uniform gradient, no riffle and pool development, no meanders (curves) and very steep banks. The vegetation is frequently removed and replaced with riprap, concrete or other hard surfaces. During low flow periods in the summer, many channelized streams have low dissolved oxygen levels, in part due to shallow, slow-moving water. Under these conditions, they provide poor habitat for fish or other stream organisms such as benthic macroinvertebrates.

Channel: Any river, stream, creek, brook, branch, natural or artificial depression, ponded area, lakes, flowage, slough, ditch, conduit, culvert, gully, ravine, swale, wash, or natural or man-made drainageway, in or into which surface or groundwater flows, either perennially or intermittently.

Conservation development: A development designed to protect open space and natural resources for people and wildlife while at the same time allowing building to continue. Conservation design developments designate half or more of the buildable land area as undivided permanent open space.

Conservation easement: The transfer of land use rights without the transfer of land ownership. Conservation easements can be attractive to property owners who do not want to sell their land now, but would support perpetual protection from further development. Conservation easements can be donated or purchased.

Clean Water Act (CWA): The CWA is the basic framework for federal water pollution control and has been amended in subsequent years to focus on controlling toxics and improving water quality in areas where compliance with nationwide minimum discharge standards is insufficient to meet the CWA's water quality goals.

Debris Jam: Natural and man-made debris in a stream channel including leaves, logs, lumber, trash and sediment.

Designated Use: EPA requirements that states and authorized Indian Tribes specify appropriate water uses to be achieved and protected. Appropriate uses are identified by taking into consideration the use and value of the water body for public water supply, for protection of fish, shellfish, and wildlife, and for recreational, agricultural, industrial, and navigational purposes. In designating uses for a water body, States and Tribes examine the suitability of a water body for the uses based on the physical, chemical, and biological characteristics of the water body, its geographical setting and scenic qualities, and economic considerations. Each water body does not necessarily require a unique set of uses. Instead, the characteristics necessary to support a use can be identified so that water bodies having those characteristics can be grouped together as supporting particular uses.

Detention basin: A man-made structure for the temporary storage of stormwater runoff with controlled release during or immediately following a storm.

Discharge (streamflow): The volume of water passing through a channel during a given time, usually measured in cubic feet per second.

Digital Elevation Model (DEM): Regularly spaced grid of elevation points used to produce elevation maps.

Dissolved oxygen (DO): The amount of oxygen in water, usually measured in milligrams/liter.

Downcutting: The action of a stream to deepen itself, often as a result from channelization.

Drainage basin: Land surface region drained by a length of stream channel; usually 1,000 to 10,000 square miles in size.

Ecosystem: An ecological community together with its environment, functioning as a unit.

Erosion: Displacement of soil particles on the land surface due to water or wind action.

European settlement: A period in the early 1800s when European settlers moved across the United States in search of better lives. During this movement, much of the historical communities were altered for farming and other types of development.

Eutrophic: A waterbody having a high level of biological productivity. A typical eutrophic waterbody either has many aquatic plants and is clear or has few plants and is less clear. Both situations have potentially to support many fish and wildlife.

Federal Emergency Management Agency (FEMA): Government agency within the Department of Homeland Security that responds to, plans for, recovers from, and mitigates against disasters/emergencies, both natural and man-made.

Fee in lieu: Defined by the USACE and EPA as a payment "to a natural resource management entity for implementation of either specific or general wetland or other aquatic resource development projects" for projects that "do not typically provide compensatory mitigation in advance of project impacts."

Filamentous algae: Simple one-celled or multi-celled organisms (usually aquatic) capable of photosynthesis that are an indicator of high nutrient levels in the water column.

Filter strip: A long narrow portion of vegetation used to retard water flow and collect sediment for the protection of watercourses, reservoirs or adjacent properties.

Flash hydrology/flooding: A quickly rising and falling overflow of water in stream channels that is usually the result of increased amounts of impervious surface in the watershed.

Flood Insurance Rate Map (FIRM): A map prepared by the Federal Emergency Management Agency that depicts the special flood hazard area (SFHA) within a community. The FIRM includes zones for the 100-year and 500-year floodplains and may or may not depict Regulatory Floodways.

Flood problem area (FPA): One or more buildings, roads or other infrastructure in one location that are repeatedly damaged by flooding.

Floodplain (100-year): Land adjoining the channel of a river, stream, watercourse, lake or wetland that has been or may be inundated by floodwater during periods of high water that exceed normal bank-full elevations. The 100-year floodplain has a probability of 1% chance per year of being flooded.

Floodproofing: Any combination of structural and non-structural additions, changes or adjustments to structures or property which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures and contents.

Floodway: The floodway is the portion of the stream or river channel that includes the adjacent land areas to that must be reserved to discharge the 100-year flood without increasing the water surface.

General Use Water Quality Standards (State): The Illinois Pollution Control Board (IPCB), a sister Agency to the Illinois EPA, develops water quality standards in Illinois. These standards serve to protect aquatic life, human health or wildlife, although wildlife based criteria have not yet been derived.

Geographic Information System (GIS): A computer system for capturing, storing, querying, analyzing, and displaying geospatial data.

Geospatial Data: Describes both the locations and characteristics of spatial features.

Glacial Drift: Earth and rocks which have been transported by moving ice or land ice.

Global Positioning System (GPS): Satellite mapping systems that enable locators and mapping to be created via satellite.

Grassland: An area such as a prairie or a meadow dominated by grass or grass-like vegetation.

Green infrastructure: An interconnected network of waterways, wetlands, woodlands, wildlife habitats, and other natural areas; greenways, parks and other conservation lands, farms, and forests of conservation value; and wilderness and other open spaces that support native species, maintain natural ecological processes, sustain air and water resources and contribute to the health and quality of life.

Greenways: A protected linear open space area that is either landscaped or left in its natural condition. It may follow a natural feature of the landscape such as a river or stream, or it may occur along an unused railway line or some other right of way. Greenways also provide wildlife corridors and recreational trails.

Groundwater recharge: Primary mechanism for aquifer replenishment which ensures future sources of groundwater for commercial and residential use.

Headwaters: Upper reaches of tributaries in a drainage basin.

Hydraulic and Hydrologic modeling: Engineering analysis that predicts expected flood flows and flood elevations based on land characteristics and rainfall events.

Hydraulic structures: Low head dams, weirs, bridges, levees, and any other structures along the course of the river.

Hydric inclusion soil: A soil unit (usually adjacent to hydric soils) that are not wet enough to form hydric properties but do have some hydric properties.

Hydric soil: Soil units that are wet frequently enough to periodically produce anaerobic conditions, thereby influencing the species composition or growth, or both, of plants on those soils.

Hydrograph: A way of measuring and graphing stream flow, or discharge, as it varies with time.

Hydrologic Soil Groups (HSG): Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups based on the soil's runoff potential. The four Hydrologic Soils Groups are A, B, C and D. A's generally have the smallest runoff potential and D's the greatest.

Hydrology: The scientific study of the properties, distribution, and effects of water on the earth's surface, in the soil and underlying rocks, and in the atmosphere.

Hydrophytic vegetation: Plant life growing in water, soil or on a substrate that is at least periodically deficient in oxygen as a result of excessive water content; one of the indicators of a wetland.

Illinois Department of Natural Resources (IDNR): A government agency established to manage, protect and sustain Illinois' natural and cultural resources; provide resource-compatible recreational opportunities and to promote natural resource-related issues for the public's safety and education.

Illinois Department of Transportation (IDOT): The Illinois Department of Transportation focuses primarily on the state's policies, goals and objectives for Illinois' transportation system and provides an overview of the department's direction for the future.

Illinois Environmental Protection Agency (Illinois EPA): Government agency established to safeguard environmental quality, consistent with the social and economic needs of the State, so as to protect health, welfare, property and the quality of life.

Illinois Natural Areas Inventory (INAI): A survey conducted by the Illinois Department of Natural Resources to catalogue high quality natural areas, threatened and endangered species and unique plant, animal and geologic communities for the purpose of maintaining biodiversity.

Illinois Nature Preserves: State-protected areas that are provided the highest level of legal protection, and have management plans in place.

Illinois Pollution Control Board (IPCB): An independent agency created in 1970 by the Environmental Protection Act. The Board is responsible for adopting Illinois' environmental regulations and deciding contested environmental cases.

Impervious cover/surface: An area covered with solid material or that is compacted to the point where water cannot infiltrate underlying soils (e.g. parking lots, roads, houses, patios, swimming pools, tennis courts, etc.). Stormwater runoff velocity and volume can increase in areas covered by impervious surfaces.

Impervious Cover Model: Simple urban stream classification model based on impervious cover and stream quality. The classification system contains three stream categories, based on the percentage of impervious cover that predicts the existing and future quality of streams based on the measurable change in impervious cover. The three categories include sensitive, impacted, and non-supporting.

Incised channel: A stream that has degraded and cut its bed into the valley bottom. Indicates accelerated and often destructive erosion.

Index of Biotic Integrity (IBI): The IBI is based on fish surveys with the rating dependent on the abundance and composition of the fish species in a stream. Fish communities are useful for assessing stream quality because fish represent the upper level of the aquatic food chain and therefore reflect conditions in the lower levels of the food chain. Fish population characteristics are dependent on the physical habitat, hydrologic and chemical conditions of the stream, and are considered good indicators of overall stream quality because they reflect stress from both chemical pollution and habitat perturbations. For example, the presence of fish species that are intolerant of pollution are an indicator that water quality is good. The IBI is calculated on a scale of 12 to 60, the higher the score the better the stream quality.

Infiltration: That portion of rainfall or surface runoff that moves downward into the subsurface soil.

Invasive vegetation/plant: Plant species that are not native to an area and tend to out-compete native species and dominate an area (e.g. European buckthorn or garlic mustard).

Loess: A fine-grained, unstratified accumulation of clay and silt deposited by wind.

Macroinvertebrates: Invertebrates that can be seen by the unaided eye (macro). Most benthic invertebrates in flowing water are aquatic insects or the aquatic stage of insects, such as stonefly nymphs, mayfly nymphs, caddisfly larvae, dragonfly nymphs and midge larvae. They also include such things as clams and worms. The presence of benthic macroinvertebrates that are intolerant of pollutants is a good indicator of good water quality.

Macroinvertebrate Biotic Index (MBI): Method used to rate water quality using macroinvertebrate taxa tolerance to organic pollution in streams. The method detects change in biological systems that result from the actions of human society. The MBI is very similar to the IBI except it is based on sampling macroinvertebrates (insects, worms etc.) that live in the stream rather than fish. The MBI scale is from 1 to 10, with 1 being the highest stream quality indicator and 10 being the worst. A MBI less than 5 on the 2004 revised scale indicates a good macroinvertebrate population. As with fish, the presence of pollution-intolerant macroinvertebrate species is an indicator of good water quality. Since macroinvertebrates are less mobile than fish, the MBI is a good index to evaluate upstream/downstream impacts of point source discharges.

Management Measures: Also known as Best Management Practices (BMPs) are non-structural practices such as site planning and design aimed to reduce stormwater runoff and avoid adverse development impacts - or structural practices that are designed to store or treat stormwater runoff to mitigate flood damage and reduce pollution. Some BMPs used in urban areas may include stormwater detention ponds, restored wetlands, vegetative filter strips, porous pavement, silt fences and biotechnical streambank stabilization.

Marsh: An area of soft, wet, low-lying land, characterized by grassy vegetation and often forming a transition zone between water and land.

Meander (stream): A sinuous channel form in flatter river grades formed by the erosion on one side of the channel (pools) and deposition on the other (point bars).

Mitigation: Measures taken to eliminate or minimize damage from development activities, such as construction in wetlands or Regulatory Floodplain filling, by replacement of the resource.

National Flood Insurance Program (NFIP): Managed by the Mitigation Division within the Federal Emergency Management Agency (FEMA), participants in the NFIP adopt and enforce floodplain management ordinances to reduce future flood damage and in exchange are eligible to receive federally funded flood insurance.

National Wetland Inventory (NWI): U.S. Fish and Wildlife Service study that provides information on the characteristics, extent, and status of U.S. wetlands and deep-water habitats and other wildlife habitats.

Native vegetation/plants: Plant species that have historically been found in an area.

Natural community: An assemblage of plants and animals interacting with one another in a particular ecosystem.

Natural divisions: Large land areas that are distinguished from each other by bedrock, glacial history, topography, soils, and distribution of plants and animals.

No-net-loss: A policy for wetland protection to stem the tide of continued wetland losses. The policy has generated requirements for wetland mitigation so that permitted losses due to filling and other alterations are replaced and the net quality wetland acreage remains the same.

Nonpoint source pollution (NPS or NPSP): Refers to pollutants that accumulate in waterbodies from a variety of sources including runoff from the land, impervious surfaces, the drainage system and deposition of air pollutants.

National Pollutant Discharge Elimination System (NPDES Phase II): Clean Water Act law requiring smaller communities and public entities that own and operate an Municipal Separate Storm Sewer System (MS4) to apply and obtain an NPDES permit for stormwater discharges. Permittees at a minimum must develop, implement, and enforce a stormwater program designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable. The stormwater management program must include these six minimum control measures:

1. Public education and outreach on stormwater impacts
2. Public involvement/participation
3. Illicit discharge detection and elimination
4. Construction site stormwater runoff control
5. Post-construction stormwater management in new development and redevelopment
6. Pollution prevention/good housekeeping for municipal operations.

Nutrients: Substances needed for the growth of aquatic plants and animals such as phosphorous and nitrogen. The addition of too many nutrients (such as from sewage dumping and over fertilization) will cause problems in the aquatic ecosystem through excess algae growth and other nuisance vegetation.

Open space: Any land that is not developed and is often set aside for conservation or recreation purposes. It can be either protected or unprotected. Protected open space differs from unprotected in that it is permanently preserved by outright ownership by a body chartered to permanently save land, or by a permanent deed restriction such as a conservation easement. Open space is important to a watershed's hydrology, habitat, water quality, and biodiversity.

Outwash: Sand and gravel deposits removed or washed out from a glacier.

Partially open parcel: Parcels that have been developed to some extent, but still offer some opportunities for open space and Best Management Practice (BMP) implementation. They typically include private residences with acreage exceeding the surrounding minimum zoning, partly developed industrial sites, or institutions (churches, schools, etc.) with extensive grounds.

Point source pollution: Refers to discharges from a single source such as an outfall pipe conveying wastewater from an industrial plant or wastewater treatment facility.

Pollutant load: The amount of any pollutant deposited into waterbodies from point source discharges, combined sewer overflows, and/or stormwater runoff.

Pool: A location in an active stream channel usually located on the outside bends of meanders, where the water is deepest and has reduced current velocities.

Prairie: A type of grassland characterized by low annual moisture and rich black soil characteristics.

Preventative measures: Actions that reduce the likelihood that new watershed problems such as flooding or pollution will arise, or that those existing problems will worsen. Preventative techniques generally target new development in the watershed and are geared toward protecting existing resources and preventing degradation.

Rain gage station: Point along a stream where the amount of water flowing in an open channel is measured. The USGS makes most streamflow measurements by current meter. A current meter is an instrument used to measure the velocity of flowing water. By placing a current meter at a point in a stream and counting the number of revolutions of the rotor during a measured interval of time, the velocity of water at that point is determined.

Regulatory floodplain: Regulatory Floodplains may be either riverine or non-riverine depressional areas. Projecting the base flood elevation onto the best available topography delineates floodplain boundaries. A flood prone area is Regulatory Floodplain if it meets any of the following descriptions:

Any riverine area inundated by the base flood where there is at least 640 acres of tributary drainage area.

Any non-riverine area with a storage volume of 0.75 acre-foot or more when inundated by the base flood.

Any area indicated as a Special Flood Hazard Area on the FEMA Flood Insurance Rate Map expected to be inundated by the base flood located using best available topography.

Regulatory floodway: The channel, including on-stream lakes, and that portion of the Regulatory Floodplain adjacent to a stream or channel as designated by the Illinois Department of Natural Resources-Office of Water Resources, which is needed to store and convey the existing and anticipated future 100-year frequency flood discharge with no more than a 0.1 foot increase in stage due to the loss of flood conveyance or storage, and no more than a 10% increase in velocities. Where interpretation is needed to determine the exact location of the Regulatory Floodway boundary, the IDNR-OWR should be contacted for the interpretation.

Remedial measures: Used to solve known watershed problems or to improve current watershed conditions. Remedial measures include retrofitting drainage system infrastructure such as detention basins and storm sewer outfalls to improve water quality, adjust release rates, or reduce erosion.

Remnant: A small fragmented portion of the former dominant vegetation or landscape which once covered the area before being cleared for human land use.

Retention facilities: A facility designed to completely retain a specified amount of stormwater runoff without release except by means of evaporation, infiltration or pumping.

Retrofit: Refers to modification to improve problems with existing stormwater control structures such as detention basins and conveyance systems such as ditches and storm sewers. These structures were originally designed to improve drainage and reduce flood risk, but they can also be retrofitted to improve water quality.

Ridge: A line connecting the highest points along a landscape and separating drainage basins or small-scale drainage systems from one another.

Riffle: Shallow rapids, usually located at the crossover in a meander of the active channel.

Riparian: Referring to the riverside or riverine environment next to the stream channel, e.g., riparian, or streamside, vegetation.

Runoff: The portion of rain or snow that does not percolate into the ground and is discharged into streams by flowing over the ground instead.

Savanna: A type of woodland characterized by open spacing between its trees and by intervening grassland.

Section 319: see U.S. Environmental Protection Agency Section 319.

Sediment: Soil particles that have been transported from their natural location by wind or water action.

Sedimentation: The process that deposits soils, debris and other materials either on other ground surfaces or in bodies of water or watercourses.

Silt: Fine mineral particles intermediate in size between clay and sand.

Stakeholders: Individuals, organizations, or enterprises that have an interest or a share in a project. (*see also Watershed Stakeholders*).

Stormwater management: A set of actions taken to control stormwater runoff with the objectives of providing controlled surface drainage, flood control and pollutant reduction in runoff.

Stream corridor: The area of land that runs parallel to a stream.

Stream reach: A stream segment having fairly homogenous hydraulic, geomorphic and riparian cover and land use characteristics (such as all ditched agriculture or all natural and wooded). Reaches generally should not exceed 2,000 feet in length.

Streambank stabilization: Techniques used for stabilizing eroding streambanks.

Stream monitoring: Chemical, biological and physical monitoring used to identify the causes and sources of pollution in the river and to determine the needs for reduction in pollutant loads, streambank stabilization, debris removal and habitat improvement.

Substrate (stream): The composition of the bottom of a stream such as clay, silt or sand.

Subwatershed: Any drainage basin within a larger drainage basin or watershed.

Subwatershed Management Unit (SMU): Small unit of a watershed or subwatershed that is delineated and used in watershed planning efforts because the effects of impervious cover are easily measured, there is less chance for confounding pollutant sources, boundaries have fewer political jurisdictions, and monitoring/mapping assessments can be done in a relatively short amount of time.

Swale: A vegetated channel, ditch or low-lying or depressional tract of land that is periodically inundated by conveying stormwater from one point to another. Swales are often used in natural drainage systems instead of stormsewers.

Threatened and Endangered Species (T&E): An "endangered" species is one that is in danger of extinction throughout all or a significant portion of its range. A "threatened" species is one that is likely to become endangered in the foreseeable future.

Till: A heterogeneous mixture of clay, silt, sand, gravel, stones, and boulders deposited directly by and underneath a glacier without stratification.

Topography: The relative elevations of a landscape describing the configuration of its surface.

Total dissolved solids (TDS): A measure of the dissolved solids in water sample.

Total suspended solids (TSS): The organic and inorganic material suspended in the water column and greater than 0.45 micron in size.

Treatment Train: Several Management Measures/Best Management Practices (BMPs) used together to improve water quality, infiltration and reduce sedimentation.

Total Maximum Daily Load (TMDL): A TMDL is the highest amount of a particular pollutant discharge a waterbody can handle safely per day.

Trophic State Index (TSI): Trophic State is a measure of the degree of plant material in of a body of water. It is usually measured using one of several indices (TSI) of algal weight (biomass): water transparency (Secchi Depth), algal chlorophyll, and total phosphorus.

Turbidity: Refers to the clarity of the water, which is a function of how much material including sediment is suspended in the water.

United States Environmental Protection Agency Section 319 (Section 319): Section 319 of the Clean Water Act encourages and funds nonpoint source pollution control projects (any indirect pollution, like runoff, stormwater discharge, road salt, sediment, etc.) or NPS reduction at the source.

United States Geological Survey (USGS): Government agency established in 1879 with the responsibility to serve the Nation by providing reliable scientific information to describe and understand the Earth; minimize loss of life and property from natural disasters; manage water, biological, energy, and mineral resources; and enhance and protect our quality of life.

United States Army Corps of Engineers (USACE): Federal group of civilian and military engineers and scientists that provide services to the nation including planning, designing, building and operating water resources and other Civil Works projects. These also include navigation, flood control, environmental protection, and disaster response.

USDA TR55 Document: A single event rainfall-runoff hydrologic model designed for small watersheds and developed by the USDA, NRCS, and EPA.

Urban runoff: Water from rain or snow events that runs over surfaces such as streets, lawns, parking lots and directly into storm sewers before entering the river rather than infiltrating the land upon which it falls.

Vegetated buffer: An area of vegetated land to be left open adjacent to drainageways, wetlands, lakes, ponds or other such surface waters for the purpose of eliminating or minimizing adverse impacts to such areas from adjacent land areas.

Vegetated swale: An open channel drainageway used along residential streets and highways to convey stormwater and filter pollutants in lieu of conventional storm sewers.

Velocity (of water in a stream): The distance that water can travel in a given direction during a period of time expressed in feet per second.

Watershed: An area confined by topographic divides that drains to a given stream or river. The land area above a given point on a waterbody (river, stream, lake, wetland) that contributes runoff to that point is considered the watershed.

Watershed stakeholder: A person who has a personal, professional, legal or economic interest in the watershed and the outcome of the watershed planning process.

Watershed partner(s): Key watershed stakeholders who take an active role in the watershed management planning process and implementing the watershed plan. Partners in Woods Creek watershed include Algonquin, Crystal Lake, Lake in the Hills, and Crystal Lake Park District.

Waters of the United States (WOUS): For the purpose of this Ordinance the term Waters of the United States refers to those water bodies and wetland areas that are under the U. S. Army Corps of Engineers jurisdiction.

Watershed Vulnerability Analysis: Rapid planning tool for application to watersheds and sub-watersheds that estimates future and impervious cover and provides guidance on factors that might alter the initial classification or diagnosis of a watershed or sub-watershed.

Wetland: A wetland is considered a subset of the definition of the Waters of the United States. Wetlands are land that is inundated or saturated by surface or ground water at a frequency and duration sufficient to support, under normal conditions, a prevalence of vegetation adapted for life in saturated soil conditions (known as hydrophytic vegetation). A wetland is identified based upon the three attributes: 1) hydrology, 2) hydric soils and 3) hydrophytic vegetation.

Wet meadow: A type of wetland away from stream or river influence with water made available by general drainage and consisting of non-woody vegetation growing in saturated or occasionally flooded soils.

11.2 Appendix 2. History of Apple Canyon Lake

1967 Branigar Lake Properties, Inc. identified 3000 acres in Thompson Township, Jo Daviess County, as a desirable location to develop a planned lake community. Land acquisition included 23 parcels adjacent to a three mile stretch of the Hell's Branch Stream.

1968 Bauer Engineering was hired by Branigar to design, engineer, and oversee the construction of a dam that will impound the waters of Hell's Branch.

1969 April 22, 1969, Apple Canyon Lake Property Owner's Association was incorporated as an Illinois not-for-profit Corporation. Branigar began selling 2,721 single family residential lots.

1970 Dam construction was completed. The lake filled to 800.0' pool level by November, 1970. Resulting 440 acre lake, average depth 30 ft., capacity 1 billion gallons, watershed size 9,749.2 acres, average daily spillway release 250,000 gallons or 174 gallons per minute (0.3877 cfs).

1972 Watershed erosion and accumulating sediment in bay inlets was recognized by the Property Owners Association as a threat to the lake environment.

1973 Branigar deeded common property and all existing amenities except Apple Cove and the Marina Building to ACLPOA clear and free of debt.

1975 Dan Harm completed the first documented soil erosion & sedimentation report of Apple Canyon Lake.

1975 Branigar's final settlement agreement with the Association included a $40,000 cash payment. The Board of Directors deposited money in a special lake fund, $13,000 designated for a master lake study.

1976 Conservation Committee was established. The Committee's first major goal focused on stabilizing erosion on Association property. Over 40,000 trees and shrubs were planted over a five-year period. Strategically placed dry dams and check dams were constructed on Association property.

1977 NALCO Environmental Sciences completed major sedimentation, erosion, and water quality study. Study addressed such things as silt in inlets, chemical and biological analysis, point sources of erosion, evaluations of beaches, trails, fish and wildlife, herbicide program and erosion control practices. NALCO recommended hydraulic dredging as the most efficient and economical method of removing silt from the lake.

October 15, 1977, a special assessment of $135.00 per lot was approved by the ACL membership. The purpose of the assessment was: (1) purchase of a hydraulic dredging system and construct settling ponds, and (2) pay associated operating expenses.

Erosion control structures including check dams and dry dams continued to be constructed on Association Property.

Roy Mann, ACL General Manager, scheduled meetings with famers in the watershed, trying to gain cooperation for the construction of beneficial erosion control structures. The goal was to reduce erosion of nutrient rich farmland into Apple Canyon Lake.

In the fall of 1977, the first settling pond was built in President's Bay.

1978 By the spring of 1978, 135,000 cubic yards of silt had accumulated in eight bay inlets, targeted by the NALCO report. The three major areas of concentration were North Bay (95,000 $yd.^3$, 58.88 acre-feet), President's Bay (18,000 $yd.^3$, 11.16 acre-feet), and Winchester Bay (12,000 $yd.^3$, 7.44 acre-feet).

On February 22, a "Mud Cat" dredge was delivered to ACL. President's Bay was the first bay dredged while a spoils pond is constructed in North Bay.

1979 Dredging in North Bay began while a dredge pond was constructed at Hawthorne Bay.

1980 Dredging was completed in North Bay.

1981 Hawthorne Bay was dredged while additional spoils ponds were constructed at Independence and Winchester Bays. Independence Bay dredging began this same year.

1982 Dredging at Independence Bay was completed as well as at Winchester Bay.

1983 Dredging was not active this year; the Mud Cat was leased to The Galena Territory Association, Inc.

1984 ACLPOA, Jo Daviess County SWCD, and Jo Daviess County SCS (NRCS) entered into an agreement designed to reach mutual watershed objectives by working together to preserve and restore the lake environment at Apple Canyon Lake. A cost-share program was established to pay farmers a portion of the costs associated with constructing dry dams, grassed waterways, and other eligible soil erosion control projects. ACL began participation in the Illinois Volunteer Lake Monitoring Program (VLMP). Frank Loftus volunteered to collect bi-monthly water samples and record secchi (clarity) readings.

1985 Hawthorne Bay and Independence Bay were dredged, averaging 3-5 ft. of sediment removal per square foot.

1986 President's Bay and Winchester Bay were dredged. "Apple Canyon Lake, A Bay Study", a follow-up study to the 1977 NALCO Report, was completed by Biologist Bruce Muensch, Project Leader for the NALCO Report.

1987 North Bay dredging began.

1988 North Bay dredging was completed and Independence Bay is dredged. Dredging was considered complete at this time with an estimated 150,000 – 200,000 $yd.^3$ of silt removed from the Lake since 1978.

1989 Dredging was not conducted this year; the dredge was leased to Inland Dredge Co, Burlington, WI.

1990 Dredge was repaired and refurbished by Inland Dredge Co., with a total cost of $18,645.

1992 Dredge was leased to Lake Summerset.

1993 ACLPOA passed a $1,525,000.00 capital improvement referendum. $250,000 was earmarked for improving lake quality.

1995 The dredge was leased to The Galena Territory Association, Inc. Fehr- Graham & Associates prepared a preliminary evaluation of siltation ponds for ACL and a soft-sediment survey for ACL.

1996 Cochran & Wilken, Inc., prepared a Diagnostic Feasibility Study and Management Plan of Apple Canyon Lake. ACLPOA purchased an aquatic weed harvester.

1997 Southwind Construction Corporation was awarded a contract to dredge Apple Canyon Lake.

1998 Southwind Construction Corporation mobilized to ACL on April 20, 1998. A 60-ton Ellicot 370 hydraulic dredge was used to dredge and remove 63,245 $yd.^3$ of sediment from 16 bays and coves at ACL. Dredging was completed on July 31, 1998. The completion of lake dredging concluded planned lake quality improvements associated with the 1993 capital improvement referendum. A total of $425,229.00 was spent to improve lake quality (dredging/erosion control- $262,632.00, lake engineering- $47,581.00, aquatic weed harvester- $115,016.00. 300 ft. of longitudinal peaked stone toe protection (LPSTP) and boulder weirs are installed in Hell's Branch (MNEA-02) below the spillway to address in-stream erosion issues. An additional 533 ft. of LPSTP is installed in Winchester Bay (MNEAE-01).

1999 Winchester stream bank stabilization project was completed. This is the first of many stream bank stabilization projects completed on Association property. ACLPOA received free technical assistance from the Jo Daviess SWCD. Each project qualified for and received 75% cost share funding through the State of Illinois C-2000 Program.

2000 1,145 ft. of stream stabilization is completed on Hell's Branch (MNEA-03).

2001 Koester detention pond was constructed in an effort to minimize sediment entering President's Bay. No dredging was completed at ACL and the dredge was leased to The Galena Territory Association (GTA). Shallow bays totaling 45 acres were treated in early May with the herbicide, Navigate, to control Eurasian Water Milfoil.

Frank Loftus passed away in December. Darryle Burmeister volunteered to assume responsibilities as ACL representative for the Volunteer Lake Monitoring Program.

2003 ACLPOA and Jo Daviess SWCD entered into a professional services agreement for conservation related technical assistance. Resource Conservationist Lester Johnson was designated to provide assistance on an as-needed basis.

A detention pond located adjacent to the 9th hole on the golf course was renovated. Sediment was stockpiled from the Hawthorne Bay spoils pond.

2004 Hawthorne Bay soil was made available for sale. Soil sold out in three months. Bays were again treated for Eurasian Water Milfoil. A second sediment pond was created at Winchester Bay. Soil was stockpiled from North Bay sediment pond.

2005 Marina shoreline is stabilized; a concrete seawall is erected at the Cove. Sediment retention pond is constructed for dredge spoils at Winchester Bay.

2006 President's Bay is dredged.

2008 Turbidity curtain is installed at the entrance to President's Bay (MNEAG-01) to control suspended sediments from reaching anoxic zones in deeper water. The project is funded in part as a special project through the Illinois Department of Agriculture's C-2000 program.

2009 Four rock riffles, two bed keys, and two hundred ninety feed of LPSTP are installed in President's Bay.

2010 Four rock riffles, eight bed keys, and four hundred eighty feet of LPSTP are installed in a tributary of Hells Branch (MNEA-02) before it enters into North Bay. Estimated time of survey conducted at Apple Canyon Lake.

2011 Two rock riffles, five bed keys, and 1035 feet of LPSTP is installed in the tributary stream feeding Independence Bay (MNEAC-01).

2012 Two rock riffles and 425 feet of LPSTP are installed in the stream feeding Winchester Bay (MNEAE-01), funded in part by the Illinois Department of Agriculture's SSRP program.

2013 ACL applies for and receives a Clean Water Act Section 319(a) grant. The shoreline is assessed for degree of stabilization. 425 feet of LPSTP and two rock riffles were installed. Hell's Branch (MNEA-02) below ACL spillway is assessed for smallmouth bass habitat. The silt pond and turbidity curtain BMPs in Presidents Bay are excavated to remove sediment collected.

2014 Data collection begins for the watershed plan. One thousand feet of President's Bay's shoreline is stabilized.

11.3 Appendix 3. Apple Canyon Lake Watershed Survey

The completion date of this survey is not known but is suspected to be approximately 2010 – 2011. This survey was not used to develop this plan and concerns are not up to date with the stakeholder group which developed this plan. However, there are interesting pieces of information from this survey and it should not be forgotten. Grammatical errors have been left in place uncorrected, as received.

Table 11-1. Apple Canyon Watershed Survey – Question 1.

Overall, how would you rate the water quality of Apple Canyon Lake?						
Answer Options	**Poor**	**Fair**	**Good**	**Very Good**	**Excellent**	**Response Count**
a) Overall	1	8	38	45	7	99
b) For canoeing / kayaking / boating.	2	2	33	42	23	102
c) For fishing.	0	4	29	44	19	96
d) For swimming / wading.	7	23	39	25	8	102
e) For water-skiing.	1	11	37	37	11	97
f) For eating fish caught in the Lake.	2	10	35	32	13	92
g) For picnicking / activities near water.	5	14	32	28	19	98
h) For scenic beauty / enjoyment.	2	8	20	23	46	99
					Answered Question	**102**
					Skipped Question	**1**

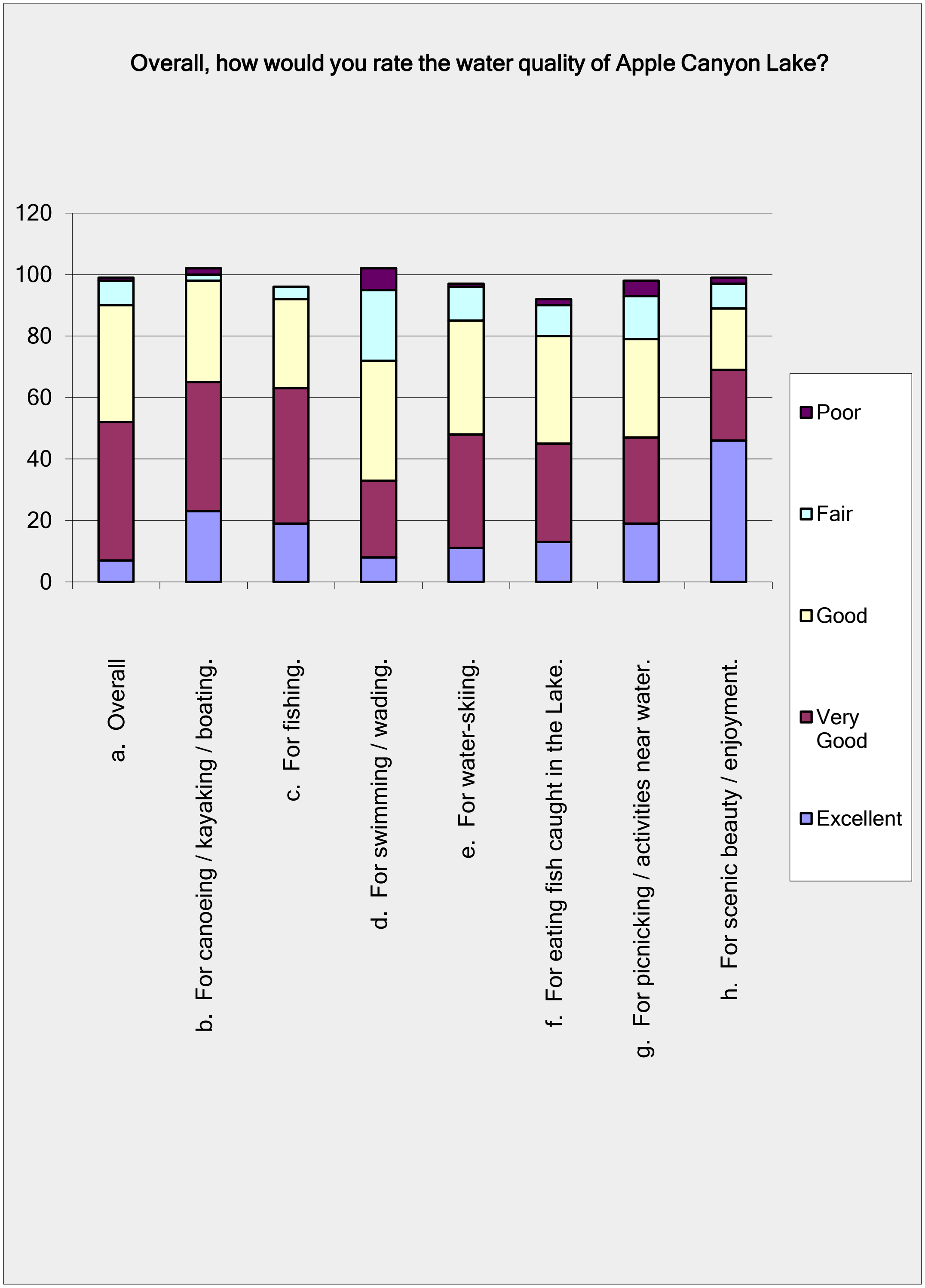


Figure 11-1. Graphic corresponding to Table 11-1.

Table 11-2. Comments relating to Question 1.

Number	Response Date	Comment (300 character limit)
1	Dec 2, 2011 2:19 AM	The lake seems to have an algae bloom problem which has gotten worse over the years
2	Dec 1, 2011 3:20 AM	After heavy spring rains, exclusive of the 13 in. rainfall last and this year.
3	Nov 29, 2011 10:58 PM	Great lake for various activities
4	Nov 29, 2011 2:51 PM	Since we built our home in 1996, the water quality has deteiorated substantially.
5	Nov 29, 2011 12:41 AM	I didn't answer questions related to fishing as we really don't fish (I know - our loss!). Water at beach OK in June but gradually gets worse (algae, cloudy, etc) as the summer goes on. Picnicking/activites near water are pretty much limited to the beach. This is nice, but limited given the amount of shoreline we have.
6	Nov 28, 2011 10:59 PM	that is why we love it
7	Nov 28, 2011 9:00 PM	Scenic beauty is lost with the sight and smell of all the algae in the bay areas
8	Nov 28, 2011 5:28 PM	I believe the water quality has declined somewhat recently perhaps do to runoff from the record rains
9	Nov 15, 2011 7:24 PM	quality not so good at north end of lake
10	Nov 6, 2011 12:16 AM	Water quality very good for swimming in middle of bays, but not as good near shore off of private docks, etc.
11	Oct 26, 2011 1:25 AM	The lakeshore is overgrown and only those who live on the lake or have a boat can enjoy the view of the lake.
12	Oct 25, 2011 11:14 PM	There is too much summer time spongee stuff floating around, is this because of too much phosphorus in the lake? I know that does affect fish eggs that reside on rocks such as those for walleye.
13	Oct 24, 2011 9:55 PM	Other than algea blooms, the water is great.
14	Oct 24, 2011 7:20 PM	There is a lot of algae. I wish more people knew about how to avoid polluting the lake with fertilizers and chemicals, and septic systems. I am concerned about the water quality for eating fish and swimming. Have their been any studies reporting water quality for these activities? I'm not sure what picknicking has to do with water quality.

Table 11-3. Apple Canyon Watershed - Question 2.

Below is a list of water pollutants and conditions that are generally present in most water bodies to some extent. The pollutants and conditions become a problem when present in excessive amounts. In your opinion, which of the following potential impairments may be a problem at Apple Canyon Lake?		
Answer Options	**Response Percent**	**Response Count**
a) Excess soil washing into the water.	55.7%	54
b) Excess nitrogen from lawns / cropland.	67.0%	65
c) Excess phosphorus from lawns / croplands.	59.8%	58
d) Livestock waste.	47.4%	46
e) Pet waste.	13.4%	13
f) Bacteria and viruses in the water (such as e. coli / fecal coliform).	38.1%	37
g) Trash or debris in the water.	19.6%	19
h) Excess algae in the water.	72.2%	70
i) Excess aquatic plant growth in the water.	47.4%	46
j) Invasive aquatic plants and animals.	30.9%	30
k) Habitat alteration affecting fish negatively.	16.5%	16
l) Salt from road applications or water softeners.	13.4%	13
m) In-lake sediment deposits.	38.1%	37
n) Streambank / Stream Channel Erosion	39.2%	38
Answer Options con't.		**Response Count**
Comment (300 character limit)		9
Answered Question		**97**
Skipped Question		**6**

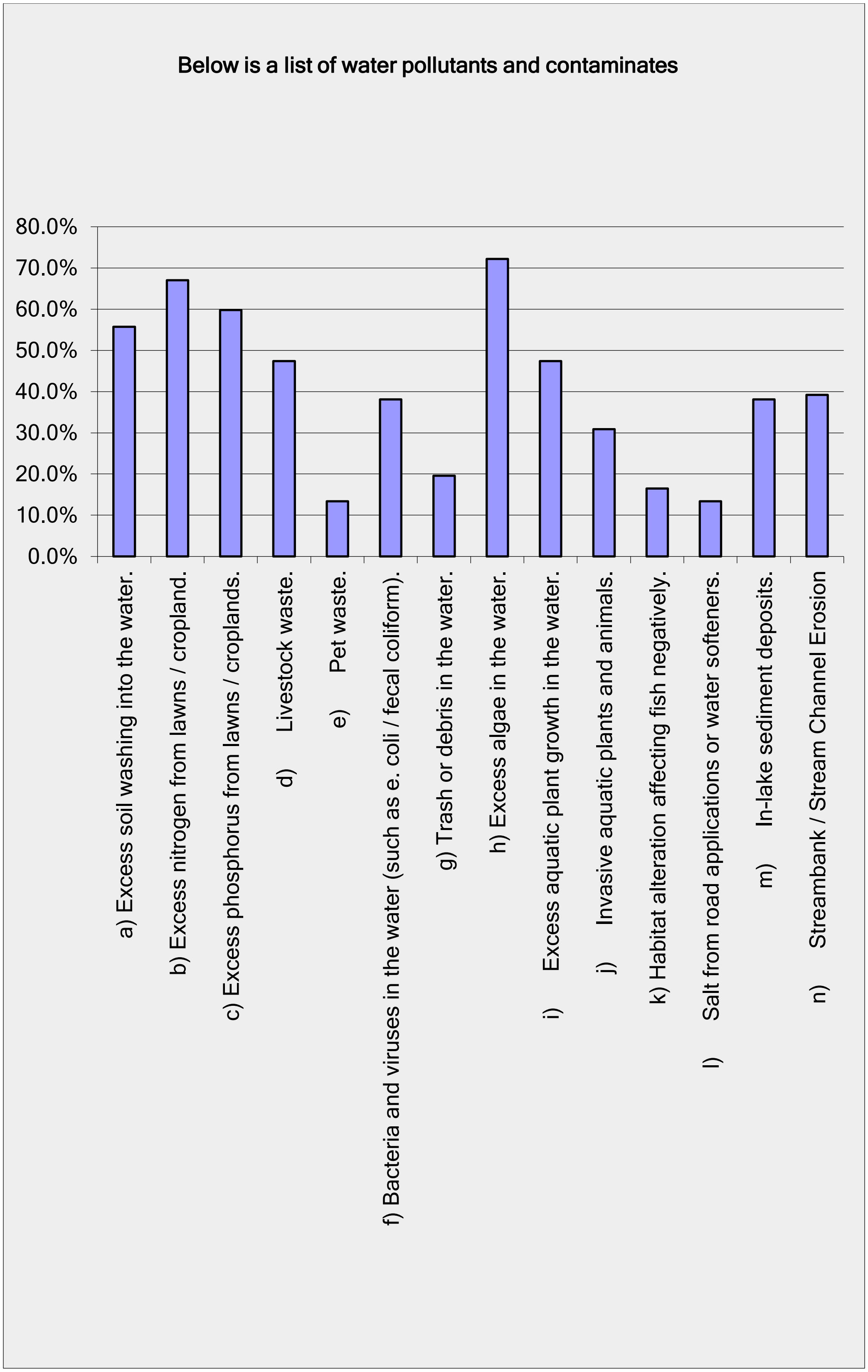


Figure 11-2. Graphic corresponding to Table 11-3.

Table 11-4. Comments relating to Question 2.

Number	Response Date	Comment (300 character limit)
1	**Nov 30, 2011 5:55 PM**	Determine effecive approaches to stagnant bays and accumulated growth
2	**Nov 29, 2011 2:53 PM**	More needs to be done to prevent waste and chemical run-off.
3	**Nov 29, 2011 4:21 AM**	I think there is alot of over-reaction re: pollutants, etc. which do little but cost $ to property owners when IEPA continues to come up with more and more POSSIBLE problems on the assumption something could happen.
4	**Nov 28, 2011 9:35 PM**	Bays are filling in due to sediment runoff & too much algae
5	**Nov 28, 2011 7:09 PM**	at times a rust color has taken over the bay, followed by a lot of dead fish...
6	**Nov 28, 2011 5:31 PM**	I think the waste from the increasing goose population needs to be addressed as soon as possible
7	**Nov 28, 2011 5:08 PM**	If the pollutants are controlled, the algae, plants, and fish will balance out.
8	**Nov 15, 2011 7:26 PM**	excessive plant growth at north end of lake
9	**Oct 24, 2011 7:22 PM**	I am very concerned about chemicals including fertilizers and other nitrogen in the water. I also don't like swimming in a green lake with a lot of algae.

Table 11-5. Apple Canyon Watershed - Question 3.

Please indicate your level of agreement or disagreement with the statements below.						
Answer Options	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Response Count**
a) The economic stability of the Apple Canyon Lake community depends upon good water quality.	0	0	2	22	72	96
b) The quality of life of the Apple Canyon Lake community depends on good water quality in local streams, rivers and lakes.	0	0	4	37	55	96
c) The water quality of Apple Canyon Lake has an impact on the value of my property.	0	1	2	25	68	96
d) The way that I care for my lawn and yard can influence water quality in local streams and lakes.	0	1	11	34	50	96
e) It is my personal responsibility to help protect water quality.	0	1	2	36	57	96
f) It is important to protect water quality even if it slows economic development.	0	3	11	43	39	96
g) What I do on my land doesn’t make much difference in overall water quality.	39	40	10	5	0	94
h) Lawn and yard-care practices (on individual lots) do not have an impact on local water quality.	39	40	8	7	1	95
i) My actions can have a beneficial impact on water quality.	0	0	9	51	35	95
j) Taking action to improve water quality is too expensive for me.	23	30	38	1	1	93

Answer Options con't.	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Response Count**
k) It is okay to reduce water quality to promote economic development.	53	34	8	1	0	96
l) It is important to protect water quality even if it costs me more.	3	5	22	45	21	96
m) I would be willing to pay more to improve water quality (for example: through local taxes or fees).	6	6	34	39	9	94
n) I would be willing to change the way I care for my lawn and yard to improve water quality.	0	1	11	48	34	94
o) I would be willing to consider implementing water quality protection practices on my property if cost-share assistance were available.	0	4	26	43	22	95
p) The pollution of surface water can also affect my drinking water supply.	0	7	19	39	29	94
Comment (300 character limit)						10
Answered Question						**96**
Skipped Question						**7**

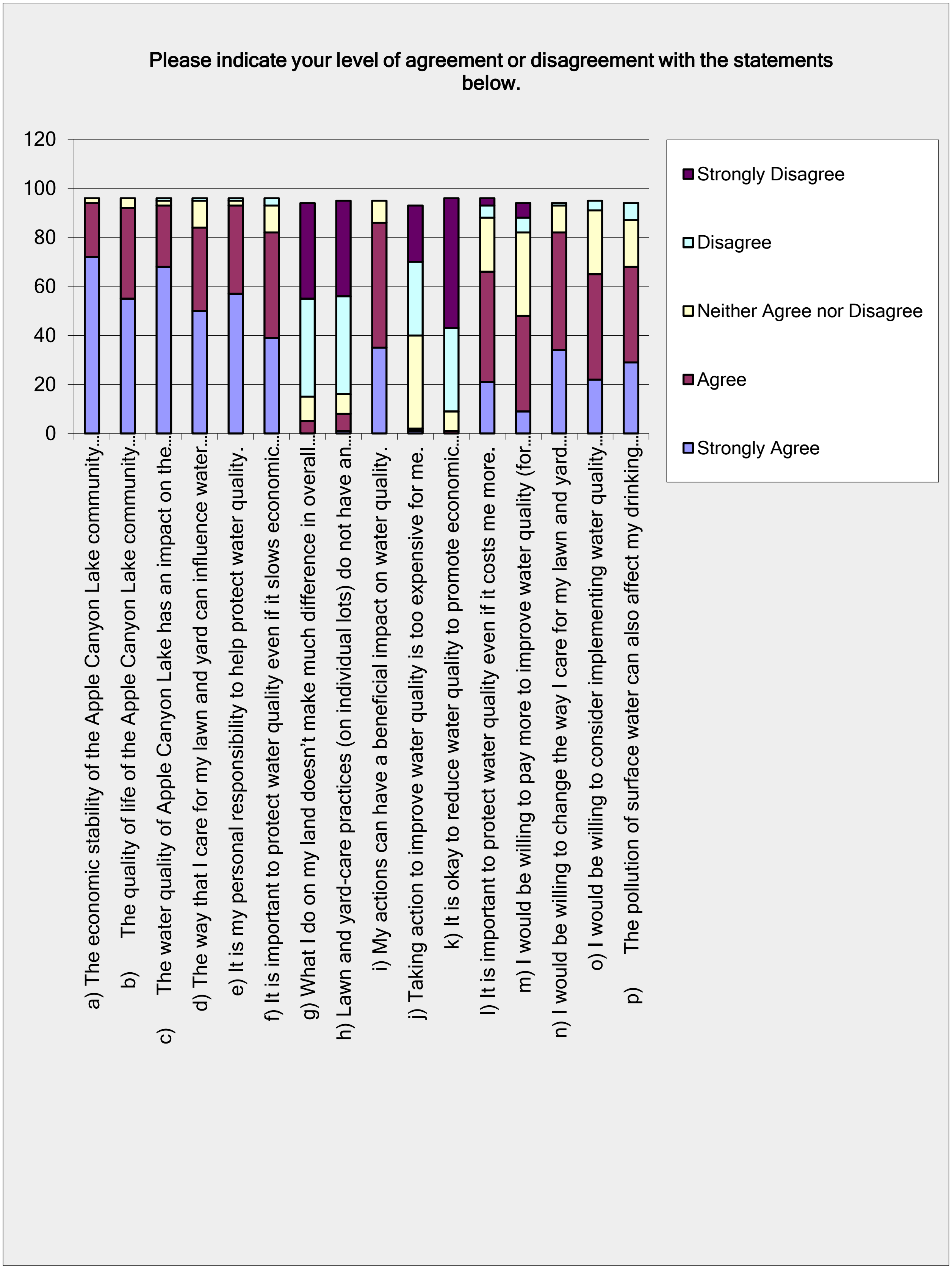


Figure 11-3. Graphic corresponding to Table 11-5.

Table 11-6. Comments relating to Question 3.

Number	Response Date	Comment (300 character limit)
1	**Dec 1, 2011 3:36 AM**	The tax burden in Jo Daviess County for Lake Property is already burdensome! My taxes are over $3000 higher @ Apple Canyon than at my suburban home AND there are no services provided other than road maintenance! High cost of ownership, which includes taxes, also has a negative impact on life and the value of Apple Canyon. If there's to be an extra tax or fee to be paid for water quality, then it needs to be borne but everyone in the County, especially as the much of the material the flows into the lake from the surrounding watershed is off Apple Canyon property.
2	**Nov 29, 2011 9:05 PM**	Our property taxes are horrible already...Fee based improvement is better based on lot ownership
3	**Nov 29, 2011 12:59 PM**	Higher taxes are an issue considering the grossly unfair property taxes on home owner. A re-allocation of tax money for water quality would be acceptable.
4	**Nov 29, 2011 4:28 AM**	This survey, like many before it, is geared to the writers' opinions and an answer they want to add more restrictions on my property. I see no facts, figures here to tell me how much anything will cost. And I am very opposed to rules set on property I OWN.
5	**Nov 28, 2011 10:59 PM**	m) My disagree comment comes from the knowledge that my six lots will cost me an additional $3000.00 per year and I feel that is enough and do not want my taxes raised in addition to being overtaxed compared to others already. n) I do not add anything to my lots and already spent about $10k in special drainage and shoreline protection for the lake. o) Twice in the past there was no cost-share assistance.
6	**Nov 28, 2011 9:44 PM**	Since my property is not near or on the lake I should not have to subsidize those property owners who do not use proper care in runoff from their property

Number	Response Date	Comment con't. (300 character limit)
7	**Nov 28, 2011 8:29 PM**	These questions are designed to produce a guilt factor in getting people to respond the way you would like to support your point of view which I am sure that the quality of the water in the lake is important. Who would disagree? I certainly don't. I think a person would almost have to burn up his lawn with too much fertilizer to have an impact on the quality of water in the lake. It would also be very expensive to put enough fertilizer on your lawn in order to impact the quality of water in the lake. By far most of the people with lots on the lake are too smart to over spend on fertilizer to the extent they are going to poison the lake with run off from their lawn. Now if some hog farm is directly dumping waste into the lake or streams that feed into the lake that of course is a concern and should be stopped. That does not mean the federal or state governments need to grant large sums of money to cause that to happen or to cause some large survey to be needed to see if there is a problem.
8	**Nov 28, 2011 5:34 PM**	I would like to see more detail when plans are considered
9	**Nov 15, 2011 7:31 PM**	The lake's water quality is very important to ACL.
10	**Oct 24, 2011 7:25 PM**	I wish more people understood the impacts of their actions and lawn-care on the lake. I hope there will be more education to follow.

Table 11-7. Apple Canyon Watershed - Question 4.

The items listed below are potential sources of water quality pollution across the country. In your opinion, how much of a potential problem are the following sources at Apple Canyon Lake?						
Answer Options	**Not a Problem**	**Slight Problem**	**Moderate Problem**	**Severe Problem**	**Don't Know**	**Response Count**
a) Soil erosion from construction sites.	12	36	22	2	16	88
b) Soil erosion from farm fields.	3	19	27	24	15	88
c) Soil erosion from eroding shorelines and / or streambanks.	3	14	35	26	10	88
d) Excessive use of lawn fertilizers and / or pesticides.	0	19	25	31	13	88
e) Excessive use of cropland fertilizers and / or pesticides.	1	11	22	39	15	88
f) Improperly maintained septic systems.	4	20	26	20	18	88
g) Improperly managed manure from farm animals.	2	14	25	26	21	88
h) Improperly managed manure from domestic pets.	25	22	11	9	21	88
i) Waterfowl waste.	9	30	22	12	15	88
j) Littering / illegal dumping of trash.	9	44	11	13	12	89
k) Poorly planned land development or redevelopment.	11	30	18	10	17	86
l) Residential stormwater runoff.	7	27	25	7	22	88
m) Drainage / filling of wetlands.	7	25	16	10	28	86
n) Salt used for road de-icing in winter.	15	28	18	5	22	88
o) Salt used for home water softeners.	17	31	7	3	30	88
p) Coal Tar-based sealants used on asphalt driveways.	19	28	9	5	27	88
q) Prescription drugs entering the water table through septic systems.	16	28	10	10	23	87
r) Atmospheric deposition of pollutants from distant industries, power plants, etc.	17	26	13	8	22	86

Answer Options con't.	Response Count
Comment (300 character limit)	5
Answered Question	**89**
Skipped Question	**14**

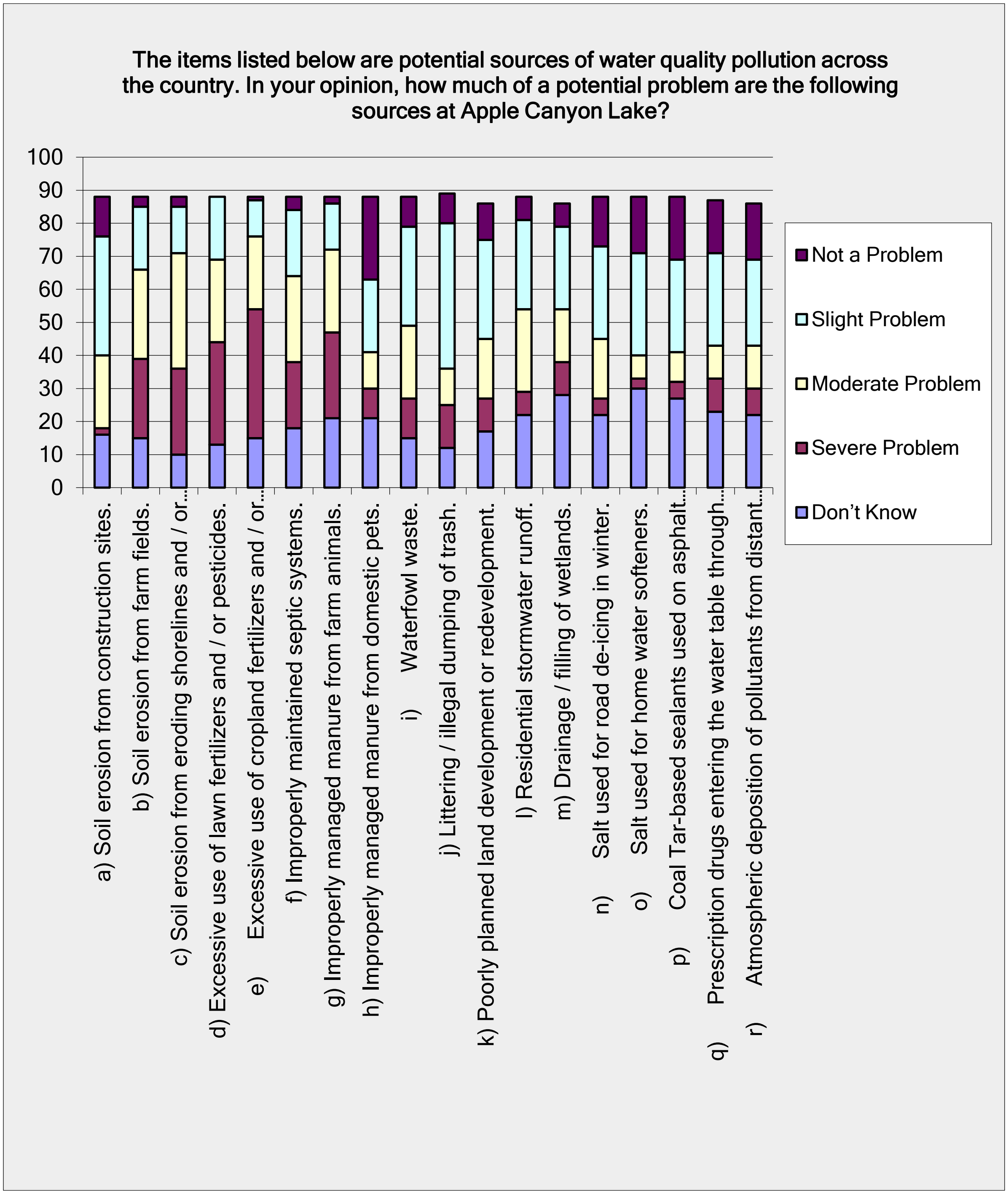


Figure 11-4. Graphic corresponding to Table 11-7.

Table 11-8. Comments relating to Question 4.

Number	Response Date	Comment (300 character limit)
1	**Dec 1, 2011 3:45 AM**	This is an interesting question. I thought there's been water quality testing done at the Lake. What do the results tell us about these various items??? Visual indicators of weed growth (much less the last few years) and sediment in the water (cloudiness) after rain storms is far more of an issue, I'd think, than prescription drug levels in the water entering through septic systems. There are other material passing through a septic system in greater quantities, at least I'd think so!!!
2	**Nov 29, 2011 4:58 PM**	Don't know on many?s really.
3	**Nov 29, 2011 2:50 AM**	Not qualified to comment.
4	**Nov 28, 2011 11:03 PM**	i) The geese in the last couple of years have become a problem and it may get worse if we choose to ignore the problem.
5	**Nov 28, 2011 8:34 PM**	I don't think a cow or a dog taking a pee in a creek that feeds water into the lake is a problem. A dairy or hog farm that is not taking appropriate steps to control where its waste is seeping is a problem, but it is not too hard to observe that is happening or to test the water in the lake to see if it is happening.

Table 11-9. Apple Canyon Watershed - Question 5.

Poor water quality can lead to a variety of consequences for communities. In your opinion, how much of a problem are the following issues in your area?						
Answer Options	Not a Problem	Slight Problem	Moderate Problem	Severe Problem	Don't Know	Response Count
a) Contaminated drinking water.	47	14	8	7	11	87
b) Polluted / closed swimming areas.	29	30	9	6	13	87
c) Contaminated fish.	25	22	9	8	22	86
d) Loss of desirable fish and wildlife species.	24	19	14	11	19	87
e) Reduced beauty of lakes or streams.	24	27	24	9	4	88
f) Reduced opportunities for water activities such as boating, canoeing, and fishing.	28	27	16	7	9	87
g) Reduced quality of water activities.	22	29	20	7	8	86
h) Excessive aquatic plants or algae.	3	28	21	25	10	87
i) Lower property values.	19	20	23	14	11	87
Comment (300 character limit)						6
Answered Question						**88**
Skipped Question						**15**

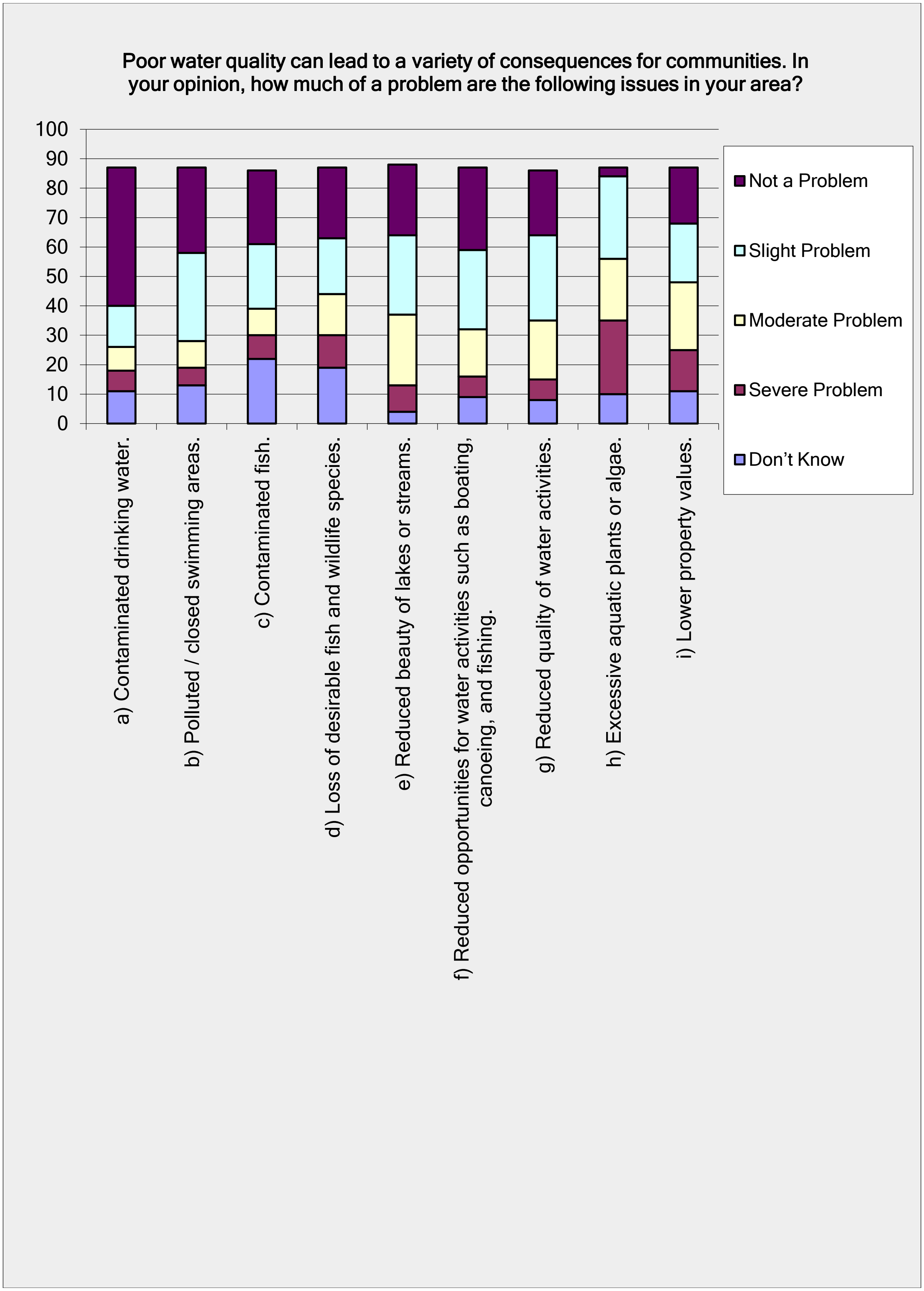


Figure 11-5. Graphic corresponding to Table 11-9.

Table 11-10. Comments relating to Question 5.

Number	Response Date	Comment (300 character limit)
1	**Dec 1, 2011 3:50 AM**	Overall, the quality of the Lake water seems very good, from a visual aspect and has been so over the many years I've been at the lake. I'd say that the plant and algae growth is lower through past efforts to try to control material that enter the Lake. But just because things are okay now, there's no room to loose ground figuratively and literally!
2	**Nov 28, 2011 11:07 PM**	a) I believe that lead may be a problem within Jo Daviess County.
3	**Nov 28, 2011 9:49 PM**	To many dogs allowed at beach - polluted sand/water for swimming
4	**Nov 28, 2011 9:11 PM**	President's Bay has an epidemic algae problem. Our children can't swim off our pier. We have to take them out on the boat to swim.
5	**Nov 15, 2011 7:42 PM**	North end of ACL is shallow and has excessive plant growth.
6	**Oct 24, 2011 7:28 PM**	Is the water quality tested? Do we know if fish quality and drinking water quality is affected?

Table 11-11. Apple Canyon Watershed - Question 6.

Please indicate which statement most accurately describes your level of experience with each Water Quality "Best Management Practice" (BMP) listed below.					
Answer Options	**Never Heard of It**	**Somewhat Familiar With It**	**Know How To Use It; But Not Using It**	**Currently Use It**	**Response Count**
a) Creating a rain garden or bioswale with native grasses and wildflowers to allow stormwater / rain gutter flow to infiltrate into the ground, rather than runoff.	13	38	20	14	85
b) Keeping grass clippings and leaves out of the roads, drainageways, and streams.	7	23	8	45	83
c) Composting grass clippings / leaves for use in my garden.	2	21	33	26	82
d) Using only phosphate-free fertilizer on my lawn.	1	15	13	51	80
e) Having my soil tested to determine the amount / type of nutrients I need to apply to my lawn.	4	30	40	5	79
f) Properly disposing of pet waste.	6	12	15	45	78
g) Having septic system pumped / maintained on a regular basis.	0	11	6	66	83
h) Restoring native plant communities as buffer strips along lawn edges.	7	16	32	27	82
i) Reducing the size of your mowed turf yard "footprint" save time / fuel, and to increase native buffers.	7	16	29	30	82
j) Re-vegetating stream banks and / or shorelines to reduce erosion, and trap nutrients & sediments.	9	24	36	11	80
k) Preventing erosion by not discharging sump pump flow / water softener discharge onto bare / poorly vegetated areas.	11	16	10	45	82
l) Removing invasive plants / shrubs.	1	22	19	39	81
m) Using Integrated Pest Management (IPM) approaches instead of pesticides.	16	22	28	15	81

Answer Options con't.	Never Heard of It	Somewhat Familiar With It	Know How To Use It; But Not Using It	Currently Use It	Response Count
n) Encouraging my landscaper to use environmentally sensitive approaches to lawn care / yard waste management / fertilizing / herbiciding.	5	17	22	36	80
o) The use of controlled burn management of natural areas to kill off invasive plants and shrubs, and to encourage the growth of native prairie / woodland / wetland species of plants.	2	22	39	18	81
Comment (300 character limit)					6
Answered Question					**85**
Skipped Question					**18**

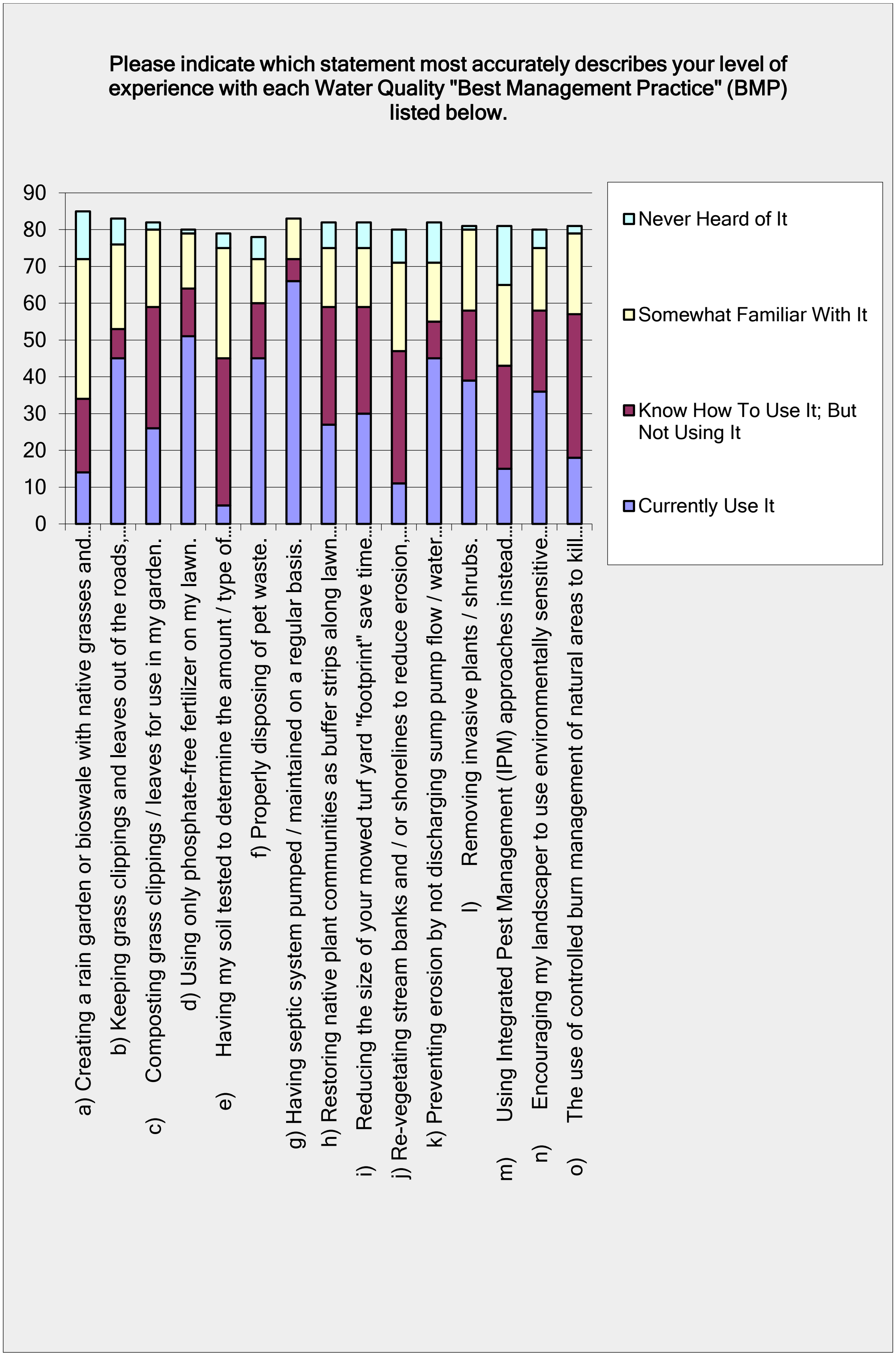


Figure 11-6. Graphic corresponding to Table 11-1.

Table 11-12. Comments relating to Question 6.

Number	Response Date	Comment (300 character limit)
1	Dec 1, 2011 4:00 AM	There's a selection missing! I don't have a pet. I don't use pesticides, have a sump pump, water softener. So if I check know how to use it, but not using it, you don't know if I don't have a pet or if I empty the supper duper pooper scooper in the Lake!
2	Nov 29, 2011 5:03 PM	Some, "J," for example, only apply to some land owners.
3	Nov 29, 2011 2:46 PM	I don't apply any supplements or fertilizers/herbicides to my lawn.
4	Nov 29, 2011 4:37 AM	I don't have "a landscaper" - we practice reasonable care in use of anything we use on the lawn - with green areas all around us, there is NO way we can remove all invasive plants/shrubs and I certainly disagree someone/agency telling me what I can or cannot plant .
5	Nov 29, 2011 3:04 AM	We currently do not own a home at ACL
6	Oct 26, 2011 1:37 AM	Our whole yard has been restored to a native prairie. We do not use fertilizers.

Table 11-13. Apple Canyon Watershed - Question 7.

When you make decisions about changing your lawn care and / or stormwater practices, how important is each of the following?						
Answer Options	**Not At All**	**A Little**	**Some**	**A Lot**	**Don't Know**	**Response Count**
a) Personal out-of-pocket expense.	0	8	34	38	1	81
b) My own views about effective lawn and yard maintenance.	0	9	28	43	1	81
c) How easily the new action fits with my current practices.	2	13	43	19	3	80
d) My own physical abilities.	7	9	31	32	2	81
e) The need to learn new skills or techniques.	15	18	31	14	3	81
f) Too much time required for implementation.	14	22	31	10	4	81
g) Not having access to the equipment that I need.	7	20	29	23	2	81
h) Lack of available information about a practice.	10	17	33	18	2	80
i) No one else I know is implementing the practice.	36	13	18	7	7	81
j) Approval of my neighbors.	36	15	22	5	3	81
k) Restrictive covenants.	8	11	24	26	11	80
l) Don't know where to get information and/or assistance about the practice.	22	20	25	8	5	80
m) Environmental damage caused by practice.	5	4	26	39	5	79
n) Environmental benefit of practice.	3	2	25	43	6	79
Comment (300 character limit)						4
Answered Question						**81**
Skipped Question						**22**

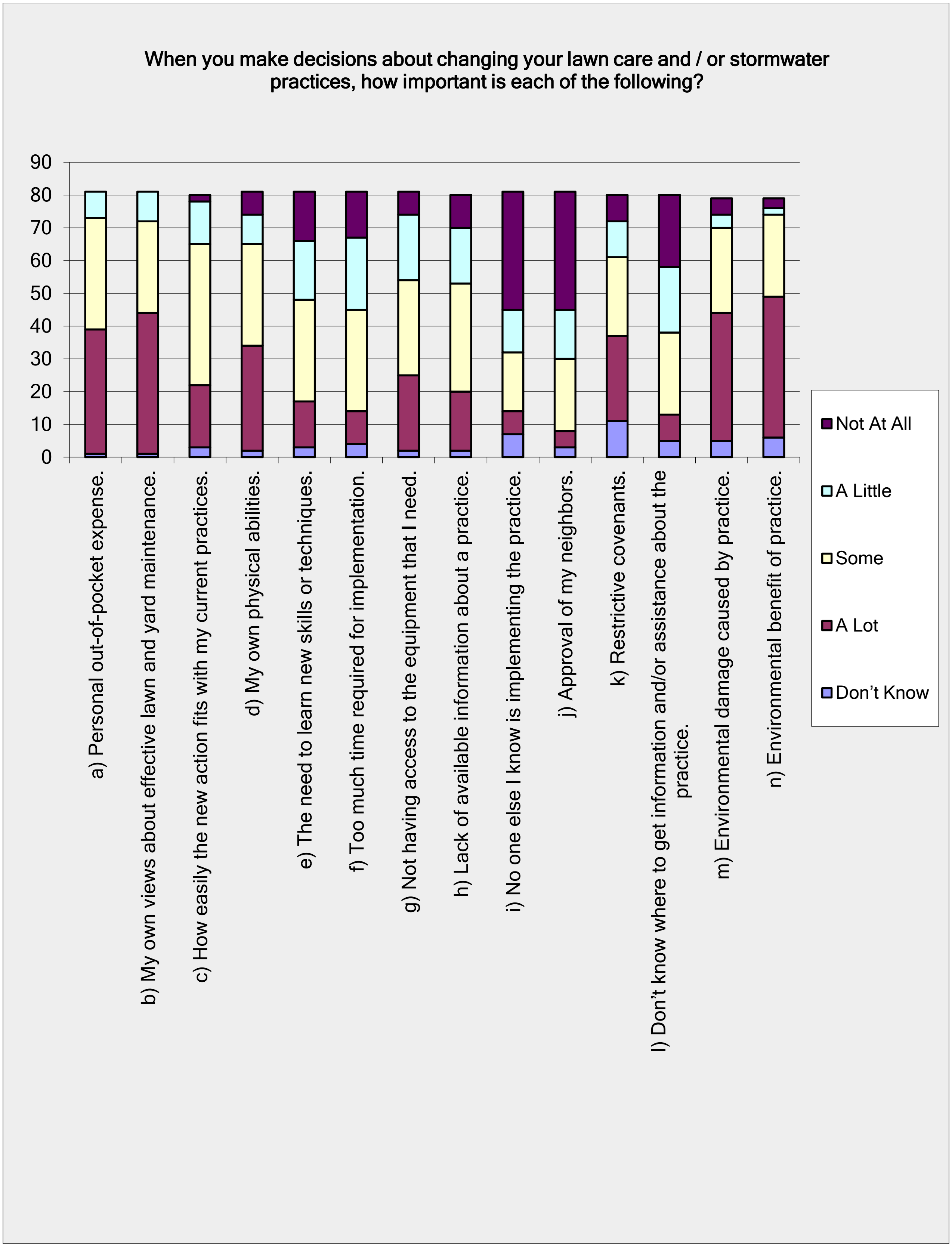


Figure 11-7. Graphic corresponding to Table 11-13.

Table 11-14. Comments relating to Question 7.

Number	Response Date	Comment (300 character limit)
1	**Nov 29, 2011 4:41 AM**	EASY on "restrictive covenants" - it will price everyone except the elite away from what has been a very nice friendly community.
2	**Nov 28, 2011 8:45 PM**	I think many environmentalists are extreme in their thinking. I think many environmental groups are trying to shape the way people think in order to implement their liberal views they have been unsuccessful in accomplishing in the political arena. They think they are smarter than the common folks and we need them to tell us how we should live and think.
3	**Nov 28, 2011 3:48 PM**	Although we hear a lot about general environmental practices, it is difficult to get specific info on what we should or should not do.
4	**Oct 24, 2011 7:33 PM**	I wish there was more assistance with invasive plant removal, burns, etc. It is very difficult and costly to get rid of garlic mustard, honeysuckle, etc.

Table 11-15. Apple Canyon Watershed - Question 8.

Below are typical Watershed Plan recommendations that could be applicable to the entire Apple Canyon Lake / Hell's Branch watershed. Please indicate your level of agreement with the following recommendations:						
Answer Options	**Strongly Disagree**	**Disagree**	**Neither Agree nor Disagree**	**Agree**	**Strongly Agree**	**Response Count**
a) Expand water quality and biological monitoring to better understand the conditions in the watershed and identify trends.	0	0	9	50	23	82
b) Identify existing nutrient management planning efforts such as managing the amount, source, and timing of the application of plant nutrients and soil amendments.	0	2	8	49	22	81
c) Protect / enhance stream corridors and wetlands through acquisition by purchase.	2	8	25	25	21	81
d) Protect / enhance stream corridors and wetlands through conservation easements.	2	4	9	38	27	80
e) Change the way landowners in the Hells Branch / Apple Canyon Lake watershed manage stormwater.	0	4	20	33	24	81
f) Improve controls on non-point source pollution such as runoff from impervious surfaces or lawns.	0	3	17	38	22	80
g) Create / pursue cost-share funding opportunities to encourage landowners to implement water quality practices.	1	2	20	36	22	81
h) Conduct public education and outreach about the watershed at community events.	0	2	13	38	29	82
i) Conduct public education and outreach about the watershed in local schools.	2	4	14	36	22	78

Answer Options con't.	**Response Count**
Comment (300 character limit)	5
Answered Question	**82**
Skipped Question	**21**

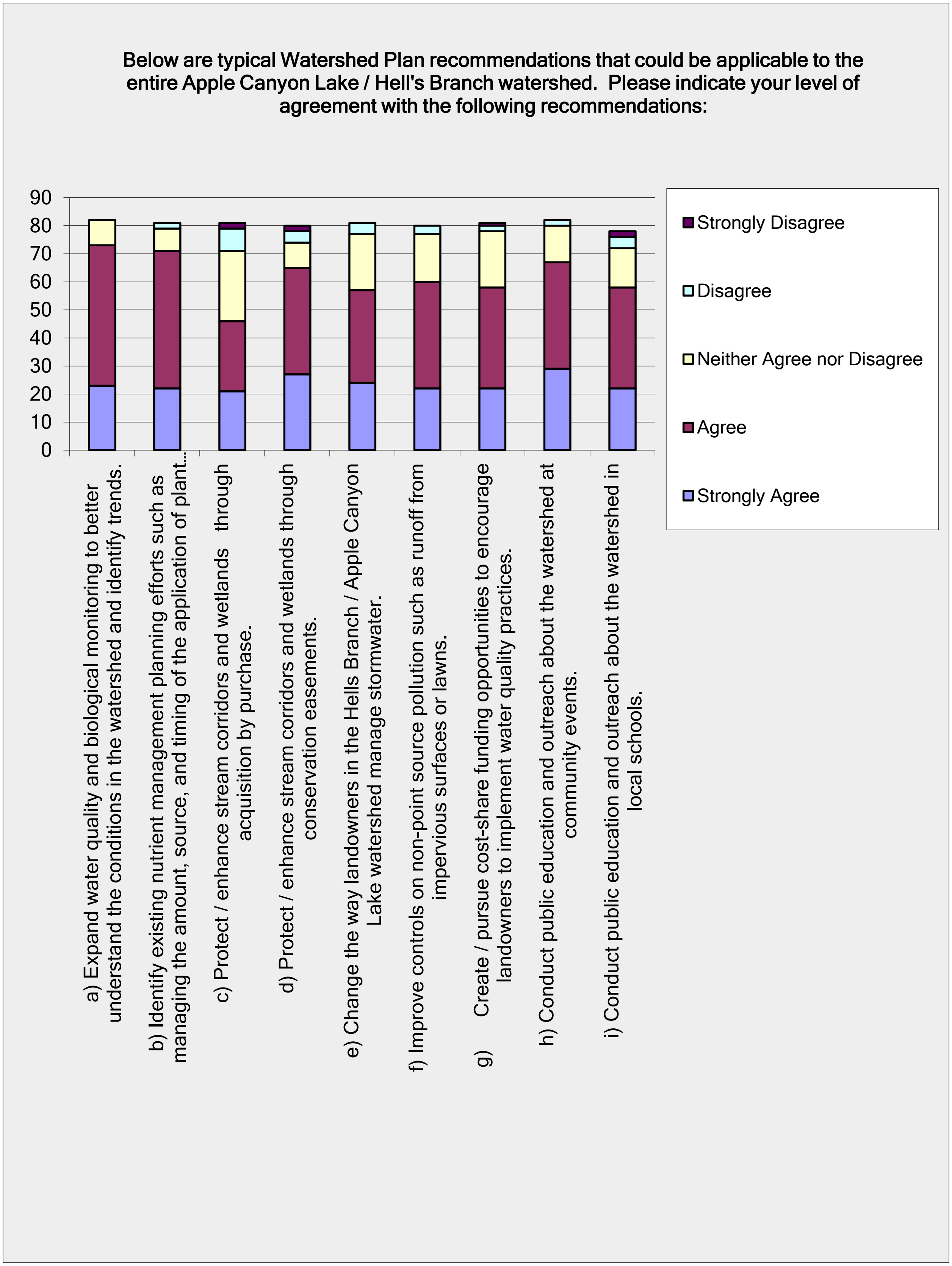


Figure 11-8. Graphic corresponding to Table 11-15.

Table 11-16. Comments relating to Question 8.

Number	Response Date	Comment (300 character limit)
1	Dec 1, 2011 4:10 AM	a) I don't know what's done now. Expand it if we need to and we're going to do something with the info obtained! c) don't purchase it if you're not going to do something with it! The current owner, with training and such, may do a better job, and with better knowledge on the owner's part, it may have a positive impact on other land usage within the watershed.
2	Nov 29, 2011 5:07 PM	Many questions don't lend themselves to "agree," "disagree" answers w/o more info.
3	Nov 29, 2011 4:45 AM	Schools are already conducting such programs. We've never had much interest in outreach programs except for the minority of extreme minded environmentalists who live here.
Number	**Response Date**	**Comment con't. (300 character limit)**
4	Nov 28, 2011 5:48 PM	I really need greater detail to better answer these very general questions
5	Nov 8, 2011 9:16 PM	public education w/ volunteers

Table 11-17. Apple Canyon Watershed - Question 9.

Apple Canyon Lake was created to have over 700 acres of Greenway areas. What ACL Greenway Area concerns do you have regarding the following issues?						
Answer Options	**Not a Concern**	**Slight Concern**	**Moderate Concern**	**Significantly Concerned**	**Don't Know**	**Response Count**
a) Loss of larger, desirable trees, such as Oaks and Hickories, from old age, disease, wind damage.	1	13	24	40	3	81
b) Lack of natural regeneration of younger desirable trees, such as Oaks and Hickories.	1	12	19	45	4	81
c) Increases in the amount of invasive, brushy species, such as Honeysuckle and Buckthorn.	1	8	18	51	3	81
d) The pending loss of all Ash trees at ACL as a result of the spread of the Emerald Ash Borer.	1	7	25	42	5	80
e) Increased woody debris load on the ACL trails / in the streams from soft-wooded trees like Box Elder, Silver Maple, Cottonwood.	4	11	32	25	9	81
f) Increases in the amount of invasive herbaceous plants, such as Garlic Mustard, Thistles, etc.	1	6	19	48	7	81
g) Increases in soil erosion on heavily shaded slopes.	2	9	18	49	3	81
h) Increases in stream channel / streambank erosion in heavily shaded areas.	2	8	21	45	3	79

Answer Options con't.	**Not a Concern**	**Slight Concern**	**Moderate Concern**	**Significantly Concerned**	**Don't Know**	**Response Count**
i) Reductions in the diversity / extent of native woodland wildflowers.	3	10	28	35	5	81
j) Reductions in the diversity / extent of native prairie remnants.	3	11	28	34	5	81
Comment (300 character limit)						5
Answered Question						**81**
Skipped Question						**22**

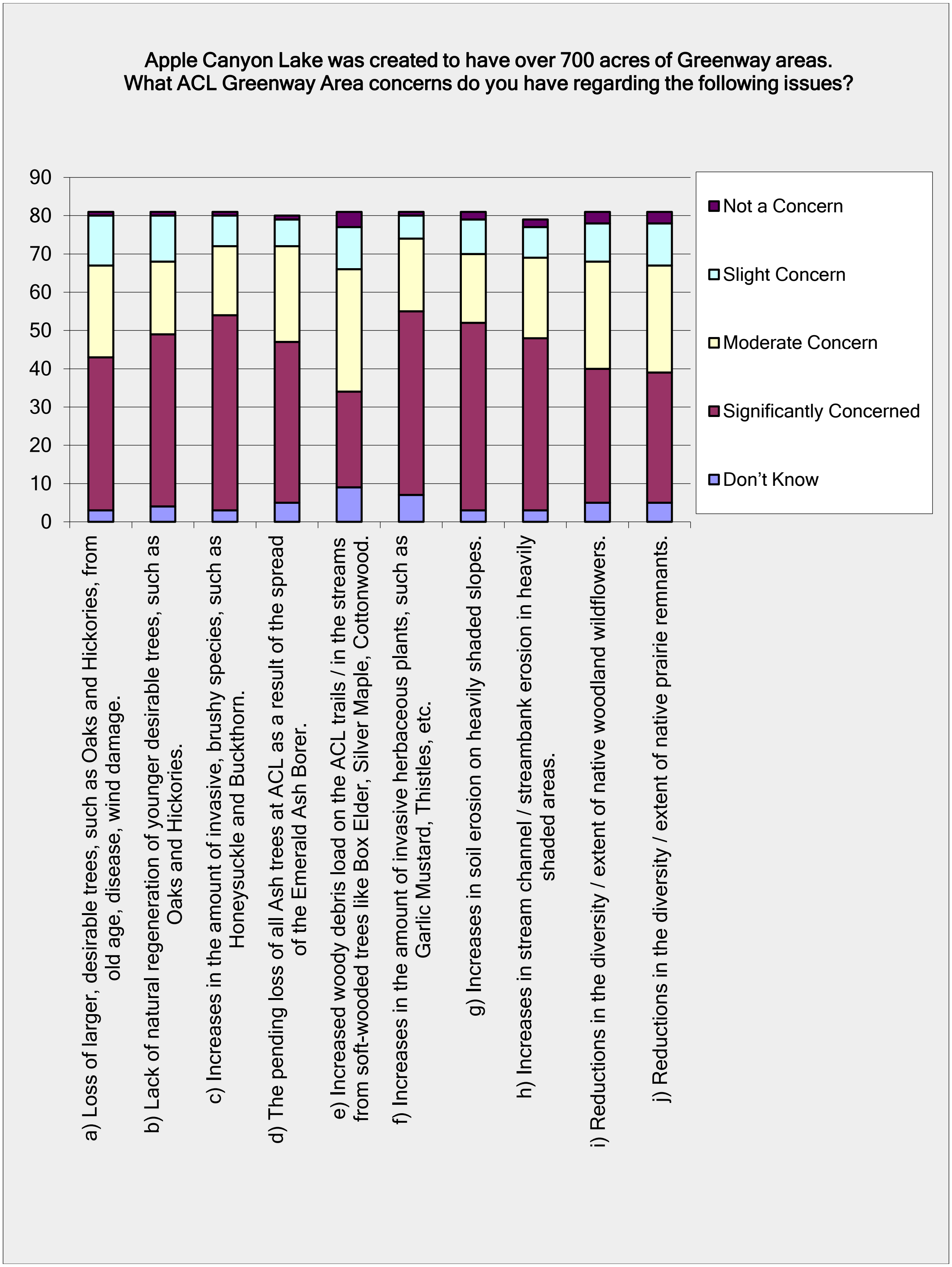


Figure 11-9. Graphic corresponding to Table 11-17.

Table 11-18. Comments relating to Question 9.

Number	Response Date	Comment (300 character limit)
1	**Dec 1, 2011 4:19 AM**	While shade on slopes and in areas around streams can be an issue, the bigger contributor is how we deal with the trail system and culverts and the materials that wash out around/over the trails in high water times. I'd think that the trees causing the shade would actually help reduce erosion with their root systems and such helping to slow the impact of fast moving water and absorbing moisture, i.e. I think there would be more erosion without the trees and resulting shade.
2	**Nov 29, 2011 12:53 AM**	Many of these items weren't previously on our radar screen.
3	**Nov 28, 2011 11:22 PM**	b) thru J... The problem has been that Conservation meant NEVER TOUCH THE GREENWAY which has not been the correct thing to do. I am glad to see that a more educated approach to conservation has been looked at as a more appropriate solution.
4	**Nov 11, 2011 12:48 AM**	I am opposed to the current trend of removing invasive plants/trees from existing greenway. I feel strongly that many property owners are using this option to obtain a better view of the lake and doubt there will be a long term benefit ot erosion control. For instance, one property owner is requesting clearance of the greenway and is currently selling his/her home. As properties change hands there is nothing to guarantee maintenance of these areas. In addition, I rather look at trees than houses from the lake. This policy hurts the asthaestics of the lake!
5	**Oct 24, 2011 7:36 PM**	I enjoy native plants, wildflowers. I am so disappointed to see them choked out by garlic mustard and honeysuckle. I am concerned about regeneration of trees.

Table 11-19. Apple Canyon Watershed - Question 10.

How long have you owned property at Apple Canyon Lake?		
Answer Options	**Response Percent**	**Response Count**
0-2 years	3.7%	3
2-5 years	8.5%	7
5-10 years	37.8%	31
10-20 years	22.0%	18
20+ years	28.0%	23
Suggestions on ACL Watershed Planning Needs / Approaches (1000 character limit)		11
Answered Question		**82**
Skipped Question		**21**

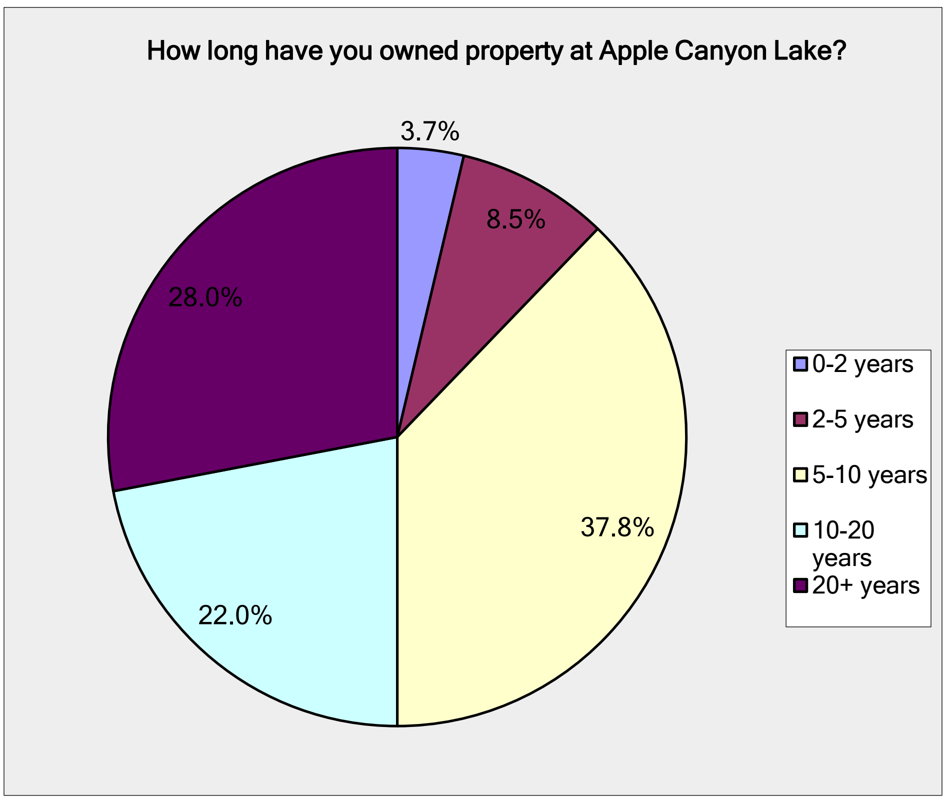


Figure 11-10. Graphic corresponding to Table 11-19.

Table 11-20. Suggestions on ACL Watershed Planning.

Number	Response Date	Suggestions on ACL Watershed Planning Needs / Approaches (1000 character limit)
1	**Dec 1, 2011 4:34 AM**	We need to first look at on-property actions! There a places on the trails that erode with heavier storms. Perhaps there's alternatives to explore on how better to control the water in these situations. In some green way path areas to docks and such, the ground has been laid bare and thus subject to erosion by the foot and ATV traffic. This access can't be taken away but perhaps other treatments for high-traffic areas need to be considered. Some lake front properties are cut all the way to the lake with no buffer zone. In other areas, buffer growth is cut away leaving exposed, steep hills which promotes erosion and run off into the lake. Some areas are protected with rip-rap. Other areas are still exposed and subject to erosion or receding shorelines. Offer co-pay programs to lot owners, even if they're lot has green-way between it and the shoreline.
2	**Nov 29, 2011 5:12 PM**	Okay, here is my "take" on the survey... Too long and too specific. Average owner (incl me) doesn't really KNOW answers to many questions and, to that extent, makes their answers relatively of minor use. A better approach might be more generalized, focusing on their reception to some general costs to them, how generally important varies environmental ill effects are to them, etc. Etc, etc, etc.
3	**Nov 29, 2011 3:17 PM**	NEED TO MOVE FORWARD QUICKLY WITH THIS PROJECT, WITH OR WITHOUT EPA FUNDING
4	**Nov 29, 2011 2:53 PM**	keep information available through the use of the Apple Core, emails etc.
5	**Nov 29, 2011 4:49 AM**	No restrictive covenants!!! Educate, encourage property owners to properly care for their lots. Do NOT set property owner against property owner (asking one to be a watcher over activities of his neighbor),
6	**Nov 29, 2011 12:54 AM**	Explore all options, keep it transparent.
7	**Nov 28, 2011 11:23 PM**	Education is a good start to the approach. Second to education is simplicity of implementation by homeowners.
8	**Nov 28, 2011 8:53 PM**	Use common sense. Don't get carried away. Stay concerned, but really think through what you recommend. Remember, there are few people who intentionally want to damage the environment. Keep in mind individual rights.

Number	Response Date	Suggestions on ACL Watershed Planning Needs / Approaches con’t. (1000 character limit)
9	Nov 15, 2011 8:02 PM	Control of sediment build-up and excessive algae growth must be investigated.
10	Nov 6, 2011 4:51 PM	Continue Lake monitoring. Create and complete Water shed plan. Educate surrounding landowners about personal benefits for cleaner water. Hire professionals to restore greenway areas that are primary buffer areas.
11	Oct 24, 2011 7:37 PM	I'd like to see more community education at social events like the Ice Cream Social, Beer & Brats, and other events with many people. I 'd like to see educational information posted near the clubhouse about how people can help. I think many people would help, but they don't know how to help or how their actions impact water quality.

11.4 Appendix 4. Best Management Practices

The following pages have been compiled to provide a source for best management practices referenced in this plan. This list is not exhaustive of all best management practices, but provides a library of many of the practices applicable and listed in the plan. Where feasible, any other best management practices are recommended and encouraged to facilitate the overall goal of improving water quality in the Apple Canyon Lake Watershed.

1. Anaerobic Digester
2. Bioswale
3. Contour Buffer Strip
4. Cover Crop
5. Denitrifying Bioreactor
6. Grade Stabilization Structure
7. Grass Lined Channel
8. Infiltration Trench
9. Nutrient Management
10. Permeable Pavement
11. Pond
12. Prescribed Grazing
13. Raingarden
14. Residue and Tillage Management
15. Riparian Forest Buffer
16. Saturated Buffer
17. Silvopasture
18. Stream Crossing
19. Stream Habitat Improvement
20. Streambank and Shoreline Protection
21. Strip Cropping
22. Subsurface Drain
23. Terrace
24. Water and Sediment Control Basin
25. Wetland Restoration

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

ANAEROBIC DIGESTER

(No.)

CODE 366

DEFINITION

A component of a waste management system that provides biological treatment in the absence of oxygen.

PURPOSE

For the treatment of manure and other byproducts of animal agricultural operations for one or more of the following reasons to

- capture biogas for energy production
- manage odors
- reduce the net effect of greenhouse gas emissions
- reduce pathogens

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Biogas production and capture are components of a planned animal waste and byproduct(s) management system.
- Sufficient and suitable organic feedstocks are readily available.
- Existing facilities can be modified to the requirements of this standard or for new construction.
- The operator has the interest and skills to monitor and maintain processes or contracts with a consultant to provide these services.

CRITERIA

General Criteria Applicable to All Purposes

Laws and Regulations. Waste treatment facilities must be planned, designed, and constructed to meet all Federal, State, and local regulations, including Iowa Administrative Code, Environmental Protection [567], Chapter 65, provisions for animal feeding operations.

Location. Digesters shall not be located within a flood plain unless the structure is protected from inundation and damage that may occur during the flood event.

Digesters shall be located so the potential impacts from breach of embankment, accidental release, and/or liner failure are minimized.

Feedstock Characteristics. The design of the digester needs to take feedstock properties into account. Extraneous material such as soil, sand, stones or fibrous bedding material (including clumps of straw), must be ground, removed, reduced, or otherwise handled. The total solids of feedstock influent to the digester shall be as required by the digester type and process design. Exclude excess water and material from the digester.

Food waste, wastewater from food processing operations, and other allowable organic substrates may be added as supplemental feedstock to a digester when the digester is designed to treat such wastes, as described in the operation and maintenance plan.

Safety. If the digester will create a safety hazard, it shall be fenced and warning signs posted to prevent using it for purposes other than intended.

Biogas is flammable, highly toxic, and

potentially explosive. The design of the digester and gas components, including the gas collection, control, and utilization system, must consider the hazards associated with normal operation and maintenance, provide adequate safety measures including appropriate earthquake loads**,** and shall be in accordance with standard engineering practice for handling a flammable gas and to prevent undue safety hazards. As a minimum:

- “Warning Flammable Gas” and “No Smoking” signs shall be posted.
- Appropriate fire protection equipment and biogas leak detection sensors, especially in confined areas shall be provided.
- Flares shall be located an appropriate distance from biogas sources. Enclosed flares shall be located as recommended by the manufacturer. Open flares shall be located a minimum distance of 95 feet (30 m) from the biogas source. The flares shall have a minimum height of 10 ft and shall be grounded or otherwise protected to minimize the chance of lightening strikes.
- A flame trap device shall be provided in the biogas line between the digester and sources of ignition or as recommended by the flame arrester manufacturer.
- The location of underground gas lines shall be marked with signs to prevent accidental disturbance or rupture. Mark exposed pipe to indicate whether gas line or of other type.

Digester Types

Plug Flow Digester

1. The total solids concentration of influent shall be 11 to 14 percent.
2. Digester retention time shall be a minimum of 20 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. The length to width ratio of digester flow path shall be a minimum of 3.5:1
5. The ratio of flow path width to fluid depth shall be less than 2.5:1.
6. The shape of the floor and walls shall facilitate the movement of all material through the digester to minimize short-circuiting flow.

Complete Mix Digester

1. Total solids concentration of manure influent shall be less than 11 percent.
2. Digester retention time shall be a minimum of 17 days.
3. Operational temperature shall be mesophilic (ranging from 35 – 40 ºC or 95 – 104 ºF).
4. Appropriate devices shall be provided, as necessary, to assure a continuous flowing and mixing process.

Covered Lagoon

The digester shall meet the General Criteria for All Lagoons given in, Waste Treatment Lagoon (359), as appropriate, and the following additional requirements:

1. Minimum Design Operating Volume. The design operating volume shall be based either on the daily volatile solids (VS) loading rate per 1,000 ft^3 or the minimum hydraulic retention time (HRT) adequate for methane production, whichever is greater. The maximum daily VS loading rate shall be selected from the values listed on the map in Figure 1. The minimum HRT shall be selected from values indicated on the map in Figure 2.
2. Required Total Volume. The required total volume of the digester shall be equal to the minimum design operating volume except where waste storage is included in the design, in which case the volume shall meet the additional criteria for Design Storage Volume in, Waste Storage Facility (313), as appropriate.

3. The digester storage volume does not need to account for rainfall in completely covered digesters.
4. Provide a minimum of 2 feet of freeboard above the digester design water surface; if rainfall is included in determining the operating volume, only 1 foot of freeboard is required.
5. Operating Depth. The operating depth of the digester shall be at least 8 feet over 50 percent or more of the bottom area.
6. Inlet and Outlet. Locate the inlet and outlet devices as far apart as practical to minimize "short circuiting." The inlet shall discharge a minimum of 12 inches below the digester liquid surface. Equip the digester with an outflow device that maintains the digester liquid surface at its design operating level.
7. Digester Cover. Design the digester cover, materials, anchorage, and all appurtenances, such as weights and floats, to capture and convey biogas to the gas collection system. The digester cover and materials shall meet the requirements of, Waste Facility Cover (367).

<u>Alternative Type Digester</u>

Types of digesters not meeting the above criteria or for a type other than listed in this standard (such as fixed film, induced blanket, or thermophilic reactors) shall be based on the documented design and performance of such existing animal waste digester and certified as such by a registered professional engineer licensed in the State of Iowa.

Digester Containment Characteristics.

1. Earthen structures shall meet the General Criteria for All Lagoons given in, Waste Treatment Lagoon (359), as appropriate.
2. Design tanks and internal components (including heat pipes) to facilitate periodic removal of accumulated solids and for corrosion protection.
3. Tanks shall meet the structural criteria for "Fabricated Structures" in, Waste Storage Facility (313), and the requirements of state and local seismic codes as applicable.
4. The following additional criteria apply:
   - Design Operating Volume. Size the digester to retain the design hydraulic and solids retention times (days).
   - Inlet and Outlet. Locate the inlet and outlet devices to facilitate process flow. Inlets shall be of any permanent type designed to resist corrosion, plugging, freeze damage, and prevent gas loss. Equip the digester with an outflow device, such as an underflow weir, that will maintain the operating level, maintain a gas seal under the cover, prevent gas loss, and release effluent directly to separation, storage, or other treatment facility.
   - Cover. Covers shall meet the requirements of, Waste Facility Cover (367). Equip tanks with suitable covers designed for accumulation and collection of biogas.
   - Heating System (if required). Heating system should be designed and installed with consideration for minimizing corrosive attack and scalding build-up on the heated surfaces.

Gas Collection, Transfer, and Control System. Design the biogas collection, transfer, and control system to convey captured gas from within the digester to gas utilization equipment or devices (flare, boiler, engine, etc.).

1. Gas collection and transfer - Pipe and/or appurtenances shall meet the following:
   - Design the gas collection system within the digester to minimize plugging.

- Securely anchor pipe and components within the digester to prevent displacement from normal forces including loads from accumulated scum.
- Design the collection and transfer pipe for wet biogas. In colder climates, protect the pipe as necessary to prevent frost buildup. The pipe size shall be no less than 3-inch diameter, unless a detailed design is performed to account for frost buildup and pressure drop in a low-pressure system. Pressurized systems shall be designed as an Alternative Type Digester.
- Pipe used for transfer of gas must include provisions for drainage of condensate, pressure and vacuum relief, and flame traps.
- Steel pipe shall meet the requirements of AWWA Specification C-200 or ASTM A53/A211 for stainless steel.
- Plastic pipe shall meet the requirements of AWWA Specification C-906 or ASTM D-3350 for HDPE.
- Pipes shall be installed to enable all sections to be safely isolated and cleaned as part of routine maintenance.

2. Gas Control
   - Equipment and components shall be conveniently located and sheltered from the elements.
   - Equipment and components shall have a service life of not less than 2 years and shall be readily accessible for replacement or repair.
   - The size of equipment and connecting pipe shall be based on head loss, cost of energy, cost of components, and manufacturers' recommendations.
   - Where electrical service is required at the control facility, the installation and all electrical wire, fixtures, and equipment shall meet the National Electrical Code, state, and local requirements.

Gas Utilization. Design and install gas utilization equipment in accordance with standard engineering practice and the manufacturer's recommendations. Include a flare to burn off collected gas.

- Equip the flare with automatic ignition and powered by battery/solar or direct connection to electrical service. The flare shall have a capacity equal to or greater than the anticipated maximum biogas production. Install a windshield to protect an open flare against wind.
- Gas-fired boilers, fuel cells, turbines, and internal combustion engines, when a component of the system, shall be designed for burning biogas directly, in a mix with other fuel, or shall include equipment for removing H_2S and other impurities from the biogas.
- Install and maintain a gas meter, suitable for measuring biogas.

Monitoring for Mesophilic and Thermophilic Digesters. Install equipment needed to properly monitor the digester and gas production as part of the system. As a minimum the following equipment is required:

- Temperature sensors and readout device to measure internal temperature of digester.
- Temperature sensors and readout device to measure inflow and outflow temperature of digester heat exchanger.

Waste Storage Facility. When a waste storage facility is a component of the waste system, it shall meet the requirements of, Waste Storage Facility (313). The volume of the digester shall not be considered in determining the storage requirement of the waste storage facility except that the volume can be reduced by the anticipated percent destruction of total solids.

CONSIDERATIONS

Location. Locate the digester as near the source of manure and as far from neighboring dwellings or public areas as practicable. Proper location should also consider slope, distance of manure transmission, vehicle access, wind direction, proximity of hydrologically sensitive areas, and visibility. Locate the digester near a suitable site for energy utilization equipment. Short distances for the transmission of biogas through buried pipe are preferable. Locate the waste storage facility, considering elevation and distance from the digester, to take advantage of gravity flow.

Manure Characteristics. Fresh manure has the most energy content; however, aged manure can be fed to the digester if properly reconstituted to the digester design total solids content. The biogas yield from aged manure (generally less than 6 months old) is dependent on the biodegradation that has taken place during the storage period. If frozen, little biodegradation will have occurred; whereas, manure in a warm, moist state could be significantly degraded and biogas production will be substantially reduced. Also, consider potential inhibitory effects of any antimicrobial agents or other contaminants in the manure or waste stream.

Collection/Mix Tank. A collection/mix tank may be included to accumulate manure, settle foreign material, pre-heat, and/or pre-treat influent waste to the appropriate total solids concentration. A volume of 1 to 3 days of manure collection, depending on the planned system management, is recommended.

Waste Transfer Pipe. A cleanout should be located immediately upstream of the digester and/or collection/mix tank. Where influent discharges below the digester operating level, depending on installation, solids can build up in the inlet pipe. The pipe can also vent gas that may build up in the transfer pipe.

Overflow Protection. Consider designing the transfer system with the capability to bypass the digester, going directly to storage or land application equipment in case of equipment failure.

Digester Type. The type of digester selected may be affected by geographical location (Figure 3), energy considerations, wastewater properties, and other design considerations (Figure 4).

Digester Design. A digester operating fluid depth of 8 feet or greater is usually more economical for tank design. Tank dividers or flow separators may be utilized to increase efficiency and prevent short-circuiting. Interior slopes should be as steep as permitted by soil properties and construction techniques.

Grounding and Cathodic Protection. Stray voltage, electrolysis and galvanic corrosion can damage pipes inside digesters. Consider the design requirements for electrodes and anodes.

Electrical Component Protection. Very small concentrations of biogas can corrode electrical hardware. Consider locating electrical controls in a separate room or building away from the digester and generator.

Temperature Maintenance: The design should include a means of maintaining the digester within acceptable operating temperature limits, where appropriate.

Gas Transfer Pipe. Exposed pipe conveying flammable gas is generally painted yellow, per IAW ASME A13.1-1996.

Gas Collection Cover. In areas of extreme wind or excessive snow, appropriate structures may be necessary to protect inflatable and floating digester covers from damage.

Air Quality. Recovering energy from the biogas may be a preferable alternative to flaring. This could reduce fossil fuel combustion and associated emissions, thereby reducing the net effect of greenhouse gases and improving air quality.

Gas Utilization. The most beneficial use of the biogas energy should be investigated and selected. Sales of carbon credits may affect the manner of utilization. Depending on the design and climate, digesters may require more than 50 percent of the biogas heat value to maintain the design temperature in the winter. Digesters can be heated by hot water from boilers burning biogas or by heat recovery from internal combustion engines and micro turbines burning biogas for power generation.

Effluent Tank. An effluent tank to hold digester effluent for subsequent mechanical solid-liquid separation may be considered due to the potential use of digested separated solids for bedding or soil amendment.

Siting and Vegetation. Analyze the visual impact of the digester within the overall landscape context and effects on aesthetics. Screening with vegetative plantings, landscaping, or other measures may be implemented to alleviate a negative impact or enhance the view. In addition, disturbed areas should be vegetated as soon as possible.

Soil Properties. Soil properties such as texture, K_{sat}, flooding, slope, water table and depth, as well as limitations related to seepage, corrosivity, or packing of soil material should be considered when designing storage structures. Refer to local soil survey information and on-site soil investigations during planning.

Nutrient Availability. Consider the effects of digestion upon nutrient availability. Land application of digester effluent, compared with fresh manure, may have a higher risk for both ground and surface water quality problems. Compounds such as nitrogen, phosphorus and other elements become more soluble due to anaerobic digestion and therefore have higher potential to move with water.

PLANS AND SPECIFICATIONS

Plans and specifications shall be prepared in accordance with the criteria of this standard and sound engineering practice, and shall describe the requirements for applying this practice to achieve its intended use.

As a minimum, the plans and specifications shall provide the following:

1. Layout and location of livestock facilities, waste collection points, waste transfer pipe, digester, biogas utilization facilities, and digester effluent storage.
2. Grading plan showing excavation, fill, and drainage, as appropriate.
3. Materials and structural details of the digester, including all premixing tanks, inlets, outlets, pipes, pumps, valves, and appurtenances as appropriate to the complete system.
4. Details of biogas collection, control, and utilization system including type of materials for pipe, valves, regulators, pressure gages, electrical power and interface as appropriate, flow meters, flare, utilization equipment, and associated appurtenances.
5. Specify insulation, heat exchanger capacity, and energy requirements as appropriate for maintaining the digester operating temperature within acceptable limits.
6. A process flow diagram with the following:
    a. Flow rates of influent, effluent, and biogas.
    b. Design total and volatile solids content of influent and effluent.
    c. Digester volume.
    d. Hydraulic and solids retention times.
    e. When applicable, heating system type and capacity, control, and monitoring.
    f. Biogas production, including methane yield.
    g. 12-month energy budget when applicable.

The following list of Construction Specifications is intended as a guide to selecting the appropriate specifications for a specific project. The list includes most but may not contain all of the specifications that are needed for a specific project:

IA-1 Site Preparation
IA-3 Structure Removal
IA-5 Pollution Control
IA-6 Seeding and Mulching for Protective Cover
IA-11 Removal of Water
IA-21 Excavation
IA-23 Earthfill
IA-24 Drainfill
IA-26 Salvaging and Spreading Topsoil
IA-27 Diversions
IA-31 Concrete
IA-32 Concrete for Nonstructural Slabs
IA-45 Plastic (PVC, PE) Pipe
IA-81 Metal Fabrication and Installation
IA-83 Timber Fabrication and Installation
IA-92 Fences
IA-95 Geotextiles

OPERATION AND MAINTENANCE

An operation and maintenance (O&M) plan shall be developed and reviewed with the owner prior to construction. The operation and maintenance plan shall be consistent with the purposes of the practice, its intended life, safety requirements, and the criteria for its design. The plan shall contain operation and maintenance requirements including but not limited to:

- Proper loading rate of the digester and total solids content of the influent.
- Accounting for the nutrient impact of all feedstock in the farm's nutrient management plan.
- Proper operating procedures for the digester.
- Estimates of biogas production, methane content, and potential energy recovery.
- Description of the planned startup procedures, normal operation, safety issues, and normal maintenance items.
- Alternative operation procedures in the event of equipment failure.
- Instructions for safe use and flaring of biogas.
- Digester and other component maintenance.
- Troubleshooting guide.
- Monitoring plan with frequency of measuring and recording digester inflow, operating temperatures, biogas yield, and/or other information as appropriate.
- Controlled temperature digesters shall be maintained at internal temperatures appropriate to the digester type and design. Mesophilic digesters shall be maintained between 35 ºC and 40 ºC (95 ºF-104 ºF) with an optimum of 37.5 ºC (100 ºF) and daily fluctuation of digester temperature limited to less than 0.55 ºC (1 ºF).
- The operating level of digesters shall be designed with appropriate freeboard and overflow or automatic shutdown devices to prevent accidental spillage of effluent or discharge into the gas collection system.

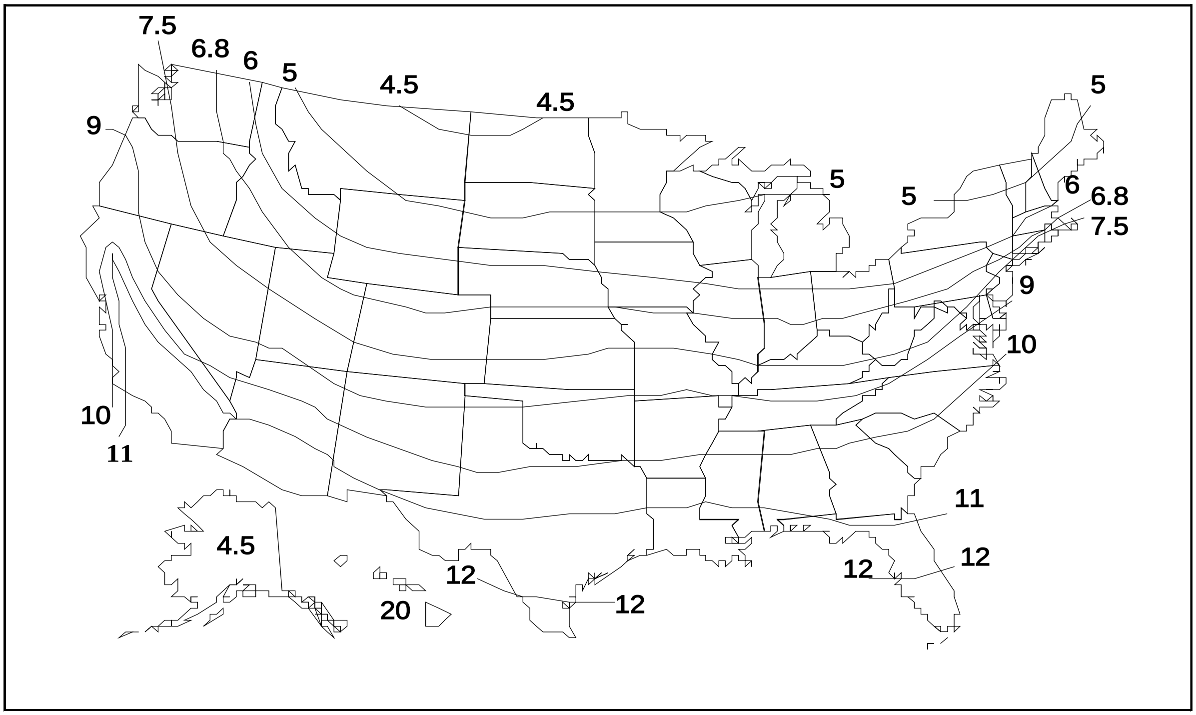


Figure 1. Covered lagoons - maximum loading rate (lb VS/1,000 ft^3/day).

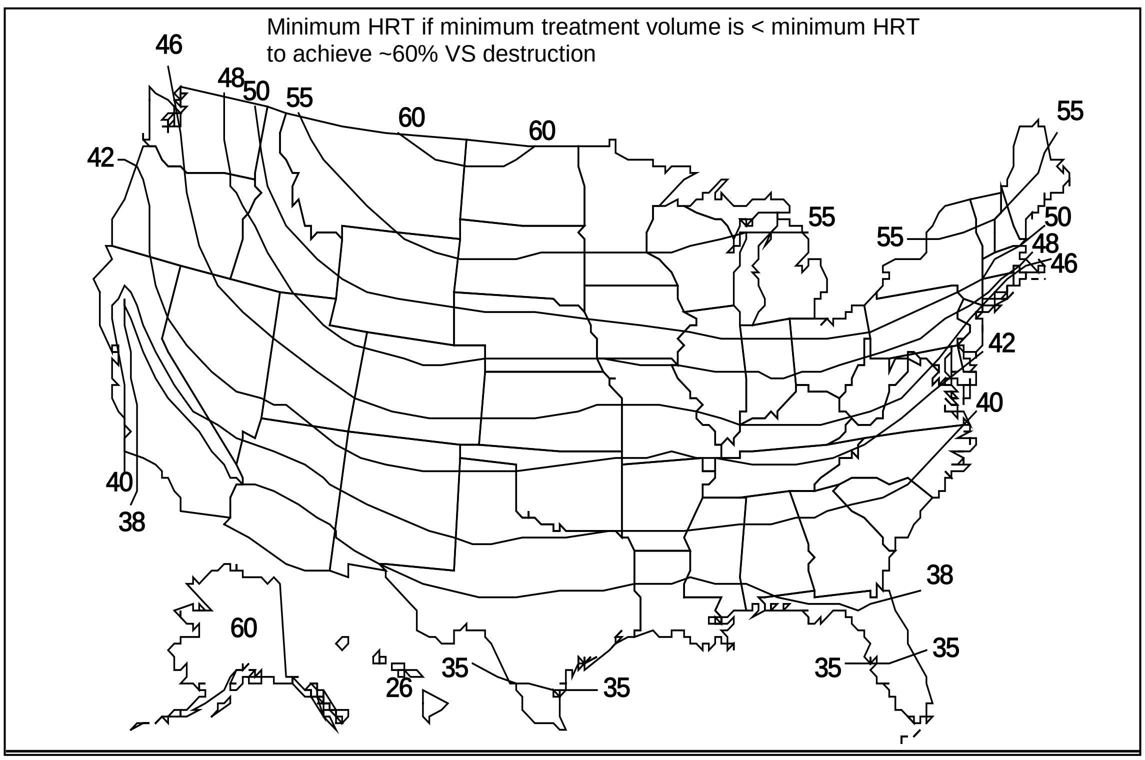


Figure 2. Covered lagoons - minimum hydraulic retention times (MINHRT) in days.

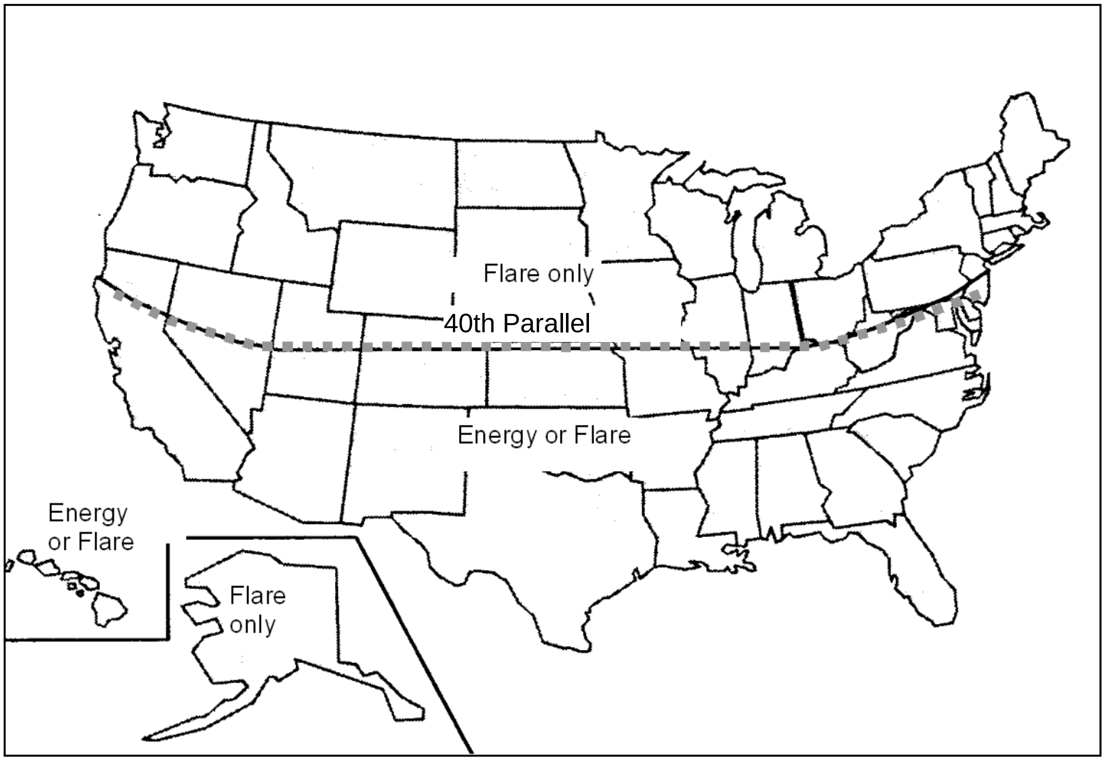


Figure 3. Covered lagoons - locations suitable for biogas to energy conversion generally fall below the 40th parallel.

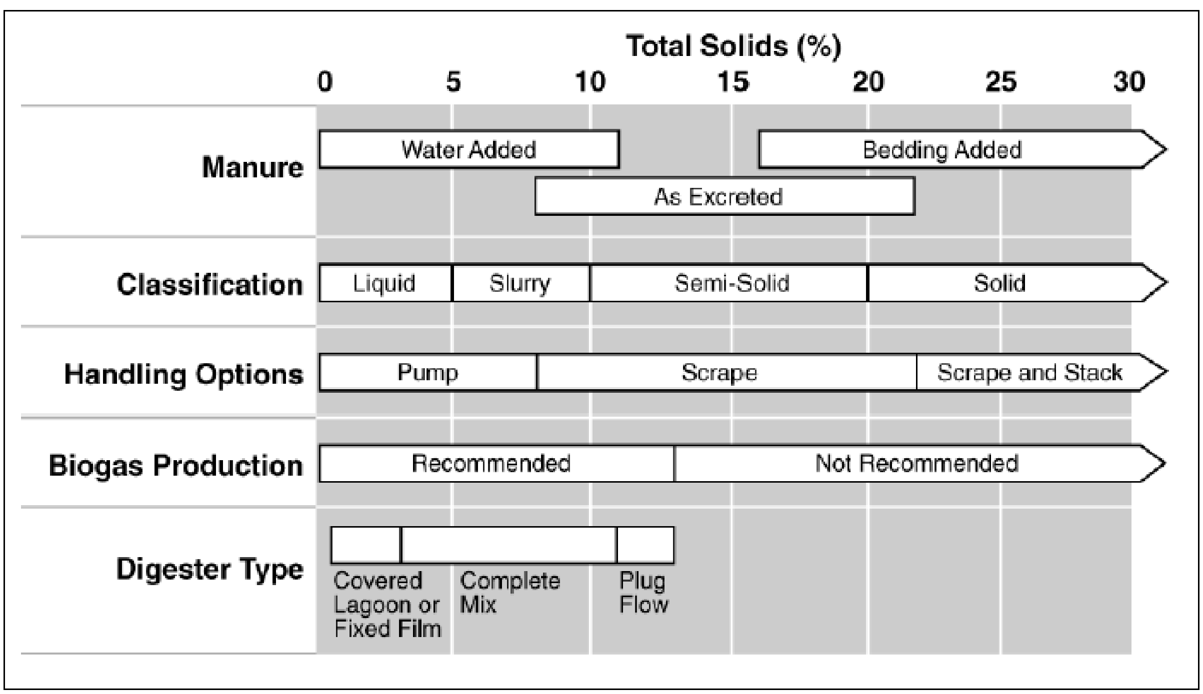


Figure 4. The type of digester selected is affected by multiple parameters and subject to specific design considerations (US EPA – AgStar).

Bioswales

. . . absorb and transport large runoff events

NRCS Natural Resources Conservation Service

2005

What are bioswales?

Bioswales are storm water runoff conveyance systems that provide an alternative to storm sewers. They can absorb low flows or carry runoff from heavy rains to storm sewer inlets or directly to surface waters. Bioswales improve water quality by infiltrating the first flush of storm water runoff and filtering the large storm flows they convey.

The majority of annual precipitation comes from frequent, small rain events. Much of the value of bioswales comes from infiltrating and filtering nearly all of this water.

Designing a bioswale

For best results, enhance and utilize existing natural drainage swales whenever possible. Existing swales can be enhanced with native plants. The thicker and heavier the grasses, the better the swale can filter out contaminants. Additionally, subgrade drains and amended soils may be needed to facilitate infiltration.

Other considerations when designing or maintaining bioswales:

- Costs vary greatly depending on size, plant material, and site considerations. Bioswales are generally less expensive when used in place of underground piping.
- Deep-rooted native plants are preferred for infiltration and reduced maintenance.
- Soil infiltration rates should be greater than one-half inch per hour.
- A parabolic or trapezoidal shape is recommended with side slopes no steeper than 3:1.
- Avoid soil compaction during installation.
- Swales should be sized to convey at least a 10-year storm (or about 4.3 inches in 24 hours).

A bioswale featuring native vegetation shows its fall colors.

Photo Courtesy Jim Patchett

NRCS Natural Resources Conservation Service

Maintaining a bioswale

Once established, bioswales require less maintenance than turf grass because they need less water and no fertilizer. Native grasses and forbs are adapted to Iowa rainfall patterns. Natives also resist local pests and disease.

A road ditch can serve as a bioswale. The rock trench and wetland vegetation are notable features, along with the natural drainageway in the background that serves as a bioswale for residential runoff.

For More Information

Find more information about low impact development and bioswales by visiting the following websites:

www.iowasudas.org
www.lid-stormwater.net
www.cwp.org
www.iowastormwater.org

Low Impact Development

Traditionally, storm water management has involved the rapid conveyance of water via storm sewers to surface waters. Low Impact Development (LID) is a different approach that retains and infiltrates rainfall on-site. The LID approach emphasizes site design and planning techniques that mimic the natural infiltration-based, groundwater-driven hydrology of our historic landscape. Bioswales are one component of LID.

Why is LID important:

to the environment?

- protects sensitive areas
- increases habitat for wildlife by preserving trees and vegetation
- protects local and regional water quality by reducing sediment and nutrient loads
- reduces streambank and channel erosion by reducing the frequent surges/bounces of higher flows from storm sewer discharges
- reduces frequent high and low flows associated with surface runoff, stabilizing stream flow volumes by restoring ground water discharges into receiving waters
- may reduce potential for flooding

to residents?

- increases community character
- improves quality of life
- more access to trails and open space
- pedestrian-friendly

to developers?

- reduces land clearing and grading costs
- reduces infrastructure costs (streets, curbs, gutters, sidewalks)
- increases community marketability

to communities?

- balances growth needs with environmental protection
- reduces infrastructure and utility maintenance costs

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

CONTOUR BUFFER STRIPS

(Ac.)

CODE 332

DEFINITION

Narrow strips of permanent, herbaceous vegetative cover established around the hill slope, and alternated down the slope with wider cropped strips that are farmed on the contour.

PURPOSE

The practice is applied to achieve one or more of the following:

- Reduce sheet and rill erosion.
- Reduce transport of sediment and other water-borne contaminants downslope
- Increase water infiltration

CONDITIONS WHERE PRACTICE APPLIES

The practice applies on all sloping cropland, including orchards, vineyards and nut crops.

Where the width of the buffer strips will be equal to or exceed the width of the adjoining crop strips, the practice Stripcropping (code 585) applies.

CRITERIA

General Criteria Applicable to All Purposes

Surface flow from contoured crop rows must be delivered to a stable outlet.

The width of the cropped strip shall be designed to accommodate some multiple of full equipment width.

No plants listed on the noxious weed list of the state will be established in a buffer strip cropping system.

Buffer strips shall not be used as travel lanes for livestock or equipment.

Buffer strips are not a part of the normal crop rotation, and shall remain in the location they were originally established until they need to be renovated or re-established.

Row Grade. Maximum row grades will be determined to ensure that runoff water will flow through the strip using the current erosion prediction technology. When the row grade of any crop strip reaches the maximum allowable design grade, a new baseline shall be established up or down slope from the last buffer strip and used for the layout of the next crop strip.

Row grades for soils included in hydrologic groups C or D or where crops to be grown are sensitive to more than 48 hours of ponded water shall be designed with grow grades no less than 0.5 percent slope. The grade along the upslope side of the vegetated buffer shall be the same as for the cropped strip directly above it.

Arrangement of Strips. A crop strip shall occupy the area at the top of the hill, unless unusually complex topography requires vegetating this area in order to establish a farmable system.

When used in combination with terraces, diversions or water and sediment control basins, the layout of the buffer strips shall be coordinated with the grade and spacing of the terraces so that the buffer strip boundaries will parallel the terraces as closely as possible. The buffer strip shall be located immediately upslope from the terrace channel or the storage area of the water and sediment control basin.

Additional Criteria to Reduce Sheet and Rill Erosion

Minimum Row Grade. The cropped strips shall have sufficient row grade to ensure that runoff water does not pond and cause unacceptable crop damage.

Maximum Row Grade. The maximum row grade shall not exceed:

- one-half of the up-and-down hill slope percent used for conservation planning,

or

- 2%,

whichever is less.

Up to 3% row grade is allowed for a maximum of 150 feet as crop rows approach a stable outlet.

When the row grade reaches the maximum allowable design grade, a new baseline shall be established up or down slope from the last contour line and used for layout of the next contour pattern.

Width of Strips. The minimum width shall be

- at least than 15 feet wide for strips planted to grasses or grass-legume mixtures with at least 50% grass and
- At least 30 feet wide when legumes are used alone or legumes make up more than 50% of the stand.

Buffer strip widths shall be increased as needed to keep the width of the cropped strips uniform.

Cropped strips shall be of uniform width between buffer strips and shall not exceed one half of the field slope length (L), used for the erosion calculation.

Vegetation. Buffer strips designed to reduce sheet and rill erosion shall be established to permanent vegetation consisting of grasses, legumes or grass-legume mixtures.

Species established shall be adapted to the site, and tolerant of the anticipated depth of sediment deposition. Use Critical Area Planting (Practice Code 342), Filter Strip (Practice Code 393), or Pasture and Hayland Planting (Practice Code 512) for acceptable seed mixtures.

The buffer strips shall have at least 95% ground cover during periods when erosion is expected to occur on the cropped strips.

The stem density for grasses and grass-legume mixtures shall be at least 50 stems per square foot, and for pure legume stands at least 30 stems per square foot.

Additional Criteria to Reduce the Transport of Sediment and Other Water-Borne Contaminants Downslope

Minimum Row Grade. The cropped strips shall have sufficient row grade to ensure that runoff water does not pond and cause unacceptable crop damage.

Maximum Row Grade. The maximum row grade within the crop strips shall not exceed

- one-half of the up-and-down-hill field slope used for conservation planning,

or

- 2%,

whichever is less.

Up to 3% row grade is allowed for a maximum of 150 feet as crop rows approach a stable outlet.

Vegetation. Buffer strips designed for the purpose shall be established to permanent sod-forming vegetation with stiff, upright stems. Use Critical Area Planting (Practice Code 342), Filter Strip (Practice Code 393), or Pasture and Hayland Planting (Practice Code 512) for acceptable seed mixtures.

Width of Strips. Buffer strips for the purpose shall be at least 15 feet wide. The buffer strip widths shall be increased as needed to keep the width of the cropped strips uniform.

The maximum width of cropped strips shall be one-half of the field slope length (L) or 150 feet, whichever is less.

Arrangement of Strips. In addition to the buffer strips established on the hillside, a buffer strip will be established at the bottom of the slope. The strip shall be two times the width of the narrowest buffer strip in the system.

Headlands or End Rows. Headlands or end rows shall be vegetated and have a minimum width of 15 feet between the end of the tilled strip and the field edge.

Additional Criteria to Increase Water Infiltration

Row Grade. The grade along the upper edge of the buffer strip shall not exceed 0.2%

CONSIDERATIONS

General. Several factors influence the effectiveness of contour buffer strips to reduce soil erosion. The factors include: 10-year, 24-hour rainfall in inches; ridge height; row grade; slope steepness; soil hydrologic group; cover and roughness; and slope length. Cover and roughness, row grade, and ridge height can be influenced by management and provide more or less benefit depending on design.

Contour buffer strips are most effective on slopes between 2 and 10 percent. This practice will be less effective in achieving the stated purpose(s) on slopes exceeding 10 percent and in areas with 10-year, 24-hour rainfall of about 6.5 inches. The practice is not well suited to rolling topography having a high degree of slope irregularity because of the difficulty meeting row grade criteria.

The practice is most effective when the slope length on the cropped strips is between 100 and 400 feet long. On slopes longer than 400 feet, the volume and velocity of overland flow exceeds the capacity of the contour ridges to contain them. Increasing residue cover and roughness will change the vegetative cover-management conditions and decrease overland flow velocities, thus increasing the slope length at which the practice is effective. Increasing roughness alone is not sufficient to produce this effect.

Contour buffer strips are more difficult to establish on undulating to rolling topography because of the difficulty of maintaining parallel strip boundaries across the hill slope or staying within row grade limits.

Areas of existing or potential concentrated flow erosion should be protected by conservation practices such as grassed waterways, water and sediment control basins, or diversion terraces.

Where contour row curvature becomes too sharp to keep equipment aligned with rows during field operations, increasing the buffer strip width can help avoid sharp ridge points. In drainage ways, establishing grassed waterways at least up to the point of sharp curvature can allow the equipment to be lifted and/or turned to meet the same rows across the turn strip.

Prior to design and layout, remove any obstructions or making changes in field boundaries or shape, where feasible, to improve the effectiveness of the practice and the ease of performing farming operations.

Prior to layout, inspect the field’s position on the landscape to find key points for starting layout or getting the width of one set of strips (one cultivated and one buffer) to pass by an obstruction or ridge saddle.

Whenever possible, run strip boundaries parallel with fence lines or other barriers.

Where row length in any one direction exceeds 500 feet, ridge height and row grades will need to be designed to ensure water flows to a stable outlet.

Wildlife Food and Cover. The following management activities may be carried out to enhance wildlife benefits as long as they do not compromise the effectiveness of the buffer strips:

- Plant herbaceous species that provide habitat enhancement for the wildlife species of concern.
- Add native forbs to the seeding mixture to increase habitat diversity.
- Mow the buffer strips every other year or every third year depending upon geographical location. The standing cover provides early and late season nesting and escape cover for many species of wildlife displaced from adjacent disturbed areas.
- Delay mowing until after the nesting period of ground-nesting species, but mow early

enough to allow for regrowth before the growing season ends.

- The maximum width between buffer strips should not exceed 300 feet.
- To enhance wildlife cover, the width of buffer strips will be increased to 30 feet or wider as determined based on the requirements for nesting and escape cover of target wildlife species.

PLANS AND SPECIFICATIONS

Specifications for installation, operation and maintenance of Contour Buffer Strips shall be prepared for each field according to the Criteria, Considerations and Operations and Maintenance described in the standard. The plans shall include, as a minimum,

- Percent land slope used for conservation planning;
- The minimum and maximum allowable row grades for the contour system;
- The designed width of the buffer strips
- The species to be established in the buffers strips
- A sketch map or photograph of the field showing:
    - ◊ the approximate location of the baselines used to establish the system;
    - ◊ the location of stable outlets for the system

This and other pertinent information shall be recorded on specification sheets, job sheets, in practice narratives in conservation plans, or other acceptable documentation.

Sheet and rill erosion reduction of the planned system shall be determined and documented using the current erosion prediction technology.

OPERATION AND MAINTENANCE

Conduct all farming operations parallel to the strip boundaries except on headlands or end rows with gradients less than the criteria set forth in this standard.

Time mowing of buffer strips to maintain appropriate vegetative density and height for optimum trapping of sediment from the upslope cropped strip during the critical erosion period(s).

Fertilize buffer strips as needed to maintain stand density.

Mow sod turn strips and waterways at least once a year.

Spot seed or totally renovate buffer strip systems damaged by herbicide application after residual action of the herbicide is complete.

Redistribute sediment that accumulates along the upslope edge of the buffer strip/crop strip interface as needed. This sediment shall be spread evenly upslope over the cultivated strip when needed to maintain uniform sheet flow along the buffer/cropped strip boundary.

If sediment accumulates just below the upslope edge of the buffer strip to a depth of 6 inches or more, or stem density falls below specified amounts in the buffer strip, relocate the buffer/cropped strip interface location.

Cultivated strips and buffer strips shall be rotated so that a mature stand of protective cover is achieved in a newly established buffer strip immediately below or above the old buffer strip before removing the old buffer to plant an erosion-prone crop. Alternate repositioning of buffer strips to maintain their relative position on the hill slope.

Renovate vegetated headlands or end row area as needed to keep ground cover above 65 percent.

REFERENCES

Foster, G.R. Revised Universal Soil Loss Equation, Version 2 (RUSLE2) Science Documentation (In Draft). USDA-ARS, Washington, DC. 2005.

Renard, K.G., G.R. Foster, G.A. Weesies, D.K. McCool, and D.C. Yoder, coordinators. 1997. Predicting soil erosion by water: A guide to conservation planning with the Revised Universal Soil Loss Equation (RUSLE).U.S. Department of Agriculture, Agriculture Handbook 703.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

COVER CROP

(Ac.)

CODE 340

DEFINITION

Grasses, legumes, and forbs planted for seasonal vegetative cover.

PURPOSE

This practice is applied to support one or more of the following purposes:

- Reduce erosion from wind and water.
- Maintain or increase soil health and organic matter content.
- Reduce water quality degradation by utilizing excessive soil nutrients.
- Suppress excessive weed pressures and break pest cycles.
- Improve soil moisture use efficiency.
- Minimize soil compaction.

CONDITIONS WHERE PRACTICE APPLIES

All lands requiring seasonal vegetative cover for natural resource protection or improvement.

CRITERIA

General Criteria Applicable to All Purposes

Select species that are compatible with other components of the cropping system.

Plant species, seeding rates, seeding dates, seeding depths will be determined using the Illinois Cover Crop Selection Tool. http://www.mccc.msu.edu/selectorINTRO.html

Customized cover crop seed mixtures may be developed by selecting individual species listed in the Illinois Cover Crop Selection Tool. The seed rates for individual species in the mixture will be calculated by multiplying the desired percent of the species by the full seeding rate recommended by the Illinois Cover Crop Selection Tool.

Cover crops may be established between successive production crops, or companion-planted or relay-planted into production crops. Select species and planting dates that will not compete with the production crop yield or harvest. Seed cover crops into soybeans when the leaves are turning yellow at approximately growth stage R7-R8. Seed cover crops into standing corn when there is at least 50% light penetration to the soil surface.

Do not burn cover crop residue.

Do not harvest cover crops for seed.

Determine the method and timing of termination to meet the grower's objective and the current NRCS Cover Crop Termination Guidelines.http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/landuse/crops/?cid=stelprdb1077238

Ensure herbicides used with crops are compatible with cover crop selections and purpose(s).

When a cover crop will be grazed or hayed ensure that crop selection(s) comply with pesticide label rotational crop restrictions and that the planned management will not compromise the selected conservation purpose(s).

If the specific rhizobium bacteria for the selected legume are not present in the soil, treat the seed with the appropriate inoculum at the time of planting.

Planting dates for wheat cover crops will observe the Hessian Fly free dates shown in the current Illinois Agronomy Handbook.

Additional Criteria to Reduce Erosion from Wind and Water

Time the cover crop establishment in conjunction with other practices to adequately protect the soil during the critical erosion period(s).

Select cover crops that will have the physical characteristics necessary to provide adequate erosion protection.

Use the current erosion prediction technology to determine the amount of surface and/or canopy cover needed from the cover crop to achieve the erosion objective.

Additional Criteria to Maintain or Increase Soil Health and Organic Matter Content

Cover crop species will be selected on the basis of producing higher volumes of organic material and root mass to maintain or increase soil organic matter.

The planned crop rotation including the cover crop and associated management activities will score a Soil Conditioning Index (SCI) value > 0, as determined using the current approved NRCS Soil Conditioning Index (SCI) procedure, with appropriate adjustments for additions to and or subtractions from plant biomass.

The cover crop shall be planted as early as possible and be terminated as late as practical for the producer's cropping system to maximize plant biomass production, considering crop insurance criteria, the time needed to prepare the field for planting the next crop, and soil moisture depletion.

Additional Criteria Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Establish cover crops as soon as practical prior to or after harvest of the production crop. (i.e. before or after harvest)

Select cover crop species for their ability to effectively utilize nutrients.

Terminate the cover crop as late as practical to maximize plant biomass production and nutrient uptake. Practical considerations for termination date may include crop insurance criteria, the amount of time needed to prepare the field for planting the next crop, weather conditions, and cover crop effects on soil moisture and nutrient availability to the following crop.

If the cover crop will be harvested for feed (hay/baleage/etc.), choose species that are suitable for the planned livestock, and capable of removing the excess nutrients present.

Additional Criteria to Suppress Excessive Weed Pressures and Break Pest Cycles

Select cover crop species for their life cycles, growth habits, and other biological, chemical and or physical characteristics to provide one or more of the following:

- To suppress weeds, or compete with weeds.
- Break pest life cycles or suppress of plant pests or pathogens.
- Provide food or habitat for natural enemies of pests.
- Release compounds such as glucosinolates that suppress soil borne pathogens or pests.

Select cover crop species that do not harbor pests or diseases of subsequent crops in the rotation.

Additional Criteria to Improve Soil Moisture Use Efficiency

In areas of limited soil moisture, terminate growth of the cover crop sufficiently early to conserve soil moisture for the subsequent crop. Cover crops established for moisture conservation shall be left on the soil surface.

In areas of potential excess soil moisture, allow the cover crop to grow as long as possible to maximize soil moisture removal.

Additional Criteria to Minimize Soil Compaction

Select cover crop species that have the ability to root deeply and the capacity to penetrate or prevent compacted layers.

CONSIDERATIONS

Plant cover crops in a timely matter and when there is adequate moisture to establish a good stand.

When applicable, ensure cover crops are managed and are compatible with the client's crop insurance criteria.

Maintain an actively growing cover crop as late as feasible to maximize plant growth, allowing time to prepare the field for the next crop, to optimize soil moisture, and prevent nitrogen immobilization.

Select cover crops that are compatible with the production system, well adapted to the region's climate and soils, and resistant to prevalent pests, weeds, and diseases. Avoid cover crop species that harbor or carry over potentially damaging diseases or insects.

Cover crops may be used to improve site conditions for establishment of perennial species.

When cover crops are used for grazing, select species that will have desired forage traits, be palatable to livestock, and not interfere with the production of the subsequent crop.

Use plant species that enhance forage opportunities for pollinators by using diverse legumes and other forbs.

Cover crops may be selected to provide food or habitat for natural enemies of production crop pests.

Cover crops residues should be left on the soil surface to maximize allelopathic (chemical) and mulching (physical) effects.

Seed a higher density cover crop stand to promote rapid canopy closure and greater weed suppression. Increased seeding rates (1.5 to 2 times normal) can improve weed-competitiveness.

Cover crops may be selected that release biofumigation compounds that inhibit soil-borne plant pests and pathogens.

Species can be selected to serve as trap crops to divert pests from production crops.

Select a mixture of two or more cover crop species from different plant families to achieve one or more of the following: (1) species mix with different maturity dates, (2) attract beneficial insects, (3) attract pollinators, (4) increase soil biological diversity, (5) serve as a trap crop for insect pests, or (6) provide food and cover for wildlife habitat management.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to achieve biological nitrogen fixation. Select cover crop species or mixture, and timing and method of termination that will maximize efficiency of nitrogen utilization by the following crop, considering soil type and conditions, season and weather conditions, cropping system, C:N ratio of the cover crop at termination, and anticipated nitrogen needs of the subsequent crop. Use LGU- recommended nitrogen credits where available from the legume and reduce nitrogen applications to the subsequent crop accordingly. "If the specific rhizobium bacteria for the selected legume are not present in the soil, treat the seed with the appropriate inoculum at the time of planting.

Time the termination of cover crops to meet nutrient release goals. Termination at early vegetative stages may cause a more rapid release compared to termination at a more mature stage.

Both residue decomposition rates and soil fertility can affect nutrient availability following termination of cover crops

Allelopathic effects to the subsequent crop should be evaluated when selecting the appropriate cover crop.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

Additional Considerations to Reduce Erosion by Wind or Water

To reduce erosion, best results are achieved when the combined canopy and surface residue cover attains 90 percent or greater during the period of potentially erosive wind or rainfall.

Additional Considerations to Reduce Water Quality Degradation by Utilizing Excessive Soil Nutrients

Use deep-rooted species to maximize nutrient recovery.

When appropriate for the crop production system, mowing certain grass cover crops (e.g., sorghum-sudangrass, pearl millet) prior to heading and allowing the cover crop to regrow can enhance rooting depth and density, thereby increasing their subsoiling and nutrient-recycling efficacy.

Additional Considerations to Increase Soil Health and Organic Matter Content

Increase the diversity of cover crops (e.g., mixtures of several plant species) to promote a wider diversity of soil organisms, and thereby promote increased soil organic matter.

Plant legumes or mixtures of legumes with grasses, crucifers, and/or other forbs to provide nitrogen through biological nitrogen fixation.

Legumes add the most plant-available N if terminated when about 30% of the crop is in bloom.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for each field or treatment unit according to the planning criteria and operation and maintenance requirements of this standard. Specifications shall describe the requirements to apply the practice to achieve the intended purpose for the practice site. Plans for the establishment of cover crops shall, as a minimum, include the following specification components using the Illinois Cover Crop, Job Sheet 340 or printouts from the Illinois Cover Crop Selector Tool.

Requirements document:

- Field number and acres
- Species of plant(s) to be established.
- Seeding rates.
- Seeding dates.
- Establishment procedure.
- Rates, timing, and forms of nutrient application (if needed).
- Dates and method to terminate the cover crop.
- Other information pertinent to establishing and managing the cover crop e.g., if haying or grazing is planned specify the planned management for haying or grazing.

OPERATION AND MAINTENANCE

Evaluate the cover crop to determine if the cover crop is meeting the planned purpose(s). If the cover crop is not meeting the purpose(s) adjust the management, change the species of cover crop, or choose a different technology.

REFERENCES

A. Clark (ed.). 2007. Managing cover crops profitably. 3rd ed. Sustainable Agriculture Network Handbook Series; bk 9.

Hargrove, W.L., ed. Cover crops for clean water. SWCS, 1991.

Magdoff, F. and H. van Es. Cover Crops. 2000. p. 87-96 *In* Building soils for better crops. 2nd ed. Sustainable Agriculture Network Handbook Series; bk 4. National Agriculture Library. Beltsville, MD.

Reeves, D.W. 1994. Cover crops and erosion. p. 125-172 *In* J.L. Hatfield and B.A. Stewart (eds.) Crops Residue Management. CRC Press, Boca Raton, FL.

NRCS Cover Crop Termination Guidelines: http://www.nrcs.usda.gov/wps/portal/nrcs/detail/national/climatechange/?cid=stelprdb1077238

Revised Universal Soil Loss Equation Version 2 (RUSLE2) website: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/rusle2/

Wind Erosion Prediction System (WEPS) website: http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/tools/weps/

USDA, Natural Resources Conservation Service, National Agronomy Manual, 4th Edition, Feb. 2011.
Website: http://directives.sc.egov.usda.gov/
Under Manuals and Title 190.

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

DENITRIFYING BIOREACTOR

Code 605

(Ea.)

DEFINITION

A structure that uses a carbon source to reduce the concentration of nitrate nitrogen in subsurface agricultural drainage flow via enhanced denitrification.

PURPOSE

This practice is applied to achieve the following purpose:

- Improve water quality by reducing the nitrate nitrogen content of subsurface agricultural drainage flow.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to sites where there is a need to reduce nitrate nitrogen concentration in subsurface drainage flow.

This practice does not apply to underground outlets from practices, such as terraces, where the drainage source is primarily from surface inlets.

CRITERIA

General Criteria Applicable to All Purposes

Notify landowner and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

Performance and Capacity. Design the capacity of the bioreactor based on one of the following:

- Treat peak flow from a 10-year, 24-hour drain flow event.
- Treat at least 15 percent of the peak flow from the drainage system.
- Treat at least 60 percent of the long-term average annual flow from the drainage system using locally proven criteria (e.g., drainage coefficient).

Disregard flow from surface inlets when calculating design subsurface drain flow for capacity purposes.

Design the bioreactor hydraulic retention time for a minimum of 3 hours at the peak flow capacity. Account for the porosity of the media and use the average depth of flow through the media. The effective volume of the reactor is calculated as:

$V = L \times W \times (d_{in} - d_{out})/2 \times P$

Where:

V = effective volume of media (ft^3)
L and W are the length and width of media chamber (ft)
d_{in} and d_{out} are the depth of the inlet water and outlet water (ft)
P is the porosity of the material (decimal percentage)

Design the bioreactor to achieve at least a 30-percent annual reduction in the nitrate nitrogen load of the water flowing through the bioreactor.

If reducing conditions may result in the production of methyl mercury, make additional provisions to ensure that stagnant conditions do not develop in the media chamber.

Media Chamber. Use a medium for the carbon source that is reasonably free from dirt, fines, and other contaminants. Distribute the media within the bioreactor to achieve a uniform flow path.

Use geotextile or plastic lining for the bottom, sides, and top of the bioreactor as needed to prevent migration of soil particles into the bioreactor and minimize bypass of treatment flow by leaching from the media chamber.

Design the bioreactor media for an expected life of at least 10 years. To create a longer lifespan, provide provisions for periodic renewal of the media.

Design the media chamber to prevent development of preferential flow pattern. For a media chamber with a length to width ratio of 4:1 or greater, use a perforated distribution pipe at the chamber inlet and a perforated collection pipe at the chamber outlet. For wider chambers, design a multiple-header distribution system so that the width served by each header is no greater than 25 percent of the chamber length.

Specify the carbon media that goes in the chamber. If wood chips are the media, specifically note that no high tannin content wood such as oak, cedar or redwood are to be used. Do not use any wood that has been treated for ground contact.

Water Control Structures. Design the bioreactor inlet and outlet water control structures to provide the required capacity and hydraulic retention time. Use the criteria in Conservation Practice Standard (CPS) Code 587, Structure for Water Control, for the design.

Select or design water control structures that control the upstream water elevation and provide safe bypass of flows in excess of the design capacity.

Select a design water surface elevation at the upstream water control structure that will prevent upslope crop damage from an elevated water table. If necessary to prevent crop damage, the bioreactor operation may include a period of time during the crop year in which the full performance and capacity of the design are not realized.

Provide a low elevation orifice or opening of some type on the outlet structure to assure the media chamber drains in a maximum of 48 hours during periods of no-drain flow.

Provide an outlet that will completely drain the media chamber to facilitate bioreactor management and maintenance.

Protection. Protect the bioreactor from intermittent surface storm flows that could result in flushing out of the established biofilm.

Construct the ground surface above the bioreactor to shed water and to allow for settlement. Dispose of excess soil excavated during the installation of the bioreactor by blending with the adjacent landscape or hauling away.

To prevent compaction of the bioreactor media, identify the bioreactor location with appropriate signage or fence the site to avoid equipment travel over the bioreactor. If there will be equipment traffic for mowing or other purposes, provide adequate cover to prevent damage to the bioreactor.

During release of tile drainage water from the water control structures, flow velocity in the tile lines must not exceed the maximum velocity prescribed by CPS Code 606, Subsurface Drain.

Protect all disturbed noncrop construction areas by seeding or mulching within 14 days of construction. See CPS Code 342, Critical Area Planting, for criteria on seed selection, seedbed preparation, fertilizing, and seeding. For installation of the denitrifying bioreactor in an existing filter strip or other conservation practice, revegetate disturbed areas according to the seeding requirements of the conservation practice disturbed by construction.

CONSIDERATIONS

Other practices and management systems can achieve a reduction of nitrate nitrogen levels separately or in conjunction with the denitrifying bioreactor. Examples include CPS Codes 590, Nutrient Management; 340, Cover Crop; and 554, Drainage Water Management.

Determining the normal nitrate levels expected in the tile discharge water prior to design work will aid in establishing design parameters.

Add inoculants to improve the function of the bioreactor.

Mix inert materials such as gravel with the required amount of reactive carbon source to provide the required bioreactor volume, porosity, and flow rate.

Situating the bioreactor on a low bench will minimize interference with the drainage needs of the area served during the growing season.

Exclude surface water from the bioreactor as much as possible by selecting a location away from areas that will pond surface water during storm events.

When designing the bioreactor using methods based on a percentage of the peak flow from the drainage system, target no more than 20 percent of peak flow for best performance.

Be aware of the effects on downstream flows or aquifers that would affect other water uses or users. For example, the initial flow from the bioreactor at start up may contain undesired contaminants.

If site topography is such that planned elevated water table upstream of the bioreactor might negatively affect crop performance, manage water levels at the upstream end of the bioreactor according to criteria in CPS Code 554, Drainage Water Management.

Maintain the design water elevations throughout the year if an elevated water table upstream of the bioreactor will not negatively affect crops.

PLANS AND SPECIFICATIONS

Develop plans and specifications for the denitrifying bioreactor that describe the requirements for applying the practice to achieve its intended purpose.

As a minimum, the plans and specifications must include:

- A plan view of the layout of the denitrifying bioreactor and associated components
- Typical cross section(s) of the bioreactor
- Profile(s) of the bioreactor including inlet(s) and outlet(s)
- Details of required structures for water level control
- Material specifications for the bioreactor media
- Seeding requirements, if needed
- Construction specifications describing site-specific installation requirements of the bioreactor and associated components.

OPERATION AND MAINTENANCE

Provide an operation and management (O&M) plan and review this with the land manager. Specified actions should include normal repetitive activities in the application and use of the practice, along with repair and upkeep of the practice. The plan must be site specific and include, but not be limited to, a description of the following:

- Planned water level management and timing.
- Inspection and maintenance requirements of the bioreactor and contributing drainage system, especially upstream surface inlets.
- Requirements for monitoring the status of the bioreactor media and replacement/replenishment of media, as needed.
- Monitoring and reporting criteria that demonstrate system performance
- Monitoring information to improve the design and management of this practice, as needed.

REFERENCES

Christianson, L. E., A. Bhandari, M.H. Helmers, and M. St. Clair. 2009. Denitrifying Bioreactors for Treatment of Tile Drainage. In: Proceedings of World Environmental and Water Resources Congress, May 17-21, 2009.

Christianson, L., A. Bhandari, and M. Helmers. 2011. Potential design methodology for agricultural drainage denitrification bioreactors. In: Proc. 2011 EWRI Congress. Reston, Va.: ASCE Environmental and Water Resources Institute.

Christianson, L., M. Helmers, A. Bhandari, K. Kult, T. Sutphin, and R. Wolf. 2012. Performance evaluation of four field-scale agricultural drainage denitrification bioreactors in Iowa. Trans. ASABE. 55(6):2163-2174.

Cooke, R.A. and N.L. Bell. 2012. Protocol and Interactive Routine for the Design of Subsurface Bioreactors. Submitted to: Applied Engineering in Agriculture, August, 2012.

Woli, K.P., David, M.B., Cooke, R.A., McIsaac, G.F., and Mitchell, C.A. 2010. Nitrogen balance in and export from agricultural fields associated with controlled drainage systems and denitrifying bioreactors. Eco. Eng., 36: 1558-1566.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

GRADE STABILIZATION STRUCTURE

(No.)
CODE 410

DEFINITION

A structure used to control the grade and head cutting in natural or artificial channels.

SCOPE

This standard applies to all types of grade stabilization structures, including a combination of earth embankments and mechanical spillways and full-flow or detention-type structures. This standard also applies to channel side-inlet structures installed to lower the water from a field elevation, a surface drain, or a waterway to a deeper outlet channel. It does not apply to structures designed to control the rate of flow or to regulate the water level in channels (587).

PURPOSE

To stabilize the grade and control erosion in natural or artificial channels, to prevent the formation or advance of gullies, and to enhance environmental quality and reduce pollution hazards.

CONDITIONS WHERE PRACTICE APPLIES

In areas where the concentration and flow velocity of water require structures to stabilize the grade in channels or to control gully erosion. Special attention shall be given to maintaining or improving habitat for fish and wildlife where applicable.

DESIGN CRITERIA

The structure must be designed for stability after installation. The crest of the inlet must be set at an elevation that stabilize upstream head cutting.

Embankment dams. Class (a) dams that have a product of storage times the effective height of the dam of 3,000 or more, those more than 35 ft in effective height, and all class (b) and class (c) dams shall meet or exceed the requirements specified in Technical Release No. 60 (TR-60).

Class (a) dams that have a product of storage times the effective height of the dam of less than 3,000 and an effective height of 35 ft or less shall meet or exceed the requirements specified for ponds (378).

The effective height of the dam is the difference in elevation, in feet, between the emergency spillway crest and the lowest point in the cross section along the centerline of the dam. If there is no emergency spillway, the top of the dam is the upper limit.

Pond size dams. If mechanical spillways are required, the minimum capacity of the principal spillway shall be that required to pass the peak flow expected from a 24-hour duration design storm of the frequency shown in table 1, less any reduction because of detention storage.

Table 1. - Design criteria for establishing minimum capacity of the principal spillway for dams with storage capacity of less than 50 acre-feet.

Maximum drainage area for indicated rainfall*			Effective height of dam	Frequency of minimum design, 24-hour duration storm
0-3 in.	3 - 5 in.	5+ in.		
----------------*acres*------------------			*ft*	*yr*
200	100	50	35 or less	2
400	200	100	20 or less	2
400	200	100	20 - 35	5
600	400	200	20 or less	5

* In a 5-year frequency, 24-hour duration storm

If the effective height of the dam is less than 20 ft and the emergency spillway has a stable grade throughout its length with no overfalls and has good vegetation along its reentry into the downstream channel, the principal spillway capacity may be reduced but can be no less than 80 percent of the 2-year frequency, 24-hour duration storm.

If criteria values exceed those shown in table 1 or the storage capacity is more than 50 acre-ft, the 10-year frequency, 24-hour duration storm must be used as the minimum design storm.

Grade stabilization structures with a settled fill height of less than 15 ft and 10-year frequency, 24-hour storm runoff less than 10 acre-ft, shall be designed to control the 10-year frequency storm without overtopping. The mechanical spillway, regardless of size, may be considered in design and an emergency spillway is not required if the combination of storage and mechanical spillway discharge will handle the design storm. The embankment can be designed to meet the requirements for water and sediment control basins (638) rather than the requirements for ponds (378).

Full-flow open structures. Drop, chute, and box inlet drop spillways shall be designed according to the principles set forth in the Engineering Field Manual for Conservation Practices, the National Engineering Handbook, and other applicable SCS publications and reports. The minimum capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 2, less any reduction because of detention storage. If site conditions exceed those shown in table 2, the minimum design 24-hour storm frequency is 25 years for the principal spillway and 100 years for the total capacity. Structures must not create unstable conditions upstream or downstream. Provisions must be made to insure reentry of bypassed storm flows.

Toe wall drop structures can be used if the vertical drop is 4 ft or less, flows are intermittent, downstream grades are stable, and tail water depth at design flow is equal to or greater than one-third of the height of the overfall.

The ratio of the capacity of drop boxes to road culverts shall be as required by the responsible road authority or as specified in table 2 or 3, as applicable, less any reduction because of detention storage, whichever is greater. The drop box capacity (attached to a new or existing culvert) must equal or exceed the culvert capacity at design flow.

Table 2. - Design criteria for establishing minimum capacity of full-flow open structures.

Maximum drainage area for indicated rainfall*			Vertical drop	Frequency of minimum design, 24-hour duration storm	
0 - 3 in.	3 - 5 in.	5+ in.		Principal spillway capacity	Total capacity
	acres		*ft*	*yr*	*yr*
1,200	450	250	5 or less	5	10
2,200	900	500	10 or less	10	25

*In a 5-year frequency, 24-hour duration storm.

Table 3. - Design criteria for establishing minimum capacity of side-inlet, open weir, or pipe-drop-drainage structure.

Maximum drainage area for indicated rainfall*			Vertical drop	Frequency of minimum design, 24-hour duration storm	
0 - 3 in.	3 - 5 in.	5+ in.		Receiving channel depth	Total capacity
	acres		*ft*	*ft*	*yr*
1,200	450	250	0 - 5	0 - 10	--
1,200	450	250	5 - 10	10 - 20	10
2,200	900	500	0 - 10	0 - 20	25

*In a 5-year frequency, 24-hour duration storm.

Island-type structures. If the mechanical spillway is designed as an island-type structure, its minimum capacity shall equal the capacity of the downstream channel. For channels with very small drainage areas, the mechanical spillway should carry at least the 2-year, 24-hour storm or the design drainage curve runoff. The minimum emergency spillway capacity shall be that required to pass the peak flow expected from a design storm of the frequency and duration shown in table 2 for total capacity without overtopping the headwall extensions of the mechanical spillway. Provision must be made for safe reentry of bypassed flow as necessary.

Side-inlet drainage structures. The design criteria for minimum capacity of open-weir or pipe structures used to lower surface water from field elevations or lateral channels into deeper open channels are shown in table 3. The minimum principal spillway capacity shall equal the design drainage curve runoff for all conditions. If site condition values exceed those shown in table 3, the 50-year frequency storm shall be used for minimum design of total capacity.

Landscape resources. In highly visible public areas and those associated with recreation, careful considerations should be given to landscape resources. Landforms, structural materials, water elements, and plant materials should visually and functionally complement their surroundings. Excavated material and cut slopes should be shaped to blend with the natural topography. Shorelines can be shaped and islands created to add visual interest and valuable wildlife habitat. Exposed concrete surfaces may be formed to add texture or finished to reduce reflection and to alter color contrast. Site selection can be used to reduce adverse impacts or create desirable focal points.

General criteria. Earth embankment and emergency spillways of structures for which criteria are not provided under the standard for ponds (378) or in TR-60 must be stable for all anticipated conditions. If earth spillways are used, they must be designed to handle the total capacity flow indicated in tables 2 or 3 without overtopping the dam. The foundation preparation, compaction, top width, and side slopes must ensure a stable dam for anticipated flow conditions. Discharge from the structure shall be sufficient that no crop damage results from flow detention.

Necessary sediment storage capacity must equal the expected life of the structure, unless a provision is made for periodic cleanout.

The earth embankment pond structures are potentially hazardous and precautions must be taken to prevent serious injury or loss of life. Protective guardrails, warning signs, fences, or lifesaving equipment shall be added as needed.

If the area is used for livestock, the structures, earthfill, vegetated spillways, and other areas should be fenced as necessary to protect the structure. Near urban areas, fencing may be necessary to control access and exclude traffic that may damage the structure or to prevent serious injury or death to trespassers.

Protection. The exposed surfaces of the embankment, earth spillway, borrow area, and other areas disturbed during construction shall be seeded or sodded as necessary to prevent erosion. If climatic conditions preclude the use of vegetation, nonvegetative coverings such as gravel or other mulches may be used.

PLANS AND SPECIFICATIONS

Plans and specifications for installing grade stabilization structures shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose.

PLANNING CONSIDERATIONS FOR WATER QUANTITY AND QUALITY

Quantity

1. Effects on volumes and rates of runoff, evaporation, deep percolation and ground water recharge.

2. Effects of the structure on soil water and resulting changes in plant growth and transpiration.

Quality

1. Ability of structure to trap sediment and sediment-attached substances carried by runoff.

2. Effect of structure on the susceptibility of downstream stream banks and stream beds to erosion.

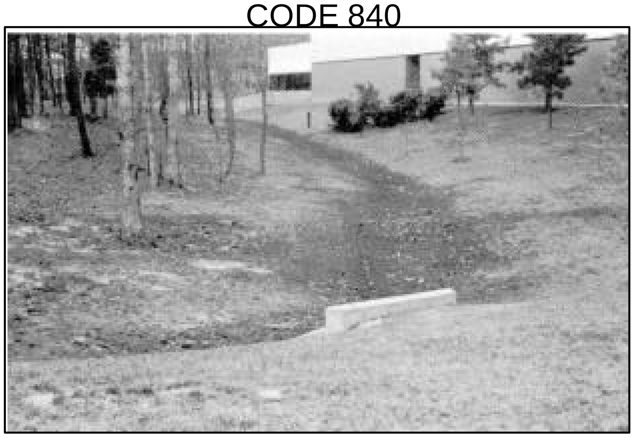
3. Effects of the proposed structure on the movement of dissolved substances to ground water.

4. Effects on visual quality of downstream water resources.

NATURAL RESOURCES CONSERVATION SERVICE
ILLINOIS URBAN MANUAL
PRACTICE STANDARD

GRASS-LINED CHANNEL

(acre)
CODE 840



(Source: NC Erosion and Sediment Control Field Manual)

DEFINITION

A natural or constructed channel that is shaped or graded to required dimensions and established with suitable vegetation for stable conveyance of runoff.

PURPOSE

The purpose of this practice is to convey and dispose of concentrated surface runoff without damage from erosion, deposition, or flooding.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to construction sites and developing areas where:

1. Concentrated runoff will cause damage from erosion or flooding;
2. Sufficient depth of soil materials are present to allow establishment of vegetation that will stabilize the cross section and grade of the channel;
3. Slopes are generally less than 5%;
4. Space is available for a relatively large cross section.

Typical uses include roadside ditches, channels at property boundaries, outlets for diversions, and other channels and drainage of low areas.

CRITERIA

Capacity - As a minimum, grass-lined channels shall carry the peak runoff from the 10-year frequency, 24-hour duration storm. Where flood hazard exists, increase the capacity according to the potential damage. For grass-lined channels with a grade of less than 1 percent, out-of-bank flow may be permitted if such flow will not cause erosion, property or flooding damage. The minimum channel capacity in such cases shall be a 2-year frequency storm. Channel dimensions may be determined by using design tables with appropriate retarding factors or by Manning's formula using an appropriate "n" value. When retarding factors are used, the capacity may be based on "C" retardance and stability on "E" retardance, where the waterway will be regularly mowed and otherwise maintained.

Velocity - The maximum permissible velocities of flow shall not exceed the values shown in Table 1.

Cross section - The channel shape may be parabolic, trapezoidal, or V-shaped, depending on the need and site conditions. The design water surface elevation of a grass-lined channel receiving water from diversions or other tributary channels shall be equal to or less than the design water surface elevation in the diversion or other tributary channels. The parabolic shape is the preferred cross section. The triangular cross-section concentrates flow in the "v" of the channel causing higher and more erosive velocities. When vegetated triangular channels are used, the minimum side slopes should be 6:1 or flatter.

Drainage - Base flow shall be handled by a stone lined center, subsurface drain, or other suitable means since sustained wetness usually prevents adequate vegetative cover. The cross-sectional area of the stone lined center or subsurface drain size to be provided shall accommodate a flow rate of 0.1 cfs/acre or by actual maximum base flow.

Where tile is used along the channel, it should be located as close to 1/3 of the channel (top) width from the center of the waterway as practical. The top of the tile should be at least 2.0 feet (up to 4 feet, where possible) below the bottom of the channel, except where soil or outlet conditions make this depth unpractical. The tile shall meet the requirements shown in the practice standard SUBSURFACE DRAIN 945.

Alignment - Minor changes may be made to improve alignment. Care must be taken to avoid exposing soil materials (such as sodium soils or high clay content glacial till subsoil) that are not conducive to the establishment and maintenance of adequate vegetative cover.

Outlets - All grass-lined channels shall have a stable outlet with adequate capacity to prevent ponding or flooding damages. Appropriate measures must be taken to dissipate the energy of the flow to prevent scouring of the outlet channel. Examples of acceptable outlets include but are not limited to GRASS-LINED CHANNELS 840, IMPOUNDMENT STRUCTURE - FULL FLOW 841, IMPOUNDMENT STRUCTURE - ROUTED 842, INFILTRATION TRENCH 847, LEVEL SPREADER 870, and ROCK OUTLET PROTECTION 910.

Establishment of vegetation - Grass-lined channels shall be vegetated according to the practice standard PERMANENT VEGETATION 880.

Side slopes - Side slopes shall not be steeper than a ratio of 2 horizontal to 1 vertical. They should be designed to accommodate the equipment used for maintenance. Where planned to be crossed by large equipment, trapezoidal channels shall have side slopes of 8:1 or flatter and be protected according to the practice standard STABILIZED CONSTRUCTION ENTRANCE 930. When triangular (V-shaped) channels are used, the minimum side slopes should be 6:1 or flatter.

Sedimentation protection - Protect permanent grass-lined channels from sediment produced in the watershed, especially during the construction period. This can be accomplished by the effective use of diversions, sediment traps, protected side inlets and vegetative filter strips along the channel.

Construction - The grass-lined channel will be constructed meeting the requirements of Construction Specification 27 - DIVERSIONS AND WATERWAYS.

CONSIDERATIONS

Generally, channels should be located to conform with and use the natural drainage system. Channels may also be needed along development boundaries, roadways, and back lot lines. In all situations channels should be located so that they do not make sharp, unnatural changes in direction or grade of flow. Avoid channels crossing watershed boundaries or ridges.

Major reconfiguration of the drainage system often entails increased maintenance and risk of failure.

Establishment of a dense, erosion resistant vegetation is essential. Construct and vegetate grass-lined channels early in the construction schedule before grading and paving increase the rate of runoff.

All grass-lined channels should be designed to permit easy crossing of equipment during construction and maintenance.

If local ordinances permit, storm sewers may be used to extend existing agricultural tile or base flow across a development. They may also be used as an under drain for the channel if the conduit is open jointed.

Geotextile fabrics or special mulch protection such as fiberglass roving or straw and netting provide stability until the vegetation is fully established. It may also be necessary to divert water from the channel until vegetation is established or to line the channel with sod. Rock checks or filter fabric checks may also be needed to protect the channel before vegetation is established. Sediment traps may be needed at channel inlets and outlets.

Applicable state drainage laws, traditional case law precedent and local ordinances and regulations must be observed in locating grass-lined channels.

PLANS AND SPECIFICATIONS

Plans and specifications for installing grass-lined channels shall be in keeping with this standard and shall describe the requirements for applying the practice to achieve its intended purpose. At a minimum include the following items:

1. Channel location and alignment.
2. Grade, depth and width.
3. Channel cross section type.
4. Seeding specifications and dates.
5. Subsurface drainage, if needed.

All plans shall include the installation, inspection, and maintenance schedules with the responsible party identified.

The grass-lined channel will be constructed meeting the requirements of Construction Specification 27 DIVERSIONS AND WATERWAYS. Standard drawings WATERWAY PLAN IL-540 P, T, or V may be used as the plan sheet.

OPERATION AND MAINTENANCE

During the establishment period, inspect grass-lined channels after every rainfall.

After grass is established, check the channel at regular intervals and after every heavy rainfall event. Immediately make repairs. It is particularly important to check the channel outlet and all road crossings for bank stability and evidence of piping or scour holes. Remove all significant sediment accumulations to maintain the designed carrying capacity. Keep the grass in a healthy, vigorous condition at all times, since it is the primary erosion protection for the channel.

NRCS IL   October 2001

urbst840.doc

TABLE 1

PERMISSIBLE VELOCITIES FOR CHANNELS LINED WITH VEGETATION

Channel Slope (%)	Lining	Permissible Velocity (ft./sec.) [1/]
0 – 5	Tall fescue Kentucky bluegrass Smooth bromegrass	5
	Grass-legume mixture	4
	Red fescue Redtop	3
	Small grains [2/]	2.5
5 – 10	Tall fescue	5
	Kentucky bluegrass Smooth bromegrass	4
	Grass-legume mixture	3
Greater than 10	Tall fescue Kentucky bluegrass Smooth bromegrass	3

[1/] For highly erodible soils, permissible velocities should be decreased 25%. An erodibility factor (K) greater than 0.35 would indicate a highly erodible soil. Erodibility factors (K-factors) for Illinois soils are available in every NRCS office.

[2/] For temporary seedings.

BMP 6.4.4: Infiltration Trench

An Infiltration Trench is a "leaky" pipe in a stone filled trench with a level bottom. An Infiltration Trench may be used as part of a larger storm sewer system, such as a relatively flat section of storm sewer, or it may serve as a portion of a stormwater system for a small area, such as a portion of a roof or a single catch basin. In all cases, an Infiltration Trench should be designed with a positive overflow.

Key Design Elements

- Continuously perforated pipe set at a minimum slope in a stone filled, level-bottomed trench
- Limited in width (3 to 8 feet) and depth of stone (6 feet max. recommended)
- Trench is wrapped in nonwoven geotextile (top, sides, and bottom)
- Placed on uncompacted soils
- Minimum cover over pipe is as per manufacturer.
- A minimum of 6" of topsoil is placed over trench and vegetated
- Positive Overflow always provided

  Deed restrictions recommended

  Not for use in hot spot areas without pretreatment

Potential Applications

Residential: Yes
Commercial: Yes
Ultra Urban: Yes
Industrial: Yes
Retrofit: Yes
Highway/Road: Yes

Stormwater Functions

Volume Reduction: Medium
Recharge: High
Peak Rate Control: Medium
Water Quality: High

Water Quality Functions

TSS: 85%
TP: 85%
NO3: 30%

Other Considerations

- **Protocol 1. Site Evaluation and Soil Infiltration Testing** and **Protocol 2. Infiltration Systems Guidelines** should be followed, see Appendix C

Description

An Infiltration Trench is a linear stormwater BMP consisting of a continuously perforated pipe at a minimum slope in a stone-filled trench (Figure 6.4-1). Usually an Infiltration Trench is part of a **conveyance system** and is designed so that large storm events are conveyed through the pipe with some runoff volume reduction. During small storm events, volume reduction may be significant and there may be little or no discharge. All Infiltration Trenches are designed with a **positive overflow** (Figure 6.4-2).

An Infiltration Trench differs from an Infiltration Bed in that it may be constructed without heavy equipment entering the trench. It is also intended to convey some portion of runoff in many storm events.

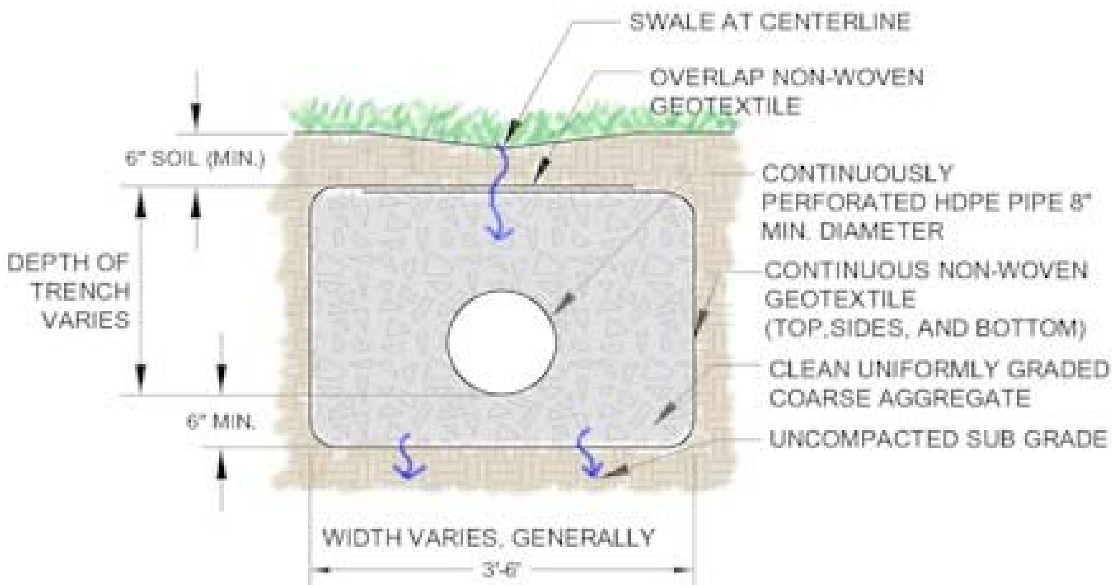


Figure 6.4-1

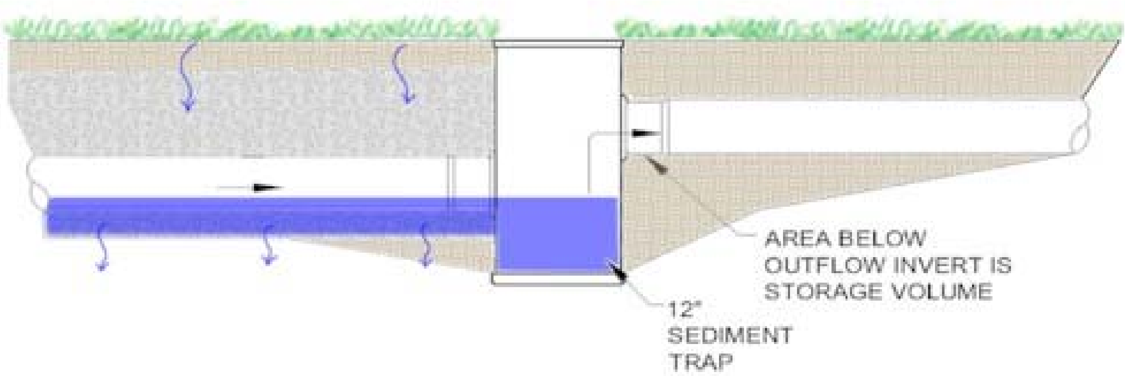


Figure 6.4-2

All Infiltration Trenches should be designed in accordance with Appendix C. Although the width and depth can vary, it is recommended that Infiltration Trenches be limited in depth to not more than six (6) feet of stone. This is due to both construction issues and Loading Rate issues (as described in the Guidelines for Infiltration Systems). The designer should consider the appropriate depth.

Variations

Infiltration Trenches generally have a vegetated (grassed) or gravel surface. Infiltration Trenches also may be located alongside or adjacent to roadways or impervious paved areas with proper design. The subsurface drainage direction should be to the downhill side (away from subbase of pavement), or located lower than the impervious subbase layer. Proper measures should be taken to prevent water infiltrating into the subbase of impervious pavement.

Infiltration Trenches may also be located down a mild slope by “stepping” the sections between control structures as shown in Figure 6.4-3. A level or nearly level bottom is recommended for even distribution.

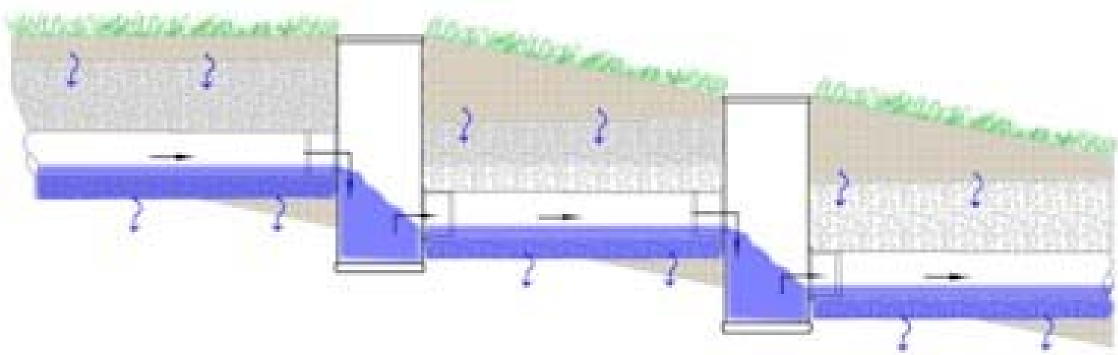
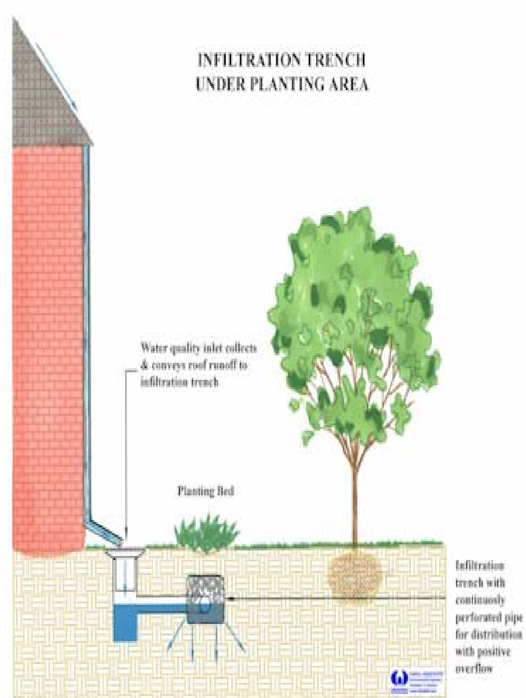


Figure 6.4-3

Applications

- **Connection of Roof Leaders**

Roof leaders may be connected to Infiltration Trenches. Roof runoff generally has lower sediment levels and often is ideally suited for discharge through an Infiltration Trench. A cleanout with sediment sump should be provided between the building and Infiltration Trench.



- **Connection of Inlets**

Catch Basins, inlets and area drains may be connected to Infiltration Trenches, however sediment and debris removal should be addressed. Structures should include a sediment trap area below the invert of the pipe for solids and debris. In areas of high traffic or areas where excessive sediment, litter, and other similar materials may be generated, a water quality insert or other pretreatment device is needed.

- **In Combination with Vegetative Filters**

An Infiltration Trench may be preceded by or used in combination with a Vegetative Filter, Grassed Swale, or other vegetative element used to reduce sediment levels from areas such as high traffic roadways. Design should ensure proper functioning of vegetative system.

- **Other Applications**

Other applications of Infiltration Trenches may be determined by the design professional as appropriate.

Design Considerations

1. Soil Investigation and Percolation Testing is required (see Appendix C, Protocol 2)
2. Guidelines for Infiltration Systems should be met (i.e., depth to water table, setbacks, Loading Rates, etc. See Appendix C, Protocol 1)
3. Water Quality Inlet or Catch Basin with Sump (see Section 6.6.4) recommended for all surface inlets, designed to avoid standing water for periods greater than the criteria in Chapter 3.
4. A continuously perforated pipe should extend the length of the trench and have a positive flow connection designed to allow high flows to be conveyed through the Infiltration Trench.
5. The slope of the Infiltration Trench bottom should be level or with a slope no greater than 1%. The Trench may be constructed as a series of "steps" if necessary. A level bottom assures even water distribution and infiltration.
6. Cleanouts or inlets should be installed at both ends of the Infiltration Trench and at appropriate intervals to allow access to the perforated pipe.
7. The discharge or overflow from the Infiltration Trench should be properly designed for anticipated flows.

Detailed Stormwater Functions

Infiltration Area

The Infiltration Area is the bottom area of the Trench*, defined as:

Length of Trench x Width of Trench = Infiltration Area (Bottom Area)

This is the area to be considered when evaluating the Loading Rate to the Infiltration Trench.
* Some credit can be taken for the side area that is frequently inundated as appropriate.

Volume Reduction Calculations

Volume = Depth* (ft) x Area (sf) x Void Space

*Depth is the depth of the water surface during a storm event, depending on the drainage area and conveyance to the bed.

Infiltration Volume = Bed Bottom Area (sf) x Infiltration design rate (in/hr) x Infiltration period* (hr) x (1/12)

*Infiltration Period is the time when bed is receiving runoff and capable of infiltration. Not to exceed 72 hours.

The void ratio in stone is approximately 40% for AASTO No 3. If the conveyance pipe is within the Storage Volume area, the volume of the pipe may also be included. All Infiltration Trenches should be designed to infiltrate or empty within 72 hours.

Peak Rate Mitigation Calculations
See Chapter 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement
See Chapter 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

1. Protect Infiltration Trench area from compaction prior to installation.
2. If possible, install Infiltration Trench during later phases of site construction to prevent sedimentation and/or damage from construction activity. After installation, prevent sediment laden water from entering inlets and pipes.
3. Install and maintain proper Erosion and Sediment Control Measures during construction.
4. Excavate Infiltration Trench bottom to a uniform, level uncompacted subgrade free from rocks and debris. Do NOT compact subgrade.
5. Place nonwoven geotextile along bottom and sides of trench*. Nonwoven geotextile rolls should overlap by a minimum of 16 inches within the trench. Fold back and secure excess geotextile during stone placement.
6. Install upstream and downstream Control Structures, cleanouts, etc.
7. Place uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
8. Install Continuously Perforated Pipe as indicated on plans. Backfill with uniformly graded, clean-washed aggregate in 8-inch lifts, lightly compacting between lifts.
9. Fold and secure nonwoven geotextile over Infiltration Trench, with minimum overlap of 16-inches.
10. Place 6-inch lift of approved Topsoil over Infiltration Trench, as indicated on plans.
11. Seed and stabilize topsoil.
12. Do not remove Inlet Protection or other Erosion and Sediment Control measures until site is fully stabilized.
13. Any sediment that enters inlets during construction is to be removed within 24 hours.

(from left to right) Installation of Inlets and Control Structure; Non-woven Geotextile is folded over Infiltration Trench; Stabilized Site

(Clockwise from top left) Infiltration Trench is on downhill side of roadway; Infiltration Trench is installed; Infiltration Trench is paved with standard pavement material

Maintenance and Inspection Issues

- Catch Basins and Inlets should be inspected and cleaned at least 2 times per year.
- The vegetation along the surface of the Infiltration Trench should be maintained in good condition, and any bare spots revegetated as soon as possible.
- Vehicles should not be parked or driven on a vegetated Infiltration Trench, and care should be taken to avoid excessive compaction by mowers.

Cost Issues

The construction cost of infiltration trenches can vary greatly depending on the configuration, location, site-specific conditions, etc. Typical construction costs in 2003 dollars range from $4 - $9 per cubic foot of storage provided (SWRPC, 1991; Brown and Schueler, 1997). Annual maintenance costs have been reported to be approximately 5 to 10 percent of the capital costs (Schueler, 1987).

Specifications

The following specifications are provided for information purposes only. These specifications include information on acceptable materials for typical applications, but are by no means exclusive or limiting. The designer is responsible for developing detailed specifications for individual design projects in accordance with the project conditions.

1. Stone for infiltration trenches shall be 2-inch to 1-inch uniformly graded coarse aggregate, with a wash loss of no more than 0.5%, AASHTO size number 3 per AASHTO Specifications, Part I, 19th Ed., 1998, or later and shall have voids 40% as measured by ASTM-C29.

2. Non-Woven Geotextile shall consist of needled nonwoven polypropylene fibers and meet the following properties:

a. Grab Tensile Strength (ASTM-D4632)
b. Mullen Burst Strength (ASTM-D3786)
c. Flow Rate (ASTM-D4491)
d. UV Resistance after 500 hrs (ASTM-D4355) 70%
e. Heat-set or heat-calendared fabrics are not permitted
Acceptable types include Mirafi 140N, Amoco 4547, and Geotex 451.

3. Pipe shall be continuously perforated, smooth interior, with a minimum inside diameter of 8-inches. High-density polyethylene (HDPE) pipe shall meet AASHTO M252, Type S or AASHTO M294, Type S.

References

Brown and Schueler, *Stormwater Management Fact Sheet: Infiltration Trench.* 1997.

Schueler, T., 1987. *Controlling urban runoff: a practical manual for planning and designing urban BMPs*, Metropolitan Washington Council of Governments, Washington, DC

SWRPC, The Use of of Best Management Practices (BMPs) in Urban Watersheds, US Environmental Protection Agency,1991.

Nutrient Management

Illinois Job Sheet - 590 **APRIL 2003**

Definition
Nutrient management is managing the source, rate, form, timing, and placement of nutrients.

Purpose
Nutrient management effectively and efficiently uses scarce nutrient resources to adequately supply soils and plants to produce food, forage, fiber, and cover while minimizing environmental degradation.

Where Used
Nutrient management is applicable to all lands where plant nutrients and soil amendments are applied.

Conservation Systems
Nutrient management may be a component of a conservation. It is used in conjunction with Crop Rotation, Residue Management, Pest Management, conservation buffer practices, and/or other practices needed on a site-specific basis to address natural resource concerns and the landowner's objectives. The major role of nutrient management is to minimize nutrient losses from fields, thus helping protect surface and ground water supplies.

Nutrient Management Planning
Nutrient management components of the conservation plan will include the following information:

- field map and soil map
- crop rotation or sequence
- results of soil, water, plant, and organic material samples analyses
- expected yield
- sources of nutrients to be applied
- nutrient budget, including credits of nutrients available
- recommended nutrient rates, form, timing, and method of application
- location of designated sensitive areas
- guidelines for operation and maintenance

Nutrient management is most effective when used with other agronomic practices, such as cover and green manure crops, residue management, conservation buffers, water management, pest management, and crop rotation.

General Nutrient Management Considerations

- Test soil, plants, water and organic material for nutrient content.
- Set realistic yield goals.
- Apply nutrients according to soil test recommendations.
- Account for nutrient credits from all sources.
- Consider effects of drought or excess moisture on quantities of available nutrients.
- Use a water budget to guide timing of nutrient applications.
- Use cover and green manure crops where possible to recover and retain residual nitrogen and other nutrients between cropping periods.
- Use split applications of nitrogen fertilizer for greater nutrient efficiency.

Guidelines for Operation and Maintenance

- Review nutrient management component of the conservation plan annually and make adjustments when needed.
- Calibrate application equipment to ensure uniform distribution and accurate application rates.
- Protect nutrient storage areas from weather to minimize runoff and leakage.
- Avoid unnecessary exposure to fertilizer and organic waste, and wear protective clothing when necessary.
- Observe setbacks required for nutrient applications adjacent to waterbodies, drainageways, and other sensitive areas.
- Maintain records of nutrient application as required by state and local regulations.
- Clean up residual material from equipment and dispose of properly.

Nutrient Management Assessment

Make a site-specific environmental assessment of the potential risk of nutrient management. The boundary of the nutrient management assessment is the agricultural management zone (AMZ), which is defined as the edge of field, bottom of root zone, and top of crop canopy. Environmental risk is difficult to assess beyond the AMZ.

Within an area designated as having impaired or protected natural resources (soil, water, air, plants, and animals), the nutrient management plan should include an assessment of the potential risk for nitrogen and phosphorus to contribute to water quality impairment.

The Leaching Index (LI), Nitrogen Leaching and Economic Analysis Package (NLEAP), the Phosphorus Index (PI), erosion prediction models, water quality monitoring, or any other acceptable assessment tools may be used to make risk assessments.

Evaluate other areas that might have high levels of nutrients, produced or applied, that may contribute to environmental degradation. For example, areas with high livestock concentrations or large areas of high-intensity cropping, such as continuous potatoes, corn, or specialty crops, may be contributing heavy nutrient loads to surface or ground water.

Conservation practices and management techniques will be implemented with nutrient management to mitigate any unacceptable risks.

Nutrient Management Plan

Crop Year _______

Producer: ________________________ Planner: _______________________ Date: ______________

Tract: _______ Field: _______ Acres: _______ Soil(s): _______________________________

Soil P Supplying Power ______ Planned P Buildup Level ______ Lime Group ______

Crop and Yield Information		
Crop Rotation: (circle planned crop)	5 Yr. Average Yield	Yield + 5%

Current Soil Test Levels (use lb/ac on P and K)						
Soil Test Date	CEC	pH	N	P	K	Other

Total Recommended Nutrients (per acre) to Meet Expected Yield					
	Lime	N	P2O5	K2O	Other
Buildup					
Maintenance					
Total					

Nutrient Credits				
Credits	N	P2O5	K2O	Other
Nitrogen credit from previous legume crop				
Manure applications				
Other				
Total Credits				

Additional Nutrients to be Applied					
	Lime (tons)	N	P2O5	K2O	Other
Amount to be Applied (lb/ac)					

Specify Rate Form Method and Timing of Nutrient Applications
WHEN APPLYING NITROGEN IN THE FALL: USE AN INHIBITOR WHEN SOIL TEMP. IS LESS THAN 60^o OR WAIT UNTIL SOIL TEMP. IS LESS THAN 50^o IF NOT USING AN INHIBITOR

Other Recommendations:

Previous Fertility Program										
Field Information			Last 5 Yields					Total Fertilizer Normally Applied		
Tract	Field	Crop	Year 1	Year 2	Year 3	Year 4	Year 5	N	P	K

In addition to nutrient rates shown on the front side of this sheet, the following requirements are needed to meet NRCS's Nutrient Management Standard:

- Rate, timing, and placement of nutrients are based on current University of Illinois (U of I) recommendations.
- Nutrient management plan shall comply with all applicable federal, state, and local laws and regulations.
- Realistic expected yields will be calculated using the following method:
  - ♦ Use the actual yields for each field from the past 5 years
  - ♦ Discard any yields that differ more than 25% from the average yield
  - ♦ Average the remaining yields and <u>multiply by 1.05 and record on front of this sheet</u>
- Nutrient management plans will be based on soil tests no older than 4 years. Soil samples will be collected using U of I guidance and analyzed in an approved soil test laboratory. At a minimum, soil tests will include pH, phosphorus, and potassium.
- No maintenance phosphorus fertilizer is recommended when soil test Phosphorus is > 70, 65, or 60 lb/ac on Low, Medium, and High phosphorus supplying soils respectively.
- If soil test Phosphorus values are > 300 lb./ac., manure should not be applied. If manure is applied, phosphorus applications from all sources will not exceed crop removal rates
- Fall applications of nitrogen will be delayed until:
  - ♦ Soil temperature is less than 60 degrees when a nitrification inhibitor (e.g. N-Serve) is used
  - ♦ Soil temperature is less than 50 degrees when a nitrification inhibitor is not used
- Nitrogen applications will be delayed until spring on all coarse textured soils i.e. sand, loamy sand, and sandy loam
- Nutrients will not be applied to frozen, snow covered, or saturated soil if the risk for runoff exists.
- Nutrient values of manure and organic by-products will be determined prior to land application based on laboratory analysis or acceptable 'book values' recognized by NRCS.
- This plan was developed based on NRCS nutrient management requirements and applicable federal, state, and local regulations. This plan may need to be revised if any of these requirements change.
- This plan should be reviewed and revised, at a minimum, with each soil test cycle.

I agree with this nutrient management plan and I intend to follow the plan as prepared. I will consult with my planner or NRCS before making any changes in this plan.

I certify that implementation of this plan will meet NRCS's Nutrient Management Standard.

____________________ Landowner/Operator   __________ Date

____________________ NRCS Employee   __________ Date

____________________ Planner   __________ Date

3.3 Permeable Pavement

Type of BMP	LID - Infiltration
Treatment Mechanisms	Infiltration, Evaporation
Maximum Drainage Area	10 acres
Other Names	porous pavement, pervious concrete, pervious asphalt, pervious gravel pavement, cobblestone block, modular block, modular pavement

Description

Permeable pavements can be either pervious asphalt and concrete surfaces, or permeable modular block. Unlike traditional pavements that are impermeable, permeable pavements reduce the volume and peak of stormwater runoff as well as mitigate pollutants from stormwater runoff, provided that the underlying soils can accept infiltration. Permeable pavement surfaces work best when they are designed to be flat or with gentle slopes. This factsheet discusses criteria that apply to infiltration designs.

The permeable surface is placed on top of a reservoir layer that holds the water quality stormwater volume, $V_{BMP.}$ The water infiltrates from the reservoir layer into the native subsoil. Tests must be performed according to the Infiltration Testing Section in Appendix A to be able to use this design procedure.

In some circumstances, permeable pavement may be implemented on a project as a source control feature. Where implemented as a source control feature (sometimes referred to as a 'self-retaining' area), the pavement is not considered a 'BMP' that would be required to be designed and sized per this manual. Where permeable pavement receives runoff from adjacent tributary areas, the permeable pavement *may* be considered a BMP that must be sized according to this manual. Consult the Engineering Authority and the WQMP for any applicable requirements for designing and sizing permeable pavement installations.

Siting Considerations

The WQMP applicable to the project location should be consulted, as it may include criteria for determining the applicability of this and other Infiltration-based BMPs to the project.

Permeable pavements can be used in the same manner as concrete or asphalt in low traffic parking lots, playgrounds, walkways, bike trails, and sports courts. Most types of permeable pavement can be designed to meet Americans with Disabilities Act (ADA) requirements. Permeable pavements **should not** be used in the following conditions:

- Downstream of erodible areas
- Downstream of areas with a high likelihood of pollutant spills
- Industrial or high vehicular traffic areas (25,000 or greater average daily traffic)
- Areas where geotechnical concerns, such as soils with low infiltration rates, would preclude the use of this BMP.

Sites with Impermeable Fire Lanes

Oftentimes, Fire Departments do not allow alternative pavement types including permeable pavement. They require traditional impermeable surfaces for fire lanes. In this situation, it is acceptable to use an impermeable surface for the fire lane drive aisles and permeable pavement for the remainder of the parking lot.

Where impermeable fire lanes are used in the design, the impermeable surface must slope towards the permeable pavement, and the base layers shall remain continuous underneath the two pavement types, as shown in Figure 1. This continuous reservoir layer helps to maintain infiltration throughout the pervious pavement site, and can still be considered as part of the total required storage area.

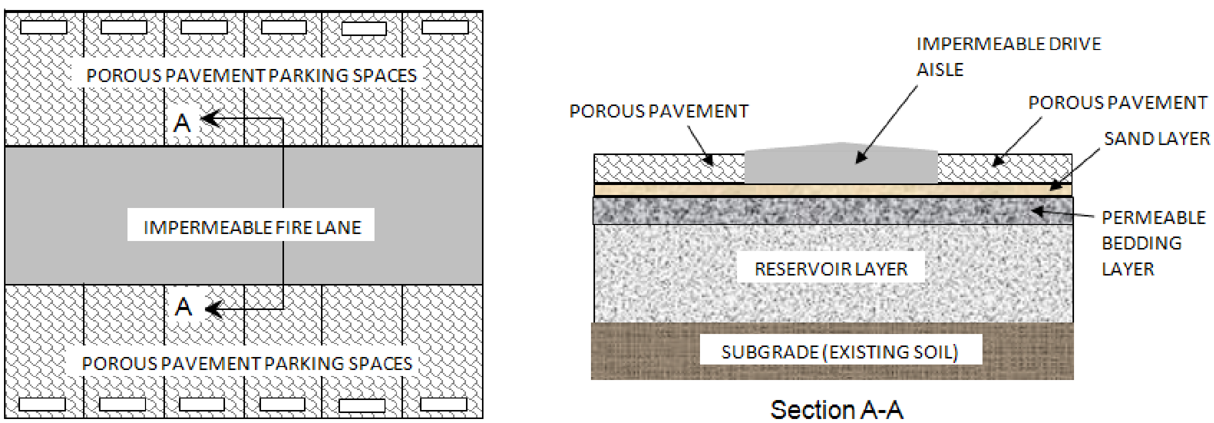


Figure 1: Impermeable Fire Lanes

Also, while a seal coat treatment may be used on the impermeable fire land, traditional seal coat treatments **shall not** be used on permeable pavement.

Setbacks

Always consult your geotechnical engineer for site specific recommendations regarding setbacks for permeable pavement. Recommended setbacks are needed to protect buildings, walls, onsite wells, streams and tanks.

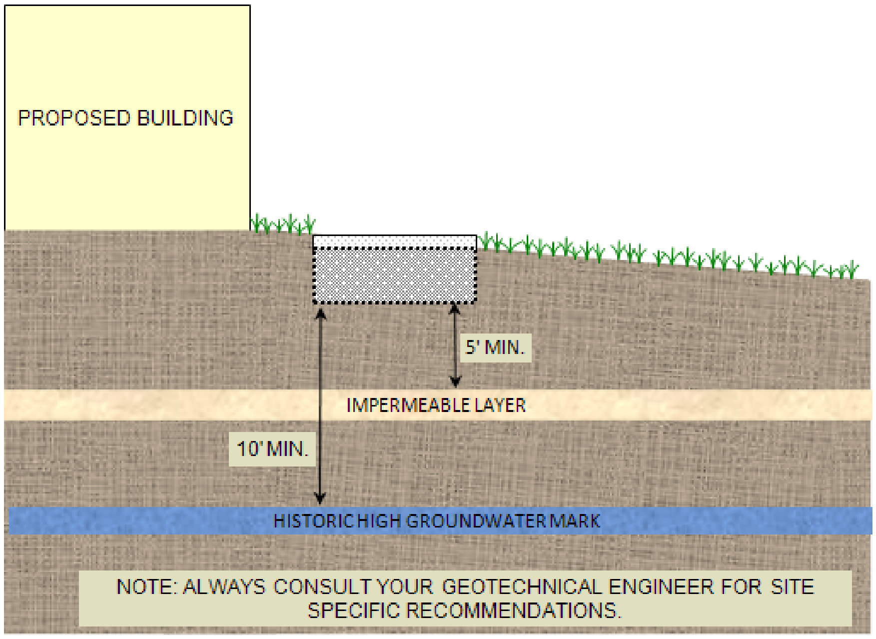


Figure 2: Permeable Pavement Setback Requirements

A minimum vertical separation of 10 feet is required from the bottom of the reservoir layer to the historic high groundwater mark, see Figure 2. A minimum vertical separation of 5 feet is required from the bottom of the reservoir layer to any impermeable layer in the soil. If the historic high groundwater mark is less than 10 feet below the reservoir layer section, or less than 5 feet from an impermeable layer, the infiltration design is not feasible.

Design and Sizing Criteria

To ensure that the pavement structural section is not compromised, a 24-hour drawdown time is utilized for this BMP instead of the longer drawdown time used for most volume based BMPs.

Reservoir Layer Considerations

Even with proper maintenance, sediment will begin to clog the soil below the permeable pavement. Since the soil cannot be scarified or replaced, this will result in slower infiltration rates over the life of the permeable pavement. Therefore, the reservoir layer is limited to a maximum of 12 inches in depth to ensure that over the life of the BMP, the reservoir layer will drain in an adequate time.

***Note**: All permeable pavement BMP installations (not including Permeable Pavement as a source control BMP i.e. a self-retaining area) must be tested by the geotechnical engineer to ensure that the soils drain at a minimum allowable rate to ensure drainage.. See the Infiltration Testing Section of this manual for specific details for the required testing and applied factors of safety.*

Sloping Permeable Pavement

Ideally permeable pavement would be level, however most sites will have a mild slope. If the tributary drainage area is too steep, the water may be flowing too fast when it approaches the permeable pavement, which may cause water to pass over the pavement instead of percolating and entering the reservoir layer. If the maximum slopes shown in Table 1 are complied with, it should address these concerns.

Table 1: Design Parameters for Permeable Pavement

Design Parameter	Permeable Pavement
Maximum slope of permeable pavement	3%
Maximum contributing area slope	5%

Regardless of the slope of the pavement surface design, the bottom of the reservoir layers **shall be flat and level** as shown in Figure 3. The design shown ensures that the water quality volume will be contained in the reservoir layer. A terraced design utilizing non-permeable check dams may be a useful option when the depth of gravel becomes too great as shown in Figure 3.

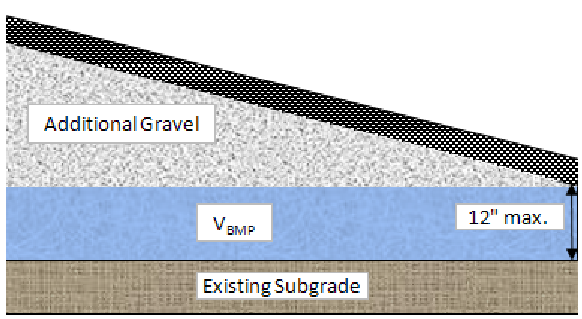


Figure 3: Sloped Cross Sections for Permeable Pavement

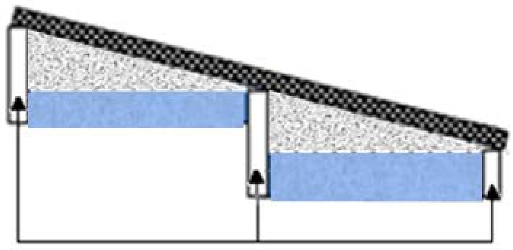


Figure 4: Permeable Pavement with Non-permeable Check Dams

In Figure 4, the bottom of the gravel reservoir layer is incorrectly sloped parallel to the pavement surface. Water would only be allowed to pond up to the lowest point of the BMP. Additional flows would simply discharge from the pavement. Since only a portion of the gravel layer can store water, this design would result in insufficient capacity. This is not acceptable.

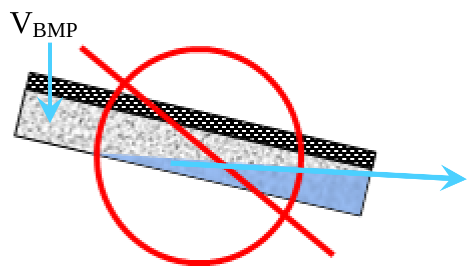


Figure 5: Incorrect Sloping of Permeable Pavement

To assure that the subgrade will empty within the 24 hour drawdown time, it is important that the maximum depth of 12 inches for the reservoir layer discussed in the design procedure is not exceeded. The value should be measured from the lowest elevation of the slope (Figure 4).

Minimum Surface Area

The minimum surface area required, A_S, is calculated by dividing the water quality volume, V_{BMP}, by the depth of water stored in the reservoir layer. The depth of water is found by multiplying the void ratio of the reservoir aggregate by the depth of the layer, b_{TH}. The void ratio of the reservoir aggregate is typically 40%; the maximum reservoir layer depth is 12”.

Sediment Control

A pretreatment BMP should be used for sediment control. This pretreatment BMP will reduce the amount of sediment that enters the system and reduce clogging. The pretreatment BMP will also help to spread runoff flows, which allows the system to infiltrate more evenly. The pretreatment BMP must discharge to the surface of the pavement and not the subgrade. Grass swales may also be used as part of a treatment train with permeable pavements.

Liners and Filter Fabric

Always consult your geotechnical engineer for site specific recommendations regarding liners and filter fabrics. Filter fabric may be used around the edges of the permeable pavement; this will help keep fine sediments from entering the system. Unless recommended for the site, impermeable liners are not to be used below the subdrain gravel layer.

Overflow

An overflow route is needed in the permeable pavement design to bypass storm flows larger than the V_{BMP} or in the event of clogging. Overflow systems must connect to an acceptable discharge point such as a downstream conveyance system.

Roof Runoff

Permeable pavement can be used to treat roof runoff. However, the runoff cannot be discharged beneath the surface of the pavement directly into the subgrade, as shown in Figure 6. Instead the pipe should empty on the surface of the permeable pavement as shown in Figure 7. A filter on the drainpipe should be used to help reduce the amount of sediment that enters the permeable pavement.

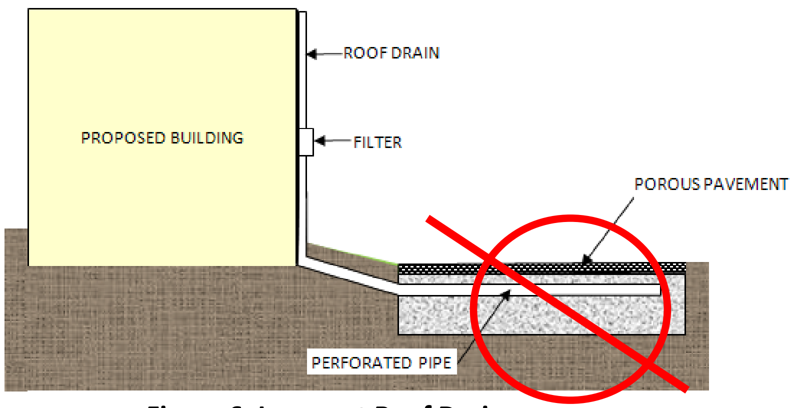


Figure 6: Incorrect Roof Drainage

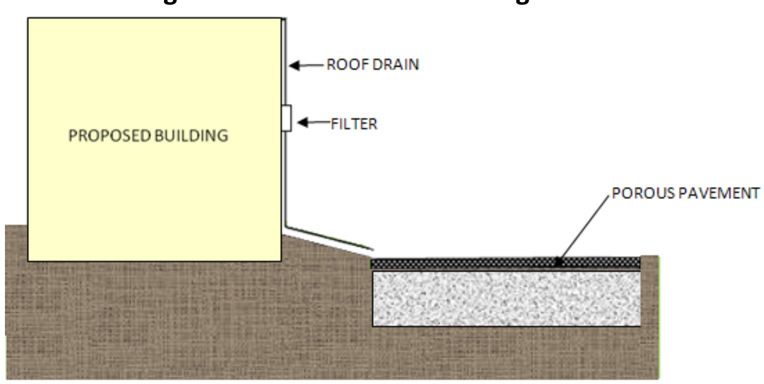


Figure 7: Correct Roof Runoff Drainage

Infiltration
Refer to the Infiltration Testing Section (Appendix A) in this manual for recommendations on testing for this BMP.

Pavement Section
The cross section necessary for infiltration design of permeable pavement includes:

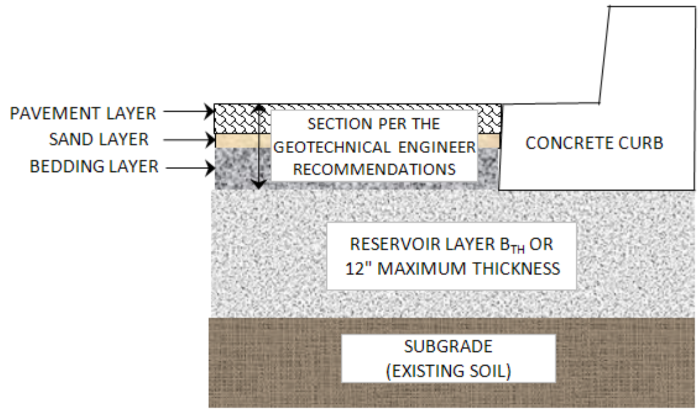


Figure 8: Infiltration Cross Section

- The thickness of the layers of permeable pavement, sand and bedding layers depends on whether it is permeable modular block or pervious pavement. A licensed geotechnical or civil engineer is required to determine the thickness of these upper layers appropriate for the pavement type and expected traffic loads.
- A 12” maximum reservoir layer consisting of AASHTO #57 gravel vibrated in place or equivalent with a minimum of 40% void ratio.

Inspection and Maintenance Schedule –Modular Block

Schedule	Activity
Ongoing	• Keep adjacent landscape areas maintained. Remove clippings from landscape maintenance activities. • Remove trash and debris
Utility Trenching and other pavement repairs	• Remove and reset modular blocks, structural section and reservoir layer as needed. Replace damaged blocks in-kind. • Do not pave repaired areas with impermeable surfaces.
After storm events	• Inspect areas for ponding
2-3 times per year	• Sweep to reduce the chance of clogging
As needed	• Sand between pavers may need to be replaced if infiltration capacity is lost

Inspection and Maintenance Schedule –Pervious Concrete/Asphalt

Schedule	Activity
Ongoing	• Keep adjacent landscape areas maintained. Remove clippings from landscape maintenance activities. • Remove trash and debris
Utility Trenching other pavement repairs	• Replace structural section and reservoir layer in kind. • Re-pave using pervious concrete/asphalt. Do not pave repaired areas with impermeable surfaces.
After storm events	• Inspect areas for ponding
2-3 times per year	• Vacuum the permeable pavement to reduce the chance of clogging
As needed	• Remove and replace damaged or destroyed permeable pavement

Design Procedure Permeable Pavement

1. Enter the Tributary Area, A_T.

2. Enter the Design Volume, $V_{BMP,}$ determined from Section 2.1 of this Handbook.

3. Enter the reservoir layer depth, b_{TH} for the proposed permeable pavement. The reservoir layer maximum depth is 12 inches.

4. Calculate the Minimum Surface Area, A_S, required.

$$A_S(\mathrm{ft}) = \frac{V_{BMP}\ (\mathrm{ft}^3)}{(0.4\ \times\ b_{TH}\ (\mathrm{in}))/12(\mathrm{in/ft})}$$

   Where, the porosity of the gravel in the reservoir layer is assumed to be 40%.

5. Enter the proposed surface area and ensure that this is equal to or greater than the minimum surface area required.

6. Enter the dimensions, per the geotechnical engineer's recommendations, for the pavement cross section. The cross section includes a pavement layer, usually a sand layer and a permeable bedding layer. Then add this to the maximum thickness of the reservoir layer to find the total thickness of the BMP.

7. Enter the slope of the top of the permeable pavement. The maximum slope is 3%.

8. Enter whether sediment control was provided.

9. Enter whether the geotechnical approach is attached.

10. Describe the surfaces surrounding the permeable pavement. It is preferred that a vegetation buffer is used around the permeable pavement.
11. Check to ensure that vertical setbacks are met. There should be a minimum of 10 feet between the bottom of the BMP and the top of the high groundwater table, and a minimum of 5 feet between the reservoir layer the top of the impermeable layer.

Reference Materials Used to Develop this Fact Sheet:

Adams, Michelle C. "Porous Asphalt Pavement with Recharge Beds: 20 Years and Still Working." Stormwater Magazine May-June 2003.

Atlanta Regional Commission, et. al. Georgia Stormwater Management Manual. 1st Edition. Vol. 2. Atlanta, 2001. 3 vols.

Bean, E. Z., et al. "Study on the Surface Infiltration Rate of Permeable Pavements." Water and Environment Specialty Conference of the Canadian Society for Civil Engineering. Saskatoon, 2004. 1-10.

California Department of Transportation. CalTrans Standard Plans. 15 September 2005. May 2010 <http://www.dot.ca.gov/hq/esc/oe/project_plans/HTM/stdplns-met-new99.htm>.

Camp Dresser and McKee Inc.; Larry Walker Associates. California Stormwater Best Management Practice Handbook for New Development and Redevelopment. California Stormwater Quality Association (CASQA), 2004.

Colorado Ready Mixed Concrete Association (CRMCA). "Specifier's Guide for Pervious Concrete Pavement Design, Version 1.2." 2010.

County of Los Angeles Public Works. Stormwater Best Management Practice Design and Maintenance Manual. Los Angeles, 2009.

Program, Ventura Countywide Stormwater Quality Management. Technical Guidance Manual for Stormwater Quality Control Measures. Ventura, 2002.

Sacramento Stormwater Quality Partnership and the City of Roseville. Stormwater Quality Design Manual for the Sacramento and South Placer Regions. County of Sacramento, 2007.

Taylor, Chuck. "Advanced Pavement Technology." Riverside, 2008.

Tennis, Paul D., Michael L. Leming and David J. Akers. Pervious Concrete Pavements. Silver Spring: Portland Cement Association and National Ready Mixed Concrete Association, 2004.

Urban Drainage and Flood Control District. Urban Storm Drainage Criteria Manual Volume 3 - Best Management Practices. Vol. 3. Denver, 2008. 3 vols.

Urbonas, Ben R. Stormwater Sand Filter Sizing and Design: A Unit Operations Approach. Denver: Urban Drainage and Flood Control District, 2002.

United States Department of Agriculture

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

POND

Code 378

(No.)

DEFINITION

A pond is a water impoundment made by constructing an embankment, by excavating a dugout, or by a combination of both.

In this standard, NRCS defines ponds constructed by the first method as embankment ponds, and those constructed by the second method as excavated ponds. Ponds constructed by both the excavation and the embankment methods are classified as embankment ponds if the depth of water impounded against the embankment at the auxiliary spillway elevation is 3 feet or more above the lowest original ground along the centerline of the embankment.

PURPOSE

A pond stores water for livestock, fish and wildlife, recreation, fire control, erosion control, flow detention, and other uses such as improving water quality.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all excavated ponds. It also applies to embankment ponds that meet all of the criteria for low-hazard dams as listed below:

- The failure of the dam will not result in loss of life, damage to homes, commercial or industrial buildings, main highways, or railroads, or in interruption of the use or service of public utilities.
- The product of the storage times the effective height of the dam is less than 3,000 acre-feet^2. Storage is the capacity of the reservoir in acre-feet below the elevation of the crest of the lowest auxiliary spillway or the elevation of the top of the dam if there is no open channel auxiliary spillway. The effective height of the dam is the difference in elevation, in feet, between the lowest open channel auxiliary spillway crest and the lowest point in the original cross section taken on the centerline of the dam. If there is no open channel auxiliary spillway, use the lowest point on the top of the dam instead of the lowest open channel auxiliary spillway crest.
- The effective height of the dam is 35 feet or less.

CRITERIA

General Criteria Applicable to All Purposes

Notify landowner and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

Design a minimum sediment storage capacity equal to the design life of the structure, or provide for periodic cleanout. Protect the drainage area above the pond to prevent sedimentation from adversely affecting the design life.

Design measures necessary to prevent serious injury or loss of life in accordance with requirements of NRCS National Engineering Manual (NEM), Part 503, Safety.

Protection. Seed or sod the exposed surfaces of earthen embankments, earth spillways, borrow areas, and other non-crop areas disturbed during construction in accordance with the criteria in NRCS Conservation Practice Standard (CPS) Code 342, Critical Area Planting. When necessary to provide surface protection where climatic conditions preclude the use of seed or sod, use the criteria in CPS Code 484, Mulching, to install inorganic cover material such as gravel.

Cultural resources. Evaluate the existence of cultural resources in the project area and any project impacts on such resources. Provide conservation and stabilization of archeological, historic, structural, and traditional cultural properties when appropriate.

Site conditions. Select or modify the site to allow runoff from the design storm to safety pass through (1) a natural or constructed auxiliary spillway, (2) a combination of a principal spillway and an auxiliary spillway, or (3) a principal spillway.

Select a site that has an adequate supply of water for the intended purpose via surface runoff, groundwater, or a supplemental water source. Water quality must be suitable for its intended use.

Reservoir. Provide adequate storage volume to meet user demands for all intended purposes. Account for sedimentation, season of use, evaporation loss, and seepage loss when computing the storage volume.

Criteria Applicable to Embankment Ponds

Geological investigations. Use pits, trenches, borings, reviews of existing data or other suitable means of investigation to characterize materials within the embankment foundation, auxiliary spillway, and borrow areas. Classify soil materials using the Unified Soil Classification System (ASTM D2487).

Foundation cutoff. Design a cutoff of relatively impervious material under the dam and up the abutments as required for preventing seepage. Locate the cutoff at, or upstream from, the centerline of the dam. Extend the cutoff deep enough to intercept flow and connect with a relatively impervious layer. Combine seepage control with the cutoff as needed. Use a cutoff bottom width adequate to accommodate the equipment used for excavation, backfill, and compaction operations. Design cutoff side slopes no steeper than one horizontal to one vertical.

Seepage control. Include seepage control if (1) foundation cutoff does not intercept pervious layers, (2) seepage could create undesired wet areas, (3) embankment stability requires seepage control, or (4) special problems require drainage for a stable dam. Control seepage by (1) foundation, abutment, or embankment filters and drains; (2) reservoir blanketing; or (3) a combination of these measures.

Top width. Table 1 provides the minimum top widths for dams of various total heights. Total height is the vertical distance between the settled top of the dam and the lowest elevation at the downstream toe.

Design a minimum width of 16 feet for one-way traffic and 26 feet for two-way traffic for the top of dams used as public roads. Design guardrails or other safety measures where necessary and follow the requirements of the responsible road authority. For dams less than 20 feet in total height, maintenance considerations or construction equipment limitations may require increased top widths from the minimum shown in Table 1.

Table 1. Minimum top width for dams.

Total height of dam *(feet)*	Top width *(feet)*
Less than 10	6
10–14.9	8
15–19.9	10
20–24.9	12
25–34.9	14
35 or more	15

Side slopes. Design each side slope with a ratio of two horizontal to one vertical or flatter. Design the sum of the upstream- and downstream-side slopes with a ratio of five horizontal to one vertical or flatter. As required, design benches or flatten side slopes to assure stability of all slopes for all loading conditions.

Slope protection. Design special measures such as berms, rock riprap, sand-gravel, soil cement, or special vegetation as needed to protect the slopes of the dam from erosion. Use NRCS Engineering Technical Release (TR) 210-56, A Guide for Design and Layout of Vegetative Wave Protection for Earth Dam Embankments, and TR-210-59, Riprap for Slope Protection against Wave Action, as applicable.

Freeboard. Design a minimum of 1.0 feet of freeboard between design high-water-flow elevation in the auxiliary spillway and the top of the settled embankment. Design a minimum 2.0 feet of elevation difference between the crest of the auxiliary spillway and the top of the settled embankment when the dam has more than a 20-acre drainage area or more than 20 feet in effective height. Design a minimum of 1.0 feet of freeboard above the peak elevation of the routed design hydrograph to the top of the settled embankment, when the pond has no auxiliary spillway.

For structures where the principal spillway carries the entire design storm without an auxiliary spillway, provide an alternate route for storm flows in excess of the design event without overtopping the dam. This can be done by setting the top of the settled embankment at least 1 foot above the natural ground surface at one or both ends of the embankment. If site topography is too steep, design an opening in natural ground at one end of the embankment at least 10 feet wide and 1 foot lower than the top of the embankment, similar to an auxiliary spillway but without a designed exit slope.

Settlement. Increase the height of the dam by the amount needed to ensure that the settled top elevation of the dam equals or exceeds the design top elevation. Design a minimum of 5 percent of the total height of the dam associated with each dam cross section, except where detailed soil testing and laboratory analyses or experience in the area shows that a lesser amount is adequate.

Principal spillway and pipe conduit through the embankment. Design a pipe conduit with needed appurtenances through the dam, except where rock, concrete, or other types of lined spillways are used, or where a vegetated or earth spillway can safely handle the rate and duration of base flow.

The minimum capacity for pipe conduits must be adequate to discharge the runoff from the storm frequency in Table 2 or 3, as applicable, prior to auxiliary spillway flow.

Design a minimum of 0.5-feet difference between the crest elevation of the auxiliary spillway and the crest elevation of the principal spillway when the dam has a drainage area of 20 acres or less. Design a minimum of 1.0-foot difference when the dam has a drainage area of over 20 acres.

Provide an antivortex device for a pipe conduit designed for pressure flow. Design the inlet and outlet to function for the full range of flow and hydraulic head anticipated.

Design adequate pipe conduit capacity to discharge long-duration, continuous, or frequent flows without causing flow through the auxiliary spillway. Design a principal spillway pipe with a minimum inside diameter of 4 inches. Design pipe with a minimum inside diameter of 1-1/4 inches for water supply pipes or for pipes used for any other non-principal spillway purpose.

Design pipe conduits using ductile iron, welded steel, corrugated steel, corrugated aluminum, reinforced concrete (pre-cast or site-cast), or plastic. Do not use cast iron or unreinforced concrete pipe if the dam is 20 feet or greater in total height. Dual wall plastic pipe (corrugated plastic with smooth interior) is not approved for use in a pond dam with a permanent pool.

Design and install pipe conduits to withstand all external and internal loads without yielding, buckling, or cracking. Design rigid pipe for a positive projecting condition. Design flexible pipe conduits in accordance with the requirements of NRCS National Engineering Handbook (NEH), Part 636, Chapter 52, Structural Design of Flexible Conduits. Tables of allowable fill heights for different materials are available as Illinois Supplements to the Engineering Field Handbook, Chapter 17.

Design connections of flexible pipe to rigid pipe or other structures to accommodate differential movements and stress concentrations. Design and install all pipe conduits to be watertight using couplings, gaskets, caulking, water stops, or welding. Design joints to remain watertight under all internal and external loading, including pipe elongation due to foundation settlement.

Design a concrete cradle or bedding for pipe conduits if needed to reduce or limit structural loading on pipe and improve support of the pipe.

Design outlet structures, such as cantilever pipe outlet sections and impact basins, to dissipate energy as needed.

Table 2. Spillway Capacity Requirements – Non Permit Dams			Minimum Design Frequency (24-Hour Duration Storm)	
Drainage Area, acres	Effective Dam Height[1], ft	Storage[1], ac-ft	Principal Spillway, year	Auxiliary Spillway, year
0-20	0-20	<50	5	10
0-20	21-35	<50	10	25
>20	0-35	<50	10	25
All Others	0-35	≥50	25	50

[1]As defined under “Conditions Where Practice Applies.”

Table 3. Spillway Capacity Requirements – Permit Dams[3]			Minimum Design Frequency (24-Hour Duration Storm)	
Drainage Area, acres	Dam Height[1], ft	Impounding Capacity[2], ac-ft	Principal Spillway, year	Auxiliary Spillway, year
All	All	All	25	100

[1] Dam height is the elevation difference measured from the natural ground at the downstream toe to the top of the embankment.

[2] Impounding capacity is the volume in the pond below the top of the embankment.

[3] Permit dam requirements are listed in Illinois Administrative Code (Reference 1).

Corrosion protection. Provide protective coatings for all steel pipe and couplings in areas that have traditionally experienced pipe corrosion or in embankments with saturated soil resistivity less than 4,000 Ohm-cm or soil pH less than 5. Protective coatings may include asphalt, polymer over galvanizing, aluminized coating, or coal tar enamel.

Ultraviolet protection. Use ultraviolet-resistant materials for all plastic pipe or provide coating or shielding to protect plastic pipe exposed to direct sunlight.

Cathodic protection. Provide cathodic protection for coated welded steel and galvanized corrugated metal pipe where soil and resistivity studies indicate that the pipe needs a protective coating and where the need and importance of the structure warrant additional protection and longevity. If the original design and installation did not include cathodic protection, consider establishing electrical continuity in the form of joint-bridging straps on pipes that have protective coatings. Add cathodic protection later if monitoring indicates the need.

Filter diaphragms. When the effective height of the dam is 15 feet or greater and the effective storage of the dam is 50 acre-ft. or more, provide filter diaphragms to control seepage on all pipes extending through the embankment with inverts below the peak elevation of the routed design hydrograph. Design filter diaphragms or alternative measures as needed to control seepage on pipes extending through all other embankments or for pipes with inverts above the peak elevation of the routed design hydrograph.

Design the filter diaphragm in accordance with the requirements of NEH, Part 628, Chapter 45, Filter Diaphragms. Locate the filter diaphragm immediately downstream of the cutoff trench, but downstream of the centerline of the dam if the foundation cutoff is upstream of the centerline or if there is no cutoff trench.

To improve filter diaphragm performance, provide a drain outlet for the filter diaphragm at the downstream toe of the embankment. Protect the outlet from surface erosion and animal intrusion.

Ensure filter diaphragm functions both as a filter for adjacent base soils and as a drain for seepage that it intercepts. Materials for the filter diaphragm must meet the requirements of NEH Part 628, Chapter 45, Filter Diaphragms, Section 628.4503(d), Filter and Drain Gradation.

When using anti-seep collars in lieu of a filter diaphragm, ensure a watertight connection to the pipe. Limit the maximum spacing of the anti-seep collars to 14 times the minimum projection of the collar measured perpendicular to the pipe, or 25 feet, whichever is less. Locate anti-seep collars no closer than 10 feet apart. Use a collar material that is compatible with the pipe material.

When using anti-seep collars, design the collars to increase the seepage path along the pipe within the fill by at least 15 percent. Seepage path along the pipe is defined as the minimum length of pipe within the earthfill.

Trash guard. Install a trash guard at the riser inlet to prevent clogging of the conduit, unless the watershed does not contain trash or debris that could clog the conduit.

Pool Drain. Provide a pipe with a suitable valve to drain the pool area if needed for proper pond management or if required by State law. The designer may use the principal spillway conduit as a pond drain if it is located where it can perform this function.

Auxiliary spillways. A dam must have an open channel auxiliary spillway, unless the principal spillway is large enough to pass the peak discharge from the routed design hydrograph and the trash that comes to it without overtopping the dam. The minimum criteria for acceptable use of a closed conduit principal spillway without an auxiliary spillway consist of a conduit with a cross-sectional area of 3 feet^2 or more, an inlet that will not clog, and an elbow designed to facilitate the passage of trash.

Design the minimum capacity of a natural or constructed auxiliary spillway to pass the peak flow expected from a total design storm of the frequency and duration shown in Table 2 or 3, less any reduction creditable to the conduit discharge and detention storage.

Design the auxiliary spillway to safely pass the peak flow through the auxiliary spillway, or route the storm runoff through the reservoir. Start the routing either with the water surface at the elevation of the crest of the principal spillway or at the water surface after 10 days' drawdown, whichever is higher. Compute the 10-day drawdown from the crest of the auxiliary spillway or from the elevation attained from impounding the entire design storm, whichever is lower. Design the auxiliary spillway to pass the design flow at a safe velocity to a point downstream where the flow will not endanger the dam.

A constructed auxiliary spillway consists of an inlet channel, a control section, and an exit channel. Design the auxiliary spillway with a trapezoidal cross section. Locate the auxiliary spillway in undisturbed or compacted earth or in-situ rock. Design for stable side slopes for the material in which the spillway is to be constructed. Design a minimum bottom width of 10 feet for dams having an effective height of 20 feet or more.

Design a level inlet channel upstream from the control section for the distance needed to protect and maintain the crest elevation of the spillway. If necessary, curve the inlet channel upstream of the level section to fit existing topography. Design the exit channel grade in accordance with NEH Part 628, Chapter 50, Earth Spillway Design, or with equivalent procedures.

Spillway dikes or shaped exit channels should be used as needed to ensure that spillway flows remain in the spillway and do not damage the earth embankment. The constructed spillway dike should have a side slope of 2:1 or flatter, a minimum top width of 4 feet and a minimum height of 2 feet above the outlet channel grade.

Structural auxiliary spillways. When used for principal spillways or auxiliary spillways, design chute spillways or drop spillways according to the principles set forth in NEH, Part 650, Engineering Field Handbook; and NEH, Section 5, Hydraulics; Section 11, Drop Spillways; and Section 14, Chute Spillways. Design a structural spillway with the minimum capacity required to pass the peak flow expected from a total design storm of the frequency and duration shown in Table 2 or 3, less any reduction creditable to the conduit discharge and detention storage.

Criteria for Excavated Ponds

Runoff. Design a minimum of 1.0 feet of freeboard above the peak elevation of the routed design hydrograph. Design a pipe and auxiliary spillway that will meet the capacity requirements of Table 2. Consider runoff flow patterns when locating the excavated pond and placing the spoil.

Side slopes. Design stable side slopes in the excavated area no steeper than one horizontal to one vertical.

Watering Ramp. When wildlife or livestock need access to stored water, use the criteria in NRCS CPS Code 614, Watering Facility, to design a watering ramp.

Inlet protection. Protect the side slopes from erosion where surface water enters the pond in a natural or excavated channel.

Excavated material. Place the material excavated from the pond so that its weight does not endanger the stability of the pond side slopes and so that the soil will not wash back into the pond by rainfall. Dispose of excavated material in one of the following ways:

- Uniformly spread to a height that does not exceed 3 feet, with the top graded to a continuous slope away from the pond.
- Uniformly place or shape reasonably well, with side slopes assuming a natural angle of repose. Place excavated material at a distance equal to the depth of the pond, but not less than 12 feet from the edge of the pond.
- Shape to a designed form that blends visually with the landscape.
- Provide for low embankment construction and leveling of surrounding landscape.
- Haul material offsite.

CONSIDERATIONS

Visual resource design. Carefully consider the visual design of ponds in areas of high public visibility and those associated with recreation. The shape and form of ponds, excavated material, and plantings are to relate visually to their surroundings and to their function.

Shape the embankment to blend with the natural topography. Shape the edge of the pond so that it is generally curvilinear rather than rectangular. Shape excavated material so that the final form is smooth, flowing, and fitting to the adjacent landscape rather than angular geometric mounds. If feasible, add islands to provide visual interest and to attract wildlife.

Fish and wildlife. Locate and construct ponds to minimize the impacts to existing fish and wildlife habitat.

When feasible, retain structures such as trees in the upper reaches of the pond and stumps in the pool area. Shape upper reaches of the pond to provide shallow areas and wetland habitat.

If operations include stocking fish, use CPS Code 399, Fishpond Management.

Vegetation. Stockpile topsoil for placement on disturbed areas to facilitate revegetation.

Consider selecting and placing vegetation to improve fish habitat, wildlife habitat and species diversity.

Water quantity. Consider effects upon components of the water budget, especially—

- Effects on volumes and rates of runoff, infiltration, evaporation, transpiration, deep percolation, and groundwater recharge.
- Variability of effects caused by seasonal or climatic changes.
- Effects on downstream flows and impacts to environment such as wetlands, aquifers, and social and economic impacts to downstream uses or users.

Water quality. Consider the effects of—

- Erosion and the movement of sediment, pathogens, and soluble and sediment-attached substances that runoff carries.
- Short-term and construction-related effects of this practice on the quality of downstream watercourses.
- Water-level control on the temperatures of downstream water to prevent undesired effects on aquatic and wildlife communities.
- Wetlands and water-related wildlife habitats.
- Water levels on soil nutrient processes such as plant nitrogen use or denitrification.
- Soil water level control on the salinity of soils, soil water, or downstream water.
- Potential for earth moving to uncover or redistribute toxic materials.
- Livestock grazing adjacent to the pond. Consider fencing to keep livestock activities out of direct contact with the pond and dam.

PLANS AND SPECIFICATIONS

Prepare plans and specifications that describe the requirements for applying the practice according to this standard. As a minimum, include the following items:

- A plan view of the layout of the pond and appurtenant features.
- Typical profiles and cross sections of the principal spillway, auxiliary spillway, dam, and appurtenant features, as needed.
- Structural drawings adequate to describe the construction requirements.
- Requirements for vegetative establishment and/or mulching, as needed.
- Safety features.
- Site-specific construction and material requirements.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator.

As a minimum, include the following items in the operation and maintenance plan:

- Periodic inspections of all structures, earthen embankments, spillways, and other significant appurtenances.
- Prompt repair or replacement of damaged components.
- Prompt removal of sediment when it reaches predetermined storage elevations.
- Periodic removal of trees, brush, and undesirable species.
- Periodic inspection of safety components and immediate repair, if necessary.
- Maintenance of vegetative protection and immediate seeding of bare areas, as needed.

REFERENCES

Illinois Administrative Code, Title 17: Conservation, Chapter I: Department of Natural Resources, Subchapter h: Water Resources, Part 3702: Construction and Maintenance of Dams.

American Society for Testing and Materials. Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System), ASTM D2487. West Conshohocken, PA.

USDA NRCS. Engineering Technical Releases, TR-210-60, Earth Dams and Reservoirs. Washington, DC.

USDA NRCS. National Engineering Handbook (NEH), Part 628, Dams. Washington, DC.

USDA NRCS. NEH, Part 633, Soil Engineering. Washington, DC.

USDA NRCS. NEH, Part 636, Structural Engineering. Washington, DC.

USDA NRCS. NEH, Part 650, Engineering Field Handbook. Washington, DC.

USDA NRCS. National Engineering Manual. Washington, DC.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

PRESCRIBED GRAZING

(Acre)

Code 528

DEFINITION

Managing the harvest of vegetation with grazing and/or browsing animals.

PURPOSE

Prescribed Grazing may be applied as part of a conservation system to achieve one or more of the following:

- Improve or maintain desired species composition and vigor of plant communities.
- Improve or maintain quantity and quality of forage for grazing and browsing animals' health and productivity.
- Improve or maintain surface and/or subsurface water quality and quantity.
- Improve or maintain riparian and watershed function
- Reduce accelerated soil erosion, and maintain or improve soil condition.
- Improve or maintain the quantity and quality of food and/or cover available for wildlife.
- Manage fine fuel loads to achieve desired conditions.
- Extend the grazing season

CONDITIONS WHERE PRACTICE APPLIES

Prescribed Grazing applies to all lands where grazing and/or browsing animals are managed.

CRITERIA

General criteria applicable to All Purposes

Removal of herbage will be in accordance with site production limitations, rate of plant growth, the physiological needs of forage plants, and the nutritional needs of the animals. Refer to tables 1, 2, and 3; and Chapter 5, section 2 of the National Range and Pasture Handbook for additional guidance.

Adequate quantity and quality of drinking water will be supplied at all times during periods of occupancy.

Intensity, frequency of defoliations, timing, season of grazing, and duration of grazing and/or browsing will be adjusted to meet the desired objectives for the plant communities and the associated resources, including the grazing and/or browsing animal. The length of the grazing period should be based on the length of the rest period needed for recovery of the forage resource and reduction of second bite opportunity.

Manage kind of animal, animal number, grazing distribution, length of grazing and/or browsing periods, and timing of use to provide grazed plants sufficient recovery/rest time to meet planned objectives. The recovery/rest period of non-grazing can be provided for the entire year or during the growing season of key plants. Deferment (non-grazing period less than one year) and/or rest (non-grazing period equal to or greater than one year) will be planned for critical periods of plant needs. Refer to Table 2 and the Illinois Graze4 Worksheets for additional guidance.

Provide deferment or rest from grazing or browsing to ensure the success of prescribed fire, brush management, seeding or other conservation practices that cause stress or damage to key plants.

Protect soil, water, air, plant and animal resources when locating livestock feeding, handling, and watering facilities.

Plan the placement of supplemental feeds (salt, mineral and other supplementation feeders) away from water and shade sources to distribute livestock throughout the pasture and encourage uniform grazing.

Manage grazing and/or browsing animals to maintain adequate vegetative cover on sensitive areas (i.e. riparian, wetland, habitats of concern, and karst areas).

Develop contingency plans (i.e. having extra feed on hand, reducing stocking rate, providing adequate water during a drought, etc…) to deal with expected episodic disturbance events (i.e.. flooding, drought, insect infestations, wildfire, etc…).

Manage livestock movements based on plant growth, available forage, and allowable utilization target; and not calendar dates.

Additional Criteria to Improve or Maintain the Health and Vigor of Plant Communities

Duration and intensity of grazing and/or browsing will be based on desired plant health and expected productivity of key forage species to meet management objectives. Refer to Tables 1 and 2 for rest period guidance.

Plan periodic deferment from grazing and/or browsing to maintain or restore the desired plant community following episodic events, such as flooding, wildfire or severe drought.

Where appropriate, soil test periodically for nutrient status and soil reaction and apply fertilizer and/or soil amendments accordingly to improve or maintain plant vigor. For soil sampling and testing guidelines, refer to the Grazing in Illinois Manual. Composite samples should be collected by field. No composite sample should represent more than 20 acres for pastures that are uniform and 10 acres for pastures that are non-uniform. Additional samples should be collected where soil types, topography, or other features are non-uniform. Composite samples are obtained by collecting at least 15-20 sub-samples.

Incorporate at least 30% legumes (20% for sheep pastures), by weight, into grass pastures to provide for a nitrogen source for the pasture. Note: 30% legumes by weight would visually appear as about 60% cover when looking across the pasture.

Grazing use on native warm season grasses and grass like species will not remove more than 50 percent, by weight, of the current year's growth of the identified key grazing species when grazed during the growing season, and not more than 60 percent when grazed during the dormant season. Table 1 can be utilized as a tool to help determine the percent of weight removed of common grasses by estimating the percent of the plant height removed.

Grazing use, for sustainable management purposes, on browse (woody) species will not remove more than 65 percent of the current years' growth of the designated key browse species.

Grazing use on pasturelands; the designated key species will not be grazed closer than the minimum plant heights shown in Table 1. Also, grazing use should not be initiated on pastureland until the designated key species has reached the minimum height shown in Table 1. To maintain the health and vigor of the designated key species, these species should attain the minimum plant height as shown in Table 1 before the first killing frost.

All domestic grazing animals must be removed from the grassland unit being deferred.

In some cases the planned grazing sequence may be changed for short periods to take advantage of rapid spring growth and seasonal forages such as annual forages, crop aftermath, etc.

Additional criteria to Improve or Maintain Quantity and Quality of Forage for Grazing and Browsing Animals' Health and Productivity

Movement of animals will be scheduled to improve and/or maintain animal health and performance and to reduce or prevent the spread of disease, parasites, and contact with harmful insects and toxic plants.

Plan grazing and/or browsing to match forage goals of the producer for quantity and quality within the capability of the resource to respond to management.

Supplemental feed and/or minerals will be balanced with the forage consumption to meet the desired nutritional level for the kind and class of grazing and/or browsing livestock.

Dietary needs of livestock will be based on the National Research Council's Nutrient Requirements of Domestic Animals or similar scientific sources (Refer to USDA Natural Resources Conservation Service computer program "NUTBAL" and the GANLAB http://cnrit.tamu.edu/ganlab/ for more detailed information). Appropriate adjustments need to be made for increased energy demand required by browsing or grazing animals foraging for food including travel to and from pasture site.

Shelter in the form of windbreaks, sheds, shade structures, and other protective features will be used where conditions warrant protecting livestock from severe weather, intense heat/humidity, and/or predators. For more information see Conservation Practice Standard Windbreak/Shelterbelt Establishment (Code 380).

The grazing manager needs to initiate a monitoring program to document actual grazing dates, livestock performance, climatic conditions, vegetation utilization, and changes in plant communities over time. Monitoring is needed to analyze results and to develop the following years grazing schedule. IL 528-1 Documentation Record for Grazing Management, the current NRCS Pasture Condition Score Sheet, or other record keeping systems should be used to aid in record keeping.

When multiple pastures are grazed in rotation, begin grazing in a different pasture each year.

On pastureland, grassland, rangelands, or native pasture, provide grazing and rest periods to meet the desired objectives for plant communities and associated resources in each pasture including the grazing animals. Refer to Table 1 for minimum and maximum grazing heights and dates to begin rest for the winter protection. Use Table 2 for grazing and rest periods during the growing season.

Where applicable, biosecurity safeguards will be put in place to prevent the spread of disease between on-farm or ranch classes of livestock and between livestock farm or ranch units.

Additional Criteria to Improve or Maintain Surface and/or Subsurface Water Quality and Quantity

Minimize concentrated livestock areas to enhance nutrient distribution and improve or maintain ground cover. Locate loafing areas, watering facilities, feeding locations (including winter feeding areas), and sacrifice areas away from waterbodies, and maintain adequate, vegetated buffers between concentration areas and waterbodies.

Plan intensity, frequency, timing and duration of grazing and/or browsing to:

- Minimize deposition or flow of animal wastes into water bodies,
- Minimize animal impacts on stream bank or shoreline stability.
- Provide adequate ground cover and plant density to maintain or improve infiltration capacity, reduce runoff, and reduce evaporation.
- Provide adequate ground cover and plant density to maintain or improve filtering capacity of the vegetation.
- Plan animal access points away from shade.

Additional Criteria to Improve or Maintain Riparian and Watershed Function

Minimize concentrated livestock areas to enhance nutrient distribution and improve or maintain ground cover and riparian/floodplain plant community structure and functions.

Plan Intensity, frequency, timing, and duration of grazing and/or browsing to provide adequate ground cover and plant density to maintain or improve infiltration capacity, reduce runoff, and filtering capacity of the vegetation.

Exclude livestock or practice flash grazing of paddocks adjacent to or perpendicular across streams. Remove livestock when recommended stubble height is attained (Refer to Table 1).

Plan animal access points away from shade.

Maintain adequate riparian community structure and function to sustain associated riparian, wetland, floodplain and stream species.

Additional Criteria to Reduce Accelerated Soil Erosion and Maintain or Improve Soil Condition

Minimize concentrated livestock areas, trailing, and trampling to reduce soil compaction, excess runoff, and erosion.

Maintain the amount of vegetative cover needed to prevent accelerated soil erosion due to wind and/or water erosion. Refer to recommended minimum grazing plant heights in Table 1.

Duration, intensity, frequency, and season of grazing and/or browsing shall be managed to minimize soil compaction, sustain high levels of vegetative cover, and reduce detrimental effects on soil condition. Refer to grazing and rest periods recommended in Table 2.

Additional Criteria to Improve or Maintain the Quantity and Quality of Food and/or Cover Available for Wildlife

Identify species of concern in the objectives of the prescribed grazing plan.

Plan intensity, frequency, timing and duration of grazing and/or browsing to provide for the development and maintenance of the plant structure, density and diversity needed for the desired fish and wildlife species of concern. See Conservation Practice Standard Upland Wildlife Habitat Management (Code 645).

When needed, the prescribed grazing plan will be designed to result in the plant community meeting the needs of the animals of concern as to cover, shelter, food, nesting cover, water, etc... The habitat management guides in the FOTG should be used to provide assistance in writing the plan.

Additional Criteria to Manage Fine Fuel Loads to Achieve Desired Conditions

Intensity, frequency, timing and duration of grazing and/or browsing will be planned to reduce hazardous fuel loads.

Intensity, frequency, timing and duration of grazing and/or browsing will be planned to manage fuel continuity, load, and other conditions in order to facilitate prescribed burns. See Conservation Practice Standard Prescribed Burning (Code 338).

CONSIDERATIONS

Protect soil, water, air, plant and animal resources when locating livestock feeding, supplement, handling, and watering facilities.

Livestock feeding, handling, and watering facilities will be designed and installed in a manner to improve and/or maintain animal distribution. Facilities will be designed and installed to minimize stress, the spread of disease, parasites, and contact with harmful organisms and toxic plants.

Avoid grazing riparian areas when soils are saturated. Graze only in times when vegetation will recover. Consider using lighter weight animals for creep grazing of riparian areas to reduce impact on vegetation.

Consider a grazing system that provides forage for as much of the year as possible to minimize supplemental feed cost (i.e. crop aftermath, summer and winter annuals, native warm season grasses, and stockpiling).Consider a grazing system that incorporates the use of native, warm season grasses for drought tolerance, wildlife habitat, or to meet forage needs during the summer when cool season grasses are not at peak production.

Consider strip grazing to improve harvest efficiency and prolong grazing days.

Consider locating winter feeding areas away from waterbodies, on lower slopes, and in a location central to grazing acres.

Consider using natural or artificial shelter as part of the Prescribed Grazing practice when appropriate.

Design the grazing program to the cooperator's goals and resources. Animal husbandry requirements (breeding programs, etc.) may affect the design of the grazing plan and need to be considered.

Stubble heights can be used in conjunction with monitoring to ensure resource conservation and producer objectives are met. For guidance see Table 1.

Where practical and beneficial, start the grazing sequence in a different management unit each growing season.

When weeds are a problem prescribed grazing and/or browsing should be implemented in conjunction with other pest or brush management practices to promote resistance to invasive or noxious species and maintain desired plant communities.

Prescribed Grazing should consider the needs of other enterprises utilizing the same land such as wildlife and recreational uses.

Consider improving carbon sequestration in biomass and soils through management of grazing and/or browsing.

PLANS AND SPECIFICATIONS

A Prescribed Grazing Plan will be prepared for the operating unit or portion of an operating unit being addressed. The plan will be recorded in a manner that is readily understood and usable by the decision maker. The content of the documentation will depend upon the size and complexity of the operating unit and the details required for the grazing plan.

A prescribed grazing plan will include the following information:

1. Goals and objectives clearly stated

2. Resource Inventory (The 528 Illinois inventory worksheet or other worksheets will be used for documentation) that identifies:

    a. existing resource conditions and concerns. (The current Pasture Condition Scoresheet is to be used to document this.)

    b. ecological site or forage suitability group if available

    c. identifies opportunities to enhance resource concerns

    d. location and condition of structural improvements such as fences, water developments, etc. including seasonal availability and quality of watering sites.

3. An inventory (Forage Inventory) of the expected forage quantity, quality, time of availability and species for each management unit. Also, document any special problems inventoried such as location of toxic plants, invasive plants, etc. (The Illinois Graze4 Worksheets or other comparable worksheets will be used to document items 3-5).

4. For each kind and class of domestic livestock and grazing/browsing wildlife species of concern, document the animal numbers and forage demands by month, nutritional surpluses, and deficiencies from the forage resources and supplemental feed requirements needed to meet the desired nutritional level. Also, document any special needs of animals such as nesting cover, etc.

5. Development of a planned grazing schedule for livestock which identifies periods of grazing, resting, and other treatment activities, or needs, for each management unit. The grazing schedule is to be used as a guide and cannot take the place of daily observations which reflect changing climatic conditions and changes in supply and demand. Refer to Tables 1 thru 3 and the National Range and Pasture Handbook for additional guidance.

6. A contingency plan that details potential problems (i.e., flooding, drought, insects, etc...) and guidelines for adjusting the grazing prescription to insure resource goals are achieved in an economically feasible manner without resource degradation.

7. Monitoring plan developed with appropriate records to assess whether the grazing strategy is meeting objectives. Identify the key areas and key plants that the manager should evaluate when making grazing management decisions.

8. IL-528-1 Documentation Record for Grazing Management or other record keeping systems will be used to document annual grazing information.

Stocking Rates

Appropriate estimated stocking rates will be calculated and used as a guide to aid in determining forage supply and demand (Refer to the Illinois Graze4 Worksheets, or other appropriate tools).

Adjust livestock numbers and/or grazing time to match forage demand to forage yield.

Harvest Efficiency

The length of the grazing cycle determines the harvest efficiency. The shorter the grazing cycles are below 7 days the higher the harvest efficiency.

Harvest efficiency will be optimized based on the objectives and goals of the client.

Grazing and Rest Period

A prescribed grazing plan includes minimum grazing heights from Table 1, a balance with forage growth by the month from Table 3 and min/max rest and grazing periods from Table 2, to sustain the proper forage growth and longevity. When grazing the first one or two pastures in the spring, beginning minimum heights can be lower than the recommended height.

The following formulas are used to estimate animal numbers or grazing days:

$$\textbf{A.N.} = \frac{\textbf{T.F.P./Ac. X Ac. X \%H.E.}}{\textbf{A.W. X I.R. X Days}} \qquad \textbf{Days} = \frac{\textbf{T.F.P./Ac. X Ac. X \%H.E.}}{\textbf{A.W. X I.R. X A.N.}}$$

A.N. = Animal Number

T.F.P. = Total Forage Production (Total above ground biomass in lbs./acre dry weight)

Ac. = Acres

% H.E. = % Harvest Efficiency

- continuous grazing = 25%-30%
- 7 day grazing period = 35%
- 6 day grazing period = 40%
- 5 day grazing period = 45%
- 4 day grazing period = 50%
- 3 day grazing period = 55%
- 2 day grazing period = 60%
- 1 day grazing period = 65%
- ½ day grazing period = 70–75%

A.W. = Animal weight (pounds)

I.R. = Intake Rate in % body weight

Guide:

Dry cow	2.0%
Annual ave. production, Beef	2.6%
Lactating cows	3–4%
Dairy cows	2.5-3.5 + grain
Lactating sheep/goats	3.5-4%
Dry sheep/goats	3%
Doelings/ewes	3%
Horses	2-3% + grain

Days = Days of grazing planned

During rapid growth, short rest periods are necessary; as growth slows rest periods need to be lengthened. (See TABLE 2 for minimum and maximum rest periods)

$$GP = \frac{\text{Rest Period needed in days}}{\text{No. of pasture} - \text{No. of herds}}$$

(GP = Grazing Period)

Remove all livestock from a resting pasture.

Begin grazing sequence each year in a different pasture.

Livestock Stress

Systems shall be developed that subject animals to a minimum amount of handling stress.

Livestock water shall be provided that is adequate in quantity and quality.

OPERATION AND MAINTENANCE

Operation: Prescribed Grazing will be applied on a continuing basis throughout the grazing period for all planned grazing units.

Adjustments will be made as needed to ensure that the goals and objectives of the grazing plan are met.

Maintenance: Evaluations of the current grazing plan should be made periodically to monitor the results of the plan on all of the resources and for the planned goals and objectives. If the planned goals or objectives are not being met or there is degradation of any of the resources including animal performance, the plan needs to be adjusted accordingly.

All facilitating and accelerating practices (i.e. Fence (382), Herbaceous Weed Control (315), Integrated Pest Management (595), Brush Management (314), Forage and Biomass Planting (512), etc.) that are needed to effect adequate grazing and/or browsing distribution will be maintained in good working order and will be operated as intended.

REFERENCES

Barnes, R.F., D.A. Miller, and C.J. Nelson. 1995. Forages, The Science of Grassland Agriculture, 5th Ed. Iowa State University Press, Ames, IA.

Bedunah, D. J. and R. E. Sosebee, Editors. 1995. Wildland Plants. Physiological Ecology and Developmental Morphology. Society for Range Management, Denver, CO.

Heitschmidt, R. K. and J. W. Stuth eds. 1991. Grazing Management an Ecological Perspective. Timber Press

Hodgson, J. and A.W. Illius. Editors. 1996. Ecology and Management of Grazing Systems. CABI, Wellingford, UK.

Holechek, J. L., R. D. Pieper and C. H. Herbel. 2000. Range management principles and practices. 5th edition. Prentice Hall, NJ.

Smith, D., R.J. Bula, and R.P. Walgenbach. 1986. Forage Management 5th ed. Kendall/Hunt Publ. Co Dubuque, Iowa.

Vallentine, J.F. 2001. Grazing management. Academic Press, San Diego, CA.

Voisin, A. 1959. *Grass productivity*. Philosophical Library, New York.

USDA - NRCS (SCS) Forage Production and Management Reference Manual.

USDA - NRCS Grazing in Illinois Manual. http://www.il.nrcs.usda.gov/technical/grazing/GrzMan.html

United States Department of Agriculture, Natural Resources Conservation Service. 2003. National Range and Pasture Handbook. Washington, DC.

TABLE 1: Minimum Heights of Forage Species for Initiating and Terminating Grazing

SPECIES AND MIXTURES	**Minimum/ Optimum Height of Vegetative Growth 1/**	**Minimum Grazing Height 2/**	**Minimum Regrowth Before Killing Frost**	**Approximate Date to Begin Rest for Winter protection, by Plant Suitability Zones 3/**		
COOL SEASON (C3s)	INCHES Begin Grazing	INCHES End Grazing	INCHES	I	II	III
Alfalfa	10	3	6	9/1-10/1	9/15-10/15	9/20-10/20
Annual Crabgrass	8	3	6	9/1-10/1	9/1-10/1	9/1-10/1
Annual Lespedeza	8	4	5/	9/1-10/1	9/15-10/15	9/20-10/20
Annual Lespedeza with Orchardgrass or Tall Fescue	8	4	8	9/1-10/1	9/15-10/15	9/20-10/20
Birdsfoot Trefoil	10-12	5-6	5	9/1-10/1	9/15-10/15	9/20-10/20
Brassicas (Turnips, Radishes, Kale, etc… Fall	12-14	4	NA	NA	NA	NA
Chicory	6	2	6	9/1-10/1	9/15-10/15	9/20-10/20
Kentucky Bluegrass, Perennial Ryegrass	4-6	2-3	4	4/	4/	4/
Kentucky Bluegrass, Perennial Ryegrass with a clover legume	4-6	4	5	9/1-10/1	9/15-10/15	9/20-10/20
Ladino White Clover	8	3	6	9/1-10/1	9/15-10/15	9/20-10/20
Orchardgrass, Tall Fescue and other non-jointed grasses	8	3	6	4/	4/	4/
Orchardgrass, Tall Fescue and other non-jointed grasses with a clover legume	6-8	3	8	9/1-10/1	9/15-10/15	9/20-10/20
Orchardgrass, Tall Fescue and other non-jointed grasses with Alfalfa	8-10	3	8	9/1-10/1	9/15-10/15	9/20-10/20
Pearl Millet	18-20	4-6	NA	NA	NA	NA
Red and Alsike Clover	8-10	3	8	9/1-10/1	9/15-10/15	9/20-10/20
Reed Canarygrass 7/	8	4	6	9/1-10/1	9/15-10/15	9/20-10/20
Reed Canarygrass with a legume	8	4	6	9/1-10/1	9/15-10/15	9/20-10/20
Small Grains	8-10	3	NA	NA	NA	NA
Sorghum-Sudangrass	18-24	8-10	NA	NA	NA	NA
Timothy, Smooth Bromegrass and other jointed grasses	8	4	8	9/1-10/1	9/15-10/15	9/20-10/20
Timothy, Smooth Bromegrass and other jointed grasses with a legume	8	4	8	9/1-10/1	9/15-10/15	9/20-10/20
WARM SEASON (C4s)						
Big Bluestem	18	8 6/	10	9/10-10/10	9/15-10/15	9/20-10/20
Eastern Gamagrass	20	10	15	9/10-10/10	9/15-10/15	9/20-10/20
Indiangrass	18	8 6/	10	9/10-10/10	9/15-10/15	9/20-10/20
Switchgrass	18	8 6/	10	9/10-10/10	9/15-10/15	9/20-10/20

1/ Minimum plant heights are to be reached before grazing is permitted or following a rest period resulting from rotational grazing. When grazing the first one or two pastures in the spring, beginning minimum heights can be lower than the recommended height.
2/ Minimum plant heights below which grazing is not permitted.
3/ Protection from fall grazing is required for one month before a killing frost. Remove livestock on or before the dates shown and do not permit grazing before a killing frost occurs.
4/ No restrictions.
5/ Allow to set seed during growing season
6/ Leave a 10" stubble at end of grazing season until after first killing frost
7/ Reed Canarygrass is not recommended for use in pastures due to wildlife concerns and its invasive nature. If present it is recommended that the pasture be renovated, otherwise the grazing guidelines above for management should be followed.

TABLE 2: Grazing Management Guidelines.

Pasture Kind	Min-Max Grazing Periods (days) 1/	Min-Max Rest Periods (days) 2/	Minimum Pastures Needed (number) 3/
Single Species - 1 specie planting (essentially a monoculture)			
Introduced:			
cool season	10 - 22	20 - 45	3
warm-season	10 - 22	20 - 45	3
legume	6 - 9	25 - 35	5
Native:			
warm-season	1 -17	20 - 50	4
Simple Mixtures - 2 - 4 similar species and/or legumes			
Introduced:			
cool-season	8 -15 / 6 - 11	25 - 45	4/5 w/legumes
warm-season	8 -15 / 6 - 11	25 - 45	4/5 w/legumes
Native:			
warm-season	8 -12	30 - 50	5
Complex Mixtures - 5 or more dissimilar species			
Introduced:			
cool-season	5 - 9	25 - 45	6
warm-season	5 - 9	25 - 45	6
Native			
warm-season	4 - 7	30 - 50	8

1/ "Min-Max Grazing Periods" are determined by the Min-Max Rest Period necessary for adequate recovery of the pasture following grazing, and also limits second bite opportunity. However, second bites occur if livestock are left in a pasture longer than 5 days.

2/ "Min-Max Rest Periods" provide time for pastures to recover from grazing. The pasture's potential growth rate and current growing conditions regulate the length of the rest period. (rapid growth, rapid rotation - slow growth, slow rotation.

3/ "Minimum Pastures Needed" is a relationship between necessary rest period and appropriate grazing period. Increasing pasture numbers reduces length of grazing period; increases pasture rest time, improves harvest efficiency, and provides higher forage quality. A minimum of three pastures must be included in the plan to meet prescribed grazing standards for grass pastures and a minimum of five pastures for pastures containing grass legume mixtures.

TABLE 3-1. FORAGE PRODUCTION

	Total	Percent of Total Yield Available in Each Month**												
Pasture/Forage Type*	Yield**	%Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
Northern IL (NRCS Plant Suitability Zone 1) -- Optimum Management***														
Alfalfa	6.00				5	23	24	18	15	10	5			100
Alfalfa/Orchardgrass	5.50				6	23	24	18	13	11	5			100
Alfalfa/Smooth Bromegrass	5.20				6	23	24	18	13	11	5			100
Big Bluestem	3.40					3	14	37	32	14				100
Big Bluestem/Indiangrass	3.40					3	12	37	36	12				100
Birdsfoot Trefoil/cool season grass	3.40				5	14	32	23	12	8	6			100
Bluegrass, Kentucky/Dutch Wh. Clover	3.60				8	28	29	9	7	12	7			100
Bluegrass, KY/Tall Fescue/Ladino Cl.	4.20				9	20	20	17	10	11	11	2		100
Bluegrass, KY/Orchardgrass/Ladino Cl.	4.20				7	23	24	16	10	14	6			100
Bluegrass, KY/Orchardgrass/Red Cl.	4.50				6	19	24	20	12	14	5			100
Bluegrass, KY/Tall Fescue/Red Cl.	4.50				5	20	20	19	11	13	10	2		100
Bromegrass, Smooth	4.50				8	31	27	11	6	11	6			100
Bromegrass, Smooth/Ladino Clover	4.80				8	25	25	15	10	10	7			100
Bromegrass, Smooth/Red Clover	5.10				8	22	25	15	15	10	5			100
Brush, (for Goat pasture)	1.60				4	25	28	28	10	5				100
Brush, Grass, and Forbes for Goats	3.20				5	23	23	22	15	9	3			100
Chicory	3.00				5	11	32	24	13	10	5			100
Corn (Green Grazed)	5.80					10	40	40	10					100
Corn Stalk Residue	2.00										100			100
Eastern Gama Grass	5.50					8	30	35	22	5				100
Fescue, Tall (not stockpiled)	4.80				9	26	25	13	7	12	6	2		100
Fescue, Tall (stockpiled)	5.50				9	20	20	13	8	15	13	2		100
Fescue, Tall/Ladino Clover	4.90				9	20	23	15	10	11	10	2		100
Fescue, Tall/Red Clover	5.30				5	20	20	19	11	13	10	2		100
Fescue, Tall/Red Clover (stock piled)	5.70				5	20	20	10	10	15	15	5		100
Indiangrass	3.40					2	12	34	38	14				100
Millet, Pearl	4.50					1	15	31	31	19	3			100
Oats (August seeding)	1.60								12	40	40	8		100
Oats (March-April seeding)	2.90				20	35	35	10						100
Orchardgrass	4.50				7	27	20	14	12	13	7			100
Orchardgrass/Ladino Clover	4.70				9	23	23	14	11	15	5			100
Orchardgrass/Red Clover	4.80				5	20	23	19	13	15	5			100
Orchardgrass/Red Clover (stockpiled)	5.50				5	20	20	10	10	15	15	5		100
Orchardgrass/Tall Fescue/Ladino Clover	5.20				9	22	22	14	7	11	13	2		100
Orchardgrass/Tall Fescue/Red Clover	5.50				5	20	21	18	12	13	8	3		100
Red Clover	3.50				6	25	33	17	9	6	3	1		100
Reed Canarygrass	4.40				5	19	27	20	12	11	5	1		100
Rye, Cereal (Aug. seeded)	2.10			3	22	28	10		5	15	10	7		100
Ryegrass, Italian/Annual (Aug. seeded)	2.00				15	30	20	5		2	10	13	5	100
Ryegrass, Perennial/Ladino Clover	4.50				8	30	25	12	5	10	7	3		100
Ryegrass, Perennial/Red Clover	4.80				5	22	25	18	8	10	10	2		100
Sorghum-sudangrass	4.70					1	13	32	34	20				100
Switchgrass	3.90					11	24	32	23	10				100
Timothy	3.50				8	23	34	10	6	14	5			100
Triticale, Fall seeded	3.10			2	23	30	10		5	15	10	5		100
Turnips (Aug. seeded)	3.20								12	38	35	15		100
Turnips/C. Rye (Aug. seeded)	5.80			3	22	25			5	15	15	10	5	100
Turnips/C. Rye/Oats (Aug. seeded)	3.80			5	25	20			5	15	15	10	5	100
Turnips/Oats (Aug. seeded)	3.90								12	38	35	15		100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences (disease resistance, winter hardiness, environmental factors, etc.) between varieties will exist and these differences, are not reflected in the yield and monthly production.

***Optimum Management: A high plant density exists; pH., P, & K are at optimal levels; nitrogen is applied to grass dominant paddocks; undesirable weeds are controlled; and controlled grazing (rotational or MIG) is practiced.

TABLE 3-2. FORAGE PRODUCTION

Pasture/Forage Type*	Total Yield**	%Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
		Percent of Total Yield Available in Each Month**												
Northern IL (NRCS Plant Suitability Zone 1) -- Average Management***														
Alfalfa	3.90				5	23	24	18	15	10	5			100
Alfalfa/Orchardgrass	3.60				6	23	24	18	13	11	5			100
Alfalfa/Smooth Bromegrass	3.40				6	23	24	18	13	11	5			100
Big Bluestem	2.50					3	14	37	32	14				100
Big Bluestem/Indiangrass	2.50					3	12	37	36	12				100
Birdsfoot Trefoil/cool season grass	2.20				5	14	32	23	12	8	6			100
Bluegrass, Kentucky/Dutch Wh. Clover	2.30				8	28	29	9	7	12	7			100
Bluegrass, KY/Tall Fescue/Ladino Cl.	2.70				9	20	20	17	10	11	11	2		100
Bluegrass, KY/Orchardgrass/Ladino Cl.	2.70				7	23	24	16	10	14	6			100
Bluegrass, KY/Orchardgrass/Red Cl.	3.00				6	19	24	20	12	14	5			100
Bluegrass, KY/Tall Fescue/Red Cl.	3.00				5	20	20	19	11	13	10	2		100
Bromegrass, Smooth	3.00				8	31	27	11	6	11	6			100
Bromegrass, Smooth/Ladino Clover	3.10				8	25	25	15	10	10	7			100
Bromegrass, Smooth/Red Clover	3.40				8	22	25	15	15	10	5			100
Brush, (for Goat pasture)	2.60				4	25	28	28	10	5				100
Brush, Grass, and Forbes for Goats	3.10				5	23	23	22	15	9	3			100
Chicory	2.00				5	11	32	24	13	10	5			100
Corn (Green Grazed)	3.90					15	35	40	10					100
Corn Stalk Residue	2.00										100			100
Eastern Gama Grass	3.60					8	30	35	22	5				100
Fescue, Tall (not stockpiled)	3.10				9	26	25	13	7	12	6	2		100
Fescue, Tall (stockpiled)	3.50				9	20	20	13	8	15	13	2		100
Fescue, Tall/Ladino Clover	3.00				9	20	23	15	10	11	10	2		100
Fescue, Tall/Red Clover	3.50				5	20	20	19	11	13	10	2		100
Fescue, Tall/Red Clover (stock piled)	3.80				5	20	20	10	7	15	15	8		100
Indiangrass	2.50					2	12	34	38	14				100
Millet, Pearl	3.00					1	15	31	31	19	3			100
Oats (August seeding)	1.10								12	40	40	8		100
Oats (March-April seeding)	1.80				20	35	35	10						100
Orchardgrass/Tall Fescue/Ladino Clover	3.40				9	22	22	14	7	11	13	2		100
Orchardgrass/Tall Fescue/Red Clover	3.50				5	20	21	18	12	13	8	3		100
Orchardgrass	3.00				7	27	20	14	12	13	7			100
Orchardgrass/Ladino Clover	3.00				9	23	23	14	11	15	5			100
Orchardgrass/Red Clover	3.10				5	20	23	19	12	16	5			100
Orchardgrass/Red Clover (stockpiled)	3.50				5	20	20	10	10	15	15	5		100
Red Clover	2.30				6	25	33	17	9	6	3	1		100
Reed Canarygrass	2.90				5	19	27	20	12	11	5	1		100
Rye, Cereal (Aug. seeded)	1.30			3	22	28	10		5	15	10	7		100
Ryegrass, Perennial/Ladino Clover	3.00				8	30	25	12	5	10	7	3		100
Ryegrass, Perennial/Red Clover	3.10				5	22	25	18	8	10	10	2		100
Ryegrass, Italian/Annual (Aug. seeded)	1.30			15	30	20	5			2	10	13	5	100
Sorghum-sudangrass	3.00					1	13	32	34	20				100
Switchgrass	2.60					11	24	32	23	10				100
Timothy	2.20				8	23	34	10	6	14	5			100
Triticale, Fall seeded	2.10			2	23	30	10		5	15	10	5		100
Turnips (Aug. seeded)	2.10								12	38	35	15		100
Turnips/C. Rye (Aug. seeded)	3.90			3	22	25			5	15	15	10	5	100
Turnips/C. Rye/Oats (Aug. seeded)	2.50			5	25	20			5	15	15	10	5	100
Turnips/Oats (Aug. seeded)	2.60								12	38	35	15		100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences (disease resistance, winter hardiness, environmental factors, etc.) between varieties will exist and these differences, are not reflected in the yield and monthly production.

***Average Management: Bare or open soil areas exist in paddocks; pH., P, & K are below optimal levels; nitrogen is not applied to grass dominant paddocks; undesirable weeds are not controlled; and paddocks receive limited rest periods.

TABLE 3-3. FORAGE PRODUCTION

Pasture/Forage Type*	Total Yield**	%Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
		Percent of Total Yield Available in Each Month**												
Central IL (NRCS Plant Suitability Zone 2) -- Optimum Management***														
Alfalfa	5.60			2	8	19	21	15	10	16	7	2		100
Alfalfa/Orchardgrass	5.20			3	9	21	20	13	8	10	12	4		100
Alfalfa/Smooth Bromegrass	4.90			4	10	25	20	10	7	9	12	3		100
Big Bluestem	3.90					10	33	32	20	5				100
Big Bluestem/Indiangrass	3.90					8	20	27	30	15				100
Birdsfoot Trefoil/cool season grass	3.40			2	9	22	23	16	10	10	7	1		100
Bluegrass, Kentucky/Dutch Wh. Clover	3.00			2	14	28	21	6	4	7	12	6		100
Bluegrass, KY/Tall Fescue/Ladino Cl.	4.70			2	11	20	21	12	8	9	13	4		100
Bluegrass, KY/Orchardgrass/Ladino Cl.	4.40			1	9	21	24	12	9	10	10	4		100
Bluegrass, KY/Orchardgrass/Red Cl.	4.80			1	5	22	24	12	9	13	10	4		100
Bluegrass, KY/Tall Fescue/Red Cl.	4.90			3	9	20	19	14	9	10	12	4		100
Bromegrass, Smooth	3.90			2	15	23	20	10	6	8	10	6		100
Bromegrass, Smooth/Ladino Clover	4.30			3	10	23	23	9	7	8	12	5		100
Bromegrass, Smooth/Red Clover	4.90			2	8	22	23	10	9	10	12	4		100
Brush, (for Goat pasture)	1.60				5	28	29	25	7	6				100
Brush, Grass, and Forbes for Goats	3.30			2	12	21	22	12	9	10	8	4		100
Chicory	3.30				7	19	20	20	13	15	6			100
Corn (Green Grazed)	5.80					15	25	25	25	10				100
Corn Stalk Residue	1.90										100			100
Crabgrass, Annual	1.90					5	23	30	22	15	5			100
Eastern Gama Grass	5.30					12	21	31	25	8	3			100
Fescue, Tall/Lespedeza	5.10			2	10	17	16	13	11	11	14	5	1	100
Fescue, Tall (not stockpiled)	5.00			5	16	20	20	8	5	10	13	3		100
Fescue, Tall (stockpiled)	5.70			5	15	17	16	8	5	12	13	8	1	100
Fescue, Tall/Ladino Clover	4.90			2	15	18	21	10	8	9	12	4	1	100
Fescue, Tall/Red Clover	5.20			2	12	20	19	12	8	10	12	4	1	100
Fescue, Tall/Red Clover (stockpiled)	5.70			2	10	17	20	15	6	12	14	3	1	100
Indiangrass	3.90					7	15	30	32	12	4			100
Millet, Pearl	4.60					9	25	30	25	10	1			100
Oats (August seeding)	2.00								10	35	35	20		100
Oats (March/April seeding)	2.70			8	25	37	29	1						100
Orchardgrass	4.40			5	15	21	20	9	7	10	10	3		100
Orchardgrass/Ladino Clover	4.70			5	15	23	22	7	7	9	10	2		100
Orchardgrass/Red Clover	4.80			3	12	20	19	12	8	10	12	4		100
Orchardgrass/Red Clover (stockpiled)	5.50			2	10	17	17	15	6	15	15	3		100
Orchardgrass/Tall Fescue/Ladino Clover	5.10			7	18	21	20	7	7	8	9	3		100
Orchardgrass/Tall Fescue/Red Clover	5.30			5	10	20	21	14	9	10	8	3		100
Red Clover	3.80			4	9	23	24	16	9	8	6	1		100
Reed Canarygrass	4.70			4	14	21	21	12	7	12	9			100
Rye, Cereal (Aug. seeded)	2.90		5	14	28	21	2			2	10	12	6	100
Ryegrass, Italian/Annual (Aug. seeded)	2.60		1	15	30	20	5			8	14	6	1	100
Ryegrass, Perennial/Ladino Clover	4.60			7	21	20	15	5	5	9	12	6		100
Ryegrass, Perennial/Red Clover	4.90			5	13	25	18	9	4	10	10	6		100
Sorghum-sudangrass	5.30					1	12	31	31	23	2			100
Switchgrass	4.60					15	34	28	18	5				100
Timothy	3.50			2	12	29	30	6	5	11	5	0		100
Triticale, Fall seeded	3.40			3	32	30	10			5	15	5		100
Turnips (Aug. seeded)	3.60								5	35	35	23	2	100
Turnips/C. Rye (Aug. seeded)	5.70		3	30	20	10			2	10	15	8	2	100
Turnips/C. Rye/Oats (Aug. seeded)	4.70		2	15	28	21			2	10	15	5	2	100
Turnips/Oats (Aug. seeded)	4.20								5	35	35	23	2	100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences (disease resistance, winter hardiness, environmental factors, etc.) between varieties will exist and these differences, are not reflected in the yield and monthly production.

***Optimum Management: A high plant density exists; pH., P, & K are at optimal levels; nitrogen is applied to grass dominant paddocks; undesirable weeds are controlled; and controlled grazing (rotational or MIG) is practiced.

TABLE 3-4. FORAGE PRODUCTION

Pasture/Forage Type*	Total Yield**	Percent of Total Yield Available in Each Month** %Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
Central IL (NRCS Plant Suitability Zone 2) -- Average Management***														
Alfalfa	3.60			2	8	19	21	15	10	16	7	2		100
Alfalfa/Orchardgrass	3.40			3	9	21	20	13	8	10	12	4		100
Alfalfa/Smooth Bromegrass	3.10			4	10	25	20	10	7	9	12	3		100
Big Bluestem	2.70					10	33	32	20	5				100
Big Bluestem/Indiangrass	2.70					8	20	27	30	15				100
Birdsfoot Trefoil/cool season grass	2.30			2	9	22	23	16	10	10	7	1		100
Bluegrass, Kentucky/Dutch Wh. Clover	2.10			2	14	28	21	6	4	7	12	6		100
Bluegrass, KY/Tall Fescue/Ladino Cl.	2.90			2	11	20	21	12	8	9	13	4		100
Bluegrass, KY/Orchardgrass/Ladino Cl.	2.90			1	9	21	24	12	9	10	10	4		100
Bluegrass, KY/Orchardgrass/Red Cl.	3.10			1	5	22	24	12	9	13	10	4		100
Bluegrass, KY/Tall Fescue/Red Cl.	3.30			2	9	20	19	14	9	10	13	4		100
Bromegrass, Smooth	2.30			2	15	23	20	10	6	8	10	6		100
Bromegrass, Smooth/Ladino Clover	2.60			3	10	23	23	9	7	8	12	5		100
Bromegrass, Smooth/Red Clover	3.10			2	8	22	23	10	9	10	12	4		100
Brush, (for Goat pasture)	1.30				5	28	29	25	7	5	1			100
Brush, Grass, and Forbes for Goats	2.30			2	12	21	22	12	9	10	8	4		100
Chicory	2.30				7	19	20	20	13	15	6			100
Corn (Green Grazed)	4.60					10	30	30	20	10				100
Corn Stalk Residue	2.00										100			100
Crabgrass, Annual	2.00					5	23	30	22	15	5			100
Eastern Gama Grass	3.50					12	21	31	25	8	3			100
Fescue, Tall (not stockpiled)	2.30			5	16	20	20	8	5	10	13	3		100
Fescue, Tall (stockpiled)	3.60			5	15	17	16	8	5	12	13	8	1	100
Fescue, Tall/Ladino Clover	3.10			2	15	18	21	10	8	9	12	4	1	100
Fescue, Tall/Lespedeza	3.60			2	10	17	16	13	11	11	14	5	1	100
Fescue, Tall/Red Clover	3.00			2	12	20	19	12	8	10	12	4	1	100
Fescue, Tall/Red Clover (stockpiled)	3.40			2	10	17	20	12	6	10	14	8	1	100
Indiangrass	2.70					7	15	30	32	12	4			100
Millet, Pearl	3.00					9	25	30	25	10	1			100
Oats (August seeding)	1.30								10	35	35	15	5	100
Oats (March/April seeding)	1.70			8	31	31	29	1						100
Orchardgrass	2.90			5	15	21	20	12	7	10	10			100
Orchardgrass/Ladino Clover	3.00			5	15	23	22	7	7	9	10	2		100
Orchardgrass/Red Clover	3.10			3	12	20	19	12	8	10	12	4		100
Orchardgrass/Red Clover (stockpiled)	3.50			2	10	17	17	15	6	15	15	3		100
Orchardgrass/Tall Fescue/Ladino Clover	3.40			7	18	21	20	7	7	8	9	3		100
Orchardgrass/Tall Fescue/Red Clover	3.50			5	10	20	21	14	9	10	8	3		100
Red Clover	2.50			4	9	23	24	16	9	8	6	1		100
Reed Canarygrass	3.10			4	14	21	21	12	7	12	9			100
Rye, Cereal (Aug. seeded)	1.70		2	14	28	24	2			2	11	12	5	100
Ryegrass, Italian/Annual (Aug. seeded)	1.70		1	15	30	20	5			8	14	6	1	100
Ryegrass, Perennial/Ladino Clover	3.00			7	21	20	15	5	5	9	12	6		100
Ryegrass, Perennial/Red Clover	3.10			5	13	25	18	9	4	10	10	6		100
Sorghum-sudangrass	3.30					1	12	31	31	23	2			100
Switchgrass	3.00					15	34	28	18	5				100
Timothy	2.50			2	12	29	30	6	5	11	5			100
Triticale, Fall seeded	2.10			3	32	30	10			5	15	5		100
Turnips (Aug. seeded)	2.30								5	33	35	25	2	100
Turnips/C. Rye (Aug. seeded)	3.90		3	30	20	10			2	10	15	8	2	100
Turnips/C. Rye/Oats (Aug. seeded)	3.10		2	15	28	21			2	10	15	5	2	100
Turnips/Oats (Aug. seeded)	2.90								5	35	35	23	2	100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences (disease resistance, winter hardiness, environmental factors, etc.) between varieties will exist and these differences, are not reflected in the yield and monthly production.

***Average Management: Bare or open soil areas exist in paddocks; pH., P, & K are below optimal levels; nitrogen is not applied to grass dominant paddocks; undesirable weeds are not controlled; and paddocks receive limited rest periods.

TABLE 3-5. FORAGE PRODUCTION

Pasture/Forage Type*	Total Yield**	Percent of Total Yield Available in Each Month** %Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
Southern IL (NRCS Plant Suitability Zone 3) -- Optimum Management***														
Alfalfa	5.20			2	16	21	15	15	10	12	9			100
Alfalfa/Orchardgrass	4.90			3	14	19	18	13	10	11	10	2		100
Big Bluestem	4.60					14	28	29	24	5				100
Big Bluestem/Indiangrass	4.60					10	20	25	30	15				100
Bluegrass, Kentucky/Dutch Wh. Clover	2.30			2	17	28	15	5	3	7	16	7		100
Bluegrass, KY/Tall Fescue/Ladino Cl.	5.10			7	19	21	20	5	4	6	12	5	1	100
Bluegrass, KY/Orchardgrass/Ladino CL.	4.70			7	19	20	19	5	5	6	12	7		100
Bluegrass, KY/Orchardgrass/Red Cl.	4.90			4	13	20	19	13	8	8	10	5		100
Bluegrass, KY/Tall Fescue/Red Cl.	5.20			5	13	20	18	12	7	7	12	5	1	100
Brush, (for Goat pasture)	1.60				8	25	29	25	7	5	1			100
Brush, Grass, and Forbes for Goats	3.30			2	12	21	22	12	9	10	8	4		100
Chicory	3.50				7	19	20	20	13	15	6			100
Corn (Green Grazed)	5.90					15	25	25	25	10				100
Corn Stalk Residue	2.00										100			100
Crabgrass, Annual	2.30					5	23	35	22	15				100
Eastern Gama Grass	5.20				8	21	26	25	15	5				100
Fescue, Tall (not stockpiled)	5.20			6	15	20	18	7	4	10	13	6	1	100
Fescue, Tall (stockpiled)	5.90			3	12	15	18	6	5	13	15	10	3	100
Fescue, Tall/Ladino Clover	4.90			7	17	20	19	6	5	7	13	5	1	100
Fescue, Tall/Lespedeza	4.70			4	11	17	16	13	10	11	12	5	1	100
Fescue, Tall/Red Clover	5.20			4	12	19	19	12	6	9	12	6	1	100
Fescue, Tall/Red Clover (stockpiled)	5.90			2	10	20	17	12	6	10	14	8	1	100
Fescue, Tall/Red Clover/Lespedeza	5.20			4	10	16	20	13	10	11	10	5	1	100
Indiangrass	4.60					10	15	25	30	15	5			100
Lespedeza, Annual	2.60					17	27	23	14	11	8			100
Millet, Pearl	4.60					9	25	30	25	10	1			100
Oats (August seeded)	2.00								10	35	35	20		100
Oats (March/April seeded)	2.60			5	20	40	35							100
Orchardgrass	4.20			3	16	20	17	9	6	10	13	6		100
Orchardgrass/Ladino Clover	4.60			8	18	20	20	7	5	6	11	5		100
Orchardgrass/Red Clover	4.80			4	13	20	18	14	6	10	10	5		100
Orchardgrass/Red Clover (stockpiled)	5.50			2	10	17	17	15	6	15	15	3		100
Orchardgrass/Tall Fescue/Ladino Clover	5.10			7	19	20	19	5	4	7	13	5	1	100
Orchardgrass/Tall Fescue/Red Clover	5.20			5	13	19	18	13	7	7	11	6	1	100
Red Clover	3.90			4	11	20	20	15	9	8	8	5		100
Reed Canarygrass	4.90			6	18	22	22	17	5	8	2			100
Rye, Cereal (Aug. seeded)	3.30			15	20	30	5			5	10	10	5	100
Ryegrass, Italian/Annual (Aug. seeded)	3.30			4	20	29	24			5	10	7	1	100
Ryegrass, Perennial/Ladino Clover	4.70			8	22	25	17	2	3	7	10	6		100
Ryegrass, Perennial/Red Clover	4.90			7	15	20	17	8	3	13	11	6		100
Sorghum-sudangrass	5.90					5	18	34	25	15	3			100
Switchgrass	5.20					15	39	28	13	5				100
Triticale, Fall seeded	3.30		5	10	20	30				5	15	10	5	100
Turnips (Aug. seeded)	3.90								5	35	35	20	5	100
Turnips/C. Rye (Aug. seeded)	5.60		3	20	30	7				10	15	10	5	100
Turnips/C. Rye/Oats (Aug. seeded)	5.60		5	10	30	20				5	15	10	5	100
Turnips/Oats (Aug. seeded)	4.60								5	35	35	20	5	100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences (disease resistance, winter hardiness, environmental factors, etc.) between varieties will exist and these differences, are not reflected in the yield and monthly production.

***Optimum Management: A high plant density exists; pH., P, & K are at optimal levels; nitrogen is applied to grass dominant paddocks; undesirable weeds are controlled; and controlled grazing (rotational or MIG) is practiced.

TABLE 3-6. FORAGE PRODUCTION

Pasture/Forage Type*	Total Yield**	%Jan	%Feb	%Mar	%Apr	%May	%Jun	%Jul	%Aug	%Sep	%Oct	%Nov	%Dec	Total
		Percent of Total Yield Available in Each Month**												
Southern IL (NRCS Plant Suitability Zone 3) -- Average Management***														
Alfalfa	3.40			2	16	21	15	15	10	12	9			100
Alfalfa/Orchardgrass	3.30			3	14	19	18	13	10	11	10	2		100
Big Bluestem	3.00					14	28	29	24	5				100
Big Bluestem/Indiangrass	3.00					10	20	25	30	15				100
Bluegrass, Kentucky/Dutch Wh. Clover	1.60			2	17	28	15	5	3	7	16	7		100
Bluegrass, KY/Tall Fescue/Ladino Cl.	3.30			7	19	21	20	4	5	6	13	4	1	100
Bluegrass, KY/Orchardgrass/Ladino Cl.	3.00			7	19	20	19	5	5	6	12	7		100
Bluegrass, KY/Orchardgrass/Red Cl.	3.30			4	13	20	19	13	8	8	10	5		100
Bluegrass, KY/Tall Fescue/Red Cl.	3.40			5	13	20	18	12	5	7	13	6	1	100
Brush, (for Goat pasture)	1.20				8	25	29	25	7	5	1			100
Brush, Grass, and Forbes for Goats	2.10			2	12	21	22	12	9	10	8	4		100
Chicory	2.60				7	19	20	20	13	15	6			100
Corn (Green Grazed)	5.90					15	25	25	25	10				100
Corn Stalk Residue	2.00										100			100
Crabgrass, Annual	1.60					5	23	35	22	15				100
Eastern Gama Grass	3.40				8	21	26	25	15	5				100
Fescue, Tall (not stockpiled)	3.40			6	15	20	18	7	4	10	13	6	1	100
Fescue, Tall (stockpiled)	3.80			3	12	15	18	6	5	13	15	10	3	100
Fescue, Tall/Ladino Clover	3.30			7	17	20	19	6	5	7	13	5	1	100
Fescue, Tall/Lespedeza	3.00			4	11	17	16	13	10	11	12	5	1	100
Fescue, Tall/Red Clover	3.40			4	12	19	19	12	6	9	12	6	1	100
Fescue, Tall/Red Clover (stockpiled)	3.90			2	10	20	19	12	6	10	12	8	1	100
Fescue, Tall/Red Clover/Lespedeza	3.40			4	10	16	20	13	10	11	10	5	1	100
Indiangrass	3.00					10	15	25	30	15	5			100
Lespedeza, Annual	1.70					17	27	23	14	11	8			100
Millet, Pearl	3.00					9	25	30	25	10	1			100
Oats (August seeded)	1.30								10	35	35	20		100
Oats (March/April seeded)	1.70			5	20	40	35							100
Orchardgrass	2.70			3	16	20	17	9	6	10	13	6		100
Orchardgrass/Ladino Clover	3.00			8	18	20	20	7	5	6	11	5		100
Orchardgrass/Red Clover	3.30			4	13	20	18	14	6	10	10	5		100
Orchardgrass/Red Clover (stockpiled)	3.50			2	10	17	17	15	6	15	15	3		100
Orchardgrass/Tall Fescue/Ladino Clover	3.30			7	19	20	19	5	4	7	13	5	1	100
Orchardgrass/Tall Fescue/Red Clover	3.40			5	13	19	18	13	7	7	11	6	1	100
Red Clover	2.60			4	11	20	20	15	9	8	8	5		100
Reed Canarygrass	3.30			6	18	22	22	17	5	8	2			100
Rye, Cereal (Aug. seeded)	1.70			15	20	30	5			5	10	10	5	100
Ryegrass, Italian/Annual (Aug. seeded)	2.10			4	15	29	24	5		5	10	7	1	100
Ryegrass, Perennial/Ladino Clover	3.00			8	22	25	17	2	3	7	10	6		100
Ryegrass, Perennial/Red Clover	3.30			7	15	20	17	8	3	13	11	6		100
Sorghum-sudangrass	3.80					5	18	34	25	15	3			100
Switchgrass	3.40					15	39	28	13	5			100	100
Triticale, Fall seeded	2.10				15	20	30			5	15	10	5	100
Turnips/C. Rye/Oats (Aug. seeded)	3.60		5	10	30	20				5	15	10	5	100
Turnips (Aug. seeded)	2.60								5	35	35	20	5	100
Turnips/C. Rye (Aug. seeded)	3.60		3	20	30	7				10	15	10	5	100
Turnips/Oats (Aug. seeded)	3.00								5	35	35	20	5	100

*The listing of forage species is not meant to be all inclusive, rather the listing represents species commonly grown in this region of Illinois.

**Yields and monthly production figures were obtained from a wide variety of sources and should be considered a guide, and not absolute values. Differences between varieties will exist and these differences, are not reflected in the yield and monthly production. (disease resistance, winter hardiness, environmental factors, etc.)

***Average Management: Bare or open soil areas exist in paddocks; pH., P, & K are below optimal levels; nitrogen is not applied to grass dominant paddocks; undesirable weeds are not controlled; and paddocks receive limited rest periods.

Rain Gardens

Iowa Rain Garden Design and Installation Manual

Rain Gardens

Iowa Rain Garden
Design and Installation Manual

This Rain Garden Design Manual is the first of its kind in Iowa and can be used as a resource document. It is a work in progress that will be periodically updated to reflect new knowledge and techniques. Please visit www.iowastormwater.org for more information.

The Iowa Rain Garden Design and Installation Manual was assembled in cooperation with the following conservation partners:

Iowa Storm Water Education Program
www.iowastormwater.org

Iowa Stormwater Partnership
www.iowastormwater.org

Iowa Department of Agriculture and Land Stewardship
www.iowaagriculture.gov

Rainscaping Iowa — Landscapes for clean water
www.rainscapingiowa.org

DNR
www.iowadnr.gov

USDA NRCS — United States Department of Agriculture, Natural Resources Conservation Service
www.ia.nrcs.usda.gov

IOWA life | changing®
www.iowalifechanging.org

Polk Soil & Water Conservation District
www.polk-swcd.org

Living Roadway Trust Fund
www.iowalivingroadway.com

USDA is an equal opportunity provider and employer.

Table of Contents

Connection to Water Quality

What is a Rain Garden?

A rain garden captures rain from rooftops, driveways, yards and streets. A rain garden is a depression or a shallow bowl made in the landscape that is level from side to side and end to end. Runoff that travels to a rain garden is temporarily ponded - but it doesn't stay ponded for long. Capturing runoff in a rain garden allows water to infiltrate into the soil rather than run into storm drains. Dirty runoff that enters storm drains is sent directly to "receiving waters" - our rivers, streams, lakes, ponds or wetlands.

Rain gardens are an infiltration-based storm water management practice that relies on soils with good percolation rates to help manage rainfall to protect water quality. By installing rain gardens, homeowners can create landscapes that add beauty, wildlife habitat and interest to a yard while helping manage storm water more sustainably. Rain gardens are a key practice for creating landscapes that are both beautiful and hydrologically functional - that is - landscapes that hold and infiltrate rainfall rather than generating runoff that causes water quality problems and contributes to flooding.

Why Install A Rain Garden?

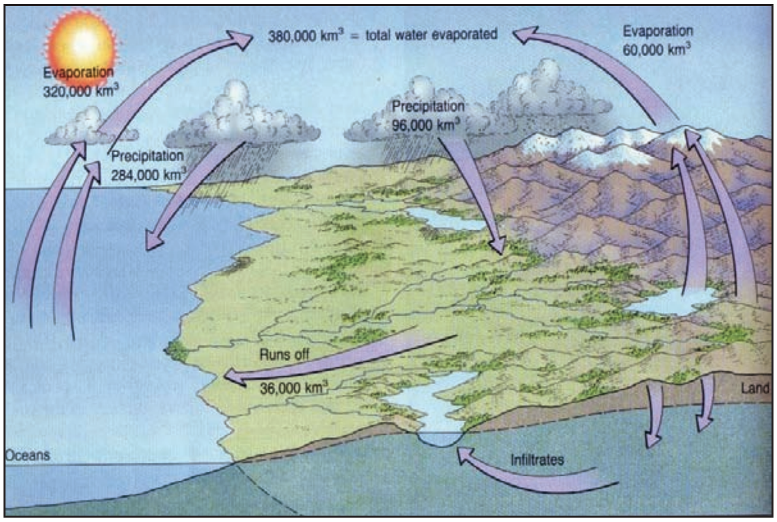
Homeowners may be surprised to learn that hundreds of thousands of gallons of rain falls on an urban lot in a year. In Iowa, rainfall averages anywhere from 28-36 inches per year. That means an acre of land in Iowa will receive anywhere from 760,000 to 977,500 gallons of rain in a typical year. The owner of a half acre urban lot in central Iowa would receive approximately 434,500 gallons of rain each year (a little less in western Iowa; a little more in eastern Iowa).

It is hard to visualize how much water 434,500 gallons actually is. Imagine capturing all that rainfall in 50 gallon barrels. You'd need a row of barrels more than 4 miles long to hold all the rain a typical lot receives. To calculate how many gallons of rainfall a property receives, go to www.jcswcd.org. You'll find a tool to perform a rain water audit. The audit will calculate how many gallons of rain a property receives and how much of that rainfall might be leaving the property as runoff.

An urban property generating storm water runoff contributes to water quality degradation. Storm water runoff from rooftops, driveways, yards and streets carries pollutants such as hydrocarbons, heavy metals, sediment, bacteria, grass clippings, floatable litter, or nutrients. Storm water runoff carries these pollutants directly to receiving waters without any treatment.

Storm water runoff also causes frequent bounces in stream flows. These "flashy" flows (high flows/low flows) cause stream corridor erosion, which contributes sediment to stream flows. Storm water also increases flood potential. Installation of rain gardens is one way to capture and infiltrate storm water and reduce a property's contribution to water quality degradation, flashy stream flows and flooding.

IDALS-DSC Photo



Understanding Urban Hydrology

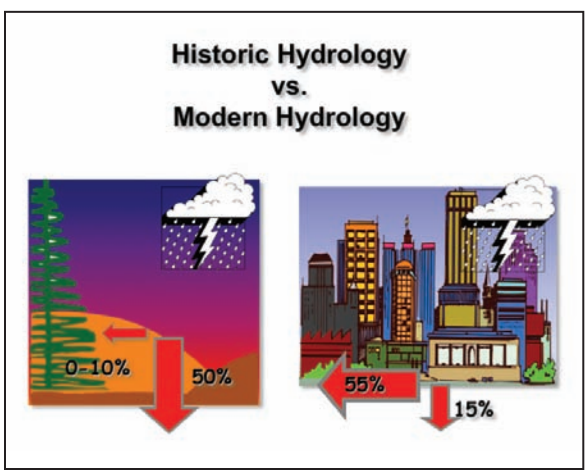
A hydrologically functional landscape holds and infiltrates rainfall. Hydrologically dysfunctional landscapes generate runoff. Urban landscapes generally are hydrologically dysfunctional, because they generate runoff with almost every rainfall event. Because runoff transports pollutants to receiving waters, installing rain gardens helps restore hydrologic functionality to our landscapes.

Hydrologic Cycle

The hydrologic cycle is all about how water moves. When it rains, water is either absorbed by the landscape or runs off. Water eventually moves to receiving waters and the oceans. Water also evaporates back into the atmosphere. It rains again and the cycle repeats itself.

Historical Hydrology

Historically, the hydrologic cycle behaved much differently than it does today. Prior to European settlement, infiltration dominated the cycle and runoff was a rare component. Back then, Iowa was dominated by prairie. The prairie ecosystems infiltrated the vast majority of rainfall. Consequently, surface waters were fed by cool, clean groundwater discharge rather than runoff. Before the prairie systems were altered and eliminated, surface waters had good water quality, stable water levels and flooding was minimized.



The tallgrass prairie ecosystem was dominated by grasses and flowering species (forbs) that had deep root systems. Native prairie grasses have fibrous roots that reach six to eight feet deep into the soil profile. Some of the tap rooted forbs send roots twice that deep. Each year a significant percent of the root system of the prairie died off and decayed. Consequently, the prairie developed deep, rich, porous soils. Prairie soils typically had 10 percent organic matter (OM) content or more. About half of prairie soil was pore space—small spaces between granules of soil. These two features – high organic matter content and high porosity – gave the prairie landscapes the ability to infiltrate most rainfall into the soil.

The high organic matter content made the soil act like a sponge and soak up rain. The pore space in the soil allowed the absorbed rain to percolate down through the soil. Consequently, runoff would have been a rare thing on the prairie. About 10 percent of annual precipitation would have moved as runoff, and this would have been mostly from snow melt. More than 90 percent of rainfall would have been absorbed on the landscape.

About 40 percent of rain either evaporated or was used by growing plants and returned to the atmosphere by a process called “evapotranspiration.” About 50 percent of rainfall infiltrated and moved down through the prairie soils. Some went to recharge deep aquifers - or reservoirs of water located deep down in bedrock. But at least half would have moved as groundwater flow. Groundwater is water in saturated soils that moves slowly down gradient through the soil to discharge at low points on the landscapes where wetlands, streams, rivers or lakes are located.

The key point is that streams, rivers, wetlands, and lakes were historically fed and maintained mostly by groundwater discharge and not by surface runoff. Historically, the hydrologic system was **infiltration-based and groundwater-driven**. A groundwater driven system would have been a very stable, functional system. A constant supply of cool, clean and slowly released groundwater would have yielded receiving waters that maintained very stable water levels and had very stable (clean) water chemistry.

Rain gardens can help restore hydrologic functionality to our modern urban landscapes and help them mimic the historic hydrology. If we restore hydrologic functionality we will help improve water quality, maintain stable stream flows, and reduce flooding potentials.

Dysfunctional Hydrology in Modern Landscapes

Our modern hydrology is very different from the historic hydrology. Urban landscapes have impervious surfaces such as pavement or rooftops. We also have compacted green space, which often features turf on compacted soils—soils that have little or no pore space. If soil is compacted water can't move into and percolate through it. Urban landscapes that can't infiltrate water generate problematic runoff when it rains. We have changed from the historic infiltration-based and groundwater driven hydrology to a **runoff-driven hydrologic system**. Runoff is the root of water quality problems, stream corridor degradation and flooding. Reducing runoff is the key to restoring a more stable, functional hydrologic cycle and rain gardens can play a key role in accomplishing this important goal.

Photo by Wayne Petersen

A hydrologically dysfunctional landscape. Water that can't percolate into the soil profile seeps out into the street two hours after a rain storm occurred.

Photo by Wayne Petersen

Eroded urban stream banks result from the flashiness of runoff-driven hydrology.

Rain Garden Location

Location is Critical

Proper location is one of the most important components of successful rain garden installation. The first step in planning a rain garden is walking a property during a rainfall event. It is important to get out in the rain, and watch how runoff moves on the site. **A rain garden must be located so that runoff moves to it.**

If you have a low spot where water ponds, it might be a good site for a rain garden – but maybe not. A rain garden is an infiltration-based storm water management practice that relies on soils with good percolation rates – or soils that allow water to easily move down through the soil profile. If you have a spot that ponds water for an extended period of time (i.e. long enough to kill grass) it does not percolate well enough for a rain garden to work properly.

A rain garden should impound water for about 12 hours (maybe up to 24 hours). If it rains in the afternoon, a rain garden should not have standing water by morning. You do not want water standing in a rain garden for an extended period of time.

(Note: Infiltration refers to the rate that impounded water moves into the soil. Percolation refers to the rate water moves through the soil profile after it has infiltrated. Percolation rates are expressed in inches of downward movement per hour. These terms sometimes are used interchangeably, but there is a difference.)

Soils Investigation

Since adequate infiltration and percolation rates are essential for a rain garden to function properly, a soils investigation must be done at a proposed site for a rain garden. If the soils investigation indicates poor percolation rates, then find an alternative site for the rain garden or install a bioretention cell. (See Appendix 6, page 24, for information about bioretention cells.)

A comprehensive soils investigation will allow you to estimate what the percolation rate will be for your rain garden site. You should choose a site that has a percolation rate of 1 inch per hour if possible. The Iowa Stormwater Management Manual (www.ctre.iastate.edu/PUBS/stormwater/index.cfm) requires a minimum of 0.5 inches per hour for infiltration-based storm water management practices.

Analysis Options

Sieves are one tool used for lab analysis of soil texture.

Lab Analysis: The best way to ensure adequate percolation rates is a comprehensive soils investigation. (See Appendix 3, page 21.) The local Extension Service office will have information on how to do soil sampling and provide soil sample kits that can be submitted to Iowa State University for analysis for a modest fee. The lab analysis can determine “soil texture” which is the percent of sand, silt, and clay your soils contain. The soil texture will indicate what the percolation rate will be. Loam indicates a relatively even mixture of sand, silts, and clay. You should have loam soils, or sandy loam soils. Loam has a percolation rate of 0.5 inches per hour. Sandy loam will have percolation rates of about 1 inch per hour. If you have loamy sand or sand, amend the soils with compost to reduce percolation rates. (See Appendix 3, page 21 for more information about soil texture and percolation rates.) A soil probe can be used to collect soil samples or dig samples with a shovel.

Ribbon Test: Another simple way to investigate soil suitability is the ribbon test. This test will estimate clay content, which is usually linked to percolation rates. The higher the clay content the lower the percolation rate, in most cases. Use a soil probe, shovel, or clam shell posthole digger


Polk SWCD Photo

A **ribbon test** used to estimate clay content.


NRCS Photo

Soil Samples can be collected using a soil probe.

to gather samples of soil from beneath the rain garden at 1 foot increments down to at least 3 feet deep. Roll the samples into a cigar shape. Add a little water if the soil is not moist. Pinch the sample between your thumb and finger into a flat ribbon. If the soil won't ribbon and breaks off as you squeeze it, the soils should have low clay content and good percolation rates.

If it extends out no more than an inch before breaking off, the clay content should still be low enough to have adequate percolation rates. If it ribbons out more than an inch before breaking it is questionable that adequate percolation rates exist. If it ribbons out 2 inches the clay content is definitely too high and percolation rates will be too low for rain garden installation.

Percolation Test:

A simple percolation test can be done at a proposed rain garden site. A percolation test will indicate whether water will move down through the soil or not. But, percolation tests are not necessarily a reliable way to predict how water will move through soil, so do the ribbon test too. To conduct a percolation test, remove sod and topsoil. Dig a hole with a clam shell posthole digger. Dig one hole in the center of the proposed rain garden site on the down slope side. Dig this hole about 1.5 feet deep. Dig another hole in the center of the rain garden, but at the upslope edge of the rain garden layout. Make this hole go down to about 3 feet deep. Do the same at the ends of the rain garden.


Polk SWCD Photo

A **percolation test** should be conducted at any proposed rain garden site.

Fill the holes with 12 inches of water. If it drains away in 12 to 24 hours, percolation rates may be adequate. After 24 hours fill the hole with another 12 inches of water and repeat the percolation test. If it drains away again in 12 hours percolation rates should be about 1 inch per hour. If it drains down in 24 hours, percolation rates should be about 0.5 inches per hour. If it doesn't drain down in 24 hours, plan on including a sub drain system. (See Appendix 6, page 24 on bioretention cells.) An additional percolation test method is described in Appendix 3, page 21. **Soils investigations** are critical to successful rain garden installation. If impounded water in a rain garden does not rapidly drain away, anaerobic conditions can develop – which means oxygen is eliminated from pore spaces in the soil profile. Anaerobic conditions will kill beneficial microbes in the soil that help breakdown pollutants and protect water quality. Extended periods of standing water can also kill plants, create odor problems and provides mosquito habitat.

Seek technical assistance from your local Soil and Water Conservation District (SWCD) if you have questions about the suitability of the soil at a proposed rain garden site.

One Call

Another key item in locating a rain garden is the presence or absence of utilities. While you typically will not be doing deep excavation, you will be doing some digging. Be sure there are no phone lines, gas lines, or other infrastructure in the area you will be digging. **Call "Iowa One Call" at 800-292-8989** to request assistance locating utilities. Call at least 48 hours before you want to start installing a rain garden.

Other Location Considerations

- Rain gardens should never be located upslope from a house or closer than 10 feet from a foundation. Thirty to 40 feet away from a foundation is recommended if the site allows. Roof water can be directed to a rain garden by extending tile from downspouts to the rain garden, or by creating a swale that will convey runoff to the rain garden.
- Avoid locating rain gardens under trees. There will always be some excavation involved with rain garden installation, and excavation under the drip line of a tree canopy will cause damage to a tree's roots. In addition, there is a much wider selection of plant species to choose from in sunnier locations.
- Rain gardens should not be installed in areas with high water tables (some sites in central Iowa), or areas with shallow soils over bedrock (some sites in northeast Iowa). There should be at least 4 feet of soil profile between the bottom of a rain garden and the normal high water table or bed rock. Soil survey information from the Soil and Water Conservation District will indicate whether the potential for high water tables exist or whether shallow bedrock might exist.
- Rain gardens should not be on located on steep slopes that can become unstable when saturated (some sites in deep loess soils of western Iowa).
- If excessive slope exists, installing a rain garden will be more of a challenge. Retaining walls are usually needed to create a level depressional area for a rain garden on steep slopes.
- Rain gardens should only be installed when surrounding landscapes are stabilized and not subject to erosion. If a rain garden will be installed in conjunction with final landscaping of new construction, install the rain garden after everything else is well vegetated. Sediment entering a rain garden will create a crusted surface that will limit infiltration.

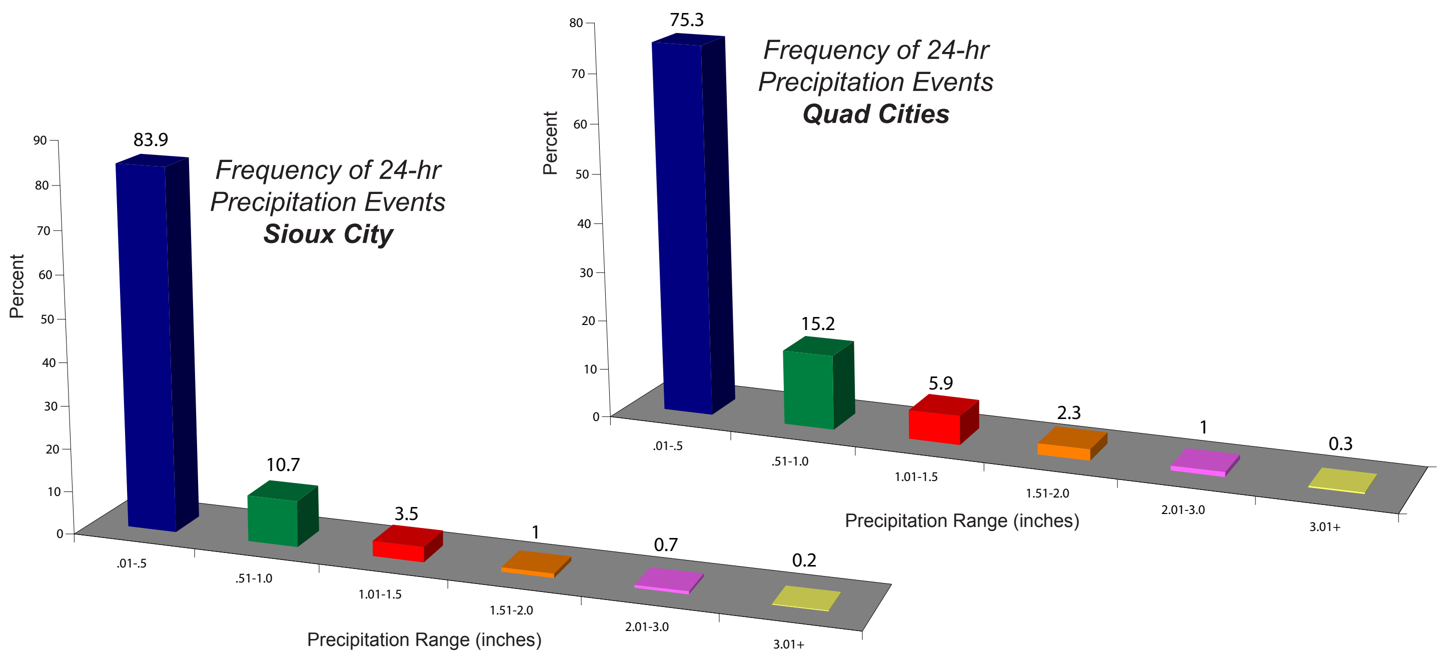
Photo by Wayne Petersen

What not to do: *A rain garden located in a city park lacks a mowed border, is not weeded, is not level, does not drain, stands water until the system goes anaerobic and creates odor problems. Park users wanted the rain garden removed, before the parks and recreation department corrected the problems.*

Rain Garden Design

Water Quality Volume (WQv)

The Iowa Stormwater Management Manual provides design standards that ensure that infiltration-based storm water management practices will infiltrate 90 percent of rainfall events. Analysis of historical rainfall data for Iowa shows that 90 percent of rainfall events are less than 1.25 inches in 24 hours. Therefore, rain gardens should be designed to handle the runoff from 1.25 inches of rain. This size of an event is called the **water quality volume (WQv)**.



(Rainfall data was summarized for all measurable precipitation from 1948 through 2004 by Ray Wolf of the National Weather Service in Davenport. Note how 90 percent of rainfall is about 1"/24 hrs.)

Rain gardens are generally used in residential settings. It is important for homeowners to manage the WQv because residential property is the major land use in any city. If runoff is not managed properly on residential property, water quality improvement, hydrological functionality, and stabilization of stream flows will not be achieved.

In addition, some cities and Soil and Water Conservation Districts (SWCD) are now offering financial incentive to homeowners who install rain gardens or other infiltration-based practices. To be eligible for this assistance, the installation must follow the design standards in the Iowa Stormwater Management Manual, which will manage the WQv. Check with your local SWCD to see if cost-sharing is available in your community.

In a single family residence there will almost always be enough space to design a rain garden to handle runoff from a 1.25 inch rain. But if space is limited, a smaller than recommended rain garden can be installed. About 80 percent of rainfall is 0.5 inches or less, according to historical rainfall patterns. However, rain gardens that do not manage the water quality volume will not be eligible for financial assistance programs.

Calculating Size and Depth

Here's the process for determining the correct surface area and depth for a rain garden:

1. Measure the size of the area that will contribute runoff to the rain garden in square feet. If you're capturing roof runoff from a downspout, measure the length and width of the roof that drains to the downspout. (Just pace it out or measure it with a tape measure on the ground.)

2. Sizing of the rain garden will depend on the depth of the rain garden and the percolation rates you have at the site. Remember – you should have a minimum percolation rate of 0.5"/hr.

3. With a **percolation rate of 0.5"/hr:**
   a. Multiply the impervious surface area calculated above by **20%** (0.2) if the rain garden will have **6 inches of depth**.
   b. Multiply the impervious surface area calculated above by **16%** (0.16) if the rain garden will have **8 inches of depth**.
   c. Multiply the impervious surface area calculated above by **14%** (0.14) if the rain garden will have **9 inches of depth**.

4. With a **percolation rate of 1"/hr or more:**
   a. Multiply the impervious surface area calculated above by **10%** (0.1) if the rain garden will have **6 inches of depth**.
   b. Multiply the impervious surface area calculated above by **8%** (0.08) if the rain garden will have **8 inches of depth**.
   c. Multiply the impervious surface area calculated above by **7%** (0.07) if the rain garden will have **9 inches of depth**.

   (These calculations will yield the square feet of surface area needed to impound and infiltrate runoff from a 1.25" rain. Actually, there is a safety factor built in by following this method. The square footage calculated and the depth specified assumes you will have 100% of a 1.25 inch rain impounded in the rain garden all at once. Typically this won't happen. You'll have infiltration and percolation occurring as soon as runoff enters the rain garden and you'll typically have a small percentage of water retained in gutters. Also, there is a lag time in the runoff reaching the rain garden so it all doesn't arrive at the same point in time.)

5. Once the square footage of surface area is determined, consider various dimensions that yield a length x width that equals the square feet of surface area needed and fits the site. It is best to install long and narrow rain gardens so work can be done from the side when digging, planting, and doing maintenance.

6. Rain gardens should have a designated outlet to convey runoff away safely when a rainfall event occurs that is larger than 1.25 inches. It is guaranteed that this will happen and you don't want water flowing out of a rain garden that causes damage. Outlets will typically be an armored – or reinforced – low spot in a berm or at the end of a rain garden. Be sure that any flows from the rain garden are conveyed in a way that does not cause erosion or damage property or infrastructure below the site.

7. One other thing to consider is whether to include capacity for runoff from the lawn above a rain garden. Ideally, a lawn will have adequate soil quality so that it absorbs and infiltrates the WQv and lawn runoff will not have to be included in the design. Soil quality restoration is recommended for lawns above a rain garden if a lawn generates runoff. This will help create a combination of practices which is always better than reliance on a single practice system. Soil quality restoration guidelines are available in Chapter 2E-5 of the Iowa Storm Water Management Manual. Find it online at www.ctre.iastate.edu/PUBS/stormwater/documents/2E-5SoilQualityRestoration.pdf.

8. On small rain gardens, it is better to increase surface area and stay with the 6 inch depth. Nine inches of depth may look "too deep" in a small rain garden.

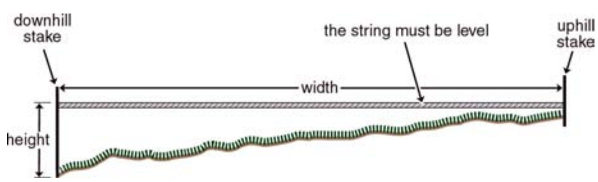
Installation Techniques

Because most rain garden sites have slope and because you need to create a level depressional area for your rain garden, the most common installation approach is the "cut and fill" technique. With cut and fill, a small berm or dam is built at the lower edge of the rain garden, using material excavated from the upper side of the rain garden.

- Lay out the shape of the rain garden with a rope or flags. Give yourself a few days to look at the layout from different perspectives. Adjust the layout to make sure the rain garden fits into the landscape nicely and provides a pleasing addition to the yard.

- Rain gardens should be laid out on the contour–that is across the slope. Long and narrow rain gardens are recommended, so make the long sides lay across the slope and have the narrow ends running up and down the slope.

- Place stakes at the upper edge of the rain garden and stakes at perpendicular angles on the lower edge of the rain garden. Tie a rope at the base of the upper stake. Then tie the rope to the lower stake at an elevation that is level with the ground at the upper stake. Use a carpenter's level to make sure the rope is level.

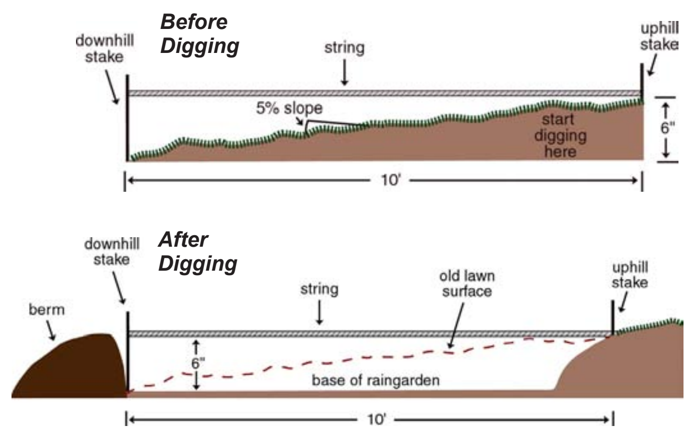


The string should be tied to the base of the uphill stake, then tied to the downhill stake at the same level.

- Now measure the distance from the ground at the lower stake to the rope. This tells you how much the slope has dropped from the upper stake to the lower stake. To get a level surface in the rain garden, you'll have to excavate to that depth at the upper stake.

- It is important that the rain garden be level from side to side and end to end so that water infiltrates uniformly across the bottom of the rain garden. This is important to maximize the capacity for impounding water and for uniformly spreading the infiltration workload evenly over the bottom of the rain garden.

Between 3% and 8% slope lawn



- Before excavation begins, be sure existing turf is killed or removed.

- Remove and stockpile topsoil.

- Excavate subsoil and use it as fill material to create a berm on the lower edge of the rain garden. Stomp the fill down in 2 inch lifts to make sure it's compacted. (You want the berm compacted, but this is the only place in the yard you want compaction.)

- Make sure the berm is constructed level across the top. Use a carpenter's level and a long 2 x 4 board to make sure the top of the berm is level.

To impound 6 inches of water, build a berm 8 inches high on the lower edge of the rain garden. Leave one end or both ends of the rain garden 2 inches below the berm to serve as an overflow outlet. If you want 8 inches of depth, build the berm 10 inches high and leave the end(s) only 8 inches high. If you want 9 inches of depth, build the berm 12 inches high and leave the end(s) only 9 inches high.

***Above:** Rain gardens must be level side to side, end to end, and the berm must be level. Note the low spot on the berm. **Right:** A rain garden installed in a morning by Heard Gardens.*

- The cut slope on the upper edge of the rain garden should be sloped back to a stable slope. Calculate and create a 3:1 slope or flatter. (3 ft. back for every 1 ft. of depth of cut.)
- Protect the cut slope above the depth of water that will be impounded with erosion control blankets or heavy mulch until vegetation is established.
- Create a designated outlet to accommodate storms that exceed the capacity of the rain garden. Remember – these are designed to capture and manage 90 percent of rainfall events. The storms that exceed design capacity must have an outlet and be conveyed away from the rain garden in a nonerosive, non-damaging manner.

Photos on this page courtesy of NRCS.

NRCS Photo

A retaining wall was installed to create a level rain garden on this sloping site in Madison County.

IDALS-DSC Photo

A rain garden in Dickinson County with a backdrop retaining wall.

Steep Sites

If steep slopes exist at the site of a proposed rain garden, a retaining wall system will probably be needed. Retaining walls can help overcome steep slopes, but they need to be designed and installed properly. A retaining wall can be built up to create a level depression on a sloping site. Another alternative is to cut into a slope to create a level depression and have a back drop retaining wall that holds the cutslope soil in place. A design professional should be hired to ensure proper installation of retaining wall systems.

Inlets

It is best if runoff can enter a rain garden as a sheet flow, but often it will enter as a concentrated flow from a tile line, downspout, or swale. Don't let concentrated flows scour out soil and mulch where water enters the rain garden. The inlet area can be "armored" with flagstones or other protective products. Some rain gardens have a flagstone path that continues from the inlet area down the center line of the rain garden. This adds an attractive feature that prevents scour and ensures that foot traffic is concentrated in a designated area when planting, weeding or doing other maintenance. Place a geotextile fabric over the soil before placing rock so erosion doesn't occur below the rocks.

Outlets

Having a proper way to outlet flows from heavy rains that exceed design capacity is important. Leaving one or both ends of the berm lower than the berm at the down slope edge of the rain garden is probably the easiest way to outlet excessive flows. You should "armor" or "reinforce" these outlet areas to prevent erosion. Make the back slope of the outlet a 5:1 slope – that is, it should toe out 5' for every foot of height. In this case, if your notch height is 6 inches (0.5 ft) then it should toe out 2.5 feet from the top edge of the notch. This will allow water to flow out and down in a stable manner. Make sure the area down stream from the outlet is stabilized with strong vegetative cover.

Two common problems with newly installed rain gardens is the flooding of young plants before they are well established, and suffocation of small young plants that get covered by floating mulch when ponding occurs. To prevent flooding and mulch suffocation, leave the outlet site(s) only 1 inch above the bottom of the rain garden so very little ponding occurs until the plants have time to grow taller than the depth of the ponding area. This should take a month or so – maybe longer. When plants are taller than the ponding depth, the outlet can be filled to pond 6"-9" of water so the rain garden will function as it should.

When the opening in the outlet is filled, make sure there isn't a seam between the existing berm and the new fill material. This means you should dig a little trench into the existing berm and as you fill the notch, pack the new fill solidly into the trench.

Site Preparation

Any sod or other existing vegetation that is not going to be dug up needs to be removed before installation of the rain garden. If you don't eradicate all pre-existing grass you will be fighting it as competing, undesirable vegetation in the future. You can cut, dig and roll the sod and use it somewhere else in the yard; or you can spray it with a herbicide such as Roundup® and wait a couple of weeks for it to die out. You can also lay down plastic, a thick layer of newspaper or cardboard anchored with rocks to kill the grass. These products should suppress existing vegetation in a couple of weeks. If time allows, give the site time to allow any weed seeds that may be in the top level of the soil time to germinate. Then remove any regrowth again before installing the rain garden.

Install an edging material along the edge of the rain garden to a depth of at least 4 inches. Edging will provide a barrier that prevents the roots of surrounding sod from creeping back into the rain garden planting. This can be done as a final touch of the rain garden installation. Another alternative is to install a brickwork edge backed by a woven geotextile that will physically block roots from spreading into the rain garden.

Soil Amendments

If a thorough soil analysis indicates good percolation rates (1"/hr or more) and good organic matter content (OM 5%+) exists, you won't need to do any soil amending. But if percolation rates are around 0.5 inches per hour and OM content is low (2% is common), plan on amending the soils with some compost, and possibly sand. If you are amending with compost only to increase organic matter content, over-excavate the site by 2 inches. Then place 2 inches of compost and rototill to a depth of 6 inches. (See Appendix 8, page 26.)

Photo by Steve Anderson, Dickinson SWCD

A rain garden in Okoboji has brick work edging and a mulch barrier.

If you have a site with low percolation rates of 0.5 inches per hour, you might want to amend the soil mixture in the top 6 inches with sand and compost. Washed concrete sand has more diversity of aggregate size. You want this. Do not use masonry sand, which has uniformly fine sized particles which can actually slow percolation rates. If amending the rain garden with sand, use only washed concrete sand.

Create a soil media consisting of 50% compost. Over-excavate the bottom of the rain garden by 6 inches. Backfill it with 3 inches of sand and 3 inches of compost. Rototill to create a uniform blend of sand and compost.

Photo by Wayne Petersen

During this rain garden installation the area was over-excavated in sandy subsoil and backfilled with a soil amended with compost to increase organic matter content.

What to Plant

NRCS Photo

Native plant species are recommended for rain gardens for a couple of important reasons. First, they will develop deep root systems (6 ft. deep and beyond). The deep roots of the natives will help build and maintain high organic matter content and porosity. The deep roots will also have the ability to go down and find water during dry periods. Once established many native species tolerate temporary impoundment of water and/or extended periods of dry weather. You also don't have to fertilize native species – in fact you should not fertilize them.

A monoculture border (all one species) will give the rain garden a defining edge and a well kept appearance. Typically the border will be a low growing grass, such as blue grama or sideoats grama if you are using natives. The border can be planted on the sloping edge of the rain garden.

On the floor of the rain garden, plant a variety of species that bloom throughout the growing season. Plant clumps of each species, with spacing of 1 - 1.5 feet apart. Select lower growing native plants that don't grow more than 3 - 4 feet high.

Install potted plants that establish readily during the first year. While natives are recommended some people may want to blend in some of their favorite horticultural cultivars. Select plants that meet your aesthetic values, but consider the amount of input needed to keep any non-natives alive (water during drought, fertilizer), and the effects of those inputs on nearby native species. Some natives will grow unusually large if given fertilizer and others will just die.

A short list of favorite native species for rain gardens is provided in Appendix 9, page 27.

Many plant lists recommended for rain gardens include species adapted to wet conditions. Since rain gardens should drain down readily, wet loving species will probably not thrive. Some plants that prefer dryer conditions may not thrive in a rain garden that might stay moist during periods of extended rainfall. Over the course of the first 2-3 years of plant establishment, be prepared to supplement plantings until suitable species have established themselves.

When you are planting the rain garden, try to minimize foot traffic. Work from the side if possible. On larger, wider rain gardens build small bridges that span the width of the rain garden and work from them. Screw 2 x 8 foot sheet(s) of plywood board to the 2" ends of long 2 x 4 inch boards to make a nice working platform. Or lay an extension ladder across the rain garden with a 2 x 8 foot piece of plywood board on it to provide a work platform. It will be impossible to eliminate all foot traffic but keep it to a minimum.

Mulching

Mulching the rain garden surface is usually recommended to provide a weed barrier and to conserve moisture for young plants during the first year. Mulching continues to help suppress weeds in following years. You should use a 2-3 inch layer of shredded hardwood mulch. When planting small plugs, it is easier to place the mulch before planting. Then spread the mulch before installing the plug and pull it back around the little plant after it is in place.

Mulch is often sold in bags that cover about 10 sq ft per bag. Calculate the number of bags of mulch needed by dividing the square footage of rain garden surface area by 10 to get the number of bags of mulch needed. A 150 sq. ft. rain garden would require 15 bags of mulch.

Rain Garden Maintenance

During the first year be prepared to water a rain garden if timely rainfall does not occur. Water at least once a week during establishment if it doesn't rain.

The most important thing about rain garden maintenance is to keep it looking good. Studies have found that rain gardens, especially when native plants are used, are well accepted if they appear to be orderly and well kept. Select lower growing species that stay upright. Keep plants pruned if they start to get "leggy" and floppy. Deadhead (cut off the old flower head) after a plant is done blooming.

Perhaps the most important maintenance item is to keep the rain garden weeded, especially the first couple of years when natives are establishing. Native plants spend much of their energy establishing deep root systems the first year or two. So expect a bit of an "ugly duckling" in year one. Usually in year two and certainly in year three native plants will have developed into a "swan" and will put on a spectacular show of color and texture that attracts butterflies, birds and beneficial insects.

Once established, your rain garden shouldn't require much maintenance. This is especially true if weeds are diligently kept from setting seed the first couple years. When mature, the garden should be free of bare areas except where stepping stones may be located. Reducing weed competition early and getting natives well established is key to low maintenance. Once well established, native species will prevent annual weeds from being a persistent problem – weeds just can't compete with vigorous, deep-rooted native species. Keep an eye out for a build-up of sediment or organic matter where runoff enters the rain garden. If a lip of material begins to build up over time you will have to clean it out to ensure runoff easily enters the rain garden.

Rain gardens should only be installed when surrounding landscapes are stabilized and not subject to erosion. So if you're planning a rain garden in conjunction with final landscaping of new construction, install the rain garden after everything else is well vegetated. Sediment entering a rain garden will create a crusted surface that will limit infiltration. But even with stabilized landscapes, some sediment can move with runoff. So keep an eye out for any build-up of fine sediment on the floor of the rain garden.

A few other maintenance items to watch for:

- Water standing for more than 12-24 hours.
- Vegetation has died and needs replacing.
- Erosion is visible on the berm, the cut slope, the floor of the rain garden, or where the rain garden outlet(s) overflows.
- A low spot has developed on the berm due to settling.

How Much Work Is Installing a Rain Garden?

Each site and each rain garden will be unique, so it's impossible to say how much work or time it will take to install a rain garden. A big part of rain garden installation is the planning and design. Give yourself plenty of time to plan things out before starting to install a rain garden. If you have a good design in hand and the rain garden is laid out and you've got a good crew on hand, you may be able to install a small rain garden in an afternoon. If it's a challenging or larger site, and you're doing the work yourself it could take a full weekend or more to install a rain garden. But regardless of how much time it takes, make sure installing a rain garden is a pleasurable gardening experience.

How much time to budget for maintenance is also site dependant. For the first year, keeping the rain garden weeded will be the biggest time demand. After establishment, weeding workload should go down.

How Much Will A Rain Garden Cost?

Cost of a rain garden will depend on its size and complexity. Obviously, if you're on a steep slope and using a retaining wall system, your costs will be higher than if you're installing a simple cut/fill rain garden on gentle slopes.

Cost will also depend on how much of the work a landowner does. If the site has good soils that need little or no amendment and a landowner is willing to put in the sweat equity, the major costs will be plants and the mulching. Cost could be as low as $3-$5 per sq. ft. of surface area in this situation. Figure plant costs of $2-$3 per plant and calculate the number of plants needed by dividing the sq. ft. of surface area by 1-1.5 ft., which is the recommended spacing for most native plants and many cultivars. Add another$1/sq. ft. for mulch.

When amending soil, factor in the cost of compost and/or sand. Calculate quantity of material needed and estimate about $10-$15/ton for materials. Add more if you'll be having the materials delivered. If you're doing a more complicated system (soil amendment, fancier inlet/outlets, larger plant stock) costs could range from $5 - $10 per sq. ft. of surface area. If a vendor/contractor is doing design and installation, costs could run $20+ per. sq. foot of surface area.

Additional costs associated with rain garden installation can occur. If a rain garden will be installed as part of new construction, then design downspouts, yard slopes, and the slope of a driveway to shed water to a designated rain garden site. But if a site is being retrofitted to add rain gardens there may be extra expense in getting water to a rain garden. Driveways, for instance are generally sloped to direct water into the street gutters and then to the storm sewers. It might be necessary to install a grated gutter that directs water to a rain garden in a setting like this, which obviously adds costs. Or, extra time and expense may be needed to install tile or construct swales to get downspout runoff directed to a rain garden. The cost of renting a rototiller or sod cutter may also be a part of rain garden installation. As with most home improvement projects there may be some unanticipated things that might add to costs.

When Not to Install a Rain Garden

In most settings, a rain garden can be successfully installed. But there may be certain situations where a rain garden might not be the right practice to install. One of the major limiting factors for rain gardens is compacted soils that won't allow water to percolate through the soil profile. This is a special concern where new construction has altered and compacted the soil profile from construction traffic.

In some settings, a high water table may exist and minimize the amount of percolation that can occur. If water table elevations are near the soil surface at your site, turn to an alternative practice such as soil quality restoration to help your landscape better absorb rainfall. A review of soil maps and soil survey information for your site will help you evaluate potential limiting factors such as a high water table. You can get soil survey information from your local SWCD. Soil surveys are not always helpful, though, if the site has been significantly altered by land disturbing activities associated with construction.

There may be a few rare situations where space is limited to accommodate a properly designed rain garden, but in most residential settings this shouldn't be a problem. In western Iowa, you might find sites where the deep loess soils on extremely steep sites or on fill could become unstable if infiltration of rainfall is enhanced by a rain garden. In northeast Iowa, some sites might have shallow soils over fractured bedrock. Percolation of pollutants to groundwater could be a concern on sites like this.

Soil quality restoration is best performed as part of final landscaping with new construction. It involves deep tillage to shatter compacted soils and incorporation of compost to achieve desired organic matter content. Strive for 5% organic matter, which usually can be achieved by incorporating 1 - 3 inches of compost into the soil. On existing landscapes with turf over compacted soils, you can improve soil quality through aeration and the application of compost. You can aerate by either pulling shallow plugs or punching deep holes into the soil profile (8-9 inches) through deep-tined aeration.

Photo by Rebecca Kauten

Deep tined aeration

Apply a compost blanket after aeration to help fill the holes with the high organic matter content that compost offers (30%-60% OM). Adding grass seed to the compost application will supplement existing patchy turf. You can apply compost by hand, with a small front end loader, or by hiring a pneumatic blower truck to spread compost.

Photo by Jennifer Welch

Compost blanket application

Common Mistakes

- Installing a rain garden on soils that lack adequate percolation rates.
- Poor maintenance – mostly insufficient weeding the first year after installation. Annual weeds that are not pulled will re-seed rapidly, creating an unkempt looking rain garden.
- Planting species that are too tall for the area. Carefully note the height ranges for the recommended species; if you have a small bed do not plant the taller species.
- Use of fertilizer. Native species do not need fertilizing, and often will grow too tall and flop over if they encounter rich conditions.
- Improper plant placement – put drought tolerant species on the sides of the rain garden and more water tolerant plants in the wetter areas of the rain garden.
- Improper location of the rain garden; water does not naturally flow to the site, or outflows are directed toward the building foundation.

Final Considerations

Rain gardens are a great practice that can be installed in most residential settings. But they are not necessarily a "magic bullet." Remember, there are some settings where limiting factors may affect rain garden design and performance and in some settings you may need to rely on the treatment train concept – a combination of practices working together to manage water sustainably. Rain gardens are usually used to manage water that falls on an urban lot. But when you look at most residential settings, what makes up the majority of impervious surfaces? It's the streets, of course. Transportation surfaces constitute up to 70 percent of imperviousness. So, do everything possible to manage water that falls on roofs and driveways and yards – then take on the challenge of organizing a neighborhood project that manages road runoff.

The right of ways between curbs and sidewalks often have infrastructure that may make it a challenge to retrofit and add rain gardens. But in some settings it may be possible to install rain gardens up slope from storm sewer intakes and make curb cuts that let road runoff enter the rain garden rather than going directly into the storm sewers. In some cases, managing road runoff will require the installation of a rain garden for road runoff on private land. This means an easement or other formal agreement between the property owner and the municipality will be needed that establishes procedures for installing, paying for, and maintaining the rain garden. A public – private demonstration project that manages road runoff has been installed in Okoboji. New developments in Okoboji are now being designed to manage road runoff in this way.

The installation of one rain garden by one homeowner does little to impact the hydrologic instability and the water quality problems we have in Iowa. But the cumulative affect of individual actions will ultimately lead to tangible changes in improved water quality, more stable stream flows, and reduced flooding potentials.

Here is a perfect retrofit opportunity. A curb cut could be installed in the adjacent green space. The polluted street runoff that goes into the nearby lake would be cleaned up, cooled off, and slowly released to improve water quality in the lake.

Appendix 1

Rain Garden Design and Installation Checklist

Site Location:

- ☐ Water is redirected or flowing toward the rain garden.
- ☐ Rain garden is located at least 10 feet away from building foundations, utilities and septic systems.
- ☐ Rain garden is downhill from building foundations.
- ☐ Rain garden is not installed where there is a shallow depth to the water table (when you dig a hole <4 feet deep and you find groundwater), or shallow soils over bedrock.

Soil Test:

- ☐ ***Ribbon test***: Dig several holes and conduct a ribbon test of the soils in the area where you wish to place a rain garden to estimate the amount of clay and determine if there are adequate percolation rates. Dig the hole below the depth of the proposed rain garden depression. If the soil won't ribbon and breaks off as you squeeze it, the soils should have low clay content and good percolation rates in order for the rain garden to drain properly.
- ☐ ***Percolation test***: Dig several holes and conduct a percolation test of the soils in the area where you wish to place a rain garden. Dig the hole below the depth of the proposed rain garden depression (or bowl) to determine if the soil will soak up (or percolate) water at an adequate rate to support a rain garden. Water should drain away in 12-24 hours for adequate percolation rates.
- ☐ ***Soil analysis***: Contact your local County Cooperative Extension office.

Sizing the Rain Garden:

Most rain events in Iowa (90%) generate less than 1.25 inches of runoff. This is the Water Quality Volume (WQv). The **"Iowa Rain Garden Design and Installation Manual"** provides detailed information on how to size a rain garden to manage the WQv. If bigger rains occur the Rain Garden will handle the first flush which moves most of the pollutant load.

- ☐ Measure the length by width of the impervious surface (driveway, rooftop, compacted yards) that contributes runoff to the rain garden. __________ **square feet**
- ☐ Select percolation rate based on your soils: **.5 inches/hour** **1inch/hour**
- ☐ Based on the desired depth (6, 8, or 9 inches) select the factor to use to determine the rain garden surface area needed: __________**factor**
- ☐ Multiply the square feet of impervious surface __________**square feet** by the factor_________ to get square feet of rain garden surface area.
- ☐ Rain garden square feet: ____________**rain garden square feet**
- ☐ Rain garden area: _________**feet (length)** _________**feet (width)**

Appendix 1 Cont...

Rain Garden Design and Installation Checklist

Installation:

- ☐ Layout the shape of the garden, then kill-off and remove the turf.
- ☐ Place the garden on the contour. It is best to install long and narrow rain gardens so that digging, planting and maintenance are easier.
- ☐ Use the cut and fill technique to create a berm on the downslope side.
- ☐ Make sure that the bottom of the depression is level from side-to-side and end-to-end.
- ☐ Refill the depression with the removed top soil or amended soil that consists of 50% compost and 50% sand.
- ☐ An outlet is needed on the downslope end for large rainfall events.
- ☐ An inlet may also be needed if you have flow from a downspout or tile line.
- ☐ Stabilize the soil surface at the inlet and outlet as needed
- ☐ Apply mulch to the rain garden

Plant Selection:

- ☐ Native plant species are recommended for rain gardens. Once they are established they will tolerate the short periods of ponded water and/or extended periods of dry weather.
- ☐ Number of plants needed for rain garden ___________**plants**
- ☐ A maintenance plan is in place for watering and weeding necessary during the the first year.

Appendix 2

Tools Needed (for installation of rain garden by a homeowner)

- Clam shell post hole digger
- Shovel
- Rakes
- Rope
- Wooden stakes
- Flags
- String
- A carpenter's level
- Tape measure
- Materials for removing existing vegetation (Round-up, plastic, cardboard, sodcutter, etc.)
- Work gloves
- Wheel barrow
- Rototiller

Photo by Jennifer Welch

A rototiller is used to prepare a rain garden site in Madison County.

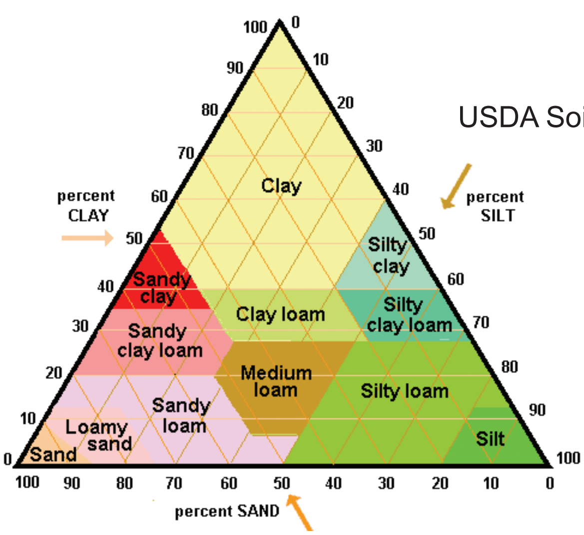
Appendix 3

Soil Texture and Percolation Rates

Hydrologic soil properties classified by soil texture

Soil Texture Class	Hydrologic Soil Group	Effective Water Capacity (C_w) (in/in)	Minimum Percolation Rate (in/hr)	Effective Porosity (in^3/in^3)
Sand	A	0.35	8.27	0.025 (0.022-0.029)
Loamy sand	A	0.31	2.41	0.024 (0.020-0.029)
Sandy loam	B	0.25	1.02	0.025 (0.017-0.033)
Medium Loam	B	0.19	0.52	0.026 (0.020-0.033)
Silt loam	C	0.17	0.27	0.300 (0.024-0.035)
Sandy clay loam	C	0.14	0.17	0.020 (0.014-0.026)
Clay loam	D	0.14	0.09	0.019 (0.017-0.031)
Silty clay loam	D	0.11	0.06	(0.026 (0.021-0.032)
Sandy clay	D	0.09	0.05	0.200 (0.013-0.027)
Silty clay	D	0.09	0.04	0.026 (0.020-0.031)
Clay	D	0.08	0.02	0.023 (0.016-0.031)
Note: Minimum rate: soils with lower rates should not be considered for infiltration BMPs				

Source: Rawls et al., 1982



USDA Soil Textural Classification

Note that 50-60 percent sand puts soils in the sandy loam textural class, which has a percolation rate of 1 inch per hour.

Appendix 4

Design Exercises

Exercise 1

Assume you have a 2000 sq. ft. house. You have 4 downspouts taking equal amounts of runoff. Therefore, 2000 sq. ft. divided by 4 downspouts = 500 sq. ft. / downspout. Measure it out to confirm. 25 ft. L x 20 ft. W = 500 sq. ft. You can add a safety factor in and account for the slope of the roof by multiplying the measured area by 12% - or 0.12. In this example 500 sq. ft. x 0.12 would yield an additional 60 sq. ft., making the total area to design for 560 sq. ft.

Assume you have perc rates of 0.5 in./hr. and want a depth of 6 inches:

560 sq. ft. x .20 (from text) = 112 sq. ft. of surface area needed for the rain garden.

Now determine the dimensions of the rain garden:

112 sq. ft. ÷ 10 ft. W = 11 ft. L x 10 ft. W (Try to go longer and more narrow.)

112 sq. ft. ÷ 7 ft. W = 16 ft. L x 7 ft. W (Not bad...can you comfortably work 3.5 ft. in from either side to do planting, weeding, etc. without having to walk and compact the surface of the rain garden?)

Does that length fit the site? (Remember, the roof line you're managing water from is 25 ft. long).

112 sq. ft. ÷ 5 ft. W = 22 ft. L x 5 ft. W (Easy to work from the sides but may be getting too long for the site).

Exercise 2

Assume you have the same house dimensions but have perc rates of 1 in./hr. You want to stay with the 6 inches of depth for your rain garden.

Once again you'll have 560 sq. ft. of impervious surface to manage runoff from.

560 sq. ft. x 0.10 (from text) = 56 sq. ft. of surface area needed for the rain garden

Now determine the dimensions of the rain garden:

56 sq. ft. ÷ 10 ft. L = 10 ft. L x 6 ft. W

56 sq. ft. ÷ 12 ft. L = 12 ft. L x 5 ft. W

Note: Don't get too worried about going to a shorter and wider layout if it fits the site better. But do pay attention to traffic and compaction on the bottom of the rain garden. You could lay boards across the top of the garden to do planting and weeding or you can create decorative paths through the planting and confine foot traffic to the pathways. And remember, a rain garden doesn't have to be square or rectangular. It can be any shape you desire or that fits the site best. These dimensions are guidelines for sizing, so try to get this square footage even if the rain garden is an irregular shape. If you end up a little larger or a little smaller, that's fine. Remember, you can't make a rain garden too big and you have a safety factor built into the design if you end up a little smaller.

Appendix 5

Temporarily Impounded Water Calculations

(The formula on Appendix 4 covers this, but if you're curious about how much water you're managing you can calculate it with this formula):

Sq. ft. of impervious surface ÷ 43,560 sq. ft. = _______ acres of impervious surface.

______ acres of impervious surface x 27,152 gallons/ac./inch of rain = _____gallons/inch.

______ gallons/ac./inch x 1.25 inches = ________gallons/1.25 inches (WQv).

______ gallons x 0.1337 cu. ft./gal. = ______ cu. ft. of runoff to manage.

Exercise 1

From the example above we know we have 560 sq. ft. of impervious surface to manage. So,

560 sq. ft. ÷ 43,560 sq. ft./ac. = 0.013 ac. of impervious surface

0.013 ac. x 27,152 gallons/ac./inch = 353 gallons of rain/inch from the downspout

349 gallons/inch x 1.25 inches = 441 gallons for the WQv

436 gallons x 0.1337 cu. ft./gallon = 59 cu ft of water

With a rain garden surface area of 112 sq. ft. x 0.5 ft. deep = ~56 cu. ft. of available storage. That's close enough to the 59 cu. ft. of water being generated. Remember, not 100 percent of the rainfall will reach the rain garden, and there will have been some infiltration before the last of the runoff arrives.

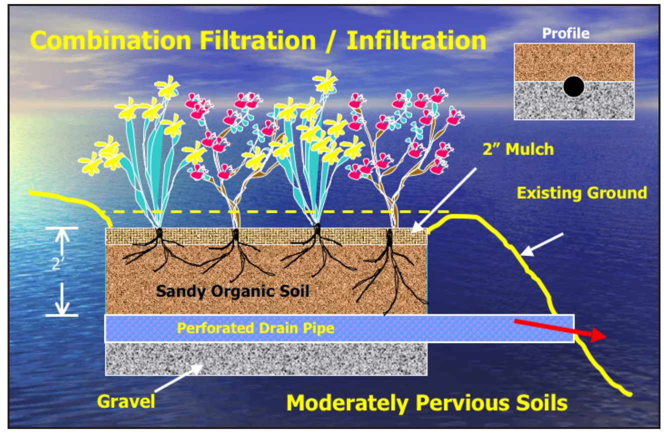
Exercise 2

With percolation rates of 1 inch/hr., we will have about half the cu. ft. of temporary storage. We had a surface area of 56 sq. ft. x 0.5 ft. of depth = about 28 cu. ft. of storage. We still have 59 cu. ft. of water to manage. So, doubling the percolation rate offsets the reduced storage we have, compared to what we needed above.

Appendix 6

Bioretention Cells

A bioretention cell - or a bio-cell - is designed with a specified square footage of surface area and a specified depth, just like a rain garden. But a bio-cell has an engineered sub-grade that extends to frost line (42-48 inches). The sub-grade of a bio-cell has an 8-12 inch gravel bed with a perforated drain tile embedded in it. It has 24-30 inches of an “engineered” soil mix – typically about 60% sand, 25% compost, and 15% topsoil. Ponding depth of the bio-cell is typically in the 6-9 inch range, like a rain garden.



A bioretention cell is used where impounded water is not able to infiltrate into the surrounding soils, typically because the natural soils have been altered and compacted. The drain tile in the gravel bed ensures that water moves through the engineered soil mix. Bacteria in the soil mixture captures and breaks down pollutants. Water released from the bio-cell is cleaned up and cooled off, after moving down to frost line where the soil maintains a constant temperature of 50-some degrees. Water is slowly released via the drain tile, mimicking the way groundwater releases as it moves down gradient in natural soils.

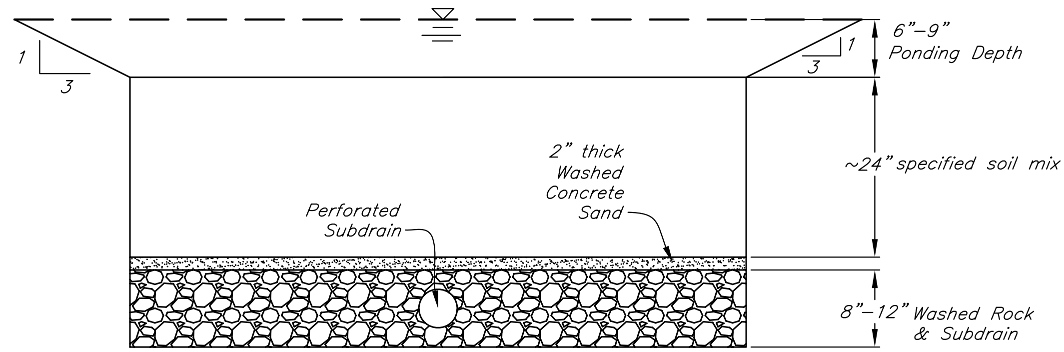
The tile of a bio-cell needs a place to outlet so water that has moved through the cell can be released. This means that a downhill site is needed to outlet the tile – or in some cases the sub-drain tile is outletted into a storm sewer located near the bio-cell. Typically bioretention cells are used to treat large expanses of impervious surfaces, such as large parking lots in commercial settings, but they may be needed in residential settings, too.

Another option for sites with questionable percolation rates (0.5 to 1 inch/hour) is to install an enhanced rain garden. If you have a place to outlet a tile, dig a trench down the centerline of the rain garden to frost line. Install a 1” - 2” layer of washed, 1” rock. Place a perforated drain tile in the trench. Bed the trench in another 8” - 10” layer of washed, 1” rock. Place a 2” layer of washed concrete sand on the rock. Fill the trench with the specified soil mix. (See Appendix ?, page ?). This would allow you to use the design factor from the 1” per hour chart and downsize the surface area of the rain garden.

Appendix 7

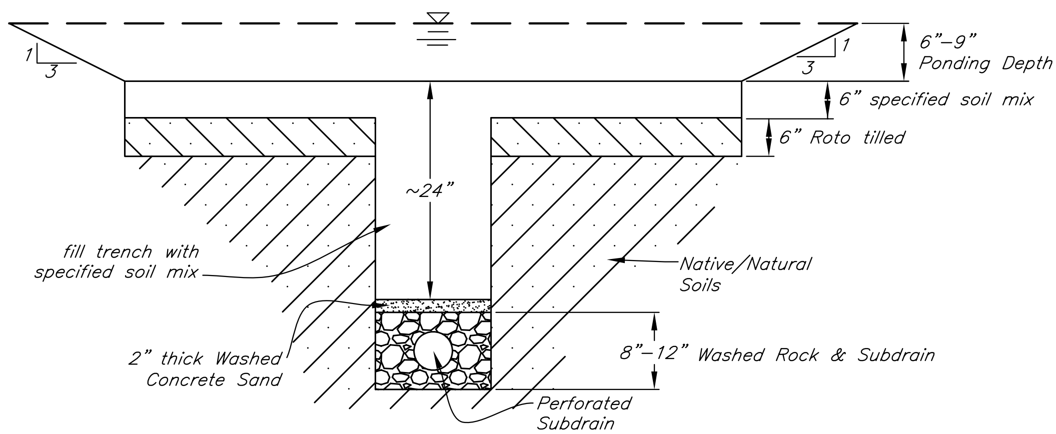
Typical Cross Sections for Infiltration Cells

Typical Bioretention Cell Cross Section



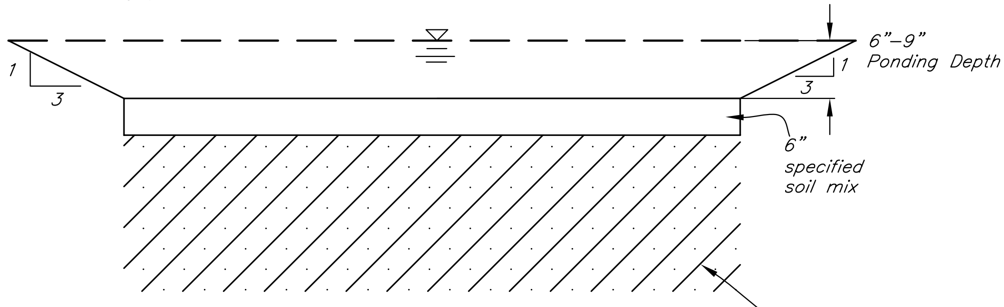
Percolation Rates less than 0.5"/hour

Enhanced Rain Garden Cross Section



Percolation Rates of 0.5"/hour to 1"/hour

Typical Rain Garden Cross Section



Percolation Rates of 1"/hour or more

Appendix 8

Calculating Soil Amendments

How much compost to add:

1. Depth of a 3-inch layer of compost is 0.25 feet (3” ÷ 12” = 0.25 ft. of compost).

2. Multiply 0.25 ft. of compost x ____ sq. ft. of rain garden surface area = ____cu. ft. of compost needed.

3. Convert ____ cu. ft. needed to ____cubic yards by dividing ___cu. ft. by 27 = ____cu. yd. needed.

4. Multiply cu. yd. needed by 1200 lbs. to calculate the weight of compost needed. ____ cu. yd. x 1200 lbs./cu. yd. of compost = ____ lbs. of compost needed.

5. If you’re buying bagged compost from a store divide the ____ lbs. of compost needed by the weight of the bag to determine the number of bags needed.

6. If compost is being purchased in bulk from a composting facility it will usually be sold by the ton. Divide ____ lbs. of compost needed by 2,000 = ____ tons needed.

A heaping load of compost on a full sized pick up truck will weigh about 1.5 tons. It never hurts to have too much compost. What might not be needed for amending a rain garden’s soil can be used to mulch trees or gardens or simply spread as a light layer on turf, which will increase organic matter content and make a yard better able to absorb rain.

How much sand to add:

1. 3” of sand ÷ 12” = 0.25 ft. of sand.

2. 0.25 feet of sand x ____sq. ft. of surface area = ___cu. ft. of sand needed.

3. Convert to cubic yards by dividing ___ cu. ft. by 27 cu. ft. per cu. yd. = ____ cu. yds. needed.

4. Sand is usually sold by the ton at sand pits so multiply the cu yd needed by 1.5 to convert your needs to ___ tons of sand.

Appendix 9

Native Plant Favorites for Soils with Good Percolation Rates

Common Name	Height	Comments	Forb/Grass
Blue grama	1-2 ft	makes a good border	grass
Bottle gentian	1 ft	novel purple flowers	forb
Butterfly milkweed	1-4 ft	emerges late spring; no milky sap	forb
Columbine	1-2 ft	orange flower stalk may add 1 ft	forb
Culver’s root	3-6 ft	can get tall; for moderatley moist soils	forb
Fox sedge	1-3 ft	may not tolerate drought	grass
Golden alexander	1-3 ft	yellow dill-like flower, mod moist soils	forb
Little bluestem	2 ft	nice rusty color all winter	grass
Mountain mint	1-3 ft	for moist soils	forb
Nodding onion	1-2 ft	for moderately moist soils	grass
Pale purple coneflower	4 ft	most overused native; only in S. Iowa	forb
Prairie blazing star	2-5 ft	for moist soils	forb
Prairie smoke	1 ft	makes a good border	forb
Sideoats grama	2-3 ft	red anthers; not as tidy as little bluestem	grass
Silky aster	1-2 ft	loved by rabbits	forb

Websites with native plant lists for rain gardens:

- http://prrcd.org/inl/recommended_plants.htm
- http://www.dnr.state.wi.us/runoff/rg/plants/PlantListing.html

Rain Gardens

Iowa Rain Garden Design and Installation Manual

Acknowledgements

This document was created, reviewed, edited, and approved by the Iowa Stormwater Partnership under the direction of Wayne Petersen, Iowa Department of Agriculture and Land Stewardship-Division of Soil Conservation (IDALS-DSC). Thanks to those who reviewed and provided input on content.
Reviewers include:

- Inger Lamb and Anita Maher-Lewis, Prairie Rivers Resource Conservation & Development (RC&D)
- Jennifer Welch, Polk Soil and Water Conservation District (SWCD)
- Pat Sauer, Iowa Storm Water Education Program (ISWEP)/IAMU
- Kathleen Gibbons, Iowa Association of Municipal Utilities (IAMU)
- Brenda Nelson, Nelson Design
- Rich Maaske, IDALS-DSC
- Steve Anderson, Dickinson SWCD
- Kim Proctor, IDALS-DSC
- Rebecca Kauten, Black Hawk SWCD
- Eric Schmechel, Dubuque SWCD
- Amy Johannson, Scott SWCD
- Amy Bouska, Johnson SWCD
- Mark Masteller, Iowa Department of Transportation (IDOT)
- John Paulin, Prairie Rivers RC&D
- Doug Adamson, RDG Planning & Design
- Stacy Schlader, USDA Natural Resources Conservation Service (NRCS)
- Christian Osborn, USDA-NRCS

Thanks to Jason Johnson, USDA-NRCS, for assistance formatting the manual.

First Printing March 2008
Second Printing May 2008
Third Printing October 2009

Residue and Tillage Management, No-Till/Strip-Till/Direct Seed (329)
Residue Management, Seasonal (344)
Residue and Tillage Management, Mulch-Till (345)
Residue Tillage Management, Ridge-Till (346)

Illinois Job Sheet – 329, 344, 345, 346 *September 2011*

Photos courtesy of NRCS

What is Residue Management?

Residue Management is leaving last year's crop residue on the soil surface by limiting tillage and other disturbances such as bailing and grazing. Residue tillage and management practices include no-till, strip-till, mulch-till and ridge-till.

Conservation Benefits

Crop residue and tillage management practices reduce soil erosion by wind and water. Crop residue can maintain or develop soil tilth, add organic matter, improve water infiltration, and reduce soil moisture loss when left at or near the soil surface. Less tillage reduces soil compaction.

Considerations

Crop selection, including variety will influence residue amounts produced. Higher plant population and narrower rows will increase residue distribution at harvest. Equally important is the crop rotation. Crop rotations that include high residue producing crops such as corn, sorghum (milo), and small grains maximize the benefits of crop residue tillage and management practices.

Planning for residue cover begins at harvest. Ensure the combine spreads ample residue evenly over the field. The amount of residue left on the surface determines the erosion reduction benefit.

Leave crop stubble as high as possible during harvest. Standing residue is most effective for reducing wind erosion.

Fragile residues (soybeans, sunflowers, sugar beets, etc.) are more easily buried with tillage.
Use straight points and sweeps on chisel plows instead of twisted points as twisted points can bury 20% more residue.

Set tillage tools to work at shallower levels.

Reduce speed – slower speeds leave more residues on the soil surface.

Implement dealers and manufacturers can provide information on how to adjust, modify and operate implements to leave more residues on the surface.

No-Till and Strip-Till

No-till and Strip-till crops are planted into the previous crop residue that has not been tilled (no-till) or into narrowly tilled strips that leave the rest of the field untilled (strip-till).

Fertilizer can be applied either in the fall or in the spring either in a band, broadcast, or injected. Weeds are typically controlled before planting with burn down and/or pre-emerge herbicides. Post emergence herbicides are often used during the growing season. Cultivation can also be used for emergency or rescue weed control only.

NRCS – ILLINOIS
September, 2011

Ridge-till

Crops are planted on ridges that are formed the previous year at the last cultivation using a specialized cultivator.

During the planting operation, crop residue is cleared from the row middles and moved to the furrow. The crop is planted in rows on a raised ridge. Fertilization and weed control are the same as for no-till and strip-till. A ridge-till system is limited to row crops.

Mulch-till

The entire soil surface is tilled, either in the fall and/or the spring. The crop residue is partially incorporated, but enough remains on the soil surface to protect the soil from erosion. The amount of residue buried depends primarily on the type of tillage implement, speed and depth of the operations. Residue type and degree of decomposition also influences burial depth during tillage. There are more options for weed control and fertilization with mulch-till systems. The possibility of burying too much residue and increasing erosion must be considered.

The photos are examples of what various amounts of residue looks like.


Corn 25% residue


Corn 50% residue


Corn 75% residue


Soybeans 25% residue


Soybeans 50% residue


Soybeans 75% residue

Crop residue and tillage management effects on soil erosion and organic matter can also be predicted using the Revised Universal Soil Loss Equation, Version 2 (RUSLE 2). RUSLE 2 is a software program available to the public. The software and database files can be obtained at the following website. http://fargo.nserl.purdue.edu/rusle2_dataweb/

Producer Name	**Date**
FSA Tract Number	**Fields**
Planned by	

Crop	Previous Crop	Tillage Method[1/]	% Ground Cover After Planting

[1/] NT=No-till, Strip-till MT=Mulch till RT= Ridge till

NRCS - ILLINOIS
September, 2011

Estimates of residue cover remaining after machinery operations.

Tillage operation	Corn/Small Grain	Soybeans
After harvest	.75 - .95	.65 - .80
Over winter decay	.80 - .95	.70 - .80
Moldboard Plow	.00 - .10	.00 - .05
Chisel – Sweeps*	.70 - .85	.50 - .60
Chisel – Straight Point*	.60 - 80	.40 - .60
Chisel-Twist Point*	.50 - .70	.30 - .40
Disk-Offset	.30 - .60	.20 - .40
Disk-Tandem(Primary.)	.70 - .80	.40 - .50
Disk-Tamdem(Secndry.)	.30 - .60	.20 - .40
Field Cult. (Primary)	.35 - .70	.50 - .70
Field Cult (Secondary)	.70 - .80	.50 - .60
Soil Finisher	.50 - .70	.30 - .50
Harrows	.70 - .90	.60 - .80
Drills-Hoe	.50 - .80	.40 - .60
Drills – double disk	.80 - .95	.60 - .80
Drills – no-till	.75 - .95	.60 - .85
Planter-double disk	.85 - .95	.75 - .85
Planter-row cleaners	.60 - .80	.50 - .60
Planter-no-till coulter	.75 - .95	.70 - .90
Planter – wide fluted	.65 - .85	.55 - .80
Planter-ridge-till	.40 - .60	.20 - .40
Anhydrous Applicator	.75 - .85	.45 - .70

• - Reduce values by .05 - .10 when chisel is equipped with cutting coulters or disks.

Use this method to calculate your estimated residue cover:

After harvest x operation x operation x operation x operation x operation x operation = % cover remaining
_____ x _____ x _____ x _____ x_____ x _____ x _____ = _____

Here is an example:
.95 (%after harvest) x .90 (over winter) x .60 (chisel – straight points) x .80 (field cultivate w/sweeps) x .90 (plating) = .37, or 37% ground cover remaining after planting. Check estimates by measuring residue.

The above chart has been developed from research data. For each machine listed, the numbers are the ranges of crop residue expected to be left after one pass with that piece of equipment. The actual residue level can vary widely and should be measured. You should make some test passes, check residue cover, and make needed adjustments to equipment or operation, such as speed and depth. Set equipment to work shallower, drive slower, and use tillage points that fracture the soil rather than turn or throw the soil.

NRCS – ILLINOIS
September, 2011

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

RIPARIAN FOREST BUFFER

(Acre)
CODE 391

DEFINITION

An area predominantly trees and/or shrubs located adjacent to and up-gradient from watercourses or water bodies.

PURPOSES

- Create shade to lower water temperatures to improve habitat for aquatic organisms.
- Create or improve riparian habitat and provide a source of detritus and large woody debris.
- Reduce excess amounts of sediment, organic material, nutrients and pesticides in surface runoff and reduce excess nutrients and other chemicals in shallow ground water flow.
- Reduce pesticide drift entering the water body.
- Restore riparian plant communities.
- Increase carbon storage in plant biomass and soils.

CONDITIONS WHERE PRACTICE APPLIES

Riparian forest buffers are applied on areas adjacent to permanent or intermittent streams, lakes, ponds, and wetlands. They are not applied to stabilize stream banks or shorelines.

CRITERIA

General Criteria Applicable To All Purposes

Position and design the riparian forest buffer to achieve sufficient width, length, vertical structure/density and connectivity to accomplish the intended purpose(s).

Where subsurface drains (tile lines) cross a tree/shrub planting, and where these drains will remain functional:

(1) Install sealed conduit through the planting and extend a minimum for 100 feet from rows of large trees (capable of reaching heights greater than 60 feet) and 50 feet from all other trees and shrubs.

(2) Avoid planting trees and shrubs within 50 feet of either side of functional subsurface drains.

Assess the severity of bank erosion and its influence on existing or potential riparian trees and shrubs. Watershed-level treatment or bank stability activities may be needed before establishing a riparian forest buffer.

Maintain overland flow through the riparian area as sheet flow.

Control excessive sheet-rill and concentrated-flow erosion in the areas immediately adjacent and up-gradient of the buffer site.

Dominant vegetation will consist of existing, naturally regenerated, or seeded/planted trees and shrubs suited to the soil and hydrology of the site and the intended purpose(s). Limit natural regeneration to sites not suited to any kind of tree planting. The tree planting plan developed for establishing the buffer will include justification for use of natural regeneration. See Conservation Practice Standard TREE/SHRUB ESTABLISHMENT (Practice Code – 612) for additional criteria and specifications for natural regeneration and tree planting.

Conduct necessary site preparation and planting at a time and manner to insure survival and growth of selected species for achieving the intended purpose(s). See Conservation Practice Standards TREE/SHRUB SITE PREPERATION (Practice Code – 490) and TREE/SHRUB ESTABLISHMENT (Practice Code – 612) for additional criteria and specifications.

Use tree and shrub species that are native and non-invasive. For plantings and seeding, only use viable, high-quality and adapted plant materials. Select species from Table 1, Plant List for Riparian Forest Buffers, or from Conservation Tree/Shrub Suitability Groups located in Section II of the Illinois Field Office Technical Guide. Improved and locally accepted cultivars or purpose-specific species may be substituted in place of the listed plantings.

No single species will make up more than 50% of the total number of species planted.

Favor tree and shrub species that have multiple values such as those suited for timber, nuts, fruit, florals, browse, nesting, and aesthetics. When adapted to conditions, use heavy-seeded species marked with an asterisk in Table 1.

Control or exclude livestock as necessary to achieve the intended purpose. Use the criteria in Conservation Practice Standards PRESCRIBED GRAZING (Practice Code – 528) and/or ACCESS CONTROL (Practice Code – 472), as applicable.

Livestock control must include a grazing prescription that addresses duration, intensity, season/frequency of use, and alternative water sources. Where planned riparian buffer function will be impaired by livestock overuse (trampling, compaction, over utilization of woody cover, etc.) livestock must be immediately removed from the riparian area. Evaluate and reduce or eliminate livestock access to keep the riparian area fully functional.

Control or eliminate harmful plant and animal pests present on the site as necessary to achieve and maintain the intended purpose. If pesticides are used, use the criteria in Conservation Practice Standard PEST MANAGEMENT (Practice Code – 595).

Extend the vegetation a minimum width to achieve the purpose(s). Begin measurement at and perpendicular to the normal water line, bank-full elevation, or the top of the bank as determined locally. (see Figure 1) The forested buffer will consist of a minimum of two zones as established in the table below.

Minimum Zone Widths

Stream Order	Zone 1	Zone 2	Total
1st & 2nd	25 feet	25 feet	50 feet
3rd & Larger	25 feet	75 feet	100 feet

Stream order can be determined using a USGS 7.5 minute quad map: first order streams are those which have no tributaries and are at the uppermost level of a watershed. Two first order streams join to form a second order stream, two second order streams join to form a third order stream, etc.

Zone 2, for any stream order classification, may be increased to include areas of overland out-of-bank flow and/or scour erosion, up to the width of the 100-year floodplain. Document evidence of scour erosion, debris deposits or sediment deposition by observation during a site visit or by evaluation of aerial photography.

Maximum combined width of zones 1 and 2 is defined by the 100-year floodplain (see Figure 2). The 100-year floodplain can be determined from Federal Emergency Management Agency (FEMA) maps or other documented materials. Additional assistance may be obtained from the Illinois Water Survey in determining the 100-year floodplain. On small streams with floodplains less than 50 feet wide the maximum combined width of zones 1 and 2 is 50 feet.

Periodic removal of some forest products such as high value trees, medicinal herbs, nuts, and fruits is permitted provided the intended purpose is not compromised by the loss of vegetation or harvesting disturbance.

Trees to be harvested should be marked by a forester to avoid “highgrading” the stand. Direct felling and skidding of trees away from the water course or water body. Conduct skidding in a manner to prevent creation of ephemeral channels perpendicular to the stream.

Control concentrated flow erosion, excessive sheet and rill erosion or mass soil movement in the up-gradient area immediately adjacent to zone 2 prior to establishment of the riparian forest buffer.

Figure 1 Minimum Widths for Riparian Buffers

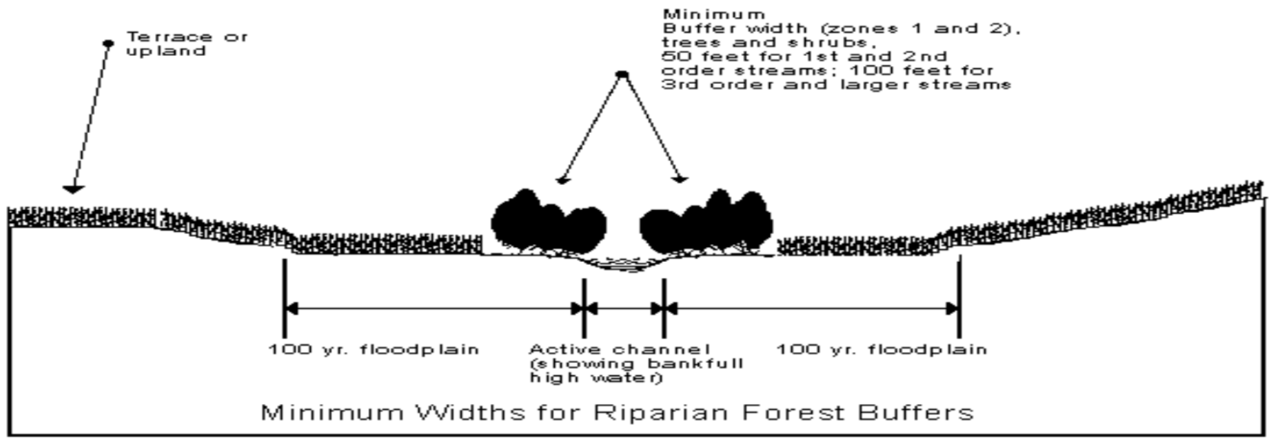
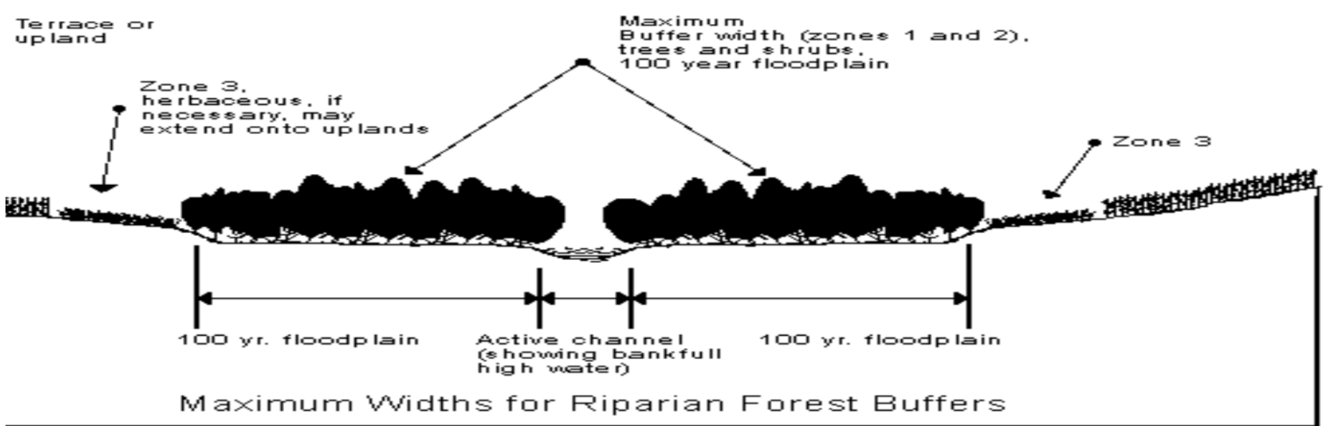


Figure 2 Maximum Widths for Riparian Buffers



Additional Criteria to Reduce Excess Amounts of Sediment, Organic Material, Nutrients and Pesticides in Surface Runoff and Reduce Excess Nutrients and Other Chemicals in Shallow Ground Water Flow

Extend the width beyond the minimum in high nutrient, sediment, and animal waste application areas, where the contributing area is not adequately treated or where an additional level of protection is needed.

Existing, functional underground drains through the riparian area can pass pollutants directly to the outlet. Where such pollutants are to be filtered, use Conservation Practice Standard STRUCTURE FOR WATER CONTROL (Practice Code – 587), to accomplish DRAINAGE WATER MANAGEMENT (Practice Code – 554). Alternative to drainage water management, the structure for water control can be used to distribute drainage water through perforated drain pipe set parallel to the riparian area, using criteria in SUBSURFACE DRAIN (Practice Code – 606) to allow passage and filtration of drain water through the riparian forest root zone. Caution is advised that saturated conditions in the riparian and adjacent areas may limit existing land use and management, and may cause bank stability problems.

Zone 3

Where ephemeral, concentrated flow or sheet and rill erosion and/or sedimentation are concerns in the area up-gradient of Zone 2, an additional Zone 3 will be established (see figure 2). Zone 3 is a vegetated strip consisting of grasses or grasses and forbs. Stiff-stemmed grasses established at the up-gradient edge of Zone 2 will accelerate deposition of sediment. Use minimum and maximum width and vegetative establishment criteria from Conservation Practice Standard FILTER STRIP (Practice Code – 393) in designing Zone 3.

Zone 3 may be included in the 100 year flood plain or it may begin at the boundary of the 100-year floodplain and extend onto adjacent uplands.

Manage the dominant tree canopy to maintain maximum vigor of overstory and understory species. Periodic thinning and/or prescribed burning may be necessary to allow adequate light to reach the forest floor to maintain a good cover of grasses and forbs. Forest canopy cover may reach 100% during the first 10-15 years but should be thinned to approximately 80% to maintain vigor and influence species composition of both the understory and overstory.

Additional Criteria to Create Shade to Lower or Maintain Water Temperatures to Improve Habitat for Aquatic Organisms

Select buffer species listed in Table 1 capable of achieving desired height and crown density required for shade production. Place drooping or wide-crowned trees and shrubs nearest the water course or body. Establish the buffer canopy to achieve at least 50 percent crown cover with an average projected canopy shade (shadow) length equal to or greater than the width of the water course or 30 feet for water bodies.

Summer Sun Shadow Lengths

Listed below is a shadow length table for design tree heights in Illinois.

10:00 AM to 2:00 PM

Tree Height (ft)	June	July	August
40	23	25	32
50	29	31	40
60	35	38	48
70	41	44	56
80	47	50	64
90	52	57	72

(Source: ASHRAE Handbook, 1972.)

To determine the appropriate combination of shadow length relative to tree height, Identify the appropriate month of concern then select the appropriate shadow length that equals the water body dimensions that need shading. The tree height value on the left will be the needed projected mature height for the design shading lengths. Account for effective tree heights when determining shading lengths. Adjustments should be made for incised streams and topographic features that would add to the effective height of woody vegetation. For example, a tree 50 feet tall along an incised stream with normal flow elevation 10 feet below stream bank would have an effective tree height of 60 feet.

Additional Criteria to Create or Improve Riparian Habitat and Provide a Source of Detritus and Large Woody Debris

Extend the width beyond the minimum to meet the minimum habitat requirements of the wildlife or aquatic species of concern.

Establish plant communities that address the target aquatic and terrestrial wildlife and pollinator needs and have multiple values such as habitat, nutrient uptake and shading. The establishment of diverse native woody and herbaceous species will enhance wildlife and pollinator values.

Within Zone 1 as a minimum, establish, favor or manage species capable of producing stems and limbs of sufficient size to provide an eventual source of large woody debris for in-stream habitat for fish and other aquatic organisms. See Table 1 for recommended species.

Riparian Wildlife Width Guidelines

The following guidelines represent the standard minimum riparian forest buffer widths for selected species:

Species	Minimum Width (ft.)
Bald eagle, cavity nesting ducks, heron rookery, turkey, pileated woodpecker	600
Beaver, dabbling ducks, mink, song birds, squirrels, mink	300
Deer, frog, salamanders	200

Minimum widths are the sum of the combined width of Zone 1 and Zone 2 on one or both sides of water courses or water bodies.

Additional Criteria for Increasing Carbon Storage in Biomass and Soils

Maximize width and length of the riparian forest buffer.

Select plants that have higher rates of carbon sequestration in soils and plant biomass and are adapted to the site to assure strong health and vigor. Plant the appropriate stocking rate for the site.

CONSIDERATIONS

Avoid tree and shrub species which may be alternate hosts to undesirable pests. Consider species diversity should be considered to avoid loss of function due to species-specific pests.

Consider allelopathic impacts of plants.

The location, layout and density of the buffer should complement natural features, and mimic natural riparian forests.

Maximize widths, lengths, and connectivity of riparian forest buffers.

The species and plant communities that attain biomass more quickly will sequester carbon/ faster. The rate of carbon sequestration is enhanced as riparian plants mature and soil organic matter increases.

Complex ownership patterns of riparian areas may require group planning for proper buffer design, function and management.

Favor tree and shrub species that are native and have multiple values such as those suited for timber, biomass, nuts, fruit, browse, nesting, aesthetics and tolerance to locally used herbicides. Consider species that resprout to facilitate prompt regeneration after harvest or any impact. If black walnut is to be planted refer to Guide to Selection of Soil Suitable for Growing Black Walnut in Illinois in REFERENCES.

For sites that have a history of being wet or flooded, consider using plants produced by a containerized air-root pruning method.

Air root-pruned plant stock tends to be larger plants with thick, fibrous roots and capable of beginning seed production within 4-5 years.

Where feasible, consider alternative water sources, such as tanks, ponds, wells and pumps for livestock water supply needs.

A riparian forest buffer will be most effective when used as a component of a sound resource management system that includes integrated crop management and sediment and erosion control practices.

Consider the positive and negative impacts beaver, muskrat, deer, rabbits and other local species may have on the successful management of the riparian and stream system.

PLANS AND SPECIFICATIONS

Prepare specifications for applying riparian forest buffer practices for each site. Use approved specification sheets, Illinois job sheets, technical notes, and narrative statements in the conservation plan, or other acceptable documentation. Incorporate requirements for operation and maintenance of the practice into site specifications.

Plant List

Table 1 lists woody plant species (trees and shrubs) commonly associated with and suited to riparian areas. Key attributes are listed for each plant to assist with the design process for establishing new buffers. For additional species recommendations, based on soils, see Conservation Tree/Shrub Suitability Groups, Section II of the Illinois Field Office Technical Guide.

Where equipment access corridors are necessary adjacent to stream channels, recommended low shrub species include but are not limited to: red-osier dogwood (Cornus stolonifera), gray dogwood (C. racemosa), buttonbush (Cephalanthus occidentalis), arrow-wood (Viburnum recognitum), swamp privet (Forestiera acuminata), and winterberry (Ilex verticillata.

Planting Rates

Initial plant densities for trees and shrubs should be based on their potential height, crown characteristics and growth form, in addition to planting objectives. Refer to practice standard TREE/SHRUB ESTABLISHEMENT (Practice Code – 612), Planting Rates – General, for guidelines on planting densities.

Preparation of Planting Sites

Refer to practice standard TREE/SHRUB SITE PREPARATION (Practice Code – 490) for specifications on preparing planting or seeding sites.

OPERATION AND MAINTENANCE

Periodically inspect the riparian forest buffer and protect the buffer from adverse impacts such as excessive vehicular and pedestrian traffic, pest infestations, concentrated flows, pesticides, livestock or wildlife damage and wildfire.

Replace dead trees or shrubs and control undesirable vegetative competition until the buffer is, or will progress to, a fully functional condition.

Conduct maintenance activities (periodic harvests or thinning) to keep the riparian zones in a healthy, vigorous growing condition. During any manipulation of species composition, stand structure and stocking by cutting or killing selected trees and understory vegetation will maintain the intended purpose(s). Refer to standard Conservation Practice Standard FOREST STAND IMPROVEMENT (Practice Code – 666).

Fertilizers, pesticides and other chemicals used to maintain buffer function shall not impact water quality or non-target species.

As applicable, control concentrated flow erosion or mass soil movement in the up-gradient area immediately adjacent to Zone 2 to maintain buffer function.

Develop additional operation and maintenance requirements on a site-specific basis to assure performance of the practice as intended.

REFERENCES

Guide to Selection of Soil Suitable for Growing Black Walnut in Illinois. Losche, C.K., W.M. Clark, E.E. Voss, and B.S. Ashley, 1980. USDA-Forest Service and USDA-Soil Conservation Service, 38 pp.

Hunter, M.L., Jr. 1990. Wildlife, Forests, and Forestry: Principles of Managing Forests for Biological Diversity. Prentice Hall, Inc. 370pp.

Olson, Rich and W.A. Hubert, 1994. Beaver: Water Resources and Riparian Habitat Manager. University of Wyoming. Laramie, WY.

Rosgen, David L. 1994. A Classification of Natural Rivers. Catena: An Interdisciplinary Journal of Soil Science, Hydrology, Geomorphology, Vol. 22, No. 3, Elsevier Science. Amsterdam, Netherlands.

Schultz, R.C., J.P. Colletti, T.M. Isenhart, W.W. Simpkings, C.W. Mize, and M.L. Thompson. 1995. Design and Placement of a Multi-species Riparian Buffer Strip. Agroforestry Systems 29:201-225.

State of Maryland, Department of Natural Resources, Public Lands, Forest Service, 1993. Soil Erosion and Sediment Guidelines for Forest Harvest Operations in Maryland. BMP Pocket Guide. Annapolis, MD.

U.S. Department of Agriculture, Forest Service, Northeastern Area State and Private Forestry, 1991. Riparian Forest Buffers -- Function and Design for Protection and Enhancement of Water Resources. NA-PR-07-91. Prepared by: David J. Welsh. Radnor, PA.

U.S. Department of Agriculture, Forest Service, Southern Region, 1992. Stream Habitat Improvement Handbook. Tech. Publ. R8-TP 16. Prepared by: Monte E. Seehorn, Atlanta, GA.

U.S. Department of Agriculture, Forest Service, Intermountain Research Station, 1989. Managing Grazing of Riparian Areas in the Intermountain Region. General Technical Report INT-263. Prepared by: Warren P. Clary and Bert F. Webster. Ogden, UT.

Minnesota Extension Service, University of Minnesota, 1996. At the Water's Edge: The Science of Riparian Forestry, BU-6637-S Edited by Steven B. Laursen, St. Paul, MN.

Understanding the Science Behind Riparian Forest Buffers: The Effects on Plant and Animal Communities. Klapproth, J.C. and J.E. Johnson, 2000. VA CES Pub. No. 420-152.

Table 1. Tree and Shrub Plant List for Riparian Forest Buffers

Species (Common/Scientific)		pH Range	Flooding Tolerance	Large Debris	Shade Value	Wildlife Merit	Height (feet)	IL Plant Suitability Zone
arrow-wood	Viburnum recognitum	5.1-6.5	H	L	L	H	8	All
baldcypress	Taxodium distichum	6.1-6.5	VH	M	M	M	80	II, III
birch, river	Betula nigra	4.0-6.5	M	H	M	M	50	All
buttonbush	Cephalanthus occidentalis	6.1-6.5	VH	L	L	L	10	All
cottonwood	Populus deltoides	6.6-7.5	H	H	M	H	90	All
dogwood, gray	Cornus racemosa	6.1-8.5	H	L	L	H	8	All
red-osier	Cornus stolonifera	6.1-8.5	H	L	L	H	12	All
hackberry	Celtis occidentalis	6.6-8.5	M-L	M	M	M	60	All
*hickory, shellbark	Carya laciniosa	5.0-6.6	M	M	H	H	70	All
water	Carya aquatica		VH	M	M	H	70	III
holly, swamp	Ilex decidua	4.0-8.5	VH	L	L	M	16	All
winterberry	Ilex verticillata	4.5-8.0	VH	L	L	M	20	II, III
locust, honey	Gleditsia triacanthos	6.1-7.5	H	H	M	L	70	All
* water	Gleditsia aquatica		VH	M	M	L	60	III
maple, boxelder	Acer nagundo	5.1-7.5	M	H	M	M	40	All
silver	Acer saccharinum	5.5-7.5	M	H	H	M	80	All
red	Acer rubrum	4.5-6.5	M	M	H	M	70	All
*oak, bur	Quercus macrocarpa	4.0-8.5	H	M	H	H	80	All
pin	Quercus palustris	5.5-6.5	M-L	H	M	H	75	All
willow	Quercus phellos	4.5-6.5	M	M	H	H	70	III
shingle	Quercus imbricaria		M	M	M	H	65	All
overcup	Quercus lyrat	4.5-7.5	VH	M	H	H	70	II, III
swamp white	Quercus bicolor	6.6-7.5	M-H	M	H	H	70	All
cherrybark	Quercus pagodafolia	4.5-6.0	M	M	H	H	75	III
swamp chestnut	Quercus michauxii	4.5-6.5	M-H	M	H	H	75	III
shumard	Quercus shumardii		M-L	M	H	H	80	II, III
*pawpaw	Asimina triloba	4.7-7.2	M	L	L	H	25	All
*pecan	Carya illinoensis	6.6-7.5	M	M	H	H	80	All
*persimmon	Diospyros virginiana	6.1-6.5	M	M	M	H	50	II, III
privet, swamp	Forestiera acuminata		VH	L	L	L	14	All
sugarberry	Celtis laevigata	4.4-7.7	M-L	M	M	H	80	II, III
sweetgum	Liquidambar styraciflua	4.5-7.0	M	H	H	H	90	III
sycamore	Platanus occidentalis	6.6-8.5	H	H	M	H	90	All
water tupelo	Nyssa aquatica		VH	H	H	H	90	III
*walnut, black	Juglans nigra	6.6-8.5	M-L	M	M	H	80	All
willow, black	Salix nigra	6.6-7.5	H	H	L	M	60	All
sandbar	Salix exigua (interior)	4.0-7.8	VH	L	L	L	6	All
peachleaf	Salix amygdaloides	6.6-7.5	H	L	L	L	30	All
pussy	Salix discolor	6.6-7.5	H	L	L	L	20	I

*****Heavy seeded species preferred for seeding and planting to increase species diversity.

VH = very high; **H** = high; **M** = medium; **L** = low

pH Range: from Hightshoe, G.L., 1988, Native Trees, Shrubs and Vines for Urban and Rural America and/or IL NRCS PLANTS Database.

Flooding Tolerance: General capacity of the plant to withstand standing water. **VH** = able to survive deep, prolonged flooding for more than one year; **H** = able to survive deep flooding for one growing season, with mortality occurring if flooding is repeated the following year; **M** = able to survive flooding or saturated soils for 30 consecutive days during the growing season; **L** = unable to survive more than a few days of flooding during the growing season without mortality.

Large Debris: Potential for the plant to produce debris larger than ten inches in diameter before senescence. H = large debris likely within life span of the plant; M = large debris possible within life span of the plant; L = large debris unlikely within life span of the plant.

Shade Value: The density or fullness of shade provided by an individual plant's crown in full leaf out condition. H = large crown providing full shade; M = partially open or medium sized crown that provides patchy or incomplete shade; L = very open or small crown that provides minimal shade.

Wildlife Merit: The potential for the plant to provide useful cavity sites and/or quality fruit production for wildlife. H = excellent large cavity potential and/or high quality fleshy fruit or nut production; M = moderate cavity potential or fruit production; L = low cavity potential and dry, non-nut fruit production.

Height: Potential height at physical maturity.

Illinois Plant Suitability Zone: See Illinois NRCS Field Office Technical Guide, Section I - Maps.

Riparian Forest Buffer

Wildlife Job Sheet Insert *391W*

Natural Resources Conservation Service (NRCS)—Illinois ***July 2001***

Riparian forest buffer
Photo courtesy of L. Betts

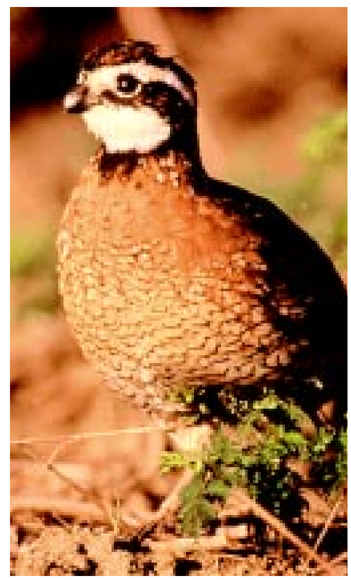
Part I. Planning and Design Considerations

Applicability of Practice

All waterways from small creeks to major rivers have a riparian zone or floodplain. These areas are periodically flooded and represent a transition zone between upland and aquatic habitats. Riparian forest buffers established next to streams, lakes, ponds, seeps, or wetlands potentially provide many benefits to immediate and downstream aquatic habitats. These improvements to aquatic habitats may include improved water quality, cooler water temperatures, reduced soil erosion, stabilized stream banks, improved floodplain function, and recharge of groundwater aquifers. Properly functioning riparian areas are highly productive systems. Productivity of these areas is sustained by high inputs of leaf litter and periodic flooding which facilitates the rapid breakdown of litter and recycling of nutrients. Juxtaposition of riparian areas between upland and aquatic habitats and structural diversity of vegetation caused by frequent disturbances further contribute to the high use of riparian habitats by both resident and nonresident wildlife and aquatic species. Properly designed and maintained riparian forest buffers may serve as breeding habitat, important travel or migration corridors for wildlife, shelter in winter, and critical resting and refueling stops for migratory songbirds during spring and fall.

Site Considerations

- Landowner objectives (types of wildlife use and agricultural use of the riparian area)
- Watershed objectives
- Adjacent waterbody use (e.g., recreation) and fish habitat condition
- Upland conditions and practices affecting riparian functions
- Soil qualities (texture, depth, moisture content)
- Stream channel type (constrained or unconstrained) and relationship to floodplain
- Connection to upstream and downstream habitat or to other nearby wildlife cover
- Width of area and ability to accommodate desired wildlife species
- Special wildlife needs (e.g., threatened or endangered species)



Northern bobwhite
Photo courtesy of J. M. Huspeth

Design Considerations

Fish and wildlife design considerations in Midwestern agricultural landscapes include (1) appropriateness of woody versus grass vegetation; (2) buffer width; (3) food value of plants; (4) plant selection to create non-uniform vegetative structure; (5) placement of plants within buffer; (6) adjacent land uses; and (7) opportunities to link the riparian area with other wildlife habitats. Soil survey and historical records should be referenced to decide whether to plant grass

Red-eared turtles
Photo courtesy of USDA NRCS

or woody plants in project area. As is true for all linear or strip habitats (e.g., fencerows, roadsides, or other buffer practices), wider buffers with non-uniform vegetative structure and irregularly clustered vegetative plantings will accommodate more species of wildlife than narrow, single species stands planted in rows. Where wildlife is the primary design consideration, the design should seek to increase width and structural diversity of plantings. Wildlife responses to width of riparian forest buffers are not well understood; consequently, recommended buffer widths vary widely among species. In the absence of better information, it is recommended that the width of riparian forest buffers extend to boundary of 100-year floodplain. Minimum width is that needed to protect adjacent aquatic habitat. In the Midwest, buffer strips should be a minimum of 50 ft wide for first and second order streams and 100 ft wide for larger streams. Where woody plants are appropriate, buffers should be designed with herbaceous, shrub, and tree zones. Tall trees with spreading canopies should be planted streamside to a width of 25 ft (four or five plants) to provide shade, leaf litter, and large woody debris to the stream. Outside (upslope) edge of tree zone should be planted with two or more rows of shrubs and 20–24 ft of native grasses and forbs. Refer to the table in Part II to determine plant species most suitable to meet the fish and wildlife objectives. Selection of multiple native woody species and irregular placement of plants within zones is preferable to planting single species in rows.

Maintenance Considerations

The amount of maintenance required and the method used to maintain the vegetation of the riparian forest buffers depends on the fish, wildlife, and habitat goals; tree insect and disease issues; and weather. Riparian forest buffers are vulnerable to adverse impacts caused by upland management practices. The best place to address these impacts is in the uplands at the point of origin, rather than at the edge of the buffer. Because of its importance for filtering surface run-off, maintenance of the herbaceous zone must be done carefully. Timing of maintenance of shrub and tree zones is critical if nesting or migratory birds use the buffer. To minimize disturbance to nesting forest birds and avoid tree insect and disease problems, prune and thin from October through April. To encourage use by cavity nesters, allow dead and dying trees to remain. If removal is necessary, then do so selectively retaining a minimum of one snag/200 ft. Additionally, nest boxes that are properly sized for desired species may be erected.

Part II. List of Trees and Shrubs with Medium to High Value for Wildlife

Common Name	Scientific Name	pH Range[1]	Flooding Tolerance[2]	Wildlife Merit[3]	Height (feet)[4]	IL Plant Suitability Zone[5]
Arrowwood, southern	*Viburnum dentatum*	5.1–6.5	H	H	8	All
Ash, green	*Fraxinus pennsylvanica*	6.1–7.5	M	M	60	All
Ash, white	*Fraxinus americana*	6.1–7.5	L	M	70	All
Baldcypress	*Taxodium distichum*	6.1–6.5	VH	M	80	II, III
Birch, river	*Betula nigra*	4.0–6.5	M	M	50	All

—Continued

Part II. List of Trees and Shrubs with Medium to High Value for Wildlife (continued)

Common Name	Scientific Name	pH Range[1]	Flooding Tolerance[2]	Wildlife Merit[3]	Height (feet)[4]	IL Plant Suitability Zone[5]
Cottonwood, eastern	*Populus deltoides*	6.6–7.5	H	H	90	All
Dogwood, gray	*Cornus racemosa*	6.1–8.5	H	H	8	All
Dogwood, red-osier	*Cornus stolonifera*	6.1–8.5	H	H	12	All
Hackberry	*Celtis occidentalis*	6.6–8.5	M–L	M	60	All
Hickory*, shellbark	*Carya laciniosa*		M	H	70	All
Hickory, water	*Carya aquatica*		VH	H	70	III
Holly, swamp	*Ilex decidua*	4.0–8.5	VH	M	16	All
Maple, boxelder	*Acer nagundo*	5.1–7.5	M	M	40	All
Maple, red	*Acer rubrum*	4.5–6.5	M	M	70	All
Maple, silver	*Acer saccharinum*	5.5–7.5	M	M	80	All
Oak*, bur	*Quercus macrocarpa*	4.0–8.5	H	H	80	All
Oak*, cherrybark	*Quercus pagodafolia*		M	H	75	III
Oak*, overcup	*Quercus lyrata*		VH	H	70	II, III
Oak*, pin	*Quercus palustris*	5.5–6.5	M-L	H	75	All
Oak*, shumard	*Quercus shumardi*		M–L	H	80	II, III
Oak*, swamp chestnut	*Quercus michauxii*		M–H	H	75	III
Oak*, swamp white	*Quercus bicolor*	6.6–7.5	M–H	H	70	All
Oak*, willow	*Quercus phellos*		M	H	70	II
Pawpaw*	*Asimina triloba*		M	H	25	All
Pecan*	*Carya illinoensis*	6.6–7.5	M	H	80	All
Persimmon*	*Diospyros virginiana*	6.1–6.5	M	H	50	II, III
Sugarberry	*Celtis laevigata*		M–L	H	80	II, III
Sweetgum	*Liquidambar styraciflua*		M	H	90	III
Sycamore	*Platanus occidentalis*	6.6–8.5	H	H	90	All
Walnut*, black	*Juglans nigra*	6.6–8.5	M–L	H	80	All
Water tupelo	*Nyssa aquatica*		VH	H	90	III
Willow, black	*Salix nigra*	6.6–7.5	H	M	60	All
Winterberry, common	*Ilex verticillata*	4.5–8.0	VH	M	20	II, III

*Heavy-seeded species preferred for seeding and planting to increase species diversity.

[1]pH Range: from Hightshoe, G. L., 1988, *Native Trees, Shrubs and Vines for Urban and Rural America.*

[2] Flooding Tolerance (or general capacity of the plant to withstand standing water): VH = able to survive deep, prolonged flooding for more than one year; H = able to survive deep flooding for one growing season, with mortality occurring if flooding is repeated the following year; M = able to survive flooding or saturated soils for 30 consecutive days during the growing season; L = unable to survive more than a few days of flooding during the growing season without mortality.

[3]Wildlife Merit: The potential for the plant to provide useful cavity sites and/or quality fruit production for wildlife. H = excellent large cavity potential and/or high quality fleshy fruit or nut production; M = moderate cavity potential or fruit production; L = low cavity potential and dry, non-nut fruit production.

[4]Height: Potential height at physical maturity.

[5]Illinois Plant Suitability Zones. See Illinois NRCS Field Office Technical Guide, Section II - Climatic Data.

Part III. Specifications Sheet

Use Specification Sheet provided with general Riparian Forest Buffer Job Sheet. Include fish and wildlife species expected to use area and maintenance specifications relevant to this species or assemblage. Consider instream habitat component needs (water temperature, minimum flows, wood and organic debris, sediment-free substrates) when designing maintenance or other riparian uses such as timber harvest, grazing, water withdrawal for irrigation, or recreation.

NATURAL RESOURCES CONSERVATION SERVICE
CONSERVATION PRACTICE STANDARD

SATURATED BUFFER

CODE 604
(FT.)

DEFINITION

A subsurface, perforated distribution pipe is used to divert and spread drainage system discharge to a vegetated area to increase soil saturation.

PURPOSE

Install the practice to achieve one or more of the following purposes:

- To reduce nitrate loading to surface water from subsurface drain outlets.
- To enhance or restore saturated soil conditions in riverine, lacustrine fringe, slope, or depression hydrogeomorphic landscape classes.

CONDITIONS WHERE PRACTICE APPLIES

This practice is applicable to crop land with a subsurface drainage system that can be adapted to discharge to a vegetated area.

Apply this practice where the soils and topography are capable of maintaining a raised water table without adverse effects to channel banks, shorelines, or adjacent land.

This practice does not apply to drainage systems or underground outlet systems that have surface inlets which allow entry of soil and debris capable of plugging the distribution pipe(s).

Do not use this practice to discharge septic system effluent or animal waste.

CRITERIA

General Criteria Applicable to All Purposes

Design and install measures according to a site-specific plan in accordance with all local, State, Tribal, and Federal laws and regulations. Apply measures that are compatible with improvements planned or being carried out by others.

Conduct geologic and soil investigations to confirm:

- Conditions, such as a restrictive layer or a water table, are present to create saturated conditions when water is diverted from the subsurface drainage system.
- The absence of pockets or layers of high conductivity soil which could provide preferential flow paths.

- A minimum of 0.75 percent organic carbon (1.2 percent organic matter) in the top 2.5 feet of soil.
- The absence of abandoned drain pipes or clay tile in the buffer area that could continue to drain the buffer.

The minimum width of the vegetated buffer zone is 30 feet.

Locate and design the system to maximize the amount of subsurface drainage water distributed to the potentially saturated soil zone. Ensure there are no adverse impacts to adjacent lands.

Avoid placing the distribution pipe along any channels incised deeper than 8 feet, unless a slope stability analysis shows an acceptable level of safety against saturated streambank failure.

Provide a minimum cover of 1 foot over the top of the distribution pipe.

Flow. Use an appropriate model, such as DRAINMOD, to estimate flow into and through the saturated buffer. If such a model is unavailable, use the following to calculate minimum buffer dimensions:

- Soil saturated hydraulic conductivity and average drain flow rate during the growing season to compute the length of distribution pipe required to provide adequate infiltration capacity for the required design flow.
- Soil drainable porosity, saturated hydraulic conductivity, and elevation difference along with the lateral distance that leached water will travel from the distribution pipe to reach an outlet, to determine the retention time in the buffer. Minimum hydraulic retention time for the drainage water in the saturated buffer is 3 hours.

Minimum design flow into the saturated buffer is 15 percent of the maximum capacity of the drainage system.

Water control structure. Design the water control structure using the criteria found in WI NRCS Conservation Practice Standard (WI NRCS CPS) Structure for Water Control (Code 587). Locate the water control structure where it is accessible for water table observation and for operation and maintenance.

Design the water control structure to maintain the design water table elevation over the distribution pipe during the management period based on expected flow rates from the subsurface drainage system.

Use nonperforated pipe for the overflow pipe for the greater of 20 feet or a distance sufficient to avoid draining the saturated soil zone around the water control structure.

Distribution pipe. Design the distribution pipe and overflow pipe according to the criteria found in WI NRCS CPS Subsurface Drain (Code 606). Ensure the capacity of the distribution pipe is larger than the available infiltration rate of the soil.

Situate the distribution pipes on a topographic contour or grade to facilitate uniform groundwater inflow to the saturated zone. Add additional water control structures as needed for flow uniformity. The maximum elevation difference between structures is three feet.

Vegetation. Vegetate the soil saturation area and any other disturbed areas to prevent erosion and to utilize nitrogen from the drain water.

Protect all disturbed areas from erosion within 14 days of construction by seeding or mulching. Refer to WI NRCS CPS Conservation Cover (Code 327), or Critical Area Planting (Code 342) for criteria on seed selection, seedbed preparation, fertilizing, and seeding. The area shall be planted to a mix of hydrophytic species suitable for wet soil conditions.

Additional Criteria to Reduce Nitrate Loading

To reduce nitrogen loading, the saturated buffer will create a shallow water table.

Ensure saturated conditions are within the high soil organic carbon region of the soil profile when adequate drain flows exist. Design the system to maintain a water table within 12 inches of the ground surface at the location of the distribution pipe.

Additional Criteria to Enhance or Restore Saturated Soil Conditions

Design the system to replicate groundwater levels shown in the "Water Features" section of the Soil Survey Report.

CONSIDERATIONS

Consider using other practices and management systems in conjunction with this practice to achieve a reduction of nitrate-nitrogen levels. Examples include WI NRCS CPS Nutrient Management (Code 590), Cover Crop (Code 340), Drainage Water Management (Code 554), Denitrifying Bioreactor (Code 605), and Constructed Wetland (Code 656).

Consider adding an envelope around the drain to improve exit flow. Refer to criteria in WI NRCS CPS Subsurface Drain (Code 606).

For cost-effectiveness, consider locating the saturated buffer where it will intercept a subsurface drain outlet draining at least 15 acres.

Consider installing observation wells in the buffer midway between the distribution pipe and the stream bank or shoreline to facilitate water table documentation and sampling.

A saturated buffer may infiltrate less overland flow than a nonsaturated buffer.

Consider measures to reduce the potential for root plugging of distribution lines by woody species. Set planted trees back far enough that distribution lines will not be under the drip line of mature tree canopies. Plant herbaceous species in areas over distribution lines. If the riparian area is currently in trees, either clear the trees or establish an herbaceous zone outside the tree line for the water distribution area.

PLANS AND SPECIFICATIONS

At a minimum, include the following in the plans:

- A plan view of the layout of the water distribution system.
- Profile(s) of the existing drain, distribution pipe, and outlet channel.
- Details of required structure(s) for water level control.
- Vegetation establishment requirements.
- Construction specifications that describe site-specific installation requirements.

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan following the applicable criteria in WI NRCS CPS Drainage Water Management (Code 554). Review this plan with the land manager. Specified actions include normal repetitive activities in the application and use of the practice (operation), and repair and upkeep of the practice (maintenance). At a minimum, include a description of the following:

- Planned water level management and timing.
- Inspection and maintenance requirements of the water control structure(s), distribution pipe(s), and contributing drainage system, especially upstream surface inlets.
- Periodic removal of invasive trees or shrubs to reduce distribution line plugging.
- If the site is to be monitored, include the monitoring and reporting requirements designed to demonstrate system performance and provide information to improve the design and management of this practice. At a minimum, record water levels (elevations) at the control structure, observation ports, and if used, observation wells. Record water levels biweekly when a water table is present and following precipitation events that result in high flows.

REFERENCES

Jaynes, D.B. and T. Isenhart. 2011. Re-saturating Riparian Buffers in Tile Drained Landscapes. A Presentation of the 2011 IA-MN-SD Drainage Research Forum. November 22, 2011. Okoboji, IA.

Jaynes, D.B. and T. Isenhart. 2012. Re-saturating Riparian Buffers using Tile Drainage. Unpublished.

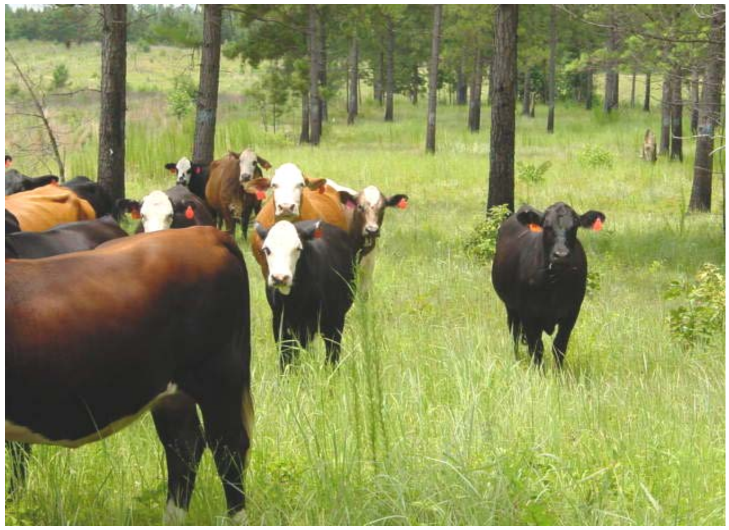
Jaynes, D.B. and T.M. Isenhart, 2014. Reconnecting Tile Drainage to Riparian Buffer Hydrology. Journal of Environmental Quality 43:631-638. doi: 10.2314/jeq2013.08.0331. Advances in Agronomy 92:75-162.

Silvopasture Establishment
Illinois Forestry Information Sheet (IL381-IS)

USDA Natural Resources Conservation Service - Illinois June 2014

Silvopasture: Integrating Trees, Forages and Livestock

What is Silvopasture?



Silvopasture is an agroforestry practice that is specifically designed and managed for the production of trees, tree products, forage and livestock. Silvopasture results when forage crops are deliberately introduced or enhanced in a timber production system, or timber crops are deliberately introduced or enhanced in a forage production system. As a silvopasture practice, timber and pasture are managed as an integrated managed grazing system. Silvopasture is ***not*** the indiscriminate grazing of forest land.

Silvopastoral systems are designed to produce a high-value timber component or alternative forest product, while simultaneously providing short-term cash flow from the livestock component. Overall, silvopastures can provide cost-effective economic returns while creating a sustainable system with many environmental benefits. Well-managed silvopastures also offer diversified marketing opportunities that can help stimulate rural economic development.

Planning Considerations

Before a new silvopasture practice is established, implications of merging forestry and livestock systems should be explored thoroughly for economic and environmental considerations. In addition, local land use, zoning, cost-share programs and tax regulations should be investigated. Forest and agricultural land may have separate zoning and land-use regulations accompanied by divergent tax assessments. Environmental requirements (e.g., planting trees, stream-side protection, and wildlife habitat maintenance) may also vary with land use.

Plants

When making tree and forage crop selections, consider potential markets, soil types, climatic conditions, equipment needs, and species compatibility. On marginally productive lands, some conifer species are well-suited for silvopastures because they can adapt to diverse growing sites, respond rapidly to intensive management and may permit more light to reach the forest floor compared to certain hardwood species. However, native or adapted conifers that would be suited to Illinois conditions are somewhat limited and should be assessed on the individual site basis and also provide a suitable tree crop for the intended market. Select and use trees and planting/harvesting patterns that are suitable for the site, compatible with planned practices and provide desired economic returns and ecosystem services. Clovers or other pasture legumes are often seeded into grass pastures to provide highly nutritious forage for livestock and to convert atmospheric nitrogen into an organic form which plants and animals can use. Competition between trees and pasture is reduced by selecting pasture plants with non-competing growth cycles to trees or are shallower rooted. For example, cool season grasses (such as orchardgrass or timothy) and legumes (such as ladino or red clover) can be seeded into pine stands with little detrimental impact upon growth of either trees or pasture plants.

Trees in pasture provide shelter for livestock during periods of inclement weather. This can significantly improve animal performance during particularly hot or cold times of the year. Trees provide evaporative cooling, reduce radiant heat loss at night, and reduce wind speed. These buffered environmental conditions allow animals to spare energy for growth, particularly under hot conditions. Increased gain, milk yield, and conception rates have been reported for cattle or sheep grazing pastures with trees in warm environments. The tree/timber component should be capable of providing the desired products and be:

- marketable,
- fast growing,
- non-toxic to intended livestock,
- non-invasive,
- native (if possible) and
- compatible with the site (soil, temperature, precipitation, planted forages).

Forage growing under the shady, low wind environment near trees tends to mature more slowly and, therefore, be lower in fiber and more digestible than that growing out in the open. The forage component should be a perennial crop that is:

- suitable for livestock grazing,
- compatible with the site (soil, temperature, precipitation, planted trees),
- productive under partial shade and moisture stress, and
- responsive to intensive grazing management.

Species Selection for Trees

Tree species should be suited to the site and growing conditions, meet the desired objectives of the system and be tolerant and safe for the livestock used. Native trees should be favored wherever possible. The following table is an abbreviated list of suitable tree species.

Table 1. Examples of trees suitable for use in slivopasture			
Uplands			
Bur oak	*Quercus macrocarpa*	**Sugar maple**	*Acer saccharum*
Red oak	*Quercus rubra*	**Shagbark hickory**	*Carya ovate*
White oak	*Quercus alba*	**Pecan**	*Carya illinoinensis*
Black walnut	*Juglans nigra*	**Persimmon**	*Diospyros virginiana*
Pine species	*Pinus spp.*	**Chinkapin oak**	*Quercus muehlenbergii*
Bottomlands			
Persimmon	*Diospyros virginiana*	**Black walnut**	*Juglans nigra*
Silver maple	*Acer saccharinum*	**Pecan**	*Carya illinoinensis*
Swamp white oak	*Quercus bicolor*	**Bur oak**	*Quercus macrocarpa*
Kentucky Coffeetree	*Gymnocladus dioicus*	**Shellbark hickory**	*Carya laciniosa*

Tree Planting Stock

Tree planting stock should be at least 1-3 feet tall with at least 3/8-inch caliper. The large initial size is required to facilitate their protection from fire, reduce competition from grass, and damage from livestock. Seedlings may be planted by hand or machine. Newly planted seedlings should be protected (barrier fence) until their height growth is above the browse reach of livestock. Utilize conservation practice standard TREE/SHRUB ESTABLISHMENT (Practice Code – 612).

Tree Establishment

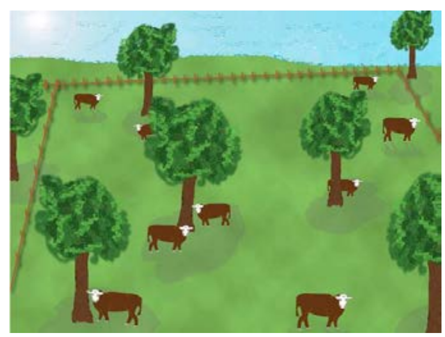
Tree establishment in existing grass fields can be difficult. Items to consider for tree establishment include:

- Site preparation – On sites that have been in pasture and are subject to compaction ripping the soil surface down or adjacent to the planted tree rows before planting will improve growth and survival.
- Weed control – At a minimum, a vegetation free area at least 2 feet in all directions from the tree should be controlled for 2 to 3 years after planting.
- Number of trees – Pine is usually planted at a rate of 200 to 400 trees per acre and hardwoods are generally planted at a rate of 100 to 300 trees per acre. (28 - 48 for container trees >1 gallon)
- Protection – Protect the trees from grazing during establishment utilizing protective measures such fencing or by utilizing the field for hay until the trees are tall enough and strong enough to withstand grazing pressure.
- Utilize conservation practice standards TREE/SHRUB SITE PREPERATION (Practice Code – 490) and TREE/SHRUB ESTABLISHMENT (Practice Code – 612).

Tree Layout & Spacing

Spacing distance between woody plants and row sets should be based on landowner objectives, tree and shrub environmental requirements, light requirements and growth periods of the forage, and machinery requirements.

Plant trees in single, double or triple row-sets; cluster plantings may also be used. When multiple row woody plant sets are used, stagger within row tree spacing with adjacent row to maximize growing space.

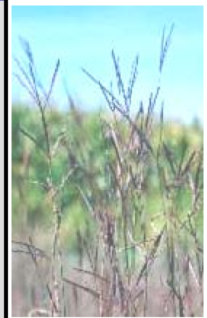
  

For existing forest plantations/stands, reduce stocking levels to at least a 50% stocking level for the normal stand or adjust the canopy density to accommodate the needs of the forage species. Trees should be as uniformly spaced as possible for even shade distribution. Utilize the assistance of a professional forester to identify opportunities to reduce stocking in order to maintain a desirable residual stand to achieve desired forestry goals.

Species Selection for Grass/Legumes

Grasses and legumes should be favored that are tolerant of partial shade and moisture stress, and responsive to intensive grazing management. Suggested examples of possible grasses and legumes for silvopasture use are listed in Table 2. Utilize conservation practice standards FORAGE AND BIOMASS PLANTING (Practice Code – 512) for species selection, establishment and management.

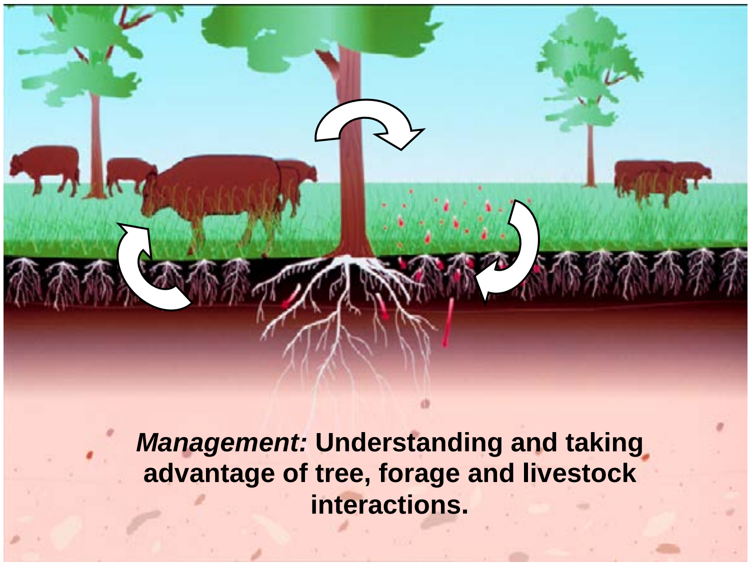
Table 2. Examples of grasses and legumes suitable for use in silvopasture			
Grasses			
Native			
Big bluestem	*Andropogon gerardii*	**Canada wildrye**	*Elymus canadensis*
Little bluestem	*Schizachyrium scoparium*	**Eastern gamagrass**	*Tripsacum dactyloides*
Switchgrass	*Panicum virgatum*	**Virginia wildrye**	*Elymus virginicus*
Indiangrass	*Sorghastrum nutans*		
Introduced			
Novel endophyte fescue	*Festuca spp.*	**Orchardgrass**	*Dacthlis glomerata*
Kentucky bluegrass	*Poa pratensis*	**Timothy**	*Phileum pretense*
Smooth bromegrass	*Bromus inermis*	**Ryegrass**	*Lolium perenne*
Legumes:			
Native			
White prairie clover	*Petalostemon candidum*	**Roundhead lespedeza**	*Lespedeza capitata*
Leadplant	*Amorpha canescens*	**Showy tick trefoil**	*Desmodium canadense*
Introduced			
Annual lespedeza	*Kummerowia striata*	**White clover**	*Trifolium repens*
Alfalfa	*Medicago sativa*	**Red clover**	*Trifolium pratense*
Birdsfoot trefoil	Lotus corniculatus		



Livestock

Potential livestock choices include cattle, sheep, goats, horses, or large game animals such as bison, deer, and elk. The selected livestock system must be compatible with tree, forage, and environmental requirements. In general, browsing animals such as sheep, goats or deer are more likely to eat trees; whereas, large grazing animals such as cattle or elk are more likely to physically break young trees. Younger livestock are more prone to damage trees than older, more experienced animals. Livestock activity is more likely to impact hardwood trees than conifers. Silvopasture establishment within existing forestland in Illinois will be in conjunction with a management intensive rotational grazing system. The appropriate rotational grazing system will be designed to include multiple paddocks, short grazing intervals and appropriate rest periods for forage regrowth. Carrying capacities and grazing intervals will be designed based on the type of livestock being grazed, forage being produced and trees being used in order to optimize tree health and production. Conifers, although not really palatable to livestock, are most likely to be browsed after spring bud break when foliage is still light green in color. Livestock prefer variety in their diet. They will often consume a small amount of tree foliage each day. This small amount of browsing may accumulate to unacceptable levels when animals are in the silvopasture for prolonged periods. Browsing damage can sometimes be eliminated by removing a few problem animals. Trampling of seedlings and livestock rubbing on tree saplings may be a problem, particularly with cattle. Where livestock damage must be avoided, young silvopastures may be hayed, or trees protected from livestock by chemical repellents, electric fences, individual tree shelters or rigid mesh tubes. Once the top branches of trees grow above the reach of livestock and a thick layer of bark has developed, potential for tree damage by livestock browsing is minimal and silvopastures may be managed similar to traditional pastures. Utilize conservation practice standards PRESCRIBED GRAZING (Practice Code – 528) for managing forage and livestock.

Management



Management: **Understanding and taking advantage of tree, forage and livestock interactions.**

At a minimum, a vegetation free area at least 2 feet in all directions from the tree should be controlled for 2 to 3 years after planting. Young trees will benefit from vegetation control after planting. Herbaceous plants and many brush species may be effectively suppressed by prescription grazing, mechanical treatment or chemical application. A commonly used approach when planting trees into established pastures is to spray a strip or circle around trees to provide a two to four foot diameter competition-free zone around each tree.

Livestock grazing must be intensively managed. Silvopasture establishment in Illinois will be in conjunction with a management intensive rotational grazing system. A successful silvopasture requires understanding forage growth characteristics and managing the timing and duration of grazing to avoid compaction, root and bark damage, overgrazing of forage and browsing of young tree seedlings or elongating shoots.

Some things to consider when setting up a silvopasture system include the following items:

- Keep livestock within 800 feet of water
- Make paddocks as near to square as possible
- Follow landscape lines for paddock boundaries
- Make paddocks of similar grazing capacity
- Plan lanes for livestock movement
- Identify and control poisonous plants
- Practice rotational grazing and follow conservation practice standard PRESCRIBED GRAZING (Practice Code – 528).

Livestock should be excluded from tree plantings during vulnerable periods. Similar approaches can minimize damage by trampling or rubbing. Improper management of silvopastures can reduce desirable woody and herbaceous plants by over-grazing and soil compaction. When introducing livestock to newly-established silvopastures: 1) have plenty of feed on hand; 2) provide water, minerals, and supplements away from new trees; and 3) be willing to accept some seedling damage. Thus, proper management is the key to success when implementing silvopastoral systems.

Available management tools include:

- tree harvesting, thinning and pruning
- fertilization to improve both forage and tree production
- planting legumes for nitrogen fixation and forage production
- multi-pasture, rotational grazing
- rotational prescribed fire
- supplemental feeding
- water source infrastructure (e.g., stock tanks, photovoltaic pumps, hydraulic rams, etc.)
- locating salt/mineral licks and walkways to encourage uniform livestock distribution
- fencing (e.g., standard or electric), tubing, plastic mesh, repellents, and seasonal livestock exclusion to reduce damage to young seedlings

Hardwood silvopasture system developed from an existing forest stand.

Conifer silvopasture system developed from an existing grass pasture.

References

The following references have been used in the development of this information sheet.

Adapted from MO NRCS 381 - Information Sheet 2005: Silvopasture Establishment and Management (IS-MO381)

Fike, J. H., Buergler, A. L., Burger, J. A., and Kallenbach, R. L. 2004. Considerations for establishing and managing silvopastures. Online. Forage and Grazinglands.

Garrett, H. E., Kerley, M. S., Ladyman, K. P., Walter, W. D., Godsey, L. D., and Van Sambeek, J. W. 2004. Hardwood silvopasture management in North America. Agroforestry Systems 61: 21-33.

Lin C. H., McGraw, R. I., George, M. F., and Garrett, H. E. 1999. Shade effects on farage crops with potential in temperate agroforestry. Agroforestry Systems 44:109-119.

“Silvopasture: An Agroforestry Practice”. 1997. Agroforestry Notes. National Agroforestry Center. AF Note-8.

“The Biology of Silvopastoralism”. 1997. Agroforestry Notes. National Agroforestry Center. AF Note-9.

“Agroforestry in the United States”. 1996. Agroforestry Notes. National Agroforestry Center. AF Note-1.

For additional information on silvopasture, contact your local USDA Service Center.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

STREAM CROSSING

(No.)

CODE 578

DEFINITION

A stabilized area or structure constructed across a stream to provide a travel way for people, livestock, equipment, or vehicles.

PURPOSE

- Provide access to another land unit
- Improve water quality by reducing sediment, nutrient, organic, and inorganic loading of the stream
- Reduce streambank and streambed erosion.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to all land uses where an intermittent or perennial watercourse exists and a ford, bridge, or culvert type crossing is needed.

CRITERIA

Apply this standard in accordance with all local, State, Tribal, and Federal regulations, including flood plain regulations and flowage easements.

Identify significant cultural resources or threatened or endangered species that could be affected by the implementation of the practice.

Utilities and Permits. The landowner and/or contractor shall be responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

The landowner shall obtain all necessary permissions from regulatory agencies, including but not limited to the Illinois Department of Agriculture, US Army Corps of Engineers, US Environmental Protection Agency, Illinois Environmental Protection Agency and Illinois Department of Natural Resources – Office of Water Resources, or document that no permits are required.

Location. Locate stream crossings in areas where the streambed is stable or where it can be stabilized (see NRCS Conservation Practice Standard, Channel Bed Stabilization, Code 584). Do not place crossings where channel grade or alignment changes abruptly, excessive seepage or instability is evident, overfalls exist (evidence of incision and bed instability), where large tributaries enter the stream, or within 300 feet of known spawning areas of listed species. Avoid wetland areas.

Discourage livestock loafing in the stream by locating crossings, where possible, out of shady riparian areas or by including gates in the design.

Install stream crossings perpendicular to the direction of stream flow where possible. Fully consider the natural lateral migration pattern of the stream in the design. Avoid skews on all but the smallest streams.

Access Roads. Where the stream crossing is installed as part of a roadway, size the crossing according to NRCS Conservation Practice Standard, Access Road, Code 560.

Width. Provide an adequate travel-way width for the intended use. Make “livestock- only” crossings no less than 6 feet wide and no more than 30 feet wide, as measured from the upstream end to the downstream end of the stream crossing, not including the side slopes.

Side Slopes. Make all side slope cuts and fills stable for the channel materials involved. Make the side slopes of cuts or fills in soil materials no steeper than 2 horizontal to 1 vertical (2:1). Make rock cuts or fills no steeper than 1.5 horizontal to 1 vertical (1.5:1).

Stream Approaches. Blend approaches to the stream crossing with existing site conditions, where possible. Use streambank soil bioengineering practices as appropriate and feasible. Make the approaches stable, with gradual ascent and descent grades which are not steeper than 4 horizontal to 1 vertical (4:1), and of suitable material to withstand repeated and long term use. Make the minimum width of the approaches equal to the width of the crossing surface.

Divert surface runoff around the approaches to prevent erosion. Direct roadside ditches into a diversion or away from the crossing surface.

Configure the crossing approaches (gradient and curves) to properly accommodate the length and turning radii of vehicles using the crossing.

Rock. All rock must be able to withstand exposure to air, water, freezing, and thawing. Use rock of sufficient size and density to resist mobilization by design flood flows.

Use appropriate rock sizes to accommodate the intended traffic without damage to the livestock, people, or vehicles using the crossing.

Fencing. Exclude livestock access to the crossing through the use of fence and gates, as needed.

Install cross-stream fencing at ford crossings, with breakaway wire, swinging floodgates, hanging electrified chain, or other devices to allow the passage of floodwater and large woody material during high flows.

Design and construct all fencing in accordance with NRCS Conservation Practice Standard, Fence, Code 382.

Vegetation. Plant all areas to be vegetated as soon as practical after construction. If completion does not coincide with appropriate planting dates for permanent cover, use a cover of temporary vegetation to protect the site until permanent cover can be established. Native or functioning-as-native plant species are preferred. Use NRCS Conservation Practice Standard, Critical Area Planting, Code 342, where vegetation is unlikely to become established by natural regeneration, or where acceleration of the recovery of vegetation is desired.

In areas where the vegetation may not survive, use NRCS Conservation Practice Standard, Heavy Use Area Protection, Code 561.

Bridge Crossings

Design bridges in a manner that is consistent with sound engineering principles and adequate for the use, type of road, or class of vehicle. Design bridges with sufficient capacity to convey the design flow and transported material without appreciably altering the stream flow characteristics. Design bridges to fully span the stream, passing at least the bankfull flow where the design flow is not dictated by regulation.

Bankfull flow is the discharge that fills a stream channel up to the elevation at which flow begins to spill onto the floodplain.

Adequately protect bridges so that out-of-bank flows safely bypass without damaging the bridge or eroding the banks.

Vehicle and pedestrian bridges must be designed in accordance with the current American Association of State Highway and Transportation Officials Load and Resistance Factor Design (LRFD) bridge design specifications (AASHTO, 2010).

Evaluate the need for safety measures such as guardrails and reflectors at bridge crossings.

Acceptable bridge materials include concrete, steel, and wood.

Culvert Crossings

Design culverts in a manner consistent with sound engineering principles and adequate for the use, type of road, or class of vehicle. For culverts associated with a road, culvert design flow shall meet the criteria in NRCS Conservation Practice Standard, Access Road, Code 560. The design flow for culverts not associated with a road will be the 2-year, 24-hour storm discharge, or bankfull flow, whichever is less. Design culverts with sufficient capacity to convey the design flow and transported material without appreciably altering the stream flow characteristics.

Design culverts to minimize habitat fragmentation and to minimize barriers to aquatic organism movement.

Do not use culverts where large flows of sediment or large woody material are expected, or where the channel gradient exceeds 6 percent.

Evaluate the need for safety measures such as guardrails at culvert crossings.

Crossings shall be adequately protected so that out-of-bank flows safely bypass without damaging the structure or eroding the streambanks or the crossing fill.

At least one culvert pipe shall be placed with its entire length set six inches below the existing stream bottom. Additional culverts may be used at various elevations to maintain terrace or floodplain hydraulics and water surface elevations.

Make the barrel length of the culvert adequate to extend the full width of the crossing, including side slopes, and inlet or outlet extensions.

Acceptable culvert materials include concrete, corrugated metal, corrugated plastic, new or used high quality steel, and any other materials that meet the requirements of NRCS Conservation Practice Standard, Structure for Water Control, Code 587. Culverts made from approved used materials must be free of all chemical and hazardous material residues prior to installation.

Ford Crossings

The following criteria apply to all ford crossings:

Make the cross-sectional area of the crossing equal to or greater than the natural channel cross-sectional area. Make a portion of the crossing depressed at or below the average stream bottom elevation when needed to keep base flows or low flows concentrated.

Match ford shape to the channel cross-section to the extent possible.

Provide cutoff walls at the upstream and downstream edges of ford-type stream crossings when needed to protect against undercutting.

Evaluate the need for water depth signage at ford crossings.

To the extent possible, the top surface of the ford crossing shall follow the contours of the stream bottom but in no case shall the top surface of the ford crossing be higher than 0.5 foot above the original stream bottom at the upstream edge of the ford crossing.

Make the downstream edge of the ford crossing with a low-flow hydraulic drop less than 0.5 foot above the original stream bottom.

Concrete Fords

Use concrete ford crossings only where the foundation of the stream crossing is determined to have adequate bearing strength.

Use concrete with a minimum compressive strength of 3,000 psi at 28 days, with a ratio of water to cementitious materials of 0.50 or less. Use coarse aggregate of 0.75 to 1 inch nominal size. If designed for freezing conditions, use concrete with 4 to 8 percent air-entrainment.

Use a minimum thickness of 5 inches of placed concrete. Pour the concrete slab on a minimum 4-inch thick gravel base, unless the foundation is otherwise acceptable.

Construct toe-walls at the upstream and downstream ends of the crossing. Make the toe-walls a minimum of 6 inches thick and 18 inches deep. Extend the toe-walls in the stream approaches to the bankfull flow elevation.

Precast concrete panels may be used in lieu of cast-in-place concrete slabs. To the extent possible, the panels shall follow the contours of the stream bottom in order to avoid potential problems with sediment accumulation. Use concrete units that have adequate reinforcement for transportation and placement.

Dewatering of the site and toe-walls is required during placement of the concrete to maintain the proper water/cement ratio. Flowing water will erode concrete that is not sufficiently hardened. The stream must be diverted or retained from flowing over the concrete for at least 12 hours after placement of the concrete.

During construction, aquatic species must be removed from the construction area according to State protocols.

Rock Fords and the Use of Geosynthetics

Coarse aggregate or crushed rock ford crossings are often used in steep areas subject to flash flooding and where normal flow is shallow or intermittent. When the site has a soft or unstable subgrade, use geotextiles in the design of rock ford crossings.

Dewater and excavate the channel bed to the necessary depth and width and cover with geotextile material. Install the geotextile material on the excavated surface of the ford and extend it across the bottom of the stream and at least up to the bankfull flow elevation.

Cover the geotextile material with at least 6 inches of crushed rock. If geocells are used, specify minimum 6-inch deep geocells, and follow manufacturer's recommendations regarding maximum stream velocity. Use durable geosynthetic materials and install them according to the manufacturer's recommendations, including the use of staples, clips, and anchor pins.

Design all rock ford stream crossings to remain stable for the bankfull flow. Bankfull flow is the discharge that fills a stream channel up to the elevation at which flow begins to spill onto the floodplain. Compute channel velocities and choose rock size using procedures in NEH630; NEH654 TS14N; and EFH Chapter 16 (NEH650), Appendix 16A, or other procedures approved by the State Conservation Engineer.

Where rock is used for ford crossings for livestock, use a hoof contact zone or alternative surfacing method over the rock.

CONSIDERATIONS

Avoid or minimize the use of or number of stream crossings, when possible, through evaluation of alternative trail or travel-way locations. Assess landuser operations to consolidate and minimize the number of crossings. Where feasible, use existing roads.

Evaluate proposed crossing sites for variations in stage and discharge, tidal influence, hydraulics, fluvial geomorphic impacts, sediment transport and flow continuity, groundwater conditions, and movement of woody and organic material. Increase crossing width or span to accommodate transport of large woody material in the flow. Design passage features to account for the known range of variation.

For culvert crossings, consider incorporating natural streambed substrates throughout the culvert length for passage of aquatic organisms (see Bunt and Abt, 2001, for sampling procedures). Natural streambeds provide passage and habitat benefits to many life stage requirements for aquatic organisms and may reduce maintenance costs.

Consider all life stages of aquatic organisms in the stream crossing design to accommodate their passage, in accordance with the species' requirements. Design criteria are available in NEH Part 654, Technical Supplement 14N, Fish Passage and Screening Design; US Forest Service low-water design guidance (USFS, 2006); and stream simulation guidance (USFS,2008). Each State also has specific design criteria for culverts and stream crossings (e.g., MassDOT, 2010). See also Harrelson, et al. 1994, for stream reference site descriptions.

Where a stream crossing is installed to remove an existing barrier to the passage of aquatic organisms, consider using NRCS Conservation Practice Standard, Aquatic Organism Passage, Code 396.

Consider relevant aquatic organisms in the design and location of crossings to improve or provide passage for as many different aquatic species and age classes as possible.

Consider the habitat requirements of other aquatic or terrestrial species that may be affected by construction of a stream crossing. For example, a crossing may be designed with features that also promote safe crossing by terrestrial vertebrates.

Ford crossings have the least detrimental impact on water quality when their use is infrequent. Ford crossings are adapted for crossing wide, shallow watercourses with firm streambeds. If the stream crossing is to be used frequently, or daily, as in a dairy operation, a culvert crossing or curbed bridge should be used, rather than a ford crossing.

Locate stream crossings to avoid adverse environmental impacts and consider the following:

- Effects on upstream and downstream flow conditions that could result in increases in erosion, deposition, or flooding. Consider habitat upstream and downstream of the crossing to avoid fragmentation of aquatic and riparian habitats.
- Short-term and construction-related effects on water quality.

- Overall effect on erosion and sedimentation that will be caused by the installation of the crossing and any necessary stream diversion.
- Effects of large woody material on the operation and overall design of the crossing.
- Consider adding a well-graded rock riprap apron on the downstream edge of concrete crossings to dissipate flow energy.
- Ford crossings should not be placed immediately downstream from a pipe or culvert because of potential damage from localized high velocity flows.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for stream crossings in keeping with this standard. The plans and specifications must clearly describe the requirements for applying the practice to achieve its intended purpose.

As a minimum, include the following in plans and specifications:

- Location of stream crossing.
- Stream crossing width and length with profile and typical cross sections.
- Design grades or slopes of stream approaches.
- Thickness, gradation, quantities, and type of rock or stone.
- Type, dimensions, and anchoring requirements of geotextile.
- Thickness, compressive strength, reinforcement and other special requirements for concrete, if used.
- Vegetative requirements that include seed and plant materials to be used, establishment rates, and season of planting.
- Location, type, and extent of fencing required.
- Method of surface water diversion and dewatering during construction.
- Location of utilities and notification requirements.

OPERATION AND MAINTENANCE

Develop an operation and maintenance plan and implement it for the life of the practice.

Include the following items in the operation and maintenance plan, as a minimum:

- Inspect the stream crossing, appurtenances, and associated fence after each major storm event and make repairs if needed.
- Remove any accumulation of organic material, woody material, or excess sediment.
- Replace surfacing stone used for livestock crossing as needed.

REFERENCES

AASHTO, 2010. American Association of State Highway and Transportation Officials Load and Resistance Factor Design (LRFD) Bridge Design Specifications, Customary U.S. Units, 5th Edition, with 2010 edits; ISBN Number: 1-56051-451-0.

Bunte, Kristin; Abt, Steven R. 2001. Sampling surface and subsurface particle-size distributions in wadable gravel-and cobble-bed streams for analyses in sediment transport, hydraulics, and streambed monitoring. Gen. Tech. Rep. RMRS-GTR-74. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Research Station. 428 p (http://www.fs.fed.us/rm/pubs/rmrs_gtr74.html)

Harrelson, Cheryl C; Rawlins, C. L.; Potyondy, John P, 1994. Stream channel reference sites: an illustrated guide to field technique. Gen. Tech. Rep. RM-245. Fort Collins, CO: U.S. Department of Agriculture, Forest Service, Rocky Mountain Forest and Range Experiment Station. 61 p. (http://www.stream.fs.fed.us/publications/PDFs/RM245E.PDF)

MassDOT, 2010. Design of Bridges and Culverts for Wildlife Passage at Freshwater Streams. Massachusetts Department of Transportation, Highway Division. (http://www.mhd.state.ma.us/downloads/projDev/Design_Bridges_Culverts_Wildlife_Passage_122710.pdf)

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

STREAM HABITAT IMPROVEMENT AND MANAGEMENT

(Ac.)

CODE 395

DEFINITION

Maintain, improve or restore physical, chemical and biological functions of a stream, and its associated riparian zone, necessary for meeting the life history requirements of desired aquatic species.

PURPOSE

1. Provide suitable habitat for desired fish and other aquatic species.
2. Provide stream channel and associated riparian conditions that maintain stream corridor ecological processes and hydrological connections of diverse stream habitat types important to aquatic species.

CONDITIONS WHERE PRACTICE APPLIES

All streams and their adjoining backwaters, floodplains, associated wetlands, and riparian areas where geomorphic conditions or habitat deficiencies limit reproduction, growth, survival and diversity of aquatic species.

CRITERIA

Planned stream habitat improvements will:

- address the aquatic species and life history stages for which the stream is being managed;
- be based on a site-specific assessment of local hydrology, channel morphology, geomorphic setting, fish and other aquatic species present, riparian and floodplain conditions, and any habitat limitations including water quantity and quality, food supply, and restriction of upstream and downstream movement of aquatic species using the NRCS Stream Visual Assessment Protocol, Version 2 or comparable evaluation tool;
- when applied, result in a conservation system that meets or exceeds the minimum quality criteria for stream habitat established in Section III of the FOTG.

Manage adjoining riparian areas to support a diverse vegetation community suitable for the site conditions and desired ecological benefits. Such benefits include stream temperature moderation, recruitment of instream large wood and fine organic matter, input of riparian nutrients, habitat for terrestrial insects and other riparian dependent species, streambank integrity, and filtration of contaminants from surface runoff.

Design in-stream structures to be compatible with the dynamic nature of streams and rivers, facilitate natural geomorphic recovery when possible, and minimize disruption of recreational and other traditional uses of the stream corridor. Structures installed for the purposes of this standard will meet the criteria of the applicable NRCS Conservation Practice Standard(s), including 560 – Access Road, 410 – Grade Stabilization Structure, 378 – Pond, 500 – Obstruction Removal, 578 – Stream Crossing, 580 – Streambank and Shoreline Protection and 584 – Channel Bed Stabilization.

Structures installed for the purposes of this standard will not:

- impede or prevent passage of fish and other aquatic organisms at any time, unless intended to isolate populations of native species of conservation concern;
- cause excessive bank erosion;
- cause unintentional lateral migration, aggradation or degradation of the channel;

- hinder channel-floodplain interactions.

Where practical, restore or maintain stream habitat and channel-forming processes such as natural flow regime, meander migration, sediment transport, recruitment and storage of large wood, and floodplain interactions with the stream.

All stream and riparian activities will occur within state and federal guidelines with regard to timing of spawning, incubation, and rearing of aquatic organisms, and breeding and nesting of terrestrial organisms.

Manage livestock by exclusion, single-point access to the stream or other appropriate practices to sustain a healthy stream corridor and associated habitats.

CONSIDERATIONS

Any stream habitat management project is most effective when applied within the context of overall watershed conditions and with clear objectives for stream management goals. Stream habitat management provisions should be planned in relation to other land uses that may affect stream corridors.

Before designing and implementing stream habitat improvements, consider the known or expected concerns within the watershed, such as point and non-point source pollution, water diversions, and land management activities likely to influence stream habitat conditions. In order to determine whether these or other special situations exist, consult with the Illinois Department of Natural Resources (IDNR) Streams Biologist and/or the NRCS State Biologist during planning. Additional measures that should be taken singularly or in combination to improve stream habitat include:

1. Complete a general assessment of watershed conditions that are likely to affect the functions of the stream and its riparian area.
2. Incorporate stream habitat improvements into a conservation plan that addresses soil quality, prescribed grazing, nutrient management, pest management, and other management practices for reducing non-point sources of pollution.
3. Provide fish passage upstream and downstream and allow movement of other aquatic species and organic matter to the extent possible and when compatible with state and federal fish management objectives (see Conservation Practice Standard Aquatic Organism Passage, Code-396).
4. Reduce or manage excessive runoff due to watershed development, roads or land use activities.
5. Restore or protect riparian and floodplain vegetation and associated riverine wetlands.
6. Maintain adequate in-stream flows to sustain diverse habitats for fish and other aquatic species, especially during critical life history stages of spawning, incubation and rearing.
7. Provide heterogeneous and complex physical habitat components consistent with the physiographic setting and important to fish and other aquatic species in the watershed. These include where appropriate: suitable spawning substrates; pools; overhead cover; riparian vegetation and structural elements such as boulders and/or large wood; or structures that also provide structural elements such as lunkers, streambarbs, rock riffle grade controls, and bendway weirs. In many warm water streams in Illinois emphasis should be placed on complex pools with much of the pool greater than 30 inches in depth, instream cover, and stable, well vegetated banks with healthy riparian areas in perennial vegetation.
8. Provide instream barriers to exclude aquatic nuisance species from upstream habitats where prescribed by state and federal fish management agencies to protect native fish populations.
9. Provide screens on water pumps, diversion ditches, or any area where unintentional entrainment of aquatic species is likely to occur.
10. Improve floodplain-to-channel connectivity for development of seasonal or permanent backwater, wetland and off-channel habitats consistent with the local climate and hydrology of the stream.
11. Maintain natural surface water, hyporheic, and ground water interactions to the extent possible.

12. Control spread of exotic plant and animal species.
13. Manage recreational and other land use activities to minimize impacts on stream banks, riparian vegetation and water quality.

PLANS AND SPECIFICATIONS

Plans and specifications shall be developed for each site where stream corridor management and improvement actions are to be implemented.

The plan will include detailed goals and objectives of the planned actions, a site description, the dates and sequence in which improvements or management actions will be completed, a vegetation planting plan, maintenance requirements, and monitoring guidelines for evaluating the effectiveness of the conservation actions. The plan shall specify:

- location and extent of modification of the stream reach to accomplish the planned purpose;
- riparian plant species and stocking rates if needed to accomplish the planned purpose;
- planting dates, as well as the care and handling of seed or other planted materials to ensure an acceptable rate of survival;
- site protection and preparation requirements for establishment or recruitment of riparian vegetation if needed;
- drawings to illustrate installation or implementation requirements.

OPERATION AND MAINTENANCE

A detailed operation and maintenance plan shall be developed for all applications. The plan shall provide for periodic inspection and prompt repair or modification of any structures that are found to cause excessive streambank or streambed instability. All structural measures shall be evaluated on an annual basis. Post-project monitoring and evaluation of stream and riparian habitat conditions shall be conducted to determine if actions implemented are providing for management of the stream corridor habitats as planned. Any repair actions, if needed, shall comply with state and federal guidelines for protecting spawning, incubation and rearing times of aquatic species and breeding and nesting times of terrestrial species.

REFERENCES

Bureau of Land Management. 1998. Riparian Area Management: A User Guide to Assessing Proper Functioning Condition and the Supporting Science for Lotic Areas. TR-1737-15.

Federal Interagency Stream Restoration Working Group (FISRWG). 1998. National Engineering Handbook 653 – Stream Corridor Restoration: Principles, Processes and Practices.

NRCS. 1998. The Practical Streambank Bioengineering Guide.

NRCS. 2002. Streambank Soil Bioengineering Field Guide for Low Precipitation Areas.

NRCS. 2005. National Biology Handbook Part 620. Aquatic and Terrestrial Habitat Resources.

NRCS. 2006. National Engineering Handbook Part 654. Stream Restoration Design Handbook.

NRCS. 2009. National Biology Handbook Part 614, Subpart B. Stream Visual Assessment Protocol. Version 2.

Roni, P. 2005. Monitoring stream and watershed restoration. American Fisheries Society, Bethesda, MD.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

STREAMBANK AND SHORELINE PROTECTION

(Ft.)

CODE 580

DEFINITION

Treatment(s) used to stabilize and protect banks of streams or constructed channels, and shorelines of lakes, reservoirs, or estuaries.

PURPOSE

- To prevent the loss of land or damage to land uses, or facilities adjacent to the banks of streams or constructed channels, shoreline of lakes, reservoirs, or estuaries including the protection of known historical, archeological, and traditional cultural properties.
- To maintain the flow capacity of streams or channels.
- Reduce the offsite or downstream effects of sediment resulting from bank erosion.
- To improve or enhance the stream corridor for fish and wildlife habitat, aesthetics, recreation.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies to streambanks of natural or constructed channels and shorelines of lakes, reservoirs, or estuaries where they are susceptible to erosion. It does not apply to erosion problems on main ocean fronts or beaches, or similar areas of complexity.

CRITERIA

General Criteria Applicable to All Purposes

Treatments shall be in accordance with all applicable local, state and federal laws and regulations.

Treatments applied shall seek to avoid adverse effects to endangered, threatened, and candidate species and their habitats, whenever possible.

Treatments applied shall seek to avoid adverse effects to archaeological, historic, structural, and traditional cultural properties, whenever possible.

An assessment of unstable streambank or shoreline sites shall be conducted in sufficient detail to identify the causes contributing to the instability (e.g. livestock access, watershed alterations resulting in significant modifications of discharge or sediment production, in channel modifications such as gravel mining, head cutting, water level fluctuations, boat-generated waves, etc.).

Proposed protective treatments to be applied shall be compatible with improvements being planned or installed by others.

Protective treatments shall be compatible with the bank or shoreline materials, water chemistry, channel or lake hydraulics, and slope characteristics above and below the water line.

End sections of treatment areas shall be adequately anchored to existing treatments, terminate in stable areas, or be otherwise stabilized to prevent flanking of the treatment.

Protective treatments shall be installed that result in stable slopes. Design limitations of the bank or shoreline materials and type of measure installed shall determine steepest permissible slopes.

Designs will provide for protection of installed treatments from overbank flows resulting from upslope runoff and flood return flows.

Internal drainage for bank seepage shall be provided when needed. Geotextiles or properly designed filter bedding shall be incorporated with structural measures where there is the potential for migration of material from behind the measure.

Treatments shall be designed to account for any anticipated ice action, wave action, and fluctuating water levels.

Riprap used for streambank or shoreline protection will be sized consistent with guidelines found in the Engineering Field Handbook, Chapter 16.

Livestock traffic along treated streambanks and shorelines shall be limited to stable access points.

All disturbed areas around protective treatments shall be protected from erosion. Disturbed areas that are not to be cultivated shall be protected as soon as practical after construction.

Vegetation shall be selected that is best suited for the site conditions and achieves the intended purpose(s).

If natural revegetation will not produce adequate cover for the intended purpose, a vegetative management plan shall be prepared in accordance with NRCS conservation practice standard Critical Area Planting, Code 342.

Utilities and Permits. The landowner and/or contractor shall be responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

The landowner shall obtain all necessary permissions from regulatory agencies, including but not limited to the Illinois Department of Agriculture, US Army Corps of Engineers, US Environmental Protection Agency, Illinois Environmental Protection Agency and Illinois Department of Natural Resources – Office of Water Resources, or document that no permits are required.

Additional Criteria for Streambanks

Stream segments to be protected shall be classified according to the inventory and evaluation procedure of Technical Supplement 3C to the National Engineering Handbook, Part 654. Segments shall be evaluated for further degradation or aggradation.

A site assessment shall be performed to determine if the causes of instability are local (e.g. poor soils, high water table in banks, alignment, obstructions deflecting flows into bank, etc.) or systemic in nature (e.g. aggradation due to increased sediment from the watershed, increased runoff due to urban development in the watershed, degradation due to channel modifications, etc.). The assessment need only be of the extent and detail necessary to provide a basis for design of the bank treatments and reasonable confidence that the treatments will perform adequately for the design life of the measure.

Changes in channel alignment shall not be made without an assessment of both upstream and downstream fluvial geomorphology that evaluates the affects of the proposed alignment. The current and future discharge-sediment regime shall be based on an assessment of the watershed above the proposed channel alignment.

Bank protection treatment shall not be installed in channel systems undergoing rapid and extensive changes in bottom grade and/or alignment unless the treatments are designed to control or accommodate the changes. Bank treatment shall be constructed to a depth at or below the anticipated lowest depth of streambed scour.

If the failure mechanism is a result of the degradation or removal of riparian vegetation, stream corridor restoration shall be implemented, where feasible, (see Additional Criteria for Stream Corridor Improvement) as well as treating the banks.

•

Toe erosion shall be stabilized by treatments that redirect the stream flow away from the toe or by structural treatments that armor the toe.

Where rock riprap is used for bank or toe protection, undercutting by scour shall be prevented by one of the following methods of riprap placement:

- Key riprap into the bottom of the channel to a depth equal to the design riprap thickness or 2 feet, whichever is greater, below the anticipated lowest scour line, or

Design and place riprap as Stone Toe Protection in sufficient quantity to allow for launching of material into anticipated scour while maintaining design height**.**

Where toe protection or other structural measures alone are inadequate to stabilize the bank, the upper bank shall be shaped to a stable slope and vegetated, or shall be stabilized with structural or soil-bioengineering treatments.

Channel clearing to remove stumps, fallen trees, debris, and sediment bars shall only be performed when they are causing or could cause unacceptable bank erosion, flow restriction, or damage to structures. Habitat forming elements that provide cover, food, pools, and water turbulence shall be retained or replaced to the extent possible.

Treatments shall be functional and stable for the design flow and sustainable for higher flow conditions.

Treatments shall not induce an increase in natural erosion.

Treatments shall not limit stream flow access to the floodplain.

Where flooding is a concern, the effects of protective treatments shall not increase flow levels above those that existed prior to installation.

Additional Criteria for Shorelines

All revetments, bulkheads or groins are to be no higher than 3 feet above mean high water.

Structural shoreline protective treatments shall be keyed to a depth to prevent scour during low water.

For the design of structural treatments, the site characteristics below the waterline shall be evaluated for a minimum of 50 feet horizontal distance from the shoreline measured at the design water surface.

The height of the protection shall be based on the design water surface plus the computed wave height and freeboard.

When vegetation is selected as the protective treatment, a temporary breakwater shall be used during establishment when wave run up would damage the vegetation.

Additional Criteria for Stream Corridor Improvement

Stream corridor vegetative components shall be established as necessary for ecosystem functioning and stability. The appropriate composition of vegetative components is a key element in preventing excess long-term channel migration in re-established stream corridors. The establishment of vegetation on channel banks and associated areas shall also be in accordance with conservation practice standard Critical Area Planting, Code 342.

Treatments shall be designed to achieve habitat and population objectives for fish and wildlife species or communities of concern as determined by a site-specific assessment or management plan. Objectives shall be based on the survival and reproductive needs of populations and communities, which include habitat diversity, habitat linkages, daily and seasonal habitat ranges, limiting factors and native plant communities. The type, amount, and distribution of vegetation shall be based on the requirements of the fish and wildlife species or communities of concern to the extent possible.

Treatments shall be designed to meet aesthetic objectives as determined by a site-specific assessment or management plan. Aesthetic objectives shall be based on human needs, including visual quality, noise control, and microclimate control. Construction materials, grading practices, and other site development elements shall be selected and designed to be compatible with adjacent land uses.

Treatments shall be designed to achieve recreation objectives as determined by a site-specific assessment or management plan. Safety requirements shall be based on type of human use and recreation objectives.

CONSIDERATIONS

When designing protective treatments, consideration should be given to the changes that may occur in the watershed hydrology and sedimentation over the design life of the treatments.

Consider utilizing debris removed from the channel or streambank into the treatment design when it is compatible with the intended purpose to improve benefits for fish, wildlife and aquatic systems.

Use construction materials, grading practices, vegetation, and other site development elements that minimize visual impacts and maintain or complement existing landscape uses such as pedestrian paths, climate controls, buffers, etc.

Avoid excessive disturbance and compaction of the site during installation.

Utilize vegetative species that are native and/or compatible with local ecosystems. Avoid introduced, invasive, noxious or exotic species that could become nuisances. Consider species that have multiple values such as those suited for biomass, nuts, fruit, browse, nesting, aesthetics and tolerance to locally used herbicides. Avoid species that may be alternate hosts to disease or undesirable pests. Species diversity should be considered to avoid loss of function due to species-specific pests. Species on noxious plant lists should not be used.

Select plant materials that provide habitat requirements for desirable wildlife and pollinators. The addition of native forbs and legumes to grass mixes will increase the value of plantings for both wildlife and pollinators.

Treatments that promote beneficial sediment deposition and the filtering of sediment, sediment-attached, and dissolved substances should be considered.

Consider maintaining or improving the habitat value for fish and wildlife by including treatments that provide aquatic habitat in the treatment design and that may lower or moderate water temperature and improve water quality.

Consider the need to stabilize side channel inlets and outlets and outlets of tributary streams from erosion.

Consider aquatic habitat when selecting the type of toe stabilization.

Consider maximizing adjacent wetland functions and values with the project design and minimize adverse effects to existing wetland functions and values.

Wildlife may need to be controlled during establishment of vegetative treatments. Temporary and local population control methods should be used with caution and within state and local regulations.

When appropriate, establish a buffer strip and/or diversion at the top of the bank or shoreline protection zone to help maintain and protect installed treatments, improve their function, filter out sediments, nutrients, and pollutants from runoff, and provide additional wildlife habitat.

Consider conservation and stabilization of archeological, historic, structural and traditional cultural properties when applicable.

Consider safety hazards to boaters, swimmers, or people using the shoreline or streambank when designing treatments.

Protective treatments should be self-sustaining or require minimum maintenance.

PLANS AND SPECIFICATIONS

Plans and specifications for streambank and shoreline protection shall be prepared for specific field sites based on this standard and shall describe the requirements for applying the practice to achieve its intended purpose. Plans shall include treatments to minimize erosion and sediment production during construction and provisions necessary to comply with conditions of any environmental agreements, biological opinions or other terms of applicable permits.

OPERATION AND MAINTENANCE

An operation and maintenance plan shall be prepared for use by the owner or others responsible for operating and maintaining the system. The plan shall provide specific instructions for operating and maintaining the system to insure that it functions properly. It shall also provide for periodic inspections and prompt repair or replacement of damaged components or erosion.

REFERENCES

National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

STRIPCROPPING

(Ac.)

CODE 585

DEFINITION

Growing row crops, forages, small grains, or fallow in a systematic arrangement of equal width strips across a field.

PURPOSE

- Reduce soil erosion from water and transport of sediment and other water-borne contaminants
- Reduce soil erosion from wind
- Protect growing crops from damage by wind-borne soil particles

CONDITIONS WHERE PRACTICE APPLIES

The practice applies on cropland or other land where crops are grown.

Although the practice may be applicable on steeper slopes; however, slopes exceeding 12 percent will make the practice less effective.

The practice has the greatest impact where cropped or fallow strips having less than 10 percent cover are alternated with close grown and/or grass/legume strips or strips of *residue management, no/till/strip-till* with 75 percent or greater surface cover.

The practice is not well suited to rolling topography having a high degree of slope irregularity where contouring is also planned.

The standard does not apply to situations where the widths of alternating strips are not generally equal or where the land is treated with c*ontour buffer strips.*

CRITERIA

General Criteria Applicable To All Purposes

Number of Strips. A stripcropping system shall consist of two or more strips.

Alignment of Tillage and Planting Operations. All tillage and planting operations will follow the strip line established.

Vegetative Cover. Vegetation in a stripcropping arrangement consists of crops and/or forages grown in a planned rotation.

No two adjacent strips shall be in an erosion-susceptible condition at the same time during the year. However, two adjacent strips may be in erosion-resistant cover at the same time.

Erosion-resistant strips shall be crops or crop residues that provide the needed protective cover during those periods when erosion is expected to occur.

Acceptable protective cover includes a growing crop, including grasses, legumes, or grass-legume mixtures, standing stubble, residue with enough surface cover to provide protection, or surface roughness sufficient to provide protection.

A vegetative cover shall be selected that is tolerant of the anticipated depth of sediment deposition.

When the erosion-resistant strip is in permanent vegetation, the species established shall either be tolerant to herbicides used on the cropped strips or protected from damage by herbicides used on the cropped strips.

Width of Strips. The required width of strips shall be determined using currently approved erosion prediction technologies to achieve the planned erosion reduction.

Additional Criteria To Reduce Soil Erosion From Water and Transport Of Sediment And Other Water-borne Contaminants

Alignment of Strips. Strip boundaries shall run parallel to each other and as close to the contour as practical.

Strip Width. Base strip widths on the planning objective and the approved erosion prediction technology. Erosion-susceptible strip widths shall not exceed 50 percent of the slope length used for erosion prediction or 150 feet whichever is less.

The erosion-resistant and erosion-susceptible strips shall be of approximately equal width. If a correction strip is required, that strip may vary in width but shall be no narrower than the widest working field implement used to traverse the strip.

Where field contours become too sharp to keep machinery aligned with the contour during field operations, establish sod turn-strips on sharp ridge points. The strips shall be wide enough to allow the equipment to be lifted and/or turned and meet the same rows across the turn strip.

Arrangement and Vegetative Condition of Strips. Strips susceptible to erosion shall be alternated down the slope with strips of erosion-resistant cover. Erosion-susceptible strips are generally defined as consisting of row crops or fallow with less than 10 percent surface residue cover and little surface roughness during the period of time when erosion potential is the greatest. An erosion-resistant strip generally consists of dense grasses and/or legumes, hay crops nearing the end of the first year, or row crops with surface cover greater than 75 percent during the period of time when erosion potential is the greatest. In conditions where little surface cover is present, surface roughness will be considered erosion resistant if roughness depressions are at least 7 inches in depth during the period of time when erosion potential is the greatest.

Minimum Row Grade. Row grades for soils with slow to very slow infiltration rates (soil hydrologic groups C or D), or for crops sensitive to ponded water conditions for periods of less than 48 hours, shall be designed with positive row drainage of not less than 0.5 percent on slopes where ponding is a concern.

Maximum Row Grade. The row grade shall be aligned as closely as possible to the contour to achieve the greatest erosion reduction, but still be practicable to operate equipment and provide positive row drainage.

The maximum row grade guidelines shall not exceed 2 percent or one-half of the up and down hill slope percent used for erosion prediction, whichever is less. Up to 3 percent row grade may be permitted within 150 feet of the approach to a grassed waterway, field border, or other stable outlet.

Row grades between strip guidelines shall not exceed the lesser of 4 percent or ½ of the field slope.

Minimum Ridge Height. The ridge height shall be sufficient to reduce soil erosion compared to rows oriented up and down the slope. As a minimum, the practice shall create at least a 0.5 to 2-inch ridge height during the period of the rotation that is most vulnerable to soil erosion. The required ridge height will be determined using on-site conditions and current erosion prediction technology.

The minimum ridge height is not required for strips of close-grown crops, such as small grains or meadow.

The minimum ridge height is not required where the practice *residue management, no-till/strip-till* is used parallel with the strip boundaries if at least 50 percent surface residue is present between the rows after planting.

Critical Slope Length. The computation of critical slope length shall be determined using approved water erosion prediction technology.

When *stripcropping* is applied in conjunction with *contour farming*, the critical slope length is 1.5 times the critical slope length determined for *contour farming*.

A stripcropping layout shall not occur on a slope longer than the critical slope length unless supported by other practices that reduce slope length below critical (e.g., diversions, terraces).

Stable Outlets. Stable outlets shall be established as necessary where runoff results in concentrated flow erosion. Acceptable stable outlets include *grassed waterways, field borders, filter strips, water and sediment control basins*, or *underground outlets* for *terraces and diversions*.

Headlands/End Rows. On fields where row crops and tillage are a part of the rotation, headlands/end rows with a slope steeper than the maximum allowable row grade for that field shall be maintained in permanent sod or planted using *residue management, no-till/strip-till*.

Additional Criteria To Reduce Soil Erosion From Wind

Alignment of Strips. Strip boundaries shall run parallel to each other.

Orientation and Width of Strips. Strips shall be oriented as close to perpendicular to the prevailing wind erosion direction as practical.

The width of strips shall be determined using the currently approved wind erosion prediction technology. Calculation shall account for the effects of other practices in the conservation system.

The effective width of strips shall be measured along the prevailing wind erosion direction for those periods when wind erosion is expected to occur and for which the system is designed.

When the orientation of erosion-susceptible strips deviates from perpendicular to the prevailing wind erosion direction, the width of these strips shall be correspondingly reduced as per direction given in Wind Erosion section of the National Agronomy Manual.

Additional Criteria To Protect Growing Crops From Damage By Wind-borne Soil Particles

Alignment of Strips. Strip boundaries shall run parallel to each other.

Orientation and Width of Strips. Strips shall be oriented as close to perpendicular to the prevailing wind erosion direction as practical.

The effective width shall be measured along the prevailing wind erosion direction during those periods when sensitive crops are susceptible to damage by wind-borne soil particles.

The width of strips shall not exceed the width permitted by the crop tolerance to wind erosion during specific crop stage periods, as specified in the National Agronomy Manual, other accepted technical references, or other planned crop protection objectives.

CONSIDERATIONS

Off-site transport of sediment and sediment-borne contaminants is reduced by the stripcropping.

Stripcropping may need to be used in combination with other conservation practices to meet the goals of the resource management system.

Strip widths may be adjusted, within the limits of the criteria above, to accommodate widths of farm equipment to minimize partial or incomplete passes.

Design and install the strip layout to best facilitate operation of machinery used on the strips. To avoid point rows and partial machine passes, lay out strip widths to have some multiple of full width passes of seeding implements or sprayers.

The *conservation crop rotation* on stripcropped fields should be consistent with the farm enterprise crop mix and/or associated livestock operation. These will influence the proportion of row crops, close growing crops, and meadow crops.

To avoid wide fluctuations in acreage of different crops from year to year, fields having identical crop rotations can be set up that are nearly equal in size and have offset years of rotation commencement. The number of fields needed to produce a nearly constant acreage of each crop for each year in the rotation is equal to one half of the years in the rotation. Even-year rotation lengths are preferable to odd-year rotation lengths for ease of design.

Considerations Specific To Erosion by Water

The effectiveness of the stripcropping is maximized when the strips are as close as possible to the contour.

Prior to design and layout, *obstruction removal* or changes in field boundaries or shape should be considered, where feasible, to improve the effectiveness of the practice and the ease of performing field operations across the slope.

Prior to layout, inspect the field to find key points for commencing layout or getting a full strip width to pass by an obstruction or ridge saddle. Whenever possible, run the strip boundary parallel with fence lines or other barriers, as long as row gradient criteria are met. Account for access road widths when they must cross the field, and adjust the strip boundary on either side accordingly.

When the practice is used in combination with *diversions* or *terraces*, coordinate the strip layout with the diversion or terrace grade and spacing so that strip boundaries will parallel terraces wherever possible within the criteria for row grade. Where grass-back or narrow-base terraces are used, allow for the uncropped width along the terrace so that the same strip width is maintained for all strips in the field.

Retaining as much crop residue as possible on the soil surface by using residue management practices can maximize critical slope lengths. Certain tillage practices, such as uphill plowing and deep tillage with heavy implements, can also be used to increase random roughness, allowing deposition to occur in depressions between soil clods and increase critical slope length. However, if the most erosion-susceptible strips of the field are kept very rough, in high ridges, or under heavy residue most of the year, there is little need for stripcropping as an erosion and sediment control practice. Little sediment will be delivered to the protective cover strips.

Wildlife benefits will be enhanced by delaying mowing on sod turn-strips and *grassed waterways* until after the nesting season.

Considerations Specific To Erosion By Wind

The effectiveness of the stripcropping is maximized when the strips are oriented as close to perpendicular as possible to the prevailing wind erosion direction for the period for which the system is designed.

Alternative practices that may be used to separate erosion-susceptible strips include *cross wind ridges, herbaceous wind barriers*, or *windbreak/shelterbelt establishment*.

PLANS AND SPECIFICATIONS

Specifications for installation and maintenance of Stripcropping shall be prepared for each field or treatment unit according to the Criteria described in this standard.

Specifications shall be recorded on specification sheets, job sheets, narrative statements in the conservation plan, or other acceptable documentation.

OPERATION AND MAINTENANCE

Sediment accumulations along strip edges shall be smoothed or removed and distributed over the field as necessary to maintain practice effectiveness.

When headlands are in permanent cover, renovate as needed to keep ground cover above 65 percent. No-till renovation of headlands is recommended, but in any case should only include the immediate seedbed preparation and reseeding to a sod-forming crop with or without a nurse crop. Maintain full headland width to allow turning of farm implements at the end of a tilled strip to double back on the same strip.

Operation and Maintenance Specific To Erosion By Water

Conduct all farming operations parallel to the strip boundaries except on end rows that have gradients flatter than the criteria set forth in the standard or where the end rows have at least 75 percent residue cover.

Plant correction areas as closely as possible to the contour. Using no-till in the correction areas or seeding close-grown crops rather than row crops increases options.

Mow sod turn-strips and *grassed waterways* at least once a year. Harvesting is optional.

Operation and Maintenance Specific To Erosion By Wind

Erosion-resistant strips in rotation shall be managed to maintain the planned vegetative cover and surface roughness during periods when wind erosion is expected to occur. The protective cover must be adequate to inhibit the initiation of wind erosion and the surface roughness will be sufficient to trap saltating soil particles originating upwind.

REFERENCES

Cropland Cover-Management Conditions, Chapter 6, Table 6-4. In *Predicting Soil Erosion by Water, A Guide to Conservation Planning with the Revised Universal Soil Loss Equation (RUSLE). 1997.* USDA Agricultural Research Service, Agricultural Handbook No. 703].

Chepil, W.S. and Woodruff, N.P., 1963. The Physics of Wind Erosion and its Control. Adv. Agron., 15: 211-302.

Woodruff, N.P., Lyles, L., Siddoway, F.H. and Fryrear, D.W., 1972. How to Control Wind Erosion. U.S.D.A., A.R.S. Agric. Inf. Bull. No. 354

Natural Resources Conservation Service

CONSERVATION PRACTICE STANDARD

SURFACE DRAIN, MAIN OR LATERAL

Code 608

(Ft.)

DEFINITION

An open drainage ditch for moving the excess water collected by a field ditch or subsurface drain to a safe outlet.

PURPOSE

This practice is applied for one or more of the following purposes:

- To convey excess surface or shallow subsurface water from a field ditch to a safe outlet.
- To convey excess subsurface water from a subsurface drain to a safe outlet.

CONDITIONS WHERE PRACTICE APPLIES

This standard applies to ditches that receive and convey drainage water from surface and subsurface drains.

This standard does not apply to collection of water from the surface or subsurface of the field. Use Conservation Practice Standard (CPS) Code 607, Surface Drain, or Code 606, Subsurface Drain, for that function.

CRITERIA

General Criteria Applicable to All Purposes

If wetlands are present, then complete an appropriate wetland determination per established procedures.

Notify landowner and/or contractor of their responsibility to locate all buried utilities in the project area, including drainage tile and other structural measures. The landowner is also required to obtain all necessary permits for project installation prior to construction.

Drainage Requirements. Locate and design mains and laterals to serve as integral parts of a surface or subsurface drainage system that meets the conservation and land use needs.

Capacity. Size the ditch capacity to provide for the removal of excess water, based on climatic and soil conditions and the needs of the crops. Base the design capacity of the ditch on the watershed area; the topographic, soil, and land use information; and use of the appropriate drainage curves or coefficients.

In irrigated areas, the capacity analysis will include the effect of irrigation water deliveries, irrigation canal or ditch losses, soil stratification and permeability, deep percolation losses, field irrigation losses, subsurface drain discharge, and quantity of surface water to be carried by the drainage ditch.

Whether the outlet is by gravity flow or by pumping, design the outlet to be sufficient for the quantity and quality of water conveyed.

Protect the structural integrity and flow capacity of existing structures, such as bridges or culverts within the system.

Hydraulic Grade Line. Determine the hydraulic grade line for drainage ditch design from control points, including elevations of significant low areas served by the ditch and hydraulic grade lines of any tributary ditches and the outlet. Set the hydraulic grade line of the ditch low enough to provide positive drainage into the ditch during the design flow event, plus calculated freeboard, or a minimum of 0.5 feet.

Account for the effects of hydraulic losses caused by culverts, bridges, or other obstructions in the channel section in the design. Design culverts and bridges with sufficient hydraulic capacity and depth to satisfy drainage needs and to minimize obstruction to flow. Use CPS Code 578, Stream Crossing.

Depth. Design the drainage ditch deep enough to allow for normal siltation. For a ditch that serves as an outlet for subsurface drains, design for a normal water surface at or below the invert of the outlet end of the drain. The normal water surface is the elevation of the usual base flow during the growing season. Where site conditions allow, design the flow line elevation of the main or lateral to be at least 1 foot lower than the invert elevations of subsurface drains or field ditches that outlet into the main or lateral.

Cross Section. Design the ditch cross section to meet the combined requirements of capacity, limiting velocity, depth, side slopes, bottom width, and, if needed, allowances for initial sedimentation, all below the design hydraulic grade line. Design side slopes based on site conditions to be stable and meet maintenance requirements.

Where a low-flow or two-stage channel is planned, use the design process in NRCS National Engineering Handbook (NEH), Part 654.1005.

Use the drainage guide or other local information to determine side slope limits for specific soils and/or geologic materials. If such information is not available, set the design side slopes in the main or lateral no steeper than those recommended for ordinary conditions in NRCS NEH, Part 650, Engineering Field Handbook (EFH), Chapter 14, Section 650.1412 (d). Account for side-slope stability during rapid drawdown conditions in the design.

Velocity and Capacity. Ensure stability of the ditch bottom and side slopes. Base the maximum permissible design velocity, or maximum permissible stress, on site conditions. Avoid potential for excessive sedimentation by accounting for the soils and sediment delivery amount for the particular location. Without site specific information, the minimum design velocity is 1.4 feet per second.

The velocity for newly constructed channels with drainage areas in excess of 1 square mile must meet the stability requirements specified for the CPS Code 582, Open Channel.

Use Manning's equation to determine the design velocity. Select Manning's n value based on channel hydraulic radius, channel alignment, an aged channel condition, and probable vegetative growth expected under normal maintenance. Unless special site studies are available to justify other values, use the appropriate Manning's n factor in NRCS NEH, Part 650, EFH, Chapter 14, Section 650.1412 (d), or in the local drainage guide, to determine the required design capacity.

Berms and Spoil Banks. Locate any adjacent berms at a safe distance from the drain and shape berm-side slopes as required to:

- Provide access for maintenance equipment; eliminate the need for moving spoil banks in the future;
- Provide for work areas and facilitate spoil bank spreading; prevent excavated material from washing or rolling back into ditches; and

- Lessen sloughing of ditch banks caused by heavy loads near the edge of the ditch banks.

Spread spoil material as soon as practical in accordance with NRCS CPS Code 572, Spoil Spreading.

Where spoil material is placed along the ditch rather than spread over adjacent fields, ensure that the spoil banks have stable side slopes. Make provision to convey water flows through the spoil bank and into the ditch without causing serious erosion. Maximum berm height is 3 feet above original ground. Minimum berm width is shown in Table 1.

Table 1 - Minimum berm width as a function of ditch depth

Ditch depth (ft)	Minimum berm width (ft)
<6	8
6–8	10
>8	15

Related Structures and Ditch Protection. Protect drainage mains and laterals against erosion where surface water or shallow ditches enter deeper ditches. Use suitable measures such as chutes, drop structures, pipe drops, grassed waterways, critical area planting, filter strips, or specially graded channel entrances to minimize side inlet erosion. Use grade control structures, bank protection, or other suitable measures if necessary to reduce velocities and control erosion. Grade control structures must meet the criteria in NRCS CPS Code 410, Grade Stabilization Structure.

Protect structures from washout by flows exceeding design capacity.

Design each structure for an open-ditch system according to NRCS standards for the kind of structure and type of construction used.

Provide a travel way, if needed, for movement and operation of equipment required for maintenance of the channel.

Channel Vegetation. Establish vegetation according to CPS Code 342, Critical Area Planting. If natural revegetation will adequately control erosion, provide documentation regarding the time for establishment of protection and needed efforts to control invasive species.

CONSIDERATIONS

When planning this practice, consider—

- The use of a low-flow or two-stage channel design.
- Impacts of sedimentation downstream.
- Possible damages above or below the point of discharge that might involve legal actions or other offsite impacts.
- Potential impacts on wetlands.
- Impacts on cultural resources.
- Use of riparian buffers, filter strips, and fencing.
- Potential water quality effects of soluble pollutants and sediment-attached pollutants.
- Impacts to wildlife.
- Impacts of invasive species movement and establishment through the drainage network.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for constructing the drainage main or lateral in keeping with this standard and describing the requirements for constructing the practice to achieve its intended purpose.

The owner or operator is responsible for securing all required permits or approvals and for performing in accordance with such laws and regulations. The landowner and/or contractor is responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

Plans and specification must include, but are not limited to—

- Typical cross sections of the lateral.
- Grade of drains.
- Spacing of drains.
- Location of drains.
- Detail of structures.
- Vegetative requirements, if applicable.
- Outlet protection, if needed.

OPERATION AND MAINTENANCE

Provide a site-specific operation and maintenance plan to the landowner or operator before the practice is installed.

Include guidance in the plan for the routine maintenance and operational needs of the drainage ditch. Include guidance on periodic inspections and post-storm inspections to detect and minimize damage to the drain.

REFERENCES

USDA NRCS National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 14, Water Management (Drainage).

USDA NRCS National Engineering Handbook, Part 654, Stream Restoration Design, Chapter 10, Two-Stage Channel Design.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

TERRACE

(Ft.)

CODE 600

DEFINITION

An earth embankment, or a combination ridge and channel, constructed across the field slope.

PURPOSE

This practice is applied as part of a resource management system for one or more of the following purposes:

- Reduce erosion and trap sediment
- Retain runoff for moisture conservation

CONDITIONS WHERE PRACTICE APPLIES

This practice applies where:

- Soil erosion caused by water and excessive slope length is a problem.
- Excess runoff is a problem.
- There is a need to conserve water.
- The soils and topography are such that terraces can be constructed and reasonably farmed.
- A suitable outlet can be provided.

CRITERIA

General Criteria Applicable to All Purposes

Spacing. Space terraces at intervals across the slope to achieve the intended purpose. The maximum spacing of terraces for erosion control is that necessary to achieve the soil loss tolerance (T) or other soil loss criteria that is documented in the Field Office Technical Guide. Include both the terrace system with planned as-built slopes and cultural practices such as residue management when determining soil loss. The slope length used when checking soil loss for a proposed terrace spacing is the distance from the terrace ridge to the next lower terrace channel measured along the natural flow direction. Maximum spacing for erosion control based on soil loss tolerance may be increased by as much as 10 percent to provide better location, alignment to accommodate farm machinery or to reach a satisfactory outlet.

Determine the maximum spacing for erosion control by either method 1 or method 2.

Method 1. Vertical Interval Equation. Refer to the Engineering Field Handbook, Chapter 8, Terraces for use of the Vertical Interval Equation.

Method 2. Revised Universal Soil Loss Equation Version 2 (RUSLE2). Use the proposed as-built slopes and cultural practices (including residue management) in the RUSLE2 model to determine a slope length that will achieve the allowable soil loss tolerance (T) in the inter-terrace interval.

Alignment. To accommodate farm machinery and farming operations, design cropland terraces with long gentle curves, where feasible. When multiple terraces are used in a field, design the terraces to be as parallel to one another as practicable.

Capacity. Design terraces to have enough capacity to control the runoff from a 10-year frequency, 24-hour storm without overtopping. For terrace systems designed to control excess runoff or to function with other structures, choose a larger design storm that is appropriate to the risk associated with the installation.

For terraces with underground outlets, the capacity to contain the design storm can be a combination of storage and out flow through the underground outlet. For terraces that store runoff (storage or level terraces), increase the storage capacity by the estimated 10-year sediment accumulation, unless the Operation and Maintenance Plan specifically addresses the periodic removal of sediment.

For terraces with open outlets, base the terrace channel size on the capacity using the densest and longest vegetation. Base the capacity of the channel on a bare earth channel for cropped fields or in the case of a permanently vegetated channel, the appropriate vegetation. For bare earth channels use a Manning's n value of 0.035 or greater to calculate capacity. For permanently vegetated channels, refer to Conservation Practice Standard (412), Grassed Waterway for design criteria to determine capacity.

Terrace Cross Section. Proportion the terrace cross section to fit the land slope, the crops grown, and the farm machinery used. Avoid the use of terrace cross-sections that result in disturbance of all of the soil in the spacing between terraces. Add ridge height if necessary to provide for settlement, channel sediment deposits, ridge erosion, the effect of normal tillage operations, or safety. At the design elevation, the ridge must have a minimum width of 3 ft. For terraces with open outlets, design the capacity of the outlet to be equal to or greater than the capacity of the terrace channel.

Design all farmable terrace slopes no steeper than 5:1 in order to allow safe operation of farming equipment. For non-farmable terrace slopes, the steepest slopes allowable are 2 horizontal to 1 vertical unless an analysis of site-specific soil conditions indicate that steeper slopes will be stable.

Topsoiling. Salvage topsoil from the footprint of the construction area of the terrace to spread over the excavated slopes and terrace ridges to facilitate restoration of the field unless the excavated slope or ridge surface is of similar texture as the available topsoil.

Channel Grade. Design the terrace channel to be stable with non-erosive velocities but with sufficient grade to prevent damage to crops or to prevent delay of farming activities from prolonged ponding.

For cultivated terraces, base the channel stability on a bare earth condition using a maximum Manning's n value of 0.035. For permanently vegetated channels, base the channel stability on the appropriate vegetation. Refer to Conservation Practice Standard 412, Grassed Waterway and Engineering Field Handbook, Part 650, Chapter 7 and Illinois supplements for design criteria and procedures to determine stability for both bare and vegetated conditions.

In the upper reaches of a channel, grades may be increased to improve alignment. For terraces with an underground outlet, channel grades can be steeper within the impoundment area.

Level Terraces. The volume of water stored in level terraces is proportional to the length. To reduce the potential risk from failure, do not design level terraces with lengths that exceed 3,500 feet unless the channel is blocked at intervals not exceeding 3,500 feet. Level terraces can have either full or partial end closures or be open-end. If a partial end closure is used, areas downstream from the end closure must be protected from flow that will exit from the closure before the design storm is reached.

Outlets. All terraces must have adequate outlets. The outlet must convey runoff water to a point where it will not cause damage.

Vegetated outlets are suitable for gradient or open-end level terraces. Grassed waterways or naturally vegetated drainage ways may be used as a vegetated outlet. Install and stabilize grassed waterways prior to the construction of the terrace so that the terrace will have a stable outlet when it is constructed. The capacity of the vegetated outlet must be large enough so that the water surface in the outlet is at or below the water surface in the terrace at the design flow.

Underground outlets are suitable for use on all terrace types. The outlet consists of an intake and an underground conduit. If underground outlets are required, use Conservation Practice Standard, 620, Underground Outlet.

Underground outlets may be designed for either pressure or gravity flow. If a pressure system is designed, all pipes and joints must be adequate to withstand the design pressure, including surges and vacuum. For gravity flow systems, use a flow-restricting device such as an orifice or weir to limit flow into the conduit or choose conduit sizes that are large enough to prevent pressure flow.

Design the outlet so that the flow release time does not exceed the inundation tolerance of the planned crop or 48 hours, whichever is less. If sediment retention is a primary design goal, adjust the release rate according to sediment particle size. Locate the intake structure for the underground outlet to accommodate farming operations and to allow for sediment accumulation.

Soil infiltration may be used as the outlet for level terraces. Soil infiltration rates, under average rainfall conditions, must permit infiltration of the design storm from the terrace channel within the inundation tolerance of the planned crops.

Combinations of different outlet types may be used on the same terrace system to optimize water conservation, improve water quality, and to accommodate farming operations or to provide for economical installation.

Vegetation. Stabilize all areas planned for vegetation as soon as possible after construction. Refer to Conservation Practice Standard, 342, Critical Area Planting or state planting guide for seeding criteria and as needed, use the criteria in Conservation Practice Standard, 484, Mulching.

Additional Criteria Applicable to Retaining Runoff for Moisture Conservation

For terraces installed to conserve moisture, perform a water budget analysis to determine the volume of water that must be collected to meet the requirements of the water budget. As a minimum, the terrace must still meet the design storm and sediment volume requirements in the **Capacity** section of this standard.

CONSIDERATIONS

One of the keys to a successful terrace system is to make sure that the terrace layout fits the farm equipment. This includes making curves long and gentle and spacing terraces so that the operator can make an even number of trips between terraces in order to end up on the same side of the field they started on.

Terrace ridges and cut slopes can introduce steep and potentially hazardous slopes into a crop field. Where slopes will be farmed, make sure they can be safely negotiated with the operator’s equipment. Where steep slopes are unavoidable make sure the operator is aware of the location and potential danger of the slopes.

The soil survey can be a valuable resource when planning and designing terrace systems. The soil survey can identify potential problems such as the presence of layers in the soil profile that will limit plant growth. Field investigations can then identify problem areas to avoid such as shallow bedrock or dense, acid or saline layers that will adversely affect plant growth if construction brings them into the root zone.

Steep sided terraces that are in permanent vegetation can provide significant areas of habitat for wildlife. Consider planting native species that provide food and cover for wildlife. Do not mow these areas until after the nesting season to improve wildlife production.

Hillside seeps in a crop field can cause cropping problems. Consider aligning terraces and/or installing subsurface drainage to intercept and correct seepage problems. Install the drainage prior to terrace construction by using Conservation Practice Standard 606, Subsurface Drain.

Erosion can be a problem at the outfall of an underground outlet. To ensure an adequate outlet, protect the outfall of the underground outlet so that it is stable.

Outlets from terraces might provide a direct conduit to receiving waters for contaminated runoff from cropland. Terraces should be installed as part of a conservation system that addresses issues such as nutrient and pest management, residue management and filter areas.

Intakes for underground outlets can be easily damaged during cultivation, planting and harvesting operations. Using brightly colored inlets, barriers around the inlet or otherwise clearly marking the inlet will help prevent damage.

PLANS AND SPECIFICATIONS

Prepare plans and specifications for terraces that describe the requirements for applying the practice according to this standard. As a minimum the plans and specifications must include:

- A plan view of the layout of the terrace system.
- Typical cross sections of the terrace(s).

- Profile(s) or planned grade of the terrace(s).
- Details of the outlet system.
- If underground outlets are used, details of the inlet and profile(s) of the underground outlet.
- Seeding requirements if needed.
- Bill of materials needed for the construction.
- Site specific construction specifications that describe in writing the installation of the terrace system.

OPERATION AND MAINTENANCE

Prepare an operation and maintenance plan for the operator to follow for the design life of the terrace system. The minimum requirements to be addressed in the written operation and maintenance plan are:

- Periodic inspections, especially immediately following significant runoff events.
- Prompt repair or replacement of damaged components.
- Maintenance of terrace ridge height, channel profile, terrace cross-sections and outlet elevations.
- Removal of sediment that has accumulated in the terrace channel to maintain capacity and grade.
- Regular cleaning of inlets for underground outlets. Repair or replacement of inlets damaged by farm equipment. Removal of sediment around inlets to ensure that the inlet remains the lowest spot in the terrace channel.
- Where vegetation is specified, complete seasonal mowing, control of trees and brush, reseeding and fertilizing as needed.
- Notification of hazards about steep slopes on the terrace.

REFERENCES

USDA, NRCS. 2004. Revised Universal Soil Loss Equation, Ver. 2 (RUSLE2).

USDA, NRCS. National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 7, Grassed Waterways.

USDA, NRCS. National Engineering Handbook, Part 650, Engineering Field Handbook, Chapter 8, Terraces.

Water and Sediment Control Basin

Conservation Practice Job Sheet 638

Definition

A water and sediment control basin (WASCOB) is an earth embankment or combination ridge and channel constructed across the slope of minor water courses to form a sediment trap and water detention basin.

Purpose

The purpose of this practice is to improve farmability of sloping land, reduce erosion, trap sediment and reduce and manage runoff. WASCOBs are constructed across small drainageways where they intercept runoff. The runoff is detained in the basin where sediment is allowed to settle out. The runoff is slowly released through an outlet. WASCOBs generally use an underground outlet that carries the runoff in a pipe to a receiving stream or ditch.

Where used

This practice is used on cropland sites where:

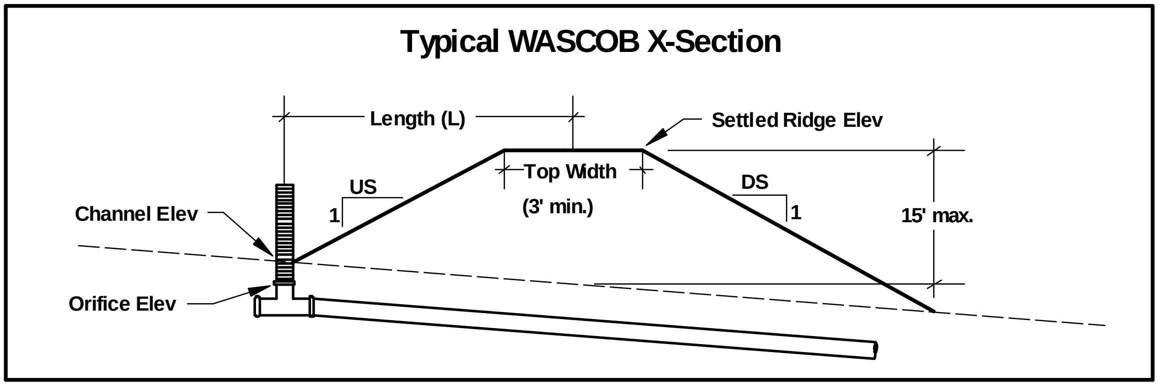
- The topography is generally irregular.
- Water concentrates and causes gullies to form.
- Sheet and rill erosion is controlled by other conservation practices.
- Runoff and sediment are causing damage.
- Adequate outlets can be provided.

WASCOBs alone may not be sufficient to control sheet and rill erosion. For this reason, additional practices may be needed to adequately protect sloping upland areas from erosion.

Conservation management system

Crop rotations and residue management that leave the crop residues on the soil surface are commonly used in conjunction with this practice to reduce sheet and rill erosion. On fields where contouring is not practical, farming across the slope will help to reduce the velocity of runoff water.

Underground outlets from WASCOBs can provide a direct conduit to receiving waters for contaminated runoff from crop land. Install WASCOBs as part of resource management plan that addresses issues such as nutrient and pest management, residue management and filter areas.



Earth Embankment

Construct embankments at least 5% higher than design height to allow for settlement. WASCOBs should not exceed 15 feet in height. The embankment slopes must be no steeper than 2 horizontal to 1 vertical. The sum of the horizontal components of the upstream and downstream slopes of the embankment must be 5 or greater. All slopes that will be farmed must be no steeper than those on which farm equipment can operate safely.

Minimum Top Width of Embankments

Fill Height (feet)	Top Width (feet)
0 – 5	3
5 - 10	6
10 –15	8

Basin Capacity

As a minimum, the WASCOB must have sufficient capacity to control the runoff from a 10-year frequency, 24-hour duration storm. In addition the WASCOB must have the capacity to store at least the anticipated 10-year sediment accumulation, or it must be cleaned on a regular basis to maintain the required capacity.

Outlets

A WASCOB must have an adequate outlet. The outlet must convey runoff water to a point where it will not cause damage. Outlets are usually underground outlets but other types of outlets such as pipe drop structures, soil infiltration, stabilized channels or a combination of outlet types are acceptable. The outlet should remove the water quickly enough so that crops are not injured but slowly enough to allow sediment to settle out.

Topsoil

Where necessary to restore or maintain productivity, spread topsoil over areas disturbed by construction. Topsoil can be salvaged and stockpiled from the site of the WASCOB prior to construction.

Operation and maintenance

Conduct the following operation and maintenance activities to ensure the practice works properly.

- Conduct periodic inspections, especially immediately following significant runoff events.
- Promptly repair or replace any damaged components.
- Maintain the basin ridge height and outlet elevations.
- Remove sediment that has accumulated in the basin to maintain capacity and grade.
- Regularly clean inlets for underground outlets.
- Repair or replace inlets damaged by farm equipment.
- Remove sediment around inlets to ensure that the inlet remains the lowest spot in the basin.

See site specific O&M requirements on page 3.

Specifications

Site-specific requirements are listed on the specifications sheet. Additional provisions are entered on the job sketch sheet. Specifications are prepared in accordance with the NRCS Field Office Technical Guide. See practice standard Water and Sediment Control Basin (638).

Water and Sediment Control Basin – Job Sheet

Landowner_______________________________________ Field number____________________

Purpose (check all that apply)	
☐ Convey concentrated flow runoff	☐ Other (specify):
☐ Reduce gully erosion	
☐ Protect/improve water quality	

WASCOB	1	2	3
Settled Ridge (Elev)			
Settlement Allowance (FT)			
Channel Inlet Elev			
L			
Upstream slope ratio			
Topwidth			
Downstream slope ratio			
Orifice Plate Elev			
Orifice Plate Dia (in)			
Seeding area (acres)			
Estimated fill yardage			
Main Drain Line			
Elevation			
Diameter (in)			
Grade (%)			

Site Preparation

Add site specific details for site preparation

Embankment Construction

Add site specific details for embankment construction

Underground Outlet

Add site specific details for underground outlet installation

Operation and Maintenance

Add site specific details O&M

Water and Sediment Control Basin – Job Sheet

Plan view or aerial photograph WASCOB installation site shown below.

Scale 1"=________ ft. (NA indicates sketch not to scale: grid size=1/2" by 1/2")

Additional Specifications and Notes:

Water and Sediment Control Basin – Job Sheet

As – Built Measurements

WASCOB	**1**	**2**	**3**
Settled Ridge (Elev)			
Channel Inlet Elev			
Upstream slope ratio			
Topwidth			
Downstream slope ratio			
Orifice Plate Elev			
Orifice Plate Dia (in)			
Seeding area (acres)			
Main Drain Line			
Diameter (in)			
Grade (%)			

CHECK OUT:

Amount Completed: _____________number.   Mark As-Built location on plan map

Remarks____
_

Checked by: ____________________________________   Date: ______________

Approved by: ____________________________________   Date: ______________

The United States Department of Agriculture (USDA) prohibits discrimination in its programs on the basis of race, color, national origin, sex, religion, age, disability, political beliefs and marital or familial status. (Not all prohibited bases apply to all programs.) Persons with disabilities who require alternative means for communication program information (Braille, large print, audiotape, etc.) should contact the USDA Office of Communications (202) 720-2791.

To file a complaint of discrimination write USDA, Director, Office of Civil Rights, Room 326-W, Whitten Building, 14th and Independence Avenue, SW, Washington, DC 20250-9410 or call (202) 720-5964 (voice or TDD). USDA is an equal opportunity provider and employer.

NATURAL RESOURCES CONSERVATION SERVICE

CONSERVATION PRACTICE STANDARD

WETLAND RESTORATION

(Ac.)

CODE 657

DEFINITION

The return of a wetland and its functions to a close approximation of its original condition as it existed prior to disturbance on a former or degraded wetland site.

PURPOSE

To restore wetland function, value, habitat, diversity, and capacity to a close approximation of the pre-disturbance conditions by restoring:

- Conditions conducive to hydric soil maintenance.
- Wetland hydrology (dominant water source, hydroperiod, and hydrodynamics).
- Native hydrophytic vegetation (including the removal of undesired species, and/or seeding or planting of desired species).
- Original fish and wildlife habitats.

CONDITIONS WHERE PRACTICE APPLIES

This practice applies only to natural wetland sites with hydric soils which have been subject to the degradation of hydrology, vegetation, or soils.

This practice is applicable only where the natural hydrologic conditions can be approximated by actions such as modifying drainage, restoring stream/floodplain connectivity, removing diversions, dikes, and levees, and/or by using a natural or artificial water source to provide conditions similar to the original, natural conditions.

This practice does not apply to:

- The treatment of point and non-point sources of water pollution (Constructed Wetland - 656);
- The rehabilitation of a degraded wetland, the reestablishment of a former wetland, or the modification of an existing wetland, where specific wetland functions are augmented beyond the original natural conditions; possibly at the expense of other functions.(Wetland Enhancement - 659);
- Wetland restorations requiring construction of an embankment with significant (Class II) or high (Class III) hazard classification as defined by the Illinois Department of Natural Resources – Office of Water Resources.
- The creation of a wetland on a site location which was historically non-wetland (Wetland Creation - 658).
- The management of fish and wildlife habitat on wetlands restored under this standard.

CRITERIA

General Criteria Applicable to All Purposes

The purpose, goals, and objectives of the restoration shall be clearly defined in the restoration plan, including soils, hydrology, vegetation, and fish and wildlife habitat criteria that are to be met and are appropriate for the site and the project objectives.

These planning steps shall be done with the use of a functional assessment-type procedure, or a state approved equivalent. The objectives will be determined by an analysis of current and historic site functions. They will be based on those functions which can reasonably be supported by current site constraints. Data from historic and recent aerial photography and/or other remotely sensed data, soil maps, topographic maps, stream gauge data, intact reference wetlands, and historical records shall be gathered.

The soils, hydrology and vegetative conditions existing on the site, the adjacent landscape, and the contributing watershed shall be documented in the planning process.

The nutrient and pesticide tolerance of the plant and animal species likely to occur shall be evaluated where known nutrient and pesticide contamination exists. Sites suspected of containing hazardous material shall be tested to identify appropriate remedial measures. If remedial measures are not possible or practicable, the practice shall not be planned.

The availability of sufficient water rights should be reviewed prior to restoration.

Upon completion, the site shall meet soil, hydrology, vegetation and habitat conditions of the wetland that previously existed on the site to the extent practicable.

Where offsite hydrologic alterations or the presence of invasive species impact the site (e.g., main ditches, channelized streams and levees), the design shall compensate for these impacts to the extent practicable (e.g., increased water depth, berms or macrotopography).

Invasive species, federal/state listed noxious plant species, and nuisance species (e.g., those whose presence or overpopulation jeopardize the practice) shall be controlled on the site as necessary to restore wetland functions. The establishment and/or use of non-native plant species shall be discouraged.

Where adjoining land is used for grazing or is open to livestock, the wetland shall be fenced to exclude the livestock. If grazing is planned in the wetland area, a prescribed grazing plan will be developed to ensure the planned wetland functions are maintained. See Conservation Practice Standard Prescribed Grazing - 528.

Utilities and Permits. The landowner and/or contractor shall be responsible for locating all buried utilities in the project area, including drainage tile and other structural measures.

The landowner shall obtain all necessary permissions from regulatory agencies, including but not limited to the Illinois Department of Agriculture, US Army Corps of Engineers, US Environmental Protection Agency, Illinois Environmental Protection Agency and Illinois Department of Natural Resources – Office of Water Resources, or document that no permits are required.

<u>Criteria for Hydric Soil Restoration</u>

Restoration sites will be located on soils that are hydric.

If the hydric soil is covered by fill, sediment, spoil, or other depositional material, the material covering the hydric soil shall be removed to the extent needed to restore the original soil functions.

Soil hydrodynamic and bio-geochemical properties such as permeability, porosity, pH, or soil organic carbon levels shall be restored to the extent needed to restore hydric soil functions.

<u>Criteria for Hydrology Restoration</u>

The hydroperiod, hydrodynamics, and dominant water source of the restored site shall approximate the conditions that existed before alteration. The restoration plan shall document the adequacy of available water sources based on groundwater investigation, stream gauge data, water budgeting, or other appropriate means.

Existing drainage systems shall be utilized, removed or modified as needed to achieve the intended purpose.

The work associated with the wetland shall not adversely affect adjacent properties or other water users unless agreed to by signed written letter, easement or permit.

Management of water control structures, if needed, will be based on the actions needed to maintain a close approximation of the site's original hydroperiods (timing, frequency, duration, and depth).

The site's natural water supply should be used to reestablish the site's hydrology to approximate the hydrologic conditions of the wetland type. If this is not possible, an alternate natural or artificial water supply can be used; however, these sources shall not be diverted from other wetland resources. If the alternate water source requires energy inputs, these shall be estimated and documented in the restoration plan.

To the extent technically feasible, reestablish macrotopography and/or microtopography. Use reference sites within the local area to determine desired topographic relief. The location, size, and geometry of earthen structures, if needed, shall match that of the original macrotopographic features to the extent practicable. For more information and specifications for macro and microtopography restoration, see Illinois Biology Technical Note #20 "Using Micro and Macrotopography in Wetland Restoration."

Excavations from within the wetland shall remove sediment to approximate the original topography or establish a water level that will compensate for the sediment that remains.

Wetland restoration sites that exhibit soil oxidation and/or subsidence, resulting in a lower surface elevation compared to pre-disturbance, shall take into account the appropriate hydrologic regime needed to support the original wetland functions.

Subsurface Drain Removal or Destruction. Subsurface drains shall be removed or rendered inoperable throughout the wetland. The effects of a subsurface drainage system may be eliminated by performing one or more of the following:

- Removing or rendering inoperable a portion of the drain at the downstream edge of the site.
- Modifying the drain with a structure for water control.
- Replacing the drain with non-perforated pipe throughout the wetland site.
- Outletting the drain in the watershed above the wetland area.
- Routing the drain around the wetland area.

The minimum length of drain to be removed or rendered inoperable is shown in **Table 1**. If present, within the distance in **Table 1**, sumps for drainage pumping plants shall be removed, or filled and capped according to state law.

If present, all sand and gravel bedding and filtering material or other flow enhancing material will also be removed from the subsurface drain. The trench will be filled or compacted to achieve a density equal to the adjacent material.

Where embankments will be constructed, all subsurface drains shall be removed starting at the minimum distance shown on **Table 1** downstream of the embankment center line and extending to 15 feet upstream from the upstream toe of the embankment. Or, the drain under the embankment shall be removed and a structure excavation with a 4 foot bottom width and not less than 1:1 side slopes shall be extended to one foot below the invert elevation of the drain, under the fill. The drain can be reinstalled (non-perforated material only) and the back fill in the trench shall be compacted in 6 inch or smaller lifts, to the original ground elevation.

Table 1. Drain Removal Requirements

Minimum length of subsurface drain to be removed or rendered inoperable

Or

Minimum length of surface drain to be filled with ditch plug. (The length is measured parallel to the direction of the surface drain flow along the top of the settled ditch plug.)

*Soil Permeability (inches per hour)	*Soil Texture	**Minimum Distance from Wetland
> 2.0	Sandy & Organics	150 feet
0.6 - 2.0	Loamy	100 feet
< 0.6	Clayey	50 feet

* Where the permeability and texture vary in the soil profile above the drain flow line, determine which layer(s) are critical for the type of drainage system. Standard values for permeability and texture for each soil map unit are found in the Field Office Technical Guide.

** Lateral effects of drainage features computed according to EFH Chapter 19 procedures can be substituted for the minimum distances shown in **Table 1** (except for drains under embankments).

Installation of non-perforated subsurface drain around or through the wetland may be necessary to allow upstream drainage systems to continue to function properly.

Remaining functional subsurface drains that are modified by a wetland restoration shall have an end cap installed on the upstream end or other satisfactory end seal installed to prevent soil from filling the drain.

Surface Drain Removal. Where an open channel has been constructed to drain the wetland, the channel will be filled with earth, rendered inoperable, or controlled with a water control structure to restore the wetland hydrologic conditions. Installation of alternative drainage around the wetland may be necessary to allow upstream drainage systems to continue to function properly.

Ditch plugs without water control structures may be used for surface drain removal where flow duration and rate will not cause erosion.

The minimum length of channel to be filled will be as shown in **Table 1**.

The side slopes on ditch plugs will be 5(H):1(V) or flatter. Settled height of ditch plugs shall be at least 0.5 feet higher than the adjacent overflow area. All ditch plug fill will be compacted as for earth embankments.

Embankments. Provisions shall be made to safely store, pass or divert the flow from the minimum design storm as shown in **Table 2**. For embankment height exceeding the ranges listed in **Table 2**, design storms shall meet the criteria in Conservation Practice Standard Pond – 378.

Table 2. Wetland Embankment Spillway Requirements

Drainage Area[1] (acres)	Maximum Impounding Capacity2 (acre-feet)	Embankment Height3 (feet)	Minimum Design Frequency (24-hr Duration Storm)	
			Principal Spillway4 (year)	Open Spillway5 (year)
0-20	< 50	<= 10	5	10
0-20	>= 50	<= 6	5	25
>20	< 50	<= 10	10	25
>20	>= 50	<= 6	10	25
All	>= 50	6-10	25	100

[1] Drainage area represents the contributing watershed to the wetland from upland areas and does not include the drainage area of any adjacent watercourse that may occasionally flood into the wetland.

[2] Impounding capacity is the volume in the wetland below the top of the embankment.

[3] Embankment height is the elevation difference measured from the top of the settled embankment to the lowest elevation at the downstream toe of the embankment.

[4] All embankment wetlands shall include a principal spillway, except where a lined open spillway is used, or where the rate and duration of flow can be safely handled by a vegetated open spillway.

[5] The design discharge of the principal spillway may be subtracted from the requirement for the open spillway.

The minimum top width for an embankment less than 10 feet in height (as defined in **Table 2**) is 6 feet; for other embankment heights, the top width criteria in Conservation Practice Standard 378 – Pond must be met. For embankments located on a floodplain, where overtopping of the embankment by flow from the floodway into the wetland is likely, the minimum top width is 10 feet. If the embankment is to be used for vehicular traffic, the minimum top width is 12 feet.

All embankment wetlands shall include a principal spillway, except where a lined open spillway is used, or where the rate and duration of flow can be safely handled by a vegetated open spillway. The principal spillway shall consist of a closed conduit, a full flow open structure, or a water control structure (stoplog structure).

For wetlands with a drainage area of 20 acres or less, the principal spillway crest elevation shall not be less than 0.5 feet below the open spillway crest elevation. For wetlands with a drainage area over 20 acres, this difference shall not be less than 1.0 feet. All wetlands shall have a freeboard of not less than 1.0 feet between the design water surface in the open spillway and the top of embankment.

Embankment side slopes shall be 3(H):1(V) or flatter. For vegetated open spillways or low areas along the embankment, side slopes shall be 5:1 or flatter.

All embankment wetlands shall include an open spillway at least 10 feet wide. The open spillway may be in a natural low area without shaping. The open spillway shall be stabilized using vegetative or mechanical protection designed to withstand the maximum anticipated flow velocity during operation, including flood flows into the wetland from an adjacent stream, if applicable. Mulching of vegetative spillways is required.

For embankments located on a floodplain, where overtopping of the embankment by flow from the floodway into the wetland is likely, the open spillway may be on level natural ground, in excavation, or on an area of the embankment where the height from the top of the embankment to the downstream toe is 2 feet or less. The level section of the open spillway must be at least 25 feet long in the direction of flow and at least 100 feet wide. The design flow depth should be 0.5 feet or less.

When design discharge of the principal spillway is considered in calculating peak outflow from the open spillway, the inlet elevation of the principal spillway shall be such that the entire principal spillway design storm is handled before the open spillway operates.

All fill will be compacted as needed to achieve the desired densities. To account for settlement, the earth fill height will be increased by at least 5% for mineral soils compacted by construction equipment operating over the fill area, and by at least 10% where fill is dumped, bulldozed, and shaped with limited compaction. The earth fill height will be increased by 20% where a mixture of mineral and organic soils is used. Fills using all organic soils shall be increased by at least 33% to account for settlement.

New embankments shall not be built with any portion of the earthfill closer to any property line than the product of the maximum ponded water depth times 10, unless a specific written agreement exists between landowners allowing the same.

Principal Spillway. If baseflow (including seepage, drainage flow or spring flow) exists, a principal spillway shall be provided.

When the water control structure is intended for manipulating water level for the operation and maintenance of the wetland, the drawdown capacity of the structure shall be adequate to remove 85% of the normal pool volume in 14 days.

To prevent clogging of the conduit, an appropriate trash guard shall be installed at the inlet or riser, and an animal guard shall be installed at the outlet.

Avoid placing a water control structure in an inside embankment corner to minimize blockages due to debris and beaver activity.

Principal spillways that may impede the movement of target aquatic species or species of concern shall meet the criteria in Conservation Practice Standard Fish Passage - 396.

Spillway Pipes. Non-perforated conduit shall be used downstream of a water control structure for distance as shown in **Table 1**, and under any embankment. The connections of the water control structure and non-perforated conduit will be watertight for the pressure developed at the maximum pool level.

Materials for spillway pipes shall meet the requirements of Conservation Practice Standard (CPS) Pond - 378. Seepage control according to CPS 378 shall be provided if the conduit is of smooth pipe larger than 8 inches, or if the conduit is of corrugated pipe larger than 12 inches in diameter.

Vegetation on Embankments. Immediately after construction and prior to holding water against the newly constructed embankment, the entire embankment and spillway area shall be seeded to a protective vegetative cover . Use Conservation Practice Standard Critical

Area Planting – 342 for seeding recommendations.

Shallow Water Excavation. To restore irregular ground features and varying inundation periods, excavated wetlands shall have a variety of depths which range from ground level to a maximum depth of 4 feet. A minimum of 2/3 of the surface area of the excavated wetland shall have water depths of 0 to 18 inches. Side slopes in the excavated area shall be 6:1 or flatter.

Criteria for Vegetative Restoration

Hydrophytic vegetation restoration shall be of species, diversity, and richness typical for the wetland type(s) being established and the varying hydrologic regimes and soil types within the wetland. Preference shall be given to native wetland plants with localized genetic material.

Where natural colonization of target species can realistically be expected to occur within 5 years, sites may be left to revegetate naturally. If not, the appropriate species will be established by seeding or planting.

Adequate substrate material and site preparation necessary for proper establishment of the selected plant species shall be included in the plan.

Where planting and/or seeding is necessary, the minimum number of native species to be established shall be based on a standard reference wetland with the type of vegetative communities and species planned on the restoration site:

- Where the dominant vegetation will be herbaceous community types, a subset of the original vegetative community shall be established within 5 years, or a suitable precursor to the original community will be established within 5 years that creates conditions suitable for the establishment of the native community. Species diversity and richness shall be addressed in the planning of herbaceous communities. Seeding rates shall be based upon the percentage of pure live seed and labeled with a current seed tag from a registered seed laboratory identifying the germination rate, purity analysis, and other seed statistics.
- Where the dominant vegetation will be forest or woodland community types, vegetation establishment will include a mix of woody species (trees and/or shrubs) adequate to establish the standard reference plant community.

Tree and shrub planting will follow the criteria in Conservation Practice Standard Tree/Shrub Establishment - 612.

Where trees are to be established, trees will be planted along elevation contour lines to facilitate placing trees at the elevation which will have the optimum depth and duration of inundation for each species.

CONSIDERATIONS

Soil Considerations

Consider making changes to physical soil properties, including:

- Increasing or decreasing saturated hydraulic conductivity by mechanical compaction or tillage, as appropriate.
- Incorporating soil amendments.
- The effect of construction equipment on soil density, infiltration, and structure.

Consider changes in soil bio-geochemical properties, including:

- Increasing soil organic carbon by incorporating compost.
- Increasing or decreasing soil pH with lime, gypsum, or other compounds.

Hydrology Considerations

Consider the general hydrologic effects of the restoration, including:

- Impacts on downstream stream hydrographs, volumes of surface runoff, and groundwater resources due to changes of water use and movement created by the restoration.

Consider the impacts of water level management, including:

- Increased predation due to concentrating aquatic organisms, including herptivores, in small pool areas during draw downs.

- Increased predation of amphibians due to high water levels that can sustain predators.
- Decreased ability of aquatic organisms to move within the wetland and from the wetland area to adjacent habitats, including fish and amphibians as water levels are decreased.
- Increases in water temperature on-site, and in off-site receiving waters.
- Changes in the quantity and direction of movement of subsurface flows due to increases or decreases in water depth.
- The effect changes in hydrologic regime have on soil bio-geochemical properties, including: oxidation/reduction; maintenance of organic soils; and salinity increase or decrease on site and on adjacent areas.

<u>Vegetation Considerations</u>

Consider:

- The relative effects of planting density on fish and wildlife habitat versus production rates in woody plantings.
- The potential for vegetative buffers to increase function by trapping sediment, cycling nutrients, and removing pesticides.
- The selection of vegetation for the protection of structural measures that is appropriate for wetland function.
- The potential for invasive or noxious plant species to establish on bare soils after construction and before the planned plant community is established.
- The use of prescribed burning to restore wetland and adjacent plant communities.

<u>Fish and Wildlife Habitat Considerations</u>

Consider:

- The addition of coarse woody debris (dead snags, tree stumps or logs) on sites to be restored to woody plant communities for an initial carbon source and fish and wildlife cover.
- The potential to restore habitat capable of supporting fish and wildlife with the ability to control disease vectors such as mosquitoes.
- The potential to establish fish and wildlife corridors to link the site to adjacent landscapes, streams, and water bodies and to increase the site's colonization by native flora.
- The need to provide barriers to passage for unwanted or predatory species.

PLANS AND SPECIFICATIONS

Plans and specifications for this practice shall be prepared for each site. Plans and specifications shall be recorded using approved specifications sheets, job sheets, or other documentation. The plans and specifications for structural features will include, at a minimum, a plan view, quantities, and sufficient profiles and cross-sections to define the location, line, and grade for stakeout and checkout. Plans and specifications shall be reviewed and approved by staff with appropriate job approval authority.

OPERATION AND MAINTENANCE

A separate Operation and Maintenance Plan will be prepared for sites that have structural features. The plan will include specific actions for the normal and repetitive operation of installed structural items, especially water control structures, if included in the project. The plan will also include the maintenance actions necessary to assure that constructed items are maintained for the life of the project. It will include the inspection schedule, a list of items to inspect, a checklist of potential damages to look for, recommended repairs, and procedures for documentation.

Management and monitoring activities needed to ensure the continued success of the wetland functions may be included in the above plan, or in a separate Management and Monitoring Plan. In addition to the monitoring schedule, this plan may include the following:

- The timing and methods for the control of water levels, nutrient managment, application of pesticides, prescribed burning, or mechanical vegetative treatments.
- Circumstances when the use of biological control of undesirable plant species and pests (e.g. using predator or parasitic

species) is appropriate, and the approved methods.

- Actions which specifically address any expected problems from invasive or noxious species.
- The circumstances which may require the removal of accumulated sediment.
- Conditions which indicate the need to use haying or grazing as a management tool, including timing and methods.

REFERENCES:

Executive order 13112, Invasive Species, February 3, 1999. Federal Register: Vol.64, No.25. Feb. 8, 1999. http://frwebgate.access.gpo.gov/cgi-bin/getdoc.cgi?dbname=1999_register&docid=99-3184-filed.pdf

Galatowitsch, Susan, et al, 1994. Restoring Prairie Wetlands: an ecological approach. Iowa State University Press, Ames, IA. 246 pp.

Hall, C.D. and F.J. Cuthbert. 2000. Impact of a controlled wetland drawdown on Blanding's Turtles in Minnesota. Chelonian Conservation Biology. Vol. 3, No. 4, pp. 643-649Hurt, G.W. and V.W. Carlisle, 2001.

Illinois Administrative Code, Title 17: Conservation, Chapter I: Department of Natural Resources, Subchapter h: Water Resources, Part 3702: Construction and Maintenance of Dams.

Kingsbury, Bruce & Joanne Gibson, 2002. Habitat Management Guidelines for Amphibians and Reptiles of the Midwest. Partners in Amphibian & Reptile Conservation, Ft Wayne IN, 57 pp.

Kwak, T.J. 1988. Lateral movement and use of floodplain habitat by fishes of the Kankakee River, Illinois. Am. Midland Naturalist 120(2): 241-249.

Maschhoff, Justin T & James H. Dooley, 2001. Functional Requirements and Design Parameters for Restocking Coarse Woody Features in Restored Wetlands, ASAE Meeting Presentation, Paper No: 012059.

USDA-NRCS. Hydric Soil Technical Note 13, Deliberations of the National Technical Committee for Hydric Soils (NTCHS). ftp://ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/note13.pdf

USDA, NRCS, 2003. ECS 190-15 Wetland Restoration, Enhancement, Management & Monitoring. 425 pp. ftp://ftp-fc.sc.egov.usda.gov/WLI/wre&m.pdf

USDA, NRCS. Wetland Restoration, Enhancement, or Creation, Engineering Field Handbook Chapter 13, Part 650. 121 pp. ftp://ftp-fc.sc.egov.usda.gov/WLI/wre&m.pdf

USDA, NRCS. 2010. Field Indicators of Hydric Soils in the U.S., Version 7.0. L.M. Vasilas, G.W. Hurt, and C.V. Noble (eds.). USDA, NRCS in cooperation with the National Technical Committee for Hydric Soils. ftp://ftp-fc.sc.egov.usda.gov/NSSC/Hydric_Soils/FieldIndicators_v7.pdf

USDA-NRCS. 2000. Illinois Biology Technical Note 20 Using Micro and Macrotopography in Wetland Restoration. 7pp. http://efotg.sc.egov.usda.gov/references/public/IL/bio20.pdf

11.5 Appendix 5. Quality Assurance Project Plan

Quality Assurance Project Plan: Apple Canyon Lake Watershed Management Plan

Apple Canyon Lake Property Owners Association
14A157 Canyon Club Dr.
Apple River, IL 61001

Version 5
May 2014

SECTION A. PROJECT MANAGEMENT

A1 Approval Sheet

Tim Ridder
ACLPOA , General Manager

5/28/14
Date

Mike Malon
Jo Daviess SWCD, Resource Conservationist

5-28-14
Date

Amy Walkenbach
IEPA Bureau of Water, Watershed Management

5-29-14
Date

Michelle Rousey
IEPA Bureau of Water, Quality Assurance Coordinator

5-29-14
Date

A2 Table of Contents

Acronyms and Abbreviations

ACL	Apple Canyon Lake
ACLPOA	Apple Canyon Lake Property Owners Association
ACL-WMP	Apple Canyon Lake Watershed Management Plan
BMP	Best Management Practices
BOW	Bureau of Water
CAR	Corrective Action Report
CFR	Code of Federal Regulations
DQO	Data Quality Objective
DO	Dissolved Oxygen
GPS	Global Positioning System
IEPA	Illinois Environmental Protection Agency
JDSWCD	Jo Daviess County Soil & Water Conservation District
LCS	Laboratory Control Spike
MDL	Method Detection Limit
NIST	National Institute of Standards and Technology
NRCS	Natural Resource Conservation Service
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
QA/QC	Quality Assurance / Quality Control
QAO	Quality Assurance Officer
QMP	Quality Management Plans
RPD	Relative Percent Difference
SOP	Standard Operating Procedure
SVAP2	Stream Visual Assessment Protocol, Version 2
TSS	Total Suspended Solids
USEPA	United States Environmental Protection Agency
VLMP	Volunteer Lake Monitoring Program

A3 Distribution List

A copy of this Quality Assurance Project Plan (QAPP) will be distributed in electronic format via e-mail to each person signing the approval sheet and also the individuals listed in Section A4 Project/Task Organization. Individuals participating in this study may request additional copies of the QAPP from personnel listed in Section A4.

The original approved QAPP containing the Approval Sheet with signatures and dates will be retained by the Illinois Environmental Protection Agency (IEPA) Bureau of Water (BOW) Quality Assurance Officer (QAO).

This document has been prepared according to the United States Environmental Protection Agency publication *EPA Requirements for Quality Assurance Project Plans (QA/R-5)* (May 2001).

A4 Project/Task Organization

An organizational chart illustrating the Apple Canyon Lake Watershed Management Plan (ACL-WMP) study group hierarchy is presented in Figure 1. (See Table 1 for ACL-WMP study group contact information.)

The following individuals are responsible for project management:

<u>Project Director</u> – Tim Ridder, Apple Canyon Lake Property Owners Association (ACLPOA)

<u>Project Managers</u> – Mike Malon, Jo Daviess County Soil and Water Conservation District (JDSWCD)

<u>Sample Collectors</u> – Mike Malon, JDSWCD, and Intern, ACLPOA

The Project Director is responsible for oversight of the project as it pertains to the Apple Canyon Lake Watershed Management Plan, currently under review for acceptance for 319 Grant funding.

The Project Managers are responsible for the execution of the entire project. This includes tasks such as quality assurance (QA) and quality control (QC); execution of field activities; and preparation, analysis, data generation, Sample Collectors, and data reporting of the environmental samples.

The IEPA QAO, Michelle Rousey, is responsible for oversight of preparing the QAPP.

A Project Manager from the IEPA, Amy Walkenbach, will also be involved in QA/QC oversight and work with the ACL-WMP team.

The IEPA Laboratory Manager, Celeste Crowley, is responsible for the preparation, analysis, data generaton and data reporting of the inorganic samples.

A5 Problem Definition and Background

In 2012, the Illinois Integrated Water Quality Report and Section 303(d) List included ACL among its list of downward trending lakes with specific reference to lower Secchi disk transparency readings between 1979 and 2006 (p. 102). Due to this information and noticeable deterioration of the watershed, in regards to both nutrient loading and erosion, the ACLPOA has found it to be imperative that a comprehensive watershed plan be developed. ACLPOA has invested $4.6 million in conservation practices since the early 1990s to address water quality issues. These investments have been focused on remediating immediate problems without the aid of a comprehensive plan which would identify and prioritize water quality issues.

A comprehensive water monitoring program based on an approved QAPP will provide baseline data and establish connections to complete monitoring of the goals set, to assure that the goals are being met. The purpose of the ACLPOA effort is to participate, as a full partner with IEPA, in documenting the water quality of Apple Canyon Lake and its surrounding tributaries. This QAPP will describe this water monitoring will be used to obtain data which meets standardized and accepted protocol for documenting the water quality of Apple Canyon Lake tributaries, with the long-term objective of improving water quality.

A6 Project/Task Description

A comprehensive watershed plan will be developed over the course of two years by using a variety of quality assurance protocol. The primary data source will be a water monitoring program based on 7 tributary sites that feed into the lake and 2 outflow sites downstream from the lake. Figure 2 is a site map of these locations. Table 2 provides descriptions of the sampling areas. At these 9 sites around the lake, both chemical and physical data will be recorded monthly (from March to October) and after significant rain events (>1"/24 hrs). Laboratory testing of sample concentrations will take place within approved standardized methods outlined for each element of the monitoring strategy. Chemical testing will be completed by the IEPA laboratory while additional parameters will be performed in situ where appropriate (dissolved oxygen., temperature, conductivity, etc.). Analytical results will be submitted to IEPA, Bureau of Water, Watershed Management Section or their designee, monthly. Table 3 describes the sampling schedule. A combination of methodology and devices are used to create a protocol focused on concentrations, total phosphorus, dissolved phosphorus, nitrate/nitrite, total suspended solids (TSS), ammonia nitrogen, and total Kjeldahl nitrogen, along with levels of pH, and dissolved oxygen (DO). Physical assessments are simultaneously taken for stream volume, velocity, clarity, specific conductivity and temperature. Complete field procedures are described in Appendix 1. Table 4 describes the containers, field preservation, and holding time for the samples.

The watershed plan will also involve data acquired from a number of other projects as well. These projects include the ongoing Volunteer Lake Monitoring Program (VLMP) which ACLPOA has participated in since 1984, recently moving to Tier III status. Stream Corridor Assessments will also be conducted by JDSWCD Resource Conservationist over the next two years. This project will be based on protocols established by the National Resource Conservation Service (NRCS) Stream Visual Assessment Protocol, version 2 (SVAP2), adapted for Illinois (January 2014), and will work with a combination of global positioning system (GPS) technology and visual assessment to provide continuous stream condition data at a watershed scale. Finally, Abraxis test strips will be used to monitor Mycrocystin concentrations in high use areas and areas where cyanobacteria blooms are common.

A7 Quality Objectives and Criteria

A summary of the minimum measurement criteria and data quality objectives (DQOs) are presented in Table 5.

A7.1 Precision

Precision is a measure of agreement among repeated measurements of the same property under identical, or substantially similar, conditions; calculated as either the range or as the standard deviation. Precision may also be expressed as a percentage of the mean of the measurements, such as relative range or relative standard deviation (coefficient of variation).

Precision will be measured in the laboratory during the analysis of matrix spike and matrix spike duplicate samples.

The analyses of the duplicate samples are considered acceptable if the calculated relative percent difference (RPD) of the measurements is within the acceptance limits listed in Table 5.

The results of the duplicate analyses are used to calculate the RPD for evaluating precision using the following formula:

RPD = [(A – B) / (A + B)/2] *100

where

A = Original sample concentration

B = Duplicate sample concentration

A7.2 Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction. Field and lab bias will be limited by a standardized field and lab protocol that will require repetition and duplication of work.

A7.3 Accuracy

Accuracy is a measure of the overall agreement of a measurement to a known value. Accuracy includes a combination of random error (precision) and systematic error (bias) components that are due to sampling and analytical operations.

Accuracy will be measured during the analysis of environmental water by using laboratory control spikes (LCS). In the laboratory, samples of deionized water will be fortified (or spiked) with the analytes of interest. These LCS samples will be analyzed with each batch of water extracts. The analyses of the LCS samples are considered acceptable if the calculated concentrations for all analytes of interest are within the acceptance limits listed in table 5.

The results of the spiked samples are used to calculate the percent recovery for evaluating accuracy using the following formula:

Percent Recovery = [(S - U) / T] * 100

where

S = Spiked sample concentration

U = Unspiked sample concentration

T = True spike concentration

A7.4 Representativeness

Representativeness is the measure of the degree to which data accurately and precisely represents a characteristic of a population, parameter variations at a sampling point, a process condition, or an environmental condition.

Representativeness of data will be ensured using established laboratory procedures and their consistent application. To aid in the evaluation of the representativeness of the sample data, laboratory blank samples will be evaluated for the presence of contaminants.

A7.5 Comparability

Comparability is a measure of the confidence with which one data set or method can be compared to another.

Comparability will be maximized by using standard analytical methods and standardized, documented sampling techniques. Documentation will include all sampling locations, conditions, and field sampling methods. All results will be reported in standard units or, for field parameters, as defined in the method. All laboratory and field calibrations will be performed using standards traceable to the calibration protocol described in the device manuals.

A7.6 Completeness

Completeness is a measure of the amount of valid data needed to be obtained from a measurement system.

The percent completeness is calculated by dividing the number of valid sample results by the total number of samples planned, and multiplying the result by 100 percent. Completeness will be reported as the percentage of all measurements judged valid. The following equation will be used to determine completeness:

$$\text{Percent Completeness} = (V/T) * 100$$

where

V = Valid number of sample results

T = Total number of samples planned

For this project, the quality assurance (QA) objective for degree of completeness for both field and laboratory data is 90 percent. If completeness is less than the target of 90 percent the Project Director and Project Managers will evaluate the data to determine whether there are enough data to complete the study or if additional data collection is necessary.

A7.7 Sensitivity

Sensitivity is the capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest.

Many analytes measured for this project are present in analytically low concentrations throughout the tributaries. All analytes are subject to chemical, biological, and physical processes that will alter their presence in the tributaries. It is the intent of this project to employ methods of measurements that will detect and quantify all analytes of interest wherever possible.

Although there are many intended and potential uses of the data, minimum measurement criteria will be established at the lowest analyte concentration required for planned uses of the measurement data. Minimum measurement criteria are State of Illinois water quality standards for general use waters where applicable. Where no minimum measurement criteria can be identified, the water samples will be analyzed to the lowest concentration readily achievable by the IEPA laboratory. The monitored parameters and the established minimum measurement criteria are shown in Table 5.

Table 5 also gives the minimum measurement objectives for the project. The minimum measurement objectives will be set at approximately one-fifth of the minimum measurement criteria shown to ensure that analytes will be measured with reasonable accuracy at the minimum measurement criteria concentrations, and measured to reasonable levels below the minimum measurement criteria.

The minimum measurement objective for any analyte will be achieved when the analytical procedure selected for sample analysis can be shown to have a method detection limit (MDL) at or below the minimum measurement objective. Table 5 compares the minimum measurement objective against the reporting limit achieved by the IEPA laboratory. All analytes meet the minimum measurement objective.

Analyte MDLs shall be determined by the USEPA method given in the Code of Federal Regulations (CFR), Volume 40, Part 136, Appendix B. The MDL is defined as "the minimum concentration of a substance that can be measured and reported with 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte." Since the MDL procedure is based upon precision obtained for a standard greater than the MDL, it also is a measure of method sensitivity at concentrations near the MDL.

For analytes without minimum measurements criteria, the minimum measurement objectives will be understood to be the MDL level that is readily achievable using analytical methods generally employed at the IEPA laboratory. For parameters where MDLs are not applicable such as pH, temperature, and dissolved oxygen, the minimum measurement objectives shown in Table 5 are the sensitivity to be obtained by the measurement method. The accuracy, precision, and completeness for each parameter are also indicated in Table 5.

A8 Special Training/Certifications

Prior to sample collection, all sample collectors shall be trained in the proper sample collection procedures. All staff involved in sampling as part of this project will be instructed by the project manager on how to properly and consistently collect samples from the identified stream sites. Sites have been selected to represent conditions for those water bodies in order that improvements in the watershed and lake can be documented. All staff involved in collecting water samples are trained using the same methods employed by the Project Managers.

A9 Documentation and Records

Sample collection records, field notebooks, and all records of field activities shall be retained for five years by the Project Managers responsible for coordinating the execution of those field activities. Sample collection records shall document proper sampling protocol performed in the field. All records shall be retained at both the ACLPOA maintenance office as well as the JDSWCD office, in Elizabeth, IL.

The Project Managers shall retain all laboratory analytical results and all correspondence with IEPA laboratory. Chain-of-custody forms submitted for the IEPA laboratory shall also be retained along with analytical results. Two copies of results will be filed. One copy will be kept on record at the ACLPOA maintenance office and a second copy will be kept on file at the JDSWCD office in Elizabeth, IL.

The Project Director shall be made aware of any problems encountered during any phase of the project.

SECTION B. DATA GENERATION AND ACQUISITION

B1 Sampling Process Design (Experimental Design)

Sampling Stations

Data sampling stations are described in Table 2, stations were refined during a field reconnaissance by the Project Managers. Sample location sites were selected according to the following criteria:

Site 1: Determines non-point source pollutant loading from cattle operation

Site 2: Determines the effectiveness of detention pond upstream

Site 3: Determines the nutrient load from the entire Hell's Branch Creek upstream from North Bay

Site 4: Determines the nutrient load from the entire tributary upstream from Winchester Bay

Site 5: Determines the nutrient load from the entire tributary upstream from Independence Bay

Site 6: Determines the nutrient load from the entire tributary upstream from Hawthorne Bay

Site 7: Determines non-point source pollutant loading from golf course (within ACL watershed)

Site 8: Determines the water quality downstream of golf course (outside ACL watershed)

Site 9: Determines the water quality downstream of ACL spillway (Hell's Branch outside ACL watershed)

Sampling stations may be added or deleted based on evaluation by the ACLPOA or the Project Managers.

Sampling Frequency

Stream sampling will be completed once a month at the beginning of each month, and after significant rain events (defined here as >1"/24 hrs). Streams will be sampled through the open water season (approximately March-October) of each year.

The sampling process is designed to obtain a large amount of chemical, and physical data from several tributaries leading into the lake, and two streams flowing out from the lake. The design is formatted to develop an understanding of what is being introduced to the lake via its watershed and where the introductions are taking place. Nutrient loading is studied by the collection of total phosphorus, dissolved phosphorus, ammonia, total kjeldahl nitrogen, and nitrate/nitrite data. Physical data collection includes D.O., depth and velocity measurement across a stream transect, air temperature, water temperature, recent rainfall and current weather conditions.

Sample Method

Sampling will be conducted in a manner that minimizes the chances of contamination. Lab samples will be collected in sterile sample containers provided by the IEPA. Table 4 lists the required containers and preservation techniques for each parameter. Sample collection personnel will be instructed not to touch the inside of the sample containers or caps.

The lab sample will be taken directly from the stream. The sample will be collected in the middle of the channel at its thalweg or deepest part of stream, while facing upstream. Samples will be collected directly into their respective lab sample containers, immediately capped, and then stored on ice until Prepared for shipping. Samples will be tested within the accepted hold times listed in Table 4. All observations will be recorded on the field form located in the appendix.

Selection of Parameters for Monitoring

Parameters for chemical analysis were selected because these specific nutrients and other parameters will be beneficial to set objectives for water quality improvement, prioritize locations for best management practice (BMP) locations, and assess future changes to water quality resulting from implementation of BMPs. Most of the parameters selected for monitoring are identified as Pollutants of Concern by IEPA in their 303(d) listing of the stream segments and/or recommended through correspondence with IEPA.

B2 Sampling Methods

Sampling

The Project Managers or the Managers' designee will be responsible for the water quality samples and chain of custody. Each sample container is to be labeled with a permanent waterproof marker. Sample container labels include site name (as designated by IEPA) and date sample was collected. Information included on the chain of custody forms includes the site name, date and time the sample was collected, collector's name, sample matrix, and the analytes requested. The Project Managers or Managers' designee will be responsible for packing the samples on ice and ensuring their viability until they can be delivered to the lab.

Information on field conditions, such as deviations from written procedures, operating condition of the equipment, and other unusual occurrences will be documented on the field sheets (Appendix). It is important to be able to trace the path of a sample from collection in the field through laboratory analysis should any problems occur.

Temperature, DO, and pH are measured in the field using a YSI Inc. equivalent field probe: Hach Quanta Hydrolab®. These readings are measured directly in stream and at mid depth.

Refer to Section B5.1 Field Quality Control for individuals responsible for corrective action.

B3 Sample Handling and Custody

All sample containers are chilled in an ice-filled cooler immediately after collection and kept on ice during transport to the IEPA laboratory. Table 4 describes field collection containers and field preservation. All samples will be properly preserved and analyzed within the specified holding times.

Samples are to be transported to the IEPA laboratory within the prescribed holding times. Samples will be taken to the IEPA laboratory by a member of the sampling team.

The laboratory shall record temperature upon arrival at the laboratory using a thermometer calibrated against a National Institute of Standards and Technology (NIST) traceable certified thermometer. Samples that require thermal preservation are refrigerated after sample acceptance at the laboratory.

When received by the laboratory, the samples are logged into the laboratory database. Maximum holding times before analysis, as stated in applicable laboratory method standard operating procedures (SOPs) are followed.

Refer to Section B5.2 Laboratory Quality Control for individuals responsible for corrective action.

B4 Analytical Methods

All methods used by the laboratory for data analysis shall be USEPA approved methods listed in 40 CFR Part 136. Table 4 describes holding times as established in 40 CFR Part 136.

The IEPA lab will perform all ex situ laboratory analyses. In the event a new contract lab needs to be chosen, the ACLPOA will first receive approval by the IEPA Quality Assurance Officer.

B5 Quality Control

B5.1 Field Quality Control

All field operations personnel are responsible for ensuring proper sampling methods, sample preservation, and sample custody of the delivered samples are followed.

An investigation and corrective action report (CAR) prepared by the responsible supervising field personnel in the event of a QC issue will be submitted to the Project Managers. The Project Managers will then forward this report to the Project Director.

The accuracy and precision of all data measurements must be quantifiable. Analytical procedures used for data analysis must be performed in accordance with approved standard methods. Data measurements should be recorded in a controlled environment in which a QC program can be maintained.

B5.2 Laboratory Quality Control

The IEPA laboratory is responsible for implementing its QA/QC Manual which is an internal QA plan for laboratory procedures. The laboratory is responsible for the accuracy and reliability of analytical methods and final data reports according to their QA/QC Manual.

An investigation and CAR will be submitted to the Project Managers and the Project Director as QC issues arise. The IEPA laboratory is responsible for providing data qualifiers and/or case narratives to inform the Project Managers and the Project Director of any analytical exceptions that fall outside of routine method protocols. Each laboratory's QA/QC Manual will contain the procedures for QC and for calculating QC statistics.

B6 Instrument/Equipment Testing, Inspection, and Maintenance

All laboratory equipment shall be routinely maintained according to the manufacturer's manuals. Any equipment used for field data measurements shall be tested and inspected prior to sampling events and after the equipment returns from the field.

An adequate supply of spare parts shall be maintained by each laboratory for equipment maintenance. Spare parts shall be routinely inventoried.

The field probe used to gather on site information is a Hach Quanta Hydrolab®, and has an apparatus which requires constant moisture in between uses. The probe is stored downward facing in a container of water and then transferred to a protective casing during testing. The probe will be inspected before every testing day to check for loose o-rings, cracks, etc. Once a month a new Teflon membrane, DO electrolyte, and rubber o-ring will replace the used one on the DO sensor. Once a month pH electrolyte and salt tablets will be replaced in the pH sensor. Adequate supplies of spare parts for the testing equipment shall be kept on-hand at the JDSWCD office in Elizabeth, IL.

New Geotech 0.45 µm medium capacity disposable filter cartridges are used in the field for filtering test samples for dissolved phosphorus testing through a peristaltic pump.

B7 Instrument/Equipment Calibration and Frequency

Instruments used in the field and in the laboratory shall be calibrated prior to use according to the manufacturer's manual. The laboratory shall calibrate instruments according to internal QA plans. The laboratory is also to keep adequate records of equipment calibration and to use NIST traceable standards when possible.

Field probes shall be calibrated on the day of the sample event, and the calibration shall be confirmed upon return that same day. Calibrations will involve the use of reagent blanks, local barometric pressure, and pH buffers. A verification calibration will also be conducted after each testing. All calibration data will be recorded on the field equipment calibration log book.

B8 Inspection/Acceptance of Supplies and Consumables

Supplies and consumables used in the field shall be inspected by the field operations teams to guarantee their usability. Supplies and consumables used in laboratory procedures shall be inspected by laboratory managers to confirm compliance with laboratory Quality Management Plans (QMPs) and SOPs.

All reagents and devices used for testing with the water probe and accessories are all products of the Hach Quanta Hydrolab®.

Lab sample containers for this project originate from the IEPA. The Project Managers or Managers' designee will be responsible for inspecting sample containers before leaving for the field each time. The sample containers are inspected for cracks, ill-fitting lids, and other obvious defects before use and discarded if defects are present.

B9 Non-direct Measurements

The Project Managers will review water quality data from previous sampling and monitoring projects and may use this data for comparative purposes.

B10 Data Management

Field books, field measurement records, and other data gathered in the field shall be maintained for five years in project files by the Project Managers and the Project Director. All documents are kept in locked file cabinets at the JDSWCD office in Elizabeth, IL.

The Project Manager and intern will convey all laboratory analytical data using their standard laboratory report format to the Project Director and IEPA. All data communicated to the IEPA shall be verified by the Project Manager for reliability and usability.

Digital copies of the data shall be compiled into a spreadsheet using Microsoft Office Excel 2010. This file is held on a secure United States Department of Agriculture (USDA) server at the JDSWCD office in Elizabeth, IL.

SECTION C. ASSESSMENT AND OVERSIGHT

C1 Assessments and Response Actions

The sampling team will be evaluated by the Project Director to determine if sampling protocol is followed. QC issues related to field activities will require an investigation and corrective action plan submitted to the Project Manager and/ or Project Director.

Laboratories involved in data analysis shall maintain internal QA programs described in their QMPs. Laboratories shall maintain QC checks for procedures. When the possibility of QC problems arise that may affect the usability of data, an investigation and CAR will be submitted by the Project Manager and reviewed by the Project Director

Performance evaluations of the sampling teams will be conducted by the sampling team but led by the Project Manager. This assessment is made through the internal audit (as follows). Quality control and noncompliance issues related to field activities will require an investigation and corrective action plan submitted to the Project Manager and the Project Director.

Also, the Project Managers shall make certain that the project data associated with any quality control or other nonconformance issue is made available to data users with the appropriate data qualification. When data previously released to data users may have been affected by a quality control problem or other nonconformance issue, the Project Managers shall notify other data users of the problem. Quality control problems will be addressed through internal audit procedures. The internal audit will take place at the mid-point of the sampling season (approximately August, though month may change based on field conditions). The project manager and project director will review the QAPP and SOP to be sure that all requirements are being met. All data sheets and record keeping will be reviewed for completeness and correlation to the procedures outlined in this QAPP.

C2 Reports to Management

The Project Managers will receive investigation and CARs in case of any QC issue and will forward these reports to the Project Director. Reports shall be prepared by the Project Director documenting the QC issue, the corrective action taken, and the outcome of the corrective action and how it impacts the data.

Any QA problems affecting the final reported values shall be reported to the Project Managers and any other data users.

Data summary reports will be issued to the ACLPOA Conservation Committee as data becomes available from the IEPA lab. Final reporting will incorporated into the watershed management plan for ACLPOA and the Hells Branch watershed. This watershed management plan will be reviewed by IEPA BOW, ACLPOA management.

SECTION D. DATA VALIDATION AND USABILITY

D1 Data Review, Verification, and Validation

The Project Managers and the Project Director will review final analytical reports and address any issue related to data reliability as mentioned in pertinent investigation and correction action plans. Qualified laboratory results will be listed as such in any reports or data submitted to the Project Managers. It will be the responsibility of the Project Managers to determine the usability of any qualified data.

D2 Verification and Validation Methods

Sample collection and field measurement records shall be verified by field technicians and the records kept by the Project Managers. Laboratory data shall be verified by the Project Managers. Field and laboratory records shall be archived by the Project Managers.

In the case of data verification resulting in a change to data, the Project Managers shall document any corrections.

The Project Managers shall be informed if data accuracy, reliability, or usability has been reduced as the result of errors in stored data or corrupted data files. The Project Managers shall make any necessary corrections to the data and document the reasons the corrections were made.

D3 Reconciliation with User Requirements

The Project Managers shall review data and its usability and determine if it meets the requirements of the study objectives as stated in Section A5, Problem Definition and Background.

The execution of the study shall follow the procedures outlined in this QAPP. Personnel listed in Section A4, Project/Task Organization are responsible for implementation of the QC measures during each stage of the project.

The QAPP shall be reviewed annually, as needed, by all persons listed on the approval page. The review shall determine issues to be addressed as the project progresses. Issues to be discussed may include:

1. The number and location of sampling stations.
2. The frequency of sampling.
3. Sampling procedures.
4. Parameters measured.
5. Data quality objectives and minimum measurement criteria.
6. Analytical procedures.
7. Project reporting.
8. Corrective actions taken.

The study shall be modified only as directed by the Project Managers. Changes in procedures shall not be made without the approval of the Project Managers. All changes shall be documented in a memorandum that will be distributed to those listed on the Approval Sheet.

The Project Manager shall update the QAPP, as needed, after review and keep a separate record of changes.

FIGURES

Figure 1 – Study Organizational Chart

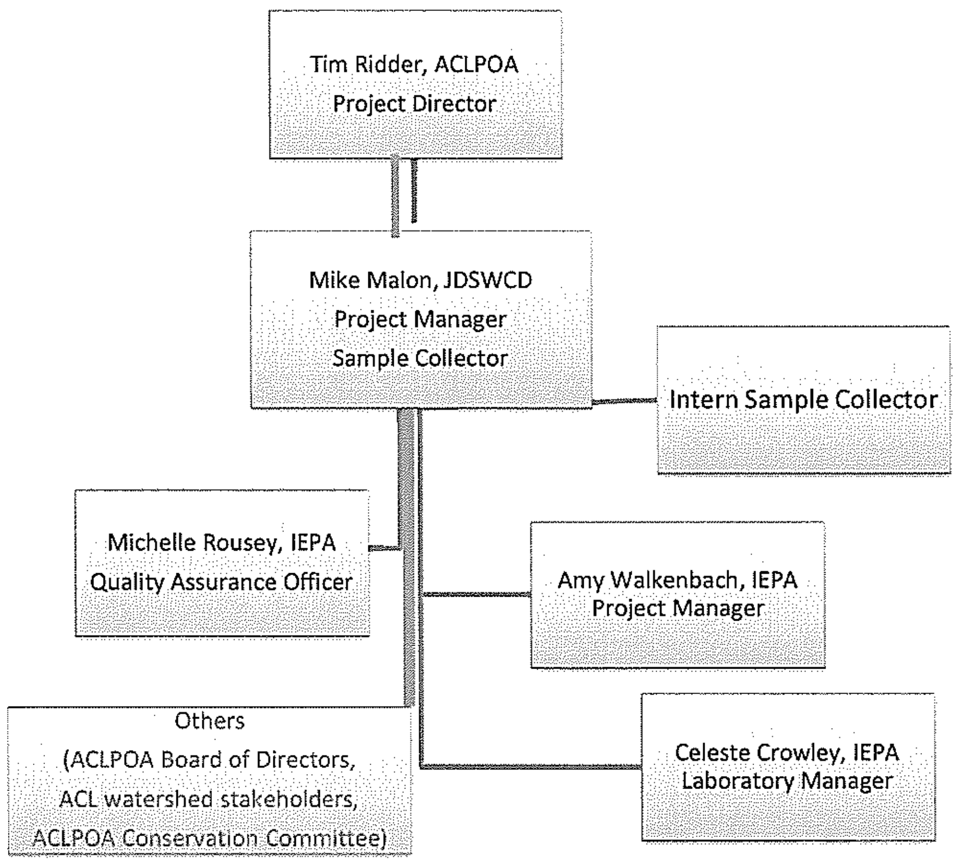
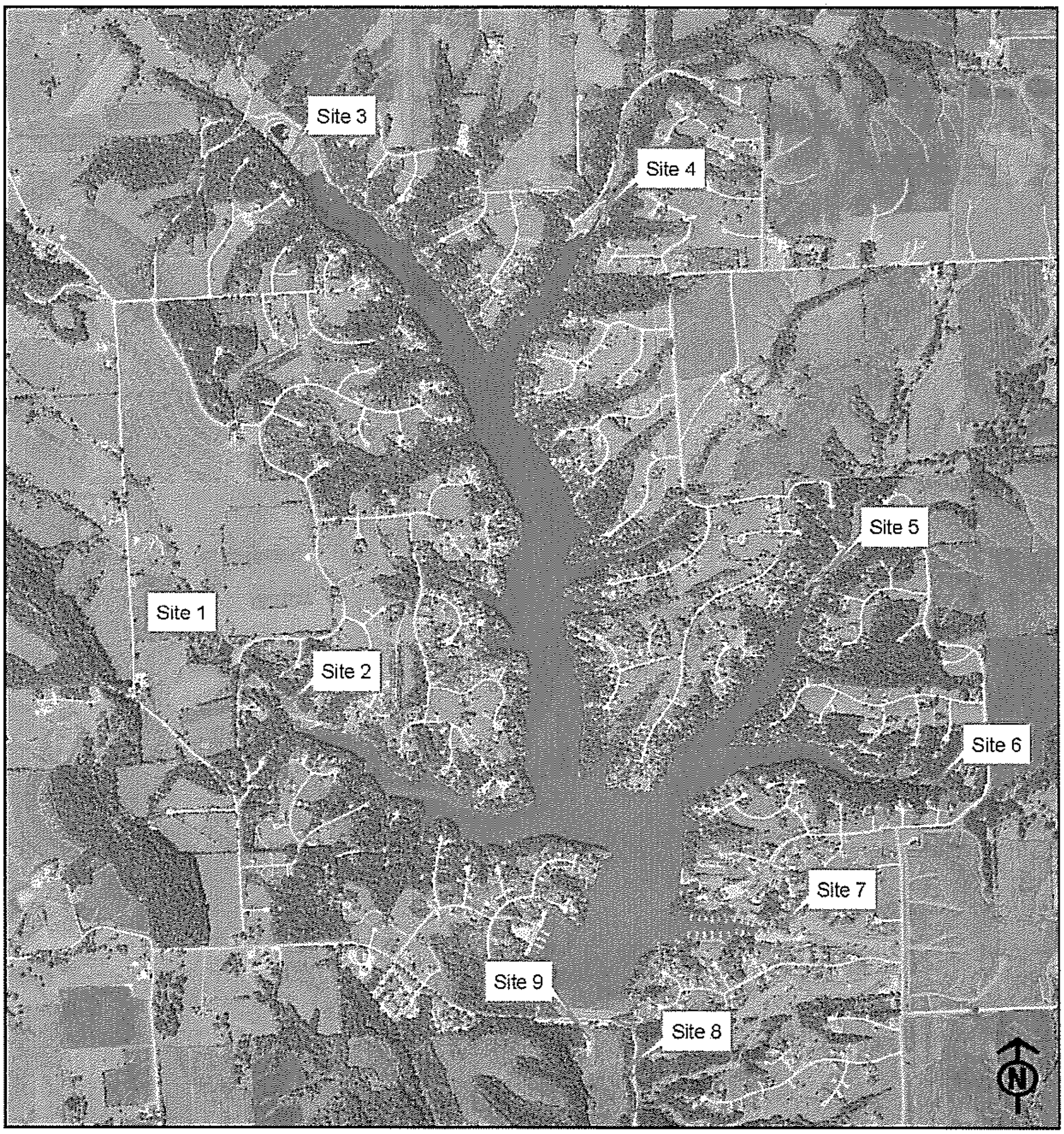


Figure 2 – Site Map



TABLES

Table 1 – Study Contact Information

Name	Title (Project)	Organization	Phone #
Tim Ridder	Project Director	ACLPOA	815-492-2238
Mike Malon	Project Manager, Sample Collector	JDSWCD	815-858-3418
Michelle Rousey	Quality Assurance Officer	IEPA	217-785-3944
Amy Walkenbach	IEPA Project Manager	IEPA	217-782-3362
Celeste Crowley	Laboratory Manager	IEPA	217-557-0274

Table 2 – Site Descriptions

Site	Description
1	Wet detention pond, downstream from cattle grazing fields. West of Site 2 and Presidents' Bay
2	Koester's Creek. Tributary creek to Presidents' Bay, downstream from Site 1
3	Hell's Branch Creek. Primary tributary creek to ACL, feeding into North Bay
4	Tributary creek to Lake, feeding into Winchester Bay
5	Tributary creek to Lake, feeding into Independence Bay
6	Tributary creek to Lake, feeding into Hawthorne Bay
7	Wet detention pond, downstream from golf course (inside ACL watershed). Upstream from Marina Bay
8	Creek flowing outside ACL watershed downstream from golf course
9	Hell's Branch Creek, downstream from ACL spillway

Table 3 – Sampling Schedule

Site	Monthy (March - October)	Time
1	1st Workday of month	8:00 am
2	1st Workday of month	8:30 am
3	1st Workday of month	9:00 am
4	1st Workday of month	9:30 am
5	1st Workday of month	10:00 am
6	1st Workday of month	10:30 am
7	1st Workday of month	11:00 am
8	1st Workday of month	11:30 am
9	1st Workday of month	12:00 pm

Storm Event Samples	
Site Number (by priority)	Storm Event
3	≥1" rain event, sampled at peak discharge
4	≥1" rain event, sampled at peak discharge
2	≥1" rain event, sampled at peak discharge

Table 4 – Sample Container, Parameters, Field Preservation, and Holding Times

Sample Container	Parameter	Method	Preservative	Holding Time
250 to 500-ml HDPE	Total Phosphorus	EPA 365.1	H_2SO_4, pH<2, Cool, ≤6°C	28 days
250 to 500-mL HDPE	Dissolved Phosphorus	EPA 365.1	H_2SO_4, pH<2, Cool, ≤6°C	28 days
250 to 500-mL HDPE	Nitrate/Nitrite	EPA 353.2	H_2SO_4, pH<2, Cool, ≤6°C	28 days
250 to 500-mL HDPE	Total Kjeldahl Nitrogen	EPA 351.2	H_2SO_4, pH<2, Cool, ≤6°C	28 days
250 to 500-mL HDPE	Ammonia	EPA 350.3	H_2SO_4, pH<2, Cool, ≤6°C	28 days
250 to 500-mL HDPE	Total Suspended Solids	Standard methods 2540 D-1997	Cool, ≤6°C	7 Days
In-Field	Dissolved Oxygen	Standard methods 4500-O G-2001	N/A	N/A
In-Field	pH	EPA 150.2	N/A	N/A
In-Field	Temperature	Standard methods 2550 B-2000	N/A	N/A
In-Field	Specific Conductivity	EPA 120.1	N/A	N/A

Table 5 – Minimum Measurement Criteria and Objectives

Parameter	Minimum Measurement Criteria	Minimum Measurement Objectives	Method* MDL[1]	Reporting Limit	MS/MSD* Accuracy (% recovery)	MS/MSD* Precision[P] (RPD)	LCS* Accuracy (% recovery)	Completeness
Total Phosphorus	No Standard	NA	0.0034 mg/L	0.005 mg/L	90-110	20%	90-110	90%
Dissolved Phosphorus	No Standard	NA	0.0034 mg/L	0.005 mg/L	90-110	20%	90-110	90%
Nitrate/Nitrite	No Standard	NA	0.031 mg/L	0.1 mg/L	90-110	20%	90-110	90%
Total Kjeldahl Nitrogen	No Standard	NA	0.16 mg/L	0.5 mg/L	90-110	28.5%	90-110	90%
Ammonia	15 mg/L	3.0 mg/L	0.058 mg/L	0.1 mg/L	90-110	20%	90-110	90%
Total Suspended Solids	No Standard	NA	NA	4 mg/L	NA	34.5%	NA	90%
Dissolved Oxygen	(March-July) ≥5.0 mg/L or ≥6.0 ave. over 7 days (August-February) ≥3.5 mg/L or ≥4.0 ave. over 7 days or 5.5 mg/L ave. over 30 days	±0.2 mg/L ≤20 mg/L ±0.6 mg/L >20 mg/L	NA	NA	In Field	In Field	In Field	In Field
pH	≥6.5, ≤9	±0.2 pH units	NA	NA	In Field	In Field	In Field	In Field
Temperature	≤2.8°C above natural temperatures	±0.2°C	NA	NA	In Field	In Field	In Field	In Field
Specific Conductance	No Standard	±(0.5% if reading + 0.001 mS/cm)	NA	NA	In Field	In Field	In Field	In Field

NA = Not applicable
* Limits are current and subject to change
[P] = Precision is based on sample/sample duplicate when accuracy (MS/MSD) is not available.
[1] = Method Detection Limit (MDL) from the IEPA laboratory

REFERENCES

Illinois Environmental Protection Agency – Bureau of Water. (2012). Illinois Integrated Water Quality Report and Section 303(d) List, 2012. Volume I: Surface Waters. *Clean Water Act Sections 303(d), 305(b) and 314.* IEPA.

Joint Committee on Administrative Rules. (2012). State of Illinois Water Quality Standards for General Use Waters. Sections 302: 204, 205, 206, 209, and 212. Illinois General Assembly.

United States Environmental Protection Agency. (2012). Code of Federal Regulations. 40 CFR Parts 136, 260, et al. *Federal Register.* Federal Archives and Records Administration.

United States Environmental Protection Agency. (May 2001). EPA Requirements for Quality Assurance Project Plans (QA/R-5). (EPA/240/B-01/003). Washington, D.C.

APPENDICES

JO DAVIESS COUNTY SOIL AND WATER CONSERVATION DISTRICT

Standard Operating Procedure for Stream Water Quality Sample Monitoring

At Apple Canyon Lake

227 N. Main Street, P.O. Box 502, Elizabeth, IL 61028

5/1/2014

Contents

1.0 Scope and Application

This Standard Operating Procedure (SOP) provides guidelines for the collection, preservation, and handling of water samples collected by Sample Collectors from tributary streams at Apple Canyon Lake. Water samples are analyzed for inorganic constituents and field observations recorded at the time samples are collected. These chemical results and physical findings may be used to support recommendations made in the comprehensive watershed plan for Apple Canyon Lake Property Owners Association and the Apple Canyon Lake watershed (HUC 070600050601). Equipment calibration, maintenance, and necessary commodities (bottles, filters, etc.) needed for collections are described. This SOP also includes description of standard Quality Assurance (QA) and Quality Control (QC) practices used by field staff when collecting water samples.

2.0 Summary of Method

2.1 Water quality samples must accurately represent the chemical composition of the stream at the time the sample is collected. To this end, a systematic method for collection of water samples and quality assurance measures are in place for sample collectors to ensure collection of representative samples. Depending on stream depth and flow conditions, samples may be collected by wading or collected from a bridge. Sample collections must be consistent at each site at each sampling interval.

2.1.1 Due to unique preservation or the potential for cross-contamination, some samples for specific parameters are collected using a direct grab method.

2.2 QA/QC procedures are in-place to assure samples are representative of the stream sampled and not affected by outside contamination. Sample bottles for each parameter are provided by the IEPA and issued for field use. Field meters are calibrated daily as per manufacturers' specifications and the results of the calibration are recorded in a bound log book.

2.3 In-stream measurements of Dissolved Oxygen, pH, Specific Conductance and Temperature are determined using a multi parameter meter (Hach Quanta Hydrolab) and recorded at the time of sample collection. Additional observations of conditions that may affect the water sample are recorded.

3.0 Interferences and Corrective Action

3.1 Dirt, oils and other foreign substances on equipment used to collect a water sample can cause contamination to the sample and bias the laboratory result. Sample collection bottles and peristaltic pump tubing and any other equipment that comes into contact with the sample at the time of collection and subsequent processing are cleaned and rinsed with ambient stream water prior to sample collection.

3.2 Field meters used to assess the physio/chemical condition of the stream need routine calibration. All field meters are calibrated per program requirements prior to use, following manufacturers guidelines and using certified standards and buffers.

3.3 Established sample locations may at times be affected by local disruption that block the technician's access to the stream, and/or cause an unusual condition in the stream. Typically this is a result of road and bridge construction that force the closing of roads and also may result in unusual in-stream conditions (e.g., an unrepresentatively high level of sediment due to in-stream construction). If the stream is impacted, attempt to relocate the collection location upstream. Note any change of sample collection location. If a sample cannot be collected a short distance upstream, the conditions should be noted and the sample collection postponed.

4.0 Safety

Collection of a water sample requires staff to be exposed to the elements and in, on or over bodies of water for each sampling event. Safety in these situations requires an awareness of your surroundings. Consult the currently approved Bureau of Water Field Safety Manual for general safety guidelines and precautions applicable to stream water samples.

4.1 Collecting a stream water sample often requires wading into or being on the water. Prior to wading to collect a sample, determine the safety of entering the stream. Be aware that stream depth, velocity and substrate all influence the ability to safely wade a stream. Collecting a sample by boat requires following all guidelines of safe boating.

4.2 Field personnel routinely come into direct contact with waterborne pathogens. Wash hands with soap and water and/or an appropriate hand sanitizer routinely after handling samples. Verify that immunizations are current.

4.3 Acid or base compounds are used as preservatives in some sample bottles. Acid is used as a decontamination rinse for sampling equipment. Both compounds will cause burns to skin and clothing. Wear safety glasses and an apron when handling. Flush skin with copious amounts of water if contacted.

5.0 Instrument Calibration

Calibrate instruments used to determine in-situ water parameter values as scheduled in the Quality Assurance Project Plan (QAPP).

5.1 Multi-parameter meters are used to determine spot in-situ values for water temperature, pH, specific conductance, and dissolved oxygen. These meters consist of a hand-held surface unit (read-out), cable and sonde unit which house the sensors. These are intricate but generally durable field instruments and require routine calibration. This SOP and the QAPP require daily calibration prior to using these meters. Refer to the manufacturer's Operating Manual for calibration, operation and trouble-shooting measures.

6.0 Cleaning of Sampling Equipment

Clean all equipment that comes into contact with sample water in order to avoid cross-contamination from previous samples. Conduct a thorough cleaning prior to QA/QC sampling (see section 7.0). Where applicable, scrub equipment with a nylon bristle brush, non-phosphate detergent, and rinse with 5% hydrochloric acid (HCl) and de-ionized water (DIW). Rinse all equipment and commodities with a volume of ambient water prior to use.

Note: Use caution when handling hydrochloric acid (HCl). HCl can cause severe burns to skin and clothing. Flush with copious amounts of fresh water if contacted.

6.1 Clean the interior of the churn splitter by using a small amount of non-phosphate detergent, a nylon bristle brush and rinsing with DIW. Use a small volume (~ 150mL) of 5% HCl to rinse the churn splitter and discharge the HCl through the spigot. Triple rinse the churn using DIW, discharging the water through the spigot of the churn. Rinse the churn (discharge a volume through the spigot) with ambient water immediately prior to use.

6.2 Run a volume (~100mL) of non-phosphate detergent and water solution through the silicone tubing in the peristaltic pump used to filter for dissolved constituents. Rinse the tubing with DIW and then with a volume (~100mL) of HCl. Rinse with a volume (~250mL) of DIW. Place the tubing ends in a clean plastic bag for storage.

6.3 Rinse the pump tubing with DIW after use at each station.

7.0 Equipment and Supplies

The following list of equipment and supplies needed to complete a routine sample collection. Use of the equipment and supplies is described in separate sections in this SOP.

Appropriate SOP document
Appropriate Request for Laboratory Analysis sheets
Field Parameter Forms
Clipboard
Waterproof black pen
Waterproof marker
Waterproof paper
Weighted Bottle Sampler (WBS) with rope
Appropriate sample collection containers
Appropriate sample collection bottles for laboratory submission
Sample Meter (Hach Quanta Hydrolab)
Sample Meter calibration/maintenance kit
Appropriate pH Buffers (7.00 and 4.00 or 10.00)
Appropriate Specific Conductance Standards: high (± 1400 S/cm) and mid (±700 S/cm)
Multi-parameter Meter Calibration Log with Temperature and D.O.Chart
Peristaltic Pump & Dissolved Parameter In-Line Filters
Cooler(s) with ice
De-ionized water (DIW)
5% HCl solution
Alcohol Thermometer
Non-phosphate detergent
Kim-wipes and paper towels
Zip-lock plastic bags
Tap water and hand soap
90% isopropyl alcohol
Long rubber gloves
Chest waders
Rain Gear
First Aid kit, change of clothing, and flashlight
Life jacket
Station description book
Watch

8.0 Unique Sampling Equipment Description

8.1 A Weighted Bottle Sampler (WBS) is a metal framed sampling device that is attached to a rope hand-line to allow sample collection from a bridge or boat. An adjustable lock-ring encircles the mouth a narrow-mouth bottle and holds the bottle upright while collecting water sample. Narrow mouth plastic, glass, or sterile plastic bottles are used as appropriate for the sample volume and constituent being analyzed. The bare metal surface of the WBS should be painted with epoxy paint to reduce potential metal contamination to the sample.

8.2 The churn splitter is a bucket like container used to produce a composite sample and keep particles in suspension while distributing sub-sample volumes into appropriate containers. The composited samples are taken from the churn splitter for analysis of all total and dissolved and suspended inorganic constituents, including metals. By moving a rod protruding from the removable top attached to and internal disk up and down (hence the term "churn"), the volume of sample water in the bucket is well mixed (homogenized) and particulates remain suspended. The well mixed sample is drawn into the appropriate individual sample parameter bottles through a spigot near the bottom of the churn. Use a slow steady pace while churning.

8.3 A peristaltic pump complete with Teflon tubing is used to draw a volume of sample water. Generally, the pump is used to pass sample from the churn splitter through a 45μm filter to obtain a sample to be analyzed for dissolved parameters. The filters are single use, disposable capsules that are attached to the outlet end of the Teflon hose for direct filling of the sample bottle.

9.0 Water Quality Sample Collection

It is essential for all water quality samples to represent the condition of the stream at the time a sample is collected. Generally, samples are collected while wading the stream using a hand held bottle (HHB) or from a bridge using a weighted bottle sampler (WBS) suspended by a rope. Also, programmatic or environmental conditions may require using unique sampling procedures such as a grab sample.

9.1 Hand Held Bottle: If stream depth and flow conditions allow, collect a representative sample by wading the stream along a transect perpendicular to stream flow by immersing a hand-held bottle at multiple evenly-spaced verticals. Multiple dips of the bottle at each interval may be necessary to collect a suitable amount of sample. Each individual sub-sample volume is composited in a churn splitter. Use one clean bottle for the entire cross section at each site.

- Prior to sampling, choose a cross section (transect) of stream that can be waded safely. Be aware that stream depth, velocity and substrate all influence the ability to safely wade a steam.

- Determine the number of sample verticals to collect water sub-samples at along the transect. Generally, locate the sample transect in the stream that provides a well-mixed sample both across the stream width as well as within the water column. The number of sample verticals is dependent on the stream width. Collect a sample using one (1) vertical at the center of flow for streams less than 10' wide. Three (3) verticals should be sampled on streams ranging in width from 10-30'. Collect samples at five (5) verticals on streams over 30' wide. Additional vertical sub-samples may be collected at the samplers discretion. The total number of verticals and dips per vertical is based on the amount of sample volume needed. In narrow or very shallow streams each vertical will require multiple dips to get a sufficient amount of water.
- Prior to commencing the sample collection, determine the transit rate for the bottle to be used to collect each sub-sample at each vertical. At the center of flow; face upstream, hold the bottle so as not to obstruct the opening and with the bottle out in front (upstream) of sampling technicians body, submerge the sample bottle to the stream bed and without hesitating at the stream bed raise it to the surface prior to the bottle completely filling. Note this equal transit rate (ETR) and use it for each subsample collection at each sample interval. Use this test-rate sample as a rinse for the sample bottle and churn splitter.
- Use care in ensuring that the mouth of the bottle does not come into contact with the stream bed and/or the bed is not disturbed immediately upstream of the sample bottle.
- Sample all verticals at each station the same number of times. At each vertical, lower the bottle from water surface to bottom and up again at a constant ETR and composite into the churn splitter.
- Tip the churn splitter slightly and slowly pour the sub-sample on the wall of the churn to avoid artificially aerating the sample.
- Return to the center of flow to deploy the multi-parameter meter and collect single point grab samples.

9.2 Weighted Bottle Sampler: If the stream is non-wadable (due to depth, unsafe velocity, inability to access stream, etc.) collect a sample from a bridge using a weighted bottle sampler (WBS). The stream is sampled at equal width intervals from the bridge by lowering and raising the WBS at each transect interval. Multiple dips of the bottle may be necessary to collect a suitable amount of sample. Composite each individual sub-sample volume into the churn splitter. Use a clean collection bottle for the entire cross section at each site.

- Generally, the sample is collected from the up-stream side of the bridge unless safety or other issues require the sample to be collected from the down-stream side of the bridge.
- Determine the number of sample verticals to collect water sub-samples at along the transect. Generally, locate the sample transect in the stream that provides a well-mixed sample both across the stream width as well as within the water column. The number of sample verticals is dependent on the stream width. Collect a sample using one (1)

vertical at the center of flow for streams less than 10' wide. Three (3) verticals should be sampled on streams ranging in width from 10-30'. Collect samples at five (5) verticals on streams over 30' wide. Additional vertical sub-samples may be collected at the samplers discretion. The total number of verticals and dips per vertical is based on the amount of sample volume needed. In narrow or very shallow streams each vertical will require multiple dips to get a sufficient amount of water.

- Use care to ensure that if fine material is re-suspended when the WBS comes in contact with the stream bed they are not collected as part of the sub-sample. If this is the case when sampling, discard the collected sample and resample at that vertical.

- Collect an equal number of dips at each vertical. At each vertical, lower bottle from water surface to bottom and up again at a constant ETR and composite into the churn splitter.
- Maximum sampling depth is dependent upon the capacity of the bottle and the rate of filling. In the event the depth at a site is such that a suitable equal transit rate (ETR) cannot be established the opening of the bottle should be reduced with the appropriate bottle lid with a hole drilled in it. Keep a supply of lids with various sizes of holes in the vehicle.
- Tip the churn splitter slightly and slowly pour the sub-sample on the wall of the churn to avoid artificially aerating the sample.
- Return to the center of flow to deploy the multi-parameter meter and collect single point grab samples.

9.3 Grab Sample: A single point sample (or grab) is collected when specific parameter requirements, field conditions or program guidelines dictate. A grab sample is collected by submerging a sample bottle to one (1) foot below the water surface (if stream depth allows) at the center of flow in the stream. Use a hand held bottle when wading the stream and a rope suspended WBS when collecting a sample from a bridge. Multiple dips of the bottle may be necessary to collect a suitable amount of sample. If appropriate for the sample parameter(s), composite each sub-sample volume into the churn splitter. For those parameters need to be sample discretely, sample and pour off directly to the lab sample bottle or sample directly using the lab sample bottle. Use a clean collection bottle at each site.

- Prior to sampling by wading, choose a cross section (transect) of stream that can be traversed safely. Be aware that stream depth, velocity and substrate all influence the ability to safely wade a stream.
- If sampling from a bridge using a WBS, the sample is generally collected from the up-stream side of the bridge unless safety or other issues require the sample to be collected from the downstream side of the bridge.

- At the center of flow, submerge the sample bottle to a depth of approximately one (1) foot and raise it out of the water prior to the bottle completely filling. Use this sample as a rinse for the sample bottle and churn splitter.
- At the center of flow, submerge the sample bottle to a depth of approximately one (1) foot and raise it out of the water prior to the bottle completely filling. Repeat the grab sample (multiple dips) to get a sufficient amount of water.
- Tip the churn splitter slightly and slowly pour the sub-sample on the wall of the churn to avoid artificially aerating the sample.
- Return to the center of flow to deploy the multi-parameter meter and collect single point grab samples.

10.0 Sample Processing

Sample bottles to be delivered to the laboratory for specific constituent analysis are filled from the water in the churn splitter upon returning to the sampling vehicle. Bottles needed for specific parameters are listed below in Table 1. Programmatic requirements dictate the bottles needed for each station; however sample preparation process remains consistent.

10.1 Using waterproof marker, clearly mark each sample bottle for analysis with an appropriate identifying code unique to the station. Complete all field data sheets associated with the station.

10.2 To fill the "total" constituent bottles: Start the churning process and while churning, open the spigot to flush the spout with approximately 20mL of sample and while continuing to churn and dispense sample, move an empty sample bottle into the sample stream and fill the bottle to the shoulder. Securely cap the bottle and place in a cooler with ice. Repeat for each of the sample bottles needed for "total" analysis. Avoid breaking the surface of the sample water in the bucket when raising the paddle so the sample is not artificially aerated. Sample should not be removed for total constituents when the level falls below the churn spigot level. However, sample remaining in the churn (below the spigot level) may be used for filter subsamples. Churn splitters are made of polyethylene and therefore, are not used in compositing samples for analyses of organic substances.

10.3 To fill the "dissolved" constituent bottles: A peristaltic pump is used to pass sample water through a filter. See Section 9.3 for general information and Section 6.2 for the procedure to clean the pump tubing. Ensure that the peristaltic pump tubing is clean and place a clean cartridge filter into the outlet end of the peristaltic pump tubing. Place the inlet end of the tubing into a clean receptacle with approximately 100mL of DIW and pass through the filter to rinse any residue from the filter. Place the intake end of the tubing into the churn splitter and allow approximately 100mL of filtered sample to pass. Place an empty sample bottle into the sample stream and fill the bottle to the shoulder. Securely cap the bottle and place in a cooler with ice. Repeat for each of the sample bottles needed for "dissolved" analysis.

11.0 Sample Handling

11.1 Samples are subject to degradation due to several factors after collection and during transport to the laboratory for analysis. In order to minimize this change, some of the sample bottles used for delivery to the lab contain preservatives to stabilize the sample in transport. The holding and transport time prior to analysis is also a critical factor in sample stability. Refer to Table 1 for preservation method and holding time requirements for specific samples.

11.2 All water samples must be cooled as soon as possible after collection to ≤ 6° C. Bring a sufficient number of coolers in the field to adequately hold the bottles scheduled for collection. Use a volume of ice equal to the volume of sample bottles in each cooler to reduce and/or hold the temperature at ≤ 6° C. Current air temperature dictates the amount of cooling necessary to hold the samples at the appropriate temperature. In extremely hot summer weather, drain melt water and re-fill each cooler with ice throughout the day as necessary. Conversely, if holding samples overnight in cold temperatures, the coolers may have to be moved indoors to protect the samples from freezing.

Table 1. Container, Preservation Technique and Holding Time Requirements for Water Samples Collected

IMPORTANT – HOLD ALL SAMPLES AT ≤ 6° C – IMPORTANT

Parameter	Container and Preservative	Holding Time
Total Suspended Solids (TSS)	500 mL HDPE, none	7 days
Phosphorus (total)	1000mL HDPE, H_2SO_4	28 days
Ammonia	1000mL HDPE, H_2SO_4	28 days
Nitrate/Nitrite	1000mL HDPE, H_2SO_4	28 days
Total Kjeldahl Nitrogen	1000mL HDPE, H_2SO_4	28 days
Phosphorus (dissolved)	250mL HDPE, H_2SO_4	28 days

12.0 Field Observations

In-situ measurement for determining water temperature, pH, specific conductance, and dissolved oxygen are obtained using a multi-parameter meter. These meters consist of a hand-held surface unit (read-out), cable, and sonde unit which houses the sensors. Air temperature is determined using an alcohol filled stick thermometer. Record field measurements and all other pertinent field observations on a field data sheet.

12.1 To measure in-situ parameters: affix the protective housing on the sonde around the sensors. Submerge the sonde to one foot depth in the center of stream flow, turn on the meter, start the stirrer (if so equipped) and allow the probes to equilibrate to the ambient stream conditions. When the readings stabilize, record the water temperature, specific conductance, pH and dissolved oxygen values on a field data sheet.

12.2 Hang the air temperature thermometer in the shade and out of the influence of any large heat source and allow it to equilibrate to ambient temperature. Record the air temperature value to nearest degree on the field data sheet.

12.3 In-situ water parameters, sampling method employed, location of sample collection and weather conditions all influence the water sample collected for analysis. The field data sheet provides a systematic outline for recording all the pertinent information for each sample collection. Ideally, each sample is collected as per the procedures outlined in this SOP; however, there are times when conditions mandate sampling outside of these guidelines. Properly document the sample collection method used and any variation from the prescribed method for each station sampled.

13.0 Field Trip Checklist

- ✓ Have all SOPs pertinent to the sample collection being conducted in the vehicle at the time of sampling.
- ✓ Review the equipment and supply list while preparing for a trip.
- ✓ Before departing on a field trip, check the operation, calibration and battery condition of field instruments to insure they are in good working condition.
- ✓ Sufficient sample collection bottles (allowing for a fresh bottle for each station) should be cleaned and available. Unless pre-rinsed or preserved, rinse these bottles thoroughly with ambient stream water before using to collect a sample.
- ✓ Start the day with sufficient coolers and ice to store and chill all samples to $\leq 6°C$.
- ✓ Complete the appropriate Request for Laboratory Analysis Sheets and record all field values, weather conditions and special notes on a field data sheet.
- ✓ Remove all field instruments from an unheated vehicle during very cold weather to prevent freezing. Protect all calibration buffers and standards, reference solutions, distilled water and rinse acid from freezing. Likewise, remove samples from the vehicle to prevent freezing.
- ✓ A documented improperly collected sample is better than no sample at all. If stream conditions are such that you are not able to follow the proper sampling procedure, you may modify methods in order to collect a sample. If it is necessary to deviate from the normal sampling procedure, document the sample collection method on all field data sheets.
- ✓ If a site cannot be sampled as scheduled or you encounter any other problems in the field, notify your supervisor.

FIELD DATA FORM

Station Code									
Collector									
Date (mm/dd/yyyy)									
Time (24:00)									
Trip ID									
Visit Number									
Air Temp °C									
Water Temp °C									
D.O. mg/L									
Conductivity									
pH									
Depth (ft.)									
Width (ft.)									
Velocity (ft.)									
Sampler Used									
No. of Verticals/Dips	V D	V D	V D	V D	V D	V D	V D	V D	V D
Precip in last 24 hours									
Weather									
Volume Filtered (mL)									
Comments									

11.6 Appendix 6. University of Wisconsin Platteville, Water Quality Analysis

Apple Canyon Lake

A Study of Lake Quality

University of Wisconsin Platteville

Project Team: Curtis Veit, Josh Koopmann,
Jessica Norman, Sarah Beam

Executive Summary

This report outlines the water quality analysis of Apple Canyon Lake, located in Jo Daviess County in Illinois. The analysis was conducted due to the annual algal blooms that were occurring in the lake. The project started with a data analysis of lake quality that had been gathered prior to the water quality assessment. Using the information gathered from the data analysis, a watershed analysis was conducted to determine where the different nutrients were coming from. The National Land Cover Database (NLCD) was analyzed for the watershed, including 13 tributary watersheds and the lake border watershed present in the system. HydroCAD, STEPL, and ABCD models were then used to determine the runoff characteristics from these watersheds contributing to the lake. The model's results indicate that the majority of nutrient loadings entering the lake likely come from agricultural land. The analyzed data suggests that subwatershed 1 from Tributary 1 (Hell's Branch) contributes the largest quantity of runoff and has the greatest area of cropland. This led to the hypothesis that subwatershed 1 adds the largest percentage of nutrient runoff into Apple Canyon Lake. Additionally, abnormally high temperatures have occurred beginning each year from 2009-2015. This temperature change may have led to earlier and more severe algal blooms than in previous decades. Case studies of lake reservoirs with similar characteristics were researched and included for comparison. Recommendations for how to continue this project, as well as, different stormwater treatment techniques to reduce the runoff nutrients that enter the lake are summarized.

Table of Contents

List of Figures

List of Tables

Section 1: Introduction

1.1 Background

Apple Canyon Lake is a privately owned 400 acre lake located in northern Illinois (Figure 1). This lake is denoted by a star in Figure 1. An aerial photo of the lake can be seen in Figure 2. The lake was filled in the 1970s and is contained by an earthen dam on the south end of the lake. There are 13 tributaries that feed into the lake and there are no spring-fed inputs. Apple Canyon Lake Homeowner's Association is composed of the houses surrounding the lake. The Association consists of 840 homes with 2460 lots and 360 year-round residents. All the homes are on septic systems. A golf course is located near the south end of the lake. A majority of the watershed is made up of agricultural land.

Figure 1. Map of Illinois; location of lake marked by the star

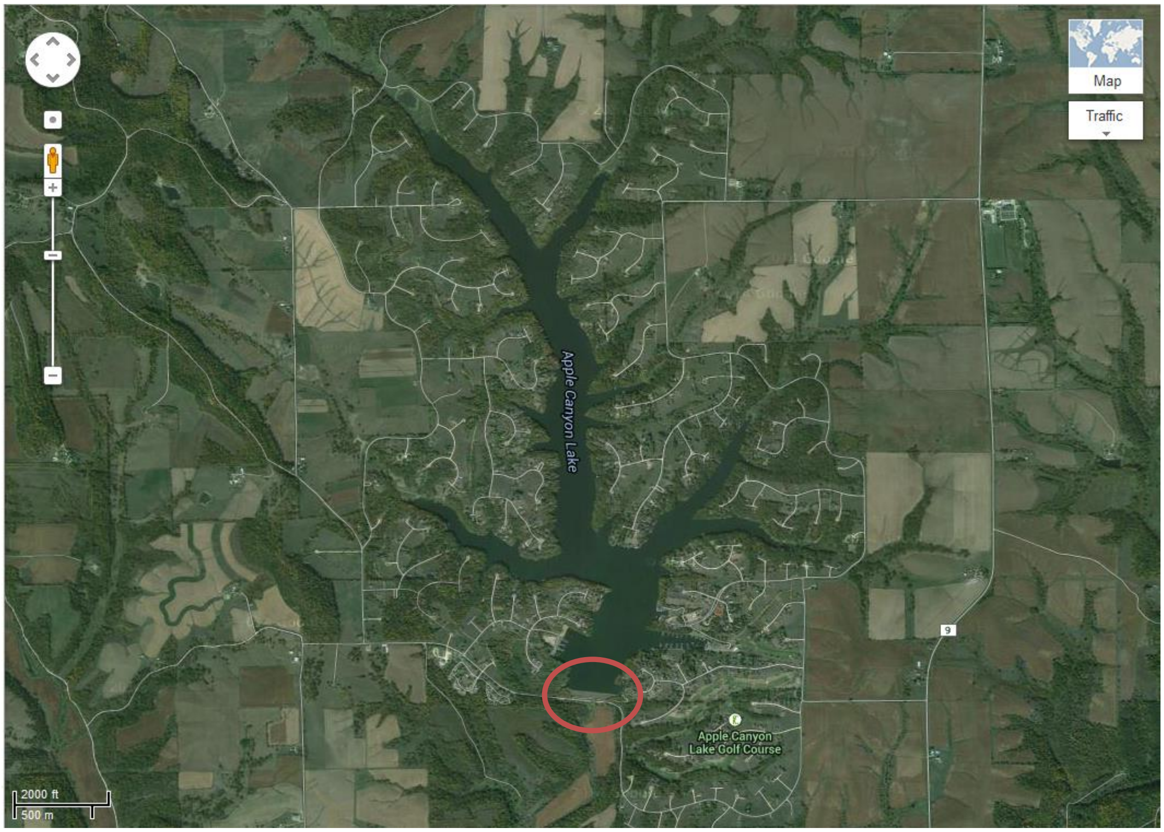


Figure 2. Aerial map of Apple Canyon Lake; earthen dam circled in red

1.2 Problem Statement

Apple Canyon Lake has been experiencing annual algal blooms for the last 15 plus years that have raised concerns among the residents about the water quality of the lake. HydroPioneering was contacted by the Homeowner's Association to conduct a hydrologic study of the lake to determine how water quality has changed over time and what activities are responsible. Currently, silt ponds and annual dredging are used to assist in sediment control, but an overall analysis of lake quality may lead to economically better nutrient control options.

1.3 Project Scope

To accurately and efficiently determine lake water quality, models were created and used for analysis. The models that were used include HydroCAD, STEPL, and the ABCD model to help identify the causes of the algal blooms in the lake. The computer program R was used to determine correlations with provided data and Microsoft Excel was used for further analysis. Team members were responsible for creating the models and providing appropriate results. Meetings were conducted throughout the project timeline with advisors and clients. These meetings were held to get feedback on the progress of the project and to get answers to questions that arose.

1.4 Project Objectives

Objectives of this project include:

- Complete a statistical analysis for Apple Canyon Lake based on water quality data collected over the past two decades,
- Learn and implement multiple modeling systems and the use of the program R for statistical correlations,
- Create and analyze ArcMap maps of the surrounding land topography,
- Research existing sediment and nutrient management through corresponding case studies,
- Analyze impact of surrounding farm fields on the lake water quality and quantity of pollutants.

1.5 Budget

The main expense for this project was transportation costs to travel to the site; two trips were taken. Another expense for the project was the cost in printing out a PACCE poster.

1.6 Deliverables

At different stages of the project, updates on the project were assessed through advisor meetings. At the mid-term meeting, an update on the statistical analysis of the lake was given. Upon completion of the project, a final report of the objectives and a project presentation will be given.

1.7 Challenges

Learning the models and the program R were major challenges that the project faced. The members of the project team had limited experience working with the programs but throughout the course of the project learned the necessary programs. Other challenges that arose were the ability to find accurate and useful data that showed significant statistical trends for the analysis of the watershed.

1.8 Constraints

One of the main constraints in executing the project was limited time and the learning curve associated with new programs. Determining the information that needed to be calculated and analyzed was important to present meaningful information for the lake quality. Another constraint that the project faced was the quantity and quality of data that needed to be analyzed. The accuracy of the water quality analysis on the lake was based on the data provided.

Section 2: Data Analysis

Section 2.1: Data and sources of information

To begin an analysis on Apple Canyon Lake, data was collected by volunteers of the lake and submitted to the Illinois EPA since 1999. This data included sample date, location, depth, and the following water quality parameters:

- Alkalinity
- Ammonia
- Chloride
- Chlorophyll A
- Chlorophyll B
- Chlorophyll C
- Inorganic nitrogen
- Kjeldahl nitrogen (KN)
- Pheophytin A
- Total dissolved solids (TDS)
- Total phosphorus (TP)
- Total suspended solids (TSS)
- Volatile suspended solids (VSS)

Additionally, land use data for this area was obtained from Mike Malon who works for the Jo Daviess County Soil and Water Conservation District. That data originated from a website through George Mason University that utilized National Agriculture Statistics Service (NASS) data and coincided with the same time frame as the lake monitoring period. Secchi depth measurements for the lake were obtained from the Illinois EPA website. The final data set that was examined was weather data obtained from the National Climatic Data Center (NCDC) which included precipitation (snow, total, monthly max) and temperature (monthly extremes, maximum, minimum, and average).

Section 2.2: Adjustments

To start analyzing the data sets, each needed to be organized in a way that they could be easily compared. An example of the how the data was organized was that the sampling times for the water quality parameters and secchi depth were averaged for a month and then assigned to be for the first day of that month. This allowed the water quality parameters and secchi depth to match up with the monthly weather data. Additionally, variables such as sample depth were filtered out to reduce the amount of differences when comparing to other variables.

Section 2.3: Trends

Once the data was adjusted into a common format, different parameters were compared to one another. The trends in time were first analyzed to determine how different water quality parameters changed over time. Initially, this analysis was performed with a program called R, which is a statistical program that relies on packages and scripts to create tables and graphs. This program was used because it can create organized graphs from a small amount of code. Once the code is written, examining other variables is trivial.

From the R analysis, Figures 3-5 were created to integrate how water quality parameter concentrations were distributed across the lake and how concentrations changed over time. From these figures, several visual trends were identified for further analysis. As seen in Figure 3, location RMJ-1 (near the dam) shows a clear spike in total phosphorus within the recent years. The concentrations of VSS mirror the concentrations of TSS. This suggests that mainly organic solids have been contributing to the total suspended solids within the lake. It can also be seen in Figure 4 that both ammonia and inorganic nitrogen have spiked within the recent years. Chlorophyll A was also noted to be increasing in recent years (Figure 5). After using R for the visual analysis, Microsoft Excel was then used to perform the rest of the statistical analysis because it was less complicated and more efficient to compare data sets.

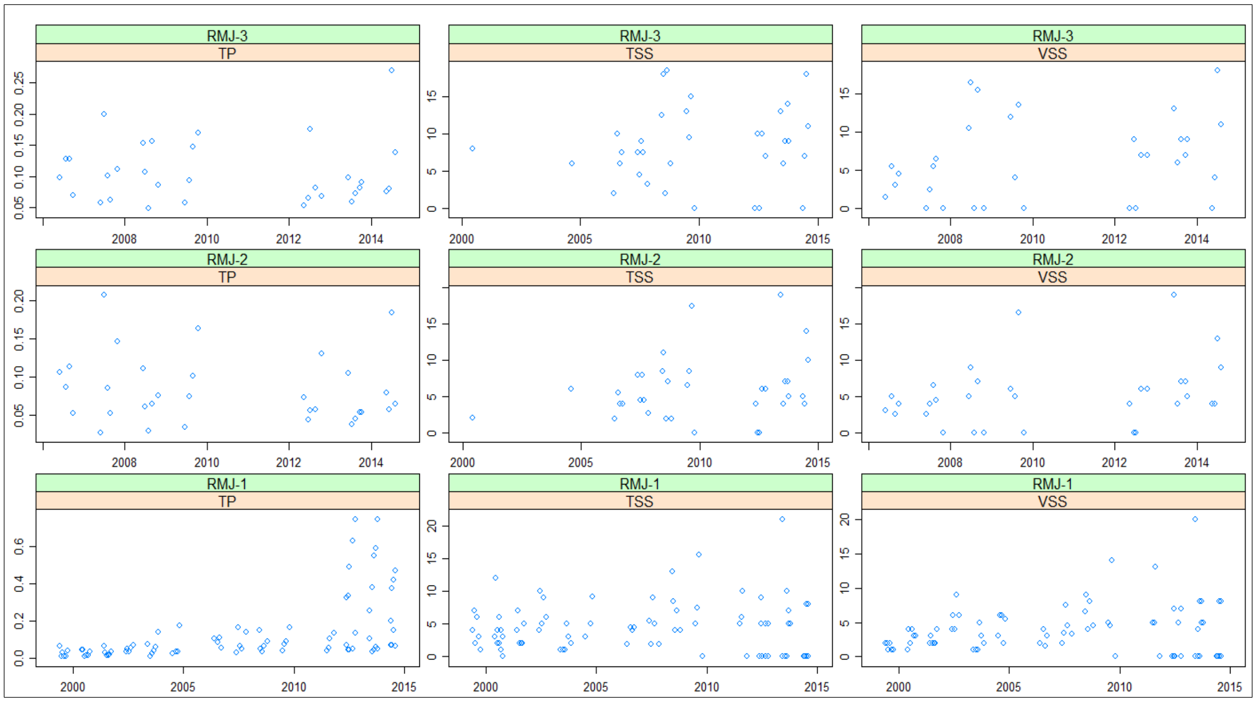


Figure 3. TP, TSS, and VSS concentrations at different sampling locations over time

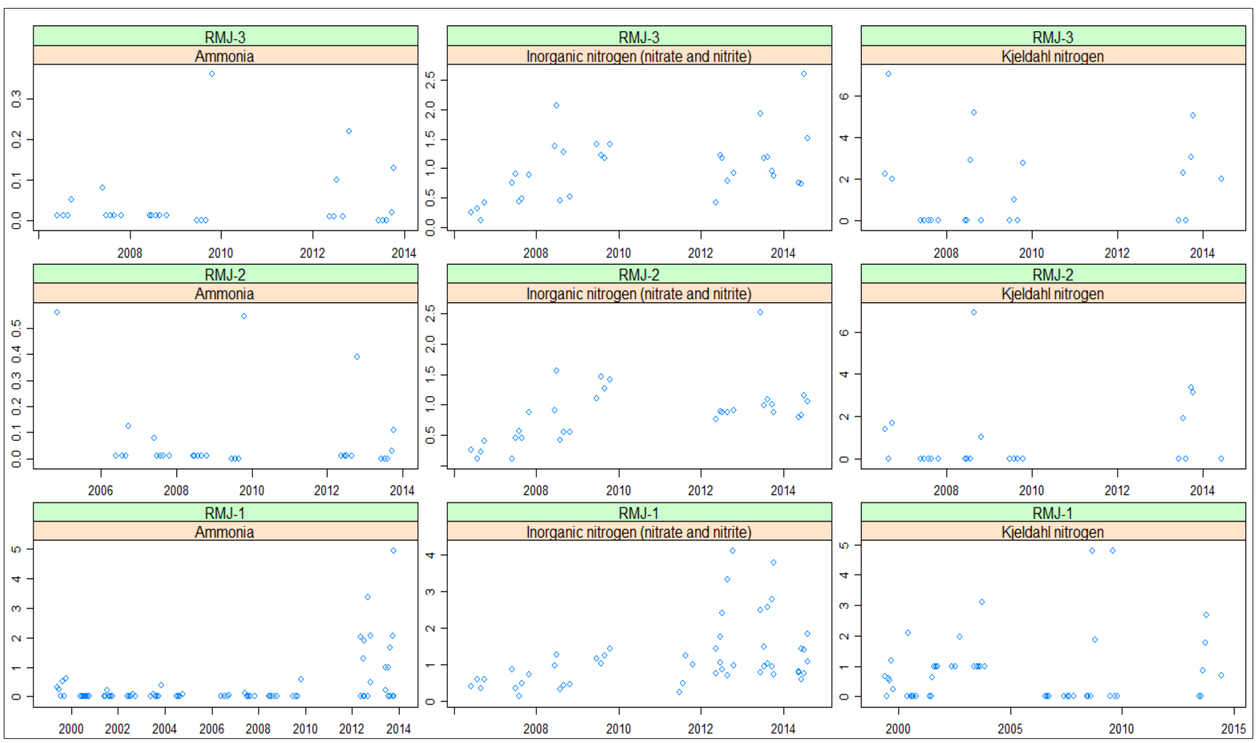


Figure 4. Ammonia, inorganic nitrogen, and Kjeldahl nitrogen, concentrations at different sampling locations over time

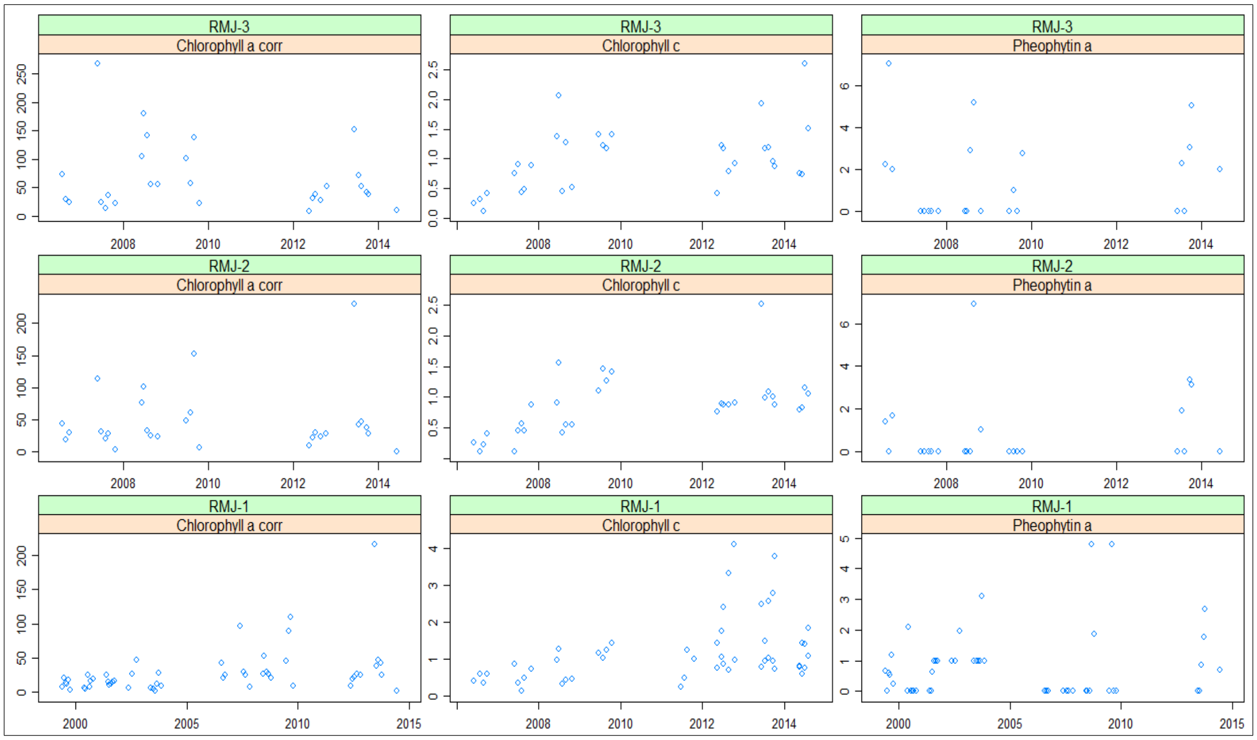


Figure 5. Chlorophyll A, chlorophyll C, and Pheophytin A concentrations at different sampling locations over time

In Excel, a correlation analysis was performed on all of the variables to see how they varied with each other. It was determined that if two variables varied with each other enough to produce a coefficient of determination (R^2) value greater than 0.25, then it was worth looking into. The R^2 value is a statistical measure of the closeness of fit of the data to a regression line; an R^2 value gives the analyzer a quantitative measure of how accurately the data exemplifies a pattern. The closer an R^2 value is to 1.0, the more the data fits a trend. In this watershed analysis where a single variable can be influenced by many other variables, an R^2 value of 0.25 was chosen to be most reasonable after discussion with advisors. Table 1 shows the R^2 results of the correlation matrix of how the individual variables related to each other. In the table, greater correlations are identified by how green their background is.

Table 1. Correlation Matrix (R^2) chart of all the data sets

	Date	Chlorophyll A	Kjeldahl nitrogen	Pheophytin A	Ammonia	Chlorophyll C	Inorganic nitrogen	TP	TSS	VSS
Date	1.000									
Chlorophyll A	0.180	1.000								
Kjeldahl nitrogen	0.455	0.073	1.000							
Pheophytin A	0.059	0.013	0.000	1.000						
Ammonia	0.230	0.000	0.412	0.056	1.000					
Chlorophyll C	0.186	0.465	0.013	0.076	0.018	1.000				
Inorganic nitrogen	0.074	0.000	0.012	0.075	0.012	0.015	1.000			
TP	0.632	0.042	0.451	0.081	0.431	0.030	0.025	1.000		
TSS	0.045	0.430	0.085	0.013	0.004	0.259	0.003	0.028	1.000	
VSS	0.126	0.399	0.167	0.025	0.000	0.281	0.015	0.083	0.771	1.000
Secchi depth	0.224	0.293	0.143	0.066	0.024	0.313	0.129	0.213	0.289	0.314
Extreme max daily precp.	0.003	0.003	0.002	0.005	0.058	0.000	0.089	0.041	0.046	0.018
Maximum snow depth	0.009	0.002	0.136	0.083	0.395	0.007	0.024	0.199	0.016	0.004
Total precip.	0.003	0.001	0.042	0.045	0.167	0.008	0.096	0.055	0.043	0.004
Total snowfall	0.006	0.676	0.193	0.145	0.372	0.761	0.001	0.130	0.121	0.032
Extreme max temp.	0.000	0.001	0.223	0.081	0.322	0.001	0.047	0.263	0.001	0.003
Extreme min temp.	0.000	0.000	0.188	0.037	0.364	0.018	0.049	0.281	0.017	0.000
Monthly mean max temp.	0.000	0.001	0.210	0.052	0.341	0.019	0.039	0.264	0.008	0.000
Monthly mean min temp.	0.000	0.000	0.221	0.057	0.386	0.016	0.049	0.285	0.011	0.000
Monthly mean temp.	0.000	0.001	0.217	0.054	0.366	0.018	0.044	0.276	0.010	0.000

After reviewing Table 1, several relationships were identified for further analysis. Some of the things that were used to determine if the correlation between the variables was useful were the amount of data points to establish a trend and if any of the trends were changing. One example of when a correlation was strong according to the table but not significant was when looking at Chlorophyll A and C with snowfall. In this example, there were very few data points to look at because when snowfall occurs (winter), sampling (summer) was usually not happening except for a few instances. One relationship that was fairly inconsistent was TSS over time, which indicates that different concentrations of sediment leave the land surface (Figure 6). Even though the trendline indicates that it is increasing, it is not changing enough to consider it a significant trend. One reason why the relationship may not fit a trend is because when planting occurs the soil is less compact and more susceptible to running off during a storm event. Likewise, a similar storm event over a compacted soil will not produce as much TSS.

The relationships that are presented to be important are the relationships that are greater than or equal to the 0.25 R^2 parameter. Other considerations are relationships with a large sample size, as well as, relationships that were determined to have a causal link. In comparison to TSS, total phosphorus and Kjeldahl nitrogen show increasing concentrations over time, signifying that the watershed, in terms of land use or practices, is changing over this time period (Figure 7).

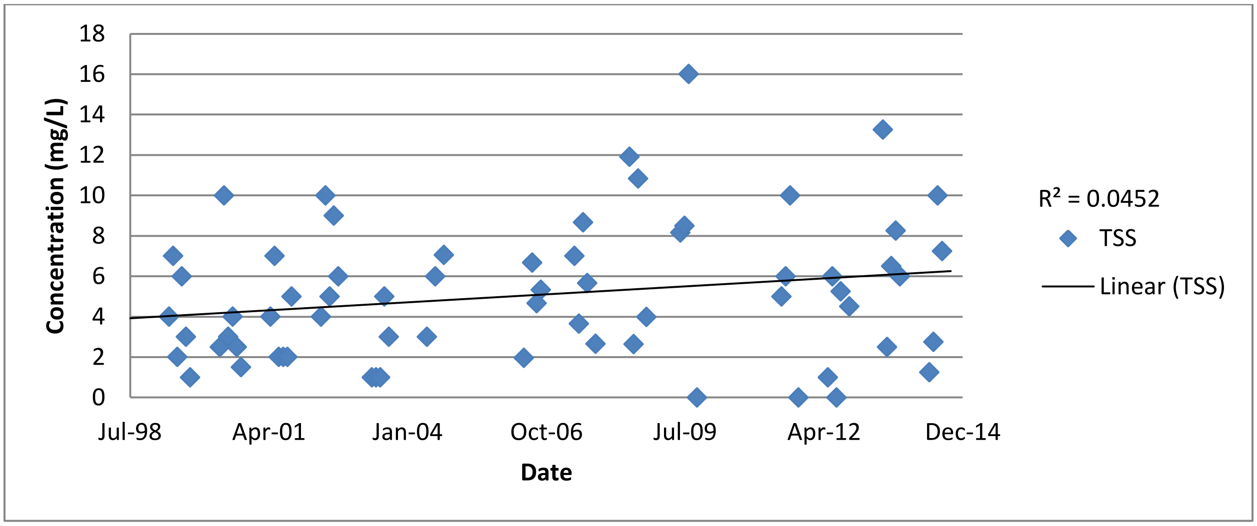


Figure 6. Total suspended solids over time

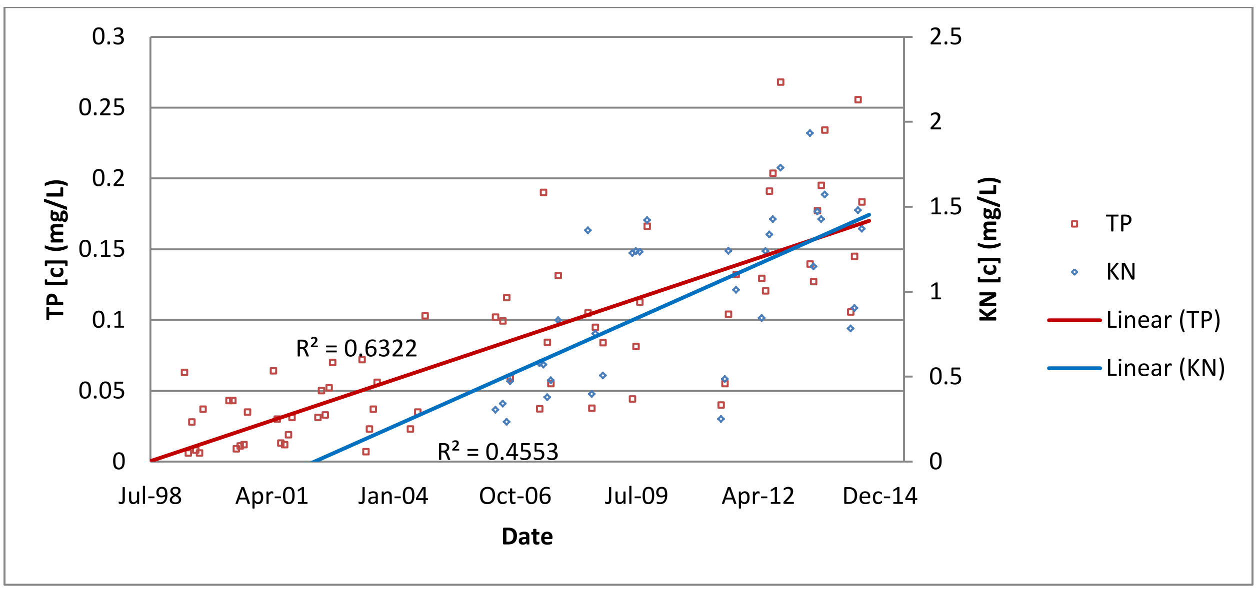


Figure 7. Concentration of total phosphorus and Kjeldahl nitrogen over time

The relationship between the concentrations of chlorophyll A vs. chlorophyll C, which are shown in Figure 8, indicates that when chlorophyll A is present there will also be a certain level of chlorophyll C. Chlorophyll A is primarily responsible for blue/green algae and chlorophyll C is associated with red/brown algae. Also seen in Figure 8, the concentrations of chlorophyll A are significantly higher compared to chlorophyll C. This results in the majority of the algal blooms being blue/green with just a few spots of red/brown, as indicated from the sampling reports. The next relationship that was analyzed was total suspended solids vs. chlorophyll A, shown in Figure 9. This shows that higher concentrations of TSS will result in higher chlorophyll A concentrations. This relationship shows that TSS could be used as an indicator of algal blooms. A strong relationship in terms of R^2 values found was between chlorophyll A and C vs. secchi depth, shown in Figure 10. This relationship indicates that as the concentration of chlorophyll A and C increase, the visibility in the lake drops significantly after the algae have had time to grow. In an environment where nutrients are in abundance, the algal blooms can occur with little restriction.

Some trends that did not have a high R^2 value, but were significant, were chlorophyll A and secchi depth over time. Figure 11 shows that the range of concentrations has increased significantly and has an upward trend indicting that the concentration is increasing over time. Figure 12 shows that over time the visibility in the lake has been decreasing.

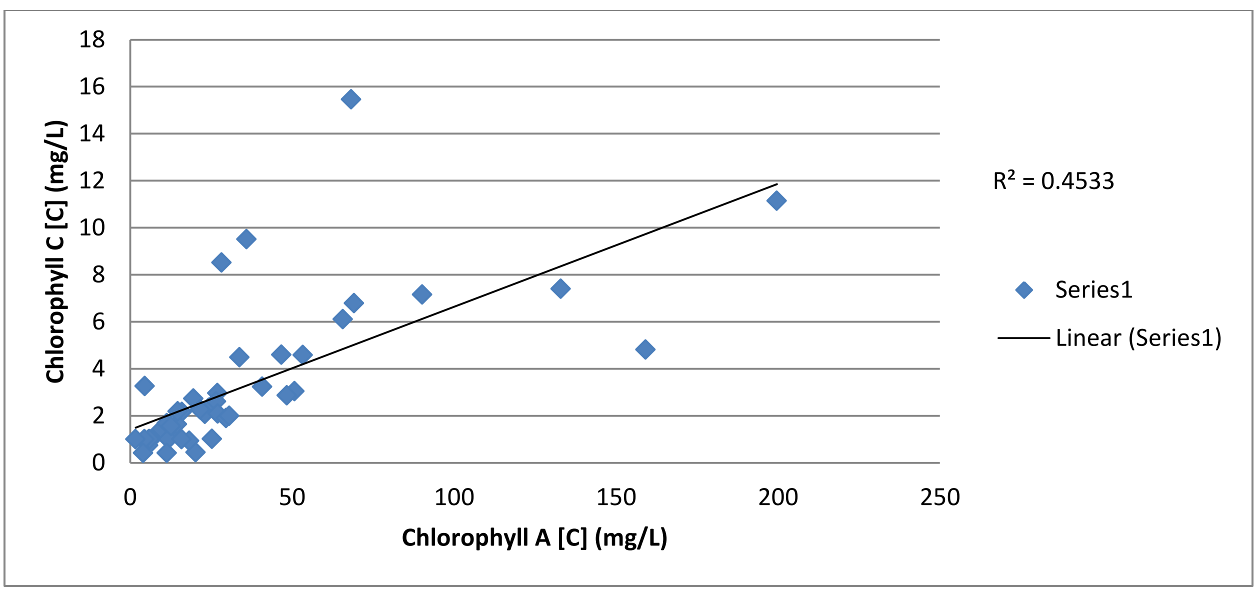


Figure 8. Concentration of chlorophyll A and chlorophyll C with respect to time

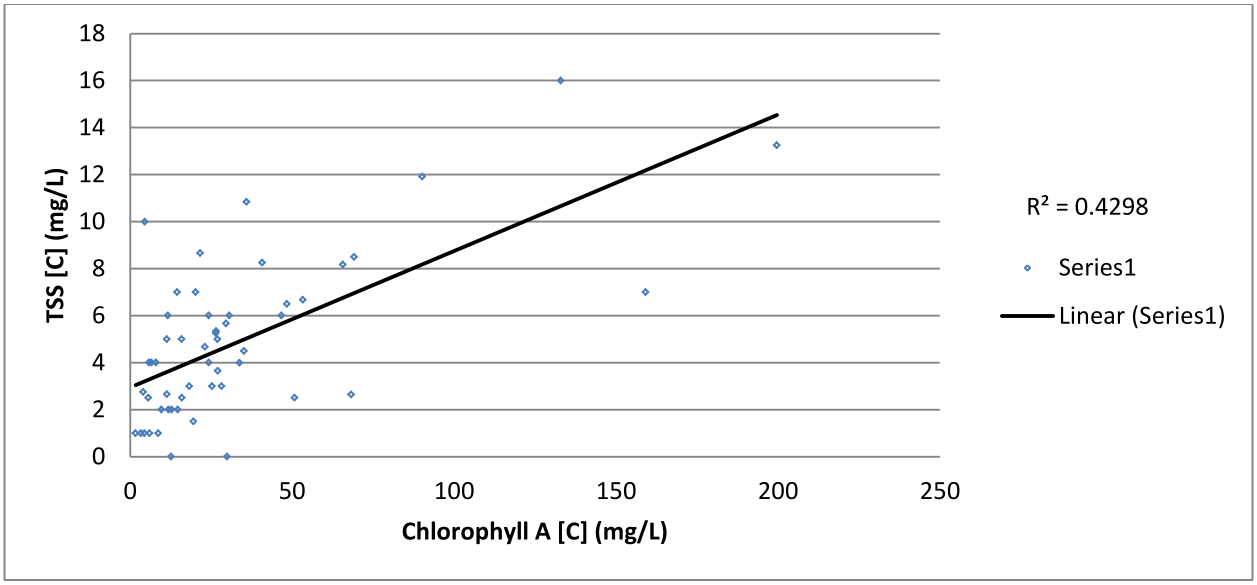


Figure 9. Total suspended solids vs chlorophyll A with respect to time

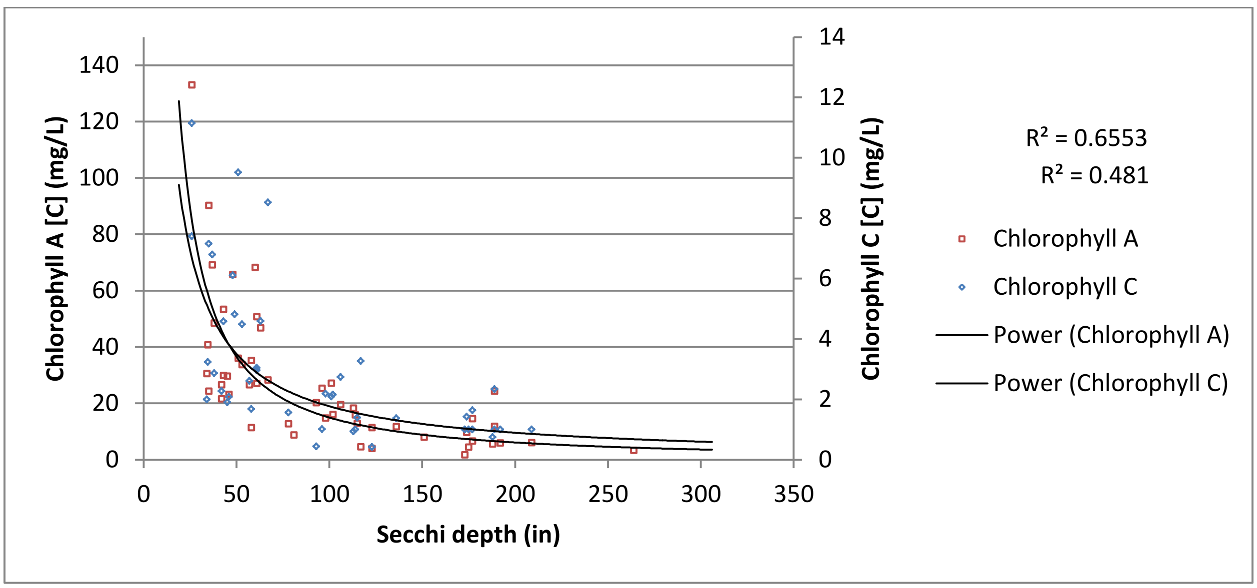


Figure 10. Chlorophyll A and C vs Secchi depth with respect to time

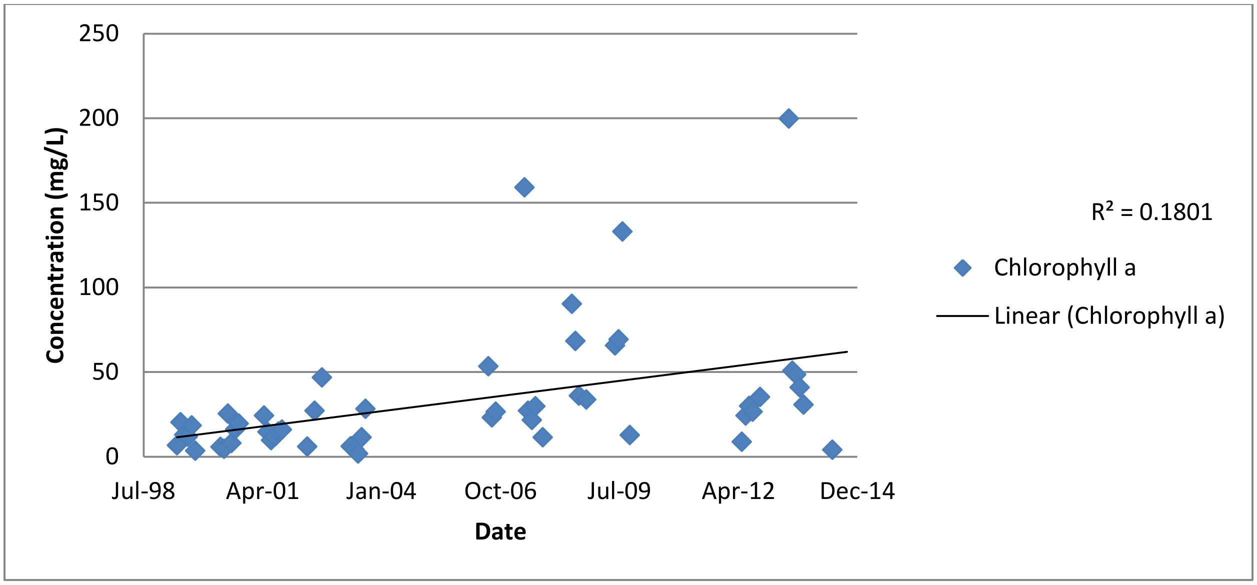


Figure 11. Chlorophyll A over time

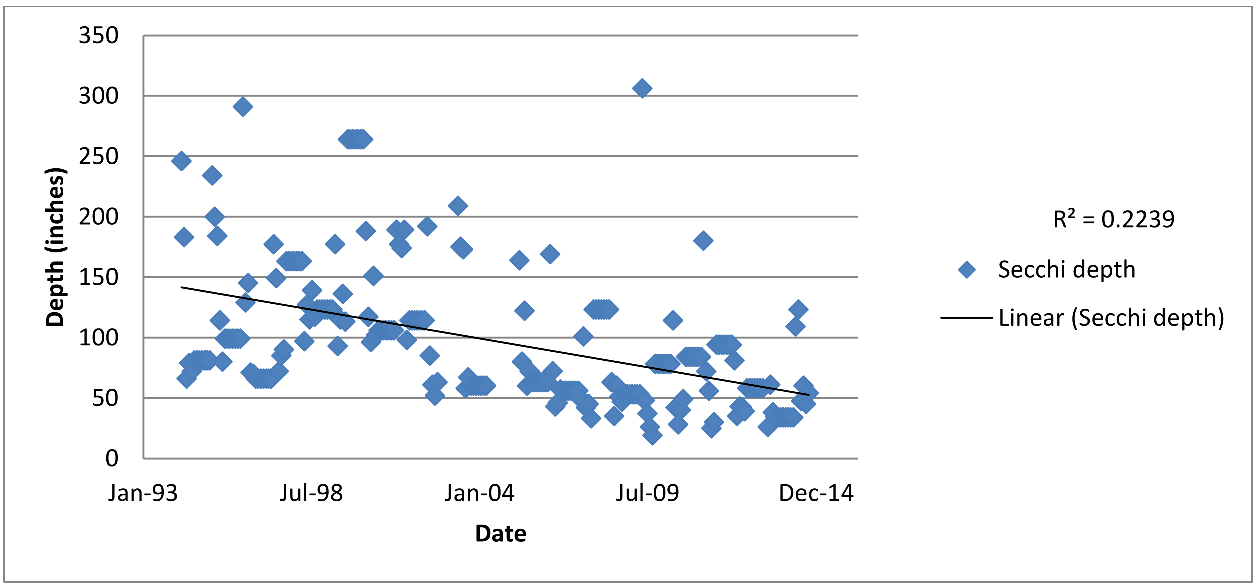


Figure 12. Secchi depth over time

The final trend that was found from the analysis was the temperature over the last few years because the clients mentioned that the last few algal blooms were worse than previous years. The trend that was found was that the average and low temperatures in February were significantly above freezing and slightly below freezing at night, as shown in Figure 13. This indicates that melting occurred earlier in the year than when it typically occurs. By getting these warmer days earlier, it means that the water temperature could warm up sooner. Warmer waters are more ideal for algal blooms to grow. The recent increase in February temperatures allowed the algal blooms to begin earlier and last longer than if melting did not occur so early.

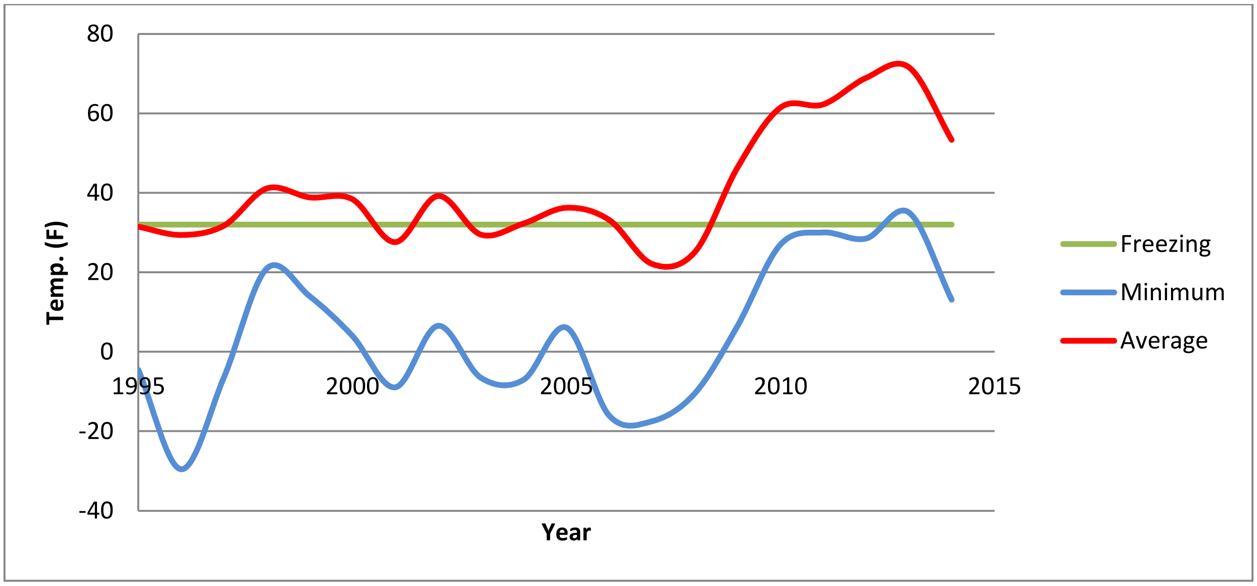


Figure 13. February temperatures over time

In summary, the majority of the suspended solids are organic and the total phosphorus, Kjeldahl nitrogen, and chlorophyll A have been increasing over time. This in turn has resulted in a steady decline in visibility in the lake. The reason or causes for these trends are discussed later in the report.

Section 3: Watershed Analysis

The next step of the analysis of the lake quality began with a study of the lake watershed, as well as, the watersheds of the 13 individual tributaries and the lake border watershed. This analysis identified the type of land use in the watershed. The purpose of the watershed analysis was to provide data in order to calculate the runoff quantity and quality. Runoff characteristics are important since runoff is the main contributor of water into the lake which would, in turn, affect the water quality of the lake.

3.1 Watershed Change over Time

From National Land Cover Database (NLCD) data, land use of the overall watershed was identified for the years 2001, 2006, and 2011. NLCD data was obtained from the United States Geological Survey (USGS) National Map Viewer website. The data was uploaded as a raster file to ArcMap and aligned with the watershed map provided by Mike Malon. From this data, the watershed could be viewed as a whole, and assumptions could be made on possible factors that may be influencing the growth of algal blooms in the lake.

The National Agricultural Statistics Service (NASS) data was provided by Mike Malon from 1999 to 2014. Unlike the NLCD data that combined cultivated crops as one category, this data separated it out as the individual crop type during each year. NLCD data was determined, however, to be a more accurate data source then the NASS data due to certain discrepancies or imprecise data. For example, the NASS data from both 2000 and 2011 was considered to be unusable due to cloud cover and inaccurate land use, respectively. NLCD data was used for the overall watershed analysis while the NASS data was used for crop comparison over the provided years.

By comparing land use data over the course of the three years analyzed, the change in land use between each year was identified. It was determined that land use had not changed significantly when comparing NLCD data between the years 2001 and 2011 (Figures 14 and 15).

It was assumed that from 2011 to 2014 land use did not change significantly. The 2011 NLCD data was used as a current, up to date, land use data source.

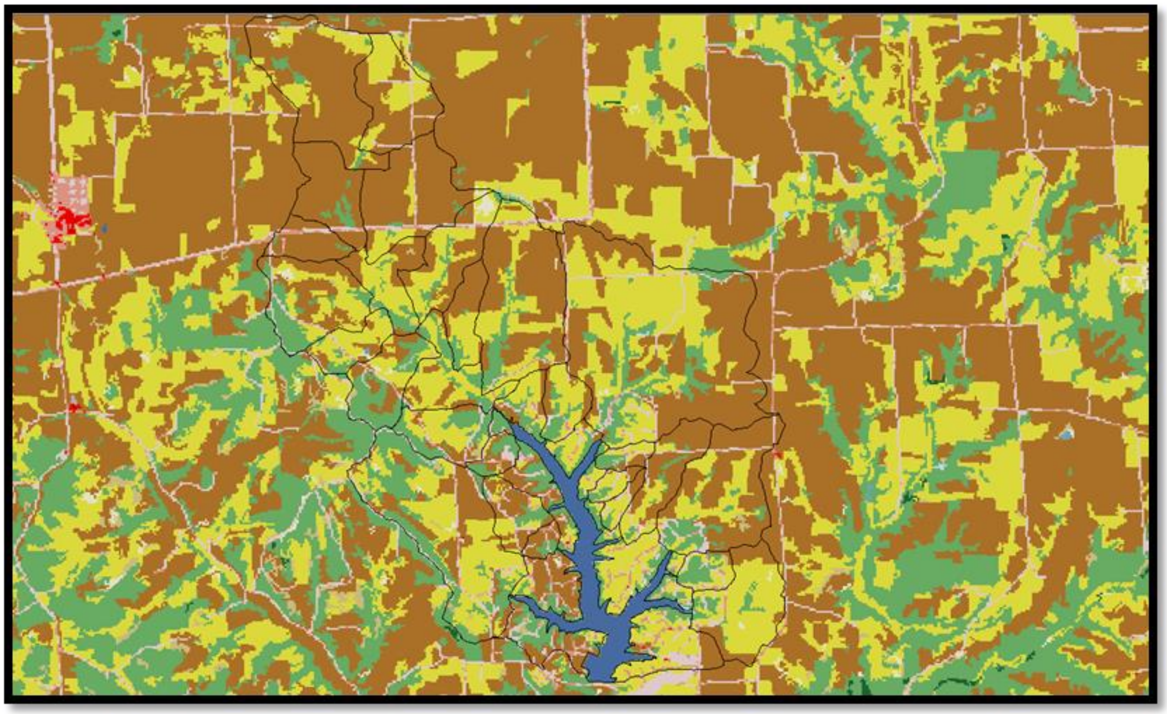


Figure 14. NLCD 2001 Map of Watershed

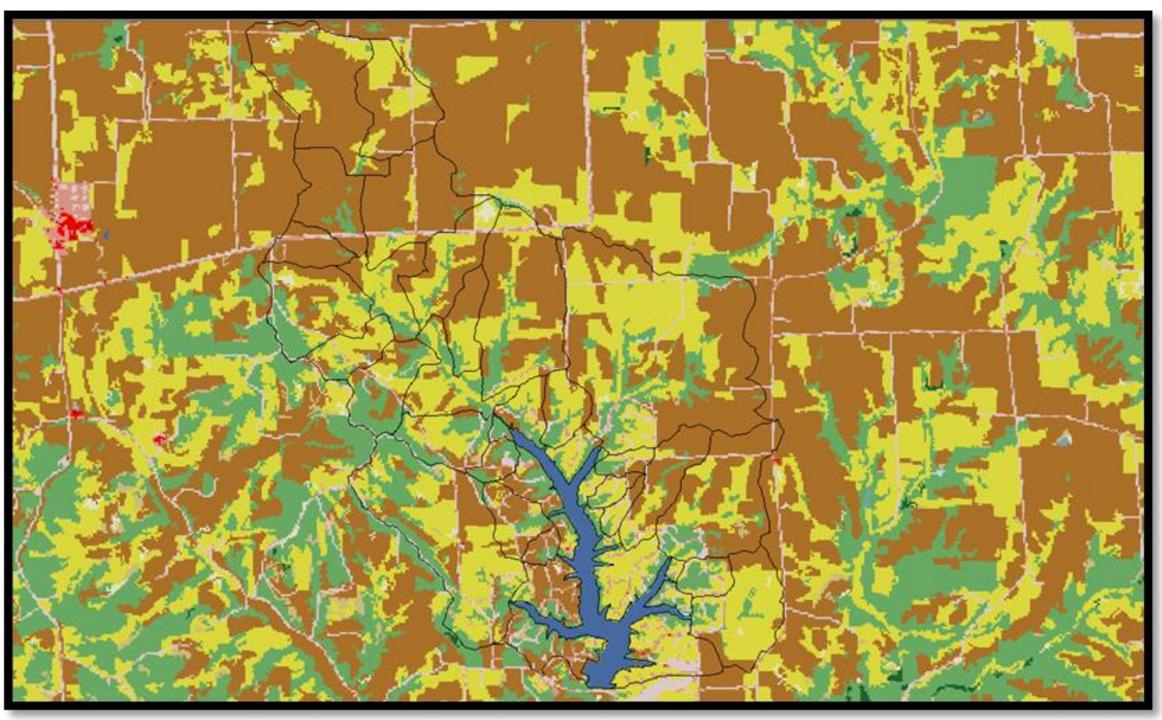


Figure 15. NLCD 2011 Map of Watershed

3.2 Current Land Use in the Watershed

As stated in the previous section, 2011 land use data was used as the current land use in the watershed. After compiling the land use types in ArcMap, percentages were determined for each land use type in the watershed (Figure 16). The largest land cover types in the watershed are cultivated crops (42%) and hay/grass/pasture (33%). Developed areas only account for about 7% of the watershed, 5% of which is developed open space. Developed open space was determined to be lawns and park areas. Based on these land use types, the watershed surrounding the lake is primarily agricultural land. By knowing the type of land use in the watershed, a number of conclusions and models were developed to help determine the cause of the algal blooms in the lake.

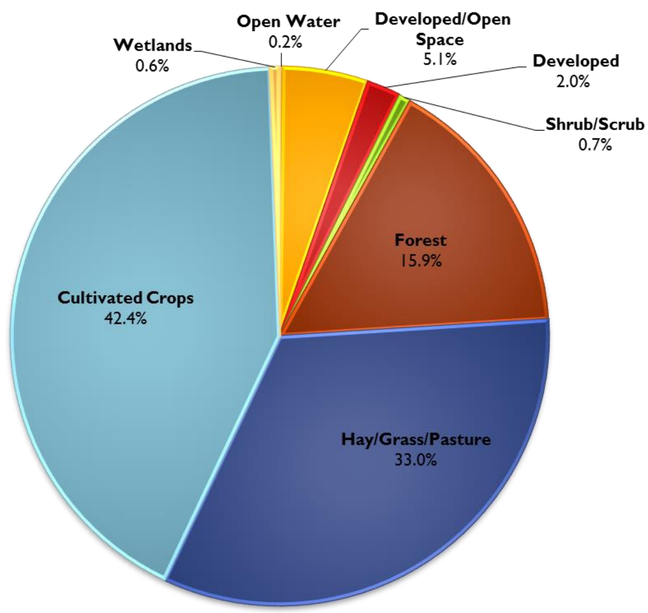


Figure 16. Land Use Percentages in Lake Watershed

An initial concern that was made about the algal blooms in the lake was the use of fertilizer and lawn products on residential green space in the watershed. Due to the low percentage of developed open space, it was determined that fertilizer use would not be the main contributor to the poor lake quality.

The golf course, located to the southeast of the lake, was considered to be a potential source of nutrient pollution. From the watershed boundary analysis, the golf course is not located in the lake watershed, except for a small portion of the northern reach of the golf course. Since the majority of the golf course is not located in the lake watershed, rainwater that lands on the course would not run off into the lake. This runoff from the course would run off to another water source south of the lake. It was determined that fertilizer use on the golf course would not be a significant contributor to poor lake quality.

3.3 Individual Subwatershed Characteristics

The overall watershed was broken up into 13 subwatersheds as well as the watershed that directly borders the lake (Figure 17). The individual watersheds were clipped from the initial watershed map that was provided in ArcMap. Watersheds were color coded to allow for easier separation. By separating these areas in ArcMap, land use data would be easier to analyze after it was uploaded into the ArcMap file.

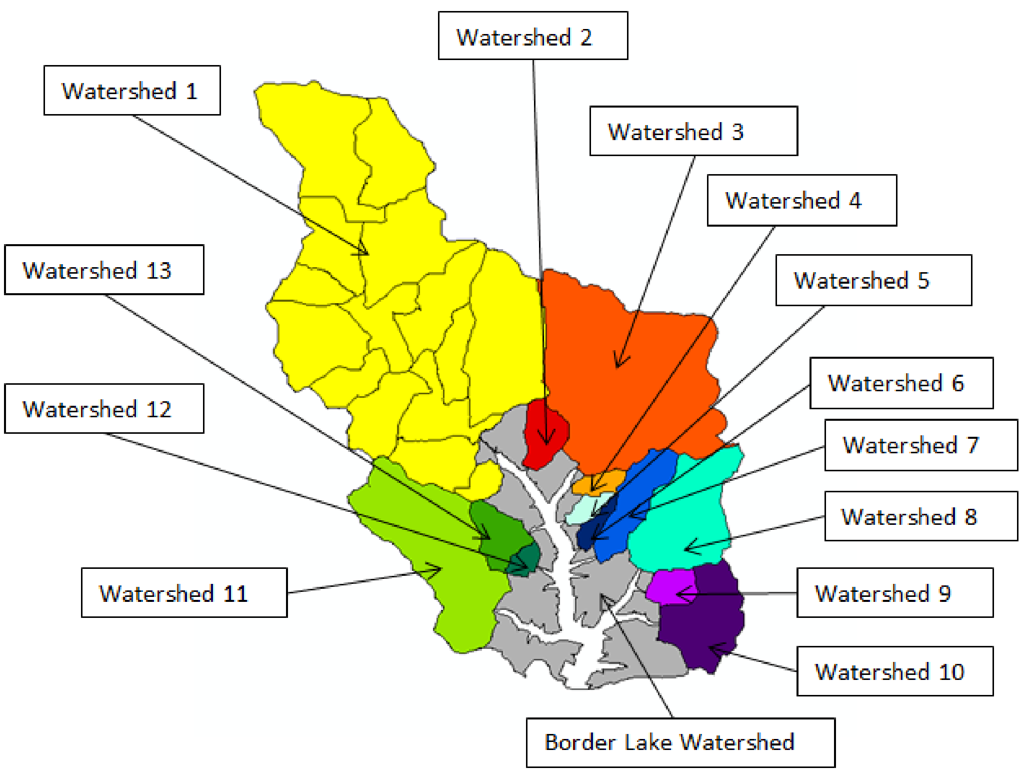


Figure 17. 13 Subwatersheds and Border Lake Watershed

Land use data for each of the individual watersheds was identified using ArcMap and NLCD data. The NLCD data areas were clipped so land use information was available for each individual tributary watershed. From the clipped NLCD data, the percent land use composition of each tributary watershed was identified so it could be further analyzed (Figure 18). From this information, conclusions could be made to identify factors that may lead to the algal blooms in the lake based on specific types of land use in the tributaries.

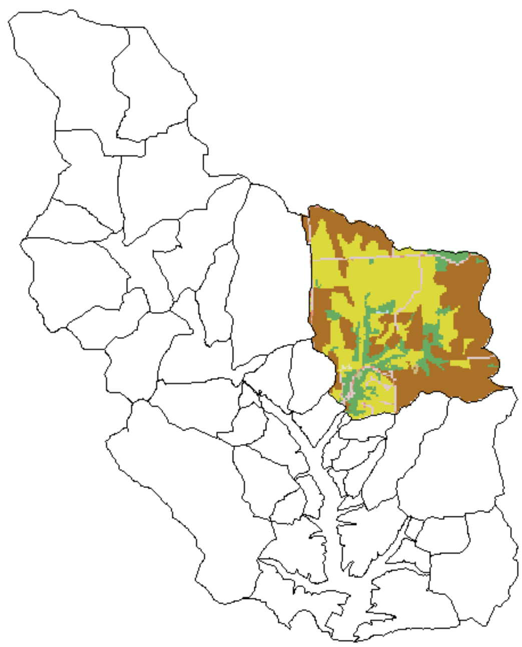


Figure 18. Clipped land use for subwatershed

The percent of land that each subwatershed accounts for in the total overall watershed was calculated. Figure 19 shows how the percentages of the individual watersheds compare to each other. Watershed 1 has the largest land area, accounting for about 44% of the total lake watershed. The next closest watershed area is Watershed 3 which accounts for about 17% of the total lake watershed. Watersheds 4, 5, 6 and 12 have the smallest watershed areas, each accounting for less than 1% of the total watershed area.

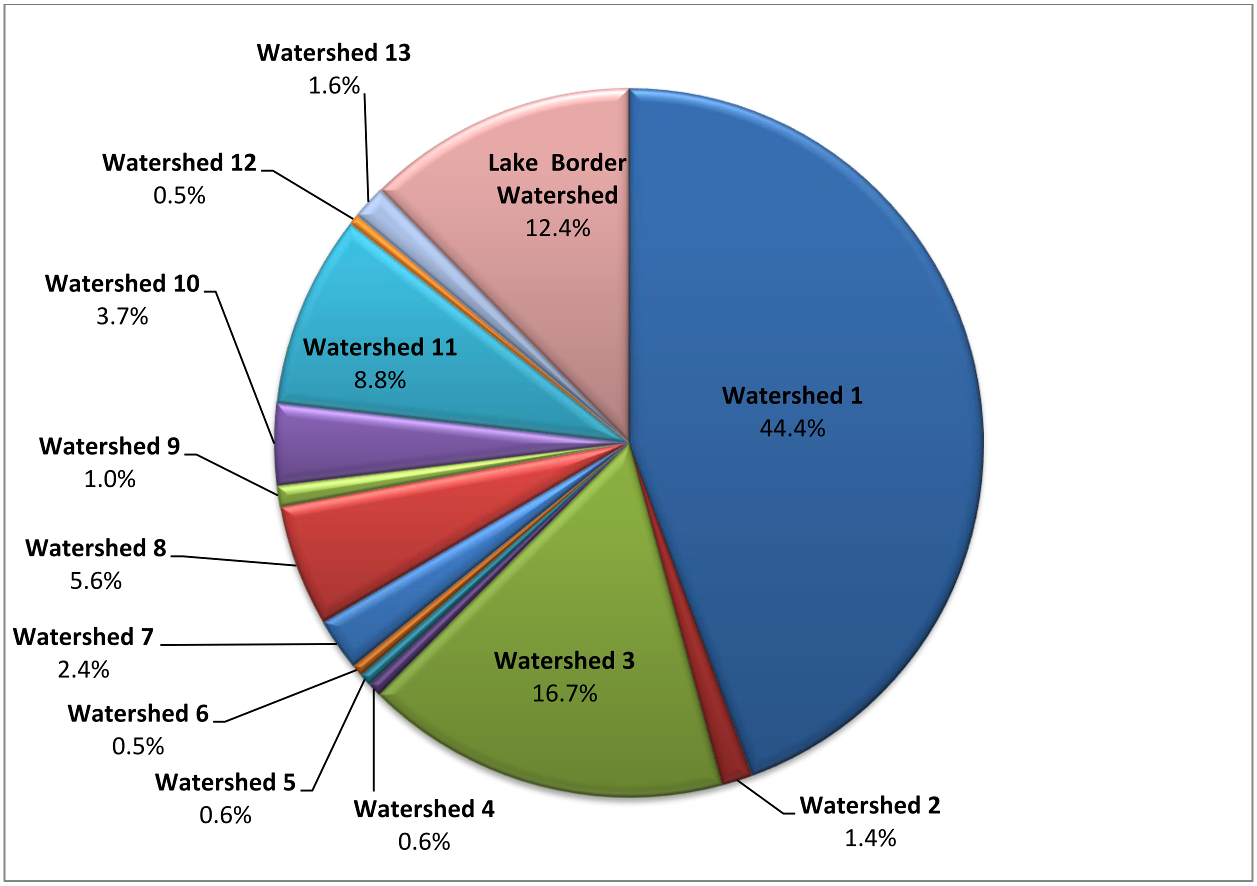


Figure 19. Tributary watershed percentages of overall watershed

3.4 Land use and Water Quality Trends

As mentioned earlier, the relative land use in the Apple Canyon Lake watershed has not changed significantly over the last decade, as shown in Figure 20, which brings up the question as to why the algae problem has become worse. However, within each major land use there are sub categories to which they can be broken into. One group that was broken down further was cropland. Cropland was broken down into the types of crops grown, and in this case the major crops are corn and soybeans, as seen in Figure 21. From that figure it can be seen that when less area is planted with soybeans, more area is planted with corn and vise-versa, with a recent trend of corn being planted more. It is this trend that is interesting because as corn planting has increased over time, certain water quality parameters entering the lake have also increased in concentration. The water quality parameters that show the strongest relationship with corn are Kjeldahl nitrogen and total phosphorus. As seen in Figures 22 and 23, the rate of increase is nearly identical, signifying that they are happening at the same time. Considering that all other land uses are staying the same, the relationship can be upgraded to a causal one. In summary, the data suggests that the increase in corn planted is leading to increased concentrations in Apple Canyon Lake. As phosphorus and nitrogen are key components of causing algal blooms, it can be said that planting more corn likely leads to an increased probability of algal blooms.

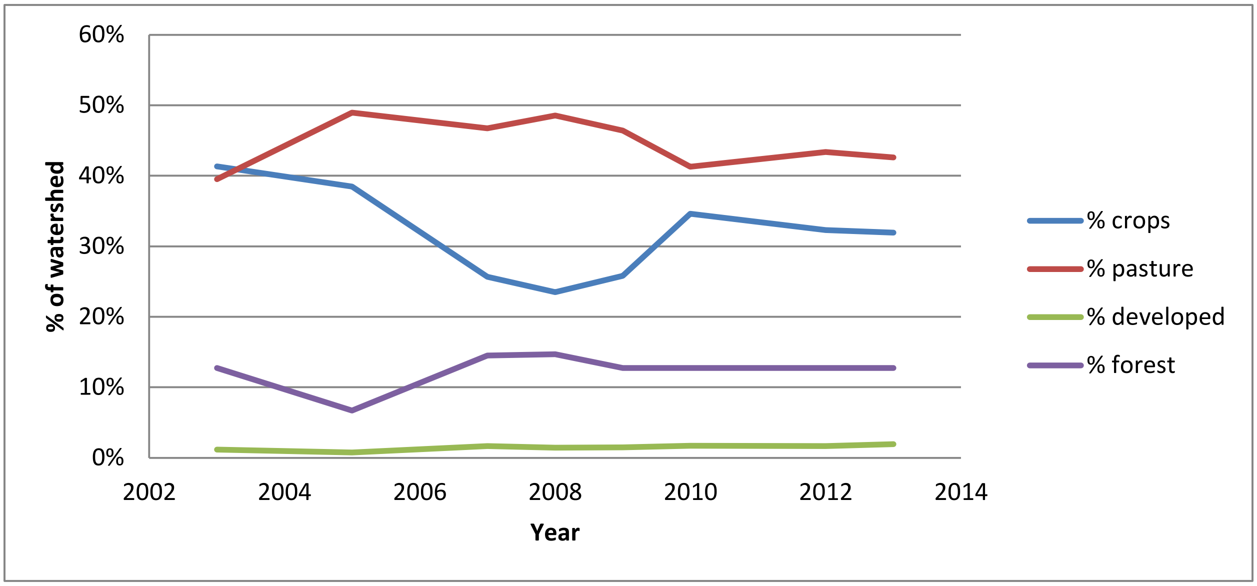


Figure 20. Land use change over time.

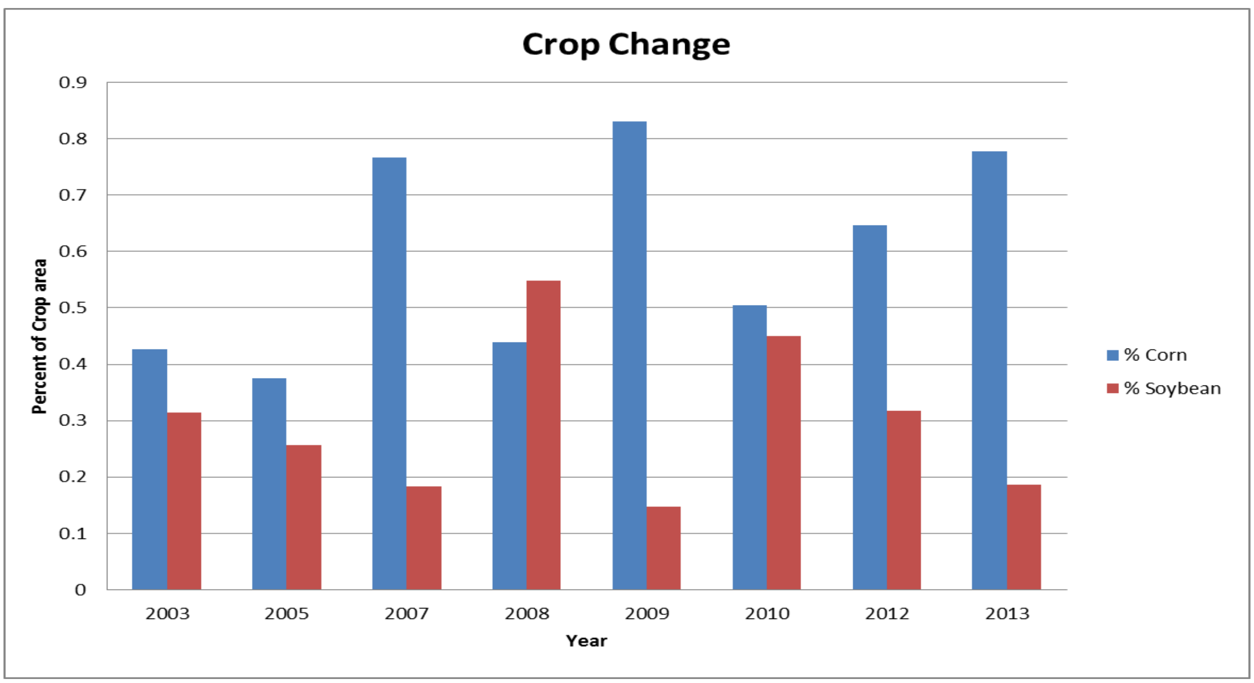


Figure 21. Major crops planted over time

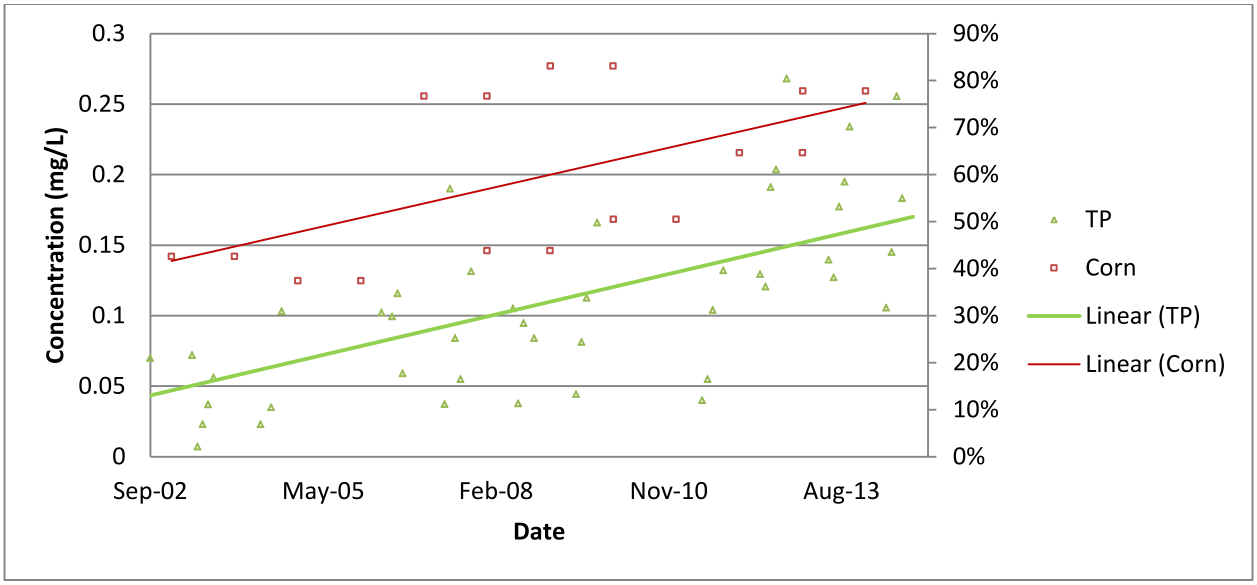


Figure 22. Concentration of total phosphorus and corn percentage of crop land over time

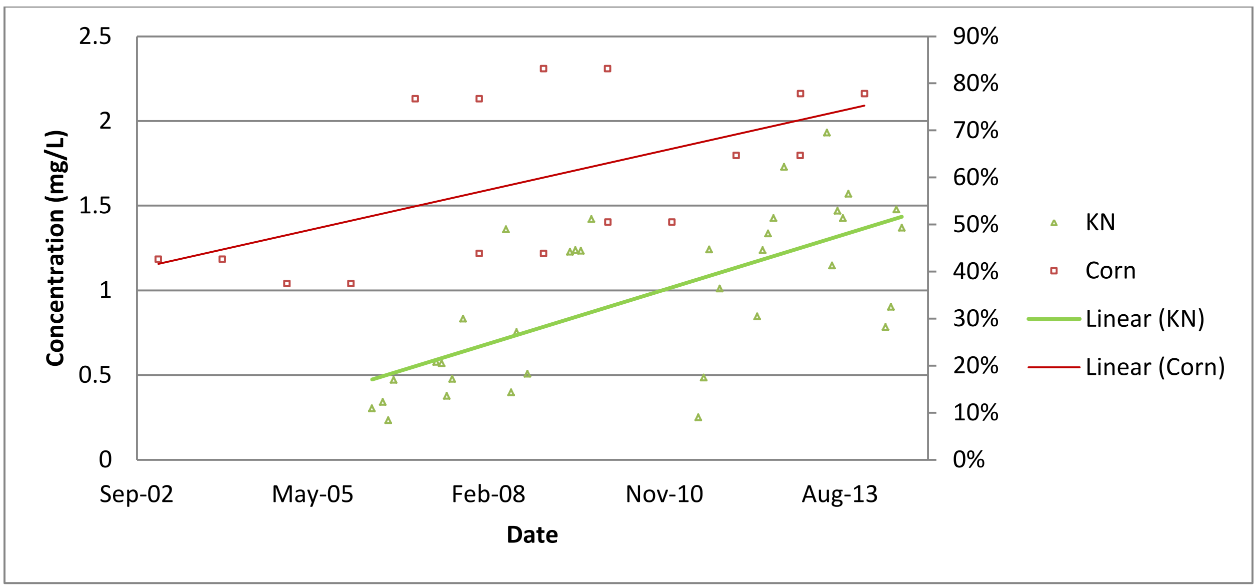


Figure 23. Concentration of Kjeldahl nitrogen and corn percentage of crop land over time

Crop prices were looked at as an indicator of algal blooms. The crop price data came from the University of Illinois Farm.doc website. From Figure 24, the change in crop prices for corn, wheat, and soybeans were plotted over time. Due to the general increase in corn and soybean prices having similar trends, it was determined that the crop price per bushel was not directly correlated to the type of crop planted in the watershed.

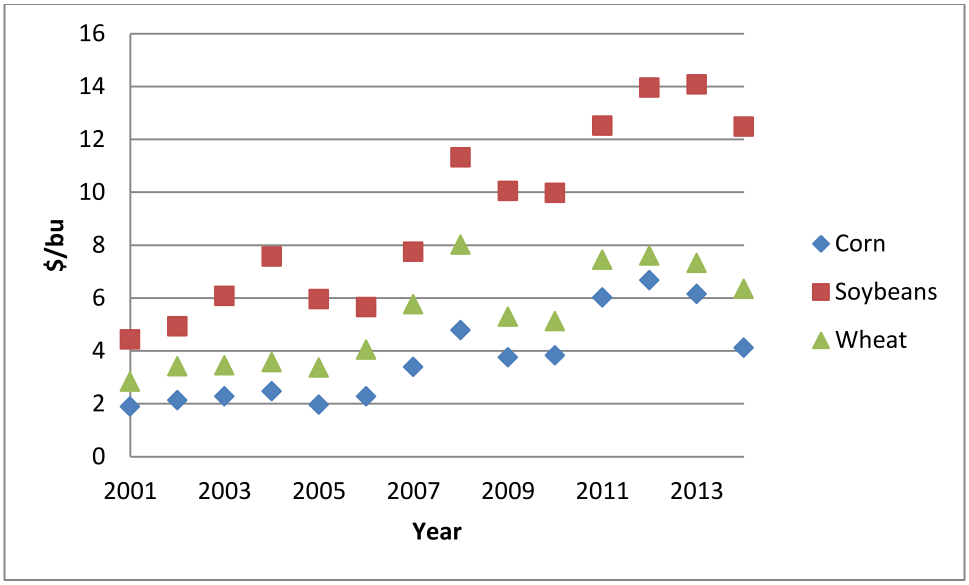


Figure 24. Crop prices over time

Section 4: Runoff Analysis

4.1 Runoff Quantity

HydroCAD modeling was used to assess the quantity of water runoff entering the lake from a given storm. HydroCAD was chosen as modeling software since it is used professionally by engineers to model stormwater runoff. The model was separated into 13 tributaries, as well as, the watershed surrounding the lake. An IDF curve was uploaded into HydroCAD from the National Oceanic Atmospheric Administration (NOAA). The Soil Conservation Service (SCS) method for runoff calculation was used for the model. To complete the model, land use information and time of concentration values were needed.

To determine land use for each of the tributary watersheds, information was obtained from the NLCD data and put into ArcMap. As stated above, it was assumed that land use has not changed since 2011 and the land use data obtained from 2011 was used in the model. Land use was used in HydroCAD to determine CN values. A CN value is a runoff curve number that is used to describe the groundcover for a particular area of the watershed. Due to HydroCAD and NLCD data having different land use descriptions, assumptions were made to find what HydroCAD descriptions fit the NLCD data descriptions. These assumptions are displayed in Table 2 in the Appendix. The area, in acres, of the different land use areas was also specified in the model. These values were taken from the ArcMap model that was described in the previous section. Soil type in the watershed was needed to calculate the CN value so the NRCS Web Soil Survey was used to determine soil type. Silt loam was determined to be the primary soil type for this region which is classified as a type B soil and was used for the HydroCAD model.

Time of concentration was another input needed in the model. Time of concentration is the time it takes for a drop of water to travel from the most hydraulically remote point in the watershed to the point of collection. This does not necessarily mean the farthest point from the collection point, which is the tributary or lake, but the water path that takes the most travel time.

Time of concentration (tc) was broken up into sheet flow, shallow concentrated flow, and, if a stream was present in the watershed leading to the tributary, channel flow. Sheet flow is overland flow of runoff that is defined as a thin layer of water forming a thin film on the land surface. It generally only occurs at the head of the watershed and only flows this way for about 200 feet – 300 feet. For the HydroCAD model, a sheet flow of 200 feet was used. Shallow concentrated flow occurs after sheet flow and lengths vary depending on the size of watershed. If a channel is present, shallow concentrated flow turns into channel flow, or flow that occurs in a stream, which eventually leads into the tributary or body of water. The rainfall intensity vs. duration that was used to run this model can be seen in Figure 1 in the Appendix. Flow paths for each of the watersheds are displayed in Figure 25 and were calculated from ArcMap.

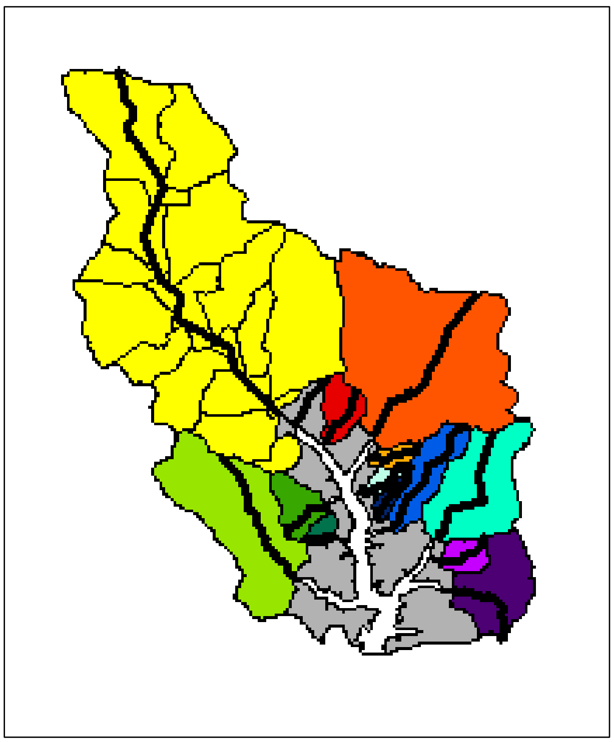


Figure 25. Apple Canyon Lake flow paths (black) and tributary watersheds

After running the HydroCAD models, runoff volumes and peak flows were generated for each of the tributaries, as well as the lake border watershed. Three different storm events were analyzed: 2-year 24-hour storm event, 10-year 24-hour storm event, and the 25-year 24-hour storm event. Runoff volume percentages were calculated based on average total runoff from the entire watershed for each of these events. Data is displayed in Tables 2, 3, and 4. Average percentages of the three events were put in a pie chart to visually depict how each tributary compares with each other in terms of runoff volume (Figure 26). The runoff volumes and peak flows can be used as a comparison number if BMPs are constructed for this lake by the tributaries.

Table 2. 2-Year 24-hour storm event data

Watersheds	Peak Flow (cfs)	Total Runoff Volume (af)	Percent Contribution (%)
1	891	234	47.5%
2	37.2	5.9	1.2%
3	327	83.1	16.9%
4	16.2	2.6	0.5%
5	14.2	2.4	0.5%
6	15.2	2.4	0.5%
7	118	14.2	2.9%
8	174	30.5	6.2%
9	24.9	3.3	0.7%
10	127	16.9	3.4%
11	215	42.3	8.6%
12	31	2.7	0.5%
13	47.4	8.1	1.6%
Lake Border	437	44.4	9.0%
Total		492.8	100.0%

Table 3. 10-year 24-hour storm event

Watersheds	Peak Flow (cfs)	Total Runoff Volume (af)	Percent Contribution (%)
1	2050	509	46.6%
2	98.6	13.9	1.3%
3	773	184	16.8%
4	42.7	6.2	0.6%
5	37.6	5.6	0.5%
6	38.8	5.6	0.5%
7	264	30	2.7%
8	704	65.9	6.0%
9	75.2	8.4	0.8%
10	317	38.7	3.5%
11	530	95.3	8.7%
12	71	5.9	0.5%
13	112	17.9	1.6%
Lake Border	1190	106	9.7%
Total:		**1092.4**	**100.0%**

Table 4. 25-year 24-hour storm event

Watersheds	Peak Flow (cfs)	Total Runoff Volume (af)	Percent Contribution (%)
1	2836	697	46.3%
2	141	19.5	1.3%
3	1075	253	16.8%
4	61.3	8.7	0.6%
5	56.9	7.9	0.5%
6	55.2	7.8	0.5%
7	361	40.7	2.7%
8	554	89.9	6.0%
9	112	12.1	0.8%
10	450	53.8	3.6%
11	745	132	8.8%
12	97.5	8	0.5%
13	156	24.5	1.6%
Lake Border	1723	150	10.0%
Total:		**1504.9**	**100.0%**

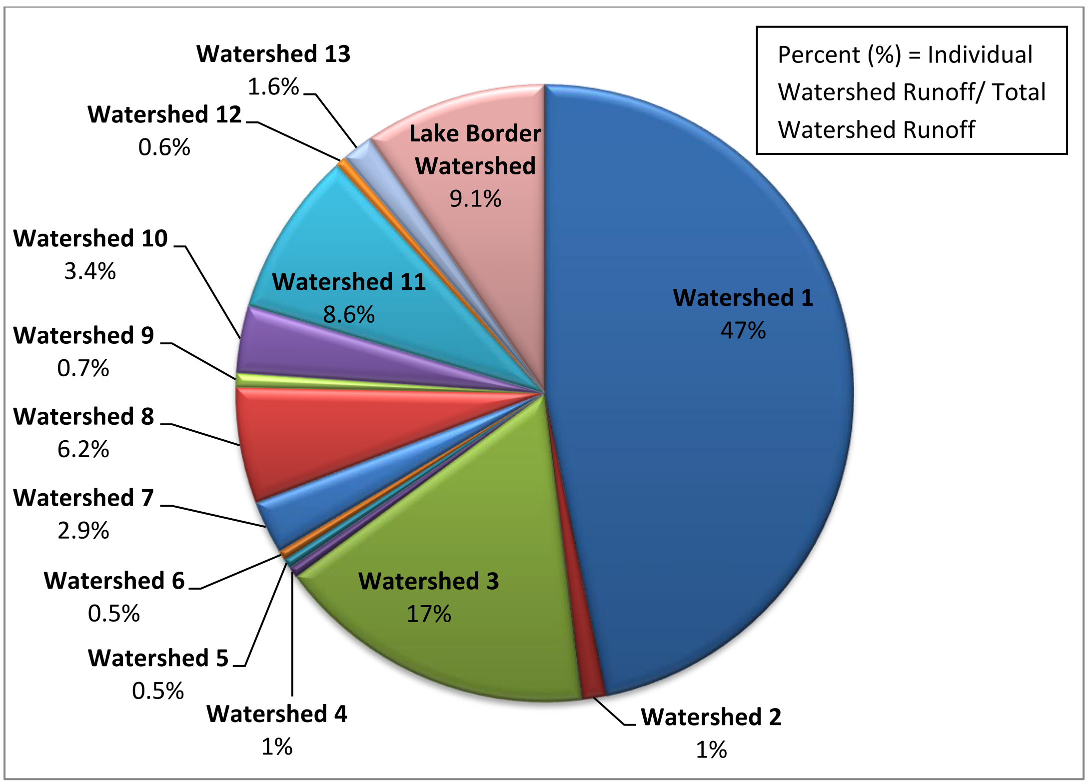


Figure 26. Tributary contribution to watershed

The watersheds that make up the majority of the runoff volume are watersheds 1, 3, 11, and the lake border watershed. When comparing the individual tributary watershed area percentages to the overall watershed, the two graphs are almost identical. This correlation means that land area has a large influence on the amount of runoff going into the lake and each individual watershed has similar land cover.

4.2 ABCD water balance model

In addition to modelling the runoff of each individual tributary in a single storm event through HydroCAD, an ABCD water balance model was created to quantify the volume of runoff for the watershed over a two decade time period. The ABCD model is able to calculate monthly runoff amount every month from 1998 to 2014 for the entire watershed area surrounding Apple Canyon Lake. The entire water balance was based on two smaller water balances of 1) the water balance determining the soil moisture and 2) the water balance determining the volume of groundwater (Figure 27). Equations 1 and 2 show the soil moisture and groundwater water balances, respectively. The variable "t" signifies the current time step, while "t-1" represents the value of the previous time step.

$$Equation\ 1{:}\ \ Soil\ Moisture\ (t) + ET(t) + Runoff\ f(t) + Recharge\ (t) \\ = Soil\ Moisture\ (t-1) + Precipitation\ (t)$$

$$Equation\ 2{:}\ \ Groundwater\ (t) + Discharge\ (t) = Groundwater\ (t-1) + Recharge\ (t)$$

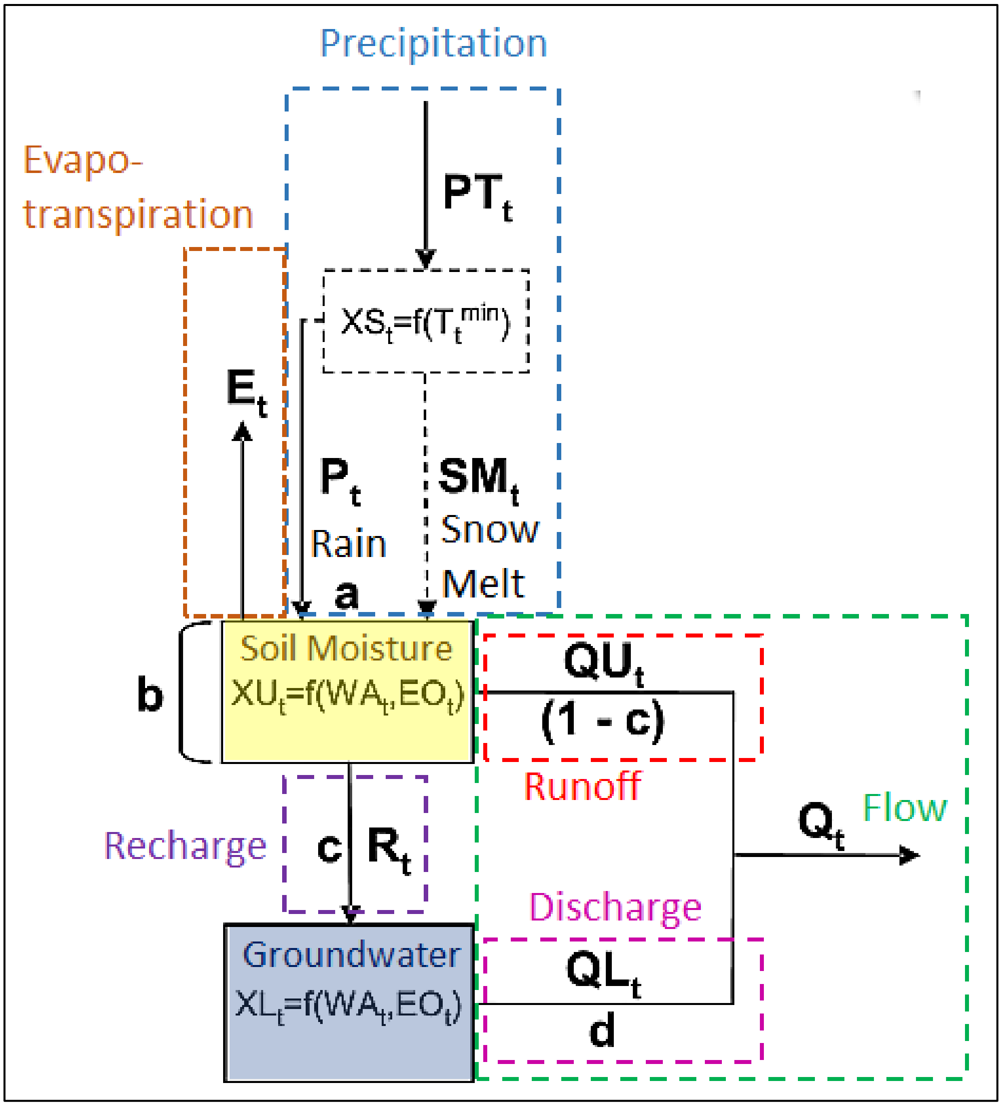


Figure 27. Components of the ABCD water balance model

The ABCD model uses precipitation and temperature data from NCDC met station in Apple River Canyon, IL from December 1998 to March 2015 (Figure 28).

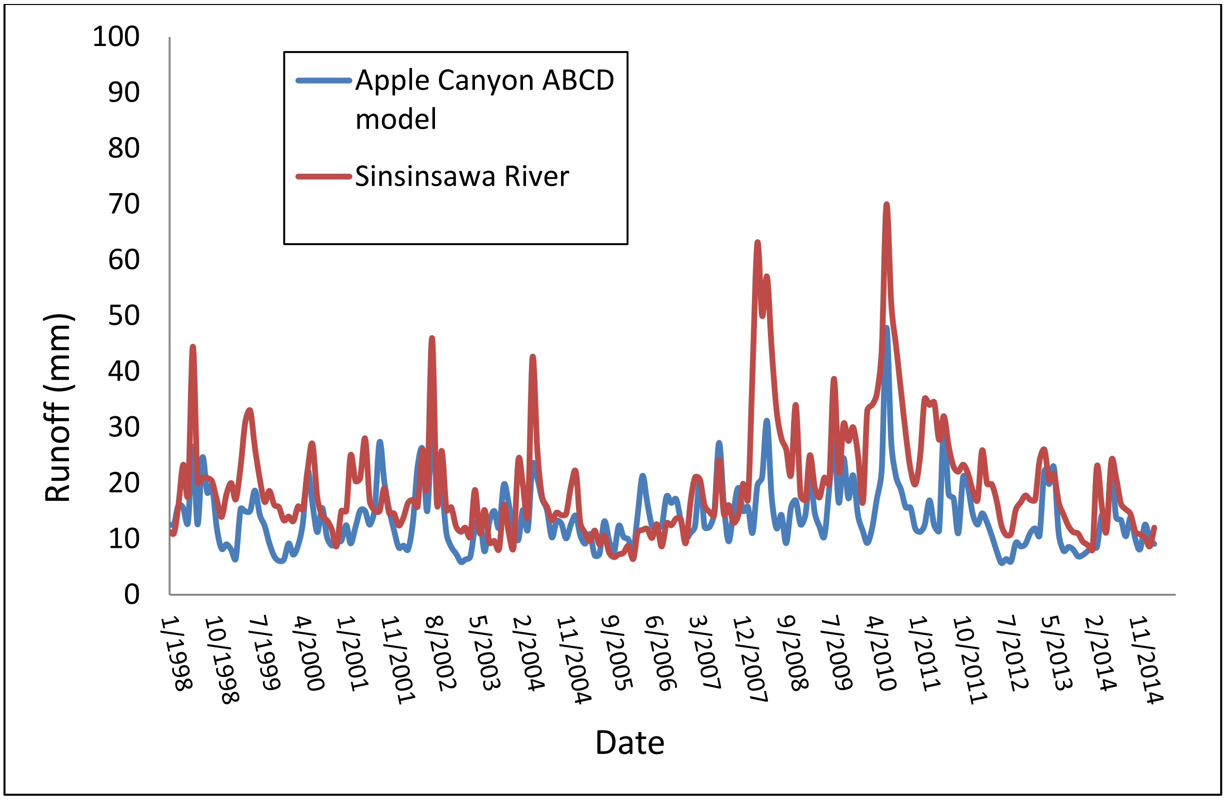


Figure 28. ABCD model created based on Apple Canyon data and compared to Sinsinawa River discharge

From the temperature data, averages were used in congruence with the empirical Hargreaves model to find potential evapotranspiration (PET) (Equation 3). R_α is the total incoming extraterrestrial solar radiation, C_t is a temperature reduction based on the amount of relative humidity, $\delta_t^{1/2}$ is the difference between mean low and high monthly temperatures, and $T_{avg.d}$ is the mean temperature at a point in time. Equations 4-9 consist of the components of the Hargreaves model that derive the values in the PET calculation.

$$Equation\ 3\text{:}\ \ PET = 0.0075 * R_\alpha * C_t * \delta_t^{\frac{1}{2}} * T_{avg.d}$$

$$Equation\ 4\text{:}\ \ R_\alpha = 15.392 * d_r(w_s * sin\emptyset * sin\delta + cos\delta * sinw_s$$

$$Equation\ 5\text{:}\ \ C_t = 0.035(100 - w_\alpha)^{1/3} \quad w_\alpha \geq 54\%$$

$$Equation\ 6\text{:}\ \ C_t = 0.125 \quad w_\alpha < 54\%$$

$$Equation\ 7\text{:}\ \ d_r = 1 + 0.033 * \cos\left(\frac{2\pi * J}{365}\right)$$

$$Equation\ 8:\ \delta = 0.4093 * sin\left(\frac{2\pi * J}{365} - 1405\right)$$

$$Equation\ 9:\ w_s = \arccos(-tan\emptyset * tan\delta)$$

In the ABCD model, snow melt, effective precipitation, and effective evapotranspiration were found using the “a”, “b”, “c”, and “d” components. The parameter “a” quantifies the volume of runoff and recharge in terms of precipitation from rain and snow melt. The parameter “a” assumes that the saturation of the soil in which the precipitation is falling on is less than the maximum saturation. The parameter “b” identifies the soil saturation level after taking into account precipitation runoff, recharge, and evapotranspiration. The parameter “c” gives the groundwater recharge to surface runoff ratio. The parameter “d” determines the rate of groundwater discharge.

Data found in the ABCD model was compared to actual runoff amounts recorded from a nearby river – Sinsinawa River near Menominee, IL (Figure 28). The ABCD model was calibrated by multiple methods to check its accuracy and find the best fit to the observed Sinsinawa River data. Although the R-correlation was below 0.5, the model could be used as an estimate of runoff values. A user of the ABCD model would only need to input precipitation and temperature data of a time step, and the model would use programmed water balance equations to calculate a runoff value for the entire watershed area. This runoff value could then be used in correlation with nutrient loadings to quantify runoff water quality parameters at each time step.

4.3 STEPL: Spreadsheet Tool for Estimating Pollution Load

To determine the nutrient loading that enters into the lake, a freely available model from the EPA was used. STEPL, which is an acronym for Spreadsheet Tool for Estimating Pollution Load, uses watershed characteristics such as location, land use, animal count, septic systems, soil type, and best management practices (BMP) to estimate total loadings to the system. The model is built in a spreadsheet environment and most of the data that was entered into this model was obtained by using the EPA’s on-line STEPL data servers. To access the data that was relevant to this project, the location and watershed was selected from the series of drop down menus.

The next step in the process was to enter the values from the servers to the Excel spreadsheet. Within the spreadsheet, variables such as average precipitation, pollutant loading per land use, and runoff numbers were pre-entered based on other spreadsheets that are referenced within it; these values could be changed if more accurate/current information was available. For the purposes of this project, the pre-entered values were used. An estimated value of two months of manure applied was also selected. Within the broad scope of urban land use, the model required that it should be broken down further into sub-urban uses. These uses included commercial, industrial, institutional, transportation, multifamily, single family, urban cultivated, vacant (developed), and open space. The breakdown of values used for this part can be seen in Table 5 and were estimated based on google map images.

Table 5. Subcategories of urban land use and distribution by percent

Commercial %	Industrial %	Institutional %	Transportation %	Multi-Family %	Single-Family %	Urban-Cultivated %	Vacant (developed) %	Open Space %
5	0	0	15	0	63	2	5	10

The next step was to determine more realistic values for nutrient loadings into the lake by including the BMPs currently in use. For this analysis, BMPs were only considered to be used for cropland. The reasoning for limiting BMPs for urban land use was because the overall load from other sources in the watershed is considerably larger. Estimating the type and size of BMPs for urban area would also be very inaccurate.

In the analysis, three scenarios were used to compare their effectiveness. The first scenario was with no BMPs so it could be used as a baseline for the other two. The second scenario was meant to represent current conditions with 75% of the cropland area utilizing contour farming. This percentage was estimated by Mike Malon based on his observations of the area over recent years. The third scenario is a hypothetical one in which the 99% of the cropland area participated in contour farming and 1% of cropland area was converted to filter strips that would help remove contaminates before they entered the tributaries.

After the above information was run through the STEPL spreadsheet, the estimated nutrient load from each land use was calculated. The breakdown of the nutrient load can be seen in Figure 29, where it clearly indicates that nearly 90% of each type of loading is coming from cropland and pastureland, respectively. This confirmed that cropland and pastureland are the areas that should primarily be looked at for improvements and efficiencies to reduce the load. When comparing the load reduction from the three scenarios described above, Table 5 shows that by utilizing filter strips, the loading of all nutrient parameters can be significantly reduced. The reduction that results from using filter strips should reduce the amount of sediment dredged per year, increase water clarity, and decrease the effects of algal blooms. Again, the reduction of nutrient loadings will not eliminate the problem due to the land use within the watershed, but it will improve the overall water quality of the lake.

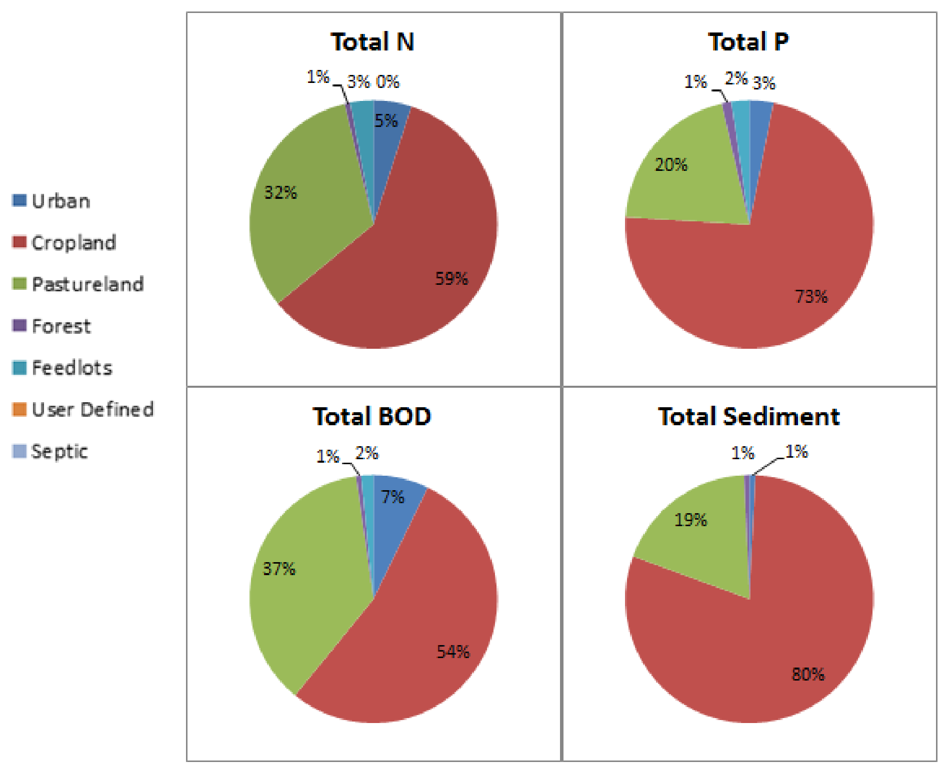


Figure 29. Nutrient loading by land use for current conditions using scenario 2

Table 6. Nutrient reduction from different BMP scenarios

Scenario	N Reduction	P Reduction	BOD Reduction	Sediment Reduction
S1	0%	0%	0%	0%
S2	22%	26%	12%	26%
S3	55%	65%	31%	67%
S3-S2	33%	39%	19%	41%

Section 5: Case Studies

In order to get an idea of how to control the algal blooms, a few case studies were researched. The two case studies discussed, have a lot of similarities with Apple Canyon Lake and can be used as examples when looking at possible BMPs to implement. These case studies show how BMPs can increase the water quality of a lake.

5.1 Green Valley Lake, Iowa

According to the Environmental Protection Agency (EPA), Green Valley Lake is a 390 acre impoundment of the Platte River located in southern Iowa. It was built in 1952 and by the 1970's was having a large number of water quality problems including sedimentation, turbidity and excess growths of blue-green algae. The pollution source was determined to be the agricultural land. The contributing watershed has an area of 5,202 acres, 72% used for farming. Between 1968 and 1978, sedimentation reduced the lake area by 10% and the lake volume at a rate of 8,635 cubic meters per year. Algal blooms occurred in the summers, leading to low dissolved oxygen (DO) and ultimately reduced the fish population.

The Iowa Department of Natural Resources (IDNR) implemented a Phase II restoration Project in 1980 with several goals in mind. The goals included reducing sediment/nutrient delivery to lake to the acceptable levels by installing BMPs on cropland within the watershed, reducing suspension of nutrients within the lakebed by deepening shallow water areas and monitoring chemical, physical, and biological parameters to detect changes within the water quality.

In order to achieve these goals, two approaches were taken. First, BMPs were installed on agricultural land to reduce soil erosion. By the time the project was completed, the following BMPs had been implemented: 3 grade stabilization structures, 39 tile intake terraces, 1 diversion, 6 grassed waterways and 16 water sediment control basins. Second, in order to retard water flow and cause sediment to settle out before getting into the lake, two sediment/nutrient retention dikes were installed in the two main arms of the lake.

The lake was monitored for six years. This included testing for several different parameters such as water clarity, sediment delivery, and phosphorus and nitrogen loading. Over the six-year monitoring period, surprisingly, water clarity had declined. This was attributed to an increase in populations of bullhead and carp within the lake; the problem was well documented within several other Iowa lakes as well. The sediment delivery was reduced enough to cut the lake volume loss in half from 8,635 cubic meters/year to 4,318 cubic meters/year. Nitrogen levels decreased in shallow depths and phosphorus levels decreased throughout the lake. Overall, the lake experienced fewer algal blooms after the restoration and an improvement in overall water quality.

5.2 Governor Bond Lake, IL

According to the EPA, Governor Bond Lake is 775 acres that was built in the late 1960s to supply Greenville and other surrounding communities with a source of water. The lake suffered from extreme algal growth and turbidity, which landed it on the 1998 303(d) list of impaired lakes. The Illinois EPA identified the potential causes for the bad water quality as manganese, phosphorus, total suspended solids, total nitrogen and chlorophyll a /excessive algal growth. The main source for the majority of the pollutants was attributed to storm runoff from agricultural land due to about 80% of the watershed being cropland with the remaining 20% composed of pasture, forest, urban and other land uses.

In 2002, the Illinois EPA had completed nutrients and sediment total maximum daily loads (TMDLs) for the lake. Between 2002 and 2006, a series of BMPs were implemented in order to fulfill the goals set forth by the TMDLs. Four stormwater wetland basins (SWBs) were constructed on the two main tributaries of Governor Bond Lake—two on each branch. Each basin was designed to ultimately remove nutrients and suspended sediments from the stormwater runoff for the majority of the watershed. Within the basins, wetland plants absorb and filter nutrients and other soluble nonpoint source pollutants while sediment settles to the bottom. Shoreline protection and stabilization practices around the lake were also applied using concrete seawalls, steel seawalls, riprap and riparian plantings (vegetated filter strips) to reduce another source of sediment entering the lake. Overall, the water quality of the lake was greatly improved after implementing the BMPs. There was an estimated 75% reduction in total suspended solids, 45% reduction in phosphorus and 28% reduction in total nitrogen that contributed to the lake.

Conclusions:

This project examined the water quality of Apple Canyon Lake to attempt to diagnose the cause of annual algal blooms. The project started with a data analysis of lake water quality that was gathered prior to the water quality assessment. Using the information gathered from the data analysis, a watershed analysis was conducted to determine where the different nutrients were coming from. The NLCD data was analyzed for the watershed, including 13 tributary watersheds and the lake border watershed present in the system. To determine the runoff characteristics from these watersheds contributing to the lake, HydroCAD, STEPL, and ABCD models were applied. The models' results indicate that the majority of nutrient loadings entering the lake come likely from agricultural land. The analyzed data suggests that subwatershed 1 from Tributary 1 (Hell's Branch) contributes the largest quantity of runoff and has the greatest area of cropland. One conclusion that was made was that subwatershed 1 adds the largest percentage of nutrient runoff into Apple Canyon Lake. Additionally, abnormally high temperatures have occurred beginning each year from 2009-2015. This temperature change may have led to earlier and more severe algal blooms than in previous decades. Case studies of lake reservoirs with similar characteristics were researched and can be used as a reference for reducing algal blooms.

Recommendations:

Runoff and stormwater treatment recommendations that could be implemented in order to help control the amount of sediment and nutrients entering the lake are provided. For example, according to IDEQ Storm Water Best Management Practices Catalog, vegetative buffer strips are a possible BMP that could be installed between farm fields and the streams contributing to Apple Canyon Lake. They are inexpensive, require low maintenance and reduce pollutant discharge by capturing and holding sediments and other storm water pollutants. Constructed wetlands are also a possible BMP that could be implemented due to the effective removal of suspended solids, total phosphorus, total nitrogen, and other storm water runoff pollutants. According to the Pennsylvania Stormwater Management Manual, once established, the wetlands would need little maintenance. The vegetation could be harvested about once a year to increase the nutrient removal efficiency and sediment should be removed typically every 3 to 7 years. Typical costs range from $30,000 to $65,000 per acre but depend heavily on amount of earthwork and planting.

Additionally, it is recommended that future sampling include streamflow rates. Monitoring of the tributaries concentrations and flows will also help in determining where the majority of the nutrient loading is coming from. Individually, concentration and flow do not accurately represent the whole story. By accounting for both and converting to a common unit, the source of algal blooms and nutrient loadings will be better understood.

References:

Han, W., Yang, Z., Di, L., Yue, P., 2014. A geospatial Web service approach for creating on-demand Cropland Data Layer thematic maps. Transactions of the ASABE, 57(1), 239-247. http://nassgeodata.gmu.edu/CropScape/

Idaho Department of Environmental Quality (2005). Vegetative Buffer Strip. *Catalog of Storm water Best Management Practices for Idaho Cities and Counties.* Retrieved from http://www.deq.idaho.gov/media/617614-37.pdf

"Monthly Temperature and Precipitation." National Climatic Data Center (NCDC). N.p., n.d. Web. 22 Apr. 2015.

NOAA's National Weather Service. (2014). [Precipitation and temperature data for Apple River Canyon SP, IL US,]. *NOAA National Climatic Data Center* Retrieved from http://www1.ncdc.noaa.gov/pub/orders/cdo/507870.dat

NOAA's National Weather Service. (2014). [Precipitation data for given locations]. *NOAA Atlas 14 Point Precipitation Frequency Estimates: IL*. Retrieved from http://hdsc.nws.noaa.gov/hdsc/pfds/pfds_map_cont.html?bkmrk=wi

Pennsylvania Department of Environmental Protection. BMP #: Constructed Wetlands. *Pennyslvania Stormwater Management Manual.* Retrieved from http://www.bfenvironmental.com/pdfs/ConstrWetlands.pdf

"Secchi Depths." Illinois Environmental Protection Agency. N.p., n.d. Web. 22 Apr. 2015.

United States Environmental Protection Agency. Illinois: Governor Bond Lake. Retrieved From the Environmental Protection Agency website: http://water.epa.gov/polwaste/nps/success319/il_govlake.cfm

United States Environmental Protection Agency. (1995, September). Watershed and In-lake Practices Improve Green Valley Lake, Iowa. Retrieved From the Environmental Protection Agency website: http://water.epa.gov/type/lakes/clnlake.cfm

United States Geological Survey. (2014). [Land use data for given location]. *The National Map Viewer*. Retrieved from http://viewer.nationalmap.gov/viewer/

United States Geological Survey. (2014). [Precipitation and discharge data for Sinsinawa River near Menominee, IL]. *Illinois Department of Natural Resources*. Retrieved from http://waterdata.usgs.gov/nwis/dv?referred_module=sw&site_no=05414820

University of Illinois. (2015). Farmdoc. *US Average Farm Price Received Database*. Retrieved from http://www.farmdoc.illinois.edu/manage/uspricehistory/us_price_history.html

Walker, Jeff D. (2014). [ABCD water balance model theory and calibration]. *ABCD Water Balance Model.* Retrieved from http://abcd.walkerjeff.com/calibration.html

Appendix:

Table 1. HydroCAD assumptions of land use

NLCD Denotation	HydroCAD Denotation
Developed/Open Space	50-75% Grass Cover (Fair)
Developed/Low Intensity	Residential 1 acre
Deciduous Forest	Woods (Fair)
Shrub/Shrub	Brush (Fair)
Hay/Grass/Pasture	Pasture, Grassland (Fair)
Cultivated Crop	Straight Row (Good)
Herbaceous	Herbaceous (Fair)
Woody Wetland	Woods (Good)

Table 2. Corn Prices over time

farm.doc

US Monthly Average Corn Price Received for the 2001 - 2014 Calendar Year(s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg*
						$/bu.							
2001	1.98	1.96	1.96	1.89	1.82	1.76	1.87	1.90	1.91	1.84	1.85	1.98	1.89
2002	1.97	1.93	1.94	1.91	1.93	1.97	2.13	2.38	2.47	2.34	2.28	2.32	2.13
2003	2.33	2.34	2.33	2.34	2.38	2.34	2.17	2.15	2.20	2.12	2.20	2.31	2.27
2004	2.39	2.61	2.75	2.89	2.87	2.79	2.51	2.34	2.20	2.15	2.05	2.04	2.47
2005	2.12	1.95	2.02	2.00	1.98	2.03	2.11	1.95	1.90	1.82	1.77	1.92	1.96
2006	2.00	2.02	2.06	2.11	2.17	2.14	2.14	2.09	2.20	2.54	2.87	3.01	2.28
2007	3.05	3.44	3.43	3.39	3.49	3.51	3.32	3.26	3.29	3.29	3.43	3.76	3.39
2008	3.97	4.53	4.70	5.15	5.28	5.48	5.24	5.26	5.02	4.37	4.26	4.10	4.78
2009	4.36	3.87	3.86	3.85	3.97	4.03	3.60	3.33	3.25	3.61	3.65	3.59	3.75
2010	3.66	3.55	3.55	3.41	3.48	3.41	3.49	3.65	4.08	4.32	4.55	4.82	3.83
2011	4.94	5.64	5.53	6.35	6.30	6.38	6.32	6.88	6.37	5.71	5.84	5.86	6.01
2012	6.07	6.28	6.35	6.34	6.33	6.37	7.14	7.63	6.89	6.77	7.02	6.87	6.67
2013	6.96	7.04	7.13	6.97	6.97	6.97	6.79	6.21	5.40	4.61	4.35	4.41	6.15
2014	4.42	4.35	4.51	4.71	4.71	4.49	4.05	3.63	3.48	3.56	3.58	3.78	4.11

- *The average in the above table is the calendar year average.

Table 3. Soybean prices over time

farm.doc

US Monthly Average Soybeans Price Received
for the 2001 - 2014 Calendar Year(s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg*
						$/bu.							
2001	4.68	4.46	4.39	4.22	4.33	4.46	4.79	4.85	4.53	4.09	4.16	4.20	4.43
2002	4.22	4.22	4.38	4.47	4.64	4.88	5.35	5.53	5.39	5.20	5.46	5.46	4.93
2003	5.51	5.55	5.59	5.82	6.07	6.09	5.82	5.68	6.06	6.60	7.05	7.17	6.08
2004	7.35	8.28	9.28	9.62	9.56	9.08	8.46	6.83	5.84	5.56	5.36	5.45	7.56
2005	5.57	5.42	5.95	6.03	6.20	6.58	6.84	6.15	5.77	5.67	5.62	5.77	5.96
2006	5.88	5.67	5.57	5.52	5.68	5.61	5.61	5.23	5.24	5.52	6.07	6.18	5.65
2007	6.38	6.87	6.95	6.88	7.13	7.51	7.56	7.72	8.18	8.36	9.41	10.00	7.75
2008	9.96	11.70	11.50	12.00	12.10	13.20	13.30	12.80	10.70	9.94	9.38	9.24	11.32
2009	9.97	9.55	9.12	9.79	10.70	11.40	10.80	10.80	9.75	9.44	9.53	9.80	10.05
2010	9.79	9.41	9.39	9.47	9.41	9.45	9.79	10.10	9.98	10.20	11.10	11.60	9.97
2011	11.60	12.70	12.70	13.10	13.20	13.20	13.20	13.40	12.20	11.70	11.70	11.50	12.52
2012	11.90	12.20	13.00	13.70	14.00	13.90	15.40	16.20	14.30	14.20	14.30	14.30	13.95
2013	14.30	14.60	14.60	14.40	14.90	15.10	15.30	14.10	13.30	12.50	12.70	13.00	14.07
2014	12.90	13.20	13.70	14.30	14.40	14.40	13.10	12.40	10.90	9.97	10.20	10.30	12.48

- *The average in the above table is the calendar year average.

Table 4. Wheat prices over time

farm.doc

US Monthly Average Wheat Price Received
for the 2001 - 2014 Calendar Year(s)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Avg*
						$/bu.							
2001	2.84	2.83	2.87	2.86	2.98	2.74	2.63	2.74	2.85	2.87	2.87	2.88	2.83
2002	2.87	2.83	2.87	2.83	2.81	2.92	3.21	3.63	4.21	4.38	4.25	4.06	3.41
2003	3.89	3.70	3.55	3.37	3.33	3.08	2.95	3.35	3.39	3.44	3.61	3.68	3.45
2004	3.68	3.77	3.83	3.88	3.82	3.55	3.37	3.27	3.36	3.43	3.46	3.40	3.57
2005	3.43	3.36	3.42	3.35	3.31	3.23	3.20	3.24	3.35	3.43	3.47	3.54	3.36
2006	3.52	3.66	3.79	3.81	4.09	4.01	3.89	3.91	4.06	4.59	4.59	4.51	4.04
2007	4.54	4.71	4.75	4.89	4.88	5.03	5.17	5.64	6.75	7.65	7.36	7.74	5.76
2008	7.93	9.98	10.60	10.00	8.87	7.62	7.16	7.64	7.43	6.67	6.28	5.97	8.01
2009	6.21	5.79	5.70	5.74	5.84	5.67	5.13	4.83	4.48	4.47	4.79	4.85	5.29
2010	4.92	4.73	4.70	4.42	4.33	4.17	4.50	5.44	5.83	5.87	6.13	6.45	5.12
2011	6.71	7.43	7.54	8.04	8.16	7.40	7.10	7.61	7.55	7.29	7.26	7.19	7.44
2012	7.04	7.10	7.19	7.11	6.67	6.70	7.93	8.04	8.27	8.38	8.46	8.29	7.60
2013	8.12	7.97	7.78	7.71	7.68	7.32	6.93	6.87	6.80	7.00	6.85	6.73	7.32
2014	6.66	6.49	6.75	6.82	7.08	6.49	6.16	5.98	5.74	5.71	6.05	6.11	6.34

- *The average in the above table is the calendar year average.

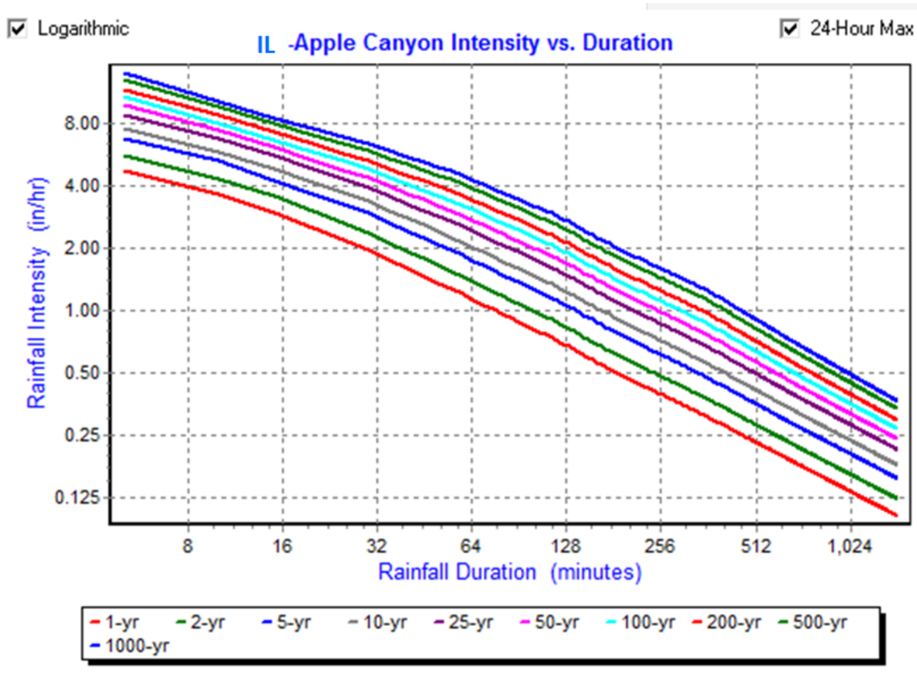


Figure 1. Storm data used in HydroCAD

11.7 Appendix 7. University of Wisconsin Platteville, Dry Dam Report

APPLE CANYON LAKE: DRY DAM EVALUATION, REPAIR, AND MAINTENANCE

Final Report

Nicolette Rizzo, Dan Scherer, James Seibert, Cassie Yustus

Executive Summary

This report provides Apple Canyon Lake residents with an evaluation of the existing conditions at fourteen dry dam locations in Apple River, Illinois. The report also includes potential construction and maintenance measures to ensure the safety of the Dry Dam Structures (DDSs) and the surrounding areas. Engineering analyses were conducted to verify the location, purpose, and viability of each DDS.

The project was conducted in three phases: evaluation; repair recommendations; and cost estimates. Phase 1 focused on providing an evaluation of each dry dam based on observation of each dry dam and identification of existing dry dam conditions. Inspections were conducted using a checklist form created by DAM Consulting. Phase 2 focused on the repair of the DDS, recommending feasible solutions for each of the dry dam concerns identified in Phase 1. Five structures were determined to be the most problematic, based on visual inspections, and were selected based on Hazard Classifications. Based on the results of the hydrologic analyses and inspections, two design alternatives were proposed for each of the five problematic structures. Phase 3 focused on maintenance recommendations for the design life of each of the structures and implementation costs were estimated for each design alternative.

Implementation of these alternatives should effectively reroute runoff, reducing the velocities at the sites and minimizing future erosion at the sites. The total recommended construction cost for the five selected sites was estimated to be approximately $288,000. Conclusions and recommendations are provided using applicable codes and regulations, in collaboration with the Apple Canyon Lake Homeowners Association representative.

Table of Contents

Table of Figures:

Table of Tables:

1.0 Introduction

1.1 Background Information:

DAM (Design And Maintenance) Consulting – *Civil/Environmental Engineering Services* was tasked with evaluating, and providing repair and maintenance recommendations for dry dam structures (DDS). These are located within the Apple Canyon Lake Homeowners Association (ACLHA) property limits located in Thompson Township, Illinois as seen in the Figure 1 location map. ACLHA sought engineering consulting to verify the location, purpose, and viability of each DDS. DAM Consulting sought to provide Apple Canyon Lake residents with an evaluation of the existing conditions of the dry dams, and potential construction and maintenance measures to ensure the safety of the DDS and the surrounding areas.

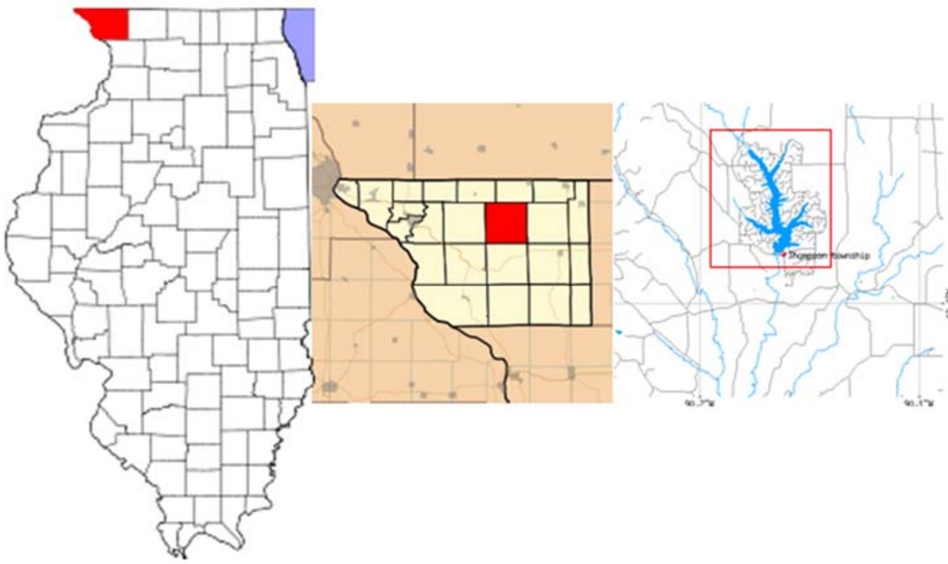


Figure 1 Location of project site.

1.2 Problem Statement:

The purpose of this project was to provide ACLHA with an evaluation of existing conditions of fourteen dry dams. The five most problematic structures were selected based on the visual inspections. The project also included recommended construction and maintenance measures for the five structures. Construction and maintenance was conducted to ensure the safety of the DDS and the surrounding areas. Based on the results of the analyses and inspections, two design alternatives were proposed to the client with cost estimates for each of the five problematic structures.

1.3 Project Objectives:

The project was divided into three phases in order to provide a separate deliverable for each portion of the project were: evaluation; determining repair recommendations; and calculating the cost estimates. Phase 1 focused on providing an evaluation using field observation and identification of existing dry dam conditions. Phase 2 focused on repair of the DDS, recommending feasible solutions for the identified dry dam concerns determined in Phase 1. Phase 3 focused on cost estimates and maintenance recommendations for the design life of the structures. Due to time constraints, Phases 2 and 3 were only completed for the five most problematic structures. The objectives for each phase are listed below.

Phase 1: Observation and Identification of Existing Dry Dam Conditions

Phase 1 included the following objectives:

1. Review historical site conditions using information provided by the client.
2. Increase familiarity with engineering standards, data reporting, and overall consulting experience.
3. Develop a procedure (in checklist form) for a dam analysis in order to more efficiently complete site analysis.
4. Perform site visits, observing current conditions and identifying existing concerns.

Phase 2: Recommendation of Feasible Solutions for Identified Dry Dam Concerns

Phase 2 included the following objectives:

1. Identify the five most problematic structures by reviewing the observations conducted during Phase 1.
2. Analyze alternative solutions using computer software to test the efficiency of potential methods.
3. Compile and prioritize a list of feasible solutions for future implementation.

Phase 3: Estimate Cost and Maintenance for Alternative Solutions

Phase 3 included the following objectives:

1. Determine the design life for each investigated structure.
2. Propose a feasible maintenance/repair schedule for each individual structure.
3. Provide an estimated maintenance/repair cost analysis.

1.4 Project Constraints:

The project constraints include:

1. Design and maintenance standards following Illinois Department of Natural Resources (IL DNR) and other applicable codes.
2. Accessibility of DDSs due to private property boundaries, minimal access roads, and/or hindering obstructions. Additionally, accessibility of structures is limited to the hours of 8am-5pm.
3. Site evaluations must be conducted prior to the seasonal change to ensure the proper function of the structure is observed.

1.5 Project Deliverables:

DAM Consulting provided ACLHA with the following deliverables:

1. A technical report including inspection checklists, hydrologic analyses results, cost estimates, design recommendations, and maintenance recommendations.
2. Presentation of findings to the Property Owners Association of Apple Canyon Lake.

1.6 Changes to Scope of Work:

DAM Consulting was originally tasked with inspecting and providing construction repair, maintenance recommendations, and cost analyses for 22 structures. Due to time constraints, Phase 1 inspections were only completed on 14 structures that were selected by the client. Additionally, Phases 2 and 3 were completed only for the five most problematic structures.

2.0 Phase 1 – Observation and Identification of Existing Dry Dam Conditions

Phase 1 focused on providing an evaluation through observation and identification of existing dry dam conditions. The location of each structure can be seen in the Retention Structure Location Map in Appendix A.

All recommendations and existing conditions were based only on visual inspection unless otherwise noted and discussed in Section 3.0. Inspections were conducted using a checklist form created by DAM Consulting. All inspection checklists, comments, and observations noted during the inspections are included in Appendix B. Each structure was evaluated using standards developed by the Connecticut Department of Energy and Environmental Protection (CDEEP). The CDEEP developed two primary standards that were utilized when evaluating structures: "Overall Dam Condition Selection Standards" and "Hazard Classification of Dams." The "Overall Dam Condition Selection Standards" provide definitions to classify the condition of an existing structure ranging from "Good" to "Unsatisfactory" (Table 1). The "Hazard Classification of Dam" assisted in the assessment of risk for the structure. Risk is defined in terms of consequences of failure and the probable damage and loss that would be associated with the failure. For additional details of the CDEEP refer to Appendix K. The observations of the existing DDS conditions are included in the following sections. Note that all references to the "trail" refer to the recreational trail extending around the perimeter of Apple Canyon Lake.

Table 1 CDEEP Primary Standards

Hazard Classification	Definition
Class AA	Negligible hazard potential to roadways and structures
Class A	Low hazard potential to agricultural land and unimproved roadways
Class BB	Moderate hazard potential to unoccupied storage structures and low volume roadways
Class B	Significant hazard potential to primary roadways, habitable structures, and possible loss of life
Class C	High hazard potential to main highways, habitable structures, and probable loss of life
Condition	Definition
Good	The dam is well maintained and no existing safety deficiencies are recognized
Satisfactory	No significant deficiencies are recognized
Fair	No critical deficiencies
Poor	Deficiencies are present that require remedial action.
Unsatisfactory	Deficiencies are present that require immediate or emergency action.

2.1 Structure 2: Thunder Court Dry Dam

2.1.1 Structure Information

The general purpose of Structure 2 is to collect upstream runoff into the existing Hickenbottom riser (Figure 2). A Hickenbottom riser is a type of surface inlet designed by Hickenbottom, Inc.[1] that is placed at the bottom of a depression to rapidly drain surface water into a system of buried drains lines. The Hickenbottom riser is located in a ditch line, which runs parallel to the trail. The riser itself has a 12 inch diameter with 1 inch diameter slots spaced 3 inches vertically and 2 inches horizontally. There is a berm following the riser to prevent runoff from continuing to flow downstream. The runoff is routed into the riser which prevents overtopping of the trail. Overtopping could potentially result in downstream erosion.

2.1.2 Existing Concerns Observed

The following concerns were observed:

1. Degradation of the material on the berm, due to overtopping.
2. Debris collected in the riser, which prevents maximum efficiency of flow.
3. The sediment accumulated around the riser, which exposes a height of only 16 inches of the 53-inch riser (Figure 2). Sedimentation drastically decreases the efficiency of flow into Apple Canyon Lake.
4. A mudslide occurred upstream, most likely from rainfall and/or the velocity of runoff. This would be the cause of the sediment accumulated around the riser.

Figure 2 Exposed portion of Hickenbottom riser at Structure 2.

This site was deemed one of the five most problematic structures. Design considerations and recommendations for this site are discussed in Section 3.1. Structure 2 was determined to be a Hazard Class A dam (low hazard), in fair condition. If the structure were to fail, there would be minimal economic loss.

[1] (Hickenbottom Incorporated, 2013)

2.2 Structure 5: Winchester Dry Dam

2.2.1 Structure Information

The general purpose of Structure 5 is to reroute runoff, through a downstream trail, to prevent overtopping of the trail. The structure is fed by two streams that are flowing from the South and East. The water is rerouted through a corrugated riser that has 1-inch by 3-inch slots cut into it with approximately 1 foot spacing's (Figure 3 and Figure 4). The slots allow runoff to drain at a controlled rate.

2.2.2 Existing Concerns Observed

The structure was in satisfactory condition, appearing to be well maintained with no existing safety deficiencies. The hazard classification was Class A (low hazard); if the structure was to fail, only the unimproved roadway would potentially be damaged.

Figure 3 Corrugated riser at Structure 5.

Figure 4 Corrugated riser with 1 inch by 3 inch slots.

2.2.3 Recommendation Based on Existing Conditions

Continuation of current site management practices is recommended for this site, including clearing of vegetation.

2.3 Structure 7: Washington Cove Culvert

2.3.1 Structure Information

Structure 7 is a six-foot diameter culvert fed by an additional culvert upstream. The upstream culvert is a six-foot diameter culvert, located under Lake Road. A pooling area is located directly downstream from the Lake Road culvert. The pooling area is caused by erosion, which is a result of the outlet of the Lake Road culvert being too high. Water drops two feet from the outlet to the pooling area. The Structure 7 culvert contains riprap around the inlet and outlet and is located underneath a recreational trail (Figure 5). It was noted that heavy construction vehicles from the adjacent rock quarry frequently drive over the trail.

2.3.2 Existing Concerns Observed

The following concerns were observed:

1. The two-foot outlet height of the culvert under Lake Road.
2. Erosion upstream and downstream of the structure (Figure 6 and Figure 7).
3. Trees interfering with the area of flow.
4. Inadequate riprap under the outlet of the Lake Road culvert and around the inlet of Structure 7 culvert.
5. Compression of the culvert pipe under the trail. The compression was thought to be caused from vehicle impact loads and the repetitive loading on the trail on top the culvert.
6. Scouring occurring under Lake Road. Scouring is the removal of soil by water which undermines the structure, compromising its structural integrity.

Figure 5 Comparison of riprap placement at culvert inlet in Structure 7.


Figure 6.Upstream erosion at Structure 7.


Figure 7 Culvert upstream of culvert 7 (under Lake Road).

Overall the structure was determined to be Class A (low hazard), in satisfactory condition. However, if the current erosion, scour, and compression of the pipe are allowed to continue it is predicted that the structural integrity will rapidly degrade. The degradation could lead to the pipe collapsing or sedimentation from scour and erosion being transported downstream and into Apple Canyon Lake.

The site was deemed one of the five most problematic sites. Design considerations and recommendations for this site are discussed in Section 3.2.

2.4 Structure 8: Constitution Dry Dam

2.4.1 Structure Information

The general purpose of Structure 8 is to reroute runoff through a trail downstream to prevent overtopping. Runoff from upstream farm fields is routed into a culvert that was constructed underneath the trail. The structure has been vegetated over.

2.4.2 Existing Concerns Observed

The following concerns were observed:

1. Overgrowing vegetation was blocking pipe (Figure 8).
2. Downstream riprap was larger in size than the upstream riprap.
3. Farm field upstream of the structure may have nutrients running off during large rain events (Figure 9)

Figure 8 Structure 8 upstream corrugated pipe with overgrown vegetation pulled back.

Figure 9 Farm field on left of picture and roadway on right of picture looking downstream of Structure 8.

The structure was determined to be Class A condition. There would be minimal loss to the condition of the roadway and minimal economic loss if the structure was to fail. The structure had no significant deficiencies and overall condition was deemed satisfactory through visual inspection.

2.4.3 Recommendation Based on Existing Conditions

Dam Consulting recommended that routine maintenance be performed at the site to clear the vegetation in the flow path of the pipe.

2.5 Structure 11: Hawthorne Dry Dam

2.5.1 Structure Information

The general purpose of the structure is to control the flowrate and velocity of the runoff. The structure is a hooded inlet that allows the runoff to flow at full capacity without air intrusions. The inlet prevents the pipe from acting like a milk jug when water is being dumped out.

2.5.2 Existing Concerns Observed

The following concerns were observed:

1. Erosion occurring underneath the outlet of the structure.
2. The downstream culvert was damaged and eroded (Figure 10 and Figure 11). If the culvert continues to undercut, the structure could collapse resulting in the road collapsing.
3. Erosion occurring downstream of outlet.

Figure 10 Culvert damage downstream of Structure 11.

Figure 11 Erosion occurring downstream of Structure 11.

The Structure was determined to be Hazard Class BB. If the structure failed, there would be damage to a low volume roadway with moderate economic loss. The overall condition of the structure was deemed good because it is well maintained with no existing safety deficiencies.

2.5.3 Recommendation Based on Existing Conditions

Routine maintenance and monitoring of the erosion under the outlet is recommended.

2.6 Structure 12: #9 Hole/Marina

2.6.1 Structure Information

Structure 12 consists of four dry dams, all installed to slow down and reroute the flow of runoff on the golf course. A retention pond was installed to collect runoff from a culvert that passed under the golf cart trail. The culverts are fed by two dry dams. The first dry dam is a culvert located by the fence in Figure 12 and is fed by a riser located East of the white fence. The second dry dam is a riser in the woods located North of the culvert. The culvert, which is fed by the two dry dams, discharges the runoff into a pond (Figure 13). The forth dry dam is a pond containing riprap and vegetation. Vegetation covered most inlet and outlet structures. However, grates and other protection measures prevent obstruction of the flow channel (Figure 14).

Figure 12 Culvert fed by two dry dams at Structure 12.

Figure 13 Structure 12 where all water collected flows into.

Figure 14 Grates on Structure 12 dry dam to block large debris.

The structure was determined to be in good condition with a hazard classification of BB. Only minor damage to the golf course could potentially occur if the structure was to fail. Minor damage was specified as flooding of the golf course.

2.6.2 Recommendation Based on Existing Conditions

Dam Consulting recommended that the maintenance schedule and work that is ongoing at the structure continue, which included clearing vegetation.

2.7 Structure 13: Fairway Dry Dam A

2.7.1 Structure Information

Structure 13 is an earthen dam with a culvert pipe rerouting runoff through it and discharging into a stream channel on the south side. The purpose of the structure is to control water velocity and settle out solids. A detention pond is located upstream of the structure, which collects runoff from Structure 14, Fairway Dry Dam B (Figure 15). The purpose of a detention pond is to store water temporarily and slowly drain into the receiving channel. The detention bond has a width of 50 feet and a length of 240 feet. The trees bordering the detention pond contained watermarks, with a height of 6.5 feet, indicating flooding.

2.7.2 Existing Concerns Observed

The following concerns were observed:

1. The culvert pipe was located on top of a hill and had a tree blocking the inlet.
2. Excessive vegetation noticed upstream of the clearing.
3. Clay soil in the clearing may be preventing the water from infiltrating the soil properly.
4. Erosion of the structure noticed on both the upstream and downstream sides of the structure itself along with evidence of water over-topping the structure.
5. Damage to culvert pipe on the outlet side (Figure 16).
6. Height of the culvert outlet was higher the stream floor causing excess erosion.

Figure 15 Detention pond upstream of Structure 13.

Figure 16 Outlet of culvert at Structure 13.

DAM Consulting determined Structure 13 to be a Class A, in poor condition. If the structure were to fail, there would be damage to unimproved roadways along with minor economic loss. The site was deemed one of the five most problematic sites. Design considerations and recommendations are discussed in Section 3.3.

Structure 13 was the only structure that was close to a wetland as seen in Figure 17. Further information about this wetland can be seen in Appendix G[2]. The structure itself is outside of the delineated wetland boundaries. However, all recommendations for site improvements of the structure shall be to not disturb the wetland area upstream of the structure. The wetland structure should not be disturbed because of the additional permitting, regulations and other cost associated with disturbing a wetland area. All other structures were checked using the Nation Wetland Inventory website in order to visually confirm that the structures were outside of the wetland boundaries.

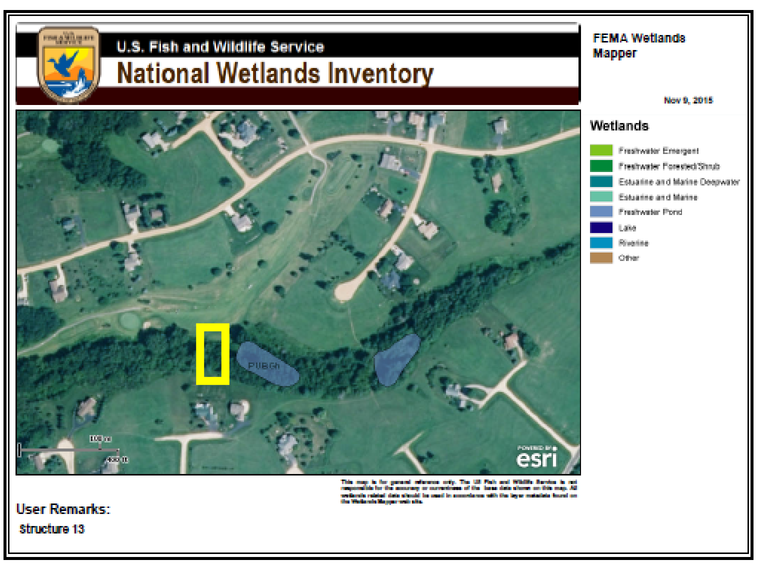


Figure 17 National wetlands inventory map showing wetland near Structure 13 (located inside the yellow box).

---

[2] (U.S. Fish & Wildlife Service, 2015)

2.8 Structure 14: Fairway Dry Dam B

2.8.1 Structure Information

The general purpose of Structure 14 is to reroute runoff through a trail perpendicular to the flow path in order to prevent overtopping. Structure 14 consists of a riser that has been recently reconstructed (Figure 18). Riprap has been placed downstream from the riser outlet.

2.8.2 Existing Concerns Observed

The following concerns were observed:

1. Two trees upstream of the structure may need to be removed.
2. Trees downstream of structure heading towards Structure 13 should be removed to widen flow channel.
3. Standing water was noticed on the upstream side of riser. This was due to the riser elevation being higher than the upstream surface elevation.

Figure 18 Structure 14 with two trees on left side of photo which may need to be removed.

The structure was determined to be a Hazard Class A. Economic loss to Structure 13 directly downstream may result from failure. The overall dam condition was deemed good because there were no existing dam safety deficiencies.

2.8.3 Recommendation Based on Existing Conditions

Dam Consulting recommended that trees upstream and downstream of the structure be removed to maintain structural stability. Additionally, the flow path to Structure 13 should be cleared.

2.9 Structure 15: Sand Trap Dry Dam

2.9.1 Structure Information

Structure 15 was a large earthen dam, containing no discharge pipes. Due to the amount of overgrown vegetation, a full dry dam evaluation could not be performed.

2.9.2 Existing Concerns Observed

Structure 15 is extremely over vegetated (Figure 19). Due to the limited access of the site, no further observations were made.

Figure 19 Aerial photograph of structure 15.

2.9.3 Recommendation Based on Existing Conditions

Dam Consulting recommends that small trees and vegetation be cleared to gain access to the structure.

2.10 Structure 18: Koester's Pond

2.10.1 Structure Information

Structure 18 is a retention pond located in close proximity to a farm field. The retention pond contains a permanent pool of water and allows particles to settle. The pond slowly discharges into a 12-inch PVC pipe which exits onto grouted riprap (Figure 20) and continues to flow into a culvert underneath a roadway.

2.10.2 Existing Concerns Observed

Upon inspection, Structure 18 was determined to be a Class AA dam in good condition. The only concern observed was a crack in the culvert abutment (Figure 21).

Figure 20 Outlet pipe structure 18.

Figure 21 Cracked abutment Structure 18.

2.10.3 Recommendation Based on Existing Conditions

Ongoing maintenance at the structure was recommended. DAM Consulting recommends that the abutment crack be monitored and repaired if cracking continues to the point of structural failure from lateral earth pressure.

2.11 Structure 19: Apache Dry Dam

2.11.1 Structure Information

The general purpose of Structure 19 is to control flowrate in the area. The structure consists of two 36-inch culvert pipes, a 15-inch drain tile, and an 8-inch Hickenbottom riser (Figure 22 and Figure 23). The water collects in these structures and flows through pipes that were constructed underneath the nearby trail.

2.11.2 Existing Concerns Observed

Dam Consulting determined Structure 19 to be a Class AA Dam in good condition. The structure is functioning as designed and any damage suffered due to the failure of the structure would result in minimal economic loss.

Figure 22 Hickenbottom riser at Structure 19.

Figure 23 Culvert pipe at Structure 19.

2.11.3 Recommendation Based on Existing Conditions

Recommendations included monitoring the pipes and riser to ensure flow is not obstructed by any debris.

2.12 Structure 20: Bedrock Stairs Dry Dam

2.12.1 Structure Information

Structure 21 is an earthen dam, located near the recreational trail, which controls the speed of runoff. The purpose of the structure is to prevent erosion and settle out solids. The structure consists of a riser installed upstream that drains through the structure and discharges into a stream (Figure 24 and Figure 25). The stream then runs through two culvert pipes under the recreational trail (Figure 26).

2.12.2 Existing Concerns Observed

The following concerns were observed:

1. Trees located on structures
2. Debris in stream could potentially back up flow of water

Figure 24 Upstream riser of Structure 20.

Figure 25 Outlet pipe of Structure 20.

Figure 26 Culverts under the trail at Structure 20.

This structure was determined to be a Class A dam in good condition. The dam is functioning as intended. If the structure were to fail only the unimproved roadway would be damaged.

2.12.3 Recommendation Based on Existing Conditions

Recommendations include routine clearing of the pipes.

2.13 Structure 21: Broken Lance Dry Dam

2.13.1 Structure Information

The general purpose of Structure 21 is to collect the upstream runoff into a corrugated pipe riser and reroute the runoff through an earthen berm, which was a walking trail (Figure 27 and Figure 28). The corrugated pipe riser contains a trash rack to block large debris from entering the riser.

2.13.2 Existing Concerns Observed

The following concerns were observed:

1. The high velocities from the downstream, corrugated pipe caused erosion to the ground surface. The discharged water cut deep into the sides of the downstream flow channel, causing the channel to have a slope of 80% (Figure 29).
2. The downstream bank of the earthen berm was eroded due to water overtopping the trail and washing away the soil (Figure 30).
3. Roots were grown into the side of the channel, which caused concerns for dam stability as the roots can undermine the structure and cause failure.
4. The channel leading to the riser contained debris (e.g. loose plants and branches) which could clog the riser.
5. Riser size appeared to be too small to efficiently handle the flow demand of a significant storm.
6. The height of the riser increased the pooled water depth resulting in erosion on the upstream slope.


Figure 27 View of walking trail from top of Structure 21.


Figure 28 Upstream side of Structure 21 with trash rack overgrown with vegetation.

Figure 29 Downstream drop of corrugated pipe for Structure 21.

Figure 30 Downstream side of channel being washed away at Structure 21.

The structure was given a hazard classification of B meaning that if the structure was to fail the economic loss could be significant. This was concluded for the following reasons: the potential loss of a small bridge downstream of the structure and the structure doubled as a trail which connects around all of Apple Canyon Lake. The structure was also determined to be in poor condition because it required engineering analysis and remedial action.

The site was deemed one of the five most problematic sites. Design considerations and recommendations for this site are discussed in Section 3.4.

2.14 Structure 22: Blue-Gray Dry Dam

2.14.1 Structure Information

Structure 22 was washed out in 2011 and no longer exists. The original piping of the structure was still in place but was not in useable condition.

2.14.2 Existing Concerns Observed

The following concerns were observed:

1. The existing reinforced concrete pipe (12-inch diameter and 25-feet long) was damaged and needs to be removed (Figure 31).
2. Soil conditions were soft and soil was saturated with water indicating the need for a dry dam.
3. Vegetation needs to be cleared leading to the structure if equipment needs to access the site (Figure 32).

Figure 31 Structure 22 failed reinforced concrete pipe.

Figure 32 Access to the proposed structure is through dense brush.

If Structure 21 were rebuilt, the structure would be a Class A structure, meaning that the runoff could damage the adjacent agricultural land and have minimal economic loss.

The site was deemed one of the five most problematic sites. With the increased development in the area, Dam Consulting recommended to rebuild the dry dam to control the flow and minimize erosion. Design considerations and additional recommendations for this site are discussed in Section 3.5.

3.0 Phase 2 – Design Alternatives for Identified Dry Dam Concerns

Phase 2 focused on the repair of the DDS by recommending feasible solutions for the concerns identified in Section 2.0. Of the 14 structures visually inspected in Phase 1, five structures were determined to be the most problematic (Structures 2, 7, 13, 21, and 22). Basic measurements required for hydrologic analyses of each structure were obtained using survey equipment. Measurements included lengths, diameters and heights relative to the top of the DDS. These measurements were determined using local elevations, which are point elevations with respect to one another.

Hydrologic analyses were conducted on each of the five structures to determine if the existing structure can convey the 100-year, 24 hour storm event. Hydrologic analyses were conducted using the following methods:

- ArcGIS, which is software for analyzing spatial and geographic data[3]. ArcGIS with Jo Daviess County LiDAR data was used to delineate the watershed contributing to the structure using. The delineation provided watershed geometry and land use characteristics in order to calculate the time of concentration and peak flow.
- HydroCAD, which is software for modeling stormwater runoff and designing stormwater best management systems[4]. HydroCAD was used to calculate the peak flow of the 100-year, 24 hour storm event from the contributing watershed. Peak flow was calculated using the Rational Method in HydroCAD and later verified using the SCS Method through hand calculations. Hand calculations can be seen in Appendix C. The Rational and SCS methods are defined below.
    - The Rational Method uses an empirical formula based on the runoff coefficient (C), the storm intensity (I), and the area of the watershed (A). The Intensity Duration Frequency (IDF) curve was entered into HydroCAD from the National Oceanic and Atmospheric Administration (NOAA) National Weather Service database, Appendix F[5]. The rainfall duration is equal to the time of concentration using this method. The runoff coefficient is based on the soil type and land cover, which was determined using the United States Department of Agriculture Web Soil Survey database, Appendix E[6].
    - The SCS Method uses an equation based on the runoff curve number (CN) and the time of concentration (t_c). The runoff curve number is a weighted average derived from the type of land use.

After modeling the existing conditions, alternative solutions were brainstormed for the structures that were unable to convey the 100-year, 24 hour storm event. Additional hydrologic analyses were conducted on the proposed alternative solutions using the following methods:

---

[3] (Esri, 2014)
[4] (HydroCAD Softwar Solutions LLC, 2011)
[5] (NOAA's (National Oceanic and Admospheric Administration) National Weather Service, 2015)
[6] (United States Department of Agriculture, 2013)

- HydroCAD was used to design feasible culverts that were able to convey the 100-year, 24 hour storm event. Culvert designs were based on the slope, diameter, material, and exit type.
- FlowMaster, which is a program that performs hydraulic calculations for conveyance systems[7]. FlowMaster was used to design feasible open channels that were able to convey the 100-year, 24 hour storm event. Open channel designs were based on the side slope, length, channel slope, depth, and allowable velocity.

The watershed characteristics and runoff peak flows for each structure calculated using the methodology described previously shown in Table 2 and Table 3. The hydrologic analyses and alternatives of each individual structure was will be discussed on a structure by structure basis in the following sections.

Table 2 Watershed Characteristics of 5 Problematic Structures

	Structure 2	Structure 7	Structure 13	Structure 21	Structure 22
Watershed Area (acres)	11.4	214	59	38	62
Hydrologic Soil Group	B	B	B	B	B
C Value (weighted)	0.36	0.46	0.62	0.36	0.30
CN Value (weighted)	65	75	68	59	63
Time of concentration, weighted (min)	22.50	82.26	29.31	17.75	26.23

Table 3 Peak Flows of 5 Problematic Structures

	Structure 2	Structure 7	Structure 13	Structure 21	Structure 22
Rational Method (cfs)	21.9	244	170	65.5	63.9
SCS Method (cfs)*	27.4	368	136	82.9	130.3

3.1 Structure 2: Thunder Court Dry Dam

Structure 2 was determined to be one of the five problematic structures. This was due to an upstream mudslide, which caused sediment and other debris to accumulate around the riser, preventing maximum efficiency of flow.

3.1.1 Hydrologic Analyses of Existing Structure

Using ArcGIS, the calculated watershed was 11 acres. An initial hydrologic analysis returned a peak flow of 22 cubic feet per second (cfs). Based on manufacturing specifications, the existing

[7] (Bentley Systems, Incorporated, 2009)

12-inch Hickenbottom Riser can only convey a flow of 5 cfs at a maximum water depth of 6 feet (Figure 33). Due to the inability of the riser to convey the peak flow, two alternative solutions were analyzed. Hydrologic Analyses of Structure 2 can be seen in Appendix C and D.

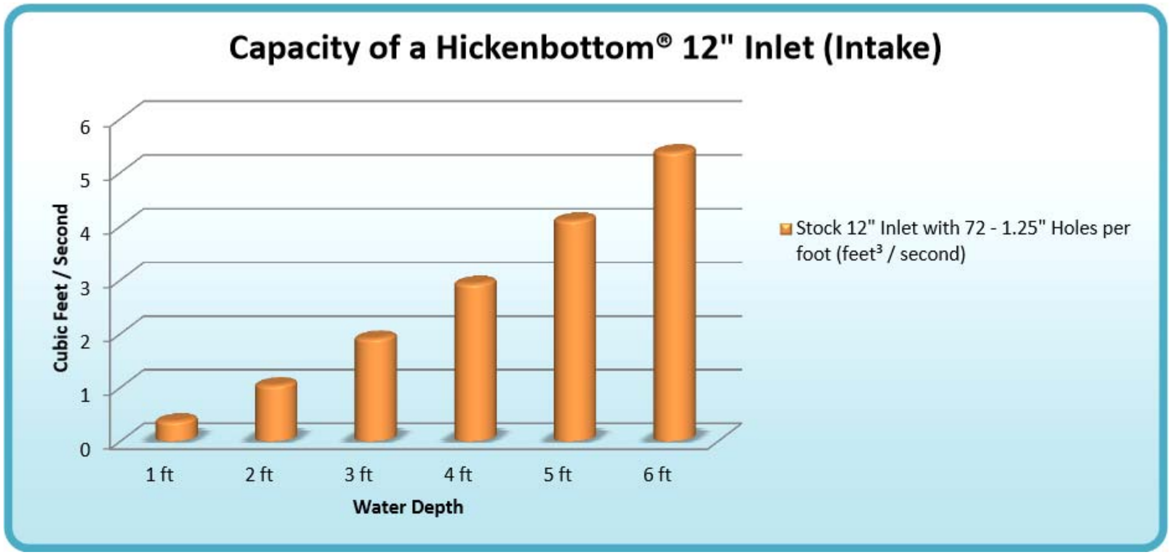


Figure 33 Capacity of a Hickenbottom 12" inlet.[8]

3.1.2 Alternative Solutions

A general overview of the structure location and alignment are shown in Figure 34. AutoCAD drawings can be found in Appendix I. Two alternative designs are described in the subsequent section.

[8] (Hickenbottom Incorporated, 2013)

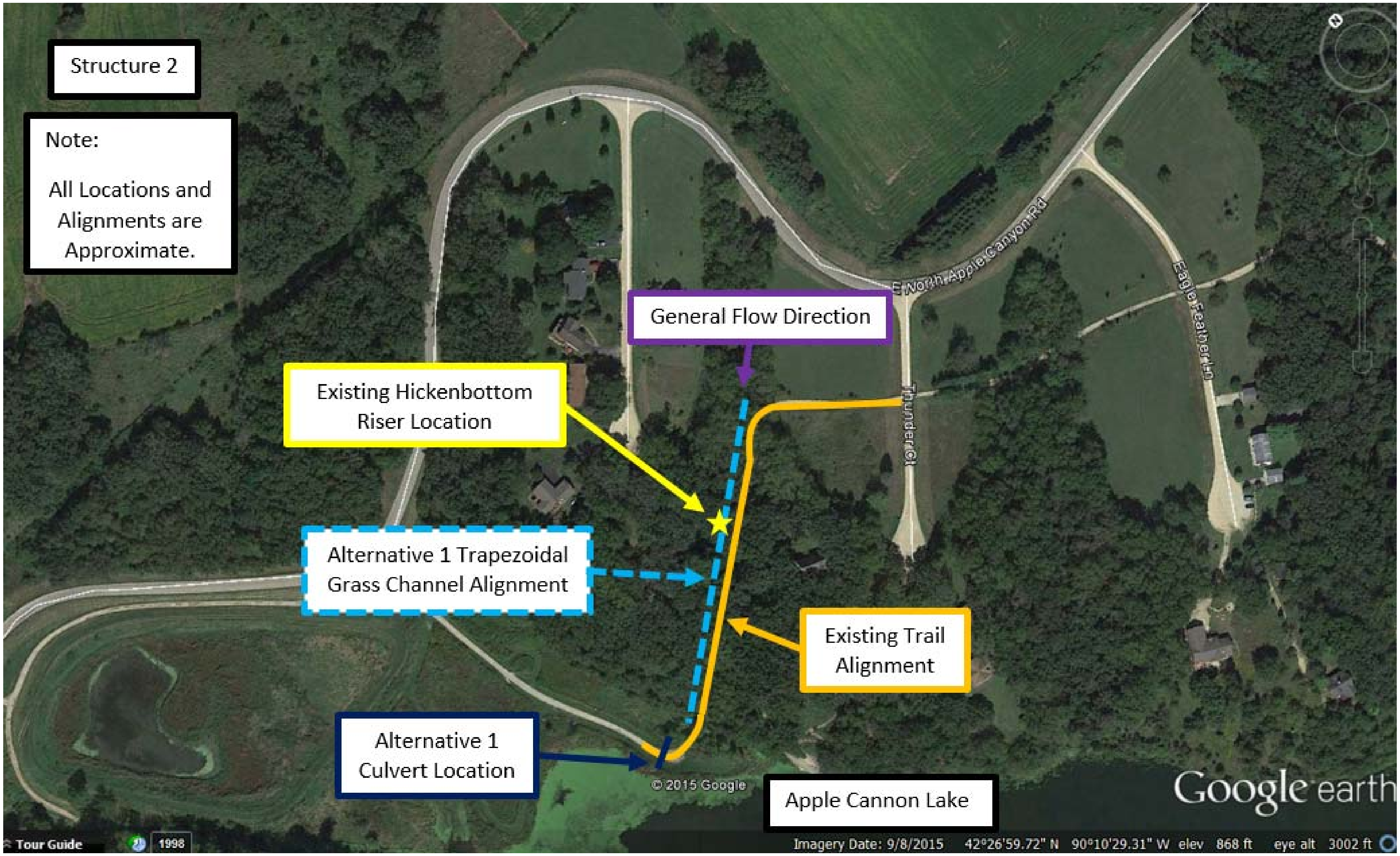


Figure 34 Structure 2 approximate alternatives locations and alignments.

3.1.2.1 Alternative 1: Trapezoidal Grass Channel

Alternative 1 is to remove the existing riser and earthen structure and replace it with a trapezoidal grass channel (Figure 35). Velocity at the existing structure exceeds the allowable 3 ft/s[9]. This channel will effectively slow the velocity of the runoff to 2 ft/s. This velocity is below the allowable velocity which will prevent erosion. The channel follows the path of accumulation, mimicking the ditch line parallel to the trail, for a length of 600 feet. This alternative would require the addition of a culvert through a trail that intersects the channel. HydroCAD was used to design a 600-foot long, 24-inch Reinforced Concrete Pipe (RCP) culvert pipe which can convey the peak flow of 22 cfs. Following the culvert, the runoff discharges into the lake. FlowMaster recommended the channel dimensions to be 8 feet wide at the top, 4 feet wide at the bottom, and 2 feet deep (Appendix I, page 4).

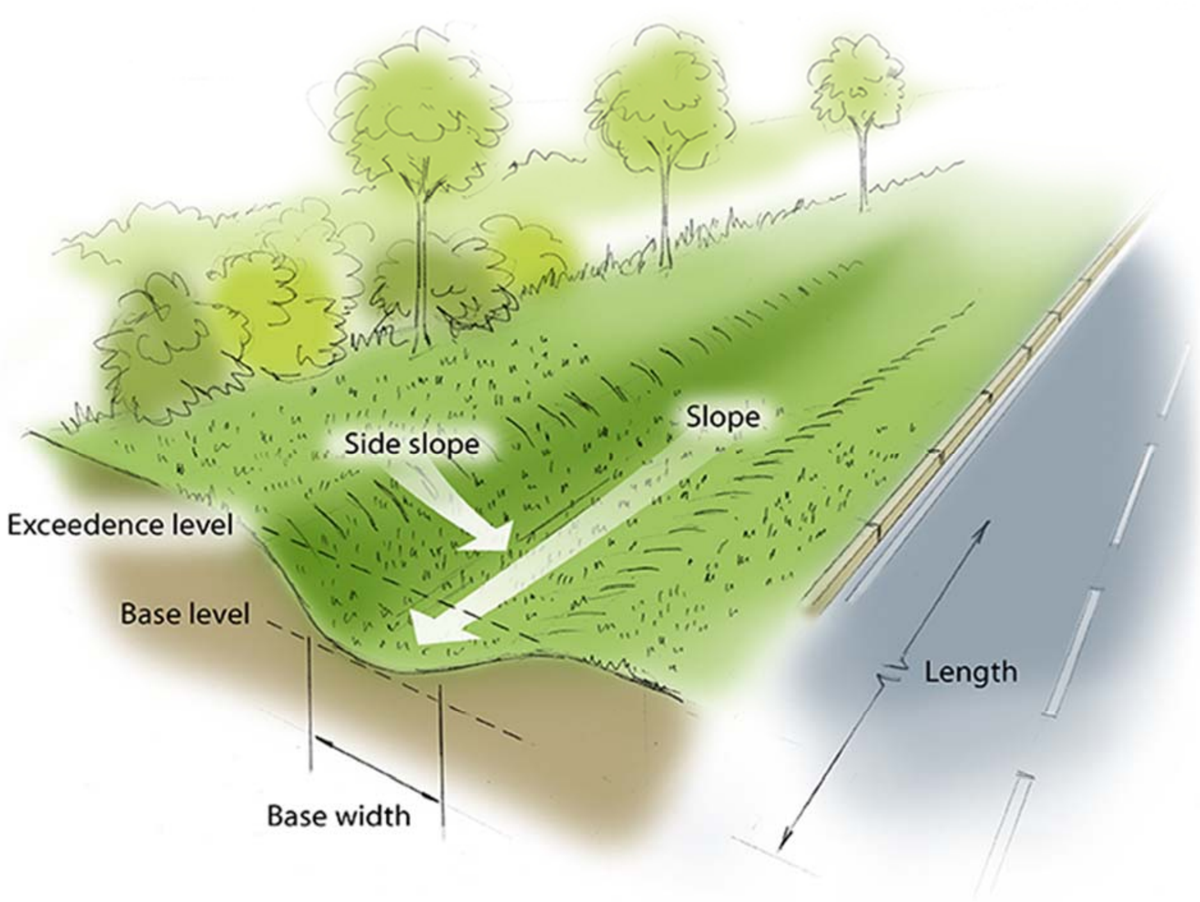


Figure 35 Typical Cross-section of a trapezoidal grass channel.

3.1.2.2 Alternative 2: Excavation with Regular Maintenance

Alternative 2 is to leave the existing structure in place. Excavation would be required to fully expose the Hickenbottom Riser and the maximize capacity of flow (Appendix I, Page 5). Based on the model, the current conditions of the riser can convey a flow of 0.7 cfs. If the riser was fully

[9] (United States Department of Agriculture, 2007)

exposed, the maximum flow that the riser could convey is 6 cfs. This is still substantially lower than the peak flow of 22 cfs. This alternative would require regular clearing of sediment and debris build up obstructing the inlets of the riser.

3.2 Structure 7: Washington Cove Culvert

Structure 7 was determined to be one of the five problematic structures. This was due to erosion around the side slope and compression of the culvert pipe.

3.2.1 Hydrologic Analyses of Existing Structure

Using ArcGIS, the calculated watershed was 214 acres. An initial hydrologic analysis returned a peak flow of 244 cfs. The existing culvert can convey a peak flow of 206 cfs with 37 cfs overtopping the trail (Appendix B, Figure 3). Hydrologic analyses of Structure 7 can be seen in Appendix B.

Two alternative solutions were analyzed to prevent erosion upstream and downstream of the structure. Both alternatives include the following repairs:

- Removal of trees to reduce the amount of debris falling into the drainage area and allow for the placement of more uniform slope protection.
- Placement of larger riprap under the Lake Road culvert pipe to reduce the amount of scouring and prevent the riprap from being carried downstream.
- Riprap placed around the inlet of the culvert pipe in the structure to prevent downstream erosion.
- Additional fill between the road and the culvert pipe to reduce pressure on the pipe.

From these observations DAM Consulting recommends two alternatives for this structure.

3.2.2 Alternative Solutions

A general overview of the structure location and alignment are shown in Figure 36. AutoCAD drawings can be found in Appendix I.

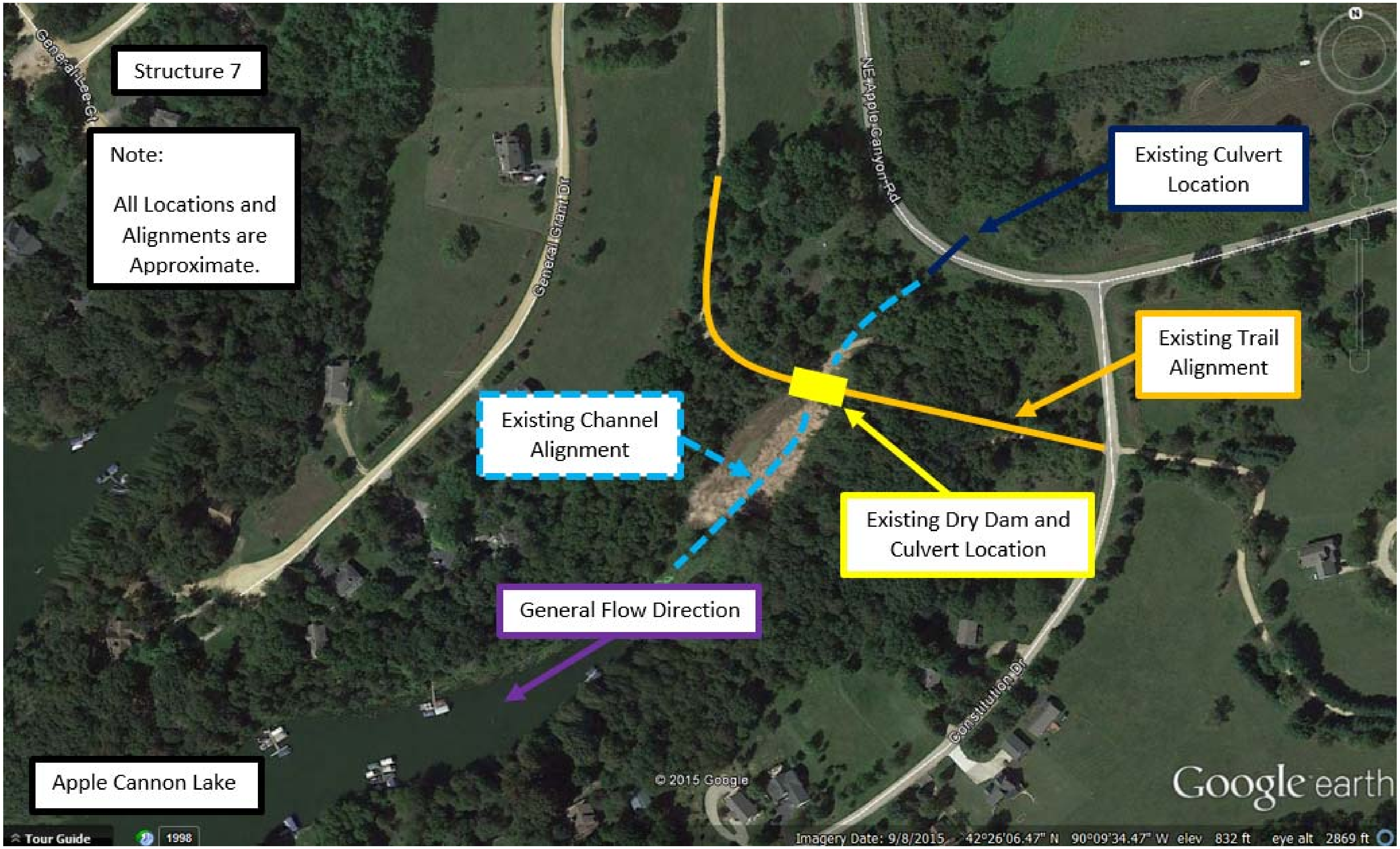


Figure 36 Structure 7 approximate alternatives locations and alignments.

3.2.2.1 Alternative 1: Addition of Cover to Existing Structure

Alternative 1 includes adding 1 foot of cover on top of the existing culvert pipe. The additional fill will decrease the stress acting on the culvert pipe (Figure 37). If the 100-year, 24 hour storm occurred with this alternative, 30 cfs of water would overtop the structure for approximately 40 minutes. The overtopping of the structure is unlikely to cause significant damage to the structure, as the velocity of the water overtopping the structure will be minimal. Overtopping is acceptable for the 100-year, 24 hour storm event because of the short duration of overtopping and low velocity of the overflow waters.

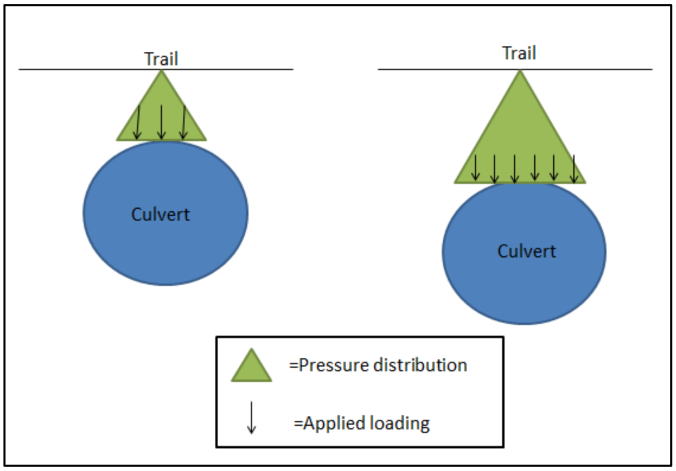


Figure 37 Diagram of pressure distribution on culvert.

3.2.2.2 Alternative 2: Replacement of Existing Pipe with 60" Reinforced Concrete Pipe

Alternative 2 is to remove the existing culvert pipe underneath the trail and replace it with a 42-foot long, 60-inch diameter Reinforced Concrete Pipe (RCP) culvert. The RCP culvert is stronger than the existing 72-inch diameter Corrugated Metal Pipe (CMP). This additional strength will increase the factor of safety, allowing for heavy vehicles to pass over the trail without damaging the pipe. The factor of safety is the ratio of the allowed load over the applied load. If the 100-year, 24 hour storm event occurred for this alternative, 12 cfs of water would overtop the structure for approximately 10 minutes. Overtopping is acceptable for the 100-year, 24 hour storm event because of the short duration of overtopping and low velocity of the overflow waters.

3.3 Structure 13: Fairway Dry Dam A

Structure 13 was chosen to be one of the five problematic structures. Structure 13 has a culvert that will not flow at full capacity before overtopping. The height of the culvert outlet was noted to be four feet above the ground elevation, which led to excess erosion downstream.

3.3.1 Hydrologic Analysis of Existing Structure

Using ArcGIS, the calculated watershed was 59 acres. An initial hydrologic analysis returned a peak flow of 170 cfs. The existing culvert was improperly located to function at full capacity. The existing culvert is located such that several inches of the culvert inlet is above the trail elevation. Flow will overtop the trail before the existing culvert flows full. Hydrologic Analyses of Structure 13 can be seen in Appendix C and D. Neither alternative impact the wetland because they are outside of the wetland location (Figure 17)

3.3.2 Alternative Solutions

A general overview of the structure location and alignment are shown in Figure 38 AutoCAD drawings can be found in Appendix I.

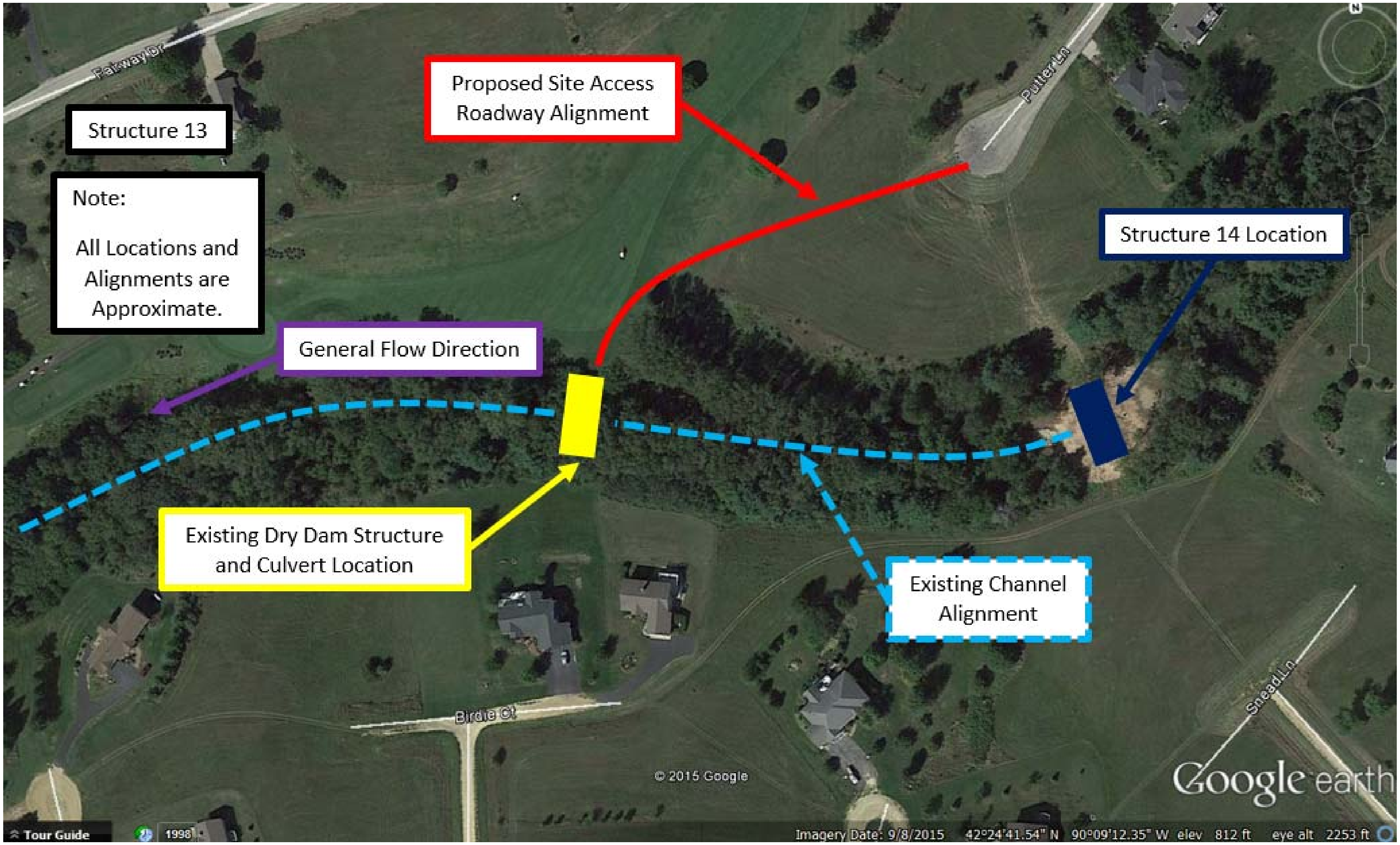


Figure 38 Structure 13 approximate alternatives locations and alignments.

3.3.2.1 Alternative 1: Replace Structure with 2 Culverts

Alternative 1 is to remove the existing culvert and replace it with two 15 feet long, 36-inch RCP culverts. The location of the culverts would be moved to the center of the earthen berm (trail), as the existing culvert is located at the highest elevation of the detention pond. The peak flow flowing from the detention pond into the DDS was calculated, in HyroCAD, as 170 cfs. The peak flow discharging from the structure was 159 cfs. No overtopping of the earthen berm would occur.

3.3.2.2 Alternative 2: Maintenance on Existing Structure

Alternative 2 is to leave the existing structure in place while performing maintenance upstream and downstream of the culvert. A large tree is located near the inlet of the structure and needs to be removed as it is obstructing the flow of runoff. Damage to the culvert pipe was observed and should be repaired to stabilize the structure and maximize the flow. Rocks should be placed underneath the outlet of the structure to prevent further erosion from occurring. Erosion was also observed downstream of the channel. However, no recommendations were made as the downstream channel is outside of the scope of the project.

The detention pond located upstream of the dry dam, which has been deemed a wetland by the National Fish and Wildlife Service, contains a top layer of transported sediment. If proper permitting and approval was granted, the wetland could be restored to its' original conditions. This would include excavation of the transported sediment, which would increase the infiltration in the pond and decrease the amount of runoff flowing through the structure. However, no additional cost estimates or hydrologic analyses were conducted as this was outside of the scope of the project.

3.4 Structure 21: Broken Lance Dry Dam

Structure 21 was determined to be one of the five most problematic structures. The erosion downstream and scour occurring on the upstream slope were the reasons this structure needed improvement.

3.4.1 Hydrologic Analysis of Existing Structure

Using ArcGIS, the calculated watershed was 38 acres. An initial hydrologic analysis returned a peak flow of 66 cfs. The existing structure was not modeled in HydroCAD, however, due to the erosion on the downstream slope from overtopping of the berm, it was evident that the riser was inadequate to handle the peak flow for the 100-year, 24 hour storm event. The hydrologic analyses of Structure 21 can be seen in Appendix C and D.

Two alternatives were designed for the site. Both alternatives include the following repairs: rehabilitation of the structure with riprap, clearing of debris from the downstream channel, and installing a new 30-inch RCP.

3.4.2 Alternative Solutions

A general overview of the structure location and alignment are shown in Figure 39. AutoCAD drawings can be found in Appendix I.

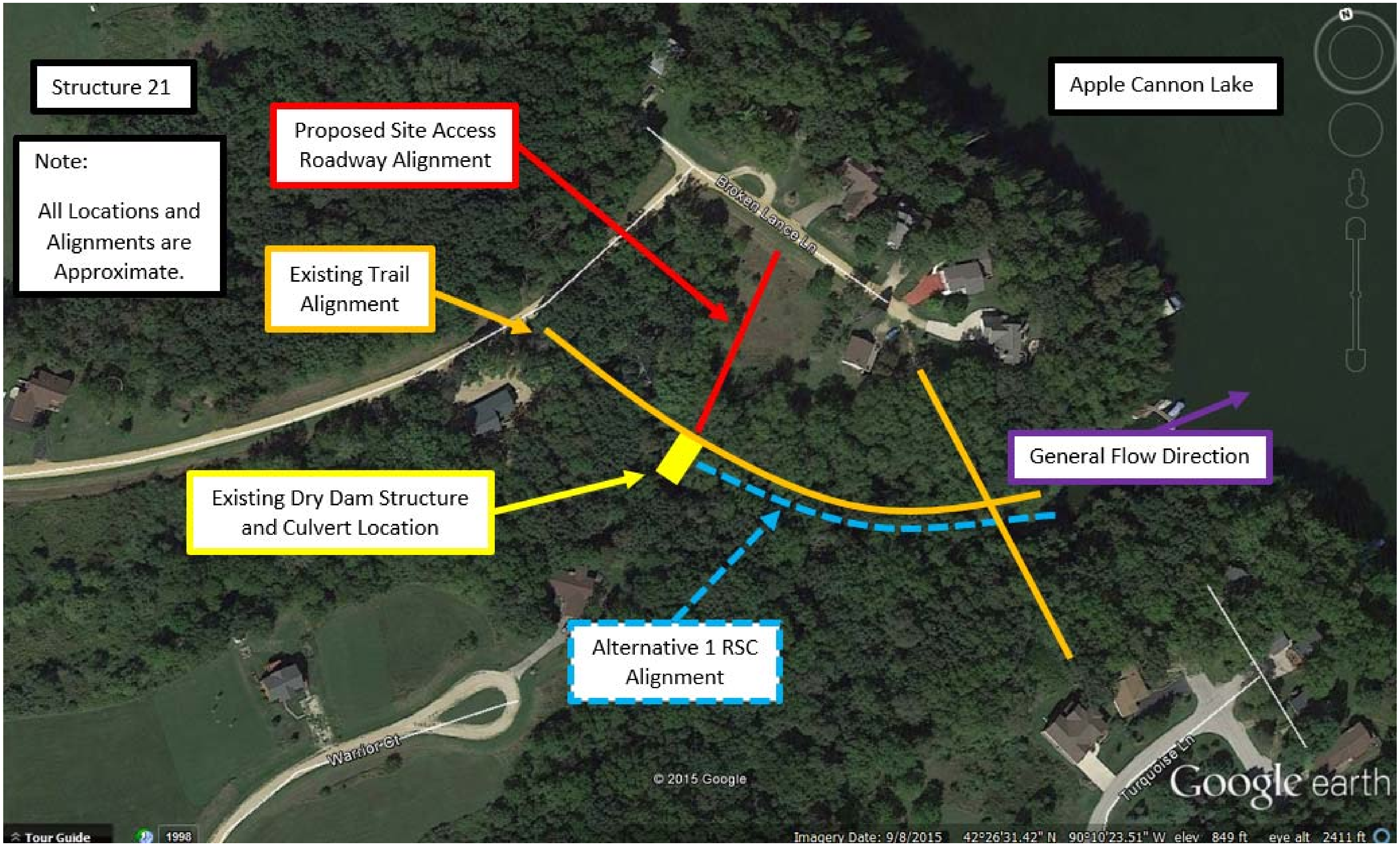


Figure 39 Structure 21 approximate alternatives locations and alignments.

3.4.2.1 Alternative 1: New Pipe with Regenerative Storm Water Conveyance Channel (RSC)

Alternative 1 is to install a new 30-inch RCP culvert through the berm and add a regenerative storm water conveyance channel starting at the berm and eventually discharging into Apple Canyon Lake (Figure 40 and Figure 41). "RSC utilizes a series of shallow aquatic pools, riffle weir grade controls, native vegetation and underlying sand and woodchip beds to treat, detain, and convey storm flow"[10]. These are typically implemented to convey flows for 100-year, 24 hour storm events, as well as minimize channel erosion impacts. Alternate pools and riffles were installed if the change in elevation did not exceed 5 percent (Figure 40). The riffles have a width of 5 feet and a length of 10 feet. The pools are 5 feet wide, 20 feet long, and a maximum depth of 3 feet. For steep slopes, cascades were installed followed by three pools. The cascades have a width of 5 feet and a length of 8 feet. For this particular design, a total of 4 riffles, 16 pools, and 4 cascades were installed. The total channel length will extend 500 feet before the runoff discharges into Apple Canyon Lake. For material sizing and selection, refer to Appendix I drawing page 18-23.

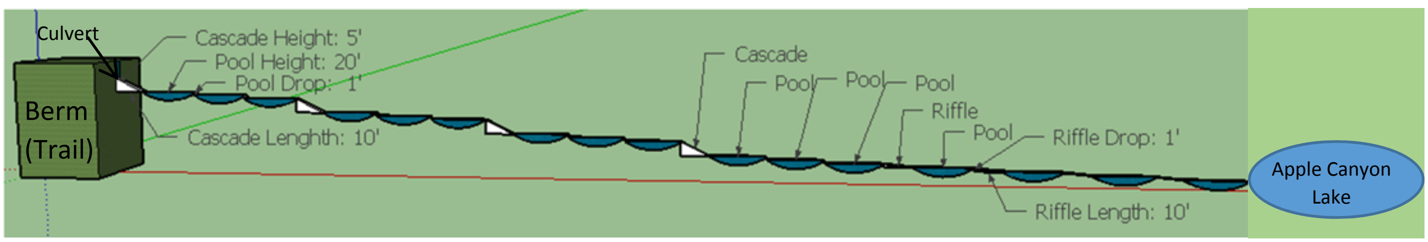


Figure 40 Riffles, pools, and cascades for Structure 21.

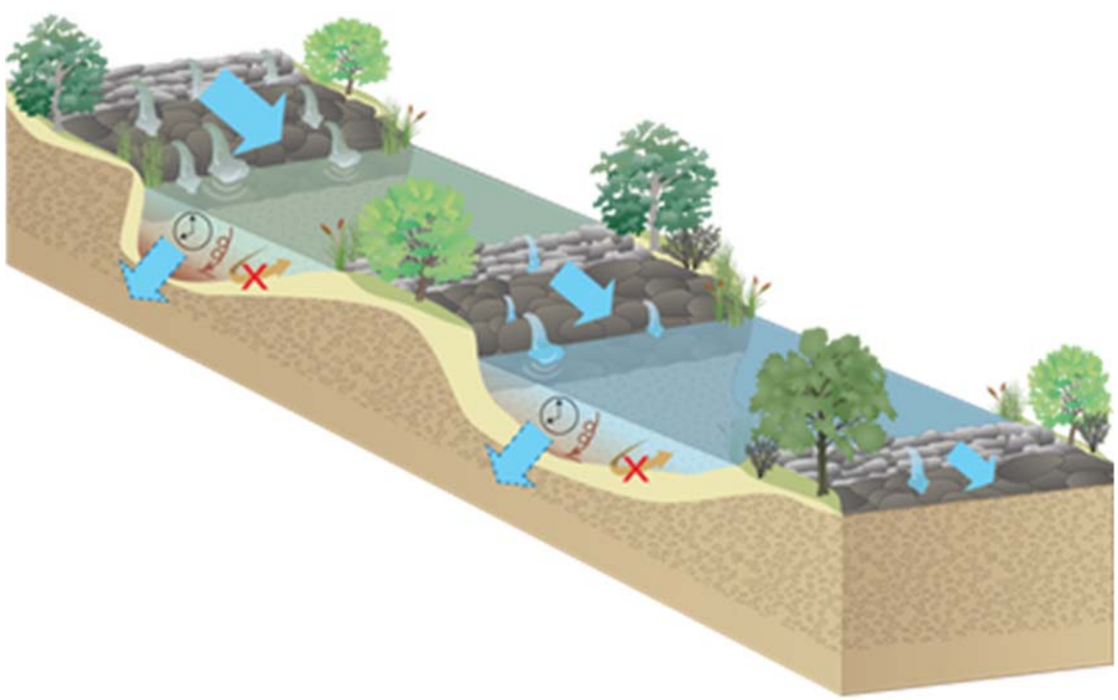


Figure 41 Typical cross-section of a RSC channel.

[10] (Regenerative Stormwater Conveyance System (RSC) , 2012)

3.4.2.2 Alternative 2: Installation of New Pipe

Alternative 2 includes removing the existing culvert pipe and replacing it with a 30-inch RCP culvert. The existing channel shall remain, with the repairs listed in 3.4.1.

3.5 Structure 22: Blue-Gray Dry Dam

Structure 22 was chosen as one of the five most problematic structures because a major storm washed it out and erosion control measures needed to be put in place.

3.5.1 Hydrologic Analyses of Existing Structure

Using ArcGIS, the calculated watershed was 61 acres. An initial hydrologic analysis returned a peak flow of 64 cfs. Due to the washout of the previous structure in 2011, the runoff is free flowing on a natural path that matches the current topography. The runoff is currently eroding the natural path. Two alternative solutions were analyzed in order to route the runoff and prevent erosion. Hydrologic Analyses of Structure 22 can be seen in Appendix C and D.

3.5.2 Alternative Solutions

A general overview of the structure location and alignment are shown in Figure 42. AutoCAD drawings can be found in Appendix I.

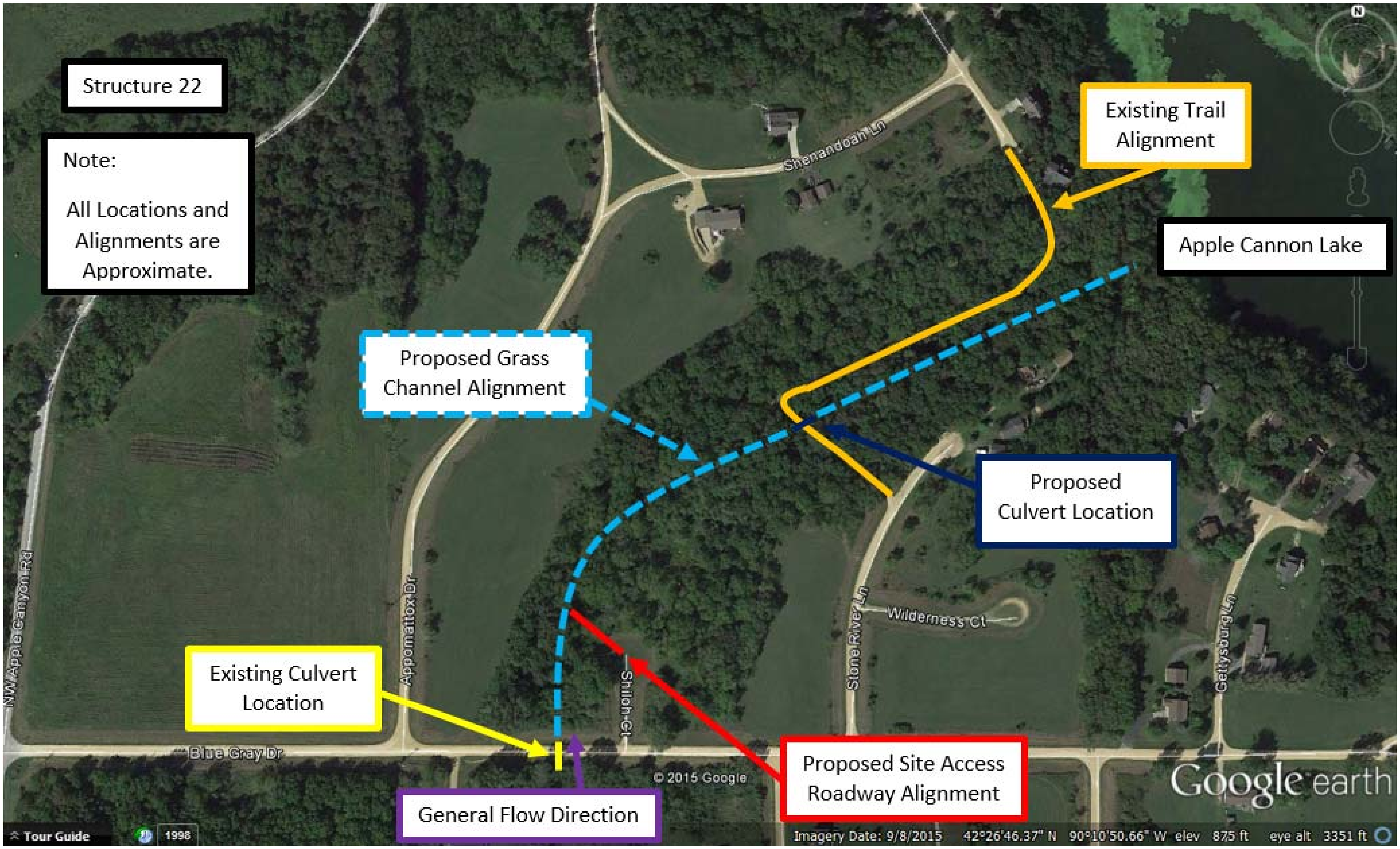


Figure 42 Structure 22 approximate alternatives locations and alignments.

3.5.2.1 Alternative 1: Trapezoidal Grass Channel

Alternative 1 is to implement an approximate 1900-foot long trapezoidal grass channel. The velocity at the existing structure is over the allowable 3 feet per second[11]. This channel will effectively slow the velocity of the runoff to 2.4 ft/s. This velocity is below the allowable velocity which will prevent erosion. The channel follows the path of accumulation for a total length of 1 foot, mimicking the ditch line parallel to the trail. This alternative would require the addition of a culvert through a trail that intersects the channel. HydroCAD was used to design a 15-foot long, 24-inch RCP, groove end projecting culvert pipe that was able to successfully convey the peak flow of 64 cfs. Following the culvert, the channel continues for an additional approximately 850 feet to the lake. The channel was designed to continue, following the culvert, to prevent the runoff from eroding the natural path of stormwater runoff while flowing to Apple Canyon Lake. FlowMaster determined the optimal channel dimensions to be 12 feet wide at the top, 4 feet wide at the bottom, and 4 feet deep (Appendix I, Page 24).

3.5.2.2 Alternative 2: Triangular Grass Channel

Alternative 2 is to implement an approximate 1900-foot triangular grass channel in the same alignment as Alternative 1. Velocity at the existing structure is over the allowable 3 ft/s[12]. This channel will effectively slow the velocity of the runoff to 2.5 ft/s. This velocity is below the allowable velocity which will prevent erosion. The channel will follow the same flow path and contain the same culvert as Alternative 1. The recommended channel dimensions using FlowMaster are: 12 feet wide at the top, 6 feet deep, and side slopes of 1 ft/ft (Appendix I, Page 25).

[11] (United States Department of Agriculture, 2007)
[12] (United States Department of Agriculture, 2007)

4.0 Phase 3 – Cost Estimates for Alternatives and Recommend the Most Feasible Solution

The materials, equipment, and labor required for each alternative were quantified through hand calculation and then entered into RS Means Online. RS Means is an estimating software used to calculate project costs. A detailed cost breakdown of the listed prices and sample calculation can be found in Appendices H and J. Design construction repair drawings by hand and using AutoCAD can be found in Appendices H and I respectively. The general maintenance for these structures is the same and is shown in Table 4 below. When estimating riprap requirements for each structure, the Illinois Department of Transportation (IDOT) guidelines were followed. The estimate does not include any architectural or engineering fees, purchases of permits and/or easements, or right of way purchases. The durations of the maintenance tasks should continue throughout the life of the structure. Typical life expectancies for culvert pipes metal and concrete, are around 100 years. Additionally, grass channels shall last as long as the channel is properly maintained. When estimating the project cost in order to accurately represent an actual cost that a contractor would submit as a lump sum bid the following information was added to the RS means subtotal: RS Means unit cost data, mobilization cost at 10% of the subtotal, 5.5% sales tax applied to material price only, survey and inspection at 5% of the subtotal, contingency at 10% of the subtotal, and overhead and profit at 15% of the subtotal.

Table 4 General Maintenance Schedule for All of the Structures[13]

Maintenance Tasks	Frequency
Check for new erosion	After every 100-year storm event, once every other month
Check structural stability	Annually
General Inspection	Annually
Inspection of drainage area or channel	Every rainfall exceeding 0.5 inches
Remove sediment build up	As needed, based on annual inspections
Remove/replace dead plants	Inspect once a week or the first two months, then as needed
Repair damage	As needed, based on annual inspections
Stabilize any bare or eroded areas in the channel	As needed, based on annual inspections
Trash removal	As needed, based on annual inspections
Vegetation fertilization	Once during initial seeding
Watering new vegetation	Once a week during the first two months
Weeding	As needed, based on annual inspections

4.1 Structure 2: Thunder Court Dry Dam

4.1.1 Cost Estimates

Alternative 1, a trapezoidal grass channel with the addition of a 24-inch RCP culvert pipe, has a total cost of $44,000 and Alternative 2, excavation around existing riser, has a total cost of $2,000. The cost breakdown for the alternatives can be seen in Table 5.

[13] (Regenerative Stormwater Conveyance System (RSC) , 2012)

Table 5 Structure 2 Cost Comparison

Description	Unit Price			Alternative 1			Alternative 2		
				Unit		Line Total	Unit		Line Total
Clearing & Grubbing	$ 3,577.30	per	Acre	0.48	Acre	$ 1,717.10		Acre	$ -
Clear & Grubbing (Cut & Chip)	$ 5,264.03	per	Acre		Acre	$ -	0.02	Acre	$ 105.28
Excavation	$ 1.78	per	B.C.Y.	1777	B.C.Y.	$ 3,163.06	104	B.C.Y.	$ 185.12
Backfill	$ 5.67	per	E.C.Y.	15	E.C.Y.	$ 85.05		E.C.Y.	$ -
Backfill by Hand	$ 27.50	per	L.C.Y.		L.C.Y.	$ -	15	L.C.Y.	$ 412.50
Pipe Cover	$ 33.57	per	L.C.Y.	3	L.C.Y.	$ 100.71		L.C.Y.	$ -
Haul - Out Material	$ 4.19	per	L.C.Y.	2475	L.C.Y.	$ 10,370.25		L.C.Y.	$ -
Errossion Matting	$ 0.55	per	S.Y.	2329.56	S.Y.	$ 1,281.26	110.44	S.Y.	$ 60.74
Silt Fence	$ 1.16	per	L.F.	100	L.F.	$ 116.00		L.F.	$ -
Rip- Rap No. 4	$ 31.73	per	Ton	29.5	Ton	$ 936.04		Ton	$ -
Topsoil	$ 2.89	per	S.Y.	2329.56	S.Y.	$ 6,732.43	110.44	S.Y.	$ 319.17
24" RCP Pipe	$ 51.23	per	L.F.	25	L.F.	$ 1,280.75		L.F.	$ -
24" RCP End Wall	$ 2,442.88	per	Ea.	2	Ea.	$ 4,885.76		Ea.	$ -
Geotextile Fabric	$ 3.47	per	S.Y.	40	S.Y.	$ 138.80		S.Y.	$ -
Subtotal						$ 30,807.21			$ 1,082.81
Mobilization (10% Subtotal)						$ 3,080.72			$ 108.28
Survey and Inspection (5% Subtotal)						$ 1,540.36			$ 54.14
Contingency (10% Subtotal)						$ 3,080.72			$ 108.28
Overhead & Profit (15% Subtotal)						$ 4,621.08			$ 162.42
Total Price						$ 43,130.09			$ 1,515.93
Rounded Total Price						**$ 44,000.00**			**$ 2,000.00**

4.1.2 Design and Maintenance Recommendation

DAM Consulting recommends a trapezoidal grass channel as the best alternative for Structure 2 (Alternative 1). Although the grass channel is more expensive, this alternative is recommended based on its ability to convey the 100-year, 24 hour storm event. This alternative will be able to maintain the allowable velocity of 3 ft/s. The vegetation on the channel sides will provide slope stability for the soil, preventing further erosion. Additionally, the channel provides time for sediments to settle out before entering Apple Canyon Lake.

4.2 Structure 7: Washington Cove Culvert

4.2.1 Cost Estimates

Alternative 1, placement of riprap at inlets and outlets of culverts, has a total cost of $47,000 and Alternative 2, same as previous alternative with the addition of a 60-inch RCP culvert replacing the existing 72-inch CMP, has a total cost of $74,000. The cost breakdown and comparison of each alternative can be seen in Table 6.

Table 6 Structure 7 Cost Comparison

Description	Unit Price	Alternative 1		Alternative 2	
		Unit	Line Total	Unit	Line Total
Remove 72" CMP	$ 34.74 per L.F.	L.F.	$ -	42 L.F.	$ 1,459.08
Clearing & Grubbing	$ 3,577.30 per Acre	0.06 Acre	$ 214.64	0.06 Acre	$ 214.64
Excavation	$ 1.78 per B.C.Y.	130.97 B.C.Y.	$ 233.13	130.97 B.C.Y.	$ 233.13
Backfill	$ 5.67 per E.C.Y.	E.C.Y.	$ -	131 E.C.Y.	$ 742.77
Pipe Cover	$ 33.57 per L.C.Y.	L.C.Y.	$ -	170.51 L.C.Y.	$ 5,724.02
Haul - Out Material	$ 4.19 per L.C.Y.	30.31 L.C.Y.	$ 127.00	499.22 L.C.Y.	$ 2,091.73
Rip- Rap No. 6	$ 32.24 per Ton	981.18 Ton	$ 31,633.24	220.49 Ton	$ 7,108.60
60" RCP Pipe	$ 235.26 per L.F.	L.F.	$ -	42 L.F.	$ 9,880.92
60" RCP End Wall	$ 11,713.37 per Ea.	Ea.	$ -	2 Ea.	$ 23,426.74
Geotextile Fabric	$ 3.47 per S.Y.	392.67 S.Y.	$ 1,362.56	392.67 S.Y.	$ 1,362.56
Subtotal			$ 33,570.57		$ 52,244.19
Mobilization (10% Subtotal)			$ 3,357.06		$ 5,224.42
Survey and Inspection (5% Subtotal)			$ 1,678.53		$ 2,612.21
Contingency (10% Subtotal)			$ 3,357.06		$ 5,224.42
Overhead & Profit (15% Subtotal)			$ 5,035.59		$ 7,836.63
Total Price			$ 46,998.81		$ 73,141.87
Rounded Total Price			**$ 47,000.00**		**$ 74,000.00**

4.2.2 Design and Maintenance Recommendation

DAM Consulting recommends leaving the existing pipe in place as the best alternative for Structure 7. This alternative was recommended because it is more cost effective than Alternative 2. Alternative 1 was more cost effective because it is has the ability to convey the 100 year, 24 hour peak flow without requiring the costs associated with replacing the pipe. The addition of the riprap will prevent further scouring and erosion around the culvert inlet and outlets. By adding 1 foot of fill, the area of the pressure distribution will be increased which will distribute the applied loading over a larger area which decreases the stress on the culvert

4.3 Structure 13: Fairway Dry Dam A

4.3.1 Cost Estimates

Alternative 1, the addition of 2 36-inch RCP culverts through the structure with rip rap on the slopes, has a total cost of $61,000 and Alternative 2, riprap around the existing culvert pipe, has a total cost of $3,000. The cost summary of each alternative can be seen in Table 7.

Table 7 Structure 13 Cost Comparison

Description	Unit Price				Alternative 1			Alternative 2		
					Unit		Line Total	Unit		Line Total
Remove 24" CMP	$	10.37	per	L.F.	30	L.F.	$ 311.10		L.F.	$ -
Clearing & Grubbing	$	3,577.30	per	Acre	0.01	Acre	$ 35.77	0.01	Acre	$ 35.77
Excavation	$	1.78	per	B.C.Y.	241.8	B.C.Y.	$ 430.40	11	B.C.Y.	$ 19.58
Backfill	$	5.67	per	E.C.Y.	114	E.C.Y.	$ 646.38		E.C.Y.	$ -
Pipe Cover	$	33.57	per	L.C.Y.	48.92	L.C.Y.	$ 1,642.24		L.C.Y.	$ -
Haul - Out Material	$	4.19	per	L.C.Y.	188	L.C.Y.	$ 787.72	13.75	L.C.Y.	$ 57.61
Silt Fence	$	1.16	per	L.F.	350	L.F.	$ 406.00	50	L.F.	$ 58.00
Rip- Rap No. 6	$	32.24	per	Ton	626.56	Ton	$ 20,200.29	48.95	Ton	$ 1,578.15
36" RCP Pipe	$	111.02	per	L.F.	60	L.F.	$ 6,661.20		L.F.	$ -
36" RCP End Wall	$	2,710.03	per	Ea.	4	Ea.	$ 10,840.12		Ea.	$ -
Geotextile Fabric	$	3.47	per	S.Y.	311.11	S.Y.	$ 1,079.55	30	S.Y.	$ 104.10
Subtotal							$ 43,040.77			$ 1,853.21
Mobilization (10% Subtotal)							$ 4,304.08			$ 185.32
Survey and Inspection (5% Subtotal)							$ 2,152.04			$ 92.66
Contingency (10% Subtotal)							$ 4,304.08			$ 185.32
Overhead & Profit (15% Subtotal)							$ 6,456.12			$ 277.98
Total Price							$ 60,257.09			$ 2,594.49
Rounded Total Price							**$ 61,000.00**			**$ 3,000.00**

4.3.2 Design and Maintenance Recommendation

DAM Consulting recommends Alternative 1, the installation of two 36-inch concrete culvert pipes, as the best alternative for Structure 13. Alternative 1 is recommended based on the pipes' ability to convey the peak flow of the 100-year, 24 hour storm event. By moving the culverts underneath the center of the berm, more runoff will be able to directly flow through the culverts. Additionally, no overtopping of the earthen berm would occur. All work done should occur downstream of the structure and on the structure itself as to not disturb the wetland. Any work performed farther upstream should only be done with the proper permits.

4.4 Structure 21: Broken Lance Dry Dam

4.4.1 Cost Estimates

Alternative 1, an RSC channel and a 30-inch RCP culvert has a total cost of $51,000 and Alternative 2, a 30-inch RCP culvert replacement, has a total cost of $29,000. The cost summary of each alternative can be seen in Table 8.

Table 8 Structure 21 Cost Comparison

Description	Unit Price				Alternative 1			Alternative 2		
					Unit		Line Total	Unit		Line Total
Remove 24" CMP	$	10.37	per	L.F.	75	L.F.	$ 777.75	75	L.F.	$ 777.75
Clearing & Grubbing	$	3,577.30	per	Acre	0.28	Acre	$ 1,001.64		Acre	$ -
Excavation	$	1.78	per	B.C.Y.	615	B.C.Y.	$ 1,094.70	738	B.C.Y.	$ 1,313.64
Backfill	$	5.67	per	E.C.Y.	654	E.C.Y.	$ 3,708.18	550	E.C.Y.	$ 3,118.50
Pipe Cover	$	33.57	per	L.C.Y.	28	L.C.Y.	$ 939.96	28	L.C.Y.	$ 939.96
Gravel Bank Run	$	33.57	per	L.C.Y.	111.6	L.C.Y.	$ 3,746.41		L.C.Y.	$ -
Sand (For Woodchip Mix)	$	30.39	per	L.C.Y.	111.6	L.C.Y.	$ 3,391.52		L.C.Y.	$ -
Haul - Out Material	$	4.19	per	L.C.Y.	207	L.C.Y.	$ 867.33	207	L.C.Y.	$ 867.33
Errosion Matting	$	0.55	per	S.Y.	220	S.Y.	$ 121.00	264	S.Y.	$ 145.20
Silt Fence	$	1.16	per	L.F.	1200	L.F.	$ 1,392.00	300	L.F.	$ 348.00
Cobbles	$	31.73	per	Ton	12.08	Ton	$ 383.30		Ton	$ -
Boulders	$	32.24	per	Ton	60	Ton	$ 1,934.40	0.6	Ton	$ 19.34
Woodchip & Sand Placement	$	301.67	per	M.S.F.	1.8	M.S.F.	$ 543.01		M.S.F.	$ -
Topsoil	$	2.89	per	S.Y.	220	S.Y.	$ 635.80	220	S.Y.	$ 635.80
Aster Plants	$	31.96	per	Ea.	100	Ea.	$ 3,196.00		Ea.	$ -
30" RCP Pipe	$	89.80	per	L.F.	75	L.F.	$ 6,735.00	75	L.F.	$ 6,735.00
30" RCP End Wall	$	2,585.15	per	Ea.	2	Ea.	$ 5,170.30	2	Ea.	$ 5,170.30
Geotextile Fabric	$	3.47	per	S.Y.	120	S.Y.	$ 416.40	5	S.Y.	$ 17.35
Subtotal							$ 36,054.70			$ 20,088.17
Mobilization (10% Subtotal)							$ 3,605.47			$ 2,008.82
Survey and Inspection (5% Subtotal)							$ 1,802.74			$ 1,004.41
Contingency (10% Subtotal)							$ 3,605.47			$ 2,008.82
Overhead & Profit (15% Subtotal)							$ 5,408.21			$ 3,013.23
Total Price							$ 50,476.59			$ 28,123.45
Rounded Total Price							**$ 51,000.00**			**$ 29,000.00**

4.4.2 Design and Maintenance Recommendation

DAM Consulting recommends the Regenerative Storm Water Conveyance System as the best alternative for Structure 21. Alternative 1 is recommended based on its ability to convey the flow for the 100-year, 24 hour storm event and prevent erosion in the channel downstream of the berm. By replacing the existing riser with a culvert, it will decrease the maximum water elevation in the channel, which will reduce the impact and wave action against the berm. The added vegetation on the berm will provide slope stability of the soil, preventing further erosion. Additionally, the woodchips needed for the bedding of the RSC System could be recycled from cleared trees or debris located along the channel, which provided cost savings.

4.5 Structure 22: Blue-Gray Dry Dam

4.5.1 Cost Estimates

Alternative 1, a trapezoidal grass channel with a 24-inch RCP culvert replacement, has a total cost of $85,000 and Alternative 2, a triangular grass channel with a 24-inch diameter RCP culvert, has a total cost of $86,000. The cost comparison for each of the proposed channels can be seen in Table 9.

Table 9 Structure 22 Cost Comparison

Description	Unit Price			Alternative 1			Alternative 2		
				Unit		Line Total	Unit		Line Total
Clearing & Grubbing	$ 3,577.30	per	Acre	0.91	Acre	$ 3,255.34	0.91	Acre	$ 3,255.34
Excavation	$ 1.78	per	B.C.Y.	3188	B.C.Y.	$ 5,674.64	2998	B.C.Y.	$ 5,336.44
Backfill	$ 5.67	per	E.C.Y.	9	E.C.Y.	$ 51.03	9	E.C.Y.	$ 51.03
Pipe Cover	$ 33.57	per	L.C.Y.	3	L.C.Y.	$ 100.71	3	L.C.Y.	$ 100.71
Haul - Out Material	$ 4.19	per	L.C.Y.	4450	L.C.Y.	$ 18,645.50	4184	L.C.Y.	$ 17,530.96
Errosion Matting	$ 0.55	per	S.Y.	5961.33	S.Y.	$ 3,278.73	6696	S.Y.	$ 3,682.80
Silt Fence	$ 1.16	per	L.F.	4100	L.F.	$ 4,756.00	4100	L.F.	$ 4,756.00
Rip Rap No. 4	$ 31.73	per	Ton	29.5	Ton	$ 936.04	29.5	Ton	$ 936.04
Topsoil	$ 2.89	per	S.Y.	5961.33	S.Y.	$ 17,228.24	6696	S.Y.	$ 19,351.44
24" RCP Pipe	$ 51.23	per	L.F.	25	L.F.	$ 1,280.75	25	L.F.	$ 1,280.75
24" RCP End Wall	$ 2,442.88	per	Ea.	2	Ea.	$ 4,885.76	2	Ea.	$ 4,885.76
Geotextile Fabric	$ 3.47	per	S.Y.	40	S.Y.	$ 138.80	40	S.Y.	$ 138.80
Subtotal						$ 60,231.54			$ 61,306.07
Mobilization (10% Subtotal)						$ 6,023.15			$ 6,130.61
Survey and Inspection (5% Subtotal)						$ 3,011.58			$ 3,065.30
Contingency (10% Subtotal)						$ 6,023.15			$ 6,130.61
Overhead & Profit (15% Subtotal)						$ 9,034.73			$ 9,195.91
Total Price						$ 84,324.15			$ 85,828.50
Rounded Total Price						**$ 85,000.00**			**$ 86,000.00**

4.5.2 Design and Maintenance Recommendation

DAM Consulting recommends a trapezoidal grass channel as the best alternative for Structure 22. Alternative 1 is recommended based on its ability to convey the 100 year, 24 hour storm event and is more cost effective. Additionally, the trapezoidal grass channel is a more traditional type of channel and is easier to construct. It is easier to construct because it has a flat bottom, compared to the sharp angle on a triangular grass channel.

5.0 Conclusions

Dam Consulting was tasked with evaluating existing DDSs and providing repair and maintenance recommendations for the evaluated structures. In Phase 1, Dam Consulting made comments and field notes on the existing conditions of all of the structures. Specifically the notes were in regards to what DAM Consulting visually saw needed to be monitored, investigated and repaired. Each structure was also given an overall condition assessment and Hazard Classification. All recommendations were given for the respective structure based on the field notes. Following the field investigations, five problematic structures were determined and analyzed at depth. In general the overall condition of all structures inspected were satisfactory or better, meaning that by visual inspection no significant deficiencies were recognized and only minor maintenance was required. Also, in general these structures were Class BB or higher, meaning that if the structures were to fail at minimum damage would occur to low volume roadways with moderate economic loss or equivalent based on the structures given location.

Phase 2 focused on repair of the DDS by recommending feasible solutions for the identified dry dam concerns determined in Phase 1. Based on the results of the hydrologic analyses and inspections, two design alternatives were proposed for each of the five problematic structures. The cost estimates were provided for each alternative (Table 10). Phase 3 focused on cost and maintenance recommendations for the design life of structures.

Table 10 Cost Summary of All Alternatives

Structure	Alternative 1	Alternative 2
2	Grass Channel with 24-inch Diameter RCP Culvert	Excavation Around Existing Riser
	$44,000	$2,000
7	Placement of Riprap at Inlet and Outlets of Culverts	Alternative 1 with 60-inch Diameter RCP Culvert Replacement
	$47,000	$74,000
13	(2) 36-Inch Diameter RCP Culvert Replacement and Riprap	Riprap Around Existing CMP Culvert
	$61,000	$3,000
21	RSC Channel and 30-inch Diameter RCP Culvert Replacement	30-inch Diameter RCP Culvert Replacement
	$51,000	$29,000
22	Trapezoidal Grass Channel with 24-inch Diameter RCP Culvert Replacement	Triangular Grass Channel with 24-inch Diameter RCP Culvert Replacement
	$85,000	$86,000
Total Cost	**$288,000**	**$194,000**

The five most problematic structures were selected for the following reasons:

- Structure 2 was selected due to an upstream mudslide, which caused sediment and other debris to accumulate around the riser, preventing maximum efficiency of flow.
- Structure 7 was selected due to erosion around the side slope and compression of the culvert pipe.

- Structure 13 was selected because the structure has a culvert that will not flow at full capacity before overtopping. The height of the culvert outlet was noted to be four feet above the ground elevation, which led to excess erosion downstream.
- Structure 21 was selected due to erosion downstream and scour occurring on the upstream slope were the reasons this structure needed improvement.
- Structure 22 was selected because a major storm washed it out and erosion control measures needed to be put in place.

6.0 Recommendations

General recommendations for the remaining structures, that were not deemed problematic, are as follows:

1. Clear vegetation along the flow channel specifically vegetation blocking either the entrance or exit of the pipe.
2. Continue to routinely monitor the slope and structural stability of these structures because site conditions can rapidly change with severe weather.
3. Continue to monitor any and all erosion and runoff specifically from any adjacent farm field into Apple Cannon Lake.
4. Consider widening all flow channels because in doing so it would lower the waters velocity and in turn reduce the amount of possible erosion occurring.

For the five most problematic structures, the following recommendations were made:

- Structure 2 Thunder Court Dry Dam: Grass channel with a 24-inch Reinforced Concrete Pipe (RCP) culvert. This alternative is recommended based on its ability to convey the 100-year, 24 hour storm event. This alternative will be able to maintain the allowable velocity of 3 ft/s. The vegetation on the channel sides will provide slope stability for the soil, preventing further erosion. Additionally, the channel provides time for sediments to settle out before entering Apple Canyon Lake.
- Structure 7 Washington Cove Culvert: Placement of riprap at inlet and outlets of culverts. This alternative was more cost effective because it is has the ability to convey the 100 year, 24 hour peak flow without requiring the costs associated with replacing the pipe. The addition of the riprap will prevent further scouring and erosion around the culvert inlet and outlets. By adding 1 foot of fill, the area of the pressure distribution will be increased which will distribute the applied loading over a larger area which decreases the stress on the culvert.
- Structure 13 Fairway Dry Dam A: (2) 36-inch diameter RCP culvert replacement and riprap. Alternative 1 is recommended based on the pipes' ability to convey the peak flow of the 100-year, 24 hour storm event. By moving the culverts underneath the center of the berm, more runoff will be able to directly flow through the culverts. Additionally, no overtopping of the earthen berm would occur. All work done should be done downstream of the structure and on the structure itself as to not disturb the wetland. Any work done farther upstream should only be done with the proper permits.
- Structure 21 Broken Lance Dry Dam: RSC channel and 30-inch diameter RCP culvert replacement. Alternative 1 is recommended based on its ability to convey the flow for the 100-year, 24 hour storm event and prevent erosion in the channel downstream of the berm. By replacing the existing riser with a culvert, it will decrease the maximum water elevation in the channel, which will reduce the impact and wave action against the berm. The added vegetation on the berm will provide slope stability of the soil, preventing further erosion. Additionally, the woodchips needed for the bedding of the RSC System could be recycled from cleared trees or debris located along the channel, which provided cost savings.

- Structure 22 Blue-Gray Dry Dam: Trapezoidal grass channel with 24-inch diameter RCP culvert replacement. Alternative 1 is recommended based on its ability to convey the 100 year, 24 hour storm event and is more cost effective. Additionally, the trapezoidal grass channel is a more traditional type of channel and is easier to construct. It is easier to construct because it has a flat bottom, compared to the sharp angle on a triangular grass channel.

Implementation of these alternatives should effectively reroute runoff and reduce the velocity to prevent future erosion. Conclusions and recommendations have been provided based upon applicable codes, regulations and in collaboration with the Apple Canyon Lake Homeowners Association representative.

References

Bentley Systems, Incorporated. (2009). Flowmaster.

Connnecticut Department of Energy and Enviromental Protection. (2014, 02 11). DAM SAFETY PROGRAM DAM INSPECTION REPORT FORM - FOR REGULATORY INSPECTION.

Esri. (2014). ArcGIS 10.2.2.

Hickenbottom Incorporated. (2013, January 5). Hickenbottom 12-inch Flow Chart. Fairfield.

HydroCAD Softwar Solutions LLC. (2011). HydroCAD Stormwater Modeling System.

Illinois Department of Transportation. (1994, Agust). *Rock Outlet Protection*. Retrieved November 9, 2015

NOAA's (National Oceanic and Admospheric Administration) National Weather Service. (2015, September 30). *Precipitation Frequency Data Server*. Retrieved November 9, 2015, from http://hdsc.nws.noaa.gov/hdsc/pfds/

(2012). *Regenerative Stormwater Conveyance System (RSC)* . West Virginia Department of Enviornmental Protection.

The Gordian Group. (2015, November). *RSMeansOnline*. Retrieved November 9, 2015, from www.rsmeansonline.com

U.S. Fish & Wildlife Service. (2015, November 4). *National Wetlands Inventory - Wetlands Mapper*. Retrieved November 9, 2015, from http://www.fws.gov/wetlands/data/mapper.HTML

United States Department of Agriculture. (2007, Agust). *Chapter 8 Threshold Channel Design*. Retrieved November 9, 2015, from http://directives.sc.egov.usda.gov/viewerFS.aspx?hid=21433

United States Department of Agriculture. (2013, December 6). *USDA Web Soil Survey*. Retrieved November 9, 2015, from http://websoilsurvey.sc.egov.usda.gov/App/WebSoilSurvey.aspx

11.8 Appendix 8. University of Wisconsin Platteville, Hidden Springs Erosion report

UNIVERSITY OF WISCONSIN
PLATTEVILLE

Erosion Control: Hidden Spring Cove

Rut Breakers Inc.

University of Wisconsin-Platteville

Andrea Knutson, Anooj Kothari, Devin Peterson, Nancy Streu

12/15/2015

Executive Summary

Over the years significant erosion has occurred in the valleys of Hidden Spring Cove at Apple Canyon Lake, Illinois. Erosion is the transport of soil from one location to another. This erosion has resulted in the formation of steep gullies in the natural stream channels.

Rut Breakers Inc. was contacted to analyze the erosion problems and design a solution. Upon visiting the site and some quick analysis, the area of Hidden Spring Cove was determined to have three sites of severe erosion, but not all three could be addressed given the time constraints. The site for design was then narrowed down to the forested area of the watershed to the east of Pioneer Drive, closest to the lake. This area contains only one of the three points of severe erosion. The other two points of severe erosion were located along the outskirts of the watershed and should be analyzed in the future.

Several options were explored for controlling the erosion to the east of Pioneer Drive. These options included rock riffle, riprap along the entirety of the channels, gabion staircases, settling ponds, and regenerative stormwater conveyance (RSC). A decision matrix was used to compare each option based on feasibility, accessibility, effectiveness, cost, and client preference. The results of the decision matrix indicated that RSC would be the optimal method for this location.

RSC is an erosion control system implemented in severely eroded channels and outfalls. RSC helps restore eroded channels back to a natural state and prevent future erosion. RSC replicates naturally found stream structures such as cascades, riffles, and pools.

A RSC system was designed for the two channels east of Pioneer Drive. A settling pond was designed at the convergence of the two channels. Downstream of the settling pond, the bank slopes of the channel would be reduced and revegetated with native plants.

This design would decrease the erosion in the lower portion of the Hidden Spring Cove watershed as requested by the client. The estimated cost of this recommendation would be about $70,000. The construction of the RSC should take roughly 2 months to complete, starting with construction stake out.

Table of Contents

List of Figures

List of Tables

1. Introduction

Rut Breakers Inc. was contacted by the Apple Canyon Lake Authority through the University of Wisconsin-Platteville's Civil and Environmental Engineering Department to design a solution for erosion issues along Apple Canyon Lake. The purpose of this project was to analyze one specific cove, Hidden Spring Cove, by delineating the watershed, identifying sources of erosion, and proposing a solution to restore the channel to a more natural state.

1.1 Background

Apple Canyon Lake is located in the northwestern portion of Illinois in the City of Apple River (Figure 1). Hidden Spring Cove is on the west side of Apple Canyon Lake and has a watershed that is approximately 44 acres (Figure 2). The runoff in the watershed has developed into three main channels that meet and flow into Hidden Spring Cove (Figure 3).

The erosion has caused the channels to widen and increased the nutrient loadings to Apple Canyon Lake. The increased erosion has also resulted in damage to streamside vegetation to the point where vegetation can no longer provide bank stabilization. The erosion is occurring at multiple point sources, all of which should be looked at in the future (2.2 Areas of Erosion).

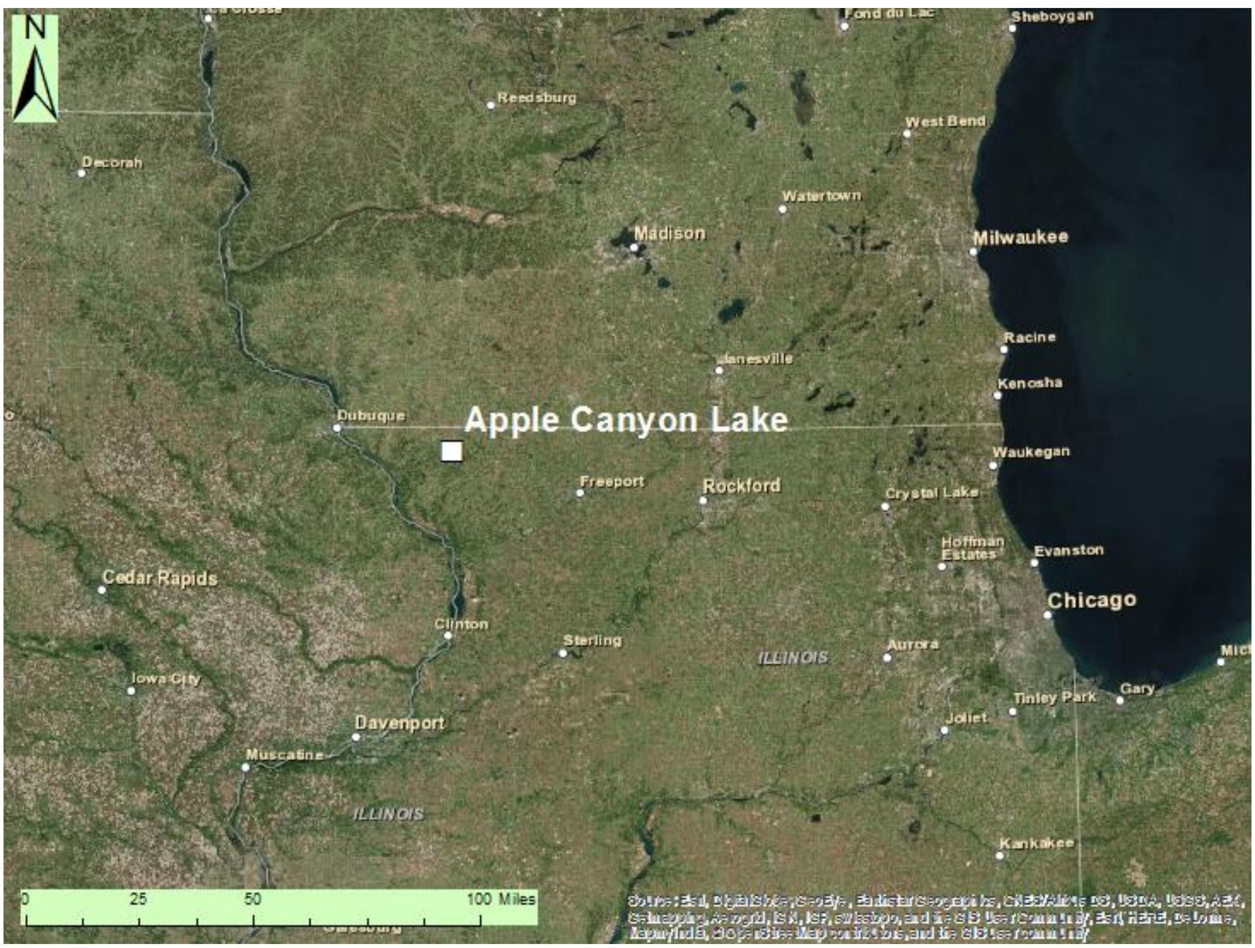


Figure 1. Location of Apple Canyon Lake.

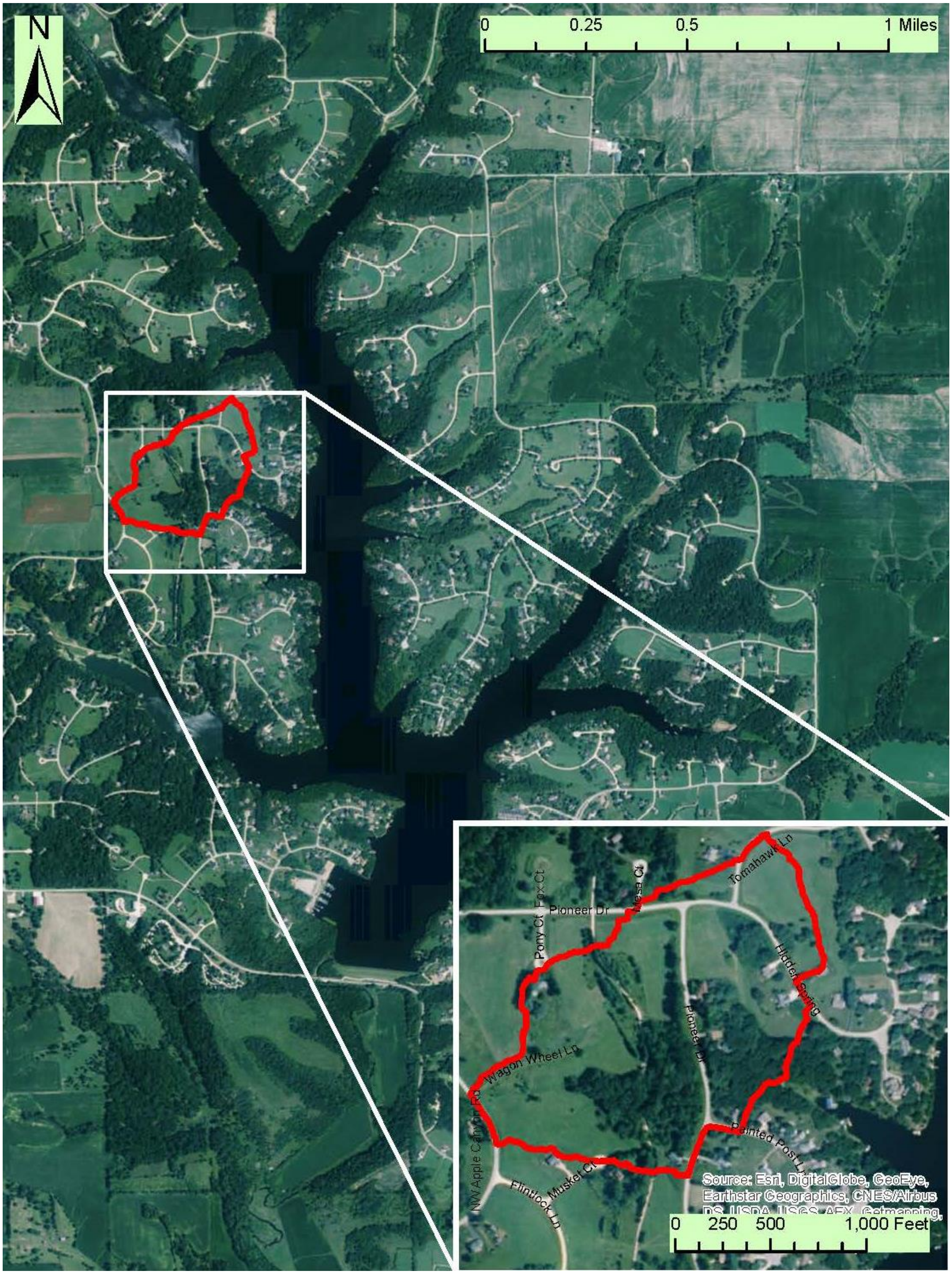


Figure 2. Hidden Spring Cove location and watershed.

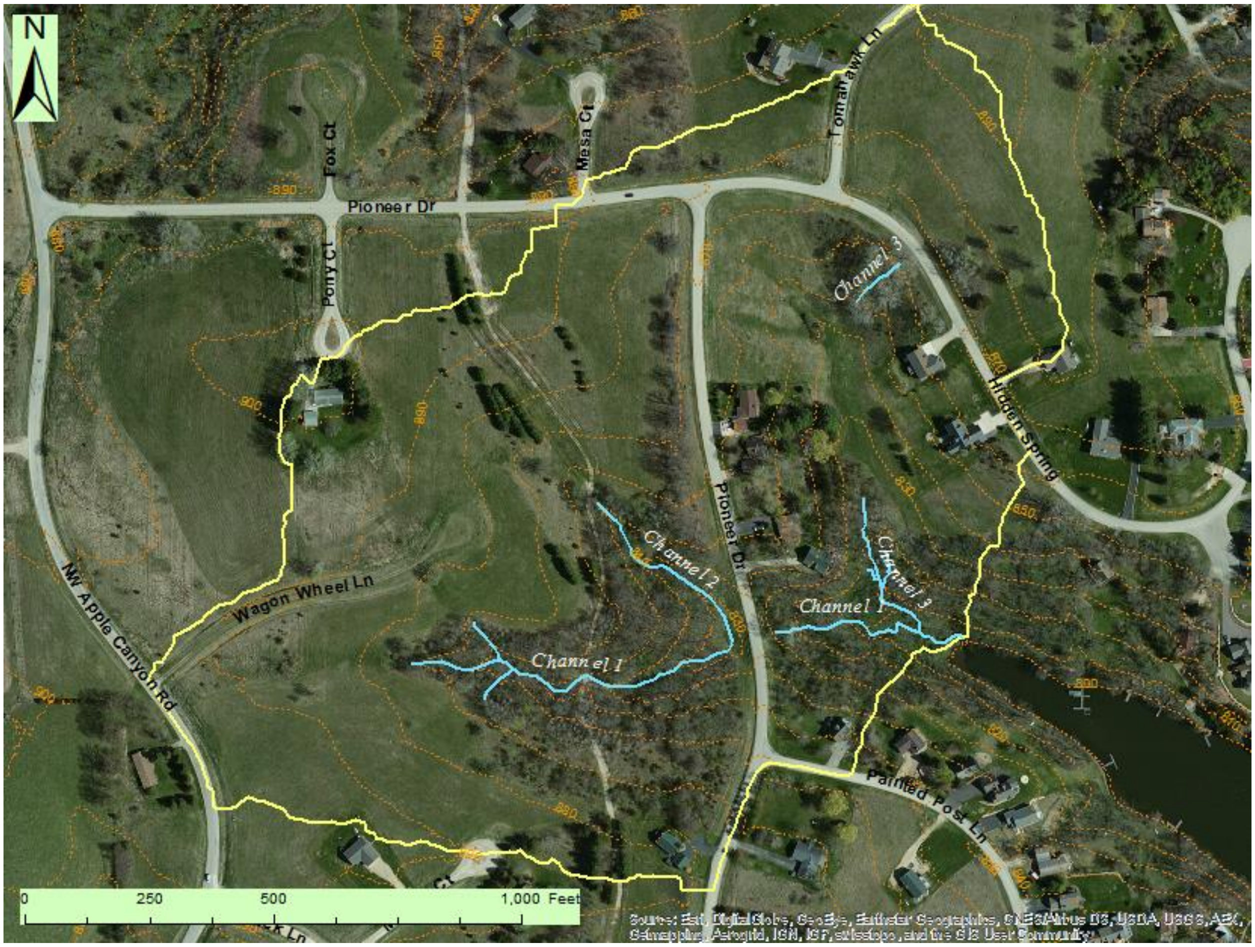


Figure 3. Channelized flow in the watershed of Hidden Spring Cove.

1.2 Problem Statement

The purpose of this project is to address the excessive erosion issues occurring within the lower part of the main channel in Hidden Spring Cove at Apple Canyon Lake in Apple River, IL. The erosion is resulting in sediment and associated nutrients entering into the lake. The goal of the project is to 1) identify specific areas of erosion for management, and 2) offer recommendations to stabilize these areas to prevent further erosion within the main channel of Hidden Spring Cove.

1.3 Objectives

1. Identify areas of major erosion within the watershed of Hidden Spring Cove.
2. Investigate the possible causes of erosion. These include, but are not limited to, soil properties, slopes and land features within the watershed, velocity of runoff, structures, and land use within the watershed (Figure 2).
3. Analyze the Hidden Spring Cove watershed:
    - Delineate the watershed
    - Calculate peak flows at strategic points within the watershed using the 2, 5, 10, and 20-year storm events
    - Estimate channel velocity and erosive capacity for the storms listed above

4. Recommend three erosion control systems for the area to the east of Pioneer Drive in the Hidden Spring Cove watershed (Figure 4). Make recommendations based on feasibility, accessibility, effectiveness, and cost using a decision matrix.
5. Provide cost estimates for all the recommended erosion control systems based on the cost of all materials needed and labor.
6. Provide a construction plan set for one of the recommended erosion control systems that includes a design for the erosion control system.

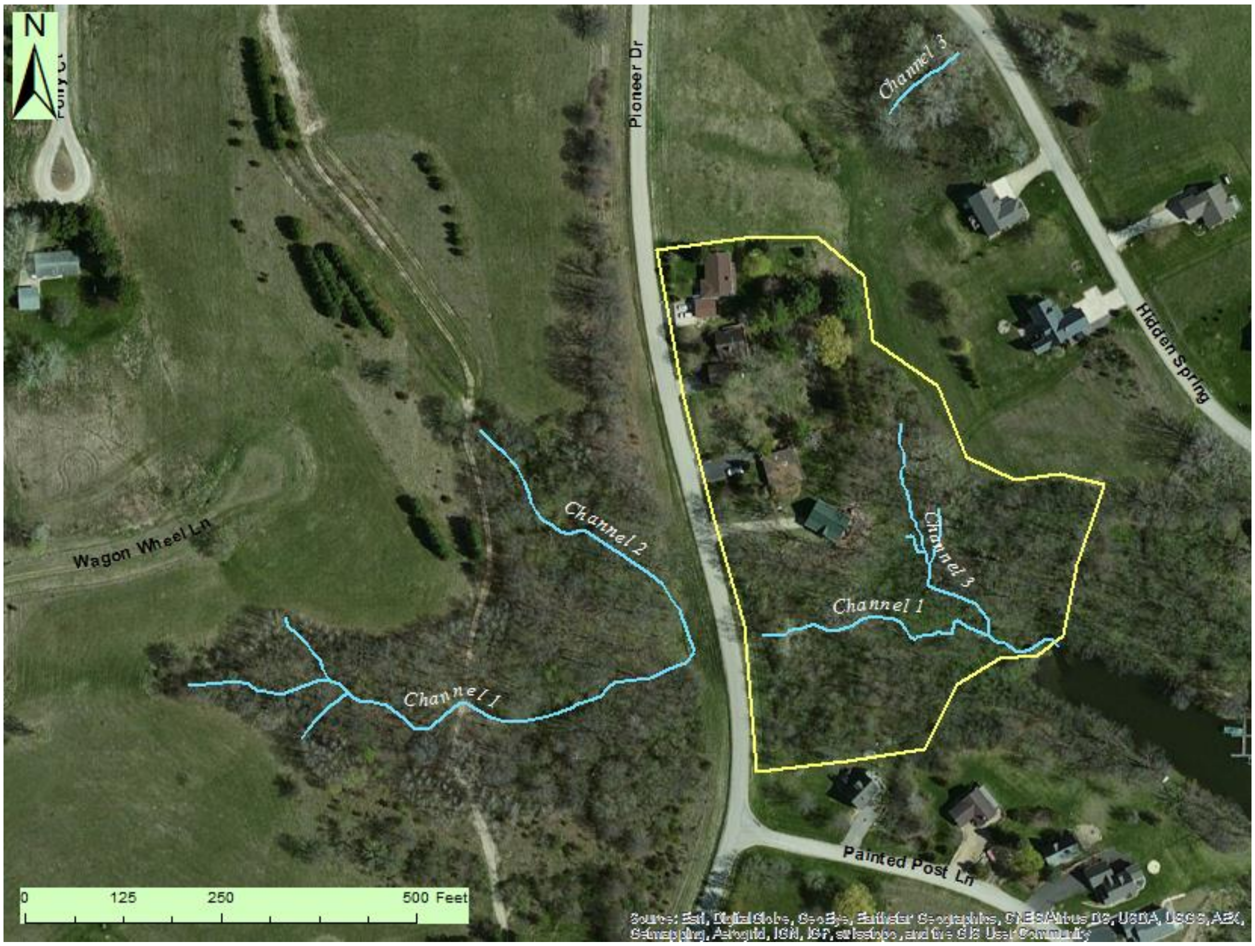


Figure 4. Site for evaluation and design alternatives.

1.4 Constraints

During the startup phase of the project, constraints were identified from discussion with the project sponsor and State and Federal regulations. As the project proceeded, new constraints arose and were addressed. One primary constraint is the limited space for personnel and machinery to gain access to the design area, especially along the channel edge and nearest the lake. State and federal regulations constrain the design through Illinois DNR standards that are mandatory to follow, specifically Conservation 2000. In addition, allowable work hours within the community are between 8 am and 5 pm and construction should take place in the summer or fall when rain fall is the lowest.

2. Site Visits

2.1 Surveying Data

Survey data were collected on three separate site visits. Four survey hubs were set as control points to access all areas of interest. The first control point was set on the east edge of Pioneer Drive (CP 1). The second control point (CP 2) was set to the west of Pioneer Drive and was used as a back site from CP 1 to set a consistent axis for data collection. The third control point (CP 3) was located along Channel 1 before the convergence with Channel 3. The fourth control point (CP 4) was set along Channel 3. All survey points were analyzed to obtain location and elevation as related to CP 1 and CP 2.

Data was collected for survey points along Channels 1 and 3 (Figure 5). This data was used to create elevation profiles of the flowlines of each channel (see 3.3 Channel Profiles).

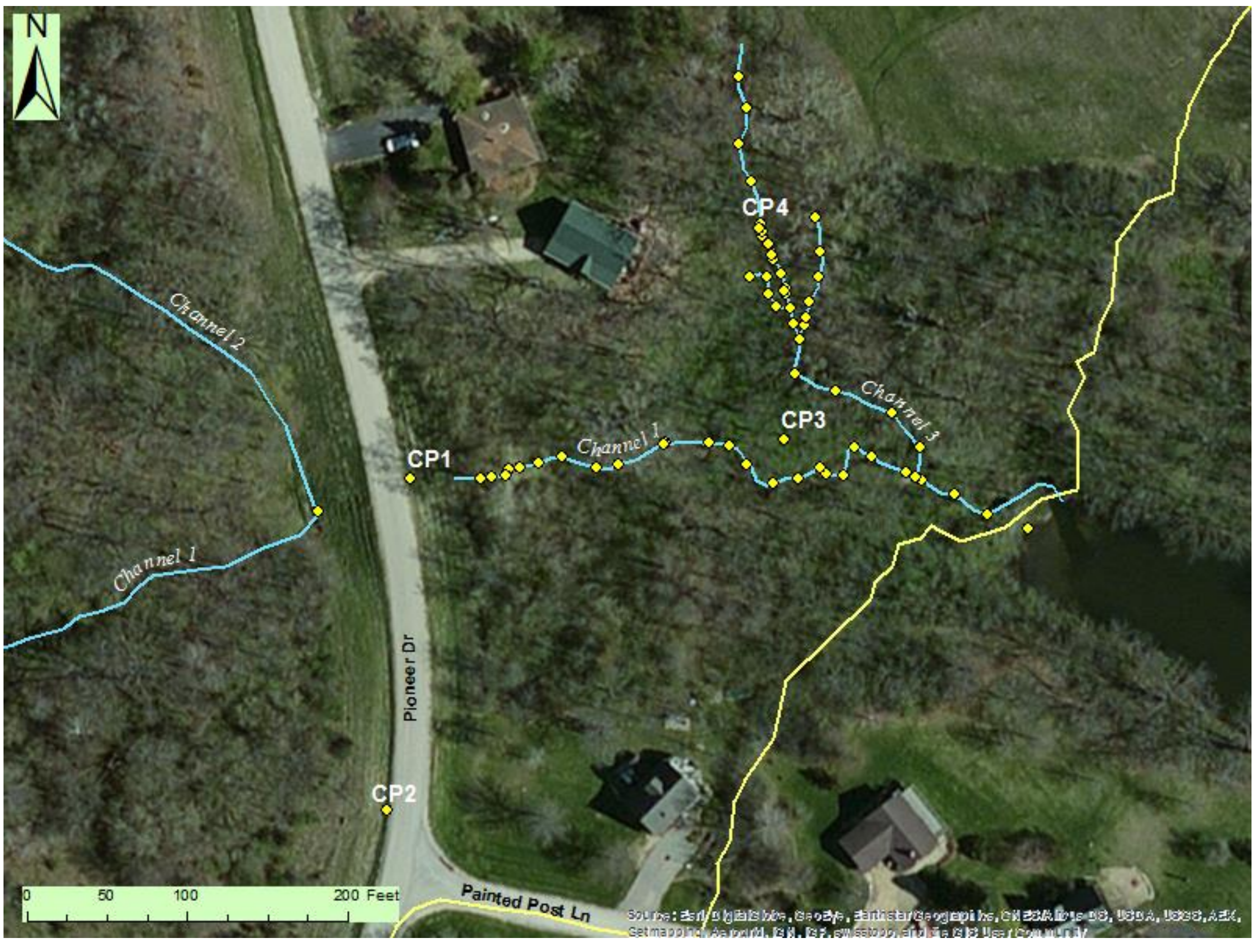


Figure 5. Elevation profile survey points.

On the third site visit, transect data was collected. A transect is a set of elevation data perpendicular to the flow of the channel that creates a cross section (Figure 6). Steep slopes on the transects indicate the flow of stormwater runoff has eroded the soil. These transects were used to estimate the amount of cut and fill required along the channel and to accurately depict where the most severe erosion was occurring along the flow path.

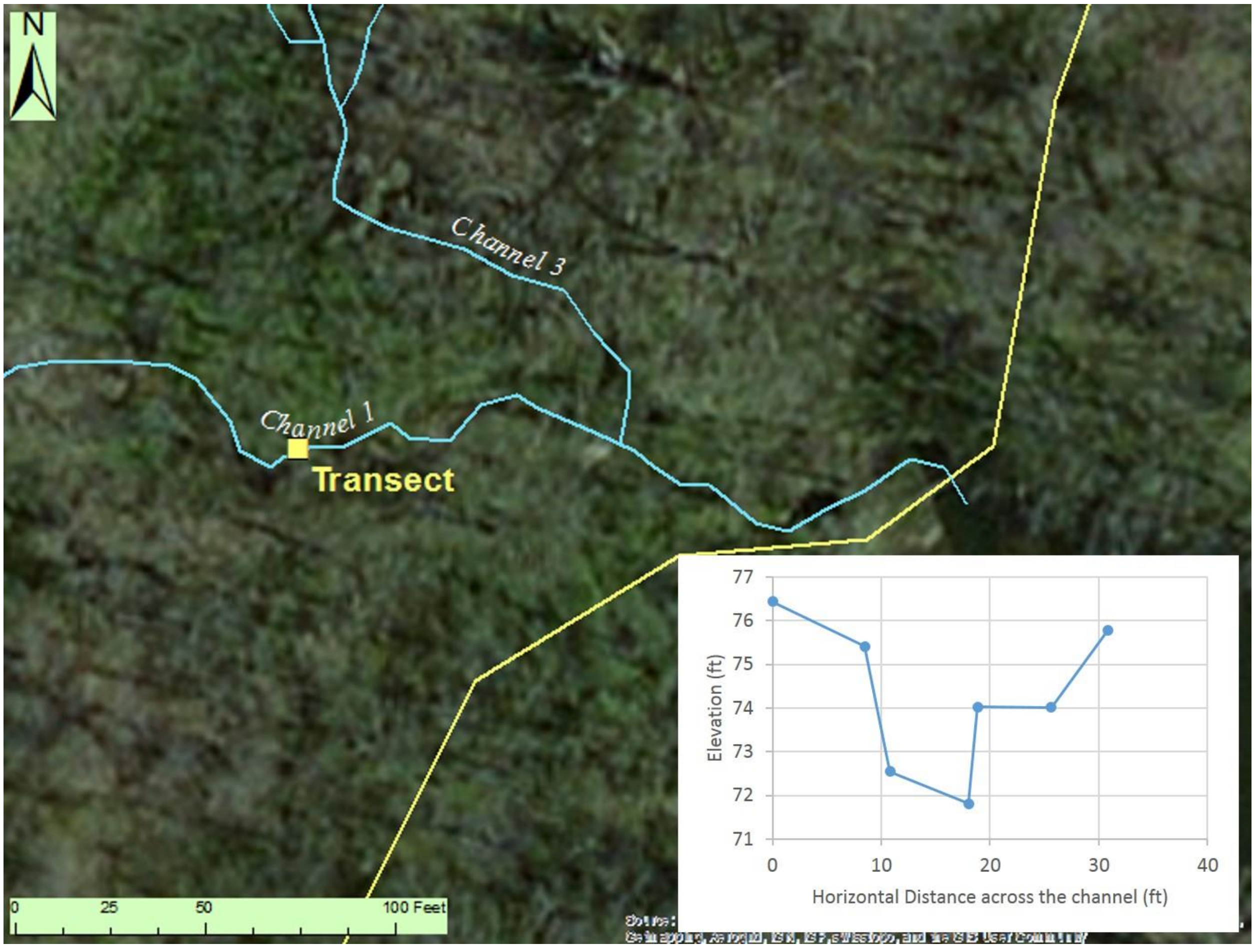


Figure 6. Example survey transect.

2.2 Areas of Erosion

Erosion has occurred throughout most of the natural channels within the Hidden Spring Cove watershed. Several locations were found to have significant or severe erosion. These locations have been highlighted in yellow in Figure 7.

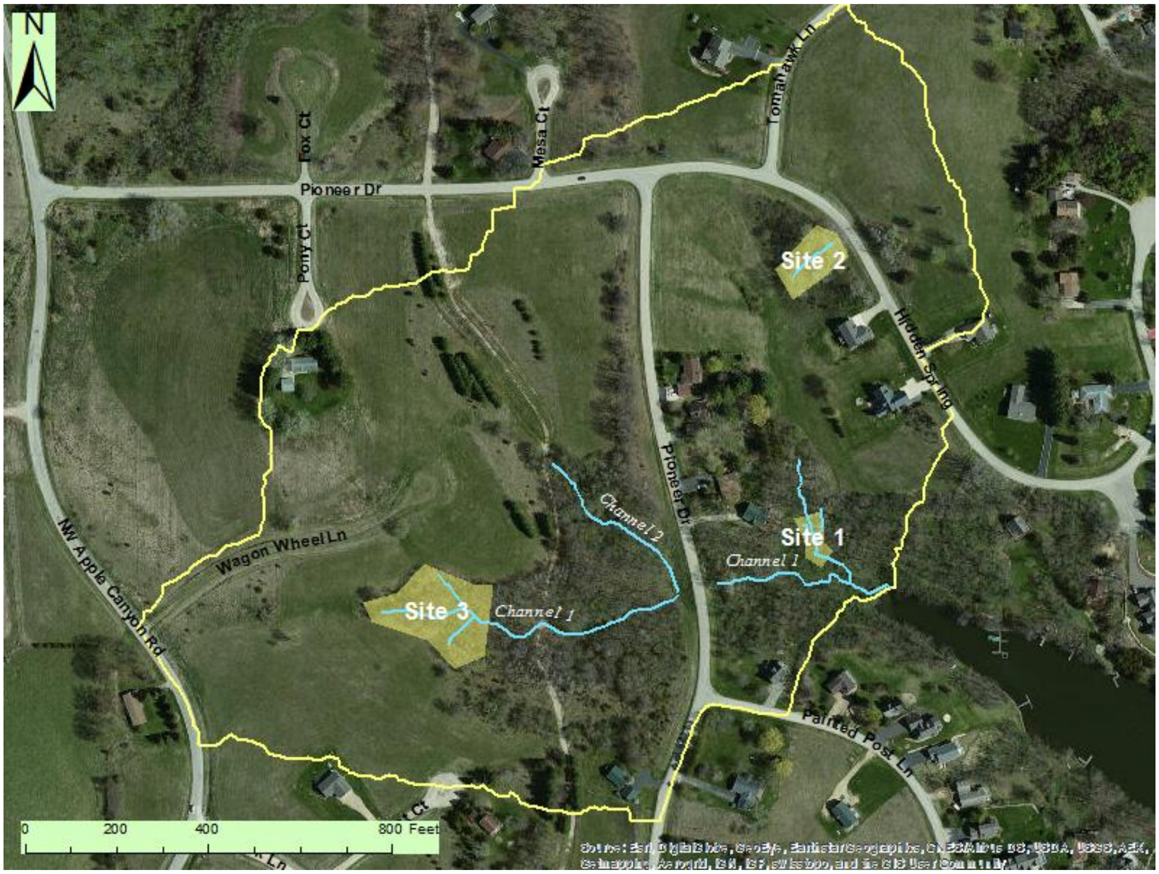


Figure 7. Areas of severe erosion.

Site 1 was located in the lower portion of Channel 3. The channel in this site had vertical banks with heights of approximately five feet (Figure 8). There were also two five foot drops along the flow channel (see 3.3 Channel Profiles).

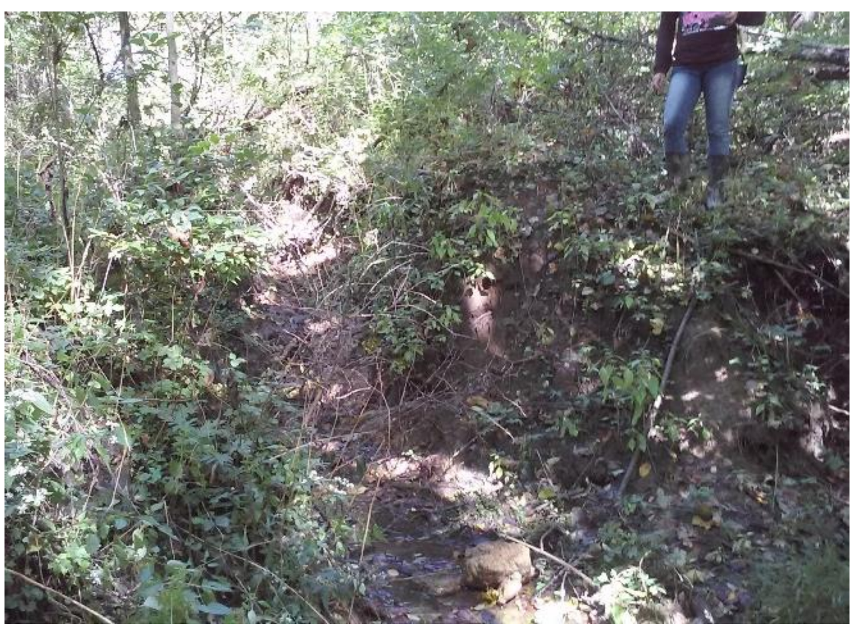


Figure 8. Site 1 bank erosion.

Site 2 was located at the outer reaches of Channel 3. Upstream of this site there was an 18 inch culvert that ran under Hidden Spring Road. The outlet of the culvert was about six feet from the tree line. A few feet inside the tree line there was severe erosion, starting with a six foot deep gully (Figure 9 and Figure 10). This gully gradually became shallower until disappearing roughly halfway through the wooded area.

Figure 9. Site 2 gully.

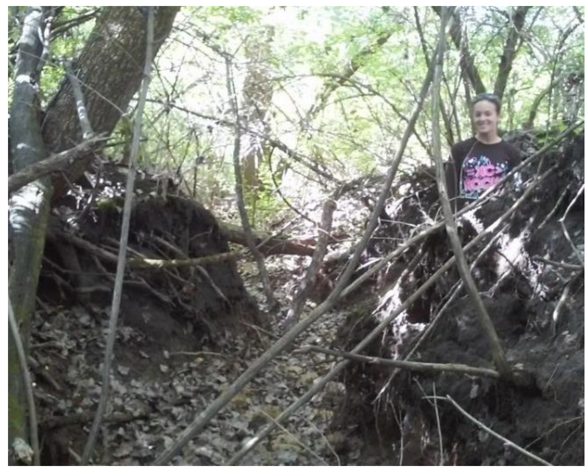


Figure 10. Site 2 gully.

Site 3 was located at the outer reaches of Channel 1. The channel branched out in three directions in this area (Figure 11). The southernmost branch has begun to channelize and thus started to erode (Figure 12). The middle branch had gullies forming that were approximately 1 to 2 feet deep (Figure 13). The northernmost branch had the most severe erosion of the three. The erosion in this branch removed significant soil around the tree roots resulting in 6 foot deep gullies (Figure 14).

Figure 11. High erosion Site 3 channels.

Figure 12. Site 3 south channel erosion.

Figure 13. Site 3 middle channel erosion.

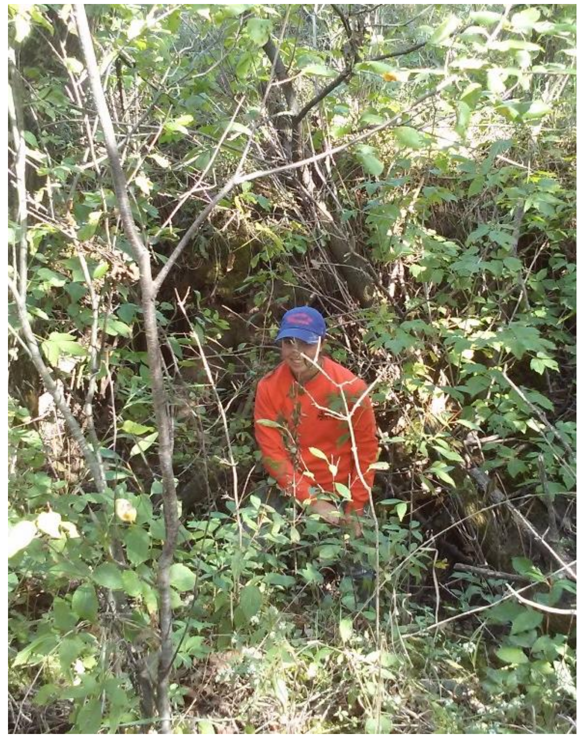
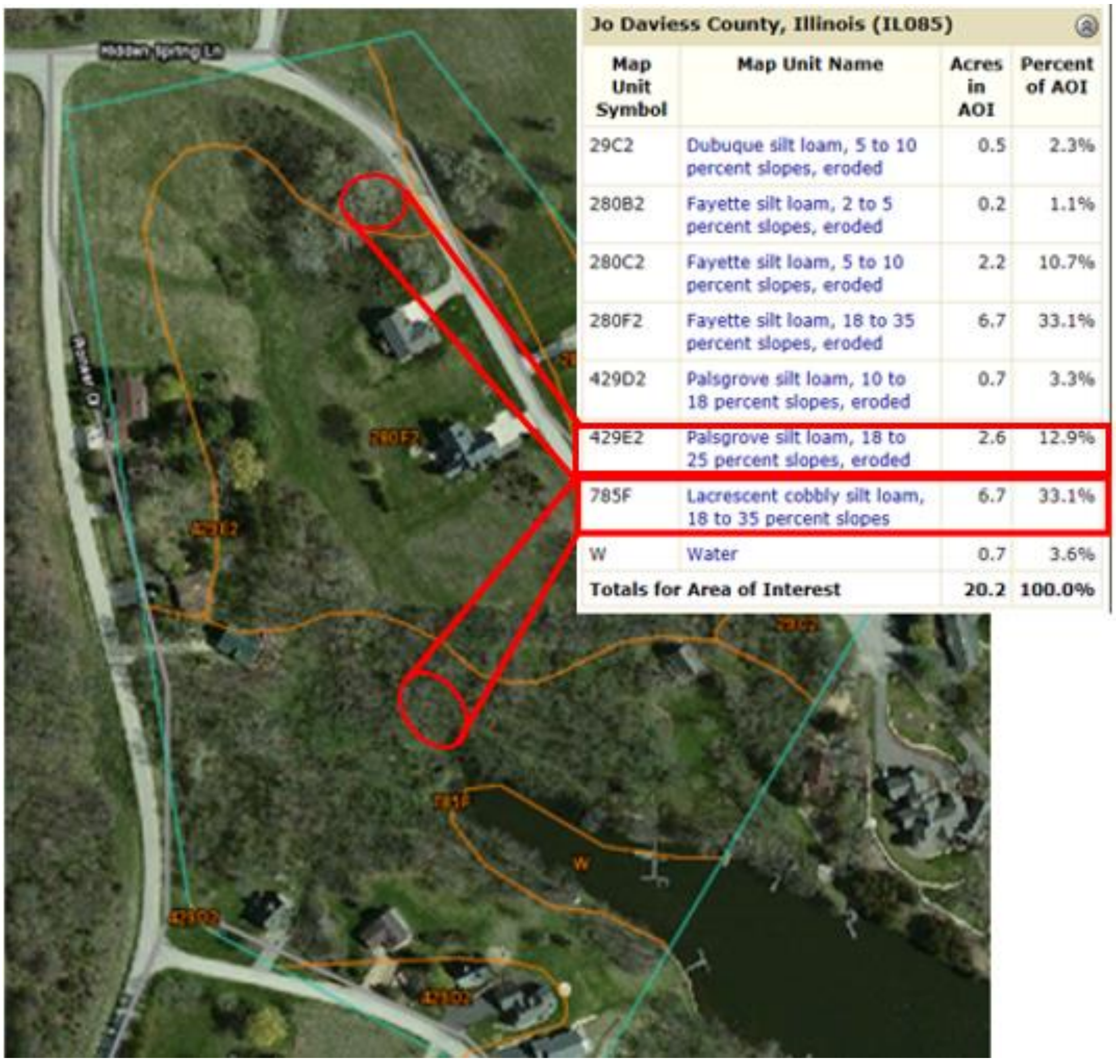


Figure 14. Site 3 north channel erosion.

2.3 Soil Samples

To determine the types of soils located within the watershed of Hidden Spring Cove, soil samples were collected at specific locations where erosion was most severe. These locations included a soil horizon located within a gully in Site 1 and a soil horizon located within a gully in Site 3 (Figure 15). The soil type was necessary to accurately calculate the runoff generated from a storm event and determine the causes of erosion.

A USCS texture analysis was performed on the collected soil samples to determine the soil type. Both soil samples were determined to be silty loam with small amounts of clay. The USDA Web Soil Survey indicated that the soil in this area was silty loam (Figure 15). The results of the USDA Web Soil Survey and the texture analysis were mostly consistent with each other. Data from USDA Web Soil Survey also showed that the soils were significantly eroded, which was to be expected.



Jo Daviess County, Illinois (IL085)			
Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
29C2	Dubuque silt loam, 5 to 10 percent slopes, eroded	0.5	2.3%
280B2	Fayette silt loam, 2 to 5 percent slopes, eroded	0.2	1.1%
280C2	Fayette silt loam, 5 to 10 percent slopes, eroded	2.2	10.7%
280F2	Fayette silt loam, 18 to 35 percent slopes, eroded	6.7	33.1%
429D2	Palsgrove silt loam, 10 to 18 percent slopes, eroded	0.7	3.3%
429E2	Palsgrove silt loam, 18 to 25 percent slopes, eroded	2.6	12.9%
785F	Lacrescent cobbly silt loam, 18 to 35 percent slopes	6.7	33.1%
W	Water	0.7	3.6%
Totals for Area of Interest		20.2	100.0%

Figure 15: Results from Soil Web Survey.

3. Watershed

3.1 Watershed Delineation

The watershed of Hidden Spring Cove was delineated using LiDAR data and ArcGIS software. LiDAR data is accurate elevation data that is obtained by analyzing the reflection of a laser off the surface of the Earth. This data is readily obtainable for every square meter of many regions in the United States. The area that drains to the pour point was defined based on LiDAR elevation data.

The pour point was at the mouth of Hidden Spring Cove and the delineated watershed was 44 acres (Figure 16).

Figure 16. Pour point and Hidden Spring Cove watershed.

3.2 Design Area

After analysis of the entire watershed, Rut Breakers Inc. determined that not all areas of erosion could be addressed within this project. After discussion between Rut Breakers Inc. and the client, an agreement was reached that erosion control design recommendations would only be made for a portion of the watershed of Hidden Spring Cove. This portion included the lower section of Channel 1, to the east of Pioneer Drive, and the lower section of Channel 3 (Figure 17).

Figure 17. Design recommendation area.

3.3 Channel Profiles

Survey and LiDAR elevations were plotted for Channels 1 and 3 within the design area. The elevation profile of Channel 1, from Pioneer Drive to Apple Canyon Lake, can be seen in Figure 18. The elevation profile of Channel 3, from the edge of the trees to the intersection with Channel 1, can be seen in Figure 19. The survey data was calibrated using a LiDAR elevation point. The point used was located where the two channels met and is indicated in the elevation profile by a star. Four points, indicated by triangles in the profiles, were included to provide an idea of where the changes in elevation occur along the channel.

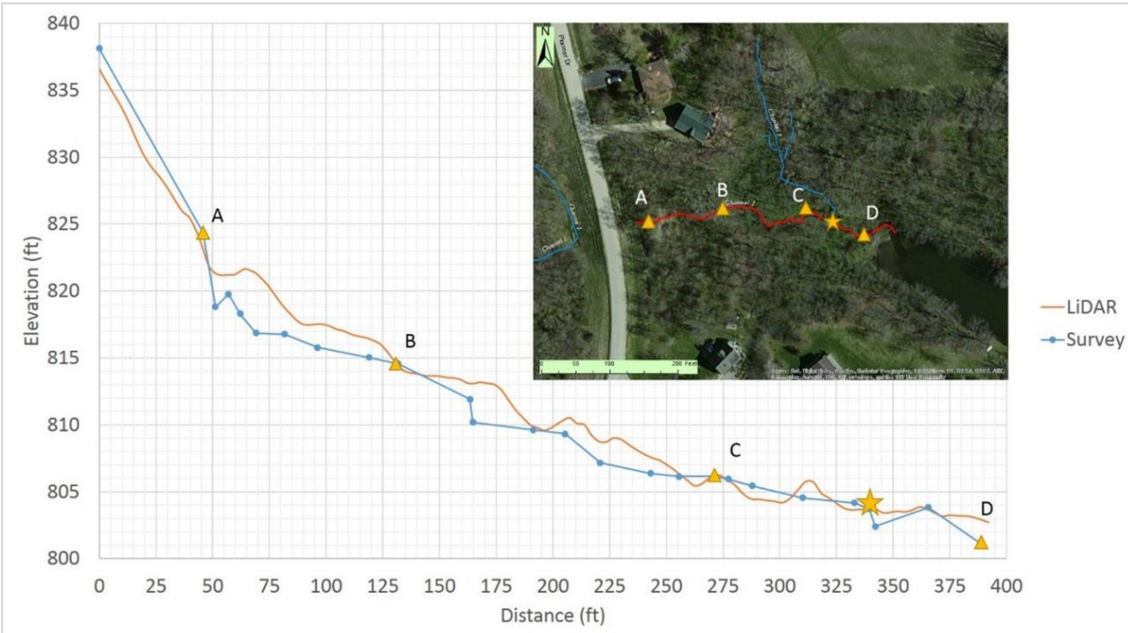


Figure 18. Elevation Profile of Channel 1.

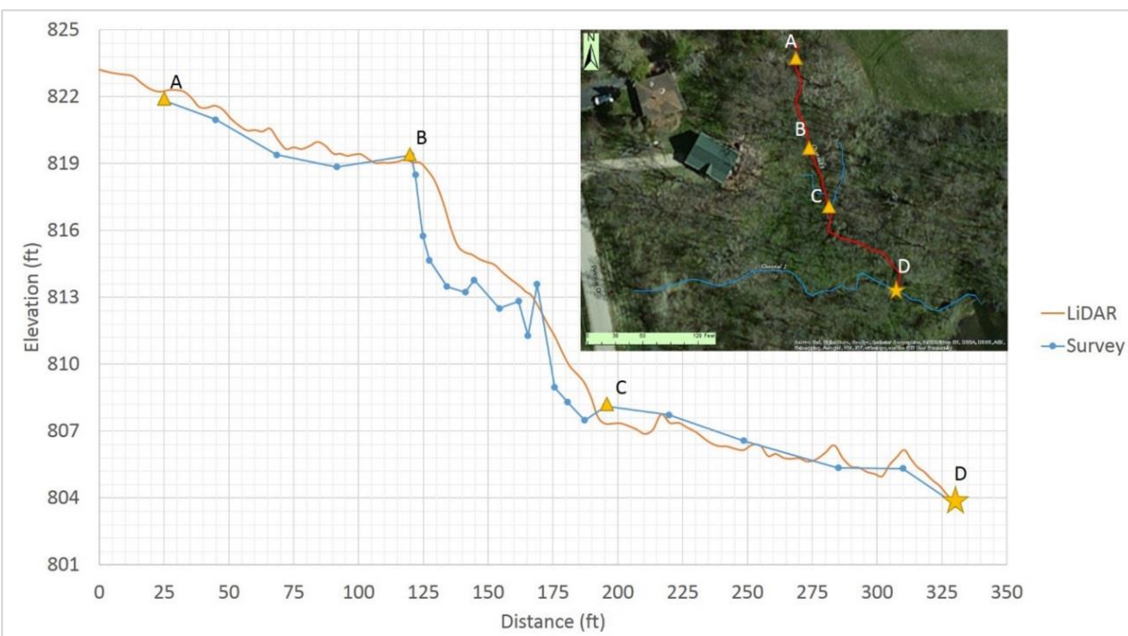


Figure 19. Elevation Profile of Channel 3.

3.4 HydroCAD Model of Current Conditions

A HydroCAD model was developed to determine current characteristics of runoff within the watershed and sub-watersheds. Areas of each type of ground cover and the longest flow length were measured using ArcGIS software. The flow for several storm events into the lower section of Channel 1 and through Channel 3 can be seen in Table 1. The 100-year storm event was used for the erosion control design.

Table 1. Runoff Values for 25, 50 and 100-Year Storm Events

	Inflow (cfs)	
Storm Event	Channel 1	Channel 3
25-yr	36	30
50-yr	45	42
100-yr	52	53

4. Erosion Control Methods

4.1 Research

Research was conducted based on data collected from site visits to Hidden Spring Cove. Based on soil samples, survey data, and various models of the system, Rut Breakers Inc. researched possible solutions to reduce the erosion in the watershed. The possible solutions were narrowed down to five options that were believed to have the most potential for success. A cost estimate was calculated for each of the options with the understanding that a more thorough cost estimate would be calculated for the recommended method. The recommended method was determined using a decision matrix (see 4.7 Decision Matrix).

4.2 Option 1 – Rock Riffle

The first method investigated was a rock riffle. Rock riffle design involves strategically placing boulders perpendicular to the flow channel to create a ponding effect. This ponding effect allows for settling of particulate matter (Figure 20). Riprap would be placed at strategic locations along Channels 1 and 3 to reduce the velocity of water. Slowing down the water would reduce erosion of the channel banks and return back to natural conditions. A cost estimate was determined based on required excavation, materials cost, and labor cost (Appendix C: Cost Estimates). The cost estimate for Option 1 was approximately $70,000 (Department of Inspections and Permits.) (Revegetation of Disturbed Areas).

Figure 20. Rock riffle example (New discharge regulations for land development).

4.3 Option 2 – Riprap along Entire Channel

The next method included implementing riprap along the entire channel and would reduce erosion by decreasing the velocity of water in the channels. This method would include the removal of years of eroded soil that has been transported to downstream locations and return the channels to a natural slope. The riprap would prevent a free surface of soil from being exposed along the stream, and thus prevent sediment from being eroded.

The entirety of Channels 1 and 3 would be excavated to remove the transported soil and start to develop a more natural stream bank. A stair-step effect would be built on the side slopes of the channels (Figure 21). Riprap would be placed in the bottom of the channel and on the first step. The upper steps would be vegetated with specific plant species that have a root system as such to hold the soil in place.

Figure 21. Riprap channel (Level 2).

The removal of soil from the channels could be extensive and result in much higher construction costs. Also, large areas would need to be completely cleared to allow construction equipment and crews to access the area and complete construction.

A cost estimate was calculated based on excavation estimates, cost of materials, and labor (Appendix C: Cost Estimates). The estimated cost for Option 2 was approximately $58,000 (Revegetation of Disturbed Areas) (Department of Inspections and Permits.)

4.4 Option 3 – Gabion Staircases

Option 3 included placing gabion baskets along the channel in a stepping fashion. Gabion baskets are wire baskets filled with various sized rocks to help slow down velocities and protect the underlying soil (Figure 22 and Figure 23). This gabion staircase option would involve placing gabion baskets in locations of high slope along the Channels 1 and 3. This method would be effective in areas that experience high flows as were seen in Hidden Spring Cove.

Figure 22. Up close view of gabion basket (Gabions Confine Stone For Erosion Protection and Retaining Soil).

Figure 23. Gabion basket staircase (Quality Gabion Mattress for Slope Stability)

A gabion staircase would allow for the use of smaller rocks which normally would not be able to withstand high flow on their own. Gabion baskets would also provide high stability and would not lose their structural integrity from a break or two in the wires. Due to the space in between the rocks, vegetation could grow through the rocks, increasing aesthetics. Gabion baskets were found to be easy to install and could be filled with material on the site, decreasing the cost of construction.

A cost estimate was calculated based on excavation estimates, cost of materials, and labor (Appendix C: Cost Estimates). The estimated cost for Option 3 was approximately $50,000 (Revegetation of Disturbed Areas) (Department of Inspections and Permits.).

4.5 Option 4 – Settling Ponds

The use of settling ponds was also investigated. The main purpose of the settling ponds would be to settle out suspended solids in the stormwater runoff. The settling ponds would also slow down the runoff to some extent by collecting water in the ponds and only allowing water to flow down the rest of the channel if the storm event was large enough.

Settling ponds would involve constructing two ponds along Channel 1 (Figure 24). The first pond would be located at the downstream end of the culvert under Pioneer Drive. The second pond would be at the intersection of Channels 1 and 3.

Figure 24. Settling pond locations.

Sizing of the ponds would be based on settling rates of solids and runoff volumes.

A cost estimate was calculated based required excavation, cost of materials, and labor (Appendix C: Cost Estimates). The cost estimate for Option 4 was approximately $23,000 (Revegetation of Disturbed Areas) (Department of Inspections and Permits.).

4.6 Option 5 – Regenerative Stormwater Conveyance

The final option investigated was a regenerative stormwater conveyance system. Regenerative stormwater conveyance (RSC) is a restoration method for eroded outfalls and drainage channels. RSC utilizes a strategic series of cascades, riffles, and pools over a sand and woodchip bed (West Virginia Stormwater Management and Design Guidance Manual) (Figure 25).

Figure 25. Regenerative Stormwater Conveyance (West Virginia Stormwater Management and Design Guidance Manual).

A riffle is a shallow and wide channel lined with cobbles, while a pool is a shallow pond with the same width as the riffle sections. These components reduce velocity, restore the channel bed, and decrease particulate matter loadings. The entire length of the channels, including the pooled areas, is lined with a mixture of sand and woodchips. This lining increases infiltration of the stormwater along the channels.

The cost was estimated based on the amount of soil to be excavated, the cost of materials, and labor (Appendix C: Cost Estimates). The cost estimate for Option 5 was approximately $65,000 (Department of Inspections and Permits.) (Revegetation of Disturbed Areas).

4.7 Decision Matrix

A decision matrix (Table 2) was used to determine the optimal erosion control option for Hidden Spring Cove. This matrix was developed using five different criteria. Those criteria were feasibility, accessibility, effectiveness, cost, and client preference.

The erosion control options received a score for each criteria. Scores ranged from one to five, with one being the lowest. Each criteria was assigned a weight based on its overall importance. The criteria weight was then multiplied by the score and added up for each erosion control option. Cost scores were given based on the cost estimates for each option, with the lowest cost receiving a five. If client preference received a one, the option received an overall score of zero.

Based on client preference, the gabion staircase option received a score of zero. The settling ponds received the next lowest score due to ineffectiveness. Rock riffle and riprap along the entire channel received the second and third highest scores, respectively. RSC received the highest score of 68. Therefore, the RSC was determined to be the optimal erosion control method for the design area of Hidden Spring Cove.

Table 2. Decision Matrix

	Feasibility	Accessibility	Effectiveness	Cost	Client Preference	Total	Client Comments
Rock Riffle	5	5	4	2	4	64	This is our second choice
Riprap Along Entire Channel	4	3	5	3	2	53	Seems excessive, I think riprap should only be needed in some areas.
Gabion Staircases	5	5	5	3	1	0	No.
Settling Ponds	4	3	1	5	3	43	I like the idea of settling ponds. If the regenerative stormwater design is not chosen, we should combine a pond with the rock riffles.
Regenerative Stormwater Conveyance	5	3	5	2	5	68	I like this the best
Criteria Weights	4	2	4	1	4		

5. Erosion Control Design

5.1 Design Process

Based on the results from the decision matrix, regenerative stormwater conveyance was selected and a design was developed. Each channel was designed separately so the natural channel slopes could be utilized. For the design, the area was broken into Channel 1, Channel 3, and Lower Channel 1 (Figure 26).

Figure 26. Channels for design.

The West Virginia Stormwater Management and Design Guidance Manual (2012) was referenced for general design guidelines of the RSC systems. The following paragraphs explain the design process in detail and sample calculations for the design process were recorded in Appendix A: Sample Calculations.

The riffle section was designed as a wide channel bed of cobbles. An average diameter of cobble was selected. The depth of the cobble was set to be two times the cobble diameter. This was done to ensure that the bottom of the riffle would be completely covered by rock and to prevent sediment underneath the channel from eroding.

To ensure the cobble size selected would be able to withstand the velocity that the system required, velocity (v) was calculated using Manning's Equation (Equation 1). Manning's roughness coefficient (n), hydraulic radius (R_h), and slope in the direction of the flow path (S) were needed to calculate velocity. Manning's roughness coefficient was calculated based on the depth of flow in the riffle channel (d) and average cobble size (d_o) (Equation 2). The hydraulic radius (R_h) was calculated based on the width of the riffle cross section (W) and the depth of the cross section (D) (Equation 3). Initial values for some of these parameters had to be assumed, and then the process iterated to convey the necessary flow.

Equation 1:

$$v = \frac{1.49}{n} * \left(R_h{}^{2/3}\right) * \left(S^{1/2}\right)$$

Equation 2:

$$n = \frac{d^{1/6}}{(21.6 * \log\left({}^{d}/_{d_0}\right) + 14.0)}$$

To determine the hydraulic radius, an initial width of the cross section was assumed, and the depth of the riffle was calculated from 5% of the width. From the surveyed transects of the channels, the width ranged from 10 to 30 feet. The design width of the riffle should be greater than 10 feet, and the depth should be set to 5% to 10% of the width.

Equation 3:

$$R_h = \frac{2(DW^2)}{(3 * W^2) + (8 * D^2)}$$

The flow (Q) was calculated to ensure that the design would be able to convey the 100-year storm event as calculated by HydroCAD (3.4 HydroCAD Model of Current Conditions). Flow conveyed by the designed riffle sections was calculated based on velocity and the cross sectional area of the channel (A) (Equation 4).

Equation 4:

$$Q = v * A$$

Flow in the channel was required to be subcritical to prevent the cobbles from being lifted up and transported. Subcritical flow can be ensured by a Froude number less than one. Therefore, Froude number (F_r) was calculated based on velocity (v), acceleration due to gravity (g) and the channel depth (d) (Equation 5).

Equation 5:

$$Fr = \frac{v}{\sqrt{g * d}}$$

Cobble diameter and channel width were iterated until the conveyed flow was greater than the 100-year storm and Froude number was less than one.

Next, the pools were designed. The channel width determined in the above calculations was set equal to the pool width. The optimum pool length was determined to be greater than 10 feet and the storage of the pools was calculated from the total volume of all pools added together.

At the entrance of each pool a boulder weir would be placed at a 50% slope to stabilize the pool walls and give an inlet for each pool. The diameter size of the weir boulders was calculated to be 4 times the diameter of the riffle cobble, 40 inches. The weirs would be lined with a geosynthetic filter fabric in order to stabilize the ground at the steep slope, and prevent the slope from failing. The boulders would also be buried at least 6 inches below the bottom of the pool in order to provide maximum bank stabilization.

When the slope of the channel exceeded 5%, a cascade followed by three consecutive pools was required. The boulders in the cascade sections were determined to be equal diameter as the boulders in the weir sections and the slope should be between 30% and 50%. The cascade sections would also require a geosynthetic filter fabric to be placed under the boulders in order to provide slope stabilization.

The sand bed was designed by multiplying the total channel length by the desired channel depth and width. The depth of the sand bed should be between 1 and 3 feet to allow the greatest potential storage capacity while being a reasonable depth.

The total volume of storage capacity was determined by adding the volume capacity of the pools to the volume capacity of the sand bed. The total storage capacity was used to ensure the entire control system had enough storage to hold a 1-year storm event. Another factor that was added into the overall storage capacity was the designed settling pond located at the intersection of Channel 1 and Channel 3 (5.4 Lower Channel 1 Design).

5.2 Channel 1 Design

To begin the design of Channel 1, riprap at the downstream side of the culvert under Pioneer Drive was necessary. A Class I riprap would be required to handle the amount of flow coming from the culvert. The riprap would span 17 feet and would have an initial 3:1 slope from the culvert to the bank of the stream channel as seen in Figure 27 and Figure 28. The riprap would sit on top of nonwoven geotextile fabric made from polypropylene fiber. Nonwoven geotextile fabric would allow water to pass through into the soil while ensuring the existing soil stays in place (Geotextiles). A Class I riprap material was selected with a diameter of 18 inches. This was selected due to the ability to withstand the flow from a 100-year storm event. The riprap was designed to end at the beginning of the first riffle section of Channel 1 which would begin the design downstream towards Apple Canyon Lake.

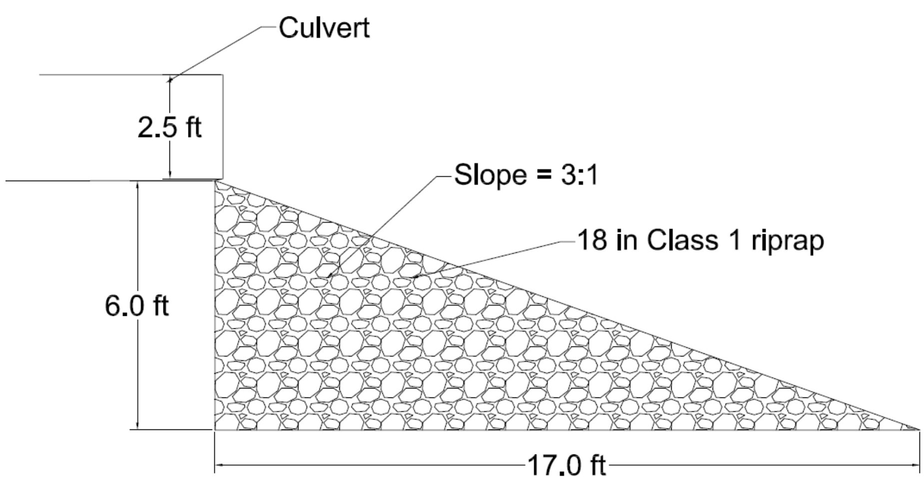


Figure 27. Riprap under culvert design.

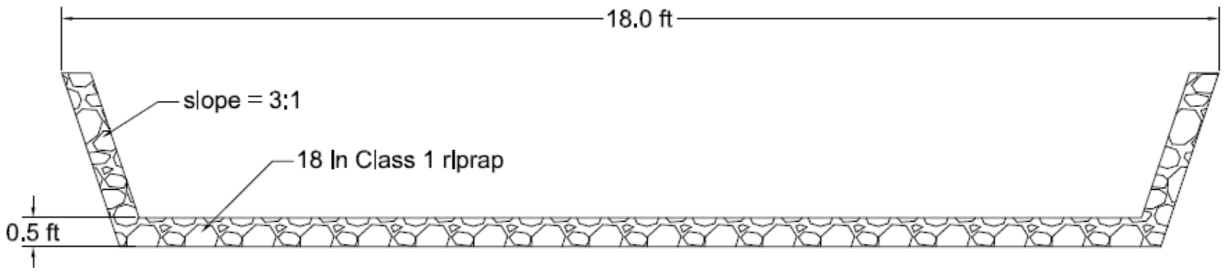


Figure 28. Riprap cross section.

The riffle design resulted in an average cobble size of 10 inches, and a depth of cobble twice of that, 20 inches. The width of the channel was determined to be 18 feet and the riffle depth was set as 5% of the width, 0.9 feet. The riffle slope in the direction parallel to flow was determined to be 10%. The cross section of this design can be seen in Figure 29.

These values resulted in a channel hydraulic radius of 0.963 feet, a Manning's coefficient of 0.067, and a velocity of 5.0 feet per second. The allowable velocity for a cobble size of 10 in was 8.8 feet per second, so these values were acceptable based on the allowable velocity.

Next the flow and Froude number were checked, the flow was calculated to be 54.0 cubic feet per second. The flow from the 100-year storm would result in a value of 52.1 cubic feet per second which was calculated using HydroCAD and the time of concentration from the delineated watershed. The Froude number was calculated to be 0.93 which is subcritical flow value, and results in stable flow throughout the channel.

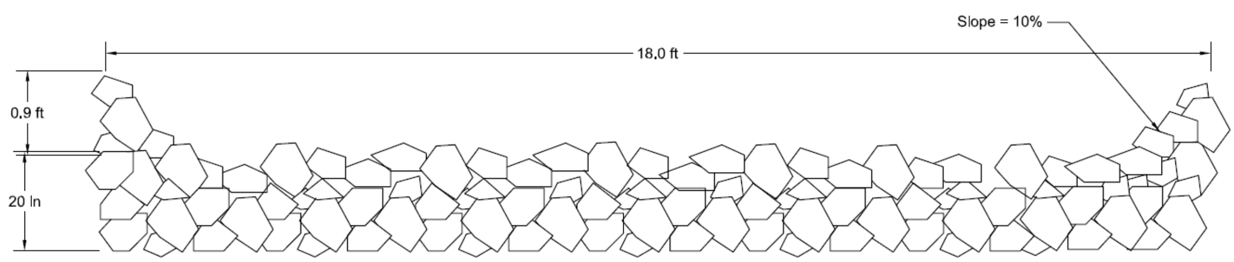


Figure 29. Designed cross section of riffle

The design section of Channel 1, starting after the end of riprap from the culvert, had an average slope of 5%; therefore, no more than one cascade was needed in the design. The pattern of riffle, cascades, and pools were designed. The main constraint of this design was the natural topography of the land and the channel transect data. The pattern was determined in order to minimize cut and fill areas, while still satisfying all design constraints.

To provide adequate storage capacity, different patterns were tested against the surveyed elevations to ensure a minimum length of 10 feet. After many iterations using excel, the pattern represented in Table 3 and Figure 30 was developed.

Table 3. Design Pattern for Channel 1

	Length	Slope
End of riprap	0	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Cascade	10	40%
Pool	15	-
Pool	15	-
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Joint Pool	5	60%

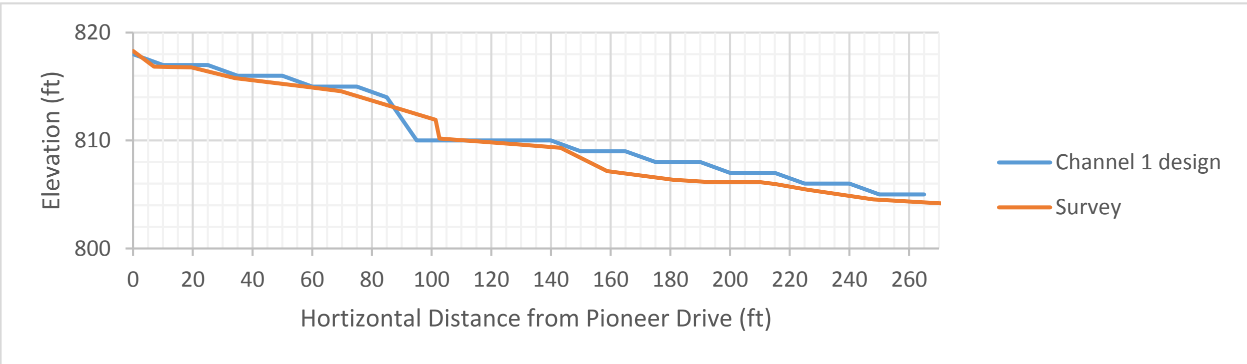


Figure 30. Survey data and Channel 1 design elevation.

This design includes 10 feet of riffle at a 10% slope followed by a 15 foot pool repeated three times consecutively (Figure 31). A 10 foot of riffle at a 10% slope was followed by a 10 foot cascade at a 40% slope followed by 3 consecutive pools at a 0% slope shown in Figure 32. Finally, the previous riffle-pool pattern was repeated again five times.

This pattern was the best option to take advantage of the natural topography. The pattern also took into account the areas of worst erosion from the surveyed channel transect data, which occurred from distance zero to distance 100.

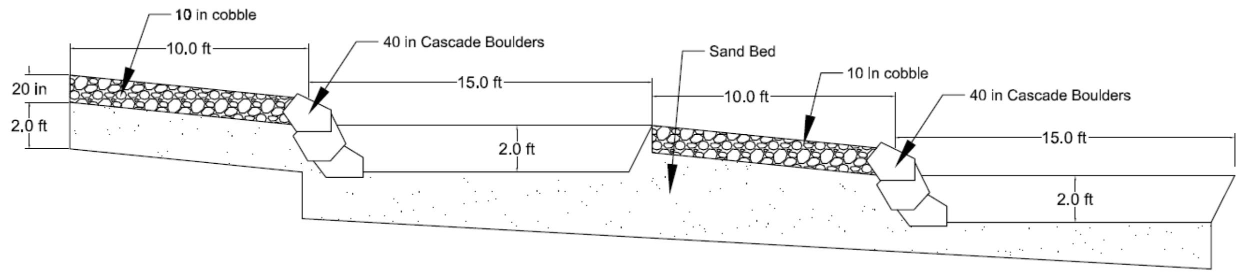


Figure 31. Alternating riffle and pool pattern located from distance 0 to 70 and 140 to 269.

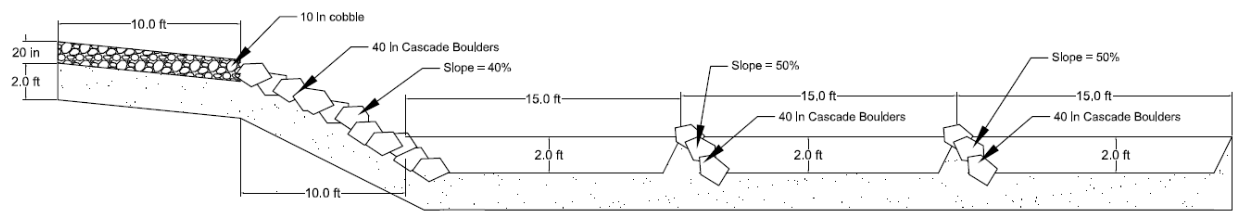


Figure 32. Riffle, cascade, and three consecutive pool pattern located from distance 70 to 140.

After the design pattern was developed, the storage volume was calculated based on the total volume of the pools. The total pool volume was calculated to be 2476 cubic feet. The volume of the sand bed was calculated by multiplying the length of the design system, 269 feet, by the sand bed depth and width. The sand bed volume was calculated to be 3874 cubic feet. The total storage capacity held in the Channel 1 design pool and sand bed was 6250 cubic feet.

5.3 Channel 3 Design

Channel 3 was designed in a similar fashion as Channel 1. The design began after the first 120 feet of lower Channel 3 due to minimal slope and erosion (point B in Figure 33). No culvert is directly flowing into the lower portion of Channel 3, so no riprap section was needed.

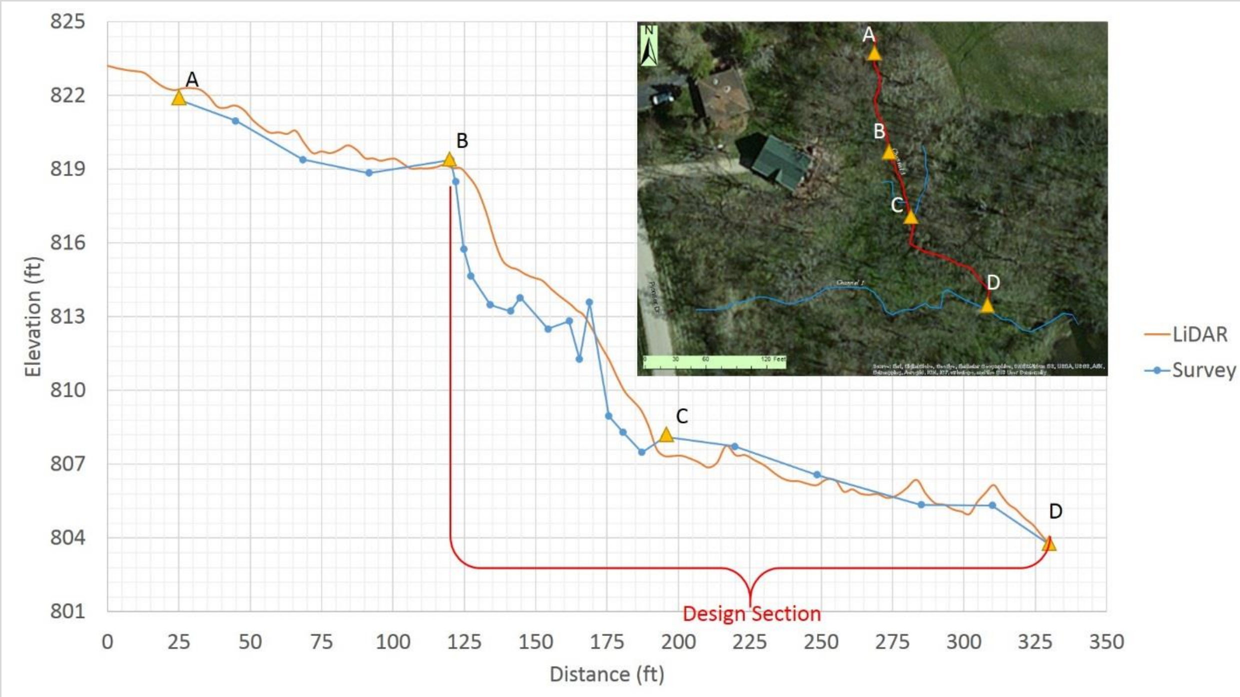


Figure 33. Design section of Channel 3.

The design section of Channel 3 had an average slope of 7.5%. Therefore two cascades were needed in the design. A design pattern was created based on the constraints of the cascade, pool, and riffle lengths, as well as the existing elevations of the channel (Table 4 and Figure 34).

Table 4. Design Pattern for Channel 3

	Length	Slope
Cascade	10	50%
Pool	15	-
Pool	15	-
Pool	15	-
Riffle	10	10%
Cascade	10	50%
Pool	15	-
Pool	15	-
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	10	10%
Pool	15	-
Riffle	5	10%
Joint Pool	10	60%

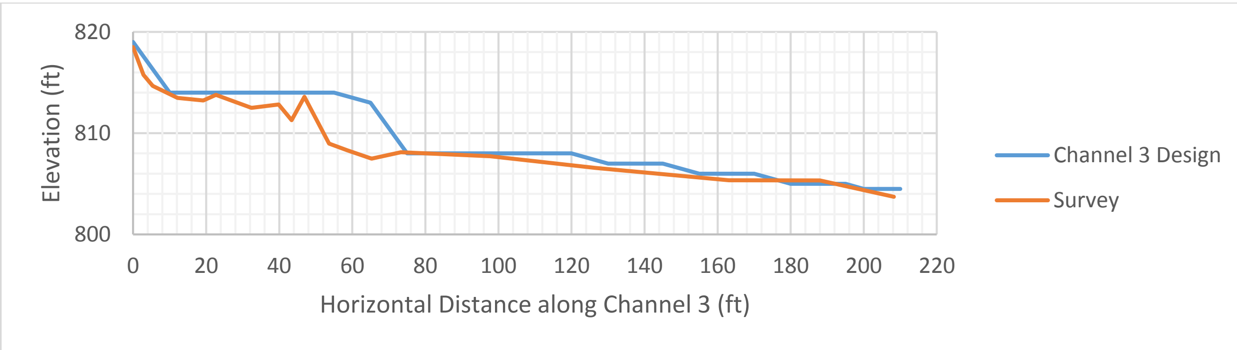


Figure 34. Survey data and Channel 3 design elevation.

Both cascades were designed to be 10 feet long and have a 50% slope. The boulders for the cascades were determined to be approximately 40 inches in diameter. Each cascade was designed to be followed by three 15 foot long pools that overall had a 1 foot elevation drop. A 10 foot long riffle section was also placed between the two cascade-pool sequences. These cascade-pool sequences stretch from a distance of 120 feet to 240 feet and have an elevation of 819.5 feet to 807.5 feet along the channel profile.

Starting at a distance of 240 feet, three riffle-pool sequences were designed (Figure 35). Each riffle was designed to be 10 feet long with a 10% slope. The riffles were calculated to need cobbles of 10 inch diameter, and therefore a thickness of 20 inches. The width of the riffle channels was calculated to be 18 feet wide and 0.85 feet deep in order to convey the 100-year storm event. Given a 100-year storm event there would be a velocity of 5.0 feet/second in the riffle sections. The 100-year storm event results in a Froude number of 0.93, which is less than 1 and therefor indicates subcritical flow. The three pools were all designed to be 15 feet long (Figure 36).

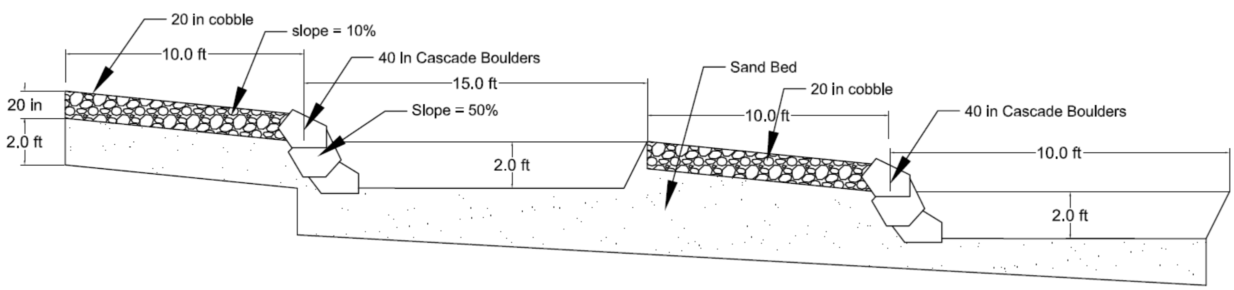


Figure 35. Riffle-pool sequence.

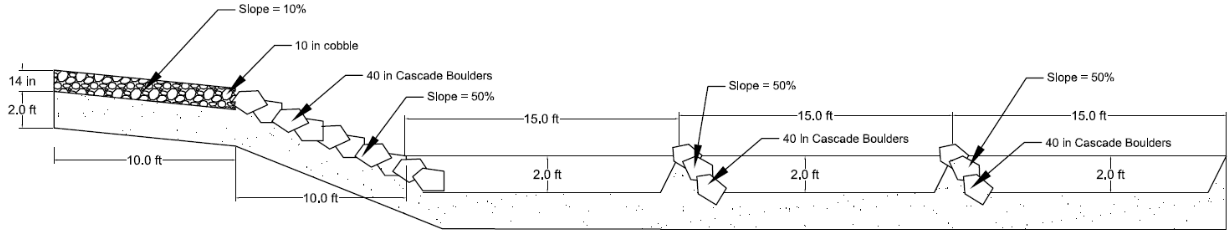


Figure 36. Riffle- Cascade-Consecutive Pools Sequence

All the pools along the Channel 3 design were determined to be 15 feet long to hold an adequate volume of water and allow the design to fit in the given length of the channel. Each pool was designed to be 18 feet wide, the same width as the riffles. A depth of 2 feet was used for each pool to aid in increasing the water storage volume.

Below the entire length of the channel a sand bed would be laid to allow for stormwater to infiltrate into the soil. The optimal sand bed for Channel 3 was determined to have a depth of 2 feet and a width of 12 feet.

5.4 Lower Channel 1 Design

Channel 1 and Channel 3 converge about 75 feet upstream of Apple Canyon Lake. At this point a settling pond was designed to handle and slow down part of the excess flow coming down both of these channels and settle out total suspended solids. The settling pond was sized to be able to contain one half of the flow from a 1-year storm event for runoff volumes pre-regenerative stormwater conveyance implementation. This means any excess water would overflow the pond, by way of a v-notch weir, and enter into the lower portion of the channel flowing towards the lake. The pond was design by using Equations 6 and 7 for the sizing of a settling pond.

Equation 6:

$$Depth = Inflitration\ rate * Drawdown\ time$$

Equation 7:

$$Area = \frac{Volume\ of\ Runoff\ to\ Infiltrate}{Depth}$$

The desired pond depth was calculated to be 5 feet. The infiltration rate was determined to be 0.13 inches per hour based on the soil results from USDA web soil survey which can be seen in Section 2.3 Soil Samples (Table 5). The drawdown time was calculated to be 18 days based on the depth and the infiltration rate. The pond was designed to be an oval with lengths of 20 and 26 feet. Therefore the volume of the pond was calculated to hold roughly 1,630 cubic feet.

Table 5. DNR Values for Infiltration Rates Based on Soil Texture (WiDNR)

Soil Texture[1]	Design Infiltration Rate Without Measurement inches/hour[2]
Coarse sand or coarser	3.60
Loamy coarse sand	3.60
Sand	3.60
Loamy sand	1.63
Sandy loam	0.50
Loam	0.24
Silt loam	0.13
Sandy clay loam	0.11
Clay loam	0.03
Silty Clay loam	0.04[3]
Sandy clay	0.04
Silty clay	0.07
Clay	0.07

The channel section following the pond was designed differently than the rest of Channels 1 and 3. A RSC system would not be effective in this section of the channel because there was a very low slope of 4.5%. Along with the elevation change being small, the surveyed channel transects showed that this section had the least amount of erosion. The location with the most erosion along this section had banks approximately 2 feet high (Figure 37). In order to mitigate this section of channel, the slopes would be cut back to a 30% grade which is that of a natural stream bank.

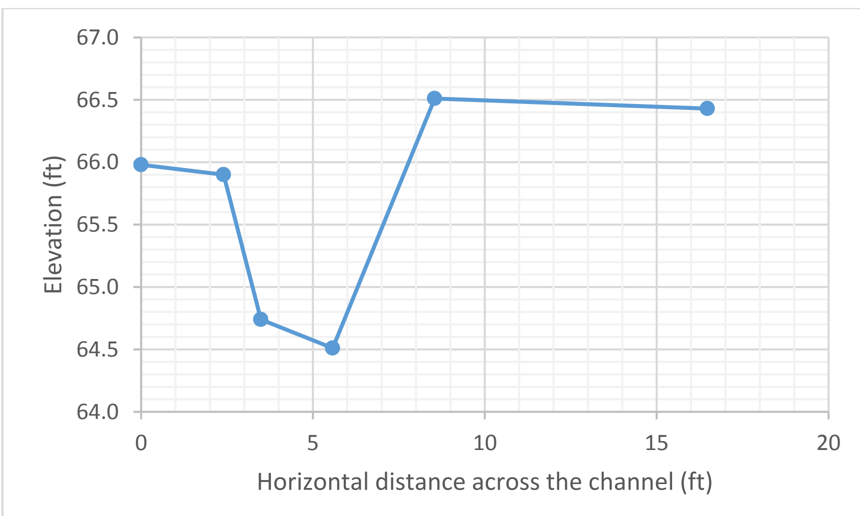


Figure 37. Lower Channel 1 transect example.

5.4.1 Infiltration Basin Caveat

The option of implementing a settling pond was designed using infiltration rates and determined to not be feasible for implementation due to multiple caveats. The caveats include poor soil texture and limitations of the size of the pond. The poor soil would not allow for sufficient infiltration of the desired storm events, resulting in a large drawdown time and eventual failure of the pond. Due to space constraints, the pond could not be designed large enough for it to infiltrate the water within a reasonable time span. The maximum depth of the pond was constrained by the depth of the water table and bedrock. A deeper pond would result in penetration of the water table, cause the pond to fill with groundwater, and not allow for infiltration of water or settling of particulate matter.

Due to these caveats, the infiltration basin at the convergence of Channel 1 and Channel 3 may need to be revised to a dry pond. A dry detention pond would allow for temporary storage of the stormwater for gradual release into Apple Canyon Lake over a period of approximately 24 hours. The overall velocity of the water would decrease and the detention pond would provide for limited settling of particulate matter. A dry pond was viewed more favorably than a wet detention pond due to the limited amount of space in that area and would achieve the overall goal of reducing the velocity of the stormwater runoff.

5.5 HydroCAD Post Design

After the design was finalized, a HydroCAD model was created using the specifications of the design. Peak flows and volume of water entering the lake for initial conditions were compared to post design conditions. In general, peak flows were slightly reduced. The length of time that the flow was at or near peak flow was reduced by the design. Total volume of water entering the lake from Channel 1 was reduced by about 0.3 ac*ft for all storm events. The results from Channel 3 showed a reduction in peak flow, but were inconclusive for volume of water entering the lake. Table 6 and Table 7 display the results of Channel 1 and Channel 3, respectively.

Table 6. Channel 1 Pre vs. Post Design Analysis

Channel 1	Peak Flow (cfs)		Volume Entering Lake (ac*ft)	
	Pre Design	Post Design	Pre Design	Post Design
1-yr	1.6	0.5	0.47	0.18
2-yr	5.4	4.0	0.90	0.60
5-yr	15.9	16.5	1.76	1.46
10-yr	24.6	24.0	2.59	2.30
25-yr	35.8	35.8	3.95	3.65
50-yr	44.9	44.9	5.39	5.09
100-yr	52.1	52.0	6.77	6.46

Table 7. Channel 3 Pre vs. Post Design Analysis

Channel 3	Peak Flow (cfs)		Volume Entering Lake (ac*ft)	
	Pre Design	Post Design	Pre Design	Post Design
1-yr	1.7	0.5	0.20	0.13
2-yr	5.0	3.5	0.39	0.35
5-yr	12.1	11	0.77	0.79
10-yr	19.1	18	1.15	1.15
25-yr	30.3	29	1.76	1.76
50-yr	42.2	40	2.41	2.34
100-yr	53.3	50	3.03	2.95

5.6 Revegetation

The base of the pools should be revegetated with native wetland plants. These types of plants were determined to be the most feasible choice because the regenerative stormwater conveyance design results in pools that will fill quickly during storm events and allow water to slowly infiltrate into the ground (Shaw and Schmidt). Therefore, plants need to be able to withstand significant water fluctuations.

A zone three plant community was chosen to be implemented in the design (Table 8). The zone three plant community was determined to be the best choice because the ponds should only be storing water during large storm events, as the rest should be infiltrated into the ground or flow into the lake. Some specific plant species in this zone can be seen in Appendix D: Revegetation Species.

Table 8. Plants Communities Based on Specific Water Zones

ZONE	PLANT COMMUNITY	HYDROLOGY
1	Submergent zone	1.5-6 feet of water
2	Emergent zone	0-18 inches of water
3	Wet meadow zone	Permanent moisture
4	Floodplain zone	Flooded during snowmelt and large storms
5	Upland zone	Seldom or never inundated (the upland zone includes prairie and forest plant communities)

5.7 WinSLAMM Model

The post development design was modeled using WinSLAMM. WinSLAMM is software that models the removal of sediment, phosphorous, nitrogen, and other nutrients in the runoff. This analysis was performed to determine the percentage of total suspended solids that would be removed by the implementation of this control system. The results from WinSLAMM showed a 45% reduction in total suspended solids in Channel 1 and a 41% reduction in Channel 3 (Figure 38 and Figure 39). The accuracy and reliability of using WinSLAMM for nonresidential purposes may play a factor into why the results are showing such low removal. Based off research, RSC removes about 90% total suspended solids (West Virginia Stormwater Management and Design Guidance Manual).

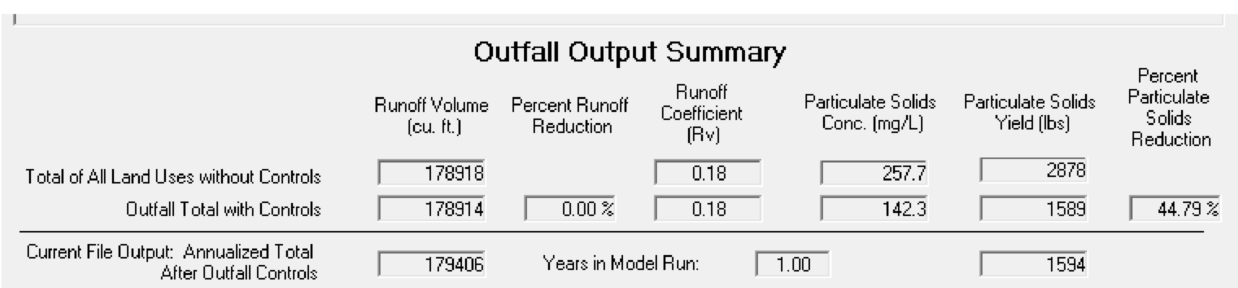


Figure 38. WinSLAMM output data for Channel 1.

Outfall Output Summary

	Runoff Volume (cu. ft.)	Percent Runoff Reduction	Runoff Coefficient (Rv)	Particulate Solids Conc. (mg/L)	Particulate Solids Yield (lbs)	Percent Particulate Solids Reduction
Total of All Land Uses without Controls	178918		0.18	257.7	2878	
Outfall Total with Controls	178914	0.00 %	0.18	152.1	1699	40.97 %
Current File Output: Annualized Total After Outfall Controls	179406	Years in Model Run:	1.00		1703	

Figure 39. WinSLAMM output for Channel 3.

5.8 Maintenance Requirements

Following implementation of the design, a maintenance schedule should be followed to ensure proper function of the RSC design (West Virginia Stormwater Management and Design Guidance Manual). Table 9 summarizes the necessary procedures that should be followed. Following a routine maintenance schedule would be vital to keep track of structural stability and to make sure that the RSC is functioning properly.

Table 9. Summary of RSC Maintenance

Maintenance Tasks	Frequency
• Inspection after storm events • Check for erosion by riffle structures • Water new vegetation • Stabilize or repair any structures that do not meet the criteria	After Installation
• Routine Vegetation maintenance • Clean up area	4 times a year
• Removal of any dead plants • Stabilize the contributing drainage area to prevent erosion	As needed
• Check structurally stability • Remove invasive plants • Conduct maintenance inspection	Annually
• Remove sediments in pools • Repair any structural damage	Once every 2 to 3 years

5.9 Cost Analysis

An engineering cost estimate was calculated using multiple sources (**Error! Reference source not found.**). The total cost estimate for the RSC was calculated to be approximately $70,000. Cost was determined by estimating the amount of volume that would needed to be cut and filled from the channel transects. All cut material would be recycled and used in areas that needed to be filled to reduce cost. The total amount of volume that needed to be filled in the channels was approximately 600 cubic yards. The cost of riprap, sand, and geotextile fabrics were researched and the estimated (**Error! Reference source not found.**). The cost estimate also incorporates a 10% mobilization fee for equipment and shipment of materials. A $400 per acre estimate was included for the cost of vegetation based off an EPA study regarding vegetation for the purpose of erosion control (EPA, Seeding).

6. Conclusion

The residents of Apple Canyon Lake wanted to control the erosion in the coves of the lake before further issues were caused. Rut Breakers Inc. was contracted to design erosion control for one specific cove on the lake, Hidden Spring Cove. Based on a decision matrix, RSC was determined to be the optimal design for the long term solution in this location. The RSC has the ability to slow the flow of water coming down the channel and prevent further erosion. The design also settles out nutrients before they reach the lake which will improve the water quality in the lake. The RSC was designed for two channels within the watershed of Hidden Spring Cove with a settling pond at the point of convergence and a revegetated channel from the settling pond to the lake.

8. Additional Recommendations

8.1 Culvert Recommendations

All culverts within the watershed of Hidden Spring Cove were located and documented (Figure 40 and Table 10). Several culverts were found to be damaged or inadequate for the incoming flow. All culverts are recommended to be analyzed and assessed for effectiveness.

Figure 40. Culverts in the Hidden Spring Cove watershed.

Table 10. Culverts in Hidden Spring Cove Watershed

Culvert	Diameter (in)	Culvert	Diameter (in)
C1	30	C11	40
C2	14	C12	18
C3	14	C13	18
C4	14	C14	14
C5	16	C15	14
C6	14	C16	18
C7	14	C17	14
C8	18	C18	12
C9	14	C19	14
C10	18	C20	14

During the second site visit the culvert that extends under Pioneer Drive was noticed to have a smaller diameter then the culvert that extends under the walking path upstream from Pioneer Drive. The client also noted that during large storm events the stormwater often overtopped Pioneer Drive at this location. Rut Breakers Inc. recommends that the culvert under Pioneer Drive be further investigated and modeled using CulvertMaster to determine the appropriate size for the culvert. The culvert should then be replaced with one of the appropriate size to prevent stormwater from over topping the road.

8.2 Recommendations for Areas of Severe Erosion

Rut Breakers Inc. recommends that the two areas of severe erosion along Hidden Spring Road and near Wagon Wheel Lane be analyzed and erosion control measures be designed for them (Figure 41). The design for these two sites should be implemented prior to implementation of the RSC design to the east of Pioneer Drive. Implementation of erosion control structures in Site 2 and 3 would likely decrease the flow and volume of water coming into the section to the east of Pioneer Drive as well as decrease the sediment carried by the runoff. In turn, this would decrease the stress on the lower parts of Channels 1 and 3 and decrease the amount of maintenance that would have to be performed on these channels.

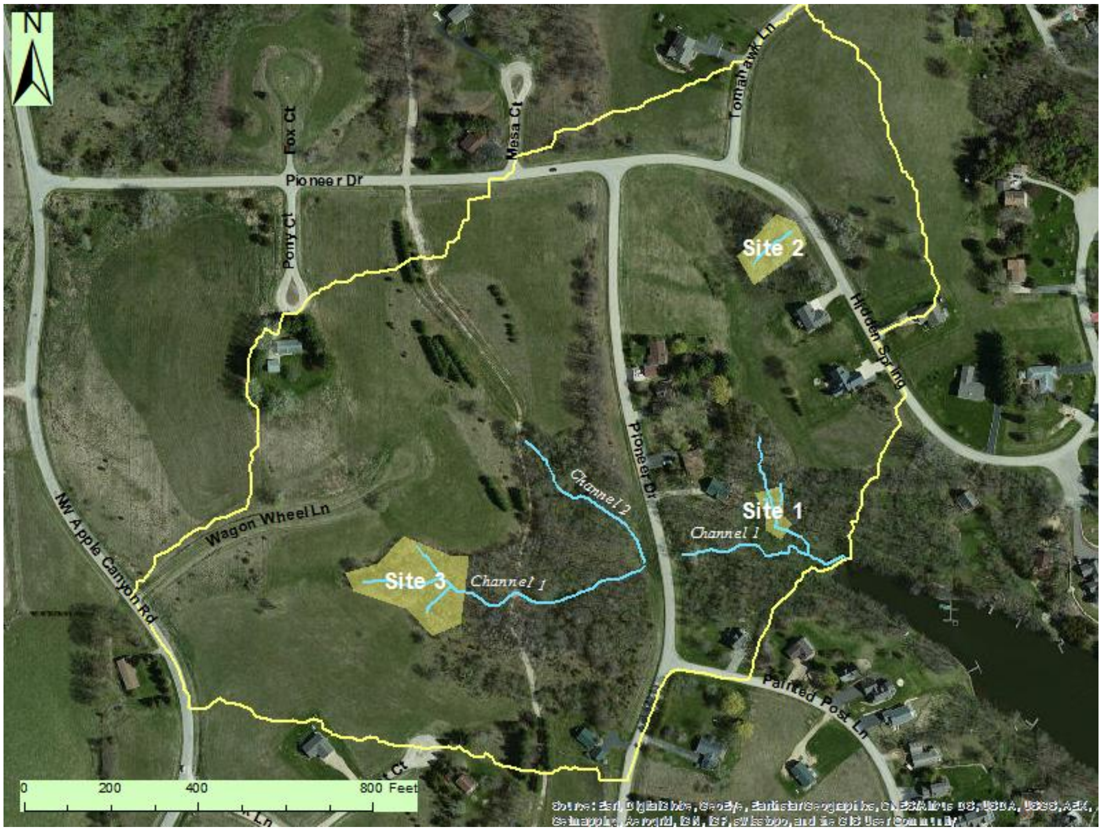


Figure 41. Areas of erosion.

8.3 Water Sampling Recommendations

The client requested that water samples be collected to test for levels of particulate matter, nitrogen, and phosphorus to analyze the amount of nutrients entering the lake. An initial water sample was taken on the second site visit. The water flowing through Channel 1 was determined to be spring fed and little particulate matter was present at the time of sampling. Therefore, testing was not performed on the sample.

Due to time and project constraints, further water sampling was not completed. If water sampling is needed, it must be collected during a storm event to ensure the sample represents the nutrients that would be entering the lake from erosion. Along with sampling during a storm event, multiple samples must be taken into account for variations in the content.

An ISCO sampler is recommended to be used for sampling (Teledyne Isco). Sequential portable samplers will allow for multiple samples to be taken over time and would result in more representative samples. The sequential portable ISCO samplers can be set to take samples at high waters levels, when a storm event takes place, preventing personnel from having to be out in the field the moment a storm event begins.

Bibliography

Braen, Dirk. *How Much Does Rip Rap Cost?* 21 August 2015. Web. 30 October 2015. <http://www.braenstone.com/2015/08/rip-rap-cost/>.

Conservation. 2014. Bureau of Land and Water Resources. Web. 30 October 2015. <https://www.agr.state.il.us/conservation/>.

"Department of Inspections and Permits." n.d. *www.aacounty.org.* Web. 31 October 2015.

EPA. *Seeding*. n.d. Web. 30 October 2015. <http://water.epa.gov/polwaste/npdes/swbmp/Seeding.cfm>.

Erosion Control Blankets. 2015. Lowes. Web. 30 October 2015. <http://www.lowes.com/Building-Supplies/Erosion-Control/Erosion-Control-Blankets/_/N-1z0xc4t/pl#!>.

Gabions Confine Stone For Erosion Protection and Retaining Soil. 2015. Web. 30 September 2015. <http://www.sitefabric.com/products/erosion-sediment-control/gabions/>.

Geotextiles. n.d. Web. 01 11 2015. <http://www.usfabricsinc.com/products/geotextiles>.

Level 2. n.d. Web. 30 October 2015. <http://tnepsc.org/page.asp?ID=5>.

New discharge regulations for land development. 9 March 2010. Web. 30 September 2015. <http://www.dust-control-inc.com/blog/index.php/tag/chemical-flocculant/>.

Quality Gabion Mattress for Slope Stability. n.d. Web. 30 September 2015. <http://www.gabionbarriers.com/gabionbarriers/gabion-mattress.html>.

"Regenerative Step Pool Storm Conveyance (SPSC)." December 2012. *Anne Arundel County, Maryland.* Anne Arundel County. Web. 30 October 2015. <www.aacounty.org/DPW/Watershed/StepPoolStormConveyance.cfm>.

"Revegetation of Disturbed Areas." n.d. *United States Environmental Protection Agency.* EPA. PDF. 15 October 2015. <water.epa.gov/polwaste/nps/forestry/upload/ch3h.pdf>.

Shaw, Daniel and Rusty Schmidt. "Plants for Stormwater Design." July 2003. *PCA.* Web. 30 October 2015. <http://www.pca.state.mn.us/index.php/view-document.html?gid=5651>.

Teledyne Isco. *Portable Samplers*. 2013. Web. 19 November 2015. <http://www.isco.com/products/products2.asp?PL=20110&image=Samplers4.jpg>.

Unit Prices. 2012. Anne Arundel County. PDF. 30 October 2015. <http://www.aacounty.org/IP/Resources/PWAUnitPriceList.pdf>.

Web Soil Survey. 6 December 2013. Web. 15 October 2015. <http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm>.

"West Virginia Stormwater Management and Design Guidance Manual." November 2015. *West Virginia Department of Environmental Protection.* West Virginia Department of Environmental Protection. PDF. 30 September 2015.

<http://www.dep.wv.gov/WWE/Programs/stormwater/MS4/Documents/Specification_4.2.7_Regenerative_Stormwater_Conveyance_WV-SW-Manual-11-2012.pdf>.

WiDNR. "Site Evaluation for Stormwater Infiltration." Feb 2004. *Wisconsin Department of Natural Resources.* Web. 22 november 2015. <http://dnr.wi.gov/topic/stormwater/documents/dnr1002-infiltration.pdf>.

Appendix A: Sample Calculations

Design of Riprap

$$Elevation\ Change = 825\ ft - 819\ ft = 6\ ft$$

$$Velocity\ of\ Flow\ (v) = \frac{1.49}{n} * R_h^{\frac{2}{3}} * S^{\frac{1}{2}}$$

$$v = \frac{1.49}{0.056} * (0.62ft)^{\frac{2}{3}} * (.1\ ft/ft)^{\frac{1}{2}} = 3.5\ ft/s$$

$$Area\ of\ Flow\ (trapezoid)(A) = bd + zd^2$$

$$A = (18 * .5) + (3 * .5^2) = 9.75\ ft^2$$

$$Hydraulic\ Radius\ (for\ a\ trapezoid)\ (R_h) = \frac{2(D_r * W^2)}{3 * W^2 + 8 * {D_r}^2}$$

$$R_h = \frac{2(0.5\ ft * (18\ ft)^2)}{3 * (18\ ft)^2 + 8 * (0.5\ ft)^2} = 0.33\ ft$$

$$Velocity\ of\ Flow\ (v) = \frac{1.49}{n} * R_h^{\frac{2}{3}} * S^{\frac{1}{2}}$$

$$v = \frac{1.49}{0.056} * (0.33\ ft)^{\frac{2}{3}} * (0.3\ ft/ft)^{\frac{1}{2}} = 6.96\ ft/s$$

$$Allowable\ Flow\ (Q) = v * A$$

$$Q = 6.96\ ft/s * 9.75\ ft^2 = 67.86\ cfs$$

Slope of riprap is 3:1 from culvert outlet to channel bank. Riprap will be have a 0.5 foot flow depth and length of 17 feet and width of 18 feet. The design meets the requirement of the 100 storm event of 52.8 cfs.

Design of Regenerative Stormwater Conveyance

**sample calculations shown are for Channel 3

Existing Channel:

$$Elevation\ at\ Head\ of\ Channel = 81.25\ ft$$

$$Elevation\ at\ End\ of\ Channel = 65.58\ ft$$

$$Elevation\ Change = 81.25\ ft - 65.58\ ft = 15.67\ ft$$

Elevation Change ~ 16 ft -> therefore, without any cascades, 16 riffle-pool sections are required

$$Length\ of\ Channel = 210\ ft$$

$$Slope = \frac{Elevation\ Change}{Length\ of\ Channel}$$

$$Slope = \frac{15.67\ ft}{210\ ft} = 0.075\ ft/ft = 7.5\%$$

Slope = 7.5% > 5% -> therefore one or more cascades are required in design

General Design:

Through trial and error and looking at the elevation profile of the channel, the optimal sequence and sizing of cascades, riffles, and pools was determined.

The following constraints were used:

$$Cascade\ Slope \leq 50\%$$

$$Cascade\ Length \leq 10\ ft$$

$$Cascade\ must\ be\ followed\ by\ 3\ pools$$

$$Lenght\ of\ Riffle \leq 10\ ft$$

$$Lenght\ of\ Pool \geq 10\ ft$$

The optimal sequence and sizing are shown in Table 4 in 5.3 Channel 3 Design.

$$2\ Cascades\ of\ Lenght = 10\ ft$$

$$4\ Riffles\ of\ Length = 10\ ft$$

$$9\ Pools\ of\ Length = 15\ ft$$

Riffle Section:

Assume:

$$Cobble\ Size\ (d_o) = 6\ in = 0.5\ ft\ \ (should\ be\ 4 - 15\ in)$$

$$Riffle\ Channel\ Width\ (W) = 10ft\quad (required\ to\ be\ 8 - 20\ ft)$$

$$Slope\ of\ Riffle\ Channel\ (S) = 0.1\ ft/ft$$

Calculate:

$$Depth\ of\ Cobble\ (d_c) = 2 * d_o$$

$$d_c = 2 * 6\ in = 12\ in = 1\ ft$$

$$Riffle\ Channel\ Depth\ (D_r) = \frac{W}{20}$$

$$D_r = \frac{10\ ft}{20} = 0.5\ ft$$

$$Manning's\ Roughness\ Coefficient\ (n) = \frac{D_r^{\frac{1}{6}}}{21.6 * \log(D_r/d_o) + 14.0}$$

$$n = \frac{0.5\ ft^{1/6}}{21.6 * \log(0.5\ ft/0.5\ ft) + 14.0} = 0.064$$

$$Hydraulic\ Radius\ (for\ a\ parabola)\ (R_h) = \frac{2(D_r * W^2)}{3 * W^2 + 8 * D_r^{\ 2}}$$

$$R_h = \frac{2(0.5\ ft * (10\ ft)^2)}{3 * (10\ ft)^2 + 8 * (0.5\ ft)^2} = 0.33\ ft$$

$$Velocity\ of\ Flow\ (v) = \frac{1.49}{n} * R_h^{\frac{2}{3}} * S^{\frac{1}{2}}$$

$$v = \frac{1.49}{0.064} * (0.33\ ft)^{\frac{2}{3}} * (0.1\ \ ft/ft)^{\frac{1}{2}} = \ 3.5\ ft/s$$

$$Area\ of\ Flow\ (for\ a\ parabola)\ (A) = \frac{2}{3} * D_r * W$$

$$A = \frac{2}{3} * 0.5\ ft * 10\ ft = 3.33\ ft^2$$

$$Allowable\ Flow\ (Q) = v * A$$

$$Q = 3.5\ \ ft/s * 3.33\ ft^2 = 11.8\ cfs$$

$$Froude\ Number\ (F_r) = \frac{v}{\sqrt{g * D_r}}$$

$$Gravitational\ Acceleration\ (g) = 32.2\ ft/s^2$$

$$F_r = \frac{3.5\ ft/s}{\sqrt{32.2\ ft/s^2 * 0.5\ ft}} = 0.883$$

The flow from the 100-year storm event (as modeled in HydroCAD) was 53.33 cfs.

The above calculations were iterated several times by changing cobble size and channel width in an Excel file. Iterations continued until the following constraints were met:

$$v \leq maximum\ velocity\ based\ on\ cobble\ size \text{ (Table A-1)}$$

$$Q \geq 53.33\ cfs\ (100 - year\ storm\ event)$$

$$F_r \leq 1$$

Table A-1. Allowable Velocity Based on Cobble Size (West Virginia Stormwater Management and Design Guidance Manual)

Cobble size (d_o) (in)	Allowable velocity (ft/s)
4	5.8
5	6.4
6	6.9
7	7.4
8	7.9
9	8.4
10	8.8
11	9.2
12	9.6
15	10.4

The results upon achieving all constraints were:

$$d_o = 10\ in \ \rightarrow v \leq 8.8\ ft/s$$

$$d_c = 20\ in$$

$$W = 18\ ft$$

$$D_r = 0.9\ ft$$

$$v = 5.0\frac{ft}{s} < 8.8\ ft/s$$

$$A = 10.8\ ft^2$$

$$Q = 54.0\ cfs > 53.33\ cfs$$

$$F_r = 0.929 < 1$$

Storage Volume:

Defined Values:

$$Pool\ Width\ (W_p) = Riffle\ Width\ (W) = 18\ ft$$

$$Pool\ Length\ (L_p) = 15\ ft$$

$$Length\ of\ System\ (L_s) = 210\ ft$$

Assumed Values:

$$Depth\ of\ Pool\ (D_p) = 2\ ft \quad (required\ at\ 1.5 - 3\ ft)$$

$$Depth\ of\ Sandbed\ \ (D_s) = 2\ ft\ (required\ at\ 1.5 - 3\ ft)$$

$$Side\ Slopes\ of\ Pools\ (perpendicular\ to\ flow) = 3{:}\,1$$

$$Front\ and\ End\ Slopes\ of\ Pools\ (parallel\ to\ flow) = 2{:}\,1$$

Calculated:

$$Width\ of\ Sandbed\ (W_s) = W_p * \frac{2}{3}$$

$$W_s = 18\ ft * \frac{2}{3} = 12\ ft$$

$$Pool\ Bottom\ Width\ (W_{po}) = W_p - D_p * 3 * 2$$

$$W_{po} = 18\ ft - 2\ ft * 3 * 2 = 6 ft$$

$$Pool\ Bottom\ Length\ (L_{po}) = W_p - D_p * 2 * 2$$

$$L_{po} = 15\ ft - 2\ ft * 2 * 2 = 7 ft$$

$$Volume\ Stored\ by\ all\ Pools\ (V_p) = \frac{W_p * L_p + W_{po} * L_{po}}{2} * D_p * \#\ of\ pools$$

$$V_p = \frac{18\ ft * 15\ ft + 6\ ft * 7\ ft}{2} * 2\ ft * 9 = 2808\ ft^3$$

$$Volume\ Stored\ by\ Sandbed\ (V_s) = L_s * W_s * D_s * 0.4$$

$$V_s = 210\ ft * 12\ ft * 2\ ft * 0.4 = 2016\ ft^3$$

$$Total\ Storage\ Volume\ (T_v) = V_p + V_s$$

$$T_v = 2808\ ft^3 + 2016\ ft^3 = 4824\ ft^3$$

Design of Settling Pond

$$V = 0.347\ acre - ft$$

$$V = 16291\ ft^3$$

$$Depth = Inflitration\ rate * Drawdown\ time$$

$$5\ ft = 0.13 *\ Drawdown\ time$$

$$Drawdowntime = 18\ days$$

$$Area = \frac{Volume\ of\ Runoff\ to\ Infiltrate}{Depth}$$

$$Area = \frac{(\frac{1}{2} * 6782.4 ft^3)}{5\ ft}$$

$$Area = 1630\ ft^3$$

$$Area\ of\ an\ oval = \ \pi * L_1 * L_2$$

$$L_1 = 20\ ft$$

$$L_1 = 26\ ft$$

Appendix B: Plan Views

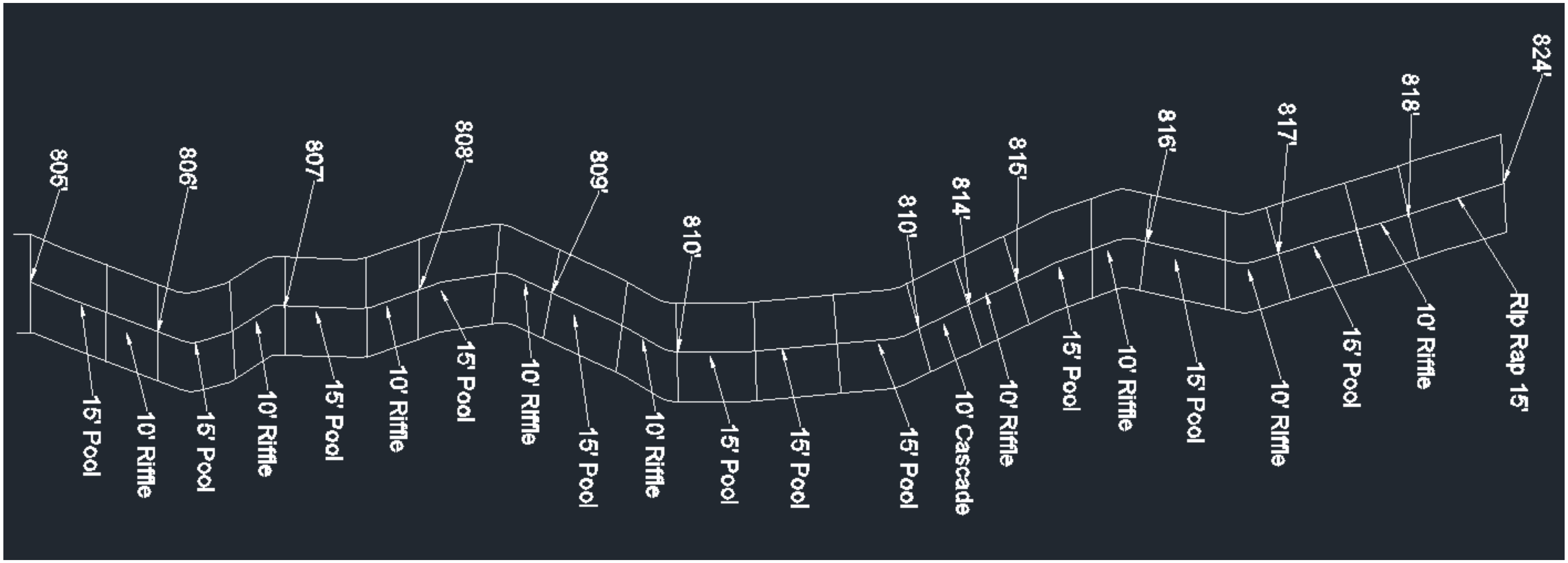


Figure B-1. Plan view Channel 1.

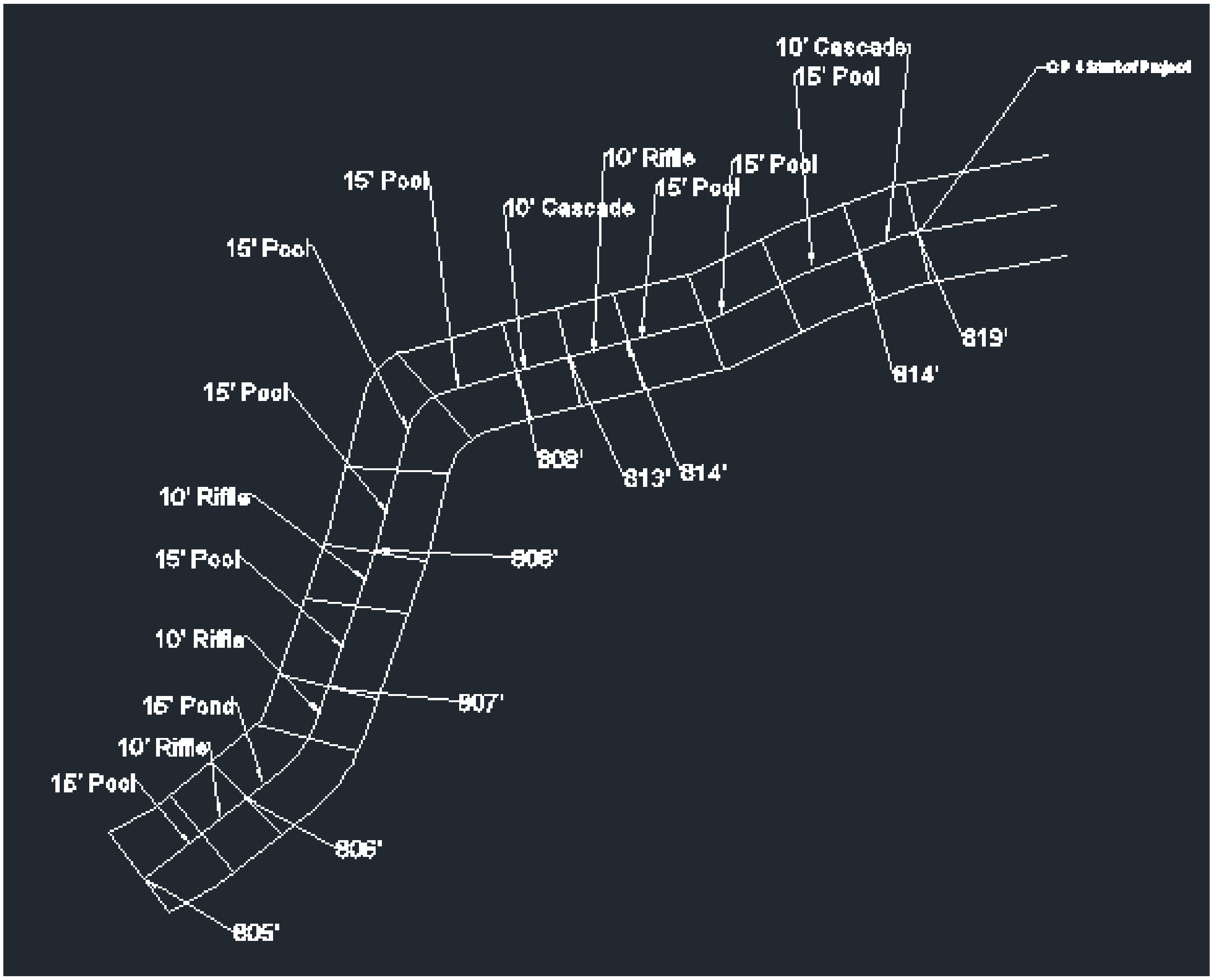


Figure B-2. Plan view Channel 3

Appendix C: Cost Estimates

Option 1: Rock Riffle

Riprap costs				
		cost per cubic yard	cubic yards needed	
bottom of channel	Clas 3 riprap	$ 125.00	35	$ 4,375
step 1	class 1 riprap	$ 40.00	180	$ 7,200
Geotextile Fabric	Nonwoven	$2.00/sq yd	9248	18496
				$30,000
Total Cost for Option 1		$ 70,950.00		

Soil Excavation per cubic yard	
Dirt Removal Labor/3 hr	150
Disposal Costs	35
Equipment Allowance	400
total cost per cubic yard	585
total cubic yards excavated	70
total soil excavation cost	$40,950.00

Option 2: Riprap along entire stream

Soil Excavation per cubic yard	
Dirt Removal Labor/3 hr	150
Disposal Costs	35
Equipment Allowance	400
total cost per cubic yard	585
total cubic yards excavated	70
total soil excavation cost	$40,950.00

Riprap costs				
		cost per cubic yard	cubic yards needed	
bottom of channel	Clas 3 riprap	$ 125.00	80	$10,000.00
step 1	class 1 riprap	$ 40.00	180	$ 7,200.00
Geotextile Fabric		40		
				$17,200.00
overall cost of option 2:		$ 58,291.88		

Revegetation costs		
	introduced grasses	Native grasses
cost per acre	$ 100.00	$ 176.00
number of acres	0.75	0.38
total cost	$ 75.00	$ 66.88

Option 3: Gabion Staircases

Soil Excavation per cubic yard	
Dirt Removal Labor/3 hr	150
Disposal Costs	35
Equipment Allowance	400
total cost per cubic yard	585
total cubic yards excavated	70
total soil excavation cost	$40,950.00

Gabion Staircase Cost			
Material	Quantity	Unit Cost	Total Cost
Gabions (stone,basket, filter cloth)	18	400	7000
Overall Cost of Option 3	$48,050.00		

Option 4: Settling Pond

Settling Pond	Volume in Pool (ft^3)	Cost from EPA Guidelines
Channel Intersection	8213.5	$ 14,089.92
	Total Cost	$ 22,760

Duration (Minutes)	Duration (Hours)	100-Year 24-Hour Total Rainfall (Inches)	100-Year 24-Hour Rainfall A Intensity (Inch/Hr)	Proposed 100yr-24hr Avg. Runoff Flowrate (CFS)	Proposed 100yr-24hr Runoff Volume (CFT)	Maximum Allowable Release Rate (CFS)	Bankfull 2yr-24hr (2.42 Inche Volume (CFT)	Total Required Storage Volume (CFT)	
5	0	1.16	14	52	15618	290	32854	32854	
10	0	1.69	10	38	22754	290	32854	32854	
15	0	2.11	8	32	28409	290	32854	32854	
30	1	3.16	6	24	42546	290	32854	32854	
60	1	4.44	4	17	59780	290	32854	32854	
120	2	5.66	3	11	76206	290	32854	32854	
180	3	6.1	2	8	82130	290	32854	32854	
360	6	7.44	1	5	100172	290	32854	32854	
720	12	7.96	1	2	107173	290	32854	32854	
1440	24	8.75	0	1	117810	290	32854	32854	
						Required Storage (CFT)			32854.4

Selected Option: Regenerative Stormwater Conveyance

ITEM	UNIT	Amount	UNIT PRICE	TOTAL
Mobilization - 10% of total Cost		1		$ 6,000.00
Survey Stake Out - 5% of total Cost		1	$ 100.00	$ 3,000.00
Clearing and Grubbing	SY	200	$ 2.00	$ 400.00
Sand Fill (Filter Bed Area)	CY	430	$ 60.00	$ 26,000.00
Sandstone Boulders	CY	25	$ 240.00	$ 6,000.00
Crushed Gravel Fill	CY	600	$ 13.50	$ 8,500.00
riprap:				
class 1	ton	30	$ 40.00	$ 1,500.00
7" Cobble for Riffle	ton	220	$ 22.50	$ 5,000.00
Geotextile	SY	240	$ 6.12	$ 1,500.00
Wood Chips (30% mix in Filter Bed Area)	CY	150	$ 25.00	$ 4,000.00
Excavation:		60	32.5	$ 2,000.00
Blaze Orange Fence	linear ft	1200	$ 3.25	$ 4,000.00
Plantings (Trees, Shrubs, Herbs, and SAV)	Acre	2	$ 400.00	$ 1,000.00
Subtotal				$ 60,000
TOTAL				$ 70,000

Sources of cost include: (Unit Prices) (Erosion Control Blankets) (Braen)

Appendix D: Revegetation Species

Scientific Name	Common Name
Trees and Shrubs	
Acer saccharinum	Silver maple
Alnus incana	Speckled alder
Amorpha fruticosa	Indigo bush
Aronia melanocarpa	Black chokeberry
Betula nigra	River birch
Celtis occidentalis	Hackberry
Cephalanthus occidentalis	Buttonbush
Cornus amomum	Silky dogwood
Cornus sericea	Red-osier dogwood
Fraxinus nigra	Black ash
Fraxinus pennsylvanica	Green ash
Physocarpus opulifolius	Ninebark
Populus deltoides	Eastern cottonwood
Quercus bicolor	Swamp white oak
Salix discolor	Pussy willow
Salix exigua	Sandbar willow
Salix nigra	Black willow
Sambucus pubens	Red-berried elder
Spiraea alba	Meadowsweet
Viburnum lentago	Nannyberry
Viburnum trilobum	High bush cranberry
Forbs and Ferns	
Anemone canadensis	Canada anemone
Aster lucidulus	Swamp aster
Aster puniceus	Red-stemmed aster
Boltonia asteroides	Boltonia
Impatiens capensis	Jewelweed
Lobelia cardinalis	Cardinal flower
Lobelia siphilitica	Blue lobelia
Lysimachia thrysiflora	Tufted loosestrife
Physostegia virginiana	Obedient plant
Potentilla palustris	Marsh cinquefoil
Scutterlaria lateriflora	Mad-dog skullcap
Silphium perfoliatum	Cup plant
Symplocarpus foetidus	Skunk cabbage
Vernonia fasciculata Ironweed	Ironweed
Grasses, Sedges and Rushes	
Carex comosa	Bottlebrush sedge
Elymus virginicus	Virginia wild rye
Leersia oryzoides	Rice-cut grass
Panicum virgatum	Switchgrass
Scirpus atrovirens	Green bulrush
Spartina pectinata	Prairie cord grass

11.9 Appendix 9. 2016 Aquatic Plant Survey Report

Aquatic Plants at Apple Canyon Lake

Virginia van Vianen[1] & Mike Malon[2]

[1]Michigan Technological University, [2]Jo Daviess County Soil and Water Conservation District

Summary

Aquatic plants have many benefits to lakes, and affect many common recreational uses such as fishing, swimming, and boating. Invasive aquatic plants can crowd out native plants, and have other detrimental effects on aquatic ecosystems. Apple Canyon Lake is a 400-acre recreational impoundment in northwest Illinois. An aquatic plant survey was conducted to better understand the plant communities present in the lake. The survey was carried out twice, once in early June and once in mid-July. Each time, the whole littoral zone of the lake (shallow area of the lake capable of supporting plant growth) was traveled, all plant populations were identified and marked on aerial photos, and later digitized using ArcMap for analysis.

A total of seven native species and three invasive species were found in Apple Canyon Lake in June. All 10 species were found in July along with four additional native species. In June, total coverage was 9.00% of the whole lake, and 29.33% of the littoral zone. In July, these numbers decreased by 67.12% to 2.96% of the whole lake and 9.64% of the littoral zone. In particular, invasive species concentrations decreased by over 95% as a result of mid-summer die-off of Curly Leaf Pondweed and use of herbicide specific to Eurasian Water Milfoil. However, broad-spectrum herbicide resulted in declines in all species. Two species that were found in a preliminary survey in 2012 were not observed again in 2016, and no new species were found in 2016. Management recommendations focus on early-season or fall applications of endothall herbicide to reduce concentrations of Curly Leaf Pondweed prior to reproduction.

1. Introduction

1.1 Aquatic Plants

Aquatic plants are an essential part of any lake ecosystem. They take up nutrients such as nitrogen and phosphorous from the water column. The decrease of nutrients prevents the growth of algal blooms, which have the potential to release harmful toxins into the water. Aquatic plants also stabilize hydrosoils and inhibit erosion, reducing the amount of sediment in the water and increasing clarity.

Aquatic plants are very important to fish populations. While photosynthesizing, plants release dissolved oxygen into the water, which is the main source of oxygen for fish. These plants provide refuges for juvenile fish and food in the form of invertebrates that shelter in the plants as well. Other aquatic species, such as waterfowl and turtles, also use aquatic plants for food and shelter.

However, many invasive aquatic plant species have also spread extensively, often assisted by birds, fish, and boaters using multiple bodies of water. These plants often start their life cycles earlier than native plants, giving them a tendency to colonize lakes in dense mats of a single species, which shade out native species. These plants often have detrimental effects on both diversity and water quality.

These dense mats can lead to an overabundance of juvenile fish, leading to a stunted adult population and a substantial decrease in the invertebrates they feed on. This in turn leads to lower levels of other animals that depend on macroinvertebrates, such as waterfowl. Waterfowl also tend to not graze on invasive species.

Invasive species can also have strong negative effects on recreation, as dense stands can interfere with boat motors, impede swimming, and decrease quality of fishing.

1.2 Apple Canyon Lake

Apple Canyon Lake is a 412.86 acre lake in northwestern Illinois. The closest towns are Apple River, Stockton, Elizabeth, and Scales Mound. The lake is an impoundment of Hell's Branch Creek, which is a tributary of the Apple River. The surrounding watershed is the Apple Canyon Lake Watershed (HUC 070600050601). The lake is part of the Driftless ecoregion, which encompasses parts of Illinois, Wisconsin, Iowa, and Minnesota where glaciers did not reach during the last two glaciation events. The lake is surrounded by a residential community, whose members participate in many activities in the lake such as boating, fishing, and swimming. The Apple Canyon Lake Property Owners Association (POA) manages the lake. Water quality data suggests that Apple Canyon Lake is a eutrophic lake (high nutrient levels and productivity), though it occasionally passes into hypereutrophic levels (extremely high nutrient levels and productivity). The high nutrient levels cause extensive growth of aquatic plants and algae. Because the lake is highly utilized recreationally, it is important to the POA to understand the effects that aquatic plants have on the lake.

A 2011 survey revealed that 47.7% of property owners feel that excess aquatic plant growth was a current impairment on the lake, and 30.9% believe that invasive plants and animals are an impairment (Malon et al., 2016). The survey also reports that 25% believe that excessive plants and algae are a severe problem, 21% believe they are a moderate problem, 28% a slight problem, and 3% no problem (note that these figures include concern over algae growth in addition to plant growth).

1.3 History of Management

In 2001 and 2004, the herbicide Navigate, a brand name of 2,4-D, was used to control excessive growth of invasive Eurasian Water Milfoil in the lake. The herbicide was applied solely in shallow bays (Malon et al., 2016).

Reward®, a brand name of diquat, is also applied frequently. Diquat is a contact herbicide that works quickly, but it does not prevent aquatic plants from resprouting in the same season. Diquat is more effective in warmer temperatures, and tends to be applied in summer. Diquat has been the lake's herbicide of choice in recent years.

The POA has also acquired Renovate®, a brand name of triclopyr. Triclopyr is a selective herbicide that acts only on Eurasian Water Milfoil. The POA began to apply Renovate in 2016.

In addition to herbicide application, the lake maintains a weed harvester that is used on a weekly basis at peak plant presence, mainly to provide access to docks that are set far into bays. The lake aims to reduce labor and operating costs of the weed harvester by 33% by the year 2021, 50% by 2026, and 70% by 2036 (Malon et al., 2016).

1.4 Previous Aquatic Plant Surveys and Objectives

In 2012, a preliminary aquatic plant survey was performed that focused on certain high traffic areas. The whole lake was not catalogued, but this survey set the precedent for the survey performed in 2016. The preliminary survey covered the marina, Independence and Hawthorne Bays, and the spillway/Nixon Beach area.

The objective of the 2016 aquatic plant survey is to understand the spatial and temporal coverage of aquatic plant species present in Apple Canyon Lake, and the ecological effects of the plant community. The results of this survey are used to create management recommendations that can balance maintaining the benefits of native species while also aiming to reduce invasive species.

2. Methods

The complete littoral zone of the lake was traveled in early June 2016 and mid-July 2016, and all plant populations found and identified by visual inspection were marked on aerial photos. If necessary, plants were pulled for closer inspection and identification. Data was mainly collected by boat, but in some areas with high concentrations of docks, such as the marina, data was collected by traveling onto the docks by foot.

All data was digitized using the GIS program ArcMap to create a map of aquatic plant presence and coverage for each species, and total plant coverage. Analysis also included other data from previous studies and programs, such as the bathymetric map of Apple Canyon Lake, and Volunteer Lake Monitoring Program water quality data from the Illinois Environmental Protection Agency.

3. Results

3.1 Determination of Littoral Zone

Data was first collected in June 2016, when the Secchi disk reading was 3.59 m. The following equation was used to determine the maximum depth of colonization of plants in the lake (Canfield et al., 1985):

$$\log MDC = 0.79*\log SD + 0.25$$

Where SD is the Secchi depth reading in meters and MDC is the maximum depth of colonization in meters. Using the June 2016 secchi depth with this equation gives an MDC of 4.88 m. The littoral zone, or area within this depth capable of supporting plant growth, occupies approximately 127 of the lake's 413 acres. Approximately 30% of the lake surface area is within the littoral zone.

3.2 Coverage and Species

Overall, 14 species were found in Apple Canyon Lake this summer; 11 native species and 3 invasive species. Tables 1 and 2 list these species, along with the total coverage in acres and percent coverage of the lake. In June, the most abundant species was the invasive Curly Leaf Pondweed. In July, the most prevalent was native Coontail. It is worth noting that plants also tend to overlap in their ranges, which is why the coverage areas and percentages for each species do not sum to the total plant coverage and percent.

Table 1. List of native plants in Apple Canyon Lake and coverage data.

Common Name	Scientific Name	June Coverage (acres)	June Coverage (percent)	July Coverage (acres)	July Coverage (percent)
Coontail	*Ceratophyllum demersum*	14.89	3.61	6.87	1.66
Elodea	*Elodea canadensis*	11.29	2.73	0.77	0.19
White Water Lily	*Nymphae odorata*	6.16	1.49	2.98	0.72
Duckweed	*Lemna sp.*	2.99	0.72	2.29	0.55
Fries Pondweed	*Potamogeton friesii*	2.52	0.61	0.66	0.16
Bulrush	*Scirpus sp.*	0.33	0.08	0.12	0.03
American Pondweed	*Potamogeton nodosus*	0.06	0.01	0.02	<0.01
Water Celery	*Vallisneria americana*	0	0	1.09	0.26
Cattail	*Typha sp.*	0	0	0.29	0.07
Arrowhead	*Sagittaria sp.*	0	0	0.20	0.05
Sago Pondweed	*Potamogeton pectinatus*	0	0	<0.01	<0.01

Table 2. List of invasive species at Apple Canyon Lake and coverage data.

Common Name	Scientific Name	June Coverage (acres)	June Coverage (percent)	July Coverage (acres)	July Coverage (percent)
Curly Leaf Pondweed	*Potamogeton crispus*	25.02	6.06	0.77	0.18
Eurasian Water Milfoil	*Myriophyllum spicatum*	7.27	1.76	0.31	0.08
Reeds Canary Grass	*Phalaris arundinacea*	0.21	0.05	0.06	0.01

Two plants were observed in the 2012 survey that were not observed in either 2016 survey. Table 3 lists these species. All species that were located in 2016 were also located in 2012; no new species were found.

Table 3. Plants listed in the 2012 survey that were not observed in 2016.

Common Name	Scientific Name
Southern Naiad	*Najas guadalupensis*
Water Star Grass	*Heteranthera dubia*

Table 4 includes coverage for all plants and classes at Apple Canyon Lake. This table also includes the coverage of the littoral zone. Coverage was much higher in the June survey than the July survey. Coverage was higher for invasive species than native plants in June, but higher for native plants in July.

Table 4. Area and percent coverage for all plants, including total and littoral zone coverage.

Cover Type	June Total Coverage (acres)	June Total Coverage (percent)	June Littoral Zone Coverage (percent)	July Total Coverage (acres)	July Total Coverage (percent)	July Littoral Zone Coverage (percent)
All plants	37.16	9.00	29.33	12.22	2.96	9.64
Invasive plants	28.88	6.99	22.79	1.15	0.28	0.91
Native Plants	22.96	5.56	18.12	11.52	2.79	9.09

From the June survey to July survey, decreases were noted among all plant types and species. Table 5 lists the percent change and area change for all species. Changes for all plants and plant types are listed at the bottom. The decline of invasive species was much higher than the decline in native species, though some individual native species experienced large declines.

Table 5. Percent and area change in cover for all species and plant types.

Cover	Change (percent)	Change (acres)
Curly Leaf Pondweed	**-96.92%**	**-24.25**
Eurasian Water Milfoil	**-95.74%**	**-6.96**
Elodea	-93.18%	-10.52
Fries Pondweed	-73.80%	-1.86
Reeds Canary Grass	**-71.43%**	**-0.15**
American Pondweed	-66.67%	-0.04
Bulrush	-63.64%	-0.21
Coontail	-53.86%	-8.02
White Water Lily	-52.11%	-3.12
Duckweed	-23.41%	-0.70
All plants	-67.12%	-24.94
All invasive plants	-96.02%	-27.38
All native plants	-49.82%	-11.44

Invasive species indicated in bold type.

3.3 Maps

Figure 1 shows locations of all plants at Apple Canyon Lake in June 2016.

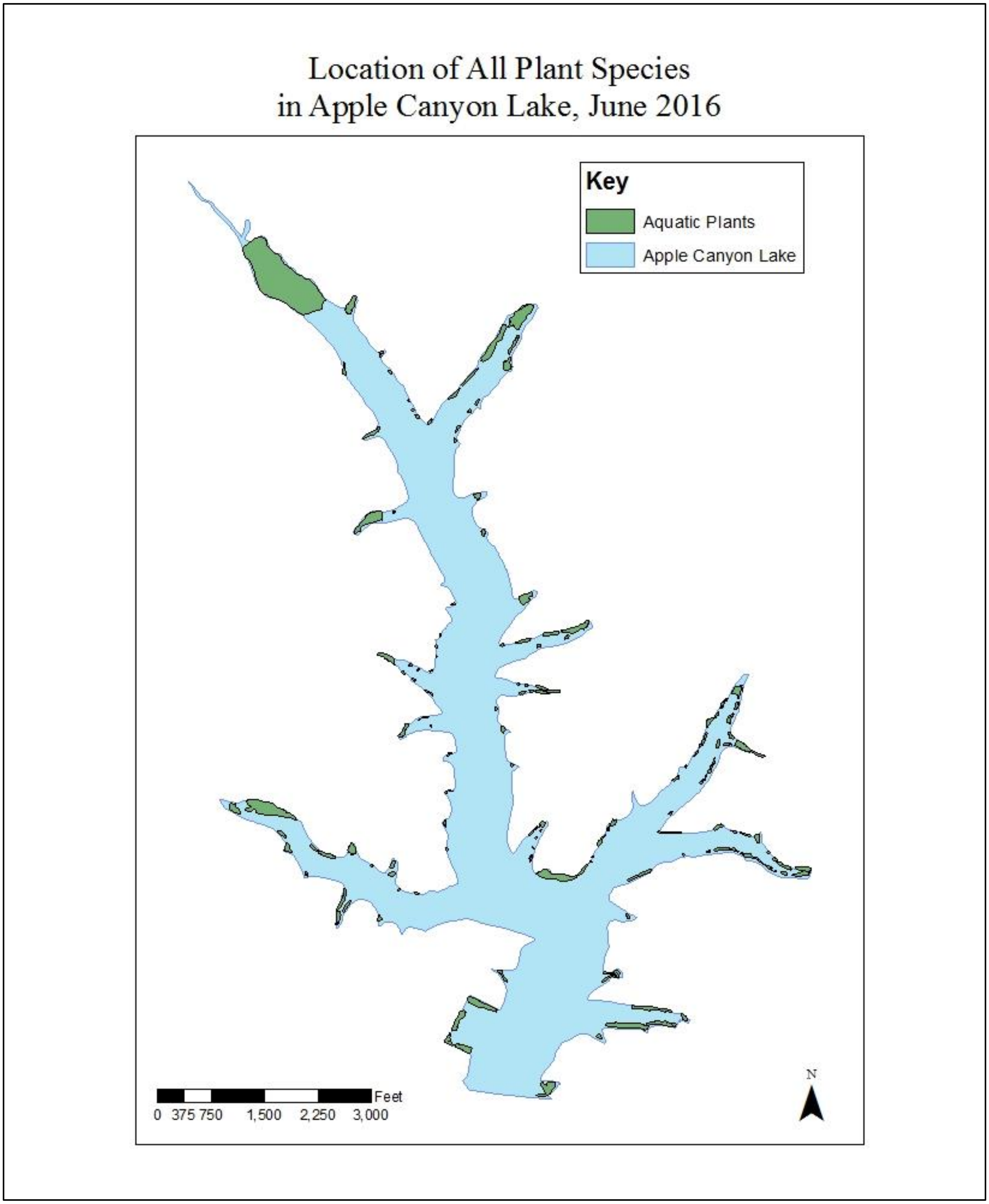


Figure 1. Aquatic plant coverage for June 2016.

Figure 2 shows locations of all plants at Apple Canyon Lake in July 2016:

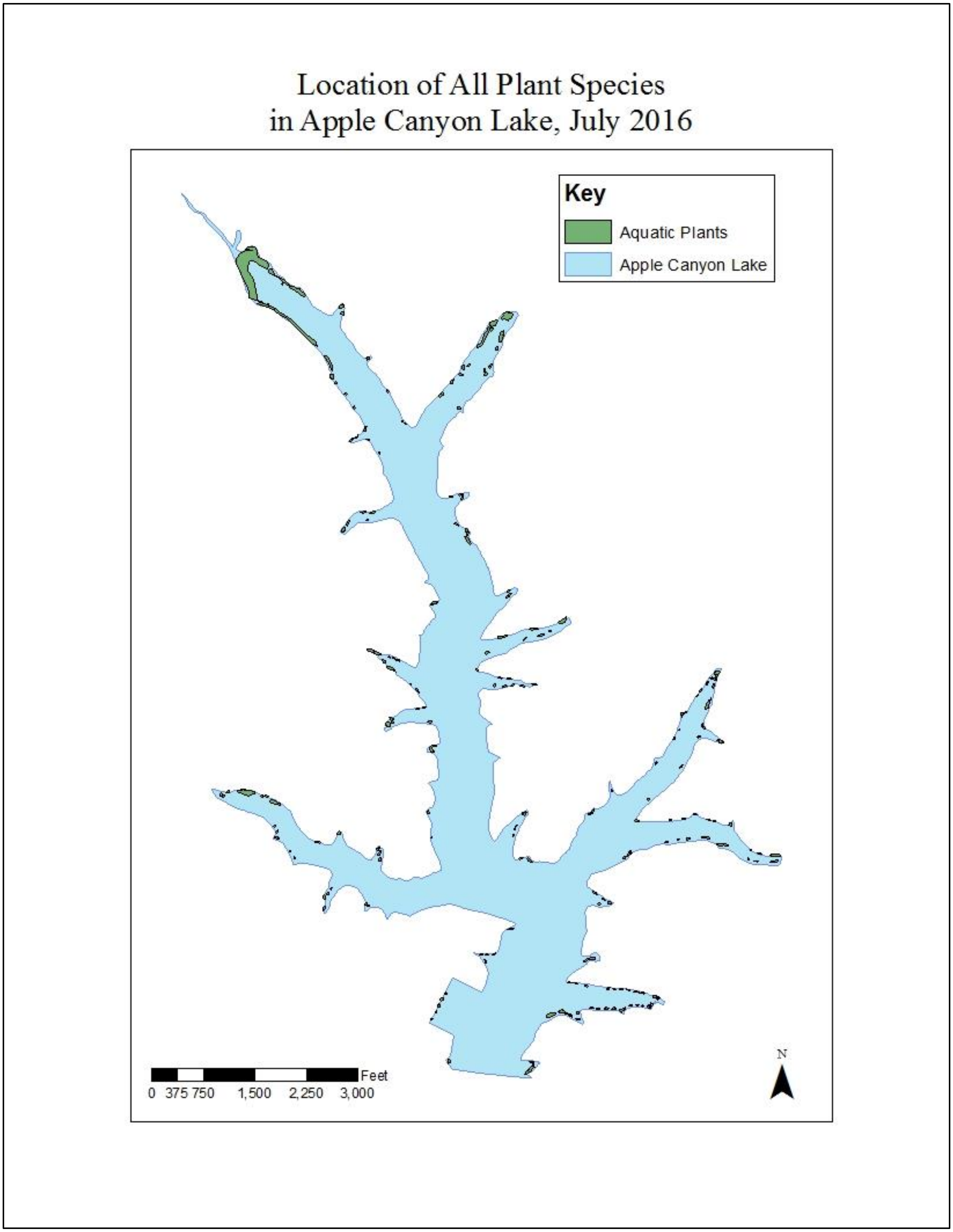


Figure 2. Aquatic plant coverage for July 2016.

Figures 3-5 show both June and July coverage together in closer scale to illustrate the change between the two months.

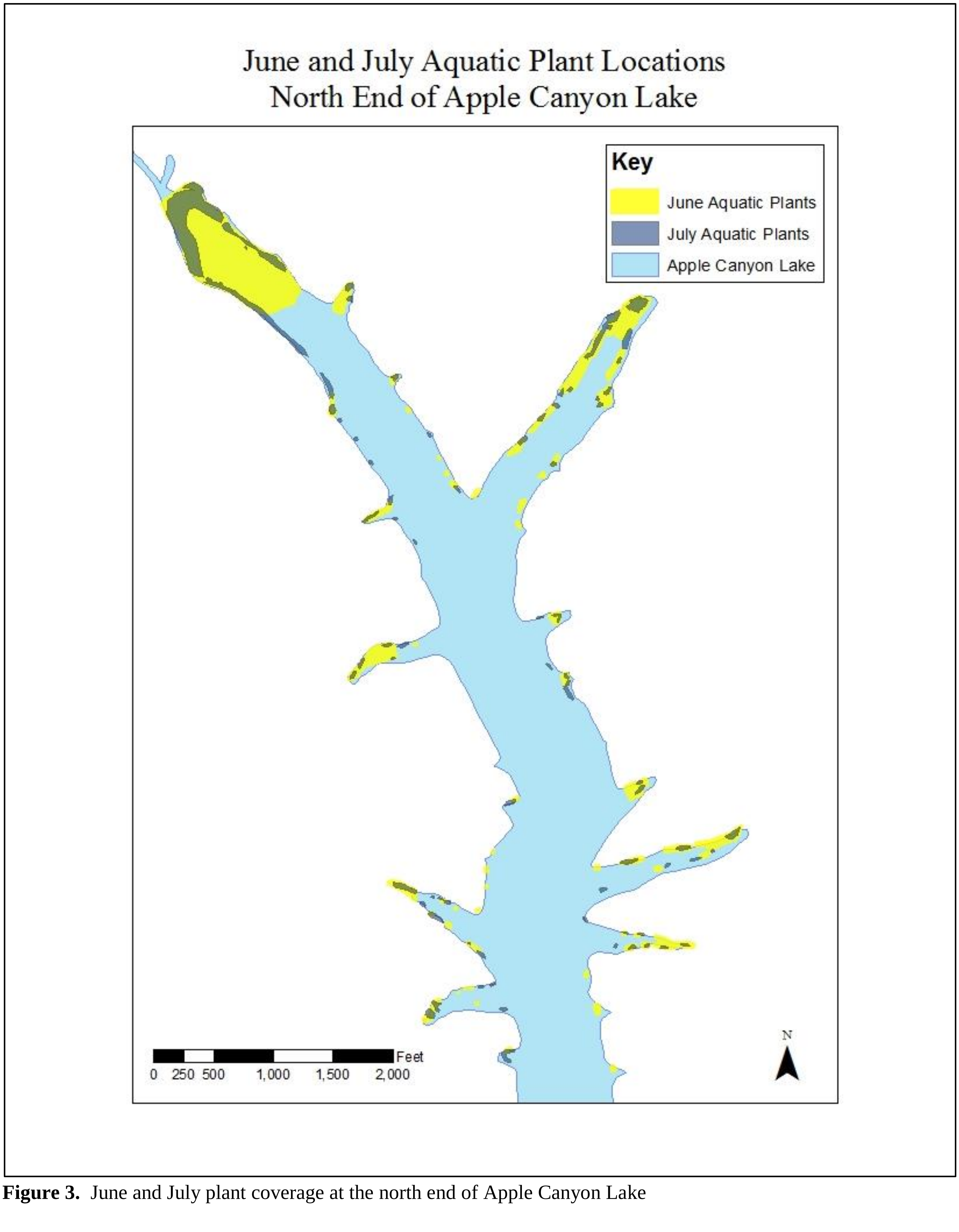


Figure 3. June and July plant coverage at the north end of Apple Canyon Lake

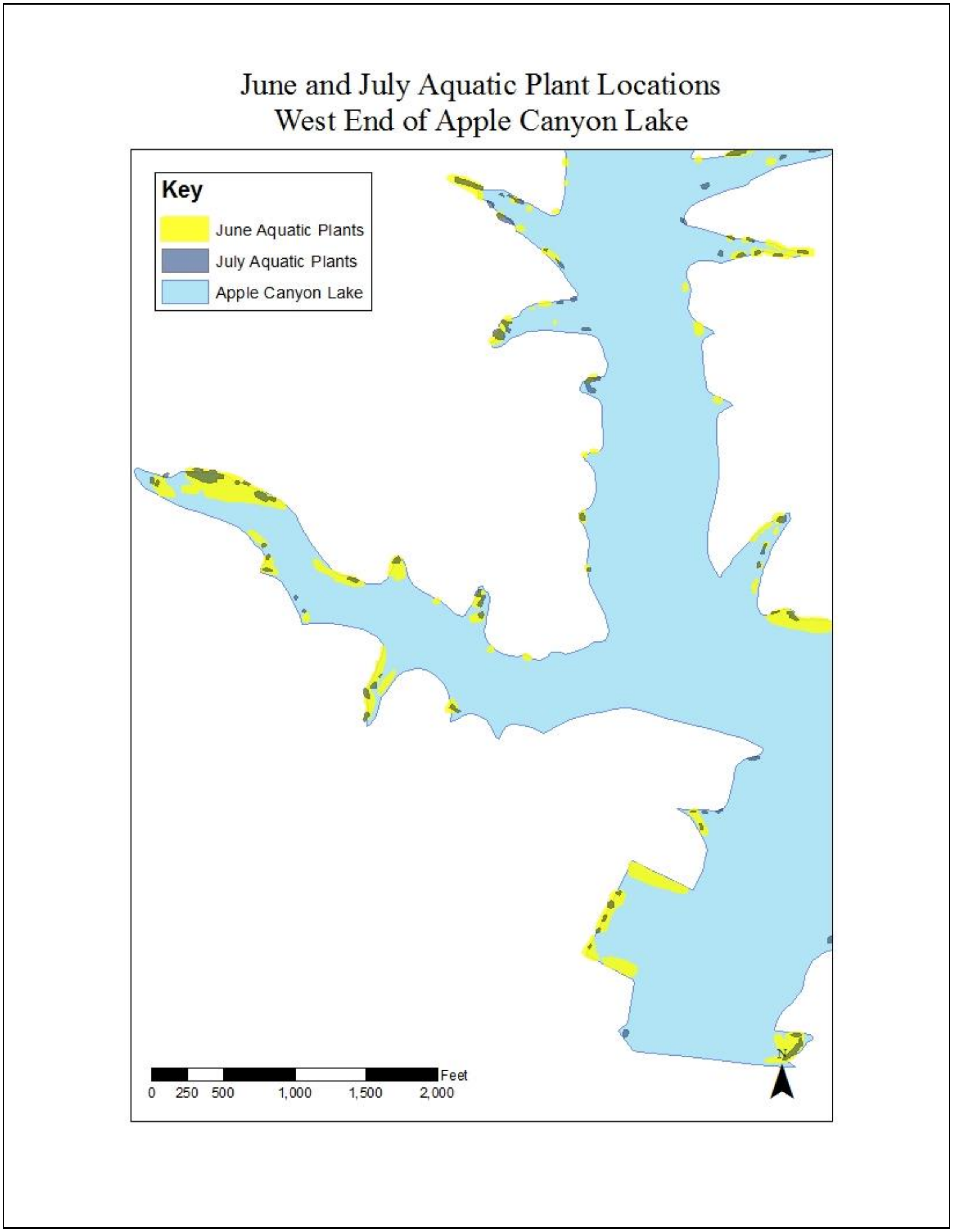


Figure 4. June and July plant coverage at the west end of Apple Canyon Lake.

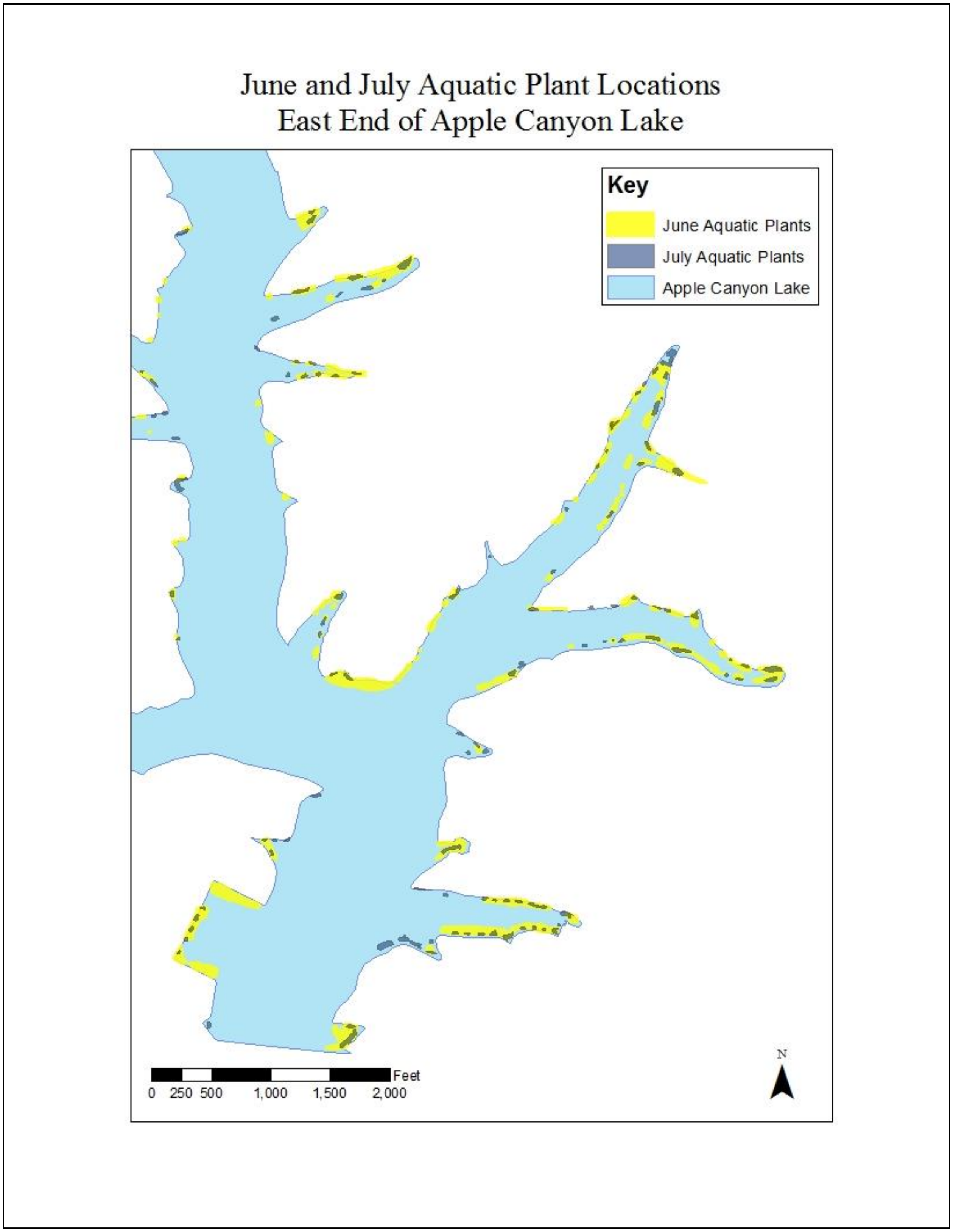


Figure 5. June and July plant coverage at the east end of Apple Canyon Lake.

4. Discussion

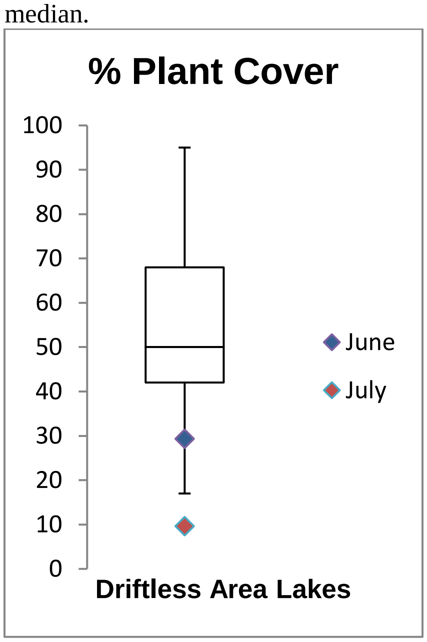
4.1 Lake Cover

Most of the aquatic plants at Apple Canyon Lake occur in areas of very shallow water, such as inlets, and to a much lesser extent near docks. 287 docks exist at the lake, of which 158 (55%) were impacted by aquatic plants in June and 105 (37%) were impacted in July. Only a small number of plants were found growing near maximum depth of growth, mainly Curly Leaf Pondweed, which likely contributes to the high coverage area found with this species.

A total of seven native species and three invasive species were found in June. Three of the total species observed, Bulrush, Water Lily, and Reeds Canary Grass, are emersed species. One, Duckweed, is a floating species. The remaining six are submersed species. Native species accounted for 5.56% of lake cover, and invasive species 6.99%. Invasive species covered 5.92 acres more than native species. Total plant coverage was 9.00%, which is lower than most similar lakes; ACL is in the lower 25th percentile for Driftless Area lakes, where the interquartile range was approximately 40 – 70% coverage (Nichols, 2000). This comparison is shown in Figure 6. Plant coverage is much lower than expected, with less than a third of the littoral zone being occupied by plant growth.

In July, four additional native species were found, emersed, Cattail and Arrowhead, and submerged, Water Celery and Sago Pondweed. Total coverage decreased to 2.96% of the lake and 9.64% of the littoral zone, a 67% decrease in coverage from June. The concentration of invasive species declined much more sharply than native species, with a decrease of 96% from June to July. All individual species found in both June and July also decreased. Invasives Curly Leaf Pondweed and Eurasian Water Milfoil had the highest decreases, followed by native Elodea. Duckweed experienced the least decline at 23.41%. Native plants covered 10.37 more acres than invasive species in July.

Figure 6. Comparison of Apple Canyon Lake plant cover with other Driftless area lakes. The lower end of the line represents the minimum and upper end represents the maximum. The lower end of the box represents the 25th percentile and the upper end of the box represents the 75th percentile. The line through the box represents the median.



The large decrease in Curly Leaf Pondweed is likely mainly due to its annual mid-summer die off, and the decline of Eurasian Water Milfoil is likely caused by the use of the herbicide triclopyr. The declines in all other species were likely related to the wide use of broad-spectrum herbicides and the use of the weed harvester in the lake.

4.2 Ecological Assessment

Various models can be used to assess lake health mathematically. Here, two are used to assess the health of Apple Canyon Lake through its aquatic plant communities. First, the Trophic State Index is calculated, which measures eutrophication in the lake. Second, two different methods are used to assess the diversity of the lake and compare it to similar lakes.

4.2.1 Trophic State Index

The trophic state of the lake is often evaluated to assess lake health. Lakes can be classified as oligotrophic, having low nutrient concentrations and low productivity, or eutrophic, having high concentrations and high productivity. Mesotrophic is an intermediate classification, and hypereutrophic refers to extremely high productivity. Typically, the Carlson scale is used to classify a lake using phosphorous concentrations, chlorophyll-A concentrations, and Secchi depth. Variables are scored on a scale of 0-100, where 100 indicates highest enrichment and 0 indicates no enrichment. A TSI score lower than 40 indicates an oligotrophic lake, a TSI score greater than 50 indicates a eutrophic lake, and a TSI score greater than 65 indicates a hypereutrophic lake. Typically all variables for a lake fall into a similar range, and finding values that don't fit often indicates some type of problem.

Porcella (1979) also created a lake evaluation index which can be used to evaluate the trophic state of a lake. While Carlson's trophic state index is the more commonly used method, Porcella's index takes more variables into account, including the percent macrophyte cover and nitrogen. Porcella's index is scored using the same system as Carlson. Using the lake evaluation index, Table 6 shows the estimated Trophic State Index (TSI) scores at Apple Canyon Lake for June 2016 and July 2016, calculated with data obtained from the Volunteer Lake Monitoring Program.

Table 6. Calculated Trophic State Index scores for Apple Canyon Lake using the Porcella scale.

Variable	June TSI Score	July TSI Score
Percent Macrophyte Cover	29.33	9.64
Secchi Depth	41.58	46.95
Chlorophyll-a	60.85	51.06
Total Phosphorous	61.96	56.37
Total Nitrogen	79.34	86.86
Trophic State Index	**59.40**	**55.65**

The overall June score using Porcella's method is 59.40 and July score is 55.65, which are both considered eutrophic. The TSI value for percent macrophyte cover is much lower than all other TSI values for the lake. Percent macrophyte cover is consistent with an oligotrophic lake (TSI score < 40), while almost all other values are consistent with a eutrophic lake (TSI score > 50) or hypereutrophic lake (TSI score > 65). The lake is not supporting as many plants as a lake with its nutrient concentrations typically does, which is especially surprising given the high clarity in the lake. Instead, most of the nutrient concentrations are supporting algae growth. Algal growth has the potential to create toxic harmful algae blooms; therefore, it is preferable that high nutrient concentrations support aquatic plants.

4.2.2 Assessing Diversity

Many standard methods exist to assess diversity in lakes, as well as compare specific lakes to similar lakes. These methods vary widely; some are general methods that can be used in a broad variety of situations, while others are specific to a region. In each of the methods used here, the data from Apple Canyon Lake is compared to data from Wisconsin lakes in the Driftless Area. Even though ACL isn't in WI, it is a part of the Driftless ecoregion and comparing data to these lakes is likely more accurate than comparing to other IL lakes. Two methods are used and described here, along with their justifications for being chosen.

Simpson's Index (SI) gives a mathematical value to species diversity. It is considered a dominance index, because it takes into account how frequently a species is encountered in a community. Because some species were encountered more than others, SI fits well. Mathematically, SI is the probability that any two plants chosen at random are different species. Therefore, a score of 1 is the highest possible SI value. The June SI value is 0.781, and the July SI value is 0.701. The July value indicates a lake in the lower 25th to 50th percentile of similar lakes, exhibiting a lower diversity than a majority of other Driftless area lakes (Nichols, 2000). The June value is in the 50th to 75th percentile. This comparison is shown in Figure 7.

Figure 7. Comparison of Apple Canyon Lake Simpson's Index to other Driftless area lakes.

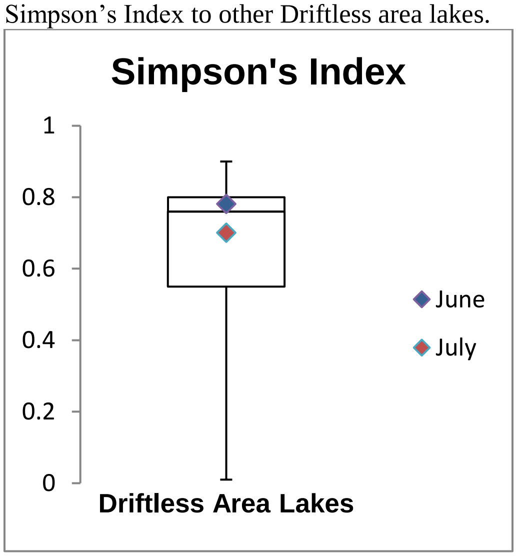
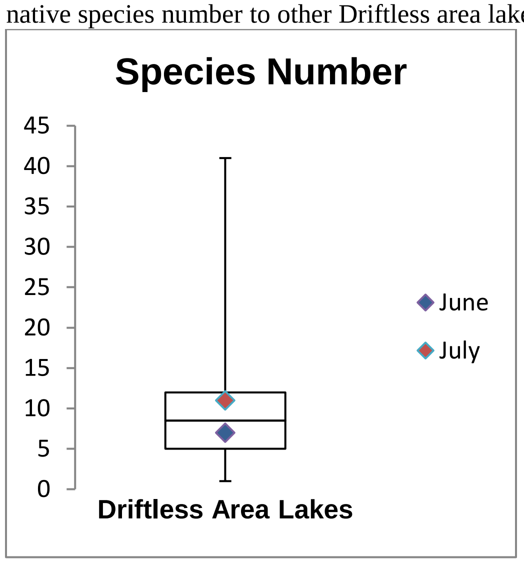


Figure 8. Comparison of the Apple Canyon Lake native species number to other Driftless area lakes.



Nichols et al. (1998) proposed a method to assess aquatic plant communities in Wisconsin lakes. This method uses two indices, the Average Coefficient of Conservatism (C) and the Florist Quality Index (I). Each plant is given a coefficient of conservatism ranging from 1-10 that indicates how sensitive each species is to disturbance, with most sensitive plants given a 10. Disturbances can include mechanical disturbances such as motor boat traffic, chemical disturbances such as change in nutrient levels, or biological disturbances such as the introduction of invasive species. The Floristic Quality Index uses C along with the number of species present to assign a value to the overall quality of the plant community.

These numbers can then be compared with similar lakes. It is worth noting that the Floristic Quality Index only takes into consideration native species, not invasive species.

In July, Apple Canyon Lake had a C value of 4.58 and an I value of 15.88. These values, along with the number of native species, were compared to other lakes in the Driftless Area. The number of native species, 11, is just under the 75th percentile (the June number, 7, is between the 25th and 50th percentile). A C value of 4.58 is just below the 25th percentile, and the I value of 15.88 is between the 50th and 75th percentile.

June had a higher C value (5.29, 25th to 50th percentile), but a lower I value (13.98, 25th to 50th percentile). The decrease in C values can likely be attributed to the fact that plants that were able to colonize after the Curly Leaf Pondweed die-off and survive herbicide treatments are less sensitive to disturbance. However, the higher number of species resulted in an overall increase in I value. These values indicate that Apple Canyon Lake has similar, but generally lower quality of the aquatic plant community to other lakes in the ecoregion. Figures 8-10 show the comparison between these values in Apple Canyon Lake and other Driftless area lakes.

Figure 9. Comparison of Apple Canyon Lake's average coefficient of conservatism to other Driftless area lakes.

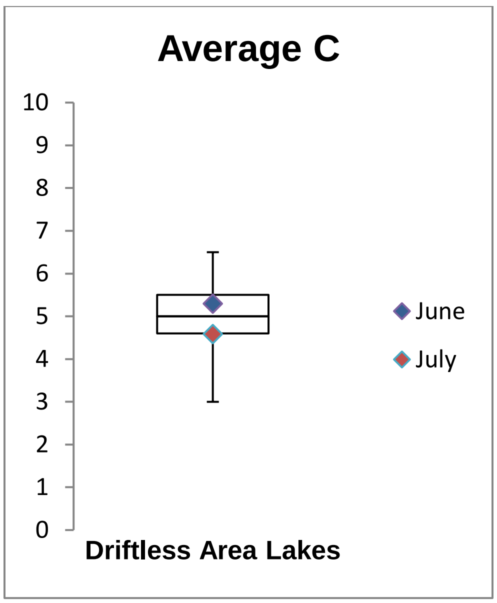
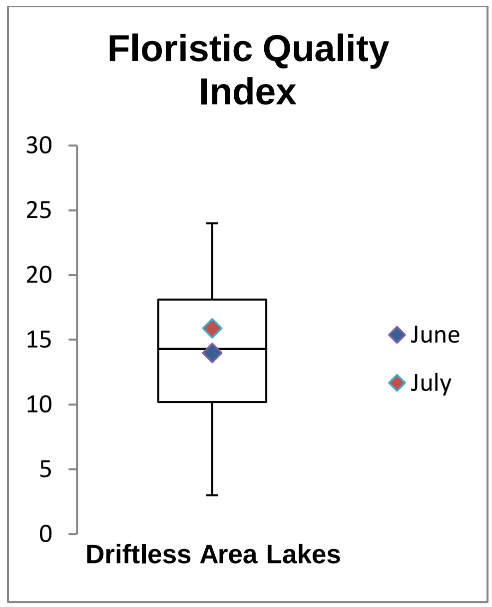


Figure 10. Comparison of Apple Canyon Lake's floristic quality index to other Driftless area lakes.

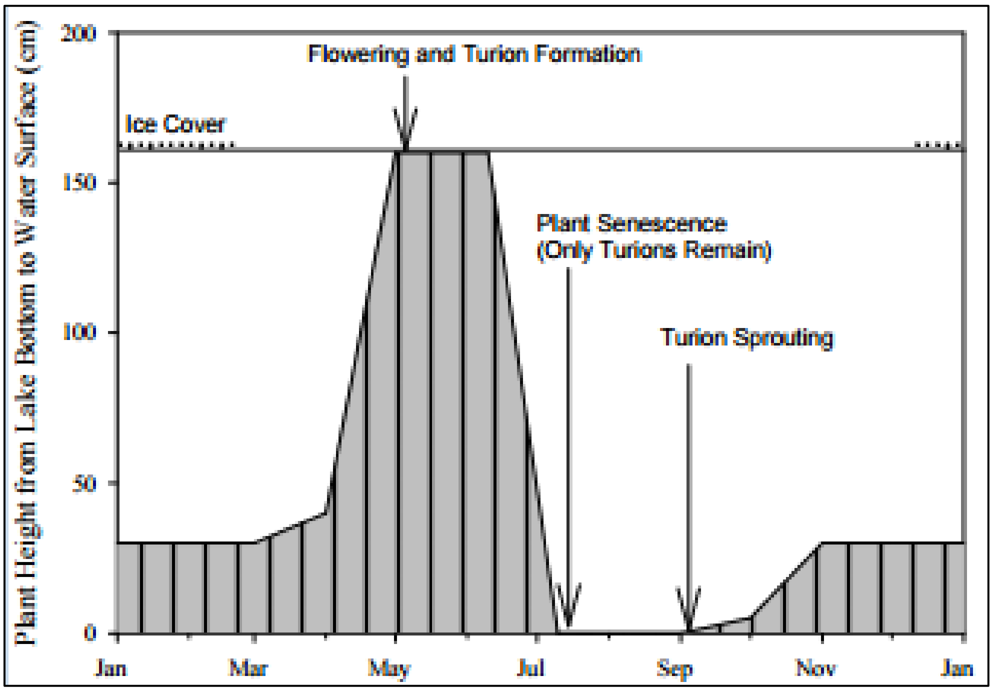


4.3 Invasive Species Effects

Though total plant coverage at Apple Canyon Lake is low, the plant covering the most area in June was the invasive Curly Leaf Pondweed (CLP). This is especially concerning as it was present in low quantities in the 2012 survey. In the 4 years since the 2012 survey, it has spread quickly and shaded out many native plants. CLP was present at many of the docks and inlets around the lake. Lake residents report anecdotally that CLP in 2016 is much more prevalent than even 2015, implying much of the spread occurred this past year. A large part of this is likely due to the areas of higher depth it colonized, where other plants were unable to photosynthesize. CLP also sprouts in the fall, and the mild winter and lower ice cover in 2015-2016 compared to previous years was also likely a factor in the spread. However, there are many areas where CLP has spread and covered areas where the 2012 survey showed exclusively native plants.

CLP is unique in that it peaks in the early spring and releases reproductive buds called turions. It then has a large die-off mid-July, and the new turions germinate in the fall. The plant continues to grow throughout the entire winter, even under snow and ice. Figure 11 shows a graphic visualization of the CLP life cycle. Turions can lie dormant for many years. The July die-off triggers a large decrease in dissolved oxygen levels, which is harmful to fish. It also releases nutrients that are then available to algal blooms. Overall, the water quality of the lake decreases after the die-off. While the use of Reward® (diquat) is effective in curbing back CLP during its peak growth, it isn't applied until after the plants have dropped their turions, and therefore isn't effective at controlling future growth of CLP. Therefore, the large decrease in CLP observed in July will not affect growth of CLP in 2017 and future seasons.

Figure 11. Graphic depicting the life cycle of Curly Leaf Pondweed, courtesy of the Mississippi State Georesearch Institute.



Eurasian Water Milfoil (EWM) and Reeds Canary Grass (RCG) were also present, but in lesser amounts. EWM tended to be found in large mats with other plants, and was patchier in its coverage. Hand-pulling is realistic for Reeds Canary Grass, but levels of CLP and EWM make hand-pulling an infeasible strategy. Renovate® (triclopyr) is often used as a single-species herbicide against EWM, and the milfoil weevil (*Euhrychiopsis lecontei)* is often used as a biological control. However, EWM tends to be found in small patches around the whole lake, so introduction of the milfoil weevil would be difficult, and likely impractical. In addition, the milfoil weevil achieves little control on lakes with high levels of boat traffic. The use of Renovate® (triclopyr) appears to be responsible for the drastic decrease of EWM.

When present, Reeds Canary Grass covered relatively small segments of shoreline (though is present in much higher numbers along tributary streams). RCG is considered an emersed plant; it roots in very shallow areas of the lake and grows well above the water line. It should be noted that there is discussion over whether or not RCG is an invasive species. Though there are both native and exotic strains present in the Midwest, almost no native strains remain. In addition, RCG grows aggressively and can displace native plants. Therefore, for the sake of this management plan, Reeds Canary Grass is considered invasive; however, it is not as much of a concern as CLP or EWM.

4.4 Habitat Suitability Indices

Habitat suitability indices for largemouth bass (Stuber et al., 1982b), bluegill (Stuber et al., 1982a), and walleye (McMahon et al., 1984) were calculated to determine whether Apple Canyon Lake provides sufficient habitat for these species, specifically in regards to macrophyte cover. Table 7 contains HSI values along with food, cover, water quality, and reproduction coefficients, and trophic status coefficient (C_{Other}) for largemouth bass, bluegill, and walleye. HSI values are scored on a scale from 0 - 1.0, with 0 - 0.1 signifying poor habitat, 0.2 - 0.4 signifying fair, 0.5 - 0.7 signifying good, and 0.8 - 10.0 signifying excellent habitat.

Table 7.

Species	C_{Food}	C_{Cover}	$C_{Water\ Quality}$	$C_{Reproduction}$	C_{Other}	HSI	Assessment
Largemouth Bass	0.95	0.52	1.00	0.47	NA	**0.69**	**Good**
Bluegill	0.55	0.55	0.97	0.89	NA	**0.76**	**Good/Excellent**
Walleye	0.65	0.84	0.40	0.20	0.50	**0.20**	**Fair**

Largemouth Bass received an HSI in the “good” range. The biggest limitation to Largemouth Bass habitat is aquatic plant cover. Optimal condition for adults and juveniles is 40 - 60% cover of the littoral area, and for fry is 40 - 80% cover. Littoral zone cover in July was less than 10%. Many of the other conditions such as water quality were ideal for Largemouth Bass, leading to an overall score of good. However, increasing the aquatic plant cover would improve conditions highly.

Bluegill habitat received the highest rating with a value between the “good” and “excellent” range. The largest limitation to Bluegill was also plant cover. Optimal macrophyte cover for Bluegill is 15 - 30% of the littoral zone. In the early summer, aquatic plant cover fell into that range, but decreased to below ideal range over the course of the summer. Again, many other conditions were ideal for Bluegill leading to the score of good/excellent.

Walleye habitat received the lowest rating of “fair”. Walleye were largely limited by macrophyte cover as well. Ideal plant cover for Walleye is 25 - 35%, which again was in the early summer range, but not late summer. Spawning habitat for Walleye is also poor. Increasing plant cover will support individuals but without improving spawning habitat populations will not be self-sustaining. Ideal substrate is coarse gravel (2.5 - 15cm diameter), which there is little of in ACL. A majority of the depth suitable for Walleye spawning is covered in silt, which isn’t usable substrate. There are some boulders in areas with riprap. Increases in plant cover and boulders, and the addition of coarse gravel spawning beds would improve Walleye spawning habitat and likely contribute to a sustainable Walleye population.

While many variables, such as water chemistry, are ideal for these three desirable gamefish species, plant cover limits habitat suitability for all three species. Allowing for an increase in cover, even to 30% of the littoral zone (close to early summer values), will improve conditions for all three species. An increase to 30% plant cover with no other changes would improve the Largemouth Bass score to 0.74

(good/excellent) and Bluegill to 0.81 (excellent). Limiting herbicide treatments to before native plants grow would ideally provide space for native plants to spread. Limiting broad spectrum herbicide treatments will also prevent decreases in native plant growth. In addition, placing coarse gravel beds (2.5-15cm rock) in areas between 1 and 5 feet of depth will significantly improve habitat for both Walleye and Bluegill. Placing 0.75 acres of gravel beds would improve the Bluegill score to 0.78 (good/excellent) and the Walleye score to 0.4 (fair). Figure 12 proposes locations for three gravel spawning beds. The total area for all three beds is approximately 0.85 acres, which has an estimated cost of $34,840. Individually, the northern and southwest gravel beds would each cost $10,920, and the southeast gravel bed would cost $13,000.

Figure 12. Proposed locations of gravel beds.

4.5 Management

For native plants, the highest concentrations found were those of Coontail and Elodea in June, and Coontail and Water Celery in July. These plants tended to cover wide areas when present, and could possibly rise to nuisance levels if the invasive species are removed. The coverage tends to be most dense in the shallow bays and inlets. Dense mats of Coontail and Elodea can also restrict dock access in the bays.

The lake maintains a weed harvester to clear lanes through some of the larger plant beds, especially near docks. While this is important for dock access, this is not a permanent, sustainable solution. One of the biggest concerns about weed harvesters is that they can spread invasive species, such as EWM which can sprout from cuttings (CLP does not spread through these means). This is also a temporary solution. The harvester doesn't remove the roots of any plants, so they quickly return and harvesting must be repeated many times in a season (often weekly) to keep the desired area clear.

Since the native plants are at low levels already, management actions should be chosen with care not to reduce the native plant population any more than absolutely necessary. Apple Canyon Lake also tends towards high algal levels, so care should be taken to choose a treatment that will not increase algae, such as triploid grass carp or large-scale herbicide application during peak growth season. Continuing broad-spectrum herbicide treatments has no benefit. Using broad spectrum herbicides removes large quantities of native plants, and the POA is only leaving more areas clear to be colonized by invasive species in the future. Cutrine Plus® algaecide is currently used to control algae. Label instructions for all algaecide and herbicide applications should be followed exactly in order to have the least impact on aquatic organisms.

At this point, the only management strategy likely to be effective, while not causing further impairment, is herbicide application. Since the primary species to be controlled is CLP, a form of endothall should be used as it has been shown to clearly be effective. Endothall is ideally applied in cooler temperatures, between 10-16ºC (50-60.8ºF), for maximum effectiveness (Poovey, 2002). Early season applications of endothall have been shown to highly reduce CLP before native plants have germinated, leading to overall increases in native plants (JaKa, 2015). In addition, applying herbicides early in the season before the plants have grown substantially will reduce dissolved oxygen depletion, and subsequent potential fishkills. The POA can continue to use the weed harvester when excessive growth of native plants inhibits dock access. In addition, the POA must obtain all permits necessary for herbicide application for desired areas from the Illinois EPA, and follow the guidelines of these permits.

Two cautions should be noted with this treatment method. First, CLP turions can lie dormant for up to five years, so the POA will have to apply endothall for multiple years, even if CLP appears to be eradicated. Second, the removal of CLP will leave gaps for other plants in the lake to colonize, which can include EWM. Studies have shown that EWM is also very sensitive to endothall, but in some cases, EWM has increased after treatment (Skogerboe & Getsinger, 2002; JaKa, 2015). The POA can continue to use Renovate® (triclopyr) to control EWM as necessary.

An alternative would be to apply endothall treatments in the fall, after the October turions sprouting. This would also eliminate plants during early growth stages where there would be significantly less decay. Though little research has been done on fall applications, the potential benefits of decreased decaying biomass may make this the better option. However, removing CLP in the fall would also likely create additional gaps which could be easily colonized by EWM. Therefore, the POA would need to use triclopyr to supplement the endothall to control all invasive species.

Currently, Reeds Canary Grass presents no severe problem at the lake, in part because of its small spread. However, that could easily change in the future. The POA should work to hand-pull plants from the isolated areas around the lake where it is found. As some of these areas are directly next to property owner shorelines, the POA will likely have to work with the property owners. As Reeds Canary Grass is an effective shoreline stabilizer, pulling it from tributary streams may have more negative effects than positive effects on the lake as a whole. Monitoring will be important, as Reeds Canary Grass along streams will produce seeds that will likely flow into the lake.

The POA will also need to continue to educate residents about how to prevent the spread of invasive species. Other aquatic invasive plants present in the Midwest include Hydrilla, Fanwort, and Water Chestnut. These species are not currently present in ACL, but that could easily change with just a few plants brought in on a boat. If budget permits in the future, adding a boat wash station could benefit property owners.

5. Management Recommendations

1. The POA needs to develop a formal aquatic plant management plan.
2. The POA needs to apply early-season or fall endothall treatments no later than mid-May in 2017 or no earlier than mid-October in 2016 for a minimum of 3 years. The weed harvester can continue to be used when necessary to provide channels to docks. All herbicide treatments need to be documented, as per Illinois law.
3. If Eurasian Water Milfoil levels rise post-herbicide treatment, the POA needs to apply Renovate® (triclopyr) to reduce levels. All herbicide treatments will be documented.
4. The POA needs to continue to educate residents about the various invasive species in the lake, and educate on practices designed to limit introduction of invasive species to the lake. Outreach can occur through the Apple Core, the lake newspaper, or through venues such as Canyon Kids Camp.
5. The aquatic plant survey will be conducted every five years to track further changes to the plant community, and management strategies reassessed. The drastic changes observed between 2012 and 2016 indicate that changes can occur very quickly. Informal monitoring for invasive species will be continued every year.
6. Water quality needs to continue to be assessed in the lake to look for trends in changes in nutrient concentrations, as well as the response to aquatic plant management.
7. The POA needs to work with property owners to pull all Reeds Canary Grass around the shoreline.
8. Budget permitting, the POA should add a boat wash station to the marina to help prevent the future spread of invasive species.
9. The POA should place coarse gravel beds to improve spawning habitat for Walleye. Gravel should be 1.5 - 25cm diameter and will ideally be placed in areas between 1 and 5 feet of depth, in locations where sedimentation will not cover beds. Figure 10 suggests three possible locations.

Sources Cited

Canfield, D. E., Langeland, K. A., Linda, S. B., and Haller, W. T. (1985). Relations between water transparency and maximum depth of macrophyte colonization in lakes. Journal of Aquatic Plant Management 23: 25-28

JaKa, J. (2015). Control of Curlyleaf Pondweed (Potamogeton crispus) with endothall herbicide treatments and the response of the native plant community in suburban lakes. Retrieved from the University of Minnesota Digital Conservancy, http://hdl.handle.net/11299/174786.

Malon, M., Hederman, M., Hinze, C., and van Vianen, V. (2016). Apple Canyon Lake Watershed Based Management Plan. Retrieved from http://www.applecanyonlake.org/applecore/files/ACL__DRAFT_WATERSHED_PLAN%20(2)%2003%2009%2016.pdf

McMahon, T. E., Terrell, J. W., and Nelson, P. C. (1984). Habitat suitability information: Walleye. U.S. Fish and Wildlife Service. FWS/OBS-82/10.56. 43 pp.

Nichols, S. A. (1998). Floristic quality assessment of Wisconsin lake plant communities with example applications. Lake and Reservoir Management 15(2):133-141.

Nichols, S., Weber, S., and Shaw, B. (2000). A proposed aquatic plant community biotic index for Wisconsin lakes. Environmental Management 26(5):491-502.

Poovey, A. G., Skogerboe, J., and Owens, C. (2002). Spring treatments of diquat and endothall for curlyleaf pondweed control. Journal of Aquatic Plant Management 40:63-67.

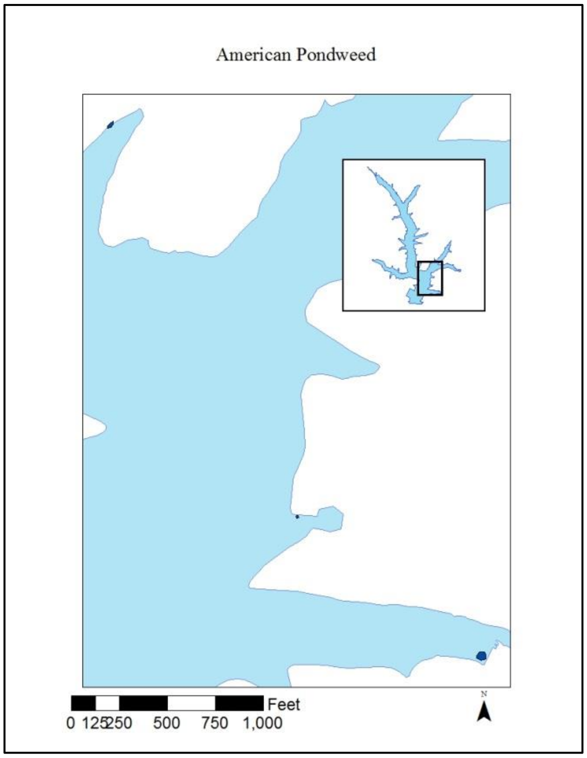
Porcella, D. B., Peterson, S. A., and Larson, D. P. (1979). Proposed method for evaluating the effects of restoring lakes.

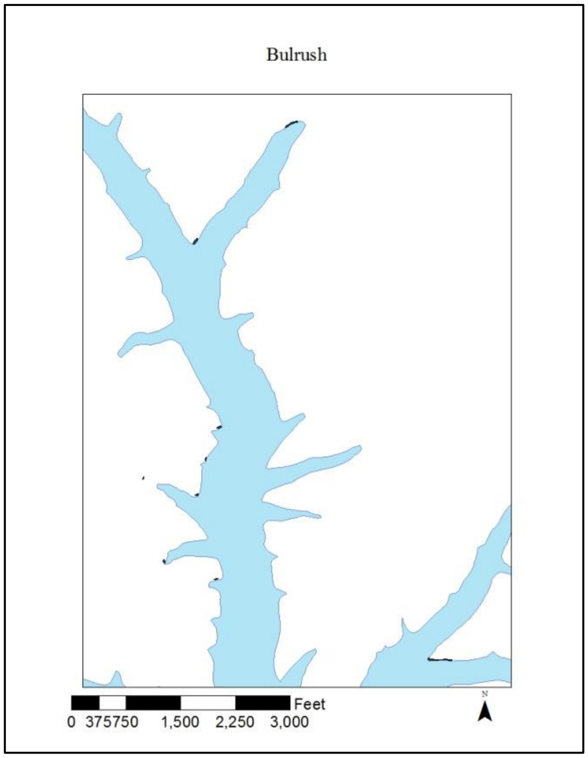
Skogerboe, J., and Getsinger, K. (2002). Endothall species selectivity evaluation: Northern latitude aquatic plant community. Journal of Aquatic Plant Management 40:1-5.

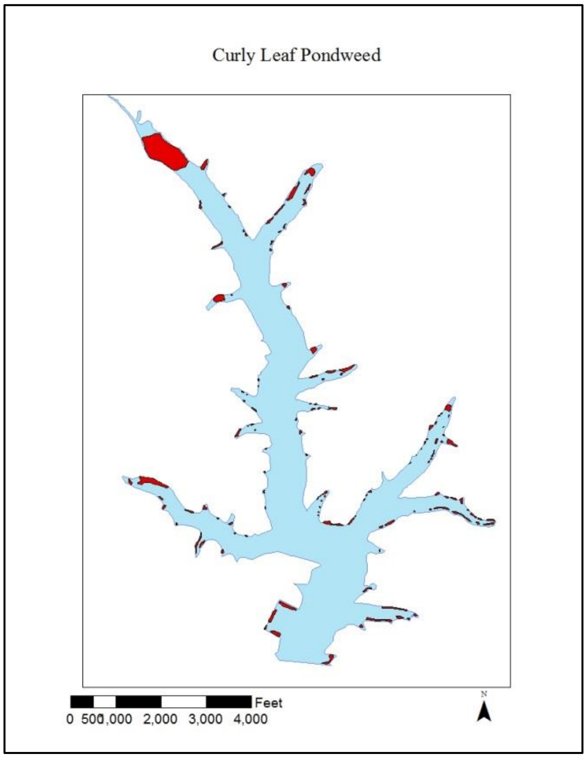
Stuber, R.J., Gebhart, G., and Maughan, O. E. (1982a). Habitat suitability index models: Bluegill. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.8. 26 pp.

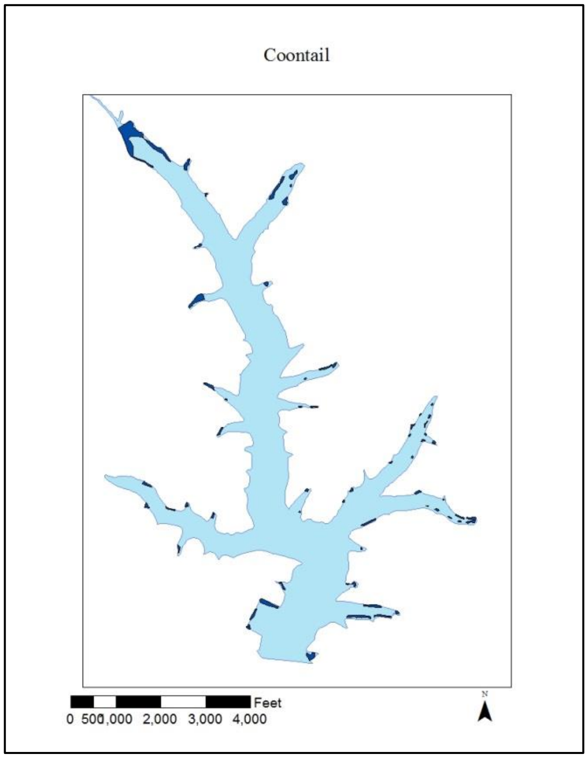
Stuber, R. J., Gebhart, G., and Maughan, O. E. (1982b). Habitat suitability index models: Largemouth Bass. U.S.D.I. Fish and Wildlife Service. FWS/OBS-82/10.16. 32 pp.

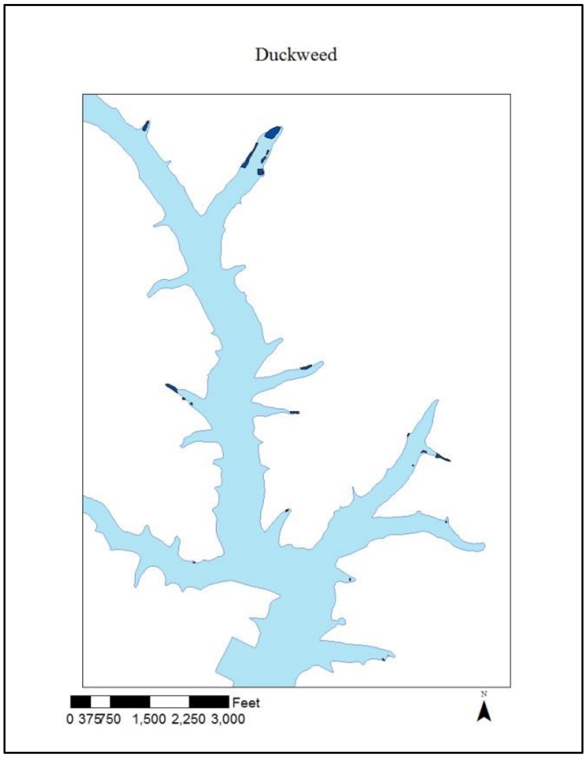
Appendix 1: Plant maps for individual species, June 2016.

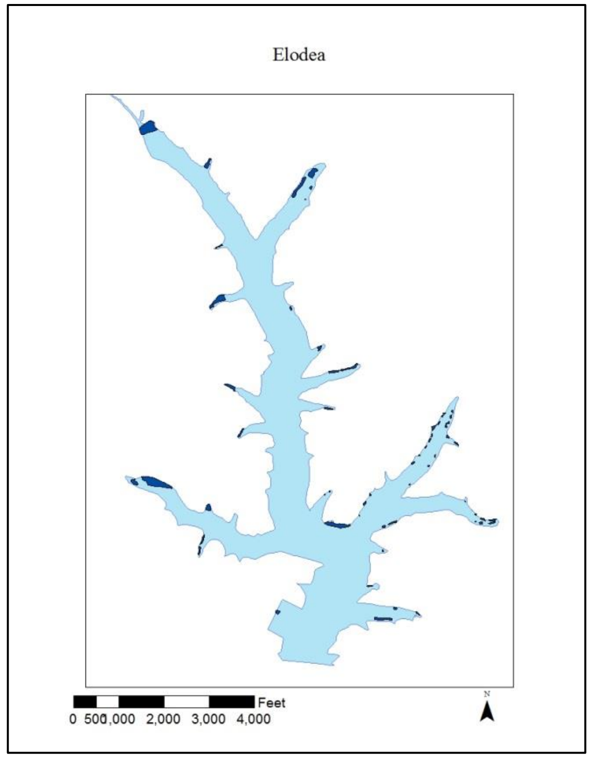


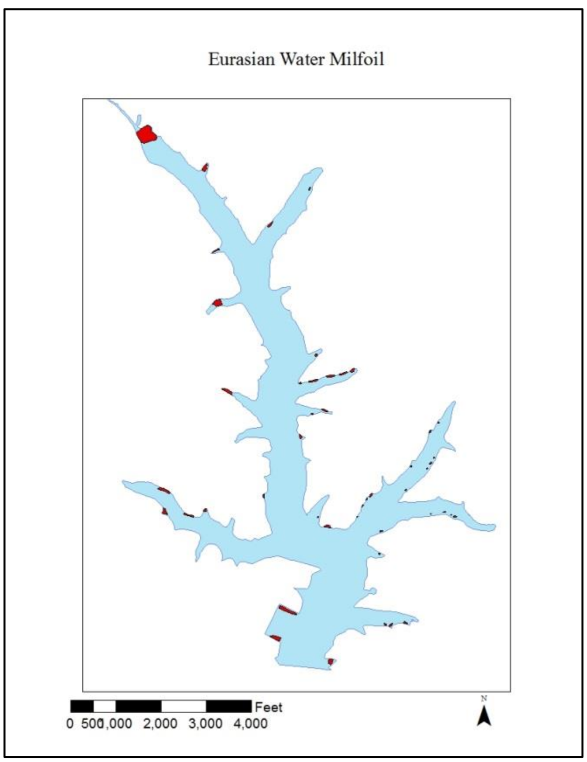


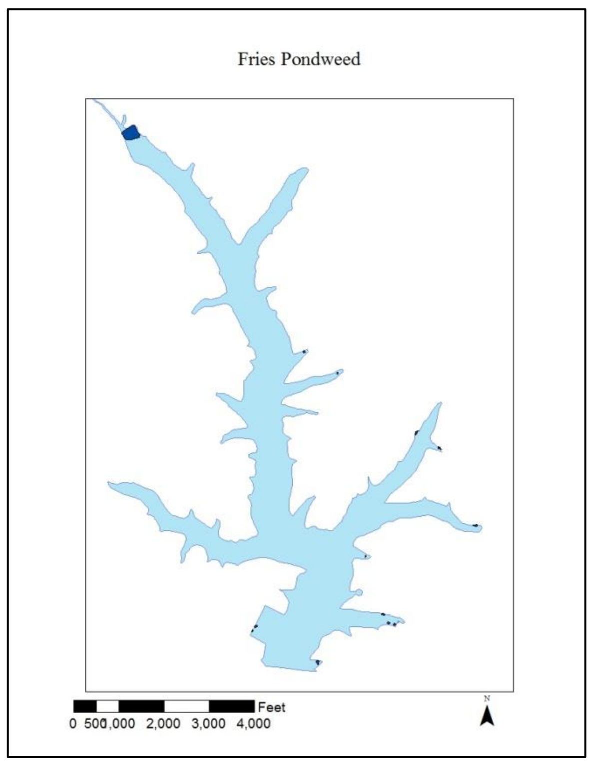


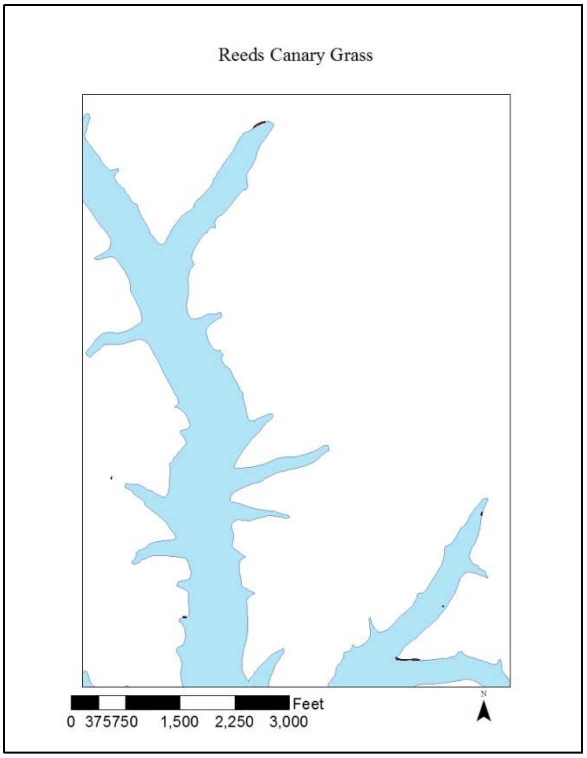


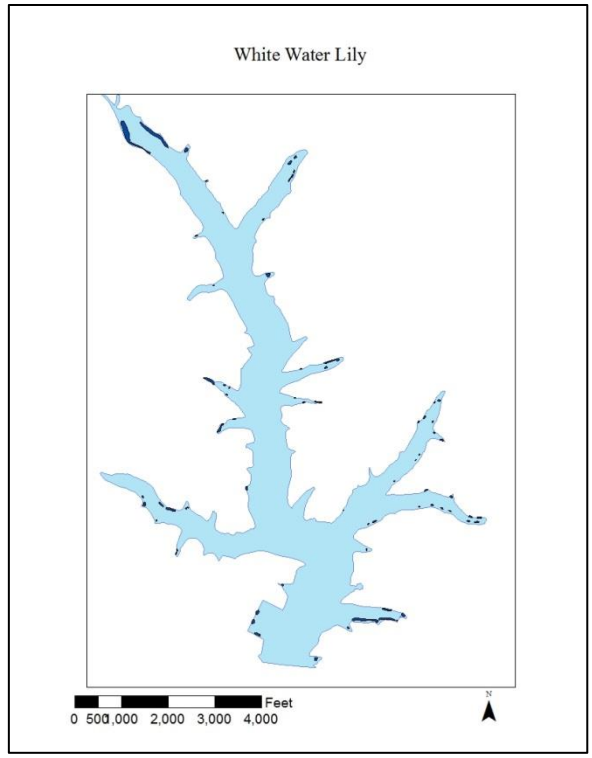

Duckweed
Feet
0 375750 1,500 2,250 3,000
N


Elodea
Feet
0 5001,000 2,000 3,000 4,000
N

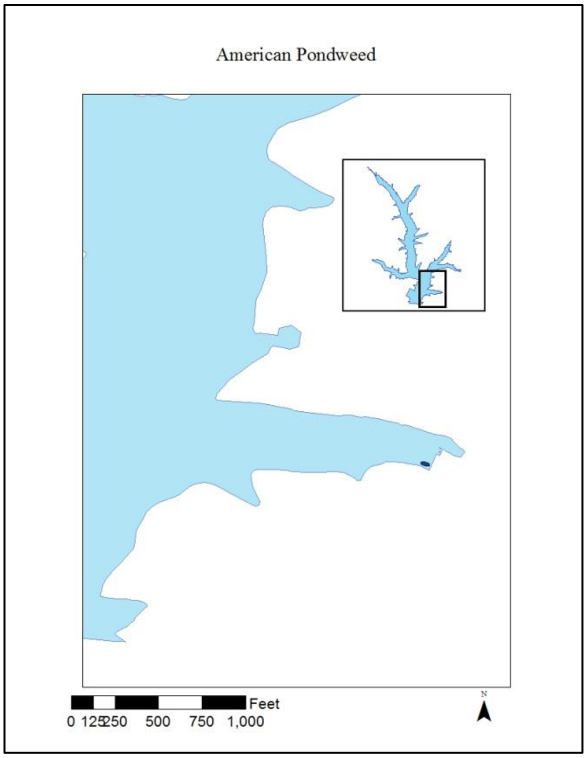

Eurasian Water Milfoil
Feet
0 5001,000 2,000 3,000 4,000
N

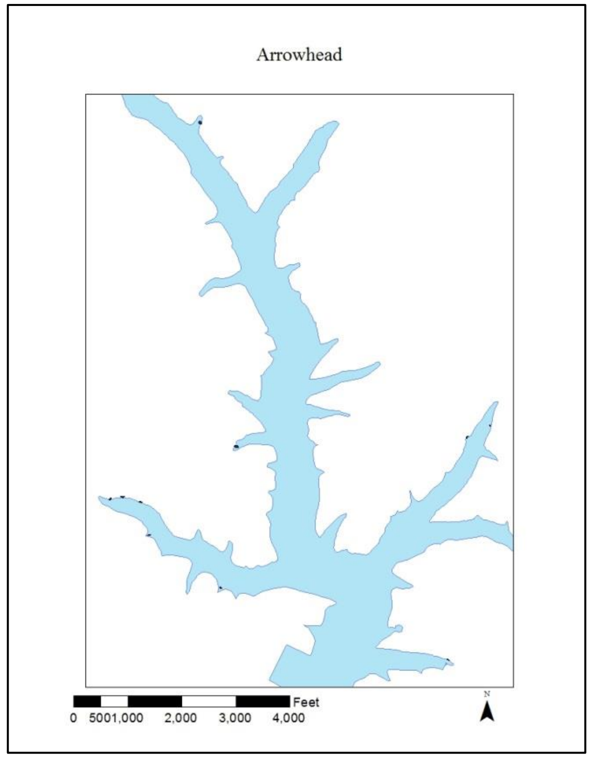

Fries Pondweed
Feet
0 5001,000 2,000 3,000 4,000
N

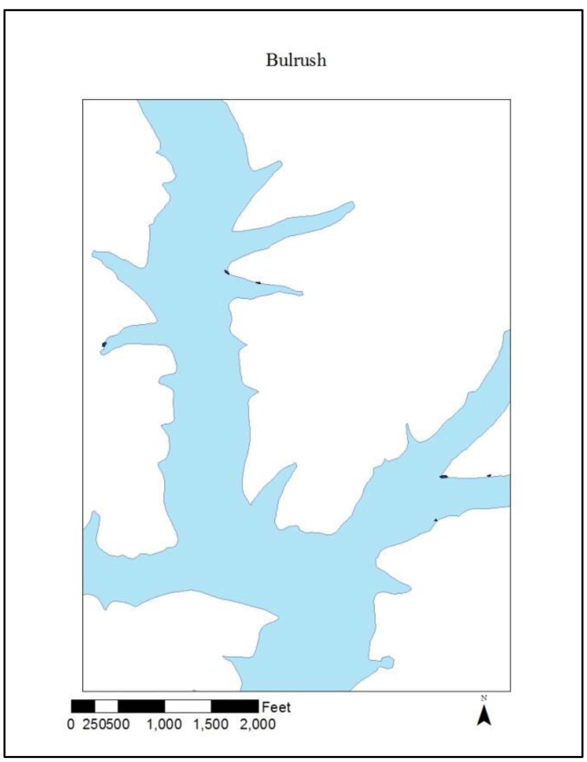

Reeds Canary Grass
Feet
0 375750 1,500 2,250 3,000
N

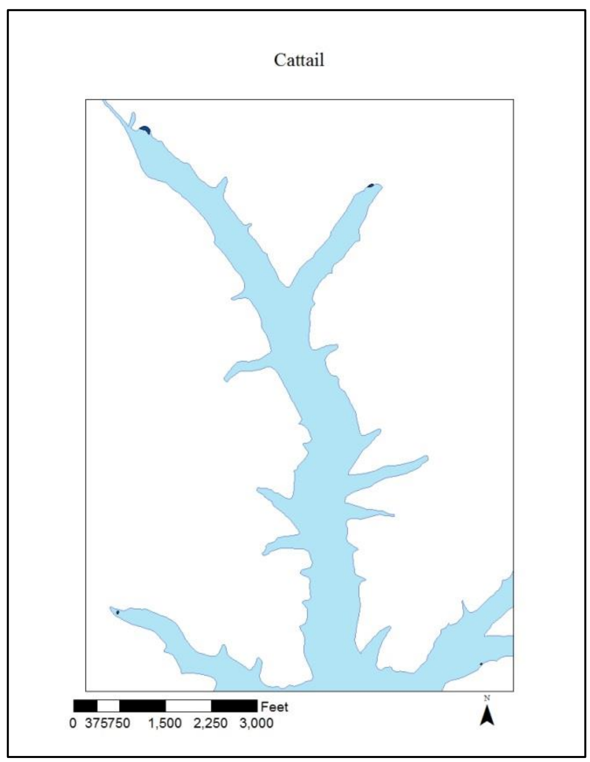

White Water Lily
Feet
0 5001,000 2,000 3,000 4,000
N

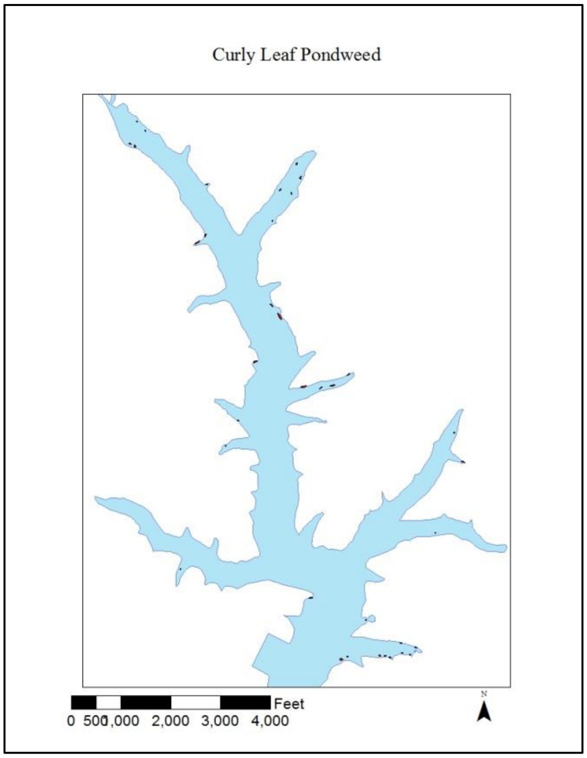
Appendix 2: Plant maps for individual species, July 2016.

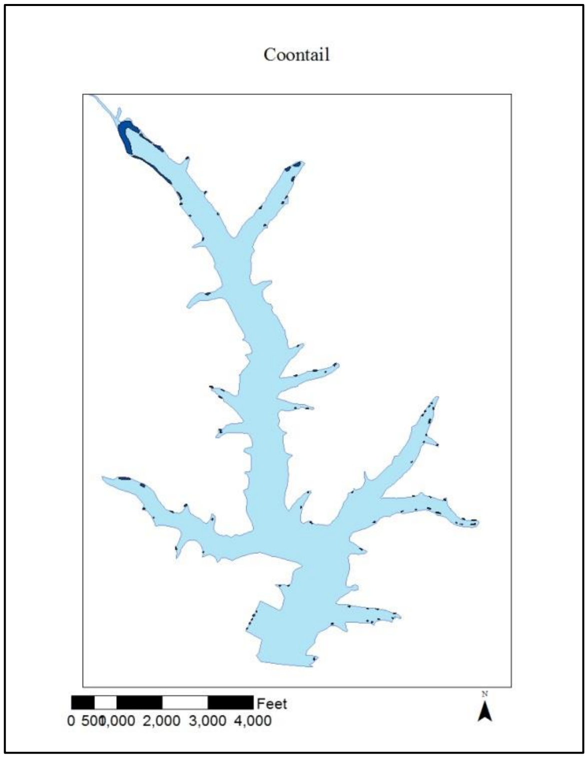


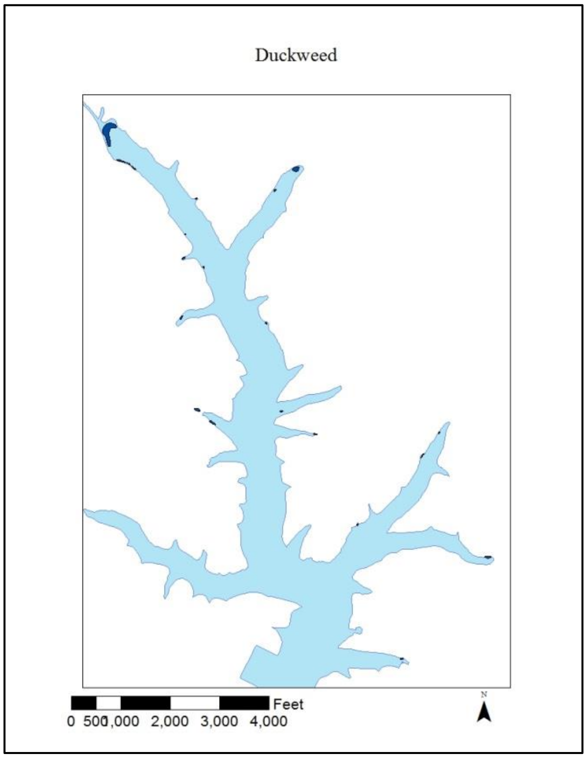


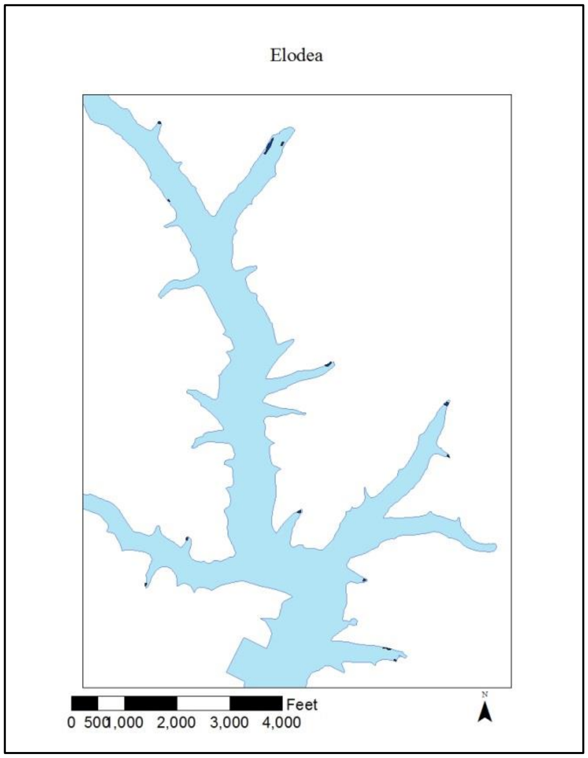


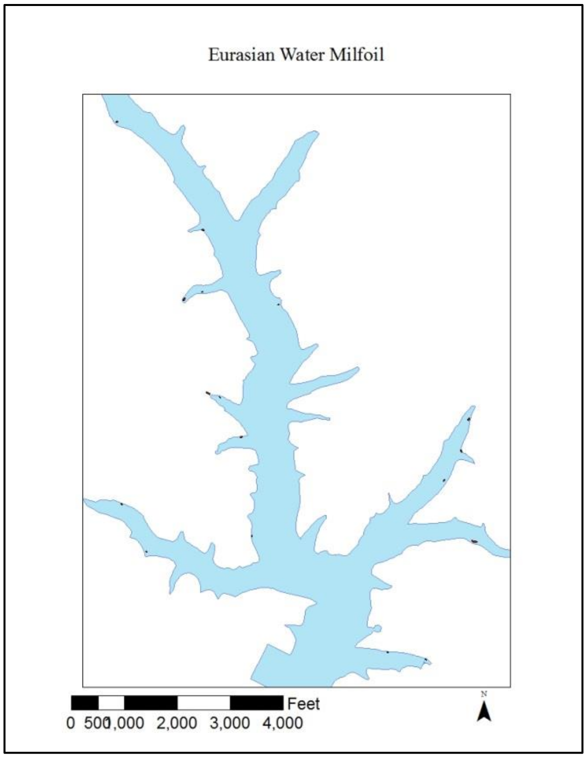


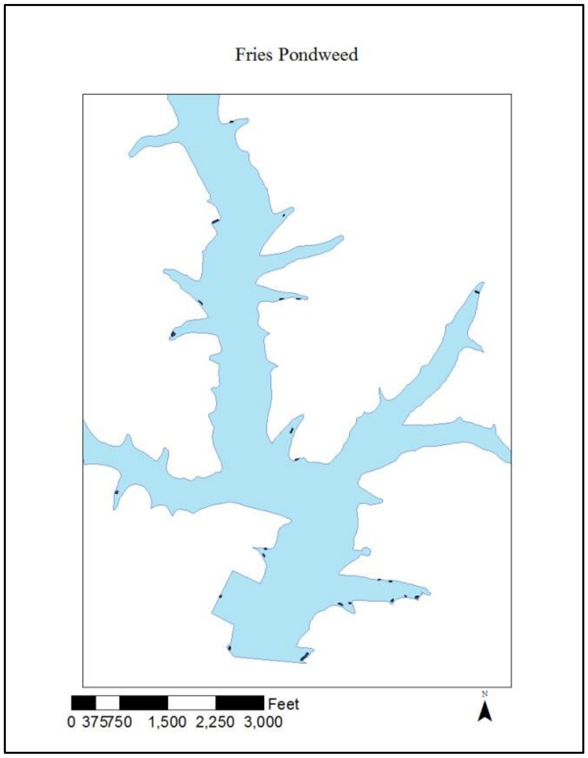

Curly Leaf Pondweed
Feet
0 500 1,000 2,000 3,000 4,000
N

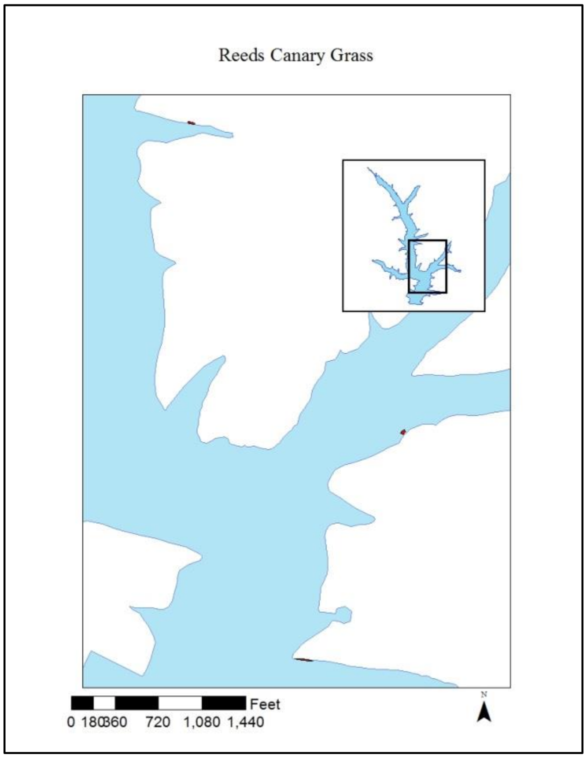

Coontail
Feet
0 500 1,000 2,000 3,000 4,000
N

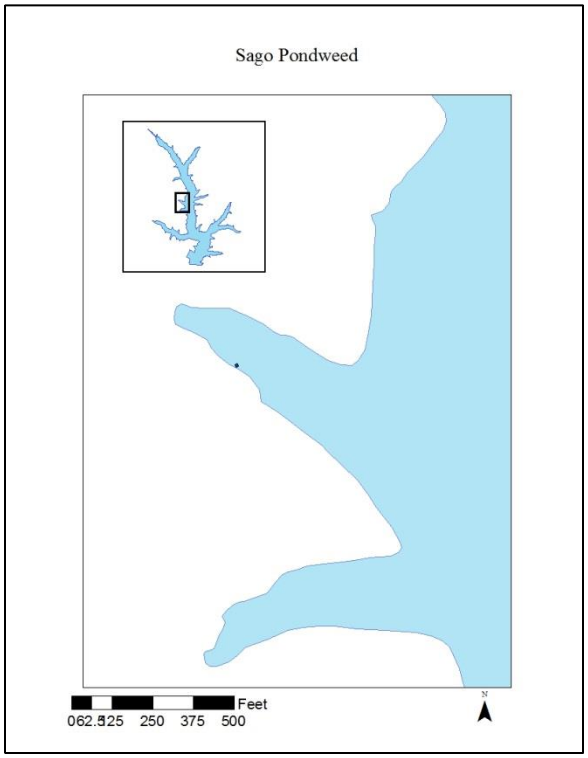

Duckweed
Feet
0 500 1,000 2,000 3,000 4,000
N

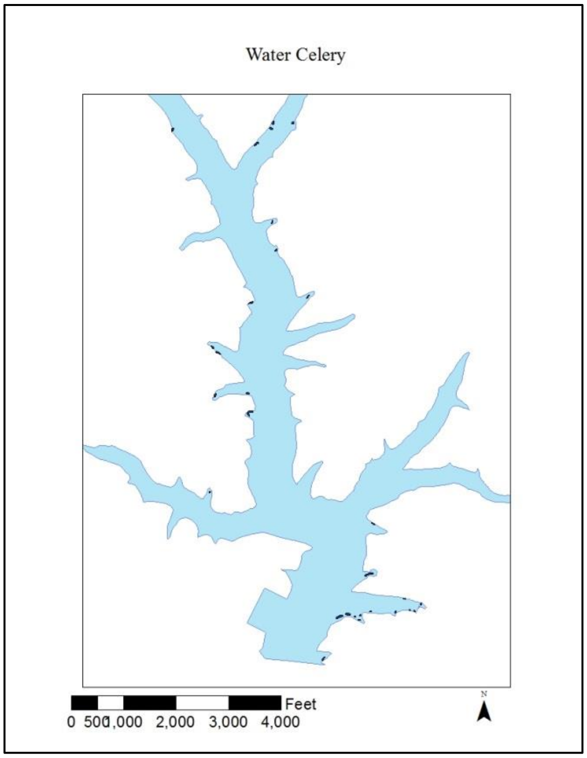

Elodea
Feet
0 500 1,000 2,000 3,000 4,000
N

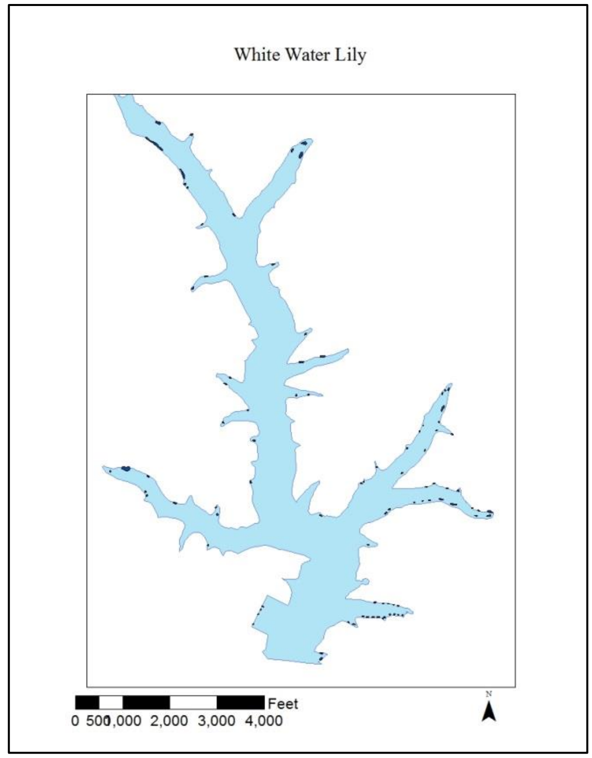

Eurasian Water Milfoil
Feet
0 500 1,000 2,000 3,000 4,000
N


Fries Pondweed
Feet
0 375 750 1,500 2,250 3,000
N


Reeds Canary Grass
Feet
0 180 360 720 1,080 1,440
N


Sago Pondweed
Feet
0 62.5 125 250 375 500
N


Water Celery
Feet
0 500 1,000 2,000 3,000 4,000
N


White Water Lily
Feet
0 500 1,000 2,000 3,000 4,000
N