Soap Creek Watershed Project Evaluation

October 2016

Iowa Flood Center | IIHR—Hydroscience & Engineering
The University of Iowa
C. Maxwell Stanley Hydraulics Laboratory
Iowa City, Iowa 52242

Iowa Watersheds Project Phase II: Soap Creek Watershed Evaluation of Project Performance

October 2016

IIHR Technical Report No. 507

Prepared by:
Iowa Flood Center | IIHR—Hydroscience & Engineering
The University of Iowa
C. Maxwell Stanley Hydraulics Laboratory
Iowa City, Iowa 52242

Acknowledgements

The Iowa Flood Center and IIHR—Hydroscience & Engineering would like to thank the following agencies and organizations for providing data and engaging in discussions that contributed to this assessment:

Soap Creek Watershed Management Authority (WMA), previously known as Soap Creek Watershed Board
Davis County Soil and Water Conservation District (Davis SWCD)
Chequest Creek Advisory Committee
Iowa Department of Natural Resources (IDNR)
Natural Resources Conservation Service (NRCS)

Cover photograph. Soap Creek Flood Mitigation Structure, Davis County. Photograph by Iowa Flood Center.

Table of Contents

List of Figures

List of Tables

1. Introduction

Heavy rains and subsequent flooding during the summer of 2008 brought economic, social, and environmental impacts to many individuals and communities in watersheds across the state of Iowa. In the response and recovery aftermath, a handful of Watershed Management Authorities — bodies consisting of representatives from municipalities, counties, and soil and water conservations districts — have formed to tackle local challenges with a unified watershed approach.

In 2010, Iowa received $8.8 million from the U.S. Department of Housing and Urban Development (HUD) to assist with ongoing disaster recovery programs following these devastating floods. The Iowa Flood Center (IFC), a unit of the University of Iowa's IIHR—Hydroscience & Engineering, led an effort called the Iowa Watersheds Project. Its goal was to evaluate and implement flood reduction methods in Iowa watersheds. The Soap Creek Watershed, in a collaboration of the Soap Creek Watershed Management Authority (previously known as Soap Creek Watershed Board) and the Chequest Creek Advisory Committee, was one of four watersheds (Figure 1.1) selected to demonstrate a watershed approach for flood risk reduction.

In Phase I of the project, the Iowa Flood Center conducted a hydrologic assessment of the Soap Creek Watershed (IFC, 2014). The assessment characterized the water cycle of Soap Creek using historical observations on the adjacent Fox River, as well as investigated trends observed for Soap Creek within the broader context of historic changes in land use and weather patterns. Researchers developed a hydrologic model of Soap Creek, using the Hydrologic Engineering Center Hydrologic Modeling System (HEC-HMS), to quantify the impact existing flood mitigation structures play in the watershed, to identify areas in the watershed with high runoff potential, and to run simulations to help understand the potential impact of alternative flood mitigation strategies in the watershed. For scenario development in Soap Creek, researchers primarily focused on understanding the impacts of increasing infiltration.

Modeling results and scenario simulations from the Phase I hydrologic assessments are being added to the Iowa Watershed Decision Support System (IoWaDSS), as part of an Iowa Flood Center project funded by the U.S. Army Corps of Engineers Institute for Water Resources. The system aims to assemble data, tools, and models in one place to: (i) inform watershed stakeholders of the current status and forecasts in Iowa watersheds, (ii) support the assessment of alternative strategies for sustainable watershed resources, (iii) provide real-time, integrated data, and simulation models from multiple disciplines, and (iv) facilitate collaboration and the sharing of resources and model results across agencies and communities. A video tutorial of the IoWa DSS can be found at https://www.youtube.com/watch?v=-yIikldRrXA. Modeling results for the Soap Creek Watershed and the Turkey River Watershed are now available online (http://iowawatersheds.org/dev/dss_alpha/). Results for the Upper Cedar River Watershed may be added to the IoWaDSS in the future.

In Phase II of the project, researchers identified smaller catchments (known as a HUC12 subwatersheds) in the Turkey River, Upper Cedar River, and Chequest Creek Watersheds (Figure 1.1) for development and construction of flood mitigation projects. In Soap Creek, a portion of the Soap and Chequest Creek funding was allocated to develop additional flood mitigation projects within the watershed. The additional flood mitigation structures were located based on land owner willingness and selected by a ranking schedule developed by the Soap Creek Watershed Board. IFC researchers evaluated the flood mitigation performance of the new projects through additional hydrologic modeling. This report describes the assessment results for Phase II of the project for the Soap Creek Watershed.

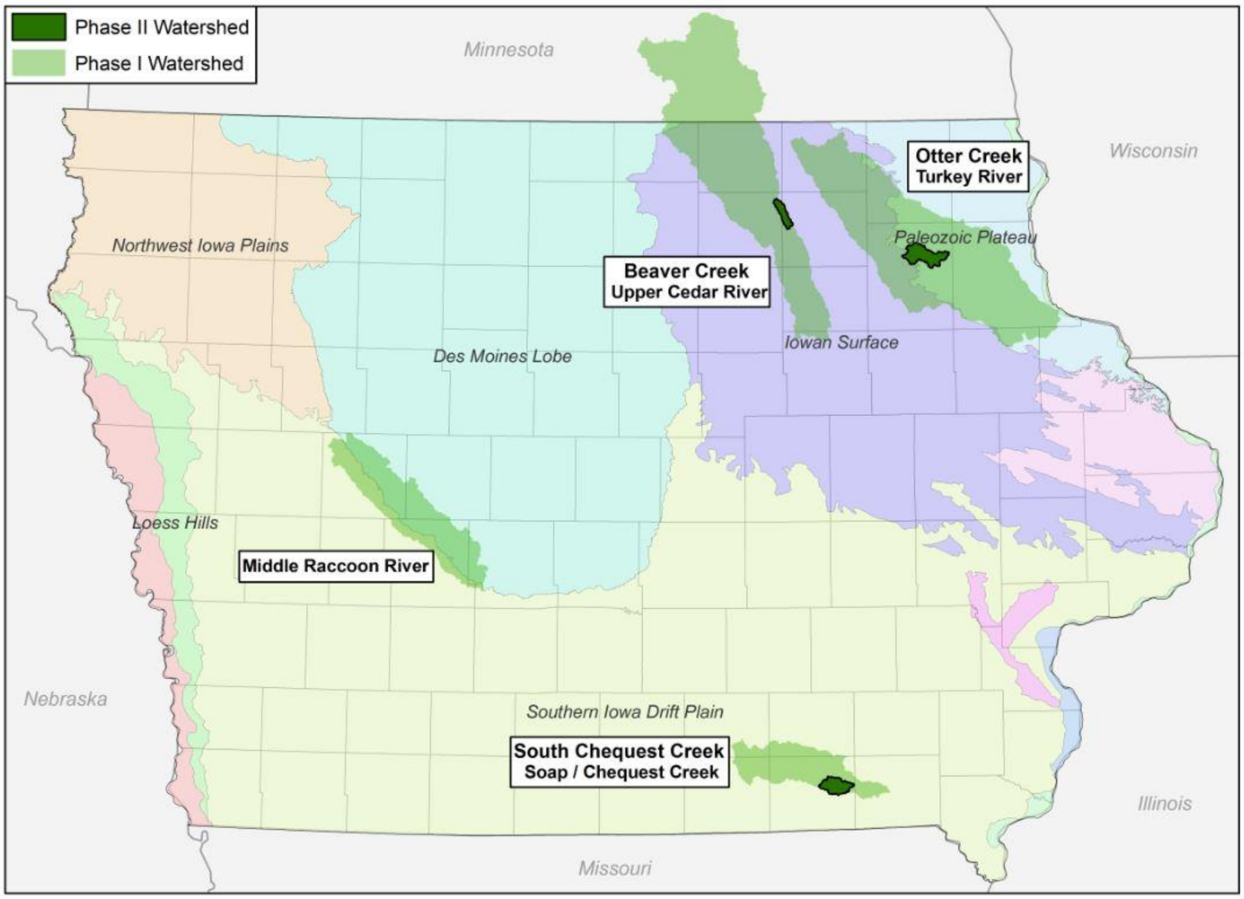

Figure 1.1. Iowa Watersheds Project, Phase I and Phase II selected watersheds.

2. Conditions in the Soap Creek Watershed

This chapter provides an overview of current Soap Creek Watershed conditions including hydrology, geology and soils, topography, and land use.

a. Hydrology

The Soap Creek Watershed as defined by the boundary of ten-digit Hydrologic Unit Code (HUC10) 0710000907 has a drainage area of approximately 258 square miles. It is located in Southeast Iowa and is a sub-watershed within the Lower Des Moines River Watershed, eight-digit Hydrologic Unit Code (HUC8 0710009).

The Soap Creek Watershed falls within a portion of Appanoose, Davis, Monroe, and Wapello Counties. Soap Creek flows from west to east, with two headwater branches, North and South Soap Creek. These two branches come together in Davis County and flow continues eastward. Little Soap Creek traverses southern Wapello County and enters Soap Creek northeast of Floris, Iowa. Soap Creek then continues to its outlet, discharging into the Des Moines River approximately 12 miles southeast of Ottumwa. Two large recreational lakes are located in the watershed: Lake Sundown, a 470 acre private lake situated on South Soap Creek, and Lake Wapello, a 287 acre state-owned lake suited on Pee Dee Creek.

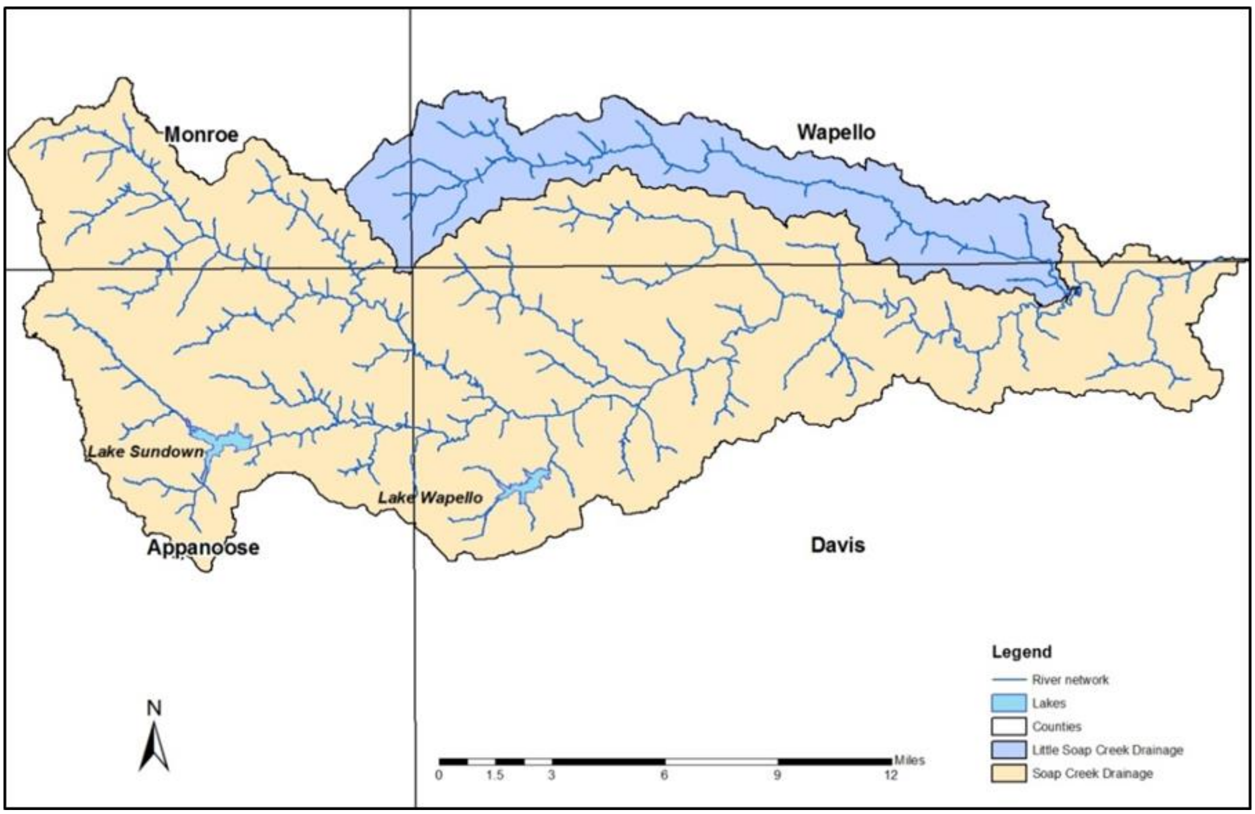

Figure 2.1. The Soap Creek Watershed drains approximately 258 square miles.

Average annual precipitation for this region of Southeast Iowa is roughly 39 inches (PRISM Climate Group, 2016, 1981-2010 normal precipitation), with about 80% of the annual precipitation falling April through September. During this period, thunderstorms capable of producing torrential rain are possible with the peak frequency of intense storms occurring in June. However, Soap Creek is surface flow dominated and whenever heavy rainfall occurs during the year, large river flows can occur.

b. Geology and Soils

The entire Soap Creek Watershed is located within the Southern Iowa Drift Plain (see Figure 2.2). This region is dominated by glacial deposits left by ice sheets that extended south into Missouri over half a million years ago. The deposits were carved by deepening episodes of stream erosion and only a horizon line of hill summits mark the once-continuous glacial plain. Numerous rills, creeks, and rivers branch across the landscape shaping the old glacial deposits into steeply rolling hills and valleys. A mantle of loess drapes the uplands and upper hill slopes (Iowa Geological & Water Survey, The Iowa Department of Natural Resources, 2013).

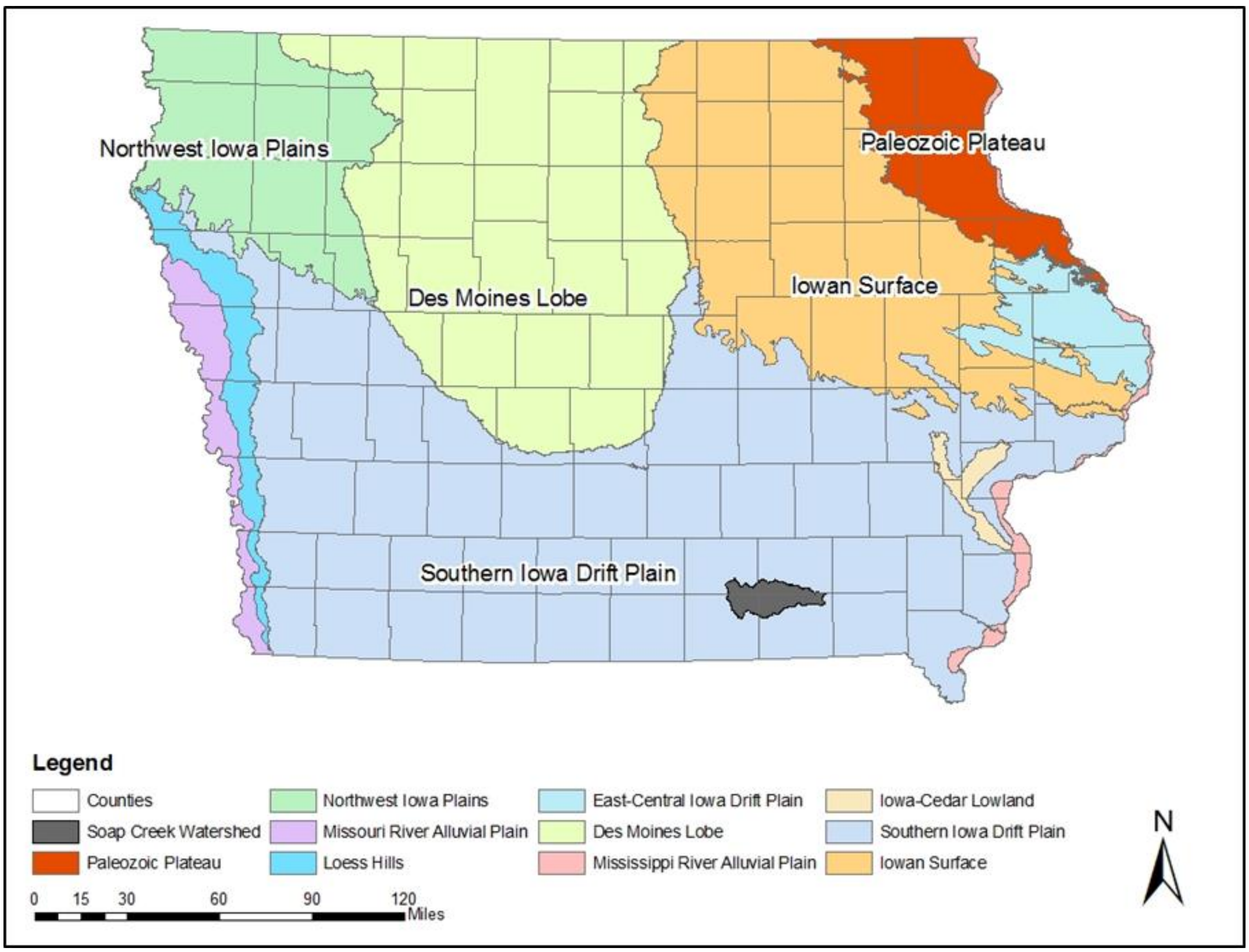

Figure 2.2. Landform Regions of Iowa. Soap Creek Watershed shown in Southeast Iowa.

Soils are classified into four Hydrologic Soil Groups (HSG) by the Natural Resources Conservation Service (NRCS) based on the soil's runoff potential. The four HSG's are A, B, C, and D, where A-type soils have the lowest runoff potential and D-type have the highest. In addition, there are dual code soil classes – A/D, B/D, and C/D – assigned to certain wet soils. In the case of these soil groups, even though the soil properties may be favorable to allow infiltration (water passing from the surface into the ground), a shallow groundwater table (within 24 inches of the surface) typically prevents much from doing so. For example a B/D soil will have the runoff potential of a B-type soil if the shallow water table were to be drained away, but the higher runoff potential of a D-type soil if it is not. Complete descriptions of the Hydrologic Soil Groups can be found in USDA-NRCS National Engineering Handbook, Part 630 – Hydrology, Chapter 7 (Natural Resource Conservation Service, 2004a).

The Southern Iowa Drift Plain in Southeast Iowa consists of Grundy, Haig, and Arispe soils on the headland ridges with slopes generally 9 percent or less. These soils typically contain 42 to 48 percent clay in the subsoil. Many of the side slopes that are steeper than 9 percent developed in glacial till. These soils classify as primarily HSG C and D type soils, resulting in areas that range from moderate to high runoff potential. The soil distribution of the Soap Creek Watershed per digital soils data (SSURGO) available from the USDA-NRCS Web Soil Survey (WSS) is shown in Figure 2.3.

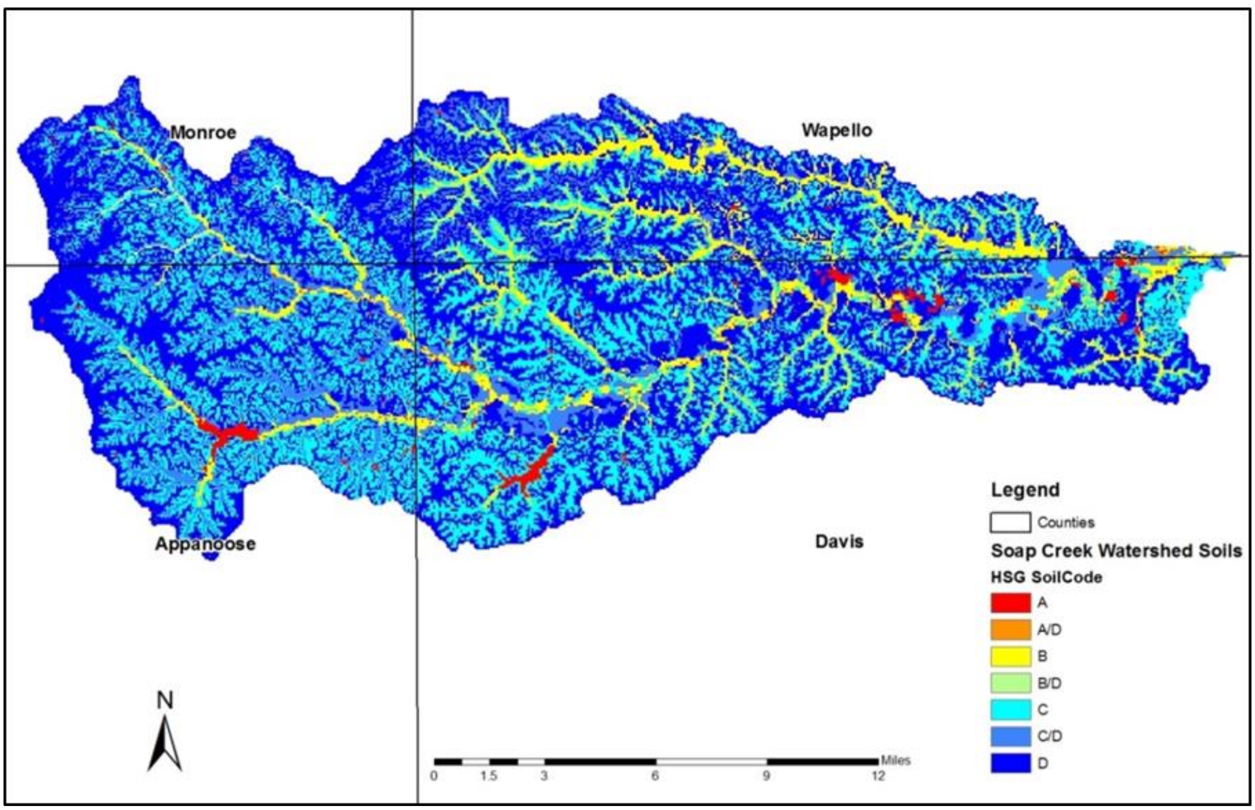

Figure 2.3. Distribution of Hydrologic Soil Groups in the Soap Creek Watershed. Hydrologic Soil Groups reflect the degree of runoff potential a particular soil has, with A-type representing the lowest runoff potential and D-type representing the highest runoff potential.

The map illustrates the dominance of D-type soils in the headland areas and exposed C-type soils in the eroded rills of the watershed. This distribution of soils is the primary reason Soap Creek is surface flow dominated, as infiltration rates and capacity of these soils are quite low. Table 2.1 shows the approximate percentages by area of each soil type for the Southern Iowa Drift Plain in the Soap Creek Watershed.

Table 2.1. Approximate Hydrologic Soil Group percentages by area of the Soap Creek Watershed.

Hydrologic Soil Group	***Runoff Potential***	***Percent of Watershed Area***
A	Low	0%
A/D		0%
B	Moderately Low	8.9%
B/D		0.3%
C	Moderately High	32.7%
C/D		10.0%
D	High	48.1%

c. Topography

The topography of the Soap Creek Watershed reflects its geologic past and is characterized by irregular narrow ridges with steep slopes and narrow gullied valleys. Elevation ranges from 1,023 feet to 600 feet at the outlet (see Figure 2.4). Land slopes are between 0-161% (A flat surface is 0%, a 45 degree surface is 100 percent, and as the surface becomes more vertical, the percent rise becomes increasingly larger.) Figure 2.5 shows the land surface slopes within the watershed.

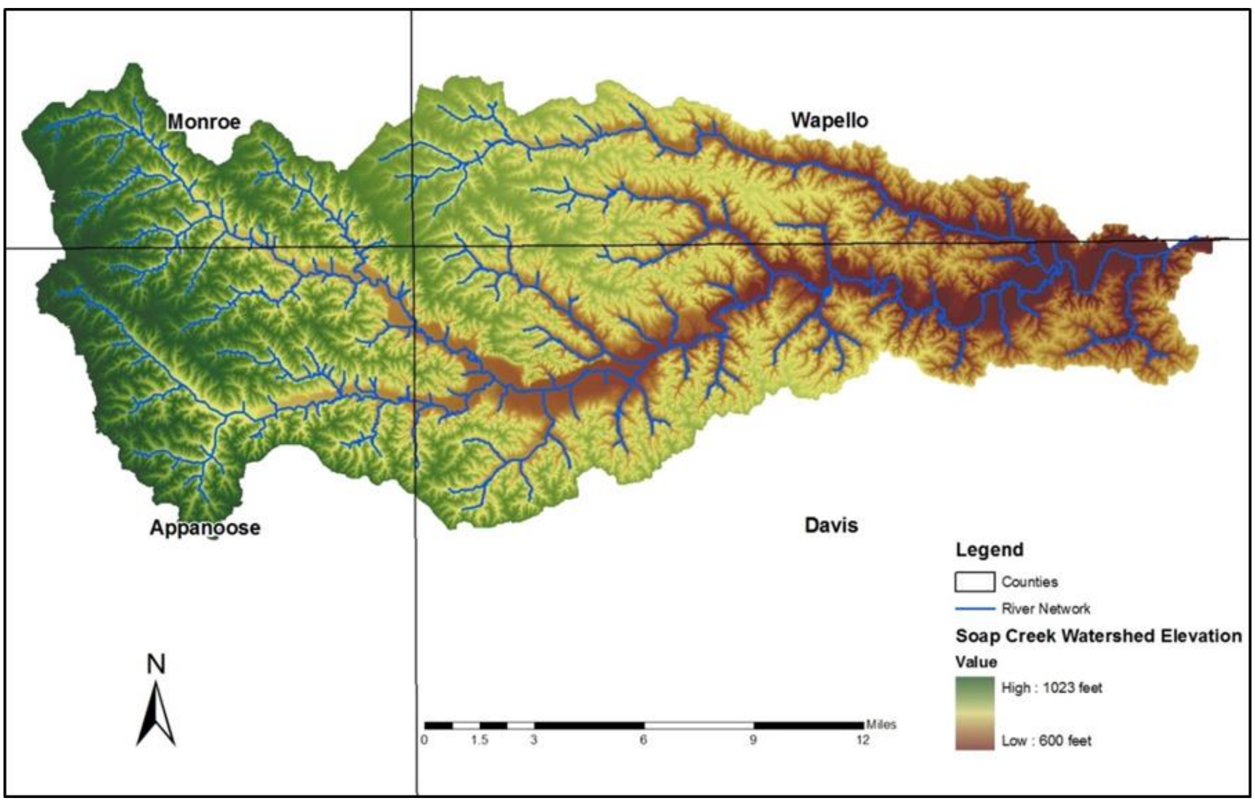

Figure 2.4. Topography of the Soap Creek Watershed.

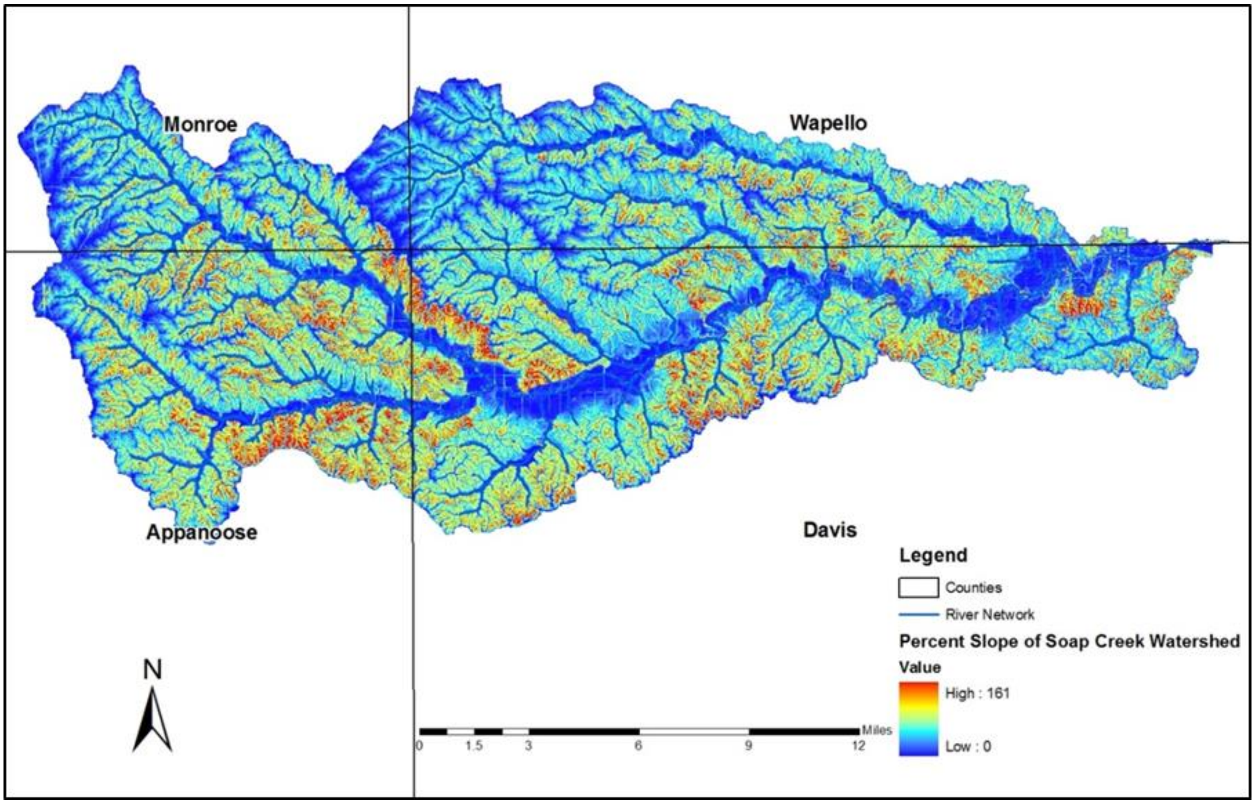

Figure 2.5. Land surface slopes within the Soap Creek Watershed.

d. Land Use

The Soap Creek Watershed is comprised of approximately 40% grass/hay and 35% deciduous forest, evenly distributed within the watershed (see Figure 2.6). Other land uses include cultivated crops (15%), water (5%), and developed (5%) per the 2009 High Resolution Land Cover (HRLC) Data Set. There are several small cities in the watershed: Moravia, Blakesburg, Unionville, Udell and Floris. Approximately 90% of the land within the watershed is privately owned.

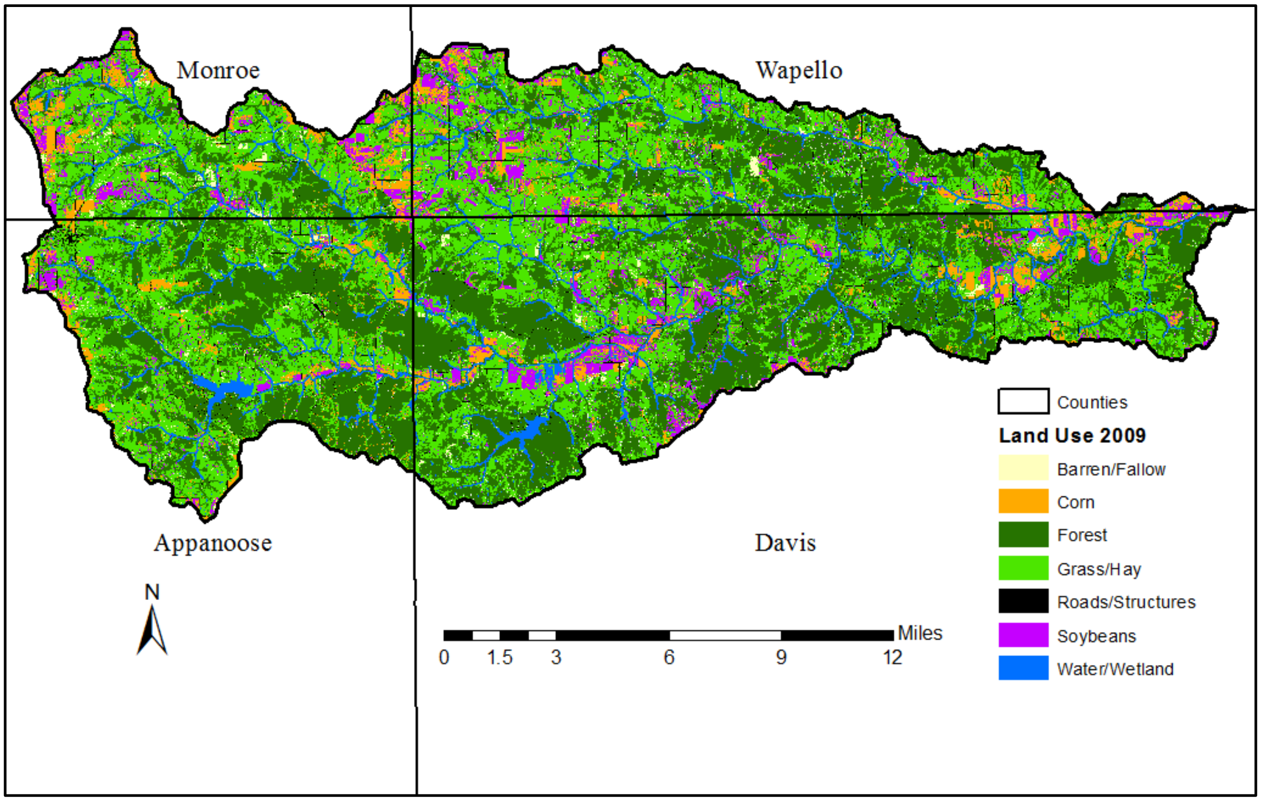

Figure 2.6. Land use composition in the Soap Creek Watershed per the 2009 HRLC.

3. Project Inventory

To meet the primary goal of the Iowa Watersheds Project, a total of $1,500,000 was allocated to the Soap and Chequest Creek Watersheds. $1,050,000 was assigned to the South Chequest Creek Watershed to plan, implement, and construct watershed improvement projects directed at reducing flood damage and $450,000 was assigned to Soap Creek to develop additional flood mitigation structures within the watershed. In addition to these flood mitigation projects, other conservation best management practices (BMP's) were funded through state and federal cost share programs to help protect watershed resources. Project locations of the additional structures in Soap Creek were selected based on volunteer landowner interest and a ranking system developed by the Soap Creek Watershed Board.

The projects built in the South Chequest Creek Watershed are intended to serve as demonstration projects for other landowners to visit to understand what the projects consist of as the Chequest Creek Advisory Board and the Davis County Soil and Water Conservation District looks to implement the practices in other locations across the Chequest Creek Watershed. The landowners in the Soap Creek Watershed have been gracious in their willingness to allow visitation to the existing flood mitigation projects that have been constructed in the watershed. This chapter describes the Iowa Watersheds Project Phase II projects built in the Soap Creek Watershed.

a. Iowa Watersheds Project Phase II Flood Mitigation Projects

Many ponds in Iowa, including 132 in Soap Creek, have been constructed to provide flood storage. A schematic of a typical flood storage pond is illustrated in Figure 3.1. The pond is created by constructing an earthen embankment across the stream. The pond usually holds some water all the time (permanent pond storage). However, if the water level rises high enough, an outlet passes water safely through the embankment. This outlet is called the principal spillway. Typically, this principal spillway consists of a pipe passing through the embankment and discharging water back to the stream downstream of the embankment. As the water level rises during a flood, more water is temporarily stored in the pond. Eventually, the water level reaches the auxiliary spillway elevation. The auxiliary spillway is constructed as a means to release water rapidly so the flow does not damage or overtop the earthen embankment. The volume of water stored between the principal spillway elevation and the auxiliary spillway elevation is called the flood storage.

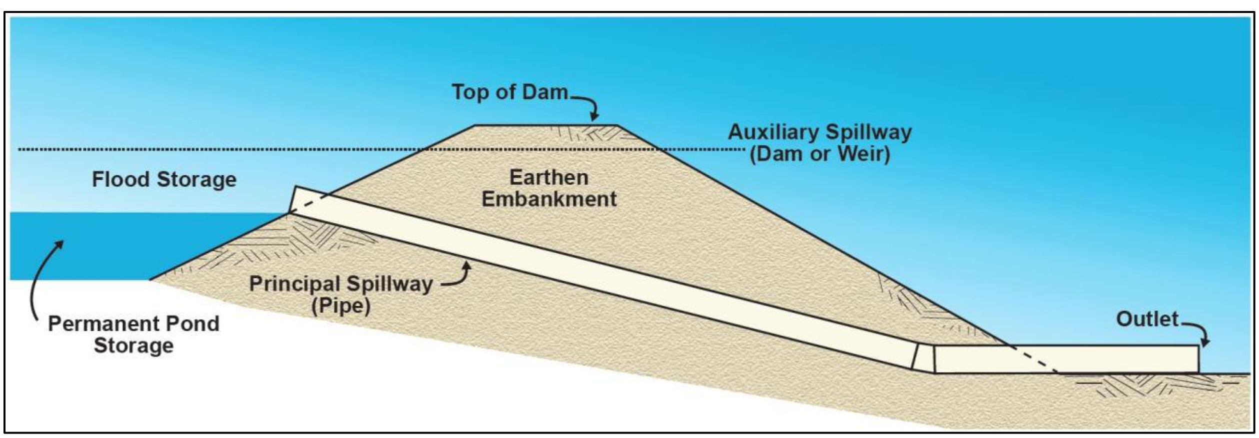

Figure 3.1. Schematic of pond constructed to provide flood storage.

As a part of Iowa Watersheds Project Phase II in the Soap Creek Watershed, 8 new ponds were constructed, proving an additional 247 acre-feet of flood storage. Beyond just flood storage, more storage is provided as the water level rises higher than the elevation of the auxiliary spillway up to the top of the dam. The storage from the principal spillway elevation to the top of dam is often called total storage. The 8 additional ponds in Soap Creek provide potential total storage of nearly 407 acre-feet.

The project designs were completed by a private consulting engineering firm and were built to NRCS Practice Codes No. 410 (NRCS 1985), No. 378 (NRCS 2011), and Iowa Department of Natural Resources (IDNR) Technical Bulletin No. 16 (IDNR 1990). Project locations have been numbered from 1 to 8 for IFC tracking purposes and are shown in Figure 3.2. Ponds 1-6 are located in the headwaters of the Little Soap Creek (HUC12) Watershed and ponds 7 & 8 are located in the south-central part of the Middle Soap Creek (HUC12) Watershed. Also shown in Figure 3.2 are the locations of the existing flood mitigation structures (black triangles) that have been constructed in Soap Creek through 2013, as well other potential sites (purple cross) identified in the original Soap Creek Watershed Plan. Ponds 1-5 have been constructed upstream of Soap 90-85, pond 6 has been constructed upstream of Soap 90-84, and ponds 7 & 8 have been constructed upstream of Soap 26-63. The IFC pond ID # and the property owner as given on the design documentation is provided in Table 3.1.

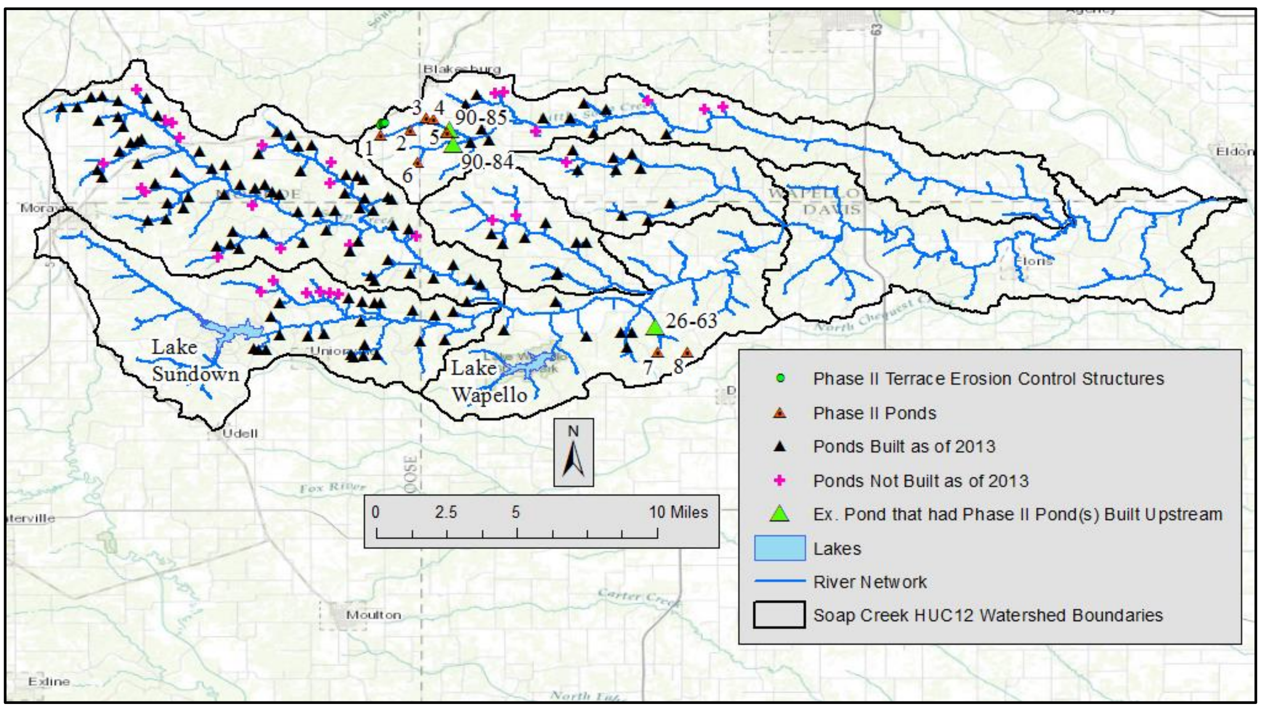

Figure 3.2. Iowa Watersheds Project Phase II project locations in the Soap Creek Watershed.

Table 3.1. Iowa Watersheds Project Phase II flood mitigation projects in the Soap Creek Watershed.

Pond ID #	*Property Owner*
1	Herman and Mike Leffler
2	A.K. Brittain Farms
3	Bruce Klyn
4	Jeff Johnson
5	Jim Sampson
6	Chad Leffler
7	Gerald Paluska
8	Charles Swaim

Figure 3.3 shows the earthen embankment of one of the Iowa Watersheds Project flood mitigation structures in the Soap Creek Watershed after construction has been completed, the area has been reseeded, and the pond has been filling (taken 11/3/2015).

Figure 3.3. Earthen embankment of one of the Iowa Watersheds Project ponds constructed to provide flood storage.

b. Erosion Control Structures

In southeast Iowa, erosion of soil is quite common. Flood mitigation ponds constructed in the Soap Creek watershed have experienced higher than anticipated sedimentation rates. As the sediment settles out of the runoff and remains in the pond, the flood and total storage capacity is diminished. As a part of Phase II project construction, 6 terrace water and sediment control basins were also built. A terrace water and sediment control basin is 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. This practice may be applied as part of a resource management system for one or more of the following purposes; to reduce watercourse and gully erosion, to trap sediment, and/or to reduce and manage local onsite and downstream runoff (NRCS Code No. 638). The locations of the terrace water and sediment control structures are upstream of Ponds 1-5 and can also be seen in Figure 3.2.

c. Hydraulics of Flood Mitigation Structures

Pond projects can reduce flood damages by storing water during high runoff periods. That is, storage ponds hold floodwaters temporarily, and release water at a lower rate. Therefore, the peak flood discharge downstream of a storage pond is lowered. The effectiveness of any one storage pond depends on its size (storage volume) and how quickly water is released. Ponds are engineered to efficiently utilize their available storage for large floods (typically in the 10- to 50-year return period range). Figure 3.4 shows two hydrographs for one of the Phase II pond locations. The larger magnitude hydrograph is the inflow to the pond (or what would pass downstream if the pond wasn't there) and the smaller magnitude hydrograph is what is coming out of the pond. The solid black line would be exceeded in magnitude by the outflow hydrograph if the auxiliary spillway was activated during this storm event. However, the auxiliary spillway was not activated and the pond stored a significant volume of water while only discharging out the principal spillway during the event.

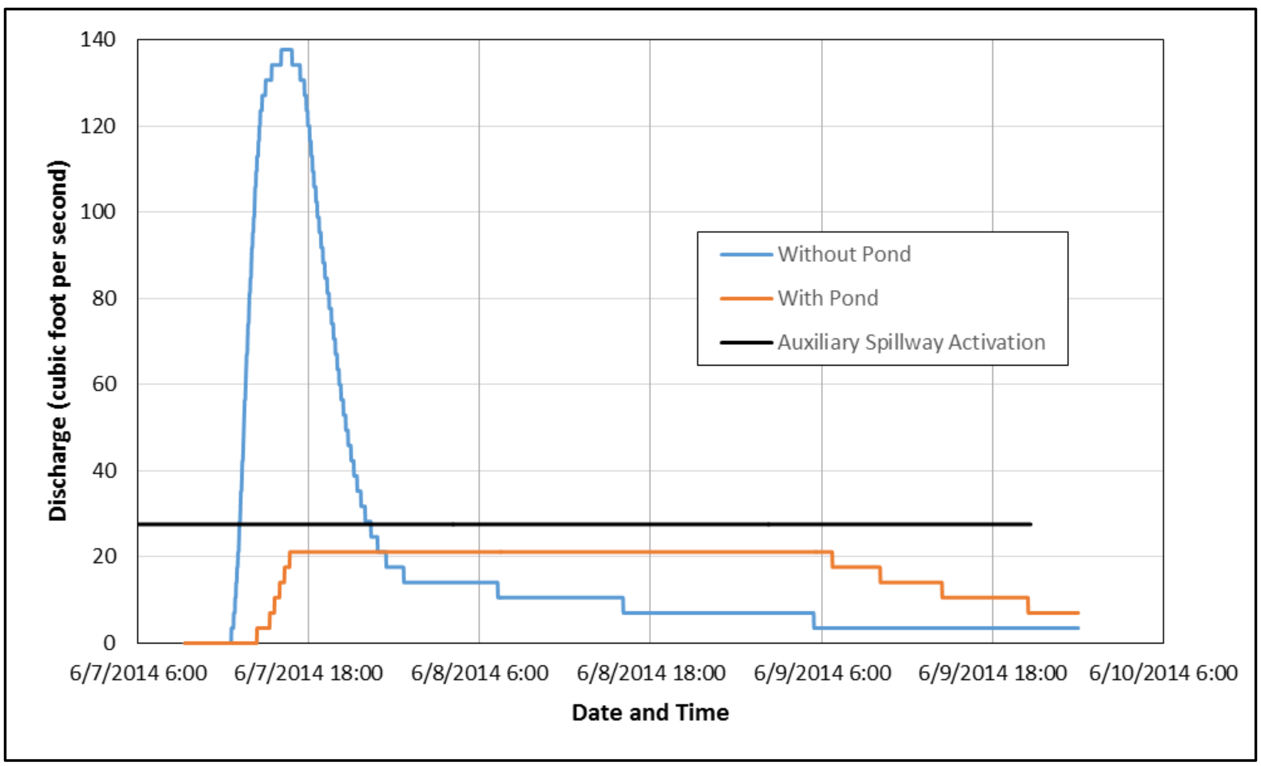

Figure 3.4. Inflow and outflow hydrographs for one of the Iowa Watersheds Project Phase II pond projects.

To determine the pond volume and outflow characteristics of the 8 Iowa Watersheds Project ponds, design documentation was obtained from the design engineer and/or Bloomfield NRCS and Davis County SWCD field office staff. This included the project plans, which describe how the project was built, as well as hydrologic design information used to select the principal and auxiliary spillway outflow structures. Each pond's stage (elevation)-storage relationship was determined by the consulting engineer as a part of the predesign topographic analysis and was included in a table in the design plans. For hydrologic modeling purposes, the pond's stage-discharge table is needed to route rainfall runoff through the pond at the appropriate magnitude throughout the duration of the simulation. Iowa Flood Center engineers determined the stage-discharge relationship for each project based on the final design specifications for the principal spillway (pipe) size and slope, and the width and retardance class of the auxiliary spillway. WinPond hydrologic routing software was used to verify the stage-discharge relationship that was derived for discharges associated with elevations ranging between the principal spillway and the top of dam. Discharge in the event of dam overtopping was estimated based on design documentation from similar ponds designed for Soap Creek and the same values were used for all 8 Phase II projects in the Soap Creek Watershed. Figure 3.5 shows an example of a stage-storage relationship of one of the ponds and the developed stage-discharge relationship for the same pond. Stage-storage tables as provided by the consulting engineer and stage-storage-discharge tables as used for hydrologic modeling for each of the 8 Phase II projects have been included in Appendix A of this report.

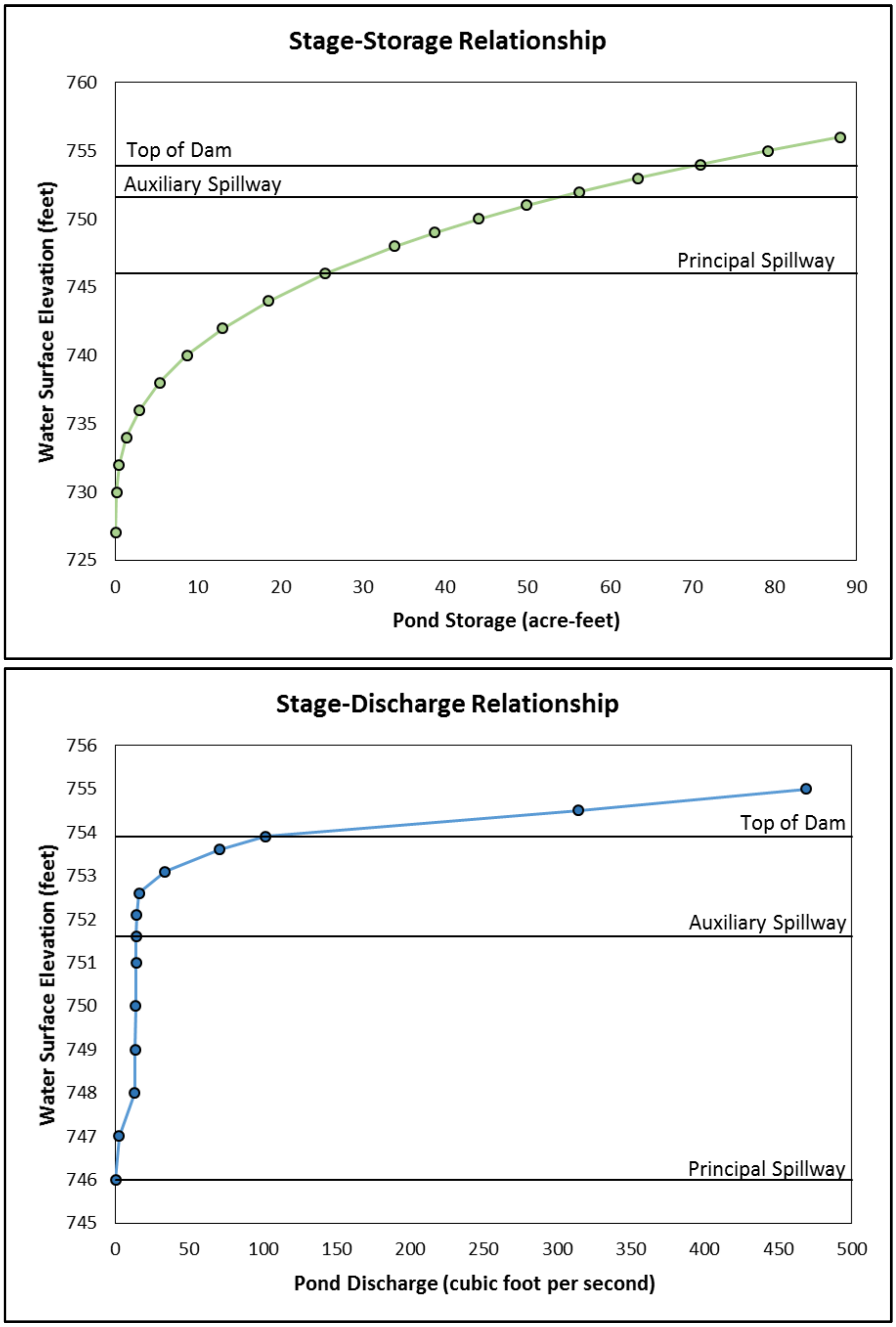

Figure 3.5. Pond hydraulic relationships for one of the Iowa Watersheds Project Phase II flood mitigation projects: (top) Stage (Elevation) – Storage relationship, and (bottom) Stage – Discharge relationship. The elevations of the principal spillway, the auxiliary spillway, and the top of dam are indicated.

d. Project Summary

The projects constructed through the Iowa Watersheds Project provide multiple benefits both on and off site. Landowners enjoy the farm ponds on their property for the aesthetic beauty, recreation, and for the wildlife they attract. In addition, landowners can use the ponds to water livestock and control erosion on their land. The target locations of the new flood mitigation structures were determined by a ranking system developed by the Soap Creek Watershed Board but placing the project was done with landowner's input and guidance from the NRCS and SWCD field office staff from the four counties (Appanoose, Davis, Monroe, and Wapello), in a manner that worked with the landowner's needs and goals for the ground. The flood mitigation projects create water storage on the landscape that reduces downstream flooding, protecting people, farm land, and public and private infrastructure. The pond structures are able to provide significant savings in federal, state, and local road and bridge maintenance costs by managing runoff to reduce and mitigate structural and nonstructural flood damage.

Figure 3.6. Iowa Watersheds Project Phase II projects: (top) flood mitigation pond and (bottom) terrace water and sediment control structure.

4. Simulation of Flood Control Project Performance

The United States Army Corps of Engineers' Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS), a mathematical lumped-parameter hydrologic model, was used to evaluate Soap Creek Watershed's response to different rainfall scenarios in the Iowa Watersheds Project Phase I. Model development and calibration is detailed extensively in the Phase I Hydrologic Assessment of the Soap Creek Watershed (IFC, 2014). The HMS model was updated to contain elements to represent the flood mitigation projects constructed as a part of Phase II of the Iowa Watersheds Project.

a. Model Configuration

The Soap Creek Watershed, as modeled using HEC-HMS, is approximately 258 square miles. For modeling purposes, the watershed was divided into 642 smaller drainages areas, called subbasins in HMS. The average subbasin area is approximately 0.39 square miles (250 acres) with the largest subbasin area being 3.9 square miles (2,500 acres). The watershed division was executed to ensure there was a subbasin outlet at the outlet location of each of the 132 flood mitigation structures that were constructed in the watershed as of 2013. Additionally, two reservoirs, Lake Sundown and Lake Wapello, were incorporated into the HMS model. Even though these two large lakes were not designed or built for flood mitigation efforts, their ability to hold extra water during times of flooding cannot be neglected. Stage-storage-discharge relationships were obtained for each pond and reservoir from Iowa Department of Natural Resource's Office of Dam Safety in Des Moines, Iowa and from regional NRCS offices. Figure 4.1 shows the subbasin delineation for use in the Soap Creek Watershed.

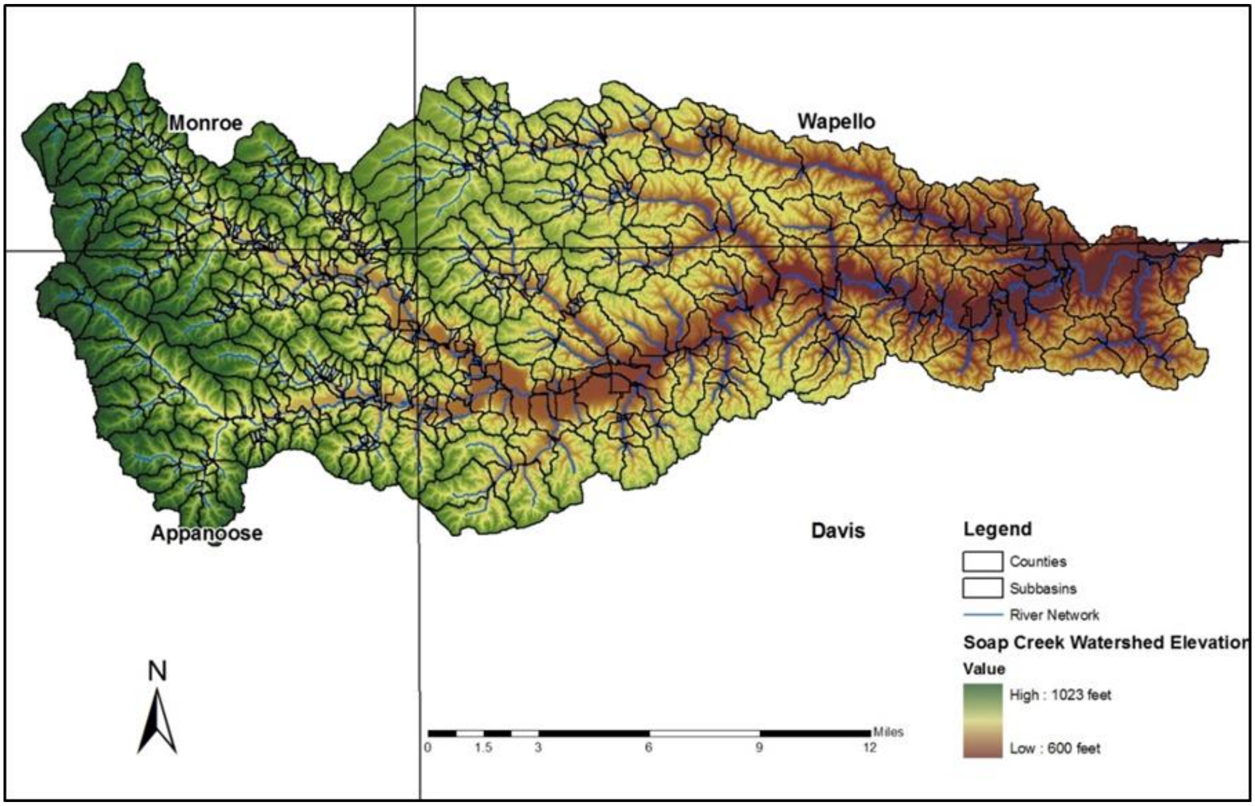

Figure 4.1. HMS model development of the Soap Creek Watershed. The watershed was divided into 642 subbasins for modeling. Additional elements were added in HMS to represent the flood mitigation projects constructed as a part of Phase II of the Iowa Watersheds Project.

b. Rainfall Inputs

Radar Rainfall Estimates

Stage IV radar rainfall estimates were used as the precipitation input for simulations of actual (historical) rainfall events known to have occurred within the watershed. The Stage IV data is produced by the National Center for Environmental Prediction (NCEP) by taking Stage III radar rainfall estimates produced by the 12 National Weather Service (NWS) River Forecast Centers across the continental United States and combining them into a nationwide 4 km x 4 km (2.5 mile x 2.5 mile) gridded hourly precipitation estimate data set. These data are available from January 2002 – present.

The use of radar rainfall estimates provides increased accuracy of the spatial and temporal distribution of precipitation over the watershed and Stage IV estimates provide a level of manual quality control performed by the NWS that incorporates available rain gage measurements into the rainfall estimates. Actual storms using Stage IV data were the basis for model calibration and validation in the Phase I Hydrologic Assessment. Figure 4.2 shows the gridded cumulative rainfall estimates for a storm that occurred April 17-18, 2013 in the Soap Creek Watershed.

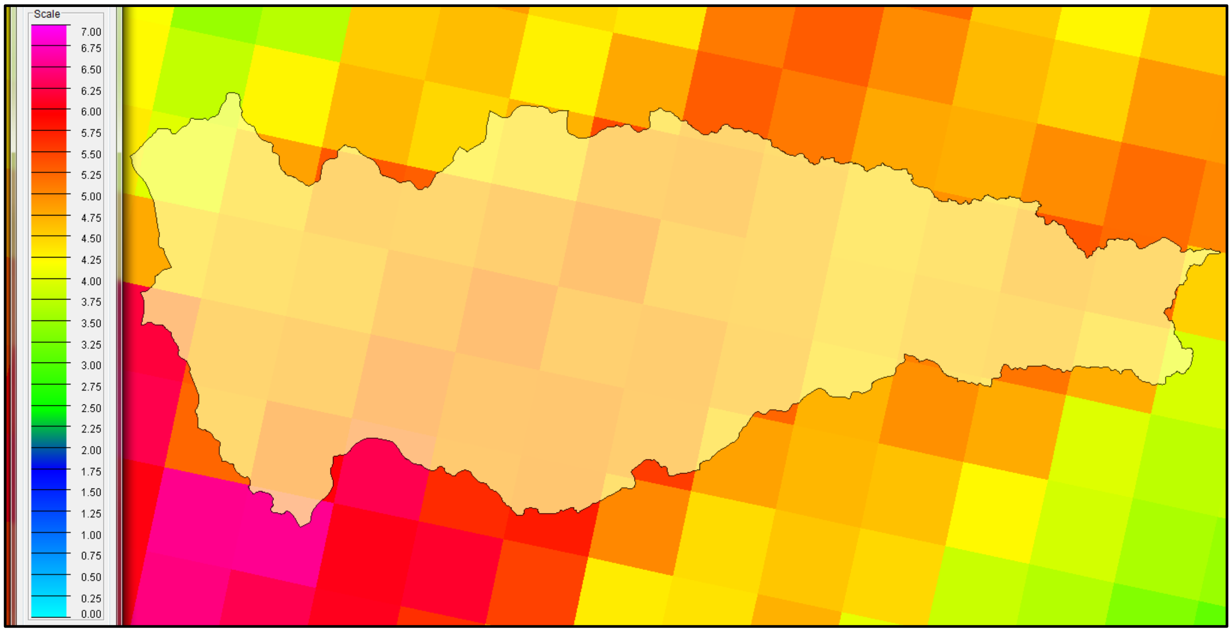

Figure 4.2. Demonstration of the gridded Stage IV radar rainfall product used as the precipitation input for historical storms in the Soap Creek HMS model. The Stage IV product provides hourly rainfall estimates for each 4 km x 4 km grid cell. The scale shown refers to the total depth of rainfall (in inches) estimated for a 37 hour period (April 17, 2013, midnight to April 18, 2013, 1 p.m.) in which rainfall exceeded 4.5" across the entire watershed.

Hypothetical Rainfall

Hypothetical storms, or "design" storms were developed for comparative analyses such as project performance based on known rainfall amounts. These design storms apply a uniform depth of rainfall across the entire watershed with the same timing everywhere, and as the name indicates are generally used locally at the project scale to design the outlet structures of the project. Peak discharge reductions can be assessed along the stream based on the "without ponds" and "with ponds" conditions to evaluate the influence of several ponds combined.

Soil Conservation Service (SCS) Type-II distribution, 24-hour storms were used for all design storms. Precipitation values (rainfall depths) for 10-, 25-, 50-, and 100-year average recurrence interval, 24-hour storms were derived using the online version of NOAA Atlas 14 – Point Precipitation Frequency Estimates (NOAA, 2013). The 24-hour rainfall depths used are 4.3 inches, 5.3 inches, 6.1 inches, and 7.0 inches respectively.

c. Evaluation of the Flood Mitigation Structures

The HEC-HMS model created for the Soap Creek Watershed was a useful tool to assess the performance of the flood mitigation projects (ponds) constructed in the watershed. This chapter quickly summarizes a few of the results presented in the Phase I hydrologic assessment and then analysis of the Phase II projects is presented.

Summary from Phase I Hydrologic Assessment

With the flood mitigation ponds added to the HEC-HMS model used in the Phase I Hydrologic Assessment of the Soap Creek Watershed (IFC, 2014), peak flood discharges were reduced across the watershed. At the outlet of the subbasins that the ponds have been included, the peak discharge reductions ranged from 60 to 95 percent. On a local scale, these ponds have had a significant impact to the discharges observed immediately downstream of each project. As you move further downstream from the project site, more direct runoff occurs from areas that are not routed through a pond and the stream discharge increases. When evaluating the effect of the 132 existing flood mitigation structures (built as of 2013) on peak discharges along Soap Creek with design rain events, peak discharges were reduced by about 40% at the upstream most point of interest to a reduction of about 28% at the outlet at the Des Moines River depending on the amount of rainfall. As a reminder as stated in the Phase I Hydrologic Assessment (IFC, 2014), actual peak flow reductions realized will depend on rainfall characteristics, such as when, where, and how much rain the watershed experiences. For the large event experienced in April 2013 using radar rainfall estimates, the simulated peak discharge reduction as a result of the existing flood mitigation structures at the same upstream point of interest is simulated to be 36 percent and then 20 percent peak discharge reduction at the outlet at the Des Moines River.

Phase II Pond Performance with Hypothetical Rainfall

The flood mitigation projects completed as a part of Phase II were constructed upstream of existing flood mitigation projects. Two ponds were built upstream of Soap 26-63, one large pond was built upstream of Soap 90-84, and five ponds were built upstream of Soap 90-85. In general, ponds like those constructed as flood mitigation projects in the Soap Creek Watershed are typically designed to have the auxiliary spillway able to safely pass the runoff generated by a 50-year average recurrence interval design storm without having the water surface in the pond get near the top of the dam. For this section, the evaluation of the 50-year (6.1 inches) and 100-year (7.0 inches) rainfall from SCS Type-II 24-hour storms will be discussed in detail. The new structures were analyzed to investigate the following:

1) the effect they have on reducing the peak discharge at the new project's location
2) the amount of flood storage the new ponds provide
3) the effect they have on reducing the peak discharge coming into the existing ponds
4) the amount flood storage reduced in the existing ponds
5) the effect the new pond(s) may have on the outflow from the existing pond

The new structures will also act as sediment traps to prevent the sediment accumulation from making it to the larger existing structures. The flow reductions realized can later be used to estimate the sediment reductions, and are not done as part of this analysis.

Individual Pond Performance

This section summarizes the performance of the individual ponds constructed as a part of the Iowa Watersheds Project Phase II based on the different design rainfall depths. Table 4.1 details each new pond's performance when experiencing the 50-year 24-hour design rainfall (6.1 inches) and Table 4.2 details each pond's performance with the 100-year 24-hour design rainfall.

Table 4.1. Pond performance of the Iowa Watersheds Project Phase II flood mitigation projects in the Soap Creek Watershed. Performance shown is for the 50-year, 24-hour design storm (6.1 inches of rain).

Pond ID #	Auxiliary Spillway (A.S.) Elevation (ft)	Max. Water Surface Elevation (ft)	A.S. Activated	Flood Storage Used (%)	Total Storage Used (%)	Peak Discharge Reduction (%)
1	896.4	895.01	No	64.2	36.1	40.0
2	883.5	884.38	Yes	100	82.3	95.7
3	869.5	869.75	Yes	100	71.3	94.7
4	871.5	872.38	Yes	100	72.4	92.7
5	868.4	869.09	Yes	100	61.5	86.7
6	879.5	877.62	No	74.9	45.6	89.0
7	795.8	794.95	No	82.0	52.3	87.3
8	826.6	827.76	Yes	100	83.7	89.1

Table 4.2. Pond performance of the Iowa Watersheds Project Phase II flood mitigation projects in the Soap Creek Watershed. Performance shown is for the 100-year, 24-hour design storm (7.0 inches of rain).

Pond ID #	Auxiliary Spillway (A.S.) Elevation (ft)	Max. Water Surface Elevation (ft)	A.S. Activated	Flood Storage Used (%)	Total Storage Used (%)	Peak Discharge Reduction (%)
1	896.4	896.0	No	90.9	51.1	46.7
2	883.5	884.61	Yes	100	87.5	90.7
3	869.5	870.41	Yes	100	82.6	92.3
4	871.5	872.70	Yes	100	80.3	85.7
5	868.4	869.42	Yes	100	69.5	82.4
6	879.5	878.94	No	93.2	56.7	90.8
7	795.8	795.93	Yes	100	64.9	89.4
8	826.6	828.41	Yes	100	92.7	80.5

In the 50-year event, all but three ponds had flow coming from the auxiliary spillway. In other words, this size event would have utilized approximately 203.8 of the possible 247 ac-ft of flood storage, or about 82.5 percent of the potential flood storage the new projects provide. We can also look at the potential total storage (the storage from the principal spillway to the top of dam of each structure) in the watershed from the new projects and this sized event utilizes approximately 55 percent of the potential total storage available. Of the unused potential total storage, a majority of that occurs in Pond #6.

For those ponds that did not reach the auxiliary spillway, Pond #6, has been identified as a medium hazard class structure in which it was designed to a higher criteria (7.8" rainfall in 6 hours), whereas the other structures were designed as low hazard class. For the other two, Pond

#1 and Pond #7, the rainfall to runoff conversion method selected for the IFC Soap Creek Watershed model produces a lower peak discharge and the peak arrives at the pond slightly later than when using the method the consulting engineer utilized under the NRCS design guidance. Thus with these two ponds, the relationship of how much water is coming into the pond versus what the principal spillway can discharge is lower and the result is that the water surface in the pond of the IFC model does not reach as high as when using the design guidance methodology. The volume of water that passes through the pond with the IFC method versus the design method is almost the same however.

For the 100-year event, all but two auxiliary spillways were activated, Pond #1 and Pond #6. No dams were overtopped with this event, thus the designed auxiliary spillways provided adequate relief for the volume of runoff coming into the ponds. 96 percent of the possible flood storage was utilized and about 66 percent of the potential total storage was used with this size of event. Figure 4.3 shows the simulated hydrographs at Pond #6 – C. Leffler for a 100-year rainfall event with and without the pond. The auxiliary spillway was not activated for this event, thus the pond stored a large volume of water and discharge was only from the principal spillway.

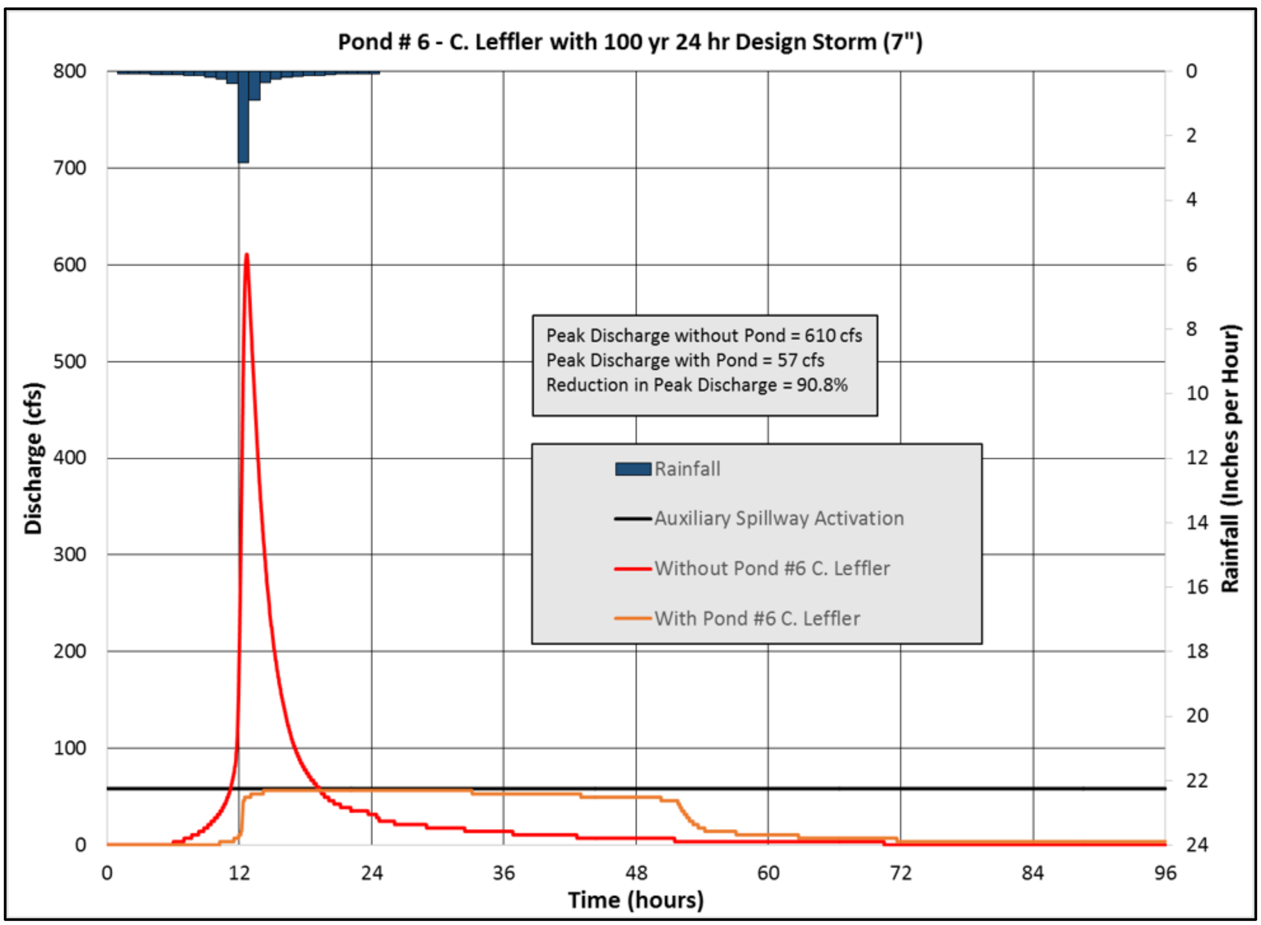

Figure 4.3. Simulated hydrographs at Pond # 6 – C. Leffler for the 100-year average recurrence interval design storm (7.0" of rain) for the without and with new pond scenarios. The auxiliary spillway was not activated for this event. This pond is built upstream of Soap 90-84.

Effect on Downstream Existing Flood Mitigation Structures

Placing the new flood mitigation structures upstream of existing structures reduces the peak discharge coming into the existing structure and results in the existing structure having a lower peak storage volume, thus lowering the water surface in the existing structure. This section will investigate the two structures upstream of Soap 26-63, the large structure upstream of Soap 90-84, and the five structures placed upstream of Soap 90-85. After identifying the impacts the new structures have on the inflow, storage, and water surface elevation of the existing structure, the resulting outflow from the existing structure will be discussed.

Soap 26-63

Two new flood mitigation structures, #7 (Paluska) and #8 (Swaim) were built upstream of Soap 26-63. For the 50-year design storm (6.1 inches of rainfall), adding the two new structures reduced the peak discharge coming into Soap 26-63 by approximately 240 cfs (1232 cfs to 992 cfs), or about 19.5 percent. The peak storage in Soap 26-63 was reduced by about 22.9 ac-ft, or 7.3 percent, lowering the water surface by 0.6 feet. Using the IFC Soap Creek hydrologic model, the water surface elevation in Soap 26-63 without the new flood mitigation structures was approximately 759.7 feet (auxiliary spillway = 759.5 feet), thus all discharge from the pond for the 50-year event can be attributed to the principal spillway. The discharge from the principal spillway was simulated to be 67 cfs. In lowering the water surface elevation by adding the 2 new structures, the discharge from Soap 26-63 remained coming from the principal spillway. Reducing the depth of water only results in a slight decrease in the amount of water being pushed through the pipe. The outflow from Soap 26-63 for the 50-year event after adding the new structures was 64 cfs.

For the 100-year event (7.0 inches of rainfall), adding the two new structures reduced the peak discharge coming into Soap 26-63 by approximately 280 cfs (1495 cfs to 1215 cfs), or about 18.7 percent. The peak storage in Soap 26-63 was reduced by about 8.8 ac-ft, or 2.5 percent and the water surface elevation was reduced by 0.3 feet. For this event, the water surface elevation in Soap 26-63 without the new flood mitigation structures was approximately 760.7 feet (auxiliary spillway = 759.5 feet), resulting in an outflow discharge of 145 cfs; approximately 65 cfs from the pipe and 80 cfs from the spillway. Lowering the water surface by adding the new structures reduces the peak discharge to about 92 cfs, a reduction of about 36.5 percent with approximately 65 cfs from the pipe and 27 cfs from the spillway. Figure 4.4 shows the inflow and outflow hydrographs for Soap 26-63 for the 100-year event. Figure 4.5 then shows the same hydrographs along with the new inflow and outflow hydrographs after adding the new Iowa Watersheds Project Phase II flood mitigation structures.

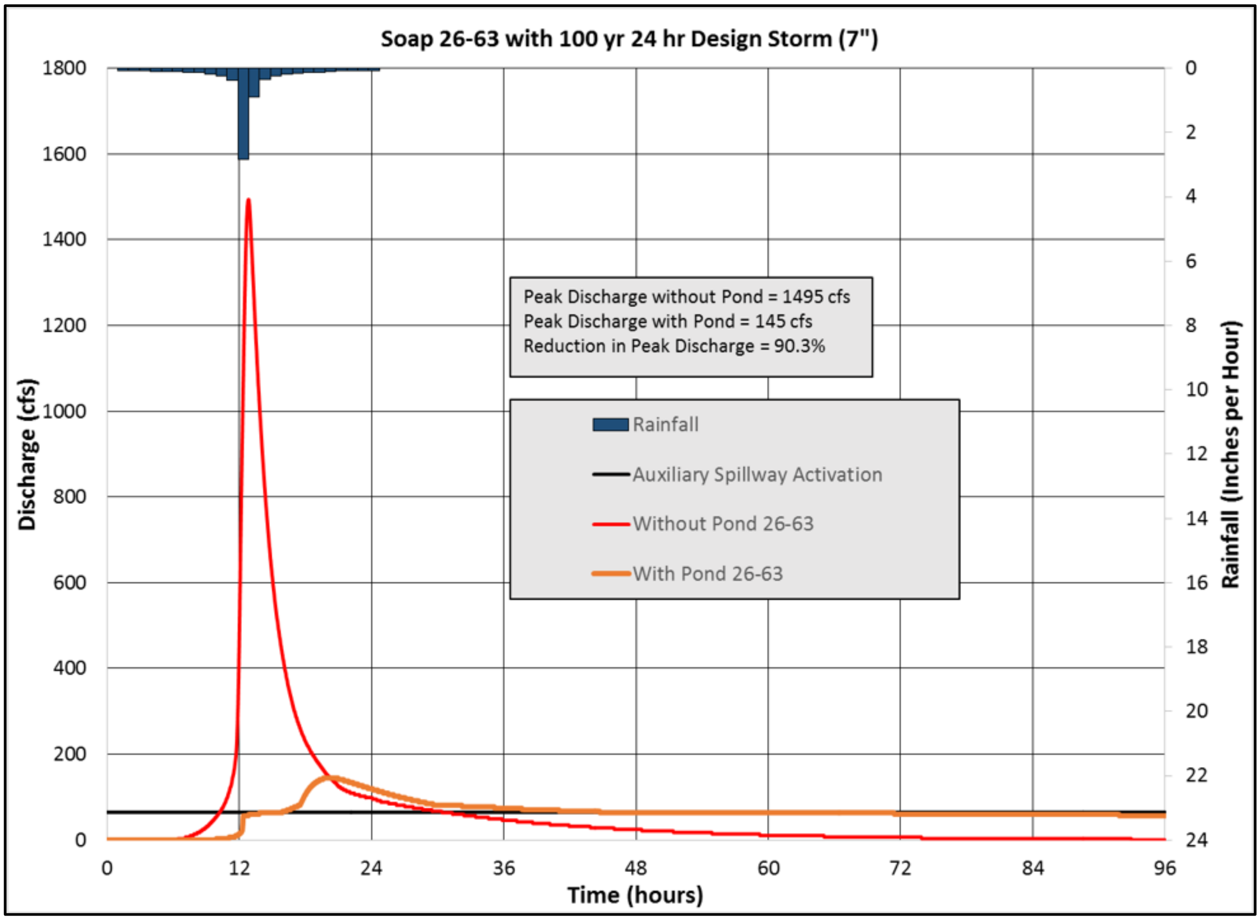

Figure 4.4. Simulated hydrographs at Soap 26-63 for the 100-year average recurrence interval design storm (7.0” of rain) for the without and with pond scenario. The auxiliary spillway of Soap 26-63 was activated for this event.

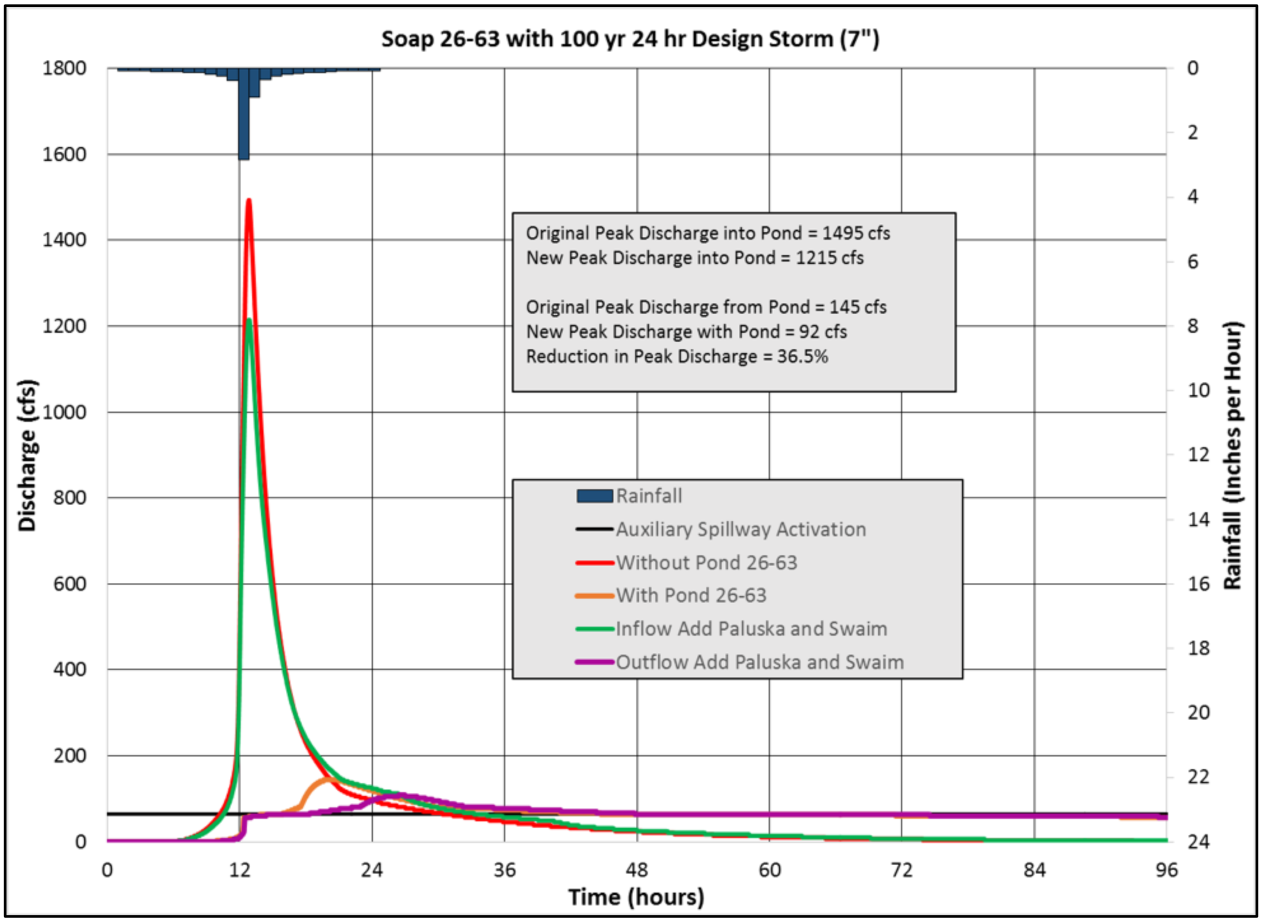

Figure 4.5. Simulated new hydrographs at Soap 26-63 for the 100-year average recurrence interval design storm (7.0" of rain) after adding the new flood mitigation structures upstream. The auxiliary spillway was still activated for this event, but discharge from Soap 26-63 was reduced by about 36.5 percent.

One other way to describe the impact of adding the two new structures upstream of Soap 26-63 is to think about how much rain from a design event would be needed to activate the emergency spillway on Soap 26-63. From the simulation of the 50-year event (6.1 inches of rain) prior to adding the two new pond structures, the water surface elevation just reached the auxiliary spillway, thus any additional rainfall would have led to discharge coming from the auxiliary spillway. By adding the two new flood mitigation structures, Soap 63-63 can now have a 6.5 inch design rain event applied to the watershed before the auxiliary spillway is activated. Figure 4.6 illustrates the hydrographs for Soap 26-63 with a 6.5 inch 24-hour design rain event applied along with corresponding new hydrographs after adding the new flood mitigation structures.

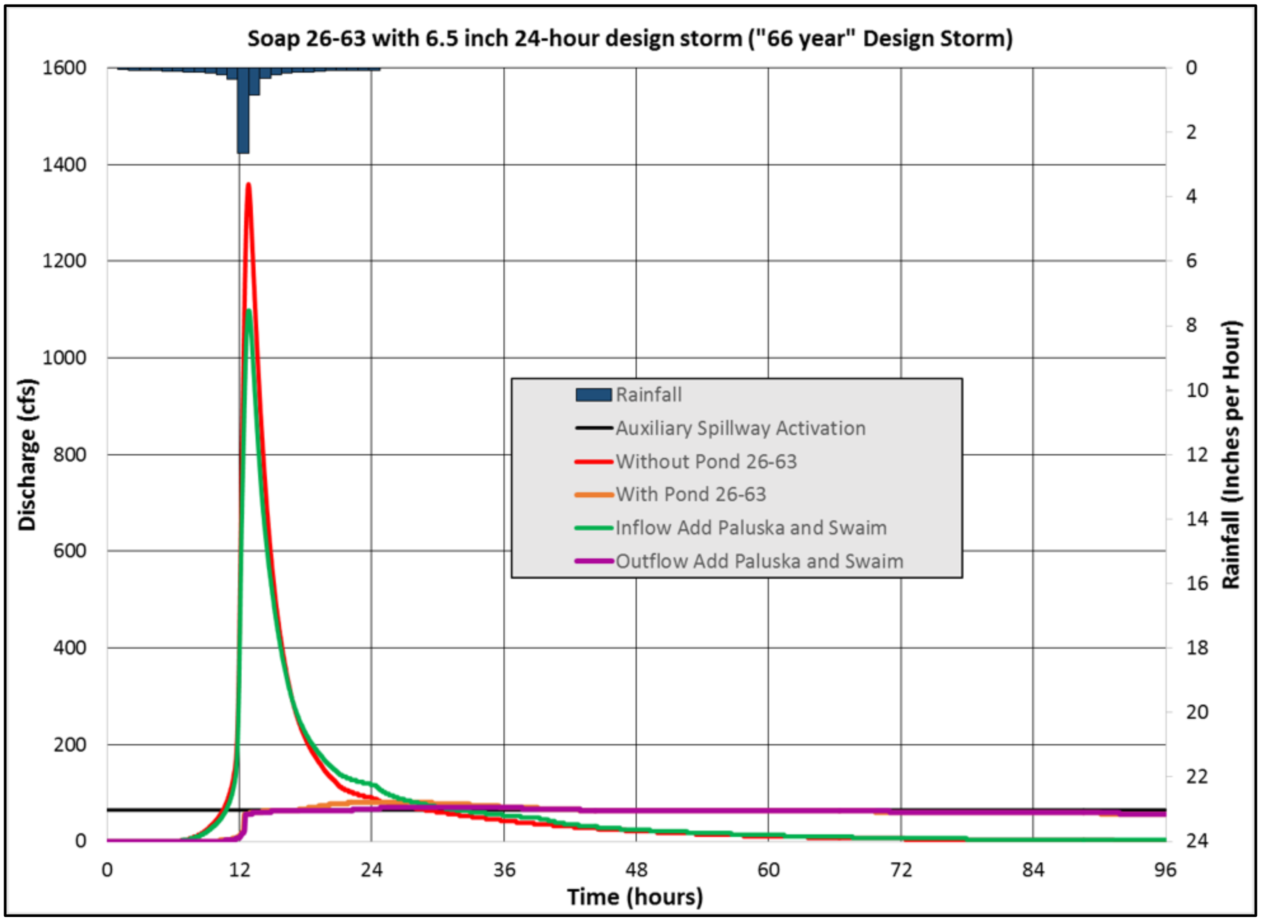

Figure 4.6. Simulated new hydrographs at Soap 26-63 for a 6.5 inch design storm after adding the new flood mitigation structures upstream. The auxiliary spillway of Soap 26-63 was originally activated for this event, but by adding the 2 new flood mitigation structures, is no longer activated for this sized event.

Soap 90-84

One large pond (#6 – C. Leffler) was built upstream of Soap 90-84. This pond provides 129.4 ac-ft of the 247 ac-ft of potential flood storage provided by the eight new flood mitigation structures. For the 50-year design storm (6.1 inches of rainfall), adding the new structure reduced the peak discharge coming into Soap 90-84 by approximately 244 cfs (1360 cfs to 1116 cfs), or about 18 percent. The peak storage in Soap 90-84 was reduced by about 37.2 ac-ft, or 7.3 percent, lowering the water surface by 0.5 feet. Using the IFC Soap Creek hydrologic model, the water surface elevation in Soap 90-84 without the new flood mitigation structures was approximately 849.1 feet (auxiliary spillway = 849.0 feet), thus all discharge from the pond for the 50-year event can be attributed to the principal spillway. The discharge from the principal spillway was simulated to be 60 cfs. In lowering the water surface elevation by adding the new structure, the discharge from Soap 90-84 remained coming from the principal spillway. Reducing the depth of water only results in a slight decrease in the amount of water being pushed through the pipe. The outflow from Soap 90-84 for the 50-year event after adding the new structures was 57 cfs.

For the 100-year event (7.0 inches of rainfall), adding the new structure reduced the peak discharge coming into Soap 90-84 by approximately 296 cfs (1624 cfs to 1328 cfs), or about 18.2 percent. The peak storage in Soap 90-84 was reduced by about 31.2 ac-ft, or 5.3 percent and the water surface elevation was reduced by 0.4 feet. For this event, the water surface elevation in Soap 90-84 without the new flood mitigation structures was approximately 850.2 feet (auxiliary spillway = 849.0 feet), resulting in an outflow discharge of 120 cfs; approximately 59 cfs from the pipe and 61 cfs from the spillway. Lowering the water surface by adding the new structure reduces the peak discharge to about 74 cfs, a reduction of about 38.3 percent with approximately 59 cfs from the pipe and 15 cfs from the spillway. Figure 4.7 shows the inflow and outflow hydrographs for Soap 90-84 for the 100-year event and also shows the new inflow and outflow hydrographs after adding the new Iowa Watersheds Project Phase II flood mitigation structure. As illustrated in Figure 4.7, the addition of Pond #6 – C. Leffler nearly adds an additional 0.9” of rain across the upstream watershed before the auxiliary spillway is activated on Pond 90-84.

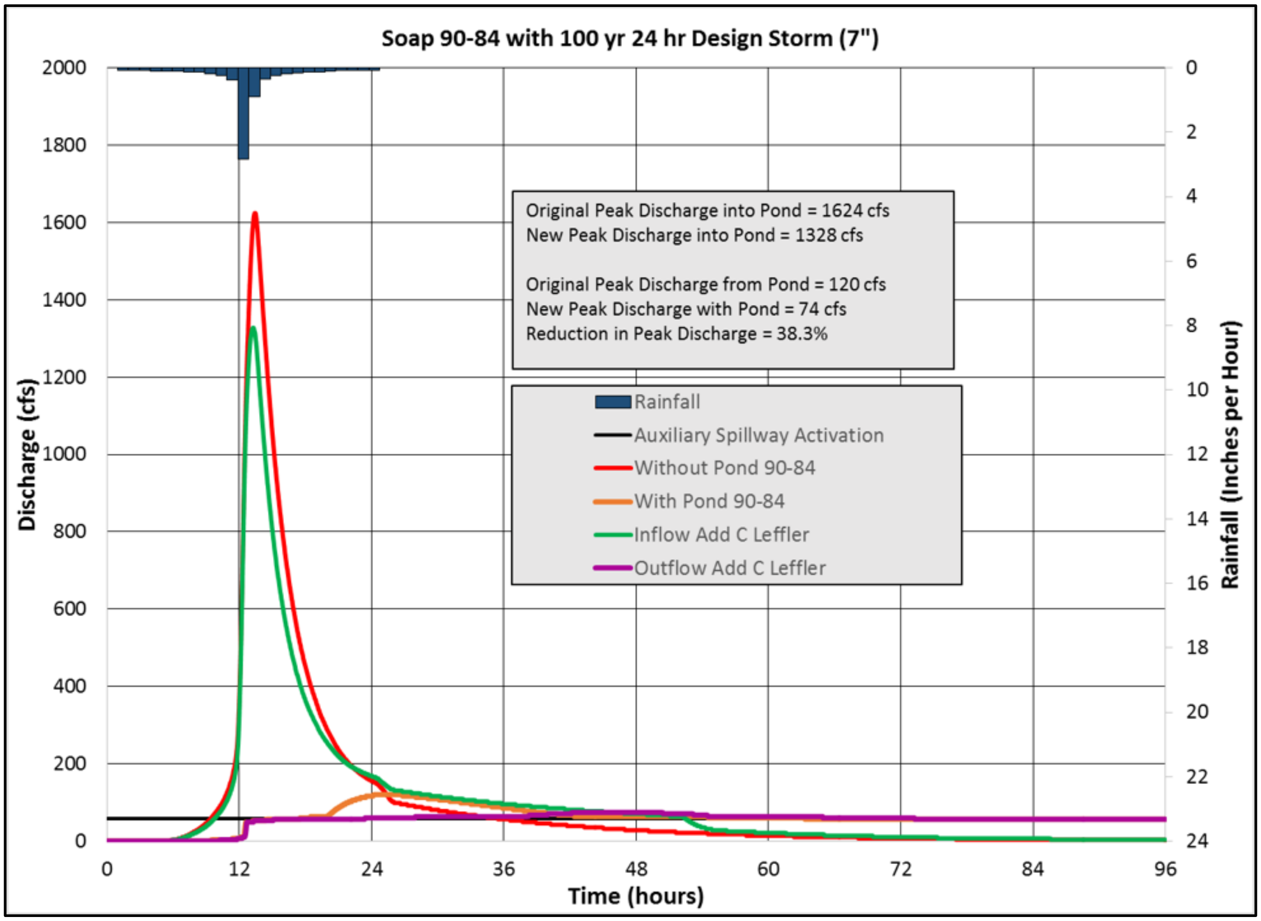

Figure 4.7. Simulated new hydrographs at Soap 90-84 for the 100-year average recurrence interval design storm (7.0" of rain) after adding the new flood mitigation structure upstream. The auxiliary spillway was still activated for this event, but discharge from the auxiliary spillway was reduced to just 15 cfs.

Soap 90-85

Five new structures were built upstream of Soap 90-85. For the 50-year design storm (6.1 inches of rainfall), adding the new structures reduced the peak discharge coming into Soap 90-85 by approximately 88 cfs (893 cfs to 805 cfs), or about 10 percent. The peak storage in Soap 90-85 was reduced by about 36.2 ac-ft, or 7.7 percent, lowering the water surface by 0.6 feet. Using the IFC Soap Creek hydrologic model, the water surface elevation in Soap 90-85 without the new flood mitigation structures was approximately 849.3 feet (auxiliary spillway = 849.5 feet), thus all discharge from the pond for the 50-year event can be attributed to the principal spillway. The discharge from the principal spillway was simulated to be 42 cfs. In lowering the water surface elevation by adding the 5 new structures, the discharge from Soap 90-85 remained coming from the principal spillway. Reducing the depth of water only results in a slight decrease in the amount of water being pushed through the pipe. The outflow from Soap 90-85 for the 50-year event after adding the new structures was 41 cfs.

For the 100-year event (7.0 inches of rainfall), adding the new structures reduced the peak discharge coming into Soap 90-85 by approximately 106 cfs (1074 cfs to 968 cfs), or about 10 percent. The peak storage in Soap 90-85 was reduced by about 25.9 ac-ft, or 4.7 percent and the water surface elevation was reduced by 0.4 feet. For this event, the water surface elevation in Soap 90-85 without the new flood mitigation structures was approximately 850.5 feet (auxiliary spillway = 849.5 feet), resulting in an outflow discharge of 92 cfs; approximately 42 cfs from the pipe and 50 cfs from the spillway. Lowering the water surface by adding the new structures reduces the peak discharge to about 53 cfs, a reduction of about 42.4 percent with approximately 42 cfs from the pipe and 11 cfs from the spillway. Figure 4.8 shows the inflow and outflow hydrographs for Soap 90-85 for the 100-year event and also shows the new inflow and outflow hydrographs after adding the new Iowa Watersheds Project Phase II flood mitigation structures. As illustrated in Figure 4.8, the addition of the five new projects, as was for 90-84, nearly add an additional 0.9" of rain across the upstream watershed before the auxiliary spillway is activated on Pond 90-85.

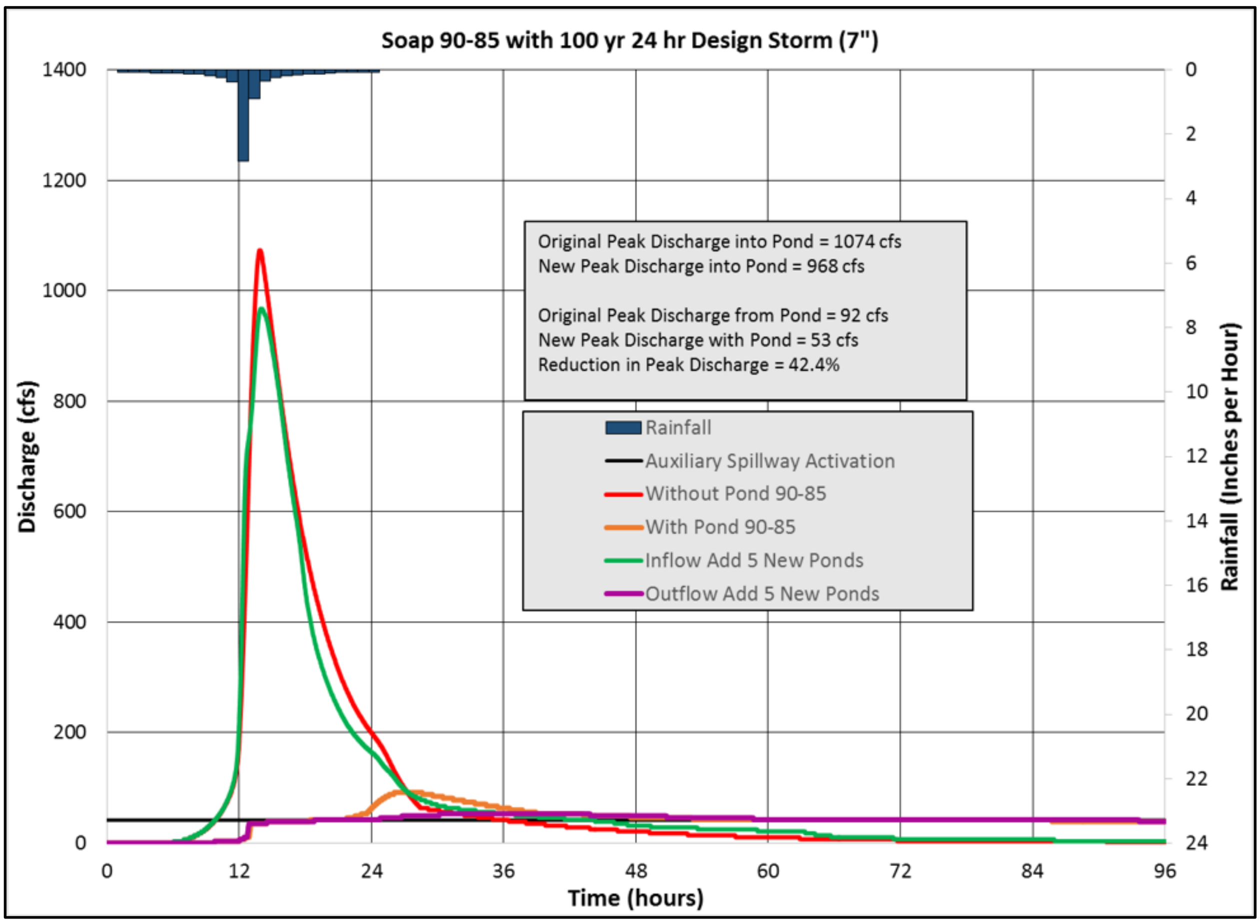

Figure 4.8. Simulated new hydrographs at Soap 90-85 for the 100-year average recurrence interval design storm (7.0" of rain) after adding the five new flood mitigation structures upstream. The auxiliary spillway was still activated for this event, but discharge from the auxiliary spillway was reduced to just 11 cfs.

d. Summary

Much has been documented about the historical hydrology of the native tall-grass prairie, with evidence suggesting the tall-grass prairie could handle up to six inches of rain without having significant runoff. This was a result of the deep, loosely-packed, organic-rich soils and the deep root systems of the prairie plants that allowed a high volume of the rainfall to infiltrate into the ground. Southeast Iowa is known to have higher-clay content, lower-infiltration soils that drive much of the runoff processes in the Soap Creek Watershed; however, a portion of this area was once home to tall-grass prairie. Based on the root structure and increased organic material in the soil resulting from a landscape with these plants, there would have been slightly better infiltration rates and a capacity to hold more water than what can be found in the watershed today. Through the Iowa Watersheds Project, it is not suggested to revert agricultural lands back to tall grass prairie, rather the intent is to identify and evaluate strategies to reduce peak flood discharges through a suite of conservation practices, while working in harmony with agriculture.

In some ways, it can be considered that using ponds to temporarily store floodwaters is an attempt to replace the loss of water that was once stored in the soils in the pre-agricultural landscape. The projects completed in the Soap Creek Watershed build resiliency in the agricultural landscape and have been embraced by the land owners that participated in the project. The projects constructed provide multiple benefits both on and off site. Landowners enjoy the farm ponds on their property for the aesthetic beauty, recreation, and for the wildlife they attract. In addition, landowners can use the ponds to water livestock and control erosion on their land. The target locations of the new flood mitigation structures were determined by a ranking system developed by the Soap Creek Watershed Board but placing the project was done with landowner's input and guidance from the NRCS and SWCD field office staff from the four counties (Appanoose, Davis, Monroe, and Wapello), in a manner that worked with the landowner's needs and goals for the ground. The landowners in the Soap Creek Watershed have been gracious in their willingness to allow visitation to the existing flood mitigation projects that have been constructed in the watershed for both other landowners and IFC researchers to learn about the ponds and how they may be incorporated on the landscape.

The HEC-HMS model developed for the Soap Creek Watershed was used to simulate runoff scenarios to evaluate the flood mitigation projects' performance. Peak discharge reductions at the projects ranged from 40.0 to 95.7 percent. On a local scale, these ponds have had a significant impact to the discharges observed immediately downstream of the pond site. As you move further downstream from the project site, more direct runoff occurs from areas that are not routed through a pond and the stream discharge increases. The existing ponds provide significant peak flow reductions throughout the watershed, while those built in Phase II of the Iowa Watersheds Project protect and enhance three of the existing structures' ability to handle large precipitation events.

5. Summary and Conclusions

The Iowa Flood Center (IFC), a unit of the University of Iowa's IIHR-Hydroscience & Engineering, has collaborated with the Soap Creek Watershed Board, the Davis County Soil and Water Conservation District, and the NRCS office staff in four local counties in Phase II of the Iowa Watersheds Project. Phase II involved the development and construction of additional flood mitigation projects within the Soap Creek Watershed. In this report, IFC researchers evaluated the flood mitigation performance of the new projects through detailed hydrologic modeling. The team developed hydrologic simulations for the Soap Creek Watershed using the HEC-HMS hydrologic model that was developed in the Phase I study of the watershed.

a. Constructed Projects

In 2014, $450,000 was allocated to the Soap Creek Watershed to plan, design, and construct eight additional flood mitigation structures (ponds) directed at reducing flood damage. The projects reduce flooding by increasing the storage capacity on the landscape and also provide a secondary benefit of improving water-quality through nutrient processing and trapping sediment. The ponds provide tertiary benefits to landowners such as improve the accessibility of their land, decrease erosion, provide a source of water for livestock, and create an area for recreation and personal enjoyment. Lastly, they add aesthetic beauty to the land and create abundant habitat for wildlife. The constructed projects act as demonstration sites to promote the adoption of additional best management practices (BMPs) and serve as locations for education and outreach opportunities.

Volunteer landowners received 75% cost share assistance on constructed projects. The project designs follow Natural Resource Conservation Service (NRCS) specifications and guidelines and projects come with a 20 year land owner maintenance agreement. With guidance from the staff at the Davis County Soil and Water Conservation District in Bloomfield, Iowa, the NRCS office staff in four local counties, and consultation from the Iowa Flood Center, the projects were sited on the landscape at the landowner's discretion.

b. Evaluation of Project Performance

The United States Army Corps of Engineers' Hydrologic Engineering Center's Hydrologic Modeling System (HEC-HMS) was used for the Soap Creek Watershed. In the HEC-HMS model, the watershed is broken down into 642 smaller units called subbasins, in which variables such as land use, soil type, slope, etc. are averaged out to a single value for the area and used to estimate runoff from that subbasin. The simulated runoff is then routed through the watershed via a system of interconnected stream networks.

The hydrologic modeling demonstrates the effectiveness of the flood mitigation projects in reducing downstream flood peaks. Just downstream of the projects themselves, peak discharge reduction for design or historical events is significant, even for large flood events. Peak discharge reductions at the projects ranged from 40.0 to 95.7 percent. As one moves downstream from the projects, the peak reduction effect diminishes. However, even at the outlet of the watershed, the 132 existing flood mitigation projects in the watershed were able to reduce peak discharges by 20 to 30 percent, which will reduce the depth of out of bank water across the flood plain. The new structures built in Phase II were built upstream of existing structures. The new structures will protect and enhance the performance of the existing structures for large rainfall events.

c. Concluding Comments

The impact of this funding and what has been learned from the watershed demonstration projects is an essential step toward long-term recovery to improve Iowa's future flood resiliency. The hydrologic assessment, watershed planning, and project evaluation will guide future decision making to expand project implementation in the Soap Creek Watershed. This work will also serve as leverage for the Soap Creek Watershed Board to seek additional funding for continued work toward their long term goals.

In January 2016, the U.S. Department of Housing and Urban Development (HUD) awarded $96.9 million to Iowa for a statewide watershed improvement program, the Iowa Watershed Approach (IWA). The IWA will address issues associated with the devastating and dangerous floods Iowa communities experience year after year. The foundation of the IWA was built on the framework and success of the Iowa Watersheds Project, which served as a significant source of leverage for the state of Iowa to receive another round of HUD funding for a new five-year project.

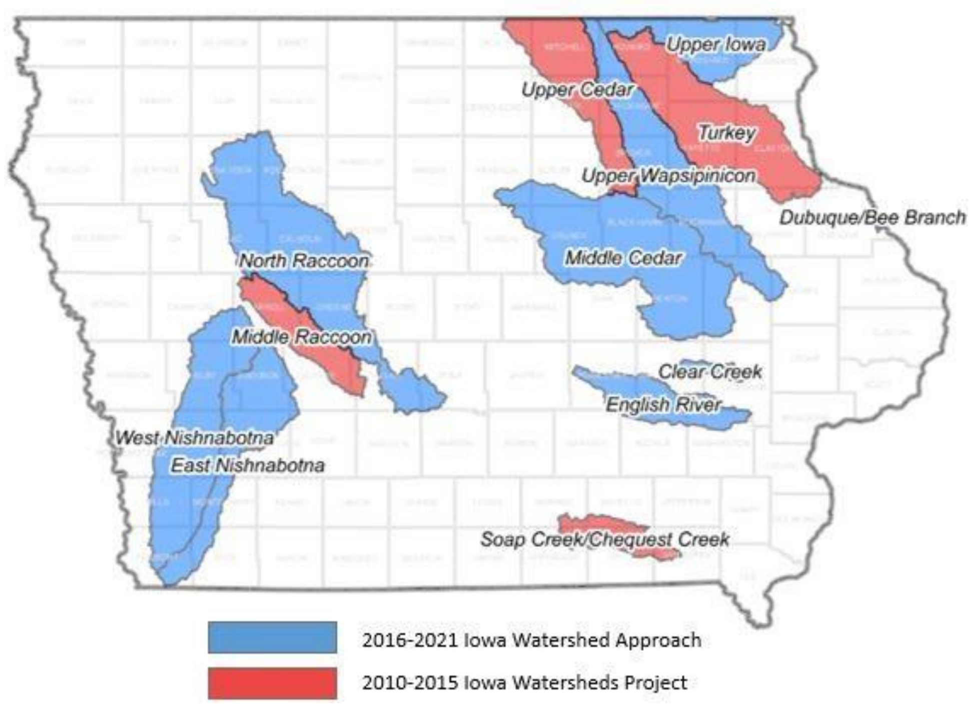

Figure 5.1. Location of watersheds selected for the Iowa Watersheds Project and the Iowa Watershed Approach.

The IWA project will work in nine new watersheds across the state: Bee Branch in Dubuque, Upper Iowa River, Upper Wapsipinicon River, Middle Cedar River, Clear Creek, English River, North Raccoon River, West Nishnabotna River, and East Nishnabotna River. Each will have the opportunity to form a Watershed Management Authority (WMA), develop a hydrologic assessment and watershed plan, and implement projects to reduce the magnitude of downstream flooding and to improve water-quality during and after flood events.

A video explaining the Iowa Watersheds Project and Iowa Watershed Approach can be accessed at https://www.youtube.com/watch?v=tODPRvs4ycU.

Appendix A – Iowa Watersheds Project Phase II Pond Stage-Storage-Discharge Relationships

Project: **H. & M. Leffler Pond** **Pond ID #1**
Drainage Area: 117 acres (0.18 square miles)
Description: The principal spillway is a 48" smooth steel pipe (SSP) riser with a 36" SSP outlet pipe, inlet elevation of 892.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 896.4 feet MSL. Top of dam at 898.4 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

H. & M. Leffler Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	882.0	0	0	
2	884.0	0.05	0.05	
4	886.0	0.19	0.29	
6	888.0	0.45	0.93	
8	890.0	0.91	2.29	
10	892.0	1.44	4.64	principal spillway: 892.0
12	894.0	2.27	8.35	
14	896.0	3.45	14.07	auxiliary spillway: 896.4
16	898.0	4.61	22.13	top of dam: 898.4
18	900.0	5.82	32.56	
20	902.0	7.09	45.47	
22	904.0	8.41	60.97	
24	906.0	10.47	79.85	
26	908.0	12.85	103.17	
28	910.0	15.70	131.72	
30	912.0	19.02	166.44	

H. & M. Leffler Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	882.0	0	0	
9.5	891.5	4.05	0	
10.0	892.0	4.64	0	principal spillway
10.05	892.05	4.73	1.04	
10.23	892.23	5.07	5.0	
10.39	892.39	5.36	10.06	
10.56	892.56	5.68	16.53	
10.61	892.61	5.77	18.72	
10.68	892.68	5.90	22.35	
10.81	892.81	6.14	28.61	
11.04	893.04	6.57	41.69	
11.44	893.44	7.31	67.2	
11.87	893.87	8.11	99.8	

continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
12.62	894.62	10.12	104.21	
13.24	895.24	11.90	107.32	
13.75	895.75	13.36	109.75	
14.10	896.1	14.47	111.42	
14.31	896.31	15.32	112.4	
14.40	896.4	15.72	112.88	auxiliary spillway
14.55	896.55	16.29	113.55	
14.72	896.72	16.97	114.35	
14.88	896.88	17.62	115.27	
15.04	897.04	18.26	116.28	
15.08	897.08	18.42	116.57	
15.18	897.18	18.83	117.94	
15.32	897.32	19.39	120.03	
15.45	897.45	19.91	123.66	
15.55	897.55	20.32	128.3	
15.58	897.58	20.44	129.6	
15.70	897.7	20.92	135.35	
15.80	897.8	21.32	142.44	
15.83	897.83	21.44	143.9	
15.90	897.9	21.73	148.67	
15.96	897.96	21.97	152.71	
15.97	897.97	22.01	153.25	
16.0	898.0	22.13	155.09	
16.07	898.07	22.50	162.15	
16.11	898.11	22.70	166.38	
16.23	898.23	23.33	178.05	
16.32	898.32	23.80	187.81	
16.33	898.33	23.85	189.3	
16.40	898.4	24.22	198.82	top of dam
16.90	898.9	26.82	303.1	
17.40	899.4	29.43	430.4	
18.0	900.0	32.56	923.09	
18.5	900.5	35.17	1574.47	

Project: **Brittain Farms Pond** **Pond ID #2**
Drainage Area: 50 acres (0.08 square miles)
Description: The principal spillway is a 6" smooth steel pipe (SSP), invert elevation of 880.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 883.5 feet MSL. Top of dam at 885.6 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Brittain Farms Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	862.0	0.00	0.00	
2	864.0	0.12	0.12	
4	866.0	0.31	0.55	
6	868.0	0.52	1.38	
8	870.0	0.75	2.65	
10	872.0	0.99	4.39	
12	874.0	1.24	6.62	
14	876.0	1.49	9.35	
16	878.0	1.82	12.66	
18	880.0	2.26	16.74	principal spillway: 880.0
20	882.0	2.83	21.83	
22	884.0	3.50	28.16	auxiliary spillway: 883.5
24	886.0	4.34	36.00	top of dam: 885.6
26	888.0	5.30	45.64	
28	890.0	6.28	57.22	
30	892.0	7.46	70.96	

Brittain Farms Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	862.0	0	0	
17.5	879.5	15.72	0	
18.0	880.0	16.74	0	principal spillway
18.2	880.2	17.25	0.08	
18.5	880.5	18.01	0.4	
18.6	880.6	18.27	0.8	
18.64	880.64	18.37	1.02	
18.66	880.66	18.42	1.26	
18.69	880.69	18.50	1.51	
18.72	880.72	18.57	1.78	
18.8	880.8	18.78	2.04	
19.0	881.0	19.28	2.06	
19.5	881.5	20.56	2.08	
20.0	882.0	21.83	2.11	
20.5	882.5	23.41	2.13	
21.0	883.0	24.99	2.16	
21.5	883.5	26.58	2.18	auxiliary spillway
22.0	884.0	28.16	2.5	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
22.4	884.4	29.73	6.11	
22.5	884.5	30.12	11.28	
22.7	884.7	30.90	20.0	
22.86	884.86	31.53	29.77	
23.3	885.3	33.26	66.22	
23.42	885.42	33.73	81.24	
23.5	885.5	34.04	92.55	
23.6	885.6	34.43	104.0	top of dam
23.8	885.8	35.22	142.37	
24.0	886.0	36.0	303.1	
24.5	886.5	38.41	430.4	

Project: **Klyn Pond Pond ID #3**
Drainage Area: 138 acres (0.22 square miles)
Description: The principal spillway is a 12" smooth steel pipe (SSP), invert elevation of 864.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 869.5 feet MSL. Top of dam at 871.6 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Klyn Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	844.0	0.00	0.00	
2	846.0	0.01	0.01	
4	848.0	0.06	0.08	
6	850.0	0.11	0.25	
8	852.0	0.28	0.64	
10	854.0	0.51	1.43	
12	856.0	0.91	2.85	
14	858.0	1.56	5.32	
16	860.0	2.49	9.37	
18	862.0	3.41	15.27	
20	864.0	4.30	22.98	principal spillway: 864.0
22	866.0	5.40	32.68	
24	868.0	6.64	44.72	auxiliary spillway: 869.5
26	870.0	7.91	59.27	top of dam: 871.6
28	872.0	9.28	76.46	
30	874.0	10.58	96.32	

Klyn Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	844.0	0	0	
19.5	863.5	21.05	0	
20.0	864.0	22.98	0	principal spillway
20.5	864.5	25.40	0.67	
20.75	864.75	26.62	1.42	
21.0	865.0	27.83	2.21	
21.1	865.1	28.31	2.46	
21.2	865.2	28.80	5.13	
21.3	865.3	29.28	7.64	
21.4	865.4	29.77	10.48	
21.5	865.5	30.25	11.35	
22.0	866.0	32.68	11.5	
22.5	866.5	35.10	11.63	
23.0	867.0	37.53	11.75	
23.5	867.5	39.95	11.9	
24.0	868.0	44.72	12.0	
24.5	868.5	47.73	12.2	
25.0	869.0	50.74	12.3	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
25.5	869.5	53.75	12.4	auxiliary spillway
26.0	870.0	59.62	12.98	
26.3	870.3	61.85	15.36	
26.5	870.5	63.57	20.4	
26.7	870.7	65.29	31.05	
26.8	870.8	66.15	36.51	
26.9	870.9	67.01	42.27	
27.0	871.0	67.86	52.5	
27.5	871.5	72.16	103.8	
27.6	871.6	73.02	116.8	top of dam
28.0	872.0	76.46	303.1	
28.5	872.5	81.42	430.4	

Project: **Johnson Pond** **Pond ID #4**
Drainage Area: 64 acres (0.10 square miles)
Description: The principal spillway is a 10" smooth steel pipe (SSP), invert elevation of 868.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 871.5 feet MSL. Top of dam at 873.6 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Johnson Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	852.0	0.00	0.00	
2	854.0	0.08	0.08	
4	856.0	0.35	0.51	
6	858.0	0.67	1.53	
8	860.0	1.02	3.22	
10	862.0	1.38	5.62	
12	864.0	1.73	8.73	
14	866.0	2.15	12.61	
16	868.0	2.70	17.46	principal spillway: 868.0
18	870.0	3.39	23.55	auxiliary spillway: 871.5
20	872.0	4.07	31.01	top of dam: 873.6
22	874.0	4.85	39.93	
24	876.0	5.73	50.51	
26	878.0	6.73	62.97	
28	880.0	7.79	77.49	
30	882.0	8.94	94.22	

Johnson Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	852.0	0	0	
15.5	867.5	16.25	0	
16.0	868.0	17.46	0	principal spillway
16.1	868.1	17.76	0.06	
16.2	868.2	18.07	0.14	
16.3	868.3	18.37	0.26	
16.5	868.5	19.98	0.56	
16.6	868.6	19.29	0.8	
16.7	868.7	19.59	1.06	
16.8	868.8	19.90	1.28	
16.9	868.9	20.20	1.57	
17.0	869.0	20.51	3.78	
17.1	869.1	20.81	5.81	
17.3	869.3	21.42	7.02	
17.5	869.5	22.03	7.07	
18.0	870.0	23.55	7.1	
18.5	870.5	25.42	7.3	
19.0	871.0	27.28	7.4	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
19.5	871.5	29.15	7.5	auxiliary spillway
20.0	872.0	31.01	7.9	
20.2	872.2	31.90	9.0	
20.5	872.5	33.24	15.44	
21.0	873.0	35.47	42.52	
21.5	873.5	37.70	99.74	
21.6	873.6	38.15	106.49	top of dam
22.0	874.0	39.93	303.1	
22.5	874.5	42.58	430.4	

Project: **Sampson Pond** **Pond ID #5**
Drainage Area: 64 acres (0.10 square miles)
Description: The principal spillway is a 6" smooth steel pipe (SSP), invert elevation of 867.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 868.4 feet MSL. Top of dam at 870.4 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Sampson Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	847.0	0.00	0.00	
2	849.0	0.01	0.01	
4	851.0	0.03	0.05	
6	853.0	0.06	0.14	
8	855.0	0.13	0.33	
10	857.0	0.24	0.70	
12	859.0	0.34	1.28	
14	861.0	0.45	2.07	
16	863.0	0.61	3.13	
18	865.0	0.80	4.54	
20	867.0	0.99	6.33	principal spillway: 867.0
22	869.0	1.20	8.52	auxiliary spillway: 868.4
24	871.0	1.40	11.12	top of dam: 870.4
26	873.0	1.80	14.32	
28	875.0	2.30	18.42	
30	877.0	2.70	23.42	

Sampson Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	847.0	0	0	
19.5	866.5	5.88	0	
20.0	867.0	6.33	0	principal spillway
20.1	867.1	6.44	0.04	
20.2	867.2	6.55	0.08	
20.3	867.3	6.66	0.17	
20.4	867.4	6.77	0.28	
20.5	867.5	6.88	0.4	
20.6	867.6	6.99	1.3	
20.7	867.7	7.10	1.4	
20.8	867.8	7.21	1.8	
20.9	867.9	7.32	2.25	
21.0	868.0	7.42	2.26	
21.4	868.4	7.86	2.27	auxiliary spillway
21.5	868.5	7.97	2.3	
22.0	869.0	8.52	2.97	
22.4	869.4	9.04	9.18	
22.5	869.5	9.17	13.89	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
22.75	869.75	9.50	28.17	
22.9	869.9	9.69	38.42	
23.0	870.0	9.82	50.0	
23.4	870.4	10.34	100.64	top of dam
24.0	871.0	11.12	303.1	
24.5	871.5	11.92	430.4	

Project: **C. Leffler Pond** **Pond ID #6**
Drainage Area: 414 acres (0.65 square miles)
Description: The principal spillway is a 24" smooth steel pipe (SSP), invert elevation of 869.0 feet MSL. The auxiliary spillway is 50 feet wide, retardance class B, with 30 foot control length, crest elevation at 879.5 feet MSL. Top of dam at 883.5 feet MSL. Designed as Medium Hazard Class Structure.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

C. Leffler Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	855.0	0.00	0.00	
4	859.0	0.34	0.37	
8	863.0	2.70	5.79	
11	866.0	4.78	16.96	
13	868.0	6.52	28.29	
14	869.0	7.31	35.20	
15	870.0	8.08	42.90	
16	871.0	8.91	51.40	
17	872.0	9.82	60.77	
18	873.0	10.79	71.07	
19	874.0	11.71	82.32	principal spillway: 869.0
20	875.0	12.66	94.50	auxiliary spillway: 879.5
21	876.0	13.69	107.68	top of dam: 883.5
22	877.0	15.01	122.03	
23	878.0	16.65	137.86	
24	879.0	17.81	155.09	
26	881.0	20.44	193.31	
28	883.0	23.03	236.78	
30	885.0	25.66	285.48	
32	887.0	28.31	339.43	

C. Leffler Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	855.0	0	0	
13.5	868.5	31.75	0	
14.0	869.0	35.2	0	principal spillway
14.5	869.5	39.05	1.36	
15.0	870.0	42.9	3.6	
15.5	870.5	47.15	7.84	
16.0	871.0	51.40	12.3	
16.2	871.2	53.27	13.9	
16.4	871.4	55.15	24.2	
16.5	871.5	56.09	31.22	
16.75	871.75	58.43	46.84	
17.0	872.0	60.77	47.22	
17.2	872.2	62.83	47.59	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
17.4	872.4	64.89	47.96	
18.0	873.0	71.07	48.91	
19.0	874.0	82.32	50.44	
20.0	875.0	94.50	51.9	
21.0	876.0	107.68	53.3	
22.0	877.0	122.03	54.7	
23.0	878.0	137.86	56.0	
24.0	879.0	155.09	57.6	
24.5	879.5	164.65	58.4	auxiliary spillway
25.0	880.0	174.20	60.22	
25.5	880.5	183.76	84.03	
25.6	880.6	185.67	110.37	
25.9	880.9	191.40	168.0	
26.0	881.0	193.31	192.42	
26.3	881.3	199.83	288.3	
26.5	881.5	204.18	375.1	
27.0	882.0	215.04	664.05	
27.2	882.2	219.39	828.77	
27.5	882.5	225.91	1060.0	
27.8	882.8	232.43	1449.35	
28.0	883.0	236.78	1719.41	
28.5	883.5	248.95	2500.16	top of dam

Project: **Paluska Pond** **Pond ID #7**
Drainage Area: 142 acres (0.22 square miles)
Description: The principal spillway is an 18" smooth steel pipe (SSP), invert elevation of 791.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 795.8 feet MSL. Top of dam at 797.9 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Paluska Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	763.0	0.00	0.00	
1	764.0	0.03	0.02	
3	766.0	0.08	0.13	
5	768.0	0.19	0.40	
7	770.0	0.34	0.93	
9	772.0	0.54	1.81	
11	774.0	0.80	3.15	
13	776.0	1.09	5.04	
15	778.0	1.42	7.55	
17	780.0	1.88	10.85	
19	782.0	2.46	15.19	
21	784.0	3.07	20.72	
23	786.0	3.79	27.58	
25	788.0	4.81	36.18	
27	790.0	5.82	46.81	principal spillway: 791.0
29	792.0	6.94	59.57	
31	794.0	8.15	74.66	auxiliary spillway: 795.8
33	796.0	9.53	92.34	top of dam: 797.9
35	798.0	10.95	112.82	
37	800.0	13.80	137.15	
39	802.0	15.30	165.83	
41	804.0	17.54	198.67	
43	806.0	19.57	235.78	
45	808.0	21.46	276.81	
47	810.0	23.41	321.68	

Paluska Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	763.0	0	0	
27.5	790.5	50.00	0	
28.0	791.0	53.19	0	principal spillway
28.7	791.7	57.66	1.65	
29.0	792.0	59.57	3.03	
29.5	792.5	63.34	5.88	
29.7	792.7	64.85	7.2	
29.8	792.8	65.61	11.86	
29.9	792.9	66.36	15.65	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
30.0	793.0	67.11	20.59	
30.2	793.2	68.62	31.46	
31.1	794.1	75.54	33.87	
32.0	795.0	83.50	34.74	
32.8	795.8	90.57	35.40	auxiliary spillway
33.3	796.3	95.41	35.84	
33.8	796.8	100.53	37.92	
34.3	797.3	105.65	55.57	
34.9	797.9	111.80	103.3	top of dam
35.3	798.3	116.47	303.1	
35.8	798.8	122.55	430.4	

Project: **Swaim Pond Pond ID #8**
Drainage Area: 102 acres (0.16 square miles)
Description: The principal spillway is a 12" smooth steel pipe (SSP), invert elevation of 823.0 feet MSL. The auxiliary spillway is 10 feet wide, retardance class B, with 30 foot control length, crest elevation at 826.6 feet MSL. Top of dam at 828.7 feet MSL.
Hydraulic Design: French-Reneker-Associates. Inc., Fairfield, Iowa

Swaim Pond: Elevation (Stage) – Pool Area – Storage relationships from design documentation.

Stage (feet)	Elevation (feet)	Pool Area (acres)	Accumulated Storage (acre-feet)	
0	794.0	0.00	0.00	
2	796.0	0.03	0.03	
4	798.0	0.08	0.14	
6	800.0	0.14	0.36	
8	802.0	0.21	0.71	
10	804.0	0.30	1.22	
12	806.0	0.45	1.97	
14	808.0	0.67	3.09	
16	810.0	0.89	4.65	
18	812.0	1.20	6.74	
20	814.0	1.50	9.44	
22	816.0	1.84	12.78	
24	818.0	2.19	16.81	
26	820.0	2.58	21.58	
28	822.0	3.06	27.22	principal spillway: 823.0
30	824.0	3.70	33.98	
32	826.0	4.32	42.00	auxiliary spillway: 826.6
34	828.0	4.97	51.29	top of dam: 828.7
36	830.0	5.62	61.88	
38	832.0	6.41	73.91	

Swaim Pond: Elevation (Stage) – Storage – Discharge relationships developed by IFC for hydrologic models.

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
0	794.0	0	0	
28.5	822.5	28.91	0	
29.0	823.0	30.6	0	principal spillway
29.66	823.66	32.83	0.68	
29.8	823.8	33.30	1.57	
30.0	824.0	33.98	2.15	
30.2	824.2	34.78	5.7	
30.3	824.3	35.18	8.44	
30.4	824.4	35.58	11.5	
30.5	824.5	35.98	12.69	
30.9	824.9	37.59	12.82	
31.0	825.0	37.99	12.86	
31.5	825.5	42.00	13.03	
32.0	826.0	44.79	13.2	continued on next page

Stage (feet)	Elevation (feet)	Accumulated Storage (acre-feet)	Discharge (cfs)	
32.6	826.6	44.79	13.4	auxiliary spillway
33.0	827.0	46.65	13.52	
33.5	827.5	48.97	14.15	
34.0	828.0	51.29	27.85	
34.7	828.7	54.47	69.88	top of dam
35.0	829.0	56.59	303.1	
35.5	829.5	59.23	430.4	

References

Fry, J., et al., 2011: Completion of the 2006 National Land Cover Database for the conterminous United States. Photogrammetric Engineering and Remote Sensing, 77 (9), 858–864.

Iowa Flood Center, 2014: Hydrologic Assessment of the Chequest Creek Watershed. IIHR Technical Report No. 490, IIHR–Hydroscience & Engineering.

Iowa Geological and Water Survey, 2010: One meter digital elevation model of Iowa. Iowa Department of Natural Resources, URL https://programs.iowadnr.gov/nrgislibx/.

Iowa Geological and Water Survey, 2013: Landform Regions of Iowa. Iowa Department of Natural Resources, URL http://www.igsb.uiowa.edu/browse/landform.htm.

Natural Resource Conservation Service, 2004a: Chapter 7 Hydrology. Part 630 Hydrology, National Engineering Handbook. U.S. Department of Agriculture. URL http://www.wcc.nrcs.usda.gov/ftpref/wntsc/H&H/NEHhydrology/ch7.pdf.

Perica, S., D. Martin, D., S. Pavlovic, I. Roy, M. St. Larent, C. Trypaluk, D. Unruh, M. Yekta, and G. Bonnin, 2013: NOAA Atlas 14, Precipitation-Frequency Atlas of the United States. National Weather Service, URL http://hdsc.nws.noaa.gov/hdsc/pfds/index.html, 297 pp.

PRISM Climate Group, 2016: Oregon State University, URL http://prism.oregonstate.edu.

Soil Survey Staff, 2014: Gridded Soil Survey Geographic (gSSURGO) Database for the United States of America and the Territories, Commonwealths, and Island Nations served by the USDA-NRCS. U.S. Department of Agriculture, Natural Resources Conservation Service, URL https://gdg.sc.egov.usda.gov/.