CLARK CREEK WATERSHED STUDY

FINAL REPORT

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PREPARED FOR

SAUK COUNTY, WISCONSIN
LAND CONSERVATION DEPARTMENT

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1 INTRODUCTION

1.1 BACKGROUND

Clark Creek experienced extraordinary floods in June of 2008, causing extensive damage to private and public property, and jeopardizing the safety of local residents and travelers on State Highway (STH) 113 south of Baraboo, Wisconsin (**Figure 1**). These events were related to massive flooding throughout southern Wisconsin caused by an extended period of very wet weather. Two flood events occurred in early June 2008: heavy rains and a large flood on June 8, and more heavy rain and an even larger flood on June 12 which caused the majority of the damage. These damages included destruction of significant portions of STH 113, failure of several highway culverts and private driveway culverts, extensive sedimentation on roadways and private property, and inundation of houses.

An initial evaluation of the flooding problems on Clark Creek and potential mitigation actions was prepared by the Federal Emergency Management Agency (FEMA) and issued to Sauk County in September 2008. This effort was based on observations conducted during a reconnaissance inspection of the watershed and subsequent analysis by FEMA personnel in communication with the County and other entities. The study identified 15 potential flood mitigation options:

- Stabilization of the creek banks to pre-1993 conditions
- Realignment of the channel of the Creek
- Installation of flow diverters to limit streambank erosion in selected areas
- Construction of sediment-trapping basins along the creek
- Construction of a dam in the upper watershed of Clark Creek to limit flood discharge
- Construction of an emergency spillway to discharge into an alternative channel near the Maxwell farm
- Realignment of STH 113
- Replacing the culverts at the Maxwell farm with a bridge
- Replacing the culverts at the Maxwell farm with a "low water crossing"
- Realignment of STH 113 culverts
- Installation of debris barriers at entrances to culverts
- Installation of perforated standpipes in lieu of standard culverts
- Acquisition of damaged or at-risk residential properties ("buyouts")
- Relocation of selected existing structures
- Elevation or flood-proofing of existing structures

As part of initial activities shortly after the June 2008 flood, the Wisconsin DNR implemented several small sediment trap/grade stabilization structures slightly upstream of the Maxwell farm, which failed during subsequent modest flood events.

Additionally, the NRCS prepared construction drawings for a project to dredge Clark Creek from downstream of CTH W to the Baraboo River in 2008. However, this project was not implemented.

Based upon the substantial damage produced by the June 2008 flood, Sauk County applied for and was granted a Community Development Block Grant from the Wisconsin Department of Commerce to aid the County in assessing and implementing flood damage control measures. The grant was specifically awarded to fund measures that will mitigate the impacts of the June 2008 flood events. The available grant funding is approximately $1 million. As currently defined, grant fundable activities are intended to be complete in year 2011; an extension of the grant timeline is possible and is under consideration by the County.

1.1 THIS REPORT

This report documents the Clark Creek Watershed Study commissioned by Sauk County, Wisconsin and conducted by Montgomery Associates: *Resource Solutions*, LLC (MARS). The study was funded by a portion of the Community Development Block Grant from the Wisconsin Department of Commerce. The purpose of this watershed study was to evaluate the wide range of potential flood mitigation measures that were identified in the September 2008 FEMA report, to identify new options that may be appropriate, and to recommend which options are likely to be feasible and cost effective.

1.2 FUTURE ACTIVITIES

Based on the results of this study, more detailed technical and financial analyses will be required to make the final selection of alternatives for implementation. Following final project selection by the County, construction documents can be completed, and implementation of the selected flood damage mitigation measures can begin.

2 DATA SOURCES AND ANALYSIS APPROACH

2.1 DATA SOURCES

This study made use of historical information on the flooding, the knowledge of local residents and officials, and previously developed reports and analysis tools. This data included:

- Discussions with Sauk County staff, the Wisconsin Department of Natural Resources (DNR), the Wisconsin Department of Transportation (DOT), the Wisconsin Department of Commerce, US Fish and Wildlife Service, and the USDA Natural Resources Conservation Service;
- Data collected during several site visits and walkovers;
- Comments provided during informational meetings on January 20 and 25, 2011;
- Photographs and data provided by residents of the watershed;
- The September 2008 FEMA report "Flooding Conditions at Clark Creek and Possible Mitigation";
- The FEMA Flood Insurance Study for Sauk County, Wisconsin and Incorporated Areas (revised December 18, 2009, FIS #55111CV001A), and the associated computer models of watershed hydrology (HEC-HMS) and the Clark Creek channel and floodplain (HEC-RAS) completed in 2005;
- Rainfall data from the National Oceanic and Atmospheric Administration weather stations in Baraboo and Portage, and NEXRAD radar;
- Rain gage data provided by local residents Dick Devine and Bill Schreiber;
- Aerial photographs provided by Sauk County and obtained from the National Agricultural Imagery Program dating from 1940 – 2010;
- Photographs of the 1993 and 2008 floods provided by Vickie Marquardt and Judd Maxwell;
- Video records and detailed descriptions provided by local resident Vickie Marquardt;
- Newspaper articles and detailed descriptions provided by Judd Maxwell;
- The US Geological Survey report "Flood of June 2008 in Southern Wisconsin", Scientific Investigations Report 2008-5235;
- Future climate change information from the Wisconsin Initiative on Climate Change Impacts (WICCI) available online at http://www.wicci.wisc.edu/;
- Monthly estimates of local rainfall from Oregon State University PRISM Climate Group; and
- An 1840 survey map from the Board of Commissioners of Public Lands available online at http://bcpl.wisconsin.gov/.
- Cost estimate data for highway modifications provided by Jewell Associates Engineers, Inc.

2.2 DATA PROVIDED IN THE FLOOD INSURANCE STUDY

Hydrologic and hydraulic analyses conducted for the December 2009 Flood Insurance Study revision for Sauk County provided valuable tools for this analysis. Wisconsin DNR conducted a hydrologic analysis of the Clark Creek watershed, which is described in an internal report dated November 2, 2007. This study tabulated rainfall and watershed data, and it developed a rainfall-runoff model for the watershed using the U.S. Army Corps of Engineers program HEC-HMS. This model subdivided the Clark Creek watershed into nine subwatersheds and utilized descriptions of the subwatershed land-use, channel characteristics, and the storage routing provided by two wetland areas to predict peak discharge rates at several points in the watershed.

The Flood Insurance Study also utilized a hydraulic model for the main stem of Clark Creek, which was developed by Ayres Associates as part of the Flood Insurance Study using the U.S. Army Corps of Engineers program HEC-RAS. This computer model included a large number of cross-sections to define the hydraulic characteristics of the channel and the various culverts across the stream to predict the velocities and water surface elevations that would result from particular discharge in the Clark Creek channel.

Both of these computer models were utilized extensively in the analyses conducted for this study.

2.3 ANALYSIS APPROACH

The analysis approach for this study included the following general steps:

- Collection and review of data on flood events, watershed characteristics, historical records of land-use, aerial photographs, historical records, and the hydrologic and hydraulic analyses that were conducted for the Flood Insurance Study;
- Meetings and discussions with local residents, Sauk County personnel, and personnel from various state agencies to gain further understanding of the June 2008 flooding;
- Analysis of the 15 preliminary mitigation alternatives identified in the September 2008 report;
- Identification and analysis of additional flood mitigation alternatives;
- Communication and meetings with Sauk County, Wisconsin DNR, Wisconsin Department of Transportation and other agencies to evaluate the feasibility, regulatory issues and implementation aspects of the identified alternatives;
- Public meetings on January 20 and January 25, 2011 to describe the range of alternatives identified and collect data and reaction from the public; and
- Development and refinement of a project report with a presentation to the County in March 2011.

3 THE FLOOD OF JUNE 2008

3.1 FLOOD DESCRIPTION AND DAMAGE

The flood of June 2008 occurred in two episodes: a first flood event on June 8 and a second major flood on June 12. The first (June 8) flood produced significant flooding primarily near the Baraboo River, whereas the second (June 12) flood produced severe damage throughout the Creek. Based on review of available data, the bulk of the physical damage to roadways and property occurred during the June 12 flood.

Significant erosion and sediment transport occurred in the channel between Tower Road and STH 113 during the June floods. However nearly all of the structural and property damages occurred from a short distance upstream of STH 113 culvert #1 at the Maxwell Farm downstream to the Baraboo River (**Figure 2**). Major impacts of the June 2008 flood are summarized below.

- STH 113 culvert #1 was blocked with woody debris and sediment (**Figure 3**), increasing the upstream flood elevation. The blockage of the culvert produced major channel overflow at the Maxwell farm and adjacent to STH 113 and was one of the major causes of flood damage along STH 113. Floodwater flowed over the highway and through the Maxwell farm, scouring out large sections of the roadway, as well as severely impacting the Maxwell Farm and outbuildings.
- Several private driveways and associated culverts were damaged between culvert #1 and the Baraboo River.
- The basements of at least eight houses were flooded.
- The CTH W culvert was severely compromised by the flood and the roadway embankment was breached to the west of the culvert.
- STH 113 was breached at culvert #3, downstream of CTH W. Water overtopped the roadway, and significant flow was diverted to the north flowing directly down the STH 113 right-of-way.
- Sediment was deposited over an extensive area of the channel and overbank areas between CTH W and the Baraboo River, and it was several feet thick in some places. Much of the stream channel from culvert #3 downstream to the Baraboo River was filled in.

The 2010 assessed value of properties adjacent to Clark Creek from upstream of the Maxwell farm to the mouth of Clark Creek on the Baraboo River totals $4.4 million, of which $3.5 million is the improvement value. The total damage cost of the June 2008 flood in this area has not previously been compiled, and site-specific damage estimates were largely unavailable. **Figure 2** shows the general location of major damages. Property values of impacted homes were compiled to aid in estimating private damages (**Figure 4**).

In addition to causing structural damage, the flood also impacted public safety, tourism, businesses, and agriculture. During the June 2008 event, floodwaters rose so quickly that evacuation by car

became impossible and several stranded residents were rescued by the amphibious Wisconsin Ducks vehicles. After floodwaters receded, the damage to the roads posed a major safety threat to residents and visitors. Land access was hazardous where the floodwaters had undercut banks and where the filled-in channel acted like quicksand. In 1993, floodwaters similar to those in 2008 swept a car off STH 113 and killed one of the three passengers, a 12-year-old boy from Illinois. STH 113 also serves as a popular tourist route providing access to Devil's Lake and Baraboo; tourism revenue was surely lost by closing STH 113 for repairs. Several businesses in the Clark Creek area were hurt by limited traffic on STH 113 or by structural impacts. The floodplain is largely agricultural, and crops were damaged by high water and extensive sedimentation. Many of these damages although very significant (and tragic) are difficult to quantify in economic terms.

A partial estimate of flood damages is summarized in **Table 1**.

Table 1. Estimated Flood Damages for June 2008

Damage element	Estimated Value
STH 113 repair from CTH W culvert to culvert #3	$30,000
CTH W culvert replacement	$100,000
STH 113 repair from culvert #1 to #2	$150,000
Debris and sediment removal from public property	$16,000
Debris removal on private property	$7,000
Safety issues	Not evaluated
Revenue loss for local business	Not evaluated
Loss to tourism	Not evaluated
Agricultural damage	Not evaluated
Channel repair – installing rip rap	$35,000
Private driveway damage	$75,000
Basement flooding	$225,000*
Damage to private outbuildings	Not evaluated
Partial estimate of June 2008 flood damage	**$638,000**

*Based on FEMA assessment methodology

Flood response efforts for public infrastructure included many days to clean up debris and sediment by DOT; replacement of the single CTH W culvert with dual 72-inch culverts; reshaping the channel banks and armoring them with rip rap between approximately STH 113 culverts #2 and #3; substantial roadway repairs of STH 113 between culverts #1 and #2, and at the CTH W crossing; and design of a dredging project for the channel downstream of STH 113 culvert #3 (not implemented).

3.2 JUNE 2008 RAINFALL

Rainfall frequency estimates based upon long-term records analysis provides a "point of departure" for evaluation of the severe rainfalls that produced the June 2008 flooding. The Wisconsin DNR

hydrologic analysis for Clark Creek that was used in preparation of the 2009 FEMA FIS study update describes 24-hour rainfall depths in the Clark Creek watershed as shown in **Table 2**.

Table 2. 24-hour rainfall depths for Clark Creek watershed

Storm Event	24-hour Rainfall depth (in)
10-year storm:	3.98
50-year storm:	5.14
100-year storm:	5.92
500-year storm:	7.01

These rainfall depths are based upon the US Weather Bureau 1961 publication Technical Paper No. 40, Rainfall Frequency Atlas of the United States. More recent rainfall frequency analyses have produced different rainfall depths than those used in the FIS study. For example, the Illinois State Water Survey Bulletin 71, rainfall frequency Atlas of the Midwest, issued in 1992, describes the 100-year 24-hour rainfall depths in the Clark Creek watershed as approximately 7.0 inches.

The June 2008 storms were extremely heavy. Although the June 12 event was more destructive, available data indicate that more rain actually fell on June 8 (**Table 3**). It appears that June 8 was approximately a 100-year rainfall, while June 12 rainfall was smaller, perhaps approximately a 25 year return period. However, the highest rainfall estimates for these events from a local rain gage monitored by local residents suggests that the rainfall as may have been even more severe.

Table 3. Total rainfall (inches) for June 2008 storms

Data Source	June 7-8, 2008	June 12, 2008
NOAA Baraboo Airport hourly data	5.79	2.00*
NEXRAD radar	6.00	4.65
Devine rain gage (resident)	9.00	6.00
Schreiber rain gage (resident)	5.70	2.41
Average	6.6	4.4
Approximate recurrence interval based on NEXRAD	100 years	25 years

* Some data missing; rainfall total likely inaccurate.

3.3 JUNE 2008 FLOOD DISCHARGE

Understanding how much water flowed down Clark Creek in June 2008 is important in evaluating flood mitigation alternatives. No stream gaging station exists on Clark Creek, so flood discharge was estimated using the computer models developed for the FEMA Flood Insurance Study.

Clark Creek has a watershed of 4.4 square miles extending from the bluffs of Devils Lake State Park down to the Baraboo River floodplain (**Figure 1**). The upper portions of the watershed are underlain by impermeable quartzite bedrock covered by a thin soil layer, with the water table within a few feet of the land surface in many locations. These natural factors contribute to rapid runoff generation during heavy rains.

An iterative procedure was used to estimate the magnitude of the June 2008 floods. The flood discharge produced by estimated rainfall was predicted using the HEC-HMS hydrologic model. This model simulates the rainfall-runoff response in several subdivided areas of the watershed (**Figure 5**) and combines runoff from each area to estimate flow in the main Clark Creek channel. The peak discharge estimates were used as input to the HEC-RAS hydraulic model to analyze the height that the flood waters reached at various portions of the watershed. These predictions of water surface elevation and extent of inundation were compared to photographs and records from residents to evaluate whether the predicted discharge was consistent with observations along Clark Creek. Adjustments were then made to model parameters to better fit observed conditions. Given the uncertainty in the rainfall data, as well as with the hydrologic and hydraulic models, several iterations of analyses were conducted to arrive at estimates of the June 2008 flood discharges.

This analysis concluded that the peak discharge estimated for the 100-year flood in the FEMA study appears to be a reasonable estimate of the June 8, 2008 discharge. At the mouth of Clark Creek, the 100-year discharge estimate is 682 cubic feet per second (cfs), as shown in **Table 4**.

During the June 12 event, soils in the watershed were extremely wet due to the heavy rain on June 8 and the extended wet conditions leading up to these storm events. The Palmer Drought Index lists soil conditions in the Baraboo area as extremely wet in June 2008. The hydrologic model was modified to reflect this condition by adjusting runoff curve numbers from the typical Antecedent Moisture Condition 2 (used in the FEMA study) to Antecedent Moisture Condition 3 (representing very wet soil). The combination of wet soil and the 100-year rainfall of 5.92 inches (approximately equal to the highest measured rainfall on June 12) results in a predicted peak discharge of 1370 cfs at the mouth of Clark Creek – more than double the 100-year discharge. This illustrates the very large impact that wet soil conditions can have on storm runoff.

Table 4. Simulated peak flood discharge on Clark Creek (cfs)

Flood Event:	**FEMA 100-year flood** [1]	**FEMA 100-year rainfall with extremely wet soil conditions** [2]
Estimate for:	June 8 flood	June 12 flood
Mouth at Baraboo River	682	1370
Kessler Rd	606	1242
1000' US STH 113	494	1022
Just US of confluence with unnamed tributary	206	397

[1] Uses Antecedent Moisture Condition (AMC) 2 runoff curve numbers.
[2] Uses AMC 3 runoff curve numbers.

Although other rainfall data indicates that the actual June 12 rainfall may have been smaller, model results for the higher rainfall more closely match observed conditions. The flood discharge estimates described above were analyzed in the Flood Insurance Study hydraulic model of the Clark Creek channel and floodplain for comparison with observations from the June 12, 2008 flood. Information on the extent of flooding was compiled from the 2008 aerial photograph, which clearly shows areas of sedimentation from the flood, and photographs and observations from local residents. To simulate the impact of debris and sediment, the hydraulic model was modified to obstruct culverts and fill in portions of the channel known to have experienced significant sediment infill (at the Maxwell Farm and downstream of CTH W). Even using the discharge of 1370 cfs for the 100-year rainfall on wet soils, the model predicts a smaller extent of flooding than appears to have actually occurred on June 12 (**Figure 6**). The estimated peak discharge of 1370 cfs substantially exceeds both the 100-year discharge (682 cfs) and the 500-year discharge (988 cfs) defined in the Flood Insurance Study. This analysis certainly has limitations in replicating such a complex flood; however, it provides a clear indication that the June 12, 2008 flood was likely to have been substantially larger than the "extreme" flood conditions defined in the Flood Insurance Study. Nevertheless, the uncertainty in estimating the June 2008 flood discharge must be considered in evaluating and designing flood mitigation alternatives.

Based on this analysis, for the purposes of this study, the June 2008 flood on Clark Creek was defined as the June 12th flood, simulated using the FEMA FIS 100-year rainfall of 5.92 inches under extremely wet soil conditions, as shown on **Table 4**. The estimated flood has a peak discharge at the Baraboo River of 1370 cfs.

3.4 THE IMPACT OF SEDIMENT AND DEBRIS

Eye-witness observations of the June 12, 2008 flood and hydraulic model analysis indicate that woody debris and sediment clogging highway culverts significantly increased flood elevations and damages. The debris jam at STH 113 culvert #1 was so large that it reportedly took approximately 100 dump truck loads to clear it after the flood (**Figure 3**). There are several miles of densely wooded stream channel upstream of this culvert, and the wet soil conditions on June 12 would have made trees more prone to toppling into the channel. The steep gradient of this reach of Clark Creek and the large flood discharge generate the power to transport large quantities of debris downstream. Currently, the channel is blocked by many fallen trees, with many more trees perched near the edge of eroding banks (**Figure 7**), so the risk of similar debris jams during the next large flood is significant.

Deposition of sand, gravel and cobbles in the floodplain downstream of CTH W created major impacts on STH 113 and private properties. It also filled in much of the stream channel, reducing its capacity to carry floodwaters and contributing to inundation of adjacent areas. The extent of sedimentation indicated on the 2008 aerial photograph and observations of the thickness of sediment deposited suggest that perhaps 50 ac-ft of sediment was deposited in the Clark Creek floodplain by the June 12 flood. Field observations and aerial photographs indicate that the watershed contains a very large volume of easily erodible sandy glacial lake and till soils. Exposed soil is present in stream banks and bars for almost the entire length of Clark

Creek from STH 113 at the Maxwell Farm upstream to Tower Rd and beyond. Several eroding bluffs, tens of feet high, are present on outside meander bends (**Figure 8**), however the source of sediment is clearly much more extensive than these individual bluffs. The surface area of the exposed stream channel is much greater than that of the bluffs, indicating that the channel is likely the primary source for eroded sediment. The size of cobbles and boulders deposited in bars along the channel indicates the power of Clark Creek during large floods (**Figure 8**). Consistent with local recollections, comparison of the 1992 and 1994 aerial photographs shows that the July 1993 flood was a significant factor in destabilizing the channel and banks of Clark Creek. Subsequent events have continued to visibly erode the channel (**Figure 9**).

3.5 FUTURE FLOOD FREQUENCY

Predictions of future flood events are inherently uncertain. The historical record shows that rainfall totals and storm intensities vary greatly from year to year, and it is difficult to predict even a short time into the future. However, information on how frequently floods like the June 2008 event can be expected to occur is useful in assessing future flood risk and the cost of flood mitigation. Several noteworthy floods have occurred on Clark Creek in recent decades (**Table 5**). Comparison of estimated discharge for these floods indicates that the July 17, 1993 and June 12, 2008 floods were significantly larger than the rest. The US Geological Survey report on the June 2008 floods estimates the recurrence interval to be greater than 500 years for the Baraboo River, and 100 to 200 years for other rivers in the region (**Table 6**).

Table 5. Comparison of recent floods on Clark Creek

Date	Rainfall Depth	Estimated Discharge [1]
July 17, 1993	~13 in	1000 – 2000 cfs [2]
June 17, 1996	3.4 in	<200 cfs
June 1, 2000	5.5 in	500 cfs
July 10, 2000	2.3 in	<200 cfs
May 20-22, 2004	4.9 in	320 cfs
June 8, 2008	5.7 – 9.0 in	600 cfs
June 12, 2008	2.4 – 6.0 in	1300 cfs [3]
July 14, 2010	2.7 in	<200 cfs

[1] Estimated from the DNR hydrologic study, except where noted otherwise.
[2] Estimated to be greater than 500-year discharge of DNR study; rainfall depth larger than study includes.
[3] Estimated using DNR hydrologic model modified to reflect wet soil conditions.

Table 6. Recurrence interval estimates for June 2008 flood for streams in region (*from USGS Scientific Investigations Report 2008-5235, Flood of June 2008 in Southern Wisconsin*).

Location	Recurrence Interval (years)
Yahara River at Windsor	50-100
Baraboo River near Baraboo	>500
South Branch Rock River at Waupun	100-200
Beaver Dam River at Beaver Dam	100-200

It is quite likely that large floods similar to those in 1993 and 2008 have occurred before. A survey map from 1840 shows the mouth of Clark Creek approximately ½ mile downstream along the Baraboo River from its current location, east of STH 113. A trace of a possible former stream channel can be seen on the modern aerial photograph (**Figure 10**). This shift in stream channel location may have been caused by a large flood sometime between 1840 and 1940, when aerial photographs show the mouth of Clark Creek on the west side of STH 113. However, the channel may have been intentionally moved to route the flow of Clark Creek upstream of the former dam on the Baraboo River, which was located near the current STH 113 bridge. Review of aerial photographs indicates that the mouth of Clark Creek moved again in 2008 (**Figure 10**).

It is apparent from local experience that large, intense rainfalls have occurred more frequently in the past several decades, and historical rainfall totals for the Baraboo area obtained from the Oregon State University PRISM project demonstrate this (**Figure 11**). In addition, many predictions of future climate conditions suggest that large storms will occur more frequently (**Figure 12**). For example, a 6-inch rainfall is currently considered 100-year event; however, in coming decades a 6-inch rainfall may become a more frequent 25- or 50-year occurrence.

This review indicates that although heavy rainfalls and associated runoff events are likely to be somewhat more common in the future, extraordinary floods such as occurred in June 2008 will likely remain very rare.

4 FLOOD DAMAGE MITIGATION ALTERNATIVES ANALYSIS

4.1 ANALYSIS APPROACH SUMMARY

Flood damage mitigation alternatives were developed and analyzed using the understanding of the flooding and flood damages obtained through data collection, and the hydrologic and hydraulic analysis described in the previous sections of this report. Each of the alternatives identified in the September 2008 FEMA report were evaluated. In addition, several alternatives that were not identified in the 2008 FEMA report were developed. Analysis of the implementation and regulatory issues associated with the alternatives was aided by our conversations with County personnel, our public meetings, and also through a series of meetings held with Wisconsin DNR and Wisconsin DOT personnel. The evaluation of the flood damage mitigation alternatives considered the following:

1 Effectiveness in substantially reducing flood damage;

2 Cost; and

3 Likelihood of receiving required permits and property owner permission.

The feasibility analysis was completed using a combination of quantitative hydrologic and hydraulic analysis, cost analyses, and evaluation of feasibility based on regulatory, property ownership and effectiveness analyses. A summary of our flood damage mitigation alternatives analysis is presented in **Table 7**, with more detailed discussion below.

Table 7. Summary of flood damage mitigation alternatives analysis

Alternatives identified in September 2008 FEMA report	Recommendation for continued detailed consideration*
Stabilization of the creek banks to pre-1993 conditions	Not recommended
Realignment of the channel of the Creek, combined with 2008 FEMA report Alternative 6, construction of emergency spillway near Maxwell farm	Recommended
Installation of flow diverters to limit streambank erosion in selected areas	Not recommended
Construction of a sediment-trapping basin along the creek	Not recommended
Construction of a dam in the upper watershed of Clark Creek to limit flood discharge	Recommended
Realignment of STH 113	Not recommended

Alternatives identified in September 2008 FEMA report	Recommendation for continued detailed consideration*
Replacing the culverts at the Maxwell farm with a bridge	Recommended for further consideration but must be combined with other measures
Replacing the culverts at the Maxwell farm with a "low water crossing"	Not recommended
Realignment of the STH 113 culverts	Recommended for further consideration but must be combined with other measures
Installation of debris barriers at entrances to culverts	Recommended for further consideration but must be combined with other measures
Installation of perforated standpipes in lieu of standard culverts	Not recommended
Acquisition of damaged or at-risk residential properties ("buyouts")	Recommended for further consideration but must be combined with other measures
Relocation of selected existing structures	Recommended for further consideration but must be combined with other measures
Elevation or flood-proofing of existing structures	Recommended for further consideration but must be combined with other measures
Additional alternatives identified in this study	**Recommendation for continued detailed consideration***
Forest management to reduce woody debris	Recommended
Distributed multiple flood storage areas in upstream watershed	Recommended
Private driveway relocation with alternative access	Not recommended
Channel dredging	Not recommended

***Refer to the detailed feasibility analysis discussion in the following sections**

4.2 FLOOD DAMAGE MITIGATION ALTERNATIVES RECOMMENDED FOR DETAILED CONSIDERATION

(1) Forest management to reduce woody debris

Description

This option would remove woody debris from the stream channel and cut standing trees that are at risk of falling into the channel during the next large flood (**Figure 7**). Work would be conducted between STH 113 and Tower Rd. The project would be designed to control debris for a specified design lifetime (say 20 years), with an intensive initial effort to remove snags and at-risk trees, and maintenance efforts at 5- or 10-year intervals to remove additional debris from the channel. At the end of the design life, the success of the project would be evaluated, and a decision would be made on whether to continue the maintenance effort into the future.

An additional component of this alternative could be to restore understory vegetation in areas of tree clearing in a way that enhances streambank stability. This could provide incremental improvement in soil erodibility, particularly for gully erosion. Judging from the erosive power of past floods, vegetation in the creek bed would probably not withstand a major event. A simple streambank monitoring program would aid in determining appropriate measures for channel erosion control.

Effectiveness

It is widely recognized that debris is a major cause of inundation and structural damages due to blockages in the stream channel and at culverts. Although this option would not reduce the discharge of floodwater, it could significantly reduce the amount of woody debris transported downstream. All properties downstream of Tower Road would benefit from this alternative, although areas near the Maxwell Farm would benefit the most. Sedimentation would likely remain an issue for those near the Baraboo River.

Cost

An allowance of approximately $100,000 is recommended for planning purposes until a more detailed estimate can be developed. Preliminary conversations with contractors indicate that they would need to inspect the site to develop a cost estimate, but that cutting operations such as this typically generate enough revenue to offset costs or possibly even produce a profit. After the snow has melted enough to improve access to this reach of Clark Creek, we recommend a site walk by a forester to help develop a management plan, and site visits by potential contractors to develop cost estimates. The cost of the project will depend on the quality of timber, access details, extent of clearing, restoration efforts, and the need to purchase easements. This reach of Clark Creek is extremely rugged and heavily wooded, making access for heavy equipment challenging, however similar conditions are encountered in many timber harvesting operations.

Implementation issues

Approximately the upper 1/3 of the reach for this maintenance is on state-owned land, and the remaining distance is on private land. Access agreements with the state and private landowners

would be required, possibly requiring purchase of easements. On the state property, it will be necessary to involve a DNR forester in designing the plan for tree removal and any restoration of understory vegetation. To be most economical, it would be desirable to conduct this work as a single sale and harvest; coordinating multiple landowners will likely be one of the most significant issues to address.

(2) Flood diversion channel

Description

A diversion channel approximately 50 feet wide would be constructed to divert flows greater than the 10-year event. Most channel routes would divert flows just upstream of STH 113 culvert #1 at the Maxwell Farm and follow one of a variety of possible routes (**Figure 13**). Two additional options for channel diversions are located further downstream.

Effectiveness

Diversion channels that begin near the Maxwell Farm could divert approximately 50% of large flood discharge, thereby reducing downstream damage in the existing channel from debris and flood volume. Properties downstream of the diversion channel structure would benefit from the reduced sedimentation and flood volume. The scale of the diversion channel that would be required was evaluated using (1) a modified version of the FEMA hydraulic model with a lateral weir added at the diversion point to estimate the discharge of the diverted flow, and (2) Hydraulic capacity calculations to estimate the size the diversion channel needed to carry this flow. The diversion was evaluated using the approximate discharge of the June 12, 2008 flood (see **Section 3.2**).

Routes #5 and #6 divert flow downstream of Maxwell Farm. These options are shorter and less expensive, but have limited benefits. Route #5, which runs on the east side of STH 113 from culvert #1 to culvert #2, would only have benefits for the road and aforementioned culverts. Route #6, which runs along the east side of STH 113 from culvert #3 to the Baraboo River, would reduce impacts for properties and structures downstream of CTH W.

Cost

$300,000 - $2,700,000 plus easements (see the **Appendix** for cost analysis details). The cost of each channel route varies due to length and depth of cut, and the need to cut through bedrock. Additionally, a range of cost estimates is provided for each channel because construction costs depend greatly on the details of spoil disposal. Hauling spoil materials to a separate site will increase costs. Alternatively, the rock spoils may be commercially valuable or could be used in the channel construction.

Implementation issues

The most difficult issue for this option may be obtaining easements for properties. Feedback from the community indicates that each of the channel routes has drawbacks for certain property owners. The new channel raises safety concerns, such as proximity to structures and a CTH W crossing. A

Chapter 30 permit would likely be required for this alternative. Discussions with the DNR indicate that this option is feasible to permit. Ongoing maintenance would be required to keep the channel free of excess debris. Agreements would also be needed to determine who would build, own, and maintain the channel. Discussions with DOT personnel have indicated that it may be feasible to let the project through the DOT.

There are significant engineering issues as well. The channel design must address the issues mentioned above, such as safety. The diversion would reduce flow in both channels, potentially causing sediment to settle. The diversion structure would have to be engineered to minimize sedimentation to prevent flooding at the upstream end of the channel. This could be costly and/or difficult to construct. Routes #1, 2 and 3 would require excavation of quartzite bedrock, which has been factored into their cost estimates, and they are located near an existing high pressure natural gas line. Details of this gas line would have to be reviewed with the utility to determine what impact it would have on design of a diversion channel.

(3) Distributed flood storage in upstream areas of the watershed

Description

A number of small storage areas would be constructed in along Clark Creek tributaries in the upper part of the watershed (**Figure 14**). These storage areas would essentially be small dry dams to provide storage during large flood events. An outlet in the berm would pass low flows and allow fish passage. The storage areas would retain water during large events and release it slowly within a few hours to a few days. Depending on the location, wetland restoration may be included as part of the flood storage creation.

Effectiveness

Peak discharge from a large flood could be reduced by 15 - 40%, depending on how many storage areas are created. All properties downstream of Tower Road could benefit from this alternative. The 40% reduction was achieved by converting approximately 160 acres of land to storage as shown in **Figure 14**. The reduction in peak discharge could significantly reduce damage downstream from sedimentation, debris, and flood volume.

The peak attenuation was determined by modifying the existing HEC-HMS model to include storage at proposed locations. The model was evaluated using the June 12, 2008 flood conditions (see **Section 3.2**). Storage areas were modeled using a 4 to 6-foot tall berm with a 4-foot diameter culvert passing low flow. High flows were passed by a 50-foot long weir at an elevation 0.5 feet lower than the berm. In some cases a secondary overflow was modeled if the berm overtopped during the 100-year event. Peak flow was evaluated at the HEC-HMS component located 1000 feet upstream of STH 113.

Cost
Approximately $500,000 - $700,000 plus long-term maintenance. Cost estimates may change based on how many storage areas are created. See the **Appendix** for details of estimated cost analysis.

Implementation issues
The primary concern for this alternative is environmental impacts, particularly for trout and wetlands. Although information is incomplete, DNR has reports that a naturally reproducing brook trout population exists in Clark Creek. Modifications to the stream network that affect habitat, flow and water quality will need to consider impacts on this population. Permit requirements for reduced impact to fish habitat may reduce the effectiveness of the storage areas for flood control. A Chapter 30 permit would be required, as well as a dam permit if the stream is considered navigable. The small dry dams would be constructed on DNR property and would be restored in conjunction with their land management plan.

Some of the proposed flood storage areas are located on restored wetland installed by US Fish and Wildlife Service (USFWS). The restoration was funded by a Federal grant of approximately $40,000 that would likely need to be returned if flood storage areas were constructed in the restored wetland. If the proposed storage areas in this wetland were eliminated, HEC-HMS predicts that the peak discharge of a large flood would only be reduced by about 15%.

The storage areas would require ongoing maintenance for flood control efficiency and environmental/permitting requirements. Agreements would also be needed to determine who would build, own, and maintain the storage areas. A small portion of the proposed storage areas are on private land, and easements may be necessary. Flood control effectiveness may be reduced if some of the land is unavailable or unsuitable for storage.

It is possible that environmental permitting issues would require design changes that would substantially reduce the effectiveness of these storage areas. If permitting issues are too restrictive, off-line storage areas could be created. These berms would hold back water for flood control but would not be located in the stream. It would be difficult to achieve the same reduction in flood discharge with offline basins.

(4) Flood control dry dam on Clark Creek near Tower Road

Description
A dry dam 20 feet or more high would be constructed at the confluence of two tributaries of Clark Creek just north of Tower Road (**Figure 15**). The dam would have no permanent pool; water would be retained during flood events and drain down through a culvert outlet within a few hours to a few days.

Effectiveness
The dam could reduce a large flood discharge by about 40%, reducing damage downstream from sedimentation, debris, and flood volume. All properties downstream of Tower Road could benefit from this alternative.

The peak attenuation was determined by modifying the existing HEC-HMS model to include storage at the dry dam. The dam was modeled as a 26-foot high weir with an overflow 100 feet long and a 6-foot diameter low-flow outlet. A dam with a culvert smaller than 6 feet in diameter would result in better flood control; however, it is likely that permitting requirements would necessitate an outlet size of 6 feet or greater for fish passage. Peak flow was evaluated at the HMS component located 1000 feet upstream of STH 113. The model was evaluated for the approximate rainfall of the June 12, 2008 flood (see **Section 3.2**).

Cost
Approximately $400,000 – $600,000 plus significant ongoing maintenance (see the **Appendix** for further detail).

Implementation issues
There are substantial environmental, permitting, and safety issues for construction of a dam. A Chapter 30 and a dam permit would be required. Permit requirements for fish passage and reduced impacts on the upstream and downstream channel habitat may significantly reduce the effectiveness of the dry dam for flood control. The dam site is located on DNR property, raising questions regarding ownership, long-term agreements and maintenance. Additionally, feedback from stakeholders indicates that most are not comfortable with a large dam upstream of their community.

(5) Purchase of structures

Description
Private properties could be purchased to remove structures from the floodplain.

Effectiveness
This option would relieve participating property owners from risk of flooding on Clark Creek. It would not reduce the flow of floodwater, debris or sediment, and therefore would not alleviate flooding impacts to other properties.

Cost
Depends on value of individual properties. Total property value along Clark Creek from STH 113 culvert #1 to the Baraboo River is $4.1 million, and the value of properties downstream of

CTH W is approximately $1.6 million. FEMA buy-out programs typically include a 25% local cost share.

Implementation issues
The Commerce grant requires that land owners be willing to sell their properties and qualify as low to moderate income households; these issues would need to be discussed with individual property owners.

Federal funding assistance may be available through a variety of grant programs administered by the Wisconsin Department of Military Affairs / Division of Emergency Management.

- The *Hazard Grant Mitigation Program* applies only when a disaster has been declared by the president anywhere in the State of Wisconsin. There is no current disaster declaration. During a disaster declaration, the federal government allocates funding depending on the level of damages, and successful projects receive 75% federal funding and 12.5% state funding, with a 12.5% local cost share.
- The *Pre-Disaster Mitigation Program* can be applied for at any time and is a national competition for federal assistance. Applicants must contribute 25% of the cost, and the local community must have an approved local mitigation plan (Sauk County does).
- The *Flood Mitigation Assistance Program, Repetitive Claims Program*, and the *Severe Repetitive Loss Program* provide federal funding to states to reduce the cost to the National Flood Insurance Program (NFIP). This funding is applicable only to structures insured through the NFIP; some of the properties damaged in June 2008 are located outside of the mapped floodplain and may not participate in the NFIP. The Flood Mitigation Assistance Program requires a 25% local cost share and prioritizes properties with multiple claims to the NFIP. The Repetitive Claims Program and the Severe Repetitive Loss Program provide up to 90-100% federal funding for properties with repeated NFIP claims.

(6) Flood proofing structures

Description
The most feasible floodproofing methods for houses along Clark Creek would be to elevate them on raised foundations or on earthen fill to raise their first floor elevations well above the elevation of the design flood, or to simply fill in basements where the first floor elevation is sufficiently above the design flood elevation. This could entail raising a structure's foundation in its existing location, placing fill and moving the structure, or placing fill and building a new structure. Basements would be eliminated, because they would remain subject to inundation directly by floodwaters or by elevated groundwater.

Effectiveness
This option could prevent inundated of houses by floodwaters during an event similar to June 12, 2008. However, it would not reduce other types of impacts, including roadway damage and sedimentation, and it would likely not provide dry-land access to houses during a large flood.

Cost
$50,000 or more per house.

Implementation issues
The integrity of each structure would need to be inspected to determine the feasibility of elevating it. Permits would be necessary for fill placement in the mapped floodplain. Potential federal funding sources are the same as described above for purchasing structures.

4.3 ALTERNATIVES TO CONSIDER IN COMBINATION WITH OTHER MEASURES

(7) Replacing STH 113 culvert #1 with a bridge

Description
This option would replace the existing concrete box culvert just downstream of the Maxwell Farm with a bridge span of approximately 40 feet to provide enough capacity to pass the 100-year flood without overtopping the highway.

Effectiveness
Increasing the conveyance of this highway crossing would somewhat reduce the upstream flood elevation, providing some relief to adjacent property owners. It would not reduce downstream flood discharge or impacts. A larger span would be less prone to debris clogging, however the volume of debris transported in the June 12, 2008 flood would likely still clog such a bridge opening.

Cost
$150,000 - $200,000

Implementation issues
Replacement of a structure on STH 113 would require the cooperation of DOT. Such a replacement is not currently in DOT's plans for the next 15 years, although it would be feasible if funded completely by the county.

(8) Culvert realignment/replacement

Description
Existing culverts on STH 113 and CTH W could be replaced with structures that have higher capacity, with larger openings aligned more parallel to flood flows.

Effectiveness
This option could modestly reduce the potential for damage to roadways and diversion of floodwaters when culverts are overwhelmed. The hydraulic model profile shows that the 100-year flood and larger events overtop STH 113 and CTH W at each culvert, raising the upstream flood elevation and affecting adjacent properties. However, even elimination of these road crossings is not likely to substantially reduce flood impacts, and larger structures would remain susceptible to clogging with debris and sediment.

Cost
$80,000 - $110,000 per culvert

Implementation issues
Replacement of structures on STH 113 would require the cooperation of DOT. Such a replacement is not currently in DOT's plans for the next 15 years, although it would be feasible if funded completely by the county.

(9) Driveway relocation

Description
This alternative would remove existing driveway culverts for 2 private residences north of CTH W with a shared driveway on the east side of these properties. The new driveway would be routed north to CTH W (**Figure 16**).

Effectiveness
Removal of the culverts would modestly reduce flooding of adjacent properties by lowering flood elevations. These culverts are also reported to cause lateral scouring of STH 113 during large floods. Residents would have dry land access during large floods.

Cost
$100,000 - $150,000, depending on route.

Implementation issues
Based on initial conversations with local property owners, it will likely be difficult to find a route for a new driveway that is acceptable. The owners of properties currently served by the driveway culverts would also have to be willing to make this change.

4.4 INEFFECTIVE OR INFEASIBLE ALTERNATIVES

(10) STH 113 realignment

Description
State Highway 113 could be routed to the east of creek downstream of existing culvert #1, which would remain (**Figure 17**). Culverts #2 and #3 would be removed, and several private driveway culverts could also be removed. New driveways would connect to the rerouted portion of STH 113. It is likely that one house would have to be removed and/or a new creek crossing would be required, depending on the exact route selected.

Effectiveness
This option would eliminate 1 or 2 crossings of Clark Creek and move a portion of the highway much farther from the Creek, reducing the risk of damage to the highway. However, the culvert #1 crossing would remain, and the highway would have to connect to the Baraboo River bridge which is a flood-prone area. Removal of highway and driveway culverts would somewhat reduce flood elevations immediately upstream, providing some reduced risk for adjacent property owners. This option would not improve downstream inundation or sedimentation.

Cost
$1,200,000 - $1,800,000

Implementation issues
This option would require the cooperation of DOT and the affected private property owners. DOT does not plan major maintenance to STH 113 in the next 15 years, and certainly not such a major reconstruction project. Finding a route suitable to affected property owners will likely be difficult.

(11) Stream channel stabilization

Description
Riprap or other armoring would be placed along the channel from Tower Rd. to STH 113 near the Maxwell Farm. This would require very large rip rap or other very durable armor, with deep embedment for toe scour protection. The channel bed would remain mobile / unarmored.

Effectiveness
This alternative would have limited benefits. Bank scour and transport of sediment would be reduced, but scouring of the stream bed would continue to generate sediment. The channel bed could also be armored, but this would significantly increase cost and environmental impacts. This option would not control scour and sediment transport downstream of STH 113.

Cost
Approximately $2,000,000 – $4,000,000.

Implementation issues
Extensive environmental permitting would be required, and potential impacts on the habitat of Clark Creek would be substantial. The project would have to be implemented on both public and private lands, and construction access and long-term maintenance easements would be required. The rugged topography and dense forest would make construction logistically very difficult.

(12) Stabilization of eroding bluffs

This option was judged to be ineffective and not evaluated in detail. Shear vanes or other hydraulic structures to divert flow away from eroding bluffs would only address a small portion of the sediment source upstream of STH 113. Given the magnitude of flood flows, the structures would have to be very large and heavily armored; typical construction with boulders would not be durable enough to withstand large floods.

(13) Channel realignment

This option was judged infeasible and not evaluated in detail. It would entail completely relocating the Clark Creek channel, rather than diverting part of the flood flows, as described above. This option would have greater impacts to the stream habitat and would require more complex permitting. It also would take away the low-flow channel that several current landowners enjoy. It also does not take advantage of the existing Clark Creek channel, which is capable of safely conveying a portion of a large flood discharge.

(14) Sediment traps

This option was judged ineffective and not evaluated in detail. As described above, the volume of sediment transported in the June 12, 2008 flood was enormous – perhaps 50 ac-ft or more. Creating enough storage along the stream channel to trap a significant portion of this sediment would be infeasible. An indication of this is the fact that the modest floods of 2010 completely filled in the sediment traps constructed recently by DNR.

(15) Channel dredging

This option was judged ineffective and not evaluated in detail. As discussed previously, the volume of sediment transported during rain events is very large. This alternative would have only temporary benefits until the next significant storm filled in the channel again. Sauk County proposed dredging the channel after the 2008 event, but the project was deemed infeasible until the cause of the flooding was addressed.

(16) Low water crossing at STH 113 culvert #1

This option was judged infeasible and not evaluated in detail. DOT has indicated that a low water crossing on STH 113 would be unacceptable. While this option might alleviate debris clogging and

scouring at this road crossing, debris would accumulate at the next constriction downstream and presumably create similar problems.

4.5 ALTERNATIVES THAT ARE ALREADY PLANNED

(17) Culvert debris barriers / standpipes

DOT plans to install a steel debris rack on the upstream side of STH 113 culvert #1 at the Maxwell Farm in the summer of 2011. While this rack would likely be overwhelmed by the volume of debris transported in June 2008, it will provide some improvement for smaller events and for large floods, if upstream debris is reduced. Designing a system to capture the huge quantity of debris transported in 2008 was judged to be infeasible, and, even if possible, trapping such a quantity of debris would run the risk of catastrophic failure of the debris trap.

(18) Watershed land use management

Most of the Clark Creek headwaters is owned by DNR and is in conservation land cover that reduces runoff generation. Over the next 10 years, DNR intends to convert the remaining working agricultural land on state property to natural habitat, such as prairie or forest. This will incrementally reduce large storm runoff; the overall impact is expected to be modest due to the relatively small fraction of the watershed that will be converted, and the underlying shallow bedrock which tends to cause rapid runoff.

5 RECOMMENDATIONS

5.1 RECOMMENDED PRIORITIZATION OF ALTERNATIVES AND ACTION PLANS

We recommend four of the alternatives that we have analyzed for detailed consideration by Sauk County for implementation. Our view of the prioritization of these alternatives is summarized below:

1 ***Forest management to reduce woody debris.*** *The accumulation of woody debris at the STH 113* culvert was a major cause of flood damage, and control of this debris would substantially reduce the potential for culvert overflow. Removal of existing woody debris in and adjacent to the Clark Creek channel would be relatively inexpensive. The County should strongly consider pursuing this action regardless of whether other flood damage mitigation actions are taken. Action plan:

   a. Develop details of tree clearing and other vegetation restoration. We have contacted DNR forester Rick Livingston, who is planning to walk the creek in early March or once the snow melt permits access and can provide recommendations.

   b. Get estimates of the cost of logging and potential market value from contractors.

   c. Evaluate the cost and procedure for temporary and permanent access easements with private landowners and the state.

   d. Evaluate contracting options

   e. Solicit bids for logging and debris removal

2 ***Flood storage dry dam in the upper reach of Clark Creek near Tower Rd***. Placement of a single earthen embankment dry dam in the upper reach of Clark Creek could substantially reduce extreme flood peak discharge. However, stream habitat impact and concern about the placement, ownership, and maintenance of a large storage reservoir in the upstream portion of the watershed may limit the County's and community's interest in this option. The County should further develop technical and environmental review of this option and reach a conclusion regarding their desire to construct, own and maintain the flood storage structures. Action plan:

   a. Confirm with DNR dam safety staff that the flood storage dam would likely be considered high hazard, and schematically evaluate the design for the low-level outlet and the emergency spillway.

   b. Confirm the likely design requirements for the culvert outlet regarding fish passage and stream habitat impacts with DNR environmental personnel. This work will probably include on-site stream habitat evaluation.

   c. Discuss the project with Wisconsin DOT. DOT may consider cost-sharing for this project, because it will reduce the discharge is arriving at the STH 113 culverts. However, DOT will probably not be willing to complete the design or be the contracting agent for the flood control storage reservoir.

d. Reevaluate planning level costs and confirm long-term operation and maintenance requirements.

e. Arrange meeting of County board members to determine if the maintenance and risk associated with owning a dam is acceptable.

f. If the alternative is supported by the County, meet with DNR to discuss permit requirements and submit a permit application.

g. Pending permit approval, develop a detailed design. The design would need to address permit requirements, safety concerns, sedimentation, fish passage, and long-term maintenance.

3 ***Flood diversion channel***. Several options for flood diversion channel layouts are described in this report. This option has the potential to very substantially reduce the potential for flood damage downstream of the diversion point. However, this alternative is relatively expensive, and the ability to implement this option will depend on acquiring a real estate corridor for the channel. The County should determine whether the real estate corridor could realistically be acquired before investing additional effort in this alternative. Action plan:

a. Arrange meeting of landowners along potential diversion routes to determine if an acceptable route can be identified.

b. Negotiate easement agreements and costs, as necessary.

c. If a route is found, meet with DNR to discuss permit requirements for the specific route and submit a permit application.

d. Wisconsin DOT has expressed a willingness to consider cost-sharing and/or being the contracting agent for the diversion channel, as it would provide relief to the STH 113 culvert crossings. Discuss cost-sharing and letting of the project through DOT to take advantage of cost savings this could provide.

e. Get construction cost estimates and potential market value of rock spoils from contractors.

f. Pending land availability and permit approval, develop a detailed design. The design would need to address sedimentation at and downstream of the diversion point, a method for crossing CTH W (e.g. a low water crossing), and a plan for long-term maintenance.

4 ***Distributed upland storage to reduce the flood discharge***. This option has the potential to be a "win-win", providing flood storage combined with native habitat restoration on state-owned (and potentially privately owned) land in the upstream portion of the watershed. The County should work with DNR land managers and other environmental personnel to confirm the number and location of storage units that could realistically be implemented, and then carefully consider costs are and benefits based on these trade-offs. Action plan:

a. Develop permit application materials and submit to DNR for review.

b. Work with DNR to develop design details that can be permitted and provide flood protection. Monitoring will be needed to determine the status of aquatic species present in Clark Creek.

c. Work with USFWS and DNR to determine options for the restored wetland off Newman Road.

d. Obtain hydraulic calculations from DNR for modifications to the USFWS wetlands, if necessary.

e. Obtain a final determination from DOT about the availability of funding for this option as part of a wetland mitigation bank.

f. Decide whether to proceed with final design and construction based on the effectiveness of the design after any modifications to accommodate permit requirements.

Additional alternatives that could be effective in providing localized benefits include:

- ***Installation of a debris barrier at Culvert #1 on STH 113***. This alternative is already being planned by Wisconsin DOT. Action plan:
  - The County should work with DOT to track design development progress and assist as necessary.

- ***Acquisition, relocation or floodproofing of existing homes or other structures***. This alternative would not alleviate the potential effects of future flooding, but would reduce potential damages at selected structures. Although FEMA cost-share funding is potentially available for assistance in these actions, it probably will not be available in the near future, and review of proposed buyout or modifications to homes may not meet FEMA benefit/cost analysis criteria. The County could choose to implement buyouts directly, without subsidy. The County should maintain contact with the state office of emergency government to confirm criteria and program funding availability. Action plan:
  - Discuss this possibility with the most affected property owners.
  - Determine eligibility of these property owners for use of Commerce grant funds.
  - Determine participation in NFIP and history of past claims.
  - Consider applying to the Pre-Disaster Mitigation Program, especially for properties without flood insurance, and to the Flood Mitigation Assistance Program, Repetitive Claims Program or Severe Repetitive Loss Program for properties with previous NFIP claims.

- ***Replacing or realigning the STH 113 culverts at the Maxwell farm (culvert #1) or the 3 State and County highway culverts further downstream***. Replacement of these structures will provide only localized benefit. The County should track pursue the more highly recommended actions before evaluating these alternatives in detail.

5.2 ADDITIONAL ACTIONS

In addition to the activities described above, we recommend that the County plan for continuing work on this project as follows:

1 The County should begin discussions promptly with the Wisconsin Department of Commerce regarding extending the eligibility period for the Community Development Block Grant. We recommend this approach because it is unlikely that the County will be able to complete decision-making, design and implementation of all of the flood damage mitigation alternatives projects it may decide to complete by the end of 2011.

2 The County should designate a lead project manager for continuing work on this project, and develop a schedule for technical activities, meetings and decision-making to be completed in the next several months. Continued progress on decision making for selecting implementation alternatives will require someone to focus on the multiple issues, options, conflicts and opportunities that need to be evaluated.

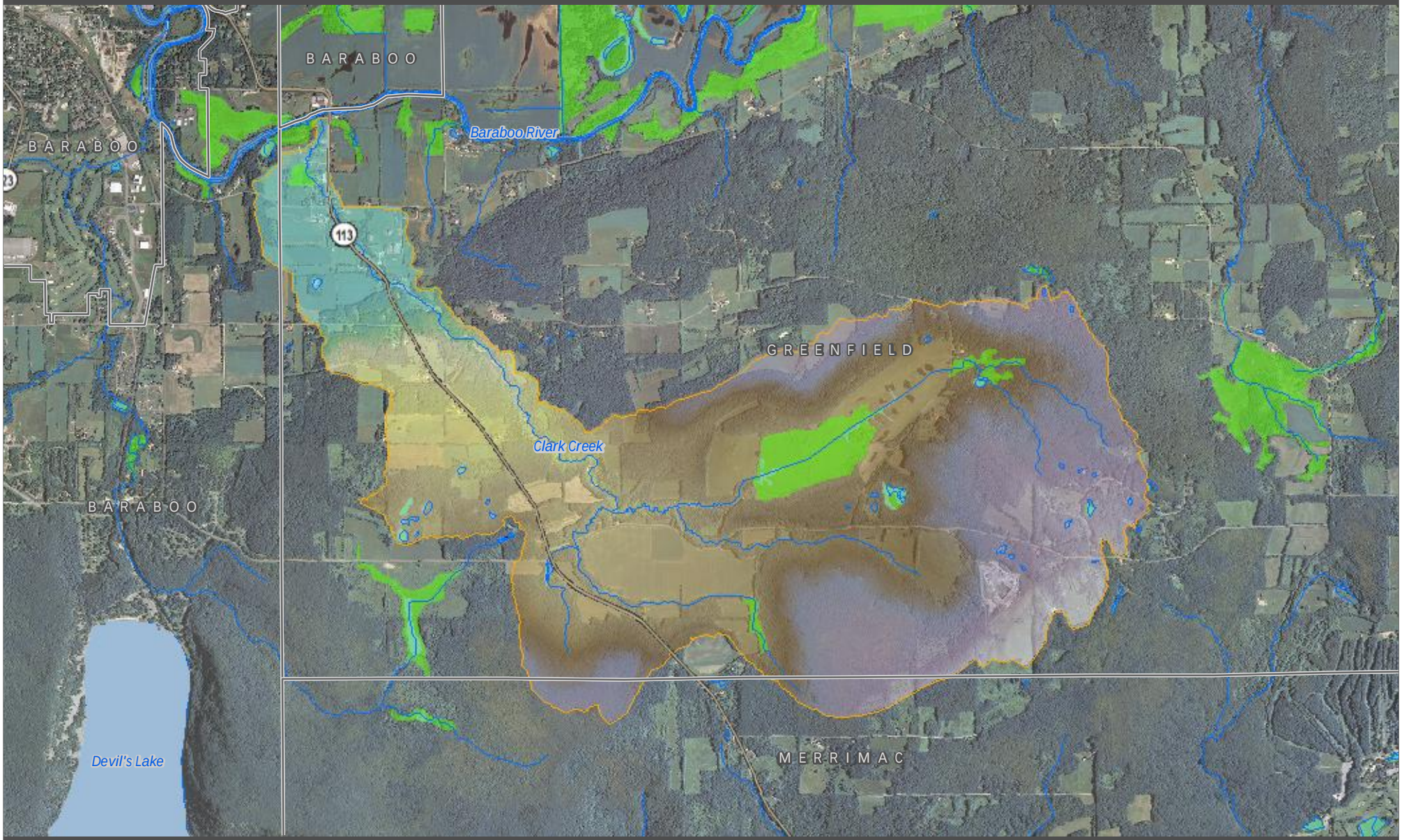
3 The County should establish regular continuing communication with Wisconsin DNR, Wisconsin DOT and other relevant organizations. We have had substantial collaborative and cooperative meetings with both DNR and DOT personnel on this project, and we have also had cooperative conversations with additional agencies such as NRCS and the US Fish and Wildlife Service. Continuing communication with these agencies, as well as with non-governmental-organizations that have an interest in this area will be essential in understanding permitting and process issues that will affect implementation of the potential alternatives.

FIGURES

Clark Creek Watershed Study
Sauk County, WI

FIGURE 1
Watershed Map

Montgomery Associates: Resource Solutions, LLC
119 South Main Street, Cottage Grove, WI 53527
(608) 839-4422 | www.ma-rs.org | 03/01/2011

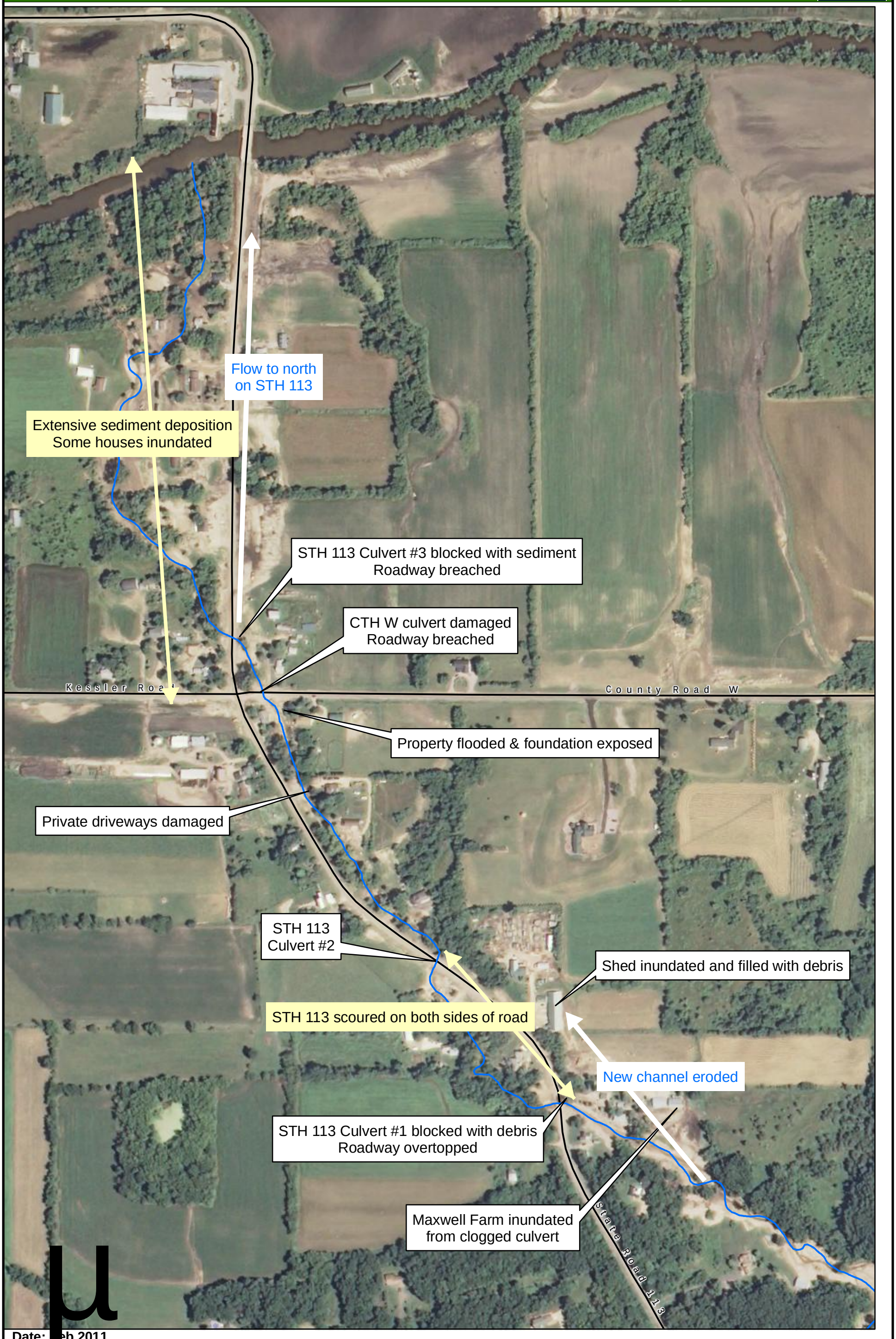


Feet
0
3,000
1 inch = 3,000 feet

Clark Creek Watershed Boundary
Wisconsin Wetlands Inventory
Hydrography
Hydrography: Water Bodies

Figure 2: Aerial Photograph of 2008 Flood Damage Area

Montgomery Associates
119 South Main Street
Cottage Grove, WI 53527



Date: Feb 2011
Developed by ACD

*Only selected damages shown. Flood damages are discussed further in report section 3.1.

Figure 3: Aerial Photograph of Debris Jam at STH 113 Culvert #1

Montgomery Associates
Resource Solutions, LLC

Figure 4: Assessed Property Values Along Clark Creek

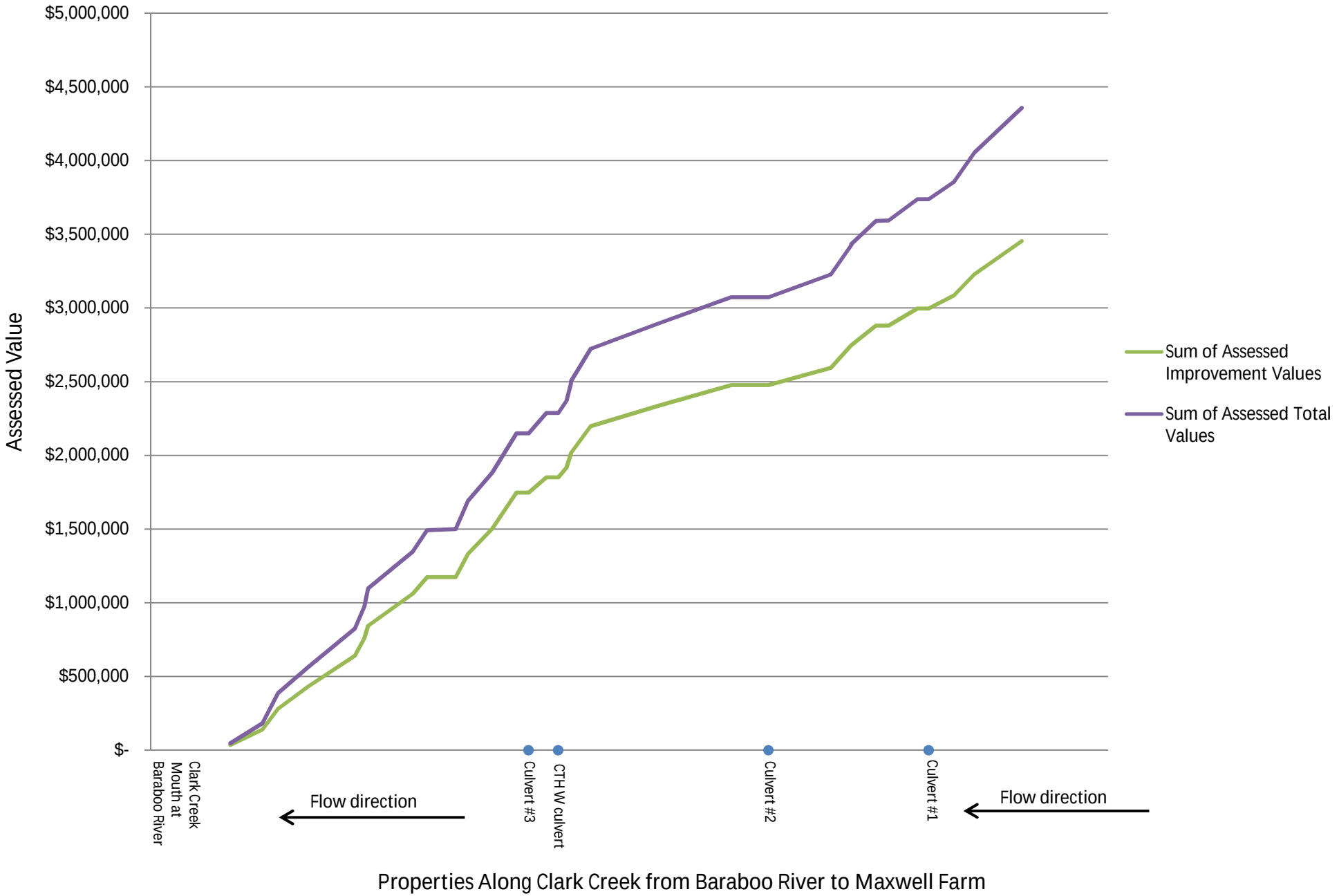
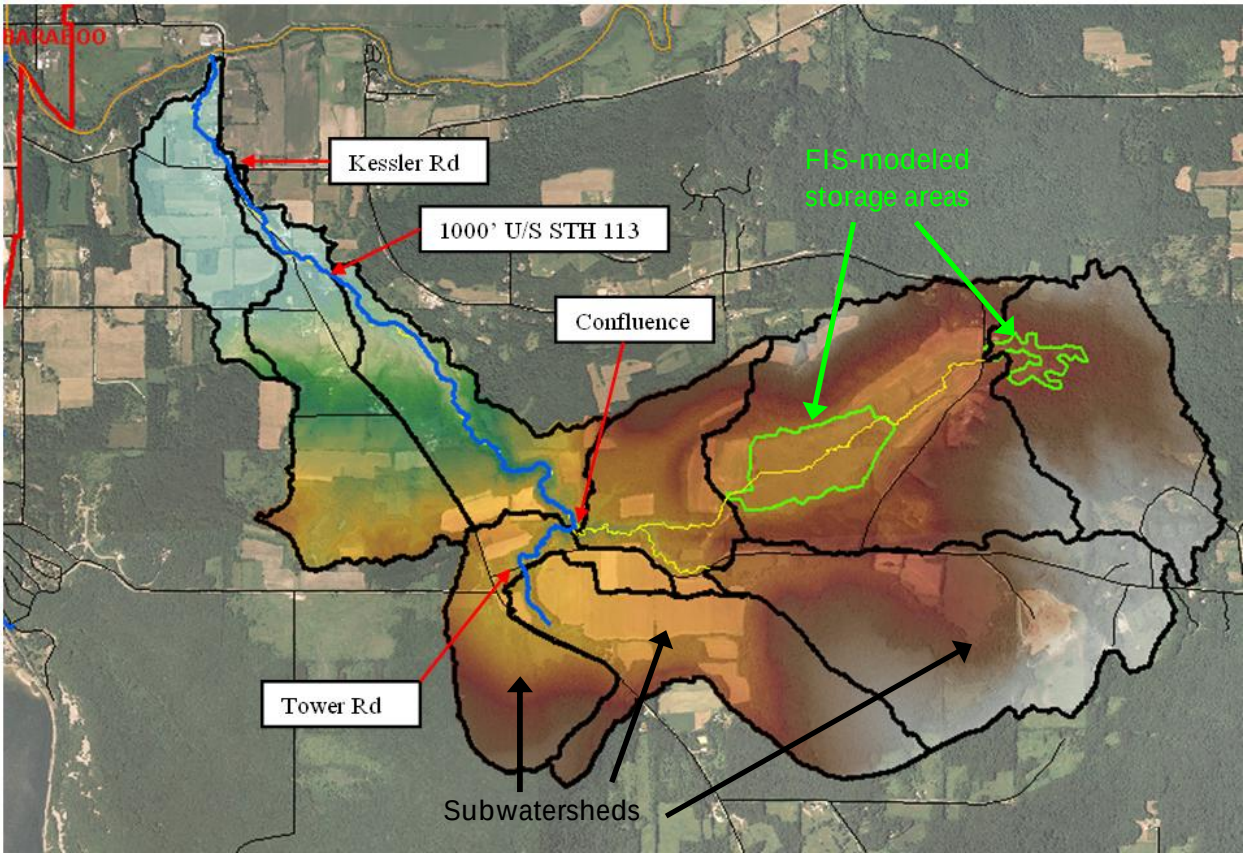


Figure 5: Watershed Hydrologic Model Layout



Above: Layout of watersheds in model. Below: HEC-HMS components.

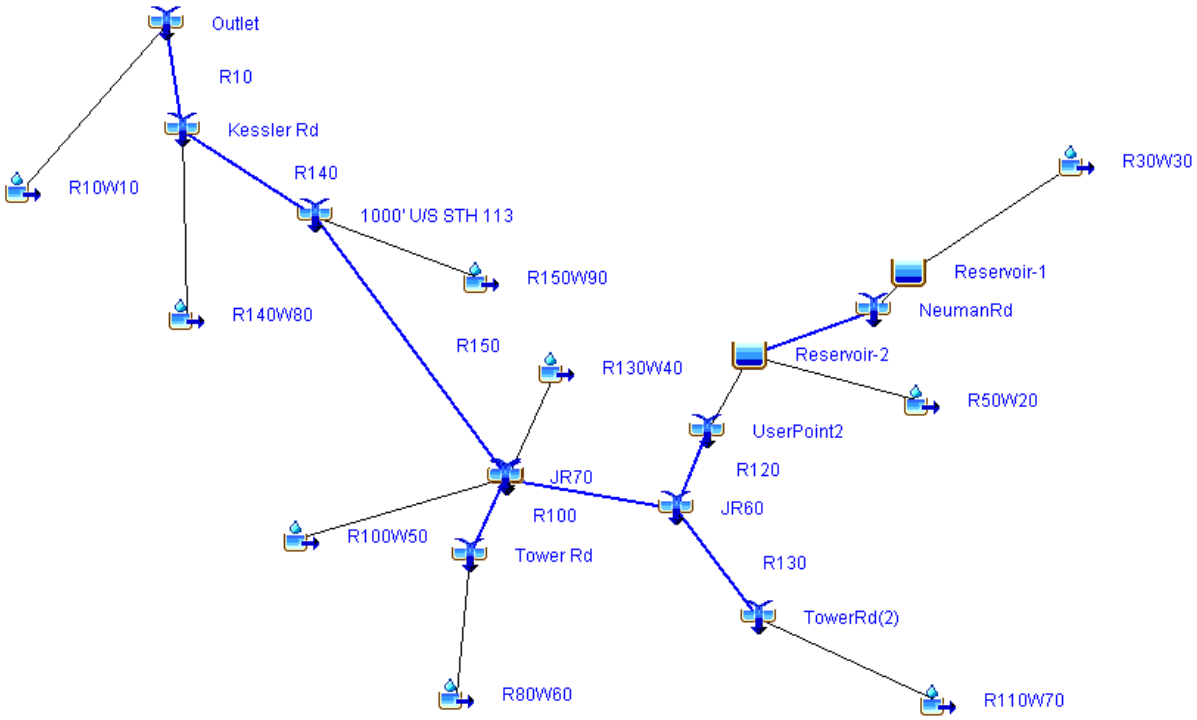
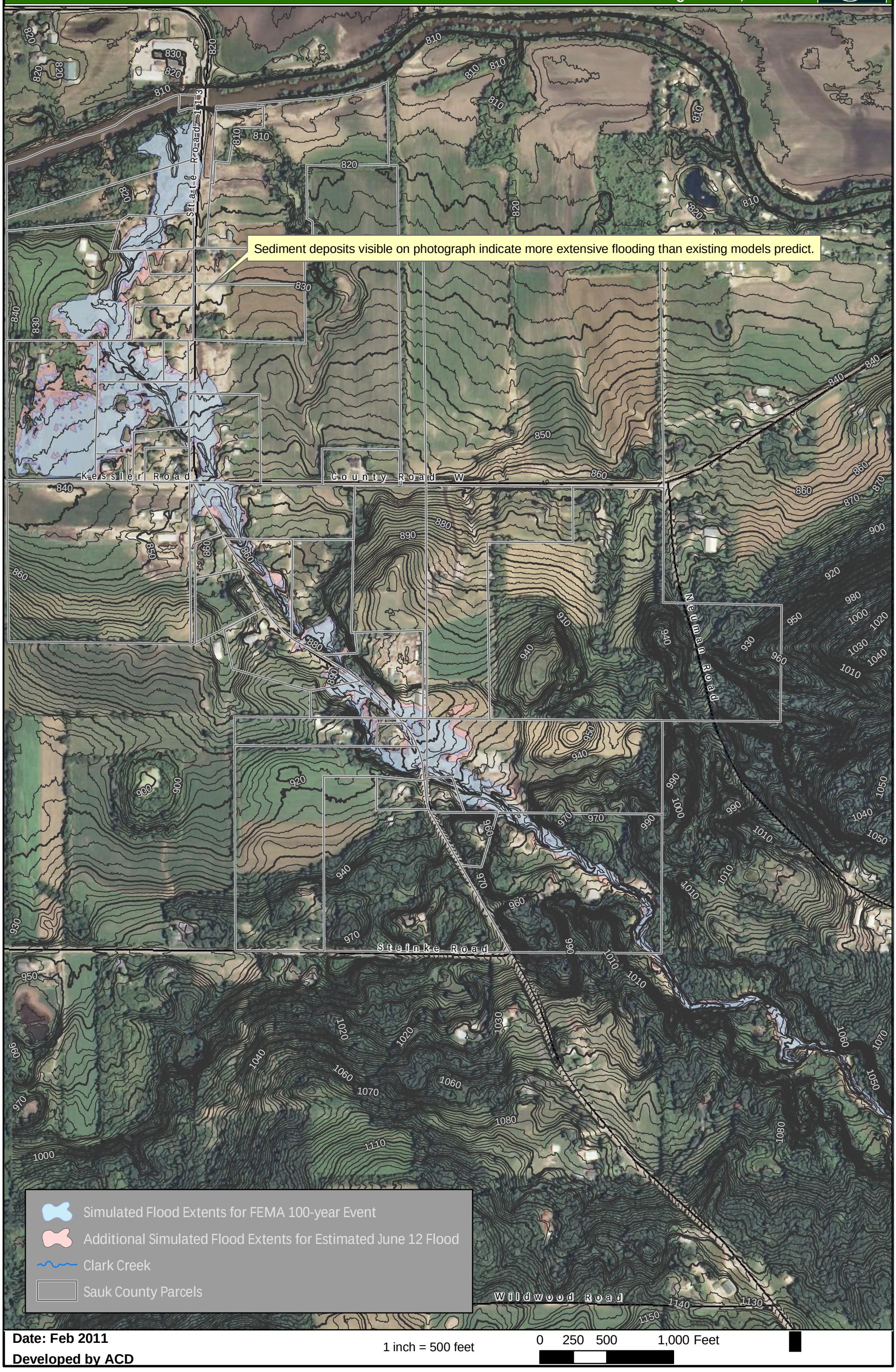


Figure 6: Hydraulic Model Simulation of June 12, 2008 Flood

Montgomery Associates
119 South Main Street
Cottage Grove, WI 53527



Date: Feb 2011
Developed by ACD

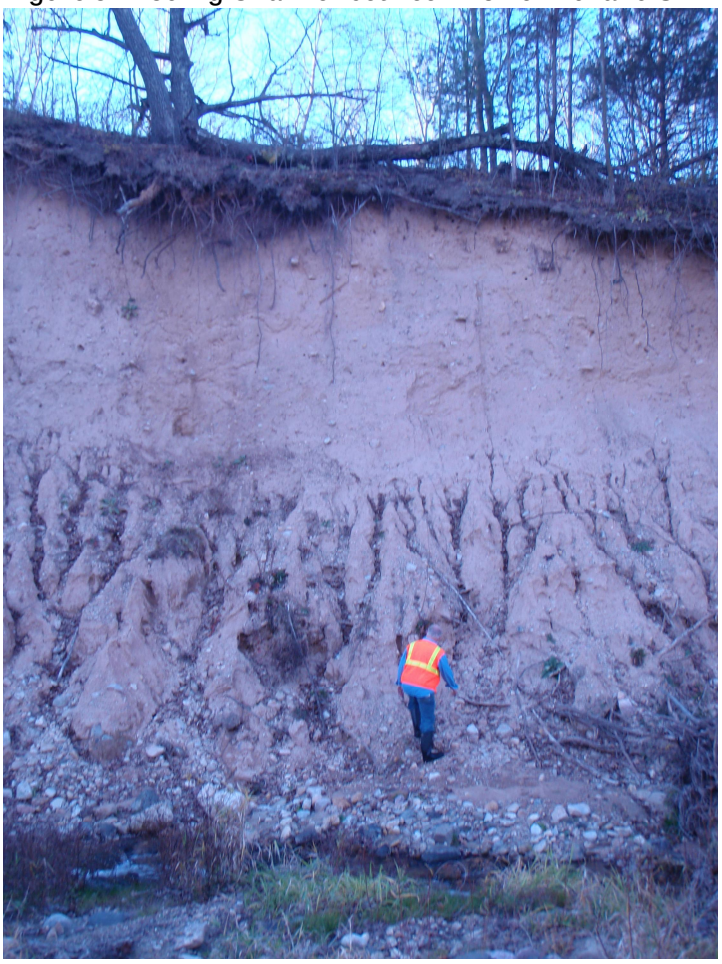
1 inch = 500 feet

0 250 500 1,000 Feet

Figure 7: Woody Debris in Clark Creek Channel Between Tower Rd. and STH 113

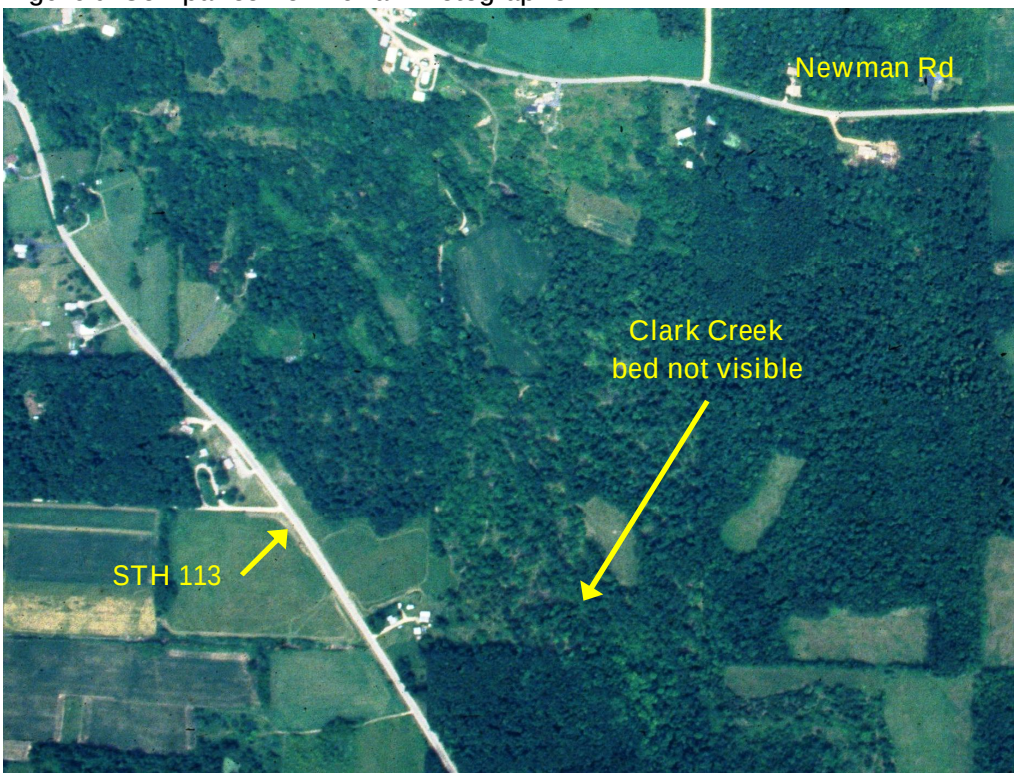
Figure 7 (continued).: Woody Debris in Clark Creek Channel Between Tower Rd. and STH 113

Figure 8: Eroding Channel between Tower Rd. and STH 113



Above: Eroding bluff. Below: Cobbles and boulders in bars along the channel.

Figure 9: Comparison of Aerial Photographs



Above: 1992 aerial. Below: 1994 aerial.

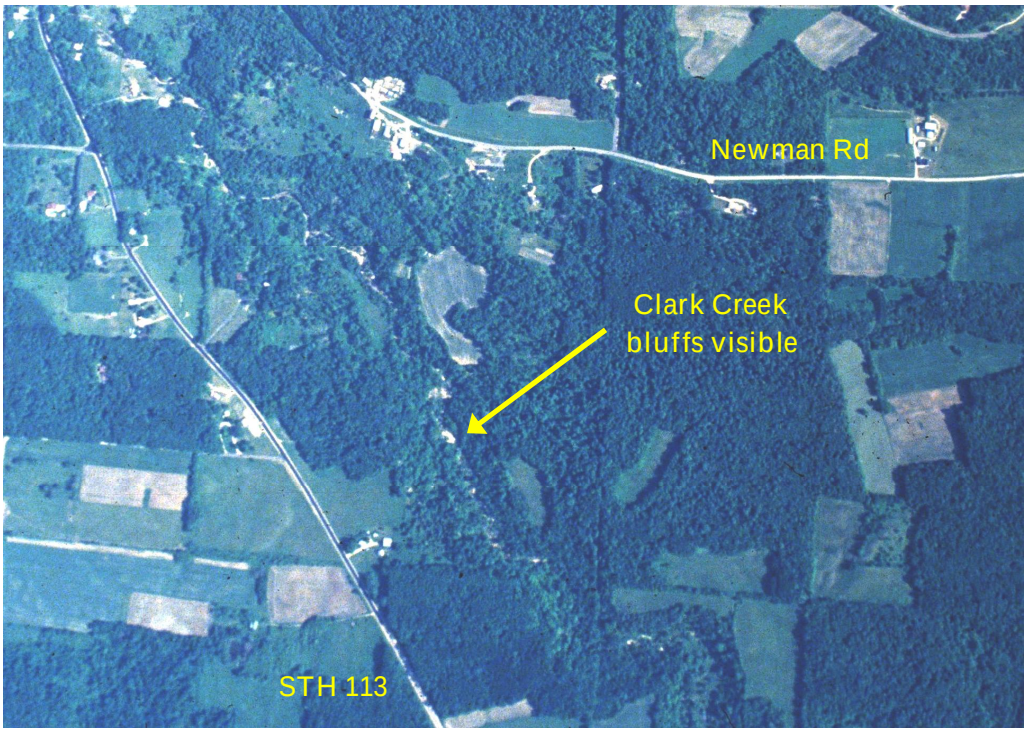
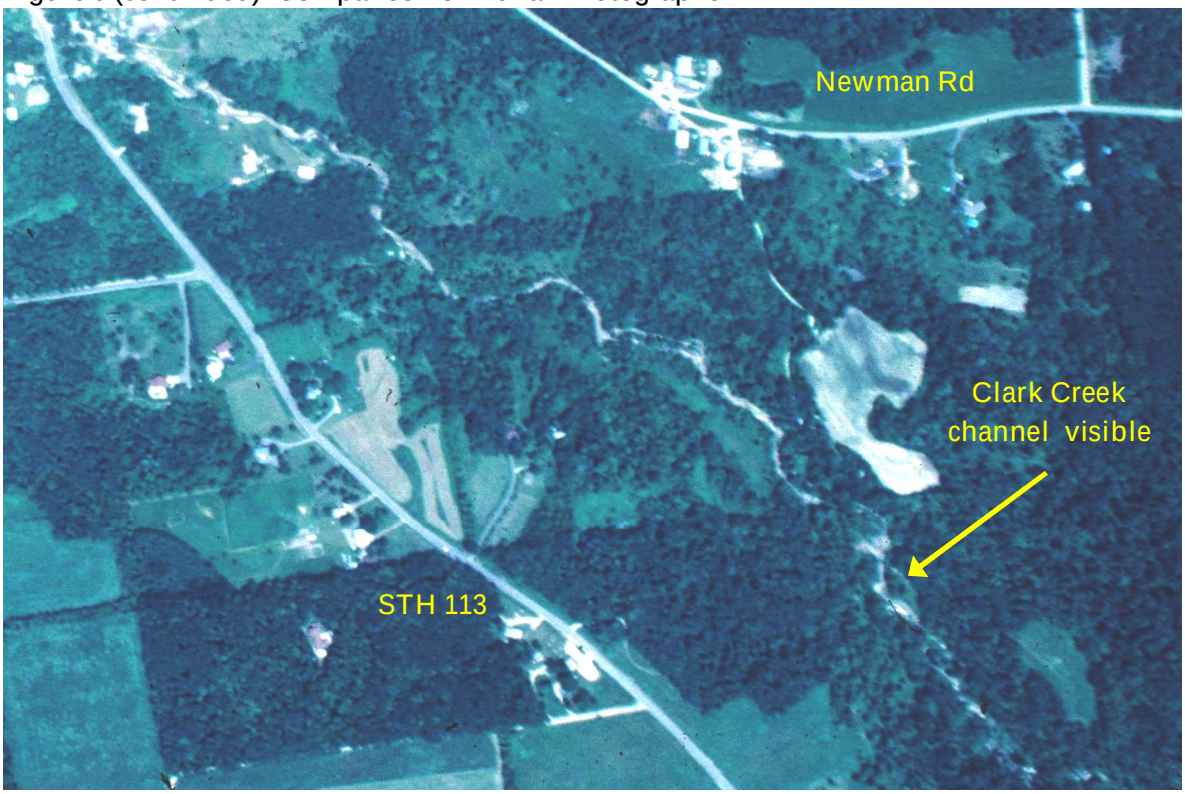


Figure 9 (continued): Comparison of Aerial Photographs



Above: 1996 aerial. Below: 2000 aerial.

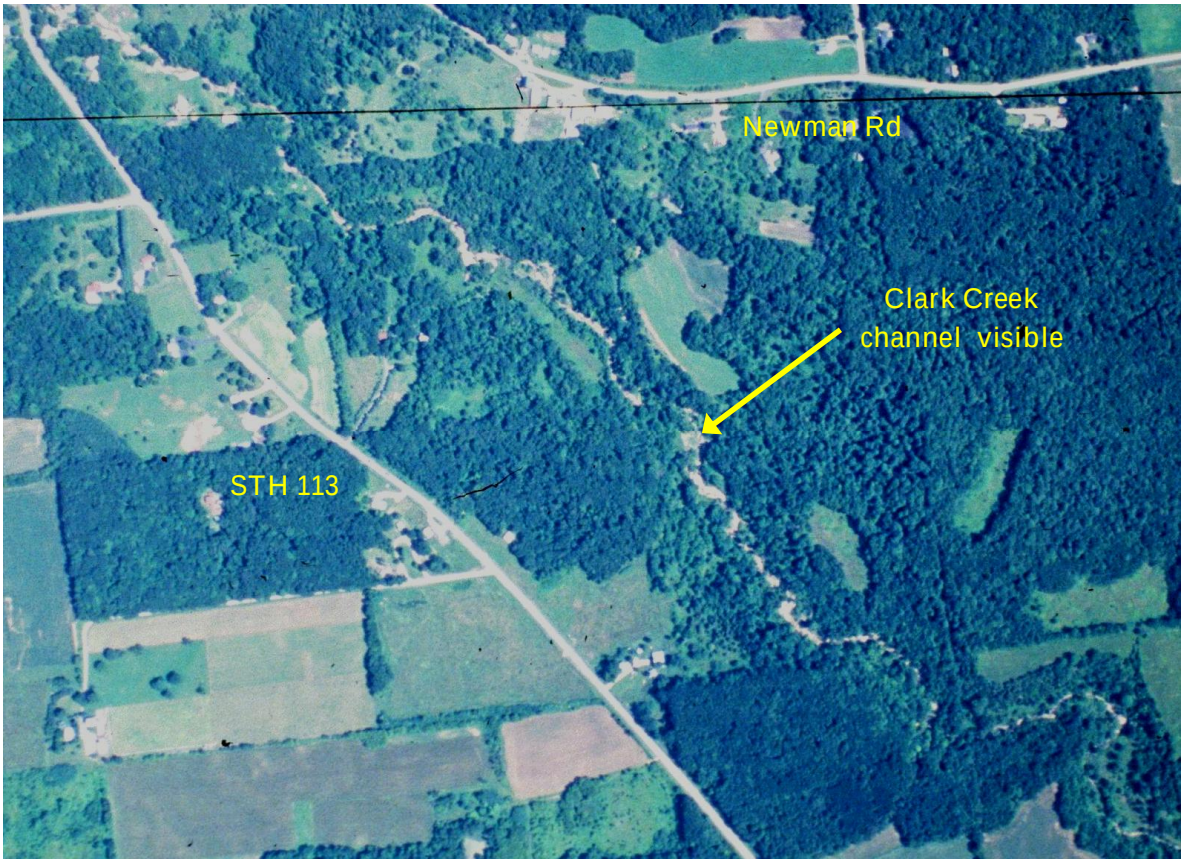


Figure 10: Change in Stream Channel Location Since 1840

Above: 1840 Survey Map. Below: 1840 Survey Map overlaid on 2010 aerial photograph showing historical changes in stream channel.

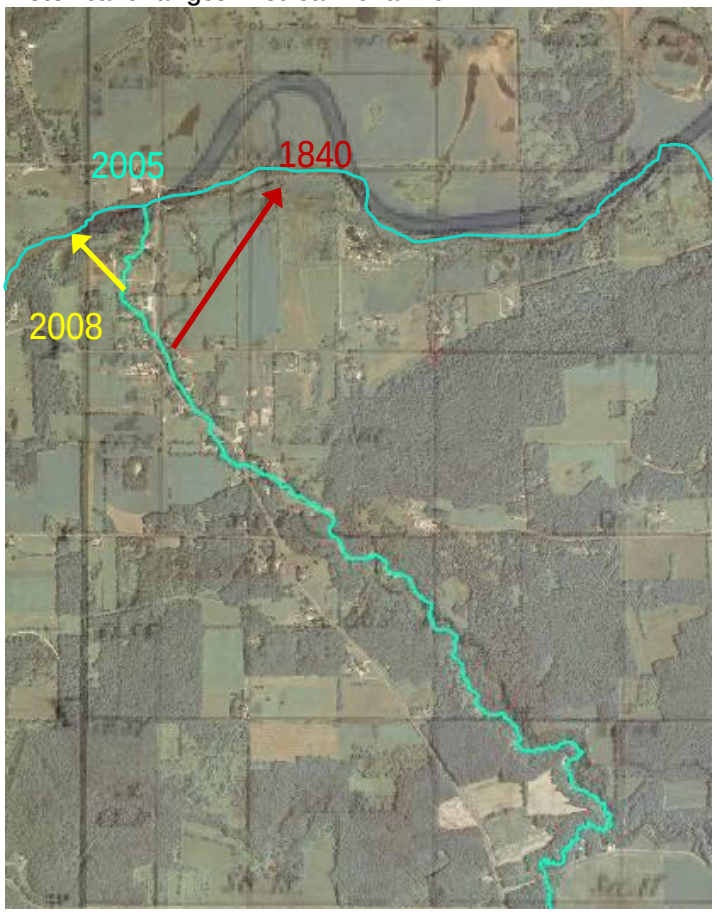
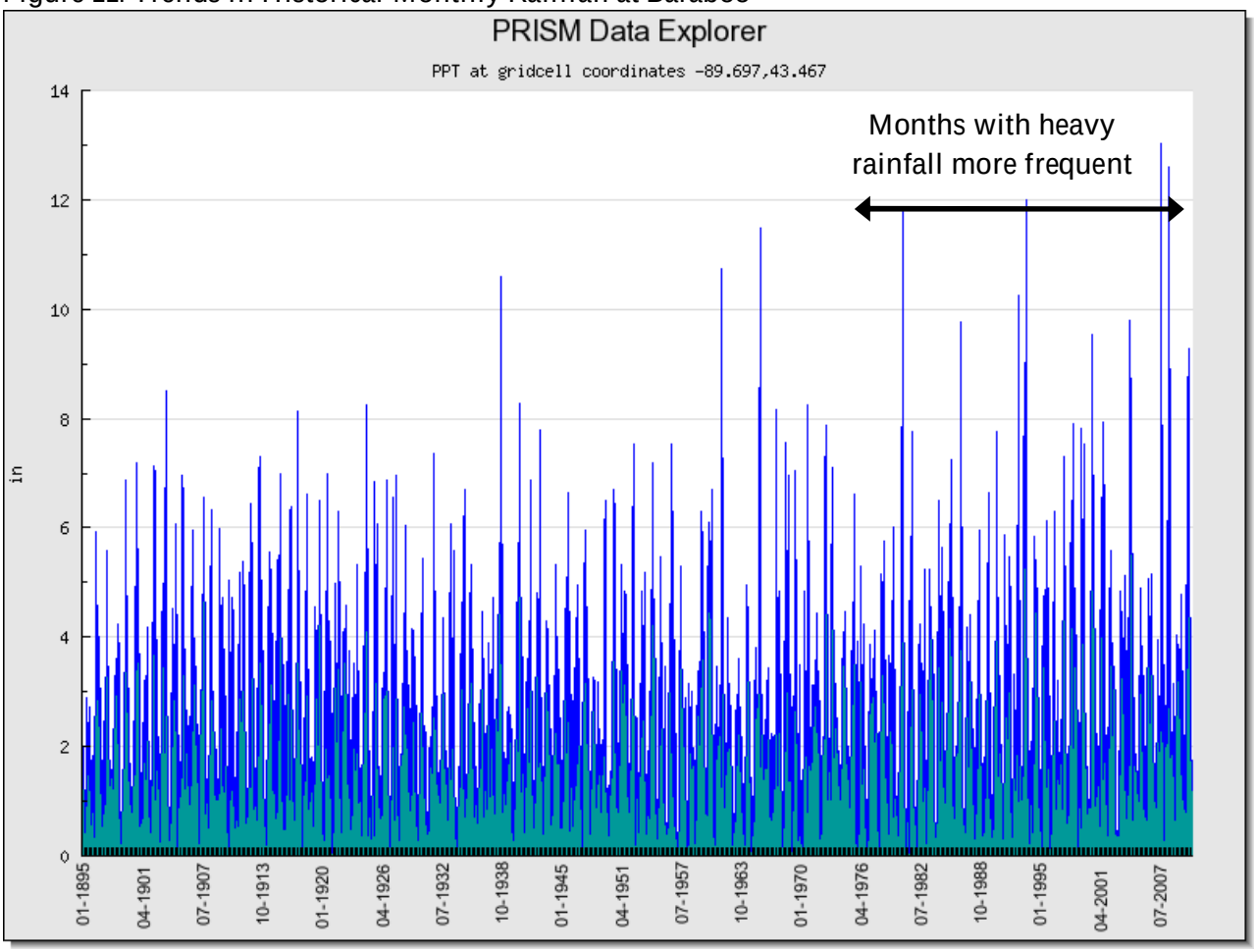
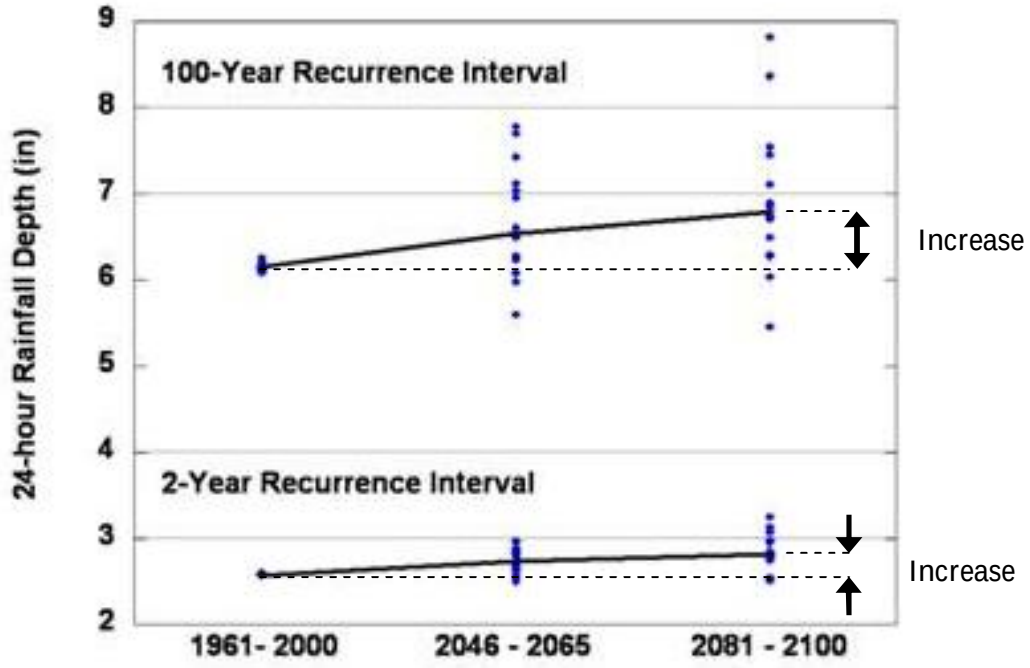


Figure 11: Trends in Historical Monthly Rainfall at Baraboo



Source: Oregon State University PRISM Climate Group

Figure 12: Predictions of Future Rainfall Frequency Due to Climate Change

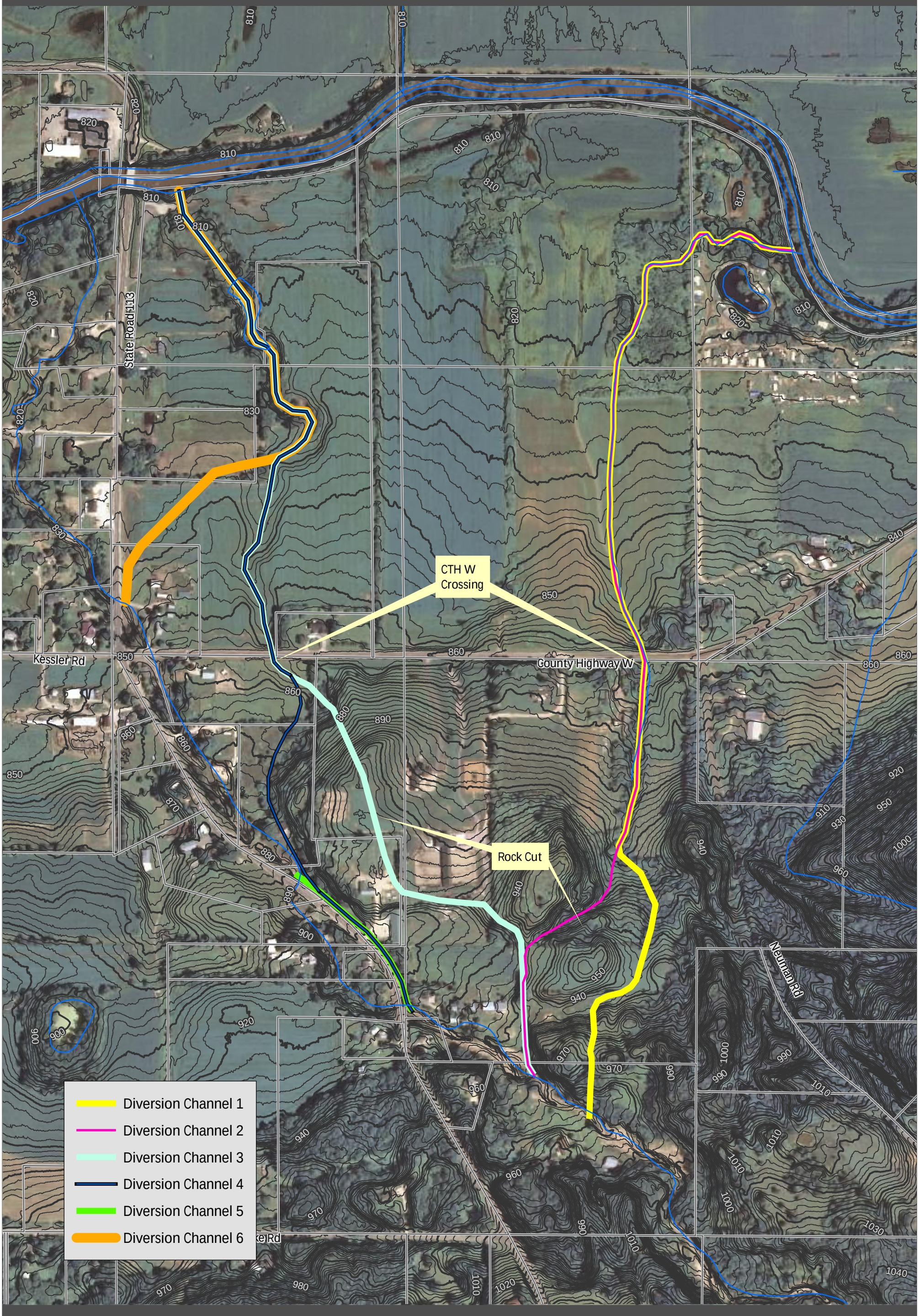


Source: Potter and Schuster analysis of data from Kucharik, Lorenz, Notaro and Vimont (University of Wisconsin-Madison)

Clark Creek Watershed Study
Sauk County, WI

FIGURE 13
Diversion Channels

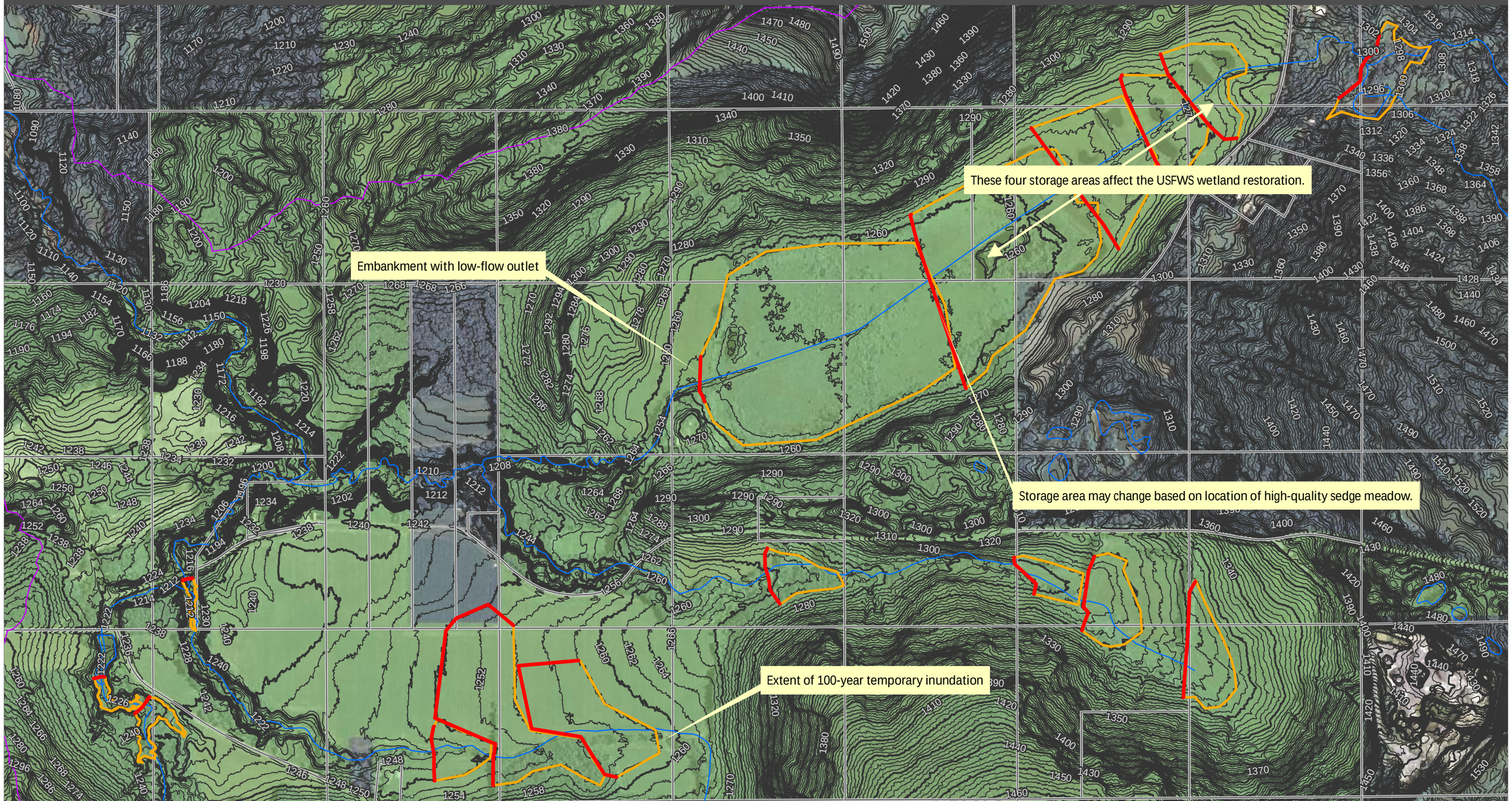
Montgomery Associates: Resource Solutions, LLC
119 South Main Street, Cottage Grove, WI 53527
(608) 839-4422 | www.ma-rs.org | 03/01/2011



Clark Creek Watershed Study
Sauk County, WI

FIGURE 14
Distributed Flood Storage Areas

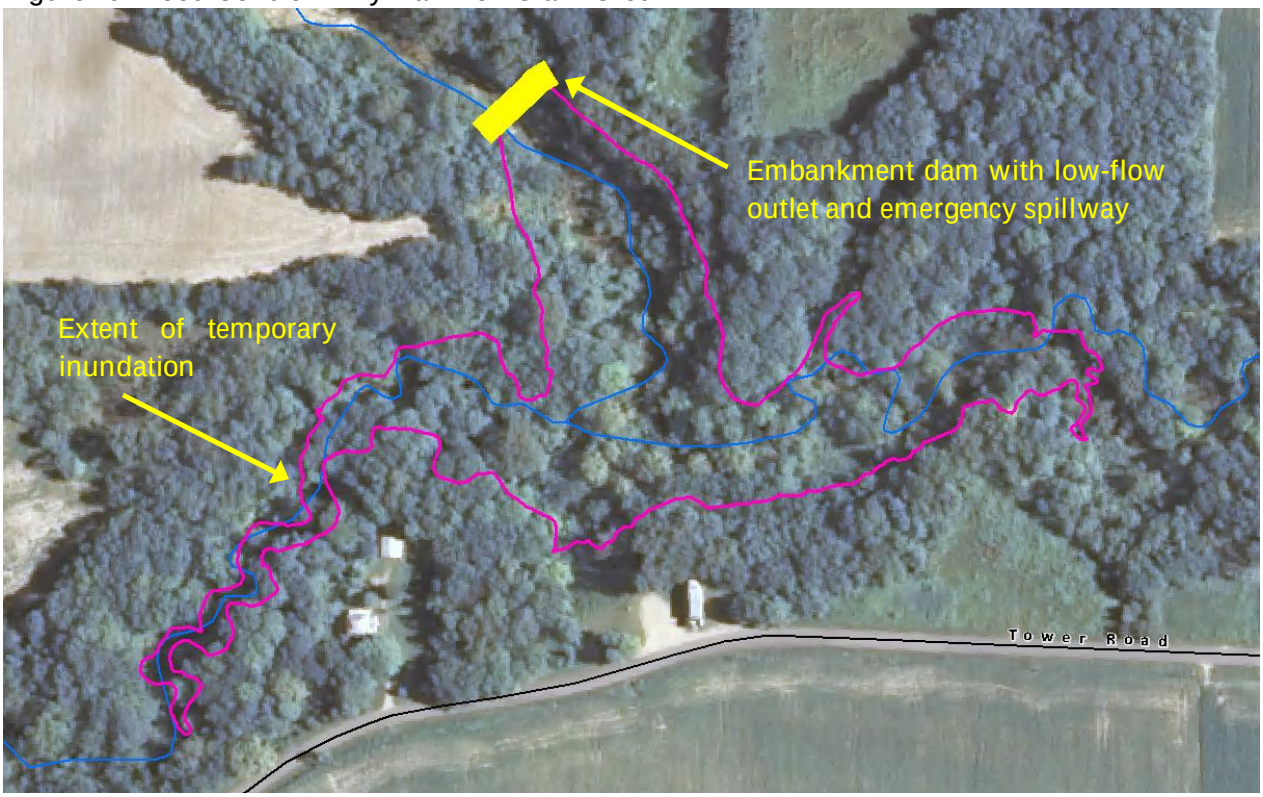
Montgomery Associates: Resource Solutions, LLC
119 South Main Street, Cottage Grove, WI 53527
(608) 839-4422 | www.ma-rs.org | 02/10/2011



Feet
0
700
1 inch = 700 feet

Potential Flood Storage Areas
Embankment with Outlet
Hydrography
Watershed Extent
Sauk County Parcels
2-foot Contours
10-foot Contours
DNR Managed Lands
Fee
Easement
Lease

Figure 15: Flood Control "Dry Dam" on Clark Creek



Above: Proposed location of dry dam. Below: Example of dry dam during flood event – note that this is a much larger dam than what would be constructed on Clark Creek.

Figure 16: Potential Driveway Relocation

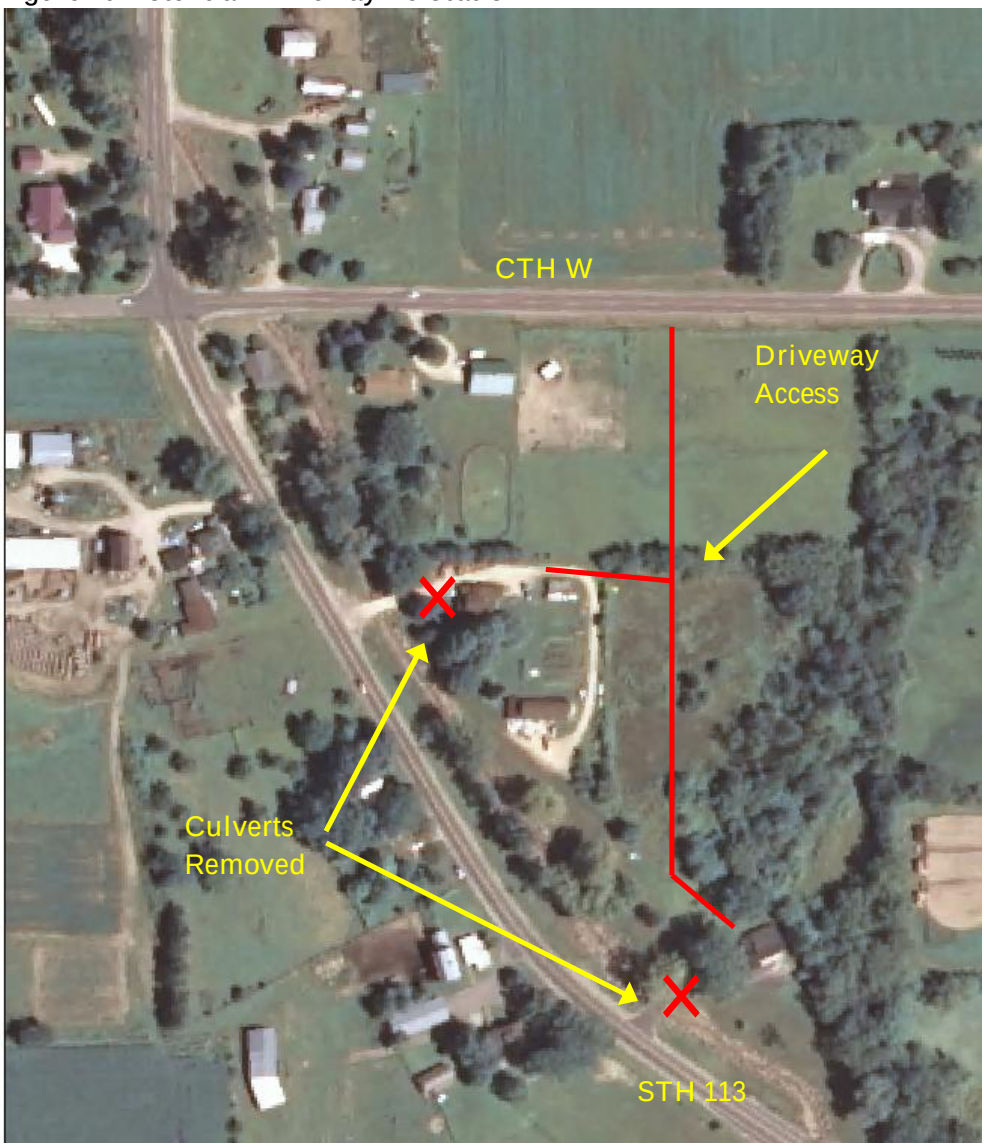
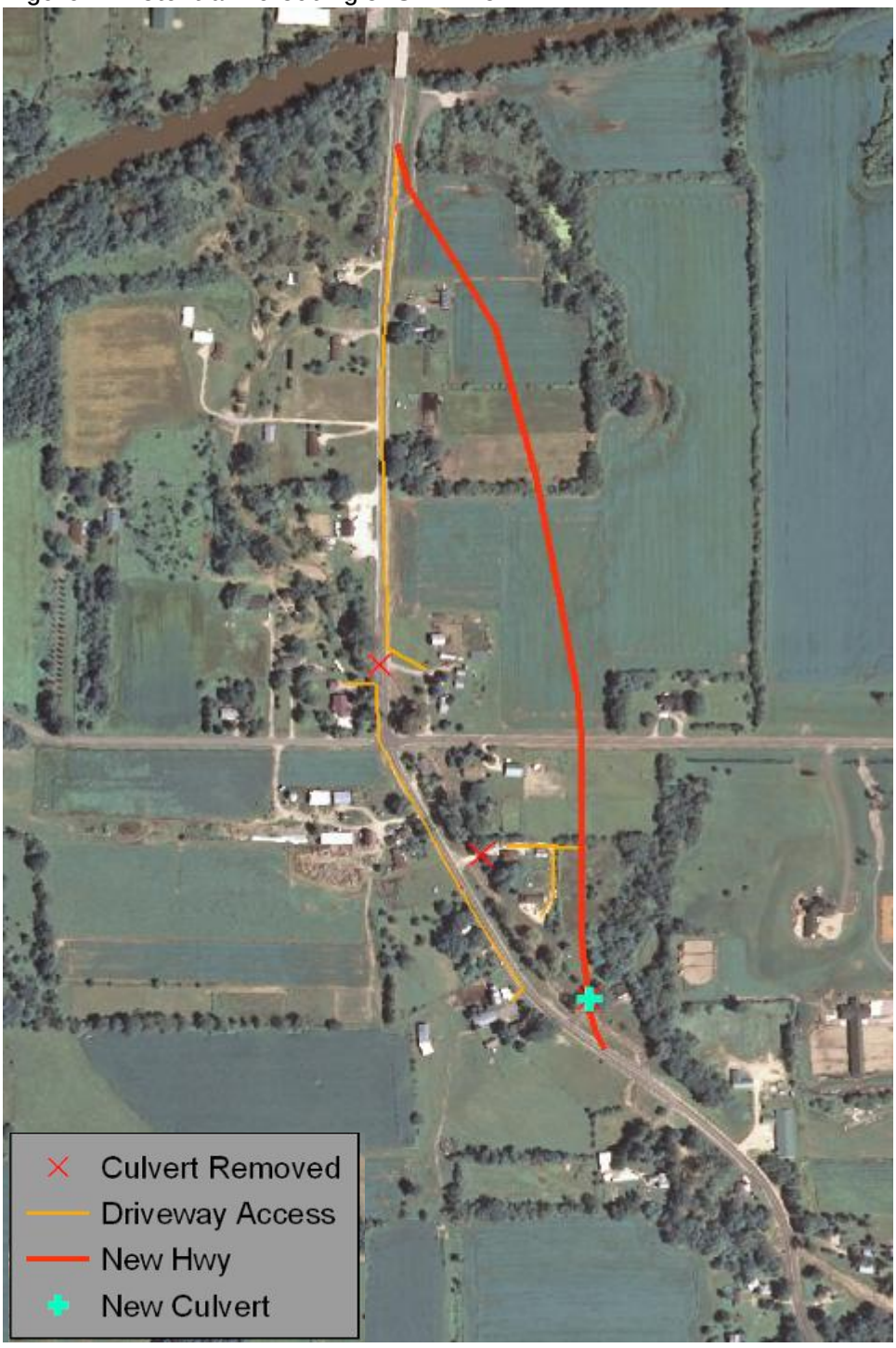


Figure 17: Potential Rerouting of STH 113



APPENDIX

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 1

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	6	AC	$ 6,000.00	$ 36,000.00
	Subtotal for Site Preparation				$ 66,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	3	EA	$ 1,000.00	$ 3,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 8,000.00
3	Construction				
3a	Rock cut & stockpile	10,900	CY	$ 12.00	$ 130,800.00
3b	Soil cut & stockpile	41,000	CY	$ 5.00	$ 205,000.00
3c	Hauling spoils	51,900	CY	$ 11.00	$ 570,900.00
3d	CTH W crossing	1	EA	$ 100,000.00	$ 100,000.00
3e	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 1,107,000.00
4	Restoration				
4a	Seeding	6	AC	$ 700.00	$ 4,200.00
4b	Turf Reinforcement Mat	3	AC	$ 34,600.00	$ 103,800.00
4c	Erosion mat	3	AC	$ 2,000.00	$ 6,000.00
	Subtotal for Restoration				$ 114,000.00
Cost - No Contingency					$ 1,300,000
Estimating Contingency (50%)					$ 650,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 900,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 2,100,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 2

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	5	AC	$ 6,000.00	$ 30,000.00
	Subtotal for Site Preparation				$ 60,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	3	EA	$ 1,000.00	$ 3,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 8,000.00
3	Construction				
3a	Rock cut & stockpile	2,200	CY	$ 12.00	$ 26,400.00
3b	Soil cut & stockpile	39,800	CY	$ 5.00	$ 199,000.00
3c	Hauling spoils	42,000	CY	$ 11.00	$ 462,000.00
3d	CTH W crossing	1	EA	$ 100,000.00	$ 100,000.00
3e	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 888,000.00
4	Restoration				
4a	Seeding	5	AC	$ 700.00	$ 3,500.00
4b	Turf Reinforcement Mat	2.5	AC	$ 34,600.00	$ 86,500.00
4c	Erosion mat	2.5	AC	$ 2,000.00	$ 5,000.00
	Subtotal for Restoration				$ 95,000.00
Cost - No Contingency					$ 1,050,000
Estimating Contingency (50%)					$ 530,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 700,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 1,700,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 3

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	6	AC	$ 6,000.00	$ 36,000.00
	Subtotal for Site Preparation				$ 66,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	3	EA	$ 1,000.00	$ 3,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 8,000.00
3	Construction				
3a	Rock cut & stockpile	27,200	CY	$ 12.00	$ 326,400.00
3b	Soil cut & stockpile	41,800	CY	$ 5.00	$ 209,000.00
3c	Hauling spoils	69,000	CY	$ 11.00	$ 759,000.00
3d	CTH W crossing	1	EA	$ 100,000.00	$ 100,000.00
3e	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 1,495,000.00
4	Restoration				
4a	Seeding	6	AC	$ 700.00	$ 4,200.00
4b	Turf Reinforcement Mat	3	AC	$ 34,600.00	$ 103,800.00
4c	Erosion mat	3	AC	$ 2,000.00	$ 6,000.00
	Subtotal for Restoration				$ 114,000.00
Cost - No Contingency					$ 1,680,000
Estimating Contingency (50%)					$ 840,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 1,100,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 2,700,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 4

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	5	AC	$ 6,000.00	$ 30,000.00
	Subtotal for Site Preparation				$ 60,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	3	EA	$ 1,000.00	$ 3,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 8,000.00
3	Construction				
3a	Soil cut & stockpile	36,900	CY	$ 5.00	$ 184,500.00
3b	Hauling spoils	36,900	CY	$ 11.00	$ 405,900.00
3c	CTH W crossing	1	EA	$ 100,000.00	$ 100,000.00
3d	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 791,000.00
4	Restoration				
4a	Seeding	5	AC	$ 700.00	$ 3,500.00
4b	Turf Reinforcement Mat	2.5	AC	$ 34,600.00	$ 86,500.00
4c	Erosion mat	2.5	AC	$ 2,000.00	$ 5,000.00
	Subtotal for Restoration				$ 95,000.00
Cost - No Contingency					$ 950,000
Estimating Contingency (50%)					$ 480,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 700,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 1,600,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 5

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	1	AC	$ 6,000.00	$ 6,000.00
	Subtotal for Site Preparation				$ 36,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	2	EA	$ 1,000.00	$ 2,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 7,000.00
3	Construction				
3a	Soil cut & stockpile	7,000	CY	$ 5.00	$ 35,000.00
3b	Hauling spoils	7,000	CY	$ 11.00	$ 77,000.00
3c	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 212,000.00
4	Restoration				
4a	Seeding	1	AC	$ 700.00	$ 700.00
4b	Erosion mat	1	AC	$ 2,000.00	$ 2,000.00
	Subtotal for Restoration				$ 3,000.00
Cost - No Contingency					$ 260,000
Estimating Contingency (50%)					$ 130,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 300,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 500,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Diversion Channel 6

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and grubbing	3	AC	$ 6,000.00	$ 18,000.00
	Subtotal for Site Preparation				$ 48,000.00
2	Erosion Control				
2a	Turbidity barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking pad	2	EA	$ 1,000.00	$ 2,000.00
2c	Silt fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 7,000.00
3	Construction				
3a	Soil cut & stockpile	21,500	CY	$ 5.00	$ 107,500.00
3b	Hauling spoils	21,500	CY	$ 11.00	$ 236,500.00
3c	Diversion structure	1	LS	$ 100,000.00	$ 100,000.00
	Subtotal for Construction				$ 444,000.00
4	Restoration				
4a	Seeding	3	AC	$ 700.00	$ 2,100.00
4b	Erosion mat	3	AC	$ 2,000.00	$ 6,000.00
	Subtotal for Restoration				$ 9,000.00
Cost - No Contingency					$ 510,000
Estimating Contingency (50%)					$ 260,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency, No Hauling of Spoils					$ 400,000
Total Estimated Cost - With Contingency and Hauling of Spoils					$ 900,000

Clark Creek Watershed Study

Sauk County, WI

Planning-Level Cost Estimates

Distributed Flood Storage Areas

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 20,000.00	$ 20,000.00
1b	Clearing and grubbing	2	AC	$ 6,000.00	$ 12,000.00
	Subtotal for Site Preparation				$ 32,000.00
2	Erosion Control				
2a	Silt fence	500	LF	$ 2.00	$ 1,000.00
	Subtotal for Erosion Control				$ 1,000.00
3	Berm Construction				
3a	Strip and replace topsoil	6000	CY	$ 9.00	$ 54,000.00
3b	Earthwork	20000	CY	$ 10.00	$ 200,000.00
3c	Low-flow culverts	480	LF	$ 78.00	$ 37,500.00
	Subtotal for Dam Construction				$ 292,000.00
4	Restoration				
4a	Seeding	11	AC	$ 700.00	$ 7,700.00
4b	Mulch	4	AC	$ 600.00	$ 2,400.00
4c	Erosion mat	7	AC	$ 8,800.00	$ 61,600.00
	Subtotal for Restoration				$ 72,000.00
Cost - No Contingency					$ 400,000
Estimating Contingency (50%)					$ 200,000
Engineering and Permitting					$ 30,000
Total Estimated Cost - No Contingency					$ 500,000
Total Estimated Cost - With Contingency					$ 700,000

Clark Creek Watershed Study
Sauk County, WI

Planning-Level Cost Estimates

Flood Control Dry Dam

NO.	ITEM DESCRIPTION	ESTIMATED QUANTITY	UNIT	UNIT PRICE	TOTAL
1	Site Preparation				
1a	Mobilization / Demobilization	1	LS	$ 30,000.00	$ 30,000.00
1b	Clearing and Grubbing	3	AC	$ 6,000.00	$ 18,000.00
	Subtotal for Site Preparation				$ 48,000.00
2	Erosion Control				
2a	Turbidity Barrier	100	SY	$ 29.00	$ 2,900.00
2b	Tracking Pad	1	EA	$ 1,000.00	$ 1,000.00
2c	Silt Fence	1000	LF	$ 2.00	$ 2,000.00
	Subtotal for Erosion Control				$ 6,000.00
3	Dam Construction				
3a	Strip and Replace Topsoil	2300	CY	$ 9.00	$ 20,700.00
3b	Earthwork	6000	CY	$ 12.00	$ 72,000.00
3c	Low-flow Culvert	190	LF	$ 325.00	$ 61,800.00
3d	Emergency Spillway	1300	CY	$ 65.00	$ 84,500.00
	Subtotal for Dam Construction				$ 239,000.00
4	Restoration				
4a	Seeding	3	AC	$ 700.00	$ 2,100.00
4b	Mulch	2	AC	$ 600.00	$ 1,200.00
4c	Erosion mat	0.5	AC	$ 8,800.00	$ 4,400.00
	Subtotal for Restoration				$ 8,000.00
Cost - No Contingency					$ 300,000
Estimating Contingency (50%)					$ 150,000
Engineering and Permitting					$ 100,000
Total Estimated Cost - No Contingency					$ 400,000
Total Estimated Cost - With Contingency					$ 600,000