CONSERVATION RESERVE PROGRAM FLOOD DAMAGE REDUCTION BENEFITS TO DOWNSTREAM URBAN AREAS

A US Army Corps of Engineers, Mississippi Valley Division Initiative

Rock Island District Pilot Project Report

Submitted to:
USDA Farm Service Agency Economic and Policy Analysis Staff

In accordance with:
The INTERAGENCY AGREEMENT
Between
U. S. DEPARTMENT OF AGRICULTURE,
FARM SERVICE AGENCY
ECONOMIC AND POLICY ANALYSIS STAFF
On behalf of the
COMMODITY CREDIT CORPORATION,
And
U.S. DEPARTMENT OF ARMY,
ARMY CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

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US Army Corps
of Engineers®
Rock Island District

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EXECUTIVE SUMMARY

Federal agencies are constantly evaluating the value their programs provide to the American people and looking for ways to provide better services at a lower cost to taxpayers. In an effort to improve the Farm Service Agency's technical and financial support to landowners and the benefits realized through the Conservation Reserve Program (CRP) they contacted the US Army Corps of Engineers to help quantify "what are the flood reduction benefits that CRP lands are providing downstream urban areas". This pilot used geographic information systems, hydrologic modeling and economics evaluations to produce objective, scientifically-credible deliverables that address this important question.

Conservation Reserve Program lands may provide hundreds of thousands to millions of dollars in flood damage reduction benefits to urban areas in the Indian Creek watershed, Linn County, Iowa (HUC-10). The type and spatial location of these conservation practices has a large effect on the hydrologic response and resulting economic benefits realized over a range of rainfall frequencies.

The physically-based Gridded Surface Subsurface Hydrologic Analysis (GSSHA) hydrologic model was used to simulate varying amounts of CRP practice within the Indian Creek watershed. Simulated reductions in CRP from current extents show that the practices currently in place have a hydrologic effect. Increases in CRP explored with GSSHA, including targeted riparian buffers and wetlands scenarios, show that riparian buffers are most effective dollar for dollar in reducing flood stages and economic losses in Indian Creek. The "without CRP" and "practice specific" scenarios were evaluated across a range of rainfall frequencies and antecedent moisture conditions. Scenarios run for typical and wetter than normal antecedent soil conditions resulted in changes in flood stage and damages for rainfall events greater than the 24-hr, 25-yr storm event. Economic data was spatially aggregated to index points representing clusters of structures within the floodplain. The index points may be compiled in any fashion such that the total cost and benefits may be evaluated for a single point, a stream segment or for the entire basin. Table ES-1 and Figure ES-1 display the difference in economic losses occurring for the entire Indian Creek basin for the respective scenarios.

Table ES 1: Indian Creek Basin Economic Damages for All Land Use Scenarios for the Wet Condition 24-hour 500-year Storm

Scenario	Damages	Change From Baseline
Total CRP Loss	$926,702	
Partial CRP Loss	$910,688	-2%
Current Land Use	$897,065	-3%
Targeted Wetland Practice-Type CRP Gain	$822,223	-11%
Targeted Riparian Practice-Type CRP Gain	$806,073	-13%
Combined Riparian and Wetland CRP Gain	$752,853	-19%

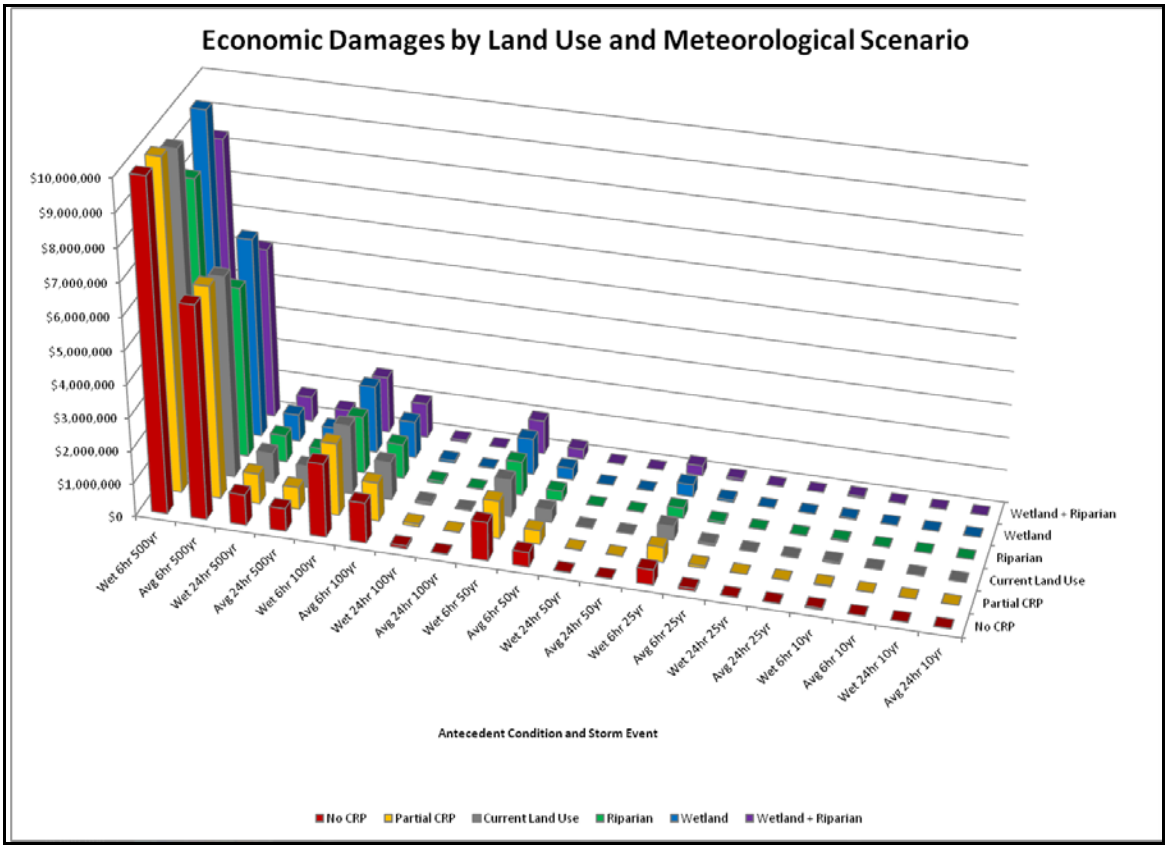

Figure ES 1: Economic Damages by Land Use and Meteorological Scenario for the Indian Creek Basin

The Total CRP Loss and Targeted Riparian Practice-Type scenarios developed for Indian Creek were evaluated using the Soil and Water Assessment Tool (SWAT) hydrologic model for the Cedar River basin. This evaluation resulted in no measurable relationship between land use changes and changes in flood stage. An extreme water quality scenario was run through SWAT as a sensitivity analysis and also resulted in no measureable relationship between land use changes and changes in flood stage. Limitations within the SWAT model design and the initial model purpose for the Cedar River SWAT model led to this result.

Results from this pilot effort will be presented on a web-based visualization tool to further communicate the spatial significance of conservation practices on hydrology and associated economic losses.

ROLES AND ACKNOWLEDGEMENTS

STUDY TEAM ROLES

Jason Smith	Pilot Study Lead / Civil Engineer
Chris Hawes	Lead Geographer / Geographic Information Systems
Greg Karlovits	Lead Hydrologist / Civil Engineer
Rick Eberts III	Lead Economist

ACKNOWLEDGEMENTS

This effort is a compilation of numerous staff contributions, many of which provided a critical supporting role. In an attempt to recognize some of the contributors of data and information the following individuals are acknowledged for their significant contributions to this Farm Service Agency effort:

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I. INTRODUCTION

A. Authority

This pilot report was developed in accordance with the Interagency Agreement signed into action on December 21, 2012 by Farm Service Agency (FSA) Administrator Juan M. Garcia and Mississippi Valley Division Commanding General John W. Peabody (see Appendix E). This pilot report fulfills key deliverables B, C and D as outlined in the aforementioned Interagency Agreement.

The authorities of the Agencies to enter into this Memorandum of Understanding are the Commodity Credit Corporation Charter Act (15 U.S.C. 714),and the Economy Act of 1932, as amended (31 U.S.C. 1535). The data described within are collected, kept confidential, and protected by the Parties pursuant to Section 1619 of the Food, Conservation, and Energy Act of 2008, P.L. 110-246; Section 2004 of the Food, Conservation, Farm Security and Rural Investment Act of 2002, P.L. 107-171; the Privacy Act of 1974; the E-Government Act of 2002; and related authorities.

B. Purpose and Partnerships

This pilot project is a partnership study effort between the FSA and the Mississippi Valley Division-Rock Island District, Army Corps of Engineers (Corps). This partnership was initiated to use existing data and models to produce objective, scientifically-credible deliverables that help the Agencies better understand and communicate the effects of existing and potential future Conservation Reserve Program (CRP) lands on downstream flooding and associated economic impacts to downstream urban areas. By better identifying the relationship between the spatial location of conservation lands and hydrologic response, the Secretary of Agriculture will be better able to provide targeted technical assistance to landowners, furthering the broad goals of USDA conservation programs and the specific goals of the CRP.

This partnership is in line with the Corps' Flood Risk Management mission area which requires evaluation of structural and non-structural measures. Lessons learned from the non-structural alternatives explored in this pilot project are relevant at a regional and to some extent a national scale.

The products from this pilot project benefit the FSA and the Corps as well as a regional interagency team that is working within the Iowa-Cedar Watershed Basin. This interagency team is composed of around 20 different Federal, state and local entities that are working together to better understand the economic, environmental and social trade-offs that are occurring for various land use futures. More info on the team activities may be found at www.iowacedarbasin.org. Following approval by the FSA, the results documented in this report will be presented on the Iowa-Cedar Interagency Coordination Team webportal alongside other watershed tools and related information.

C. Background

This pilot report builds upon successful completion of the Fiscal Year (FY) 2012 agreement which resulted in three primary products: 1) a literature review that framed the state of the science related to typical CRP conservation practices and their impact on hydrology; 2) completion of a physically-based hydrologic model that provides better understanding of how CRP-type conservation measures affect the hydrology on a small watershed scale; 3) effective transfer of CRP data to the Corps which was incorporated into a password-protected database.

1. The FY12 literature review consisted of collecting information about land use impacts on flood reduction from peer reviewed articles, Federal and state publications, conference proceedings, commission submittals, university research, periodicals, unpublished reports, and program websites. A total of 35 publications were found of which 27 were reviewed. Literature reviewed was categorically divided into physical studies, numerical modeling, general analyses, and miscellaneous with some subcategories as necessary.

   The majority of studies demonstrated decreased peak flows and volumes after implementation of various conservation practices and/or wetland restoration. Flood stage reduction was found to be most effective during small volume, more frequent peak rainfall events (generally 4% (25-yr) annual exceedance or more) and less effective with large volume, less frequent events (generally 2% (50-yr) annual exceedance or lower). Antecedent conditions play a vital role in the effectiveness of conservation measures. A common theme placed emphasis on the need for continuous simulation to accurately portray antecedent conditions within the watershed for modeling purposes.

   The majority of current publications are more conceptual. Relatively few publications actually included a physical or numerical modeling study indicating that these techniques are still largely undeveloped. This literature review provided context on the methodology for refinement of the FY13 work, including guiding some of the modeling decisions with respect to model parameterization and resolution.

2. The FY12 pilot effort improved an existing Gridded Surface Subsurface Hydrologic Assessment (GSSHA, commonly pronounced like "Geisha") model for the Indian Creek 10 digit Hydrologic Unit Code (HUC-10) watershed. GSSHA is a physically-based fully distributed hydrologic model that allows explicit simulation of the effects of land use change on the hydrology of a watershed. The model is a powerful tool that allows evaluation of the spatial significance of best management practices with regard to both location and extent. However, due to the high data requirements and computational intensity it is best suited for the evaluation of smaller basins such as those at the HUC-10 scale.

3. The FY12 pilot effectively transferred spatial level data related to conservation reserve program participants in the Cedar River Basin. This data was received through a Department of Defense secure FTP website and immediately stored in a password protected database.

D. Study Area

The Cedar River is a tributary to the Iowa River which includes some of the most fertile agricultural land in the nation. In recent years, high commodity prices and ethanol demand have contributed to landscape changes, most significantly, the conversion of low intensity agriculture (pasture and grassland) to high intensity row crops (corn and soybeans). This conversion has increased stress on fresh water systems and contributed to both Gulf of Mexico hypoxia and flooding. The Cedar River basin contains two large urban areas which both experienced record or near-record flood events in recent years, most notably 1993, 2002, and 2008. Figure 1 displays a map of the Cedar River watershed basin.

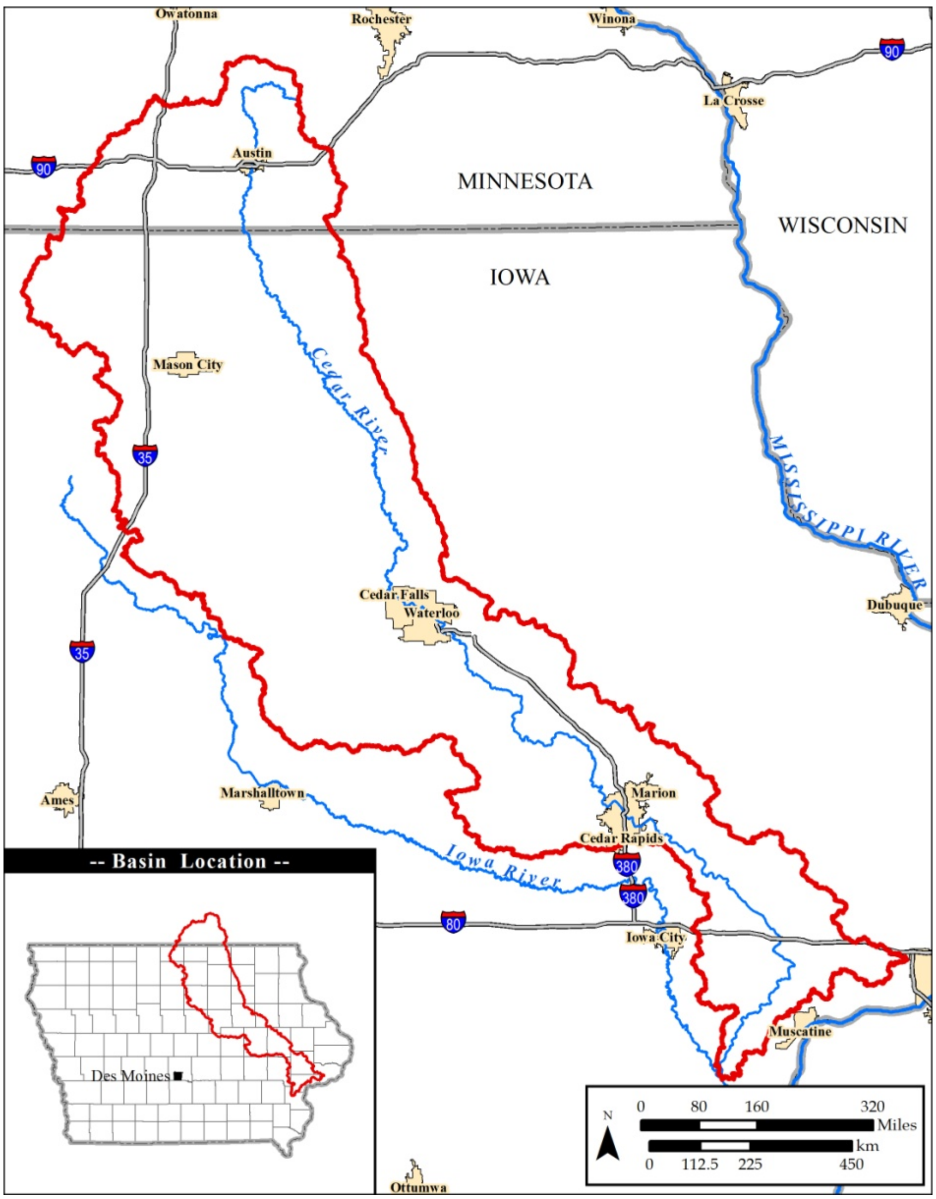

Figure 1: Map of the Cedar River Basin

This pilot effort is primarily focused on the portion of the Cedar River basin around the City of Cedar Rapids, Iowa and adjacent communities. This includes both the Indian Creek watershed which contains the eastern portion of Cedar Rapids and the Cedar River mainstem which accounts for the remainder of the City of Cedar Rapids. Figure 2 displays a map of the Indian Creek watershed basin.

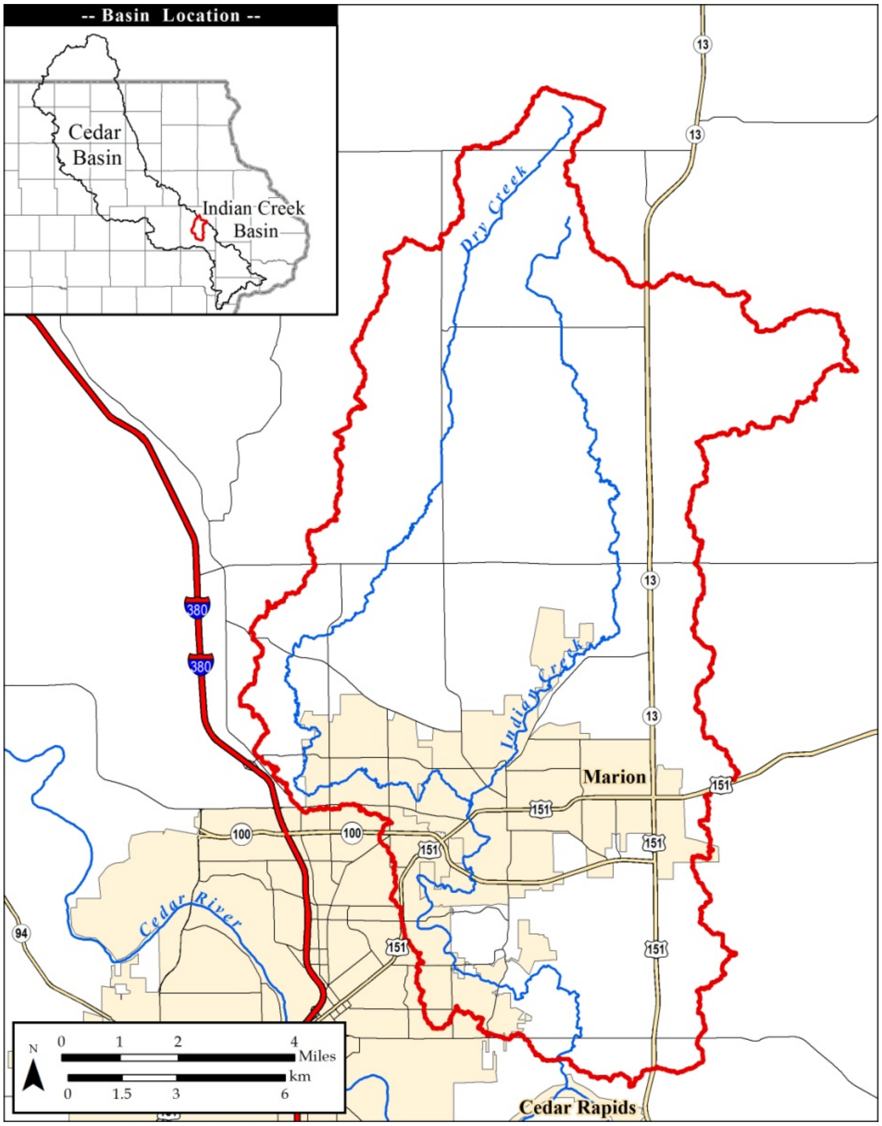

Figure 2: Map of the Indian Creek Watershed Basin

II. PURPOSE, NEED, PROBLEMS, AND OPPORTUNITIES

A. Purpose and Need

The purpose of this study is to better understand, quantify and communicate the interdependent relationship of land use, hydrologic response and socio-economic implications to users of water resources within a watershed. More specifically, the purpose is to quantify the effects of the existing and potential future CRP lands on downstream flooding and economic impacts to downstream urban areas.

Agencies, landowners and decision makers in the Cedar River basin and throughout the Midwest have a need to better understand the impact of the spatial location of CRP land use types on the watershed hydrology.

B. Problems and Opportunities

The primary problem is that the spatial significance of land use change and its effects on basin hydrology are poorly understood. The hydrologic impacts from the installation or removal of a conservation practice are fairly well understood and can be empirically observed in the immediate area of installation. But the magnitude of impacts on basin hydrology, particularly in downstream urban areas, is less well understood. This dichotomy of knowledge is, in part, due to widespread use of hydrologic models that are based on empirical relationships. These models can mute and obscure spatially explicit relationships between land use and hydrology.

The key opportunity, then, is to leverage a Corps developed, physically based model to test the spatial relationship between land use/conservation practice change and basin hydrology. The resulting information will be highly valuable to the FSA as it will afford them a better understanding of how CRP functions within a basin and the ability to provide targeted technical assistance to program participants. The FSA can also utilize the knowledge to better educate program participants on the effects their decisions related placement of conservation practices have on other residents in their watershed. Both the Corps and FSA have an opportunity to better understand economic benefits provided by lands held in conservation that target non-structural flood protection. The Corps has an opportunity to better understand the hydrologic function of a watershed with respect to land use change, within the context of non-structural flood damage reduction.

III. GOALS AND OBJECTIVES

The goal of this study is to better understand and communicate the effects of CRP lands on downstream flooding and associated economic impacts to downstream urban areas:

> **Objective 1:** Identify how the amount and placement of CRP affects basin hydrologic response to storm events spanning a range of intensities and durations under varying antecedent conditions
>
> **Objective 2:** Evaluate if this altered hydrology translates into reductions in economic damages experienced by downstream urban areas.
>
> **Objective 3:** Identify a scaling relationship of hydrologic and economic effects.
>
> **Objective 4:** Present results in a way that supports agency and landowner actions to reduce flood risk through targeted implementation of specific conservation practices.

IV. SCOPE OF WORK

There are there three distinct elements to the scope of work for this project: 1) Indian Creek evaluation, 2) Cedar River evaluation at Cedar Rapids and 3) Visualization of Results.
The first element of the scope of work is a highly detailed hydrologic and economic evaluation in the Indian Creek watershed. The second element of the scope of work is to transfer the lessons learned from the detailed modeling work in Indian Creek to the broader Cedar River basin in order to evaluate the change in economic losses at Cedar Rapids, Iowa. The final element of the scope of work is to display the results from these evaluations in a web-based visualization format that communicates the spatial significance of various CRP-type lands in preventing economic losses to urban areas.

A. Activity 1 - Indian Creek Basin Evaluation

To achieve Objective #1—adddress how the amount and placement of CRP affects basin hydrology over a range of probability events—the pilot team identified a need to gain local input on likely CRP futures as well as exploring a method to establish a range of probability events in a basin lacking a flood frequency study. To explore the likely land use scenarios the pilot team met with staff from USDA-NRCS in Linn County and the County's Soil and Water Conservation District to discuss CRP trends including what practices are most likely to convert to row crop agriculture. This discussion resulted in identification of two scenarios with reduction in CRP lands and three scenarios with increased CRP lands.

To determine a range of frequency events in a basin without a flow frequency study the pilot team explored a methodology to use available rainfall data and statistical information in NOAA's ATLAS 14 to outline a range of storm events to compare the various CRP land use scenarios.

To address how the CRP scenarios affect basin hydrology, the pilot team utilized a physically-based numerical model GSSHA. This evaluation included utilizing GSSHA to better understand the influence of CRP land use types on surface-subsurface interactions and high intensity storm events with respect to other watershed characteristics (soils, slope, etc.). Point precipitation frequency estimates were applied to the basin landscape uniformly in the GSSHA model in order to simulate the watershed's response to the varying storm events.

To achieve Objective #2—evaluate if the altered hydrology translates into reductions in economic damages experienced by downstream urban areas—the pilot team conducted an abbreviated structure inventory. This process included identification of the extents of the approximate 500-year floodplain plus 1 foot of elevation. These locations were then inventoried for structure characteristics such as 1st floor elevation. Structure value information was obtained from the county assessor and structure contents were estimated as a percentage of the total structure value.

As part of the economic assessment associated with Objective #2 an evaluation was conducted which considered the amount of rental payments being made for the respective CRP practices and explored what would be the costs and benefits or impacts associated with the reductions or additional investments in CRP in the Indian Creek watershed.

B. Activity 2 - Cedar River Basin Evaluation

To achieve Objective #1—adddress how the amount and placement of CRP affects basin hydrology over a range of probability events—the pilot team applied the scenario rules developed in Indian Creek to the broader Cedar River basin and ran a couple of them through the Soil and Water Assessment Tool (SWAT) hydrologic model recently developed by the United States Geological Survey (USGS). The SWAT model is an empirical, quasi-distributed hydrologic model that simplifies a watershed into subbasins containing spatially-discontinuous regions of homogeneous land use, soil type and slope referred to as hydrologic response units (HRU).

The SWAT model was run for the existing conditions, complete removal of CRP, and a future scenario with extensive riparian buffers. The comparison of these scenarios did not result in any appreciable changes in hydrology so a water quality enhancement land use alternative developed for another project (see Appendix D) was explored which defines much of the existing row crop as grassland. This land use scenario was run through SWAT for a series of historical rainfall events and the results led the pilot team to abandon further SWAT runs due to model limitations. Model limitations are associated with the type of hydrologic model and the purpose the model was developed by USGS (i.e. water quality versus peak flooding estimates).

For Objective #3, in the absence of meaningful SWAT model results to feed the economic evaluation at Cedar Rapids, the team was limited to inferring results from the Indian Creek analysis to the broader Cedar River Basin.

C. Activity 3 – Visualization of Results

To achieve Objective #4—present results in a way that supports agency and landowner actions to reduce flood risk through targeted implementation of specific conservation practices—the pilot team identified specific index points within Indian Creek from which all data and evaluations are aggregated.

By aggregating data and information at designated index points a user is able to compare how changes in watershed extent, land use, probability and other watershed characteristics impact flow rates and associated flood stages. Presentation of results is subject to approval by FSA.

V. METHODOLOGY

The methodology is broken into separate activities but should be understood that the activities are interrelated.

A. Indian Creek Basin Assessment

1. Geographic Information Systems. To evaluate the effect of land held in CRP on flood heights, it was necessary to develop a series of land cover/land use scenarios. The conceptual design for each scenario was formulated by the Project Delivery Team (PDT) and informed by conversations with NRCS and FSA Staff and select literature. With the concepts in place, GIS was used to build gridded representations of the concepts. The scenarios developed are as follows:

1. Current Land Use
2. Partial CRP Loss
3. Total CRP Loss
4. Targeted Riparian Practice-Type CRP Gain
5. Targeted Wetland Practice-Type CRP Gain
6. Combined Riparian & Wetland CRP Gain

As the CRP was developed to meet local ecological needs and niches, each conservation practice (CP) in the program had to be reduced to a generalized land use type that was consistent with the classifications in the Cropland Data Layer (CDL). As each of the models (GSSHA & SWAT) had different parameterization requirements and accepted different complexities of land use types, two CRP practice type crosswalks were developed. See Table A-1 and A-2 for GSSHA and SWAT crosswalk, respectively. The main drivers for crosswalk development were infiltration rates, roughness coefficients, and basic practice vegetation: grass, wetland and forest. With the crosswalks developed, CRP practice types could be converted into CDL land use types and used in scenario development.

In addition to the CRP polygon data provided by FSA, a table containing Federal rental rates paid per acre per year by contract was provided. The CRP polygon data and rental rate table were joined using contract number and county code. The result of the join was an average annual rent per acre per year for each conservation practice. These average annual rents were collapsed according to the CRP-CDL crosswalks. The specific rates are detailed in Table 1. This allowed the PDT to attach approximate Federal financial obligations to each scenario for each watershed (Cedar River and Indian Creek).

Table 1: Federal Rental Rates for CRP Type Land Uses in GSSHA and SWAT

CDL Land Use (representing CRP)	Avg Federal Rental Rate ($ per acre, per year)
Clover/Wildflowers (GSSHA)	$189.93
Switchgrass (GSSHA)	$123.47
Pasture/Grass (GSSHA)	$117.74
Wetlands (GSSHA)	$167.67
Deciduous Forest (GSSHA)	$106.48
Evergreen Forest (GSSHA)	$163.19
Mixed Forest (GSSHA)	$147.45
Grassland/Herbaceous (GSSHA)	$140.83
Pasture (SWAT-PAST)	$142.99
Wetland (SWAT-WETL)	$167.67
Forest (SWAT-FRSD)	$139.04

Actual values, including acreages and Federal financial obligation estimates used by the FSA will differ from the numbers reported by this study. This is to be expected when translating data types (polygon to raster) and aggregating financial data.

a. Scenario Development & Construction. This section will outline the general theory behind each scenario and provide the specific GIS method(s) used to create the land use grid that fed model parameters. It should be noted that in each description "watershed" will be singular, but the method described was used for both the Cedar River and Indian Creek watershed basins. CRP was converted to CDL values using the crosswalk developed for each specific model.

i. Current Land Use Scenario: This scenario attempts to illustrate the current condition of the watershed, paying particular attention to enforcing CRP polygons provided by the FSA. The current land use scenario was used as the baseline condition to which all other scenarios were compared, for both flood reduction efficacy and land type acreage changes.

CRP polygons were joined to crosswalk values and converted to a raster. Linear shaped polygons were poorly reflected in the resulting polygon so the process was repeated with line geometry to enforce them. The raster products from both conversions were merged as a representation of CRP practices in the watershed. This merged raster was combined with the CDL to produce the Current Scenario. Figure 3 shows the results of this method and Table A-3 provides a detailed land use type and cost breakdown.

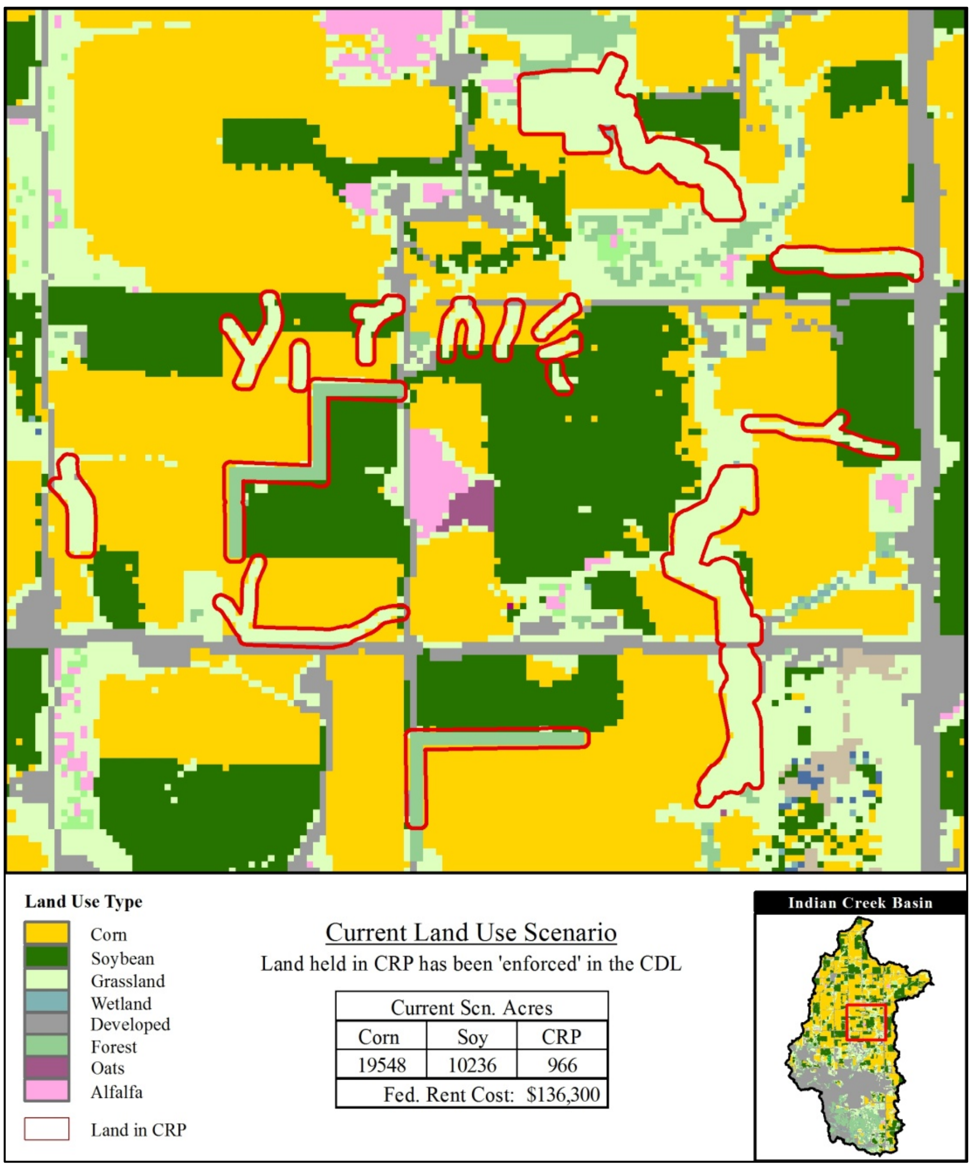

Figure 3: Current Scenario Land Use Example

ii. Partial CRP Loss Scenario: This scenario assumes that CRP payments shrink (less is paid per acre) and farmers chose not to renew contracts as the rents paid are too small. Grass-based CRP practices disappear as it is easier and cheaper to convert grass-type vegetation practices to row crops than to clear timber or drain/tile wetlands. Assuming corn and soy beans remain somewhat lucrative for the farmer: former grass-based CRP practices will convert to corn or soy. Any CRP practice that was wetland or forest based was left unchanged.

As a large number of soil types in Iowa readily support either corn or soy, conversion of CRP to crops was based on majority proximity of corn or soy to the individual CRP polygon. This was accomplished by applying a 90m buffer to each grass type CRP polygon and using these buffered polygons to generate a proportion of land use types under each polygon. The polygon was then assigned to corn or soy depending on which proportion was larger. Figure 4 shows the results of this method and Table A-4 provides a detailed land use type and cost breakdown.

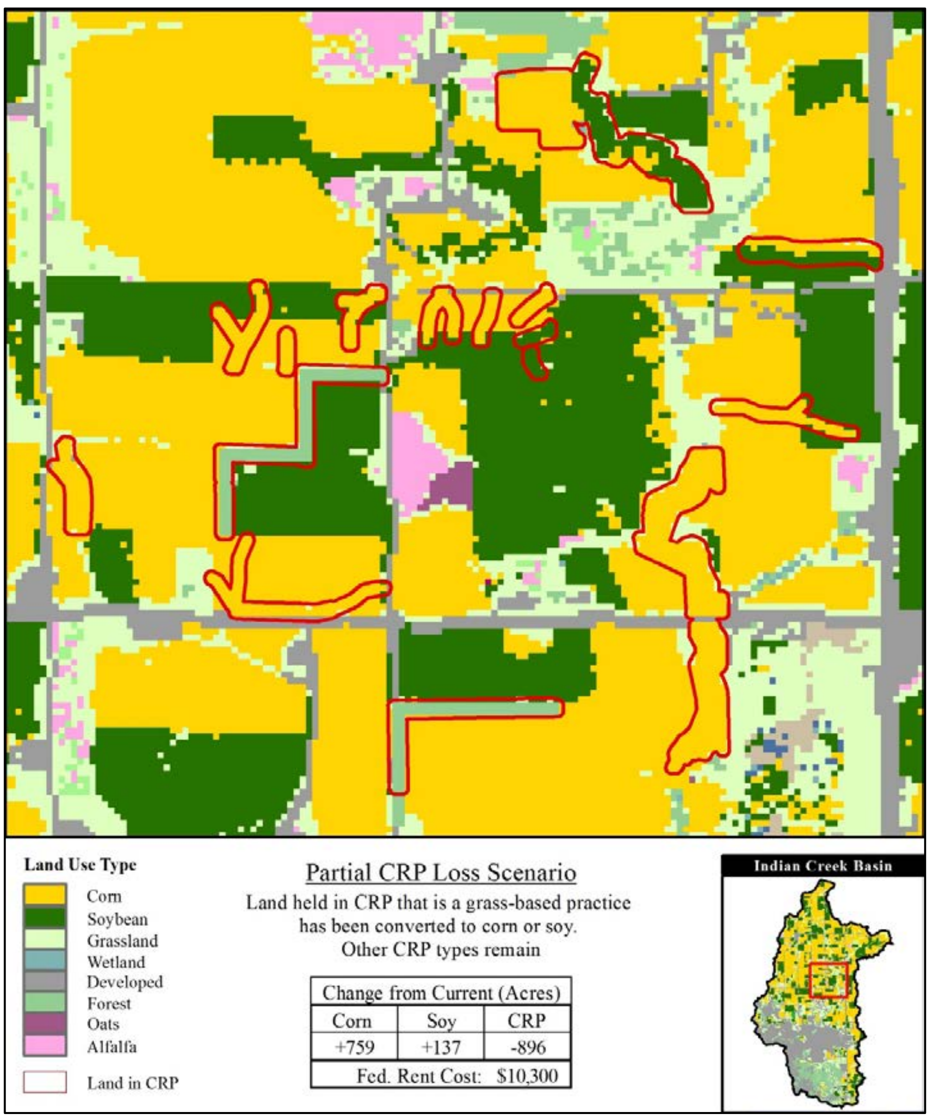

Figure 4: Partial CRP Loss Scenario Land Use Example

iii. Total CRP Loss Scenario: This scenario assumes CRP payments disappear altogether and prices on corn and soybeans increase significantly. Farmers decide it is worth the time and investment to convert all grass, wetland and forest-based CRP practices to row crops. The total loss scenario was used as a baseline against which economic results were compared.

The method used is identical to the Partial CRP Loss Scenario, except wetland and forest-based CRP practices are now included as corn or soy. Figure 5 shows the results of this method and Table A-5 provides a detailed land use type and cost breakdown.

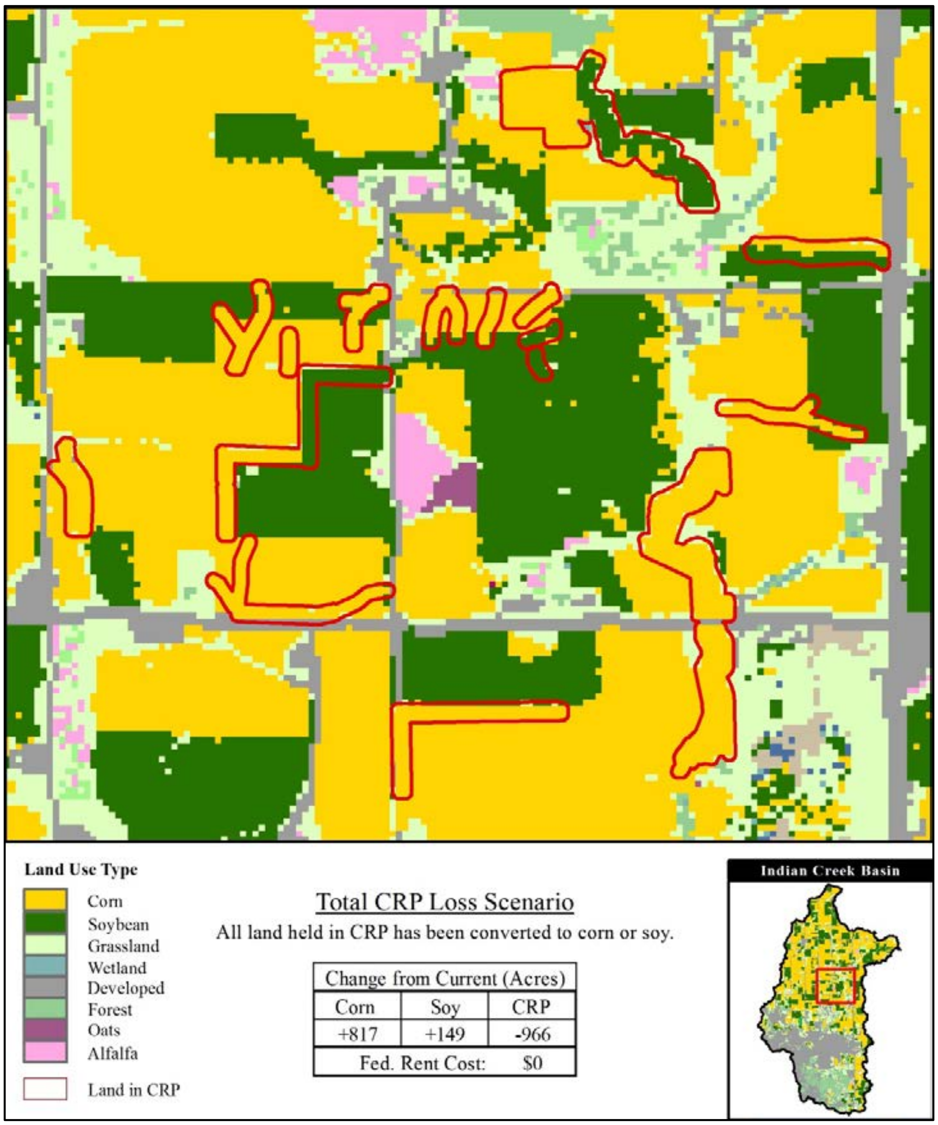

Figure 5: Total CRP Loss Scenario Land Use Example

iv. Targeted Riparian Practice Type CRP Gain: This scenario was informed by the understanding that riparian buffers reduce overland flow times and increase surface roughness, extending the time it takes runoff to reach the channel. Riparian buffers are also proven to reduce nutrient and sediment runoff from agriculture. The assumption is that the FSA will place priority on CRP contracts that institute riparian-type practices.

The National Hydrologic Dataset – High Resolution was used to identify stream channels in the watershed. This data set was buffered by 30m and converted to raster to represent riparian-type CRP practices. This was then merged with the Current Scenario. Figure 6 shows the results of this method and table A-6 provides a detailed land use type and cost breakdown.

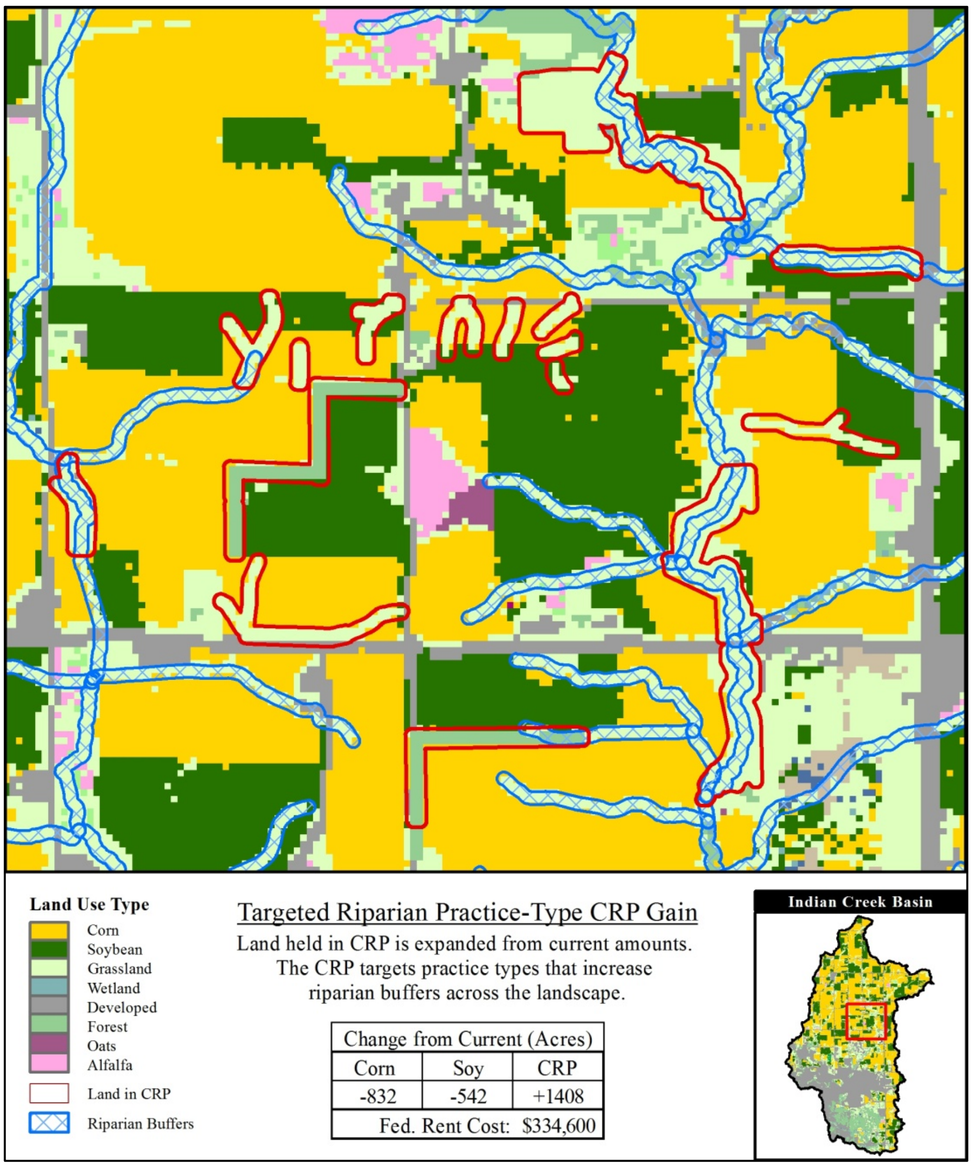

Figure 6: Targeted Riparian Practice-Type CRP Gain Land Use Example

v. Targeted Wetland Practice Type CRP Gain: The philosophy behind this scenario is much the same as the Riparian Scenario but wetlands are used as the vehicle for overland flow retardance and nutrient/sediment retention.

The method used to generate wetland areas was derived from a presentation by the Iowa DNR (Iowa Wetland Action Plan, 2010). The presentation provides a method for assigning a wetland order, much like stream order, which determines restoration priority. The technique uses a depression analysis method to identify landscape sinks that could possibly function as a wetland. These sinks are then linked by a drainage network and orders are applied according to position in the stream network. Wetland orders were not developed for this effort as it did not add value to scenario development. Once the depression analysis was complete all sinks in the landscape that were less than an acre were removed and the remaining sinks were merged with the Current Scenario as wetlands. Figure 7 shows the results of this method and Table A-7 provides a detailed land use type and cost breakdown.

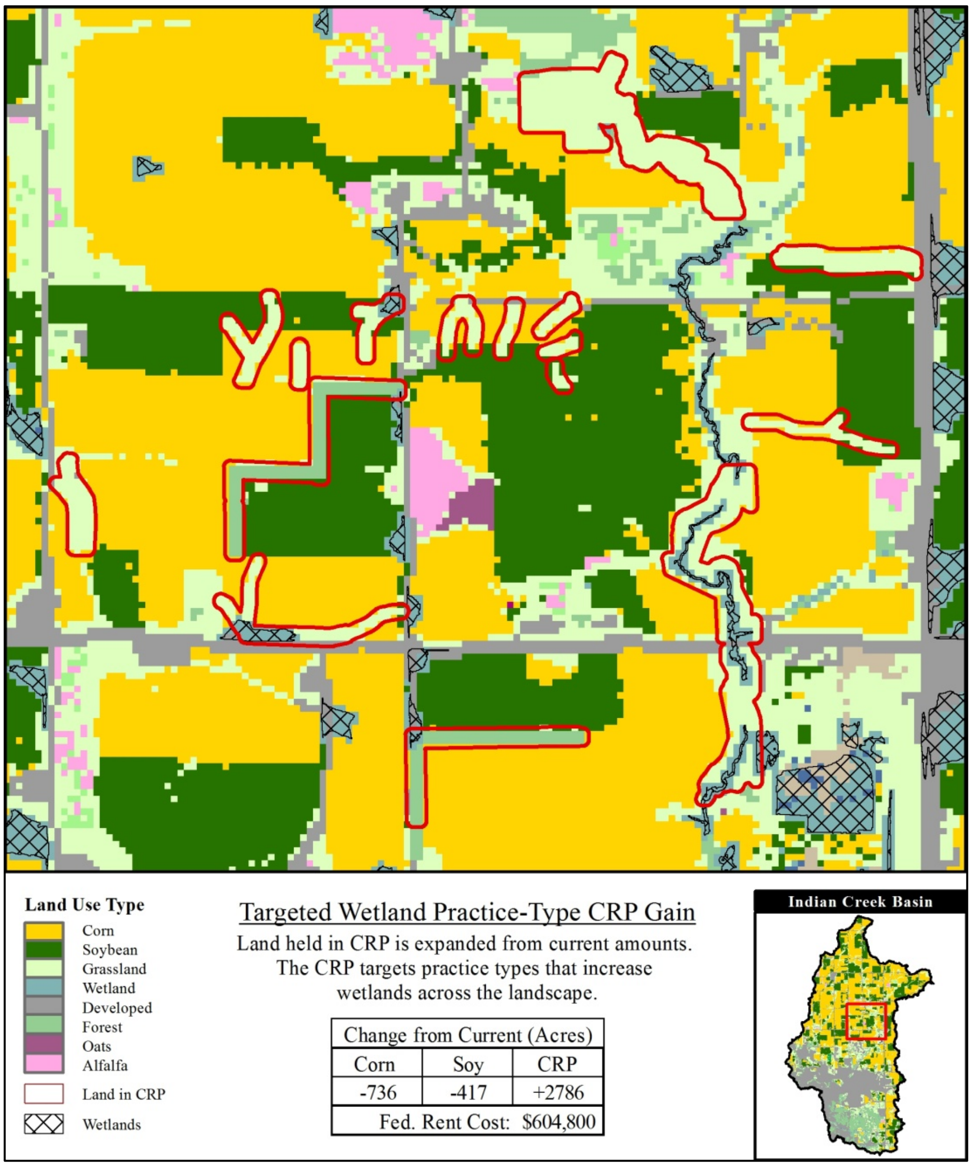

Figure 7: Targeted Wetland Practice-Type CRP Gain Land Use Example

vi. Combined Wetland & Riparian Type CRP Gain. This scenario was developed as an extreme-future scenario, to test if compounding future CRP gains would result in a more significant flow reduction. It is a combination of the riparian and wetland scenarios with priority given to the wetlands. The riparian buffers act as connectors between wetlands. It is understood that this scenario is unlikely to materialize as significant Federal investment would be required to set aside appropriate acreage.

The method to develop this scenario merges the riparian and wetland scenario CRP with the Current Scenario. Figure 8 shows the results of this method and Table A-8 provides a detailed land use type and cost breakdown.

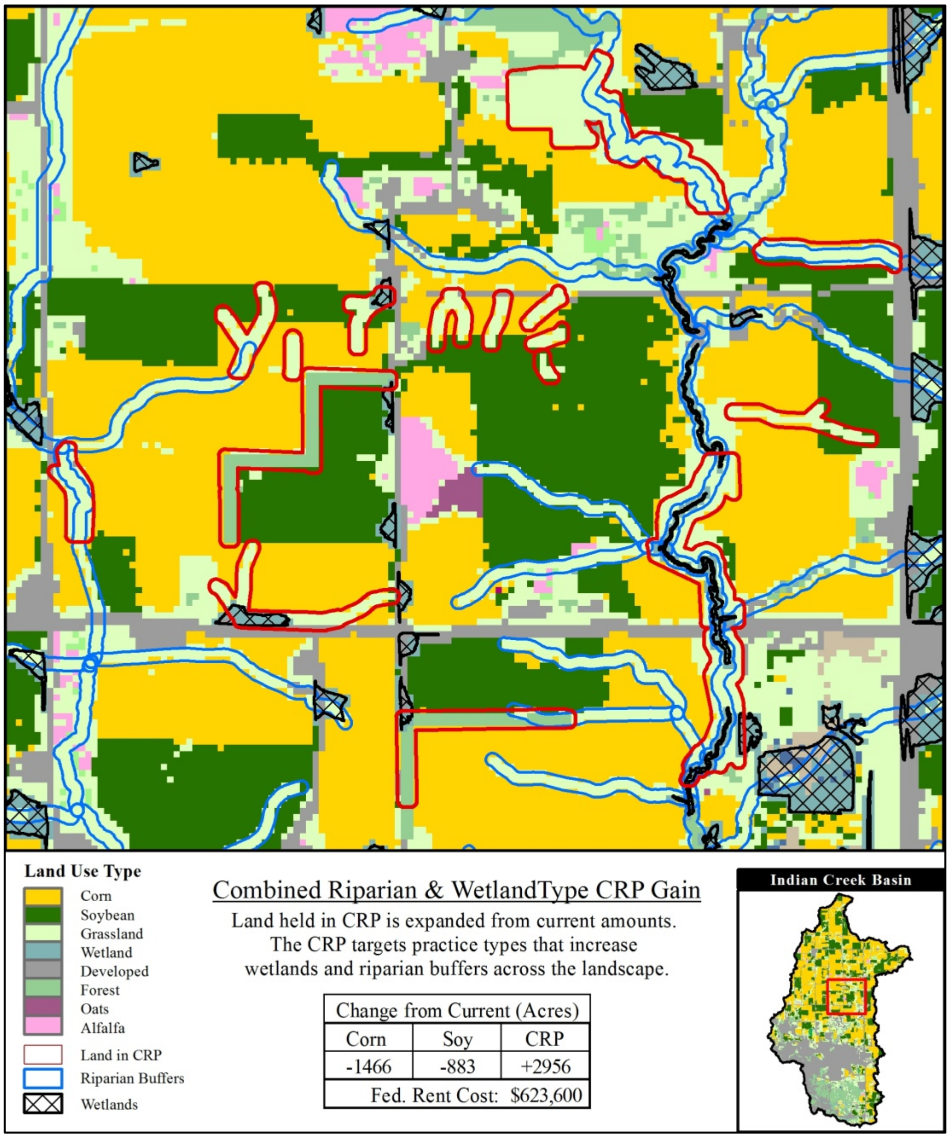

Figure 8: Combined Riparian and Wetland Type CRP Gain Land Use Example

An important part of contextualizing the CRP land use changes across scenarios is to understand how little of the basin CRP land comprise. Table 2 shows the percentage of basin area that is under CRP for each scenario.

Table 2: Basin CRP Percentages by Land Use Scenario

Land Use Scenario	Total Acres of CRP	Percent of Basin in CRP	Federal Rental Cost
Total CRP Loss	0	0.0%	$0
Partial CRP Loss	70	0.1%	$7,676
Current Land Use	966	1.6%	$114,282
Riparian CRP Gain	2374	4.0%	$334,603
Wetland CRP Gain	3752	6.3%	$604,773
Combined CRP	3922	6.5%	$623,629

b. GSSHA Model Application. Each land use scenario was re-sampled to match the grid cell size of the model (100m). These 100m land use grids were further re-classed by common parameter sets including surface roughness and evapotranspiration (ET). The land use was collapsed into 14 roughness types and 6 ET types. Reference Tables B-3 and B-8 for a detailed breakdown of roughness values and Tables B-2 and B-7 for ET types.

The land use scenarios were also collapsed into a 4-class grid. The classes were Developed, High Intensity Agriculture, Low Intensity Agriculture, and Open Water. This grid was used as a measure of soil disturbance and used in determining saturated hydraulic conductivity for the Green and Ampt infiltration parameters. See tables B-4 and B-6 for a breakdown of soil disturbance and saturated hydraulic connectivity parameters.

Due to the Conservation Reserve Program's local implementation of CP the crosswalk developed to relate CRP to CDL classes should be re-evaluated depending on:

1. ecologic region of the US;
2. typical farming practices in the watershed; and
3. specific local implementation of the conservation practices.

As Iowa is fairly ubiquitously suited for row cropping and as corn and soybean prices have remained high, the method used for deciding what each CP would convert into, should it leave CRP, was simplistic. In more complex landscapes with less soil suitability and more crop diversity the method will need to become more complex.

2. Hydrologic Modeling - GSSHA. An existing hydrologic model for the Indian Creek basin was used and improved in order to model conservation practices in a smaller subwatershed typical of the Cedar River basin. The effects of the quantity of CRP lands along with their type and placement on the hydrology of the Indian Creek basin were simulated using the GSSHA hydrologic model. GSSHA is a physically-based distributed hydrologic model that simulates 2-dimensional overland flow and groundwater, 1-dimensional channel flow and infiltration, and has a full coupling between surface and subsurface components. The model can simulate continuous hydrology or single events and produce sub-daily or sub-hourly outputs. GSSHA was developed at the Corps' Engineer Research and Development Center at the Coastal and Hydraulics Laboratory.

The Indian Creek GSSHA model was built at a 100 meter grid resolution (100 m grid and stream representation shown in figure 9). Because the model considers each grid cell explicitly in space, the relative size and position of CRP lands within the watershed are well-modeled for their effect on not only the infiltration of rainfall into the soil, but also the overland flow of excess runoff. The model is capable of simulating both Hortonian infiltration excess overland flow and saturation excess overland flow, both of which are runoff generating processes apparent in the Indian Creek basin. The physical parameters that describe the infiltration, surface runoff characteristics and evapotranspiration are known, measurable physical quantities and not conceptual or empirical parameters meant to approximate a hydrologic response. Thus varying land classifications can be compared against one another with a physical basis for their representation within the model.

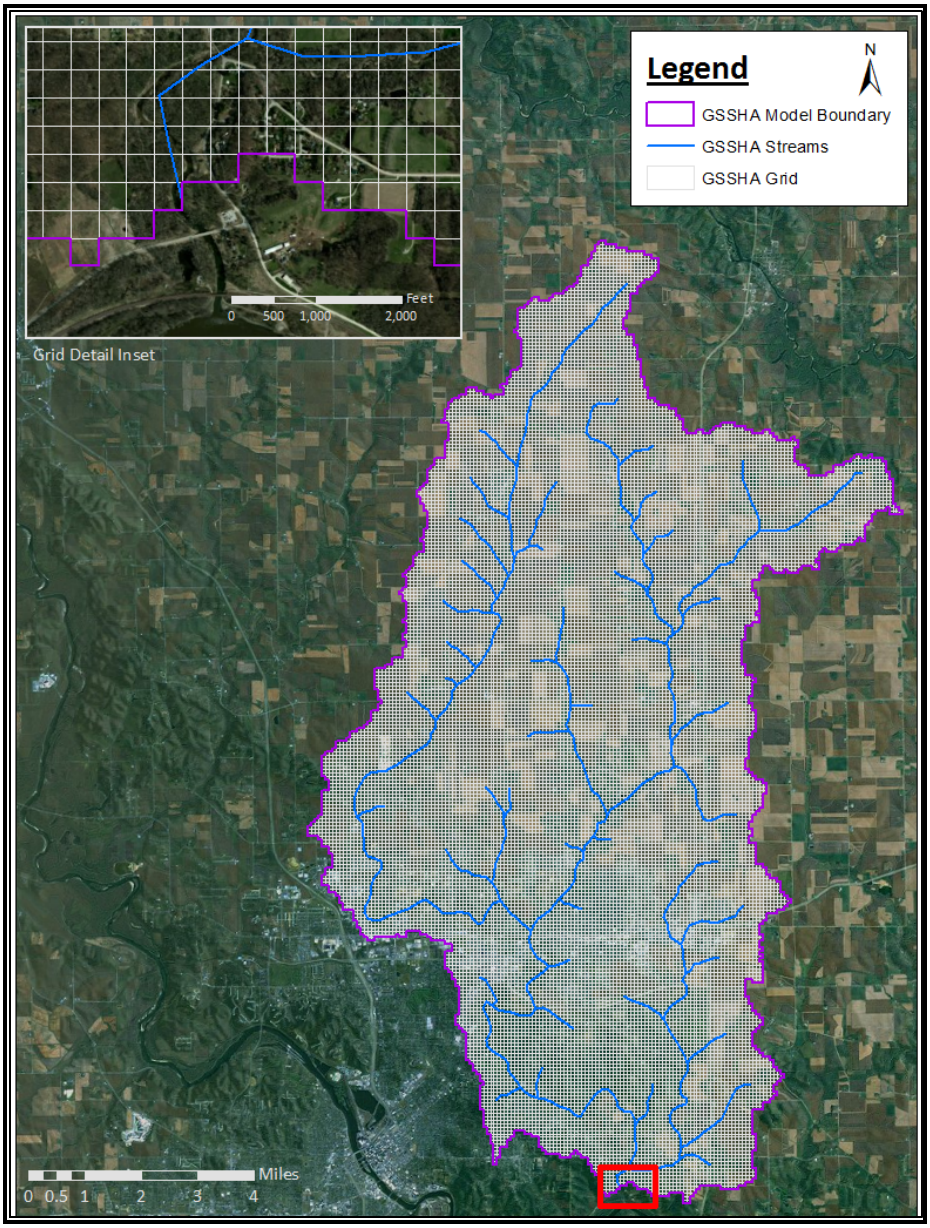

Figure 9: GSSHA Model Grid Cells and Channels

Two hydrologic simulation processes that the GSSHA model is capable of simulating but were not included in the Indian Creek model are plant interception of rainfall and farm tile drainage. Interception is a small fraction of the water balance of a very heavy rainfall event but could increase evapotranspiration rates prior to the storm, reducing soil moisture levels. Hydrologic modeling of tile drainage is complicated by the uncertainty regarding the location, quantity, size and depth of tile drains in agricultural fields. In order to accurately represent and model a tile drainage network within the GSSHA model these data are necessary. The challenge of modeling tile drainage is widespread, as there is poor documentation of where, when and how much tile has been installed over the generations of farming on any individual plot of land. This is not unique to the Indian Creek basin. Tile drainage can have effects on the soil moisture of a field prior to a rainfall event and reduce runoff by reducing the saturation level of soils, preventing saturation excess overland flow. However, during a heavy rainfall event the effect can be muted as the soil infiltration rate can be dwarfed by the rate of rainfall and becomes the controlling factor in producing runoff (Hortonian overland flow). This study did not explicitly model tile drainage in the Indian Creek basin, but the use of varying antecedent conditions can handle the effects of tile drainage implicitly.

The Indian Creek GSSHA model simulation results were compared against observed groundwater potentiometric surfaces in order to verify the groundwater simulation component of the model. There were no flow velocity observations against which to verify the 1D channel model results within GSSHA; however, simulation results from the Indian Creek HEC-RAS 1-dimensional hydraulic model were compared to the GSSHA velocity and water surface elevation results for an observed flood event that occurred in 2009. Peak water surface elevation data was observed for this event, which was used in the calibration of the HEC-RAS model. The Indian Creek HEC-RAS model was built for a separate project using surveyed river cross sections and was calibrated with high water marks from several flood events.

A review of the model’s inputs, assumptions, functionality and hydrologic results was performed by research engineers at the Corps’ Engineer Research and Development Center who are involved in the development and upkeep of the GSSHA model. Their comments and suggestions were used to improve the model.

a. Model-Driving Meteorology. Indian Creek is a challenging basin to model due to a lack of observed data. The USGS streamflow gauge at Marion was established in May 2012, which means there are currently less than two years of streamflow record. Prior to its establishment there were only low-accuracy flash flood sensors and flood high water marks to which hydraulic and hydrologic models could be calibrated. High quality sub-daily rainfall observations are only available at the Eastern Iowa Airport southwest of Cedar Rapids, IA which is well southwest of the watershed boundary. A daily COOP gauge within the basin provides some comparison between observations at the airport and in the basin, but due to the path and nature of storms in the area, significant rainfall may occur in the basin without any observations occurring at the airport, and vice-versa (see figure 10 for the location of both relative to the watershed). Additionally, the basin is near the edge of NEXRAD radar coverage from the Davenport, IA (KDVN) radar site and just beyond coverage from the radar sites at Des Moines, IA (KDMX) and La Crosse, WI (KARX), which has in the past resulted in unreliable estimates of precipitation intensity over this basin for hydrologic modeling purposes. The lack of rain gauges over the basin makes verification of NEXRAD-sourced rainfall intensities difficult. Thus, synthetic rainfall events that represent a range of storm intensities were preferred to historical storm events.

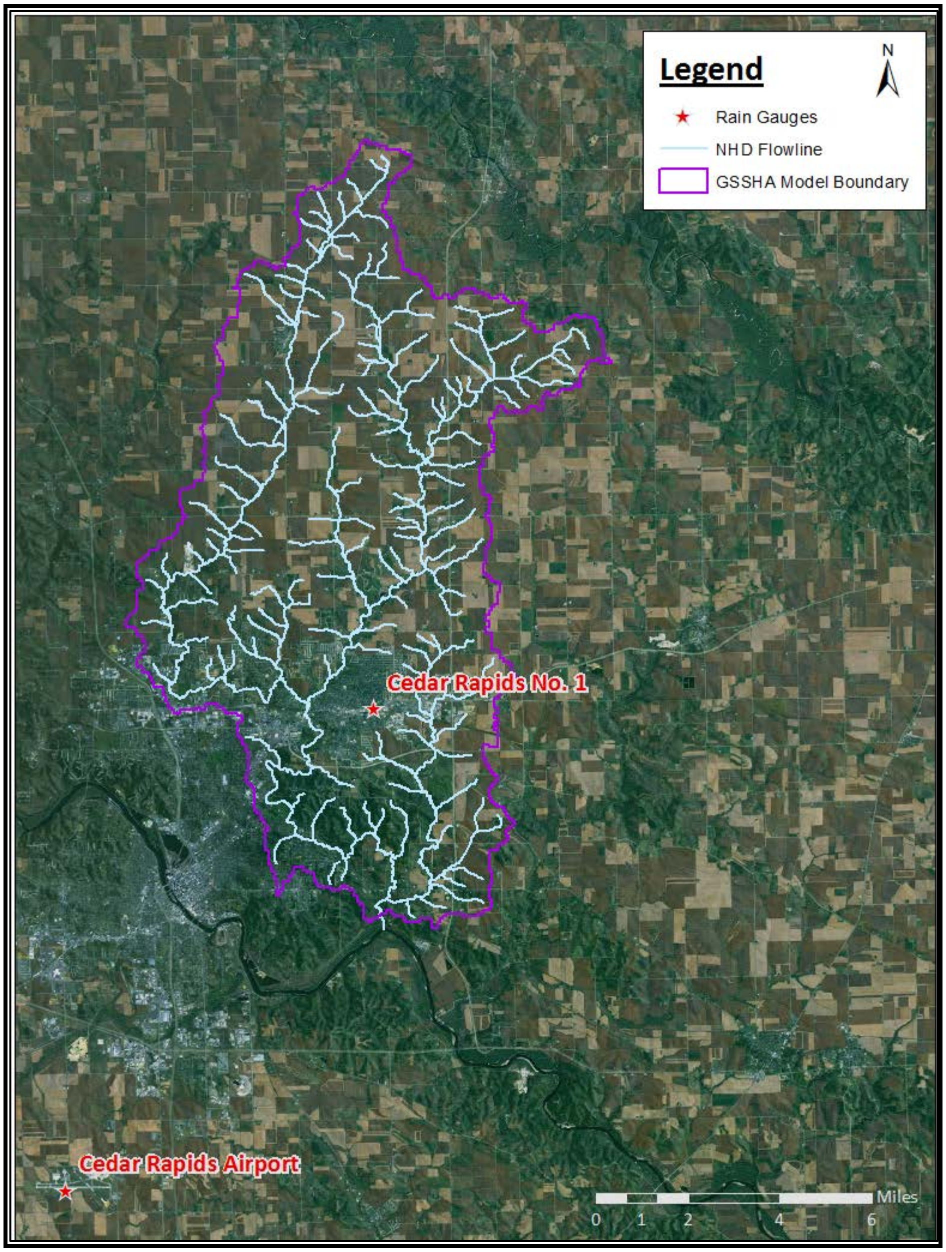

Figure 10: High Quality Rain Gauges Relative to the Indian Creek Watershed

In order to test the hydrologic response of the CRP practices against a variety of flood-causing scenarios, synthetic hydrometeorological events were created based on historical monthly total precipitation and NOAA Atlas 14 precipitation frequency estimates. Each hydrometeorological scenario was created from three variables: the duration of the rainfall event, the estimated frequency of occurrence of the rainfall event for that duration, and the amount of precipitation received over the basin for the month prior to the rainfall event. This makes it possible to explore the impacts of CRP on flood-causing events of different natures.

In the Indian Creek basin, three major mechanisms for flooding occur. One is a moderate or large rainfall event falling on soils that are saturated or near saturation due to rainfall prior to the flood event. Another mechanism is very high volume continuous or persistent rainfall, and the third is very intense, short duration rainfall events that exceed soil infiltration rates. The recent release of NOAA Atlas 14 Volume 8 v2.0 (Midwestern States) afforded an opportunity to utilize the updated point precipitation intensity estimates for various storm durations and frequencies.

The rainfall events were selected from the NOAA Atlas 14 precipitation frequency analysis (table B-1). Storms of 6 and 24 hour duration were used in this analysis, with 6 hours representing a short, highly peaked and intense storm event, and 24 hours a more persistent but high-volume rainfall event. The total rainfall from table B-1 was temporally disaggregated to half-hour incremental precipitation depths using temporal disaggregation curves based on a regional analysis of time-variant storm intensities. Curves for the 6 and 24 hour storms (24-hour shown in figure B-1) were used to determine incremental rainfall intensities for the modeled storm events. These frequency-based rainfall events were applied uniformly across the basin, which disregards the effect of storms with a strongly localized component (storms that are smaller than the watershed) or that move across the watershed and produce peak rainfall over different parts of the basin at different times. Unfortunately there were no readily available methods for producing synthetic storms of these types and this remains a limitation to this study.

The antecedent conditions for the flood events were generated using a volume-frequency approach for monthly precipitation at the Cedar Rapids No. 1 COOP precipitation gauge. Each month in the record was ranked by total monthly precipitation (figure B-2). For the “wet” condition scenarios, the month closest to the average of the top 10% wettest months was selected for use in the model (figure B-3). For the “average” condition scenarios, the month closest to the average of all months was selected (figure B-4). A “dry” condition was also considered but not ultimately utilized, as simulation results from this scenario were not informative.

The 24 hour storm duration temporal disaggregation curve from Atlas 14 was used to create subdaily rainfall for the entire month to be used in the GSSHA model, which requires rainfall data at hourly or more frequent intervals. These small events prior to the peak event are not being analyzed as part of the results, only as a method for initializing soil moisture prior to the event of interest.

b. Model Parameterization. The most important consideration when modeling the effects of change in a system is that the change is accurately represented within the model. GSSHA is a physically-based model that represents varying land uses with physical, measurable parameters. Thus, converting row crops to riparian buffer strips or removing planted forest in favor of row crops can be represented objectively within the model with hydrologic parameters specific to the land use type. In the Indian Creek GSSHA model, the changes in land use were represented through three processes: infiltration, overland flow and evapotranspiration.

The effect of changing CRP practices on infiltration was represented by changing the saturated hydraulic conductivity (K_{sat}) values to reflect the intensity of disturbance to the soil beneath. CRP practices are considered low-disturbance to the underlying soil with respect to compaction and other agricultural practices. Some soil types have infiltration parameters more sensitive to disturbance (especially compaction) and when disturbed, have reduced infiltration rates relative to their undisturbed state. The section titled *Green-Ampt Infiltration Parameter Estimation* in Appendix B describes the process in detail with the sources for the methodology.

Each land use type (including different CRP practices) has a surface roughness (referred to as Manning's 'n' value) that changes when the land cover is altered. Different types of vegetation (or bare surface such as pavement or bare fields) will resist the flow of water to different degrees. Manning's 'n' values are well-documented for a variety of crops and land uses. Similarly, different types of plants and land surfaces have different rates of evaporation or transpiration (the combination of which is referred to as evapotranspiration or 'ET'.) The parameters for these processes vary by land use, which was altered for each scenario.

The set of model parameters was constant between each model scenario run, which means that each model run has the same physical response to a land use type. The land cover was directly modified on a grid cell basis for each land use scenario. GIS analysis provided products which were used to describe land use within the model. A raster layer that used the CDL classification for land cover types was reclassified to match the ET and overland flow roughness parameter sets. These groupings are shown in Appendix B. To use the aforementioned methodology for estimating infiltration parameters, the CDL land use types were collapsed into three soil disturbance classifications (developed, low disturbance and high disturbance.) The unique combination of disturbance classification and USDA soil texture created an infiltration parameter set.

c. Scenario Combinations and Results. By combining a variety of meteorological and land use scenarios and computing the downstream flooding effects for each we are able to determine which meteorological conditions CRP practices may have the most benefit to reducing flood damages. While damages may not occur at lower intensity (higher frequency) rainfall events, there still may be some measurable flow reductions caused by changing the amount of conservation land within the watershed. 120 scenarios were tested, each with a unique combination of antecedent rainfall, duration, frequency and land use from table 3.

Table 3: GSSHA Model Run Scenario Construction

Land Use Scenario	Antecedent Rainfall	Duration	Frequency (avg return interval)
Total CRP Loss	Wet / Average	6 hours / 24 hours	10 years / 25 years / 50 years / 100 years / 500 years
Partial CRP Loss			
Current Land Use			
Targeted Riparian Practice-Type CRP Gain			
Targeted Wetland Practice-Type CRP Gain			
Combined Riparian & Wetland CRP Gain			

Each scenario combination was run with the GSSHA model. Discharge hydrographs for each simulation were produced for 28 points representing concentrations of structures in the floodplain. These "index points" were used as locations to aggregate economic data. The peak discharge at each index point was converted to a water surface elevation using a rating curve derived from the Indian Creek HEC-RAS model (see example in figure 11). The water surface elevation was considered uniform for all structures at an index point, which is supported by the relatively flat slope of the watershed. These elevation peaks were used to compute the economic flood damage at each index point. Figure 12 illustrates the relationship between flood damage and flood peak elevation, and the methodology for computing this curve is enumerated in detail in Section 3, *Economic Evaluation*.

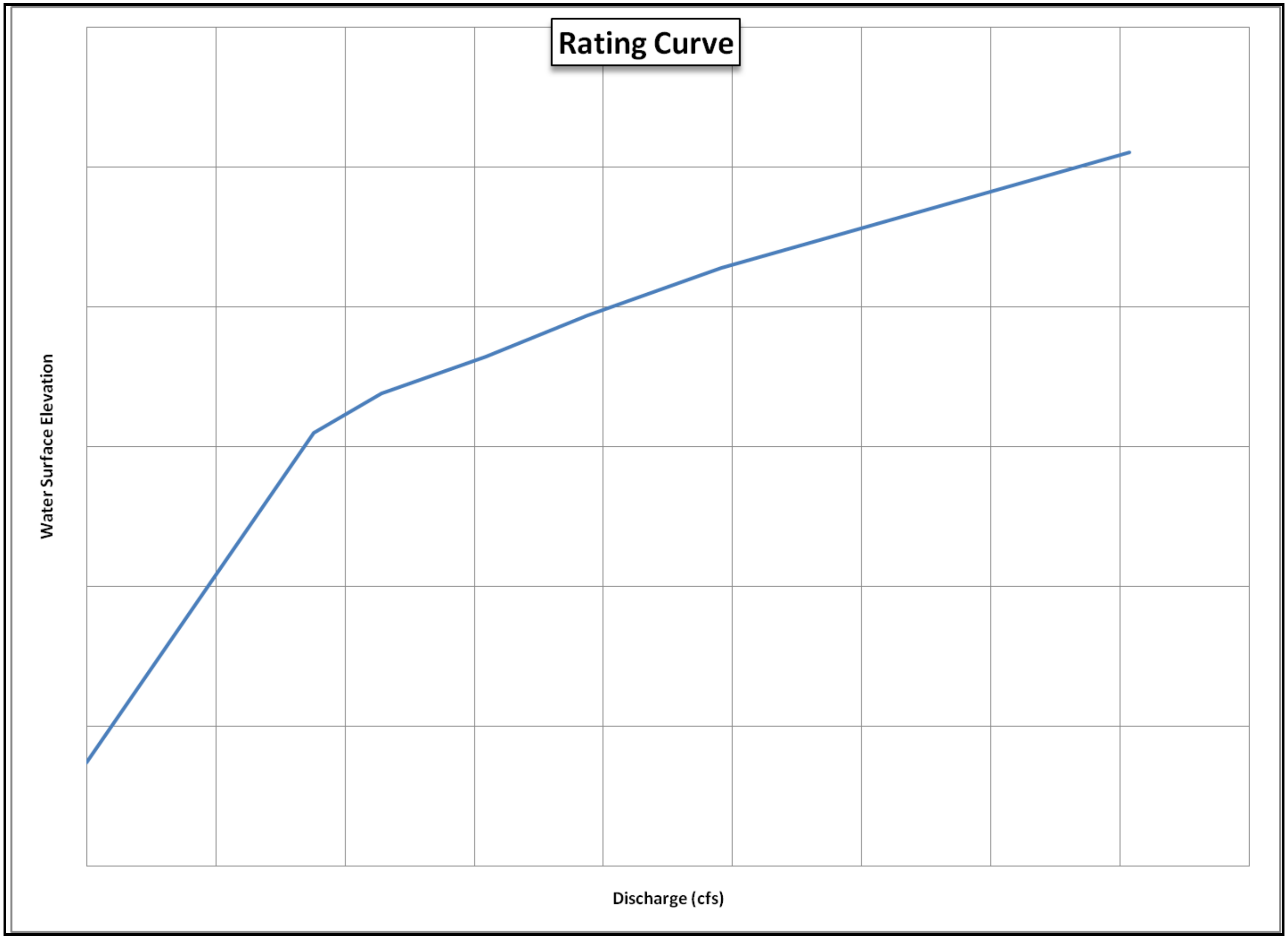

Figure 11: HEC-RAS Derived Rating Curve (typical)

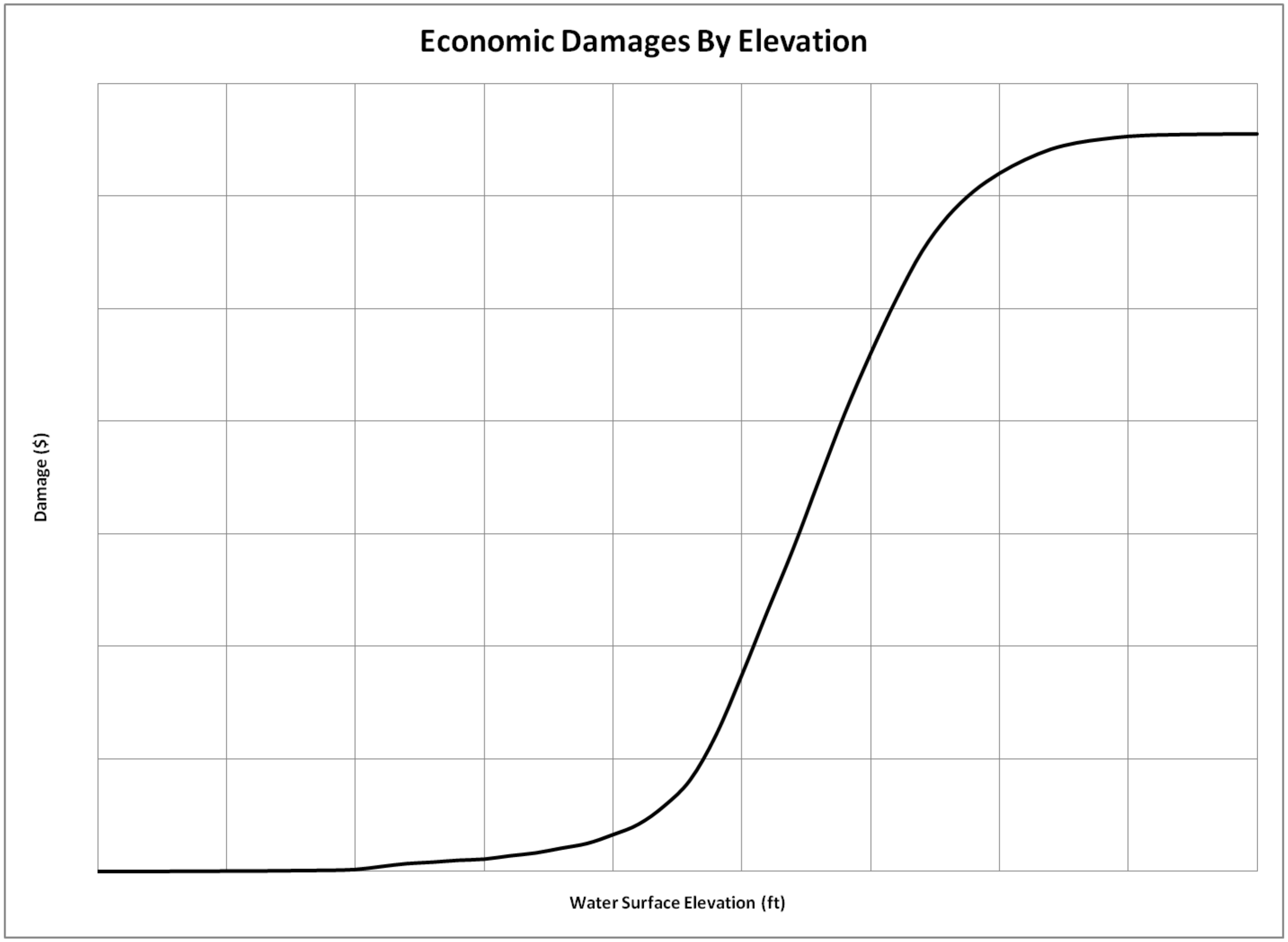

Figure 12: Flood Damages ($) by Water Surface Elevation (Typical)

3. Economic Evaluation. While discussing the economic evaluation, a scenario refers to a discrete combination of land use scenario, antecedent condition, rainfall duration and frequency. These scenarios will be written as N-Wet-6hr-500yr (Total CRP Loss, Wet antecedent condition, 6 hour duration, 500 year frequency). See Table 3 for more information.

The economic analysis for this study is very basic and mostly utilizes existing data sets. The purpose of the analysis is not to rigorously quantify all damages within the various reaches, but to provide a reasonable estimate of damages suitable for comparison of the various scenarios described elsewhere in this report. The analysis only takes into account structure damage and content damage of residential homes. Inclusion of infrastructure, traffic detour, flood fighting, commercial, and other categories of damages would have required a significant increase in the effort and cost of this part of the report with little to no value added.

The analysis itself is scenario-based, which differs from the traditional Corps method of annualizing benefits and comparing them to amortized costs (cost of a proposed alternative). This study is better suited to the scenario approach because it allows for discrete damage points and isolation of certain scenarios under certain conditions as opposed to overall flood risk.

a. Data. The data used for this analysis consisted of water surface elevations, ground elevations of structures, a structure inventory, tax assessor data, depth-damage functions from IWR (Institute for Water Resources) report IWR-92-R-3, and land use scenario descriptions. The water surface elevations were the GSSHA outputs discussed elsewhere in the report. Ground elevations for the various structures were obtained using Lidar. The structure inventory was a windshield survey conducted by the chief economist for Rock Island District. Current tax assessor data was obtained from the county and the land use scenarios are described elsewhere in the report.

The study area contained 951 structures that were identified by using the approximate .02% exceedance probability flood inundation area plus 1 foot. Of the 951 structures, 901 were used in the analysis. The structures that were not used were all labeled by the tax assessor as commercial or 'Null' (no structure type) and were removed from the inventory to simplify the analysis. From the 901 structures used, the breakdown of structure types is as follows: 11% Apartment, 17% Apartment with Basement, 7% Condos, 48% Ranch, 3% Split Level, and 14% 2-Story. All 120 scenarios (20 hydrologic events and 6 land use conditions) used the same structure inventory and assumptions for damage computation.

The structure inventory obtained first floor elevations (FFE) for all 901 of the structures used in the analysis. These FFEs are a critical component of the damage assessment and will be discussed in the methodology section. There were 951 structures in the original inventory and 901 ended up being used for the analysis. The remaining 50 (5.3%) structures were classified as businesses or had no structure type and were not included in the analysis.

b. Methodology. The program used for this analysis was Microsoft Excel. A scenario-based approach was used instead of the normal Corps method of "annualizing" damages based on a full hydrologic and hydraulic profile. These data were not available, so a scenario analysis was deemed appropriate and suitable for the needs of the study. The basic premise was to take the ground elevation of the structure, add the height to the first floor, and (if necessary) subtract 8 feet in the case of a basement. This "zero" damage point was then compared to the peak water surface elevation output from GSSHA at that Index Point in order to determine depth of flooding. Next, the depth (if >

0) was compared to the depth damage functions and a corresponding % of structure value damage. The current building value from the assessor data was multiplied by 1.5 (for rough estimates of content value, the Corps generally considers 50 percent of the value of the structure to be an acceptable surrogate for a full survey) and then further multiplied by the depth damage % to get a total damage.

$Flood\ Depth = WSE_{IP} - (Elev_{ground} + Height_{first\ floor})$	No basement
$Flood\ Depth = WSE_{IP} - (Elev_{ground} + Height_{first\ floor} - 8)$	Basement
$Percent\ damage\ to\ structure = f(Flood\ Depth)$	See table 4
$Damage\ to\ structure = (Percent\ damage * Assessed\ value * 1.5)$	

The structures were grouped into Index Points (1-28) based on proximity for the purpose of assigning water surface elevations. All structures within an Index Point received the same water surface elevation value when determining flood damages (if any). This basic method is standard Corps' practice for most flood risk management studies. This same method was used throughout all 28 index points for the complete set of 120 scenarios.

Once damages were calculated for each scenario, two economic screening techniques were used to identify events that had some measurable impact on reducing flood damages

Marginal Benefit (MB). In this study marginal benefit is the dollar amount of change in damages between any given scenario *x* and its Total CRP Loss equivalent *n* (holding constant the meteorological scenario)e.g.

$$MB_x = Damage_n - Damage_x$$

If the resulting amount is positive a marginal benefit is realized: Less damage is occurring when there is more CRP in the landscape. If the resulting amount is zero or negative, no marginal benefits are realized and the scenario is screened out.

Net Marginal Benefit (NMB). In this study, net marginal benefit is the dollar amount of damage reduction realized past what the CRP landscape costs. The CRP landscape cost is simply the total Federal rent paid out for the CRP practices in the basin.

$$NMB_x = MB_x - (CRP\ Cost)_x$$

If the resulting amount is positive, a net marginal benefit is realized; the damages reduced are greater than the cost of the land needed to affect the reduction in damages. If the amount is negative, no net benefits are realized and the scenario is screened out.

Once these two screening techniques were employed two indicators were used to determine which CRP scenario was best at reducing flood damages and to provide some temporal context to the net marginal benefits calculated. These indicators were necessary because a traditional Corps Benefit-Cost ratio could not be calculated as the damages have not been discounted or annualized. The underlying issue preventing this is the lack of a frequency or probability for the stream discharges modeled and used to calculate damages. Typically at least 30 years of streamflow record are necessary for a flow frequency analysis, and no record of that length exists for Indian Creek. There are other ways to approximate flow frequencies; however, those methods were beyond the scope and time constraints of this study.

With this in mind, the screening techniques take into account only 1 year of Federal payments for CRP practices and one scenario occurrence. They do not take into account the number of years without an event that payments would still be made.

Benefit Return Period (BRP). The benefit return period is a the number of years CRP payments can be made before the net marginal benefits for a single scenario event become zero, or a net marginal benefit is no longer realized.

$$BRP_x = \frac{NMB_x}{(CRP\ Cost)_x}$$

The benefit return period can be compared to the precipitation event frequency to see if the timelines are similar. If the BRP is equal to or greater than the return frequency that particular CRP land use scenario is effectively and efficiently reducing flood damages.

Cost-Loss Ratio (CLR). The cost loss ratio is a non-annualized version of a Benefit-Cost ratio. The ratio describes the dollars of flood damage reduction gained by $1 of CRP payment. Again, this ratio relates only 1 year of Federal payment to a single scenario occurrence.

$$CLR_x = \frac{MB_x}{(CRP\ Cost)_x}$$

If the ratio is less than 1, flood damage is being reduced, but inefficiently. If the ratio is greater than 1, flood damage is being reduced efficiently.

Using this combination of screening techniques and economic performance indicators will not result in a clear best-buy type of CRP landscape to contractually target. It does build a framework for assessing and discussing a land use scenario's ability to non-structurally reduce damages during high water events.

The following paragraphs will more fully explain the analysis' basic assumptions and data sources.

c. Basic Assumptions and Data Sources. Damages to a structure depend greatly on what type of structure it is. A split-level home has a different depth-damage equation than a 1-story home with no basement. The tax assessor data provided clear structure types for every residence and they are listed below along with the assumption about which depth-damage function would be applied to them.

Table 4: Assessor Structure Types and Associated Depth-Damage Function

Assessor Structure Type	IWR Depth-Damage Function
Ranch	1 Story, with Basement
2-Story	2 Story, with Basement
Apartment	2 Story, no Basement
Apartment, with Basement	2 Story, with Basement
Condo	2 Story, no Basement
Split Level	Split Level

The IWR depth-damage functions were taken from the IWR-92-R-3 report published in 1992. The functions used had been adjusted by the authors specifically for Rock Island, IL, which is very close to our study area. The actual depth-damage functions that were used in the analysis are available in the Economics Appendix.

The first floor elevations of structures were generally estimated during the windshield survey by counting steps up to the front door. A standard step is 8 inches tall, so 3 steps equal a 2 foot FFE. The current tax assessor data was used as a surrogate for depreciated replacement value, which is generally used in U.S. Army Corps of Engineers feasibility studies. The current building value was the field chosen for this role. Aside from the structure value, content damage is often times a significant damage category during a flood, especially those in which there is little warning. A common benchmark that is used in the absence of a full survey for content value is 50% of a structure's value. This is why the structure value is multiplied by 1.5 in the analysis. The assessor data was also used to identify structure types and assign them to depth-damage functions.

Changes in damages are measured from Total CRP Loss land use scenario as the Federal cost for this land use scenario is zero. It is assumed that by removing CRP from upstream contributing areas, flood heights downstream will increase. By holding a Total CRP Loss land use scenario as a baseline from which to measure flood damage changes, the effect CRP has on discharge and flood heights can be isolated, monetized and compared for efficacy.

B. Cedar River Basin Assessment

1. Geographic Information Systems. Please reference Indian Creek, *Section A.1.a* for a more detailed description of the land use scenario construction methods used in the SWAT model.

Land use change in SWAT was simulated by the percent change of area, by land use type, for each sub-basin. Percent change is the percent change in area from the Current Scenario to the land use scenario of interest. Once the percent change was calculated for each sub-basin the percentages were applied to each individual HRU in the sub-basin. These were then applied to the HRU input table using a script developed by Jason Ulrich, Univ. of Minnesota, Dept. of Bioproducts and Biosystems Engineering and Jim Almendinger, St. Croix Watershed Research Station, Science Museum of Minnesota. It should be noted that the initial land use conditions in SWAT were based on the 2008 CDL and not the CRP 'enforced' Current Scenario grid. This initial land use condition could not be modified to reflect the Current Scenario as the model was initially calibrated using the 2008 CDL and changing the initial land use types would necessitate a complete model rebuild and calibration.

The land use types available to change to reflect different CRP scenarios were limited by the initial land use conditions. The three land use classes used to simulate changes in CRP are: Forest, Pasture and Wetland. This required a different CRP to CDL crosswalk than that used for the GSSHA model. This crosswalk can be found in Table A-2. In addition to a limited set of CRP land use types, 16 out of the 227 sub-basins did not contain the three land use types and could not be changed to reflect changing CRP conditions.

The scenarios tested to affect hydrologic response are Total CRP Loss and Targeted Riparian Practice-Type CRP Gain. When there was a general lack of model response from the first two scenarios, a third, far more extreme, scenario was developed to test for response. This scenario is a hypothetical planning landscape that optimizes water quality in the Cedar River basin. It was developed for an on-going integrated watershed study being conducted under the Upper Mississippi River Comprehensive Plan Authority as defined in Section 459 of Water Resources Development Act 1999 (Public Law 106-53). The method used to develop this scenario is documented in Appendix D. Table 5 shows the average percentage change applied to CRP land use classes for the three scenarios. A detailed breakdown of percentage changes applied to each sub-basin for each land use scenario is reference in Table A-9. It should be noted if the percentage change is less than 100% it reflects a decrease in area and greater than 100% is an increase in area.

Table 5: Average Percentage Change Applied to Each CRP Land Use Type by Scenario For SWAT

	Pasture	Wetland	Forest
Total CRP Loss	73%	65%	84%
Riparian CRP Gain	123%	N/A	N/A
Water Quality	406%	424%	100%

2. Hydrologic Modeling

a. Hydrologic Model - SWAT. Computational limitations made it so that simulating a watershed the size of the Cedar River basin using a detailed physically-based model such as GSSHA would be infeasible. Additionally a new model for the Cedar would need to be built to perform the simulation. Instead an existing empirically-based hydrologic model for the watershed was leveraged. Simulation of the effects of varying amounts and location of conservation practices in the larger Cedar River basin was performed using the SWAT. The SWAT is an empirical, quasi-distributed hydrologic model that simplifies a watershed into subbasins containing spatially-discontinuous regions of homogeneous land use, soil type and slope referred to as hydrologic response units (HRU). The SWAT runs at a daily timestep, and uses the SCS curve number method for computing rainfall conversion to runoff. For continuous simulation, the model adjusts the curve number of each HRU during the simulation to reflect the effects of changing soil moisture, plant evapotranspiration and agricultural practices. Model streamflow output is available wherever there is a subbasin divide, and is on a daily timestep (which produces daily average discharge values). The model uses internal lookup tables to calculate curve numbers and other model parameters based on landscape characteristics, and the resulting water yield for each HRU during computation is summed over the subbasin. The SWAT model is developed at the Grassland, Soil & Water Research Laboratory, USDA-ARS in conjunction with Texas A&M University.

This study leveraged the Cedar River SWAT model built by the USGS. This model was readily available off-the-shelf with no need to build an additional Cedar River model. It was assembled with the goal of simulating streamflow and nitrate loads within the Cedar River basin (see USGS Scientific Investigations Report 2013-5002). The model was calibrated over the years 2000-2004 and validated for 2005-2010. The NASS CDL year 2008 was used for land use/land cover data and Soil Survey Geographic soil data was used for soil parameterization. Subbasin divides were created to approximately coincide with 12-digit HUC boundaries, and at points with observed streamflow, sediment or nitrate sampling data in order to calibrate the model. Figure 13 shows the spatial extent of the Cedar River model, as well as the representation of subbasins and stream reaches within the model. Figure 13 also shows the location of the Indian Creek watershed with regard to the larger Cedar River basin.

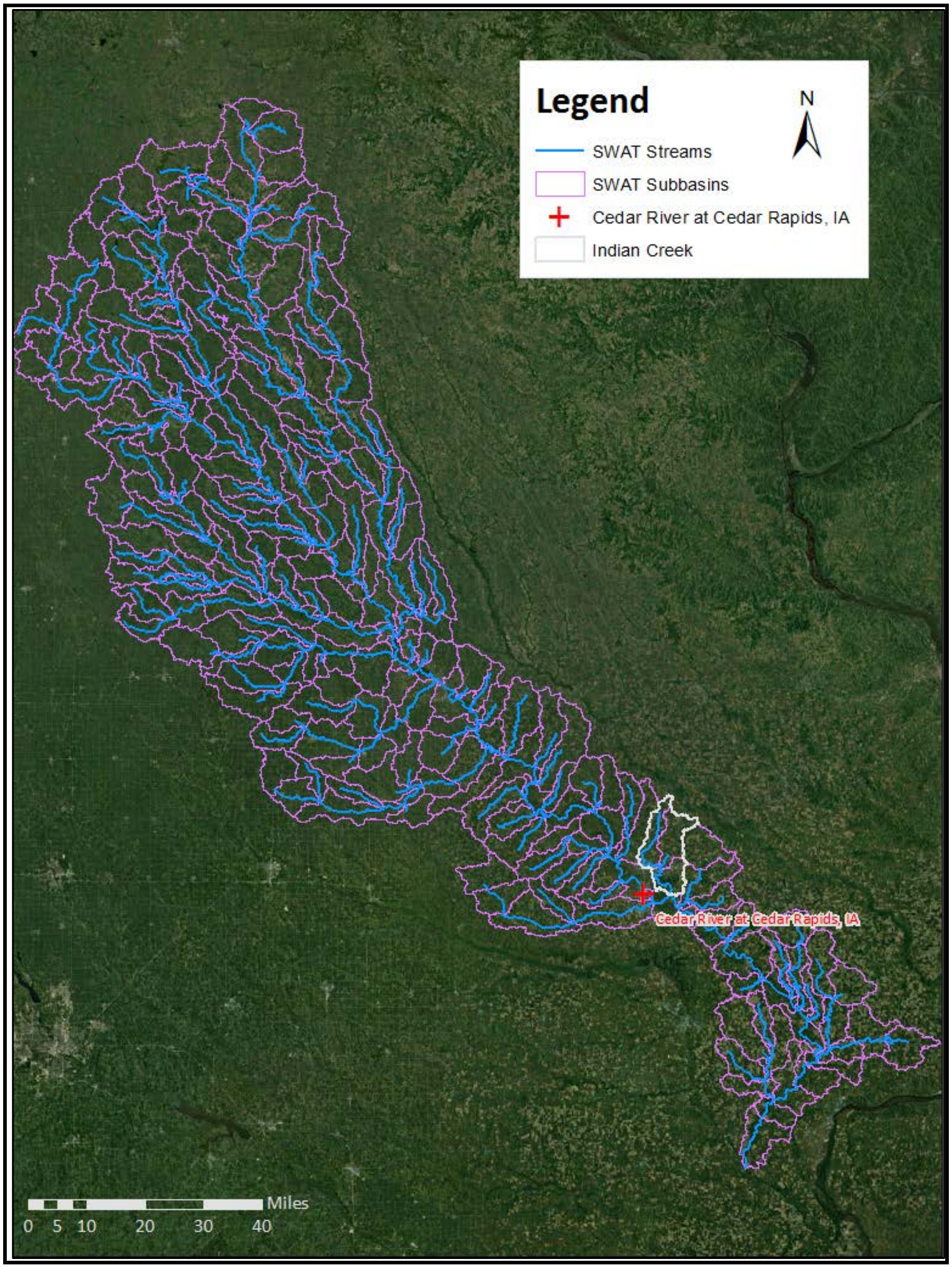

Figure 13: Cedar River SWAT Model Layout With Cedar Rapids and Indian Creek Highlighted

b. Model-Driving Meteorology. The SWAT model was run continuously for a period of 33 years (1978-2010). Daily precipitation, minimum temperature and maximum temperature from 22 NWS COOP gauges and solar radiation, wind speed and relative humidity from four Iowa State University Ag Climate gauges drove the model. Precipitation and temperature data spanned the entire period of record and radiation, wind and humidity data spanned 1988-2010. SWAT's internal weather generator created radiation, wind and humidity values for the period of 1978-1987 when data were not available. However, the model result is not sensitive to this difference as evapotranspiration calculations were carried out using the Hargreaves method, which does not rely on these meteorological variables (only daily temperature.)

c. Model Parameterization. Land use changes were modeled by altering the fraction of each subbasin covered by a given land use. HRUs cannot be added to the model once it is built without completely rebuilding the model. This significant limitation was not realized until the study was underway and an alternative method for altering land use was found. For each subbasin the existing HRU fraction parameter was modified to reflect the varying balance of row crop and grassland for each land use scenario. A modeling tool from the St. Croix Watershed Research Station allowed for an increase or decrease in targeted subbasin HRU fractions while either holding constant or altering other HRU fractions to ensure the sum of HRU fractions equaled unity. The extent of developed area remained constant, but grassland, wetland, forest and row crop fractions were traded as appropriate by scenario.

The land use scenarios were developed in GIS and converted to the equivalent SWAT land use classifications (see GIS method above.) For each land use scenario, the fraction of the area covered by each land use was computed by subbasin. The computed change in subbasin fraction for each land use was applied to the model using the automated fraction change tool. The change in land use was divided evenly among each HRU within the subbasin.

d. Scenarios and Results. Four land use scenarios were tested (see the GIS section for more details on the construction of each): a baseline scenario that reflects current land use and conservation practices, a reduced CRP scenario where non-permanent conservation practices are removed, a scenario with widespread adoption of riparian buffer strips, and an extreme land use change scenario from another project aimed at water quality improvement basin-wide. The baseline scenario runs were the results of the unchanged and calibrated USGS SWAT model, and served as the starting point for the HRU fraction changes made in the other scenarios.

For the 33 years of continuous simulation, the annual peak discharge series was extracted from the results. For each peak the stage at Cedar Rapids was computed using an approximate rating curve for the gauge at that site (see figure B-5). The rating curve was computed as a fourth-order polynomial fit ($R^2 = 0.9896$) to observed stage-discharge data at the Cedar Rapids USGS gauge (05464500 Cedar River at Cedar Rapids, IA).

3. Economic Evaluation. The economic evaluation for the Cedar River intended to make use of the detailed structure inventory that was developed as part of the Corps' Cedar Rapids General Investigation Feasibility Study. However, the methodology was dependent on achieving different flood stages for the various CRP scenarios. The only event that had the potential for significant damages (500-yr) showed zero change in the flood stage generated by the SWAT model so the economic evaluation for the Cedar River basin was not obtainable as part of this study effort.

VI. RESULTS AND DISCUSSION

A. Indian Creek Basin Assessment

1. Modeling Results and Discussion. Across all tested rainfall intensities, rainfall durations and antecedent conditions GSSHA model simulation in Indian Creek showed decreases in peak stage when conservation practices were present.

The main pathway of action that CRP lands have on reducing flood peaks is through increasing infiltration in the watershed. CRP practices are characterized by an increase in the saturated hydraulic conductivity of the soil, which allows more rainfall to infiltrate into the soil, leaving less to runoff (see the details of the methodology in Appendix B under "Green-Ampt Infiltration Parameter Estimation" for citations of the research studies that observed this relationship.) In figure 14, the difference in saturated hydraulic conductivity (K_{sat}) for the "No CRP" and "Riparian" scenarios is shown for the upland reaches of the watershed. K_{sat} is the main driver in determining the rate of rainfall infiltration using the Green-Ampt method used in the Indian Creek GSSHA model. Figure 15 shows the effect of changing K_{sat} on the overland discharge (runoff) for the headwaters of the watershed. The parts of the landscape that were urbanized or intensely farmed produced more runoff during storm events than natural landscape (such as forest or wetland) or manmade conservation areas (such as riparian buffers and grassland.)

A secondary mechanism in the reduction of flood peaks by CRP lands is the increase in overland flow roughness. The land surface has a natural resistance to flow based on the roughness of the surface and objects such as thick plant growth that would impede the flow of water. A metric called "Manning's '*n*'" is used to quantify the resistance that flow encounters in pipes, channels and overland flow. Figure 16 shows the change in *n* for the Indian Creek headwaters between the "Riparian" and "No CRP" scenarios. In this area there is an increase in the extent of thick native grasses along the creek for the "Riparian" scenario which impedes flow into the channel. Areas of decreased overland flow velocities under the "Riparian" scenario are shown in figure 17 for the wet condition 24 hour 500 year storm event. By reducing velocities, the rate of delivery of runoff to the stream is decreased, which increases the amount of time that water can infiltrate at that site. Reducing the velocity of runoff also makes the discharge hydrograph less peaked.

The sum of these effects can be seen in the discharge and stage hydrographs (figures 18 and 19 respectively) for a selected economic index point (#21) under the wet condition 24 hour 500 year storm event. At this location, the "Riparian" scenario results in a decrease in channel discharge of 520 cfs, which reduces the flood peak by approximately 1.7 ft. This would reduce flood damages at this location by approximately $40,700. The total volume of water infiltrated during the rainfall scenario increased by 1.7%, resulting in a net decrease in runoff ratio (volume of runoff divided by volume of rainfall) of 1.3%. For comparison, figures B-6 through B-11 in the appendix show discharge and stage hydrographs for other storm events at index point 21.

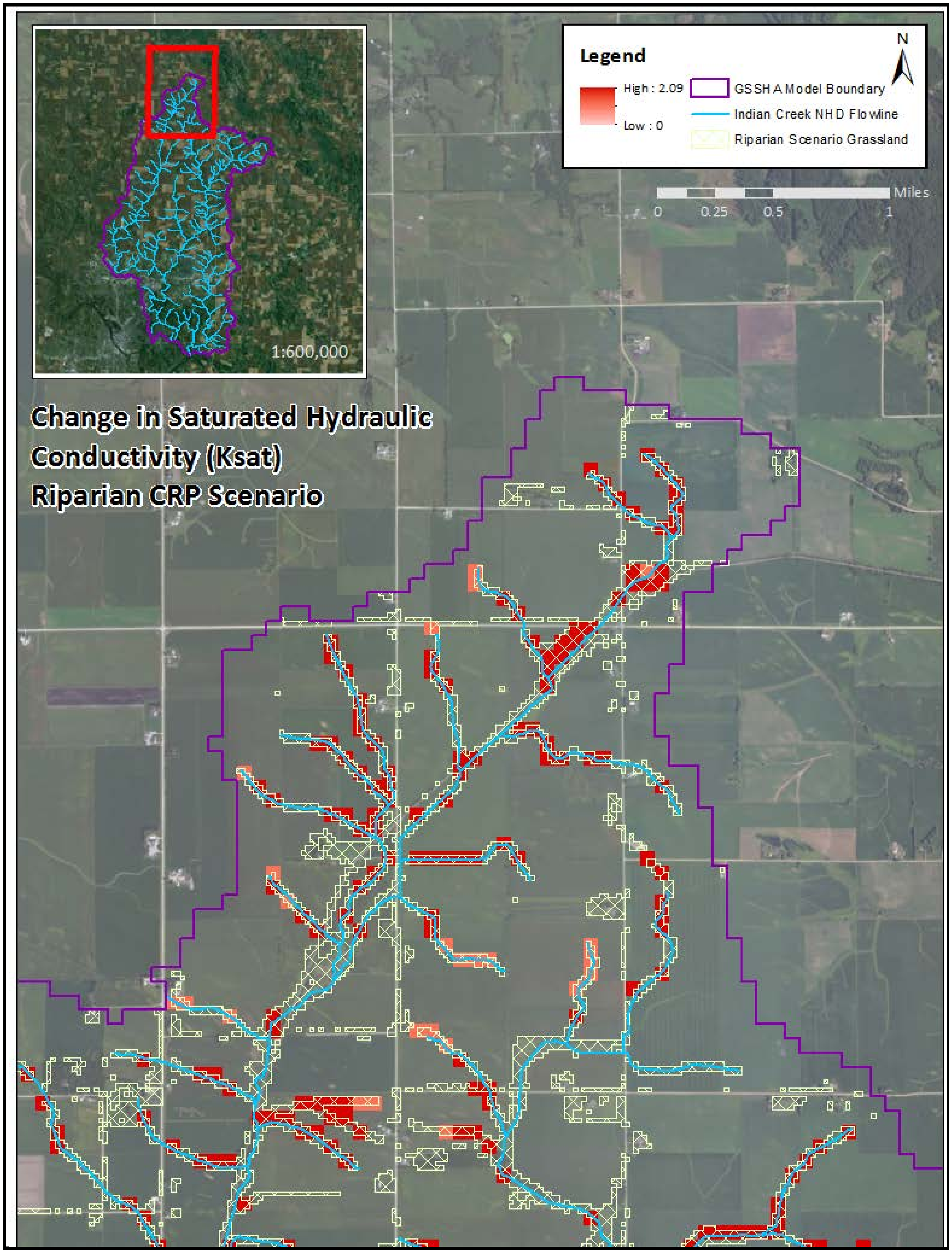

Figure 14: Changes in Saturated Hydraulic Conductivity K_{sat} for the Riparian-Targeted Scenario Relative to the Total CRP Loss Scenario for the Indian Creek Headwaters

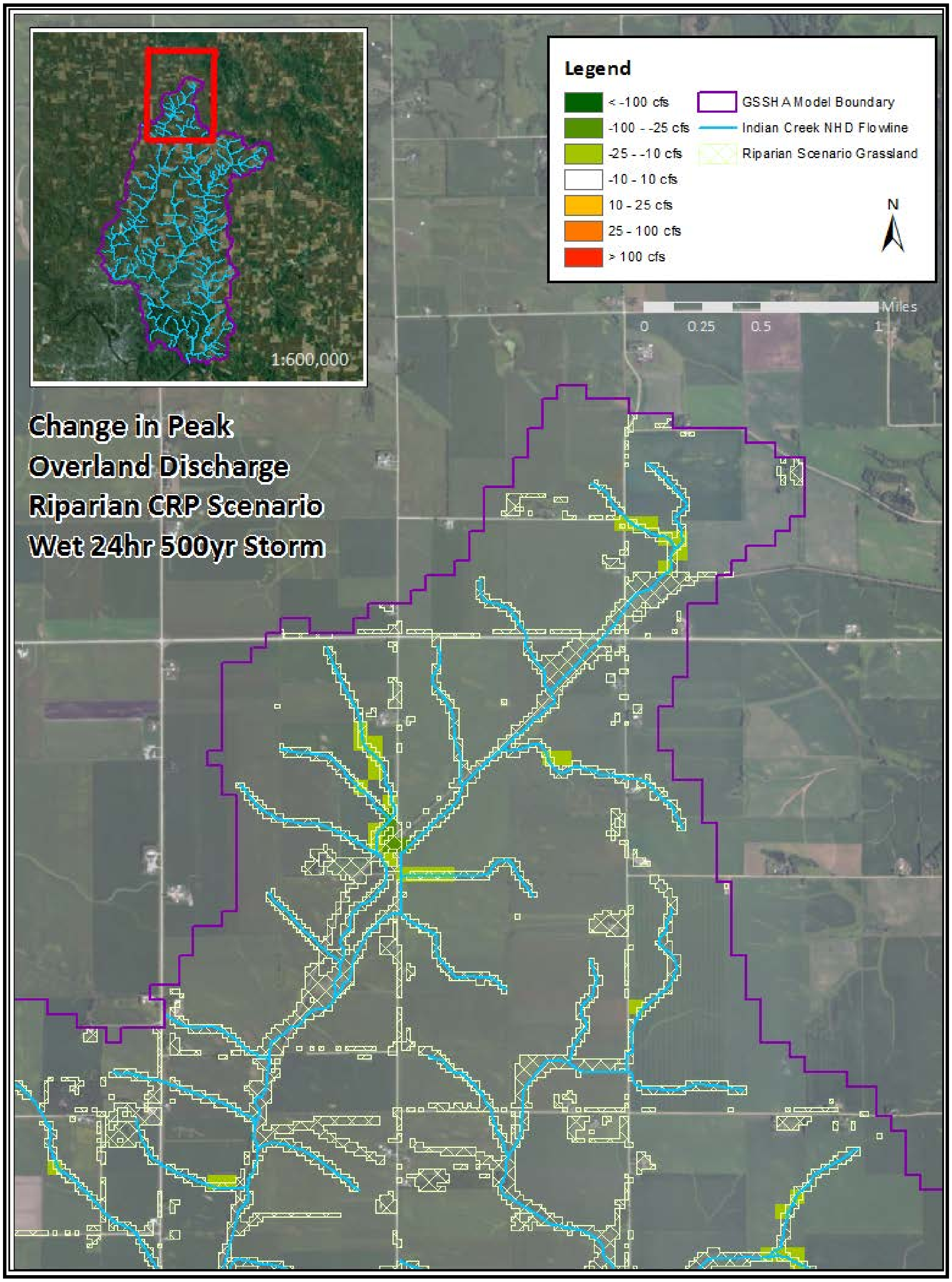

Figure 15: Changes in Peak Runoff Rate for the Riparian-Targeted Scenario Relative to the Total CRP Loss Scenario for the Indian Creek Headwaters Under the Wet Condition 24-hour, 500-year Storm

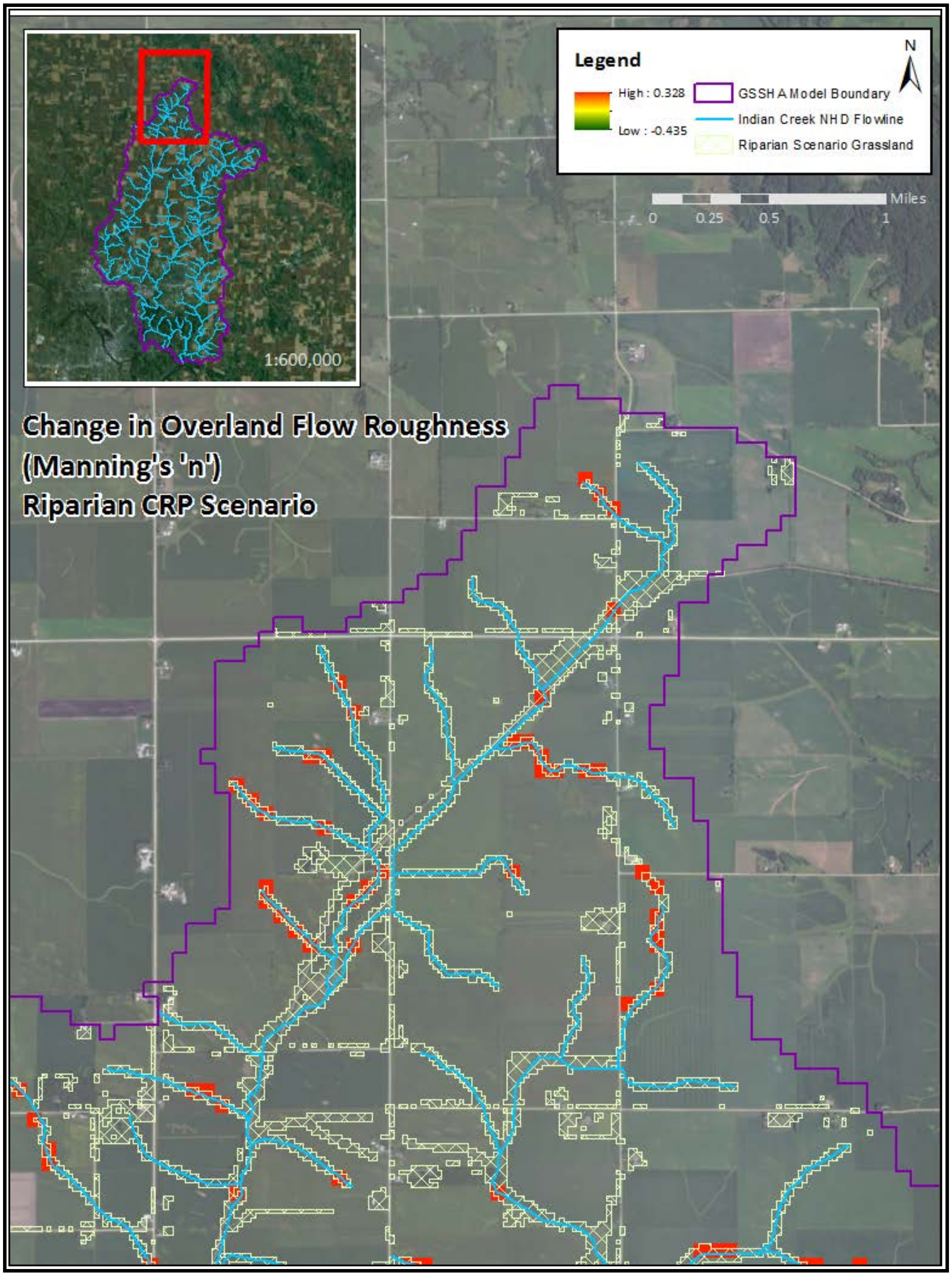

Figure 16: Changes in Surface Roughness *N* for the Riparian-Targeted Scenario Relative to the Total CRP Loss Scenario for the Indian Creek Headwaters

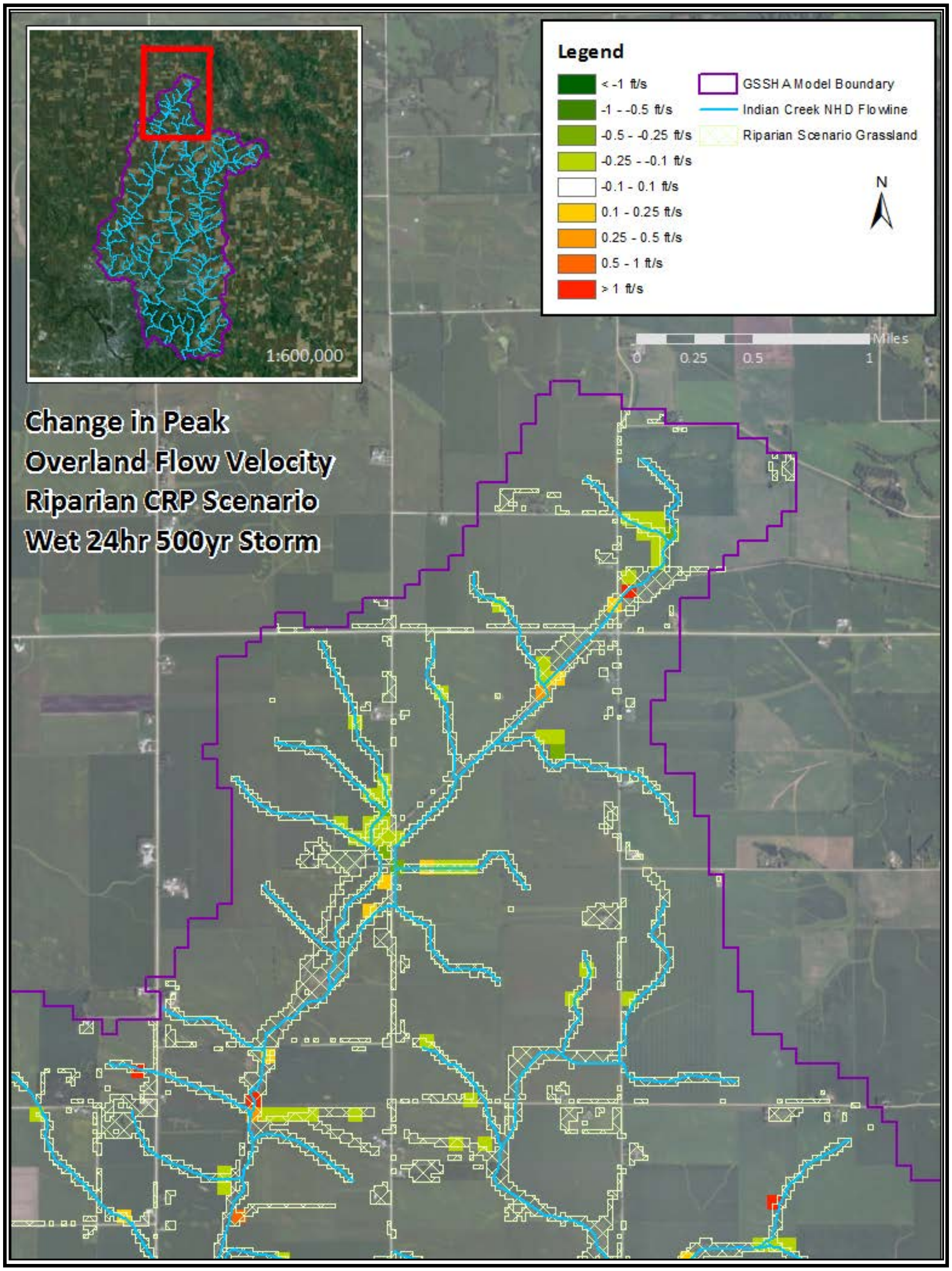

Figure 17: Changes in Peak Overland Flow Velocity for the Riparian-Targeted Scenario Relative to the Total CRP Loss Scenario for the Indian Creek Headwaters Under the Wet Condition 24-hour,. 500-year Storm

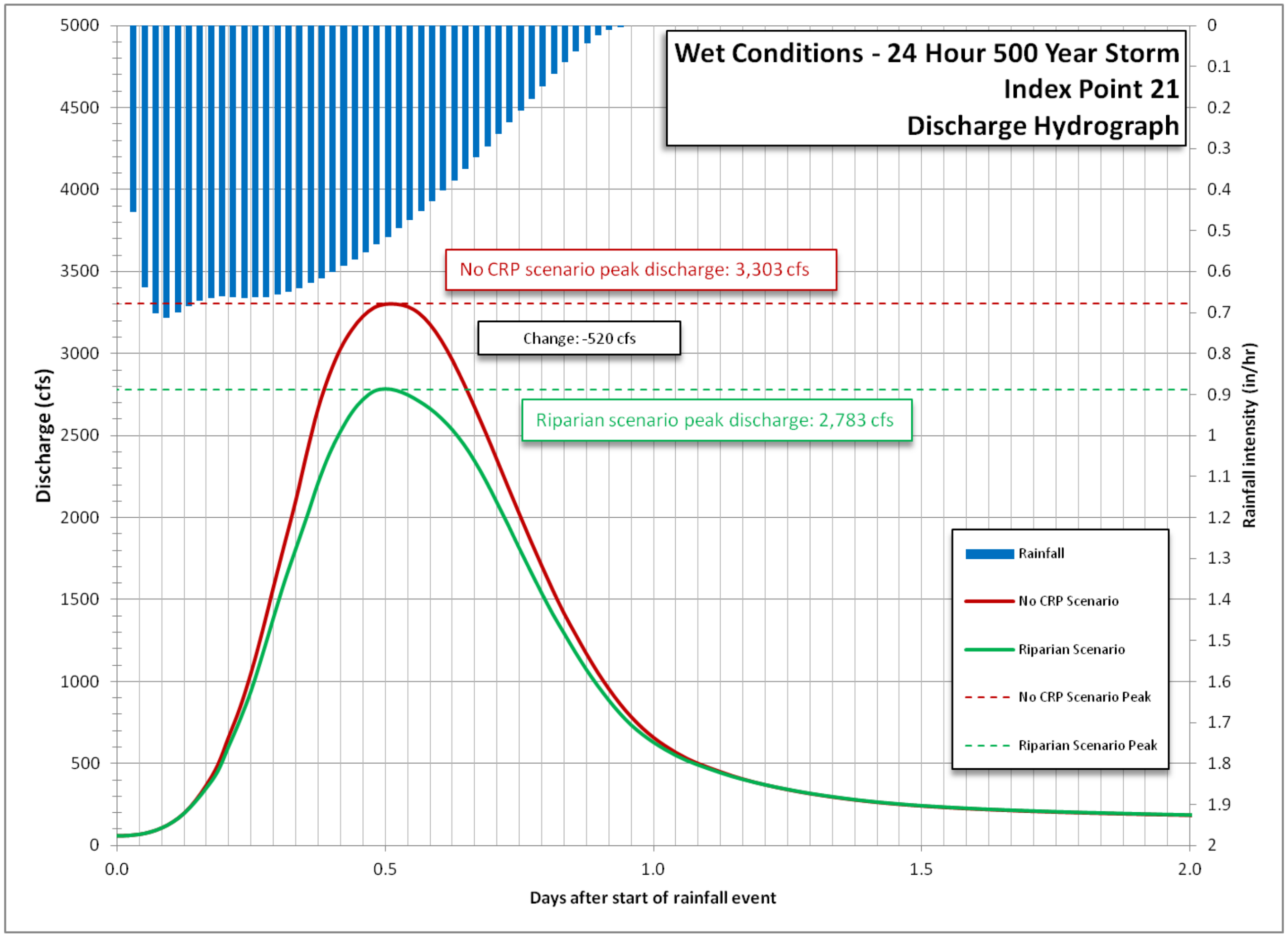

Figure 18: Index Point 21 Discharge Hydrographs for the Wet Condition 24-hour, 500-year Rainfall Even Showing the Riparian-Targeted and Total CRP Loss Scenarios

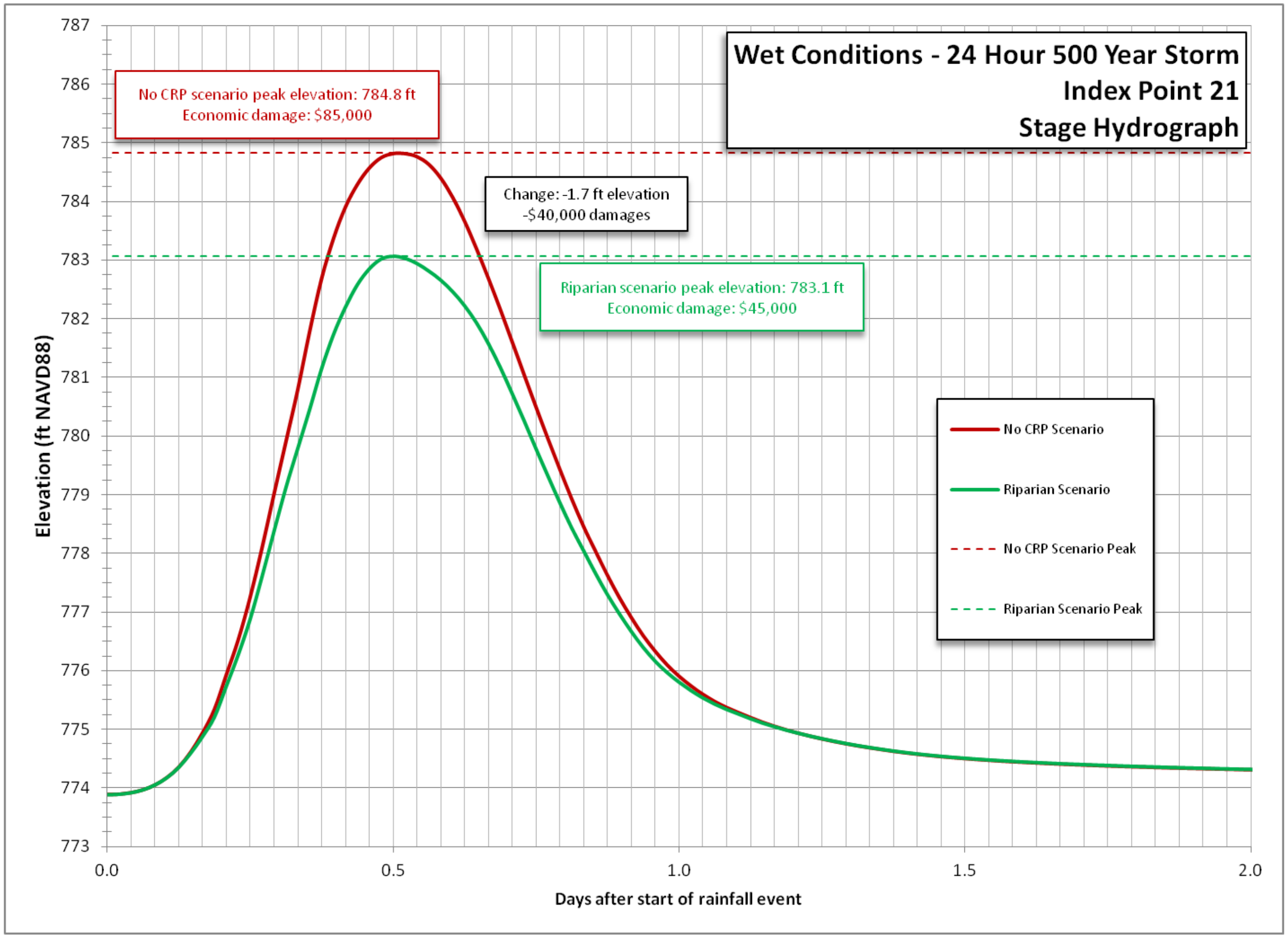

Figure 19: Index Point 21 Stage Hydrographs for the Wet Antecedent Condition 24-hour, 500-year Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

Evapotranspiration is less of a factor in determining flood peak reductions than the infiltration capacity and surface roughness. During the large rainfall events tested in this study, evapotranspiration comprised less than 2% of the total water balance (+/- 0.3%). The basin-total ET rates for scenarios with increasing amounts of CRP decreased with added CRP, as grasses have much lower ET rates than row crops. The total effect of this decrease does not affect the resulting flood peaks or economic damages. However during the month leading up to the event, the CRP scenarios increased the rate of ET which reduces soil moisture leading into the large storm event.

Important to note is that the probability of occurrence for the precipitation events being modeled in this study is assumed stationary; that is, not changing with respect to time. In reality, rainfall intensities and their associated probabilities have been changing, especially since the middle of the 20th century. Year-to-year total precipitation has been, on average, increasing over the Indian Creek basin (see figure 20). The shift in mean annual precipitation has been steady and the 30-year mean has increased from about 30 inches per year to about 37.

Of higher consequence is the increase in interannual variability of rainfall, which makes rainfall less predictable year-to-year but also makes the occurrence of extreme events more common. The increase in spread of data from the mean trend line is visually apparent in figure 20, but the blue line is a quantitative measure of the variability contained within the 30-year climate normal. The coefficient of variability (CV) has increased from 1950 and represents a measure of how much spread the data has about the mean while isolating the shift in mean that has occurred in that time period.

Increased rainfall in this area has come due to both an increase in frequency of rainfall and due to an increase in the frequency of intense rainfall. When considering the intensity of the current 100-year storm, the changing climate could increase the frequency with which that intensity is seen, making the former 100-year storm (for example) a 25-year storm. A "Responses to Climate Change" pilot study in the Indian Creek basin demonstrated the impact that shifting the frequency-intensity relationships for rainfall have on flooding. With the changes in rainfall that are possible due to climate change, CRP flood reduction benefits could play a role in adapting to a changing climate as damaging floods will likely become more frequent.

2. Economic Results and Discussion. The results of the economic analysis show the differences in dollar damages between varying land use types and hydrologic conditions. Figure 21 summarizes the results by land use type and hydrologic condition. The results at each individual Index Point are presented in the Economic Appendix (C-2 through C-7).

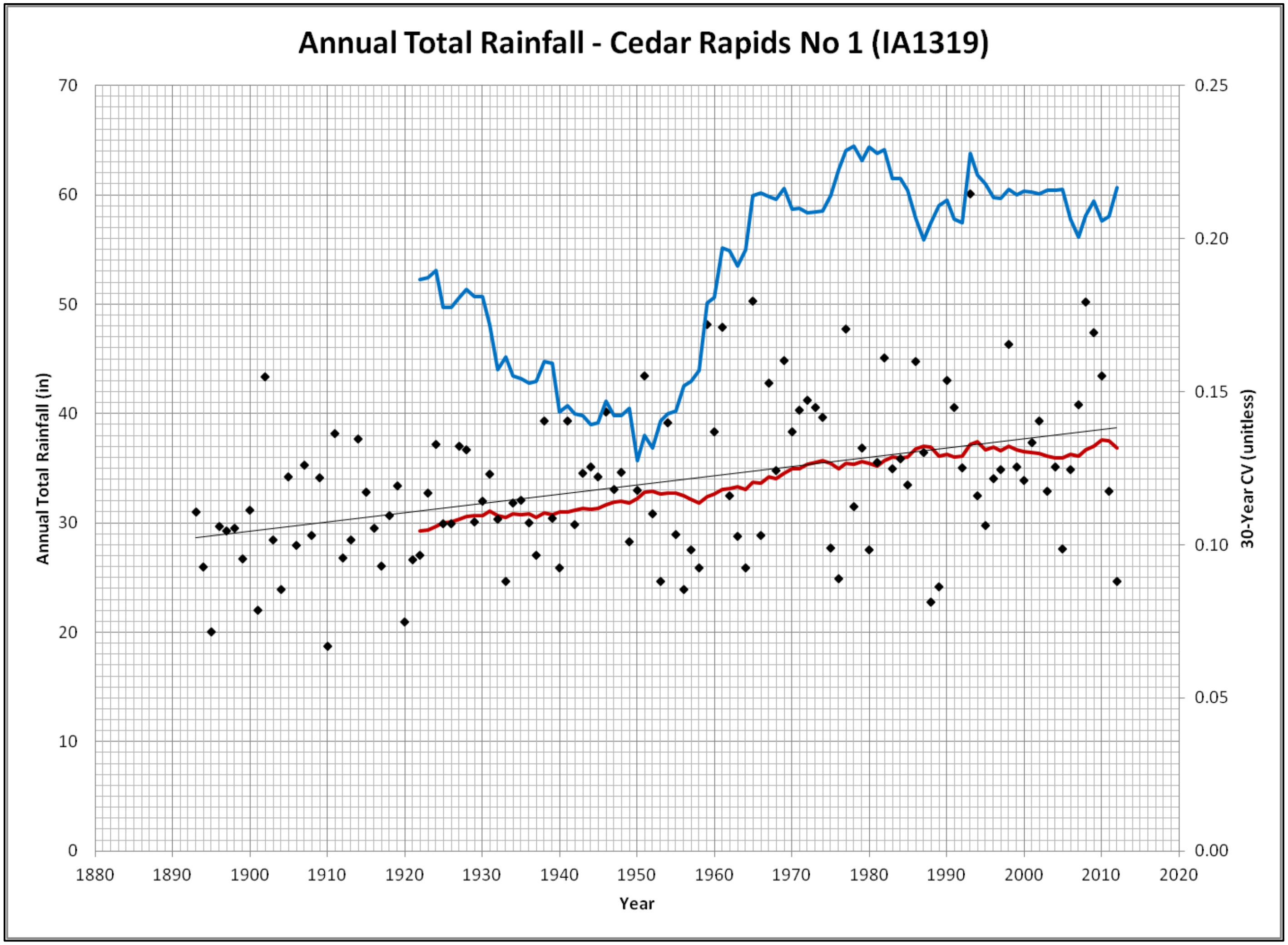

Figure 20: Annual Total Rainfall at the Cedar Rapids No. 1 Gauge, Including 30-year Mean and Coefficient of Variation for Annual Total Rainfall

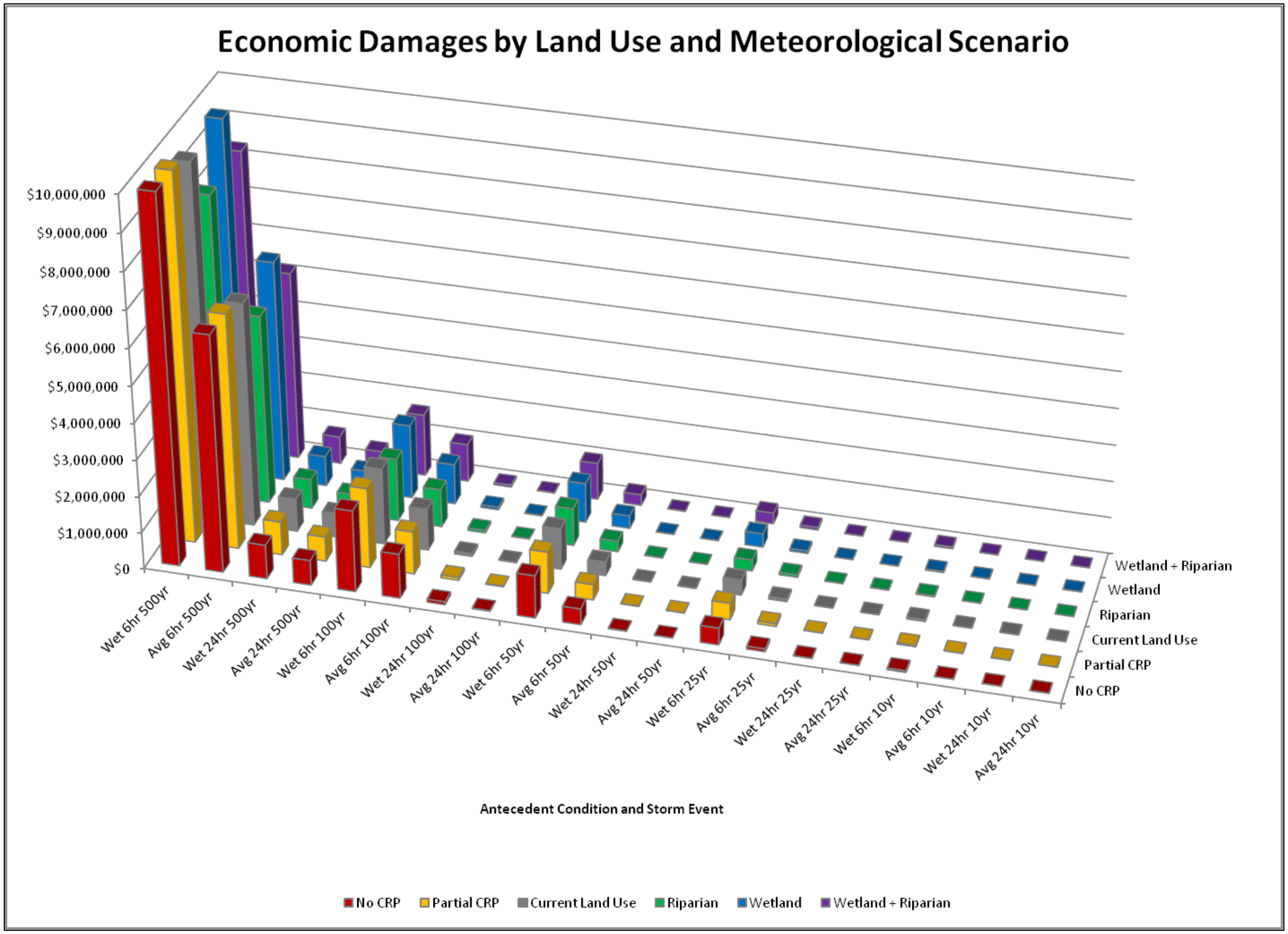

Figure 21: Economic Damages by Land Use and Meteorological Scenario

The economic analysis was designed to show differences in dollar damages for the different land use scenarios and hydrologic conditions. As can be seen in figure 21, the differing antecedent conditions have significant impacts on damages even if both storms are 500 or 100 year events.

While the economic results are interesting (for instance, that a 25-year event may cause higher water surface elevations under certain conditions than a 100-year event), there are certainly caveats that need to be addressed. The simplicity of the economics formulas are both strengths and weaknesses. The math is straightforward and the data is relatively easy to obtain for an engineering organization, but there are many damage categories that are not represented and could potentially add significantly more depth to the analysis. Things such as damages to commercial and industrial structures, traffic detour costs, infrastructure (utilities, etc), flood fighting, and other public damages could add more nuances; especially considering that different events and storm intensities may not affect these things in a linear fashion.

The scenario-based analysis used here is quite useful and a shift from normal Corps' procedures. The standard Corps method is to combine all events and damages along with their probabilities into a single value known as "average annual damage", a number that is nearly impossible to achieve in the real world, and compare that value to the amortized cost of a project(s). This method is more concerned with monetary benefits and return on investment than what may actually happen during a flood event. The scenario approach allows decision makers and stakeholders to look at events which may actually occur and hopefully over time become better informed about the risks to their communities.

With damages calculated for each scenario and a desire to better understand the relationship between costs and incremental damage reduction benefits (i.e. reduction in loss), two screening formulas were applied to each scenario. All scenarios that showed no measurable benefit were removed. The final set of scenarios is displayed in table 6. Scenarios are color coded by matching hydrologic conditions (e.g. green = wet, 6-hr, 500yr, etc.) and ranked highest to lowest (strongest to weakest) by the Cost-Loss Ratio performance indicator. It is interesting to note that scenarios attached to Partial CRP Loss land use scenarios made it through the screening process, however the magnitude of Net Marginal Benefits is significantly lower than scenarios attached to increasing CRP land use scenarios.

The data shows that the Benefit Return Periods are not consistent with the frequency of precipitation events, meaning that a net marginal benefit for a scenario will not be realized as it requires a particularly intense and infrequent storm to realize a true economic benefit. This does not mean that increasing land under CRP contract has no downstream flood reduction benefits. As the GSSHA results show there are very real decreases in discharge as CRP lands are increased in the upper part of the basin. What can be safely assumed is that the cost-loss ratio will decrease; meaning less damage reduction per dollar of CRP rent payment. When looking at the economic results of this study any cost-loss ratio above zero is a powerful indicator of the effects that strategically placed CRP practices can have on flood reduction in a watershed.

Table 6: Scenarios With Measureable Economic Benefit

Scenario	CRP Acres	Percent of Basin in CRP	Federal Rental Cost Per Year	Total Damages	Marginal Benefits	Net Marginal Benefits	Benefit Return Period (yr.)	Cost-to-Los Ratio
R-Wet-6hr-500yr	2374	4.0	$334,603	$8,263,133	$2,199,238	$1,864,635	5.6	6.6
C-Wet-6hr-500yr	966	1.6	$136,321	$9,677,012	$785,359	$649,038	4.8	5.8
P-Avg-6hr-100yr	70	0.1	$10,358	$1,167,665	$46,177	$35,819	3.5	4.5
P-Avg-6hr-500yr	70	0.1	$10,358	$6,406,908	$42,457	$32,099	3.1	4.1
P-Wet-6hr-100yr	70	0.1	$10,358	$2,187,088	$40,011	$29,653	2.9	3.9
R-Avg-6hr-500yr	2374	4.0	$334,603	$5,165,855	$1,283,510	$948,907	2.8	3.8
RW-Wet-6hr-500yr	3922	6.5	$623,629	$8,348,644	$2,113,727	$1,490,098	2.4	3.4
P-Wet-6hr-500yr	70	0.1	$10,358	$10,434,948	$27,423	$17,065	1.6	2.6
C-Avg-6hr-500yr	966	1.6	$136,321	$6,097,217	$352,148	$215,827	1.6	2.6
P-Wet-6hr-50yr	70	0.1	$10,358	$1,140,524	$22,363	$12,005	1.2	2.2
RW-Avg-6hr-500yr	3922	6.5	$623,629	$5,177,406	$1,271,959	$648,330	1.0	2.0
P-Wet-6hr-10yr	70	0.1	$10,358	$27,064	$16,835	$6,477	0.6	1.6
P-Wet-24hr-500yr	70	0.1	$10,358	$910,688	$16,014	$5,656	0.5	1.5
R-Wet-6hr-100yr	2374	4.0	$334,603	$1,719,123	$507,976	$173,373	0.5	1.5
W-Wet-6hr-500yr	3752	6.3	$604,773	$9,738,673	$723,698	$118,925	0.2	1.2
P-Avg-24hr-500yr	70	0.1	$10,358	$669,622	$11,606	$1,248	0.1	1.1
C-Wet-6hr-100yr	966	1.6	$136,321	$2,087,000	$140,099	$3,778	0.0	1.0

N - Total CRP Loss
P - Partial CRP Loss
C - Current Land Use
R - Targeted Riparian Practice-Type CRP Gain
W - Targeted Wetland Practice-Type CRP Gain
RW - Combined Riparian & Wetland CRP Gain

B. Cedar River Basin Assessment

Continuous SWAT simulation results for 1978-2010 did not show a measurable relationship between land use practice changes in the Cedar River basin and peak streamflow at Cedar Rapids, IA. Three land use scenarios and a baseline model setup were run, and even under an extreme scenario ("Water Quality") the response in peak stage was small (figure 22). The results showed no systematic relationship between the amount of CRP in the basin and peak stage at the tested urban area. For the largest flood event, which occurred in 2008, none of the land use scenarios changed the baseline flood peak elevation by more than 0.04 ft.

The model was not ideally calibrated for computing the discharge of very large hydrologic events. The five largest peaks in the model period have considerable error in the computation of their peak discharge and stage. Table 7 presents a summary of these events. Of these events, only the 2008 event caused considerable damage in Cedar Rapids and the model results showed no change in water surface elevation for this event under differing land use conditions.

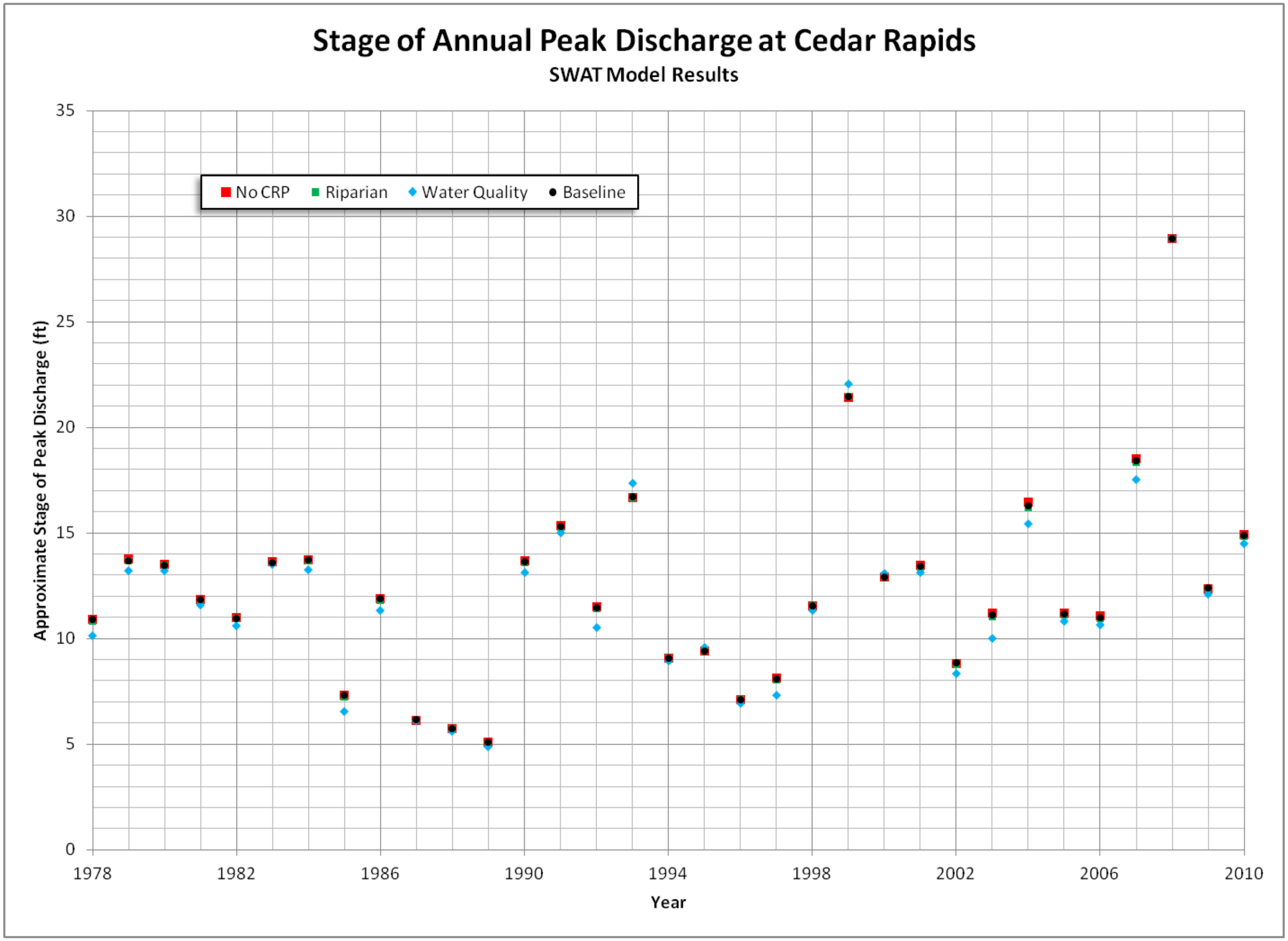

Figure 22: Annual Peak Stage at Cedar Rapids as Simulated for Four Scenarios Using the Cedar River SWAT Model

Table 7: Cedar River SWAT Model Error at Cedar Rapids, IA Gauge

Year	Observed Discharge (cfs)	Model Error (cfs)	Observed Stage[1] (ft)	Model Error (ft)
2008	140000	-19577	30.71	-1.75
1993	71000	-14037	19.50	-2.78
2004	62500	-7692	17.81	-1.51
1999	62300	18429	17.77	3.70
2010	50300	-2696	15.42	-0.53

[1] Stages computed from observed discharge and approximate rating curve used for converting SWAT discharge results, not actual observed values

SWAT was run with a daily timestep and output results are daily average values. Events that are shorter than 24 hours or demonstrate significant peaking would be underestimated using this methodology. The within-day peak of a flood event would be higher than the daily average output of the model.

The curve number method used in the SWAT model is empirical (as opposed to the physically-based simulation in GSSHA) and uses a dimensionless value to describe the runoff-generating process of a land use and soil combination. The trouble in changing these values to represent land use practices is that the change from baseline is an uncertain quantity, as it is not directly measurable. Typical values are available for different land use classification and soil type combinations; however, in practice the SWAT model is typically calibrated primarily by adjusting the curve number. Thus the model may represent the conditions under which it was calibrated, but when the land use is changed within the model it is uncertain whether the response due to land use change is accurately representing this change.

The curve number method only considers the effect of infiltration excess (Hortonian) overland flow. Runoff generated by saturated soil conditions are not captured using this methodology. In situations where significant rainfall occurs prior to a particularly large individual event or subsurface flow concentrates downslope (and possibly exfiltrates back to the surface) the curve number method does not adequately capture the runoff generating process. Additionally, the curve number methodology was only designed to predict individual flood streamflow volumes, not daily flows of typical magnitude on a continuous basis (Garen and Moore 2005).

The SWAT model considers only best management practices with regard to location at the subbasin scale. The GSSHA results showed that location of these practices relative to fields and streams is an important mechanism for explaining the hydrologic effects of CRP lands. Additionally, the small size of CPs relative to each subbasin means that when weighting runoff simulation results by the basin fraction, the ability for any change in runoff to be shown in the model is further diminished.

Often the typical values for these practices make them seem hydrologically similar. In an example below, curve number values for three land uses are shown (table 8). The HRUs have a starting curve number under normal soil moisture conditions (referred to as 'Antecedent Moisture Condition II' [AMCII]) and within SWAT this value is updated at a regular timestep to reflect changing soil moisture. In table 8 the 'Antecedent Moisture Condition III' (AMCIII) curve numbers for the land use/soil group are also shown, which represent very wet soil conditions (greater than 2.1 inches of rain in the prior 5 days for the growing season). Of note is the relatively small numerical difference between the three different land uses.

Table 8: Curve Number Example Values

SWAT Land Cover (TR-55 Classification)	CN AMCII (Avg Moisture)	CN AMCIII (Wet)	%of Basin (Baseline Condition)
CORN (Row crops, straight row, good condition)	85.0	92.9	70
PAST (Meadow)	71.0	84.9	5
URLD Residential (1/2 acre, ~25% impervious)	80.0	90.2	25

The curve number method is applied to a single rainfall event, modeling the excess precipitation (runoff). To compute the runoff for a heterogeneous subbasin, the weighted average curve number is computed using the curve number and area of each contributing area. Table 9 shows an example of the curve number method modeling the change in runoff depth for several land use scenarios and precipitation events. The percentage increase scenarios trade a fraction of the row crops in the basin for grassland, representing conservation practices. The "no row crop" scenario completely changes the corn to grassland. The "no grassland" removes all grassland and conservation practice in favor of row crops.

Table 9: Change in Excess Precipitation (Runoff Depth) in Percent from Baseline for Simple Curve Number Example

Five land use scenarios and three rainfall depths with two different antecedent conditions are shown.

	Avg 1"	Wet 1"	Avg 3"	Wet 3"	Avg 5"	Wet 5"
Increase grassland to 10%	-10%	-4%	-3%	-2%	-2%	-1%
Increase grassland to 15%	-21%	-9%	-7%	-3%	-4%	-2%
Increase grassland to 25%	-43%	-18%	-14%	-7%	-9%	-4%
No Row Crop	-132%	-58%	-46%	-23%	-30%	-15%
No Grassland	153%	18%	11%	4%	6%	2%

The resulting changes in runoff under moderate and heavy rainfall scenarios (events more likely to cause flooding) are nearly zero, which is a direct consequence of the parameterization of this subbasin. The example subbasin was parameterized as a typical subbasin within the Cedar River watershed. The curve numbers are not very different at the baseline, and realistic proportions of grassland in the Cedar River basin are very small. Also under this parameterization the urbanized areas actually have a lower curve number than row crops. As the soil moisture content increases, the curve numbers tend to converge, resulting in very little difference between their values when the soil is at its wettest. Heavy rainfall events on saturated soils are a consistent cause of flooding in the Cedar River basin, but the curve number method does a poor job of representing the landscape during these important events. In order to realize large changes in excess runoff using this method, extreme departures from a typical distribution of land use in the Cedar River basin must be tested. For the reasons discussed previously, the curve number method is inadequate for making this kind of assessment.

Due to the SWAT model limitations the only event that had the potential for significant damages (500-yr) showed zero change in the flood stage generated by the SWAT model so the economic evaluation for the Cedar River basin was not obtainable as part of this study effort.

VII. VISUALIZATION OF RESULTS

The results from the Indian Creek portion of this study are aggregated at 28 different index points in the basin. The aggregation of land use, hydrologic, hydraulic and economic data and information provide a solid foundation for visualization (and comparison) of the relationship between the spatial location of specific CRP practices and the hydrologic and economic benefits they provide to downstream urban areas.

The pilot team explored the appropriate type and level of information to have displayed for Indian Creek and developed a generic visualization dashboard to help communicate the type and format of information that may be presented. Information that is recommended for presentation include an interactive map of the index points, a map of the watershed extent, an attribute table, the stream segment associated with the urban benefits being realized and a depth-damage curve. In support of goal #3 and in accordance with the Corps/FSA Interagency Agreement this work is being conducted under, the University of Iowa, Institute for Hydroscience and Research (IIHR) who has been awarded the contract to develop the formal display for presentation of the results on the Iowa-Cedar Interagency Coordination Team website. Figure 23 displays the generic visualization dashboard.

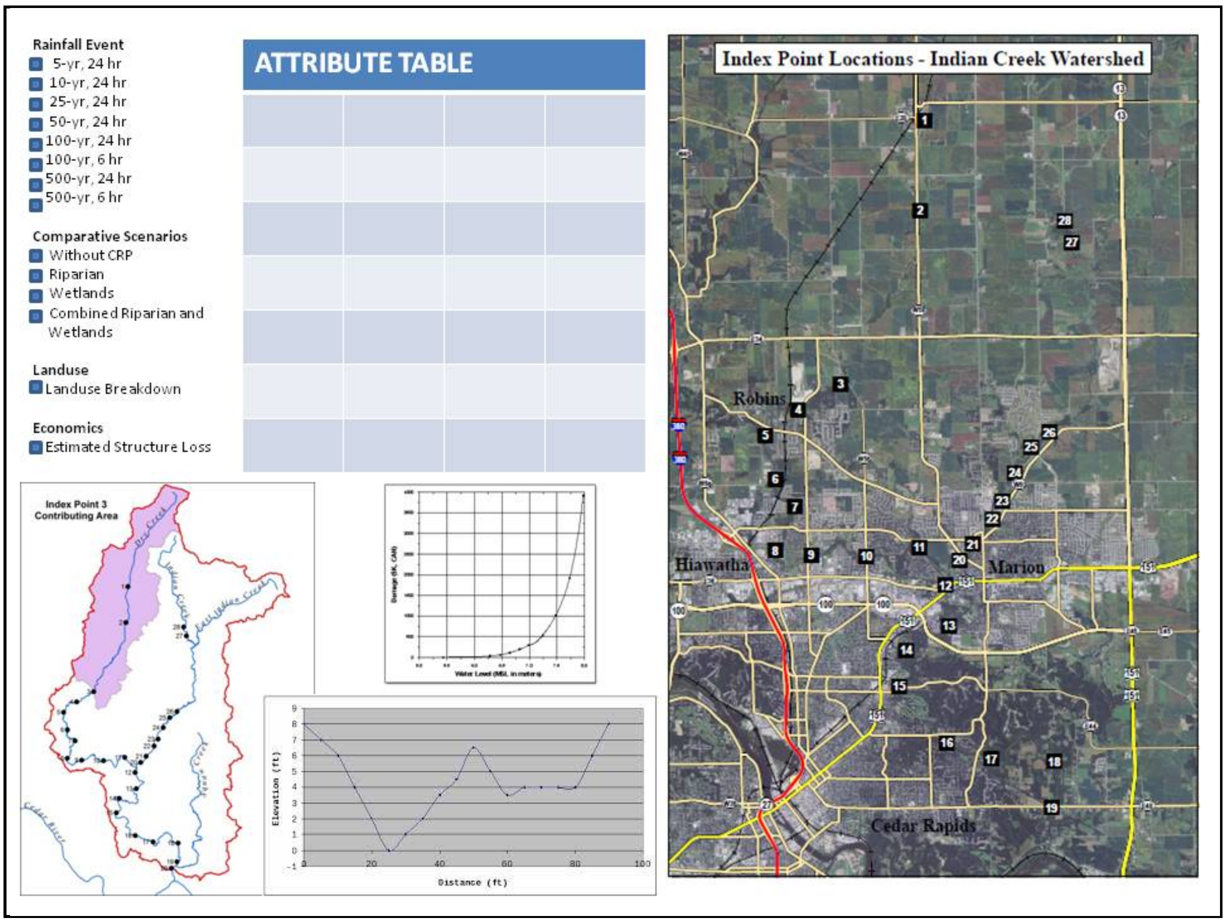

Figure 23: Generic Visualization Dashboard for Indian Creek

VIII. CONCLUSIONS

This study concludes that there are significant monetary benefits that are being realized by urban areas due to existing CRP land in the Indian Creek basin. There is an opportunity to further reduce flood stage and resulting economic losses in Indian Creek by targeting additional investment in certain conservation practices. Riparian buffers were discovered to provide the greatest value of the scenarios evaluated in terms of the amount of investment necessary versus the reduction in flood stage and associated flood damages.

By utilizing a physically-based hydrologic model, GSSHA, the pilot team was able to determine that the type and spatial location of conservation practices is hydrologically significant. Riparian buffers also provided hydraulic benefits by slowing water which resulted in greater infiltration and peak discharge attenuation. The FY12 literature review proved valuable in noting the importance of antecedent moisture condition and running continuous simulation. The GSSHA model results identified that a wet antecedent condition 25-yr storm may respond similar to an average antecedent condition 50-yr storm event. The literature review also stated that CRP-type conservation practices have the greatest impact on flood stage for smaller, more frequent flood events. While this was confirmed by GSSHA model runs, these smaller more frequent events do not result in economic losses so it was very important to uncover that CRP-type conservation practices also significantly reduce flood stage for large, infrequent, storm events which do result in significant economic damages.

Simulation of scenarios in two different types of models at two different scales demonstrated that physically-based modeling of conservation practices holds more promise in accurately capturing their effects than empirical models. The GSSHA and SWAT models have value at their respective scales and design purpose but the SWAT model limitations due to daily timestep and curve number methodology muted results in a way that questions the ability of the model to simulate the spatial significance of conservation practices in a meaningful way. While the GSSHA model is capable of simulating the spatial significance of conservation practices the data intensity limits the scale of assessment due to model runtime. The primary focus for future efforts running a physically-based model for a larger basin may be to overcome the model runtime limitations.

The economic evaluation was limited to rainfall probabilities instead of flood frequencies due to the limited period of record on the Indian Creek stream gauge. As a result, the methods used to indicate land use scenario performance do not conform to the Corps standard methodology nor are they consistent with National Economic Development (NED) policy guidance. However, using a non-standard, scenario based evaluation allows increased insight into relationships between cost and event frequency and can make that relationship more easily digestible. This insight also allows for discussions concerning climate change’s effect on event frequency and precipitation intensity to be shaped around resulting damages and the associated affect on the economic performance of various CRP futures. While a NED benefit to cost ratio was not developed, the pilot team utilized the CRP payment data provided by FSA to capture the level of investment required, period of return on investment and cost per loss prevented for the various scenarios. The benefit return period and the cost-loss ratio are meaningful because they captured that damage reduction from a 500 year event may justify as many as 5 years of targeted payments in upstream CRP lands in Indian Creek basin. The increasing occurrence of extreme precipitation events due to climate change makes it so a current 500-year event could occur more frequently in the future, narrowing the gap between the average return interval for a storm intensity and the payback period for a CRP practice that mitigates damage caused by that storm.

The economic evaluation conducted for this study did not include a complete structure inventory (roads, public infrastructure, etc.) and only captured the residential flood damages. Conducting a complete structure inventory was outside of the scope of this project but would likely have resulted in a greater reduction in flood damages for the respective scenarios. This evaluation only measured CRP land's effect on flood damage reduction and is only one part of the ecosystem services provided by lands held in the conservation reserve program. As other ecosystem services provided by CRP are valued and added to the flood damage reduction benefits the benefit-cost ratio of these lands are anticipated to rise, making the program increasing economically sustainable, especially in a future with climate change.

IX. LESSONS LEARNED

The lessons learned from this study relate primarily to the study approach. The use of a physically-based model proved to be important in determining the importance of the CRP-type conservation practice as well as its spatial location in the basin. The antecedent moisture condition had a large bearing on the flood stage for a respective rainfall event. The lesson learned from the empirical SWAT model was that it may be useful for longer term averaging for water quality and related components but even a finely calibrated model such as that developed by the USGS has inherent limitations with the timestep and curve number methodology that limit the models ability to capture spatial significance of conservation practices.

Lessons learned from the economic evaluation are that this scenario-based approach is meaningful for looking at damages for a specific event that will occur. This approach connects potential flood damages directly to rainfall events which in many ways are easier to communicate with almost all audiences and they represent flood losses that may actually be realized versus an aggregation of potential losses based on the probability of them occurring. That said, future efforts may consider working in a basin with a flood frequency study in order to compare average annual damage with the event based damage assessment to see how different they are.

One very important lesson learned is that while the fundamentals for each discipline are fairly straightforward the various disciplines must be capable of working collaboratively every step of the way. The limitations of grid size, how to represent land use scenarios and discipline specific assumptions helped frame this study's methodology and work around many potential road blocks.

Potential Future Studies. This study ran into the problem of hydrologic scale. However, a future study could establish for a larger basin the flood risk management benefits of CRP using hydrologic modeling tools. It would be possible to run a physically-based model at a coarser resolution but for a larger basin and still be computationally feasible for longer simulation time periods. However, the fine-scale terrain details required to represent CRP practices would be lost at such a scale. It would be possible to use a large, coarse scale physically-based model to simulate large-scale slow processes such as groundwater and long-term soil moisture trends and a large-scale fine model run for very limited time periods to model rapid processes such as runoff, infiltration and channel flow using the large-scale model as boundary or initial conditions.

In a different study, modeling the same size basin as Indian Creek but running at a much finer scale may better describe the benefits of CRP realized on the landscape. This model could more accurately represent the scale and location of CRP practices as well as reduce smoothing and averaging that occurs in the terrain at a coarser resolution.

Verification of the model results in the Indian Creek watershed using a similar GSSHA model for other HUC-10 sized basins with a wealth of observed hydrologic data would lend credence to the economic benefits being demonstrated. Using the same methodology to parameterize the Indian Creek model, other basins with better observations to test model response could be modeled and the effects of CRP more precisely identified.

X. REFERENCES

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CONSERVATION RESERVE PROGRAM FLOOD DAMAGE REDUCTION BENEFITS TO DOWNSTREAM URBAN AREAS

A US Army Corps of Engineers, Mississippi Valley Division Initiative
Rock Island District Pilot Project Report

APPENDIX A

GEOGRAPHIC INFORMATION SYSTEMS

Appendix A
Geographic Information Systems

SOFTWARE AND DATA

The following software was used to complete the scenario modeling:

- ESRI ArcGIS 10.1 SP 1 for Desktop with Spatial Analyst Extension
- ESRI Arc Hydro for ArcGIS 10.1
- Geospatial Modelling Environment (Version 0.7.2.1)
- R: A Language and Environment for Statistical Computing
- Microsoft Office Excel 2007

The following datasets were used to complete the scenario modeling and feed model parameterization

- 2012 Iowa Cropland Data Layer (USDA) [Publicly Avail.]
- 2010 National Hydrography Dataset – High Resolution (USGS) [Publicly Avail]
- 2007-2013 Iowa LiDAR Project – 3m Digital Elevation Model (IGS, IADNR) [Publicly Avail]
- 2013 Farm Service Agency Common Land Unit GIS Dataset (FSA) [Not Publicly Avail]
- 2011 Soil Survey Geographic (SSURGO) Database for Iowa (USDA-NRCS) [Publicly Avail]

Table A-1: Crosswalk of CRP Practice Types to CDL Land Use Classes Used for GSSHA

Practice	Title	CDL Value	CDL Description
CP1	Establishment of perm. introduced grasses and legumes	62	Pasture/Grass
CP2	Establishment of perm. native grasses	60	Switchgrass
CP3	Tree planting	143	Mixed Forest
CP3A	Hardwood tree planting	141	Deciduous Forest
CP4	Permanent wildlife habitat	171	Grassland/Herb.
CP4B	Permanent wildlife habitat (corridors), noneasement	171	Grassland/Herb.
CP4C	Permanent wildlife habitat	171	Grassland/Herb.
CP4D	Permanent wildlife habitat, noneasement	171	Grassland/Herb.
CP5	Field windbreak establishment	143	Mixed Forest
CP5A	Field windbreak establishment, noneasement	143	Mixed Forest
CP8	Grassed waterway	171	Grassland/Herb.
CP8A	Grassed waterways, noneasement	171	Grassland/Herb.
CP9	Shallow water areas for wildlife	87	Wetlands
CP9A	Shallow water areas for wildlife	87	Wetlands
CP10	Vegetative cover, already established (grass)	171	Grassland/Herb.
CP11	Vegetative cover, already established (trees)	143	Mixed Forest
CP12	Wildlife food plot	171	Grassland/Herb.
CP13	Vegetative filter strips	171	Grassland/Herb.
CP13A	Vegetative filter strips (grass)	171	Grassland/Herb.
CP13C	Vegetative filter strips (grass), noneasement	171	Grassland/Herb.
CP13D	Vegetative filter strips (trees), noneasement	171	Grassland/Herb.
CP15	Establishment of perm. veg. cover (contour strips)	171	Grassland/Herb.
CP15A	Establishment of perm. veg. cover (contour strips),	171	Grassland/Herb.
CP15B	Marginal pastureland (contour grass) on terrace	171	Grassland/Herb.
CP16	Shelterbelt establishment	143	Mixed Forest
CP16A	Shelterbelt establishment, noneasement	143	Mixed Forest
CP17	Living snow fence	143	Mixed Forest
CP17A	Living snow fence, noneasement	143	Mixed Forest
CP18	Establishment of perm. veg. to reduce salinity	171	Grassland/Herb.
CP18A	Establishment of perm. salt tolerant veg. cover	171	Grassland/Herb.
CP19	Alley cropping	171	Grassland/Herb.
CP20	Alternative Perennials	58	Clover/Wildflower
CP21	Filter strips	171	Grassland/Herb.
CP22	Riparian buffer	171	Grassland/Herb.
CP23	Wetland restoration	87	Wetlands
CP23A	Wetland restoration, non floodplain	87	Wetlands
CP24	Cross wind trap strips	171	Grassland/Herb.
CP25	Rare and declining habitat	171	Grassland/Herb.
CP26	Sediment retention	171	Grassland/Herb.
CP27	Farmable wetland pilot wetland	87	Wetlands
CP28	Farmable wetland pilot buffer	87	Wetlands
CP29	Marginal pastureland wildlife habitat buffer	171	Grassland/Herb.
CP30	Marginal wetland buffer	87	Wetlands
CP31	Bottomland timber establishment on wetland	190	Woody Wetlands
CP32	Expired hardwood tree planting	141	Deciduous Forest
CP33	Habitat for upland birds	58	Clover/Wildflower
CP35A	Emergency forestry - longleaf pine - new	142	Evergreen Forest
CP35E	Emergency forestry - softwood - new	142	Evergreen Forest
CP37	Duck nesting habitat	87	Wetlands
CP38A	State acres for wildlife enhancement - buffer	171	Grassland/Herb.
CP38B	State acres for wildlife enhancement - wetland	87	Wetlands
CP38D	State acres for wildlife enhancement - longleaf pine	142	Evergreen Forest
CP38E	State acres for wildlife enhancement - grass	60	Switchgrass
CP39	FWP - Farmable wetlands	87	Wetland
CP40	FWP - Aquaculture wetlands	87	Wetland
CP42	Pollinator habitats	58	Clover/Wildflower

Table A-2: Crosswalk of CRP Practice Types to CDL Land Use Classes Used for SWAT

Practice	Title	CDL Value	CDL Description	SWAT Class
CP1	Establishment of perm. introduced grasses and legumes	181	Pasture/Hay	PAST
CP2	Establishment of perm. native grasses	181	Pasture/Hay	PAST
CP3	Tree planting	141	Deciduous Forest	FRSD
CP3A	Hardwood tree planting	141	Deciduous Forest	FRSD
CP4	Permanent wildlife habitat	181	Pasture/Hay	PAST
CP4B	Permanent wildlife habitat (corridors), noneasement	181	Pasture/Hay	PAST
CP4C	Permanent wildlife habitat	181	Pasture/Hay	PAST
CP4D	Permanent wildlife habitat, noneasement	181	Pasture/Hay	PAST
CP5	Field windbreak establishment	141	Deciduous Forest	FRSD
CP5A	Field windbreak establishment, noneasement	141	Deciduous Forest	FRSD
CP8	Grassed waterway	181	Pasture/Hay	PAST
CP8A	Grassed waterways, noneasement	181	Pasture/Hay	PAST
CP9	Shallow water areas for wildlife	87	Wetland	WETL
CP9A	Shallow water areas for wildlife	87	Wetland	WETL
CP10	Vegetative cover, already established (grass)	181	Pasture/Hay	PAST
CP11	Vegetative cover, already established (trees)	141	Deciduous Forest	FRSD
CP12	Wildlife food plot	181	Pasture/Hay	PAST
CP13	Vegetative filter strips	181	Pasture/Hay	PAST
CP13A	Vegetative filter strips (grass)	181	Pasture/Hay	PAST
CP13C	Vegetative filter strips (grass), noneasement	181	Pasture/Hay	PAST
CP13D	Vegetative filter strips (trees), noneasement	181	Pasture/Hay	PAST
CP15	Establishment of perm. veg. cover (contour strips)	181	Pasture/Hay	PAST
CP15A	Establishment of perm. veg. cover (contour strips),	181	Pasture/Hay	PAST
CP15B	Marginal pastureland (contour grass) on terrace	181	Pasture/Hay	PAST
CP16	Shelterbelt establishment	141	Deciduous Forest	FRSD
CP16A	Shelterbelt establishment, noneasement	141	Deciduous Forest	FRSD
CP17	Living snow fence	141	Deciduous Forest	FRSD
CP17A	Living snow fence, noneasement	141	Deciduous Forest	FRSD
CP18	Establishment of perm. veg. to reduce salinity	181	Pasture/Hay	PAST
CP18A	Establishment of perm. salt tolerant veg. cover	181	Pasture/Hay	PAST
CP19	Alley cropping	181	Pasture/Hay	PAST
CP20	Alternative Perennials	181	Pasture/Hay	PAST
CP21	Filter strips	181	Pasture/Hay	PAST
CP22	Riparian buffer	181	Pasture/Hay	PAST
CP23	Wetland restoration	87	Wetland	WETL
CP23A	Wetland restoration, non floodplain	87	Wetland	WETL
CP24	Cross wind trap strips	181	Pasture/Hay	PAST
CP25	Rare and declining habitat	181	Pasture/Hay	PAST
CP26	Sediment retention	181	Pasture/Hay	PAST
CP27	Farmable wetland pilot wetland	87	Wetland	WETL
CP28	Farmable wetland pilot buffer	87	Wetland	WETL
CP29	Marginal pastureland wildlife habitat buffer	181	Pasture/Hay	PAST
CP30	Marginal wetland buffer	87	Wetland	WETL
CP31	Bottomland timber establishment on wetland	141	Deciduous Forest	FRSD
CP32	Expired hardwood tree planting	141	Deciduous Forest	FRSD
CP33	Habitat for upland birds	181	Pasture/Hay	PAST
CP35A	Emergency forestry - longleaf pine - new	141	Deciduous Forest	FRSD
CP35E	Emergency forestry - softwood - new	141	Deciduous Forest	FRSD
CP37	Duck nesting habitat	87	Wetland	WETL
CP38A	State acres for wildlife enhancement - buffer	181	Pasture/Hay	PAST
CP38B	State acres for wildlife enhancement - wetland	87	Wetland	WETL
CP38D	State acres for wildlife enhancement - longleaf pine	141	Deciduous Forest	FRSD
CP38E	State acres for wildlife enhancement - grass	181	Pasture/Hay	PAST
CP39	FWP - Farmable wetlands	87	Wetland	WETL
CP40	FWP - Aquaculture wetlands	87	Wetland	WETL
CP42	Pollinator habitats	181	Pasture/Hay	PAST

Table A-3: Current Land Use Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		19548	0	N/A	32.6
Soy		10236	0	N/A	17.1
Other Row Crops		709	0	N/A	1.2
Clover/Wildflowers	189.93	33	33	$6,268	0.1
Switchgrass	123.47	106	106	$13,088	0.2
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	396	16	$2,683	0.7
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4432	7	$745	7.4
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	47	47	$6,930	0.1
Grassland/Herbaceous	140.83	8836	757	$106,607	14.8
	Totals:	**59895**	**966**	**$114,282**	

Table A-4: Partial CRP Loss Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		20307	0	N/A	33.9
Soy		10373	0	N/A	17.3
Other Row Crops		709	0	N/A	1.2
Clover/Wildflowers	189.93	0	0	$0	0.0
Switchgrass	123.47	0	0	$0	0.0
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	396	16	$2,683	0.7
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4433	7	$745	7.4
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	47	47	$6,930	0.1
Grassland/Herbaceous	140.83	8078	0	$0	13.5
	Totals:	**59895**	**70**	**$7,676**	

Table A-5: Total CRP Loss Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		20365	0	N/A	34.0
Soy		10385	0	N/A	17.3
Other Row Crops		709	0	N/A	1.2
Clover/Wildflowers	189.93	0	0	$0	0.0
Switchgrass	123.47	0	0	$0	0.0
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	380	0	$0	0.6
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4427	0	$0	7.4
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	0	0	$0	0.0
Grassland/Herbaceous	140.83	8078	0	$0	13.5
	Totals:	**59895**	**0**	**$0**	

Table A-6: Targeted Riparian Practice Type CRP Gain Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		18714	0	N/A	31.2
Soy		9694	0	N/A	16.2
Other Row Crops		679	0	N/A	1.1
Clover/Wildflowers	189.93	33	33	$6,268	0.1
Switchgrass	123.47	106	106	$13,088	0.2
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	395	16	$2,683	0.7
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4431	7	$745	7.4
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	47	47	$6,930	0.1
Grassland/Herbaceous	140.83	10244	2165	$304,889	17.1
	Totals:	**59895**	**2374**	**$334,603**	

Table A-7: Targeted Wetland Practice Type CRP Gain Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		18812	0	N/A	31.4
Soy		9819	0	N/A	16.4
Other Row Crops		678	0	N/A	1.1
Clover/Wildflowers	189.93	32	32	$6,078	0.1
Switchgrass	123.47	74	74	$9,137	0.1
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	3080	2835	$475,276	5.1
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4021	7	$745	6.7
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	47	47	$6,930	0.1
Grassland/Herbaceous	140.83	7781	757	$106,607	13.0
	Totals:	**59895**	**3752**	**$604,773**	

Table A-8: Combined Wetland & Riparian Type CRP Gain Scenario Land Use Type and Cost Breakdown

Land Use Type	Federal Rental Rate ($ per acre per year)	Acres	CRP Acres	Federal Cost	Land Use % of Basin
Corn		18082	0	N/A	30.2
Soy		9353	0	N/A	15.6
Other Row Crops		652	0	N/A	1.1
Clover/Wildflowers	189.93	32	32	$6,078	0.1
Switchgrass	123.47	74	74	$9,137	0.1
Pasture/Grass	117.74	0	0	$0	0.0
Wetlands	167.67	2888	2642	$443,020	4.8
Open Water		72	0	N/A	0.1
Developed		15478	0	N/A	25.8
Deciduous Forest	106.48	4020	7	$745	6.7
Evergreen Forest	163.19	0	0	$0	0.0
Mixed Forest	147.45	46	47	$6,930	0.1
Grassland/Herbaceous	140.83	9199	1120	$157,720	15.4
	Totals:	**59895**	**3922**	**$623,629**	

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
1	*Sub-basin not adjustable*						
2				1.6	10.8		
3				1.4	5.2		
4				1.1	3.4		
5				1.3	5.0		
6				1.2	4.0		
7				1.2	3.9		
8				1.2	4.3		
9				1.3	4.8		
10		0.9		1.1	3.2		
11				1.3	5.8		
12					2.2		1.5
13				1.3	6.2		
14				1.1	2.9		
15				1.1	2.7		
16					1.8		1.8
17				1.3	5.6		
18	*Sub-basin not adjustable*						
19				1.3	5.6		
20				1.3	5.7		
21				1.4	6.4		
22				1.6	7.4		
23				1.1	3.2		
24		0.9		1.1	2.4	3.4	1.7
25	0.8	0.8		1.3	5.9		
26	0.9	0.7		1.1	4.0		
27	0.9	0.6			1.8		1.5

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
28	0.9		0.9	1.3	6.4		
29	*Sub-basin not adjustable*						
30	*Sub-basin not adjustable*						
31	0.7	0.2		1.1	2.9		
32	0.7	0.8	0.9	1.1	4.2		
33	*Sub-basin not adjustable*						
34	0.7	0.6	0.4	1.2	5.5		
35	0.6	0.3		1.1	4.0		
36	0.9	0.3		1.1	2.5		
37	0.8	0.6		1.1	2.5		
38	0.7	0.7			2.8		
39	0.7	0.8			2.0		
40	0.7	0.4	0.8	1.2	6.6		
41	0.7	0.9	0.9	1.1	3.3		
42	0.7	0.6	0.8	1.1	3.6		
43	*Sub-basin not adjustable*						
44	0.6	0.3	0.9		2.3		1.0
45	0.8	0.2		1.2	4.3		
46	0.9	0.3	0.9	1.1	2.7		
47	0.7	0.5		1.1	3.4		
48	0.7	0.4	0.9		1.9		
49	0.7	0.5	0.9	1.1	3.9		
50	0.9	0.5		1.3	6.8		
51	0.7	0.7		1.1	5.3		
52	0.7	0.6	0.8	1.1	4.0		
53	0.7	0.3		1.2	5.1		
54	0.8	0.9	0.9	1.1	3.3		

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
55	0.8			1.2	6.1		
56	0.7	0.6		1.3	4.8		
57	0.9	0.8		1.1	2.1		
58	0.9	0.6			2.6		
59	0.9	0.7		1.1	2.3		1.2
60	0.9	0.6	0.9		2.6		
61	0.6	0.9	0.9	1.1	3.0		1.0
62	0.9	0.6			2.0		
63	0.8	0.6		1.1	2.5		
64	0.9	0.6	0.7	1.2	4.0		
65	*Sub-basin not adjustable*						
66	0.7	0.9	0.8	1.1	2.7		0.7
67	0.7	0.4		1.1	3.3		1.0
68	0.7	0.7	0.9	1.2	5.0		
69	0.6	0.9	0.7	1.1	3.2		
70	0.7	0.8	0.9	1.1	2.8		
71	0.7	0.8	0.9	1.1	2.1		0.9
72	0.6	0.8	0.7	1.2	3.8		
73	0.7	0.5	0.8	1.3	6.2		
74	0.7	0.8	0.8	1.1	2.4		1.0
75	0.5	0.5	0.9	1.2	4.3		
76	0.8	0.6	0.8	1.1	3.6		
77	0.6	0.3	0.7	1.2	4.3		
78	0.5	0.5	0.7	1.2	3.8		
79	0.7	0.8	0.8		1.9		0.9
80	0.7	0.8	0.8		1.8		1.0
81	*Sub-basin not adjustable*						

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
82	0.5	0.6	0.8	1.4	5.7		
83	0.7	0.3	0.8	1.1	2.5		
84	0.5	0.5	0.9	1.2	4.0		
85	*Sub-basin not adjustable*						
86	0.8	0.5		1.1	4.3		
87	0.7	0.5	0.9	1.3	4.7		
88	0.6	0.7	0.9	1.5	6.0		
89	0.6	0.9	0.9	1.3	4.5		
90	0.6	0.4	0.9	1.3	5.4		
91	0.4	0.5	0.9	1.3	4.2		
92	0.6	0.9	0.7	1.2	3.3		
93	0.8	0.4	0.9	1.1	3.4		
94	0.7		0.9	1.1	3.3		
95	*Sub-basin not adjustable*						
96	0.7	0.9	0.9	1.1	2.2	3.3	0.8
97	0.7	0.2		1.1	4.9		
98	*Sub-basin not adjustable*						
99	0.6		0.6	1.2	4.5		
100	0.6	0.8	0.9	1.2	4.5		
101	0.9	0.4	0.9	1.1	4.4		
102	0.6	0.7	0.9	1.2	3.6		
103	0.8	0.8	0.9	1.2	3.1	4.2	
104	0.8	0.6	0.9	1.2	3.5		
105	0.9	0.5	0.9	1.2	3.9		
106	0.6	0.9	0.9	1.1	2.3	4.6	1.0
107	0.7	0.5	0.8	1.3	4.2		
108	0.7	0.7	0.7	1.1	3.3		

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
109	0.7	0.6		1.2	3.8		
110	0.7	0.4	0.9	1.2	3.4		
111	0.6	0.9		1.2	3.9		
112	0.8		0.9	1.1	2.1	2.3	1.0
113	0.8	0.8	0.9	1.2	4.6		
114	0.8			1.2	4.0		1.0
115	*Sub-basin not adjustable*						
116	0.8		0.9	1.1	3.3		1.0
117	0.6	0.3	0.6	1.3	4.6		
118	0.8	0.9	0.8		1.1	6.1	1.0
119	0.7			1.1	1.9	4.0	0.5
120	0.6	0.8	0.7	1.3	5.4		
121	0.8	0.9	0.9	1.1	2.6		
122	0.5	0.1	0.9	1.2	4.5		
123	0.6	0.9	0.7	1.1	2.5	4.0	
124	0.9			1.1	2.5	8.9	
125	0.9			1.1	1.9	3.2	1.0
126	0.7	0.2	0.9	1.3	5.4		
127	0.5	0.5	0.8	1.4	5.8		
128	0.6	0.8	0.8	1.2	4.5		
129	*Sub-basin not adjustable*						
130	0.6	0.9	0.9	1.2	3.5		
131	0.7	0.9	0.8	1.2	3.3		
132	0.8	0.7		1.1	3.0		
133	*Sub-basin not adjustable*						
134	0.9	0.6	0.9		1.2		
135	0.9	0.3	0.9	1.1	2.8		

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
136	0.5	0.4	0.4	1.4	6.0		
137				1.1	2.3		
138	0.8	0.9	0.7	1.6	6.8		
139	0.9			1.1	2.4	3.9	1.0
140	*Sub-basin not adjustable*						
141	0.9			1.2	3.4		
142	0.7	0.9	0.9	1.1	3.7		
143	*Sub-basin not adjustable*						
144	0.8			1.2	3.6		
145	*Sub-basin not adjustable*						
146	0.8		0.9	1.3	5.5		
147	0.7		0.5	1.7	7.9		
148	0.9		0.9	1.1	2.1	7.2	
149	0.8	0.9		1.4	6.3		
150	0.8			1.3	4.2		
151	0.8	0.2	0.9	1.4	5.7		
152	*Sub-basin not adjustable*						
153	0.6	0.1	0.7	1.5	7.8		
154	0.7	0.5	0.8	1.5	6.7		
155	*Sub-basin not adjustable*						
156	0.8		0.9	1.2	3.1	3.3	
157	0.8			1.3	4.3	3.6	
158	0.9	0.9		1.3	5.2		
159	0.8			1.6	7.6		
160	0.7			1.8			
161	0.8	0.9	0.9	1.3	5.4		
162	0.7			1.2	3.6	2.8	

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
163	0.8	0.8		1.3	4.7		
164	0.9	0.9		1.4	6.1		
165	*Sub-basin not adjustable*						
166	0.5	0.9		1.5	6.5		
167	*Sub-basin not adjustable*						
168	*Sub-basin not adjustable*						
169	0.6	0.6		1.4	6.3		
170	0.8	0.7		1.4	5.2	2.7	
171	0.7	0.5	0.9	1.1	2.9		
172	*Sub-basin not adjustable*						
173	0.6		0.9	1.4	6.0		
174	0.7	0.3		1.4	6.0		
175	0.8	0.8		1.2	3.6		
176	0.8	0.8		1.1	2.5		1.0
177	0.7	0.7	0.9	1.4	6.0		
178	0.7	0.9			1.7	2.6	1.1
179	0.6			1.2	3.5		
180	*Sub-basin not adjustable*						
181	0.6	0.9	0.9	1.4	5.8		
182	0.9	0.8		1.3	4.4		
183	0.8	0.8	0.9	1.1	2.1		0.9
184	0.8	0.9			1.5	3.1	1.1
185	0.9	0.8		1.2	3.3		1.0
186	0.9	0.6		1.2	3.7		
187	0.9	0.9	0.9	1.2	4.0		
188	0.9		0.8	1.2	4.2		
189	*Sub-basin not adjustable*						

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
190	0.6	0.9		1.4	5.1		
191	0.8			1.4	5.4		
192	*Sub-basin not adjustable*						
193	0.9			1.1	2.6	5.0	1.0
194				1.1	1.9		1.0
195	0.8	0.9	0.9	1.3	3.8		
196	0.7	0.8		1.2	3.9		0.9
197	0.8			1.1	2.9		0.9
198	0.9			1.2	3.7		
199	0.6	0.4	0.9	1.6	7.3		
200	0.8			1.1	1.8		1.0
201	0.6	0.6		1.5	6.2		
202	0.6	0.9		1.5	6.7		
203	0.7	0.9		1.1	2.2		0.8
204	0.7	0.8		1.1	2.4		1.0
205	0.6	0.2		1.6	8.2		
206	0.6	0.9		1.1	2.6	2.8	0.9
207	0.5	0.6		1.1	2.5		0.8
208	0.7			1.4	6.6		0.9
209	0.7			1.5	7.1		
210	*Sub-basin not adjustable*						
211	0.7	0.5		1.2	3.2		
212	0.7				2.0		1.0
213	0.6	0.9		1.1	3.0		1.0
214	0.8	0.4		1.6	8.1		
215	0.7	0.2	0.9	1.6	7.1		
216	0.6	0.8	0.9	1.4	6.0		

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

Table A-9: SWAT Percentage Changes[1] Applied to Each Sub-Basin Per Land Use Type and Scenario

Subbasin	No CRP PAST	No CRP WETL	No CRP FRSD	Riparian PAST	Water Quality PAST Adjustment	Water Quality WETL	Water Quality FRSD
217	0.9			1.3	5.8		0.9
218	0.7	0.9		1.1	3.3		0.9
219	0.7	0.8		1.3	4.5		
220	0.8	0.9		1.1	3.0	3.8	0.8
221	0.7	0.4	0.9	1.3	4.6		
222	0.7	0.2		1.3	5.2		
223	0.6	0.9		1.1	2.2	5.4	1.0
224	0.8	0.6		1.2	3.2		
225	0.8	0.9		1.1	2.2	7.9	
226	0.7				1.9	3.9	0.9
227	0.7	0.9		1.1	2.4	4.1	1.0
Average:	**0.7**	**0.7**	**0.8**	**1.2**	**4.1**	**4.2**	**1.0**

[1] Percent changes are expressed as a decimal and not a true percentage. Values less than 1 indicate a decrease in proportion and values greater than 1 represent an increase.

CONSERVATION RESERVE PROGRAM FLOOD DAMAGE REDUCTION BENEFITS TO DOWNSTREAM URBAN AREAS

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APPENDIX B

HYDROLOGIC MODELING AND ASSESSMENTS

Table B-1: NOAA Atlas 14 Rainfall Frequency Estimates by Duration for Cedar Rapids No. 1 Gauge (Bolded Events Included In This Analysis)

CEDAR RAPIDS NO. 1 - IA-1319									
Annual Maximum Series									
PRECIPITATION FREQUENCY ESTIMATES									
by duration for ARI:	**2**	**5**	**10**	**25**	**50**	**100**	**200**	**500**	**1000**
5-min:	0.41	0.54	0.63	0.76	0.86	0.96	1.07	1.21	1.32
10-min:	0.60	0.79	0.93	1.12	1.26	1.41	1.56	1.77	1.93
15-min:	0.74	0.96	1.13	1.36	1.54	1.72	1.91	2.16	2.35
30-min:	1.03	1.35	1.60	1.93	2.19	2.45	2.71	3.07	3.34
60-min:	1.34	1.76	2.09	2.56	2.92	3.30	3.69	4.23	4.65
2-hr:	1.65	2.17	2.58	3.18	3.65	4.15	4.67	5.39	5.97
3-hr:	1.83	2.41	2.89	3.58	4.15	4.75	5.38	6.28	6.99
6-hr:	2.15	2.84	**3.43**	**4.29**	**5.00**	**5.76**	6.58	**7.74**	8.69
12-hr:	2.48	3.28	3.97	4.97	5.80	6.70	7.66	9.02	10.13
24-hr:	2.82	3.72	**4.48**	**5.58**	**6.50**	**7.49**	8.54	**10.04**	11.26
2-day:	3.23	4.15	4.93	6.09	7.05	8.08	9.20	10.79	12.08
3-day:	3.53	4.44	5.22	6.37	7.34	8.39	9.52	11.13	12.45
4-day:	3.79	4.71	5.49	6.64	7.61	8.65	9.77	11.36	12.66
7-day:	4.46	5.48	6.31	7.48	8.43	9.43	10.48	11.95	13.12
10-day:	5.07	6.19	7.07	8.29	9.25	10.25	11.28	12.68	13.79
20-day:	6.87	8.28	9.35	10.79	11.89	13.00	14.12	15.62	16.77
30-day:	8.47	10.19	11.47	13.15	14.40	15.65	16.89	18.50	19.71
45-day:	10.61	12.81	14.41	16.44	17.91	19.33	20.69	22.41	23.64
60-day:	12.51	15.20	17.10	19.46	21.12	22.68	24.12	25.87	27.07

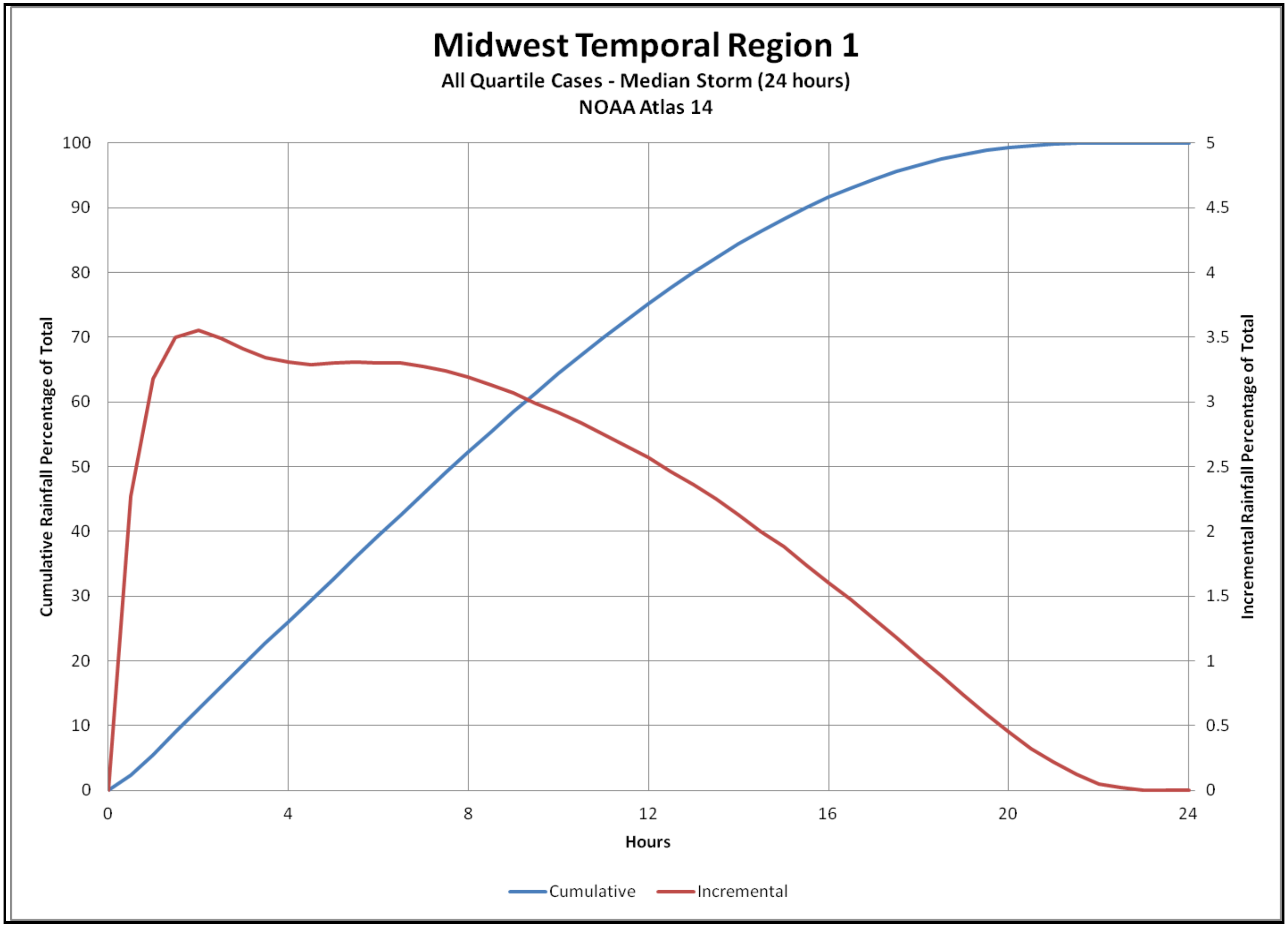


Figure B-1: Temporal Disaggregation Curves From NOAA Atlas 14 for Midwest Region 1
Here Shown for the 24-hour Event

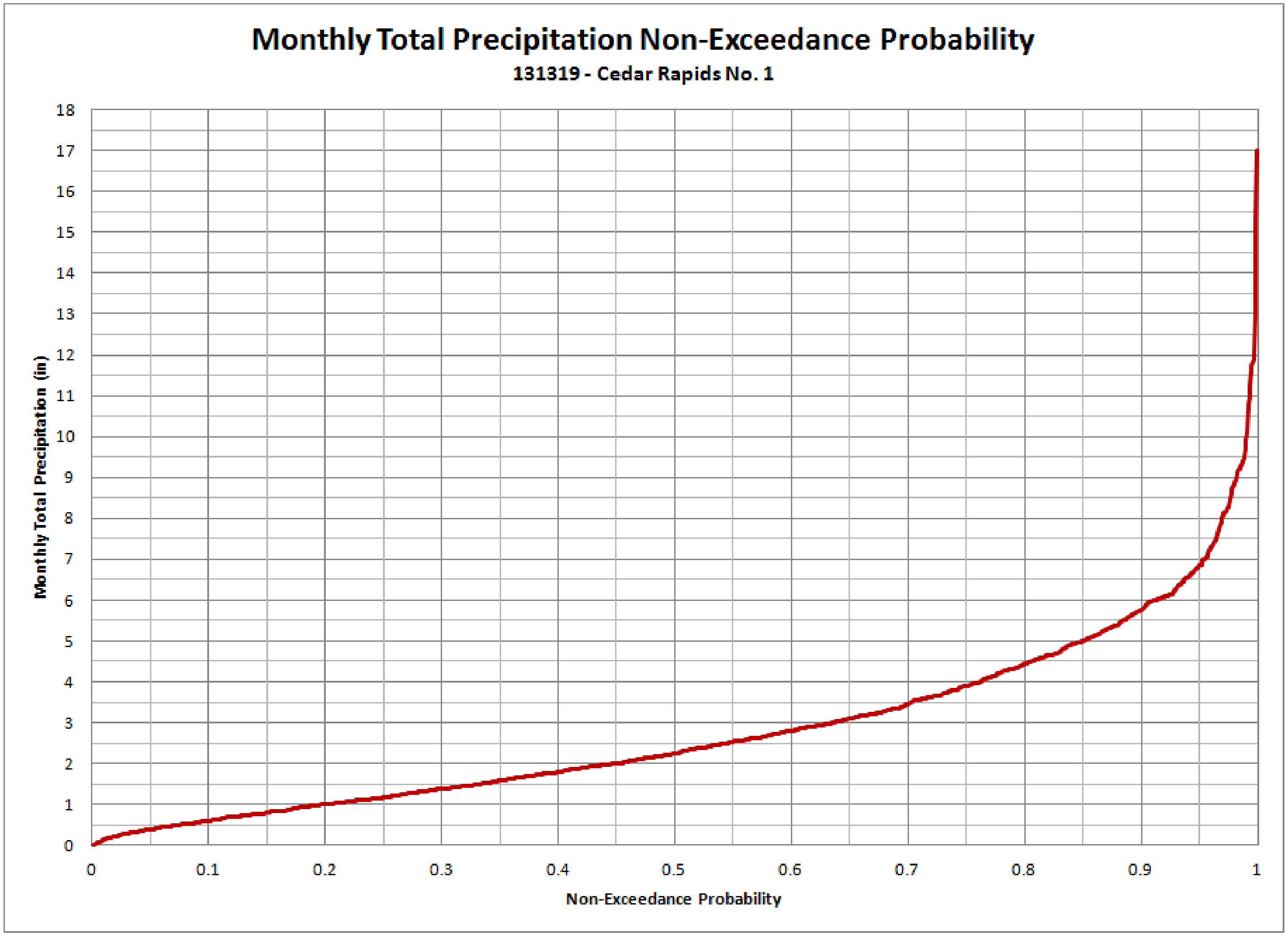


Figure B-2: Monthly Total Precipitation Frequency Curve for Cedar Rapids No. 1

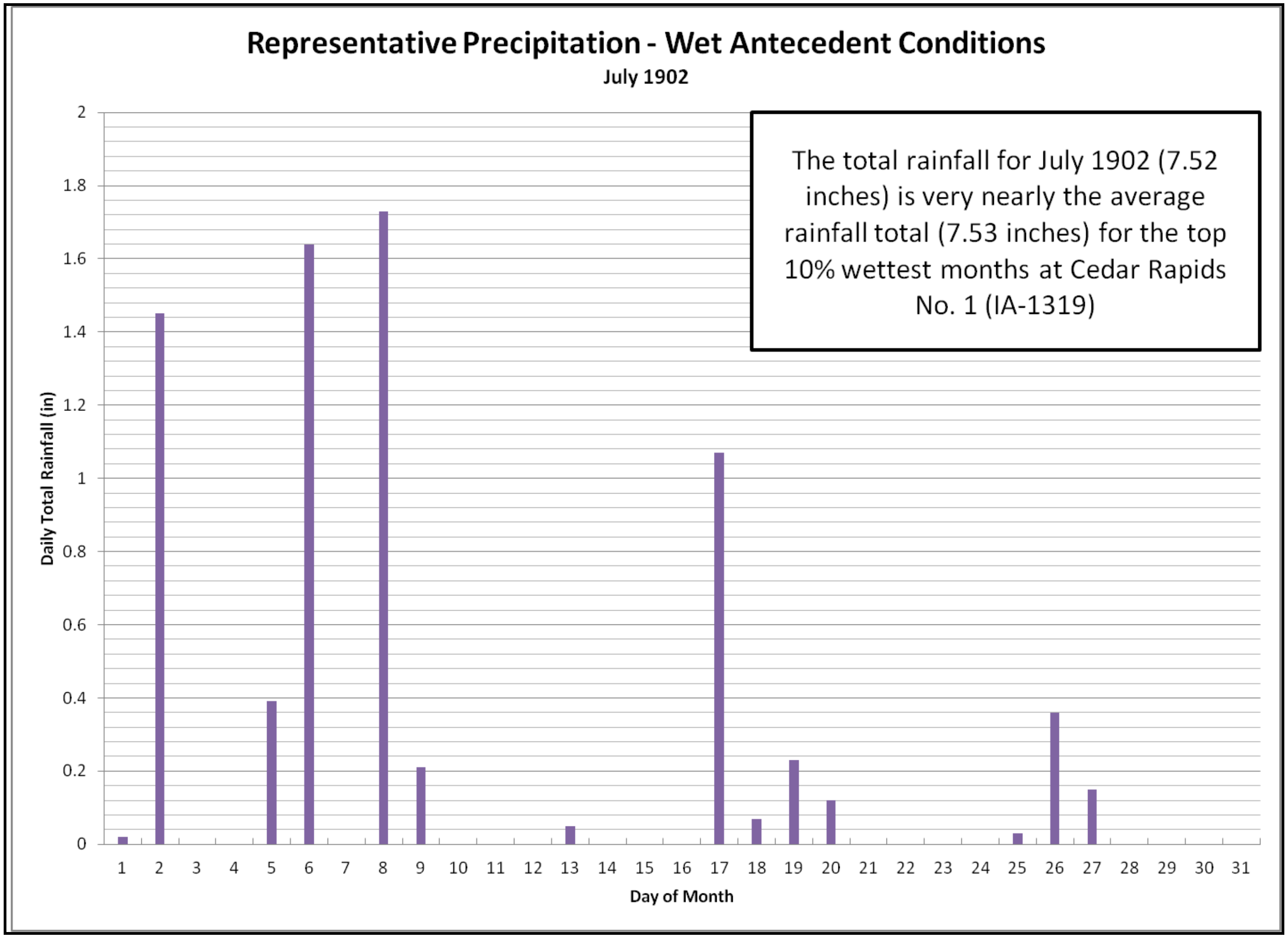


Figure B-3: Wet Antecedent Condition Scenario Precipitation

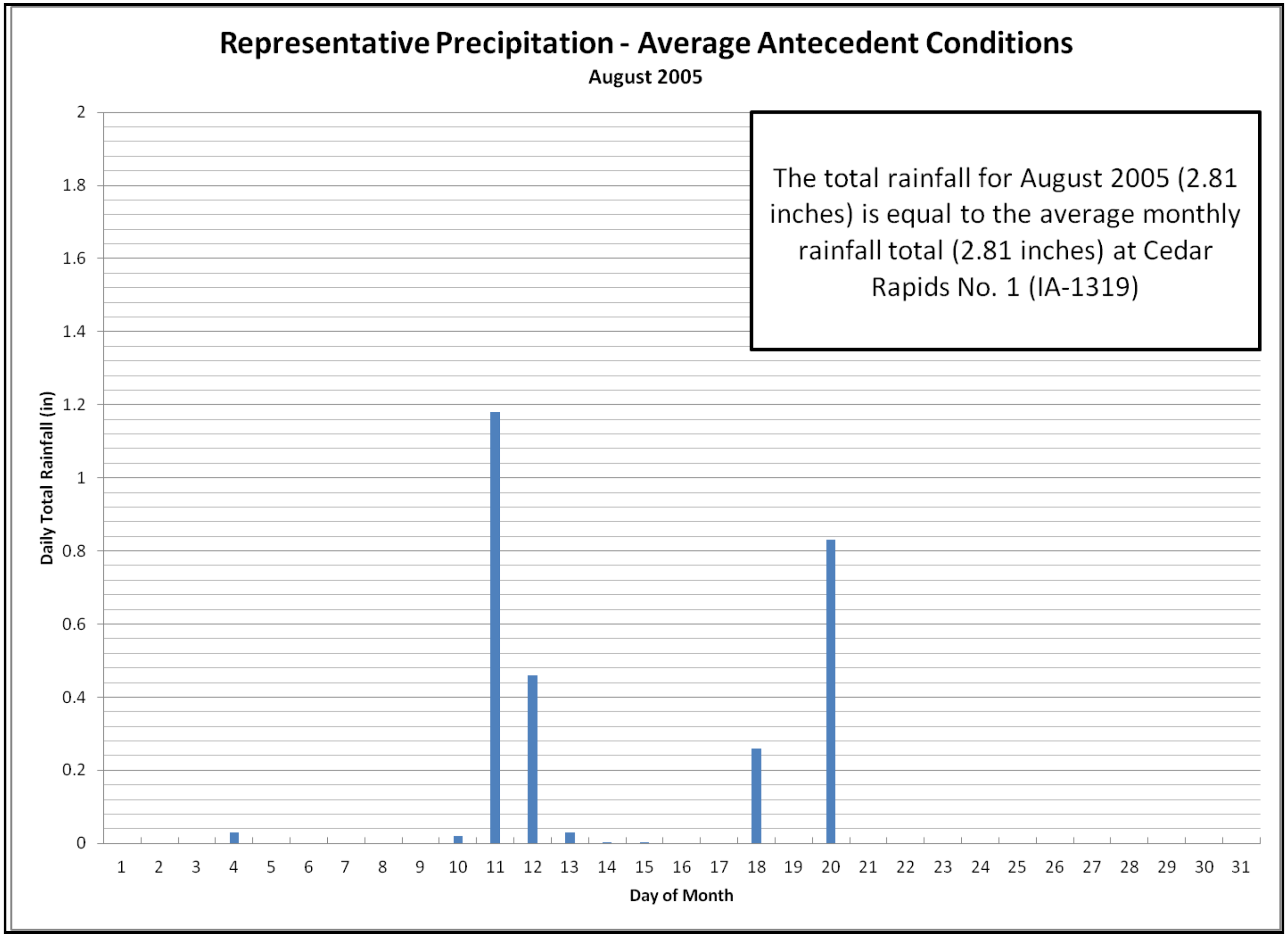


Figure B-4: Average Antecedent Condition Scenario Precipitation

INDIAN CREEK GSSHA MODEL - SPATIALLY DISTRIBUTED PARAMETERS

Evapotranspiration. Parameters are assigned based on a lumping of the land use classification from CDL.

GIS method: reclassification

Table B-2: GSSHA Evapotranspiration Map Table

GSSHA Map Index Value	CDL Land Use Classes	CDL Values	ET Description
1	Barren land, all developed land	131, 121, 122, 123, 124	Developed
2	All forest	141, 142, 143	Forest (all types)
3	Clover, hay, pasture/grass, rye, switchgrass, grassland	58, 37, 62, 27, 60, 171	Grassland (all types)
4	Alfalfa, barley, corn, oats, potatoes, soybeans, winter wheat	36, 21, 1, 28, 43, 5, 24	Row crops (all types)
5	Open water	111	Open water
6	All wetlands	87, 190, 195	Wetlands (all types)

Surface roughness. Parameters are assigned based on a lumping of the land use classification from CDL.

GIS method: reclassification

Table B-3: GSSHA surface Roughness Map Table

GSSHA Map Index Value	CDL Land Use Classes	CDL Values
1	Soybeans	5
2	Barley, winter wheat, rye, oats	21, 24, 27, 28
3	Alfalfa, other hay	36, 37
4	Clover/wildflowers	58
5	Switchgrass	60
6	Pasture/grass	62
7	Wetlands, woody wetlands, herbaceous wetlands	87, 190, 195
8	Open water	111
9	Developed (open space)	121
10	Developed (low/med/high density)	122, 123, 124
11	Barren	131
12	Deciduous, evergreen and mixed forests	141, 142, 143
13	Grassland herbaceous	171
14	Corn, potatoes	1, 43

Green and Ampt infiltration parameters. Parameters are assigned based on a unique combination of soil texture and land disturbance level.

GIS method: reclassification, combinatorial 'and'

Table B-4: GSSHA Soil Disturbance Map Table

GSSHA Map Index Value	Land Use Description	Disturbance Level
1	All developed land and open water	Developed
2	All crops	High disturbance
3	All CRP lands and non-crop including wetland and forest	Low disturbance

Table B-5: GSSHA Soil Map Table

GSSHA Map Index Value	Soil Texture	Soil Symbol
1	Clay	C
2	Clay Loam	CL
3	Loam	L
4	Loamy Sand	LS
5	Sand	S
6	Sandy Loam	SL
7	Silt Loam	ML
8	Silty Clay Loam	MCL

Table B-6: GSSHA Infiltration Parameter Map Table

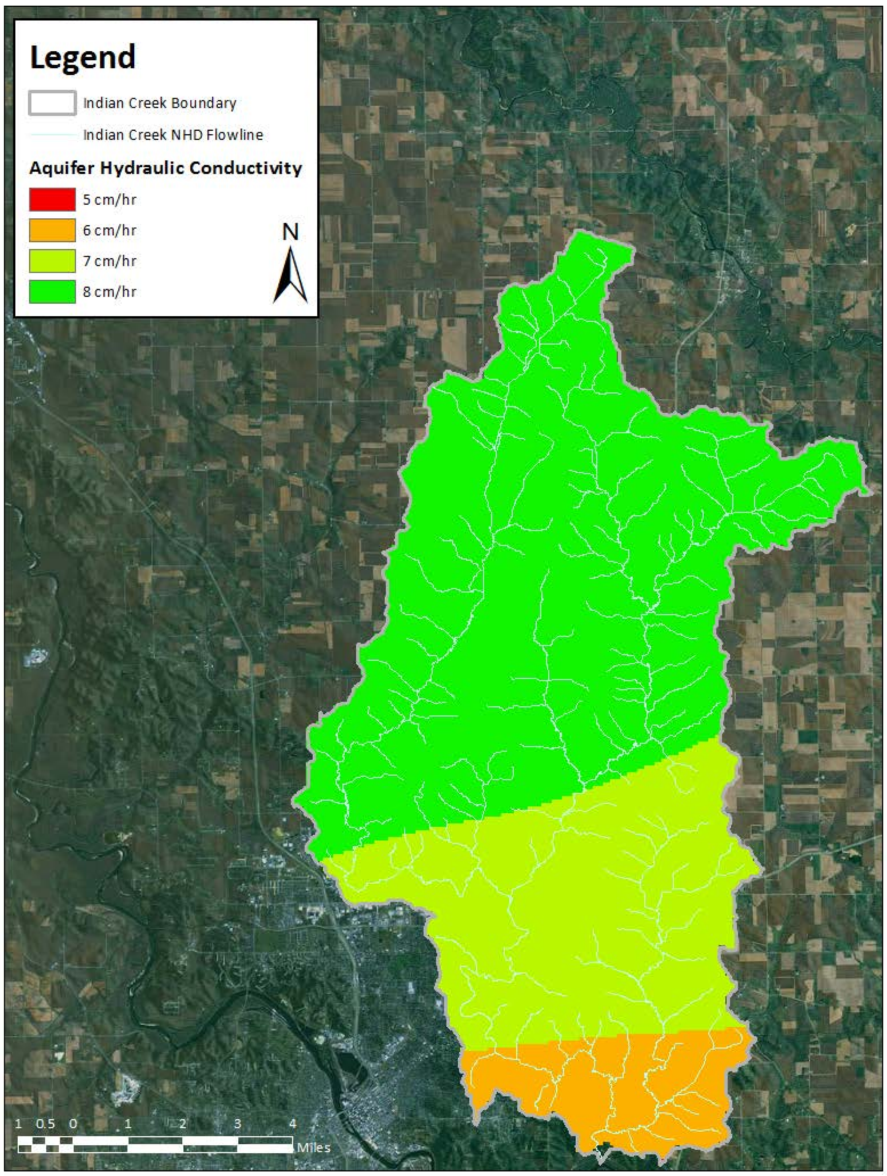
GSSHA Map Index Value	Disturbance Level	Soil Symbol
1	High	ML
2	High	CL
3	High	MCL
4	High	SL
5	Developed	SL
6	High	L
7	Low	ML
8	High	S
9	Developed	ML
10	Low	S
11	Low	L
12	Low	CL
13	Developed	L
14	Developed	CL
15	Low	MCL
16	Developed	S
17	Developed	C
18	High	C
19	Low	SL
20	Low	C
21	Developed	MCL
22	Developed	LS

Groundwater hydraulic conductivity. Groundwater hydraulic conductivity for the Silurian Aquifer was derived from the Iowa DNR's Natural Resources GIS library: http://www.igsb.uiowa.edu/webapps/nrgislibx/ and resampled to the spatial resolution of the GSSHA model.

GIS method: raster calculator, resampling

Modeled Parameters by Index Map Value

Groundwater - Aquifer Hydraulic Conductivity



Evapotranspiration

Table B-7: GSSHA Evapotranspiration Parameters

Index Map ID	Description	ALBEDO	VEG_HEIGHT	V_RAD_COEFF	CANOPY_RESIST
1	All Developed	0.26	2	0.75	86
2	All Forest	0.20	1500	0.18	150
3	All Grassland	0.16	70	0.18	100
4	All Row Crops	0.25	150	0.18	200
5	Open Water	0.06	0	1.00	0
6	All Wetlands	0.20	300	0.18	50

Overland Flow Roughness Values

Table B-8: GSSHA Overland Roughness Parameters

ID	Description	Manning's n
1	Cotton/soy	0.25
2	Small grain	0.25
3	Dense grass	0.24
4	Clover	0.15
5	Grassed waterway	0.6
6	Pasture	0.3
7	Wetland	0.85
8	Channel	0.05
9	Lawns	0.15
10	Developed	0.0137
11	Bare field	0.05
12	Forest	0.192
13	Mixed grass prairie	0.52
14	Row crops	0.15

(Source: GSSHA wiki)

Saturated Hydraulic Conductivity

Table B-9: GSSHA Saturated Hydraulic Conductivity Values

ID	Disturbance	Soil Texture	HYDR_COND (cm/hr)
1	High	Silt Loam	0.8178
2	High	Clay Loam	0.3302
3	High	Silty Clay Loam	0.7353
4	High	Sandy Loam	1.09
5	Developed	Sandy Loam	0[1]
6	High	Loam	1.0191
7	Low	Silt Loam	6.12
8	High	Sand	11.78
9	Developed	Silt Loam	0[1]
10	Low	Sand	11.78
11	Low	Loam	3.3374
12	Low	Clay Loam	0.8253
13	Developed	Loam	0[1]
14	Developed	Clay Loam	0[1]
15	Low	Silty Clay Loam	1.80
16	Developed	Sand	0[1]
17	Developed	Clay	0[1]
18	High	Clay	0.54
19	Low	Sandy Loam	1.09
20	Low	Clay	0.54
21	Developed	Silty Clay Loam	0[1]
22	Developed	Loamy Sand	0[1]

[1] GSSHA requires a non-zero value. 0.000001 was used.

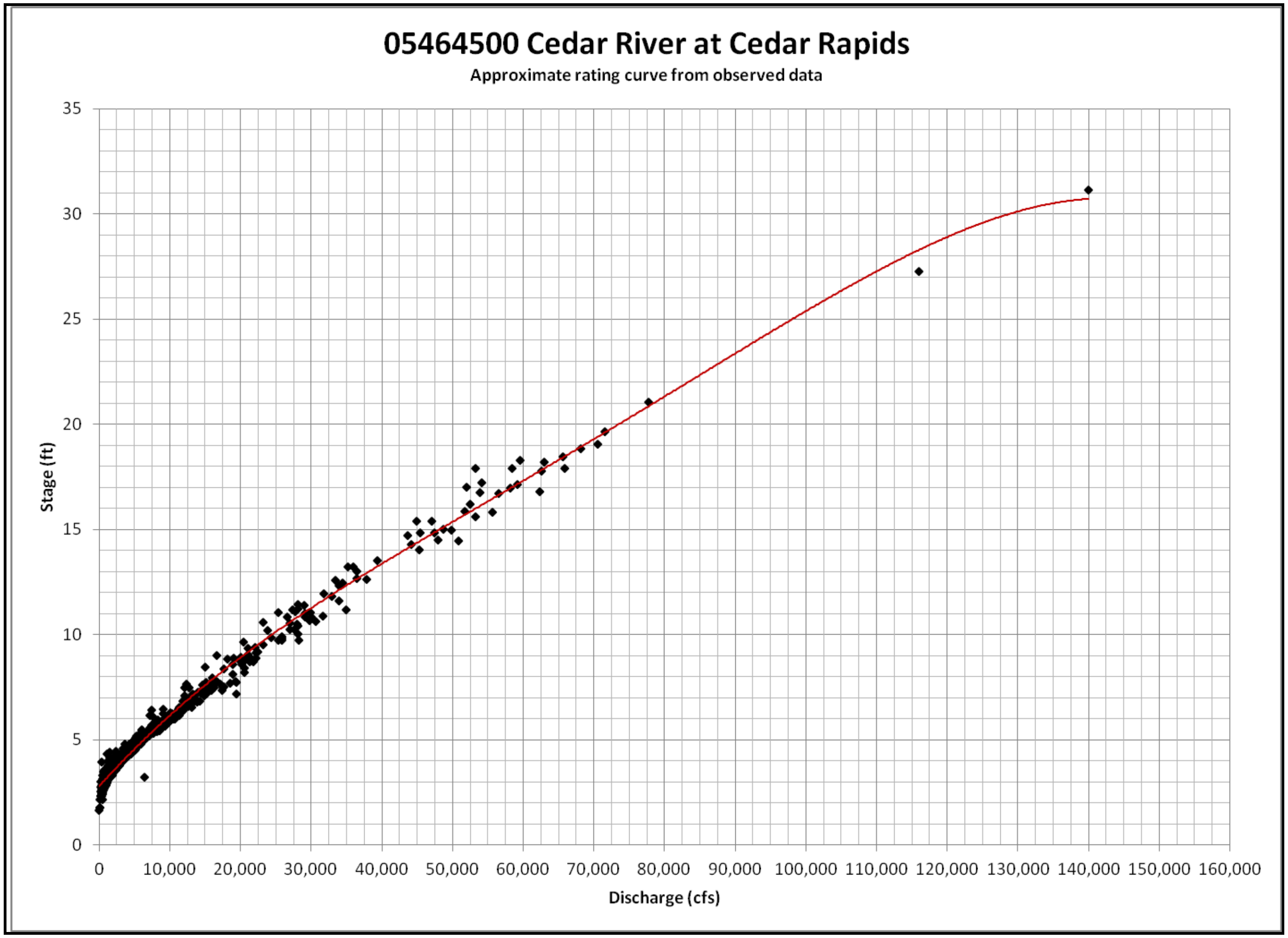


Figure B-5: Approximate Rating Curve for USGS 05464500 Cedar River at Cedar Rapids, IA

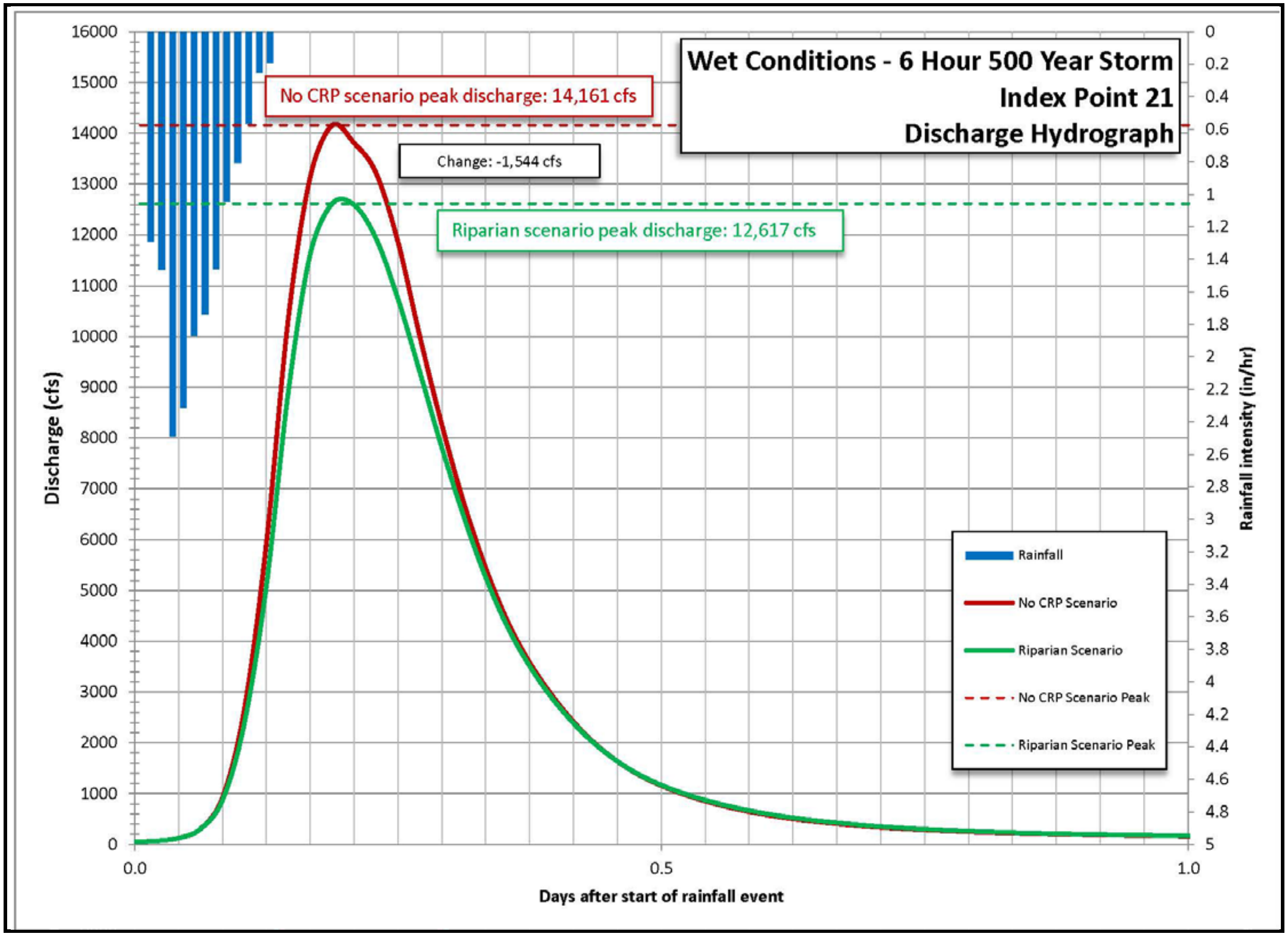


Figure B-6: Index Point 21 Discharge Hydrographs for the Wet Antecedent Condition 6-hr, 500-yr Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

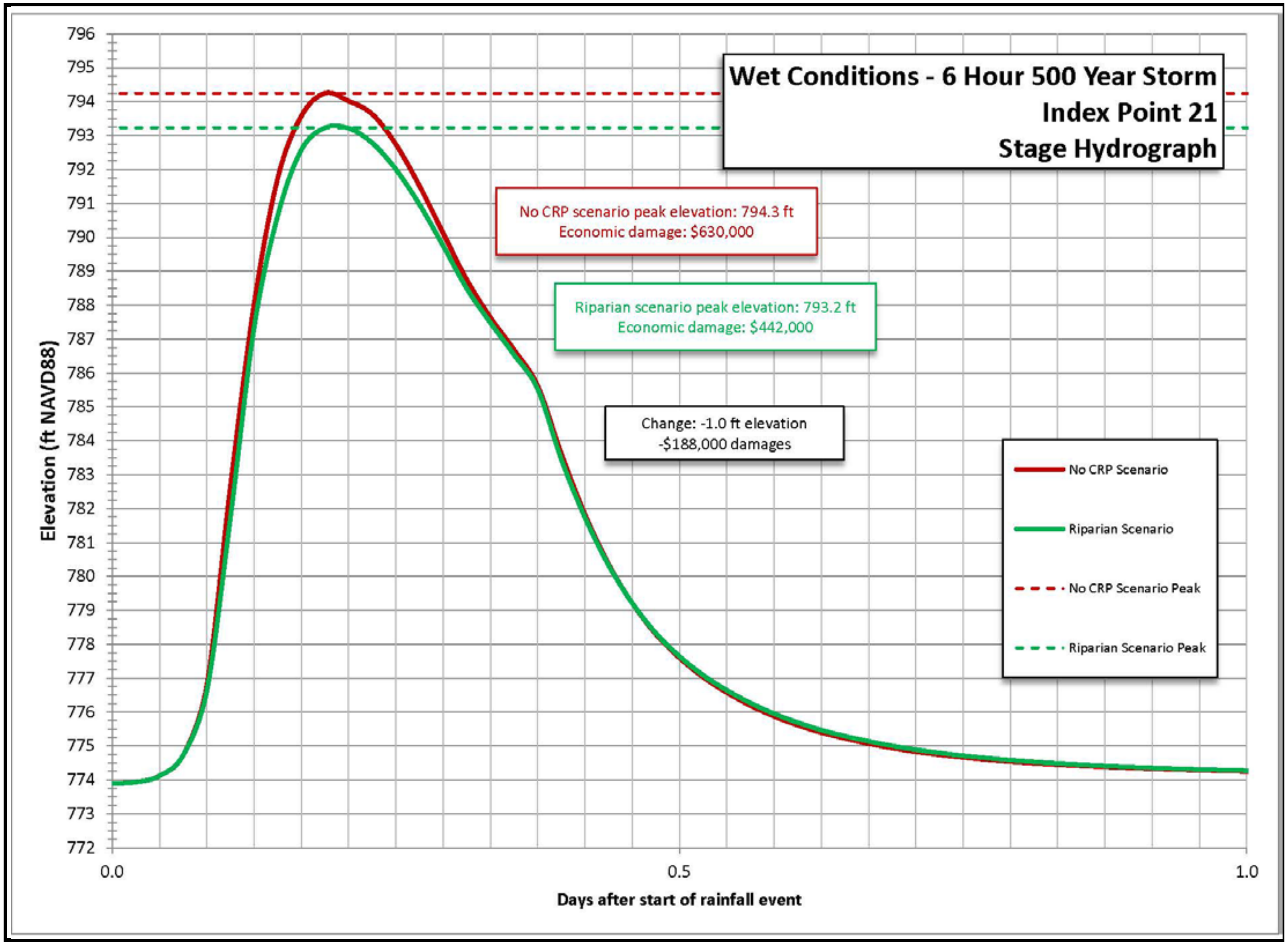


Figure B-7: Index Point 21 Stage Hydrographs for the Wet Antecedent Condition 6-hr, 500-year Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

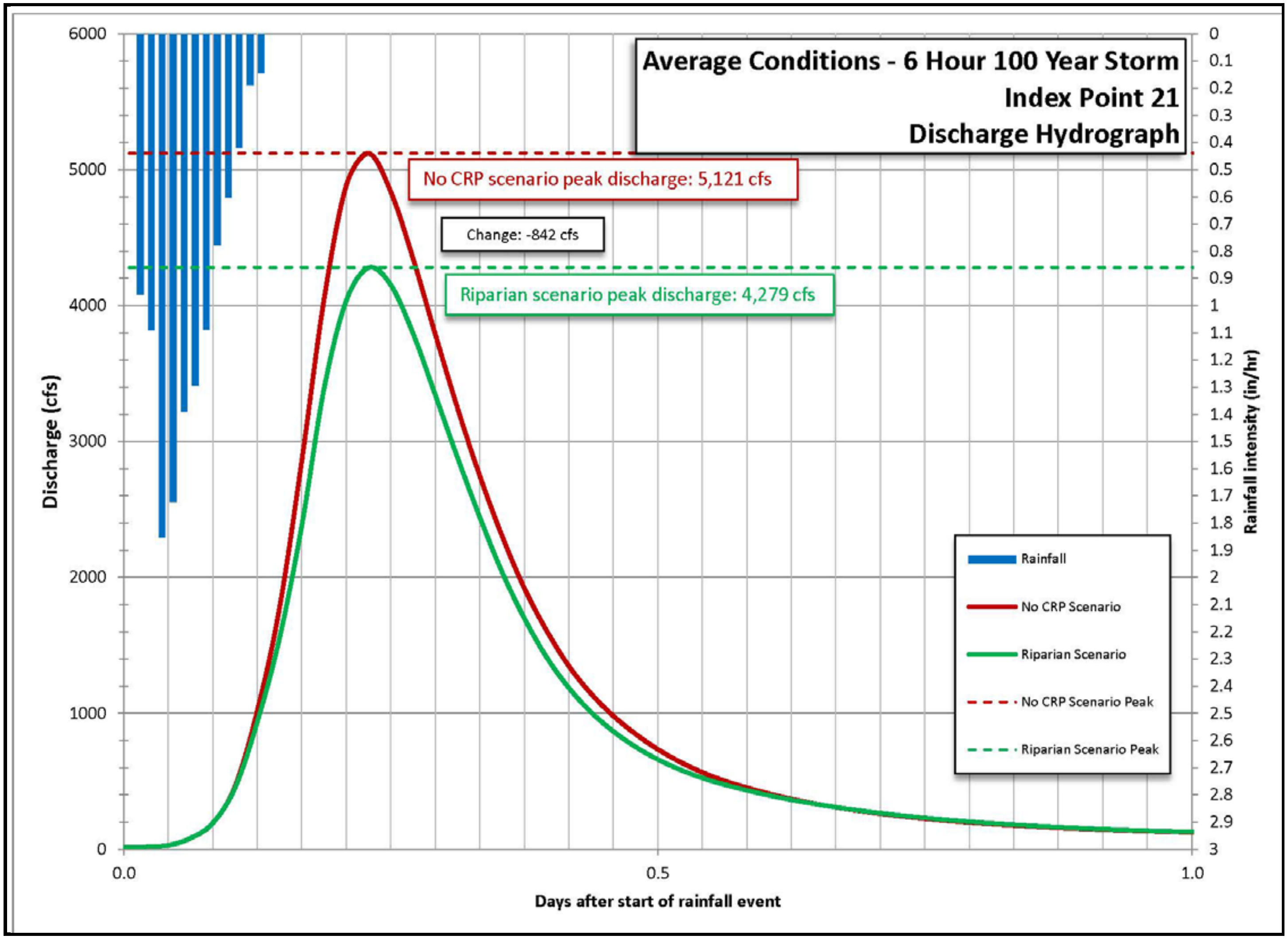


Figure B-8: Index Point 21 Discharge Hydrographs for the Average Antecedent Condition 6-hr, 100-yr Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

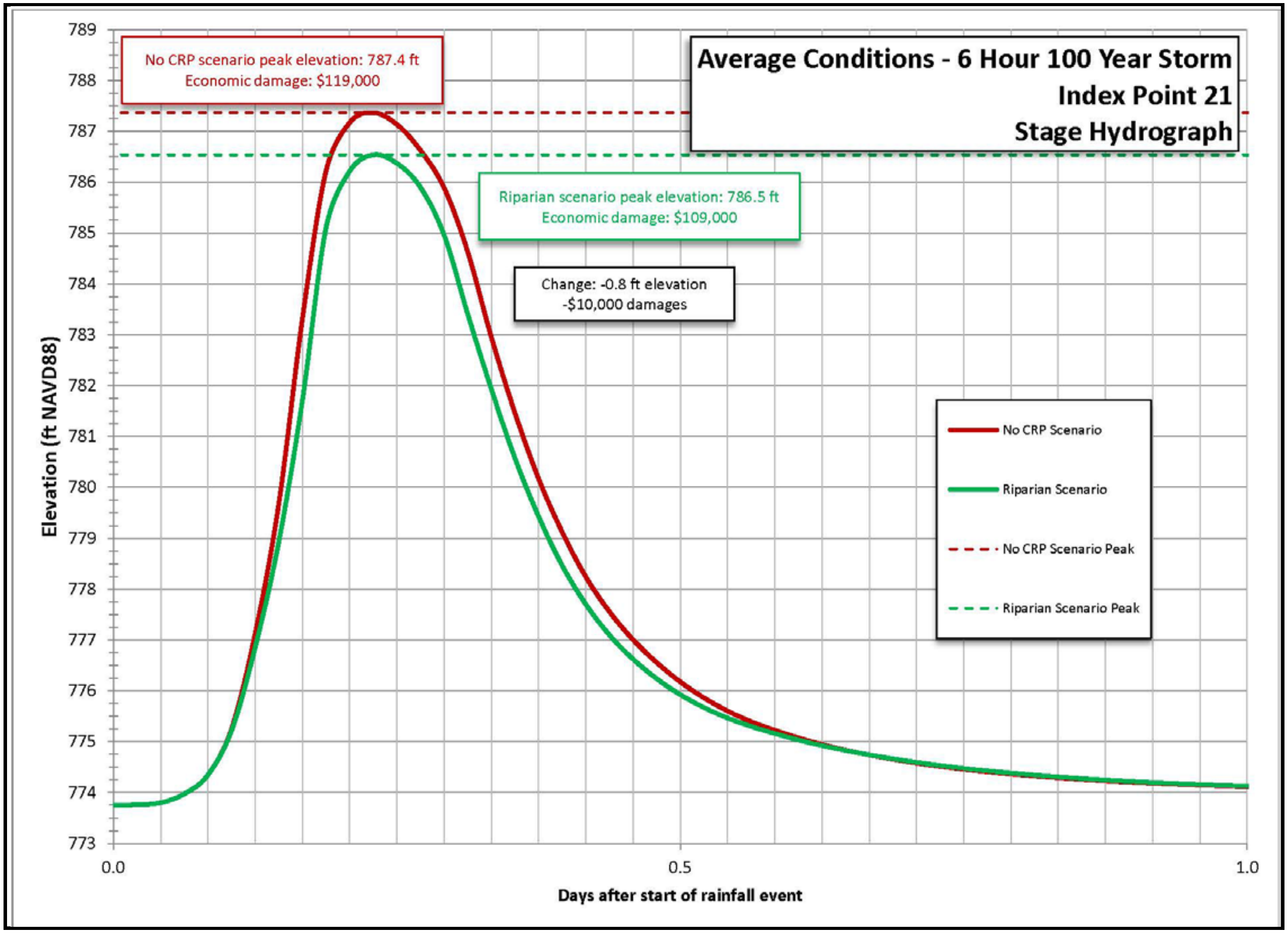


Figure B-9: Index Point 21 Stage Hydrographs for the Average Antecedent Condition 6-hr, 100-yr Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

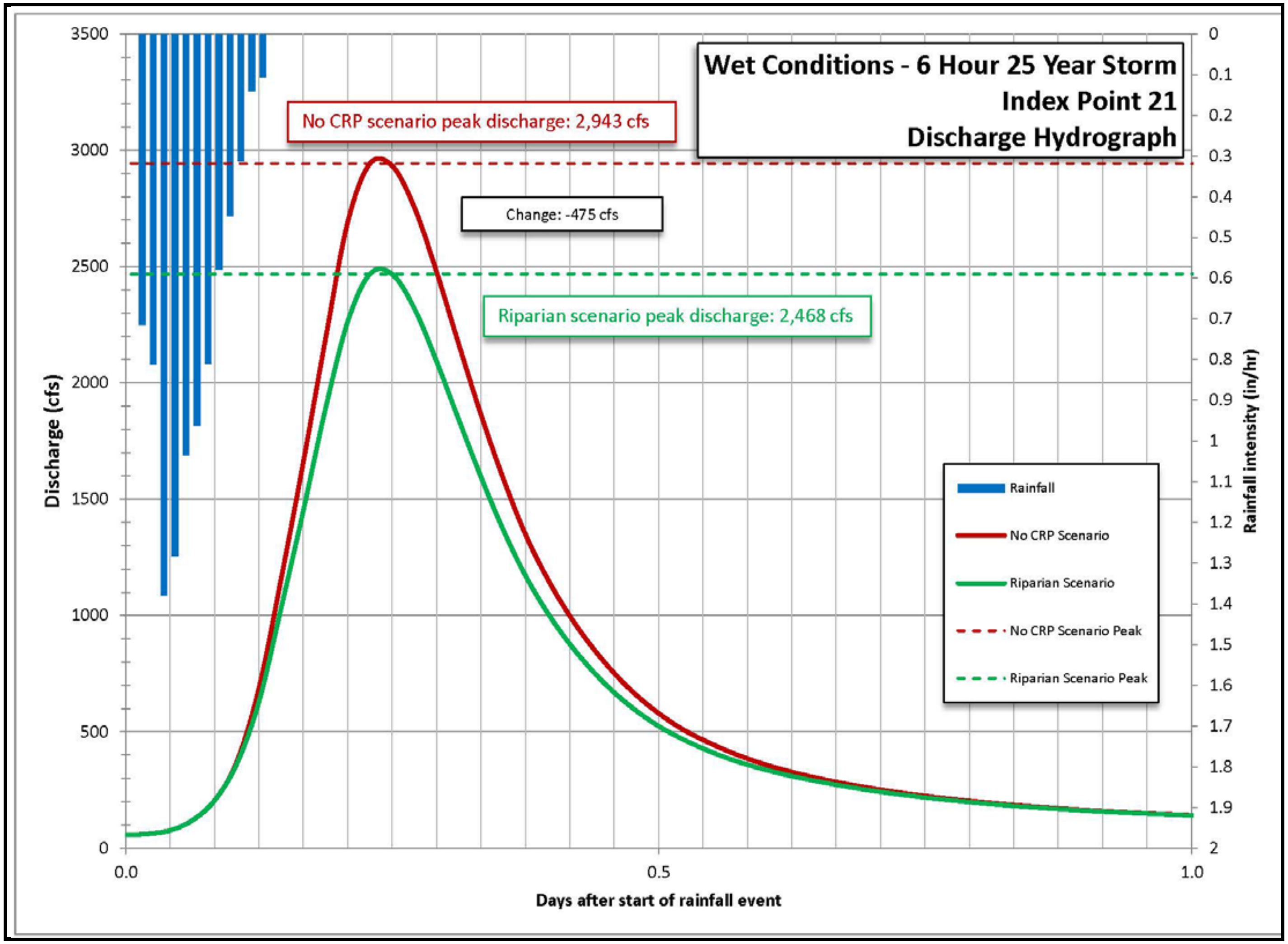


Figure B-10: Index Point 21 Discharge Hydrographs for the Wet Antecedent Condition 6-hr, 25-yr Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

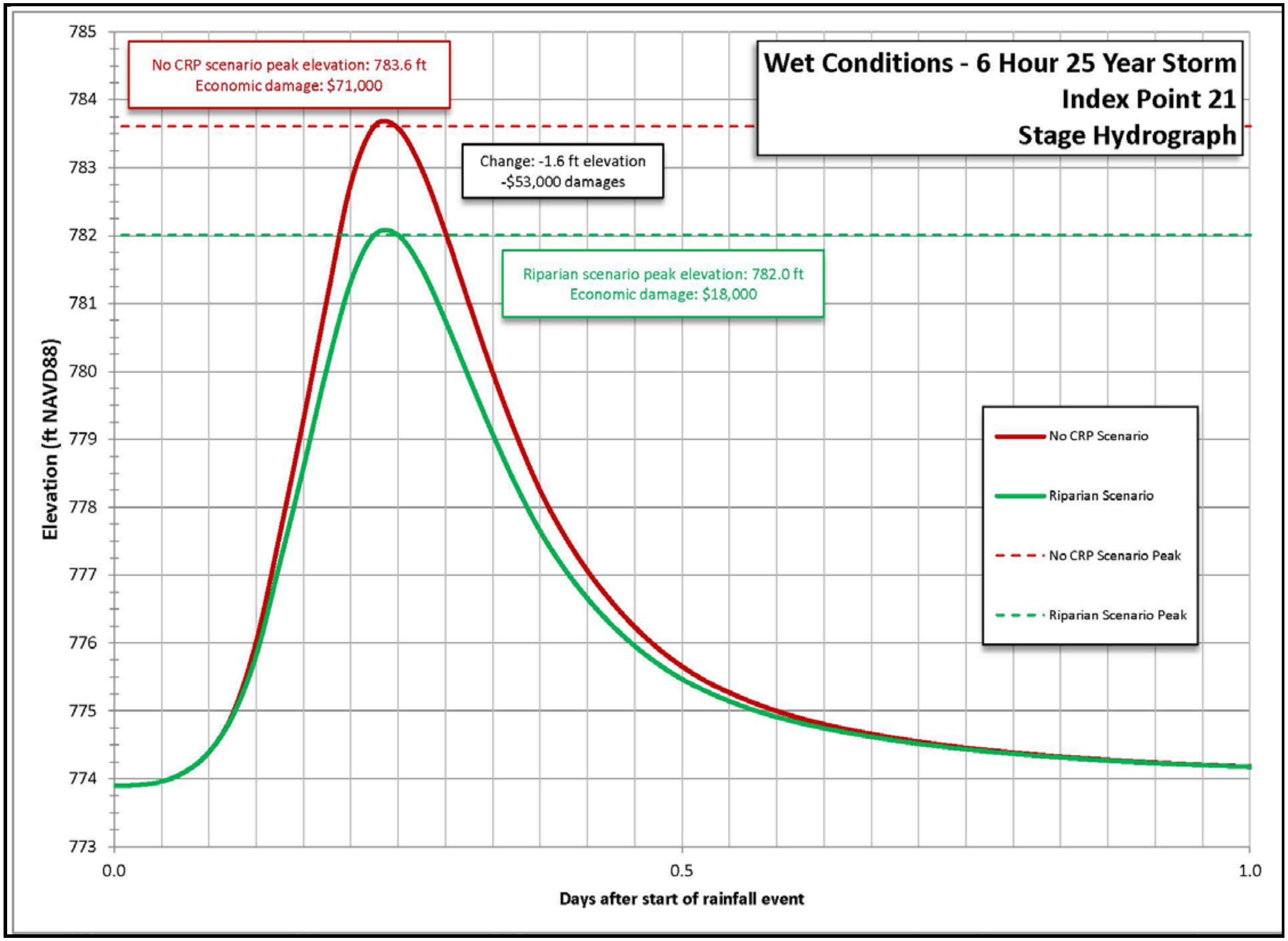


Figure B-11: Index Point 21 Stage Hydrographs for the Wet Antecedent Condition 6-hr, 25-yr Rainfall Event Showing the Riparian-Targeted and Total CRP Loss Scenarios

Green-Ampt Infiltration Parameter Estimation. Methodology based on chapter 5 of the Handbook of Hydrology (*Maidment et al. 1993)* and work by *Rawls and Brakensiek (1993), Rawls et al. (1989), Brakensiek and Rawls (1988) and Rawls et al. (1990).*

- Initial values for infiltration parameters based on Table 5.5.5 in *Handbook of Hydrology* for USDA soil texture groups.
- Bare ground effective saturated hydraulic conductivity [L T^{-1}]
  - $K = \frac{K_s}{2}$
- Wetting front suction (S_f) [L] is considered to be unaffected by management parameters
  - This value may be affected by practices that change the bulk density of the soil, such as by the introduction of organic matter
- Equation 5.5.16 (*Handbook of Hydrology*) gives S_f as a function of percent clay/sand and porosity
- All management effects are incorporated into K (conductivity parameter)
- Three categories are:
  1. bare ground outside of canopy cover
  2. ground with cover
  3. bare ground under canopy cover

1. Crusted soil, where:
   - $K = CRC * K_s$
   - $CRC = \frac{SC}{1+\left(\psi_i/L\right)}$
     - SC = correction factor for partial saturation of the soil subcrust $= 0.736 + 0.0019S$
     - S = percent sand
     - ψ_i = matric potential drop at the crust-subcrust interface $= 45.19 - 46.68SC$
     - L = wetting front depth
   - Grass and other plant materials, however, prevent soil from crusting.
2. Conductivity parameter adjusted using a macroporosity factor:
   - $K = K_S * A$
     - S = percent sand
     - C = percent clay
     - BD = bulk density of soil
     - $BD = PD * (1 - \phi)$
     - PD = particle density of soil, generally taken as 2.65 g cm^{-3}
     - Φ = soil porosity
   - For "low disturbance" areas such as rangeland,
     - $A = exp(2.82 - 0.99S + 1.94BD)$
   - For "high disturbance" areas such as agricultural land,
     - $A = exp(0.96 - 0.032S + 0.04C - 0.032BD)$

3. Bare ground effective hydraulic conductivity applies.

The land use classifications within Indian Creek were broken down by their CDL classifications, then remapped to a three-category system that describes how the land use effects infiltration:

1. Developed/open water
    - All developed CDL land use classes including open space
2. Agricultural high disturbance
    - All crops
3. Agricultural low disturbance
    - All CRP lands and non-crop non-CRP lands including wetlands and forest

The USDA soil textures were used for determining the base infiltration parameters. The three classes then used the above methods to correct the parameters based on land use:

1. $K \approx 0$
    - GSSHA will not take $K = 0$ as valid so the conductivity parameter was assigned to be negligibly small
2. Modified using the “high disturbance” macroporosity factor above
3. Modified using the “low disturbance” macroporosity factor above

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APPENDIX C

ECONOMIC EVALUATION

IWR-92-R-3 Depth-Damage Functions for Rock Island, IL area. The depth of flooding is in the left hand column and % structural damage is on the right. There are five depth-damage functions here for varying types of residential structures.

1 Story w/basement	% Dmg	1 Story w/o basement	% Dmg	2 Story w/basement	% Dmg	2 Story w/o basement	% Dmg	Split Level	% Dmg
-8	0%	-8	0%	-8	0%	-8	0%	-8	0%
-7	1%	-7	0%	-7	1%	-7	1%	-7	1%
-6	1%	-6	0%	-6	1%	-6	1%	-6	1%
-5	2%	-5	1%	-5	2%	-5	1%	-5	2%
-4	2%	-4	1%	-4	2%	-4	2%	-4	3%
-3	3%	-3	1%	-3	3%	-3	2%	-3	4%
-2	4%	-2	2%	-2	3%	-2	2%	-2	6%
-1	5%	-1	4%	-1	4%	-1	3%	-1	8%
0	8%	0	10%	0	7%	0	6%	0	12%
1	20%	1	22%	1	14%	1	10%	1	15%
2	31%	2	30%	2	21%	2	16%	2	21%
3	37%	3	35%	3	26%	3	20%	3	30%
4	41%	4	39%	4	30%	4	24%	4	40%
5	44%	5	43%	5	33%	5	28%	5	48%
6	46%	6	45%	6	35%	6	30%	6	53%
7	48%	7	47%	7	37%	7	32%	7	57%
8	49%	8	49%	8	40%	8	34%	8	61%
9	50%	9	50%	9	45%	9	38%	9	63%
10	51%	10	51%	10	48%	10	42%	10	66%

CURRENT LAND USE

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$16,454	$5,407	$2,583	$0	$0	$12,083	$2,583	$0	$0	$0	$2,583	$0	$0	$0	$0	$2,065	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$206,034	$53,937	$34,144	$11,421	$0	$128,687	$34,144	$7,389	$0	$0	$34,144	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$3,271,528	$454,143	$257,196	$133,592	$10,378	$2,012,887	$265,159	$133,592	$25,508	$0	$247,694	$27,809	$0	$0	$0	$212,762	$0	$0	$0	$0
9	$494,609	$214,678	$118,500	$61,409	$16,835	$401,579	$118,500	$33,670	$16,835	$0	$147,357	$16,835	$0	$0	$0	$101,664	$0	$0	$0	$0
10	$2,808	$1,404	$702	$702	$0	$2,106	$702	$0	$0	$0	$702	$0	$0	$0	$0	$702	$0	$0	$0	$0
11	$288,808	$131,187	$81,470	$32,805	$2,578	$216,196	$81,470	$32,805	$2,578	$371	$64,970	$2,647	$2,277	$371	$69	$48,810	$2,578	$371	$69	$69
12	$326,689	$90,637	$59,426	$34,021	$3,059	$221,487	$61,175	$34,021	$5,994	$145	$57,362	$6,139	$290	$290	$145	$48,823	$1,718	$290	$145	$145
13	$45,553	$23,699	$6,349	$4,149	$1,100	$36,649	$7,196	$4,149	$1,100	$0	$6,349	$1,100	$0	$0	$0	$5,249	$1,100	$0	$0	$0
14	$305,338	$84,489	$35,530	$11,966	$1,957	$240,457	$35,530	$9,766	$1,957	$0	$38,910	$3,913	$1,957	$0	$0	$26,940	$1,957	$0	$0	$0
15	$516,231	$53,207	$21,042	$5,854	$0	$231,889	$21,042	$5,854	$1,512	$0	$19,034	$2,615	$0	$0	$0	$17,126	$0	$0	$0	$0
16	$1,158,988	$185,483	$97,513	$32,023	$3,098	$619,750	$101,514	$32,023	$3,970	$0	$85,597	$3,970	$0	$0	$0	$60,124	$0	$0	$0	$0
17	$57,555	$11,101	$0	$0	$0	$39,571	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$26,677	$4,959	$0	$0	$0	$9,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$768,535	$109,777	$60,884	$16,570	$0	$404,346	$60,884	$16,570	$0	$0	$58,343	$0	$0	$0	$0	$34,135	$0	$0	$0	$0
21	$542,250	$159,899	$111,554	$44,597	$4,460	$346,768	$112,794	$44,597	$6,690	$2,230	$83,896	$4,460	$2,230	$2,230	$2,230	$44,597	$4,460	$2,230	$2,230	$2,230
22	$1,265,540	$406,292	$185,212	$0	$0	$933,712	$185,212	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$45,710	$11,167	$0	$0	$0	$37,889	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$17,277	$7,463	$0	$0	$0	$17,277	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$47,150	$14,242	$11,967	$5,446	$434	$32,332	$11,967	$5,446	$434	$145	$7,037	$434	$289	$145	$145	$7,037	$289	$145	$145	$145
26	$259,733	$60,591	$37,844	$17,477	$0	$141,757	$37,844	$13,097	$0	$0	$43,087	$4,102	$0	$0	$0	$33,007	$0	$0	$0	$0
27	$8,095	$3,238	$1,619	$0	$0	$6,476	$1,619	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$5,450	$0	$0	$0	$0	$3,401	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$9,677,012**	**$2,087,000**	**$1,123,535**	**$412,032**	**$43,899**	**$6,097,217**	**$1,139,335**	**$372,979**	**$66,578**	**$2,891**	**$897,065**	**$74,024**	**$7,043**	**$3,036**	**$2,589**	**$658,720**	**$12,102**	**$3,036**	**$2,589**	**$2,589**

NO CRP

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$16,454	$5,407	$2,583	$0	$0	$12,083	$2,583	$0	$0	$0	$2,583	$0	$0	$0	$0	$2,065	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$218,129	$53,937	$34,144	$11,421	$0	$146,832	$34,144	$11,421	$0	$0	$38,175	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$3,339,379	$502,411	$268,111	$143,754	$10,378	$2,174,452	$281,921	$143,754	$33,093	$0	$258,464	$33,093	$0	$0	$0	$213,670	$0	$0	$0	$0
9	$696,631	$234,417	$136,127	$61,409	$16,835	$401,579	$147,357	$44,198	$16,835	$0	$147,357	$16,835	$0	$0	$0	$101,664	$0	$0	$0	$0
10	$2,808	$1,404	$702	$702	$0	$2,106	$702	$702	$0	$0	$702	$0	$0	$0	$0	$702	$0	$0	$0	$0
11	$300,981	$131,187	$81,470	$36,657	$2,578	$216,196	$81,470	$32,805	$2,647	$371	$64,970	$2,647	$2,277	$371	$69	$50,115	$2,510	$371	$69	$69
12	$326,689	$90,637	$59,426	$35,083	$3,059	$221,487	$62,754	$35,083	$5,994	$145	$58,232	$6,139	$290	$290	$145	$48,823	$1,718	$290	$145	$145
13	$45,553	$23,699	$7,196	$5,249	$1,100	$36,649	$7,196	$4,149	$1,100	$0	$6,349	$1,100	$0	$0	$0	$5,249	$1,100	$0	$0	$0
14	$317,744	$92,117	$35,530	$11,966	$1,957	$249,238	$40,342	$9,766	$1,957	$0	$41,680	$3,913	$1,957	$0	$0	$28,347	$1,957	$0	$0	$0
15	$530,092	$57,370	$21,042	$5,854	$0	$241,548	$22,554	$5,854	$1,512	$0	$19,034	$2,615	$0	$0	$0	$18,638	$0	$0	$0	$0
16	$1,368,760	$200,584	$102,347	$34,520	$3,098	$687,491	$107,047	$34,520	$4,910	$0	$93,511	$4,910	$0	$0	$0	$68,601	$0	$0	$0	$0
17	$74,001	$11,101	$0	$0	$0	$43,116	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$30,997	$4,959	$0	$0	$0	$16,759	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$874,680	$123,834	$60,884	$18,197	$0	$424,878	$60,884	$18,197	$0	$0	$58,343	$0	$0	$0	$0	$40,232	$0	$0	$0	$0
21	$629,865	$167,614	$113,949	$70,517	$4,460	$383,461	$119,491	$70,517	$6,690	$2,230	$85,306	$4,460	$2,230	$2,230	$2,230	$44,597	$4,460	$2,230	$2,230	$2,230
22	$1,292,353	$422,695	$185,212	$0	$0	$948,186	$188,724	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$49,670	$11,167	$0	$0	$0	$37,889	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$19,628	$7,463	$0	$0	$0	$17,277	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$47,150	$14,242	$11,967	$5,446	$434	$32,332	$11,967	$5,446	$434	$145	$7,037	$434	$289	$145	$145	$7,037	$289	$145	$145	$145
26	$267,262	$67,616	$40,578	$17,477	$0	$145,929	$43,087	$15,606	$0	$0	$44,959	$4,102	$0	$0	$0	$35,809	$0	$0	$0	$0
27	$8,095	$3,238	$1,619	$0	$0	$6,476	$1,619	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$5,450	$0	$0	$0	$0	$3,401	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$10,462,371**	**$2,227,099**	**$1,162,887**	**$458,252**	**$43,899**	**$6,449,365**	**$1,213,842**	**$432,018**	**$75,172**	**$2,891**	**$926,702**	**$80,248**	**$7,043**	**$3,036**	**$2,589**	**$681,228**	**$12,034**	**$3,036**	**$2,589**	**$2,589**

Partial CRP

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$16,454	$5,407	$2,583	$0	$0	$12,083	$2,583	$0	$0	$0	$2,583	$0	$0	$0	$0	$2,065	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$218,129	$53,937	$34,144	$11,421	$0	$136,028	$34,144	$7,389	$0	$0	$38,175	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$3,337,866	$468,853	$268,111	$143,754	$10,378	$2,161,791	$278,576	$141,249	$27,809	$0	$252,904	$30,804	$0	$0	$0	$213,670	$0	$0	$0	$0
9	$696,631	$234,417	$118,500	$61,409	$0	$401,579	$118,500	$44,198	$16,835	$0	$147,357	$16,835	$0	$0	$0	$101,664	$0	$0	$0	$0
10	$2,808	$1,404	$702	$702	$0	$2,106	$702	$702	$0	$0	$702	$0	$0	$0	$0	$702	$0	$0	$0	$0
11	$297,717	$131,187	$81,470	$32,805	$2,578	$216,196	$81,470	$32,805	$2,578	$371	$64,970	$2,647	$2,277	$371	$69	$50,115	$2,510	$371	$69	$69
12	$326,689	$90,637	$59,426	$35,083	$3,059	$221,487	$61,175	$32,442	$5,994	$145	$57,362	$6,139	$290	$290	$145	$48,823	$1,718	$290	$145	$145
13	$45,553	$23,699	$6,349	$4,149	$1,100	$36,649	$7,196	$4,149	$1,100	$0	$6,349	$1,100	$0	$0	$0	$5,249	$1,100	$0	$0	$0
14	$309,058	$92,117	$35,530	$11,966	$1,957	$246,198	$35,530	$9,766	$1,957	$0	$41,680	$3,913	$1,957	$0	$0	$28,347	$1,957	$0	$0	$0
15	$530,092	$57,370	$21,042	$5,854	$0	$241,548	$21,042	$5,854	$1,512	$0	$19,034	$2,615	$0	$0	$0	$17,126	$0	$0	$0	$0
16	$1,364,169	$200,584	$102,347	$34,520	$3,098	$678,380	$106,218	$34,520	$4,910	$0	$87,209	$3,970	$0	$0	$0	$67,406	$0	$0	$0	$0
17	$74,001	$11,101	$0	$0	$0	$43,116	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$30,997	$4,959	$0	$0	$0	$9,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$874,680	$123,834	$60,884	$18,197	$0	$424,878	$60,884	$18,197	$0	$0	$58,343	$0	$0	$0	$0	$34,135	$0	$0	$0	$0
21	$626,371	$165,384	$112,794	$70,517	$4,460	$383,461	$119,491	$70,517	$6,690	$2,230	$83,896	$4,460	$2,230	$2,230	$2,230	$44,597	$4,460	$2,230	$2,230	$2,230
22	$1,292,353	$422,695	$185,212	$0	$0	$948,186	$188,724	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$45,710	$11,167	$0	$0	$0	$37,889	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$19,628	$7,463	$0	$0	$0	$17,277	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$47,150	$14,242	$11,967	$5,446	$434	$32,332	$11,967	$5,446	$434	$145	$7,037	$434	$289	$145	$145	$7,037	$289	$145	$145	$145
26	$265,347	$63,393	$37,844	$17,477	$0	$145,929	$37,844	$15,606	$0	$0	$43,087	$4,102	$0	$0	$0	$33,007	$0	$0	$0	$0
27	$8,095	$3,238	$1,619	$0	$0	$6,476	$1,619	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$5,450	$0	$0	$0	$0	$3,401	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$10,434,948**	**$2,187,088**	**$1,140,524**	**$453,300**	**$27,064**	**$6,406,908**	**$1,167,665**	**$422,840**	**$69,819**	**$2,891**	**$910,688**	**$77,019**	**$7,043**	**$3,036**	**$2,589**	**$669,622**	**$12,034**	**$3,036**	**$2,589**	**$2,589**

RIPARIAN

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$14,389	$5,407	$2,583	$0	$0	$9,777	$2,583	$0	$0	$0	$2,065	$0	$0	$0	$0	$0	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$169,795	$50,363	$19,795	$7,389	$0	$116,924	$19,795	$7,389	$0	$0	$34,144	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$2,880,355	$414,192	$240,373	$110,321	$10,378	$1,776,447	$242,251	$119,872	$27,809	$0	$232,211	$25,508	$0	$0	$0	$191,867	$0	$0	$0	$0
9	$484,529	$212,103	$101,664	$44,198	$0	$351,073	$101,664	$33,670	$16,835	$0	$136,127	$16,835	$0	$0	$0	$101,664	$0	$0	$0	$0
10	$2,808	$1,404	$702	$702	$0	$2,106	$702	$0	$0	$0	$702	$0	$0	$0	$0	$702	$0	$0	$0	$0
11	$252,750	$105,150	$69,228	$23,458	$2,578	$193,179	$76,143	$23,458	$2,578	$302	$60,071	$2,578	$371	$371	$69	$41,064	$2,277	$371	$69	$69
12	$298,759	$83,630	$58,232	$26,617	$2,914	$213,321	$59,426	$24,554	$3,059	$145	$51,608	$4,638	$290	$290	$145	$40,656	$290	$290	$145	$145
13	$45,553	$10,497	$6,349	$3,301	$1,100	$36,649	$6,349	$3,301	$1,100	$0	$6,349	$1,100	$0	$0	$0	$5,249	$0	$0	$0	$0
14	$288,158	$78,800	$32,294	$7,011	$1,957	$206,420	$32,294	$7,011	$1,957	$0	$32,775	$3,913	$1,957	$0	$0	$23,076	$1,957	$0	$0	$0
15	$386,758	$49,039	$19,034	$5,854	$0	$181,093	$19,034	$5,854	$1,512	$0	$19,034	$1,103	$0	$0	$0	$8,468	$0	$0	$0	$0
16	$971,783	$169,570	$82,945	$22,285	$3,098	$513,371	$84,842	$22,285	$4,910	$0	$80,432	$3,098	$0	$0	$0	$47,922	$0	$0	$0	$0
17	$54,216	$0	$0	$0	$0	$34,225	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$21,718	$4,959	$0	$0	$0	$9,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$614,467	$91,139	$57,421	$16,570	$0	$282,909	$60,884	$16,570	$0	$0	$58,343	$0	$0	$0	$0	$30,699	$0	$0	$0	$0
21	$441,513	$149,096	$108,996	$17,839	$4,460	$307,748	$108,996	$17,839	$4,460	$2,230	$44,597	$4,460	$2,230	$2,230	$2,230	$17,839	$4,460	$2,230	$2,230	$2,230
22	$1,003,082	$215,511	$178,940	$0	$0	$736,239	$178,940	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$37,889	$3,726	$0	$0	$0	$26,672	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$17,277	$0	$0	$0	$0	$9,815	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$37,207	$14,242	$11,099	$1,157	$289	$32,043	$11,099	$1,157	$289	$145	$7,037	$434	$289	$145	$145	$5,446	$289	$145	$145	$145
26	$230,250	$58,676	$35,809	$15,606	$0	$119,369	$35,809	$10,362	$0	$0	$40,578	$4,102	$0	$0	$0	$28,782	$0	$0	$0	$0
27	$6,476	$1,619	$1,619	$0	$0	$4,857	$1,619	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$3,401	$0	$0	$0	$0	$1,700	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$8,263,133**	**$1,719,123**	**$1,027,083**	**$302,308**	**$26,774**	**$5,165,855**	**$1,042,430**	**$293,322**	**$64,509**	**$2,822**	**$806,073**	**$67,769**	**$5,137**	**$3,036**	**$2,589**	**$559,113**	**$9,273**	**$3,036**	**$2,589**	**$2,589**

WETLAND

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$16,454	$5,407	$2,583	$0	$0	$9,777	$2,583	$0	$0	$0	$2,583	$0	$0	$0	$0	$0	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$218,129	$50,363	$30,372	$11,421	$0	$125,298	$30,372	$7,389	$0	$0	$34,144	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$3,296,266	$452,265	$252,102	$122,678	$10,378	$2,012,887	$259,599	$125,080	$25,508	$0	$234,797	$25,508	$0	$0	$0	$201,655	$0	$0	$0	$0
9	$494,609	$214,678	$101,664	$44,198	$0	$351,073	$101,664	$33,670	$16,835	$0	$118,500	$16,835	$0	$0	$0	$101,664	$0	$0	$0	$0
10	$2,808	$1,404	$702	$702	$0	$2,106	$702	$0	$0	$0	$702	$0	$0	$0	$0	$702	$0	$0	$0	$0
11	$260,372	$108,319	$76,143	$29,660	$2,578	$210,056	$76,981	$28,463	$2,578	$302	$63,148	$2,578	$371	$371	$69	$41,481	$2,510	$371	$69	$69
12	$324,187	$88,368	$59,426	$30,692	$3,059	$221,487	$59,426	$30,692	$4,638	$145	$51,608	$4,638	$290	$290	$145	$37,867	$290	$290	$145	$145
13	$45,553	$10,497	$6,349	$3,301	$1,100	$36,649	$6,349	$3,301	$1,100	$0	$6,349	$1,100	$0	$0	$0	$5,249	$0	$0	$0	$0
14	$309,058	$82,545	$34,098	$8,334	$1,957	$236,289	$35,530	$8,334	$1,957	$0	$32,775	$3,913	$1,957	$0	$0	$21,333	$1,957	$0	$0	$0
15	$515,170	$53,207	$19,034	$5,854	$0	$231,889	$21,042	$5,854	$1,512	$0	$19,034	$1,103	$0	$0	$0	$7,366	$0	$0	$0	$0
16	$1,182,165	$181,668	$93,511	$29,510	$3,098	$623,335	$97,513	$29,510	$4,910	$0	$84,842	$3,098	$0	$0	$0	$52,760	$0	$0	$0	$0
17	$66,280	$10,000	$0	$0	$0	$39,571	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$26,677	$4,959	$0	$0	$0	$9,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$780,256	$107,605	$60,884	$16,570	$0	$404,346	$60,884	$16,570	$0	$0	$58,343	$0	$0	$0	$0	$30,699	$0	$0	$0	$0
21	$544,395	$157,883	$110,143	$44,597	$4,460	$362,082	$112,794	$44,597	$6,690	$2,230	$70,517	$4,460	$2,230	$2,230	$2,230	$17,839	$4,460	$2,230	$2,230	$2,230
22	$1,267,265	$406,292	$185,212	$0	$0	$938,024	$185,212	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$45,710	$11,167	$0	$0	$0	$37,889	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$17,277	$7,463	$0	$0	$0	$17,277	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$47,150	$14,242	$11,099	$3,709	$289	$32,043	$11,967	$3,709	$434	$145	$7,037	$434	$289	$145	$145	$5,446	$289	$145	$145	$145
26	$265,347	$58,676	$37,844	$17,477	$0	$141,757	$37,844	$10,362	$0	$0	$37,844	$4,102	$0	$0	$0	$28,782	$0	$0	$0	$0
27	$8,095	$3,238	$1,619	$0	$0	$6,476	$1,619	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$5,450	$0	$0	$0	$0	$3,401	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$9,738,673**	**$2,030,246**	**$1,082,785**	**$368,703**	**$26,919**	**$6,053,630**	**$1,102,081**	**$347,531**	**$66,162**	**$2,822**	**$822,223**	**$67,769**	**$5,137**	**$3,036**	**$2,589**	**$568,522**	**$9,506**	**$3,036**	**$2,589**	**$2,589**

WETLAND AND RIPARIAN

Index Point	wet6_500	wet6_100	wet6_50	wet6_25	wet6_10	avg6_500	avg6_100	avg6_50	avg6_25	avg6_10	wet24_500	wet24_100	wet24_50	wet24_25	wet24_10	avg24_500	avg24_100	avg24_50	avg24_25	avg24_10
1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
2	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
3	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
4	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
5	$14,389	$5,407	$2,583	$0	$0	$9,777	$2,583	$0	$0	$0	$2,065	$0	$0	$0	$0	$0	$0	$0	$0	$0
6	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
7	$173,510	$50,363	$19,795	$7,389	$0	$118,782	$19,795	$7,389	$0	$0	$30,372	$0	$0	$0	$0	$15,679	$0	$0	$0	$0
8	$2,889,942	$408,769	$240,373	$110,321	$10,378	$1,777,131	$240,373	$122,678	$27,809	$0	$230,333	$21,280	$0	$0	$0	$178,445	$0	$0	$0	$0
9	$482,252	$210,965	$102,366	$44,900	$16,835	$350,637	$102,366	$33,670	$16,835	$0	$102,366	$16,835	$0	$0	$0	$90,552	$0	$0	$0	$0
10	$9,233	$6,155	$6,155	$3,078	$0	$9,233	$6,155	$3,078	$0	$0	$3,078	$0	$0	$0	$0	$0	$0	$0	$0	$0
11	$256,218	$99,967	$62,705	$21,015	$2,510	$189,026	$68,710	$21,015	$2,578	$302	$55,770	$2,578	$371	$371	$69	$30,997	$2,277	$371	$69	$69
12	$287,513	$81,090	$56,327	$23,919	$1,718	$216,407	$57,521	$22,713	$3,059	$145	$50,338	$3,059	$290	$290	$145	$32,751	$290	$290	$145	$145
13	$50,714	$13,143	$8,995	$3,301	$1,100	$41,942	$8,995	$2,200	$1,100	$0	$6,572	$1,100	$0	$0	$0	$5,472	$0	$0	$0	$0
14	$283,347	$76,154	$29,648	$7,011	$1,957	$201,127	$29,648	$7,011	$1,957	$0	$31,452	$3,913	$0	$0	$0	$18,819	$1,957	$0	$0	$0
15	$389,143	$47,256	$19,034	$5,854	$0	$181,093	$19,034	$5,854	$1,512	$0	$19,034	$0	$0	$0	$0	$7,366	$0	$0	$0	$0
16	$961,451	$168,630	$82,945	$22,285	$3,098	$513,371	$84,842	$23,044	$4,910	$0	$75,824	$3,098	$0	$0	$0	$44,758	$0	$0	$0	$0
17	$54,216	$0	$0	$0	$0	$34,225	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
18	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
19	$21,718	$4,959	$0	$0	$0	$9,918	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
20	$689,981	$87,703	$44,133	$16,570	$0	$285,262	$58,712	$16,570	$0	$0	$56,171	$0	$0	$0	$0	$28,814	$0	$0	$0	$0
21	$440,118	$149,096	$108,996	$17,839	$4,460	$305,395	$108,996	$17,839	$4,460	$2,230	$44,597	$4,460	$2,230	$2,230	$2,230	$11,149	$4,460	$2,230	$2,230	$2,230
22	$1,006,908	$215,511	$178,940	$0	$0	$737,217	$178,940	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
23	$37,810	$3,726	$0	$0	$0	$26,633	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
24	$15,885	$0	$0	$0	$0	$9,119	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
25	$35,483	$16,312	$11,099	$1,157	$289	$33,250	$11,099	$1,157	$289	$145	$7,037	$434	$289	$145	$145	$5,446	$289	$145	$145	$145
26	$241,496	$58,225	$37,428	$15,606	$0	$122,245	$37,428	$10,362	$0	$0	$37,844	$0	$0	$0	$0	$26,867	$0	$0	$0	$0
27	$3,401	$0	$0	$0	$0	$1,700	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
28	$3,916	$1,958	$1,958	$0	$0	$3,916	$1,958	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Total	**$8,348,644**	**$1,705,389**	**$1,013,480**	**$300,245**	**$42,345**	**$5,177,406**	**$1,037,155**	**$294,580**	**$64,509**	**$2,822**	**$752,853**	**$56,757**	**$3,180**	**$3,036**	**$2,589**	**$497,115**	**$9,273**	**$3,036**	**$2,589**	**$2,589**

CONSERVATION RESERVE PROGRAM FLOOD DAMAGE REDUCTION BENEFITS TO DOWNSTREAM URBAN AREAS

A US Army Corps of Engineers, Mississippi Valley Division Initiative
Rock Island District Pilot Project Report

APPENDIX D

ALTERNATIVE LANDSCAPE SCENARIOS

Appendix D
Alternative Landscape Scenarios

I. PURPOSE

The purpose of this study was to translate the concepts in the Nassauer et al. (2007) study into an automated GIS scripting methodology that will specifically reproduce the three alternative landscape scenarios for the Iowa-Cedar watershed (figure D-1) and more generally to develop a framework for designing alternative landscapes over large earth areas.

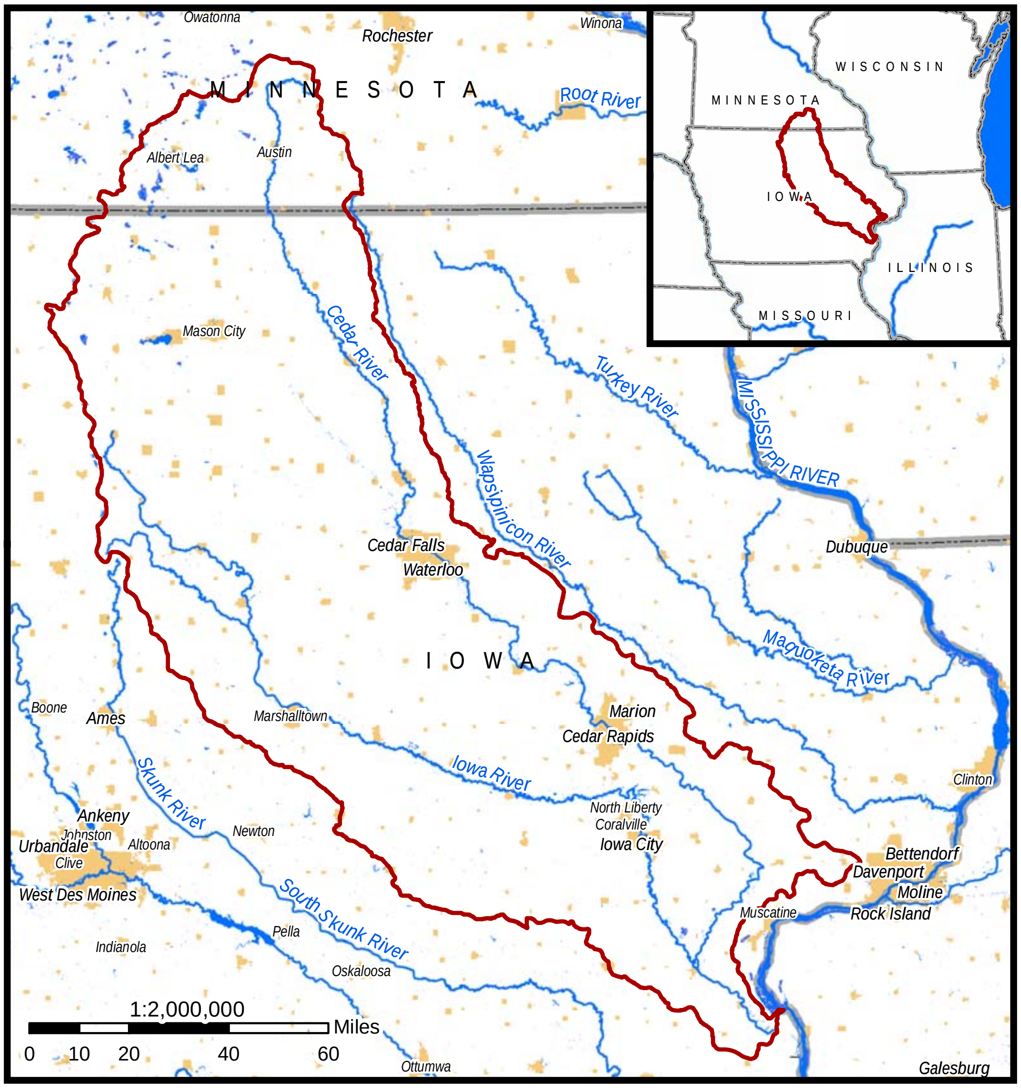

Figure D-1. The Iowa-Cedar Watershed

II. PROBLEM

Many of the water resource issues affecting our society (flood risk management, water quality and quantity, etc.) will require an increasing degree of ecoregional planning to resolve. However, methodologies to help describe possible alternative landscapes are not widely understood or applied.

The alternative landscape development methodology used by Nassauer et al. (2007) required experts with local knowledge to manually draw conservation features on a map. Although useful at the case study level, this manual technique cannot be scaled to large watersheds such as the Iowa-Cedar. Local experts may be able to draw conservation features with great detail, informed by rich local knowledge, but these idiosyncrasies make the resulting maps difficult to reproduce.

III. OBJECTIVE

Develop a methodology to create alternative landscape scenarios (following the spirit of the Nassauer et al. Study), but using automated GIS rules and widely available spatial datasets. This methodology will allow the application of the approach to other regions and larger areas.

IV. DESIGN PRINCIPLES

To achieve this objective, the strategy used in this study was to develop layers modularly to build-up scenarios. These complex scenarios cannot be built from a single query of existing data (e.g., NLCD, SSURGO, NWI, NHD), but require complex data manipulation steps to derive the needed factors to construct a scenario. Each scenario is based on a specific set of assumptions about how land will be used. Once these assumptions are established, spatial datasets must be found (or created) to operationalize each assumption. Often suitable datasets do not exist to represent certain scenario assumptions and the assumption must be dropped. National datasets cannot simply be taken off the shelf as-is, but must usually be manipulated or combined with other datasets to represent each assumption. This operationalization process requires refining and converting each assumption, usually in narrative form, into a specific set of practical GIS rules.

The task of creating scenarios becomes tractable only if each scenario is decomposed into a series of components to represent each assumption (e.g., agriculture, riparia, wetlands, urban, water). Specific GIS rules can then be developed to construct each component. This decomposition into component parts is not only necessary on a practical level for the GIS analyst, but also aids in eliciting input and feedback from subject matter experts (SMEs). Breaking each scenario into a series of assumptions, and then breaking each assumption into a series of GIS rules, allows SMEs the ability to visually review the effects of each rule. With this granular level of understanding of the GIS rules, SMEs are able to provide substantive input based on field knowledge and expertise into how the GIS rules should be altered to more accurately represent the assumptions being modeled.

Once the component parts for each scenario have been built, these components can be combined to create scenarios. The combination is primarily a layering exercise, but it can also include more complex conditional rules. The component architecture of the scenarios again becomes useful for easily eliciting SME input. As SMEs review each scenario, they are easily able to recommend adding or deleting layers or reordering layers to better represent the assumptions of each scenario. Once the components are built, the à la carte structure of the component layers allows rapid prototyping and tweaking of new or existing scenarios.

V. DESIGN PRINCIPLES SUMMARY

- Develop a set of reusable component base layers that can be used in an à la carte fashion to build-up scenarios piecewise.
- Develop automated GIS scripting rules to construct component base layers. This approach makes the method reproducible, supporting application to new areas.
- Use widely available, regional GIS datasets (e.g., NLCD, SSURGO, NWI, NHD, NED) to support application to large areas.
- Demonstrate a GIS methodology for defining landscapes constructed from specific policy alternatives.

VI. SCENARIO GOALS

The first step was to determine the goal of each scenario. This study used the scenarios (without modification) that were developed through the rigorous process described in the Nassauer et al. 2007 study. The goals for each of the three alternative landscape scenarios are.

1. **Increasing Agricultural Commodity Production**. The main goal of this scenario is to increase commodity production over the short term (Nassauer et al. 2007, p. 49).
2. **Improving Water Quality and Reducing Downstream Flooding.** This scenario has related goals of improving water quality and reducing downstream flooding (Nassauer et al. 2007, p. 51).
3. **Enhancing Biodiversity.** The goal of this scenario is to enhance biodiversity in the context of agricultural production (Nassauer et al. 2007, p. 52).

VII. SCENARIO ASSUMPTIONS

The next step was to develop a set of concise assumptions that characterize each scenario. Since each scenario was explicitly described in Nassauer et al. 2007, the task was to convert the narrative description of each scenario into a set of assumptions. The assumptions below were summarized from their narrative and reorganized for conciseness.

A.. Increasing Agricultural Commodity Production Assumptions (Nassauer et al. 2007, p. 49-50)

1. The primary crops are assumed to be corn and soybeans in a continuous rotation managed with precision agriculture.
2. All highly productive land is cultivated in row crops using conventional technologies, including land that was wooded or CRP. Any area of at least 3 acres of highly productive land accessible by combine is cultivated.
3. Field size is limited only by steep slopes, public roads, and maximum combine loads.

4. Only fields larger than 30 acres with low soil productivity are planted in perennial crops.
5. Fossil fuel is affordable or alternative fuels become more widely available (i.e., corn-based ethanol).
6. Farms continue to increase in size, resulting in fewer larger farms and rural depopulation.
7. Few grazing livestock enterprises are present (except confined animal feeding operations (CAFOs)), therefore no hedgerows or fencerows exist to buffer the stream network.
8. Since all productive land is in production, biodiversity is greatly reduced.
9. Federal programs subsidize and encourage large-scale industrialized agriculture.
10. No-till and precision agriculture are widely adopted.
11. Conventional Business Management Practices (BMPs) are extended to newly cultivated land (e.g., EQUIP), but no reserve land program (e.g., CRP) exists.
12. Extensive tile drainage is used to bring new land into cultivation.
13. Patches of non-crop cover occur where precision agriculture identifies less productive land (as small as one combine header width) or as large as 30 acres. These patches are mowed annually and sprayed with herbicide for weeds.
14. Perennial herbaceous buffer strips (20ft) are required on streams.
15. Stream buffers and dramatically diminished woodlands are the only perennial cover remaining.
16. Native species biodiversity is limited to woodland left on the least productive soils in isolated patches.

B. Improving Water Quality and Reducing Downstream Flooding Assumptions (Nassauer et al. 2007, p. 51-52).

1. Widespread adoption of innovative practices to improve water quality and hydrologic regimes are encouraged through comprehensive, long-term cost-share programs and performance monitoring.
2. Farm-scale water quality outcomes are achieved by adopting integrated livestock and grain enterprises employing perennial cover for rotational grazing.
3. Livestock production with perennial cover for rotational grazing predominates on rolling land vulnerable to erosion.
4. Rotational grazing occurs on less productive land (LCC 4-8) and perennial forage crops are planted adjacent to all streams.
5. Corn rotations occur on highly productive land (LCC 1-3). Any area of at least 3 acres of highly productive land accessible by combine is cultivated.
6. Any field that has at least 75 percent highly productive cropland (LCC 1-3) is assumed to be cultivated.
7. Woodlands adjacent to pasture are maintained for grazing rather than being converted to cultivation.

8. Erosion is reduced by using conventional BMPs (e.g., no-till, rotations, strip cropping, filter strips).
9. An innovative network of practices is used to detain storm water and sediment.
10. Steep upland slopes in cultivated fields contain a filter strip of native herbaceous cover halfway up the slope. These strips link small detention ponds parallel to the slope.
11. Discharge ponds are used to remove nutrients and sediment from the tile and ditch drainage network.
12. Off-channel nutrient uptake ponds are located every 1.5 miles at county drain line stream outlets.
13. Off-channel nutrient uptake ponds are located at all stream-road crossings.
14. Large off-channel ponds, meanders, oxbows are located in low-gradient stream reaches and planted with native species to provide habitat, infiltration, and storage.
15. Stream buffers of 50-100 feet are intended to substantially improve water quality and reduce flashiness and flooding.
16. No land is removed from production as a conservation area or bioreserve.
17. Mesic woodlands are maintained for grazing.
18. Rural population increases (compared to the other scenarios) since farmers are needed to manage livestock in rotational grazing and the landscape is more appealing to tourists, hunters, telecommuters, retirees, etc, resulting in more vibrant small towns.

C. Enhancing Biodiversity Assumptions (Nassauer et al. 2007, p. 52-54).

1. Perennial grasses are grown for market enterprise.
2. A new reserve program purchases less productive land from willing sellers to create a permanent bioreserve network.
3. On agricultural land, networks of wide stream buffers and biodiversity BMPs connect to the bioreserves.
4. Reserve sites are selected to maximize heterogeneity within a broad ecosystem type, maximize interior conditions (640 acres), and core habitat without homes, roads, or trails.
5. The core reserve is extended wherever adjacent land of at least 40 acres has soils that are relatively unproductive.
6. Small detention ponds filter water before entering reserve boundaries.
7. Woodland reserves are buffered from highways with a herbaceous edge to help drivers see animals to prevent accidents.
8. A stream corridor of continuous perennial vegetation creates a diversity of riparian and aquatic ecosystems. It extends 100 feet from ephemeral streams, 200 feet from perennial streams, and 300 feet from stream with a trail.

9. Cost sharing for innovative, biodiversity BMPs exists in a biodiversity zone (0.25 mile buffer) around reserves and stream corridors. Within this zone perennial strip intercropping, organic crops, and agroforestry are encouraged on appropriate soils.
10. The biodiversity zone is extended outward into any area of 3 acres of productive soils (LCC 1-3) that is accessible by combine.
11. Outside the biodiversity zone, farmers use conventional BMPs, no-till, and precision agriculture for row crops. But small patches of less productive soil or if half of a field does not have highly productive soil, these areas are planted with native perennial cover.
12. Field size is limited only by steep slopes, public roads, and maximum combine loads.
13. Few grazing livestock enterprises are present (except CAFOs), therefore no pasture and little hay are on the land.
14. CAFO waste treatment must meet standards for tertiary municipal waste treatment.
15. Farms continue to increase in size, resulting in fewer larger farms, but depopulation does not occur since the landscape is more appealing to tourists, hunters, telecommuters, retirees, etc, resulting in more vibrant small towns.

VIII. IDENTIFY SUITABLE INPUT DATASETS

The next step was to identify GIS datasets that can be used to operationalize the scenario assumptions. When choosing GIS datasets, here are some factors to consider:

- Does the dataset fully cover my study area?
- Do I have access to the dataset (e.g., permission, affordable)?
- Does the dataset contain the attributes needed?
- Does the dataset cover the required time period?
- Does the dataset have the required spatial or temporal resolution?

A decision was made at the beginning of this project to restrict the study to using a minimal set of national datasets to ensure that the methodology developed here could be easily extended to other locations in the Continental United States. All of the datasets used in this study largely meet the above criteria and any characteristics of these datasets (i.e., spatial/temporal resolution) are accepted as study limitations. Here is a list of the datasets used:

- **NAVTEQ.** NAVTEQ is a company that produces and compiles physical infrastructure data (i.e., roads, public land). This is a proprietary dataset and the 2011 version of the dataset was used for this study. This dataset was not used extensively and could be replaced by public datasets due to excessive cost.

- **NED.** National Elevation Dataset: The US Geologic Survey (USGS) maintains the NED as a repository of elevation data for the nation. The most current version (study initiation 6/2011) of the 10m NED for the study area was used for this project.

- **NHD.** National Hydrography Dataset: The USGS maintains the NHD as a repository of hydrography for the nation. The most current version (study initiation 6/2011) of the 24k NHD was used for this project.

- **NLCD.** National Land Cover Dataset: The Multi-Resolution Land Characteristics Consortium (MRLC) maintains the NLCD as a nationwide land cover dataset. The NLCD 2006 version was used for this study. The NLCD 2006 was used as the baseline for this study since it was the most current comprehensive landcover dataset for the Continental United States at the time of this study.
- **NWI.** National Wetland Inventory: The US Fish and Wildlife Service (USFWS) maintains the NWI as a repository of wetlands data for the nation. The most current version (study initiation 6/2011) was used for this project.
- **PAD-US.** Protected Areas Database of the Unites States: PAD-US is developed by a partnership of public and private agencies whose goal is to systematically inventory protected open space in the US. The PAD-US CBI Version 1.1 was used for this study.
- **SSURGO.** Soil Survey Geographic Database: The USDA Natural Resource Conservation Service (NRCS) maintains the SSURGO as a repository of soils data for the nation. The most current version (study initiation 6/2011) was used for this project.

IX. IDENTIFY REQUIRED LAND COVER CLASSES

The next step was to identify the land cover classes to use in the scenarios. Since the NLCD 2006 was used as the baseline (figure D-2), any land cover classes that will be used in the scenarios should be able to cross-walk to the NLCD 2006 land cover classes.

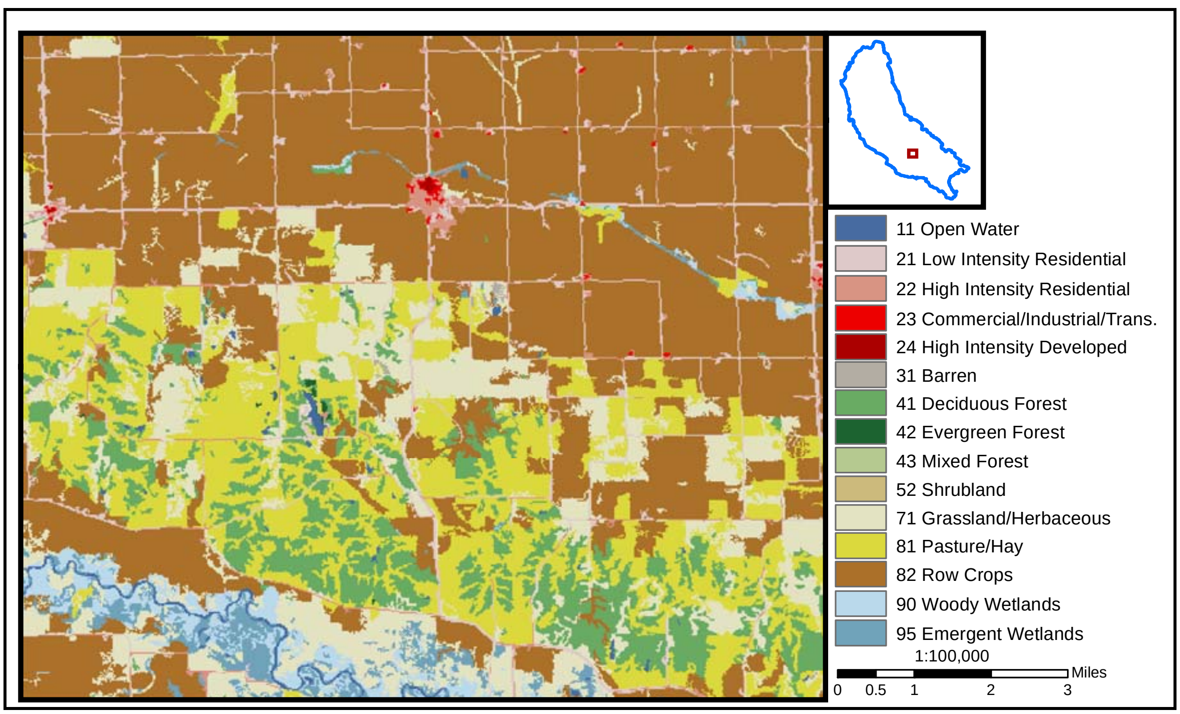

Figure D-2. National Land Cover Dataset (NLCD) 2006. Example near Blairstown, IA

Table D-1 describes the land cover classes chosen for the scenarios and the crosswalk to NLCD 2006. The number of land cover classes for the scenarios was kept small for simplicity and clarity of understanding. As the NLCD is based on Anderson levels (Anderson, et al., 1976), the Developed, Forest, Shrubland, and Wetland classes were collapsed, moving from the Anderson level III in the NLCD to Anderson level II for the scenarios. Since the study area is in the Midwest where the vast majority of the land use is devoted to agriculture, the Anderson level III classes were maintained for the scenarios. The scenarios describe two potential classes that do not neatly fit into the NLCD taxonomy (i.e., Riparia, Bioreserve). Based on the description of the scenarios, these two classes could contain forest or herbaceous cover. Since they are so important to the scenarios and rather than simply shoe-horning them into an existing class, two additional classes were created for them.

Table D-1. NLCD 2006 Land Cover Class to Scenario Crosswalk

NLCD 2006 Code	NLCD 2006 Class Description	Scenario Code	Scenario Class Description
11	Water, Open Water	11	Water
21	Developed, Low Intensity Residential	20	Developed/Barren
22	Developed, High Intensity Residential		
23	Developed, Commercial/Industrial/Transportation		
24	Developed, High Intensity		
31	Barren, Bare Rock/Sand/Clay		
41	Forest, Deciduous Forest	40	Forest/Shrubland
42	Forest, Evergreen Forest		
43	Forest, Mixed Forest		
52	Shrubland, Shrub/Scrub		
71	Herbaceous, Grassland/Herbaceous	71	Grassland/Herbaceous
81	Planted/Cultivated, Pasture/Hay	81	Pasture/Hay
82	Planted/Cultivated, Row Crops	82	Row Crops
90	Wetlands, Woody Wetlands	90	Wetlands
95	Wetlands, Emergent Herbaceous Wetlands		
		100	Riparia
		110	Bioreserve

X. DEVELOP GIS RULES

The next step was to develop a set of GIS rules to operationalize the assumptions of each scenario. The essence of this step is to determine how to use the identified datasets to assign land to the land cover classes above following the assumptions above. This step requires developing an intimate understanding of the input datasets with all of their capabilities and limitations. This detailed understanding is necessary to determine how the input datasets can be queried, combined, or manipulated to operationalize each assumption. This is necessarily an iterative process that requires the input of SMEs relevant to each assumption.

XI. SSURGO NON-IRRIGATED CAPABILITY CLASS

This study relies heavily on the SSURGO Non-Irrigated Capability Class (niccdcd) described in table D-2 for assigning land to land use classes. This SSURGO variable is described in the NRCS National Soil Survey Handbook, Land Capability Classification (LCC, Part 622). Since the Midwest is dominated by farming, beginning the analysis by assigning land use based on agricultural suitability seemed like a practical starting point. See the pseudo-code below for how niccdcd/LCC is used throughout the analysis.

Table D-2. SSURGO Non-Irrigated Capability Class Definitions
(Source: USDA, NRCS National Soil Survey Handbook, Land Capability Classification, 622)

Class	Description
1	Soils have slight limitations that restrict their use.
2	Soils have moderate limitations that reduce the choice of plants or require moderate conservation practices.
3	Soils have severe limitations that reduce the choice of plants or require special conservation practices, or both.
4	Soils have very severe limitations that restrict the choice of plants or require very careful management, or both.
5	Soils have little or no hazard of erosion but have other limitations, impractical to remove, that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
6	Soils have severe limitations that make them generally unsuited to cultivation and that limit their use mainly to pasture, range, forestland, or wildlife food and cover.
7	Soils have very severe limitations that make them unsuited to cultivation and that restrict their use mainly to grazing, forestland, or wildlife.
8	Soils and miscellaneous areas have limitations that preclude their use for commercial plant production and limit their use to recreation, wildlife, or water supply or for esthetic purposes.

XII. BIORESERVE

The Bioreserve selection process required a series of steps to identify potential land cover classes for inclusion in the bioreserve, a fragmentation step, and a series of steps to identify core areas. Several different combinations of layers and steps were tried to arrive at the final bioreserve criteria used in this study. Here are the steps used to create the Bioreserve land cover class for the third scenario:

- Identify: public land, LCC (classes 5-8), riparian areas (streams with a 90m buffer), and existing forest
- Fragment these potential bioreserve areas using roads
- Eliminate edge areas by shrinking the boundary of the fragments by 100m
- Identify core areas greater than 12 acres
- Add the 100m edge back to these selected cores
-

Like the niccdcd/LCC derived layers and Bioreserve layer, other base layers were developed to construct the three scenarios. A detailed description of these techniques is not presented here, but the code used to calculate these layers are listed in Appendix A for those who are interested. Here is the human readable pseudo-code used to develop the GIS code in the next step:

XIII. INCREASING AGRICULTURAL COMMODITY PRODUCTION GIS RULES (figure D-3)

A. Agriculture: SSURGO Non-irrigated capability class (niccdcd) - Classes 1-5 = Row crop, Classes 6-7 = Grassland/Herbaceous, Classes 8 = Forest/Shrubland

B. Steep Slopes: >10% slope (NED 10m, shrink-expand simplified), SSURGO niccdcd used to assign land cover (Classes 1-4 = Pasture/Hay, Classes 5-6 = Grassland/Herbaceous, Classes 7-8 = Forest/Shrubland)

C. Forest: NLCD 2006 Forest classes (41, 42, 43)

D. Riparia: 10 m permanent perennial buffer on Streams/Waterbodies/Wetlands (NHD, NWI), Grassed Waterways (flow accumulation > 6.2 acres)

E. Bioreserve: Existing public land (PAD-US)

F. Developed: NLCD 2006 Developed and Barren classes (21, 22, 23, 24, 31)

G. Wetlands: NWI, NHD, & NLCD wetlands (emergent, forested, shrub)

H. Water: NHD

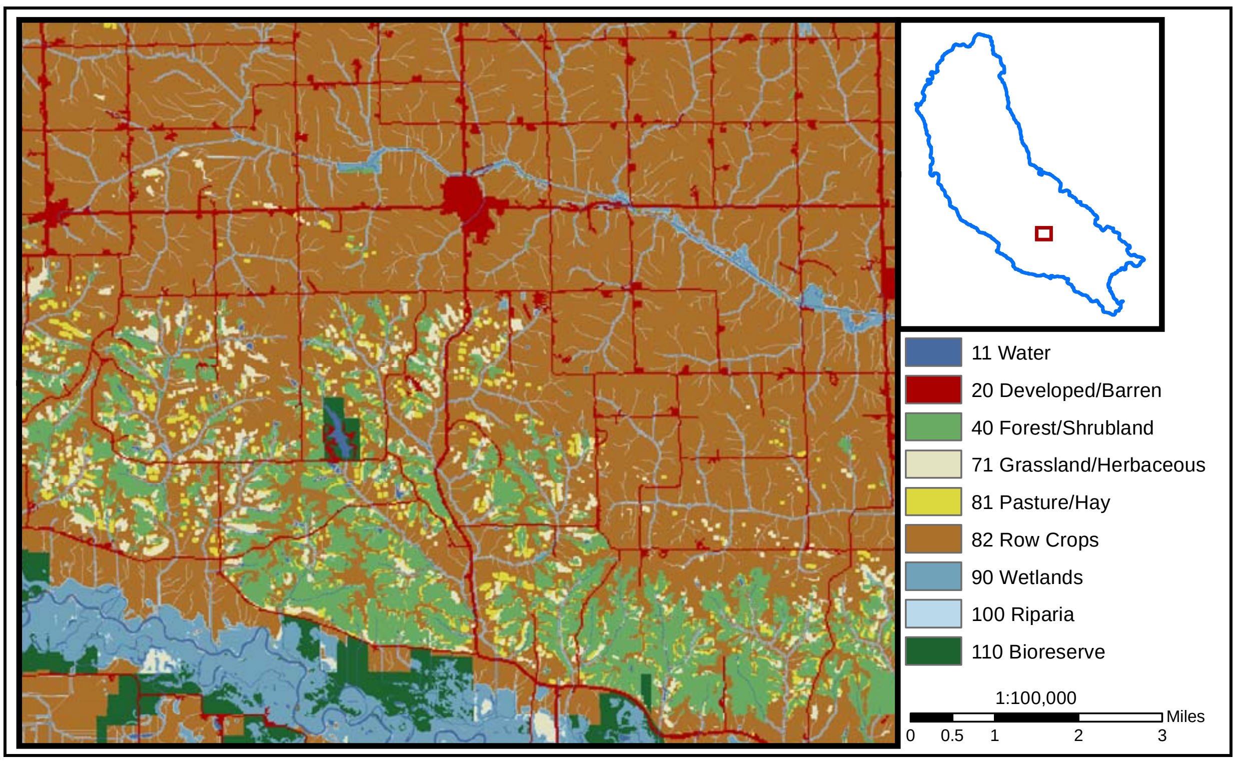

Figure D-3. Increasing Agricultural Commodity Production Scenario. Example near Blairstown, IA

XIV. IMPROVING WATER QUALITY AND REDUCING FLOODING GIS RULES (figure D-4)

A. Agriculture: SSURGO Non-irrigated capability class (niccdcd) - Classes 1-3 = Row crop, Classes 4-5 = Pasture/Hay, Classes 6-7 = Grassland/Herbaceous, Classes 8 = Forest/Shrubland

B. Steep Slopes: >10% slope (NED 10m, expand-shrink simplified), SSURGO niccdcd used to assign land cover (Classes 1-4 = Pasture/Hay, Classes 5-6 = Grassland/Herbaceous, Classes 7-8 = Forest/Shrubland)

C. Forest: NLCD 2006 Forest classes (41, 42, 43)

D. Riparia: 30m permanent perennial buffer on Streams/Waterbodies/Wetlands (NHD, NWI), 200m perennial crop buffer (niccdcd used to assign land cover, Classes 1-4 = Pasture/Hay, Classes 5-6 = Grassland/Herbaceous, Classes 7-8 = Forest/Shrubland), Grassed Waterways (flow accumulation > 6.2 acres)

E. Bioreserve: Existing public land (PAD-US)

F. Developed: NLCD 2006 Developed and Barren classes (21, 22, 23, 24, 31)

G. Wetlands: NWI, NHD, & NLCD wetlands (emergent, forested, shrub)

H. Water: NHD

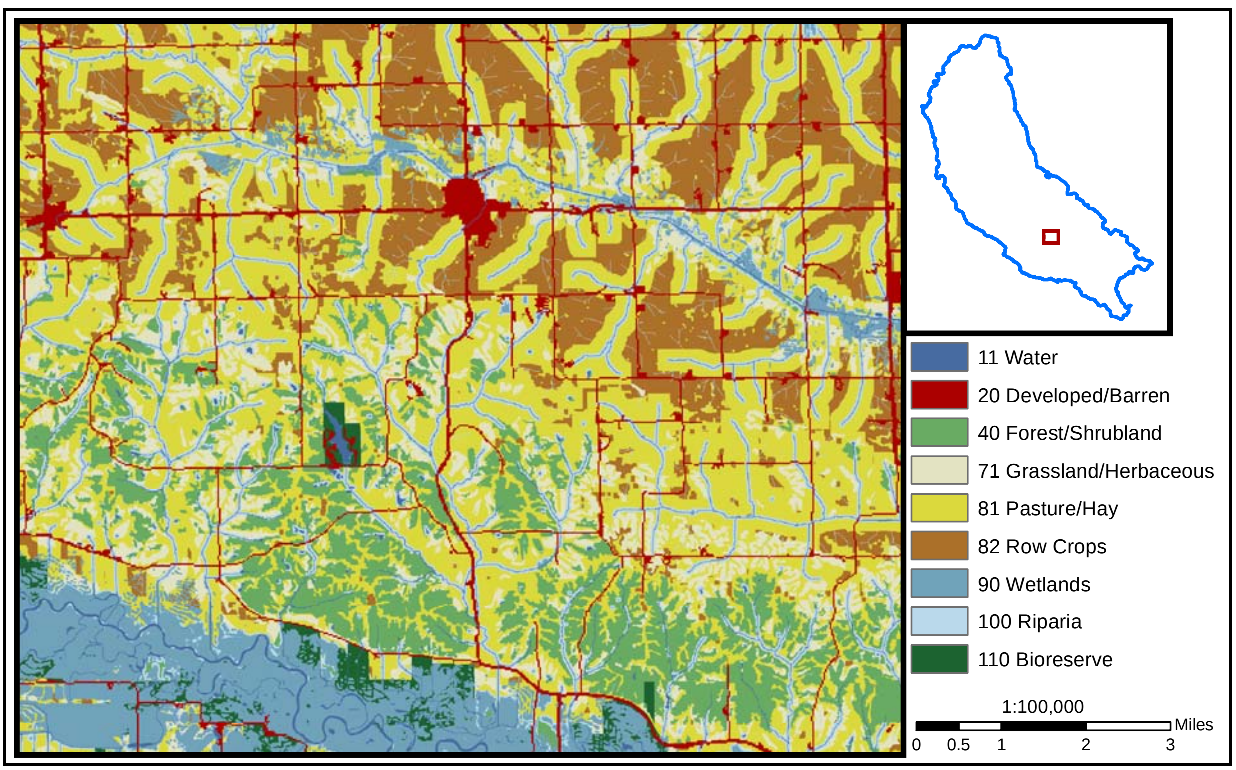

Figure D-4. Improving Water Quality and Reducing Downstream Flooding Scenario. Example nr Blairstown, IA

XV. ENHANCING BIODIVERSITY GIS RULES (figure D-5)

A. Agriculture: SSURGO Non-irrigated capability class (niccdcd) - Classes 1-2 = Row crop, Classes 3-4 = Pasture/Hay, Classes 5-6 = Grassland/Herbaceous, Classes 7-8 = Forest/Shrubland

B. Steep Slopes: >10% slope (NED 10m, expand-shrink simplified), SSURGO niccdcd used to assign land cover (Classes 1-4 = Pasture/Hay, Classes 5-6 = Grassland/Herbaceous, Classes 7-8 = Forest/Shrubland)

C. Forest: NLCD 2006 Forest classes (41, 42, 43)

D. Riparia: 90m permanent perennial buffer on Streams/Waterbodies/Wetlands (NHD, NWI), Grassed Waterways (flow accumulation > 6.2 acres)

E. Bioreserve: Existing public land (PAD-US) + Identified Bioreserve (see description)

F. Developed: NLCD 2006 Developed and Barren classes (21, 22, 23, 24, 31)

G. Wetlands: NWI, NHD, & NLCD wetlands (emergent, forested, shrub), Topographic Wetness Index (TWI) identified wet areas

H. Water: NHD

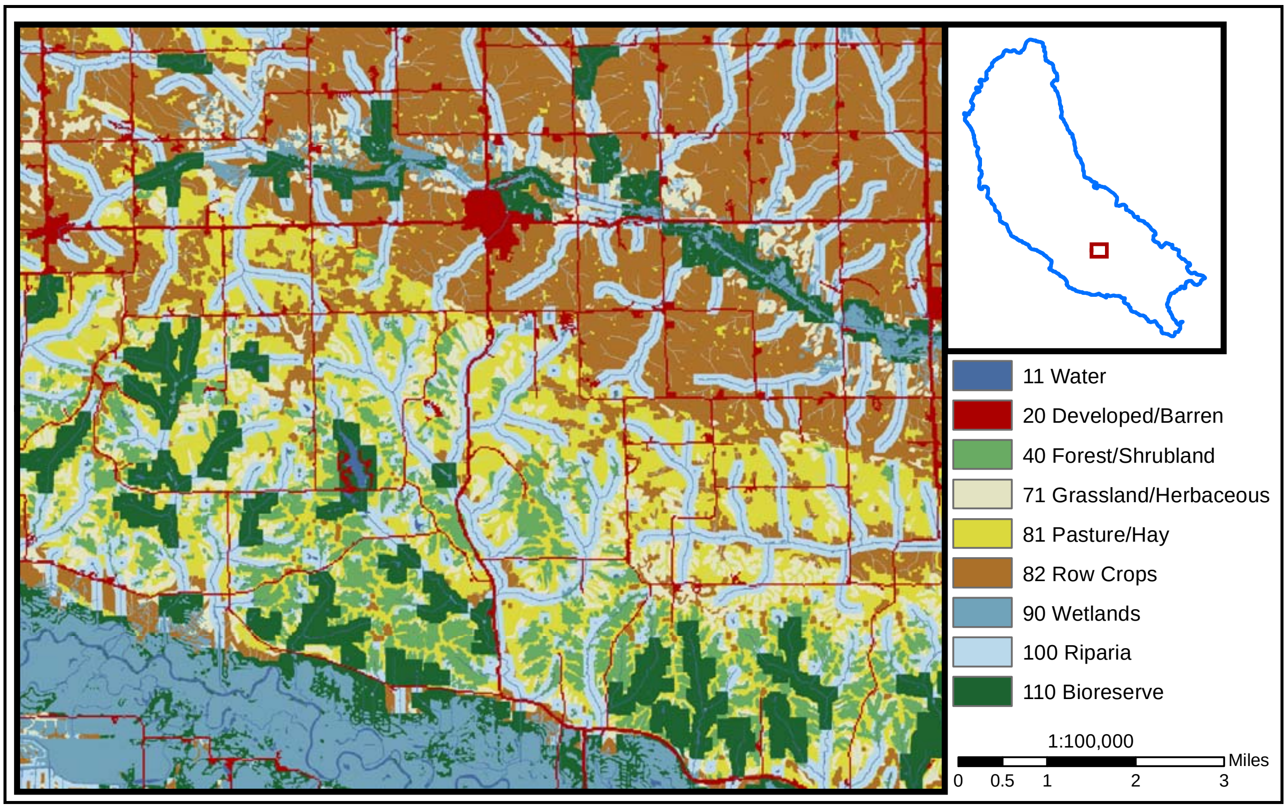

Figure D-5. Enhancing Biodiversity Scenario. Example near Blairstown, IA

XVI. DEVELOP GIS CODE

The next step was to develop the actual GIS code that implements the easily digested, human-readable pseudo-code above. This GIS code is not discussed here, but is supplied for the interested reader in Appendix A.

XVII. ASSUMPTIONS NOT ADDRESSED

Many of the assumptions identified in the Nassauer et al. study were not able to be implemented in this study. Many of these assumptions could not be implemented due a lacked of relevant GIS data, required site-specific knowledge, or were based on complex decision rules not easily automated using existing GIS tools. The specific assumptions not implemented are discussed below for each scenario.

XVIII. AGRICULTURAL COMMODITY PRODUCTION SCENARIO

- *Field size constraints due to ownership and equipment requirements (assumptions b, d, and m)* – These rules deal with practical farm-level decision rules about in-field management and field configuration to account for soil fertility and equipment requirements. Seamless cadastral data is not available for the study area. Even if land ownership data were available, modeling farm-level decisions is a complex process and well beyond the resolution needed to develop alternative regional landscapes.
- *Farmstead placement (assumption e)* – This assumption deals with the locations of farmsteads under a rural depopulation scenario due to larger farm sizes and outmigration. Modeling the spatial placement of specific homesteads is well beyond the resolution needed to develop alternative regional landscapes.

XIX. IMPROVING WATER QUALITY AND REDUCING DOWNSTREAM FLOODING SCENARIO

- *Field size constraints due to ownership and equipment requirements (assumptions e and f)* – These assumptions are not addressed for the reasons described above.
- *Farmstead placement (assumption e)* – This assumption is not addressed for the reasons described above.
- *Orientation of one land use type versus another (assumption g)* – This assumption describes a decision rule that states one land use should occur adjacent to another land use type (i.e., woodlands adjacent to pasture should be maintained for grazing). These types of adjacency rules can be problematic for raster-based analysis unless the rule is modified somewhat (e.g., identify all pasture, region group woodland, identify woodland regions within one pixel of pasture, and maintain those woodland regions...).
- *Off-channel ponds for stormwater/sediment detention and nutrient uptake (assumptions i through n)* – These assumptions describe the placement of stormwater/sediment/nutrient detention ponds. However their description does not provide the complex criteria necessary for the placement of these ponds. A great deal of

research and development would be necessary to design an automated GIS method for the placement of these ponds which was beyond the scope of this study.

XX. ENHANCING BIODIVERSITY SCENARIO

- *Field size constraints due to ownership and equipment requirements (assumptions k and l)* – These assumptions are not addressed for the reasons described above.
- *Farmstead placement (assumption o)* – This assumption is not addressed for the reasons described above.
- *Orientation of one land use type versus another (assumptions e and j)* – These assumptions are not addressed for the reasons described above.
- *Off-channel ponds for stormwater/sediment detention and nutrient uptake (assumption f)* – This assumption is not addressed for the reasons described above.
- *Bioreserve delineation process (assumptions d, e, and g)* – These assumptions describe a complex bioreserve construction process. Only a simplistic bioreserve selection process was implemented based on a basic core size analysis technique. A more robust bioreserve delineation process was beyond the scope of this project.
- *Stream order riparian buffer scheme (assumption h)* – This assumption specified riparian buffers 100 feet ephemeral streams, 200 feet from perennial streams and 300 feet from streams with a trail. Considering the lack of data on trails, stream flow, and the methodological debate surrounding the distinction between ephemeral and perennial streams, a single 300 feet buffer was used.
- *0.25 mile Biodiversity Zone buffer (assumption i)* – This assumption was not implemented as a map layer as it describes the activities that take place (not one of the mappable land use classes) within a 0.25 mile Biodiversity Zone buffer area surrounding the Bioreserve areas.

XX1. LIMITATIONS

These rules were only roughly adapted from the detailed landscape construction rules described in Nassauer et al. (2007). Their incomplete narrative of the detailed manual process used to construct these scenarios therefore required interpretation and inferences to be drawn. They specifically chose manual techniques to achieve a high degree of detail; development of automated GIS rules was not their purpose (personnel communication). They chose the manual techniques to achieve more nuances and ruled-out an automated GIS approach because it could not achieve the detail required. Professional judgment and feedback from colleagues was used to approximate the Nassauer et al. outputs (which are only slightly similar). Therefore, the rules presented here should be evaluated further, adjusted, and adapted to meet the needs of specific projects.

Nassauer et al. describe a great deal of farm-level rules that are very difficult, if not impossible, to automate using GIS. No attempt was made to develop rules for many farm-level phenomena as described above. Therefore, the target scale for this product is not the site level but the meso-scale. This is not to say that GIS techniques could not develop site level datasets. It is simply that the national datasets chosen to achieve regional coverage for this study are meso-scale datasets. These methods could be used with fine resolution data to possibly develop site-specific landscape scenarios. All quantitative analysis is limited by the availability of data of a given quality and geographic extent. More sophisticated or refined rules can be created as better data and tools become available.

Prescriptive (or normative) modeling is almost always subject to criticism. Usually the criticism is due to the misunderstanding of the original purpose of the model. These scenarios should not be used without a clear understanding of the assumptions used to create each element. The purpose of this white paper is to describe each element so that users understand exactly how each scenario was constructed. These three particular scenarios were designed as extreme cases of ideal landscapes designed to meet specific goals. Therefore, these landscapes should not be thought of as realistic depictions of what the landscape will probably look like. Some of the assumptions have the possibility of being adopted and others are extremely unlikely. One unrealistic feature of this approach is that each BMP is applied consistently across the landscape. A more realistic approach would be to model the piecemeal adoption of BMPs, although this is much more difficult.

Because the goals of these three scenarios represent extreme ideal (hypothetical) cases, the results should not be applied to individual sites. The purpose of these scenarios is not to provide a realistic picture of the future, but an examination of what the future might look like under certain alternative assumptions. The opportunity to compare three extremely different outcomes and the policies that gave rise to these scenarios is the purpose on this type of analysis.

This bioreserve selection process is extremely simplistic and should not be thought of as anything other than a proof of concept. No SME feedback was obtained for this portion of the study and as a result its quality suffered. A more robust bioreserve selection process should be used in the future.

No effort was made in this study to account for future urban growth. NLCD 2006 urban areas were simply applied to all future scenarios. However, this method allows the results from urban growth models to be used if available.

XXII. FURTHER WORK

Incorporate a more diverse set of BMPs. Currently, only the most common BMPs have been included or those whose spatial footprint is easy to define (e.g. riparian buffers). Other relevant BMPs with spatial footprints more difficult to define will require special effort by interdisciplinary teams of biologists, agronomists, hydrologists, etc.

The workflow on this project was not ideal. Assumptions developed for another study (whose goal was not the development of automated GIS mapping rules) were used as the starting point. In the future, it would be more productive to have a group of SMEs iteratively develop assumptions for a scenario based on what can be automated using existing GIS tools and data. In this way there will be more of a one-to-one relationship between assumptions and GIS rules; assumptions will only exist that can be implemented.

Another step could be added that explicitly identifies the policy instruments necessary to affect each BMP. In this way a tight connection between the policy and the resulting landscape is identified.

XXIII. REFERENCES

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CONSERVATION RESERVE PROGRAM FLOOD DAMAGE REDUCTION BENEFITS TO DOWNSTREAM URBAN AREAS

A US Army Corps of Engineers, Mississippi Valley Division Initiative
Rock Island District Pilot Project Report

APPENDIX E

INTERAGENCY AGREEMENT

Between The

U. S. DEPARTMENT OF AGRICULTURE,
FARM SERVICE AGENCY
ECONOMIC AND POLICY ANALYSIS STAFF
On behalf of the
COMMODITY CREDIT CORPORATION,
and
U.S. DEPARTMENT OF ARMY,
ARMY CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

DEPARTMENT OF THE ARMY
CORPS OF ENGINEERS, ROCK ISLAND DISTRICT
PO BOX 2004 CLOCK TOWER BUILDING
ROCK ISLAND, ILLINOIS 61204-2004

REPLY TO
ATTENTION OF

CEMVR-PM-M

12/21/2012
Approved

DEC 04 2012

MEMORANDUM FOR Commander, US Army Corps of Engineers, Mississippi Valley Division (CEMVD-PD-SP/Harris), PO Box 80, 1400 Walnut Street, Vicksburg, Mississippi 39181-0080

SUBJECT: Request for Review and Approval of Agreement to Provide Support for Others Work with the U.S. Department of Agriculture, Farm Service Agency.

This agreement is identical to the agreement signed by the Commanding General on August 2nd, 2012 with exception to the key deliverables and funding amount. This agreement is the second in a two year partnering opportunity between the USDA-FSA and USACE-MVD.

1. The subject request for support for others work has been requested by the U.S. Department of Agriculture Farm Service Agency. This work will provide support for the Secretary of Agriculture to better provide technical and financial assistance to landowners by helping target high priority areas for conservation funding. This work will provide the Corps and their customers with a better understanding of the methods of accounting for non-structural measures and their spatial significance in Flood Risk Management evaluations.

2. The subject agreement has been signed by the Director of the Farm Service Agency to provide FY13 funding of $195,000 to the Rock Island District to engage in the activities described in the enclosed scope of work. This agreement is follow-on work resulting from successful execution of key deliverables from an FY12 agreement.

3. The subject agreement has undergone legal review by the Rock Island District Office of Counsel in coordination with MVD's Office of Counsel. The Memorandum of Law Review has been enclosed as well as the referenced supporting documents.

4. The agreement complies with the ER 1140-1-211 Appendix C checklist (copy is attached). The work can be accomplished without compromising or creating delays in the accomplishments of our missions. The work requirement does not exceed 10 years. The work is within MVD's geographic boundaries. The work does not violate any of our other regulations.

5. The point of contact is Mr. Jason Smith, Study Manager/Civil Engineer, (309)794-5690, or e-mail: jason.t.smith2@usace.army.mil.

6 Encls
as

Mark J. Deschenes
MARK J. DESCHENES
COL, EN
Commanding

INTERAGENCY AGREEMENT

Between The

U. S. DEPARTMENT OF AGRICULTURE,
FARM SERVICE AGENCY
ECONOMIC AND POLICY ANALYSIS STAFF
On behalf of the
COMMODITY CREDIT CORPORATION,
And
U.S. DEPARTMENT OF ARMY,
ARMY CORPS OF ENGINEERS
MISSISSIPPI VALLEY DIVISION

This agreement is entered into by and between the Department of the Army (DOA), United States Army Corps of Engineers (USACE), Mississippi Valley Division (MVD), and the Department of Agriculture (USDA), Farm Service Agency (FSA) on behalf of the Commodity Credit Corporation (CCC). This agreement is a cooperative effort that supports activities necessary to evaluate the economic benefits that Conservation Reserve Program (CRP) lands provide to downstream urban areas within a watershed context. This agreement covers the specific activities related to evaluating existing data sets and tools to determine where existing and potential future CRP lands provide the greatest flood reduction benefits to downstream urban areas. A Memorandum of Agreement (MOA) between FSA and USACE provides the umbrella agreement that will facilitate this collaborative effort to develop hydrologic and economic models to quantify the effects of CRP lands on downstream urban areas. An initial agreement between USACE and FSA, signed in FY2012, provided initial modeling, data sharing, and preparation work necessary to undertake this analysis. By better identifying the relationship between the spatial location of conservation land and hydrologic response, the Secretary of Agriculture will be better able to target technical assistance (TA) to landowners, thereby furthering the broad goals of USDA conservation programs and the specific goals of the CRP. To efficiently accomplish this goal, this agreement authorizes a cooperative effort that supports activities to develop information of common interest to the agencies.

I. AUTHORITY

The authorities of the Agencies to enter into this Memorandum of Understanding (MOU) are the Commodity Credit Corporation (CCC) Charter Act (15 U.S.C. 714), and the Economy Act of 1932, as amended (31 U. S. C. 1535). To the extent that future grants and/or cooperative agreements are issued by the Agencies to any vendor or university pursuant to this Agreement, they will be issued in adherence to all applicable Federal laws and regulations. The data described within are collected, kept confidential, and protected by the Parties pursuant to section 1619 of the Food, Conservation, and Energy

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Act of 2008, P.L. 110-246; section 2004 of the Food, Conservation, Farm Security and Rural Investment Act of 2002, P.L. 107-171; the Privacy Act of 1974; the E-Government Act of 2002; and related authorities.

II. BACKGROUND

The purpose of this agreement, between FSA and USACE-Mississippi Valley Division, is to quantify the effects of existing and potential future CRP lands on downstream flooding and economic impacts to downstream urban areas, focusing on Cedar Rapids, Iowa. These efforts in the Cedar River Basin, documented in a report format and following acceptance by FSA, will be presented on the Iowa-Cedar Interagency team web portal along with other watershed tools and related information. By quantifying and identifying the effects of the CRP, USACE will enable the Secretary of Agriculture to better target lands for enrollment in the CRP and more effectively provide technical and financial assistance to agricultural landowners.

USACE is an internationally recognized leader in engineering research and implementation whose civil works missions include understanding and management of the Upper Mississippi River Basin of the United States. USACE and USDA have developed a long-term, mutually beneficial, working relationship to identify agricultural non-structural activities that have the potential to beneficially or adversely impact flood damage reduction strategies and ecosystem sustainability.

The multi-disciplinary structure of USACE provides a single source of objective scientific knowledge and application focused on flood damage reduction strategies and ecosystem sustainability that has no regional corollary in the private sector in the Upper Mississippi River Basin. The USACE Rock Island District within the Mississippi Valley Division is recognized as a leader in comprehensive watershed planning, navigation, flood damage reduction, and environmental restoration in the region. Examples of the Rock Island District's expertise include the Upper Mississippi Comprehensive Plan, which that was submitted to Congress in 2008, as well as on-going oversight for 3 flood control reservoirs and numerous miles of levee systems that provide flood damage reduction benefits to urban and agricultural lands. In addition, the Rock Island District's Environmental Management Program (EMP) recently celebrated 25 years of restoration work and has become an international success story drawing visitors from China, India, and other countries. The Rock Island District has hydrologic and economic modelers who are experts in evaluating agriculturally-dominated landscapes due to their institutional knowledge from years of working in the heart of the nation's most agriculturally productive lands.

The services provided by Rock Island District as identified in this agreement represent a collaborative venture between the USACE and USDA-FSA to produce objective, scientifically-credible deliverables. The FY12 pilot agreement that this effort builds upon resulted in a literature review that frames the state of the science related to typical CRP conservation practices and their impact on hydrology. In addition, the FY12 pilot achieved successful completion of a physically-based hydrologic model that provides better understanding of how CRP-type conservation measures affect the hydrology on a small watershed scale. The third activity in the FY12 pilot effectively transferred CRP data to the Corps and was incorporated into a password-protected database, which sets the stage for the scientifically-credible deliverables that are outlined in this agreement.

III. PURPOSE

The purpose of this agreement is to continue the partnership between the USACE and the FSA, on behalf of the CCC, to bring the sharing of USDA and ACE data and information into full compliance with all authorities. This agreement also identifies and quantifies the effects of CRP lands within a watershed context in order to enable the Secretary of Agriculture to better target lands for CRP enrollment and to more effectively provide technical and financial assistance to agricultural landowners.

IV. RESPONSIBILITIES

A. USACE agrees to:

1. Provide a comprehensive investigation of the relationship between existing and potential CRP practices, their spatial location in the Indian Creek watershed as a function of hydrologic response over a range of probability events, and validate the hydrologic model's applicability across the broader Cedar River watershed. Impacts will be identified by using various GIS techniques, and further developing and using hydrologic and hydraulic models.

2. Identify to the best of their ability, within the project scope, the economic benefits provided by currently-enrolled CRP lands on downstream urban and rural communities over the same range of probability events defined in #1.

3. Identify to the best of their ability, within the project scope, the economic benefits provided by CRP lands under various future land use scenarios to downstream urban and rural communities over the same range of probability events defined in #1.

4. Collaborate with FSA and other participating agencies to share data and information in accordance with agency requirements.

5. Protect the confidentiality of data provided by FSA by using the data for assessment purposes only. Reports and products will represent sensitive data in maps and other materials at a county or larger spatial scale and will be subject to FSA review and approval, prior to public release.

6. Work with FSA where appropriate to identify lands for enrollment in the CRP to permit more effective delivery of financial and technical assistance to individual landowners participating in the CRP.

7. Utilize the data provided by FSA for the defined project only and for no other purposes.

8. Provide brief written quarterly reports to FSA.

B. FSA agrees to:

1. Continue to assist USACE with the acquisition of Common Land Unit data with landuse/landcover codes and conservation practice annotations for CRP (including Conservation Reserve Enhancement Program and Farmable Wetland Program lands) for the study area.

2. Provide information that will assist USACE in developing a conceptual approach design, including the identification of conservation practices and conservation benefits that are to be addressed, the location of CRP contracts in the study area, the precision and frequency of reporting requirements, data gaps that need to be addressed for FSA reporting requirements, and USDA data as needed to support the collaborative work.

3. Contribute expertise to support data collection, analysis, and production of deliverables, including CRP decision support tools.

4. Provide comments to USACE on draft deliverables, including feedback to the Rock Island District to ensure that outputs satisfy agency needs and that the inputs and data requirements required for model development are available.

5. Contribute funding to support data synthesis and incorporation of results into a web portal platform.

C. Strict adherence to laws regarding confidentiality of information:

It is mutually agreed upon by all parties that:

All parties will abide fully by the privacy provisions contained in "Information Gathering" found at section 1619 of Public Law 110-246 (codified at 7 U.S.C. 8791) ("Section 1619") and the "Administrative Requirements for Conservation Programs," found at section 2004 of Public Law 107-171 (codified at 16 U.S.C. 3844) ("Section 2004"). Specifically, USACE-Mississippi Valley Division, Rock Island District, and its collaborators will use the digital coverages provided by USDA only for the purpose of conducting the Conservation Reserve Program (CRP) Flood Damage Reduction Benefits to Downstream Urban Areas Project. Reporting of any results beyond the research team must use aggregate data only, and in a manner that ensures the complete confidentiality of individual landowners and program participants. These provisions will also apply to any agency, organization or individuals funded or otherwise supported by the USACE-Mississippi Valley Division, Rock Island District, to conduct any work

Island District, to conduct any work associated with the CRP Flood Damage Reduction Benefits to Downstream Urban Areas Project. Additionally, all parties agree to keep the data in a secure site. All of the other provisions of the above-noted laws will also apply and must be abided with fully; failure of any party to abide by such provisions may result in immediate termination of this Agreement by FSA.

Rock Island District has the authority to publish results; any published results will be based on aggregated data in conformance with Section 1619.

V. FUNDING AND PAYMENT PROCEDURES

A. Upon final signatures of this agreement, funding for FY2013 work of $195,000 will be obligated to support this agreement

B. USACE-MVD will obtain reimbursement from FSA via the use of the Intergovernmental Payment and Collection System (IPAC) on a monthly basis. FWS will reference the following accounting citations when IPAC transactions are processed:

FSA Accounting information
Agreement Number: 13-IA-MRE CRP TA #TBD
Appropriation NO: TBD
DUNS Number: 095355392
BETC - DISB: TBD
Federal Customer Agency Location Code: 00004992
Federal Customer Treasury Fund Account Symbol: 12X4336

USACE Accounting information
DUNS #, TBD
BETC - COLL, ALC #, TBD
Treasury Account Symbol - TBD

VI. PERIOD OF AGREEMENT

A. The period of this agreement shall be from the date of the last signature until December 31, 2014.

B. This agreement is renewable upon mutual written agreement of the parties concerned. If renewal is desired, the parties shall discuss it prior to the termination of the original agreement. This agreement may be modified with the consent of all participants. This agreement may also be modified upon 30 written days' notice of one party to the other. Notification must be made to USDA-FSA, Budget Division, Stop 0575, 1400 Independence Avenue. S.W., USDA-FSA, Budget Division, Stop 0575, 1400 Independence Avenue. S.W., Washington, DC 20250-0575, if any alterations, due to renewal or modification, are made.

C. If termination of services is desired prior to the expiration of this agreement, the agency requesting the termination will request, in writing, deactivation of the account, citing the IAG number, appropriate account numbers, and date of termination.

VII. DELIVERABLES AND TARGET DATES OF COMPLETION

A. **Quarterly reports:** Provide brief 1-3 page quarterly reports (January 15th, April 15th, July 15th, and October 15th) detailing accomplishments, progress, and barriers to successful completion of the project.

B. **CRP Placement on Hydrologic Response:** A comprehensive summary of the relationship between existing and potential CRP practices, their spatial location in the Indian Creek watershed study area as a function of the hydrologic response, and the applicability of localized results generated from a very data intensive model to a larger and more broad scale area (the Cedar River watershed) using less data intensive and more popularly used model(s) (i.e. relationship between physically based model and lumped parameter model). (June 2013)

C. **Economic Analysis of Current CRP Lands:** A comprehensive report that includes tabular presentation of the with/without analysis of the hydrologic and economic benefits realized by downstream urban areas due to currently enrolled CRP lands. (October 2013)

D. **Economic Analysis of Potential Future CRP Lands:** A comprehensive report that includes tabular presentation of the with/without analysis of the potential hydrologic and economic benefits realized by downstream urban areas due to lands targeted for future enrollment of CRP. (October 2013)

E. **Presentation and Webportal Display:** Results from the study will be presented in a formal presentation for the Farm Service Agency's Economic and Policy Analysis Staff (EPAS) and other interested parties at a location of their choosing. Following presentation of the study results and receipt of the findings, the results from the study will be merged into the web-based webportal tool currently under development at the University of Iowa's Institute for Hydroscience and Research (IIHR). (Presentation – September 2013; Webportal – December 2013)

VIII. TECHNICAL AND ADMINISTRATIVE CONTACTS

A. USACE

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2. Ms. Linda Weiman (Administrative)
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B. FSA

1. Dr. Skip Hyberg (Technical)
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   1400 Independence Avenue, S.W.
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2. Mr. Armando Sanchez (Administrative)
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   Email: Armando.Sanchez@wdc.usda.gov

IX. SIGNATURES:

11/19/2012

JUAN M. GARCIA
Administrator
Farm Service Agency

DATE

12/21/2012

JOHN W. PEABODY
Major General, U.S. Army
USACE, Mississippi Valley Division Commander

DATE