FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED BASIN

AN IOWA SILVER JACKETS FLOOD RISK MANAGEMENT TEAM INITIATIVE

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USACE National Flood Risk Management Program
for Iowa Silver Jackets Pilot Project

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EXECUTIVE SUMMARY

In 2011, the Iowa Silver Jackets (SJ) team identified that while there are numerous products being developed by various Federal and state governmental agencies that there is no single standard to identify the current and potential future flood risk in the state of Iowa. Over the past year, hundreds of calls were made to local communities and numerous tools were developed to assess flood risk in the Iowa-Cedar Watershed Basin. This effort uncovered that large communities in the Iowa-Cedar basin have the greatest flood risk based on total structure loss and total population at risk. However, many small and medium sized communities have equal to or greater per capita flood risk. In addition, some of these small and medium communities may be increasing future flood risk by encouraging floodplain development to boost their local economy.

In order to evaluate flood risk the SJ team developed a georeferenced database that identified all of the communities within the Iowa-Cedar watershed boundary and established which communities had developed products such as hazard mitigation plans, future landuse plans and zoning ordinances. The team then used the Federal Emergency Management Agency's Hazard United States (FEMA-HAZUS) and GIS-based tools to quantify the estimated current flood risk (structure loss and population at risk) at the census block level and per capita by community. Future flood risk was qualitatively identified by evaluating the upstream potential for landuse change. The level of floodplain management being deployed through future landuse planning, hazard mitigation planning or other zoning/building ordinances also contributes to the potential future flood risk.

A combination of methods to quantify flood risk in the Basin was utilized. The HAZUS computer program was able to be deployed readily for areas that have US Federal Emergency Management Agency (FEMA)-Flood Insurance Rate Maps (FIRM) but given only 22 of the 33 counties had FIRM products a significant gap was identified for evaluating the entire basin. In order to fill this gap the SJ team used a US Department of Agriculture - Natural Resources Conservation Service (NRCS) landform method to delineate an approximate floodplain extent. The landform method evaluation determined that this method has data gaps and inconsistencies that prevent use for estimating structure losses and population at risk.

The HAZUS computer program which utilizes FIRM delineated floodplain boundaries was used to quantify current flood risk based on total structure loss, total population at risk, per capita structure loss and per capita population at risk. This information along with other landuse and model information were used in support of a stakeholder engagement process in the Indian Creek watershed, which contains part of Cedar Rapids, Iowa. Given the recent completion of a Chief's report for the Cedar Rapids General Investigation report for Cedar Rapids the pilot team decided to evaluate how the HAZUS area-weighted average method compares to the USACE traditional HEC-FDA method. The pilot team determined that the HAZUS area-weighted average method was underestimating structure losses for the census blocks that were evaluated.

The areas where HAZUS was most significantly underestimating losses coincided with industrial complexes, such as Quaker Oats. Future efforts may benefit from manually inputting structure loss data associated with industrial complexes into HAZUS to improve structure loss estimates. While the magnitude of underestimation may benefit from greater analysis, this pilot concluded that HAZUS consistently underestimated the values and therefore a correlation could be drawn between where high, moderate and low potential structure losses and population at risk are occurring. This correlation makes HAZUS an effective screening tool to help identify where to focus resources for further evaluation over a large spatial area.

Without a hydraulic model to generate new flood profiles based on potential future conditions from which to quantitatively compare structure losses and changes in population at risk the pilot team looked to landuse breakdown as a qualitative metric to consider how the floodplain inundation extent may increase. Based on NRCS correspondence, pasture and grassland areas are the most likely land uses to convert to row crops. Considering this information communities that have lots of upstream lands in pasture are subject to a greater likelihood of increases in the floodplain inundation extent. In addition to upstream landuse, the likelihood of a communities flood risk increasing is also qualitatively linked to the ordinances they have or have not adopted which are identified in the georeferenced database.

The strength of the georeferenced database developed for this study is not its display on paper but that it is georeferenced and can be used as a dynamic tool to continue to track flood risk in the Iowa-Cedar basin by updating information as it becomes available and to add communities and categories as necessary to capture all relevant elements of the flood risk management cycle (response, recovery, mitigation, and preparation).

Floodplain Management and Communication
of Risk in the Iowa-Cedar Watershed

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Flood Risk Management Team Initiative

ROLES AND ACKNOWLEDGEMENTS

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An Iowa Silver Jackets
Flood Risk Management Team
Initiative

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FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED BASIN

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I. INTRODUCTION

The State of Iowa has delegated floodplain management decisions to the local units of government. This has resulted in a mosaic of zoning ordinances throughout the state which vary from highly restrictive to essentially non-existent. Only those communities that choose to participate in the National Flood Insurance Program are assured to have passed a floodplain ordinance and require a floodplain permit for development. Those communities that do not choose to participate may or may not have zoning regulations that govern the type and extent of development in the floodplain. The Iowa-Cedar Watershed Basin (Iowa-Cedar Basin) is a prime example, containing three highly urbanized areas along with dozens of cities and small rural townships. The urban areas primarily regulate the type of development in the 1.0% event (100-yr) probability zone, while the City of Cedar Falls regulates the 0.2% event (500-yr) probability zone; however there is little consistency between the smaller townships and rural communities with regard to floodplain management.

With a mosaic of ordinances the various governmental entities (Federal, state and local) have fragmented information related to flood risk which is dispersed between the multiple agencies. This fragmentation results in a lack of understanding of which communities have significant ordinances in place to prevent current and future flood losses to their communities and those downstream.

II. PURPOSE, GOALS AND OBJECTIVES

A. Purpose

The purpose of this study is to compile flood risk management data and information into a central location that may be used by various governmental entities to assist in managing current and future flood risk.

B. Goals and Objectives

The goal of this study effort is to provide Federal, state and local organizations zoning and technical information in a meaningful way to encourage actions that lower current and future flood risk in the Iowa-Cedar Basin. The study has three objectives:

Objective 1: to increase understanding of flood risk by compiling a database of zoning ordinances and other technical information.

Objective 2: to quantify current and future flood risk and identify how to lower flood risk by community adoption of various floodplain management measures. A map format will be utilized to assist in indentifying where high potential loss areas exist and where gaps occur in zoning.

Objective 3: to communicate the results from this study to various Federal, state and local governmental agencies along with other stakeholders with responsibilities to manage flood risk in the Iowa-Cedar Basin.

III. SCOPE OF WORK

The scope of work includes three different and distinct activities required to achieve the goal and objectives.

A. Activity 1 (Objective 1) - Data Collection

To achieve Objective 1, staff with the US Army Corps of Engineers (Corps), Rock Island District, Iowa Department of Natural Resources (IA DNR), US Federal Emergency Management Agency (FEMA), Iowa Homeland Security and Emergency Management Department (IAHSEMD) floodplain management staff and others compiled an electronic database of zoning ordinances. Gaps identified in the electronically available information were filled in by contacting the local communities via phone and email to seek the necessary information. Some of the specific information follows (Appendix A, *Database Fields and Abbreviated Data* provides a complete list):

- Is populated area recognized as a community in FEMA's Community Status Book Report?
- Is the FEMA recognized community participating in the National Floodplain Insurance Program (NFIP) or not?
- Has populated area has ever been mapped and if so what year it was most recently mapped?
- Does populated area prescribe to higher standards then NFIP minimum?
- Has populated area developed a hazard mitigation plan that is on file with the state?

B. Activity 2 (Objective 2) - Quantify Flood Risk

To achieve Objective 2, information was collected related to the size of the special flood hazard area, the economic value of structures at risk, and the type of current floodplain/zoning/building regulations are in place for a respective community. See Appendix A for a complete list.

After compiling the database fields that identify current and potential flood risk, actions were identified that may benefit communities participating in the Community Rating System (CRS) that may lower flood risk for the communities and the Nation.

C. Activity 3 (Objective 3) - Risk Communication

To achieve Objective 3, the results from Activities 1 and 2 were disseminated to community stakeholders in the Indian Creek basin as well as the Iowa-Cedar Interagency Watershed Coordination Team and other Iowa Silver Jackets partners such as the Iowa Council of Governments; the Iowa Association of Floodplain and Stormwater Management; the Association of State Floodplain Managers; and others. Results were communicated to Federal, state and local government representatives and other stakeholders through various workshops, conferences and formal meetings.

IV. BACKGROUND

A. Study Area

The Iowa-Cedar Basin is a tributary to the Mississippi River which includes some of the most fertile agricultural land in the Nation and debatably in the world. In recent years, high commodity prices and ethanol demand has contributed to landscape changes, including conversion from pasture and other agricultural crops to cultivated row crops, primarily corn and soy beans. Landscape conversion has increased stress on fresh water sustainability and contributed to both Gulf hypoxia and epic flooding. The Iowa-Cedar Basin contains three large urban areas which have experienced monumental flood events in recent years, most notably in 1993, 2002, and 2008. Figure 1 displays a map of the Iowa-Cedar Watershed Basin.

B. Problems, Issues of Concern and Opportunities

The primary problem is that there is a lack of understanding of the current flood risk in the Iowa-Cedar Basin which has experienced significant economic impacts in recent years due to monumental flood events. There are concerns that as urban areas continue to expand and market prices increase for corn and soybeans that land use changes within the Basin may have dramatic impacts on the Basin's hydrology. Similarly, there is concern that the changing climate may also have dramatic impacts on the Basin's hydrology. Hydrologic variation due to landuse and climate changes may result in greater current flood risk but future flood risk is contingent on how communities manage their current flood risk and which actions are taken (i.e. mitigation, adoption of ordinances and zoning regulations, watershed master plan, etc.) to make communities more resilient to flooding.

The Iowa-Cedar Basin is not unique within the Midwestern region in terms of its row crop dominated landscape. However, the Basin is unique in having strong interagency cooperation through the Iowa-Cedar Interagency Watershed Coordination Team. The Interagency Team is composed of approximately 20 different Federal and state governments and non-governmental organizations www.iowacedarbasin.org. The Interagency Team has an Iowa-Cedar Watershed Basin coordinator who works directly with local governmental entities such as the County Conservation Boards; Resource Conservation Districts; Soil and Water Conservation Districts; and Townships and Municipalities. This partnership with local governmental entities combined with agency level involvement of the Silver Jackets partners provides a unique opportunity to identify, communicate flood risk and take actions at multiple jurisdictional levels.

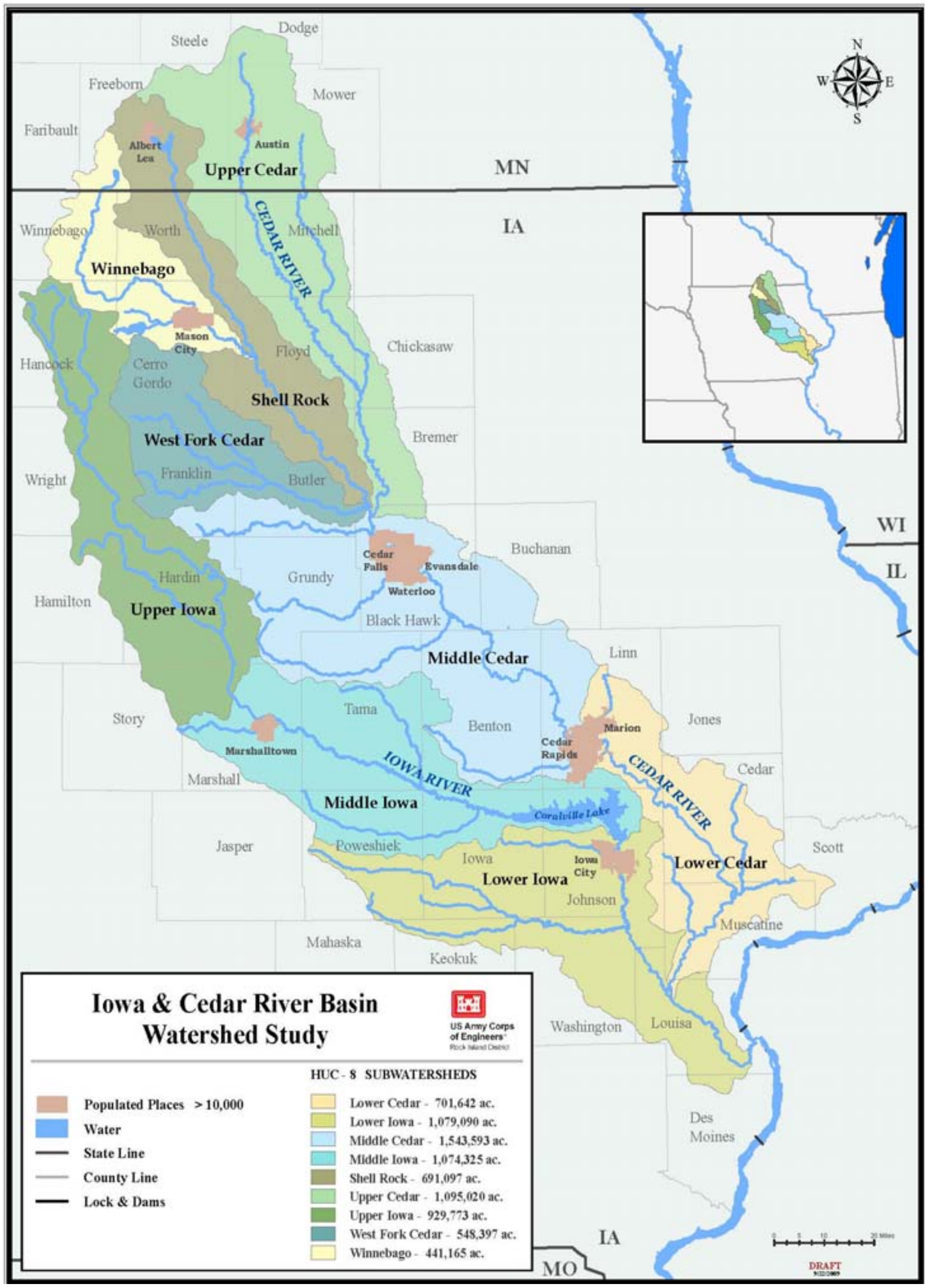


Figure 1. Map of the Iowa-Cedar Watershed Basin

V. METHODOLOGY AND RESULTS

Although the methodology is broken into separate activities, the activities are interrelated.

A. Activity #1- Data Collection

In order to begin assembling a central database, the pilot team had to identify the communities in the Basin to collect information. The team initially identified the communities in the Basin using the US Census data, however as detailed calls were made there were numerous other communities that were identified within the Basin. This exercise uncovered that there are numerous ways that a community may be identified and that some of the confusion between agencies when discussing flood risk of a community is due to the unique identifier that agencies use to define communities. An example of this is that communities within the census are identified by the Federal Information Processing Standard (FIPS) numbers but FEMA assigns a community a Community Identification Number (CID) which is partially related to the FIPS number.

In an effort to capture as many communities as possible, the database was assembled to include a number of unincorporated communities which should be governed by the county ordinances and zoning regulations but were included for the sake of thoroughness. During this data collection process Silver Jacket agency partners presented information they had available concerning the various aspects of flood risk in the Iowa-Cedar Basin. Some of the information that was obtained from the various partners and assembled into the database is as follows.

- FEMA – Structure Loss Point Data, NFIP Community Address Book for Iowa and Minnesota.
- IA DNR – Preliminary FEMA-FIRM maps, Information related to Special Flood Hazard Areas
- IAHSEMD – Hazard Mitigation Plans, Communities adopted standard higher then state minimum.
- US Department of Agriculture (USDA) - Natural Resources Conservation Service (NRCS) – landform method for floodplain delineation.

The collection of data and information was broken down into demographic information, current flood risk and future flood risk. Demographic information collected includes basic information such as the community population, location in the Basin including state, county and Hydrologic Unit Codes, FIPS community identification number, and a community point of contact.

Current flood risk information collected includes both qualitative and quantitative elements. Qualitative information collected include whether the community is recognized by FEMA, whether they are participating in the NFIP, if the community has been mapped, and if they have received insurance payments in the past. Quantitative information collected includes items such as the size of the Special Flood Hazard Area, the area weighted average of the population within the 1% (or 0.2% where applicable) probability boundary and the area weighted average of the estimated value of structures at risk within the 1% (or 0.2% where applicable) probability event boundary.

Information collected in the database related to potential future flood risk is primarily qualitative in that it captures whether a community has adopted various ordinances or building codes. Additional information included in the database include landuse breakdown to help a community infer how much hydrologic change is likely to occur to the community due to future upstream landuse conversions (Agriculture to urban, natural to agriculture, etc.). In addition, future landuse plan maps may be used to express future flood risk quantitatively but requires a good deal of extra effort to convert into a product that may be used to communicate changing flood risk. Such an effort was made in the Indian Creek basin and is described in detail in the Risk Communication section of this report.

Some of the database statistics are presented in Table 1. An abbreviated version of the database is displayed in Appendix A. The strength of the database is not its display on paper but that it is georeferenced and can be used as a dynamic tool to continue to track flood risk in the Iowa-Cedar Basin by updating information as it becomes available and to add communities and categories as necessary to capture all relevant elements of the flood risk management cycle (response, recovery, mitigation, and preparation).

Table 1. Summary of Database Statistics

Demographics	**Number of Communities**
Total Communities [1]	270
FEMA Recognized	181
Participating in NFIP	151
Communities with a FIRM Map Product	193
Proactive Planning	
Adopted Standards higher than NFIP minimum	7
Developed Hazard Mitigation Plans	17
Developed a Comprehensive Plan	88
Developed a Future Landuse Plan Map	47
Regulatory	
Adopted Zoning Ordinance	128
Adopted Subdivision Ordinance	104
Adopted Stormwater Management Ordinance	56
Adopted Sensitive Areas Ordinance	80
Quantitative Risk	
Communities evaluated in HAZUS for 100-yr frequency event	138
Communities evaluated in HAZUS for 500-yr frequency event	42
Communities with HAZUS estimated *structure losses* greater than $1,000,000	33
Communities with HAZUS estimated *people impacted* greater than 500	28
Communities with *per capita* estimated *structure losses* greater than $1,000	32
Communities with *per capita* estimated *people impacted* greater than 25%	66

[1] Unable to contact 69 of these communities to gain Proactive Planning and Regulatory Information

B. Activity #2 - Quantify Flood Risk

1. Current Flood Risk

a. Floodplain Delineation Approach. In order to quantify current flood risk the pilot team sought to identify the number of structures located within the 1% (or 0.2% where applicable) probability event boundary. As the pilot team began assembling data and information it was identified that for an area the size of the Iowa-Cedar Basin that FEMA-Federal Insurance Rate Maps (FIRM), which delineate the 1% (and 0.2% where applicable) probability event, have not been developed for the entire floodplain. While some preliminary inundation extent products were able to be obtained from the IA DNR, only 22 of the 33 counties that make up the Iowa-Cedar Basin were determined to have FEMA-FIRM maps. In an effort to quantify the current flood risk in the entire basin an alternative method was explored to delineate the floodplain extent and estimate the economic value of structures at risk. (Note from here forward the use of FIRM maps will be used to describe the 1% probability event (or 0.2% where applicable) boundary unless specified otherwise). Figure 2 displays where FIRM maps have been developed and areas where maps have not been developed yet.

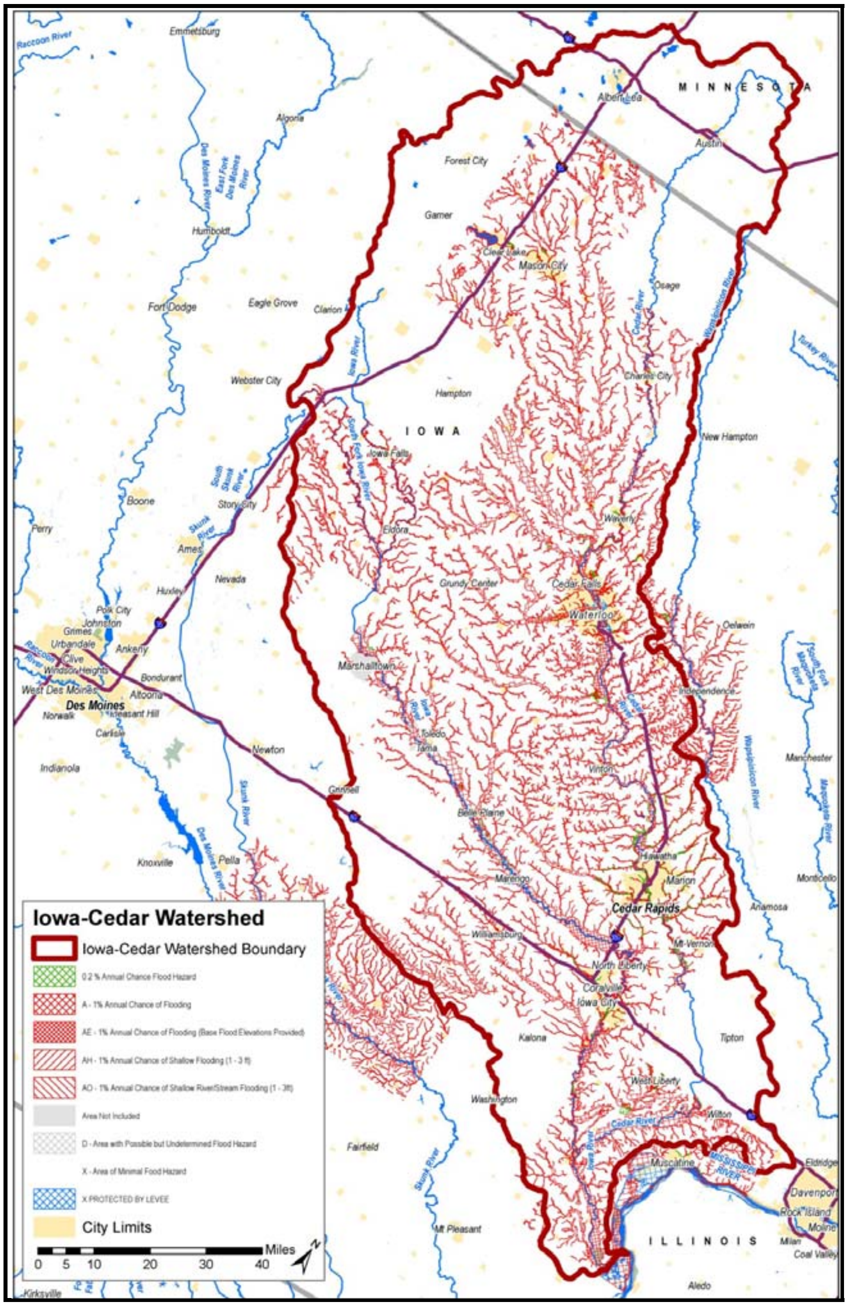


Figure 2. Locations Where FIRM Maps Exist Within the Iowa-Cedar Basin

Lacking a delineated floodplain section for 11 of the 33 counties composing the Iowa-Cedar Basin, the pilot team utilized the landform delineation method developed by the USDA-NRCS. This method delineates the floodplain based on the landform characteristic as presented in their respective county level soil surveys. Using this approach at a broad scale the size of the Iowa-Cedar Basin resulted in what appeared to be a good representation of the floodplain extent in the Iowa portion of the watershed but a weaker representation of the floodplain extent in Minnesota (Figure 3). The level of detail in the soil surveys is believed to be the reason for this discrepancy.

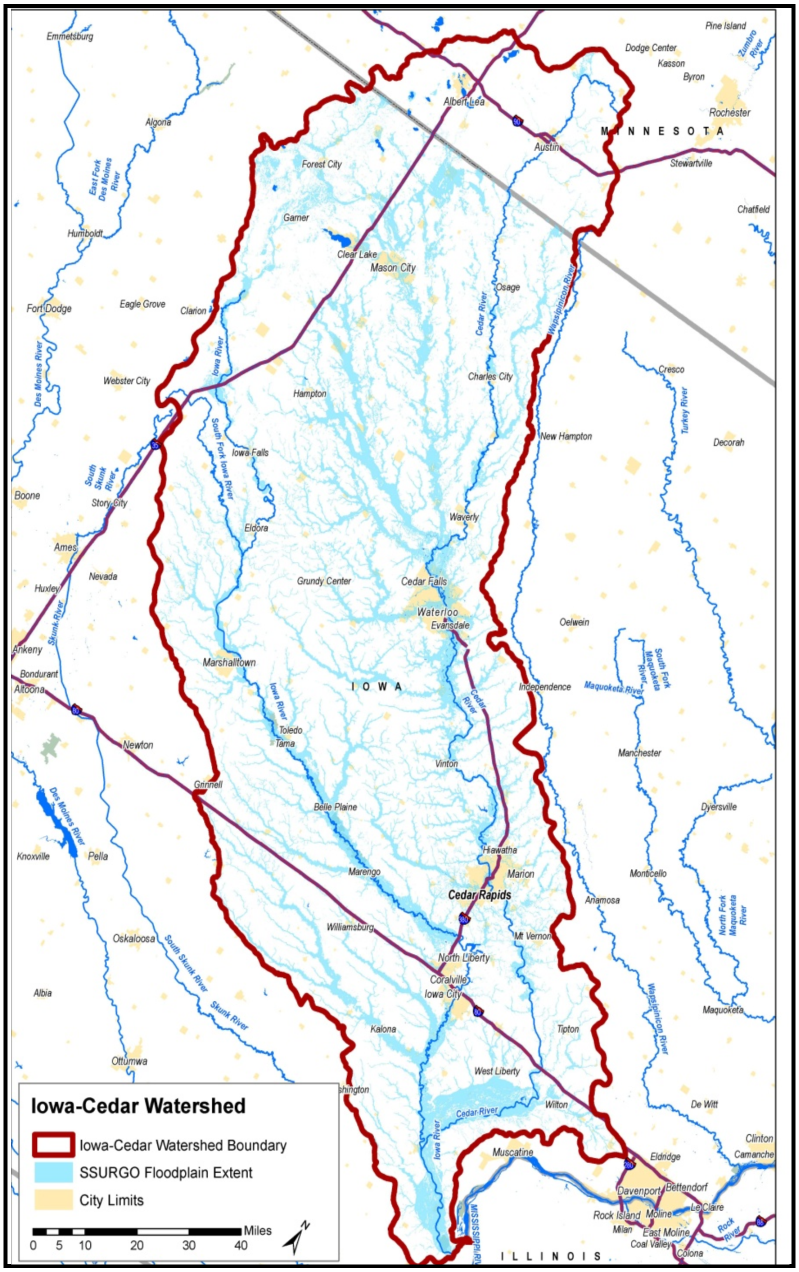


Figure 3. Landform Method of Floodplain Delineation at the Iowa-Cedar Basin Scale

While Iowa appeared to provide good landform data to delineate the floodplain, zooming down into specific areas in the Basin uncovered that this method is overestimating the floodplain extent and in some cases identifying upland areas as floodplain areas. In order to evaluate how well the landform method of floodplain delineation compared to hydrologically determined inundation extents like those presented in the FIRM maps the two layers were overlaid. This overlay identified that in some stream sections the landform method fits the FIRM maps well, in other areas it completely omits some sections of the stream network and in the remaining areas it overestimates the stream sections. An example of this overlay is shown in Figure 4.

The landform method is not tied to a specific probability event but to the geomorphic properties of the floodplain which is undesirable because it often overestimates the extent of flooding based on current considerations in a hydrologic evaluation. However, this method is favorable because it may be applied in rural areas absent of hydraulic tools and it accounts for the dynamic nature of the floodplain to delineate the floodplain extent. The dynamic nature is important to account for when considering how floodplain extents may change over time due to potential landuse and climate changes.

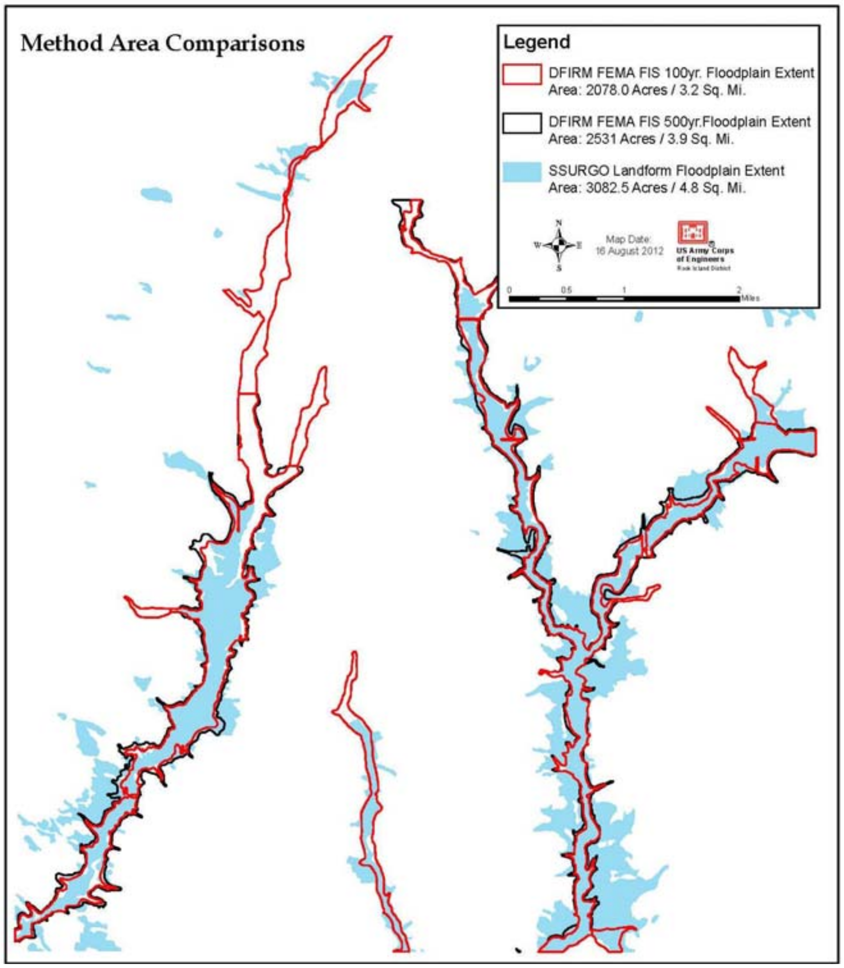


Figure 4. Overlay of NRCS Landform Method and FIRM Defined Floodplain Extents

b. Economic Evaluation. In order to capture the economic value of structures at risk the pilot team identified FEMA's Hazard United States (HAZUS) program as most favorable for providing estimated structural losses at both a census block level and a community level for those 22 counties that do have preliminary or approved FIRM maps. The pilot team also used the economic information in HAZUS to estimate the structure losses in the remaining 11 counties without FIRM maps by using the landform delineated boundary. However, estimating structural losses using the landform method was difficult because the channel depth was unable to be calculated due to the right and left inundation extents not being approximately equal as should occur in a water surface. In an effort to overcome this problem a method was explored to determine if there is a scaling relationship between the total structure loss and the depth/damage structure loss. A statistical approach was taken to evaluate these methods and resulted in no conclusive evidence that a scaling relationship may be applied generally to describe economic values at risk in the Basins that lack hydrologically delineated floodplain extents (i.e. FIRM maps).

Given that 22 of the 33 counties do have FIRM map products the pilot team was able to quantify the current flood risk throughout the Basin at a census block level and a community level. For an area the size of the IA-Cedar only display of flood risk at a community level makes sense.

In development of the community level analysis the study team recognized that small communities were quickly overlooked when considering flood risk based on estimated total structure losses or population affected due to their relatively low structure losses and small populations compared to larger municipalities (Figure 5. This raised the question whether small communities did in fact have lower current flood risk. The pilot team investigated this by normalizing the data to account for flood risk potential per person (per capita). Per capita flood risk offers what percentage of a community's population lives within the estimated floodplain boundary and how much does it cost either an entire community or the affected people if the cost to rebuild was distributed locally versus nationally through the National Flood Insurance Program (NFIP) (Figures 6 and 7). Understanding these relationships has recently become more important due to recent rule changes for the NFIP which now require the program to be actuarially sound.

The pilot team present 5 different ways of representing current flood risk at a community level.

- **Total Structure Loss data** reflects the compiled estimated structure losses based on an area-weighted average of each census block and a depth to damage relationship.
- **Population Affected** reflects the compiled estimated population within the delineated floodplain based on an area-weighted average of each census block.
- **Structural Loss per Capita** reflects the Total Structure Loss divided by the total population of the community
- **Structural Loss per Affected** reflects the Total Structure Loss divided by only the Population Affected within the community.
- **Population Affected per Capita** reflects the proportion of the Population Affected compared to the total population of the community.

The five different maps are provided in Figures 5, 6, and 7. Population Affected per Capita is provided in two figures to allow viewing of the relationship between structural losses and population affected. While this information is provided in defined maps the strength of the geodatabase is that it allows a governmental entity or a local community to view flood risk many different ways including identifying flood risk at a census block level to assist with response, recovery, mitigation and planning.

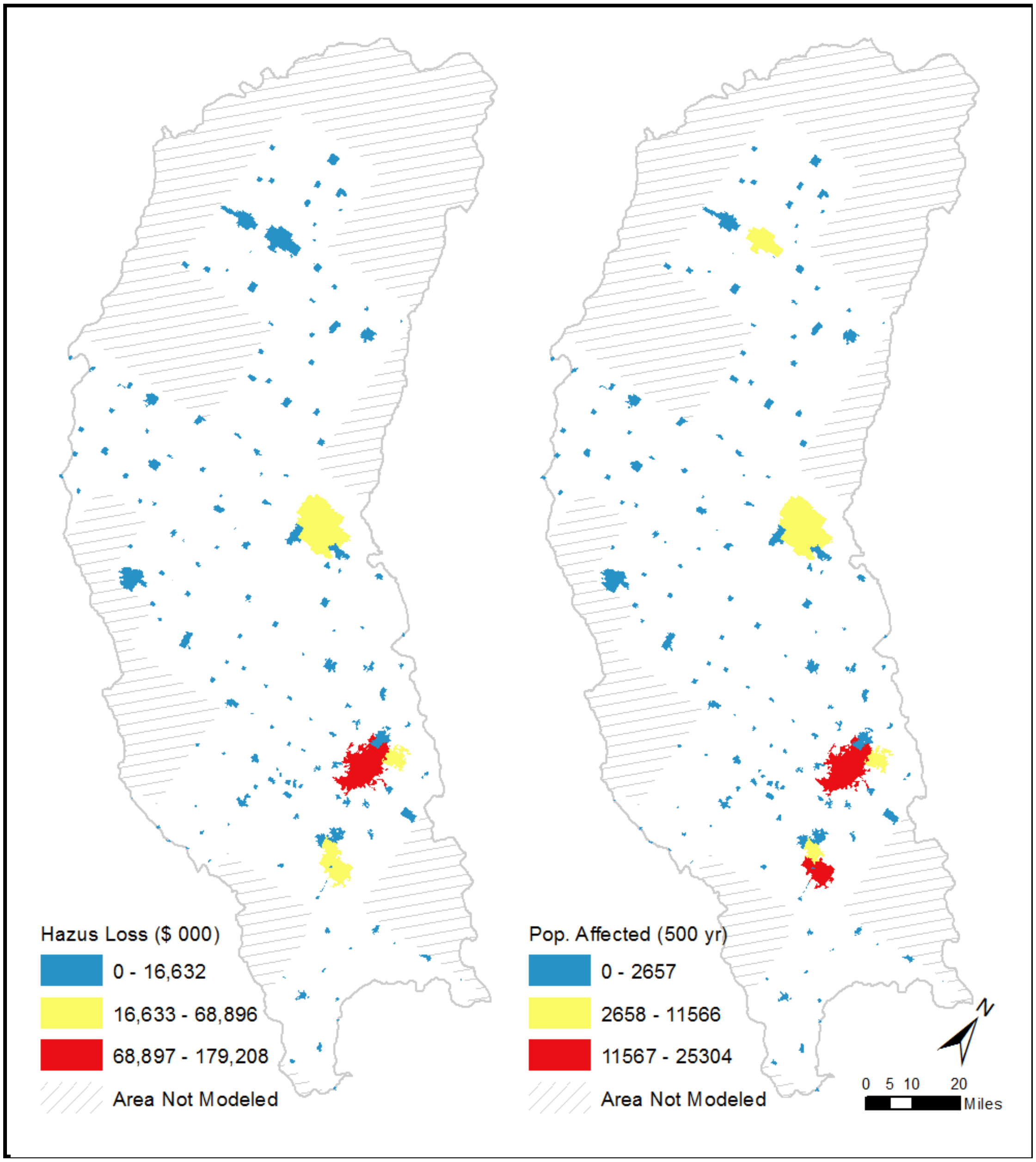


Figure 5. Total Structure Loss and Population Affected
(Note. Color breaks are based on natural breaks in the data.)

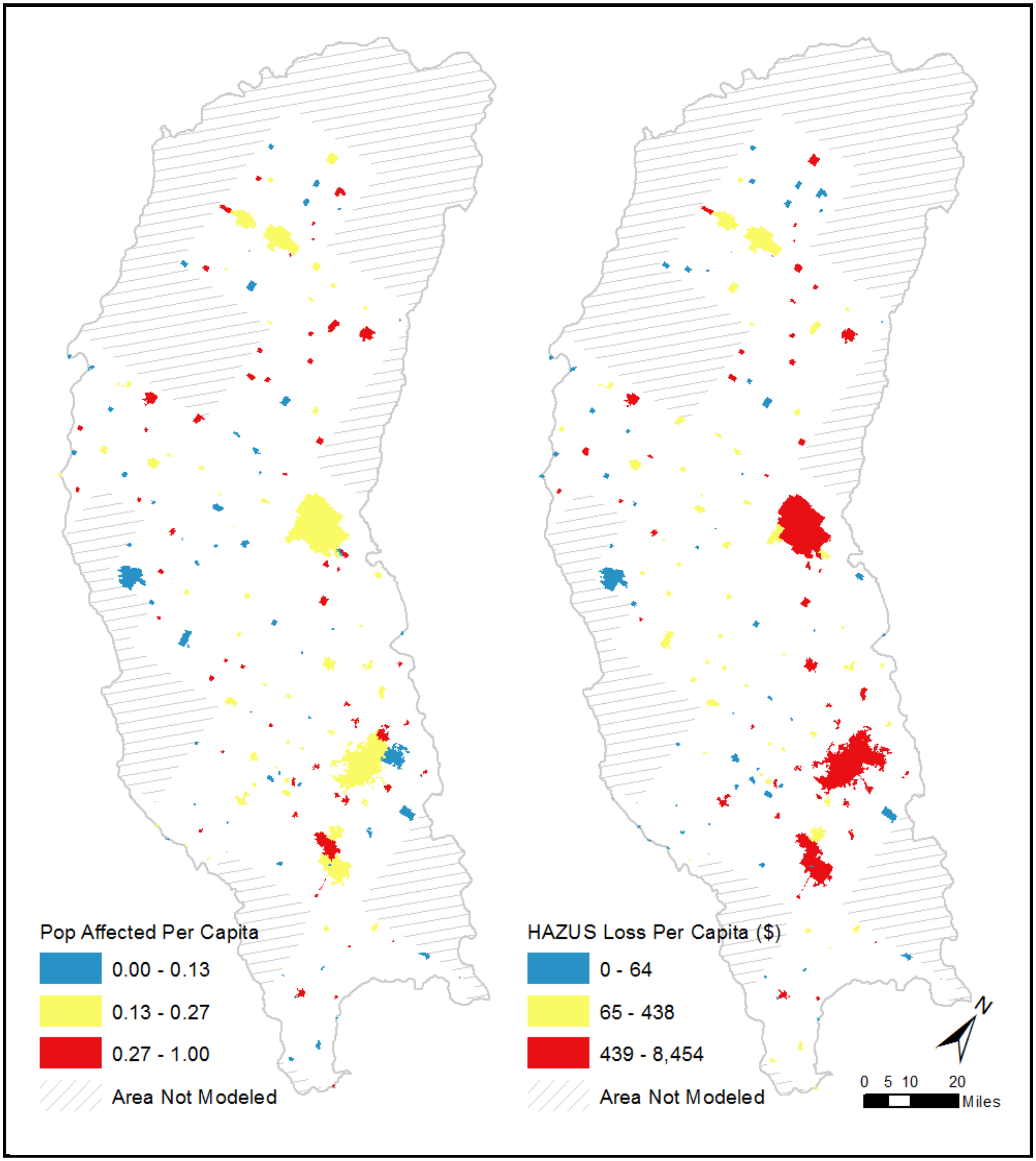


Figure 6. Population Affected Per Capita and Structural Loss Per Capita
(Note. Colors divide the communities into the top, middle and bottom third for each respective map.)

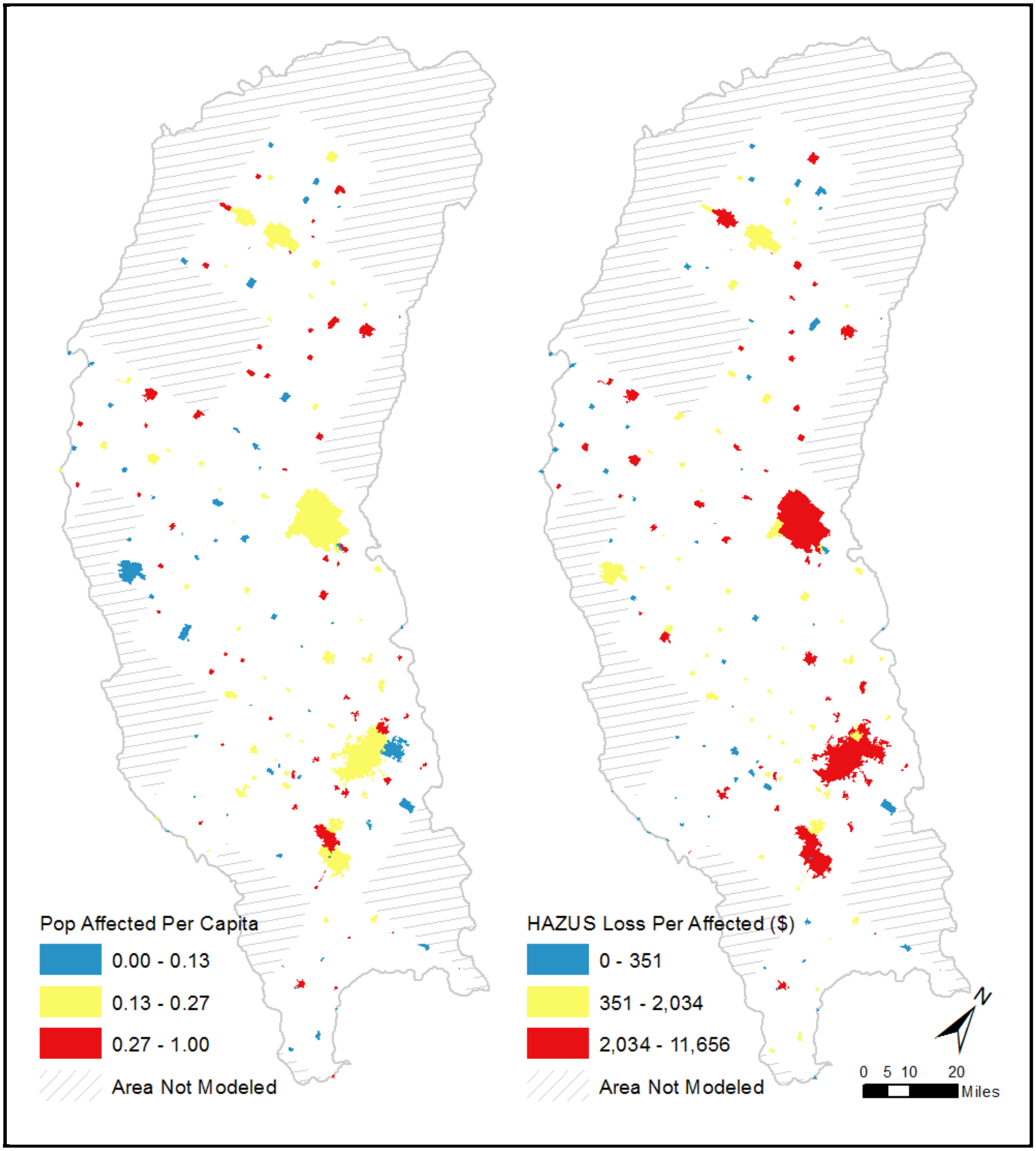


Figure 7. Population Affected Per Capita and Structural Loss Per Affected
(Note. Colors divide the communities into the top, middle, and bottom third for each respective map)

2. Future Flood Risk. The majority of the information collected to frame the level of future flood risk is qualitative and simply provides some understanding to what extent a community has been proactive in developing comprehensive plans or other land management strategies for how their communities will develop into the future. Some of this qualitative information that may assist in understanding future flood risk is related to whether a community is actively engaged in adoption of ordinances such as a subdivision ordinance, sensitive areas ordinance and storm water management regulations. These types of actions are important components in the Community Rating System (CRS). For example, the sensitive areas ordinance may reflect the amount of natural lands to remain which provide a variety of watershed services (i.e. water quantity, water quality, recreation, habitat and wildlife, etc.). Preserving open space in the floodplain is a practice that scores a significant amount of points in the new CRS guidelines which was recently approved by the Office of Management and Budgets (OMB).

In an effort to gain a basic causal understanding of how future flood risk is likely to change based on landuse changes the pilot team evaluated the existing landuse on a county level and also delineated the landuse based on that inside of the delineated floodplain extent and that outside of the floodplain extent. This information is important because it helps in understanding whether a community is likely to incur changes in flood flows due to upstream landuse changes. Specifically, as land use changes from pasture to row crop or from row crop to urban there is a direct hydrologic change which results in greater runoff to downstream communities.

The spatial location of the various landuse types and land management methods may have a significant impact on the hydrologic processes including the timing and extent of runoff to a stream network. For example, a recent article in the Journal of Water Quality identified that 10% of the watershed area planted with a prairie filter strip at the watershed outlet outperformed 20% of the watershed area planted with a combination of prairie filter strips distributed throughout the watershed (Helmers, 2011). This publication and related articles point out the significance of the floodplain landuse, upland depression areas and tile drainage (Schottler) in their hydrologic impacts on future flood risk.

Figure 8 was created in an effort to better understand the relationship between the total county landuse breakdown and the floodplain landuse breakdown.

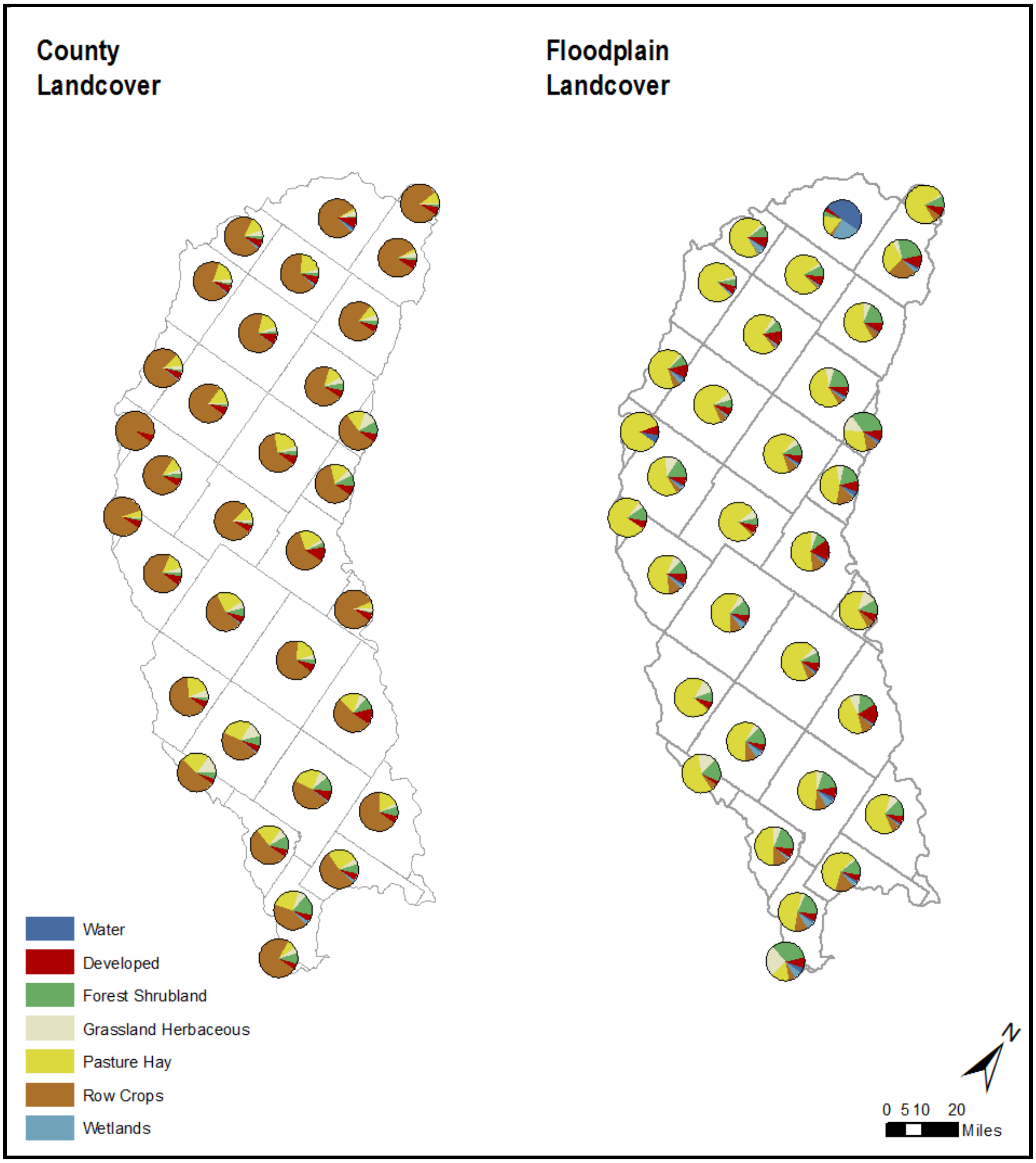


Figure 8. Floodplain Landuse Breakdown by County Within the Iowa-Cedar Watershed Extent

While these landuse maps may lead to some ideas on how a community's flood risk may change in the future it is ideal to have a defined future landuse plan that displays how the landuse is likely to change based on county planning and zoning actions. An example of how to use the existing conditions information along with a future landuse map to communicate current and future flood risk is presented in the next section, *Risk Communication*, which highlights a public engagement process in the Indian Creek watershed basin, IA.

C. Activity #3 – Risk Communication

This activity was intended to effectively disseminate information to stakeholders and decision makers that communicates the impacts of landuse and land management decisions on current and future flood risk. This effort had a unique opportunity to leverage this Silver Jackets pilot with various other interagency efforts culminating in a series of stakeholder driven workshops in the Indian Creek watershed basin. This unique opportunity provided a venue to gain local input and to communicate risk to state and community level decision makers. This facilitated workshop series in Indian Creek was one of the venues that flood risk information was communicated. The Indian Creek workshop was the best case scenario for risk communication because the group of stakeholders was engaged in a workshop series which allowed trust building between the facilitators and participants. This type of engagement cannot be duplicated in a brief presentation to stakeholder groups. However, the Indian Creek effort was highlighted in numerous conferences and workshops to help other stakeholders visualize the process for identifying the current and future flood risk and the potential actions that may be taken to manage that risk.

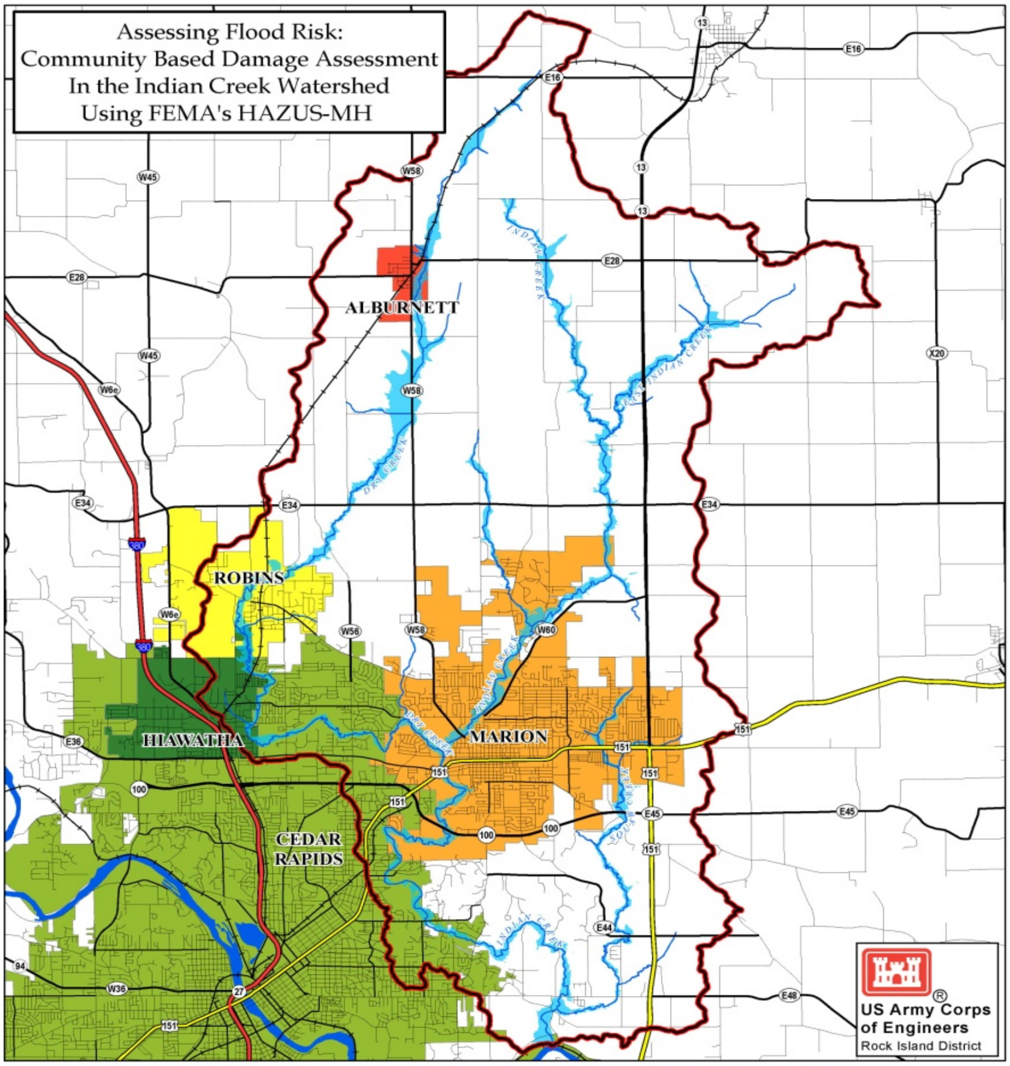
The specific venues that the Indian Creek effort was highlighted include the 2012 National Flood Risk Management Conference in Harrisburg Pennsylvania, the 2013 Iowa Water Conference in Ames Iowa, the Iowa-Cedar Interagency Coordination Team meeting in November 2012 and the River Resources Coordinating Council meeting on February 26, 2013.

In addition to the conferences and workshops that flood risk was communicated, this effort has gained attention from the University of Nebraska and the Institute for Water Resources for the technical merits of the comparative analysis. Communication of risk through the universities and institutes may provide a more robust dissemination of the methods and results then initially anticipated.

The figures developed for the Indian Creek workshop series that were used to display the current and potential future flood risk are presented in figures 9 through 15.

Figure 9 displays current flood risk based on structure loss at a community level as discussed in prior sections. However, this figure was the first HAZUS run completed in the Basin which was based on interpolating elevations based on cross-sections. This method proved to overestimate the depth of flooding in the Basin and therefore the related structural losses. This was especially evident in Alburnett where the cross-sections had significant spacing between them. The HAZUS runs for the whole basin used a more favorable method which defined the elevation for the FIRM floodplain extent from the LIDAR derived digital elevation model (DEM). Although the specific structure loss per capita numbers are higher in this Indian Creek example than those displayed in the Basin wide maps they reaffirm that HAZUS is a screening tool that provides an understanding of which areas justify greater investigation. Similarly, they support the Basin finding that smaller communities, like Alburnett, may have equal or greater flood risk than larger cities on a per capita basis.

Figure 10 was developed by the pilot team to identify current flood risk at a census block level using an area-weighted average method.



Community Name	HAZUS Census Blocks Affected	HAZUS Total Structural Loss	HAZUS Total Population of Affected Blocks	Total Community Population	HAZUS Sturctural Loss Per Capita (In Affected Blocks)	HAZUS Structural Loss Per Capita (Entire Community)
CITY OF ALBURNETT	1	$1,496,000	29	681	$51,586	$2,197
CITY OF CEDAR RAPIDS	14	$14,690,000	1706	127,905	$8,611	$115
CITY OF HIAWATHA	4	$761,000	741	7113	$1,027	$107
CITY OF MARION	48	$21,921,000	2532	35212	$8,658	$623
CITY OF ROBINS	10	$4,204,000	390	8182	$10,779	$514

Notes:
Structural Loss refers to a combination of building and building content damage. This damage was assesed through HAZUS 2.1 using default inventories, valuation parameters and replacement values. Model inputs are as follows: NED 10m elevation grid & 10m Depth grid derived from FEMA cross section & 100yr flood water surface elevations.

Total Structural Loss is an aggregation of census block structural losses that are within the boundaries of each town.

Structural Loss Per Capita (In Affected Blocks) is the total structural loss divided by the population of only the blocks that experienced flood damages.

Structural Loss Per Capita (Entire Community) is the total structural loss divided by the entire population of the community.

Method notes:
HAZUS provides area weighted damage estimates based on the depth of flooding within a given census block. The methodology assumes an even distribution of structures throughout each block.This may lead to generalized results. For more information refer to the HAZUS 2.1 Technical Manual, available online through FEMA.

Legend
▭ Indian Creek Watershed
— Indian Cr. Streams
🟦 Approximate 100yr Flood Extent
Structural Damage Per Capita
🟩 $107
🟩 $115
🟨 $514
🟧 $623
🟥 $2,197

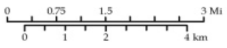
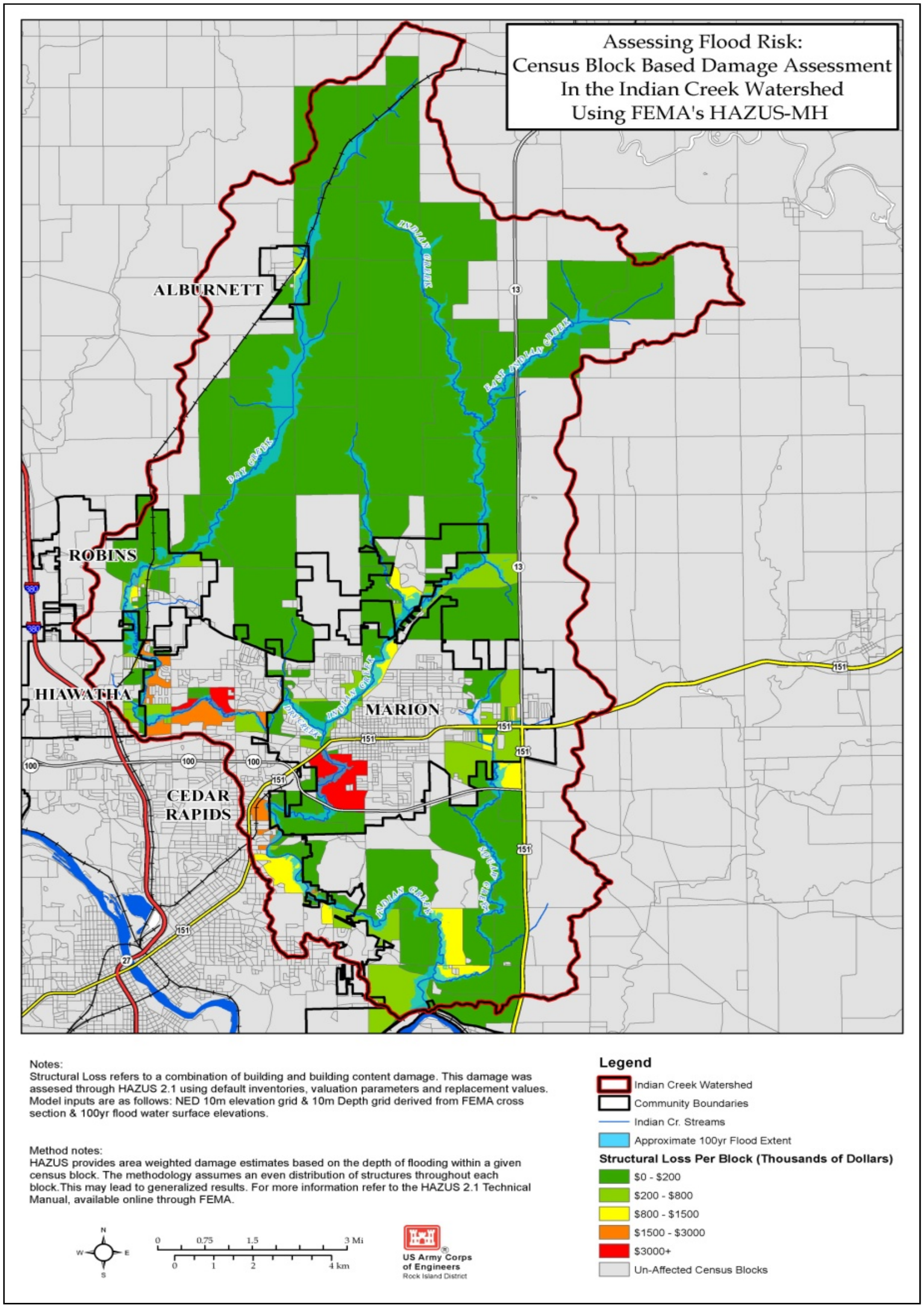


Figure 9. Current Estimated Structural Loss By Community in the Indian Creek Watershed Basin



Notes:
Structural Loss refers to a combination of building and building content damage. This damage was assesed through HAZUS 2.1 using default inventories, valuation parameters and replacement values. Model inputs are as follows: NED 10m elevation grid & 10m Depth grid derived from FEMA cross section & 100yr flood water surface elevations.

Method notes:
HAZUS provides area weighted damage estimates based on the depth of flooding within a given census block. The methodology assumes an even distribution of structures throughout each block.This may lead to generalized results. For more information refer to the HAZUS 2.1 Technical Manual, available online through FEMA.

Legend
- ▭ Indian Creek Watershed
- ▭ Community Boundaries
- — Indian Cr. Streams
- 🟦 Approximate 100yr Flood Extent

Structural Loss Per Block (Thousands of Dollars)
- 🟩 $0 - $200
- 🟩 $200 - $800
- 🟨 $800 - $1500
- 🟧 $1500 - $3000
- 🟥 $3000+
- ⬜ Un-Affected Census Blocks

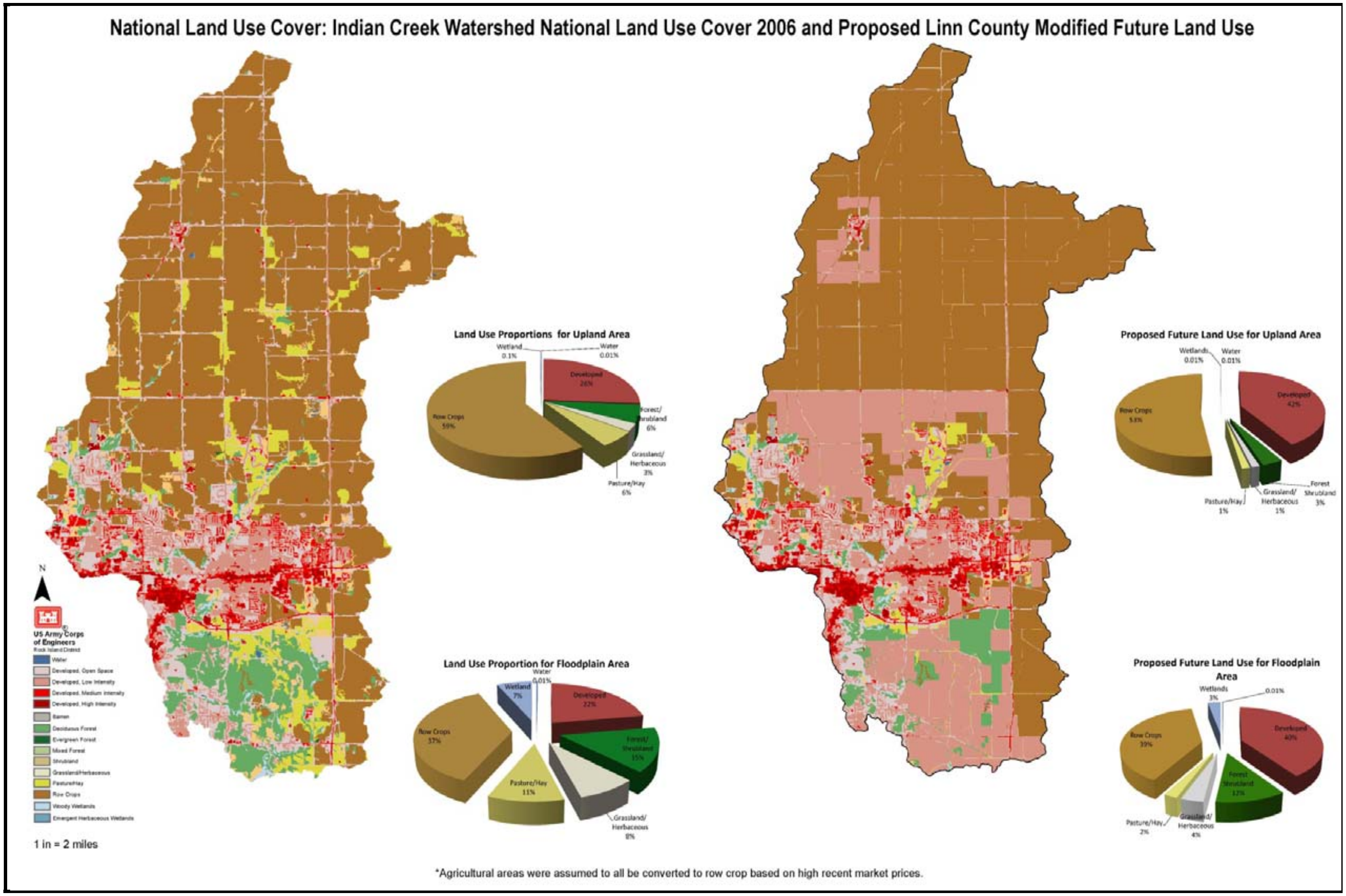
Figure 10. Current Estimated Structural Loss by Census Block in the Indian Creek Watershed Basin

As part of one of the workshops a floodplain management working group provided input concerning the following questions.

- *Who defines the floodplain boundary?*
- *Can a floodplain boundary change?*
- *What are appropriate uses of the floodplain?*
- *What is an acceptable level of flood risk in Indian Creek?*

Participants identified that a floodplain boundary is defined by both physical parameters and political influence, and that the floodplain boundary can change by either influence. Participants offered that appropriate land uses within the floodplain are natural areas, agriculture (minus Confined Animal Feeding Operations), recreational trails, campgrounds and sports fields. Participants indicated that there is an acceptable level of risk for flooding of structures like vending buildings at stadiums and similar low-damage type structures.

After the participants described an acceptable level of flood risk the group was then presented with existing condition information in the form of landuse pie charts displaying the land use inside and outside of the floodplain as defined by the most current FIRM map (Figure D-1). These pie charts helped to frame the amount of the floodplain that is currently developed (22%) and what are the other related floodplain landuses. In order to begin to evaluate the future flood risk for Indian Creek the pilot team obtained the Linn County Rural Landuse Policy Plan (Figure D-2 and http://www.linncounty.org/content.asp?Page_Id=783&Dept_Id=25) which provides a preview of the estimated type of development to occur within the county in the coming years (estimated 2020 build out). The rural land use plan was cross-referenced to the National Land Cover Dataset (NLCD) 2006 land use types to allow for direct comparison between existing and future conditions (Figure 11). By cross-walking these landuse types a direct comparison was able to be made between the current and proposed future land uses within the FIRM defined floodplain boundary.



*Agricultural areas were assumed to all be converted to row crop based on high recent market prices.

Figure 11. Existing and Future Land Use by 2006 NLCD Land Use Types

Participants were surprised that given the number of residences impacted in the 2002 and 2010 flood events that Linn County's land use plan allowed residential or commercial development within the defined floodplain to nearly double from 22 to 40 percent (Figure D-3). As part of this engagement process it was uncovered that Linn County is currently revisiting this landuse plan. The participants were hopeful that it will better reflect their values to not have additional people bear the consequences of flooding in their homes.

While it is clear that landuse development puts more structures at risk for flooding in the defined floodplain boundary it does not address the causal relationship that as more development occurs that the hydrology is altered which may change the extent of the inundation extent resulting from a 1% probability event. This change in inundation extent may redefine the floodplain boundary. In order to address how probability changes may alter the floodplain boundary the stakeholder participants were presented with hydrologic responses for historical, current, and future land uses (Figure D-4) based on the Hydrologic Engineering Center – Hydrologic Modeling System model results (developed for another USACE study effort in Indian Creek - model under review at time of stakeholder workshops so shown as unofficial). The results were displayed on a hydrograph and inundation map to help frame how much land use changes contribute to changes in peak discharges and corresponding inundation extents. The hydrograph results that were displayed are for one moderately large (approximately 4 percent annual exceedance probability (25-yr return period)) storm in August 2009, which many people remember and could relate to easily. The future land use condition (shown as "future build out 2020") was based on Linn County's future land use plan. The pilot team also decided to include a hypothetical 100 percent impervious scenario as a sensitivity analysis. When participants questioned the validity of a 100 percent impervious scenario, one agricultural grower noted that frozen soils can perform as completely impervious to rain and thus this scenario may not be as extreme as some may think.

After the group was provided a sense of the hydrologic response to land use changes, the next step was to add a plausible climate change scenario, CRCM-CGCM3[1]. Figure 12 presented future flood risk by displaying combinations of land use and the climate change scenario together on the same hydrograph.

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[1] More information is available on the climate change evaluation methods in the report titled Climate Modeling and Stakeholder Engagement to Support Adaptation in the Iowa-Cedar Watershed (Smith et al, 2013).

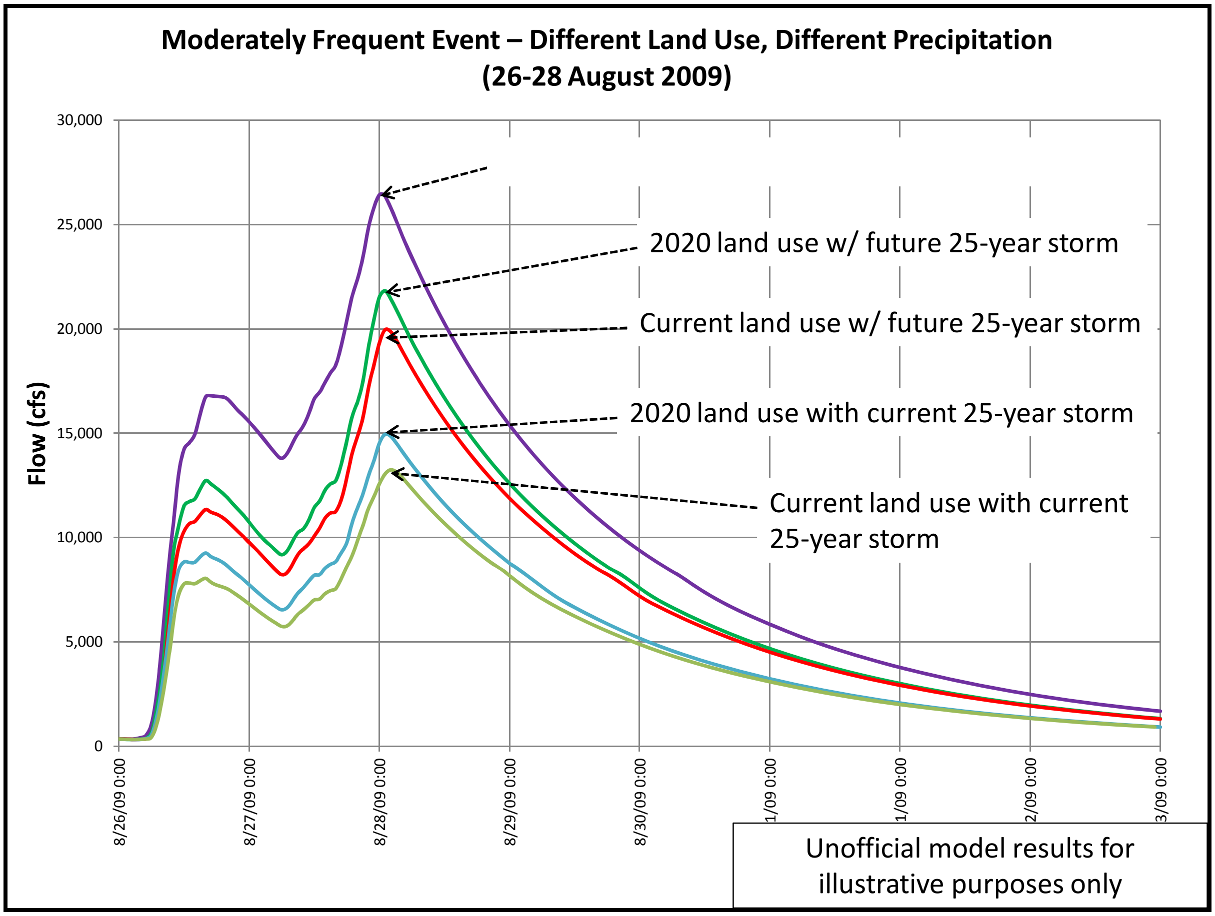


Figure 12. Combined Land Use and Climate Change Scenarios

The hydrographs provided the workshop participants a sense of the order of magnitude of change between the scenarios; however, participants were most interested in knowing what these changes look like on the landscape and how they relate to changes in the floodplain extent. An area in the watershed was selected to display the inundation extent using a recently developed HEC-RAS model (developed for another USACE study in Indian Creek – model under review at time of stakeholder workshops so shown as unofficial). Figures 13 and 14 display potential future flood risk based on changes in inundation extent resulting from a future 25-yr return interval storm under climate change and a 100 percent impervious scenario, respectively.

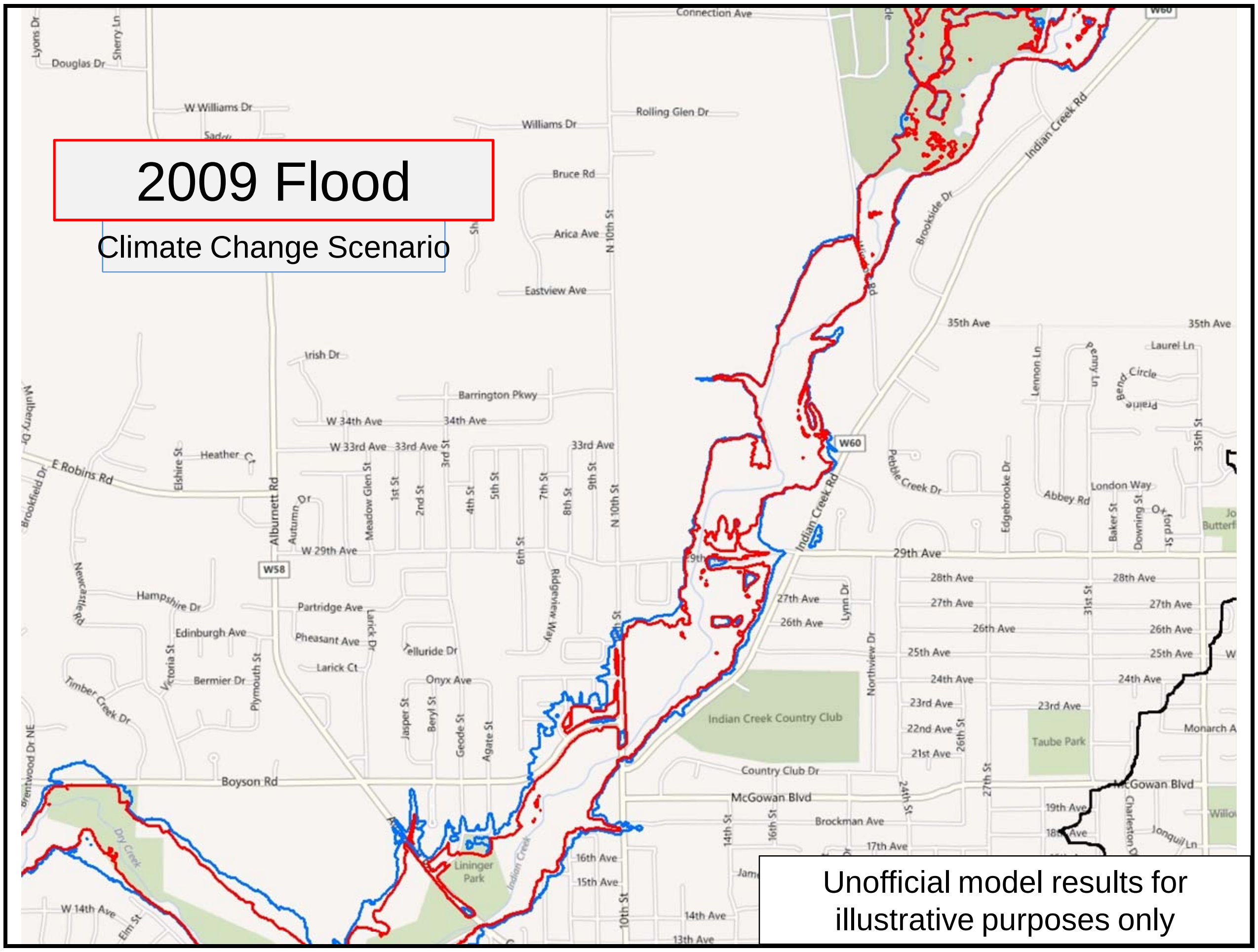
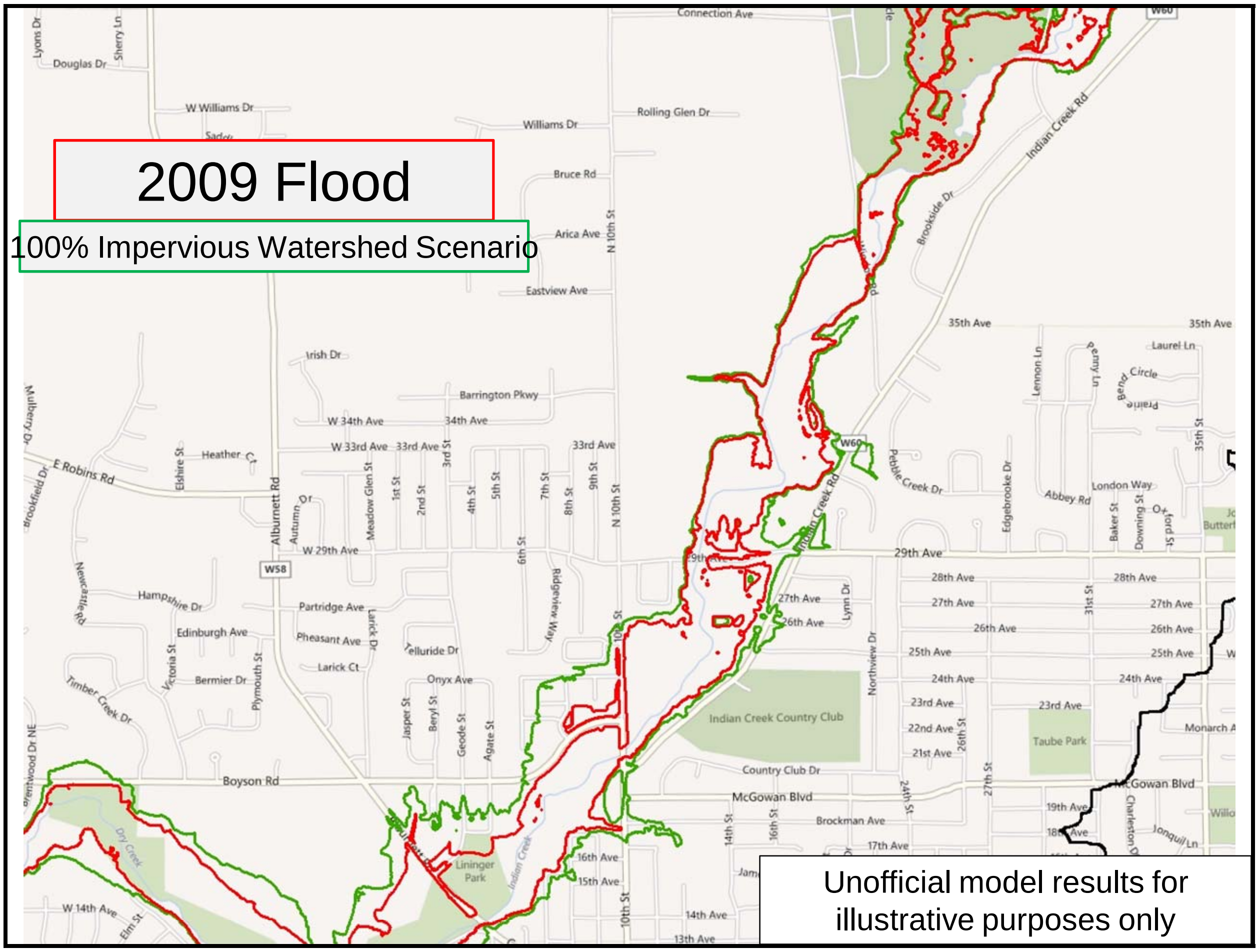


Figure 13. Inundation Extent of Current Land Use With Climate Change Scenario


2009 Flood

100% Impervious Watershed Scenario

Unofficial model results for illustrative purposes only

Figure 14. Inundation Extent of 100% Impervious Watershed Scenario

The workshop participants noted that uncertainties surrounding land use and climate change seem daunting when viewing the data on a hydrograph but that seeing the inundation extent puts in perspective where to leave room for the river.

In an effort to identify tangible actions that may be taken, aerial imagery and GIS data layers were utilized to locate rural and urban locations of concern to discuss potential CRS-type actions that could be taken to manage current and future flood risk. Structural and non-structural measures discussed included outreach and education, zoning and floodplain regulation, upstream impoundments, and levees and detention basins to name a few. Figure 15 displays an urban residential site where CRS structural and non-structural measures were discussed and may be implemented to manage flood risk.

Stream channelized, possible meandering in future. Erosion off construction site.

Figure 15. Potential Location for CRS Measures To Be Applied to Manage Flood Risk

VI. COMPARATIVE ANALYSIS

During this pilot effort, a fundamental question arose concerning how the Corps' traditional method for quantifying structure losses compares with more rapid and less expensive methods such as using FIRM and HAZUS to measure benefits. This section is provided to compare and contrast the different methods examined to delineate the floodplain and estimate economic losses as a means to quantify current and future flood risk. A full description of the techniques used for each method used to delineate the floodplain and estimate economic losses is provided in Appendix B and E, respectively.

A. Comparative Analysis of Floodplain Delineation Methods

This project identified that there are a variety of methods to delineate the floodplain boundary and all of them have varying levels of detail and are useful for certain purposes. The landform method was the broadest floodplain delineation method evaluated. This method was able to fairly accurately estimate the floodplain extent in some locations but in others left substantial gaps in the floodplain boundary and/or expanded to upland areas well beyond the floodplain boundary. Due to the non-contiguous nature of the landform method data it was not possible to identify the right and left banklines without additional quality control which is too time consuming and lacks accuracy for a basin of this spatial extent. Without clearly delineated banklines to estimate the flood profile it was not possible at this time to generate a meaningful depth grid for use in HAZUS.

There were two techniques used with the FIRM inundation extents and HAZUS economic data, each having inherent uncertainty. Both methods used the LIDAR derived a DEM to identify the elevations associated with the FIRM map. The first method used the DEM for the cross-sections designated in the FIRM map and interpolated elevations between the cross-sections. The second method used the DEM to assign elevations for numerous points along the inundation lines demarcated on the FIRM map. Both methods resulted in inaccuracies associated with a tilted Water Surface Elevation (WSE) which impacted the depth grid that was generated and the resulting economics. The cross-section technique has a greater risk of inaccurately capturing the flood depth, especially in those areas that have widely spaced cross-sections due to interpolation between data points.

Assigning elevations to an inundation line may reduce the amount of error caused by interpolation but still is vulnerable to error considering that slight changes in the horizontal position of the edge of the floodplain extent may affect the elevation value that gets assigned to the edge of water. In Figure 16, notice how a slight left to right shift of the edge of water causes the derived WSE to change. The effect of this type of shift on the WSE depends on the shape of the underlying terrain. On the left side of Figure 16, a given rightward horizontal shift causes the WSE to decrease, while a rightward horizontal shift of an equal amount on the right side of Figure 16 causes the WSE to increase. It is also important to notice that when the underlying terrain is steeply sloping (as on the left side of Figure 16), error in the horizontal position of the edge of water will cause greater error in the WSE estimate than in areas where the terrain is less steeply sloping (as on the right side of Figure 16).

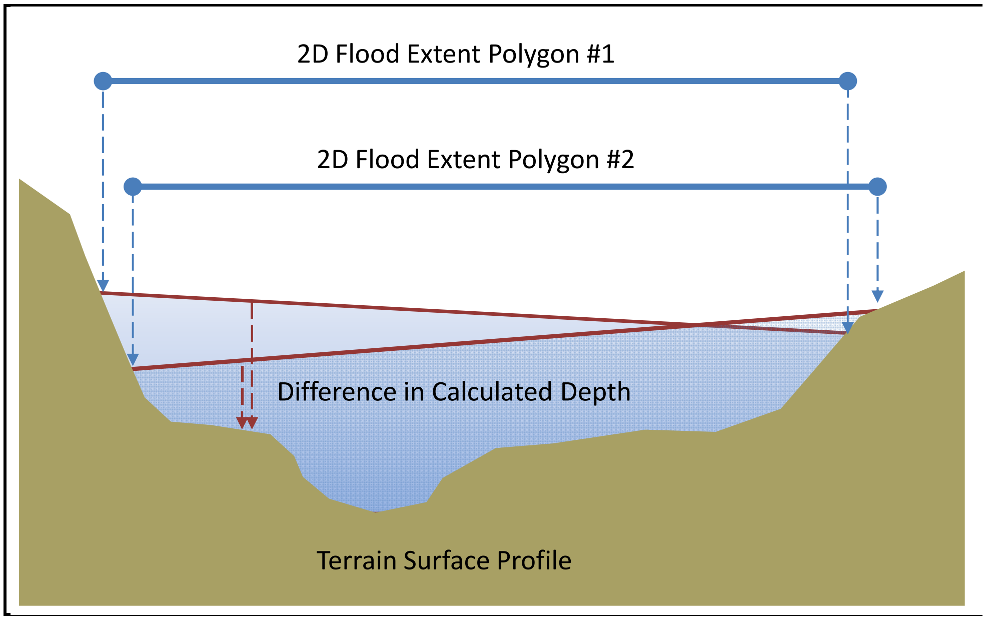


Figure 16. Differences in Flood Extent Boundaries Translate Into Different Derived Depths

Although slight horizontal position errors in floodplain extent boundaries have little impact on area flooded, they can have a profound effect on derived depths of flooding, especially in high slope areas.

Figure 17 displays the depth grid associated with this undulating WSE, where a cross-section between points A and B may tilt or vary as much as 15 meters in depth. Close examination of this area reveals several other examples of under and over estimation of water surface elevation and their related depths.

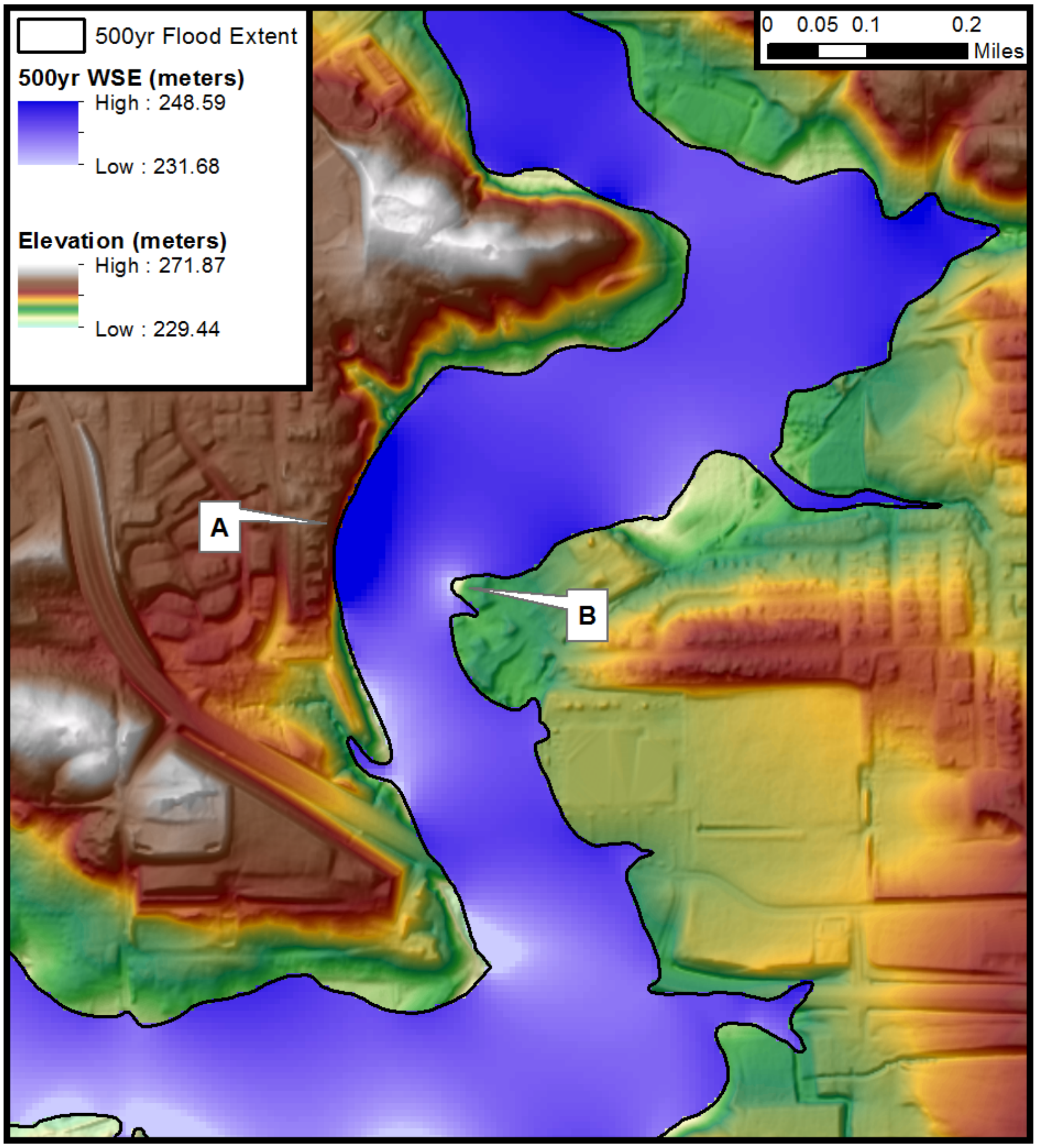


Figure 17. Derived 500-yr Water Surface Elevation Over Digital Elevation Model (undulation of WSE is extremely marked between points A and B. Location: Indian Creek, Cedar Rapids, IA.)

Considering that much of the study area is not steeply sloping, error in depths are expected to be low and concentrated in high slope areas. However, error in depth estimates was of particular interest in this study since depth of flooding is a primary input to HAZUS in the calculation of structure losses.

B. Accuracy Assessment of Economic Methods

HAZUS can be used to generate flood loss estimates over a large region which raises the question of how HAZUS compares with more detailed (and more costly) site level flood loss estimation techniques. In order to address this question, an accuracy assessment was conducted to gauge the validity of the HAZUS estimates. To determine the accuracy of HAZUS estimates, HAZUS structure loss estimates were compared to a detailed economic and hydrologic analysis performed by the US Army USACE of Engineers, Rock Island District for Cedar Rapids, Iowa (USACE, 2011).

The USACE method utilized a well-vetted, standard methodology for determining economic structure losses due to flooding using detailed hydraulic and hydrologic models for given flood frequencies and performing detailed structure inventory surveys to determine structure values for the purpose of performing benefit-cost analysis. While the USACE methods are well accepted and produce valid results, they are not quick or inexpensive and because they are localized they are not scalable to the regional level. Figure 18 displays the economic reaches evaluated in the USACE Cedar Rapids study which were used for statistical comparison with the HAZUS flood loss estimates.

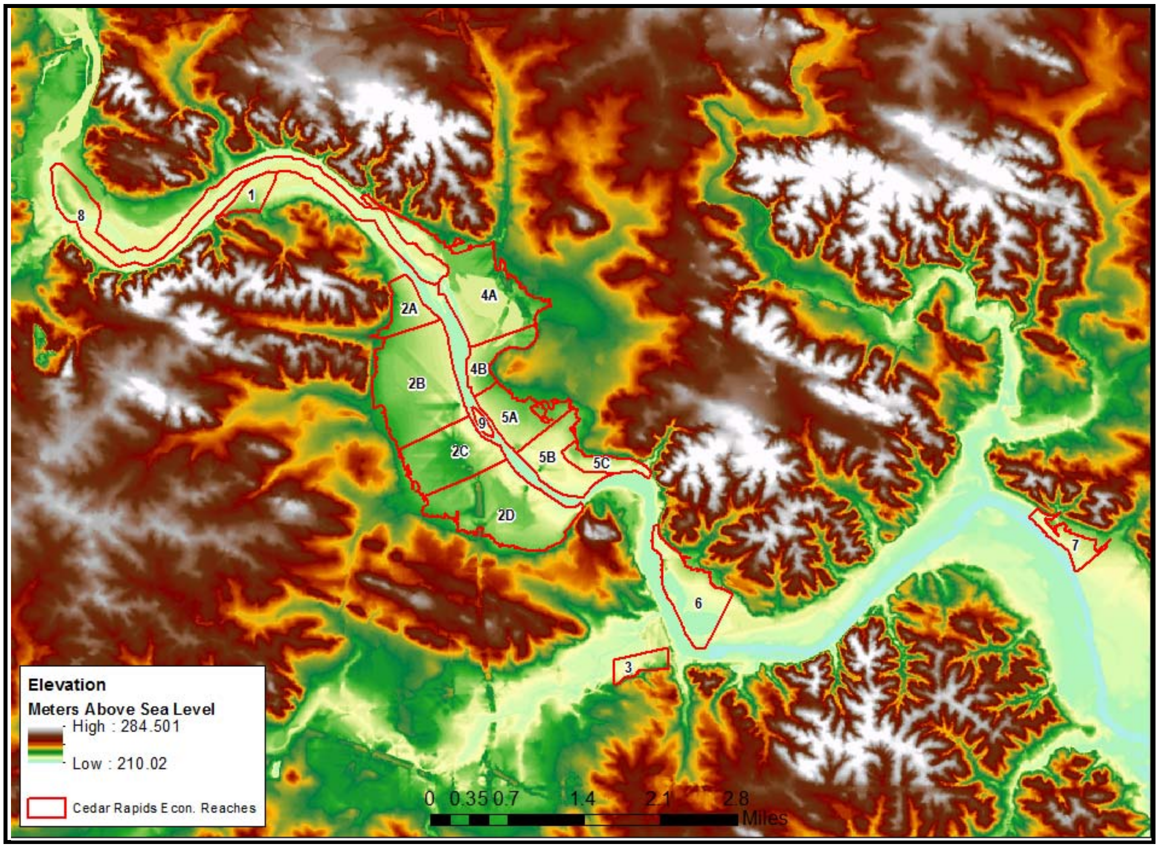


Figure 18. USACE Cedar Rapids Study Economic Reaches

The hydrologic and hydraulic modeling work conducted in support of the 2011 Cedar Rapids feasibility study resulted in a WSE for the 500-yr flood frequency event that was higher than that identified in the most current FIRM map for this area. Therefore, the first task in the statistical comparison was to determine if HAZUS can generate economic loss estimates similar to the detailed USACE method using the same flood depths (USACE derived WSE depths). The second task in the statistical comparison was intended to measure the performance of a more real-world scenario. Determine how well HAZUS loss estimates compare to the detailed USACE method while using off-the-shelf (OTS) DFIRM flood extents to generate flood depths. This is an attractive option since it uses OTS flood extents and OTS flood loss software (HAZUS), allowing large regions to be analyzed cost-effectively.

Task 1. Can the HAZUS method approximate the detailed USACE method loss estimates?
To determine if HAZUS can generate economic loss estimates similar to the detailed USACE method while using the same flood depths, HAZUS was run using the flood depth grid generated for the Cedar Rapids Study and results were summarized by the economic reaches identified in Figure 18. A scatter plot was developed to compare the two methods. The scatter plot demonstrated that HAZUS is consistently underestimating flood losses when compared to the detailed USACE method. See Appendix E, *Accuracy Assessment of HAZUS Flood Loss Estimate* to view the scatter plot.

To explore if there was a statistical relationship, a regression analysis was performed to measure the ability of the HAZUS method to predict the USACE method flood loss estimates. In this model, the detailed USACE economic loss method served as the dependent variable and the HAZUS economic loss method served as the independent variable (Figure 19). The HAZUS method was able to predict 37% of the variation in the USACE method flood loss estimates. Although the HAZUS estimates were consistently low, the regression analysis was able to adjust the estimates for most economic reaches, except for three outliers (economic reaches 4B, 5C, and 3).

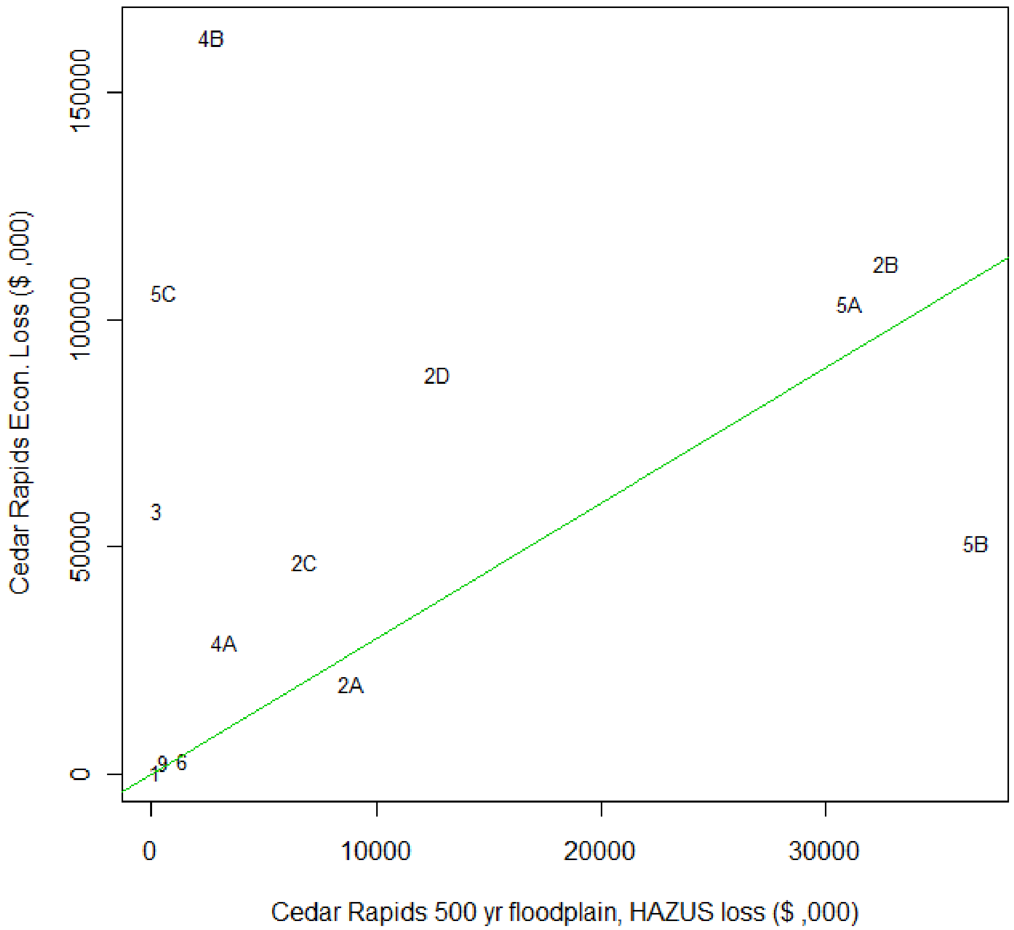


Figure 19. Regression Analysis of HAZUS/Cedar Rapids 500-yr and Detailed USACE Loss

This analysis uses the same detailed 500-yr flood depths for both economic loss methods (detailed USACE on Y-axis, HAZUS on X-axis) to focus on the difference between the economic loss methods while holding the flood depths constant. $R^2 = 0.37$, F = 8.66 (1 and 12 DF), p-value = 0.01, n = 13. Plot labels represent economic reaches.

Task 2. Determine how well HAZUS loss estimates compare to the detailed USACE method while using off-the-shelf FIRM flood extents to generate flood depths. A similar regression analysis (through the origin) was performed on the HAZUS results produced using the FIRM 500-yr inundation extent. In this model the detailed USACE economic loss method served as the dependent variable and the HAZUS (FIRM) economic loss method served as the independent variable (Figure 20). The HAZUS (FIRM) method was able to predict 45% of the variation in the USACE method flood loss estimates. Although the HAZUS (FIRM) estimates were consistently low, the regression analysis was able to adjust the estimates for most economic reaches, except for three outliers (economic reaches 4B, 5C, and 3).

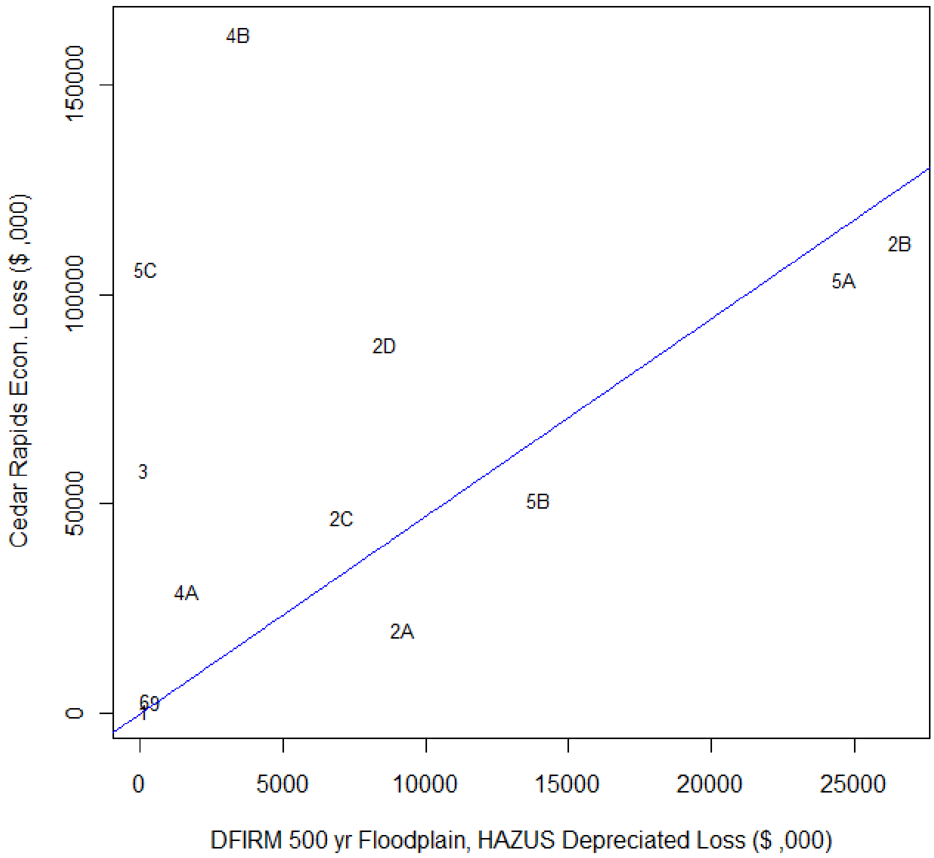


Figure 20. Regression Analysis of HAZUS/DFIRM Method and Detailed USACE Loss

This analysis tests how well HAZUS using DFIRM derived 500-yr flood depths can predict detailed USACE flood losses (detailed USACE on Y-axis, HAZUS/DFIRM on X-axis). $R^2 = 0.45$, $F = 11.64$ (1 and 12 DF), p-value = 0.005, $n = 13$, $\beta_1 = 4.708$, S.E. = 1.38. Plot labels represent economic reaches.

C. Sources of Error

The prior section regression analysis highlights that although HAZUS is generally underestimating flood losses when compared to the detailed USACE method, three economic reaches were substantially underestimated (economic reaches 4B, 5C, and 3). Upon close examination of these economic reaches, it was determined that these three economic reaches were all characterized by being almost exclusively industrial (Figure 21). All three economic reaches are dominated by a single industrial facility. Two other underestimated economic reaches (2D and 4A), although not dominated by a single industrial facility, contain a high proportion of industrial facilities. It is believed that this "industrial error" is due to the method in which HAZUS proportions structure values by economic sector, although further investigation is required. Regardless of the exact mechanism, HAZUS is clearly not adequately accounting for industrial facility values in its default configuration. Using level 2 features in HAZUS may allow for a user to input economic loss information for these industrial areas to improve that results.

Figure 21. Industrial Error. 4B – Quaker Oats/Pepsico

D. Analysis Conclusions

Although the sample size used in the study is extremely small, the findings suggest that use of HAZUS with DFIRM derived flood depth are promising for generating regional flood loss estimates. However, this study's use of the default Level 1 HAZUS approach indicates that several refinements are necessary to prevent generating flood loss estimates that are substantially lower than expected when compared to the better vetted and more detailed USACE methodology. The next logical step would be to assemble a larger sample of high quality economic loss estimates against which HAZUS estimates can be tested to determine if the findings of this study can be replicated.

This study points to the need to shift from HAZUS Level 1 analysis (default settings) to Level 2 analysis (more localized input data) to improve the quality of flood loss estimates. Use of HAZUS "significant structures" to capture the value of high value facilities should serve as a cost effective method of removing the greatest source of error identified in this small study. The second most cost effective source of error to remove would likely be replacing regional depth damage functions with more localized functions if available.

VII. CONCLUSIONS

This project has successfully developed a central database of local, state and federal data which describes flood risk for the Iowa-Cedar watershed basin. Technical evaluation and quantification of the existing flood risk identified that floodplain management may require a two pronged approach. This two pronged approach may consist of actions to lower overall flood risk potential in large communities and take actions to lower flood risk per capita in smaller communities. Actions that may be considered for lowering overall flood risk for larger communities may include both non-structural and structural measures.

Non-structural measures may include evaluating the up-stream landuse and determining if up-stream landuse change may make an appreciable change on the flood profile in order to lower flood risk or at least provide some additional resiliency. Other non-structural measures to be considered may include structure buy-outs and adoption of floodplain ordinances to assure future development accounts for the "potential" future conditions (floodplain extent) with regard to landuse and climate changes. Structural measures that may be considered include the use of berms, levees and floodwalls to provide a physical barrier to flood pulses.

This project identified that there are a variety of methods to delineate the floodplain boundary and all of them have varying levels of detail and are useful for certain purposes. The landform floodplain delineation method was the broadest floodplain delineation method evaluated. This method was able to accurately estimate the floodplain extent in some locations but in others left substantial gaps in the floodplain boundary and/or expanded to upland areas well beyond the floodplain boundary. This method was determined to be unable to generate a reasonable depth grid based without significant manual data correction. FEMA FIRM maps were used as the gauge for the accuracy of the landform method. Evaluation of the digital FIRM maps identified minor inconsistencies with the right and left bank water surface elevation. This inconsistency is likely due to the resolution of the topographic data used to develop the inundation extent and possibly also because the inundation boundaries are often smoothed to be more visually appealing for mapping purposes. Inconsistencies in the water surface elevation may have minor to major impacts on estimates of economic losses.

Potential economic losses (Structure loss) associated with flooding were estimated using the FEMA HAZUS computer program. The HAZUS program outputs along with an area weighted average approach effectively identified areas with high, moderate and low potential for economic impacts due to structure loss. This tool was determined to be an effective tool for screening a watershed to see which census blocks and/or communities have the greatest potential flood risk. While the area weighted average method may overestimate the amount of infrastructure in the floodplain boundary, this method is valuable in helping to screen where the greatest potential for losses may occur if the floodplain inundation changes due to climate and/or landuse changes.

The structure losses associated with the HAZUS area weighted average method was compared to the landform method (assuming total loss of structure) and a recently completed USACE HEC-FDA method for Cedar Rapids, IA. The landform method did not have a correlation with economic losses and thus was not highlighted in detail in the report or technical appendices. The HAZUS and HEC-FDA comparison concluded that the HAZUS area weighted average is consistently underestimating structure losses, especially in areas with large industrial facilities. However, because HAZUS is consistently underestimating structure loss it was determined that HAZUS is an effective screening tool for determining areas of high, moderate and low flood risk.

Although the sample size used in the study is extremely small, the findings suggest that use of HAZUS with DFIRM derived flood depth are promising for generating regional flood loss estimates. However, this study's use of the default Level 1 HAZUS approach indicates that several refinements are necessary to prevent generating flood loss estimates that are substantially lower than expected when compared to the better vetted and more detailed USACE methodology. The next logical step would be to assemble a larger sample of high quality economic loss estimates against which HAZUS estimates can be tested to determine if the findings of this study can be replicated. Note that this recommendation is consistent with an IWR/NIWR pilot effort underway with the University of Nebraska.

This study points to the need to shift from HAZUS Level 1 analysis (default settings) to Level 2 analysis (more localized input data) to improve the quality of flood loss estimates. Use of HAZUS “significant structures” to capture the value of high value facilities should serve as a cost effective method of removing the greatest source of error identified in this small study. The second most cost effective source of error to remove would likely be replacing regional depth damage functions with more localized functions if available.

VIII. LESSONS LEARNED

Lessons learned from this study cross the spectrum from technical evaluation to human behavior. The following bullet points identify many of the lessons learned:

- Some small communities stated they are promoting development in their floodplain areas because these areas are the most desirable land for development. These small rural communities are in need of the economic boost from residential, commercial and industrial taxation. The extent to which this is occurring is not fully understood or documented but is a consideration in accounting for future flood risk.
- Some communities are not recognized by FEMA in the community address book as either participating or not participating in the NFIP.
- There are very few communities in the Iowa-Cedar Watershed Basin that are adopting floodplain ordinances more strict then the NFIP minimum, have developed future landuse plans and developed hazard mitigation plans.
- The landform floodplain delineation method may be improved by manually eliminating upland areas and the connecting gaps in the floodplain boundary where appropriate.
- Structure loss and population at risk estimates are effective communication tools in a formal stakeholder engagement process.
- HAZUS is an effective screening tool to identify areas with potentially high, moderate and low flood risk (structure loss and population at risk) at a census and community level
- HAZUS structure loss estimates may be improved utilizing level 2 features such as, manually inputting structure value data for large industrial complexes and replacing regional depth damage functions with more localized functions if available.
- Evaluation of a section of stream in the Indian Creek basin uncovered that there were significant differences in water depths associated with interpolating cross-sections versus assigning LIDAR derived elevations along the inundation line. These differences in depth resulted in significant differences in estimated structure losses in HAZUS, especially in areas where cross-sections are far apart.

- HAZUS area-weighted average structure loss estimates may be improved by clipping out the water/floodway from the census blocks areas.
- There are relatively few communities that have high flood risk based on total structure loss and total population at risk. These high risk areas are primarily in large urban areas.
- There are numerous small and medium sized communities that have high flood risk based on structure loss per capita and population at risk per capita. Some communities have greater than 27% of their population residing within the defined floodplain boundary (based on the area weighted average method).

IX. REFERENCES

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FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED

An Iowa Silver Jackets Flood Risk Management Team Initiative

APPENDIX A

Database Fields and Abbreviated Database

Floodplain Management and Communication
of Risk in the Iowa-Cedar Watershed Basin

An Iowa Silver Jackets
Flood Risk Management Team Initiative

Appendix A
Database Fields and Abbreviated Database

DEMOGRAPHIC INFORMATION														
Community Name	**County**	**State**	**FIPS Number**	**HUC Code**	**HUC Name**	**Acres**	**Population 2010**	**Point of Contact Info**	**Responded**	**FEMA Recognized**	**FEMA CID**	**nfip_status**	**date_mapped**	**Rec'd NFIP Payments**
Ackley	Hardin	IA	1900190	7080205	Middle Cedar	1543593	1589	Removed for Report	Y	Y	190386	Participating	06/19/12(M)	N
Adams	Mower	MN	2700190	7080201	Upper Cedar	1095020	787	Removed for Report	Y	Y	270308#	Participating	8/15/1979	N
Ainsworth	Washingto	IA	1900730	7080209	Lower IA	1079090	567	Removed for Report	Y	Y	190525	Participating	01/16/13(M)	Y
Albert Lea	Freeborn	MN	2700694	7080202	Shell Rock	691096.8	18016	Removed for Report	Y	Y	270135#	Participating	5/3/1982	N
Albion	Marshall	IA	1900955	7080208	Middle IA	1074325	505	Removed for Report	Y	Y	190542	Participating	11/16/11(M)	N
Alburnett	Linn	IA	1901000	7080206	Lower Cedar	701642.4	673	Removed for Report	Y	Y	190692#	Participating	4/5/2010	N
Alden	Hardin	IA	1901045	7080207	Upper IA	929772.8	787	Removed for Report	Y	Y	190138	Participating	06/19/12(M)	N
Alexander	Franklin	IA	1901090	7080207	Upper IA	929772.8	175	Removed for Report	Y	Y	190387	Non-Participating	12/18/2012	N
Allison	Butler	IA	1901315	7080202	Shell Rock	691096.8	1029	Removed for Report	Y	Y	190544	Non-Participating	9/16/2011	N
Amana	IA	IA	1901720	7080208	Middle IA	1074325	442	Removed for Report	Y	N	N/A	N/A	N/A	N
Aplington	Butler	IA	1902395	7080205	Middle Cedar	1543593	1128	Removed for Report	Y	Y	190335	Participating	09/16/11(M)	N
Aredale	Butler	IA	1902620	7080204	West Fork Cedar	548397.1	74	Removed for Report	Y	Y	190035	Participating	09/16/11(M)	Y
Atalissa	Muscatine	IA	1903385	7080206	Lower Cedar	701642.4	311	Removed for Report	Y	Y	190211	Participating	NSFHA	N
Atkins	Benton	IA	1903475	7080205	Middle Cedar	1543593	1670	Removed for Report	Y	Y	190548#	Participating	6/3/2008	N
Austin	Mower	MN	2702908	7080201	Upper Cedar	1095020	24718	Removed for Report	Y	Y	275228#	Participating	8/18/1992	N
Barnes City	Mahaska	IA	1904555	7080209	Lower IA	1079090	176	Removed for Report	Y	N	N/A	N/A	N/A	N
Bassett	Chickasaw	IA	1904780	7080201	Upper Cedar	1095020	66	Removed for Report	Y	Y	190957#	Non-Participating	9/28/2012	N
Beaman	Grundy	IA	1905140	7080205	Middle Cedar	1543593	191	Removed for Report	Y	Y	190400#	Participating	10/19/2005	N
Belle Plaine	Benton	IA	1905590	7080208	Middle IA	1074325	2534	Removed for Report	Y	Y	190015#	Participating	06/03/08(M)	N
Belmond	Wright	IA	1905680	7080207	Upper IA	929772.8	2376	Removed for Report	Y	Y	190303	Participating	03/01/11(L)	N
Bennett	Cedar	IA	1905770	7080206	Lower Cedar	701642.4	405	Removed for Report	Y	Y	190051	Participating	09/04/85(M)	N
Bertram	Linn	IA	1906175	7080206	Lower Cedar	701642.4	294	Removed for Report	Y	Y	190438A	Participating	4/5/2010	N
Blairsburg	Hamilton	IA	1906760	7080207	Upper IA	929772.8	215	Removed for Report	Y	N	N/A	N/A	N/A	N
Blairstown	Benton	IA	1906805	7080205	Middle Cedar	1543593	692	Removed for Report	Y	Y	190320#	Participating	6/3/2008	N
Blooming Prairie	Steele	MN	2706580	7080201	Upper Cedar	1095020	1996	Removed for Report	Y	N	N/A	N/A	N/A	N
Bolan	Worth	IA	1907255	7080201	Upper Cedar	1095020	33	Removed for Report	N	N	N/A	N/A	N/A	N
Bradford	Franklin	IA	1908020	7080204	West Fork Cedar	548397.1	99	Removed for Report	N	N	N/A	N/A	N/A	N
Brandon	Buchanan	IA	1908155	7080205	Middle Cedar	1543593	309	Removed for Report	Y	Y	190328#	Participating	7/16/2008	N

PROACTIVE PLANNING

Community Name	Developed Comp Plan	Comp Plan URL	Adopted Ordinances Above NFIP Minimum	Developed Hazard Mitigation Plan	Developed Future Land Use Map	Future Land Use Map URL	% of Future LU Plan Currently Developed
Ackley	N	N	N	N	U	U	U
Adams	N	N	N	N	N	N	U
Ainsworth	N	N	N	N	N	N	U
Albert Lea	Y	N	N	N	U	U	U
Albion	N	N	N	N	N	N	U
Alburnett	Y	N	N	N	U	U	U
Alden	N	N	N	N	N	N	80
Alexander	N	N	N	N	N	N	U
Allison	N	N	N	Y	U	U	U
Amana	Y	N	N	N	N	N	100
Aplington	N	N	N	Y	N	N	U
Aredale	N	N	N	Y	N	N	U
Atalissa	U	N	N	Y	U	U	U
Atkins	N	N	N	Y	N	N	U
Austin	Y	N	N	N	U	U	U
Barnes City	N	N		N	N	N	U
Bassett	N	N	N	N	N	N	U
Beaman	N	N	N	N	N	N	U
Belle Plaine	Y	N	N	Y	U	U	80
Belmond	Y	N	N	Y	U	U	U
Bennett	N	N	N	Y	N	N	U
Bertram	N	N	N	N	N	N	U
Blairsburg	N	N		N	N	N	U
Blairstown	N	N	N	Y	N	N	U
Blooming Prairie	Y	N	N	N	U	U	U
Bolan	U	N	N	N	U	U	U
Bradford	U	N	N	N	U	U	U
Brandon	N	N	N	N	N	N	U

REGULATORY

Community Name	Adopted Model Floodplain Ordinance	Adopted Restricted Residence Ordinance	Active Planning Commission	Adopted Subdivision Ordinance	Adopted Two Mile Agreement	Adopted Stormwater Mgmt Ordinance	Adopted Sensitive Areas Ordinance	Adopted Wetlands Ordinance	Adopted Steep Slopes Ordinance	Adopted Wildlife Ordinance	Adopted Building Codes	Building Code Types	Building Code Name	Adopted Electrical Code	Electrical Code Name	Adopted Plumbing Code	Plumbing Code Name	Adopted Mechanical Code	Mechanical Code Name	Adopted Fire Code	Fire Code Name
Ackley	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Adams	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Ainsworth	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Albert Lea	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Albion	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Alburnett	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Alden	Y	U	Y	N	U	Y	Y	U	U	U	Y	U	2009	U	U	U	U	U	U	U	U
Alexander	U	U	U	N	U	N	N	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Allison	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Amana	N	U	Y	Y	U	N	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Aplington	N	U	U	U	U	U	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Aredale	N	U	U	U	U	U	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Atalissa	N	U	U	U	U	U	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Atkins	N	U	U	U	U	U	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Austin	N	U	U	U	U	U	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Barnes City	N	U	U	N	U	N	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Bassett	N	U	N	N	U	N	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Beaman	N	U	U	U	U	N	N	N	N	N	U	U	U	U	U	U	U	U	U	U	U
Belle Plaine	Y	U	Y	Y	U	Y	Y	U	U	U	Y	U	State	U	U	U	U	U	U	U	U
Belmond	Y	U	U	U	U	U	Y	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Bennett	U	U	N	Y	U	N	N	U	U	U	Y	U	State	U	U	U	U	U	U	U	U
Bertram	Y	U	Y	N	U	Y	Y	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Blairsburg	U	U	U	U	U	U	N	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Blairstown	Y	U	N	N	U	N	Y	U	U	U	Y	U	State	U	U	U	U	U	U	U	U
Blooming Prairie	U	U	U	Y	U	N	N	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Bolan	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Bradford	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U	U
Brandon	Y	U	U	U	U	U	Y	U	U	U	U	U	U	U	U	U	U	U	U	U	U

QUANTITATIVE FLOOD RISK										
Community Name	**Acres in 100/500yr Floodplain**	**Population Affected 100/500yr Floodplain**	**Population Affected 100/500yr Per Capita**	**HAZUS_Structure ContentLoss (000's)**	**Loss Per Capita (Community)**	**Loss Per Capita (Affected)**	**Flood Frequency**	**Total Area (sq mi)**	**% of Community in the Floodplain**	**% of Community Upland**
Ackley	422	491	31%	$445	$280	$906	100	2.5	27	73
Adams	0	0	0%	$0	$0	$0	No FIRM	1.0	0	100
Ainsworth	0	0	0%	$0	$0	$0	No FIRM	0.4	0	100
Albert Lea	0	0	0%	$0	$0	$0	No FIRM	12.5	0	100
Albion	1	0	0%	$0	$0	$0	100	0.6	0	100
Alburnett	95	287	43%	$235	$348	$817	500	0.8	17	83
Alden	134	120	15%	$269	$342	$2,242	100	1.7	29	71
Alexander	0	0	0%	$0	$0	$0	No FIRM	4.3	0	100
Allison	9	6	1%	$3	$3	$495	100	2.9	6	94
Amana	176	145	33%	$1,497	$3,386	$10,322	100	1.1	22	78
Aplington	29	84	7%	$76	$67	$906	100	0.8	9	91
Aredale	225	44	59%	$90	$1,223	$2,056	100	1.0	14	86
Atalissa	65	258	83%	$2,629	$8,454	$10,191	100	0.1	75	25
Atkins	65	231	14%	$352	$211	$1,522	100	1.1	9	91
Austin	0	0	0%	$0	$0	$0	No FIRM	10.8	0	100
Barnes City	0	0	0%	$0	$0	$0	100	0.6	0	100
Bassett	0	0	0%	$0	$0	$0	No FIRM	0.4	0	100
Beaman	29	12	6%	$23	$120	$1,917	100	0.2	6	94
Belle Plaine	183	651	26%	$809	$319	$1,243	100	3.2	22	78
Belmond	0	0	0%	$0	$0	$0	No FIRM	2.8	0	100
Bennett	0	0	0%	$0	$0	$0	No FIRM	0.2	0	100
Bertram	250	250	85%	$691	$2,352	$2,765	500	1.7	5	95
Blairsburg	0	0	0%	$0	$0	$0	100	0.6	0	100
Blairstown	28	202	29%	$410	$593	$2,031	100	0.5	10	90
Blooming Prairie	0	0	0%	$0	$0	$0	No FIRM	1.4	0	100
Bolan	130	14	42%	$1	$27	$63	100	2.9	2	98
Bradford	0	0	0%	$0	$0	$0	No FIRM	0.6	0	100
Brandon	38	75	24%	$105	$340	$1,400	100	0.3	8	92

FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED

An Iowa Silver Jackets Flood Risk Management Team Initiative

APPENDIX B

Floodplain Delineation and Flood Loss Estimation Using HAZUS

Floodplain Management and Communication
of Risk in the Iowa-Cedar Watershed Basin

An Iowa Silver Jackets
Flood Risk Management Team Initiative

Appendix B
Floodplain Delineation and Flood Loss Estimation Using HAZUS

I. INTRODUCTION

Estimating flood risk using HAZUS requires the input of a water depth grid. Water depth is the key piece of data used by HAZUS to calculate flood loss. These water depth grids can be generated from flood extent polygons such as those found in FEMA's DFIRM dataset. Unfortunately, there is not yet nationwide coverage of DFIRM data and it will take several years before complete coverage exists.[2] To delineate floodplains where DFIRM data does not yet exist, this study evaluated the use of NRCS's Soil Survey Geographic Database (SSURGO) which contains a landform attribute that has several floodplain classes which were used to identify floodplain soil map units. These floodplain soil map units were compared with DFIRM floodplain extents to determine if the SSURGO derived floodplain could be used in areas where DFIRM data did not yet exist.

II. GENERATING DEPTH GRIDS FROM FLOOD EXTENTS

FEMA's DFIRM dataset (distributed as the National Flood Hazard Layer,) contains a feature class called Flood Hazard Area. This polygon delineates the floodplain for various flood frequencies (i.e., 1.0% annual chance, 0.2% annual chance). The rationale for deriving depth grids from these 2D extents is that these floodplain delineations are based on detailed analysis described in county Flood Insurance Studies (FIS) and updated periodically. Although each study invariably becomes out-of-date as hydrologic conditions change, the DFIRM dataset is the authoritative Federal dataset for flood insurance. However, generating depth grids from these floodplain extents is not perfect due to several factors discussed in the following text.

The approach for generating depth grids from DFIRM flood extents is based on a series of relatively simple GIS operations and can be performed using any floodplain extent. These steps, illustrated in Figure B-1, are as follows:

1. From the DFIRM Flood Hazard Area feature class, select polygons that represent the 1.0% (aka 100 year) and 0.2% (aka 500 year) flood hazard area and dissolve into a single multipart polygon feature.[3] Convert the polygon to a polyline.
2. Densify the line to create tightly spaced vertices. These vertices must be spaced closely enough to represent changes in elevation along the floodplain edge.
3. Convert these vertices to points.
4. Using the highest resolution Digital Elevation Model (DEM) available, assign ground elevation values to the points representing the edge of the floodplain. This study used a 3 meter, LIDAR derived DEM.

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[2] To achieve the greatest study area coverage, preliminary DFIRM data was used where available.

[3] Selection of 100 year *and* 500-yr flood hazard areas creates a floodplain extent representing the highest defined flood risk for that area. The 500-yr (0.2% annual chance) flood hazard has not been delineated in most rural areas, typically only being delineated in densely populated urban areas. Rather than exclude the 500-yr areas (in urban areas where most of the population resides), we chose to create a mixed 100/500-yr floodplain for this study. Therefore, this assumption should be recognized and care applied when interpreting results.

5. Create a TIN using the edge of floodplain point elevations. The resulting TIN represents the water surface elevation (WSE) of the 100 year (in rural areas) and 500-yr (in urban areas) flood. The WSE surface is exported as a raster.
6. The WSE raster is subtracted from the DEM to create a depth grid (increasing positive numbers denoting deeper water, increasing negative numbers denoting increasing height above the water surface).

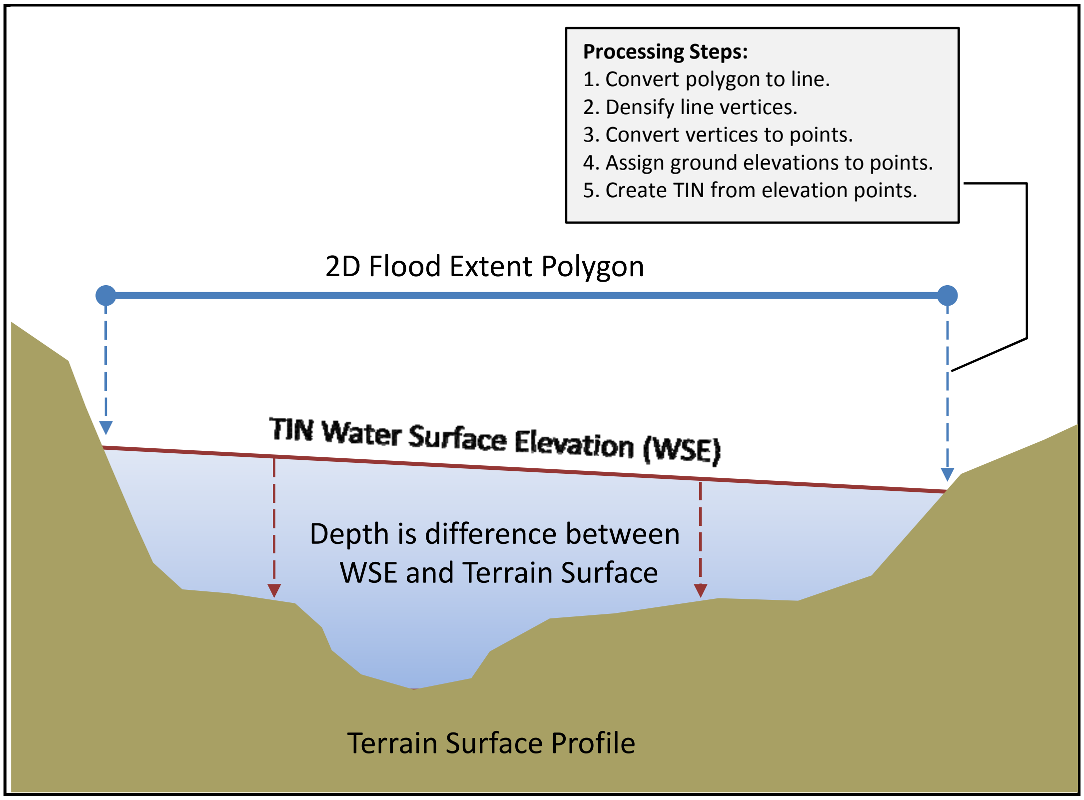

Figure B-1. Method Used to Derive Depths from 2D Flood Extents

Flood extent polygon is converted to points. Elevation values are assigned to those points. A TIN is created from the elevation points to create a water surface elevation raster. The difference between the WSE and terrain is the water depth.

III. POTENTIAL SOURCES OF ERROR IN DERIVED DEPTH GRIDS

Generation of accurate water surfaces and depth calculations depends on how well the floodplain extent polygon correlates to the DEM used in this analysis. Since it is not always known what DEM was used to generate the DFIRM floodplain extents (many older flood insurance studies used topographic data of lower resolution than available today), discrepancies between the floodplain extent and the DEM will be manifest by the creation of a tilted water surface. Figure B-2 illustrates the problem using a simple cross-sectional diagram. Slight changes in the horizontal position of the edge of the floodplain extent affect the elevation value that gets assigned to the edge of water. In Figure B-2, notice how a slight left to right shift of the edge of water causes the derived WSE to change. The effect of this type of shift on the WSE depends on the shape of the underlying terrain. Whereas on the left side of Figure 2, a given rightward horizontal shift causes the WSE to decrease, a rightward horizontal shift of an equal amount on the right side of Figure 2 causes the WSE to increase. It is also important to notice that when the underlying terrain is steeply sloping (as on the left side of Figure B-2), error in the horizontal position of the edge of water will cause greater error in the WSE estimate than in areas where the terrain is less steeply sloping (as on the right side of Figure B-2). Although slight horizontal position errors in floodplain extent boundaries have little impact on area flooded, they can have a profound effect on derived depths of flooding, especially in high slope areas. Considering that much of the study area is not steeply sloping, error in depths are expected to be low and concentrated in high slope areas. Error in depth estimates is of particular interest in this study since depth of flooding is a primary input to HAZUS in the calculation of flood losses.

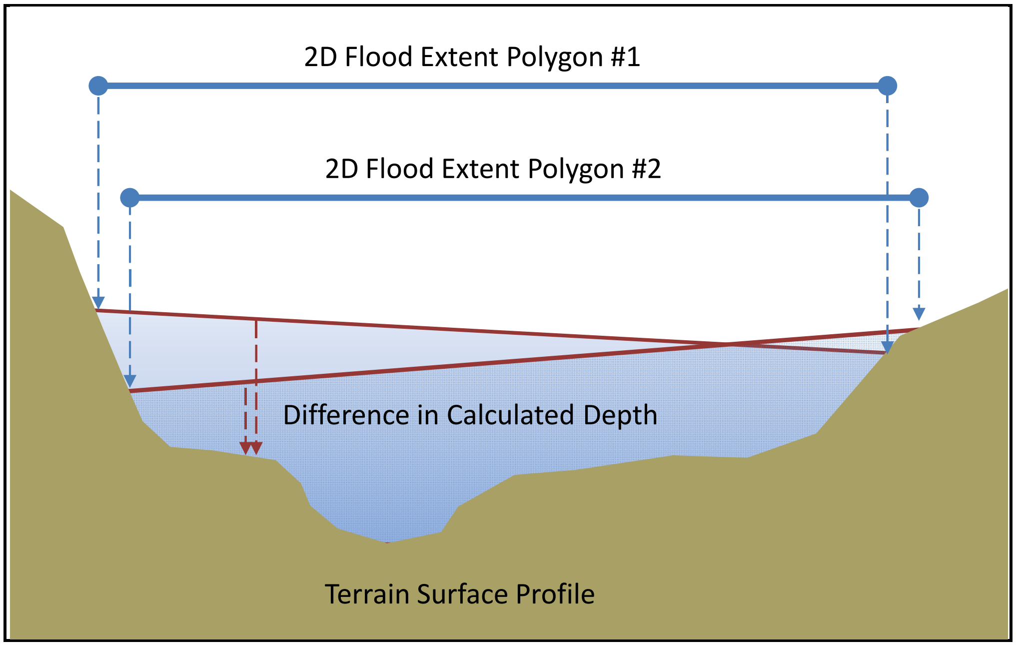

Figure B- 2. Differences in Flood Extent Boundaries Translate into Different Derived Depths
Horizontal error in delineation of flood extent boundary will cause error in derived WSE surface and derived depth surface.

Given these general relationships sketched in Figure B-2, let us examine how these principles affect real data. Figure B-3 shows the DFIRM 500-yr flood extent created in step 1 above for a portion of Indian Creek, Cedar Rapids, Iowa (flow is from North to South). Notice how the floodplain extent near point A is delineated on a relatively higher elevation area than portions upstream and downstream of A. The method described above will cause the derived water surface elevation to be very high near point A. Likewise, the floodplain extent near point B is delineated on a relatively lower elevation area than portions upstream and downstream of B. The method described above will cause the derived water surface elevation to be very low near point B. Since points A and B adjacent to one another, this orientation will cause the WSE to undulate in this area of the floodplain. Close examination of this area of interest will reveal several other examples of under and over estimation of water surface elevation.

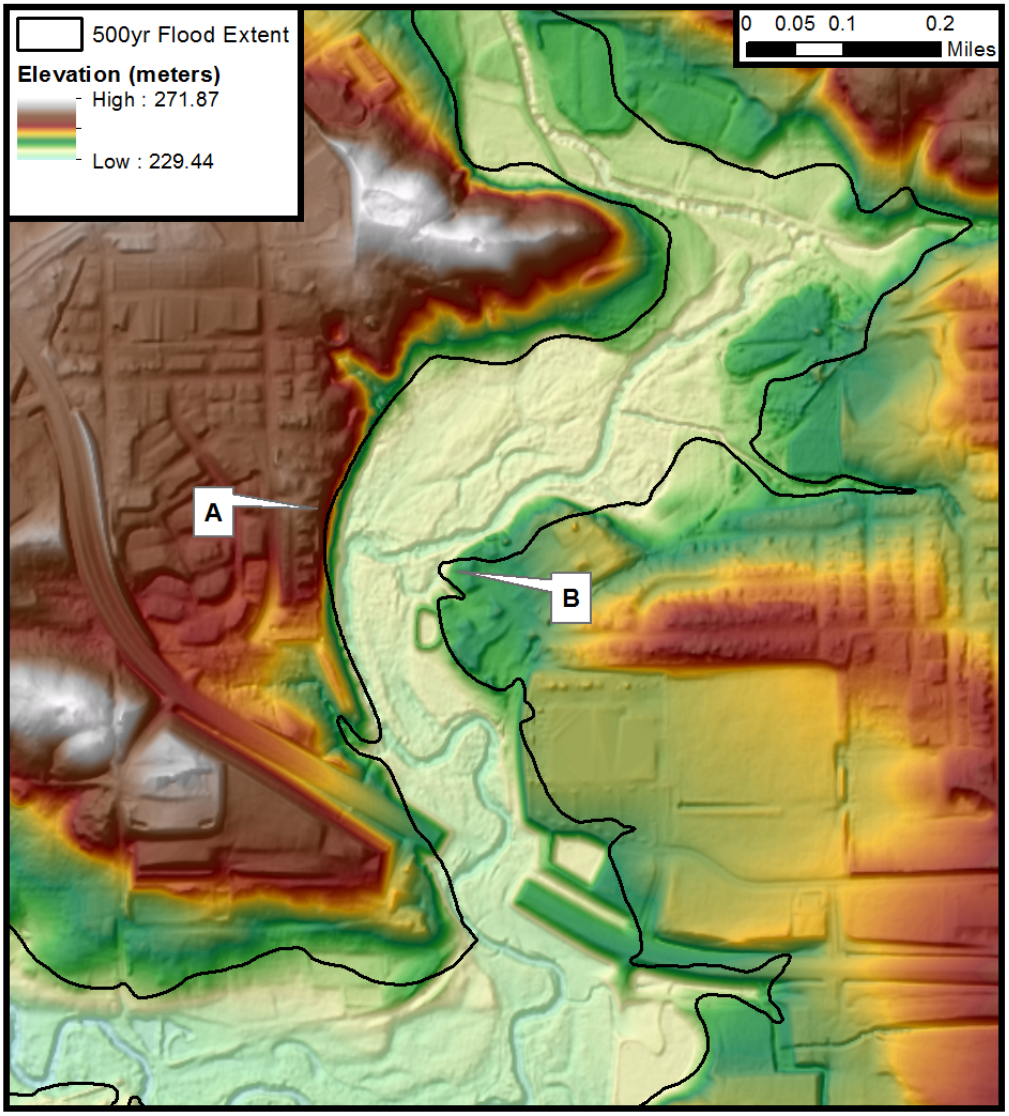

Figure B-3. DFIRM 500-yr Flood Extent Over Digital Elevation Model

A. Highlights a situation where the flood extent boundary falls on an area of relatively higher elevation (DEM color ramp is red rather than green).

B. Highlights a situation where the flood extent boundary falls on an area of relatively lower elevation (DEM color ramp is tan rather than green). Location. Indian Creek, Cedar Rapids, IA

Figure B-4 shows the derived WSE produced by step 5 above. Notice the extreme undulation of the WSE grid in the area around points A and B. Although this extreme WSE undulation is possibly due to river hydraulics, it could also be due to inaccuracies in the delineation of the floodplain extent. Any cartographic smoothing done to make the boundary "pretty" will introduce error into this procedure as the floodplain boundary will no longer correspond to the DEM. As anticipated based on Figure B-2, since the terrain around point A is steeply sloping, slight horizontal position errors in the floodplain will result in large WSE errors. In the case of point A, they result in high estimates of WSE, causing a bulge in the WSE at that point. Although in this case there could be a sound reason for this extreme WSE bulge, this case highlights the potential error in WSE possible with this method.

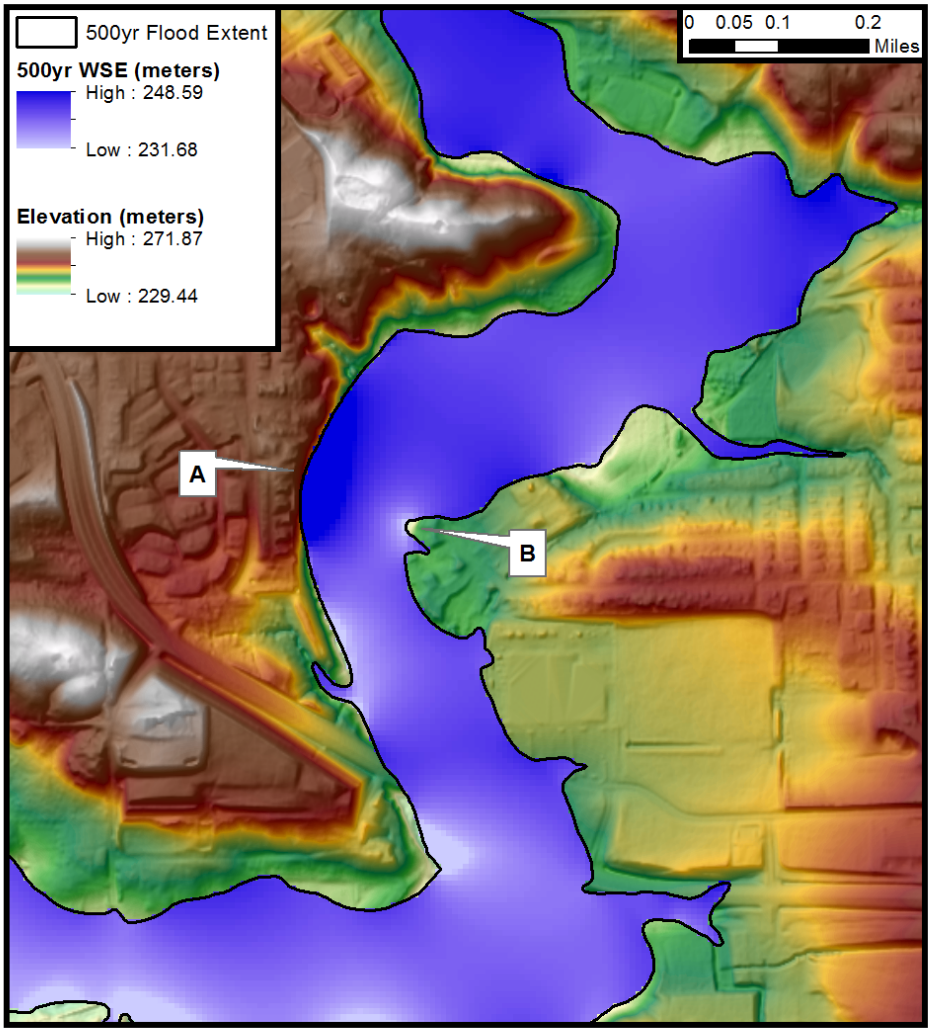

Figure B-4. Derived 500-yr Water Surface Elevation over Digital Elevation Model

Notice undulation of WSE is extremely marked between points A and B. Is this due to error in flood extent delineation or the behavior of flood waters in an outside versus inside bend? Location. Indian Creek, Cedar Rapids, IA

Figure B-5 shows the resulting depth grid produced by step 6 above. In the area of the WSE bulge, depths are extremely high, (as high as 12 meters deep compared to only 2 meters deep in adjacent areas). However, despite this localized bulge in WSE, depths appear reasonable in areas not subject to extreme WSE undulation (areas immediately upstream and downstream of points A and B). Considering that flood damages rapidly increase to 100% loss over a given flood depth, freakish depths due to localized WSE errors may not introduce unacceptable error into HAZUS loss estimates. Additionally, if these WSE errors are located in unpopulated areas, then they will inject minimal error into the HAZUS flood loss estimate. A systematic study with scenarios constructed of known error would need to be designed to quantify the HAZUS flood loss estimate impacts of depths generated using this method.

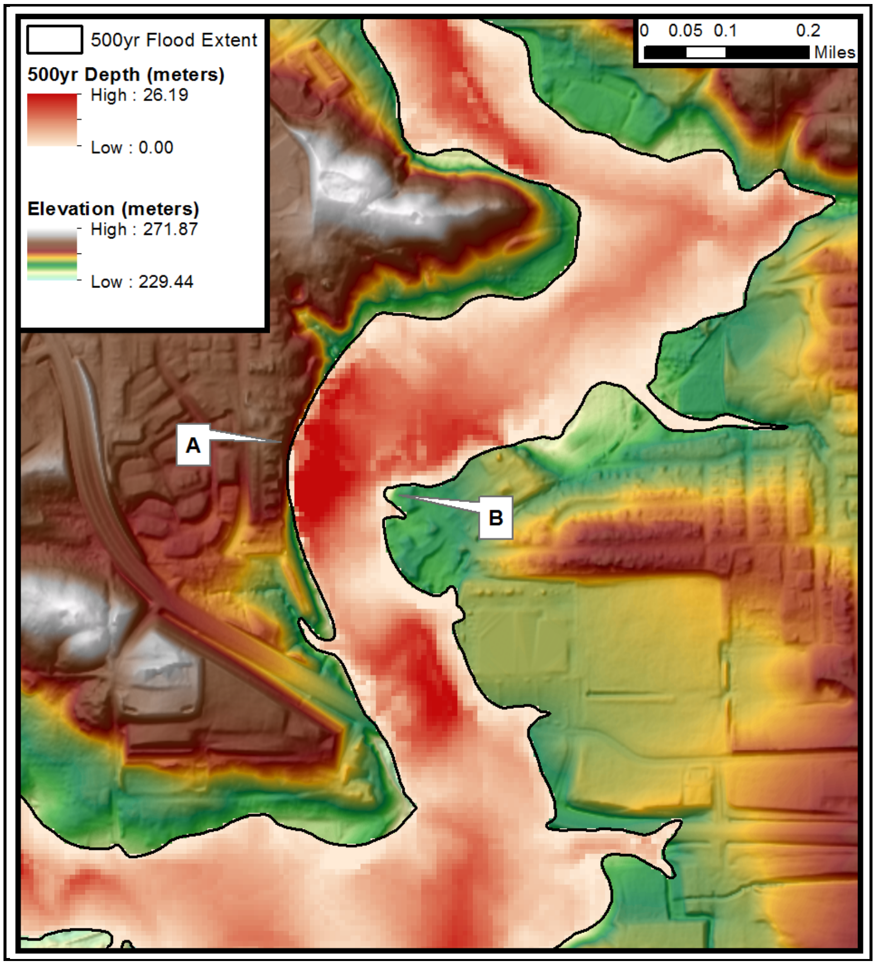

Figure B-5. Derived 500-yr Depth Over Digital Elevation Model

Notice depths are extremely high adjacent to point A (as high as 12 meters). However, despite these errors, depths appear reasonable in areas not subject to extreme WSE undulation (areas immediately upstream and downstream of points A and B). Location. Indian Creek, Cedar Rapids, IA

IV. USING SSURGO FLOODPLAIN LANDFORM TO DELINEATE FLOODPLAINS

Since DFIRM floodplain delineation has not been completed for all portions of the study area, an alternative method of floodplain delineation was needed to achieve complete coverage. Interagency collaboration with NRCS staff resulted in the identification of a possibility of using the NRCS SSURGO soils database to help delineate floodplains. Iowa NRCS staff suggested the use of the "landform" attribute of the SSURGO for this purpose. The SSURGO derived floodplain extent was developed by selecting map units whose dominant component had a landform value of "flood plain", "stream terrace", "terraces", or "alluvial fans". These map units were dissolved into a single polygon and is displayed in blue in Figure B-6.

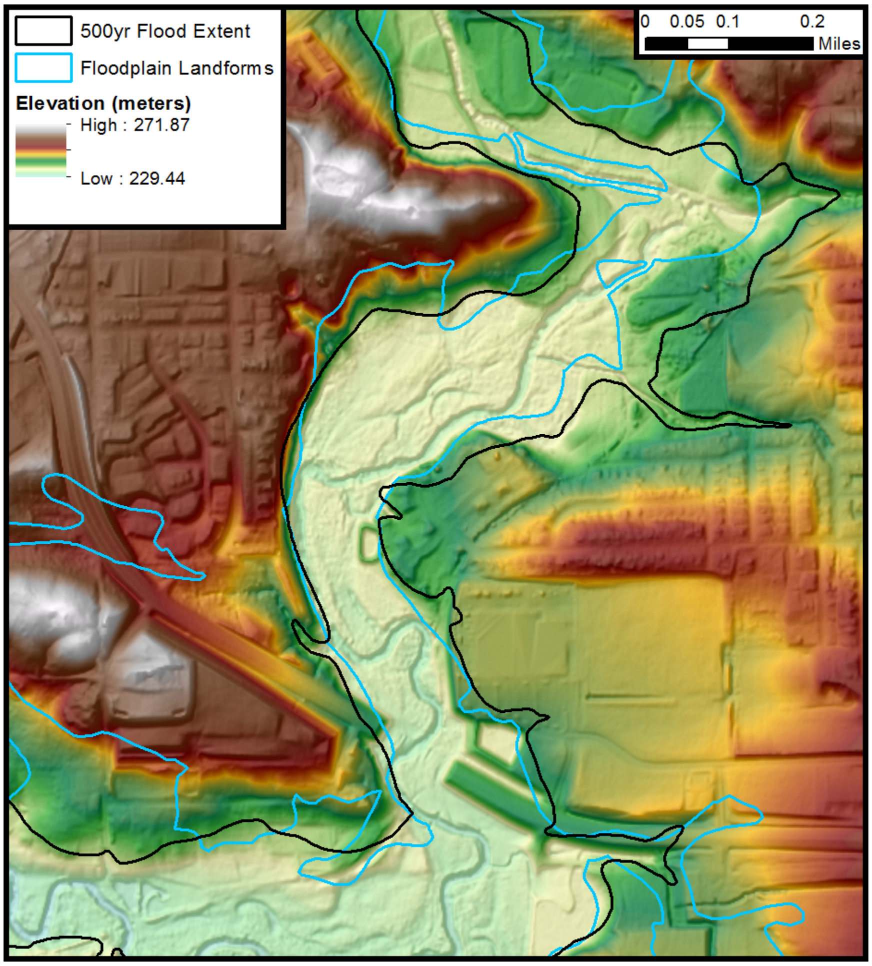

Figure B-6. DFIRM 500-yr Flood Extents Compared to SSURGO Floodplain Landform Extents

Although the SSURGO floodplain landform extents generally conform to the shape of the DFIRM floodplain, use of these SSURGO floodplain landform extents to generate depths would result in wildly erroneous depth surfaces. Location. Indian Creek, Cedar Rapids, IA

Given what was learned from creating depths from DFIRM flood extents, floodplain extent delineated using the SSURGO landforms was evaluated. Comparison of the SSURGO floodplain landform with the DFIRM 500-yr floodplain extent and the LIDAR derived DEM reveals some significant differences. Although at scales coarser than Figure B-6 (1:10,000) the SSURGO floodplain landform may appear to generally conform to the DFIRM floodplain extent and floodplain area estimates are similar, at finer scales substantial differences are revealed.

Notice in Figure B-6 the numerous places where the floodplain landforms stray significantly out of the floodplain and up into upland areas. Conversely, notice the numerous places where the floodplain landform underestimates the floodplain area. Visual review of the data demonstrated that depths generated from the floodplain landforms would create wildly undulating WSE grids and depth grids that would wildly overestimated flood depths in many areas. It was determined that depth estimates derived from these floodplain extents would contain an unacceptable level of error for use in HAZUS flood loss estimation.

Based on the visual analysis described for Figure B-6, the SSURGO floodplain landforms were deemed unsuitable for use in generating depth grids as input to HAZUS in areas where DFIRM data was not available. Therefore, it was determined that no HAZUS analysis could be performed in areas where DFIRM data was not available as no suitable floodplain delineation could be identified that permitted adequate depth grids to be produced.

However, it should be noted that at coarser scales the SSURGO floodplain landforms generally conform to the DFIRM delineated 500-yr floodplain (Figure B-7). Figure B-7 shows that in a majority of locations, the SSURGO derived floodplain represents a flood frequency much greater than the 500-yr flood frequency. This observation is consistent with the geomorphologic processes that created the soil map units selected to create the SSURGO floodplain extent. As a result, floodplain area estimates (DFIRM and SSURGO) were found to be roughly similar when aggregated to areas such as the census block, municipality, and county. One conclusion that can be drawn from this observation is that calculations made using floodplain area estimates contain less error than use of the SSURGO floodplain landforms for depth calculations.

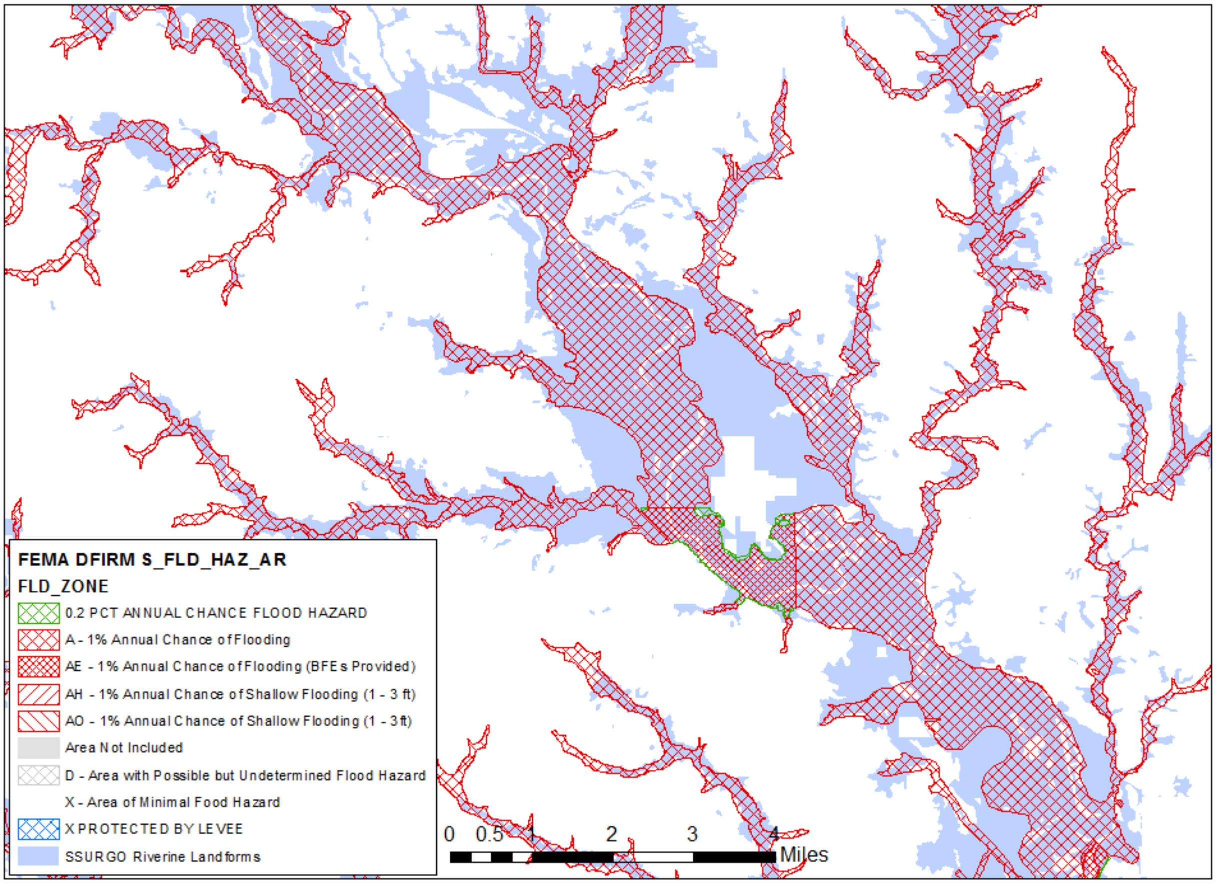

Figure B-7. DFIRM Flood Extents Compared to SSURGO Floodplain Landform Extents

V. HAZUS FLOOD LOSS ESTIMATION

HAZUS flood loss estimates were generated using the default Level 1 approach described in the HAZUS User Manual (FEMA, p. 1-4). This study supplied floodplain information to HAZUS via the User Defined Depth Grid approach. Depth grids were derived from DFIRM Flood Hazard Area polygons using the method described above in ArcGIS and then submitted to HAZUS. The study area was broken into multi-county sections to comply with Microsoft Access database storage limits (the default underlying database used by HAZUS). The Riverine Flood Hazard Type was run for each section of the study area, the results were exported, and the sections combined to form the study area. Estimates (by census blocks) were generated for general building stock depreciated replacement value for building and contents.

VI. SSURGO FLOOD LOSS ESTIMATION

It was demonstrated above that creating depths from SSURGO floodplain landforms would produce nonsensical results, but that calculations based on floodplain area may be less subject to error. It was also demonstrated that the SSURGO floodplain landforms represent a floodplain much larger than that of the 500-yr flood frequency (0.2 annual chance). Given these limitations, a method was developed that calculated the value of structures located in the SSURGO geomorphic floodplain to help assess flood risk for areas where DFIRM data does not yet exist. This value does not represent expected flood losses, but as the total value of structures in the geomorphic floodplain, should serve as an index of flood risk.

The census tables supplied with HAZUS were used as the source of structure and content values for this analysis. This data is supplied by census tract. Therefore, an area weighted approach was used to scale the structure and content values per census block by the proportion of the census block located in the SSURGO geomorphic floodplain. Census block areas were calculated, the census blocks were clipped to the SSURGO geomorphic floodplain boundary, the area of the census blocks in the floodplain was calculated, and the proportion of the census block in the floodplain was calculated. This proportion was then used to scale the census block's total structure and content value using the area weighted proportion method to obtain an estimate of the likely total value of structures and their contents in the floodplain. This estimate of the total value of structures and contents in the floodplain was classified into three groups using terciles and displayed using a High/Medium/Low symbology to represent flood risk.

VII. REFERENCES

FEMA (n.d.) HAZUS-MH 2.0 User Manual. URL. www.fema.gov/library/viewRecord.do?id=4713

FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED

An Iowa Silver Jackets Flood Risk Management Team Initiative

APPENDIX C

Future Flood Risk - Landuse Tables for the Iowa-Cedar Basin

Appendix C
Future Flood Risk - Landuse Tables for the Iowa-Cedar Basin

Counties	**State**	**% of County in Watershed**	**% Water**	**% Developed**	**% Forest/Shrubland**	**% Grassland/Herbaceous**	**% Pasture/Hay**	**% Row Crops**	**% Wetlands**
Benton	Iowa	100.00	1.09	7.45	9.13	4.21	69.38	7.21	1.50
Black	Iowa	89.28	2.14	17.46	9.13	4.71	53.14	12.04	1.35
Bremer	Iowa	46.15	3.92	8.79	17.83	6.82	45.27	15.43	1.93
Buchanan	Iowa	24.15	0.48	6.71	12.00	11.98	61.18	7.17	0.47
Butler	Iowa	100.00	1.25	6.84	10.57	5.07	66.17	8.67	1.41
Cedar	Iowa	76.42	1.41	6.70	14.40	7.79	61.10	7.28	1.30
Cerro	Iowa	100.00	0.89	11.93	8.79	4.90	69.25	1.87	2.07
Chickasaw	Iowa	16.36	2.02	9.12	33.36	13.52	29.95	10.65	1.32
Des Moines	Iowa	5.56	4.40	8.49	33.11	26.68	15.18	5.42	6.71
Dodge	Minnesota	13.94	0.22	7.09	9.46	1.50	73.57	7.15	0.99
Floyd	Iowa	99.30	2.34	7.87	20.23	7.17	55.69	5.14	1.49
Franklin	Iowa	100.00	0.69	6.73	7.11	5.76	71.34	6.42	1.92
Freeborn	Minnesota	95.79	48.35	3.46	4.65	0.90	16.83	1.82	23.68
Grundy	Iowa	100.00	0.25	7.17	5.96	6.91	77.49	1.95	0.27
Hamilton	Iowa	13.43	7.13	7.94	0.31	0.00	84.05	0.00	0.56
Hancock	Iowa	48.75	0.43	6.55	5.51	3.43	80.34	0.69	2.97
Hardin	Iowa	89.54	1.96	6.91	16.78	11.34	56.48	4.47	2.05
Iowa	Iowa	100.00	1.41	6.24	15.00	4.62	56.87	10.18	5.57
Jasper	Iowa	1.43	0.00	5.33	0.14	0.00	94.53	0.00	0.00
Johnson	Iowa	100.00	3.61	8.88	17.23	6.22	46.89	9.74	7.40
Jones	Iowa	0.84	0.00	5.27	1.37	0.00	93.37	0.00	0.00
Keokuk	Iowa	17.98	0.34	3.11	19.47	13.91	56.37	5.99	0.79
Linn	Iowa	98.43	1.48	16.80	14.81	8.69	46.97	10.07	1.10
Louisa	Iowa	67.26	1.99	6.18	20.57	2.29	50.68	11.81	6.46
Mahaska	Iowa	0.41	0.88	5.76	7.56	16.81	68.98	0.00	0.00
Marshall	Iowa	80.85	2.18	7.72	11.66	7.57	56.92	11.46	2.46
Mitchell	Iowa	88.60	1.53	6.93	19.62	5.33	59.46	6.25	0.87
Mower	Minnesota	71.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Muscatine	Iowa	42.68	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Poweshiek	Iowa	78.08	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Scott	Iowa	6.74	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Steele	Minnesota	1.25	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Story	Iowa	9.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Tama	Iowa	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Washington	Iowa	40.42	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Winnebago	Iowa	28.82	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Worth	Iowa	100.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wright	Iowa	48.92	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Note: % county in watershed indicates how much of county falls within watershed boundary; % landuse denotes the amount of each respective landuse category making up the county which lies within the watershed boundary.

FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED

An Iowa Silver Jackets
Flood Risk Management Team
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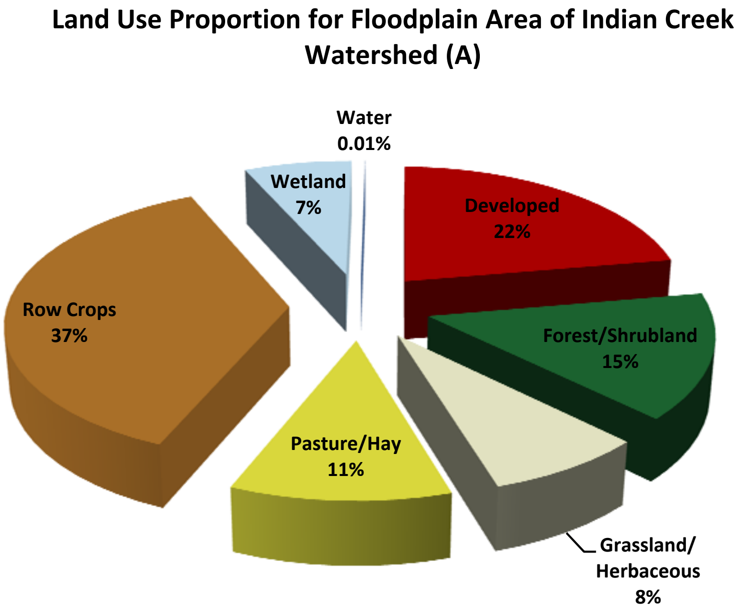
APPENDIX D
Risk Communication - Indian Creek Flood Risk Documents


Land Use Proportion for Floodplain Area of Indian Creek Watershed (A)

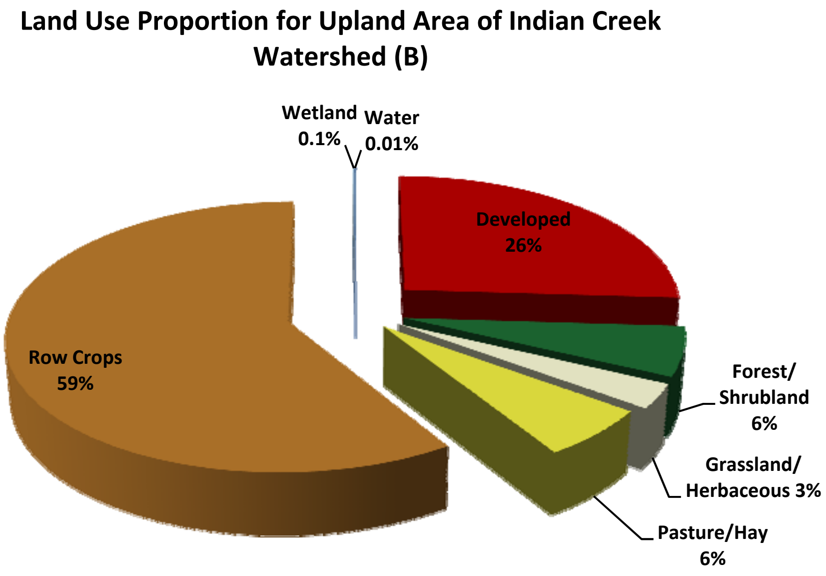

Land Use Proportion for Upland Area of Indian Creek Watershed (B)

Figure D-1. Comparison of Land Use Proportions (A)Within and (B) Outside of the 1% Annual Exceedance Probablity Floodplain Based on Approved FEMA-FIRM Map

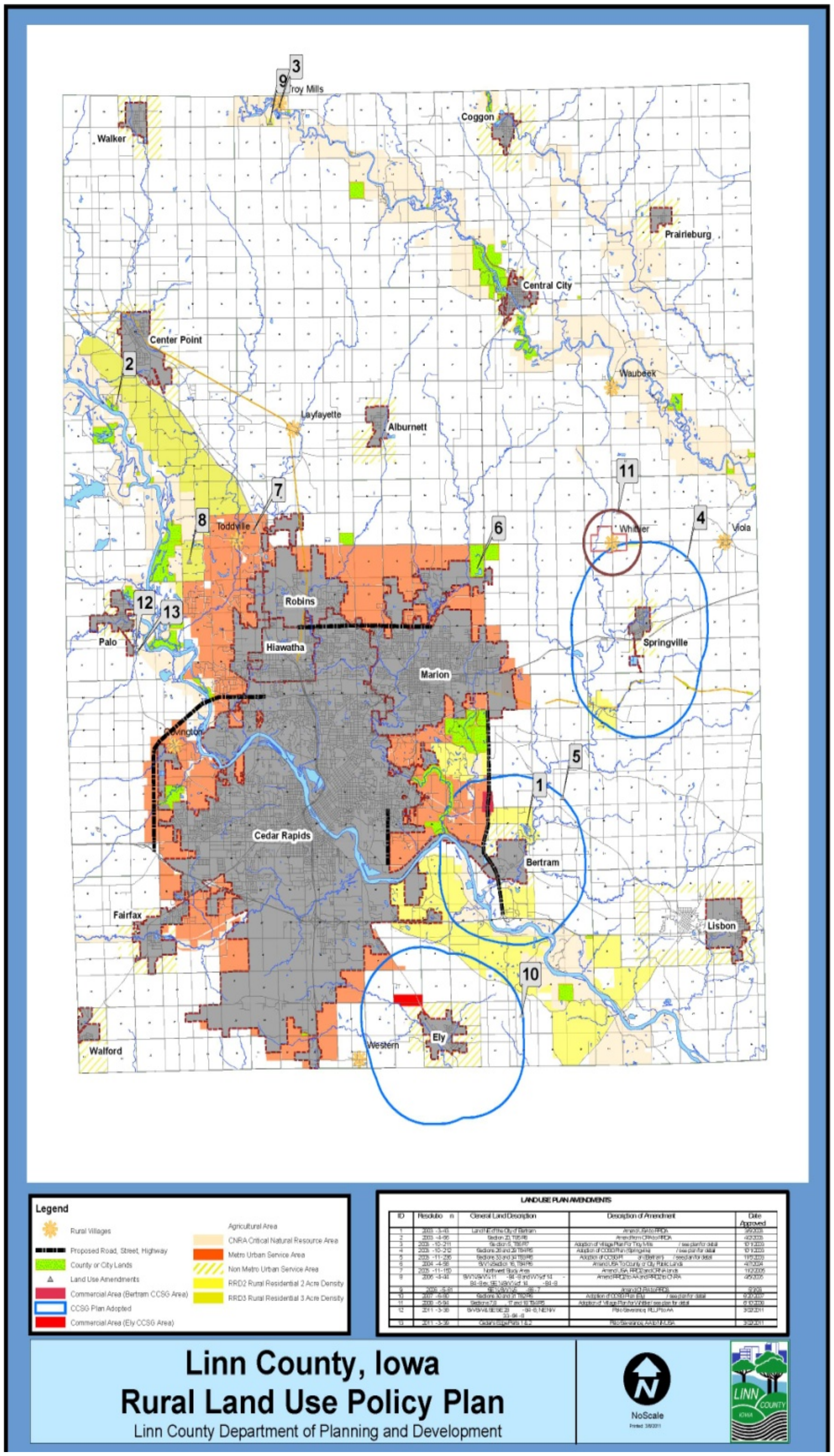
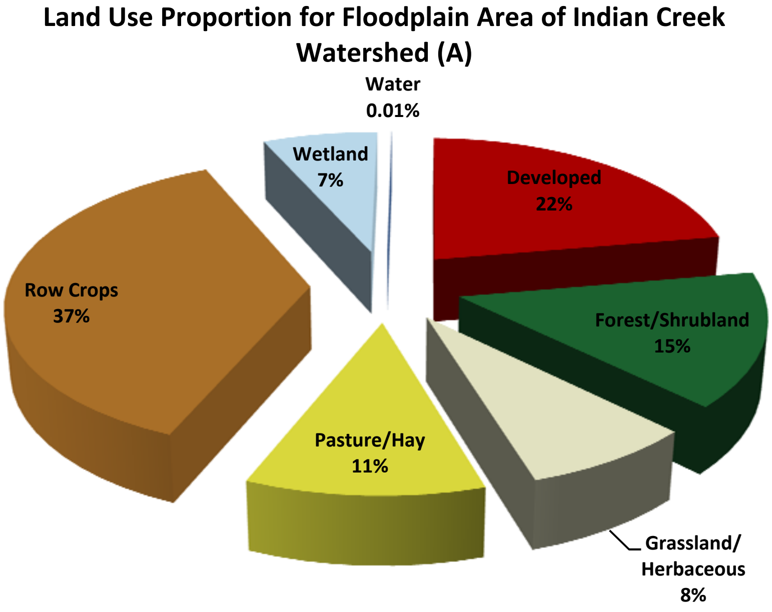


Figure D-2. Linn County Rural Land UsePolicy Plan



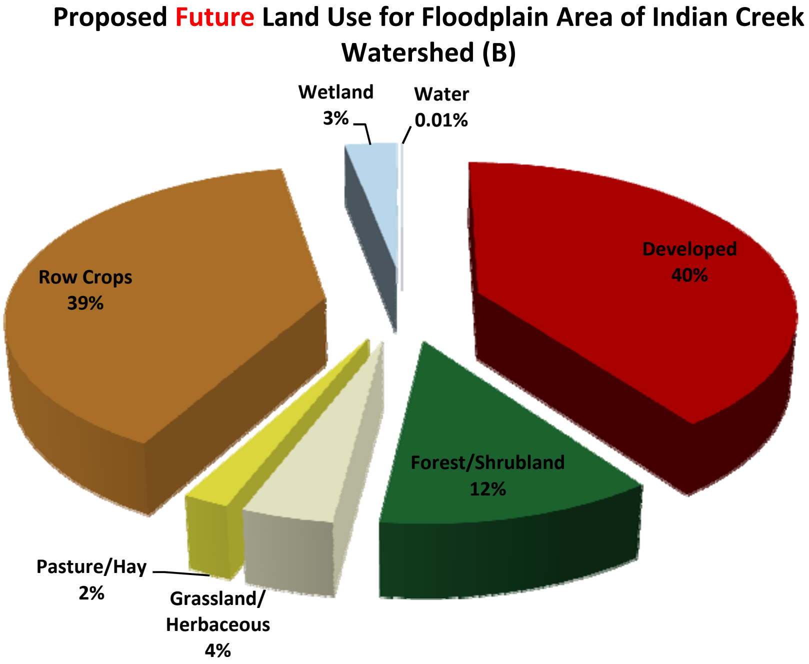


Figure D-3. Comparison of (A) Current and (B) Future Floodplain Land Use Proportions

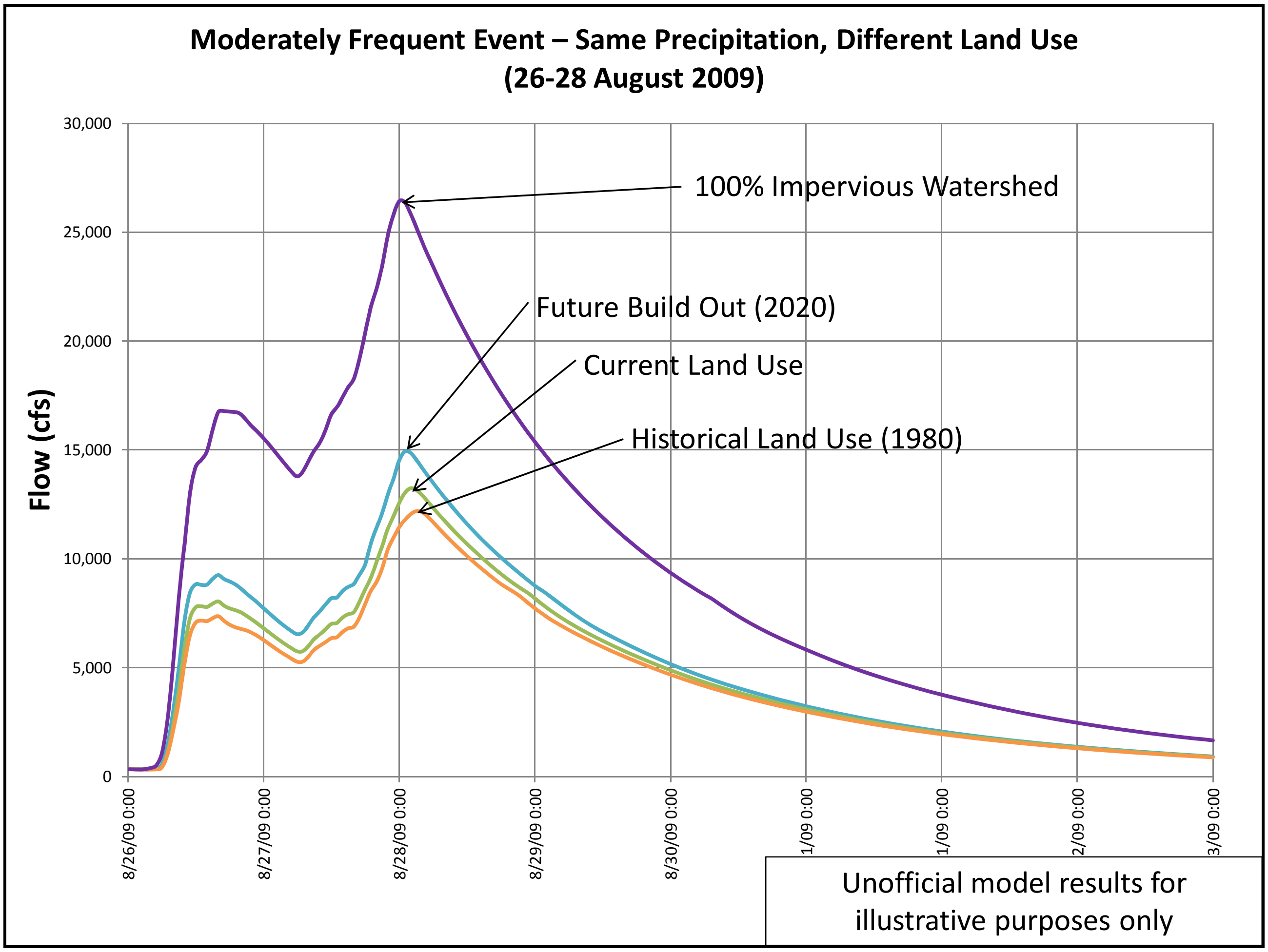


Figure D-4. Hydrologic Comparison of Land Use and Potential Impervious Landscape Response

FLOODPLAIN MANAGEMENT AND COMMUNICATION OF RISK IN THE IOWA-CEDAR WATERSHED

An Iowa Silver Jackets Flood Risk Management Team Initiative

APPENDIX E

Accuracy Assessment of HAZUS Flood Loss Estimate

Floodplain Management and Communication
of Risk in the Iowa-Cedar Watershed Basin

An Iowa Silver Jackets
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Appendix E
Accuracy Assessment of HAZUS Flood Loss Estimate

I. INTRODUCTION

Although HAZUS can be used to generate flood loss estimates over a large region, an accuracy assessment of these estimates was deemed necessary to gauge the validity of these estimates. Therefore, to determine the accuracy of HAZUS estimates, HAZUS flood loss estimates (using the DFIRM 500-yr floodplain) were compared to a detailed economic analysis performed by the US Army Corps of Engineers, Rock Island District for Cedar Rapids, Iowa (USACE, 2011).

II. DETAILED USACE ECONOMIC LOSS ESTIMATION METHOD

For the purpose of selecting projects and performing benefit-cost analysis, the Corps has developed a well-vetted, standard methodology for determining economic loss due to flooding. This method involves creating detailed hydraulic and hydrologic models for given flood frequencies and performing detailed structure inventory surveys to determine structure values. These two pieces of information are combined to evaluate a range of scenarios to determine flood losses. Although these methods are well accepted and produce valid results, they are not quick and are not cheap. Since this method was designed for relatively localized study areas, this method does not scale well to the regional level.

III. STATISTICAL COMPARISON

The statistical comparison involves calculating HAZUS flood loss for the economic reaches defined in the Cedar Rapids Study and comparing the estimates (Figure E-1). Task 1 was to determine if HAZUS can generate economic loss estimates similar to the detailed Corps method while using the same flood depths. Task 2 of this accuracy assessment was to determine if HAZUS and DFIRM generated flood depths generate economic loss estimates similar to the detailed Corps method. Whereas the purpose of the first task is more esoteric (Can the HAZUS method approximate the detailed USACE method loss estimates?), the purpose of the second task is to measure the performance of the HAZUS method in a more real-world scenario. Determine how well HAZUS loss estimates compare to the detailed Corps method while using off-the-shelf (OTS) DFIRM flood extents to generate flood depths. This is an attractive option since it uses OTS flood extents and OTS flood loss software (HAZUS), allowing large regions to be analyzed cost-effectively.

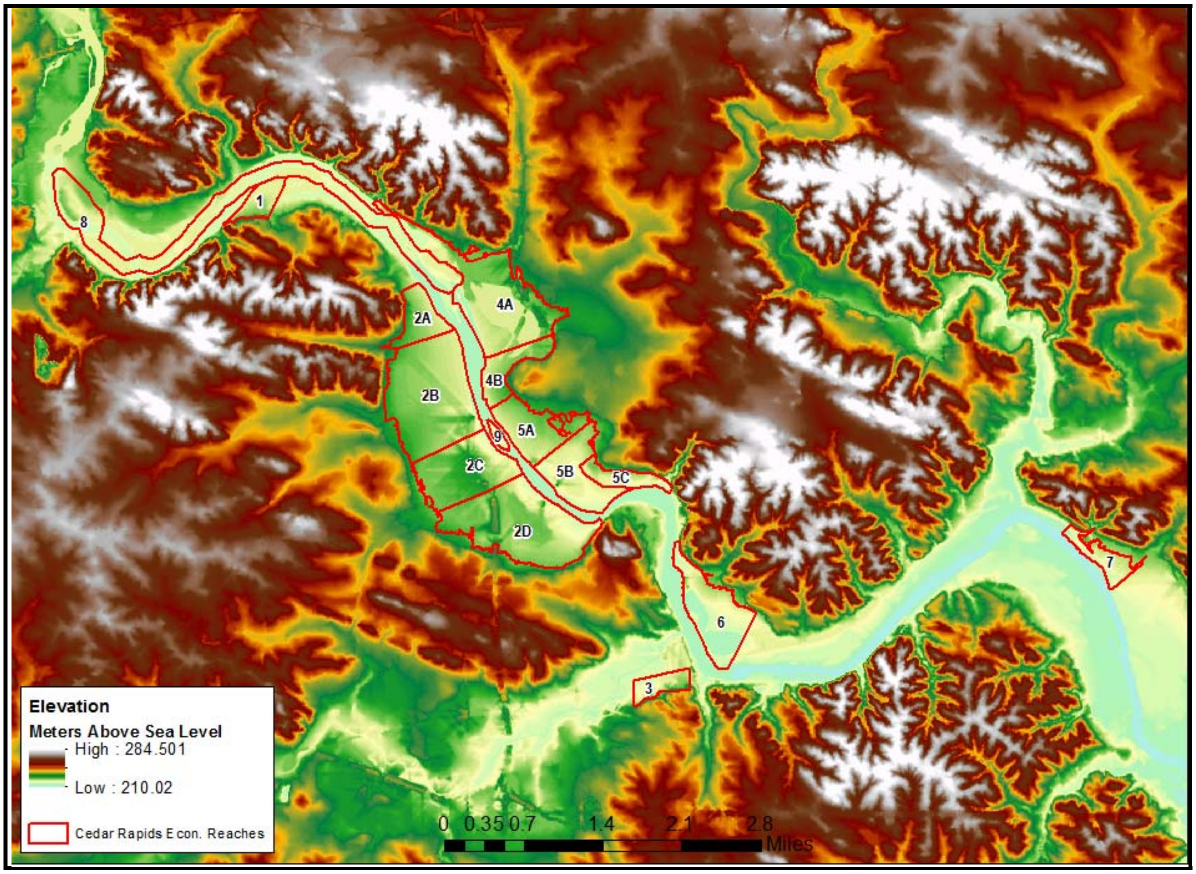

Figure E-1. Cedar Rapids Study Economic Reaches (USACE)

A. Task 1. Can the HAZUS method approximate the Corps' detailed method loss estimates?
To determine if HAZUS can generate economic loss estimates similar to the Corps' detailed method while using the same flood depths, HAZUS was run using the flood depth grid generated for the Cedar Rapids Study and results were summarized to the economic reaches identified in Figure E-1. Figure E-2 is a scatter plot comparing the estimates produced by the two methods. The plot labels correspond to the economic reaches in Figure E-1. The red line in Figure E- 2 represents the perfect correlation line (since the scales for both axes are equal); all economic reach labels would array close to this line if the two methods produced similar estimates. Figure E-2 clearly demonstrates that HAZUS is consistently underestimating flood losses when compared to the detailed Corps method. Some economic reaches are sorely underestimated (those falling in the upper left portion of the scatter plot).

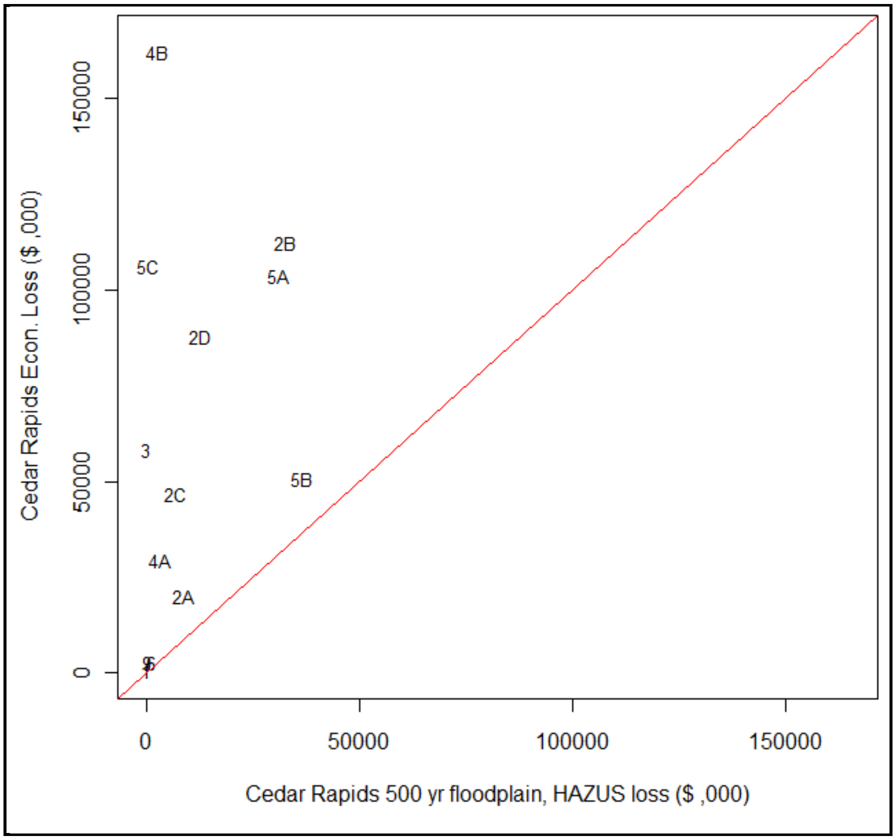

Figure E-2. Comparison Between the Corps' Detailed Economic Loss Method and HAZUS Economic Loss Method

This scatter plot compares the detailed USACE economic loss method using detailed hydraulics and hydrology derived 500-yr flood depths on the Y-axis and the rapid HAZUS economic loss method using detailed hydraulics and hydrology derived 500-yr flood depths on the X-axis. Plot labels represent economic reaches. Notice that the HAZUS method dramatically underestimates USACE method losses.

To further explore this relationship, a regression analysis (through the origin) was performed to measure the ability of the HAZUS method to predict the Corps' method flood loss. In this model (Figure E-3), the detailed Corps' economic loss method served as the dependent variable and the HAZUS economic loss method served as the independent variable. The HAZUS method was able to predict 37% of the variation in the Corps' method flood loss estimates. Although the HAZUS estimates were consistently low, the regression analysis was able to adjust the estimates for most economic reaches, except for three outliers (economic reaches 4B, 5C, and 3).

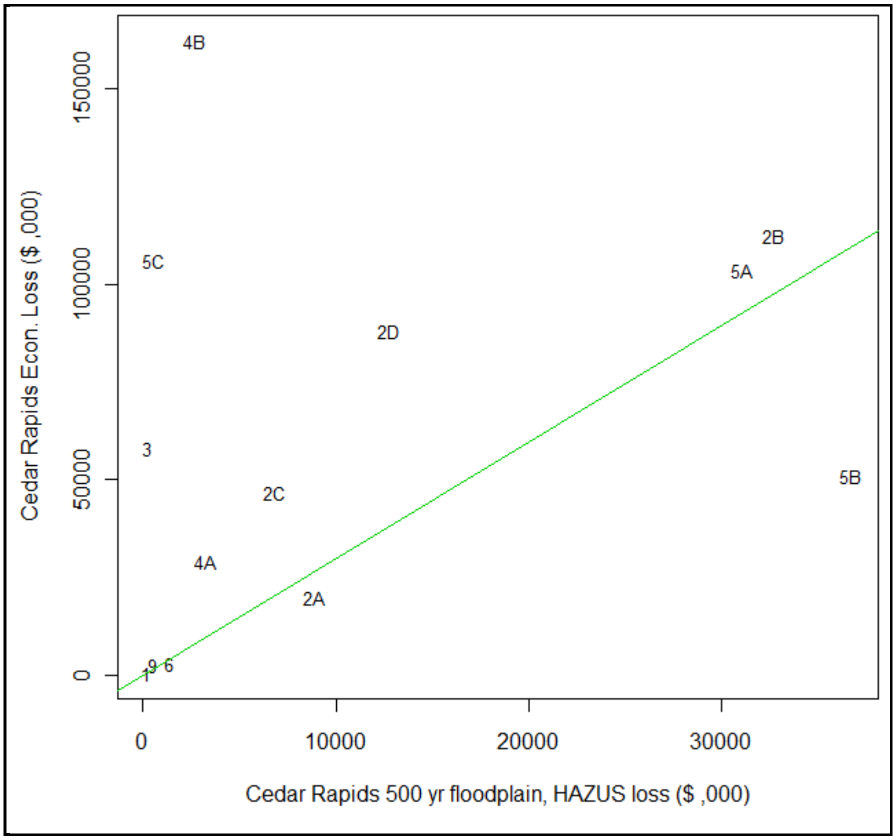

Figure E-3. Regression Analysis Testing the Ability of the HAZUS/Cedar Rapids 500-yr Method to Predict Detailed USACE Economic Loss

This analysis uses the same detailed 500-yr flood depths for both economic loss methods (detailed USACE on Y-axis, HAZUS on X-axis) to focus on the difference between the economic loss methods while holding the flood depths constant. $R^2 = 0.37$, F = 8.66 (1 and 12 DF), p-value = 0.01, n = 13. Plot labels represent economic reaches.

B. Task 2. Determine how well HAZUS loss estimates compare to the detailed Corps method while using off-the-shelf DFIRM flood extents to generate flood depths. A regression analysis (through the origin) was performed to measure the ability of the HAZUS method using DFIRM flood extents to generate flood depths to predict USACE method flood loss. In this model (Figure E- 4), the detailed Corps economic loss method served as the dependent variable and the HAZUS economic loss method served as the independent variable. The HAZUS method was able to predict 45% of the variation in the Corps' method flood loss estimates. Although the HAZUS estimates were consistently low, the regression analysis was able to adjust the estimates for most economic reaches, except for three outliers (economic reaches 4B, 5C, and 3). The configuration of Figure E-3 matches closely that of Figure E- 4, indicating that the DFIRM 500-yr flood depths generally match those created for the Cedar Rapids Study (GIS analysis confirms this). The Beta coefficient of this model indicates that the HAZUS/DFIRM method produces estimates 5 times less than the Corps' method estimates.

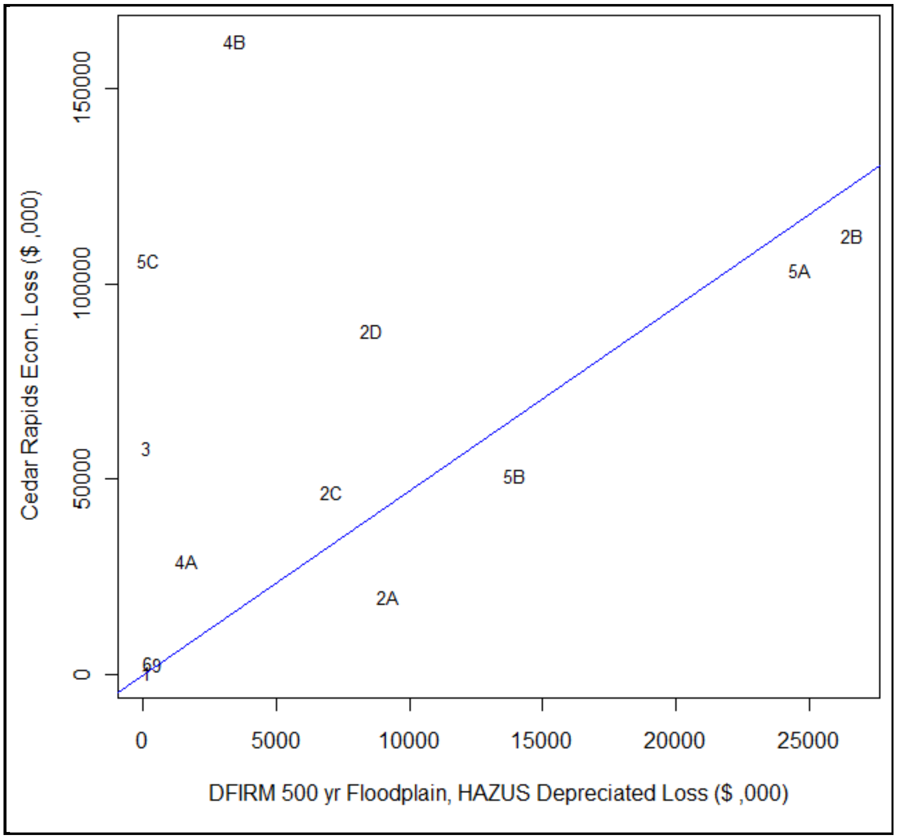

Figure E-4. Regression Analysis Testing the Ability of the HAZUS/DFIRM Method to Predict Detailed USACE Economic Loss

This analysis tests how well HAZUS using DFIRM derived 500-yr flood depths can predict detailed USACE flood losses (detailed USACE on Y-axis, HAZUS/DFIRM on X-axis). $R^2 = 0.45$, $F = 11.64$ (1 and 12 DF), p-value = 0.005, $n = 13$, $\beta_1 = 4.708$, S.E. = 1.38. Plot labels represent economic reaches.

IV. SOURCES OF ERROR

The above analysis highlights that although HAZUS is generally underestimating flood losses when compared to the detailed Corps method, three economic reaches were substantially underestimated (economic reaches 4B, 5C, and 3). Upon close examination of these economic reaches, it was determined that these three economic reaches were all characterized by being almost exclusively industrial. All three economic reaches are dominated by a single industrial facility (Figures E-5, E-6, and E-7). Two other underestimated economic reaches (2D and 4A), although not dominated by a single industrial facility, contain a high proportion of industrial facilities. It is believed that this “industrial error” is due to the method in which HAZUS proportions structure values by economic sector, although further investigation is required. Regardless of the exact mechanism, HAZUS is clearly not adequately accounting for industrial facility values in its default configuration.

This "industrial error" could be cost-effectively addressed by using HAZUS' significant structures option that allows a user to supply a feature class of significant structures and their values. Significant structures could be identified across a large study area using cost-effective air photo interpretation. Additionally, cost-effective economic valuation techniques could be used to rapidly value the significant structures identified.

However, user defined significant structures only help remove the "industrial error" in those economic reaches dominated by industry. Other techniques will need to be identified to cost-effectively improve the estimation of residential and commercial land use classes (those economic reaches which fall close to the regression line, but are still substantially underestimated). These other cost-effective techniques will likely involve using local experts to adjust the valuation tables to more closely represent regional conditions.

Figure E-5. Industrial Error. 4B – Quaker Oats/Pepsico

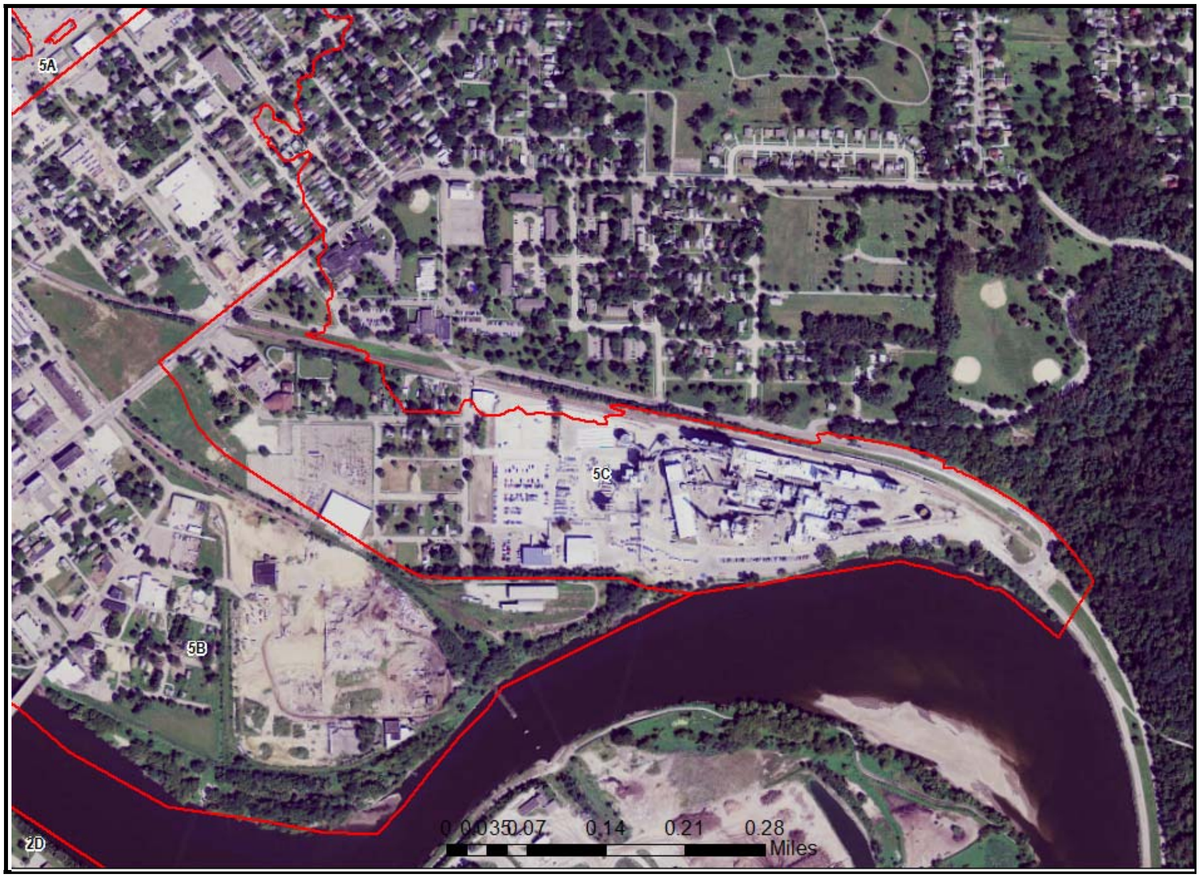

Figure E- 6. Industrial Error. 5C – Cargill Corn Milling

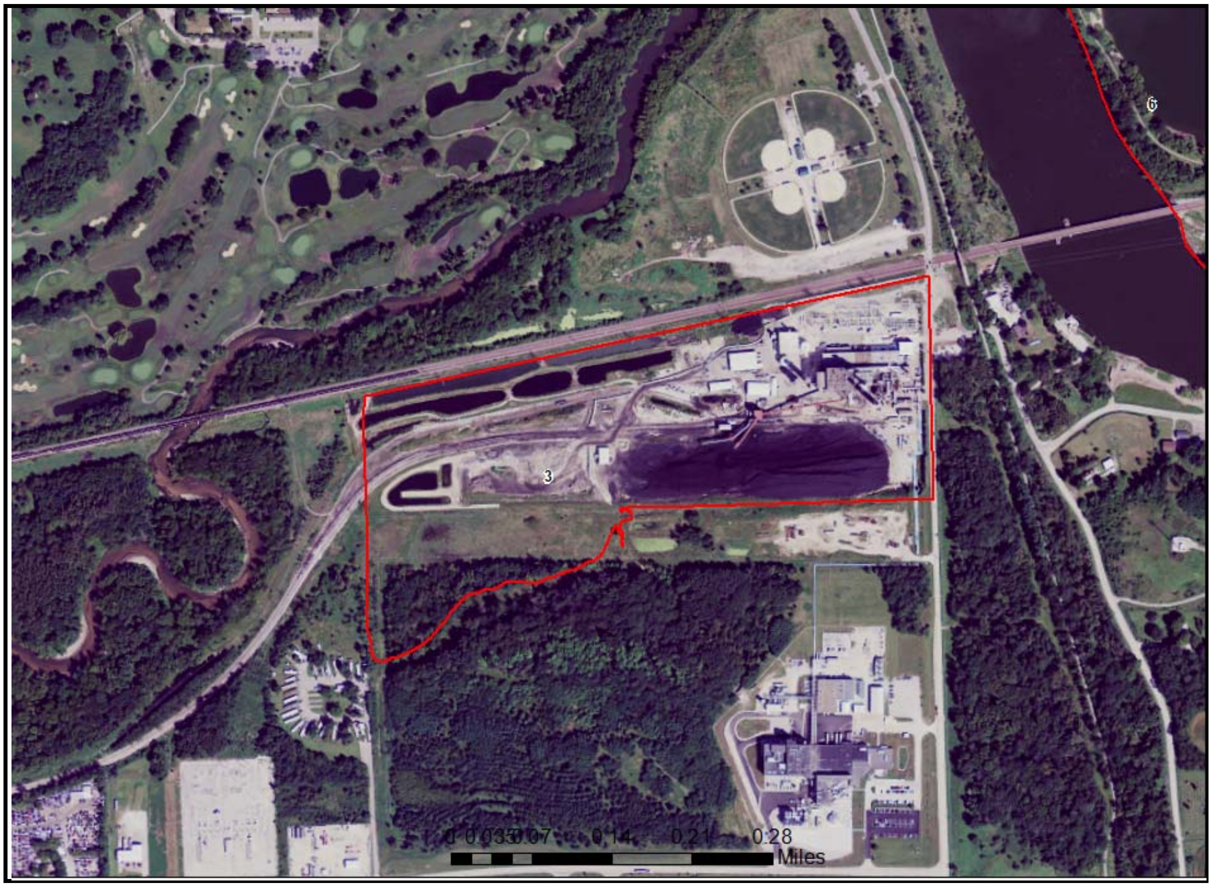

Figure E-7. Industrial Error. 3, Alliant Energy Power Plant

V. CONCLUSIONS

Although the sample size used in the study is extremely small, the findings suggest that use of HAZUS with DFIRM derived flood depth are promising for generating regional flood loss estimates. However, this study's use of the default Level 1 HAZUS approach indicates that several refinements are necessary to prevent generating flood loss estimates that are substantially lower than expected when compared to the better vetted and more detailed USACE methodology. The next logical step would be to assemble a larger sample of high quality economic loss estimates against which HAZUS estimates can be tested to determine if the findings of this study can be replicated.

This study points to the need to shift from HAZUS Level 1 analysis (default settings) to Level 2 analysis (more localized input data) to improve the quality of flood loss estimates. Use of HAZUS "significant structures" to capture the value of high value facilities should serve as a cost effective method of removing the greatest source of error identified in this small study. The second most cost effective source of error to remove would likely be replacing regional depth damage functions with more localized functions if available.

REFERENCES

US Army Corps of Engineers (2011). *Cedar Rapids, Iowa Flood Risk Management Project, Feasibility Study Report with Integrated Environmental Assessment*, Appendix B, Economic Analysis. Rock Island District, Rock Island, IL.