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Executive Summary

To reach the goal of mitigating the impact of future flooding for the City of Ames, Iowa, this Study utilized state-of-the art complimentary work that is occurring in the Squaw Creek and South Skunk River watershed, performed by the Iowa Flood Center (IFC), Iowa Department of Transportation (Iowa DOT), the City of Ames, and Iowa State University, incorporated it into a seamless hydraulic modeling framework, developed mitigation alternatives, screened the alternatives including benefits, costs, and environmental impacts, effectively communicated the major issues to the public in a way that facilitated constructive discussion, and identified implementable combinations of flood damage mitigation alternatives and strategies.

The City hosted a series of workshops and Public Meetings that integrated the knowledge and expertise of the City, the public, and the project team into the decision-making process. This public involvement plan was instrumental in gathering stakeholder specific input on the Study. Web content was developed to provide clear and succinct information about the progress of planning and opportunities for the public to get involved. The website served as an online portal for all potential stakeholders to find ongoing information about the project, updates on different milestones reached throughout the planning process, and opportunities to participate and provide input and feedback on the project planning. In addition, the website provided a link to the online public open house meetings and online comment form.

The number and severity of flood events that have occurred in the City on the South Skunk River and Squaw Creek since the time the existing flood insurance maps were created has increased. The starting point for the Study was to update the existing hydrology associated with the three USGS stream gages located in the City. Updating the hydrology provides a new baseline from which to visualize inundation associated with probabilistic flood events as well as to evaluate performance of flood mitigation alternatives.

To incorporate additional information and sensitivity into the flood mitigation alternatives analysis several hypothetical, extreme flooding scenarios were developed based on recent high intensity flood causing rainfall events. These additional flooding scenarios provided tangible flood events that occurred in very similar conditions to the City, both in distance and in hydrometeorology characteristics. The additional data allowed the City to bracket the results of the more traditional flood frequency analysis by incorporating these extreme flood events into the evaluation. The updated FFA flows provide a statistically-based peak flood discharge that has an associated probability and the Iowa-based flood-causing rainfall events provide a peak discharge based on extreme events that have occurred in Iowa over the last five years.

The Iowa Flood Center hydraulic model developed and calibrated by IIHR-Hydroscience and Engineering was used as a tool to develop baseline hydraulic conditions, create inundation maps, and to evaluate flood mitigation alternatives and strategies. It also provided the hydraulic information for the benefit cost analysis.

Twelve flood mitigation alternatives and strategies were identified as part of the preliminary screening phase of the Study. Ten alternatives were selected for additional analysis and evaluated using a detailed screening process including hydraulic analysis, benefit cost analysis, and environmental review. After the detailed screening, to take advantage of commonalities between conveyance improvements and levee alternatives, the best alternatives were combined into three alternatives.

A detailed summary of the benefit cost analysis results is presented as well as for rankings. Whether the rankings occur based on Net-Benefits or benefit cost ratio (BCR) the ranking is:

- Combined Alternative 1 – Conveyance Improvements – Channel and Bridge Improvements
- Combined Alternative 3 – Two Regional Storage Reservoirs
- Combined Alternative 2 – Levees to provide 100-Year Flood Protection and Alt 1
- Combined Alternative 2 – Levees to provide 500-Year Flood Protection and Alt 1

It is also recommended that the City consider the implications of their current floodplain ordinance on water surface elevations during more extreme floods.

1.0 Introduction and Background

A feasibility study of flood mitigation alternatives for the City of Ames, Iowa (City) was conducted by HDR Engineering, Inc. (HDR) specifically to address flood damage associated with the Squaw Creek and the South Skunk River This flood mitigation study (Study) involved updating flood hydrology, performing additional extreme flood inundation mapping by incorporating recent flood causing Iowa based rainfall events into the analysis,, updating the Iowa Flood Center's (IFC's) Squaw Creek and Skunk River hydraulic models, updating the City inundation maps based on the updated IFC models, developing flood mitigation alternatives with City and public input (Greater Ames Community), screening the alternatives including economic and environmental components, and presenting the best alternatives and strategies for future implementation. The result of the Study is a thorough documentation of the process that HDR conducted, both technically and with public input, with a list of actions that the City can enact to reduce the impact of flooding for the Greater Ames Community.

1.1 Project and Study Area

The City is situated at the confluence of Squaw Creek and South Skunk River in Story County, Iowa. The Squaw Creek watershed encompasses a total of 204 square miles at the U.S. Geological Survey (USGS) gage location at Lincoln Way (05470500). The South Skunk River watershed encompasses a total of 315 square miles at USGS gage location at West Riverside Road (05470000) and 556 square miles at USGS gage location at U.S. Highway 30 (05471000), below the confluence with the Squaw Creek. The Study Area extends outside of the City limits, into both Hamilton and Boone counties. Figure 1 provides a map of the Greater Ames area included in the Study.

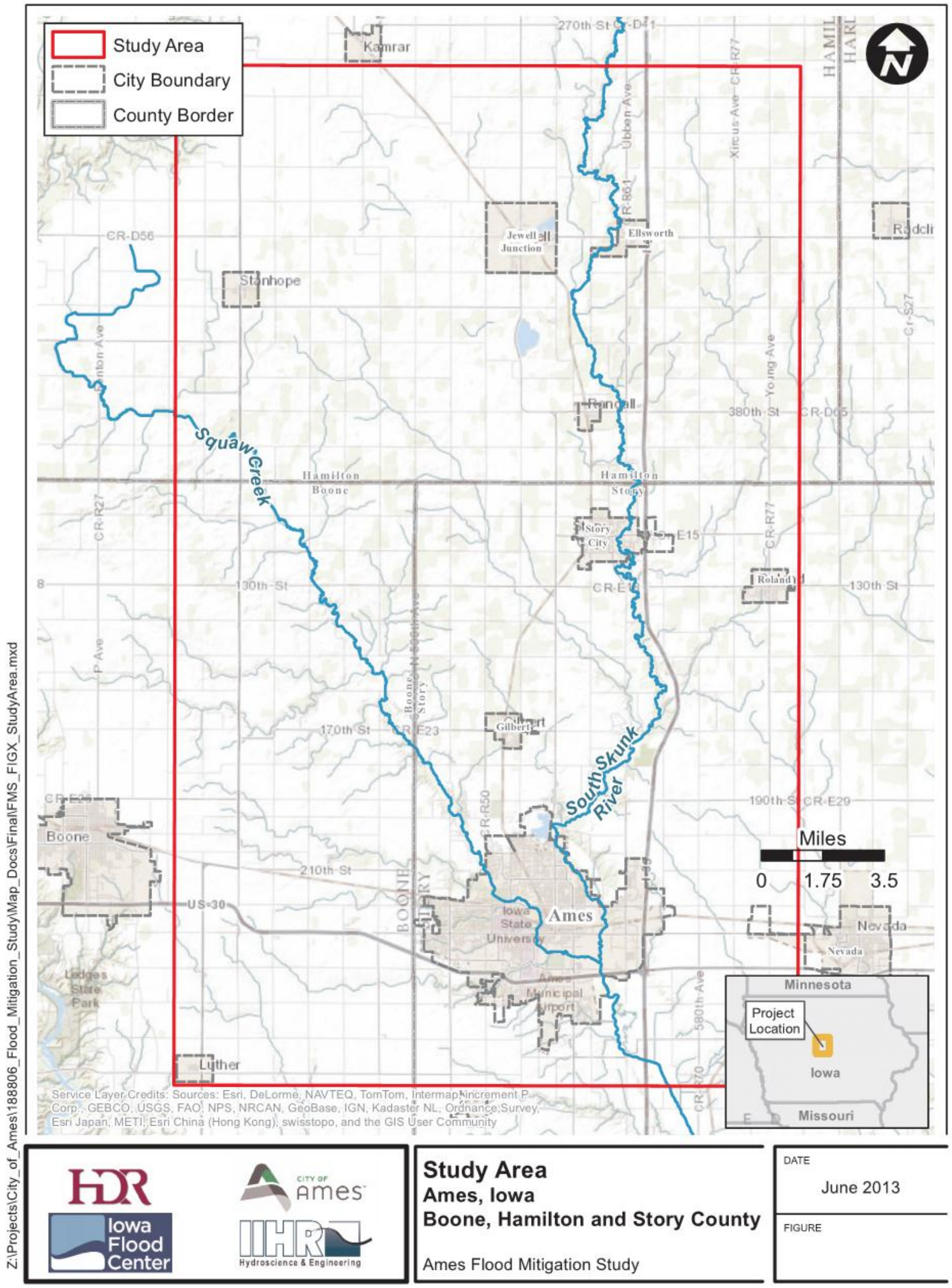

Figure 1. Ames Flood Mitigation Study Area.

1.2 Purpose

In August 2010, the City experienced significant flooding from Squaw Creek and the South Skunk River, with widespread damage to City and Iowa State University property. The peak flood stage in 2010 exceeded the previous record by more than a foot. Major flood events have previously occurred in the City in 1965, 1975, 1990, 1993, 1996, 2007, and 2008 (see Figures 2 and 3). In 1996, the City responded to the 1993 floods with a Floodplain Management Study which outlined several potential flood mitigation alternatives (Snyder & Associates 1996). As a result of the 2010 floods and in consideration of the frequency in which flood damages have occurred within the City and surrounding area, the City Council has established a goal to mitigate the impact of future flooding on the Greater Ames Community by updating the 1996 study. This report is a feasibility study detailing potential solutions for the City.

To reach the goal of mitigating the impact of future flooding in the City, this Study utilized state-of-the art complimentary work that is occurring in the watershed, performed by the IFC, Iowa Department of Transportation (Iowa DOT), the City, and Iowa State University, incorporated it into a seamless hydraulic modeling framework, developed mitigation alternatives, screened the alternatives including benefits, costs, and environmental impacts, effectively communicated the major issues to the public in a way that facilitated constructive discussion, and identified implementable combinations of flood damage mitigation alternatives and strategies.

The process that achieves the goal described above is discussed in greater detail in the chapters and appendices that follow.

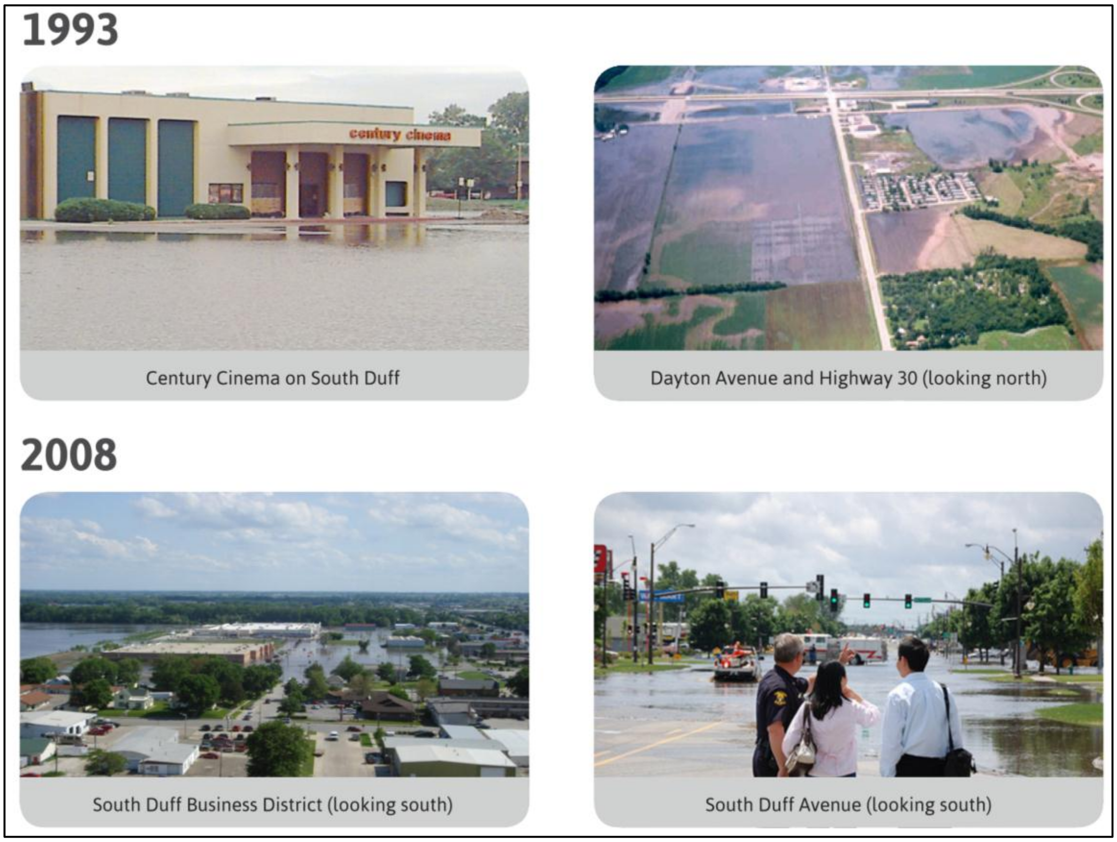

Figure 2. Images from 1993 and 2008 Flooding in Ames, Iowa.

Figure 3. Images from 2010 Flooding in Ames, Iowa.

2.0 Description of Problem Identification Process

For this Study, it was essential that the public be informed and involved through the duration. Gathering public input and comments on the Study, alternatives, and findings was conducted in a variety of methods, as described in more detail below.

2.1 Public Engagement Process

The City hosted a series of workshops and Public Meetings that integrated the knowledge and expertise of the City, the public, and the project team into the decision-making process. This public involvement plan was instrumental in gathering stakeholder specific input on the Study. Figure 4 illustrates the sequence of phased implementation and input that was gathered and used throughout the Study. Table 4 illustrates the specific details for each public meeting and the materials presented at Public Meetings 1, 2, and 3 are presented in Appendix A.

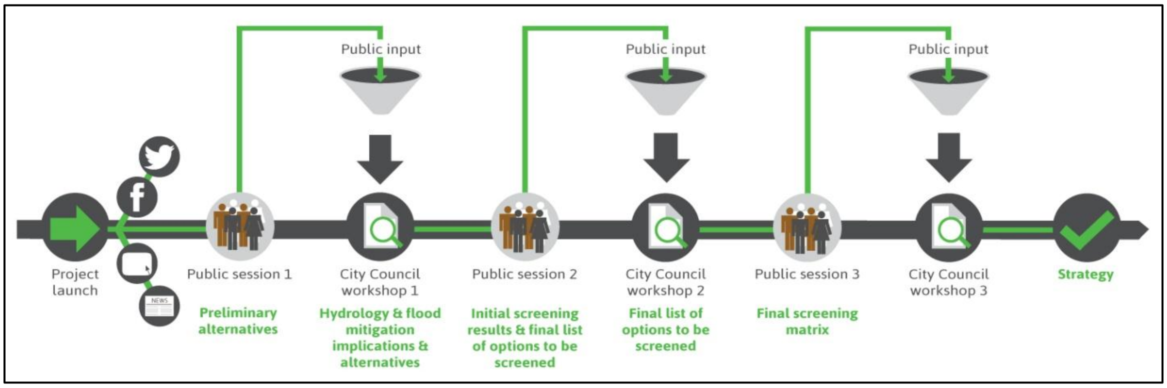

Figure 4. Public Engagement Process and Study Workflow.

Table 1. Summary of Public Meetings.

Meeting	Date/Location	Objective	Format	Results
Public Meeting 1	Tuesday, October 2, 2012 6–8 p.m. Holiday Inn Wednesday, October 3 1–3 p.m. Hampton Inn	Presented the preliminary alternatives screening criteria	Open house meeting One-on-one interactions with City officials and project team members Informational display boards and handouts	54 attendees
Public Meeting 1 – Open Microphone Public Format	Wednesday, October 10, 2012 6–8 p.m. Scheman Building Thursday, October 11 1–3 p.m. City Hall, Council Chambers	Allowed members of the public to make public statements regarding the Study using trained meeting facilitator.	Open microphone public forum	44 attendees 21 comments
Public Meeting 2	November 14, 2013 1–3 p.m. and 6–8 p.m.	Presented the results of the initial screening to the public and the selection of the final alternatives to be screened.	Formal presentation followed by open microphone comment period display boards and handouts	58 attendees 18 comments
Public Meeting 3	April 10, 2013 1–3 p.m. and 6–8 p.m.	Presented the final screening matrix	Formal presentation followed by open microphone comment period Informational display boards and handouts	112 attendees 32 comments
Online Public Meeting	Launched October 2, 2012	Same material presented on-line as was available during Public Meeting 1, 2, and 3	Web	2,431 page views 504 unique visitors 171 comments

The public engagement resources utilized during the course of this project also included outreach collateral materials that were used throughout the Study to ensure identified stakeholder groups were made aware of the opportunities to participate in the Study process. These outreach collateral materials included door hangers, direct mail invitations, monthly newsletters, school newsletters, and neighborhood association newsletters. Electronic communication tools that were used throughout the Study included a project website, social media alerts and share links, and email invitations to public meetings. Web content was developed to provide clear and succinct information about the progress of planning and opportunities for the public to get involved. The website served as an online portal for all potential stakeholders to find ongoing information about the project, updates on different milestones reached throughout the planning process, and opportunities to participate and provide input and feedback on the project planning. In addition, the website provided a link to the online public open house meetings and online comment form.

2.2 Outreach Tools and Techniques

The following outreach was used to promote awareness of the Study and attendance at the meetings. Multiple methods of outreach were developed to ensure identified stakeholder groups and the general public was made aware of the opportunities to participate in the study process.

2.2.1 Postcards

A total of 8,599 postcard invitations were mailed to landowners in the 100-year and 500-year floodplain; postcards were mailed 2 weeks prior to each Public Meeting. The purpose of the postcard invitation was to invite the public to the public meetings and provide them with the Study information and opportunities to comment.

2.2.2 Door Hanger

An 11-inch by 3-inch door hanger was placed in 1000 mobile home and multi-family units. They were placed on the front doors of homes located in the Homestead Colony Mobile Home Park and several other specified neighborhood communities. The door hangers invited the public to participate in the Public Meetings and online public open house meetings. The door hangers provided directions to the City's website for more information and only were used to promote Public Meeting 1, Session 1.

2.2.3 Social Media Alerts and Share Links

Three weeks prior to the Public Meetings, Social Media Alerts (two per week) were posted on both the City's Facebook and Twitter accounts. Each week leading up to the Public Meetings, two alerts were posted. The purpose of the alerts was to encourage participation in the Public Meeting, either traditional or online format. To take advantage of online networking opportunities, social media share links are embedded in the project website and online public meeting.

2.2.4 Neighborhood Association Email

Along with an email to the Neighborhood Associations quarterly Neighborhood Associations newsletter included mention of the Study and the upcoming Public Session meetings. The purpose of the email was to encourage participation in the public engagement process, describe the methods by which they will be informed of upcoming events, and find more information at the City's website.

2.2.5 Email Invitation

An html formatted email invitation was mailed to all identified stakeholders and participants who provided email contact information at the Public Meetings or on the City's email notification distribution list. The email invitations were distributed 2 weeks prior to each Public Meeting and were used to introduce the public to the project and to invite participation in the Public Meetings and online public open house meeting. The email will provide a link to the online open house public meeting. A reminder email was also sent out prior to every Public Meeting.

2.2.6 City Newsletter

Multiple articles were published in the City's newsletter, *City Side*. The article ran in October 2012, January 2013, and March 2013. The purpose of the newsletter article was to promote the upcoming Public Meetings and encourage City residents to participate and provide input.

2.2.7 Website, Online Meeting, and Comment Form

Information regarding the City's flood mitigation planning was provided on the City's home page. A link directly from the City's website guided the reader to the online meeting.

The online meeting served as an online portal for all interested parties to find information about the project, updates on different milestones reached throughout the planning process, and opportunities to participate and provide input and feedback on the project planning. The same information presented at each of the Public Meetings was presented in an online, self-directed open house meeting. The online meeting provided an electronic comment form. The form was made accessible throughout the online meeting experience. As of April 11, 2013, the City's website generated 1,795 visits; the online meeting generated 644 visits, with 101 comments submitted on the online comment form, for a total of 745 unique visits.

2.3 Comments

To provide mitigation solutions to the City, three questions were asked of the public during Public Meeting 1, Session 1. Responses are listed below and were indicative of many of the comments received at Public Meetings 1, 2, and 3.

1. How have you been impacted by flooding?

- Sewer backup
- Access to roads
- Repairs and maintenance
- Flooding from the municipal
- High water approximately 100-150 feet away from house
- Damage to mobile homes
- Lack of emergency response

airport

- Flooded homes and apartments
- Taxpayer impacts
- Lack of drinking water
- Loss of business revenue

2. What do you think are the flooding issues impacting the Greater Ames Community?

- Older businesses on South Duff Avenue
- Mobile Home Court
- Restricted water flow by bridges and small river channel
- Watersheds above Ames
- Fill along South Duff
- Loss of property
- Displacement from homes
- Cost of clean-up and repairs
- Building in the floodplain
- Flooding to the east of the airport
- Too much development on floodplains
- Too much development on College Creek on either side of South Dakota Avenue
- U.S. Highway 30 across the Skunk River
- Amount and speed of rainwater to the north of Ames needs to be controlled

3. How do you think these flooding issues should be solved?

- Promote businesses on Airport Road
- Restrict development on South Duff
- Build reservoir
- Prevent fill
- Buyout businesses in the floodplain
- Watershed-wide solutions
- Limit building in the floodplain
- Stop promoting urban sprawl
- 500-year plain and ordinances to prevent building on the floodplain
- A dam on South Skunk and/or Squaw Creek
- Enlarge Squaw Creek channel
- Have businesses construct water holding ponds
- Watershed management
- Build water outlet in the highway
- Put water pumps into buildings
- Using engineering judgments
- Make plans using a higher standard
- Provide information regarding FEMA programs

- Re-using old buildings rather than building new ones
- Provide a statewide solution
- Better storm water management
- Dayton Road conveyance

Additional public input was solicited to provide feedback on the alternatives and strategies to the project team. A summary of public input is listed below:

- 100-year flood data is ineffective
- Consider environmental impacts
- Consider dredging creeks while dry
- Consider upstream containment structures
- Consider conservation measures
- Consider floodplain ordinance modifications for all alternatives and strategies
- Better emergency management
- Listen to impacted parties
- Consider stopping and or limiting development in the floodplain
- Upstream and downstream impacts should be considered
- The whole watershed should be addressed, not just Ames
- The City should consider property buy-outs
- Environmental impacts should be quantified

2.4 Council Workshops

In tandem with the Public Meetings, the City Council participated in workshops to inform all council members of the current progress of the project. The following table illustrates the objectives and participants for each workshop. The presentations given at City Council Workshops 1, 2, and 3 are contained in the Appendix A.

Table 2. Summary of Council Workshops.

Meeting	Objective	Participants
Workshop 1 (October 16, 2012)	Presented hydrology, discussed project implications, and began development of screening criteria for application against all potential flood mitigation alternatives	City Council members and project team
Workshop 2 (November 20, 2012)	Discussed the status of the Study Discussed the initial screening criteria Presented the results of the initial screening of alternatives and strategies Gathered feedback on flooding issues and mitigation strategies	City Council members, City staff, and project team
Workshop 3 (April 16, 2013)	Presented the final screening matrix Determined combinations to further evaluate	City Council members, City staff, and project team

3.0 Update of Existing Flood Hydrology

3.1 Updated Flood Frequency Analysis

The number and severity of flood events that have occurred in the City on the South Skunk River and Squaw Creek since the time the existing flood insurance maps were created has increased. The starting point for the Study was to update the existing hydrology associated with the three USGS stream gages located in the City. Updating the hydrology provides new baseline from which to visualize inundation associated with probabilistic flood events as well as to evaluate performance of flood mitigation alternatives. This was done specifically to address the fact that the largest peak flows that the City has experienced have occurred in the time since the City's effective flood insurance maps were developed.

HDR updated the existing base flood hydrology in the South Skunk River and Squaw Creek based on historical gage flows at three USGS river gages in the Study Area. This was based on a regional skew weighted Bulletin 17B (USGS 1982) approach and calculated with HEC-SSP (USACE 2008). The regional skew coefficient utilized was -0.40 (USGS 2013). This will be referred to as the updated flood frequency analysis (FFA) or the updated flows.

USGS gages are South Skunk River near the City (Gage No. 05470000), Squaw Creek at the City (Gage No. 05470500), and South Skunk River below Squaw Creek near the City (Gage No. 05471000). This gage location is downstream from the confluence of the Squaw Creek. The gage locations are shown in Figure 5. The stream records contain 86, 55, and 48 systematic events (annual peaks), respectively.

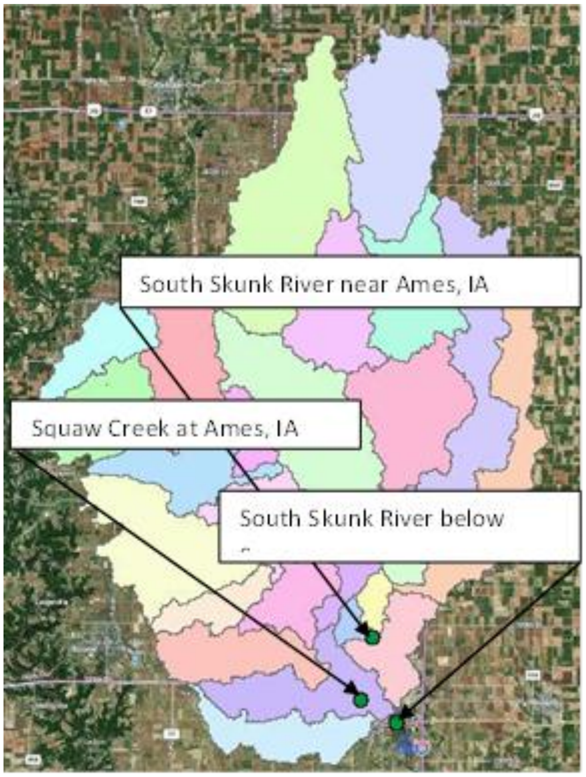

Figure 5. USGS Gages within Squaw Creek and South Skunk River Watersheds.

Table 3 shows the Federal Emergency Management Agency (FEMA) effective flows (FEMA 2008) and the updated FFA flows for the three USGS stream gages located in the watershed. As shown in the table, the updated FFA flows at all three gages increased for the 10, 2, 1 and 0.2 percent annual chance storms. At the base flood (or the 1 percent annual chance flood), the increase ranges from 15 to 25 percent. The increase was due to the fact that the largest peak flows that the City has experienced have occurred in the time since the FEMA effective flows were developed. The output from the FFA is included in Appendix B.

The statistical significance of the updated FFA is described by FEMA (FEMA 2002). The new flood discharges shall be adopted if the previous flood discharges do not fall within the 95 and 5 percent confidence limits (90 percent confidence interval) of the recent estimates; the previous flood discharges shall be adopted if they fall within the 75 and 25 percent confidence limits (50 percent confidence interval) of the recent estimates.

At the 1 percent annual chance level the trend is consistent. The FEMA effective 1 percent annual chance discharge at all three gages falls within the 90 percent confidence interval (defined by the 95 percent and 5 percent confidence limit) and fall outside of the 50 percent confidence interval (defined by the 75 percent and 25 percent confidence limit). There is no guidance from FEMA to support the City adopting the updated FFA discharges based on statistical significance, but there is no support for the City to continue with the effective discharges either. This means that FEMA will not require the City, as a part of being in the National Flood Insurance Program (NFIP) to adopt new discharges and base flood elevations as a result of the FFA. It is left to the City to work out the implications of either path, with input from City council and well as the City planning department. Adopting new discharges, and floodplain maps, allows potentially more protection of property through identification of properties in the highest risk. However expanding the area known as the floodway fringe may have impacts related to development that may not fit within the long term plans for the City. The details of the FFA are included in Appendix B.

Table 3. Updated Annual Flood Probability Discharge (cubic feet per second [cfs]).

USGS Gage	Source	Annual flood-probability discharge (cfs)			
		10-percent	2-percent	1-percent	0.2-percent
South Skunk River near Ames, IA	Updated FFA	6,800	10,200	11,600	14,900
	FEMA Effective Flows	6,280	9,000	10,100	12,600
Squaw Creek at Ames, IA	Updated FFA	8,260	15,800	20,000	32,600
	FEMA Effective Flows	7,570	13,700	17,000	26,300
South Skunk River below Squaw Creek near Ames, IA	Updated FFA	14,500	24,100	28,900	41,800
	FEMA Effective Flows	12,700	19,700	23,000	31,400

3.2 Iowa-Based Flood Causing Rainfall Reconstruction

To incorporate additional information into the flood mitigation alternatives analysis several hypothetical, extreme flooding scenarios were developed based on recent high intensity flood causing rainfall events. These additional flooding scenarios provided tangible flood events that occurred in very similar conditions to the City, both in distance and in hydrometeorology characteristics. The additional data allowed the City to bracket the results of the more traditional flood frequency analysis by incorporating these extreme flood events into the evaluation. The updated FFA flows provide a statistically-based peak flood discharge that has an associated probability and the Iowa-based flood-causing rainfall events provide a peak discharge based on extreme events that have occurred in Iowa over the last five years.

Rainfall data from recent flooding events over the region were both spatially and temporally transposed, utilizing rain gage and radar data from five recent Midwest storm events over the Ames Watershed. This transposition was completed in such a way to adhere to the meteorological principles that are specific to storms that impact the Ames Watershed. An assessment of each storm event was conducted to adjust the data to accurately portray a storm that would be physically possible over the region.

Five storm events were selected based on the event being very recent and/or having had a severe flooding impact. Each of these Iowa-based storms produced the equivalent of the 200 to 1,000-year flood in its watershed. This method was selected to supplement the traditional theoretical rainfall-runoff flood construction for two reasons. The first was that constructed rain events with an annual probability of less that 0.01 (100-year) have a large band of uncertainty. Both the 100-year and 500-year rainfall runoff events were computed using the City hydrologic model – and to supplement these theoretical storm constructions, actual historical rainfall events were added to the analysis since they were extremely severe, local, and recent. The second reason was that for communicating with the public it was more favorable to use a named historic rainfall runoff event (or flood) as a very rare event (Ames 2010, Dubuque 2011) rather than a storm with a number such as the 500-year or 1,000 year rainfall. The storm events analyzed are as follows:

1. Ames August 8–11, 2010 Storm
2. Ames August 8–11, 2010 Storm with Transposed 2nd Wave of Rainfall
3. Dubuque July 27–28, 2011 Storm
4. Lake Delhi Dam Failure July 24, 2010
5. Upper Iowa River June 7–8, 2008 Storm

3.2.1 Collection of Rainfall Data

The five storm scenarios that were incorporated in the analysis are outlined and summarized below. In each set of graphics, the daily rainfall totals for each historical rainfall event as it would have occurred in the Ames watershed subbasin were superimposed over local features for reference purposes.

1. The August 8–11, 2010, event that severely impacted the City and Story County. This well-documented storm event included three distinct periods of rainfall that occurred in the drainage basin at large. The first period of rainfall was from 9:00 p.m. on August 8, through 5:00 a.m. on August 9 (Figure 6a). The figures are contoured with the daily rain total by sub-basin, with red being the highest daily total and green being the smallest. The second period of rainfall was 1:00 a.m. through 7:00 a.m. on August 10 (Figure 6b). The final and greatest period of total rainfall was between 7:00 p.m. on August 10, and 2:00 a.m. on August 11 (Figure 6c). Storm total values peaked near 10 inches as a maximum peak value with total basin average values over 7 inches, which is significant given the area (over 500 square miles) where it occurred.
2. A slightly adjusted version of the Ames storm with the effective replacement of the second wave of precipitation during the event was constructed. This period of rainfall was from 1:00 a.m. through 7:00 a.m. on August 10. was the wave of this period with the least amount of precipitation that occurred in the basin As a result, a substitution was made with rainfall that occurred the southeast of the basin centered near and north of Oskaloosa, Iowa, during nearly the same time period on August 10. The logic behind this effective replacement of period of

storm activity is centered around the knowledge that strong, local storm activity can be shifted relatively small distances given small changes in meteorological conditions especially summertime thunderstorm activity such as that in August 2010 in central Iowa. There was an area of very strong precipitation just to the west of the Squaw Creek and Skunk River basins; however, this area of precipitation (the heaviest amounts) did not have actual observed rainfall amounts, only radar estimated values to verify the heaviest rainfall values for analysis and verification and thus was not analyzed. The precipitation in the Oskaloosa area was more widespread with respect to volume and coverage and could be considered comparable to the amount of precipitation amounts that occurred in the area just to the west of the basin (see Figure 6d).

3. The extreme flooding event that occurred in and around Dubuque, Iowa on the evening and early morning hours of July 27 and 28, 2011, was developed for input into the model. This storm's peak observed values were actually in far northwestern Illinois in Jo Daviess County with amounts exceeding 13 inches near Galena, Illinois, with peak sub-basin amounts near 11 inches plus in about a 13-hour time frame from 6:00 p.m. on August 27 to 7:00 a.m. on August 28, which well exceeds the 1000-year value for the peak rainfall values (see Figure 7).
4. Another event with notable rainfall that resulted in headlines in Iowa included the storms that resulted in the failure of the dam at Lake Delhi on July 24, 2010. This event did result in peak observed rainfall totals in excess of 13 inches in 48 hours (3:00 a.m. July 22 through 3:00 a.m. July 24) (see Figure 8).
5. The final event produced for this task was the recreation and transposition of the flooding event on the Upper Iowa River on June 7 and 8, 2008. Most of the rainfall that resulted in significant flooding in this basin (including an estimated 500-year plus flood event in Decorah). Peak rainfall values more than 10.50 inches in a 30 plus hour period were observed from 11:00 a.m. June 7 to 8:00 p.m. June 8, 2008 (see Figure 9).

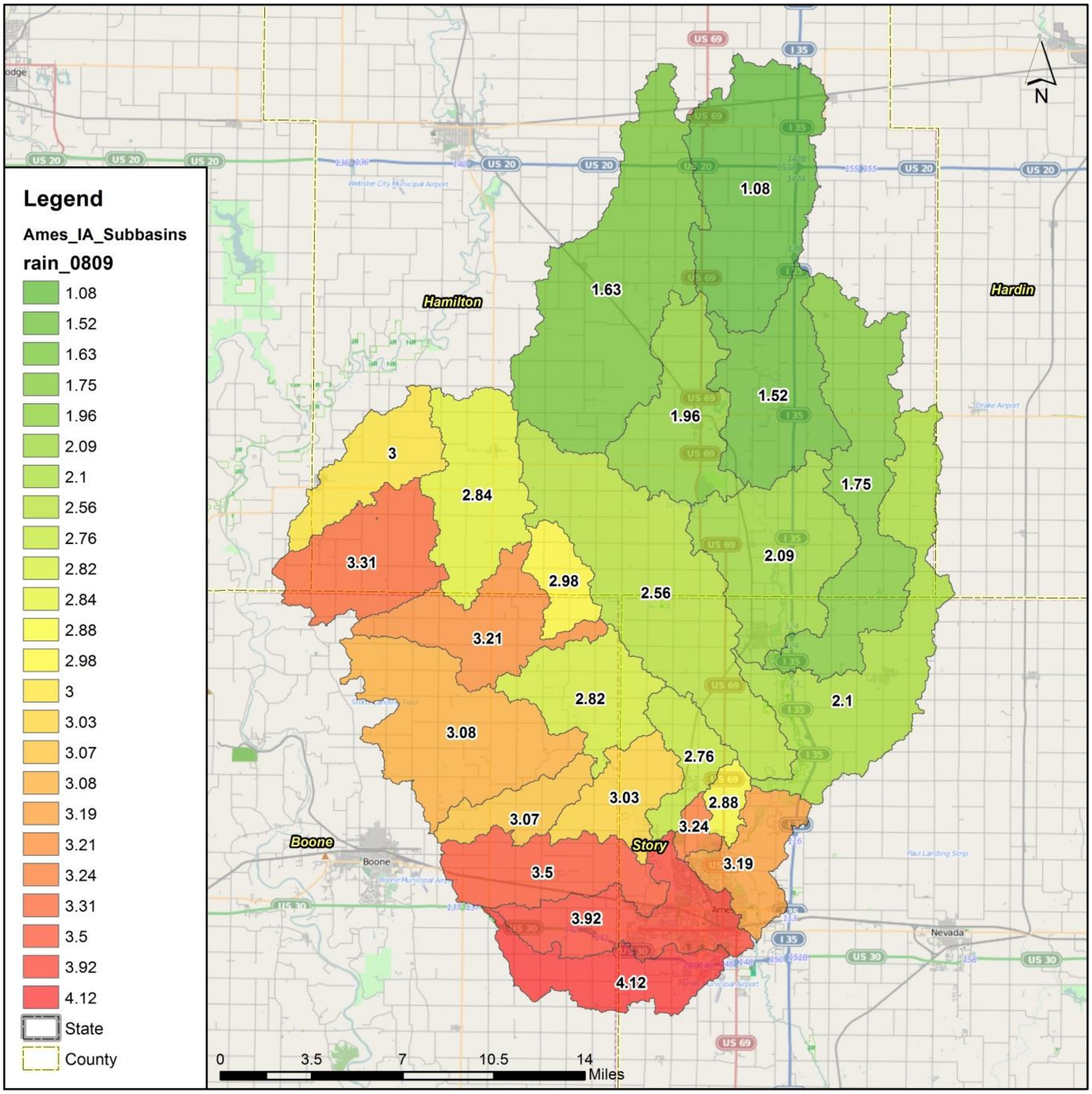

Figure 6a. Ames (original) with 8/9/2010

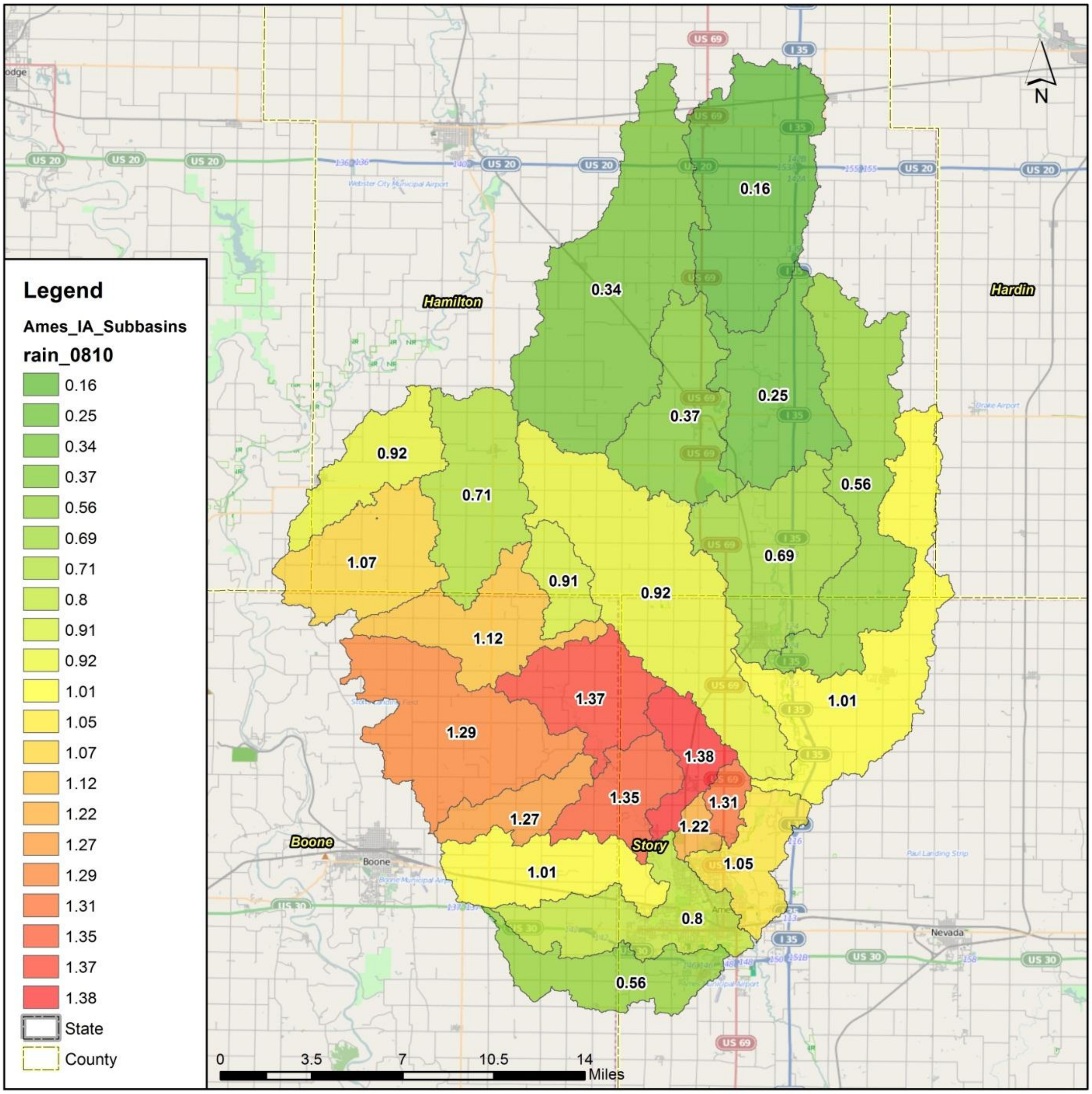

Figure 6b. Ames (original) with 8/10/2010

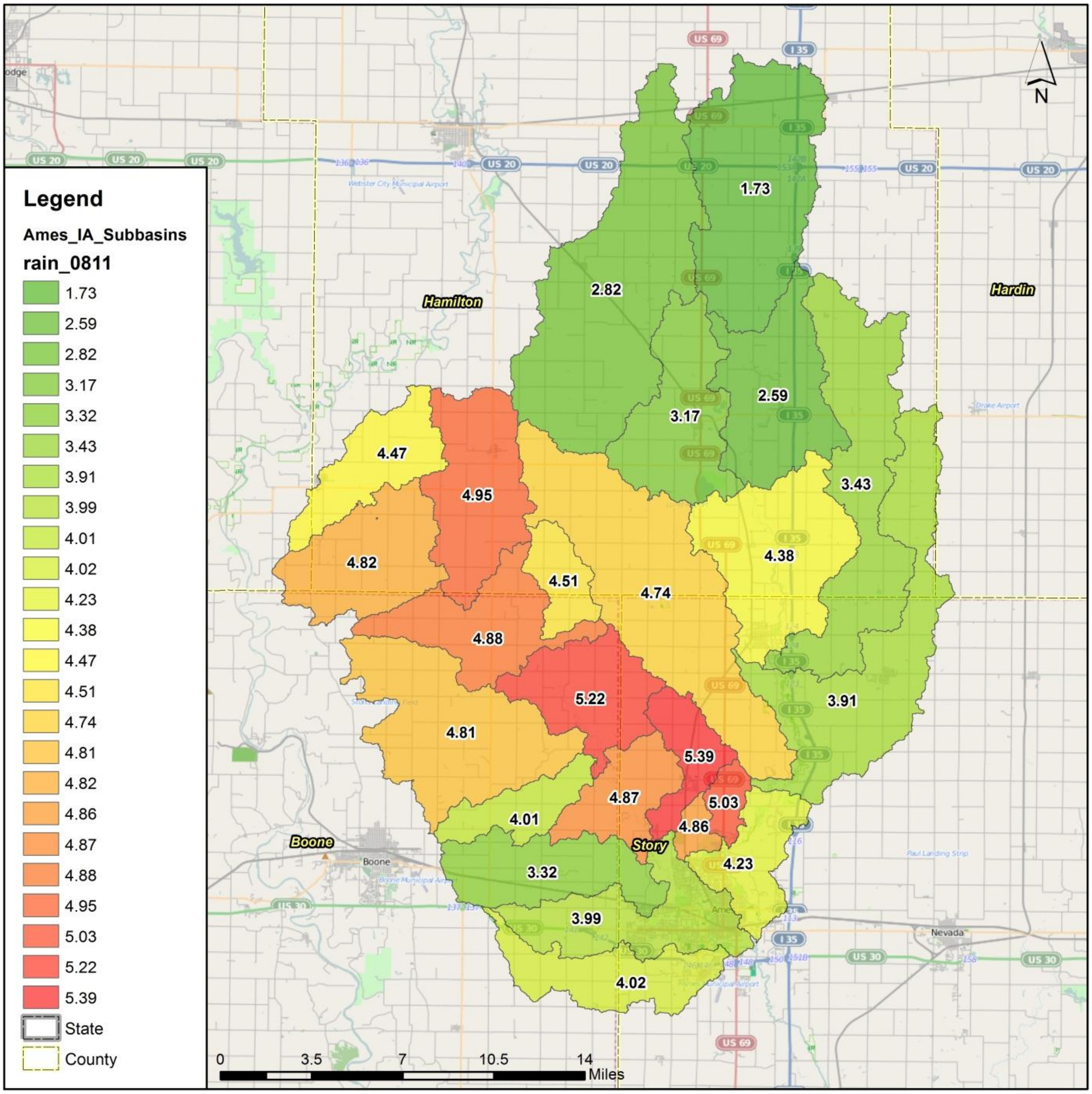

Figure 6c. Ames (original) with 8/11/2010

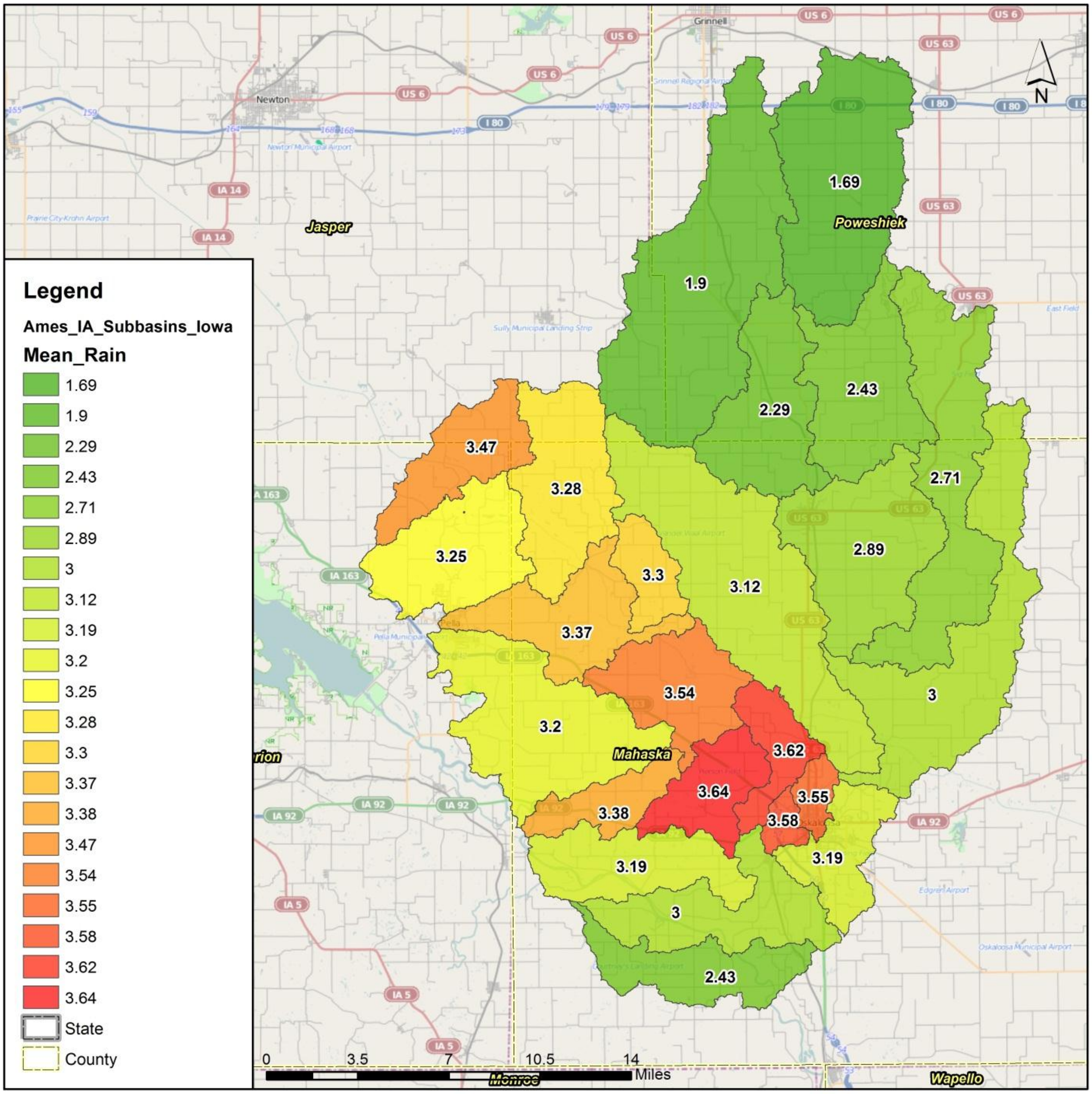

Figure 6d. Ames Storm with the Second Storm Period Substitution Outlined Above (8/10/2013).

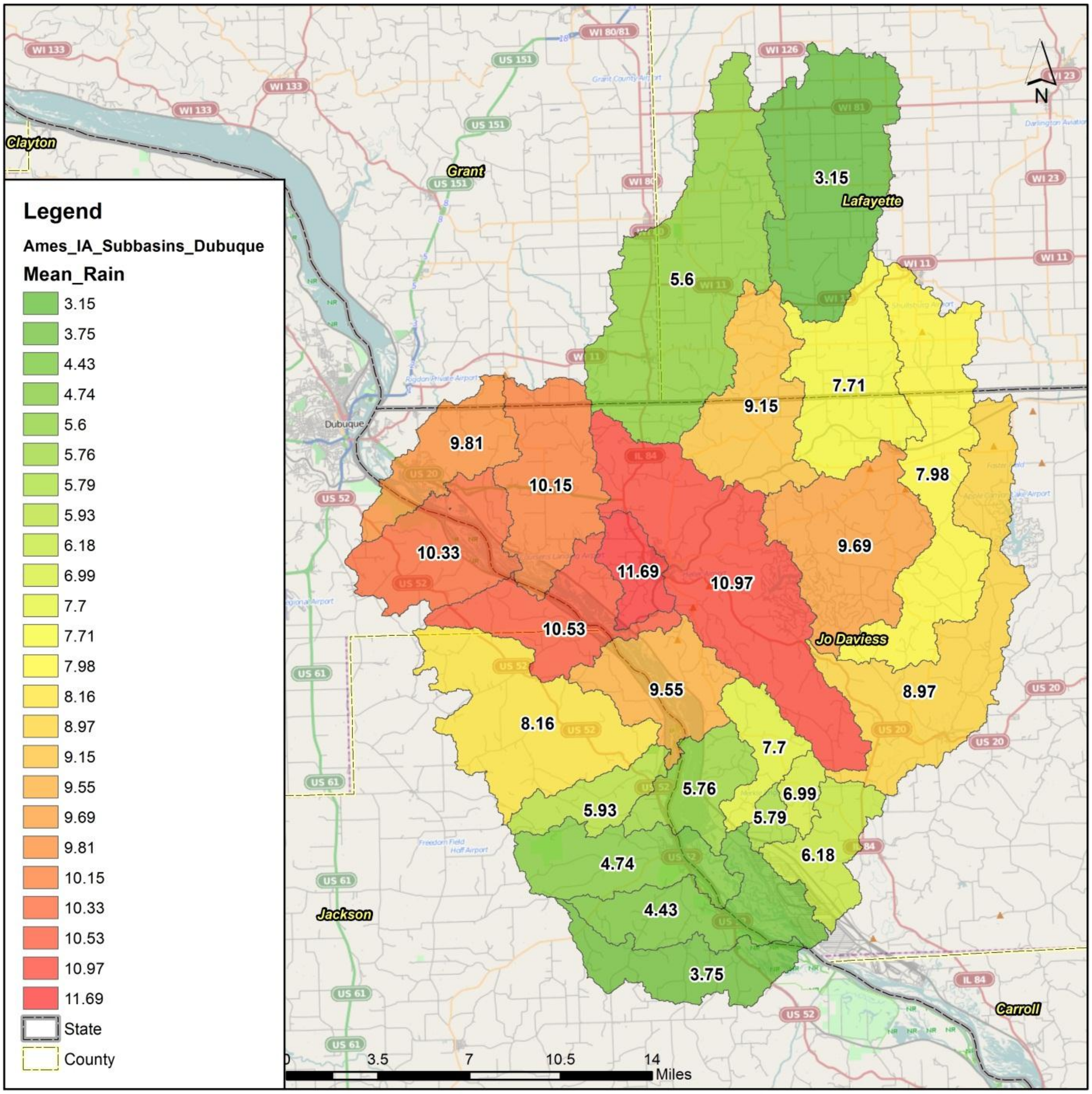

Figure 7. Dubuque Event.

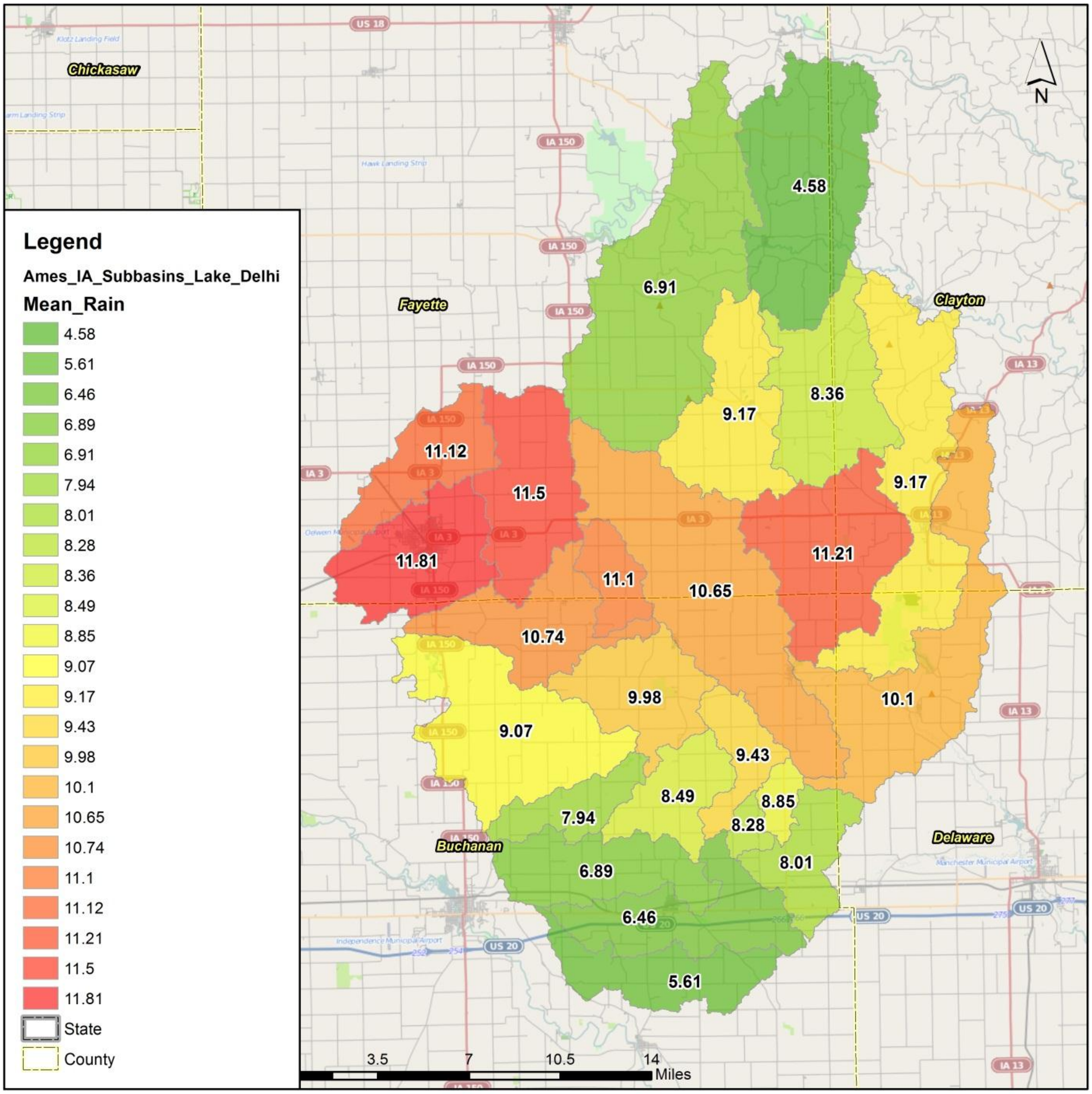

Figure 8. Lake Delhi Event.

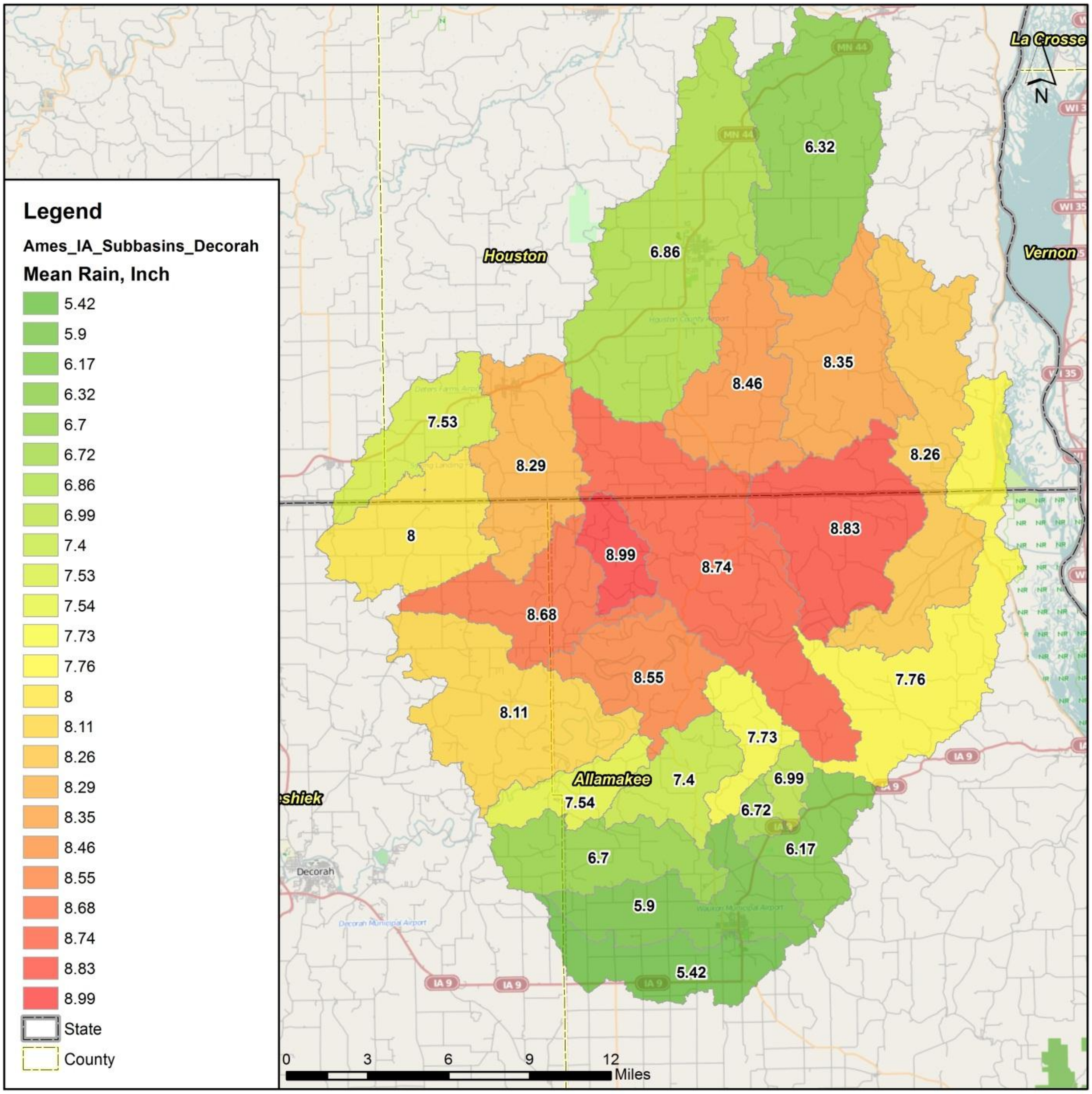

Figure 9. Upper Iowa/Decorah Event.

3.2.2 Storm-Specific Isohyetal and Temporal Construction

The method through which these five events were converted from observed rainfall values to values compatible for the model in this analysis is outlined below.

The original spatial analysis for the Ames August 2010 storm event was accomplished through use of 24-hour rainfall analyses provided by the National Weather Service (NWS) Advance Hydrologic Prediction Service (AHPS) where radar estimated rainfall data is combined with surface observations to produce a 2 kilometer by 2 kilometer analysis grid. These analyses were manually examined for each of the 24-hour periods (which coincide with the three separate periods of rainfall outlined above) and then examined with respect to the actual observed rainfall values. Through this process, the rainfall values were manually compared to the AHPS analyses and some adjustments were made to these gridded values to be better in line with the overall 24-hour analyses for the basin/sub-basin area. Once the 24-hour values were adjusted (if need be), they were interpolated to the sub-basin values provided by the definition of the model. It should be noted that this analysis technique was used for this particular storm event in use for a prior project for the Papio-Missouri Natural Resources District by HDR (by coincidence). The following four storm events were produced in a different manner due to time constraints and available data.

Rainfall data was acquired from a wide variety of sources including the Community Collaborative Rain Hail and Snow network (CoCoRaHS) network, NWS Cooperative Network, and supplemental hourly rainfall data from the NWS ESRL network. All of these observations were reviewed for consistency with respect to time and space. Once this step was completed, a two-dimensional analysis was created through use of spatial analysis techniques available in geographic information systems (GIS). These analyses were then compared with the Storm Total Precipitation estimation product produced by National Weather Service Radar (NWS NEXRAD) site used for each event to ensure that the two-dimensional pattern was recreated with a reasonable level of consistency within the basin/sub-basin footprint. Once this analysis was complete, the separate sub-basin rainfall values were computed from the two-dimensional analyses.

The two-dimensional analyses for each of these events (as translated to each of the sub-basins) are included below with an outline of the basin/sub-basin area transposed over the original area where the storm occurred.

The transposition of these events over the basin footprint was made to maximize the rainfall in the overall Squaw Creek and Skunk River combined basins, especially with the wider east-west axis of the overall basin near the north-south center point. The other three events have maximized rainfall patterns that were largely oriented in an east-west fashion with some slight variances. The results would differ if moved over the urbanized areas of the City with less overall volume, but more potential sub-basin impacts.

Once the overall sub-basin rainfall values for the total storm event were derived for a given event, the temporal distribution of these events was constructed. This step was performed with the Base Reflectivity data from the NWS NEXRAD site that provided the best coverage of this event where it took place. Given the number of sub-basins in the model, the sub-basins were combined into groups of eight. The Base Reflectivity data for the center point of each of these eight sub-basin groups was extracted for each approximate 5-minute by 5-minute radar scan for the event duration. A standardized radar-to-rainfall algorithm was then used to calculate a temporal distribution of the rainfall at each center point. This temporal distribution was normalized (starting at 0 and increasing to 1), then applied to the applicable sub-basin value that the point is grouped with for 15-minute intervals. An example of the distribution of these events with respect to the transposed footprint of the Squaw Creek and Skunk River sub-basins for the Dubuque July 27–28, 2011, event can be seen in Figure 10 with an example of these points with Base Reflectivity data in Figure 11.

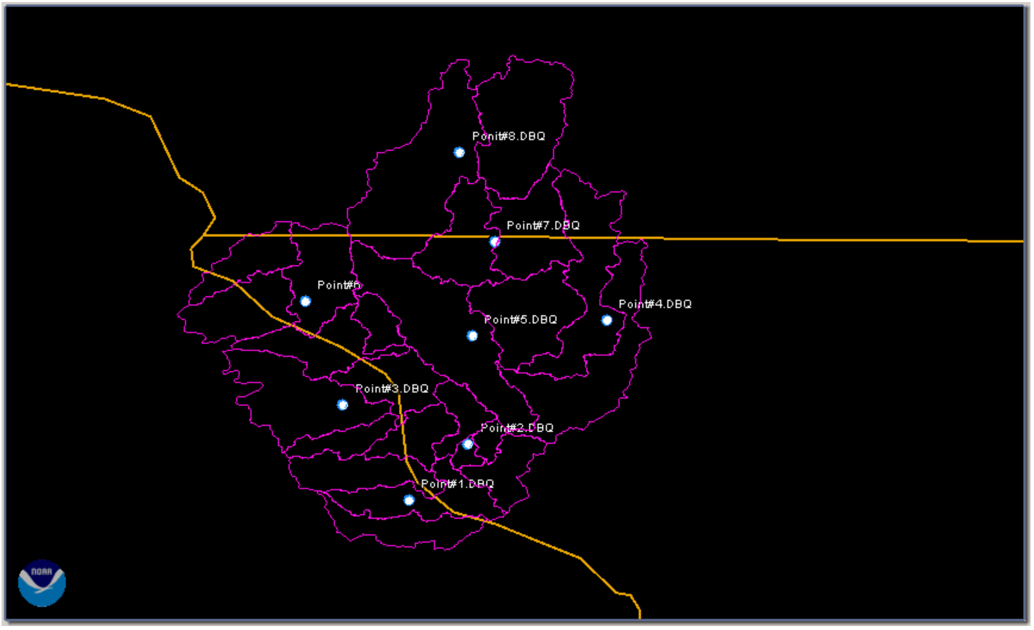

Figure 10. Example of the Eight Base Reflectivity Radar-based Extraction Points Used to Develop the Temporal Distributions Across Various Sub-basin Groups.

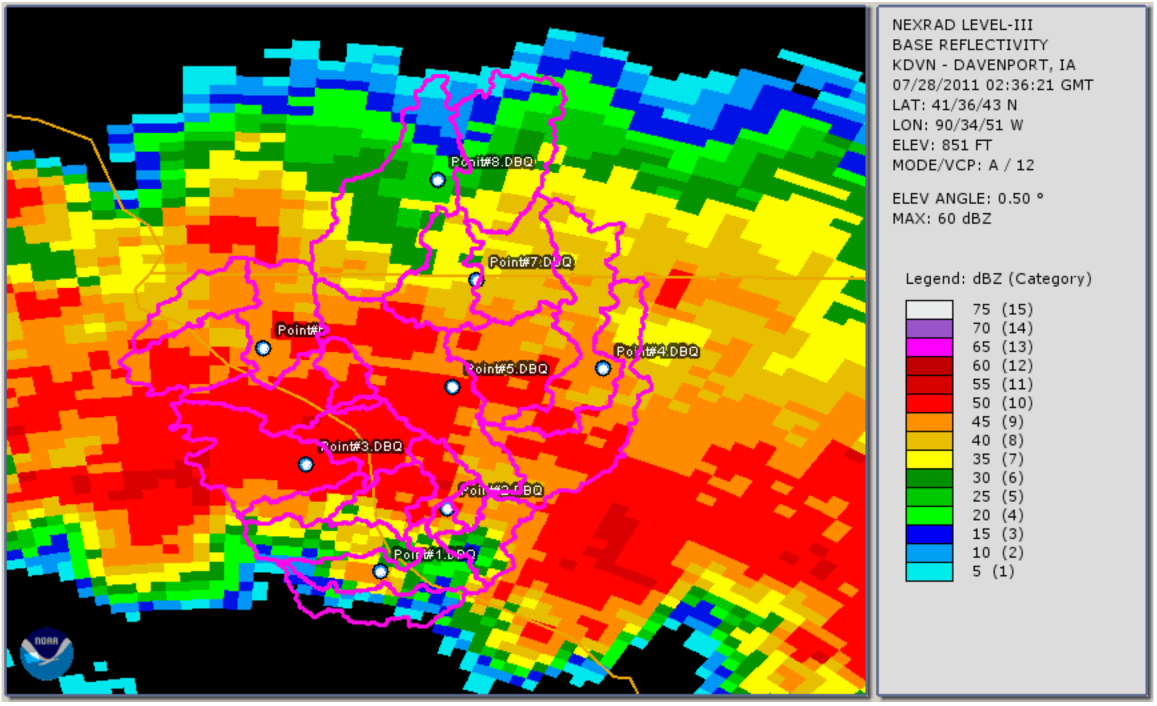

Figure 11. Example of the Eight Base Reflectivity Radar-based Extraction Points with Base Reflectivity Data Used to Develop the Temporal Distributions Across Various Sub-basin Groups. Radar Data is for 9:36 p.m. July 27, 2011.

3.3 Hydrologic Modeling

The hydrologic model was obtained from the City (HEC-HMS, Version 3.5). The model was recently calibrated and updated to reflect the current condition of the Ames Watershed, based on expected ranges for antecedent moisture conditions (AMC) of different events (Schmieg, Franz, Rehmann, and van Leeuwen 2011). For the Study, the parameterization was not adjusted. A total of 24 sub-basins were used to estimate the rainfall-runoff relationship of the 560 square mile watershed. Figure 12 shows the sub-basin boundaries and the HEC-HMS sub-basin names. The sub-basin curve numbers and lag times were set according to the Reparameterization report (Schmieg, Franz, Rehmann, and van Leeuwen 2011) based on AMC.

For verification purposes, sub-basin rainfall (two-dimensional 2 kilometers [km] by 2 km grid) for the Ames August 2010 storm event was applied to the hydrologic model. When comparing the results of the hydrologic model when utilizing the 2 km by 2 km gridded rainfall to the City's model results (Schmieg, Franz, Rehmann, and van Leeuwen 2011), the best comparison results when using the AMC 1 basin model. Although the City's model documentation (Schmieg, Franz, Rehmann, and van Leeuwen 2011) noted according to SCS guidance that AMC 1 corresponded to a total 5-day period of precipitation of less than 1.4 inches, the Ames August 2010 storm event previous 5-day total precipitation across the watershed was 1.85 inches. For the storm events, AMC

1 was used for the previous 5-day period precipitation up to 1.85 inches. The AMC values for the storms analyzed in the HEC-HMS model are reported in Table 4.

The City's model documentation (Schmieg, Franz, Rehmann, and van Leeuwen 2011) presented a range of lag times recommended for the different AMC events. The HEC-HMS results were very sensitive to the lag times. When verifying that the Ames August 2010 storm event (2 km by 2 km grid) compared well to the City's documentation, the middle range of lag times typically produced the closest match to the report values (see Figure 13). The modeled peak flows matched the measured USGS peak flows within a reasonable tolerance. The middle range of lag times for each AMC condition were used in the analysis. The baseflow for each sub-basin was determined by obtaining an average baseflow per square mile based on USGS mean daily flow for August 1–7, 2010, at the three stream gage locations within the City before the Ames August 2010 storm event.

Table 4. Antecedent Moisture Conditions for Storms Analyzed

Storm Event	AMC	Previous 5-day period Precipitation Total (inches)
Ames August 8-11, 2010 Storm	1	1.85
Ames August 8-11, 2010 Storm with Transposed 2nd Wave of Rainfall	1	1.85
Dubuque July 27-28, 2011 Storm	3	2.75
Lake Delhi Dam Failure July 24, 2010	1	0.52
Upper Iowa River June 7-8, 2008 Storm	1	1.53

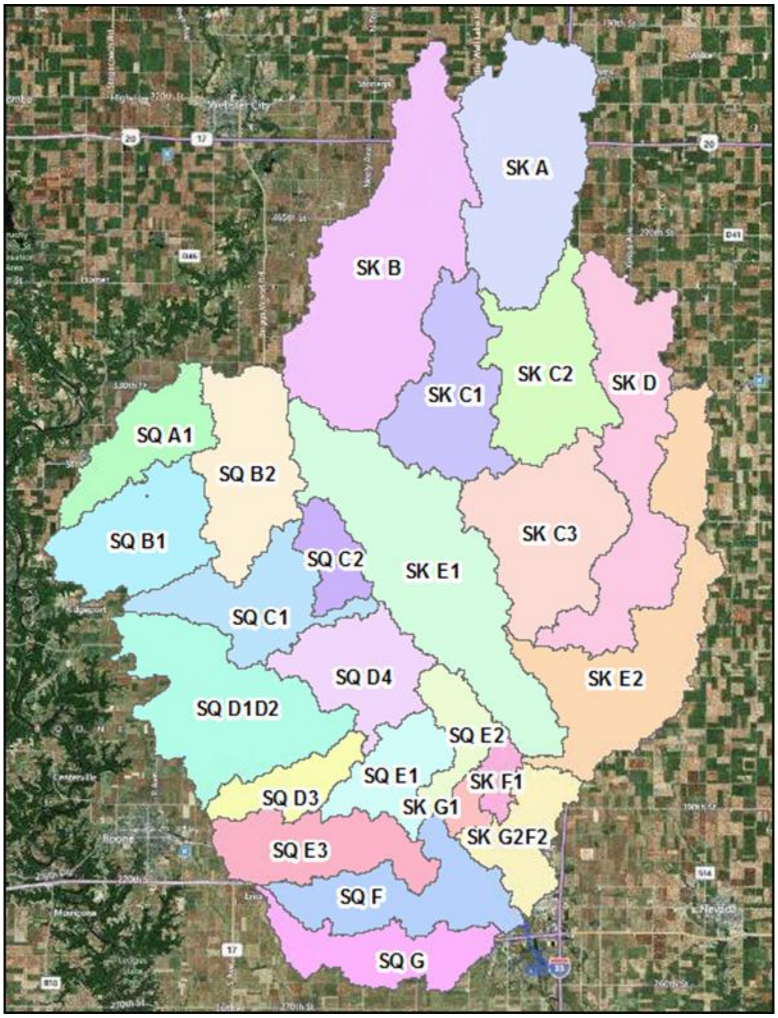

Figure 12. Ames Watershed Sub-basin Boundaries.

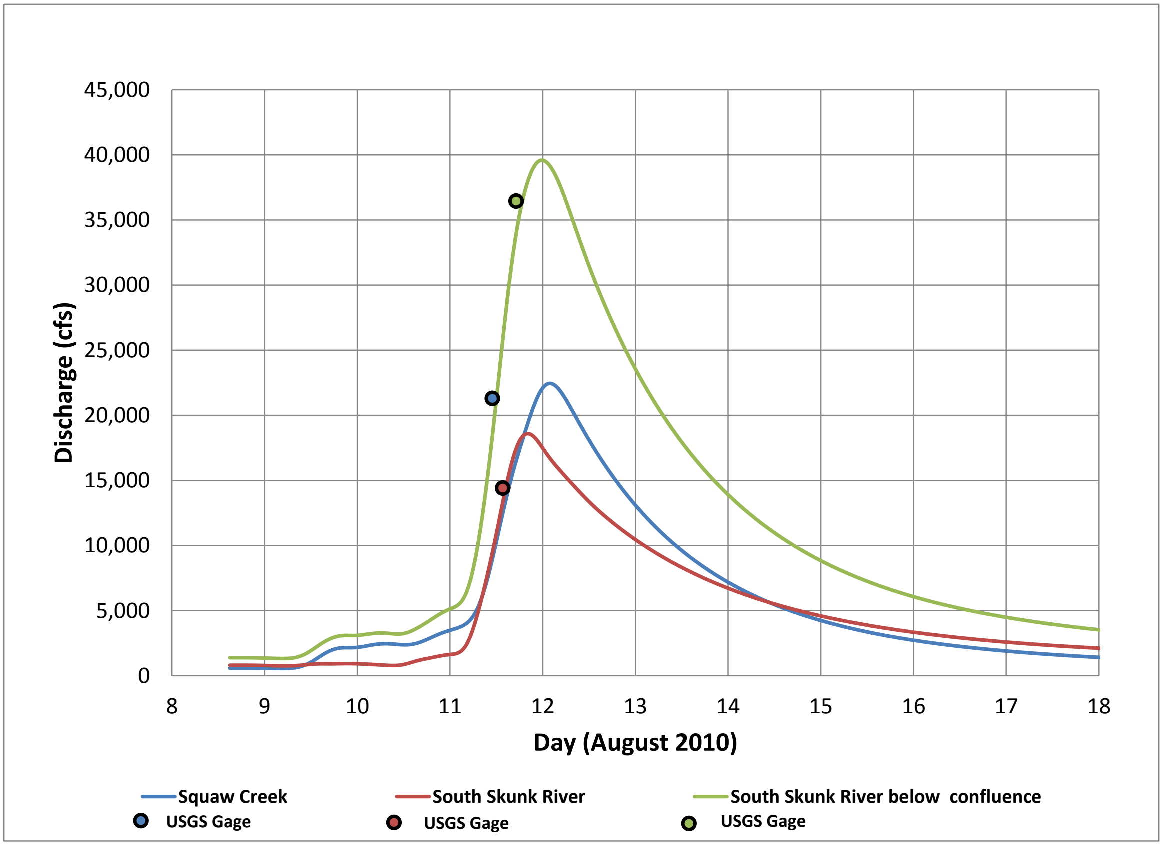

Figure 13. Ames August 2010 Flood Event, Modeled 2010 Event with HMS compared to USGS Peak Gage Measurements.

Table 5 summarizes the estimated rainfall and runoff volumes with the City's hydrologic model for the five storms evaluated below the confluence of the Squaw Creek and South Skunk River compared to the 5- and 100-year existing conditions rainfall event.

Table 5. Summary of Rainfall and Runoff Volumes (acre-feet).

Storm	Total Rainfall Volume (acre-feet)[1]	Total Runoff Volume (acre-feet)[2]
5-year Existing Storm	119,000	15,700
100-year Existing Storm	197,000	55,100
Ames August 8-11, 2010 Storm	214,000	69,000
Upper Iowa River June 7-8, 2008 Storm	215,000	77,000
Ames August 8-11, 2010 Storm with Transposed 2nd Wave of Rainfall	275,000	120,000
Dubuque July 27-28, 2011 Storm	233,000	187,000
Lake Delhi Dam Failure July 24, 2010	266,000	103,000

1. The summation of each sub-basin rainfall amount multiplied by the sub-basin drainage area.
2. The summation of each sub-basin total runoff multiplied by the sub-basin drainage area. No adjustment made for storage.

Table 6 summarizes the estimated peak discharges for the five storms, the effective FEMA discharges, the updated FFA discharges, and the 100-year discharge (from City Hydrologic model) evaluated at various locations along the Squaw Creek and South Skunk River.

As part of the alternatives analysis, the City hydrologic model was utilized to analyze the impact of storage alternatives on flood peaks and water surface elevations. The use of the City hydrologic model in the alternatives analysis is predicated on its ability to produce runoff and peak discharges that are reasonable when compared to the FFA discharges listed in Table 3. As described in Section 3.1, the peak discharges associated with the FFA (see Table 3) have been derived mathematically and are based on historical flows at the three USGS gage locations within the City limits. Associated with each peak flow is also a 90 percent confidence interval (5 percent and 95 percent confidence limits), and it stands to reason that if the 1 percent annual chance rainfall is applied to the City hydrologic model, then it should produce a peak runoff amount that falls within the 90 percent confidence interval at the 1 percent annual chance level. With additional calibration events the City hydrologic model may perform better in this regard. The City hydrologic model may have been skewed toward reproducing the 2010 event, and it could be improved with calibration to a broader range of events and conditions. For the alternatives analysis, the City hydrologic model served as an adequate tool for evaluating alternatives that required flood water storage.

Table 6. Summary of Peak Discharges (cfs).

Storm	Squaw Creek – at South Duff Avenue[1]	South Skunk River – at Lincoln Way[2]	South Skunk River below Squaw Creek – near Highway 30[3]
FIS 1-Percent Annual Chance Flood (Effective 100-Year Flood)	17,000	10,100	23,000
1-Percent Annual Chance Flood	20,000	11,600	28,900

Storm	Squaw Creek – at South Duff Avenue[1]	South Skunk River – at Lincoln Way[2]	South Skunk River below Squaw Creek – near Highway 30[3]
(Updated FFA Discharges)			
100-yr Existing (City Hydrologic Model)	16,000	15,800	32,950
FIS 0.2-Percent Annual Chance Flood (Effective 500-Year Flood)	26,300	12,600	31,400
0.2-Percent Annual Chance Flood (Updated FFA Discharges)	32,600	14,900	41,800
Ames August 8-11, 2010 Storm	22,700	18,900	39,590
Ames August 8-11, 2010 Storm with Transposed 2nd Wave of Rainfall	29,300	30,500	57,120
Dubuque July 27-28, 2011 Storm	84,300	89,800	172,000
Lake Delhi Dam Failure July 24, 2010	24,000	33,900	53,900
Upper Iowa River June 7-8, 2008 Storm	14,400	23,800	37,400

1. Corresponds to HEC-HMS SqwCOMB7
2. Corresponds to HEC-HMS Before U.S. Highway 30 Skunk
3. Corresponds to HEC-HMS U.S. Highway 30 Junction

4.0 Update of Existing Hydraulics and Inundation Maps

The hydraulic model for the Ames Watershed (Squaw Creek and South Skunk River) was obtained from the IFC (IIHR-Hydroscience and Engineering 2012). The hydraulic model was based on topography extracted from Iowa DNR LiDAR (2008). The horizontal resolution was one meter and the vertical uncertainty was 20 centimeters. The channel bathymetry was measured by IIHR (2011, 2012). On-foot measurements using RTK GNSS, connected to the Iowa DOT's Real-time Network (IaRTN). The bridges and structures were based on information from Iowa DOT, LiDAR, City of Ames, and IIHR measurements. For the purpose of this evaluation, the IIHR hydraulic model is considered to be the best available data.

See Appendix C for more detailed information on IIHR's development, methodology, and calibration of the hydraulic model. HDR updated the steady-state hydraulic model by adding the updated FFA discharges. The model extends from Interstate 35 (downstream) to north of Riverside Road (upstream) on the South Skunk River and from the confluence with the South Skunk River (downstream) to north of Cameron School Road (upstream) on the Squaw Creek.

To establish the baseline hydraulic conditions for the flood mitigation study (based on updated hydrology - Section 3), HDR computed water surface elevations through the City with the IIHR model. This was done for the 2-, 5-, 10-, 25-, 50-, 100-, and 500-year flood events. The water surface elevations were then projected onto topography developed from Iowa DNR LiDAR (2008), which provides the basis for the inundation maps.

In Appendix D, the baseline inundation maps are presented, and each recurrence interval has two maps associated with it, the northern part (Upper) of the City and southern (Confluence) part of the City. These inundation maps are also presented in an interactive environment on the Iowa Flood Information System website (http://ifis.iowafloodcenter.org/ifis/main/?v=a).

Additionally, to incorporate additional sensitivity analysis into the flood mitigation alternatives analysis, five hypothetical, extreme flooding scenarios were developed based on recent high intensity flood causing rainfall events. Their peak discharges were presented in Table 6. There are two main reasons for mapping the five resultant flood events. Practically speaking, the most extreme event, known as the Dubuque event, has more than four times the peak discharge in the South Skunk River below the confluence with Squaw Creek, and mapping the inundation associated with it is helpful to the City from an emergency management perspective. These five events also provide additional baseline hydraulic conditions for the Study, allowing mitigation alternatives and strategy performance to be evaluated during the most extreme events. In Appendix E, the baseline inundation maps from Iowa-based flood causing rainfall events are presented, and each recurrence interval has two maps associated with it, the northern part (Upper) of the City and southern (Confluence) part of the City. These inundation maps are also presented in an interactive environment on the Iowa Flood Information System website (http://ifis.iowafloodcenter.org/ifis/main/?v=a).

For comparison purposes, Table 7 summarizes the water surface elevations (WSELs), for the existing conditions plus the five Iowa-based rainfall events evaluated at South Duff (Squaw Creek) and the South Skunk River (above and below confluence with Squaw Creek).

These water surfaces throughout the City limits provide the basis for the alternatives analysis including the Benefit Cost Analysis.

Table 7. Summary of Water Surface Elevations (NAVD88).

Storm/Event	Squaw creek – at South Duff Avenue[1]	South Skunk River – at Lincoln Way[2]	South Skunk River below Squaw Creek – at Highway 30[3]
FIS 1-Percent Annual Chance Flood (Effective 100-Year Flood)	888.5	886.6	883.1
1-Percent Annual Chance Flood (Updated FFA Discharges)	889.0	886.0	884.2
FIS 0.2-Percent Annual Chance Flood (Effective 500-Year Flood)	891.0	887.8	884.6
0.2-Percent Annual Chance Flood (Updated FFA Discharges)	891.8	887.2	886.1
Ames August 8-11, 2010 Storm	890.0	887.4	886.4
Ames August 8-11, 2010 Storm with Transposed 2nd Wave of Rainfall	891.9	890.3	887.7
Dubuque July 27-28, 2011 Storm	896.9	893.9	889.6
Lake Delhi Dam Failure July 24, 2010	890.5	889.3	887.6
Upper Iowa River June 7-8, 2008 Storm	887.8	887.5	886.1

1. Corresponds to FEMA Squaw Creek XS A and HEC-RAS Sta. 1269.733
2. Corresponds to FEMA Skunk River XS E and HEC-RAS Sta. 6050.319
3. Corresponds to Skunk River XS B and HEC-RAS Sta. 3540.118

5.0 Initial Mitigation Alternatives

Flood mitigation alternatives were identified as part of the preliminary screening phase of the Study. The following sections document the identification of the alternatives and the analysis conducted.

5.1 Development and Description of Initial Mitigation Alternatives

Twelve initial alternatives were identified through discussion with project stakeholders and public input. These alternatives are described below.

1. Do-Nothing: This alternative does not include permanent infrastructure improvements or floodplain development restrictions. This alternative assumes temporary flood protection measures for access and property would be employed by the City and private property owners.
2. Centralized Flood Storage (Ames Reservoir plus Squaw Creek Dry Detention): This alternative would involve construction of two reservoirs for flood control, Ames Lake (a multi-purpose flood control reservoir on the Skunk River with 89,500 acre-feet of flood control storage) and Squaw Creek Detention Reservoir (SC-1) (a single purpose flood control detention dam).
3. Regional Flood Storage (Tributary Detention and Smaller Main Stem Dams): This alternative evaluated 14 sites for use as multi-purpose projects.
4. Floodplain Storage: This alternative included construction of small impoundments along the main channel of the Squaw Creek and the South Skunk River that store flood waters. The impoundments consisted of modifying road crossings by raising the road grade and decreasing the size of bridge and culvert openings, taking advantage of floodplain storage not previously utilized for flood control purposes.
5. Conservation Measures in Watershed: This alternative evaluated small detention sites in the watershed that could contribute to flood reduction and constructed wetlands administered under the Iowa Department of Agriculture and Land Stewardship's Conservation Reserve Enhancement Program (CREP) that could be used for flood control.
6. Diversion: This alternative includes diverting flood waters around the City by either diverting Squaw Creek at Cameron School Road to the Skunk River via Ada Hayden Reservoir or diverting Squaw Creek upstream from Cameron School Road to the Skunk River downstream from the Ames Municipal Airport.
7. Conveyance Improvements: This alternative consisted of improving the conveyance of the river channel by clearing or excavating the river channel. This also included modifying bridge obstructions.

8. Flood Proofing: This alternative involved structural improvements to buildings to flood-proof such as site grading and improvements to facilitate flood fighting closures and/or raising structures to above the 500-year or to the 2010 level.
9. Levees along Skunk River: This alternative involved protecting property areas along the Skunk River by constructing a levee (berm and floodwall) combination.
10. Levees along Squaw Creek: This alternative involved constructing a levee (berm and floodwall) and necessary appurtenances to protect properties along South Duff to either the 500-year or the 2010 event.
11. Property Buyouts: This alternative included purchase of structures and property potentially impacted by 500-year event or 2010 event.
12. Floodplain Ordinance Modification: This alternative includes modifications to the floodplain ordinance, including 100-year floodplain becomes the floodway; 2010 inundation limit becomes the floodway; regulate to the base flood plus 5 feet; modify floodplain extent to be extent of the floodplain associated with base flood plus 3 feet; regulate to the 500-year event; redefine the floodway based on new modeling; enact compensatory storage requirements; develop and maintain two-dimensional model that can quantify impact of individual structures on floodplain; and adopt a lifetime cumulative damage limit for properties in the floodplain.

5.2 Criteria/Metrics for Initial Screening

For the preliminary screening, the above-mentioned alternatives were defined to a conceptual level to make qualitative comparisons. Alternatives were evaluated based on the level of protection that could be provided, feasibility, property impacts, regulatory, technical, and ease of implementation.

Prior to the initial screening of the twelve alternatives provided above, the screening criteria were developed. The criteria utilized during the screening process are described below.

- Existing 100-Year Protection Level: This criteria evaluation determines whether the alternative provides flood mitigation at the existing 100-year, or 1 percent annual chance storm event.
- Updated 100-Year Protection Level: This criteria evaluation determines whether the alternative provides flood mitigation at the updated 100-year, or 1 percent annual chance storm event.
- 2010 Flood Event Protection: This criteria evaluation determines whether the alternative provides flood mitigation at the peak WSEL and flow associated with the 2010 Squaw Creek and South Skunk River flood event.
- 2010 Event with Transposed 2nd Day Rainfall: This criteria evaluation determines whether the alternative provides flood mitigation at the WSEL and flow associated

with the 2010 Transposed 2nd Day Rainfall Squaw Creek and South Skunk River flood event.

- Flood Mitigation: Flood mitigation is provided at the specified storm event with freeboard. In accordance with Title 44, Chapter 65.10 of the Code of Federal Regulations (44 CFR 65.10) for certified levees, freeboard is defined as a minimum of 3 feet above the 1 percent annual chance storm WSEL. Additional requirements include that an additional 1 foot of freeboard is required within 100 feet of a bridge (upstream or downstream) and an additional 0.5 foot of freeboard is required at the upstream end of the levee. For the levee and floodwall alternatives listed herein, 3 feet of freeboard above the design WSEL is provided for each alternative, unless specifically noted otherwise.
- Feasibility - Property Impacts/Regulatory/Technical/Ease of Implementation: This criteria evaluation considers the feasibility of that particular alternative in terms of property impacts, regulatory consideration, technical feasibility, and ease of implementation.

6.0 Initial Screening Analysis and Results

A screening matrix was developed that includes: a brief description of the alternative, the results of the screening evaluation using the criteria listed above, and a brief description of the results of the screening process. This matrix is provided as Table 8 on the following pages. Based on the initial screening, ten out of the twelve alternatives were selected for further analysis. However, four of the ten alternatives that were carried forward were not able to provide a stand alone solution. The other two alternatives were not further analyzed due to the inability to meet flood damage reduction objectives or economically infeasible.

Table 8. City of Ames Flood Mitigation Study – Preliminary Screening.

Alternative/Strategy	Alternative/Strategy Description	Level of Flood Protection: Existing 1% Annual Chance Flood Event – Squaw Creek	Existing 1% Annual Chance Flood Event – Skunk River	Updated 1% Annual Chance Flood Event – Squaw Creek	Updated 1% Annual Chance Flood Event – Skunk River	2010 Event – Squaw Creek	2010 Event – Skunk River	2010 Event with Transposed 2nd Day Rainfall – Squaw Creek	2010 Event with Transposed 2nd Day Rainfall – Skunk River	Feasibility Property Impacts/Regulatory/Technical/ Ease of Implementation	Preliminary Screening Results
1. Do-Nothing	No permanent infrastructure improvements or floodplain development restrictions enacted; temporary measures for access and property protection would be employed by the City and private property owners.	N	N	N	N	N	N	N	N	It is not possible to protect property in flood prone areas from flood damage due to the short amount of warning time available. This would be easy to implement.	A do-nothing approach is unacceptable from a social, political, and economic point of view. Alternative will be carried forward for comparative purposes with other alternatives.
2. Centralized Flood Storage (Ames Reservoir plus Squaw Creek Dry Detention)	The United States Army Corps of Engineers (USACE) (July 1987) re-evaluated Ames Lake, a multi-purpose flood control reservoir on the Skunk River with 89,500 acre-feet of flood control storage (5.2 inches of rainfall runoff). A reservoir with reduced flood capacity was also investigated (51,000 acre-feet (3.0-inches of rainfall). USACE (July 1987) evaluated Squaw Creek Detention Reservoir (SC-1), a single purpose flood control detention dam with a dry reservoir. Its flood storage capacity was approximately 20,500 acre-feet (2.1 inches of rainfall runoff) at the top of the spillway, and 52,000 acre-feet (6.1 inches of rainfall runoff) at the top of the dam.	Y	Y	Y	Y	Y	Y	Y	Y	At the time of the evaluation, both a larger, authorized multi-purpose reservoir, and a smaller multi-purpose reservoir were found not to be feasible for economic (larger) and political (smaller) reasons. For reference the volume associated with a 1 percent annual chance rainfall is: 55,100 acre-feet. The volume associated with the Ames August 2010 storm event is: 69,000 acre-feet. The runoff volume associated with the Ames August 2010 storm event (Transposed Rainfall) is: 120,000 acre-feet. The large reservoir impacted 5,000 acres in its flood pool including residences and farmsteads and the smaller reservoir impacted 3,620 acres. The dry detention site at flood pool requires 1,430 acres of flood pool.	Alternative is carried forward. Locating structures on the main channel allows design to likely limit flood damage for all four design events. Environmental, social, and property impacts are substantial and will be identified, in conjunction with costs and potential flood reduction benefits.
3. Regional Flood Storage (Tributary Detention + Smaller Main Stem Dams	USACE (July 1987) evaluated 14 sites (including the Large Reservoir and Dry Detention Alternatives above) for use as multi-purpose projects.	Y	Y	Y	Y	P	P	N	N	USACE was specifically looking for sites that met the surface area and watershed area requirements leading to multi-purpose project, and only four sites had potential as a multi-purpose project. Several sites may have possibilities as a single purpose (flood control) site. This could impact up to 14,000 acres of private land.	Alternative is carried forward. The detention projects could be designed to meet flood damage reduction objectives. The combination of main stem and tributary detention controls runoff from over half of the watershed. This is a significant enough magnitude to likely meet the 1 percent annual chance flood and potentially the Ames August 2010 storm event flood damage reduction objectives.
4. Floodplain Storage	A series of small impoundments along the main channel of the Squaw Creek and Skunk River that store flood waters.	P	P	P	P	N	N	N	N	This is alternative is technically feasible and property impacts are limited to land near floodplains, but significant amount of property would be required to	Alternative is carried forward, though not as a stand-alone solution. This alternative provides additional storage in the floodplain and will provide some

Alternative/Strategy	Alternative/Strategy Description	Level of Flood Protection								Feasibility Property Impacts/Regulatory/Technical/ Ease of Implementation	Preliminary Screening Results
		Existing 1% Annual Chance Flood Event		Updated 1% Annual Chance Flood Event		2010 Event		2010 Event with Transposed 2nd Day Rainfall			
		Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River		
										gain the storage. Preliminary investigation shows that creating impoundments by modifying county road crossings and/or building weirs can provide on average 500 acre-feet of additional flood storage per county road crossing/and or weir. Based on initial calculations, floodplain storage would require 55 crossing modifications as well as property purchases and/or easement along the entire length of Squaw Creek and the Skunk River to control half the storm volume from the 100-year event. It would require 70 crossing modifications to meet the 2010 protection requirements. This alternative has a significant amount of environmental as well as private property impact. From an implementation perspective, many of these modifications may have limited negative impact, and therefore may be able to be enacted as funds become available.	benefit by reducing the amount of flood flow in the river. It is recommended that the alternative be analyzed in additional detail to facilitate combination with other alternatives.
5. Conservation Measures in watershed	The National Resources Conservation Service (NRCS) – Soil Conservation Service performed an analysis in 1985, looking at small detention sites in the watershed that could contribute to flood reduction. The Iowa Department of Agriculture and Land Stewardship administer the CREP program - Conservation Reserve Enhancement Program, which consists of constructed wetlands for flood control and water quality improvements.	N	N	N	N	N	N	N	N	The SCS found that only 2 percent of the watershed could be controlled by small flood control and conservation projects with a drainage area of less than 5 square miles (typically 30 to 50 percent is required to have an impact). Within the Skunk River and Squaw Creek watershed there are 4 developed sites and approximately 50 more that have been identified by Iowa Department of Agriculture and Land Stewardship (IDALS). A typical size of a restored wetland project would contain 4.5 acre-feet of flood storage, assuming they each control 1,000 acres, have 100 acres of space, and are on average less than 3 feet deep. The number of restored wetlands in the watershed to make a significant difference would be approximately 6,100.	Alternative is carried forward, though not as a stand-alone solution. This alternative provides additional storage as well as water quality benefits and will provide some benefit by reducing the amount of flood flow in the river. It is recommended that the alternative be analyzed in additional detail to facilitate combination with other alternatives.

Alternative/Strategy	Alternative/Strategy Description	Level of Flood Protection: Existing 1% Annual Chance Flood Event – Squaw Creek	Existing 1% Annual Chance Flood Event – Skunk River	Updated 1% Annual Chance Flood Event – Squaw Creek	Updated 1% Annual Chance Flood Event – Skunk River	2010 Event – Squaw Creek	2010 Event – Skunk River	2010 Event with Transposed 2nd Day Rainfall – Squaw Creek	2010 Event with Transposed 2nd Day Rainfall – Skunk River	Feasibility Property Impacts/Regulatory/Technical/ Ease of Implementation	Preliminary Screening Results
										The number and extent of potential CREP sites are limited by topography and drainage patterns, resulting in insufficient storage volume to make this a viable stand-alone alternative. The impacts on private property are significant. From an implementation perspective, many of the wetland restoration sites may have limited negative impact, and therefore may be able to be constructed as funds/property become available.	
6. Diversion	A diversion consists of diverting flood waters around the City. This diversion consists of two alternatives. The first is diverting Squaw Creek at Cameron School Road to the Skunk River via Ada Hayden Reservoir. This is approximately a 3-mile diversion that also takes advantage of any additional storage provided by Ada Hayden Reservoir. The second alternative consists of diverting Squaw Creek upstream from Cameron School road to the Skunk River downstream from the Ames Municipal Airport. This is approximately a fourteen mile diversion.	Y	N	Y	N	Y	N	P	N	This alternative requires acquisition of significant right-of-way, impacts the landscape, and requires commitment of significant construction dollars.	This alternative is carried forward. It can be designed to meet flood reduction objectives, especially along Squaw Creek.
7. Conveyance Improvements	Conveyance improvements generally include channel improvements (clearing, excavating, shaping, and lining) and bridge modifications. Two specific elements: At least two bridges – U.S. Highway 30 Bridge over the Skunk River and South Duff Bridge over Squaw Creek – have been shown through hydraulic modeling and observed during flood events to restrict flows. The Iowa DOT has looked at increasing the length of the U.S. Highway 30 Bridge. The increased conveyance would lower flood levels in the lower reaches of Squaw Creek (South Duff area) during high flow events. Conveyance Improvements include modification of road embankments in and around South Duff to	N	N	N	N	N	N	N	N	Conveyance improvements are technically feasible; however significant issues to be addressed include environmental impacts, land acquisition, and transportation system impacts. Many of the improvements could be easily implementable, such as, channel shaping near a bridge. As part of this alternative any impact downstream of the City due to conveyance improvements would be quantified.	Alternative is carried forward, though not as a stand alone option. The enactment of any one conveyance improvement does not meet the project objectives. However, conveyance improvements will likely be combined with other alternatives to lower WSELs and reduce flood damages.

Alternative/Strategy	Alternative/Strategy Description	Level of Flood Protection								Feasibility Property Impacts/Regulatory/Technical/ Ease of Implementation	Preliminary Screening Results
		Existing 1% Annual Chance Flood Event		Updated 1% Annual Chance Flood Event		2010 Event		2010 Event with Transposed 2nd Day Rainfall			
		Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River		
	lower flood levels in this area. This could include removing buildings and elevated roads in the South Duff commercial area to lower flood levels experienced in this area. This also includes blocking an overflow path that initiates when the Squaw Creek leaves its banks upstream from the South 4th Bridge.										
8. Flood Proofing	Structural improvements to buildings to dry-proof; site grading/improvements to facilitate flood fighting closures. Structures would be raised to above 500-year or to the 2010 level.	Y	Y	Y	Y	N	N	N	N	Flood-proofing all impacted structures to the 2010 or 500-year event is likely technically feasible. Even though flood-proofing measures may prevent property damage, evacuation will be required due to utility and access impacts. As part of response to the 1993 flood, flood proofing private property with funds from FEMA was made available to the City's residents, but was not widely implemented.	Alternative is not carried forward. Alternative does not meet flood damage reduction goals. Flood proofing is possible for up to 3 feet. The City's history with this alternative is not positive.
9. Levees along Skunk River	Several property areas along the Skunk River could be protected from floods by constructing a levee (berm/floodwall) combination. The two areas include both sides of the Skunk River between Lincoln Way and Union Pacific Railroad as well as a levee along the Freel Drive extension.	Y	Y	Y	Y	Y	Y	Y	Y	Levees are technically feasible. Interior drainage, underseepage, and space constraints for levee footprint are issues that must be addressed for alternative to meet objectives.	Alternative is carried forward. The alternative can be designed to meet objectives.
10. Levees along Squaw Creek	The property along South Duff could be protected by a levee (berm/floodwall) and necessary appurtenances. The likely alignment – partially studied by USACE – would tie into high ground near South 4th and Squaw Creek and run along the Creek before turning northward after protecting the commercial development built up near South Duff and tying into high ground along Lincoln Way. Protection to either the 500-year or the 2010 Event.	Y	Y	Y	Y	Y	Y	Y	Y	Levees are technically feasible. Interior drainage, underseepage, and space constraints for levee footprint are issues that must be addressed for alternative to meet objectives.	Alternative is carried forward. The alternative can be designed to meet objectives.
11. Property Buyouts	Purchase of structures and property potentially impacted by 500-year event or 2010 Event.	N	N	N	N	N	N	N	N	Buyout of impacted properties is technically feasible, although the magnitude of the economic impact on the City of removing the commercial and residential property is substantial and extends beyond the short term expense of acquisition.	Alternative is not carried forward. In select situations it could be combined with another alternative.

Alternative/Strategy	Alternative/Strategy Description	Level of Flood Protection								Feasibility Property Impacts/Regulatory/Technical/ Ease of Implementation	Preliminary Screening Results
		Existing 1% Annual Chance Flood Event		Updated 1% Annual Chance Flood Event		2010 Event		2010 Event with Transposed 2nd Day Rainfall			
		Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River	Squaw Creek	Skunk River		
12. Floodplain Ordinance Modification	100-year floodplain becomes the floodway. This strategy would limit development within the regulatory 1 percent annual chance footprint. 2010 inundation limit becomes the floodway. This strategy would limit development within the 2010 inundation footprint. Regulate to the base flood plus 5 feet. This strategy would allow development within the current regulatory floodplain but require the finished flood elevations to be 5 feet higher than the base flood (1 percent annual chance) Modify floodplain extent to be extent of the floodplain associated with base flood plus 3 feet. This strategy modifies the area where development is allowed but restricted to be the base flood plus 3 feet. Regulate to the 500-year Event. This strategy modifies the area where development is allowed but restricted to be the 500-year floodplain. Redefine the floodway based on new modeling. This strategy requires a new floodway to be developed and adopted. Enact compensatory storage requirements. This strategy requires adoption of new municipal code that would require any fill that is put into the floodway fringe to be compensated by removing floodway fringe elsewhere in the fringe. Develop and maintain two-dimensional model that can quantify impact of individual structures on floodplain. This strategy requires a development of a model – or adoption from Iowa DOT model to use for regulation of the floodplains. Adopt a lifetime cumulative damage limit for properties in the floodplain.	N	N	N	N	N	N	N	N	These are easily implementable and technically feasible but impact on economic development needs to be analyzed. Also, adopting new development standards in the floodplain may lesson the storage requirement from the storage alternatives (Centralized Flood Storage, Regional Flood Storage, Floodplain Storage). They have limited impacts on environmental resources.	This alternative is being carried forward though not as a stand-alone solution. None of these strategies provide protection for existing infrastructure. The differences in these strategies will be quantified and the best will be combined other strategies or alternatives enacted in the future.

Key:
Y = Yes, alternative provides respective level of flood protection.
N = No, alternative does not provide respective level of flood protection.
P = Alternative possibly provides respective level of flood protection; more detailed analysis required.

7.0 Detailed Evaluation of Screened Alternatives

As discussed above, ten alternatives were selected for additional analysis. The methodology for evaluating the final alternatives described in the following sections.

7.1 Update of Hydrology and Hydraulics and Development of Inundation Maps

As part of the detailed analysis, HDR modified the City Hydrologic model and the IIHR hydraulic model to reflect the screened alternatives. HDR executed the IIHR hydraulic model for the 2-, 5-, 10-, 25-, 50-, 100-, 200-and 500-year events for each alternative. HDR executed the hydraulic model for three Iowa-based extreme flood events; the Ames August 2010 storm event, the 2010 Ames (transposed rainfall) event, and the 2011 Dubuque flood event. The results of the analysis (inundation maps) are presented in Appendix D and F and a summary of impacts as they relate to each alternative is presented in the next section. These inundation maps are also presented in an interactive environment on the Iowa Flood Information System website (http://ifis.iowafloodcenter.org/ifis/main/?v=a).

7.2 Benefit Cost Analysis

Benefit Cost Analysis (BCA) is a conceptual framework that quantifies in monetary terms as many of the costs and benefits of a project as possible. Benefits are broadly defined. They represent the extent to which people impacted by the project are made better-off, as measured by their own willingness-to-pay. In other words, central to BCA is the idea that people are best able to judge what is good for them, what improves their well-being or welfare.

BCA also adopts the view that a net increase in welfare (as measured by the summation of individual welfare changes) is a good thing, even if some groups within society are made worse-off. A project or proposal would be rated positively if the benefits to some are large enough to compensate the losses of others.

Finally, BCA is typically a forward-looking exercise, seeking to anticipate the welfare impacts of a project or proposal over its entire life-cycle. Future welfare changes are weighted against today's changes through discounting, which is meant to reflect society's general preference for the present, as well as broader inter-generational concerns.

In particular, the methodology involved includes: 1) establishing damages to properties and infrastructure under the with and without project scenarios; 2) assessing benefits with respect to flood risk outcomes for each of 10 return periods and converting those to probability weighted (expected annual) damages; 3) measuring benefits in dollar terms, whenever possible, and expressing benefits and costs in a common unit of measurement; and 4) discounting future benefits and costs with the real discount rates recommended by USACE (3.85 percent).

Economic benefits considered in the analysis result primarily from the reduction of damages from overbank flooding in the Squaw Creek and Skunk River. Damages are grouped into the following categories:

- Residential - includes single family and multi-family units, houses, apartments, duplexes, and mobile and manufactured homes. Damage includes physical damage to the structure, and damage to contents including household items and personal property.
- Commercial and Industrial- includes retail stores, restaurants, service stations and repair garages, office buildings, warehousing, and transportation facilities. Damage includes both structure and contents including equipment, furniture, supplies, and merchandise.
- Public – includes schools, churches, libraries, and government service buildings. Damages include losses to the buildings and contents.
- Estimates of flood damage reductions were used as the screening criteria during the plan formulation process.

7.2.1 Approach to Alternative Screening Using Economics

During the alternative screening, it is important to identify the best or most cost-effective alternative plans from the set of all possible economically viable alternative plans. Once the most cost-effective alternative plans are identified, a recommended alternative can then be selected. The economic criteria which are used to do this are:

- The benefit/cost ratio (BCR), where benefits of the alternative plan are divided by its costs (average benefit approach); and
- The net benefits, which are calculated as the value of the benefits gained minus the costs.

The BCR of flood damage reduction benefits to project costs is used first in plan formulation and screening. A value of 1.0 signifies the break-even point of a plan where benefits equal costs. Viable alternatives are those with a BCR greater than 1.0. Comparing alternatives with similar components using the BCR helps identify the most cost-effective alternatives.

The BCR is not typically used for selection of a recommended course of action. Using the BCR in this case may result in maximized average benefits, but not maximization of total benefits over total cost. Net benefits, which show the difference between benefits and costs for each alternative plan, are more often used to make recommendations from among the most cost effective alternatives. The recommended course of action should be the one that maximizes net benefits from flood damage reductions.

7.2.2 Methodology

A primary objective in flood damage reduction studies is to determine the expected annual damage (EAD) along a river reach taking into account all possible flood scenarios and to compare changes in the damage resulting from various alternative plans over the study period. EAD is approximately equivalent to an average annual damage estimate, taking into account all possible storm events that might occur, from very frequent to very infrequent. The determination of EAD in a flood management study must take into account interrelated hydrologic, hydraulic, geotechnical, and economic information. Specifically, EAD is determined by combining the stage frequency and stage-damage functions and integrating the resulting damage-frequency function. Stage refers to WSEL.

In addition, for many studies, most of the rivers have levees. Adding levees to channels keeps more flowing water from breaking out into adjacent land area. However, as the volume of water behind the levee rises, the probability of levee failure increases. Once levees have failed and water enters the floodplain, then stages in the floodplain (which inundate structures and crops) become more critical to the EAD computation than stages in the river channel.

To estimate the potential risk from future flooding along the Squaw Creek and South Skunk River, a comprehensive flood risk model was constructed using methodology similar to the USACE HEC-FDA model. The model computes EAD resulting from flood events in the City. Below, Figure 14 outlines the structure of the EAD computations inside the flood risk model the following sections describe the sources of the key inputs.

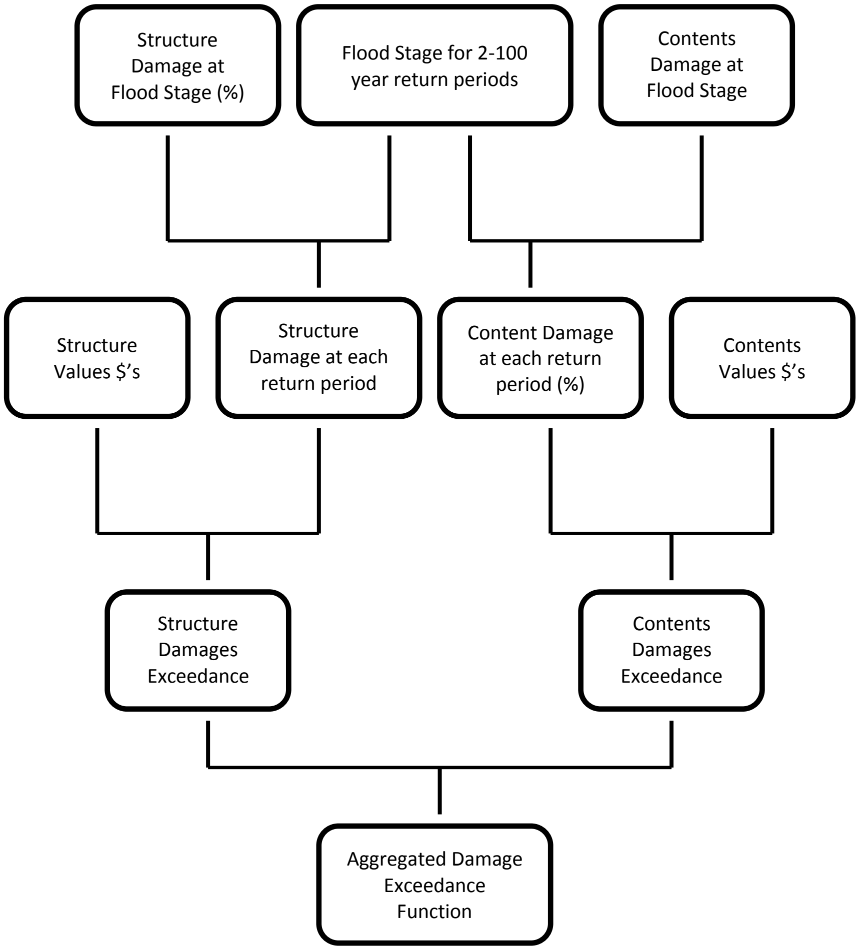

Figure 14. City of Ames, Iowa Flood Risk Assessment Model Structure and Logic Diagram.

7.2.3 Damage Reaches

Damage reaches are spatial floodplain areas used to define consistent data for plan evaluations and to aggregate structure and other potential flood inundation damage information by stage of flooding. A damage reach is delineated by beginning and ending stations along the stream and extent into the floodplain. Damage reaches are integral to both the hydraulic and economic analysis, and can be specified for the right or left banks of the floodplain. Index locations are assigned for each damage reach to aggregate structure stage-damage functions for flood damage analysis calculations. The damage reaches were examined at the 100-year level and the 500-year level to identify areas with the highest concentrations of damages. Figure 15 illustrates the 100-year flood event and the areas in red comprise 40 percent of total structures and 99 percent of property damage (in dollars). Figure 16 shows that at the 500-year flood event, 60 percent of total structures comprise of 99 percent of property damage (in dollars).

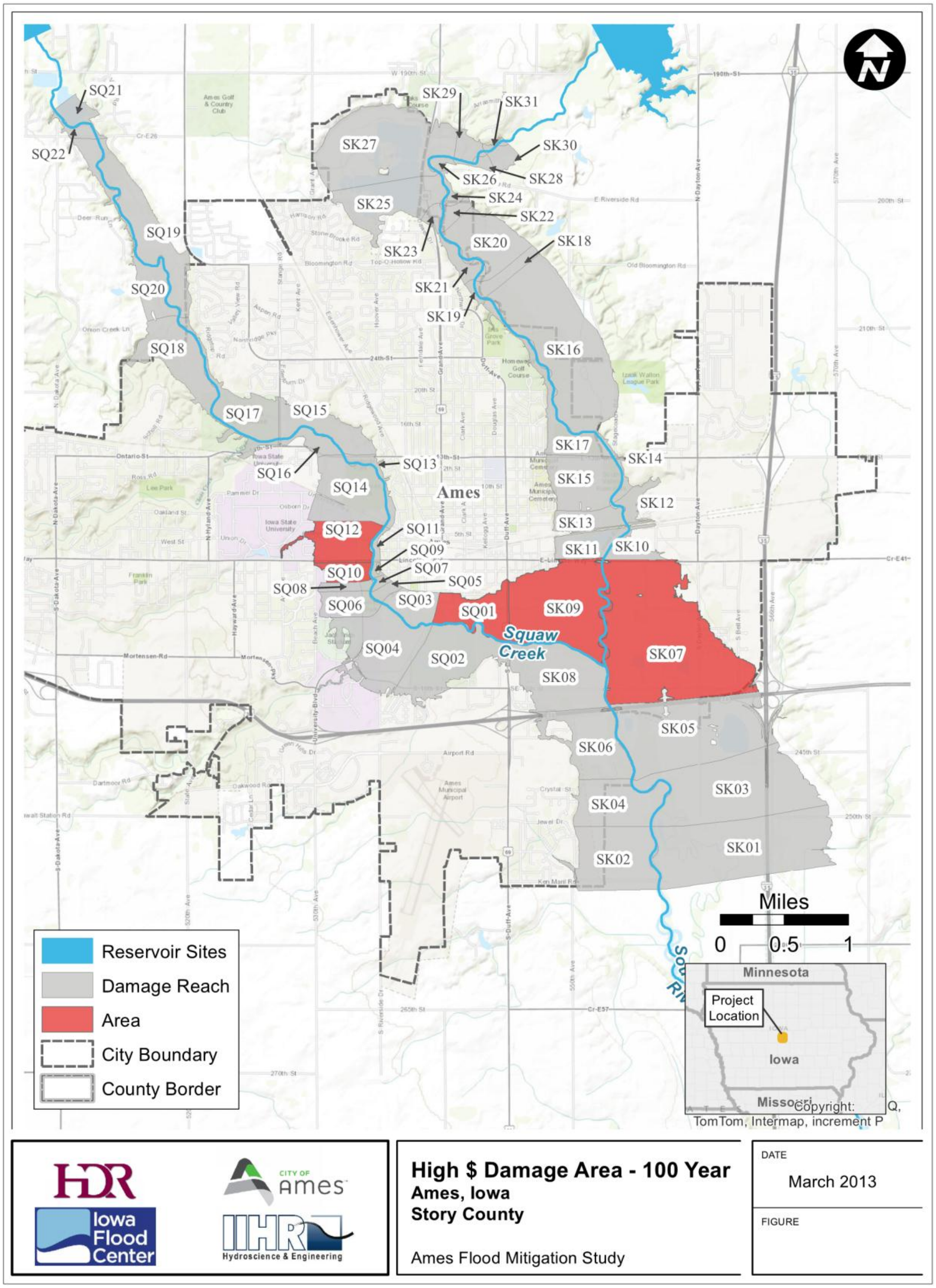

Figure 15. 100-Year Flood Event (40 Percent of Total Structures and 99 Percent of Property Damage).

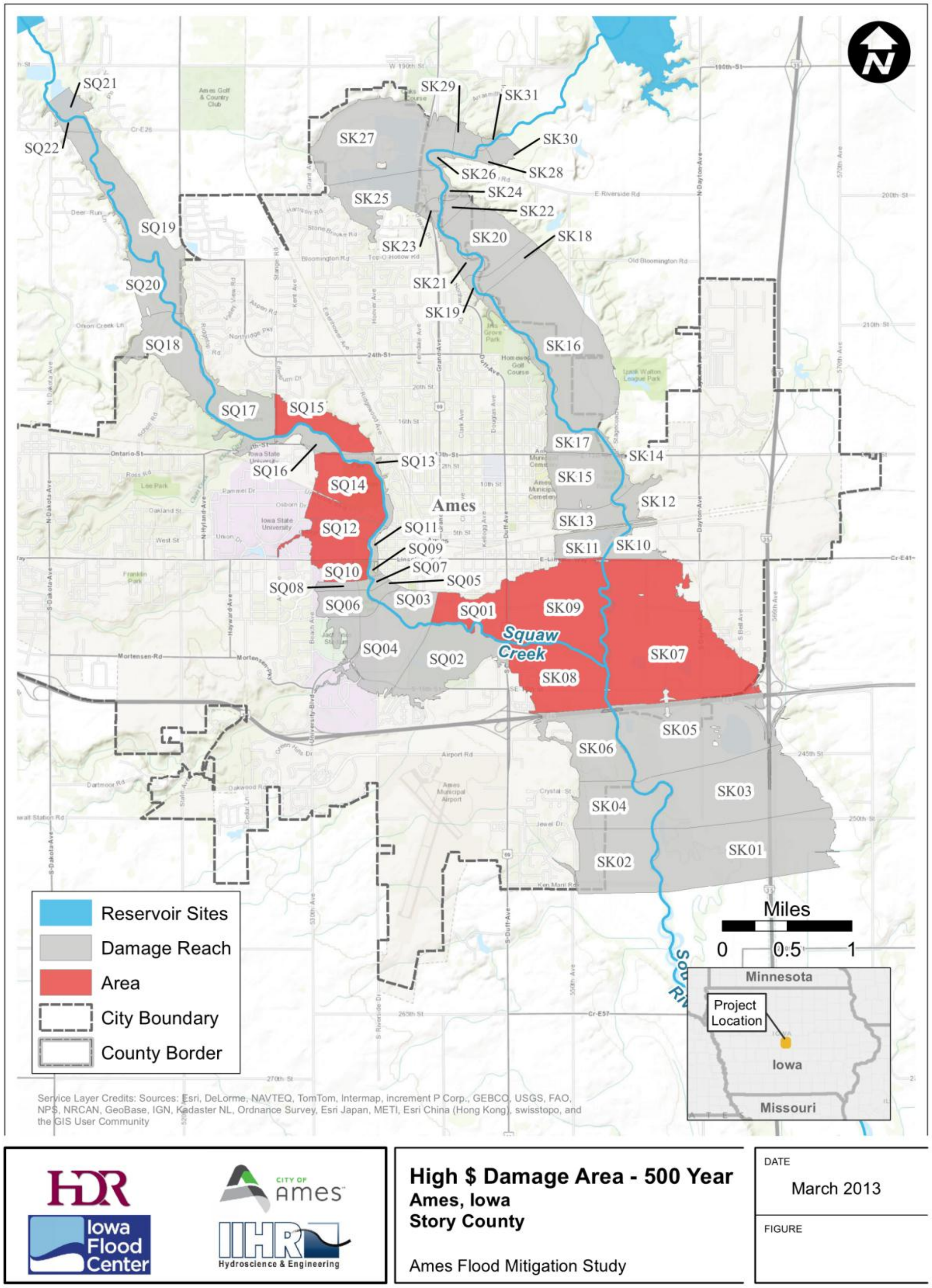

Figure 16. 500-Year Flood Event (60 Percent of Total Structures and 99 Percent of Property Damage).

7.2.4 Hydrologic and Hydraulic (H&H) Inputs

The hydraulic inputs necessary to run the model were obtained from the IFCHEC-RAS model along the Squaw Creek and South Skunk River. The WSEL inputs include stage relationships covering the 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 200-year, 500-year, 675-year, and 1,000-year return periods. From each condition, a set of functions for exceedance-stage were developed for each damage reach at each structure in GIS. The stage of the water at each return period can then be related to structure elevations and depth-damage functions to determine the monetary value of flood damages using aggregated stage-damage functions.

7.2.5 Depth-Damage Functions

Depth-damage functions form the link between the H&H data inputs and the structure and contents values and elevations to determine the monetary value of flood damages. These functions identify the percentage of damage to the structure and contents for each stage of flooding. Functions for damages to residential property structure and contents were obtained from USACE Economic Guidance Memorandum EGM 04 01. An aggregate depth damage function for commercial and industrial properties in the study area was used based on curves obtained from the USACE Chicago District.

7.2.6 Structure Inventory

The final component to the flood assessment model was the detailed inventory of all structures in the study area. The structure inventory database contains data fields that capture address, geographical coordinates, stream index location, valuation data, structure elevations, and structure type. The base inputs include parcel address information and coordinates, which were assigned using parcel databases received from the City, Story County, and Iowa State University.

Stream stationing is assigned using geo-referenced cross sections provided from the hydraulic model. Structure values (replacement cost, less depreciation) is based off of assessed values with no adjustment for market factors. The remaining data for structure type and elevation were assigned using available Light Detection and Ranging (LiDAR) data.

Elevation data was assigned based on data collected in field surveys, LIDAR data and assumptions for foundation heights. The following sections describe how elevation data were assigned for each dataset and for each community.

General assumptions for average foundation heights were obtained from similar planning studies and are specific to each structure type. Foundation heights for residential properties ranges between 1.5 and 2 feet above ground with tests for model sensitivity performed at minus 0.2 feet and plus 0.1 feet. Commercial and Industrial properties were assumed to have average foundation heights of 0.25 feet with tests for sensitivity performed at minus 0.2 feet and plus 0.1 feet.

Ground stages are required for structures. In this case, the model computes first floor elevations based on foundation height plus ground elevation. Ground elevations were obtained from county LIDAR data for most structures.

7.2.7 Damage Computation

A critical step in the economic analysis is the identification of the without project conditions, which includes not only existing conditions, but also future without project conditions expected to occur over the 50-year analysis period. For this analysis the existing condition and future without project condition are assumed to be equivalent. The EAD were converted to present value damages using a 50 year planning horizon with future benefits discounted.

Without project flood damages were computed using the inputs described above with hydraulic model outputs (flood stages) based on conditions which included no flood risk protection. Once baseline or without project damages are determined the model is rerun utilizing hydraulic model outputs (flood stages) incorporating flood risk measures. The benefits and costs of any proposed projects are determined by comparing without project versus estimated with-project conditions.

"Without project" water surface elevations and flood damages were computed based on the FFA discharges and the IIHR hydraulic model. The 675-year water surface elevations were calculated from the 500-year and 100o-year water surface elevations. The 1,000 year water surface elevation was estimated by using the 2011 Dubuque rainfall event. "With project" water surface elevations and flood damages were computed with an equivalent methodology as the "Without project", except for the alternatives that relied on flood storage for flood damage reduction. Storage alternatives required the use of the City hydrologic model to calculate a relative reduction in peak flow between the "without project" and "with project." This relative reduction was then applied to the FFA discharges, simulated with the IIHR hydraulic model, and a flood damages calculated.

7.3 Alternative Costs

An engineer's opinion of approximate costs was developed for each screened alternative. It is based on the configuration of the alternative (as shown in the figures shown later in Section 8). The main assumptions and methodology are provided below. A schematic and to the extent required a three-dimensional surface model (levees, diversion, earthen embankment) of the improvements for each alternative was created and used to estimate project quantities and impacts. The unit costs were estimated based on recent construction cost bid tabulations from projects located in Iowa except for the U.S. Highway 30 Bridge modification (Iowa DOT estimate) and Conservation Measures (Constructed Wetlands – Iowa Department of Agriculture and Land Stewardship). The extent of the levee and flood control reservoir footprints, together with the parcel boundaries obtained from the City and Story County were utilized to estimate easement costs and land acquisition costs. These costs are based on a preliminary level of assessment. If design moves forward, additional details may affect final design cost. The 35 percent contingencies applied to each engineer's opinion of approximate costs accounts for uncertainty at this level of design. A standard 7.5 percent of the improvement costs were utilized to estimate mobilization. The opinion of approximate cost for each alternative is provided in Appendix G.

7.4 Environmental Review

An environmental review was performed to determine the potential project impacts for the ten alternatives developed during the screening process. The assessment included the following: environmental, threatened and endangered (T&E) species, archeological, hazardous materials, wetlands, and permitting requirements.

The environmental review was tailored to support potential federal and state funding applications that have environmental compliance requirements, as well as future permitting requirements. This assessment included a desktop environmental and archaeological survey based on available documents and literature.

The entire report is provided in Appendix H and summarized as appropriate for each alternative in Section 8.

Preliminary evaluations indicate that potential impacts on T&E species and wetlands may occur; however, it is anticipated that these potential impacts would be eliminated during the design phase.

8.0 Final Screening and Summary of Mitigation Alternatives

The following sections provide a visual description of each alternative and the summary of the detailed screening.

8.1 Do-Nothing

The Do-Nothing alternative does not include permanent infrastructure improvements or floodplain development restrictions. This alternative assumes that temporary measures for access and property protection would be employed by the City and private property owners. It is the baseline from which all the other alternatives and strategies are measured.

8.2 Conservation Measures in Watershed

The Conservation Measures in Watershed alternative evaluates small detention sites in the watershed that could contribute to flood reduction and constructed wetlands administered under the Iowa Department of Agriculture and Land Stewardship's CREP that could be used for flood control. Figure 17 shows the location of the potential sites. Table 9 reports the results of the benefit cost analysis. Figure 18 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 10 reports the highlights and issues from the environmental review. In summary:

- Limited flood protection value for the City
- Limited number of sites available
- Partnering opportunities with State of Iowa and counties in Ames Watershed

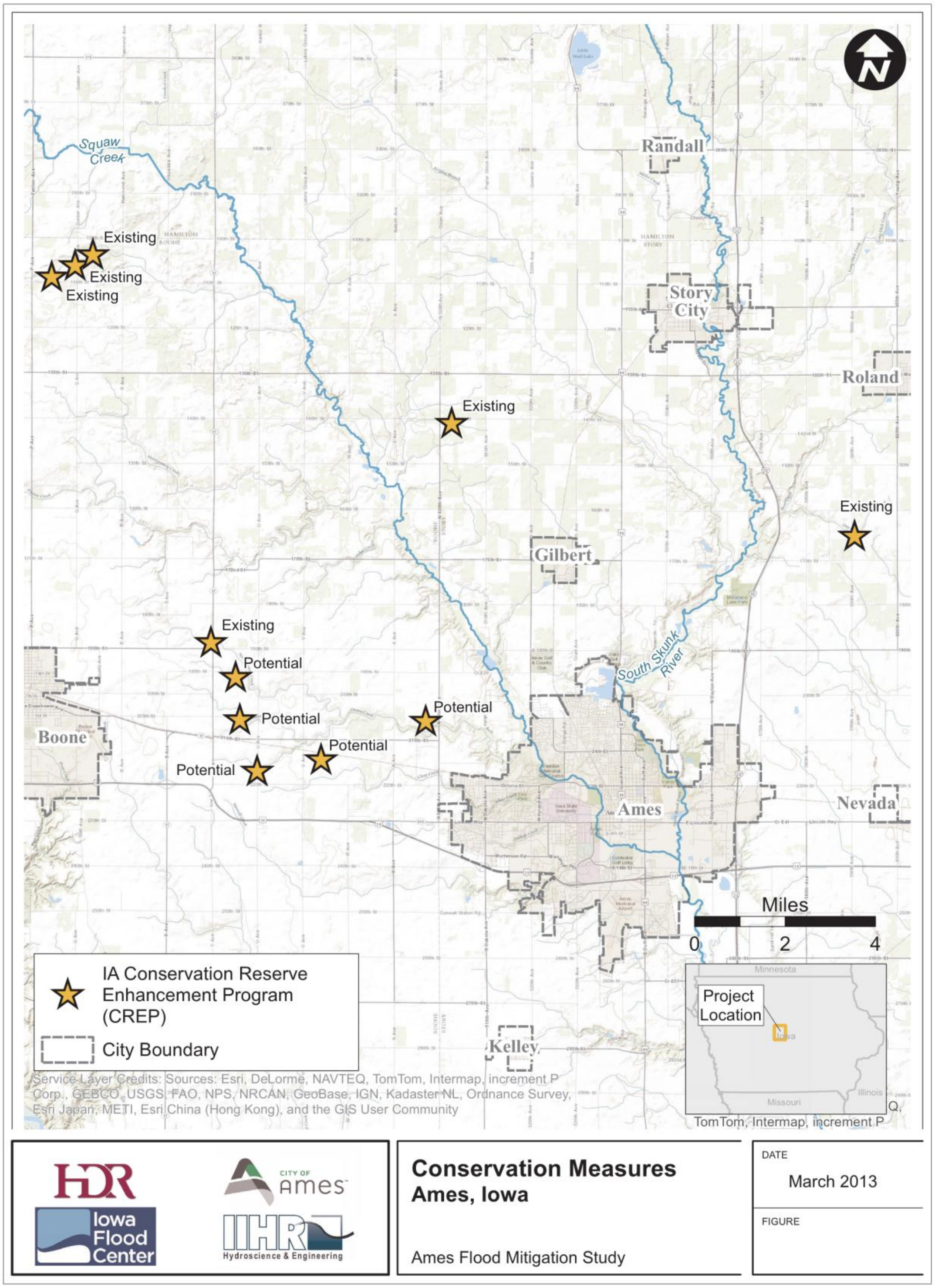

Figure 17. Conservation Measures in Watershed.

Table 9. Benefit Cost Results – Conservation Measures in Watershed.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$2,025,000	$122,230	$0	0.00

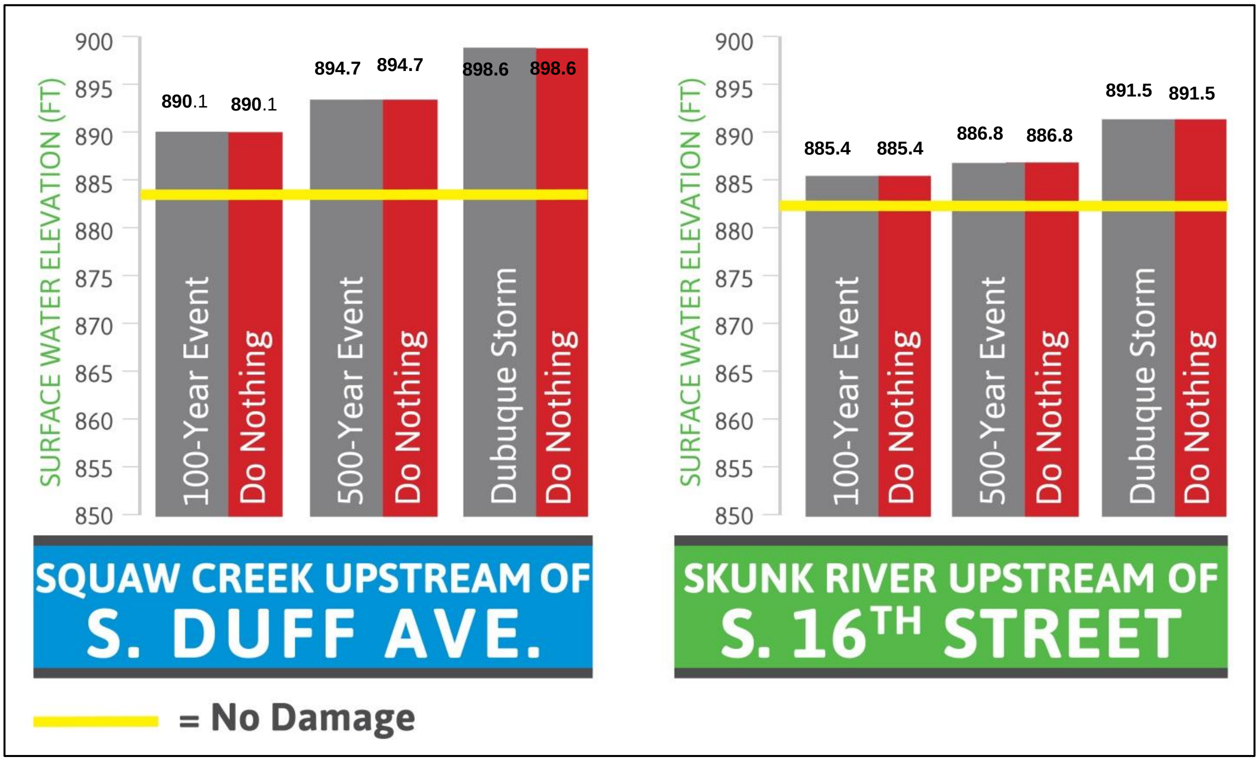

Figure 18. Comparative Hydraulic Results at Two Locations - Conservation Measures in Watershed.

Table 10. Environmental Review Summary – Conservation Measures in Watershed.

Land Use	Impacts to Agricultural land. (1,326 acres)		
Farmland	Impacted.		
Parks, Recreation & Conservation Areas	No impact.		
Wetlands	Would increase existing wetland conservation areas in partnership with the Iowa Department of Agriculture and Land Stewardship.		
Surface Water	No impact.		
Threatened & Endangered Species	No impact.		
Cultural Resources – Historical & Archaeological	No impact.		
Socio-Economic Resources	No impact.		
Environmental Justice	No impact.		
Transportation	No impact.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	No impact.		
Air Quality	No impact.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (Provide no flood level of reduction.)	Do the benefits outweigh the costs? ☒	Is this alternative free of major environmental impacts? ☑

8.3 Centralized Flood Storage (Ames Reservoir and Squaw Creek Dry Detention)

The Centralized Flood Storage (Ames Reservoir and Squaw Creek Dry Detention) alternative involved construction of several reservoirs for flood control, including Ames Lake (a multi-purpose flood control reservoir on the Skunk River with 51,000 acre-feet of flood control storage, and Squaw Creek Detention Reservoir, a single purpose flood control detention dam with 20,500 acre-feet of flood control storage). Figure 19 shows the location of the potential sites. Table 11 reports the results of the benefit cost analysis. Figure 20 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 12 reports the highlights and issues from the environmental review. In summary:

- Not free of major environmental impacts
- Cost prohibitive
- Does provide 450-year level of flood protection on both Squaw Creek and Skunk River

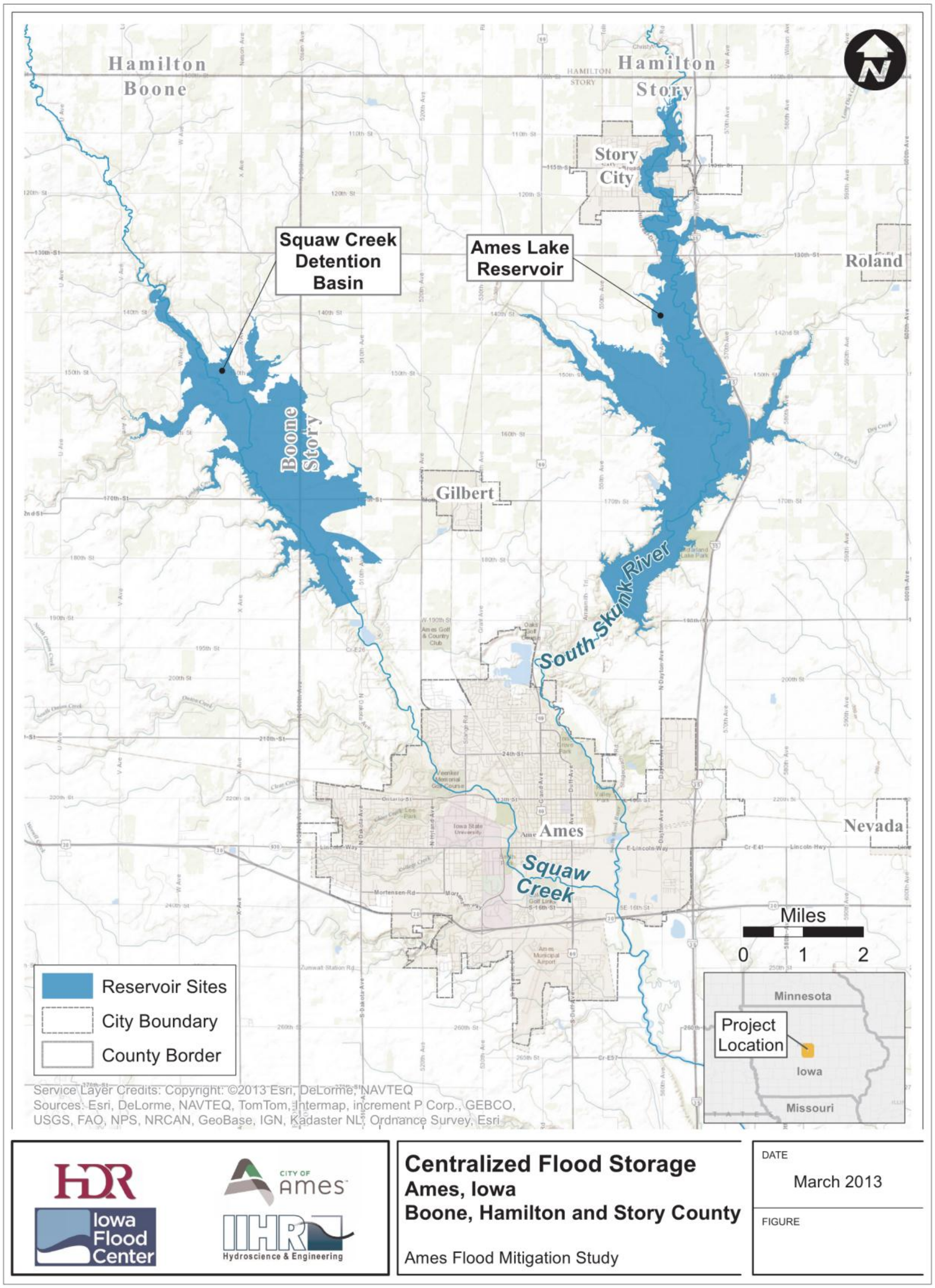

Figure 19. Centralized Flood Storage.

Table 11. Benefit Cost Results – Centralized Flood Storage.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$198,243,000	$11,966,036	$3,250,900	0.31

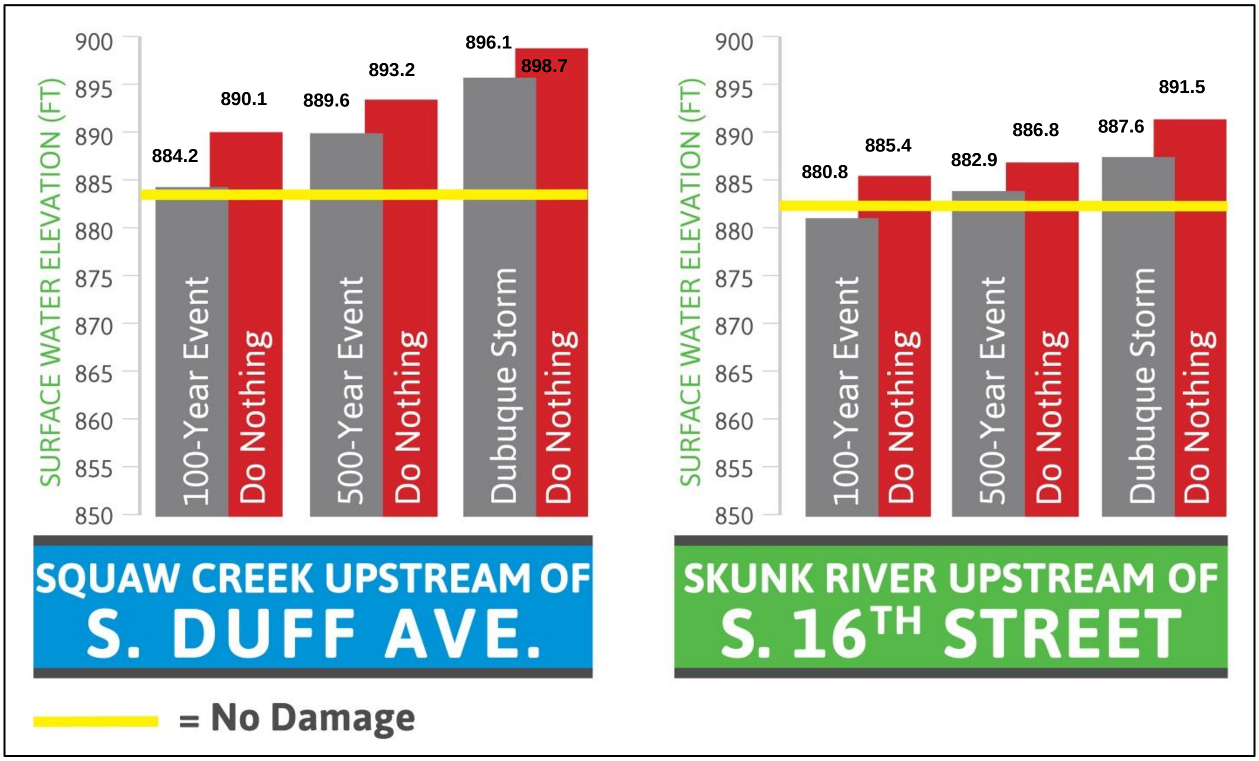

Figure 20. Comparative Hydraulic Results at Two Locations – Centralized Flood Storage

Table 12. Environmental Review Summary – Centralized Flood Storage.

Land Use	Impacts to residential & agricultural land uses NW of Ames. Residential, agricultural and Public Lands NE of Ames & Story City. Housing developments in Western Story County and Eastern Boone County. Scattered farm residences in both counties. (10,660 acres)
Farmland	Impacted.
Parks, Recreation & Conservation Areas	Impacts to Story City Park, River Bend Municipal Golf Course, 12 conservation and recreation areas between Ames and Story City.
Wetlands	Impacts to approximately 840 acres.
Surface Water	Impacts to approximately 15 miles of Skunk River and approximately 7.5 miles of Squaw Creek.
Threatened & Endangered Species	Potential impacts.
Cultural Resources – Historical & Archaeological	Impacts to 93 archaeological sites and 17 historic structures with the construction of SR-1, and 17 archaeological sites and 46 historical structures with the construction of SC-1.
Socio-Economic Resources	Impacts to approximately 150 residences from construction of SR-1 and 75 residences from construction of SC-1. Construction of SR-1 and SC-1 would preclude further development in and near affected areas. Construction of SR-1 would also affect Story City's wastewater treatment plant, a school and associated athletic facilities, and 2-3 businesses in Story City.
Environmental Justice	Impacts to minorities, low-income, elderly and LEP populations.
Transportation	Impacts to US 69, Broad Street in Story City, 130th, 150th, 170th, 180th, and 190th Streets, as well as local roads with the construction of SR-1. Construction of SC-1 would affect 140th, 150th, 160th, 170th, and 180th Streets.
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.
Regulated Materials	15 leaking UST's within 1 mile of SR-1. 1 leaking UST is within the proposed footprint of SR-1.
Air Quality	Would generate minor amounts of emissions from construction equipment and fugitive dust from soil disturbance.
Performance Criteria	Does it meet at least a 500-year level of protection? ☑ (Skunk River only; 100 –year level on Squaw.) Do the benefits outweigh the costs? ☒ Is this alternative free of major environmental impacts? ☒

8.4 Regional Flood Storage (Tributary Detention and Smaller Main Stem Dams)

The Regional Flood Storage (Tributary Detention and Smaller Main Stem Dams) alternative evaluated eight sites for use as multi-purpose projects. These sites had been previously identified and named in Soil Conservation Service (SCS) and USACE studies (USACE 1987). On Squaw Creek – SC-2 (Above the County Line), SC-3 (Squaw Creek and Mackey), SC-4 (Montgomery Creek at Prairie Creek), SC-6 (Onion Creek near Mouth) were evaluated. On the South Skunk River SR-2 (South Skunk River near at Ellsworth), SR-4 (Bear Creek at Interstate 35), SR-6 (Keigley Branch at State Highway 221), and SR-7 (Long Dick Creek at Interstate 35) were evaluated. Figure 21 shows the location of the potential reservoir sites. Table 13 reports the results of the benefit cost analysis. Figure 22 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 14 reports the highlights and issues from the environmental review. In summary:

- Not free of major environmental impacts
- Cost prohibitive
- It does provide 450-year level of flood protection on both Squaw Creek and South Skunk River

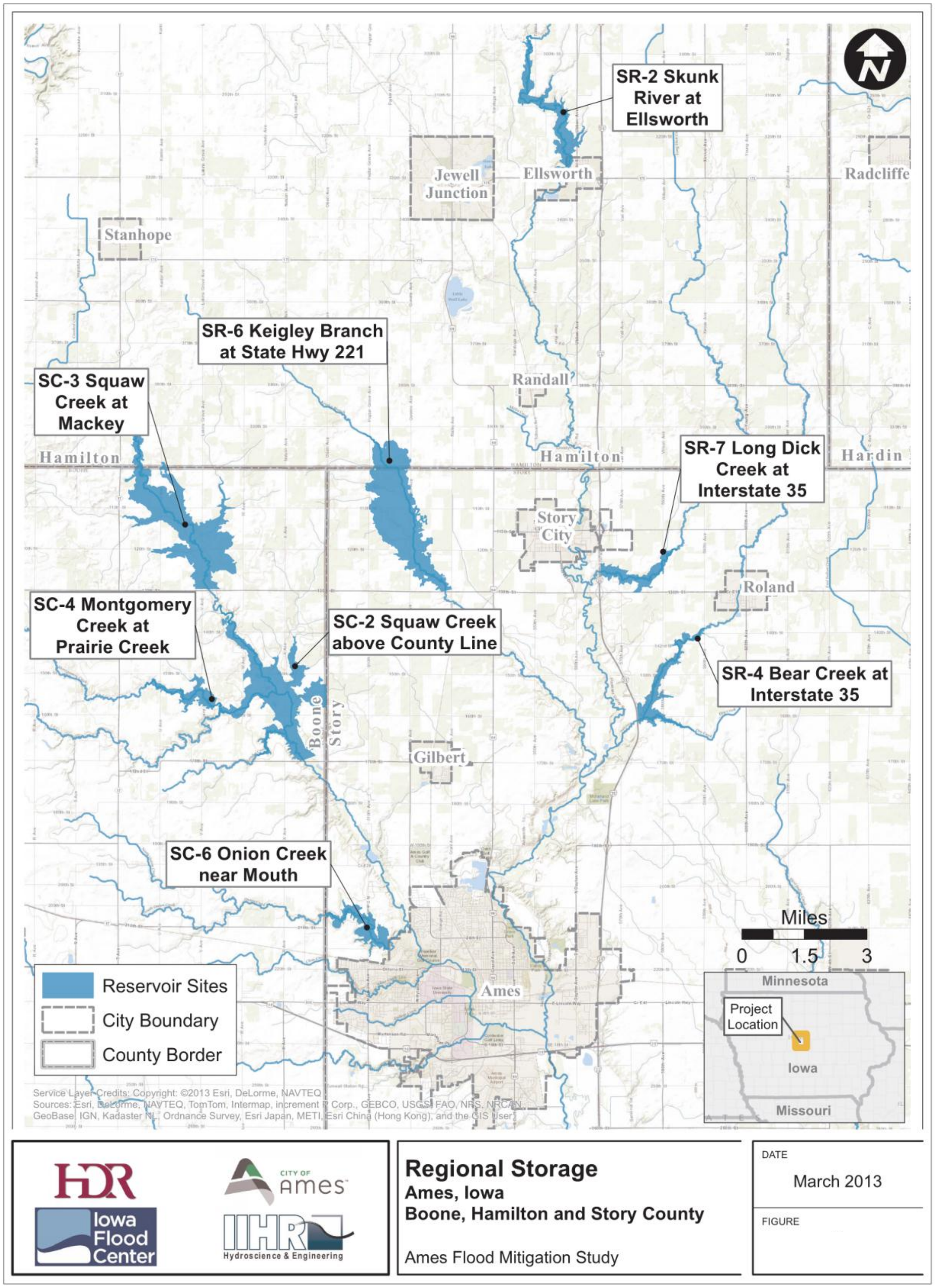

Figure 21. Regional Flood Storage.

Table 13. Benefit Cost Results – Regional Flood Storage.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$145,339,000	$8,777,000	$3,217,000	0.43

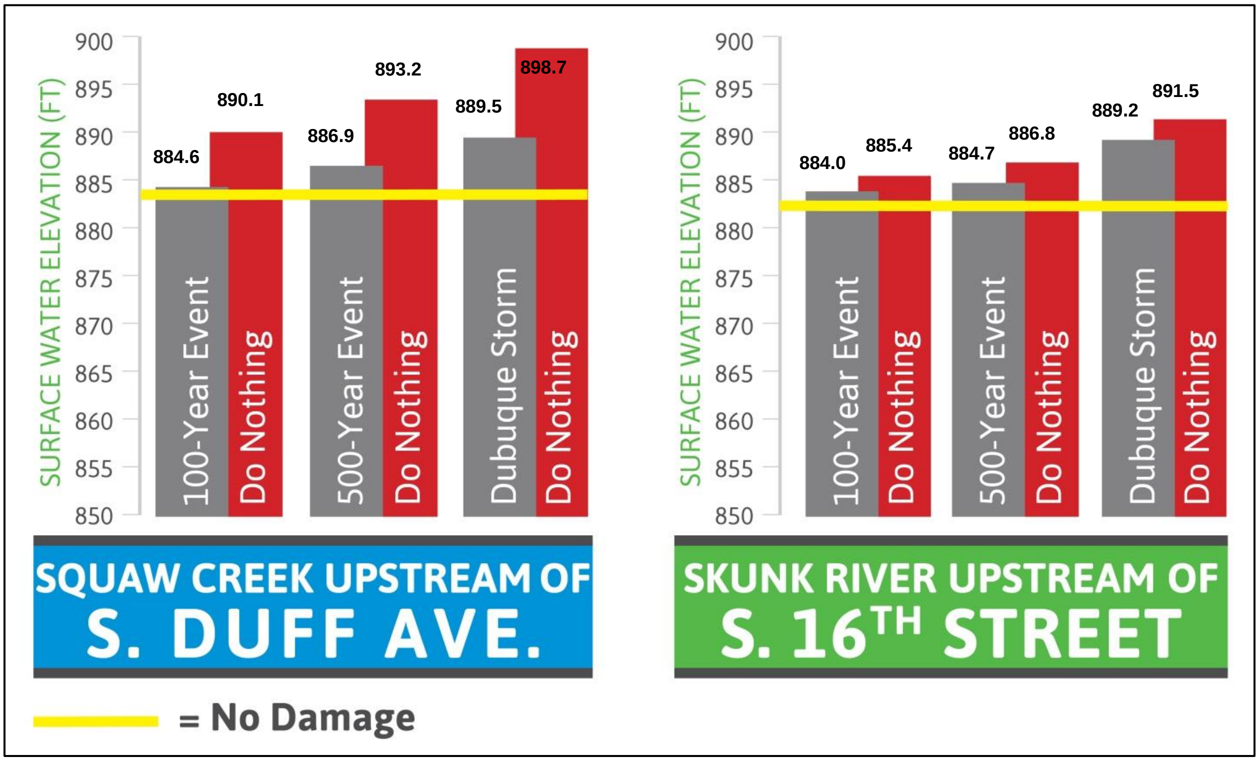

Figure 22. Comparative Hydraulic Results at Two Locations – Regional Flood Storage.

Table 14. Environmental Review Summary – Regional Flood Storage.

Land Use	Impacts to residential developments, cemeteries, and agricultural land. (7,355 acres)		
Farmland	Impacted.		
Parks, Recreation & Conservation Areas	Impacts to the Bob Pyle Marsh WMA.		
Wetlands	Impacts to approximately 800 acres.		
Surface Water	Impacts to approximately 5.5 miles of Skunk River; approximately 5.3 miles of the Keigley Branch of the Skunk River; approximately 3.0 miles of Bear Creek, and approximately 2.8 miles of Long Dick Creek. This alternative would also flood approximately 10.5 miles of Squaw Creek, approximately 2.7 miles of Montgomery Creek, and approximately 2.6 miles of Onion Creek.		
Threatened & Endangered Species	Potential impacts.		
Cultural Resources – Historical & Archaeological	Impacts to 18 archaeological sites and 22 historic structures.		
Socio-Economic Resources	Impacts to approximately 110 residences, farms, and acreages.		
Environmental Justice	No impacts.		
Transportation	Impacts to 100th, 110th, 120th, 130th, 140th, 150th, and 160th Streets, as well as local roads.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	15 leaking UST's, 1 Iowa contaminated site and 1 non-NPL Superfund site.		
Air Quality	Would generate minor amounts of emissions from construction equipment and fugitive dust from soil disturbance.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (100-year level on Squaw; 100-year level on Skunk)	Do the benefits outweigh the costs? ☒	Is this alternative free of major environmental impacts? ☒

8.5 Floodplain Storage

The Floodplain Storage alternative included construction of small impoundments along the main channel of the Squaw Creek and the South Skunk River that store flood waters. The impoundments consisted of modifying road crossings by raising the road grade and decreasing the size of bridge and culvert openings, taking advantage of floodplain storage not previously utilized for flood control purposes. Two locations were evaluated on Squaw Creek (Boone County – 160th Street) and 13th Street in the City. On the South Skunk River, the 170th Street crossing was evaluated. Figure 23 shows the location of the potential sites. Table 15 reports the results of the benefit cost analysis. Figure 24 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 16 reports the highlights and issues from the environmental review. In summary:

- Positive BCR
- Would require coordination with the county
- Not free of major environmental impacts
- Reduces the flood levels at the 100-year flood 2 feet on Squaw Creek

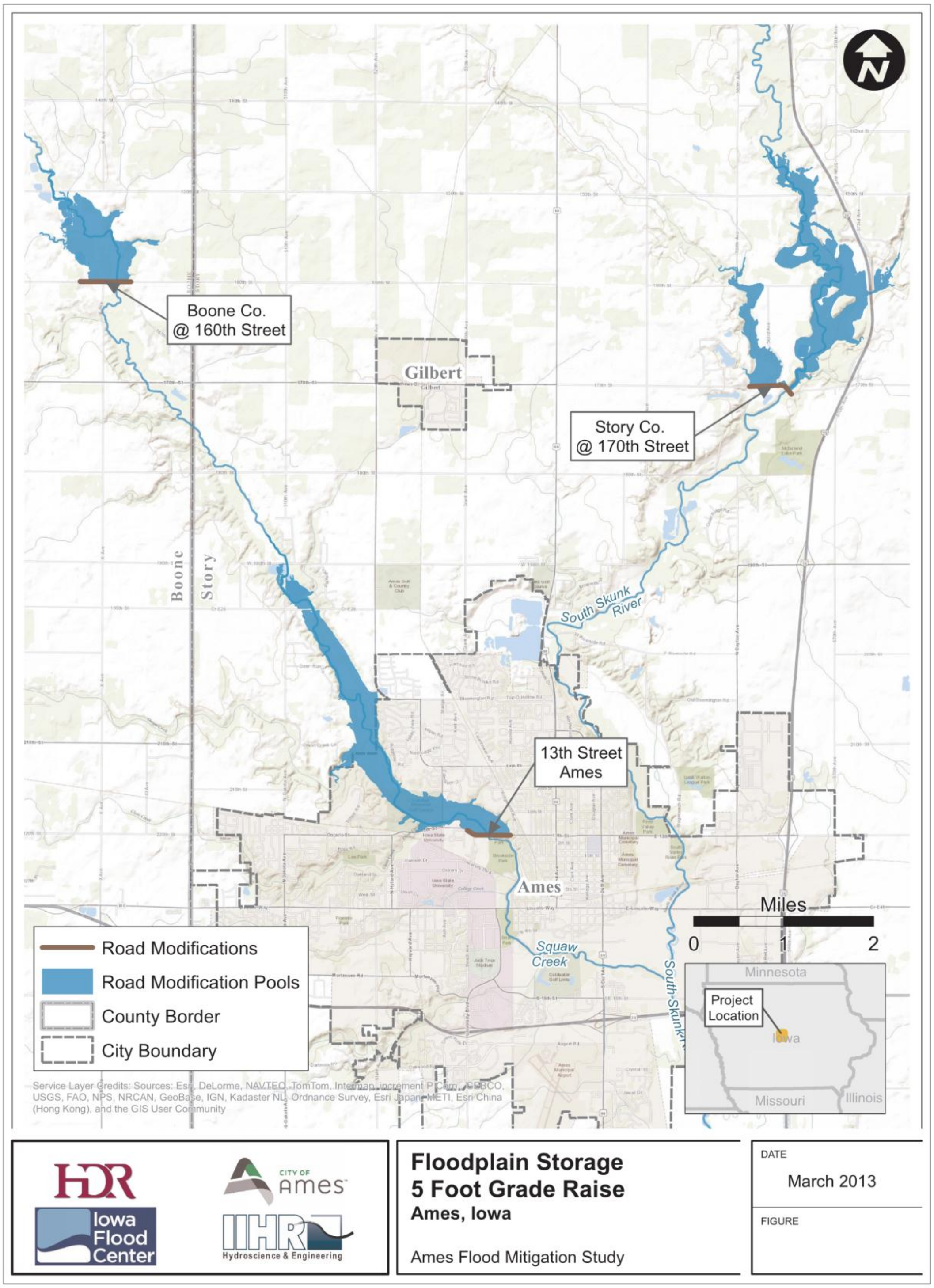

Figure 23. Floodplain Storage.

Table 15. Benefit Cost Results – Floodplain Storage.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$41,000,000	$2,475,000	$2,786,900	1.31

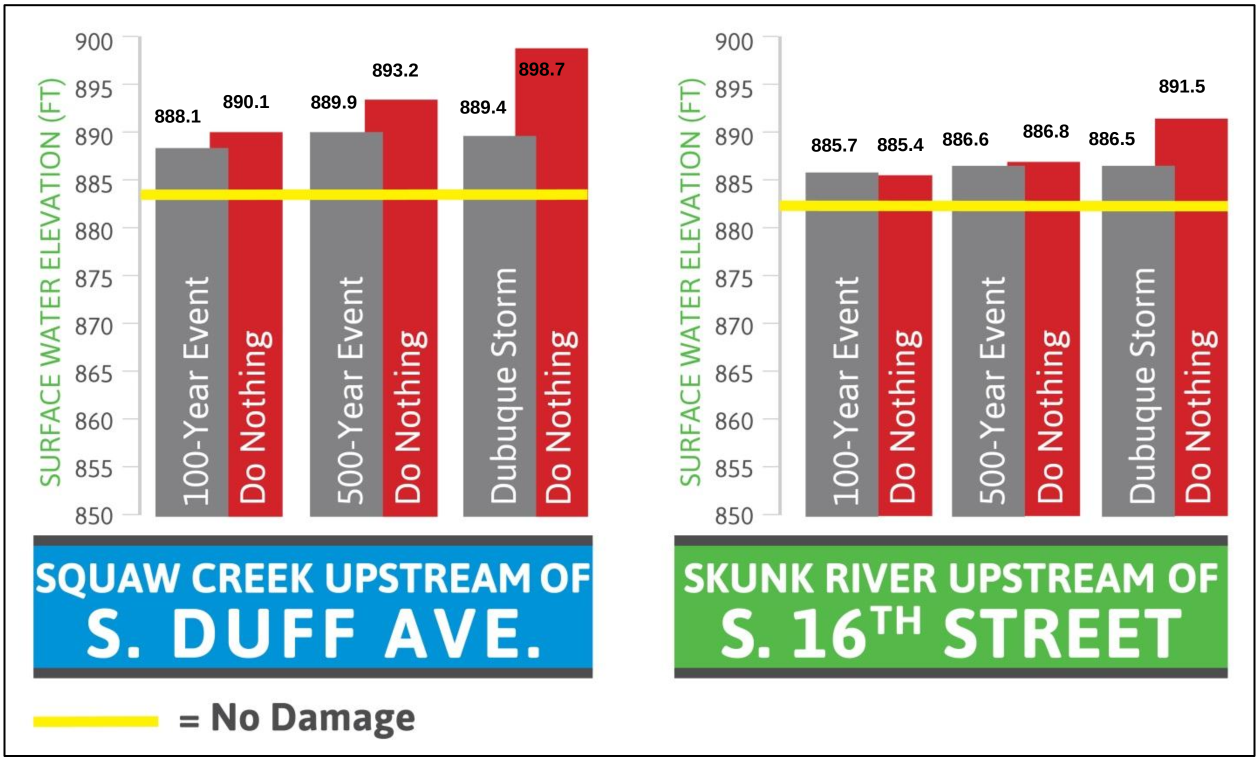

Figure 24. Comparative Hydraulic Results at Two Locations – Floodplain Storage.

Table 16. Environmental Review Summary – Floodplain Storage.

Land Use	Impacts to residential area (ISU housing), recreation land, parks and conservation land, and agricultural land uses. (709 acres)		
Farmland	Impacted.		
Parks, Recreation & Conservation Areas	Impacts to Skunk River Greenbelt WMA, Crooked Bend WMA, Bear Creek Area, and Soper's Mill County Park, Veenker Memorial Golf Course, part of the Ames High Prairie State Preserve, the Furman Aquatic Park in Ames, and the ISU Stable Run Disc Golf Course.		
Wetlands	Impacts to approximately 540 acres.		
Surface Water	Impacts to approximately 6.5 miles of Squaw Creek and approximately 2.5 miles of Skunk River.		
Threatened & Endangered Species	Potential impacts.		
Cultural Resources – Historical & Archaeological	Impacts to 66 archaeological sites and 5 historic structures.		
Socio-Economic Resources	Impacts to part of the ISU housing area, approximately 25 residences, 2 businesses, a golf course, and a water park.		
Environmental Justice	Impacts to minorities, low-income, elderly and LEP populations.		
Transportation	Impacts to 150th, 160th, 170th, and 190th Streets. Would also require raising the following roads 5 feet and modifying bridges/culverts at these locations: Boone County Road 160 at Squaw Creek, Story County Road 170 at the Skunk River, and 13th Street in Ames at Squaw Creek.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	10 leaking UST sites, 1 non-NPL Superfund site, and 1 Iowa contaminated site within 1 mile of the 13th Avenue site in Ames.		
Air Quality	Would generate minor amounts of emissions from construction equipment and fugitive dust from soil disturbance.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (Reduced 100-year flood height of 2-ft on Squaw.)	Do the benefits outweigh the costs? ☑	Is this alternative free of major environmental impacts? ☒

8.6 Diversion

The Diversion alternative consists of two different options; Diversion 1 and Diversion 2. Diversion 1 consists of diverting flood waters around the City by diverting Squaw Creek at Cameron School Road to the Skunk River via Ada Hayden Reservoir. Diversion 2 consists of diverting flood waters around the City by diverting the Squaw Creek upstream from Cameron School Road to the Skunk River south of the Airport. Figure 25 illustrates where the potential diversions were located.

Table 17 reports the results of the benefit cost analysis for Diversion 1 and Figure 26 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street.

Table 18 reports the results of the benefit cost analysis for Diversion 2 and Figure 27 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street.

Table 19 reports the highlights/issues from the environmental review.

In summary Diversion 1:

- Reduces 100-year flood 5 feet on Squaw Creek
- Benefits outweigh the costs
- Not free of major environmental impacts

In summary Diversion 2:

- Reduces 100-year flood 5 feet on Squaw Creek
- Cost prohibitive
- Not free of major environmental impacts

Table 17. Benefit Cost Results – Diversion 1.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$49,243,000	$2,972,329	$3,042,700	1.22

Table 18. Benefit Cost Results – Diversion 2.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$1,095,000,000	$66,095,000	$3,192,300	0.06

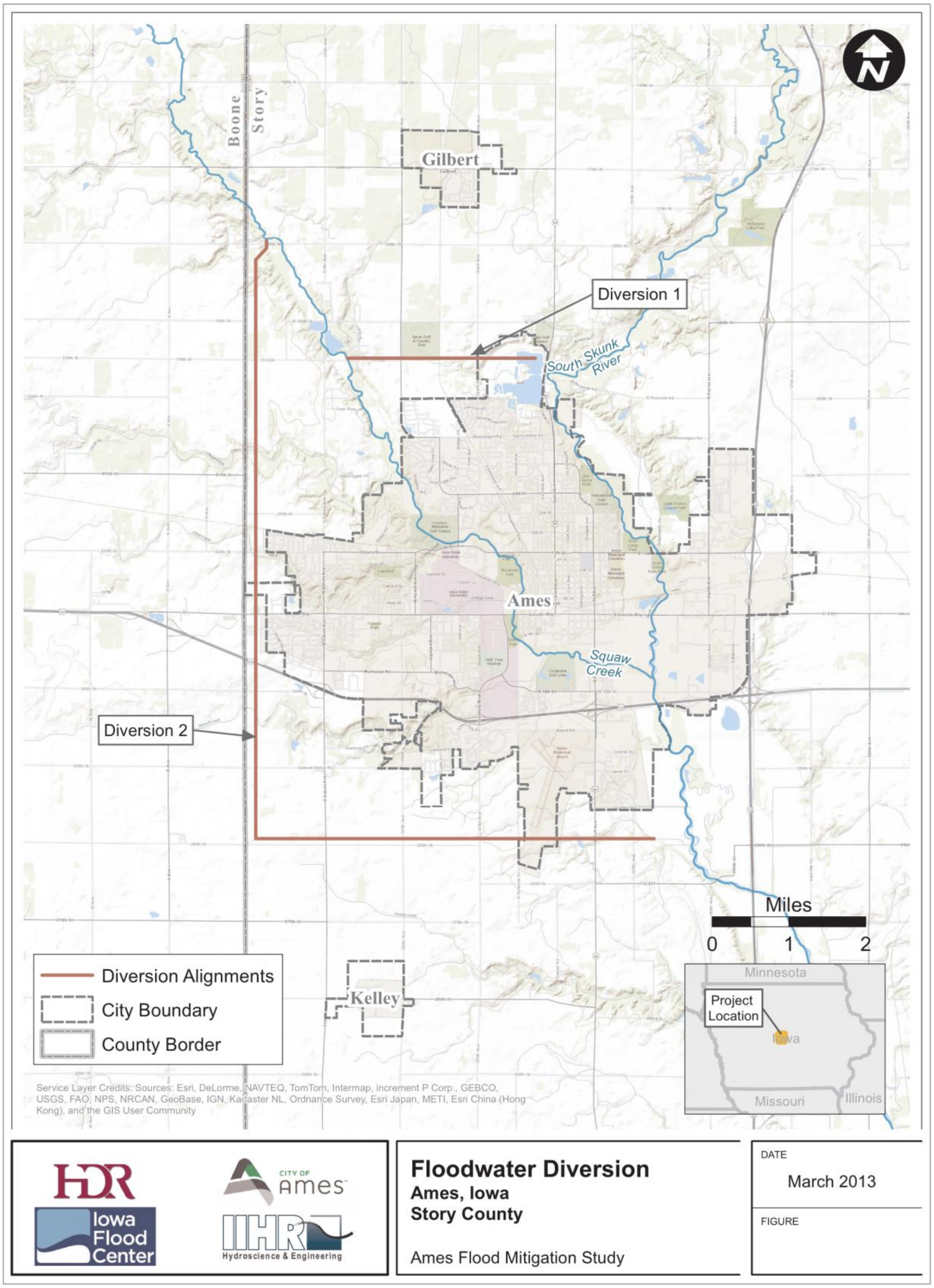

Figure 25. Diversion 1 and 2.

Table 19. Environmental Review Summary – Diversion 1 and 2 (combined).

Land Use	Impacts to small areas of residential and commercial, southern edge of Ames Municipal Airport, recreation, conservation, and agricultural land. (1,370 acres)		
Farmland	Impacted.		
Parks, Recreation & Conservation Areas	Would divide the Ames Golf and Country Club and the Ada Hayden Heritage Park by creating a channel through these areas.		
Wetlands	Impacts to approximately 10 acres.		
Surface Water	No impacts to existing streams; however construction of these diversions would create a total of 17 miles of new stream channel. Construction of these diversions would affect flow in both the Skunk River and Squaw Creek.		
Threatened & Endangered Species	Potential impacts.		
Cultural Resources – Historical & Archaeological	Impacts to 9 archaeological sites and 7 historic structures.		
Socio-Economic Resources	Impacts to approximately 60 residences, a 25-residence trailer park, approximately 5 businesses, and the approach lighting in the clear zone of the Ames Municipal Airport.		
Environmental Justice	Impacts to minorities, low-income, elderly and LEP populations.		
Transportation	Would cut across several roads in Ames, including US 30, Lincoln Way, South Duff Avenue, George Washington Carver Avenue, 180th Street, 520th Avenue, and 530th Avenue. Bridges would need to be constructed, or in some cases, reconstructed. Potential impacts to the UPRR tracks and airspace at the Ames Municipal Airport.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	5 leaking USTs within 1 mile.		
Air Quality	Would generate minor amounts of emissions from construction equipment and fugitive dust from soil disturbance.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (Reduced 100-year flood height of 5-ft on Squaw; 100-year protection on Skunk.)	Do the benefits outweigh the costs? ☒	Is this alternative free of major environmental impacts? ☑

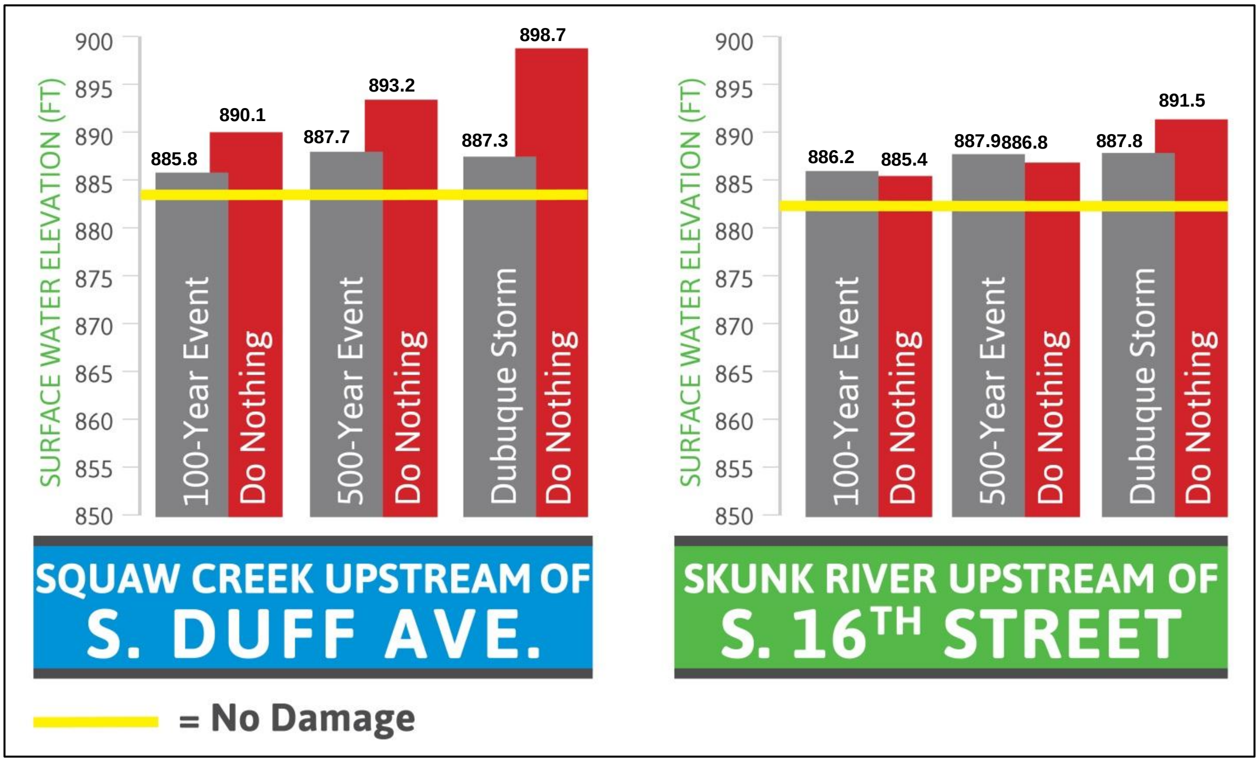

Figure 26. Comparative Hydraulic Results at Two Locations – Diversion 1.

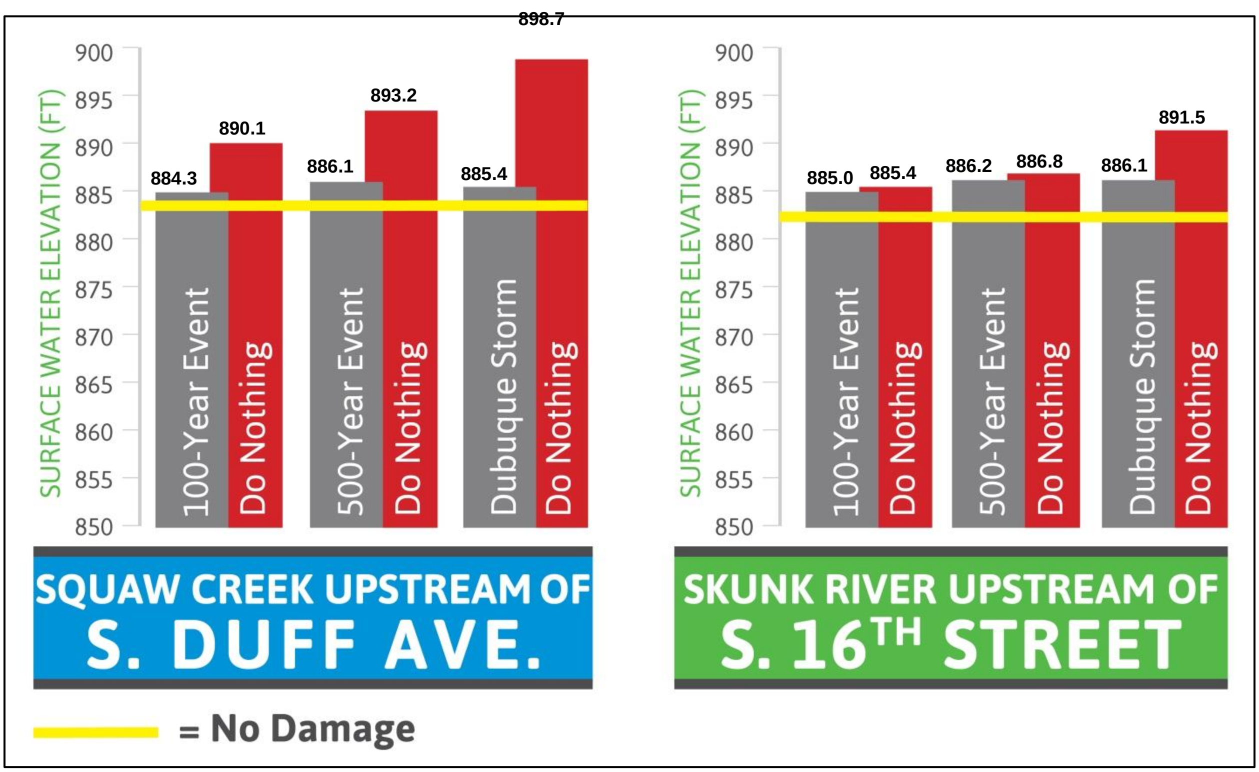

Figure 27. Comparative Hydraulic Results at Two Locations – Diversion 2.

8.7 Conveyance Improvements (Clear Squaw Creek Channel, South Duff Bridge/Channel Improvement, U.S. Highway 30 Bridge Modification)

The Conveyance Improvements alternative consists of three different project areas; Clear Squaw Creek Channel, South Duff Bridge/Channel Improvement, and U.S. Highway 30 Bridge Modification. The Cleared Channel alternative involved the clearing the river channel of vegetation through the City along Squaw Creek from the confluence with the South Skunk River upstream to Lincoln Way. The South Duff Bridge/Channel Improvements alternative involved the reshaping of the Squaw Creek channel 2,000 feet upstream and 2,000 feet downstream from the South Duff Bridge, and the U.S. Highway 30 Bridge modification included increasing the length of the U.S. Highway 30 Bridge an additional 430 feet.

Figure 28 illustrates where the potential conveyance projects were located.

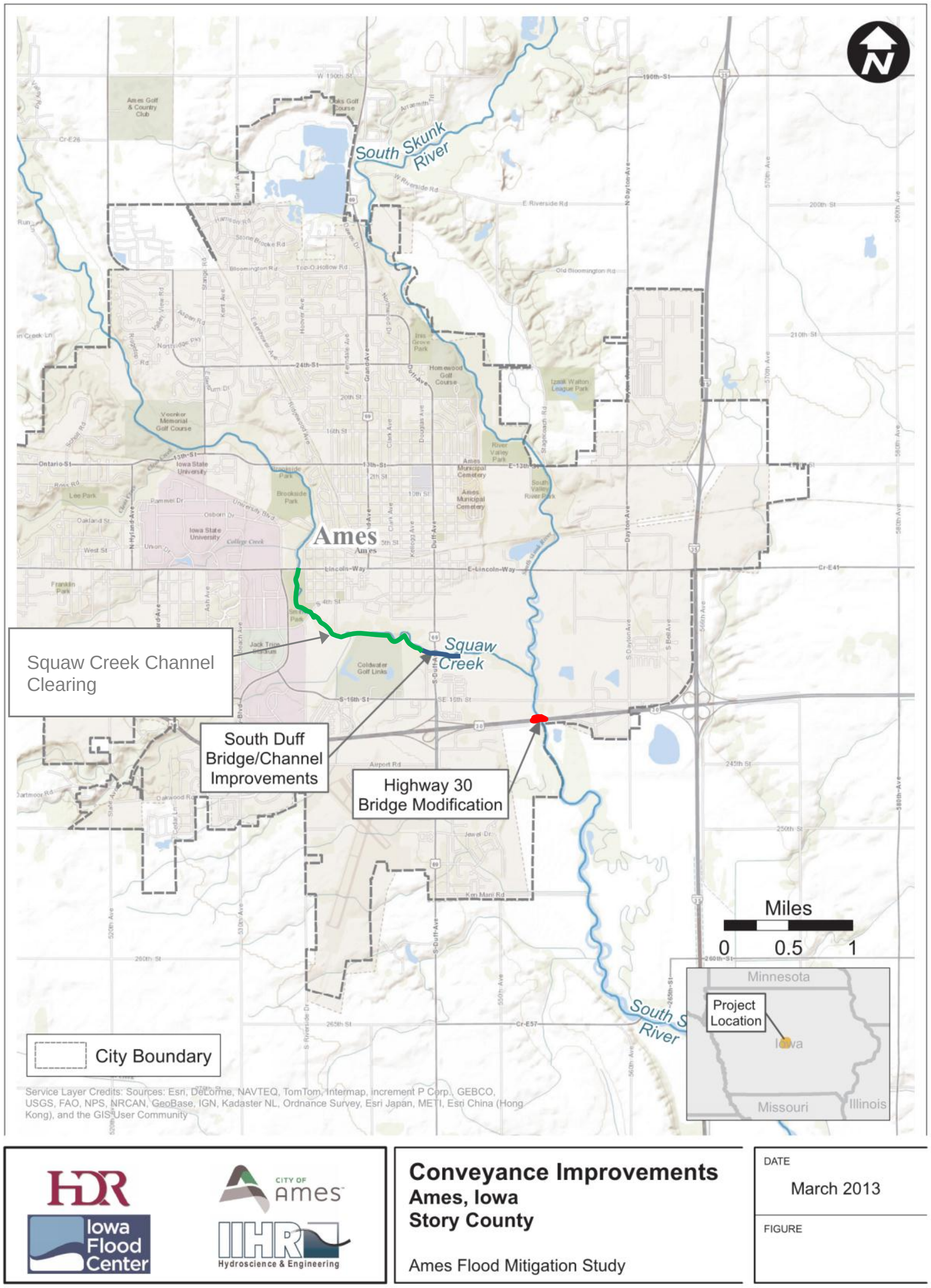

Figure 28. Conveyance Improvements.

Table 20 reports the results of the benefit cost analysis for the Squaw Creek Channel Clearing and Figure 29 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street.

Table 21 reports the results of the benefit cost analysis for the South Duff Bridge/Channel Improvement and Figure 30 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street.

Table 22 reports the results of the benefit cost analysis for U.S. Highway 30 Bridge Modification and Figure 31 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street.

It is important to note that the benefit cost analysis is applied to each conveyance improvement component individually. The results are not additive in any way. However, the results of the environmental review are indicative of impacts to the three areas as a group.

Table 23 reports the highlights/issues from the environmental review.

In summary the Squaw Creek Channel Clearing:

- Reduces 100-year flood 2 feet on Squaw Creek
- Benefits outweigh costs
- Free of major environmental impacts

In summary the South Duff Bridge/Channel Improvement:

- Reduces 100-year flood 2 feet on Squaw Creek
- Benefits outweigh costs
- Free of major environmental impacts

In summary the U.S. Highway 30 Bridge Modification:

- Reduces 100-year flood 2.5 feet on the South Skunk River
- Benefits outweigh costs
- Free of major environmental impacts

Table 20. Benefit Cost Results – Conveyance Improvements – Clear Squaw Creek Channel.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$2,943,000	$177,641	$2,436,700	15.63

Table 21. Benefit Cost Results – Conveyance Improvements – South Duff Bridge Channel Improvements.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$4,715,000	$284,599	$2,086,900	7.73

Table 22. Benefit Cost Results – Conveyance Improvements – U.S. Highway 30 Bridge Modification.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
$7,740,000	$467,190	$2,097,300	4.73

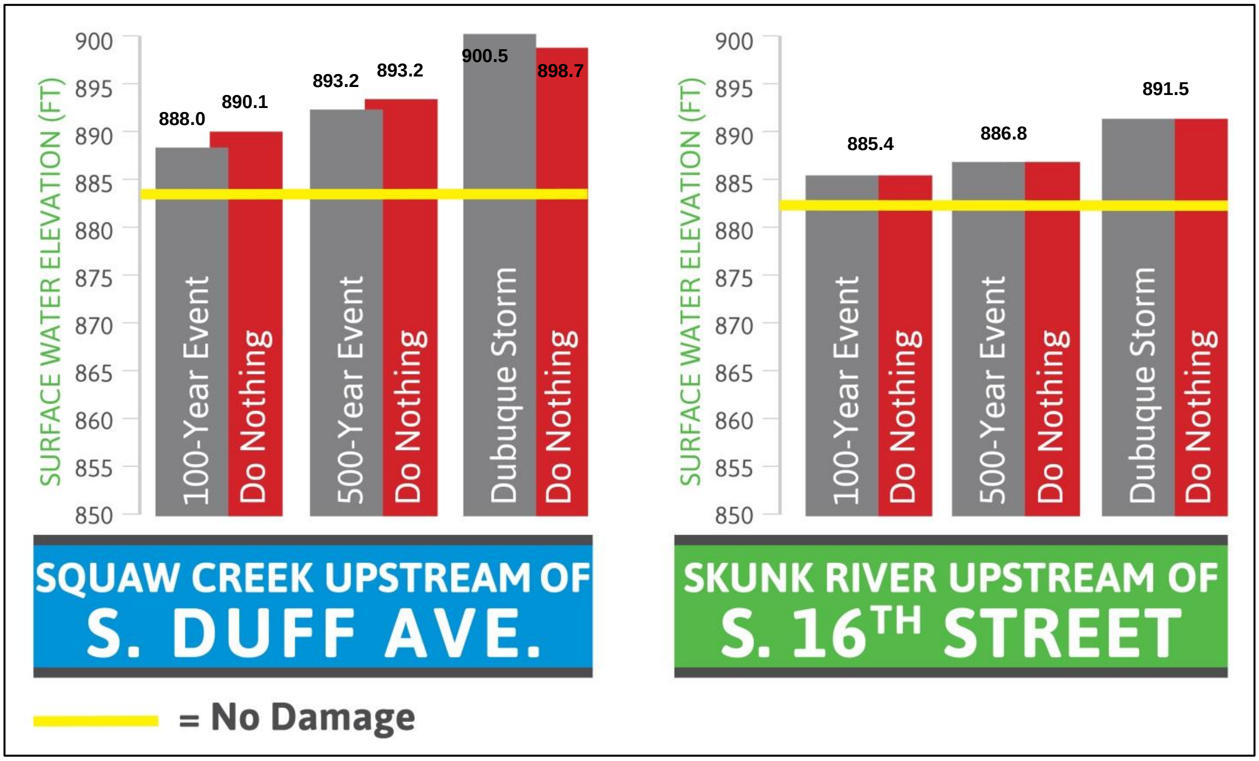

Figure 29. Comparative Hydraulic Results at Two Locations - Clear Squaw Creek.

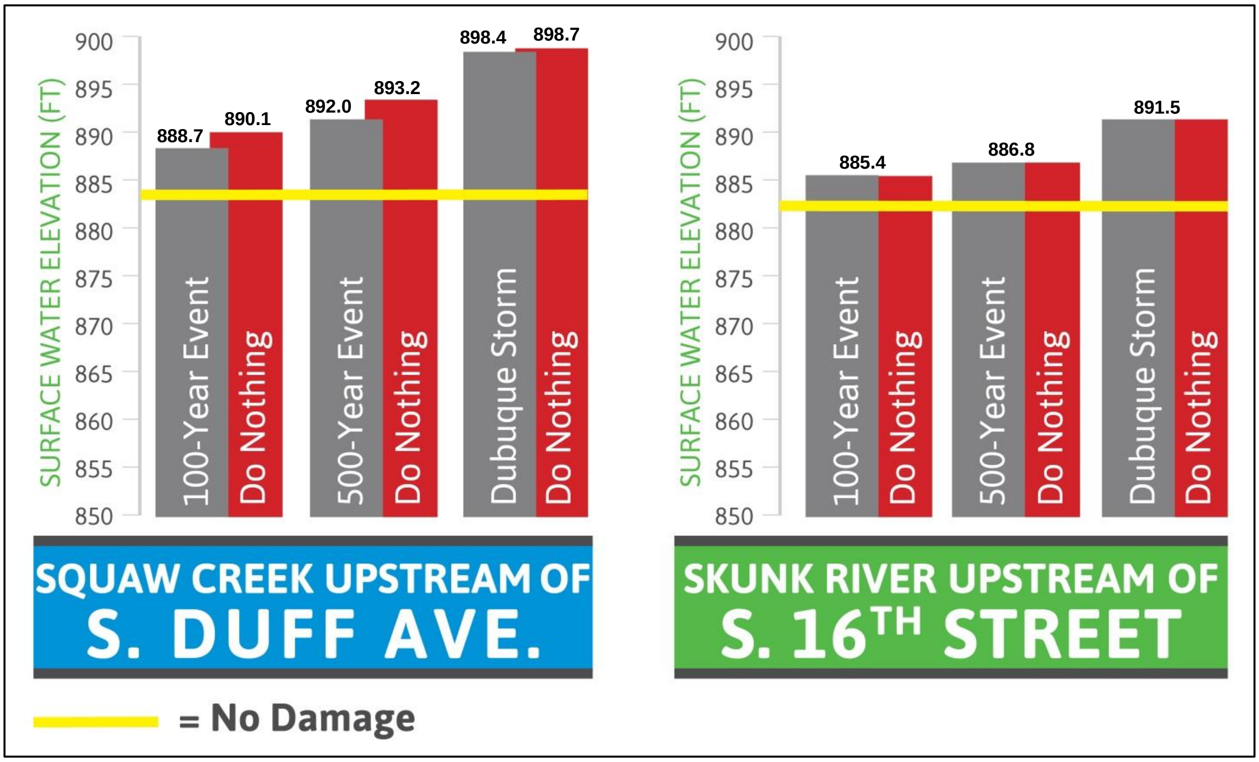

Figure 30. Comparative Hydraulic Results at Two Locations - South Duff Bridge/Channel Modification.

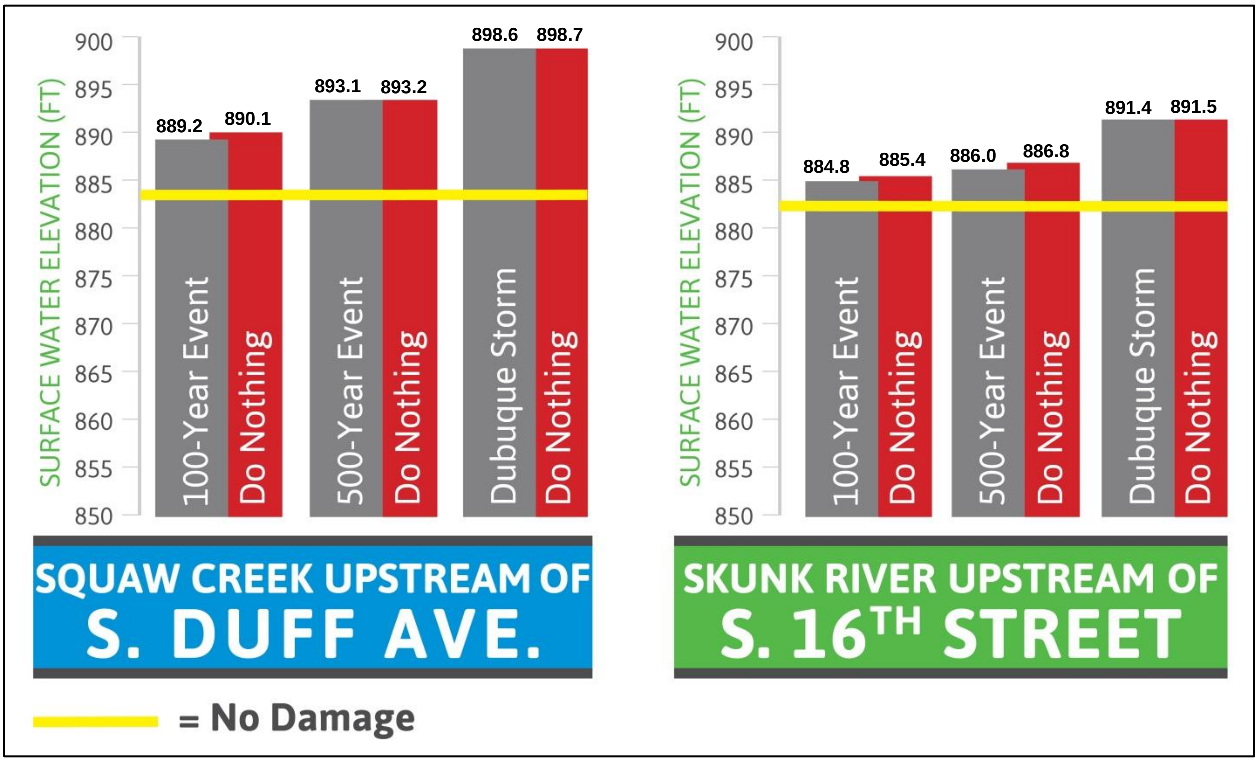

Figure 31. Comparative Hydraulic Results at Two Locations – U.S. Highway 30 Bridge Modification.

Table 23. Environmental Review Summary – Conveyance Improvements (combined).

Land Use	Impacts to small areas of commercial land adjacent to South Duff Road Bridge, open space, agricultural land adjacent to US 30 bridge. (70 acres)		
Farmland	Impacted.		
Parks, Recreation & Conservation Areas	No impact.		
Wetlands	No impact.		
Surface Water	Impacts to short stretches of stream channel near the South Duff Bridge and the Highway 30 Bridge during construction.		
Threatened & Endangered Species	Potential impacts.		
Cultural Resources – Historical & Archaeological	Impacts to 3 archaeological sites and 2 historic structures.		
Socio-Economic Resources	Impacts to businesses adjacent to the South Duff Road bridge and open space and agricultural land adjacent to the US 30 bridge.		
Environmental Justice	No impact.		
Transportation	Temporary impacts to roads within the Project Area. Would also require the lengthening of Hwy 30 Bridge over the Skunk River and the South Duff Bridge over Squaw Creek.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	31 leaking UST sites, 2 non-NPL Superfund site, and 6 no leaking USTs within the proposed footprints are within 1 mile.		
Air Quality	Would generate minor amounts of emissions from construction equipment and fugitive dust from soil disturbance.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (Reduced 100-year flood height of 2.5-ft on Skunk.)	Do the benefits outweigh the costs? ☑	Is this alternative free of major environmental impacts? ☑

8.8 100 and 500-year Levee Protection

The 100-year Levee Protection alternative involves protecting property areas along Squaw Creek and the South Skunk River by constructing a levee to 3 feet above the updated 100-year WSEL. Figure 32 shows the location of the potential levee alignment. Table 24 reports the results of the benefit cost analysis. It is important to note that interior drainage for the levee system (needed for coincident riverine flood event and heavy rainfall event) accounts for almost half of the cost. Figure 33 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 26 reports the highlights and issues from the environmental review. In summary:

- Protects to 100-year level
- Benefits do not outweigh costs

- Free of major environmental impacts
- Opportunities for combination with conveyance improvements

The 500-year Levee Protection alternative involves protecting property areas along Squaw Creek and the South Skunk River by constructing a levee to the 500-year WSEL. Figure 32 shows the location of the potential levee alignment. Table 25 reports the results of the benefit cost analysis. It is important to note that interior drainage for the levee system (needed for coincident riverine flood event and heavy rainfall event) accounts for almost half of the cost. Figure 33 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. Table 26 reports the highlights and issues from the environmental review. In summary:

- Protects to 500-year level
- Benefits do not outweigh costs
- Free of major environmental impacts

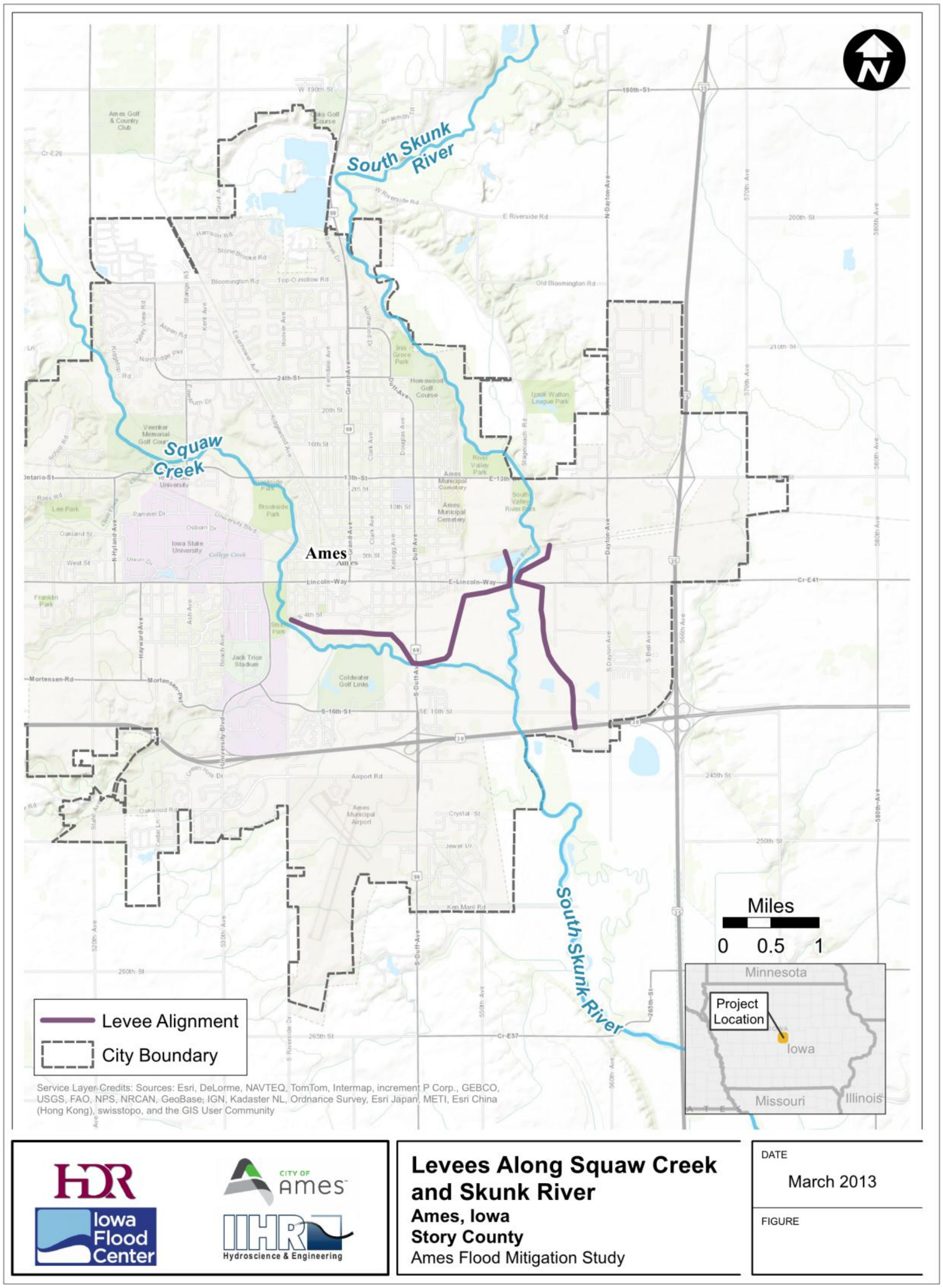

Figure 32. Levee Alignment (Both 100-year and 500-year Level of Protection).

Table 24. Benefit Cost Results – Conveyance Improvements – 100-year Levee Protection.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
Skunk River $4,818,000	Skunk River $290,817	Skunk River $121,400	Skunk River 0.26
Squaw Creek $6,079,000	Squaw Creek $366,931	Squaw Creek $174,600	Squaw Creek 0.48

Table 25. Benefit Cost Results – Conveyance Improvements – 500-year Levee Protection.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
Skunk River $5,333,000	Skunk River $321,902	Skunk River $198,100	Skunk River 0.62
Squaw Creek $7,688,000	Squaw Creek $462,844	Squaw Creek $174,600	Squaw Creek 0.38

Table 26. Environmental Review Summary – 100 Year Levee Protection.

Land Use	Impacts to commercial and agricultural land. (10 acres)		
Farmland	No impact.		
Parks, Recreation & Conservation Areas	No impact.		
Wetlands	No impact.		
Surface Water	No impact.		
Threatened & Endangered Species	Potential impacts.		
Cultural Resources – Historical & Archaeological	Impacts to 3 archaeological sites and 24 historic structures.		
Socio-Economic Resources	Impacts to approximately 10 to 15 businesses.		
Environmental Justice	Impacts to minorities, low-income, elderly and LEP populations.		
Transportation	Temporary impacts to roads within the Project Area. Potential impacts to the UPRR tracks.		
Noise	Construction of any alternative selected would be temporary and intermittent. It is not anticipated that any unacceptable noise levels would be generated by construction of the selected alternatives.		
Regulated Materials	45 leaking UST sites, 6 non-NPL Superfund sites, and 6 Iowa contaminated sites are within 1 mile. 1 leaking UST is located within the footprint of the Squaw Creek levee.		
Air Quality	No impacts.		
Performance Criteria	Does it meet at least a 500-year level of protection? ☒ (The alternative meets the 100-year protection on Squaw & Skunk.)	Do the benefits outweigh the costs? ☒	Is this alternative free of major environmental impacts? ☑

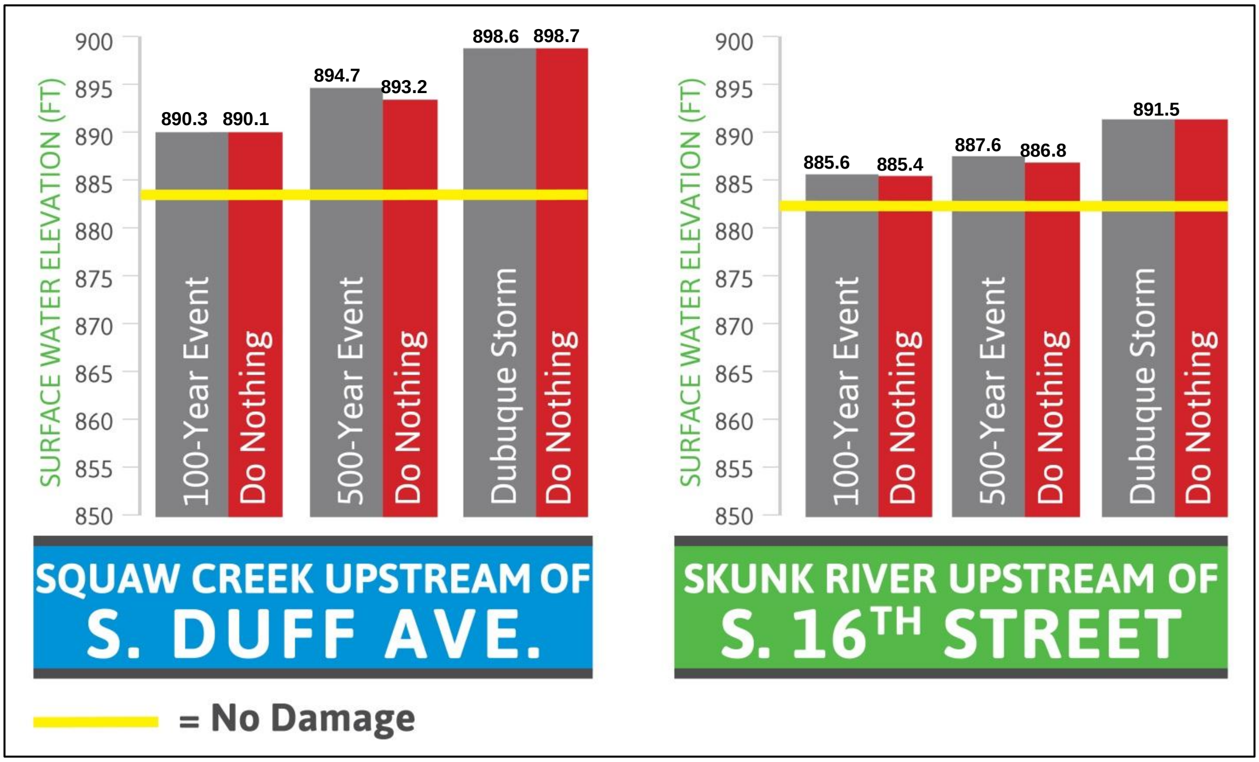

Figure 33. Comparative Hydraulic Results at Two Locations – 100-year and 500-year Protection.

8.9 Floodplain Ordinance Modification

The Floodplain Ordinance Modification alternative includes modifications to the floodplain ordinance for the City. The floodway, determined by FEMA, by definition, is the area that the river needs to convey flood flows. It is defined thorough a FEMA defined hydraulic modeling process, starting with existing conditions during the 100-year flood event. The next step is to model hypothetical development in the floodplain until the water surface elevations rise 1-ft when compared to the existing conditions. The area that is not developed in this exercise is defined as the floodway.

The current City floodplain ordinance restricts development in the floodway and the floodway fringe. Buildings is not allowed in the floodway. and Outside of the floodway but still in the floodplain, building are required to have a finished floor elevation of 3-feet above the 100-year water surface elevation.

The effects of floodplain development allowed under the current ordinance were evaluated with the hydraulic model to identify the implications on the updated 100-yr and 500-yr flood levels. Figures 34 and 35 show at two different locations:

- 100-yr FIS elevation associated with FEMA effective flows

- Comparison of water surface elevations for the 100-yr updated flows under existing conditions and fully developed (allowable under current ordinance) floodplain conditions.
- Comparison of water surface elevations for the 500-yr updated flows under existing conditions and fully developed (allowable under current ordinance) floodplain conditions.

Under the current City floodplain ordinance, it is expected the difference between the water surfaces at the 100-year existing conditions and the 100-year full floodway fringe development (allowable under current ordinance) condition would be no more than 1-ft. With full floodway fringe development the water would rise 1-ft. Figures 34 and 35 indicate that at one location (South Duff) that is indeed the case, with the difference being 0.5 ft. At the other location (S.5th Apartments), that is not the case, with the difference being 2.5 ft.

The larger increase in WSEL at the S. 5th Apartments is the result of:

- Larger discharge being associated with the 100-year FFA event than the existing effective FIS 100-year discharge (See Table 3),
- Inundation limits being defined with LiDAR-based topography which is more accurate than the topography that the previously adopted flood inundation maps were based on, and
- A full floodplain development condition (Floodway Only) in the FEMA effective floodway hydraulic model that is too restrictive given larger discharges

For the 500-year event, the difference between the water surface elevations in the existing conditions and the full floodway fringe development (Floodway Only) is 1 ft at South Duff and 4.5 ft at the South 5th Apartments.

This perfectly illustrates the trade-offs and the risks associated with allowing (but restricting) development in the floodplain (the City's current floodplain ordinance). Developing the floodway fringe (outside the floodway) and requiring buildings to be 3-ft above the 100-year FIS water surface elevations attempts to strike a balance between allowing some development, protecting property during a 100-year flood event (and the 500-year flood without any freeboard) by virtue of staying above the flood, but it also accepting some residual flood risk and may exacerbate flooding impacts and damages during the most extreme events.

However, the impact of allowing development in the floodway fringe on water surface elevations during the more extreme events (500-year flood and greater) is magnified, with the modeling showing that the comparison yields several feet of difference between the existing conditions and the fully developed floodplain conditions. The more extreme floods, by definition, have a much lower probability of occurring and under current ordinance the City has accepted the risk of more infrequent flood events.. The City also has the unique perspective of having several of the largest floods on record having occurred over the last 20 years.

Several modifications were considered to the ordinance. They aren't evaluated in the same way as the other alternatives (costs, benefits, flood protection, and environmental review), but they are brought forward for the City to consider. The modifications include (some of these are mutually exclusive):

- 100-year floodplain becomes the floodway;
- 2010 inundation limit becomes the floodway;
- Regulate to the base flood plus 5 feet;
- Modify floodplain extent to be extent of the floodplain associated with base flood plus 3 feet;
- Regulate to the 500-year event;
- Redefine the floodway based on new modeling or a new recurrence interval;
- Enact compensatory storage requirements;
- Develop and maintain two-dimensional hydraulic model that can quantify impact of individual structures on floodplain;
- Adopt a lifetime cumulative damage limit for properties in the floodplain

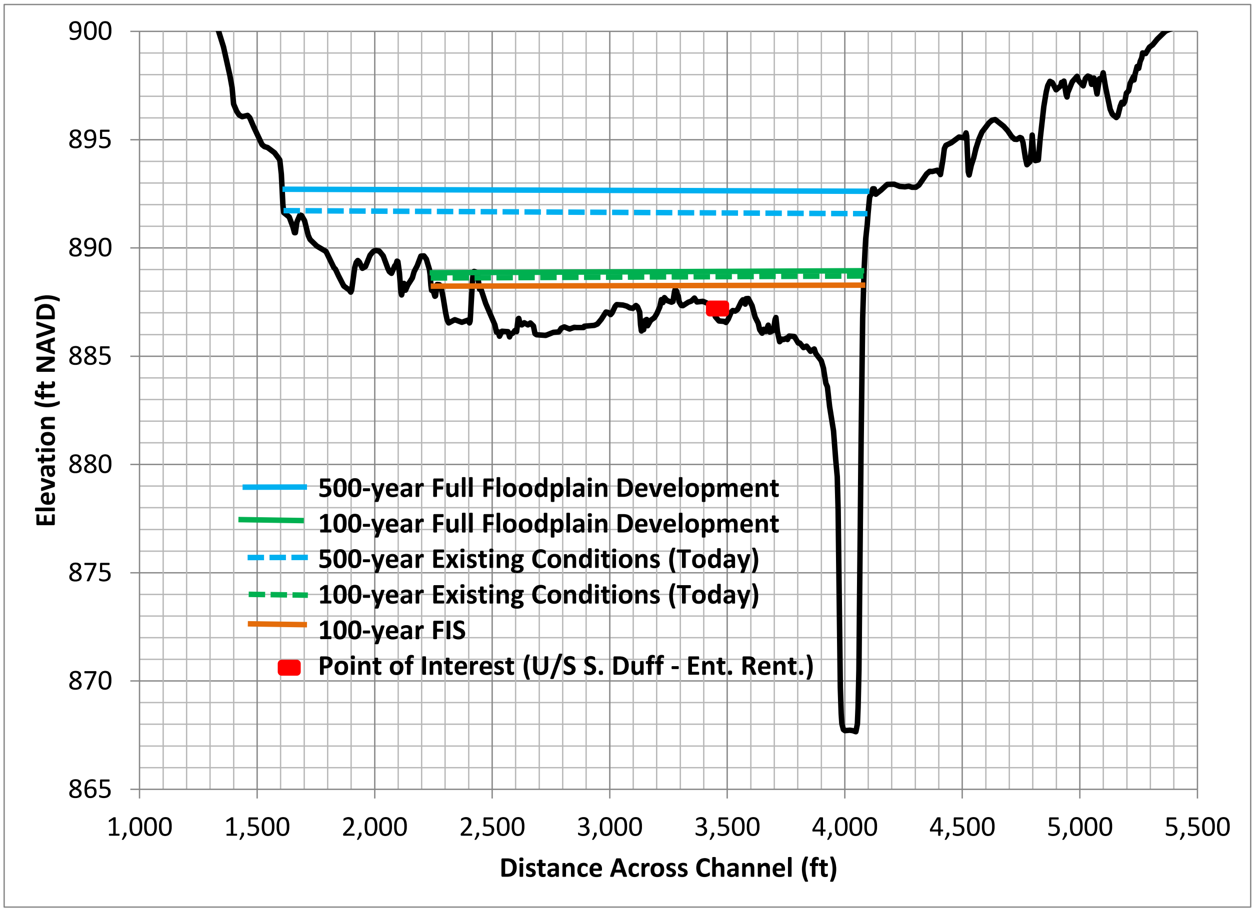

Figure 34. Comparison of Existing Conditions (With updated FFA discharges), Effective Flood Insurance 100-year Elevations and Fully Developed Conditions just Upstream from South Duff Avenue (XS 1269).

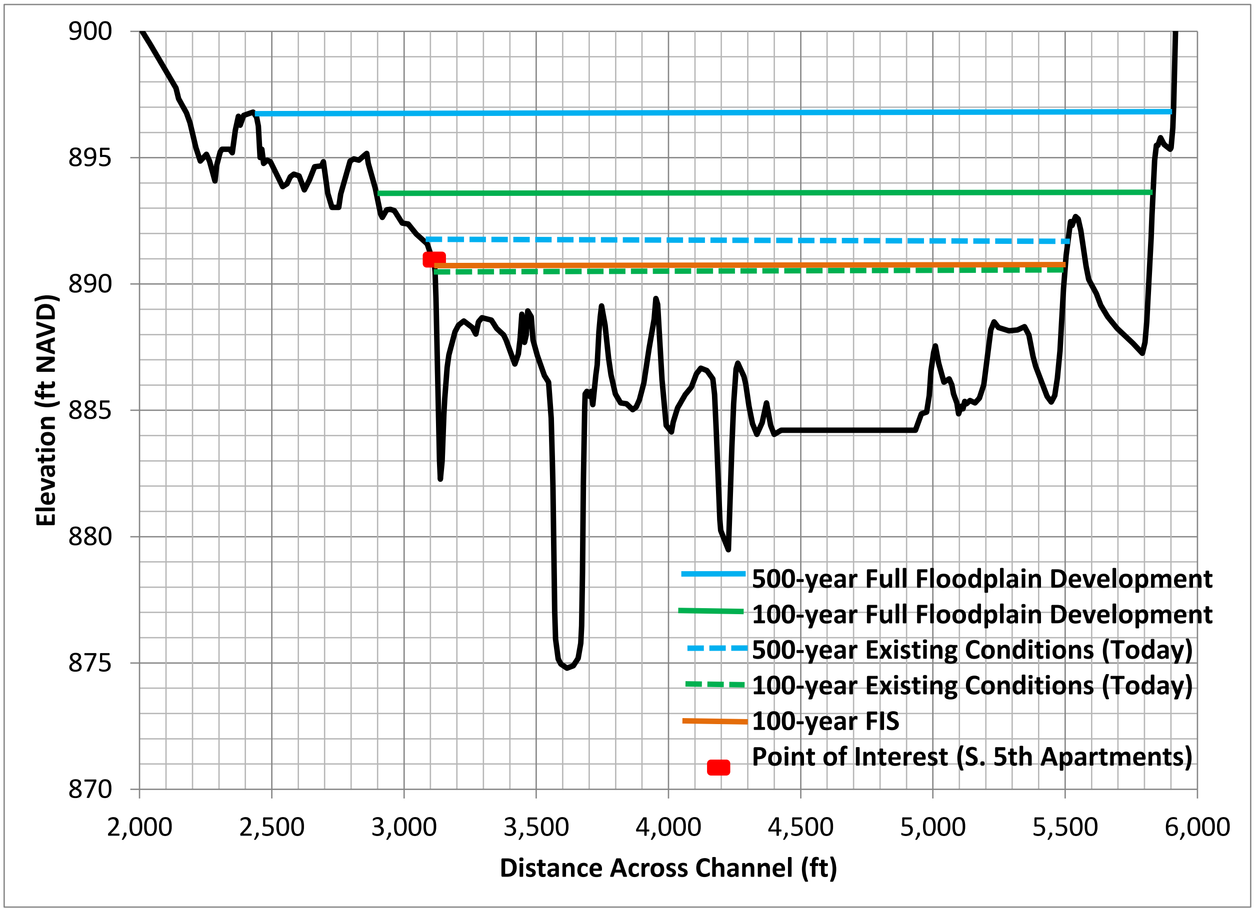

Figure 35. Comparison of Existing Conditions (With updated FFA discharges), Effective Flood Insurance 100-year Elevations and Fully Developed Conditions at the Apartment Complex on 5th (XS 2339).

9.0 Recommendations

As a result of the analysis of the screened alternatives, three combined alternatives were identified as optimizations that could be combined to maximize the benefits for the City. It is also recommended that the City consider the implications of their current floodplain ordinance on water surface elevations during more extreme floods as described in Section 8.10. They are described in the following sections.

9.1 Combination Alternative 1 - Conveyance Improvements

The first combination maximized BCR, and consisted of combining the US HWY 30 bridge modification with channel modifications at the South Duff Bridge. This alternative involves protecting property areas along Squaw Creek and the South Skunk River by improving conveyance along the South Skunk River at South Duff (channel improvements) and by enacting the bridge lengthening at U.S. Highway 30 (additional 430 feet). See Figure 36. Table 27 reports the results of the benefit cost analysis, at 3.5. Figure 37 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. In summary:

- Lowers damage during every flood event compared to “no project” or existing condition
- Benefits outweigh costs
- Free of major environmental impacts

Table 27. Benefit Cost Results – Conveyance Improvements.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
(Hwy 30 Mod. $7,740,000) (Channel Improvements at S. Duff ($4,715,000) Total $12,455,800	$751,800	$2,634,900	3.5

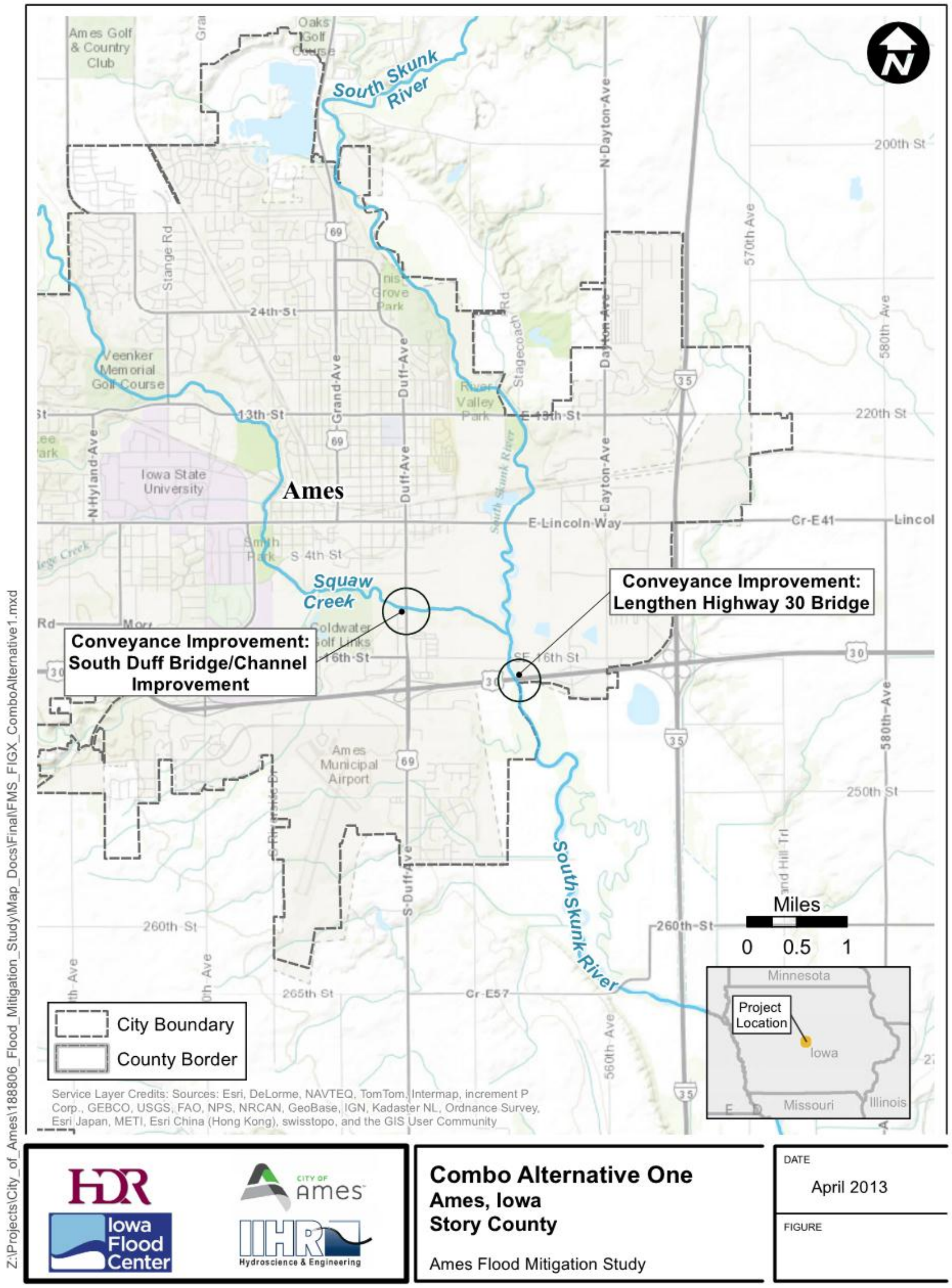

Figure 36. Combination Alternative 1 – Conveyance Improvements.

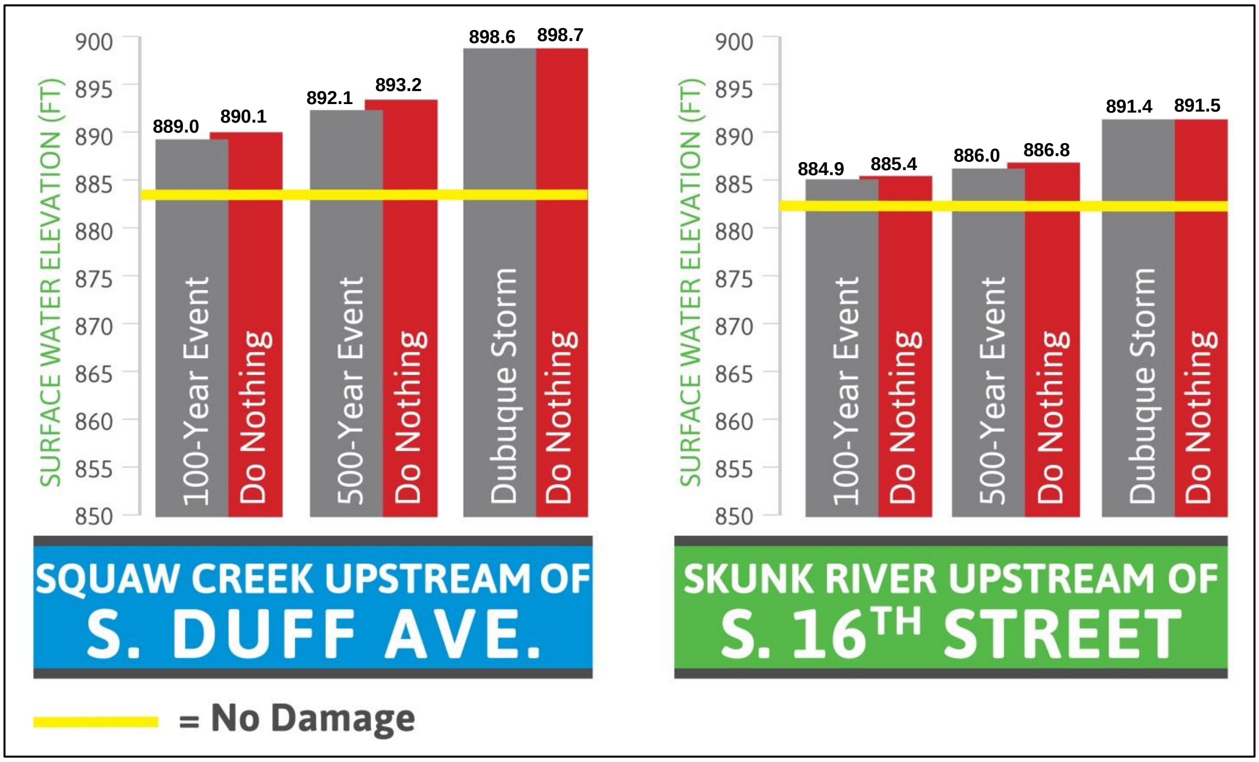

Figure 37. Comparative Hydraulic Results at Two Locations – Combined Alternative 1 – Conveyance Improvements.

9.2 Combination Alternative 2– 100 and 500-year Levees Including Conveyance Alternatives.

The second combination provided more complete protection below the 100-year and 500-year flood levels and combined the channel conveyance improvements with a 100-year protection levee and then with a 500-year protection levee. This quantified the incremental improvements compared to Combined Alternative 1 and increased overall benefits. This alternative involves protecting property areas along Squaw Creek and the South Skunk River by constructing a levee to 3 feet above the updated 100-year WSEL, constructing a levee to the updated 500-year flood elevation. A levee was also included to protect property along just south of the South Duff Bridge. See Figure 38. It also includes improving conveyance along the South Skunk River at South Duff (channel improvements) and by enacting the bridge lengthening at U.S. Highway 30 (additional 430 feet). Figure 39 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street, for both configurations. Table 28 and 29 summarize the benefit cost analysis. In summary:

- Lowers damage during every flood event
- Provides complete protection for events at the 100-year and below and the 500-year and below

- Benefits outweigh costs
- Free of major environmental impacts

Table 28. Benefit Cost Results – Conveyance Improvements – 100-year Levee Protection.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
(Hwy 30 Mod. $7,740,000) (Channel Improvements at S. Duff ($4,714,000) 100-year Levee ($11,657,000) **Total $24,111,000**	$1,455,417	$2,699,200	1.85

Table 29. Benefit Cost Results – Conveyance Improvements – 500-year Levee Protection.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
(Hwy 30 Mod. $7,740,000) (Channel Improvements at S. Duff ($4,714,000) 500-year Levee ($14,059,000) **Total $26,513,000**	$1,600,379	$2,747,400	1.72

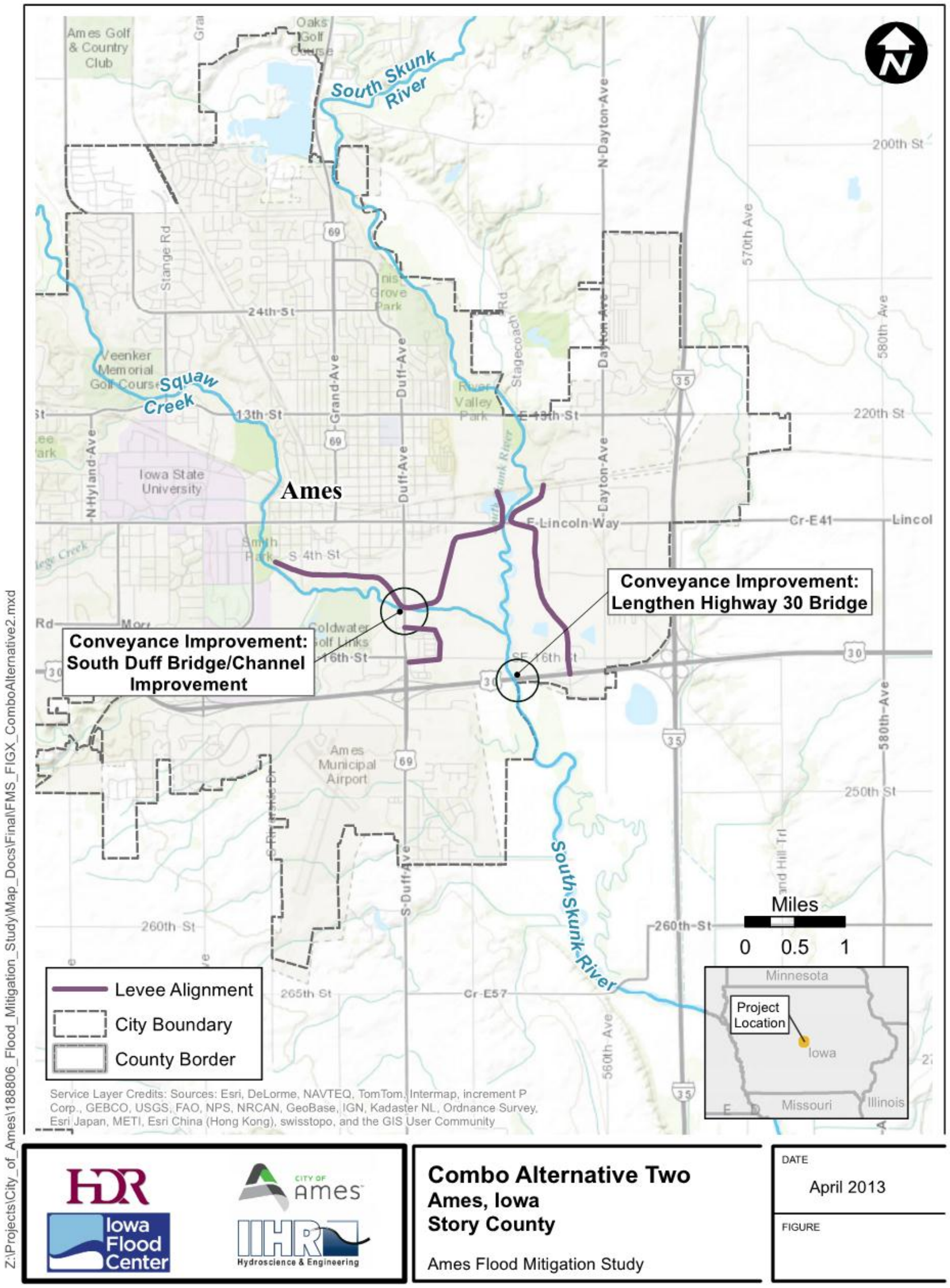

Figure 38. Combination Alternative 2 – 100-year and 500-year Levee Protection Including Conveyance Improvements.

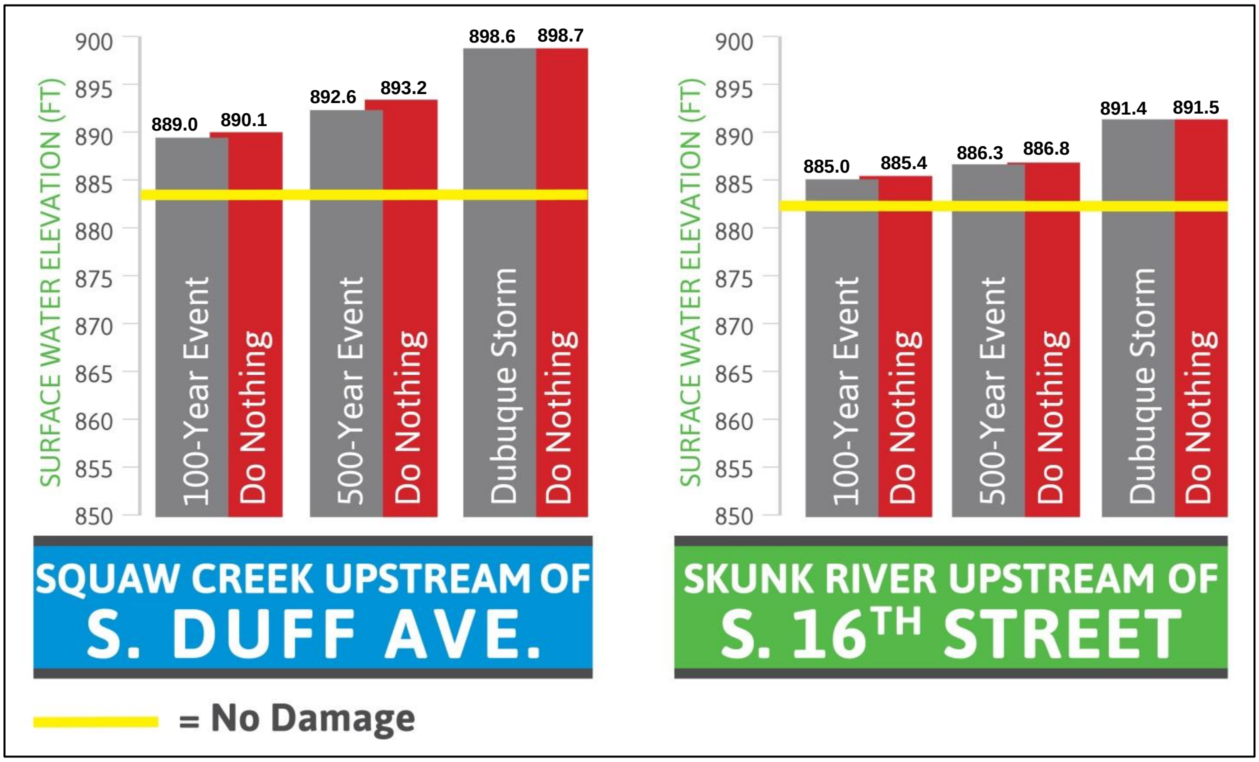

Figure 39. Comparative Hydraulic Results at Two Locations – Combined Alternative 2 – 100-year and 500-year Levee Protection Including Conveyance Improvements.

9.3 Combination Alternative 3– Two Regional Storage Reservoirs

The third combination alternative took advantage of two regional storage reservoirs and has more net benefits than Combined Alternative 1. These sites had been previously identified and named. On Squaw Creek – SC-6((Onion Creek near mouth of Squaw Creek) and SR-2 (South Skunk River near at Ellsworth), See Figure 40. Table 30 is a summary of the benefit cost analysis. Figure 41 shows hydraulic performance, referenced at two locations of interest, Squaw Creek upstream of South Duff and South Skunk River upstream from South 16th Street. In summary:

- Lowers damage levels during every flood event
- Prevents floodwaters from entering Ames, up to a certain level
- Benefits outweigh costs
- Smaller environmental impacts than both Centralized Storage and Regional and Tributary Storage

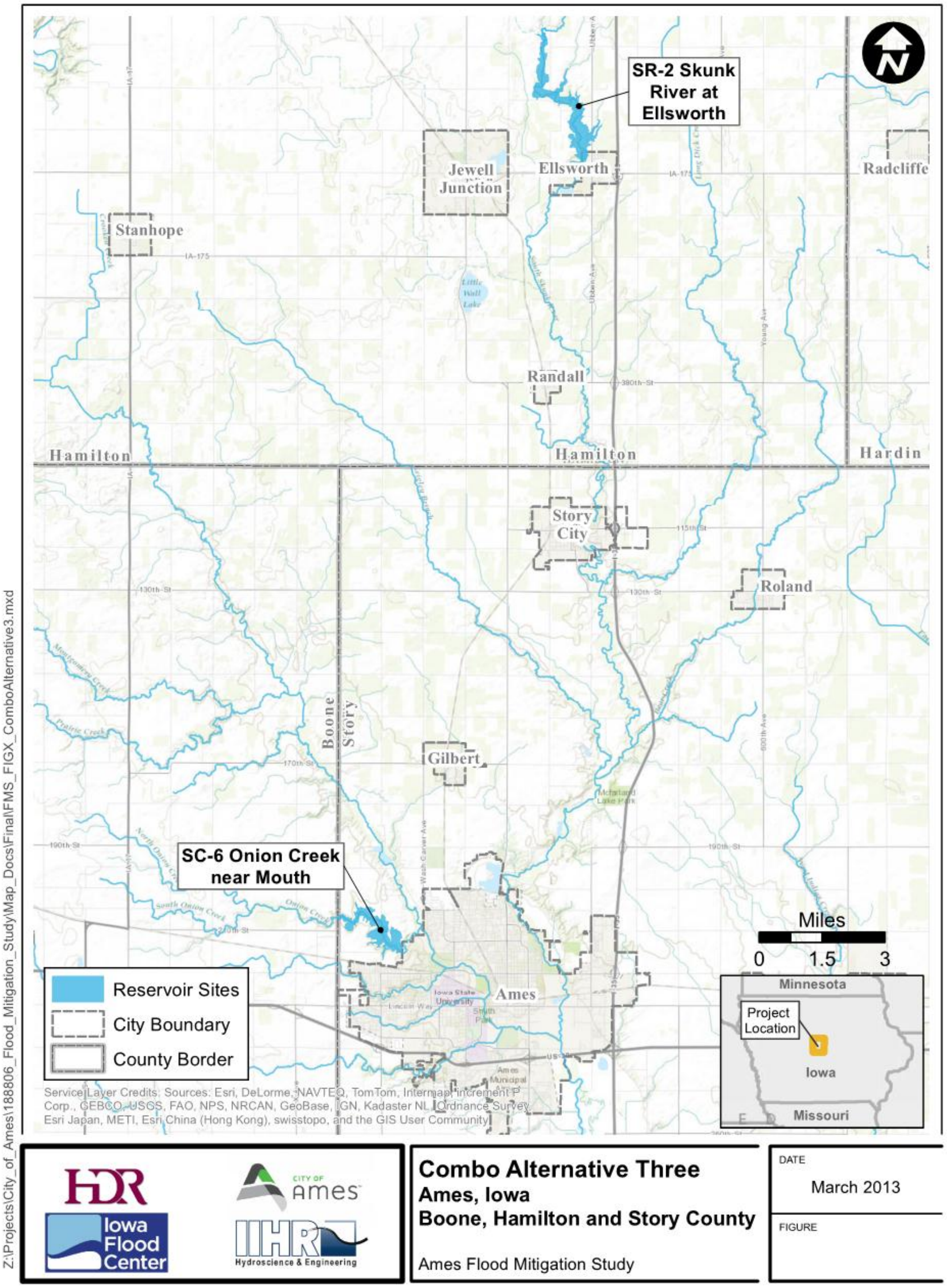

Figure 40. Combination Alternative 3 – Two Regional Storage Reservoirs.

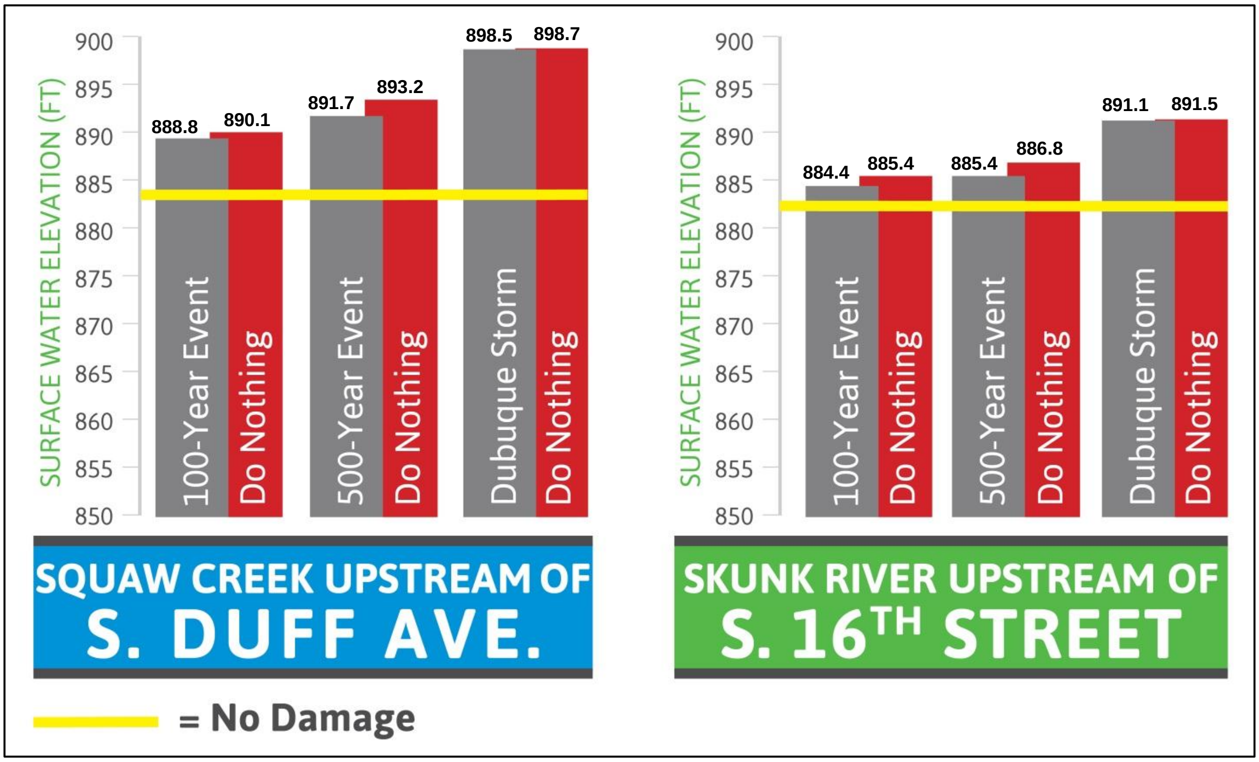

Figure 41. Comparative Hydraulic Results at Two Locations – Combined Alternative 3 – Two Regional Storage Reservoirs.

Table 30. Benefit Cost Results – Two Regional Storage Reservoirs.

Construction Costs	Annual Cost (including O&M)	Annual Benefits	BCR
(Squaw Creek $13,185,000) (S. Skunk River $8,735,000) Total $21,920,000	$1,323,100	$2,856,700	2.16

9.4 Summary of Recommendations

Table 31 is a detailed summary of the benefit cost analysis results for combined alternative 1, 2, and 3. For reference Table 32 contains the original screened alternatives. The rankings of the combined alternatives based on Net-Benefits or BCR are:

- Combined Alternative 1 – Conveyance Improvements
- Combined Alternative 3 – Two Regional Storage Reservoirs
- Combined Alternative 2 – 100-Year Flood Protection
- Combined Alternative 2 – 500-Year Flood Protection

It is also recommended that the City consider the implications of their current floodplain as described in Section 8.9.

Table 31. Detailed Benefit Cost Analysis for Combined Alternatives.

		Combined Alternatives			
		Alt 1	**Alt 2**		**Alt 3**
	No Action	*Conveyance Improvements (S.Duff, HWY 30)*	*100-Yr Levees (including Alt 1)*	*500-Yr Levee (including Alt 1)*	*Two Regional Storage Reservoirs*
Project Costs					
First Cost	0	$12,455,000	$24,112,100	$26,513,700	$21,920,000
Annual O&M	$0	$186,825	$361,682	$397,706	$328,800
PV O&M	$0	$4,118,677	$7,973,500	$8,767,672	$7,248,606
Total PV Costs	**$0**	**$16,573,677**	**$32,085,600**	**$35,281,372**	**$29,168,606**
Annualized First Costs	$0	$564,964	$1,093,736	$1,202,673	$994,301
Total Annualized Costs	**$0**	**$751,789**	**$1,455,417**	**$1,600,379**	**$1,323,101**
Expected Annual Damages (EAD)					
Without Project	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200
With Project (Residual)	$3,832,200	$1,197,300	$1,133,000	$1,084,800	$975,500
EAD Reduced (Benefits)	**$0**	**$2,634,900**	**$2,699,200**	**$2,747,400**	**$2,856,700**
PV Benefits	$0	$58,088,055	$59,505,590	$60,568,189	$62,977,778
Economic Metrics					
BCR	0.00	3.50	1.85	1.72	2.16
Net-benefits	$0	$41,514,378	$27,419,990	$25,286,817	$33,809,172
Ranking based on BCR	5	1	3	4	2
Ranking Based on Net-benefits	5	1	3	4	2

Table 32. Detailed Benefit Cost Analysis for Screened Alternatives.

		Detailed Screening											
		Storage			**Diversions**		**Conveyance Improvements**			**Levees**			
	No Action	*Centralized*	*Regional*	*Floodplain*	*Alternative 1*	*Alternative 2*	*Cleared Channel*	*Highway 30*	*South Duff Bridge*	*Squaw 100*	*Skunk 100*	*Squaw 500*	*Skunk 500*
Project Costs													
First Cost	0	$198,243,000	$145,339,000	$41,000,000	$49,243,000	$1,095,000,000	$2,943,000	$7,740,000	$4,715,000	$6,079,000	$4,818,000	$7,668,000	$5,333,000
Annual O&M	$0	$2,973,645	$2,180,085	$615,000	$738,645	$16,425,000	$44,145	$116,100	$70,725	$91,185	$72,270	$115,020	$79,995
PV O&M	$0	$65,555,905	$48,061,368	$13,558,068	$16,283,901	$362,099,626	$973,205	$2,559,499	$1,559,178	$2,010,232	$1,593,238	$2,535,689	$1,763,541
Total PV Costs	**$0**	**$263,798,905**	**$193,400,368**	**$54,558,068**	**$65,526,901**	**$1,457,099,626**	**$3,916,205**	**$10,299,499**	**$6,274,178**	**$8,089,232**	**$6,411,238**	**$10,203,689**	**$7,096,541**
Annualized First Costs	$0	$8,992,391	$6,592,642	$1,859,778	$2,233,684	$49,669,687	$133,496	$351,090	$213,874	$275,746	$218,547	$347,824	$241,907
Total Annualized Costs	**$0**	**$11,966,036**	**$8,772,727**	**$2,474,778**	**$2,972,329**	**$66,094,687**	**$177,641**	**$467,190**	**$284,599**	**$366,931**	**$290,817**	**$462,844**	**$321,902**
Expected Annual Damages (EAD)													
Without Project	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200	$3,832,200
With Project (Residual)	$3,832,200	$140,900	$36,100	$580,300	$219,100	$69,500	$1,054,900	$1,620,200	$1,631,500	$3,735,300	$3,710,800	$3,635,700	$3,634,100
EAD Reduced (Benefits)	**$0**	**$3,691,300**	**$3,796,100**	**$3,251,900**	**$3,613,100**	**$3,762,700**	**$2,777,300**	**$2,212,000**	**$2,200,700**	**$96,900**	**$121,400**	**$196,500**	**$198,100**
PV Benefits	$0	$81,377,068	$83,687,451	$71,690,215	$79,653,099	$82,951,127	$61,227,354	$48,764,954	$48,515,838	$2,136,222	$2,676,341	$4,331,968	$4,367,241
Economic Metrics													
BCR	0.00	0.31	0.43	1.31	1.22	0.06	15.63	4.73	7.73	0.26	0.42	0.42	0.62
Net-benefits	$0	-$182,421,837	-$109,712,916	$17,132,146	$14,126,198	-$1,374,148,499	$57,311,149	$38,465,455	$42,241,661	-$5,953,009	-$3,734,898	-$5,871,721	-$2,729,300
Ranking based on BCR	13	10	7	4	5	12	1	3	2	11	9	8	6
Ranking Based on Net-benefits	6	12	11	4	5	13	1	3	2	10	8	9	7

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Appendix A

Public Meetings, Online Meetings, Comments and Council Workshops (Electronic Only)

Appendix B

Hydrology and HEC-HMS Files (Electronic Only)

Appendix C

Hydraulics and HEC-RAS Files (Electronic Only)

Appendix D

Baseline Inundation Maps FFA

Appendix E

Baseline Inundation Maps Iowa Based Rainfall Events

Appendix F

Detailed Study Hydraulics Inundation Maps

Appendix G

Costs

Appendix H

Environmental Review (Electronic Only)