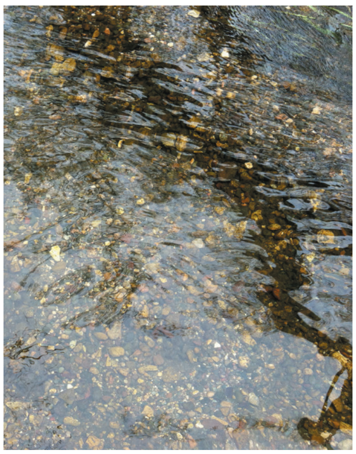
Squaw Creek
Watershed Management Authority

# Squaw Creek Watershed Management Plan



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Prairie Rivers of Iowa

EOR water ecology community

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## List of Acronyms

| | |
|---|---|
| ACPF | Agricultural Conservation Planning Framework |
| AFO | Animal Feeding Operation |
| ATV | All Terrain vehicle |
| AU | Animal Units |
| BEHI | Bank Erosion Hazard Index |
| CC | Continuous Corn |
| cfs | cubic feet per second |
| cfu | Colony Forming Units |
| Cl | Chloride |
| cm | centimeters |
| COOP | Cooperative Observer Program |
| CREP | Conservation Reserve Enhancement Program |
| CRP | Conservation Reserve Program |
| CS | Corn/Soybean |
| DNR | Department of Natural Resources |
| DO | Dissolved Oxygen |
| EPA | Environmmental Protection Agency |
| EPT | Ephemeroptera, Plecoptera, and Trichoptera ( macro-invertebrates) |
| EQIP | Environmental Quality Incentives Program |
| ET | Evapotranspiration |
| GIS | Geographic Information Systems |
| GWW | Grassed Waterways |
| HA | Hectares |
| HUC | Hydrolic Unit Code |
| IA | Iowa |
| IBI | Index of Biotic Integrity |
| IFIS | Iowa Flood Information System |
| INRS | Iowa Nutrient Reduction Strategy |
| ISU | Iowa State University |
| ITPHS | Imminent Threat to Public Health and Safety |
| LIDAR | Light Detection And Ranging |
| MDLs | Minimum Detection Limits |
| mg/L | milligrams per Litre |
| mL | Milliliters |
| MPCA | Minnesota Pollution Control Agency |
| MRTN | Maximum Return To Nitrogen |
| MS4 | Municipal Separate Storm Sewer System |
| N | Nitrogen? |
| N/A | Not Applicable |
| NA | Not Applicable |
| NBS | Near Bank Shear Stress |
| NOAA | Nation Oceanic and Atmospheris Association |

| | |
|---|---|
| NPDES | National Pollutant Discharge Elimination System |
| NRCS | Natural Resources Conservation Service |
| NRWs | Nutrient Removal Wetlands |
| NS | Non Supporting |
| NTUs | Nephelometric Turbidity Units |
| NWS | National Weather Service |
| org/day | organisms per day |
| P | Phosphorus |
| pH | a measure of acidity of basicity |
| PO4 | Phosphate |
| ppb | parts per billion |
| ppm | parts per million |
| PS | Partially Supporting |
| PSA | Public Service Announcement |
| RASCAL | Rapid Assessment of Stream Condition Along Length |
| SOM | Soil Organic Matter |
| SSTS | Subsurface Sewage Treatment Systems |
| SSURGO | Soil Survey Geographic Database |
| STP | Standard conditions for temperature and pressure |
| STRIPS | Science-based Trails of Rowcrops Integrated with Prairie Strips |
| SWAT | Soil and Water Assessment Tool |
| SWCD | Soil and Water Conservation District |
| TKN | Total Kjehldahl Nitrogen |
| TMDL | Total Maximum Daily Load |
| TP | Total Phosphorous |
| UA/UAA | Use Attainability/Use Attainability Analysis |
| USACE's FLUX32 | U.S. Army Corps of Engineers' windows based interactive software program |
| USDA | United States Department of Agriculture |
| USDA-ARS | United States Department of Agriculture - Agricultural Research Service |
| USEPA | United States Environmental Protection Agency |
| USGS | United States Geological Survey |
| UV | Ultra Violet |
| WASCOB | Water and Sediment Control Basins |
| WMA | Watershed Management Authority |
| WW | Warm Water |
| WWTF | Waste Water Treatment Facility |
| WWTP | Waste water Treatment Plant |

# Executive Summary

The Squaw Creek Management Plan was developed through a year-long series of meeting of the Watershed Management Authority Board and representatives of Emmons & Olivier Resources and the Prairie Rivers of Iowa RC&D. The planning process began with a series of meetings to describe the existing conditions within the watershed and the challenges facing its water resources. The Board of Managers took this information and developed a set of goals for the future of the watershed. Based on these goals, a set of strategies/approaches was developed.

## Watershed Assessment

The watershed assessment was built around three main areas; a general characterization of the watershed, a summary of the existing health of the streams within the watershed and an exploration of the sources of pollutants generated in the watershed.

## Watershed Characterization (Section 2)

The watershed characterization section includes a description of the watersheds hydrology. The subwatersheds and stream network is defined and mapped. Watershed factors influencing health of streams, including landuse/land cover, soils, topography, groundwater, climate are also summarized. The general finding of the watershed characterization is that the agricultural land cover that dominates the watershed, along with climatic elements play the largest role in defining the character of Squaw Creek and its tributaries.

## Stream Health (Section 3)

The examination of stream health included in the plan is built around a summary of water quality measurements and an assessment of stream stability. Water quality monitoring data from the past decade was reviewed and summarized by the common parameters/pollutants. Stream stability was evaluated through a comparison of two recently conducted steam assessment projects in the watershed. The past water quality monitoring data shows that Squaw Creek and its tributaries have very high levels of nutrients, sediment and fecal bacteria, all of which are of concern for stream health. The stream assessment indicates that the streams are exhibiting symptoms of being within a hydrologically altered watershed; there are areas of extreme instability throughout the watershed.

## Pollutant Source Assessment (Section 4)

After determining that there were nutrient and fecal bacteria concerns in Squaw Creek the next step was to assess the likely sources and magnitude of contribution occurring in the watershed. A water quality model was constructed for the watershed using land cover, crop rotation, land use, topography, soils and climatic data. The model was used to determine which areas in the watershed produce a disproportionate rate of nutrients. These areas, referred to as hot-spots in the plan, are used to prioritize future management. An assessment of potential sources of fecal bacteria was also conducted for the watershed utilizing available data on animal feeding operations, grazing animals, failing septic systems, pets and wildlife. Of the sources assessed, manure from confined animal operations is the most abundant in the watershed.

## Goals and Objectives (Section 5)

Following a complete review of the watershed assessment, the Board of Managers developed goals and objectives for future conditions in the watershed. The goals were developed through a series of meetings and considerable discussion. Measurable objectives were developed for each of the goals. The goals of the watershed management plan are as follows;

- Increase people's awareness and understanding of the individual connections and efforts within the watershed
- Improve water quality in the watershed
- Reduce the effects associated with altered hydrology (heavy flows, diminished base flow) within the watershed
- Increase the variety of habitat for animal and plant life in the watershed
- Create outstanding recreational opportunities in the watershed
- Work cooperatively to identify stakeholders and resources and facilitate partnerships to implement the watershed plan

## Implementation Strategies (Section 6)

A game plan to meet the objectives defined for the future of the watershed was developed based on the six main goals described above. While approaches were detailed for each of the goals, the primary focus of the implementation strategies section is on the approach for education/outreach and water quality improvement goals, and more specifically the water quality improvement objectives dealing with nutrient reduction. A detailed work plan was developed for the education/outreach component of the plan that stresses the importance of establishing a watershed coordinator to facilitate implementation of the plan. The nutrient reduction strategy component of the implementation section consisted of a robust BMP analysis including; a review of the pollutant hot-spots, BMP performance data, cost-effectiveness and terrain suitability.

## Monitoring Plan (Section 7)

A plan for on-going monitoring of Squaw Creek has been developed that focuses on the downstream USGS gage site as an anchor point to evaluate trends in water quality.

## Funding Source (Section 8)

Funding alternatives available for watershed management activities are provided.

# 1. Introduction

The mission of the Squaw Creek Watershed Management Authority is to engage, educate and encourage all citizens to improve the health, stewardship and resiliency of our watershed resources.

## 1.1. Watershed Management Authority

In 2010, Iowa lawmakers passed legislation authorizing the creation of Watershed Management Authorities (Iowa Code Chapter 466b). A Watershed Management Authority (WMA) is a mechanism for cities, counties, Soil and Water Conservation Districts (SWCDs) and stakeholders to cooperatively engage in watershed planning and management. The Squaw Creek Watershed Management Authority was formed in 2012 through execution of a signed agreement between members known as a Chapter 28E Agreement (refer to Appendix 1: Squaw Creek WMA 28E Agreement for full text of document). Generally, the purpose of the Squaw Creek WMA is to:

- Assess and reduce flood risk;
- Assess and improve water quality;
- Monitor federal flood risk planning and activities;
- Educate residents of the watershed regarding flood risks and water quality; and
- Allocate moneys made available to the Authority for purposes of water quality and flood mitigation.

It is important to note that, per Iowa Code, WMAs do NOT have taxing authority or the right to acquire property through eminent domain.

Membership in the Squaw Creek WMA is based on the hydrologic boundary of the Squaw Creek Watershed which is shown in Figure 1-1 and summarized in Table 1-1.

**Table 1-1**. Membership of the Squaw Creek Watershed Management Authority

| Member | Primary Representative | Additional Representatives Involved in Plan Process |
|---|---|---|
| City of Ames | Ann Campbell | Bob Kindred |
| City of Stanhope | Suzie Moore | |
| City of Stratford | Travis Sonksen | |
| City of Gilbert | Jonathan C. Popp | Frank Rydl, Sonia Arellano |
| Story County | Paul Toot | |
| Story County SWCD | Erwin Klaas | |
| Boone County | Thomas Foster | |
| Boone County SWCD | Kevin M. Griggs | |
| Webster County | Keith Dencklau | |
| Webster County | Sam Adams | |
| Hamilton County | Jean Eells | |

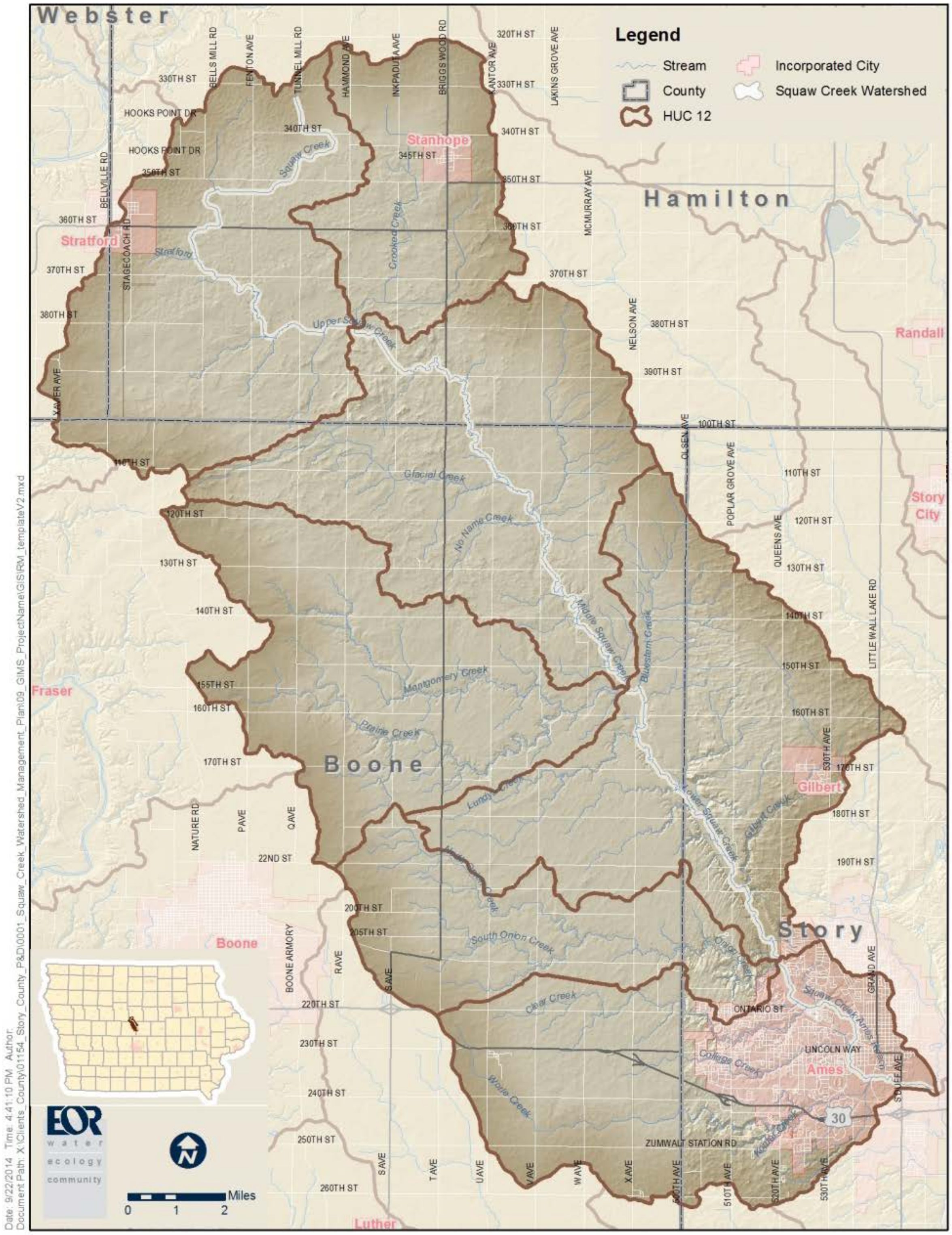


**Figure 1-1.** Political Subdivisions within the Squaw Creek Watershed

## 1.2. Acknowledgements

The Squaw Creek WMA members would like to thank the following individuals for their contribution to the planning process:

Leanne Harter, Darren Moon – Story County
Chris Anderson, Tom Isenhart - ISU
John Dunn, Tracy Warner – City of Ames
Willie Ubben – Local Contractor
Mark Tomer, David James, Sarah Porter – National Laboratory for Agriculture and the Environment
Mary Skopec, Iowa DNR
John Pohlman, Mike Lazere, Rick Dietz – Squaw Creek Watershed Coalition

## 1.3. Plan Development Process

This plan was developed through a series of workshop meetings with the Squaw Creek WMA Board of Managers. The initial meetings in the process were used to discuss the fundamentals of watershed management and to describe the challenges facing the Squaw Creek Watershed. An overview of the watershed assessment was provided as a means to describe the general condition of the watershed and the quality of its resources. Additional detail from the watershed assessment was provided at each subsequent meeting. As the technical aspects of the watershed assessment were being formulated, the WMA Board appointed a Technical Advisory Committee to review information and to provide input on technical matters. In the late winter and early spring of 2013 a series of listening sessions was held with the public in several locations throughout the watershed. The purpose of the listening sessions was to introduce people to the newly formed WMA, to describe the watershed management planning process and to solicit input on the plan. The meetings had an educational element in that watershed management basics were described and the condition of the Squaw Creek watershed was summarized. A summary of the issues that were raised by the public at the listening sessions is provided in Appendix 2: Listening Session Input.

**Figure 1-2.** Listening Session in Stanhope, IA

# 2. Watershed Characterization

## 2.1. Hydrology

Squaw Creek is part of the larger South Skunk River Watershed (HUC 8) which, after combining with the North Skunk River, becomes the Skunk River. Figure 2-1 shows the hydrologic map for the State of Iowa and where the Squaw Creek watershed lies. The Skunk River flows into the Mississippi River which ultimately drains into the Gulf of Mexico. It is important to understand the hydrologic setting of the Squaw Creek watershed and the challenges facing downstream areas. Many communities draw their drinking water from downstream rivers and countless people are dependent on the rivers and the Gulf of Mexico for their livelihoods. While having clean water within the small streams of the Squaw Creek watershed may not seem important, dependable flows of clean water are essential to the economies of downstream populations. Hypoxia/dead zone issues in the Gulf of Mexico are well documented but closer to home; reaches of the South Skunk River are impaired due to elevated bacteria levels.


**Figure 2-1.** Squaw Creek Watershed Hydrologic Setting

### 2.1.1. **Subwatersheds**

Table 2-1 summarizes the 7 main subwatersheds (HUC 12) within the watershed. We have developed an alternate naming convention for the subwatersheds that is hopefully more intuitive than the HUC12 names. In the case where a large reach (and associated direct drainage area) of Squaw Creek is within the subwatershed the name is appended with "Squaw Creek". In other cases where the subwatershed is the drainage area to a unique resource that named creek stands alone. This is the case for Montgomery and Onion Creek Subwatershed.

**Table 2-1.** Subwatersheds of the Squaw Creek Watershed

| Subwatershed | HUC 12 | HUC 12 Name | Area (acres) | Percent of Total |
|---|---|---|---|---|
| Crooked Creek | 070801050301 | Crooked Creek 2 | 11,618 | 7.90% |
| Drainage Ditch192 - Squaw Creek | 070801050302 | Drainage Ditch 192 | 24,355 | 16.60% |
| Montgomery Creek | 070801050303 | Montgomery Creek | 21,643 | 14.70% |
| Crooked Creek -Squaw Creek | 070801050304 | Crooked Creek 3 | 26,164 | 17.80% |
| Onion Creek | 070801050305 | Onion Creek | 12,733 | 8.70% |
| Lundys Creek -Squaw Creek | 070801050306 | Lundys Creek | 27,167 | 18.50% |
| Worle Creek -Squaw Creek | 070801050307 | Worrell Creek | 23,273 | 15.80% |

#### *Crooked Creek Subwatershed*

The Crooked Creek subwatershed is located in the northeastern end of the watershed and, along with the Drainage Ditch 192- Squaw Creek subwatershed, can be partially considered the headwaters of Squaw Creek (some maps alternatively refer to Crooked Creek as a branch of Squaw Creek). The subwatershed is approximately 12,000 acres. The City of Stanhope is located in the subwatershed which is entirely within Hamilton County. Other resources in the subwatershed include an un-named tributary that flows from southeast of Stanhope and meets up with Crooked Creek near where it drains into Squaw Creek. The subwatershed is also heavily ditched and tiled.

#### *Drainage Ditch 192 – Squaw Creek Subwatershed*

This subwatershed is located in the northwestern end of the watershed and can be considered the headwaters of Squaw Creek. The subwatershed is roughly 24,000 acres. The eastern half of the City of Stratford is within the subwatershed. Portions of Webster, Boone and Hamilton County are within the subwatershed. It is the only subwatershed that extends in to Webster County. Hydrologically, the subwatershed is heavily ditched and tiled. Other than Upper Squaw Creek, the subwatershed has

Drainage Ditch 192, Stratford Creek and Drainage Ditch 245. The subwatershed outlet is defined as the confluence with Crooked Creek.

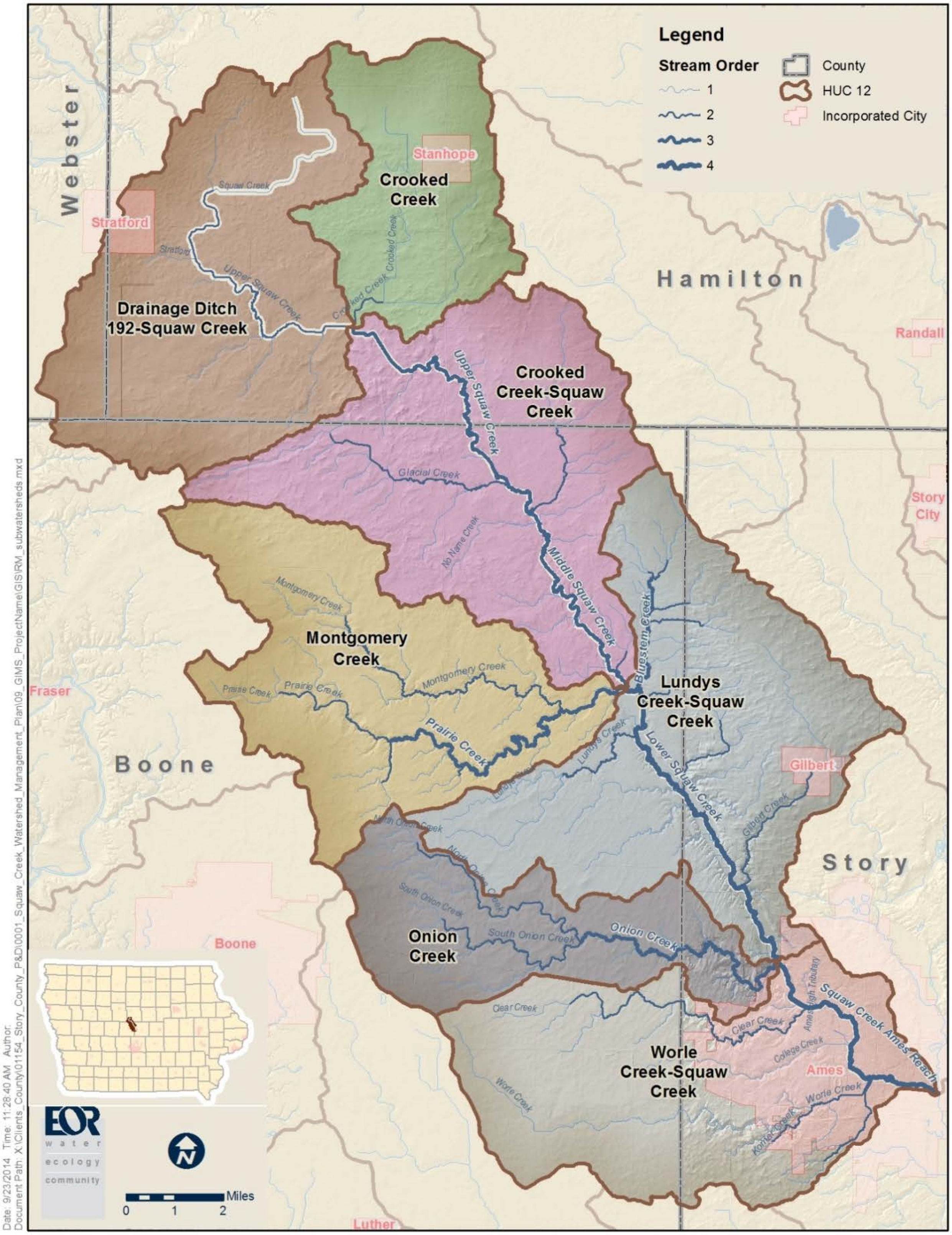

**Figure 2-2.** Squaw Creek Subwatersheds

### *Montgomery Creek Subwatershed*

The Montgomery Creek subwatershed is located in the west central portion of the watershed and lies entirely within Boone County. The subwatershed is roughly 22,000 acres. Drainage within the subwatershed runs mainly eastward through Montgomery and Prairie Creeks and their numerous tributaries. The subwatershed drains into Squaw Creek approximately at its midpoint.

### *Crooked Creek – Squaw Creek Subwatershed*

This subwatershed is in the north central part of the watershed along the northern boundary of Booke County. It also extends slightly into southern Hamilton County. The subwatershed is approximately 26,000 acres. Squaw Creek becomes well defined within the subwatershed. It runs from below the point at which Crooked Creek joins Squaw Creek down to the point at which Montgomery Creek drains into Squaw Creek. Squaw Creek becomes a recreational use stream within the subwatershed. Specifically, at the confluence with Glacial Creek it transitions to a Class 2A stream. Further information on the classification can be found in the watershed assessment section. In addition to Squaw and Glacial Creeks the subwatershed contain Scott Drainage Ditch 292 and several small un-named tributaries.

### *Onion Creek Subwatershed*

The Onion Creek subwatershed is located in the southern portion of the watershed and drains approximately 13,000 acres of Boone County and a portion of Story County, including a very small portion of the City of Ames. Onion Creek branches into North and South Onion Creek midway up the subwatershed. Onion Creek drains into Squaw Creek near the northern border of the City of Ames.

### *Lundy's Creek – Squaw Creek Subwatershed*

This subwatershed is located in the eastern portion of the watershed and straddles the boundary between Boone and Story Counties. The City of Gilbert is within the subwatershed. It is approximately 27,000 acres. Besides the mainstem of Squaw Creek, the subwatershed includes Lundy's Creek, Little Bluestem Creek and Gilbert Creek/Drainage Ditch 70 as well as several small un-named tributaries. The outlet of the subwatershed is defined as the confluence with Onion Creek.

### *Worle Creek – Squaw Creek*

This subwatershed is at the lower end of the watershed and contains its outlet into the South Skunk River. Boone and Story Counties are located within the subwatershed as is a large portion of the City of Ames. The subwatershed contains several tributaries; Clear, College and Worle Creeks in addition to the mainstem of Squaw Creek itself. There are approximately 23,000 acres of land in the subwatershed nearly half of which is developed to various degrees.

### 2.1.2. **Hydrologic Model Drainage Areas**

In addition to the 7 major HUC12 subwatersheds we have delineated drainage areas that are on the order of ~500 acres each. This further refinement was needed for the watershed modeling and will be used to report the results of that analysis (Figure 2-3). Also shown in the figure are the modeled reaches.

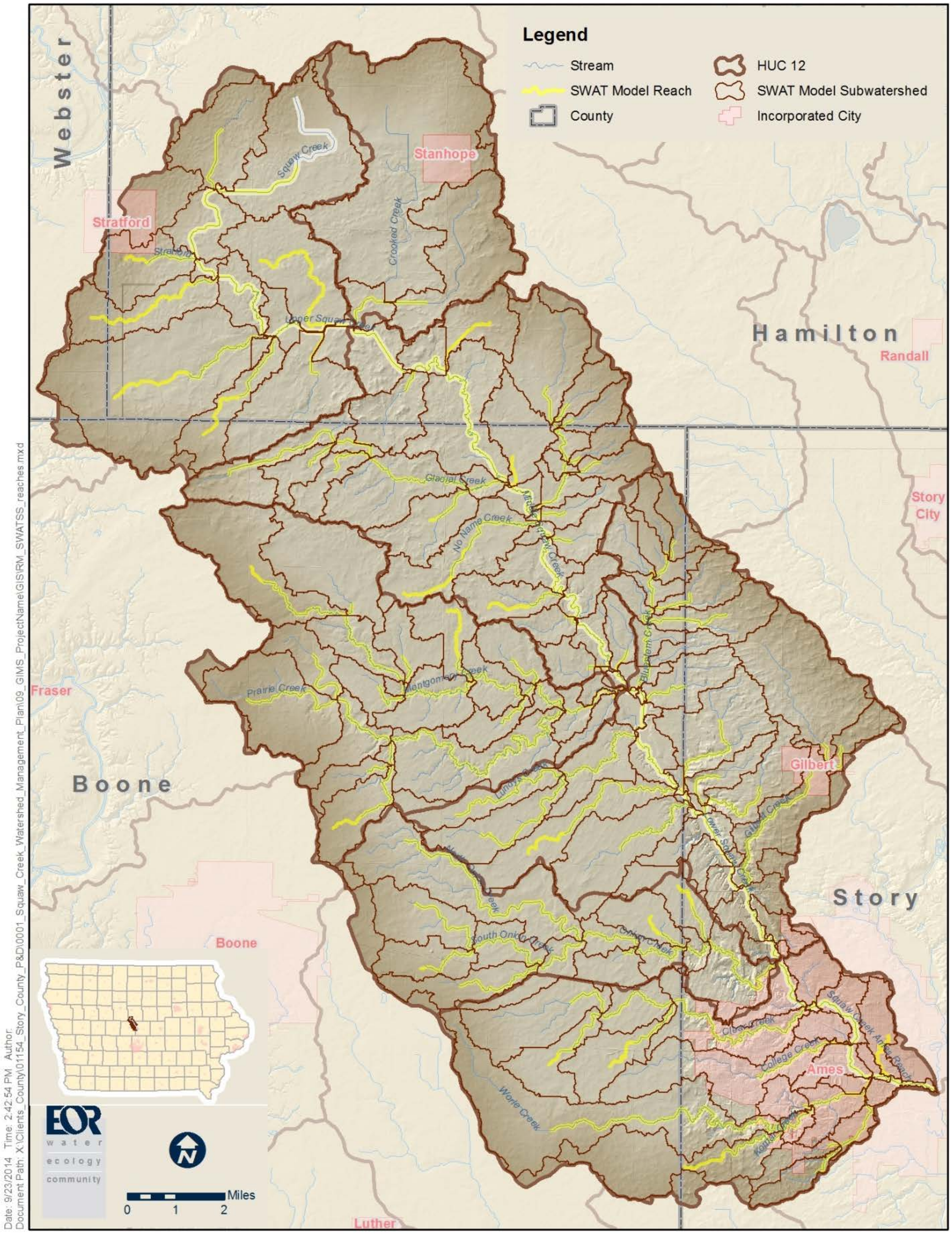


**Figure 2-3.** Watershed Model Drainage Areas and Stream Reaches

#### 2.1.3. **Stream Reaches**

For the purpose of describing discreet units of the mainstem Squaw Creek we have developed a stream reach naming convention. The reaches were defined by changes in stream use, tributary inputs and common land use. The reaches are shown in Figure 2-2. The water quality analysis is based on these reaches

***Upper Squaw Creek***

This is the upsteam-most reach of Squaw Creek. It extends from above the confluence of Glacial Creek to the headwaters of Squaw Creek. The rationale behind breaking the reach at Glacial Creek is that is the point along the stream where the Class A1 Primary Contact Recreational Use designation ends (see Appendix 3: Recreational Use Assessment and Attainability Analysis). Upper Squaw Creek is designated as a Class B(WW2) water.

Upper Squaw Creek runs through the Crooked Creek – Squaw Creek and Drainage Ditch 192 – Squaw Creek Subwatersheds.

***Middle Squaw Creek***

This reach of Squaw Creek runs, looking downstream, from the confluence with Glacial Creek to the confluence with Montgomery Creek. It is the upper-most portion of the Class A1 Primary Contact Recreational Use designation.

Middle Squaw Creek runs within the southern half of the Crooked Creek – Squaw Creek Subwatershed.

***Lower Squaw Creek***

This reach of Squaw Creek runs, looking downstream, from the confluence of Montgomery Creek to the confluence of Onion Creek and is designated as a A1 Primary Contact Recreational Use water.

Lower Squaw Creek runs entirely within the Lundy’s Creek Subwatershed.

***Squaw Creek Ames Reach***

This is the reach of Squaw Creek that lies below Onion Creek to the outlet of Squaw Creek into South Skunk River. The reach is designated as a A1 Primary Contact Recreational Use water

Squaw Creek Ames Reach runs entirely within the Worle Creek – Squaw Creek Subwatershed.

Further description of each reach of Squaw Creek and its tributaries can be found in the stream health section.

## 2.2. Watershed Topography

The figure on the following page (Figure 2-4) depicts the topographical relief and varying slopes found within the watershed. It was derived using LIDAR data. The slope and topographical data was used in developing watershed model input parameters and to determine the most appropriate sites for conservation practices.

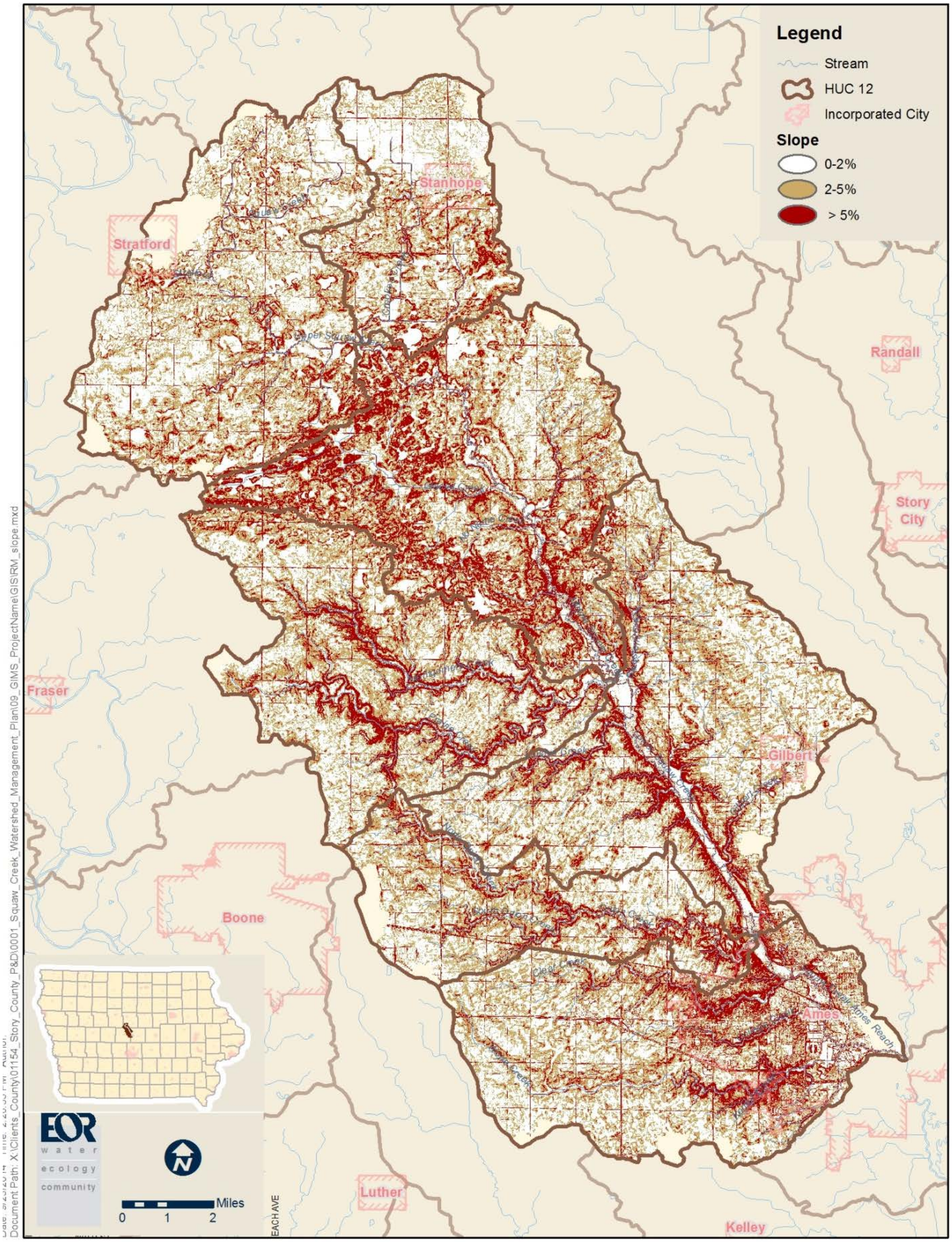


**Figure 2-4.** Slopes within the Squaw Creek Watershed

## 2.3. Land Cover/Land Use

The land uses and land cover, both natural and human influenced, within a watershed are the main factors in determining the quality and character of its water resources. Land use within the Squaw Creek watershed is heavily agricultural with some urban land use found primarily in the lower subwatersheds (Table 2-2).

We have provided two land use maps for the watershed. The first, (Figure 2-5) is a high resolution land cover map produced from aerial imagery in 2009. This figure does an excellent job of depicting the various land covers within the watershed, particularly the forested riparian areas along the major stream reaches and the varied land cover within the developed portions of the watershed. Of note, however, is the observation that this mapping may be over predicting the presence of ponds and wetlands, particularly in the northern portions of the watershed. It is possible that the mapping was developed during a wet period. The second land use map (Figure 2-6) was built for the watershed modeling and integrates cropping rotational information from the past 6 years. This land use mapping was provided by David James of the USDA-ARS. The crop rotations have been combined for display purposes. Within the model there are 16 distinct land uses when all of the various crop rotations are taken into consideration. Additionally, the model also discretizes the various crop rotations as to whether they occur on surface inlet draintile or subsurface draintile. Refer to the SWAT Modeling section for further information. The land use summary of Table 2-2 uses the second land use classification.

**Table 2-2.** Land Use of the Squaw Creek Watershed

| Land Use | Acres | % of Watershed |
|---|---|---|
| Corn Soybean | 105,225 | 71.6% |
| Continuous Corn | 12,561 | 8.5% |
| Conservation Corn Rotation | 3,694 | 2.5% |
| Forest | 3,953 | 2.7% |
| Grass | 11,331 | 7.7% |
| Urban | 10,107 | 6.9% |
| Ponds/Wetlands | 129 | 0.1% |

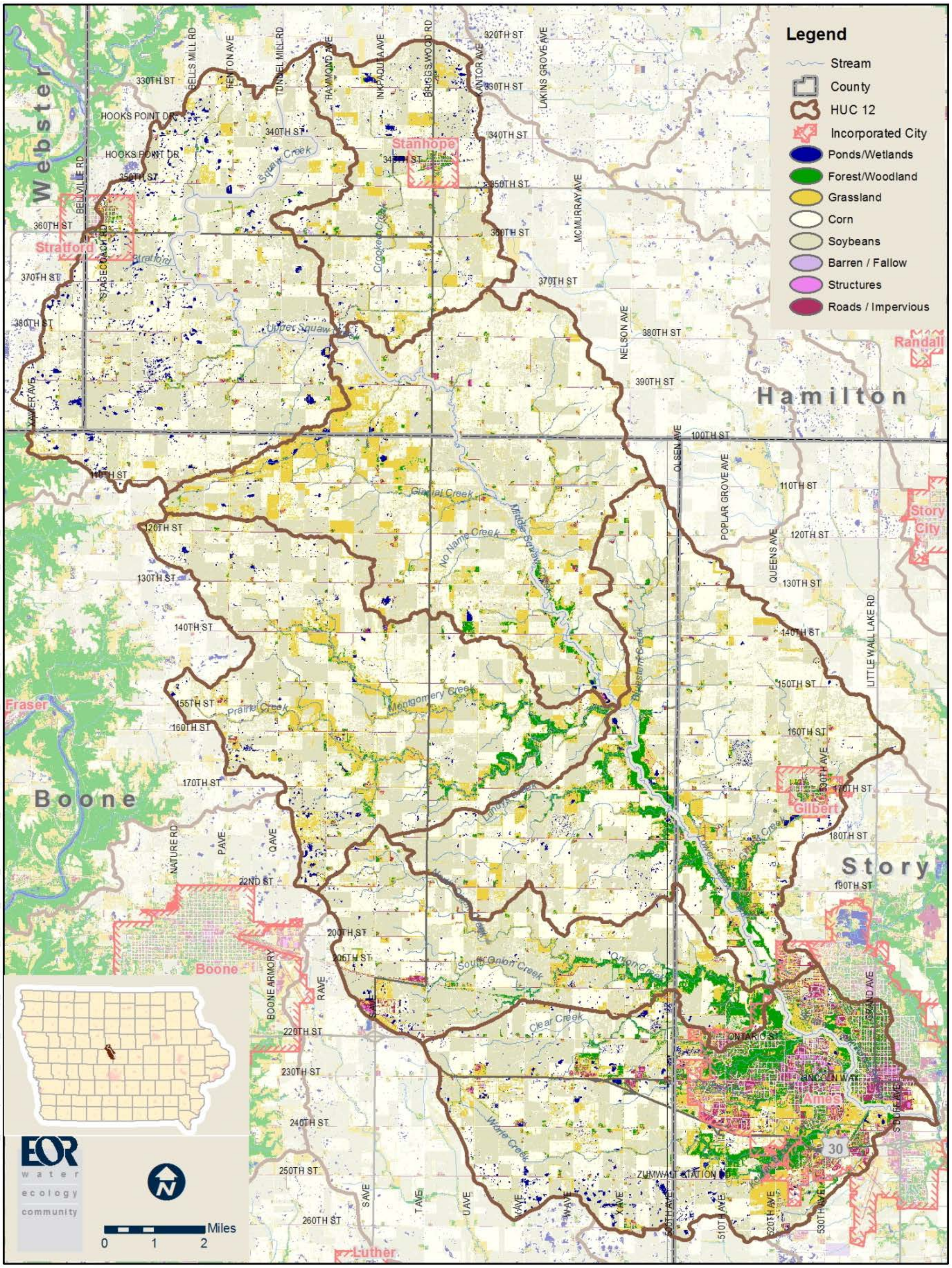


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**Figure 2-5.** High Resolution Land Cover Squaw Creek Watershed 2009

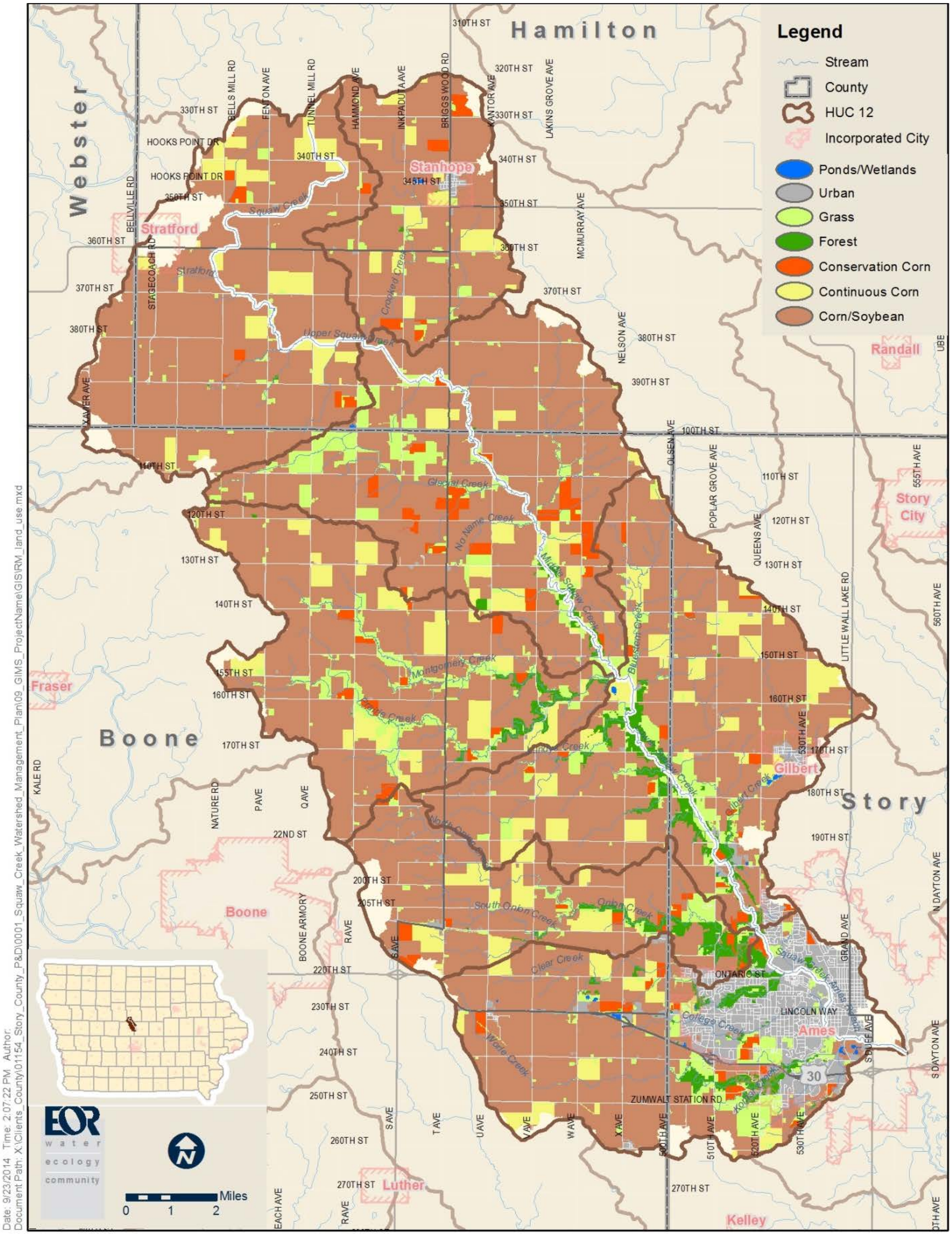



**Figure 2-6.** Land Use Squaw Creek Watershed

## 2.4. Climate

Climate information is one of the first aspects examined in watershed studies. Stream runoff is largely determined by rainfall patterns as moderated by temperature, evaporation, vegetation, ponds/storage, slopes and land uses such as agricultural fields and impervious surfaces in the urban setting. The Squaw Creek area has what is referred to as a humid continental climate with extremes of both cold and heat.

### 2.4.1. Temperature

National Oceanic and Atmospheric Administration (NOAA) climate data from Ames, IA were summarized with corresponding average, maximum and minimum monthly temperatures plotted by month (Figure 2-7). The average annual temperature is about 50° F with hot and humid summers often near or exceeding 90° F. Peak average daily summer temperatures (about 85° F) are typically observed in July with slightly lower averages noted for June and August. Winters can be harsh dropping well below freezing in December, January and February. The remaining 'cold' months of November, March and April typically have average daily maximum temperatures above freezing (32°F). Broadly speaking, daily average minimum and maximum temperatures vary about 15- 25° F.

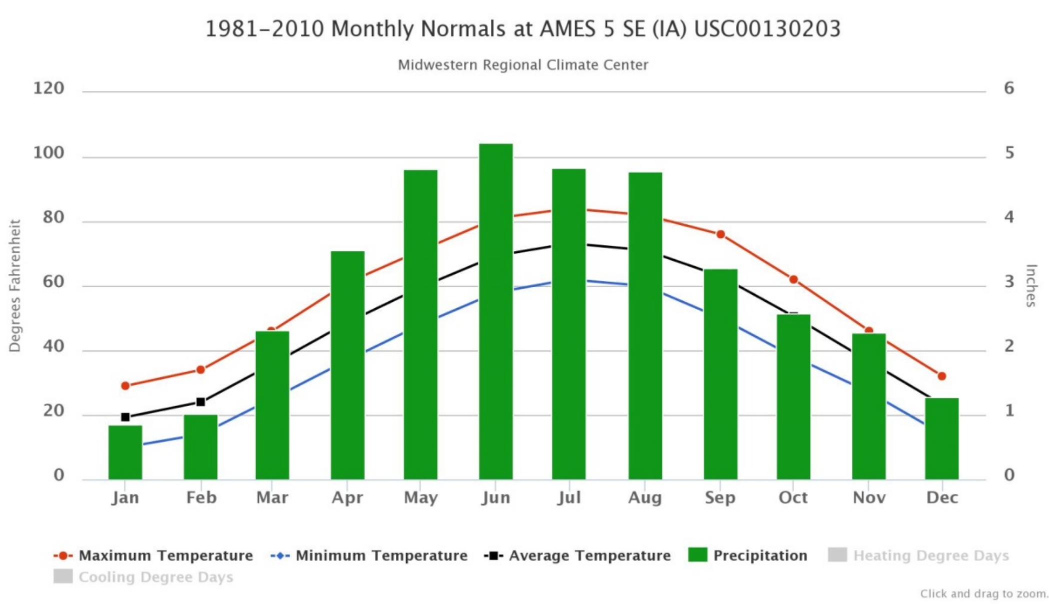



**Figure 2-7.** Average monthly climate data for Ames, IA. NOAA's Midwestern Regional Climate Center

It has been noted that the regional temperatures have increased. To evaluate this, average annual minimum and maximum temperatures for Ames, IA (Station 8 WSW) were plotted in Figure 2-8 and Figure 2-9. While there can be seen a slight increase in average annual maximum temperatures, the increasing pattern is much more pronounced for the average annual minimum temperatures. Annual minimum temperature values have increased about 2-3 degrees F from 1970 to 2013. Other studies have also noted that since 1970: (1) the nighttime temperatures have increased more than the daytime temperatures; (2) daily minimum temperatures have increased in the summer and winter; (3) daily maximum temperatures have risen in winter but declined substantially in the summer (Report to the Governor and Iowa General Assembly, 2011.)

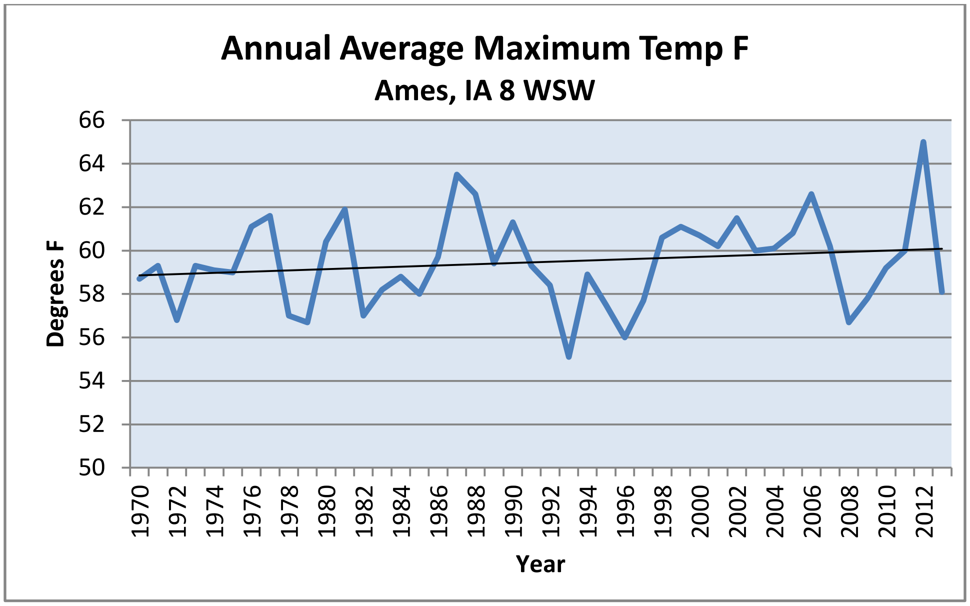



**Figure 2-8.** Annual Average Maximum Temperature 1970-2013, Ames IA

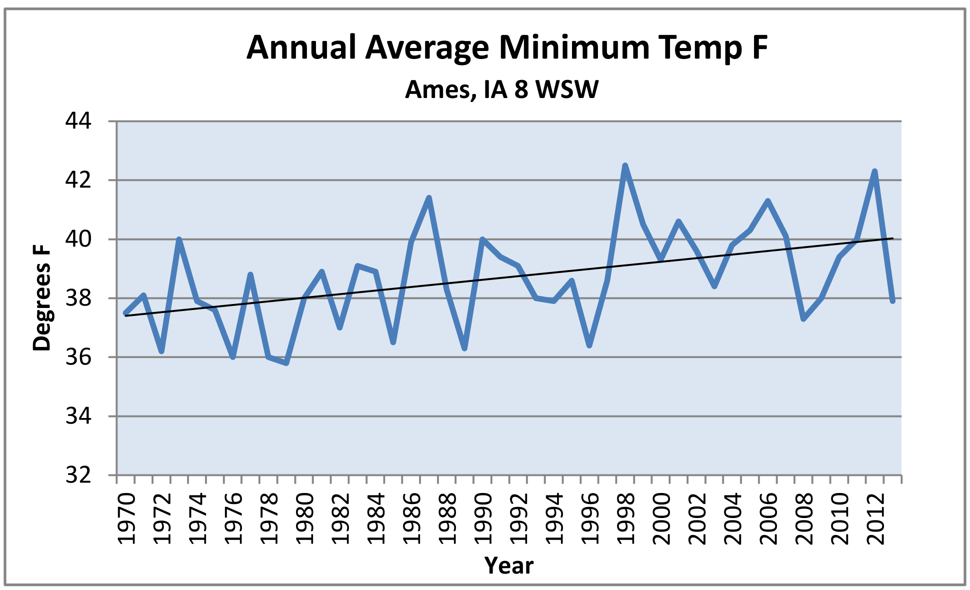



**Figure 2-9.** Annual Average Minumum Temperature 1970-2013, Ames IA

### 2.4.2. **Rainfall**

Annual average precipitation totals about 35.8 inches +/- 8.0 inches with the growing season typically having the highest rainfall totals of about 3.5 inches to 5 inches per month. Annual rainfall measured at the Ames, IA site during the 1970 – 2013 time period has varied from about 21 inches (1981) to 56.4 inches (1993 flood) (Figure 2-10). For the same time period, growing season (May-October) rainfall averaged about 21.5 +/- 6.9 inches with values that ranged from about 10.4 inches (1976) to 45.72 inches (1993) (Figure 2-11). Most recently drier growing season conditions were noted in 2012-2013 with about

11.7 and 14.8 inches recorded, respectively. In contrast, 2010's growing season was noted to be 39.3 inches. Hence, considerable variability has been noted over the past 10 years.

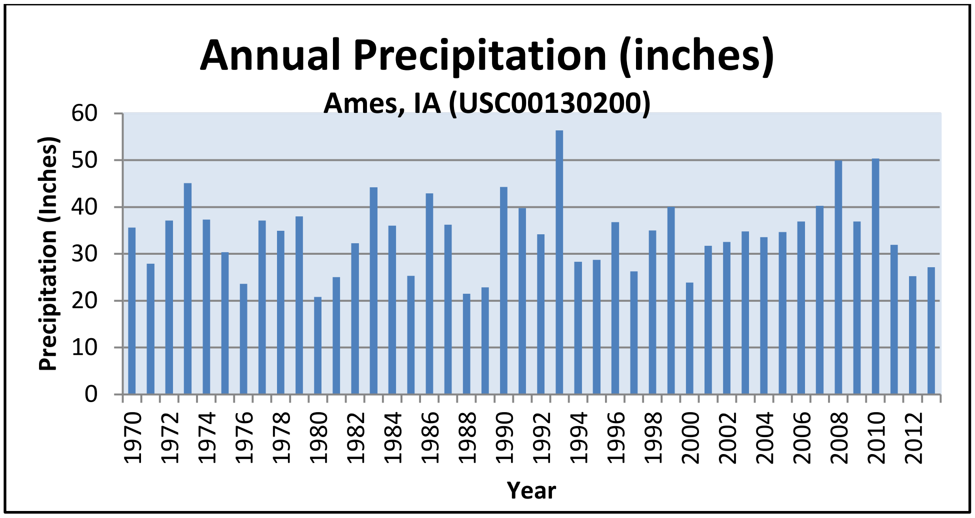



**Figure 2-10.** Annual Precipitation 1970-2013, Ames IA

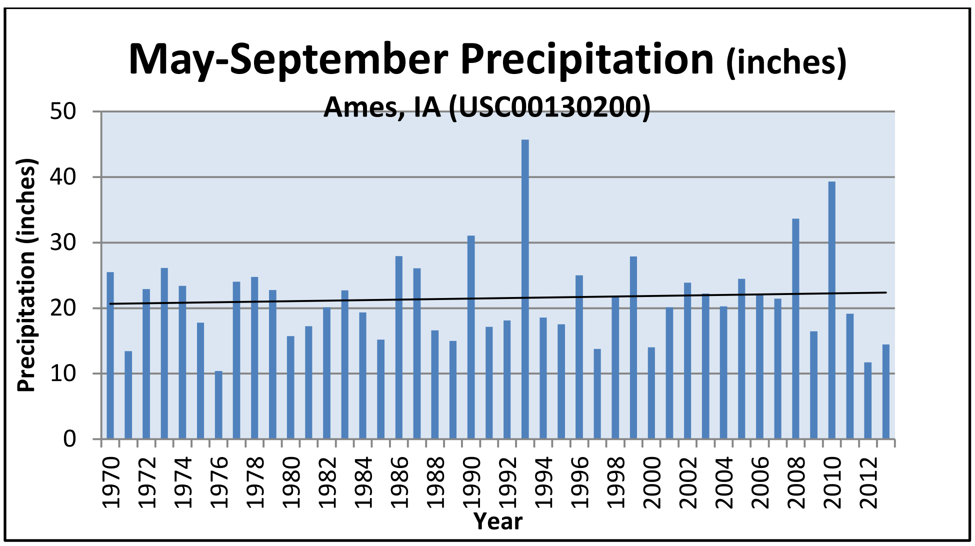



**Figure 2-11.** Growing Season (May-Sept) Precipitation 1970-2013, Ames IA

### 2.4.3. **Storm Intensities and Rainfall Amounts**

Of increasing interest is the intensity of storms and the amounts of rainfall that occur over longer periods. This was examined by looking at rainfall intensity (or inches of rain per 2 hours, 24 hours etc.) and the duration of storm events (very short time periods such as 5 minutes to much longer periods up to 60 days). Annually, two hour storms of 1.63 inches up to 24 hour storms of 2.74 inches are to be expected. These totals increase to 2.38 inches (over two hours) to 3.88 inches (24 hour storms) inches when looking at storms that occur every five years. Hence, cloud bursts of this intensity and amounts should be typically expected.

Wet periods can be evaluated based on the occurrences of back-to-back events over 2 or more days, for example. The State of Iowa recently sponsored an update of the rainfall records by NOAA in what is called Atlas 14 (NOAA, 2013) that characterizes storms for all areas of the State. From this report, data from Ames, IA was summarized and expressed in terms of common occurrences (annually expected) versus the much less common storms (such as the one per 100 year storm). These storm terms are confusing as the later means that there is a 1/100 or 1 percent chance of a storm at a specific location. Values are now included for the 1 per 1000 year events or 0.1 percent chance of occurring over an area on any one day.

From the updated NOAA records (through 2009), a 2.74 inch storm over 24 hours can be expected each year in the Ames area. In a similar fashion, a 4.5 inch storm over 24 hours can be expected every 10 years, 6.99 inch storm per 24 hours can be expected every 100 years and 9.96 inch storm per 24 hours can be expected every 1000 years. Also noted has been the increase in summer storms (those exceeding 1.25 inches per 24 hours) and depending upon storm speed and tracks, are capable of producing summer flooding events. In general, the more common storms have not increased appreciably, however larger storms have increased particularly in the eastern half of Iowa

From a stormwater management perspective, water quality designs (such as stormwater ponds) typically focuses on 1-2 year frequency events (about 2.74 – 3.15 inches/day), roadway drainage on the 10 year events (about 4.5 inches/day) and flood prevention designs based on the 100 year events (about 6.99 inches/day).

### 2.4.4. **Wet Periods**

Back-to-back storms extending over several days may be a better yard stick for evaluation of impacts to fields, cities and stream runoff. For a perspective, longer events occurring over **2-4 days** were defined using the same NOAA Atlas 14 data with precipitation totals noted as follows:

- Annual recurrence: 3.13 to 3.63 inches
- 5 year recurrence: 4.34 to 5.09 inches;
- 10 year recurrence: 5.01-5.93 inches and
- 100 year recurrence: 7.65 to 9.05 inches. (Similar to the August 9-11, 2010 back-to-back event.)

Wet periods, or back-to-back rain events occurring within four days with rainfall totals ranging from 3 to 5 inches, can be expected to generate substantial runoff volumes. Hence, stormwater runoff from both agricultural and urban settings should consider a variety of innovative practices to encourage retaining and slowing runoff for rainfalls of this magnitude as possible. This same range of rainfall was noted to generate peak Squaw Creek instantaneous and daily average flows.

### 2.4.5. **Growing Season Length**

The growing season, defined as the period between spring and fall dates with 32 degree or lower temperatures, has averaged about 168 days (plus or minus a standard deviation of 16 days) from 1970 to 2013 with a range of 140 to 204 days. Using this definition, the growing season length by year was plotted with a general increasing pattern noted since 1970 (Figure 2-12). In general longer growing seasons are also linked to earlier snowmelts, longer ice-free periods on lakes and streams and longer aquatic growing seasons in lakes, streams and wetlands. The latter aspect means that algae and bacteria also have more days to grow and assume nuisance levels given excessive nutrient supplies.

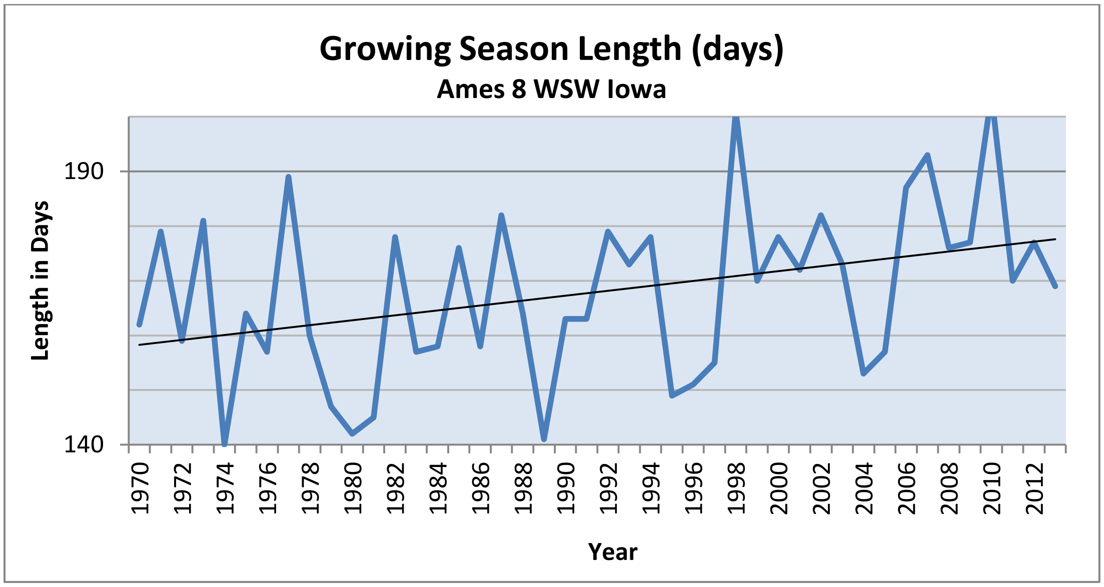



**Figure 2-12.** Growing Season Length 1970-2013

### 2.4.6. **Evaporation**

The amount of water that is vaporized and lost into the atmosphere is called evaporation. For estimating losses from the surface of a shallow lake or ponds, changes in daily water levels are measured by use of a standardized pan open to the atmosphere (or Class A Pan Evaporation). Over an average year, evaporation amounts to about 38-40 inches (NOAA, 1983) for this portion of Iowa with the highest evaporation rates encountered during the peak temperatures of the growing season. Losses from crops and vegetated areas are referred to as evapotranspiration (ET) or crop water use, are similarly affected by temperatures and vary by crop.

### 2.4.7. **Severe Weather**

Squaw Creek is at the center of America's Heartland which is one of the most active weather areas of the country (and world) resulting from the mixing of Canadian and Western weather fronts with the typically warm and moist frontal systems from the Gulf of Mexico. Accordingly, Iowa's summer humidity and dew-points have been noted to increase by about 13% over the past 35 years providing greater fuel for development of thunderstorms. The severe weather period begins in the spring with the largest number of Iowa related tornadoes occurring in May and June. Iowa averages about 45-50 tornados a year with the majority having the weakest rating. However, there has been a substantial rebound of tornado activity in 2014 (53 tornadoes) after two quiet years (2012-2013). Considerable variability of weather is common to the area including 'catastrophic' incidents with losses from straight-line winds, hail (most common) and tornadoes.

### 2.4.8. **Variable and Changing Climate**

Of the climate data summarized above and from leading Iowa researchers, there have been several key changes noted over the past 40 years that affect farms, cities, landscapes and waters. These measured changes include:

- Precipitation amounts, the frequency and intensity of large storms and back-to-back storms have been defined by recent NOAA updates of precipitation data. In general, the large (and less frequent) storms have increased by 4% to 20+% depending upon location and storm size. The more common storms (occurring less than every ~25 years) have changed small percentages. More precipitation occurs in the first half of the year and less in the second half. Precipitation increases are typically greater on the eastern half of Iowa than the west, with Squaw Creek being smack in the middle. These trends are expected to continue well into the future.
- The amount of moisture in the atmosphere has increased as measured by humidity and dew point temperatures by about 13% (Report to the Governor and Iowa General Assembly, 2011). Atmospheric moisture fuels thunderstorms and severe weather. Squaw Creek is in the center of America's Heartland that is one of the most active weather areas of the world as evidenced by the number of tornadoes and severe weather events. 2014 has been an active severe weather year following two relatively quiet years (2012-2013).
- Growing seasons, or the length of time between spring and fall freezing dates, have increased by about 5 to 15 days as defined from the Ames, IA weather record (1970-2013).
- Warmer winter and spring temperatures may translate into earlier and slower snow melts reducing springtime flooding incidence at the critical time when vegetation and cover crops are typically at low levels.

Climatologists have continued to refine changing climate assessment techniques and projections. In short, there is widespread agreement that many of the above patterns are going to continue but with considerable wet and dry year-to-year variability likely. In general, factors affecting increased stream flows and flooding are to become more frequent. Hence, watershed management should incorporate innovations that retain water on the land as much as possible.

**Report to the Governor and the Iowa General Assembly, 2011. Climate Change Impacts on Iowa. Climate Change Impacts Committee.** **http://www.iowadnr.gov/Environment/ClimateChange/ClimateChangeAdvisoryCo.aspx**

## **2.5. Soils**

The soils within the Squaw Creek Watershed are primarily Nicollet, Clarion, Canisteo, Lester and Webster. They are loams, silty loams and clay loams. For modeling purposes we have defined the hydrologic soil groups which are depicted in (Figure 2-13). The primary soil hydrologic groups and B ad B/D which are moderately well drained and moderately well drained with a high water tables, respectively. In the northern part of the watershed there are heavier, C/D soils associated with prairie pothole nature of that area.

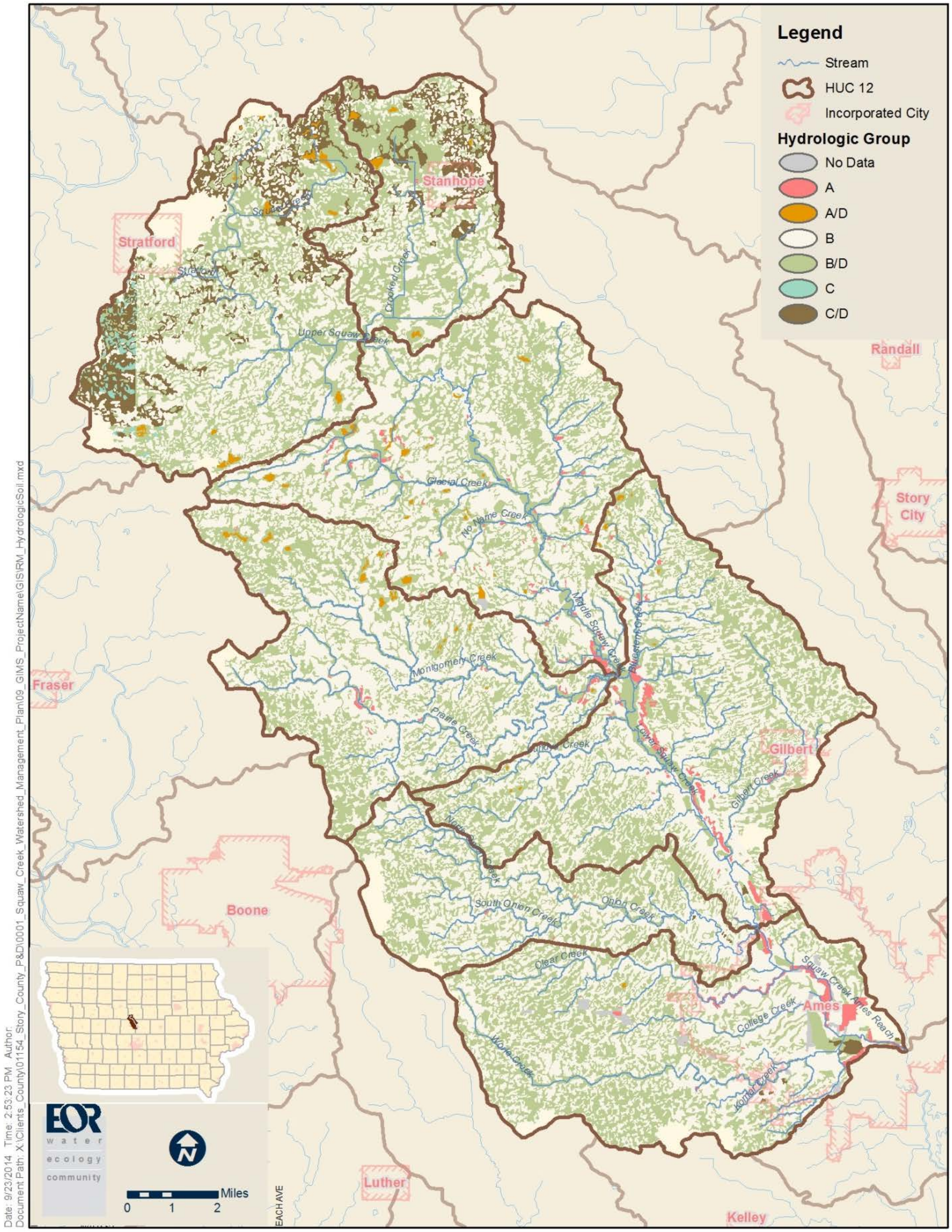



**Figure 2-13.** Soils by Hydrologic Soil Class

## 2.6. Groundwater

The following is a cursory examination of the groundwater system of the watershed based on review of available data. Additional analysis of the groundwater system is currently being developed by researchers at Iowa State.

### 2.6.1. **Surficial Hydrogeology**

The watershed is covered by glacial drift commonly associated with two periods of glaciation, the Late Wisconsin Episode (Des Moines Lobe) and the earlier Hudson Episode. Since the glacial period, the surface has been worked and re-worked by rivers and streams, eroding valleys leaving significant alluvial deposits.

Figure 2-14 shows the locations of surficial aquifers. The alluvial aquifers consist mainly of sand and gravel transported and deposited by modern streams and make up the floodplains and terraces in major valleys. Alluvial deposits are shallow, generally less than 50-60 feet.

The drift aquifer is the thick layer of clay- to boulder-size material (till) deposited over the bedrock by glacial ice. The composition of the glacial drift varies considerably, and in many places does not yield much water. There are however, lenses or beds of sand and gravel in the drift, which are thick and widespread enough to serve as dependable water sources. Usually one or two sand layers can be found in most places that will yield minimum water supplies for domestic wells.

The buried channel aquifers consist of stream alluvium of partially filled valleys that existed before the glacial period. The valleys were overridden by the glaciers, and are now buried under the glacial drift. They may or may not coincide with present day alluvial valleys (Thompson, 1982).

Figure 2-15 shows the depth to groundwater throughout the watershed. The alluvial and drift aquifers are visible as the areas with the least depth to groundwater.

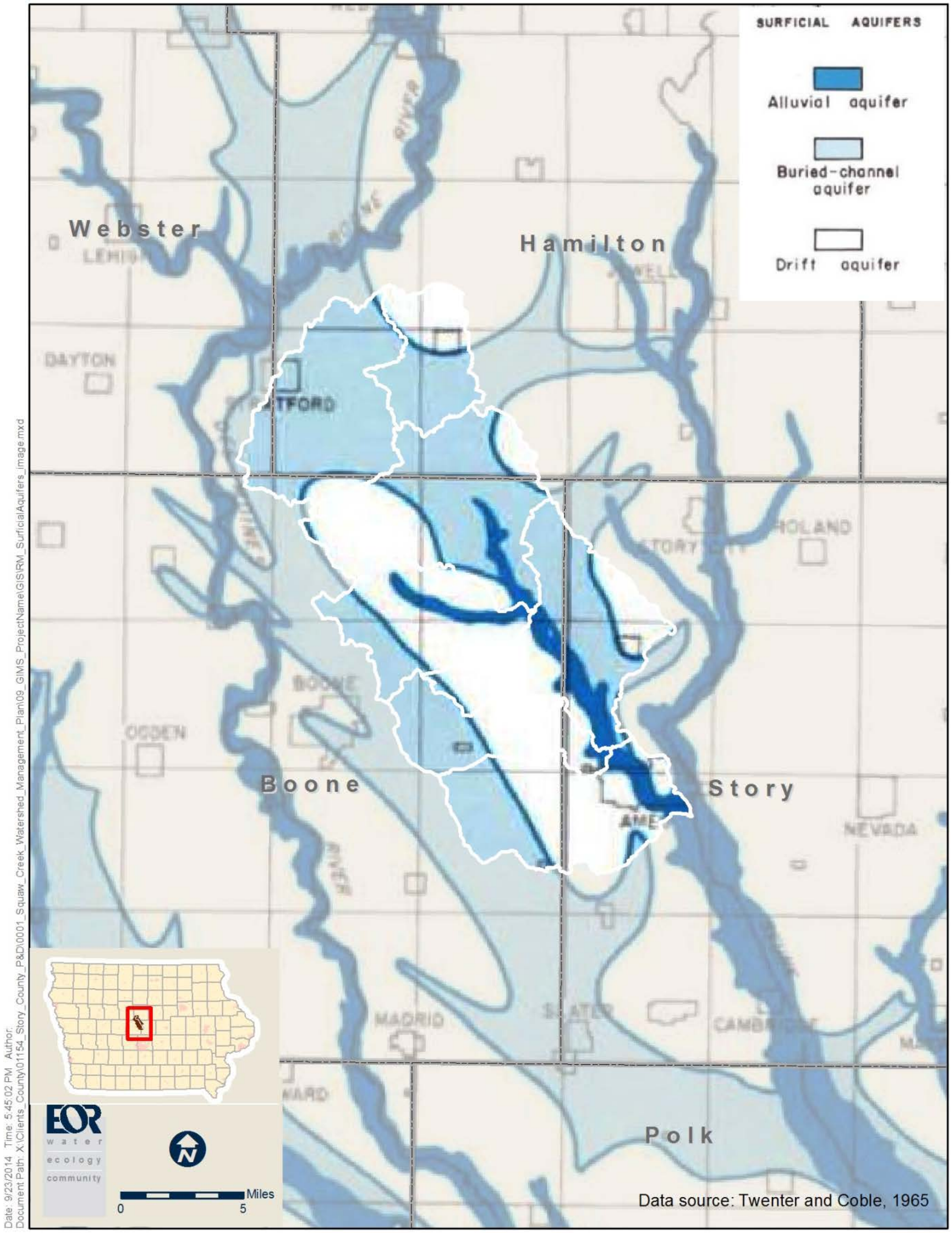



**Figure 2-14.** Surficial Aquifers

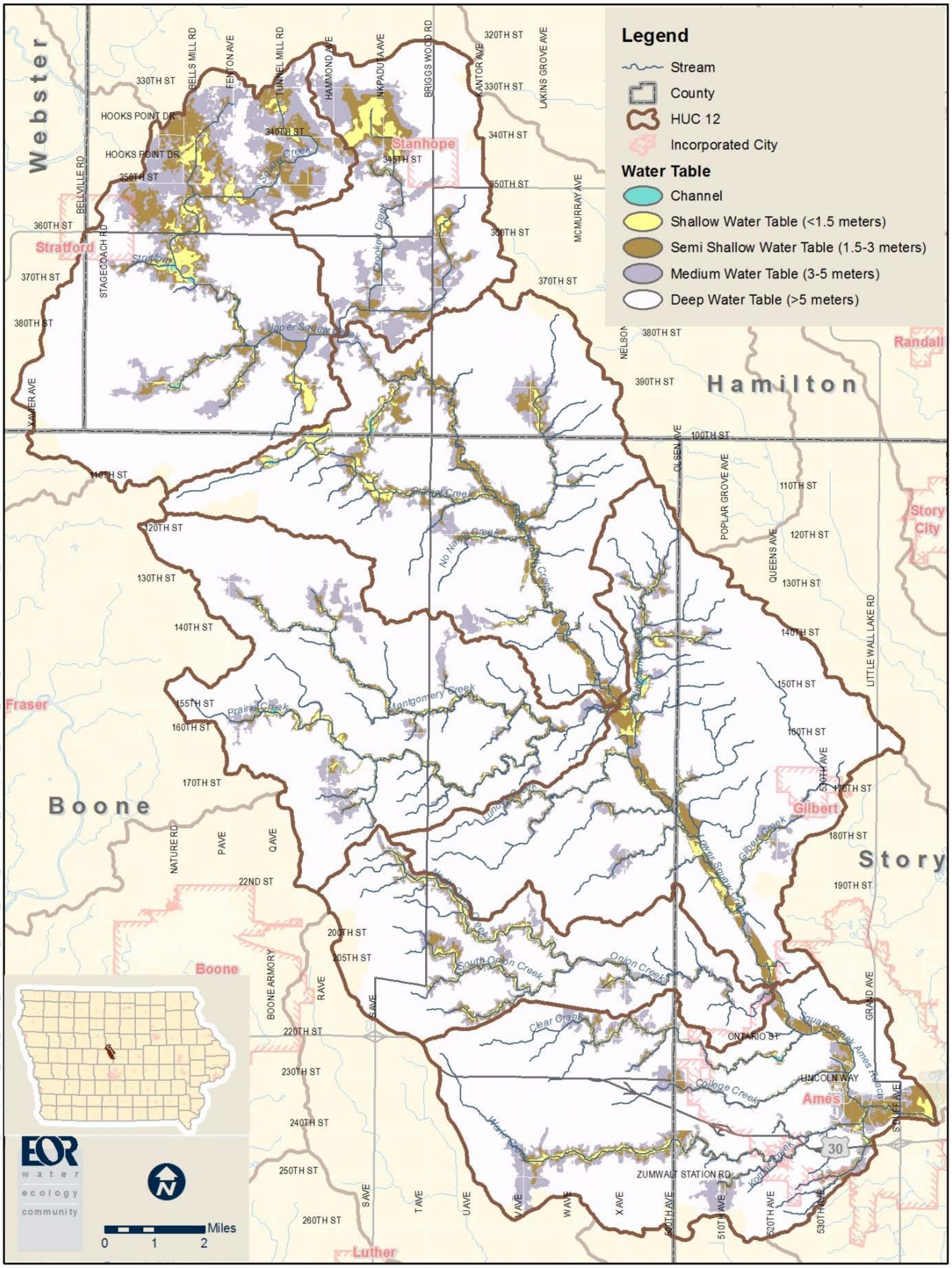



**Figure 2-15.** Depth to Groundwater

### 2.6.2. Bedrock Hydrogeology

Below the drift and other surficial materials is a thick sequence of layered rocks, formed from deposits of rivers and shallow seas that alternately covered the state during the last 600 million years. Table XX lists the geologic and hydrogeologic characteristics of the rock units underlying the watershed. These rocks are primarily shales, siltstones, sandstones, thin coal beds and minor limestone beds. Because shales predominate, the Pennsylvanian sequence acts as an aquiclude and only locally can water be produced. Most of the water from the Pennsylvanian is found in the sandstone layers within the Cherokee Group. In general, the water is highly mineralized, with high concentrations of dissolved solids, sulfate, and sodium (Thompson, 1982).

**Table 2-3.** The Aquifers and Rocks of Central Iowa (Twenter and Coble, 1965)

| Aquifers | General thickness (feet) | Age of rocks | Name of rock units | General description of rock units |
|---|---|---|---|---|
| Surficial<br>Alluvial<br>Buried-channel<br>Drift | 0-380 | Quaternary (0-1 million years old) | Undifferentiated | Primarily alluvium and drift composed of gravel, sand, silt, and clay |
| | 0-900 | Cretaceous (63-135 million years old) | Undifferentiated | Shale, limestone, and sandstone; in Webster County only |
| | 0-550 | Permian (230-280 million years old) | Fort Dodge beds | Gypsum and shales; in Webster County only |
| | | Pennsylvanian (280-310 million years old) | Undifferentiated | Shale, sandstone, thin limestones, and coal |
| Upper Bedrock | 0-475 | Mississippian (310-345 million years old) | Ste. Genevieve<br>St. Louis<br>Warsaw<br>Keokuk<br>Burlington<br>Gilmore City<br>Hampton | Shale and limestone<br>Limestone, sandy<br>Shale and dolomite<br>Dolomite and limestone<br>Dolomite and limestone<br>Limestone<br>Limestone and dolomite |
| | 5-200 | | McCraney<br>English River<br>Maple Mill<br>Aplington<br>Sheffield | Limestone<br>Siltstone<br>Shale<br>Dolomite<br>Shale |
| Middle Bedrock | 400-750 | Devonian (345-405 million yrs | Lime Creek<br>Cedar Valley<br>Wapsipinicon | Dolomite and shale<br>Limestone and dolomite<br>Limestone, dolomite, and shale |

| Aquifers | General thickness (feet) | Age of rocks | Name of rock units | General description of rock units |
|---|---|---|---|---|
| | | old) | | |
| | 330-700 | Silurian (405-425 million years old) | Undifferentiated | Dolomite and sandy dolomite |
| | | Ordovician (425-500 million years old) | Maquoketa<br>Galena<br>Decorah<br>Platteville | Dolomite and shale<br>Dolomite and chert<br>Limestone and shale<br>Limestone, shale, and sandstone |
| Lower Bedrock | 375-560 | | St. Peter<br>Prairie du Chien | Sandstone<br>Dolomite and sandstone |
| | | Cambrian (500-600 million years old) | Jordan<br>St. Lawrence | Sandstone<br>Dolomite |
| | 350-550 | | Franconia<br>Galesville<br>Eau Claire<br>Mt. Simon | Sandstone, siltstone, and shale<br>Sandstone<br>Sandstone, shale, and dolomite<br>Sandstone |
| | - - - - - - - - | Precambrian (600 million to 2 billion years old) | | Igneous and metamorphic rocks, locally overlain by sedimentary rocks that are chiefly sandstone |

The Mississippian Aquifer (Upper Bedrock Aquifer) is heavily used, and consists of a series of limestones and dolostones. The Devonian-Silurian Aquifer (Middle Bedrock Aquifer) is used by several communities and rural residents. The main water-producing units in the Devonian-Silurian are a series of limestones and dolostones. The Cambro-Ordovician aquifer is the major deep aquifer in the county, and includes the St. Peter Sandstone, the Prairie du Chien dolomite, and the Jordan Sandstone, the latter being the major water producer (Thompson, 1982).

Figure 2-16 shows the uppermost bedrock present throughout the watershed.

**References**

Thompson, C.A., 1982. “Groundwater Resources of Story County.” Iowa Geological Survey Open File Report 82-85 WRD.

Twenter, F.R. and R.W. Coble, 1965. “The Water Story in Central Iowa.” Iowa Water Atlas WA-1. Iowa Geological Survey.

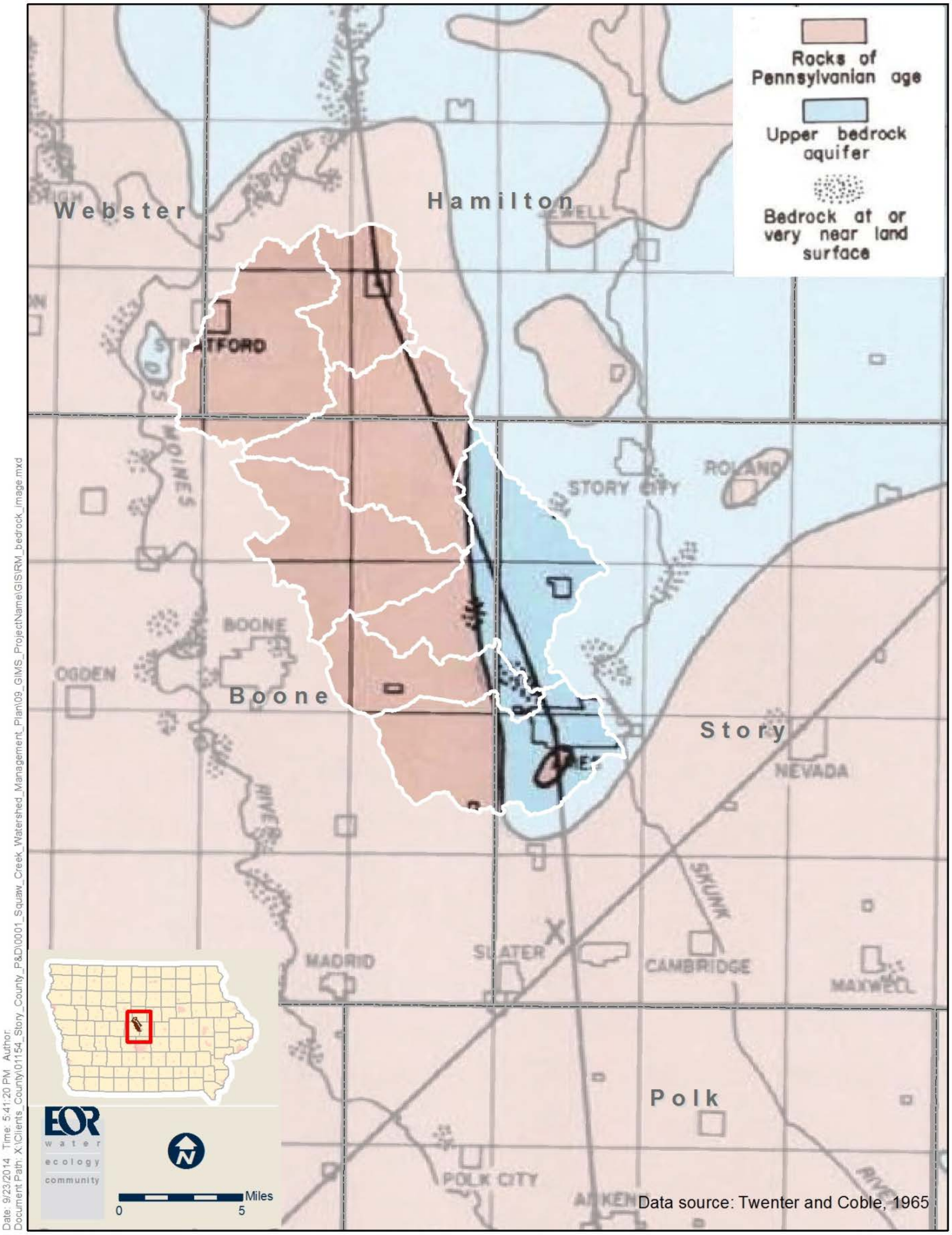



**Figure 2-16.** Uppermost Bedrock

# 3. Stream Health

The following section describes the current state of the watershed streams. The section begins with a discussion of water quality conditions in the various streams of the watershed. This assessment is based on the water quality monitoring that has been done in various locations throughout the watershed by the City of Ames and by the Squaw Creek Watershed Coalition from 2007 to 2013.

The second topic covered is the stream assessment. This assessment looks beyond the quality of water within the streams and focuses on the factors that shape the stream; stream flows, sediment load and streambank stability factors. These two sub-sections summarize the current conditions of the streams and serve as the framework for setting future goals for the watershed and illustrate the challenges the WMA faces. Following this section, which identifies what the issues in the watershed are, the focus changes to look at what are the causes. The Pollutant Source Assessment looks into the specific sources of pollutants; nutrients, bacteria and sediment as well as stream flow. While stream flow is not a pollutant it is included since the volume and rate of flow within the stream is intricately tied to the delivery of pollutants and excess flows can lead to degradation in stream quality and habitat. Sources of sediment, nutrients and stream-flow were assessed using a hydrologic model and the source of bacteria, specifically *E. coli*, was assessed using a methodology that examines the generation of fecal material within the watershed as well as the potential of that material to be delivered to the stream.

## 3.1. Stream Water Quality

Stream flows, or the amount of water that runs off the land and its water quality are inseparable watershed responses. As more water is diverted from agricultural and urban surfaces, it has a greater power to move soil and pollutants such as nitrogen and phosphorus from the land. This sub-section summarizes the water quality of Squaw Creek and watershed tributaries (based on several years of volunteer monitoring data) and compares this data to available stream water quality criteria. **In short, water quality within Squaw Creek and watershed tributaries is quite poor, exceeding several water quality criteria and standards.**

Several national and regional studies have documented relationships of stream water quality (sediments, nutrient and bacteria) and beneficial uses relating to recreation suitability and aquatic biological communities. Nutrients, particularly nitrogen and phosphorus are natural components of aquatic ecosystem function. However, excessive amounts can lead to detrimental effects upon aquatic biota and recreation opportunities. Nutrients originate from a variety of sources both natural and man-made. Human activities include industrial sources, municipal sources (stormwater, wastewater) and agricultural (animal wastes, fertilizer and erosion-caused sediments). The loss of nutrients is increased by intensive land uses such as impervious surfaces in urban areas (streets, curbs/gutters, rooftops, parking lots) and agricultural equivalent practices (exposed soil, tile drainage and ditches). Both intensive land uses are essential for maintaining society; however, additional treatment is required to prevent degradation of downstream receiving water bodies. As was learned during the 1970's-1990's from industrial and municipal 'pipe' discharges, receiving water bodies have limited pollutant assimilative capacities for nutrients and sediments. Excess amounts cause imbalances that degrade conditions for fisheries, insects, aquatic life and downstream water supplies.

Nutrient enrichment (eutrophication) leads to modification of the aquatic food web by increased aquatic plant growth, frequently producing nuisance conditions such as green algae covering on rocks and substrates and increased bacteria. Increased amounts of aquatic plants and bacteria in turn result in an increase in respiration, decreased dissolved oxygen (particularly at night), altered food resources and habitat structures. In general, these changes can lead to invasion by nonnative species and increases in blue-green algae that can produce algal toxins harmful to aquatic and terrestrial organisms as well as drinking water supplies.

Much of this assessment will focus on water flow and nutrients, particularly phosphorus and nitrogen as these nutrients drive a wide array of river, stream and lake biological responses affecting beneficial uses. In small rivers and wadeable streams, nutrient loading is more likely to result in increased amounts of benthic algae (periphyton) attached to rocks and hard substrates creating slippery surfaces, increased organic matter and bacteria. Increased organic matter causes increased respiration (at night) and consumption of dissolved oxygen. As nutrient concentrations increase, the daily summer oxygen concentrations may reach high levels (e.g. over 8 mg/L) and then collapse to very low levels (e.g. less than 4 mg/L) in the night. These boom-bust oxygen cycles are accompanied by loss of biota and shift to more pollution tolerant species with negative affects to native species and recreational beneficial uses. Periodic scouring of stream attached (benthic) algae is possible during high flow events, washing all of the organic matter to downstream water bodies.

### 3.1.1. Water Classification and Designated Uses

Iowa's surface water classifications are described in IAC 61.3(1) as two main categories, General Uses and Designated Uses. Designated use segments are water bodies which maintain flow throughout the year or contain sufficient pooled areas during intermittent flow periods to maintain a viable aquatic community. Squaw Creek has been classified as a Class A1 and B (WW-2) stream from its Mouth (S12, T83N, R24W, Story County) to the confluence with Glacial Creek).

***2014 Lake Erie Algal Bloom***

*In early August, 2014 a severe algal bloom in Lake Erie resulted in the closure of the Toledo Water System. Over 500,000 people were left without safe drinking water and 70 people were treated at local hospitals for related health concerns. The algal bloom has been attributed to excess nutrients being washed into the lake from a heavily agricultural watershed. While algal blooms are a common occurrence in Lake Erie, their frequency and severity has increased in recent years.*

*Typically, algal blooms can be a nuisance, impacting recreational use of the lake. In this case, the bloom contained a type of algae known as cyanobacteria algae, or blue-green algae, which produces a toxin, microcystin, which is harmful to humans and wildlife. Tests of the Toledo Drinking Water System, which draws its water from Lake Erie, indicated levels of microcystin more than double the World Health Organization's threshold.*

***Clean Water Act***

*Under the Clean Water Act, States are required to develop lists of impaired waters. These are waters that are too polluted or otherwise degraded to meet the water quality standards set by the State. The law requires that States establish priority rankings for waters on the lists and develop a Total Maximum Daily Load (TMDL) for these waters. A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still safely meet water quality standards. While there are not currently any listed impaired waters in the Squaw Creek Watershed the area does contribute drainage to impaired waters downstream.*

***Class A1 Primary Contact Recreational Use Streams*** - waters in which recreational or other uses may result in prolonged and direct contact with the water involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing, and water contact recreational canoeing.

***Class B (WW-2) Warm Water Streams -*** waters in which flow or other physical characteristics are capable of supporting a resident aquatic community that includes a variety of native nongame fish and invertebrate species. The flow and other physical characteristics limit the maintenance of warm water game fish populations. These waters generally consist of small perennially flowing streams.

The Iowa DNR has created multiple categories for stream reaches in Iowa using the Integrated Report (IR) method (**Table 3-1**). Although many stream reaches across the state, especially smaller tributaries, have not been categorized. IR-assessed reaches within the Squaw Creek Watershed are listed by classification in **Table 3-1**. Note that Worle, College and Onion Creeks have been listed as "potentially impaired" (e.g. Category 3b-u).

**Table 3-1.** Iowa Integrated Report Categories for stream designated use and assessed reaches in the Squaw Creek Watershed.

| Category | Sub-category | Description | Reaches in Squaw Creek Watershed |
|---|---|---|---|
| **1** | | All designated uses met. | None |
| **2** | **a** | At least one designated use met; insufficient data to determine whether other uses are met. | Squaw Creek (Aquatic Life) mouth to Glacial Creek |
| | **b** | At least one designated use is met with at least one other use potentially impaired based on an "evaluated" assessment. | None |
| **3** | **a** | Insufficient data to determine whether any designated uses are met. | Squaw Creek (Primary Recreation) mouth to Glacial Creek, Clear Creek, North Onion Creek, South Onion Creek, Glacial Creek, Unnamed Trib to Glacial Creek |
| | **b** | Insufficient data to determine whether any designated uses are met but at least one use is potentially impaired based on an "evaluated" assessment. | None |
| | **3b-c** | The aquatic life use of a stream segment within the calibrated range of the biological assessment protocol has been assessed as potentially impaired | None |
| | **3b-u** | The aquatic life use of a stream segment outside the calibrated range of the biological assessment protocol has been assessed as potentially impaired | Worle Creek (NS) College Creek (PS), Onion Creek (PS) mouth to confluence with North and South Onion Creeks, |
| | **b** | Impairment is based on results of biological monitoring or a fish kill investigation where specific causes and/or sources of the impairment have not yet been identified. | None |

***Western Corn Belt Plains***

*Level III subdivision of Ecoregion IV: Corn Belt and Northern Great Plains*

*The Western Corn Belt Plains is characterized by plains and over 75 percent of the land in agricultural uses such as corn, soybean, and feedlot operations, although there are also many urban, suburban, and industrial areas as well. The soils are nutrient-rich and greatly influence both surface and subsurface water quality. Nitrogen and phosphorus are often elevated in this region's waters due to agricultural or livestock runoff and wastewater effluent. Pesticides can also be a problem in waters, as is suspended sediment and elevated bacteria.*

*Lakes and streams in this ecoregion range from mildly eutrophic to hypereutrophic and are used for fishing, recreation, and are important for wildlife habitat Native vegetation was dominantly tall grass prairie. (USEPA 2000)*

### 3.1.2. Applicable Water Quality Standards and Criteria

In an effort to define the level of water quality within the Squaw Creek watershed we need to compare monitored values to either a State Standard, when available or to a criteria that has been established for streams of similar nature.

The Iowa Department of Natural Resources is the agency delegated to manage water quality in Iowa. It does so by issuance of water quality standards that establish numeric and narrative criteria to protect present and future designated uses of the surface waters. Designated uses refers to state identified uses of waters such as public water supply, agricultural, industrial, primary contact recreation (swimming, wading), fisheries, wildlife and associated biologic communities. The term 'criteria' refers to scientific assessments of ecological and human health impacts recommended for controlling discharges or releases of pollutants. States base their enforceable water quality standards upon various pollutant criteria and are a critical basis for assessing attainment of designated uses and measuring progress toward meeting the federal Clean Water Act's water quality goals. In this case, Iowa water quality standards have been developed for E.coli (bacteria), pH, dissolved oxygen and chloride. In cases where water quality standards have not been developed, there are EPA regional and state criteria such as the new proposed stream nutrient criteria for wadeable warmwater streams including Total Kjeldahl nitrogen (TKN), total phosphorus, filamentous algae, dissolved oxygen diel range (daily minimum and maximum dissolved oxygen levels) and seston algae (floating in the water) chlorophyll-a. Other water quality criteria developed for similar areas by the USEPA or Minnesota have been recommended to guide watershed management decisions such as turbidity/total suspended solids.

**Iowa State Water Quality Standards**

Iowa's water body designated uses are specified by Iowa DNR (2010) with applicable water quality standards specified by Iowa Administrative Code, Chapter 61. Applicable state stream water quality standards have been developed for

Escherichia coli (*E. coli*), dissolved oxygen, pH and chloride. Iowa does not have stream nutrient standards for phosphorus or nitrogen (there are drinking water standards for nitrogen but those are not applicable here) so general aquatic eco-region criteria are described for reference purposes.

**Ecoregion Water Quality Criteria**

Water quality varies regionally due to natural landscape characteristics and for this purpose, aquatic ecoregions were derived by the USEPA (Omernik, 1987) to describe geographic areas of similarity based on natural communities, soils, land surface forms and use, water quality and geological characteristics. The ecoregion framework has proven utility in defining regional patterns of water quality, aquatic communities and refinement of water quality criteria and standards. The Squaw Creek Watershed falls within Ecoregion VI: Corn Belt and Northern Great Plains and more specifically within Level III aquatic ecoregion Western Corn Belt Plains.

**Table 3-2.** Water Quality Criteria for Ecoregion VI, stream use classes A1 and B (WW-2)

| Parameter | Description/Qualification | Ecoregion Criteria | State Standard | Draft State Criteria |
|---|---|---|---|---|
| Total Phosphorus (TP) *See Note 1* | Reference Condition Nutrient Criteria (USEPA, 2000)<br>Draft State Criteria based on June 15- Oct 15 (except for Daily DO Range based on July 1 – Sept. 15 data) | 0.076 mg/L | | 0.100 mg/L* |
| Total Nitrogen (TN) | | 2.18 mg/L | | |
| Total Kjeldhahl N (TKN) | | | | 0.80 mg/L* |
| Nitrate+Nitrite Nitrogen | Class C (drinking water source) | | 10.0 mg/L | |
| Nitrite | | | 1.0 mg/L | |
| *E. coli* Bacteria Class A1 Recreation Waters | Geometric Mean (minimum 5 samples in a given year, 3/15-11/15) | 126 org/100mL | 126 org/100mL | |
| | Maximum Sample | 235 org/100mL | 235 org/100mL | |
| Dissolved Oxygen (DO) | Min for at least 16 hours of every 24-hour period | | 5.0 mg/L | |
| | Min at any time WW-2<br>Min at any time WW-1 | | 4.0 mg/L<br>5.0 mg/L | |
| | Daily (Diel) DO Range | | | < 5.0 mg/L |
| Chloride (Cl) | Chronic (based on hardness and sulfate concentrations) | | 389 mg/L | |
| | Acute (based on hardness and sulfate concentrations) | | 620 mg/L | |

* Median values.

Note 1: Orthophosphate Phosphorus estimated to very generally approximate Total Phosphorus (elemental) by conversions but further sampling and laboratory analyses are required for corroboration.

### 3.1.3. **Stream Flows**

Prior to evaluating nutrient and pollutant concentrations and loads it is important to understand the hydrology of the watershed. The flow network as described in Section 2.1 consists of a series of ditches, small creeks and Squaw Creek. A long-term flow monitoring station (USGS station 05470500) is located at Lincoln Way in Ames. The station shows considerable variability as estimated by average annual flows from 1970 to 2013. During this time period, average annual values varied from 13.6 cubic feet per second (cfs) (1981) to 528 cfs (1993 Flood) with an overall annual median value of about 161cfs (Figure 3-1).

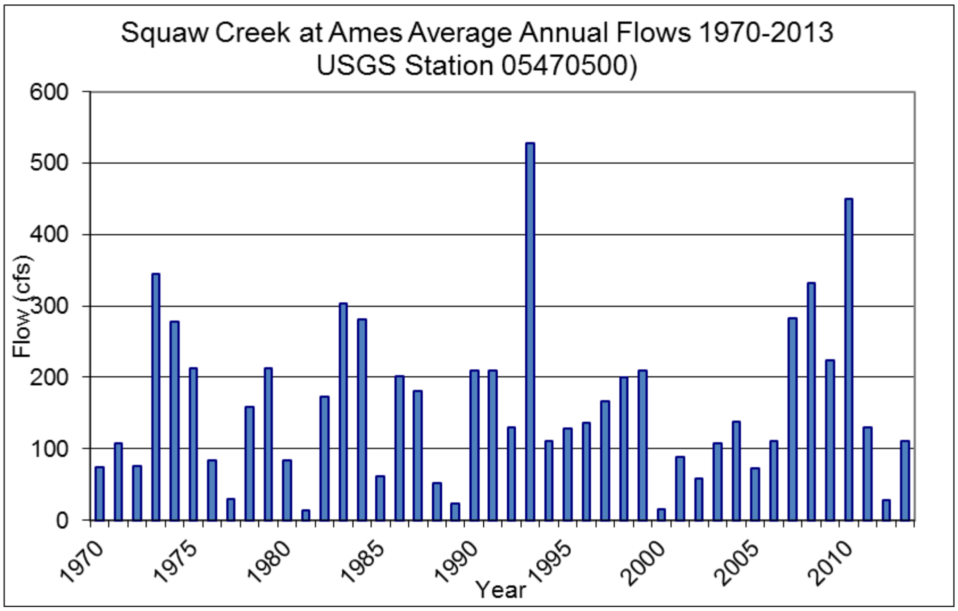



**Figure 3-1.** Squaw Creek at Ames, IA (USGS Station 05470500) Annual Average Flows

#### *Average Annual Flows*

Looking at the most recent years (2000-2013), the annual average flows show the considerable contrast of wet and dry years (Figure 3-2) with 10 years having less than average flows and 4 years greatly exceeding long-term averages. Transitions appear abruptly shifting from dry to wet (2006-2007) and then from wet conditions noted in 2010 to much lower flow conditions of 2011/2012. The magnitude of the wet/dry shifts are of particular note as 2001/2012 experienced average annual low flows on the order of 16-27 cfs (or drier than about 95% of annual flows from 1970-2013) to the much higher flows of 2010 (e.g. 450 cfs). In this regard, wet and dry year flows differed by a factor of about 28.

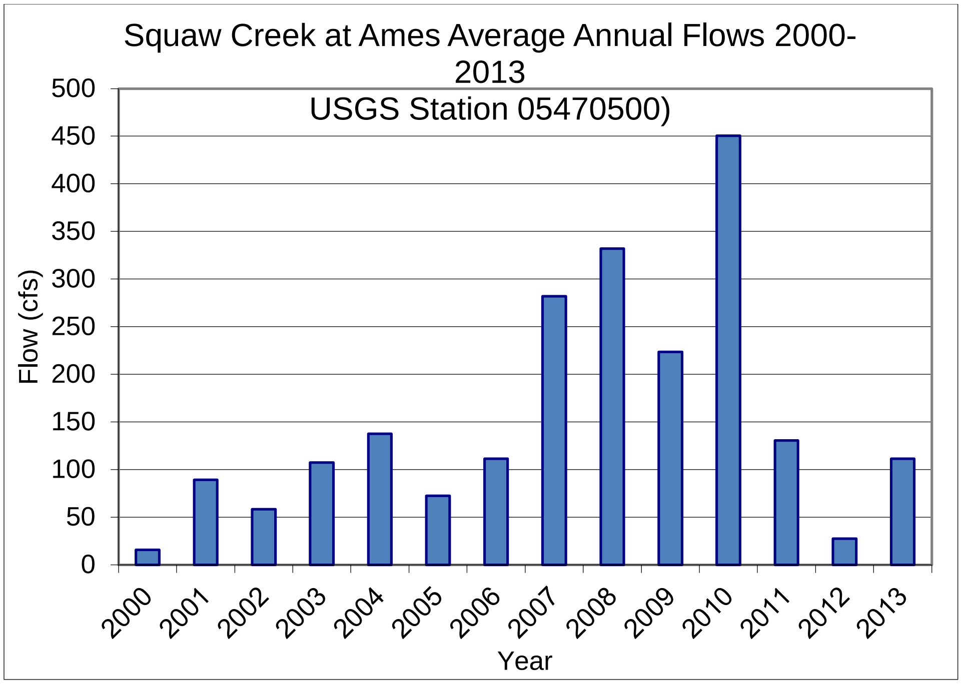



**Figure 3-2.** 2000-2013 Annual Average Flows at Ames, IA.

For reference, the peak annual flows of 1993 averaged about 528 cfs (Table 3-3). **This range of annual flows is extreme and indicates that Squaw Creek has relatively low upland flow buffering capabilities from storage by wetlands, lakes or ponds.**

**Table 3-3.** Squaw Creek At Ames, IA, frequency of annual average flows by percentile for 1970-2013 (USGS Station 05470500).

| Percentile | Average Annual Flow (cfs) |
|---|---|
| 10% | 36 |
| 25% | 81 |
| 50% | 134 |
| 75% | 210 |
| 90% | 297 |

### *Average Monthly Flows*

Shifting to a closer examination of Squaw Creek's flows, average monthly values monitored from 1970-2013, reflect the climate and precipitation patterns noted previously. Average monthly flows increase significantly from winter flows of ~ 50 cfs to typical peak flows of about 365 cfs noted by June (Figure 3-3). Sharp declines in average monthly flows were noted for the last half of the growing season (July-September) when peak evapotranspirational losses are expected.

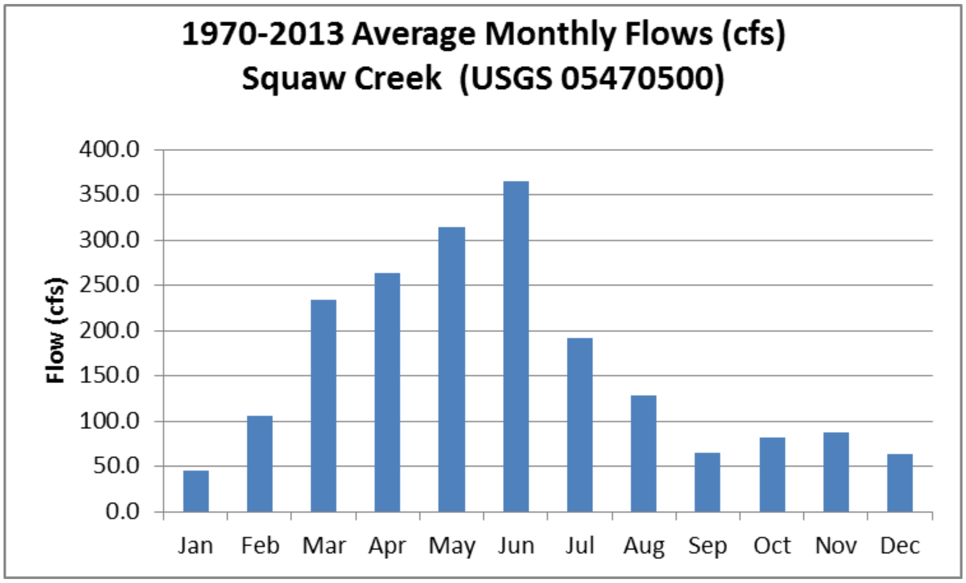



**Figure 3-3.** Squaw Creek (Ames, IA) average monthly flows (cubic feet per second)

Average monthly flows for Squaw Creek at Ames from the USGS from 1981 to 2014 were summarized in Table 3-4 below by 'wet'(blue) and 'dry' (grey) monthly conditions based on examining 25th percentile (dry) and 75th percentile (wet) conditions. Wet and dry periods seem to occur in series with 2000-2003 having several back-to-back dry months and the converse being true for the 2007-2010 wet period (blue patches in the table). A dry period followed in 2012-2013 with more low to very low flow months.

**Table 3-4.** Monthly Stream Flows USGS Gage Station, Ames IA

| Year | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 2000 | 3.9 | 17.7 | 18.0 | 10.2 | 25.7 | 77.3 | 15.6 | 2.3 | 0.2 | 0.3 | 2.7 | 0.6 |
| 2001 | 0.0 | 0.4 | 307.3 | 165.2 | 298.6 | 211.6 | 30.0 | 8.8 | 38.2 | 19.0 | 25.4 | 29.4 |
| 2002 | 16.7 | 38.0 | 43.9 | 80.7 | 234.2 | 125.8 | 40.3 | 41.2 | 2.8 | 29.5 | 25.3 | 12.6 |
| 2003 | 5.0 | 3.5 | 21.2 | 95.6 | 398.3 | 193.7 | 472.0 | 14.9 | 3.0 | 1.0 | 15.7 | 8.3 |
| 2004 | 13.1 | 141.2 | 297.1 | 153.4 | 414.8 | 410.9 | 140.4 | 44.6 | 11.4 | 5.8 | 15.9 | 15.6 |
| 2005 | 15.3 | 149.0 | 64.0 | 151.6 | 222.2 | 134.6 | 53.4 | 37.0 | 12.2 | 10.4 | 11.0 | 12.9 |
| 2006 | 67.8 | 33.5 | 62.4 | 241.8 | 293.0 | 68.2 | 63.6 | 51.6 | 422.7 | 180.8 | 140.7 | 146.5 |
| 2007 | 206.4 | 84.8 | 556.3 | 742.1 | 675.1 | 299.7 | 57.6 | 213.5 | 63.6 | 369.9 | 109.1 | 41.2 |
| 2008 | 29.5 | 23.4 | 363.9 | 608.3 | 722.3 | 1145.0 | 415.5 | 127.4 | 28.5 | 99.6 | 195.3 | 63.9 |
| 2009 | 24.6 | 279.3 | 392.5 | 439.5 | 450.7 | 575.0 | 138.4 | 33.3 | 7.1 | 191.9 | 232.9 | 101.2 |
| 2010 | 88.8 | 69.2 | 843.8 | 224.1 | 343.1 | 609.2 | 679.1 | 1734.0 | 234.3 | 111.8 | 150.4 | 49.1 |
| 2011 | 45.7 | 164.5 | 139.6 | 271.0 | 294.4 | 242.7 | 76.5 | 18.6 | 9.0 | 4.0 | 5.8 | 4.8 |
| 2012 | 2.6 | 6.0 | 29.4 | 105.2 | 127.8 | 32.5 | 4.1 | 3.8 | 2.0 | 0.1 | 0.0 | 0.0 |
| 2013 | 4.0 | 6.6 | 169.7 | 144.9 | 612.9 | 334.3 | 47.3 | 6.6 | 1.6 | 6.7 | 6.0 | 0.4 |
| 2014 Preliminary Data | 0 | 1.4 | 66 | 55 | 141 | 403 | 514 | 50 | | | | |
| | | | | | | | | | | | | |
| 1981-2013 | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| Monthly Means | 42 | 104 | 223 | 267 | 340 | 378 | 225 | 140 | 55 | 71 | 78 | 62 |
| Dry Months 25th % | 5 | 23.4 | 62.4 | 94.6 | 139.1 | 99.3 | 40.3 | 14.9 | 3.03 | 5.48 | 11 | 8.34 |
| Wet Months 75th % | 63 | 149 | 325.4 | 311.8 | 512.2 | 575 | 285.3 | 71.6 | 33.2 | 99.6 | 138.5 | 101.2 |

### *Daily Average Flows*

A more detailed view of (1) daily average flows and (2) instantaneous peak flows were examined for the 2003-2013 time period (Figure 3-4). In this plot the highest daily average flows were on the order of 15,900 cfs in August, 2010 and about 7,300 cfs in 2008. The remaining time periods had much lower variability of daily flows as 2003-2006 and 2011-2013 were below average runoff years.

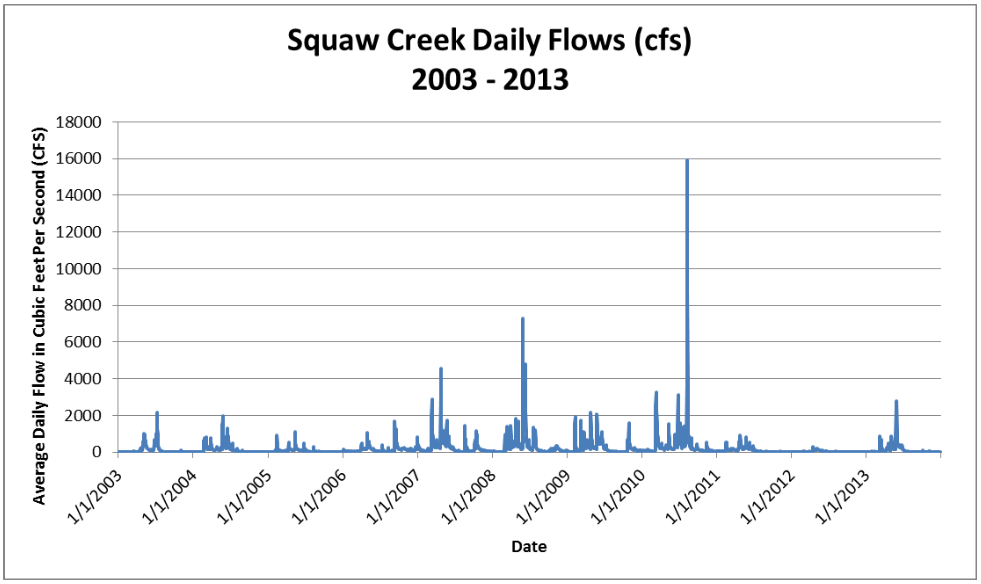



**Figure 3-4.** 2003-2013 Daily Flows in cfs for Squaw Creek (USGS 05470500) at Ames, IA.

### *Historical Peak Events*

From a flooding perspective, instantaneous peak flows are of particular interest. Squaw Creek peak flows can be substantially greater than daily average flows indicating rapid runoff responses. For example, the peak flow of 12,600 cfs was noted on May 30, 2008 versus the daily average of ~7,300 cfs. In a similar fashion, the peak flow of 22,400 cfs was noted on August 11, 2010 versus the daily average of 15,900 cfs. Generally, instantaneous peak flows of the most recent 14 years were attributable to snow melt (2001, 2005, and 2009) or due to back-to-back storms of the preceding ~14 days with rainfall totals ranging from about 3 inches to 6.5 inches (2000, 2002,2003, 2004, 2007, 2008, 2011,and 2013). The massive peak flow of August 11, 2010 was preceded by a very large amount of rainfall (about 10.4 inches) in the preceding ~14 days. Back-to-back storms with total rainfalls of 3-6 inches appear to be a trigger for the large peak runoff events in the Squaw Creek Watershed.

Squaw Creek's peak flows were further summarized from the USGS flow gauging station data (Station 054070500) in Figure 3-5 where dramatically increased peak events have occurred since ~1970. Although missing data from ~1930 until 1964, peak events from 1918 through the 1920's and the 1960's were less than ~7,000 cfs. However, from 1970 to 2013, there were four years with peak flows 5,000 - 10,000 cfs, four years with peak flows 10,000 to 15,000 cfs and two years with peak flows greater than 20,000 cfs (e.g. 1993 and 2010). For perspective, flows greater than 5,000 cfs are ~25 times typical summer flows, flows greater 10,000 cfs are ~50 times typical summer flows and flows greater than 20,000 cfs are approaching ~100 times typical summer flows. **The range of peak to typical flows to intense rainfall events is indicative of the Squaw Creek system as having substantially 'flashy' or rapid runoff hydrology.**

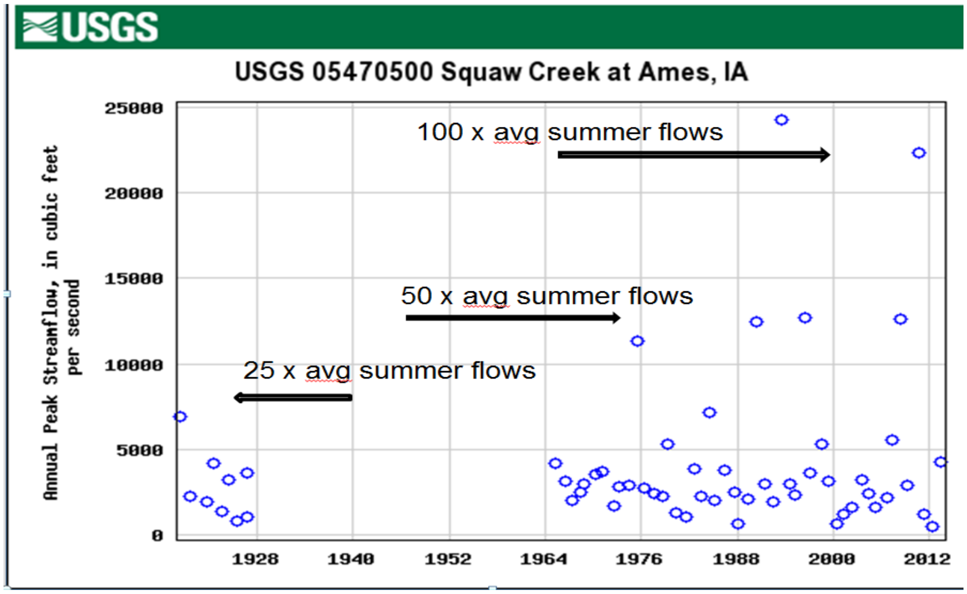



**Figure 3-5.** Squaw Creek annual peak flows in cfs for USGS (Station 05470500)

### *Additional Stream Gage Information*

Water levels of Squaw Creek and its 15 tributaries are monitored at 25 gauge stations on an hourly basis, located throughout the watershed (Table 3-5). This stream gauge information is immediately uploaded to the Iowa Flood Information System (IFIS) in real-time, which is available to the public online at: http://ifis.iowafloodcenter.org/ifis/en/. The water level gauge information also includes updated flood stage information. This allows the user to observe the current water level and know the water level that would be considered a flood.

In addition to this real-time gauge data, the IFIS website contains a number of useful tools related to flood prediction. For the Inundation Maps tool, users can adjust the river water levels to simulate how much flooding will occur at various storm events and rates of flow. For example, users can adjust the tool from a 2 to 500 year storm event or the water levels up to 25 ft. and view the flooded areas respectively. This feature is available for 13 Iowa cities including Ames. Another helpful tool, called the Flood Risk Calculator, allows the user to determine the probability of a 10-year flood occurring within a 2-year period. This calculator can be scaled from 1-99 years and is capable of predicting the probability of storm events ranging up to 500 years. Thus, a user could use these tools to determine that a 100-year storm event will inundate their property and there is only a 14% chance that such an event will happen over the course of 15 years.

**Table 3-5.** Squaw Creek gage locations

| Stream Name | Gage Location |
|---|---|
| Squaw Creek | 360th Street, Hwy 175, Stratford |
| North Branch Crooked Creek | Inkpaduta Avenue, Stanhope |
| South Branch Crooked Creek | Briggs-Wood Road, Hwy 7 |
| Squaw Creek | Inkpaduta Avenue, Stanhope |
| Glacial Creek | U Avenue, Story Cty |

| Stream Name | Gage Location |
|---|---|
| Talynns Creek | V Avenue, StoryCty |
| Squaw Creek | 120th Street, Story Cty |
| Squaw Creek | Ames |
| Prairie Creek | 160th Street, Boone |
| Montgomery Creek | Boone |
| Prairie Creek | V Avenue, Gilbert |
| Squaw Creek | 160th Street, Gilbert |
| Gilbert Creek | 520th Ave, G. Washington Carver Avenue, Gilbert |
| Squaw Creek | Ames |
| North Branch Onion Creek | Hwy 17, T Avenue, Boone |
| North Branch Onion Creek | V Avenue, Boone |
| South Branch North Fork Onion | U Avenue, Boone |
| South Branch South Fork Onion Creek | U Avenue, Boone |
| Squaw Creek Tributary | Stratford |
| Clear Creek | 500th Avenue, County Road R38, Ames |
| Onion Creek | N 500th Ave, County Road R38, Ames |
| Worle Creek | X Avenue, Ames |
| Squaw Creek | Strange Rd, Ames |
| Squaw Creek | Ames |
| Squaw Creek | South Duff Ave, Ames |

### 3.1.4. **Water Quality Monitoring**

Stream monitoring provides information to compare monitored conditions to stream standards and criteria, detect changes over time, and support future watershed rehabilitation efforts. The ability of a monitoring program to detect such changes and the reliability of the comparisons depend upon the nature and design of the monitoring program.

Monitoring efforts of water quality in the Squaw Creek and its tributaries have been ongoing since about 2000 and incorporate conservation programs that engage students and citizens in volunteer monitoring. Different water quality parameters have been assessed at varying sampling frequencies and dates over time and have been used to compare to water quality criteria and standards. The number of samples per site varied considerably and over time. Volunteer monitoring efforts relied upon 'kit' analyses of nitrate and phosphorus concentrations and hence, values are reported in coarse intervals such as 0.1 ppm. Bacterial samples were analyzed by an established laboratory.

Beginning at the headwaters, available data were combined into a database and analyzed along the stream network. Refer to Figure 2-2 in the Watershed Characterization section for the stream network.

Squaw Creek reaches are defined as follows:

- Upper Squaw Creek – This is the reach of Squaw Creek that is above the Primary Recreation use reach which is defined as being at the confluence with Glacial Creek.

- Middle Squaw Creek – This reach of Squaw Creek runs between the confluence with Montgomery Creek and the confluence with Glacial Creek.
- Lower Squaw Creek – This reach extends from the confluence of Onion Creek to the confluence of Montgomery Creek
- Squaw Creek Ames Reach – This is the reach of Squaw Creek that lies below Onion Creek to the outlet of Squaw Creek into South Skunk River.

Note that the data does not include flows that will increase along Squaw Creek. As previously noted in the climate section, the sampling period of record includes several wet and dry periods that will affect runoff that cannot be pro-rated without flow data. For example, the most recent five years (2009-2013) have higher runoff periods (2009-2010), a transition year (2011) followed by two drier years (2012-2013)). Hence, averaging of the data helps define the broad water quality picture.

Over the years, sampling dates have varied somewhat from January through November, however, most recent sampling (2009-2013) tended to occur in May and October. Peak events were sampled on occasion, but not sufficient to characterize loading that is highly dependent upon sampling of the higher runoff periods (such as spring runoff and storm events). Reported concentrations for parameters having less than the Minimum Detection Limits (MDLs) were halved for calculation of averages in this analysis with values exceeding the reporting level for turbidity tube transparencies of greater than 60 cm were assigned a value of 65 cm.

This evaluation begins with an examination of all of the data for patterns and exceedance of Iowa water quality standards and appropriate watershed management numeric targets or criteria. Criteria are numeric values that are used when standards are not available or have not yet been developed for common water quality measures such as nutrients. Refer to section 3.1.2 Applicable Water Quality Standards and Criteria for further explanation. The Iowa Department of Natural Resources is examining stream nutrients and biological responses at this time.

Data from 2000-2013 were summarized by Squaw Creek reach (Upper Squaw Creek, Middle Squaw Creek, Lower Squaw Creek and Squaw Creek Ames Reach) for mainstem sites (Table 3-6) and its tributaries (Table 3-7) beginning at the headwaters and proceeding downstream. Average values were calculated by parameter for nitrate plus nitrite nitrogen, orthophosphate, E.coli, transparency and chloride.

**Table 3-6.** Average Monitored Concentrations for Squaw Creek Mainstem Reaches

| Mainstem Reach | Nitrite + Nitrate N mg/L | Ortho phosphate mg/L | *E. coli* (org/100mL) | Transparency (cm) | Chloride (mg/L) |
|---|---|---|---|---|---|
| Upper Squaw Creek | 5.20 | 0.245 | 689 | 38.5 | 25.7 |
| Middle Squaw Creek | 6.74 | 0.297 | 2767 | 38.0 | 27.0 |
| Lower Squaw Creek | 6.84 | 0.263 | NA | 32.0 | 29.7 |
| Squaw Creek Ames Reach | 5.34 | 0.297 | 1380 | 41.3 | 39.4 |

**Table 3-7.** Average Monitored Concentrations and Number of Samples for Squaw Creek Tributaries by Subwatershed

| Stream | Nitrite + Nitrate (mg/L) | | Orthophosphate (mg/L) | | *E. coli* (org/100mL) | | Transparency (cm) | | Chloride (mg/L) | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Average | N | Average | N | Average | N | Average | N | Average | N |
| **Drainage Ditch 192 – Squaw Creek Subwatershed** | | | | | | | | | | |
| Stratford | 5.529 | 12 | 0.3 | 11 | 267 | 2 | 35 | 12 | 17.6 | 12 |
| **Crooked Creek Subwatershed** | | | | | | | | | | |
| Crooked Creek | 3.019 | 8 | 0.314 | 7 | N/A | 0 | 30 | 8 | 29 | 7 |
| **Crooked Creek – Squaw Creek Subwatershed** | | | | | | | | | | |
| Glacial Creek | 3.123 | 42 | 0.219 | 43 | 89 | 27 | 60 | 43 | N/A | 0 |
| Scott Drainage Ditch 292 | 5.65 | 13 | 0.108 | 12 | N/A | 0 | 54 | 14 | 21.1 | 10 |
| No Name Creek | 6.517 | 12 | 0.185 | 13 | N/A | 0 | 54 | 13 | N/A | 0 |
| **Montgomery Creek Subwatershed** | | | | | | | | | | |
| Montgomery Creek | 4.749 | 118 | 0.156 | 120 | 1,180 | 96 | 49 | 122 | N/A | 0 |
| Prairie Creek | 5.074 | 118 | 0.318 | 120 | 1,941 | 95 | 48 | 122 | N/A | 0 |
| **Lundy's Creek – Squaw Creek Subwatershed** | | | | | | | | | | |
| Bluestem Creek | 4.373 | 43 | 0.229 | 41 | 461 | 29 | 57 | 43 | 30.1 | 41 |
| Gilbert Creek | 6.911 | 14 | 0.393 | 14 | N/A | 0 | 51 | 14 | N/A | 0 |
| **Onion Creek Subwatershed** | | | | | | | | | | |
| Onion Creek | 4.901 | 58 | 0.247 | 60 | N/A | 0 | 42 | 63 | N/A | 0 |
| **Worle Creek – Squaw Creek Subwatershed** | | | | | | | | | | |
| Clear Creek | 6.214 | 169 | 0.233 | 169 | 407 | 57 | 57 | 176 | 39.9 | 168 |
| Ames High Tributary | 3.321 | 46 | 0.189 | 47 | 300 | 5 | 58 | 47 | 106.1 | 38 |
| College Crk | 2.771 | 119 | 0.234 | 111 | 100 | 1 | 49 | 123 | N/A | 0 |
| College Creek Trib | 1.675 | 51 | 2 | 51 | N/A | 0 | 56 | 51 | 205.6 | 40 |
| Worle Creek | 7.348 | 59 | 0.186 | 58 | 1,078 | 6 | 50 | 63 | 31.5 | 56 |
| Komar Creek | 5.753 | 15 | 0.271 | 14 | N/A | 0 | 48 | 18 | 21.5 | 15 |
| Worle S.Branch | 7.165 | 13 | 0.242 | 12 | N/A | 0 | 47 | 13 | 38.5 | 12 |
| Moore Park | 5.485 | 13 | 0.169 | 13 | N/A | 0 | 43 | 13 | 23.3 | 13 |

### 3.1.5. **Nitrogen**

Nitrogen is an important measurement, particularly the dissolved forms, as it increases productivity on farm fields, urban lawns and streams/lakes. Nitrate nitrogen is the dominant dissolved fraction with typically very small amounts of nitrite nitrogen present (which can be quite ephemeral). Hence, discussion will focus on the combined nitrate plus nitrite nitrogen with concentrations that vary seasonally from biological activity and nutrient inputs (fertilizer, wastewater and urban runoff). While nitrate is one of the primary forms of nitrogen used by plants for growth, excess amounts to groundwater and streams can cause human health concerns. At concentrations greater than 10 mg/L, it has been linked to methemoglobinemia ("blue baby syndrome"). Hence ground water recharge areas associated with public drinking water sources can have drinking water source management area plans to limit nitrate and other drinking water pollutants. Secondly, as nitrate nitrogen is very soluble, it can be transported long distances downstream to large impoundments and the Gulf of Mexico as one of the primary contributors to low or no oxygen areas (hypoxic zones). Phosphorus is another pollutant contributing to the anoxic zones in coastal areas.

Total nitrogen consists of dissolved (nitrate plus nitrite) and organic nitrogen (total Kjeldahl nitrogen). In this case, organic nitrogen monitoring data were not available and comparisons are based on dissolved nitrogen values. Nitrate and nitrite are inorganic and dissolved forms of nitrogen used for increasing productivity, with concentrations that vary seasonally from biological activity and nutrient inputs. They are formed through the oxidation of ammonia (NH 3-N) by nitrifying bacteria (nitrification). They are converted to other nitrogen forms by denitrification and plant uptake. Nitrite concentrations are typically quite low in aquatic systems and hence, discussion will focus on nitrite plus nitrate nitrogen levels.

**Dissolved nitrogen concentrations were monitored by volunteers throughout the Squaw Creek watershed. Nitrate and nitrite nitrogen concentrations were assessed by volunteers using kit analyses and hence concentration ranges were limited to coarser reporting levels, approximately 0.2 to 0.5 mg/L. All monitoring data was averaged by site and summarized in Table 3-6 and Table 3-7.**

Nitrate plus nitrite concentrations range from around 5 mg/L to 7 mg/L throughout the mainstem Squaw Creek. Low tributary values were noted for Crooked Creek, Glacial, Ames High and College Creek with College Creek Tributary having the lowest value of about 1.7 mg/L. High tributary concentrations were noted for Clear and Worle Creeks with values exceeding 6.0 mg/L.

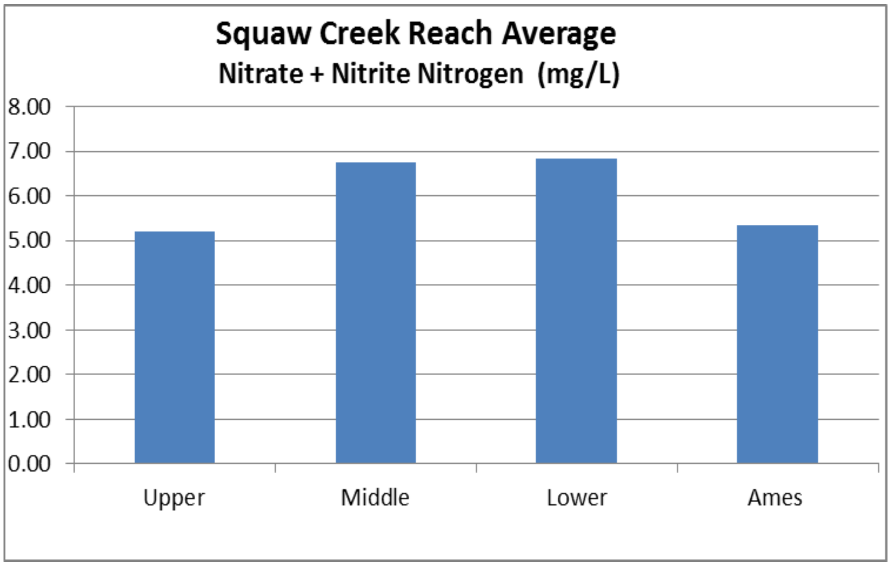



**Figure 3-6.** Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Mainstem Reach

While mainstem and tributary average nitrate plus nitrite concentrations were quite elevated throughout the monitoring network these averages do not exceed the drinking water standard of 10.0 mg/L. T**he dissolved nitrogen concentrations exceed the ecoregion total nitrogen criteria of 2.18 mg/L) generally by a factor of 1.5 to 4.** Since organic nitrogen monitoring data was not available, total nitrogen concentrations may be greater than indicated by just dissolved forms.

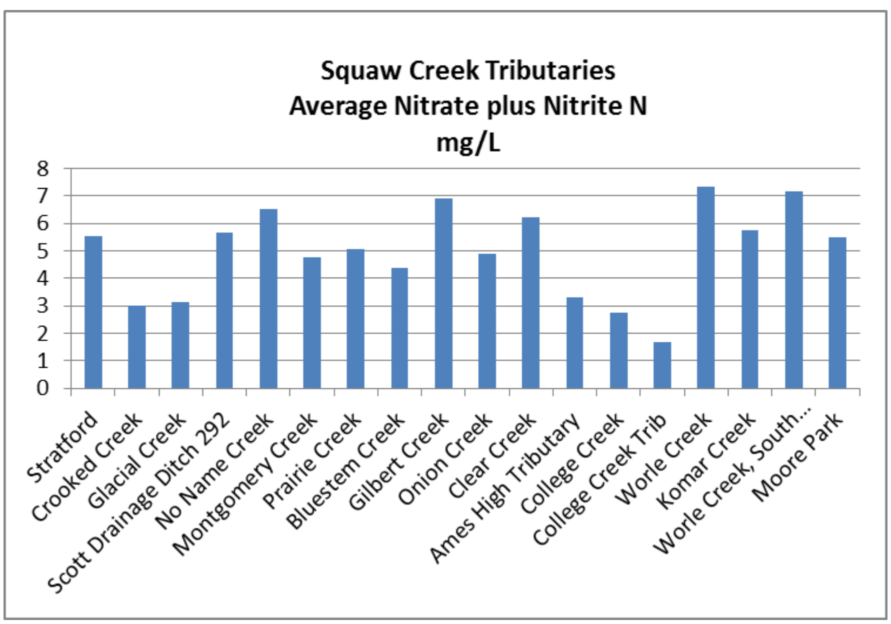



**Figure 3-7.** Average Nitrate + Nitrite Nitrogen Concentrations by Squaw Creek Tributaries

### 3.1.6. **Phosphorus**

Phosphorus is a primary nutrient for plant growth on the land and in the water. On the land, soil phosphorus concentrations measured in the part per million range are closely followed by agricultural and urban land owners. However, in water, phosphorus concentrations in the part per billion range are monitored with excess phosphorus levels occurring at concentrations **much lower** than values measured in soils.

Phosphorus concentration in water is a primary focus of applied watershed management as this element drives a wide array of river, stream and lake biological responses affecting beneficial uses. Excess phosphorus concentrations lead to increased algae that float in the stream or are attached to rocks and substrates, increased organic matter, increased bacteria that lead to boom-bust daily oxygen concentration cycles that limit aquatic life. In severe cases, massive algal mats and scums can be generated by blue-green algae that also can produce toxins such as microcystin that can affect wildlife and drinking water supplies.

Phosphorus is typically monitored in two forms: dissolved phosphorus (forms most readily used by crops as well as aquatic plants resulting in increased productivity); and total phosphorus (found in both dissolved and particulate forms). Volunteer monitoring of Squaw Creek examined dissolved orthophosphate phosphorus as determined by Chemetrics kit analyses with a range of 0 to 1.0 ppm (or 1000 ppb) of phosphate in 0.1 mg PO4/L increments. Precision and accuracy data were not analyzed. To convert the orthophosphate (PO4) to elemental orthophosphorus (P) concentrations, values are multiplied by 0.33. One more conversion was required, as most water quality criteria are expressed as total phosphorus. For this purpose, total phosphorus concentrations were assumed to be about 3 times the average dissolved phosphorus. Hence, lumping both conversions together, the original orthophosphate phosphorus concentrations measured by volunteer monitoring were estimated to be approximately equivalent to total phosphorus calculated values. Additional sampling and use of a certified laboratory will be required for more detailed comparisons.

Orthophosphate concentrations were noted to fluctuate much less than nitrate plus nitrite nitrogen, ranging from around 0.25 mg/L in Upper Squaw Creek to about 0.3 mg/L in the Squaw Creek Ames Reach. Tributary orthophosphate concentrations had a much larger range varying from lowest values observed at Scott Drainage Ditch 292 (0.108 mg/L) to typical ranges in the 0.200 to 0.300 mg/L range for most sites. The highest value was noted for the College Creek Tributary with an exceptionally high value of 2.0 mg/L.

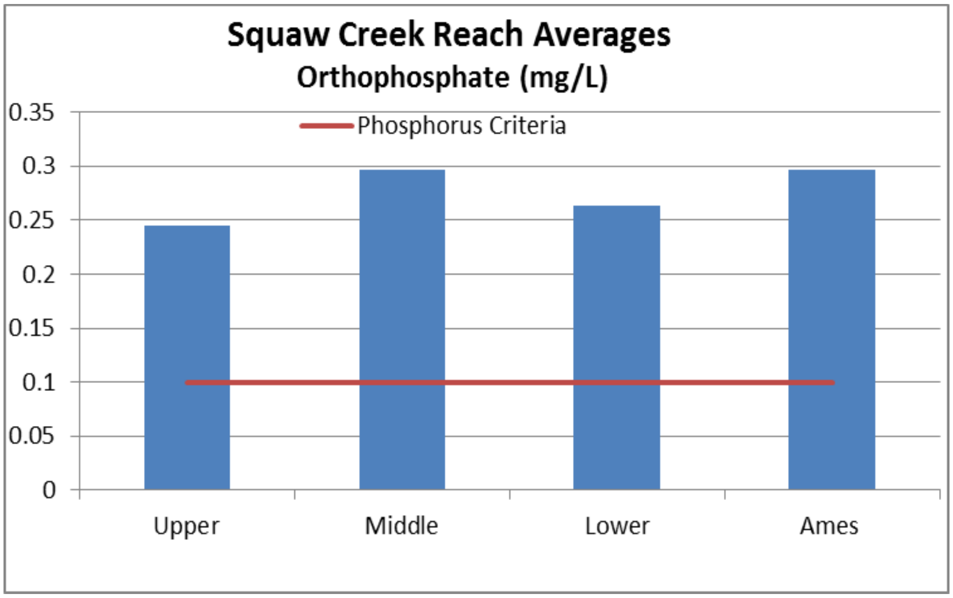



**Figure 3-8.** Average Orthophosphate Concentrations by Squaw Creek Mainstem Reach

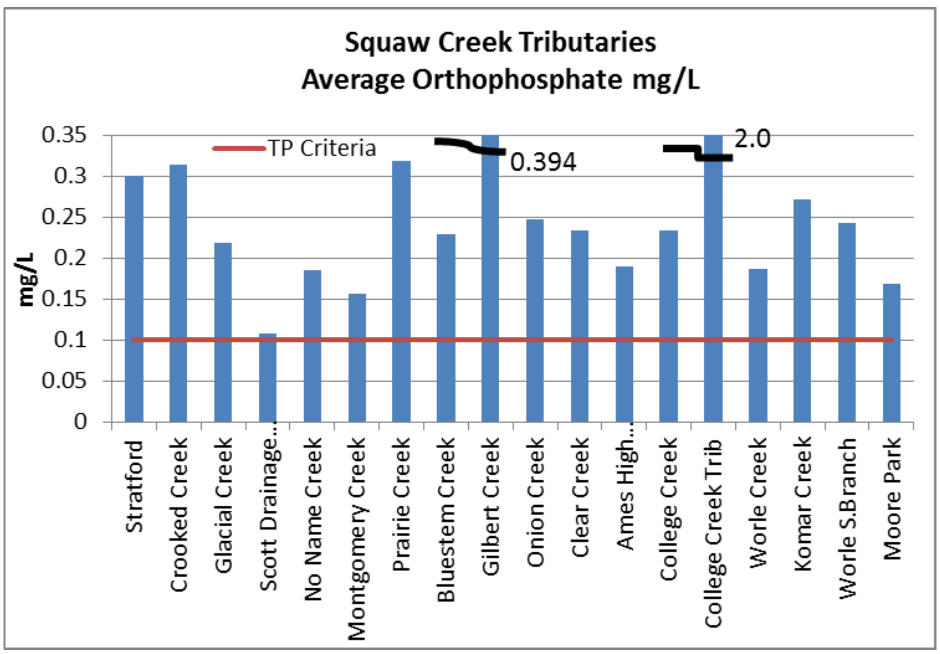



**Figure 3-9.** Average Orthophosphate Concentration by Squaw Creek Tributaries

**The monitored orthophosphate concentrations (and generally approximately total phosphorus concentrations) for all the mainstem and tributaries exceed ecoregion derived phosphorus criteria (0.076 mg/L) and the draft State criteria of 0.1 mg/L, except for Scott Drainage Ditch 292.**

### 3.1.7. **Transparency**

Transparency is a measure of water clarity and is affected by the amount of material suspended in water. As more material is suspended, less light can pass through, making it less transparent. Suspended materials may include soil, algae, plankton, and microbes. Transparency is measured using a transparency tube and is measured in centimeters. It is important to note that transparency is different than turbidity; transparency is a measure of water clarity measured in centimeters, while turbidity measures how much light is scattered by suspended particles using NTUs (Nephelometric Turbidity Units).

Low transparency (or high number of suspended particles) is a condition that is rarely toxic to aquatic animals, but it indirectly harms them when solids settle out and clog gills, destroy habitat, and reduce the availability of food. Furthermore, suspended materials in streams promote solar heating, which can increase water temperatures (see *Water Temperature*), and reduce light penetration, which reduces photosynthesis, both of which contribute to lower dissolved oxygen. Sediment also can carry chemicals attached to the particles, which can have harmful environmental effects. Sources of suspended particles include soil erosion, waste discharge, urban runoff, eroding stream banks, disturbance of bottom sediments by bottom-feeding fish (carp), and excess algal growth."

Transparency tube monitoring was conducted over the time 2004-2013 with average values per tributary reflecting all of the snapshot measures from January through November with more measurements typically noted for May and October during the spring and fall IOWATER statewide snapshot events (Figure 3-10). As stream flows are a dominant factor affecting erosion and runoff, higher flows (generally March through June) can be expected to be capable of carrying greater amounts of suspended materials and causing lower transparency. Squaw Creek flows are quite variable with transparency tube measurements also being highly variable. Monitoring based on storm events and peak flows (as used for defining pollutant loading) versus lower flow periods can be expected to affect average values.

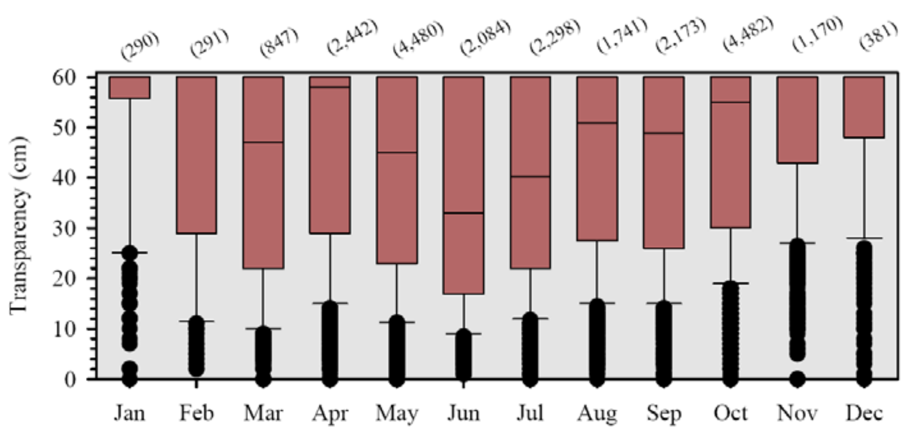



**Figure 3-10.** Box Plots of Statewide Transparency by Month

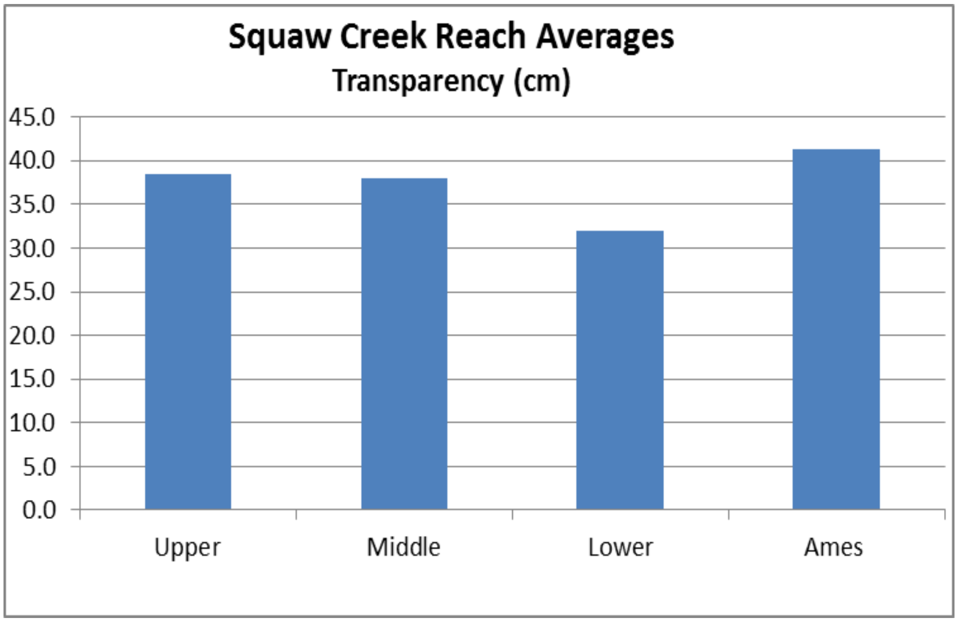



**Figure 3-11.** Average Transparency by Squaw Creek Mainstem Reaches

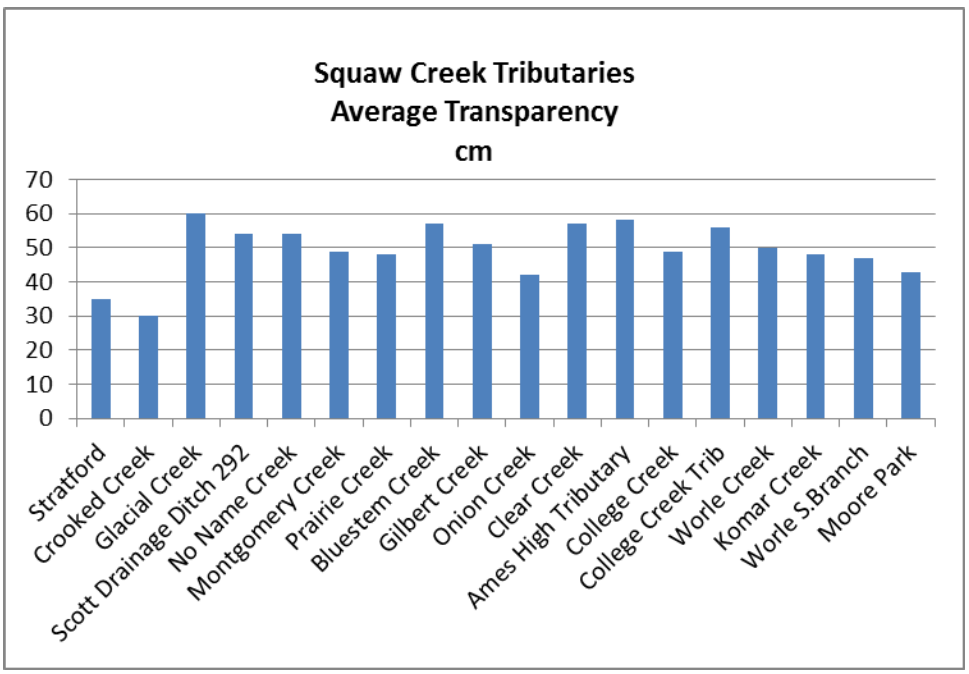



**Figure 3-12.** Average Transparency by Squaw Creek Tributary

### 3.1.8. **Chloride**

Chloride is present (generally as sodium chloride) in all natural waters, although the concentration can vary from a few milligrams per liter or less, to several thousand milligrams per liter in some ground waters. Water soluble chloride concentrations are from natural sources, industrial, municipal wastewater, septic effluent and the use of deicers applied to impervious surfaces for public safety concerns. Concentrated animal operation wastes and some agricultural inorganic fertilizers also influence chloride concentrations. Chloride concentrations in excess of 250 mg/L can be detected by taste. Iowa water quality standards for B(WW-2) waters are based on a formula with assumed hardness. The chronic and acute standards are 389 and 620 mg/L respectively.

http://www.iowadnr.gov/InsideDNR/RegulatoryWater/WaterQualityStandards/Nutrients.aspx

Average chlorides for mainstem reaches range from approximately 25-40 mg/L (Figure 3-13). All are well below the chronic standard. Tributary average chloride concentrations (Figure 3-14) generally were in the 20-40 mg/L range but Ames High Tributary and College Creek Tributary had average values of 106 and 205.6 mg/L, respectively. The lowest average concentration value of 17.6 mg/L was noted for the Stratford site. All of these averages were less than the chloride standards. However peak samples of 600 and 246 were noted for the College Creek Tributary site (2004 and 2005, respectively), suggesting that this area deserves further future examination. For this purpose, a certified laboratory should process samples including chloride, hardness and sulfate.

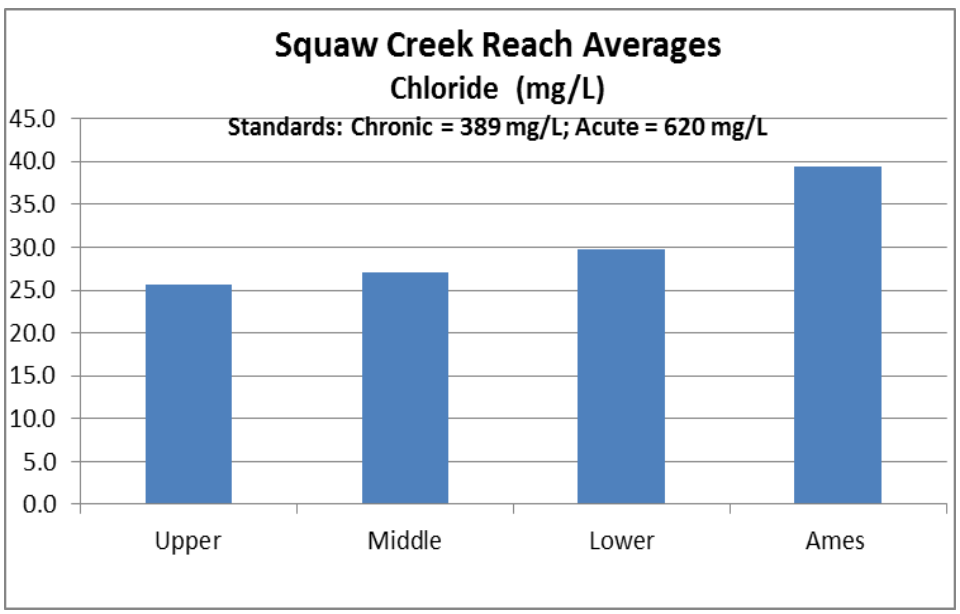



**Figure 3-13.** Average Chloride Concentration by Squaw Creek Mainstem Reach

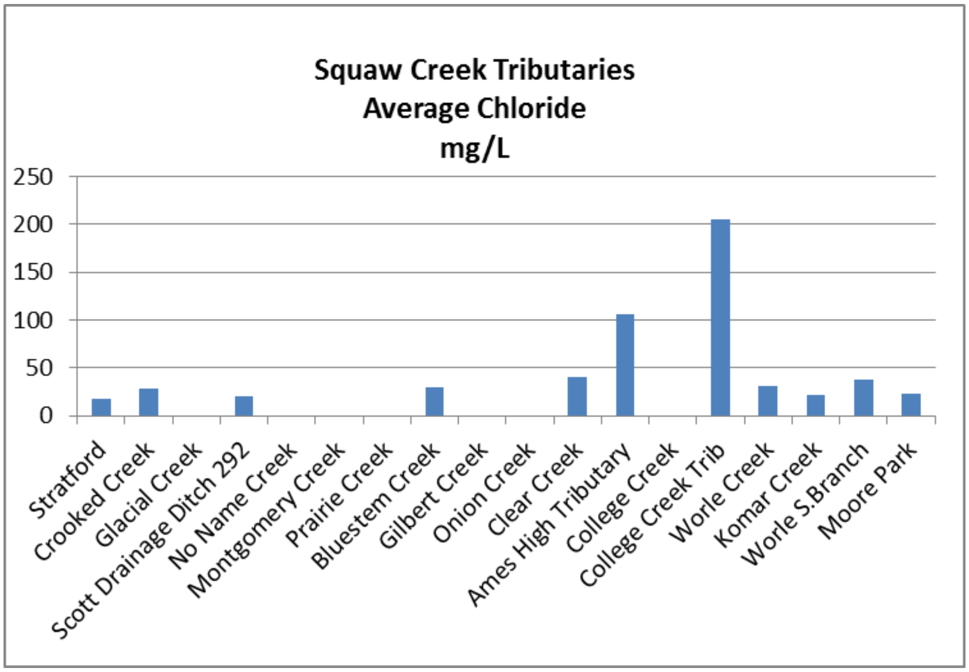



**Figure 3-14.** Average Chloride Concentration by Squaw Creek Tributary

### 3.1.9. **Dissolved Oxygen**

Iowa water quality standards for B(WW-2) waters specify a minimum dissolved oxygen value of 5.0 mg/L for at least 16 hours of every 24 hour period and a minimum value of 4.0 mg/L at any time.

Dissolved oxygen (DO) concentrations are critical for maintenance of aquatic fish and other aquatic life. DO plays an important role in the chemistry and natural degradation of pollutants in a water body and reduced DO concentrations can lead to taste and odor problems in water. DO concentrations can become very low during very high temperatures and low flow conditions, or during the fall when algae and other plants begin to die-off.

Volunteer monitoring was limited to daylight conditions when DO values are likely high. Mainstem Squaw Creek sites have a narrow range of average dissolved oxygen concentrations varying from 8.9 to 9.3 mg/L or parts per million. However, concurrently noted minimum values ranged from 4 to 6 mg/L while a maximum value of 12 mg/L was noted for each site. Tributary dissolved oxygen concentrations showed more variability with average values ranging from 6.6 mg/L to 10.3 mg/L while minimum values ranged from 1 mg/L to 6 mg/L with each station having a peak value of 12.0 mg/L. The difference between maximum and minimum dissolved oxygen concentrations is referred to as DO flux which should be about 4 mg/L or less on a daily scale. On a broader scale based on all of the data, the tributary DO flux values ranged between 4 (Scott Drainage and Crooked Creek) to 11 mg/L (College Creek) which is symptomatic of over-nutrient enriched systems. Eight of the tributaries were noted to have instantaneous minimum values of 4.0 mg/L and may violate DO standards. A closely related analyte, pH can become elevated during periods of maximum aquatic productivity resulting from enrichment.

### 3.1.10. **pH**

pH is an analytical term used to express the intensity of the acidity or alkalinity of a solution that varies as to water chemistry and system productivity. pH values for most aquatic systems should be around 7-8 pH units with highly productive systems having daily peak values that can be above 8.5 units (basic) from algal photosynthesis. pH is impacted by the types and concentrations of acids and bases in the water. pH affects the toxicity, reactivity, and solubility of many chemical compounds, and thus has a wide impact on the relative health of the water system.

Average pH values for the mainstem Squaw Creek sites ranged between 8.1 to 8.7 units while the tributaries had a slightly larger range of average values from 7.6 units (Stratford) to 8.7 units (Montgomery and Prairie Creeks). The range of minimum and maximum pH units per site largely reflects algal productivity with observed mainstem site values varying about 2-4 units and the tributaries having a somewhat smaller range of 1-3 units. **In conjunction with the DO values, higher pHs and pH ranges suggest elevated algal productivity within the Squaw Creek flow network.**

### 3.1.11. ***E. coli* Bacteria**

Water-borne pathogens include a wide variety bacteria, viruses, protozoa microorganisms such as Giardia and Cryptosporidium that are capable of producing gastrointenstinal illnesses and other symptoms that can be severe. Testing for all of the potential pathogens would be prohibitively expensive and therefore monitoring has focused on indicator organisms such as fecal coliforms and its sub-group known as Escherichia coli (*E.coli*). Bacterial levels are affected by sunlight, nutrient levels, seasonal weather, stream flows, temperatures, and distance from pollution sources such as livestock manure practices, wildlife activity, sewage overflows. Stream and pond sediments can harbor bacteria populations. These factors will vary spatially and temporally and, therefore, should be considered in sampling site selection and data interpretation. To compare values to the Iowa water quality geometric mean of 126 org/100mL, a minimum of five samples are required in a single year from March 15$^{th}$ to November 15$^{th}$. However, stream reaches may also be listed on the 303(d) list as impaired if single samples exceed 235 org/100mL.

***E. coli* geometric means for the mainstem sites of Squaw Creek were very high and well above the state water quality standard (Figure 3-15).** Note that *E. coli* monitoring data was not available for the Lower Squaw Creek reach. Nearly half of the tributaries did not have *E.coli* data (8 out of 17 tributaries); however sites with data had a smaller range with average values ranging from 100 to 1,941 org/100 ml.

Note that the state standard for *E. coli* applies only to Class A1 Recreational Use waters so for Squaw Creek it only applies to Middle Squaw Creek, Lower Squaw Creek and Squaw Creek Ames Reach.

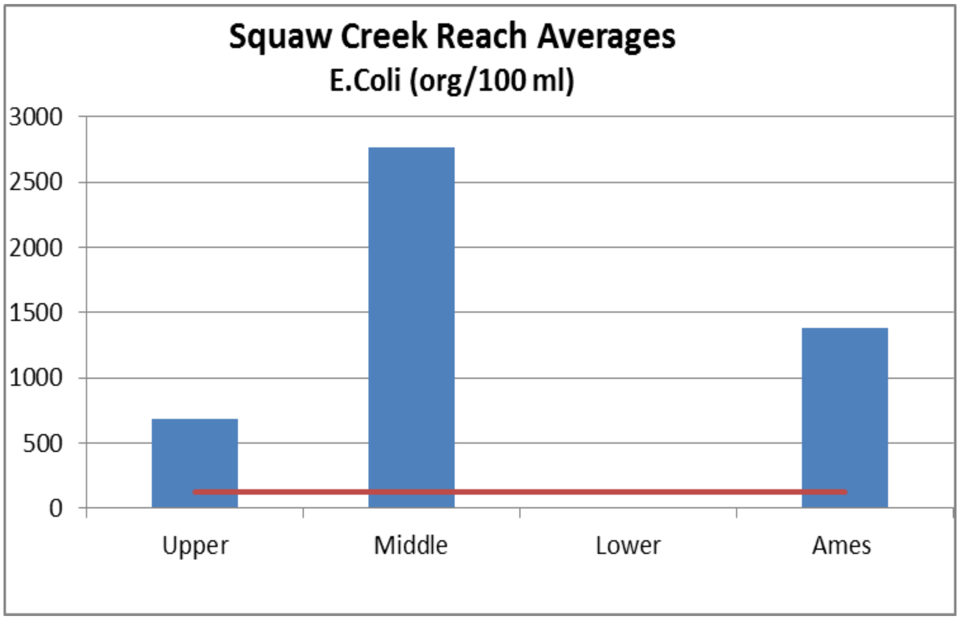



**Figure 3-15.** Geometric Mean *E. coli* Organism by Mainstem Reach

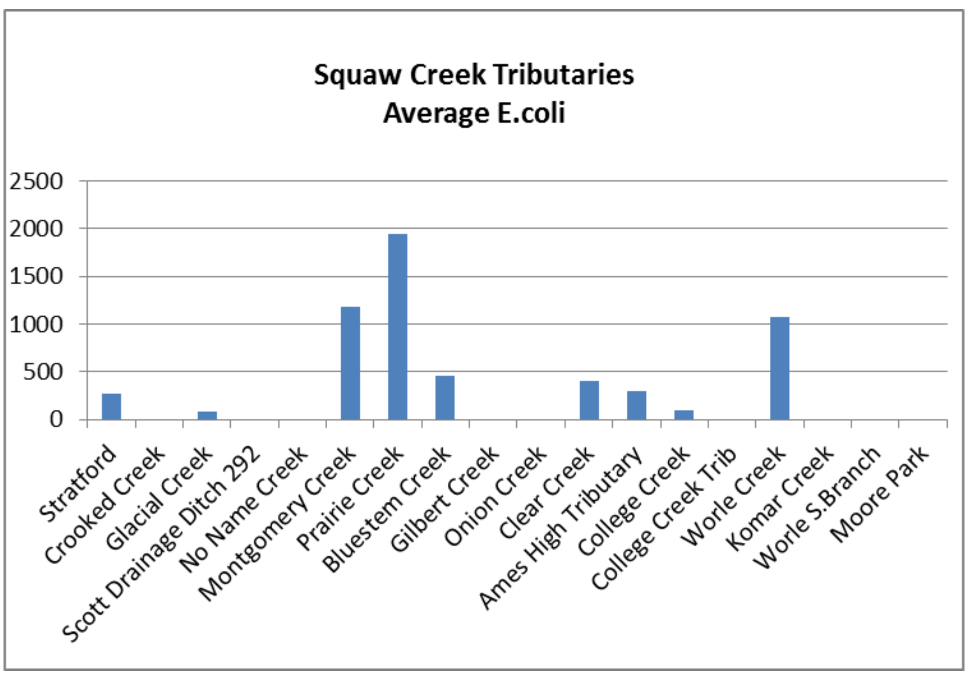



**Figure 3-16.** Geometric Mean of *E. coli* Organism by Squaw Creek Tributary

### 3.1.12. **Macroinvertebrates**

Aquatic biota can be used indicators of water quality and stream habitat. Standards have been set up for collecting and interpreting biological data used to assess stream health. Environmental stressors to stream biota include several types of factors including;

- water chemistry,
- temperature,
- dissolved oxygen,
- flow extremes,
- habitat, and
- toxins.

Standards for assessing the health of biotic communities in streams are determined at regional scales such that streams can be compared. Stream standards are set by reference reaches that support healthy aquatic communities. For Squaw Creek, Iowa IBI standards 47b (Des Moines Lobe Ecoregion) apply. A defined process is used to evaluate aquatic biotic communities to determine if a selected stream or stream reach is fully supporting the type of species and composition of species expected for a given stream type in a given location. Streams not meeting standards can be listed as “Impaired” and may trigger a more extensive study focusing on identifying the stressors to the biotic community and developing a plan for addressing the stressors and improving biotic health.

Biotic data has been collected in the Squaw Creek Watershed since 2000. These data have been collected at various locations throughout the watershed. Some sites were monitored with annual regularity and others more sporadically. Streams with a consistent, long-term, robust data record can be useful in interpreting trends, and if collected following established protocols, may be used to assess stream health against established standards. Although the available data has not been interpreted against known standards as part of this effort, it is possible to make some inferences about the relative health of streams in the Squaw Creek Watershed as well developing a list of candidate stressors that may negatively affect biotic communities. This can be accomplished by reviewing existing data and through a watershed investigation.

Squaw Creek has a reasonably robust data set that spans a 10-yr period. From the data collected it appears that during years of moderate annual flow, three key aquatic macroinvertebrate orders were consistently represented in the population. Three orders frequently used in water quality assessment include Ephemoptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). These three orders (aka “taxa”) are often referred to collectively as EPT (Table 3-8) . Note the years highlighted in red text reflect the healthiest communities and somewhat correspond with years with flows closer to the average annual (see previous flow tables).

Although the data is not conclusive, it does appear as though drought periods had a negative effect on the EPT taxa as did the extremely high flow event in 2010. In general it could be inferred that vast swings in flow is a stressor on these macroinvertebrates. This primarily stems from the habitat requirements of these that include gravel substrates (not embedded with silt), woody debris for grazing, suitable oxygen levels and good water quality. When required habitat components are missing or degraded, a negative response in population diversity and density is expected.

**Table 3-8** Macroinvertebrate species presence % in stream surveys Lower Squaw Creek

| Year | Number of Samples | Caddisfly | Mayfly | Stonefly |
|---|---|---|---|---|
| 2000 | 1 | 0% | 0% | 0% |
| 2001 | 10 | 20.0% | 60.0% | 90.0% |
| 2002 | 5 | 20.0% | 80.0% | 60.0% |
| 2003 | 4 | 0% | 0% | 0% |
| 2004 | 7 | 57.1% | 71.4% | 100% |
| 2005 | 5 | 100% | 80.0% | 100% |
| 2006 | 5 | 100% | 100% | 100% |
| 2007 | 1 | 100% | 100% | 100% |
| 2008 | 2 | 100% | 100% | 100% |
| 2009 | 7 | 71.4% | 71.4% | 71.4% |
| 2010 | 1 | 100% | 100% | 100% |
| 2011 | 3 | 0% | 0% | 33.3% |

Looking at the monitoring results of individual streams within the watershed is more problematic than interpreting information from the more thorough Lower Squaw Creek dataset. If all data are combined, some generalizations could be interpreted for the relative health of the macroinvertebrate community for each stream. For example, Table 3-9 summarizes the number of samples taken over the 10+ years and the percentage of samples containing which taxa. Note that for the macroinvertebrate analysis only two primary reaches of Squaw Creek were used as compared to the four reaches described in the water quality analysis sections above. In this case the Lower Squaw Creek coorelates to the Ames Reach, Lower and Middle Squaw as described above.

**Table 3-9.** Summary of EPT taxa for biological monitoring conducted in the Squaw Creek Watershed (2001-2011)

| Creek | Number of Samples | % of Samples with Tricoptera (Caddisflies) | % of Samples with Ephemoptera- (Mayflies) | % of Samples with Plecoptera (Stoneflies) |
|---|---|---|---|---|
| Clear Creek | 10 | 10% | 20% | 0% |
| College Creek | 33 | 15% | 33% | 9% |
| Lower Squaw Creek | 51 | 45% | 57% | 67% |
| Onion Creek | 11 | 36% | 55% | 27% |
| Upper Squaw Creek | 24 | 33% | 54% | 50% |
| Worle Creek | 8 | 13% | 50% | 50% |
| Grand Total | 137 | 31% | 47% | 41% |

From a cursory review of the table above, some conclusions may be drawn. For example Clear Creek appears to have a relatively lower representation of EPT in samples taken, however, of the 10 samples taken, the majority were taken early in the 10-yr monitoring period. As interpreted from the more thorough dataset on Lower Squaw Creek, it appears as though this time period did not support a robust EPT population. From that evidence, the health of EPT taxa on Clear Creek cannot easily be interpreted. College Creek on the other hand does have a sampling record that sufficiently spans the monitoring period and findings suggest the EPT taxa are not very consistently represented. The causal pathway resulting in poor EPT representation requires an understanding of the physical and chemical characteristics of the stream as well as its watershed. An evaluation process that carefully considers all candidate stressors and causal pathways is required.

## 3.2. Stream Stability

While previous sections have described the general characteristics of the watershed and the quality of water flowing within its creeks, the following section turns the focus to the health of watershed streams from a physical standpoint.

Stream geomorphology and hydrology have a direct influence on stream health and biological integrity. Streams essentially act as conveyance channels for water and sediment flowing through the watershed. Land-use and climate change have a strong influence on stream stability and water quality as described in previous sections. There have been substantial flow increases in most Iowa rivers over the past 30 years contributing to sediment loading from streambanks. The sediment that is eroded contributes to water quality degradation and in-stream aquatic life. Occasionally it can also contribute to increased water elevations downstream if sediment accumulations block conveyances or greatly reduces available storage. In the Squaw Creek watershed data suggests there is an excessive amount of sediment accumulation in the lower reaches of Squaw Creek that may be contributing to higher water levels.

In the upper part of the watershed, stream bank erosion can cause other problems as well. For example loss of farmland from bank erosion can be substantial over time. This was shown by Odgaard (1987) where he calculated that 3000 acres of farmland were lost to bank erosion along the nearby Des Moines River over a 50 year period. Although some of that land is built back via the development of point bars within the river corridor, typically those areas are too sandy and low in elevation to be usable as farmland.

### 3.2.1. **Past Studies**

Much of what will be described in the follow section has been derived from the following two primary studies that were conducted on Squaw Creek and its tributaries.

- Wagner, M.M. (2012). Ames Stream Assessment 2011. Ames, Iowa. Final Report, February 6, 2012.
- Wendt, A. A. (2007). Watershed Planning in Central Iowa: An Integrated Assessment of the Squaw Creek Watershed for Prioritization of Conservation Practice Establishment

The Wagner study was a quantitative analysis limited to the lower watershed (City of Ames portions of Onion Creek, Worle Creek-Squaw Creek and Lundys Creek-Squaw Creek subwatersheds). Forty-one miles of perennial streams where assessed, which includes streams outside of the study area (Ada Hayden Creek & South Skunk River). The study yielded an estimate of sediment loading (from streambanks only) and made a critical temporal comparison between 2006 & 2011 observations. The Wendt assessment covered the entire Watershed, but intentionally excluded ditches. A stream corridor assessment was conducted on randomly selected stretches of Squaw Creek and its major tributaries. Wendt utilized the Iowa Department of Natural Resource developed Rapid Assessment of Stream Condition Along Length (RASCAL) assessment protocol.

### 3.2.2. **Depiction of Stream Resources**

The Squaw Creek watershed contains an estimated ~290 miles of streams, most of which are smaller perennial or intermittent streams. On average about 61% of stream miles in this region are intermittent, meaning that they are dry for a period of the year.

For the purposes of understanding and communication the streams of the Squaw Creek Watershed have been defined by Stream Order. Stream Order is a hierarchy of relative stream size. Stream sizes range from the smallest, first-order, to the largest, the twelfth-order (the Mississippi River is a $10^{th}$ order stream). The largest stream order within this watershed is the main stem of Squaw Creek below the Montgomery Creek confluence, which is a $4^{th}$ order stream.

A portion of the lower order streams in this watershed are formally drainage ditches and/or function as drainage ditches, a percentage of which likely have intermittent flow. Squaw Creek and some if its larger tributaries do have perennial stream flow and may be able to support a variety of fish and aquatic life. See Figure 3-17 for illustration of stream order.

The Wendt (2007) study provides a general perspective of physical characteristics for Squaw Creek Watershed streams. Greater than 58% of all survey sites had sand or finer dominate streambed substrate (Table 3-10). This result is not unexpected, but of note because fine silty or sandy substrates support fewer animals, as there is less cover and reduced levels of oxygen. Additionally, fine substrate is unstable, moving around particularly during times of increased flow such as flooding and this can cause abrasive damage to animals in the waterway.

Relative streambank stability and stream health can be derived from the stream bank 1) stability, 2) % without vegetation and 3) bank height evaluations portrayed in Table 3-11

Also of note from the Wendt (2007) study was the high percentage of livestock access to streams (Table 3-12) and average poor stream condition associated with these sites.

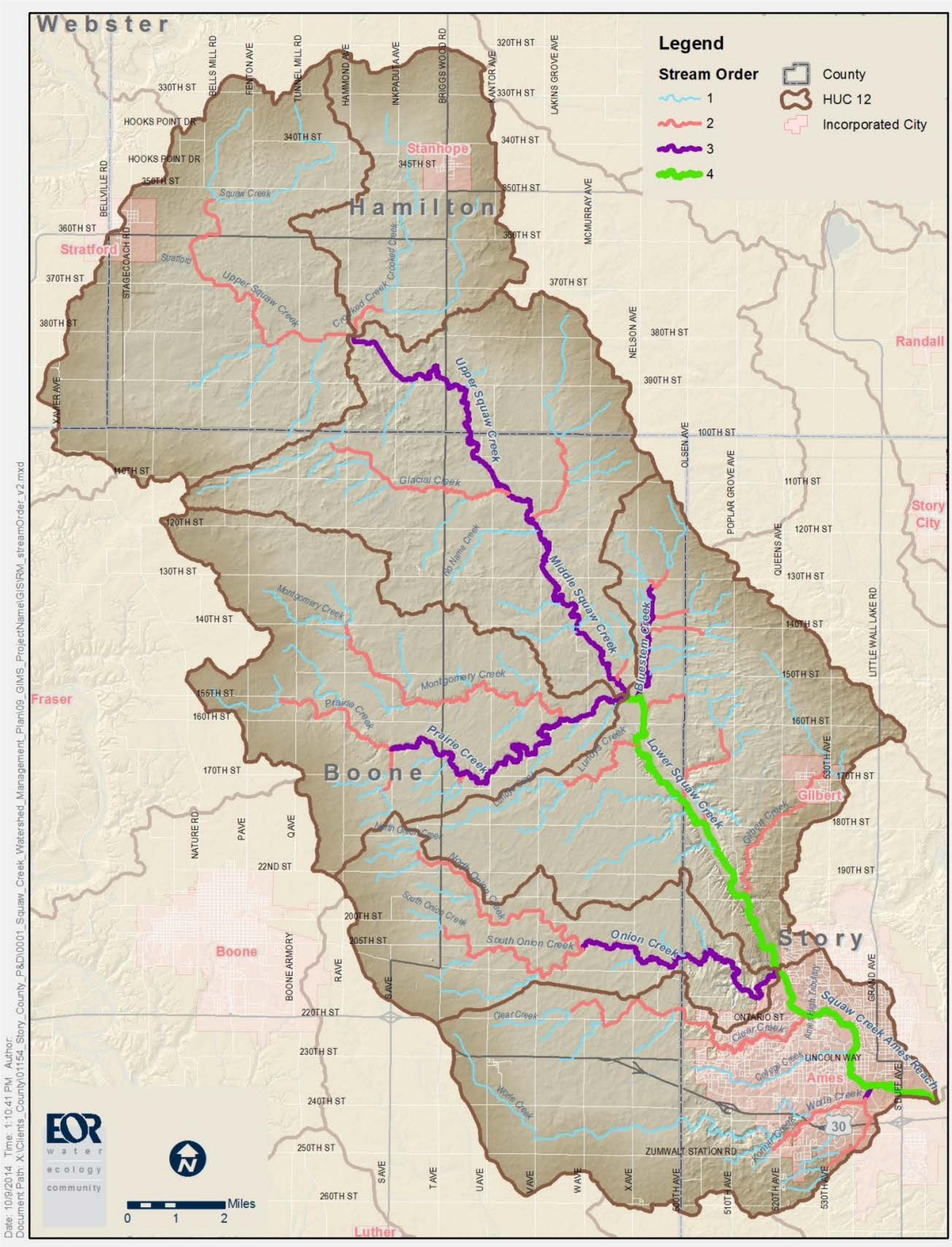



Figure 3-17. Squaw Creek Watershed illustrating Stream Order.

**Table 3-10.** Dominant stream substrate for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

| Substrate | Boulder | Cobble | Gravel | Sand | Silt/clay |
|---|---|---|---|---|---|
| % of each | 5 | 9.1 | 27.6 | 45.9 | 12.4 |

**Table 3-11.** Streambank condition and parameters for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

| Bank stability | Artificially stable | Stable | Moderately Stable | Moderately Unstable | Unstable |
|---|---|---|---|---|---|
| % of surveys | 1.2 | 11.8 | 48.6 | 29.8 | 8.7 |

| % bare banks | 0-20% | 20-40% | 40-60% | 60-80% | 80-100% |
|---|---|---|---|---|---|
| % of surveys | 43.4 | 30.6 | 13.6 | 8.1 | 4.3 |

| Bank height | 0-3 ft | 3-6 ft | 6-10 ft | 10-15 ft | >15 feet |
|---|---|---|---|---|---|
| % of each | 8.7 | 74 | 14.5 | 1.4 | 1.4 |

**Table 3-12.** Livestock access to stream for all streams surveyed within the Squaw Creek Watershed by Wendt (2007); surveys were completed at 340-346 locations

| Livestock access | Yes | No |
|---|---|---|
| % of each | 22.3% | 77.7% |

### 3.2.3. **Stream Conditions in Squaw Creek Watershed**

The integrity of surface waters can be affected by actions on the landscape that are directly adjacent to the waterbody, or at the farthest-most up-gradient point in a watershed. In the case of the Squaw Creek Watershed the compounding hydrology manipulations and changes (e.g. direct connectivity via drainage) as well as the direct stream manipulations (e. g. ditching) have predictable impacts on the tributaries of the watershed. Watershed studies and general observations tell us that upper watershed streams are degrading (lowering of stream bed via scour) and as a result becoming isolated from the floodplain. Streams predictably respond to this unstable state and increased bank erosion occurs in an attempt to evolve to a more stable state. This increase in sediment supply has resulted in the aggradation (sediments raise the stream bed) of some downstream stream reaches. Stability conditions are exacerbated in the lower watershed streams by more impervious surfaces and more stream restrictions (i.e. crossings, bank armament, utilities, etc.).

Channel stability is an important factor determining a stream's overall health. A stable stream is defined as one that can transport water and sediment while maintaining the channel's width, depth, pattern, and longitudinal profile. Stable streams have predictable shapes based on their watersheds. These shapes are dynamic but their proportions stay relatively unchanged. Channel instability (excessive erosion and/or sedimentation) is more likely to be a sign of poor health and a response to stream disturbance.

Drawing on stream assessment components of the Wendt (2007) study, a general snapshot of stream health can be depicted from the bank conditions parameters of the RASCAL survey. Streambank stability is illustrated for the ~346 sites surveyed by Wendt (2007) in Figure 3-18.

More detailed data on the stability and health of stream systems within the City of Ames is available via the Wagner (2012) study. Streambank erosion potential was estimated with the Bank Erosion Hazard Index (BEHI) by Wagner (2012). BEHI is a tool originally developed by David Rosgen as a method of assessing the condition of channel banks, and their potential for erosion, as a way to inventory stream bank condition over large areas and prioritize efforts for remedial action. The system is based on assigning point values to stream segments, preferably 100 feet in length and/or 2-3 meander lengths, based upon a number of bank metrics including ratio of bank height to bankfull height, ratio of root depth to bank height, root density, surface protection, bank angle, bank materials, and stratification of bank material. Wagner collected BEHI data on 35 miles of perennial stream within the study, the results of which is illustrated in Figure 3-19.

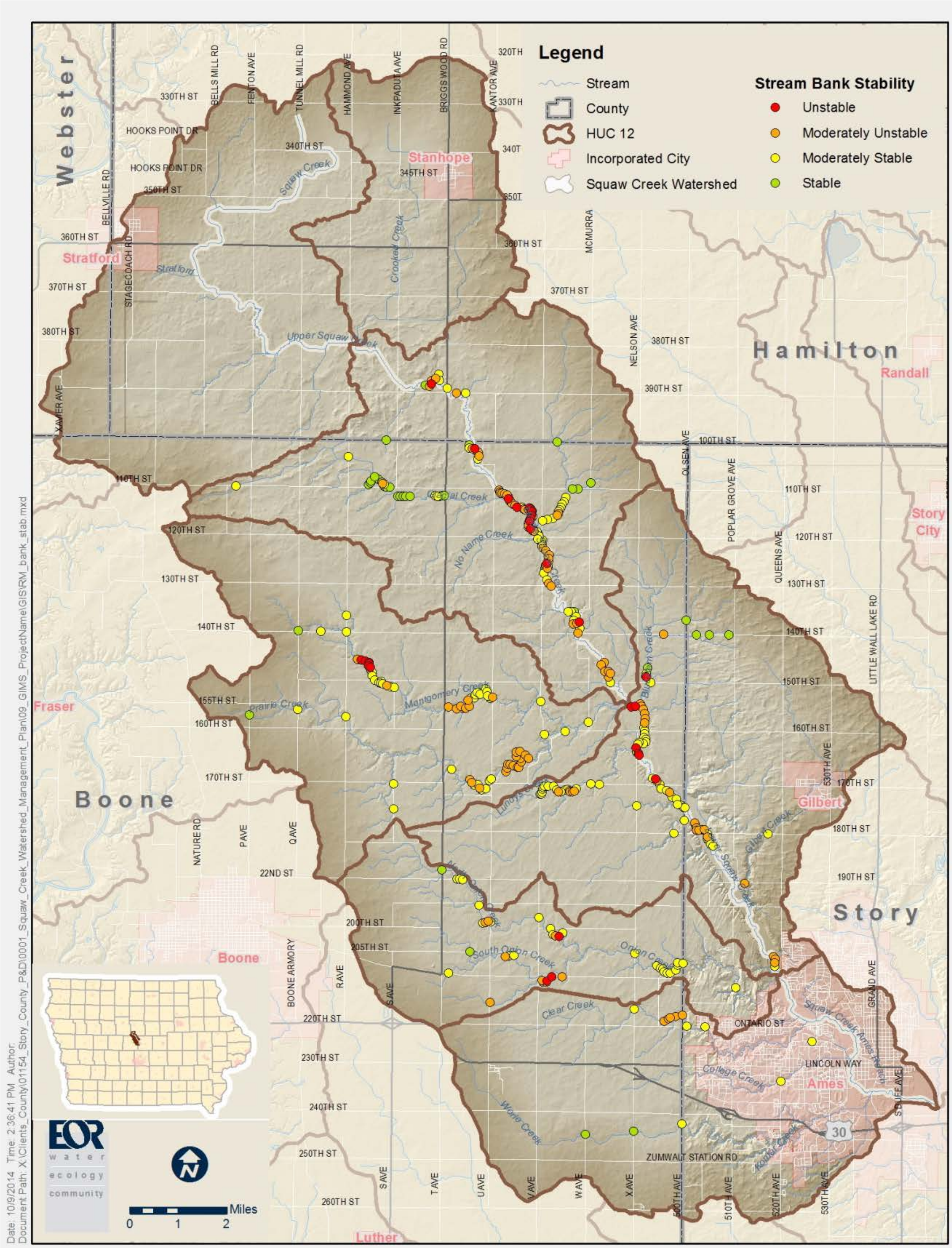



**Figure 3-18.** Streambank stability rating for ~346 sites surveyed; excerpt parameter from Wendt (2007)

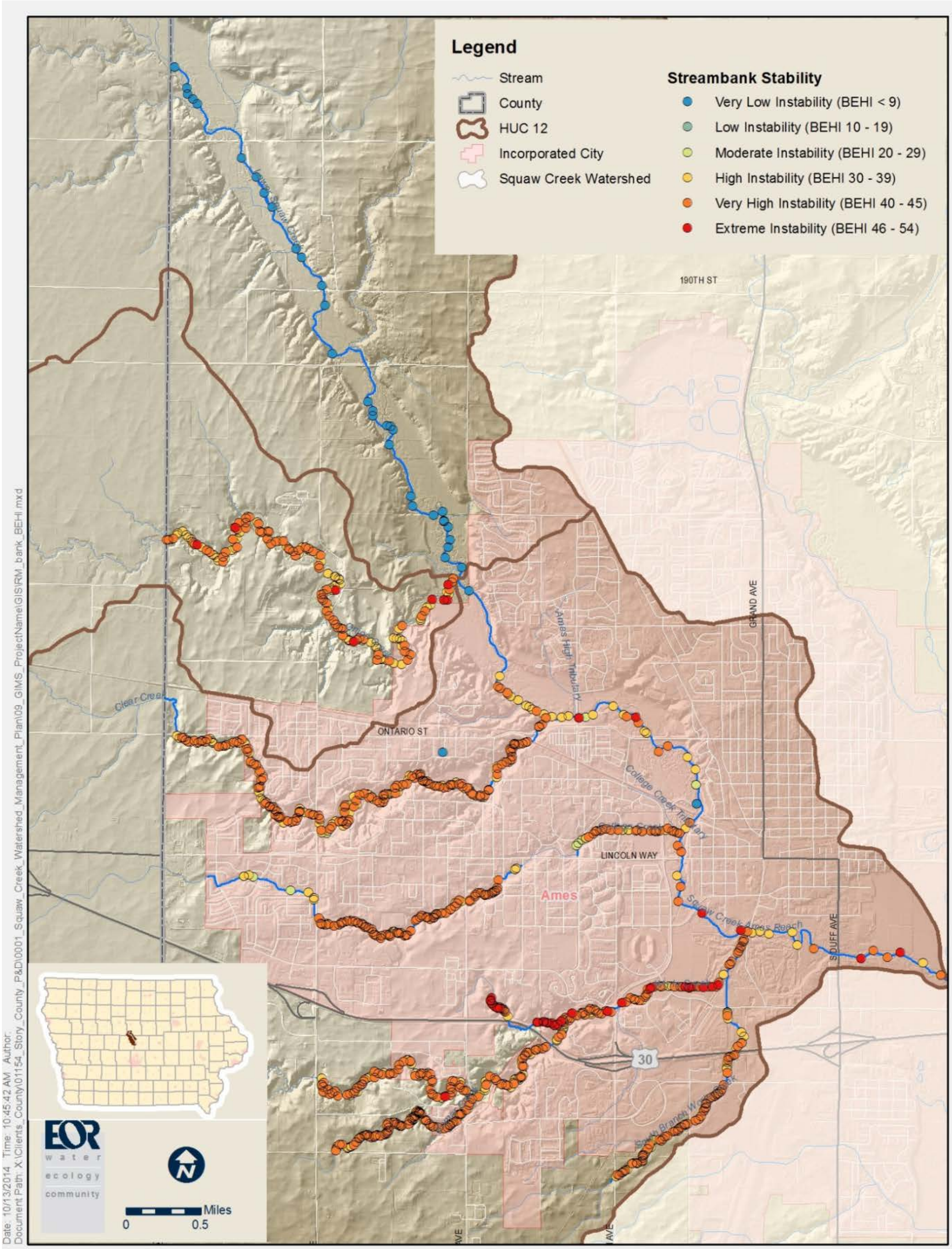



**Figure 3-19.** Streambank stability of Ames streams derived from Wagner (2012) Bank Erosion Hazard Index (BEHI)

Wagner (2012) also assessed and classified the Ames streams using Simon's (1989) six-stage model of channel evolution. Stream segments are reported by the dominant channel process observed: downcutting/widening, aggrading, laterally migrating or stable. Channel evolution is a conceptual model describing the relative stability or instability of stream channel segments. Stability in a channel changes based on changes in stream-edge landcover, disturbances in the channel itself or change in the nature of stormwater runoff reaching it; once a disturbance occurs, the effects on the channel stability are somewhat predictable. The current stage of evolution in a channel is useful in identifying appropriate stabilization or restoration methods. Table 3-13 summarizes the percentage of survey sites by channel stage. Of particular note are the low percentage of stable sites and the high percentage of aggrading sites. Aggradation involves the raising of the streambed elevation, an increase in width/depth ratio, and a corresponding decrease in channel capacity. Over-bank flows occur more frequently with less-than-high-water events. Excess sediment deposition in the channel and on floodplains is characteristic of the aggrading river. Often, the cause of aggradation is an increase in upstream sediment load and/or size of sediment exceeding the transport capacity of the channel. Aggradation can be a result of instability caused by over-widening of the channel with a resultant decrease in stream power and shear stress. Adverse consequences associated with aggradation include channel avulsion (complete abandonment and initiation of a new channel) and major changes in the evolution of stream types. The sediment supply and adverse effects on beneficial uses can be very high due to the corresponding adjustments of the channel.

**Table 3-13.** Channel stability state for streams within the City of Ames, Iowa and vicinity as assessed by Wagner (2012).

| Stream name | % downcutting / widening | % aggrading | % Lateral migration moderate | % lateral migration severe | % stable |
|---|---|---|---|---|---|
| Squaw Creek | - | 61 | 37 | 0 | 2 |
| Onion Creek | 4 | 18 | 65 | 4 | 9 |
| Clear Creek | - | 43 | 48 | 1 | 8 |
| College Creek | - | 9 | 49 | 17 | 25 |
| Worle Creek | 22 | 20 | 25 | 30 | 3 |

The BEHI assessment in combination with estimates of near bank shear stress (NBS) provide an estimate of sediment loading rates from streams within the City of Ames and vicinity. Based on graphs that predict lateral erosion rates from BEHI and NBS values, sediment loading was estimated at 35,000 tons of gross streambank erosion for the river reaches examined in the Wagner study area alone, not including the entire upper watershed (Table 3-14). In terms of sediment loading, streams with higher streambanks tend to contribute more sediment to the total load. In this study the mainstem of Squaw Creek had the highest streambank heights at about 10 feet. Worle Creek had the highest sediment loading rate on a per length basis (0.18 tons / linear foot / year) despite being a much smaller stream. That is because Worle Creek was assessed to be undergoing severe lateral migration over about one-third of its length.

**Table 3-14.** Estimates of gross bank erosion based on the Bank Erosion Hazard Index (BEHI) and near bank shear stress (NBS) for streams within the City of Ames, Iowa and vicinity (not accounting for sediment deposited in the stream) from Wagner 2012

| Stream name | 2011 estimated gross stream bank erosion (tons) | Length of stream surveyed (miles) | loading of sediment by stream banks (Tons/yr/linear ft) |
|---|---|---|---|
| Lower Squaw Creek | 8044 | 9.78 | 0.16 |
| Onion Creek | 3528 | 4.5 | 0.15 |
| Clear Creek | 3889 | 5.25 | 0.14 |
| College Creek | 2526 | 4.4 | 0.11 |
| Worle Creek | 9353 | 9.75 | 0.18 |
| **TOTALS** | 28,340 | 35.11 | 0.15 (avg) |

A substantial percentage of the sediment supply likely originates upstream of the area investigated by Wagner (north of Ames). However, data does not exist to specifically quantify. Coarse estimates can be made by extrapolating existing data from the Worle Creek subwatershed. Using an estimated 180 miles of streams in the watershed reported by Wendt (2007), assuming moderate BEHI and NBS scores with the bank heights in the range of 3-10 feet, a gross annual streambank erosion estimate of 133,000 tons/year is obtained.

Moving into the downstream reaches of Squaw Creek there appears to be considerable deposition of sediment occurring below the Drainage Ditch 70 confluence. Wagner found that 61% of the 9.78 miles of Squaw Creek surveyed were aggrading or accumulating sediment within the channel (Table 3-13). It is possible that much of the sediment mobilized from upstream areas in the large flood of 2010 were carried downstream and deposited in the lower reaches of Squaw Creek. In-stream sediment aggradation can be problematic in that it can increase lateral migration next to areas of sediment deposits. It can also lead to flooding issues if channel capacity is reduced by making the channel shallower. Over time the channel could cut through and/or transport these deposits depending on future stream flow and sediment load levels.

# 4. Pollutant Sources

The following section describes the methodologies used to determine the source and magnitude of pollutant loading from the watershed. The source assessment focuses on flow (as a critical component to load determination – see water quality discussion for further information), nitrogen, phosphorus, sediment and bacteria. The methodology for determining the magnitude of loading for flow, nitrogen, phosphorus and sediment was to construct a Soil and Water Assessment Tool (SWAT) Model whereas the methodology for determining the source of bacteria (*E. coli*) was based on estimates of various source types (animals, humans), bacteria production rates and delivery factors.

## 4.1. SWAT Modeling

The amount of flow and water quality pollutants in a river at any given point in time is a result of a complex set of processes occurring within its upstream watershed. The extents of rainfall and evaporation in both the short term (days) and longer-term (weeks, months) are the primary factors in river flow and water quality patterns. The degree to which soils allow rainfall to soak into the soil and enter the nearest stream via shallow groundwater or drain tile vs. runoff across the land surface is also extremely important.

The proportion of surface runoff vs. groundwater flow greatly influences river water quality in terms of pollutants such as nitrogen, phosphorus and sediment. In the Squaw Creek watershed, because of the nature of the soils and flat, prairie pothole topography, sediment enter rivers via surface runoff while phosphorus and nitrogen are transported to rivers in both surface runoff and drain tile (and/or groundwater flow). Land management such as agricultural cropping and tillage practices as well as urban stormwater practices also affects the nature of flow and pollutants.

To better understand the distribution of flow, nitrogen, phosphorus and sediment sources in the Squaw Creek watershed a hydrologic and water quality model was built using the SWAT modeling framework. SWAT's primary strength is simulation of watershed flow and pollutant loading in agricultural watersheds. Results from the model were critical in targeting and prioritizing source areas for improving water quality downstream. The goal of the modeling phase was to generate a map of small watersheds (<1000 acres) identifying where the most significant pollutant sources were predicted to exist. These "hotspot" subwatersheds would then serve as priority areas to explore reduction strategies by implementing best management practices (BMPs).

The model was used to simulate average annual flow and water quality (nitrate, total phosphorus, sediment) for the period 1994-2010 (i.e., 17-year annual averages). Data required to set up and run the model focused on properties and processes in the watershed that are the primary drivers of flow and water quality: rainfall and evaporation, soils, land cover and management practices, and topography. A summary of data sources is presented in Table 4-1.

**Table 4-1.** Data sources used by the SWAT watershed model

| Required Model Data | Source |
|---|---|
| Precipitation | 2 NWS COOP stations and gridded weather data |
| Evaporation | Temperature, wind speed, dew point, solar radiation from gridded weather data |
| Soils | SSURGO high resolution data (digital county soil survey) |
| Land Cover | Field/Parcel scale data of crop rotations, non-ag land uses |
| Management practices<br>Timing, tillage, fert.<br>Feedlots and manure<br>Drain tile | TAC and local agricultural professionals<br>Iowa DNR maps of feedlots, manure applied areas<br>Public ditch and tile maps; advice from local drain tile professionals |
| Topography | Hydro-corrected LiDAR digital elevation data |

The model was calibrated for flow and nutrient concentrations found at the USGS gaging station in Ames. Calibration is process whereby simulated model data is compared with observed data to evaluate its predictive capability. Model parameters are then adjusted until the model matches the observed data to an acceptable level. In this case, continuous daily flow data measured at the Squaw Creek USGS gauging station in Ames was used to calibrate flow. Nutrient calibration was done through a comparison to annual mean concentrations at the same monitoring station. The model was less rigorously calibrated than is the case with models designed for more intensive uses such TMDL projects. This model was deemed calibrated when reasonable confidence of the model's ability to determine the *relative* distribution of flow and pollutants was reached.

#### 4.1.1. **Priority Source Areas: Volume, Sediment, Phosphorus, Nitrate**

Model results for flow are presented in Figure 4-1. Note that areas of higher flow in the watershed are driven by agricultural tile drainage which drains a higher fraction of infiltrated rainfall to streams than un-tiled land. This is the reason that agricultural land is predicted to have higher flows than urban and residential Ames area. Model results for nitrate are presented in Figure 4-2. Note that areas of higher nitrate are primary a function of drain tile and corn rotations. This combination of practices is predicted to have the highest export of nitrate. Model results for phosphorus are presented in Figure 4-3 and results for sediment are presented in Figure 4-4. Note that areas of higher total phosphorus and sediment are driven by higher slope agricultural areas that are more susceptible to soil erosion. Since soil binds to applied phosphorus fertilizer and manure, sediment and phosphorus export are very interrelated. Additional areas with high phosphorus loading occur in the developed portion of the watershed. The range of values associated with the rankings is found in Table 4-2.

**Table 4-2** Range of Values for Low/Medium/High Ranking for Figures

| Constituent | Low Range | Medium Range | High Range |
|---|---|---|---|
| Sediment – tons/acre | < 0.12 | 0.12 – 0.21 | > 0.21 |
| Total Phosphorus – lb/acre | < 0.50 | 0.50 – 0.77 | > 0.77 |
| Flow – inches/year | < 9.0 | 9.0 – 9.6 | > 9.6 |
| Nitrate lb/acre | < 15.4 | 15.4 – 32.0 | > 32.0 |

Four key general conclusions from the SWAT modeling were:

- Corn and soybean agriculture are estimated to contribute 97% of the nitrogen and 92% of the phosphorus loading in the Squaw Creek watershed.
- Tile drained land (which is estimated to comprise 70% of the total agricultural area) is estimated to contribute 86% of the total nitrogen loading in the Squaw Creek watershed.
- Approximately 33% of the total agricultural N and P loads are estimated to originate from 20% of the agricultural land.
- Urban areas are estimated to contribute roughly equivalent amounts of phosphorus per acre compared to corn and soybean agriculture; given urban landuse comprises about 5% of the total land area, it contributes about 5% of the total watershed P loading.

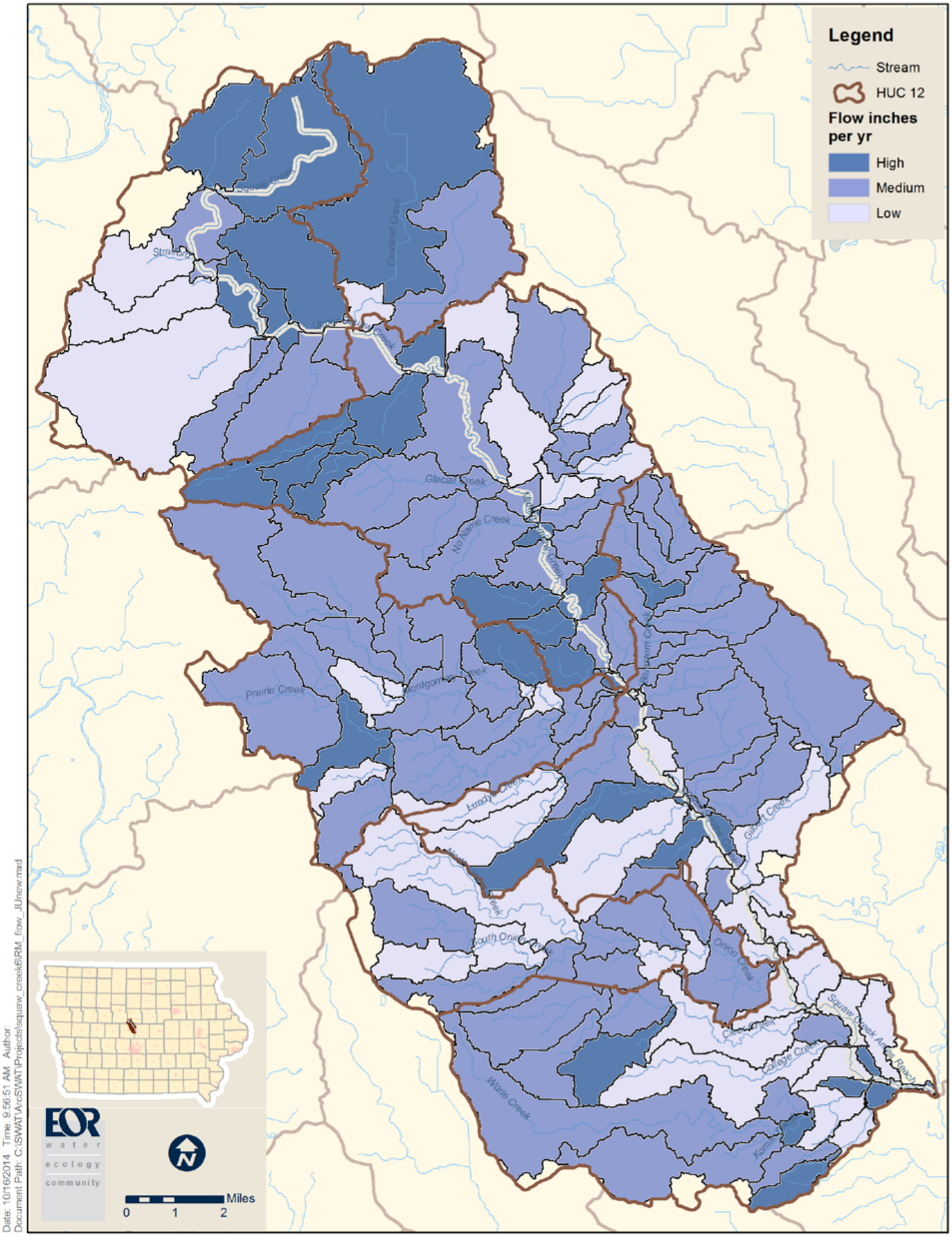



**Figure 4-1.** SWAT Model Flow by Drainage Area (inches/year)

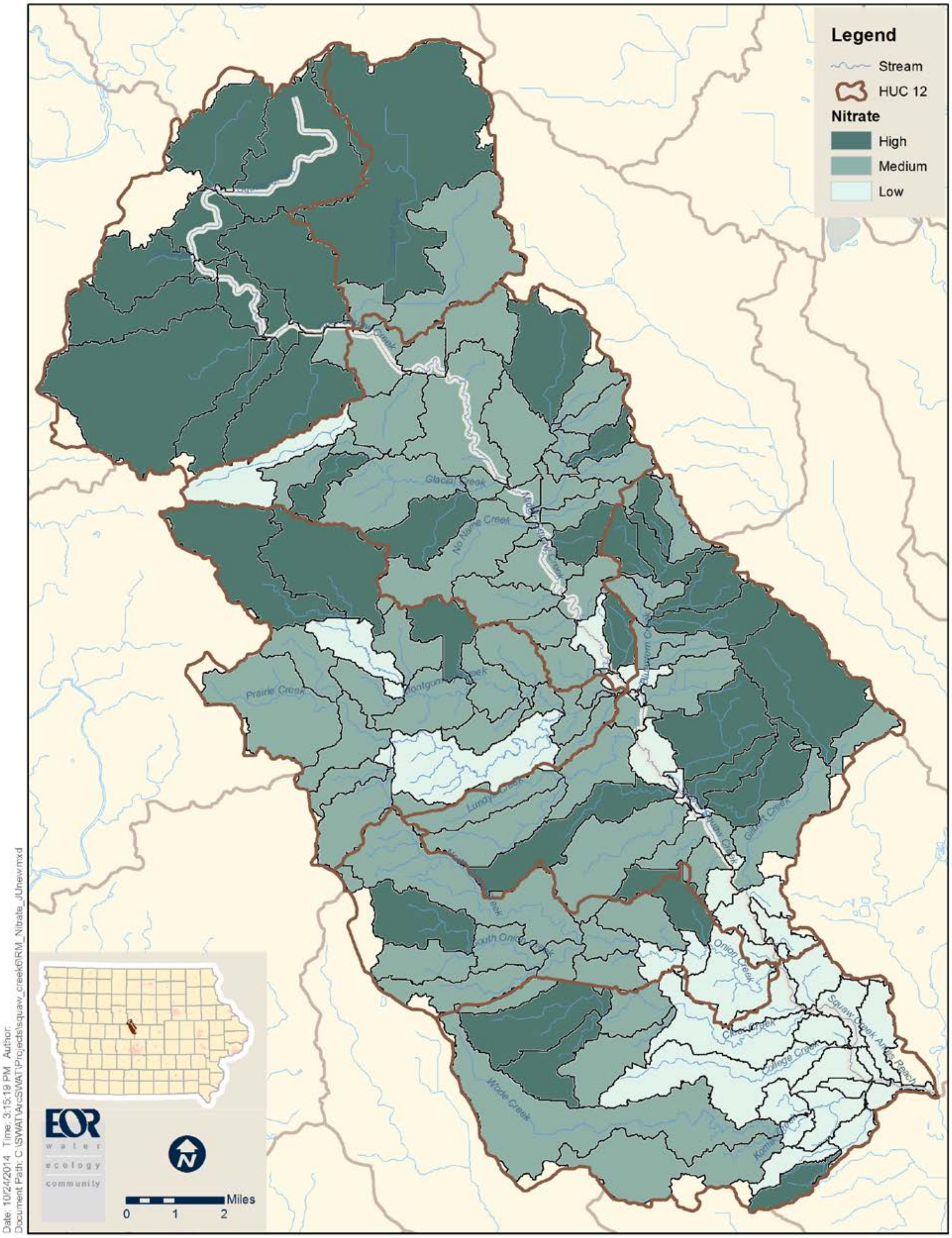



**Figure 4-2.** SWAT Model Nitrate Load by Drainage Area (lbs/acre per year)

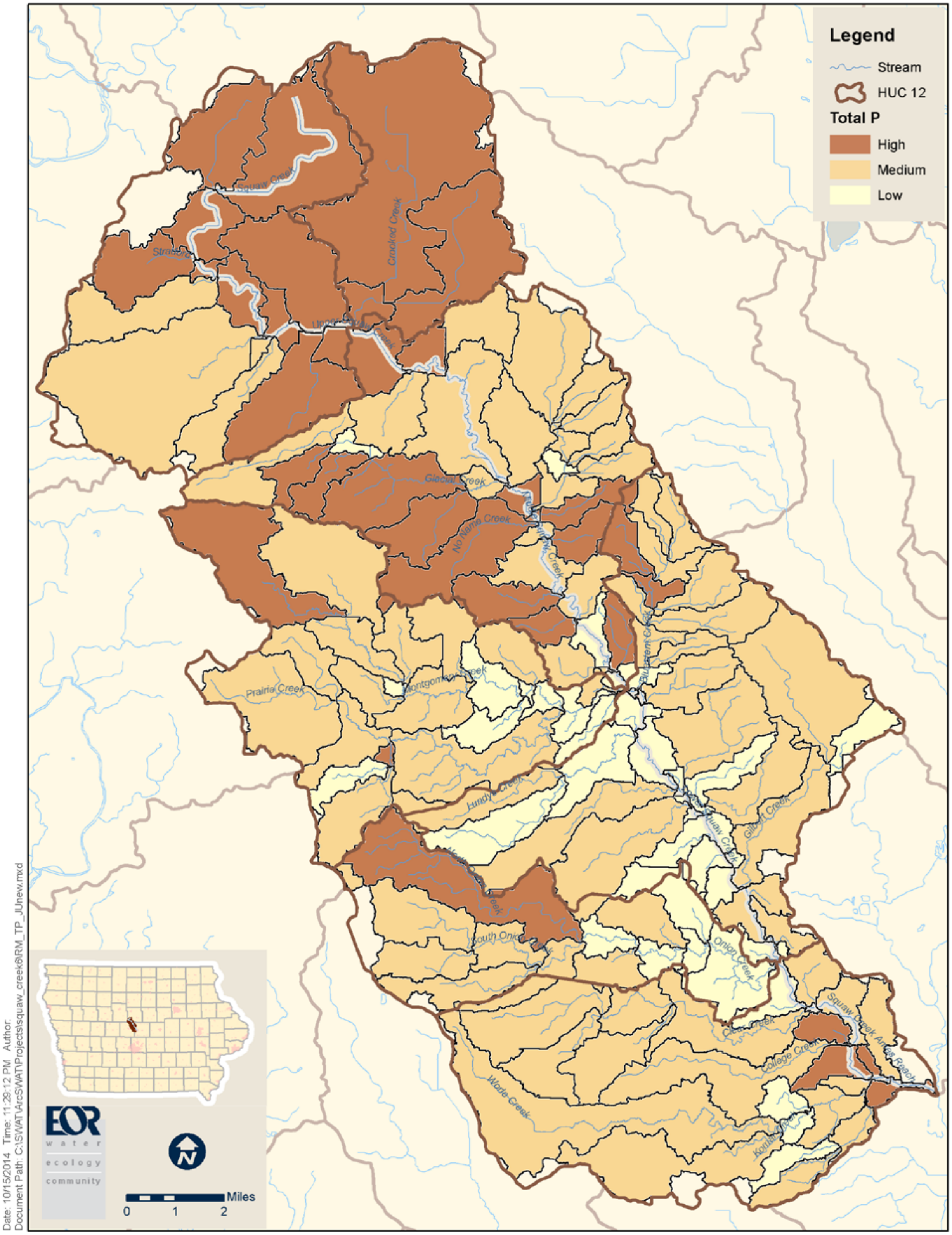



**Figure 4-3.** SWAT Model Phosphorus Load by Drainage Area (lbs/acre per year)

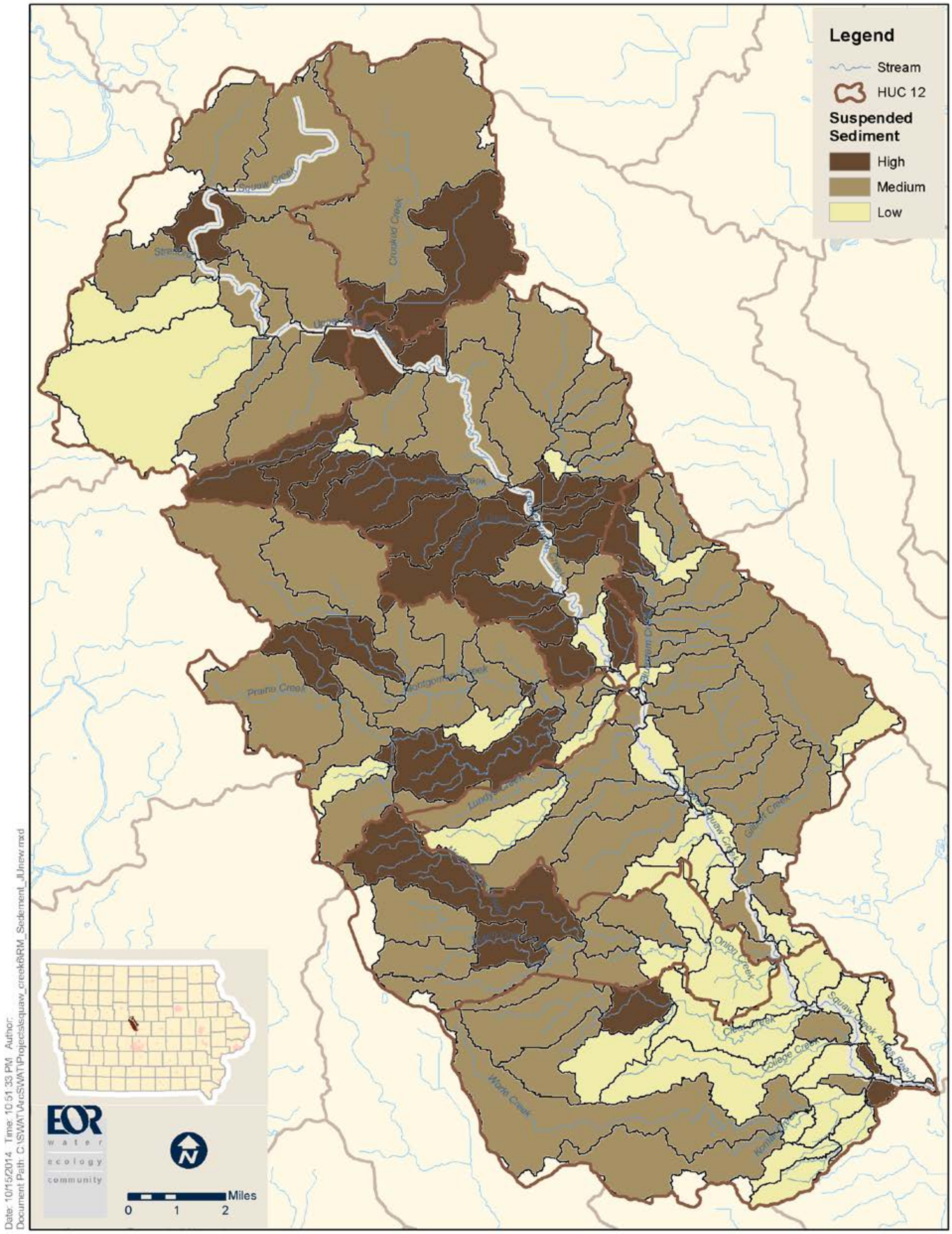



**Figure 4-4.** SWAT Model Sediment Load by Drainage Area (tons/acre per year)

## 4.2. Bacteria Source Assessment

Humans, pets, livestock, and wildlife all contribute bacteria to the environment. These bacteria, after appearing in animal waste, are dispersed throughout the environment by an array of natural and man-made mechanisms. Bacteria fate and transport is affected by disposal and treatment mechanisms, methods of manure reuse, imperviousness of land surfaces, and natural decay and die-off due to environmental factors such as ultraviolet (UV) exposure and detention time in the landscape. The following discussion highlights sources of bacteria in the environment and mechanisms that drive the delivery of bacteria to surface waters.

To evaluate the potential sources of bacteria to surface waters and to assist in targeting future reduction strategies, a desktop analysis was conducted for sources that are potentially contributing *E. coli* in the watershed. These populations may include livestock (cattle, swine or poultry), humans and wildlife (deer).

Populations were calculated using published estimates for each source on an individual subwatershed basis in the Squaw Creek Watershed. This is typically a GIS exercise where population estimates are clipped to the individual subwatershed boundaries.

Bacteria production estimates are based on the bacteria content in feces and an average excretion rate (with units of colony forming units (cfu)/day-head; where *head* implies an individual animal). Bacteria content and excretion rates vary by animal type, as shown in Table 4-3. All production rates obtained from the literature are for fecal coliform rather than *E. coli* due to the lack of *E. coli* data. The fecal coliform production rates were converted to *E. coli* production rates based on 200 fecal coliforms to 126 *E. coli* per 100 mL.

**Table 4-3.** Bacteria production by source

| Source Category | Producer | *E. coli* Production Rate [cfu/day-head] | Literature Source |
|---|---|---|---|
| Humans | Humans | 1.26 x 109 | Metcalf and Eddy 1991 |
| Companion Animals | Dogs | 3.15 x 109 | Horsley and Witten 1996 |
| Livestock | Cattle | 2.08 x 1010 | Zeckoski et al. 2005 |
| | Hogs | 6.93 x 109 | Zeckoski et al. 2005 |
| | Poultry | 6.76 x 107 | Zeckoski et al. 2005 |
| Wildlife | Deer | 2.21 x 108 | Zeckoski et al. 2005 |

### 4.2.1. **Humans**

Human sources are divided by whether the waste is collected and sent to a Waste Water Treatment Facility (WWTF) or if it is treated by an individual system.

#### *Waste Water Treatment Facilities*

The WWTFs located in the Squaw Creek Watershed with surface water discharges are summarized in Table 4-4. Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 126 org/ 100 mL (Table 4-4). Note that while a large portion of the City of Ames is in the watershed the discharge location of the waste water treatment facility is into the South Skunk River rather than Squaw Creek so it is not included here. Issues related to the maintenance and potential breaks of the waste water collection system would still have an impact on Squaw Creek but those sources are not accounted for in this methodology since known issues have been addressed in the past and the City and volunteers actively monitor the system for failures and address them when found.

**Table 4-4.** WWTP design flows and permitted bacteria loads

| Subbasin | Name of WWTF | Permit # | Design Flow [mgd] | Equivalent Bacteria Load as *E. coli*: (billion org/day) |
|---|---|---|---|---|
| Crooked Creek | Stanhope STP | 4045001 | 0.085 | 0.405 |
| Lundys Creek – Squaw Creek | Gilbert STP | 8531001 | 0.125 | 0.596 |
| | South Squaw Valley | 8500302 | 0.020 | 0.095 |
| Worle Creek – Squaw Creek | United Community School | 0800500 | 0.0037 | 0.018 |

#### *Individual Septic Systems*

Unsewered populations were determined using the 2010 Census data (U.S. Census Bureau 2011). Total unsewered population was obtained for each subwatershed using block groups; census block groups that overlap subwatershed boundaries were distributed between each applicable subwatershed on an area-weighted basis. Only rural populations were assumed to be unsewered. So, block groups that fell within the city limits of Ames, Stanhope, Gilbert, and Stratford were not included. It was assumed that subsurface sewage treatment systems (SSTS) were installed to treat raw sewage from this rural population. "Failing" SSTS are specifically defined as systems that are failing to protect groundwater from contamination. Failing SSTS were not considered a source of fecal pollution to surface water. However, systems which discharge partially treated sewage to the ground surface, road ditches, tile lines, and directly into streams, rivers and lakes are considered an imminent threat to public health and safety (ITPHS). ITPHS systems also include illicit discharges from unsewered communities (sometimes called "straight-pipes"). Straight pipes are illegal and pose an imminent threat to public health as they convey raw sewage from homes and businesses directly to surface water. Community straight pipes are more commonly found in small rural communities. The number and specific location of ITPHS are unknown for the watershed so two thresholds were used so that the relative contribution from ITPHS to the total load of bacteria in the watershed could be determined Table 4-5. This table is not intended to suggest that ITPHS systems contribute excess bacteria to Squaw Creek.

**Table 4-5.** Estimates of rural population based on 2010 Census data and ITPHS population in each subwatershed

| Subwatershed | Estimated Rural Population | ITPHS Load 10% Failure Rate (billion org/day) | ITPHS Load 50% Failure Rate (billion org/day) |
|---|---|---|---|
| Crooked Creek | 189 | 23.8 | 119.1 |
| Drainage Ditch 192 – Squaw Creek | 346 | 43.6 | 218.0 |
| Montgomery Creek | 504 | 63.5 | 317.5 |
| Crooked Creek – Squaw Creek | 495 | 62.4 | 311.9 |
| Onion Creek | 639 | 80.5 | 402.6 |
| Lundys Creek – Squaw Creek | 1,205 | 151.8 | 759.2 |
| Worle Creek – Squaw Creek | 777 | 97.9 | 489.5 |

#### 4.2.2. **Livestock**

The total number of livestock in each subwatershed was estimated by the Iowa DNR animal feeding operation (AFO) database and the 2012 USDA Agricultural Census county data. The DNR AFO database is current to 2014 and the registered number of animals is known. AFO's with less than 500 animal units (AU) are not required to register with the Iowa DNR or obtain a manure management plan. Therefore, in order to estimate the number of unregistered animals in the watershed, data from the 2012 USDA Agricultural Census was used and then area-weighted to each subwatershed.

**Table 4-6.** Livestock summary results by subwatershed in animal units

| | Registered | | Estimated Unregistered | | |
|---|---|---|---|---|---|
| Subwatershed | Pigs (billion org/day) | Cows (billion org/day) | Pigs (billion org/day) | Cows (billion org/day) | Poultry (billion org/day) |
| Drainage Ditch 192 – Squaw Creek | 26,805 | 0 | 310 | 3,296 | 0.29 |
| Crooked Creek | 84,906 | 0 | 633 | 7,811 | 0.60 |
| Crooked Creek – Squaw Creek | 51,656 | 30,146 | 337 | 11,670 | 0.73 |
| Montgomery Creek | 4,990 | 0 | 513 | 12,105 | 0.82 |
| Lundys Creek – Squaw Creek | 6,071 | 0 | 302 | 6,615 | 0.40 |
| Onion Creek | 16,632 | 0 | 1,213 | 13,075 | 0.75 |
| Worle Creek – Squaw Creek | 12,058 | 17,048 | 468 | 7,956 | 0.48 |

### 4.2.3. **Wildlife**

Bacteria can be contributed to surface water by wildlife (e.g. raccoons, deer, geese, and ducks) dwelling in waterbodies, within conveyances to waterbodies, or when their waste is carried to stormwater inlets, creeks, and ditches during stormwater runoff events.

No reliable wildlife population estimates were available besides for annual deer estimates by county. Therefore, only deer were included in wildlife as a source. Surveys conducted by the DNR from 2007 through 2012 were used to calculate an average deer population by county and then area-weighted to each subwatershed. Based on previous assessment deer represent approximately one half of the wildlife *E. coli* contribution. Table 4-7 summarizes the estimate contribution from deer based on DNR survey and the resultant estimate for all wildlife by subwatershed.

**Table 4-7.** Deer bacteria estimates by subwatershed

| Subwatershed | Deer *E. coli* (billion org/day) | Wildlife *E. coli* (billion org/day) |
|---|---|---|
| Drainage Ditch 192 – Squaw Creek | 8.3 | 16.6 |
| Crooked Creek | 21.3 | 42.6 |
| Crooked Creek – Squaw Creek | 39.5 | 79 |
| Montgomery Creek | 38.4 | 76.8 |
| Lundys Creek – Squaw Creek | 21.9 | 43.8 |
| Onion Creek | 39.6 | 79.2 |
| Worle Creek – Squaw Creek | 34.3 | 68.6 |

### 4.2.4. **Pets**

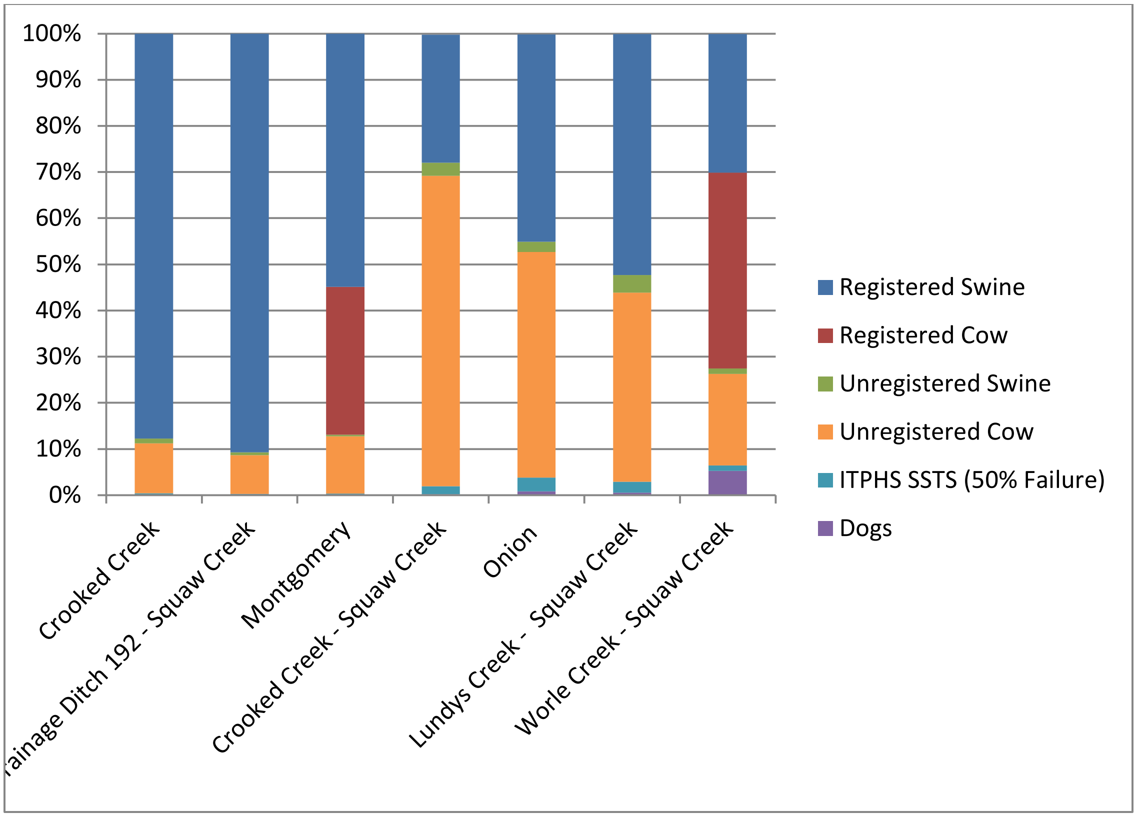
Pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways. The contribution of pet waste to waterbodies is more pronounce in urban areas where impervious surfaces and storm sewer network allow waste to easily wash off into streams. It is less significant in rural areas where the waste is typically trapped on the landscape. Pet populations within the watershed were estimated using American Veterinary Association estimates of dogs and cats per household and Tiger block census data. An adjustment factor was applied to impervious surfaces.

**Table 4-8** Pet bacteria estimates by subwatershed

| Subwatershed | Pets *E. coli* (billion org/day) |
|---|---|
| Drainage Ditch 192 – Squaw Creek | 15 |
| Crooked Creek | 52 |
| Crooked Creek – Squaw Creek | 29 |
| Montgomery Creek | 36 |
| Lundys Creek – Squaw Creek | 108 |
| Onion Creek | 167 |
| Worle Creek – Squaw Creek | 2109 |

### 4.2.5. **Priority Bacteria Source Areas**

The source assessment information is summarized by subwatershed in Figure 4-5 with the relative abundance of each source shown. Note, again, that these numbers refer to the production of bacteria from each source based on the estimated populations within the watershed as described above. There is no direct correlation from any of these sources to the bacteria concentrations that are found in the stream. The assessment is provided to show what the likely sources are so that efforts can be prioritized. The locational information developed in estimating the livestock numbers is provided in Figure 4-6 as a way of identifying potential hot spots for bacteria. Further prioritization is provided in Figure 4-7 where areas of likely high bacteria production are intersected with the streams. The priority areas indicate where manure could potentially be applied within 1000 ft of a stream based on the assessment methodology conducted. Note that there is NO evidence to suggest that manure is actually being applied near the streams in any of these areas.




*Note that WWTP, unregistered poultry estimates, and wildlife are not shown because they contribute <1% of the total bacteria load in each subwatershed.

**Figure 4-5.** Relative bacteria load by source in each subwatershed

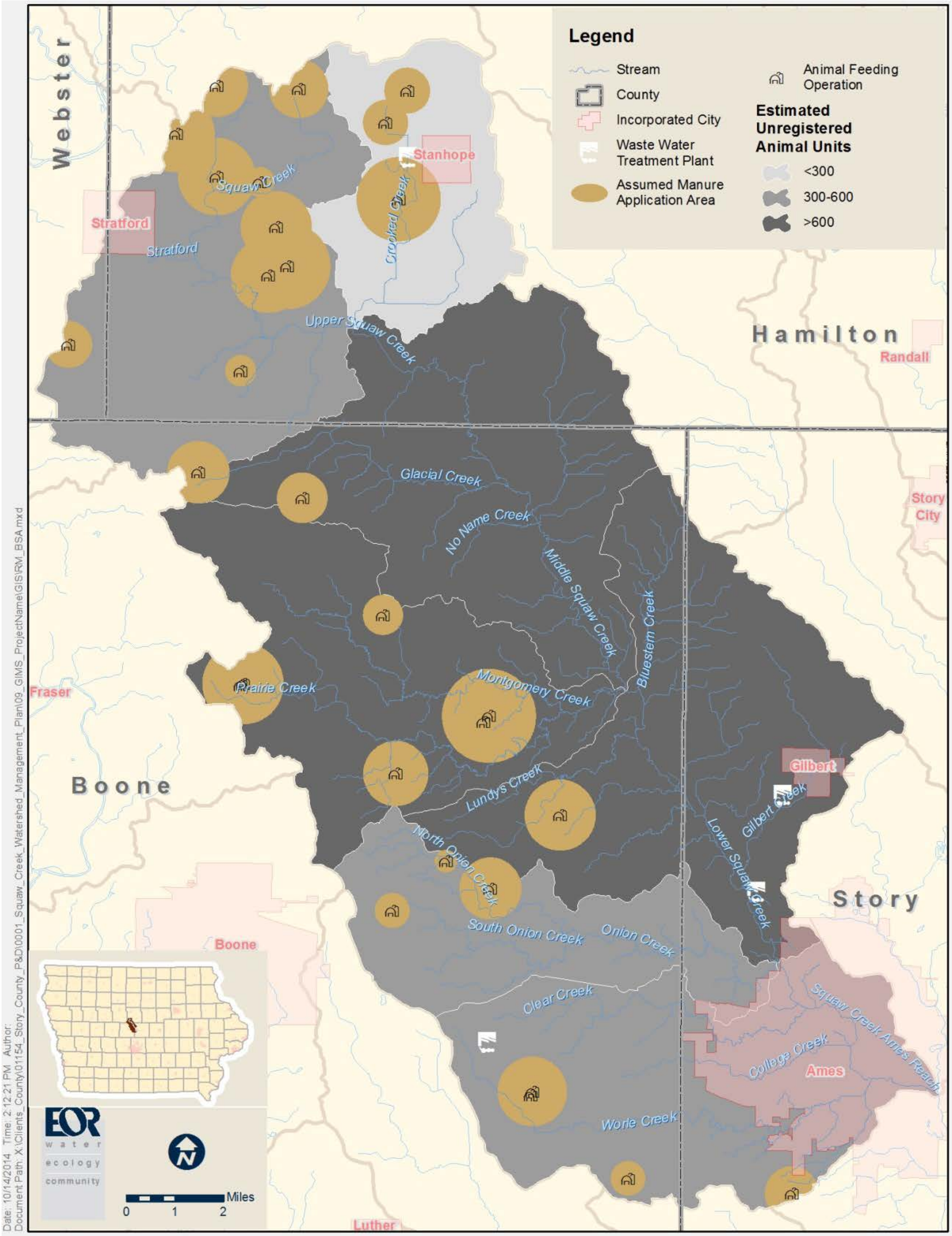



**Figure 4-6.** Bacteria sources in the Squaw Creek Watershed

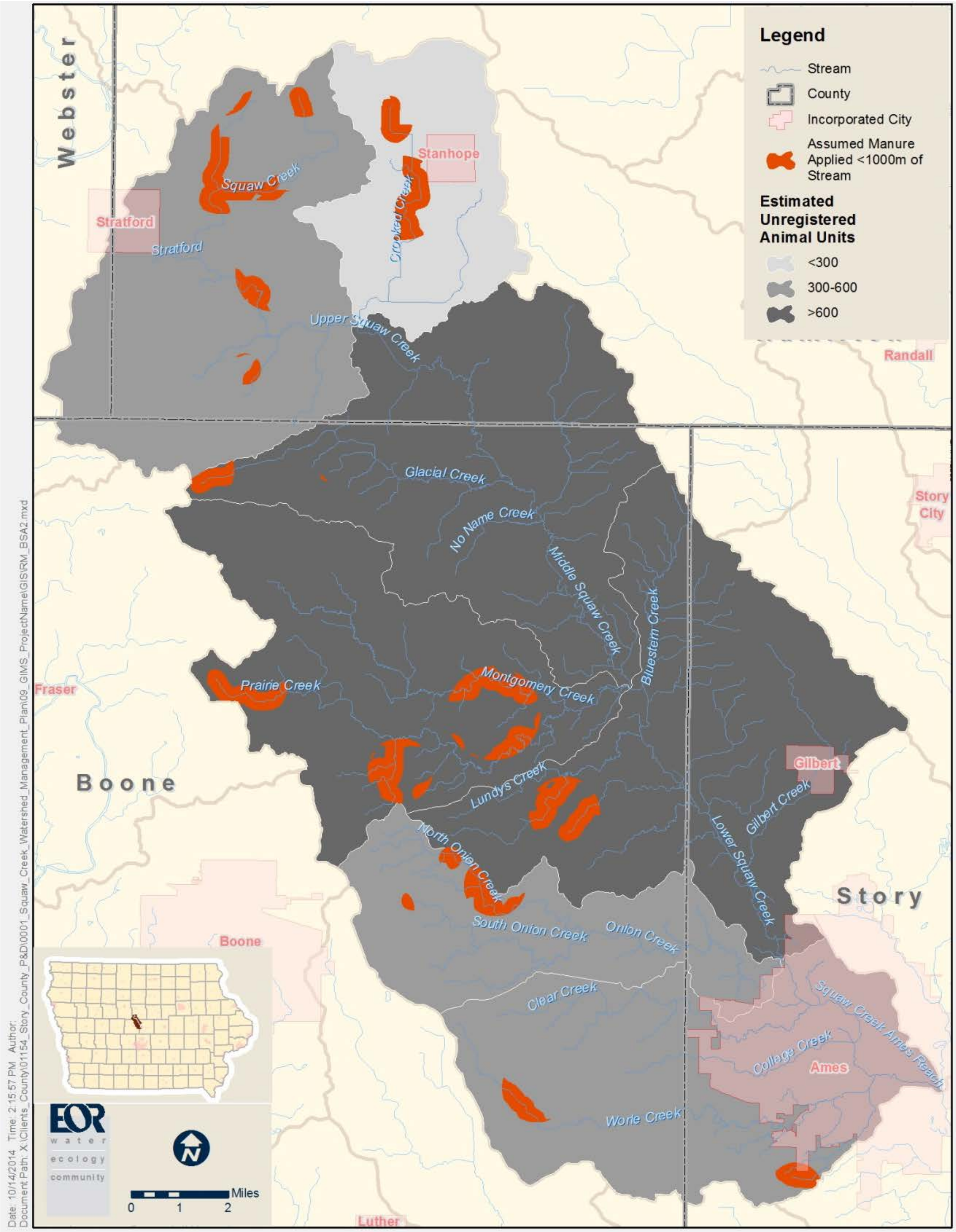



**Figure 4-7.** Manure Management Priority Areas

# 5. Goals and Objectives

The WMA developed the following set of goals and objectives through a series of meetings during the summer of 2014. The goals were developed based on input received from area residents during listening sessions held around the watershed and were built around an understanding of the watershed formed by the assessment work described in earlier chapters of the plan.

## 5.1. Increase people's awareness and understanding of the individual connections and efforts within the watershed

Two elements of this goal are to raise awareness of watershed issues AND for that awareness to be translated into action. Residents, businesses and landowners will become familiar with the concept of what a watershed is and will understand how land uses and practices within the watershed effects streams.

Increasing awareness of watershed issues; namely, how our actions on the land affect the character of our waters, is a fundamental goal of the watershed management plan. Creating an informed community and empowering residents to become stewards of the watershed is the foundation of a successful watershed management organization. The ability to affect change within a watershed is most powerful when it originates from local residents.

While the planning process began to introduce the concepts of watershed management to local officials and residents in the area, there is still a need to increase the basic understanding of watershed dynamics. This begins with the basic concept that, while the creeks in the area are severely degraded they do present an opportunity to be a valuable asset to the community. Without this core understanding, it is difficult to convince people that action is needed. Building on this concept, the next step is to make the connection between the actions we take and the affect those actions have to the creeks. Finally, it is critical to illustrate that there are things that can be done in the watershed to improve the quality of the creeks.

***Education/Outreach Objectives***

*Objective 1.1 Conduct an on-going marketing campaign to raise awareness of watershed problems, causes, possible remedies, opportunities, organization goals, and cooperative initiatives being undertaken*

*Objective 1.2 Develop a watershed stewardship ethic among landowners, producers and managers, business owners, residents and local government*

*Objective 1.3 Enhance awareness of recreation activities and opportunities along the creek*

***Water Quality Objectives***

*Objective 2.1 Achieve a 29% reduction in Total Phosphorus based on the Iowa Nutrient Reduction Strategy*

*Objective 2.2 Achieve a 41% reduction in Nitrogen based on the Iowa Nutrient Reduction Strategy*

*Objective 2.3 Meet the Iowa E. Coli bacteria Standard*

*Objective 2.4 Determine existing turbidity levels and develop goal for improving turbidity and clarity within the streams of the watershed*

*Objective 2.5 Monitor the condition of water quality in the watershed to detect trends and to evaluate the success of watershed management activities*

## 5.2. Improve water quality in the watershed.

Ultimately the goal is to improve water quality in the watershed so the streams can be safely used by residents and visitors. The main water quality constituents of concern are fecal bacteria, sediments and nutrients which lead to algal blooms. Improving water quality within Squaw Creek is the cornerstone of the watershed management plan. The WMA developed several specific objectives by which they will measure progress towards achieving this goal. The implementation portion of the watershed management plan contains a detailed strategy for meeting these objectives.

The rationale behind the specific numerical objectives for this goal is based on observed conditions (monitoring data) from the watershed and either the Iowa Chapter 61 Water Quality Standards or the specific reduction level identified in the Iowa Nutrient Reduction Strategy.

**For phosphorus the objective is to achieve a 29% reduction in phosphorus loading from the watershed.** This level of reduction is based on the Iowa Nutrient Reduction Strategy which establishes this as the goal for non-point source (watershed) load for the state. The outcome of this load reduction in terms of water quality in the creek can be estimated using the average existing concentration of total phosphorus in Squaw Creek at the monitoring station at Lincoln Way in Ames which is ~ 300 µg/. The 29% reduction in watershed phosphorus loading would result in an in-stream TP concentration of approximately 213 µg/. A comparison of that resultant concentration with alternative standards is shown in Table 5-1.

**For nitrogen the objective is to achieve a 41% reduction in phosphorus loading from the watershed.** This level of reduction is also based on the Iowa Nutrient Reduction Strategy which establishes this as the goal for non-point source (watershed) load for the state. The outcome of this load reduction in terms of water quality in the creek can be estimated using the average existing concentration of nitrate-nitrogen in Squaw Creek at the monitoring station at Lincoln Way in Ames which is 6.8 mg/. The 41% reduction in watershed loading would result in an in-stream nitrate-nitrogen concentration of approximately 3.8 mg/. A comparison of that resultant concentration with alternative standards is shown in Table 5-1.

**For *E. coli* bacteria the objective is to meet the Iowa Chapter 61 Water Quality Standard of 126 organisms/100ml** expressed as the geometric mean of growing season measurements. This is a public health based standard and accordingly applies to all streams that have recreational use or simply have human contact.

Turbidity measurements have not been taken to an adequate level in Squaw Creek to allow for a concrete determination of existing conditions. Transparency measurements have been collected historically but a correlation to turbidity is not available. There is not a state standard or a reduction strategy developed for turbidity at this time. As a consequence, the objective for turbidity is to determine the existing levels and develop a goal or improvement (existing turbidity levels are assumed to be high based on visual observation).

The specific objectives were developed through discussion with the WMA Board members. Several alternative objectives representing a range of standards were considered. The State Standards and Nutrient Reduction Strategies were selected as the most reasonable, defensible levels. The range of standards that were considered for phosphorus and nitrogen are shown in Table 5-1.

**Table 5-1** Range of Standards/Criteria for Nutrients

| Existing Condition @ USGS Gage Lincoln Way | | Iowa Nutrient Reduction Strategy | MN State Standard | EPA Ecoregion 25th percentile | Draft Iowa State Criteria | EPA Ecoregion Average |
|---|---|---|---|---|---|---|
| Phosphorous | 300 µg/L | 213 µg/L | 150 µg/L | 118 µg/L | 100 µg/L | 76 µg/L |
| Nitrogen | 6.5 mg/L | 3.8 mg/L | NA | 3.3 mg/L | NA | 2.18 mg/L |

A monitoring plan has been developed for the watershed and can be found in Section 7 Monitoring Plan. The plan will allow the WMA to evaluate trends in water quality and to assess the effectiveness of their efforts.

## 5.3. Reduce the effects associated with altered hydrology (heavy flows, diminished base flow) within the watershed.

The goal is to restore a more natural flow regime (magnitude, frequency, duration, timing/seasonality & rate of change) by reducing hardscape/urban connectivity, storing water in appropriate places within the watershed and increasing shallow groundwater recharge. Restored hydrology will result in less erosive, destructive flows within the stream and will increase the natural base-flow within the stream during times of draught. Property loss due to erosion and sedimentation will also be reduced.

This WMA goal focuses on addressing heavy flows and diminished base flows that occur in the stream because these are the conditions that limit recreational use of the creek, diminish aquatic habitat, and cause property damage.

The goal is to restore a more natural flow regime. In general terms, natural hydrologic systems display less extreme conditions than those of altered watersheds. Altered hydrologic systems are typically described as "flashy". Streams respond very quickly and dramatically to storm events. Even minor storms cause increases in stream flow. Watersheds with natural hydrology have more tempered responses to storm events. In a natural watershed rainfall typically soaks into the ground, is stored within the soil and is taken up by vegetation rather than being shed off the land and into the stream. As a result, more water moves within the soil either moving vertically into the groundwater aquifer or flowing laterally to slowly contribute base flow to the stream.

While quantifiable objectives have not been developed, the following describes the desired changes in hydrologic conditions for the watershed.

The magnitude of high flow rates will be lessened over time. Magnitude refers to the maximum flow rate within the stream. While we have no control over the severity of rains, the stream response to a given storm event is a function of the health of the watershed. Reducing the magnitude of streamflows is important as these flows result in the most

***Hydrology Objectives***

*Objective 3.1 The watershed will continue to provide ample clean water to replenish local aquifer/drinking water supplies.*

*Objective 3.2 Critical groundwater recharge areas within the watershed will be identified and protected*

*Objective 3.3 Peak streamflow rates resulting from small, common rainfall events (2 year peak discharge rates) will be reduced from current conditions*

*Objective 3.4 Peak streamflow rates resulting from large rainfall events (100-year peak discharge rates) will be reduced from current conditions*

*Objective 3.5 Shallow groundwater recharge of streams in the watershed will be increased*

*Objective 3.6 Restore hydrology and consistent baseflow to the creek and its tributaries* damage to streambanks and the greatest threat to property.

It is common practice to use the 100 year storm event when evaluating “large” storm events. The WMA acknowledges that the type of watershed improvements contemplated by this watershed management plan will have limited impact on these very large storm events. During these types of events, most of the watershed is saturated, meaning that most of the storage has been taken up and all runoff flows directly to the stream. However, the types of practices that the WMA is encouraging will have a combined positive affect on the hydrology of the watershed and, given enough adoption could eventually improve the watershed response to extreme storm events.

Critical flow rates (those flow rates that cause most damage within the stream) will occur less frequently. As with the magnitude of high flow rates, a healthy watershed will dampen the stream response for storm events which will result in less frequent damaging steamflows. In addition to the magnitude and frequency, the duration for which a stream is at critical flow rate is an important consideration and is tied to the health of the watershed.

The stream response to small rainfall events is a common measuring stick used in watershed management to gauge the health of the watershed. Small rainfall events are typically defined as any rainfalls that are less than 2-year storms. These storm events are important from a water quality standpoint because they account for the vast majority of runoff on an average annual basis. In some areas as much as 95% of the storm related flows can be attributed to storm events under the 2 year event.

Restoring the natural hydrology of the watershed will also replenish the shallow groundwater flow that is important in maintaining stream baseflow. Reestablishing the balance between surface and shallow groundwater flows can minimize the periods when the larger streams have no flow and help maintain flow for longer periods of time for streams that are intermittent or ephemeral. Lack of reliable flow has been identified as one of the primary stressors to aquatic life in Squaw Creek.

In addition to restoring the flow of water within the shallow groundwater system, a healthy watershed will also help to replenish the local aquifer. The interaction between surface and groundwater is extremely complex, particularly so in the Squaw Creek Watershed. Throughout the Squaw Creek corridor there are areas where water from the creek is being lost to the aquifer and other areas where groundwater is being discharged into the stream.

The importance of maintaining a healthy supply of drinking water cannot be overstated. In many areas around the region drinking water supplies are at risk due to excessive pumping, inadequate recharge or as a result of polluted surface water.

An important first step in protecting the local drinking water aquifer is to identify the areas within the watershed that are recharging surface water to the groundwater system. The level of protection afforded these areas should be very high. Protection strategies would focus on the land use activities within these critical areas such as storage of chemicals, paving over for parking or siting of animal feeding operations as examples.

## 5.4. Increase the variety of habitat for animal and plant life in the watershed

The Squaw Creek Watershed will be recognized for its ecologically diversity.

The goal is to increase ecological diversity in the Squaw Creek Watershed. Ecological diversity includes biodiversity and habitats that maintain ecological processes and structures, regional and historical context, and sustainable cultural practices. Ecological diversity is important because the variety of habitats provide several functions and services that are important to both wildlife species and humans. Ecological integrity is increased by maintaining high quality and diverse habitats, that support many wildlife species, as well as and the people who live in the Squaw Creek Watershed.

Ecological diversity in the Squaw Creek Watershed will be increased by maintaining a landscape that has a diversity of high quality habitats that provide fundamental services that are necessary to both wildlife and humans. Ecosystem services are the processes by which the environment produces resources that we rely on and often take for granted. Examples of ecosystem services include water quality and flood control, oxygen production and carbon storage, wildlife habitat, pollination of native and agricultural plants, recreational activities, and aesthetic values.

***Habitat Objectives***

*Objective 4.1 Stream and riparian areas will become healthy ecosystems providing habitat for a wide variety of native fish, invertebrate, plant and animal species*

*Objective 4.2 Key natural resources within the watershed, including wetlands and upland prairies will be identified and protected to prevent the loss or degradation of fish and wildlife habitat*

*Objective 4.3 Opportunities to create wildlife habitat, as well as greenways and wildlife corridors, throughout the watershed will be explored*

*Objective 4.4 Low impact stormwater and drainage water management approaches will be prioritized over conventional structural approaches such as riprap, impervious surfaces, and piped conveyances.*

***Recreation Objectives***

*Objective 5.1 A recreational master plan will be developed to guide siting and extent of recreational use of Squaw Creek, its tributaries and riparian zone*

*Objective 5.2 A viable fisheries will be established in reaches of Squaw Creek where the flow regimes are conducive*

*Objective 5.3 The publicly accessible riparian corridors throughout the watershed will provide passive and non-passive recreational opportunities*

*Objective 5.4 Appropriate riparian areas along Squaw Creek and its tributaries will be identified and managed for a recreational trail system*

*Objective 5.5 Appropriate reaches within Squaw Creek will be identified and managed for water-based recreational opportunities such as canoeing and kayaking.*

## 5.5. Create outstanding recreational opportunities in the watershed

The Squaw Creek Watershed will be a recreational asset to residents of the watershed and will become a destination for visitors.

Based on input received at the watershed listening sessions the WMA adopted the goal of making the watershed a recreational asset. It is apparent that, while there is currently some recreational use of Squaw Creek, the resource is largely untapped. Squaw Creek and some of the larger tributaries have the potential to provide recreational opportunities for watershed residents and visitors. Stream based recreation in Iowa has been shown to increase quality of life for residents and to have economic value in terms of tourism.

An essential objective towards reaching this goal will be to establish a recreational master plan for the Squaw Creek riparian area. The plan would identify the areas most suitable for recreational use and would evaluate water based recreation on the stream as well as use of the riparian area for a system of trails.

Many of the current uses of Squaw Creek; canoeing, kayaking, wading and fishing, are limited due to a variety of factors described in the watershed assessment chapter of the Plan. One of the primary objectives for reaching the recreation goal is to expand the current recreational use of Squaw Creek and tributaries. This objective refers to expanding the extent to which recreational use is appropriate, and improving the character of the stream to allow greater use. An example would be to remove the dead, overhanging trees that are common in some reaches of the stream. This will need to be done in conjunction with hydrologic improvements described above, which will help to stabilize the stream banks and prevent further tree falls.

## 5.6. Work cooperatively to identify stakeholders and resources and facilitate partnerships to implement the watershed plan.

Building partnerships and cooperating with existing groups and initiatives are keys to successful implementation of the watershed management plan.

The individual members of the WMA each play a role in managing the watershed whether it is their own conservation efforts; like the City of Ames restoring reaches of Squaw Creek or the Boone Soil and Water Conservation District offering technical assistance on agricultural practices, or by identifying ways to incorporate watershed improvements into everyday activities.

The Squaw Creek WMA is not alone in its desire to improve conditions in the watershed. There are several regional and state-wide groups that have similar water quality improvement missions. Examples include the Iowa Rivers Revival and Clean Water Iowa. Other groups, while formed for different purposes, have common objectives. An example would be the Practical Farmers of Iowa. The WMA recognizes the importance of collaborating with these groups and taking advantage of the specific experience and insight they have. Other entities like the Iowa DNR or Region 7 EPA have funding opportunities that the WMA can tap to implement its programs.

***Partnership Objectives***

*Objective 6.1 Identify opportunities to assist the Cities, Counties and SWCDs and other stakeholders on their watershed management and conservation efforts*

*Objective 6.2 Utilize existing State and non-profit watershed management and conservation related initiatives*

*Objective 6.3 Identify and actively pursue funding opportunities, locally and at the State and Federal level*

*Objective 6.4 Identify and empower local watershed stewards to build watershed management ethic at grassroots level*

# 6. Implementation Strategies

The following section describes specific strategies to address the objectives established by the WMA. The section is organized by the six main goals of the WMA defined above. Each section defines the strategies specific to that goal although there is significant overlap between goals. For instance many of the action items outlined in the Education/Outreach section are also found in the water quality, recreation and habitat goals. Also, the strategies for meeting the water quality goals overlap with the strategies for restoring the natural hydrology of the watershed.

## 6.1. Education/Outreach Strategies

Increasing awareness of watershed issues is the foremost goal of any watershed management plan. The following are the proposed strategies for meeting the WMA goal of increasing people's awareness and understanding of the individual connections and efforts within the watershed. This goal is built around education and awareness of all members within the watershed. In order to develop a strong educational effort, we must recognize that there are three types of members we will be speaking to over the next ten years. First, folks who know little or nothing about their watershed and whom we are starting at ground zero to inform and engage. Second, people who need more intensive education to continue to build their knowledge and who are looking to change their behaviors. And third, those persons who are very knowledgeable and may be able to craft information needed for educating the other two audiences.

We will continuously develop our educational process to: identify and analyze our target audience, create appropriate messages, package the message using the appropriate media, events and leveraging resources, and distribute our messages. This will ensure that the information we have assembled in our plan can be utilized well through education, that the water quality goals we have set will be understood and inspire all members in the watershed to assist in reaching our goals. And that after twenty years, we will have a healthier watershed to live, work and play in.

The first strategy is to educate landowners and residents in our watershed so that by 2035, 80% can identify their watershed. The following action steps will be used to achieve this strategy;

- Promote using website and social media
- Develop Maps for distribution and electronically
- Press Releases
- Water Quality Celebrations
- City/County marked boundaries - signage

We will use an outreach campaign through the media to support the strategies identified in the plan for meeting the other five goals of the watershed.

Each year the following action steps will be employed to increase awareness of the objectives and progress towards meeting those goals;.

- Press Releases
- Field days
- Water monitoring results
- Increasing habitat

Promoting stewardship in the watershed will be done by holding field days in the watershed. Up to 3 field days per year will be held on specific topical issues including cover crops, soil health, nutrient management BMPs, stream restoration, hydrology and other topics to be identified.

Conducting field days will consist of;

- Planning each Year and Identifying Field Days
- Securing hosts and partners
- Conduct a press campaign to inform the public about the Field Days
- Develop educational materials and utilize partner materials to educate and inform landowners of ways to improve their soil, move water through their soils and save money in their farming operations.

As watershed stewards begin to emerge in the watershed we will develop and launch a recognition program, i.e. conservation award to recognize efforts each year that honors 1 city, 1 county, 1 urban resident or business and 1 farm/producer for conservation efforts. The recognition should keep stewards motivated and encourage others to join in to the effort.

Specifically, developing the recognition program will consist of;

- Develop a process with peer review
- Identify an award plaque
- Promote winners at the Annual Meeting

A baseline for current recreational opportunities/uses of the stream will be developed through an audit/survey program. The information to be gathered will be important for future watershed management decision (see the recreational enhancement strategies) so the audit will be conducted by 2017.

The audit will consist of the following steps;

- Survey residents for what recreation they prefer and are currently participating in.
- Map current recreation locations and continue to add to the map each year.
- Develop a recreation plan to support community interests in 2018.
- Announce and promote the recreational plan in 2018-2025.

While restoring a viable fishery in Squaw Creek will likely require restoring the natural stream hydrology, establishing a stock and catch fishery is an excellent tool to build interest in the stream and to foster watershed stewardship. Establishing fishing as an activity in the stream will be accomplished by 2020

Specifically the following steps will be taken;

- Partner with Iowa Rivers Revival, DNR Fisheries and others to create a plan for building fishing opportunities along the stream.
- Hold fishing forums/kids competition by 2018
- Develop an educational campaign utilizing PSAs, videos, newspaper ads and newsletter articles to link fishing and water quality together. Begin campaign in 2018-25

Building upon the goal of enhancing the recreational value of the stream and its riparian corridor, a regional river trail plan will be developed in the watershed (see the recreational enhancement strategies). An outreach campaign will be built into the trail system to promote the mission of the watershed and to increase awareness of watershed issues.

The following steps will be taken following development of the trail plan, which is envisioned to occur by 2017;

- Incorporate our trail plan into the Story and Boone Counties master trail plans by 2018
- Develop river trail signage by 2019.
- Develop a river trail event to promote a clean water trail in Squaw Creek Watershed in 2019 and then every year after until 2035.

## 6.2. Strategies for Improving Water Quality

The following section describes the recommended approach for improving water quality in the watershed and meeting the specific nutrient reduction objectives adopted by the WMA. At the heart of this approach is the subwatershed-scale nutrient reduction strategy that was developed through the use of the Agricultural Conservation Planning Framework (ACPF) developed by the National Laboratory for Agriculture and the Environment, USDA Research Service in Iowa (Tomer et al., 2013, 2014). The tool consists of a set of GIS terrain analysis applications which are used within a conservation framework to optimize the placement of structural BMPs on the landscape.

### 6.2.1. **Introduction and Approach**

Best Management Practice (BMP) strategies were analyzed for all areas within the watershed, from farm fields to the urban areas. Since corn and soybean agriculture comprises the majority of the watershed these areas contribute far and away the greatest proportion of nitrogen in terms the total loading mass and also in terms of the nitrogen yield per unit area. This is a consequence of the amount of commercial fertilizer and manure applied to support crop production but also the inherent nutrient content of the watershed's soils which, due to their glacial and prairie land cover histories, are some of the most productive soils on Earth. Agricultural sources of phosphorus also dominate the total watershed loads but, unlike for nitrogen, urban and channel (stream bed and bank erosion) sources are also significant. As a result, the primary focus of the subwatershed nutrient reduction strategies is on agricultural BMPs, although approaches to control nutrient loading from urban areas is also addressed.

BMP strategies were analyzed by taking into account the following factors:

- **Watershed Hot Spots**: areas within the watershed where the SWAT modeling predicts higher than average nutrient production rates. See Figure 4-2 for nitrogen hot spots and Figure 4-3 for phosphorus hot spots
- **BMP Performance**: research-based nutrient removal rates for a suite of BMPs
- **BMP Cost**: the cost associated with BMPs from an installation AND lost income standpoint
- **Terrain Suitability**: the watershed was evaluated for areas where the terrain is most suited to implement specific structural BMPs

***Watershed Hot Spots***

Targeted land cover and management areas are general areas where nutrient yields are highest -- e.g., N or P pounds/acre/year entering stream channels from adjacent lands and where prioritization planning should begin. These areas present more practical BMP opportunities as costs for implementation would generally be a function of size of the area treated and independent of the amount of nutrient treated. Potential target areas were predicted using the SWAT modeling task outlined in Section 4. Results from the SWAT simulations are useful for developing context around current nutrient sources and proportions and better understanding the targeting and results of BMP scenarios. Key general conclusions from the SWAT modeling were:

- Corn and soybean agriculture are estimated to contribute 97% of the nitrogen and 92% of the phosphorus loading in the Squaw Creek watershed.
- Tile drained land (which is estimated to comprise 70% of the total agricultural area) is estimated to contribute 86% of the total nitrogen loading in the Squaw Creek watershed.
- Approximately 33% of the total agricultural nitrogen and phosphorus loads are estimated to originate from 20% of the agricultural land.
- SWAT modeling predicts roughly equivalent phosphorus yields between Squaw Creek watershed urban and agricultural areas (~0.7 lbs/ac/yr)
- Urban areas comprise about 5% of the total watershed area and contributing approximately 5% of the total watershed phosphorus load. Urban landuse is primarily concentrated in the City of Ames where low density residential comprises over 70% of the area (from 2006 National Land Cover Dataset).

These findings reinforce the importance of developing BMP strategies that address agricultural practices and tile drainage in particular.

***BMP Performance***

Nitrogen and phosphorus reductions associated with BMPs were compiled from existing research and prior experience. Most of the reduction estimates came from the 2014 Iowa Nutrient Reduction Strategy (INRS, 2014). Although much variability in BMP effectiveness exists across studies, average values were used to provide estimates of expected outcomes and were necessary to calculate and analyze cost-effectiveness.

***BMP Costs***

Costs per acre per year were estimated based on information in the INRS and EQIP (Environmental Quality Incentives Program) BMP database. Total nitrogen and phosphorus percent reductions were divided by unit costs to generate a cost-effectiveness index. This index is designed to the show relative difference between BMPs. Negative cost and cost-effectiveness indicate BMPs that have been demonstrated to

***Iowa Nutrient Reduction Strategy***

*The Iowa Nutrient Reduction Strategy is a science and technology-based framework to assess and reduce nutrients to Iowa waters and the Gulf of Mexico. The strategy outlines a pragmatic approach for reducing nutrient loads discharged from the state's largest wastewater treatment plants, in combination with targeted practices designed to reduce loads from nonpoint sources such as farm fields. Working together, the Iowa Department of Agriculture and Land Stewardship, the Iowa Department of Natural Resources, and the Iowa State University College of Agriculture and Life Sciences developed this proposed strategy.*

result in a net profit. Reductions, costs and cost-effectiveness are all discussed in detail in the following section.

***Terrain Suitability***

Terrain Suitability is based on the notion that certain Ag BMPs are much more practical to implement if the topography in the targeted area maximizes the effectiveness of the practice and minimizes the installation and operating costs. An example of this concept is a nutrient removal wetland for which research has shown that denitrification is maximized when the wetland pool is shallow enough to support emergent wetlands plants but is continually filled. These attributes have been shown to be tied to existing depressional pool volume and the ratio between pool area and contributing upslope drainage area. Moreover, installation costs will minimized if an existing (presumably drained) depression already exists and requires minimal design and excavation. A set of automated GIS tools was used to analyze terrain suitability for several types of structural BMPs and is discussed in detail later in this section.

### 6.2.2. **Best Management Practice Selection**

BMPs were selected based on inclusion in the 2014 Iowa Nutrient Reduction Strategy (INRS) as well as input from residents of the watershed and from emerging research. Soil organic matter, grassed waterways and saturated buffers are specific practices that were added to those found in the INRS. Urban BMPs were selected based on input received by City of Ames Municipal Engineer Tracy Warner.

While the selection of BMPs uses many of the widely accepted practices in place today, we acknowledge that the field is rapidly evolving and new practices are being researched constantly. For the purpose of our analysis we used practices that had available performance and cost information. We encourage the use of emerging technologies to address nutrient reduction.

BMPs to be evaluated for applicability in the Squaw Creek Watershed are split into the following four major categories:

### *In-field Practices*

The first grouping of practices include nutrient management practices as well as conservation practices associated with changes in in-field management practices; use of conservation crops, no-tillage techniques and increasing soil organic matter.

Nutrient Management Practices

These practices are grouped together for purpose of the evaluation. They generally represent changes in the type or timing of nutrient application and are low cost (if not cost-positive) practices that can be implemented by individuals across the watershed.

Reduce nitrogen application rate to the MRTN: Reduce the nitrogen application to the level which maximizes yield vs. fertilizer costs which is expressed as the Maximum Return To Nitrogen (MRTN). In the Squaw Creek Watershed the MRTN rate is 133 lb N/ac on Corn/Soy and 190 lb N/ac on Cont.

Use a nitrification inhibitor: Nitrification inhibitors slow the microbial conversion of ammonium-nitrogen to nitrate-nitrogen. The practice specifically uses nitrapyrin and applies only to fall application of anhydrous ammonia.

Eliminate fall anhydrous nitrogen application: Moving fall anhydrous N fertilizer application to spring pre-plant prevents denitrification and leaching during late fall, winter and spring.

Sidedress all spring applied nitrogen: Sidedressing applies nitrogen during the periods of plant demand (late spring/early summer) rather than the spring which reduces the risk of loss from early spring rainfall/leaching events.

Reduce phosphorus application rates: Reduce phosphorus application rates in fields that have high to very high soil test phosphorus content. This practice minimizes phosphorus fertilizer over-application. In general the soils in the Squaw Creek Watershed have high P soil concentrations.

Manure injection/ Phosphorus banding: Manure injection/phosphorus fertilizer banding involves injecting liquid manure and banding solid inorganic fertilizers within all no-till acres. Placing phosphorus at the root zone can increase phosphorus availability and allow for reduced application rates.

Cover crops: Although there are many options available for cover crop species the analysis uses fall-planted rye. Cover crops reduce soil erosion and limit the amount of nitrate-N leaching from the soil during the late fall-winter-early spring.

Convert intensive tillage to conservation tillage: The practice consists of switching from moldboard to chisel plowing which leaves at least 30% crop residue on the fields before and after planting to reduce soil erosion.

Convert conservation tillage to no-till: The practice consists of switching existing chisel plowing to no-till where the ground is not tilled as to not disturb the soil. This increases

***Soil Health***

*America's soil and water conservation districts, along with their traditional partner, the Natural Resources Conservation Service (NRCS) have made soil health a long-term priority. As it gains momentum, the soil health movement has embraced all landscapes, from crop and grazing lands to forests and even urban settings. Agriculture producers and their conservation partners are on a mission. Their goal is to grow robust crops and enrich soil health and reduce input costs. These producers have pioneered soil health principles that include no-till, cover crops, increased plant diversity and minimum soil disturbance. Soil health is site specific and local champions are the keys to adoption of soil health systems. Soil health systems build resilience to weather extremes, including droughts and flooding.*

water infiltration, organic matter retention, nutrient cycling, and reduction of soil erosion.

Increasing organic matter: For analysis purpose it is assumed that the organic matter is increased by 100% which would take the soils in the watershed from an estimated 3% to 6%. Increased organic matter provides both greater water and nutrient retention preventing leaching and increasing soil fertility. Soil organic matter and is a major factor in the productivity and sustainability of agronomic systems. Currently, the primary practices for building SOM are planting cover crops, reducing tillage and applying manure rather than commercial fertilizer. Applying manure was not considered in this analysis because without more specific guidance on application rates, methods and timing, increases in nitrogen and phosphorus loading may result. Instead, cover crops in conjunction with no-till were incorporated into the BMP scenario analysis. This BMP was not included within the INRS BMP list but was added after discussions with the project's technical advisors and input received from watershed residents. Percentage reduction of nitrogen was estimated based on SWAT model simulations whereby available soil water storage and soil carbon were increased to reflect the doubling of organic matter.

### *Edge-of-Field Practices*

These practices are typically larger, sometimes structural practices that are terrain dependent. In contrast to the in-field practices, these BMPs can only be installed in areas that support them. This siting was done through use of the ACPF tools as described below.

Nutrient Removal Wetlands: This BMP is a shallow depression created in the landscape where aquatic vegetation is typically established. Nutrient removal wetlands can be a cost-effective approach to reducing nitrogen loadings in watersheds dominated by agriculture and tile drainage. A 0.5% to 2% range in wetland pool-to-watershed ratio permits the wetlands to efficiently remove nitrogen runoff from large areas and data has shown that 40% to 90% of the nitrate flowing into the wetland can be removed. These wetlands and surrounding grassland buffers also provide environmental benefits beyond water quality improvement such as increases in wildlife habitat, carbon sequestration, and flood water retention (Crumpton et al., 2006).

Denitrification bioreactors: These are trenches in the ground packed with carbonaceous material such as wood chips that allow colonization of soil bacteria that convert nitrate in drainage water to nitrogen gas. Installed at the outlet of tile drainage systems, bioreactors usually treat 40-60 acres of farmland. Note that the performance numbers shown for this practice account for the assumption that only 50% of the available runoff gets routed into the practice.

Water and Sediment Control Basins (WASCOBS): These are small earthen ridge-and-channel or embankments built across a small watercourse or area of concentrated flow within a field. They are designed to trap agricultural runoff water, sediment and sediment-borne phosphorus as it flows down the watercourse; this keeps the watercourse from becoming a field gully and reduces the amount of runoff and sediment and phosphorus leaving the filed. WASCOB's are usually straight slivers that are just long enough to bridge an area of concentrated flow and are generally grassed. The runoff water detained in a WASCOB is released slowly, usually via infiltration or a pipe outlet and tile line (Minnesota Department of Agriculture).

Riparian Buffers: These are vegetated zones immediately adjacent to a stream and are generally designed to trap sediment and phosphorus laden surface runoff, which is important but not uniformly opportune along streams. However, different designs and vegetation can improve water quality in different ways. Where vegetation roots can interact with the water table, carbon cycling and denitrification may be enhanced. In areas where the water table depth and overland runoff is high, stiff-stemmed grasses may be beneficial to intercept and reduce runoff and sediment from reaching the stream. Where appreciable amounts of neither runoff nor groundwater can be intercepted, benefits such as stream bank stabilization may be possible (Tomer et al. 2013).

Controlled Drainage: Controlled drainage describes the practice of installing water level control structures within the drain tile system. This practice reduces nitrogen loads by raising the water tables during part of the year, thereby reducing overall tile drainage volume and nitrate load. The water table is controlled through the use of gate structures that are adjusted at different times during the year. When filed access is needed for planting, harvest or other operations, the gate can be opened fully to allow unrestricted drainage. When the gate is used to raise local water table levels after spring planting season, this may allow more plant water uptake during dry periods, which can increase crop yields. Controlled drainage may be used on field with flat topography, typically one percent or less slope.

Grassed Waterways: These are constructed channels that are seeded to grass and drain water from areas of concentrated flow. The vegetation slows down the water and the channel conveys the water to a stable outlet at a non-erosive velocity. Grassed waterways should be used where gully erosion is a problem. These areas are commonly located between hills and other low-lying areas on hills where water concentrates as it runs off the field (NRCS, 2012). The size and shape of a grassed waterway is based on the amount of runoff that the waterway must carry, the slope, and the underlying soil type. It is important to note that grassed waterways also trap sediment entering them via field surface runoff and in this manner perform similarly to riparian buffer strips.

Grassed waterways were not included as part of the INRS BMP list but were added as in-field sediment/particulate P trapping alternative. Note that the percent reduction in this analysis was estimated based on riparian buffer percent reduction as both BMPs' trapping mechanisms are similar. However, reductions due to decreased gully development were not evaluated; consequently reductions used in this study could likely by *under* estimations of grassed waterway effects.

Saturated Buffers: Saturated buffers are a vegetated area, typically a riparian area along a stream or ditch where draintile water is dispersed in a manner that maximizes its contact with the soils and vegetation of the area. Draintile lines that typically discharge directly to the ditch or stream are intercepted and routed into a new draintile pipe that runs parallel to the ditch or stream. This allows drain water to exfiltrate and saturate the buffer area. The contact with soil and vegetation results in denitrification. Note that the performance numbers shown for this practice account for the assumption that only 50% of the available runoff gets routed into the practice.

## *Land Use Changes*

The following practices involve taking agricultural land out of production. As is noted in the cost section these are fairly high-cost practices primarily as a result of the loss of income that results. The analysis that is provided assumes that these practices, if implemented, would be targeted to the hot-spots identified by the SWAT modeling. The practices would be further targeted by looking into the yield history of the specific fields so that the practices would only be placed in low-yield areas. This would help to minimize the cost per acre of the practices.

Perennials/Energy Crops: The practice consists of converting Corn/soybean lands to perennial or energy crops. Perennial Crops are CRP long-term (10-15 years) program intended to reduce soil erosion by converting land to perennial crops. Energy Crops are perennial crops, such as switchgrass, that produce biomass that can be used as bio-energy feedstock. These crops improve soil cover, reduce soil erosion, and reduce nitrogen and phosphorus loss.

In the combined scenario analysis that follows, we have used the '10% of the watershed' approach that is being championed by the Science-based Trails of Rowcrops Integrated with Prairie Strips (STRIPS) program - http://www.leopold.iastate.edu/news/strips-video

Pasture/Land Retirement: This practice removes land from agricultural production and converts it perennial vegetation to limit soil erosion. This is a long-term CRP program (10-15 year). The established vegetation is a near natural system that has animal habitat and soil improvement benefits.

Extended Rotation: is a rotation of corn, soybean, and at least three years of alfalfa or legume-grass mixtures managed for hay harvest. These crops provide soil cover, reduce soil erosion, and reduce phosphorus loss.

## *Urban Practices*

Urban BMPs are part of the approach to address runoff impacts. Urban runoff management is somewhat different from agricultural settings in that the added impervious surfaces are a large factor. In those cases, the nutrient concentrations are higher than natural or background conditions, plus the compounding factor of much higher runoff volumes. Modern stormwater standards, such as those employed by the City of Ames, require runoff volume reductions along with nutrient treatment. To conceptualize this in the urban setting, new development and redevelopment were segregated were generalized based on their different settings and driver for implementation:

- New development – BMPs as part of urban development that must meet current City standards
- Re-development – BMPs required as part of redevelopment per City standards
- Voluntary/incentive-based retrofitting – public/city-led retrofits and cost share programs to incentivize existing businesses and homeowners

It is important to note that in urban settings like Ames, often the reductions are internalized into the permitting and development process. In this manner, the impacts of development pay their own way to protect water quantity and quality. Since the costs for development and redevelopment are internalize via permitting, those costs are not shown here as external costs to be funded. For voluntary or incentive-based retrofits, there will need to be some funding provided to implement possible city or watershed projects and to provide incentive payments to those wishing to improve their existing site. Generalized urban BMPs and estimated reductions are presented in Table 6-1. These BMPs, reductions and costs were determined based on EOR's experience in urban BMP planning.

Urban BMP scenarios were split into three general areas and the following assumptions on level of implementation:

- New development BMPs from conversion of agricultural land; applied to the City of Ames comprehensive plan's estimation of an additional 2,500 acres by the year 2030
- Redevelopment BMPs for an assumed 10% of existing development by 2030
- Voluntary/Incentive based BMPs for an assumed 10% of existing development by 2030

SWAT modeling predicts roughly equivalent phosphorus yields between Squaw Creek watershed urban and agricultural areas (~0.7 lbs/ac/yr) with urban areas comprising about 5% of the total watershed area and contributing approximately 5% of the total watershed P load. Urban landuse is primarily concentrated in the City of Ames where low density residential comprises over 70% of the area (from 2006 National Land Cover Dataset).

The following examples of BMPs currently being installed in Ames was provided by Tracy Warner, City of Ames Municipal Engineer. New development/post construction stormwater BMPs being implemented currently include:

- rain gardens
- enhanced rain gardens
- bioretention cells
- bio-swales/vegetated swales
- soil quality restoration
- native landscape/turf/plantings

- Pervious/Porous pavement

Voluntary BMPs that are funded by cost-share or rebate include:

- Rain Barrels
- Rain Gardens
- Native Landscape
- Trees
- Soil Quality Restoration

The community can also implement additional BMPs, sometimes at a regional scale to address past development impacts and to meet new stormwater non-degredation standards. The watershed should work cooperatively with the city to identify additional publically or grant funded projects that can mitigate impacts to water quality, volume, and flooding. These will likely be driven by both local problem areas along with sites that become opportunities that present themselves.

### 6.2.3. **BMP Performance**

Nitrogen and phosphorus reductions associated with BMPs were compiled from existing research and prior experience. Most of the reduction estimates came from the 2014 Iowa Nutrient Reduction Strategy (INRS, 2014). Although much variability in BMP effectiveness exists across studies, average values were used to provide estimates of expected outcomes and were necessary to calculate and analyze cost-effectiveness. The average removal rate for each practice is found in Table 6-1.

Removal rates for nitrogen are highest in BMPs that either convert agricultural land to pasture or perennials or where agricultural land is treated at the edge of field through de-nitrification BMPS such as nutrient removal wetland, denitrification bio-reactors, and saturated buffers.

Phosphorus removal rates are highest for no-till, and practices that are aimed at trapping sediment since phosphorus is generally tied to sediment particles. Moderate to high rates of phosphorus removal are also seen in land retirement practices.

### 6.2.4. **BMP Costs**

Agricultural BMP costs were based on analysis from the INRS and data from the EQIP database which accounts for the installation costs and lost revenues associated with each practice. The costs and cost-effectiveness values presented in Table 6-1 are based on costs per year per acre. These calculated costs are straight-forward for nutrient management BMPs but costs for edge-of-field and land use change BMPs are primarily related to initial installation costs which can be substantial compared to the nutrient management costs. Therefore, nutrient removal wetland, sediment basin and bioreactor BMPs were assumed to have a 20 year life span whereby installation costs are spread across 20 years. Similarly, riparian buffers, grassed waterways and land use change BMPs were assumed to have a 5 year life span – this reduced life span takes into account that these BMPs may be more easily re-introduced to agriculture if so desired than the aforementioned BMPs.

Moreover, edge-of-field BMP costs are associated with the BMP itself – the area doing the treatment: the wetland or sediment basin, bioreactor, riparian buffer or grassed waterway strip – not the upslope area treated. Therefore, to calculate cost per year per acre, the cost was divided by the upslope treatment area. Treatment areas for nutrient removal wetlands and sediment basins were assumed to be 100 times the impoundment pool area (using Tomer 2013 guidelines); 40 acres per bioreactor; 25 times the grassed waterway and riparian buffer areas (based on the ACPF analysis described later).

This cost division across multiple years and treated acres makes these BMPs much more cost-effective and viable alternatives or supplements to the nutrient management BMPs.

The costs of urban BMPs represents two aspects. As discussed previously, the costs of treating runoff from urban development is absorbed into the development process, or internalized, by meeting the City of Ames stormwater standards in the ordinances, as it done in most communities. For voluntary retrofits, there would be a cost to implement those. Costs of retrofits can vary greatly based on which BMP is used, how it fits the local situation, the intensity of the development being treated (residential, commercial, industrial, etc.) and if land or easement purchase is needed. A very generalized and approximate cost was used that represents some typical low impact practices, such as raingardens, at a moderate level of development imperviousness, approximately 40% impervious, and not factoring land costs, was used to approximate urban BMP costs. The installation cost of the practice was divided by 20 years to get an annual cost. Some additional on-going maintenance costs were included based on recently summarized data by a Ramsey-Washington Metro Watershed District study of raingarden maintenance costs with raingarden costs in the range of $200/yr for a raingarden treating a few urban residential lots. In reality, actual costs will vary greatly, so these values serve as a placeholder until better information is available through a feasibility study of specific sites.

It is important to note that the cost estimates for these BMPs do not take into account any potential cost savings or economic benefit that may be provided by the practice. For instance, increasing soil organic matter may eventually reduce fertilizer need and increase yield.

The cost of nutrient removal BMPs ranges widely from the zero to positive cost nutrient management BMPs to the very high cost of the land retirement practices. Note that with land retirement practices there would be an attempt to focus only on the lowest yield fields which would reduce the overall cost of the practice from what is reported.

**Table 6-1.** Selected BMPs, estimated reductions per unit area and costs

| | Category | Practice | % N | % P | Est. Cost $/ac/yr |
|---|---|---|---|---|---|
| In-field Practices | Nutrient Management Practices | Reduce nitrogen application rate to MRTN | 10 | 0 | (2.00) |
| | | Use a nitrification inhibitor | 9 | 0 | (3.00) |
| | | Eliminate fall anhydrous nitrogen | 6 | 0 | (35.00) |
| | | Sidedress all spring applied nitrogen | 7 | 0 | 0.00 |
| | | Reduce phosphorus application rates | 0 | 17 | (12.00) |
| | | Manure injection/Phosphorus | 0 | 24 | 14.55 |
| | | Cover crops | 31 | 29 | 77.78 |
| | | Convert intensive tillage to conservation tillage | 0 | 33 | 26.00 |
| | | Convert conservation tillage to no-till | 0 | 90 | 18.58 |
| | | Increase soil organic matter | 10 | 0 | NA |
| Edge-of-Field Practices | | Nutrient Removal Wetlands[1, a] | 52 | 58 | 9.41 |
| | | Denitrification Bioreactors[2, a] | 43 | 0 | 29.61 |
| | | Sediment Basins[1, a] | 0 | 85 | 5.90 |
| | | Riparian Buffers[3, b] | 91 | 58 | 6.78 |
| | | Controlled Drainage [a] | 33 | 0 | 0.74 |
| | | Grassed Waterways[3, b] | 0 | 58 | 30.58 |
| | | Saturated Buffers [a] | 50 | 0 | 7.52 |
| Land Use Changes | | Perennials/Energy Crops[c] | 72 | 34 | 698 |
| | | Pasture and/or Land Retirement [c] | 85 | 75 | 585 |
| | | Extended alfalfa rotations[c] | 42 | 59 | 71 |
| Urban Practices | | New Development | 0 | 65 | N/A |
| | | Existing Development: Re- | 0 | 50 | N/A |
| | | Existing Development: Voluntary (Rebates/Incentives) | 0 | 50 | 3,000 |

[1] Assumed 1:100 ratio between pool area and upslope drainage area for /acre/yr costs
[2] Assumed one bioreactor treats 40 acres for /acre/yr costs
[3] Assumed 1:25 ratio between vegetated treatment area and upslope drainage area for /acre/yr costs
[a] Assumed lifespan of 20 years for /acre/yr costs
[b] Assumed 5year commitment for /acre/yr costs
[c] Assumed 5year commitment for /acre/yr costs

### 6.2.5. **Terrain Suitability**

Beyond the conceptual and modeled estimates of removal potential from applying various BMPs to the watershed, the task of determining where the BMPs should actually be placed is an important step. To place BMPs on inappropriate locations will reduce their effectiveness (increase costs) and likewise, targeting BMPs to locations where they will provide the most benefit will increase their effectiveness (decrease costs). In a large agricultural watershed like this, a prioritization and targeting framework is warranted to ensure efficient use of resources and avoid an inefficient “shotgun effect.”

The ACPF features an ArcGIS toolbox that helps optimize the placement of structural BMPs on the landscape by evaluating terrain suitability using high-resolution digital elevation data (LiDAR). These BMPs are referred to here as “terrain-dependent” as the terrain in which they are placed affects both cost and effectiveness.

With assistance from the ACPF authors, the GIS toolbox was implemented for the seven HUC-12 subwatersheds in the Squaw Creek watershed. Five terrain-dependent, structural Ag BMPs were analyzed and included: grassed waterways (GWWs), nutrient removal wetlands (NRWs), water and sediment control basins (WASCOBs), riparian buffers, and controlled tile drainage. LiDAR with a 3 meter resolution was used as the topographic input data for the GIS tools used to assess potential sites.

The primary numerical output from the GIS analyses necessary for BMP scenario reduction analyses was the upslope drainage area calculation for each sited BMP aggregated at the HUC-12 subwatershed level. These cumulative drainage areas represented the source areas to be treated for which the BMP percent reductions were applied.

Based upon the outcomes of the Agricultural Conservation Planning Framework (ACPF) Toolbox, there are numerous potential opportunities in the Squaw Creek Watershed to install best management practices to improve water quality:

- The total length of potential grassed waterways is 1,483 km with a total drainage area of 40,069 HA comprising 83% of the agricultural land.
- The total nutrient removal wetland drainage area of 24,020 HA comprising 50% of the agricultural land.
- The total water and sediment control basin (WASCOB) total drainage area of 4,684 HA comprising 10% of the agricultural land.
- Critical zone riparian buffers have a drainage area of 4,207 HA (9% of agricultural land), multi-species buffers have a drainage area of 13,204 HA (27% of agricultural land), stiffed-stem grasses have a drainage area of 14,471 HA (30% of agricultural land)
- Deep-rooted vegetation buffers have a drainage area of 2,132 HA (4% of agricultural land).

Results of the ACPF GIS analyses are presented for each HUC-12 subwatershed in Appendix 4: Agricultural Conservation Planning Framework Findings. The results generally show an abundance of potentially suitable sites for all the analyzed BMPs except controlled drainage, which was found to have a negligible amount of suitable drainage area. The field-scale maps of potential BMP locations are useful for watershed planning but require on-site inspection to validate their suitability.

### 6.2.6. **BMP Scenarios and Reduction Results**

BMP scenarios were developed to assess the potential reductions available in the Squaw Creek Watershed from single BMPs and combinations of BMPs. Single BMP scenarios were taken directly from those outlined in the Best Management Practice Selection section and serve as a benchmark for the performance of individual BMPs on applicable N and P source areas in the watershed. The findings of the single BMP analysis illustrates the uppermost reduction that each practice can provide in the watershed. Since no single BMP is realistically going to be applied across the entire watershed, we have developed combined BMP scenarios that focus on most cost-effective BMPs combined in sequence – upslope to downslope – in shared treatment areas and in-parallel at relatively low levels of adoption. These combined scenarios form the basis for the plan's overall BMP implementation recommendations.

#### *Single BMP Scenarios*

Twenty one scenarios were developed each focusing on a single BMP, based on those outlined BMP Selection section above, to illustrate the maximum impact a given BMP can have. The scenarios combine a single practice with a treatment area for which to estimate nutrient reductions. For non-structural BMPs, the existing extents of continuous corn and corn/soybean and specific tillage practices were used as treatment extents whereas terrain-dependent BMP scenarios were based on results of the ACPF terrain analyses so treatment extent was equivalent to the cumulative upslope drainage areas delineated for individual sited practices. In the case of non-structural BMPs, *existing* implementations of practices were estimated in the INRS for the Squaw Creek region; for structural BMPs it was assumed none were currently implemented.

BMP scenarios were evaluated at the HUC-12 subwatershed scale based on the SWAT simulated spatial distributions of existing nutrient loading. The general procedure for calculating scenario reductions is summarized in the following figure:

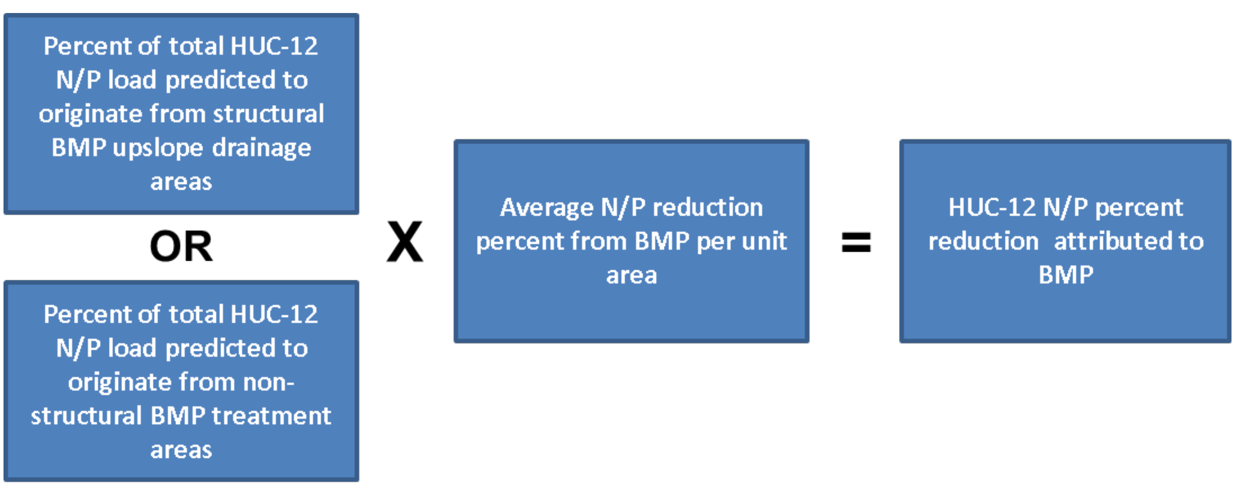



**Figure 6-1.** BMP scenario reduction analysis procedure for HUC-12 subwatersheds

Scenario results for each of the seven HUC-12 subwatersheds were aggregated for the entire Squaw Creek watershed and presented in Table 6-2. This table presents several pieces of information for each BMP scenario:

- BMP (from Table 6-1) and description/extent of scenario
- BMP effectiveness expressed as percent reduction per unit area (from Table 6-1)
- Scenario treatment acres and percentage of total Ag acres (determined based on estimates of existing conditions from INRS or ACPF terrain analyses)
- Percentage of Squaw Creek total N and P loads originating from scenario treatment area (from SWAT model)
- Percent reduction of total Squaw Creek watershed N and P loads resulting from scenario

Table 6-2 shows a wide range of N and P watershed-wide reductions. Generally, N and P nutrient management BMPs offer significant reductions without any terrain dependent constraints; however, because of issues producing consistent corn and soybeans yields with some of the most effective non-structural BMPs such as non-till (82% P reduction) and cover crops (30% N reduction), widespread adoption could be relatively impractical unless the science and management of these BMPs is advanced or funding sources are in place to reimburse farmers.

Structural (terrain dependent) BMPs offer some advantages in that their placement can be constrained so as to limit the amount of productive farm land taken out of production necessary for their installation and maintenance; this is particularly true with field edge riparian buffers. The ACPF terrain analyses showed great potential for treating large portions (~60%) of farm land with nutrient removal wetlands and buffers both of which show very strong reduction effectiveness for both nitrogen and phosphorus.

In terms of watershed-wide reduction goals, the N and P reduction goals of 41% and 29%, respectively, could be achieved with riparian buffers draining roughly half the total watershed (about 1/3 less than amount scoped by the ACPF toolset). Similar to riparian buffers, full implementation of no-till on all continuous corn (CC) and corn/soybean (CS) acres would far surpass the phosphorus goal and the extent could be scaled back by almost 2/3.

Reduction results from Table 6-2 can be easily modified to reflect implementations at less than 100% (i.e., reduce CC or CS acres treated by 50% per se) by multiplying the desired fraction by the N and/or P watershed load reduction percentage. In fact, reducing the implementation treatment extent will likely result in a more efficient scenario <u>if</u> the reduced area is targeted to hotspots from the SWAT modeling maps. This is because predicted N and P yields were not normally distributed but were skewed toward the higher loads; therefore selecting the top 25% of treatment area in terms of hot spots will likely target much more than 25% of the total watershed load. Table 4-2 shows the range of predicted concentrations at ranges 0-25%, 25-75% and 75-100% and can used as a guide to optimize selection of treatment areas.

Table 6-2 also illustrates the scale of urban BMP reductions with the respect to the entire Squaw Creek watershed P load. While the urban BMPs make a significant impact on Ames P loading, their effect is very small when compared to the whole watershed P load. Several assumptions are utilized to make these planning-level estimates and assessing the progress of implementation in the near future should be used to guide and update what is a realistic adoption rate.

**Table 6-2.** Illustrative compilation of maximum application of each Ag BMP as physically feasible, excluding interactions between BMPs

| | | Scenario | N reduction % per unit area | P reduction % per unit area | Treated acres | Treated % | Treated % of total N load | Treated % of total P load | Total N load reduction % | Total P load reduction % |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | BMP Effectiveness | | BMP Scenario Treatment Areas | | | | Squaw Watershed-wide Scenario Results | |
| In-field Practices | Nutrient Management Practices | Reduce nitrogen application rate to the MRTN | 10% | 0% | 118,657 | 100% | 97% | 92% | 10% | 0% |
| In-field Practices | Nutrient Management Practices | Sidedress all spring applied nitrogen | 7% | 0% | 118,657 | 100% | 97% | 92% | 7% | 0% |
| In-field Practices | Nutrient Management Practices | Use a nitrification inhibitor | 9% | 0% | 29,664 | 25% | 24% | 23% | 2% | 0% |
| In-field Practices | Nutrient Management Practices | Eliminate fall anhydrous nitrogen application | 6% | 0% | 29,664 | 25% | 24% | 23% | 1% | 0% |
| In-field Practices | Nutrient Management Practices | Reduce phosphorus application rates | 0% | 17% | 118,657 | 100% | 97% | 92% | 0% | 16% |
| In-field Practices | Nutrient Management Practices | Manure injection/ Phosphorus banding on all current no-till acres | 0% | 24% | 9,493 | 8% | 8% | 7% | 0% | 2% |
| In-field Practices | | Increase soil organic matter by 100% (3% to 6%) | 10% | 0% | 118,657 | 100% | 97% | 92% | 10% | 0% |
| In-field Practices | | Cover crops (rye) on all corn/soybean and cont. corn acres | 31% | 29% | 118,657 | 100% | 97% | 92% | 30% | 27% |
| In-field Practices | | Cover crops (rye) on all no-till acres | 31% | 29% | 9,493 | 8% | 8% | 1% | 2% | 0% |
| In-field Practices | | Convert all existing tillage to no-till | 0% | 90% | 109,164 | 92% | 90% | 91% | 0% | 82% |
| In-field Practices | | Convert all existing intensive tillage to conservation tillage | 0% | 33% | 57,857 | 53% | 48% | 45% | 0% | 15% |
| Edge-of-field Practices | | Denitrification Bioreactors on <u>all</u> tile drained acres | 43% | 0% | 83,462 | 70% | 86% | 64% | 37% | 0% |
| Edge-of-field Practices | | Nutrient Removal Wetlands on <u>applicable</u> tile drained areas | 52% | 58% | 59,258 | 50% | 61% | 45% | 32% | 26% |
| Edge-of-field Practices | | Sediment Basins on all <u>applicable</u> acres | 0% | 85% | 11,575 | 10% | 10% | 9% | 0% | 8% |
| Edge-of-field Practices | | Riparian Buffers on all <u>applicable</u> acres | 91% | 58% | 84,051 | 71% | 69% | 65% | 63% | 38% |
| Edge-of-field Practices | | Grassed Waterways on all <u>applicable</u> acres | 0% | 58% | 99,013 | 83% | 81% | 77% | 0% | 44% |
| Edge-of-field Practices | | Controlled Drainage on all <u>applicable</u> tile drained acres | 33% | 0% | 500 | 0% | 0% | 0% | 0% | 0% |

| | | BMP Effectiveness | | BMP Scenario Treatment Areas | | | | Squaw Watershed-wide Scenario Results | |
|---|---|---|---|---|---|---|---|---|---|
| | **Scenario** | **N reduction % per unit area** | **P reduction % per unit area** | **Treated acres** | **Treated %** | **Treated % of total N load** | **Treated % of total P load** | **Total N load reduction %** | **Total P load reduction %** |
| | Saturated Buffers on all applicable tile drained acres | 50% | 0% | 83,462 | 70% | 86% | 64% | 41% | 0% |
| Landuse Changes | Perennial crops on 10% of Agricultural Land | 72% | 34% | 11,865 | 10% | 20% | 20% | 14% | 6.8% |
| | Pasture/Land Retirement on 10% of Agricultural Land | 85% | 75% | 11,865 | 10% | 20% | 20% | 17% | 15% |
| | Double the amount of extended rotation acreage | 42% | 59% | 3,560 | 3% | 3% | 3% | 1% | 2% |
| | New development BMPs | 0% | 65% | 1,000 | 0.5% | 0.5% | 0.5% | 0% | 0.3% |
| | Redevelopment BMPs | 0% | 50% | 1,000 | 0.5% | 0.5% | 0.5% | 0% | 0.3% |
| | Voluntary/Incentive based BMPs | 0% | 50% | 2,500 | 1.3% | 1.3% | 1.3% | 0% | 0.7% |

### *Combined BMP scenarios*

In most cases, using multiple BMPs to accomplish reductions is the most logical, practical approach and is one of the primary themes of the Tomer field-to-stream continuum. Different individual BMPs may be implemented on different treatment areas -- i.e., in parallel -- or different individual BMPs may combined within a single treatment area, positioned in sequence from field downslope to the receiving stream or lake -- i.e., in series. However, in the case of serial scenarios, simply summing reduction percentages is not appropriate as multiple BMPs working in series (i.e., "treatment train") are not additive. Most likely a more conservative, multiplicative type of approach (i.e., multiplying each BMP reduction percentage by the next one downslope until the stream is reached) would give reasonable cumulative reductions for multiple BMP scenarios. In this way, countless combinations of scenarios could be developed to achieve nutrient reduction goals.

Several combined scenarios were analyzed for this study that took into account multiple BMPs applied in-series, in-parallel and both. As mentioned, many combinations are possible; however, this analysis focused on those BMPs with the greatest potential cost-effectiveness for reducing both nitrogen and phosphorus. The resulting scenario was intended as a general framework as to which BMPs were the most cost-effective and the estimated level of adoption and associated costs needed to achieve the WMA established objectives for nitrogen and phosphorus reductions in the watershed.

As such, these results represent a set of practicable recommendations that can serve as a starting point for looking at many different possible scenario strategies.

Several criteria steered the combined scenario formulation:

- All scenarios contained adoption of in-field nutrient management BMPs that optimize nutrient application rates and timings and that have been demonstrated to result in a net profit for continuous corn and corn/soybean rotations.
- Tile drained areas were the focus of all the scenarios due to their disproportionate contribution of nitrogen and comparable contribution of phosphorus relative to non-tiled drained areas.
- BMPs that addressed both nitrogen and phosphorus were emphasized over those addressing one or the other.
- Scenarios containing structural BMPs were constrained as to not exceed the actual number of potential treatment sites and their upslope drainage areas as determined by the terrain suitability analysis (ACPF).
- The cumulative effects of BMPs placed in series are not additive; therefore a step-wise, field-to-stream calculator was developed to provide estimates assumed reasonable.

## *Approach to Meeting the WMA Nutrient Reduction Objectives*

An approach to meet the WMA nutrient reduction objectives was developed in order to illustrate the magnitude of BMPs that would be needed in the watershed. The approach is presented in Table 6-3. The process to develop this approach was an iterative analysis aimed to determine combinations of cost-effective BMPs and factoring in the estimated level of BMP adoption as described above.

The approach achieves the 41% nitrogen reduction goal, exceeds the 29% P reduction goal and initiates increases in soil organic matter on 20% of the agricultural land. It consists of the following:

- Implementing nutrient management BMPs on 40% of the agricultural land in the watershed
- Implementing cover crops plus no-till on half of these acres (i.e., 20% of total agricultural acres)
- Installing edge-of-field structural BMPs to treat runoff from 40% of the total agricultural area
- Adopting perennials/pasture/land retirement BMPs on 4% of agricultural land targeted on lands with the highest nutrients yields per the hot-spots analysis
- Installation of appropriate BMPs to treat 45% of the urban area
- All of these BMPs are assumed to be placed in areas of drain-tile

**Table 6-3.** Approach to Meet Squaw Creek WMA Nutrient Reduction Objectives

| | BMP | Treatment Area | | | | Squaw Creek Watershed-wide Reductions | |
|---|---|---|---|---|---|---|---|
| | | % of watershed | Acres | % of Ag | % of N/P | % N reduc. | % P reduc. |
| In-Field Practic | Nutrient Management | 32% | 47,463 | 40% | 49%/36% | 9% | 6% |
| | Cover Crops | 16% | 23,731 | 20% | 29%/18% | 10% | 4% |
| | No-Till | 16% | 23,731 | 20% | 29%/18% | 0% | 16% |
| Edge-of-field Practices | Nutrient removal wetlands[1,2]<br>Riparian buffers [1,2,3]<br>Bioreactors<br>Sediment Basins<br>Grassed Waterways<br>Saturated Buffers | 32% | 47,463 | 40% | 49%/36% | 20% | 13% |
| Land Use Changes | Perennial energy crops<br>Pasture/Land retirement<br>Alfalfa/corn rotations | 3% | 4,746 | 4% | 5%/4% | 4% | 1% |
| | **Urban BMP Category/Practice** | **% of watershed** | **Acres** | **% of Urban** | | **% N reduc.** | **% P reduc.** |
| Urban | New & Existing Development BMPs | 3% | 4,500 | 45% | 2%/2% | 0% | 1% |
| | | | | | **TOTAL REDUCTIONS:** | **43%** | **41%** |

[1] BMPs are assumed to be implemented upslope to downslope -- within the same area

[2] These BMPs were emphasized in the analysis because of high N and P reduction potential

**The gross cost <u>per year</u> for this scenario is roughly $2,400,000 with a cost <u>per acre per year</u> of $45. When EQIP cost-sharing (roughly 50% depending on BMP) is factored in, these numbers decrease to roughly $1,200,000 and $23 <u>per acre per year</u>, respectively. These are planning-level cost estimates and should be used with that consideration in mind.**

As described in the watershed hot-spots description above, 33% of the total agricultural nutrient loads originate from 20% of the agricultural lands. Targeting these areas will effectively lower the overall cost because less land would be necessary to achieve reduction goals (or, a higher reduction could be achieved for the same cost).

Additional cost-share and incentive programs beyond EQIP may be available (e.g., CRP, CREP, etc.) for farmers to implement practice and grant sources may be available to the WMA to provide assistance in implementing practices.

For Urban implementation BMPs in terms of costs, a what-if scenario was done. The voluntary/incentive retrofit improvements that are external and will likely need public funding to implement. A very general look at voluntary retrofits considers the existing developed land of Ames of approximately 7,000 acres, times the potential scale of implementation of 10%, divided by the 15 years of the planning horizon of this plan. While the values could vary widely due to many assumptions, the estimated scale of costs was around $2,100,000 per year. Since that is along the scale of all the agricultural implementation costs discussed below, whereas the proportion of contribution in this case is less than 5% of pollutants (runoff volume could be higher). Therefore these values are not included in the proposed cost totals. This does, however, point to a trend being discussed nationally about funding from urban areas being used upstream on agricultural settings to provide outcomes that benefit the urban areas, somewhat akin to pollutant credit trading. Since the cost/lb pollutant removed can be much more effectively spent upstream, this may make sense. The other aspect is the pragmatic approach that problems in urban areas (flooding, water quality degredation, stream erosion) may be more effectively solved upstream, due to lower costs per unit benefit and where other funding mechanisms are very limited.

#### 6.2.7. **Streambank Erosion Load**

Estimating nutrient load contributions in river systems from streambank erosion is an area of active research. It is a difficult parameter to estimate since stream erosion is variable, the nutrient content of the soils varies significantly, the ability of that nutrient to leach out of the sediment phase varies, and in-stream dynamics of sediment transport and biological uptake complicates the net transport of nutrients downstream. While progress is being made in the literature, we did not have an accurate way to account for this input, so it was not separately quantified or added to the estimates. That said, it is still an area of concern and likely contributor to overall loadings and impacts to stream health and downstream streams and reservoirs. So while not explicitly quantified, there are several strategies within the implementation section and BMPs that address streambank erosion and these should be a priority so as to establish a more stable streambank. Efforts have already been started by the City of Ames on stream stability.

### 6.2.8. **Priority Bacteria Reduction Strategies**

Many of the conservation practices/BMPs described above have a dual benefit of removing bacteria from runoff or preventing it from becoming washed off in the first place but there are several additional practices that apply specifically to bacterial pollution. The following are the strategies to specifically address bacteria pollution in the Squaw Creek Watershed.

#### *Manure Management*

The following is a general approach to addressing bacterial pollution to the stream as a result of animal manure.

- Identify known sources that are directly contributing bacteria to waterbodies (e.g. areas where livestock have access to streams), using local knowledge; windshield surveys, interviews with landowners, etc.
- Continue baseline monitoring of the stream reach and add additional monitoring stations along the stream reach and tributaries to help pin point potential sources of bacteria.
- Promote the use of manure injection or incorporation of manure on all land where manure is applied.
- Promote good manure application practices such as:
    - Applying manure to relatively dry fields
    - Avoiding steep sloping areas
    - Avoiding areas near water bodies or drain tile intakes
    - Avoiding vulnerable locations for spreading manure
    - Avoiding areas prone to flooding
    - Avoiding applying on frozen soil
- Conduct education and outreach to ensure that good manure management practices are understood and followed.

#### *Private Septic System Management*

An intensive inspection of private septic systems could be conducted throughout the Watershed to determine the location of any illicit discharges/straight pipes and to assess the condition of all septic systems. This effort, commonly referred to as a sanitary sweep, could be eligible for grant funding. Following the identification of failing septic systems a course of action to correct these systems will need to be coordinated with the landowners, the Counties and Iowa DNR.

#### *Education/Outreach*

Education efforts focus on bringing greater awareness to the issues surrounding bacteria contamination and methods to reduce loading and transport of bacteria. Education efforts targeted to the general public are commonly used to provide information on the status of impacted waterways as well as to address urban and rural sources of bacterial contamination. Education efforts may emphasize aspects such as cleaning up pet waste or managing the landscape to discourage nuisance congregations of wildlife and waterfowl. Education can also be targeted to municipalities, wastewater system operators, land managers, producers, and other groups who play a key role in the management of bacteria sources.

***Urban Education***

In urban areas, residents should be provided education on sources of bacterial contamination in urban stormwater, and how urban stormwater affects local water quality. For example, education should focus on reducing bacterial sources from pet and wildlife waste. Providing guidelines to reduce bacterial contamination in urban settings should include:

- Maintaining taller vegetation around ponds and creeks which may deter geese as well as filter stormwater runoff
- Pet waste collection on/ near impervious surfaces, in dog parks, and within riparian areas.
- Discouraging wildlife feeding, especially in riparian areas.

***Rural Education***

Sources of bacterial contamination in waterbodies in rural areas are most often due to livestock production (including feedlot and pasture management), manure and septage management, and failing septic systems. Training and educational materials should be provided to producers and landowners on the importance of reducing bacterial contamination in waterbodies from these sources. Some examples of education that can be provided are listed below.

- Ensure livestock producers are aware of appropriate manure management practices
- Encourage producers to work with grazing specialists on feedlot/ pasture management particularly in riparian areas
- Provide information on and encourage the use of agricultural BMPs, such as buffer strips and fencing around riparian areas,
- Provide education on how to maintain individual septic systems, as well as inspect for or detect leaks

### *Pet Waste Control*

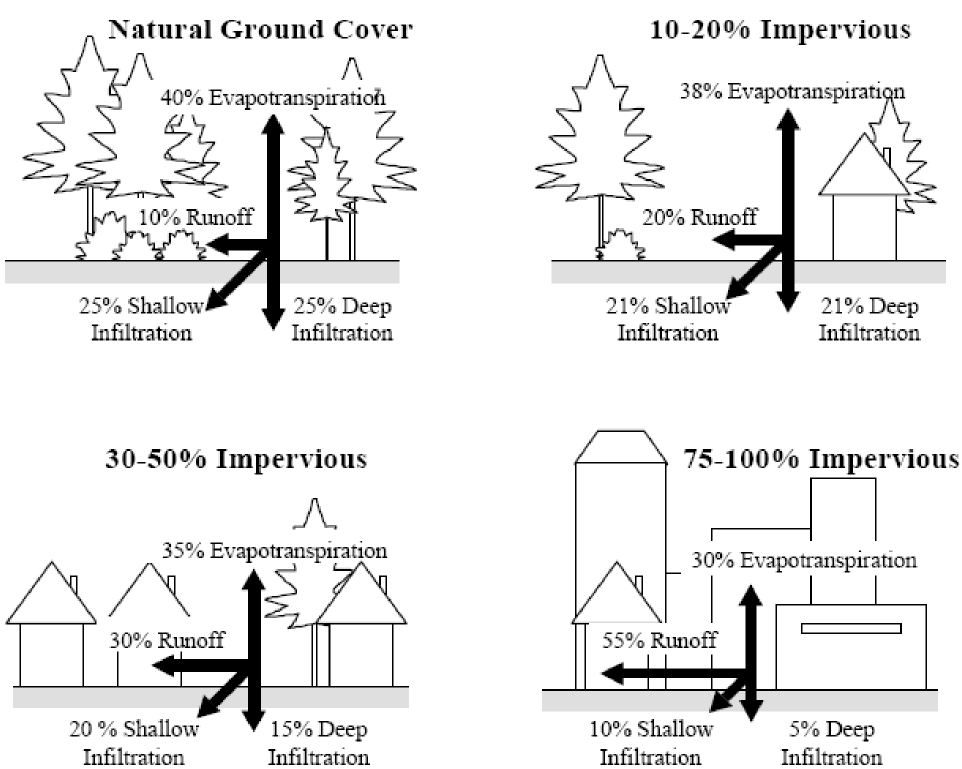
The City of Ames has an ordinance that requires proper disposal of pet waste and litter in a timely manner as a method for reducing bacterial pollution in urban areas. This ordinance could be extended to other developed areas within the Watershed.

## 6.3. Hydrology Strategies

The following describes the recommended strategies for meeting the objectives of the goal to reduce the effects associated with altered hydrology (Goal 5.2) within the watershed.

### 6.3.1. Background on Restoring Natural Hydrology in a Watershed

The study of runoff management and how best to control impacts of human activities on the land has consistently over the past 5-10 years focused more and more on the differences in volume of runoff between land uses. The extra volume generated when land uses are converted, whether it be from forest to row crop agriculture or agriculture to urban, is significant (Figure 6-2). The extra runoff water tends to carry increased loads of pollutants (nutrients, sediment, other contaminants), either originating from the new land use or simply because the extra power of the additional water is more efficient at washing off the pollutant, rather than being trapped in the natural vegetation and porous soils. Many studies are now also showing the dramatic effects and negative impacts on the stability and erosion in streams and rivers due to increased runoff. The bank erosion that occurs impacts streams in two ways: it adds more pollutants (sediment and nutrients) to the water and it makes the stream configuration less natural which lacks habitat for things that live in the stream. Added to that, stream erosion also takes away upland and can threaten structures.




Source: Adapted from Arnold and Gibbons, 1996

**Figure 6-2** Changes in hydrology associated with land use changes

### 6.3.2. Recommended Approach for Restoring Hydrology

While for many years the discussion was about controlling the peak flow rate (that maximum flow at a given instant in time) and less on the volume of flow (total water over a longer time period), and how to capture pollutants at the "end of the pipe/system" that is no longer the emphasis. The problems were too large to address, the solutions were not always very effective, and the costs were becoming so high, that the management of runoff has been shifting more toward the source of the problem: increased volume of water.

The practices that are described in the Strategies for Improving Water Quality section of the plan have additional benefits of restoring natural hydrology for the watershed by reducing runoff volume. That reduction in runoff volume can then translate into less erosion/instability, better stream health, and reduced flooding. And while much attention is often given to the need to address flooding and larger storms, it is also important to understand that the stream in low flow ("base flow") can be significantly improved when the water is retained in the system and allowed to seep out slowly.

Many of the agricultural practices proposed not only are effective at having benefits of reducing nutrient and sediment contamination, but also aid in reducing runoff volumes and the flashy flows in a stream. This contributes to overall improvement to the stream. Some of those practices being considered that have a positive impact on reducing runoff volumes and/or significantly slow the runoff include, and a relative level of impact expected (Table 6-4):

A variant on volume control that has been adopted in the Iowa Stormwater Management Manual (http://www.iowadnr.gov/Environment/WaterQuality/WatershedImprovement/WatershedBasics/Stormwater/StormwaterManual.aspx) is extended detention. This is holding runoff in storage areas to the extent that it is slowly releasing runoff significantly long, thus partially mimicking the reduced, slow flows in a natural stream. By managing the flows in this way, the erosive power of the flashy, intense flows are lowered and stream stability is improved. An example of how this could be used effectively in the Squaw Creek watershed, would be to utilize

***City of Ames Flood Mitigation Study***

*The City of Ames Flood Mitigation Study (Feb 2014) evaluated alternative to address flood damage associated with the Squaw Creek and Skunk Creek. The study involved updating hydrailic modeling, performing additional flood inundation mapping, and screening various mitigation alternatives including economic and environmental components. The Study determined that the highest ranking alternatives were; conveyance improvements, two regional storage reserviors and levees to provide 100-year flood protection.*

low-lying flood plains and/or large natural depressions that are not actively cropped as a storage areas, and controlling the outflow with a control structure. This can be done in a way that delays flows, helping the stream and downstream, while not permanently flooding the flood plain areas. Similarly, nutrient removal wetlands can also be configured with an outlet to retain water and slowly release it. These situations need to be carefully designed, considering the effects upstream, on adjacent lands, and the basin itself to find a good fit that meets multiple needs.

**Table 6-4.** Volume control effectiveness of potential BMPs

| | Category | Practice | Volume control effectivness |
|---|---|---|---|
| In-field Practices | Nutrient Management Practices | Reduce nitrogen application rate to | NA |
| | | Use a nitrification inhibitor | |
| | | Eliminate fall anhydrous nitrogen | |
| | | Sidedress all spring applied nitrogen | |
| | | Reduce phosphorus application rates | |
| | | Manure injection/Phosphorus banding | |
| | | Cover crops | Medium |
| | | Convert intensive tillage to conservation tillage | Medium |
| | | Convert conservation tillage to no-till | Medium |
| | | Increase soil organic matter | High |
| Edge-of-Field Practices | | Nutrient Removal Wetlands | Low |
| | | Denitrification Bioreactors | Low |
| | | Sediment Basins | Low |
| | | Riparian Buffers | Low/medium |
| | | Controlled Drainage | Medium/high |
| | | Grassed Waterways | Low/medium |
| | | Saturated Buffers | Low/medium |
| Land Use Changes | | Perennials/Energy Crops | High |
| | | Pasture and/or Land Retirement | High |
| | | Extended alfalfa rotations | High |

For urban areas, many of the impacts to urban runoff are difficult to control without first addressing the runoff volume. Many studies have shown that as the impervious areas (hard surfaces such as streets, roofs, parking lots, etc.) increase, there is a clear trend in decreasing stability and health of streams and rivers. Reflecting this trend, the City of Ames has a stormwater ordinance that explicitly has a volume control requirement. Many of the new urban stormwater practices being incorporated and required by the new city codes are aimed at reducing runoff volume, and thus reducing pollutants and volume impacts. Strategies for addressing the flooding that occurs in the lower part of the watershed are not expressly contained in this plan. A detailed assessment of the flooding issues has been conducted by the City of Ames and mitigation strategies have been developed.

## 6.4. Habitat Improvement Strategies

Within the Squaw Creek Watershed, improving the quality of stream and riparian habitats will be beneficial to native fish species, invertebrates that provide food for fish, as well as other wildlife that utilize the habitats. Maintaining healthy fish and wildlife populations increases recreational opportunities for anglers, hunters, birders, and other that enjoy viewing wildlife in a natural setting.

Natural resources such as remaining prairie and wetlands should be protected to prevent further loss and degradation. In addition to providing recreational opportunities such as hunting, fishing, hiking, and wildlife observation, these habitats provide a number of other services that often go overlooked. For example, wetlands increase water quality by filtering nutrients and pollutants prior to entering larger waterbodies. Wetlands also act as flood control reservoirs by storing water and slowly releasing it into the watershed.

Prairies are also a very important part of the landscape, as they once covered nearly 80% of what is now the state of Iowa. Prairies provide habitat for rare and endangered plant and animal species, as well as wildlife species that are prized for hunting, and invertebrate species that are critical for pollination of native and agricultural plants. Deep-rooted prairie plants prevent soil loss and erosion by holding the soil in place, which ultimately improves water quality. Prairie plants are also very important for sequestering carbon from the atmosphere which would help to mitigate climate change.

Restoration or rehabilitation, as well as habitat reconstruction are methods to increase and improve habitat. Ecological restoration is the process of assisting the recovery of an ecosystem that has been degraded, damaged, or destroyed; whereas, reconstruction is the process of rebuilding habitat on land that has been converted to other uses, such as agriculture. When done correctly and given an appropriate amount of time, restoration and reconstruction of habitats is often successful. When a degraded habitat has been restored, it is less likely to succumb to outside pressures such as invasive species.

When choosing habitats to protect and restore, patches of land that connect one intact habitat to another are often the most valuable. These tracts of land are referred to as wildlife corridors because they allow wildlife species to move across the landscape with a reduced risk of interacting with humans. Wildlife corridors increase wildlife populations by reducing mortality, especially of species that are very vulnerable to habitat fragmentation. Many species do not have the capability to move through a human-modified landscape. Turtles, for example, have very high mortality rates due to roads.

Another way habitat can be increased is by engineering and design of low impact stormwater and drainage water management features rather than conventional structural approaches such as impervious surfaces.

## 6.5. Stream Restoration/Recreational Enhancement Strategies

The following section describes the general strategies for restoring streams in the watershed as well as more specific areas that are recommended for action.

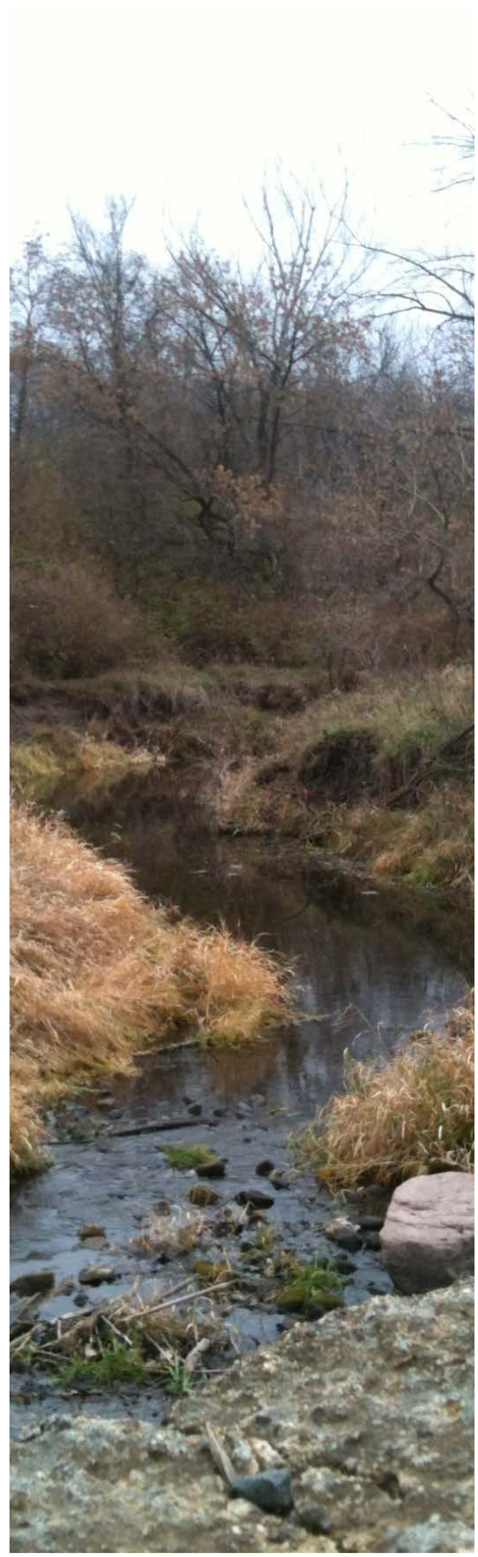
### 6.5.1. General Strategies for Restoring Streams

**Worle Creek, portions of Crooked Creek, Onion and Montgomery Creeks were all found to be in need of increased riparian buffers.** Simply establishing vegetative cover in riparian zones areas will help reduce sediment load from stream banks. However targeting the outer bends of stream sections with poor riparian vegetation cover where most stream erosion occurs would increase the effectiveness of targeted buffer practices. In areas of excessive streambank erosion, loss of farmland or important fish habitat areas, streambank bioengineering may be called for. This practice uses vegetative materials in combination with structural tools, such as rock at the toe of the streambank. The ACPF tool described in above section identified the appropriate location and type of riparian buffers. Refer to Appendix 4 for maps of the types of riparian buffers possible for each subwatershed.

In the upper subwatersheds there is apparent need for grazing management and buffer establishment/ enhancement.

In channelized reaches (ditches) the development of more environmentally-friendly two-stage ditches would help reduce the downstream transport of sediment and nutrients, while improving fish habitat and reducing future maintenance costs. Two-stage ditches make the most sense where the drainage area is big enough that the pollutant removal is substantial, but not so big that natural stream forces of erosion overwhelm the channel. This is typically in the range of one – ten square miles in drainage area, give or take a few square miles. In the headwaters or middle reaches of Crooked Creek, Drainage ditch 159, Montgomery Creek and Onion Creek are examples of the appropriate setting for two-stage ditches.

Streams are significant sources of sediment in Squaw Creek. Sediment is important because it affects water quality and in-stream aquatic life and can influence flooding issues



downstream. Therefore it should be a goal of the watershed management plan to reduce excessive bank erosion to protect farmland, improve in-stream fish habitat and to reduce downstream flooding issues. The Cox et al. (2011) study in Iowa showed that much of the sediment thought to be coming from sheet erosion in fields is actually coming from field gullies. The use of grassed waterways and improved water retention practices to reduce runoff are critical for gully control. The ACPF tools described in previous sections identified specific locations where grassed waterways could be sited. Refer to Appendix 4 for maps showing the locations of potential grassed waterways for each subwatershed.

Factors that influence the landowner adoption of management practices need to be better understood for management success. Despite evidence that water quality has decreased in the region over the past 50 years, landowners were found to have different perceptions of changes to stream water levels and water quality (Wagner and Gobster 2007). This indicates the need to connect with landowner concerns and values so that landowner identify with the issues being addressed and will more likely adopt the management practices. Refer to the Education/Outreach strategies for a discussion of the watershed efforts to engage and influence landowners and residents of the watershed.

### 6.5.2. **Specific Stream Protection and Restoration Approaches**

Data collected for the Squaw Creek Watershed Stream Assessment was analyzed to formulate 11 restoration priority sites. The stream assessment randomly selected sites based on land use types proportionately representative of the entire watershed. Approximately 58 miles of stream were surveyed, which is about one-third of total stream miles within the watershed. As a result, the following recommendations are based only on data collected from randomly selected sites.

Priorities were formulated based on the condition of riparian habitat, amount of permanent vegetation on banks, stream bank height, surrounding land use, and substrate embeddedness. Considerations were also based on a cost/benefit analysis and the perceived outcomes of restoration efforts. Sites that have the opportunity to yield many benefits from simpler restoration efforts, such as establishing a buffer from grazing, were also included in these lists. Sites characteristic of a reference reach (Table 6-5) require management strategies that emphasize enhancement and protection rather than restoration (Table 6-6).

**Table 6-5.** Stream sites prioritized for protection/enhancement efforts

| Priority | Stream Name | Habitat Condition | Degradation | Restoration Recommendations |
|---|---|---|---|---|
| 1 | Upper Squaw Creek | Excellent | 10-15’ high banks<br>Low shade | Reshape banks<br>Enhance gravel substrate |
| 2 | Lower Squaw Creek | Excellent | Log dammed channel<br>Sandy substrate<br>Unstable banks | Remove trees that cause channel instability<br>Increase scouring<br>Enhance habitat features |
| 6 | Upper Squaw Creek | Excellent | Unstable banks<br>60-80% bare ground<br>Low shade | Reshape banks<br>Enhance cobble substrate |

**Table 6-6.** Stream sites prioritized for restoration efforts

| Priority | Stream Name | Habitat Condition | Degradation | Restoration Recommendations |
|---|---|---|---|---|
| 3 | Bluestem Creek | Average | 15'+ high banks<br>80-100% bare ground<br>Unstable banks<br>Low shade | Enhance gravel substrate<br>Reshape and seed banks<br>Fence off cattle |
| 4 | Middle Squaw Creek | Average | Silted substrate<br>6-10' high banks<br>Low shade<br>Unstable banks | Reshape banks<br>Fence off cattle |
| 5 | Scott Drainage Ditch 292 | Poor | Low shade<br>40-60% bare ground<br>Silted substrate<br>Moderately unstable banks | Enhance cobble substrate |
| 7 | Glacial Creek | Poor | Silted substrate<br>Moderately unstable banks<br>Low shade | Increase scouring<br>Enhance gravel substrate |
| 8 | North Onion Creek | Poor | 40-60% bare ground<br>Unstable banks<br>Heavily eroded pasture site<br>Low shade | Fence off cattle<br>Enhance gravel substrate<br>Seed banks |
| 9 | Upper Squaw Creek | Average | Sandy substrate<br>Unstable banks<br>60-80% bare ground<br>Low shade | Reshape banks<br>Increase scouring<br>Seed banks |
| 10 | Montgomery Creek | Average | 6-10' high banks<br>80-100% bare ground<br>Unstable banks<br>Sandy substrate | Reshape and seed banks<br>Increase scouring |
| 11 | Clear Creek | Average | Debris dammed channel<br>80-100% bare ground<br>Sandy substrate<br>Unstable banks | Remove debris<br>Increase scouring<br>Seed banks |

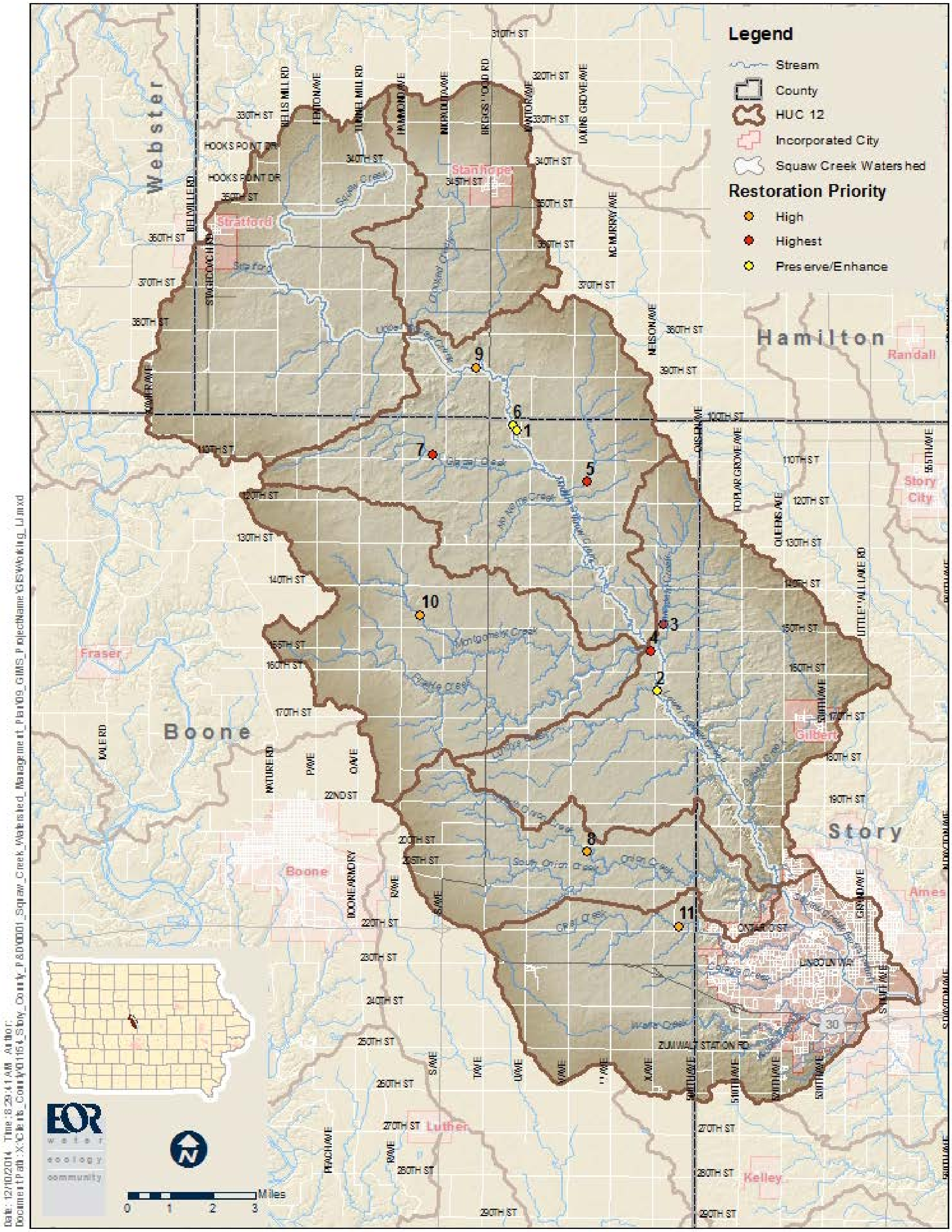



**Figure 6-3.** Priority Stream Restoration Sites

### 6.5.3. **Strategies to Enhance Recreational Opportunities**

As discussed in section 5.5, the lack of recreational uses of Squaw Creek and its tributaries was identified as an issue by residents of the watershed during the listening session. As a result, the WMA established a goal to enhance the recreational opportunities within the watershed. There are two primary approaches for increasing recreational values of the creek and its corridor. The first involves developing the recreational capacity of the stream itself for water-based recreation and the second involves creating a trail system throughout the riparian area adjacent to the stream.

#### *Water Trail*

Currently there are a several challenges to using Squaw Creek for water-based recreation like canoeing, kayaking, etc. Many of the challenges were noted at the listening session held in Ames in the spring of 2014. Beyond concerns about the quality of water within the stream, there are currently no formal access points and there are numerous stream-bank trees that have fallen into the stream making navigation difficult and potentially dangerous. The long term goal would be to create a water trail that would include the entire extent of the designated Recreation Use portion of the stream (mouth up to the confluence with Glacial Creek). Some additional assessment and planning will be needed before a water trail could be developed. In addition to address navigational issues involving obstacles within the stream, the condition of the various road crossings along the stream will need to be assessed and safety issues (access, flow, etc.) will need to be addressed. A communication system will be needed whereby users can determine whether or not the creek is at a safe, navigable condition.

#### *Regional River Trail*

As described in the education/outreach strategies section, a regional river trail system is envisioned for the Squaw Creek corridor. A trail master plan will need to be developed, in cooperation with the Counties and Cities within the watershed. The plan will identify feasible areas for trail development within the riparian corridor of the creek, connections to existing trails and roadways, and outline approaches for acquiring easements. The trail will be used to create a connection to the stream, both physically and from a stewardship standpoint. Education will be a critical component of the trail system. Signs describing watershed issues and messages aimed at what can be done to improve water quality in the watershed will be emphasized. Demonstration projects will be incorporated into the trail system so there will be highly visible examples of watershed management practice available to users of the trail. Potential demonstration projects to be tied to the trail system would be stream restorations, riparian or saturated buffers or a simple practice such as fencing to manage cattle access to the stream.

#### *Crossing Study*

A common analysis that can provide a wealth of information for watershed management is a crossing study. The study consists of a survey of crossings within a particular reach of stream. In the case of Squaw Creek watershed, a crossing study should be conducted on the recreation reaches of Squaw Creek (mouth to confluence with Glacial Creek). The crossing study would entail a physical measurement and description of each crossing and an assessment of the crossings role in allowing for fish passage, recreational use and hydraulics.

## 6.6. Strategies for Facilitating Partnerships

This work of implementing a successful watershed plan will not be done with one organization or with a few people. It will be most important to build partnerships and cooperate with existing groups and initiatives to successfully implement the watershed management plan. It is our intention from the beginning to build a collaborative, informed effort in order to accomplish our goals. Through these partnerships we will share a common bond in that we would like to see our watershed improve its' water quality and maintain or improve the quality of life. And in this case, quality of life refers mostly to the character of the area and access to clean air and water and outdoor recreation.

This goal also means a commitment to identifying yearly plans with a budget, building strategic plans for projects and setting goals each year. Our efforts should not be underfunded for the work ahead, and we commit to identifying significant resources each year to achieve our plans goals.

The key to effectively manage the watershed, and specifically to foster the types of partnerships that are necessary to achieve all of the goals of the watershed is to hire a watershed coordinator. This should be one of the first priorities of the watershed and should be accomplished by April 1, 2015.

Specific actions to be taken to hire a watershed coordinator include the following

- Develop a five-year budget with expenses for a watershed coordinator by Dec. 2014.
- Create a job description and job announcement by Feb. 1, 2015
- Post job announcement and interview in late Feb.-early Mar. 2015

Identifying and applying for state and federal grants will be a necessary component to managing the watershed and will be considered an on-going activity throughout the course of the watershed plan period.

Specifically the watershed coordinator will;

- Identify watershed grants that are targets for funding.
- Apply for at least one grant a year.
- Meet with partners and stakeholders to identify additional financial support needed yearly.

Working together with our partners is a priority and will be accomplished by meeting at least once a year to identify partnership efforts for the year.

Specifically, the following course of action will be taken;

- Identify planning meetings in the first quarter of each year to our partnership efforts.
- Follow-up each meeting with a plan for the year starting in the second quarter/year.
- Provide regular updates at the Management Board meetings on progress of plan.

An annual meeting to celebrate accomplishments and to bring attention to the watershed work will be held.

The following specific task will be conducted;

- Begin planning the Annual Meeting in the last quarter of each year.
- Hold the Annual Meeting in the first quarter of each year.
- Develop a "State of the Watershed Report" to be delivered at the Annual Meeting
- Make "Conservation Awards" at Annual Meeting

# 7. Monitoring Plan

The primary goal of monitoring is to provide information to support future resource management decisions. These decisions may be based on comparison of monitored conditions to standards, changes detected from completed restoration and protection measures, or changes in watershed land uses or long-term climate changes. The ability to detect such changes in water quality and the reliability of comparisons depend upon the nature and design of the monitoring program.

An intense monitoring effort over several years is recommended to adequately assess pollutant loading and to detect trends. Trend monitoring should be conducted at the USGS flow gauging station at Ames, IA (Station 05470500) as the long-term primary site. Upstream secondary stations can be added over time in a leap-frog method of identifying hot spots or areas of relatively good water quality.

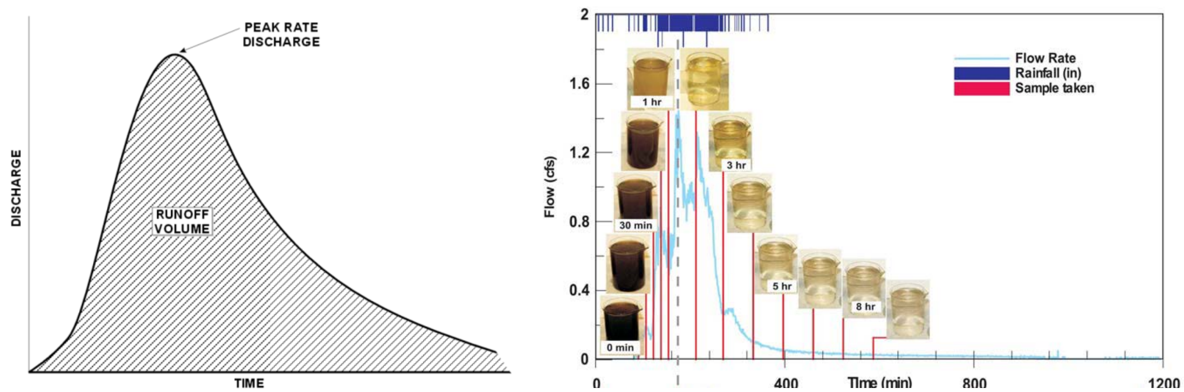
## 7.1. Flows

The first and most important step is to characterize the creek's flows over time – how much water flows each day, month and year. Since pollutant loads (such as pounds of sediment or phosphorus per year) are calculated by multiplying stream flows by sampled pollutant concentrations this requires measuring continuous stream flows. This is done by use of computerized flow gauging stations that record the depth of the stream every 15 minutes or so. The depth of the stream is converted into stream flows based upon mathematical relationships derived from numerous measurements of flows and depths across the stream channel each year. The USGS (the nation's stream monitoring experts) maintains a continuous flow gauging site at the Ames, IA (Station 05470500) that can be utilized. Additional flow stations described in the Stream Water Quality section can also be used when assessing other reaches of the stream or tributaries.

## 7.2. Pollutant Concentrations

The next step is sampling of pollutant concentrations. This could be accomplished by Iowa State students, City of Ames staff or trained volunteers. Typically, the majority of annual loads occur during high flows (storm events and times with the highest monthly flows which for Squaw Creek are March-July). To adequately characterize water quality it is recommended to collect at least 25 samples per year. The samples should be collected during all seasons with a primary focus on high flow events and time periods. Automatic flow-paced sampling should be used to monitor water quality. This will allow for sampling of each storm event's rising and declining limbs of the storm hydrograph (peak and recession of flows). The below figures depict the general concept of storm event sampling. Rising water levels at the beginning of a storm typically have higher pollutant concentrations that decline with receding water levels. If funding is not available (or until funding becomes available) grab sampling could be done at the USGS station with recording of instantaneous river gauge height, date and time noted for each sample. Multiple grab samples would need to be taken over the course of a storm event. Monitored pollutants should include; total phosphorus, soluble reactive phosphorus, total suspended solids, nitrate-nitrogen.

**Figure 7-1** Visualization of water quality over course of storm event




Graphics courtesy of Pat Baskfield, MPCA.

All samples should be analyzed by one certified laboratory familiar with these parameters and supporting standard EPA laboratory quality assurance methods including low level detection/reporting limit (e.g. less than 10 ppb) capabilities for total phosphorus and soluble reactive phosphorus. The laboratory should report analytical results via electronic spreadsheet format within ~14 days of sample receipt. The initial samples should be closely examined within this time period for reasonableness and laboratory detection limits.

## 7.3. Bacteria (*E.coli*) Monitoring

Bacteria monitoring should also be done at the USGS Primary Site at Ames. For comparison to standards, sampling should occur at least 5 times per month per site, from April through October, to obtain geometric mean concentrations for comparison to Iowa *E.coli* standards. A certified analytical laboratory should be used for all samples. Standardized sampling protocols have been established for monitoring *E. coli* in streams.

## 7.4. Biological Monitoring

It is recommended that biological monitoring be conducted in the Squaw Creek Watershed as a way to evaluate water quality trend. The biological monitoring protocol should ensure long-term stream health trends can be interpreted as well as a data set that can be used to target stressors.

## 7.5. Compiling the Data and Calculating Loads

The end result of the intensive monitoring is the calculation of water flows and nutrient/sediment losses from the land expressed as loads or pounds of phosphorus or sediment per acre per year. Wet years can have larger losses that may need to be adjusted for rainfall for inter-year comparisons (pounds P /acre/inch of precipitation). Very large storms can be expected to produce large amounts of runoff and associated pollutants and hence, the emphasis should be on evaluating average values for more typical years.

The more intensive trend monitoring data requires more rigorous compiling of continuous daily flows along with the sampling data for calculation of loads such as with the USACE's FLUX32 software. Sample file formats can be provided to facilitate data reduction. Chronic and acute standard exceedances (E.coli and dissolved oxygen) and loads can be assessed along the flow network stations identifying areas of concern or improvement over time. This could include adjustment for climatic conditions. Urban and agricultural BMP can also be assessed directly by monitoring of representative stormwater discharges with automated equipment.

## 7.6. Future Phased Monitoring Approach:

Upstream tributaries can be added to the monitoring effort in the future to support modeled predictions of watershed hot spots, determine compliance to water quality standards; and to conduct detailed stream loading. Monitoring data could also be used to evaluate the performance of upper watershed areas from restoration efforts.

In the future it is recommended that priority consideration be given to monitoring Squaw Creek above the confluence of Montgomery/Prairie Creeks and Squaw Creek above the confluence of Onion Creek.

Secondary stations should be added further upstream on the mainstem of Squaw Creek. Secondary sites should have water level staff gauges installed and be periodically flow-gauged for correlation with downstream Squaw Creek flows. This would provide a cost savings but still require intensive grab and automatic flow-paced sampling. This is a kind of leap-frogging of stations is used to identify high and low loading watershed areas.

# 8. Funding Sources

The following is a description of available funding sources for watershed management efforts that was adapted from the Iowa Stormwater Education Program.

## Iowa Department of Agriculture and Land Stewardship

Water Quality Initiative accepts applications on an annual basis for projects focused on improving water quality in urban areas. Preference points are given to projects within nine priority watersheds and the projects selected will be announced in March.
Watershed Development and Planning Grants are issued by the Division of Soil Conservation for Districts and watershed partners to complete projects regarding watershed assessment, problem source identification, partnerships, and landowner support.
Water Protection Fund and/or Watershed Protection Fund offers financial assistance to SWCDs interested in watershed implementation grants and those interested are encouraged to contact IDNR.
Watershed Improvement Review Board - The Board awards grants to improve water quality and flood prevention. Eligible applicants are local watershed improvement committees, soil and water conservation districts, counties, county conservation boards, public water supply utilities and cities. The Iowa Legislature makes annual appropriations to the Watershed Improvement Fund, which the WIRP administers.

## Iowa Economic Development Authority

Vision Iowa - River Enhancement Community Attraction and Tourism Program was created to assist projects that will provide recreational, cultural, entertainment and educational attractions.
Community Development Block Grants can be used to fund water and sewer facilities and must comply with the Green Streets criteria. Applications are guided by the CDBG annual application workshop, which is held in conjunction with the Water and Wastewater Infrastructure Funding Summit.

## Iowa Department of Natural Resources - All DNR Grants

Grant Programs
319 Watershed Planning Grant is designed to assist interested groups in developing a Watershed Management Plan, which identifies problems in the watershed and proposes solutions for better water quality. Applicants are encouraged to contact their IDNR Basin Coordinator.
319 Watershed Implementation Grant is designed to assist interested groups in putting their Watershed Management Plan into Action. Applicants are encouraged to contact their IDNR Basin Coordinator.
Land and Water Conservation Fund (LWCF) is a competitive, federally funded grant program that provides match funds of 50% for outdoor recreation area development and acquisition. All Iowa's cities and counties are eligible to participate and deadline is in March of each year.

Resource Enhancement and Protection (REAP) funding is appropriated by the Iowa Legislature and signed into law by the Governor. The program is divided into four categories.

City Park & Open Space: Grant amount dependent on city size and is specifically for parkland expansion and multi-purpose recreation development

County Conservation: Thirty percent of this fund is automatically and equally allocated to all 99 counties to be used for and easements or acquisition, capital improvements, stabilization and protection of resources, repair and upgrading of facilities, environmental education, and equipment. Another thirty percent is allocated based on population and the remaining forty percent is available through competitive grants.

Conservation Education Program: An annual amount of $350,000 is administered by a five-member board to landowners, naturalists, and educators. Funds are divided according to a standard application and mini-grants.

Loan Programs

Clean Water State Revolving Fund is jointly administered by the Iowa Finance Authority (IFA) and DNR

Clean Water Program is designed for publicly owned wastewater treatment works and non-point source project (both public and private entities). A list of priority projects is outlined by the Intended Use Plan on quarterly basis and projects, which determines the eligibility of a project's application

Storm Water Loan Program are available at 3% interest for municipalities that are required to have an MS4 permit.

Water Resource Restoration Sponsored Projects Program reduces the overall interest rates on loans for project designed to improve water quality where the wastewater treatment facility is located. Applications are approved by the Environmental Protection Commission on an annual basis.

## State Soil Conservation Commission

Research and Demonstration Grant Program provides funds to collaborative research teams to explore ways to improve sustainable agriculture and treatment of nonpoint source pollution. Proposals are reviewed by the State Soil Conservation Committee and individual grants cannot exceed $75,000.

## United States Environmental Protection Agency

Environmental Education Sub-Grants are issued to local education agencies, state schools, colleges, non-profit organizations, noncommercial education broadcasting, and tribal education agencies. Applications are accepted through February each year.

Environmental Justice Small Grants supports communities working on solutions to local environmental and public health issues through collaborative partnerships. Approximately $1 million dollar is administered each year with individual grants up to $30,000. Applications are accepted through January.

Urban Waters is a large initiative that improves coordination among federal agencies and collaborates with community-led revitalization efforts to improve the Nation's water systems. Sponsored projects receive support in a number of different ways.

## National Forest Service

Urban and Community Forestry Challenge Cost Share grants provide funding that helps enhance urban forest stewardship, support new employment opportunities, and help build resilience in the face of climate change. Recipients are announced in June each year.

## NGOs

Ducks Unlimited – Living Lake Initiative is established to provide support in enhancing shallow lake complexes.

Keep Iowa Beautiful – Community Beautification Grants are intended for communities or organization of 5,000 or less.

Pheasants Forever – Local Chapters often provide food plot and native grass seed to landowners.

Trees Forever – Working Watersheds Buffers & Beyond program provides a 50% cost share (up to a maximum of $2,000) to implement a water quality project or demonstration site. Riparian buffer plantings are the main focus of the program, but other innovative projects are also considered

## Private Foundations

Community Foundation is useful tool for researching local foundations.

Coca-Cola – Community Support program supports water stewardship, healthy living , recycling, and education.

McKnight Foundation – Environment grantmaking is divided into projects that revolve around restoring water quality in the Mississippi River and that improve the resilience of Midwest Climate and Energy.

Walton Foundation – freshwater initiative supports projects which sustain healthy communities in the Mississippi River Basin.

## Appendix 1: Squaw Creek WMA 28E Agreement

Squaw Creek Watershed Management Authority Agreement
Between Story County, Boone County, Webster County, Hamilton County, City of Ames, City of Gilbert, City of Stanhope, City of Stratford, Story County Soil and Water Conservation District, Boone County Soil and Water Conservation District,
Hamilton County Soil and Water Conservation District, and Webster County
Soil and Water Conservation District

This Joint and Cooperative Agreement (hereinafter referred to as the "Agreement") is entered into pursuant to the authority of the *Code of Iowa*, Chapter 28E on this
day of____________________, 2012 by and between Story County, Iowa; Boone County, Iowa; Hamilton County, Iowa; Webster County, Iowa; the City of Ames Iowa; the City of Gilbert, Iowa; the City of Stratford, Iowa; the City of Stanhope, Iowa; the Story County Soil and Water Conservation District; the Boone County Soil and Water Conservation District; the Hamilton County Soil and Water Conservation District; and the Webster County Soil and Water Conservation District. All entities shall be referred to hereinafter as the "Cooperators".

WHEREAS, Iowa Code section 466B of the *Code of Iowa* authorizes two (2) or more political subdivisions, defined as including cities, counties and/or soil and water conservation districts, all of which must be located within the same United States Geological Survey Hydrologic Unit Code 10 watershed, to enter into agreement under Chapter 28E of the *Code of Iowa* to establish a watershed management authority to enable cooperation in supporting watershed planning and improvements for the mutual advantage of the political subdivisions involved; and

WHEREAS, pursuant to *Code of Iowa* Section 466B.22, a watershed management authority may perform all of the following duties:

1. Assess the flood risks in the watershed.
2. Assess the water quality in the watershed.
3. Assess options for reducing flood risk and improving water quality in the watershed.
4. Monitor federal flood risk planning and activities.
5. Educate residents of the watershed area regarding water quality and flood risks.
6. Seek and allocate moneys made available to the Authority for purposes of water quality and flood mitigation.
7. Make and enter into contracts and agreements and execute all instruments necessary or incidental to the performance of the duties of the Authority. The Authority shall not acquire property by eminent domain.

and;

WHEREAS, the counties of Story, Boone, Hamilton, and Webster; and the cities of Ames, Gilbert, Stanhope, and Stratford; and the Soil and Water Conservation Districts of Story, Boone, Hamilton, and Webster deem establishment of the Squaw Creek Watershed Management Authority (the Authority), a watershed management authority encompassing all of the Squaw Creek watershed, a Hydrologic Unit Code 10 (HUC 10) watershed, to be of mutual advantage; and

WHEREAS, it is mutually desired to enter into this Agreement pursuant to *Code of Iowa* Chapter 28E for the purpose of establishing the Squaw Creek Watershed Management Authority to carry out watershed planning and improvements in the Squaw Creek watershed

NOW THEREFORE, it is agreed by and between the parties as follows: SECTION 1.

IDENTITY OF THE PARTIES.

1.1 The Counties of Story, Boone, Hamilton, and Webster are each a municipality of the State of Iowa, organized and operating pursuant to *Code of Iowa* Chapter 331. Their respective addresses are:

Story County 900 Sixth Street
Nevada, Iowa 50201

Boone County 201 State
Street
Boone, Iowa 50036

Hamilton County
2300 Superior Street, Suite 3 Webster City, Iowa
50595

Webster County 701 Central
Avenue
Fort Dodge, Iowa 50501

1.2 The Cities of Ames, Gilbert, Stanhope, and Stratford are each a municipality of the State of Iowa, organized and operating pursuant to *Code of Iowa* Chapter 364. Their respective addresses are:

City of Ames
515 Clark Avenue
Ames, Iowa 50010

City of Gilbert
119 Main Street, P.O. Box 29
Gilbert, Iowa 50105

City of Stanhope
600 Main Street, P.O. Box 128
Stanhope, Iowa 50246

City of Stratford
805 Shakespeare Avenue
Stratford, Iowa 50249-0218

1.3 The Soil and Water Conservation Districts of Story, Boone, Hamilton, and Webster are each a governmental division of the State of Iowa as defined in *Code of Iowa* Section 161A3(6) and a soil and water conservation district established pursuant to Iowa Code Section 161A5(1). Their respective addresses are:

Story County SWCD 510 South
11th Street Nevada, Iowa 50201

Boone County SWCD 1602 Snedden
Drive
Boone, Iowa 50036

Hamilton County SWCD 1921 Superior
Street
Webster City, IA 50595-3145

Webster County SWCD 1898
Kountry Lane Fort Dodge, IA 50501

SECTION 2. SQUAW CREEK WATERSHED BOUNDARY

The area within this Agreement shall be known as the Squaw Creek Watershed Boundary. This Boundary is shown in Attachment A.

SECTION 3. PURPOSE.

3.1 The purpose of this Agreement is to provide for the manner in which the parties shall cooperate with one another to successfully encourage, plan for, and implement watershed activities within the Squaw Creek watershed, including but not limited to the following activities authorized pursuant to *Code of Iowa* Section 466B.22:

3.1.1 Assess the flood risks in the watershed.

3.1.2 Assess the water quality in the watershed.

3.1.3 Assess options for reducing flood risk and improving water quality in the watershed.

3.1.4 Monitor federal flood risk planning and activities.

3.1.5 Educate residents of the watershed area regarding water quality and flood risks.

3.1.6 Seek and allocate moneys made available to the Authority for purposes of water quality and flood mitigation.

3.1.7 Make and enter into contracts and agreements and execute all instruments necessary or incidental to the performance of the duties of the Authority. The Authority shall not acquire property by eminent domain.

SECTION 4. NO SEPARATE ENTITY CREATED.

4.1 It is the intention of this Agreement that there be no new or additional legal or administrative entity created by this Agreement, nor that the inherent governmental powers of any Cooperator be affected in any way beyond the terms of this Agreement.

4.2 A joint board of the Cooperators known as the Squaw Creek Watershed Management Authority Board (the Board) shall be responsible for coordinating watershed planning and improvements. The Board shall be comprised of one appointee from each county, city, and district participating in this Agreement.

4.3 Once established, the Board will develop governing bylaws.

SECTION 5. DURATION.

This Agreement shall be in effect in perpetuity until terminated pursuant to Section 13.

SECTION 6. POWERS AND DUTIES.

6.1 The parties to this Agreement shall retain all powers and duties conferred by law but shall work together in the exercise of such powers and the performance of this Agreement. These powers shall not be transferred to the Watershed Management Authority. Each party shall be responsible for:

6.1.1 identifying opportunities for funding and in-kind support for the undertaking of watershed planning and improvements within the Squaw Creek watershed;

6.1.2 identifying opportunities for infrastructure development and planning capable of assessing and mitigating flood risks in the watershed;

6.1.3 identifying the most effective best management practices for water quantity and water quality improvements in the watershed;

6.1.4 participating in educational/outreach programs regarding water quality and flood risks;

6.1.5 identifying opportunities for infrastructure development and planning to assess and mitigate water quality in the watershed;

6.1.6 providing support for the administration of any projects, including technical, financial and clerical, as agreed to by the Cooperators;

6.1.7 securing such financing, including grants, loans and the issuance of bonds of loan agreements, as determined by the respective party to be necessary or desirable to achieve the objectives of the agreement;

6.1.8 designing and bidding of projects;

6.1.9 administering contracts; and

6.1.10 observing construction.

SECTION 7. MANNER OF FINANCING.

The Board may solicit, accept and receive donations, endowments, gifts, grants, reimbursements and other such funds as necessary to support work pursuant to this Agreement. It is agreed and understood by the parties hereto that no financial obligations upon any cooperator are intended to be created hereby.

No action to contribute funds by a Board member of the Authority is binding on the Cooperator that he or she represents without official approval by the governing body of that Cooperator. No Cooperator may be required to contribute funds to the Authority, except to fulfill any obligation previously made by official action by the governing body of the Cooperator.

The Board will review each opportunity for funding or in-kind support. After review of the opportunity, a fiscal agent will be nominated. The fiscal agent would be a Cooperator or other organization meeting the fiscal agent standards outlined in the bylaws. Should no Cooperator or other organization accept the nomination of fiscal agent for the opportunity, the opportunity will not be considered.

SECTION 8. ENTIRE AGREEMENT.

This Agreement represents the entire understanding among the Cooperators and no Cooperator is relying on any representation or understanding which may have been made by another

Cooperator and which is not included in this Agreement.

SECTION 9. SEVERABILITY/INVALIDITY.

If any term, provision or condition of this Agreement shall be determined to be invalid by a court of law, such invalidity shall in no way effect the validity of any other term, provision or condition of this Agreement, and the remainder of the Agreement shall survive in full force and effect unless to do so would substantially impair the rights and obligations of the Cooperators to this Agreement or substantially frustrate the attainment of the purposes of this Agreement.

SECTION 10. GOVERNING LAW.

This Agreement shall by governed by and interpreted under the laws of the State of Iowa.

SECTION 11. AMENDMENTS.

11.1 This Agreement may be amended at any time by an affirmative vote of the majority of the governing bodies of all Cooperators. Any Cooperator desiring an amendment to this Agreement shall notify the other Cooperators of its desire, and the reasons for the request.

11.2 Such a request shall be in writing to the other governing bodies of the Cooperators, and shall be considered by their governing body without unreasonable delay and within no more than ninety (90) days of receipt.

11.3 If the request is agreed to by the other Cooperators, each Cooperator shall prepare and submit to the others a certified resolution confirming the affirmative vote of the Cooperator's governing body.

11.4 The Amendment shall take effect ten (10) days following receipt of the last such resolution by the other Cooperators. Amendments shall be filled and recorded as required by Section 16 hereof.

SECTION 12. ADDITIONAL COOPERATORS

12.1 A City, County, or Soil and Water Conservation District within the Squaw Creek Watershed who is not a Cooperator, may request, in writing to all Cooperators, to become a Cooperator.

12.2 Such a request shall be considered an Amendment and shall follow the steps outlined in Section 11 hereof.

SECTION 13. TERMINATION OF AGREEMENT.

This agreement shall terminate upon the mutual agreement of the governing bodies of all Cooperators in the Authority. Upon termination, all property and money then owned by the

Authority shall be distributed equally among its members after payment of all debts. Any funds donated under a stipulation limiting their use shall be dispersed consistent with the owner's direction. The governing body of each jurisdiction may individually terminate their participation in the agreement after providing the Authority a written 90 notice of intent.

SECTION 14. EFFECTIVE DATE.

This Agreement shall take effect upon execution by the Cooperators as required by law, and filing with the Secretary of State in an electronic format.

SECTION 15. NOTICES.

Notices under this Agreement shall be in writing and delivered to the representative of the party to receive notice (identified below) at the address of the party designated to receive notice for each Cooperator as set forth in this Agreement. The effective date of any notice under this Agreement shall be the date of actual delivery of such notice and not the date of dispatch. The preferred means of notice shall be either actual hand delivery, certified US Mail, return receipt requested with postage prepaid thereon, or by recognized overnight delivery service, such as FedEx or UPS.

Notices shall be delivered to the following persons at each Cooperator: Story

County: Chairperson, Story County Board of Supervisors
Story County Administration Building 900 Sixth Street
Nevada, Iowa 50201

Boone County: Chairperson, Boone County Board of Supervisors
Boone County Administration 201 State Street
Boone, Iowa 50036

Hamilton County: Chairperson, Hamilton County Board of Supervisors
Hamilton County Administration
2300 Superior Street, Suite 3 Webster City, Iowa 50595

Webster County: Chairperson, Webster County Board of Supervisors
Webster County Administration 701 Central Avenue
Fort Dodge, Iowa 50501

Ames: Mayor, City of Ames City
Hall
515 Clark Avenue
Ames, Iowa 50010

Gilbert: Mayor, City of Gilbert City
Hall
119 Main Street, P.O. Box 29
Gilbert, Iowa 50105

Stanhope: Mayor, City of Stanhope City
Hall
600 Main Street, P.O. Box 128
Stanhope, Iowa 50246

Stratford: Mayor, City of Stratford City
Hall
805 Shakespeare Avenue
Stratford, Iowa 50249-0218

Story County Soil and Water Conservation District:
Chairperson, Story County SWCD 510 South 11th Street
Nevada, Iowa 50201

Boone County Soil and Water Conservation District:
Chairperson, Boone County SWCD 1602 Snedden Drive
Boone, Iowa 50036

Hamilton County Soil and Water Conservation District:
Chairperson, Hamilton County SWCD 1921 Superior Street
Webster City, IA 50595-3145

Webster County Soil and Water Conservation District:
Chairperson, Webster County SWCD 1898 Kountry Lane
Fort Dodge, IA 50501 SECTION 16.

RECORDATION.

This Agreement shall be recorded pursuant to the requirements of *Code of Iowa*, Chapter 28E.

SECTION 17. ENTIRE AGREEMENT.

This Agreement and attachments attached hereto constitute the entire Agreement, among the Cooperators and supersedes or replaces any prior agreements among the Cooperators relating to its subject matter.

SECTION 18. NO WAIVER.

The waiver or acceptance by any Cooperator of a breach or violation of any provisions of this Agreement by another cooperator shall not operate as, or be construed to be, a waiver of any subsequent breach.

SECTION 19. NO ASSIGNMENT OR DELEGATION.

Neither this Agreement, nor any right or obligation under it, may be assigned, transferred or delegated in whole or in part to any outside party without the prior written consent of all the Cooperators.

SECTION 20. AUTHORITY AND AUTHORIZATION.

Each party to this Agreement represents and warrants to the other that it has the right, power and authority to enter into and perform its obligations under this Agreement; and that it has taken all requisite actions necessary to approve the execution, delivery and performance of this Agreement, and that this Agreement constitutes a legal, valid and binding obligation upon itself in accordance with the terms of the Agreement.

SECTION 21. HEADINGS AND CAPTIONS.

The paragraph headings and captions set forth in this Agreement are for identification purposes only and do not limit or construe the contents of the paragraphs.

SECTION 22. COUNTERPARTS.

The Cooperators agree that this Agreement has been or may be executed in several counterparts, each of which shall be deemed an original and all such counterparts shall together constitute one and the same instrument.

# Appendix 2: Listening Session Input

Listening sessions were held throughout the watershed to notify residents about the planning process, to introduce the topic of watershed management, and to solicit input. Sessions were held as follows:

| | |
|---|---|
| March 10, 2014 | Stanhope Community Center |
| March 11, 2014 | Gilbert City Hall |
| March 13, 2014 | Iowa State University (Squaw Creek Watershed Coalition) |
| April 28, 2014 | Ames City Hall |
| April 29, 2014 | Iowa State University |

The input received at the listening sessions can be generalized as to falling into the following five major categories;

- ***Coordination and Partnerships*** – Residents feel it is important to recognize that there are many other entities involved in conservation efforts in the watershed and that coordinating efforts was important.
- ***Current Watershed Management Efforts*** – Residents felt that there was already a great deal of progress being made towards enacting conservation practices and cleaning up the creeks.
- ***Funding/Financing*** – The primary concern for residents about any new protection efforts in the watershed was the financial impact.
- ***Resource Concerns*** – Many specific concerns about the health/safety of the creeks in the watershed were mentioned.
- ***Tools/Approaches to Solutions*** – The question of 'how' can we improve the health of the creeks was commonly raised.

## Coordination and Partnerships

| Comment | Session |
|---|---|
| Need to coordinate with existing NRCS assistance programs. | Gilbert |
| Requirements of federal programs can be an obstacle for some conservation practices | Gilbert |
| Important to recognize the authority of Drainage District. | Gilbert |
| Addressing stream erosion on own is difficult because of permit fees and requirments of NRCS | Gilbert |
| FSA is doing a great deal but can't help in low production areas; away from field, i.e. timber pasture areas. | Gilbert |
| Watershed Authority could help bridge gap where other programs don't apply | Gilbert |
| Important for Ag and urban areas to understand what each other are doing in terms of conservation. Suggest a tour | Gilbert |
| Having a watershed coordinator would be helpful | Gilbert |

| Comment | Session |
|---|---|
| Important role for WMA would be to build partnerships and provide support for willing landowners | Gilbert |
| Important for WMA to not overlap with other organizations | Gilbert |
| Hamilton County has the most drainage districts in the country | Stanhope |
| Drainage Districts assess for maintenance and improvements that are made. Not an annual tax | Stanhope |
| I-DNR does not do a good job with conservation practices on their land | Stanhope |
| Important that the WMA work with people not fight with them | Stanhope |
| Important to work together | Stanhope |
| Importance of working with areas that are not currently covered by an assistance program | Stanhope |
| Need to work with other agencies | Squaw Creek Coalition |
| Important of partnering and multi-agency agreements | Squaw Creek Coalition |
| Important to have a coordinator for multiple agencies and groups in the watershed | Squaw Creek Coalition |
| Plan must have buy-in across the watershed for the WMA to be sucessful and long-lasting | Squaw Creek Coalition |
| Important to have crossover between farmers, rural and urban residents | Squaw Creek Coalition |
| Important to engage landowners and renters of ag lands | Squaw Creek Coalition |
| Important to make face to face contact with people to engage them and encourage them to try new things | Squaw Creek Coalition |
| Partnering will be critical to success | Ames |
| Importance of bridging gaps where NRCS funding is not available - conservation on non-ag areas | Ames |
| Importance of local groups versus large entities like NRCS | Ames |
| Hamilton County has over300 drainage districts and no rural zoning. | Ames |
| Researchers at Iowa state willing to assist in technical work, specifically modeling and addressing groundwater | ISU |
| Importance of coordinating and learning from other WMAs throughout state | ISU |
| Partnering will be critical to success | ISU |
| ISU is an MS4 and has their own requirements and programs for stormwater management | ISU |
| “Authority” in name of organization is concerning | Ames/Stanhope |

## Current Watershed Management Efforts

| Comment | Session |
|---|---|
| Lawn care practices play a role in nutrients getting to stream but are not regulated; Ames has been working with lawn care professionals | Gilbert |
| Farmers are currently asked to meet Nutrient Reduction Strategy to comply with farm programs eligibility | Stanhope |
| Iowa is looked at as a leader in the area of Nutrient Reduction Strategies | Stanhope |
| Farmers are very conscious about the amount of nutrients they put on their land. | Stanhope |
| There is a CREP wetland for Nitrate removal in Northern Boone County | Stanhope |
| Farmers in the area are already doing a great deal of things to prevent nutrients from washing into stream | Stanhope |
| People want to be recognized for what they've been doing already | Stanhope |
| Some farmers are using "stabilized nitrogen" that holds in the soil better | Stanhope |
| Ag retailers are working with farmers to meet nutrient reduction goals. | Stanhope |
| Similar effort in the Boone Watershed has caused a mind shift; credit given to monitoring to demonstrate benefits | Ames |
| City of Ames is working hard to make improvements to the creek | Ames |
| City of Ames adopted post-construction stormwater rules recently that include requirements for water quality treatment, rate and volume control, soil management | Ames |
| City of Ames has been actively implementing stormwater BMPs; bio-retention, raingardens, pervious pavement, rainbarrel program, planting natives | Ames |
| City encourages use of green infrastructure | Ames |
| Ames has low impact design alternative for senstive areas | ISU |
| Pervious pavements have been installed within the City of Ames and have held up well to snow plowing | ISU |

## Funding/Financing

| Comment | Session |
|---|---|
| Financial and/or technical assistance should be available to help landowners stabilize stream on their property | Gilbert |
| Important to identify future funding sources and position the WMA to be a competitive for them | Gilbert |
| Solutions need to be cost effective and sustainable | Gilbert |
| Crop and livestock production should be prioritized in the plan | Stanhope |

| Comment | Session |
|---|---|
| Need to have a cost benefit analysis done for conservation practices | Stanhope |
| Need to consider that the value of land changes day to day | Stanhope |
| Concern that the Plan could eventually lead to taxation | Stanhope |
| Concern that local tax money may be used for watershed program | Stanhope |
| Concern that Plan money could have been better spent | Stanhope |
| Costs for implementing practices need to be covered | Squaw Creek Coalition |
| Could City of Ames money be spent up in the watershed | Squaw Creek Coalition |
| How will WMA be sustained financially after plan is developed | Squaw Creek Coalition |
| Finding financing for the plan needs to be a priority | Squaw Creek Coalition |
| Importance of looking for cost share programs and funding opportunities | Ames |
| Funding opportunities need to be exploredm for example Iowa Code 418 | Ames |
| WMA should be more successful in getting grants and funding than the individual members | ISU |

## Resource Concerns

| Comment | Session |
|---|---|
| Bank erosion on North Onion Creek | Gilbert |
| Large storm events washed down woody material; causes log jams and local damage | Gilbert |
| Concern about potential impact of cornstover removal - less residue left on fields | Gilbert |
| Concern about building within the floodplain | Gilbert |
| Building within the floodplain led to flooding problems | Stanhope |
| Concerned that the primary focus of the WMA is flood control NOT water quality | Stanhope |
| Recognize need to stablize creek banks | Stanhope |
| Important to separate flooding issues from water quality issues | Stanhope |
| Farmers are interested in reducing nutrients but not flow of water | Stanhope |
| Brookside Park is an important area to the community | Squaw Creek Coalition |
| Wildlife buffer strips are important | Squaw Creek Coalition |
| More areas of the stream could be used for fishing if quality was improved | Squaw Creek Coalition |
| Game  fishing and aquatic recreation are important | Squaw Creek Coalition |
| Need to consider the value of ecological diversity and habitat for birds, and pollinating insects | Squaw Creek Coalition |

| | |
|---|---|
| Canoeing used to be common in Northridge Heights but increased bank erosion and related tree-fall has limited opportunity. Would use more if creek were 'cleaned up' | Ames |
| Meandering of the stream is natural and important | Ames |
| Ditching and connection of stormsewer is not helping flooding | Ames |
| Streambank erosion is an issue for smaller farmers | ISU |
| Importance of understanding the hydraulics that influence flooding in Ames | ISU |
| Low base flow conditions having an impact on biological health of streams | ISU |

## Tools/Approaches to Solutions

| Comment | Session |
|---|---|
| Concern about potential impact of large "dams" on creek | Gilbert |
| Need to target strategic areas- model to determine high priority areas and work there first; ag and urban | Gilbert |
| Concern that best practices be tailored to specific areas not one-size-fits-all aproach | Gilbert |
| Land use policy plans are an important tool for watershed management | Gilbert |
| Natural background nutrient levels need to be considered | Gilbert |
| Important to look into the various sources of Bacteria getting into streams | Gilbert |
| WMA needs to report back on what the plan becomes | Gilbert |
| Concern that having the plan may put a "bulls-eye" for further enforcement | Gilbert |
| Farmers do not want to slow water down, they want to drain it off faster so that they can work the soils | Stanhope |
| Concern that the WMA may be considering a dam that would raise the water table | Stanhope |
| Concern that drain tiles may become regulated | Stanhope |
| One size does not fit all when it comes to conservation practices | Stanhope |
| There are a lot of opportunities for people to do "one more thing" | Stanhope |
| Education is a critical component | Stanhope |
| Not interested in having a sign at farm stating that they are a certified conservation farmer | Stanhope |
| There needs to be more education and outreach to help people understand the watershed and their role in its quality | Squaw Creek Coalition |
| Important to be able to demonstrate the benefits of conservation practices | Squaw Creek Coalition |

| Comment | Session |
|---|---|
| Important that accurate information is delivered to residents of the watershed | Squaw Creek Coalition |
| Demonstration projects would be a valuable tool in gaining acceptance of conservation practices | Squaw Creek Coalition |
| Need to monitor the effectiveness of conservation practice | Squaw Creek Coalition |
| Dry basins should be considered as an option for capturing and storing heavy rainfalls | Squaw Creek Coalition |
| Would like to see the lower portion of the creek reshaped from Duff to mouth to lower flood levels but also to improves wildlife and quality of stream | Squaw Creek Coalition |
| Important to state what the goals of the WMA are and what activities will be used to meet those goals | Squaw Creek Coalition |
| Reduction in fertilizer and other chemical use should be a priority | Squaw Creek Coalition |
| Voluntary actions are not likely to make a difference, regulation will be needed | Ames |
| Encourage conducting field trips so ag and urban practices can be shared - see what each other are doing | Ames |
| Flood improvement project in City includes increasing capacity through Hwys 30 and 35 | Ames |
| City is committed to work with their residents to install conservation practices | Ames |
| Additional, improved monitoring is needed to establish impairment on Squaw and tributaries | Ames |
| Important to determine priority areas throughout the watershed, both ag and urban and site appropriate practices accordingly | ISU |
| The Ames surface water management ordinance ordinance should be expanded to all of the developed/developing parts of the watershed | ISU |
| Groundwater/surface water interaction is important to understand. | ISU |
| CREP wetlands are a critical tool for reducing nitrate and there is room to build more in the watershed | ISU |

# Appendix 3: Recreational Use Assessment and Attainability Analysis

# Iowa Department of Natural Resources
# Recreational Use Assessment and Attainability Analysis

## I. SITE INFORMATION

| | |
|---|---|
| Waterbody Name: | Squaw Creek |
| Assessed Reach: | Mouth (S12, T83N, R24W, Story Co.) to confluence with an unnamed tributary (NW ¼, S9, T85N, R25W, Boone Co.) (97,700 feet – 18.5 miles) |
| NPDES Affected Facility | South Squaw Valley Association (39)<br>Iowa State University Power Plant (52) |
| Basin: | Skunk |
| Counties: | Story & Boone |
| Date of Field Study: | 9/12/2005 |
| Site IDs: | 6 sites (39 (1-6)) – See overall map for details |

Field Work Performed by: Tetra Tech

Date: 2/18/2009

## II. STREAM CHARACTERISTICS

a) Public Access:

The assessed portion of Squaw Creek flows through rural agricultural and forest ground as well as through the City of Ames. There are numerous bridge crossings along the assessed reach that would allow for access and there are numerous residences along the assessed reach within the city limits.

Public Lands:
There are numerous city parks and trails within the City of Ames that border Squaw Creek. Among these are Brookside Park, Stuart Smith Park, Moore Memorial Park, and Squaw Creek Path. There are no public lands along Squaw Creek outside of the City of Ames.

b) Physical Dimensions:

The assessment covered the distance starting at the mouth up to an unnamed tributary (NW ¼, S9, T85N, R25W, Boone Co.). The stream was primarily a run with few riffles and pools. The width varied between 23 feet wide at sites 39-3 and 39-6 to 61 feet wide at site 39-2. The maximum depth observed throughout the stretch was 40 inches (Site 39-2) and the average depth was between 3 and 21 inches. The stream flow conditions found are considered adequately representative for the sites assessed.

1. Average Width (Range): 23 – 61 feet
2. Average Depth (Range): 3 – 21 inches
3. Maximum Depth: 40 inches

c) Predominant Substrate:

Squaw Creek was primarily a sandy substrate with traces of cobble, gravel, and silt. The approximate percentages for Squaw Creek as a whole is 80% sand, 10% cobble, and 5% each for gravel and silt.

d) Flow:

Perennial Flow (streams that hold water throughout the year) ☒

| | |
|---|---|
| Intermittent Flow (stream that holds water during wet portions of the year) | ☐ |
| Ephemeral Flow (channel that holds water only during and immediately after rain event) | ☐ |

e) Additional Comments:

All field measurements were recorded in meters. Those measurements have been converted to feet and inches (and rounded to the nearest foot or inch) for use in this report.

## III. EVIDENCE OF RECREATIONAL USE

There was little evidence of recreational uses found at any of the assessed sites. Footprints were noted at 3 of the assessed sites, and ATV tracks were found at 1 of the sites. There were no forms of recreational evidence found at Sites 39-1, or 39-6.

Survey Responses:
In total there were 13 recreational use surveys completed for Squaw Creek. These surveys noted swimming, child's play, canoeing, and fishing to be common recreational activities in Squaw Creek. The majority of this surveys listed specific locations within the city limits of Ames including Brookside Park, Stuart Smith Park, Moore Memorial Park, Veenker Golf Course, and the Duff, 13th, and 4th Street road crossings. There were 2 comments received that noted wading had been witnessed at Cameron School Road.

There were 6 other public surveys submitted to the department. The surveys stated that activities such as canoeing, kayaking, swimming, fishing, trapping and children's play have occurred throughout the spring and summer of every year throughout the assessed area's of Squaw Creek.

## IV. POTENTIAL USE/SURROUNDING CONDITIONS

There is a segment of Squaw Creek that flows through residential areas and parks within the City of Ames that would allow for numerous recreational activities. The remaining portions of Squaw Creek flow primarily through agricultural and forested areas with few residences. Access to the stream outside of the city limits would be restricted to road crossings or private property.

## V. POINT SOURCES

Were there any point source dischargers on the stream segment: Yes ☐ No ☒

South Squaw Valley Association and the Iowa State University Power Plant discharge to tributaries of Squaw Creek. There are no direct NPDES permitted point source dischargers noted in the assessed reach.

## VI. CONCLUSION

Field work for preparation of this UA/UAA was conducted September 12, 2005. Squaw Creek is receiving effluent from South Squaw Valley Association and the Iowa State University Power Plant by indirect discharge. Squaw Creek is listed as a perennial stream throughout the assessed reach from the mouth (S12, T83N, R24W, Story Co.) to confluence with an unnamed tributary (NW ¼, S9, T85N, R25W, Boone Co.) according to the USGS 1:100,000 DLG Data Set. The creek has an overall drainage area of 230.56 square miles.

Squaw Creek passes through both urban and rural areas along the assessed reach. The city of Ames has many road crossings and public parks that would allow for access. The segment that flows through rural areas does have road crossings, but there are no public accesses or parks. The potential for recreational activities is diminished in the rural areas due to lack of access.

There were 2 points assessed for maximum and average depths at each of the 6 sites in the 18.5 mile affected reach of Squaw Creek, resulting in 12 sampling points. Only 1 site (39-2) had adequate depths for primary contact recreation with a maximum depth of 40 inches and average depths of 21 inches. The other five sites had an average maximum depth of 11 inches and an average overall depth of 7 inches.

There were a total of 19 recreational use surveys completed for Squaw Creek. These surveys noted swimming, child's play, canoeing, and fishing to be common recreational activities in Squaw Creek. The majority of this surveys listed specific locations within the city limits of Ames including Brookside Park, Stuart Smith Park, Moore Memorial Park, Weenker Golf Course, Duff, 13th, 4th, 120th, 140th and 150th, 160th, E18, and County Hwy R-38, . There were 2 comments received that noted wading had been witnessed at Cameron School Road.

Several segments of Squaw Creek received comments regarding recreational activities. These comments noted child's play, swimming, canoeing, kayaking and fishing occurred on a regular basis throughout the summer months. Three of the six assessed sites were located in this segment of the creek and only one of the sites showed adequate depth to support Primary Contact Recreational uses.

The depth criteria guidelines used by the department to help determine if Primary Contact Recreational use (Class A1) is attainable typically will exclude streams that are not able to support a Class A1 use due to the overall lack of flow needed to support activities that result in direct and prolonged contact with the water, involving considerable risk of ingesting appreciable quantities of water sufficient to pose a health hazard. While these guidelines are effective in most situations, there are cases where a stream demonstrates that it can support the Class A1 use despite the lack of flow that typically distinguishes a stream that can support Primary Contact Recreational uses.

Despite the lack of flow; the comments received show that Squaw Creek does support Primary Contact Recreational uses throughout the recreation season.

The depth criteria guidelines used by the department to help determine if Primary Contact Recreational use (Class A1) is attainable typically will exclude streams that are not able to support a Class A1 use due to the overall lack of flow needed to support activities that result in direct and prolonged contact with the water, involving considerable risk of ingesting appreciable quantities of water sufficient to pose a health hazard. While these guidelines are effective in most situations, there are cases where a stream demonstrates that it can support the Class A1 use despite the lack of flow that typically distinguishes a stream that can support Primary Contact Recreational uses.

Based on analysis of the data from the assessed sites, the department recommends a Class A1 Primary Contact Recreational use designation apply from the mouth (S12, T83N, R24W, Story Co.) to confluence with an unnamed tributary (NW1/4, S9, T85N, R25W, Boone Co.). These recommendations are consistent with types of uses observed in these areas and the ability for the creek and surrounding areas to support such uses.

Class (A1) Primary Contact Recreational Use

"Waters in which recreational or other uses may result in prolonged and direct contact with the water, involving considerable risk of ingesting water in quantities sufficient to pose a health hazard. Such activities would include, but not be limited to, swimming, diving, water skiing, and water contact recreational canoeing."

<u>Recommended Recreational Use Designation:</u>

| | |
|---|---|
| Primary Use | ☒ - See description above |
| Secondary Use | ☐ |
| Children's Recreation | ☐ |
| No Recreational Use | ☐ |

# Appendix 4: Agricultural Conservation Planning Framework Findings

Output from the ACPF tools for each of the HUC-12 subwatersheds within the Squaw Creek Watershed are provided in this appendix. Information for each subwatershed includes:

- Table summarizing the extent of each BMP within the subwatershed
- Figure showing potential grassed waterway sites and soil runoff risk
- Figure showing potential nutrient removal wetland sites
- Figure showing potential sediment basin sites
- Figure showing potential riparian buffers

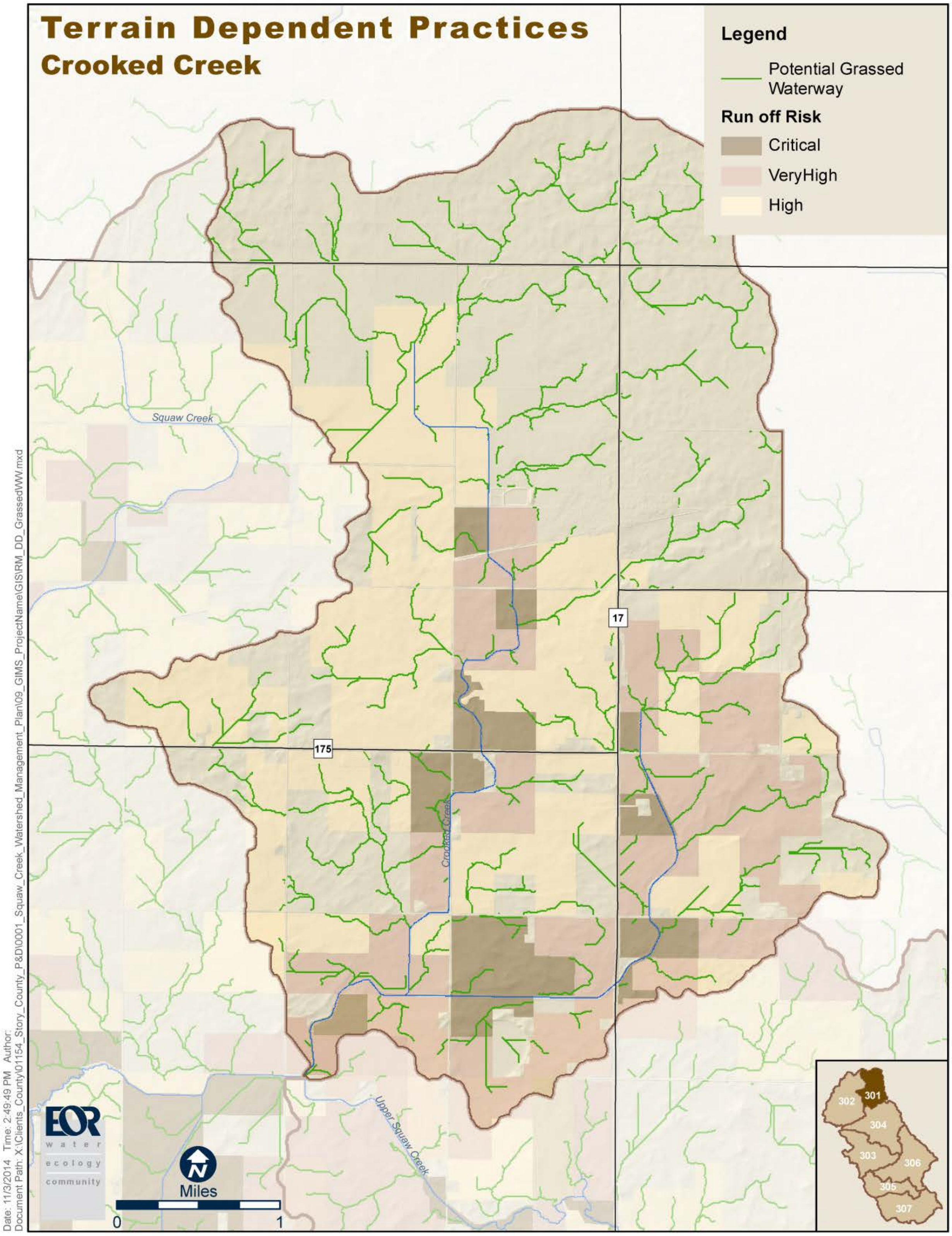
Guide to the Subwatershed Figures

| | |
|---|---|
| Crooked Creek Subwatershed | A4 Figure 1 to A4 Figure 4 |
| Drainage Ditch 192-Squaw Creek Subwatershed | A4 Figure 5 to A4 Figure 8 |
| Montgomery Creek Subwatershed | A4 Figure 9 to A4 Figure 12 |
| Crooked Creek-Squaw Creek Subwatershed | A4 Figure 13 to A4 Figure 16 |
| Onion Creek Subwatershed | A4 Figure 17 to A4 Figure 20 |
| Lundy's Creek – Squaw Creek Subwatershed | A4 Figure 21 to A4 Figure 24 |
| Worle Creek Squaw Creek Subwatershed | A4 Figure 25 to A4 Figure 28 |

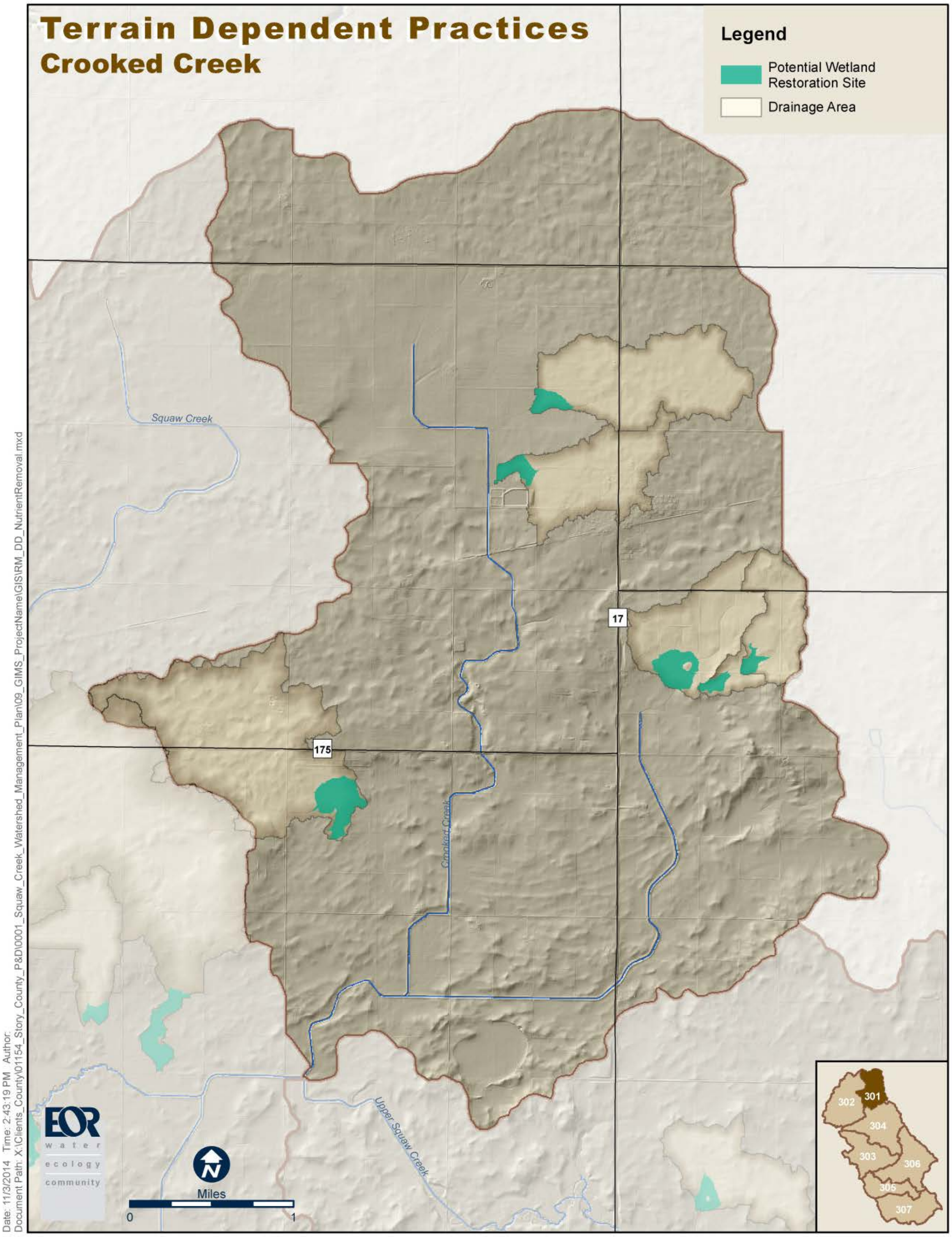
## Crooked Creek Subwatershed ACPF Findings

| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 137 |
| | Drainage Area (HA) | 4,340 |
| Nutrient Removal Wetlands | Pool Area (HA) | 15 |
| | Drainage Area (HA) | 725 |
| Sedimentation Basins | Pool Area (HA) | 0.36 |
| | Drainage Area (HA) | 114 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 653 |
| Multi-Species Buffers | Drainage Area (HA) | 150 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 2,610 |
| Deep-rooted Vegetation | Drainage Area (HA) | 17 |

**A4 Table 1.** Terrain dependent best management practices summary in Crooked Creek Subwatershed.

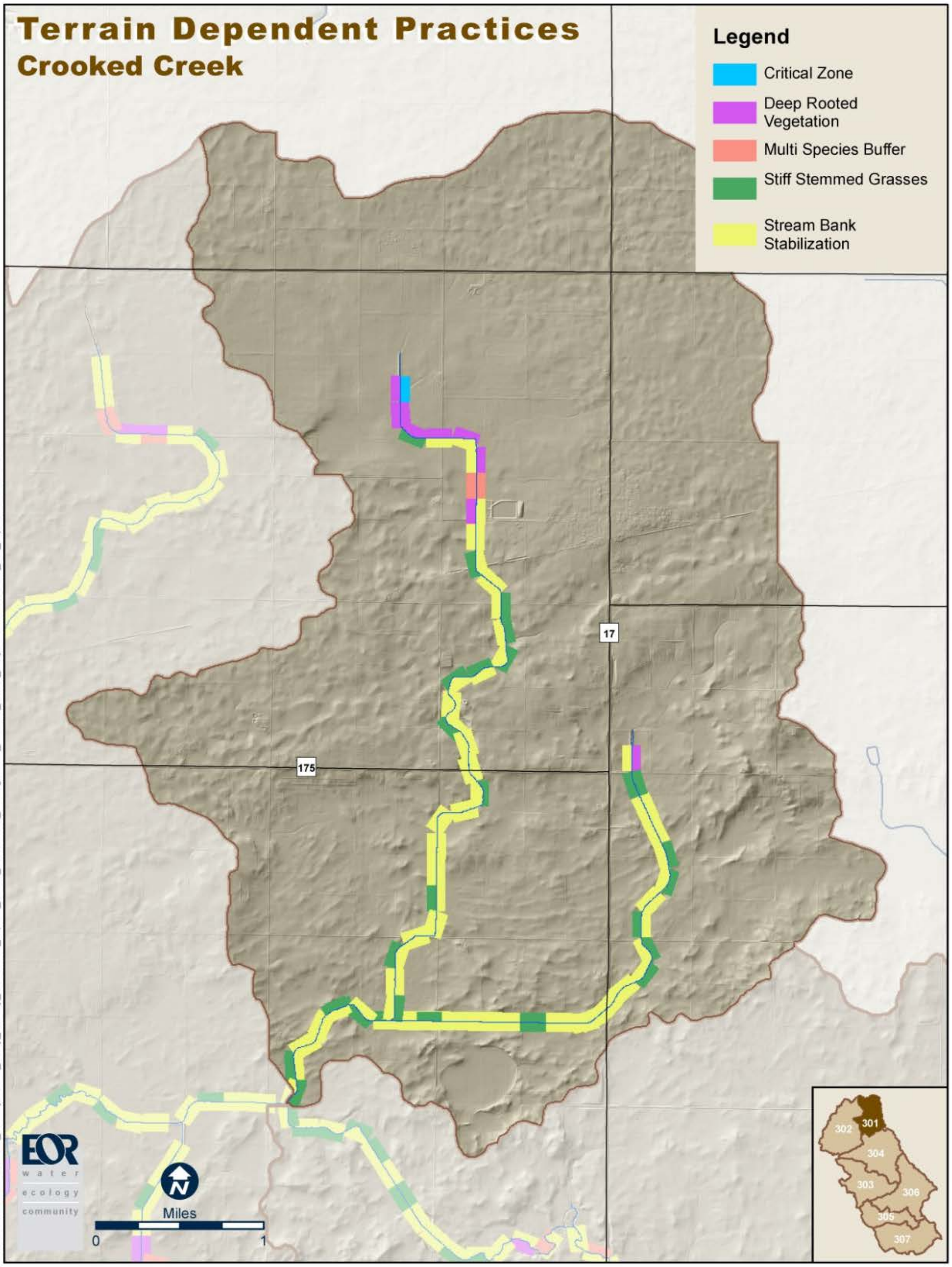



**A4 Figure 1.** Potential grassed waterway sites and soil runoff risk in Crooked Creek Subwatershed.




**A4 Figure 2**. Potential nutrient removal wetland sites in Crooked Creek Subwatershed.


**A4 Figure 3**. Potential sediment basin sites in Crooked Creek Subwatershed

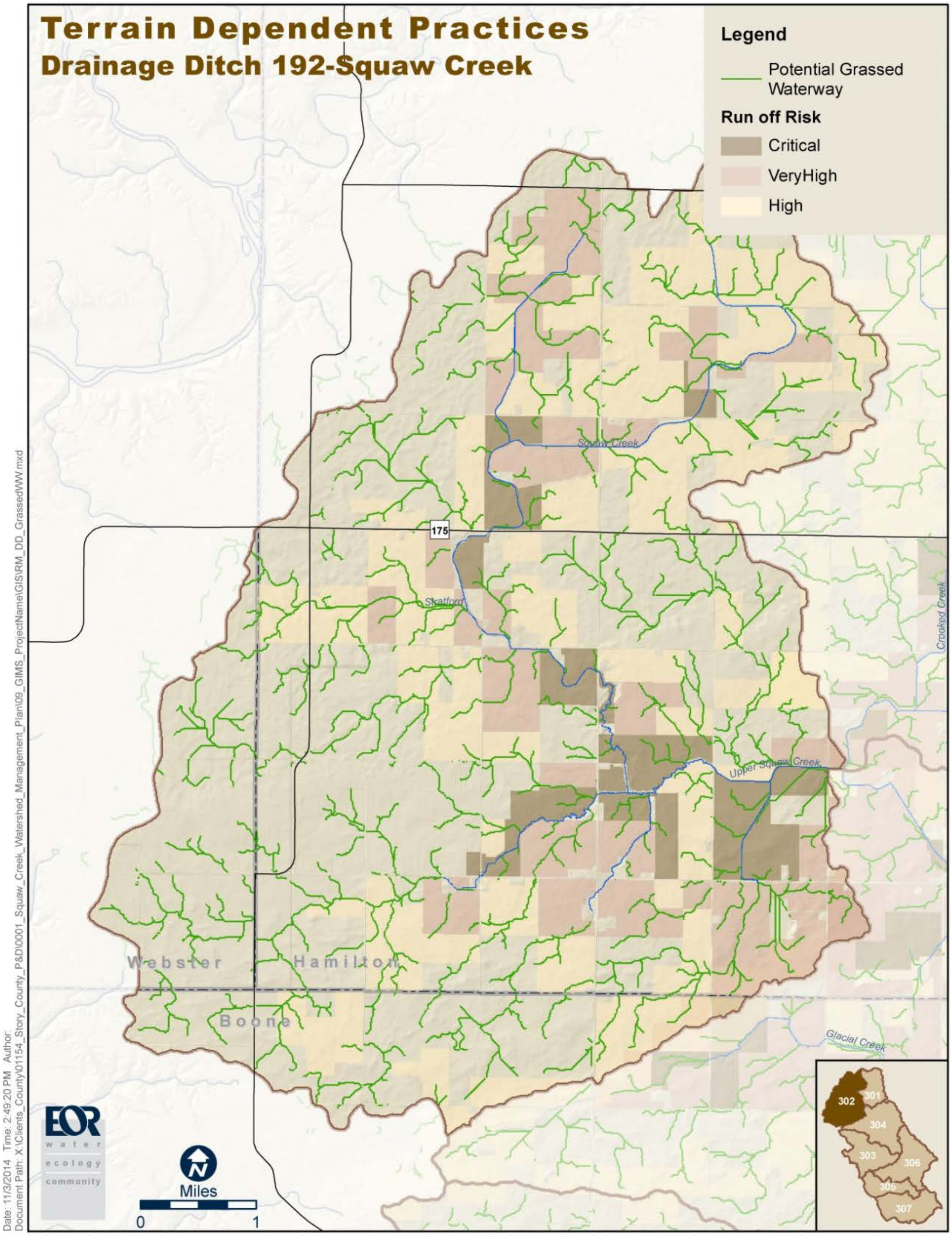



**A4 Figure 4**. Potential riparian buffers in Crooked Creek Subwatershed.

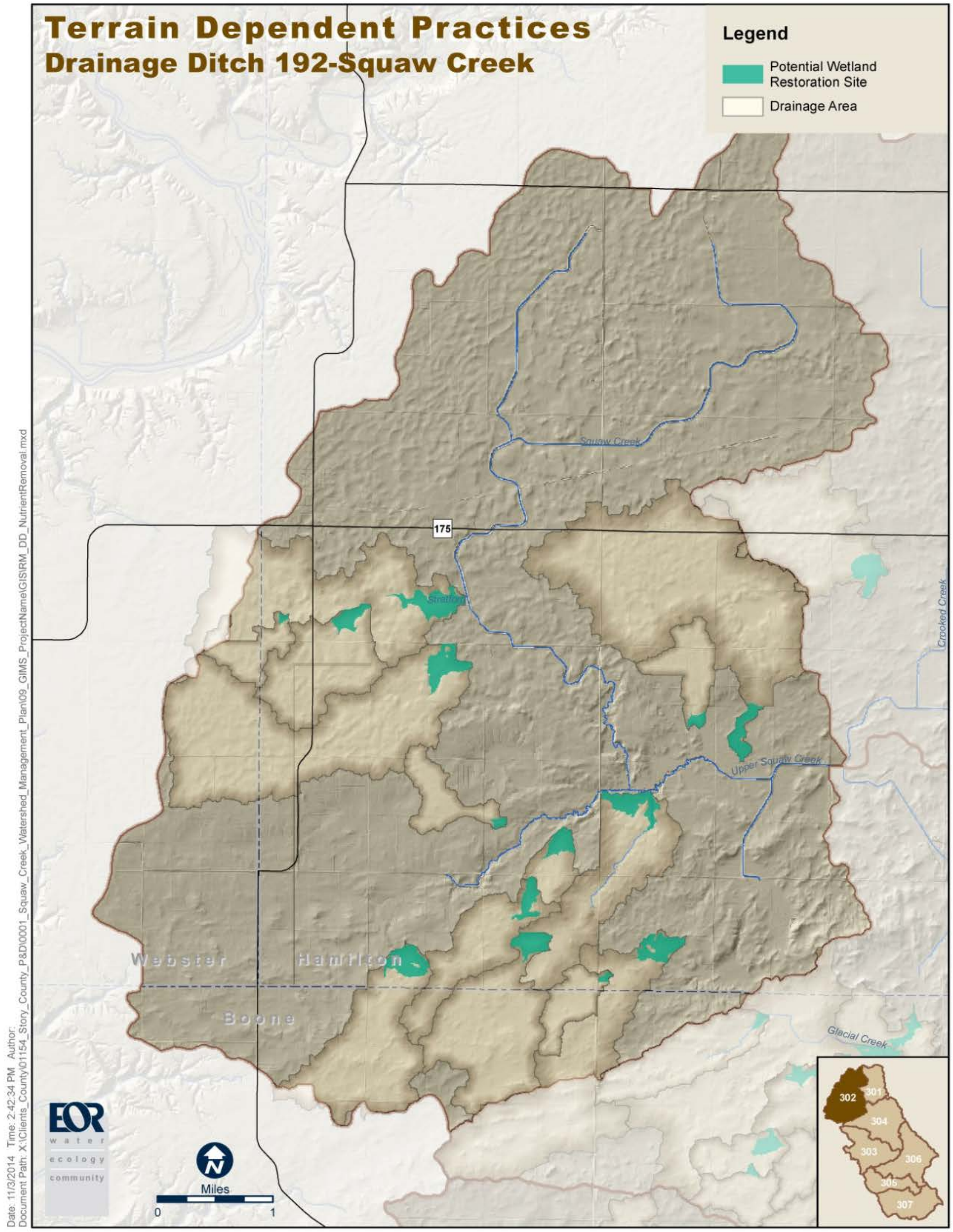
## Drainage Ditch 192-Squaw Creek Subwatershed ACPF Findings

A4 Table 2. **Terrain dependent best management practices summary in the Drainage Ditch 192 - Squaw Creek Subwatershed**

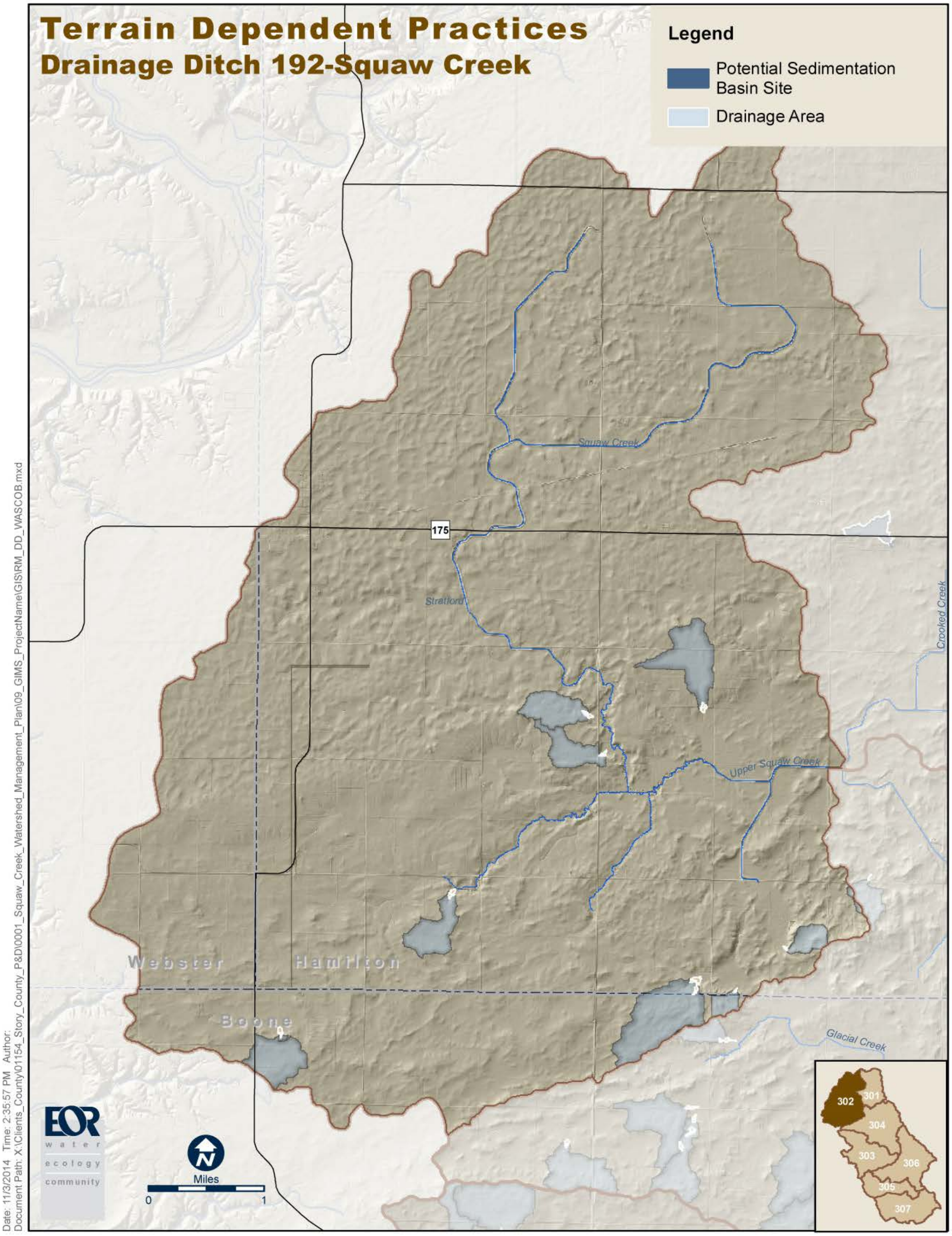
| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 247 |
| | Drainage Area (HA) | 7,832 |
| Nutrient Removal Wetlands | Pool Area (HA) | 55 |
| | Drainage Area (HA) | 3,445 |
| Sedimentation Basins | Pool Area (HA) | 3 |
| | Drainage Area (HA) | 322 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 659 |
| Multi-Species Buffers | Drainage Area (HA) | 2,777 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 2,334 |
| Deep-rooted Vegetation | Drainage Area (HA) | 189 |



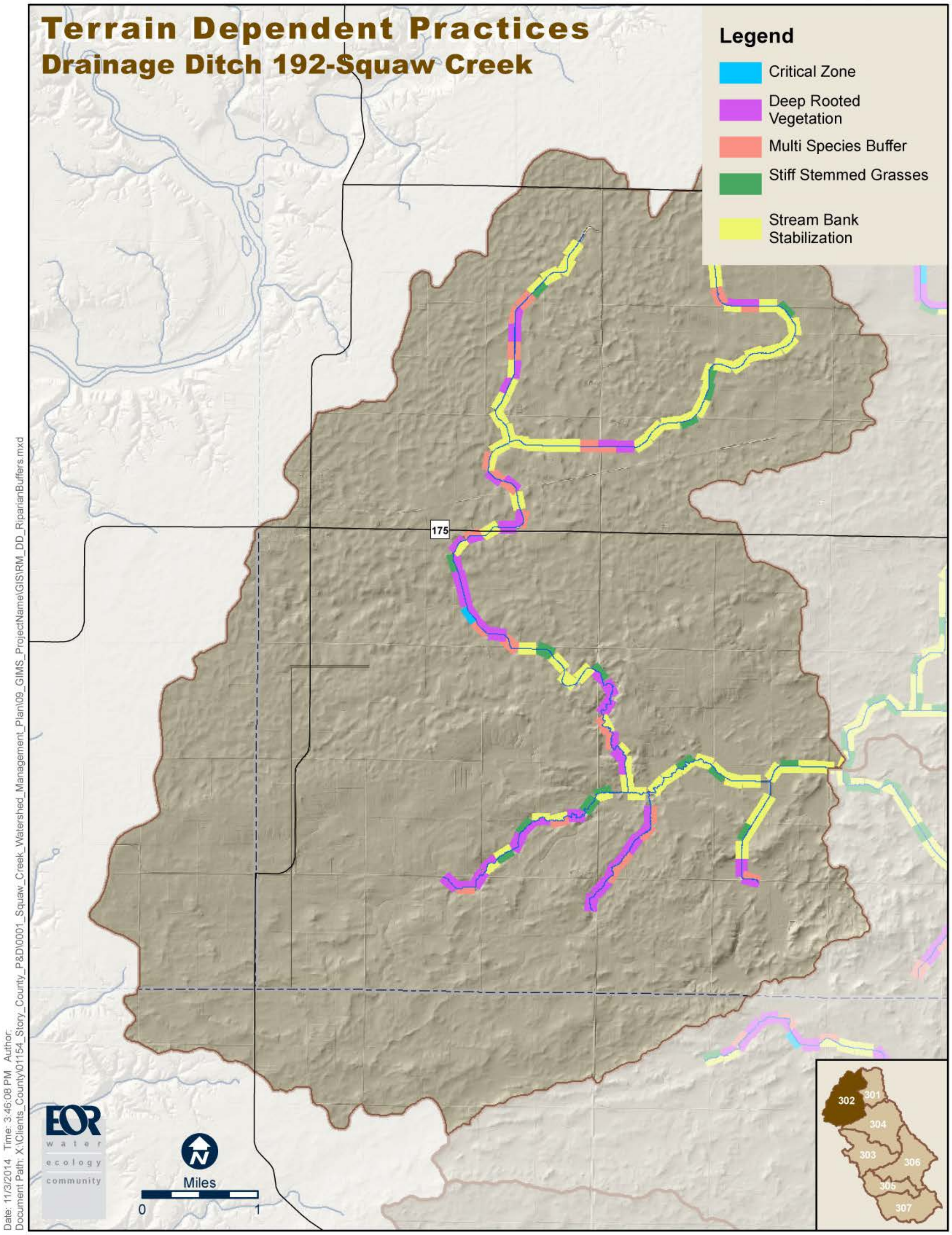

**A4 Figure 5**. Potential grassed waterway sites and soil runoff risk in Drainage Ditch 192 – Squaw Creek Subwatershed.




**A4 Figure 6**. Potential nutrient removal wetland sites in Drainage Ditch 192 – Squaw Creek Subwatershed.




**A4 Figure 7.** Potential sediment basin sites in Drainage Ditch 192 – Squaw Creek Subwatershed.

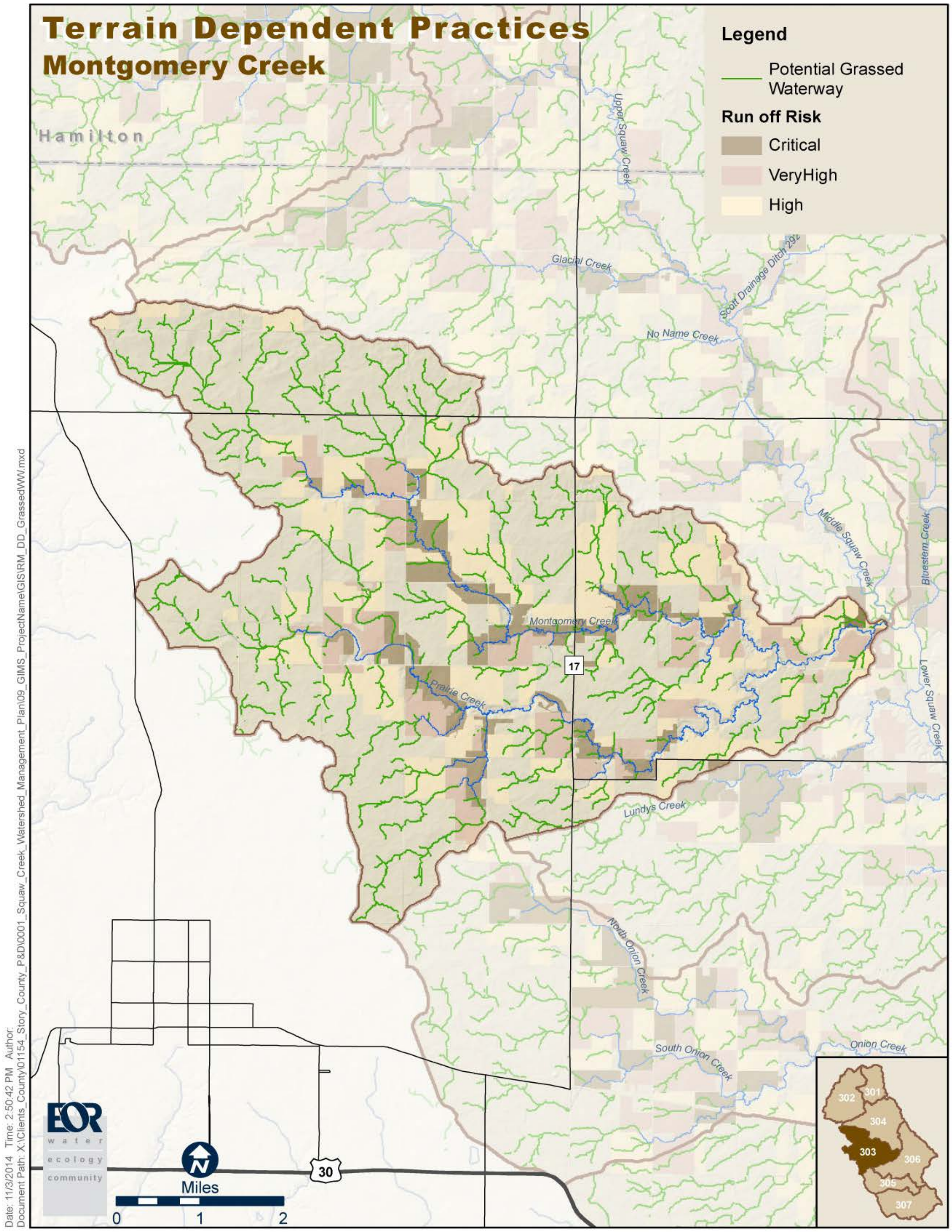



**A4 Figure 8**. Potential riparian buffers in Drainage Ditch 192 – Squaw Creek Subwatershed.

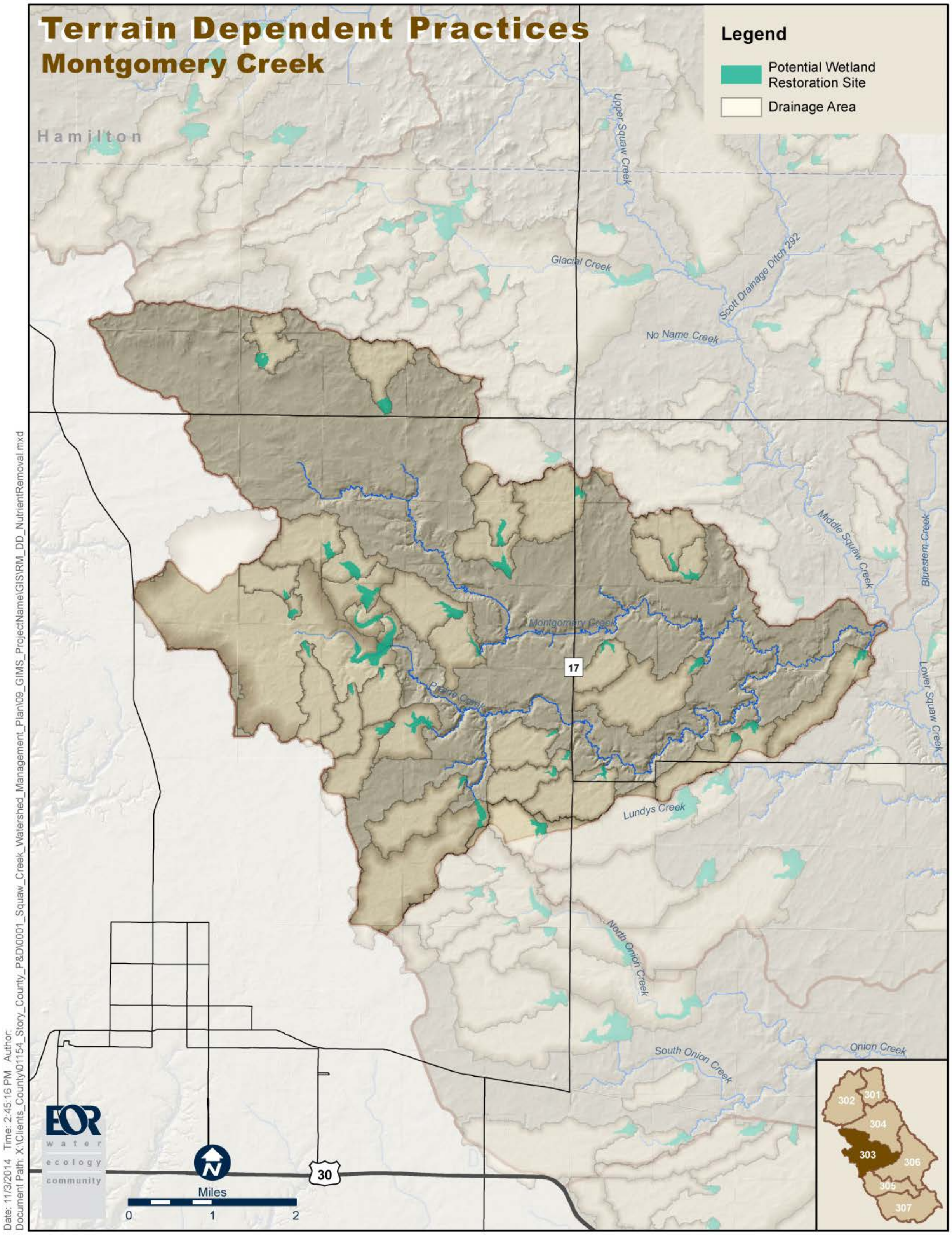
## Montgomery Creek Subwatershed ACPF findings

**A4 Table 3**. Terrain depended best management practices summary in the Montgomery Creek Subwatershed.

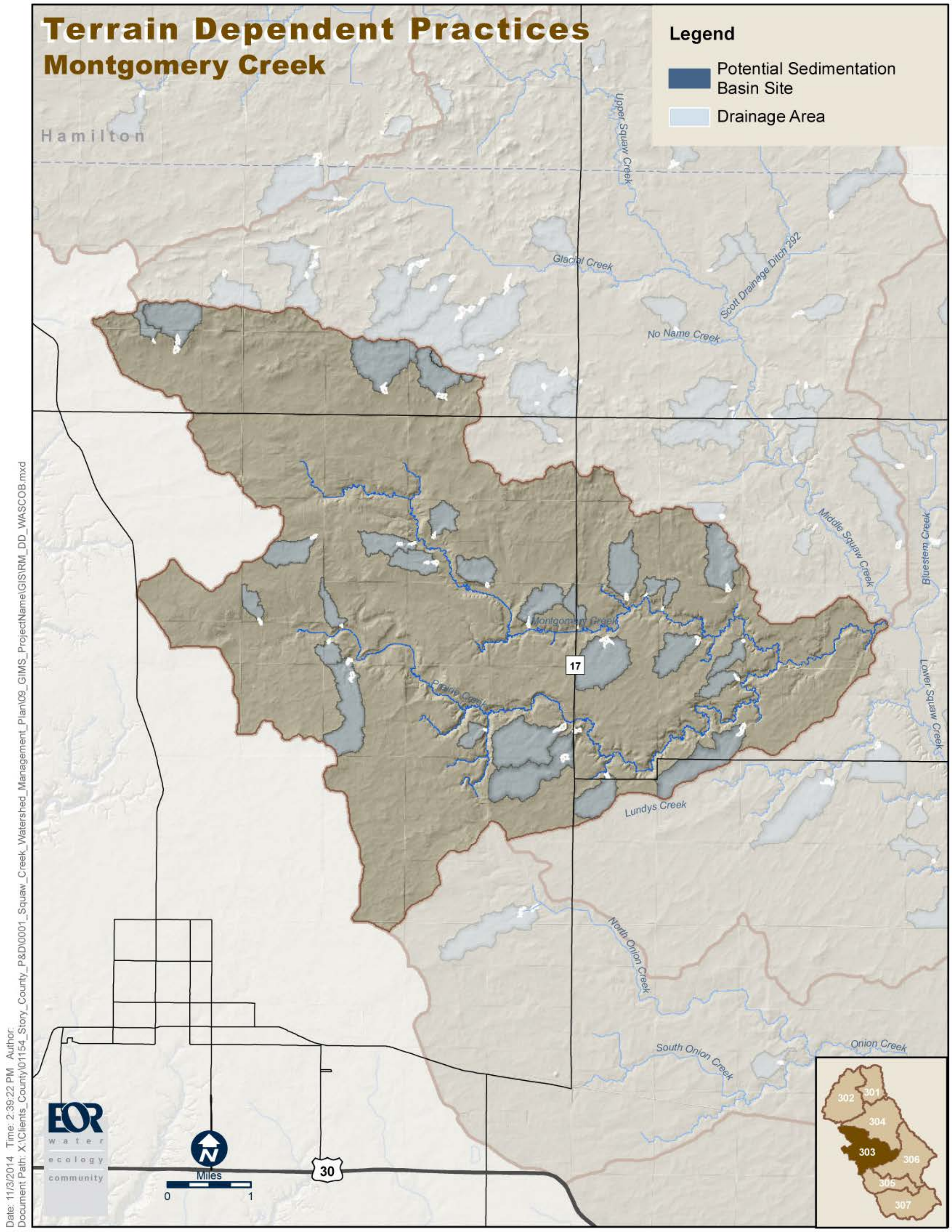
| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 221 |
| | Drainage Area (HA) | 8,440 |
| Nutrient Removal Wetlands | Pool Area (HA) | 50 |
| | Drainage Area (HA) | 4,152 |
| Sedimentation Basins | Pool Area (HA) | 11 |
| | Drainage Area (HA) | 1,257 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 328 |
| Multi-Species Buffers | Drainage Area (HA) | 2,452 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 1,130 |
| Deep-rooted Vegetation | Drainage Area (HA) | 511 |



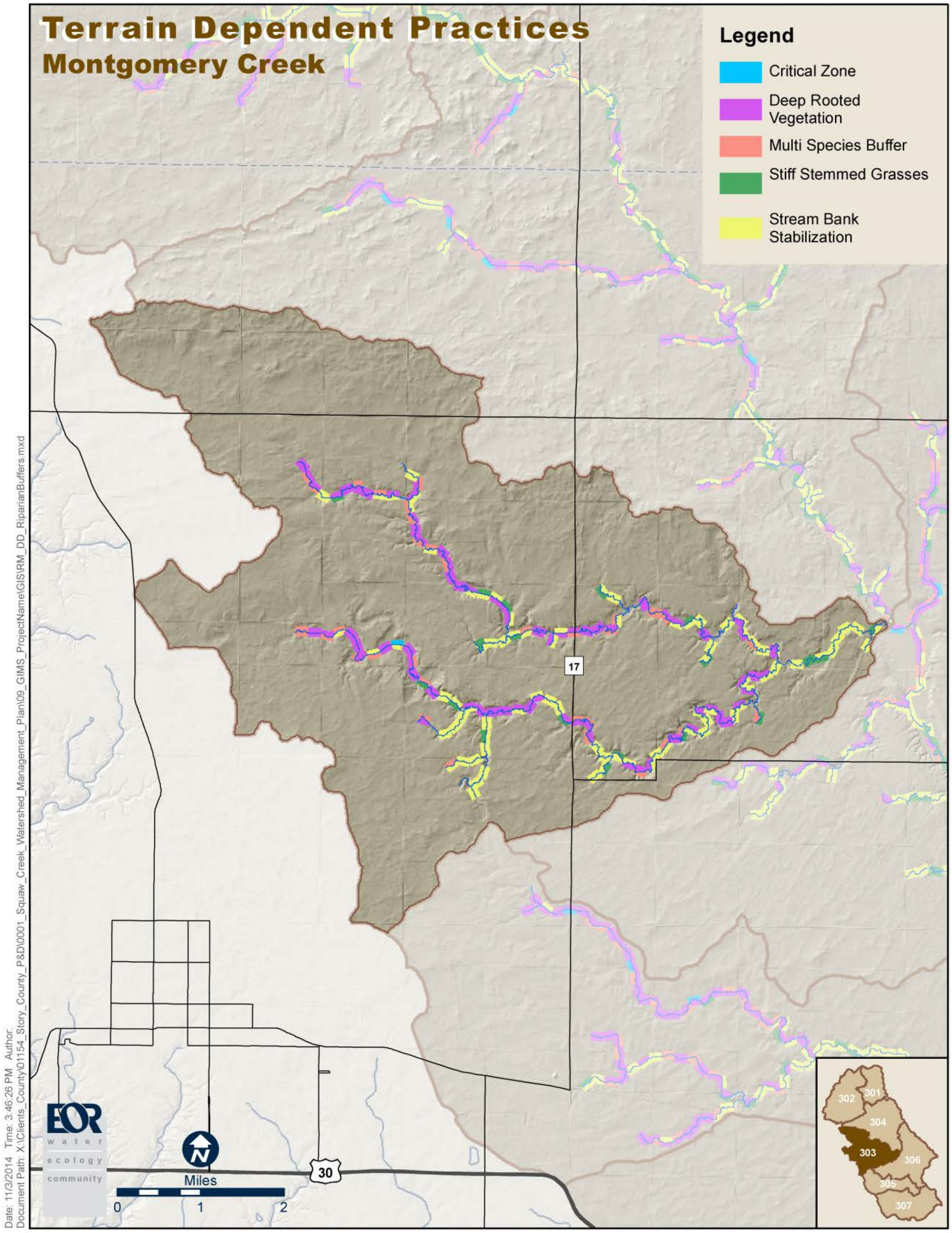

**A4 Figure 9**. Potential grassed waterway sites and soil runoff risk in Montgomery Creek Subwatershed.




**A4 Figure 10**. Potential nutrient removal wetland sites in Montgomery Creek Subwatershed.




**A4 Figure 11**. Potential sediment basin sites in Montgomery Creek Subwatershed.

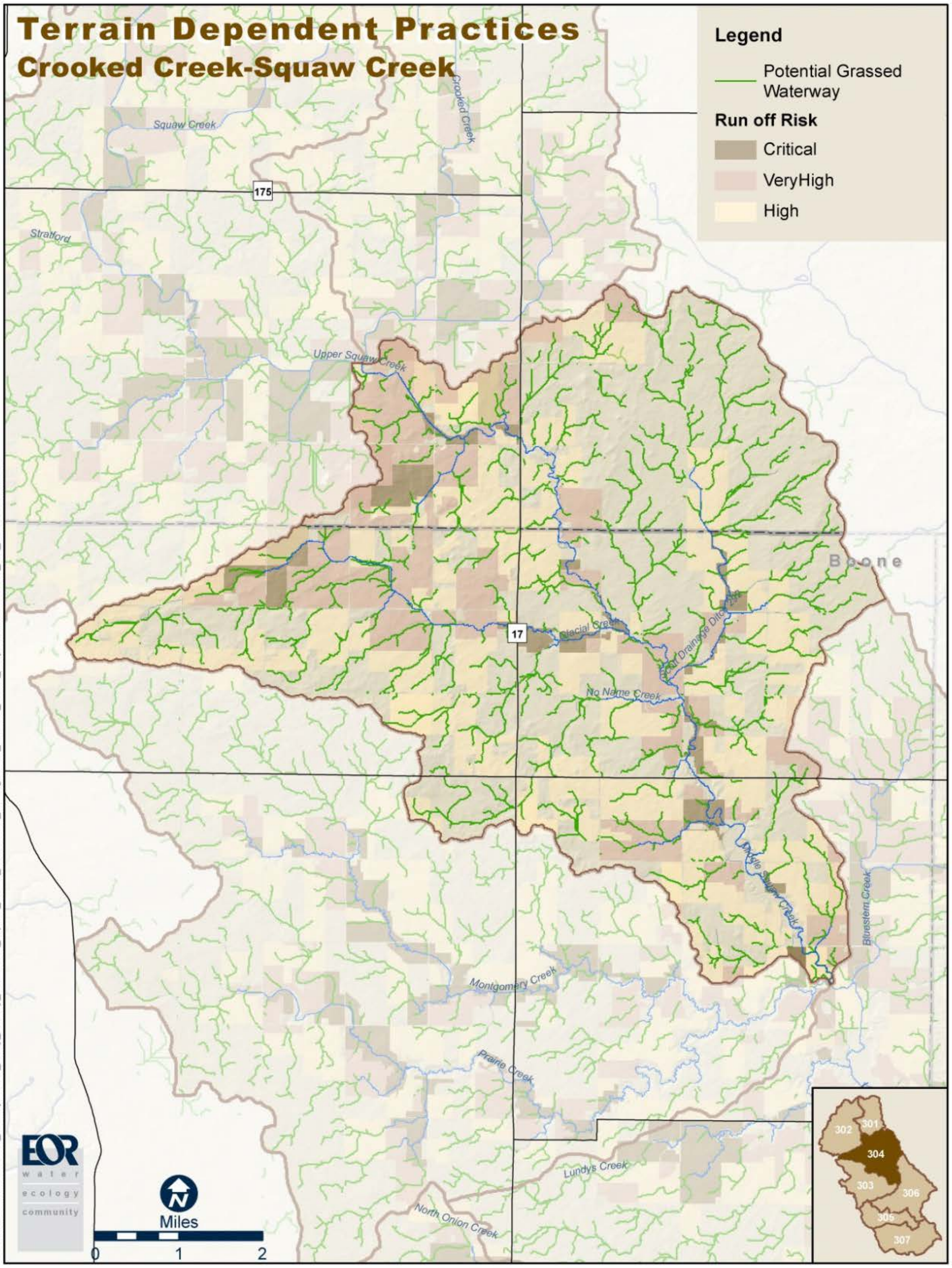



**A4 Figure 12**. Potential riparian buffers in Montgomery Creek Subwatershed.

## Crooked Creek-Squaw Creek Subwatershed ACPF Findings

**A4 Table 4**. Terrain dependent best management practices summary in the Crooked Creek - Squaw Creek Subwatershed.

| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 301 |
| | Drainage Area (HA) | 7,672 |
| Nutrient Removal Wetlands | Pool Area (HA) | 63 |
| | Drainage Area (HA) | 4,715 |
| Sedimentation Basins | Pool Area (HA) | 12 |
| | Drainage Area (HA) | 1,383 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 1,355 |
| Multi-Species Buffers | Drainage Area (HA) | 2,234 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 2,759 |
| Deep-rooted Vegetation | Drainage Area (HA) | 405 |

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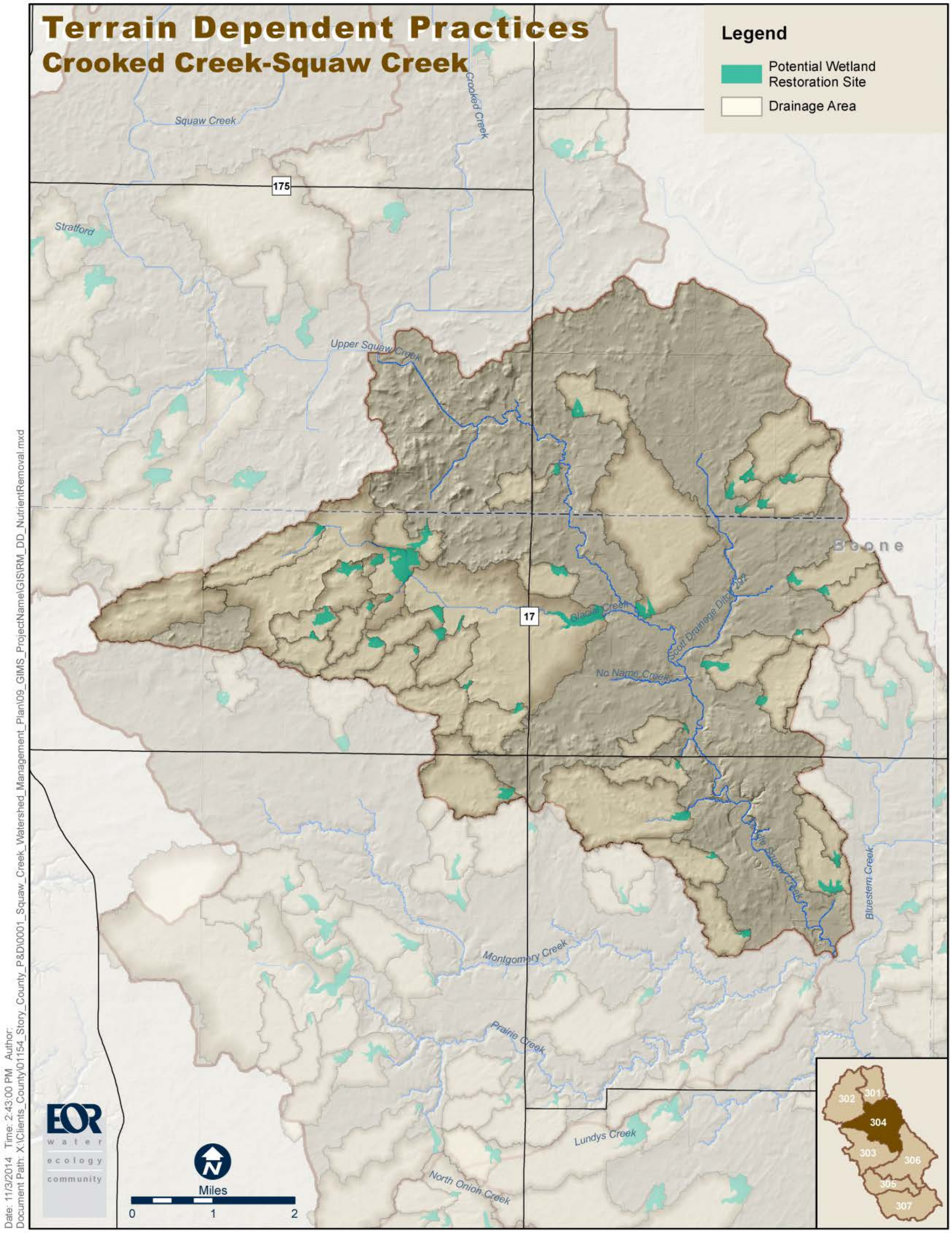
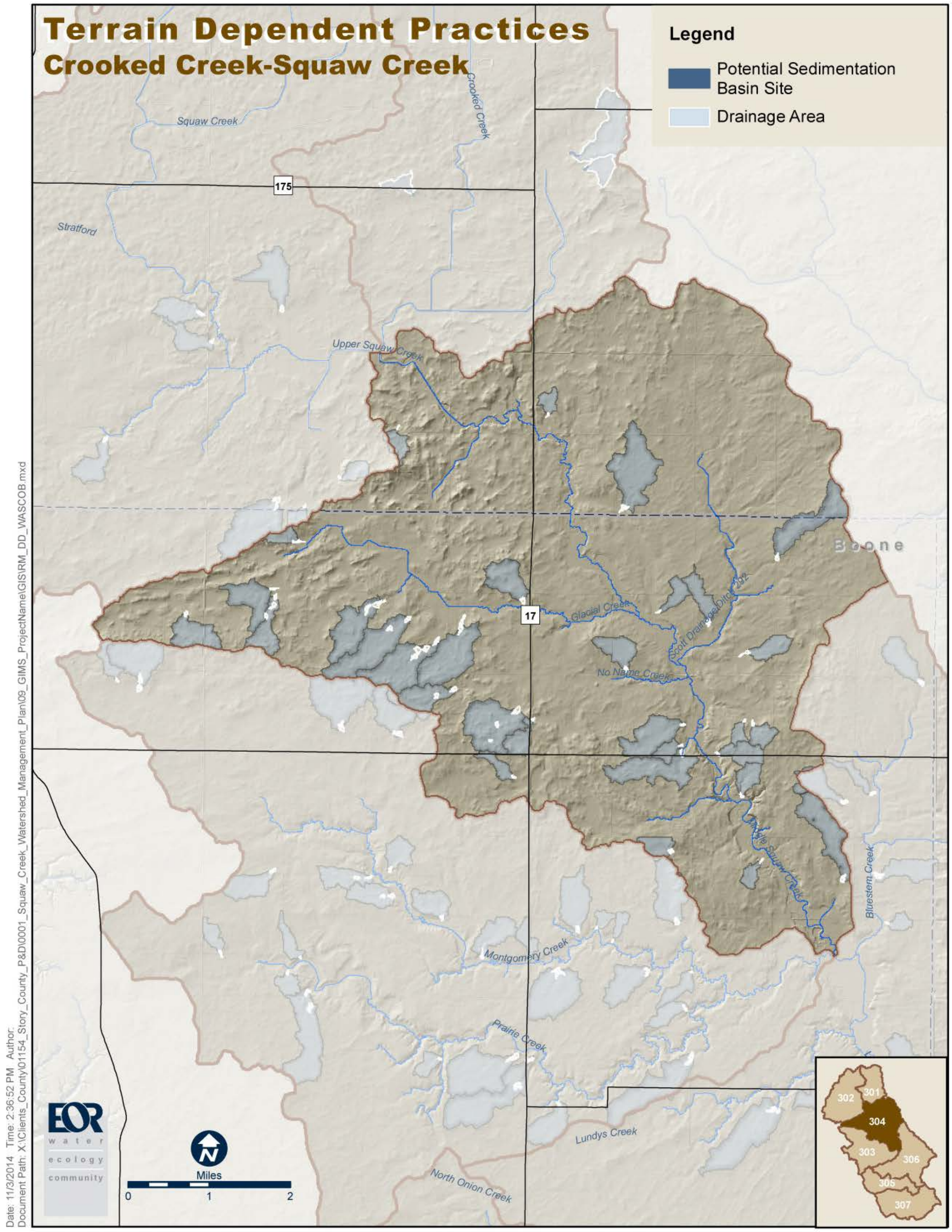
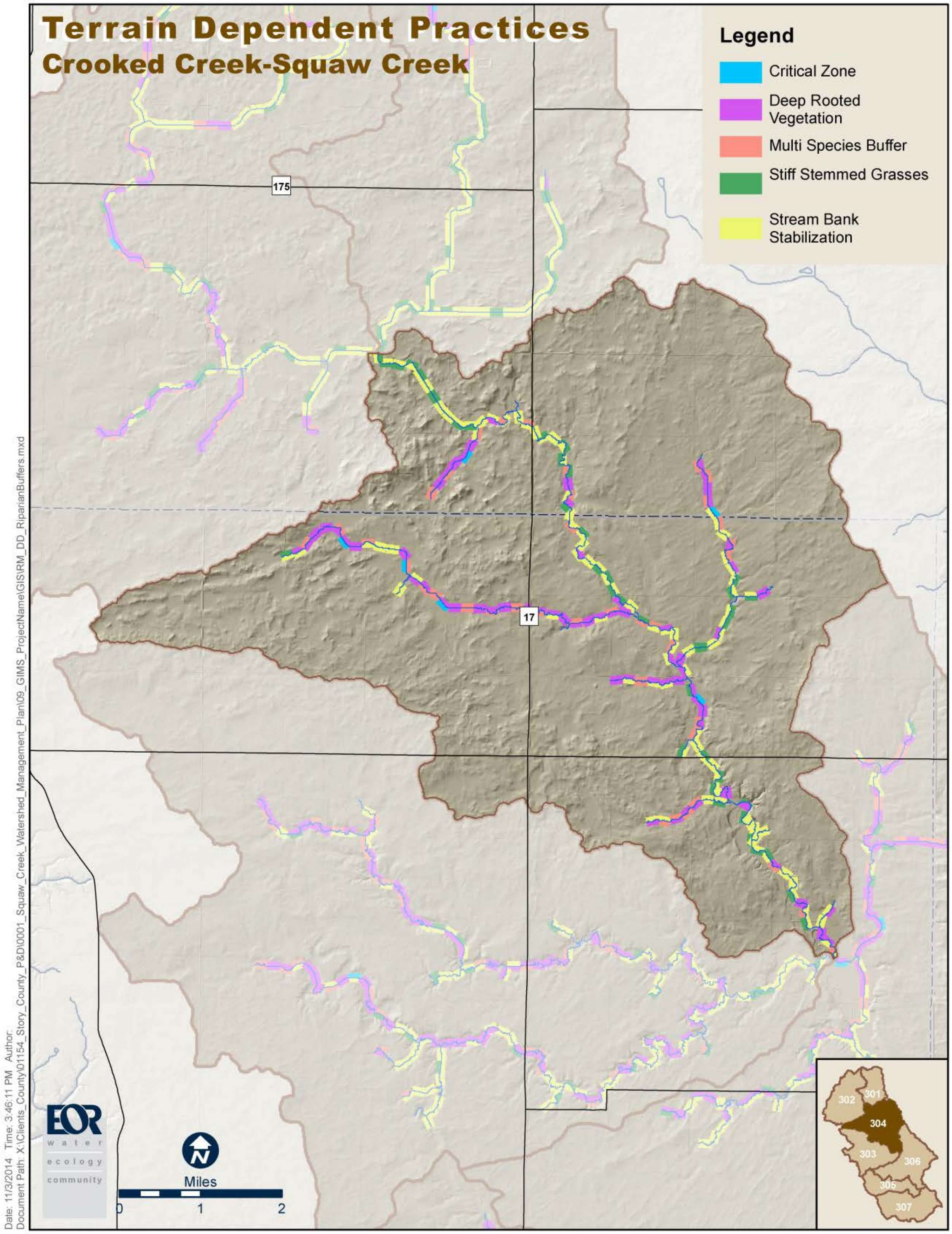
**A4 Figure 13**. Potential grassed waterway sites and soil runoff risk in Crooked Creek – Squaw Creek Subwatershed.




**A4 Figure 14**. Potential nutrient removal wetland sites in Crooked Creek – Squaw Creek Subwatershed.




**A4 Figure 15**. Potential sediment basin sites in Crooked Creek – Squaw Creek Subwatershed.

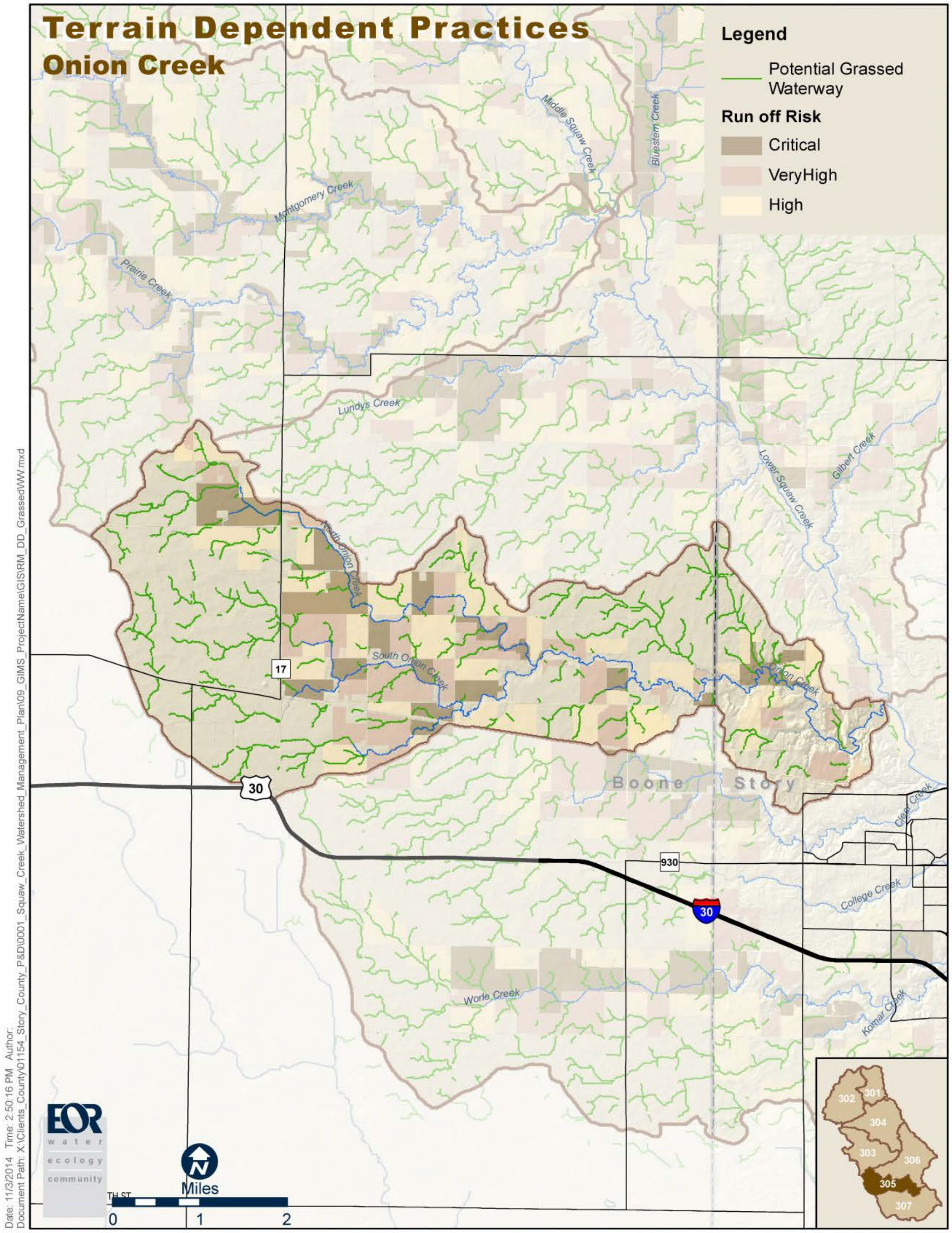



**A4 Figure 16**. Potential riparian buffers in Crooked Creek – Squaw Creek Subwatershed.

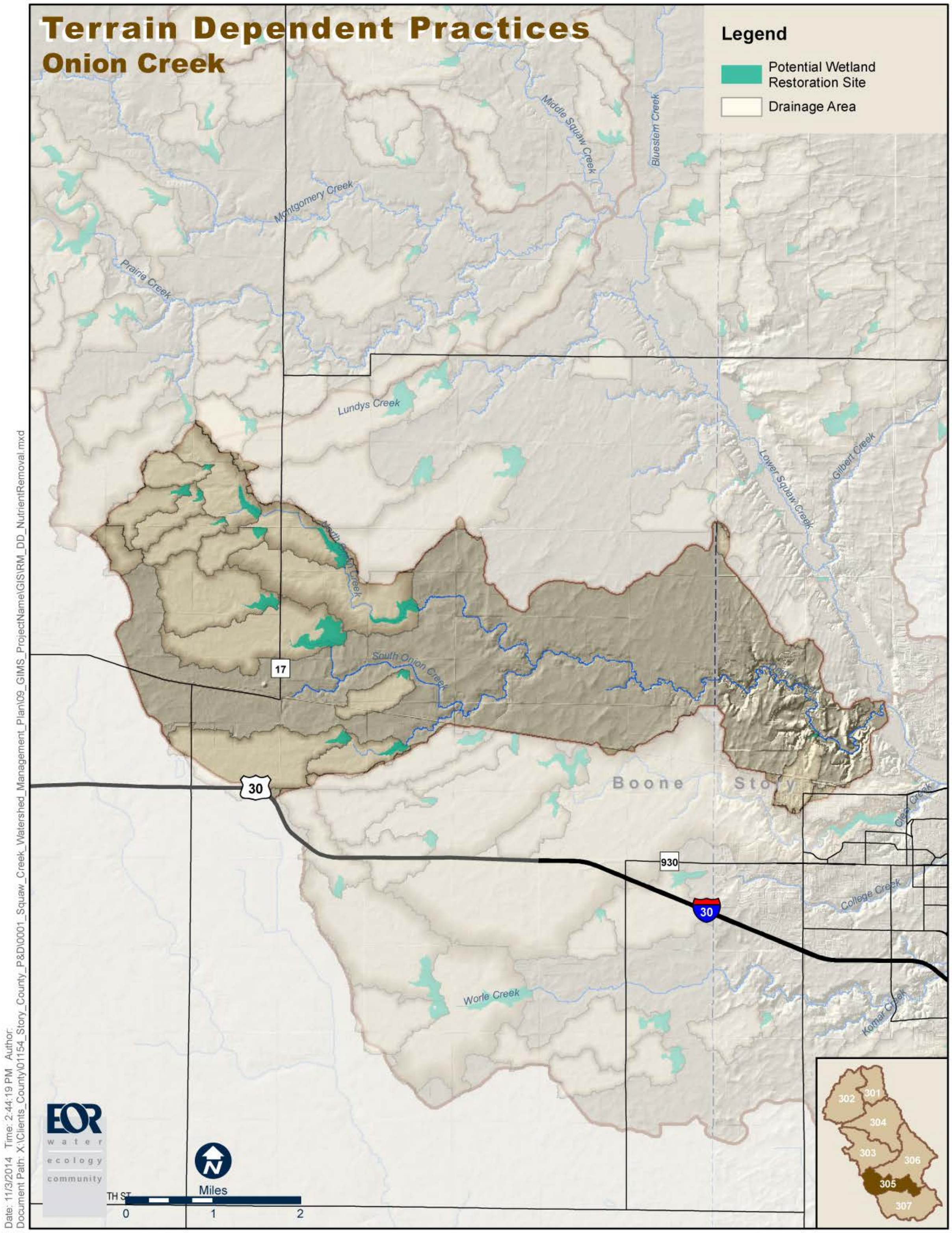
## Onion Creek Subwatershed ACPF Finding

**A4 Table 5**. Terrain dependent best management practices summary in the Onion Creek Subwatershed.

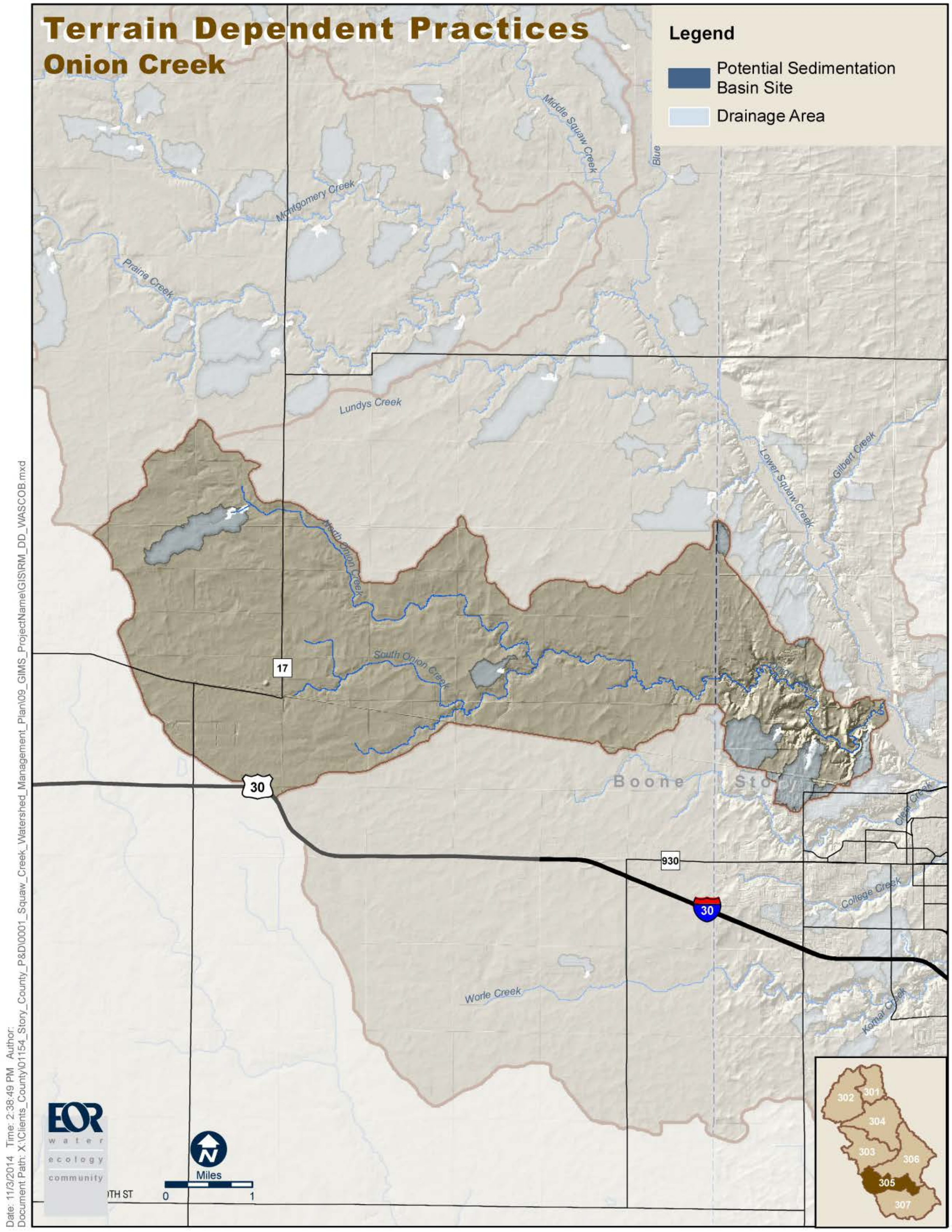
| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 128 |
| | Drainage Area (HA) | 3,162 |
| Nutrient Removal Wetlands | Pool Area (HA) | 33 |
| | Drainage Area (HA) | 1,907 |
| Sedimentation Basins | Pool Area (HA) | 3 |
| | Drainage Area (HA) | 302 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 259 |
| Multi-Species Buffers | Drainage Area (HA) | 878 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 1,432 |
| Deep-rooted Vegetation | Drainage Area (HA) | 351 |



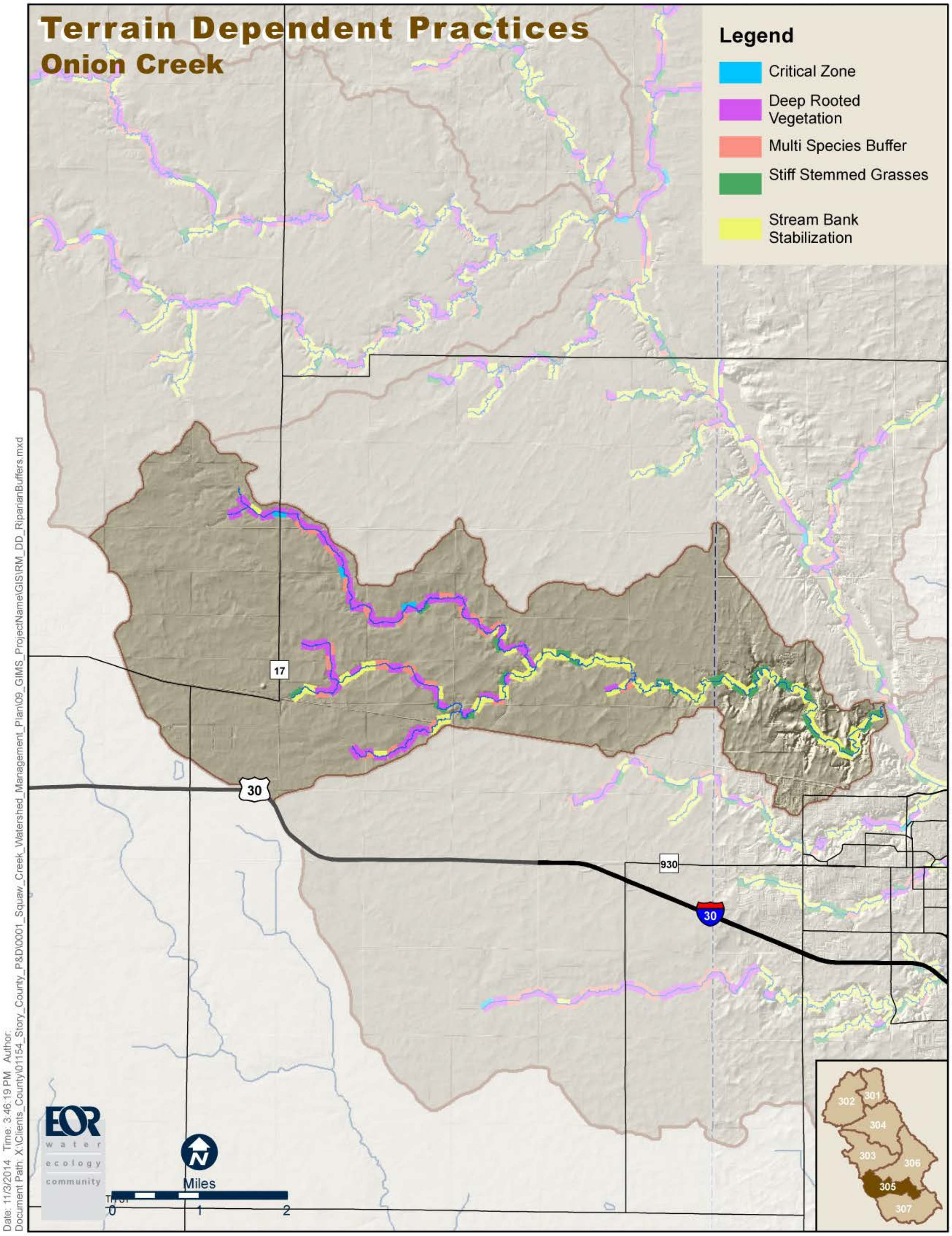

**A4 Figure 17**. Potential grassed waterway sites and soil runoff risk in Onion Creek Subwatershed.




**A4 Figure 18**. Potential nutrient removal wetland sites in Onion Creek Subwatershed.




A4 Figure 19. Potential sediment basin sites in Onion Creek Subwatershed.

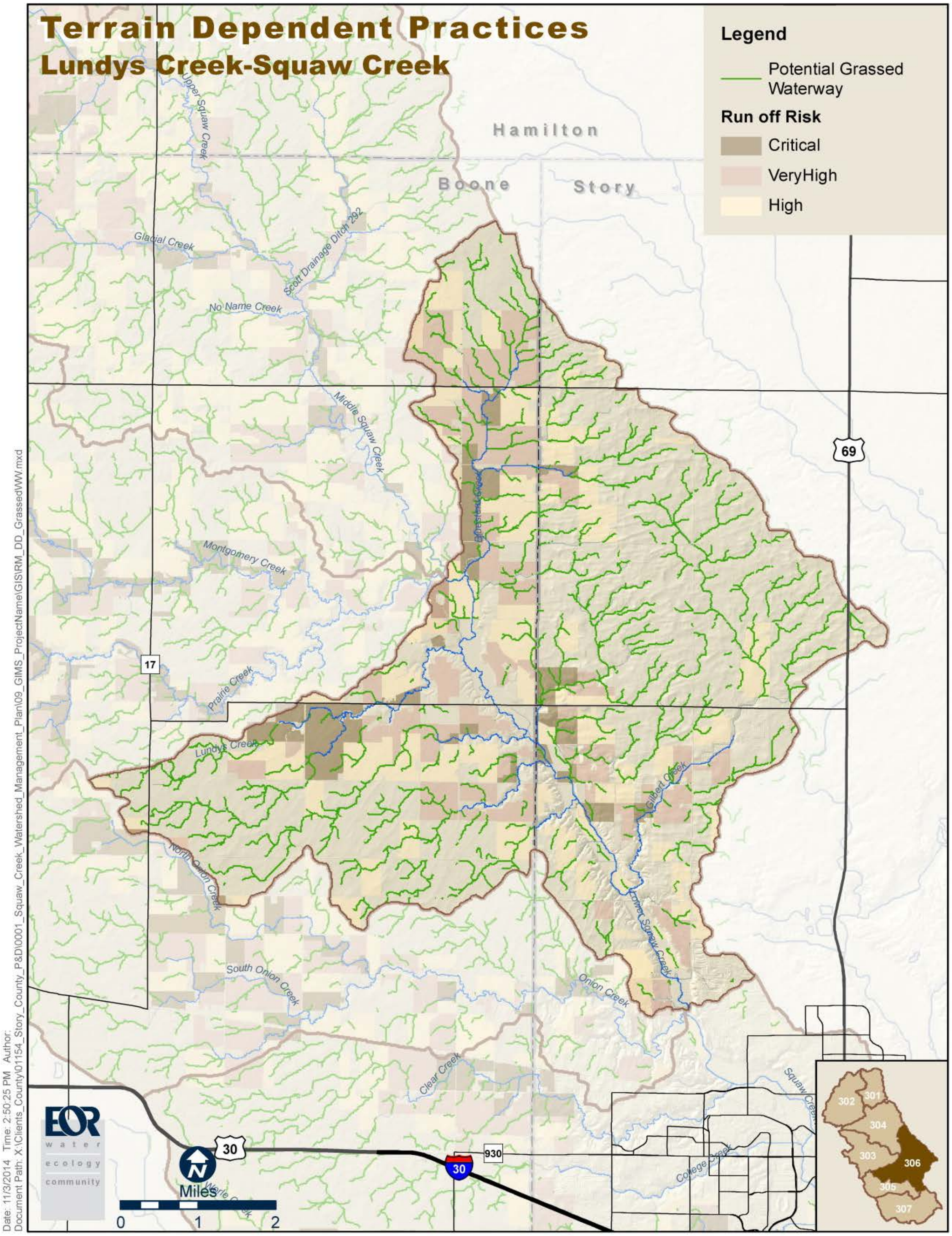



**A4 Figure 20**. Potential riparian buffers in Onion Creek Subwatershed.

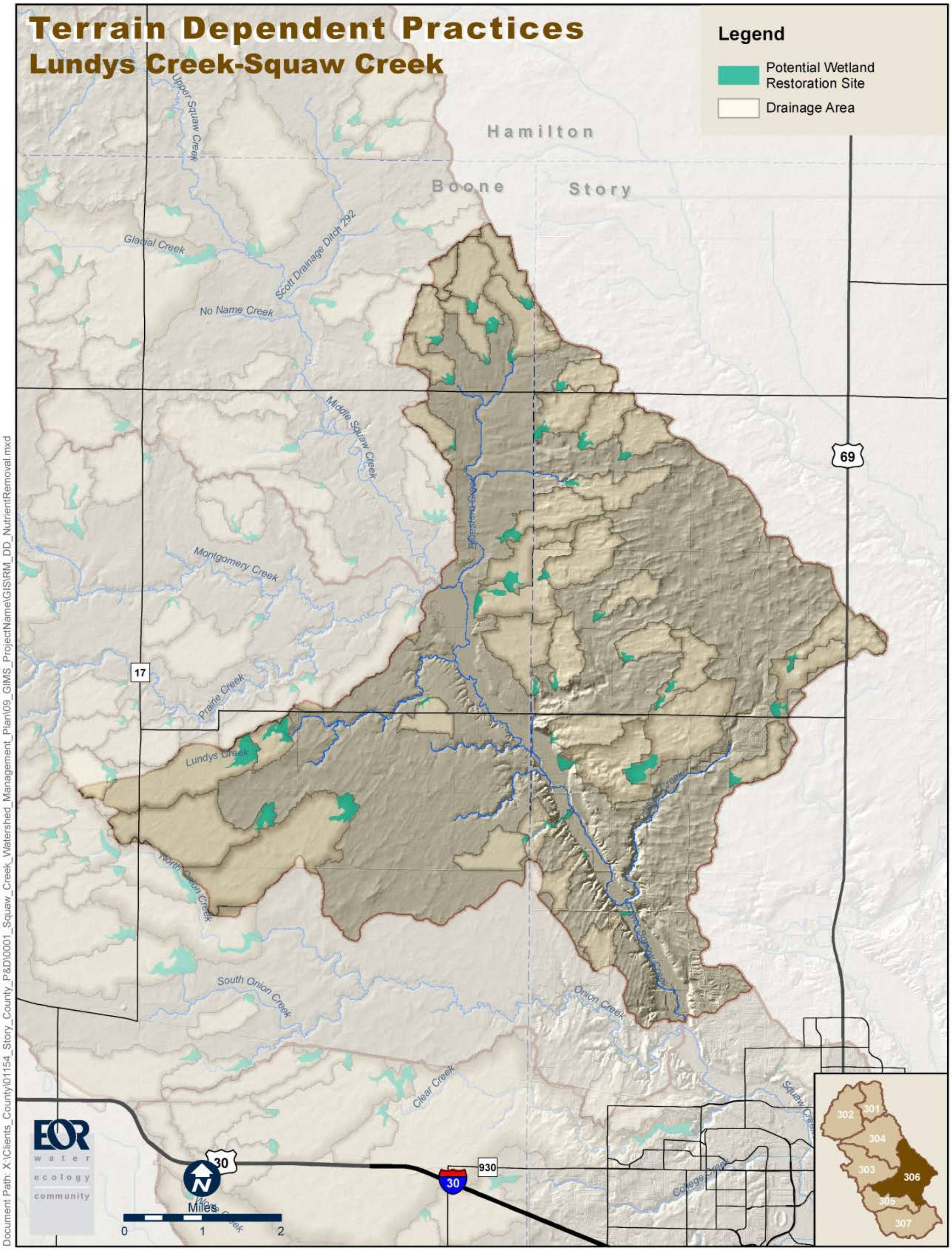
## Lundy's Creek – Squaw Creek Subwatershed ACPF Findings

**A4 Table 6**. Terrain dependent best management practices summary in the Lundys Creek - Squaw Creek Subwatershed.

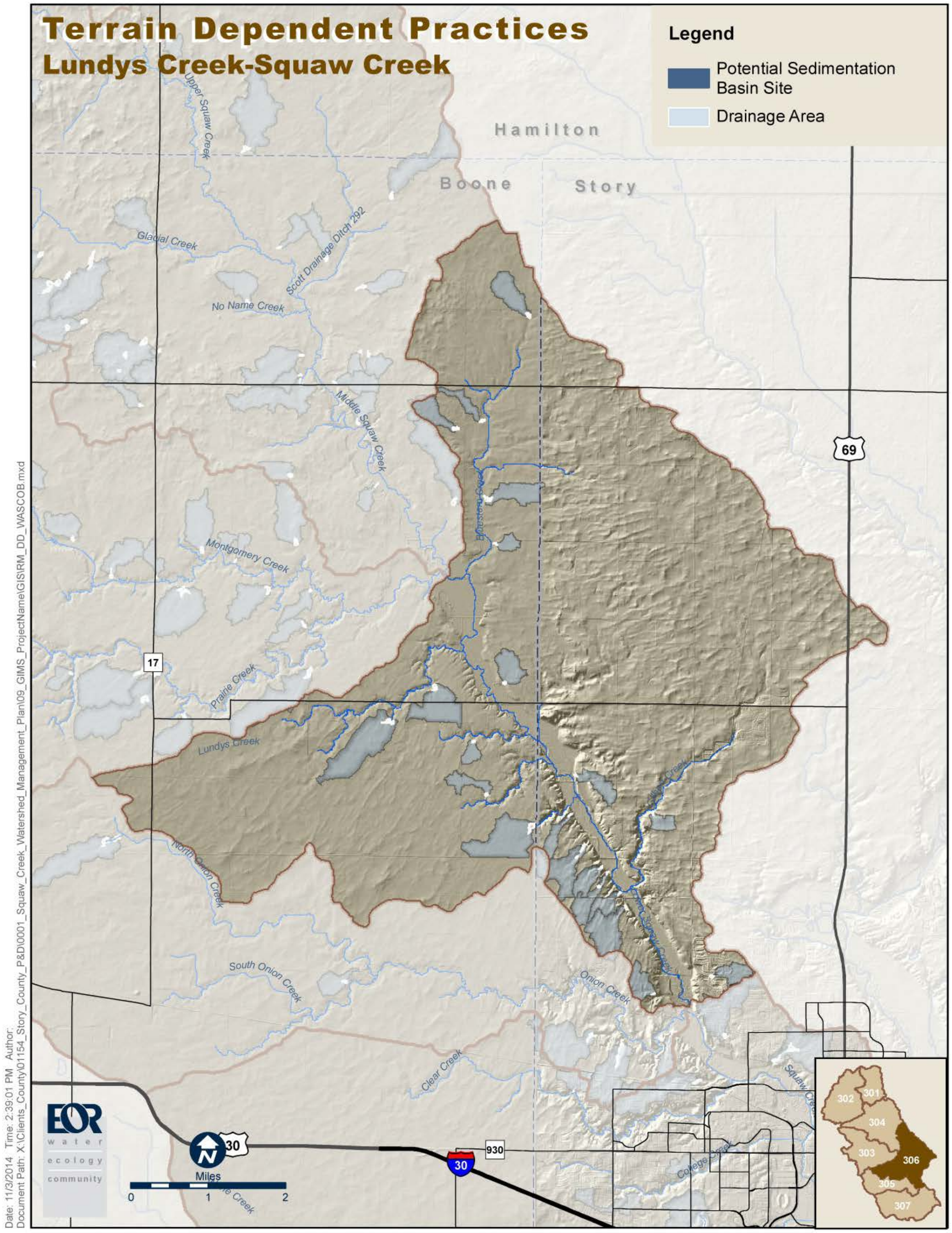
| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 287 |
| | Drainage Area (HA) | 6,192 |
| Nutrient Removal Wetlands | Pool Area (HA) | 72 |
| | Drainage Area (HA) | 4,210 |
| Sedimentation Basins | Pool Area (HA) | 6 |
| | Drainage Area (HA) | 776 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 571 |
| Multi-Species Buffers | Drainage Area (HA) | 2,783 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 2,207 |
| Deep-rooted Vegetation | Drainage Area (HA) | 309 |



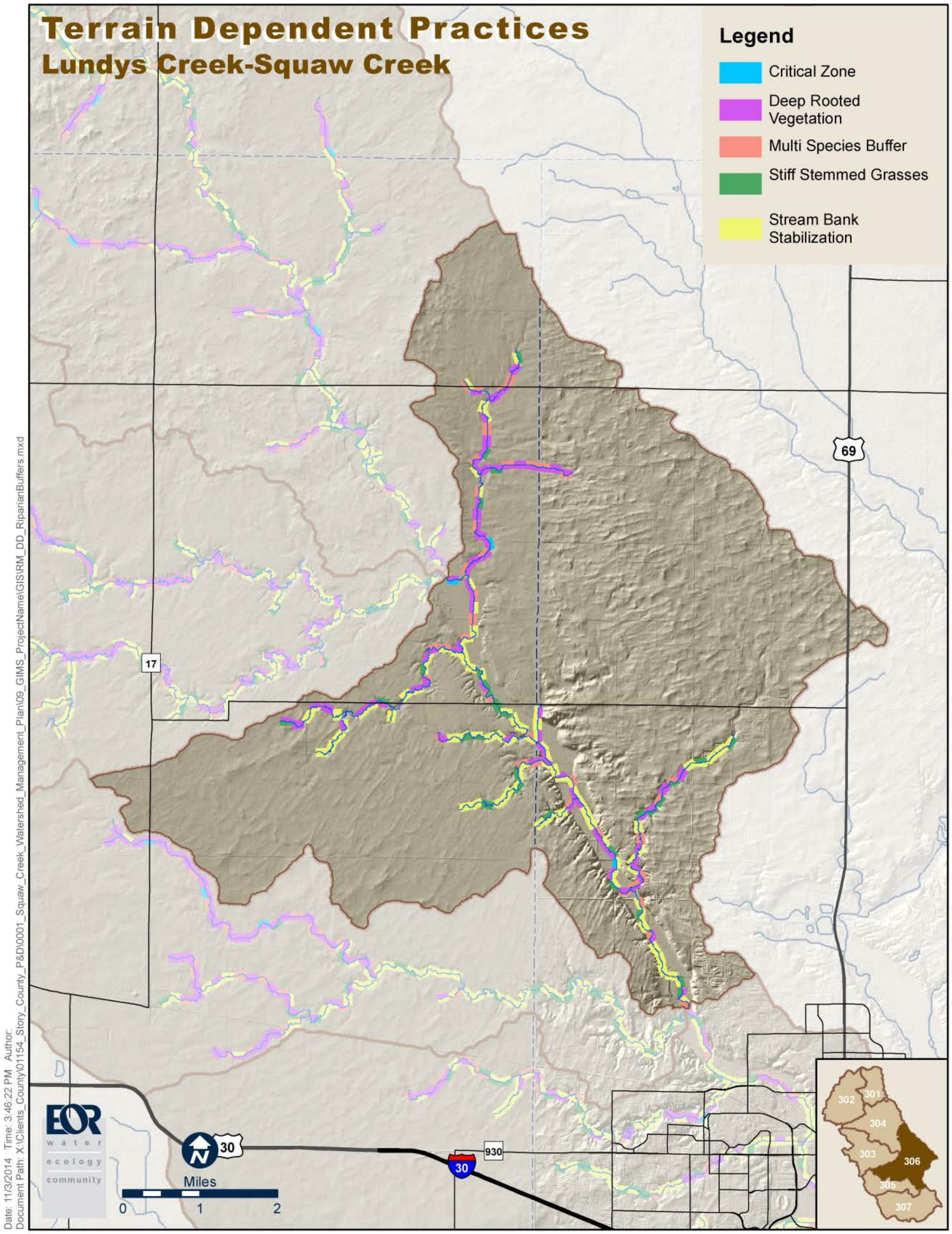

**A4 Figure 21**. Potential grassed waterway sites and soil runoff risk in Lundys Creek - Squaw Creek Subwatershed.




A4 Figure 22. Potential nutrient removal wetland sites in Lundys Creek – Squaw Creek Subwatershed.




**A4 Figure 23**. Potential sediment basin sites in Lundys Creek – Squaw Creek Subwatershed.

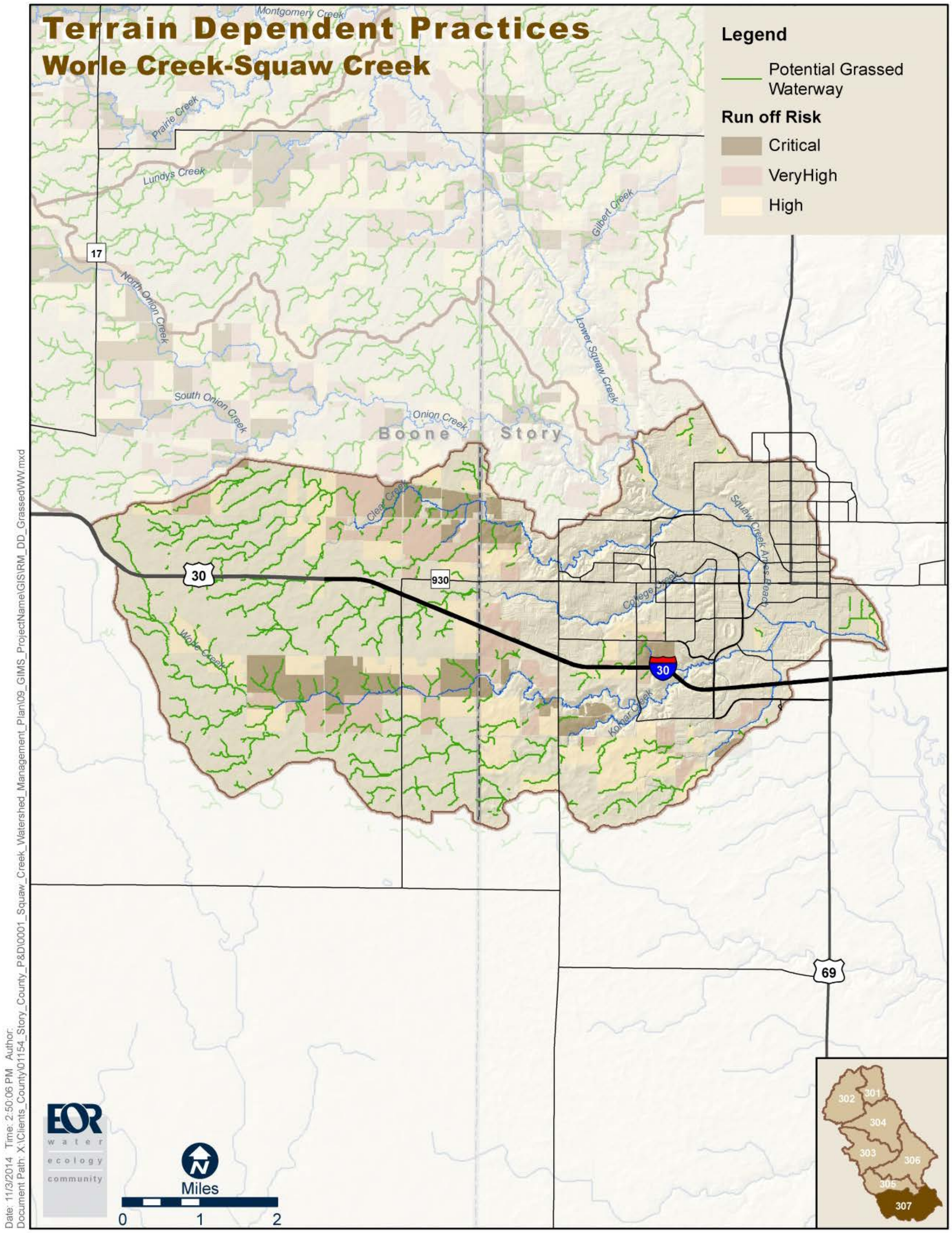



**A4 Figure 24**. Potential riparian buffers in Lundys Creek – Squaw Creek Subwatershed.

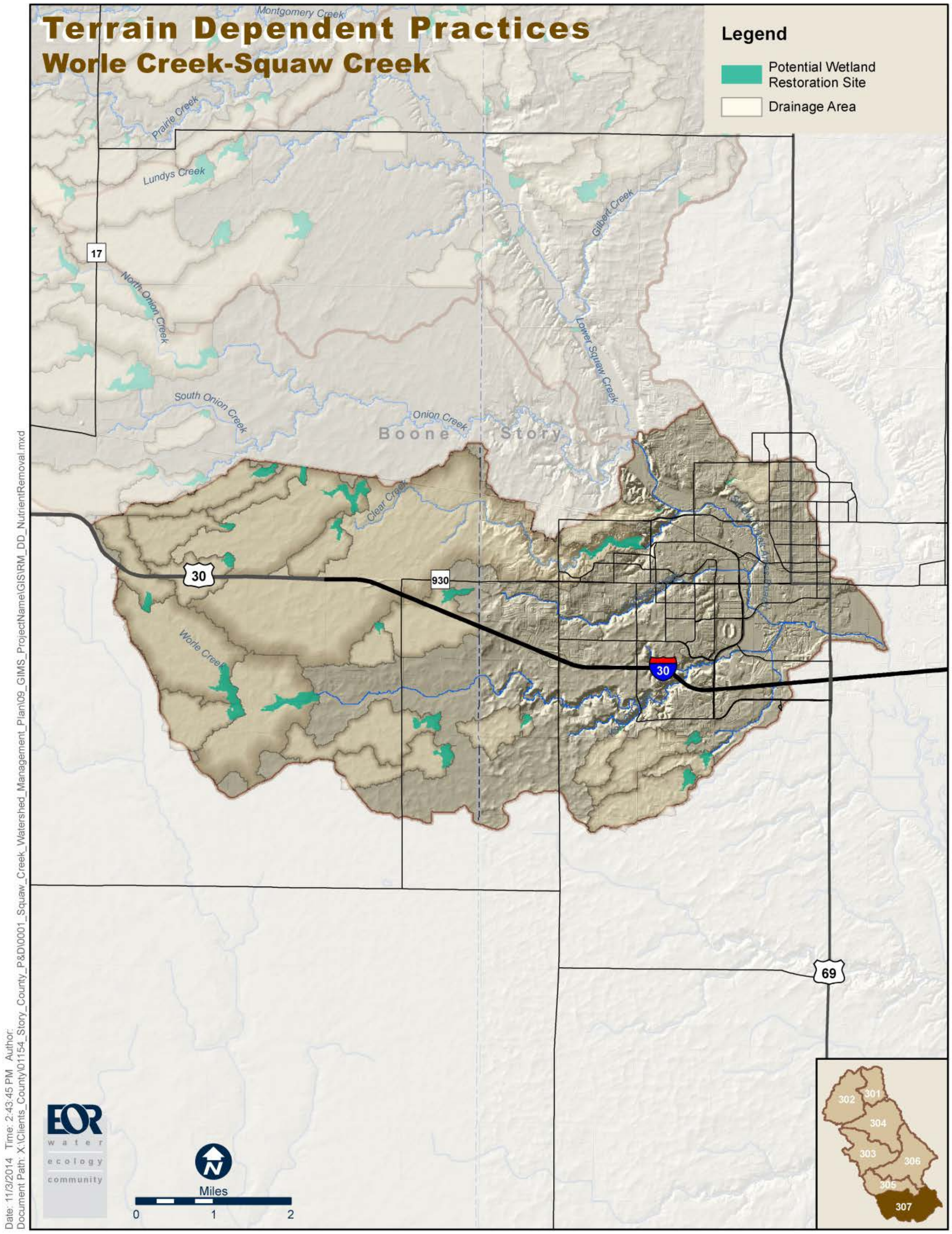
## Worle Creek Squaw Creek Subwatershed ACPF Findings

**A4 Table 7**. Terrain dependent best management practices summary in Worle Creek - Squaw Creek Subwatershed.

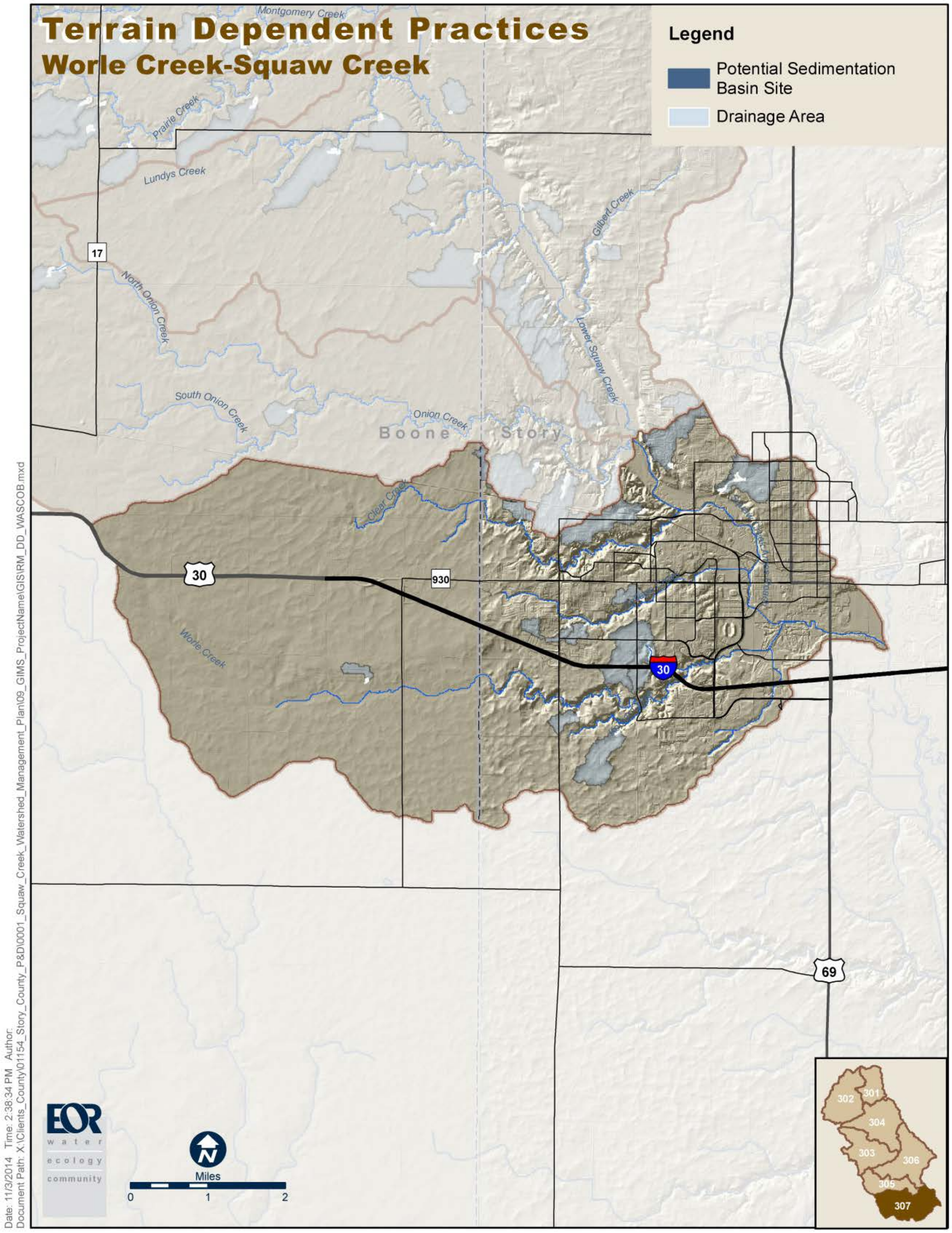
| Practice | Unit | Result |
|---|---|---|
| Grassed Waterways | Length (km) | 163 |
| | Drainage Area (HA) | 2,467 |
| Nutrient Removal Wetlands | Pool Area (HA) | 59 |
| | Drainage Area (HA) | 4,865 |
| Sedimentation Basins | Pool Area (HA) | 4 |
| | Drainage Area (HA) | 531 |
| Riparian Buffers | | |
| Critical Zones | Drainage Area (HA) | 382 |
| Multi-Species Buffers | Drainage Area (HA) | 1,929 |
| Stiff-stemmed Grasses | Drainage Area (HA) | 1,996 |
| Deep-rooted Vegetation | Drainage Area (HA) | 350 |



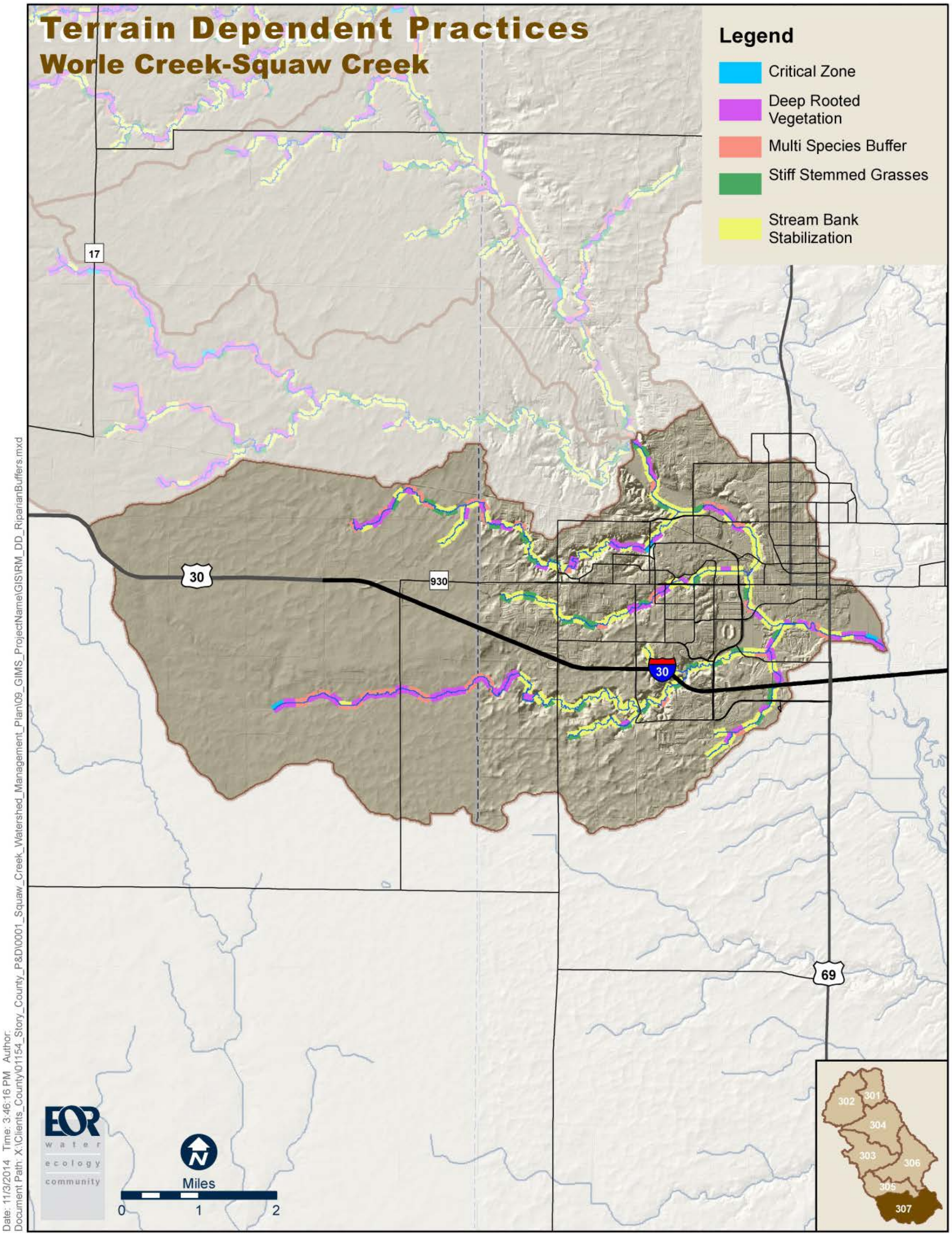

**A4 Figure 25**. Potential grassed waterway sites and soil runoff risk in Worle Creek – Squaw Creek Subwatershed.




**A4 Figure 26**. Potential nutrient removal wetland sites in Worle Creek – Squaw Creek Subwatershed.




**A4 Figure 27**. Potential sediment basin sites in Worle Creek – Squaw Creek Subwatershed.




**A4 Figure 28**. Potential riparian buffers in Worle Creek – Squaw Creek Subwatershed.