Table of Contents

Table of Figures

Table of Tables

1. Water Resources

1.1. Iowa Water Classification

Iowa's surface water classifications are described in IAC 61.3(1) as two main categories, **Designated Uses** and **General 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. Designated use classifications pertinent to the Keigley Branch – South Skunk River Watershed are described below in Table 1-1.

General use segments are intermittent watercourses and those watercourses which typically flow only for short periods of time following precipitation and whose channels are normally above the water table. These waters do not support a viable aquatic community during low flow and do not maintain pooled conditions during periods of no flow.

1.2. Iowa Waters Designated Uses

Primary contact recreational use: Class A1 - 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, canoeing and kayaking.

Secondary contact recreational use: Class A2 - *Waters in which recreational or other uses may result in contact with the water that is either incidental or accidental. During the recreational use, the probability of ingesting appreciable quantities of water is minimal. Class A2 uses include fishing, commercial and recreational boating, any limited contact incidental to shoreline activities and activities in which users do not swim or float in the water body while on a boating activity.*

Children's recreational use: Class A3 - *Waters in which recreational uses by children are common.*
Class A3 waters are water bodies having definite banks and bed with visible evidence of the flow or occurrence of water. This type of use would primarily occur in urban or residential areas.

Warm water Type 1: Class BWW-1 - *Waters in which temperature, flow and other habitat characteristics are suitable to maintain warm water game fish populations along with a resident aquatic community that includes a variety of native nongame fish and invertebrate species. These waters generally include border rivers, large interior rivers, and the lower segments of medium-size tributary streams.*

Warm water Type 2: Class BWW-2 - *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.*

Human health: Class HH - *Waters in which fish are routinely harvested for human consumption or waters both designated as a drinking water supply and in which fish are routinely harvested for human consumption.*

Table 1-1. Surface Water Designated Use Classifications for Keigley Branch – South Skunk River Watershed Streams

Stream	Reach Description	Designated Use Classification*					
		A1	A2	A3	BWW-1	BWW-2	HH
Bear Creek	Mouth (Story Co.) to the city of Roland WWTP outfall	✓				✓	
	From North Line of Story County to confluence with unnamed tributary in Hamilton County	✓			✓		
Keigley Branch	Mouth to confluence with unnamed tributary (AKA DD 1) in Story County (Formerly designated for Class B(W) uses).	✓			✓		
	From confluence with unnamed tributary (AKA DD 1) to headwaters in Hamilton County	✓			✓		
Long Dick Creek	Mouth (Story Co.) to bridge crossing (N. line, S34, T86N, R23W) Hamilton County	✓				✓	
	N. Line of Hamilton County to Headwaters in NE ¼, S8, T87N, R23W, Hamilton County	✓			✓		
South Skunk River	From confluence with Squaw Creek to the Ames Water Works Dam in River Valley Park at Ames	✓				✓	
	From the Ames Waterworks Dam to the County Road at the N. line S6, T85N, R23W, Story County approximately 1 mile NNE of Story City	✓			✓		✓
	N. line S6, T85N, R23W, Story Co. to confluence with D.D. No. 71	✓				✓	

** Designated uses are based on the most recent assessment data provided by the Iowa DNR's ADBNet website: https://programs.iowadnr.gov/adbnet/*

Table 1-2. Surface Water Designated Use Summary for Keigley Branch – South Skunk River Watershed Streams

Designation Class	Description	Number of Designated Stream Segments
Class A1	Primary contact recreational use	9
Class BWW-1	Warm water Type 1	5
Class BWW-2	Warm water Type 2	4
Class HH	Human Health	1

1.3. Impaired Waters

Stream and lake impairments are described in relation to their surface water classification and designated uses (Table 1-3). The State of Iowa has developed water quality standards for lakes and streams so that these waters support recreational uses and aquatic life (fish and macroinvertebrates). Four stream reaches and one lake within the Keigley Branch – South Skunk River Watershed are listed on EPA's 303 D list of impaired waterbodies due to elevated pollutant and bacteria levels and/or aquatic life impairments (Figure 1-1).

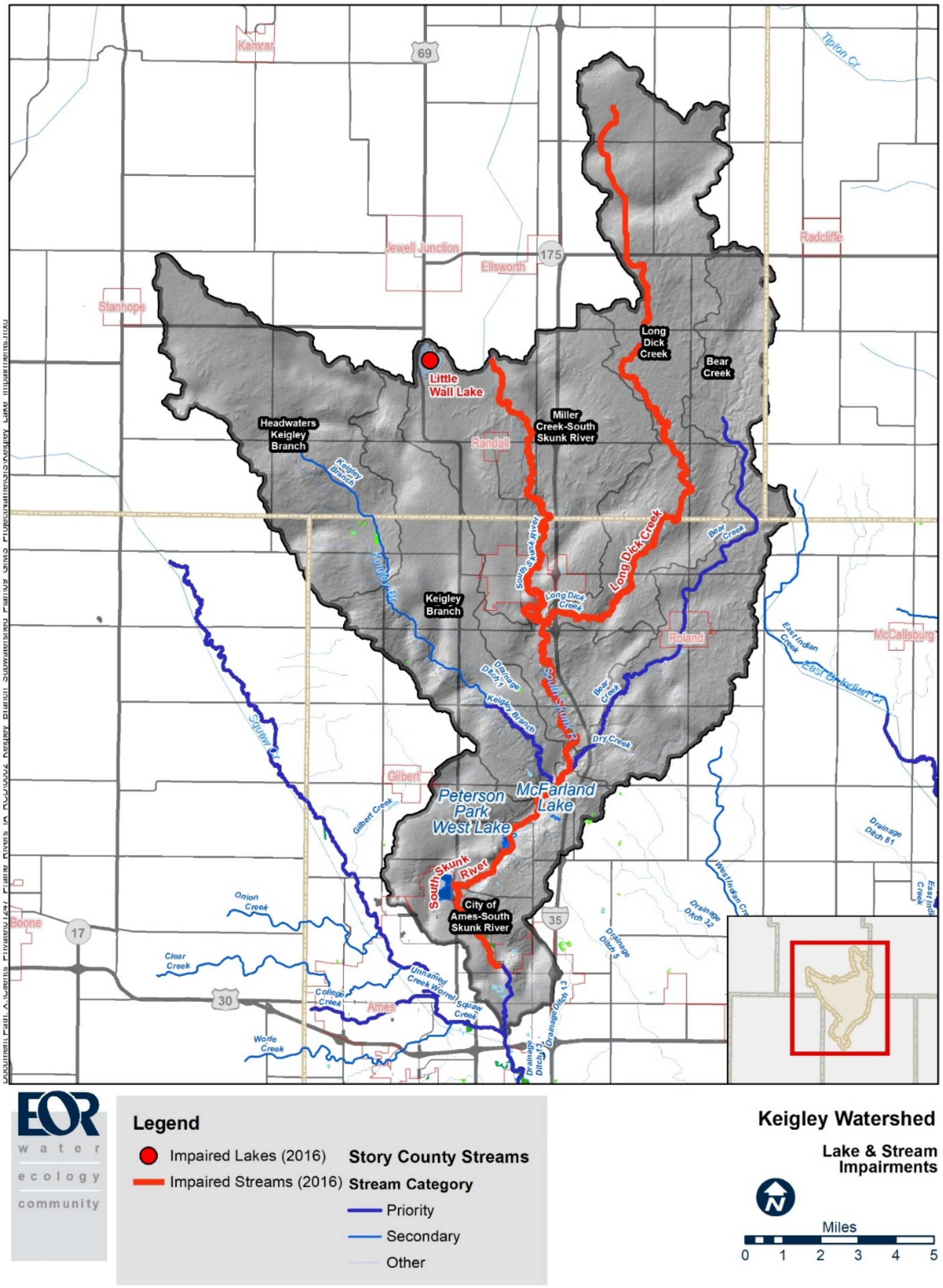


Figure 1-1. Impaired streams and lakes within the Keigley Branch – South Skunk River Watershed.

Table 1-3. Keigley Branch – South Skunk River Impaired Streams and Lakes

Waterbody	Category	Impaired Use	Primary Stressor	Use Support	Rationale
Little Wall Lake	4a	Narrative criteria violation: aesthetically objectionable conditions	Algal Growth: Chlorophyll a; Turbidity	Not Supporting	Ambient monitoring: Iowa DNR-lakes
Long Dick Creek - Mouth to N. line of Hamilton Co.	5b	Aquatic Life	Biological (Low DO; Organic Enrichment)	Partially Supporting	Low biotic index
Long Dick Creek - N. Line of S34 (SE1/4), T86N, R23W, Hamilton Co. to Headwaters in NE1/4, S8, T87N, R23W, Hamilton Co.	5p	Primary Contact; Aquatic Life	Indicator Bacteria; Biological	Partially Supporting	Single-sample maximum criterion exceeded in significantly > 10% of samples; Low Biotic Index
South Skunk River - Ames Water Works dam to the Co. Rd. (approximately 1 mile NNE of Story City)	5a	Primary Contact	Indicator Bacteria	Partially Supporting	> 10% of samples > 400 orgs/100 mL
South Skunk River - North line of Story Co. to confluence with Drainage Ditch 71 in Hamilton Co.	5b	Aquatic Life	Biological	Partially Supporting	Low biotic index

4a - All TMDLs need to result in attainment of all applicable water quality standards have been approved or established by EPA
5a- Water is impaired or threatened by a pollutant stressor and a TMDL is needed
5b- 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
5p- Impairment occurs on a waterbody presumptively designated for Class A1 primary contact recreation use or Class B(WW1) aquatic life use.

1.4. Streams

The following section describes the current state of the watershed streams. The designated uses identified for each stream carry with them a set of goals for human-based recreational uses as well as fish and aquatic life. The use designation process carried out by the Iowa DNR includes an evaluation of the natural characteristics of a water resource to determine the water's highest 'attainable' use. Next, a discussion of current water quality conditions in the various streams of the watershed is provided in the context of the designated uses and associated goals which have been identified for each resource. This assessment is based on the water quality monitoring that has been done in various locations throughout the watershed by the City of Ames, the Iowa Geological Survey, Iowa Volunteer Water Monitoring Program and the Iowa Department of Natural Resources from 2007 to 2017.

The final 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.

1.4.1. South Skunk River

Description

The South Skunk River is the most significant stream within the Keigley watershed. The origin of the South Skunk River is in Hamilton County approximately 19 miles upstream of Story City. The 185 mile long river flows generally southward west of Interstate 35 through the City of Ames. It joins the North Skunk River in Keokuk County to form the Skunk River which ultimately drains to the Mississippi River 5 miles south of Burlington, Iowa. The South Skunk River's stream banks are in poor condition, 21 of the 23 high priority streambank instability sites identified in the Keigley Branch Watershed were identified in close proximity to the South Skunk River channel.

Skunk River Greenbelt / Water Trail

Story County has developed the Skunk River Greenbelt/ Water Trail which encompasses most of the river within the county, from mile 246 in Story City to mile 212 at the Schreck Access (Hwy 210). Portions of the trail provide amenities for bicycling, canoeing, cross country skiing, fishing, kayaking, and hiking. There are eleven public river accesses on the South Skunk River within Story County.

Designated Recreational Uses

The South Skunk River is listed as a Class A1 waterbody, indicating it is capable of supporting primary recreational uses such as swimming and kayaking. The stretch of the South Skunk River from the Ames Waterworks Dam to the northern Story County line is listed as a Class BWW-1 waterbody, indicating this reach is capable of supporting a warm water game fish population. Anglers can expect to catch channel catfish, bullhead, smallmouth bass, and buffalo.

Impaired Reaches

The stretch of the South Skunk River below Ames Waterworks Dam to the northern Story County line is impaired for biological life based on low fish and macroinvertebrate biotic index scores. The stretch of the South Skunk River from the northern Story County line to the confluence with Drainage Ditch 71 is also impaired for biological life.

Figure 1-2. South Skunk River

1.4.2. Keigley Branch

Description

The Keigley Branch starts in Hamilton County and travels 15 miles southwest before joining the South Skunk River. Only one high priority streambank site was identified; overall stream bank health is good.

Designated Recreational Uses

The Keigley Branch supports primary recreational uses. Gamefish production is limited.

Impaired Reaches

An insufficient amount of data has been collected on this stream to determine whether or not any stream reaches are impaired for their designated use.

Figure 1-3. Keigley Branch of the South Skunk River.

1.4.3. Bear Creek

Description

Bear Creek originates within Hamilton County just a few miles north of the Story County boundary. The 16 mile long creek flows generally southwest through the City of Roland before joining the South Skunk River northeast of Ames. Bear Creek's stream banks appear to be in good condition, only 1 high priority streambank instability site was identified in close proximity to the creek channel.

Designated Recreational Uses

Bear Creek is listed as a Class A1 waterbody, indicating it is capable of supporting primary recreational uses such as swimming and kayaking. The Bear Creek headwaters reach is listed as a Class BWW-1 waterbody, indicating this reach is capable of supporting a warm water game fish population. Prior to the changes in Iowa's surface water classification, Bear Creek's headwaters reach was classified only for general uses due to the inability of the stream to support a viable aquatic community at low-flow conditions. The mainstem Bear Creek reach is listed as a class BWW-2 waterbody. The class BWW-2 aquatic life uses for the mainstem reach are currently assessed as fully supported.

Figure 1-4. Bear Creek

Impaired Reaches

Results from biological monitoring conducted by the DNR in 2003 and 2007 suggest the Class B (WW1) aquatic life uses should be considered partially supporting (PS) in the headwaters and fully supporting (FS) in the downstream reach. A fish kill occurred in the headwaters reach on August 27, 2001. Approximately 2,500 fish, mostly minnows, shiners, and creek chubs were killed. The source of the kill was traced to a hog confinement facility.

1.4.4. Long Dick Creek

Description

Long Dick Creek starts approximately 1 mile north of the Story County border and flows 9 miles southwest before joining the South Skunk River just south of Story City. Long Dick Creek's stream banks appear to be in good condition, only one high priority streambank site was identified.

Designated Recreational Uses

Long Dick Creek supports primary recreational uses. Gamefish production is limited.

Impaired Reaches

Biological monitoring conducted on the headwaters portion of Long Dick Creek in Hamilton County suggest the Class B-WW1 aquatic life uses should be considered partially supporting (PS). Bacteria sampling conducted on the headwaters portion of Long Dick Creek exceeded Class A1 criterion (126 orgs/100 ml) in 2008 and 2009; however, the class A1 (primary contract recreation) uses currently remain assessed as partially supported. Biological monitoring conducted on the mainstem reach of Long Dick Creek in 2003 and 2008 suggest the Class B-WW2 aquatic life uses should be considered partially supporting (PS). No bacteria sampling has been conducted on the mainstem reach of Long Dick Creek.

Figure 1-5. Long Dick Creek

1.5. 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 the Keigley Branch 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 the Keigley Branch 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 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.

In an effort to define the level of water quality within the Keigley Branch 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.

Table 1-4 Surface Water Designated Use Classifications for the Keigley Branch – South Skunk River Watershed's Streams

Stream	Description	Surface Water Designated Use Classification
South Skunk River	Confluence with Indian Cr. (Jasper Co.) to Ames Waterworks Dam	Primary contact recreational use Class A1 Warm water Type 2: Class BWW-2
	Ames Waterworks Dam to N. line S6, T85N, R23W, Story Co.	Primary contact recreational use Class A1 Warm water Type 1: Class BWW-1 Human Health
	N. line S6, T85N, R23W, Story Co. to confluence with D.D. No. 71	Primary contact recreational use Class A1 Warm water Type 2: Class BWW-2
Keigley Branch	Mouth to N. line of S35, T85N, R24W, Story Co	Primary contact recreational use Class A1 Warm water Type 2: Class BWW-2
Bear Creek	Mouth (Story Co.) to the city of Roland WWTP outfall	Secondary contact recreational use Class A2 Warm water Type 2: Class BWW-2
Long Dick Creek	Mouth (Story Co.) to bridge crossing (N. line, S34, T86N, R23W, Hamilton Co.)	Primary contact recreational use Class A1 Warm water Type 2: Class BWW-2

1.5.1. Applicable Water Quality Standards and Criteria

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.

Table 1-5. Iowa State Stream Water Quality Standards

Parameter	Description/ Qualification	State Standard
E. coli Bacteria	Class A1 Streams	Long Term Geometric Mean =126 MPN/100ml Maximum Sample MPN/100ml = 235 MPN/100ml
Dissolved Oxygen (DO)	Warm Water Type 1	Min for at least 16 hours of every 24-hour period 5.0 mg/L Min at any time 5.0 mg/L
	Warm Water Type 2	Min for at least 16 hours of every 24-hour period 5.0 mg/L Min at any time 4.0 mg/L
Chloride (Cl)	All Streams	Chronic (based on hardness and sulfate concentrations)389 mg/L
		Acute (based on hardness and sulfate concentrations)
pH	All Streams	The pH shall not be less than 6.5 nor greater than 9.0. The maximum change permitted as a result of a waste discharge shall not exceed 0.5 pH units.

1.5.2. General water quality criteria

In addition to the specific numeric criteria described above for designated use classes, the following criteria are applicable to all surface waters including general use and designated use waters, at all places and at all times.

a. Such waters shall be free from substances attributable to point source wastewater discharges that will settle to form sludge deposits.
b. Such waters shall be free from floating debris, oil, grease, scum and other floating materials attributable to wastewater discharges or agricultural practices in amounts sufficient to create a nuisance.
c. Such waters shall be free from materials attributable to wastewater discharges or agricultural practices producing objectionable color, odor or other aesthetically objectionable conditions.
d. Such waters shall be free from substances attributable to wastewater discharges or agricultural practices in concentrations or combinations which are acutely toxic to human, animal, or plant life.
e. Such waters shall be free from substances, attributable to wastewater discharges or agricultural practices, in quantities which would produce undesirable or nuisance aquatic life.
f. The turbidity of the receiving water shall not be increased by more than 25 Nephelometric turbidity units by any point source discharge. IAC 1/18/17 Environmental Protection[567] Ch 61, p.9
g. Cations and anions guideline values to protect livestock watering may be found in the “Supporting Document for Iowa Water Quality Management Plans,” Chapter IV, July 1976, as revised on November 11, 2009.
h. The Escherichia coli (E. coli) content of water which enters a sinkhole or losing stream segment, regardless of the water body’s designated use, shall not exceed a Geometric Mean value of 126 organisms/100 ml or a sample maximum value of 235 organisms/100 ml. No new wastewater discharges will be allowed on watercourses which directly or indirectly enter sinkholes or losing stream segments

1.6. Stream 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 Keigley Branch watershed have been ongoing since about 2000 and incorporate data collected by the Iowa DNR and data collected by 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 water quality data were summarized by parameter (Nitrate, Phosphate, Bacteria, Transparency, and Chloride) to determine the total number of samples by parameter collected along each stream reach (Long Dick Creek, Miller Creek, Bear Creek, Keigley Branch Headwaters, Keigley Branch, and South Skunk River Reaches) beginning at the headwaters and proceeding downstream. Over the years, sampling dates have varied somewhat from January through November, however, most recent sampling (2009-2016) tended to occur in May and October.

Keigley Branch watershed reaches are defined as follows:

- South Skunk River Miller Creek - The South Skunk River enters the Keigley Branch Watershed as a fourth-order stream, several small unnamed tributaries enter the South Skunk within this subwatershed.
- South Skunk River City of Ames– The South Skunk River is a larger fourth-order stream in this subwatershed, transitioning to a fifth-order stream as it leaves the Keigley Branch HUC-10 and connects with Squaw Creek
- Keigley Branch Headwaters– The Keigley Branch itself begins as two separate first-order drainage ditches that form a second order stream south of a deep marsh at 370th street
- Keigley Branch – The Keigley Branch becomes a third order stream before discharging to the South Skunk River
- Long Dick Creek – Long Dick Creek starts out as two separate first order streams that join together to form a second order stream before joining the South Skunk River near the City of Roland
- Miller Creek – Miller Creek represents the only named tributary to the South Skunk River in the Miller Creek HUC-12 watershed
- Bear Creek – Bear Creek starts out as two separate first order streams that join together to form a second order stream before joining the South Skunk River near Story City.

Table 1-6. Number of Samples for Keigley Branch Streams and Tributaries.

Stream	Nitrite + Nitrate	Orthophosphate	*E. coli*	Transparency	Chloride
Bear Creek	52	36	NA	52	17

Stream	Nitrite + Nitrate	Orthophosphate	*E. coli*	Transparency	Chloride
Long Dick Creek	56	56	12	56	54
Keigley Branch Headwaters	1	1	NA	1	1
Keigley Branch	42	25	NA	39	7
South Skunk River – City of Ames	101	90	185	96	189
South Skunk River – Miller Creek	9	15	3	3	3

1.6.1. 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, discussions will focus on nitrite plus nitrate nitrogen levels.

Dissolved nitrogen concentrations were monitored by volunteers throughout the Keigley Branch 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.

Dissolved nitrogen (nitrate plus nitrite) concentrations range from around 4.5 mg/L to 5.8 mg/L throughout the mainstem South Skunk River reaches (South Skunk-Miller Creek, South Skunk-City of Ames). While mainstem average nitrate plus nitrite concentrations were elevated throughout the monitoring network, these averages do not exceed the drinking water standard of 10.0 mg/L.

High nitrate concentrations were noted for the Keigley Branch Headwaters and Keigley Branch reaches where average concentrations approached the drinking water standard of 10 mg/L. The high concentrations observed in the Keigley Branch Headwaters should be considered carefully as only 4 samples were collected from this reach. A total of 42 nitrate samples were collected from the Keigley Branch reach, observed dissolved nitrogen concentrations were similarly high with an average dissolved nitrogen concentration of 8.4 mg/L. Since organic nitrogen monitoring data was not available, total nitrogen concentrations may be greater than indicated by just dissolved forms.

Observed dissolved nitrogen concentrations in Bear Creek and Long Dick Creek were also high with average concentrations of 5.7 and 7.4 mg/L respectively.

1.6.2. 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 the South Skunk River and other tributaries in the Keigley Branch watershed 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.

Average orthophosphate concentrations for the South Skunk River-City of Ames (0.1 mg/L) reach were significantly lower than observed concentrations in the South Skunk River-Miller Creek (0.5 mg/l) reach. The reduction in observed orthophosphate concentrations is likely result from the largely intact forested and wetland buffers that surround this stretch of the South Skunk River. The presence of intact, forested buffers is likely helping to offset phosphorus loads derived from the surrounding agriculturally dominated upland landscape.

Average tributary orthophosphate concentrations ranged from 0.1 mg/L at Long Dick Creek to 0.3 mg/L in the Keigley Branch Headwaters.

1.6.3. 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 (T-tube) monitoring data is available for all sites over the entire monitoring time from 2000-2017. Average observed transparency tube readings for the Keigley Branch watershed were compared with average values of statewide transparency based on data collected from IOWATER statewide snapshot events. Fifty percent of the results for samples collected statewide were between 51 and 60 centimeters, and values recorded as 60+ were considered to be 60. 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. The South Skunk River and tributary flows within the Keigley Branch subwatershed 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.

1.6.4. 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 and tributary reaches alike range from approximately 13-35 mg/L. All are well below the chronic standard. The lowest average concentration value of 19.3 mg/L was noted for the Long Dick Creek site; Bear Creek had the highest average concentration (34.3 mg/L). All of these averages were less than the chloride standards; furthermore, the peak Chloride concentration for all samples (100) noted for the South Skunk River – City of Ames site in February, 2001 was still well below the chronic standard. These data suggest that chlorides are not a major pollutant of concern at this time in the Keigley Branch watershed.

1.6.5. 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.

However, concurrently noted minimum values ranged from 4 to 6 mg/L while a maximum value of 12 mg/L or higher were noted for each site. 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 3.8 (Miller Creek) to as high as 17.7 mg/L (South Skunk River-City of Ames) which is symptomatic of over-nutrient enriched systems. A closely related analyte, pH can become elevated during periods of maximum aquatic productivity resulting from enrichment.

1.6.6. 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 South Skunk River and tributaries within the Keigley Branch watershed ranged between 7 to 8.8 units. The observed value of 7.0 for the Keigley headwaters branch should be considered carefully as there was only one sample collected from this site. On average, both tributary and mainstem reaches had pH values between 8.5 and 8.8. 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 observed DO flux, higher pHs and pH ranges suggest elevated algal productivity within the Keigley Branch watershed flow network.**

1.6.7. *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 15th to November 15th. However, stream reaches may also be listed on the 303(d) list as impaired if single samples exceed 235 org/100mL.

The South Skunk River – City of Ames reach and Long Dick Creek (2009 only) were the only monitoring sites in the Keigley Branch watershed with data available to analyze E. coli geometric mean concentrations. The other monitoring sites did not contain data on *E. coli* concentrations. ***E. coli* geometric means for the mainstem South Skunk River – City of Ames reach were above 126 org/100mL in 2006, 2007, 2009, and 2010 (**Figure 2-14**). Similarly, *E. coli* concentrations in Long Dick Creek were significantly above the EPA criteria of 126 org/100ml in 2009; the only year with available data.** Note that the state standard for *E. coli* applies only to Class A1 Recreational Use waters which for the Keigley Branch watershed include all streams and tributaries except for Bear Creek.

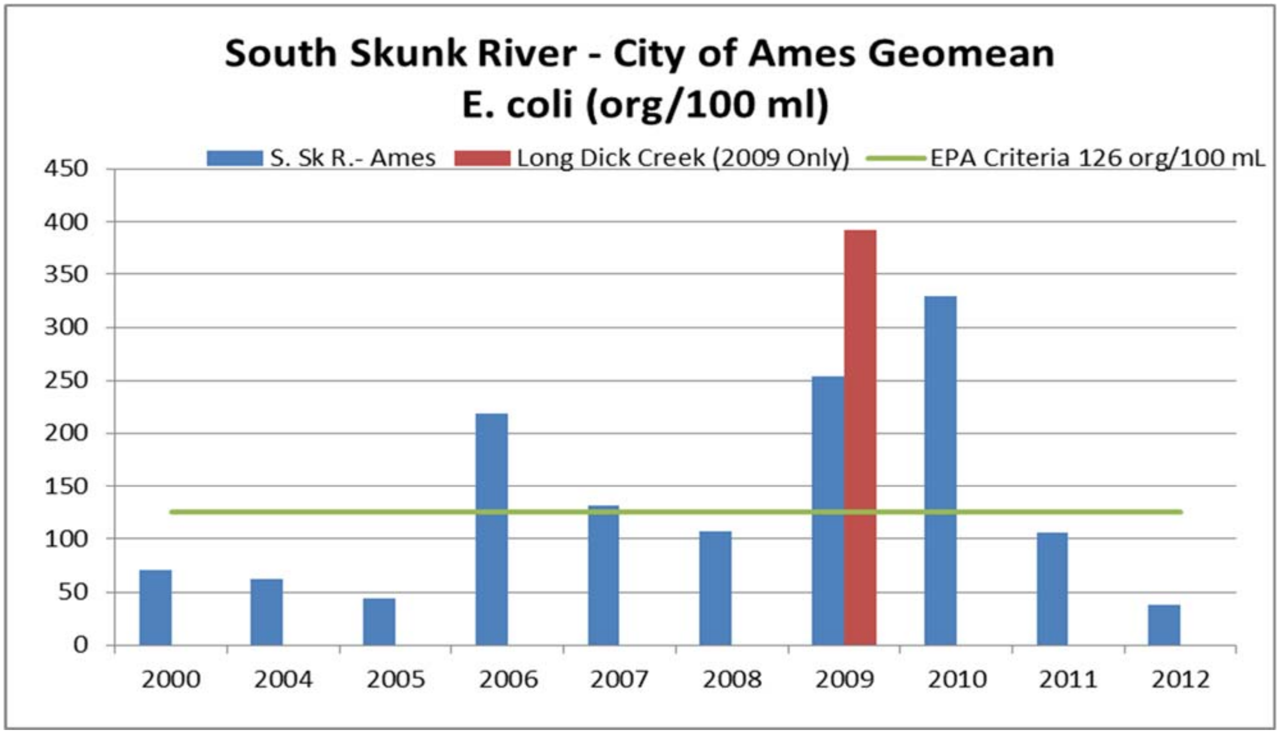


Figure 1-6. E. coli geometric means for the mainstem South Skunk River – City of Ames

1.6.8. Macroinvertebrates

Aquatic biota can be useful 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 the South Skunk River, Iowa Benthic Macroinvertebrate Index of Biotic Integrity (BMIBI) warm-water 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.

The most recent biotic data collected in the Keigley Branch Watershed was collected on the South Skunk River near Ames in 2015; however, data at various locations throughout the watershed exists as far back as 1997. 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.

Calculation of the Iowa BMIBI for warm-water streams consists of twelve metrics which are summed together and multiplied by 0.833 to evaluate stream health on a scale from 0-100. Metrics used include taxa richness metrics which look at the total number of species sampled and proportional abundance metrics that look at the types and composition of pollution-intolerant species sampled within a given stream reach. Three orders used in the Iowa BMIBI assessment include Ephemoptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). These three orders (aka "taxa") are often referred to collectively as EPT. A complete description of all twelve metrics (including percent abundance of EPT taxa) is available on the Iowa DNR's BIONET website: https://programs.iowadnr.gov/bionet/Docs/Codex/BMIBI-Warm%20Water. Calculated BMIBI scores are then compared with scores from previously identified reference sites located in the extant ecoregion.

Twelve of the 18 streams within the Keigley Branch watershed had an average BMIBI score of good or better including two sites with an excellent rating. Six of the 18 streams within the Keigley Branch watershed had an average BMIBI score of fair or worse including one reach of the South Skunk River located upstream of the Story City Wastewater Treatment Plant with a poor rating (

Table 1-8).

Table 1-7. Iowa Benthic Macroinvertebrate Index of Biotic Integrity warm-water criteria

BMIBI Range	Stream Quality	Macroinvertebrate Community	EPT Taxa
0-30	Poor	Severely impaired macroinvertebrate community	Rare or not present

BMIBI Range	Stream Quality	Macroinvertebrate Community	EPT Taxa
31-55	Fair	Total taxa richness and EPT taxa richness are noticeably reduced from optimum levels	EPT are dominant but lack sensitive EPT taxa
56-75	Good	Good numbers of taxa are present, including several sensitive species	EPT taxa are fairly diverse and dominate the community
76-100	Excellent	High numbers of taxa present including sensitive species, trophic specialists, and representatives from all major functional feeding groups	EPT taxa are diverse and dominate the community

Table 1-8. Keigley Branch watershed BMIBI average score

Site Name	Average BMIBI Score	Percent EPT	BMIBI Ranking
Bear Creek Roland WWTP DS	40.5	36.58%	Fair
Bear Creek Roland WWTP US	58	52.81%	Good
Bear Creek Skunk River Greenbelt	72.25	74.29%	Good
Keigley Branch - Gilbert	80	83.64%	Excellent
Long Dick Creek - Ellsworth (LDC2)	71	51.00%	Good
Long Dick Creek - Roland (LDC1)	41.3	15.78%	Fair
Long Dick Creek - Roland (Old LCD2)	50.5	50.52%	Fair
South Skunk River - Ames	66.5	71.56%	Good
South Skunk River - Ames - Hinds Research Center	50.4	65.94%	Fair
South Skunk River - Ames - Lincolnway Bridge	70	86.00%	Good
South Skunk River - Ames - River Valley Park	81	88.99%	Excellent
South Skunk River - Ames - Squaw Creek Confluence	69	80.10%	Good
South Skunk River - Ames US1	47	37.70%	Fair
South Skunk River - Randal	56.5	51.67%	Good
South Skunk River - Story City DS WWTP	59	70.71%	Good
South Skunk River - Story City US Storm	63	49.29%	Good
South Skunk River - Story City US WWTP	30	1.74%	Poor
South Skunk River - Story City US WWTP 200	63	19.58%	Good

Looking at the monitoring results of individual streams within the watershed only provides a snapshot for a given stream reach for the date on which the assessments were conducted. If all data are combined, some generalizations can be interpreted for the relative health of the macroinvertebrate community for the Keigley Branch watershed as a whole. For example, BMIBI scores for all sites in the Keigley Branch watershed can be grouped together by year the BMIBI assessment was conducted to better assess trends in BMIBI scores in comparison with average annual flows (247 cfs).

Year	Average BMIBI Score	Number of Samples	Annual Flow (CFS)	BMIBI Ranking
1995	71.00	1	215.8	Good
1997	62.00	15	241.3	Good
2003	49.50	6	137.6	Fair
2007	58.00	2	397.8	Good

2008	59.67	3	537.8	Good
2009	47.00	1	355.6	Fair
2011	57.00	1	199.2	Good
2013	54.80	5	218.3	Fair-Good
2014	45.50	2	217.6	Fair
2015	55.00	1	321.7	Fair-Good

From the data collected, it appears that the healthiest communities highlighted in red text were observed during assessments conducted in 1995 and 1997; annual flows were near the normal annual average during these years. However, assessments conducted in 2013 and 2014, during years in which annual flows were also near the annual average, yielded comparatively lower average BMIBI scores. Furthermore, observed BMIBI years were also ranked as good in years with significantly lower than average annual flows (e.g., 2011) as well as in years with higher than average annual flows (e.g., 2007-2008). Overall, a direct relationship between annual flow and corresponding BMIBI scores cannot be inferred, likely due to the limited sample size. In general, additional macroinvertebrate monitoring is needed to identify the key stressors to the macroinvertebrate community. Data collected to date would suggest that the existing macroinvertebrate community on streams in the Keigley-Branch watershed is generally in the fair to good range.

1.6.9. Stream Flows

In addition 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 2.5 consists of a series of ditches and small creeks, subsurface tile drainage, Bear Creek, Long Dick Creek, the Keigley Branch of the South Skunk River and the South Skunk River itself. A long-term flow monitoring station (USGS station 05470000) is located on the South Skunk River in Ames above the confluence with Squaw Creek. The station shows considerable variability as estimated by average annual flows from 1970 to 2016. During this time period, average annual values varied from 18.1 cubic feet per second (cfs) (1989) to 751.8 cfs (1993 Flood) with an overall annual median value of about 247cfs (Figure 1-7).

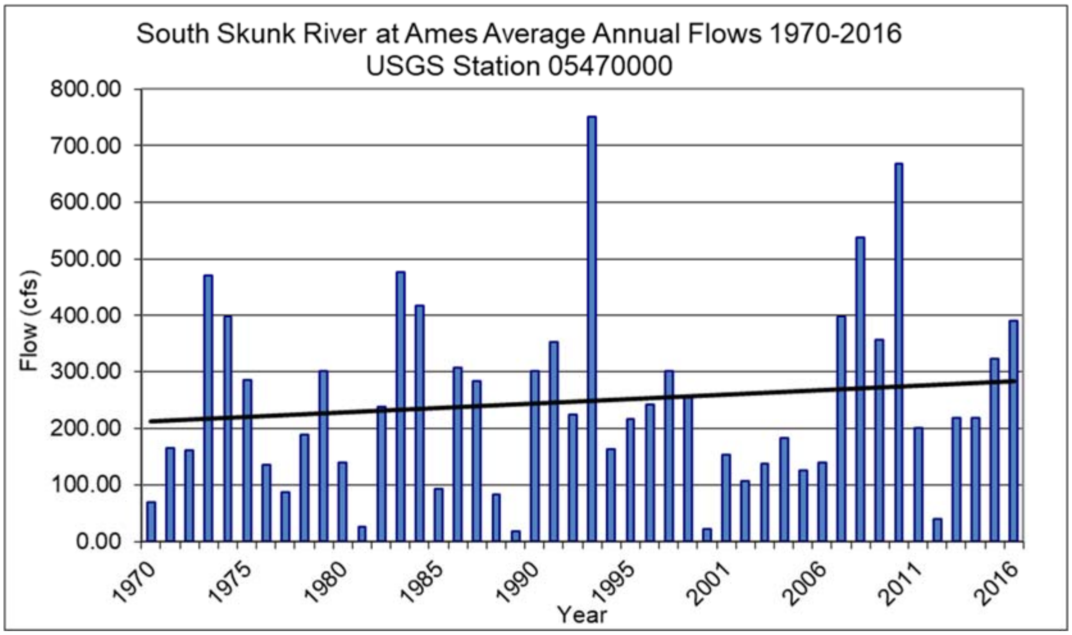


Figure 1-7. South Skunk River at Ames, IA (USGS Station 05470500) Annual Average Flows

Average Annual Flows

Looking at the most recent years (2000-2016), the annual average flows show the considerable contrast of wet and dry years (Figure 1-8) with 11 years having less than average flows and 6 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 2000/2012 experienced average annual low flows on the order of 22-39 cfs (or drier than about 95% of annual flows from 1970-2016) to the much higher flows of 2010 (e.g. 667 cfs). In this regard, wet and dry year flows differed by a factor of about 30.

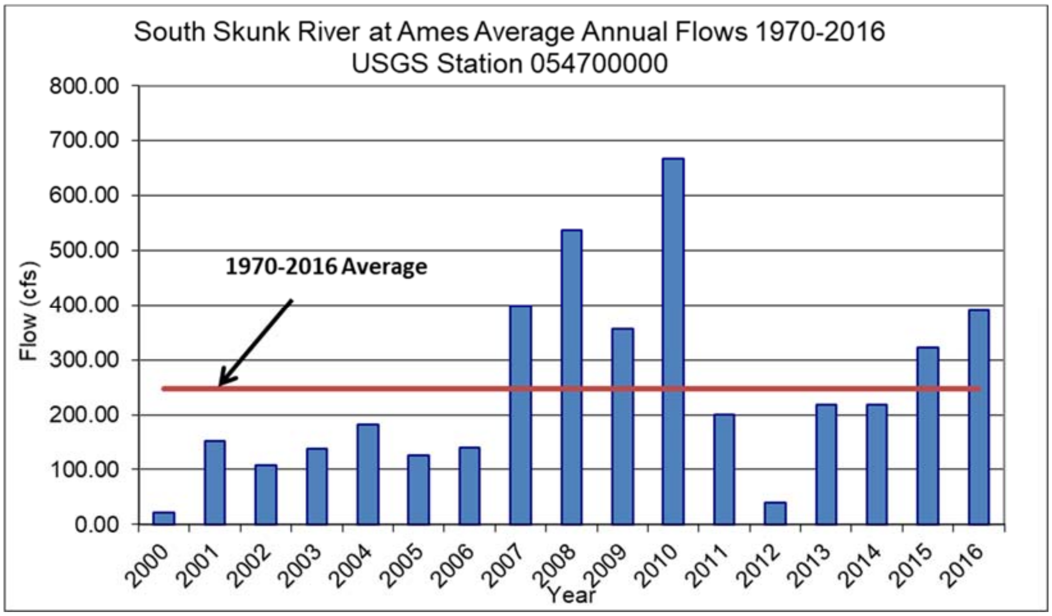


Figure 1-8. 2000-2013 Annual Average Flows at Ames, IA.

For reference, the peak annual flows of 1993 averaged about 752 cfs (Table 1-9). **This range of annual flows is extreme and indicates that the South Skunk River has relatively low upland flow buffering capabilities from storage by wetlands, lakes or ponds.**

Table 1-9. South Skunk River at Ames, IA, frequency of annual average flows by percentile for 1970-2016 (USGS Station 05470000).

Percentile	Average Annual Flow (cfs)
10%	77
25%	138
50%	218
75%	318
90%	445

Average Monthly Flows

Shifting to a closer examination of South Skunk River flows within the Keigley Branch watershed, average monthly values monitored from 1970-2016, 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 1-9). Sharp declines in average monthly flows were noted for the last half of the growing season (July-September) when peak evapotranspirational losses are expected.

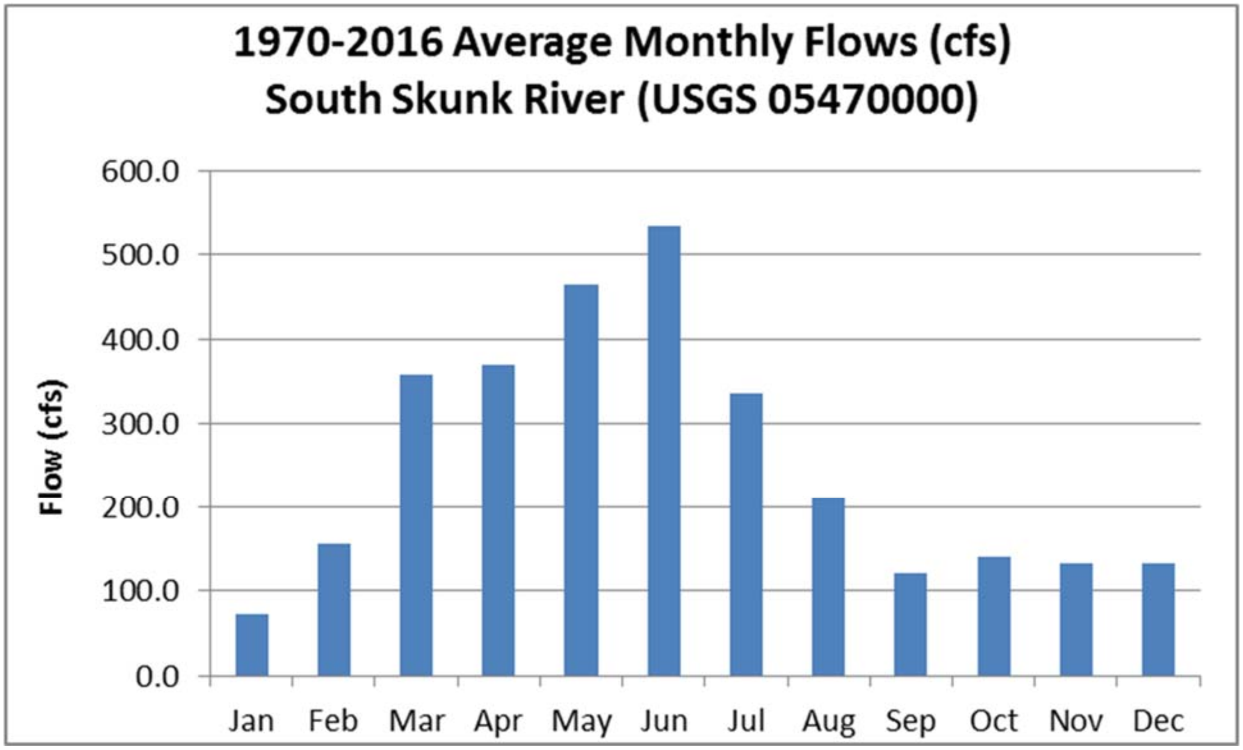


Figure 1-9. South Skunk River (Ames, IA) average monthly flows (cubic feet per second)

Average monthly flows for the South Skunk River at Ames from the USGS from 2000 to 2016 were summarized in Table 1-10 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 1-10. Monthly Stream Flows USGS Gage Station, Ames IA

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2000	5.4	15.8	12.5	5.4	12.3	144.0	41.5	7.3	1.5	5.7	8.8	4.1
2001	3.4	3.4	518.7	305.6	487.1	356.6	55.8	16.5	57.1	36.0	53.1	59.5
2002	31.3	72.8	69.4	147.0	379.7	226.0	113.5	68.4	29.8	105.5	65.9	33.1
2003	12.9	14.4	40.9	191.4	549.5	223.4	377.8	18.8	3.7	2.0	13.5	9.1
2004	14.9	127.2	239.3	173.8	614.0	640.5	250.6	86.4	22.3	11.5	30.5	29.0
2005	20.5	178.8	94.5	301.2	419.7	253.4	124.6	34.4	13.3	13.2	17.5	18.1
2006	110.7	75.1	94.9	220.1	397.6	108.5	67.6	44.1	504.9	194.1	181.6	230.2
2007	320.1	130.3	728.1	1070.0	748.0	517.2	99.1	391.2	147.7	784.6	186.2	87.2
2008	48.1	36.9	560.9	1023.0	993.5	2095.0	492.1	122.4	30.5	122.6	331.3	156.0
2009	92.5	407.1	796.7	710.9	739.0	599.3	248.4	59.1	16.9	447.0	514.6	171.0
2010	116.4	174.1	1604.0	331.1	588.0	773.0	1086.0	1804.0	331.5	182.3	226.9	93.8
2011	71.0	251.5	219.2	428.2	409.6	382.8	106.2	21.9	10.4	3.7	9.7	13.5
2012	9.1	13.9	53.4	103.6	179.3	72.2	10.9	2.1	1.2	4.4	10.4	5.4
2013	5.3	12.2	302.8	213.8	1352.0	570.7	102.7	13.6	3.6	4.1	6.5	3.6
2014	2.0	1.1	101.6	156.2	323.8	841.8	963.0	44.6	150.9	291.7	108.9	123.5
2015	98.5	80.7	128.8	224.9	369.8	413.5	144.6	1215.0	640.8	227.6	285.0	1129.0
2016	293.2	528.7	348.1	206.3	391.0	365.8	69.4	188.3	659.8	256.2	124.8	
Mean	**73.8**	**124.9**	**347.9**	**341.9**	**526.7**	**504.9**	**256.1**	**243.4**	**154.5**	**158.4**	**128.0**	**135.4**
Dry Months 25th%	10.0	14.8	94.6	178.2	382.5	232.9	76.8	19.6	11.1	7.2	14.5	13.5
Wet Months 75th%	97.0	163.2	476.1	339.2	607.5	592.2	254.7	171.8	153.6	219.2	185.1	135.4

Daily Average Flows

A more detailed view of (1) daily average flows and (2) instantaneous peak flows were examined for the 2006-2017 time period (Figure 1-10). In this plot, the highest daily average flows were on the order of 12,400 CFS in August, 2010 and 9,500 CFS in June, 2008. The remaining time periods had much lower variability of daily flows, especially the period from 2011-2013 which were below average runoff years.

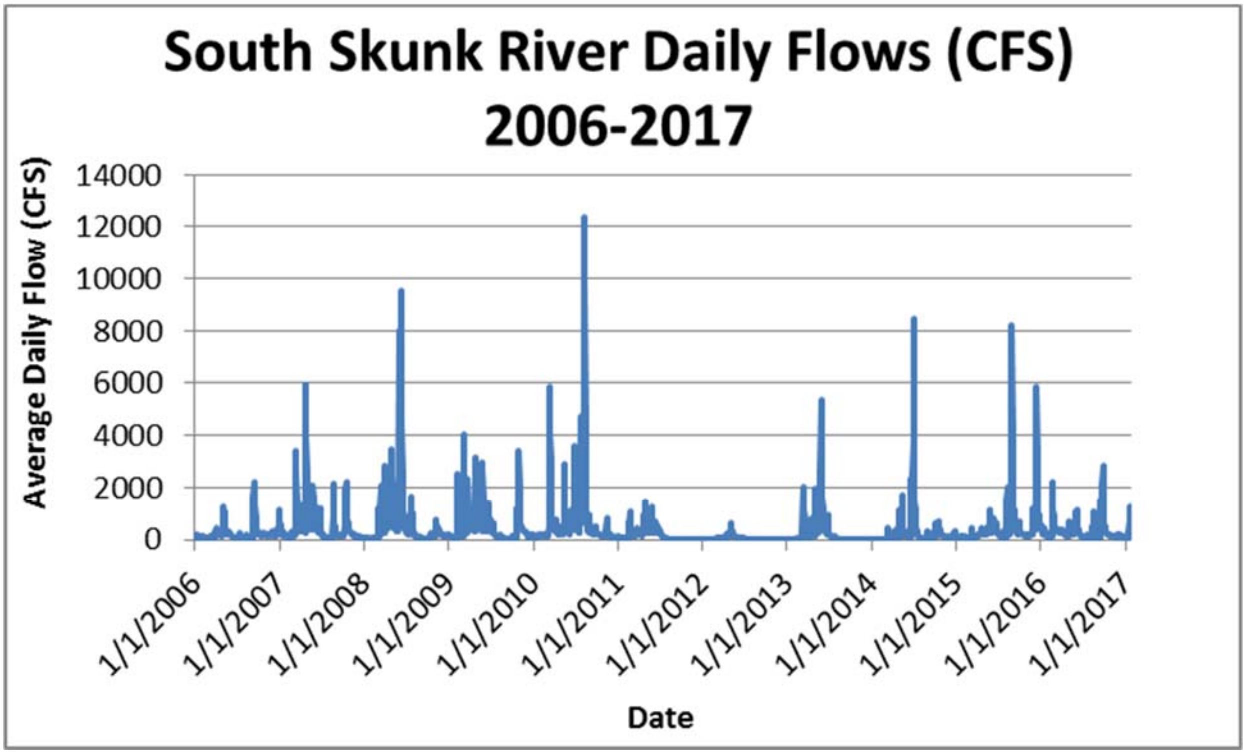


Figure 1-10. 2006-2017 Daily Flows in cfs for the South Skunk River (USGS 05470000) at Ames, IA.

Historical Peak Events

From a flooding perspective, instantaneous peak flows are of particular interest. South Skunk River peak flows can be substantially greater than daily average flows indicating rapid runoff responses. For example, the peak flow of 11,000 cfs was noted on May 30, 2008 versus the daily average of ~9,500 cfs. In a similar fashion, the peak flow of 14,800 cfs was noted on August 11, 2010 versus the daily average of 12,400 cfs. Generally, instantaneous peak flows of the most recent 14 years were attributable to snow melt (2009, 2015) or due to back-to-back storms of the preceding ~14 days with rainfall totals ranging from about 3 inches to 6.5 inches (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 Keigley Branch Watershed.

The top 100 South Skunk River historic crests for USGS 05470000 at Ames, IA are shown in comparison with the river's flood stage (12.5 feet) in Figure 1-11. It is important to note that 12 of the 19 (63%) historic crests with a measured stage above flood stage (12.5 feet) have occurred since 2008.

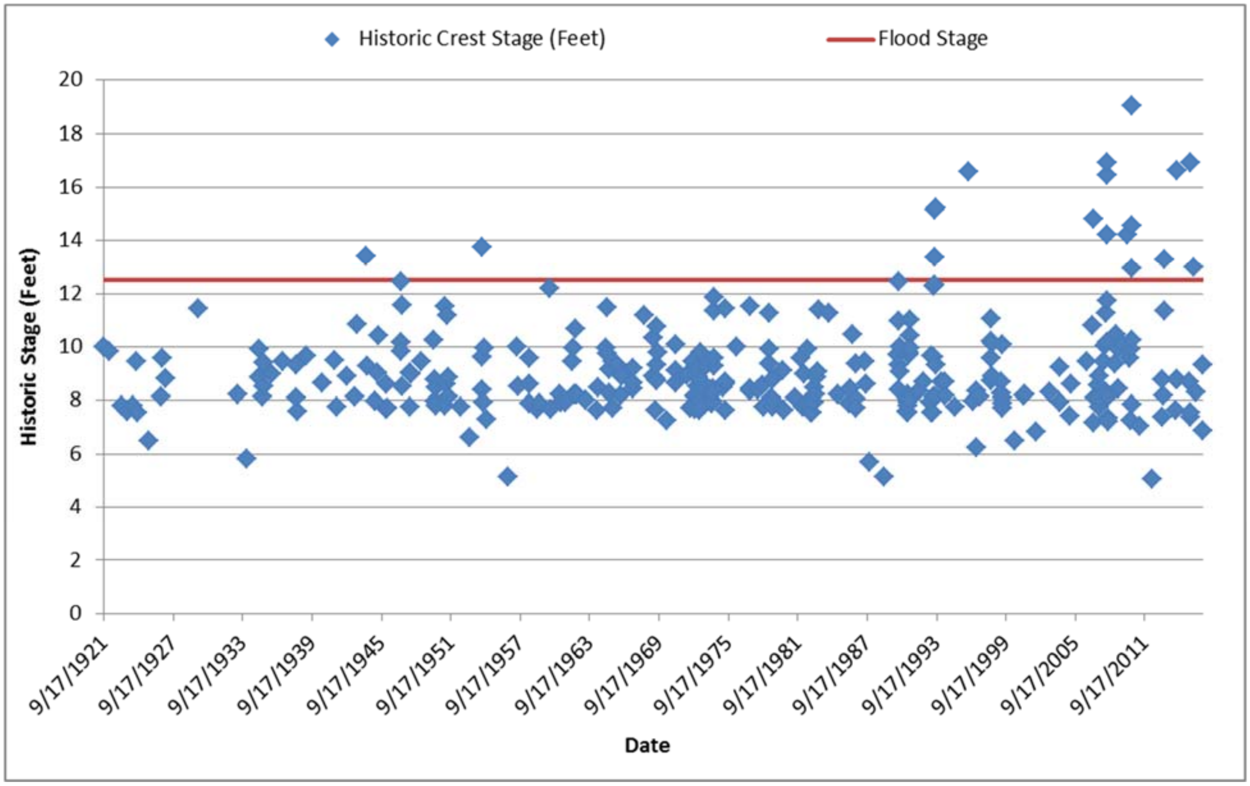


Figure 1-11. Top 100 historic crests (stage) for the South Skunk River USGS Station 0504070000

South Skunk River peak flows were further summarized from the USGS flow gauging station data (Station 054070000) in Figure 1-12 where dramatically increased peak events have occurred since the 1990's and 2000's. Peak events from the 1920's through the 1980's were generally less than ~7,000 cfs. However, from 1990 to 2016, there were ten years with peak flows 5,000 - 10,000 cfs, five years with peak flows 10,000 to 15,000 cfs and two years with peak flows greater than 14,000 cfs (e.g. 1996 and 2010). For perspective, flows greater than 5,000 cfs are ~15 times typical summer flows, flows greater 10,000 cfs are ~30 times typical summer flows and flows greater than 14,000 cfs are approaching ~40 times typical summer flows. **The range of peak to typical flows to intense**

rainfall events is indicative of the Keigley Branch watershed as having substantially 'flashy' or rapid runoff hydrology.

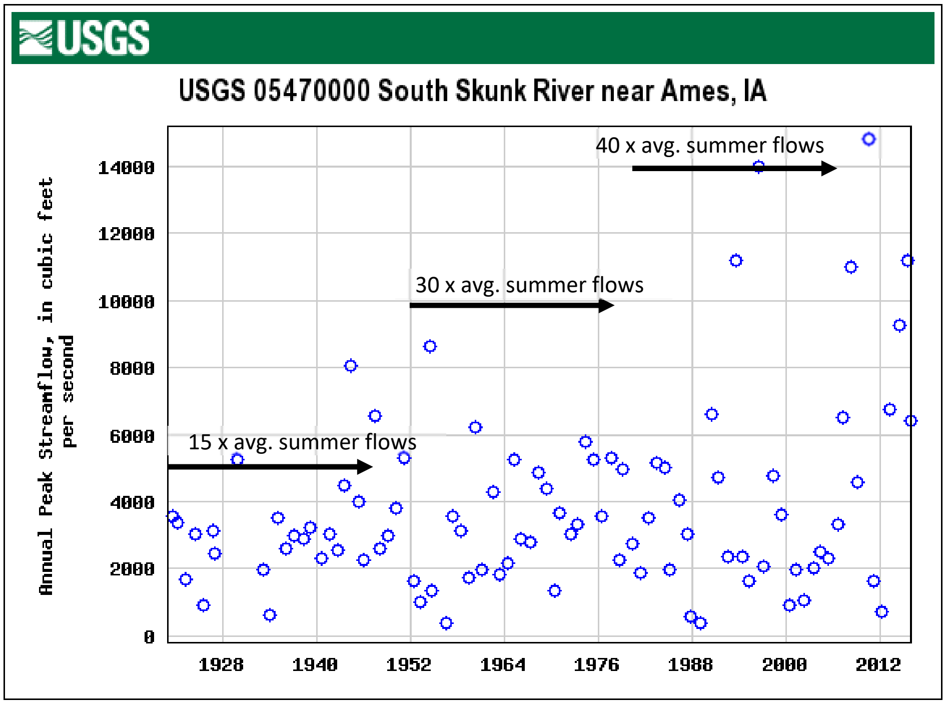


Figure 1-12. South Skunk River annual peak flows in cfs for USGS (Station 05470000)

Additional Stream Gage Information

Water levels of the South Skunk River are monitored at 6 other gauge stations (not including USGS station 05470000) on an hourly basis within the Keigley Branch watershed (Table 1-11). 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 1-11. Keigley Branch Watershed gage locations

Stream Name	Gage Location
Bear Creek	Near intersection of 150th Street and 580th Avenue southeast of Roland
Long Dick Creek	115th Street north of Roland
Keigley Branch	Near intersection of 140th Street and Highway 69 south of Story city
South Skunk River	South of 390th Street. S of 390th St., E of County R61 near Randall
South Skunk River	North of 130th Street
South Skunk River	E. 13th St. Ames, Iowa

1.7. Stream Geomorphic Assessment

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.

Within the Keigley Branch watershed, available stream stability data is limited to two streams including 1) the portion of the South Skunk River City of Ames reach that is between Riverside Road to the north and Highway 30 to the south and 2) the Ada Hayden Tributary from the intersection of W190th Street and Grant Avenue to the mouth which discharges into the west side of a lake complex located just outside (northwest) of the city of Ames.

1.7.1. Past Studies

The Wagner (2012) study was the only quantitative analysis conducted for stream reaches in the Keigley Branch watershed. The study yielded an estimate of sediment loading (from streambanks only) and made a critical temporal comparison between 2006 & 2011 observations. This study and analysis of available GIS data was used to describe the conditions of existing stream resources within the Keigley Branch watershed.

- Wagner, M.M. (2012). Ames Stream Assessment 2011. Ames, Iowa. Final Report, February 6, 2012.

1.7.2. Stream Conditions in Keigley Branch 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 Keigley Branch 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 Wagner (2012) study, a general snapshot of stream channel conditions and streambank erosion potential can be depicted based on the observed stability and health of the stream systems. Stream stability for all evaluated stream segments in the Keigley Branch watershed were re-illustrated for the 52 sites surveyed by Wagner (2012) in Figure 1-13. Within the Keigley Branch watershed, Wagner collected BEHI data on a 4.5 mile stretch of the mainstem South Skunk River located within the City of Ames as well as 5.2 miles of first order tributary streams located just northwest of the City of Ames. Streambank erosion potential for each of these "Ames stream" reaches was estimated with the Bank Erosion Hazard Index (BEHI) as part of the Wagner (2012) study.

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 (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.

In contrast, the Ada Hayden Tributary was identified as one of the least stable stream reaches of the 41 miles of perennial streams analyzed. Of particular note, portions of the Ada Hayden tributary were observed to be downcutting and/or widening, particularly in the upper headwater portion of this tributary. Downcutting involves stream reaches that are actively degrading which involves the lowering of the stream bed via scour. Overtime, this can result in a streambank that becomes isolated from the floodplain as well as large, unstable stream banks. Widening streams include stream reaches that are continuously widening and eroding the stream bank until a new active floodplain has established that is above the channel elevation.

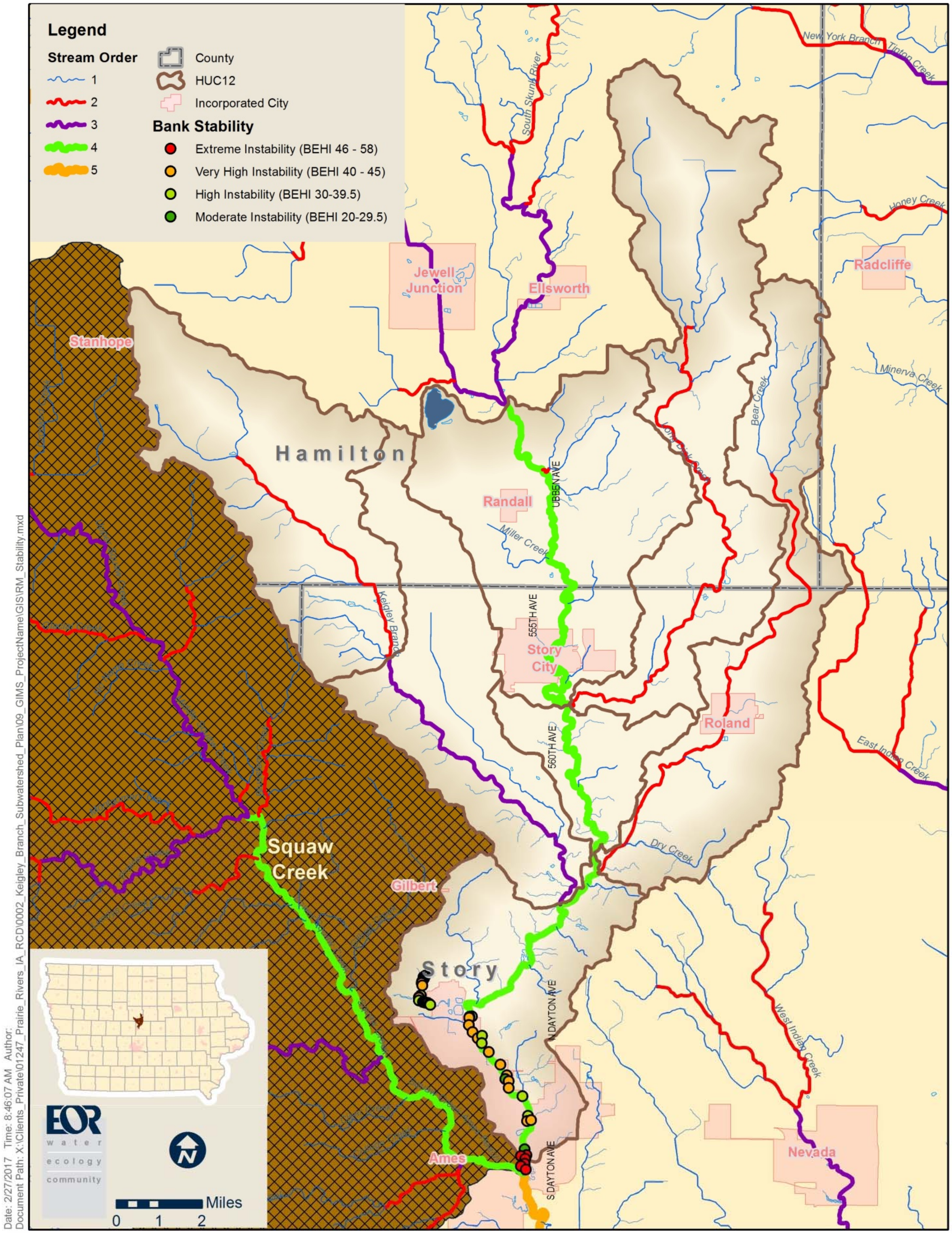


Figure 1-13. Streambank stability of Ames streams derived from Wagner (2012) Bank Erosion Hazard Index (BEHI)

The presence of degrading streams in the tributary branches of the watershed means that aggradation of sediment will likely occur in downstream reaches. 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. 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 1-12. 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
South Skunk River	-------	-------	76	12	12
Ada Hayden Tributary	71	9	20	-------	-------

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 8,060 tons of gross streambank erosion for the two stream reaches examined in the Keigley Branch watershed alone (Table 1-13). The South Skunk Rover reach had the highest sediment loading rate on a per length basis (0.22 tons / linear foot / year) even though the assessed portion of the South Skunk River is considered to be more stable than Ada Hayden Creek. High sediment loading rates on the South Skunk River are a result of the fact that more than three-fourths of the total assessed stream length was classified as undergoing moderate lateral migration. Lateral migration in this stretch of the South Skunk River occurs as a result of aggregated sediment derived from upstream degrading tributaries. The stream continuously works to redistribute these aggregated sediments as the river winds its way laterally across a continuously changing stream channel, thus discharging large sediment loads. Over time the channel will cut through and/or transport these deposits depending on future stream flow, this explains the high sediment load levels.

Table 1-13. Estimates of gross bank erosion based on the Bank Erosion Hazard Index (BEHI) and near bank shear stress (NBS) for streams within the Keigley Branch watershed (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)
South Skunk River	7060	5.95	0.22
Ada Hayden Tributary	1000	1.43	0.13
TOTALS	8060	7.38	0.21

1.7.3. Eroded Streambanks

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.

LiDAR data was used to evaluate stream bank stability within the Keigley Branch – South Skunk River Watershed by combining Stream Power Index (SPI) with steeply sloped (>18%) near channel areas that were larger than 1 acre in size. The stream power index (SPI) calculation measures the erosive power of overland flow as a function of local slope and upstream drainage area which is derived from the LIDAR data. High SPI values located in riparian areas with steep slopes are typically correlated with near-channel, active erosion problems (e.g., gullies, ravines) on the landscape. Results from this analysis identified 268 locations along almost every stream in the Keigley Branch – South Skunk River Watershed.

With the goal of identifying the highest priority sites in the Keigley Branch – South Skunk River Watershed, this analysis was refined to identify those locations that were greater than 35% slope, within 100' of a road crossing or 500' of a manmade structure, and intersected areas with high stream banks. High stream banks were identified using the University of Nevada's Height above River (HAR) tool which uses LiDAR data to calculate the difference in height between the stream channel and the adjacent stream bank. The intersection of these layers identified 23 high priority sites (Figure 1-14). The large number of sites is a reflection of the "flashy" nature of the Keigley Branch – South Skunk River Watershed's streams which tend to respond very quickly and dramatically to storm events especially during the periods of the year when row crops are not fully established. In flashy streams, periodic increases in flow depth and velocity result in an increase in the amount of force produced by flowing water against the streambank which can remove soil particles from the banks, and in some cases lead to bank failure, slumping, and overall bank instability. The NRCS GIS Engineering Toolbox for Arc GIS was used to identify critical slopes through calculation of stream power index (SPI). The stream power index (SPI) calculation measures the erosive power of overland flow as a function of local slope and upstream drainage area. High SPI values located in areas with slopes >35% are typically correlated with near-channel, active erosion problems (e.g., gullies, ravines) on the landscape. A Height Above River (HAR) layer was also created using a HAR *GIS Tool* developed by researchers at the University of Nevada. This tool uses LiDAR data to measure the difference in elevation between the stream channel and near stream areas. The published Restoration Layer identified near stream areas (within 175' of stream centerline) with critical bank heights (> 30 feet) that intercepted areas with greater than 35% slope, and were also within 100 feet of any manmade structure or 500 feet of a road.

In addition to identification of priority streambank erosion sites using the analysis described above, the ACPF tool evaluates the stream riparian area to determine likely erosion areas. These areas are displayed in the Story County ACPF Web Map as 'critical zone' riparian areas.

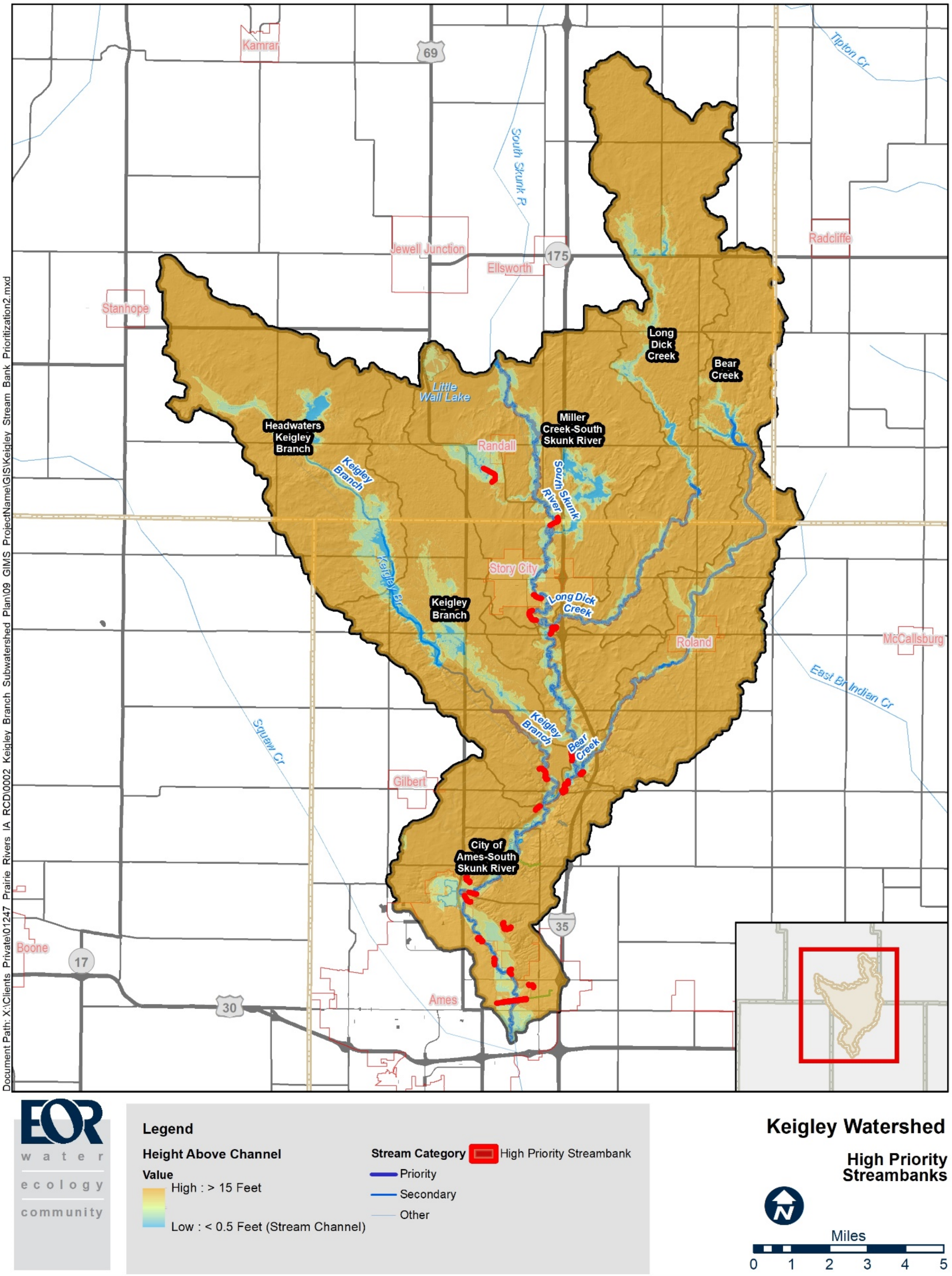


Figure 1-14. High Priority Streambanks

1.8. Lakes and Wetlands

There are 4 lakes larger than five acres that are either managed by the City of Ames or Iowa DNR as public fisheries (Figure 1-15). Lakes in the watershed provide recreational opportunities for County residents and visitors. Common recreational activities observed in Story County's lakes including boating (electric trolling motors only), fishing, swimming, canoeing and kayaking. They also provide fish and wildlife habitat that is scarce within the watershed.

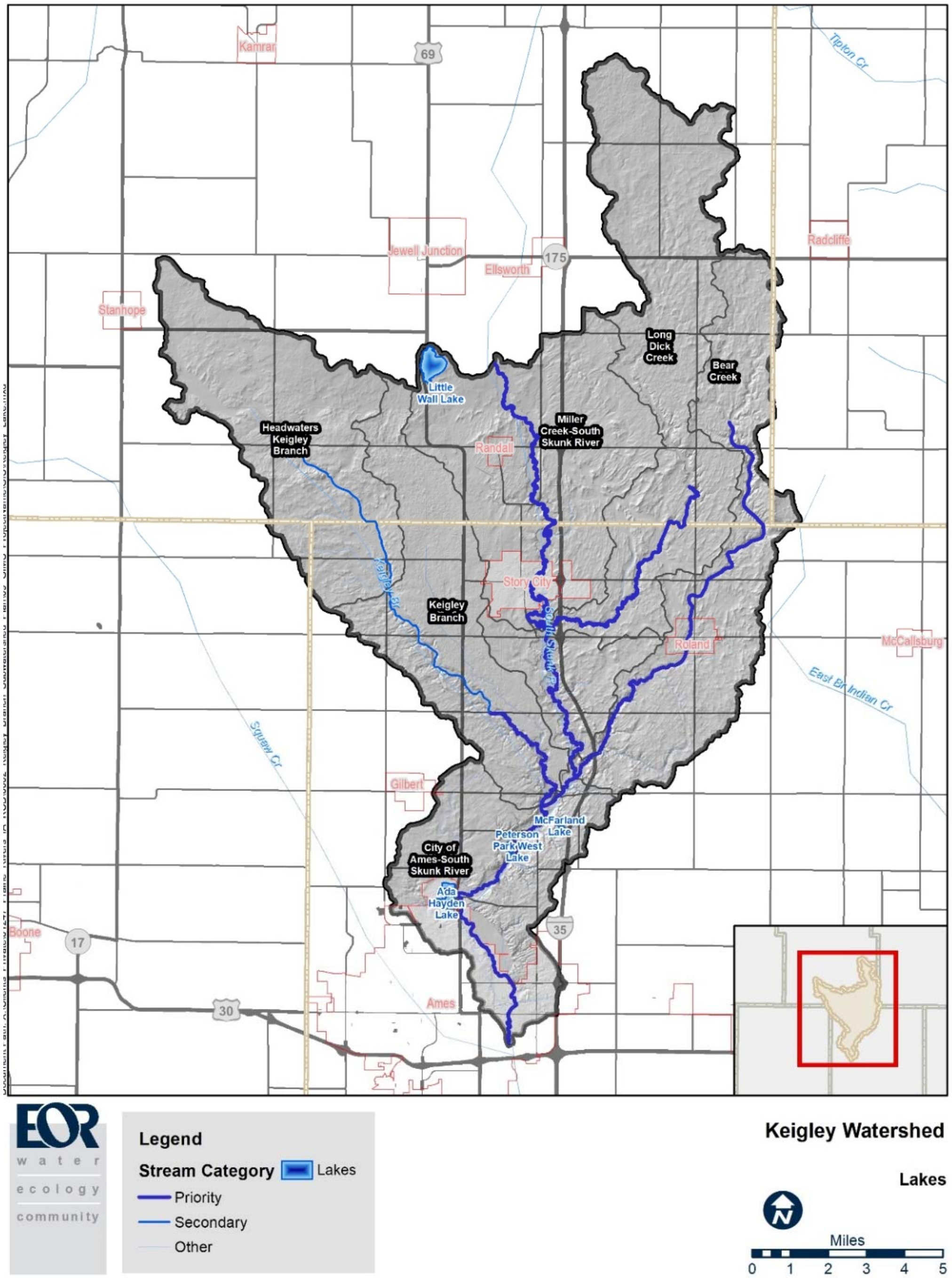


Figure 1-15. Keigley Branch – South Skunk River Watershed Lakes.

1.8.1. Little Wall Lake

Figure 1-16. Little Wall Lake Bathymetric Map

Little Wall Lake is a 249 acre lake located 1.5 miles south of Jewell, Iowa. This lake represents one of the few natural lakes in Iowa formed as a result of glacial movement. Little Wall Lake has an extremely small watershed to lake ratio (less than 1:1), as a result, lake water levels are maintained through pumping and periodic dredging.

Grass carp stocked in the early 1990s have largely eliminated the majority of the aquatic vegetation from Little Wall Lake. A healthy aquatic plant community can help to maintain a clear-water, aquatic plant-dominated state which is the ecologically preferred state. The absence of aquatic vegetation in Little Wall Lake has ultimately contributed to excessive algae blooms which limit the recreational value of the waterbody.

Little Wall Lake working group is working with the DNR to discuss concerns with regards to lake levels and future lake management. The group is looking into future management of the past used lake dredging project containment site, low dose rotenone treatment to remove grass carp and yellow bass, alternate water sources for lake level enhancement during dry years, and improved public access facilities and opportunities.

Despite the water quality challenges, Little Wall Lake Park remains a popular destination and was recently identified as the 4th best park in Iowa according to TripBlazer.com. From 2002-2005, Little Wall Lake averaged more than 56,000 visitors annually, resulting in a net economic impact of $4.08 million to the local community which in turn supported 81 local jobs. Popular recreation activities at Little Wall Lake include camping, boating, fishing, canoeing/kayaking, walking, and swimming. The lake is stocked annually with a variety of gamefish species including largemouth bass, northern pike, channel catfish, and walleye.

1.8.2. Ada Hayden Heritage Park Lake

Ada Hayden Heritage Park Lake is the largest lake within the Keigley Branch Watershed at 137 acres. This popular recreational lake is divided into two separate lake basins (North and South) within Ada Hayden Heritage Park located in the City of Ames.

The park provides amenities for boating (electric motor only), biking, nature viewing, and fishing. Crappie, bluegill, Wiper (Hybrid White Bass/Striper), and largemouth bass can all be caught within the lake. Rainbow trout, brook trout, and channel catfish are also stocked annually and provide additional angling opportunities. In the early 2000's the lakes were converted into an emergency water source for the City of Ames, Iowa.

The City of Ames is working with the State Hygienic Laboratory to conduct water quality monitoring. Historical water quality data suggests good water quality near the surface but poor water quality near the bottom of the lake. Monitoring results from the major tributaries to Ada Hayden Lake have identified high nutrient loads from the watershed. Furthermore, constructed wetlands adjacent to the lake have been identified as potential sources of phosphorus and sediment, the likely result of sediment resuspension caused by carp feeding activities.

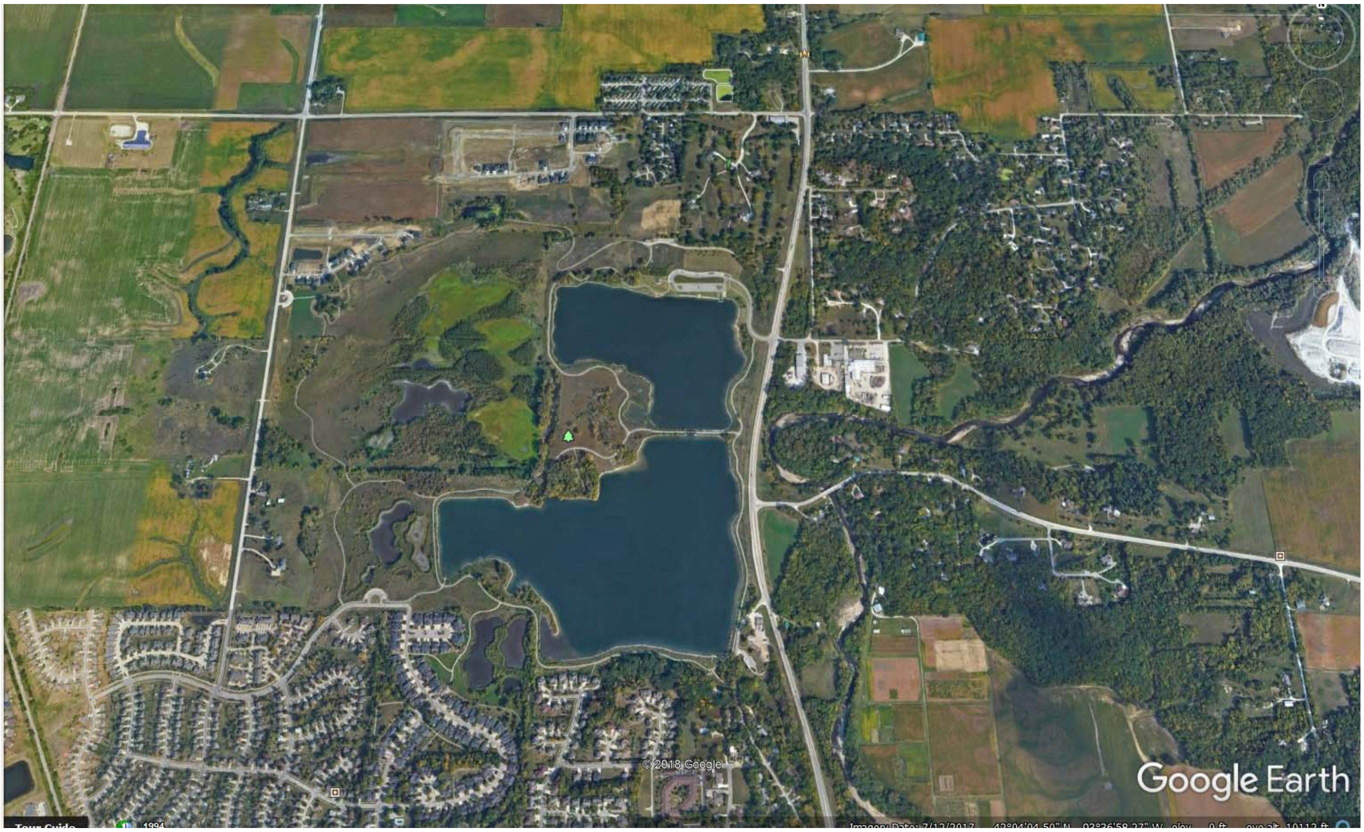


Figure 1-17. Ada Hayden Lake

1.8.1. Peterson Park West Lakes

Peterson Park West contains four gravel pit lakes with a combined area of 31 acres located along the Skunk River Greenbelt. Collectively these lakes are referred to as Peterson Park Lake West Lakes or Lake.

The park provides amenities for swimming, canoeing, kayaking, fishing, and public hunting. Fisheries surveys conducted by the DNR found abundant bluegill, crappie, largemouth bass and channel catfish within the lake. Peterson Park West Lake also contains a swimming beach.

Figure 1-18. Peterson Park West Lakes

1.8.1. McFarland Lake

McFarland Lake is a 6.5 acre lake stocked with bluegill, bass, and catfish located in the 200 acre McFarland Park. McFarland Park offers over 5.5 miles of natural surface trails that weave through tall grass prairie and woodlands as well as around the McFarland Lake and along the South Skunk River.

The park provides amenities for canoeing, kayaking, fishing, and picnicking. The park also features the Touch-a-Life Trail, a hard surfaced trail which winds through a variety of native plant communities including prairies, savanna, and the lake.

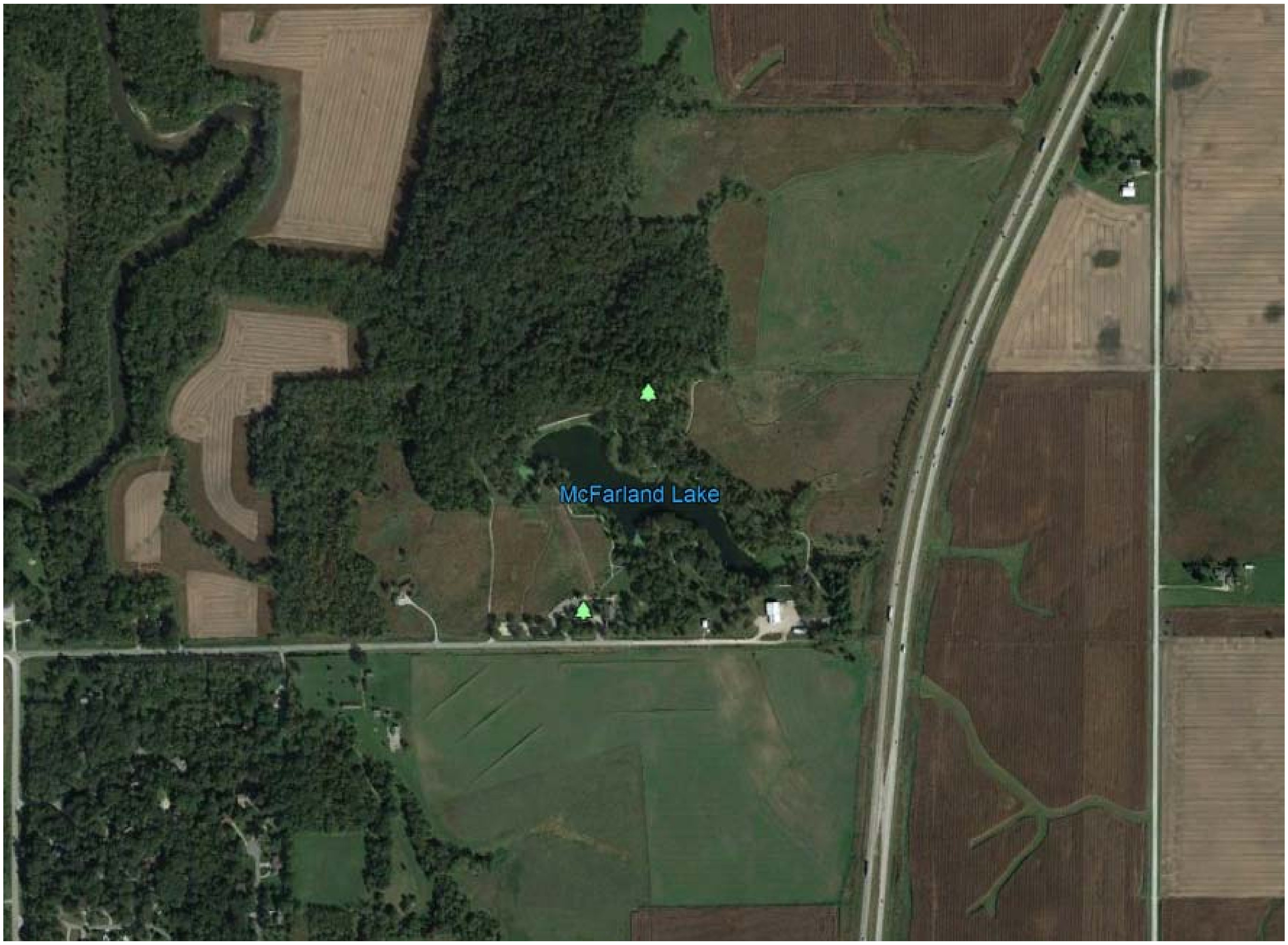


Figure 1-19. McFarland Lake

2. Watershed Characterization

2.1. Watershed Network

The Keigley Branch - South Skunk River 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 Keigley Branch South Skunk River 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 Keigley Branch 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 Keigley Branch – South Skunk River 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 Skunk River are impaired due to elevated pollutant and bacteria levels.

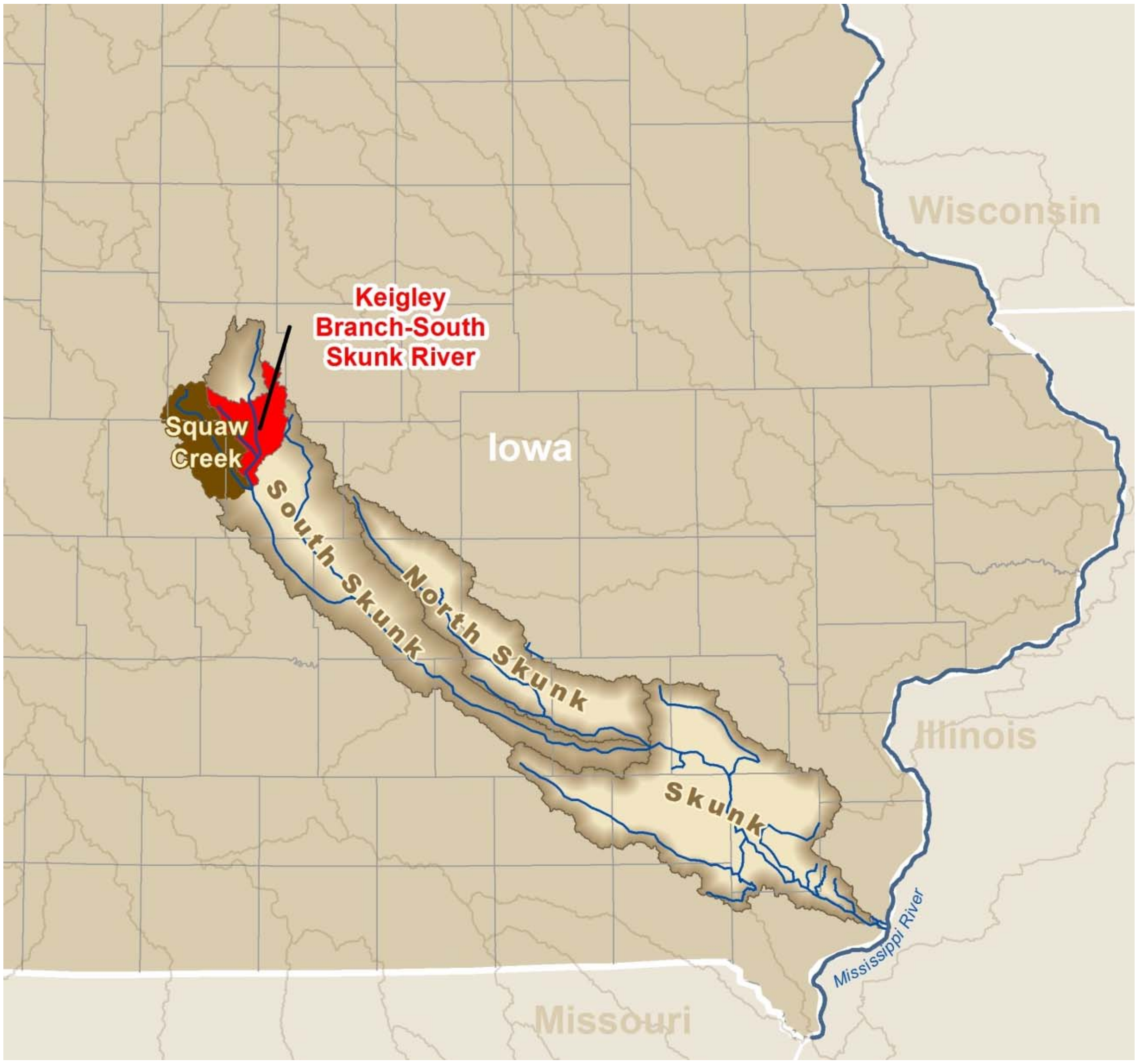


Figure 2-1. Keigley Branch of the South Skunk River Watershed Hydrologic Setting

2.1.1. Subwatersheds

The Keigley Branch-South Skunk River HUC-10 watershed is made up of six HUC-12 subwatersheds. HUC 12 Subwatersheds are the smallest unit within the USGS system. At the subwatershed scale, landowners are likely to have personal relationships and a small, dedicated group can have a meaningful role in improving the health of a subwatershed. Table 2-1summarizes the HUC-12 subwatersheds grouped by the stream within each subwatershed. The major resources of the watershed are the South Skunk River and its primary tributaries; Keigley Branch, Long Dick Creek and Bear Creek. Figure 2-2 illustrates the subwatersheds within the Keigley Branch –South Skunk River HUC-10. Throughout this report the term "watershed" will be used to refer to the Keigley Branch-South Skunk River HUC-10 watershed and the term "subwatershed" will be used to refer to any of the six HUC-12 Subwatersheds.

Table 2-1. HUC-12 Subwatersheds of the Keigley Branch-South Skunk River HUC-10 Watershed

HUC 12 Name	HUC-12	Area (acres)	% of Keigley Watershed
Long Dick Creek	070801050401	23,565	20%
Miller Creek-South Skunk River	070801050402	21,038	18%
Bear Creek	070801050403	18,496	16%
Headwaters Keigley Branch	070801050404	18,107	16%
Keigley Branch	070801050405	15,254	13%
City of Ames-South Skunk River	070801050406	19,675	17%

Bear Creek Subwatershed

The Bear Creek subwatershed is located in the eastern most portion of the watershed and drains approximately 18,500 acres of portions of Hamilton County and Story County, and a small portion of Hardin County. The City of Roland is located near the center of the subwatershed. Bear Creek starts out as two separate first order streams that join together to form a second order stream just south of 370th street. Hydrologically, most of the wetlands appear to be sufficiently drained with the exception of a few small prairie pothole wetlands. Dry Creek, a first order stream, represents the only named tributary to Bear Creek in this subwatershed.

Headwaters Keigley Branch Subwatershed

The Headwaters Keigley Branch subwatershed is located in the northwestern corner of the watershed. The subwatershed is 18,107 acres and includes portions of Hamilton, Boone, and Story Counties. The City of Stanhope is located just west of the subwatershed. The primary stream within this subwatershed is the upper reach of Keigley Branch. Other water resources in the subwatershed include several smaller first-order drainage ditches that drain a largely agricultural landscape. The Keigley Branch itself begins as two separate first-order drainage ditches that form a second order stream south of a deep marsh at 370th street. While portions of the subwatershed are clearly ditched and tile drained, some prairie-pothole wetlands remain.

Keigley Branch Subwatershed

This subwatershed is located immediately south and east of the Headwaters Keigley Branch subwatershed in the northwestern third of the watershed. The subwatershed is roughly 15,000 acres. Story City is located just east of the subwatershed. The northern half of the subwatershed is in Hamilton County while the southern half is in Story

County. Several first order tributaries join the Keigley Branch within this subwatershed, the Keigley Branch becomes a third order stream within this subwatershed.

Long Dick Creek Subwatershed

This subwatershed is in the north eastern part of the watershed. The northern two-thirds of the subwatershed are in Hamilton County while the southernmost-third is in Story County. The subwatershed is approximately 23,500 acres. Long Dick Creek starts out as two separate first order streams that join together to form a second order stream just north of 330th street east of Ellsworth. The Creek bypasses a fairly large pond located at the intersection of Young Avenue and 400th Street as it drains southwest towards it's confluence with the South Skunk River just south of Story City. Hydrologically, most of the wetlands appear to be sufficiently drained with the exception of a few small prairie pothole wetlands.

Ames- South Skunk River Sub watershed

This subwatershed is at the lower, southernmost end of the watershed. The subwatershed is situated between Story City to the north and Ames to the south and is completely within Story County. The subwatershed contains several unnamed first-order tributaries which drain towards the South Skunk River. The South Skunk River is a fourth-order stream in this subwatershed, transitioning to a fifth-order stream as it leaves the Keigley Branch HUC-10 watershed and connects with Squaw Creek. There are approximately 20,000 acres of land in the subwatershed. This subwatershed contains a much larger percentage of intact forested and wetland areas and in general is well buffered by forests. Several gravel pits either intersect the River itself or are located immediately adjacent to the River. This stretch of the South Skunk River is more sinuous in comparison with upstream stretches.

Miller Creek- South Skunk River Subwatershed

The Miller Creek South Skunk River subwatershed is located in the north-central portion of the watershed. The northern half of the subwatershed is in Hamilton County while the southern half is in Story County. The subwatershed is roughly 21,000 acres. The city of Randal is located in the center of the subwatershed and Story City is located in the bottom third of the subwatershed. Drainage within the subwatershed consists of the South Skunk River which runs north and south dividing the subwatershed into an eastern and western section. Miller Creek represents the only named tributary to the South Skunk River in this subwatershed. Several first order tributaries also flow into the South Skunk River which is a fourth-order stream in this subwatershed. Little Wall Lake (248 acres, maximum depth of 14 feet) is located in the northwestern most lobe of the Miller Creek subwatershed. Hydrologically, some prairie-pothole wetlands appear to be intact; however, it is clear that attempts have been made to drain these wetlands.

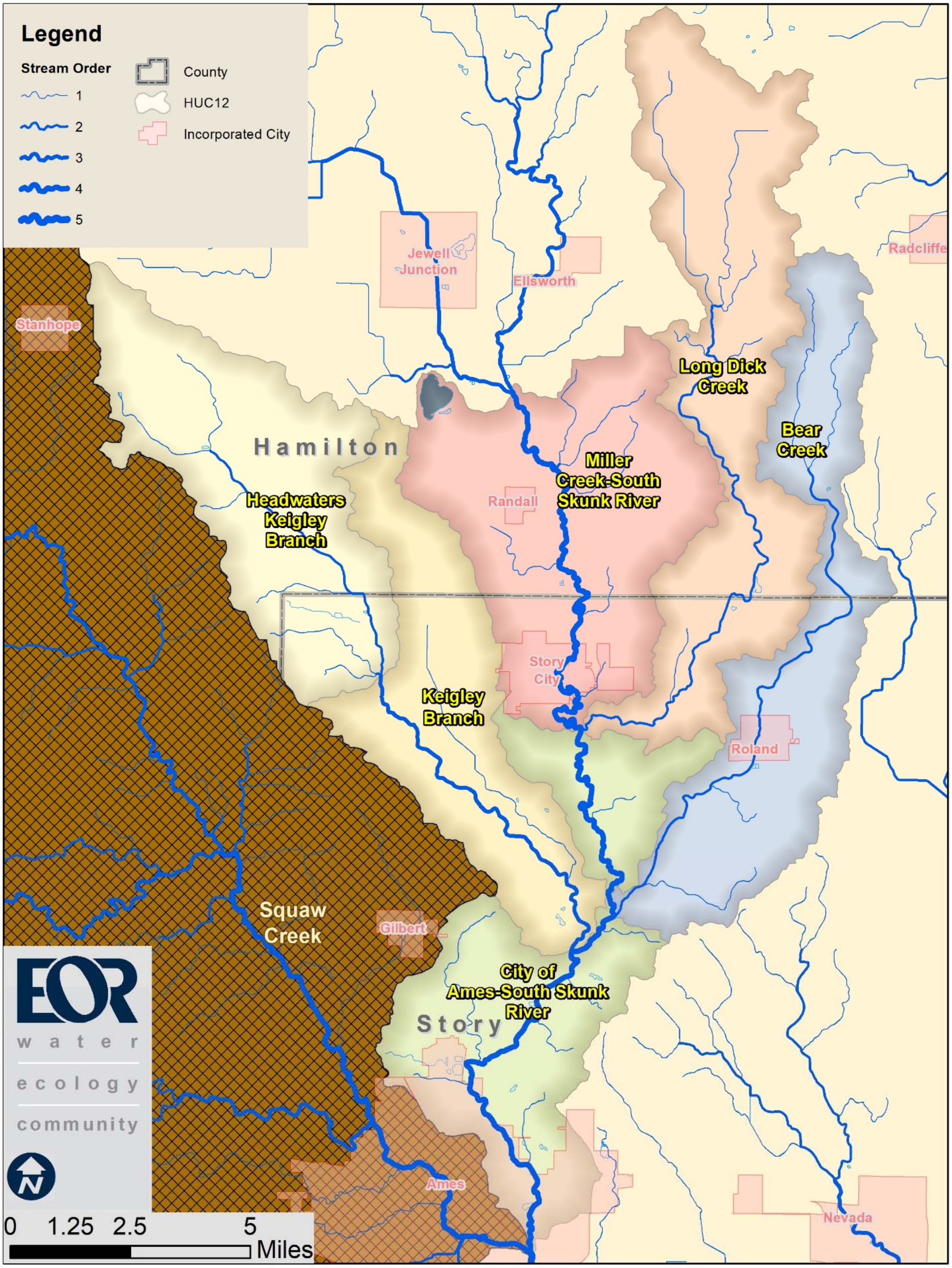


Figure 2-2. Keigley Branch South Skunk River HUC-12 Subwatersheds

2.2. Watershed Topography

Figure 2-3 depicts the topographical relief and varying slopes found within the watershed. It was derived using LIDAR data. The vast majority of the watershed has slopes of less than 2% with steeper sloped areas adjacent to the major streams, most notably the lower reaches of the South Skunk River.

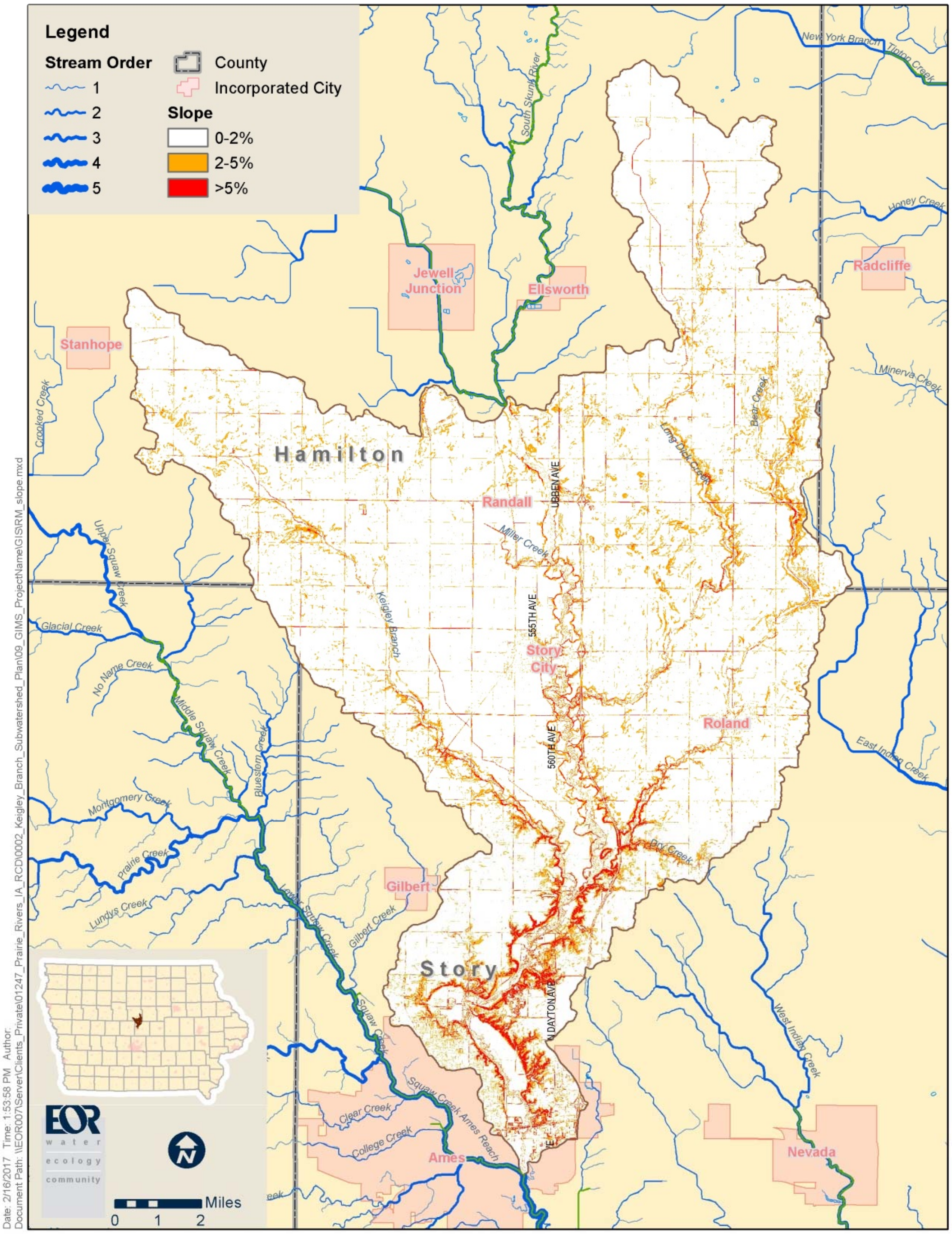


Figure 2-3. Slopes within the Keigley Branch South Skunk River Watershed

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 Keigley Branch South Skunk River watershed is heavily agricultural with some urban land associated with the built environments within Story City, Ames, Randal, and Roland. The land use summary of Table 2-2 along with the accompanying pie chart (Figure 2-4) integrates cropping rotational information from the past 6 years. This land use mapping was provided by data through the USDA-ACPF Land-Use Viewer. The crop rotations have been combined for display purposes.

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 within the Ames- South Skunk River subwatershed and the varied land cover within the developed portions of the watershed.

Table 2-2. Land Use of the Keigley Branch South Skunk River Watershed

Land Use	Acres	% of Watershed
Corn/Soybean	94,471	81%
Urban	7,764	7%
Grass/Pasture	5,223	4%
Other Cropland	4,111	4%
Forest	2,744	2%
Ponds/Wetlands	1,825	2%
Total		**116,138**

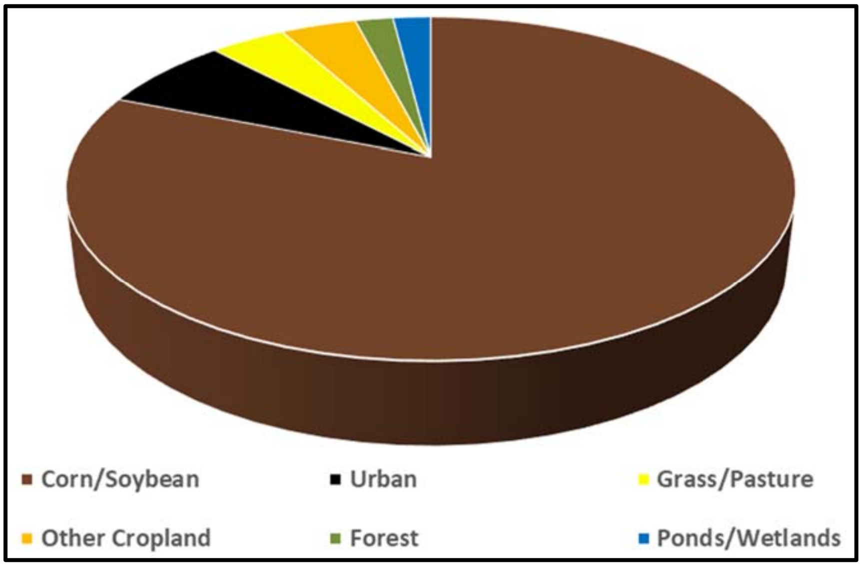


Figure 2-4 Land Use of the Keigley Branch South Skunk River Watershed

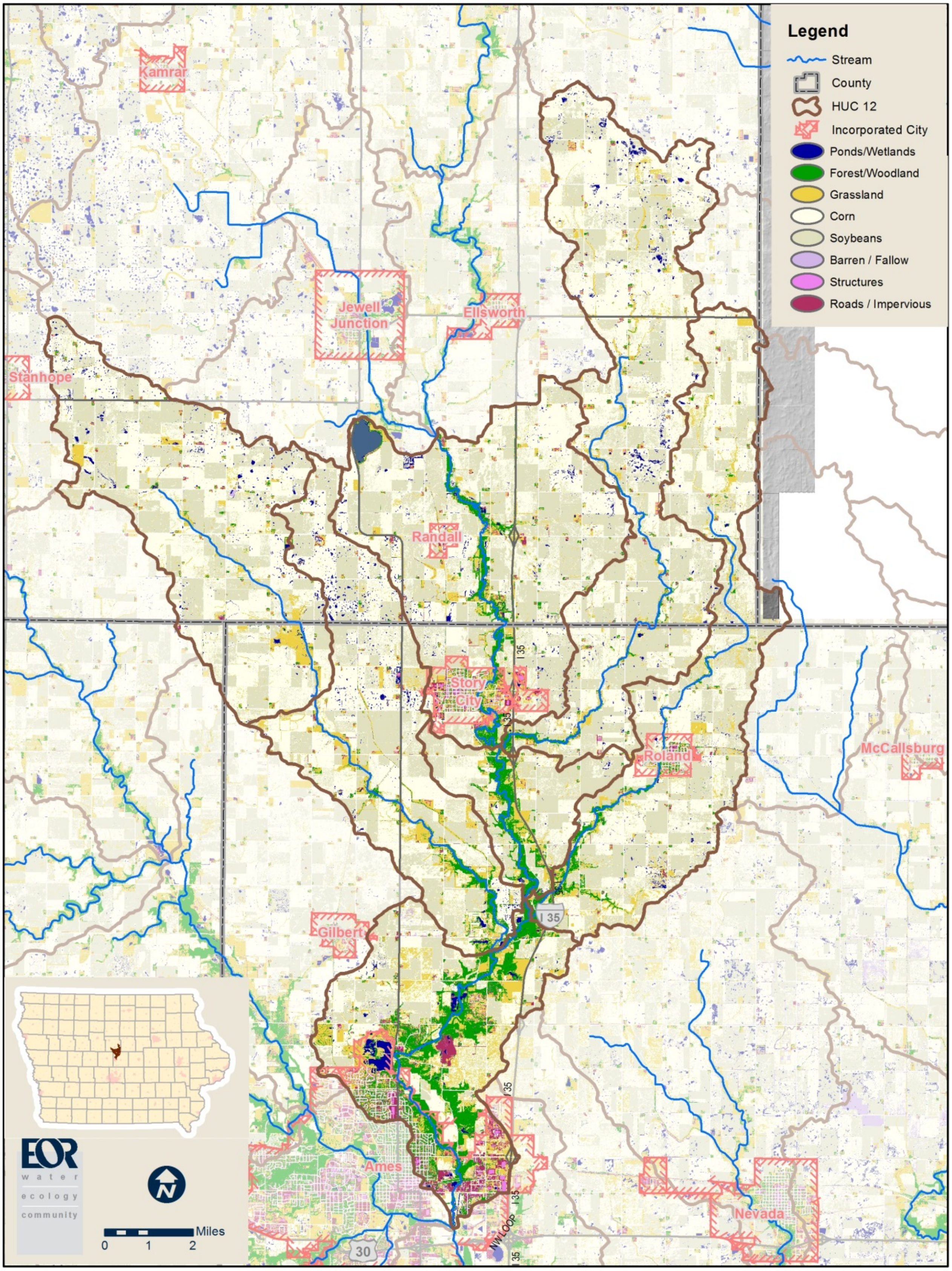


Figure 2-5. Keigley Branch South Skunk River Watershed - High Resolution Land Cover

2.4. Climate

Climate is the prevailing weather patterns for an area over a long period of time. This section describes patterns of temperature, rainfall, storm intensities, growing season length, evaporation, and severe weather for the Keigley Branch watershed. Climate conditions are one of the primary factors that influence the volume and quality of runoff from the landscape.

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 3-6). There are two weather stations within the City of Ames; station 5 SE and station 8 WSW. These weather stations were chosen because the City of Ames is located within the Keigley Branch watershed and because each station contains climatic data dating back to 1970’s or earlier with 100% data coverage (no missing values). 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.

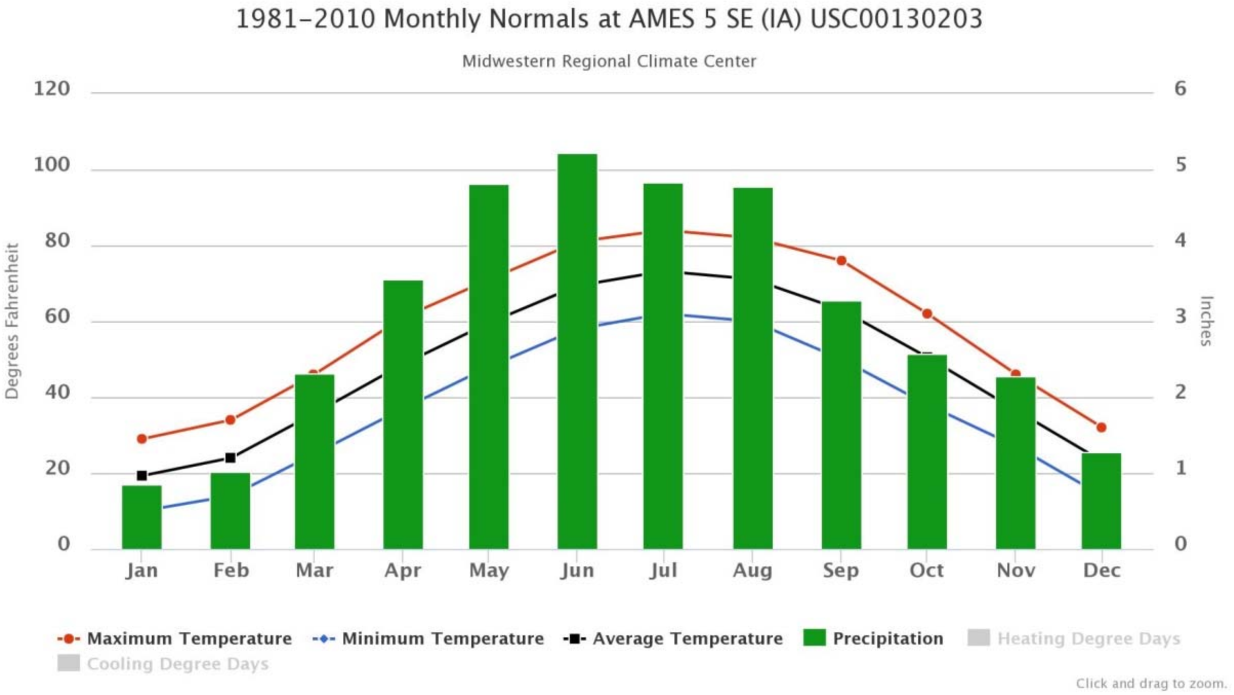


Figure 2-6. Average monthly climate data for Ames, IA. NOAA’s Midwestern Regional Climate Center

It has been noted that average regional temperatures have increased over time. To evaluate this pattern, average annual minimum and maximum temperatures for Ames, IA (Station 8 WSW) were plotted for the time period 1970 to 2013 in Figure 2-6 . 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).

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 2-7). 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 2-8). 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.

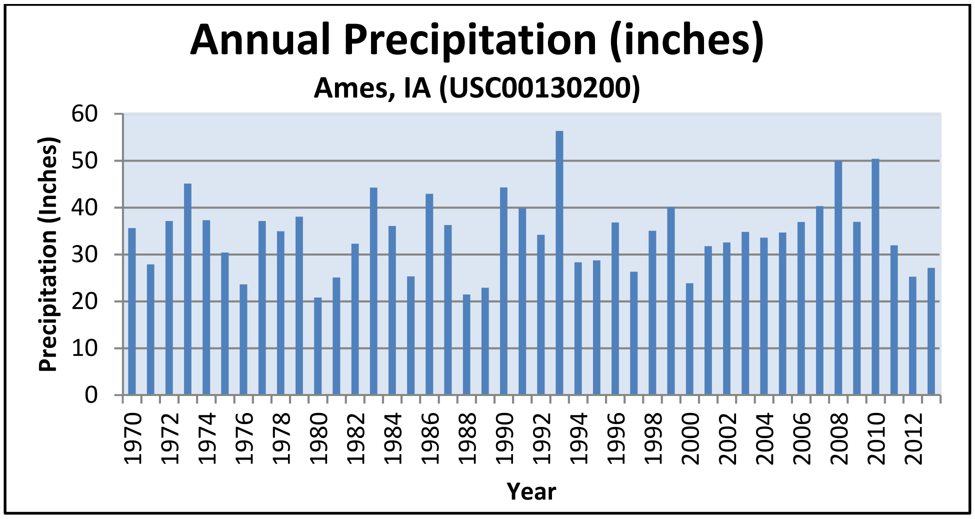


Figure 2-7. Annual Precipitation 1970-2013, Ames IA

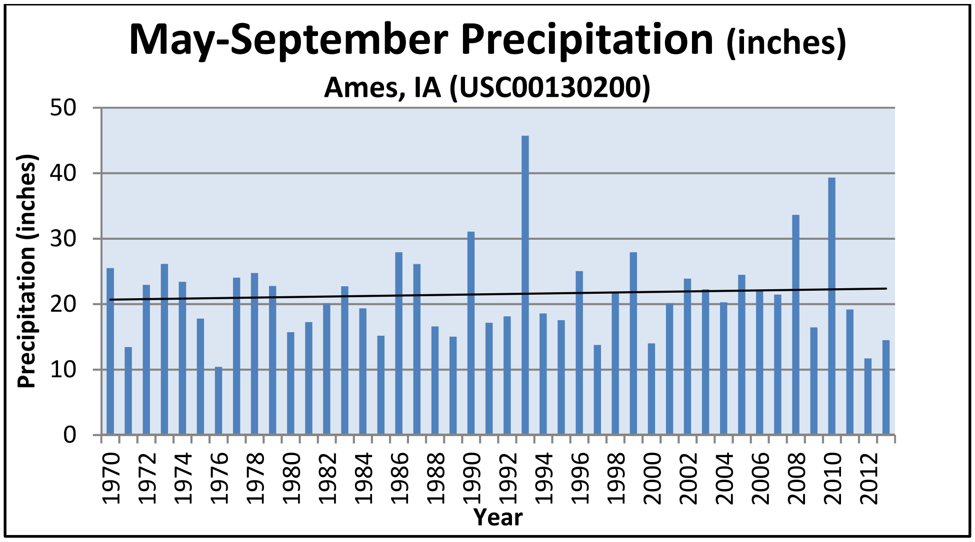


Figure 2-8. Growing Season (May-Sept) Precipitation 1970-2013, Ames IA

2.4.3. 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 Story County 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. Story County 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.
- 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.

Source: 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 Soil Survey Geographic (SSURGO) soils GIS layer available from the United States Department of Agriculture (USDA) were clipped to the watershed boundary. The USDA SSURGO GIS layer contains tabular data including hydrologic soil group classification; the tabular data was joined to the spatial data via a common attribute (Map Unit Symbol). Each Map Unit Symbol corresponds to a soil series description which describes the major characteristics of the soil profile for the given Map Unit.

The Natural Resource Conservation Service (NRCS) has classified soil series into Hydrologic Soils Groups (HGS) based on the soil's runoff potential. There are four major HSGs (A, B, C, and D) and 3 dual HSG groups (A/D, B/D, and C/D). HSG A soils have the lowest runoff potential whereas HSG D soils have the greatest. Dual soil series include those soils that have an upper soil profile which is conducive to allowing water to infiltrate similar to a type A, B, or C soil and an underlying confining layer within 60 inches of the soil surface that restricts the downward movement of water. The first letter applies to the drained condition, if undrained, the soil will act more like a D soil with a higher runoff potential and lower infiltration rates.

Group A soils consist of sand, loamy sand, or sandy loam soil types. These soils have very low runoff potential and high infiltration rates.
Group B soils consist of silty loams or loams. These soils have moderately high infiltration rates and low runoff potential.
Group C soils consist of sandy clay loam. The have low infiltration rates and consist of soils with a layer that impedes the downward movement of water and soils. These soils have moderately high runoff potential.
Group D soils consist of clay loam, silty clay loam, sandy clay, silty clay, or clay soils with the highest runoff potential. These soils have very low infiltration rates and a high water table.

The hydrologic soil groups in the watershed are illustrated in Figure 2-9. The primary soil hydrologic groups are B and B/D which are moderately well drained and moderately well drained with a high water tables, respectively. These soil series are associated with the upland areas within the Keigley Branch- South Skunk River Watershed. Mapped soil series in the uplands include primarily Clarion, Wadena, and Storden. They are loams, silty loams and clay loams.

Soil series located within the many concave depressions associated with former prairie-pothole wetlands include Brownton, Coland, Kossuth, Hanlon, and Ottosen. These soils series are especially prevalent in the northern part of the Keigley Branch Headwaters subwatershed where there are heavier, hydrologic group C/D soils associated with the large number of intact prairie-pothole wetlands.

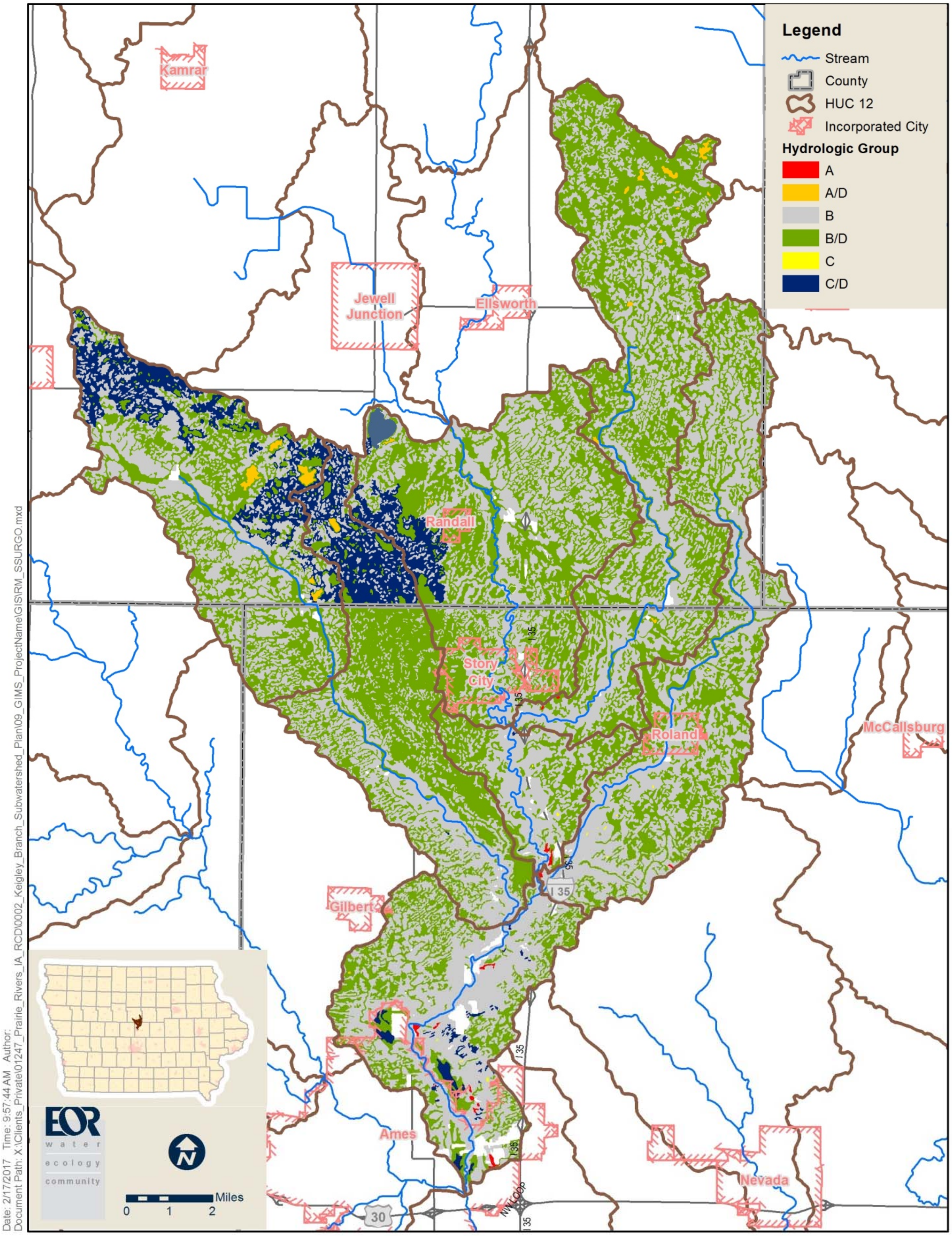


Figure 2-9. Soils by Hydrologic Soil Class

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.

The Cambrian-Ordovician aquifer covers nearly the entire state of Iowa. 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). The Cambrian-Ordovician aquifer is confined by a series of geologic units comprised of shale, dolomite and limestone that control downward groundwater transport to the aquifer. Generalized hydrogeological cross-sections for Iowa including the Skunk River are shown in (Figure 2-10). In the Keigley Branch watershed, the Cambrian-Ordovician aquifer is covered by the Mississippian Aquifer which overlays a series of confining layers consisting of limestone, dolomite, and shale. In the Keigley Branch watershed, these confining layers include the Cherokee group, Meramec series, and Osage Series (Figure 2-11).

Recharge to the Mississippian aquifer is from precipitation where the bedrock is at or near the surface, leakage to the aquifer from the South Skunk River and its tributaries, and groundwater inflow from areas outside of the Keigley Branch watershed. The Mississippian Aquifer is heavily used as a drinking and industrial water supply. 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.

Figure 2-12 shows the depth to groundwater throughout the watershed. This map was created by estimating the depth to water table by calculating the elevation differences between each point on the landscape and the stream-channel using the Agricultural Conservation Planning Framework (ACPF) toolbar for ArcGIS 10.3. This approach assumes the stream channel elevations provide an estimate of the local water table depth, the stream channel elevation is then extended laterally into the riparian zone to depict where exchange between stream water and shallow riparian groundwater is most likely to occur.

2.6.2. Source Water Protection Areas and Highly Vulnerable Groundwater Wells

The Iowa DNR has also developed a GIS layer depicting Groundwater capture zones – the land surface area that has been determined to provide water to a public water supply well based on available geologic and hydrogeologic information. Groundwater capture zones located in areas with high vulnerability for aquifer and well contamination should be prioritized as source water protection areas (Figure 2-13). The Iowa DNR operates a Source Water Protection Program which requires a Phase 1 Assessment which defines the source water area and susceptibility to contamination. Two highly susceptible wells have been identified (Ames and Story City) within the watershed (Figure 2-14). Observed nitrate concentrations in well-water quality samples have remained below the 10 mg/L drinking standard (Figure 2-15). Communities can coordinate with the IDNR to conduct a site investigation to determine if the contaminant is from a point or non-point source.

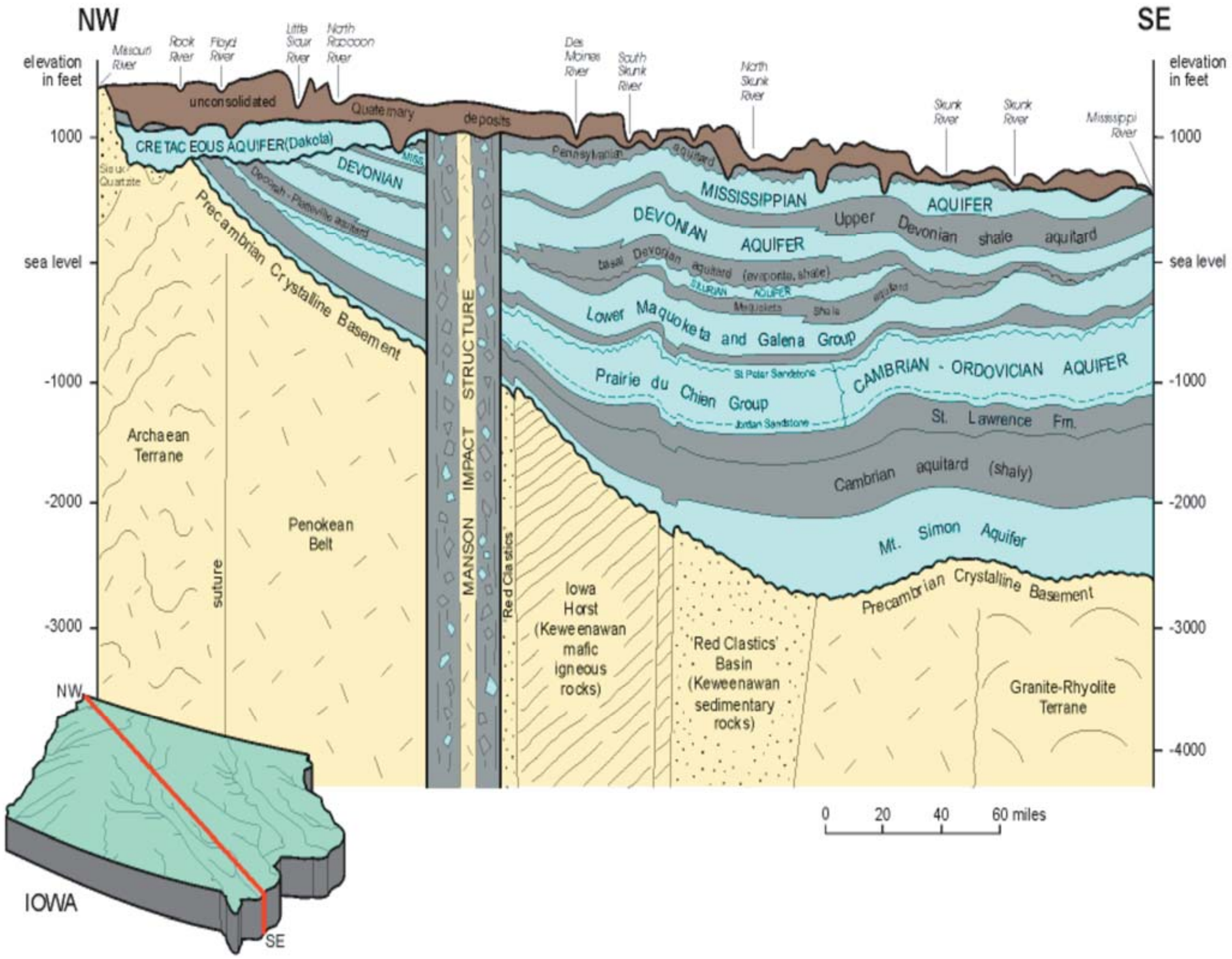


Figure 2-10. Generalized hydrogeological cross-section from northwestern to southeastern Iowa (modified from Prior and others, 2003).

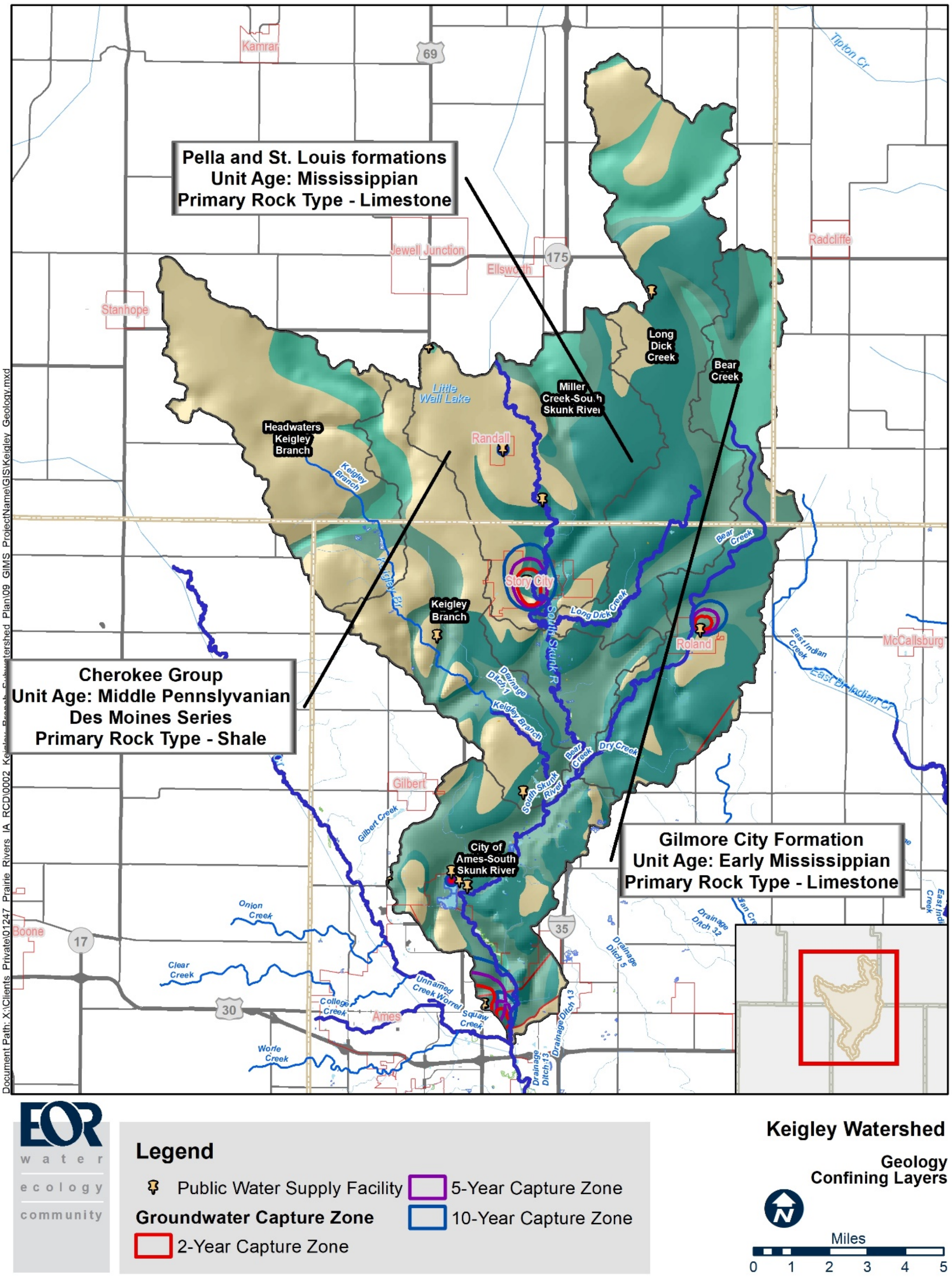


Figure 2-11. Public water supply facility location and groundwater capture zones in relation to bedrock confining layers within the Keigley Branch watershed.

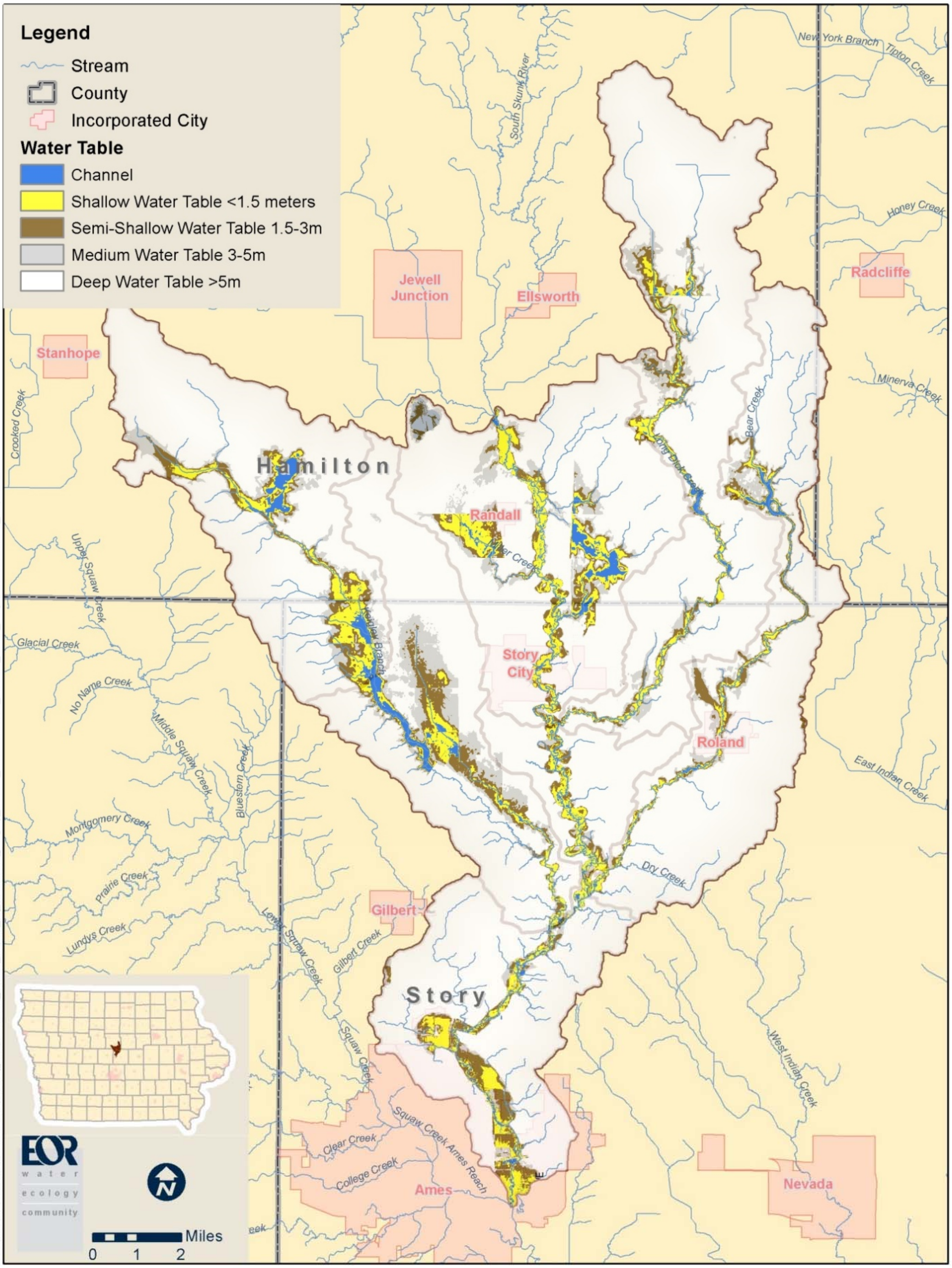


Figure 2-12. Depth to Groundwater

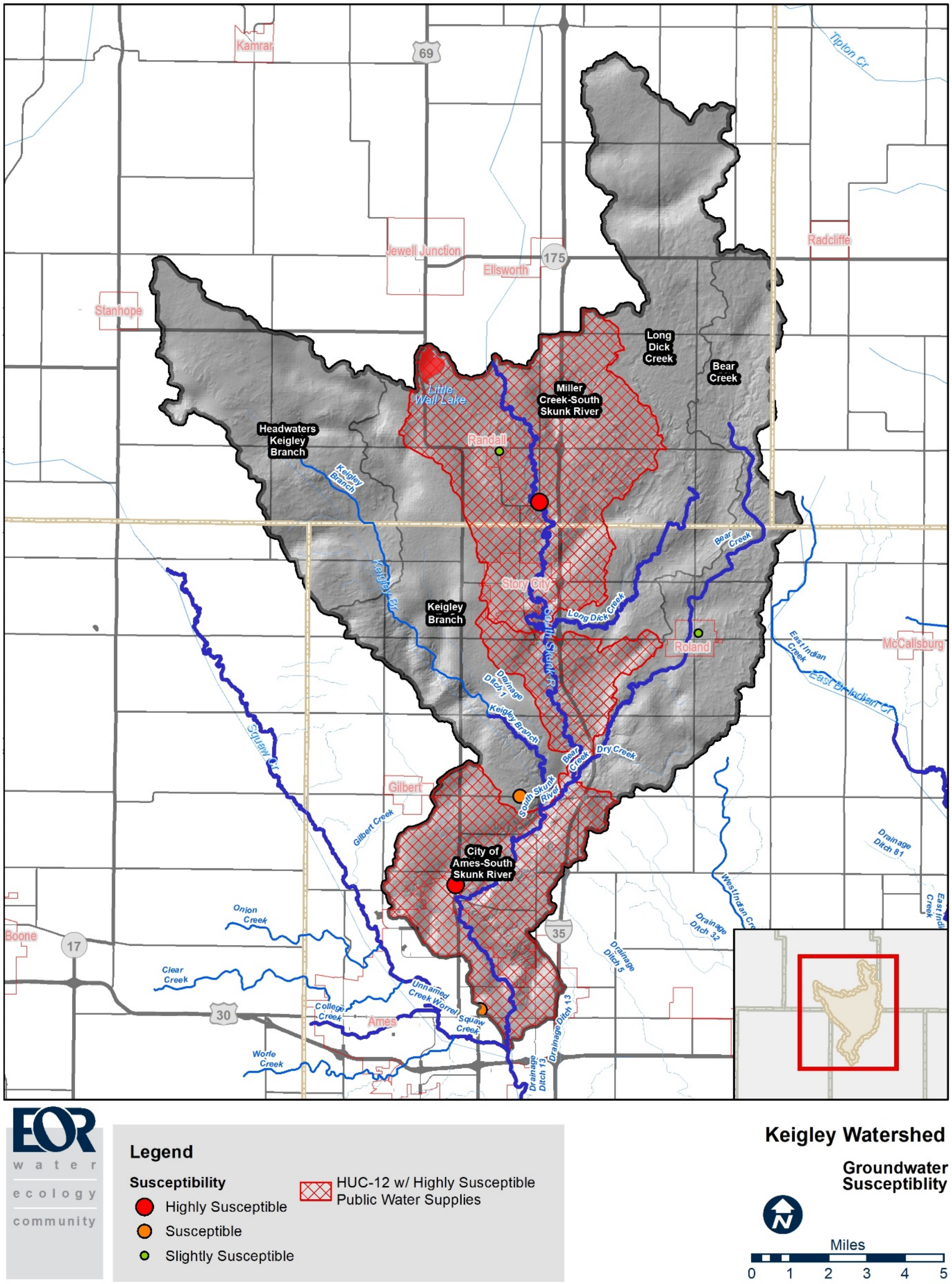


Figure 2-13. Susceptibility of Groundwater drinking sources to pollution according to the Iowa Source Water Mapper.

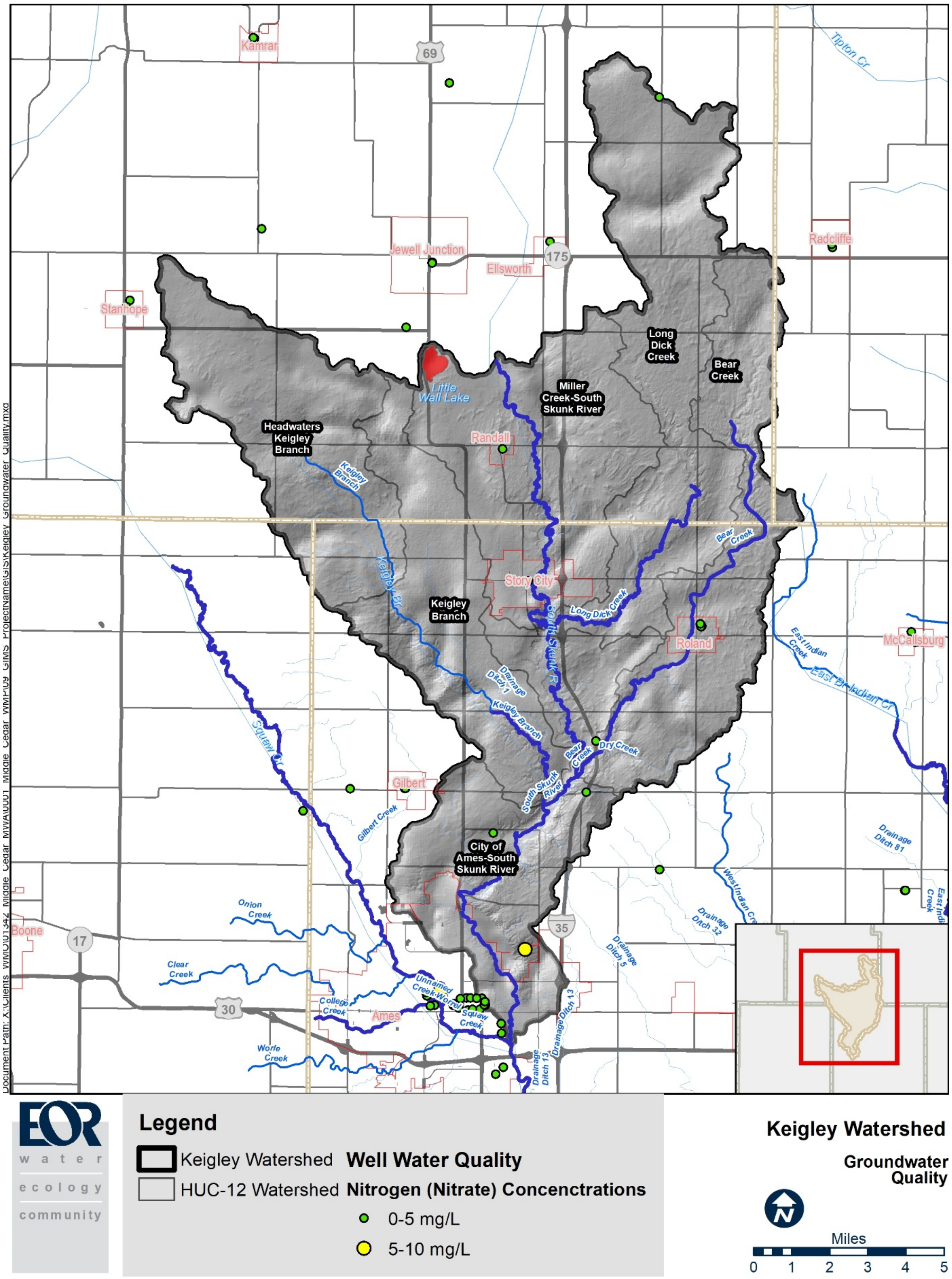


Figure 2-14. Groundwater Well Quality

2.6.3. 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 2-3 lists the geologic and hydrogeologic characteristics of the rock units (confining upper bedrock layers) described in section 2.6.1. These rocks are primarily shales, siltstones, sandstones, thin coal beds and 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). Figure 2-15shows groundwater vulnerability to pollution based on aquifer depth and bedrock characteristics.

Table 2-3. Groundwater Availability Modeling of the Mississippian Aquifer North-Central Iowa (Gannon and McKay, 2013)

Aquifers	General thickness (feet)	Age of rocks	Name of rock units	General description of rock units
Mississippian	0-775	Carboniferous Pennsylvanian-Middle (298-323 million years old)	Cherokee Group	Carbonaceous shale, clay, siltstone, with lesser sandstone, and thick coal beds; minor but persistent limestone beds
	0-150	Carboniferous Mississippian-Late (359-299 million years old)	St. Louis and Pella Formation	The St. Louis formation is characterized by interbedded dolomite (part sandy), sandstone, limestone, and green-gray shale. The Pella formation is characterized by calcareous shale and limestone.
	0-75 feet	Carboniferous Mississippian-Early (359-299 million years old)	Gilmore City Formation	Primarily fragmental limestone.

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.

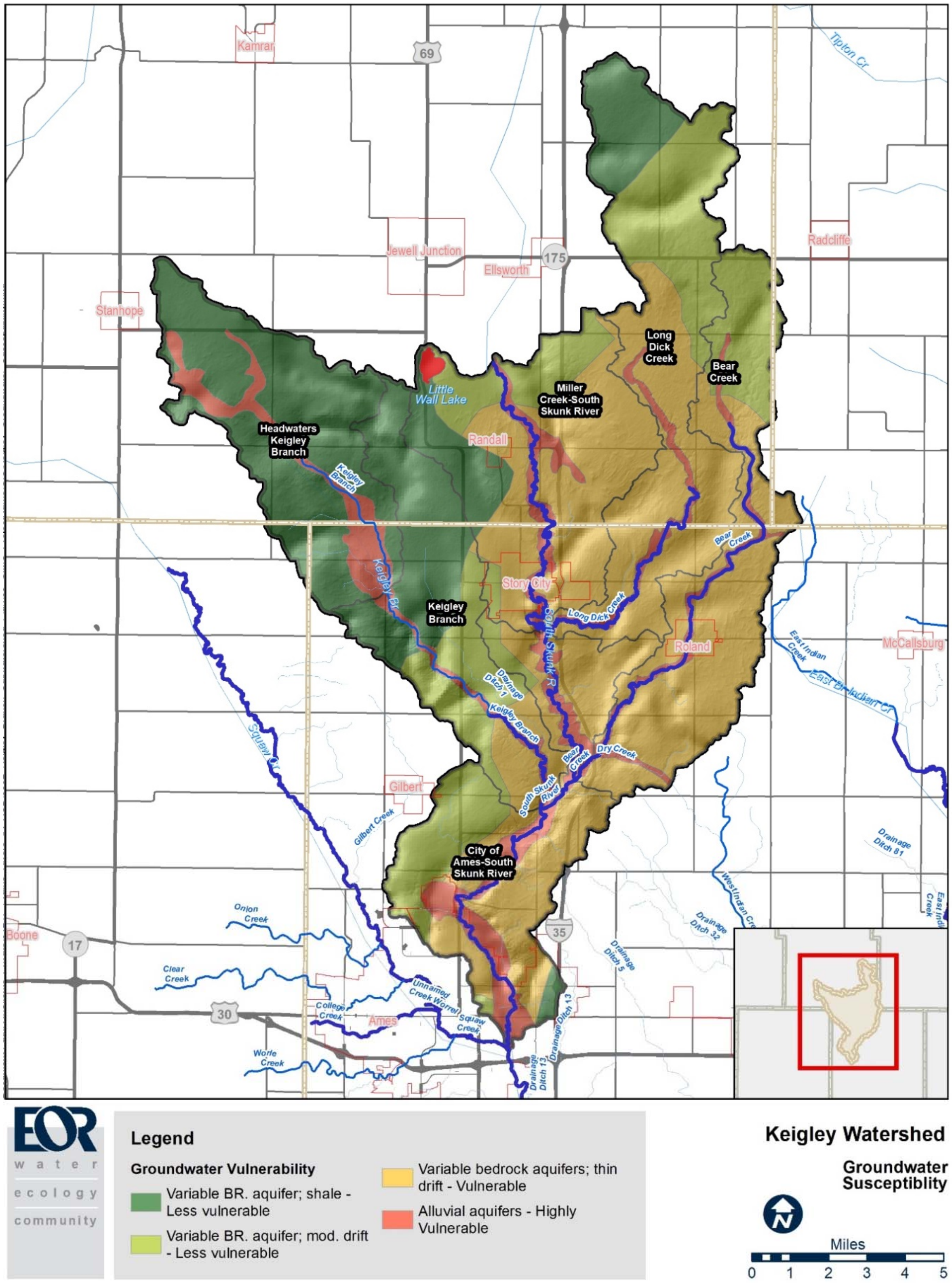


Figure 2-15. Groundwater vulnerability to pollution based on aquifer depth and bedrock characteristics

3. Pollutant Sources

3.1. Total Phosphorus

Unit area loads (UALs) for total phosphorus (TP) were used to determine the source and magnitude of pollutant loading for each Subwatershed (HUC-12) within the Keigley Branch – South Skunk River Watershed. UALs are used to provide an estimate of how much load is typically derived from a given area for a particular land use. Site-specific UALs were available for the Squaw Creek Watershed which used a Soil and Water Assessment Tool (SWAT) Model to assess TP loads. Results from the SWAT model were compared to UALs from relevant literature to obtain recommended UALs for the Keigley Branch – South Skunk River Watershed. The recommended UALs are largely based on UALs from published UAL data from the Minnesota Pollution Control Agency, the U.S. Army Corps of Engineers, and UALs found in the EPA's pollutant loading application (PLOAD).

Multiplying the UAL for a particular land use by the total area of the selected land use within a given subwatershed (HUC-12) allows for a comparison of total load generated by subwatershed (HUC- 12), and the proportion of the total load generated by a given land use practice (Figure 3-1). Modeled TP loading rates for subwatersheds in the Keigley Branch – South Skunk River Watershed (0.23-0.56 pounds/acre/year) fell within the range of watershed loading data provided in the Iowa DNR 2004 report. This report contains nitrogen and phosphorus budgets for all Iowa Watersheds including the South Skunk River which was found to have a TP loading rate of 0.39 pounds/acre/year.

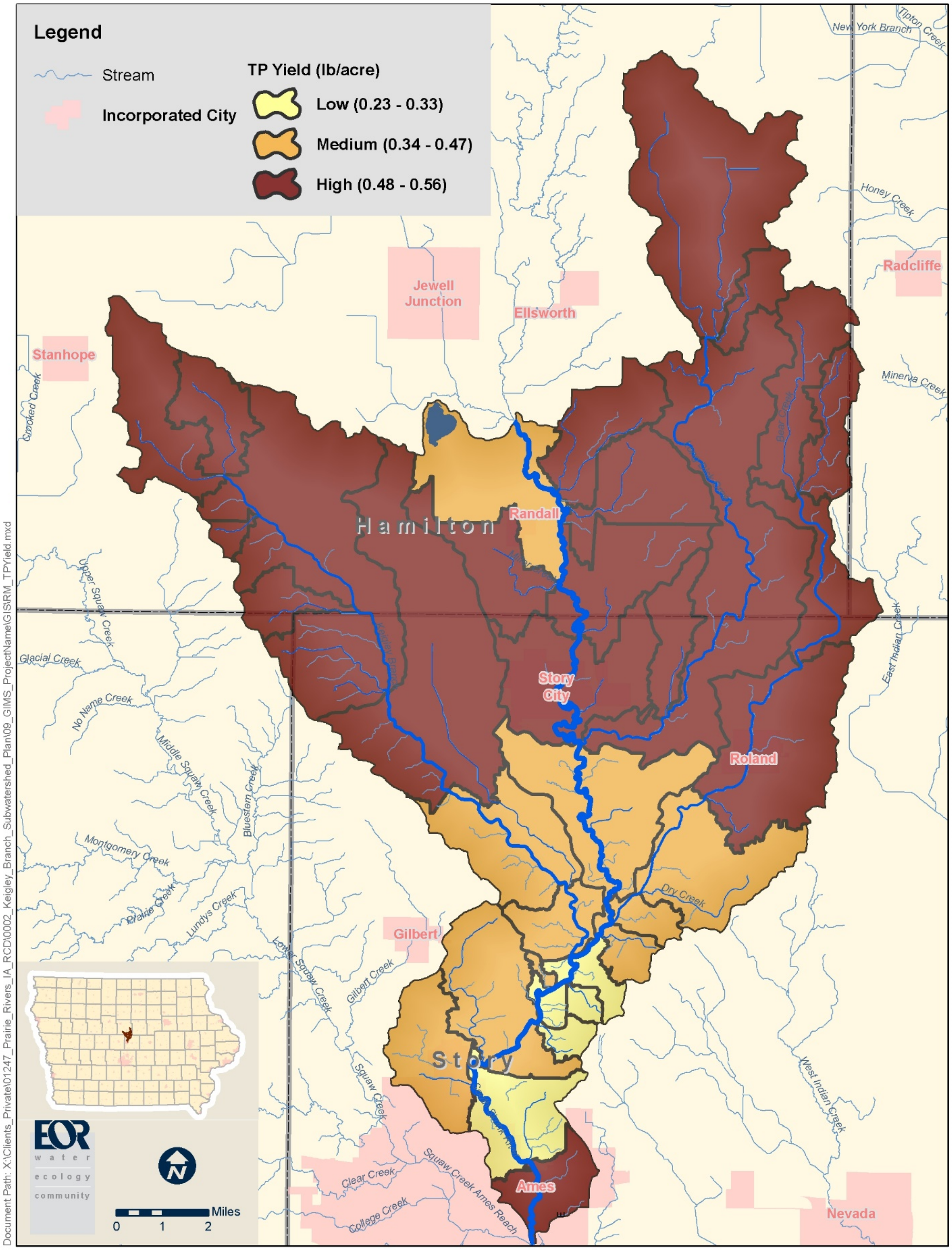


Figure 3-1. Keigley Branch – South Skunk River Watershed Subwatershed (HUC-12) Total Phosphorus Yields (Lbs/Acre/Year)

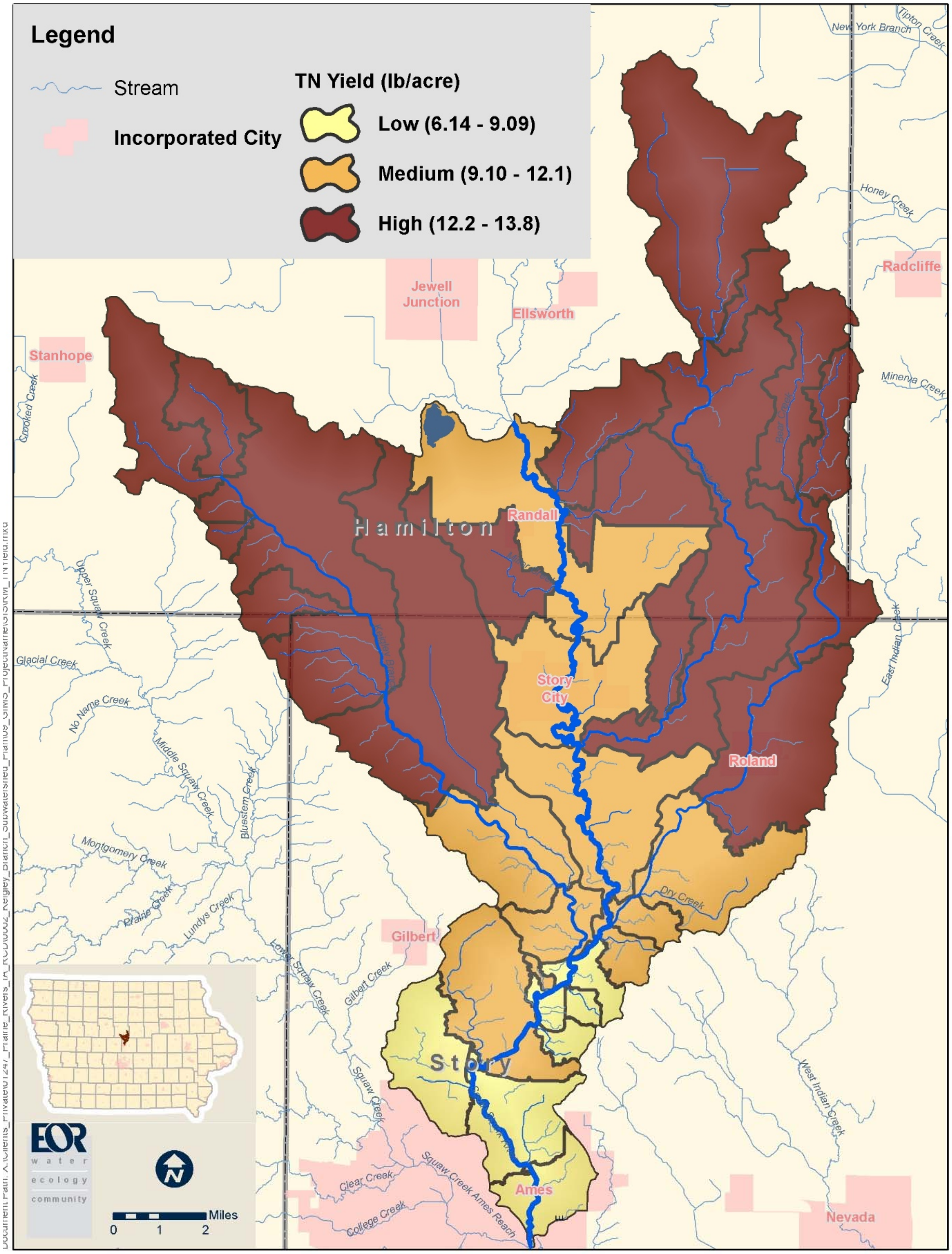


Figure 3-2. Keigley Branch – South Skunk River Watershed Subwatershed (HUC-12) Total Nitrogen Yields (Lbs/Acre/Year)

3.2. Total Suspended Solids

Total Suspended Solids is an important measurement of the amount of material suspended instream which is sometimes referred to as turbidity. As more material is suspended, less light can pass through, making it less transparent. Suspended materials may include soil, algae, plankton, and microbes.

Excess turbidity can significantly degrade the aesthetic qualities of waterbodies. People are less likely to recreate in waters degraded by excess turbidity. Also, turbidity can make the water more expensive to treat for drinking or food processing uses. Excess turbidity can also harm aquatic life, aquatic organisms may have trouble finding food, gill function may be affected, and spawning beds may be buried.

Unit area loads (UALs) for total suspended solids (TSS) were used to determine the source and magnitude of pollutant loading for each Subwatershed (HUC-12) within the Keigley Branch – South Skunk River Watershed. Site-specific UALs were available for the Squaw Creek Watershed which used a Soil and Water Assessment Tool (SWAT) Model to assess TSS loads. Results from the SWAT model were compared to UALs from relevant literature to obtain recommended UALs for the Keigley Branch – South Skunk River Watershed. The recommended UALs are largely based on UALs from published UAL data from the Minnesota Pollution Control Agency, the U.S. Army Corps of Engineers, and UALs found in the EPA’s pollutant loading application (PLOAD).

Multiplying the UAL for a particular land use by the total area of the selected land use within a given Subwatershed (HUC-12) allows for a comparison of total load generated by Subwatershed (HUC- 12), and the proportion of the total load generated by a given land use practice (Figure 3-2). Modeled TSS loading rates for subwatersheds for the Keigley Branch – South Skunk River Watershed (650-1,900 pounds/acre/year; equivalent to 0.33-0.95 tons/acre/year) are relatively high in comparison with observed loads from other Iowa watersheds. A 2011 USGS study of select Minnesota Rivers reported an average annual basin TSS yield for the Des Moines River near the border of Minnesota and Iowa at 313 pounds/acre/year (Ellison et. al., 2013). The Des Moines River watershed has similar land use (extensive cultivation) in the watershed with similar topographic relief. Values for the Squaw Creek Watershed ranged from 240 to 420 pounds/acre/year, equivalent to 0.12- 0.21 tons/acre/year.

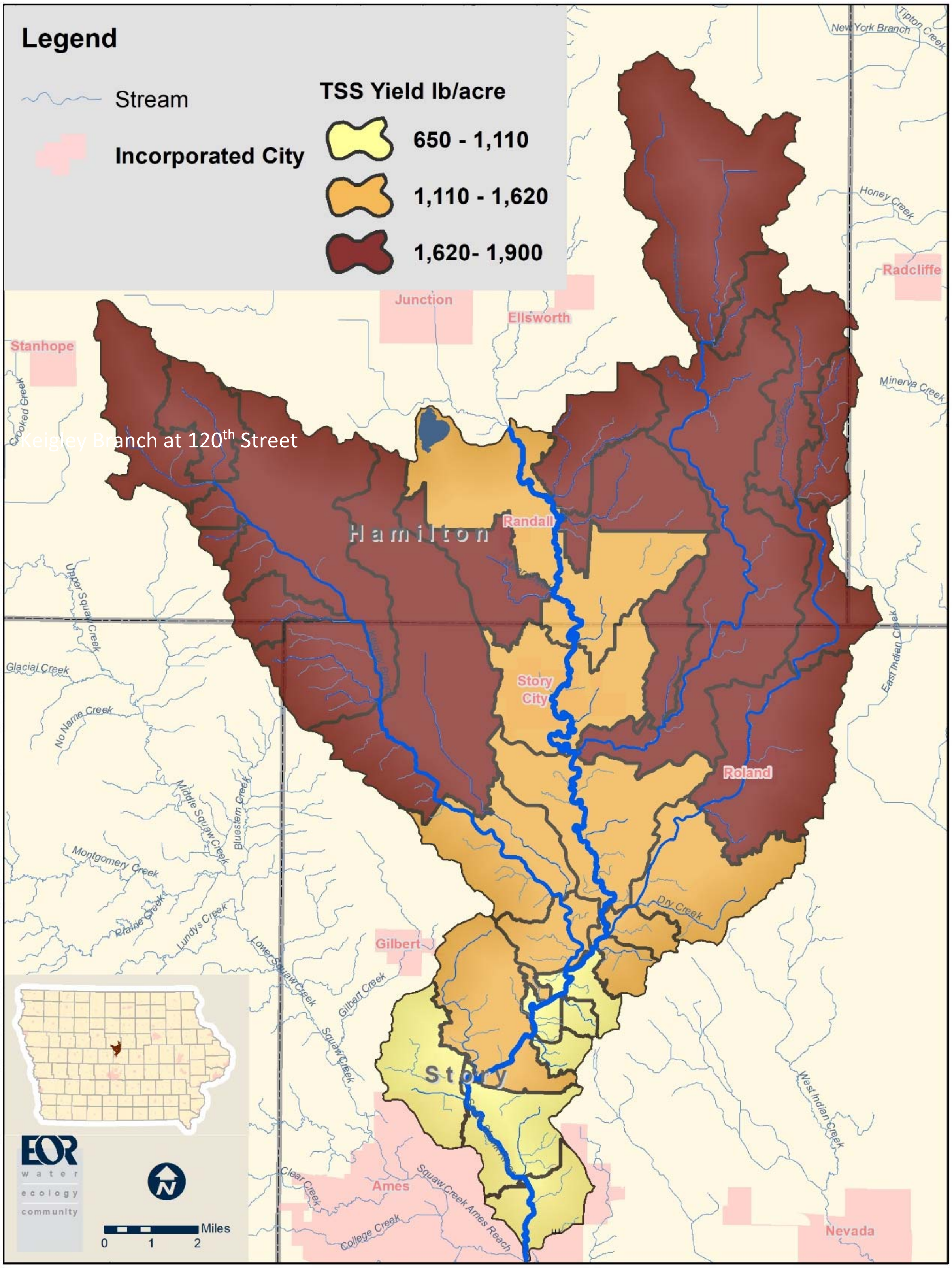


Figure 3-3. Keigley Branch – South Skunk River Watershed Subwatershed (HUC-12) Total Suspended Solids Yield (Lbs/Acre/Year)

3.3. 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 Keigley Branch 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 3-1. 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 3-1. Bacteria production by source

Source Category	Producer	*E. coli* Production Rate [cfu/day-head]	Literature Source
Humans	Humans	1.26×10^{9}	Metcalf and Eddy 1991
Companion Animals	Dogs	3.15×10^{9}	Horsley and Witten 1996
Livestock	Cattle	2.08×10^{10}	Zeckoski et al. 2005
	Hogs	6.93×10^{9}	Zeckoski et al. 2005
	Poultry	6.76×10^{7}	Zeckoski et al. 2005
Wildlife	Deer	2.21×10^{8}	Zeckoski et al. 2005

3.3.1. 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 municipal WWTFs located in the Keigley Branch Watershed with surface water discharges are summarized inTable 3-2. Bacteria loads from NPDES-permitted WWTFs was estimated based on the design flow and permitted bacteria effluent limit of 126 org/ 100 mL (Table 3-2). 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 downstream of the Keigley Branch watershed 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 the surface water resources within the Keigley Branch watershed 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 3-2. WWTP design flows and permitted bacteria loads

Subbasin	Name of WWTF	Permit #	Design Flow [mgd]	Equivalent Bacteria Load as *E. coli*: (billion org/day)
Bear Creek	Roland City of STP-FD-1	8570001	0.311	1.48
Miller Creek	Story City Stp-FD-1	8584001	1.362	6.49
City of Ames-South Skunk River	Hickory Grove Court, Llc-FD-1	8500600	0.0069	0.032
City of Ames-South Skunk River	Iowa Dot Rest Area #20 I35 Story City-FD-1	8500903	0.0039	0.019
City of Ames-South Skunk River	Homestead Colony MHP-FD-1	8500603	0.0096	0.046
City of Ames-South Skunk River	Iowa Dot Rest Area #19 I35 Story City-FD-1	8500902	0.0048	0.023

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, Story City, and Roland 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 in Table 3-3. This table is not intended to suggest that ITPHS systems contribute excess bacteria to streams in the Keigley Branch watershed.

Table 3-3. 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)
Bear Creek	2,417	304.5	1,522.5
City of Ames-South Skunk River	1,681	211.8	1,058.9
Headwaters Keigley Branch	1,100	138.6	692.9
Keigley Branch	3,039	382.9	1,914.7
Long Dick Creek	1,948	245.4	1,226.9
Miller Creek-South Skunk River	1,930	243.2	1,215.9

3.3.2. Livestock

The total number of livestock in each subwatershed was estimated by the Iowa DNR animal feeding operation (AFO) database by means of the Iowa Natural Resources Geographic Information Systems (NRGIS) Library. The Iowa DNR updates the feedlot data within the GIS layer in the NRGIS library on a monthly basis. The DNR AFO database is current to December, 2016 and the registered number of animals is known. This database also includes information on AFO's with less than 500 animal units (AU) even though these feedlot operations are not required to register with the Iowa DNR or obtain a manure management plan. A complete breakdown of total livestock present within each subwatershed in animal units is provided in Table 3-4. Multiplying the total number of animal units provided in Table 3-4 by the amount of bacteria produced by each animal type in Table 3-4 allows for an estimation of total bacteria load from livestock.

Table 3-4. Livestock summary results by subwatershed in animal units

Subwatershed	Swine	Cows	Poultry	Horse	Sheep/Lamb
Bear Creek	32,536	950	18,000	-------	-------
City of Ames-South Skunk River	2,753	713	2,351	51	498
Headwaters Keigley Branch	40,266	1,396	61,000	-------	-------
Keigley Branch	50,879	-------	55,000	-------	-------
Long Dick Creek	116,919	1,340	147,500	-------	-------
Miller Creek-South Skunk River	109,754	-------	91,000	-------	-------

3.3.3. 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 3-5 summarizes the estimate contribution from deer based on DNR survey and the resultant estimate for all wildlife by subwatershed.

Table 3-5. Deer bacteria estimates by subwatershed

Subwatershed	Deer *E. coli* (billion org/day)	Wildlife *E. coli* (billion org/day)
Bear Creek	36.4	72.8
City of Ames-South Skunk River	41.1	82.2
Headwaters Keigley Branch	32.2	64.5
Keigley Branch	30.3	60.7
Long Dick Creek	40.5	81.0
Miller Creek-South Skunk River	36.6	73.2

3.3.4. Pets

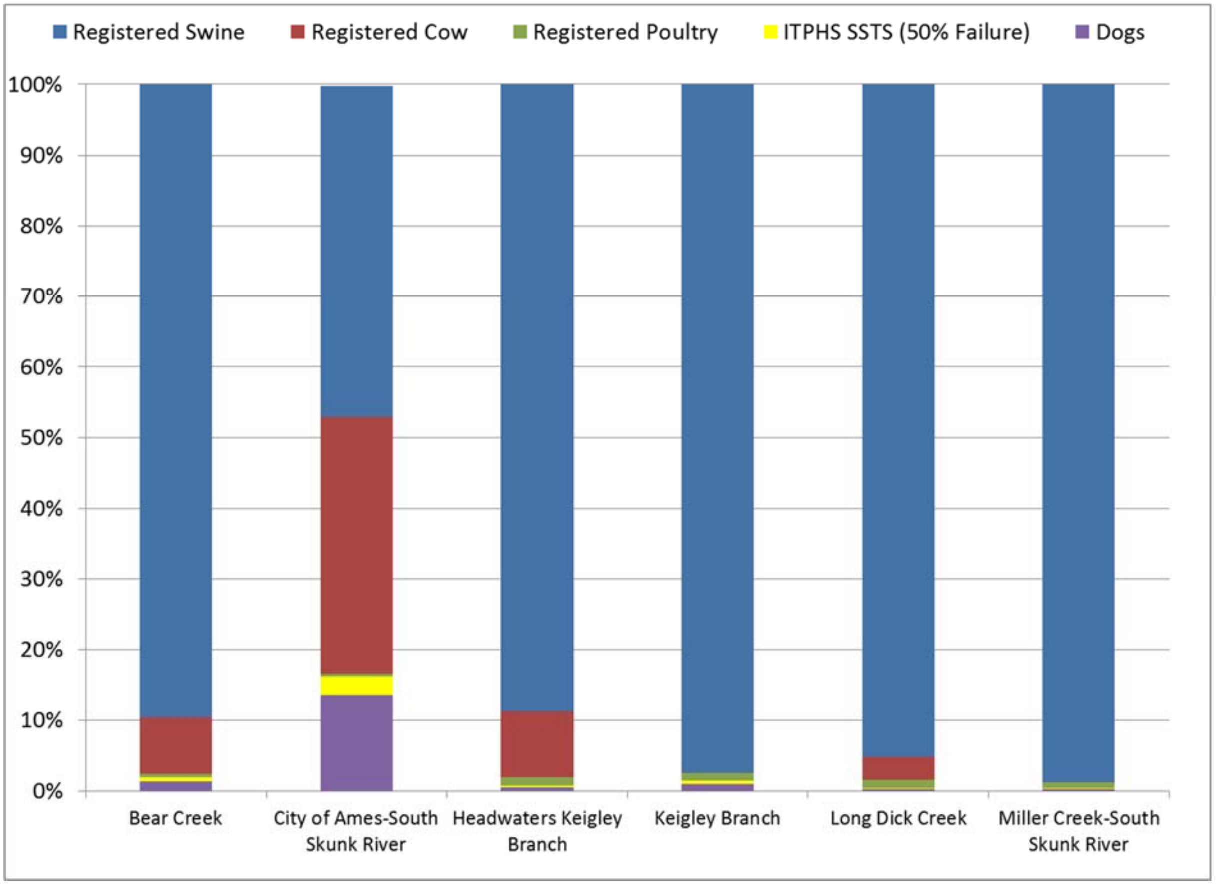
Pets (dogs and cats) can contribute bacteria to a watershed when their waste is not properly managed. When this occurs, bacteria can be introduced to waterways. The contribution of pet waste to waterbodies is more pronounced in urban areas where impervious surfaces and storm sewer network allow waste 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.

Table 3-6 Pet bacteria estimates by subwatershed

Subwatershed	Pets *E. coli* (billion org/day)
Bear Creek	3,591
City of Ames-South Skunk River	5,522
Headwaters Keigley Branch	1,617
Keigley Branch	3,519
Long Dick Creek	2,239
Miller Creek-South Skunk River	2,219

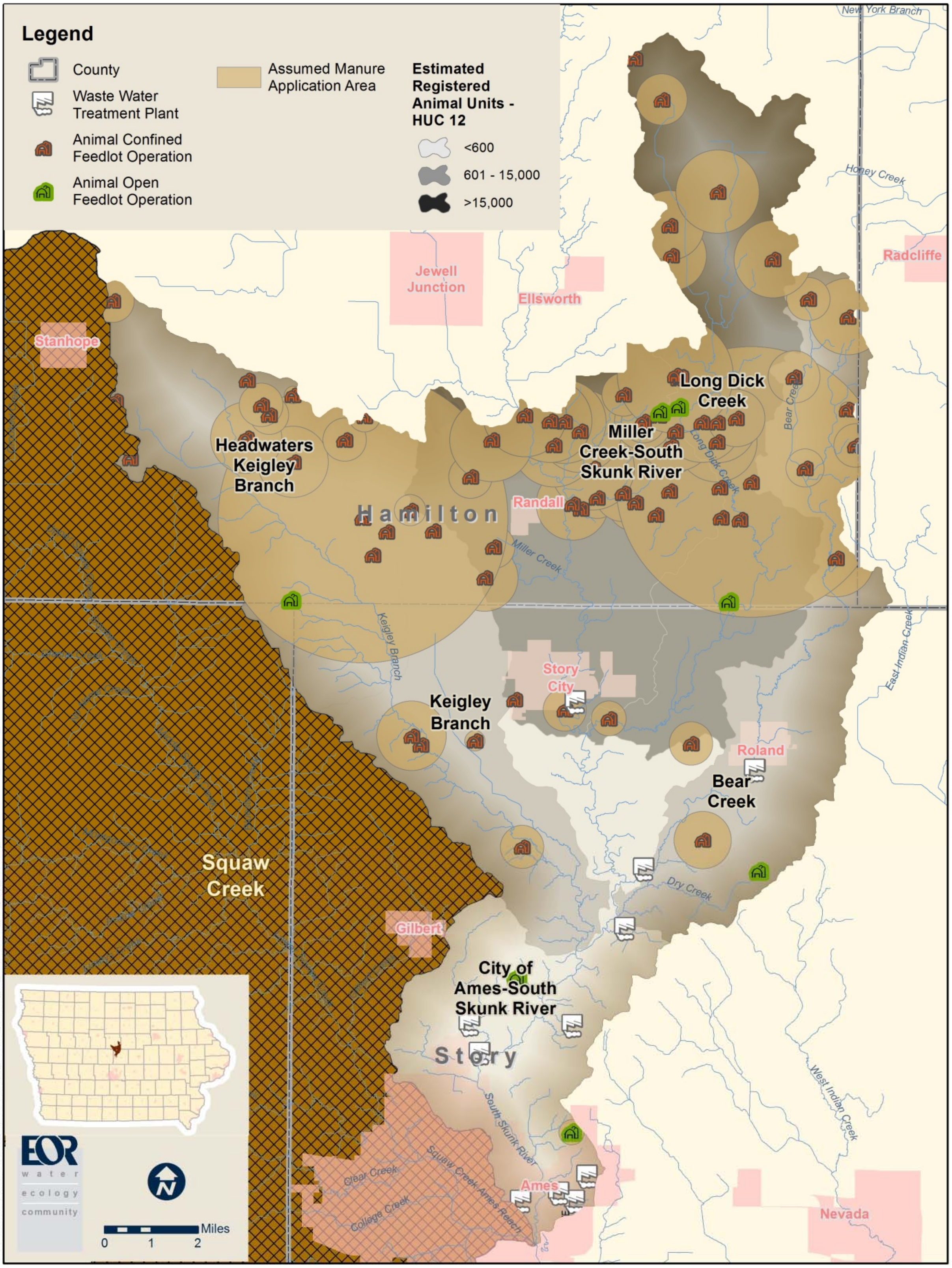
3.3.5. Priority Bacteria Source Areas

The source assessment information is summarized by subwatershed in Table 3-6 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 3-4 as a way of identifying potential hot spots for bacteria. Further prioritization is provided in Figure 3-6 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 and wildlife are not shown because they contribute <1% of the total bacteria load in each subwatershed.

Figure 3-4. Relative bacteria load by source in each subwatershed



Date: 2/28/2017 Time: 8:46:24 AM Author:
Document Path: X:\Clients_Private\01247_Prairie_Rivers_IA_RCD\0002_Keigley_Branch_Subwatershed_Plan\09_GIMS_ProjectName\GIS\RM_BSA.mxd

Figure 3-5. Bacteria sources in the Keigley Branch Watershed

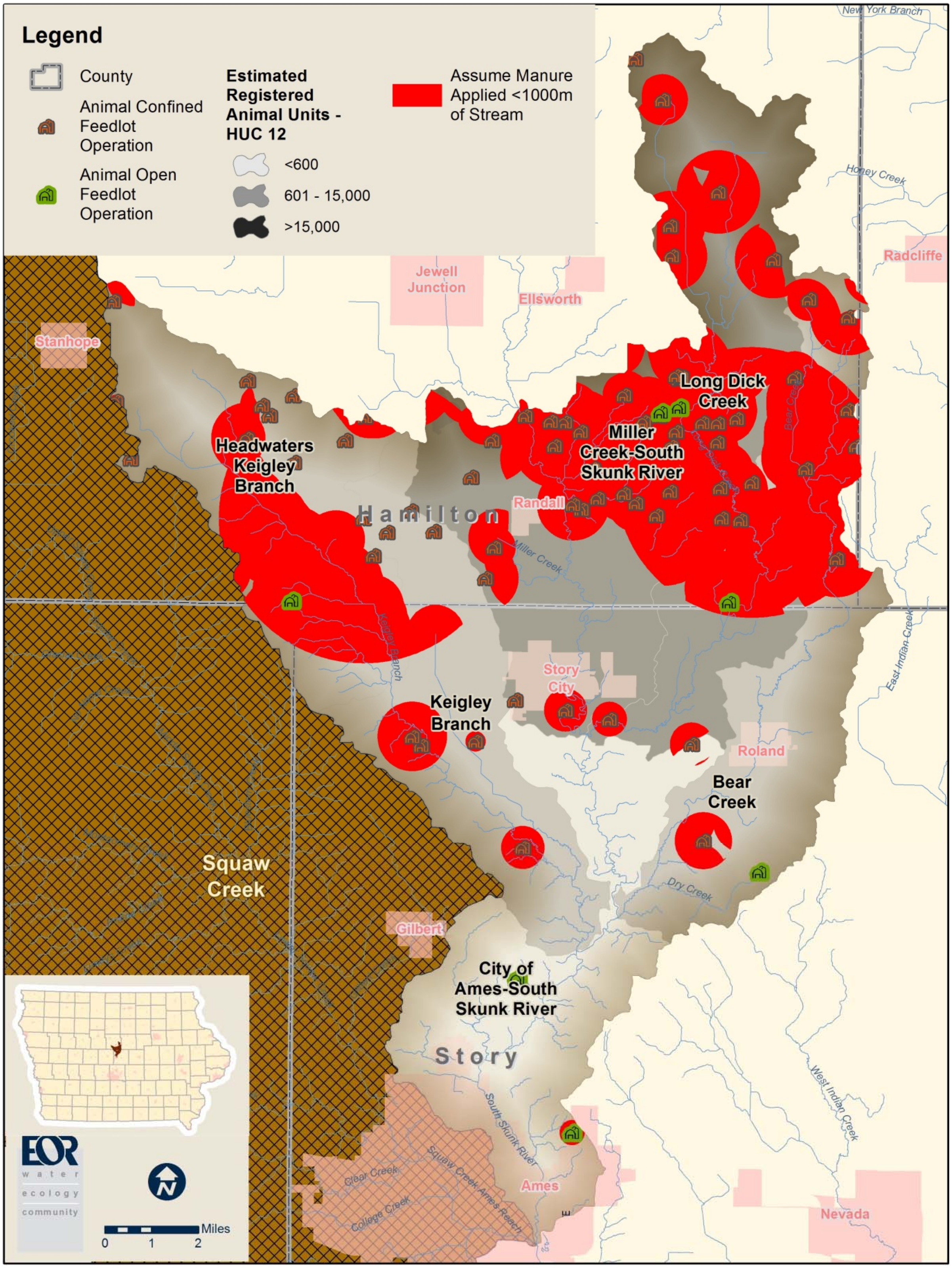


Figure 3-6. Manure Management Priority Areas

4. ACPF Modeling

4.1. Recommended Approaches for Agricultural Runoff

The Agricultural Conservation Planning Framework (ACPF) Version 2.2 was run for the HUC-12s within Story County not previous studied through past management plans. HUC-12 subwatersheds with a minimal footprint within Story County were not evaluated. The ACPF is a GIS-based tool developed by the Agricultural Research Service (USDA-ARS) that analyzes “soils, land use, and high-resolution topographic data to identify a broad range of opportunities to install conservation practices in fields and in watersheds”.[i] The ACPF tools identify suitable locations for terrain-dependent conservation practices.

The follow agricultural conservation practices were sited across the County:

- Grassed Waterways
- Contour Buffer Strips
- Nutrient Removal Wetlands
- Edge-of-Field Bioreactors
- Water and Sediment Control Basins (WASCOB)
- Drainage Water Management
- Drainage Water Recycle
- Saturated Riparian Buffers

The results of the ACPF analysis are not suitable for printing in a report so a web-based mapping application was developed. The mapping tool can be viewed on an interactive map which can be found on the watershed management page of the Story County website (www.storycountyiowa.gov).

Additionally, the ACPF is useful for identifying both the fields that are most likely to contribute runoff to a stream, and the most appropriate vegetation type for riparian buffers – all based on their positions in the landscape. The outputs of the tool are stored in a file geodatabase, and useful attributes such as drainage area and footprint area are calculated and included.

4.1.1. Soil Health Practices

Cover Crops: Cover crops is a term to describe any crop grown primarily for the benefit of the soil rather than the crop yield. Cover crops are typically grasses or legumes (planted in the fall between harvest and planting of spring crops) but may be comprised of other green plants. Cover crops prevent erosion, improve the physical and biological properties of soil, supply nutrients, suppress weeds, improve the availability of soil water, and break pest cycles among various other benefits. More information on cover crop use in Iowa can be found at: https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs142p2_005818.pdf

Extended Crop Rotations: An extended crop rotation is a farming practice that includes a rotation of corn, soybean, and two to three years of alfalfa or legume-grass mixtures managed for hay harvest. Extended rotations reduce the application and loss of both nitrate-N and P. Due to growing nitrogen fixing legumes three years in a row, very little, if any nitrogen needs to be applied in the subsequent corn year. Additional information can be found at: https://www.cleanwateriowa.org/extended-crop-rotation/

Nitrification Inhibitors: When ammonia or ammonium N is added to the soil, it is subject to a process called nitrification. Soil bacteria convert the ammonia (NH3) or ammonium (NH4) to nitrate (NO3). This conversion is strongly temperature dependent and occurs quickly under warm soil temperature conditions. Using a nitrification inhibitor with early spring applications of ammonia or ammonium nitrogen will slow the conversion to nitrate until it can be readily used by crops. This will allow the crop to take up more of the N.

4Rs of Nutrient Management: The 4Rs of nutrient management refer to fertilizer application techniques focused on minimizing the risk of nutrient loss from the field. The principles of the 4R framework include:

Right Source – Ensure a balanced supply of essential nutrients, considering both naturally available sources and the characteristics of specific products, in plant available forms.

Right Rate – Assess and make decisions based on soil nutrient supply and plant demand.

Right Time – Assess and make decisions based on the dynamics of crop uptake, soil supply, nutrient loss risks, and field operation logistics.

Right Place – Address root-soil dynamics and nutrient movement, and manage spatial variability within the field to meet site-specific crop needs and limit potential losses from the field.

Recently a program called 4R Plus was developed by a coalition of organizations dedicated to conservation stewardship for Iowa's farmers. 4R Plus is a nutrient management and conservation program to make farmers aware of practices that bolster production, build soil health and improve water quality in Iowa. The program is guided by a coalition of more than 25 organizations, including agribusinesses, conservation organizations, commodity and trade associations, government agencies and academic institutions. To learn more, visit www.4RPlus.org.

4.1.2. In-field Management Practices

Contour Buffer Strips: Contour buffer strips are strips of grass or a mixture of grasses and legumes that run along the contour of a farmed field. They alternate down the slope of a field with wider cropped strips. Established contour buffer strips can significantly reduce sheet and rill erosion. Strips slow runoff and trap sediment. Contaminants such as sediment, nutrients, and pesticides are removed from the runoff as they pass through a buffer strip. Buffer strips may also provide food and nesting cover for wildlife and pollinators. Additional information can be found at:
https://www.nrcs.usda.gov/wps/portal/nrcs/detail/null/?cid=nrcseprd413956

Terraces: A terrace is an earth embankment, channel, or a combination ridge and channel constructed across the slope to intercept runoff water. This practice generally applies to cropland but may also be used on other areas where field crops are grown such as wildlife or recreation lands. Terraces serve several purposes including; reducing slope length for erosion control, intercepting and directing runoff, and preventing gully development. Additional information can be found at:

https://www.nrcs.usda.gov/Internet/FSE_DOCUMENTS/nrcs143_026229.pdf

Drainage Water Management: 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 field 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.

Drainage Water Recycling: Drainage water recycling (also commonly referred to as a Closed-Loop System), diverts surface and subsurface drainage water into on--farm ponds or reservoirs, where it is stored until it can be used by the crop later in the season. Tile drainage occurs mostly in the spring, while crop water use in mid- to late summer may result in periods when insufficient water is available. Drained water stored in the spring can provide value to crops in the summer. Drainage water recycling can be a closed loop system where the drained water from a field is recirculated onto the same field, or water drained from one field can be used to irrigate a different field. Irrigation may be through subirrigation that raises the soil water table by flooding the subsurface drain tiles (above), or sprinkler systems such as a center pivot, or other technologies.

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 performs similarly to riparian buffer strips.

No-till: No-till is a way of growing crops or pasture from year to year without disturbing the soil through tillage. No-till increases the amount of water that infiltrates into the soil, the soil's retention of organic matter and its cycling of nutrients. It can also reduce or eliminate soil erosion, increase the amount and variety of life in and on the soil. The most powerful benefit of no-tillage is improvement in soil biological fertility, making soils more resilient.

4.1.3. Edge of Field Practices

Denitrifying bioreactors: Denitrifying bioreactors 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.

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).

Perennial Cover: Perennial cover refers to the practice of converting cropland to a permanent perennial vegetative cover and/or trees to accomplish any of the following: reduce soil erosion and sedimentation, improve water quality, enhance wildlife habitat, improve soil quality, or manage plant pests.

Water and Sediment Control Basin (WASCOB): Water and sediment control basins 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).

4.1.4. Riparian Area Management

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.

Riparian Buffers: The ACPF tools identify a variety of riparian buffers based on the primary function they serve. The riparian buffer types are as follows:

Critical Zone- sensitive areas: identified as areas with a high level of surface runoff delivery

The ACPF tools were run for each HUC-12 subwatershed and processed using a custom set of scripts written in the R programming language. Essentially, these scripts aggregated the individual BMP features and created a summary for each HUC-12 containing the total number of BMPs of each type, as well as total footprint and drainage areas.

Then, a spreadsheet tool was developed in Microsoft Excel that uses the BMP summaries to apply pollutant loading values to the drainage areas, along with pollutant reduction values that are unique to each BMP. The pollutant reduction estimates were derived from a combination of sources, but were primarily taken from the Iowa Nutrient Reduction Strategy. Existing BMP adoption rates were estimated using a combination of sources, including feedback for specific watersheds from the Iowa Soybean Association, as well as using the results from the Iowa BMP Mapping Project (Table 4-1). After subtracting off the existing pollutant reductions using estimates for the existing adoption rate of each BMP, the tool was used to develop a scenario for each of the HUC-12 subwatersheds in the Keigley Branch – South Skunk River Watershed with the goal of reaching the Iowa Nutrient Reduction Strategy targets for Nitrogen and Phosphorus reductions across the watershed. Target adoption rates, recommended protection strategies and restoration opportunities are summarized for each of the HUC-12s within the Keigley Branch – South Skunk River Watershed in the following section.

Table 4-1: Existing Adoption Rate Assumptions.

	BMP Name	Existing Adoption (%) by Subwatershed					
		Keigley Branch	Headwaters Keigley	Bear Creek	Long Dick Creek	City of Ames - South Skunk	Miller Creek South Skunk
Soil Health Management	Cover crops	1%	1%	1%	1%	1%	1%
	Extended rotations	1%	1%	1%	1%	1%	1%
	Nitrogen management: nitrification inhibitor	50%	50%	50%	50%	50%	50%
	Nitrogen management: rate control	10%	10%	10%	10%	10%	10%
	Nitrogen management: source control	20%	20%	20%	20%	20%	20%
	Nitrogen management: timing control	50%	50%	50%	50%	50%	50%
	Phosphorus management: placement control	50%	50%	50%	50%	50%	50%
	Phosphorus management: rate control	50%	50%	50%	50%	50%	50%
	Phosphorus management: source control	50%	50%	50%	50%	50%	50%
In-Field Management	Contour buffer strips	0%	0%	0%	0%	0%	0%
	Terraces	100%	56%	100%	49%	16%	39%
	Drainage water management	0%	0%	0%	0%	0%	0%
	Grassed waterways	53%	44%	42%	31%	48%	11%
	No-Till	20%	20%	20%	20%	20%	20%
Edge-of-Field Management	Denitrifying bioreactors	0%	0%	0%	0%	0%	0%
	Nutrient removal wetlands	0%	0%	0%	0%	0%	0%
	Perennial cover	1%	1%	1%	1%	1%	1%
	WASCOBs	100%	83%	100%	52%	69%	75%
Riparian Management	Riparian buffer: Critical zone buffer	76%	83%	63%	75%	82%	73%
	Riparian buffer: Deep-rooted vegetation buffer	84%	80%	63%	70%	79%	86%
	Riparian buffer: Multi-species buffer	88%	79%	56%	69%	72%	85%
	Riparian buffer: Stiff stem grass buffer	80%	80%	70%	54%	82%	71%
	Riparian buffer: Stream stabilization buffer	80%	80%	66%	57%	87%	83%
	Saturated buffers	0%	0%	0%	0%	0%	0%

4.1.5. Bear Creek

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes
Bear Creek 070801050403	Keigley Branch-South Skunk River	South Skunk	Bear Creek, Dry Creek 1 Unnamed Creek/Ditch	

Recommendations:

- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
- Encourage the City of Roland to:
    - Adopt the Model Stormwater Ordinance (Appendix D).
    - Incorporate Low Impact Development practices (Section 4.4) in public improvement projects.
- Establish a Sentinel Site: General water quality monitoring station on Bear Creek at the IFC Gage south of Roland (BEARCREEK01)
- Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide

Soil Health	Cover crops	15%		3830 acres
	Extended rotations	2%		270 acres
	Nitrogen management: nitrification inhibitor	95%		12050 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	9.34	Miles	
	Terraces	NA		
	Drainage water management	27	Fields	
	Grassed waterways	15.87	Miles	
	No-Till	2%		1340 acres
Edge of Field	Denitrifying bioreactors	12	Reactors	
	Nutrient removal wetlands	9	Wetlands	
	Perennial cover	2%		270 acres
	WASCOBs	NA		
	Riparian Buffer	95%		

Riparian Management	Saturated Buffers	10.17	Miles

4.1.6. City of Ames – South Skunk River

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes
City of Ames-South Skunk River 070801050406	Keigley Branch-South Skunk River	South Skunk	**South Skunk River** 9 Unnamed Creeks/Ditches	Ada Hayden Peterson Park Lakes McFarland Pond

Recommendations:

- Improve water quality in South Skunk River resulting in having it removed from the Iowa Impaired Waters List.
- Increase public awareness of kayaking, angling, and non-motorized recreational opportunities on the South Skunk River.
- Expand and enhance public access to the South Skunk River Greenbelt through acquisition of key parcels identified as containing biologically significant native plant communities. Focus on floodplain and upland timber habitat.
- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
- Protect Ada Hayden Lake from carp feeding activities.
- Evaluate implementation options for secondary treatment measures from watershed sources including the constructed wetlands.
- Further develop public use areas, road access, forest habitat and fisheries in the popular Skunk River Greenbelt.
- Support continued monitoring of Ada Hayden Lake.
- Consider establishing a Sentinel Site: Full monitoring station at South Skunk River near Ames Hwy E18 (USGS Station ESKI4)
- Develop citizen monitoring program for Peterson Park West Lake and McFarland Lake.
- Encourage the City of Ames to:
    - Incorporate Low Impact Development practices (Section 4.4) in public improvement projects.
- Adopt the strategies that address bacteria pollution identified in Section 4.5.
- Follow the recommendations for bacteria contamination from rural areas.
    - Prioritize bacteria source controls that reduce direct sources of bacteria from livestock and manure runoff.
- Follow the recommendations for bacteria contamination from urban areas.
    - Prioritize bacteria source controls that reduce bacteria from pets and humans.
- Prioritize conservation practices that reduce phosphorus loading.

- Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide

Soil Health	Cover crops	15%		2130 acres
	Extended rotations	2%		150 acres
	Nitrogen management: nitrification inhibitor	95%		6710 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	3.22	Miles	
	Terraces	1.09		
	Drainage water management	39	Fields	
	Grassed waterways	5.45	Miles	
	No-Till	2%		750 acres
Edge of Field	Denitrifying bioreactors	10	Reactors	
	Nutrient removal wetlands	4	Wetlands	
	Perennial cover	2%		150 acres
	WASCOBs	NA		
Riparian Management	Riparian Buffer	95%		
	Saturated Buffers	1.40	Miles	

4.1.7. Headwaters Keigley Branch

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes
Headwaters Keigley Branch 070801050404	Keigley Branch-South Skunk River	South Skunk	Keigley Branch 2 Unnamed Creeks/Ditches	

Recommendations:

- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
  - Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide

-

Soil Health	Cover crops	15%		4190 acres
	Extended rotations	2%		290 acres
	Nitrogen management: nitrification inhibitor	95%		13180 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	4.14	Miles	
	Terraces	0.20		
	Drainage water management	54	Fields	
	Grassed waterways	13.40	Miles	
	No-Till	2%		1460 acres
Edge of Field	Denitrifying bioreactors	10	Reactors	
	Nutrient removal wetlands	14	Wetlands	
	Perennial cover	2%		290 acres
	WASCOBs	NA		
Riparian Management	Riparian Buffer	95%		
	Saturated Buffers	0.08	Miles	

4.1.8. Keigley Branch

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes
Keigley Branch 070801050405	Keigley Branch-South Skunk River	South Skunk	Keigley Branch, Lower Reach Keigley Branch, Upper Reach Drainage Ditch 1	

Recommendations:

- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
- Establish a Sentinel Site: General water quality monitoring station on Keigley Branch at the existing USGS Station (05469990 Keigley Branch) near Story City, IA.
- Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide

Soil Health	Cover crops	15%		3180 acres
	Extended rotations	2%		220 acres
	Nitrogen management: nitrification inhibitor	95%		9990 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	1.59	Miles	
	Terraces	NA		
	Drainage water management	57.5	Fields	
	Grassed waterways	3.75	Miles	
	No-Till	2%		1110 acres
Edge of Field	Denitrifying bioreactors	11	Reactors	
	Nutrient removal wetlands	6	Wetlands	
	Perennial cover	2%		220 acres
	WASCOBs	NA		
Riparian Management	Riparian Buffer	95%		
	Saturated Buffers	3.50	Miles	

4.1.9. Long Dick Creek

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes
Long Dick Creek 070801050401	Keigley Branch-South Skunk River	South Skunk	**Long Dick Creek,** 1 Unnamed Creek/Ditch	

Recommendations:

- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
- Improve water quality in Long Dick Creek resulting in having it removed from the Iowa Impaired Waters List.
- Establish a Sentinel Site: General water quality monitoring station on Long Dick Creek at the IFC Gage: Long Dick Creek near Roland (LNGDCKCR01).
- Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide.

Soil Health	Cover crops	15%		5050 acres
	Extended rotations	2%		350 acres
	Nitrogen management: nitrification inhibitor	95%		15880 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	4.91	Miles	
	Terraces	0.75		
	Drainage water management	54.5	Fields	
	Grassed waterways	19.38	Miles	
	No-Till	2%		1760 acres
Edge of Field	Denitrifying bioreactors	13	Reactors	
	Nutrient removal wetlands	8	Wetlands	
	Perennial cover	2%		350 acres
	WASCOBs	NA		
Riparian Management	Riparian Buffer	95%		
	Saturated Buffers	11.11	Miles	

4.1.10. Miller Creek-South Skunk River

HUC-12 Subwatershed	HUC-10 Watershed	HUC-8 Subbasin	Streams (impaired in bold)	Lakes (impaired in bold)
Miller Creek-South Skunk River 070801050402	Keigley Branch-South Skunk River	South Skunk	**South Skunk River** 2 Unnamed Creeks/Ditches	**Little Wall Lake**

Recommendations:

- Encourage adoption/installation of the following suite of agricultural conservation practices designed to meet the Iowa Nutrient Reduction Strategy goals for N (41%) and P (29%) reduction countywide.
- Improve water quality in South Skunk River resulting in having it removed from the Iowa Impaired Waters List.
- Increase public awareness of kayaking, angling, and non-motorized recreational opportunities on the South Skunk River.
- Expand and enhance public access to the South Skunk River Greenbelt through acquisition of key parcels identified as containing biologically significant native plant communities. Focus on floodplain and upland timber habitat.

- Establish a Watershed Management Authority to cover the Keigley Branch-South Skunk River HUC-10 as well as the two upstream HUC-10s in the upper portion of the South Skunk River HUC-8 (Headwaters South Skunk River and Drainage Ditch 71).
- Encourage Story City to:
    - Adopt the Model Stormwater Ordinance (Appendix D).
    - Incorporate Low Impact Development practices (Section 4.4) in public improvement projects.
- Adopt the strategies that address bacteria pollution identified in Section 4.5.
- Follow the recommendations for bacteria contamination from rural areas.
    - Prioritize bacteria source controls that reduce direct sources of bacteria from livestock and manure runoff.
- Follow the recommendations for bacteria contamination from urban areas.
    - Prioritize bacteria source controls that reduce bacteria from pets and humans.
-

Soil Health	Cover crops	15%		3410 acres
	Extended rotations	2%		240 acres
	Nitrogen management: nitrification inhibitor	95%		10740 acres
	4Rs of Nutrient Management	90%		
In Field	Contour buffer strips	3.69	Miles	
	Terraces	0.43		
	Drainage water management	53	Fields	
	Grassed waterways	23.70	Miles	
	No-Till	2%		1190 acres
Edge of Field	Denitrifying bioreactors	14	Reactors	
	Nutrient removal wetlands	10	Wetlands	
	Perennial cover	2%		240 acres
	WASCOBs	NA		
Riparian Management	Riparian Buffer	95%		
	Saturated Buffers	3.96	Miles	

-

---

[i] North Central Region Water Network. The Agricultural Conservation Planning Framework (ACPF): A Watershed Planning Tool. [accessed 2018 Apr 26]. http://northcentralwater.org/acpf/.