FINAL
JORDAN CREEK WATERSHED RECOVERY AND MANAGEMENT PLAN

JUNEAU WATERSHED PARTNERSHIP

SOUTHEAST ALASKA WATERSHED COALITION

CONNECT - INFORM - PARTICIPATE

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Cover Photo: Jordan Creek flowing through the greenbelt in the lower watershed. Photo courtesy of John Hudson.

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Juneau Watershed Partnership

Our mission is to promote watershed integrity in the City and Borough of Juneau through education, research and communication while encouraging sustainable use and development.

Acronyms

ADF&G	Alaska Department of Fish and Game
AHPS	Advanced Hydrologic Prediction Service
APDES	Alaska Pollutant Discharge Elimination System
ATV	All-Terrain Vehicle
CBJ	City and Borough of Juneau
DEC	Alaska Department of Environmental Conservation
DNR	Alaska Department of Natural Resources
D.O.	Dissolved Oxygen
DOT&PF	Alaska Department of Transportation and Public Facilities
EPA	US Environmental Protection Agency
EVR	East Valley Reservoir
FEMA	Federal Emergency Management Agency
JIA	Juneau International Airport
JWP	Juneau Watershed Partnership
MWP	Mendenhall Watershed Partnership
NRCS	Natural Resources Conservation Service
SAWC	Southeast Alaska Watershed Coalition
TDS	Total Dissolved Solids
TMDL	Total Maximum Daily Loads
TSS	Total Suspended Solids
UAS	University of Alaska Southeast
USGS	US Geological Survey
USFS	US Forest Service
USFWS	US Fish and Wildlife Service
WQS	Water Quality Standard

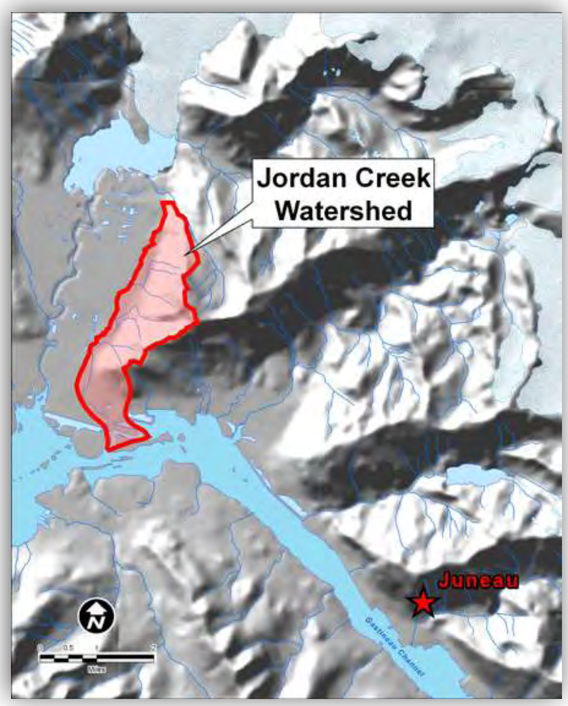

Figure 1. The Jordan Creek watershed

Units of Measurement

°C	Celsius
CFS	Cubic Feet per Second
°F	Fahrenheit
ft	Feet
in	Inches
mg/L	Milligram per Liter
mm	Millimeters
NTUs	Nephelometric Turbidity Units
µS/cm	Micro-Siemens per Centimeter

Purpose and Need

Jordan Creek is an impaired anadromous fish stream located in the Mendenhall Valley of Juneau, Alaska (Figure 1). Jordan Creek was listed as an Impaired Waterbody by the State of Alaska in 1998 due to non-attainment of sediment, dissolved oxygen, and residue (debris) standards. Stormwater runoff from urban areas was identified as being the major source of pollutant delivery to the stream. The lower portion of the watershed (downstream of Egan Drive) is densely urbanized compared to the upper watershed. Most of the natural land cover in this area has been replaced with roads, parking lots, and buildings. Urbanization in the lower watershed has resulted in stream channelization, loss or impairment of wetland and riparian habitat, and increased stormwater runoff.

Due to its impaired status, several assessments and monitoring efforts were completed for the Jordan Creek watershed. Carson Dorn, Inc. developed the first watershed assessment in 2002 for the City and Borough of Juneau (CBJ). This was followed by 10 years (2003 – 2013) of water quality monitoring financially supported by the CBJ and the Alaska Department of Environmental Conservation (DEC). The U.S. Geological Survey (USGS) developed a base-line condition report in 2004 and then studied the hydrology and flood profiles of Jordan Creek below Egan Drive in 2006. To address water quality impairments, two Total Maximum Daily Loads (TMDLs) were approved: one for debris approved in 2005, and one for sediment and dissolved oxygen approved in 2009. A TMDL is a study that determines the maximum amount, or "load," of specific pollutants that a waterbody can receive and still maintain Water Quality Standards (WQS) and recommends load reductions for each pollutant source to achieve waterbody recovery.

The *Jordan Creek Watershed Recovery and Management Plan* (2006) (herein referred to as the 2006 *Plan*) completed by the Natural Resources Conservation Service (NRCS) was the first overall management plan for the watershed. The purpose of the 2006 Plan was to summarize information about the watershed, identify impacts to water quality and fish habitat, and recommend policies and actions to improve habitat conditions throughout the watershed. However, the 2006 Plan's site-specific actions, including stabilizing the East Valley Reservoir (EVR) tributary, removing the Sasha Street bridge, and addressing all-terrain vehicle (ATV) impacts, were recommendations for the upper watershed intended to reduce problems in the lower watershed. Since its publication, most of these actions have been addressed but there continue to be on-going concerns. Several separate efforts have since been conducted to identify site-specific actions in the lower watershed to improve water quality and habitat conditions, but there has not been a comprehensive effort to compile this information into a cohesive updated management plan.

This *Jordan Creek Assessment and Management Plan* will build upon the 2006 Plan by providing a more focused effort on the lower watershed. The densely-developed lower watershed is and will continue to be a strong influence on the watershed's health. A focused effort on the lower Jordan Creek watershed is necessary as the 2006 Plan is a decade old and does not adequately address current management challenges, particularly in the lower watershed where new information is available to inform management. In addition, the lower watershed will likely see on-going re-development as community needs change, providing opportunities to improve water quality and habitat conditions. While the focus on the lower Jordan Creek watershed is important, the watershed in its entirety cannot be ignored. The purpose of this *Jordan Creek Assessment and Management Plan* is to assess current conditions, incorporate information developed since the 2006 Plan, and identify new or update existing policies and actions needed to continue improving the health of the Jordan Creek watershed.

Contents

Figure 2. Jordan Creek watershed with some features labeled for reference.

Watershed Description

The Jordan Creek watershed is located on the east side of the Mendenhall Valley in Juneau, Alaska. The mainstem is approximately 3.5 miles long and the system drains a watershed of about four-square miles (Figure 2). Jordan Creek is primarily influenced from rainfall, with secondary inputs from groundwater. The groundwater springs that contribute to the flow are located above the Thunder Mountain Trailer Park. The surficial headwaters originate on the western edge of Thunder Mountain on Tongass National Forest lands at an elevation of 2,800 feet. The headwaters are typically clear but the stream develops a brown tint midway along its length. The mainstem, which has a nearly level course, passes through a combination of undeveloped and moderately to densely urbanized land before discharging into the Mendenhall Wetlands at the Juneau International Airport. The Jordan Creek watershed is generally discussed in terms of the upper and lower watersheds, which are above and below Egan Drive, respectively.

Climate and Weather

The maritime climate of Juneau, Alaska is influenced by the proximity of the ocean and the mountains and consists of mild winters and cool summers. As measured at the Juneau International Airport (JIA), average summer temperatures range from 40 to 64 degrees Fahrenheit; winter temperatures range from 20 to 35 degrees Fahrenheit. Juneau receives an annual average of 58 inches of precipitation near the JIA, with heavier rains occurring in the fall. Snowfall may occur as early as October and as late as April. Near the JIA, Juneau averages 97 inches of snowfall annually.

Table 1. Monthly climate summary for Juneau International Airport, Alaska (Station #504100) for the period from 09/01/1936 to 06/09/2016. Data from the Western Regional Climate Center.

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Average Max. Temperature (F)	30.0	34.4	38.5	47.6	55.5	61.7	63.9	62.6	55.8	47.0	37.5	32.8	47.3
Average Min. Temperature (F)	19.7	23.3	26.4	32.2	39.3	45.5	48.6	47.8	43.3	37.0	28.3	23.8	34.6
Average Total Precipitation (in.)	4.50	3.93	3.47	2.88	3.43	3.16	4.41	5.49	7.58	8.02	5.61	5.21	57.68
Average Total Snow Fall (in.)	26.8	18.5	14.8	2.6	0.0	0.0	0.0	0.0	0.0	1.1	12.4	20.9	97.1
Average Snow Depth (in.)	5	6	3	0	0	0	0	0	0	0	1	4	2

Landscape: Geology, Soils and Vegetation

During the Pleistocene, the Juneau area was covered by ice. The Mendenhall Valley was exposed when these ice sheets began retreating about 17,000 BC (Barnwell and Boning, 1968). This allowed for the ocean to extend into the valley, leading to deposition of unconsolidated marine sediments along the valley bottom. Approximately 4,500 BC, a mix of glacial and stream processes created a graded glacial outwash plane in front of the ice sheet. During this time, tidal and wave action formed deposits at the seaward end of the glacial outwash plane. The Mendenhall Glacier began to re-advance during the Little Ice Age around 1,000 BC, reaching its maximum extent around 1750 AD. This can be noted by end moraine deposits located in the upper valley (Miller, 1975; Figure 3).

Since 1750, the Mendenhall Glacier has been receding. This recession is contributing to regional uplift due to isostatic rebound. However, uplift in the Juneau area may not be solely due to isostatic effects of glacial recession. It has been noted by Hudson et al (1982), that tectonic processes may also be a factor, with uplift resulting from the of built up tension along the Queen Charlotte-Fairweather transform fault system, located along the Pacific Coast of the Alaska pan-handle. Uplift rates in the Juneau area were 0.05 foot per year for the period 1936 to 1962 (Hicks and Shofnos, 1965). Similar rates were found during the period 1959 to 1979, resulting in a total uplift of 0.92 feet for this period (Hudson et al, 1982).

The Mendenhall Valley's geologic history created a base of unconsolidated deposits along the valley bottom, which are overlain by more recent marine, alluvial (deposited by streams), and colluvial (deposited by gravity, as in landslides) surficial deposits generally dating back to the Little Ice Age. Human-made fill is the primary surficial deposits in the lower watershed near the JIA (Figure 3).

On Thunder Mountain, bedrock consists of volcanic and sedimentary rocks from the Cretaceous and Jurassic periods. This includes rock types such as breccia, tuff, greywacke, slate, and conglomerates. There is also a band of carbonate rock (carbonaceous slate phyllite) from the Triassic Period in the upper watershed. Such carbonate rocks located throughout the area are the source of Juneau's most successful mines. An inactive prospect dubbed the "Dutch Lady" is located on Thunder Mountain within this band of carbonate rocks (Figure 4). It was discovered prior to 1911 with main commodity being gold. This is the only documented prospect in the watershed. There are several local faults in the Juneau area: the Gastineau Channel fault and the Fish Creek fault.

Much of Jordan Creek's main channel flows through stratified, well-drained, fine sandy loam. However, large areas of poorly drained soils with discontinuous layers of iron-containing materials exist in the upper main channel (Schoephorster and Furbish, 1974).

The undeveloped parts of the Jordan Creek watershed are vegetated by plant species typical of the coastal Sitka spruce – Western hemlock forest of Southeast Alaska. Overstory vegetation includes Sitka spruce, Western hemlock, and black cottonwood. Understory vegetation includes salmonberry, blueberry, devil's club, five-leaf bramble, gold thread, a variety of ferns, mosses and lichens. Alpine vegetation such as mountain hemlock, deer cabbage, heather, and lichens begin to dominate at about 600 meters above sea level. Riparian areas are usually populated by red alder, a variety of willow species, grasses, and sedges, with graminoid species dominating near the Mendenhall Wetlands State Game Refuge. Wetlands are found in low-lying areas throughout the watershed. Growing season is typically from end of April to end of September.

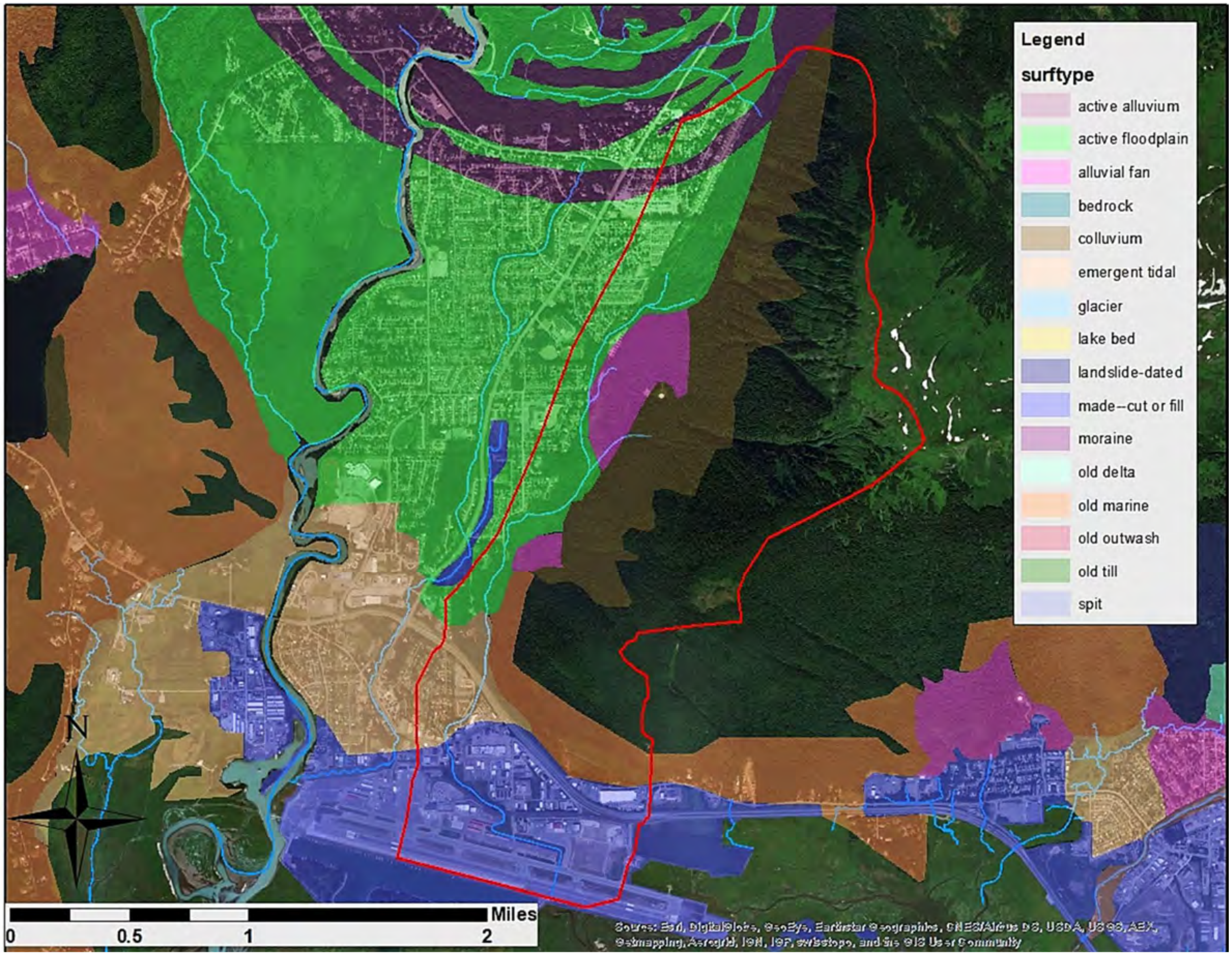

Figure 3. Surficial geology of the Jordan Creek watershed.

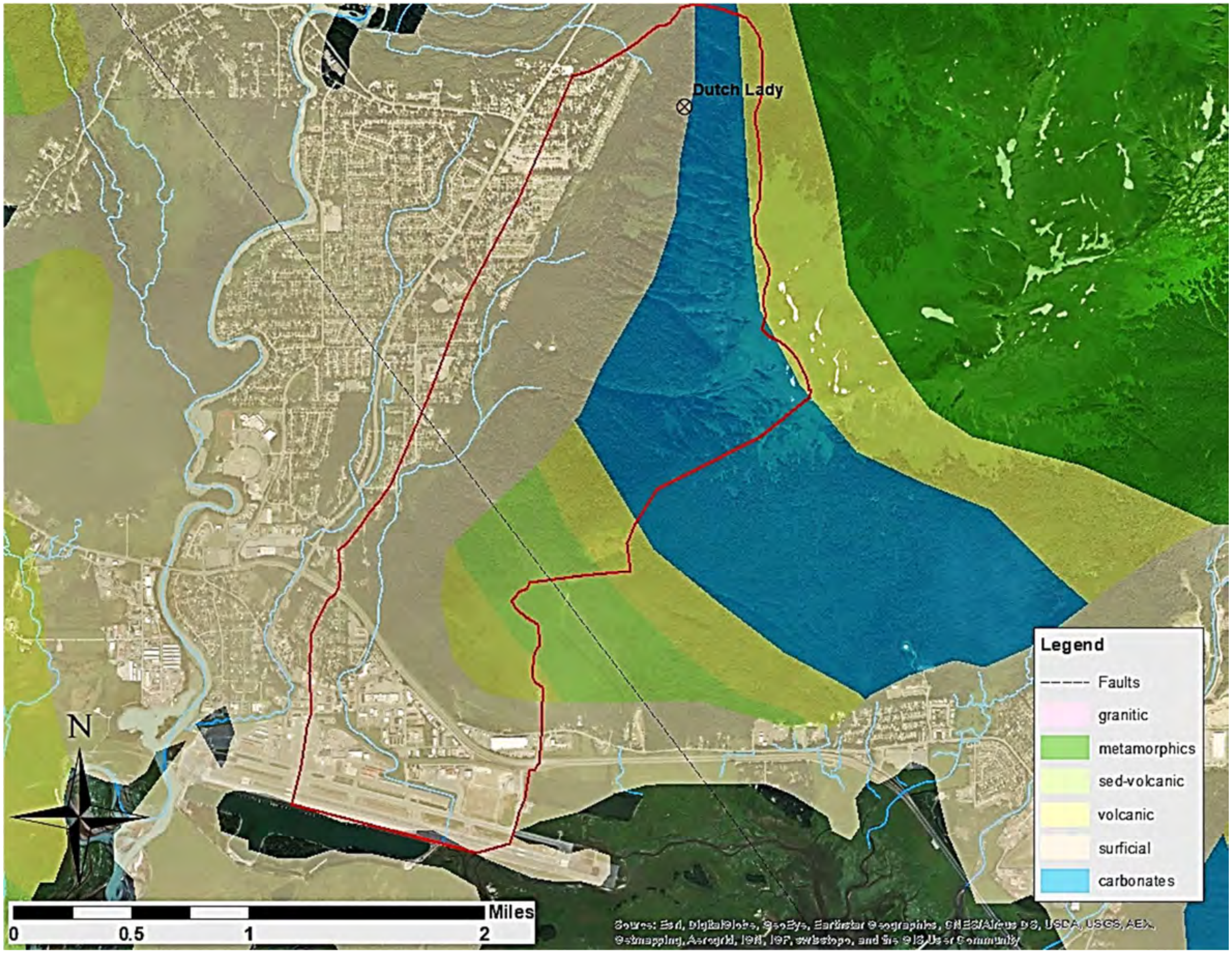

Figure 4. Bedrock geology of the Jordan Creek watershed including other geologic features.

Hydrology

Surface Water

As the Mendenhall Glacier retreated in 1750, melt water from the glacier created the ancestral channels of modern-day Duck and Jordan Creeks. After the moraine material dammed glacial meltwater, creating Mendenhall Lake, overflow from the lake continued to add water to the braided channels that formed in the Mendenhall Valley until the early 1900s. Around this time, the terminal moraine was breached by the lake water and the resultant channel became the Mendenhall River, which now is the sole outlet of the glacial melt water (Figure 5; Barnwell and Boning 1968).

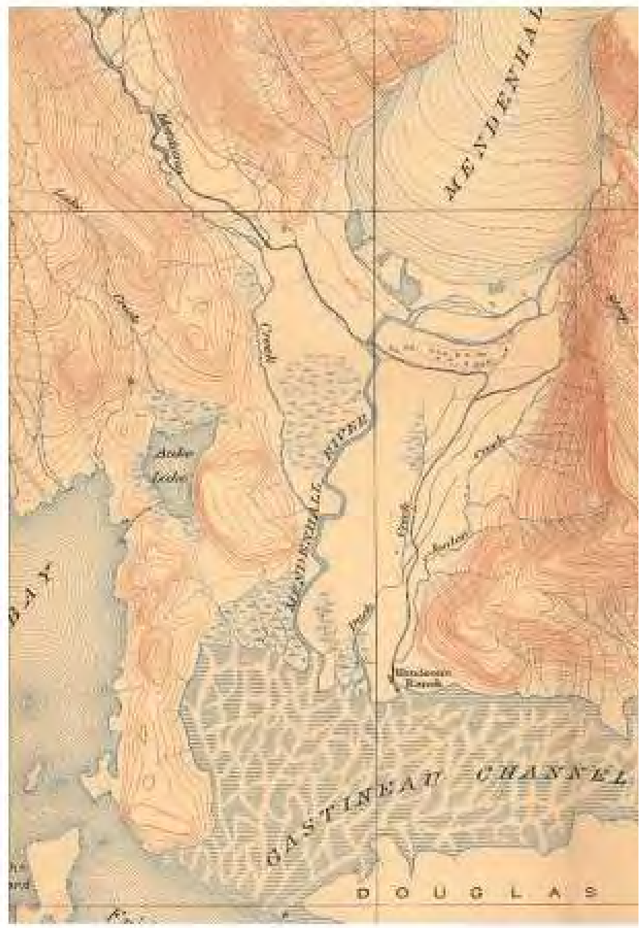

Figure 5. Mendenhall Valley in 1912. From Knopf.

Hydrological conditions in Jordan Creek were monitored by the U.S. Geological Survey's (USGS) stream gage (#15052475) from May 1997 until it was decommissioned in October 2005. A new gage (JRDA2) was installed by the National Weather Service's Advanced Hydrologic Prediction Service (AHPS) in 2012. Occasional discharge measurements were also taken at other sites as part of monitoring efforts. Currently, the data from the two gaging stations are not comparable, as the USGS provides their gage data as discharge in cubic feet per second (CFS) and the AHPS provides only the stage height (Figure 6).

Overall, Jordan Creek has low stream power with flows averaging about 7.3 cubic feet per second. However, Jordan Creek is a "flashy" watershed, with flows quickly rising and falling roughly in correlation with precipitation. Jordan Creek's flow is nearly cyclic, with two periods of high and low flows. High flows occur in the early spring (April and May) during snow melt and in the fall (September and October) when Juneau experiences frequent rain storms. Low flows occur in winter (November to March) when the stream experiences freezing temperatures and in the summer (June – August) during prolonged periods of dry weather (Figure 6).

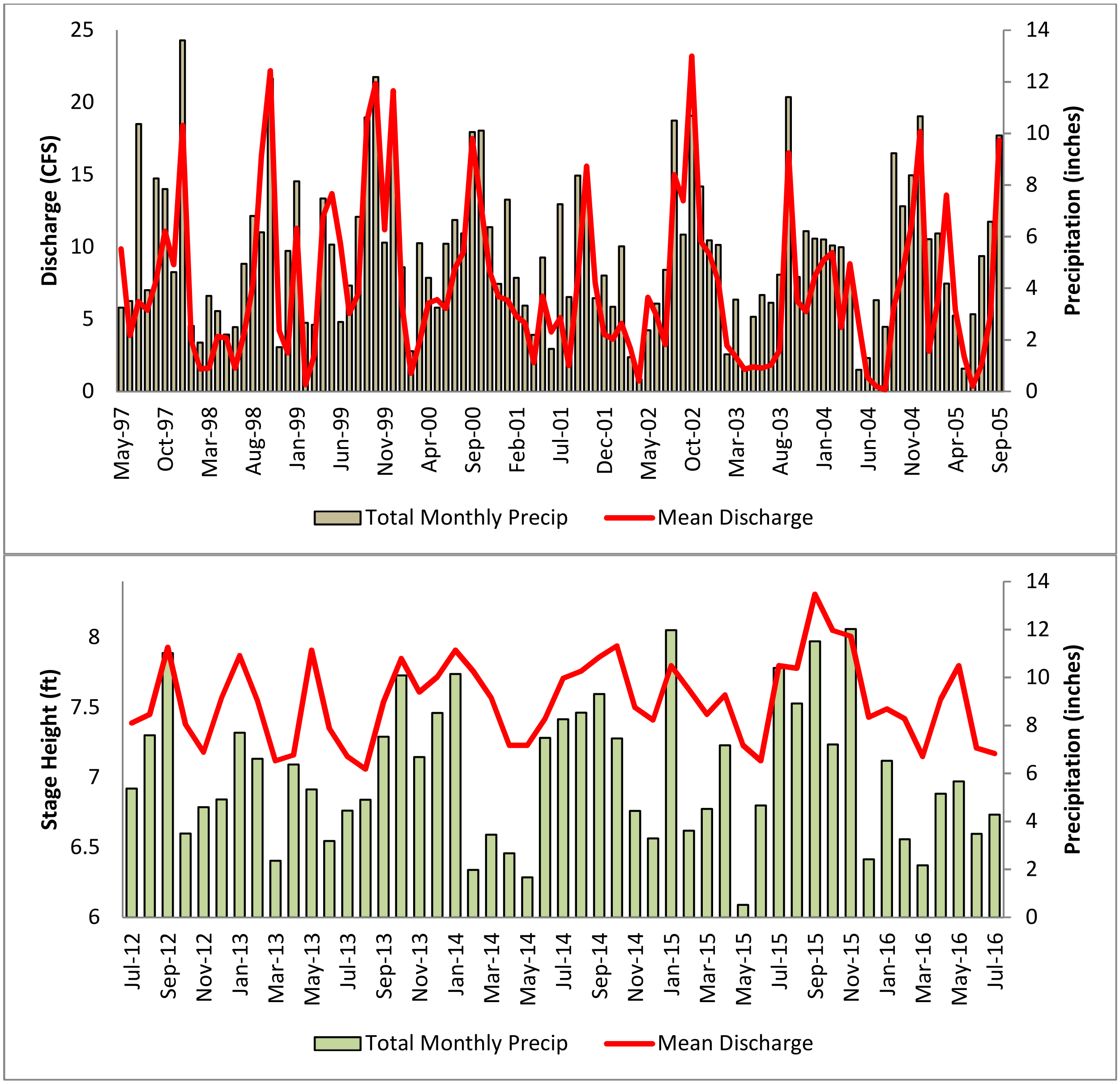

Figure 6. (Top) Mean monthly discharge measurements (in cubic feet per second, or CFS) taken at the U.S. Geological Survey's (USGS) stream gage station (#15052475) on Jordan Creek from May 1997 until it was decommissioned in October 2005. (Bottom) Mean monthly stage height (in feet) of the Advanced Hydrologic Prediction Service's (AHPS) stream gage on Jordan Creek from July 2012 to July 2016. Both the USGS and AHPS data is provided in comparison to the total monthly precipitation (in inches) measured at the Juneau International Airport.

During fall storms, lower Jordan Creek may be subject to flooding. Nearly the entire length of the mainstem is currently a Federal Emergency Management Agency (FEMA) designated regulatory floodway, and much of the lower watershed is subject to the 100-year or 500-year flood (Figure 7). However, the CBJ is currently in the process of updating the FEMA maps for Jordan Creek, so the boundaries of these flood zones are likely to change after the publication of this report.

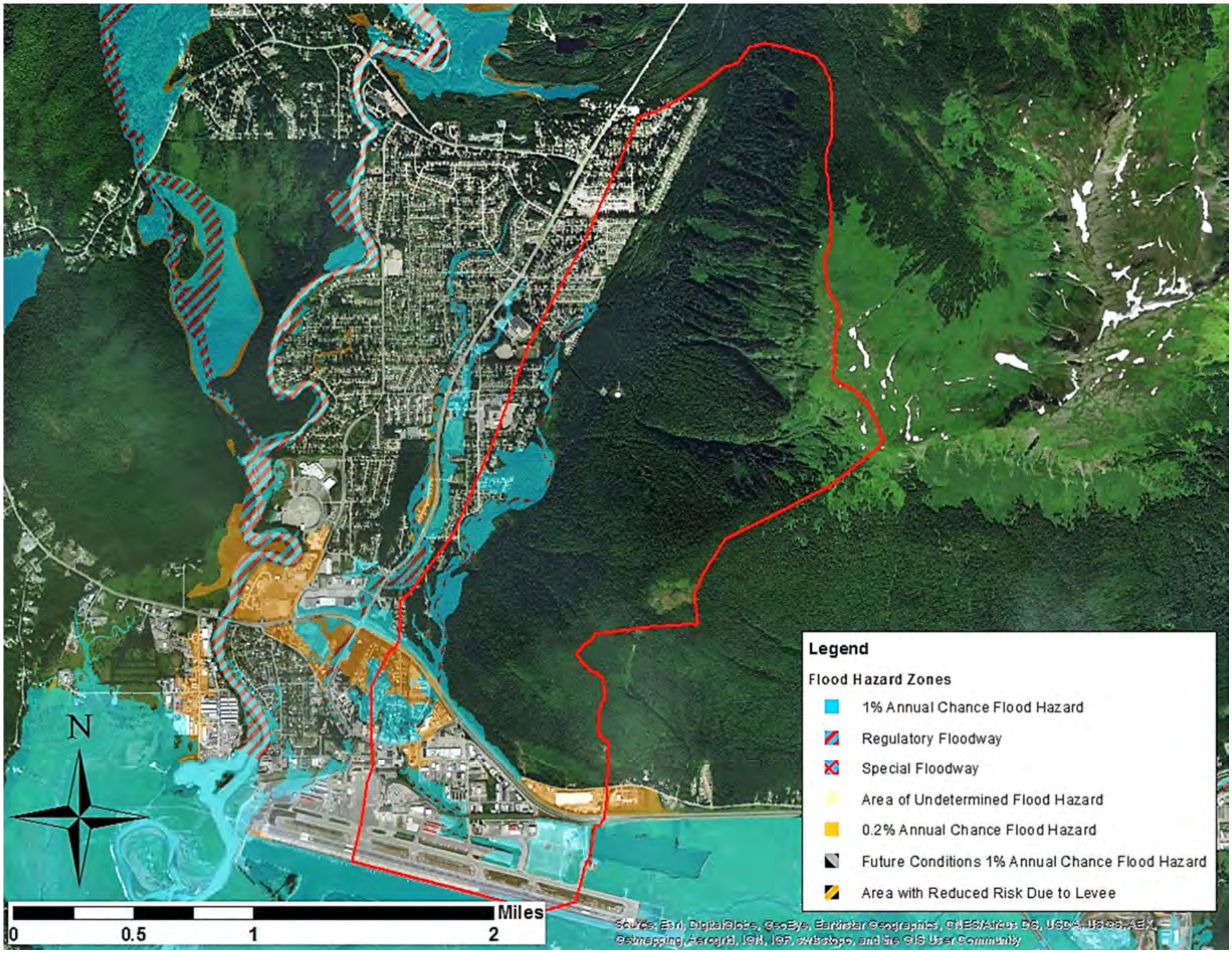

Figure 7. Federal Emergency Management Agency (FEMA) flood hazard zones in the Jordan Creek watershed.

Jordan Creek most frequently experiences flooding between Glacier Highway and Egan Drive, where the floodplains of Duck and Jordan Creeks converge. Backwater conditions during high flows also contribute to minor flooding problems along Gail Street (Carson Dorn, 2002). According to the AHPS, Jordan Creek will begin to inundate areas along the edges of the creek near Race Realty and the Jordan Square building when their stream gage is at a stage level of 9.2 feet. The designated Flood Stage is at 9.7 feet and the Moderate Flood Stage is at 10.5 feet.

Groundwater

An aquifer is a layer of permeable substrate such as gravel or sand that can transmit water. The Mendenhall Valley has two aquifers in unconsolidated floodplain and glacial outwash deposits: a lower, confined aquifer and an upper, unconfined aquifer (Figure 8). A confined aquifer is typically a deeper aquifer where groundwater is kept below an impermeable layer. The Mendenhall Valley aquifers have numerous isolated silt/clay layers creating the boundary between the upper and lower aquifers (Barnwell and Boning, 1968; McConaghy and Bowman, 1971).

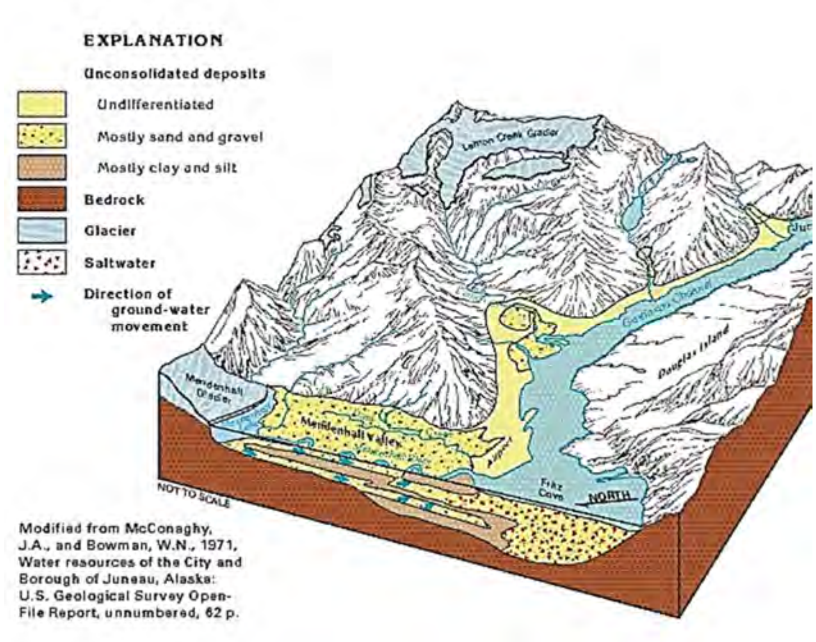

Figure 8. Diagram of groundwater conditions in the Mendenhall Valley.

The top surface of groundwater in an unconfined aquifer is often referred to as the water table, which can fluctuate in depth below the surface. The upper, unconfined aquifer interacts with the surface water (Figure 9; McConaghy and Bowman, 1971). Streams naturally interact with groundwater in one of three ways: by gaining water from groundwater inflow (called a gaining stream), losing water to groundwater through the streambed (called a losing stream), or both (Winter et al 1998). Jordan Creek interacts with groundwater in both ways and is described as having gaining and losing reaches.

In general, groundwater flows into streams occurs in the upper valley, while downstream reaches tend to lose water to the aquifer (Barnwell and Boning 1968, Osgood 1990, Alcorn and Hogan 1995). Jordan Creek receives groundwater input from several springs located at the base of Thunder Mountain, which form where groundwater intersects the land surface at the base of a mountain. Same-day stream discharge measurements taken by the USGS at six sites show that Jordan Creek tends to increase in flow from Thunder Mt. Trailer Park downstream to Nancy Street, and loses water from Nancy Street to Yandukin Drive (Host and Neal, 2004).

The Mendenhall Lake and precipitation is the primary source of recharge for the valley's aquifers (Barnwell and Boning, 1968). Early studies suggest the water table is also strongly connected to the amount of direct precipitation (McConaghy and Bowman, 1971). The water table slopes southwest (Barnwell and Boning, 1968; Osgood 1990). This essentially means that the groundwater in the unconfined aquifer flows toward the Mendenhall River.

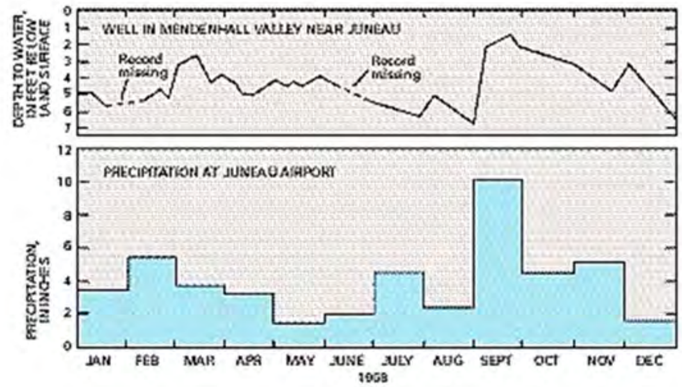

Figure 9. Measurements of depth to water in a Mendenhall Valley well and precipitation measured at Juneau International Airport. Modified from McConaghy and Bowman, 1971.

Channel Process Groups

Channel process groups are a classification system used to broadly describe streams and tributaries in terms of their hydrologic and ecologic functions. Each channel process group has a defined interrelationship between topography, geology, hydrology, and other landscape features. In Southeast Alaska, channel process groups are typically identified in accordance with the US Forest Service *Region 10 Channel Type User Guide* (Paustian et al, 1992 and 2010).

In a 2003 habitat survey, the Alaska Department of Fish and Game (ADF&G) identified three geomorphic channel types in the mainstem of Jordan Creek: shallow, groundwater-fed slough (PA3); narrow, low-gradient floodplain channel (FP3); and beaver complex (PA5) (Figure 10; Nichols and Williams, 2012). Since the 2003 ADF&G habitat survey, the US Forest Service *Region 10 Channel Type User Guide* has been updated. Therefore, the information presented here is based on the version of the *Guide* that was in use at the time the habitat survey was performed to avoid confusion.

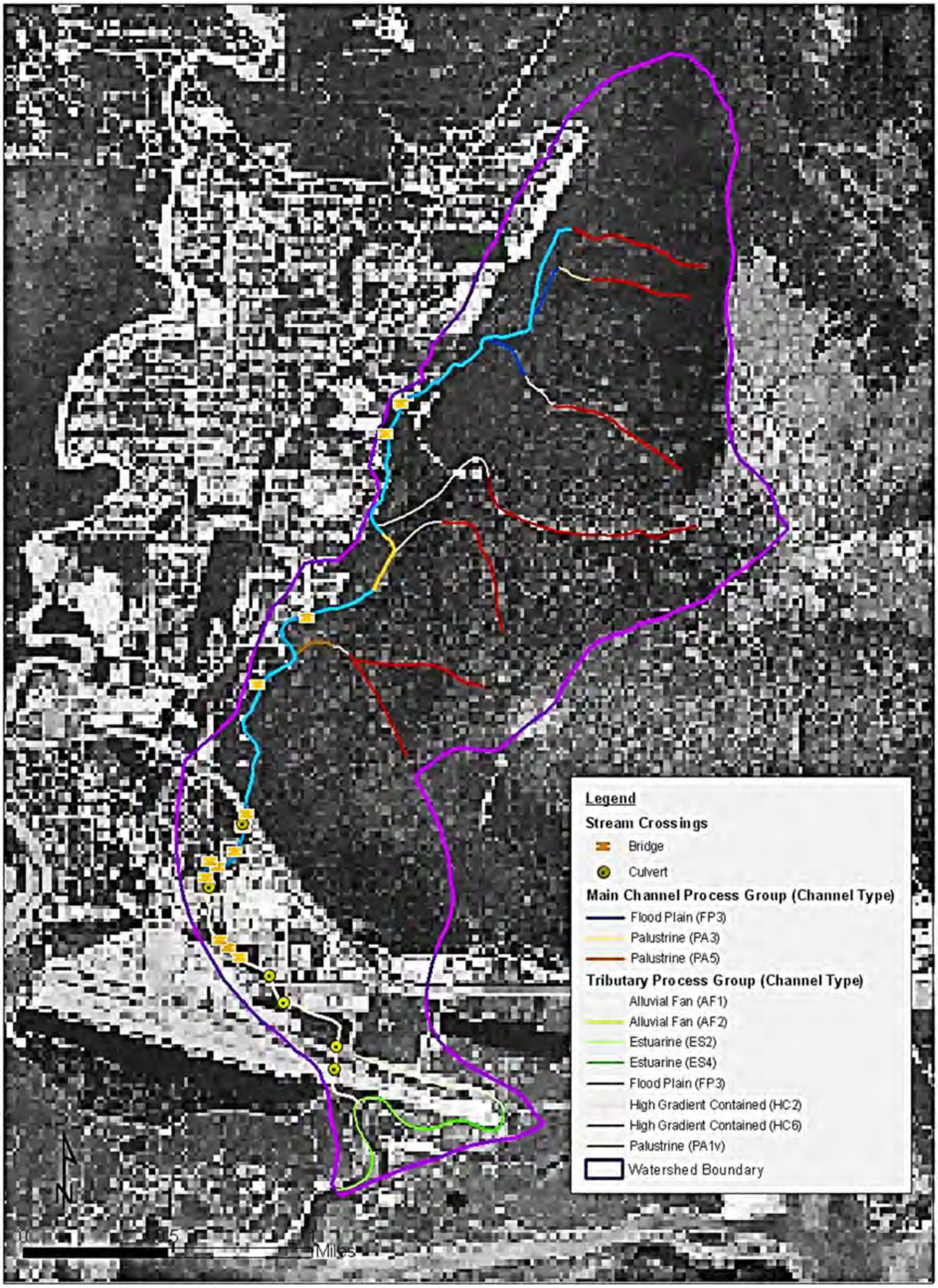

Figure 10. Data from July 2003 stream habitat survey provided by the Alaska Department of Fish and Game, Sport Fish Division for the 2006 Plan. Map created Sept. 2005.

Shallow groundwater fed sloughs (PA3) are associated with low relief glacial outwash floodplains and typically occupy relic glacial braided channels. As suggested by the channel type name, the baseflow of these channels are maintained groundwater. These channel types tend to store fine sediments due to low stream energy and low peak flows. These channels provide excellent rearing habitat for coho, sockeye, and chinook salmon, and Dolly Varden char. Land use management practices for these channel types should consider floodplain protection, reducing sediment inputs, and protecting streambanks.

Beaver Dam/Pond Channel (PA5) are associated with valley bottom floodplains and are influenced by beaver activity. Typically, beavers create these channel types from valley floodplain channels (e.g. FP3/FP4) or palustrian channels (PA1). Beaver dam/pond channel types can effectively trap sediment and reduce flood elevations. In addition, they also provide excellent rearing habitat for coho and sockeye salmon, and Dally Varden char. Deep pools created by beavers provide good overwintering habitat. Land use management practices for these channel types should consider protecting floodplains and wetlands associated with beaver pond channels.

Narrow low gradient floodplain channels (FP3) are associated with valley bottoms and flat lowlands. Where these channels occur parallel to foot slopes, like Jordan Creek, they are fed by high-gradient streams. Again, these function for sediment deposition due to low stream power. Land use management practices for these channel types should consider floodplain protection, reducing sediment inputs, and protecting streambanks. In addition, fish passage may be a concern with culvert crossings, and design and installation should avoid creating velocity barriers or scour at culvert outlets.

Fish and Wildlife

The Jordan Creek watershed supports a variety of fish and wildlife common to Juneau.

Jordan Creek is a catalogued anadromous stream (AWC#111-50-10620) supporting populations of coho, chum and pink salmon, Dolly Varden char, steelhead and coastal cutthroat trout, three-spine stickleback, sculpin and flounder. The extent of anadromous habitat is shown in Figure 11.

Mammal species include red squirrel, beaver, muskrat, porcupine, deer mouse, dusky shrew, little brown bat, Sitka black-tailed deer, mountain goat (subalpine), hoary marmot (subalpine), snowshoe hare, northern flying squirrel (nocturnal), black bear, river otter, American marten (nocturnal), short-tailed weasel and mink (Carstensen, 2013). Grey wolves are known to occur in the watershed as well (Figure 11). According to data developed by the Nature Conservancy, the upper watershed along the undeveloped toe of Thunder Mountain supports relatively good bear summer habitat and deer winter habitat.

Figure 11. A wolf in the Jordan Creek watershed capture by the US Fish and Wildlife Service Trailcam A in December 2012. Photo courtesy of John Hudson.

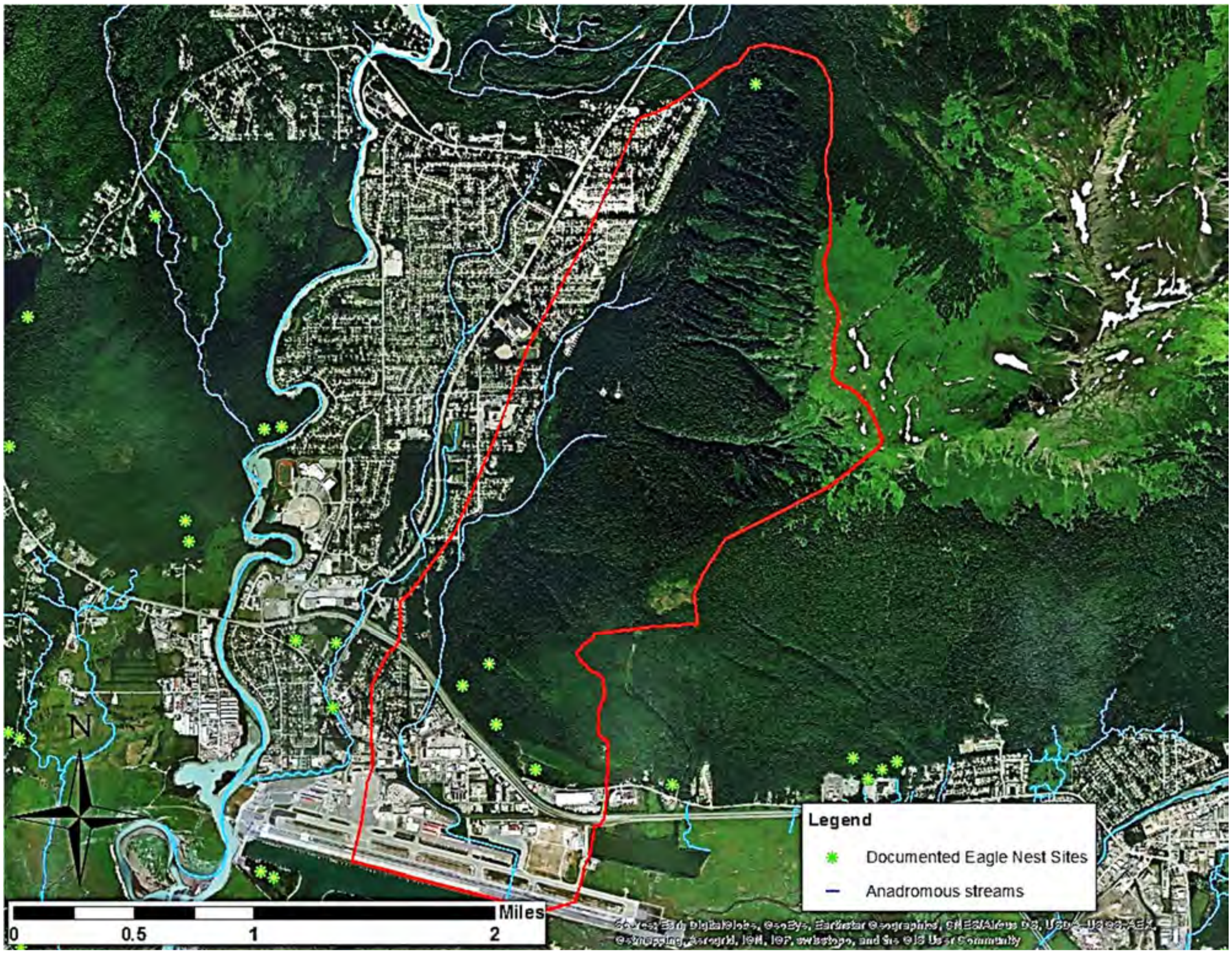

Figure 12. Designated anadromous waterbodies and identified bald eagle nests in the Jordan Creek watershed.

In addition, the upper watershed is notable for its ability to support beavers. Active beaver ponds are located approximately one mile upstream from Egan Drive (Bethers et al 2012). In the mid-1980s, these beaver ponds were noted to cover approximately 10 acres (Bethers 1985). It is possible that the beavers in the mid-watershed are migrants from the beaver population established near the Mendenhall Glacier, as there are still some corridors of intact vegetation that may promote movement into the Jordan Creek area. Recently, the JWP found evidence of beaver activity in the Jordan Creek Greenbelt, but the beaver lodge has been taken over and utilized by river otters. Beavers greatly influence in-stream habitat and stream processes in areas of Jordan Creek where they are active.

There are also a variety of bird species that utilize the watershed including waterfowl, shorebirds, raptors, and song birds. Birds are particularly numerous in and around the Mendenhall Wetland State Game Refuge. According to the U.S. Fish and Wildlife Service data regarding documented bald eagles nest sites, there are five nest sites in the watershed (Figure 12). However, this data is not regularly maintained and may be out of date.

Land Management

Development History

The Mendenhall Valley is part of the traditional Aak'w kwaan territory. The village near Auke Bay was the primary Aak'w kwaan village until the 1880's when most of the people moved to the Gold Creek area to work for the mining companies that had moved to Juneau. There are no specific references regarding traditional uses or places within the Jordan Creek watershed prior to European contact. However, land uses at that time likely included subsistence hunting, fishing and gathering. There was a big smokehouse, Te'cuns, near Duck Creek. This area was rich with cranberries, nagoonberries and wild rice, which were gathered (Goldschmidt and Haas, 1998).

Jordan Creek was named by Daniel Foster and M.Y. Hurst, who filed homestead claims near the creek in 1895. For a brief time, Jordan Creek became known as Livingston Creek, after Arthur Livingston, who located a mining claim in the creek's headwaters in 1887 and lived near the stream. Thomas Knudson renamed the creek Jordan Creek in 1903, but it is unclear whether this was derived from the name given to the stream by Foster and Hurst or renamed for Harry Jordan, who came to Juneau in 1896 and operated the Glory Hole Saloon in Douglas (Orth 1971).

In the early 1900s, the Mendenhall Valley was sparsely populated by homesteaders, mink and fox farmers, and dairy farmers. As Juneau's population began to grow, dairy farms were established across the Mendenhall Valley, where larger tracts of land were available. Major dairies that had operations in the Jordan Creek watershed include the Juneau Dairy (later renamed Smith Dairy), which operated from 1911 to 1965; the Mendenhall Dairy (1917 – 1961?); and the Alaska Dairy (1923 – 1965) (Alaska State Library, nd; CBJ, 1991).

Figure 13. Dairy cows in a creek in the Mendenhall Valley.

In 1907, the Tongass National Forest was established. However, land within the Jordan Creek watershed was not incorporated into the Tongass until two years later, when the National Forest boundaries were expanded. This placed much of the upper watershed under federal management.

The first road in the valley was built in 1903 along Duck Creek to the glacier for hauling supplies to mines on Nugget Creek. The Juneau-Eagle River road was built by the Alaska Road Commission between 1909 and 1918 to provide access to the mines north of Juneau and to several dairies and ranches in the valley. However, access to the Mendenhall Valley was primarily by boat until the 1960s (CBJ 1991).

World War II brought in development along the lower watersheds of Jordan and Duck Creeks, primarily associated with airport operations. In 1934, an emergency landing field was constructed. Two years later, Pan American Airlines/Pacific Northern Airlines (PAA/PNA) bought 20 acres to build the Juneau airport. The paved runway was constructed in 1942, with the original terminal following in 1948. PAA/PNA began service between Juneau, Seattle and Anchorage in the 1940s. These early airport developments modified the mouth of Jordan Creek. Approximately 2,500 feet of the channel from Yandukin Drive to the runway was relocated and channelized. The stream was then routed through a 375-foot corrugated culvert under the runway (MVDS, 1979).

The late 1950s and 1960s saw many changes for the Jordan Creek watershed and the Mendenhall Valley in general. The dairies became less profitable during the war due rising costs of feed and surface transportation, and air services allowing for importation of non-local dairy products. By 1965 all the dairies had closed. However, the land cleared for the dairies provided ideal property for development (CBJ, 1991).

During this time, development in the Mendenhall Valley included flood control, dikes, ditches, gravel pits, fills, storm water drainage, road development, and the building of homes and places of business. Residential areas began to appear near the airport and other locations throughout the valley. In 1954, the first subdivision, Airport Acres, was developed followed by Cascade Manor in 1958. The first tract home construction in the upper Mendenhall Valley was in 1961 in Mendenhaven. The Airport terminal was expanded in 1957 and the runway was expanded in 1961.

This development relied on utilizing excavated alluvial material for fill and construction material. This excavation created a series of dredged ponds throughout the Mendenhall Valley (MVDS, 1979). These ponds exposed groundwater and may have affected groundwater dynamics. One such operation occurred in the Jordan Creek headwaters near the Thunder Mountain Trailer park. This was known by two names: the Reid gravel pit, and the MPM gravel pit. The resultant pit, over 70 feet deep, was once used as a dump site. The pit was filled and drainage diverted to Duck Creek.

Other support activities for the increasing development also impacted the watershed. Parts of middle Jordan Creek were logged or hi-graded for spruce. At this time, there was little control of the logging. As a result, an area near the east end of Nancy Street was clearcut. Slash and logging debris remain in the area (Bethers et al 2012).

In the 1970s, residential development continued to increase in the Mendenhall Valley. This was promoted by the construction of the valley sewer system in 1973. During this time, home construction extended to the west bank of Jordan Creek in the upper watershed. Another major development was the construction of the Egan Drive Causeway (MVDS, 1979). The Nugget Mall was also developed in the 1970s. In the 1970s most of the domestic water supply for the Mendenhall Valley was drawn from ground water.

The Airport terminal was expanded again in 1984, and the runway in 1989. In 1985, the East Valley Reservoir (EVR) was constructed in the Jordan Creek watershed. The EVR is a two-million-gallon domestic water tank constructed at the apex of an alluvial fan formed by a tributary to Jordan Creek. The EVR tributary was channelized to protect the tank and three sediment traps were constructed at the end of the channelized reach. The traps prevent the fan from encroaching on Jordan Creek, which increased the risk of localized flooding at the east end of Jennifer Drive. A restoration project completed in 2009 removed alluvial fan sediments from Jordan Creek and restored the channel to increase flow conveyance.

The upper watershed remains mostly undeveloped on the eastern side, due to the lack of easily developable land along Thunder Mountain. However, residential developments lie on the western side of the upper watershed. Although these developments have not encroached upon riparian habitat along the stream, urban stormwater runoff from these areas flow directly into the stream. The most intensely developed area is below Egan Drive, where residential and commercial developments encroach on the stream. A greenbelt was established by the CBJ along a section of the lower watershed, adjacent to the

Figure 14. Series of aerial photos showing the progression of development in the Mendenhall Valley.

few remaining undeveloped parcels. Of the parcels that were undeveloped at the time the greenbelt was established, only one remains undeveloped at this time. However, apartment-style housing is planned to be constructed on this parcel in the future.

Current Ownership, Land Use and Management

Most of the upper Jordan Creek watershed is owned and managed by the U.S. Forest Service as part of the Tongass National Forest. The State of Alaska owns a large parcel of land in the mid-watershed that is managed by the Alaska Department of Natural Resources (DNR). The City and Borough of Juneau (CBJ) owns and manages several pieces of property throughout the watershed, but the properties are managed by different departments within the CBJ including the Juneau International Airport (JIA), Parks and Recreation, Lands and Resources, Juneau School District, Public Works, and Capital City Fire and Rescue. The State of Alaska Department of Transportation and Public Facilities owns and maintains highway rights of way along Glacier Highway, Egan Drive, and Mendenhall Loop Road; the CBJ owns and maintains the rights of way for city streets. The remaining property within the watershed is privately owned (Figure 15).

National Forest lands, such as the Tongass National Forest, are managed for multiple uses as set forth in the Forest Plan. Generally, national forests are managed for resource development (e.g. timber harvest) and recreation, though areas may be designated for protection (e.g. wilderness areas) or for research purposes (e.g. experimental forests). The Tongass Forest Plan (2008), designates land within the Jordan Creek watershed within the National Forest boundaries for semi-remote recreation and mineral exploration.

Land use and management on State of Alaska lands in the Juneau area is guided by the policies set forth in the *Juneau State Land Plan*. The State land within the Jordan Creek watershed is managed for habitat and recreation.

Within the CBJ boundaries, regardless of ownership, land use and development is generally guided by the policies set forth in the current CBJ *Comprehensive Plan* (2013) and regulated by the CBJ's Land Use Code. Land use designations in the upper watershed include primarily Medium (MDR) and Urban Low Density (ULDR). State lands are designated as Institutional/Public Use (IPU), and USFS lands are designated for Recreation (R). The lower watershed is primarily Commercial (C) and Light Industrial (LI) land uses. There are a few Stream Corridors (SC) designated along portions of Jordan Creek. These designations are described in further detail in Table 2.

The CBJ also has other plans that direct development of CBJ's public lands including but not limited to: the *Land Management Plan* (2016), *Areawide Transportation Plan* (2001), *Juneau Non-Motorized Transportation Plan* (2009), *Juneau Parks and Recreation Comprehensive Plan* (2007), and the *Juneau Trails Plan* (1993).

In addition to CBJ's Land Use Code, both public and private property owners are subject to other state and federal laws and regulations that guide land management and development practices.

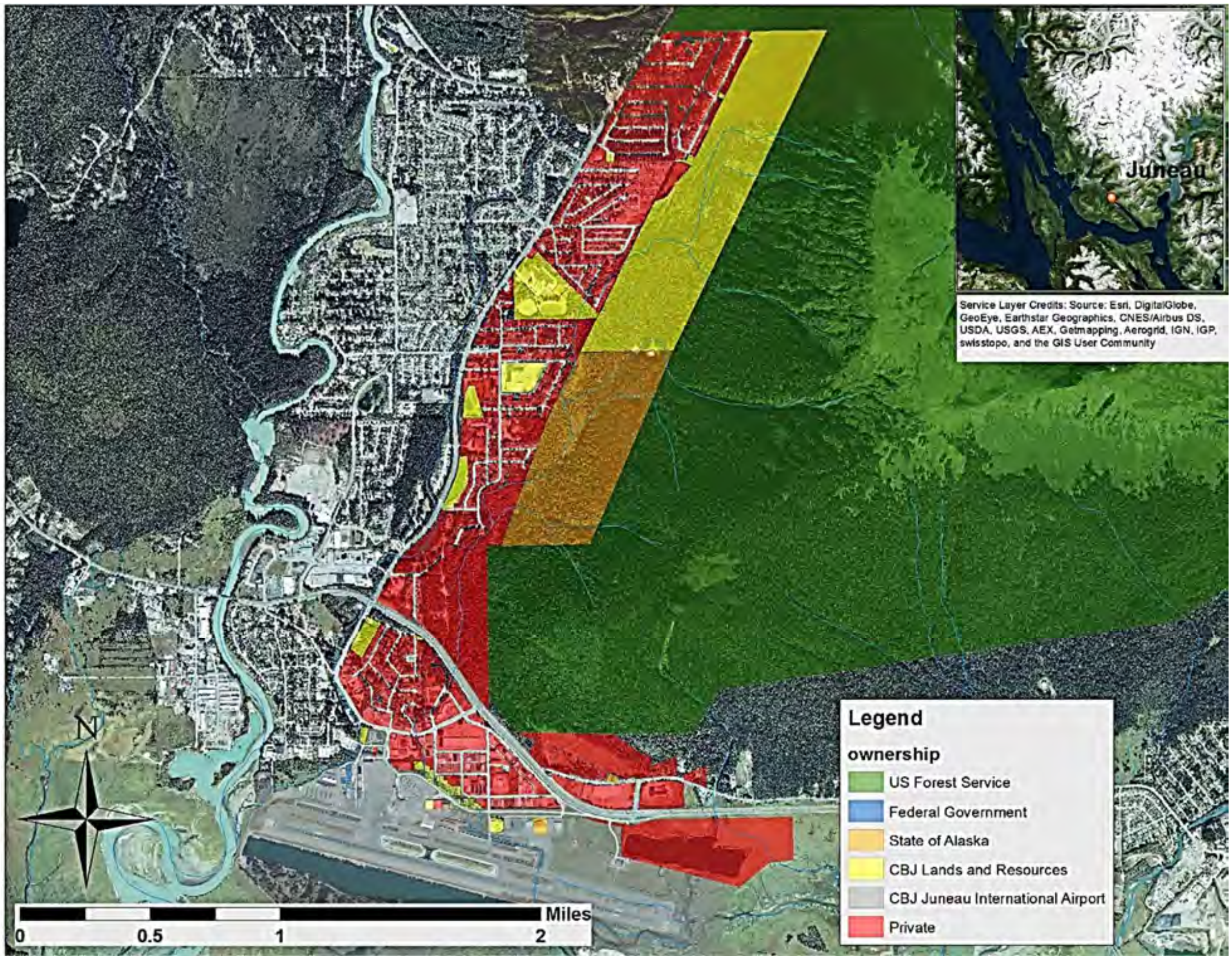

Figure 15. Land ownership in the Jordan Creek watershed.

Table 2. Designated land uses in the Jordan Creek watershed, as described in the CBJ Comprehensive Plan (2013).

Land Use Code	Definition
Medium Density Residential (MDR)	Urban residential lands for multifamily dwelling units at densities ranging from 5 to 20 units per acre. Any commercial development should be of a scale consistent with a residential neighborhood, as regulated in the Table of Permissible Uses (CBJ 49.25.300).
Urban Low Density Residential (ULDR)	Urban or suburban residential lands with detached single-family units, duplex, cottage or bungalow housing, zero-lot-line dwelling units and manufactured homes on permanent foundations at densities of one to six units per acre. Any commercial development should be of a scale consistent with a single family residential neighborhood, as regulated in the Table of Permissible Uses (CBJ 49.25.300).
Institutional/Public Use (IPU)	Lands that are in public ownership and dedicated for a variety of public uses. The public use of these lands will vary widely, so IPU-designated lands can be under any zoning district, with the uses thereon appropriate for that zone as regulated in the Table of Permissible Uses (CBJ 49.25.300); the zone of any particular public use should be the same district as the surrounding or abutting lands.
Recreation (R)	Land primarily under federal or state management for a range of resources, such as timber, minerals, fish and wildlife and recreation uses, including recreation cabins. Uses may include small-scale, visitor-oriented, and/or seasonal recreational facilities. These lands should be zoned to prevent residential, commercial, and industrial development.
Commercial (C)	Lands devoted to retail, office, food service or personal service uses. Residential and non-residential uses could be combined within a single structure, including off-street parking. Residential densities ranging from 18- to 60-units per acre are appropriate in this area, with even higher densities appropriate in mixed-use or transit-oriented developments. Ground floor retail space facing roads with parking behind the retail and housing above would be an appropriate and efficient use of the land.
Light Industrial (LI)	Land to be developed for heavy commercial or light industrial uses. Residential units should be limited to caretaker units where the occupant works directly for or owns the business for which the occupant is caretaking.

Water Supply

The Mendenhall Valley was studied by Barnwell and Boning (1968) for potential water supply as the population in the area began to grow. The groundwater was found to be moderately hard and containing high levels of iron. In the 1970s, most of the domestic water supply was drawn from groundwater. The Salmon Creek Reservoir started providing drinking water to the Mendenhall Valley in 1984. By the late 1990s, wells were abandoned in favor of the municipal water system (Carson Dorn, 2002).

However, there are still groundwater appropriations for water use in the Jordan Creek watershed and throughout the Mendenhall Valley. These appropriations are primarily for domestic use. However, there is no information as to whether these appropriations are currently being used. There is a drinking water system and protection area for the Thunder Mountain Mobile Park (Figure 16).

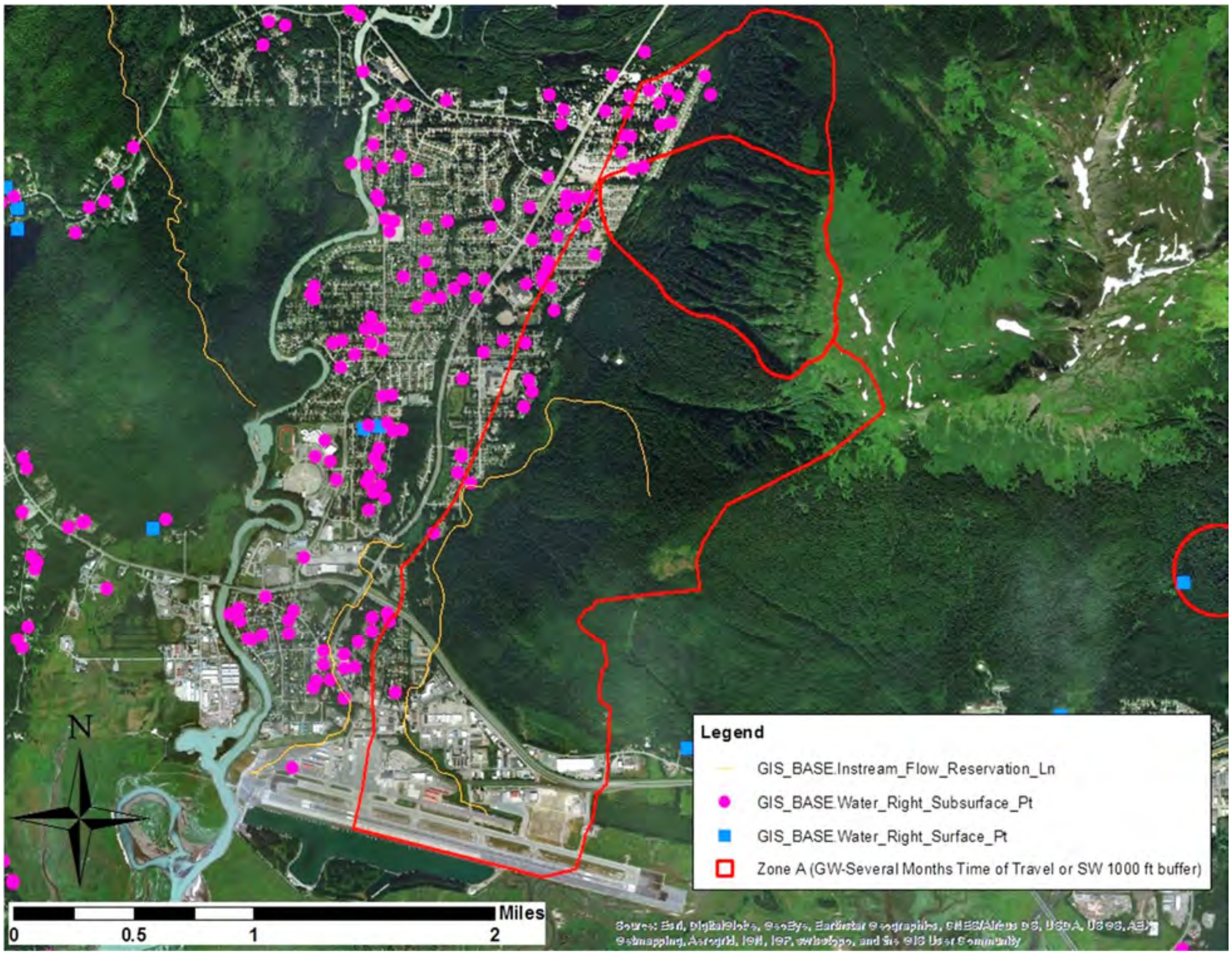

Figure 16. Subsurface water rights (purple dots), in-stream flow reservations of water (yellow line), and drinking water protection areas (red border) in the Jordan Creek watershed.

Recreation

Due to an interconnected trail system, the upper watershed supports excellent recreational opportunities such as hiking, running, mountain biking, and bird watching. Recreational opportunities are more limited in the lower watershed where urban development and private land ownership limits recreational use. This section describes the recreational facilities in the Jordan Creek watershed.

The Jordan Creek Aquatic Education Trail is a 0.3-mile long trail built in 1991 through a partnership between the ADF&G, Division of Sport Fish and the CBJ Department of Parks and Recreation. As suggested by its name, the trail's purpose was to provide access to the creek for educational opportunities. It is located near the Glacier Valley Elementary School and is accessed at the end of Jennifer Drive. The Aquatic Education Trail connects to the Thunder Mountain Trail and Under Thunder Mountain Trail.

The Thunder Mountain Trail is a three-mile long trail that climbs 2,700 feet up Thunder Mountain. It is also accessed from the end of Jennifer Drive. It is not a well-maintained trail and is only recommended to experienced hikers. The upper trail can be accessed from another trail starting at 7-mile Glacier Highway that is not as steep, but is a longer, muddier route.

The Under Thunder Mountain Trail is a 1.8-mile long trail that follows the base of Thunder Mountain and eventually connects to the Powerline Trail and the Trail of Time in the Mendenhall Glacier Recreation Area. The existing trail was completed in 2012. The trail is intended to provide a continuous trail corridor from Mendenhall Glacier Recreation Area to Egan Drive, but currently does not connect to the multi-use path at Egan Drive due to a right of way needs.

The Airport Dike Emergency Vehicle Access Road is a 1.2-mile long gravel road located on JIA property. While serving the JIA as an emergency vehicle access, it also provides access and recreational opportunities on the Mendenhall Wetlands State Game Refuge. The road ends near the mouth of Jordan Creek.

The Jordan Creek Greenbelt consists of 10 acres of undeveloped land owned by the CBJ, making it the largest vegetated area remaining in the lower Jordan Creek watershed. The existing improvements (trails and bridges) were placed by the JIA as mitigation for construction activities in the early 1990s (Parry and Seaman, 1994). After the improvements were made, the Greenbelt was designated as a Natural Area Park in 1996. Natural Area Park is defined by CBJ Parks and Recreation as: “areas of natural quality designed to serve the entire community by providing open space, access to water, and opportunities for passive and dispersed recreation activities.”

Environmental Concerns in the Lower Watershed

Watershed health is a combination of the physical, chemical and biological components of the watershed put into context of the watershed's ability to support fish and wildlife habitat, and human uses (e.g. recreation, drinking water, resources). Jordan Creek is known to suffer from dewatering, poor water quality, sedimentation and impaired in-stream and riparian habitat. While this section examines each of these problems separately in detail, they are often interconnected in complex ways.

Low Flows and Dewatering

Low and no-flow conditions have been observed in lower portions of Jordan Creek since the 1960s according to unpublished reports from ADF&G (Savell, 2006). However, it was only relatively recently that a better understanding of the processes contributing to low and no flow conditions has been uncovered.

Figure 17. Jordan Creek downstream of Egan Drive during no flow conditions.

A combination of factors contributes to low and no flow conditions in Jordan Creek (Figure 17). USGS investigations found that low and no flow conditions are connected to regional uplift affecting the surface water – groundwater interactions in the valley. In response to regional uplift, the Mendenhall River is currently incising, or down-cutting, its channel, which lowers the local water table (Figure 18). Water table elevations in the Mendenhall Valley have decreased by 3.7 centimeter (1.5 inch) per year over the last two decades (Walter et al 2004). In 2009, water table elevations in the Mendenhall Valley ranged from 1.5 to 3.2 meters (~5 – 10.5 feet) below the land surface (Neal, 2009).

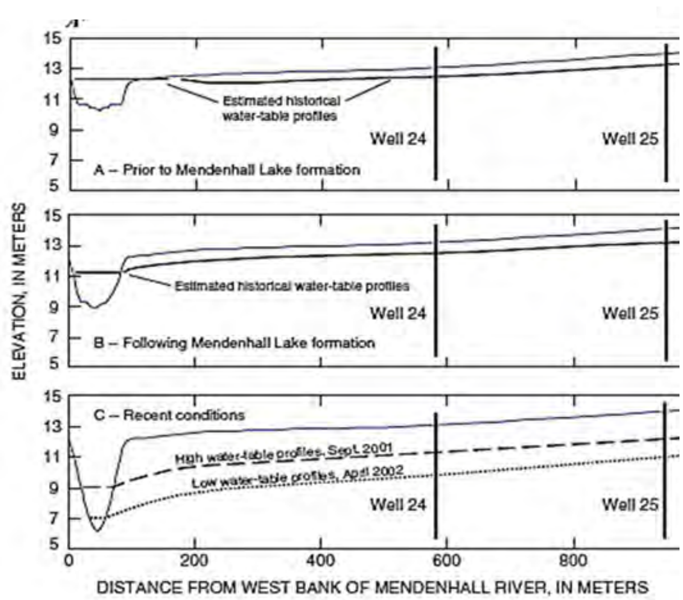

Figure 18. Mendenhall River incision and its effect on groundwater. Adapted from Neal (2009).

The incision process normally would be slowed by sediment input to the river, but Mendenhall Lake provides a sink for much of the sediment from the glacier, and Montana Creek does not provide enough sediment to affect the incision rate (Neal 2009; Neal and Host, 1999).

Lowering of the water table contributes to loss of stream flows in both Duck and Jordan Creeks, since the water table no longer intercepts the streambed (Neal, 2009; Host and Neal, 1999). An investigation by the USGS indicates Jordan Creek downstream of Egan Drive may dewater when flows at the former USGS stream gage fell below 0.6 CFS. Their analysis of stream gage data suggests Jordan Creek has flows equal to or less than 0.6 CFS about 4 percent of the time (Host and Neal, 2004). Such information and analysis is not available for the existing stream gage.

However, the upper reaches of Jordan Creek may have some hydraulic isolation from these changing dynamics. The upper main channel is located on abandoned glacial outwash deposits that are isolated to the east-side of the upper valley (Barnwell and Boning, 1968). These abandoned outwash deposits may contain sills of less porous, finer material, providing for hydraulic isolation (Vigil-Agrimis, Inc. 2002).

In addition, the water table is relatively higher on the east side of the valley, even as the water table is lowered (Figure 18). The higher water table at the base of Thunder Mountain ensures that spring water supplies Jordan Creek with groundwater inputs. Springs tend to provide perennial flow that helps maintain base flow during extended dry periods.

The lower reaches of Jordan Creek are located on floodplain deposits. These deposits likely provide a stronger hydraulic connection to the Mendenhall River, which is entirely located on these deposits (Barnwell and Boning, 1968; Vigil-Agrimis, Inc. 2002). This promotes infiltration in the lower reaches of Jordan Creek during periods of low precipitation.

Another factor identified as potentially contributing to dewatering is groundwater withdrawals from the aquifer for water supply (Bethers et al, 2012). As shown in Figure 16, there are many subsurface water rights in the Jordan Creek watershed and throughout the Mendenhall Valley. However, there is no information as to whether appropriations outside of the drinking water system for the Thunder Mountain Trailer Park are being used. It is suspected that many wells were abandoned in favor of connection to the municipal water supply (Carson Dorn, 2002). However, there is no information on the effects of well withdrawals on groundwater levels in Juneau.

To protect instream fish habitat, the ADF&G maintains an instream flow reservation for Jordan Creek (Figure 16). This water right prevents other water users from appropriating water that may affect the stream’s ability to support fish. The stream length protected by the instream flow reservation roughly corresponds with the anadromous habitat mapped by ADF&G.

A report to the CBJ by Kelly et al (2007) presents current and potential future impacts to Juneau resulting from climate change based on a review of available scientific data. In general, it is projected that Juneau will trend toward a warmer, wetter climate. Juneau is still expected to receive most of its precipitation in the fall and winter, with a shift to more rain and less snow in the lower elevations. The warmer spring and summers are expected to have less than average rainfall. This climatic trend may affect Jordan Creek’s hydrology.

As mentioned, Jordan Creek is a flashy system that responds rapidly to precipitation. More rain in the fall and winter could increase seasonal flooding. More frequent, intense floods could impact rearing and overwintering habitat by increasing sediment inputs and reducing habitat complexity by removing wood and diminishing pools.

On-going land surface uplift, lowering of groundwater, and decreased precipitation in spring and summer, will likely continue to contribute to seasonal low and no flow conditions, which could worsen over time. Decreased precipitation during these months will continue to limit both surface and ground water supplies to Jordan Creek. This may cause the stream to become more ephemeral, where it does not flow yearround. Persistent low and no flow conditions would continue to affect spawning, rearing and overwintering habitat capacity as previously described.

However, definitive conclusions cannot be made as to how Jordan Creek will respond to conditions brought on by climate change. Management strategies that could reduce the impact of climate change on the stream may include preserving thermal refugia and critical habitats, and reducing impacts from pollution and habitat deterioration that could have a cumulative effect.

Water Quality

Water quality generally refers to the condition of the chemical components of a waterbody. Traditional water quality parameters include water temperature, pH, dissolved oxygen (D.O.), turbidity, and specific conductance. Total suspended solids (TSS), total dissolved solids (TDS), dissolved iron, and other dissolved inorganic elements (sodium, chloride, sulfate, and potassium) are additional parameters that have been collected on Jordan Creek. This section discusses the available monitoring data, particularly with regards to the water quality standards and known water quality impairments.

Available Data

There are ten established monitoring stations on Jordan Creek that have been used in various water quality studies (Figure 18). The USGS established these monitoring stations, some of which were then used under other names, rather than the USGS Station number, in studies conducted by the JWP and the University of Alaska Southeast (UAS) (Figure 19 and Table 3).

The sites at Amalga Street (Station #15052450, aka JC-A), Egan Drive (#15052475, aka JC-B), and Yandukin Avenue (#15052483, aka JC-C) were regularly used from 2003 to 2013 in water quality monitoring efforts financially supported by the CBJ and the Alaska Department of Environmental Conservation (DEC). These sites have the most extensive record and this data will be discussed in further detail by parameter.

Statistical analysis including correlation analysis, analysis of variance (ANOVA) and two sample t-tests were conducted on the data as part of developing this plan to help inform the process. The results will be generalized for the public in the following discussions, but the statistical analysis is provided in Appendix C.

However, this 10-year data set and data analysis still has limitations. Periodic sampling reflects pollutant concentrations at that moment in time, and is unlikely to adequately characterize in-stream peak concentrations associated with rainfall events, or any other episodic exceedances of Water Quality Standards. In addition, water quality monitoring ended in 2013, so this may not accurately reflect current conditions.

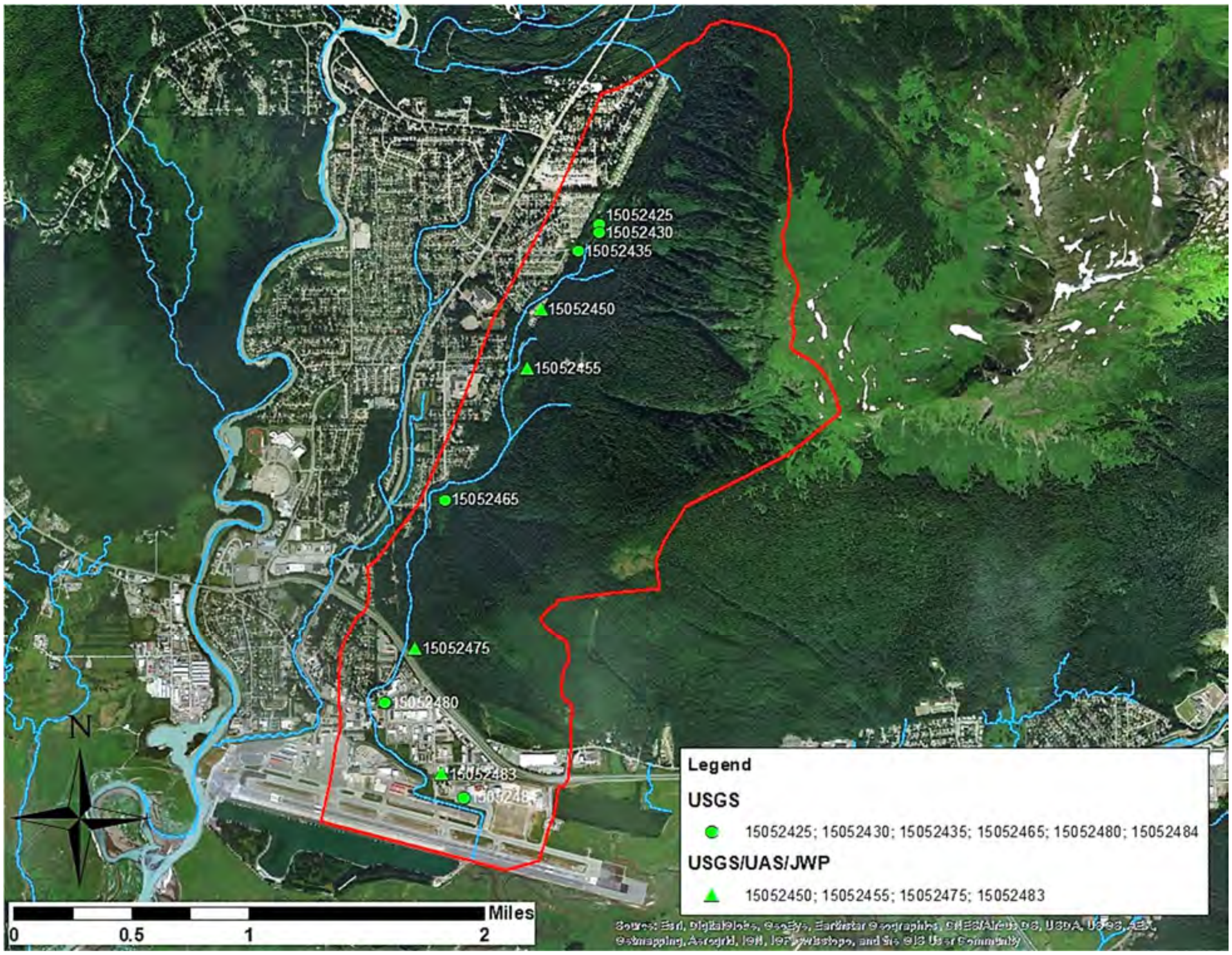

Figure 19. The U.S. Geological Survey (USGS) monitoring stations in the Jordan Creek watershed. Those used in studies by the University of Alaska Southeast (UAS) and the Juneau Watershed Partnership (JWP) are distinguished by triangles.

Table 3. Monitoring stations including their U.S. Geological Survey (USGS) station numbers, corresponding Juneau Watershed Partnership (JWP) and University of Alaska Southeast (UAS) site names, and available data.

USGS Station #	Name	Corresponding JWP/UAS Sites	Data Available
15052425	Jordan Cr Trib at Thunder Mt Trailer Pk		• 8 measurements for streamflow between May 1999 and June 2002 (USGS)
15052430	Jordan Cr Trib bl Thunder Mt Trailer Pk		• 14 measurements for streamflow between Sept. 1998 and March 2002 (USGS) • 5 sampling events for various parameters between Sept. 1998 and Aug. 1999 (reported in Host and Neal, 2004).
15052435	Jordan Cr Trib at Valley St		• 4 measurements for streamflow between May and Aug. 1999 (USGS) • 5 sampling events for various parameters between Sept. 1998 and Aug. 1999 (reported in Host and Neal, 2004).
15052450	Jordan Cr Trib at Amalga St	JC-1/JC-A	• 22 measurements for streamflow between July 1997 to June 2002 (USGS) • 12 sampling events for various parameters between July 1997 and Aug. 1999 (reported in Host and Neal, 2004). • 166 sampling events for various parameters between 2003 and 2013 (UAS/JWP)
15052455	Jordan Cr at Jennifer Dr	JC-2	• 4 measurements for streamflow between May 1999 and June 2002 (USGS) • 29 sampling events for various parameters between 2003 and 2005 (UAS/JWP)
15052465	Jordan Cr Trib at Nancy St		• 14 measurements for streamflow between March 1999 to June 2002 (USGS) • 4 sampling events for various parameters between Sept. 1998 and Aug. 1999 (reported in Host and Neal, 2004).
15052475	Jordan Cr Trib bl Egan Dr	JC-3/JC-B	• 3823 measurements for temperature between July 1999 and Sept. 2004 (USGS) • 3075 stream gage measurements for streamflow/discharge between May 1997 and Sept. 2005 (USGS) • 104 field measurements for streamflow between July 1984 and October 2005 (USGS) • 8 sampling events for various parameters between July 1997 and Aug. 1999 (reported in Host and Neal, 2004). • 138 sampling events for various parameters between 2003 and 2013 (UAS/JWP)
15052480	Jordan Cr Trib near Auke Bay		• 11 measurements for streamflow between April 1997 to March 2004 (USGS) • 5 sampling events for various parameters between Aug. 1965 and May 1968 (USGS) • 4 sampling events for various parameters between Sept. 1998 and Aug. 1999 (reported in Host and Neal, 2004).

USGS Station #	Name	Corresponding JWP/UAS Sites	Data Available
15052483	Jordan Cr Trib ab Yandukin Ave	JC-4/JC-C	• 26 measurements for streamflow between April 1997 to June 2002 (USGS) • 5 sampling events for various parameters between July 1997 and Aug. 1999 (reported in Host and Neal, 2004). • 12 sampling events for various parameters between May and June 2002 (USGS) • 138 sampling events for various parameters between 2003 and 2013 (UAS/JWP)
15052484	Jordan Cr Trib at Juneau Airport		• 2 measurements for streamflow in June 1999 (USGS) • 1 measurement for streamflow in March 2002 (USGS)

Water Quality Impairments

Water Quality Standards (WQS) are pollutant limit criteria established by the State to protect designated uses of a waterbody. In Alaska, all waterbodies are protected for all designated uses; therefore, the most stringent criterion becomes the WQS. Waterbodies identified as not meeting the WQS so as not to support their designated uses are listed as an impaired waterbody. The WQS applicable to Jordan Creek are provided in Appendix B.

Jordan Creek is listed as an impaired waterbody by the DEC for non-attainment of sediment, dissolved oxygen, and residue (debris) standards. It has been listed as impaired for these standards since 1998, with the entire length (~3 miles) of the mainstem is designated as impaired. Stormwater runoff from urban areas was identified as the major source of pollutants to the stream (DEC, 1999). A TMDL was developed to address the residue impairment in 2005, and another to address the sediment and interstitial dissolved oxygen impairments in 2009. A TMDL represents the maximum amount of a pollutant the waterbody can receive while maintaining compliance with applicable WQS.

The water quality of the lower Jordan Creek watershed is generally lower than that of the upper watershed. This is primarily due to distinct differences in the land ownership and land use trends of the upper and lower watersheds. In addition, the lower watershed suffers from the reality that water quality degradation tends to exacerbate in a downstream direction as the cumulative effects of pollutant inputs and habitat modifications take their toll on the stream.

Residues

Residues for the purposes of the WQS includes floating solids, debris, sludge, deposits, foam, scum, or other residues. The WQS for residues concentrations that may impair designated uses, cause a nuisance or objectionable conditions, result in undesirable or nuisance species, or produce an objectionable odor or tastes (Appendix B, Table B-1).

Jordan Creek was listed as impaired for residues based on professional judgment. Due to this, a technical analysis of data to evaluate any improvements is not possible. Areas along Jordan Creek continue to have problems with litter and debris that do not meet the WQS criterion (Figures 20 and 21). Litter and debris observed in Jordan Creek throughout the years include lumber scraps, plywood, paper, plastics, glass, metal, household garbage, clothing, and hazardous items such as fuel containers, batteries, and abandoned cars.

Figure 20. Example of litter found along Jordan Creek. This site is on lower Jordan Creek, just downstream of Egan Drive.

The primary sources of debris in the creek are direct inputs from littering or dumping, and indirect inputs from residential, commercial, and industrial areas where litter or loose or improperly stored garbage can be carried into the creek by wind, snowmelt, runoff, or wildlife. Littering is a chronic problem where roads and buildings are close to the creek, but is especially pronounced near food and convenience store businesses in the lower portion of the creek. Litter is also commonly associated with illegal campsites and dumps sites that occur throughout the watershed.

Household garbage pulled into the creek or the riparian area by bears is a substantial source of debris in the upper Jordan Creek watershed. Bears frequent upper Jordan Creek along Thunder Mountain, since this area provides good habitat in proximity to residential areas. Improperly stored garbage has been documented as a prime bear attractant and has been a source of concern, both from a public safety and a litter problem.

The TMDL for residues is zero, because the WQS does not allow for any unpermitted, human debris in Alaska waterbodies. However, since a complete adherence to this is not feasible, the TMDL recommends actions intended to reduce the amount of debris, including: public education and awareness, increased number and use of garbage receptacles, and increased enforcement.

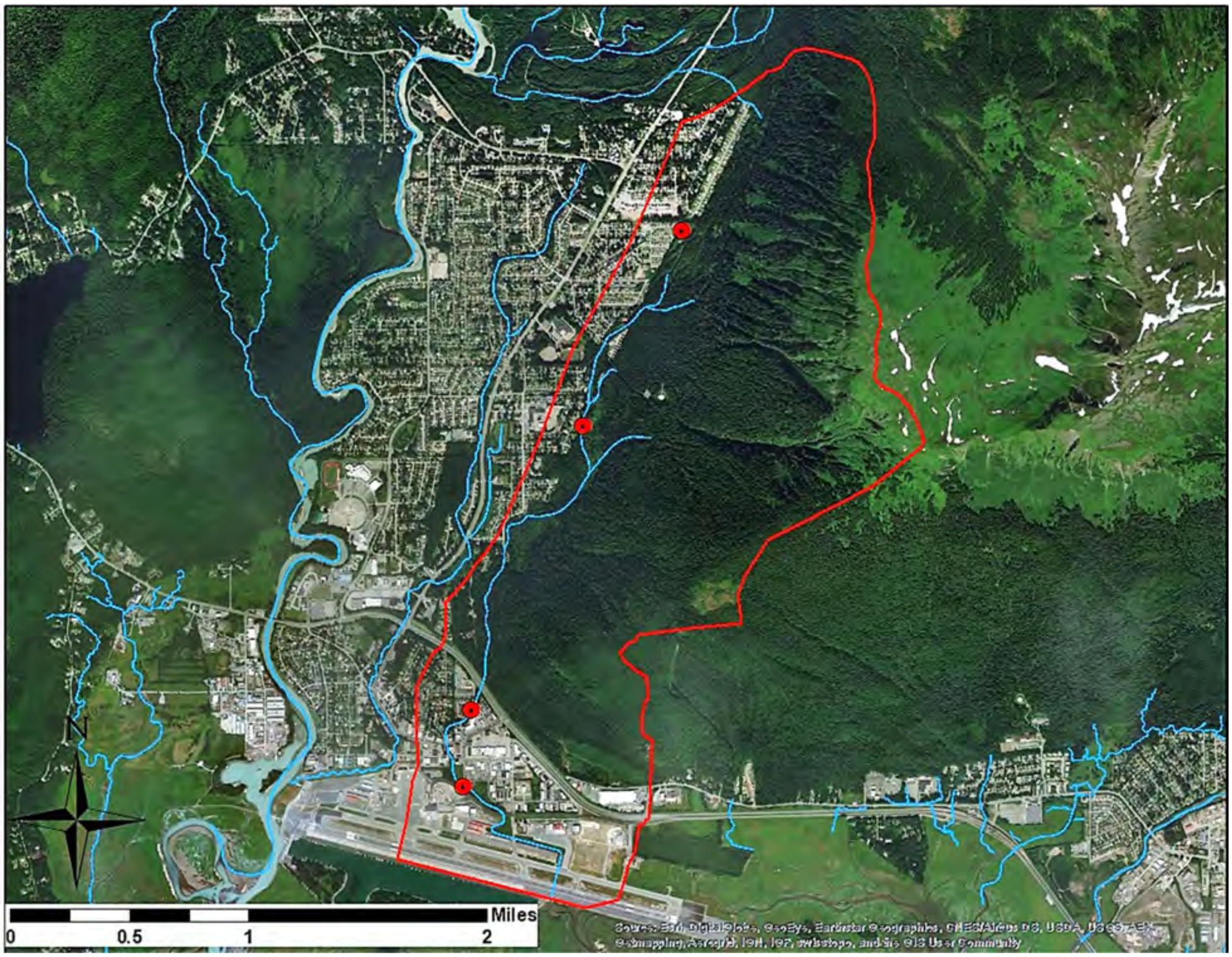

Figure 21. Garbage hotspots identified along Jordan Creek.

Sediment

Sediment inputs into Jordan Creek include natural erosion in the upper watershed, and stormwater and snow storage throughout the watershed. The WQS for the growth and propagation of fish does not allow for the accumulation of fine sediment (0.1mm to 4.0mm in diameter) to increase by more than five percent by weight above natural conditions in the gravel bed of waters used for spawning, and does not allow fine sediments to exceed a maximum of 30 percent by weight in those gravel beds (Appendix B, Table B-2). However, an extensive study of fine sediment accumulation in the streambed of Jordan Creek has not been conducted.

A limited analysis of particle size distribution in Jordan Creek's streambed was conducted by Interfluve (2008) as part of the design process for the EVR tributary rehabilitation project. Sediment samples were collected from three sites on the Jordan Creek mainstem, all of which were within 500 feet of the tributary. This data was used by the DEC for comparison with the WQS in the development of the Jordan Creek TMDL for sediment. This limited data indicated that these sites were all above the maximum of 30 percent by weight set by the WQS (DEC, 2009).

Host and Neal (2004) measured habitat characteristics along three reaches on Jordan Creek, but the study very generically characterized the streambed in terms of particle size and did not separate the fine sediment sizes from larger sizes. Rather, the full range of particle sizes present was documented for each data point. For this reason, the percent of fine sediment for each data point is unknown, except for where the data point is solely within the fine sediment range. About half of the data points on each reach had substrates entirely within the 0.1 millimeter (mm) to 4.0 mm range.

Nagorski, et al (2005) studied transects on Jordan Creek to determine whether streambeds were aggrading (accumulating streambed material) or degrading (losing streambed material). If the streambed was found to be aggrading, this could indicate that fine sediment deposits were building up the streambed. However, this study did not indicate a trend one way or the other.

The Jordan Creek TMDL for sediment focuses on reducing sediment inputs to meet the WQS. The TMDL for sediment is measured in pounds of sediment per day, and varies across different flow regimes (high, medium, low). This variation is necessary since the stream's ability to transport sediment is dependent on flow (e.g. higher flows transport more sediment and, therefore, the stream can tolerate greater inputs during high flows). The load allocation allows for a range of 0.4 pounds of sediment per day at low flow conditions to 535 pounds per day at high flow conditions. However, water quality studies in Jordan Creek have very rarely measured or discussed sediment inputs in these terms.

Since the TMDL for sediment followed the publication of the 2006 *Plan*, it recommended implementing actions in the 2006 *Plan* to reduce sediment, which included: erosion control, addressing snow storage, stabilizing streambanks, restoring the East Valley Reservoir (EVR) tributary, and education/outreach. The TMDL did not offer any other management strategies.

Due to the lack of sediment measurements in terms of the WQS or the TMDL, it is difficult to determine whether these standards are being met. The parameters of turbidity, total suspended solids (TSS), total dissolved solids (TDS), and conductivity are often used to help indicate changes in sediment load and transport in the water column. However, these parameters are not solely indicative of sediment inputs as they are influenced by other suspended and dissolved matter. These parameters are discussed further in the following sections.

Turbidity

Turbidity (measured in nephelometric turbidity units, or NTUs) is a measurement of water clarity. Turbid water is murky or otherwise colored and will scatter light. It is affected by both organic and inorganic matter suspended or dissolved in the water column. Turbidity may closely parallel total suspended solids (TSS) data, depending on the size distribution of suspended matter. Jordan Creek data indicates that turbidity and TSS have a strong, positive correlation (Appendix C, Tables C-1 to C-4).

High in-stream turbidity may contribute to high water temperature and low dissolved oxygen values. However, Jordan Creek data does not show an overall correlation between turbidity and stream temperatures, and a weak positive correlation between dissolved oxygen concentrations (Appendix C, Tables C-1 through C-4). Perhaps this is because turbidity on Jordan Creek is generally low.

The overall 10-year average is about 3.5 NTU, with levels typically remaining below 30 NTU (Table 4 and Figure 23). In general, turbidity significantly increases downstream (Appendix C, Tables C-6 and C-7). This is expected due to cumulative inputs from stormwater. However, this relationship does not hold during the warmer growing season, where the turbidity measurements at the Amalga Street site are significantly lower than the two downstream sites, but there is no difference in the turbidity measurements at the Egan and Yandukin Drive sites (Appendix C, Table C-10).

Figure 22. Turbid stormwater discharges to Jordan Creek from the Crest Street ditch near Yandukin Drive. Photo Courtesy of John Hudson.

Data shows that average turbidity measurements are lower in winter except at the Yandukin Drive site (Site C) (Appendix C, Tables C-8 and C-11). This may be explained by the fact that there is a snow storage site near the Yandukin Drive monitoring site.

The WQS for turbidity for the propagation of fish requires that turbidity not exceed 25 NTUs above natural background conditions (Appendix B, Table B-3). For comparison to the WQS, the Amalga Street site (Site A) was often used as "natural background conditions" since it is the furthest upstream. The downstream sites only exceeded the 25 NTU above the Amalga Street measurement one time during the 10-year period: on March 23, 2010 at the Yandukin Drive site (Site C). There was also one sampling event where the "background levels" at the Amalga Street site had the highest turbidity (Figure 23).

Table 4. Statistical summary of turbidity measurements (NTUs) at three sites on Jordan Creek between November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	148	135	130	413
Minimum	0.16	0.48	0.52	0.16
Average	1.83	3.72	5.27	3.53
Maximum	58.47	22.40	87.20	87.20
Standard Deviation	5.22	3.79	8.62	6.30

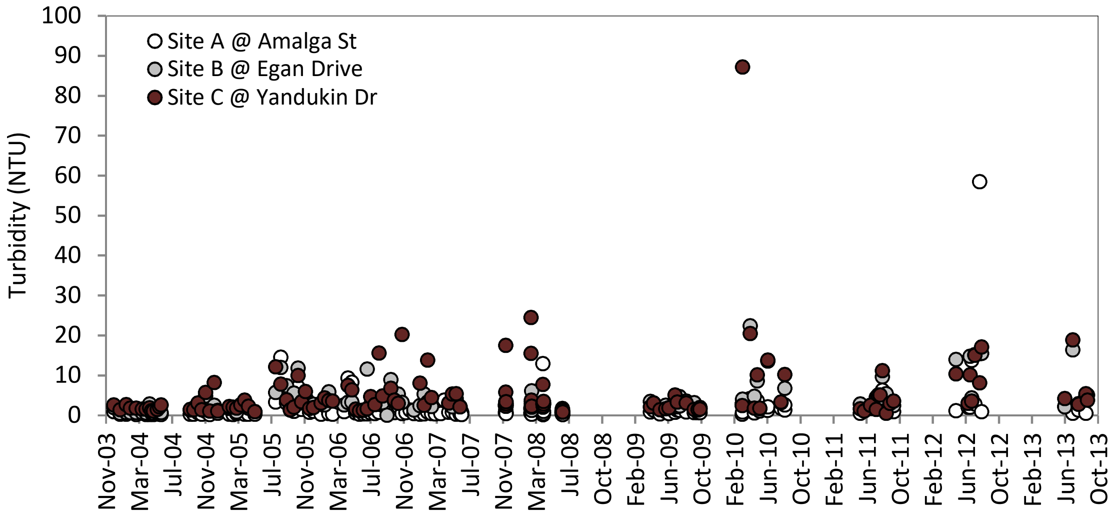

Figure 23. Turbidity measurements at three sites on Jordan Creek between November 2003 and October 2013.

The data suggests that Jordan Creek does not have chronic problems with turbidity, and that turbidity may not be strongly influencing other water quality parameters. However, turbidity is a highly variable parameter, and past monitoring may not have adequately captured the variability.

Total Suspended Solids

Total Suspended Solids (TSS) concentration, measured in milligrams per liter (mg/L) refers to solids (2 microns and greater diameter) that are not dissolved in solution and can be removed by filtration. Suspended solids include both organic and inorganic particles, and can impact water clarity (turbidity), conductivity, and temperature. As previously mention, TSS is strongly positively correlated with turbidity on Jordan Creek. However, TSS is only weakly correlated with conductivity and temperature at the Amalga Street and Egan Drive sites, with no apparent correlation at the Yandukin Drive site.

TSS ranged from Non-Detect (below the detection limit of 4 mg/L) to as high as 62 mg/L. Most samples were below 20 mg/L, and the overall 10-year average is 4.20 mg/L. There is a significant downstream effect in TSS measurements, as expected (Appendix C, Tables C-14 through C-16). However, only the TSS values at the Amalga Street site (Site A) are significantly different from the two downstream sites, but there is no significant difference between the Egan and Yandukin Drive sites (Appendix C, Table C-16).

Table 5. Statistical summary of total suspended solid measurements (mg/L) at three sites on Jordan Creek betwwen November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	134	130	127	391
Minimum	0.00	0.00	0.00	0.00
Average	2.58	4.68	5.37	4.20
Maximum	62.00	35.36	57.3	62.00
Standard Deviation	6.54	6.58	8.46	7.33

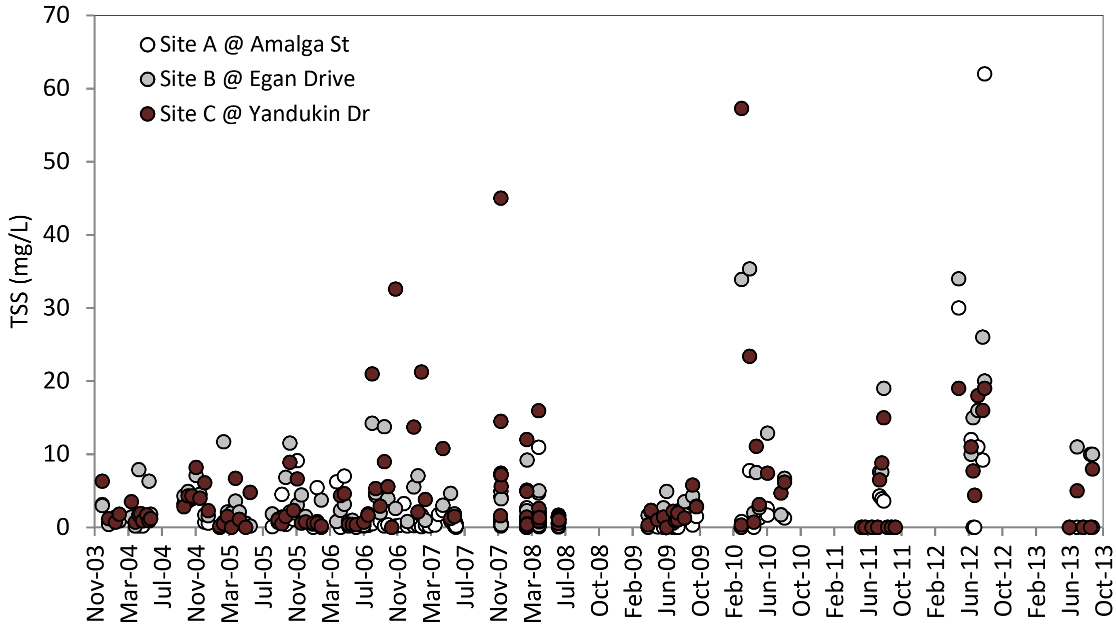

Figure 24. Total suspended solid measurements at three sites on Jordan Creek between November 2003 and October 2013.

The state has not outlined WQS for suspended sediment concentration. The Mendenhall Valley Drainage Studies indicated that valley's non-glacial surface waters have TSS values typically ranging from 0 to 10 mg/L in the winter and 0 to 100 mg/L during the rest of the year. The TSS samples collected for Jordan Creek over the 10-year period appear to be consistent with this assessment. The average TSS values are lower in the winter, except at Yandukin Drive (Site C).

This data suggests that Jordan Creek does not have a chronic problem with TSS; however, TSS is a highly variable parameter, and past monitoring may not have adequately captured the variability.

Specific Conductance

Specific conductance, or conductivity, is a measure of the ionic content of a solution and is indicative of total dissolved inorganic solids in a water sample. This type of measurement is not ion-specific. Conductivity is monitored for background purposes; an unusually high measurement may indicate a failing septic system upstream, while an unusually low measurement may indicate an oil spill upstream.

The state has not outlined specific WQS for conductivity. Values for conductivity measured on Jordan Creek ranged from -0.04 to as high as 380 micro-Siemens per centimeter (µS/cm) over the 10-year period. The overall 10-year average is about 84 µS/cm. The high conductivity values are likely reflective of the urban uses of the watershed. Nagorski et al (2004) noted that conductivity measurements were twice that measured for Montana Creek, which has not been as impacted by urban development.

The Amalga Street conductivity measurements were significantly higher throughout the 10-year sampling period (Appendix C, Table C-24). While this was thought to be due to groundwater-fed streamflow, which has high inputs of dissolved iron, there is a very weak negative correlation between conductivity and dissolved iron at the Amalga Street Site (Appendix C, Table C-2). Conductivity measurements at the Yandukin and Egan Drive sites were not significantly different (Appendix C, Table C-24).

Table 6. Statistical summary of conductivity measurements (µS/cm) at three sites on Jordan Creek between November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	166	138	134	438
Minimum	0.00	-0.04	-0.04	-0.04
Average	94.69	74.56	78.29	83.81
Maximum	172.00	114.00	380.00	380.00
Standard Deviation	27.29	22.65	37.13	30.70

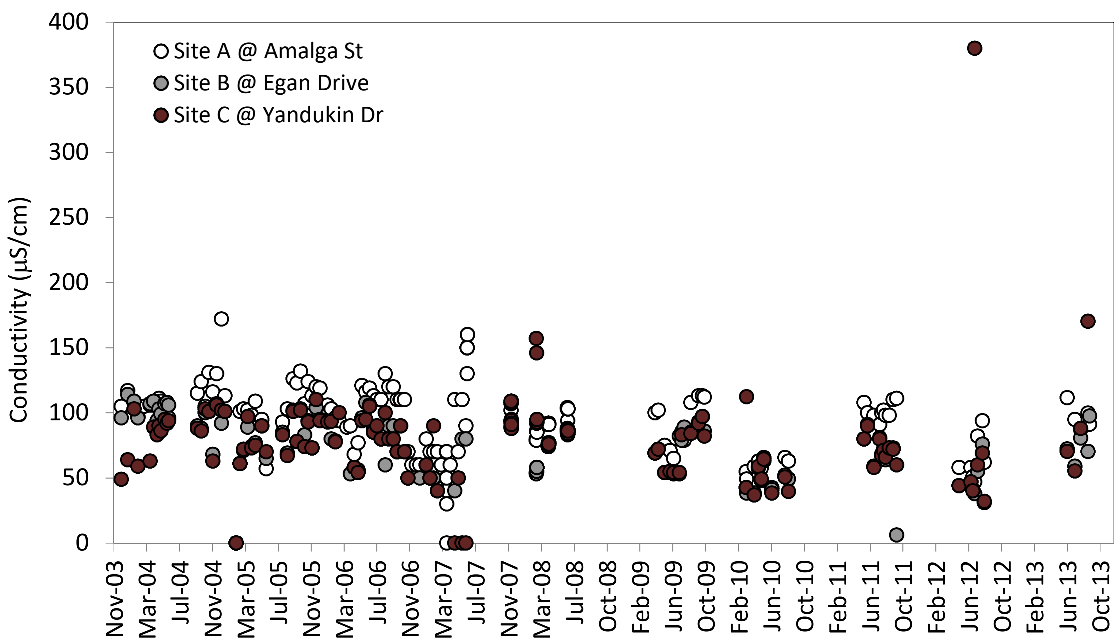

Figure 25. Specific conductance measurements at three sites on Jordan Creek between November 2003 and October 2013.

Dissolved Oxygen

Dissolved oxygen (D.O.) is a measure of oxygen content in water, expressed in units of milligrams per liter (mg/L). Introduced into water by aquatic plants and atmospheric diffusion, D.O. is essential to aquatic organism health. D.O. levels fluctuate throughout the day and year with photosynthetic rates, water velocity, and water temperature. Dissolved oxygen is consumed by microorganisms in the breakdown of organic matter and the respiratory processes of aquatic organisms like fish and aquatic insects. Low D.O. levels may indicate upstream inputs from wastewater, stormwater runoff, or failing septic systems. It is important to have D.O. available in both the water column and in the water within the interstitial spaces between the gravels in the streambed. Both are critical for fish survival. Salmonids will seek areas that have adequate dissolved oxygen concentrations.

There are separate WQS for interstitial D.O. and water column D.O. for waterbodies in Alaska. D.O. must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case, may D.O. be less than 5 mg/l to a depth of 20 centimeters in the interstitial waters of gravel used by anadromous or resident fish for spawning. For waters not used by anadromous or resident fish, D.O. must be greater than or equal to

5 mg/l. In no case, may D.O. be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110 percent saturation at any point of sample collection (Appendix B, Table B-5).

Interstitial Dissolved Oxygen

Jordan Creek is impaired, in part, due to low interstitial D.O. rather than low D.O. in the water column. Yet, only a few studies have collected interstitial D.O. measurements in Jordan Creek. The earliest interstitial D.O. measurements were taken in 1997 at fifteen locations downstream of Thunder Mountain Trailer Court, with measurements taken several times from April through June. Dissolved oxygen concentrations at two locations were below the WQS for the entire study period. Other sites had low dissolved oxygen on one or more sample dates. Only one of the fifteen sites met the WQS for interstitial dissolved oxygen concentrations throughout the study period, though measurements were not taken at all sites consistently (Savell, 2006).

Since then, only two other studies, Nagorski et al (2006) and Hudson (2008), have collected interstitial D.O. measurements. In Nagorski et al (2006), all measurements were taken in the headwaters, above the Amalga Street site (JC-A). Ten pipes were installed along a one kilometer reach and nine measurements were taken from each between mid-May and early July. Most of the measurements met the WQS. Only pipes 4 and 5 had interstitial D.O. levels that failed to meet the WQS (Figure 26).

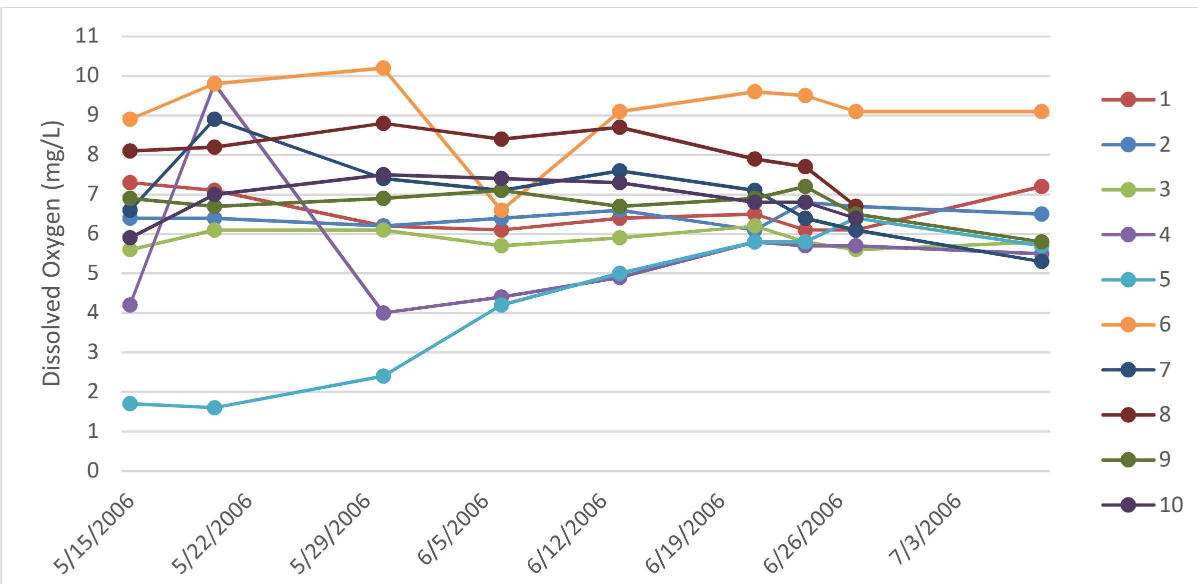

Figure 26. Interstitial dissolved oxygen measurements taken in 10 pipes installed along a one kilometer stretch in Jordan Creek above Amalga Street. Data from Nagorski et al (2006).

The 2008 study included six different sites, each with three pipes installed. Measurements were only taken once at each pipe in mid-July. In this study, most of the measurements failed to meet the WQS. In some cases, this was due to lack of interstitial water (Table 7).

Table 7. Interstitial dissolved oxygen concentrations at six locations on Jordan Creek. Measurements that failed to meet the water quality standard are bolded. NA indicates no interstitial water. Data from Hudson (2008).

Site	Pipe	DO (mg/L)
Valley Blvd.	1	5.0
	2	5.0
	3	**3.8**
Amalga St.	1	**0.3**
	2	**0.1**
	3	7.2
Jennifer Dr.	1	**4.3**
	2	**2.6**
	3	9.6
Nancy St.	1	**0.2**
	2	**0.1**
	3	**NA**
Egan Dr.	1	10.8
	2	**NA**
	3	**NA**
Teal St.	1	7.9
	2	7.9
	3	8.1

While these studies indicate that low dissolved oxygen occurs at least periodically in interstitial water, due to inconsistent sampling locations and frequency between these studies, the data cannot be used to draw any other conclusions or identify any trends. The limited data make it difficult to adequately assess the factors causing low interstitial dissolved oxygen where it occurs. Based on what is known, it is suspected that low interstitial dissolved oxygen is partly to due to groundwater influences, formation of iron flocculate, low water velocity and sedimentation.

There is no separate TMDL for interstitial dissolved oxygen. It is assumed that the TMDL for sediment will address the dissolved oxygen impairment. This assumption is based on studies linking sediment loading to low interstitial oxygen, as the spaces between streambed gravels cannot hold oxygenated water if clogged with sediment.

Water Column Dissolved Oxygen

Several studies have collected D.O. measurements in the water column of Jordan Creek. Water quality data indicates that water column D.O. is usually within the acceptable WQS, but that there may be problems with low D.O. in lower Jordan Creek resulting from higher summer water temperatures.

Data from the 10-year monitoring effort shows that water column D.O. at all three sites periodically drops below the lower limit (7mg/L) set by the WQS (Figure 27, Table 6). These drops in D.O. typically occur in early spring (March/April) and early summer (June/July).

The limited USGS data documented drops in D.O. levels below 7mg/L four times at Site 15052435 at Valley Boulevard (lowest 0.8 mg/L) and once at Site 15052475 at Egan Drive. The upper limit (17 mg/L) was approached once at JC-B and was exceeded at JC-C (Nagorski 2007, Figure 27). However, the study did not point out or explain these exceptionally high values.

D.O. levels are significantly lower at Amalga Street (Site A), with no significant difference between the two downstream sites (Appendix C, Table C-27). The Amalga Street site is primarily composed of groundwater-fed flows, and thus likely to be lower in D.O. than downstream sites. Groundwater influence also likely explains the slightly smaller range in variation at this site.

The data shows a strong, negative relationship between D.O. and water temperature at the Egan and Yandukin Drive sites (Sites B and C) (Appendix C, Tables C-3 and C-4).

Table 8. Statistical summary of dissolved oxygen measurements (mg/L) at three sites on Jordan Creek between November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	130	104	100	334
Minimum	2.55	3.10	3.06	2.55
Average	10.15	12.01	12.22	11.35
Maximum	13.79	16.80	17.40	17.40
Standard Deviation	1.59	2.20	2.35	2.25

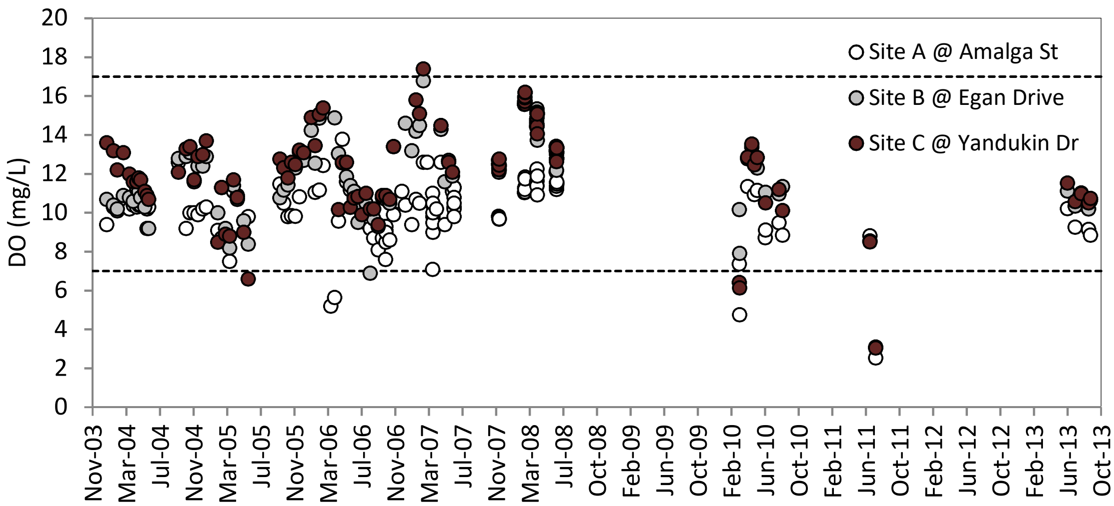

Figure 27. Dissolved oxygen (D.O.) measurements at three sites on Jordan Creek between November 2003 and October 2013. The WQS sets a lower limit at 7 mg/L and an upper limit at 17 mg/L, shown by the dashed lines.

Other Water Quality Data

Temperature

Water temperature (typically measured in degrees Celsius, ˚C) affects many processes in aquatic habitats such as the rate of photosynthesis, the amount of dissolved oxygen, metabolic rates of organisms, salmon egg development and survival, and susceptibility of organisms to toxic chemicals, diseases, and parasites. Various species can only live within a specific range of temperatures.

There is an expected seasonal pattern in water temperatures, with the lowest temperatures occurring in winter (January through March) and the highest occurring in summer (June and July) (Figures 28 and 29, and Appendix C, Tables C-36 and C-39). There is only a significant difference in stream temperatures among the monitoring sites when the data is separated by season. In the growing season (April – September), temperatures significantly increase from headwaters to downstream sites. Outside of the growing season (October – March), the Amalga Street site is significantly warmer than the two downstream sites, with no significant difference in the temperatures of the downstream sites (Appendix C, Tables C-34 through C-41). This is likely due to the groundwater origin of the Amalga Street site (Site A), since groundwater is typically warmer.

The WQS for water temperature for the propagation of fish does not allow temperatures to exceed 20˚C at any time, but also sets a maximum of 13˚C for spawning areas and egg and fry incubation and a maximum of 15˚C for migration routes and rearing areas (Appendix B, Table B-6). The WQS does not set minimum temperatures, though low temperatures can also be problematic for salmonids.

Temperature data was collected daily by the U.S. Geological Survey (USGS) at Station #15052475 from July 1999 until October 2004. This site corresponds with the Egan Drive site (Site B) used in the 10-year monitoring effort between November 2003 and October 2013. Therefore, the two data sets overlap for this site.

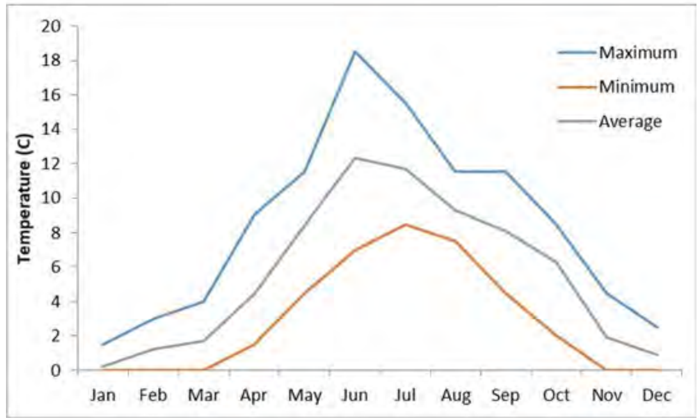

Figure 28. Monthly minimum, average and maximum temperatures recorded from July 1999 to October 2004 at the USGS Station #15052475, which corresponds with the Egan Drive site (Site B).

The USGS temperature data reports exceedances of the water quality standards between June and August 2004. During this time, the maximum recorded temperature was 13°C or higher on 38 days. For nearly 13 consecutive days in late June 2004, the maximum recorded temperatures ranged from 15.5 to 18.5°C. USGS temperature data for other sites document one other exceedance of the WQS at USGS Station 150552483 (which corresponds with the Yandukin Drive site), where water temperature was measured at 13°C.

Temperature data from the 10-year monitoring effort between November 2003 and October 2013 shows that Jordan Creek generally meets the WQS. However, there were a few noted exceedances of the WQS. The downstream sites at Egan Drive (Site B) and Yandukin Drive (Site C) had instances of temperatures just above the 13˚C requirement but still below the 15˚C requirement for migration routes and rearing habitat. The 15˚C requirement for migration routes and rearing habitat was approached once during the 10-year period (Figure 27).

Table 9. Statistical summary of temperature measurements (°C) at three sites on Jordan Creek between November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	166	138	133	437
Minimum	0.30	0.00	-0.10	-0.10
Average	5.28	5.39	5.62	5.42
Maximum	11.50	14.90	13.60	14.9
Standard Deviation	1.92	3.43	3.72	3.05

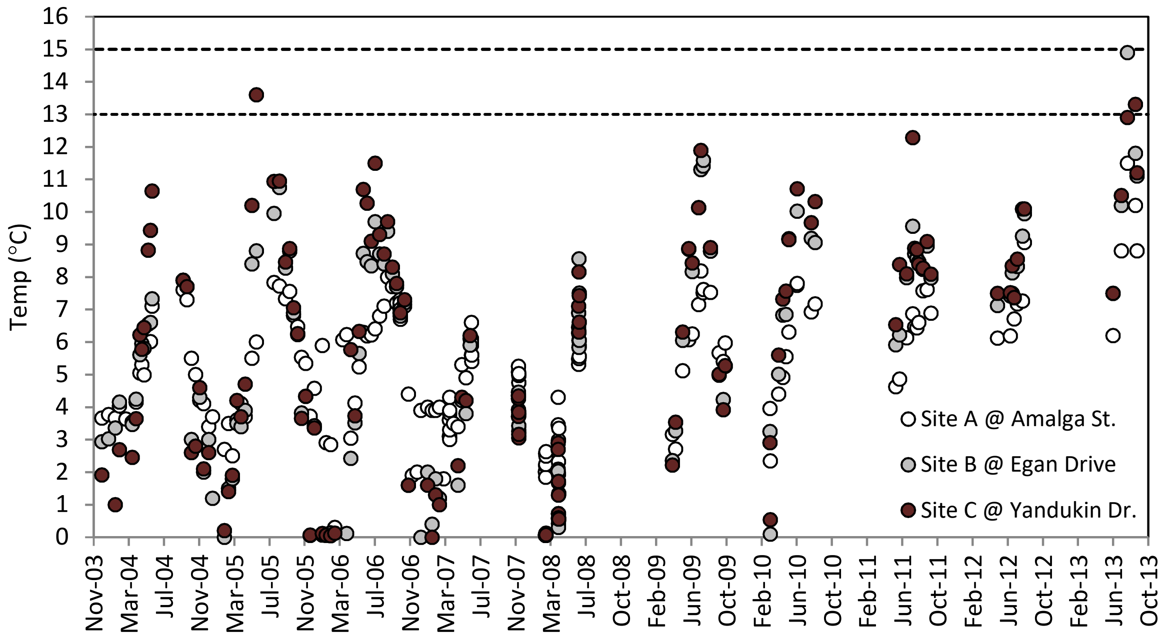

Figure 29. Water temperature measurements at three sites on Jordan Creek between November 2003 and October 2013. The WQS sets a maximum of 13˚C for spawning areas and egg and fry incubation and a maximum of 15˚C for migration routes and rearing areas, which are shown by the dashed lines.

pH

pH is unit-less, measured on a scale of 0 to 14, that indicates the acidity or alkalinity of a water sample. A pH of 7 is considered neutral; with acidity increasing as the pH gets lower and the alkalinity increasing as the pH get higher. Most aquatic species live in waters between pH 6.5 and pH 8. The survival of aquatic organisms greatly diminishes as pH becomes more than 9.0 or less than 5.0. The WQS for the propagation of fish for pH ranges from 6.5 to 8.5 (Appendix B, Table B-7).

The data demonstrates that Jordan Creek generally stays within the limits for pH set by the WQS, though Jordan Creek periodically becomes slightly acidic and does not meet the minimum pH standard. These drops in pH were not isolated to a specific monitoring site, and generally occur in winter between September and April (Figure 30). In general, average pH is lower in winter (Appendix C, Table x). Lower pH values are thought to be caused by iron-rich groundwater intrusion, which becomes the dominant source of water during cold and dry climatic periods (Nagorski et al 2006).

The Amalga Street site (Site A) pH levels are significantly different from the two downstream sites, likely due to iron-rich groundwater origin. This is supported by the data, which shows that pH has a moderately negative correlation with dissolved iron levels (more dissolved iron will lower pH) at the Amalga Street site, whereas pH has a moderately positive correlation with dissolved iron levels at the other two sites (Appendix C, Tables, C-2 through C-4). The pH levels at the two downstream sites were not significantly different from each other (Appendix C, Tables C-42 through C-44).

Table 10. Statistical summary of pH measurements at three sites on Jordan Creek between November 2003 and October 2013.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	142	114	109	365
Minimum	4.48	5.20	4.90	4.48
Average	6.67	6.92	7.02	6.85
Maximum	7.82	8.26	8.05	8.26
Standard Deviation	0.55	0.56	0.51	0.56

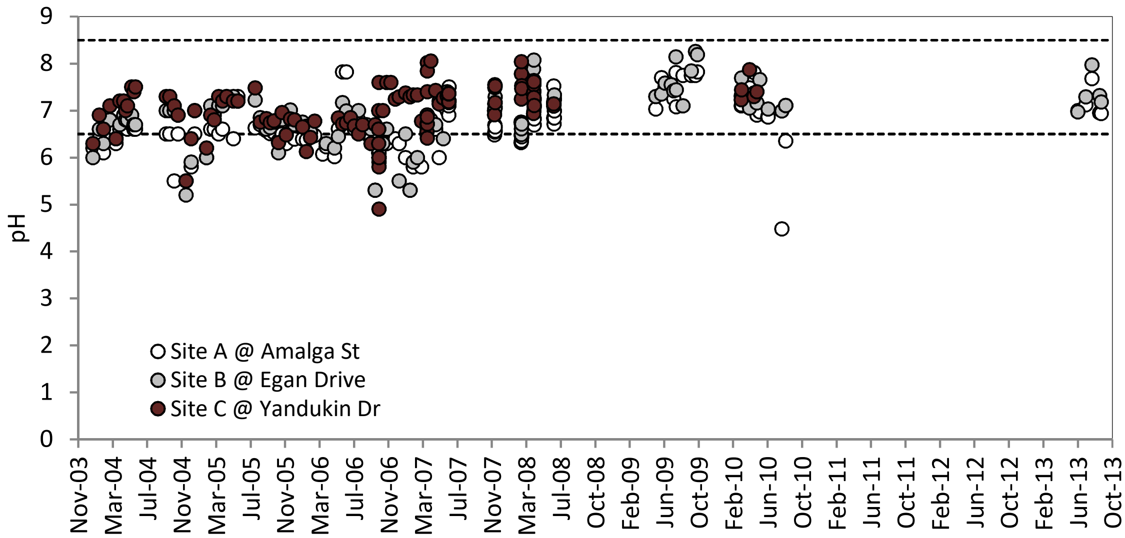

Figure 30. pH measurements at three sites on Jordan Creek between November 2003 and October 2013. The Water Quality Standard requires waters to be between 6.5 and 8.5, shown by the dashed lines.

Dissolved Iron

Iron is a heavy metal that can affect stream water quality and habitat, and is of concern in Jordan Creek. Dissolved iron is present in the groundwater throughout the Mendenhall Valley (Barnwell and Boning, 1968). Iron enters surface waters through disruption of groundwater flow by activities such as land clearing and grubbing, placing fill, gravel extraction and road construction (Carson Dorn 2002). High levels of dissolved iron can form a visible precipitate (called flocculent, or floc) through oxidation-reduction reactions with the dissolved oxygen available in the water. Iron flocculent is present in various locations throughout Jordan Creek (Figure 31).

Figure 31. Iron flocculent in Jordan Creek near the former MPM gravel pit. Photo from JWP's archives.

The formation of iron flocculent is problematic because the chemical reaction decreases the amount of dissolved oxygen that can be utilized by aquatic organisms as the dissolved iron binds with oxygen to form the precipitate. Iron bacterial processes also contribute to the reduction of dissolved oxygen. Furthermore, iron floc settles on the stream bed, fills in the spaces in the gravel, and decreases the habitat quality of fish and aquatic insects. The WQS allow for 1,000 µg/l (or 1 mg/L) of iron for the protection of aquatic life.

Jordan Creek data indicates that dissolved iron concentrations never exceeded the WQS. The overall 10-year average concentration of dissolved iron in Jordan Creek was 0.26 mg/L and measurements were generally below 0.5 mg/L. There were a few outliers: two measurements at Site A and one at Site C were above 0.5 mg/L but below 1 mg/L (Figure 32).

Early studies indicate that the groundwater iron concentrations underlying Jordan Creek increase from the upper watershed to the lower watershed, and that the surface waters likewise increase in iron concentrations as the water passes through the iron-containing soil layers in the valley (Barnwell and Boning, 1968). The former Reid gravel pit (also known as the MPM gravel pit) is thought to contribute to iron levels in the upper watershed (Carson Dorn, 2002).

However, dissolved iron measurements taken in Jordan Creek between October 2006 and June 2008 indicate that levels are not significantly different at the three monitoring sites (Appendix C, Tables C-45 and C-46). However, this is based on a relatively small number of samples.

Table 11. Statistical summary of dissolved iron measurements on three sites taken from October 2006 to June 2008.

Statistic	Site A @ Amalga St.	Site B @ Egan Dr.	Site C @ Yandukin Dr.	Overall
Number of Samples	15	15	15	45
Minimum	0.03	0.11	0.12	0.03
Average	0.23	0.29	0.28	0.26
Maximum	0.91	0.50	0.70	0.91
Standard Deviation	0.18	0.10	0.13	0.15

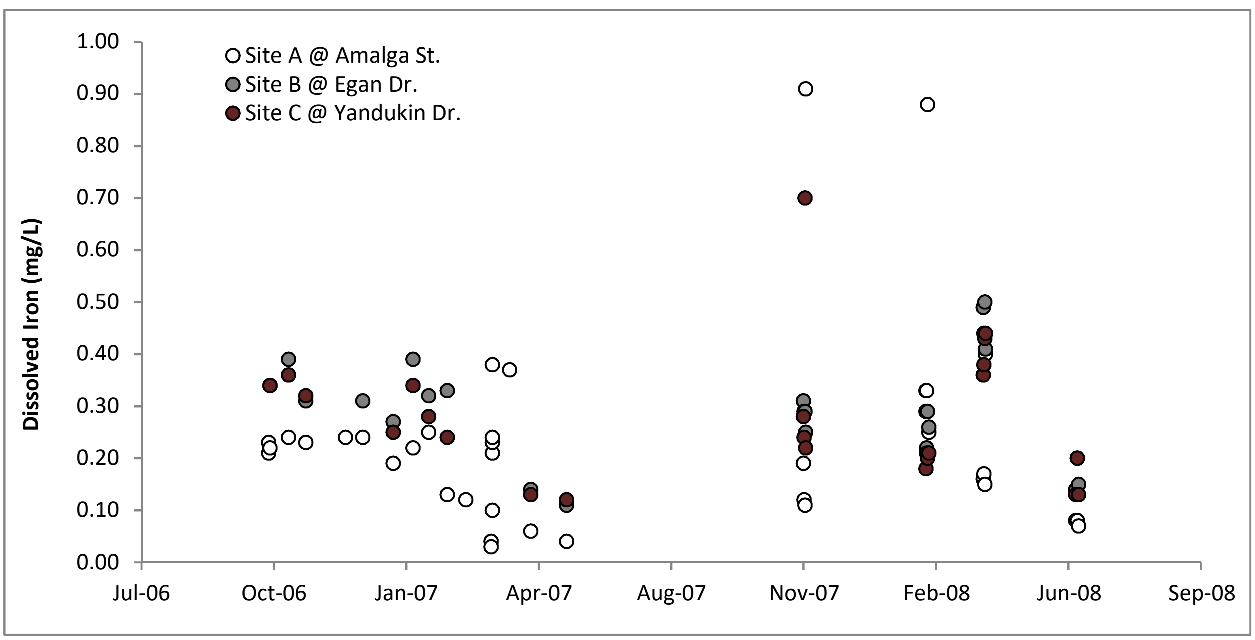

Figure 32. Dissolved iron measurements at three sites on Jordan Creek between October 2006 and June 2008.

Bioindicators

Aquatic macroinvertebrates (insects, worms, snails, etc.) can be used as bioindicators of water and habitat quality in streams because they integrate the impacts of multiple stressors over time (Rinella et al. 2003), including episodic and short-lived stressors that are difficult to document in water quality monitoring programs. In general, good water quality is indicated by large numbers and a diversity of mayfly (*Ephemeroptera*), stonefly (*Plecoptera*) and caddisfly (*Tricoptera*) larvae represented in the macroinvertebrate community. Poor water quality is indicated when the macroinvertebrate community has more pollutant-tolerant invertebrate species such as flies (*Diptera*), earthworms (*Oligochaeta*), and aquatic beetles (*Coleoptera*) present and less overall diversity.

Aquatic macroinvertebrates have been used in several studies on Jordan Creek: Milner (1996), Rinella et al. (2005), Nagorski et al (2006), and Rinella and Bogan (2010). The shift in the macroinvertebrate community over the years indicates water quality has degraded. In particular, mayfly and stonefly larvae were not as common or as diverse as they once were.

Table 12. Macroinvertebrate data from Nagorski et al (2006).

	Amalga		**Super 8 Motel**	
	5/25/1995	5/25/2006	5/25/95	5/19/2006
Invertebrate Taxon				
Ephemeroptera				
Baetidae				
Baetis			42	
Ameletidae				
Ameletus			2	1
Heptageniidae				
Epeorus			3	
Cinygmula			4	
Plecoptera				
Chloroperlidae				1
Plumiperla	12		8	
Sweltsa		6		
Capniidae		5		1
Capnia	7		10	
Nemouridae				
Zapada	39	2		
Podmosta		8	254	46
Tricoptera		54		4
Limnephilidae				
Onocosmoecus	1			1
Limnephilis		23		21
Psycholgypha		4		1
Lenarchus		6		
Lepidostomatidae				
Lepidostoma				
Diptera		1		
Ceratopogonidae		1	1	5
Chironomidae	424	427	237	527
Empididae				
Chelifera		10		1
Clinocera		3		
Tipulidae	21		13	
Dicranota		2		
Limnophila		9		1

	Amalga		Super 8 Motel	
	5/25/1995	5/25/2006	5/25/95	5/19/2006
Molophilus				1
Simuliidae	1	2	197	
Unidentified Diptera A				1
Unidentified Diptera B				1
Coleoptera				
Dytiscidae		2		
Collembola		2		
Non-Insect Taxon				
Oligochaeta	18	288	10	56
Nematoda				13
Ostracoda		314		86
Gastropoda		26		77
Bivalvia		34		172
Hydroida		1		
Hydrachnida		11		36
Total # of Individuals	523	1245	781	1053
% EPT taxa	12.1	8.8	35	7.2
EPT Taxa richness	4	8	7	7
% dominant taxon	81.1	34.3	33	50

The biological data is more telling than the water quality data collected alongside macroinvertebrates. The water quality data only indicates mild impairment, but the biological data suggests substantial impairment (Rinella and Bogan, 2010). Nagorski et al (2006) suggested that Jordan Creek no longer be used as a reference site in macroinvertebrate studies, since the macroinvertebrate data was consistent with those for other impaired water bodies in southeastern Alaska.

Fish Populations and Habitat

Jordan Creek is a catalogued anadromous stream (AWC#111-50-10620) supporting populations of coho, chum and pink salmon, Dolly Varden, steelhead and cutthroat trout. Historically, Jordan Creek was noted to have a small run of sockeye salmon. Brook trout were introduced in 1953, but were not found to be present in the mid-1980s (Bethers 198?). Though few fisheries investigations have been conducted since the 2006 *Plan*, the information available suggests that Jordan Creek may be experiencing declines in fish populations, and that fish habitat may be impacted.

Fish Population Declines

Historically, Jordan Creek was once considered a good place to fish for coho salmon, Dolly Varden and cutthroat trout. However, it has been closed to salmon fishing since 1962 and to all fishing since 1983. The closure was intended to protect declining fish stocks (Bethers 1985, Bethers et al 2012).

Various stock assessment activities conducted by the Alaska Department of Fish and Game, Sport Fish Division (ADF&G-SF) have occurred in the Jordan Creek watershed since the 1980s, focusing primarily on coho salmon. Coho salmon have been studied as an indicator for resident and anadromous fish habitat condition in Jordan Creek, since spawning, incubation, egg development, emergence and juvenile rearing all take place within the creek. Starting in 1981, annual foot counts were used to provide an index for adult coho salmon in the watershed. Then, in September 1994, escapement goals for Jordan Creek were adopted by the ADF&G. The point value for the escapement goal and goal range was set at 150 and 75 – 200, respectively. These goals were based on the foot count data through 1994 (Clark 1995).

After the minimum escapement goal was not met from 1996 to 2000, biologists became concerned about coho smolt production. From 2001 through 2006, a weir was used to estimate the outmigration of juvenile coho salmon in the spring/summer, as well as estimating adult coho salmon escapement in the fall (Figure 33).

Escapement trends were previously assessed for Jordan Creek by analyzing peak adult coho counts from 1981 through 2003. This analysis estimated the annual population decline at 3.1 percent over 21 years, and 7 percent over 15 years of the available data. These rates are considered a "biologically meaningful decline" of the coho salmon stock in Jordan Creek (Carson Dorn 2002). Escapement goals were recommended for elimination by Clark (2005) and then reported as eliminated by DerHovanisian and Geiger (2005).

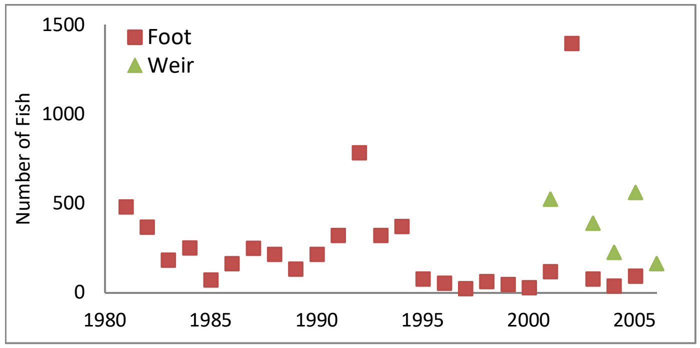

Figure 33. Survey counts for adult coho salmon for Jordan Creek. Data from Coyle, C. L. and D.C. Love. 2009.

In addition to coho salmon population studies, the abundance of emigrating Dolly Varden char and cutthroat trout has been monitored in Jordan Creek. From 2001 to 2005, the number of sea-run cutthroat trout emigrating into Jordan Creek in spring/summer has rapidly declined from 100 fish to 1 fish (Table 13). However, the weir counts for emigrating Dolly Varden are considered relatively stable over multiple years, though the counts may vary widely from year to year (Table 13). Possible causes of the cutthroat trout decline include low flow or dewatering events, warm water temperatures, pollution, and handling or weir effects (Harding and Coyle 2011).

Table 13. Emigrants other than coho salmon counted at the Jordan Creek weir during the spring by year. Data from Harding and Coyle (2011).

Year	2001	2002	2003	2004	2005
Dolly Varden	204	1133	151	77	159
Cutthroat trout	110	143	14	7	1
Juvenile cutthroat			13	--	--
Juvenile steelhead			1	--	--
Pink salmon fry			444	250	1
Chum salmon fry			1,028	792	61
Sockeye salmon fry			23	--	--
Sockeye salmon smolt			2	--	--
Sculpin			1,323	414	441
Three-spine stickleback			39	25	104

Channel Modifications and Fish Passage

Channel modifications and the use of crossing structures (e.g. culverts) to accommodate development can cause a variety of negative impacts to aquatic habitats. These may include but are not limited to the following:

- Decrease in stream habitat complexity
- Modification of stream flows and substrate composition
- Disconnecting streams from floodplains and habitats such as side channels

Historically, parts of lower Jordan Creek have been moved or channelized to facilitate development. The portion of Jordan Creek flowing through Airport property was moved to its current location during initial construction in the 1930s (Federal Aviation Administration, 2005). In 1970, approximately 1,000 foot section of Jordan Creek was channelized between Old Glacier Highway and Egan Drive (Bethers, 1985, and Bethers et al., 2012). Tributary flow into Jordan Creek was diverted away from the stream when the Egan Drive expressway was constructed (Savell, 2006). The stream is thought to have recovered from the channelization between Old Glacier Highway and Egan Drive. However, when the Glacier Highway culverts were installed in place of a bridge 1984, some of the best rearing habitat in the stream permanently altered (Bethers, 1985, and Bethers et al., 2012).

Fish passage is currently not a concern for Jordan Creek in terms of structural barriers. Stream crossings on Jordan Creek were assessed by ADF&G during a 2003 stream habitat survey. At the time of this survey, 18 stream crossing structures were identified on the mainstem including 11 undefined bridges (including four that provided pedestrian access only), four permanent bridges providing vehicular access, and three culverts. All stream crossing structures were noted to be functioning properly (Figure 10; Nichols and Williams, 2012).

There are currently five culvert crossings on lower Jordan Creek, which were assessed in 2012 by ADF&G. During this assessment, the only structure potentially impacting fish passage is the culvert located under the runway and taxiway at the Juneau International Airport (Figure 34). This culvert is approximately 1,000 feet long. In addition to crossing structures, low and no flow conditions that commonly occur in lower portions of the creek could restrict fish passage during critical life history stages such as spawning and outmigration (Table 14).

Table 14. Timing of freshwater phases of life histories of salmon species present in Jordan Creek in conjunction with low flow periods. Freshwater phase timing is from Bethers et al (2012) and no/low flow periods is based on flow data from the stream gages.

Potential for Low/No Flow Conditions		J	F	M	A	M	J	J	A	S	O	N	D
		■	■				■	■	■				■
Species	***Phase***												
Coho	Adult return								■	■			
	Spawning										■	■	
	Incubation/Emergence	■	■	■	■							■	■
	Outmigration					■	■						
Pink	Adult return							■	■				
	Spawning							■	■				
	Incubation/Emergence	■	■	■					■	■	■	■	■
	Outmigration				■	■							
Chum	Adult return						■	■	■				
	Spawning							■	■				
	Incubation/Emergence	■	■	■	■				■	■	■	■	■
	Outmigration				■	■							

Low and no flow conditions could lead to stranding and mortality of fish during spawning or outmigration. Several mortality events caused by low flows have been recorded. In September 1998, significant numbers of dead coho and Dolly Varden were found (Carson Dorn, 2002). Acute mortality events involving several hundred coho salmon smolt were observed in late spring (May–June), 2003 to 2005. These mortality events were similar in that they occurred during the first significant rainfall following a week or more of generally dry weather (and subsequent low stream flows). In addition, low flows may affect access to rearing and overwintering habitats. While rearing or overwintering, juveniles may move among areas to find suitable habitat.

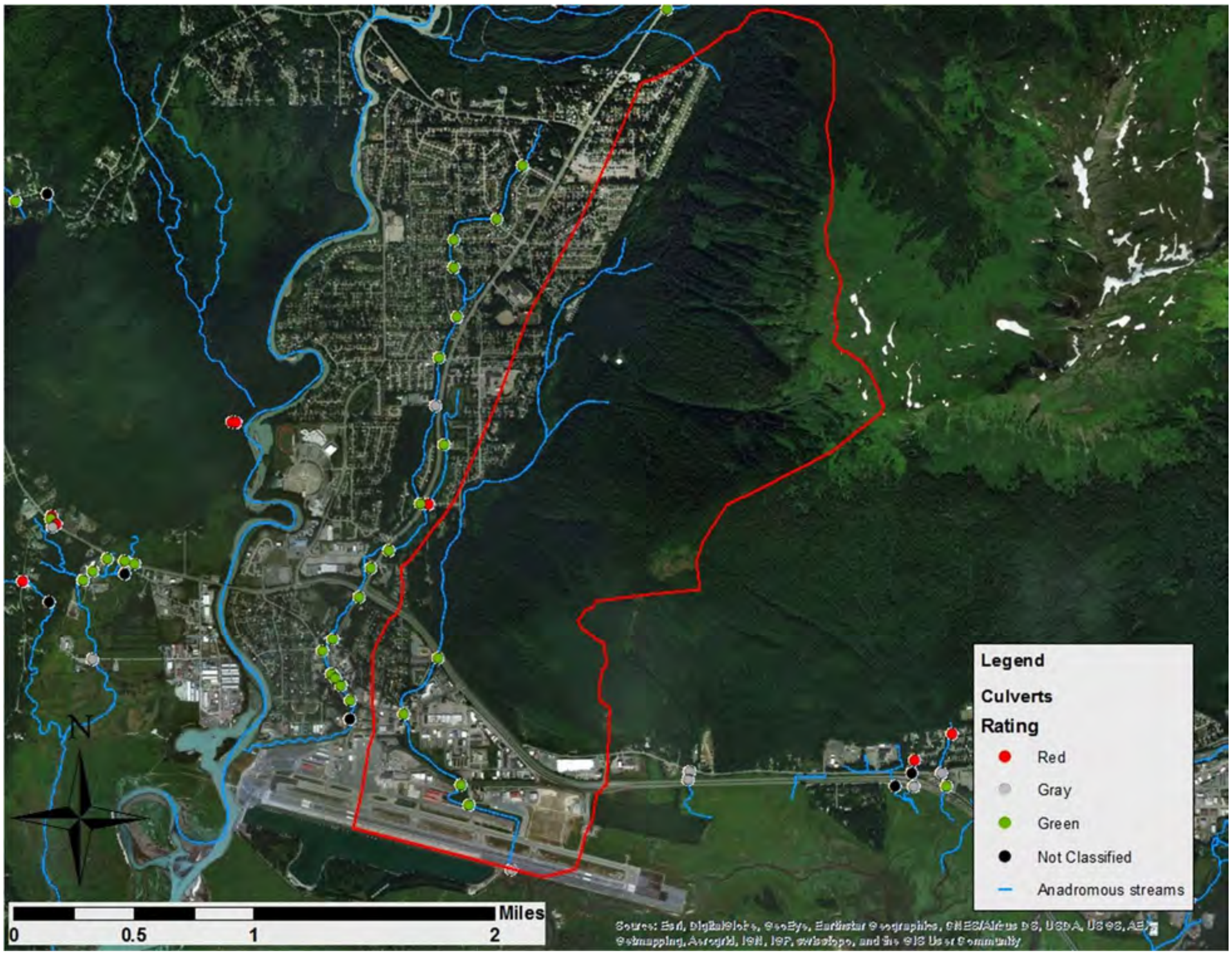

Figure 34. Culverts in the Jordan Creek watershed assessed by the Alaska Department of Fish and Game (ADF&G), including their ratings for fish passage. Green crossings allow fish passage. Red crossings have characteristics that prevent fish passage. Gray crossings may be preventing fish passage. Black crossings have not been evaluated.

Spawning Habitat

Jordan Creek is noted to have excellent spawning habitat for both resident and anadromous fish (Bethers 2012). However, Jordan Creek is only listed in the *Anadromous Waters Catalog* as spawning habitat for pink salmon. However, hydrological conditions and water quality within Jordan Creek can create suboptimal conditions for spawning habitat.

Sediment loading linked to low interstitial oxygen is the primary concern for spawning habitat in Jordan Creek. Fine substrates can reduce water exchange between the stream and redd, which can compromise temperature and dissolved oxygen levels during incubation. Low dissolved oxygen concentrations can cause serious developmental effects during incubation including smaller size at hatching, delayed or premature hatching, as well as morphological anomalies. During egg development, dissolved oxygen concentration should remain at, or near saturation. However, any temporary reductions should drop no lower than 5.0 mg/L for anadromous salmonids (Levy and Slaney, 1993). This corresponds with the WQS, and the interstitial D.O. data indicates that there at least periodic drops below the WQS.

Figure 35. Adult sockeye salmon in Jordan Creek. Photo from JWP's archives.

However, there are other concerns associated with fine sediment loading. Accumulation of fine sediment could make optimal spawning substrates difficult for female salmonids to access. In addition, alevin (sac-fry) emergence can be prevented from fine sediments. Salmon alevins generally experience difficulties when the percentage of fine sediments exceeds 20 percent of the substrate volume (Levy and Slaney, 1993). However, there is little data to show to what extent salmon spawning habitat has been impacted by sedimentation, particularly in terms of the amount of substrate that is fine sediment.

Rearing and Overwintering Habitat

Jordan Creek is listed in the *Anadromous Waters Catalog* as rearing habitat for coho salmon. Juvenile Dolly Varden and cutthroat trout are noted to be present. Despite noted declines, Jordan Creek is still considered to provide important rearing habitat for coho (Bethers 2012). Young coho tend to stay in pools among submerged woody debris, and will hide among the cover provided by rocks, stumps, undercut banks and overhanging vegetation. These habitat types are provided throughout the watershed.

Figure 36. Juvenile salmon in Jordan Creek. Photo from JWP's archives.

Since juvenile coho, Dolly Varden and cutthroat trout remain in freshwater for multiple years, overwintering habitat is important during freshwater rearing. Overwintering habitat is particularly critical for freshwater survival since it is often a limiting factor. Jordan Creek has many characteristics of the preferred overwinter habitat for juvenile coho salmon such as low stream velocity, pools with woody debris cover, side channels, and beaver ponds (Bryant 1984, Murphy et al. 1984, Heifetz et al. 1986).

Of particular note, Jordan Creek provides overwintering habitat for coho salmon nomads from other systems. These nomads are young salmon that migrate to estuarine habitats to rear during the spring and summer, and then migrate upstream in the fall to overwinter in a non-natal stream. The smolt yield of Jordan Creek is thought to be largely attributed to these nomads (Briscoe 2004).

However, rearing and overwintering habitat may be impacted by hydrologic conditions and poor water quality. Low and no flow conditions in summer and winter may not only physically prevent movement between microhabitats during rearing and overwintering, but may also cause an increase in water temperature or freezing (in summer and winter respectively), and decreases in dissolved oxygen.

Data indicates that D.O. levels in the water column periodically drop below the 6.5 mg/L limit set by the WQS, and that these drops typically occur in early spring (March/April) and early summer (June/July).

Data indicates that Jordan Creek water temperatures may be problematic for rearing and overwintering fish. While the WQS for temperature nearly correspond with the upper preferred temperature limit for salmon, it does not account for lower preferred temperature limits or lethal temperatures. The 10-year temperature data shows that water temperatures often dropped below the lower preferred limit of 12 C, and could reach lower lethal temperatures in the winter.

Riparian Areas

Riparian areas provide a variety of benefits to streams such as:

- Providing stormwater capture and treatment
- Protecting streambanks from erosion
- Providing a source of large woody debris, allowing complexity in stream habitats
- Providing cover and food resources for terrestrial invertebrates, birds, and mammals
- Delivering leaf litter, organic debris, and terrestrial invertebrates to streams, which are sources of food for fish and aquatic invertebrates
- Shading streams to maintain cool water temperatures necessary for salmon and other aquatic organisms
- Providing off-channel aquatic habitat as a flood refugium for rearing and overwintering fish

The upper watershed still has its riparian areas intact, and at least part of it is protected as state and federal public land holdings. However, development in the lower watershed encroaches on the stream and has resulted in loss or alteration of much of the riparian area (Figure 37). This is a concern for the lower watershed as it can be contributing to poor instream habitat and water quality problems.

Figure 37. An example of an encroaching parking lot on lower Jordan Creek.

According to a 2003 habitat survey conducted on Jordan Creek by the ADF&G, riparian disturbance affected nearly half (2.81 km) of the entire surveyed area (5.87 km). Urban/commercial landscaping was the most commonly observed riparian disturbance, with all occurrences noted between the airport and Egan Highway.

Impervious surfaces from parking areas and roads were also significant factors in the same area (Nichols and Williams 2012).

A riparian assessment conducted by JWP and USFWS as part of this plan had similar findings. Urban and commercial landscaping disturbances were found throughout the lower watershed. This includes mowing, pruning of trees, and storing clippings and debris close to the stream. Impervious surfaces were found to comprise 12 and 32 percent of the 25- and 50-foot setbacks, respectively.

Another significant impact on the riparian zone is the presence of invasive plant species. Invasive plant species were found to comprise 37 and 26 percent of the 25 and 50-foot setbacks along lower Jordan Creek, respectively. The following invasive plant species were identified in the riparian area: reed canarygrass (*Phalaris arundinacea*), orange hawkweed (*Hieracium aurantiacum*), creeping buttercup (*Ranunculus repens*), European mountain ash (*Sorbus acuparia*), and European bird cherry (*Prunus padus*).

Reed canary grass is currently the greatest threat as it is one of the most prevalent and highly invasive plants in the watershed, and is already impacting stream hydrology and habitat. It forms dense monocultures that displace native plant communities and constrict stream channels by promoting deposition of sediment. Such impacts can be seen throughout the lower Jordan Creek area. For example, the inlet to one of the Glacier Highway culverts is nearly blocked by reed canarygrass (Figure 38) and channel constriction is evident in the CBJ-owned greenbelt south of Jordan Avenue. Carson Dorn (2002) noted that channel constriction from "weeds" contributes to flooding problems in the lower watershed.

Figure 38. Reed canarygrass constricting the channel of Jordan Creek and blocking flow from passing through one of the Glacier Highway culverts.

European mountain ash and European bird cherry are also prevalent throughout the riparian zone in the lower watershed. However, the ecological effects of these species are largely unknown. Both species have fruits that are desirable to birds, which likely help their ability to spread. European mountain ash can hybridize with ashes species native to Alaska. Bird cherry contains a chemical that is toxic to animals such as moose and deer. It can create tall shrub layers that reduce light, moisture and available nutrients for other plant species, and can replace willow stands.

Enforcement Challenges

There are various enforceable regulatory requirements in place that protect Juneau's streams. These include but are not limited to those listed in Table 15.

Enforcement is often considered a management tool to deter individuals from violating laws and regulations by providing a mechanism to penalize violators. The 2006 *Plan* identified several actions focusing on the need for enforcement of these requirements. However, this may have inadvertently set a tone that successful management hinges heavily on enforcement, and that enforcement is completely lacking in managing problems in the Jordan Creek watershed.

While enforcement of regulatory requirements protecting water quality and fish habitat has been an admittedly on-going challenge in Juneau, there are mechanisms in place to initiate enforcement actions, if necessary. Though pro-active enforcement has suffered due to agency funding and staffing limitations, regulatory agency staff do respond to reports of violations from private citizens.

While enforcement is a necessary part of natural resource management, other tools such as education/outreach, technical assistance, monitoring and/or inspections achieve compliance by providing the tools to avoid violations. Enforcement actions should be the last resort in a successful compliance program.

Table 15. Summary of regulatory requirements applicable to activities in the Jordan Creek watershed.

Law, Regulation or Ordinance	Regulatory Agency	Regulatory Requirement
Section 402 of the Clean Water Act	Alaska Department of Environmental Conservation	Requires permit for point source discharges of wastewater or storm water from construction, industrial, or commercial operations
Section 404 of the Clean Water Act	U.S. Army Corps of Engineers	Requires permit for any discharge of dredged or fill material into waters of the United States, including wetlands.
Title 41 Fish Habitat Permit	Alaska Dept. of Fish and Game, Habitat Division	Requires permit for the construction or other activities in anadromous streams
Temporary Water Use Permit	Alaska Department of Natural Resources	Requires permit for a temporary appropriation of freshwater from any subsurface or surface source on all lands regardless of ownership
Water Right Permit/Certificate	Alaska Department of Natural Resources	Requires permit for a permanent appropriation of freshwater from any subsurface or surface source on all lands regardless of ownership
Streamside Setback Ordinance	City and Borough of Juneau	Regulates activities and uses within 25 and 50 feet of anadromous waterbodies; development permits require review and approval by CBJ

Past Restoration Efforts

Since its listing as an impaired waterbody in 1998, there have been various recovery efforts implemented on Jordan Creek. In 2009, the JWP with funding from the USFWS Coastal Conservation program conducted an inventory of habitat rehabilitation, enhancement, and mitigation projects implemented in the Juneau road-access area. A subset of the inventoried projects was then analyzed as case studies to evaluate of whether project goals and objectives were achieved, and to identify any lessons learned for future restoration. At the time of this plan, the 2009 inventory and case studies have not yet been published.

Although not an exhaustive list, the 2009 inventory does provide a glimpse of the types of efforts that have gone into restoring the health of Jordan Creek in the past. This effort identified 18 projects on Jordan Creek. This was approximately 14 percent of the total projects identified as part of the study, making Jordan Creek the third most “worked on” stream in Juneau, following Duck Creek and the Mendenhall River. Efforts on Jordan Creek include streambank stabilization, stormwater best management practices, removing or replacing bridges, wetland restoration, and fish passage improvement. Figure 39 shows the location of these projects.

The unpublished 2009 case studies of projects on Jordan Creek indicate that these efforts have been mostly successful, in terms of meeting their goals and objectives. However, monitoring efforts have not provided any definitive evidence as to if these efforts are addressing water quality and habitat concerns in the watershed. The small size of the projects relative to the watershed would make it difficult to detect any measurable impact on stream and riparian conditions. In addition, the case studies found that several projects require monitoring and maintenance to remain effective.

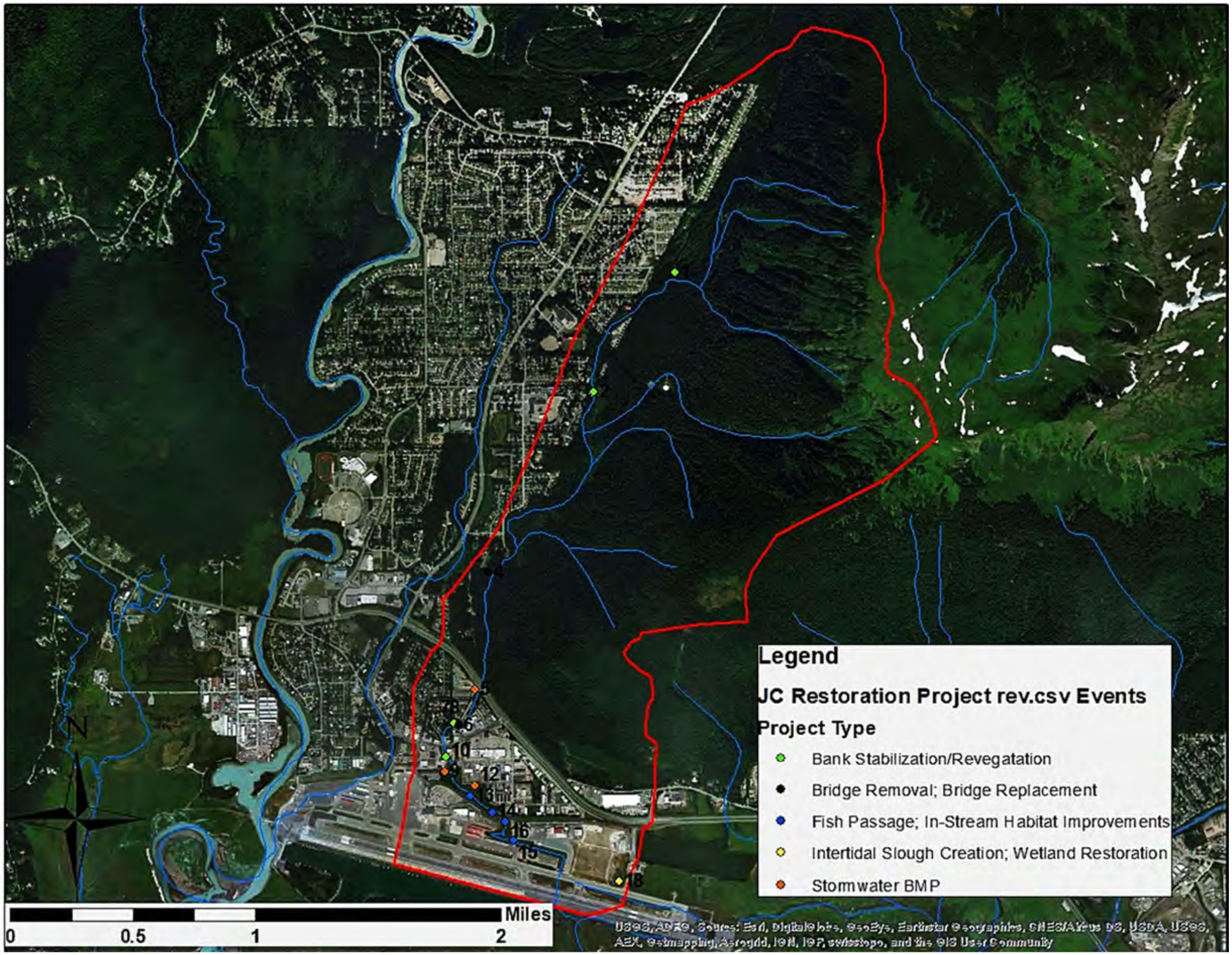

Figure 39. Restoration projects in the Jordan Creek watershed by project type.

Watershed Recovery Goals and Action Items

Methodology

The JWP began development of the watershed recovery goals and action items for this Plan by assessing and updating the 2006 *Management and Recovery Plan (2006 Plan)*. Goals, objectives and action items from the 2006 *Plan* were incorporated into this update if they were relevant for the continued improvement of Jordan Creek, such as those goals, objectives and action items that are applicable to the entire watershed, are in keeping with ongoing efforts of the JWP, or are unfulfilled but are still necessary for Jordan Creek's recovery.

Goals, objectives and action items from the 2006 *Plan* that were completed or are no longer applicable given current conditions are not included in this Plan. Also, those goals, objectives and action items that are not appropriate for a watershed level plan are not included in this plan. This plan also includes new goals, objectives and action items based on watershed activities that JWP completed in 2016 and 2017 to support development of this Plan. These included: assessing the condition of lower Jordan Creek's riparian habitat and holding stakeholder meetings.

Goals, objectives and actions

Goal 1: Jordan Creek meets state sediment water quality standards.

Objective 1.1: Prevent and reduce erosion.

Action 1.1.1 ⇒ *Discourage motorized recreation in the upper Jordan Creek corridor by eliminating/blocking access points, posting signs, and regular public outreach.*

The 2006 *Plan* stated that motorized vehicle use in the upper Jordan Creek watershed was damaging streambanks, spawning areas, floodplains, and wetlands. To help address this concern, the JWP assessed and mapped ATV trails, impacted areas, and access points in 2007. The establishment of the Under Thunder Trail has helped to prevent and discourage use in the area, including eliminating and blocking most access points and posting signs. While ATV use of the area has declined dramatically and former trails are slowly revegetating, there are still some concerns with access. The CBJ should be encouraged to block access points at Valley Blvd., Kanat' A Deyi Street, and private residences where ATVs continue to gain access to sensitive areas. Previous revegetation efforts at Valley Blvd. were impacted by the continued use of the site. Public outreach should be an on-going effort. An approved riding area has not been established but the CBJ and ATV user community continue to explore options.

Action 1.1.2 ⇒ *Enforce regulations that address riparian and stream disturbance.*

Regulations governing riparian and stream disturbance are in place at the city, state, and federal levels. Enforcement of CBJ setback ordinances, state regulations regarding protection of anadromous fish habitat, and federal laws governing wetlands and waterways help protect Jordan Creek and prevent future violations from occurring. Requiring habitat rehabilitation actions should be part of the enforcement, but will only be effective if oversight and subsequent monitoring is done. Where working cooperatively with landowners has proven ineffective, issuing citations may be necessary to restore habitat and prevent future violations. As in the past, organizations such as the JWP and neighborhood associations can assist in bringing violations to the attention of the appropriate authorities.

Action 1.1.3 ⇒ *Require and encourage best management practices that control off-site migration of sediment during land-disturbing activities.*

Best management practices (BMPs) are often included in federal, state, and city permits issued for development projects. Since the 2006 *Plan*, the CBJ published a BMP manual in and adopted it into ordinance in 2009. The Alaska Pollutant Discharge Elimination System (APDES) Construction General Permit (CGP) administered by the DEC addresses erosion control for all construction projects that disturb one acre or more of land. Enforcement of required practices is needed. Encourage CBJ and DEC to conduct site visits to ensure permit compliance related to erosion control. It is critical that such BMPs are included in permits, and that they address erosion control measures. Ensuring that the permittee follows the BMPs requires monitoring by the issuing authority. However, limited staff resources often preclude project oversight and developer interaction. In such cases, it is helpful to have community groups such as the JWP or neighborhood associations who are willing to encourage land owners and developers to use BMPs, and check to see that practices are being maintained throughout the duration of a given project.

Action 1.1.4 ⇒ *Monitor and maintain the East Valley Reservoir restoration site*

The 2006 *Plan* identified the need to address the substantial erosion that resulted from construction of the CBJ East Valley Reservoir (EVR). Prior to the construction of the EVR, the tributary would move and deposit sediment over an alluvial fan area of 8 to 12 acres. These features restricted the flow of the tributary to the southern portion, resulting in sediment deposition into Jordan Creek which impacted fish and wildlife habitat and increased localized flooding on Jennifer Drive.

A stream channel rehabilitation project was completed in August 2009 to restore flow conveyance and sediment transport and reduce the flood risk for adjacent property owners. The restoration project included excavating a new channel, stabilizing the newly formed banks, reestablishing a floodplain, providing instream cover and pools for rearing habitat, and trapping sediment in sediment basins.

Site assessment by JWP and USFWS indicates that, while the project has been successful in meeting the restoration objectives, the site requires monitoring and maintenance. It is

Figure 40. The East Valley Reservoir tributary before (above) and after (below) restoration. Photos from JWP's archives.

recommended that the CBJ create a monitoring and maintenance plan and secure support to implement it, providing for long-term project success.

Timely removal of sediment from the sediment traps next to the water tank is critical. Lack of cleaning has resulted in sediment transport into Jordan Creek where the channel was rehabilitated to reduce flood hazards related to sediment deposition.

Other improvements recommended for the EVR site include:

- To protect the stream bed and water quality, create a physical barrier to prevent the introduction of winter road gravels into Jordan Creek at the end of Jennifer Street.
- Consider cutting the toe logs along left (eastern) bank loose once riparian vegetation is well established to provide more undercut bank habitat. Retain the logs in-stream as large woody debris, where possible, to provide additional complexity and create scour pools.

Action 1.1.5 ⇒ *Rehabilitate disturbed streambanks, riparian areas, floodplains, and uplands.*

Rehabilitation of disturbed areas is much less effective than preventing damage from occurring in the first place. However, the 2006 *Plan* recognized the need to rehabilitate already disturbed areas. Several streambank rehabilitation projects have taken place in the watershed and appear to be effective. However, there are on-going stabilization problems throughout the lower watershed where foot traffic, landscaping practices and damage from other human activities have disturbed streambanks and riparian vegetation. This occurs primarily where businesses and parking lots are within the 50-foot setback. For this reason, this is also listed as Action JRC-6 in the JWP's *Restoration, Enhancement and Mitigation Opportunities Within Juneau Watersheds* for Jordan Creek.

Figure 41. Successful streambank stabilization behind Race Realty. Photo from JWP Archives.

Objective 1.2: Maintain and improve riparian areas.

Action 1.2.1 ⇒ *Educate the public about stream stewardship and the importance of maintaining riparian buffers for fish streams.*

The 2006 *Plan* recommended developing a multi-media public education campaign to educate the public about stream stewardship and the importance of maintaining riparian buffers for fish streams. This is a continuing need. Public education on stream stewardship is provided by various groups such as the JWP, Southeast Alaska Watershed Coalition (SAWC), Discovery Southeast, Trout Unlimited, Southeast Alaska Fish Habitat Partnership, as well as state and federal agencies like ADF&G, DEC and U.S. Fish and Wildlife Service. Much of the existing efforts are largely internet-based, which may limit the audience.

The JWP uses social media and its website as their primary education media. The JWP also occasionally holds stakeholder meetings and participates in public events. Such events are limited by funding, and is largely driven by project-specific needs when funding is available. The JWP created a pamphlet entitled

"Living Next to a Salmon Stream – How to be a Salmon-Friendly Landowner," which is currently available electronically and in print. This pamphlet continues to be distributed by the JWP and the CBJ to landowners.

Discovery Southeast continues to provide outdoor education to students. Their programs have fostered an appreciation of stream resources in the Mendenhall Valley and elsewhere. Support for their programs will promote awareness about resource stewardship.

The DEC has a variety of resources on their website including "Waters in the Spotlight" highlighting restoration and water quality projects; Juneau's watersheds are highlighted on this page.

Action 1.2.2 ⇒ *Improve riparian conditions and recreational amenities of the Jordan Creek Greenbelt to foster stewardship of the area.*

The Jordan Creek Greenbelt protects 10 acres of the lower stream corridor in an area zoned for commercial/light industrial uses. The existing improvements (trails and bridges) of the Greenbelt were constructed by the JIA as mitigation for construction activities in the early 1990s (Parry and Seaman, 1994). After the improvements were made, the Greenbelt was apparently designated as a Natural Area Park in 1996 (citation). A Natural Area Park designation is defined by CBJ Parks and Recreation as: areas of natural quality designed to serve the entire community by providing open space, access to water, and opportunities for passive and dispersed recreation activities.

The Jordan Creek Greenbelt has the potential to be a great neighborhood asset as a parkland, much like the Nancy Street wetland on Duck Creek. Due to its proximity to the JIA, several hotels, commercial businesses, and low-income housing, it is ideally located for residents and visitors alike to enjoy. However, the Jordan Creek Greenbelt needs some improvements to become a safe, attractive park. In its current state, the trails and bridges are in disrepair, reed canarygrass has excluded natural vegetation and constricted Jordan Creek's channel, and there are safety and debris concerns associated with illegal encampments.

The JWP developed a conceptual design for enhancing the Jordan Creek Greenbelt to address these concerns as part of the *Restoration, Enhancement and Mitigation Opportunities Within Juneau Watersheds* project.. Recommendations include installing lighting to improve visibility and safety; providing garbage cans and dog bag dispensers at key location(s) to encourage users to properly dispose of garbage and dog feces; replacing or repairing the dilapidated bridges; improving and maintaining the trails for accessibility; and installing interpretive signage to educate the public about Jordan Creek. In addition, educational brochures with a map and information about Jordan Creek can be displayed at the airport and nearby hotels for visitors. However, a formal planning process to determine neighborhood goals, objectives and actions should be conducted to develop a more fully realized design concept for the Jordan Creek Greenbelt that addresses all stakeholder concerns.

There is conflicting public information about the property's management in CBJ planning documents. The CBJ *Land Management Plan* (2016) and the *Parks and Recreation Plan* (2007) indicate the Jordan Creek Greenbelt is managed by Parks and Recreation. However, the JIA installed signs indicating it is part of airport property, and have verbally confirmed that the management designation in CBJ plans is in error (Wahto, personal communication).

If both the JIA and Parks and Recreation have a vested interest in the management of the property, a recommendation would be for their agencies to establish a memorandum of agreement (MOA) to describe the specific responsibilities of, and actions to be taken by, each of the parties so that their management goals for the Jordan Creek Greenbelt may be accomplished. The MOA can be established after the formal planning process determines the overall concept for the Greenbelt, and better defines potential roles for the agencies.

<u>Action 1.2.3</u> ⇒ *Reconstruct and improve the Jordan Creek wetland viewing platform at Jennifer Drive.*

The Jordan Creek Aquatic Education Trail, built in 1991, provides access to the creek for educational and recreational opportunities. It is located near the Glacier Valley Elementary School and is accessed at the end of Jennifer Drive. It consists of a wetland viewing platform on the east side of Jordan Creek and a 150-foot long boardwalk that connects to the Under Thunder Trail. Both the viewing platform and boardwalk suffer from rot and are in general disrepair. Reconstructing the viewing platform and boardwalk will provide safe access. In addition, the viewing platform and the boardwalk could be improved with interpretive signs to provide information on Jordan Creek. These improvements would require coordination with Alaska Department of Natural Resources as the landowner.

<u>Action 1.2.4</u> ⇒ *Reestablish riparian corridors where possible.*

The 2006 *Plan* identified the need to re-establish riparian corridors downstream of Egan Drive, particularly behind the Jordan Creek Center and Lyle's Hardware. This action presents a challenge, as the area downstream of Egan Drive has several parking lots and structures that are near the creek, and much of this was constructed prior to enactment of the setback ordinance. The 2006 *Plan* recognized that reestablishment of adequate riparian buffers may require purchasing property or easements, followed by rehabilitation efforts. While acquiring property and completely re-establishing the riparian area in lower Jordan Creek would be beneficial, it is an expensive option and, potentially, an unrealistic goal.

As an alternative, the JWP through its partnerships with agencies like the CBJ, ADF&G and USFWS, could work with landowners to improve riparian conditions on their property, to the extent practicable, through one or more of the following solutions:

- revegetating disturbed areas (see Action 1.1.4);
- installing fencing or other barriers along the 25-foot setback, at minimum, to discourage activities that could damage riparian vegetation and streambanks;
- ceasing landscaping and snow removal practices that damage riparian vegetation;
- pulling back structures and/or paved surfaces from the 25-foot setback;

<u>Action 1.2.5</u> ⇒ *Manage invasive plant species throughout the Jordan Creek watershed.*

Due to the prevalence of invasive plant species in lower Jordan Creek, restoration efforts will depend on implementing an invasive plant management program. There are several invasive plant species that are affecting riparian areas and instream habitat within the Jordan Creek watershed. Invasive plants outcompete and displace native plants that provide bank stability, shade, habitat and organic matter to stream food webs that support birds and aquatic species, including salmon. Invasive plants of concern include reed canarygrass (*Phalaris arundinacea*), orange hawkweed (*Hieracium aurantiacum*), creeping buttercup (*Ranunculus repens*), European mountain ash (*Sorbus acuparia*), and European bird cherry (*Prunus padus*). These are very prevalent in the lower watershed, where more disturbance and landscaping has allowed them to take hold.

Reed canarygrass is currently the greatest threat in the lower watershed as it is the most aggressive and is already impacting stream hydrology and habitat. Unfortunately, this species is difficult to manage. Most often, herbicide use is recommended for treatment of reed canarygrass, as mechanical methods are labor intensive and require long-term investment. Use of herbicide may be controversial if not supported by all stakeholders. However, an integrated approach using multiple control methods is usually the most effective. Other methods include: shading with native plants, covering with shade cloth or sheet mulch, cutting or mowing (this alone will not eradicate an infestation), or tilling. The effectiveness of these methods can be tested by implementing and monitoring test sites in the Jordan Creek watershed.

European mountain ash and bird cherry are also prevalent in the lower watershed. However, control measures for European mountain ash and bird cherry are largely untested. Most trees can be treated by girdling, though there have been mixed results using this method on European mountain ash along lower Jordan Creek. European mountain ash can re-sprout (form secondary replacement trunks) when cut, allowing it to spread more across the canopy, so this is not a recommended practice unless the trunk can be removed.

Creeping buttercup is the most common invasive species found in the upper watershed. It is found on along the Under Thunder trail and associated spur trails. Soil disturbance and loss of vegetation from past use of off-road vehicles has been a vector for spreading invasive plants in the upper watershed.

To be successful, invasive plant control will likely require treatment across several consecutive growing seasons and will require monitoring to determine if measures are successful. Revegetation with native riparian plants should follow successful eradication.

Action 1.2.6 ⇒ *Assess the capacity to reestablish beaver populations to increase habitat in Jordan Creek*

Since the deep pools created by beavers provide good overwintering habitat, the loss of beavers in the watershed could be a contributing factor in the declining coho salmon population. According to Paustian et al (1992), floodplain channel types present in Jordan Creek can be enhanced for rearing habitat by introducing beaver. The Washington State Stream Restoration Habitat Guidelines (Cramer, 2012) also describes beaver reintroduction as having other benefits such as elevated water tables upstream, reduced sedimentation downstream, increased water storage, improved water quality and increased waterbird habitat.

Jordan Creek historically hosted beaver populations, so it is reasonable to assume that beavers could be supported. However, there is little information regarding the current beaver population in the Jordan Creek watershed. Reconnaissance is necessary to determine beaver presence, habitat suitability, and other factors that may be influencing their presence/absence in the watershed such as trapping. It is also important to document where the introduction of beavers would conflict with adjacent land owners and uses. Utah State University developed a *Beaver Restoration Assessment Tool* that can help identify locations where beaver introduction may be appropriate. This tool could be applied or adapted for use on Jordan Creek.

The added benefit to having beavers more active in the watershed is that beavers create habitat features in a short timeframe (2-5 years) and at cost a fraction or the amount of traditional restoration work done with heavy equipment and laborers. Cramer (2012) provides guidance on beaver re-introductions if this is determined to be an appropriate approach. However, if beaver introduction is found not to be suitable, particularly because of conflicts with adjacent land uses, beaver dam analogs (human constructed structures meant to mimic beaver dams), could serve as an alternative.

Objective 1.3: Improve snow removal and storage practices.

Action 1.3.1 ⇒ *Encourage best management practices for snow plowing and storage along Jordan Creek through a targeted education and outreach campaign*

Streams and riparian areas are often used as snow storage because they are usually outside of heavy traffic areas. However, plowing snow into the riparian area can impact vegetation through soil disturbance, damage from the weight of the snow or by the plow. In addition, plowed snow often contains debris, hydrocarbons, deicing chemicals, and sand used for traction on roads and driveways. When stored in or directly adjacent to streams, pollutants enter the system as the snow melts. The 2006 Plan identified actions to develop a city-wide snow management plan and establish city-managed snow storage areas that include BMPs to prevent transport of sediment and other pollutants to streams and other waterbodies.

Figure 42. Snow being stored near Jordan Creek at Glacier Highway. The snow has been pushed into the creek and is depositing sediment in the streambed. Photo from JWP's archives.

In 2010, DOWL HKM produced a *Snow Management Assessment and Planning* report for the CBJ. This study evaluated potential snow management alternatives for the CBJ, that allows for the continuation of cost- and time-efficient snow removal services while addressing environmental concerns. This plan identified potential snow storage sites and recommended BMPs for preventing sediment from being transported offsite. In addition, the JWP produced snow storage area BMPs that were provided to the CBJ. This effectively addresses the needs identified in the 2006 *Plan*.

Though such city-wide actions would improve snow storage management throughout all of Juneau's watersheds, including Jordan Creek, it does not help to address poor snow management practices directly affecting Jordan Creek. Stream-side residents and business owners should be encouraged to implement best management practices on their properties. In addition, state and local government crews involved in snow management should be to encourage improved snow storage BMPs. Seek funding to help CBJ/landowners manage snow better.

Action 1.3.2 ⇒ *Implement recommendations in the snow management report*

To better address poor snow management practices directly affecting Jordan Creek, the JWP assessed snow management practices throughout the watershed and documented findings in a report entitled *Snow Management in Jordan Creek Watershed* in 2008. The assessment identified six sites as locations where snow was plowed into Jordan Creek or adjacent riparian areas. Most of these sites were on private (commercial) property, but a few were public road crossings where CBJ or DOT&PF plowed snow and sediment into the creek. The JWP's report made recommendations for three of these sites. Only one of these recommendations was implemented. However, many of these snow storage sites are continuing to contribute to sediment and pollutants to Jordan Creek. For example, the snow storage site on Yandukin Drive may be a factor contributing to the Yandukin monitoring site (Site C) having higher winter turbidity and TSS measurements, unlike the other monitoring sites. There may also be new sites not addressed in this report.

Objective 1.4: Improve stormwater discharges

Action 1.4.1 ⇒ *Implement recommendations in "Stormwater in the Lower Jordan Creek Watershed" report.*

The U.S. Fish and Wildlife Service mapped stormwater flow pathways and outfalls in the lower Jordan Creek watershed, and identified opportunities for implementing BMPs and green infrastructure in the various stormwater subsheds. Recommendations in their report, *Stormwater in the Lower Jordan Creek Watershed* (2015), should be considered for reconstruction and new construction projects that offer opportunities to incorporate stormwater BMPs. Priority should be given to the following recommendations:

- Improve stormwater treatment at the Jordan Creek Greenbelt discharge point near Teal Street, which is the discharge point for the largest stormwater contributing area from impervious surfaces.
- Shorten the North Jordan Avenue outfall pipe and construct an infiltration or retention basin to remove sediment and other pollutants from runoff.
- Prevent McDonald's trash compactor effluent and garbage from McDonald's and Breeze In parking lots from discharging into Jordan Creek via the Trout Street ditch.
- Install hydrodynamic separators at the downstream end of the Trout Street ditch and the Airport parking lot stormwater system

Figure 43. Garbage and sediment collected in the Trout Street ditch. Photo courtesy of John Hudson.

Action 1.4.2 ⇒ *Improve stormwater entering Jordan Creek at Valley Boulevard.*

Run-off from Trafalga Ave., Threadneedle St., Kanata Dyi, and the Thunder Mountain Trailer Park flows into Jordan Creek from a ditch that discharges into the stream near Valley Blvd. This ditch represents the only stormwater surface discharge to Jordan Creek from developed areas upstream of Egan Dr. Stormwater from this ditch is likely contributing pollutants such as sediment, hydrocarbons and other chemicals to the stream. In addition, the ditch is fed by groundwater and is used by juvenile coho salmon. Collaboration with the landowners of the properties contributing stormwater to the ditch is needed to develop and implement BMPs to address stormwater quality.

<u>Goal 2: Jordan Creek meets state dissolved oxygen water quality standards.</u>

Objective 2.1: Determine if dissolved oxygen concentrations in the water column and substrate are adequate to support designated uses.

<u>Action 2.1.1</u> ⇒ *Establish monitoring sites and analysis techniques, and monitor regularly.*

The 2006 *Plan* previously identified this need, but it has not been addressed. At that time, only one study had included measurements of interstitial dissolved oxygen. Another study followed in 2008. These studies provide several monitoring sites that can be used for future monitoring. In these studies, interstitial dissolved oxygen was measured in PVC pipes installed vertically in the streambed using a dissolved oxygen meter. Data from these studies were used in developing the TMDL approved in xx, which also recommended to have continued monitoring of interstitial D.O. However, no studies have included such measurements since the 2008 study.

Objective 2.2: Assess the influences on dissolved oxygen levels in the water column and substrate

<u>Action 2.1.1</u> ⇒ *Monitor dissolved oxygen throughout the year*

The 2006 *Plan* recommended regularly monitoring both interstitial and water column dissolved oxygen (D.O.) throughout the year. Measurements of D.O. in the water column were included in monitoring efforts since the 2006 Plan, but interstitial D.O. has not been as intensely studied. Studies maintain that oxygen levels fall below state standards seasonally or periodically in the water column. In addition, future D.O. sampling may focus on locating salmon overwintering habitat and monitoring D.O. at those locations throughout winter to identify overwintering habitats for safeguarding.

<u>Action 2.1.2</u> ⇒ *Monitor potentially influential factors in conjunction with dissolved oxygen studies.*

Several factors influence the concentration of dissolved oxygen in the water column and substrate. Therefore, to allow for more accurate data interpretation, such factors should be measured concurrently. This includes water temperature, at-site discharge and/or flow velocities (rather than relying on a gage in a different location), current and recent weather, iron concentrations, and sedimentation.

<u>Goal 3: Keep Jordan Creek free of anthropogenic debris.</u>

Objective 3.1: Remove existing debris from Jordan Creek and its tributaries.

<u>Action 3.1.1</u> ⇒ *Continue to support and expand volunteer cleanup events.*

Litter Free, a non-profit organization committed to keeping Juneau clean and encouraging recycling, organizes a community-wide cleanup each spring where residents and volunteers pick up garbage throughout the city. The JWP participates in this annual clean-up event to encourage clean-up of streams (including Jordan Creek). As part of the 2016 annual clean-up effort, the JWP initiated a garbage hotspot map on their website to help direct volunteers to the worst sites along Juneau’s streams.

The JWP used to operate an Adopt-a-Stream program, in which groups volunteered to adopt sections of a waterway. This program is currently defunct but could be re-initiated as staffing and funding levels allow.

To foster education and to get school groups involved, a program could be started at Glacier Valley Elementary and Floyd Dryden Middle School to have each class pick up trash at least once a year, and track the amount and type of trash they remove. Promoting additional cleanup events by involving local businesses and community groups would help ensure debris removal occurs on a regular basis.

Objective 3.2: Prevent debris from entering Jordan Creek and its tributaries.

<u>Action 3.2.1</u> ⇒ *Educate the public about the need to control litter for health and sanitation, animal control, protecting fish and wildlife habitat, and ensuring good water quality.*

A change in public attitude and perception toward the importance of small stream systems such as these is critical in implementing the debris TMDL. Educational and outreach programs targeted at the two nearby schools (Glacier Valley Elementary School and Floyd Dryden Middle School) are recommended to foster a sense of ownership among the residents of the area. Interpretive signs about specific habitat features and water quality to educate the public about the need for stream stewardship could be added to several locations in the watershed including: the nature trail area near Jennifer Drive, the Jordan Creek Greenbelt, and at streamside businesses such as the Super 8 Motel and the Jordan Creek Center. Educational signs could also be posted at the Breeze-In and McDonald's to encourage patrons to dispose of their garbage properly so that it doesn't get carried into the stream. Additionally, neighborhoods could be encouraged to organize junk-hauling days, where residents could group together to make efficient and cost-effective trips to the landfill.

<u>Action 3.2.2</u> ⇒ *Provide bear-proof containers in source areas for litter such as high-density housing areas and store parking lots, and promote their proper use.*

This action was identified in the 2006 *Plan;* however, locations where bear-proof containers are lacking were not specified, so there is no documentation as to the extent this was implemented. Proper storage of garbage is an on-going problem on Jordan Creek and throughout Juneau. Even where bear-proof containers are used, containers that are over filled or not properly closed still pose a problem. Proper use of bear-proof containers also needs to be encouraged. Specific locations where improved storage practices and bear-proof containers are needed should be identified so that progress towards completing this action item can be documented.

<u>Action 3.2.3</u> ⇒ *Enforce local ordinances that address garbage storage, littering, polluting water, and illegal camping.*

In March 2002, the CBJ adopted an Urban Bear Ordinance designed to keep garbage away from bears. Relevant provisions specify that garbage must be kept in a bear-resistant container or enclosure, and put out for collection no sooner than 4 a.m. on pickup day. If garbage has attracted bears and the resident or business fails to take steps to legally store the garbage, they may be cited for maintaining a bear attraction nuisance. The citation carries a $50 fine for the first offense.

Similar ordinances exist for littering, polluting water, and illegal camping. Several illegal dumping sites are in upper Jordan Creek, some of them in drainages that periodically go dry but contribute seasonal flow to Jordan Creek. Garbage associated with illegal camps or squatters is common in the Jordan Creek watershed. The mere presence of ordinances does not appear to deter people from littering. Enforcement is needed to stop such activities from occurring, and may provide funds to help in future control efforts.

Goal 4: Jordan Creek water quality is not degraded by point and nonpoint source pollution.

Objective 4.1: Assess Jordan Creek water quality.

Action 4.1.1⇒ *Continue monitoring basic water quality parameters.*

Jordan Creek was included on the impaired waters list in part because there had been preliminary data suggesting impaired water quality. Parameters such as temperature, dissolved oxygen (in the water column), pH, turbidity, and conductivity are standard for most monitoring efforts and should be considered in any future water quality studies. Continuing to collect such data will provide more information over time. However, the comparability and analysis of such data will only be possible if established sampling sites are used in future studies, and adequate quality control measures are utilized in data collection.

While the 10-year data set from 2003 to 2013 has been useful in assessing trends, future studies should consider using automated sequential sampling devices or continuous, online monitoring systems for parameters such as temperature, turbidity and dissolved oxygen to better characterize the temporal and spatial variability of these parameters. A major disadvantage to using automated or online monitoring equipment is the potential expense of the equipment.

For example, these methods will more accurately assess in-stream peak concentrations of turbidity during rain storms and snow melt events, which periodic sampling is rarely adequate to characterize. Future studies could focus on continuous sampling from initiation of rainfall until rainfall ceases for a limited number of events, coupled with discharge data. Such monitoring of turbidity is particularly important in the lower watershed to understand how stormwater runoff impacts the stream.

Action 4.1.2 ⇒ *Maintain stream gaging on Jordan Creek.*

A stream gaging station should be maintained on Jordan Creek. Discharge data collected at the historic USGS station has been useful for a variety of different studies conducted on Jordan Creek and in the Mendenhall Valley. However, the USGS gaging station on Jordan Creek was discontinued in October 2005. Although the 2006 Plan recommended that maintaining the gaging station would provide continuity in discharge information, a new stream gage was not put into operation until 2012, leaving a seven-year gap in the data.

The existing stream gage is operated by the National Weather Service. If unable to maintain the gaging station, another entity should be encouraged to take on responsibility for the station before it is discontinued to prevent another data gap. Continuous discharge information is important for assessing changes over time, which may be important for understanding hydrological changes occurring in the watershed.

Action 4.1.2 ⇒ *Develop a rating curve for the new stream gaging station on Jordan Creek.*

Although the new gage continues to provide valuable information regarding the creek's water levels, only the stage height is collected. Currently, the gage lacks a rating curve to translate stage data into discharge. Establishing a rating curve is important for potentially comparing the historic USGS data with the new data and assessing long-term trends.

Objective 4.2: Assess known and potential contaminant sources.

Action 4.2.1 ⇒ *Regularly update storm water maps to maintain inventory of potential non-point sources of pollution in the watershed.*

The 2006 *Plan* recommended an action to assess and map potential contaminants, point and nonpoint sources of pollution in the watershed. In 2008, the CBJ mapped stormwater outfalls on Juneau's impaired watersheds. However, this data did not include stormwater flow paths over land and through the stormwater system. A report entitled, *Stormwater in the Lower Jordan Creek Watershed* was (USFWS, 2015) documents stormwater flow paths in the lower watershed. The upper watershed and portions of the lower watershed were not included. In addition, over time, new development and re-development can change stormwater flow paths, create new discharge points, and incorporate stormwater BMPs could make the maps outdated. The stormwater maps should be periodically updated to maintain relatively current stormwater flow paths. Knowledge of stormwater flow paths would assist in delineating the areas contributing to the stormwater entering each waterbody, an important aspect of designing stormwater BMPs to accommodate runoff rates. This will allow for identifying additional opportunities to improve stormwater.

Action 4.2.2 ⇒ *Maintain Garbage Hot-Spot Map.*

In 2016, the JWP developed a garbage hotspot map and made it accessible on their website. This map is used to help direct volunteers during clean-up efforts to the worst sites along Juneau's streams, including Jordan Creek. This online map should be maintained and regularly updated with hot-spot locations on Jordan Creek identified or reported by the community.

Action 4.2.3 ⇒ *Assess active contaminated sites and groundwater flow into Jordan Creek and associated wetlands.*

The 2006 *Plan* previously identified this action, but it has not yet been addressed. The initial concern described in the 2006 *Plan* was potential contamination from the former Reid Pond area, though other contaminant sources were also considered. The DEC compiles information on contaminated sites that can be reviewed to identify documented sites and their potential to affect water quality in Jordan Creek. If contamination is suspected, monitoring of surface and groundwater quality, as necessary, could be used to determine the extent of the problem and whether clean-up responses are effective.

Objective 4.3: Reduce current and prevent future nonpoint source pollution.

Action 4.3.1 ⇒ *Work with appropriate land owners and responsible agencies to eliminate or reduce potential pollutants.*

Once the assessments of Objective 4.1 are completed, land owners and responsible agencies need to work cooperatively to eliminate or reduce potential pollutants. Efforts may include relatively simple tasks like public outreach and education, and more complicated projects such as contaminated soil removal. Opportunities for improving stormwater management, such as installation or improved maintenance of oil-water separators and sediment traps, should be identified.

Action 4.3.2 ⇒ *Educate the public about potential impacts of residential chemical use on water quality.*

Stream stewardship outreach campaigns should include information on how individual residential homeowners can reduce potential impacts to surface water quality. Efforts such as the storm drain stenciling project implemented by MWP several years ago should be revitalized. The project involved painting streets to remind people that gutters and drains lead to fish streams. Community hazardous waste collection days are periodically hosted at the local landfill and the CBJ now has a residential household hazardous waste program, which is funded by a utility fee. These programs should be supported by public education about potential impacts of chemicals on stream resources. A volunteer pick-up service could be initiated to facilitate collection and drop-off.

Goal 5: Jordan Creek is a productive anadromous and resident fish stream.

Objective 5.1: Maintain and improve instream fish habitat quality.

Action 5.1.1 ⇒ *Maintain building setbacks to protect riparian buffers, and revegetate disturbed areas.*

As previously discussed, riparian buffers are critical for protecting water quality and providing instream fish cover. The setback should be maintained, and may need to be extended in areas where wetland or floodplain habitat connectivity to the creek is necessary to ensure fish habitat quality. The primary oversight for maintaining riparian buffers is provided through project development and local permits, but community groups can work proactively to encourage protection of riparian areas. Organizations such as the JWP can promote good stream stewardship as well as initiating rehabilitation projects where needed.

Action 5.1.2 ⇒ *Enforce regulations governing anadromous waters.*

Enforcement of regulations governing anadromous waters is twofold—it involves working with developers and resource users to obtain necessary permits when projects include working in streams, and issuing citations for those violating relevant laws. While most developers obtain necessary permits, a review of Jordan Creek project history reveals several citations that have been issued for permit violations or code violations without a permit. With regard to illegal vehicle crossings of anadromous fish streams, enforcing regulations is complicated by lack of staff and difficulty in accessing vulnerable areas. Still, enforcement is necessary to prevent future impacts to stream resources.

Action 5.1.3 ⇒ *Assess streambed particle size distribution to identify impacted spawning habitat in Jordan Creek*

Though Jordan Creek is identified as impaired for sediment, there have been no studies assessing streambed particle size distribution to determine whether the WQS is being met. Since the WQS protects gravel beds used by anadromous fish for spawning, such an assessment can also serve to identify where spawning habitat has been impacted by fine sediment inputs and whether other problems such as insufficient gravel supply or inadequate gravels of appropriate size are limiting spawning habitat. After the initial study, an on-going monitoring effort could provide a basis to determine if measures being implemented to reduce sediment or enhance spawning habitat are improving spawning habitat conditions. This action would also fulfill Objectives 1.1 and 5.2.

Objective 5.2: Protect hydrologic and ecologic stream functions.

Action 5.2.1 ⇒ *Maintain connectivity with the floodplain by preserving open space along stream corridors.*

Further development of the floodplains associated with Jordan Creek should be avoided to protect fish habitat and attenuate potential flooding. Efforts to protect the remaining floodplain should be pursued where possible. Much of the upper watershed corridor is on public (city, state and federal government) land, which currently has minimal development and is being managed to preserve open space.

However, the CBJ's property is designated for retention/disposal, which is common for such large parcels. The CBJ deems this property suitable for future residential development due to ease of access to existing roads, and a good quantity of relatively flat, dry land (CBJ, 2006). If the CBJ disposes of property from this parcel, a protected stream corridor should be designated along Jordan Creek. Because the property is situated in the watershed where much of the flow is generated, some consideration should be given to protect a larger corridor than needed for the standard 50-foot setback. The CBJ Parks and Recreation Plan (2007) recommends a 200-foot greenbelt on each side of Jordan Creek where it traverses CBJ owned property, except for the portion on the JIA property.

In addition, Jordan Creek between Tongass Blvd. and Egan Dr. passes through three privately owned and largely undeveloped properties. The JWP, SAWC or SEAL Trust should open discussions with the landowners to learn about future plans for the properties and whether the landowners are open to protecting all or a portion(s) of their property under a conservation easement or other means. Protecting all or a portion of these parcels would help conserve valuable open space along the Jordan Creek corridor.

In the lower watershed, the stream corridor has been heavily impacted by urban development. Reestablishing floodplain corridors that have been developed is more expensive and difficult, as it involves purchasing land and/or easements, and may involve extensive rehabilitation work to restore floodplain functions. However, this may be a long-term option for restoring Jordan Creek. One opportunity in the lower watershed outside of the Jordan Creek Greenbelt involves two odd-shaped parcels in the industrial/commercial area near Airport Blvd. These parcels are not developed and are partially used for snow storage. These properties could be protected from development through purchase or a conservation easement.

Action 5.2.2 ⇒ *Remove logging slash and debris in the stream near the former clearcut at Nancy Street.*

Removal of the slash and logging debris remaining in the stream from the 1960s clearcut was originally recommended by Bethers (1985) and then re-recommended in Bethers et al (1995) and Bethers et al (2012). Bethers et al (2012) noted that some, but not all, of the debris has been removed. Removal of this material is suggested to facilitate stream flow.

Action 5.2.3 ⇒ *Assess the feasibility of enhancing Jordan Creek spawning habitat.*

There are a variety of methods that can potentially be employed to enhance spawning habitat. The enhancement method(s) used should depend on the causes of degradation, the stream type and hydraulic conditions. As mentioned, sedimentation is suspected to be impacting spawning gravels. The Washington State *Stream Habitat Restoration Guidelines* (Cramer, 2012) identifies the following techniques for enhancing spawning habitat where fine sediment impairs gravel condition: spawning gravel cleaning, riparian restoration, beaver introduction, channel modification and adding large wood.

However, data is lacking to know the extent to which spawning habitat has been impacted by sedimentation. In addition, it is unknown if other factors are limiting spawning habitat, which could inform decisions regarding enhancement techniques. For example, introduction of spawning gravels is a technique that could be employed if gravel supply is limited. According to Paustian et al (1992), groundwater fed slough channel types, like those in lower Jordan Creek, can be enhanced through the introduction of spawning gravels. The Washington State *Stream Habitat Restoration Guidelines* (2012) confirms that this technique can be used in groundwater fed streams, and describes a successful gravel supplementation project in the Suiattle Slough in Darrington, Washington. This may not be suitable if the stream has on-going sedimentation problems that would impact the newly introduced gravel.

In conjunction with assessing streambed particle size, it should be determined whether there are problems with gravel availability (see Action 5.1.3). Once the limiting factor(s) have been fully characterized, a feasibility study could be conducted to determine the appropriate approach to enhance spawning habitat. The Washington State *Stream Habitat Restoration Guidelines* (2012) provides some guidance on assessment needs for spawning enhancement projects that could be utilized.

Objective 5.3: Ensure adequate passage for resident and anadromous fish at all life stages.

Action 5.3.1 ⇒ *Continue periodic assessment and mapping of fish passage structures at all stream crossings on the mainstem and tributaries, and prioritize those needing replacement or removal.*

Most of the stream crossings on Jordan Creek were assessed and mapped by ADF&G in 2003 and again in 2012. Periodic assessment and mapping of fish passage on the main stem and tributary channels of Jordan Creek should continue as structures age and conditions change to identify future problems. As in the past, the assessment should include a description of the structure, dimensions, and age or date of installation.

Action 5.3.2 ⇒ *Replace or remove inadequate or unnecessary stream crossings.*

Since most of Jordan Creek's stream crossings are downstream of Egan Drive, ensuring fish passage is critical for returning adult salmon as well as juveniles seeking rearing habitat. While prior fish passage assessments have not identified any existing problem structures, periodic assessments should continue as described in Action 5.3.1. Information from future assessments should be used to work with landowners and resource agencies to remove or replace stream crossings as needed to improve fish passage.

Action 5.3.3 ⇒ *Avoid installing additional stream crossings if possible. Where new crossings are necessary, minimize their number and ensure that new structures are constructed to provide fish passage at all life stages.*

Minimizing the number of stream crossings necessary to provide safe access should be pursued wherever possible, and can be accomplished through development planning and design. Should stream crossings be necessary, they should be designed and installed to provide adequate passage for fish at all life stages. When considering crossing structures, it should be noted that culverts may present fish passage barriers in floodplain and palustrian channel types, which comprise the mainstem of Jordan Creek (Paustian et al, 1992). In addition, Bethers (1985) recommends that only bridges or bottomless arch culverts should be used in future road crossings of Jordan Creek. Bottomless arch culverts should only be used in locations where the floodplain is narrow and pile supported bridges that span the entire floodplain should be used in locations where floodplains are wide.

Objective 5.4: Conduct biological monitoring of Jordan Creek and its tributaries.

Action 5.4.1 ⇒ *Continue to monitor fish populations.*

Weir data gathered by ADF&G helped analyze fish population trends in Jordan Creek. Such data becomes more valuable over time, allowing for meaningful statistical analyses. However, with the elimination of the escapement goals, fish populations have not been monitored since 2005. Continuing operation of the weir or other monitoring methods will help assess the creek's biological condition.

Action 5.4.2 ⇒ *Identify and monitor spawning and overwintering areas in conjunction with water quality studies and land use activities.*

Identifying spawning areas in Jordan Creek and subsequent monitoring of these sites would help determine if a correlation exists between sediment loading, low dissolved oxygen, and the presence and quality of spawning areas in the creek. Identifying potential overwintering areas was recommended by Briscoe (2007). Once identified, overwintering sites could be monitored for temperature and dissolved oxygen to determine if they are suitable. Monitoring the areas over time would provide additional information about fish populations and productivity.

Action 5.4.3 ⇒ *Include invertebrate sampling in biological studies.*

Aquatic invertebrates have been used as indicators of water quality and stream condition. Since they spend much of their lives in the stream, near or in the substrate, invertebrates are influenced by water quality and changes in the physical environment. Invertebrates have been inconsistently included in monitoring efforts on Jordan Creek. Including invertebrate sampling with stream monitoring events may provide additional information about the overall condition of Jordan Creek. However, since it was recommended that Jordan Creek not be treated as a reference site, any macroinvertebrate monitoring on the creek will require identifying a suitable reference site for comparison.

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Appendix A: Assessment of the 2006 Plan

2006 Goals	2006 Objectives	2006 Action Items	Assessment	Recommendation
GOAL 1: Jordan Creek water quality meets state sediment water quality standards.	**Objective 1.1:** Prevent and reduce erosion.	**Action 1.1.1:** Discourage motorized recreation in the upper Jordan Creek corridor by eliminating/blocking access points, posting signs, regular public outreach, and establishing an acceptable riding area.	This action has been mostly addressed. The JWP assessed and mapped ATV impacted areas including access points in 2007. The establishment of the Under Thunder trail has included eliminating/blocking most access points and posting signs. However, the CBJ should be encouraged to block access points at Valley Blvd., Kanat' A Deyi Street, and private residences where motorized vehicles continue to gain access to this sensitive area. Public outreach is on-going. An approved riding area has not been established but the CBJ and ATV user community continue to explore options. However, this recommendation is not appropriate for a watershed level plan.	Maintain goal and objective. Maintain action item, but remove the action to "establish an acceptable riding area."
		Action 1.1.2: Enforce regulations that address riparian and stream disturbance.	Enforcement is an on-going challenge in Juneau. However, enforcement is a tool to obtain the objective/ goal. CBJ and other regulatory agencies are encouraged to conduct site visits to ensure permit compliance related to erosion control.	Maintain action item

		Action 1.1.3: Require and encourage best management practices that control off-site migration of sediment during land-disturbing activities.	This action has been mostly addressed. Regulatory processes require BMPs. The CBJ published a BMP manual in and adopted it into ordinance in 2009. The APDES Construction General Permit also addresses this for projects that disturb over an acre of land.	Maintain action item
		Action 1.1.4: Stabilize the road, tank pad, and streambanks associated with the CBJ water storage facility on the main Jordan Creek tributary.	This action has been completed. However, site assessment by JWP and USFWS indicates that site could be monitored and maintained. timely removal of sediment from the sediment traps next to the water tank is critical. Lack of cleaning has resulted in sediment transport into Jordan Creek where the channel was rehabilitated to reduce flood hazards related to sediment deposition	Delete action item. Replace with new action item: "Monitor and maintain EVR restoration site."
		Action 1.1.5: Rehabilitate disturbed streambanks, riparian areas, floodplains, and uplands.	This action continues to be on-going.	Maintain action item.
	Objective 1.2: Maintain and improve riparian areas.	**Action 1.2.1:** Educate the public about stream stewardship and the importance of maintaining riparian buffers for fish streams.	This action continues to be on-going.	Maintain objective. Maintain action item

		Action 1.2.2: Maintain riparian buffers by not granting streamside setback variances.	CBJ is currently not granting any streamside setback variances due to legal concerns with the Land Use Code ordinance language. CBJ is currently re-writing the setback ordinance. It will continue to allow for variances. It is not realistic to ask CBJ to not grant any variances if it is allowable per the ordinance.	Delete action item.
		Action 1.2.3: Enforce regulations where disturbance has occurred.	Enforcement is an on-going challenge in Juneau. However, enforcement is a tool to obtain the objective/ goal.	Delete action item and combine information with Action 1.1.2., which is similar.
		Action 1.2.4: Reestablish riparian corridors where possible.	This action has not been addressed. While improvements such as streambank stabilization and revegetation have been made along lower Jordan Creek, naturally vegetated riparian corridors have not been re-established in terms of ensuring an intact 25 and 50-ft setback.	Maintain action item.

	Objective 1.3: Improve snow removal and storage practices.	**Action 1.3.1:** Develop a city-wide snow management plan that includes best management practices for snow plowing and storage, and an education and outreach component for contractors, residents, business owners, and both state and local government crews involved in snow management.	A city-wide snow management plan was developed by DOWL HKM. A city-wide action is not appropriate for a watershed-specific plan.	Maintain objective. Delete action item.
		Action 1.3.2: Establish snow storage areas that include measures to prevent offsite transport of sediment (e.g., sediment traps, silt fencing).	This action has been minimally addressed. The JWP documented snow storage areas throughout the Jordan Creek watershed in 2008. These snow storage areas continue to operate without BMPs. Update snow storage report with new sites and reaffirm recommendations. Meet with Streets Dept. to encourage improved snow storage BMPs. Seek funding to help CBJ/landowners managed snow better.	Maintain action item.
GOAL 2: Dissolved oxygen levels in Jordan Creek meet water quality standards for designated uses.	**Objective 2.1:** Determine if dissolved oxygen concentrations in the water column and substrate are adequate to support designated uses.	**Action 2.1.1:** Establish monitoring sites and analysis techniques, and monitor regularly.	Jordan Creek has 10+ years' worth of data from several sites. Regular monitoring should continue.	Maintain goal and objective. Maintain action item.

	Objective 2.2: Assess the influences on dissolved oxygen levels in the water column and substrate.	**Action 2.2.1:** Monitor dissolved oxygen throughout the year.	Interstitial D.O. has only been studied twice in 2006 and 2008. D.O. in the water column has been monitored somewhat regularly, though not necessarily throughout the year. More monitoring, particularly of interstitial D.O. is needed.	Maintain objective. Maintain action item.
		Action 2.2.2: Monitor potentially influential factors in conjunction with dissolved oxygen studies.	At site temperature, discharge and other factors is needed with D.O. studies as described above.	Maintain action item.
GOAL 3: Keep Jordan Creek free of anthropogenic debris.	**Objective 3.1:** Remove existing debris from Jordan Creek and its tributaries.	**Action 3.1.1:** Continue to support and expand volunteer cleanup events.	This action is addressed through the annual Spring Clean-up sponsored by Litter Free and other organizations. The JWP recently published a "hot-spot" map to help direct clean-up efforts.	Maintain goal and objective. Maintain action item.
		Action 3.1.2: Remove the failed bridge at Sasha Street.	This action has been completed.	Delete action item.
	Objective 3.2: Prevent debris from entering Jordan Creek and its tributaries.	**Action 3.2.1:** Educate the public about the need to control litter for health and sanitation reasons, animal control, fish and wildlife habitat, and ensuring good water quality.	This action is on-going.	Maintain objective. Maintain action item.

		Action 3.2.2: Promote the use of bear-proof containers or centrally located trash receptacles in high-density housing areas.	This action is on-going. Need to identify locations where garbage receptacles would be beneficial and track improvements. Promote proper use of receptacles as over filled containers still pose problems.	Maintain action item.
		Action 3.2.3: Provide bear-proof garbage and recycling receptacles in source areas such as store parking lots.	This action is on-going.	Delete action item, and combine with Action 3.2.2, which is similar.
		Action 3.2.4: Enforce local ordinances that address garbage storage, littering, polluting water, and illegal camping.	Enforcement is an on-going challenge in Juneau. However, enforcement is a tool to obtain the objective/ goal.	Maintain action item.
		Action 3.2.5: Establish a bottle deposit system for the Borough.	This action has not been addressed. However, the recycling program allows for the recycling of plastic and glass bottles. A city-wide bottle deposit system is not an appropriate recommendation for the watershed plan.	Delete action item.
GOAL 4: Jordan Creek water quality is not degraded by point and nonpoint source pollution.	**Objective 4.1:** Assess Jordan Creek water quality	**Action 4.1.1:** Assess and map potential contaminants and nonpoint sources of pollution in the watershed.	This action has been mostly addressed. In 2008, the CBJ completed a storm water and outfall inventory that included the upper watershed. In 2012, the USFWS mapped the lower watershed. Maps will require regular updating as conditions change.	Maintain goal and objective. Replace action item with new action item: "Regularly update storm water maps to maintain inventory of potential non-point sources of pollution in the watershed."

		Action 4.1.2: Assess active contaminated sites and groundwater flow into Jordan Creek and associated wetlands.	This action has not been addressed. Determine if such sites exist and pose a contamination risk to Jordan Creek. Monitor surface and groundwater quality only if contamination is suspected.	Maintain action item.
	Objective 4.2: Reduce current and prevent future nonpoint source pollution.	**Action 4.2.1:** Work with appropriate landowners and responsible agencies to eliminate or reduce potential pollutants.	This action is on-going.	Maintain objective. Maintain action item.
		Action 4.2.2: Educate the public about potential impacts of residential chemical use on water quality.	This action is on-going.	Maintain action item.
GOAL 5: Jordan Creek is a productive anadromous and resident fish stream.	**Objective 5.1:** Maintain and improve instream fish habitat quality.	**Action 5.1.1:** Maintain building setbacks to protect riparian buffers, and revegetate disturbed areas.	CBJ is currently re-writing the setback ordinance. It will continue to allow for variances.	Maintain goal and objective. Maintain action item.
		Action 5.1.2: Address issues related to motorized recreation in the upper Jordan Creek corridor.	This action has been mostly addressed. See above recommendation for Action 1.1.1	Delete action item.
		Action 5.1.3: Enforce regulations governing anadromous waters.	Enforcement is an on-going challenge in Juneau. However, enforcement is a tool to obtain the objective/ goal.	Maintain action item.
	Objective 5.2: Protect hydrologic and ecologic stream functions.	**Action 5.2.1:** Maintain connectivity with the floodplain by preserving open space along stream corridors.	This action is on-going and tied to the implementation of the setback ordinance. Some specific opportunities to preserve open space should be identified.	Maintain objective. Maintain action item.

	Objective 5.3: Ensure adequate passage for resident and anadromous fish at all life stages.	**Action 5.3.1:** Assess and map fish passage structures at all stream crossings on the mainstem and tributaries, and prioritize those needing replacement or removal.	This action has been addressed. Structures have been assessed by ADF&G. No problems have been identified. It is assumed that ADF&G, DOT&PF, JWP will continue to assess structures and the need for replacement.	Maintain objective. Replace action item with new action item: "Regularly assess fish passage structures at all stream crossings on the mainstem and tributaries, and prioritize those needing replacement or removal."
		Action 5.3.2: Replace or remove inadequate or unnecessary stream crossings.	This action has been addressed. Since 2007, several crossings have been improved. As mentioned the Sasha St. bridge has been removed. In addition, this action is repetitive.	Delete action item.
		Action 5.3.3: Avoid installing additional stream crossings if possible. Where new crossings are necessary, minimize their number and ensure that new structures are constructed to provide fish passage at all life stages.	This action is on-going.	Maintain action item.
		Action 5.3.4: Clear debris from existing structures on a regular basis.	This action is on-going.	Maintain action item.
	Objective 5.4: Conduct biological monitoring of Jordan Creek and its tributaries.	**Action 5.4.1:** Continue to monitor fish populations.	Fish population monitoring has been discontinued since 2006.	Maintain objective. Maintain action item.
		Action 5.4.2: Identify and monitor spawning areas in conjunction with water quality studies and land use activities.	This action has not been addressed.	Maintain action item.

		Action 5.4.3: Include invertebrate sampling in biological studies.	Macroinvertebrate sampling has most recently occurred in 2010. Other sampling occurred in 1995 and 2006.	Maintain action item. Identify appropriate reference site for Jordan Creek.

Appendix B: Water Quality Standards Applicable to Jordan Creek

2017 Water Quality Standards

Table B-1. Residues

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	Residues are not allowed in surface waters of the state, in concentrations or amounts that have the following effects: • may impair designated uses; • cause nuisance or objectionable conditions; • result in undesirable or nuisance species; or • produce objectionable odor or taste.
	agriculture, including irrigation and stock watering	
	aquaculture	
	industrial	
Water Recreation	contact recreation	
	secondary recreation	
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		Residues are not allowed in surface waters of the state, in concentrations or amounts that have the following effects: • may impair designated uses; • cause nuisance or objectionable conditions; or • result in undesirable or nuisance species.

Table B-2. Sediment

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	No measurable increase in concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method (see note 11).
	agriculture, including irrigation and stock watering	For sprinkler irrigation, water must be free of particles of 0.074 mm or coarser. For irrigation or water spreading, may not exceed 200 mg/l for an extended period of time.
	aquaculture	No imposed loads that will interfere with established water supply treatment levels.
	industrial	No imposed loads that will interfere with established water supply treatment levels.
Water Recreation	contact recreation	No measurable increase in concentration of settleable solids above natural conditions, as measured by the volumetric Imhoff cone method (see note 11).
	secondary recreation	May not pose hazards to incidental human contact or cause interference with the use.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		The percent accumulation of fine sediment in the range of 0.1 mm to 4.0 mm in the gravel bed of waters used by anadromous or resident fish for spawning may not be increased more than 5% by weight above natural conditions (as shown from grain size accumulation graph). In no case may the 0.1 mm to 4.0 mm fine sediment range in those gravel beds exceed a maximum of 30% by weight (as shown from grain size accumulation graph) (see notes 3 and 4). In all other surface waters no sediment loads (suspended or deposited) that can cause adverse effects on aquatic animal or plant life, their reproduction or habitat may be present.

Table B-3. Turbidity

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	May not exceed 5 nephelometric turbidity units (NTU) above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 25 NTU.
	agriculture, including irrigation and stock watering	May not cause detrimental effects on indicated use.
	aquaculture	May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.
	industrial	May not cause detrimental effects on established water supply treatment levels.
Water Recreation	contact recreation	May not exceed 5 NTU above natural conditions when the natural turbidity is 50 NTU or less, and may not have more than 10% increase in turbidity when the natural turbidity is more than 50 NTU, not to exceed a maximum increase of 15 NTU. May not exceed 5 NTU above natural turbidity for all lake waters.
	secondary recreation	May not exceed 10 NTU above natural conditions when natural turbidity is 50 NTU or less, and may not have more than 20% increase in turbidity when the natural turbidity is greater than 50 NTU, not to exceed a maximum increase of 15 NTU. For all lake waters, turbidity may not exceed 5 NTU above natural turbidity.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		May not exceed 25 NTU above natural conditions. For all lake waters, may not exceed 5 NTU above natural conditions.

Table B-4. Total Dissolved Solids

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	Total dissolved solids (TDS) from all sources may not exceed 500 mg/l. Neither chlorides nor sulfates may exceed 250 mg/l.
	agriculture, including irrigation and stock watering	TDS may not exceed 1,000 mg/l. Sodium adsorption ratio must be less than 2.5, sodium percentage less than 60%, and residual carbonate less than 1.25 milliequivalents/liter.
	aquaculture	TDS may not exceed 1,000 mg/l. A concentration of TDS may not be present in water if that concentration causes or reasonably could be expected to cause an adverse effect to aquatic life.
	industrial	No amounts above natural conditions that can cause corrosion, scaling, or process problems.
Water Recreation	contact recreation	Not applicable.
	secondary recreation	Not applicable.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		TDS may not exceed 1,000 mg/l. A concentration of TDS may not be present in water if that concentration causes or reasonably could be expected to cause an adverse effect to aquatic life.

Table B-5. Dissolved Gases

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	Dissolved oxygen (D.O.) must be greater than or equal to 4 mg/l (this does not apply to lakes or reservoirs in which supplies are taken from below the thermocline, or to groundwater).
	agriculture, including irrigation and stock watering	D.O. must be greater than 3 mg/l in surface waters.
	aquaculture	D.O. must be greater than 7 mg/l in surface waters. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
	industrial	May not cause detrimental effects on established water supply treatment levels.
Water Recreation	contact recreation	D.O. must be greater than or equal to 4 mg/l.
	secondary recreation	
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		D.O. must be greater than 7 mg/l in waters used by anadromous or resident fish. In no case may D.O. be less than 5 mg/l to a depth of 20 cm in the interstitial waters of gravel used by anadromous or resident fish for spawning (see note 2). For waters not used by anadromous or resident fish, D.O. must be greater than or equal to 5 mg/l. In no case may D.O. be greater than 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.

Table B-6. Temperature

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	May not exceed 15C.
	agriculture, including irrigation and stock watering	May not exceed 30C.
	aquaculture	May not exceed 20C at any time. The following maximum temperatures may not be exceeded, where applicable: • Migration routes 15C • Spawning areas 13C • Rearing areas 15C • Egg & fry incubation 13C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms.
	industrial	May not exceed 25C.
Water Recreation	contact recreation	May not exceed 30C.
	secondary recreation	Not applicable.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		May not exceed 20C at any time. The following maximum temperatures may not be exceeded, where applicable: • Migration routes 15C • Spawning areas 13C • Rearing areas 15C • Egg & fry incubation 13C For all other waters, the weekly average temperature may not exceed site-specific requirements needed to preserve normal species diversity or to prevent appearance of nuisance organisms.

Table B-7. pH

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	May not be less than 6.0 or greater than 8.5.
	agriculture, including irrigation and stock watering	May not be less than 5.0 or greater than 9.0.
	aquaculture	May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.
	industrial	May not be less than 6.5 or greater than 8.5. If the natural condition pH is outside this range, substances may not be added that cause an increase in the buffering capacity of the water.
Water Recreation	contact recreation	May not be less than 6.5 or greater than 8.5. If the natural condition pH is outside this range, substances may not be added that cause an increase in the buffering capacity of the water.
	secondary recreation	May not be less than 5.0 or greater than 9.0.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		May not be less than 6.5 or greater than 8.5. May not vary more than 0.5 pH unit from natural conditions.

Table B-8. Fecal Coliforms/Bacteria

Designated Use		Water Quality Standard
Water Supply	drinking, culinary, and food processing	In a 30-day period, the geometric mean may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml. For groundwater, the fecal coliform concentration must be less than 1 fecal coliform/100 ml, using the fecal coliform Membrane Filter Technique, or less than 3 fecal coliform/100 ml, using the fecal coliform most probable number (MPN) technique.
	agriculture, including irrigation and stock watering	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked and for dairy sanitation of unpasteurized products, the criteria for drinking water supply, (2)(A)(i), apply.
	aquaculture	For products normally cooked, the geometric mean of samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked, the criteria for drinking water supply, (2)(A)(i), apply.
	industrial	Where worker contact is present, the geometric mean of samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml.
Water Recreation	contact recreation	In a 30-day period, the geometric mean of samples may not exceed 126 *Escherichia coli (E. coli*) colony forming units (CFU)/ 100ml, and not more than 10% of the samples may exceed a statistical threshold value (STV) of 410 *E. coli* CFU/100 ml.
	secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100 ml, and not more than 10% of the total samples may exceed 400 fecal coliform/100 ml.
Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife		Not applicable.

Appendix C: Statistical Analysis of Jordan Creek Data

Correlation Analyses

Table C-1. Correlation analysis for all parameters measured on Jordan Creek from October 2006 to June 2008. This analysis is not site-specific. Weak (0.1 – 0.3), Moderate (0.3 to 0.5), and Strong (0.5 – 1.0) correlations are highlighted, with strong correlations shaded darker. Parameters with no correlations (0 to ±0.1) are not shaded.

	Temp (°C)	*Cond (µS/cm)*	*pH*	*Turbidity (NTU)*	*DO (mg/L)*	*DO (% sat)*	*TSS (mg/L)*	*Fe (mg/L)*
Temp (°C)	1							
Cond (µS/cm)	0.044488	1						
pH	0.248976	-0.062591	1					
Turbidity (NTU)	0.079179	-0.127581	0.051924	1				
DO (mg/L)	-0.498193	-0.128440	0.104633	0.002843	1			
DO (% sat)	-0.234231	-0.069326	0.259179	0.199599	0.919452	1		
TSS (mg/L)	0.091143	-0.189119	0.055161	0.790420	-0.039854	0.083404	1	
Fe (mg/L)	-0.262964	-0.199451	0.035071	-0.061973	-0.031345	-0.182035	0.021253	1

Table C-2. Correlation analysis for all parameters measured on Jordan Creek at Amalga Street (Site JC-A) from October 2006 to June 2008. Weak (0.1 – 0.3), Moderate (0.3 to 0.5), and Strong (0.5 – 1.0) correlations are highlighted, with strong correlations shaded darker. Parameters with no correlations (0 to ±0.1) are not shaded.

	Temp (°C)	*Cond (µS/cm)*	*pH*	*Turbidity (NTU)*	*DO (mg/L)*	*DO (% sat)*	*TSS (mg/L)*	*Fe (mg/L)*
Temp (°C)	1							
Cond (µS/cm)	0.201677	1						
pH	0.145866	0.034564	1					
Turbidity (NTU)	0.212403	-0.14407	-0.067009945	1				
DO (mg/L)	-0.2892	0.069328	0.188177171	0.019456	1			
DO (% sat)	-0.09939	0.125646	0.288076519	-0.00196	0.94333	1		
TSS (mg/L)	0.247247	-0.17345	-0.043178345	0.828905	-0.07804	-0.05316	1	
Fe (mg/L)	-0.27758	-0.18637	-0.414638556	-0.0128	-0.26243	-0.41671	0.020169	1

Table C-3. Correlation analysis for all parameters measured on Jordan Creek at Egan Drive (Site JC-B) from October 2006 to June 2008. Weak (0.1 – 0.3), Moderate (0.3 to 0.5), and Strong (0.5 – 1.0) correlations are highlighted, with strong correlations shaded darker. Parameters with no correlations (0 to ±0.1) are not shaded.

	Temp (°C)	*Cond (µS/cm)*	*pH*	*Turbidity (NTU)*	*DO (mg/L)*	*DO (% sat)*	*TSS (mg/L)*	*Fe (mg/L)*
Temp (°C)	1							
Cond (µS/cm)	0.074838	1						
pH	0.328166	0.064366	1					
Turbidity (NTU)	0.305892	-0.35794	-0.037284845	1				
DO (mg/L)	-0.61156	-0.23291	-0.090756037	-0.03678	1			
DO (% sat)	-0.30017	0.19834	0.044107424	-0.05422	0.881436	1		
TSS (mg/L)	0.166714	-0.37432	0.022372883	0.744841	-0.21202	-0.1876	1	
Fe (mg/L)	-0.52861	-0.12228	0.423313249	0.699838	0.315834	-0.08818	0.068876	1

Table C-4. Correlation analysis for all parameters measured on Jordan Creek at Yandukin Drive (Site JC-C) from October 2006 to June 2008. Weak (0.1 – 0.3), Moderate (0.3 to 0.5), and Strong (0.5 – 1.0) correlations are highlighted, with strong correlations shaded darker. Parameters with no correlations (0 to ±0.1) are not shaded.

	Temp (°C)	*Cond (µS/cm)*	*pH*	*Turbidity (NTU)*	*DO (mg/L)*	*DO (% sat)*	*TSS (mg/L)*	*Fe (mg/L)*
Temp (°C)	1							
Cond (µS/cm)	-0.02065	1						
pH	0.301928	-0.0454	1					
Turbidity (NTU)	-0.06971	0.031819	0.005455964	1				
DO (mg/L)	-0.60667	0.111844	-0.184165005	-0.19091	1			
DO (% sat)	-0.28236	0.178112	0.034192269	0.075424	0.868935	1		
TSS (mg/L)	-0.03401	-0.04297	0.00150498	0.810524	-0.12953	0.014412	1	
Fe (mg/L)	-0.19793	-0.3452	0.348719204	-0.25018	-0.22851	-0.56615	0.032682	1

Analysis of Variation (ANOVA) and t-Test for Turbidity

Table C-5. Summary of turbidity measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	148	271.445	1.834088	27.24394
JC-B – Egan Dr.	135	502.2717	3.720531	14.41022
JC-C – Yandukin Dr.	130	684.9433	5.268795	74.4265

Table C-6. ANOVA results comparing turbidity measurements taken on three Jordan Creek sites from October 2006 to June 2008. This shows a significant relationship in turbidity measurements and site, $F(2, 410) = 10.87$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	823.6078	2	411.8039	10.86704	2.52E-05	3.017728
Within Groups	15536.85	410	37.89475			
Total	16360.46	412				

Table C-7. Two-Sample t-Test (assuming equal variances) results comparing turbidity measurements taken on three Jordan Creek sites from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the turbidity measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(281)= -3.45, p<0.05; the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(263)= -1.90, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(276)= -4.07, p<0.05.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	1.834088	3.720531	3.720531	5.268795	1.834088	5.268795
Variance	27.24394	14.41022	14.41022	74.4265	27.24394	74.4265
Observations	148	135	135	130	148	130
Pooled Variance	21.12395		43.84786		49.29666	
Hypothesized Mean Difference	0		0		0	
df	281		263		276	
t Stat	-3.44874		-1.90277		-4.06969	
P(T<=t) one-tail	0.000325		0.029081		3.08E-05	
t Critical one-tail	1.650294		1.650668		1.650393	
P(T<=t) two-tail	0.00065		0.058163		6.15E-05	
t Critical two-tail	1.968442		1.969025		1.968596	

Table C-8. Summary of turbidity measurements taken on Jordan Creek during the growing season (April – September) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	87	204.83	2.354368	43.42731
JC-B – Egan Dr.	78	348.3917	4.46656	21.38561
JC-C – Yandukin Dr.	74	344.5433	4.655991	21.2029

Table C-9. ANOVA results comparing turbidity measurements taken on three Jordan Creek sites during the growing season (April – September) from October 2006 to June 2008. This shows a significant relationship in turbidity measurements and site, F(2, 236) = 4.60, p<0.05.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	270.2384	2	135.1192	4.601958	0.010949	3.034083
Within Groups	6929.253	236	29.36124			
Total	7199.492	238				

Table C-10. Two-Sample t-Test (assuming equal variances) results comparing growing season (April – September) turbidity measurements taken on three Jordan Creek sites from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the turbidity measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(163)= -2.36, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(159)= -2.53, p<0.05. There is no significant difference in turbidity measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(150)= -0.25, p=0.40.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	2.354368	4.46656	4.46656	4.655991	2.354368	4.655991
Variance	43.42731	21.38561	21.38561	21.2029	43.42731	21.2029
Observations	87	78	78	74	87	74
Pooled Variance	33.01498		21.29669		33.22365	

Hypothesized Mean Difference	0	0	0
df	163	150	159
t Stat	-2.35745	-0.25295	-2.52507
P(T<=t) one-tail	0.009794	0.400326	0.006274
t Critical one-tail	1.654256	1.655076	1.654494
P(T<=t) two-tail	0.019588	0.800652	0.012547
t Critical two-tail	1.974625	1.975905	1.974996

Table C-11. Summary of turbidity measurements taken on Jordan Creek outside of the growing season (October - March) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	61	66.615	1.092049	3.54954
JC-B – Egan Dr.	57	153.88	2.699649	3.240364
JC-C – Yandukin Dr.	56	340.4	6.078571	145.249

Table C-12 ANOVA results comparing turbidity measurements from outside the growing season (October - March) taken on three Jordan Creek sites from October 2006 to June 2008. This shows a significant relationship in turbidity measurements and site, $F(2, 171) = 7.64$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	749.2502	2	374.6251	7.641644	0.000663	3.048833
Within Groups	8383.129	171	49.02415			
Total	9132.379	173				

Table C-13. Two-Sample t-Test (assuming equal variances) results comparing turbidity measurements from outside the growing season (October - March) taken on three Jordan Creek sites from October 2006 to June 2008. There are significant differences in the turbidity measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(116)= -4.73$, $p<0.05$; the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(111)= -2.09$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(115)= -3.19$, $p<0.05$.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	1.092049	2.699649	2.699649	6.078571	1.092049	6.078571
Variance	3.54954	3.240364	3.240364	145.249	3.54954	145.249
Observations	61	57	57	56	61	56
Pooled Variance	3.400283		73.60502		71.31886	
Hypothesized Mean Difference	0		0		0	
df	116		111		115	
t Stat	-4.7324		-2.09323		-3.19052	
P(T<=t) one-tail	3.16E-06		0.019303		0.000915	
t Critical one-tail	1.658096		1.658697		1.658212	
P(T<=t) two-tail	6.31E-06		0.038607		0.001831	
t Critical two-tail	1.980626		1.981567		1.980808	

Analysis of Variation (ANOVA) and t-Test for Total Suspended Solids (TSS)

Table C-14. Summary of TSS measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	134	346.0446	2.582422	38.46087
JC-B – Egan Dr.	130	608.3079	4.679291	40.34415
JC-C – Yandukin Dr.	127	681.7006	5.367721	66.00594

Table C-15. ANOVA results comparing TSS measurements taken on Jordan Creek at three sites from October 2006 to June 2008. This shows a significant relationship in TSS measurements and site, $F(2, 388) = 5.76$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	553.5595	2	276.7798	5.762396	0.003419	3.018982
Within Groups	18636.44	388	48.03206			
Total	19190	390				

Table C-16. Two-Sample t-Test (assuming equal variances) results comparing TSS measurements taken on three Jordan Creek sites from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the TSS measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(262)= -2.71$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(259)= -3.12$, $p<0.05$. There is no significant difference in the TSS measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(255)= -0.76$, $p=0.22$.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	2.582422	4.679291	4.679291	5.367721	2.582422	5.367721
Variance	38.46087	40.34415	40.34415	66.00594	38.46087	66.00594
Observations	134	130	130	127	134	127
Pooled Variance	39.38813		53.02409		51.86117	
Hypothesized Mean Difference	0		0		0	
df	262		255		259	
t Stat	-2.71401		-0.75776		-3.12309	
P(T<=t) one-tail	0.003544		0.224648		0.000996	
t Critical one-tail	1.65069		1.650851		1.650758	
P(T<=t) two-tail	0.007089		0.449296		0.001993	
t Critical two-tail	1.96906		1.969311		1.969166	

Table C-17. Summary of TSS measurements taken on Jordan Creek during the growing season (April – September) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	80	264.5772	3.307215	60.18402
JC-B – Egan Dr.	76	414.4569	5.45338	49.89361
JC-C – Yandukin Dr.	74	350.6219	4.738134	28.88943

Table C-18. ANOVA results comparing TSS measurements taken during the growing season (April – September) on three Jordan Creek sites from October 2006 to June 2008. This shows no significant difference in the TSS measurements between the Jordan Creek sites; therefore, a two-sample t-Test was not performed.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	186.9699	2	93.48496	2.000954	0.137584	3.035617
Within Groups	10605.49	227	46.7202			
Total	10792.46	229				

Table C-19. Summary of TSS measurements taken on Jordan Creek outside the growing season (October - March) at three sites from October 2006 to June 2008.

Groups	Count	Sum	Average	Variance
JC-A – Amalga St.	54	81.46736	1.508655	4.839074
JC-B – Egan Dr.	54	193.851	3.589833	25.52341
JC-C – Yandukin Dr.	53	331.0787	6.246768	118.0295

Table C-20. ANOVA results comparing TSS measurements taken on Jordan Creek at three sites outside of the growing season (October - March) from October 2006 to June 2008. This shows a significant relationship in TSS measurements and site, $F(2, 158) = 6.15$, $p<0.05$.

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	603.0118	2	301.5059	6.149413	0.00268	3.053257
Within Groups	7746.745	158	49.03003			
Total	8349.757	160				

Table C-21. Two-Sample t-Test (assuming equal variances) results comparing TSS measurements taken on Jordan Creek outside the growing season (October - March) from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the TSS measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(106)= -2.77$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(105)= -3.14$, $p<0.05$. There is no significant difference in the TSS measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(105)= -1.63$, $p=0.05$.

	JC-A	JC-B	JC-B	JC-C	JC-A	JC-C
Mean	1.508655	3.589833	3.589833	6.246768	1.508655	6.246768
Variance	4.839074	25.52341	25.52341	118.0295	4.839074	118.0295
Observations	54	54	54	53	54	53
Pooled Variance	15.18124		71.33594		60.89528	
Hypothesized Mean Difference	0		0		0	
df	106		105		105	
t Stat	-2.77548		-1.62693		-3.14019	
P(T<=t) one-tail	0.003259		0.053374		0.001097	
t Critical one-tail	1.659356		1.659495		1.659495	
P(T<=t) two-tail	0.006517		0.106749		0.002193	
t Critical two-tail	1.982597		1.982815		1.982815	

Analysis of Variation (ANOVA) and t-Test for Conductivity

Table C-22. Summary of conductivity measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	166	15718.38	94.68904	744.6706
JC-B – Egan Dr.	138	10289.7	74.56308	512.8523
JC-C – Yandukin Dr.	134	10482.8	78.22987	1378.355

Table C-23. ANOVA results comparing conductivity measurements taken on Jordan Creek at three sites from October 2006 to June 2008. This shows a significant relationship in conductivity measurements and site, $F(2, 435) = 20.52$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	35510.55	2	17755.28	20.51665	3.06E-09	3.016458
Within Groups	376452.6	435	865.4083			
Total	411963.2	437				

Table C-24. Two-Sample t-Test (assuming equal variances) results comparing conductivity measurements taken on three Jordan Creek sites from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the conductivity measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(302)= 6.91$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(298)= 4.42$, $p<0.05$. There is no significant difference in the conductivity measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(270)= -0.99$, $p=0.16$.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	94.68904	74.56308	74.56308	78.22987	94.68904	78.22987
Variance	744.6706	512.8523	512.8523	1378.355	744.6706	1378.355
Observations	166	138	138	134	166	134
Pooled Variance	639.508		939.1924		1027.489	
Hypothesized Mean Difference	0		0		0	
df	302		270		298	
t Stat	6.908608		-0.98654		4.421456	
P(T<=t) one-tail	1.45E-11		0.162375		6.88E-06	
t Critical one-tail	1.649915		1.650517		1.649983	
P(T<=t) two-tail	2.9E-11		0.32475		1.38E-05	
t Critical two-tail	1.96785		1.968789		1.967957	

Analysis of Variation (ANOVA) and t-Test for Dissolved Oxygen

Table C-25. Summary of DO measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	130	1319.76	10.152	2.519759
JC-B – Egan Dr.	104	1249.313	12.01263	4.841061

JC-C – Yandukin Dr.	100	1222.227	12.22227	5.515036

Table C-26. ANOVA results comparing DO measurements taken on Jordan Creek at three sites from October 2006 to June 2008. This shows a significant relationship in DO measurements and site, $F(2, 331) = 37.26$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	308.3249	2	154.1624	37.25561	2.55E-15	3.02301
Within Groups	1369.667	331	4.137966			
Total	1677.992	333				

Table C-27. Two Sample t-Test (assuming equal variances) results comparing DO measurements taken on three Jordan Creek sites from October 2006 to June 2008. The test was conducted for each set of sites. There are significant differences in the DO measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(232)= -7.51$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(228)= -7.96$, $p<0.05$. There is no significant difference in the DO measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(202)= -0.66$, $p=0.26$.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	10.152	12.01263	12.01263	12.22227	10.152	12.22227
Variance	2.519759	4.841061	4.841061	5.515036	2.519759	5.515036
Observations	130	104	104	100	130	100
Pooled Variance	3.550337		5.171375		3.82034	
Hypothesized Mean Difference	0		0		0	
df	232		202		228	
t Stat	-7.50594		-0.65822		-7.96312	
P(T<=t) one-tail	6.5E-13		0.255574		3.95E-14	
t Critical one-tail	1.651448		1.652432		1.651564	
P(T<=t) two-tail	1.3E-12		0.511148		7.91E-14	
t Critical two-tail	1.970242		1.971777		1.970423	

Table C-28. Summary of DO measurements taken on Jordan Creek during the growing season (April – September) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	60	615.17	10.25283	2.747309
JC-B – Egan Dr.	51	565.99	11.09784	3.710921
JC-C – Yandukin Dr.	49	550.75	11.2398	3.548673

Table C-29. ANOVA results comparing DO measurements taken on Jordan Creek at three sites during the growing season (April – September) from October 2006 to June 2008. This shows a significant relationship in DO measurements and site, $F(2, 157) = 4.83$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	31.86977	2	15.93489	4.829932	0.009213	3.053628
Within Groups	517.9736	157	3.299195			
Total	549.8433	159				

Table C-30. Two-Sample t-Test (assuming equal variances) results comparing DO measurements taken on Jordan Creek during the growing season (April - September) from October 2006 to June 2008. There are significant differences in the DO measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(109)= -2.48, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(107)= -2.91, p<0.05. There is no significant difference in the DO measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(98)= -0.37, p=0.36.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	10.25283	11.09784	11.09784	11.2398	10.25283	11.2398
Variance	2.747309	3.710921	3.710921	3.548673	2.747309	3.548673
Observations	60	51	51	49	60	49
Pooled Variance	3.189333		3.631453		3.106799	
Hypothesized Mean Difference	0		0		0	
df	109		98		107	
t Stat	-2.48434		-0.37238		-2.90807	
P(T<=t) one-tail	0.00725		0.355207		0.002211	
t Critical one-tail	1.658953		1.660551		1.659219	
P(T<=t) two-tail	0.0145		0.710414		0.004423	
t Critical two-tail	1.981967		1.984467		1.982383	

Table C-31. Summary of DO measurements taken on Jordan Creek outside of the growing season (October - March) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	70	704.59	10.06557	2.345286
JC-B – Egan Dr.	53	683.3233	12.89289	4.410324
JC-C – Yandukin Dr.	51	671.4767	13.16621	5.658254

Table C-32. ANOVA results comparing DO measurements taken on Jordan Creek at three sites outside of the growing season (October - March) from October 2006 to June 2008. This shows a significant relationship in DO measurements and site, F(2, 171) = 46.79, p<0.05.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	368.8537	2	184.4268	46.78563	6.22E-17	3.048833
Within Groups	674.0743	171	3.941955			
Total	1042.928	173				

Table C-33. Two-Sample t-Test (assuming equal variances) results comparing DO measurements taken on Jordan Creek outside of the growing season (October - March) from October 2006 to June 2008. There are significant differences in the DO measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(121)= -8.64, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(119)= -8.71, p<0.05. There is no significant difference in the DO measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(102)= -0.62, p=0.27.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	10.06557	12.89289	12.89289	13.16621	10.06557	13.16621
Variance	2.345286	4.410324	4.410324	5.658254	2.345286	5.658254
Observations	70	53	53	51	70	51

Pooled Variance	3.232741	5.022054	3.737289
Hypothesized Mean Difference	0	0	0
df	121	102	119
t Stat	-8.63623	-0.62177	-8.71192
P(T<=t) one-tail	1.4E-14	0.26774	1.03E-14
t Critical one-tail	1.657544	1.65993	1.657759
P(T<=t) two-tail	2.79E-14	0.535479	2.06E-14
t Critical two-tail	1.979764	1.983495	1.9801

Analysis of Variation (ANOVA) and t-Test for Temperature

Table C-34. Summary of temperature measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	166	875.77	5.275723	3.668547
JC-B – Egan Dr.	138	744.78	5.396957	11.87844
JC-C – Yandukin Dr.	133	747.7367	5.62208	13.86481

Table C-35. ANOVA results comparing temperature measurements taken on Jordan Creek at three sites taken from October 2006 to June 2008. This shows no significant difference in the temperature measurements between the Jordan Creek sites; therefore, a two-sample t-Test was not performed.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.95981	2	4.479905	0.478555	0.620005	3.016506
Within Groups	4062.812	434	9.361319			
Total	4071.772	436				

Table C-36. Statistical summary of temperature measurements taken on Jordan Creek during the growing season (April – September) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	89	555.51	6.241685	2.33551
JC-B – Egan Dr.	85	619.13	7.283882	7.236624
JC-C – Yandukin Dr.	77	620.21	8.054675	6.531215

Table C-37. ANOVA results comparing temperature measurements taken on Jordan Creek during the growing season (April – September) at three sites from October 2006 to June 2008. This shows a significant relationship in temperature measurements and site, $F(2, 248) = 13.06$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	137.9713	2	68.98563	13.06213	4.04E-06	3.032213
Within Groups	1309.774	248	5.281345			
Total	1447.745	250				

Table C-38. Two-Sample t-Test (assuming equal variances) results comparing temperature measurements taken on three Jordan Creek sites during the growing season (April – September) from October 2006 to June 2008. There are significant differences in the turbidity measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(172)= -3.16, p<0.05; the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(160)= -1.86, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(164)= -5.63, p<0.05.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	6.241685	7.283882	7.283882	8.054675	6.241685	8.054675
Variance	2.33551	7.236624	7.236624	6.531215	2.33551	6.531215
Observations	89	85	85	77	89	77
Pooled Variance	4.729077		6.901555		4.279861	
Hypothesized Mean Difference	0		0		0	
df	172		160		164	
t Stat	-3.16003		-1.86493		-5.63076	
P(T<=t) one-tail	0.000932		0.032012		3.81E-08	
t Critical one-tail	1.653761		1.654433		1.654198	
P(T<=t) two-tail	0.001864		0.064023		7.62E-08	
t Critical two-tail	1.973852		1.974902		1.974535	

Table C-39. Summary of Jordan Creek temperature measurements taken outside of the growing season (October - March) at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	77	320.26	4.159221	2.904665
JC-B – Egan Dr.	59	154.27	2.614746	5.291291
JC-C – Yandukin Dr.	56	127.5267	2.277262	4.574848

Table C-40. ANOVA results comparing temperature measurements taken on Jordan Creek outside of the growing season (April – September) at three sites from October 2006 to June 2008. This shows a significant relationship in temperature measurements and site, F(2, 189) = 16.73, p<0.05.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	137.9443	2	68.97215	16.72822	2.05E-07	3.043722
Within Groups	779.2661	189	4.123101			
Total	917.2104	191				

Table C-41. Two-Sample t-Test (assuming equal variances) results comparing temperature measurements taken on three Jordan Creek sites outside of the growing season (April – September) from October 2006 to June 2008. There are significant differences in the temperature measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), t(134)= 4.49, p<0.05; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), t(131)= 5.64, p<0.05. There is no significant difference in the temperature measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), t(113)= 0.81, p=0.21.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	4.159221	2.614746	2.614746	2.277262	4.159221	2.277262
Variance	2.904665	5.291291	5.291291	4.574848	2.904665	4.574848
Observations	77	59	59	56	77	56
Pooled Variance	3.937682		4.94258		3.605887	

Hypothesized Mean Difference	0	0	0
df	134	113	131
t Stat	4.498445	0.813668	5.643098
P(T<=t) one-tail	7.35E-06	0.208773	4.94E-08
t Critical one-tail	1.656305	1.65845	1.656569
P(T<=t) two-tail	1.47E-05	0.417546	9.87E-08
t Critical two-tail	1.977826	1.98118	1.978239

Analysis of Variation (ANOVA) and t-Test for pH

Table C-42. Summary of pH measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	142	946.9967	6.668991	0.308225
JC-B – Egan Dr.	114	788.78	6.919123	0.317491
JC-C – Yandukin Dr.	109	765.5333	7.023242	0.263846

Table C-43. ANOVA results comparing pH measurements taken on Jordan Creek at three sites from October 2006 to June 2008. This shows a significant relationship in pH measurements and site, $F(2, 362) = 14.21$, $p<0.05$.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.465533	2	4.232766	14.20975	1.15E-06	3.020661
Within Groups	107.8317	362	0.297878			
Total	116.2972	364				

Table C-44. Two Sample t-Test (assuming equal variances) results comparing pH measurements taken on Jordan Creek from October 2006 to June 2008. There are significant differences in the pH measurements of the Amalga Street (JC-A) and Egan Drive sites (JC-B), $t(254)= -3.56$, $p<0.05$; and the Amalga Street (JC-A) and Yandukin Drive sites (JC-C), $t(249)= -5.17$, $p<0.05$. There is no significant difference in the temperature measurements of the Egan Drive (JC-B) and the Yandukin Drive sites (JC-C), $t(221)= -1.44$, $p=0.08$.

	JC-A	*JC-B*	*JC-B*	*JC-C*	*JC-A*	*JC-C*
Mean	6.668991	6.919123	6.919123	7.023242	6.668991	7.023242
Variance	0.308225	0.317491	0.317491	0.263846	0.308225	0.263846
Observations	142	114	114	109	142	109
Pooled Variance	0.312348		0.291276		0.288976	
Hypothesized Mean Difference	0		0		0	
df	254		221		249	
t Stat	-3.55899		-1.44009		-5.17488	
P(T<=t) one-tail	0.000222		0.075628		2.35E-07	
t Critical one-tail	1.650875		1.651778		1.650996	
P(T<=t) two-tail	0.000444		0.151256		4.7E-07	
t Critical two-tail	1.969348		1.970756		1.969537	

Analysis of Variation (ANOVA) and t-Test for Dissolved Iron

Table C-45. Summary of dissolved iron measurements taken on Jordan Creek at three sites from October 2006 to June 2008.

Groups	*Count*	*Sum*	*Average*	*Variance*
JC-A – Amalga St.	15	4.23	0.282	0.071946
JC-B – Egan Dr.	15	4.53	0.302	0.012631
JC-C – Yandukin Dr.	15	4.31	0.287333	0.023064

Table C-46. ANOVA results comparing dissolved iron measurements taken on Jordan Creek at three sites from October 2006 to June 2008. This shows no significant difference in the temperature measurements between the Jordan Creek sites; therefore, a two-sample t-Test was not performed.

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	0.003218	2	0.001609	0.04484	0.956196	3.219942
Within Groups	1.506973	42	0.03588			
Total	1.510191	44				