Non-Point Source Pollution Identification

A pilot project to create a methodology using GIS modeling to determine non-point source contributions to waterbodies in the City of Kenai

14 February, 2024

The Kenai Watershed Forum
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1.0 Project Team

The Kenai Watershed Forum

The Kenai Watershed Forum (KWF) is a nonprofit organization that works to identify and address the needs of the region by providing high-quality education, restoration and research programs.

The KWF's mission is working together for healthy watersheds on the Kenai Peninsula. Through partnerships with other non-profits, government and corporate entities, the KWF works to promote and protect healthy habitat.

Saint Mary's University of Minnesota GeoSpatial Services (GSS)

GeoSpatial Services is an innovative project center of environmental scientists, geographers, and spatial analysts that integrates professional services and academic apprenticeships in the areas of natural resource assessment, geographic analysis, and contemporary mapping. The center is a federal government contractor and cooperator with membership in three Cooperative Ecosystem Study Units (CESU) within the National Network and over two decades of experience participating in hundreds of grants and cooperative agreements. During the past 15 years, GSS has completed more than 100 mapping projects for federal agencies, state departments, and private companies to map and classify over 200,000 sq. miles (130M acres) of wetland and riparian areas in the Western U.S. and Alaska. These projects were completed, reviewed, and submitted to the NWI using national standards and classification systems, including the Federal Geographic Data Committee (FGDC) and the National Wetland Mapping Standard (NWMS). GSS's permanent staff roster includes over 40 natural resource professionals with expertise in ecology, biology, forestry, geography, geomorphology, and wildlife management, each with extensive experience in spatial data inventory and analysis using GIS technology and related software. Collectively, GSS staff have over 75 years of experience in mapping and field verification of wetland and riparian ecosystems across the U.S. using established mapping protocols and classifications.

2.0 Introduction

With the growth in population on the Kenai Peninsula, there has been an increase in urban development. Urbanization often replaces once naturally vegetated landscapes and replaces them with impervious surfaces. Impervious surfaces cause rainfall and runoff that would have been slowed, absorbed and filtered through natural landscapes to flow from features such as parking lots and roads, through culverts, and directly into the waterbodies around the cities of Kenai and Soldotna. These changes to the natural landscape increase pollutant loadings, stormwater runoff volumes, and peak flow rates in urbanizing watersheds.

Impervious surfaces within a watershed contribute to and exacerbate non-point source pollution inputs to surface waters. In fact, non-point sources are generally considered the number one cause of water quality issues reported by cities, boroughs, and states**.** Runoff from impervious surfaces washes not only sediment and nutrients into streams, but pollutants such as bacteria, car fluids and other chemicals as well. Erosion caused by runoff can pose a serious threat to streams; an increase in sedimentation reduces the oxygen content of water. Nutrient loading, algae blooms, water clarity reduction, and shifts in water quality and temperature can negatively impact native fish populations, reducing the ability for the affected fish species to thrive. Increased runoff can also lead to an increase in flood peak and flooding frequency, which, in turn, can lead to escalation in streambed erosion. A consequence of stream erosion is that it can cause the rerouting of the streams, which can adversely affect spawning pathways that are critical for anadromous fish reproduction. Draining of wetlands for urbanization adds further stress to the hydrologic system, as this process can cause a decrease in water filtration, nutrient uptake and a reduction in groundwater recharge.

It is imperative that stakeholders know how urbanization is changing the landscape and understand its effects on habitats, particularly aquatic habitat. Urbanization disrupts ground water patterns, increases the flow of water, mobilizes pollutants such as nutrients and heavy metals, and contributes to increasing water temperatures. Urbanization can also contribute to the disconnection of aquatic habitats. The methods created through this project will help inform management actions on the landscape by targeting areas of pollutant input and pinpointing mitigation or intervention opportunities.

This pilot project was conducted through the cooperation of the Kenai Watershed Forum (KWF) and Saint Mary's University of Minnesota - GeoSpatial Services (GSS). The objective of this analysis was to test a proof of concept that a non-point source "hot-spot" could be identified through a GIS modeling process.

2.1 Study Area

The non-point source analysis was conducted within two HUC12's: Outlet Kenai River 190203021809 and Sports Lake-Kenai River 190203021806 (Figure 1). These two sub-watersheds encompass the majority of the cities of Kenai and Soldotna. This study area provided the best available datasets within an urbanized landscape. Urban development is occurring around natural features, such as the Kenai River, which is one of the world's premier salmon habitats. Flowing into the Kenai River are a number of creeks that wind their way through the urban development, which are subject to the runoff of the surrounding impervious surfaces.

Figure 1. Study area for the non-point source pollution: HUC12s 190203021806 and 190203021809.

3.0 Methods

The non-point source analysis required a hydro-conditioned digital elevation model (DEM) and an impervious surface layer. Additional layers needed for analysis, such as derived flow network, were created from the hydro-conditioned DEM or provided by the KWF and Kenai Borough.

3.1 Hydro-conditioning

Hydro-conditioning is the modification of an elevation model by removing digital dams in the LiDAR at culvert locations that obstruct flow across roads, driveways, hiking paths, etc. to produce the most accurate derived flow network representing the transport of water and pollutants across the landscape. The derived flow network will identify surface flow initiation higher in the sub-watersheds that can then be traced across impervious surfaces to where it ultimately flows into lentic and/or lotic hydrography.

3.2 Impervious Surfaces

Previous impervious surface mapping completed by GSS in these same sub-watersheds was used in collaboration with the derived flow network to identify contributing areas (hot spots) of non-point source pollution. To establish the best representation of non-point source pollution, specific impervious surface features were selected based on an area threshold (size in acres) and the amount of their usage. For example, putting a higher weight on a large parking lot with more vehicle traffic versus a personal driveway that would contribute less pollution. Proximity analysis could also be used to provide an indication of which impervious surface features are closest to the flow network and therefore have more potential to contribute pollutants.

3.3 Elevation Derived Flow Lines

The elevation derived flow lines were created using the Light Detection and Ranging (LiDAR) derived Digital Terrain Model (DTM) made available to GSS from the KWF. Utilizing ArcGIS Pro 3.1.3 Geoprocessing tools, the LiDAR DTM was used to develop Flow Direction (FDR) and Flow Accumulation (FAC) products. Applying a FAC threshold value representing approximately a 0.25-acre catchment flow initiation area generated the basic flow lines. These flow lines were used to represent surface hydrology within the study area and were converted to a geometric network for analysis.

3.4 Flow Network and Impervious Surface Connectivity Analysis

Impervious surfaces for the sub-watersheds were obtained from a previous impervious surface mapping project that GSS and the KWF partnered on to examine the change in urbanization across these same sub-watersheds from 1984 to 2021. The impervious surface layer was used to identify the largest surface area for contributing runoff. A good candidate for this pilot project was the City of Kenai Airport (Figure 2).

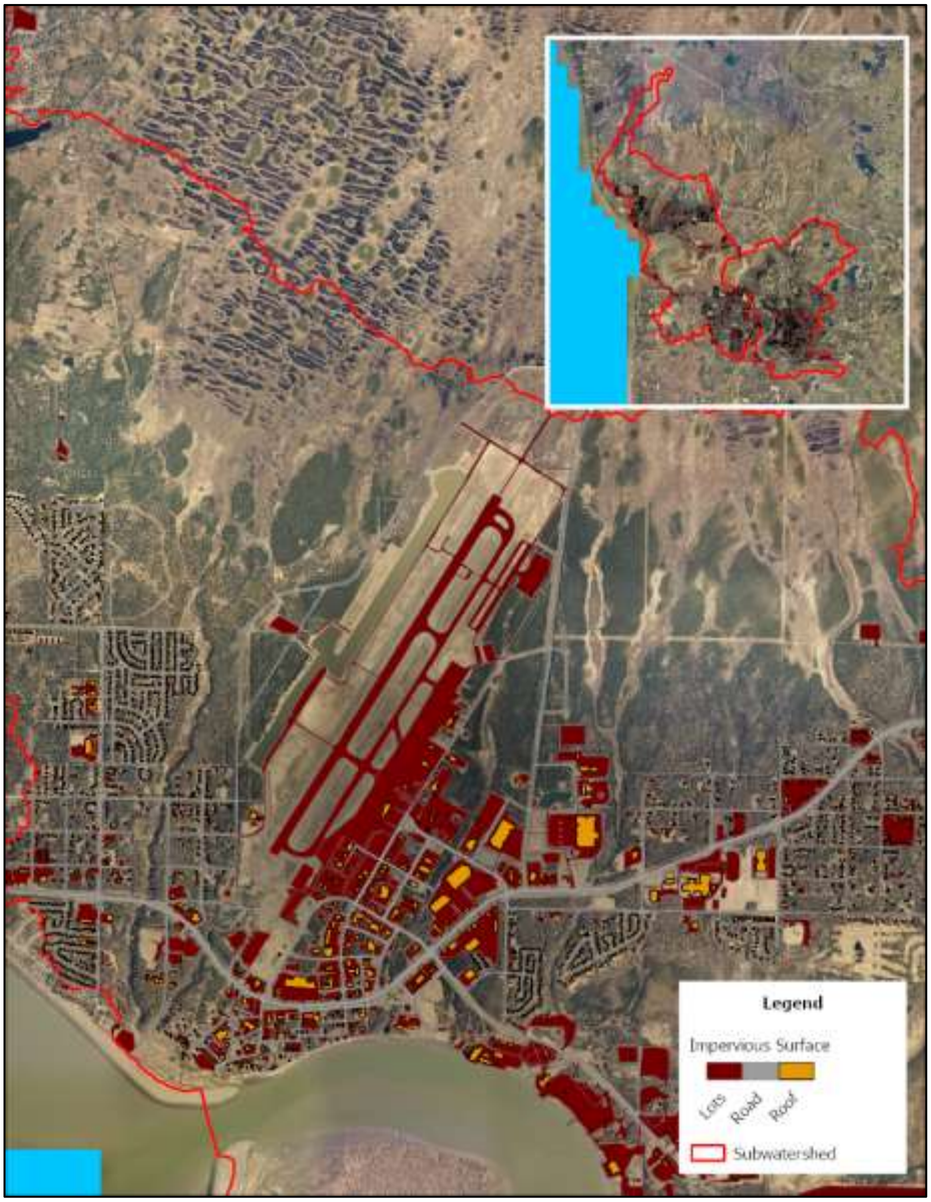


Figure 2. City of Kenai Airport.

Utilizing the elevation-derived flow lines (Figure 3), a Geometric Network was created in the Utility Network Analyst tools in ArcGIS Desktop 10.7.1, to generate network junctions and linear connectivity, which provides the capability to trace water flow up and down the network. Choice of network junctions were based on proximity to outflow near natural features, such as the point of outflow where runoff from the airport enters the creek. Network junctions that correlate with an outflow culvert were selected as an initiation point to trace the upstream accumulation of the flow network. From the upstream accumulation, impervious surfaces were selected that intersected the accumulated flow.

Figure 3. Elevation-derived flow network for the Kenai Airport.

From the same network junction, a downstream path was selected to identify a downstream flow network representing connectivity from the impervious surface features, downstream through the study area to the Kenai River (Figure 4).

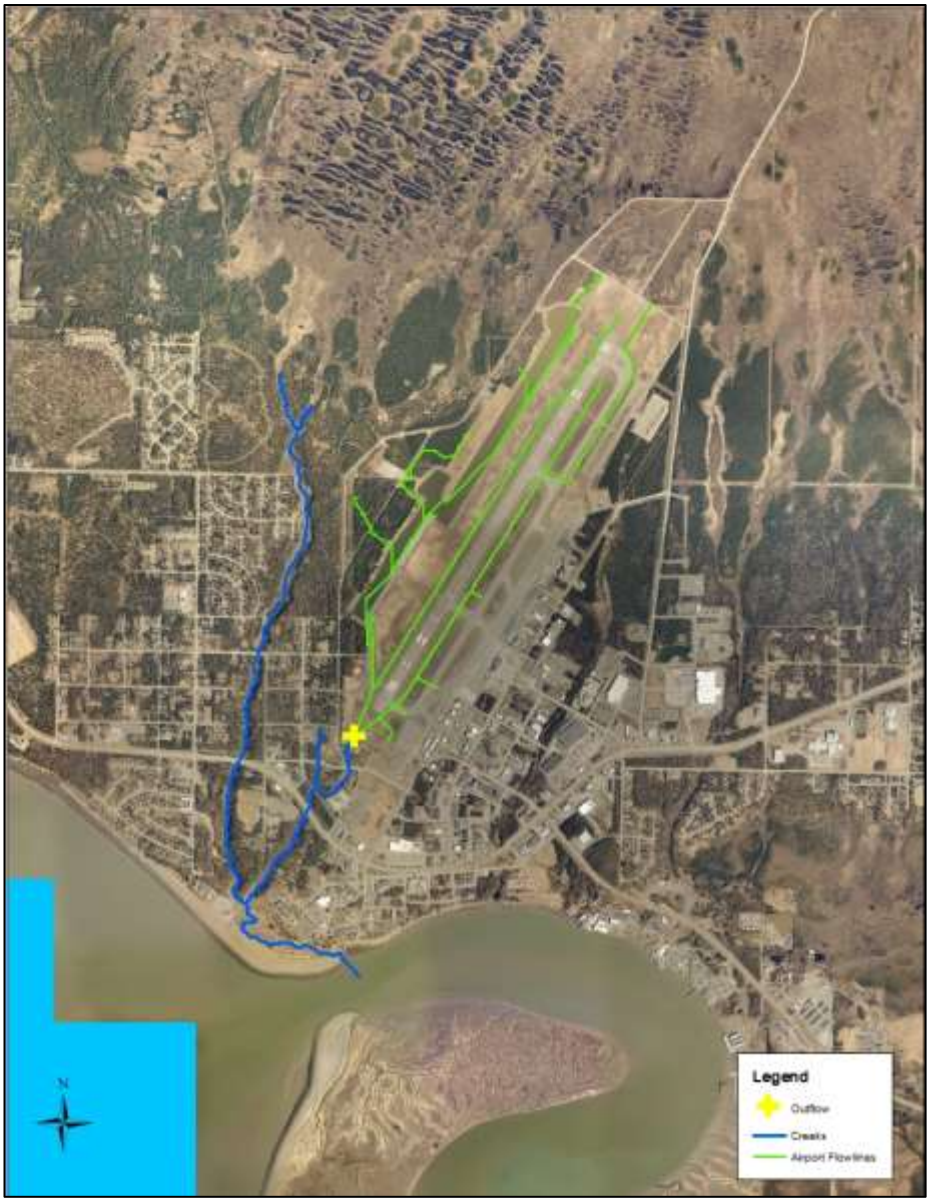


Figure 4. The portions of the flow network that run off the Kenai Airport are in green.

4.0 Results

This process could be repeated by identifying flow junctions at other outflow points, then tracing upstream accumulation to identify which and how much impervious surface area is contributing to runoff at these points of outflow.

4.1 Flow Network and Impervious Surface Analysis

The path of the flow was traced upstream from the storm drain outlet southwest of the airport, where it drains into the east fork of the unnamed creek. The network of flow lines was used to select the impervious surfaces that intersected with the network of flow lines upstream.

4.2 Impervious Surface Modification

Due to the impervious surfaces being a highly merged dataset, as seen in Figure 2, the runways needed to be split from taxiways, flight lines and ramps based on the flow direction determined from the derived flow network (Figure 5). Otherwise, erroneous calculations of the contributing acreage of impervious surface would occur.

This splitting process provided a more accurate calculation of the area of impervious surfaces that were contributing to the outflow. In this case, it was calculated that runoff from 93 acres of impervious surface poured to the outflow point southwest of the runway.

Figure 5. Impervious surface where flow direction is to the southwest culvert outlet.

5.0 Conclusions

This non-point source pollution pilot project provided an opportunity to develop a methodology that could be applied to other watersheds to determine what non-point sources are contributing runoff. This will aid in the planning process of locating and creating best management practices to contain the runoff so as to reduce the pollutants that are entering the natural habitat.

The focus of this projects analysis was the Kenai Airport, but sites that have larger surface areas which contribute to runoff and are worth consideration based on connectivity to the flow network include:

1. Wildwood Correctional Complex
2. The parking lot across from the Alaska Job Center Network (11312 Kenai Spur Hwy)
3. Kenai Shopping Center
4. Soldotna Airport
5. The gravel mine were flow crosses Beaver Loop Road. Although gravel, the compacted substrate acts like impervious surface (Appendix A).

An interesting discovery seen on the high-resolution imagery during this project was settling ponds around the Walmart parking lot (Appendix B).

Although a methodology was developed, the results of any analysis will vary based on the best available datasets that are used. The results of this pilot project were constrained by such conditions. It was fortunate that LiDAR data was available for this project. However, limitations with this LiDAR data are that it was acquired in 2008 and had a nominal point spacing of 1.4 points per meter. This posed two difficulties; first, the rapid urbanization of the Kenai Peninsula over the years from 2008 to 2023 resulted in an outdated elevation product that did not match with best available imagery and did not reflect the change in conveyance of water across the landscape due to urbanization. Second, the LiDAR's resolution was approximately 3 meters and the point density that the elevation model was created from led to a less detailed surface representation, making it difficult to locate culvert crossings. Available sewer layers did not align well with the LiDAR, which meant the sewer network could not just be burnt into the elevation model. It also made it difficult to follow the flow of water as it ran off impervious surfaces and into the sewer network, as LiDAR and sewers represented two different periods in time. Adding erroneous culverts to force the flow direction is not recommended. The culvert features added were in relation to culvert crossings that could be identified and therefore can be used as the base line for hydro-conditioning of future LiDAR.

Notwithstanding the data's spatial and temporal resolution, the methodology can be used when updated datasets have been created. This will allow for a more informed output that can be used to initiate discussions with stakeholders on best practices to reduce the amount of non-point source pollutants entering the surrounding habitat, specifically the Kenai River.

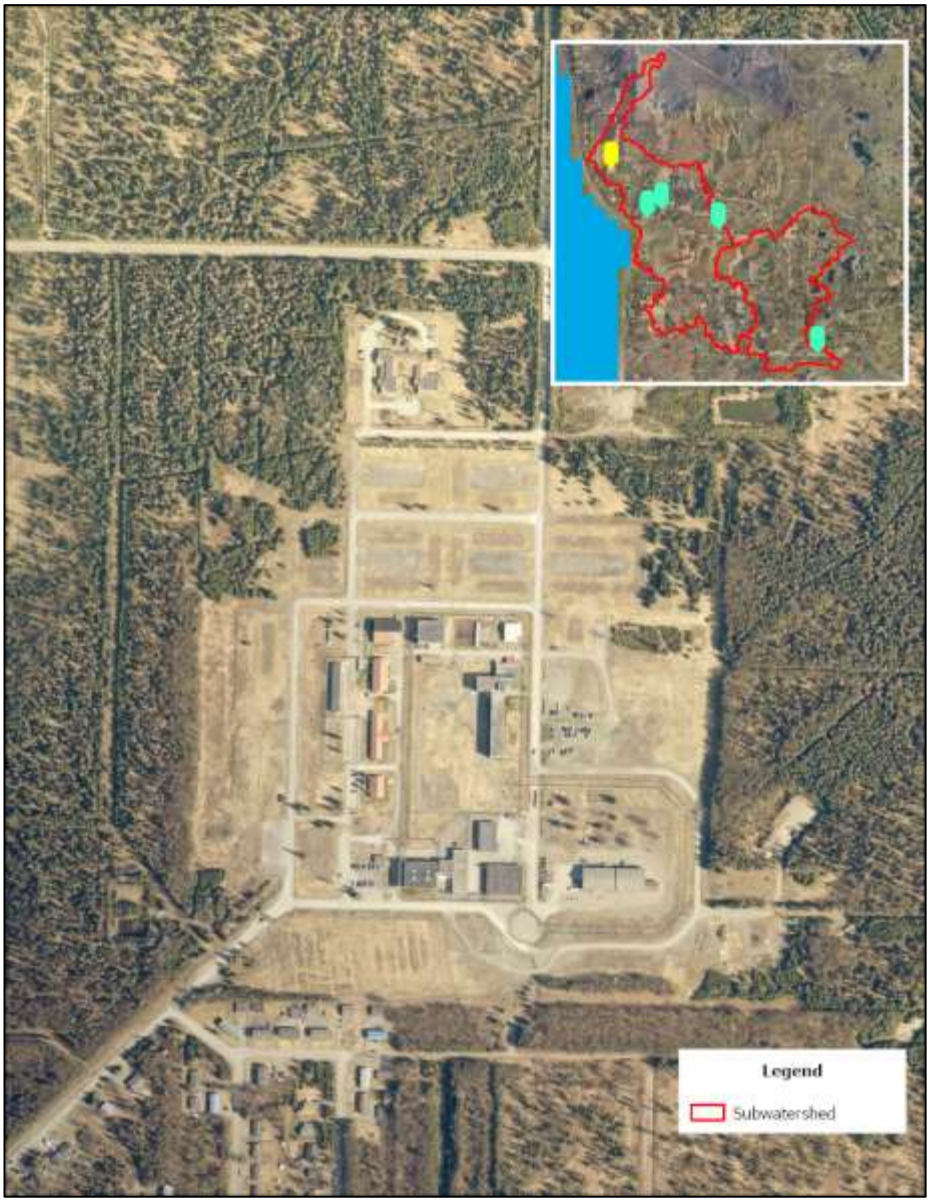
6.0 References

Knopf, J., and A. Rabine. 2022. Analyzing urban change from 1984 to 2021 on the Kenai Peninsula: Researching a semi-automated approach to impervious surface mapping. GeoSpatial Services, Saint Mary's University of Minnesota, Winona, Minnesota.

Harings, M. 2020. 2019 Field Report: Copper and Zinc Levels Throughout the Kenai River Watershed. Kenai Watershed Forum, Soldotna, Alaska.

Sires, J. 2017. A Review of Potential Zinc and Copper Pollution Sources in the Kenai River Watershed. Kenai Watershed Forum, Soldotna, Alaska.

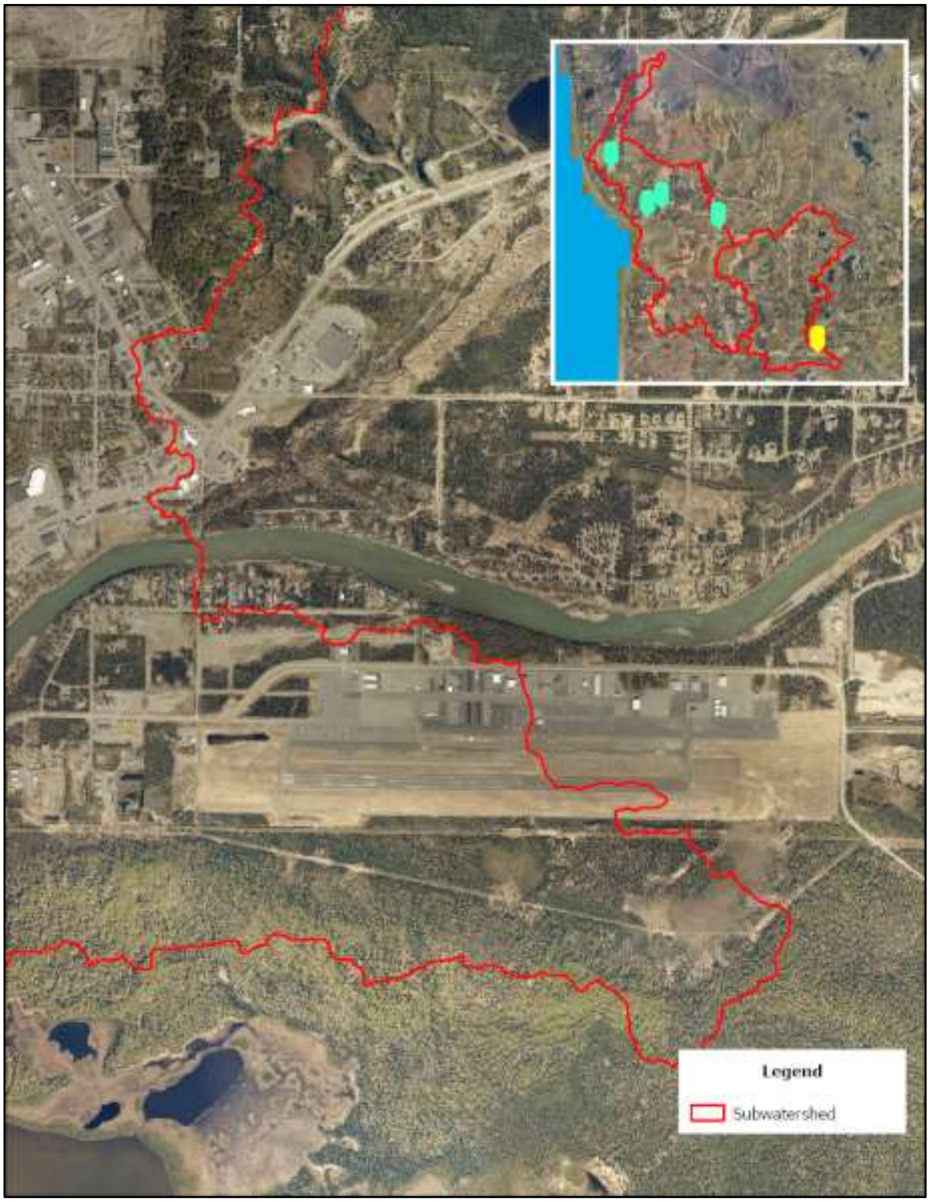
Appendix A: Other Sites of Interest



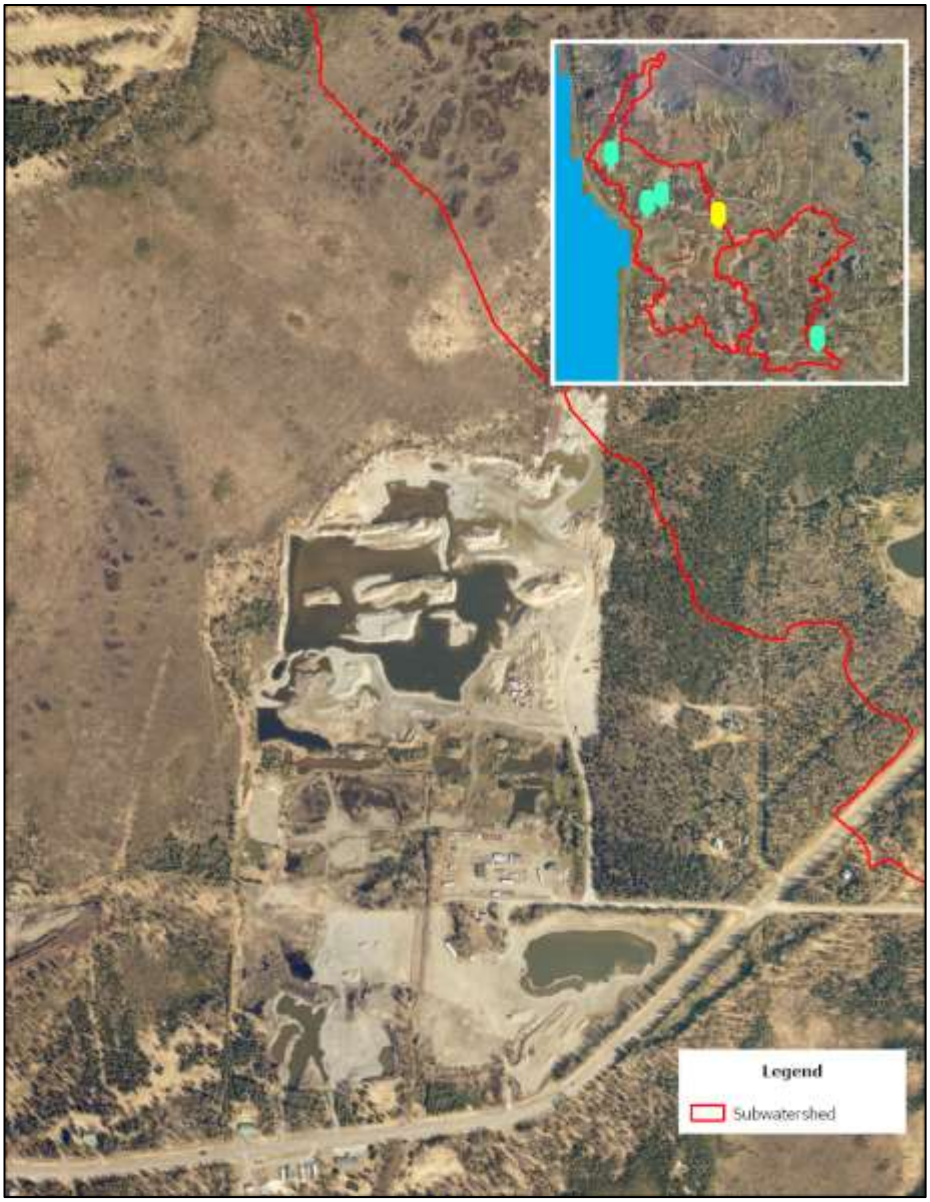
Wildwood Correctional Complex

Alaska Job Center Parking Lot

Kenai Shopping Center

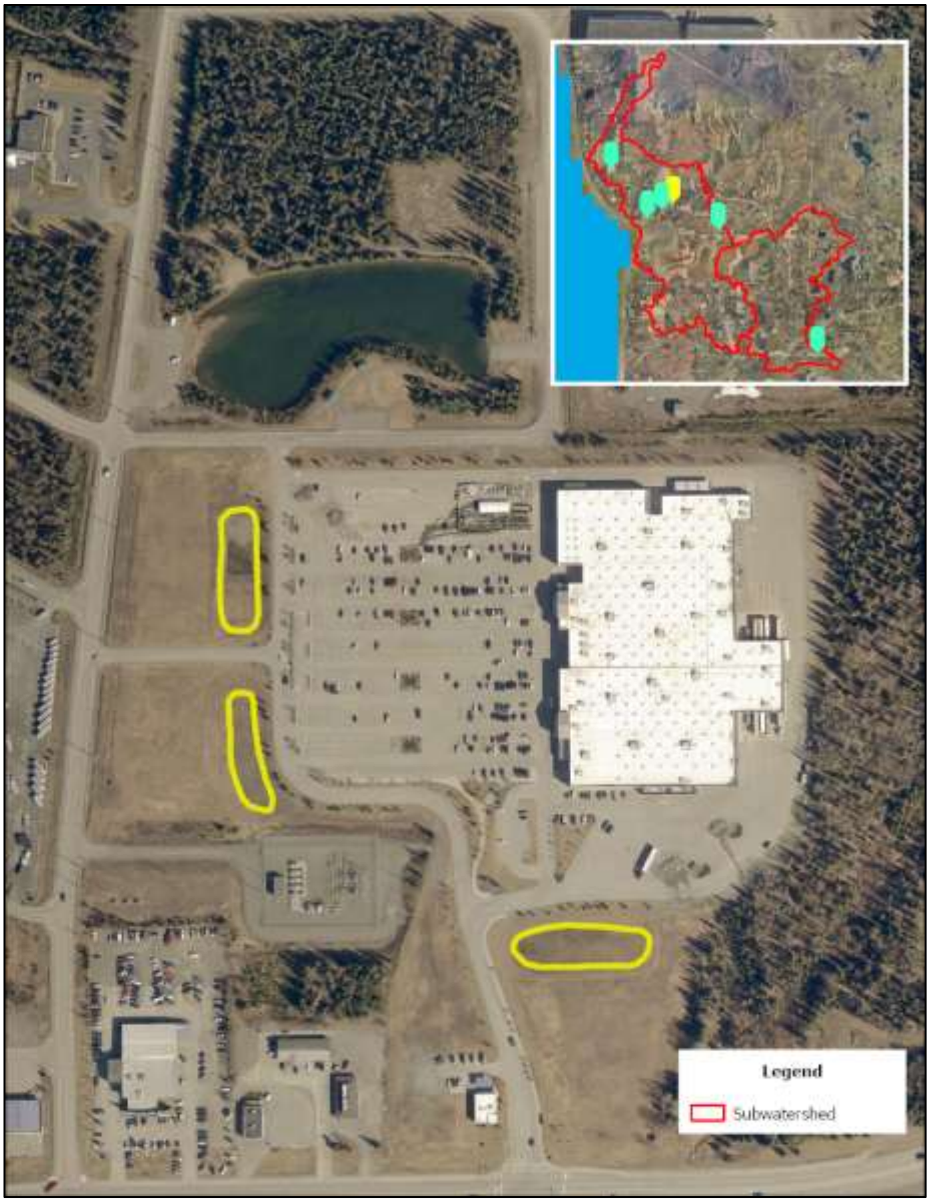


Soldotna Airport



Gravel Mine

Appendix B: Existing Ponds



Walmart parking lot. Highlighted in yellow are settling ponds.