HYDRAULIC MAPPING AND MODELING
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July 6, 2016

Memorandum

To: Royce Conlon, P.E., PDC Inc. Engineers

From: Kenneth Karle, P.E., Hydraulic Mapping and Modeling

Subject: River Behavior Considerations for Channel Excavation

There appears to be continued interest from the public and others in investigating the use of channel diversion through excavation as a potential method to solve the flooding problems at the Seward Airport. This memo provides a brief explanation of the geomorphology of braided rivers and the hydraulic forces involved in bedload transport and deposition, and should provide additional justification, if needed, for the decision to select an alternative that does not include large-scale excavation of a new channel segment in the Resurrection River alluvial fan delta.

Braided River Geomorphology-The upper 8 miles of the Resurrection River takes the form of a meandering channel confined within a narrow meandering canyon. The channel transforms into a braided river as multiple glacially-fed tributaries provide water and sediment input, and ultimately transforms into an alluvial fan delta for approximately three miles before flowing into Resurrection Bay. Salmon Creek and Japanese Creek also provide water and sediment input to the alluvial fan delta.

The alluvial fan delta is braided in nature, and consists of interconnected distributary channels formed in coarse depositional materials. River conditions that are universally attributed to braided rivers include high bank sediment supply upstream, high bank erodibility, little to no vegetation, moderately steep gradients, and flashy runoff conditions which vary from low to high flows frequently (Leopold et al, 1964, and others).

Braided rivers are generally found in steep valleys relative to other types of rivers. A common explanation for braiding states that a river needs to dissipate energy as it moves downstream. Otherwise, velocity would continue to increase, which leads to downcutting and channel erosion. However, since many rivers cannot downcut because they discharge into a water body with fixed elevation, other actions are needed to dissipate energy. By braiding, a river increases its overall length, decreases its slope, and increases the amount of energy dissipated in longer channels and in bends. Equilibrium is maintained between energy gained and energy lost. The fan delta becomes a depositional zone to maintain its grade.

Though commonly referred to as a floodplain, the wide braided gravelly and unvegetated area where the channels, both active and abandoned, and gravel bars are located are not technically floodplains, but rather part of the active fan delta.

Sediment Deposition-The shear stress at the bed τ_o is the force of moving water against the channel bed. Referred to as the tractive force, it determines the power of flow to dislodge and transport sediment particles. The equation for shear stress for steady gradually varied flow is:

$$\tau_o = \gamma \, R \, S$$

Where τ_{o} = bed shear stress
γ = specific weight of water
R = hydraulic radius
S = friction slope

As the slope S decreases, the shear stress decreases, along with the power to dislodge and transport sediment. Sediment in transport will settle out with a shallower slope.

For the 8500 foot reach upstream of the Seward Highway Bridge, the Resurrection River has an average slope of 0.005 feet/feet. The bed slope is relatively consistent; see Figure 1. In natural river systems, slopes are steepest near the headwaters and gradually flatten out near the mouth. This holds true for the Resurrection River as well. Downstream of the Seward Highway/ARRC bridges, the slope flattens out considerably. Resurrection Bay provides a fixed elevation water body (aside from tidal range). Unable to downcut, the river braids, decreases its slope, deposits sediment, and dissipates energy. The fan delta becomes a depositional zone to maintain its grade.

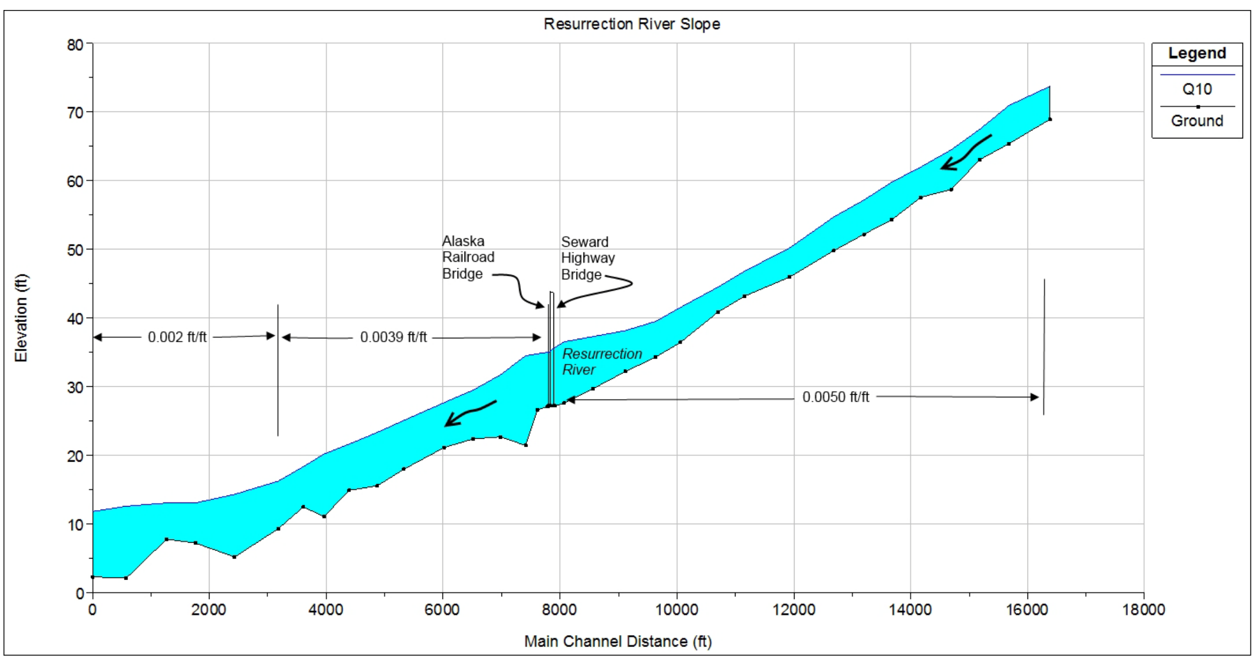

Figure 1. Resurrection River channel slopes.

Though there are several processes that are responsible for braiding, it is important to note the time frame in which these processes can occur. Researchers have noted that “Individual channels and bars in such rivers can evolve, migrate, and switch position within days or hours of competent flow, so that the overall pattern is bewilderingly variable and complex.” (Ferguson et al, 1992). Others have noted that though some processes require high water stages, some do not, and braiding can occur at constant discharges.

Resurrection River Bedload Rates and Sediment Deposition-I have been unable to locate estimates of annual bedload rates for the Resurrection River; however, the general consensus is that the bedload rates are high. Multiple reports provide descriptions of high bedload rates, active channel migration, and severe sediment deposition. The Alaska Railroad estimates that the 1995 Resurrection River flood event dumped 60,000 cubic yards of sediment in the ARR docking harbor just off the east end of the river (T. Brooks, personal communication). The Corps of Engineers notes that Seward drainages carry glacial debris that is deposited in the streams and added to the alluvial fans at outlets (COE, 2008). A report by a multi-agency task force formed to pursue a comprehensive solution to flooding in Seward noted that:

> “..streams tributary to Resurrection River drain steep glaciated subbasins and deposit large quantities of coarse bed materials in alluvial fans at their mouths. These deposited materials are subsequently picked up and moved downstream through the Resurrection River valley, particularly during flood flows. Transport of these materials constantly modifies the major stream channels. The river migrates back and forth through many distributaries located in a flood plain ranging up to 1 mile in width.”(Task Force, 1998).

A report by the Seward/Bear Creek Flood Service Area notes that streams in the Resurrection Bay watershed carry huge amounts of gravel and debris which:

> “guarantees that they will naturally meander over alluvial fans or through braided channels and definitely refuse to stay in one place.” (SBCFSA, 2009).

A series of aerial photographs of the Seward Airport area, stretching from 1950 through 2014, documents the channel migration of the Resurrection River to the southwest across the alluvial fan delta. See Appendix 1 of this memo.

Excavation of active fan deltas has been conducted frequently in Alaska, primarily to utilize the gravel. For example, a long-term gravel excavation program on the Toklat River in Denali National Park and Preserve is unique within the national park system; its success is due to the high bedload and quick replenishment rates that refill the excavated channels within a few years or less (Karle, 2010).

MHW completed a study of river processes along another wide braided river system in Southcentral Alaska for the NRCS in order to assess various options to control bank erosion. The 2004 study, *'Matanuska River Erosion Assessment Design Study Report'* (USDA, 2004) focuses on a study area that encompassed the river floodplain from the Old Glenn Highway Bridge downstream approximately 6 miles to the Bodenburg Butte area. The NRCS report included an extensive study of gravel removal as a bank erosion protection alternative. Channel excavations would be designed to reduce velocities and stresses on banks during high and moderate flow events (USDA, 2004).

The study utilized computer modeling to estimate the effect of channel excavations on flow pattern, hydraulic characteristics, and sediment transport. Excavated trenches were created within the river model and analyzed. The modeled trenches were 10 feet deep, 500 feet wide, and 2500, 3300, and 6500 feet long. The study authors acknowledged that such excavation requires construction practices of a large-scale mining operation. To be effective during moderate floods (2- to 10-year flood), the initial modeling involved the removal of approximately 2.2 million cubic yards of material. The authors noted that additional planning and modeling was needed to adjust the trenches to maximize effectiveness.

The following paragraph from the NRCS report describes a major disadvantage to this alternative. Italics have been added for emphasis.

> "From a geomorphologic perspective, the behavior of the excavated channels is of concern on the Matanuska River, since natural river instability may impact the effectiveness of the trenches to re-direct flows and reduce water levels. Since *braided channels characteristically exhibit irregular and unpredictable morphologic development, there can be no guarantee* that the proposed excavations will remain stable for a significant time period (i.e. multiple freshet seasons) to reduce flood levels and redirect flows, as intended. In addition, *there is a risk that bank erosion could continue* due to flow in the smaller subchannels even if the trenched channels are constructed. If an appreciable amount of the flow remains outside of the excavated channel, bank erosion may continue. In addition, flows through the initially straight excavations will likely erode their banks and eventually result in irregular excavated channel patterns with flow paths deviating from the constructed alignment." NRCS, 2004; p. 3-2.

Summary-Based on the general description of channel excavation for bank erosion control in the NRCS report, and the extensive experience of the authors with gravel excavation on braided rivers, I concur with ADOT&PF's recommendation that channel excavation is not a viable engineering solution to ameliorate or control flooding of the Seward Airport. There is no guarantee that an excavated channel would remain stable, or redirect flows, as intended, for the following reasons:

- Upstream of the Seward Highway Bridge, the Resurrection River, Salmon Creek and Japanese Creek all provide high inputs of sediment to the Resurrection River drainage.
- The slope of the alluvial fan delta downstream of the Seward Highway Bridge is less than the slope of the river upstream, creating a depositional environment.
- High sediment transport in the Resurrection River, even during low to moderate flows, could alter or fill an excavated channel on the alluvial fan delta within days.
- Remaining flow outside of the excavated channel may still cause sediment deposition, bank erosion, and flooding of the runway.

References

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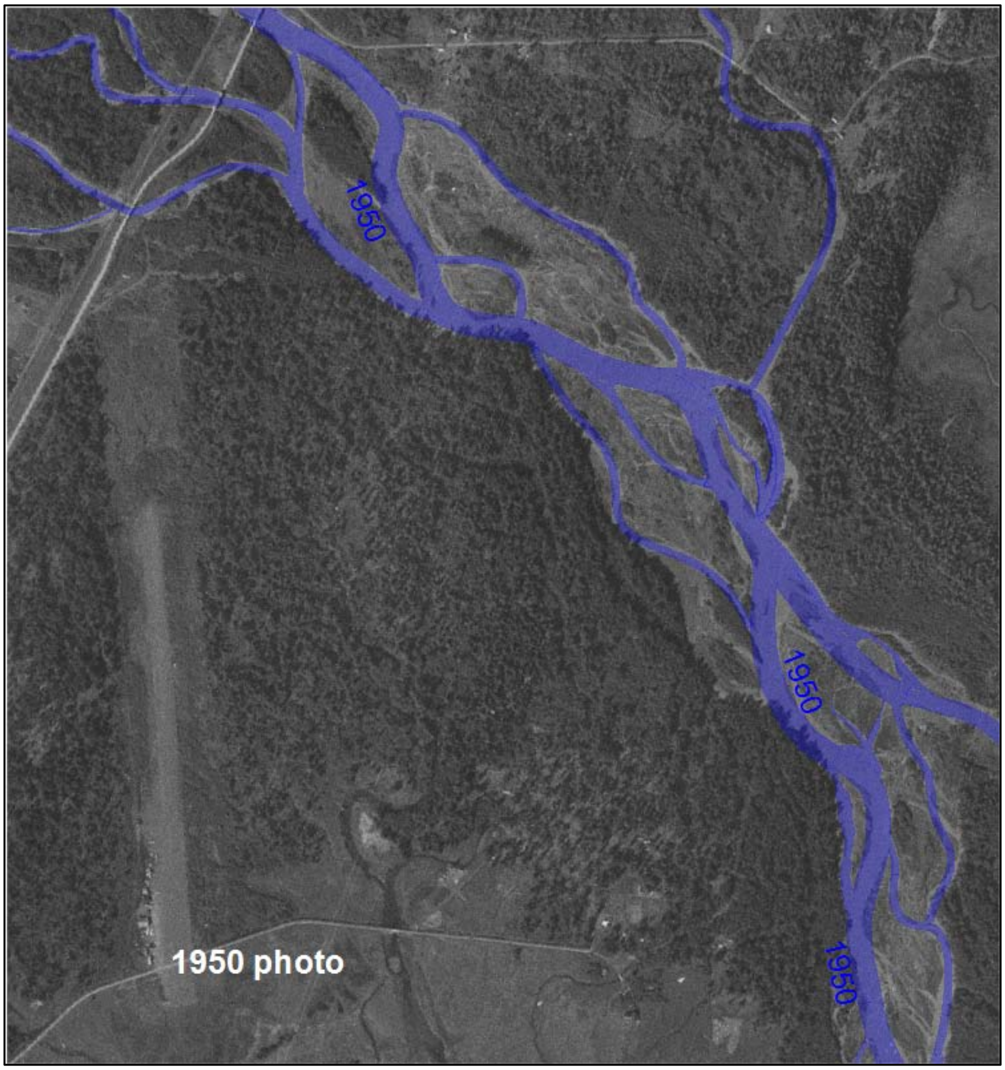
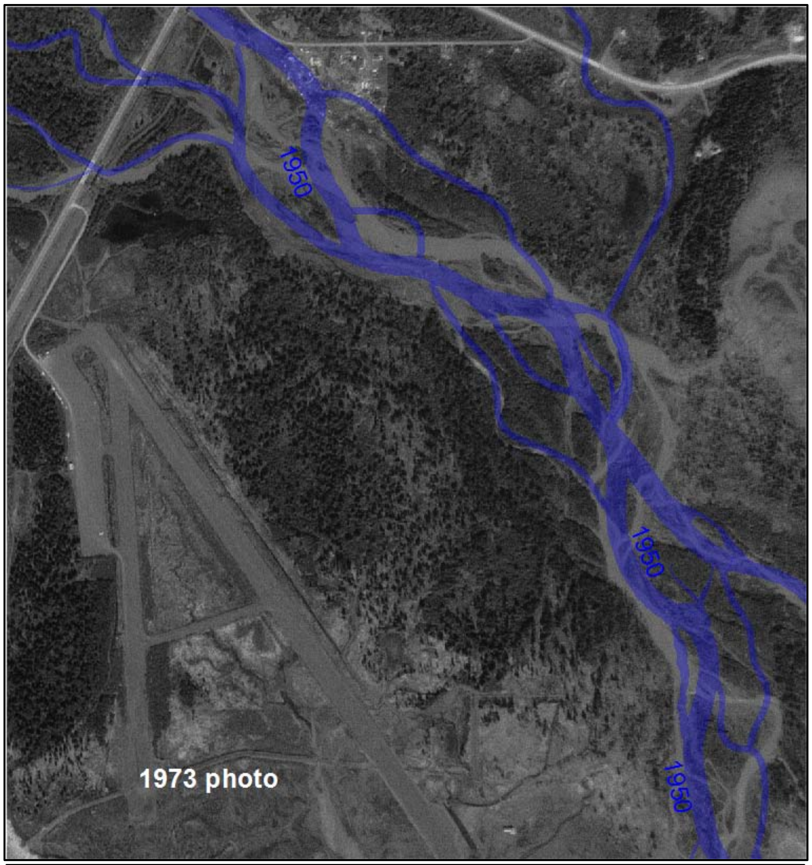
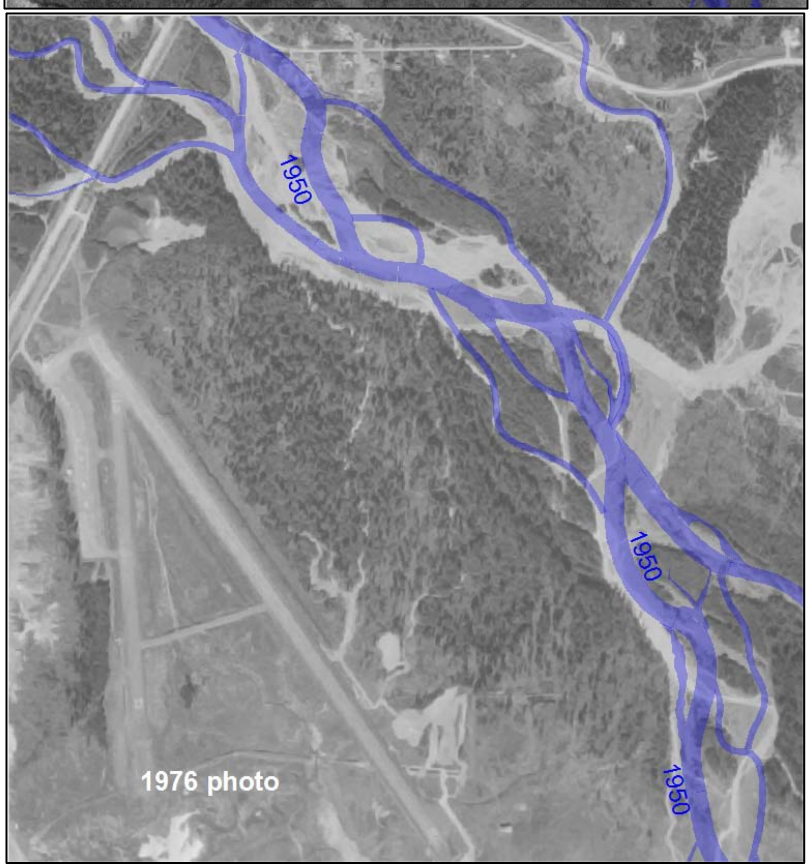
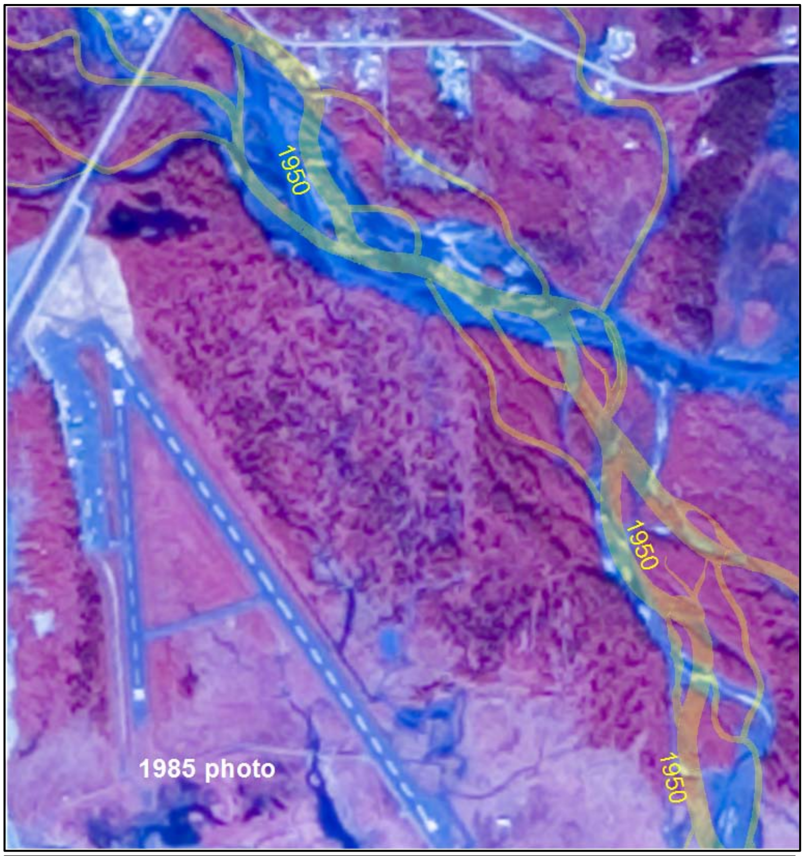
Appendix 1-Resurrection River Channel Locations, 1950 to 2014

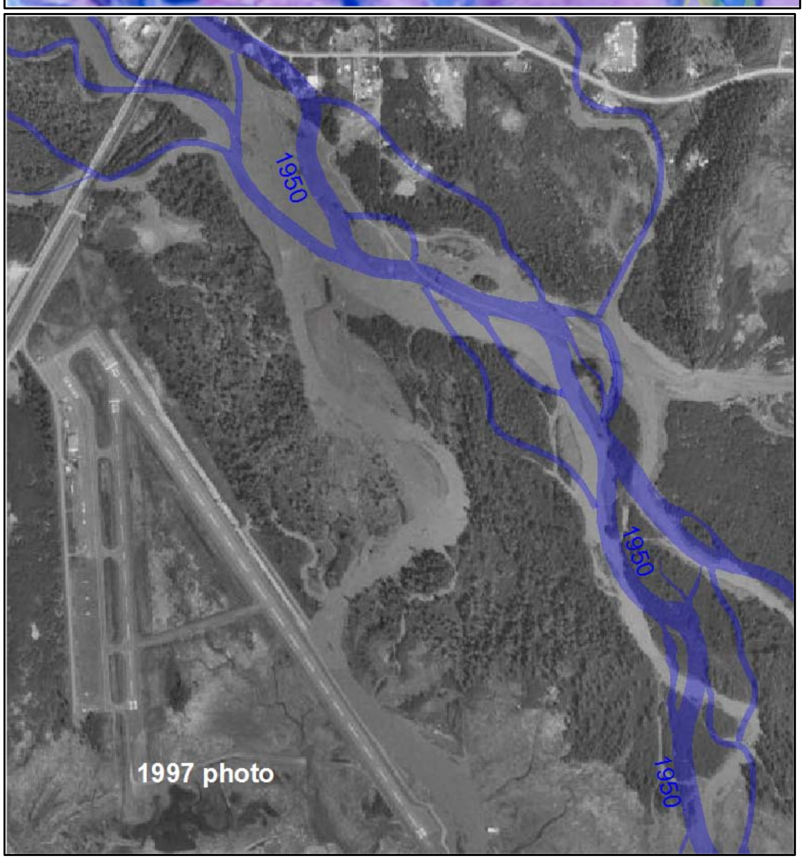
The approximate location of the Resurrection River channel in 1950 is shaded in blue, and overlain on the following aerial images: 1950, 1973, 1976, 1985 (infrared imagery-channel shaded in yellow), 1997, 2011, and 2014.




1950
1950
1950
1973 photo


1950
1950
1950
1976 photo


1950
1950
1950
1985 photo


1950
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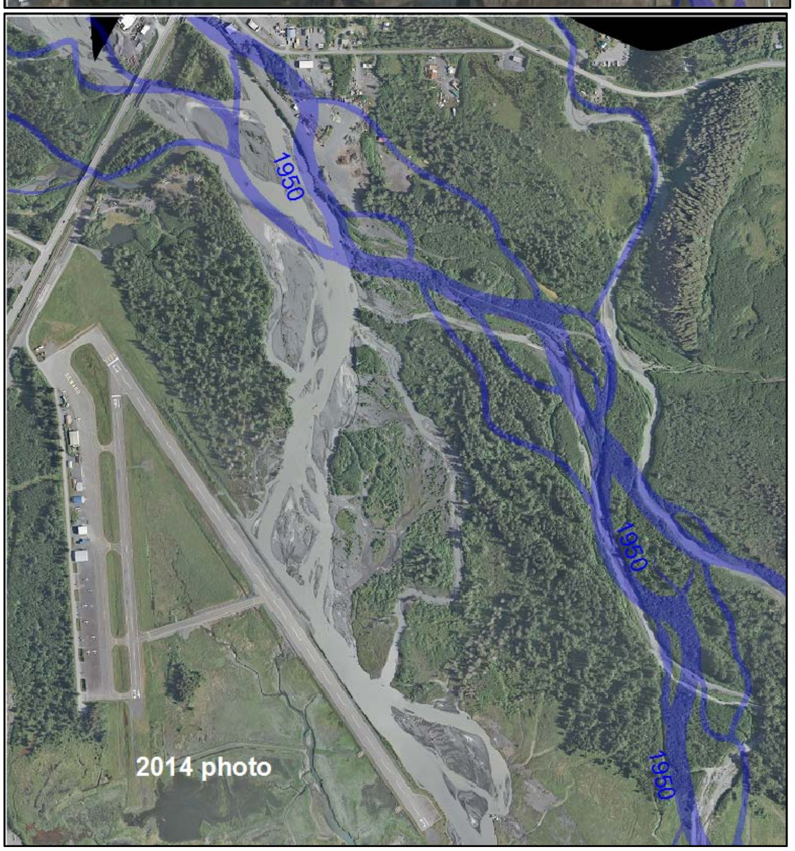
1997 photo


1950
1950
1950
2011 photo


1950
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2014 photo