APPENDIX B

Alternatives

Table of Contents

Seward Airport *Alternative Evaluation*

Alternative Descriptions	***Alternative 1.1***		***Alternative 2.2***		***Alternative 3***	
Main Runway Disposition	Raise the main runway (maintain existing length and embankment width) - protect from overtopping and protect from erosion		Allow main runway to be overtopped by floodwaters		Allow main runway to be overtopped by floodwaters	
Crosswind Runway (CW) Disposition	Raise crosswind runway on north to match raised main runway.		Offset CW runway from apron to allow Design Group II aircraft; shift threshold north to avoid VE impacts; widen to 75' (150' safety area) and lengthen to 3300' (3900' safety area)		Offset CW runway from apron to allow Design Group II aircraft; shift alignment to avoid ARRC on south end, shift north to reduce impact in VE zone; widen to 75' (150' safety area) and lengthen to 4000' (4600' safety area)	
Hydraulic Analysis	Use Q100 with 2-foot freeboard on main runway. This option is within the floodway; consider impacts to properties due to change in the floodway.		Use Q100 with 2-foot freeboard on CW; raise CW elevation; provide erosion protection		Use Q100 with 2-foot freeboard on crosswind; raise CW elevation; provide erosion protection; provide protection for the portion in the VE zone	
Evaluation Criteria	*Advantage*	*Disadvantage*	*Advantage*	*Disadvantage*	*Advantage*	*Disadvantage*
Cost						
Construction/Earthwork Cost - for comparison only -Not total project costs		$13 million		$11 million		$16 million
Maintenance & Operations (M&O)	Acts as a levee to protect the apron from 100-year flood	More snow removal and pavement surface to maintain than others - assumes the erosion protection is stable/permanent and no additional costs for M&O within the design life. More lighting and pavement markings to maintain.	M&O costs will be less; pavement and lighting for only one runway;new runway embankment acts as a levee to protect the apron from flooding	Maintain closed runway markings; assumes the stabilization is permanent and no additional costs for M&O within the design life	M&O costs less than existing. Only one runway with pavement and lighting to maintain . Embankment acts as a levee to protect the apron from flooding	Similar to Alt 2.2; although slightly more because the longer runway requires additional maintenance due to extra pavement, markings, lights, etc.
Right of Way --preliminary costs only		$1,300,000		$950,000		$950,000
FAA Funding Eligibility	Generally easier to get approval of work on existing facility	Two runways may be seen as unwarranted; Environmental Impacts could trigger scrutiny of funding	Should be eligible	None	Should be eligible for FAA funding up to 3300' length.	4000' length would require other funding sources to supplement the FAA funding.
Ability to Serve the Community's Needs						
Medevac	Longest runway - best for jets; also see wind coverage. Allows C-130 access in case of a mass casualty event (very infrequent need).		Serves the King Air 200, provides for basic medevac service	Too short for jets	Longer than Alt 2.2, 4000' length preferable for King Air pilots	Too short for long-range jets with destinations outside of Alaska
Meets General Aviation	Improves Runway. Exceeds the forecasted aviation needs.		Improves Runway most often used and adds length. Wider/longer runway accomodates operational tolerance during occasional strong winds.		Improves Runway most often used and adds length. Wider/longer runway accomodates operational tolerance during occasional strong winds.	
Search and Rescue	Improves Runway		Better Apron Access	Eliminates Longer Runway	Better Apron Access	Shorter than Alternative 1.1
Economic Development	Longest runway - supports occasional use by Lear jets, tourism opportunities, larger cargo and passenger planes; improves reliability (runway open under a greater range of conditions) and potential for aviation-related business development at the airport including Lear jets and commuter operations	No change to apron area, which limits use of large aircraft on the apron, thus limits business development.	Runway offset provides for larger aircraft (DG II) on the apron taxilane; provides more areas for use by larger aircraft and thus could provide FBO's with greater operational area	Runway too short for Beech 1900 commuter service	Runway offset provides for larger aircraft (DG II) on the apron taxilane; longer runway facilitates use by FBO's including commuter aircraft and some short range jets	
Safety, Engineering & User Considerations (Items not covered by Costs)						
Wind	Two runways provide slightly better wind coverage for small aircraft. Combined coverage DG II =99.93, DG I = 99.64	Longer runway (13/31) orientation is not as good as the "crosswind" runway. RW 13/31 coverage DG I = 91.1%, DG II = 96.0%	Provides longer/wider runway for best wind coverage orientation; DG I = 98.6% ; DG II = 99.53%. A number of pilots seem to favor improving the cross-wind versus the main runway.	Slightly reduced coverage due to single runway but meets FAA guidelines for a single runway.	Provides longest runway for best wind coverage orientation; DG I = 98.6% ; DG II = 99.53%. A number of pilots seem to favor improving the cross-wind versus the main runway.	Slightly reduced coverage due to single runway but meets FAA guidelines for a single runway.
Airspace/Runway Protection Zone (RPZ)/Approach Obstructions	**Airspace**: Higher runway, slightly less penetration of airspace	**RPZ**: Main runway has undesirable uses in the RPZ, (Public Road, Railroad) **Approach:** Existing obstructions in the RW 13 approach (road, railroad) would remain. ARRC is planning barge loading/unloading facilities under the approach of RW 34	**Approach:** Horizontal shift of runway moves the RW 34 approach away from the proposed ARRC development; Closing the main runway significantly reduces RW 13 RPZ obstructions.	RPZ: ARRC development for barge operations (jetty, access road) may occur in RPZ.	**Approach**: Horizontal shift of runway moves the RW 34 approach away from the proposed Alaska Railroad development. Significantly reduces RW 13 RPZ obstructions.	RPZ: ARRC development for barge operations (jetty, access road) may occur in RPZ. RPZ and approach extend into the planned ARRC barge basin.

Alternative Descriptions		***Alternative 1.1***		***Alternative 2.2***		***Alternative 3***	
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Evaluation Criteria		*Advantage*	*Disadvantage*	*Advantage*	*Disadvantage*	*Advantage*	*Disadvantage*
	User Function/Runway Reliability/ Level of Service (LOS)	Uses existing VASI approach aids; Higher (above the flood) runway will improve the reliability of the airport; LOS is slightly higher because capacity is increased	Long taxi path; requires displaced threshold to meet RSA requirement.	Lengthens the runway along the orientation for prevailing winds; meets the needs of the based aircraft; improves apron expansion opportunities; reduces congestion; provides full safety area; Higher (above the flood) runway will improve the reliability of the airport. Shorter taxi path.	Large infrequent aircraft, such as Coast Guard C-130 will be unable to use as well as some larger commuter aircraft.	Lengthens the runway along the orientation for prevailing winds; improves apron expansion opportunities; reduces congestion; provides full safety area. Higher (above the flood) runway will improve the reliability of the airport. Shorter taxi path.	Still limits use by infrequent large aircraft, but functions well for based aircraft, medevac, and future commuter aircraft; Single runway provides lower LOS than two runways
	Long-Term Stability/Risks	On existing embankments, which are stable except for erosion.	Greater risk of flood damage since the river is next to the runway and the "model" has variables; climate change could affect river flow; additional sediment deposition unpredictable. Requires reconstruction of runway to meet bearing capacity requirement	R/W provides flood protecton for apron. Runway is sited further from the river, less potential for flood impacts.	Potential risk to downstream (ARRC) facilities if the river moves	Provides flood protecton for apron. Runway is sited further from the river, less potential for flood impacts.	Potential risk to downstream (ARRC) facilities if river moves; is within VE zone and susceptible to tidal influence (greater potential effects from sea level rise).
	Construction Considerations		Riprap installation below water, in river channel, more difficult. Construction likely delayed (as much as 2 years) by a CLOMAR/ LOMAR process with public hearings.	No riprap placement into river channel. Results in easier installation.	Construction phasing will be most challenging. If excavation from abandoned runway is used for fill, both runways will be under construction concurrently.	Same as Alt 2.2.	Runway extends out into tidally influenced region. Requires extension of Riprap into the tidal zone. CLOMAR/ LOMAR may be required and could delay construction, but expected to be easier and quicker to obtain than Alt. 1.1. Longer runway is more flexible for construction phasing.
Environmental Considerations							
	Floodplain/Floodway Impacts	Provides flood protection for apron since runway acts a levee. Raises Main RW 2 feet above 100-year flood level.	In the floodway - increases the flood elevation by up to 4', impacts additional private properties. Permitting will face more obstacles due to public process and floodway impacts = expensive and time delays. Impacts the floodway - requires revision to the FIRM map. Process includes public involvement.	Provides flood protection for apron since runway acts a levee. Does not impact the floodway - no change to the FIRM map needed. Eventual breach of main runway would partially remove an obstruction in the floodplain/ floodway.	Greater chance for channel movement into the floodplain when flood waters breach the main runway. In floodplain - increases the flood elevation by <1 foot (with coastal flooding considered); (however based on previous discussions by DOT with FEMA and City 1' rise is okay)	Provides flood protection for apron since runway acts a levee. Eventual breach of main runway would partially remove an obstruction in the floodplain/ floodway. Construction penetrates the VE zone, but is still more likely permittable than Alt 1.1.	Greater chance for channel movement into the floodplain when flood waters breach the main runway. In floodplain - increases the flood elevation by <1 foot (with coastal flooding considered); (however based on previous discussions by DOT with FEMA and City 1' rise is okay). Does not impact floodway but a revision to the FIRM map needed to change the limits of the VE zone.
	Fish Habitat Impacts	Least impact to intertidal (coastal) EFH area for salmon and marine fish species	Requires in water work to place erosion protection; most impacts to Resurrection River mainstream, which is EFH for salmon species	Fewer impacts to intertidal EFH than Alt 3. No impacts to Resurrection River than Alt 1.1.	More impacts to intertidal EFH than Alt 1.1.	In instream impacts to the Resurrection River	Greatest impacts to intertidal EFH; but is not within marine habit.
	Wetlands Impacts	No wetlands fill associated with RW 16-34.	Most impacts to wetlands from fill in River to raise RW 13-31. May be difficult to permit because Clean Water Actequires selection of practicable alternative with least impacts.	Most permittable. Fewer acres of impacts than Alt 1.1.	Similar wetland impacts to Alt 3,but less due to shorter RW).	Fewer acres of impacts than Alt 1.1.	Similar wetland impacts to Alt 2.2 but more due to longer runway. Fill for longer RW would be harder to justify.
	Endangered Species Act (ESA)/Bald Eagle	Farthest from Resurrection Bay where sea lions, otters and harbor seals are known to be located. Most acceptable under ESA and MMPA	Possible bald eagle nest impacts (based on 2004 nest sites), more so than with other alternatives	Similar distance from Resurrection Bay as Alt 3. Less fill near or in the bay than Alt 3.	Fill in/near Resurrection Bay and possible bald eagle nest impacts	Similar distance from Resurrection Bay as Alt 2.2.	Least acceptable under ESA and MMPA. More fill than Alt 2.2 in/near Resurrection Bay.
	Human (Socioeconomic) Impacts (ROW Impacts, Compatiable Land Use)	Greater reliability of main RW and keeping both runways provides Increased capacity, higher LOS. This option would provide additional protection for the ARRC facilities	Flood plain impacts would impact more private properties adjacent to River and the affect their property values; portions of the impacted property are undeveloped and the properties lack access.	Flooding affects reduced therefore less property impacts during Q100. Longer RW 16-34, but not as long as in Alt 3.;	Loss of main RW and short length of RW 16-34 less favorable to the City from Economic development potential standpoint. Restricts access to floatplane takeout area.	Longer RW 16-34 than Alt 2.2; provides oppuntity for larger aircraft	Loss of main RW; Restricts access to floatplane takeout area.

Location	DOT&PF; Central Region Office, Bat Cave conference room	*Date/Time*	January 12, 2015, 9:30 – 12:30
Attendees	DOT: Barbara Beaton, Joy Vaughn, Morgan Merritt, Paul Janke PDC: Royce Conlon, Ken Risse (via telephone) HMM: Ken Karle (via telephone)	**Client #**	AKSAS 54857
		PDC #	14075FB
		Project Name	Seward Airport Improvements
		Prepared By	Royce Conlon in conjunction with notes provided from Barb and Joy
Subject	Draft Resurrection River bed rise report & alternatives for further evaluation		

Paul Janke provided written comments to the report which were discussed during the meeting. Key topics discussed are summarized below.

Review of Draft Resurrection River Bed Rise Report

Ken Karle provided an overview of the report: The data that was used included surveyed cross-sections (2007 & 2014) and LIDAR. Data for 1977 was also used but the location of the stream shifted between then and 2007. The analysis shows that the elevation of the thalweg downstream from the Seward Highway bridges lowered significantly from 2007 to 2014 at 13 of 15 cross-sections, with the maximum drop of 7.2 feet. However, an analysis of volumetric changes to the floodplain surfaces using the LiDAR data sets showed that there was a small rise of the floodplain surface between 2006 and 2014. Also, a cross-section analysis that focused on the main bank-to-bank unvegetated channel showed small average increases from 2007 to 2014. The overall cumulative change is so slight the comparison of the data shows less than 1” between 2007 and 2014; this would result in less than 1’ over the course 20 years even though the common perception is that all braided streams are rising.

The report also indicates that the dredge pile that was left in the floodplain upstream of the airport appears to have been a significant source of the sediment moving toward the airport, and may have played a significant role in making the flooding worse there.

Paul mentioned that M&O has done some dredging near the south end of the long RW, which may have been responsible for the observed thalweg lowering from 2007 to 2014.. Ken K was not aware of it so that information was not part of his analysis. Ken will talk to M&O (Carl High (gone till Feb) and Mike Rule) to get information about how much material was taken out. The dredging could have potentially lowered the thalweg even upstream of the dredging location due to the “head cut.”

Paul is not comfortable that the report does not explain possible causes of why the runway has overtopped multiply times in a year, if it is not bed rise. Paul acknowledged the stream could be in some kind of equilibrium, but is not comfortable with the contrast between this analysis which shows minimal bed rise and what he has observed at the southern end of the main RW embankment. He has seen more gravel bars appearing and there has been a marked increase in the frequency of overtopping events in recent years. He said that for many years, the runway was overtopped very infrequently and only at high tide. In 2012 it was overtopped 10 times, sometimes during more moderate discharges and at lower tides. (Royce noted that even though the average height of the floodplain has not risen much, looking at the graphs there does appear to be a significant amount of the floodplain that is higher.) Also, could the difference in the water surface elevations at the time of the different surveys affect the results?

There was discussion among the group, if the bed is not raising much, what is the mechanism that is causing the increase in overtopping events? (climate?) It was noted that stream gauging data is not available for the river and determining if additional flow is the cause of the over topping would be a substantial effort, and maybe non-conclusive.

Paul is commented that he was impressed with the large bed load he sees coming down the river from upstream of the bridges. (Dan Mahalak of KPB estimated it at 300,000 cy a year.) Isn't some of that that collecting in the delta? (ARRC is seeing a large amount of sediment coming out of the river – reportedly 60,000 cu yds in one storm.)

Paul also wants the report to be clearer qualitatively concerning the uncertainty introduced by, and the effect of various assumptions on the results… Ken K. said the difficulty lies in the fact that the data represent widely spaced "snapshots" in time. He said different hydrologists could arrive at widely different conclusions as to the amount of bed rise using the same data.

Barb stated that they need to understand how reliable these results are because the speed at which the bed is rising impacts whether raising the RW is a viable option. If in fact the bed is not rising very fast, it may be reasonable to raise the runway; otherwise, we would have to go back and raise the runway again too frequently.

The design discharge for determination of flood elevations to set the embankment heights was discussed. FAA guidance is written for stormwater, not rivers, and point to 10-year events, which seems too low. The State does not address the topic in the Aviation Preconstruction manual. Paul said Skip Barber's analysis used a 25-year storm, but Paul could not find a rationale for it. Paul says for highways next to rivers, the state uses a 50-year storm, but checks the 100-year level and often defaults that instead. Bush airports often use a 100-year storm, but that is for safely so that people have high ground to escape to in an emergency. Paul is going to research the topic and write a memo to issue a decision by the Department. Morgan suggested the flood frequency should consider "reasonable expenditure of FAA funds", or at least that is what FAA will be concerned about.

Morgan: Could we make dredging an option if the community agrees to participate in funding? (Paul is still concerned about liability.)

Alternatives for Evaluation: The discussion moved onto the next steps in evaluating solution including which alternatives should be evaluated.

Royce Conlon provided figures of current alternatives to facilitate discussion.

Ken Karle needs the cross-sectional area of the proposed design to analyze the effects of improvements the VE flood zone. He also needs some guidance on what “free-board” to consider. If bed rise if slight 1’ maybe adequate; given the uncertainty, maybe we should use something more? No conclusion was reached on this subject at the meeting.

Paul said that if we abandon the long RW, we should let the river take it and just protect the crosswind with erosion control. Is there a need to analyze the hydrology of the crosswind in those cases as if the long runway embankment is breached? We may need to raise the crosswind some. There was some discussion of slowing the erosion of the main RW embankment with measures that would be placed but not maintained (sheet pile? boulder filled trench?). If some sort of erosion inhibitor is used on the main runway, it should be placed so that they do not add to the volume of fill (thus does not affect the floodway. It was commented that if the design lets the main runway be breached this could have some impact on the ARRC facilities (namely the proposed jetty).The cross sections show the area between the runways is lower than the main channel. We may need to protect the runway embankment to control the channel.

No decision was made as to whether or not protection of the main runway should be considered in the alternative evaluations.

In discussing what runway length should be considered to meet the needs Morgan asked about medical evacuations and the community needs in case of emergency. The Seward Preparedness plan does mention the airport, but does not mention the services/functions of the airport, it difficult to tie the communities plan with any minimum runway length.

There was discussion about the hydraulic modeling needed to evaluate the erosion protection needed in the VE zone. Ken K. indicated the current FEMA Flood Insurance Study (FIS) includes a detailed wave height analysis of coastal flooding at specific locations, including the Resurrection River. Royce thought Shannon and Wilson has some experience with this, she will check.

Alternatives for analysis: 1.2, 2.1, 2.2, and develop Alt 3 (4000’ runway), depending on the best alignment from evaluation of 2.1 & 2.2, same with alternative 4 (4700’).

Alt 1.1 was placed on hold, (Barb send e-mail on 1/20/2014 giving the go-ahead to include it in our evaluation. Here direction further indicated “We should look at the impacts to properties on the other side of the river as a result of raising the base flood elevation. We may need to buy them out, depending on impacts.”

Alternative 2.3 was eliminated because it would impact land use of the ARRC (a portion of the RPZ) is over the area planned by ARRC for barging operations.

Each of the alternatives should show the adjacent land ownerships, so it is clear who may be impacted.

Open Issues:

- The design storm for determining the discharge which established the flood elevation will be recommended by Paul. Barb will then get FAA input on what to use.
- How much freeboard (the amount above the design flood elevation) is needed to evaluate the alternatives? The amount of freeboard is a function of the amount of bed rise and uncertainty in the flood frequency estimations. The amount of freeboard is still undetermined.
- Whether or not the Alternative should include protection of existing main runway was not decided; ie whether or not to allow the main runway to be breathed. .
- Whether or not the project scope should include further evaluation of factors that may have changed the design flows such as increased precipitation and/or temperature increase causing thaw of the upstream glaciers etc.

Action Items:

General

1) Talk to the city and borough about how they would respond to public outcry about alt 1.1. *<following the meeting, direction was provided to evaluate this alternative on 1/20/2015.>*

Paul:

1) Send Ken Karle Dan Mahalak's data / information about the sediment load.
2) Write memo about what design discharge and freeboard to use.

Ken K:

1) Provide map with section locations labeled to relate to runway and distance downstream from the bridge.
2) Provide updated cross-sections with horizontal locations labeled; increase scale to show the differential better.
3) Add historical photos showing the stockpile, if any and aerial photo prior to stockpile if available.
4) Talk to Mike Rule and/or Carl High to get details about the dredging that was done.

Royce:

1) Confirm Shannon and Wilson can provide coastal design to protect the runway in the ZE zone.
2) PDC to begin evaluations once design discharge is agreed upon.

Reference Documents:

1. Meeting Agenda, 1/12/2015
2. *Rate of Channel Bed Rise Analysis For the Resurrection River At The Seward Airport*, dated December 2014, by HMM.
3. Memorandum from Paul Janke, dated January 12, 2015 Subject: Comments on Rate of Channel Bed Rise report by HMM.
4. Graphics of the preliminary Alternatives

From: Royce Conlon
To: "Beaton, Barbara J (DOT)"
Cc: "Vaughn, Joy A (DOT)"; Ken Risse
Subject: RE: Seward Airport - Channel Bed Rise Report Notes
Date: Thursday, February 05, 2015 4:42:47 PM
Attachments: Alternatives for Consideration 15y02m01d.xlsx

Barb – good talking with you this afternoon – the follow summarizes our discussion:

You mentioned you received a copy of revised guidelines for flood plain management standards. Paul was going to incorporate some of the guidance from this revised standard into his draft memo from 1/23/2015 – also you will forward the revised standard to us for our edification. This guidance suggested a 2' freeboard which coincides with what we suggested below.

We discussed the 8 alternatives outlined in the spreadsheet sent on Monday (attached for reference); after discussion you are comfortable with PDC moving forward with evaluation of Alternatives 1.1, 2.2a and 3 and with these alternatives being developed based on Q100 discharge flows and 2' of freeboard.

I indicated we had established profiles for those three alternatives and refined the alignments (slightly); we will now apply the "template" (which is now called an "assembly" in Civil 3D) to produce the 3D model of the runway embankment from which we will cut the cross sections to give to Ken Karle to superimpose in his HEC-RAS model. You asked what the typical section looked like in terms of embankment layers. At this point we give Ken K. only the embankment outline; he will then run the model to determine the velocities that are needed to determine the "rock requirements" needed to protect the embankment – concurrently we will work with S&W to provide us conceptual recommendations of the embankment section.

We discussed the budget constraints, by looking at only the 3 alternatives suggested and by reducing the effort for the evaluation work session; we should be able to stay within the budget for the "scoping" phase.

You mentioned M&O has indicated they feel the dike built in 2013 maybe failing and as such although the project is not programmed until 2018 it could be moved up if the dike fails and causes an emergency.
I will work with Ken K and Kyle with S&W and get you a schedule for when we can have the hydro report and alternatives analysis complete.

Please let me know if I have missed any key item from our discussion.

From: Royce Conlon
Sent: Monday, February 02, 2015 6:21 PM
To: 'Beaton, Barbara J (DOT)'
Cc: Vaughn, Joy A (DOT); Ken Risse
Subject: RE: Seward Airport - Channel Bed Rise Report Notes

Barb & Joy - thanks for the notes, I served on Grand Jury duty the last 2 weeks which took 5 full days out of my schedule, so thank you for your patience.

Attached are a compilation of notes of the 1/12/2015 meeting. This compiles the notes from you, Ken K, Ken R and myself.

I will call you once you have had time to review and digest the e-mail and attachments.

Also attached you will find a summary of the alternatives that I believe have been discussed for evaluation; the table shows 5 main alternatives with twists to 3 of the alternatives for a total of 8. Our original budget was established based on an assumption of up to 3 alternatives. That being said, we can evaluate as many alternatives that are needed, but presently I'm concerned we don't have enough budget to complete the evaluation of even 3 alternatives without some other adjustments. At the bottom of this e-mail you can review my budget evaluation.

Our suggestion would be that we start by evaluating three key alternatives (those highlighted in yellow on the attached spreadsheet) and depending upon the outcome of that evaluation, we can discuss the need to evaluate additional alternatives. We selected these three alternatives because they span the range of the 8 alternatives.

- Alt 1.1 would raise the existing runway elevation, it would potentially have the greatest impact on the floodway but we will then be about to document the elimination of this alternative should the impacts turn out to be to severe;
- Alternative 2.2 with the main runway abandoned as a runway but enhanced to protect it from being breached. (such as sheetpile or a large rock core being added to the without adding fill) – This alternative would avoid both the floodway and the ZE zone.
- Option 3 extents out into the VE zone and provide an incrementally longer runway than the minimum 3300', this alterative considered that the existing main runway will be breached, thus causing the need for additional armoring of the crosswind runway. With this alternative we will have to make assumptions relative to the area that might 1st be breached and the geometry of that breach in terms of width etc.

We developed this approach in concert with Ken Karle who is also concerned with having to many options for evaluation given his budget.

Also for the purpose of the evaluations above, we propose to use the Q100 with 2 foot of freeboard; I will reply to the e-mail last week about the Q2 and Q5 separately.

Budget Evaluation

Remaining budget for Task 2 (as of 2/1/2015) = $51,500.

Remaining tasks to be completed and associated budgets based on the original task/manhour breakdown:

- Initial evaluation - $17,548
- Technical Memo/Data gap summary - $9705
- Evaluation worksession - $11,118
- Scoping report Draft - $10,712
- Scoping Report Reviews and Mtg with DOT - $7,369
- Final Scoping Report - $3,575

Total estimated to be needed ....$60,027 (thus $8500 short of the budget)

In addition we need a bit of time to incorporate the last changes into the Forecast and Facility requirements document, which will be a piece of the Draft Scoping Report.

On task that I think we can reduce, in order to stay within budget, would be to par down the evaluation worksession effort, we can trim that to include only essential staff and reduce the meeting preparation time.

FIRM: PDC		PROJECT TITLE: Seward Airport		
TASK NO: Task 1 cont.	TASK DESCRIPTION: Project Scoping		DATE:	5/7/2014
GROUP:	METHOD OF PAYMENT: FP ☐ FPPE ☐ T&E ☐ CPFF ☑	PREPARED BY: RLC		

SUB-TASK NO.	SUB-TASK DESCRIPTION	LABOR HOURS PER JOB CLASSIFICATION										
		PIC	Project Manager	Senior Engineer	Staff Engineer	Enviro Analyst	Sr.Planner / GIS	Jr.Planner /GIS Tech	CADD	Tech Editor/cler	Clerical	PLS 5
		Conlon	Conlon	Risse	Estabrook	Betts	Cotter	Hill	Varies	Dorsett	Varies	Ranson
	Develop Intial Alternatives (Layout)		2	6	30			4	8			
	Initial eval		1	6	16							
	Initial Cost of Development		1	4	20							
	Initial Environ Review		1	2	2	16						
	Land requirements		1	2								8
	Location Memo/Data Gap Summary		4	6	20	6	6	8	4	6	4	
	Evaluation worksession (Team, DOT, others TBD)											
	Prep		8	4	8	2	4	4	2		2	
	travel/attend/particpate		8	8	4	8	4				8	
B5.4	**Field Recon (travel/participate)**		16	16							12	
	Meetings with Locals		4	4		4						
	Alternative Refinement											
	Coord H&H, adjust layouts, refine costs, enviro		4	6	24	8				6	4	
B5.5	**Scoping Report**											
	Draft Report for DOT/FAA review		4	4	16	8	4	6	2	8	8	
	Data Gap/Aquistion Plan		2	6	4	4					8	
	In-House QC	4	4	4	2	2	2			4	2	
	Review meeting		4	4	2	2	2				2	
	Final Scoping Report		2	2	6	2		4			1	
TOTAL LABOR HOURS		4	66	84	154	62	22	26	16	24	51	8
*** LABOR RATES ($/HR)**		$71.15	$60.00	$52.51	$34.90	$31.00	$38.80	$24.50	$29.43	$30.00	$17.26	$43.40
LABOR COSTS ($)		$284.60	$3,960.00	$4,410.84	$5,374.60	$1,922.00	$853.60	$637.00	$470.88	$720.00	$880.26	$347.20

From: Beaton, Barbara J (DOT) [mailto:barbara.beaton@alaska.gov]
Sent: Monday, January 26, 2015 2:17 PM
To: Royce Conlon
Cc: Vaughn, Joy A (DOT)
Subject: Seward Airport - Channel Bed Rise Report Notes

Hope you had a great weekend. Attached are my notes and Joy's from our teleconference.

Thanks,

Barbara J. Beaton, P.E.
Project Manager
Aviation Design
Alaska Department of Transportation & PF
4111 Aviation Drive
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Final Hydrologic and Hydraulic Report

Seward Airport Improvements Project

Prepared for:

PDC, Inc. Engineers
1028 Aurora Drive
Fairbanks, AK 99709

And the
Alaska Department of Transportation
and Public Facilities
Central Region
Anchorage, AK 99509

Prepared by:

Hydraulic Mapping and Modeling
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Executive Summary

The Alaska Department of Transportation and Public Facilities wishes to make improvements at the Seward Airport, located on the Kenai Peninsula at the north end of Resurrection Bay. Most of the Seward Airport is located within the floodplain of the Resurrection River, on an alluvial fan at the river's mouth. The airport has flooded many times over the years, and the frequency and severity of flooding has been steadily increasing.

Though much of the Resurrection River floodplain downstream of the Seward Highway has remained unchanged, significant elevation changes have occurred at some locations. From 2009 to 2014, LiDAR data indicates that sediment deposition of between 1 to 2 feet has occurred on both banks. Several smaller areas, notably on the right bank, also show deposition of 3 to 4.5 feet. The rise in elevation is thought by some to be responsible for more frequent flooding of Runway 13/31. In addition, some areas show a decrease in elevation, as large as 3 feet.

This project has two primary purposes. The first is to develop engineering alternatives that will protect airport facilities from further damage caused by recurrent flooding, and the second is to correct airport deficiencies that may exist based on the airport's forecast function and FAA design standards. Based on existing conditions, data collection, public involvement, and input from airport stakeholders, three alternative design concepts were developed for the Seward Airport:

1) Alternative 1.1-Reconstruct Runway 13/31, upgrade erosion protection, retain Runway 16/34;
2) Alternative 2.2-Reconstruct Runway 16/34, abandon Runway 13/31 and install armor to prevent embankment erosion and channel migration;
3) Alternative 3.0-Reconstruct Runway 16/34, upgrade erosion protection, abandon Runway 13/31 and allow flooding to overtop and erode over time.

Four HEC-RAS hydraulic models were developed to analyze the water surface profile of flood events and determine the potential water surface elevation, scour depth and the range of hydraulic forces acting on the design alternatives. An Existing Ground (EG) model was developed by updating a 2010 FEMA HEC-RAS model with LiDAR topographic data and channel cross-section surveys acquired in 2014. The EG model was then modified with Civil3D surfaces to represent the runway geometries of the three design alternatives. The design flood for the hydraulic analyses was the 100-year (base) flood. Additionally, the analyses considered coastal flooding from Resurrection Bay.

Results from the hydraulic analyses included comparison graphs of the 100-yr surface profiles, floodplain maps, and estimates of channel velocities, water surface elevations, and increases in the base flood elevation from existing conditions. A summary of the results follows:

- Alt 1.1 - Water surface elevations across the floodplain east of the runway are substantially higher than those of the EG model; the maximum water surface elevation increase is 4.04 feet. Private parcels in the middle of the Resurrection River floodplain will be completely inundated during the 100-year flood. Some expansion of the eastern boundary of the floodplain will occur.

- Alt 2.2 - The maximum water surface elevation increase is 0.78 feet. Private parcels in the middle of the Resurrection River floodplain will be partially inundated, and a slight expansion of the eastern boundary of the 100-year floodplain will occur.

- Alt 3.0 - The maximum water surface elevation increase is 0.79 feet. Private parcels in the middle of the Resurrection River floodplain will be partially inundated, and a slight expansion of the eastern boundary of the 100-year floodplain will occur.

FEMA regulations prohibit encroachments, fill, new development, and other development within the adopted regulatory floodway unless the proposed encroachment would not result in any increase in the 100-year discharge. Of the three proposed design alternatives, only Alternative 1.1 involves development within an existing regulatory floodway. If selected as the engineering preferred alternative, this design would likely face substantial permitting obstacles and requires modification to the effective FIRM and Floodway Map.

Alternatives 2.2 and 3.0 do not require encroachment within the Regulatory Floodway, and will result in BFE increases of less than 1 foot. Impacts to private properties from the BFE increases are much smaller than with Alternative 1.1. However, either of these alternatives may still require a Conditional Letter of Map Revision (CLOMR).

Based on the hydraulic analysis, as well as applicable local and FEMA floodway and floodplain regulations, the engineering preferred design should be either Alternative 2.2 or 3.0. The recommended design water surface elevation for the Seward Airport Improvements project is the water surface elevation during the discharge with a 100-year return interval plus a two-foot freeboard.

Project Location and Description

The Alaska Department of Transportation and Public Facilities (ADOT&PF) wishes to make improvements at the Seward Airport (Figures 1 and 2). The Seward Airport is located on the Kenai Peninsula at the north end of Resurrection Bay, about 75 air miles, or 125 highway miles southwest of Anchorage. The State owns and operates the airport which includes a paved main runway (13/31), a paved crosswind runway (16/34), multiple taxiways and two aprons. Planned improvements may include runway/taxiway reconstruction, pavement rehabilitation, as well as installation of new airport lighting/electrical enclosure building, navigation aids, additional fencing and erosion control/armor protection.

Most of the Seward Airport is located within the floodplain of the Resurrection River, on an alluvial fan at the river's mouth. The airport has flooded many times over the years. The frequency and severity of flooding has been steadily increasing, as the delta is aggrading and thereby reducing the elevation difference between the riverbed and airport surfaces.

A major focus of this project will be to develop engineering alternatives that will protect the airport facilities from flooding damage. This report includes an analysis of the hydrologic characteristics of the Resurrection River, and a hydraulic analysis of the alternative designs for runway embankments and erosion protection.

Flooding History

As noted, there is a long history of flooding and erosion problems at the Seward Airport. Descriptions of flood events go back at least as far as 1951, when Runway 13/31 was constructed. Dozers uncovered subsurface springs, which flooded the new surface and led to the installation of subsurface drains. Heavy rainfall and seasonal high tides led to additional construction delays. Periodic flooding has occurred since then; however, the floods of 1986 and 1995 remain noteworthy for their magnitude and resultant damage to the runway embankments.

The 1995 flood shifted 90 percent of the Resurrection River's flow into a channel adjacent to Runway 13/31 (ADOT&PF, 2008). The aerial imagery in Figure 2, taken in 2014, includes an overlay of the channel's position in 1950. During the 13 years from 1995 to 2008, the runway was overtopped about 4 times. During the 4 years from 2009 to September 2013, the runway was overtopped 15 times. These instances were initially limited to the fall but are now occurring in the summer as well (June to November). The increased frequency indicates that lower flowrates, rather than only major floods, are now capable of flooding the runway.

Descriptions of the hydrology of the Resurrection River and the climate of Seward, Alaska are included in Barber (2006) and FEMA (2013). The Barber report (2006) provides an extensive description of the hydrology, climate, geomorphology, and a detailed description of the sequence and effects of some of the major flooding events, including the 1986 and 1995 floods.

A brief summary of flood events is found in Appendix A. Aerial images of the Seward Airport from 1950 to 2014, including the 1950 channel overlay, are found in Appendix B.

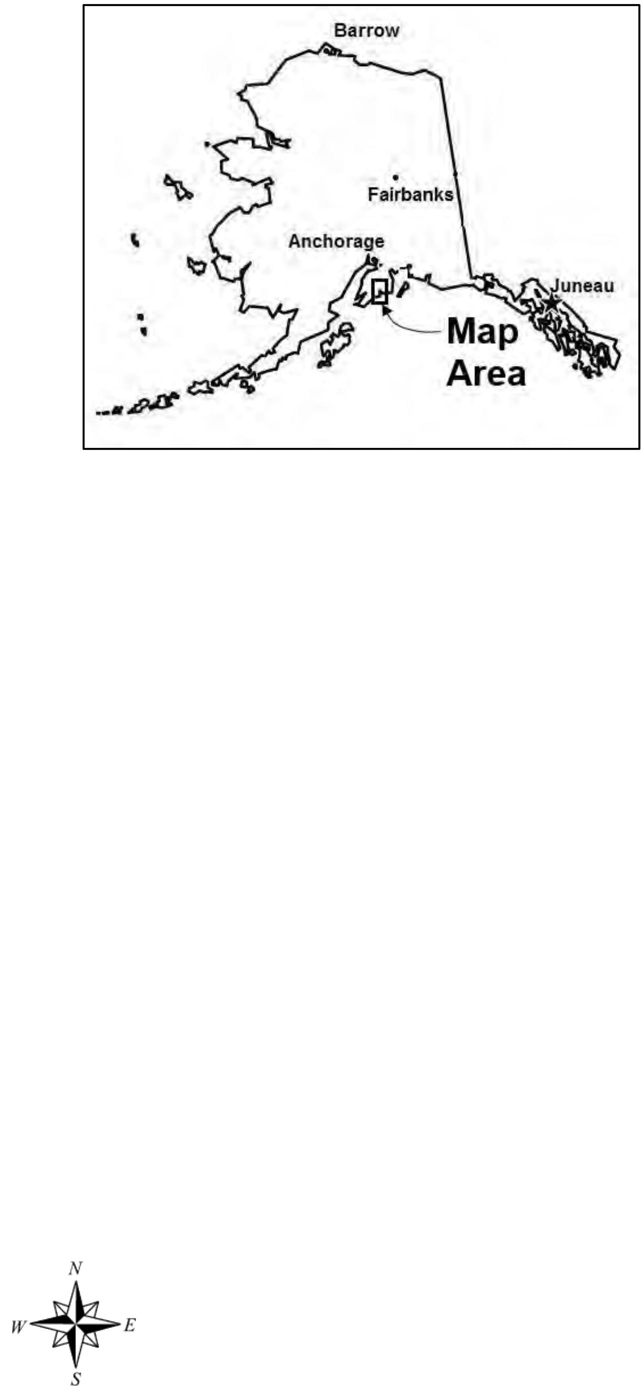


Figure 1. Project location map.

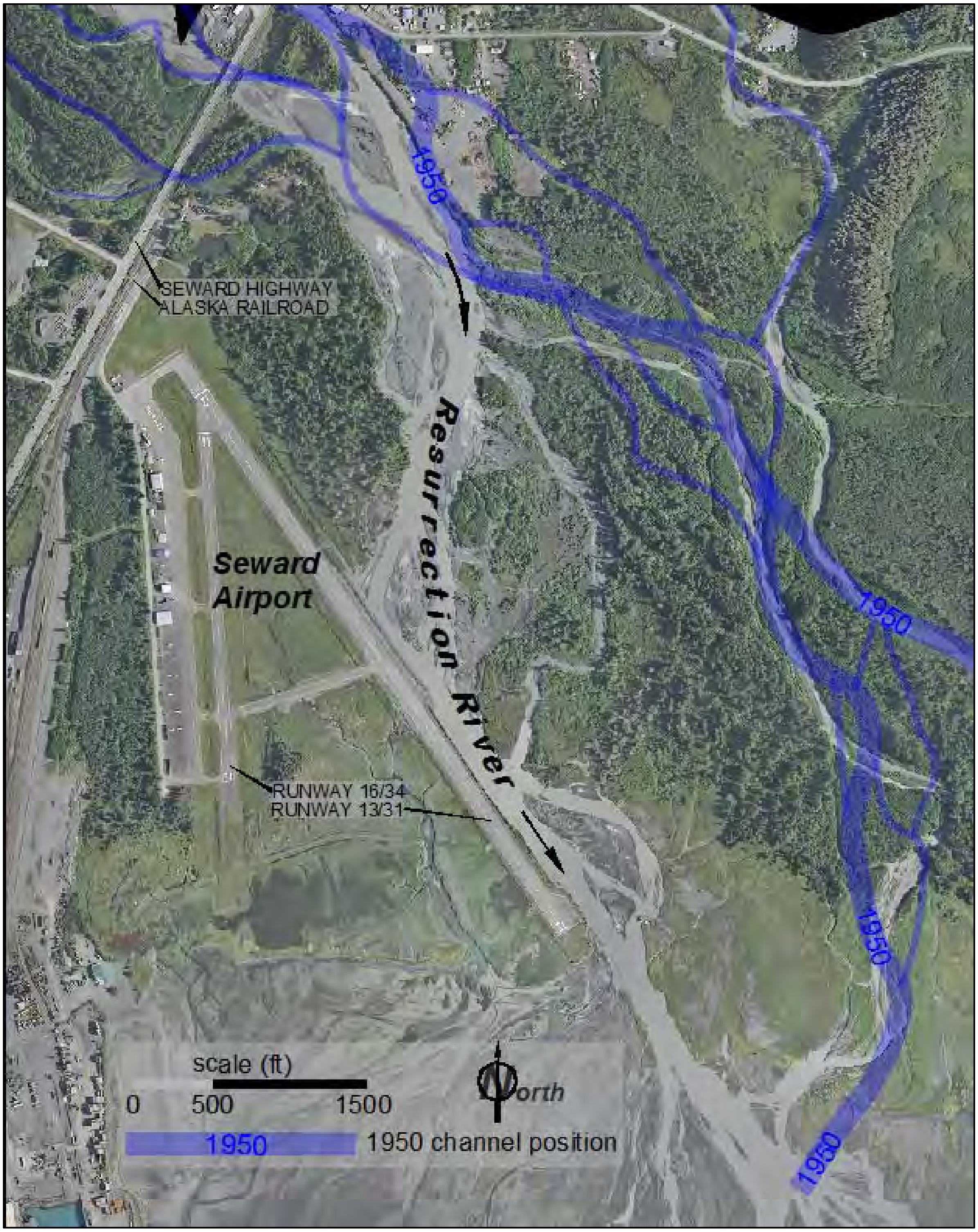


Figure 2. Project aerial imagery, August 2014. Historic channel position overlay from 1950 USGS imagery.

Hydraulic History

The U.S. Geological Survey (USGS) maintained a gaging station directly upstream from the Seward Highway crossing of the Resurrection River. Information from USGS Gage 15237700, which operated from October 1, 1964 to June 30, 1968, includes daily discharge data, daily, monthly and annual statistics, and 4 peak streamflows (USGS, 2015). A hydrograph of the gaging record is found in Figure 3.

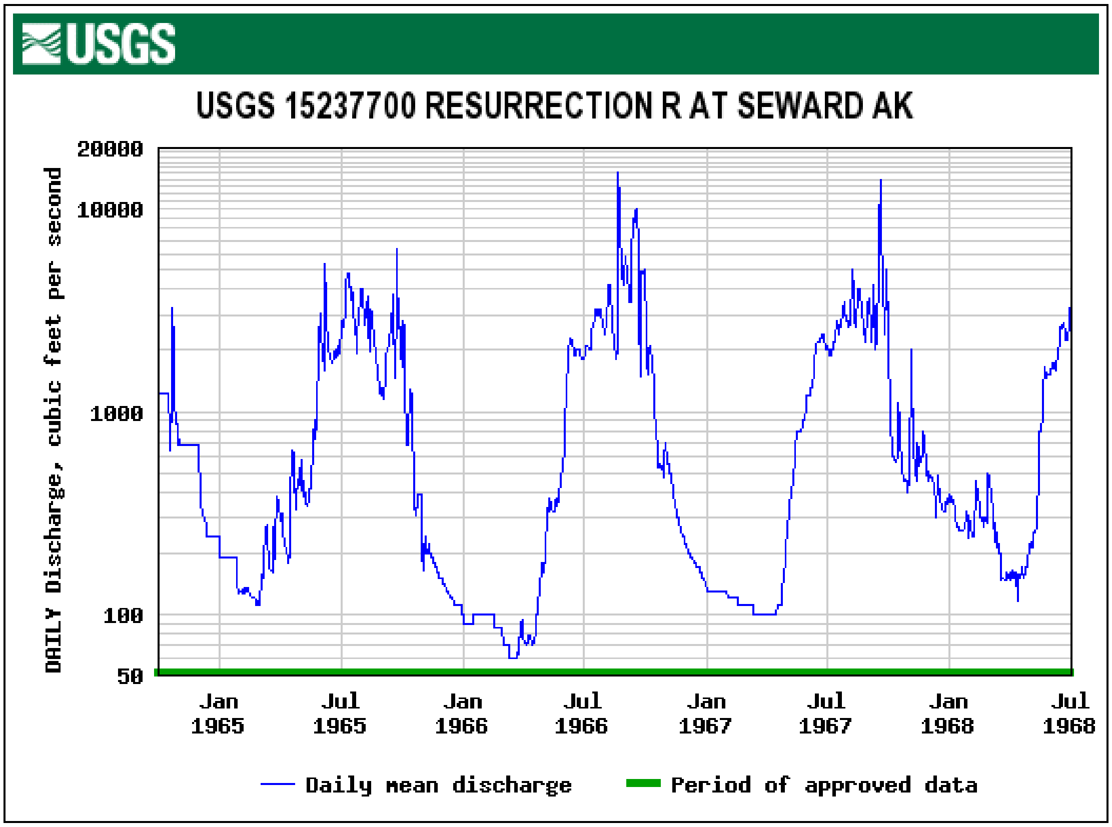


Figure 3. USGS gaging record for Resurrection River.

A hydrologic analysis was carried out in 2007 to establish peak discharge-frequency relationships for the Resurrection River. The analysis was conducted by Northwest Hydraulic Consultants, Inc. (NHC), which acted as a contractor to FEMA for the purposes of developing an updated Flood Insurance Study (FIS) for the Kenai Peninsula Borough (KPB). The analysis is described in a technical memo (NHC, 2007a). As no new stream gaging data has been collected in recent years, we utilized the existing FEMA flood frequency analysis.

NHC only provided flood magnitude estimations for the 10-year through 500-year floods. For this report, the 2-year and 5-year flood magnitudes were estimated using the techniques described in the NHC technical memo, and included in Table 1.

Table 1. Flood frequency estimations for Resurrection River (Total) to Seward Highway

Estimated Peak Flow (cfs)					
Q2	Q5	Q10	Q50	Q100	Q500
11663*	15943*	19230†	26190†	29160†	36570†

* estimated for this project using methods described in NHC (2007a).
† from NHC (2007a) for 2010 Kenai Peninsula Borough Flood Insurance Study

Long-term records indicate that on the average, the greatest monthly precipitation occurs in September and October. Discharge and flood records, such as Figure 3 and Appendix A also indicate that large floods generally occur in the later summer or autumn months. Coastal flooding is also an important climate characteristic of the Seward area, as high tides can increase the elevation and severity of Resurrection River flooding. Figure 4 illustrates seasonal variations in high tide levels, and indicates that extreme high tide levels are more likely to occur in the months from October through January.

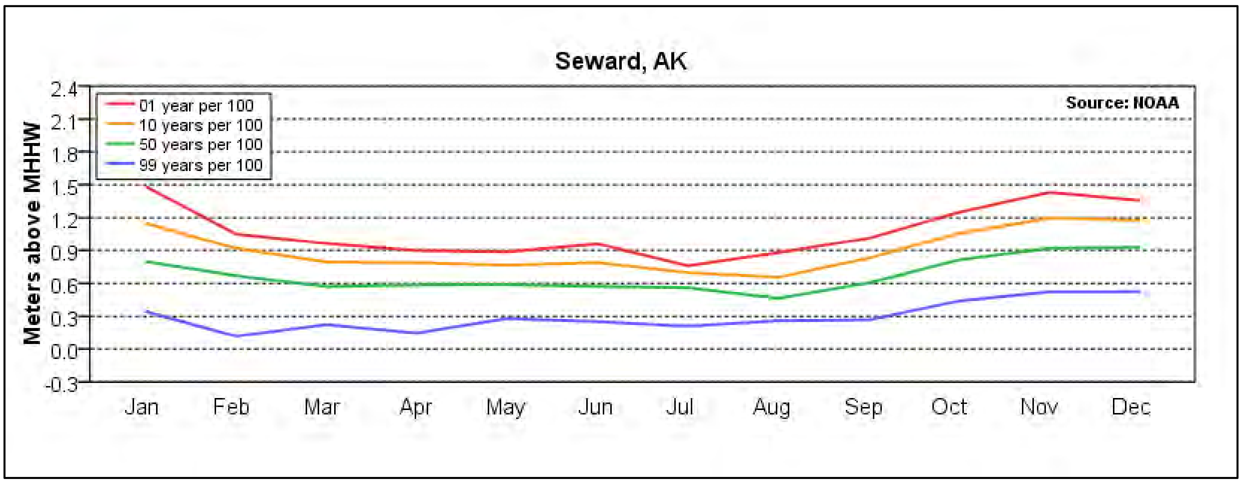


Figure 4. Seasonal variations of high tide exceedance probability levels at Seward. From NOAA (2015).

Floodplain Sediment Deposition

Some observers have noted that sections of the Resurrection River channel and floodplain have risen in elevation over time, especially in the area and downstream of where the main channel currently intersects Runway 13/31. Elevation rise has been attributed to large sediment transport rates in the Resurrection River during floods, and the subsequent deposition of that sediment within the channel and floodplain (Barber, 2006).

The potential rise in elevation is thought by some to be responsible for more frequent flooding of Runway 13/31. Potential backwater conditions in the lower reaches of the Resurrection River during high tide have also been suggested as a cause of gravel and sediment deposition (Task Force Report, 1998).

A study conducted by NHC in 2007 concluded that the bed elevation of the Resurrection River has remained fairly stable during the past 30 years. In a November 2007 memo prepared for

FEMA, NHC concluded that “Large depositional areas are not apparent along the Resurrection River in the area examined near the Seward Highway. Sediment probably has accumulated at various locations, but not in sufficient quantities to be revealed by the analysis completed here. It is likely that most sediment is transported through the reach and deposited on the delta in Resurrection Bay.” (NHC, 2007b).

The selection of a design elevation to protect against flooding is dependent on accurately forecasting the change in the flood water surface profile during the course of the project design life. Though some channels in braided river systems move horizontally and vertically with time, the primary Resurrection River channel has been adjacent to the runway for many years. However, the location where the river intersects the runway embankment has been moving upstream with time. As a result, the distance the river flows adjacent the runway has been increasing with time. Additionally, the angle that the Resurrection River main channel initially intersects runway 13/31 has been increasing; in 2013 it was roughly perpendicular. See the series of historic aerial images in Appendix B.

Due to these changes and the braided nature of the river, the probability of runway embankment erosion adjacent to the river has been increasing with time. In 2013, significant erosion on the runway 13/31 embankment occurred for the first time since erosion protection was installed in 1996. Also in 2013, significant groundwater flow was noticed under the runway embankment and at this location the embankment live load capacity was reduced (Paul Janke, personal communication). As such, a new analysis was conducted to determine if the annual rate of sediment deposition and elevation change to the longitudinal profile of the Resurrection River channel could be established.

The following data sets were assessed for use in this analysis:

Table 2. Resurrection River topographic data sets.

Year	Data Available	Data Acquired For	Data Acquired From	Vertical Datum	Vertical Accuracy
1977	cross-sections	1981 FEMA FIRM	FEMA	NGVD 29	Unknown
2006	LiDAR	FIRM update, unfinished	Kenai Watershed Forum	NAVD 88	2-4 ft contour
2009	LiDAR	2012 FEMA FIRM update 2014 FIRM draft	Kenai Peninsula Borough	NAVD 88	2 ft contour
2014	LiDAR, surveyed channel cross-sections	ADOT Seward Improvement Project	PDC, Inc.	NAVD 88	0.268 ft*

*LiDAR Fundamental Vertical Accuracy at the 95% confidence interval. See Quantum Spatial, 2014.

To estimate the rise of the lower Resurrection River channel bed over time in the vicinity of the Seward Airport, several methods were considered, including an analysis of the channel thalweg data over time and a comparison of floodplain elevation data over time. However, problems with incompatible data sets prevented several proposed comparison methods.

For example, extensive and detailed surveys of the wetted channels along the cross-section lines, including the channel thalweg, were obtained in 2014 and used to supplement the 2014 LiDAR. Comparisons to historic thalweg elevations would have provided important information regarding channel stability. Both a technical memo from NHC and the 2013 FEMA Flood Insurance Study (FIS) indicates that cross-sections used in the 2010 FEMA HEC-RAS model "were cut from 2 ft contours provided by the KPB, and augmented with in-stream survey and bridge soundings completed during the period of October-December 2007 (NHC, 2008)." However, we compared the FEMA HEC-RAS cross-sections to sections cut directly from the 2009 LiDAR data and found them identical, even through the main channels. This indicates that the wetted channels were not surveyed, and that the main channel and thalweg elevations shown in the FEMA HEC-RAS cross-sections were in fact water surface elevations measured by LiDAR, which cannot penetrate water. The HEC-RAS cross-section locations are found in Appendix C, and the 2009 and 2014 cross-sections are plotted and found in Appendix D.

Though cross-sections were originally scheduled to be surveyed to supplement the 2006 LiDAR, high water conditions prevented in-water cross-section surveys below the Seward Highway bridges (personal communication, Nick Cline, Cline & Associates, Seward). We were also unable to obtain detailed descriptions of how the 1977 cross-sections were obtained. Therefore, direct comparisons of the 2014 cross-section thalweg to the historic data sets were not possible.

LiDAR data sets of the lower Resurrection River are available for 3 years: 2006, 2009, and 2014. Volumetric changes between the topographic surfaces would provide important information regarding sediment deposition. However, the vertical accuracy of the 2006 LiDAR dataset was substantially less than the accuracy of the 2009 and 2014 LiDAR. Therefore, the sediment deposition analysis consisted of an examination of floodplain elevation changes from 2009 to 2014.

Using a GIS, elevation values from the 2014 and 2009 LiDAR datasets were compared and used to create a gridded elevation layer that calculates and illustrates the elevation difference between the two layers. As LiDAR cannot penetrate water surfaces, estimated elevation changes for a given area may be meaningless if water covered that area during the acquisition of either LiDAR dataset. Therefore, the wetted channel locations of both LiDAR datasets were blacked out of the gridded elevation difference map. See Figure 5.

Results show that though much of the Resurrection River floodplain downstream of the Seward Highway has remained unchanged, significant elevation changes have occurred at some locations. Upstream of the runway/main channel intersection, some deposition between 1 to 2 feet has occurred on both banks. Several smaller areas, notably on the right bank, also show deposition of 3 to 4.5 feet. In addition, some areas show a decrease in elevation from 2009 to 2014, as large as 3 feet.

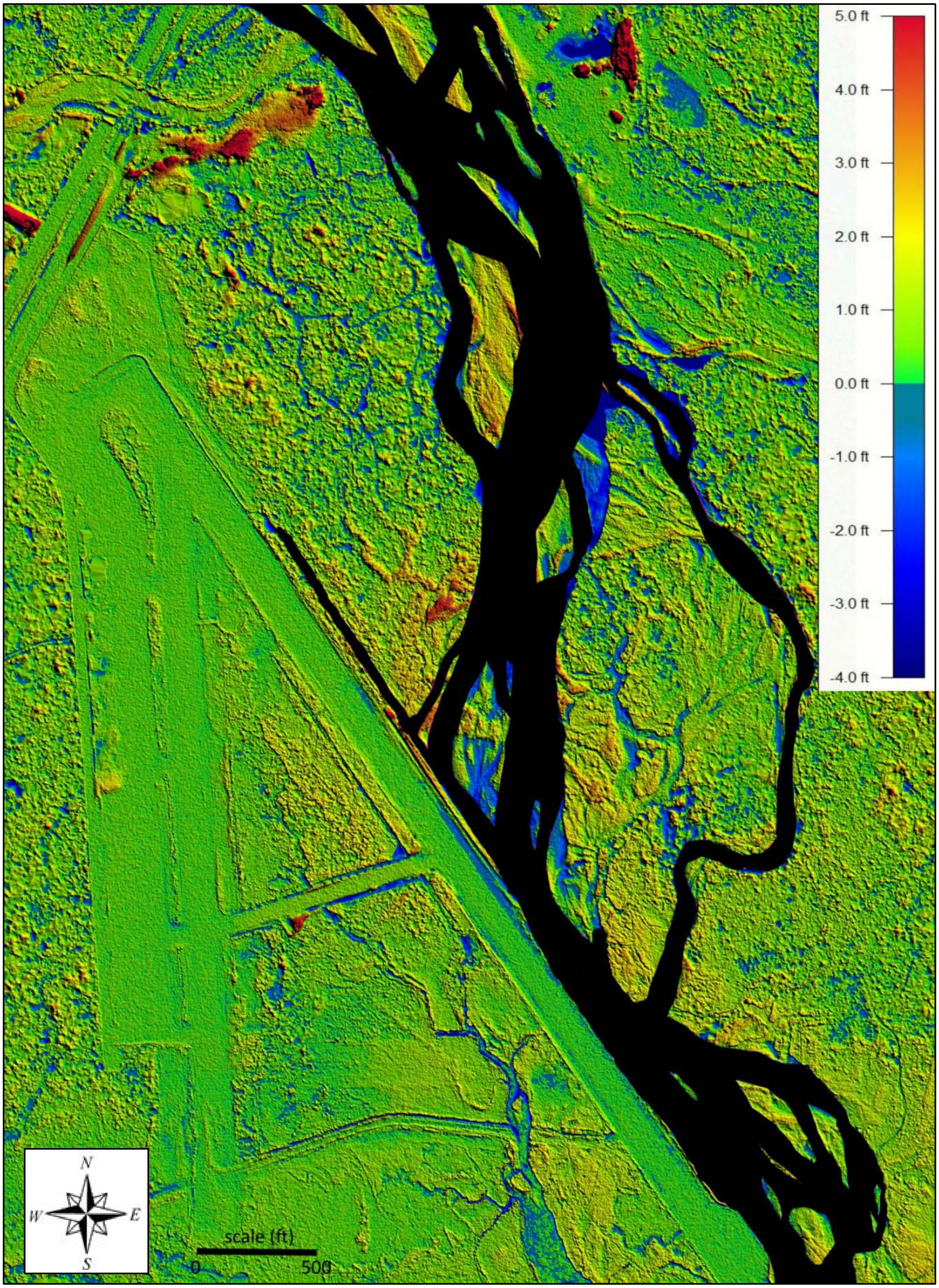


Figure 5. Elevation change from 2009 to 2014.

Between Runways 13/31 and 16/34, an elevation increase of 1 to 2 feet is observable upstream of the cross-taxiway. Sediment deposition in this area may have occurred following overtopping of Runway 13/31 by sediment-laden floodwater.

It is important to note that when considering floodplain elevation changes over time, conditions immediately prior to the acquisition of the elevation data (in this case, LiDAR) may have varied significantly from 2009 to 2014. For example, the passage of a large flood will likely result in significant sediment deposition; however, the area of deposition on the floodplain may vary depending on if a high tide occurred coincident to the flood event. Though the elevation datasets are named ‘2009’ and ‘2014,’ it is important for the reader to remember that the datasets are snapshots in time, and direct elevation comparisons for different years should be considered as approximate.

During the project team field trip to the Seward Airport on July 10, 2014, we observed the large pile of gravel sitting in the middle of the Resurrection River approximately 1600 ft upstream from the 13/31 runway. This material is part of a 350,000 yd^3 excavation that occurred following the 1995 flood as an effort to re-direct the river back to its pre-1995 channel. It is unknown if the excavated 350,000 yd^3 was placed in one pile or several.

The pile is actively eroding as the main channel is scouring the toe, and a steep face of freshly exposed gravel was clearly visible. See Figure 6. D. Mahalak (KPB) noted the possibility that material eroding from the large pile is likely being carried downstream, and may possibly be deposited near the runway embankment (personal communication, July 10, 2014).

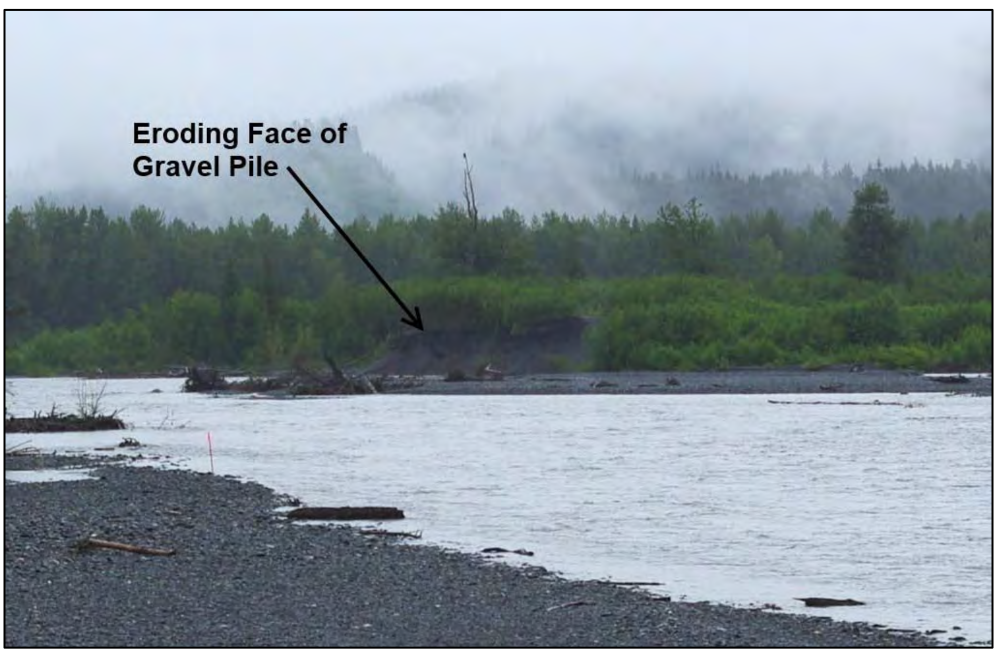


Figure 6. Photograph of eroding gravel pile on Resurrection River floodplain upstream of runway, taken July 10, 2014.

The gravel pile is located approximately 2400 ft downstream from the Seward Highway Bridge, and approximately 1600 ft upstream of the Seward Airport runway. The pile is approximately 20 feet higher than the adjacent floodplain. See Figure 7.

Changes to the pile may also be seen on Cross-section K, shown in Appendix D, which is aligned through the upper area of the pile. In 2007, the pile is distinct, with a top elevation of almost 35 feet. By 2014, the pile is no longer visible along Cross-section K.

To assess how erosion is affecting the gravel pile, AutoCad Civil3d was used to estimate the volume and footprint area of the pile for the three years that LiDAR data was obtained: 2006, 2009, and 2014. Results indicate that the gravel pile volume has decreased in size from 2006 to 2014 by 80 percent. LiDAR imagery illustrating the ongoing erosion at the gravel pile is found in Figure 8.

Table 3. Changes to gravel stockpile.

	Stockpile Volume Remaining On Floodplain (yd^3)	**Stockpile Footprint (acres)**
2006	41,593	2.41
2009	35,083	1.78
2014	8,345	0.43

Figure 7. Location of eroding gravel pile.

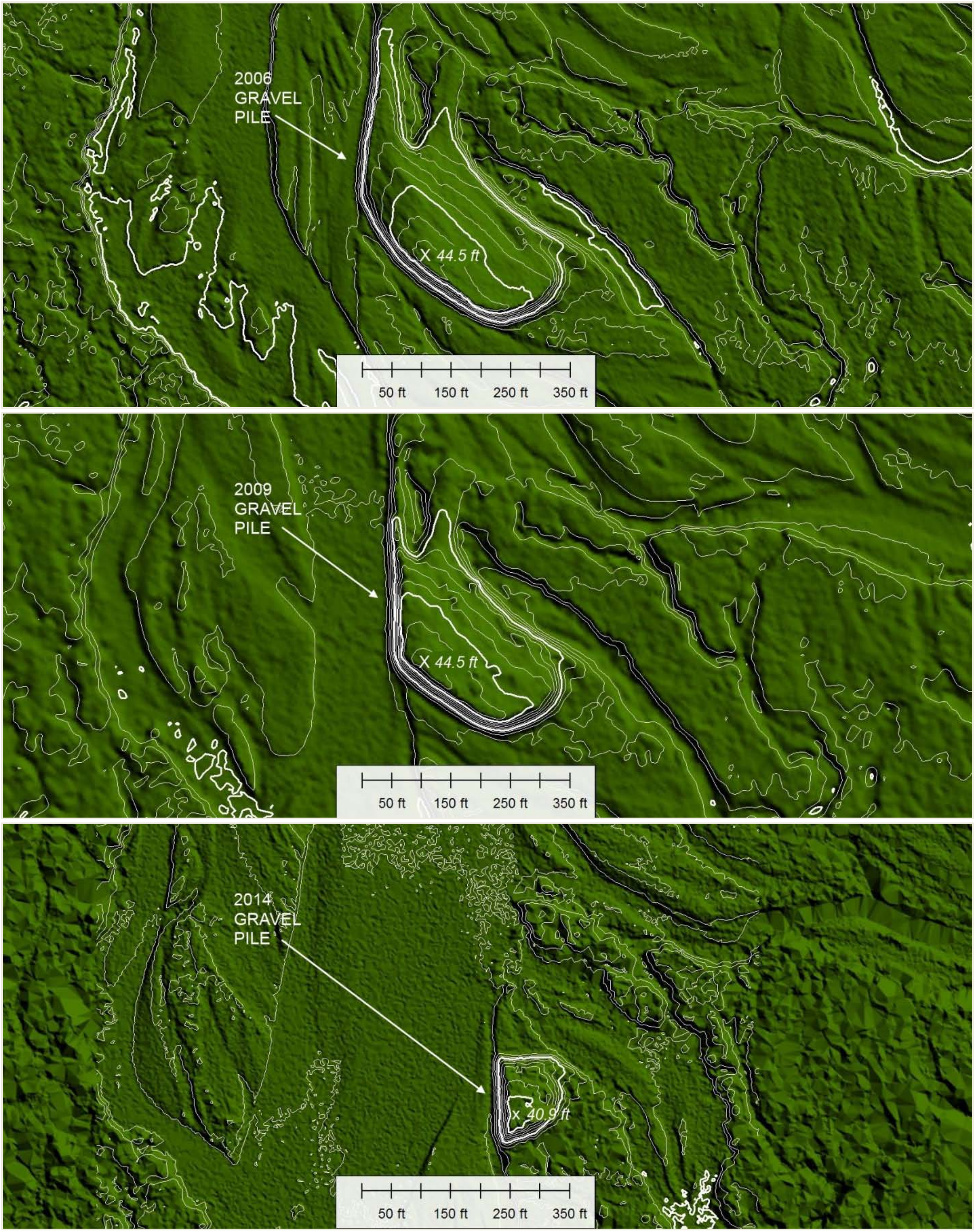


Figure 8. Changes to gravel stockpile over time. Top 2006, middle 2009, bottom 2014.

Hydraulic Modeling

A hydraulic model was used to analyze the water surface profile of flood events and determine the potential water surface elevation, scour depth and the range of hydraulic forces acting on three design alternatives developed for this project. The HEC-RAS software package was used for this analysis. Cross-sections used in the model are shown in Appendices C and D.

The HEC-RAS program is one-dimensional, meaning that there is no direct modeling of the hydraulic effect of cross section shape changes, bends, and other two- and three-dimensional aspects of flow. However, the system can handle a full network of channels, a dendritic system, or a single river reach, and the steady flow component is capable of modeling subcritical, supercritical, and mixed flow regimes water surface profiles.

The HEC-RAS analysis was conducted by performing the following tasks:

- The HEC-RAS model developed by NHC for the 2010/2013 FIS was obtained for the new analysis and modified for use in the following manner:
- Cross-sections are numbered in order from downstream to upstream, starting at River Station 144 (Cross-section A) near the Resurrection Bay coastline upstream to River Station 16456.78 (Cross-section AE)
- Fifteen cross-sections in the project area, from River Station 144 (Cross-section A) to River Station 7482 (Cross-section O) just downstream of the Seward Highway Bridges were updated with new topographic information from LiDAR acquired in 2014.
- Cross-sections from River Station 7689.403 (at the Seward Highway bridges) upstream to River Station 16456.78 were unchanged, and left in the model.
- All cross-section alignments, including the updated 15 cross-sections, matched those used for the 2010 FIS HEC-RAS analysis.
- All 15 of the updated cross-sections traverse the mapped 1% chance (100-year) floodplain; of the updated sections, only cross-sections from River Station 3589 (G) through River Station 7482 (O) traverse the mapped Regulatory Floodway.[1]
- As LiDAR imagery does not include channel information below the water surface, the wetted channel perimeters along the updated cross-sections were surveyed in 2014 by a PDC survey team using standard methods. The channel surveys were ‘cut’ into the LiDAR cross-sections to improve the topographic accuracy and provide actual channel shape and thalweg data.
- New dikes constructed upstream of the Seward Highway between 2009 and 2014 were surveyed by the PDC survey team and used to update the model.
- In addition to an Existing Ground (EG) model, design models included Alt 1.1, 2.2, and 3.0. The model runway geometries were based on Civil3D surfaces provided by PDC. See Table 4.
- Manning’s n roughness values were selected based on recent project imagery and site visits, published values for similar conditions, and engineering judgment (Chow, 1959

[1] The “Regulatory Floodway” means the channel of a river or other watercourse and the adjacent land areas that must be reserved in order to discharge the base flood without cumulatively increasing the water surface elevation more than a designated height.

and others). See Table 5.

- The design discharge is the 100-year flood. Model runs included the 2-, 5-, 10-, 50-, 100- and 500-year floods. Additional modeling was conducted to determining the low-flow runway overtopping condition.
- Model results also incorporated coastal flooding effects from the 1-percent-annual chance tide event, which govern up to Cross-section E on the Resurrection River.
- Design models included a modeled 'levee' to prevent flood water from flowing westward between the Seward Highway/Alaska Railroad tracks and the upper end of the runway embankments.

Table 4. HEC-RAS models.

Model	Features
Existing Ground (EG)	Existing runway/taxiway embankments as of July 2014.
Low Flow Runway Overtopping	Existing runway/taxiway embankments as of July 2014. Flow restricted to main channel to determine what flow level initiates Runway 13/31 overtopping.
Alternative 1.1	Reconstruct Runway 13/31 (4533 x 75 ft) with 2-ft freeboard above Q100. Install armor to protect runway 13/31. Adjust Runway 16/34 profile to match into raised Runway 13/31. Reconstruct Taxiway B & C to match into runway modifications. Eliminate Taxiways A, D & E.
Alternative 2.2	Reconstruct Runway 16/34 (3300 x 75 ft) with 2-ft freeboard above Q100. Abandon Runway 13/31 and install armor to prevent embankment erosion and channel migration. Relocate Taxiway B to match into runway modifications. Reconstruct Taxiway F to match into runway modifications. Eliminate Taxiways A, C, D, & E.
Alternative 3.0	Reconstruct Runway 16/34 (4000 x 75 ft) with 2-ft freeboard above Q100. Install armor to protect Runway 16/34. Abandon Runway 13/31 and allow flooding to overtop runway. Relocate Taxiway B & F to match into runway modifications. Eliminate Taxiways A, C, D & E.

Note that in Alternative 3.0, Runway 13/31 will be abandoned and is expected to erode over time. The Alt 3.0 HEC-RAS model geometry included the full Runway 13/31 embankment, and did not consider the effects of embankment erosion. Such embankment erosion would likely lead to lower water surface elevations over time than what is shown in the following modeling results.

Table 5. Manning's n values used in HEC-RAS models.

Manning's n Values					
channel	floodplain			pavement gravel roads	riprap
	tall grass	short shrub	tall shrub, trees		
0.035	0.08	0.10	0.15	0.015	0.06

Low Flow Runway Overtopping

One of the initial concept alternatives was Alt 1.2. Compared to Alt 1.1, this alternative would reconstruct runway 13/31 but would not raise the runway elevation. This solution would reduce potential impacts within the Regulatory Floodway but would mean the runway would be flooded on a frequent basis.

As discussed, observers have noted that Runway 13/31 has been frequently overtopped in recent years, and the rate of overtopping appears to be increasing. In 2013, the runway was overtopped an estimated 10 times (Paul Janke, personal communication). The increased frequency indicates that lower flowrates, rather than only major floods, are now capable of flooding the runway. To help evaluate the feasibility of Alt 1.2, it was necessary to estimate the amount of time the runway may be overtopped in any given year. To determine overtopping frequency, the following analysis was conducted.

The 2014 EG HEC-RAS model was utilized to determine the rate of flow required to initiate overtopping of Runway 13/31. Within the model, the flow was generally restricted to the main channel; however, based on field observations at the time of low-flow runway flooding, some flow was permitted in the smaller side channels that flow to the east of the main Resurrection River channel (Paul Janke, personal communication). A temporary levee constructed in the fall of 2013 along the lower runway embankment was not included in the model.

Based on the HEC-RAS modeling, runway overtopping begins in the vicinity of Cross-section I (River Station 4460) and extends to Cross-section H (River Station 3950) as the water rises. An existing levee and high ground adjacent to the runway protect it upstream of Cross-section I from flooding at low flows.

Because of the lack of precision in a one-dimensional hydraulic model, a range of overtopping flows was bracketed rather than selecting a single discharge. Based on the HEC-RAS modeling, initial overtopping begins at Cross-section I at a discharge of 3500-4500 cfs. At 6500 cfs, overtopping is also noted at Cross-section H. See Figure 9.

The second part of the analysis involved the use of existing daily discharge data to estimate the percentage of time that the overtopping flows occur in a year. A flow duration curve displays the relationship between streamflow and the percentage of time it is exceeded. Flow duration curves are derived using all data, rather than just high or low flows.

The U.S. Geological Survey (USGS) maintained a gaging station (15237700) directly upstream from the Seward Highway crossing of the Resurrection River. Daily discharge data from October 1, 1964 to June 30, 1968 were used to construct the flow duration curve. Each discharge in the period of record was ranked based on the total number of days in the record. For each ranking, the exceedance probability, or percent of time that each discharge is equaled or exceeded was calculated. See Figure 10.

A streamflow of 3500 cfs will be equaled or exceeded 5.62% in a given year, which is 20.5 days. A streamflow of 4500 cfs will be equaled or exceeded 3.21% in a given year, which is 11.7 days. Based on the available daily discharge record and the HEC-RAS model, the analysis indicates that Runway 13/31 will be overtopped between 12 and 21 days a year.

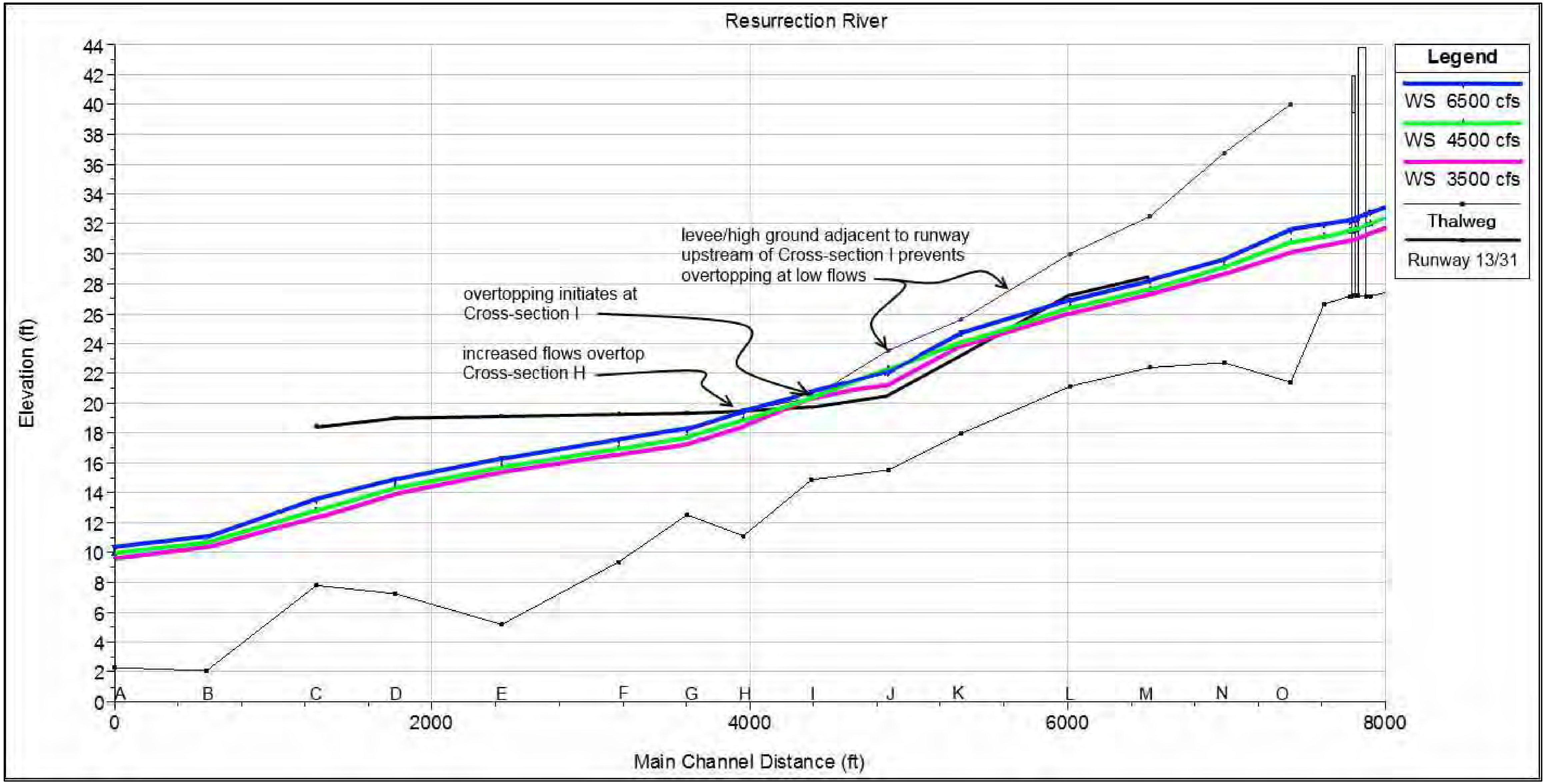


Figure 9. HEC-RAS results for runway overtopping.

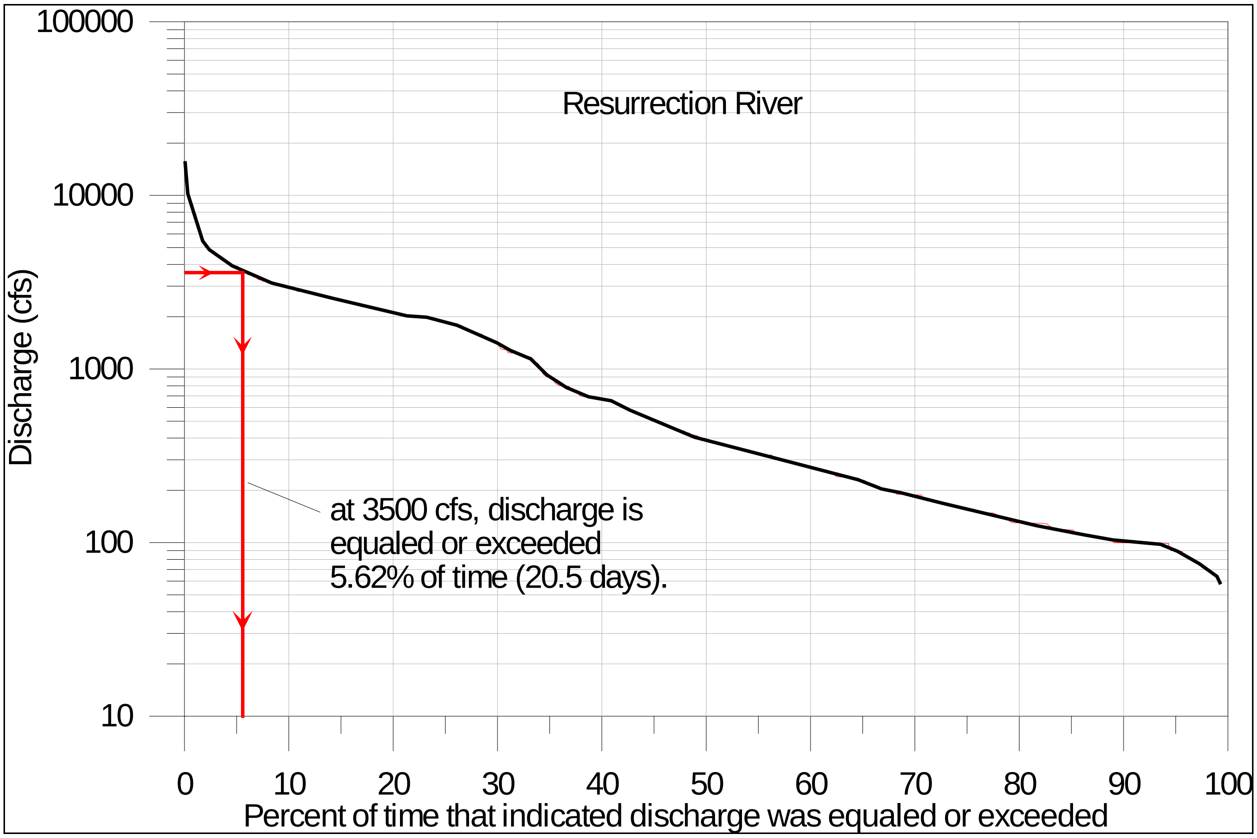


Figure 10. Flow duration curve for the Resurrection River.

Variations in weather patterns will affect the overtopping frequency at Runway 13/31. The long-term (1908-2014) Seward precipitation record shows that the 1964-1968 time period covered by the daily discharge data used to construct the flow duration curve experienced low to average precipitation. See Appendix E for the long-term Seward precipitation record. Had the daily discharge data used for the flow duration curve been obtained during a period of average precipitation, overall river discharge would have likely been greater.

In addition, future years with higher than normal precipitation will experience even more runway overtopping. For example, the months of May, July, August and October 2013 had significantly more precipitation than the long-term monthly averages, twice as much or more. The runway was overtopped an estimated 10 times in 2013. As the analysis is based on stream flow data collected during a time period of lower-than-average precipitation, the model likely underestimates the number of overtopping events.

Other climatic and hydrologic factors, such as warmer than average summer temperatures, rising floodplain elevations, and debris dam breach floods will also likely increase the frequency of overtopping events.

Based on this and other analyses, this option allowing runway overtopping was not carried forward for further, more detailed review because it was considered to be impractical; the runway would be unreliable and the costs for construction were estimated to be as much as 50% higher. M&O costs would be substantially higher than Alt 1.1 to account for frequent clearing of the debris after each overtopping event plus likely additional costs in pavement and airport lighting repairs.

Hydraulic Analyses Results for Design Alternatives

HEC-RAS results for the Existing Conditions and Alternatives 1.1, 2.2 and 3.0 are found in Table 6. For each cross-section, results include: average channel velocity, the water surface elevation, freeboard (based on preliminary design elevations for each alternative), and the increase of the water surface elevation from the EG model. Flood height increases of more than 1 foot are highlighted in bold red text.

Note that minimum federal standards limit flood height increases to 1 foot, provided that hazardous velocities are not produced. Additionally, the KPB has developed a floodplain ordinance that regulates construction and improvements in flood hazard areas. The Borough Floodplain Development Ordinance (KPB, 1986) prohibits any increase in flood levels during the base flood that result from fill, construction and other development within the regulatory floodway.[2] This no-net-rise policy applies to areas both upstream and downstream of any floodway encroachment. Note that of the three proposed design alternatives described in this report, only Alternative 1.1 involves development within an existing regulatory floodway.

The results in Table 6 include the results from coastal flooding from Resurrection Bay. The 100-year coastal flooding elevation of 16.2 feet at the Resurrection Bay in Seward is taken from the 2013 FIS (FEMA, 2013).

Additional HEC-RAS result tables, including the 500-year flood elevations, and comparisons of the elevations with and without coastal flooding, are found in Appendix F.

Comparison graphs of the 100-yr water surface profiles for the Alt 1.1, Alt 2.2 and Alt 3.0 models to the EG profile are found in Figures 11, 12, and 13.

For the four HEC-RAS models (existing conditions plus the three alternatives), floodplain maps for the 100-year flood were developed using the RAS Mapper floodplain mapping tool, and are found in Figures 14, 15, 16, and 17. The four figures include the 100-year floodplain boundaries from the EG HEC-RAS model; the 100-year floodplain coverage for Alt 1.1, 2.2, and 3.0; private parcel locations on the floodplain; cross-section lines; the locations of the two regulatory floodways (Resurrection River and Salmon Creek) from the 2013 FIRM; and the boundaries of the 1% annual chance (100-year) floodplain from the 2013 FIRM.

The full output results for the four HEC-RAS models are found in Appendix I.

[2] The “base flood” is the flood having a one percent chance of being equaled or exceeded in any given year. This is the regulatory standard also referred to as the "100-year flood" or the “1% annual chance flood.”

Table 6. Preliminary results for HEC-RAS modeling, including Existing Ground (EG) and Alternatives 1.1, 2.2, and 3.0. Results are based on the 100-year flood, and include the effects of coastal flooding (100-yr) from Resurrection Bay.

	EG				ALT 1.1					ALT 2.2					ALT 3.0				
Cross-Section &River Sta	R/W 13/31 Elev (ft)	R/W 16/34 Elev (ft)	Vel Chnl (ft/s)	W.S. Elev (ft)	R/W 13/31 Elev (ft)	Vel Chnl (ft/s)	W.S. Elev (ft)	Free-board (ft)	Elev Increase From EG (ft)	R/W 16/34 Elev (ft)	Vel Chnl (ft/s)	W.S. Elev (ft)	Free-board (ft)	Elev Increase From EG (ft)	R/W 16/34 Elev (ft)	Vel Chnl (ft/s)	W.S. Elev (ft)	Free-board (ft)	Elev Increase From EG (ft)
A 144	-	-	3.49	16.20	-	3.49	16.20	-	0.0	-	3.49	16.20	-	0	-	3.49	16.20	-	0.0
B 698	-	-	6.52	16.20	-	6.52	16.20	-	0.0	-	6.52	16.20	-	0	-	6.52	16.20	-	0.0
C 1336	18.47	-	1.00	16.20	19.08	9.43	16.20	2.88	0.0	-	1.00	16.20	-	0	18.91	1.59	16.20	2.71	0.0
D 1791	18.99	-	2.67	16.20	20.40	5.53	17.58	2.82	1.38	18.96	3.96	16.20	2.76	0	19.00	3.44	16.20	2.80	0.0
E 2432	19.15	-	3.41	16.20	22.00	6.68	19.10	2.90	2.9	19.70	4.12	16.20	3.50	0	19.58	4.09	16.20	3.38	0.0
F 3094	19.26	16.60	5.29	17.12	23.77	3.26	21.16	2.61	4.04	20.66	3.66	17.90	2.76	0.78	20.74	3.65	17.91	2.83	0.79
G 3589	19.31	20.33	6.32	19.15	24.54	4.70	22.02	2.52	2.87	22.10	5.30	19.59	2.51	0.44	22.17	5.28	19.58	2.59	0.43
H 3950	19.47	20.68	4.95	20.98	25.38	5.06	22.74	2.64	1.76	23.68	5.07	21.16	2.52	0.18	23.68	4.90	21.11	2.57	0.13
I 4460	19.59	21.27	4.70	22.24	26.38	5.64	23.63	2.75	1.39	25.12	5.16	22.52	2.60	0.28	25.15	5.09	22.45	2.70	0.21
J 4994	20.58	23.04	5.53	24.00	27.57	6.18	25.02	2.55	1.02	26.86	5.65	24.25	2.61	0.25	26.83	5.72	24.21	2.62	0.21
K 5408	23.27	24.66	5.10	25.77	29.27	5.37	26.56	2.71	0.79	28.71	5.24	25.94	2.77	0.17	28.62	5.38	25.97	2.65	0.20
L 6068	27.05	27.05	6.35	28.31	31.47	6.70	28.71	2.76	0.40	31.19	7.16	28.56	2.63	0.25	31.15	7.03	28.6	2.55	0.29
M 6545	-	-	7.62	30.21	33.00	7.18	30.51	2.49	0.30	-	6.96	30.55	-	0.34	-	7.00	30.54	-	0.33
N 7067	-	-	9.21	32.52	33.86	9.28	32.49	1.37	-0.03	-	9.49	32.42	-	-0.10	-	9.47	32.43	-	-0.09
O 7482	-	-	3.65	35.58	-	3.64	35.59	-	0.01	-	3.62	35.62	-	0.04	-	3.62	35.62	-	0.04

* note: yellow shading indicates that the cross-section traverses the Resurrection River Regulatory Floodway.

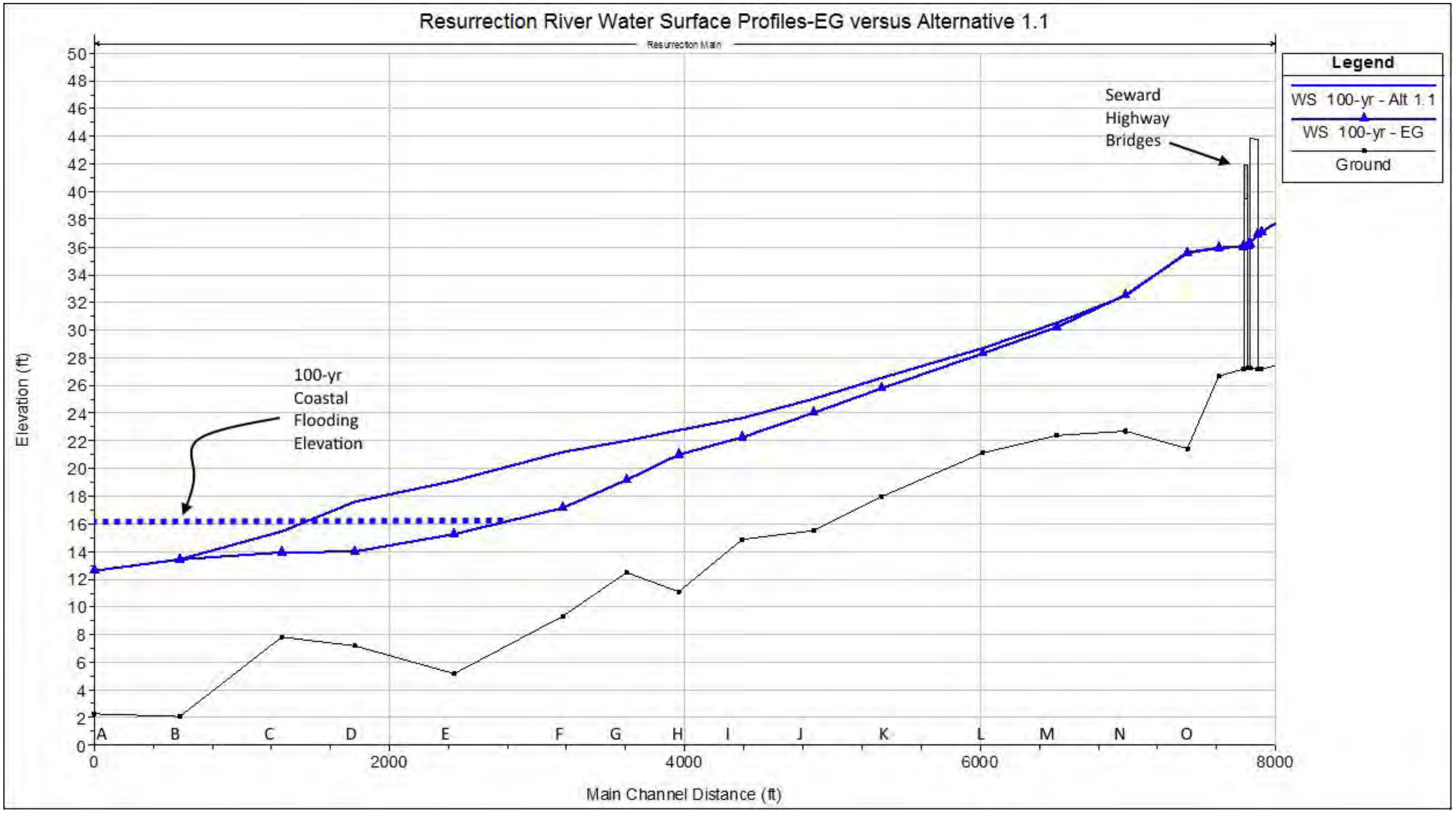


Figure 11. 100-yr water surface profile for EG and Alt 1.1.

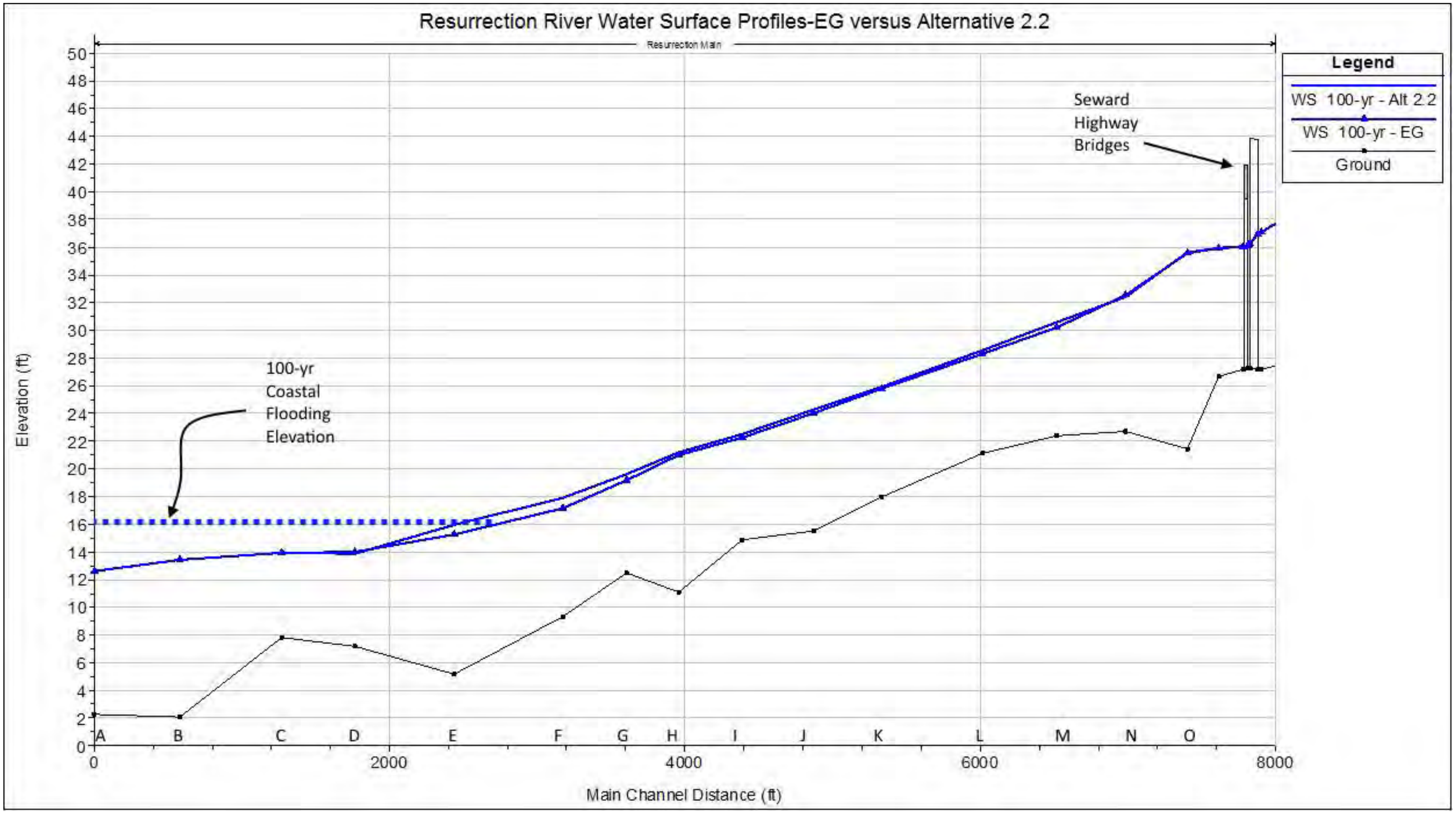


Figure 12. 100-yr water surface profile for EG and Alt 2.2.

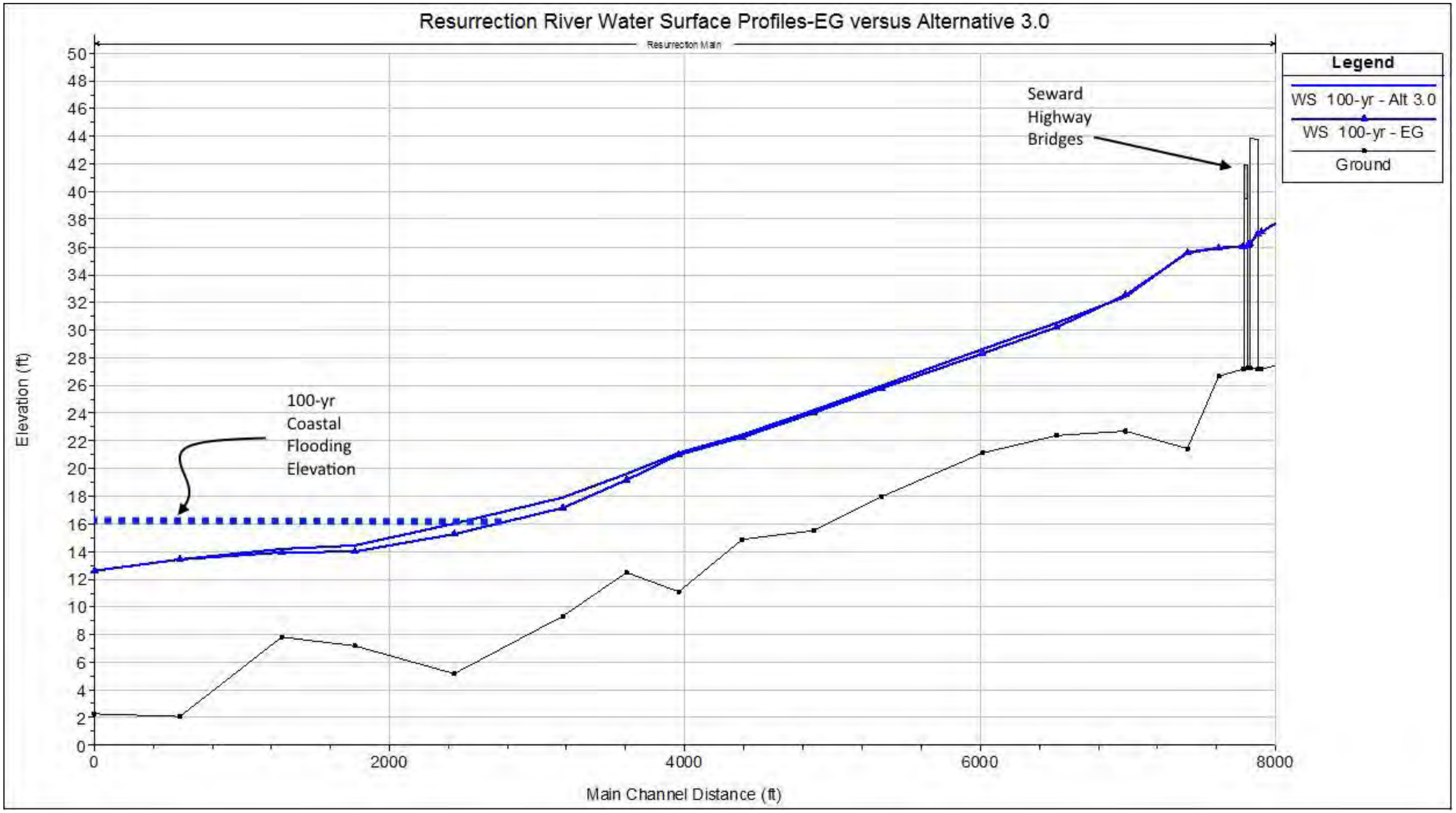


Figure 13. 100-yr water surface profile for EG and Alt 3.0.

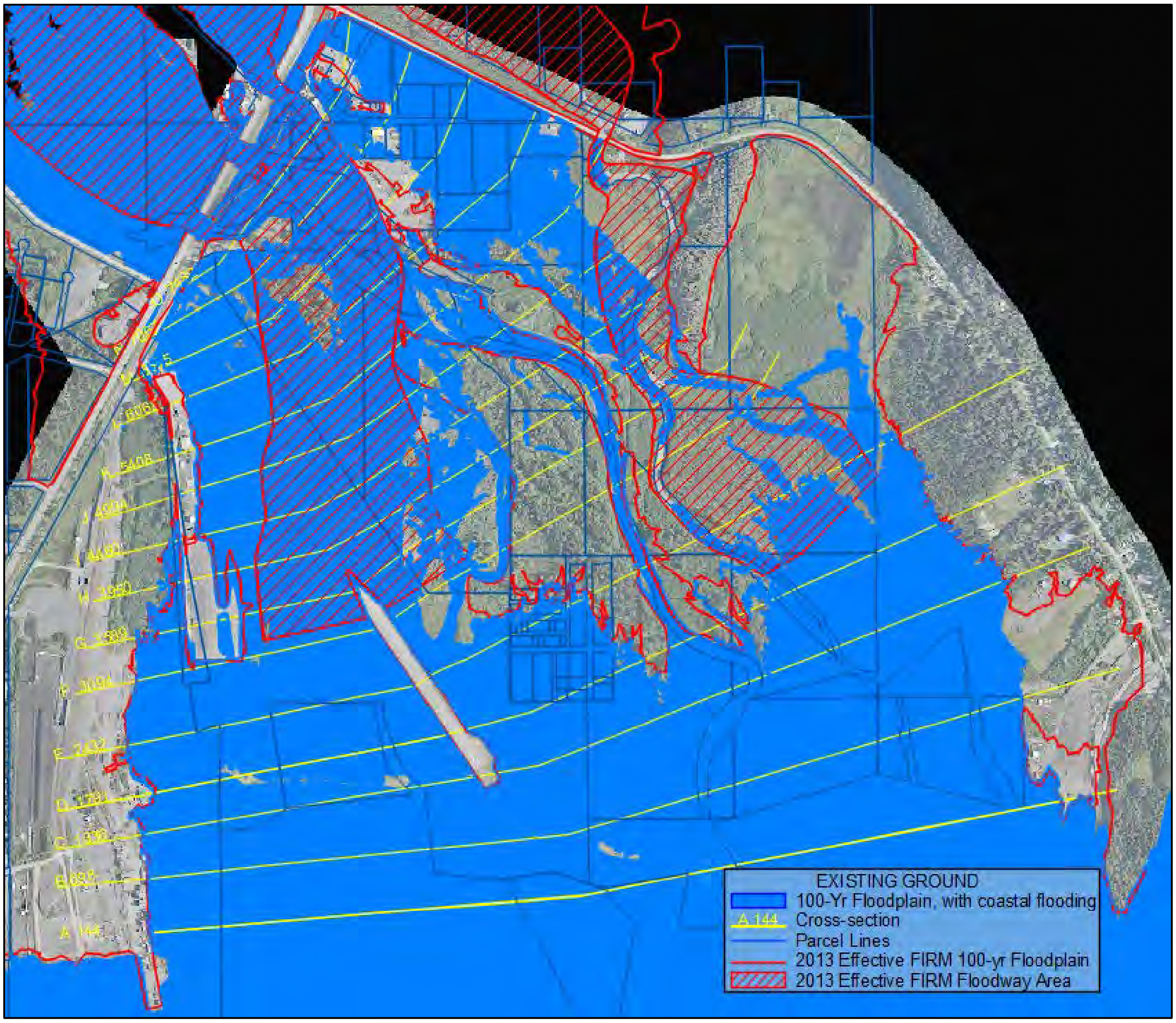


Figure 14. 100-year flood map for Existing Ground.

EG-Figure 14 shows that the 100-year flood will inundate most of the Seward Airport, including the upper half of Runway 13/31 and most of Runway 16/34. The private parcels in the middle of the Resurrection River floodplain are almost completely inundated as well, but that inundation is primarily due to the effects of coastal flooding from the 1-percent-annual chance tide event, which govern up to Cross-section E on the Resurrection River. The 100-year flood map in Figure 14 matches closely with the FEMA FIRM 100-year flood map. The 100-year floodplain downstream from the Seward Highway includes the FIRM Panels 4543, 4544, 5006, and 5007, found in Appendix H.

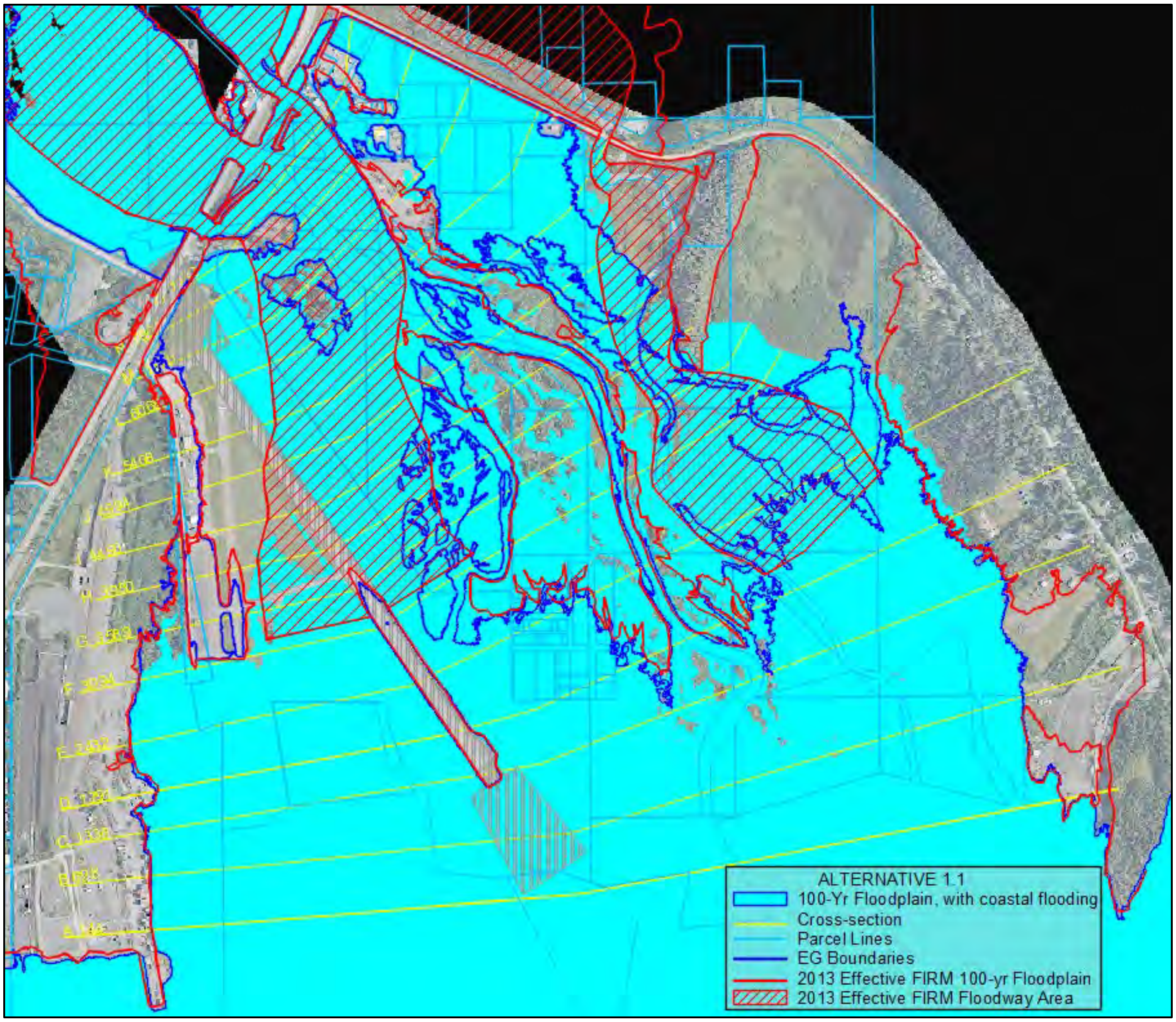


Figure 15. 100-year flood map for Alternative 1.1.

Alt 1.1-This design alternative raises the elevation of Runway 13/31 above the 100-year flood with a 2-ft freeboard. Both runways remain above the base flood elevation. The Alt 1.1 water surface elevations across the floodplain east of the runway are substantially higher than those of the EG model. Water surface elevation increases of greater than 1 foot occur from Cross-section D to Cross-section J. The maximum water surface elevation increase is 4.04 feet, and occurs at Cross-section F. The private parcels in the middle of the Resurrection River floodplain are completely inundated. At some areas of the 100-year floodplain between the Seward Highway and Resurrection Bay, the eastern limit has expanded. At Cross-sections D and E, the Alt 1.1 floodplain boundary is 70 feet to the east of the Effective FIRM floodplain (red line). At Cross-sections F and G, the Alt 1.1 floodplain boundary is 300 to 500 feet east of the EG model boundary (dark blue line). Though it is within the Salmon Creek Effective FIRM floodplain Zone AH, the Alt 1.1 water surface elevations of Cross-sections F and G are slightly higher (1-2 feet) than the FIRM base flood elevations there. At Cross-section K, the Alt 1.1 floodplain boundary is approximately 400 feet northeast of the EG model boundary, but still within the Salmon Creek Effective FIRM base flood and floodway boundary. See FIRM Panel 4544.

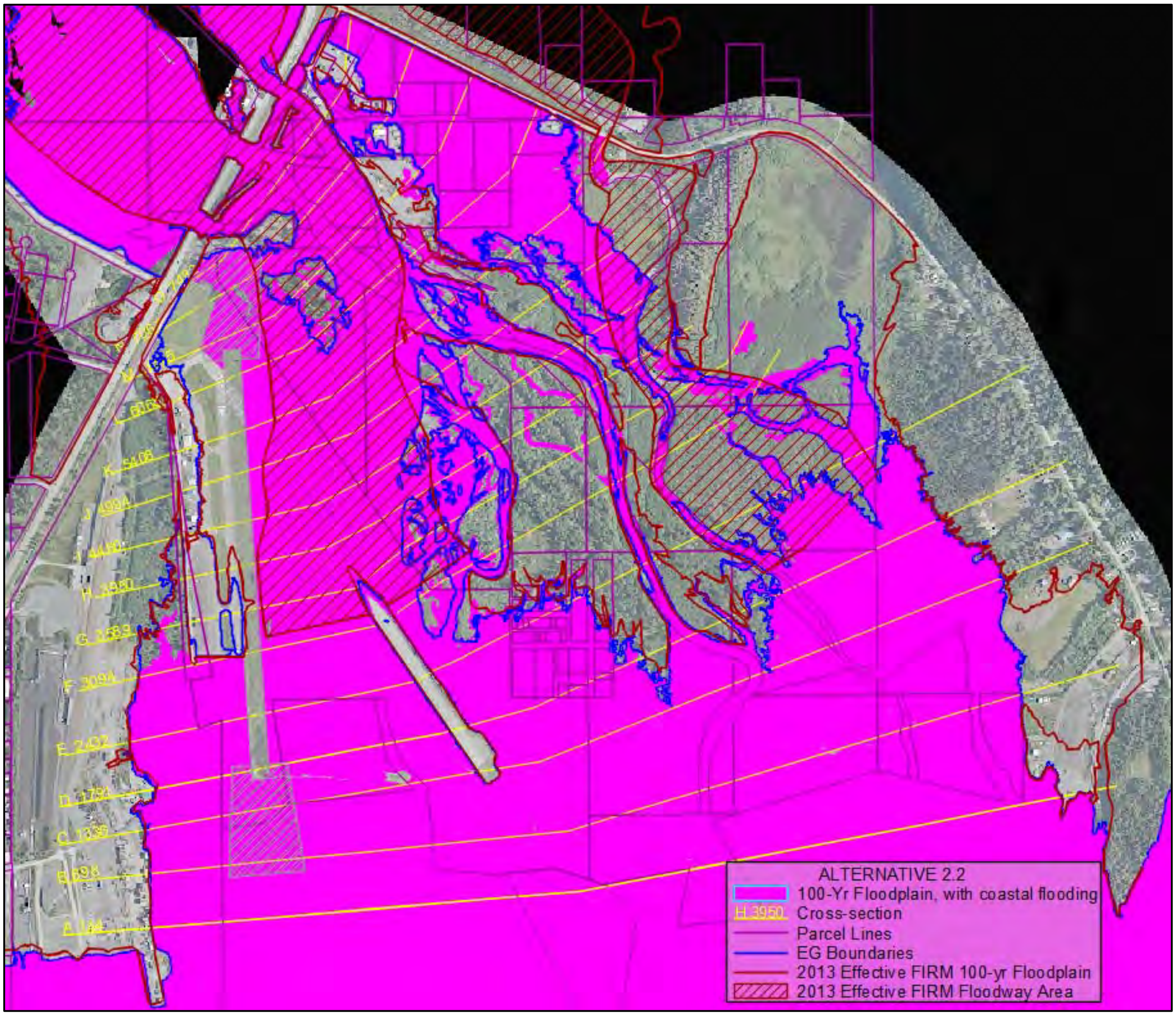


Figure 16. 100-year flood map for Alternative 2.2.

Alt 2.2-This design alternative reconstructs Runway 16/34 and raises the elevation with a 2-ft freeboard above the 100-year flood. Though Runway 13/31 is abandoned for active aircraft use, it is armored to prevent embankment erosion and channel migration.

Water surface elevation increases of less than 1 foot occur from Cross-section F to Cross-section M. The maximum water surface elevation increase is 0.78 feet, and occurs at Cross-section F. The private parcels in the middle of the Resurrection River floodplain are partially inundated. At some areas of the 100-year floodplain between the Seward Highway and Resurrection Bay, the eastern limit has slightly expanded. At Cross-section F, the Alt 2.2 floodplain boundary is 160 feet east of the EG model boundary (dark blue line); a low spot in Cross-section G 200 feet east of the EG boundary is inundated. These locations are within the Salmon Creek Effective FIRM floodplain Zone AH; however, the Alt 2.2 water surface elevations of Cross-sections F and G are lower than the FIRM base flood elevations there. At Cross-section K, the Alt 1.1 floodplain boundary is approximately 400 feet northeast of the EG model boundary, but still within the Salmon Creek Effective FIRM base flood and floodway boundary.

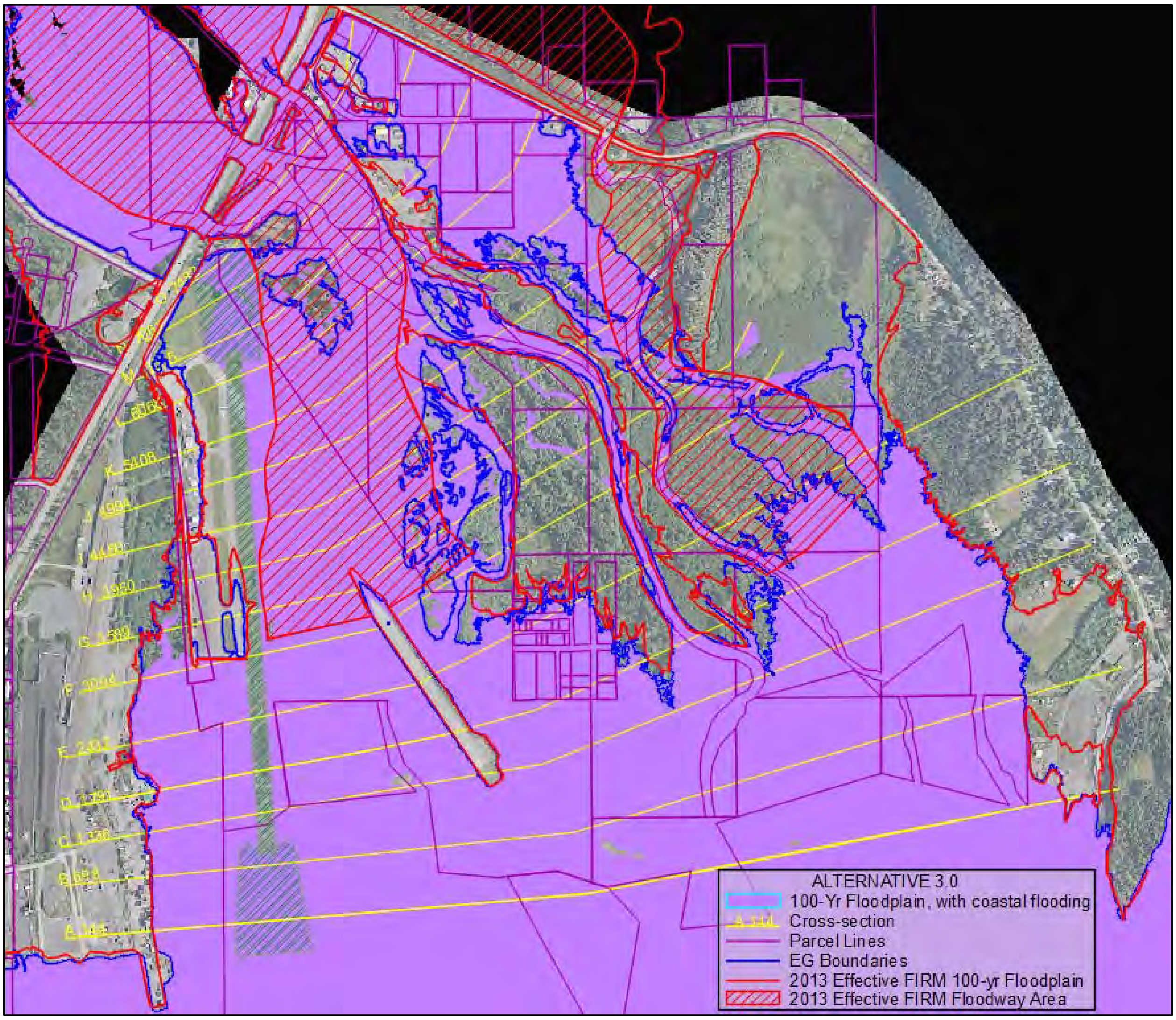


Figure 17. 100-year flood map for Alternative 3.0.

Alt 3.0-This design alternative reconstructs and lengthens Runway 16/34 and raises the elevation with a 2-ft freeboard above the 100-year flood. Runway 13/31 is abandoned for active aircraft use; it will be allowed to overtop and erode.

Water surface elevation increases of less than 1 foot occur from Cross-section F to Cross-section M. The maximum water surface elevation increase is 0.79 feet, and occurs at Cross-section F. The private parcels in the middle of the Resurrection River floodplain are partially inundated. At some areas of the 100-year floodplain between the Seward Highway and Resurrection Bay, the eastern limit has slightly expanded. At Cross-section F, the Alt 2.2 floodplain boundary is 160 feet east of the EG model boundary (dark blue line); a low spot in Cross-section G 200 feet east of the EG boundary is inundated. These locations are within the Salmon Creek Effective FIRM floodplain Zone AH; however, the Alt 2.2 water surface elevations of Cross-sections F and G are lower than the FIRM base flood elevations there. At Cross-section K, the Alt 1.1 floodplain boundary is approximately 400 feet northeast of the EG model boundary, but still within the Salmon Creek Effective FIRM base flood and floodway boundary.

Bed Scour Estimates for Embankment Toe Protection

Total scour is the sum of all scour components that are applicable for a given location. At a location where long-term aggradation occurs, conservative practice dictates that it is ignored in the total scour calculations. In addition, bed form scour is generally only considered in sand-bed channels. As the Resurrection River does not have a sand bed, scour calculations included general and bend scour components.

Because of the river/runway interface, erosion protection is required for the runway embankments. For initial planning purposes, scour was analyzed at several cross-sections for Alt 1.1, Alt 2.2, and Alt 3.0. Five methods were used for each analysis. Table 7 lists the Alternative and Cross-section analyzed, and the maximum, minimum, and average scour depth.

Table 7. Preliminary scour analysis.

Alternative & Cross-section	Total Scour (feet)		
	Maximum	Minimum	Average
Alt 1.1 Xsec 3950	11.2	3.0	5.1
Alt 1.1 Xsec 3094	8.4	2.1	4.7
Alt 2.2 Xsec 3950	12.6	2.8	5.7
Alt 2.2 Xsec 3094	11.5	1.9	5.8
Alt 3.0 Xsec 3950	12.2	2.4	5.1
Alt 3.0 Xsec 3094	11.9	2.9	5.3
Alt 3.0 Xsec 1791	11.6	2.8	5.8

The average scour depth for Runway 13/31 is 5.3 ft; Runway 16/34 is 5.4 ft. Total scour depth is subtracted from the lowest elevation in the stream bed (thalweg) to obtain the scour elevation. Additional analysis will be conducted following the selection of the preferred design alternative.

Riprap

For planning purposes, a preliminary riprap analysis was conducted at several cross-sections for Alt 1.1, Alt 2.2, and Alt 3.0. Three methods were used for each analysis. See Table 8.

Table 8. Preliminary riprap analysis.

<table>
<tr><td rowspan="4">USACE Method</td><td>Percent lighter by Weight</td><td>Rock Min/Max (lbs)</td><td>Layer Thickness (ft)</td><td>ADOT&PF Class</td></tr>
<tr><td>W100</td><td>191/477</td><td rowspan="3">1.750</td><td rowspan="3">Class II+</td></tr>
<tr><td>W50</td><td>95/141</td></tr>
<tr><td>W15</td><td>30/71</td></tr>
<tr><td rowspan="4">California Bank and Shore Protection</td><td>Percent larger Than</td><td>Rock Size (ton)</td><td>Layer Thickness (ft)</td><td>ADOT&PF Class</td></tr>
<tr><td>0-5</td><td>1.00</td><td rowspan="3">3.40</td><td rowspan="3">Class IV-</td></tr>
<tr><td>50-100</td><td>0.50</td></tr>
<tr><td>95-100</td><td>0.25</td></tr>
<tr><td rowspan="4">HEC-11 FHWA</td><td>Percent Smaller by Size</td><td>Rock Size (feet)/ Rock Weight (lbs)</td><td>Layer Thickness (ft)</td><td>ADOT&PF Class</td></tr>
<tr><td>D100</td><td>1.30/200</td><td rowspan="3">1.90</td><td rowspan="3">Class II</td></tr>
<tr><td>D50</td><td>0.95/75</td></tr>
<tr><td>D10</td><td>0.40/5.0</td></tr>
</table>

Note that the USACE method calls for a Class II +, Cal B&SP calls for Class IV-, and HEC-11 calls for Class II. Given the angle of attack of the flow to the runway embankment, Class III is recommended for embankment protection for the southern half of the Runway, including and extending upstream beyond the anticipated point of impinging flow. Above the point of impinging flow, Class II riprap is recommended. Additional analysis will be conducted following the selection of the preferred design alternative.

Due to the length of Runway 16/34 in Alternative 2.2, the embankment will extend into the Resurrection Bay intertidal zone. Additional erosion protection will be required to protect the runway embankment from wave runup and storm surge events.

Recommendations

Though FAA Advisory Circulars, the Alaska Aviation Preconstruction Manual, and the Alaska Highway Preconstruction Manual (AHPCM) do not provide a design return interval specifically applicable for an airport adjacent a river, Table 1120-1 in the AHPCM recommends using a discharge with a 100-year return interval to design culverts and channel changes in designated flood hazard areas with no reference to the type of facility. ADOT&PF interprets this recommendation to be applicable for countermeasures pertaining to both flooding and scour at airport facilities in FEMA mapped floodways and floodplains (Janke, 2015).

The braided channel of the Resurrection River adjacent to the Seward Airport has exhibited significant changes in location over time. Additionally, the frequency of runway overtopping events and the required maintenance has been increasing with time. Because of the dynamic nature of the Resurrection River at close proximity to the Seward Airport, the design guidelines should be conservative.

Panels 4543, 4544, 5006, and 5007 of the 2013 Flood Insurance Rate Map (FIRM) are found in Appendix H. Panel 4543 includes the Seward Airport and the Resurrection River Regulatory Floodway. FEMA regulations state communities shall prohibit encroachments, fill, new development, substantial improvements, and other development within the adopted regulatory floodway unless it has been demonstrated through hydrologic and hydraulic analyses that the proposed encroachment would not result in any increase in flood levels within the community of the base flood (100-year) discharge. In addition, the KPB Floodplain Development Ordinance (KPB, 1986) also prohibits any increase in flood levels during the base flood that result from fill, construction and other development within the regulatory floodway.

Also note that minimum federal standards limit the maximum allowable rise of the 100-year Base Flood Elevation (BFE) to 1 foot. FEMA's regulations allow for State and local government regulations that are more stringent (allow something less than a one foot rise) to take precedence.

Alternative 1.1 requires encroachment within the Regulatory Floodway due to construction of the raised runway. The hydraulic analysis shows a range of flood level increases within the regulatory floodway during the base flood. Additionally, BFE increases of more than 1 foot would occur in areas of the 1% chance floodplain other than the regulatory floodway. In addition to the large BFE increases, the impacts from the encroachment required by Alternative 1.1

include backing up floodwaters onto private properties in the middle of the Resurrection River floodplain. The eastern limit would expand as well toward Nash Road, potentially impacting private properties. Additionally, floodwater velocities generally increase, which could lead to erosion and embankment toe scour. Finally, the large BFE increases would result in a substantial quantity of material being needed to raise the runway embankment to the design crest elevation.

If selected as the engineering preferred alternative, this design would likely face substantial permitting obstacles and requires modification to the effective FIRM and Floodway Map. Such an action would require a Letter of Map Revision (LOMR), which is FEMA's modification to an effective FIRM, or Flood Boundary and Floodway Map, or both. LOMR reviews take up to 90 days to process, are subject to an appeal period, and usually become effective within six months after they are issued (FEMA, 2015a). The preparation of a LOMR request includes extensive hydrologic computations, hydraulic analysis, and regulatory requirements.

Alternatives 2.2 and 3.0 do not require encroachment within the Regulatory Floodway, and will result in BFE increases of less than 1 foot. Impacts to private properties from the BFE increases are much smaller than with Alternative 1.1. When including the effects from coastal flooding, there would be only small impacts (increased inundation) to the private properties in the middle of the Resurrection River floodplain. Similarly, there would be a very small expansion of the eastern limit of the 100-year floodplain toward private properties along Nash Road between the Seward Highway and Resurrection Bay. The expansions would still be contained within the Salmon Creek Effective FIRM floodplain. Average velocity increases would be less than 15 percent, though larger local increases may occur near new embankments.

However, either of these alternatives may still require a Conditional Letter of Map Revision (CLOMR). A CLOMR is FEMA's comment on a proposed project that would, upon construction, result in the modification of the existing regulatory floodway, the effective BFEs, or the Special Flood Hazard Area (FEMA, 2015b). A CLOMR is required when proposed changes will cause any increase the BFE where a regulatory floodway has been identified. Consultation with FEMA, the City of Seward, and the KPB Floodplain Administrator is suggested to determine if a CLOMR is required for either Alternative 2.2 or 3.0.

The following recommendations are based on the hydraulic analysis described in this report, as well as applicable local and FEMA floodway and floodplain regulations:

1. The engineering preferred design should be either Alternative 2.2 or 3.0.

2. In the future, long-term stockpiling of overburden and gravel in the channel or floodplain of the Resurrection River downstream of the Seward Highway bridges should be discouraged.

3. The recommended design water surface elevation for the Seward Airport Improvements project is the water surface elevation during the discharge with a 100-year (1% chance) return interval plus a two-foot freeboard.

4. The recommended design condition for erosion protection for the Seward Airport Improvements project is the discharge with a 100-year (1% chance) return interval.

References

Alaska Department of Transportation and Public Facilities (ADOT&PF). 2008. Seward Airport Master Plan. Prepared by DOWL Engineers, Anchorage, AK. July 2008.

Blench, T. 1969. Mobile-bed fluviology. University of Alberta Press, Edmonton, Canada.

Federal Emergency Management Agency (FEMA). 2013. Flood Insurance Study for Kenai Peninsula Borough, Alaska and incorporated areas. Effective September 27, 2013.

Federal Emergency Management Agency (FEMA). 2015a. FEMA Letter of Map Revision fact sheet. Accessed at https://www.fema.gov/letter-map-revision.

Federal Emergency Management Agency (FEMA). 2015b. FEMA Conditional Letter of Map Revision. Accessed at http://www.fema.gov/conditional-letter-map-revision

Janke, P. 2015. Memorandum to Project Manager, Aviation Design, Draft hydrologic and hydraulic reports comments. ADOT&PF Central Region. June 18, 2015.

Kenai Peninsula Borough (KPB). 1986. Ordinance 86-97 establishing a floodplain management program to conform to requirements of the National Flood Insurance Program. Accessed at http://www.kpb.us/river-center/resources/flood-information.

Lacey, G. 1930. Stable channels in alluvium. In Proceedings of the Institution of Civil Engineers, vol. 229.

National Oceanic and Atmospheric Administration (NOAA). 2015. Seasonal variation of exceedance probability levels, 9455090 Seward, AK. Accessed at http://tidesandcurrents. noaa.gov/est/seasonal.shtml?stnid=9455090.

Neill, C.R. 1973. Guide to bridge hydraulics. Published for Roads and Transportation Association of Canada.

Northwest Hydraulic Consultants, Inc. (NHC). 2007a. Hydrology for floodplain insurance restudy of City of Seward, Kenai Peninsula Borough, Alaska. Draft memo dated November 30, 2007. To: Debra Heiden, FEMA Region X.

Northwest Hydraulic Consultants, Inc. (NHC). 2007b. Long-term sedimentation trends on Seward, Alaska valley streams. Prepared for FEMA Region X. November 2007.

Northwest Hydraulic Consultants, Inc. (NHC). 2008. Develop hydraulic data for Resurrection River floodplain insurance studies in Seward, Kenai Peninsula Borough, Alaska, EMS-2001-CO-0067, Task Order #28. Prepared for FEMA Region X. December 22, 2008.

Pemberton, E., and J.M. Lara. 1984. Computing degradation and local scour. Technical Guideline for Bureau of Reclamation, U.S. Department of the Interior, Denver, CO.

Quantum Spatial. 2014. Seward Airport LiDAR and orthophotography-technical data report. August 20, 2014. Prepared for PDC Inc. Engineers. QSI Anchorage, AK.

Seward/Bear Creek Flood Service Area (SBCFSA). 2010. A history of flooding in Seward, Alaska 1903-2009.

Task Force Report. 1998. Resurrection River/Japanese Creek flood hazard mitigation project, Seward, Alaska. Multi-agency task force report May 8, 1998.

Thorne, C.R., and J. Lewin. 1979. Bank processes, bed material movement and planform development in a meandering river. In Rhodes, D.D. and Williams, G.P. (eds.), Adjustments of the fluvial system, Kendall/Hunt Publishing Company, Dubuque, Iowa.

U.S. Army Corps of Engineers (USACE). 1994. Hydraulic design of flood control channels. EM-1110-2-1601, Headquarters, U.S. Army Corps of Engineers, Washington, D.C.

U.S. Geological Survey (USGS). 1967. Effects of the earthquake of March 27, 1964, on air and water transport, communications, and utilities systems in south-central Alaska. By Edwin B. Eckel. Geological Survey Professional Paper 545-B.

U.S. Geological Survey (USGS). 2015. USGS 1523770 Resurrection R at Seward AK. Accessed at http://waterdata.usgs.gov/ak/nwis/inventory/?site_no=15237700&agency_cd=USGS&amp.

Williams, D., and B. Doeing. 2003. Predicting bed scour for toe erosion protection design in bank stabilization projects. Training manual for 34th Annual Conference and Expo, International Erosion Control Association.

Appendix A – Flood History at Seward Airport

1951 - Runway 15-33 was constructed with gravel in the late 1920s. During 1951 construction for Runway 12-30, dozers uncovered subsurface springs, which flooded the new surface and delayed construction equipment and led to the installation of subsurface drains. Additional delays resulted from extraordinarily heavy rainfall and seasonal high tides that interfered with the normal drainage of the airport area. (Barber, 2006; ADOT&PF, 2008)

1961 - 500 ft of south end of the runway embankment was severely damaged by erosion. (Barber, 2006).

1962 - Resurrection River Heavy flood flows spread out over east side of floodplain; severe bank erosion above and below highway; washed out Airport Road bridge (FEMA, 2014).

1964 - Following the Good Friday Earthquake, much of Seward was inundated by tsunamis in Resurrection Bay. Light airport damage, but small planes were wrecked by waves (USGS, 1967).

1966 - North portion of both runways under water (Barber, 2006).

1974 - North portion of both runways under water (Barber, 2006).

1986 - In October, Typhoon Carmen delivered 18" of rain in a 3-day period in Seward (SBCFSA, 2010). North portion of both runways under water. Approximately 200 feet of the south end of the airport's runway was damaged by floodwaters. Center taxiway between both runways was washed out in two locations (Barber, 2006).

1995 - In September, Typhoon Oscar delivered 9" of rain in 24 hours in Seward (SBCFSA, 2010). North portion of both runways was under approximately 1.5 to 2.5 feet of water. Extensive erosion of the south end of the airport runway. Center taxiway between both runways was washed out. Riprap was replaced at the end of the runway during the actual flood event (Barber, 2006). The 1995 flood shifted 90 percent of the Resurrection River's flow into a channel adjacent to Runway 12-30 (ADOT&PF, 2008).

2003 - A combination of high water from the Resurrection River and surge high tides reached the edge of the runway pavement on the south end of the runway. The north end of the runway was not flooded. No damage was reported. According to NOAA, this was a wind driven high tide event. The elevations observed did not include wave run-up (Barber, 2006).

2006 (Oct)-Typhoon Xangsane delivered 9"- 15" of rain in a 48-hour period in Seward. Airport was flooded (SBCFSA, 2010).

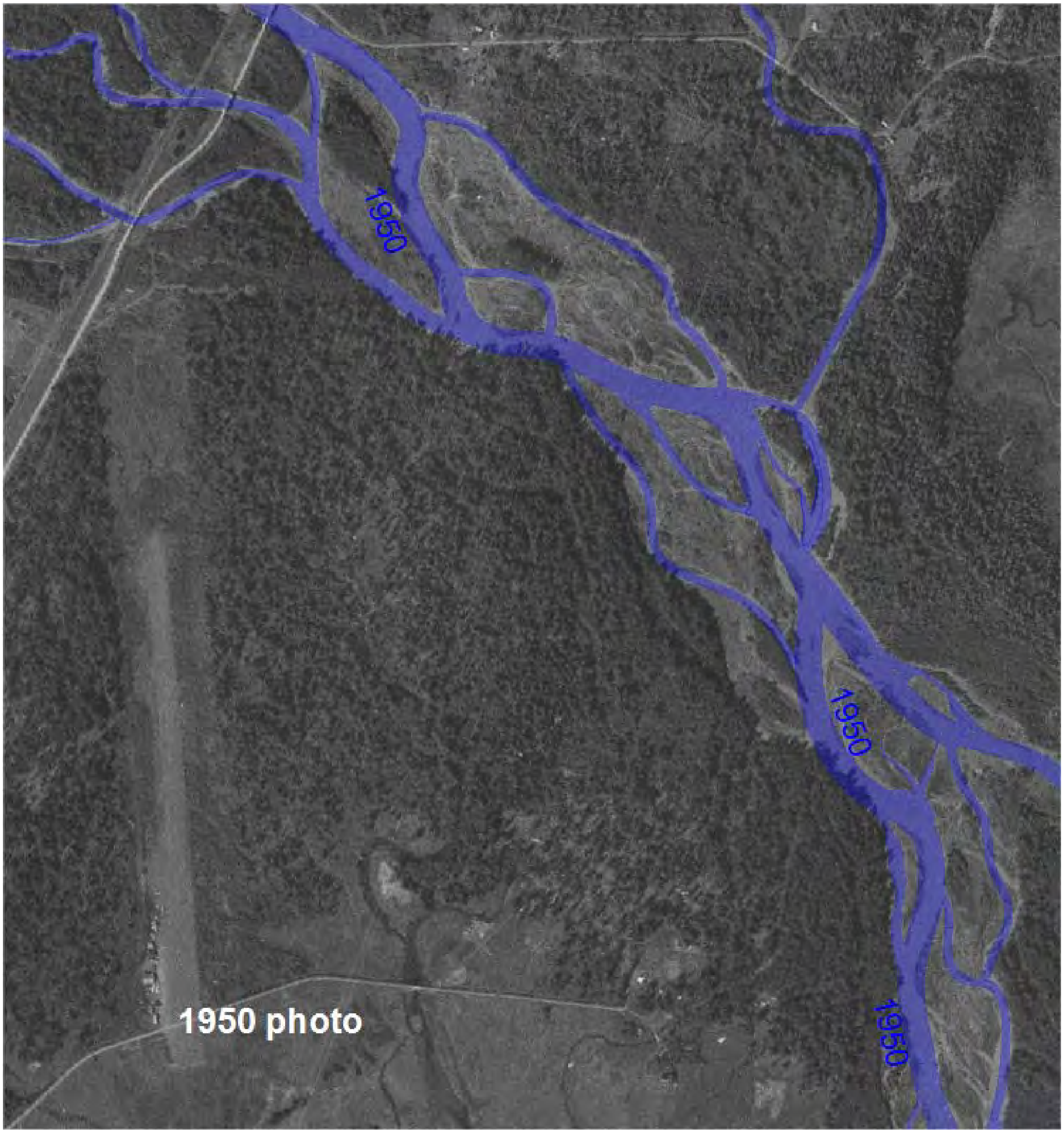
2009 (July)-Heavy rains and high tides resulted in water over the runway and taxiway (SBCFSA, 2010).

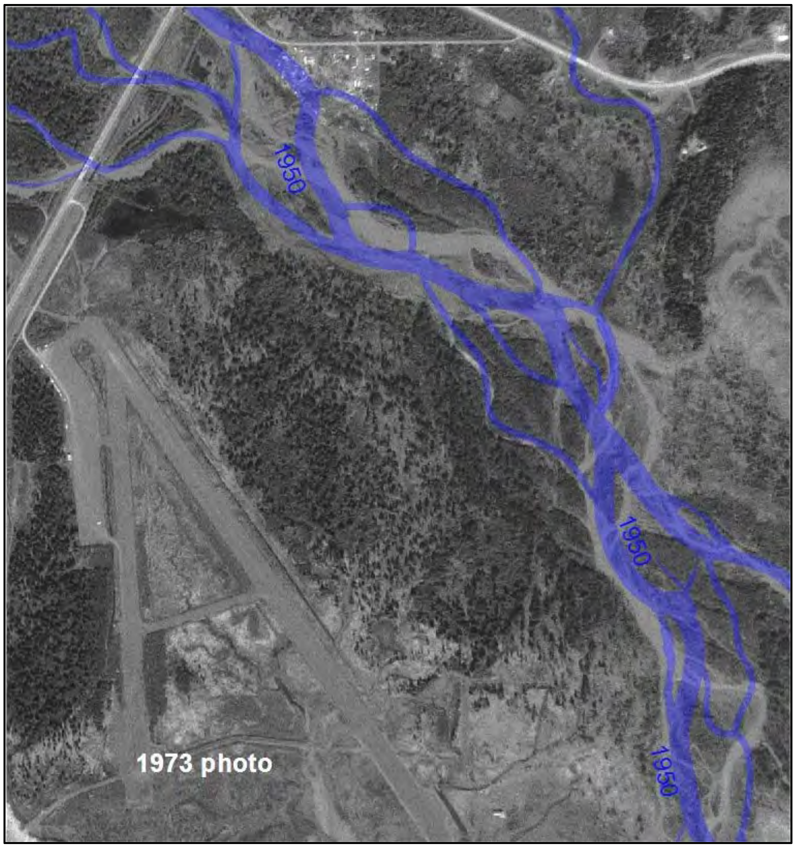
2012 (Sept) - Runway 13-31 is flooded and closed due to heavy rains (KTUU).

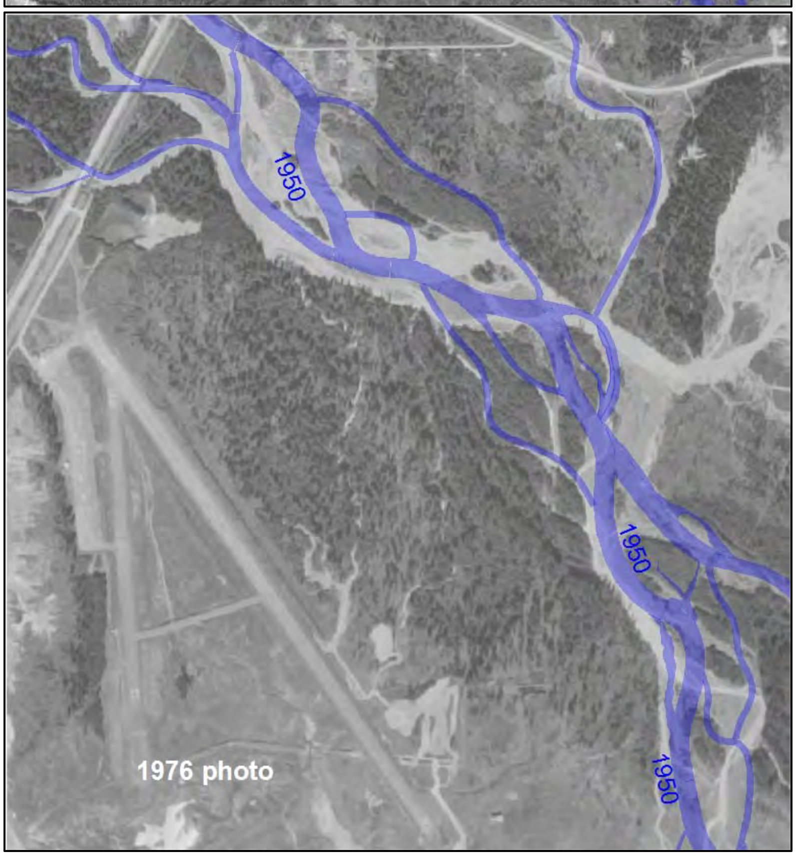
2013 - Runway 13-31 is flooded multiple times during summer and fall. Flooding in June was the result of rapid glacier melting due to record high temperatures (Seward Phoenix Log). Airport is reopened in October following construction of emergency erosion control along the runway.

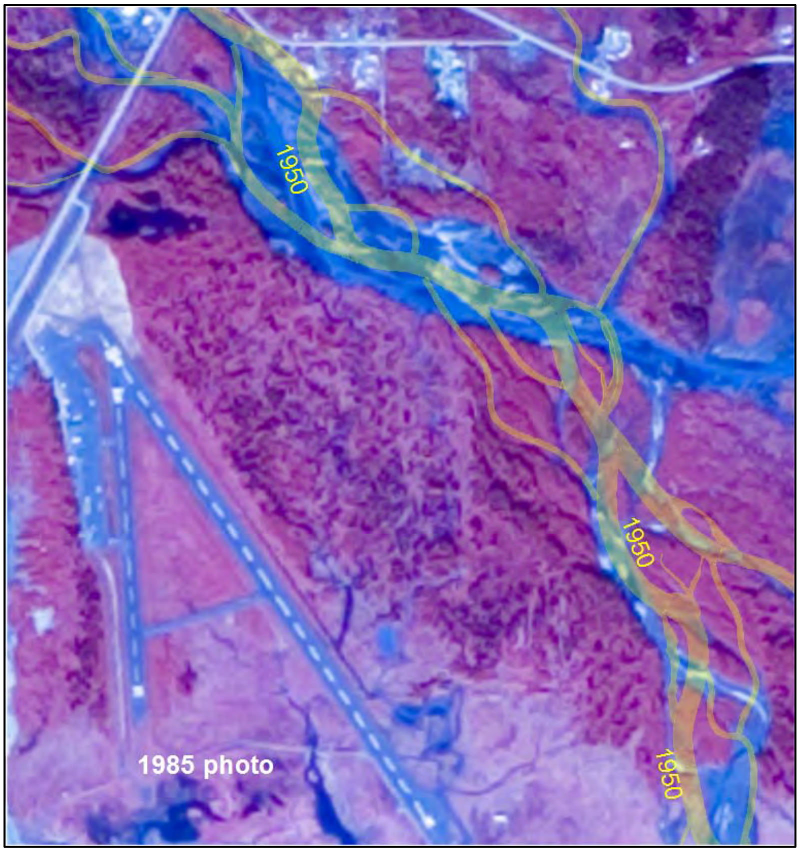
2014 - Runway 13-31 is flooded in September (Seward City News).

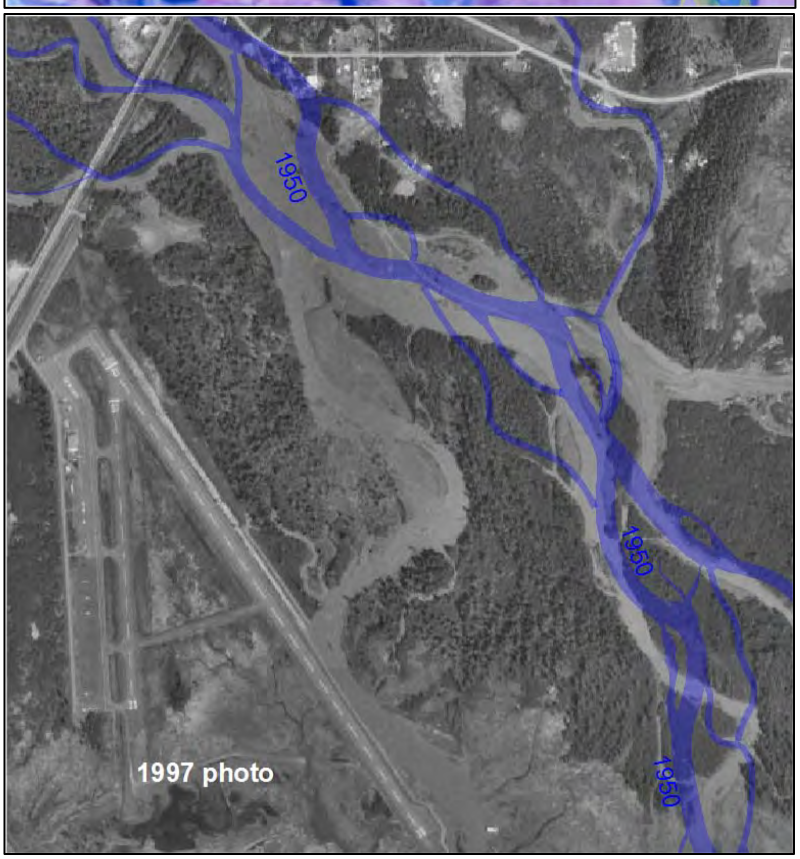
Appendix B – Aerial Imagery, 1950 to 2014



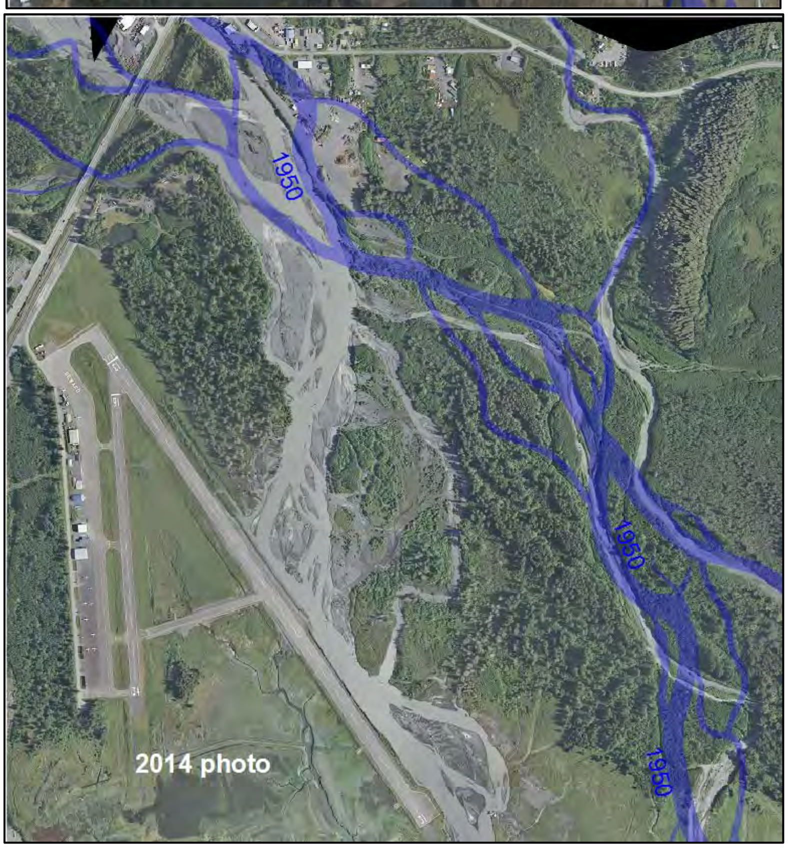

1950
1950
1950
1973 photo


1950
1950
1950
1976 photo

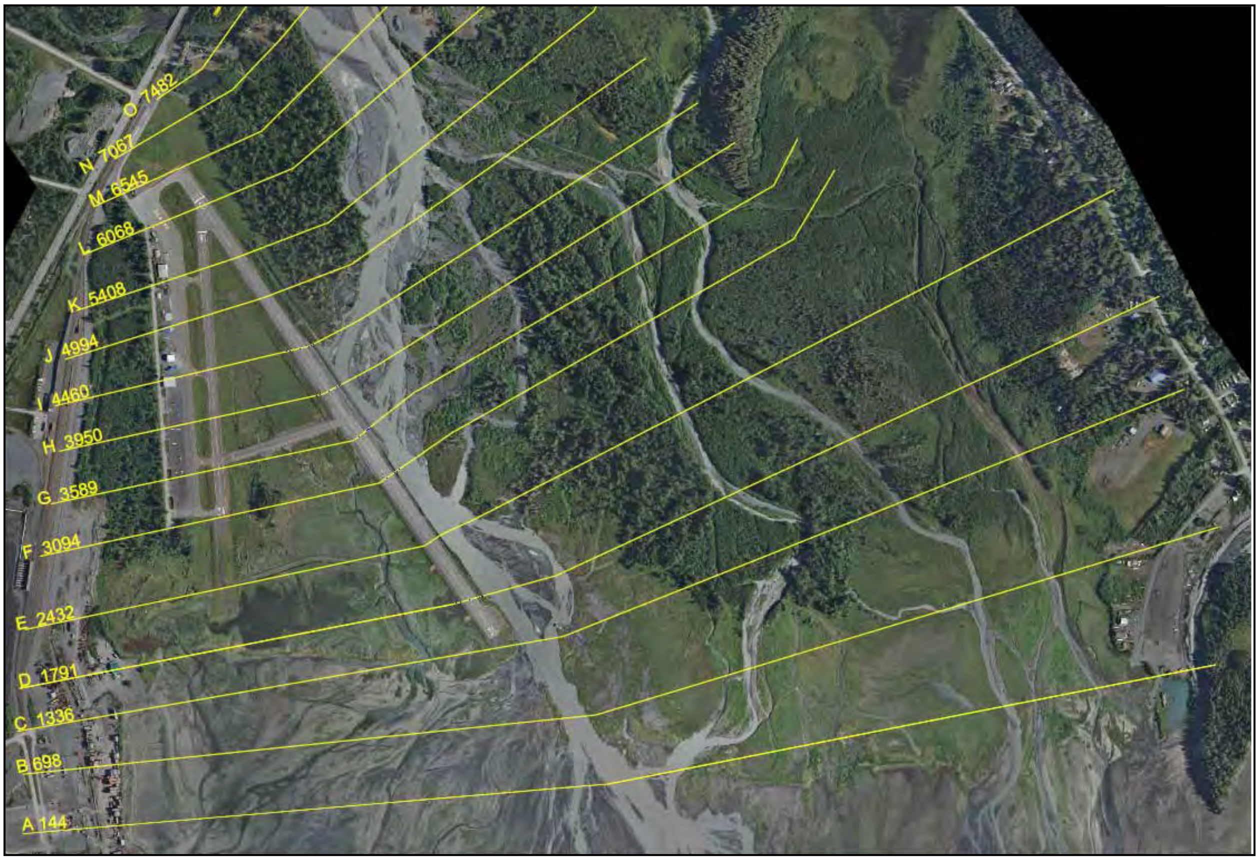

1950
1950
1950
1985 photo


1950
1950
1950
1997 photo


1950
1950
1950
2011 photo

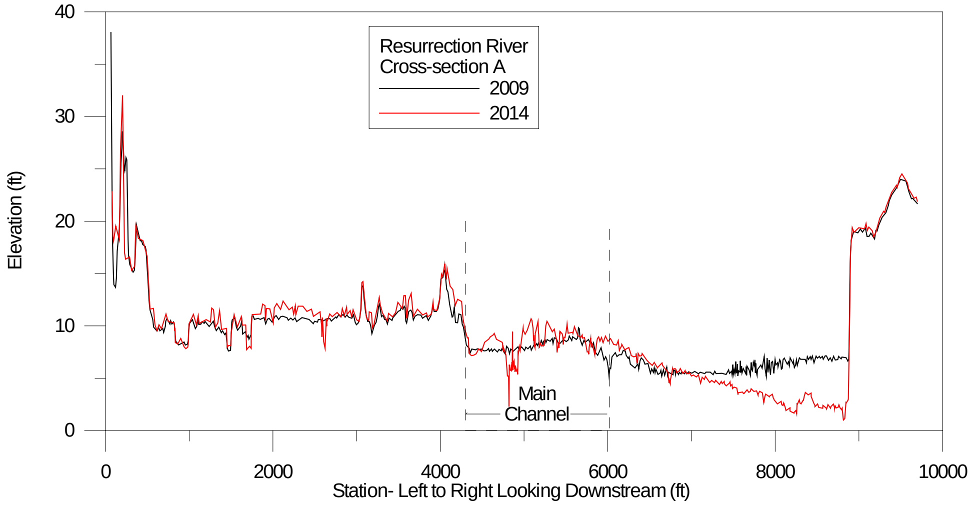

1950
1950
1950
2014 photo

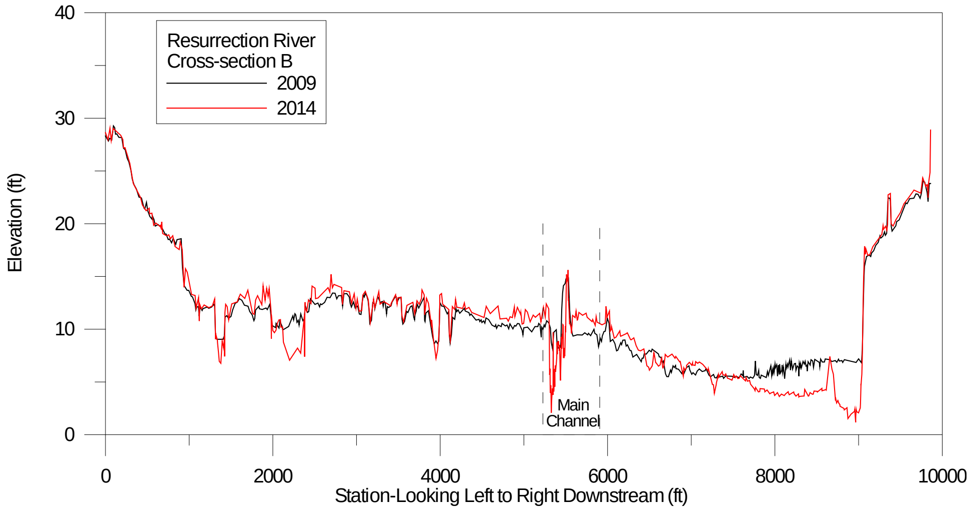
Appendix C-HEC-RAS Cross-section Locations

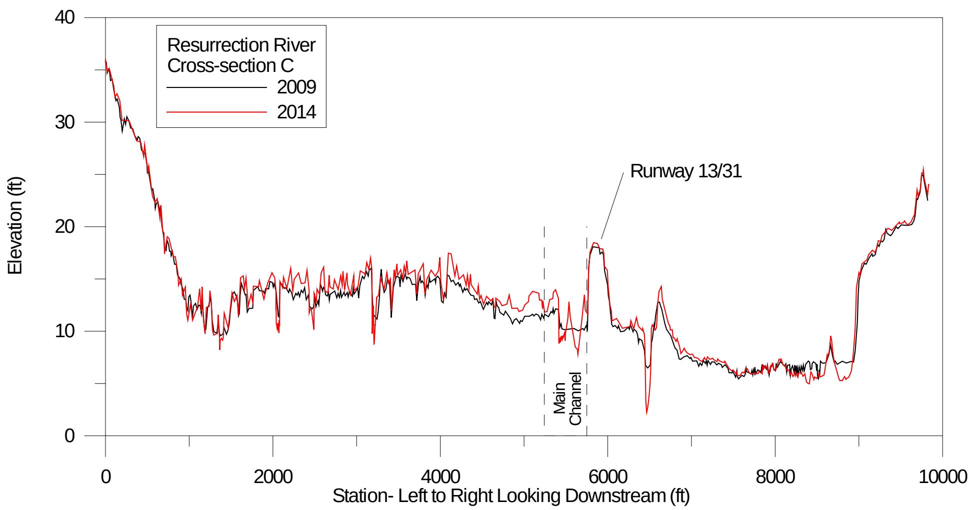


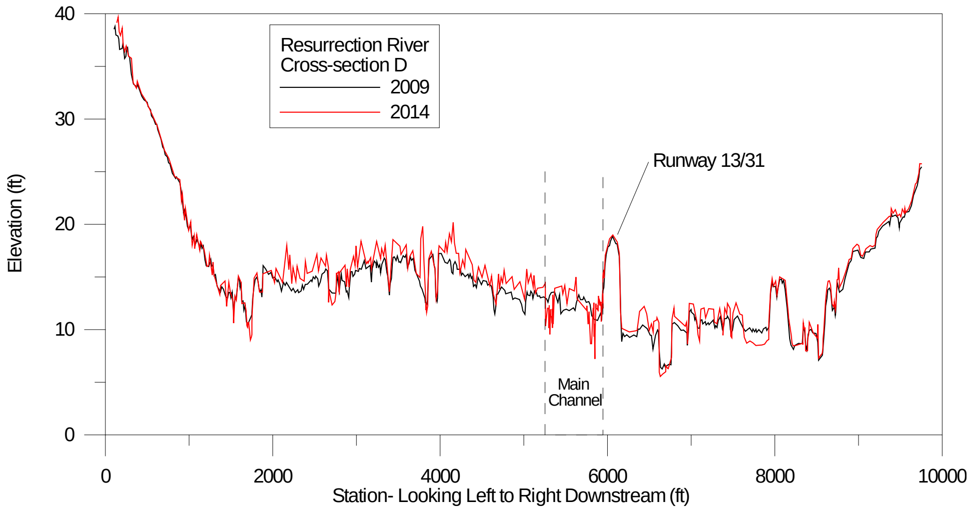
Appendix D-Cross-sections A-0 for 2009 and 2014.

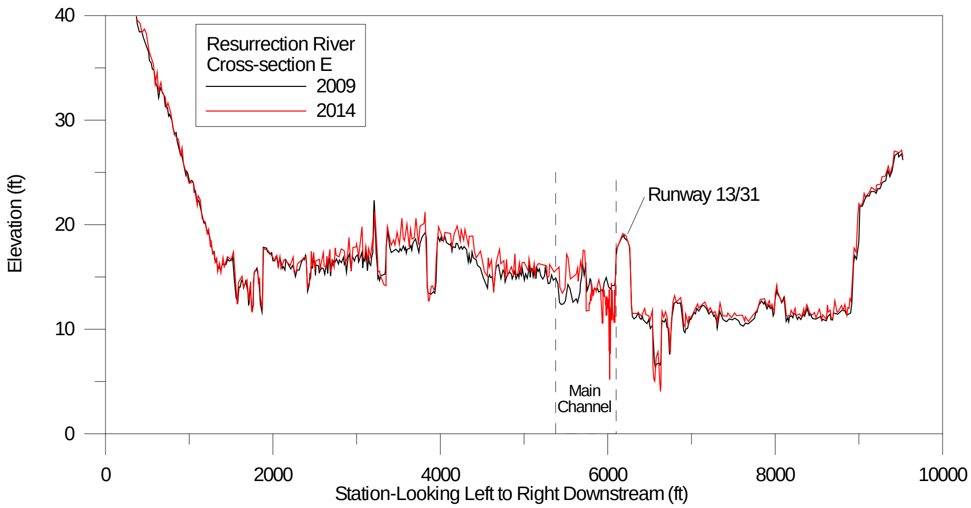
Note: main channel elevations should not be compared between years, as the 2009 sections are LiDAR-derived, with no in-channel bottom survey.

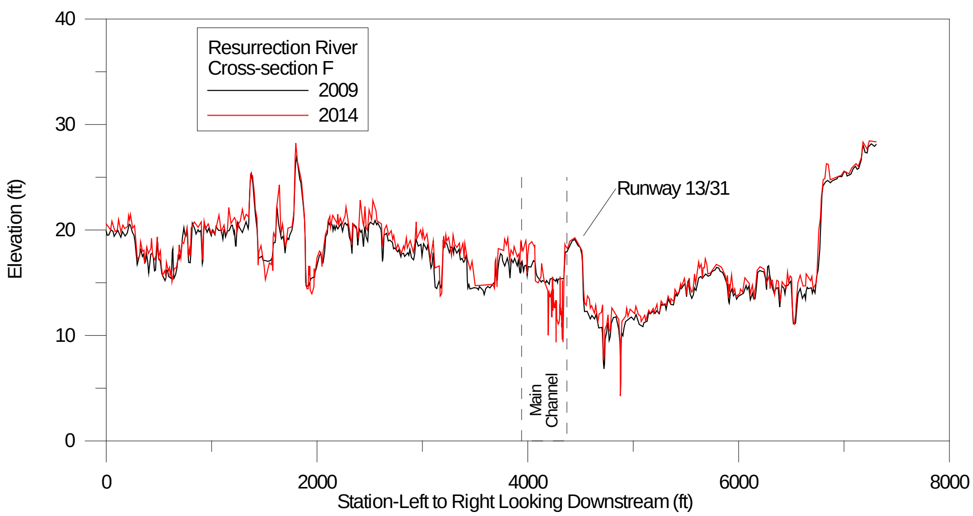


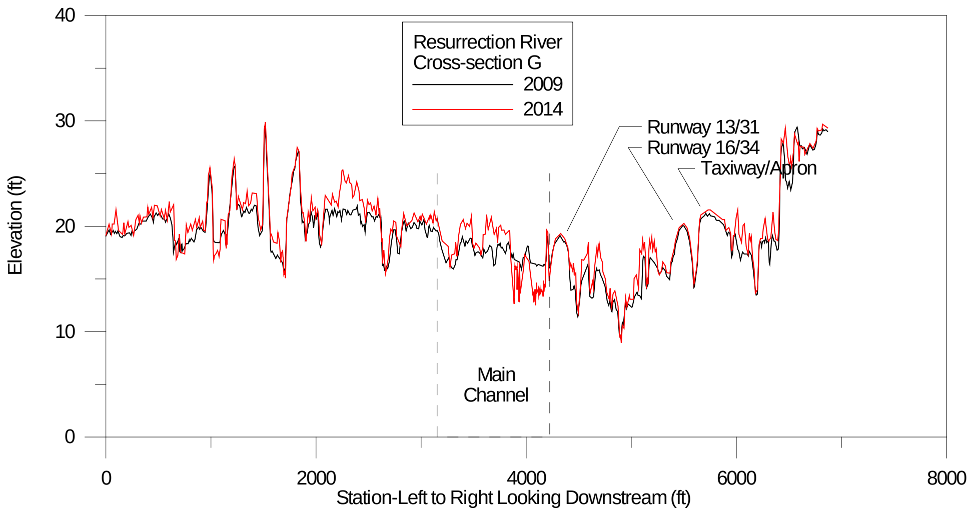


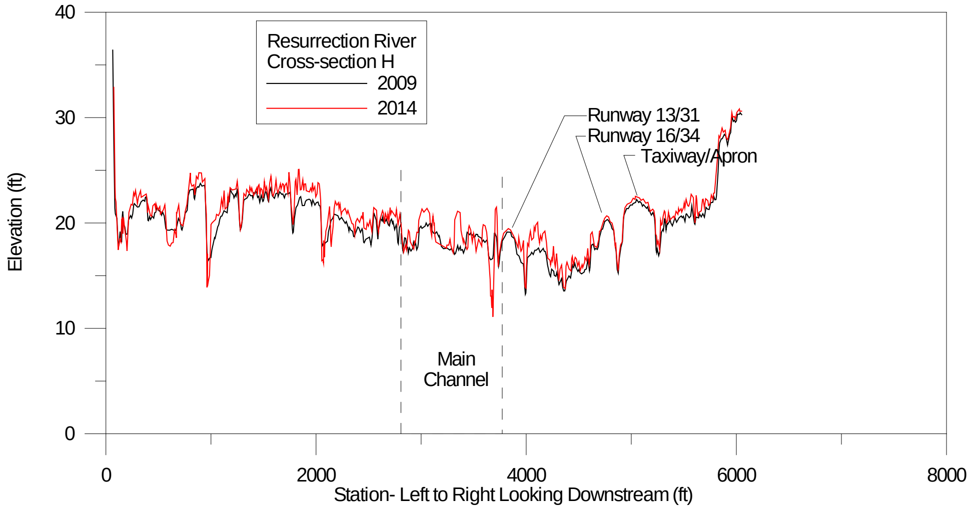


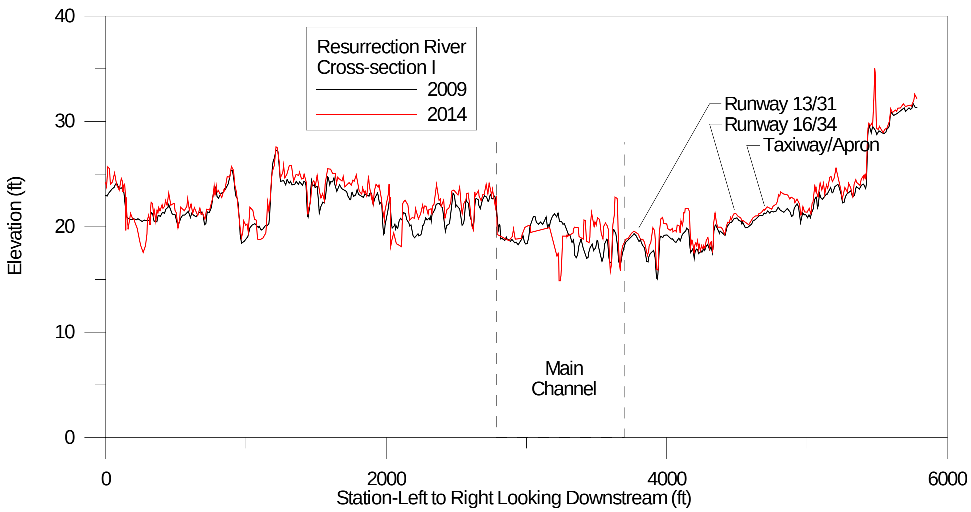

Resurrection River
Cross-section D
2009
2014
Runway 13/31
Main Channel
Elevation (ft)
Station- Looking Left to Right Downstream (ft)
0
10
20
30
40
0
2000
4000
6000
8000
10000

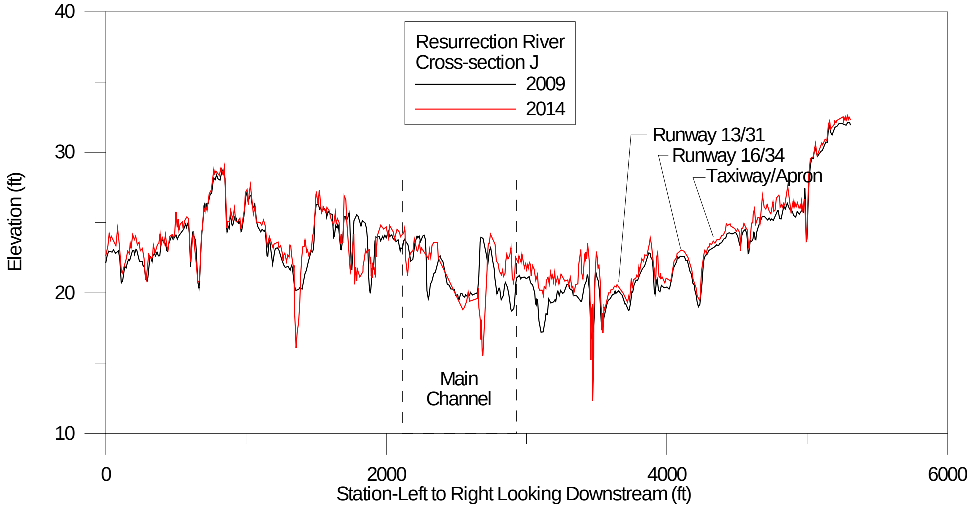

Resurrection River
Cross-section E
2009
2014
Runway 13/31
Main Channel
Elevation (ft)
Station-Looking Left to Right Downstream (ft)
0
10
20
30
40
0
2000
4000
6000
8000
10000

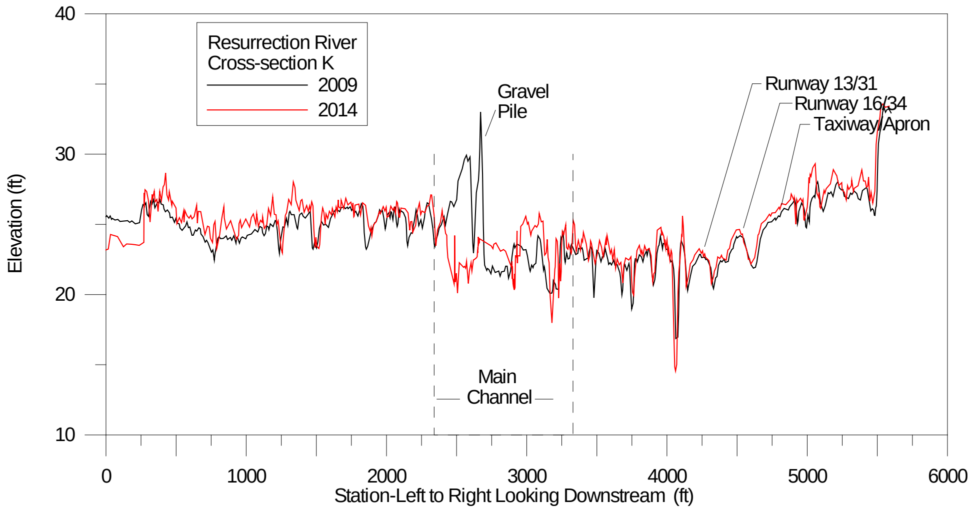

Resurrection River
Cross-section F
2009
2014
Runway 13/31
Main Channel
Elevation (ft)
Station-Left to Right Looking Downstream (ft)
0
10
20
30
40
0
2000
4000
6000
8000

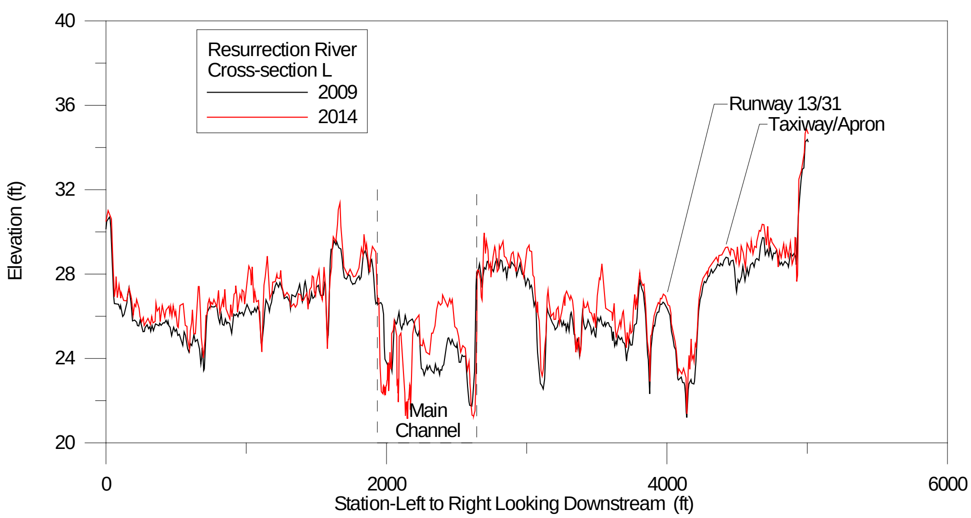

Resurrection River
Cross-section G
2009
2014
Runway 13/31
Runway 16/34
Taxiway/Apron
Main
Channel
Elevation (ft)
40
30
20
10
0
0
2000
4000
6000
8000
Station-Left to Right Looking Downstream (ft)

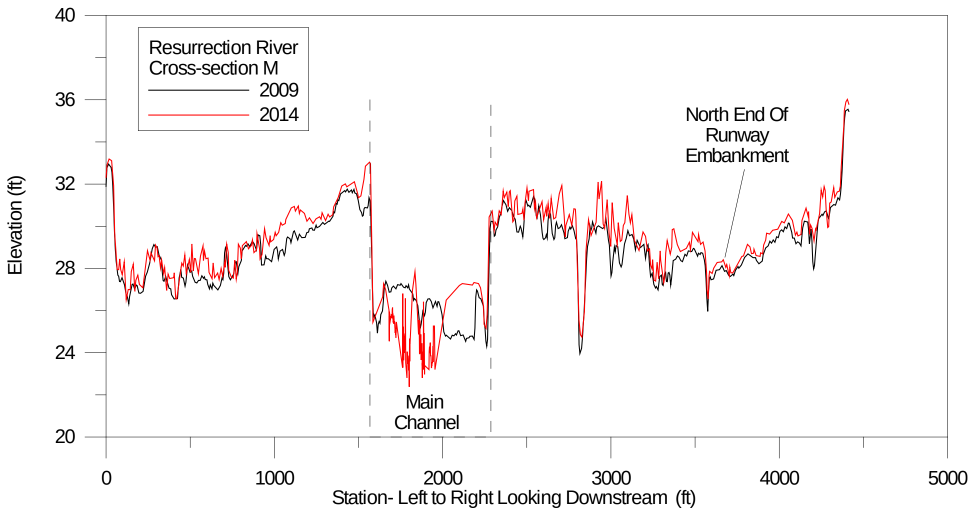

Resurrection River
Cross-section H
2009
2014
Runway 13/31
Runway 16/34
Taxiway/Apron
Main
Channel
Elevation (ft)
40
30
20
10
0
0
2000
4000
6000
8000
Station- Left to Right Looking Downstream (ft)

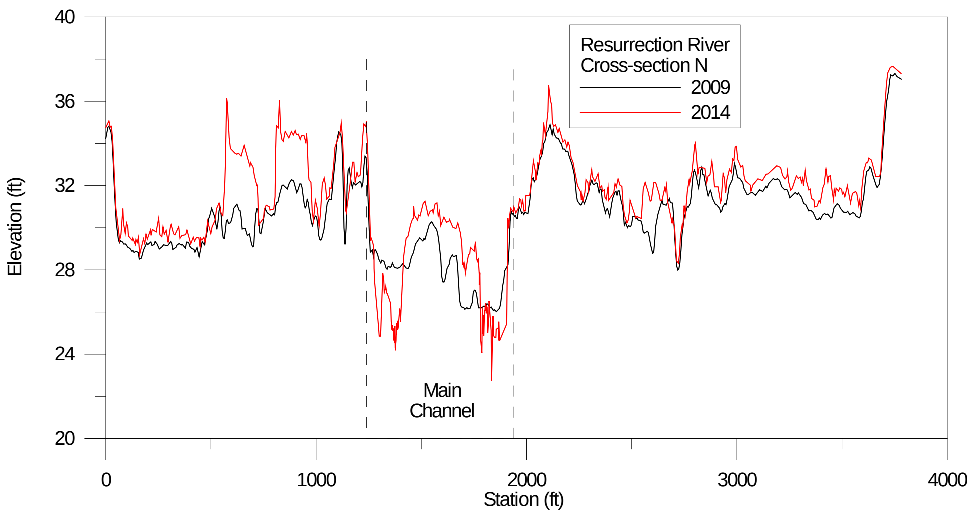

Resurrection River
Cross-section I
2009
2014
Runway 13/31
Runway 16/34
Taxiway/Apron
Main
Channel
Elevation (ft)
40
30
20
10
0
0
2000
4000
6000
Station-Left to Right Looking Downstream (ft)

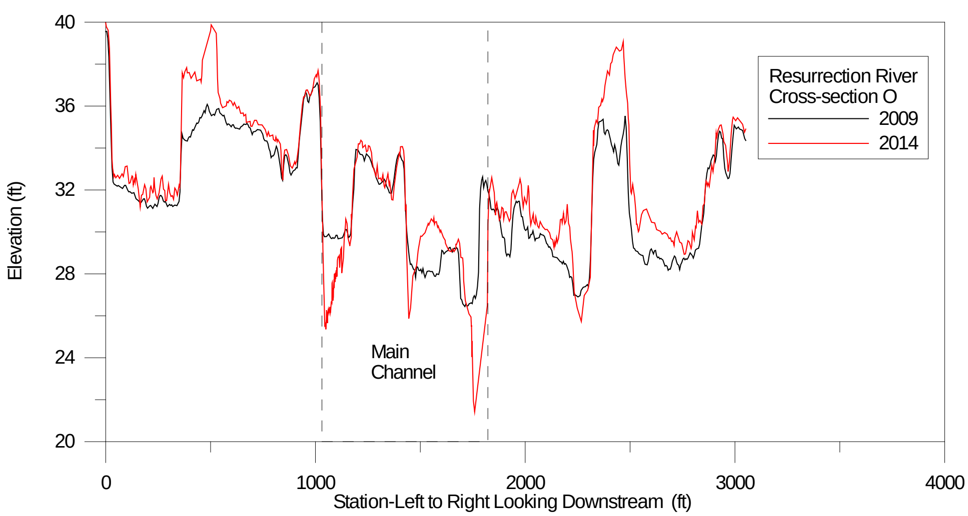

Resurrection River
Cross-section J
2009
2014
Runway 13/31
Runway 16/34
Taxiway/Apron
Main
Channel
Elevation (ft)
Station-Left to Right Looking Downstream (ft)
40
30
20
10
0
2000
4000
6000


Resurrection River
Cross-section K
2009
2014
Gravel
Pile
Runway 13/31
Runway 16/34
Taxiway/Apron
Main
Channel
Elevation (ft)
Station-Left to Right Looking Downstream (ft)
40
30
20
10
0
1000
2000
3000
4000
5000
6000


Resurrection River
Cross-section L
2009
2014
Runway 13/31
Taxiway/Apron
Main
Channel
Elevation (ft)
Station-Left to Right Looking Downstream (ft)
40
36
32
28
24
20
0
2000
4000
6000


Resurrection River
Cross-section M
2009
2014
North End Of
Runway
Embankment
Main
Channel
Elevation (ft)
40
36
32
28
24
20
0
1000
2000
3000
4000
5000
Station- Left to Right Looking Downstream (ft)


Resurrection River
Cross-section N
2009
2014
Main
Channel
Elevation (ft)
40
36
32
28
24
20
0
1000
2000
3000
4000
Station (ft)


Resurrection River
Cross-section O
2009
2014
Main
Channel
Elevation (ft)
40
36
32
28
24
20
0
1000
2000
3000
4000
Station-Left to Right Looking Downstream (ft)

Appendix E-Seward Precipitation Record

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1964	3.14	9.32	0.98	2.13	2.14	2.04	1.77	8.26	8.98	10.33	9	2.14	57.09
1965	3.5	1.64	7.41	1.86	6.15	8.83	2.02	1.75	9.86	5.26	4.58	3.08	55.94
1966	1.96	2.92	4.15	1.33	3.36	0.62	2.77	14.14	17.89	11.5	2.07	3.99	66.7
1967	2.41	3.41	2.18	1.13	0.84	3.1	3.12	8.26	26.08	5.29	12.59	3.96	72.37
1968	0.87	5.53	2.88	1.31	2.89	0.74	0.74	1.5	7	5.07	5.44	2.45	36.42
1969	0.67	4.79	2.12	3.76	3.91	3.76	1.58	2.95	5.22	21.97	6.25	17.6	74.58
1970	1	8.58	6.78	7.85	0.43	2.83	3	4.88	4.63	9.11	3.87	4.7	57.66
1971	2.29	11.62	4.17	6.52	10.37	3.66	3.84	3.72	3.38	9.75	3.87	4.58	67.77
1972	1.28	2.73	2.32	0.95	6.64	2.72	0.6	5.21	10.99	8.29	4.79	0.96	47.48
1973	3.56	5.05	3.76	8.37	8.84	1.36	1.76	2.68	6.78	4.3	2.35	8.06	56.87
1974	1.23	4.17	1.79	4.58	0.42	1.47	0.89	2.37	12.73	11.03	13.09	4.27	58.04
1975	5.18	7.61	1.55	4.25	5.85	1.63	0.8	1.83	11.75	8.4	0.21	7.5	54.73
1976	5.16	1.94	3.37	8.34	2.59	1.23	0.59	3.18	19.18	10.59	25.22	10.47	91.86
1977	15.55	13.28	1.82	9.74	6.95	2.22	2.29	7.46	6.4	8.76	0.41	1.06	75.94
1978	8.59	9.56	3.36	3.16	2.91	1.8	3.15	2.2	5.41	17.98	5.4	4.22	67.74
1979	3.53	0.07	5.26	1.15	2.77	1.95	-----	10.63	19.1	17.94	16.34	4.23	82.97
1980	6.36	13.31	3.59	5.56	6.39	2.89	3.25	3.61	7.32	19.6	8.57	2.5	82.95
1981	25.43	7.26	12.29	0.28	5.5	1.61	1.75	11.75	9.19	6.74	7.24	7.33	96.37
1982	1.47	1.79	4.56	1.02	1.11	4.26	0.14	2.1	13.07	3.23	6.9	14.84	54.49
1983	5.29	5.49	1.57	5.94	3.9	1.86	2.18	5.2	5.94	11.84	14.67	2.26	66.14
1984	11.22	3.96	11.68	6.92	2.47	0.78	0.69	6.38	10.51	9.11	3.83	4.2	71.75
1985	12.68	1.38	4.55	0.57	9.29	2.08	1.99	3.43	4.32	2.09	0.54	19.67	62.59
1986	15.43	6.89	0.66	0.33	1.22	1.18	2.26	7.88	3.07	24	9.37	18.06	90.35
1987	14.63	6.55	4.21	4.54	4.73	5.76	0.97	0.93	10.48	20.7	4.01	6.4	83.91
1988	8.29	7.16	5.35	8.01	1.14	1.06	0.55	7.59	7.36	7.36	2.22	12.78	68.87
1989	3.59	0.49	0.14	6.48	3.51	4.02	4.45	11.72	13.01	14.2	4.42	10.73	76.76
1990	6.09	2.65	3.72	0.98	3.7	2.59	6.01	2.45	12.7	6.08	0.74	3.47	51.18
1991	-----	5.88	3.02	6.76	6.78	2.98	2.29	4.02	13.73	4.25	4.1	11.63	65.44
1992	8.96	4.32	7.64	1.15	0.56	1.12	2.72	7.36	2.1	6.12	14.64	4.08	60.77
1993	3.38	8.67	4.2	4.67	2.28	1.36	2.45	12.22	15.78	6.59	10.36	13.13	85.09
1994	11.02	3.44	4.49	6.67	8.34	1.53	2.45	2.09	10	9.71	5.65	9.44	66.9
1995	6.08	3.59	4.78	5.22	9.29	3.24	3.86	2.6	29.72	9.28	0.93	6.04	84.63
1996	0.2	10.05	0.89	3.07	1.03	2.64	1.6	3.36	4.05	2.72	1.61	2.11	33.33
1997	6.57	8.53	1.24	-----	2.19	1.8	-----	-----	18.78	3.01	-----	-----	42.12
1998	1.87	---	6.37	14.71	11.43	4.98	3.07	6.58	7.71	9.95	8.63	5.52	80.82
1999	6.73	3.59	6.39	4.6	2.05	1.23	1.3	4.31	9.51	6.56	4.94	13.87	65.08
2000	8.56	7.24	5.61	3.13	1.52	2.69	4.3	4.47	3.92	9.9	14.42	15.61	81.37
2001	22.33	7.76	6.92	5.57	2.38	0.63	5.03	6.44	7.78	6.4	2.72	13.2	87.16
2002	10.69	9.18	1.71	0.98	1.08	2.26	2.03	5.1	12.39	22.19	24.42	9.1	101.13
2003	5.43	14.91	2.32	2.93	4.45	2.49	2.02	10.43	7.35	8.43	3.73	12.8	77.29
2004	3.33	10.73	4.31	11.74	1.87	4.37	4.43	1.51	7.68	11.41	13.66	8.56	83.6
2005	5.82	5.24	4.93	6.55	2.74	1.34	2.38	2.75	6.98	5.57	2.1	9.5	55.9
2006	2.37	8.71	2.22	3.58	1.06	3.78	2.06	5.87	10.66	15.36	0.58	8.58	64.83
2007	9.13	2.6	0.5	5.79	1.88	2.88	1.56	3.38	6.9	7.16	22.55	7.13	71.46
2008	2.06	9.1	8.76	4.1	1.08	1.6	3.5	1.42	14.78	6.01	3.48	1.36	57.25
2009	9.7	1.04	1.19	1.99	1.25	1.67	9.95	3.78	3.58	7.84	7.52	5.68	55.19
2010	1.45	7.57	3.86	5.34	1.96	1.86	4.71	4.03	2.87	9.81	5.45	3.57	52.48
2011	4.97	3.87	0.77	4.31	2.14	1.39	1.32	8.53	10.87	12.82	2.91	8.58	62.48
2012	3.35	8.1	2.09	2.84	3.23	1.59	4.12	3.11	26.28	2.84	0.55	7.1	65.2
2013	8.88	5.66	6.14	0.69	5.74	1.02	6.28	10.72	11.2	18.63	2.85	0.95	78.76
2014	12.38	0.62	2.4	0.61	1.28	0.74	1.82	10.03	10.52	2.9	8.6	6.8	58.7
Mean	6.51	5.99	3.90	4.28	3.68	2.34	2.62	5.36	10.34	9.73	6.89	7.40	67.97

Appendix F- Summary HEC-RAS Results

HEC-RAS analysis results for Existing Ground (EG) and Alternatives 1.1, 2.2, and 3.0.

EG

XS	River Sta	Runway 13/31 Elev (ft)	Profile	Without Coastal Flooding Effects			With Coastal Flooding Effects	
				Vel Chnl (ft/s)	W.S. Elev (ft)	Freeboard (ft)	W.S. Elev (ft)	Freeboard (ft)
A	144	-	100-yr	3.49	12.63	-	16.20	-
			500-yr	3.77	13.15	-	16.20	-
B	698	-	100-yr	6.52	13.44	-	16.20	-
			500-yr	6.80	13.96	-	16.20	-
C	1336	18.47	100-yr	1.00	13.91	4.56	16.20	2.27
			500-yr	1.18	14.46	4.01	16.20	2.27
D	1791	18.99	100-yr	2.67	13.97	5.02	16.20	2.79
			500-yr	2.99	14.53	4.46	16.20	2.79
E	2432	19.15	100-yr	3.41	15.24	3.91	16.20	2.95
			500-yr	3.86	15.80	3.35	16.20	2.95
F	3094	19.26	100-yr	5.29	17.12	2.14	17.12	2.14
			500-yr	5.68	17.64	1.62	17.64	1.62
G	3589	19.31	100-yr	6.32	19.15	0.16	19.15	0.16
			500-yr	6.20	19.64	-0.33	19.64	-0.33
H	3950	19.47	100-yr	4.95	20.98	-1.51	20.98	-1.51
			500-yr	5.20	21.42	-1.95	21.42	-1.95
I	4460	19.59	100-yr	4.70	22.24	-2.65	22.24	-2.65
			500-yr	5.08	22.64	-3.05	22.64	-3.05
J	4994	20.58	100-yr	5.53	24.00	-3.42	24.00	-3.42
			500-yr	5.99	24.39	-3.81	24.39	-3.81
K	5408	23.27	100-yr	5.10	25.77	-2.5	25.77	-2.5
			500-yr	5.56	26.16	-2.89	26.16	-2.89
L	6068	27.05	100-yr	6.35	28.31	-1.26	28.31	-1.26
			500-yr	6.78	28.69	-1.64	28.69	-1.64
M	6545	-	100-yr	7.62	30.21	-	30.21	-
			500-yr	8.26	30.60	-	30.6	-
N	7067	-	100-yr	9.21	32.52	-	32.52	-
			500-yr	10.10	32.97	-	32.97	-
O	7482	-	100-yr	3.65	35.58	-	35.58	-
			500-yr	3.95	36.22	-	36.22	-

Alternative 1.1

XS	River Sta	Runway 13/31 Elev (ft)	Profile	Without Coastal Flooding Effects			With Coastal Flooding Effects		Q100 Elev Increase		
				Vel Chnl (ft/s)	W.S. Elev (ft)	Free-board (ft)	W.S. Elev (ft)	Free-board (ft)	EG Elev (ft)	Alt 1.1 Elev (ft)	Increase (ft)
A	144	-	100-yr	3.49	12.63	-	16.20	-	12.63	12.63	0.00
			500-yr	3.77	13.15	-	16.20	-	-	-	-
B	698	-	100-yr	6.52	13.44	-	16.20	-	13.44	13.44	0.00
			500-yr	6.80	13.96	-	16.20	-	-	-	-
C	1336	19.08	100-yr	9.43	15.47	3.61	16.20	2.88	13.91	15.47	1.56
			500-yr	10.03	15.95	3.13	16.20	2.88	-	-	-
D	1791	20.40	100-yr	5.53	17.58	2.82	17.58	2.82	13.97	17.58	3.61
			500-yr	6.03	18.12	2.28	18.12	2.28	-	-	-
E	2432	22.00	100-yr	6.68	19.10	2.90	19.10	2.90	15.24	19.10	3.86
			500-yr	7.17	19.70	2.30	19.70	2.30	-	-	-
F	3094	23.77	100-yr	3.26	21.16	2.61	21.16	2.61	17.12	21.16	4.04
			500-yr	3.49	21.78	1.99	21.78	1.99	-	-	-
G	3589	24.54	100-yr	4.70	22.02	2.52	22.02	2.52	19.15	22.02	2.87
			500-yr	5.07	22.61	1.93	22.61	1.93	-	-	-
H	3950	25.38	100-yr	5.06	22.74	2.64	22.74	2.64	20.98	22.74	1.76
			500-yr	5.39	23.33	2.05	23.33	2.05	-	-	-
I	4460	26.38	100-yr	5.64	23.63	2.75	23.63	2.75	22.24	23.63	1.39
			500-yr	6.11	24.19	2.19	24.19	2.19	-	-	-
J	4994	27.57	100-yr	6.18	25.02	2.55	25.02	2.55	24.00	25.02	1.02
			500-yr	6.64	25.57	2.00	25.57	2.00	-	-	-
K	5408	29.27	100-yr	5.37	26.56	2.71	26.56	2.71	25.77	26.56	0.79
			500-yr	5.70	27.06	2.21	27.06	2.21	-	-	-
L	6068	31.47	100-yr	6.70	28.71	2.76	28.71	2.76	28.31	28.71	0.40
			500-yr	7.22	29.13	2.34	29.13	2.34	-	-	-
M	6545	33.00	100-yr	7.18	30.51	2.49	30.51	2.49	30.21	30.51	0.30
			500-yr	7.80	30.97	2.03	30.97	2.03	-	-	-
N	7067	33.86	100-yr	9.28	32.49	1.37	32.49	1.37	32.52	32.49	-0.03
			500-yr	10.07	32.98	0.88	32.98	0.88	-	-	-
O	7482	-	100-yr	3.64	35.59	-	35.59	-	35.58	35.59	0.01
			500-yr	3.95	36.22	-	36.22	-	-	-	-

Alternative 2.2

XS	River Sta	Runway 16/34 Elev (ft)	Profile	Without Coastal Flooding Effects			With Coastal Flooding Effects		With Coastal Flooding Q100 Elev Increase		
				Vel Chnl	W.S. Elev	Free-board	W.S. Elev	Free-board	EG Elev	Alt 2.2 Elev	Increase
				(ft/s)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
A	144	-	100-yr	3.49	12.63	-	16.20	-	12.63	12.63	0.00
			500-yr	3.77	13.15	-	16.20	-	-	-	-
B	698	-	100-yr	6.52	13.44	-	16.20	-	13.44	13.44	0.00
			500-yr	6.80	13.96	-	16.20	-	-	-	-
C	1336	-	100-yr	1.00	13.91	-	16.20	-	13.91	13.91	0.00
			500-yr	1.18	14.46	-	16.20	-	-	-	-
D	1791	18.96	100-yr	3.96	13.90	5.06	16.20	2.76	13.97	13.90	-0.07
			500-yr	4.25	14.45	4.51	16.20	2.76	-	-	-
E	2432	19.70	100-yr	4.12	15.94	3.76	16.20	3.50	15.24	15.94	0.70
			500-yr	4.66	16.52	3.18	16.52	3.18	-	-	-
F	3094	20.66	100-yr	3.66	17.90	2.76	17.90	2.76	17.12	17.90	0.78
			500-yr	3.14	18.59	2.07	18.59	2.07	-	-	-
G	3589	22.10	100-yr	5.30	19.59	2.51	19.59	2.51	19.15	19.59	0.44
			500-yr	5.16	20.25	1.85	20.25	1.85	-	-	-
H	3950	23.68	100-yr	5.07	21.16	2.52	21.16	2.52	20.98	21.16	0.18
			500-yr	5.39	21.66	2.02	21.66	2.02	-	-	-
I	4460	25.12	100-yr	5.16	22.52	2.60	22.52	2.60	22.24	22.52	0.28
			500-yr	5.64	22.97	2.15	22.97	2.15	-	-	-
J	4994	26.86	100-yr	5.65	24.25	2.61	24.25	2.61	24.00	24.25	0.25
			500-yr	6.11	24.70	2.16	24.70	2.16	-	-	-
K	5408	28.71	100-yr	5.24	25.94	2.77	25.94	2.77	25.77	25.94	0.17
			500-yr	5.71	26.37	2.34	26.37	2.34	-	-	-
L	6068	31.19	100-yr	7.16	28.56	2.63	28.56	2.63	28.31	28.56	0.25
			500-yr	7.70	28.96	2.23	28.96	2.23	-	-	-
M	6545	-	100-yr	6.96	30.55	-	30.55	-	30.21	30.55	0.34
			500-yr	7.56	31.01	-	31.01	-	-	-	-
N	7067	-	100-yr	9.49	32.42	-	32.42	-	32.52	32.42	-0.10
			500-yr	10.34	32.89	-	32.89	-	-	-	-
O	7482	-	100-yr	3.62	35.62	-	35.62	-	35.58	35.62	0.04
			500-yr	3.92	36.26	-	36.26	-	-	-	-

Alternative 3.0

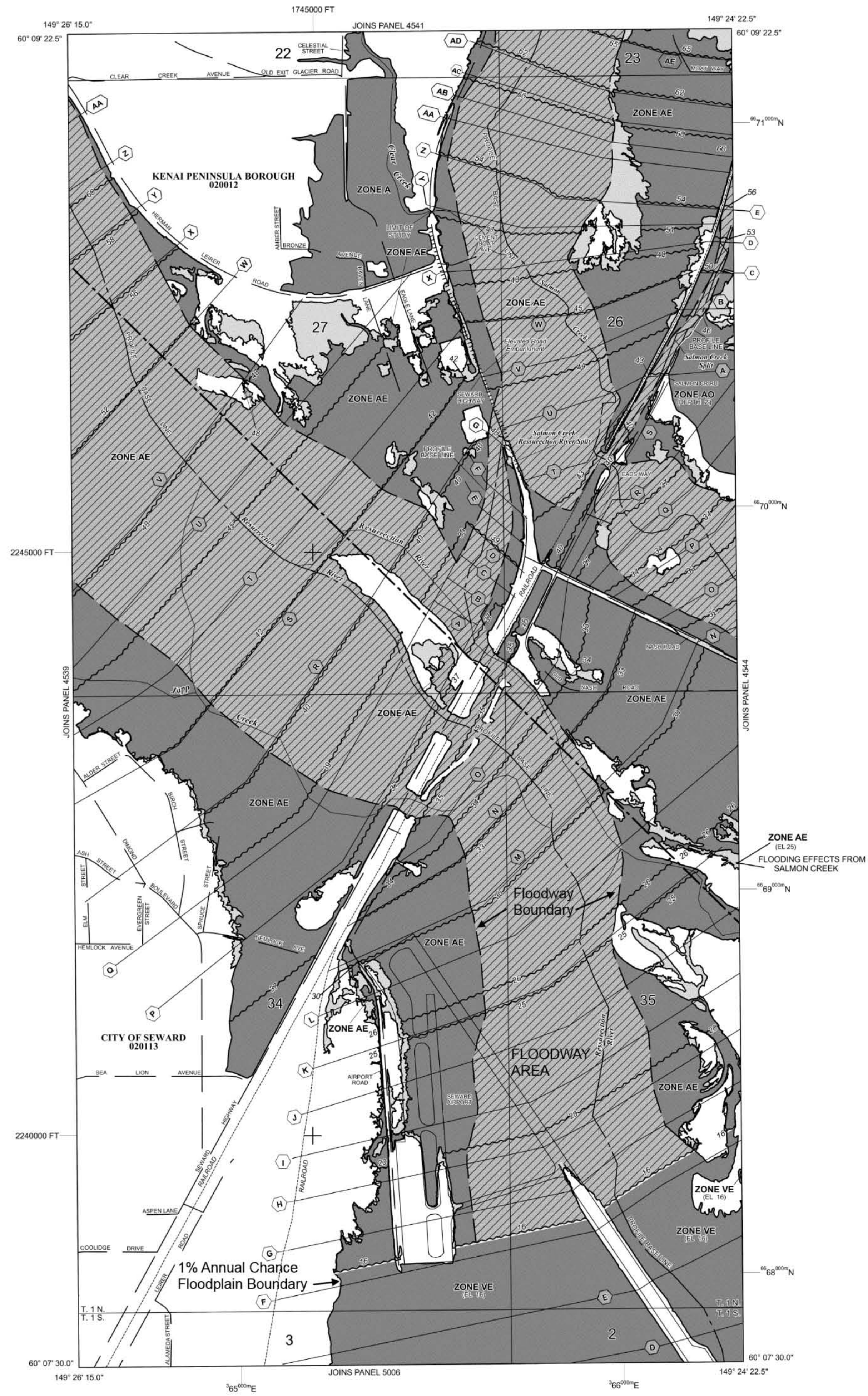
XS	River Sta	Runway 16/34 Elev (ft)	Profile	Without Coastal Flooding Effects			With Coastal Flooding Effects		With Coastal Flooding Q100 Elev Increase		
				Vel Chnl	W.S. Elev	Free-board	W.S. Elev	Free-board	EG Elev	Alt 3.0 Elev	Increase
				(ft/s)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)	(ft)
A	144	-	100-yr	3.49	12.63	-	16.20	-	12.63	12.63	0.00
			500-yr	3.77	13.15	-	16.20	-	-	-	-
B	698	-	100-yr	6.52	13.44	-	16.20	-	13.44	13.44	0.00
			500-yr	6.80	13.96	-	16.20	-	-	-	-
C	1336	18.91	100-yr	1.59	14.16	4.75	16.20	2.71	13.91	14.16	0.25
			500-yr	1.86	14.71	4.20	16.20	2.71	-	-	-
D	1791	19.00	100-yr	3.44	14.45	4.55	16.20	2.80	13.97	14.45	0.48
			500-yr	3.96	15.03	3.97	16.20	2.80	-	-	-
E	2432	19.58	100-yr	4.09	15.99	3.59	16.20	3.38	15.24	15.99	0.75
			500-yr	4.61	16.59	2.99	16.59	2.99	-	-	-
F	3094	20.74	100-yr	3.65	17.91	2.83	17.91	2.83	17.12	17.91	0.79
			500-yr	3.13	18.60	2.14	18.60	2.14	-	-	-
G	3589	22.17	100-yr	5.28	19.58	2.59	19.58	2.59	19.15	19.58	0.43
			500-yr	5.12	20.23	1.94	20.23	1.94	-	-	-
H	3950	23.68	100-yr	4.90	21.11	2.57	21.11	2.57	20.98	21.11	0.13
			500-yr	5.21	21.60	2.08	21.60	2.08	-	-	-
I	4460	25.15	100-yr	5.09	22.45	2.70	22.45	2.70	22.24	22.45	0.21
			500-yr	5.59	22.89	2.26	22.89	2.26	-	-	-
J	4994	26.83	100-yr	5.72	24.21	2.62	24.21	2.62	24.00	24.21	0.21
			500-yr	6.18	24.67	2.16	24.67	2.16	-	-	-
K	5408	28.62	100-yr	5.38	25.97	2.65	25.97	2.65	25.77	25.97	0.20
			500-yr	5.86	26.41	2.21	26.41	2.21	-	-	-
L	6068	31.15	100-yr	7.03	28.60	2.55	28.60	2.55	28.31	28.60	0.29
			500-yr	7.56	29.01	2.14	29.01	2.14	-	-	-
M	6545	-	100-yr	7.00	30.54	-	30.54	-	30.21	30.54	0.33
			500-yr	7.59	30.99	-	30.99	-	-	-	-
N	7067	-	100-yr	9.47	32.43	-	32.43	-	32.52	32.43	-0.09
			500-yr	10.30	32.90	-	32.90	-	-	-	-
O	7482	-	100-yr	3.62	35.62	-	35.62	-	35.58	35.62	0.04
			500-yr	3.92	36.25	-	36.25	-	-	-	-

Appendix G – Scour Equations and Results

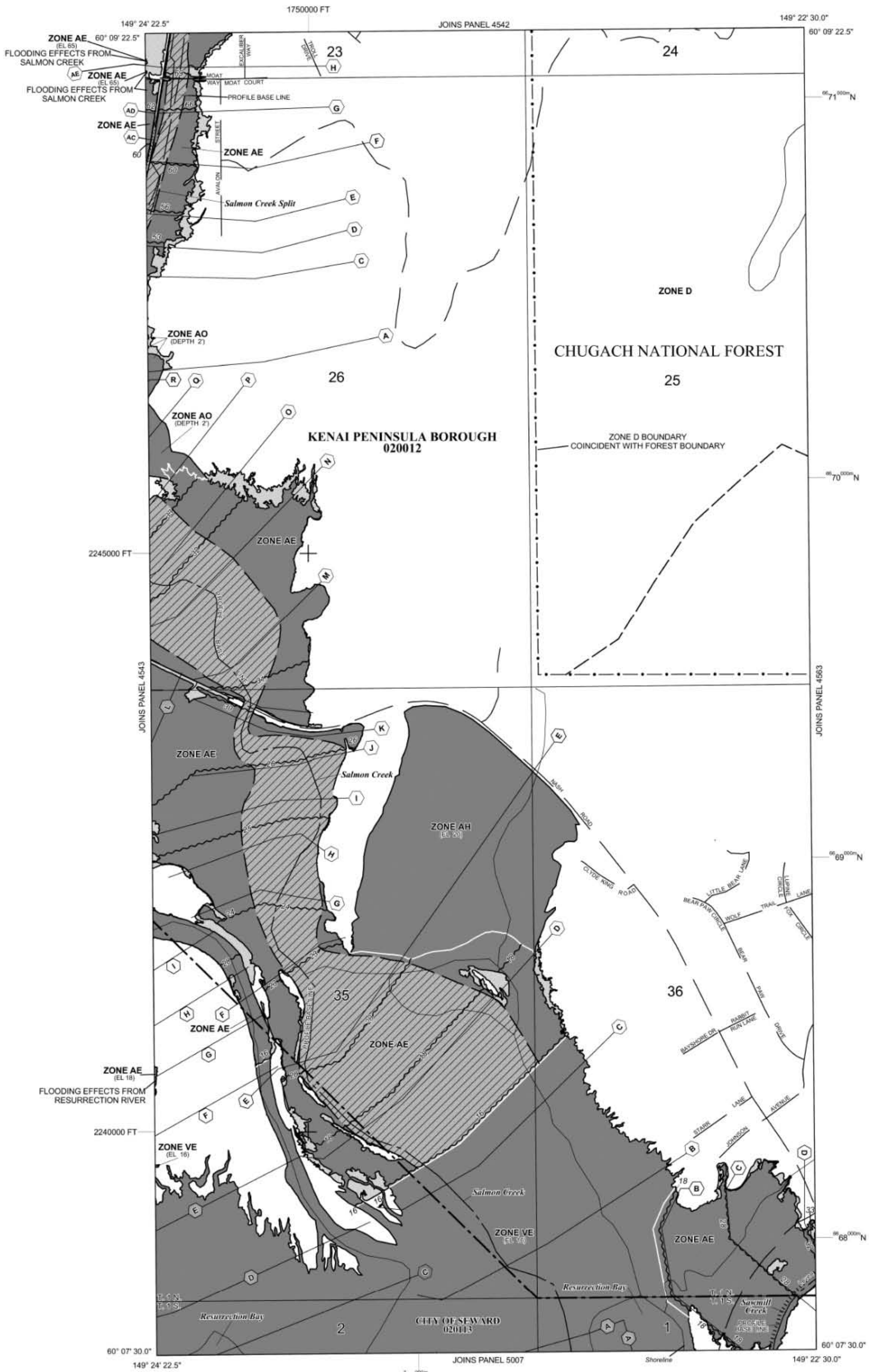
All results in units of feet.

Method	Alt 1.1 xsec 3950	Alt 1.1 xsec 3094	Alt 2.2 xsec 3950	Alt 2.2 xsec 3094	Alt 3 xsec 3950	Alt 3 xsec 3094	Alt 3 xsec 1791
Competent Velocity Corps Bend Total	-0.12 3.9 3.9	-1.66 4.05 4.05	0.27 4.26 4.53	0.47 6.74 7.21	0.21 3.04 3.25	-0.8 4.41 4.41	na
Competent Velocity Thorne Bend Total	-0.12 5.07 5.07	-1.66 5.07 5.07	0.27 5.07 5.34	0.47 5.07 5.54	0.21 4.63 4.84	-0.8 4.63 4.63	na
Neil	11.17	8.4	12.58	11.53	12.17	11.9	11.61
Lacey	2.67	3.81	2.84	1.92	2.35	2.92	2.91
Blench	2.7	2.1	3.0	2.78	2.92	2.86	2.79
Maximum	11.17	8.4	12.58	11.53	12.17	11.9	11.61
Minimum	3.0	2.1	2.84	1.92	2.35	2.86	2.79
Average	5.1	4.7	5.7	5.8	5.1	5.3	5.8

Appendix H-Flood Insurance Rate Maps for Seward Airport and Vicinity

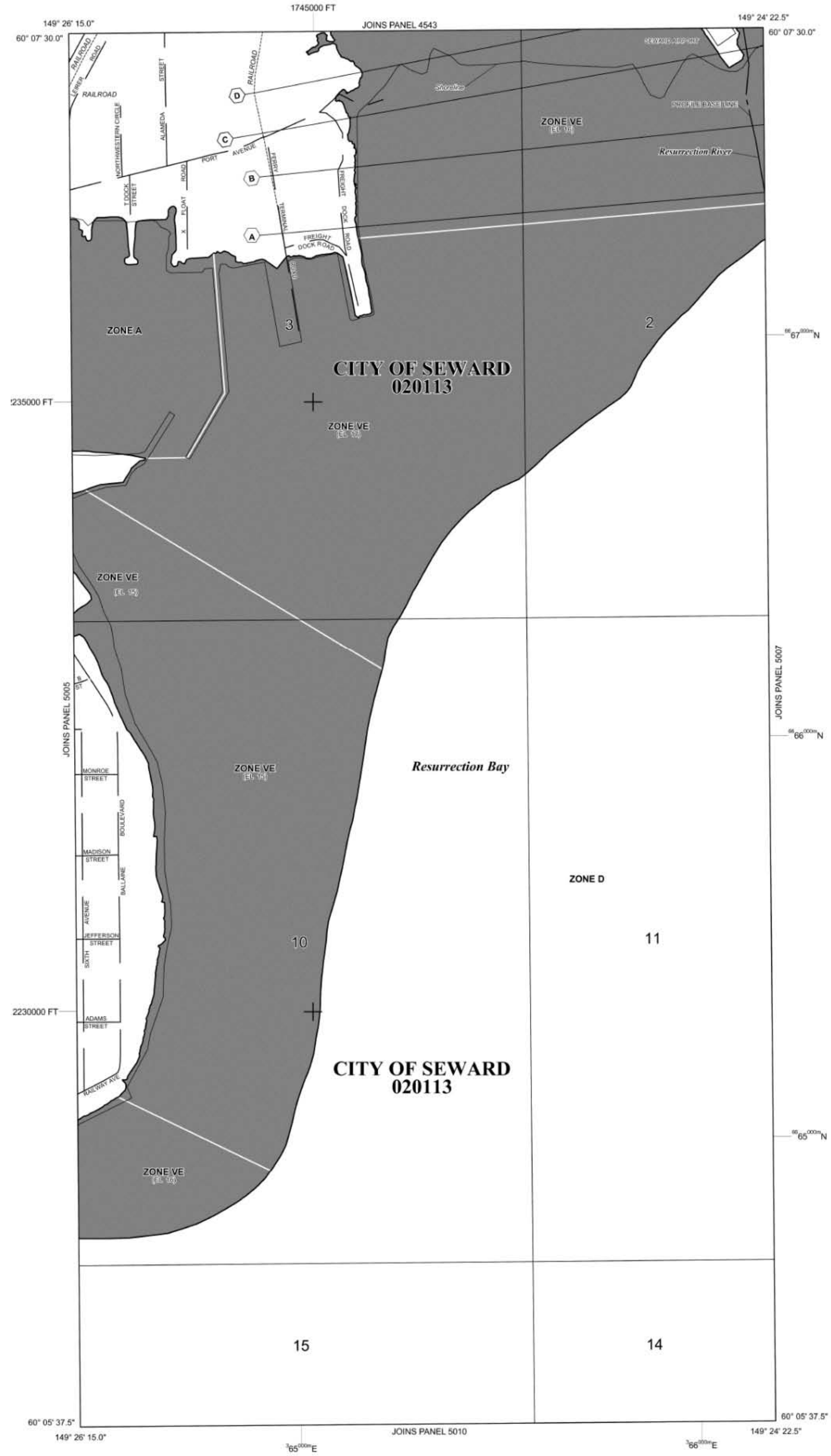


Panel 4543

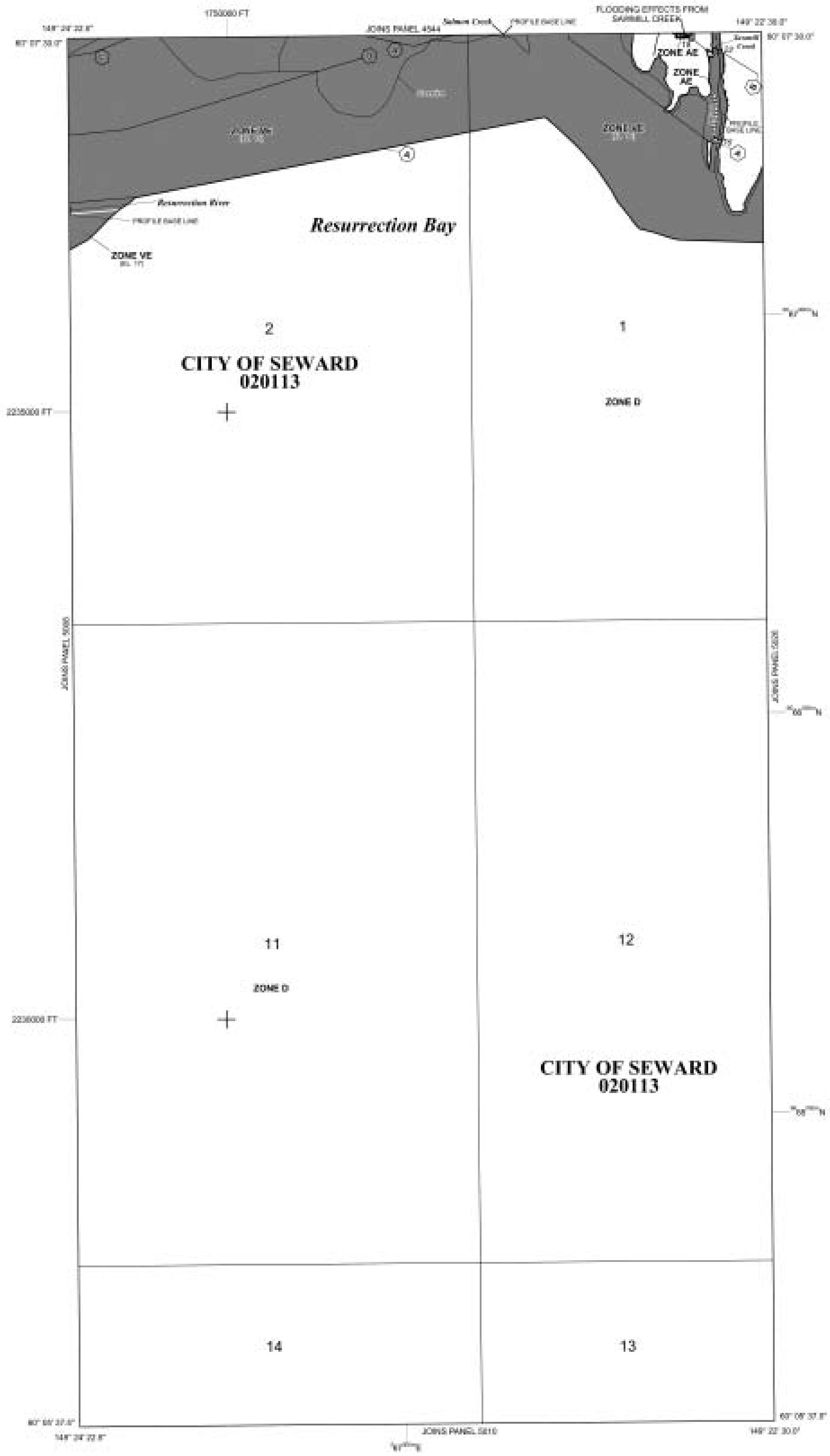


1750000 FT
149° 24' 22.5"
JOINS PANEL 4542
149° 22' 30.0"
60° 09' 22.5"
ZONE AE
(EL 65)
FLOODING EFFECTS FROM SALMON CREEK
ZONE AE
(EL 65)
FLOODING EFFECTS FROM SALMON CREEK
ZONE AE
PROFILE BASE LINE
MOAT WAY
MOAT COURT
ZONE AE
Salmon Creek Split
ZONE D
CHUGACH NATIONAL FOREST
ZONE AO
(DEPTH 2')
ZONE AO
(DEPTH 2')
KENAI PENINSULA BOROUGH
020012
ZONE D BOUNDARY
COINCIDENT WITH FOREST BOUNDARY
23
24
26
25
35
36
2
1
ZONE AE
2245000 FT
JOINS PANEL 4543
JOINS PANEL 4563
Salmon Creek
ZONE AH
NASH ROAD
CLYDE KING ROAD
LITTLE BEAR LANE
BEAR PAW CIRCLE
WOLF TRAIL
FOX CIRCLE
BAYSHORE DR
RABBIT RUN LANE
STARR
JOHNSON
AVENUE
ZONE AE
(EL 18)
FLOODING EFFECTS FROM RESURRECTION RIVER
2240000 FT
ZONE VE
(EL 16)
Salmon Creek
ZONE VE
ZONE AE
Resurrection Bay
Resurrection Bay
T. 1 N.
T. 1 S.
Sawmill Creek
CITY OF SEWARD
020113
60° 07' 30.0"
149° 24' 22.5"
JOINS PANEL 5007
Shoreline
149° 22' 30.0"

Panel 4544


1745000 FT
149° 26' 15.0"
60° 07' 30.0"
JOINS PANEL 4543
149° 24' 22.5"
60° 07' 30.0"
RAILROAD
PORT AVENUE
FREIGHT DOCK ROAD
Resurrection River
ZONE VE
ZONE A
CITY OF SEWARD
020113
2235000 FT
ZONE VE
ZONE VE
JOINS PANEL 5005
JOINS PANEL 5007
Resurrection Bay
MONROE STREET
MADISON STREET
JEFFERSON STREET
ADAMS STREET
BALLAINE BOULEVARD
SIXTH AVENUE
RAILWAY AVE
ZONE D
2230000 FT
CITY OF SEWARD
020113
ZONE VE
2
3
10
11
14
15
60° 05' 37.5"
149° 26' 15.0"
JOINS PANEL 5010
60° 05' 37.5"
149° 24' 22.5"

Panel 5006


FLOODING EFFECTS FROM
SAWMILL CREEK
JOINS PANEL 4544
ZONE AE
Resurrection Bay
ZONE VE
2
CITY OF SEWARD
020113
1
ZONE D
11
ZONE D
12
CITY OF SEWARD
020113
14
13
JOINS PANEL 5010

Panel 5007

Appendix I-Complete HEC-RAS Output Results for All Hydraulic Models

Resurrection River Existing Conditions Model 100-year Flood - HEC-RAS Standard Table 1

Reach	River Station	Total Discharge	Minimum Channel Elevation	Water Surface Elevation	Critical Water Surface Elevation	Energy Gradeline Elevation	Energy Gradeline Slope	Channel Velocity	Flow Area	Top Width	Froude Number
	(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Resurrection R	144	29160	2.29	12.63	10.47	12.79	0.001	3.49	11237.39	8100.84	0.3
Resurrection R	698	29160	2.09	13.44	12.29	13.73	0.002172	6.52	8432.63	7559.62	0.45
Resurrection R	1336	29160	7.81	13.91	8.23	13.95	0.000103	1	21357.56	5470.5	0.1
Resurrection R	1791	29160	7.22	13.97	11.5	14.1	0.00191	2.67	10254.3	3669.35	0.35
Resurrection R	2432	29160	5.18	15.24	12.98	15.35	0.002159	3.41	11151.41	3775.97	0.38
Resurrection R	3094	29160	9.35	17.12	15.29	17.33	0.004453	5.29	8899.99	3243.36	0.58
Resurrection R	3589	29160	12.51	19.15	17.61	19.52	0.005828	6.32	6570.57	2699.78	0.66
Resurrection R	3950	29160	11.1	20.98	19.63	21.23	0.003442	4.95	7516.93	3273.47	0.52
Resurrection R	4460	29160	14.88	22.24	21.12	22.53	0.002713	4.7	7042.58	3322.53	0.47
Resurrection R	4994	29160	15.53	24	23.01	24.28	0.004179	5.53	7324.38	3339.32	0.57
Resurrection R	5408	29160	17.98	25.77	24.56	26.07	0.004017	5.1	7323.43	3694.93	0.55
Resurrection R	6068	29160	21.15	28.31	27.59	28.71	0.003922	6.35	7595.72	3725.94	0.58
Resurrection R	6545	29160	22.38	30.21	29.72	30.95	0.004728	7.62	5581.69	3005.11	0.64
Resurrection R	7067	29160	22.72	32.52	32.24	33.73	0.006862	9.21	3994.18	2706.98	0.78
Resurrection R	7482	29160	21.42	35.58	31.89	35.83	0.003422	3.65	7728.7	2492.63	0.27

Resurrection River Alternative 1.1 Model 100-year Flood - HEC-RAS Standard Table 1

Reach	River Station	Total Discharge	Minimum Channel Elevation	Water Surface Elevation	Critical Water Surface Elevation	Energy Gradeline Elevation	Energy Gradeline Slope	Channel Velocity	Flow Area	Top Width	Froude Number
	(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Resurrection R	144	29160	2.29	12.63	10.47	12.79	0.001	3.49	11237.39	8100.84	0.3
Resurrection R	698	29160	2.09	13.44	12.29	13.73	0.002172	6.52	8432.63	7559.62	0.45
Resurrection R	1336	29160	7.81	15.47	15.11	16.3	0.00555	9.43	6438.17	4124.5	0.74
Resurrection R	1791	29160	7.22	17.58	15.87	17.92	0.00201	5.53	9177.76	4329.76	0.43
Resurrection R	2432	29160	5.18	19.1	17.53	19.47	0.002471	6.68	9648.79	4388.34	0.47
Resurrection R	3094	29160	9.35	21.16	18.63	21.31	0.002467	3.26	9231.95	3828.45	0.25
Resurrection R	3589	29160	12.51	22.02	20.09	22.29	0.001866	4.7	8218.07	3325.18	0.4
Resurrection R	3950	29160	11.1	22.74	21.12	23.01	0.00209	5.06	7784.23	2745.25	0.42
Resurrection R	4460	29160	14.88	23.63	22.02	23.96	0.002387	5.64	7624.6	2796	0.47
Resurrection R	4994	29160	15.53	25.02	23.58	25.37	0.003535	6.18	8015.95	2927.56	0.55
Resurrection R	5408	29160	17.98	26.56	25.01	26.86	0.003166	5.37	8219.95	3866.15	0.51
Resurrection R	6068	29160	21.15	28.71	27.98	29.22	0.003806	6.7	7623.2	3452.88	0.58
Resurrection R	6545	29160	22.38	30.51	29.72	31.18	0.003854	7.18	5594.68	2722.59	0.58
Resurrection R	7067	29160	22.72	32.49	32.14	33.73	0.007011	9.28	3955.54	2199.69	0.79
Resurrection R	7482	29160	21.42	35.59	31.89	35.84	0.003391	3.64	7748.24	2372.27	0.27

Resurrection River Alternative 2.2 Model 100-year Flood - HEC-RAS Standard Table 1

Reach	River Station	Total Discharge	Minimum Channel Elevation	Water Surface Elevation	Critical Water Surface Elevation	Energy Gradeline Elevation	Energy Gradeline Slope	Channel Velocity	Flow Area	Top Width	Froude Number
	(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Resurrection R	144	29160	2.29	12.63	10.47	12.79	0.001	3.49	11237.39	8100.84	0.3
Resurrection R	698	29160	2.09	13.44	12.29	13.73	0.002172	6.52	8432.63	7559.62	0.45
Resurrection R	1336	29160	7.81	13.91	8.23	13.95	0.000103	1	21357.56	5470.5	0.1
Resurrection R	1791	29160	7.22	13.9	12.39	14.16	0.004293	3.96	7115.37	2860.79	0.52
Resurrection R	2432	29160	5.18	15.94	13.47	16.13	0.002412	4.12	8654.95	3152.48	0.4
Resurrection R	3094	29160	9.35	17.9	15.23	18.09	0.003787	3.66	8274.8	2480.17	0.38
Resurrection R	3589	29160	12.51	19.59	17.52	19.88	0.004582	5.3	7344.26	2514.5	0.55
Resurrection R	3950	29160	11.1	21.16	19.75	21.43	0.003648	5.07	7384.36	2881.82	0.5
Resurrection R	4460	29160	14.88	22.52	21.1	22.81	0.002919	5.16	7277.65	2886.94	0.49
Resurrection R	4994	29160	15.53	24.25	23.03	24.56	0.003905	5.65	7124.58	2977.52	0.56
Resurrection R	5408	29160	17.98	25.94	24.71	26.27	0.003939	5.24	6854.12	3423.81	0.55
Resurrection R	6068	29160	21.15	28.56	27.98	29.15	0.004568	7.16	6959.14	3297.62	0.63
Resurrection R	6545	29160	22.38	30.55	29.72	31.17	0.003577	6.96	5903.48	2845.62	0.56
Resurrection R	7067	29160	22.72	32.42	32.24	33.72	0.007497	9.49	3837.62	2157.91	0.81
Resurrection R	7482	29160	21.42	35.62	31.89	35.87	0.003323	3.62	7792.32	2374.37	0.27

Resurrection River Alternative 3.0 Model 100-year Flood - HEC-RAS Standard Table 1

Reach	River Station	Total Discharge	Minimum Channel Elevation	Water Surface Elevation	Critical Water Surface Elevation	Energy Gradeline Elevation	Energy Gradeline Slope	Channe l Velocit y	Flow Area	Top Width	Frou de Num ber
	(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)	
Resurrection R	144	29160	2.29	12.63	10.47	12.79	0.001	3.49	11237.39	8100.84	0.3
Resurrection R	698	29160	2.09	13.44	12.29	13.73	0.002172	6.52	8432.63	7559.62	0.45
Resurrection R	1336	29160	7.81	14.16	9.7	14.24	0.000354	1.59	13670.97	4596.04	0.15
Resurrection R	1791	29160	7.22	14.45	12.38	14.63	0.002673	3.44	8639.81	3364.16	0.43
Resurrection R	2432	29160	5.18	15.99	13.47	16.18	0.002335	4.09	8801.9	3212.01	0.4
Resurrection R	3094	29160	9.35	17.91	15.23	18.1	0.003766	3.65	8290.38	2485.93	0.37
Resurrection R	3589	29160	12.51	19.58	17.54	19.87	0.004485	5.28	7303.85	2501.33	0.55
Resurrection R	3950	29160	11.1	21.11	19.69	21.38	0.003521	4.9	7217.75	2832.71	0.49
Resurrection R	4460	29160	14.88	22.45	21.07	22.74	0.002925	5.09	7091.07	2853.5	0.49
Resurrection R	4994	29160	15.53	24.21	23.03	24.53	0.004061	5.72	7018.85	2965.58	0.57
Resurrection R	5408	29160	17.98	25.97	24.75	26.31	0.004089	5.38	6912.41	3454.44	0.56
Resurrection R	6068	29160	21.15	28.6	27.98	29.17	0.004346	7.03	7082.23	3310.56	0.62
Resurrection R	6545	29160	22.38	30.54	29.72	31.17	0.003624	7	5869.84	2832.07	0.56
Resurrection R	7067	29160	22.72	32.43	32.24	33.72	0.007438	9.47	3851.26	2162.53	0.81
Resurrection R	7482	29160	21.42	35.62	31.89	35.86	0.003331	3.62	7787.12	2374.2	0.27

Resurrection River Existing Conditions Model 100-year Flood - HEC-RAS Standard Table 2

Reach	River Station	Energy Gradeline Elevation	Water Surface Elevation	Velocity Head	Friction Loss	Contraction And Expansion Loss	Discharge Left Overbank	Discharge Channel	Discharge Right Overbank	Top Width
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Main	144	12.79	12.63	0.16			4845.73	17997.81	6316.46	8100.84
Main	698	13.73	13.44	0.29	0.9	0.04	16622.92	8518.95	4018.14	7559.62
Main	1336	13.95	13.91	0.03	0.19	0.03	485.52	1296.84	27377.64	5470.5
Main	1791	14.1	13.97	0.13	0.13	0.03	377.74	2841.23	25941.03	3669.35
Main	2432	15.35	15.24	0.11	1.25	0	595.85	3079.65	25484.51	3775.97
Main	3094	17.33	17.12	0.21	1.95	0.03	1467.54	7734.58	19957.88	3243.36
Main	3589	19.52	19.15	0.37	2.14	0.05	2094.13	11241.82	15824.05	2699.78
Main	3950	21.23	20.98	0.25	1.69	0.01	6474.65	8376.83	14308.53	3273.47
Main	4460	22.53	22.24	0.29	1.29	0.01	5146.21	9733.63	14280.17	3322.53
Main	4994	24.28	24	0.29	1.76	0	4127.23	9447.72	15585.04	3339.32
Main	5408	26.07	25.77	0.29	1.78	0	1180.16	12264.79	15715.04	3694.93
Main	6068	28.71	28.31	0.41	2.61	0.03	4554.81	17040.59	7564.61	3725.94
Main	6545	30.95	30.21	0.74	2.14	0.1	3241.72	23284.41	2633.88	3005.11
Main	7067	33.73	32.52	1.22	2.64	0.14	1861.17	26091.15	1207.69	2706.98
Main	7482	35.83	35.58	0.24	2	0.1	2063.33	27089.45	7.22	2492.63

Resurrection River Alt 1.1 Model 100-year Flood - HEC-RAS Standard Table 2

Reach	River Station	Energy Gradeline Elevation	Water Surface Elevation	Velocity Head	Friction Loss	Contraction And Expansion Loss	Discharge Left Overbank	Discharge Channel	Discharge Right Overbank	Top Width
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Main	144	12.79	12.63	0.16			4845.73	17997.81	6316.46	8100.84
Main	698	13.73	13.44	0.29	0.9	0.04	16622.92	8518.95	4018.14	7559.62
Main	1336	16.3	15.47	0.83	2.41	0.16	12422.45	16516.23	221.32	4124.5
Main	1791	17.92	17.58	0.33	1.56	0.05	9609.94	19524.41	25.65	4329.76
Main	2432	19.47	19.1	0.37	1.54	0.01	14940.19	14168.1	51.71	4388.34
Main	3094	21.31	21.16	0.16	1.82	0.02	14249.61	14818.79	91.6	3828.45
Main	3589	22.29	22.02	0.27	0.94	0.03	7716.77	21441.83	1.4	3325.18
Main	3950	23.01	22.74	0.27	0.72	0	14984.05	14129.03	46.93	2745.25
Main	4460	23.96	23.63	0.33	0.94	0.02	10766.81	16895.06	1498.13	2796
Main	4994	25.37	25.02	0.35	1.4	0	7771.4	14365.53	7023.07	2927.56
Main	5408	26.86	26.56	0.3	1.49	0	3155.42	16781.24	9223.34	3866.15
Main	6068	29.22	28.71	0.51	2.3	0.06	6710.14	19921.37	2528.49	3452.88
Main	6545	31.18	30.51	0.67	1.92	0.05	4147.91	23434.85	1577.24	2722.59
Main	7067	33.73	32.49	1.23	2.38	0.17	1834.78	26140	1185.23	2199.69
Main	7482	35.84	35.59	0.24	2.01	0.1	2086.65	27065.87	7.48	2372.27

Resurrection River Alt 2.2 Model 100-year Flood - HEC-RAS Standard Table 2

Reach	River Station	Energy Gradeline Elevation	Water Surface Elevation	Velocity Head	Friction Loss	Contraction And Expansion Loss	Discharge Left Overbank	Discharge Channel	Discharge Right Overbank	Top Width
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Main	144	12.79	12.63	0.16			4845.73	17997.81	6316.46	8100.84
Main	698	13.73	13.44	0.29	0.9	0.04	16622.92	8518.95	4018.14	7559.62
Main	1336	13.95	13.91	0.03	0.19	0.03	485.52	1296.84	27377.64	5470.5
Main	1791	14.16	13.9	0.27	0.14	0.07	510.62	4028.52	24620.86	2860.79
Main	2432	16.13	15.94	0.19	1.96	0.01	1427.12	4745.95	22986.93	3152.48
Main	3094	18.09	17.9	0.19	1.96	0	2538.09	7075.33	19546.57	2480.17
Main	3589	19.88	19.59	0.29	1.76	0.03	2622.34	12525.4	14012.27	2514.5
Main	3950	21.43	21.16	0.27	1.55	0	7578.2	11084.69	10497.11	2881.82
Main	4460	22.81	22.52	0.28	1.38	0	6261.88	11651.85	11246.28	2886.94
Main	4994	24.56	24.25	0.31	1.74	0.01	4787.21	10481.03	13891.76	2977.52
Main	5408	26.27	25.94	0.33	1.71	0.01	1454.42	13361.74	14343.84	3423.81
Main	6068	29.15	28.56	0.59	2.8	0.08	6341.96	20489.9	2328.14	3297.62
Main	6545	31.17	30.55	0.62	2.02	0.01	4193.44	22926.32	2040.24	2845.62
Main	7067	33.72	32.42	1.3	2.34	0.2	1758.28	26286.44	1115.27	2157.91
Main	7482	35.87	35.62	0.24	2.04	0.11	2139.15	27012.79	8.07	2374.37

Resurrection River Alt 3.0 Model 100-year Flood - HEC-RAS Standard Table 2

Reach	River Station	Energy Gradeline Elevation	Water Surface Elevation	Velocity Head	Friction Loss	Contraction And Expansion Loss	Discharge Left Overbank	Discharge Channel	Discharge Right Overbank	Top Width
		(ft)	(ft)	(ft)	(ft)	(ft)	(cfs)	(cfs)	(cfs)	(ft)
Main	144	12.79	12.63	0.16			4845.73	17997.81	6316.46	8100.84
Main	698	13.73	13.44	0.29	0.9	0.04	16622.92	8518.95	4018.14	7559.62
Main	1336	14.24	14.16	0.09	0.49	0.02	1145.24	2213.36	25801.4	4596.04
Main	1791	14.63	14.45	0.18	0.36	0.03	805.58	4717.96	23636.46	3364.16
Main	2432	16.18	15.99	0.19	1.56	0	1434.02	4793.25	22932.73	3212.01
Main	3094	18.1	17.91	0.19	1.92	0	2544.37	7064.68	19550.95	2485.93
Main	3589	19.87	19.58	0.29	1.74	0.03	2569.28	12372.07	14218.64	2501.33
Main	3950	21.38	21.11	0.27	1.51	0	7177.16	10446.54	11536.29	2832.71
Main	4460	22.74	22.45	0.29	1.35	0.01	6015.98	11242.69	11901.33	2853.5
Main	4994	24.53	24.21	0.32	1.78	0.01	4750.6	10487.19	13922.21	2965.58
Main	5408	26.31	25.97	0.34	1.78	0	1568.21	13904.29	13687.5	3454.44
Main	6068	29.17	28.6	0.57	2.79	0.07	6449.49	20340.38	2370.13	3310.56
Main	6545	31.17	30.54	0.63	1.98	0.02	4161.53	22972.6	2025.87	2832.07
Main	7067	33.72	32.43	1.29	2.35	0.2	1766.94	26269.58	1123.49	2162.53
Main	7482	35.86	35.62	0.24	2.04	0.1	2132.96	27019.04	8	2374.2

HYDRAULIC MAPPING AND MODELING
Kenneth F. Karle, P.E.
1091 West Chena Hills Drive, Fairbanks, AK 99709

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.

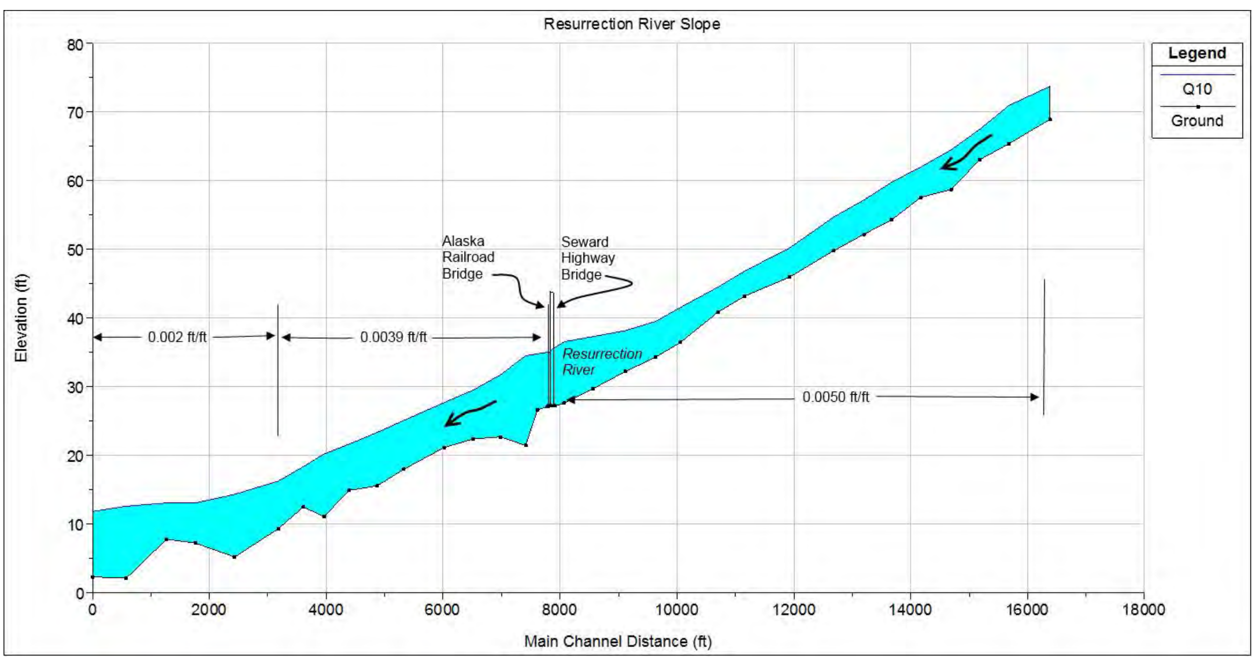


Figure 1. Resurrection River channel slopes.

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

Ferguson, R. I., P. E. Ashmore, P.J. Ashworth, C. Paola, C., and K.L. Prestegaard. 1992. Measurements in a braided river chute and lobe 1. flow pattern, sediment transport, and channel change. Water Resources Research 28(7): 1877-1886.

Karle, K.F. 2010. Toklat River excavation, monitoring, and analysis, Denali National Park and Preserve. Natural Resources Technical Report NPS/DENA/NRTR-2010/381. USDOI, National Park Service, Fort Collins, CO.

Leopold, L.B., M.G. Wolman, and J.P. Miller. 1964. Fluvial processes in geomorphology. Dover Publications, Inc. New York NY.

Seward/Bear Creek Flood Service Area (SBCFSA). 2009. Learning to live with water: a history of flooding in Seward, Alaska 1903-2009.

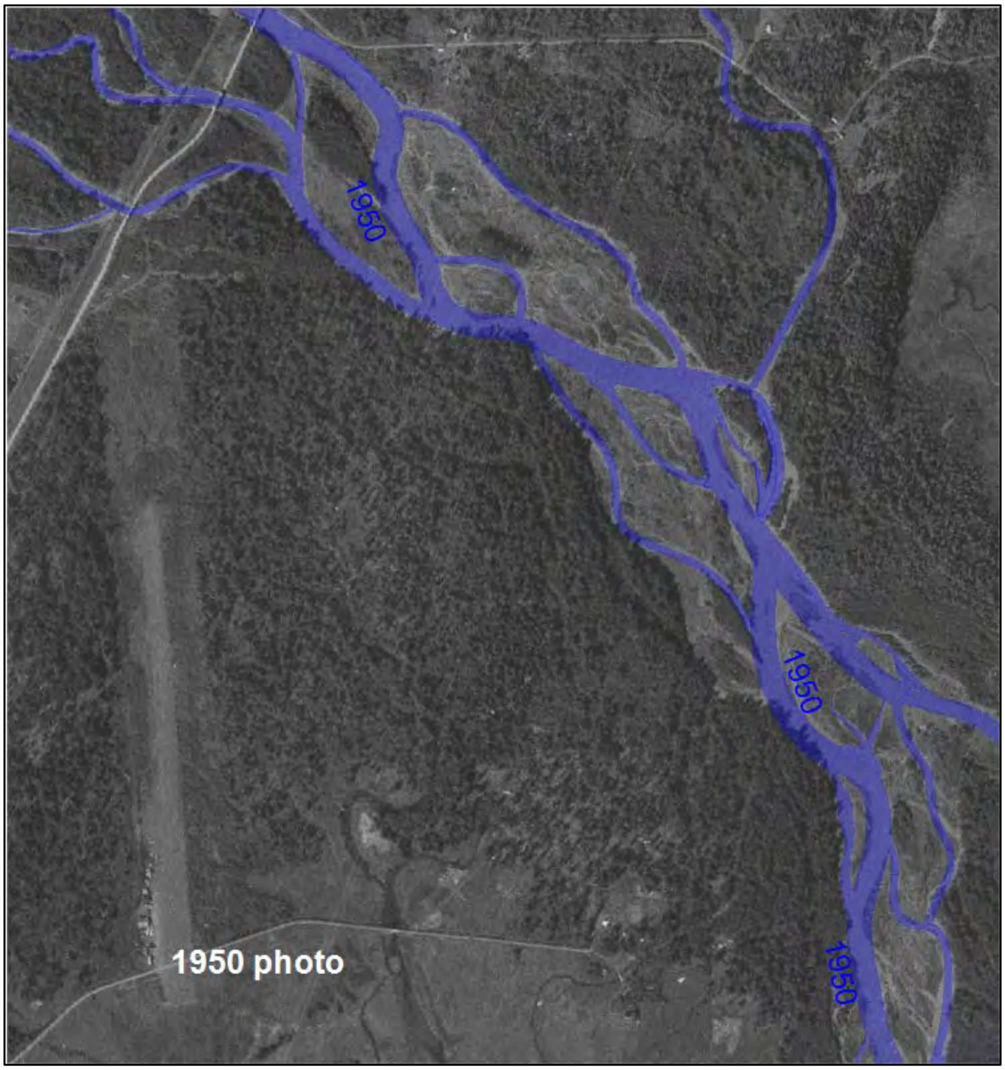
Task Force. 1998. Task force report Resurrection River/Japanese Creek flood hazard mitigation project, Seward, Alaska. May 8, 1998.

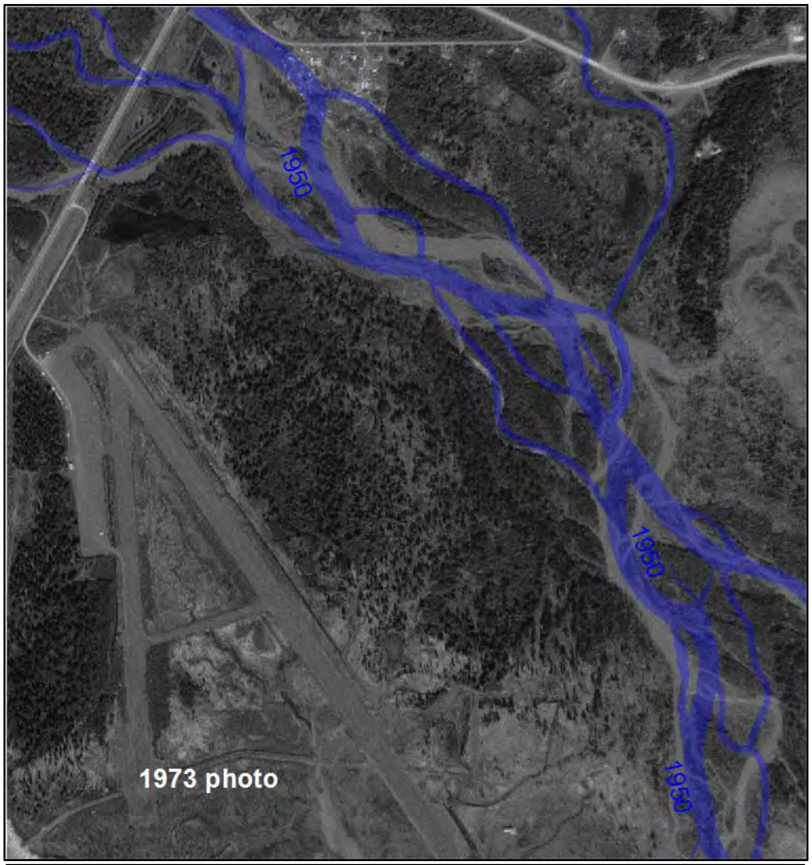
US Army Corps of Engineers (USCOE). 2008. Erosion Information Paper-Seward, Alaska. Alaska Baseline Erosion Assessment, Alaska District.

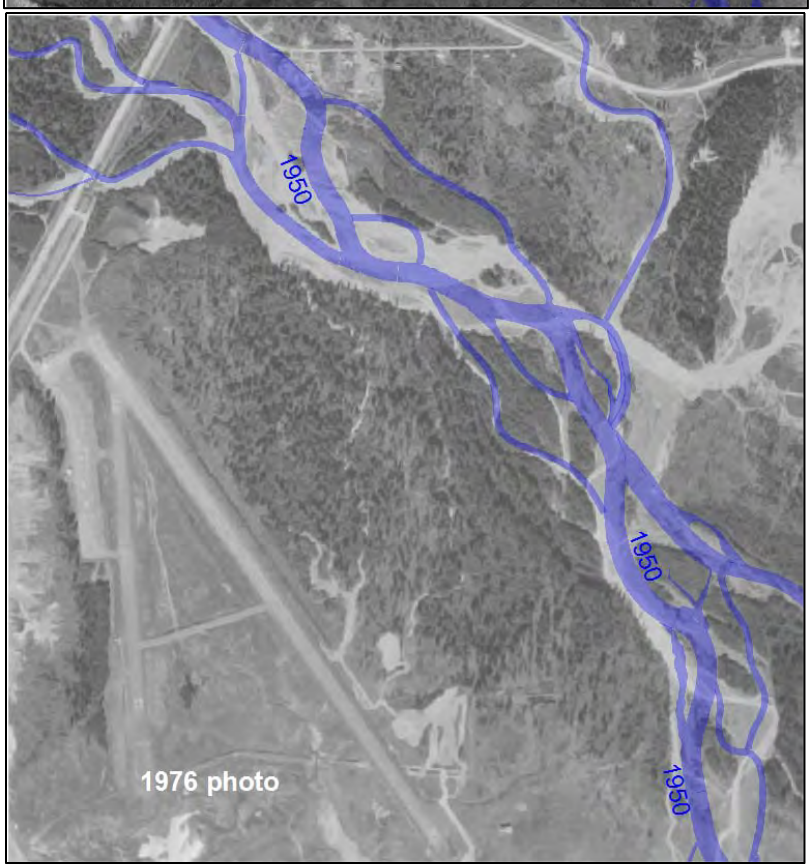
U.S. Department of Agriculture (USDA) Natural Resources Conservation Service. 2004. Matanuska River Erosion Assessment: MWH, Design Study Report Final, v. 1 and 2, variously paged.

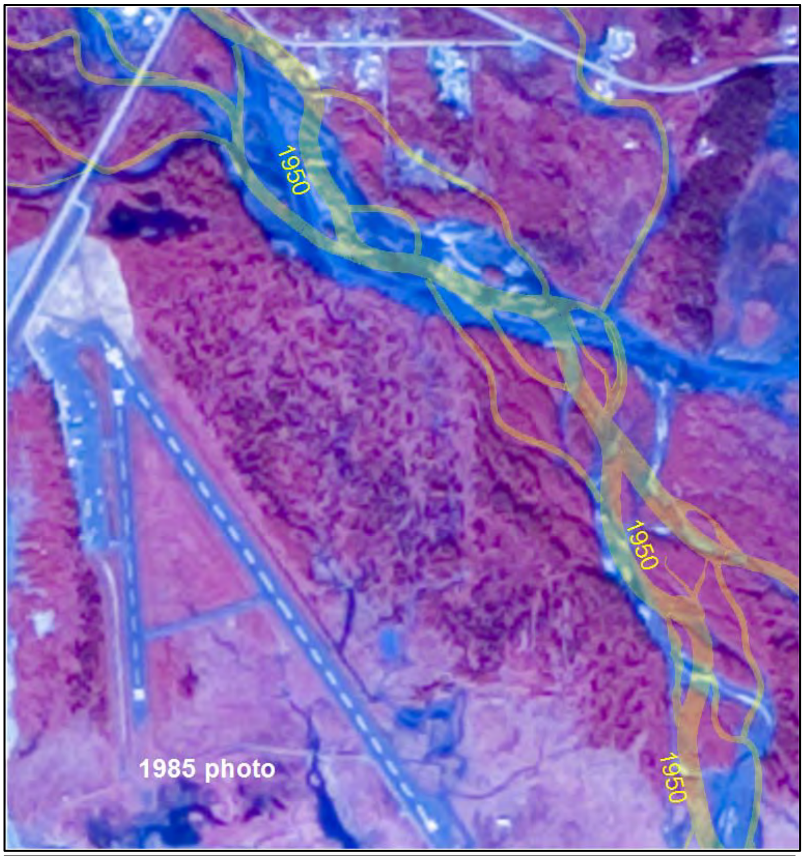
Appendix 1-Resurrection River Channel Locations, 1950 to 2014

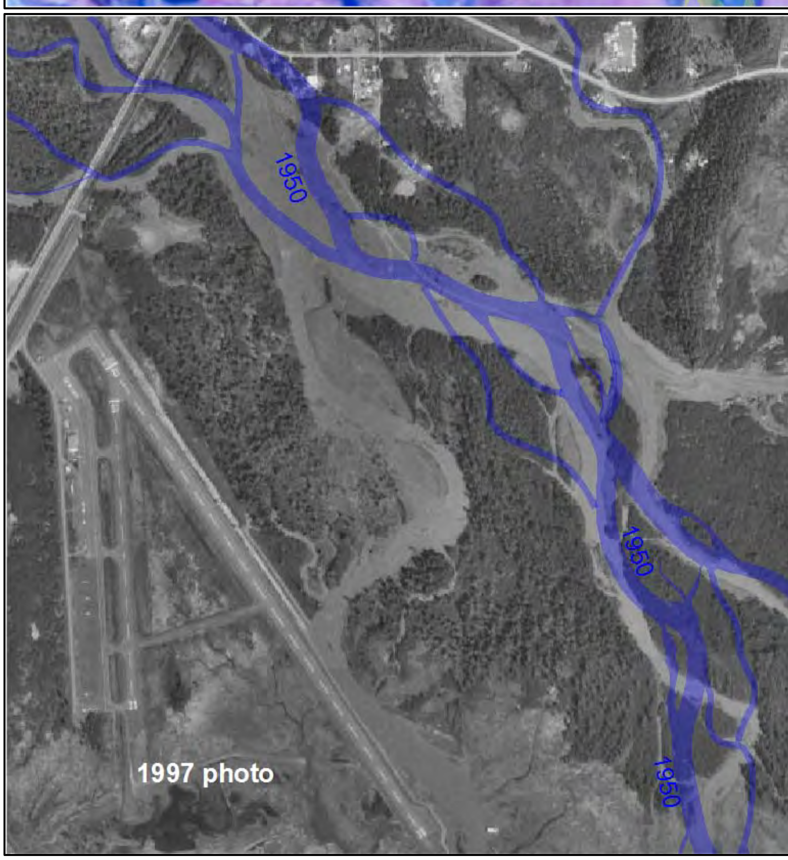
The approximate location of the Resurrection River channel in 1950 is shaded in blue, and overlain on the following aerial images: 1950, 1973, 1976, 1985 (infrared imagery-channel shaded in yellow), 1997, 2011, and 2014.



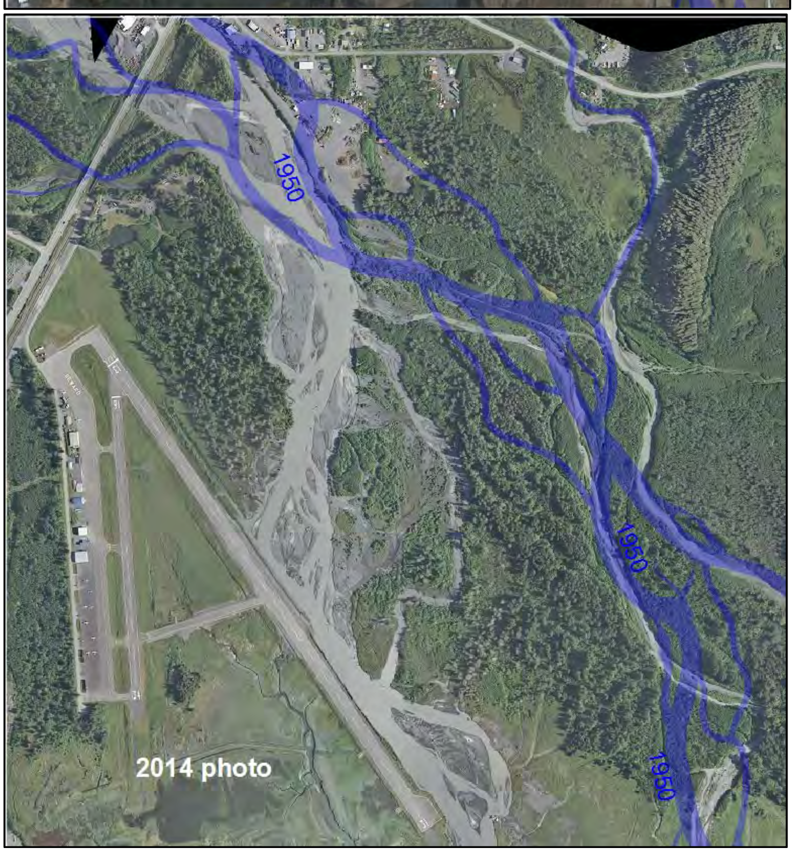

1950
1950
1950
1973 photo


1950
1950
1950
1976 photo


1950
1950
1950
1985 photo


1950
1950
1950
1997 photo


1950
1950
1950
2011 photo


1950
1950
1950
2014 photo