FINAL RESERVOIR SEDIMENTATION STUDY REPORT

BLUE LAKE PROJECT (FERC NO. 2230) EXPANSION

Prepared By:

Kathy Dubé

Prepared For:

City and Borough of Sitka Electric Department

December 2009

TABLE OF CONTENTS

TABLE OF CONTENTS I
LIST OF FIGURES I
LIST OF TABLES II
APPENDICES II
INTRODUCTION AND BACKGROUND 1
STUDY OBJECTIVES 1
METHODS 4
Study Area and Features 4
Streamflow and Lake Level Analysis 4
Extent and Depth of Delta Deposits 5
Stream Channel Cross Sections and Grain Size Data 6
Hydraulic and Sediment Transport Calculations 7
RESULTS 7
Streamflow and Lake Levels 7
Delta Deposits 10
Existing Blue Lake Creek Delta 10
Expansion-related Blue Lake Creek Delta (Potentially Inundated Area) 13
Fish Use In Blue Lake Creek 17
Length of Accessible Stream 17
Channel Width and Substrate Conditions 19
Becky, Brad and Sheldon Creeks 23
Becky Creek 24
Brad Creek 26
Sheldon Creek 28
SUMMARY 29
CONSULTATION 31
LITERATURE CITED 33

LIST OF FIGURES

Figure 1. Proposed Expanded Blue Lake Shoreline. 2
Figure 2. Blue Lake Creek Orthophoto showing Expansion Shoreline and Stream Miles 3
Figure 3. Estimated Blue Lake Creek Inflow Exceedence Values. 8
Figure 4. Blue Lake Surface Elevation Exceedence Values under Existing Conditions. 9
Figure 5. Modeled Blue Lake Surface Elevation Exceedence Values under Expansion Conditions. 9
Figure 6. Blue Lake Creek Delta Aerial View. 10
Figure 7. Existing and Estimated Future Delta Deposits. 11
Figure 8. Surveyed Longitudinal Profile of Blue Lake Creek and Adjacent Delta Deposits within the Current Reservoir. 12
Figure 9. Grain Size Distribution in Existing Delta Deposits. 13
Figure 10. Longitudinal Profile of Lake Creek Showing Existing and Estimated Expansion-related Delta Deposits. 15

Figure 11. Cross Sectional Profiles Across Existing Delta..... 16
Figure 12. Cross Sectional Profiles Across Expansion-related Delta..... 16
Figure 13. Accessible Length of Blue Lake Creek during Spawning Periods under Existing and Expansion Conditions. 18
Figure 14. Existing Blue Lake Creek Channel Cross Sections Upstream of Lake..... 20
Figure 15. Blue Lake Creek Channel Cross Sections in Current Fluctuation Zone. 21
Figure 16. Armor Layer Grain Size Distribution in Existing Blue Lake Creek Upstream of Lake. 22
Figure 17. Armor Layer Grain Size Distribution in Existing Delta Active Channel Deposits.... 22
Figure 18. Sub-armor Layer Grain Size Distribution in Existing Delta Active Channel Deposits. 22
Figure 19. Photo of Becky Creek Delta in Confined Canyon Area..... 24
Figure 20. Photo of Existing Becky Creek Delta..... 25
Figure 21. Estimated Existing and Expansion Becky Creek Delta..... 26
Figure 22. Photo of Existing Brad Creek Delta. 27
Figure 23. Estimated Existing and Expansion Brad Creek Delta. 28
Figure 24. Photo of Existing Sheldon Creek Delta..... 28
Figure 25. Estimated Existing and Expansion Sheldon Creek Delta..... 29

LIST OF TABLES

Table 1. Estimated Area, Depth, and Volume of Existing Lake Creek Delta Deposits 13
Table 2. Estimated Area, Depth, and Volume of Future Lake Creek Delta Deposits 50 Years after Expansion 17
Table 3. Comparison of Blue Lake Creek Channel Characteristics in the Exiting Delta and Upstream of the Lake..... 19
Table 4. Estimated Flow, Water Depth, and Width in Low Gradient Delta Channel. 23
Table 5. Estimated Median Monthly and Peak Flows in Becky, Brad, and Sheldon Creeks..... 24
Table 6. Reviewer Comments on Draft Reservoir Sedimentation Report..... 31

APPENDICES

Appendix A. Grain Size Data

INTRODUCTION AND BACKGROUND

The City and Borough of Sitka Electric Department ("City") recently received a new license for the Blue Lake Hydroelectric Project (FERC No. 2230, "Project") from the Federal Energy Regulatory Commission (FERC). During the relicensing process, the City's ongoing energy forecasts indicated that, in order to assure continued delivery of low cost electrical power in the face of rising energy needs in Sitka, it must expand its electrical generating base.

The City is in the process of applying for an amendment to the Project's existing FERC license to reflect two significant changes in Project design: 1) addition of a new generating turbine at or near the existing powerhouse; and 2) raising the Project dam as much as 83 above the existing spillway level. The City is exploring feasibility of these changes because of recent electric load forecasts in the face of increasing diesel fuel costs. Details of elements of the proposed expansion are described in the Scoping Document II which was distributed in June 2009.

Raising the Blue Lake dam will increase the Blue Lake surface area from 1,225 acres to 1,655 acres, a total increase of 430 acres. The majority of this increase will take place in the valley of Blue Lake Creek, the lake's primary inlet tributary (Figure 1). After the reservoir reaches the new full pool level, there will be a change in the sediment deposition and erosion patterns in the Blue Lake Creek valley.

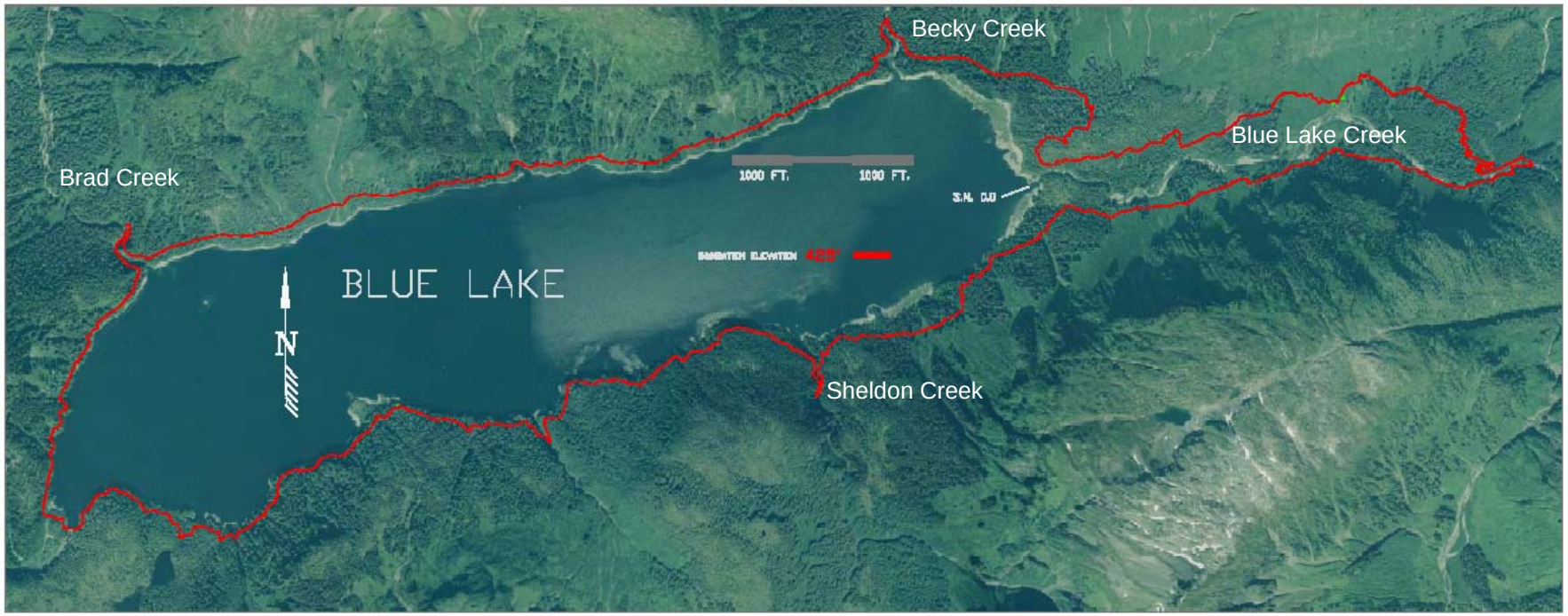
During FERC-required consultation, the USDA Forest Service (USFS) and the Sitka Conservation Society (SCS) requested evaluation of the effects of the raised pool level on sediment deposition patterns in the potentially-inundated areas of the Blue Lake Creek valley. It is known that Blue Lake Creek is an important spawning area for Blue Lake's rainbow trout population, and that it is accessed for various forms of outdoor recreation. This study describes the effect of deposition and lake level changes under the proposed expanded project configuration on fish habitat and fish passage in Blue Lake and Blue Lake Creek with the new reservoir operating levels.

In this study report, land and water elevations are referenced in feet to mean low sea level and denoted "El", as in El 342, El 425, etc. Also, Blue Lake Creek locations are noted by Stream Mile (SM) or distance in miles upstream from Blue Lake Creek's existing confluence with Blue Lake (Stream Miles are shown on Figure 2). **Revisions were made in this final December 2009 report in response to resource agency comments. Revised text is marked in bold typeface and referenced in the Consultation section at the end of the report.**

STUDY OBJECTIVES

The objectives of this Reservoir Sedimentation Study are to:

1. Determine the extent and estimated volume of sediment deposition and erosion in Blue Lake and the reach of Blue Lake Creek between El 342 (current maximum water level) and 425 (maximum Expansion-related water level), under Expansion-related reservoir operations; and



BLUE LAKE EXPANSION INUNDATION AREA
1655 ACRES, 430 ADDITIONAL ACRES

Figure 1. Proposed Expanded Blue Lake Shoreline.

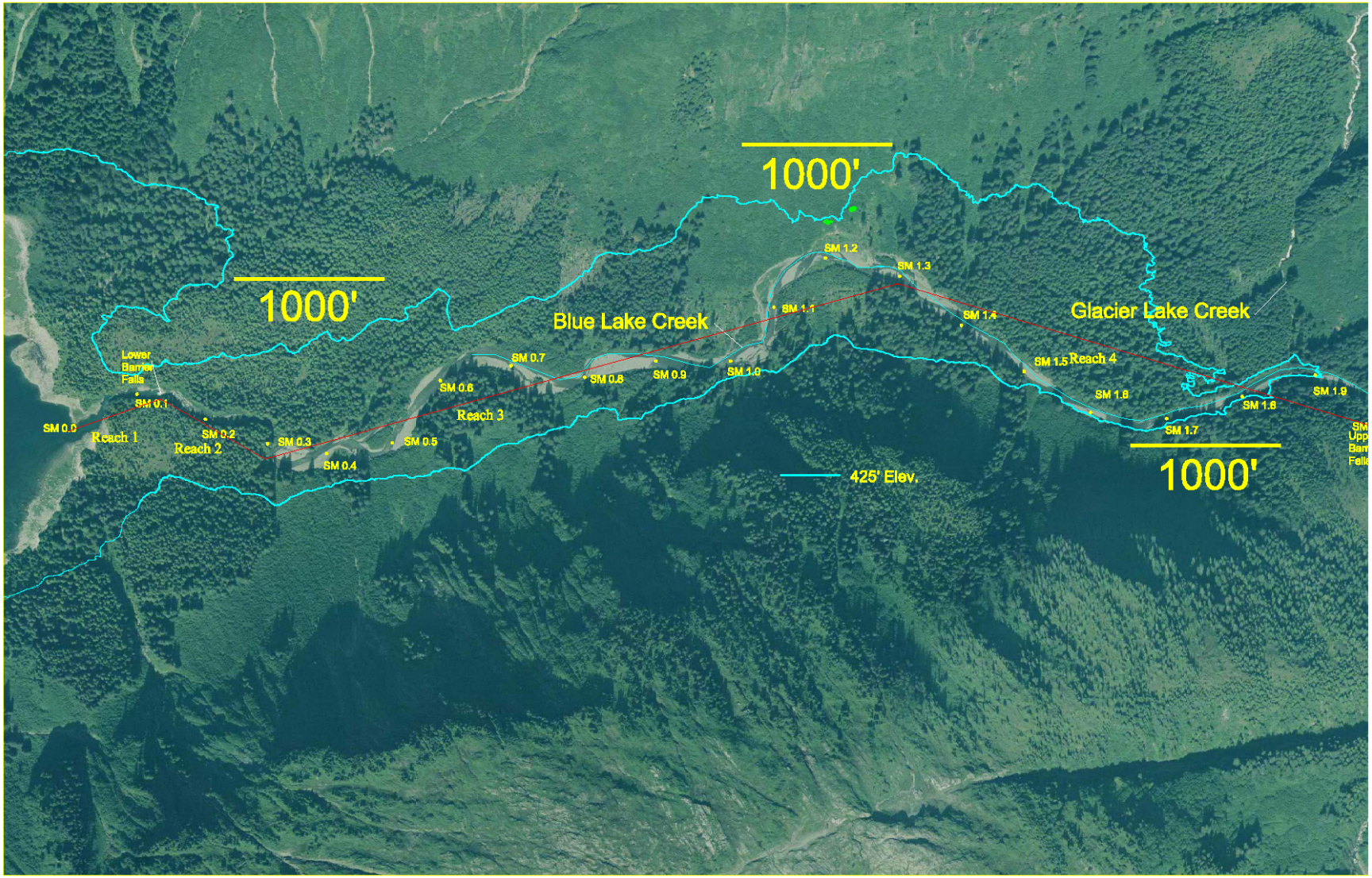


Figure 2. Blue Lake Creek Orthophoto showing Expansion Shoreline and Stream Miles

2. Evaluate probable future fish habitat and accessibility in the future inundation zone of Blue Lake Creek based on projected stream gradient/width/depth and substrate characteristics.

METHODS

STUDY AREA AND FEATURES

The reservoir sedimentation study area includes 1) the eastern end of Blue Lake, down to approximately El 180; and 2) Blue Lake Creek within the area of inundation defined by an Expansion-related maximum water surface elevation of El 425. The study area does not include other, smaller tributaries. In this report, the term "potentially-inundated area(s)" will refer to stream and land features between El 342 and 425.

Within the study area are certain features which are important to the evaluation of sedimentation effects on fish passage and habitat, including the "Lower Barrier Falls", a steep cascade at SM 0.12 which impedes upstream migration of rainbow trout at all reservoir levels below approximately El 322, and the "Upper Barrier Falls", a similar cascade at El 430/SM 2.1 which impedes fish migration at all existing and Expansion-related reservoir elevations.

STREAMFLOW AND LAKE LEVEL ANALYSIS

Streamflow and lake level data available for Blue Lake and streams in the vicinity include:

- mean daily and peak annual flows at the USGS gage on Sawmill Creek (USGS 15088000)
- Daily lake levels from Project operations records for 1992-2008

There are no systematic records of daily flows in Blue Lake Creek upstream of Blue Lake. Adjusted mean daily flow data for the USGS Sawmill Creek near Sitka, AK gage (USGS 15088000) during the pre-Project period (September 1920 to January 1923; February 1928 to September 1942; October 1945 to September 1957) were used to represent the range in flow magnitude and timing in Blue Lake Creek. The daily Sawmill Creek flows were adjusted by the ratio in drainage areas between the gage site (39.0 sq mi) and the drainage area of Blue Lake Creek upstream of Blue Lake (19.9 sq mi). This simplified adjustment was felt to be adequate to represent the range of Blue Lake Creek flows given the level of precision of the rest of the analysis. The resulting adjusted daily flows were entered into a spreadsheet for analysis. Flow exceedence values were calculated based on the daily values for each month over the 28 year pre-Project period of record. **Mean daily flows in Becky, Brad, and Sheldon creeks were calculated in the same manner.**

The Pacific decadal oscillation has been reported to affect the timing and magnitude of streamflows in Southeast Alaska (Neal et al. 2002). Neal found that winter flows were higher and summer flows were lower during warm Pacific decadal oscillation periods compared to cool oscillation periods. The Sawmill Creek data used in the streamflow analysis included 16 years during warm Pacific decadal oscillation periods and 12 years during cool periods, and so represents both oscillation periods.

Peak flows in Blue Lake Creek were estimated based on the methodology in Curran et al. 2003, using Method 4 for ungaged sites on gaged streams. Blue Lake Creek is in Region 1, so the Region 1 regression variables and the Sawmill Creek near Sitka, AK data were used for the analysis.

Existing daily Blue Lake elevation data were available from Project operators for the period 1992-2008. Lake levels under Expansion conditions were represented by daily lake elevation output from the Sitka Generation Model. The model was run using flow conditions for the period 1929-1956 to correspond to the period when daily inflow values were available for comparison. The model used a constant annual generation load of 154,000 MWh which is the average maximum annual load that the Sitka hydro system is capable of generating without excessive supplementation with diesel generation. Daily lake elevation data for both existing conditions (actual 1992-2008 elevations) and Expansion conditions (modeled elevations) were entered into a spreadsheet for analysis. Lake surface elevation values were calculated based on the daily values for each month for the existing and Expansion conditions.

The Blue Lake elevation data used in the Expansion lake level analysis included 16 years during warm Pacific decadal oscillation periods and 11 years during cool periods, and so represents both oscillation periods.

EXTENT AND DEPTH OF DELTA DEPOSITS

Topographic data available for the study area include:

- 1957 contours between elevation 220 and 360 (pre-Project stream valley);
- 2007 Light Detection and Ranging (LiDAR) survey data used to make a map with 5 foot contours above elevation 342 (current Blue Creek stream valley); and
- 2008 land survey data of the exposed Blue Lake Creek channel and closely adjacent delta area between elevation 257 and 342 (existing Blue Lake Creek delta) used to make profiles of Blue Lake Creek and the adjacent delta.

The approximate extent of current delta deposits, representing 52 years of deposition, was mapped during the May 19, 2009 site visit. Mapping was conducted based on the following data sources:

- An aerial oblique photograph of the delta taken May 18, 2008 showing the delta above elevation 260. This photograph shows areas and patterns of deposition and the active channel zone.
- The depth of delta deposits was measured at several locations in the delta. Depth in fine-grained (sand/silt) deposits was measured by probing with a piece of metal rebar to refusal. Depth in coarse-grained deposits (cobble/gravel) was estimated as measured bank height along the existing incised channel.
- The boundaries of the current active channel and several distinct cobble/gravel, gravel/sand, and sand/silt deposits were mapped using a hand-held GPS receiver during the 2009 field visit.
- Comparison of the 2008 land survey of the exposed portions of Blue Lake Creek with pre-Project (1957) elevations was used to estimate depth of channel deposits.

The mapping units were transferred to GIS to determine the area (acres) of each of the map units. An average depth was assigned to each map unit and multiplied by the map unit area to estimate the volume.

The extent and depth of delta deposits after 50 years of proposed expansion operations was estimated. The following assumptions were made:

- The same rate of sediment input from Blue Lake Creek will occur in the future, so the volume and grain size composition of delta deposits after 50 years will be approximately the same as in the current delta.
- The stream gradients in the expansion delta will be similar to the gradient in the existing delta and/or the existing Blue Lake stream channel in the area of the expansion delta (0.01-0.005). This assumption is valid because Blue Lake will continue to fluctuate annually, so during low lake levels Blue Lake Creek will cut down through the unconsolidated sediment deposited at higher lake levels, resulting in an active stream channel graded to the fluctuating lake levels.
- There will be areas outside the active channel in the expansion delta with deeper deposits of cobble and gravel, similar to those deposits in the existing delta. These will be located close to where Blue Lake Creek enters the expanded lake under near full pool conditions.

A map showing the estimated location and extent of the expansion delta was made in GIS depicting the predicted areas of active channel, cobble/gravel deposits, and sand/silt deposits. The extent of each area (acres) was measured and multiplied by the estimated average depth to provide a volume estimate.

STREAM CHANNEL CROSS SECTIONS AND GRAIN SIZE DATA

Stream channel cross sections were surveyed at three locations in upper Blue Lake Creek as part of the 2008 fisheries studies (see data in Wolfe 2009). Cross sections were surveyed at SM 1.34 (Stream Transect 1), 1.49 (Stream Transect 2), and 1.95 (Stream Transect 3). During the May 2009 field visit, three additional cross sections of Blue Lake Creek were surveyed using a tape, stadia rod, and hand level within the existing delta at SM -0.15 (Delta Transect 1), SM -0.18 (Delta Transect 2) and SM -0.35 (Delta Transect 3). Cross section data was entered into Excel for analysis and plotting.

At each of the six cross section locations, a pebble count was made across the entire width of the wetted channel to provide information on channel substrate. The pebble count was made by walking heel-to-toe across the wetted channel and selecting the particle at the toe of the field crew's boot. Grain size of each particle was measured using a gravelometer. A minimum of 100 particles was measured along each transect.

A grab sample of sub-armor material was taken close to the water's edge from a bar at each of the three delta cross section locations. In addition, grab samples of delta surface material were taken at three locations on the delta outside of the active channel, representing the cobble/gravel, gravel/sand, and sand/silt map units. All grab samples were air dried and sieved using standard 8-inch sieves and a shaker. Material retained on each sieve was weighed to the nearest gram. Particle size data was entered into Excel for analysis and plotting.

HYDRAULIC AND SEDIMENT TRANSPORT CALCULATIONS

Hydraulic analysis at each of the six stream cross sections (three in the existing delta area and three in the expansion delta area) was performed using the WINXSPRO software (Hardy et al. 2005). The analysis was performed using the existing stream gradient at all cross sections to calculate water depth, velocity, and shear stress from low water to bankfull conditions. Hydraulic analysis was also performed on Delta Transect 3 using the lowest measured slope gradient (0.005) to provide data on differences in hydraulics and shear stress at a very low gradient, simulating deposition conditions in the Expansion delta.

Discharge versus stage at each of the measured cross sections was computed using the WinXSPRO software (Hardy et al. 2005). Channel elevation and position (xy) coordinates were entered for each cross section, along with measured water slope at low flow and estimated reach-average high flow water gradient. The Jarrett equation for Manning's roughness coefficient option was chosen to estimate the stage:discharge relationship, and was checked against the estimated bankfull stage for each of the three stream transects. The Jarrett equation for Manning's roughness coefficient is internal to WinXSPRO and does not require any input on roughness elements; roughness is calculated based on water surface slope and hydraulic radius.

The WINXSPRO model output was used to determine water depth and shear stress (τ) in the channel at each of the six transects for a range of flows. Shear stress at each cross-section was compared to critical shear stress (τ^*_c) for each flow to determine the particle size that could be entrained by the flow.

The Shields' Criterion was used to determine the critical shear stress for initiation of substrate movement:

$$\tau^*_c = a(\gamma_s/\gamma_w)d_{50}$$

where: τ^*_c = critical Shields stress for mobility of particle size d50
a = constant, 0.039 for this analysis due to type of river and sediment
γ_s and γ_w are the specific weights of sediment and water, respectively
d_{50} = median particle size at threshold of mobility

RESULTS

STREAMFLOW AND LAKE LEVELS

Estimated Blue Lake Creek daily flows were calculated from the pre-1957 flow records taken at the Sawmill Creek gage (USGS 15088000). To examine the magnitude and seasonal variations in Blue Lake Creek inflow, the 10, 50, and 90 percent exceedence elevations were plotted for each month from mean daily estimated stream flow data (Figure 3). The exceedence values refer to the value that is exceeded for the specified percent of the time. For example, in June the 50 percent exceedence flow is 380 cfs, which means that during 50 percent of the days in June, mean daily inflow was estimated to be greater than 380 cfs and half of the day inflow was less than 380 cfs. The 10 percent exceedence inflow value for June is 541 cfs; 10 percent of the days

in June flows were greater than 541 cfs, and 90 percent of the days flows were lower. Note that the 50 percent exceedence value is also referred to as the median value.

Flows in Blue Lake Creek vary seasonally, with lowest flows during the months of December-April and highest median flows in June in response to snowmelt. While median flows are lower than the snowmelt peak in September-November, peak flows can occur during the fall as a result of large storms that bring heavy rains. Spawning and incubation periods for resident rainbow trout are shown on Figure 3 and will be discussed in more detail in the Fish Use in Blue Lake Creek section of this report.

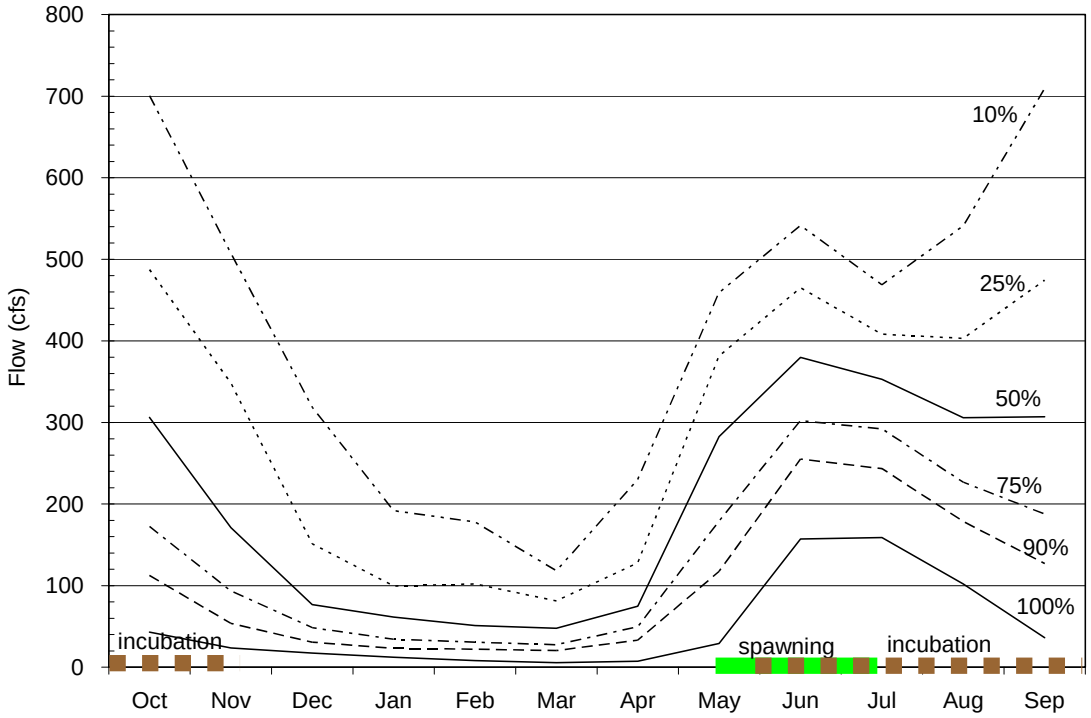


Figure 3. Estimated Blue Lake Creek Inflow Exceedence Values.

Daily water surface elevation data for Blue Lake (1992-2008) were also analyzed to provide exceedence values by month (Figure 4). Lake levels are lowest in April, with a median value of 292 feet, rising through the spring with near full pool (342 feet) conditions between August and November. Lake levels fall during the winter as the pool is drawn down to enable storage of snowmelt runoff.

Water surface elevation exceedence values were also plotted for modeled Blue Lake levels under expansion conditions (Figure 5). Lake levels under expansion conditions follow a similar pattern, with the lowest median level in April (368 feet), rising levels during the spring, and falling levels during the fall and winter. However, the operations model output suggests that lake levels would not reach near full pool (425 feet) until October/November before dropping again. Part of the reason for the lower pool under expansion is that the model was run with a higher load than current conditions to show the effects of future energy needs.

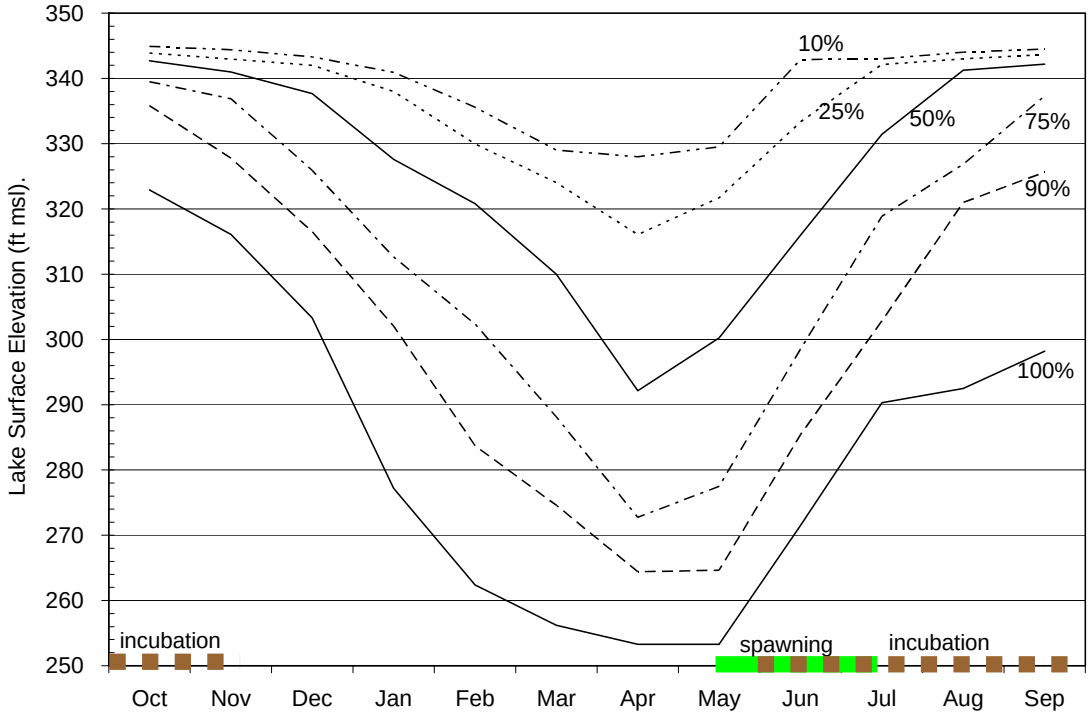


Figure 4. Blue Lake Surface Elevation Exceedence Values under Existing Conditions.

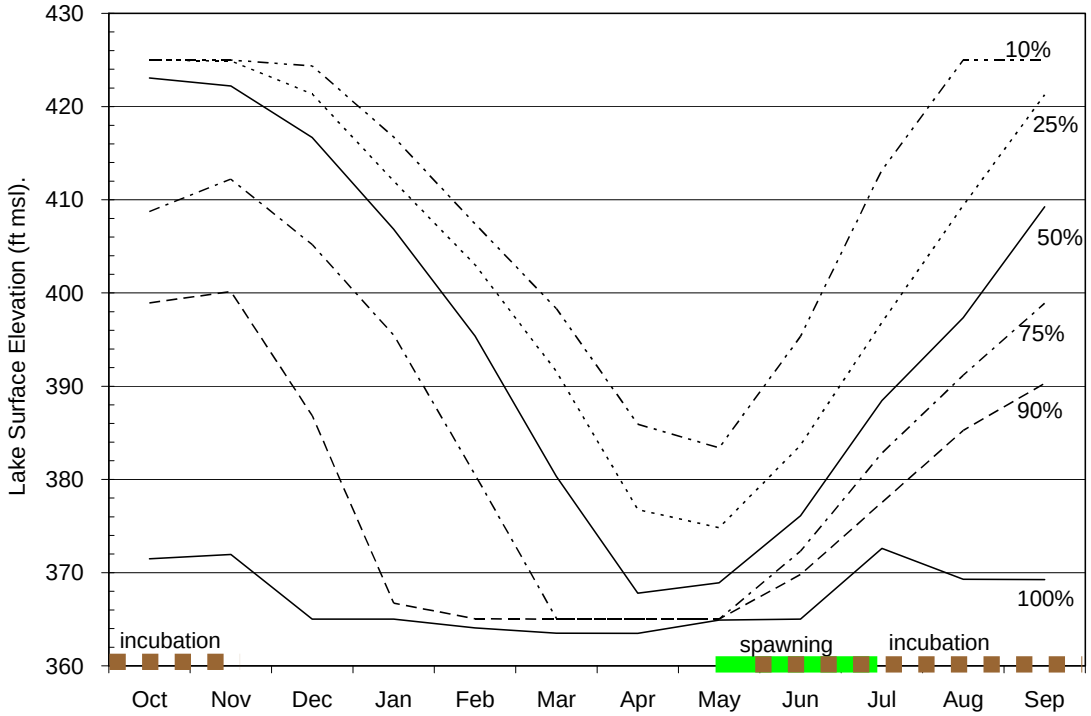


Figure 5. Modeled Blue Lake Surface Elevation Exceedence Values under Expansion Conditions.

Peak flows in Blue Lake Creek were estimated using regional regression equations to be 3,044 cfs (2-year return interval); 4,077 (5-year return interval); 4,765 (10-year return interval) and 6,828 (100-year return interval).

DELTA DEPOSITS

Sediment deposition takes place on deltas as flowing water slows and is no longer able to transport entrained material. Larger material is deposited first, with progressively finer material being deposited farther out on the delta and in the lake.

Existing Blue Lake Creek Delta

The existing Blue Lake Creek delta deposits can be seen on an aerial oblique photo of the delta taken in May 2008 when Blue Lake was near elevation 260 ft (Figure 6). The delta deposits within Blue Lake were mapped based on dominant surficial grain size as either active channel (cobble/gravel/sand), cobble/gravel/sand deposits, cobble/gravel deposits, gravel/sand deposits, or sand/silt deposits as shown on Figure 7. Note that the Blue Lake Creek and Becky Creek delta deposits overlap on the map.

Figure 6. Blue Lake Creek Delta Aerial View.

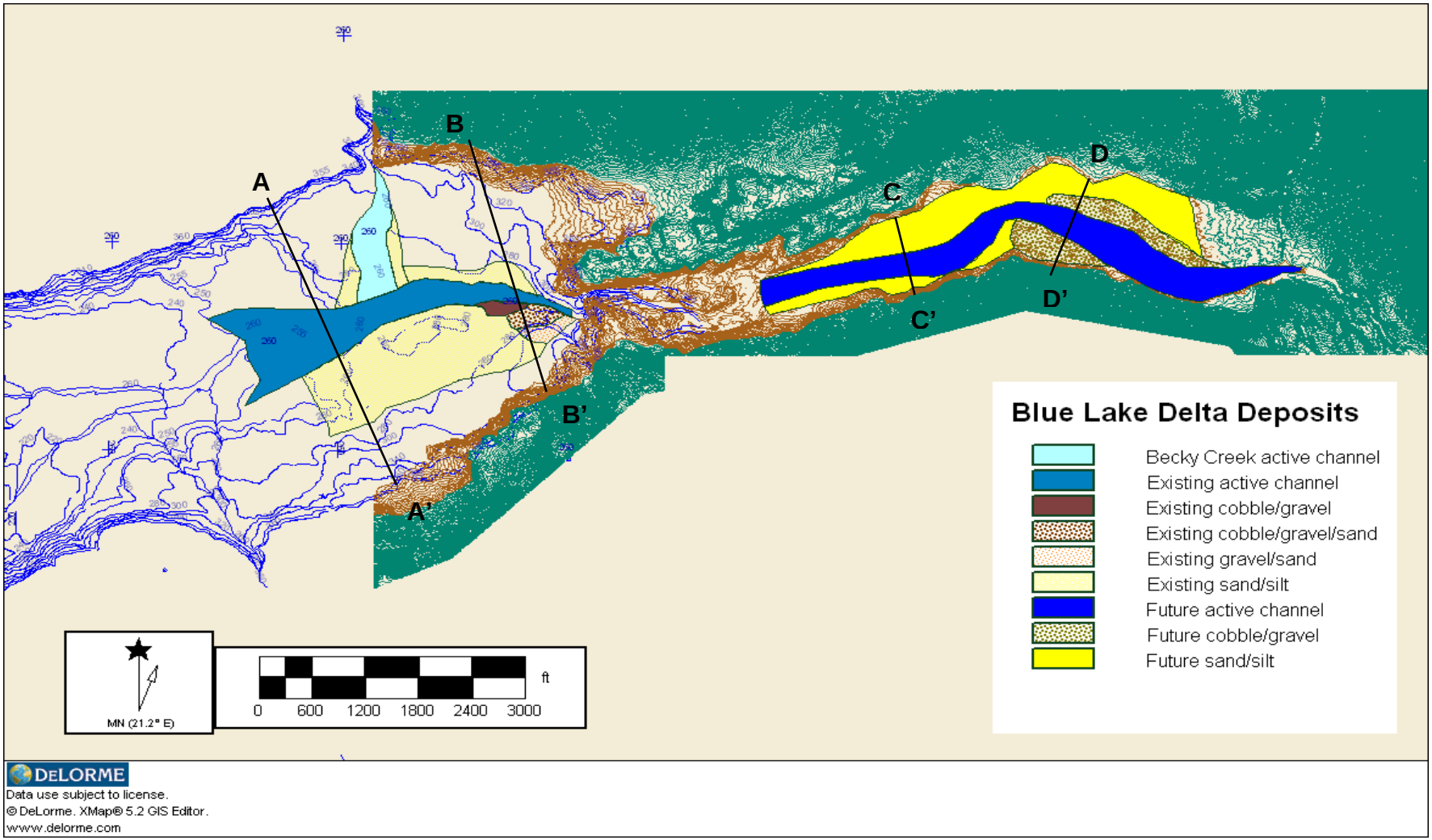


Figure 7. Existing and Estimated Future Delta Deposits.

In lakes and reservoirs with fluctuating water levels, some material that was deposited at higher lake levels is entrained and moved out along the delta within the re-established stream channel, creating a complex and dynamic pattern of sediment deposits within the active channel portion of the fluctuation zone. The lake level at the time of sediment inflow controls the elevation at which the deposits occur. This pattern can be seen in the existing Lake Creek delta deposits on a profile of the stream channel and adjacent delta surface measured during low lake levels in 2008 (Figure 8). Note that while the active stream channel is graded to the lake level at the time of the survey, there are several remnant mini-delta features evident on the adjacent delta surface, small delta-shaped lobes of cobble, gravel, and sand that were deposited when the lake level was at specific elevations when large amounts of cobble/gravel bedload entered the lake or was re-entrained. The top of each of these deposits represents the approximate lake surface elevation when the deposition occurred.

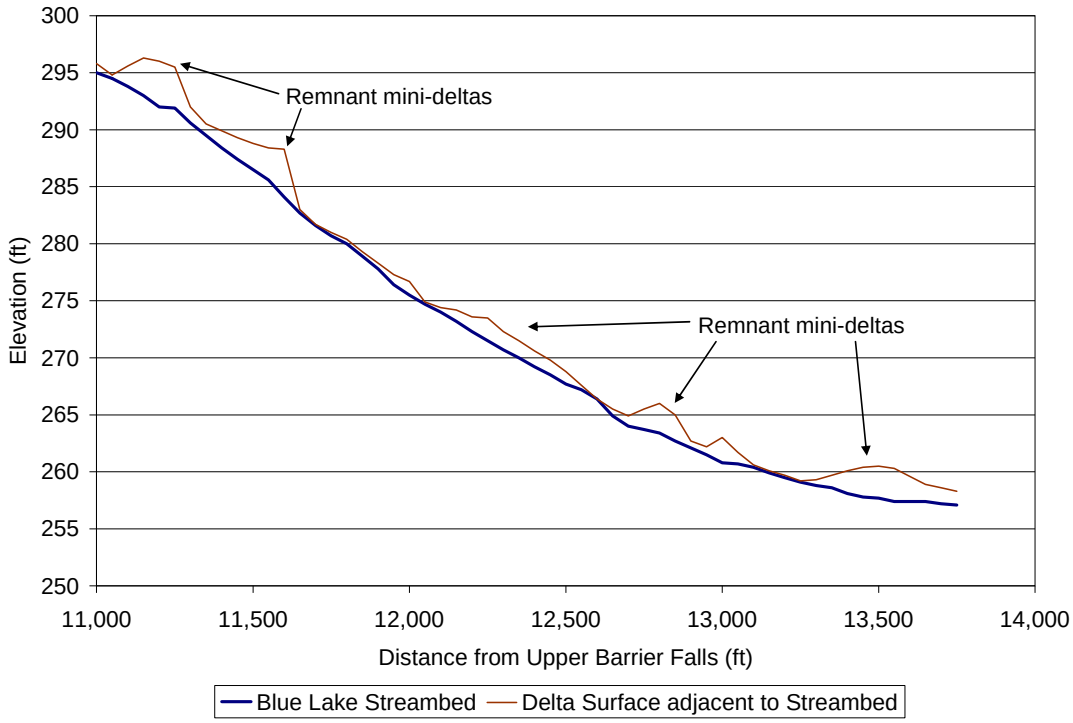


Figure 8. Surveyed Longitudinal Profile of Blue Lake Creek and Adjacent Delta Deposits within the Current Reservoir.

The area and volume of each of the existing Blue Lake Creek delta map units was estimated to provide an idea of sediment input rates. Table 1 shows the area, average depth, and volume of the current Blue Lake Creek delta. Areas/volumes of the Becky Creek delta are not included in the table.

Table 1. Estimated Area, Depth, and Volume of Existing Lake Creek Delta Deposits

Map unit	Area (acres)	Average depth (ft)	Estimated volume (cu yd)
Active channel (cobble/gravel/sand)	40	5	323,000
Cobble/gravel/sand	3	15	73,000
Gravel/sand	4	5-8	40,000
Sand/silt	57	2.5	231,000
Total	104	--	667,000

The grain size distribution across and within the delta varies greatly, but grab samples of representative surficial material were taken in the cobble/gravel/sand, gravel/sand, and sand/silt map units to provide some information on the particle size distribution (Figure 9, Appendix A). The cobble/gravel/sand and gravel/sand samples were dominated by gravel size material (70-80 percent) with the remainder of the samples sand and fines. The sand/silt sample was dominantly sand and fines.

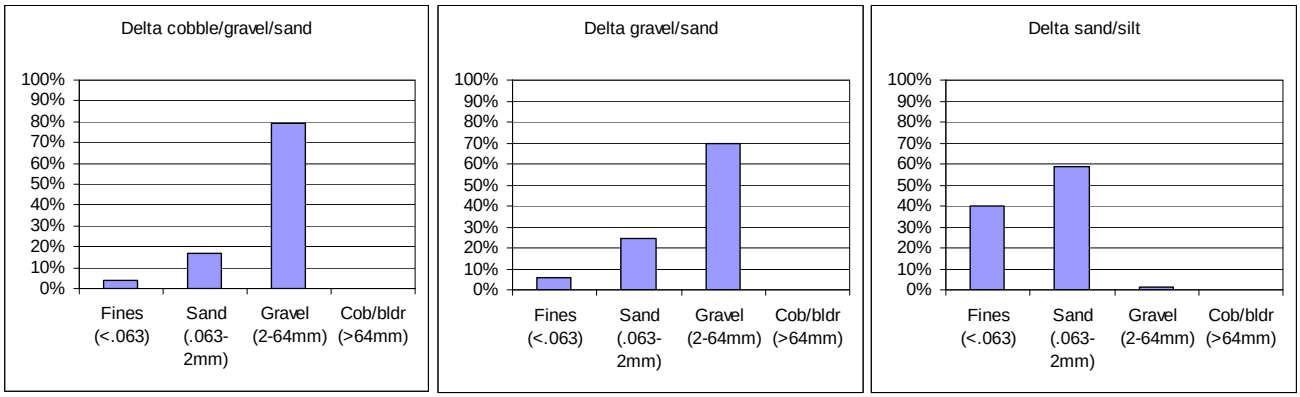


Figure 9. Grain Size Distribution in Existing Delta Deposits.

Expansion-related Blue Lake Creek Delta (Potentially Inundated Area)

The proposed change in dam height and reservoir operations will inundate areas up to elevation 425 feet. As a result, Blue Lake Creek will enter Blue Lake approximately 1.9 miles upstream of the current location. It is anticipated that Blue Lake will fluctuate between El 365 and 425 under the proposed Expansion (Figure 5, above). The distribution and depth of the Blue Lake Creek Expansion delta deposits 50 years after the change in operations were estimated based on the following assumptions:

1. The rate of sediment input will remain constant, so the volume and grain size of sediment in the Expansion delta after 50 years will be approximately equal to sediments in the existing Blue Lake Creek delta (52 years of accumulation).

2. The operations model provides a reasonable estimate of the altered timing and magnitude of reservoir fluctuations.

3. The stream profile in the new delta will be graded to the new minimum pool level in a similar manner as the existing delta, with stream gradients between 0.01 and 0.005 (similar to the gradients in the existing delta and stream channel).

4. The delta deposits in the new delta will begin close to the full pool elevation (in the existing delta the main depositional area is approximately 700 feet downstream of full pool due to the confined bedrock nature of the channel near full pool).

The estimated extent of the new Blue Lake Creek delta deposit after 50 years is shown on Figure 7 (map, above). The future active channel is anticipated to extend from full pool at El 425 (approx. SM 1.9) to maximum drawdown at El 365 (approx. SM 0.65) and contain a mix of cobble, gravel, and sand. The cobble and gravel would primarily be deposited in the upstream end of the active channel, with the percent of sand and fines increasing downstream in a manner similar to the existing active channel. Due to the relatively low gradient of the stream and valley in this reach, the active channel is anticipated to be relatively wide throughout the new fluctuation zone and would likely have multiple channel threads in some locations. Areas of cobble/gravel deposits on both sides of the active channel are anticipated to extend approximately 1,000 feet downstream from full pool and average 5 feet thick.

Figure 10 shows the original, current, and estimated Expansion-related stream profile from the Upper Barrier Falls down to elevation 200 feet. Note that the length of active channel in the Expansion delta is substantially longer than the existing delta due to the lower gradient in the Expansion fluctuation zone.

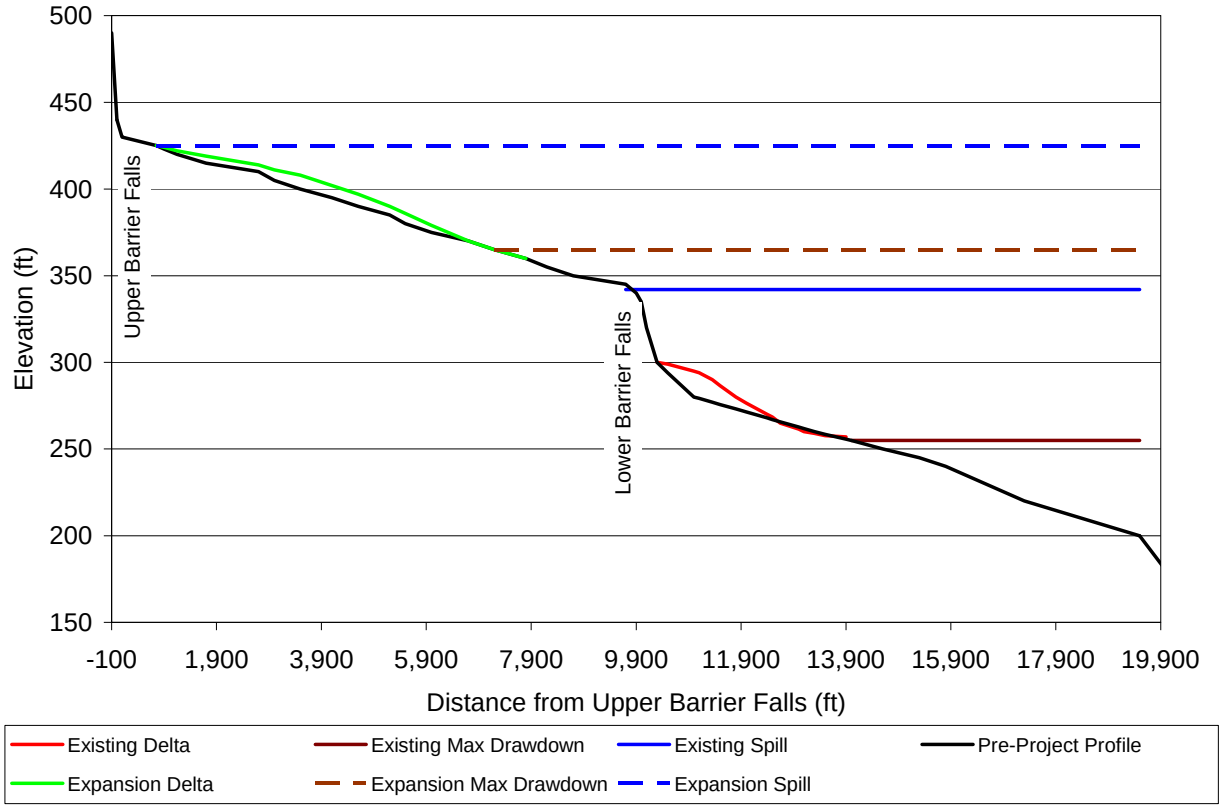


Figure 10. Longitudinal Profile of Lake Creek Showing Existing and Estimated Expansion-related Delta Deposits.

Two cross sections across the existing delta were measured at locations marked on Figure 7 (map) as section lines A-A' and B-B' (Figure 11). Two cross sections across the Expansion delta were estimated at locations marked on Figure 7 (map) as section lines C-C' and D-D' (Figure 12). Note that the delta surface elevations on both the existing and expansion delta are estimated based on depth of deposits; there are very limited current elevation measurements on these surfaces. Additionally note that the valley is much narrower in the Expansion fluctuation zone compared to the existing fluctuation zone which will affect delta development (see also Figure 7).

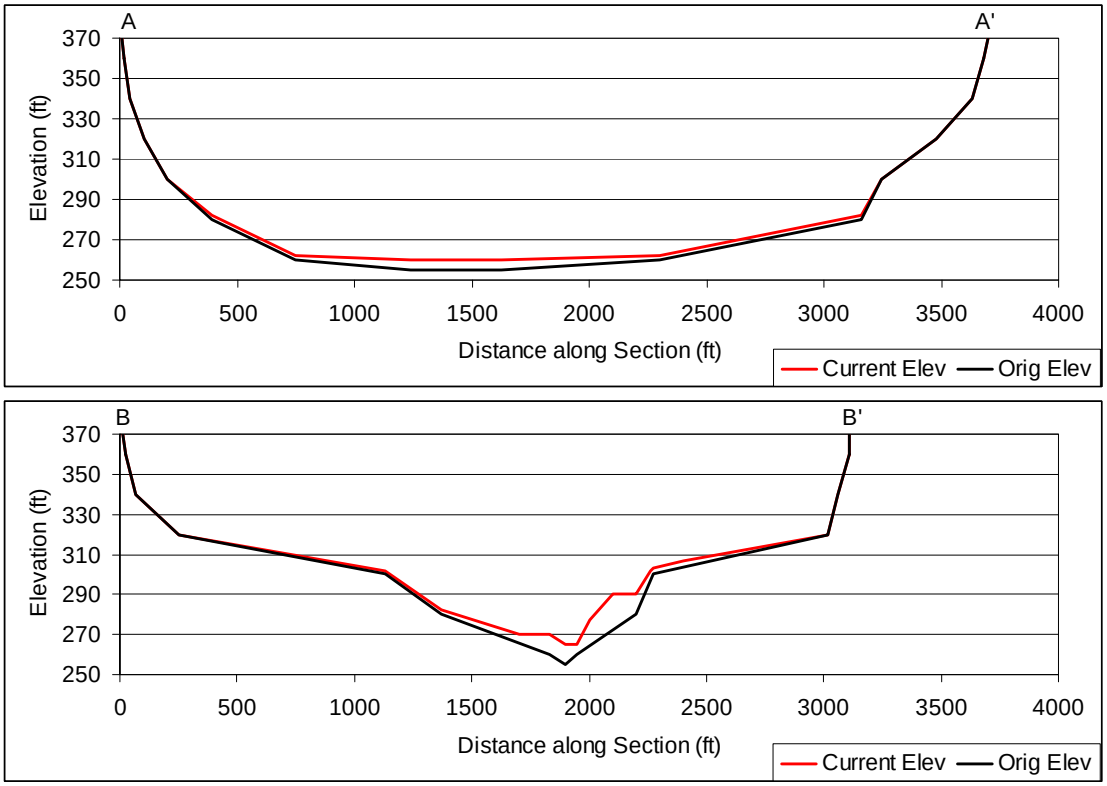


Figure 11. Cross Sectional Profiles Across Existing Delta.

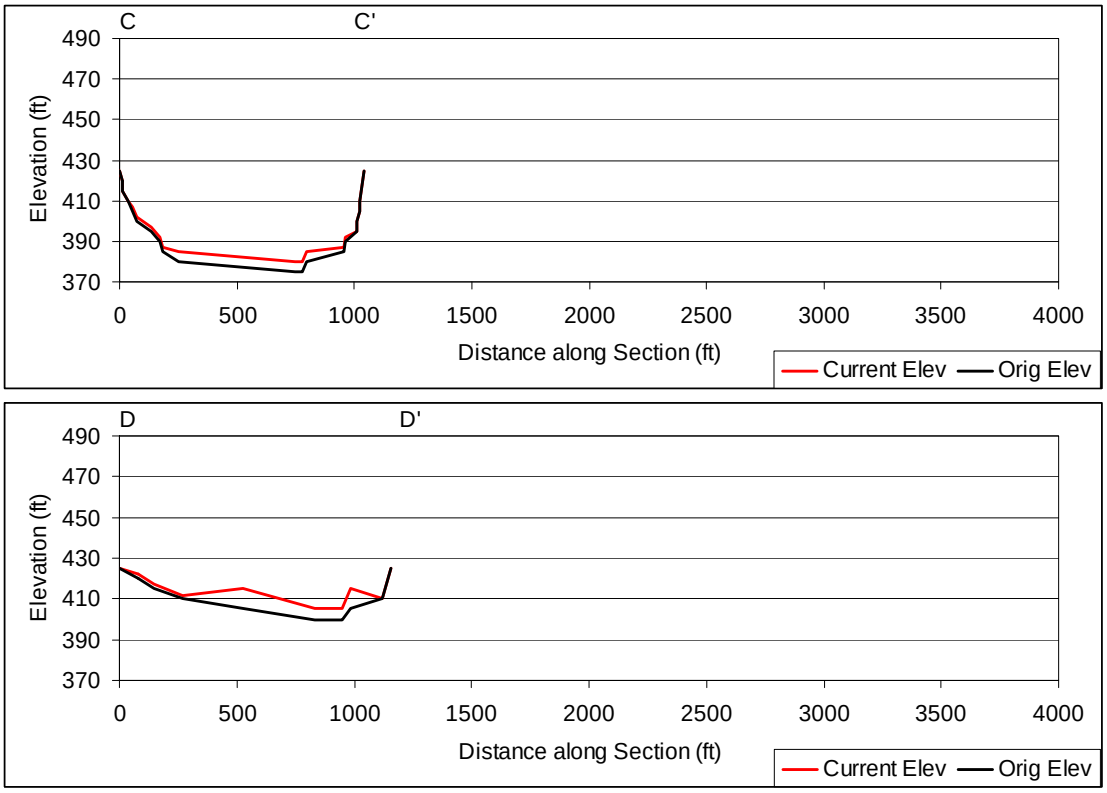


Figure 12. Cross Sectional Profiles Across Expansion-related Delta.

The area, estimated average depth, and estimated volume of the Expansion delta map units are shown in Table 2.

Table 2. Estimated Area, Depth, and Volume of Future Lake Creek Delta Deposits 50 Years after Expansion

Map unit	Area (acres)	Average depth (ft)	Estimated volume (cu yd)
Active channel (cobble/gravel/sand)	47	4	304,000
Cobble/gravel/sand	7	5	60,000
Gravel/sand	10	5	81,000
Sand/silt	48	2.5	194,000
Total	113	--	639,000

Immediately following the expansion of Blue Lake, the newly inundated Blue Lake Creek channel will have substrate characteristics similar to those in the current stream channel. The new delta will form as sediment is carried down the stream and is deposited at the new lake interface. The rate of delta growth will depend upon flows; cobble and gravel material is moved during high flows in the stream. It is expected that some sediment will move into the delta each year, with more sediment transported to the delta during the largest peak flows. As the delta is building, the substrate in the exposed channel will become gradually finer over the first few years as gravel, sand, and fines are deposited over the existing cobble materials. A detailed analysis of delta growth through time was not made due to insufficient data, however notes from a fisheries biologist trip to Becky Creek following construction of the original dam noted that "approximately 200 feet of gravel is now available" five years following dam closure (trip notes from a Fisheries Aid, SERBS, Juneau, Blue Lake Trip June 24-27, 1963).

FISH USE IN BLUE LAKE CREEK

Blue Lake and its tributaries, including Blue Lake Creek are used by resident rainbow trout. A detailed discussion of fish use is included in the Draft Fisheries Report (Wolfe 2009). This Reservoir Sedimentation Study Report includes an analysis of potential changes to rainbow trout spawning habitat and migration corridors in Blue Lake Creek.

Length of Accessible Stream

Under the existing conditions, the Lower Barrier Falls precludes upstream migration of fish from the lake into Blue Lake Creek when lake levels are below approximately 322 feet. Rainbow trout in the Blue Lake system have been found to spawn between mid-May and mid July, with the peak of spawning during June (Wolfe 2009). During this time period, lake levels are below 322 feet during May and June in the majority of years (Figure 4, in previous section). As a result, fish in Blue Lake are not able to access upper Blue Lake Creek, so they spawn in the exposed portion of Blue Lake Creek between the falls and the lake level at the time of spawning. Incubation occurs between spawning and late August to November, depending up on water temperatures.

Under expansion operation conditions, Blue Lake is expected to vary between elevation 365 and 425 feet. These lake levels will cover the Lower Barrier Falls, so resident fish will have access to exposed areas of Blue Lake Creek upstream of the lower falls, and can migrate up to the Upper Barrier Falls (SM 2.0).

An analysis of the length of Blue Lake Creek accessible to fish was made using both existing and modeled expansion conditions based on lake levels and topographic mapping. Figure 13 shows accessible stream length during the months of May, June, and July under existing and expansion conditions for the 10, 25, 50, 75, and 90 percent exceedence levels.

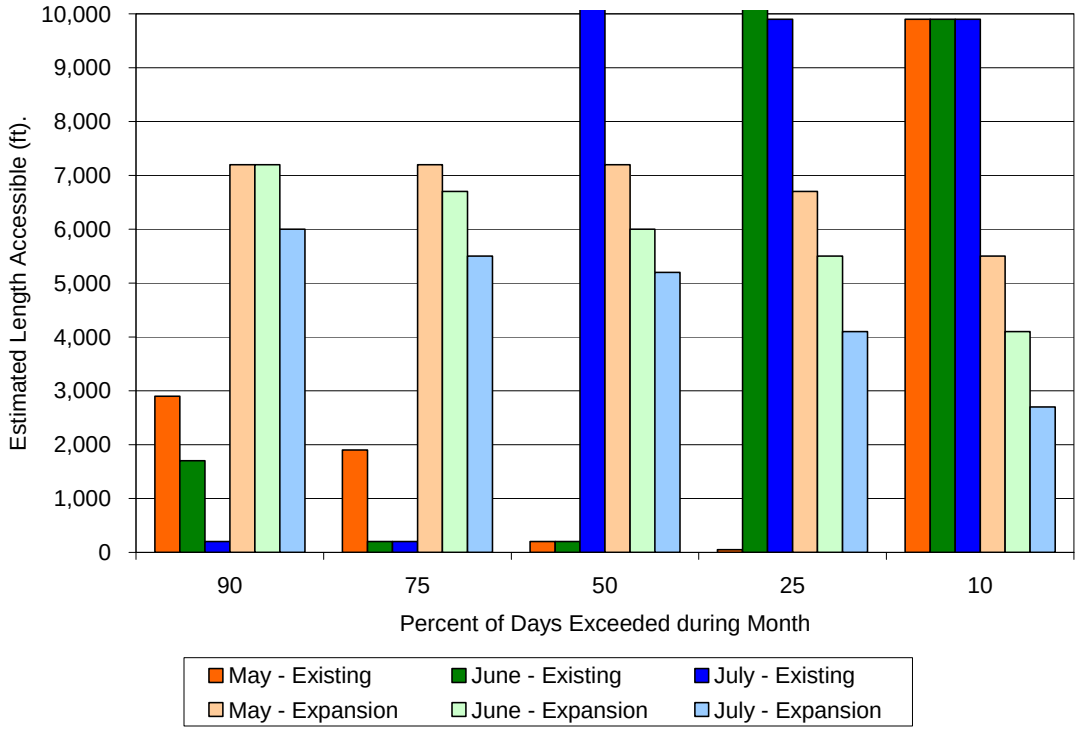


Figure 13. Accessible Length of Blue Lake Creek during Spawning Periods under Existing and Expansion Conditions.

Under existing conditions, the median (50 percent exceedence value) length of exposed Blue Lake Creek bed is 200 feet in May and June and increases to 10,100 in July as the reservoir levels rise. The Lower Barrier Falls are covered 10 percent of the days in May, 25 percent of the days in June, and 50 percent of the days in July under existing conditions, allowing fish to migrate from the lake into approximately 2 miles of upper Blue Lake Creek.

Under modeled expansion conditions, the lower Barrier Falls are covered, so fish have access to the entire exposed length of Blue Lake Creek up to the Upper Barrier Falls. Under these conditions, the accessible length at 50 percent exceedence values decreases from 7,200 feet in May to 5,200 feet in July. This analysis suggests that a longer length of Blue Lake Creek will be accessible to rainbow trout in Blue Lake during the majority of the spawning season under expansion conditions than under existing conditions.

Channel Width and Substrate Conditions

In addition to the length of stream accessible during the spawning season, the channel and substrate conditions also affect the amount of useable spawning habitat. Wolfe (2009) found that rainbow trout in the Blue Lake system preferentially spawn in areas where at least 20 percent of the substrate is in the 4-32 mm size range. Substrate dominated by small particles (less than 4 mm in size) or particles over 32 mm were not utilized. Due to the dominance of coarse substrate in many of the riffle areas in Blue Lake tributaries, spawning often took place in patches of suitable substrate surrounded by areas of less suitable substrate. This opportunistic habitat utilization behavior is common in areas where suitable habitat is limited.

Table 3 shows a comparison of the three cross sections measured in the Blue Lake Creek channel within the existing delta and three stream channel transects within the Expansion fluctuation zone (upstream of the current Blue Lake). Stream gradients at transects within the existing delta ranged from 0.016 to 0.02, higher than gradients in the reach in the Expansion delta area (0.005 to 0.01). Channel widths and bankfull depths were larger within the current delta (see also Figures 14 and 15). The substrate size within the existing delta was much finer than in the current stream channels, and provided substrate within the 4-32 mm size range preferred by spawning rainbow trout (see also Figures 16, 17, and 18 and Appendix A).

Table 3. Comparison of Blue Lake Creek Channel Characteristics in the Exiting Delta and Upstream of the Lake

Location	Channel Gradient	Bankfull width (ft)	Bankfull depth (ft)	Armor layer D_{50} (mm)
Channel within existing delta				
Delta 3, SM -0.35	0.016	240	1.38	1.0
Delta 2, SM -0.18	0.020	124	2.24	18.4
Delta 1, SM -0.15	0.020	63	3.07	34.1
Existing channel conditions upstream of Blue Lake (in area that will become delta)				
Stream 1, SM 1.34	0.010	28	0.78	73.5
Stream 2, SM 1.49	0.005	42	0.82	88.0
Stream 3, SM 1.94	0.008	25	1.02	62.9

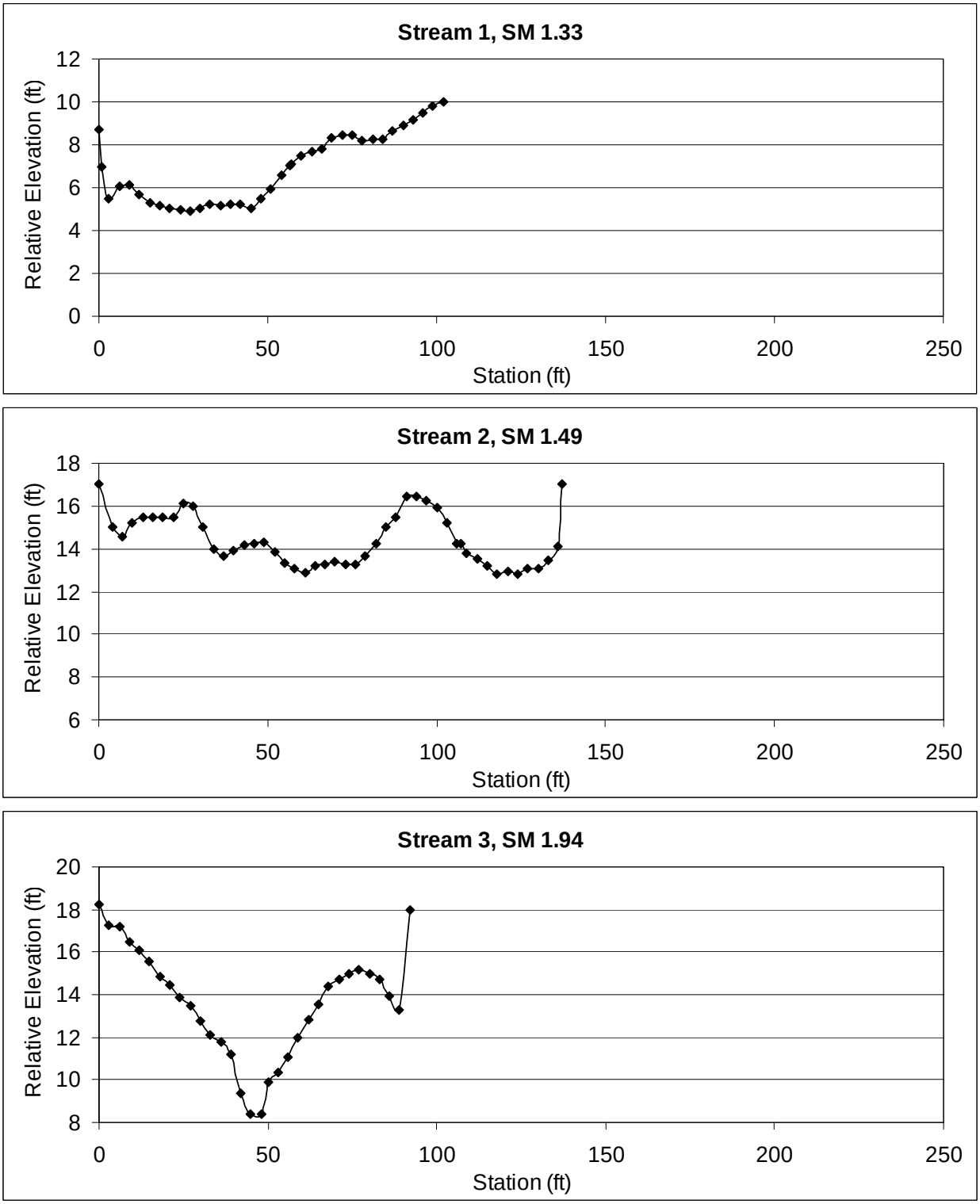


Figure 14. Existing Blue Lake Creek Channel Cross Sections Upstream of Lake

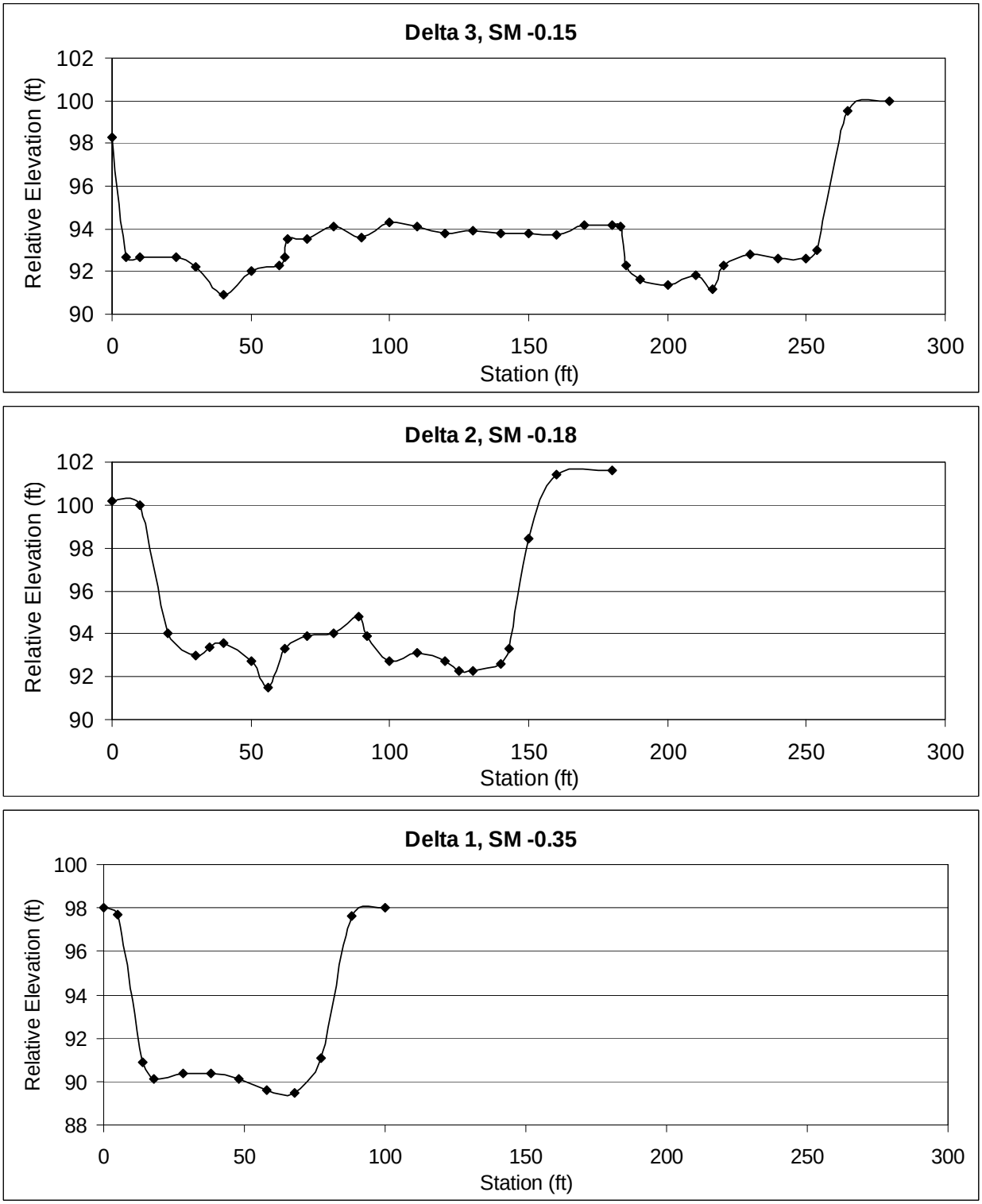


Figure 15. Blue Lake Creek Channel Cross Sections in Current Fluctuation Zone.

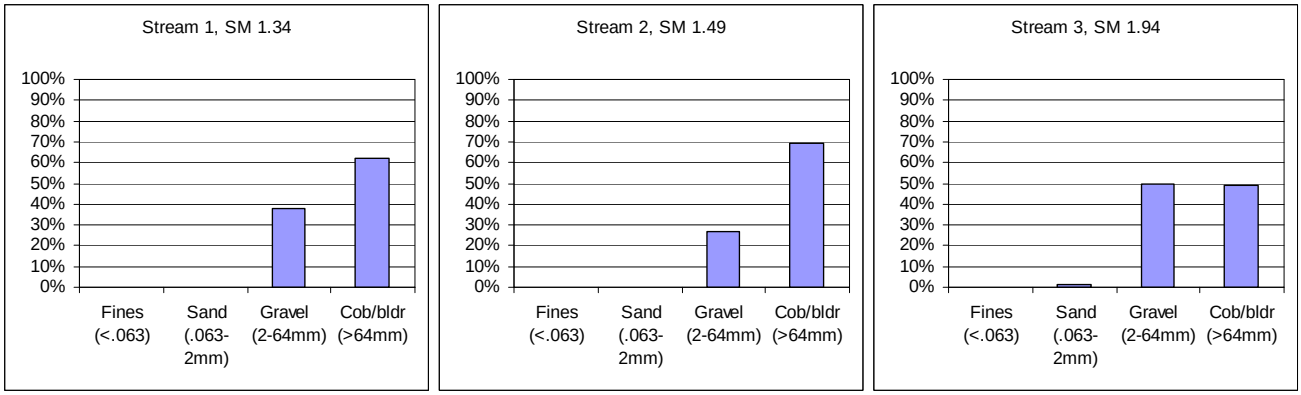


Figure 16. Armor Layer Grain Size Distribution in Existing Blue Lake Creek Upstream of Lake.

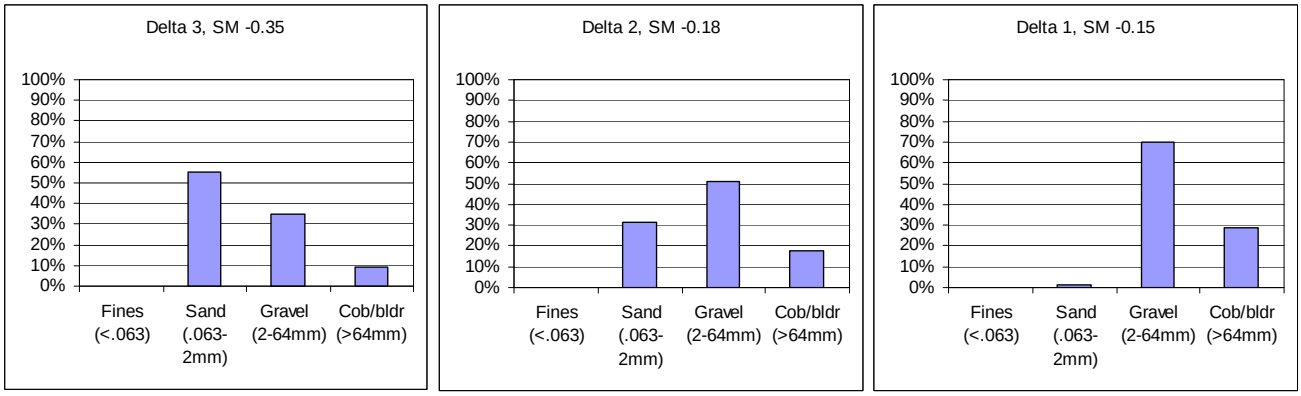


Figure 17. Armor Layer Grain Size Distribution in Existing Delta Active Channel Deposits.

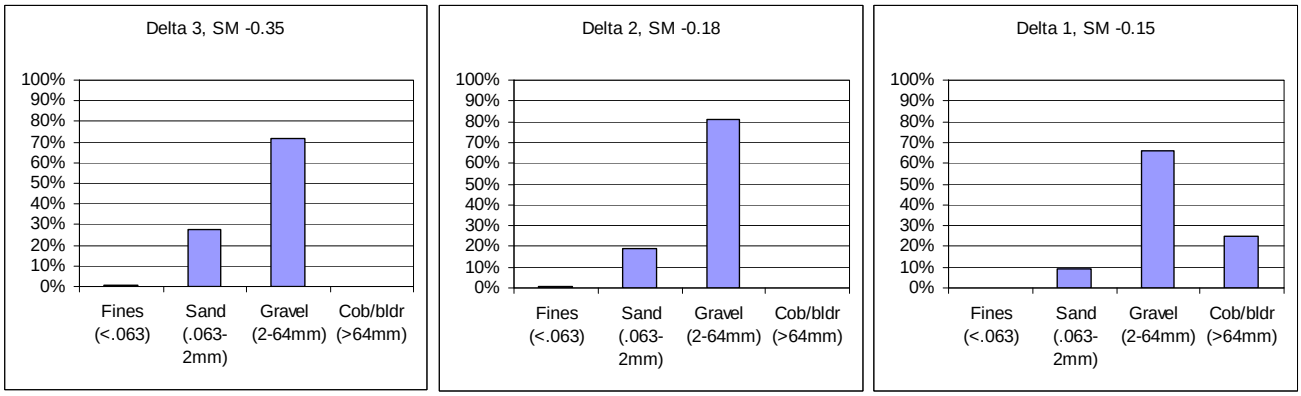


Figure 18. Sub-armor Layer Grain Size Distribution in Existing Delta Active Channel Deposits.

Under proposed Expansion-related operations, Blue Lake Creek would form a new delta within the El 425-365 foot fluctuation zone. Under current conditions the Blue Lake Creek channel in this zone is lower gradient, narrower and deeper, and has larger substrate than the existing delta

channel. In order to assess the potential channel width, depth, and substrate conditions within this fluctuation zone, it was assumed that the deposition of sediment on top of the existing channel substrate would result in channel within the new delta that was wide and low gradient (more similar to the channel at the downstream end of the current delta).

Assuming that at least some portions of the Blue Lake Creek channel in the new delta would be as wide as the widest measured current delta channel, the cross section of Delta Transect 3 was input into WINXSPRO with a slope of 0.005 to estimate channel hydraulics in a scenario of a wide, very low gradient channel. The 0.005 slope is the lowest slope measured in the existing delta and in the existing Blue Lake Creek channel within the area of the expansion scenario delta. Under the 50% exceedence flow values for the spawning period (May-July), flows of 280-353 cfs would result in an average water depth of 1.0-1.2 feet and a 125-130 foot wide channel (Table 4). Under 25% exceedence conditions, flows of 184-306 cfs would result in water depths of 0.8-1.1 feet and wetted widths of 120-127 feet. These water depths are not anticipated to preclude upstream migration or spawning of rainbow trout in the reach.

Table 4. Estimated Flow, Water Depth, and Width in Low Gradient Delta Channel.

	50% Exceedence Values			25% Exceedence Values		
Month	**Flow (cfs)**	**Average Water Depth (ft)**	**Wetted Width (ft)**	**Flow (cfs)**	**Average Water Depth (ft)**	**Wetted Width (ft)**
May	283	1.0	125	184	0.8	120
June	280	1.0	125	306	1.1	127
July	353	1.2	130	293	1.1	125

Calculation of the size of particles that could be entrained by flows within this low slope, wide channel shows that at 25-50 percent exceedence flows within the spawning period (184-353 cfs), particles in the 8-16 mm size class would be entrained at the average water depths. It is expected that, similar to the existing delta channel conditions, substrate within the deepest portion of the channel would be larger than that on the margins of the channels and would provide a mix of substrate across the channel. These size classes are within the range preferred by spawning rainbow trout, suggesting that there would be spawning habitat available within the Expansion delta stream channel.

BECKY, BRAD AND SHELDON CREEKS

Fish use has been documented in three other small tributaries to Blue Lake: Becky, Brad, and Sheldon creeks (see locations in Figure 1, above). There are limited flow, channel, and delta dimension data available for these three tributaries. A qualitative analysis of delta and substrate development in these three streams under expansion conditions is included below based on comments by the U.S. Forest Service and the Alaska Department of Fish and Game.

Characteristics of Becky, Brad and Sheldon creeks in comparison to Blue Lake Creek are shown in Table 5.

Table 5. Estimated Spawning Use, Median Monthly Flows, and Peak Flows in Blue Lake, Becky, Brad, and Sheldon Creeks.

Parameter	Blue Lake Creek	Becky Creek	Brad Creek	Sheldon Creek
Drainage Area (sq mi)	19.9	4.9	3.7	4.0
Number of Redds in Delta/Stream during Spawner Surveys	100/0	85/0	0/0	11/0
May Median Daily Flow (cfs)	283	70	53	57
June Median Daily Flow (cfs)	380	94	71	76
July Median Daily Flow (cfs)	353	87	66	71
Peak 2-year Return Flow (cfs)	3,044	943	746	796
Peak 5-year Return Flow (cfs)	4,077	1,270	1,005	1,073
Peak 10-year Return Flow (cfs)	4,765	1,488	1,178	1,257
Peak 100-year Return Flow (cfs)	6,828	2,139	1,695	1,808

Becky Creek

Becky Creek has a drainage area of 4.9 square miles. The existing delta starts in the confined canyon and flows out onto the wide Blue Lake Creek valley and merges with the Blue Lake Creek delta (see Figure 7). Figure 19 shows the Becky Creek delta in the confined, canyon reach and Figure 20 shows the middle portion of the Becky Creek delta as it leaves the canyon and flows onto the broad valley.

Figure 19. Photo of Becky Creek Delta in Confined Canyon Area.

Figure 20. Photo of Existing Becky Creek Delta.

In the photo of the confined canyon portion of the Becky Creek delta (Figure 19), several delta surfaces can be seen. These surfaces form as the lake level fluctuates and gravel/cobble material is deposited during high flows. As the lake level drops, the material in these deltas is re-worked and moved downstream resulting in a channel cut through the gravel/cobble deposits. When the lake level rises again, new delta surfaces are formed and the cycle continues.

Several longitudinal profiles of Becky Creek were plotted from existing data, including a base profile from the 1957 topographic mapping and 2007 LiDAR data (bold black line in Figure 21) and the 2008 channel profile based on a ground survey (brown line). The 2008 survey was extended (dotted brown line) based on the 2008 profile, original topography, and photographs of the delta. This extension, and the Expansion delta surface (green line) are estimates based on how we envision the Expansion delta surface will appear after 50 years. The Expansion delta will form in a high gradient, confined canyon reach, so the delta deposits will be quite mobile and will likely look similar to those in Figure 19, but shorter. As such, the length of spawning habitat available at the interface of Becky Creek will be less than in the existing project. Gravel and cobble will be deposited during high flow events at the current lake level, and then will be re-worked and transported downstream as the lake level drops.

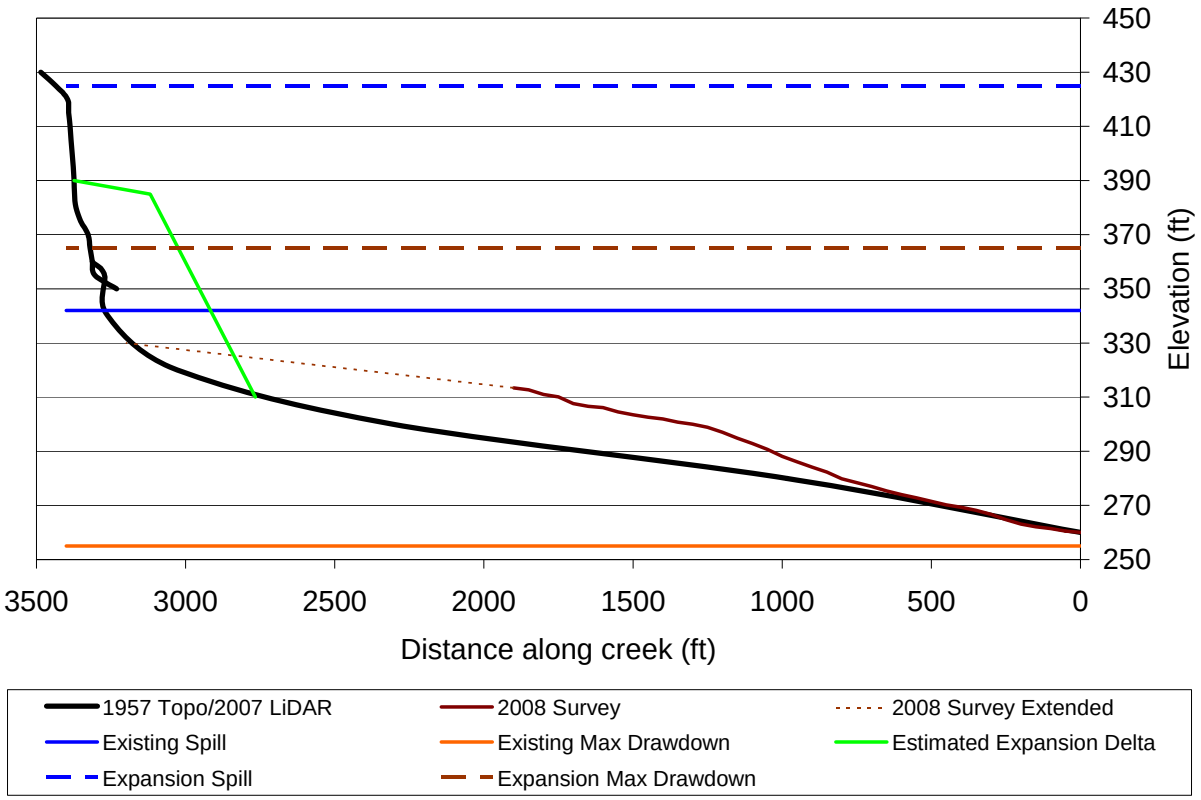


Figure 21. Estimated Existing and Expansion Becky Creek Delta.

Brad Creek

Brad Creek has a drainage area of approximately 3.7 square miles. Photos of the existing Brad Creek delta (Figure 22) show several delta surfaces formed at the mouth of the canyon where Brad Creek enters the wider valley floor. It appears that moderate Brad Creek flows may not be sufficient to transport the cobble and gravel material in the delta; the existing delta is not graded to low lake levels like the Blue Lake or Becky creek deltas.

Figure 22. Photo of Existing Brad Creek Delta.

A longitudinal profile of Brad Creek was plotted from the 1957/2007 data (Figure 23). There are no data on the existing delta profile, but an estimated delta profile was plotted based on the photograph in Figure 22. The Expansion delta will be formed in a higher gradient, confined section of Brad Creek and will likely have similar characteristics to the mobile delta deposits in the canyon section of the current Becky Creek delta (described in the previous section). A lower gradient section of Brad Creek (at approximately elevation 400) may retain some of the gravel and cobble materials through the fluctuating lake levels. The stream length of spawning habitat available at the interface of Brad Creek will be approximately equal to the existing project.

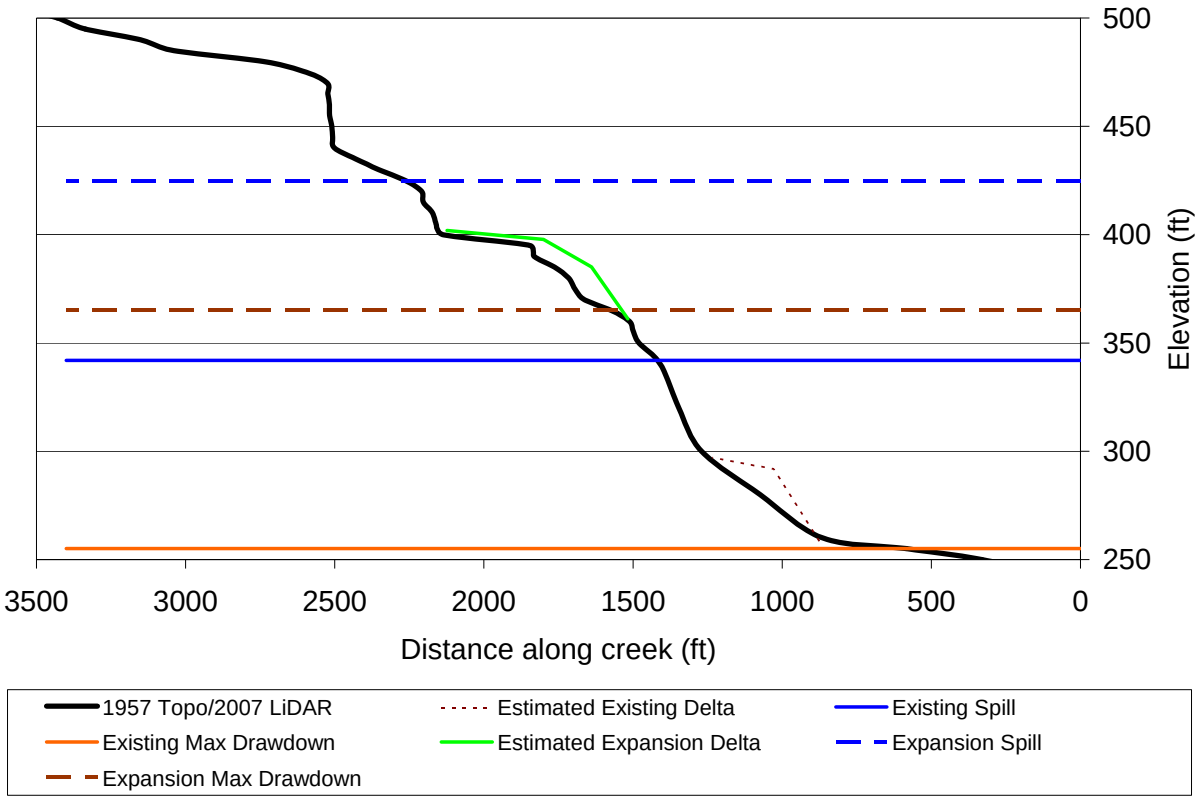


Figure 23. Estimated Existing and Expansion Brad Creek Delta.

Sheldon Creek

Sheldon Creek has a drainage area of approximately 4 square miles. The existing delta deposits are quite thin and spread across the broad valley floor (Figure 24).

Figure 24. Photo of Existing Sheldon Creek Delta.

A longitudinal profile of Sheldon Creek was plotted from the 1957/2007 topographic data (Figure 25). No data on the Sheldon Creek delta are available; an estimated existing delta surface was plotted based on photographs. The Expansion delta will be formed in a confined, higher gradient section of Sheldon Creek and will likely have similar characteristics to the current Becky Creek delta in the canyon reach. The Expansion delta in Sheldon Creek will be mobile; the substrate will be re-worked as the lake level fluctuates. The stream length of spawning habitat available at the interface of Sheldon Creek will be less than is available in the existing project.

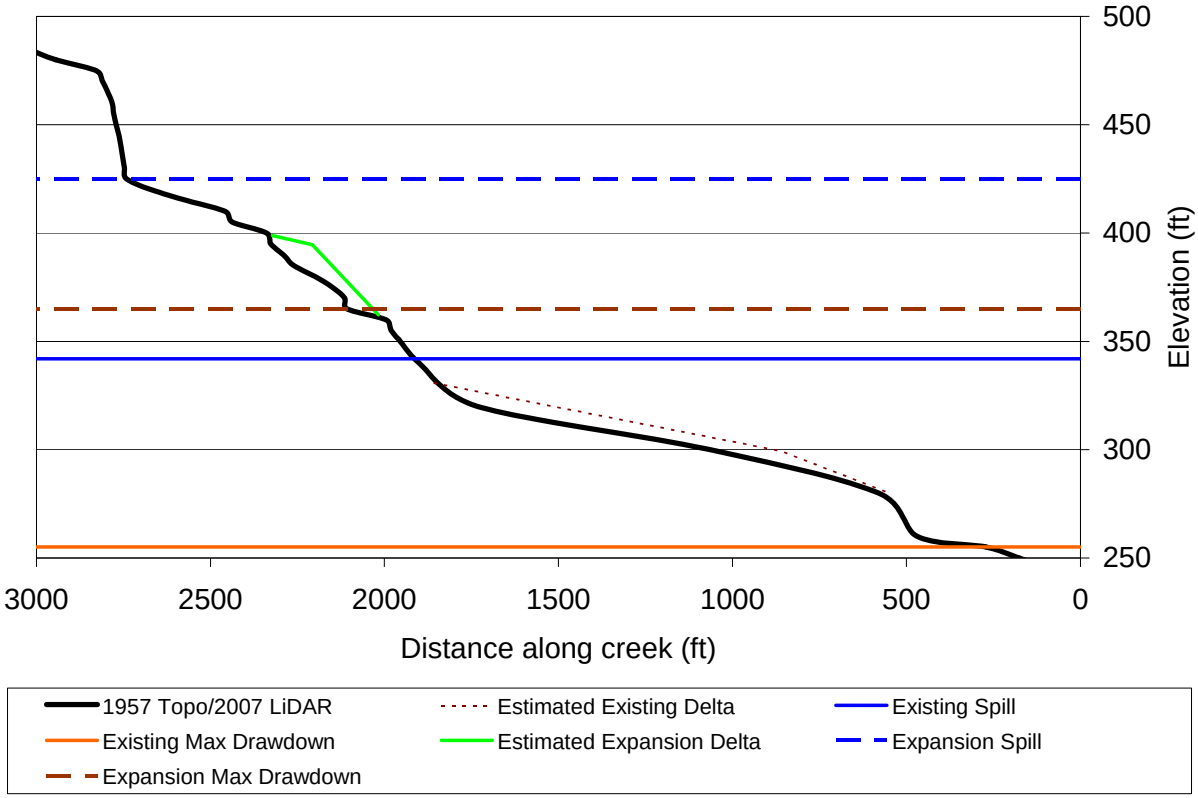


Figure 25. Estimated Existing and Expansion Sheldon Creek Delta.

SUMMARY

The City and Borough of Sitka Electric Department is evaluating raising the dam at the Blue Lake Hydroelectric Project as much as 83 feet above the current dam height to provide additional generation capacity. Operation of the Blue Lake Project under proposed Expansion conditions would inundate approximately 1.9 miles of the current Blue Lake Creek bed upstream of the existing Blue Lake and change the location of reservoir sedimentation and delta development. Rainbow trout use the current Blue Lake Creek delta for spawning and incubation. The objectives of this Reservoir Sedimentation Study are to determine the extent and estimated

volume of sediment deposition and erosion in the Expansion-related Blue Lake Creek delta; and evaluate probable fish habitat and accessibility in the future Blue Lake Creek fluctuation zone.

An estimated 667,000 cubic yards of cobble/gravel/sand/fines has been deposited in the current Blue Lake Creek delta over the 52 years since current Project operations began. Delta deposits were estimated to range from at least 15 feet deep near the head of the delta to 2-3 feet deep deposits of fines along the margins of the active channel area. The median length of exposed channel under current operations during the May-July spawning season is 200 feet in May and June and 10,100 feet in July as reservoir level rise through this time period. Stream gradients at three measured transects ranged from 0.016 to 0.020, with bankfull widths of 63-240 feet, depths of 1.38 to 3.07 feet and armor layer D_{50} ranging from 1-34 mm.

The extent and depth of delta deposits following 50 years of proposed Expansion-related operations was estimated based on valley width and gradient conditions in the current vs. proposed fluctuation zone assuming a similar rate of sediment input. It was assumed that the active channel in the Expansion delta would be similar to the widest measured transect in the existing delta, with stream gradients ranging from 0.005 to 0.01, similar to the existing delta and stream channel. Delta deposits were estimated to be 2-10 feet deep across the new delta.

Under modeled expansion conditions, the median length of exposed Blue Lake Creek bed decreases from 7,200 feet in May to 5,200 feet in July. This suggests that a longer length of Blue Lake Creek would be accessible to rainbow trout in Blue Lake during the spawning season under Expansion operations than under existing conditions. Assuming a wide (240 ft bankfull width) low gradient (0.005) channel would exist in the Expansion delta, water depths during migration and spawning were computed to range from 0.8-1.2 feet under 25-50% exceedence flows during the May-June-July spawning period which should not inhibit upstream migration of rainbow trout. It is possible that some areas of the new channel may be wider and braided than the modeled cross section, but there are wider, low gradient, braided areas within the downstream-most portions of the existing delta stream channel that do not appear to impede migration under existing conditions.

Estimated shear stress under the modeled Expansion-related channel hydraulic and flow conditions during May-June would result in entrainment of particles in the 8-16 mm size class at the average water depths. It is expected that, similar to the existing delta channel conditions, substrate within the deepest portion of the new delta channel would be larger than that on the margins of the channel and would provide a mix of substrate across the channel. These size classes are within the range preferred by spawning rainbow trout, suggesting that there would be spawning habitat available within the Expansion delta stream channel.

Future sediment deposition and spawning habitat were considered for Becky, Brad and Sheldon Creek with the limited data available. Expansion related spawning conditions will be similar to those encountered during 2005 relicensing studies (CBS 2005, Wolfe 2009). During this time spawning was concentrated along shorter lengths and in the case of Brad Creek along a steeper gradient. With the exception of Becky Creek, all future spawning will take place at a gradient that was initially less then that where spawning occurred at Brad Creek in 2005.

CONSULTATION

Comments on this report were received from Alaska Department of Fish and Game (ADF&G) dated September 30, 2009 and from USDA Forest Service (USFS) on October 2, 2009. Comments are listed in Table 6 with notations of how they were addressed in preparation of this final report.

Table 6. Reviewer Comments on Draft Reservoir Sedimentation Report

Comment Number	Comment Summary	Response and Report Location
ADF&G 1	Discuss sedimentation and habitat effects of dam raise in Becky, Brad, and Sheldon creeks.	A discussion of Becky, Brad, and Sheldon creeks has been added to the report on pages 23 through 29.
ADF&G 2	Statement on greater length of Blue Lake Creek habitat after dam raise.	Agreed.
ADF&G 3	Discuss how Blue Lake Creek habitat may change over the next 50 years, using information from original Project time frame.	A discussion of delta formation over time has been included on page17.
USFS 1	Address extent of erosion on entire reservoir perimeter.	The erosion within the fluctuation zone around the reservoir perimeter is estimated to cover 184 acres. The effects of this erosion is discussed in the Boundary Rim Stability Survey conducted by R&M Consultants, Inc. Oct 2009. This report is included in the Geotechnical investigation.
USFS 2	Statement about discrepancies in peak flows in Blue Lake Creek	The peak flow analysis used regional regression equations to predict peak flows in the streams, so the reduction in flow by Blue Lake should not affect the peak flow analysis. Estimated peak flows/discussion in Blue Lake Creek and tributaries are included on page 10 and 24. Peak flows do indeed shape the channel configuration. It is assumed that the cross sections measured in the existing delta (and used in the hydraulic analysis) are representative of a future delta channel formed under a range of low, median, and peak flows.

Comment Number	Comment Summary	Response and Report Location
USFS 3	Comment on use of daily average flows and need to use peak flows.	The hydraulic and sediment transport calculations were made for median daily flows during the spawning periods to provide information about water width and depth during normal spawning conditions. Peak flows do indeed shape the channel configuration. It is assumed that the cross sections measured in the existing delta (and used in the hydraulic analysis) are representative of a future delta channel formed under a range of low, median, and peak flows.
USFS 4	Stream gradient contradictions.	The delta channel gradients listed in Table 3 (page 19) is the local gradient surveyed at those three particular delta cross sections which are located on the steeper part of the existing delta (see Figure 10). The Assumption 3 range of delta gradients (page 14) was used in the XSPRO analysis to represent the gradient of the future (expansion) delta since the expansion delta will be constructed in a lower-gradient valley than the existing delta (again see Figure 10). [The gradient for Reach 3 in Table 11 of the Fisheries Report was incorrectly listed as 0.1 percent – this has been corrected in that report.]
USFS 5	Comment on Figure 7 and predicted extent of new (post-Expansion) delta.	The predicted lower end of the delta was graded to the maximum drawdown elevation under expansion conditions which is above the lower barrier falls (similar to how the existing delta is graded to the current maximum drawdown elevation based on the topographic surveys – See Figure 10). There would be some deposition below the maximum drawdown elevation, but we do not have any information on the current extent of these deposits (either volume or extent), so they were not included in either the current or future analysis.

Comment Number	Comment Summary	Response and Report Location
USFS 6	Effects of fish egg desiccation as flows recede.	It is possible that some redds may desiccate if flows drop before the reservoir rises. However, the warming air and water temperatures that initiate the trout spawning in the reservoir also cause an increase inflow to the reservoir causing it to rise and cover the redds, similar to the existing conditions.
USFS 7	Comment on exposed channel length as reservoir rises.	The accessible length increases when the reservoir rises enough to inundate the lower falls, allowing fish access to upstream areas.

LITERATURE CITED

Curran, J.H., D. F. Meyer, and G.D. Tasker, 2003. Estimating the magnitude and frequency of peak streamflows for ungaged sites on streams in Alaska and conterminous basins in Canada. U.S. Geological Survey Water-Resources Investigations Report 03-4188.

Hardy, T., P. Panja, and D. Mathias, 2005. WinXSPRO, A channel cross section analyzer, user's manual, Version 3.0. USDA Forest Service, Rocky Mountain Research Station, General Technical Report RMRS-GTR-147. January 2005.

Neal, EG., M.T. Walter, and C. Coffeen, 2002. Linking the Pacific decadal oscillation to seasonal stream discharge patterns in Southeast Alaska. Journal of Hydrology vol. 263, pp. 188-197.

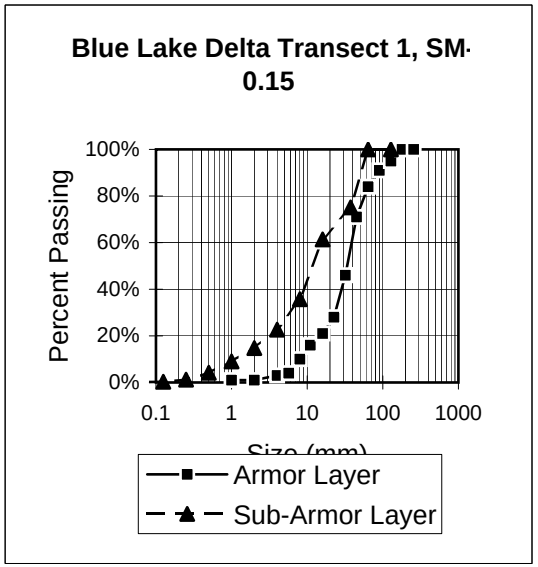
Wolfe, K., 2009. Draft 2008 Fisheries Studies Report, Blue Lake Project (FERC No. 2230) Expansion. Report prepared for City and Borough of Sitka Electric Department, May, 2009.

Blue Lake Creek Delta Sediment Samples

Station **Blue Lake Delta Transect 1, SM-0.15**

		D65=	54.9	mm	
Armor Layer		D50=	34.1	mm	
Size (mm)	**Percent**	**Cum %**	**Avg size**		**No.**
1	1%	1%	0.01		1
2	0%	1%	0.00		0
4	2%	3%	0.10		2
5.7	1%	4%	0.07		1
8	6%	10%	0.57		6
11	6%	16%	0.81		6
16	5%	21%	0.97		5
22.6	7%	28%	1.91		7
32	18%	46%	6.93		18
45	25%	71%	13.63		25
64	13%	84%	10.01		13
90	7%	91%	7.63		7
128	4%	95%	6.16		4
180	5%	100%	10.90		5
256	0%	100%	0.00		0
			59.69	mm	100
			0.1958	ft	

		D65=	21.7	mm
Sub-Armor Layer		D50=	12.4	mm
Size (mm)	**Weight (g)**	**Percent**	**Cum %**	**Avg size**
128	0	0%	100%	0
64	1,020	25%	100%	23.8829
37.5	563	14%	75%	6.96884
16	1,052	26%	61%	6.86366
8	535	13%	36%	1.56585
4	325	8%	23%	0.47561
2	234	6%	15%	0.17122
1	200	5%	9%	0.07317
0.5	121	3%	4%	0.02213
0.25	37	1%	1%	0.00338
0.125	7	0%	0%	0.00032
0.063	2	0%	0%	4.6E-05
0.003	4	0%	0%	3.2E-05
pan	4,100			40.03 mm



0.1313 ft

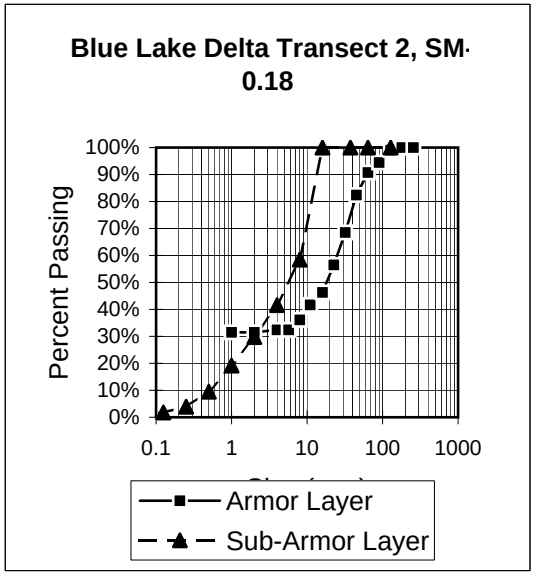
Blue Lake Creek Delta Sediment Samples

Station **Blue Lake Delta Transect 2, SM-0.18**

Armor Layer

D65= 29.3 mm
D50= 18.4 mm

Size (mm)	Percent	Cum %	Avg size	No.
1	31%	31%	0.31	34
2	0%	31%	0.00	0
4	1%	32%	0.04	1
5.7	0%	32%	0.00	0
8	4%	36%	0.35	4
11	6%	42%	0.75	6
16	5%	46%	0.89	5
22.6	10%	56%	2.78	11
32	12%	69%	4.63	13
45	14%	82%	7.57	15
64	8%	91%	6.42	9
90	4%	94%	4.04	4
128	5%	99%	7.13	5
180	1%	100%	2.02	1
256	0%	100%	0.00	0
			36.94 mm	108
			0.1212 ft	



Sub-Armor Layer

D65= 9.3 mm
D50= 6.0 mm

Size (mm)	Weight (g)	Percent	Cum %	Avg size
128	0	0%	100%	0
64	0	0%	100%	0
37.5	0	0%	100%	0
16	1,610	42%	100%	11.1113
8	654	17%	58%	2.02477
4	459	12%	42%	0.71053
2	410	11%	30%	0.31734
1	375	10%	19%	0.14512
0.5	216	6%	9%	0.0418
0.25	83	2%	4%	0.00803
0.125	41	1%	2%	0.00198
0.063	11	0%	1%	0.00027
0.003	17	0%	0%	0.00014

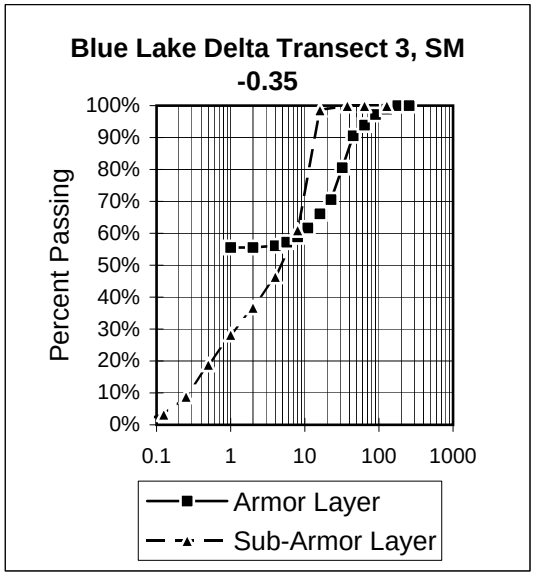
pan	3,876	14.36	mm
		0.0471	ft

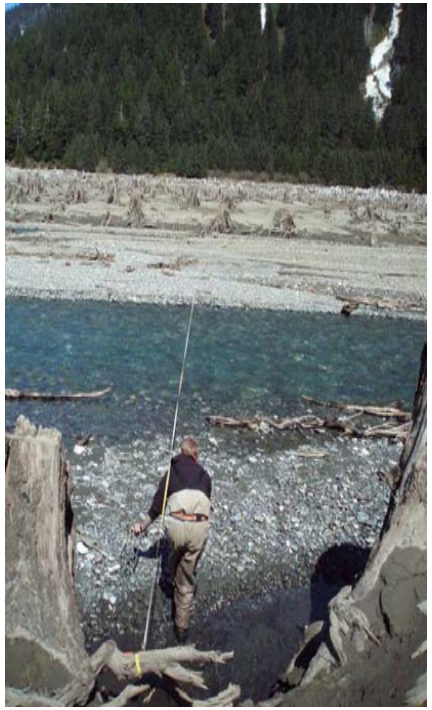
Blue Lake Creek Delta Sediment Samples

Station **Blue Lake Delta Transect 3, SM -0.35**

		D65=	14.8	mm	
Armor Layer		D50=	1.0	mm	
Size (mm)	**Percent**	**Cum %**	**Avg size**		**No.**
1	56%	56%	0.56		100
2	0%	56%	0.00		0
4	1%	56%	0.03		1
5.7	1%	57%	0.08		2
8	2%	59%	0.16		3
11	3%	62%	0.38		5
16	4%	66%	0.86		8
22.6	4%	71%	1.21		8
32	10%	81%	3.85		18
45	10%	91%	5.45		18
64	3%	94%	2.57		6
90	3%	97%	3.63		6
128	2%	99%	2.57		3
180	1%	100%	2.42		2
256	0%	100%	0.00		0
			23.75	mm	180
			0.0779	ft	

		D65=	8.8	mm
Sub-Armor Layer		D50=	5.0	mm
Size (mm)	**Weight (g)**	**Percent**	**Cum %**	**Avg size**
128	0	0%	100%	0
64	0	0%	100%	0
37.5	39	1%	100%	0.68947
16	1,068	38%	99%	10.0551
8	415	15%	61%	1.75276
4	275	10%	46%	0.58073
2	241	8%	37%	0.25447
1	266	9%	28%	0.14059
0.5	285	10%	19%	0.07517
0.25	159	6%	9%	0.02101
0.125	55	2%	3%	0.00361
0.063	16	1%	1%	0.00053



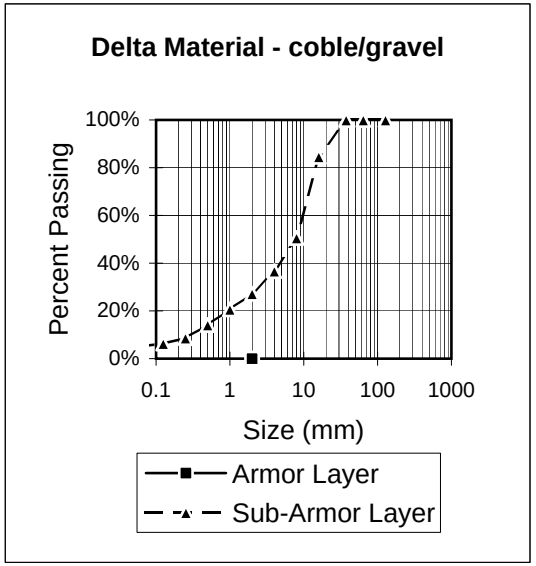


0.003	23	1%	1%	0.00026	
	2,841			13.57	mm
				0.0445	ft

Blue Lake Creek Delta Sediment Samples

Station **Delta Material - coble/gravel**

		D65=		mm	
Armor Layer		D50=		mm	
Size (mm)	**Percent**	**Cum %**	**Avg size**		**No.**
1					
2		not taken			
4					
8					
16					
32					
64					
128					
256					
				mm	0
				ft	



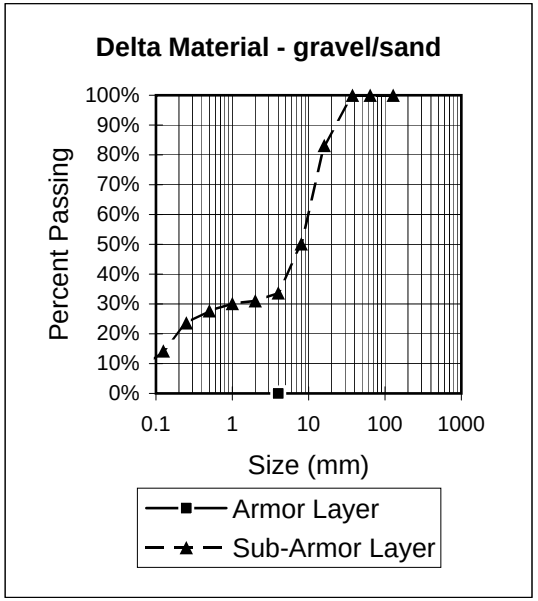
		D65=	11.4	mm	
Sub-Armor Layer		D50=	7.8	mm	
Size (mm)	**Weight (g)**	**Percent**	**Cum %**	**Avg size**	
128	0	0%	100%	0	
64	0	0%	100%	0	
37.5	519	15%	100%	7.82745	
16	1,144	34%	85%	9.09817	
8	467	14%	51%	1.66583	
4	319	9%	37%	0.56903	
2	220	7%	27%	0.19651	
1	220	7%	21%	0.09794	
0.5	185	6%	14%	0.04126	
0.25	78	2%	9%	0.00868	
0.125	38	1%	6%	0.0021	
0.063	50	1%	5%	0.00139	
0.003	125	4%	4%	0.00122	
pan	3,363			19.51	mm
				0.0640	ft

Blue Lake Creek Delta Sediment Samples

Station **Delta Material - gravel/sand**

		D65=		mm	
Armor Layer		D50=		mm	
Size (mm)	**Percent**	**Cum %**	**Avg size**		**No.**
1					
2					
4		not taken			
8					
16					
32					
64					
128					
256					
				mm	0
				ft	

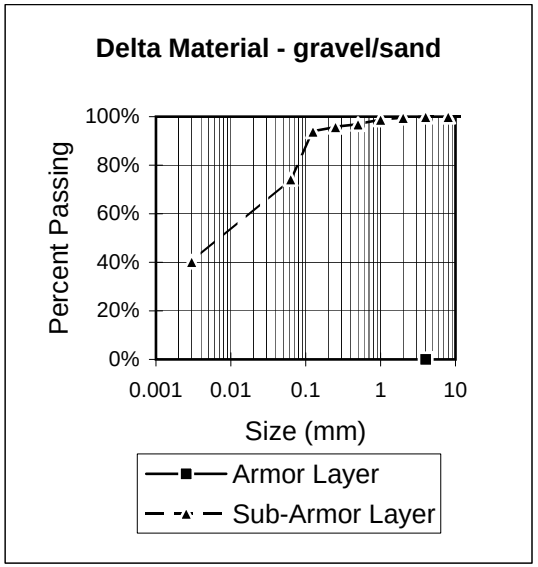
		D65=	11.6	mm	
Sub-Armor Layer		D50=	8.0	mm	
Size (mm)	**Weight (g)**	**Percent**	**Cum %**	**Avg size**	
128	0	0%	100%	0	
64	0	0%	100%	0	
37.5	434	17%	100%	8.54665	
16	850	33%	83%	8.82876	
8	423	16%	50%	1.97283	
4	68	3%	34%	0.15836	
2	24	1%	31%	0.02763	
1	63	2%	30%	0.03677	
0.5	104	4%	28%	0.03032	
0.25	242	9%	24%	0.03529	
0.125	153	6%	14%	0.01113	
0.063	67	3%	8%	0.00245	
0.003	147	6%	6%	0.00188	
pan	2,574			19.65	mm
				0.0645	ft



Blue Lake Creek Delta Sediment Samples

Station **Delta Material - gravel/sand**

		D65=		mm	
Armor Layer		D50=		mm	
Size (mm)	**Percent**	**Cum %**	**Avg size**		**No.**
1					
2					
4		not taken			
8					
16					
32					
64					
128					
256					
512					
				mm	0
				ft	



		D65=	0.1	mm	
Sub-Armor Layer		D50=	0.03	mm	
Size (mm)	**Weight (g)**	**Percent**	**Cum %**	**Avg size**	
128	0	0%	100%	0	
64	0	0%	100%	0	
37.5	0	0%	100%	0	
16	0	0%	100%	0	
8	0	0%	100%	0	
4	3	0%	100%	0.0238	
2	5	1%	100%	0.02239	
1	12	2%	99%	0.0289	
0.5	7	1%	97%	0.00823	
0.25	12	2%	96%	0.00706	
0.125	125	20%	94%	0.03683	
0.063	217	34%	74%	0.03198	
0.003	257	40%	40%	0.0133	
pan	638			0.17	mm
				0.0006	ft