Culvert Assessment and Recommendations

Fish Passage Evaluation
Holgate Creek
Haines, Alaska

April 2008

Natural Channel Design, Inc.

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Submitted to:
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BACKGROUND

Holgate Creek is a small perennial stream located in Haines, Alaska (Figure 1). Alaska Department of Fish and Game designates the stream as #115-32-094 (One-mile Creek). The stream is a tributary of the Chikat River and joins the Chilkat northwest of Pyramid Island. The stream supports several species of fish, the most abundant being Coho salmon (*Onchorhynchus kisutch*) and cutthroat trout (*Onchorhynchus clarkii*). Dolly Varden (*Salvelinus malma*) as well as sticklebacks and sculpin have also been captured in the stream. Fish passage into the stream may be a limiting factor to fish populations. Several culverts along the stream have been identified as possible barriers limiting fish access to the stream.

In 2005-2006 the Takshanuk Watershed Council (TWC) conducted a baseline assessment and monitoring project on Holgate Creek, funded by the US Fish & Wildlife Service (FWS). Their report, "Holgate Creek Assessment and Monitoring Project, December 2006" highlights several issues and opportunities, one being fish passage:

Fish passage may be a concern, particularly in times of low flow in the creek. The culvert under Mud Bay Road is considered to be undersized by Fish and Game personnel (Ben Kirkpatrick pers comm.). The current fish ladder was installed as partial compensation for this but the tendency of the cobbles within it to wash out calls into question its effectiveness. Recommendation: Survey these sites and use passage models to determine if they are indeed problems. Approach ADOT and landowners with solutions.

As a result of this, TWC under additional funding from FWS hired Natural Channel Design to conduct fish passage evaluation. This assessment focuses on the most downstream culvert which passes under Mud Bay Road at the mouth of Holgate Creek using the following protocols:

- *Tongass Road Condition Survey Protocol (GREEN-GRAY-RED)*
- *Tier I Stream Simulation Design (MOA between ADFG and ADOT)*
- *Hydraulic/critical velocity Evaluation*

Adult cutthroat trout and Coho salmon as well as juvenile Coho are the target species for movement into the stream. Fish passage issues generally focus on the ability of returning adult salmonids to migrate upstream to spawning beds during the summer months. However, juvenile Coho have been observed in the stream in the fall and their ability to move up and downstream may also be important. This pattern complicates fish passage considerations. While depth of flow and physical barriers are often the limiting factors for summer returning adult fish, the high flows characteristic of the fall season in this region make culvert flow velocities a critical parameter as well.

This report assesses the performance of the existing culvert and provides recommendations to improve fish passage. The culvert was evaluated for the following characteristics.

- Sufficient fish passage for returning adult cutthroat and Coho during the summer;
- Sufficient fish passage for Coho salmon fry in the fall;
- Adequate flood flow conveyance capacity; and
- Adverse impacts to stream function,.

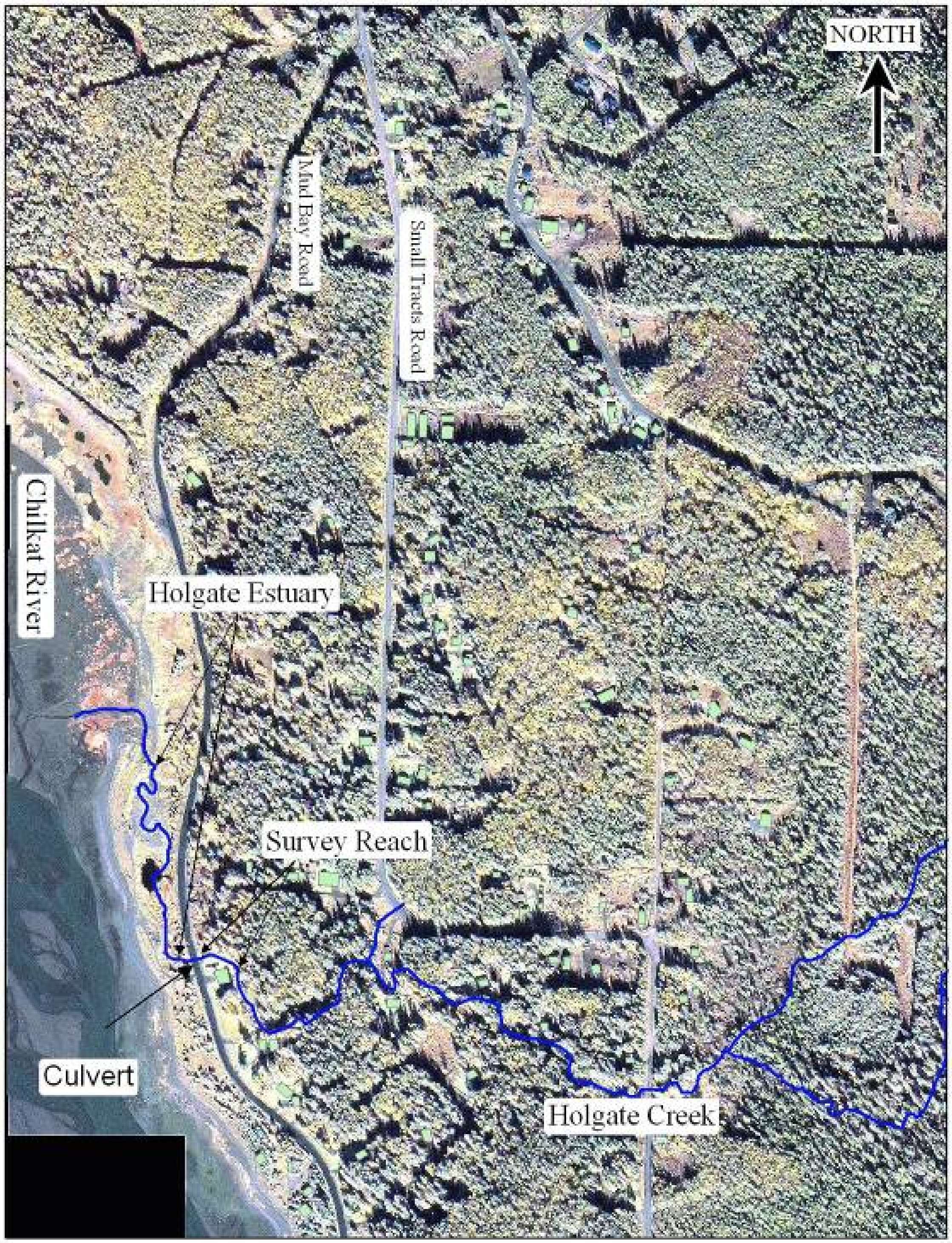

Figure 1. Project location

The culvert is located where Mud Bay Road crosses Holgate Creek near Haines, Alaska. The crossing is the most downstream culvert in the system as Holgate Creek joins the Chilkat River (left side of photo).

BIOLOGICAL DESIGN CONSIDERATIONS

Although several species of fish have been captured in Holgate Creek including Dolly Varden, stickleback and sculpin (Shields 2006), the most abundant migratory fish utilizing the stream are Coho salmon and cutthroat trout. The focus of fish passage evaluation was for cutthroat trout and coho salmon. Dolly Varden appear limited in number within the stream. Full swimming criteria for Dolly Varden are still under investigation but based on sustained swimming speed estimates for Artic char, adult Dolly Varden may be the weakest swimming fish of the Holgate community. Due to their limited numbers and lack of swimming critieria, Dolly Varden were not included in the passage evaluation. Design considerations are given in Table 1.

Table 1. Swimming criteria for migratory fish found in Holgate Creek.

(Ref: [1]CaDFG Fish Passage at Culverts, pg. IX-42 and [2]MOA with ADFG /ADOT, pg 22.)

Target Species:	Cutthroat Trout (*Salmo clarkii*)	Coho Salmon (*Oncorhyncus kisutch*)
Design Length[*2]:	250 mm (100 mm)	600 mm (60 mm)
Minimum Water Depth[*1]:	0.5 ft	0.8 ft (0.3 ft juv)
Migration Period:	Fall	July to November
Prolonged Swimming Speed[*1]:	4 fps (2 fps juv)	6 fps (1.5 fps juv)
Prolonged Time to Exhaustion[*1]:	30 min	30 min (30 min juv)
Bust Swimming Speed[*1]:	5 fps	10 fps (3 fps - juv)
Burst Time to Exhaustion[*1]:	5 sec	5 sec (5 sec - juv)
Leaping Speed[*1]:	6 fps	15 fps (4 fps - juv)

PROJECT HYDROLOGY

The hydrologic analysis requires defining the range of high and low discharges to identify the operating conditions under which the fish passage will function. Regional guidelines were developed for fish passage (MOA ADFG / ADOT&PF, 2001). Under this MOA southeast Alaska design discharges may be determined using Jones and Fahl's (1994) regional regressions. Due to concerns over variability in Southeast Alaska discharges computed with Jones and Fahl's method were compared to discharges predicted by the National Flood Frequency Program (NFF; Ries and Crouse, 2002 and Curran, Meyer, and Tasker, 2003). While the NFF program consistently gave lower discharge estimates for a given frequency, the predicted discharges for both methods were similar. Hydraulic analyses in this assessment are based on Jones and Fahl's method.

These equations require several characteristics of the stream at the project site including: watershed area, average annual precipitation, lake/pond area within the watershed, and mean minimum January temperature (see Figure 2 for Watershed Map).

Watershed area:	0.83 square miles
Average annual precipitation:	48 inches
Lake area within watershed:	0.02%
Minimum January Temperature:	19.3˚F
Mean elevation:	172 feet

Discharge estimates for various flood frequencies are presented in Table 2.

Figure 2. Watershed Map

Holgate Creek watershed includes the west slope of Mt Riley with a watershed area of 0.83 sq miles.

Table 2. Discharges for Holgate Creek for various flood frequencies.

Hydraulic analysis of fish passage used estimates from Jones and Fahl's and NFF methods.

Recurrence interval (years)	Probability (Percent Exceedence)	Jones and Fahl's (1994) Discharge (cfs)	NFF Discharge (cfs)
2	50%	89	74
5	20%	130	114
10	10%	158	142
25	4%	195	179
50	2%	224	208
100	1%	253	236

Fish passage assessment was based on a discharge equal to 40% of the 2-year as suggested by ADFG/ADOT (2001). This flow of 36 cfs is meant to correspond to the mean daily discharge that is exceeded approximately one to five percent of the time. Based on the short duration of this discharge, it appears the value is meant to represent a short duration, minimum discharge to allow fish passage. Passage at low flow was also assessed by depth criteria suggested by ADFG/ADOT (2001), where minimum depth for passage is 2.5 times the height of the caudal fin and caudal fin height is a function of body length. A discharge of 225 cfs (50-year RI) was used to evaluate flood capacity and culvert substrate stability.

EXISTING CONDITIONS

The physical components of stream and culvert were surveyed August 13, 2007. (See Appendix A Fish Passage Inventory Data Sheet and Survey Data) There is a single, 66-inch, round corrugated metal pipe passing under Mud Bay Road. The culvert length is 80 feet. The pipe is aluminum and the inlets and outlets have flared metal end sections (Figure 3).

A metal detachable fishway was placed in the culvert to hold and collect stream bedload material, providing extra roughness and slowing water velocities (Figure 4). The frame was retrofitted into the existing culvert around 1989 and originally stocked with cobble substrate. The height of the frame is 1.1 ft (0.2 times the pipe diameter), width is 3.5 ft, and cross members are every 6.6 ft (1.2 times the pipe diameter) with one centered retention grid. Frequent maintenance has been required to maintain sediment within the frame (Randy Ericsson, Cramer and Assoc., Inc., pers. comm.). At the time of the survey there was little sediment in the frame and did not appear to be enhancing fish passage. Local observations indicate passage through the culvert and lower portion of the stream may be of particular concern during dry years due to limited surface flow.

A longitudinal profile of the stream channel bed was surveyed using a laser level and tape a distance of 140 feet upstream and 300 feet downstream of the culvert to the pond edge (Figure 5). The stream channel has an average slope of approximately 0.03 ft/ft (3%). The culverts are installed at a much steeper slope of approximately 6.5%. Downstream of the culvert the slope is much lower, approximately 1%. No central bars that would indicate inadequate sediment transport were observed upstream or downstream of the culvert. A scour hole at the outlet of the culvert is only moderately deep (0.7 feet) and extends only a short distance downstream. The downstream water surface elevation is even with the culvert invert and produces no barrier (Figure 2). Upstream step pools had an average spacing of 7.5 ft with 3-in. drop.

A single representative cross-section was surveyed upstream of the crossing (Figure 6). The average bankfull (active channel) width is 8 ft with a mean depth of 0.8 ft and cross-section area of 6.5 sq ft. Section 404 of the Clean Water Act regulates discharge into Waters of the United States below the Ordinary High Water (OHW). The delineation of OHW is somewhat subjective but in this region it is commonly consistent with erosion scour lines along one or both stream banks.

Figure 3. Existing culvert outfall at Holgate Creek below Mud Bay Road.

Inlet and outlets are flared sheet metal. An in-culvert fishway was installed to collect and stabilize bedload material in a steep culvert (6.5%).

Figure 4. Metal detachable fishway.

Frame was originally meant to capture and hold sediment, creating higher roughness and slower velocities. Currently, little sediment is being held in place.

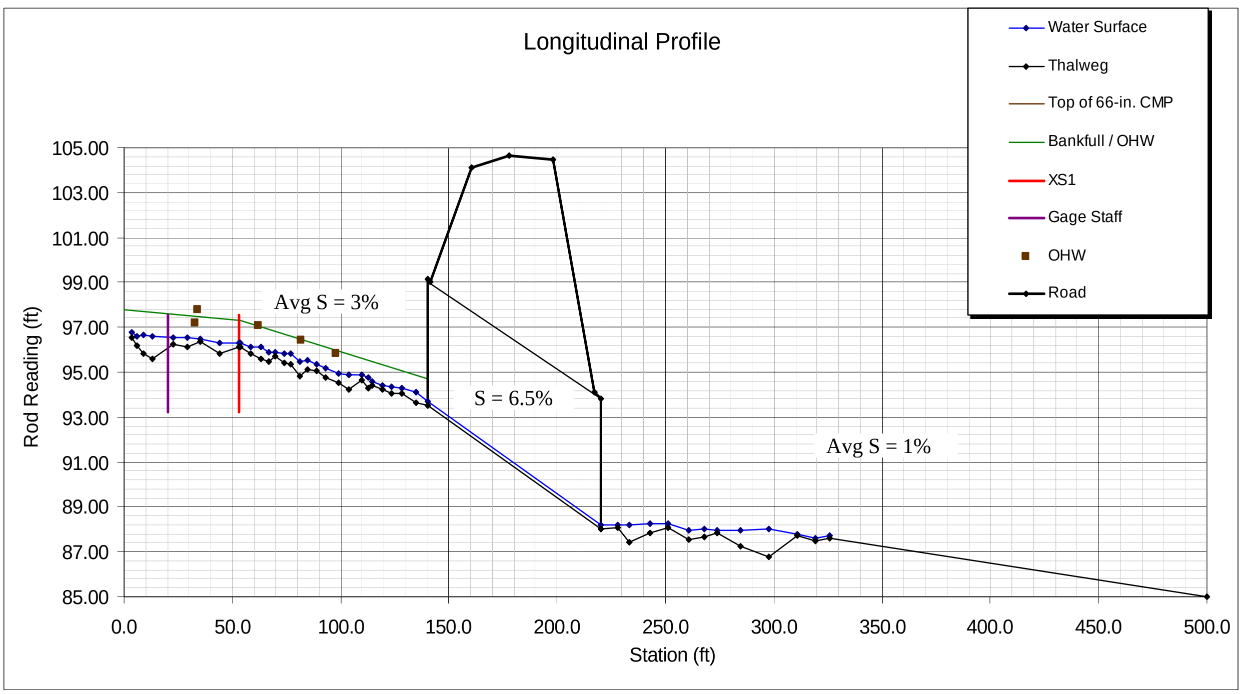

Figure 5. Longitudinal profile of Holgate Creek.

A longitudinal profile of the channel bed was surveyed above and below the culvert. The slope of the existing culvert is more than 2 times steeper than the channel bed above the culvert and nearly 6 times steeper than the downstream channel bed. The green represents the approximate elevation of OHW through the upstream project reach.

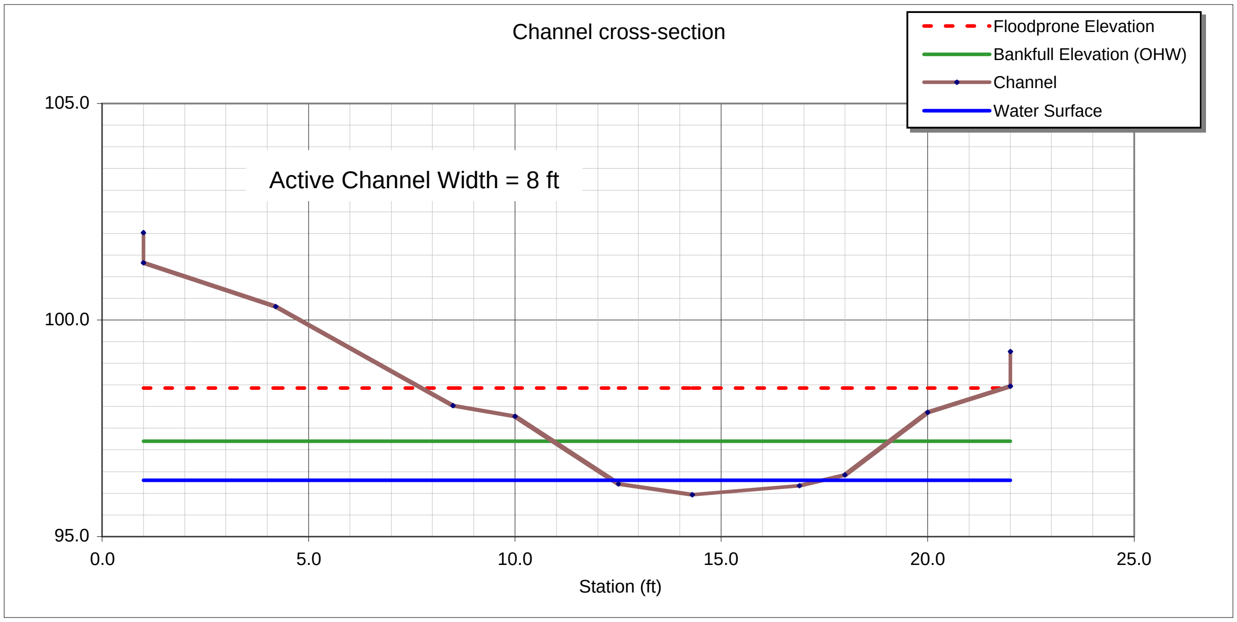

Figure 6. Typical cross-section

This cross-section was surveyed at Station 0+53 on the longitudinal profile upstream of the culvert. Ordinary High Water as defined in Section 404 of the Clean Water Act is shown in the solid green line.

Wolman Pebble counts were conducted to assess bed material particle size upstream and downstream of the culvert. The results of the pebble count suggest that the available substrate in the stream is relatively coarse (Table 3). Substrate within upstream channel steps was measured (Table 4). Most sediment passes under the current bedload collector and is not available to replenish material removed from the rack.

Table 3. Sediment particle size distribution of bed material.

Distribution indicates that approximately 85% of sediment supply available to the stream is 120 mm diameter or less. The channel below the culvert is dominated by finer particles as a result of its lower slope.

Distribution	Upstream of culvert Particle size (mm)	Downstream of culvert Particle size (mm)
D 15	0.6	0.6
D 50	20	12
D 85	120	22
D100	350	300

Table 4. Substrate particle size of steps in upstream channel.

The substrate material in the steps are composed of particles greater than the D85 of bed material, Table 3.

Distribution	Upstream Steps Particle size (mm)	Upstream Steps Particle size (ft)
D 15	140	0.5
D 50	220	0.7
D 85	280	0.9
D100	350	1.15

EVALUATION OF EXISTING CULVERTS

The existing culvert was evaluated for capacity, impacts to stream function, and fish passage.

CONVEYANCE CAPACITY

The capacity of the 66-inch culvert was estimated using Manning's equation for circular pipe section with and without a functioning bedload collector fishway. Without the fishway ladder, the culvert easily passed the flood capacity flow (Q50 = 224 cfs). Depth of flow was 33 inches with an approximate velocity of 19 ft/sec. Capacity of the culvert with a functioning fishway ladder is lower. However, the culvert still passed the Q50 design flow at a depth of 37 inches above the 1 ft substrate. Estimated velocity is 14 ft/sec. Lower velocities were the result of increased roughness in the culvert from the sediment rack.

STREAM STABILITY/FUNCTION

The primary functions of natural stream channels are to 1) convey flood flows produced by the watershed, 2) transport sediment generated by local hydrology, and 3) effectively dissipate energy. The alluvial stream channel adjusts it shape and pattern to successfully perform these functions.

An evaluation of the site and survey data did not reveal any loss of stream function. Holgate Creek is a relatively steep, single thread, gravel bed stream with steep banks and narrow floodplains. The culvert roughly mimics the channel shape upstream. Based on the conveyance capacity analysis, the culverts effectively carry flood flows. The lack of evidence of incision or aggradation suggests that sediment transport is in balance with supplies.

The slope of the culvert is twice that of the channel upstream and 6 times steeper than the downstream channel. The reason for this abrupt slope change is not clear. From study of recent aerial photography and maps, as well as site visits it appears likely that the stream was rerouted and shortened to pass directly under the road rather than follow an original course along Mud Bay Road. A direct route from upstream of the culvert, along Mud Bay Road to the current channel confluence with the Chilkat River would have a slope roughly equal to the upstream channel grade of 3%. While the slope change does not appear to affect stream function, it greatly increases velocities, shear stresses, and sediment transport all of which greatly affect fish passage.

FISH PASSAGE ASSESSMENT

Common conditions at culverts that create migration barriers include: high velocity within the culvert barrel, turbulence within the culvert, inadequate depth within the culvert, excess drop at the culvert outlet, and debris and sediment accumulation at the culvert inlet and outlet.

A tiered approach using several assessment protocols was used to evaluate fish passage. The first protocol was a red-grey-green matrix described in the June 2000, Tongass Road Condition Survey Report (Flanders & Cariello 2000). The second method was developed jointly by Alaska Fish and Game and the Alaska Department of Transportation (MOA ADFG/ADOT 2001) and uses a variety of physical characteristics to evaluate fish passage through a culvert. Finally a more site specific assessment of critical flow velocities was conducted.

Tongass Road Condition Survey Protocol (GREEN-GRAY-RED): (Flanders & Cariello 2000)

To improve assessment efficiency, a juvenile fish passage evaluation criteria matrix was developed as a first phase filter. The evaluation matrix stratifies culverts by type and establishes criteria thresholds for culvert gradient, stream constriction, debris blockage, and vertical barrier at culvert outlet (perch) specific to each stratified culvert type. The evaluation scores are entered into a matrix of green (acceptable), grey (acceptable with defects), and red (unacceptable). The existing circular culvert is rated RED (unacceptable). See Table 5 for summary.

Table 5. Fish Passage Evaluation Criteria

The existing culvert is rated RED due to excessive grade, lack of substrate coverage, low culvert span to bedwidth ratio, and potential for blockage.

Structure:	One 66-inch round CMP with 1x3 annular corrugations No substrate cover (bedload collector inoperable)
Culvert Gradient:	6.5%
Perch:	none
Culvert Span to Bedwidth:	0.57 (4.5 ft : 8 ft)
Blockage:	Debris has accumulated on the last fishway cross-member on the culvert apron end section just outside the culvert and may impede passage.

ADOT/ADFG Tier 1 Fish Passage Protocols (ADFG/ADOT 2001)

The Alaska Department of Transportation (ADOT) and Alaska Department of Fish and Game (ADFG) have adopted a 3-tier set of culvert design approaches to ensure fish passage. The Tier 1 design approach attempts to replicate natural stream channel conditions. While Tier I is meant as a design approach, the criteria can also be used to assess existing culverts and can point out critical deficiencies for fish passage. The design approach includes the following criteria for stream channels with average slopes less than 6%:

1. Culvert slope should approximate natural channel slope and should not deviate by more than 1% from the natural grade;
2. Culvert width at OHW stage must be greater than 90% of the natural channel width at OHW elevation;
3. The culvert invert shall be buried to 40% of the diameter of round pipes and 20% of the rise of arch-pipe culverts; and
4. Substrate material within the culvert should remain dynamically stable at all flood discharges up to and including a fifty-year flood.

The existing culvert FAILS to meet any of the four criteria for Tier 1 design. The culvert is installed at greater than two times the upstream grade and six times the downstream grade. Culvert diameter (66 inches or 5.5 feet) is only 57% of the upstream active channel width. The culvert is not set below channel grade and fails to maintain substrate even with the addition of the sediment rack. The lack of sediment suggests any sediment would not be dynamically stable in large floods.

Hydraulic Analysis - Critical Velocities

Flow velocities were estimated using Manning's equation for a range of discharges up to the critical fish passage discharge (36 cfs). Velocities at the minimum depth criteria were also checked (0.3 feet for juvenile Coho and 0.5 feet for Cutthroat trout) Because the sediment rack is occasionally stocked with substrate and will perform until higher discharges wash the sediment away, velocities were estimated for two scenarios: 1) assuming the sediment rack was working and 2) assuming it was not.

Both sets of calculations showed that average velocities in the culvert were barriers to adult fish passage at most discharges (Table 6). With a functioning sediment rack, velocities and depths that allow passage of adult cutthroat trout (< 4 fps) were available only at low flows. Without the functioning sediment rack (existing condition) velocities were too high except for very low flows when low water depths inhibit passage. Velocities were much too high for the Tier I design discharge of 36 cfs.

These analyses suggest that there may be low flow periods when fish can enter the stream via the culvert. This is consistent with the observations of fish in the stream. However, the steep culvert slope and inability to maintain substrate severely limits the opportunity for successful passage into the stream.

Table 6. Stream velocities in the culvert.

Velocites were calculated under two scenarios; sediment rack functioning with 1 ft of material in place and sediment rack non-functioning. Mannings 'n' for each scenario was 0.035 and 0.025 respectively.

	Functioning sediment trap (n=0.035)			Non-functioning sediment trap (n=0.025)		
	Depth (ft)	Estimated Discharge (cfs)	Mean Velocity (ft/sec)	Depth (ft)	Estimated Discharge (cfs)	Mean Velocity (ft/sec)
min. depth	0.25	4.5	4.0	0.25	1.7	4.5
	0.50	14.0	6.1	0.50	7.6	7.1
	0.75	27.2	7.7	0.75	17.8	9.1
40% of Q2	1.00	43.3	8.9	1.00	32.12	10.9
	1.25	61.6	10.0	1.25	50.4	12.4

TREATMENT OPTIONS CONSIDERED

Potential remedies included 1) modifying the existing channel and/or culvert and 2) replacing the existing culvert and modifying the upstream and/or downstream channel. These alternatives are discussed below.

DO NOTHING

The culvert will continue to be a barrier to fish due to velocities except during very low flow conditions. The steep slope and relatively narrow diameter of the existing culvert are the primary factors limiting fish passage. The slope and width produce velocities well above the critical limits for adult and juvenile Coho salmon and adult cutthroat trout.

RETROFIT EXISTING CULVERT

Effective boundary roughness is essential for fish passage. The retrofit treatment options investigated the potential to increase channel roughness in the culvert by adding larger substrate and/or installation of a fishway as follows:

1) Restore existing bedload collector to create an artificial depressed invert culvert (DIC)

The purpose of the existing detachable fishway is to provide turbulence necessary to allow fish passage in steep culverts (Clancy and Rechmuth, 1990). These culvert bedload collectors collect and stabilize sufficient bedload material to act as an embedded culvert (ADDOT&PF, 1991). Substrate material should remain dynamically stable up to a 50 year flood (MOA ADFG/ADOT&PF, 2001). Analysis of rock riprap sizing for bed stability is shown in Table 7.

Table 7. Rock Sizing Analysis

Rock riprap sizing using the ACOE Steep Slope method and Abt and Johnson method. Size is significantly greater than the substrate available.

	Discharge Jones & Fahl (cfs)	ACOE Riprap Design D84 (ft)	ACOE Riprap Design D84 (mm)	Abt and Johnson Design D85 (ft)	Abt and Johnson Design D85 (mm)
Q2	89	1.8	549	0.9	274
Q5	130	2.3	701	1.1	335
Q10	158	2.6	792	1.2	366
Q25	195	3	914	1.4	427
Q50	224	3.3	1006	1.5	457
Q100	253	3.6	1097	1.6	488

Any bed material placed inside the culvert will not remain and upstream channel recruitment of larger material cannot be replaced. Therefore, the created roughened channel within the culvert will degrade. If the bedload collector was seeded no material will remain. Existing collector has one retention grid in center of frame and at 1 foot high the majority of channel bed material can move underneath the frame.

Additional retention grids or retrofitting a horizontal spacing bar may help to hold material, but unlikely to change bedload stability concerns due to slope. Bed retention sills (steel walls) may hold bed material in culvert, but unlikely.

In addition, the gradation of the mix used for the bed inside the roughened-channel culvert should have fine materials to seal the bed and reduce porosity. If not sealed properly substantial subsurface flow will occur during low flow conditions which may not achieve the minimum depth requirements during low-flow migration.

NOT A FEASIBLE OPTION

2) Install weir-type baffles to provide stepped pools with resting areas where fish can swim from weir to the next.

A retrofitted fishway using baffles within the existing culvert was investigated using NRCS design procedures (2007). Recommended height of the baffles is a function of culvert diameter (D). The fishway was modeled for baffle heights of 0.1D and 0.15D . Using the weir formula velocities at the design discharge (40% of Q2 = 36 cfs) were estimated at 6.6 (0.15D) to 7 fps (0.1D) well above the fish passage threshold. Discharges less than 6 cfs provided acceptable velocities but that represents a much shorter duration of flow. Because these velocity values are still higher than allowable for passage of adult salmon or cutthroat at the 40% of the 2-year discharge and duration of acceptable flows and velocities was reduced the retrofitted fishway alternative was eliminated from further consideration.

NOT A FEASIBLE OPTION

It was concluded that there was no retrofit that would overcome the velocity barrier of the existing 6.5% slope and a new culvert with a lower slope is required.

CULVERT REPLACEMENT AND CHANNEL MODIFICATION

Since retrofitting of the existing culvert will not provide fish passage, the combination of culvert replacement and channel modification was evaluated. Because providing adequate fish passage requires reducing the existing culvert slope some channel modification will be required to lower the upstream channel invert and/or raise the downstream channel bed elevation.

As a starting point it was assumed that the replacement culvert should meet the basic design criteria described in the AKFG/ADOT Tier I memorandum. That is it should match upstream channel slope, have a minimum width equal to 80% of the upstream channel, and contain a natural substrate bed that can be maintained during a 50-year discharge. An evaluation of culvert sizes and shapes resulted in the recommendation for an aluminum arch pipe culvert with a width of 9.75 feet (117 inches) and a height of 6.6 feet (79 inches).

The hydraulic and critical velocity protocols described earlier were used to evaluate fish passage in this arch culvert. Water depths and mean velocities were modeled for a variety of discharges using a simple cross-section analyzer based on Manning's equation. It was assumed that culvert slope (3%) and substrate particle size and distribution (d50 = 20 mm, d85= 120 mm) were consistent with the upstream channel.

Hydraulic roughness is a method of representing the effect of coarse substrate on stream flow. It is defined as the depth of flow divided by the diameter of d85 or large common substrate particle. The shallower the flow, the greater the hydraulic roughness and increased roughness to flow. The relatively large substrate in Holgate Creek (D85 = 120 mm or 5 inches) produces large hydraulic roughness during shallow flows. To address this substrate roughness, a range of roughness coefficient values (Manning's n) were used to evaluate flows.

The critical fish passage discharge of 36 cfs (40% of Q2) was evaluated using two roughness values, one representing relatively smooth stream bed (n = 0.040) and one representing a rough stream bed (n = 0.055) The exercise resulted in a range flow depths and mean velocities (Table 8). Flows are relatively shallow for both scenarios and hydraulic roughness is large. Mannings equation is only valid under conditions of steady, uniform flow, almost certainly not the case in the shallow flow and coarse substrate. As a result, the results of this analysis should only be considered approximate. However, the actual mean velocities can be expected to be lower than the model estimates and flow depths greater, both benefits to fish passage. In addition, the rough substrate can be expected to produce a variety of local low velocity niches that will provide resting places for fish during passage. Given this scenario it is reasonable that burst swimming speeds can be utilized to gage fish passage. The modeled mean velocities for the design discharge are within burst swimming speeds for cutthroat trout. For these reasons, it appears that the arch culvert will provide adequate flow depths and velocities for fish passage. It is possible that the culvert slope can be further reduced and velocities analyzed during the final design.

A discharge of 225 cfs or the 50-year recurrence interval was used to evaluate the capacity of the arch culvert to pass large flood events. The culvert capacity at full flow is approximately 375 cfs, well above the flood design discharge of 225 cfs (Norman et.al., 2005). However, 20% or 16 inches of the culvert will be below grade and unavailable for flow. No method was readily available to assess the capacity of the reduced culvert size. The fact that the full culvert provides excess conveyance and the presence of a minimum 3 feet of available freeboard between culvert and roadway, suggests the culvert will have adequate capacity.

Two methods were used to evaluate the requirement that substrate within the culvert remain dynamically stable during a 50-year flood discharge. First, the fact that the slope and substrate gradation of the culvert is consistent with the channel upstream suggests that the balance between sediment supply and transport will be maintained. Second, an evaluation of dimensionless critical shear stress was used to evaluate the potential mobilization of large substrate particles (d84) during the high flood event. The evaluation suggested that the particles would not mobilize during the high discharges and therefore the substrate would remain dynamically stable. The installation of shallow baffles would further reduce the risk that substrate could slide along the relatively smooth culvert.

Table 8. Modeled velocities and depths for given channel roughness in proposed arch culvert.

Velocities and depths were computed using WinXSpro software assuming a rectangular channel the width of the arch culvert (9.75 ft) with a given roughness (Mannings n). Discharge targets represent the range of variability in peak discharge for Q2 event given by Jones and Fahl method. Parameters computed for two channel roughness coefficients representing relatively smooth and rough channels.

	Discharge (cfs)	Depth (ft)	Mean Velocity (ft/s)	Hydraulic Roughness (mannings n)
	25.16	0.7	3.69	0.05
n = 0.055	38.76	0.9	4.42	0.049
	46.55	1	4.77	0.049
	27.49	0.62	4.55	0.038
n=0.04	35.27	0.72	5.02	0.038
	43.82	0.82	5.48	0.37

Channel modification

In order to flatten the existing culvert slope to 3% will require changes to the upstream and/or downstream channel bed elevations. There are three options for reducing slope.

1. Restore original stream alignment above Mud Bay Road. While the cause of the abrupt slope change is unknown, it appears that the original channel alignment was shortened and steepened to facilitate construction or modification of Mud Bay Road. Holgate Creek could be realigned to run parallel to Mud Bay Road until a properly sloped culvert could carry it under the road. However, this alternative would require the cooperation of several adjacent landowners and the installation of culverts under private driveways. For these reasons, this alternative was considered impractical.
2. Steepening the upstream channel to lower the bed elevation. Lowering the upstream invert would create a slope break that would migrate upstream, incising and widening the channel. Buildings and other infrastructure are in close proximity to the stream and could be endangered by the destabilized stream channel. Grade control and other channel stabilization methods would be required to protect private property along the stream. For these reasons, this alternative is not considered practical.
3. Raise and realign channel between culvert and Chilkat River (Holgate estuary). This option would require sufficient fill to raise the stream channel 3.5 feet at the culvert outlet and continue downstream at less than 3% grade until it matches existing grade near the pond (average fill is 1.6 ft). This option would minimize impacts to the existing stream habitat and private property. Raising the channel would require a considerable amount of fill, but at 2-3% slope the channel could be rejoined to the existing channel upstream of the existing pond. This alternative is considered the best.

   Raising the stream channel would require adequate quantity and size of substrate to create an appropriate stream channel below the culvert. The fill would be thickest near the culvert gradually thinning downstream (average fill depth of 1.6 ft). The gradation of the fill will require fine materials to seal the bed and reduce porosity. Some grade control would be advisable to reduce the risk of erosion of the unconsolidated material. The use of backwatering at the outlet and drops to dissipate energy can be incorporated into the final design.

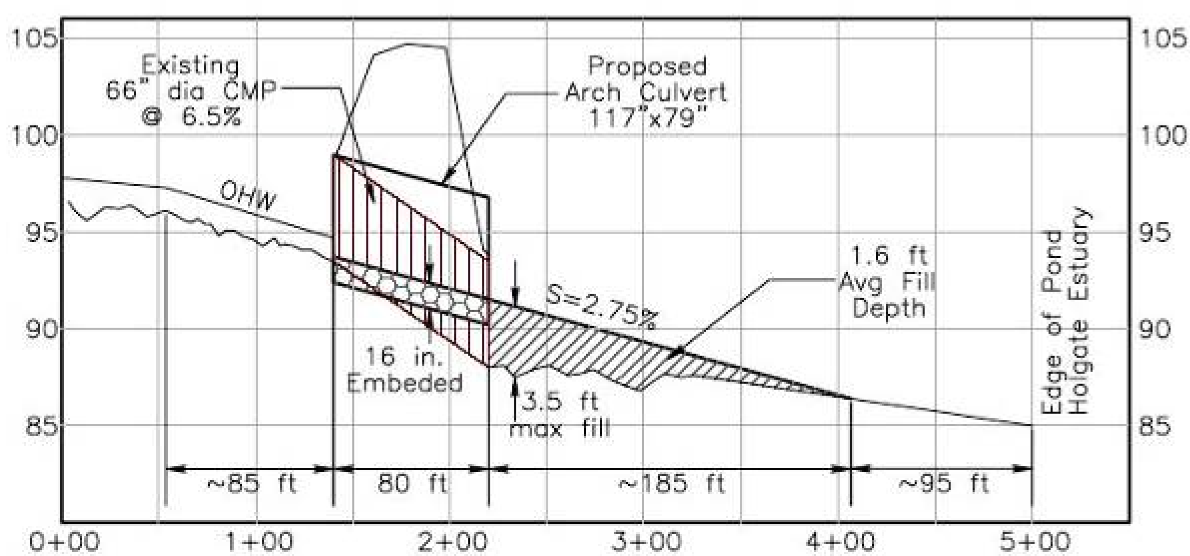

Figure 7. Channel Profile with Culvert Replacement and Channel Modification

CONCLUSION

The existing culvert alignment at Mud Bay Road appears to have resulted from a major realignment of the stream during construction of the road. This scenario is consistent with the major slope breaks in the stream around the culvert. Currently the culvert is able to convey sediment and flows adequately, however the steep slope (6.5%) creates velocities that severely hinder fish passage at required flows. Passage is possible at lower flows but the duration for passage is very limited. This result is consistent with recent observations of fish in the stream.

Excessive culvert slope is the greatest limiting factor. As a result, it is not possible to retrofit the current culvert installation to provide adequate fish passage. Therefore installation of a larger arch culvert with a slope consistent with the channel bed is recommended. Installation of new culvert will require altering the existing channel bed elevations. It is recommended that the channel between Mud Bay Road and the Holgate estuary be raised and realigned to match the new culvert outlet invert elevation. These recommendations offer an effective approach for creating effective, reliable fish passage to Holgate Creek.

Figure 8. Holgate Creek looking upstream towards the culvert

Photo taken April 18, 2008 along the berm between Holgate Creek and the Chilkat Inlet. Proposed channel modification would take place in this location.

Figure 9. Holgate Creek looking downstream towards the Holgate estuary and the Chilkat Inlet.

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APPENDIX

Photos

Fish Passage Inventory Data Sheet

Longitudinal Profile

Cross-Section

Upstream Pebble Count

PHOTOS

FISH PASSAGE INVENTORY DATA SHEET

Date: August 14, 2007
Stream Crossing Type: [ ] bridge [ ] ford [X] culvert [ ] other
Field Personnel: T.Moody, T.Shields, S.Yard, A.Shangl
Scope of Survey: Conduct fish passage evaluation (field survey, passage analysis, treatment alts)

Road: Mud Bay Road | Mile Post: | Crossroad: | Elev:

Stream Name: Holgate Creek | Tributary to: Drains into the Chilkat Inlet | Basin: West slope of Mt Riley below Lilly Lake

Quad: | Section-Township-Range: Sec 3, T31S, R59E | Lat/Long:

Flow Conditions During Survey: [X] continuous [ ] isolat. pools [ ] dry
Describe:

Fisheries Information

Fish Presence Observed During Survey: [ ] upstream [ ] downstream [ ] none
Age Classes: [ ] adults [ ] juveniles [ ] none
Species:
Juvenile Size Classes: [ ] <3" [ ] 3"-6" [ ] >6"
Number of Fish Observed: None

Stream Crossing Information

Inlet Type: [X] projecting [ ] headwall [ ] wingwall [ ] mitered [X] flared
Alignment (deg): [X] <30° [ ] 30°-45° [ ] >45°
Inlet Apron: [ ] yes [X] no
Describe: Inlet flared end section with pipe slightly projected

Outlet Configuration: [ ] at stream grade [X] free-fall into pool [ ] cascade over riprap
Outlet Apron: [X] yes [ ] no
Tailwater Control: [X] pool tailout [ ] full-spanning log or debris jam [ ] other
[ ] concrete weir [ ] boulder weir [ ] log weir [ ] no control point
Describe: outlet flared end section, apron extending 6.5 ft beyond culvert

Channel Width(s): upstream: ~10 (ft) downstream: 30+ (ft) bankfull: 10 (ft)

Depth(s): inlet invert (ft) outlet invert (ft) bankfull: (ft) pool (ft) tail crest

Culvert Information

Culvert Type: [X] circular [ ] pipe arch [ ] box [ ] open-bottom [ ] other
Dimensions: Diameter: 66 (in.) Height/Rise: (ft) Width/Span: (ft) Length: 80 (ft)

Material: [ ] SSP [ ] CSP [X] aluminum [ ] plastic
[ ] concrete [ ] log/wood [ ] other

Corrugations (width x depth): [ ] 2-2/3" x 1/2" [X] 3" x 1" [ ] 5" x 1"
[ ] 6" x 2" [ ] spiral [ ] other

Slope(s): Upstream: **3.08%** Downstream: **0.38%** Culvert: **6.08%** Bankfull/OHW: **3.00%**

Embedded: [ ] yes [X] no
Substrate Depth (ft) 1 Substrate Coverage 5%
Describe Substrate: Most material has washed away; some substrate still in frame #s 7,10,13

Pipe Condition: [ ] good [X] fair [ ] poor [ ] extremely poor
Describe: algae mark ~6" above frame
Rustline Height (ft): [ ] NP (new CSP or SSP) [ ] NA (concrete,alum,plastic)

Barrel Retrofit (weirs/baffles): [X] yes [ ] no
Type: [X] steel ramp baf [ ] Washington [ ] corner [ ] other
Describe (size, number, placement, materials): 6.6' long x 3.5' wide x 1.1' high; 13 frames

LONGITUDINAL PROFILE SHEET

Printed: 4/28/2008

Site Name	Holgate Creek @ Mud Bay Road	
Date	August 13, 2007	
Personnel	T.Moody,T.Shields,S.Yard,A.Shangl	#REF!
Watershed Area	1 mi^2	#REF!

A:
B:
C:
D:
E:
F:

Sinuosity (est) 1.1

ALLUVIAL FEATURES

	STA	ELEV		DESCRIPTION
1	33.00	97.20		Top of gravel bar
2	34.00	97.80		OHW
3	62.00	97.1		
4	82.00	96.4		OHW
5	98.00	95.85		OHW
6				
7				
8	Road Embankment			
9	140.0	93.5		
10	140	99.1		
	141.5	99.0		
11	160.5	104.1		
12	177.8	104.7		
13	197.8	104.5		
14	217.3	94.1		
15	220	93.8		
16	220	88.0		
17				
18				
19				
20				

UPSTREAM THALWEG

	STA	ELEV	SLOPE
1	0.0	96.60	
2	53.8	96.10	-0.0093
	140.0	93.50	-0.0302

DOWNSTREAM THALWEG

	STA	ELEV	SLOPE
1	220.0	88.00	
2	326.0	87.60	-0.0038

ORDINARY HIGH WATER

	STA	ELEV	SLOPE
1	0.0	97.80	
2	53.8	97.30	-0.0093
3	140.0	94.70	-0.0302

CULVERT SLOPE

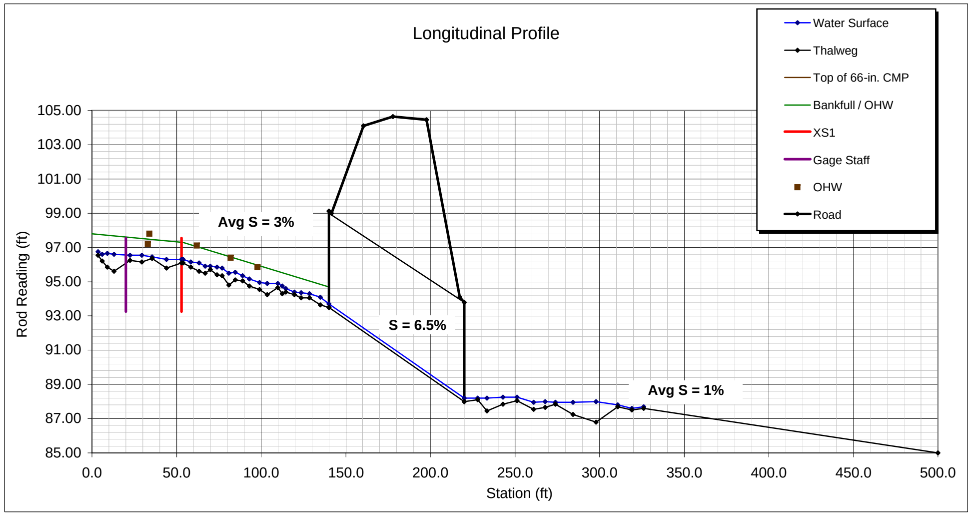
	STA	ELEV	SLOPE
1	140.0	99.00	
2	220.0	93.80	-0.0650
3			

CROSS-SECTIONS/GAGE

	STA	BKF ELEV
GAGE	20	97.61
XS-1	53	97.31
XS-2		
XS-3		
XS-4		

LONGITUDINAL PROFILE

	STA	ELEV	WATER DEPTH	WATER HT
1	3.5	96.6	0.2	96.75
2	6.0	96.2	0.4	96.60
3	9.0	95.9	0.8	96.65
4	13.0	95.6	1.0	96.60
5	22.5	96.3	0.3	96.55
6	29.5	96.2	0.4	96.55
7	35.5	96.4	0.1	96.45
8	44.0	95.8	0.5	96.30
9	53.0	96.1	0.2	96.30
10	53.8	96.1	0.2	96.30
11	58.5	95.9	0.3	96.15
12	63.4	95.6	0.5	96.10
13	66.9	95.5	0.4	95.90
14	70.0	95.7	0.2	95.90
15	74.0	95.4	0.45	95.85
16	76.9	95.4	0.45	95.80
17	81.0	94.8	0.7	95.50
18	84.6	95.1	0.45	95.55
19	89.0	95.1	0.3	95.35
20	93.0	94.8	0.4	95.15
21	99.0	94.6	0.4	94.95
22	103.6	94.3	0.65	94.90
23	109.8	94.7	0.25	94.90
24	112.5	94.3	0.45	94.75
25	114.5	94.4	0.2	94.60
26	119.6	94.3	0.15	94.40
	123.6	94.1	0.3	94.35
	128.5	94.1	0.25	94.30
	135.0	93.7	0.45	94.10
	140.0	93.5	0.2	93.70
	220	88.0	0.2	88.20
	228	88.1	0.1	88.20
	233.5	87.5	0.75	88.20
	243	87.9	0.4	88.25
	251.3	88.1	0.2	88.25
	261	87.6	0.4	87.95
	267.9	87.7	0.35	88.00
	274	87.9	0.1	87.95
	284.4	87.3	0.7	87.95
	298	86.8	1.2	88.00
	310.7	87.7	0.1	87.80
	319	87.5	0.1	87.60
	326	87.6	0.1	87.70
	500	85.0	0.5	85.50



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Version:4.0
Revised: 12/10/00

BANKFULL SURVEY FORM

Printed: 4/28/2008

(shaded cells are filled by formulas)

XS#: 1 revised

Stream Name: Holgate Creek
Date: 8/13/2003
Watershed name:
Watershed area: 1 mi^2
Personnel: T.Moody,T.Shields,S.Yard,Abby Shangl
Site Elev. ft
Longitude:
Latitude:
Flow:
(Perennial / Intermittent / Ephemeral)

Notes:
Revised

Cross-section Data (left to right looking downstream)
for riffle cross-section data

	STA	Elev	Bkf DEPTH	DIST.	AREA	NOTES
1	1.0	102.02				Top of Pin
2	1.0	101.32		0.0		0.7 ft to ground Bottom of Pin
3	4.2	100.32		3.2		
4	8.5	98.02		4.3		
5	10.0	97.77		1.5		
6	12.5	96.22	1.1	2.5		Left Edge of Water
7	14.3	95.97	1.3	1.8	2.17	Thalweg
8	16.9	96.17	1.1	2.6	3.20	Right Edge of Water
9	18.0	96.42	0.9	1.1	1.11	
10	20.0	97.87		2.0		
11	22.0	98.47		2.0		Bottom of Pin
12	22	99.27		0.0		Top of Pin
13						
14						
15						
16						
17						
18						
19						
20						
21						
22						
23						
24						
25						
26						
27						
28						
29						
30						
31						
32						
33						
34						
35						
36						
37						
38						
39						
40						
				TOTAL AREA	6.47	sq. ft

DATA ENTRY

Bankfull Slope 0.030
Water surface slope: 0.030 (from profile sheet)
Thalweg slope: 0.030 (from profile sheet)
Sinuosity (est): 1.1 (from profile sheet)

Channel Type: B4

Elevation @ Bankfull Stage: 97.30 ft
Elevation @ Water Surface: 96.20 ft
Floodprone Width: 15.0 ft
Bankfull width 8 ft

Stationing for Cross-cection: 53 ft

BANKFULL DATA

Watershed area:	1.00	mi^2	W/D ratio:	9.9
X-section area:	6.47	ft^2	Ent. Ratio:	1.9
Bankfull Width:	8.0	ft	Slope:	0.030
Mean depth	0.8	ft	D_{50}:	18.0 mm
Max. Depth:	1.3	ft	Sinuosity (est):	1.1
Floodprone width:	15	ft	Channel Type:	B4

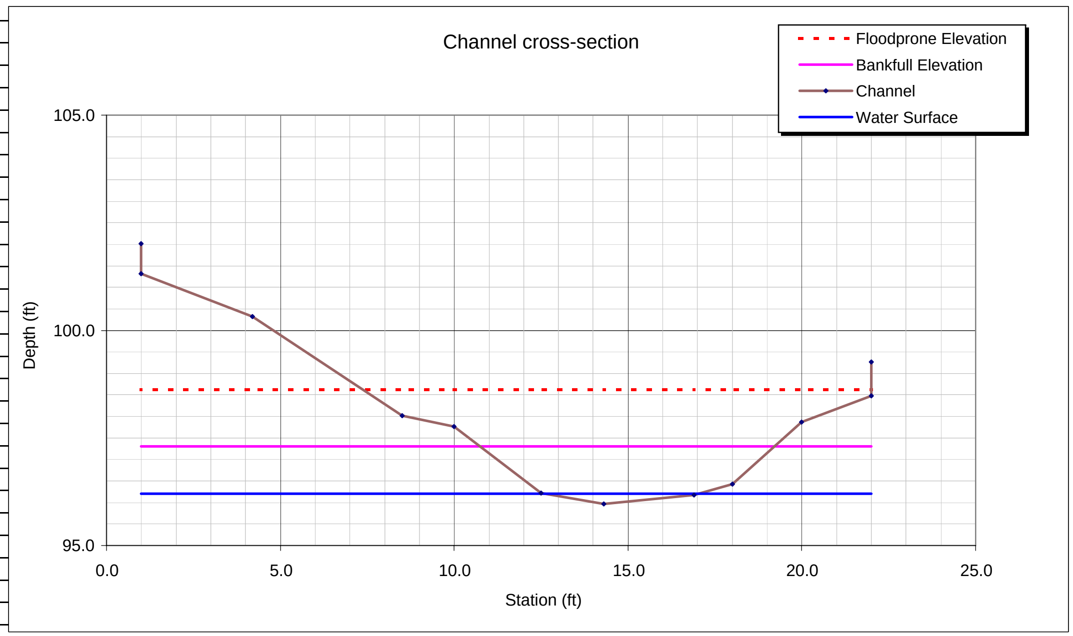
SEDIMENT TRANSPORT

D15: 0.3 mm
D50: 18 mm
D85: 120 mm
D100: 760 mm

τ_{cr} = 62.4 * d * S
τ_{cr} = 1.51457

Particle moved ______ mm
(Wiberg & Smith)

Bed material data Sampled



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Version: 4.0
Revised: 12/10/00

BED MATERIAL ANALYSIS FORM

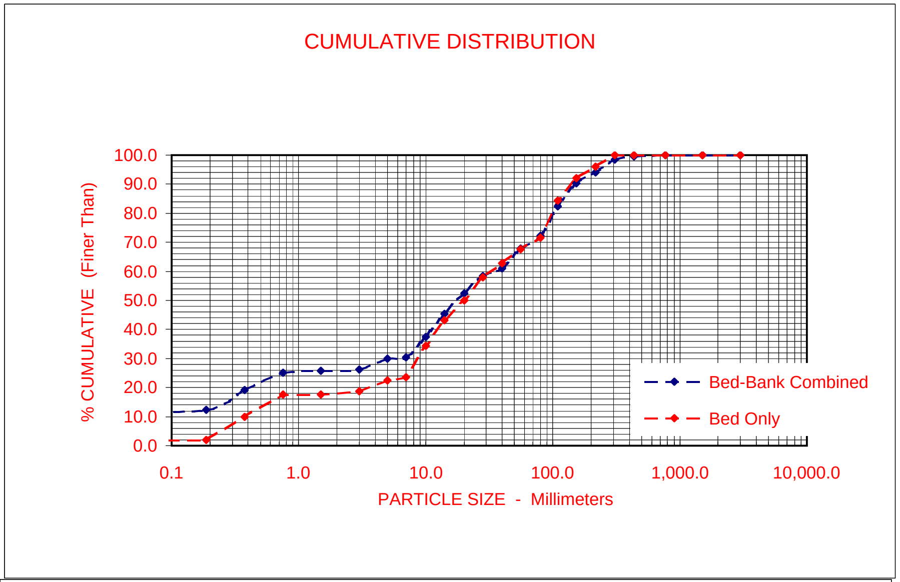
Printed: 4/28/2008

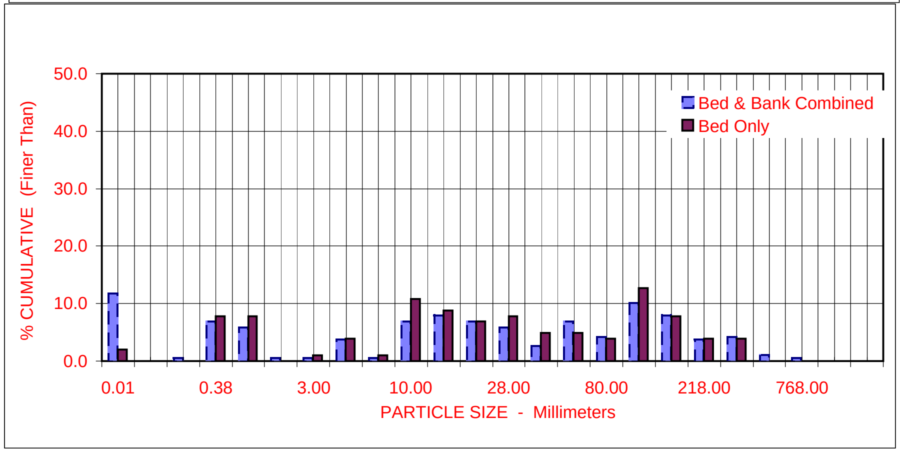
Site Name: Holgate Creek at Mud Bay
Date: 8/14/2007

	Beg and Bank	Bed Only	Step Material
d15:	0.3 mm	0.6 mm	140 mm
d50:	18 mm	20 mm	220 mm
d85:	120 mm	120 mm	280 mm
d100:	760 mm	350 mm	350 mm
Data type:	Sampled		step>d85 bed/bank
	(estimated / sampled)		

Bed & Bank Material Data

	Range (mm)		Bed	Bank	ITEM %	% CUM	ITEM %	% CUM
Silt/Clay	<.062	S/C	2	20	2.0	2.0	11.8	11.8
Very Fine	.062 - .125	S			0.0	2.0	0.0	11.8
Fine	.125 - .25	A		1	0.0	2.0	0.5	12.3
Medium	.25 - .50	N	8	5	7.8	9.8	7.0	19.3
Coarse	.50 - 1.0	D	8	3	7.8	17.6	5.9	25.1
Very Coarse	1.0 - 2			1	0.0	17.6	0.5	25.7
Very Fine	2 - 4		1		1.0	18.6	0.5	26.2
Fine	4 - 5.7	G	4	3	3.9	22.5	3.7	29.9
Fine	5.7 - 8	R	1		1.0	23.5	0.5	30.5
Medium	8 - 11.3	A	11	2	10.8	34.3	7.0	37.4
Medium	11.3 - 16	V	9	6	8.8	43.1	8.0	45.5
Coarse	16 - 22.6	E	7	6	6.9	50.0	7.0	52.4
Coarse	22.6 - 32	L	8	3	7.8	57.8	5.9	58.3
Very Coarse	32 - 45	S	5		4.9	62.7	2.7	61.0
Very Coarse	45 - 64		5	8	4.9	67.6	7.0	67.9
Small	64 - 90	C	4	4	3.9	71.6	4.3	72.2
Small	90 - 128	O	13	6	12.7	84.3	10.2	82.4
Large	128 - 180	B	8	7	7.8	92.2	8.0	90.4
Large	180 - 256	L	4	3	3.9	96.1	3.7	94.1
Small	256 - 362	B	4	4	3.9	100.0	4.3	98.4
Small	362 - 512	L		2	0.0	100.0	1.1	99.5
Medium	512 - 1024	D		1	0.0	100.0	0.5	100.0
Lrg-Vry Lrg.	1024 - 2048	R			0.0	100.0	0.0	100.0
BEDROCK					0.0	100.0	0.0	100.0
		TOTALS	102	85	100		100.0	





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