Dog Salmon Creek Watershed Assessment

Dog Salmon Creek, Port St. Nicolas Road, Prince of Wales Island

Prepared by The Nature Conservancy January 2013

Contents

Abstract

Dog Salmon Creek, located 5 miles south of Craig, on Prince of Wales Island (Figure 1), is a formerly robust pink and chum producing stream in which hydrology and freshwater ecology was impaired by logging practices that were in use prior to passage of the Alaska Forest Practices Act in the late 1980s. The land within the Dog Salmon Creek watershed is privately owned by Shaan Seet, Inc. (SSI), and SSI and The Nature Conservancy (TNC) are interested in addressing diminished watershed function within this watershed by collaborating on activities that aim to maintain and/or improve current habitat conditions. In 2012, TNC, SSI, and the U.S. Forest Service (USFS) conducted an initial watershed assessment that qualitatively and quantitatively assessed fish habitat conditions and potential improvement activities for the lower part of Dog Salmon Creek watershed. This assessment found that although this section of the watershed holds high potential to be quality habitat for coho, pink, and chum salmon, as well as other freshwater fishes, the lack of large old-growth trees in the area has diminished the amount of habitat forming large wood within the stream channel. Large wood provides cover, pool formation, and food inputs for juvenile salmon. Low densities of pool habitats and wide, flat channel morphology also indicate that fish habitat has been diminished. Suggested actions include continued assessment, including a road condition survey, revegetation of the banks near the new bridge, jam-structure placement in the portion of the stream below the bridge, and potential wood structure or riparian thinning in stream channel above the bridge. The area above the bridge appears channelized and risks decreasing in fish habitat quality in coming years, but access to this area may be difficult and costs may outweigh benefits for restoration activities at this time in these stream portions.

Introduction

Dog Salmon Creek, located 5 miles south of Craig, on Prince of Wales Island (Figure 1), is a formerly robust pink and chum producing stream in which hydrology and freshwater ecology was impaired by logging practices that were in use prior to passage of the Alaska Forest Practices Act in the late 1980s. The land within the Dog Salmon Creek watershed is privately owned by Shaan Seet, Inc. (SSI), and SSI and The Nature Conservancy (TNC) are interested in addressing diminished watershed function within this watershed by collaborating on activities that aim to maintain and/or improve current habitat conditions.

Figure 1. Dog Salmon Creek, on Prince of Wales Island.

In 2012, an initial watershed assessment of Dog Salmon Creek was initiated by TNC and SSI to collect and synthesize relevant data on the fish habitat quality of the Dog Salmon Creek watershed and recommend potential actions for maintaining, improving, and/or restoring current habitat conditions. This included synthesis of relevant data sources regarding Dog Salmon Creek, an initial assessment by TNC and U.S. Forest Service (USFS) staff of the lower portion of the watershed, and a Tier 2 aquatic habitat survey of the lower portion of the watershed. The results from these three actions are described in this document, culminating in a list of recommendations for next steps in maintaining, improving, and/or restoring habitat conditions.

Watershed Description

The Dog Salmon Creek watershed is shown in Figure 2. Current understanding of the watershed boundaries estimates that it includes about 15 km of stream. The main channel is a third order stream (Strahler 1964) with a moderate gradient mixed control channel type running into a small floodplain channel (Paustian et al. 1992) with average bank full widths of about 9 m. Several small steep tributaries feed into this main channel. The channel types of the lower watershed were confirmed by the aquatic habitat survey conducted in 2012. Although previous mapping indicated that Dog Salmon Creek is a very small watershed, it is now recognized that there is most likely an unmapped stream segment connecting this watershed to a network of headwater streams.

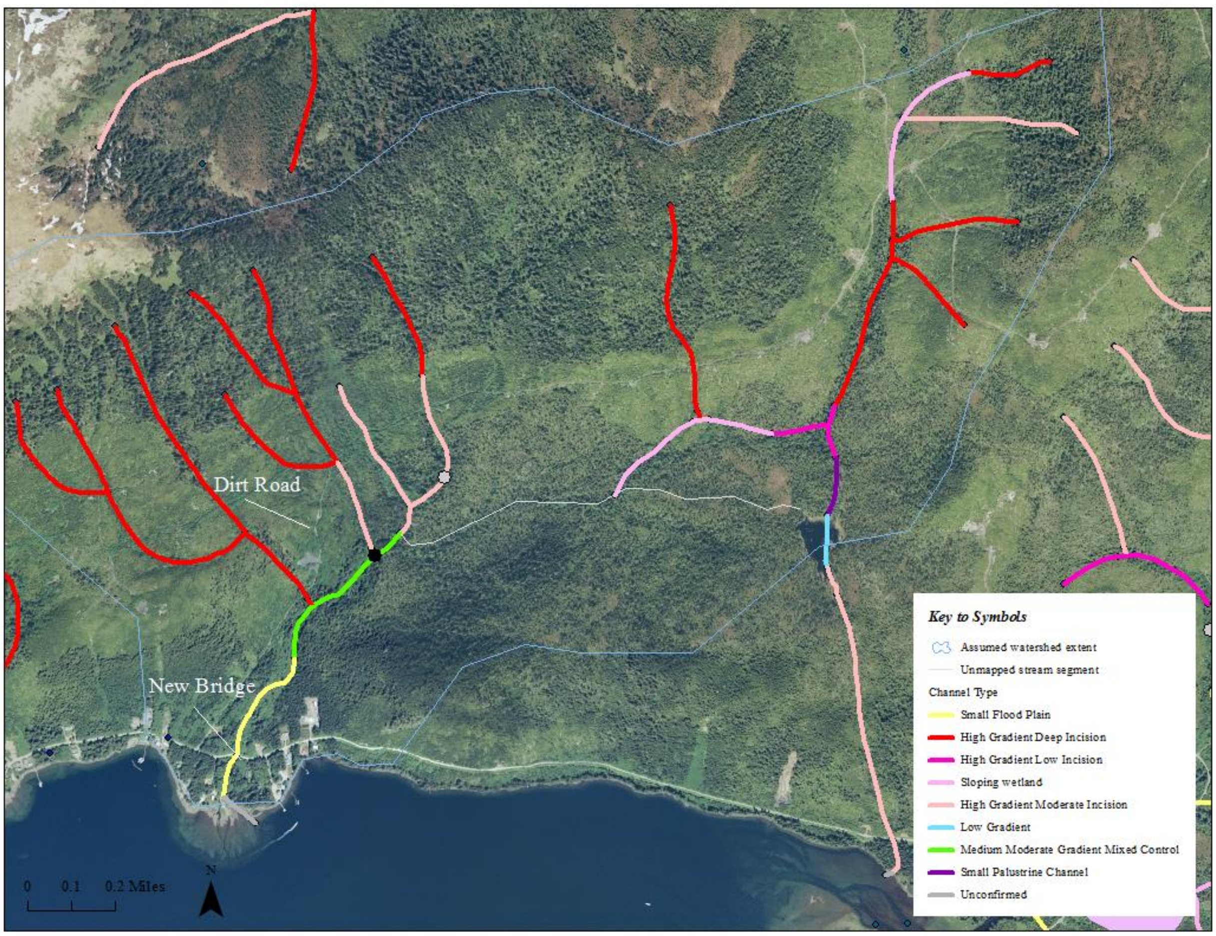


Figure 2. The assumed Dog Salmon Creek watershed. This includes channel types for all mapped waterbodies, and includes the presumed path of an unmapped stream segment that enlarges the originally mapped watershed extent.

Watershed History and Use

Current ownership of most of the watershed is by Shaan Seet Inc. The most significant land use history of this watershed in recent years includes logging of old growth forest. The lower portion of the east side of the watershed was most likely logged in the 1950s. Much of the lower stream channel was logged in the early and mid- 1980s, with the uplands being logged from the mid-1980s to late 1990s. Because a large amount of this logging was conducted prior to passage of the Alaska Forest Practices Act in the late 1980s, it is thought that the freshwater habitat within this watershed may be impaired by these logging activities. Historical photos from the 1940s show forest conditions prior to logging activities.

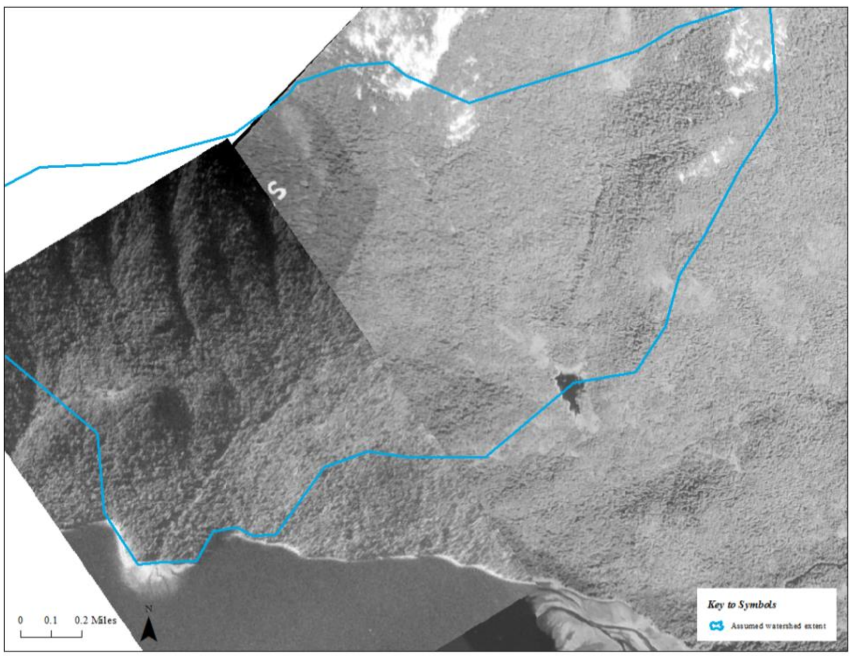


Figure 3. Aerial photographs from 1948 show forest conditions prior to commercial logging.

There were several restoration activities implemented by the Alaska Department of Fish and Game (ADF&G) in the early 1990s to address these habitat concerns. In 1992, two in-stream log structures were installed in the channel to function as sill logs, and a slide was stabilized with jute net and revegetation (Parry et al. 1993). These structures are still present in the stream channel (Figure 4).

Figure 4. A structure put in place by ADF&G in 1992 to function as a sill log. Although this structure has created a pool directly below the structure, the channel has remained mostly uniform both upstream and downstream from the structure.

In 2010, a new 100 ft bridge was built over a lower section of Dog Salmon Creek as part of improvements on Port Saint Nicholas Road. This left unvegetated banks on either side of the new bridge (Figure 5). There is also a dirt road that runs through portions of the watershed; culvert condition and potential impacts on downstream habitat conditions are currently undocumented.

Figure 5. Looking downstream at the new bridge and unvegetated banks.

Fish and Fish Habitat

Fish populations

The extent of the anadromous waters catalog for Dog Salmon Creek is shown in Figure 6. This includes documentation of pink and chum salmon spawning, and the presence of coho salmon. Adult steelhead have also been visually observed migrating through Dog Salmon Creek, although they are not officially documented in the anadromous waters catalog (Sheila Jacobson, USFS, personal observation). Minnow trapping in the lower portion of the watershed also documented the presence of juvenile (rearing) coho salmon, juvenile rainbow trout, juvenile cutthroat trout, Dolly Varden char, and freshwater sculpins. Dolly Varden char were also found in several steep tributary streams. No information about current populations or run sizes of any fish species is known about this creek.

Figure 6. Current extent of the anadromous waters catalog

Fish habitat

In the summer of 2012, several TNC, SSI, and USFS staff conducted both an initial visual survey of the lower portion of the watershed and a Tier 2 aquatic habitat survey on two reaches in this same portion (USFS 2001). The entire findings of the aquatic habitat survey can be found in Appendix A. The major findings from both surveys are summarized here.

General fish habitat

Of the channel types found within the watershed (Figure 2), only small floodplains and medium moderate gradient mixed control channels are expected to be important for salmonid spawning and rearing. The ratings for spawning and rearing of anadromous species for these two channel types are found in Tables 1 and 2, respectively.

Table 1. Spawning and rearing values for anadromous fishes in the Southeast Alaska for small floodplains (Paustian et al. 1992).

	Spawning	Rearing
Coho	High	High
Pink	Moderate	N/A
Chum	Moderate	N/A
Sockeye	High	Negligible
Chinook	Low	Negligible
Steelhead	Moderate	High
Dolly Varden	High	High

Table 2. Spawning and rearing values for anadromous fishes in the Southeast Alaska for medium moderate gradient mixed control channels (Paustian et al. 1992).

	Spawning	Rearing
Coho	Moderate	Low
Pink	Moderate	N/A
Chum	Moderate	N/A
Sockeye	Low	Negligible
Chinook	High	Negligible
Steelhead	High	Low
Dolly Varden	High	High

These stream types indicate that there is high potential for the main stem of Dog Salmon Creek to have high quality spawning habitat for coho, Dolly Varden, and steelhead, and high quality rearing habitat for coho, steelhead, and Dolly Varden. Suitable fish habitat may exist in the unmapped stream section as well, and should be assessed at another time.

Near the new bridge

The area around the new bridge was left unvegetated and filled with gravel after construction Revegetation in this area is a suggested enhancement activity as vegetation provides better freshwater habitat in the form of shade to maintain water temperature, overhanging cover for juvenile and adult salmon, and decreased sedimentation into the stream which can improve water quality and spawning habitat.

Above the bridge

There is a good deal of “legacy wood” still present in some portions of the stream (Figure 7). “Legacy wood” refers to old wood that fell into the floodplain; most likely before most logging of old growth in the area took place. However, because of the history of logging, there are fewer large trees in the vicinity to fall into these stream areas. Large wood and large woody debris (LWD) provide good fish habitat by providing cover, pool formation where juvenile fish feed and hide and adult fish spawn (in pool tail crests), and shade, and as legacy wood disappears and is not replaced, these habitats will most likely decrease in the future.

Figure 7. Large legacy wood still exists in some portions of the lower watershed, but stream condition may worsen if these structures are removed, as there are no large conifers in the riparian area to replace them.

A few hundred meters above the bridge, the river becomes more channelized with less complex habitats, low amounts of LWD, and infrequent pools (Figure 8), which indicates decreasing habitat for rearing fish. This is most likely a product of loss of wood due to logging, but there is also evidence of stream clearing. The aquatic habitat survey for this section of the stream (Reach 2) showed that overall, the stream was usually within the 75 percentile for pool-related metrics as compared to other, unmanaged streams of this type in the Tongass National Forest (see Appendix A), which means that it is still valuable as fish habitat. However, for other metrics, including those related to LWD and width-to-depth ratios, which also indicate the quality of fish habitat, this stream reach is considered in poor condition as compared to other Tongass streams.

Figure 8. Looking upstream on Reach 2. This picture exemplifies the condition of this strech of the river, with very few pools, minimal amounts of LWD, and riparian vegetation that is primarily small deciduous shrubs and trees.

The structures placed by ADF&G in the early 1990s have resulted in several additional pools, but these changes are very localized and do not appear to have resulted in adding complexity to the stream channel patterns.

Riparian vegetation in this section consists mainly of deciduous trees, as shown in Figure 9. This is notable because these smaller trees and shrubs will not create the cover and pool habitat that is formed by old-growth size trees within the stream channel. There may be some merit of riparian thinning for the purpose of “releasing” the conifers, and allowing growth of large conifers that will eventually create better fish habitat.

Figure 10. Monocultures of deciduous riparian vegetation makes it difficult for establishment of large conifers that produce important LWD.

Although this area may benefit from habitat-creating structures, such as in-stream wood structures, access to these portions of the stream may be too difficult to justify at this time given that there is still some valuable fish habitat in this section. However, it is likely that habitat through this stretch will only decrease as legacy wood is released and not replaced and if immediate action is not taken, it will be worth monitoring in the future.

Below the bridge

The area surveyed below the bridge contains some of the same characteristics as the stream area above the bridge that indicates lower quality fish habitat, including riparian vegetation dominated by deciduous vegetation and lack of pools (Figure 11). It has been observed that at low flows, some areas are too shallow for pink and chum salmon to get up the stream to spawn. The aquatic habitat survey done in this section confirmed that this section of stream is considered poor-to-fair as compared to similar streams in the Tongass National Forest, ranking consistently below the 50th percentile for categories indicative of the quality of habitat as related to pools, substrate, channel morphology, and LWD.

Figure 11. Downstream of bridge, an area with little habitat for staging spawners.

It is likely that the addition of jam-structures would be useful for creating pool habitat and altering channel morphology to make this area more conducive to both rearing fishes and to those trying to access the stream for spawning. Access to this section would be easy and make jam-structure design and implementation cost-affective.

Road condition

Initially, a road condition survey of the dirt road that runs through the watershed was intended to be completed as part of this watershed assessment. This has not yet been completed. However, from past inspection it has been noted that there may be hydrologic connectivity issues and stream diversions resulting from plugged culverts and an overall limited number of drainage structures along this road (Figure 12). This may be having negative impacts on water quality and fish habitat. Culvert replacement and/or sediment control in these high gradient streams near the road may be suggested as a result of a more formal road condition survey.

Figure 12. Failed culverts on Dog Salmon Creek may block passage.

Suggested Actions

Based on the watershed assessment, several future actions are suggested. These options should be weighed based with expert opinion, stakeholder interest, and cost-benefits in mind. These actions and considerations are detailed below

- Initially, a road condition survey of the dirt road that runs through the watershed was intended to be completed as part of this watershed assessment. It is still strongly encouraged that this be completed and included in this watershed assessment. This would include an assessment of culvert condition and sedimentation issues. This assessment could easily be completed by a trained professional with an off-road vehicle, assuming that obstacles along the road are removed. Sheila Jacobson with USFS has volunteered to direct this effort if asked.
- The stream segments that most likely exist but are not shown on current maps should be assessed for fish habitat quality. Although channel type is not known for this segment, elevation data suggestions that these areas may provide rearing habitat if no migration barrier exists. Best access to this area may be along the dirt road with an off road vehicle as walking up the stream is difficult.
- Re-vegetation of the stream banks surrounding the new bridge would be a relatively easy task to stabilize banks and provide better habitat in the short stretch of river near the road.
- The design and implementation of wood structures below the bridge could be used to refine current channel morphology and increase pool habitat for staging spawning salmon. Access to this area would be easy. An expert in stream restoration and design should be consulted for direction on this action.
- The channelized section above the bridge would most likely benefit from the input of wood structures or perhaps riparian thinning. These actions may increase pool and cover habitat for an

increase in spawning and rearing habitat. However, it is judged that access to these areas may make these actions difficult, and it is worth considering the cost-benefit associated with these actions. Again, an expert in stream restoration and design should be consulted for direction on this action.

- Monitoring of changing conditions in regard to fish habitat is useful for assessing changes and results. An aquatic habitat survey, as implemented in this watershed assessment, provides a standardized way to assessing changes in fish habitat quality. It is recommended that an aquatic habitat survey be repeated after implementation of any restoration activities to assess success of said activities. If restoration activities are not completed for areas above the bridge, it may be worth assessing conditions of this area 5-10 years in the future; as habitat is expected to deteriorate as legacy wood is lost and not replaced.

Conclusions

This watershed assessment confirms the belief that fish habitat within portions of the lower sections of the Dog Salmon Creek watershed have been influenced by logging activities and bridge and road construction, and that habitat conditions could be improved to encourage the presence of LWD and pool habitat within the stream, which would ultimately benefit fish populations. A road condition survey should be conducted to assess the influence of the dirt road running through the watershed on water quality so that potential actions related to those affects can be weighed as well. In addition, surveying of potential stream sections not currently mapped is suggested as these areas may also provide fish habitat and fish habitat improvement opportunities. Suggested actions include re-vegetation of banks near the bridge, wood structure design and implementation in areas below the bridge, and potentially wood structure placement in channelized portions above the bridge if access is determined to be feasible.

References

Parry, B. L., C. M. Rozen, and G. A. Seaman. 1993. Restoration and Enhancement of Aquatic Habitats in Alaska: Project Inventory, Case Study Selection, and Bibliography. Alaska Department of Fish and Game Habitat and Restoration Division.

Paustian, S. J. E., K. Anderson, D. Blanchet, S. Brady, M. Cropley, J. Edgington, J. Fryxell, G. Johnejack, D. Kelliher, M. Kuehn, S. Maki, R. Olson, J. Seesz, and M. Wolanek. 1992. A Channel Type Users Guide for the Tongass National Forest, Southeast Alaska. Page 179 in A. R. USDA Forest Service, editor. US Department of Agriculture, Forest Service, Alaska Region.

Strahler, A. 1964. Quantitative geomorphology of drainage basins and channel networks. Pages 39-76 in V. T. Chow, editor. Handbook of applied hydrology. McGraw-Hill, New York.

USFS. 2001. Aquatic Habitat Management Handbook. Forest Service Handbook, Juneau, Alaska.

Appendix A: Aquatic Habitat Survey

Introduction

Dog Salmon Creek, located 5 miles south of Craig, on Prince of Wales Island (Figure 1), is a formerly robust pink and chum producing stream in which hydrology and freshwater ecology was impaired by logging practices that were in use prior to passage of the Alaska Forest Practices Act in the late 1980s. The land within the Dog Salmon Creek watershed is privately owned by Shaan Seet, Inc. (SSI), and SSI and The Nature Conservancy (TNC) are interested in addressing diminished watershed function within this watershed by collaborating on activities that aim to maintain and/or improve current habitat conditions.

In order to quantitatively assess quality of fish habitat of Dog Salmon Creek, a Tier 2 aquatic habitat survey (USFS 2001) was administered in August of 2012. This report outlines the details of this survey.

Methods

Methods followed the U.S. Forest Service protocols for a Tier 2 aquatic habitat survey (USFS 2001). Two reaches were established in the lower portion of the watershed, in areas suggested as potential areas needing restoration (Figure A1). Total reach length was determined by measuring channel bed width in 5 locations along the approximate reach location and then multiplying by 20. GPS coordinates were recorded at upstream and downstream reach ends.

Stream survey: A hip chain was run up the thalweg of the entire reach. Working from downstream to upstream, habitat units (macro pools or riffles) were delineated. Habitat units were considered pools if they met a set of qualifying criteria. A pool qualifies as a macro pool if it equals or exceeds a calculated residual pool depth, where residual pool depth is defined below:

Minimum residual pool depth = ((Average Channel Bed Width)*(0.01)) + 0.15 meters

In addition, macro pools must meet minimum size criteria relative to the average channel bed width. Finally, a discreet macro pool must be separated from other habitat units by a hydraulic control.

For each habitat unit, habitat type and length was recorded. For each pool, the residual pool depth and the maximum pool depth was measured using a stadia rod. For each habitat unit, the number of pieces of Large Wood (LW) within the bank full width of the stream was recorded. Large Wood was defined as pieces of wood with diameters larger than 0.1 meters and lengths larger than 1 meter. In addition, the number of key pieces of LW was recorded for each habitat unit. Minimum dimensions of key pieces are established for ranges of average channel bed widths. In addition, lengths of undercut banks, presence of side channels, and types of disturbance were recorded for each habitat unit.

Channel morphology measurements: A channel cross section site was established at a representative riffle section in each reach by stretching a measuring tape across the channel, perpendicular to the stream thalweg. Using an engineering level, regular depth and distance measurements were made from left bank to right bank, including measurements for bank full positions, top bank locations, bottom bank locations, edge of water locations, and thalweg locations.

In addition, a longitudinal profile of the streambed was established along a representative stretch of each reach. Using an engineering level, depth and distance measurements were taken along the thalweg across the entirety of this representative stretch.

Substrate: Substrate was characterized using a pebble count (Wolman 1954). Five transects were established in a representative riffle section, and an observer walked each transect, selecting substrate located at the tip of their boot. Each particle was placed into a size class using a gravel template. A total of 20 particles were selected in each transect.

Analysis: The following metrics were calculated from the above measurements for each reach: % slope, average channel bed width, number of pools, average residual pool depth, the ratio of residual pool depth to channel bed width, mean pool size, pools / km, mean pool spacing, pool length / m, total LW, total key LW, LW / m, key LW / m, the width to depth ratio, mean bank full depth, bank full width, d50 (mean particle size), relative submergence (mean bank full depth / median particle size), and minimum residual pool depth.

Many of these metrics were then compared to Tongass National Forest habitat survey data for unmanaged (no harvest) stands (USFS 2007). For each metric, each reach was placed into the proper percentiles according to the habitat survey data, which indicates the habitat condition (Table A1).

Results

All calculated metrics for each reach are found in Table A2. Vertical and longitudinal profiles for reaches 1 and 2 are found in Figure A2 and Figure A3 respectively. Cumulative size distributions for pebble counts are found for both reaches in Figure A4.

Selected metrics are compared to Tongass National Forest (TNF) habitat survey data for Reach 1 (Table A3) and Reach 2 (Table A4). Reach 1 was found to be within the 50 percentile for most metrics related to the amount and size of pools (Residual pool depth / channel bed width, Pool size, Pools / km) as well as metrics related to LWD presence (Total LW / m and total key LW / m), as compared to unmanaged streams of similar types within the TNF. Reach 1 had a very high width to depth ratio, larger substrate, and a lower relative submergence than unmanaged streams.

Reach 2 compared slightly better to unmanaged stands in the TNF in terms of pool metrics. However, it featured much less LWD, a much smaller residual pool depth / channel bed width, and a very high width to depth ratio.

Discussion

Reach 1 was ultimately ranked as having a poor-to-fair fish habitat condition, as compared to similar stream types in the TNF. Pools represent good fish habitat as they offer cover, refuge and feeding areas for rearing salmonids, resting and staging areas for spawning fish migrating upstream, and spawning habitat in tail crests. Reach 1 had fewer pools and smaller pools than unmanaged streams in "pristine condition". Large woody debris is also an indicator of good fish habitat, as the structures create pool habitat and habitat complexity, as well as provide shade and cover for juvenile rearing salmonids. Reach 1 again had a low number of LWD and "key" wood (i.e., big pieces more likely to create habitat), meaning that quality was degraded. Large wood not only creates pools, but produces food inputs for juvenile fish. Furthermore, the width-to-depth ratio for this reach was very high, indicating increased sediment storage and/or channel widening, which can have negative impacts on pool formation and spawning substrate.

Reach 2 was ultimately ranked as having poor-to-good fish habitat condition. It appears that there are still some large pools in this area, most likely a result of legacy wood and the ADF&G sill logs. However, there were very low amounts of LWD and "key" LWD, which indicates low fish habitat quality and may impact pool formation in the future. Similar to Reach 1, the width-to-depth ratio for this reach was very high, indicating poor channel morphology features for suitable spawning substrate and rearing pools.

Both of these reaches, by the nature of their channel type, have high potential for high quality habitat. However, these metrics indicate that habitat has been degraded, mostly as a product of the loss of large wood inputs into the stream. Replacement of these large wood sources would likely improve habitat conditions for both spawning and rearing salmonids in this watershed.

Tables

Table A1. Habitat condition for various percentiles in unmanaged stands for a selection of attributes that have been found to be key indicators.

Metric	< 25 percentile	25 percentile	50 percentile	75 percentile
Width to depth ratio	Fair	Good	Fair	Poor
Key LW / m	Poor	Fair	Good	Excellent
Pools / km	Poor	Fair	Good	Excellent
Mean pool size	Poor	Fair	Good	Excellent
Residual pool depth / channel bed width	Poor	Fair	Good	Excellent

Table A2. All calculated metrics for Reaches 1 and 2.

Metric	Reach 1	Reach 2
% Slope	1.71	1.99
Reach length	170.8	206
Average channel bed width	8.54	10.3
Number of pools	6	11
Mean residual pool depth	0.54	0.34
Residual pool depth / channel bed width	0.06	0.03
Pool size	1.03	0.93
Pools / km	35.13	53.40
Pool spacing	3.33	1.82
Pool length / m	0.33	0.40
Total LW	41	36
Total key LW	21	5
Total LW / m	0.24	0.17
Total key LW / m	0.12	0.02
Width / Depth	21.39	40.16
Mean bank full width	0.52	14.8
D50	49.39	64.0
Relative submergence	10.51	5.76
Minimum residual pool depth	0.24	0.25

Table A3. Metric values for reach 1 in comparison to the Tongass National Forest habitat survey data for unmanaged stands. The percentiles into which the Dog Salmon Creek reach fits into are highlighted in yellow, and are the basis for the habitat condition.

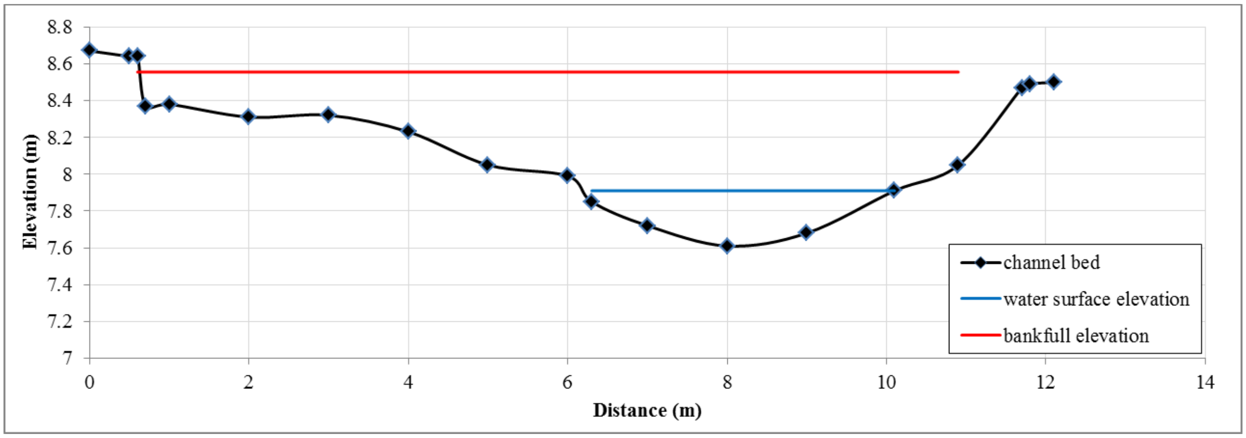
Metric	Dog Salmon Creek Reach 1	Tongass National Forest habitat survey data (percentile)				Reach 1 Habitat condition
		< 25 %	25	50	75	
Residual pool depth / channel bed width	0.06		0.06	0.07	0.09	Fair
Pool Size	1.03		0.67	1.14	1.58	Fair
Pools/km	35.13		30	40	70	Fair
Pool spacing	3.33		2.2	3.2	5.1	
Pool length / m	0.33		0.35	0.58	0.69	
Total LW / m	0.24		0.24	0.4	0.55	
Total key LW / m	0.12		0.1	0.17	0.25	Fair
Width / Depth	21.39		10.9	14.9	19	Poor
D50	49.39		22	27	39	
Relative submergence	10.51		10.6	14	23.1	

Table A4. Metric values for Reach 2 in comparison to the Tongass National Forest habitat survey data for unmanaged stands. The percentiles into which the Dog Salmon Creek reach fits into are highlighted in yellow, and are the basis for the habitat condition.

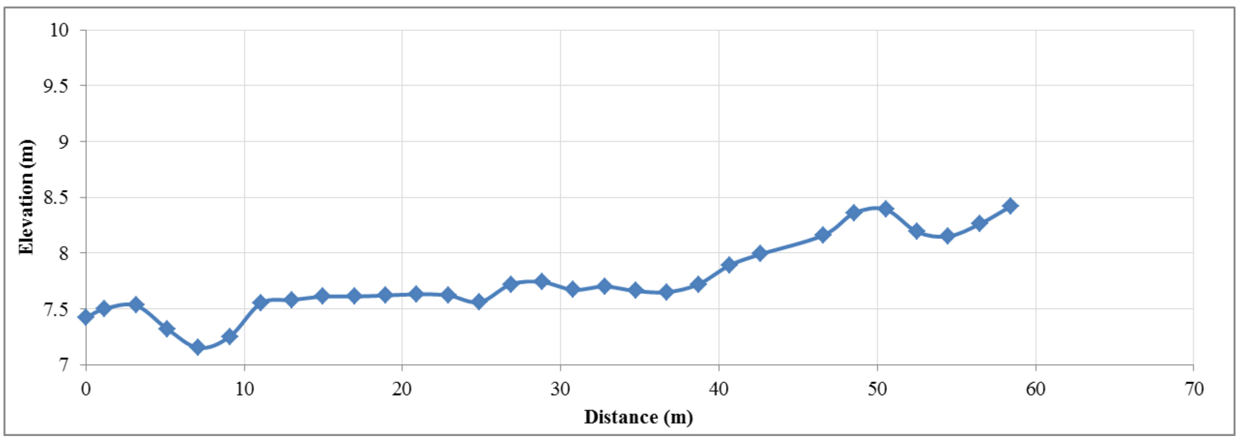
Metric	Dog Salmon Creek Reach 2	Tongass National Forest habitat survey data (percentile)				Reach 2 Habitat condition
		< 25 %	25	50	75	
Residual pool depth / channel bed width	0.03		0.04	0.04	0.05	Poor
Pool Size	0.93		0.68	0.84	0.94	Good
Pools/km	53.40		30	40	60	Good
Pool spacing	1.82		1.3	1.8	2.2	
Pool length / m	0.40		0.38	0.54	0.7	
Total LW / m	0.17		0.31	0.37	0.5	
Total key LW / m	0.02		0.06	0.11	0.15	Poor
Width / Depth	40.16		18.5	20.2	34	Poor
D50	64		15	19	34	
Relative submergence	5.76		26.5	36.9	49.4	

Figures

Figure A1. Reaches 1 and 2 on Dog Salmon Creek.



(a)



(b)

Figure A2. Vertical (a) and longitudinal (b) profiles at representative cross sections of Reach 1.

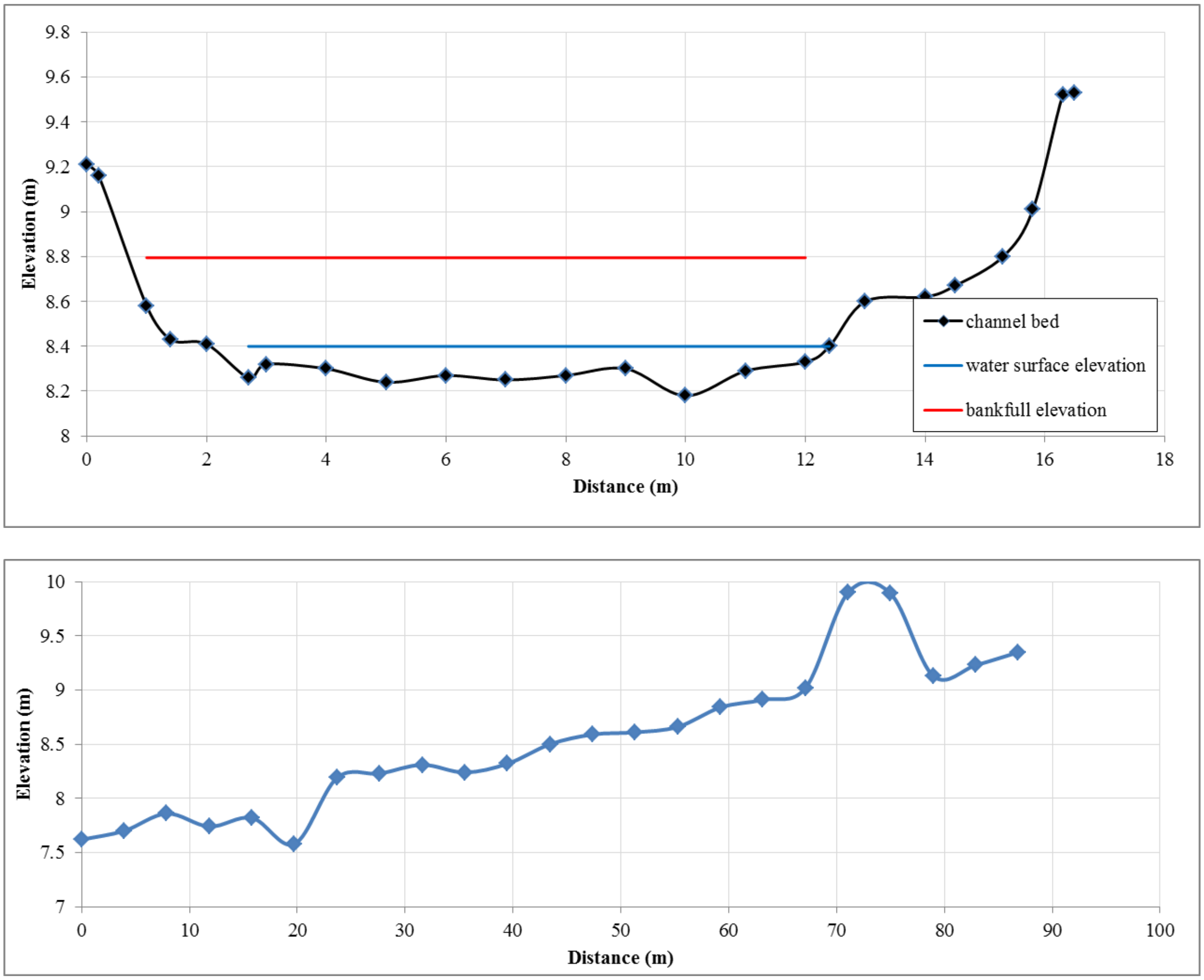
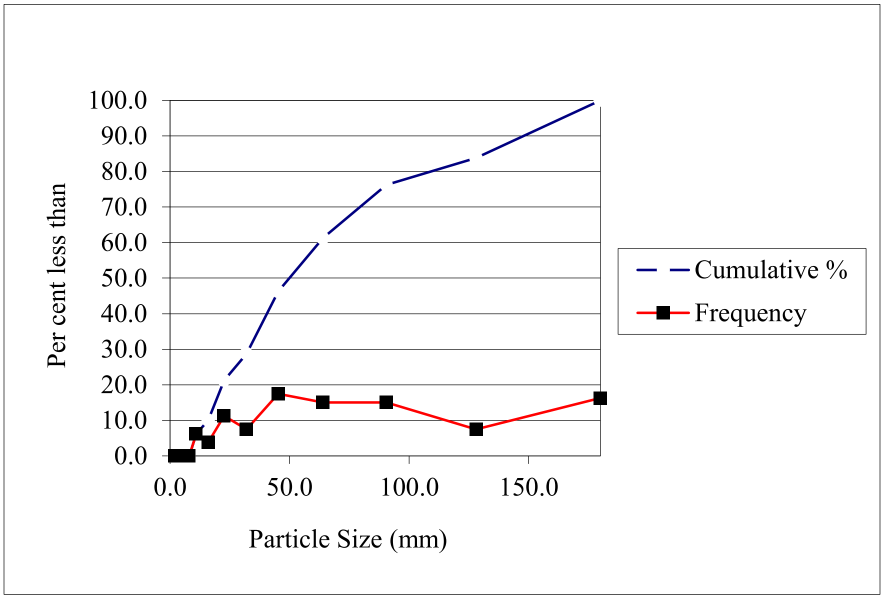
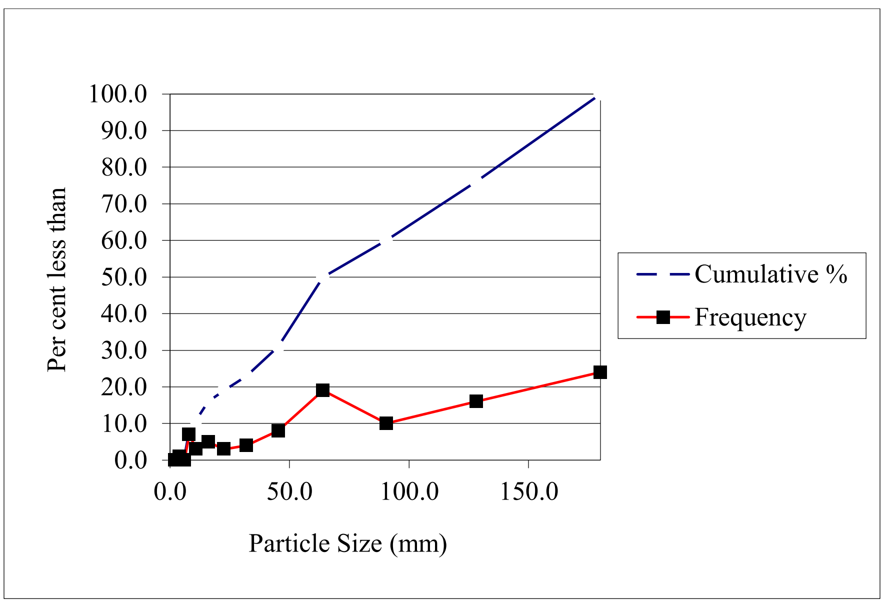


Figure A3. Vertical (a) and longitudinal (b) profiles at representative cross sections of Reach 2.



Reach 1



Reach 2

Figure A4. Cumulative size distributions for pebble counts in Reach 1 and Reach 2.

References

USFS. 2001. Aquatic Habitat Management Handbook. Forest Service Handbook, Juneau, Alaska.

USFS. 2007. Habitat Management Objectives – Statistical Update. Forest Service Handbook, Juneau, Alaska.

Wolman, M. G. 1954. A method of sampling coarse river-bed material. Transactions of the American Geophysical Union **35**:951-956.