Snohomish County Public Works Department
Surface Water Management Division

2009 Project Effectiveness Monitoring Program Report

North Meander Channel Reconnection Project, Stillaguamish River, 3-year Monitoring Results

The North Meander, Stillaguamish River
ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY

This project reconnected part of a historic meander of the Stillaguamish River at Cook Slough, which was cut off by the U.S. Army Corps of Engineers between 1936 and 1937. Channel incision of Cook Slough and levee construction since the 1930’s further isolated the North Meander, necessitating a complex feasibility, design and construction approach. Snohomish County developed a plan and excavated the eastern portion of the North Meander. The channel was subsequently reactivated by opening an inlet from Cook Slough and a new outlet to the Stillaguamish River to the north. The reconnected meander (now a side channel) is approximately 900 meters long and contains off-channel rearing and refuge habitat for anadromous salmonids as well as other species.

For the North Meander side channel restoration project, the following project goals were developed that describe functional characteristics reflecting project effectiveness:

1. Provide appropriate depths, velocities, and cover for juvenile Chinook salmon habitat during the main migration period from April to June and habitat function throughout the year.
2. Provide habitat function for rearing and over wintering juvenile coho salmon.
3. Provide year-round access to the North Meander for juvenile salmon.
4. Manage sediment ingestion by the reconnected meander and prevent degradation of the quality of habitat from sedimentation within the restored meander.
5. Prevent degradation of water quality (temperature) in Cook Slough as a result of diversion of flow to the North Meander and avoid other potential impacts that might result in Cook Slough from flow diversion.
6. Develop a design that will be self-sustaining and require little or no maintenance and operation. Incorporate any necessary features to simplify maintenance and operation.

In addition to these goals, specific monitoring requirements were included as part of project consistency with Washington’s Coastal Zone Management Program, as implemented by Department of Ecology (Order #2505, US Army Corps Ref. No. 200401408), including:

1. A habitat survey shall be performed after construction and repeated after several years to show how sediment deposition, vegetation changes, and large woody debris movement have changed habitat.
2. Sediment and temperature will be monitored as described in the Wetland Report and Functional Assessment.
3. In addition, the wetland shall be rated using the Washington State Wetland Rating System for Western Washington in years 5 and 10 to confirm no loss in overall wetland functions compared to the predevelopment wetland rating (outside the scope of this report).

In order to test these goals and monitoring objectives, Snohomish County Surface Water Management developed a monitoring plan for the North Meander project that includes multiple monitoring elements reported on in Chapters 1 and 2, including:

a. Water quality monitoring of temperature and dissolved oxygen,
b. Physical habitat inventory of woody debris, bank conditions, over-water cover, and habitat units,
c. Channel form survey at cross-section locations,
d. Photo point documentation (Appendix A)
e. Vegetation monitoring, and
f. Fish sampling during spring salmonid smolt outmigration (Chapter 2).

**Monitoring Highlights**

For each major monitoring element, we describe results to date and conclusions drawn from interpretation of the data, where appropriate, following 3 years of data collection. In most cases, additional years of monitoring information will help inform questions dependent upon a longer time period. Due to constraints on project completion thus far, we anticipate project completion and formal closure of the water quality certification in 2010. This will initiate a 10-year monitoring period, to 2020.

**Water quality** - The temperature criteria for aquatic life use at this location in the Stillaguamish River is 17.5°C Celsius and is based on a 7-Day Average of the Daily Maximum Temperature (7DADMax). We demonstrate water temperature was variable between years; is strongly dependent on snow-melt discharge during spring runoff; and is also highly dependent on air temperature following spring runoff. Water quality temperature standards did not appear to be violated during the salmon smolt migration period in spring and early summer in 2007 or 2008. In 2008, river discharge declined after snowmelt but the magnitude of summer discharge was higher than 2007 by approximately 50%. In 2008, the meander did not run dry as it did in 2007, suggesting management of water quality condition will be challenging or infeasible due to watershed-wide inter-annual changes in temperature and flow. However, maintaining continuous flow through the meander by managing sediment aggradation (and therefore flow rate and water depth) will likely limit the number of days that temperature exceeds water quality standards during hot weather, especially in the newly excavated inlet channel.

As mentioned, when discharge after snowmelt declined, air temperature strongly influenced water temperature unless and until inflow discharge became so low that local cold groundwater discharge reduced water temperature. Thermal refugia may exist at these times, but we observed very low dissolved oxygen levels in groundwater discharge plumes in 2009. Maximizing flow connectivity through sediment management may also help to maintain dissolved oxygen at suitable levels. Peak temperatures in the excavated inlet channel may be mitigated more in the future by shading from vegetation, but currently there is very little canopy cover (see Habitat below).

**Channel Form** – To identify sediment aggradation or incision/erosion within the channel that might limit habitat quality, several cross sections were surveyed within the project reach during 2007 and 2009 summer low flow conditions. Only one cross section location appears to be aggrading in elevation, approximately where aggradation and sedimentation management was designed and anticipated. Otherwise most cross section locations appear to have deepened or translated right or left. In 2009, we added a longitudinal channel thalweg survey, which will be
used for survey comparisons in future years, especially of deeper locations where sedimentation may become noticeable.

Habitat – The reconnected meander (now a side channel) is approximately 900 meters long and contains off-channel rearing and refuge habitat for juvenile salmonids and other species. We estimate the slough provides up to 12,831 m² (1.3 hectares) during summer low flow and 22,226 m² (2.2 hectares) off-channel habitat during winter. The estimated areas were calculated by drawing polygons using 2006 and 2007 aerial photos. Pess et al. (1999) estimate that 69% of side channel sloughs in the lower Stillaguamish River, which historically totaled 32.1 hectares, have been lost. Although historically a meander of the river (and not a side-channel slough), the North Meander project now augments current side-channel slough habitat by 18.5% or replaces up to 8% of the historical side-channel slough habitat lost. In 2007, based on habitat unit maximum depth, residual depth and spatial configuration, 11 distinct pools were identified during summer base flow that comprised 84% of the channel area. At low flow, the maximum depth within the channel was 1.8 meters, with a mean maximum pool depth of 1.45 meters. Mean tail depth was 0.82 meters and the mean residual depth was 0.63 meters. Over time, summer habitat area (and volume) may decrease if substantial deposition occurs. Deposition may affect the composition of habitat units as well, which could reduce pool area down from 84% of the channel area.

In 2008, the total wood tally for wet and dry pieces (but within the channel) was 1097 pieces or approximately 122 pieces/100 meters channel length. Woody debris jams were located at a frequency of 10.6 jams per kilometer, considerably higher than any other recently surveyed location in the Stillaguamish River (Haas et al. 2003). In January 2009, a flood event mobilized some fraction of the total LWD in the North Meander and re-deposited this wood within the meander, often at higher elevations and outside of the excavated channel. The number of pieces classified as being “out-of-channel” increased by 10-fold, thereby decreasing the functional wood count. Some of this “out-of-channel” LWD was used to construct 3 jams in the lower meander which were designed to catch woody debris and reduce the rate of export. Additional LWD placement in 2008 and 2009 increased the upper segment wood load to 300 pieces.

Although LWD frequency would be expected to naturally fluctuate over time, in the North Meander, LWD will likely only decrease until such time that mature trees in the Meander begin to contribute to LWD load. Currently a few large Cottonwood trees might provide LWD load in the foreseeable future (and may act as “key” pieces), but abundant LWD will likely not be contributed from the riparian buffer until planted trees mature, and then only as a result of wind throw and senescence (and not channel migration). Woody debris will also not be transported into the North Meander due to exclusion by the culvert inlet. Decay of existing LWD will therefore reduce LWD quantities over time as woody debris breaks up, sinks, or is otherwise exported out of the meander as smaller pieces or is deposited on high banks during large flood events.

Total percent center channel canopy cover was 29%. Center canopy cover within the existing historic channel was 39%, which compares favorably with other constructed/restored side-channels as reported by Morley et al. (2005). In the newly excavated inlet channel, the center canopy cover averaged 2.5%. Total percent channel edge canopy cover was 62%. Edge canopy
cover within the existing historic channel was 84%; while the inlet channel locations averaged 3%. Edge cover was estimated prior to LWD placement in the inlet channel.

Among transects and half transect locations, a total of 105 substrate samples were regularly sampled throughout the North Meander. Substrate size is classified into size classes. The dominant and sub-dominant substrate within the project channel is silt at 79% and sand at 13%. The monitoring plan does not contain specific substrate monitoring questions or hypotheses regarding function or potential change due to project implementation. We anticipate the channel will aggrade in places over time as a result of deposition of sand and silt, but no specific sediment size changes are anticipated. Additionally, estimating substrate size at transects requires judgment in some cases because depth of water and lack of water clarity requires size estimates to be made based on bottom probing with a stadia rod. In consideration of this, we believe changes in sediment will more appropriately be evaluated based on effects to channel form.

**Vegetation** – Planting areas can be separated into 3 sections for management purposes: areas left to natural recruitment, areas impacted by channel construction, and areas actively planted along the margins of the restored channel. Planted restoration areas adjacent to the restored channel are developing very well. These areas already have over 65% cover, though survival is low on some sites. Natural recruitment supplements the loss in these areas. Planted areas are growing very well and are expected to meet 10-year performance standards without intense active management.

Qualitative assessments show that areas left to natural recruitment in the central field of the meander are behind in vegetation cover and in comparison to performance standards. They are low in species diversity, and high in invasive species cover. Active management to remove invasive species and remove stored spoils will increase the possibility of meeting 10-year site goals. Without active management, the performance standards for this portion of the site will probably not be met.

Areas impacted by channel construction consist of a high percentage of emergent habitats. Cover in these areas is currently very low due to 2008-2009 construction activity on site. Invasive species cover in these areas is increasing within the disturbed areas and will require continued management until construction disturbance stops and native plants are established. The high invasive species cover impacts the current diversity and cover of emergent species on site. The amount of available emergent habitat has decreased in the wetland since the meander was built due to the steeper slopes and hardened edges within the new meander. Achieving the goals for the wetland functional assessment and the emergent habitat cover will be difficult without active management and may not be possible at some locations permanently changed by project construction.

**Fish Monitoring** – The North Meander Project is providing critical rearing and refuge habitat for salmonid and non-salmonid species during the typical spring salmonid smolt outmigration period at a location where a significant fraction of the historical side-channel habitat has been lost. At the North Meander, we observed 15 different fish species and various larval, juvenile and adult life stages. Juvenile Chinook are observed using the North Meander at densities that are
comparable to other watershed studies for similar habitat types. Based on North Meander sampling, the annually observed (2007-2009) peak density of approximately 0.12 fish/m² is equivalent to 1,200 fish per hectare. By comparison, in the Skagit River, Hayman et al. (1996) reported peak Chinook parr densities varied from 0.05-1.225 fish/m² among lower mainstem river edge habitat types, and ranged from 192-486 fish per hectare among sampled off-channel habitats. In the Port Susan estuary of the Stillaguamish River, the Stillaguamish Tribe collected wild origin Chinook salmon in the greatest sample proportions among distributary slough habitats where Chinook density ranged up to 1000 fish/hectare (in May, 2006), but mostly fell below 300 fish/hectare among all years and months (Feb-August) (Stillaguamish Tribe of Indians 2009). Finally, by applying a method developed for Skagit River Chinook salmon production estimation, we estimate Chinook salmon parr production from North Meander in 2009 was 4,715 fish among the 111-day sample period.

In addition to Chinook salmon, we caught Coho salmon (yearling and fry), steelhead, chum, cutthroat, and pink salmon within the North Meander channel. Coho salmon density by date was always greater in North Meander than Cook Slough. This finding is consistent with the expectation, based on life history habitat preferences, that coho would favor off-channel rearing habitats over mainstem river locations. In 2009, coho yearling abundance and density were presumably related to the higher abundance of coho fry in the previous year (same population cohort). However, we did not observe coho yearlings in either North Meander or Cook slough in March 2009 samples, suggesting the higher densities observed later were due to fish immigration and not overwintering in North Meander. Overall, observed coho density of fry and yearlings was low, consistently less than 0.1 fish/m². Reeves et al. (1989), in Oregon, estimated potential carrying capacity of side-channels for summer parr was 1.7 fish/m² and rearing density of spring coho fry was estimated to be 5.0 fish/m²; both considerably higher than our observations. Morley et al. (2005) observed coho density in summer (August) was 2.1 fish/m² and 1.2 fish/m² for constructed and natural channels, respectively.

Collection efficiency was not determined for our sampling, so observed densities are considered to be conservative estimates of fish use. Although ideally we would have sub-sampled all habitats represented in the North Meander, or sampled an existing side-channel location (in addition to the mainstem), this was infeasible due to sampling limitations and absence of comparable habitat. In North Meander, we excluded habitat units with woody debris from beach seine sampling due to the potential for snagging the nets. Additionally, we did not sample locations with complex bank edge habitat. Natural bank edge habitat with woody debris has been observed to contain higher densities of Chinook salmon Parr in the Skagit River compared to gravel bars or modified stream banks (Hayman et al. 1996). Although deployment of baited minnow traps in woody debris jams failed to trap Chinook parr, it’s conceivable that higher densities of Chinook and coho salmon are supported in North Meander at these other habitat-specific locations. That being the case, Chinook and coho densities reported here again likely represents an underestimate of use and overall production.

While identifying salmonid presence, relative timing, and estimated project abundance is instructive, the overall project benefit has yet to be determined, and will likely change over time. The percent entrainment of migrating salmonids, and the duration of rearing are important questions that remain unanswered. Identifying the percent and origin of salmonids entering the
project area from the watershed as a whole will help to inform project success. Establishing project-specific rearing duration could identify habitat and life history benefits that could be used to estimate potential population benefits; and applicable to other proposed projects. For example, beneficial use of lower river floodplain off-channel habitats by smaller, earlier migrating Chinook salmon fry may accrue to populations where the availability of such habitat near spawning areas is naturally scarce or historically degraded. In the South Fork Stillaguamish, where side-channel and off-channel habitats (oxbows, ponds, lakes) are naturally sparse due to the geomorphologically incised setting (relative to the North Fork Stillaguamish), a life history strategy dependent upon such down-river rearing opportunities and the restoration of such, may be highly beneficial for recovery of salmon in the Stillaguamish River basin.

**Monitoring Recommendations**

Water quality – Temperature monitoring recommendations include continued monitoring at 5 locations (plus air temperature) on an annual basis for the duration of the 10-year monitoring plan. Temperature loggers should be located at the same water depth at initial placement (if possible) or at relocation at a minimum of 3 North Meander locations (inlet, middle, and near outlet). Testing for thermal stratification at the deepest meander locations (and any correlated dissolved oxygen) is also needed and could be accomplished as part of a thermal profile (longitudinal and vertical) during flows less than 500 cfs based on the NF Stillaguamish gage. This is required to better understand the relationship between discharge, air temperature, groundwater influence, spatial and temporal temperature refugia, and the role of sediment management as it affects flow connectivity.

Habitat – Ongoing monitoring of woody debris within the next 5-10 years will include piece inventory by channel segment, anchor type and location, jam count and movement in order to help identify processes by which LWD loss occurs, at what rate LWD loss occurs, and from where within the meander the loss occurs. Such information will be used for adaptive management decision-making pertaining to woody debris load and project targets. Beginning in 2010, we recommend transect-based sampling include canopy cover measurements every 5 years. Transect based measurements also include channel dimensions which, in combination with cross section and longitudinal profile surveys, will help determine changes, if any, in total habitat area and volume.

Channel Form – Bi-yearly, we will continue to survey established cross-sections and add additional survey points of prominent channel bedform features (such as sand bars), that may not be coincident with cross sections or thalweg alignment. We will continue to supplement existing photo point locations (Appendix A) with additional photos of erosion or sedimentation for adaptive management decision-making for erosion or sedimentation. Other photo point locations may be established if any current locations become overgrown.

Vegetation – Qualitative’ Type A’ assessments will continue on a yearly basis to outline adaptive management needs for the site. Quantitative assessments will be combined into the same year for all monitoring areas starting in 2010. These areas will be monitored every 3 years. Transects will be set up in the natural recruitment areas to gather similar information. Species survival, cover, diversity, and growth will continue to be measured as part of these assessments in a
manner consistent with current methods. The 5-year wetland functional assessment will be repeated in 2010 and again in 2015.

Fish Monitoring – For fish monitoring, we recommend implementing monthly monitoring (August-February) and bi-monthly monitoring (March-July) of 3 North Meander site locations and 1 off-site comparison location (Cook Slough). We propose to test entrainment flow to determine proportion of flow and estimate fish entrainment based on flow, using test drogues, or mark-re-capture (pending discussions with Stillaguamish Tribe). Depending upon 2010 water quality observations of low dissolved oxygen, we may conduct fish sampling to evaluate site specific fish use under these water quality conditions that may limit rearing or refuge opportunity (even given cold groundwater discharge), and therefore summer habitat capacity.

Photo Monitoring - In future years, photo point monitoring will be conducted every other year, unless dramatic changes warrant annual photos. As growth of vegetation increases, some photo point locations may be moved or may only be captured during winter “leaf-off” conditions. Additionally, whole site imagery from aerial orthophotos (or oblique angles) and high resolution satellites may be available and used as part of monitoring.

**Future Potential Management/Maintenance Actions**

Major categories for project operation, maintenance and adaptive management consideration over time include;

- **Culvert inlet opening operation**
  - For fish access management - The flow through the project channel, when limited by the intake gate, may reduce the potential entrainment of fish into the channel throughout the out-migration period. The operation of the gate should be timed to lengthen entry opportunity time to the channel potentially increasing early Chinook salmon fry-migrant use and prolong rearing time within the project. We recommend closing the inlet gate prior to potential fall/winter flooding and no later than November 1. We recommend opening the center slot no later than March 1, based on observed fish use in North Meander and long-term mainstem river outmigration timing documented by the Stillaguamish Tribe (e.g. Griffith et al. 2006). We recommend opening the full inlet no later than April 1.
  - For sediment management - The estimated average (1929-2002) annual proportion of suspended sediment in Cook Slough during an open inlet condition is 16.9% (Northwest Hydraulic Consultants 2004). Between November-March, 83.1% of the estimated annual average suspended sediment would be excluded at the inlet closure. The center slot would allow some suspended sediment ingestion during March.
  - For water quality management – Water quality does not appear to be degraded within the North Meander during critical outmigration periods. During summer low flow, the open culvert would not hinder, but also would not likely help water quality.
  - For fish entrainment or attraction – pending 2010 (or later) analysis of fish entrainment, the culvert inlet area may be enhanced with additional large woody
debris placement in order to create more “backwater” habitat and local refuge at
the point of North Meander flow entrainment.

- Sediment maintenance
  - For flow connectivity management – Sediment accumulation within the over-
    excavated inlet channel is evident. Bedform (sand) elevations appear to be
    increasing based on topographic survey. In the absence of any significant thalweg
    formation within the sand bed, flow connectivity may be disrupted at base flows,
    which will affect water quality and fish movement and dispersal. Removal of
    accumulated sediment at times when flow connectivity is disrupted (3-5 years)
    will be needed.

  - For water quality management – sediment removal will facilitate summer base
    flow connectivity and reduce the number of days that low flow contributes to low
    dissolved oxygen levels.

- Woody debris loading
  - For woody debris management, recommended wood quantity targets for streams
    and rivers in Washington State (Fox and Bolton 2007) are >63 pieces/100 meters
    and >208 pieces/100m, respectively for channel widths of 6-30 meters and >30-
    100 meters. Because the North Meander project channel width ranges up to and
    exceeds 30m in places, we believe the present quantity, 122 pieces/100 meters is
    currently suitable, and ideally, should be maintained in the future at no less than
    108 pieces/100m, the median reference value for wood in channels >30m (Fox
    and Bolton 2007).

- Vegetation planting and maintenance
  - Invasive species will be managed for 3 purposes: decrease to near 0% cover those
    species as required by noxious weed laws; manage invasive plants as necessary to
    maintain native plant health in planted areas; and to increase emergent community
    diversity within the meander. Other invasive species will be kept below 15% cover; some areas may require further control to achieve other desired goals.

  - Within the natural recruitment area, additional planting will continue, as space
    and funding allows, to meet native plant cover and diversity goals. Currently,
    these areas are in a disturbed state with new soil (spoils) on a different
    hydrological regime than the former floodplain. To improve the natural
    succession of this site, either spoils will be removed from these areas, or grading
    will occur to increase topographical diversity.
CHAPTER 1

Introduction

This project reconnected part of a historic meander of the Stillaguamish River at Cook Slough, which was cut off by the U.S. Army Corps of Engineers between 1936 and 1937. Channel incision of Cook Slough and levee construction since the 1930’s further isolated the North Meander, necessitating a complex feasibility, design and construction approach. Snohomish County developed a plan and excavated the eastern portion of the North Meander. The channel was subsequently reactivated by opening an inlet from Cook Slough and a new outlet to the Stillaguamish River to the north.

The reconnected meander (now a side channel) is approximately 900 meters long and contains side-channel rearing and refuge habitat for anadromous salmonids as well as other species within the low gradient, wide alluvial floodplain of the Stillaguamish River. This type of rearing habitat for salmonid fishes, as well as off-channel, tidal and beaver-pond habitat areas have been substantially lost or modified through various land use changes since the 1930’s. Pess et al. (1999) reported that current Lower Stillaguamish River side channel slough habitat (primarily in the lower Mainstem floodplain) amounted to 31% of its historical (1930’s) extent, declining from 32.1 to 9.7 hectares. Other off-channel habitats in the Lower Stillaguamish, namely distributary sloughs and ponds, have declined in area by 81% and 91.5%, respectively. Including the loss of estuary side-channel slough habitat suggests 70% of all side channel habitat downstream from Arlington has been lost since the 1930’s (Pess et al. 1999).

We estimate the North Meander channel provides up to 12,831 m² (1.3 hectares) during summer low flow and 22,226 m² (2.2 hectares) off-channel habitat during winter (1.8 hectares, average). The estimated areas were calculated by drawing polygons using 2006 and 2007 aerial photos (see below). Specifically, Pess et al. (1999) estimate that 22.4 hectares of lower river channels were cut-off, filled or straightened. Although historically a meander of the river (and not a side-channel slough), the North Meander project now augments current side-channel slough habitat by 18.5% or replaces up to 8% of the historical side-channel slough habitat lost.

Monitoring Overview

Monitoring for this project is derived from specific project objectives and regulatory requirements. The project objectives chosen for inclusion in this monitoring plan include the following:

1. Provide appropriate depths, velocities, and cover for juvenile Chinook salmon habitat during the main migration period from April to June and habitat function throughout the year.
2. Provide habitat function for rearing and over wintering juvenile coho salmon.
3. Provide year-round access to the North Meander for juvenile salmon.
4. Manage sediment ingestion by the reconnected meander and prevent degradation of the quality of habitat from sedimentation within the restored meander.

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5. Prevent degradation of water quality (temperature) in Cook Slough as a result of diversion of flow to the North Meander and avoid other potential impacts that might result in Cook Slough from flow diversion.

6. Develop a design that will be self-sustaining and require little or no maintenance and operation. Incorporate any necessary features to simplify maintenance and operation.

As such, the monitoring plan (amended in 2008) includes the following elements, which are reported in detail below. Specific monitoring methods for each element are included in the North Meander Monitoring Plan (available from Snohomish County).

- Water quality monitoring of temperature and dissolved oxygen.
- Physical habitat inventory of woody debris, bank conditions, over-water shading, substrate size and habitat units.
- Channel form survey at cross-section locations.
- Vegetation monitoring.
- Fish sampling during spring salmonid smolt outmigration (Chapter 2).
- Photo point documentation (Appendix A).

Monitoring Results and Discussion

Water Quality Monitoring

Temperature and dissolved oxygen were monitored at several locations to determine if the new channel provides suitable water quality conditions for juvenile salmon in spring and summer.

Temperature

Water temperature was recorded mid-April through September in 2007, 2008 and 2009 using methods from Washington State Department of Ecology (2003). Continuously recording temperature loggers were placed at several locations within the North Meander and in Cook Slough (Figure 1-1) along with a temperature logger to record air temperature. In 2007, two loggers were recovered dry, and another was lost. Five loggers were placed in 2008, and three were recovered; one at the inlet in Cook Slough, one in the center of the project reach, and another 100 meters upstream of the project outlet into the Mainstem Stillaguamish. The air temperature logger was also recovered. It was placed in a shaded location in the riparian vegetation ~1.5 meters above the ground near the center of the project (Figure 1-1). 2009 data are not yet available.

Washington State Department of Ecology has designated the Stillaguamish River from the mouth to the confluence of the North and South Forks (~RM17.8) as salmonid spawning, rearing, and migration habitat area (from Table 602, Washington Department of Ecology 2006) for the purposes of aquatic life uses and temperature standards. The key characteristic of this use is salmon or trout spawning and emergence that only occur outside of the summer season (September 16 - June 14). The temperature criteria for this aquatic life use at this location in the Stillaguamish River is 17.5°C Celsius and is based on a 7-Day Average of the Daily Maximum Temperature (7DADMax).
Daily maximum temperature was extracted from temperature data from each logger and running 7DADMMax was calculated. The temperature data recovered in 2007 shows that the loggers went dry or were near to the water surface in late July. Only data from April 19th-July 24th was used.
for this analysis. The highest 7DADMax for 2007, before the loggers were compromised, was 21.3°C located near the intake and 21.7°C near the center of the project reach. Temperature data from 2008 is more reliable as loggers were placed deeper as the water level approached summer low flow. The highest 2008 7DADMax temperatures were; 20.9°C in Cook Slough at the intake to North Meander, 21.7°C near the center of the project reach, and 19.3°C downstream near the out flow of the project reach. Water temperature in 2007 was generally higher than in 2008, but the temperature difference between years based on varying logger placement depths cannot be known. Regardless, temperature in both years exceeded thermal maxima criteria.

The running 7DADMax exceeded the recommended criteria of 17.5°C on July 2nd 2007 at both logger locations then briefly dropped below the 17.5°C threshold for 3 consecutive days (7/21/07-7/23/07) before returning above on 7/24/07. Data beyond the last date was compromised by not maintaining loggers below low water levels or in locations that were well mixed later in summer.

Logger data from 2008 locations show running 7DADMax exceeded the 17.5°C criteria on 8/04/08. The 7DADMax returned below the 17.5°C threshold on 8/19/08 at the logger located near the outlet of the project reach and 8/20/08 at the Cook Slough and center project reach logger locations. The percent of days that exceeded the criteria were: 10% at the Cook Slough location, 9.6% at the center project reach location and 9% at the site nearest the outflow. The percent of loggings (every 30 minutes) that exceeded the criteria were; 7.9% at the Cook Slough location, 6.8% at the center project reach location and 6.1% at the site nearest the outflow. Table 1-1 summarizes, by location and year, the days the 7DADMax exceeded specific designated use criteria recommended temperatures.

Table 1-1. Number of days the running 7-day average of daily maximum temperatures exceeded designated use temperature criteria. The shaded column represents the regulated temperature criterion for North Meander.

<table>
<thead>
<tr>
<th>Logger Year</th>
<th>Logger Location</th>
<th>Maximum 7DADMax</th>
<th>Days &gt;13°C</th>
<th>Days &gt;16°C</th>
<th>Days &gt;17.5°C</th>
<th>Days &gt;18°C</th>
<th>Days &gt;20°C</th>
<th>Days Logged</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Intake pool ~150m from intake</td>
<td>21.3°C</td>
<td>51</td>
<td>26</td>
<td>20</td>
<td>17</td>
<td>9</td>
<td>97</td>
</tr>
<tr>
<td>2007</td>
<td>Center NM project reach</td>
<td>21.7°C</td>
<td>53</td>
<td>26</td>
<td>20</td>
<td>17</td>
<td>10</td>
<td>97</td>
</tr>
<tr>
<td>2008</td>
<td>Cook Slough/NM inlet</td>
<td>20.9°C</td>
<td>94</td>
<td>51</td>
<td>17</td>
<td>15</td>
<td>4</td>
<td>170</td>
</tr>
<tr>
<td>2008</td>
<td>Center NM project reach</td>
<td>21.7°C</td>
<td>93</td>
<td>48</td>
<td>17</td>
<td>15</td>
<td>6</td>
<td>177</td>
</tr>
<tr>
<td>2008</td>
<td>NM near outlet</td>
<td>19.3°C</td>
<td>85</td>
<td>39</td>
<td>16</td>
<td>14</td>
<td>0</td>
<td>177</td>
</tr>
</tbody>
</table>

Maximum water temperature is associated with the center of the North Meander project in both. Whereas the total number of days exceeding 17.5 degrees was the same between Cook Slough and the center of the North Meander in each year, the exceedance temperatures appear to be greater in the North Meander.
Figure 1-2 shows a graph of the running 7DADMax for 2008 temperature loggers with the 2008 air temperature represented as daily maximum temperature. 2007 temperature data is shown for comparison, though data quality was compromised in July. The temperature throughout the project reach is similar starting in April both years when flow is at intermediate levels (except there are pronounced differences between years; Figure 1-2). As flow decreased after April in 2007, and after June in 2008 (see Figure 1-3), water temperature became more influenced by daily air temperature. In August 2008 (near summer base flow), the temperature among upstream (near intake), the center, and the outflow begin to separate. Temperature in the center is slightly elevated in comparison to the intake, while there is a decrease in temperature near the outflow. The temperature separation exists and appears to persist while flow is less than 500 cfs (at the N.F. Stillaguamish gage). This temporal thermal variability could be explained by some local ground water influence that is spatially revealed as the composition of local flow contains an increasing fraction of groundwater as upstream surface flow declines. Additionally, this probe was probably the deepest among all probes in the meander and placement appears to coincide with one of the deepest habitat areas (see next section). If consistent among years, this part of the North Meander, with deeper habitat units (contacting older/deeper floodplain deposits/aquifers), could be unique in terms of thermal refuge as surface flow recedes, but this has not been tested for specifically in terms of fish response or in terms of other limiting factors, such as low dissolved oxygen. In 2007, temperature data were compromised early and spatial separation due to groundwater influence cannot be inferred.

Figure 1-2. North Meander 2007 and 2008 spring and summer temperature (7DADMax) among sample sites displayed in Figure 1-1. Temperature loggers in 2007 were compromised after July, but are shown for comparison.
Figure 1-3 compares the winter-spring-summer flow regime for 2007-2009. The delayed and prolonged spring flow in 2008 predominantly driven by abundant snow-melt (relative to 2007), in combination with greater water volume in the meander later in the spring and summer helps explain the annual temperature variation and the earlier onset of thermal influence by air temperature in 2007 (presumed) compared to 2008 (air temperature shown in Figure 1-2). In 2008, the hottest days of the year were May 16-18, at precisely the same time as maximum spring snowmelt discharge. Together, these had a negligible effect on temperatures in the meander.

![Graph showing mean monthly flow for 2007, 2008, and 2009 for the Stillaguamish River, North and South forks.](image)

In conclusion, we demonstrate water temperature was variable between years; is strongly dependent on snow-melt discharge during spring runoff; and is also highly dependent on air temperature following spring runoff. Water quality temperature standards did not appear to be violated during the salmon smolt migration period in spring and early summer in 2007 or 2008. In 2008, discharge declined after snow-melt but the magnitude of summer discharge was higher than 2007 by approximately 50%. In 2008, the meander did not run dry as it did in 2007. Maintaining continuous flow through the meander by managing sediment aggradation (and therefore water depth) will likely limit the number of days temperature exceeds water quality standards during hot weather, especially in the newly excavated inlet channel. As mentioned, when discharge after snow melt declines, air temperature strongly influences water temperature unless and until inflow discharge becomes so low that local cold groundwater sources reduce temperature. Thermal refugia may exist at these times, but we observed very low dissolved oxygen levels in groundwater discharge plumes in 2009. Maximizing flow connectivity through
sediment management may also help to maintain dissolved oxygen at suitable levels. Peak temperatures in the excavated inlet channel may be mitigated more in the future by shading from vegetation (given the size of the channel and no apparent groundwater influence), but currently there is very little canopy cover.

Temperature monitoring recommendations include continuing monitoring at 5 locations (plus air temperature) on an annual basis for the duration of the 10-year monitoring period. Temperature loggers should be located at the same water depth at initial placement (if possible) or at relocation at a minimum of 3 North Meander locations (inlet, middle, and near outlet). Testing for thermal stratification at the deepest meander locations (and any correlated dissolved oxygen) is also needed and could be accomplished as part of a thermal profile (longitudinal and vertical) during flows less than 500 cfs based on the NF Stillaguamish gage. This is required to better understand the relationship between discharge, air temperature, groundwater influence, spatial and temporal refugia, and the role of sediment management as it affects flow connectivity.

**Dissolved Oxygen (DO)**

DO samples, measured in milligrams per liter (mg/L), were taken with a calibrated Hydrolab Minisonde4a™. Measurements were taken on six dates in 2007, March 20th – May 30th, throughout the Chinook spring out-migration period (Griffith et al. 2006). The recommended criteria for the 1-day minimum DO in the aquatic life use category salmonid spawning, rearing, and migration is 8.0 mg/L. The lowest recording was 9.6 mg/L taken on May 30th at 10:30am with a water temp of 13.8°C at the temperature location 100m upstream of the project reach outflow. Average DO taken at locations in the reconnected North Meander reach averaged 11.5 mg/L; while comparison sites in the Mainstem Stillaguamish and Cook Slough averaged 11.5 mg/L. Only one sample was obtained in 2008 on April 23rd. Average DO within the North Meander reconnection was 11.4 mg/L and at mainstem sites was 11.55 mg/L. We conclude dissolved oxygen is not limiting habitat suitability for salmonids in the North Meander during spring smolt outmigration. However, in situ DO monitoring on several dates in summer 2009 revealed very low DO apparently associated with strong groundwater discharge. The spatial extent of low DO was not investigated, but limited sampling will be continued in subsequent years on a more seasonal basis, especially to determine if and how DO varies with surface discharge and the apparent influence of groundwater.

**Channel Form Monitoring**

To identify sediment aggradation or incision/erosion within the channel that might limit habitat quality, several cross sections and a longitudinal profile were surveyed within the project reach. The locations of the cross sections are shown in Figure 1-4 and include the following locations; one 10 meters downstream of the bridge near the outlet (A), one near the center of the project reach 315 meters downstream of the intake culvert (B), one at the riffle 140 meters downstream of the intake (C), one at 85 meters downstream from the inlet culvert (D), one 30 meters downstream of the intake (E), and finally, one across the downstream side of the intake culvert (F). There were extensive elevations taken along the intake structure (G, see Figure 1-4).
Figure 1-4. North Meander 2009 cross section and longitudinal profile points and 2007 habitat reference points.

Cross section elevations were surveyed during 2007 and 2009 summer low flow conditions. No cross sections were surveyed in 2008. However, Figure 1-5 shows some deposition in 2008 and
ongoing construction downstream of the inlet culvert (photos were taken at different flow levels) likely to affect cross section elevation.

Figure 1-5. 2007 (left, spring) and 2008 (right, summer) North Meander channel immediately downstream of inlet culvert. A sediment wedge is present in the 2008 photo. Woody debris was added in summer 2008.

Cross sections within the channel (A-F) are graphically represented in Figure 1-6 and include 2007 and 2009 survey points. Only one cross section location (D) appears to be aggrading in elevation, approximately where aggradation and sedimentation management was designed and anticipated. Otherwise most cross-section locations appear to have deepened or translated right or left. In 2009, we added a longitudinal channel thalweg survey, which will be used for survey comparisons in future years.
Channel changes resulting in erosion or sedimentation may not be captured based on cross-section surveys alone. In 2008, we observed new left bank erosion and cross-channel deposition immediately downstream from the inlet culvert (Figure 1-7). In response, the County placed additional woody debris along the left bank to limit stream bank shear stress and provide added habitat value (Figure 1-7). Bi-yearly, we will continue to survey established cross-sections and add additional survey points of prominent bedform features (such as sand bars), that may not be coincident with cross sections (Figure 1-4) or thalweg alignment. We will continue to supplement existing photo point locations (Appendix A) with additional photos of erosion or sedimentation for adaptive management decision-making for erosion or sedimentation.
Habitat Monitoring

Habitat monitoring is used to identify the current habitat within the channel and identify changes in the habitat over time. These data will help identify if existing habitat is suitable for salmon rearing and if it is sustained. Given the unique channel conditions, the habitat survey was performed using a modification of the Snohomish County Wadeable Stream Survey Protocol (Rustay et al. 2008). The survey was completed on August 15th 2007, during summer low flows.

Habitat Area
Total habitat area and pool area alone were determined by polygons created with 2007 aerial photos and residual depth measurements along the 900 m long channel. GPS positions were taken in 2007 at or perpendicular to each significant depth change for spatial reference (2007 Points in Figure 1-8). Using pool maximum depth, residual depth and spatial configuration, 11 distinct pools were identified (plotted in Figure 1-8), which might be at risk of future sedimentation. The maximum depth at low flow within the channel was 1.8 meters, with a mean maximum pool depth of 1.45 meters. Mean tail depth was 0.82 meters and the mean residual depth was 0.63 meters.

The total habitat area during summer low flow in 2007 was estimated to be 12,831 m². The pool area was 10,825 m², approximately 84% of the total habitat area. We estimate the slough provides up to 22,226 m² (2.2 hectares) off-channel habitat during winter based on estimates of river stage in the channel. The estimated areas were calculated by drawing polygons using 2006 and 2007 aerial photos. Pess et al. (1999) estimate that 69% of side channel sloughs in the lower Stillaguamish River, which historically totaled 32.1 hectares, have been lost. Although formerly a meander of the river (and not a side-channel slough), the North Meander project now augments side-channel slough habitat by 18.5% over the current total in the lower Stillaguamish River or replaces up to 8% of the historical side-channel slough habitat lost.

Figure 1-7. Left -2008 left bank erosion and slumping and cross-channel sedimentation immediately downstream from the inlet culvert and in-between cross-sections E and F. Right - 2009 Photo of same location.
In 2007, during summer low flow, the one riffle identified within the project was dry (at the time of the habitat survey), thereby separating habitat areas and potentially reducing directional flow through the meander, although this was not directly investigated. In 2008, no longitudinal profile was surveyed. However, it was apparent from frequent visits and known river discharge (that was substantially higher than 2007, see Figure 1-3) that this riffle did not de-water. In 2009, the surveyed longitudinal profile was very similar to 2007 depth observations. However, near the inlet culvert we measured pronounced vertical erosion downstream from the inlet culvert (a plunge pool) and pronounced sediment accumulation. This accumulation and shift downstream appears to have reduced the area (and possibly depth) of the pool immediately upstream from the riffle. Over time, summer habitat area (and volume) may decrease if substantial deposition occurs. Deposition may affect the composition of habitat units as well, which could reduce pool area from 84% of the channel area. Active sediment management may preclude some project-wide deposition.

**Bank Instability**

A stream bank stability inventory was not conducted during the 2007 habitat survey due to active maintenance of unstable banks located within the project. Bank slumping did occur during the November 2006 flood, most noticeably on the right bank at the cut through the dike near the outflow (see Figure 1-9). Wood with rootwads was used to stabilize the bank. Left bank erosion in 2008 immediately downstream of the inlet culvert (in Figure 1-7) was treated with anchored woody debris and additional high bank slumping was observed after the January 2009 flood. We
believe future slumping may occur on steeper floodplain banks that become saturated during flooding and fail under their own weight (after flood recession). These locations will likely be associated with new channel excavation (i.e., the inlet and outlet), where vegetative cover is still recovering. The rate of slumping should decline as vegetation matures and new incidences of slumping should be allowed to recover naturally or with minimal planting.

A. 2007 photo, right bank slumping near outflow.


Figure 1-9. North Meander right bank instability in 2007 (A) near Station 0 at Old Stillaguamish River channel in 2009 (B) after planting treatment in 2007.

Wood
A woody debris inventory was implemented in 2008 and 2009. Wood \( \geq 1.5 \) meters in length and \( \geq 10 \) centimeters in diameter were tallied, categorized by channel zone (wet, dry, out of channel), and overall project location (upstream, middle, and downstream segments). The spatial locations
of logjams and LWD triangle structures were recorded using GPS. To our knowledge, no as-built inventory of LWD was completed after initial construction, but based on whole channel excavation; we assume all LWD in the North Meander was placed as part of project implementation.

In 2008, the total wood tally for wet and dry pieces (but within the channel) was 1097 pieces or approximately 109 pieces/100 meters channel length. Wood in the wetted channel accounted for 55% of the wood. Wood placed (or displaced during high flow events) on bank top locations or otherwise considered out of the active channel amounted to 10% of the total wood tally. In 2008, there were 10 LWD jams containing 55% of the total wood count. Jams were located at a frequency of 10.6 jams/km, considerably higher than any other recently surveyed location in the Stillaguamish River (Haas et al. 2003). It should be noted that these jams were predominantly floating accumulations of woody debris and were not anchored by key pieces or geomorphically active (pool forming), at least at this time. There were 13 intact triangle structures located in the meander channel. Triangle structures were made from three LWD pieces cabled together at their ends and were attached to trees along the bank with rope. Many of the remaining triangles are associated with jams and/or contain additional individual pieces other than the three joined pieces, but the original number of LWD triangles placed is not known nor are there specific monitoring questions or hypotheses regarding their function or value. 2008 woody debris inventory by segment and zone is shown in Table 1-2 and Figure 1-10.

In January 2009, a large flood occurred in the Stillaguamish watershed. In the lower mainstem river, the entire floodplain was inundated and surface flow entered the North Meander by overtopping the floodplain. This flood event mobilized LWD in the North Meander and re-deposited this wood within the meander, often at higher elevation and outside of the excavated channel. Additional LWD may have been recruited from the floodplain that was not previously counted in 2008. We inventoried LWD after this flood event and focused in particular on the middle and lower segments, which are compared in Table 1-2. Within the project area, total LWD count in the channel decreased slightly, from 923 to 900 pieces. It’s possible some pieces were obscured from view due to slightly higher and more turbid water. Also, the re-arrangement of LWD may have obscured some pieces from view. Otherwise the total number of pieces in the channel decreased slightly as a result of export from the meander or outside of the channel. In the middle segment, in 2009, LWD appeared to be more associated with the wetted channel, but with fewer pieces associated with jams. Photo point photos from this middle segment in 2009 do not appear to be substantially different from 2008 (Appendix A). We conclude this middle section was little affected by the significant flooding, even though the water surface stage elevation fluctuated by as much as 4-5 meters (based on personal observation of high water marks).
Figure 1-10. Woody debris distribution among upper, middle, and lower segments in 2008 (red) and 2009 (yellow) for jams and triangle structures. GPS position for individual pieces, including newly placed LWD in the upper segment are not available.

In the lower segment, the total abundance of LWD did not change substantially, but the number of pieces in the wet channel decreased substantially and the number of pieces classified as being “out-of-channel” increased by 10-fold. The majority of these pieces appears to have been
mobilized from three large unanchored channel-spanning jams (Appendix A, pages 5-9) and distributed downstream on the left bank and at the bridge crossing (Hevly Rd.; see Appendix A, page 4). Including wood that was counted outside the channel, the total abundance increased by 80 pieces from 2008 to 2009. It’s not clear where the 80 pieces may have originated from. Some pieces could have been newly recruited from the riparian area or floodplain during flooding. Other pieces could have originated in the upper segment, which was not re-surveyed. After additional LWD placement in 2008 and 2009, the upper segment contains 300 placed pieces, mostly anchored.

Table 1-2. Woody debris abundance by section, year, and location within the channel profile.

<table>
<thead>
<tr>
<th>Section</th>
<th>Location</th>
<th>Pre-2008</th>
<th>2008</th>
<th>Post Flood</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lower</td>
<td>Total</td>
<td>381</td>
<td>381</td>
<td>371</td>
<td>434</td>
</tr>
<tr>
<td></td>
<td>in Jams</td>
<td>297</td>
<td>297</td>
<td>221</td>
<td>344</td>
</tr>
<tr>
<td></td>
<td>Out of channel</td>
<td>18</td>
<td>18</td>
<td>181</td>
<td>60</td>
</tr>
<tr>
<td>Mid</td>
<td>Total</td>
<td>542</td>
<td>542</td>
<td>529</td>
<td>480</td>
</tr>
<tr>
<td></td>
<td>in Jams</td>
<td>301</td>
<td>301</td>
<td>221</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Out of channel</td>
<td>96</td>
<td>96</td>
<td>36</td>
<td>36*</td>
</tr>
<tr>
<td>Upper</td>
<td>Total</td>
<td>0</td>
<td>174</td>
<td>174</td>
<td>300</td>
</tr>
<tr>
<td></td>
<td>in Jams</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Out of channel</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total count</td>
<td></td>
<td>923</td>
<td>1097</td>
<td>1074</td>
<td>1214</td>
</tr>
<tr>
<td>Total out of channel</td>
<td></td>
<td>114</td>
<td>114</td>
<td>217</td>
<td>96</td>
</tr>
</tbody>
</table>

* Assumed value

Recommended wood quantity targets for streams and rivers in Washington State (Fox and Bolton 2007) are >63 pieces/100 meters and >208 pieces/100m, respectively for channel widths of 6-30 meters and >30-100 meters. Because the North Meander project channel width ranges up to and exceeds 30m in places, we believe the current 2009 quantity, 124 pieces/100 meters is currently suitable, and ideally, should be maintained in the future at no less than 106 pieces/100m, the median reference value for wood in channels >30m (Fox and Bolton 2007) in Western Washington.

Although LWD frequency would be expected to naturally fluctuate over time, in the North Meander, LWD will likely only decrease until such time that mature trees in the Meander begin to contribute to LWD load. Currently a few large Cottonwood trees might provide LWD load in the foreseeable future (and may act as “key” pieces), but abundant LWD will likely not be contributed from the riparian buffer until planted trees mature, and then only as a result of wind throw and senescence (and not channel migration). Woody debris will also not be transported into the North Meander due to exclusion by the culvert inlet. Decay of existing LWD will therefore reduce LWD quantities over time as woody debris breaks up, sinks, or is otherwise exported out of the meander as smaller pieces or is deposited on high banks during large flood events that surcharge the North Meander floodplain.
Currently, it appears the bridge at Hevly Road acts to limit woody debris transport out of the North Meander. Photo documentation of LWD pinned against the bridge piers supports reveals this, though no count or estimate of woody debris load impinging on the bridge has been obtained (Figure 1-11). Future total accumulation of LWD on the bridge piers is limited to the amount of wood currently in the channel (and not anchored), but nevertheless might become a road maintenance concern. LWD that was deposited on the left bank near the bridge during the flood in January 2009 was used for construction of 3 jams in the lower segment of the meander during summer 2009. The jams were placed at constrictions in the meander to trap woody debris as it migrates down the channel. Ongoing monitoring will help to identify potential management responses, if warranted.

Ongoing monitoring of woody debris within the next 5-10 years will include piece inventory by channel segment, anchor type and location, jam count and movement in order to help identify processes by which LWD loss occurs, at what rate LWD loss occurs, and from where within the meander the loss occurs. Such information will be used for adaptive management decision-making pertaining to woody debris load and project targets.

![2005](image1)
![2007](image2)
![2008](image3)
![2009](image4)

Figure 1-11. Photo-documentation from 2005-2009 of increasing LWD abundance upstream of Hevly Road bridge, immediately upstream from the North Meander outlet and end of the project.
**Transects**
Canopy cover measurements were taken in 2007 at the center and edges of the channel at 11 equi-distant transects spaced 90 meters apart along the channel thalweg. Eight transects were located within the historic channel retaining a riparian component consisting of large deciduous trees. Three transects were located within newly cut channel at the intake or the outflow. Spatial position of each transect was obtained with a GPS.

Total percent center channel canopy cover was 29%. Center canopy cover within the existing historic channel was 39%, which compares favorably with other constructed/restored side-channels as reported by Morley et al. (2005). In the newly excavated inlet channel, the center canopy cover averaged 2.5%. Total percent channel edge canopy cover was 62%. Edge canopy cover within the existing historic channel was 84%; while the inlet channel locations averaged 3%. Edge cover was estimated prior to LWD placement in the inlet channel. Future edge cover monitoring may increase as a result of LWD cover within 30cm of the water surface as well as from vegetation cover. Habitat functions associated with canopy cover provided at this location are probably limited to edge habitat quality, overhead cover from predation, and insect food production, although these functions are not specifically being tested for. We anticipate that edge canopy cover in the inlet channel will increase most rapidly among locations as newly planted shrubs and trees grow. The exception to this will be at shore locations required for sediment management and fish sampling.

Among transects and half transect locations, a total of 105 substrate samples were regularly sampled throughout the North Meander. Substrate size is classified into size classes. The dominant and sub-dominant substrate within the project channel is silt at 79% and sand at 13%. The monitoring plan does not contain specific substrate monitoring questions or hypotheses regarding function or potential change due to project implementation. We anticipate the channel will aggrade in places over time as a result of deposition of sand and silt, but no specific sediment size changes are anticipated. Additionally, estimating substrate size at transects requires judgment in some cases because depth of water and lack of water clarity requires size estimates to be made based on bottom probing with a stadia rod. In consideration of this, we believe, changes in sediment will more appropriately be evaluated based on effects to channel form.

Beginning in 2010, we recommend transect-based sampling include canopy cover measurements every 5 years. Transect based measurements also include channel dimensions which, in combination with cross section and longitudinal profile surveys, will help determine changes, if any, in total habitat area and volume.

**Photo points**
Photos were taken at 9 locations throughout the project channel in the spring of 2007, late summer 2008, and early winter 2009, after an especially large flood. At each photo point location, a photo was taken in the downstream, 45° downstream, 90° across, 45° upstream, and upstream directions, regardless of compass direction. Appendix A represents a time series comparison among locations and years to date. In particular, the time series of photo points
depicts the increased growth and cover of vegetation within the meander and the downstream displacement of woody debris, especially among sites 2-5.

In future years, photo point monitoring will be conducted every other year, unless dramatic changes warrant annual photos. As growth of vegetation increases, inevitably some photo point locations may be moved or may only be captured during winter “leaf-off” conditions. Additionally, whole site imagery from aerial orthophotos (or oblique angles) and high resolution satellites may be available and used as part of monitoring (also see vegetation monitoring).

**Vegetation Monitoring**

Planting of disturbed areas within the North Meander Reconnection Project began in the winter following initial construction; 2005-2006. Figure 1-12 shows areas planted and areas scheduled for future plantings. Table 1-3 reports acres and planting densities for each year. 8.4 acres (~42% of the total area) have been planted to date using designs, plans, and procedures coordinated by the Snohomish County Native Plant Program. An additional 2.6 acres will be planted 2010, and 9.3 acres (~45%) will be managed for natural recruitment.

![Figure 1-12. Planting areas separated by color to indicate years planted or scheduled for future work. Pink areas will be managed for maximum natural recruitment as dredged spoils are removed from the area. Hatch marks indicate areas currently designated for vegetation monitoring.](image)

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Table 1-3. Acres planted per year, and density of plants in each area. Color codes for year correspond with Figure 1-12.

<table>
<thead>
<tr>
<th>Year</th>
<th>Acres</th>
<th>Plants</th>
<th>Plants/acre</th>
<th>Monitoring site #</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005-2006</td>
<td>3.9</td>
<td>14,660</td>
<td>3,720</td>
<td>1</td>
</tr>
<tr>
<td>2006-2007</td>
<td>2.1</td>
<td>8,555</td>
<td>4,073</td>
<td>2</td>
</tr>
<tr>
<td>2008-2009</td>
<td>2.4</td>
<td>5,414</td>
<td>2,255</td>
<td>3</td>
</tr>
<tr>
<td>2009-2010</td>
<td>2.6</td>
<td>5,000</td>
<td>1,940</td>
<td></td>
</tr>
<tr>
<td>unplanted</td>
<td>9.3</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

A wetland delineation and functional assessment was conducted in 2004 by Snohomish County (Berger 2005). Performance standards for re-vegetation according to the project proposal and Water Quality Certification Permit are interpreted as follows:

At 10 yrs from project completion, vegetated areas shall have:
80% survival of planted plants
65% cover in trees and shrubs
85% cover in emergent plant communities
15% or less cover of non native invasive plant species

"Project will be deemed complete when the wetland rating system confirms no loss of overall wetland function. Ratings will be conducted in years 5 and 10, post project completion."

Vegetation health and recovery along the North Meander project was monitored according to methods described in the 2003 Vegetation Monitoring Manual (Moore et al. 2003). The full site was monitored using a “Type A” qualitative assessment on a yearly basis. Complete vegetation assessments measure between 5 and 10% of each monitored area. These assessments currently take place on alternate years post planting. Full assessments consist of permanent transects set up perpendicular to the meander to capture a cross section of hydrological conditions. Vegetation assessments include fixed line intercept measurements for vegetation cover, 2-meter belt transects to measure survival, growth and vigor of newly planted species, and quadrat samples spaced along transects within the wetland edge to measure diversity and cover of emergent communities.

Full assessments were conducted in 2006, 2007, 2008 on monitoring sites during summer after planting. For funding reasons, these sites will be monitored all in the same year beginning in 2010. This decision delayed collection of information for this report, but will improve reporting quality for future years. Initial monitoring results from sites 1 and 2 are included in this report.

Plant Survival
The North Meander planting site is characterized by very harsh initial growing conditions. Soil conditions have been compromised due to construction and spoil storage on site. Much of the area is under direct sun exposure, and no excess water is on site through the dry summer months. Despite this, year one survival at sites 1 and 2 were quite high (Table 1-4). The data were separated by functional plant groups for adaptive management purposes.
Table 1-4. Percent (%) plant survival separated by functional plant groups for sites 1 and 2.

<table>
<thead>
<tr>
<th>VEGETATION</th>
<th>% Survival</th>
<th>Site 1</th>
<th>Site 2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2006 (YR1)</td>
<td>2008 (YR3)</td>
<td>2007 (YR1)</td>
</tr>
<tr>
<td>CONIFER</td>
<td>96</td>
<td>40</td>
<td>98</td>
</tr>
<tr>
<td>DECIDUOUS TREE</td>
<td>87</td>
<td>152</td>
<td>100</td>
</tr>
<tr>
<td>DECIDUOUS SHRUB</td>
<td>100</td>
<td>14</td>
<td>98</td>
</tr>
<tr>
<td>SALIX SPP.</td>
<td>95</td>
<td>28</td>
<td>100</td>
</tr>
<tr>
<td>TOT/AVG ALL</td>
<td>98</td>
<td>28</td>
<td>99</td>
</tr>
</tbody>
</table>

Survival at Site 1 decreased dramatically through year 3 to 28 %. This is much lower than the performance standard of 80%. Much of this planting area was mixed with pre-existing native vegetation making it difficult to distinguish established planted material from pre-existing material. Large shrub complexes were counted only one time when they may have originally consisted of more than one planting. Conservative estimates for Site 1 survival make it a poor example of true site conditions. Natural recruitment of deciduous trees into the area increased rates of survival for that functional group.

Site 2 was irrigated during the first two summers after planting. This site had high initial survival and looks to be very well established. Data for 3-year survival will be taken late in summer 2010. It is expected that survival rates will be much higher than those in Site 1.

Site 3 was not irrigated, and has patchy areas of mortality according to the qualitative assessment conducted in 2009. Causes of mortality are consistent with other areas across the site. This site did not have supplemental water, and the first summer was very hot and dry. Projections for 10-year success based on these data and on site observations suggest that although planted material alone may have a higher mortality than desired, the addition of natural recruitment of native plants will offset this to keep survival rates above 80% over all.

Vegetation cover
Vegetation cover is now measured using the line intercept method that includes all cover on the site. Previous measurements in 2006 and 2007 were conducted using individual plant cover in the belt transect. This previous method has higher variability between users and a higher estimate of cover for installed plants, yet it did not include pre-established plants which are ecologically very important to include for overall site health.

Vegetation cover on site is increasing in both planted (Table 1-5) and non-planted areas. Type A qualitative assessments show planted areas have higher cover of woody species and lower invasive cover than areas left for natural recruitment. Areas that continue to be disturbed by construction and maintenance around the site continue to have low vegetation cover and will not recover until construction related disturbance on the site is discontinued.
Table 1-5. Percent (%) vegetation cover by year and functional plant groups on site 1 and 2, with ± 1 standard deviation.

<table>
<thead>
<tr>
<th>VEGETATION</th>
<th>Site 1 2006 (YR1)</th>
<th>Site 2 2008 (YR3)</th>
<th>Site 2 2007 (YR1)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CONIFER</td>
<td>0.4±0.3</td>
<td>2±3</td>
<td>6±4</td>
</tr>
<tr>
<td>DECIDUOUS TREE</td>
<td>1±4</td>
<td>58±66</td>
<td>3±3</td>
</tr>
<tr>
<td>DECIDUOUS SHRUB</td>
<td>36±37</td>
<td>62±48</td>
<td>7±8</td>
</tr>
<tr>
<td>SALIX SPP.</td>
<td>5±18</td>
<td>22±28</td>
<td>1±1</td>
</tr>
<tr>
<td>TOT/AVG ALL</td>
<td>44</td>
<td>143</td>
<td>17±12</td>
</tr>
</tbody>
</table>

Site 1 has a pre-existing canopy over half of the transects. This deciduous canopy was not measured in 2006 giving a false low cover for deciduous trees in 2006 (1% in Table 1-5). Whereas the deciduous shrub understory was included, creating cover results much higher than expected in the first year (36% in Table 1-5). Naturally occurring and planted canopy cover were measured together in 2008.

Results for Site 2 of less than 20% cover are as expected for first year cover on an open site with no pre-existing vegetation. Most of this cover is attributable to natural recruitment throughout the site. Deciduous tree cover is low because natural recruitment of alder was not included in cover data in 2007. Cover results in 2010 may be lower than expected (relative to Site 1) due to 2009 construction damage to plants along the edge of the meander. Based on qualitative assessments, cover should still be well over 65% within the planting areas by year 10.

Taking these percent cover measurements and expanding them to cover the whole site indicates that at this time our planted sites have an average cover of 37%. There is very high variability in this number as we know some areas are well over 100% cover, and many continue to have low cover. Across the whole site, including the non planted areas, tree and shrub cover is only 15%. This number is expected to increase as disturbance on the site decreases, and as cover from natural recruitment increases over time. However, without further management for vegetation health, 65% cover across the whole construction site will not be met by year 10.

**Invasive species cover**

Across the site, invasive species cover is patchy with some areas dominated by invasive species, and others completely devoid of invasive species. To date, invasive species management has concentrated on blackberry along the forest edges, thistle and tansy in the natural recruitment areas, and reed canary grass within the planting areas. Targeted treatments will continue on a yearly basis as legally mandated for some species (Snohomish County Noxious Weed List 2009), and will also target other species within planting areas until native vegetation cover is established. Table 1-6 shows invasive species and percent cover measured within the planting areas.
Table 1-6. Invasive species cover in Sites 1 and 2 for selected species. Measurements of < 1% are noted as trace amounts.

<table>
<thead>
<tr>
<th></th>
<th>% Invasive Species Cover</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Site 1</td>
</tr>
<tr>
<td>VEGETATION</td>
<td></td>
</tr>
<tr>
<td>Canada thistle</td>
<td>2.4±5.1</td>
</tr>
<tr>
<td>Bull thistle</td>
<td>Trace</td>
</tr>
<tr>
<td>Reed canary grass</td>
<td>7.3±9.0</td>
</tr>
<tr>
<td>Himalayan Blackberry</td>
<td>Trace</td>
</tr>
<tr>
<td>Tansey Ragwort</td>
<td>Trace</td>
</tr>
<tr>
<td>Total</td>
<td>9.1±9.7</td>
</tr>
</tbody>
</table>

To date, planted areas have an average invasive species cover between 8 and 9 percent. This is well below the 15% goal for the site. Variation is high in these areas signifying small pockets of very high cover, and many areas of no cover. This variability indicates some areas will need invasive species management to keep below the 15% goals. Reed canary grass continues to be the dominant invasive along the meander and in the planting areas. Though not currently a threat to plantings, it is greatly impacting emergent plant community diversity and cover. Treatments for reed canary grass within the wetland will occur in 2010 in an attempt to increase emergent plant community health. Snohomish County is legally mandated to control species such as the thistles and tansey ragwort, which are currently mowed and sprayed on an annual basis.

**Emergent Plant Community Cover**

Emergent plant species were identified across the restoration site in the year following construction (Table 1-7). Plant cover and species diversity in these communities is highly variable due to continued construction disturbance within the meander. Measurements for emergent plant cover and density across the site will be conducted before invasive species control occurs during summer 2010. It is expected that as ground disturbance decreases, emergent communities will recover to cover levels over 85% in the newly established emergent areas by year 10. Qualitative measurements show the total area under emergent community cover has decreased across the site. This decrease in overall emergent communities is not directly a performance standard, however it does impact the wetland assessment. Due to permanent changes in topography within the meander and hydrologic connections to the wetland in the upland area, the recovery of emergent plant communities may be different than for pre-existing conditions, which will directly affect our comparison of future functional assessment compared to the original wetland assessment.
Table 1-7. Emergent species found within vernal pools of the upland spoils or within the meander channel.

<table>
<thead>
<tr>
<th>Emergent Plants 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>water plantain</strong></td>
</tr>
<tr>
<td><strong>wapato</strong></td>
</tr>
<tr>
<td><strong>toad rush</strong></td>
</tr>
<tr>
<td><strong>dagger leaf rush</strong></td>
</tr>
<tr>
<td><strong>tapper tip rush</strong></td>
</tr>
<tr>
<td><strong>mountain hair grass</strong></td>
</tr>
<tr>
<td><strong>curly leaf pondweed</strong></td>
</tr>
<tr>
<td><strong>floating leaved pondweed</strong></td>
</tr>
<tr>
<td><strong>bur-reed</strong></td>
</tr>
<tr>
<td><strong>water star wort</strong></td>
</tr>
<tr>
<td><strong>marsh cudweed</strong></td>
</tr>
</tbody>
</table>

**Conclusions and Recommendations**

Based on these data, we estimate 10-year goals for those areas already planted will be fulfilled. However, overall, vegetation establishment for the entire site is taking longer than initially expected, and therefore it is difficult to predict at this time if 10-year goals for the entire site will be fulfilled. Progress has been set back due to numerous compounding factors, including delayed planting in some zones, disturbance due to ongoing woody debris construction within the meander, and poor planting conditions in much of the upland areas.

Much of the upland area has only been seeded to establish ground cover due to the poor soil conditions resulting from the large quantities of spoils stored on site. Planting within the large upland area will be delayed until spoil removal and grading is completed. Natural recruitment of primary successional species is occurring in these areas; however, diversity of natural recruitment in these areas is very low. Improving conditions by removing spoils or by increasing topographical diversity in currently un-vegetated areas through pit-and-mound spoil displacement will increase the potential for diversity of natural plant recruitment to these areas.

As major construction and maintenance along the meander is completed, vegetation cover trends will continue to increase a few years behind the anticipated schedule. In areas of continued disturbance however, vegetation will not reach the 10-year goals after 2010, and will need continued management for invasive species.

The initial wetland functional assessment has also produced lower scores than was anticipated following project completion (preliminary wetland rating). Results and trends for the wetland assessment will be presented in the fifth year monitoring report. Currently, the overall wetland value is below estimated values due to lower emergent community cover along the meander, greater invasive species cover, lower woody plant cover, and lower species diversity than anticipated for post construction results. At the 5 year mark, we will have a better picture of what these values mean and a better understanding of whether the functional assessment trends toward the 10-year goal.
Planting areas can be separated into three sections for management purposes: areas left to natural recruitment, areas impacted by channel construction, and areas actively planted along the margins of the restored channel. Qualitative assessments show that areas left to natural recruitment in the central field of the meander are behind in vegetation cover and in comparison to performance standards. They are low in species diversity and high in invasive species cover. We recommend continued removal of dredge spoils. Invasive species will be managed for three purposes: decrease to near 0% cover those species as required by noxious weed laws, manage invasive plants as necessary to maintain native plant health in planted areas, and to increase emergent community diversity within the meander. Other invasive species will be kept below 15% cover at a minimum; some areas may require further control to achieve other desired goals.

Areas impacted by channel construction consist of a high percentage of emergent habitats. Cover in these areas is currently very low due to 2008-2009 construction activity on site. Invasive species cover in these areas is increasing within the disturbed areas and will require continued management until construction disturbance stops and native plants are established. The high invasive species cover impacts the current diversity and cover of emergent species on site. The amount of available emergent habitat has decreased in the wetland since the meander was built due to the steeper slopes and hardened edges within the new meander. Achieving the goals for the wetland functional assessment and the emergent habitat cover will be difficult without active management and may not be possible at some locations permanently changed by project construction. We recommend ongoing planting to meet project goals for planted areas. We expect various planting and maintenance objectives will require annual work, 2010-2020.

Planted restoration areas adjacent to the restored channel are developing very well. These areas already have over 65% cover, though survival is low on some sites. Natural recruitment supplements the loss in these areas. Within the natural recruitment area, additional planting will continue, as space and funding allows to meet native plant cover and diversity goals.
CHAPTER 2

Introduction

This project reconnected and reactivated part of the historic North Meander of the Cook Slough, by excavating an inlet from Cook Slough and creating a new outlet to the Stillaguamish River to the north. The reconnected meander (now a side channel slough) is approximately 900 meters long and has restored some off-channel rearing and refuge habitat capacity for juvenile salmonids and other species that was previously lost throughout the lower Stillaguamish Floodplain.

River side channel and off-channel habitat types in floodplain rivers provide rearing area capacity and refuge for salmonids (Chinook and coho salmon, in particular) during typical spring smolt outmigration (Hayman et al. 1996; Sommer et al. 2001), during summer (Nickelson et al. 1992; Beechie et al. 1994; Pess et al. 1999), and also during winter (Swales et al. 1986; Nickelson et al. 1992; Pess et al. 1999). Much of this type of floodplain habitat in rivers and estuaries (e.g., blind tidal channels, secondary side channels, ponds) has been lost in the Stillaguamish River (Pess et al. 1999) and elsewhere in Puget Sound (Beechie et al. 1994, Collins et al. 2003). These habitat types not only provide more habitat capacity but also offer variable habitat characteristics compared to mainstem rivers alone (Morley et al. 2005), which support salmonid life history requirements and diversity (Beechie et al. in press).

North Meander fish monitoring objectives include documenting use of the channel by all fish species sampled, documenting the presence and timing of salmonids within the reconnected channel, and by quantitative estimation, a range of use of the area in terms of density and abundance of certain salmonids. Fish monitoring was conducted during the salmonid parr out-migration period (Griffith et al. 2006), February through June, in 2007, 2008, and 2009. These results are compared to other regional values.

Study Area

We estimate the slough provides up to 12,800 m$^2$ (1.3 hectare) during summer low flow and 22,226 m$^2$ (2.2 hectare) off-channel habitat during winter. Area was calculated by drawing polygons using 2006 and 2007 aerial photos and by estimating area at approximately bankfull conditions for winter habitat. For juvenile salmonids, the reconnected North Meander was designed to provide side-channel habitat with low velocity, suitable depths and in- and over-water cover. Generally, juvenile fish (particularly coho and Chinook salmon) will seek these preferred habitats as refuge to avoid higher flows and velocities in the main river during winter and as rearing and foraging locations during spring outmigration to Puget Sound.

Access to the North Meander from Cook Slough is directly regulated by an adjustable inlet culvert, which can be manually closed (or partially closed) by lowering vertical gates through three vertical slots. A narrower opening can be created by removing only a portion of the gate (the center slot). Typically, the North Meander inlet gate has been closed during winter when sediment-laden floods are most likely to occur and deliver large quantities of suspended sediment to the North Meander (Northwest Hydraulic Consultants 2004). Management of North Meander sedimentation is a long term goal, as future sedimentation in this side channel could
significantly reduce available habitat area for fish and limit flow and habitat connectivity. During some sample dates, the inlet gates were closed, but otherwise were open.

Based on long-term sediment management goals, the inlet also restricts flow discharge to a maximum of 200-250 cfs. Thus, even as Cook Slough discharge increases, North Meander flow entrainment does not. Because the head differential between Cook Slough and Stillaguamish River increases with discharge, the hydraulic environment at the inlet culvert can be intense. Tests of fish entrainment and entrainment efficiency (at variable discharge) were beyond the scope of our current effort but may influence fish use, apparent habitat capacity and production potential.

The outlet from North Meander is not regulated by any built structure and directly connects with the Stillaguamish River. At this location there are low exit velocities from the North Meander to the Stillaguamish River which presumably allows upstream access from the Stillaguamish River and also affords some tame hydraulic transition from the North Meander to the Stillaguamish River.

Methods

Fish monitoring in North Meander and Cook Slough was accomplished by the use of a beach seine, and baited minnow traps, as conditions allowed. By in large, sample site locations were fixed among years, though site effort varied by year and visit (Table 2-1). Other factors that varied during the sampling period include flow (Table 2-1) and whether or not the North Meander inlet gates were closed or (partially) open (Table 2-1).

Fish collection was permitted under supervision of the Stillaguamish Tribe Department of Natural Resources. We prepared an annual proposal outlining purpose, methods, and expected “catch”. Annual reporting to the Tribe included total catch by species.

Beach Seine
A beach seine (1/8th inch knotless mesh) was used to monitor fish use of pools, backwater and slow moving channel areas with no or little wood structure or other cover. Beach seines were not used in areas containing LWD, log jams, or other cover. Small beach seine nets (4 feet deep by 30 – 50 feet long) were used in water less than 4 ft (1.2 m) deep and have relatively homogenous features (depth, water velocity, and substrate). A larger seine net (6-10 feet deep by 60-80 feet long) was used in deeper channel areas. Nets were set in a “round haul” fashion by fixing one end of the net to the bank while the other end was deployed with the current using a float tote, raft or snorkeler then returning to the shoreline in a closed half circle for final retrieval along shore. Occasionally a 2nd seine set was made to judge fish “depletion” or catch efficiency. Otherwise, a single seine sample represents a conservative estimate of the sampled area. All fish were enumerated and measured unless a representative sample could be obtained without measuring all fish (see fish handling, below). The individual seine set area was measured with a rangefinder and calculated as a semi-circle. Seine sets were performed routinely at 4 sites within the project channel (plus 2 others periodically) and 2 comparison sites in Cook Slough. Figure 2-1 shows all fish collection sampling sites.
**Baited Minnow Traps**

“Minnow” and “crawfish” traps were the Gee® style; cylindrical with two tapered openings on each end. Minnow traps were metal ¼ inch square mesh with openings tapered to ~1 inch. Craw traps were plastic ¼ inch diamond mesh with openings tapered to approximately 2 inches. Bait was placed in perforated plastic 35mm photographic film canisters suspended with wire or line in the center of the trap. Baited minnow and craw traps were placed at 5 locations throughout the North Meander channel and 3 (2 fixed, 1 variable) comparison sites located in the adjacent mainstem and Cook Slough. A variable site was added due to access difficulty at the original site #8, as well as the interest in the habitat created at the intake structure located on Cook Slough. Due to unknown minnow trap effectiveness three baited traps were placed at each of the 8 sampling locations. The use of a variety of baits and trap combinations were used. Baited traps were not used in 2009.

**Fish Handling and Data Collection**

Collected fish were held in dark green 5 gallon buckets filled with water (and aerated) from the collection site. Fish collected in traps and seines were enumerated and identified to species (salmonids) or genus (sculpins, sticklebacks). Salmonid fork lengths were recorded. The condition of salmonids were recorded (descaled, smolting appearance, injuries, etc.), where abnormal in appearance. In addition site information, trap I.D., length of time fishing, methods, date, water temperature and dissolved oxygen (DO) were measured and recorded. Fish were released immediately after sample documentation at or near their original collection site.

**Sample Effort**

In 2007, five of six sampling sessions included baited traps at all 8 sampling sites. Seine nets were used in 2007 as personnel and equipment were available, and became the primary collection method in the last three sampling sessions. Sampling in 2008 focused primarily on the use of seine nets because they caught all species routinely and in greater abundance; while baited traps were used in 2 of 4 sampling sessions and primarily captured sculpin and stickleback fishes. In 2009, within the North Meander project channel, seine net sampling was conducted in the pool downstream of the intake (site 6A), as well as the center (4A) and outflow locations (1A) to match the 2007 and 2008 efforts. Data collected from these three locations generally provide for standardization of effort among years. Sampling outside the project channel to determine species presence as a comparison to project use was accomplished. For the purpose of analysis, beach seine method and equipment similar to seining within the project was utilized. Comparison sampling was accomplished at easily accessible sites, 7A & 7A+1, on Cook Slough just upstream of the project intake. Site 7A is a riffle edge and backwater pool while site 7A+1 is a large pool of which the edge was sampled.

**Data Reduction and Expansion**

Data collected from sample efforts was entered into Excel worksheets by year. For each sampled location, as indicated, the total area sampled by the seine net was estimated or measured (using a rangefinder) in order to determine a half-circle or other shape best representing the area sampled. Catch per unit effort was calculated as density based on actual total catch and total area sampled within the North Meander Channel and separately for the Mainstem. By in large, only one seine set was conducted at each location per day. However, on several occasions we conducted depletion sampling by repeating the seine set in the same location within approximately 15
minutes after the first set. Because blocking nets were not placed upstream or downstream of our sample location, we could not assume that our fish sample came from a closed population. Nevertheless, we rarely caught more fish in a 2nd sample. In the absence of a capture efficiency estimate or fish abundance estimate based on depletion methods, we used our actual catch (across multiple sites) divided by total sampled area within the Meander or Mainstem to estimate a minimum density for each sample date for Chinook and coho salmon. Density, as it varied among dates was compared to other literature values for similar habitat types (e.g., Hayman et al. 1996)

To expand each density calculation to develop estimates of salmon abundance within the North Meander, and thereby an estimate of total use by date, each density calculation by date was multiplied by the total wetted area of the North Meander, specifically from 2007. We did not measure or estimate total area of the North Meander during each sample date, though this did vary as a result of fluctuating flows during spring (as indicated in Table 2-1). If total area on any sample date was greater than our 2007 datum, then abundance would probably be underestimated. If flow (and therefore area) was lower than the 2007 datum, then an expansion calculation would probably overestimate total abundance.
Figure 2-1. Fish sampling sites North Meander Project. Please note that 1A, 4A, 6, 6A, and 7A were the most frequently sampled sites.

Estimates of density and total use of the North Meander are affected presumably by fish behavior, river flows, and project design. Regarding project design, the inlet to the North Meander is a large culvert oriented perpendicular to Cook Slough that was placed at a depth so as to interact with river flows at all stages (including summer low flow). However during
maximum use of the North Meander during spring out-migration, it is unknown what the entrainment efficiency is and if that is affected by the inlet gate position; either partially open or fully open. Therefore no correction for variable entrainment is made.

Table 2-1. Fish sampling schedule and effort among sampling methods. Cell values represent either number of traps set overnight or number of seine sets per site.

<table>
<thead>
<tr>
<th>Date</th>
<th>Site</th>
<th>Sub-site</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>Flow,* CFS</th>
<th>Intake culvert</th>
</tr>
</thead>
<tbody>
<tr>
<td>2007</td>
<td>Seine</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>8000-15000</td>
<td>Closed</td>
</tr>
<tr>
<td>4/12/2007</td>
<td>Minnow</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4800-5500</td>
<td>Closed</td>
</tr>
<tr>
<td>5/03/2007</td>
<td>Minnow</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3800-5000</td>
<td>Open</td>
</tr>
<tr>
<td>5/15/2007</td>
<td>Seine</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>3</td>
<td>3100</td>
<td>Open</td>
</tr>
<tr>
<td>5/29/2007</td>
<td>Minnow</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2700</td>
<td>Open</td>
</tr>
<tr>
<td>6/12/2007</td>
<td>Seine</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2700</td>
<td>Open</td>
</tr>
<tr>
<td>2008</td>
<td>Seine</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2800</td>
<td>Closed</td>
</tr>
<tr>
<td>5/13/2008</td>
<td>Minnow</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>4200</td>
<td>Open</td>
</tr>
<tr>
<td>5/28/2008</td>
<td>Seine</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>6000-7000</td>
<td>Open</td>
</tr>
<tr>
<td>6/12/2008</td>
<td>Seine</td>
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<td></td>
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</table>

* Flows from NOAA Northwest River Forecast Center (http://www.nwrfc.noaa.gov/) ARLW1 gauge near Arlington on the Mainstem Stillaguamish River and may indicate the daily range.
Results

Fish Presence

Table 2-2 shows all species represented in sample catches among all years. Although not depicted here, only one bluegill (Centrarchidae) and amphibians (three northwestern salamander and two other tadpole stages) were captured in baited traps, but not in seine nets. On the contrary, minnow traps predominantly captured stickleback and sculpin (91% of total trap catch in 2007/2008) and not the majority of species otherwise caught by seine nets. Therefore our data summary, analysis, and results will focus mostly on seine net catch data - and, notably, focus on Pacific salmon (*Oncorhynchus* spp.).

In 2007, among six sample dates in March-June, 206 fish (47 salmonids) were collected with seine nets out of a total of 349 fish (51 salmonids) overall (which includes baited traps). Out of this total catch, 46 fish (8 salmonids) were collected at the mainstem comparison sites (either 1, 7, or 8; please refer to Figure 2-1). In total, eighteen 1st year Chinook salmon (i.e., parr-migrants, pre-smolts, 0+, or young-of-the-year) were collected inside the North Meander channel; eight at site 6A, nine at site 2A, and one at site 4A. At the mainstem comparison sites, seven Chinook were caught; 1 in the Old Stillaguamish River and 6 in Cook Slough. Seven out of 25 Chinook were adipose fin clipped, indicating hatchery origin. The one Chinook collected at site 1 (mainstem Stillaguamish River) on 4/12/2007 was a yearling, 99 millimeters in length. Parr-migrant Chinook were collected on 5/15/2007, 5/29/2007, and 6/11-12/2007 seine net sampling.

In 2007, Seventeen coho salmon were caught in the North Meander channel; eight at site 6A, five at site 2A, three at site 5, one at site 4A, and one at site 3-4. No coho were collected at the mainstem comparison locations. Of the 17 coho collected, 12 were yearling, 5 were young of the year (0+ age). At least one coho was collected during each sampling session after 3/20/07. Four chum fry were collected each individually at separate sample sites; 2 and 5 on 4/12/2007, 4A on 5/15/2007 and at 6A on 6/11/2007. One larger steelhead (unknown age) was caught at site 1 on the Mainstem Stillaguamish River on 4/12/2007. Two cutthroat trout were collected within the project channel; one each at site 4 on 4/12/2007 and site 2A on 6/12/2007.

In 2008, among four sample dates from March-June, 527 fish (346 salmonid) were collected with seine nets. Baited traps were used in two sampling sessions with a total catch of 51 (no salmonids). A total of 126 Chinook were collected in 2008; 124 within the North Meander Channel and 2 in Cook Slough. Eighty five of the 124 were adipose fin clipped indicating hatchery origin. No Chinook were collected on the first sampling effort, 4/24/2008. Twenty-five Chinook were collected at site 6A on 5/13/2008. On 5/28/2008, 45 Chinook were collected; eight at site 1A, twelve at site 4A, and twenty five at site 6A. Fifty-six Chinook were collected on 6/12/2008 eight at site 1A, two at site 4A, 44 at site 6A, and 2 at site 7A. Relative to 2007, Chinook parr outmigration in 2008 appeared to peak much later based on our catch. At the mainstem Stillaguamish River smolt trap, Chinook salmon 50% cumulative migration for 2007 and 2008 was reached, respectively, at April 1st and May 8th, a difference of more than 5 weeks (Griffith, J. 2009. Personal Communication).

A total of 174 coho were collected in 2008. Of these, 155 were first year fry migrants. No coho were collected on the first sample date, 4/24/2008. Coho were sampled on 5/15/2007, 5/29/2007, and 6/11-12/2007 seine net sampling.
site 7A (3), 18 at site 6A (of which, 17 were yearling), and one at site 1A. Sampling on 5/28/2008 collected coho at site 6A (14), site 4A (1), and site 1A (41, 2 yearling). Sampling on 6/12/2008 collected coho at site 1A (37), site 4A (23), site 6A (34) and site 7A (2).

A total of 12 steelhead were collected in 2008. Two were sampled on 4/24/2008 at the mainstem Cook Slough site 7A. Steelhead were caught on 5/13/2008 at site 7A (1), site 7A+1 (2), site 1A (1), and site 6A (2). Steelhead were caught on 6/12/2008 at site 6A (3) and at site 1A (1).

A total of 14 chum salmon were collected in 2008. Sampling on 4/24/2008 collected (1) at site 7A and (1) at site 6A. Mainstem Cook Slough sampling on 5/13/2008 collected (1) at site 7A and (1) at site 7A+1; while sampling in North Meander Channel site 6A collected (3) and site 4A (5). Sampling on 5/28/2008 collected (2) at site 6A. A total of 12 pink were collected in 2008. Sampling on 4/24/2008 site 7A+1 collected (3). Sampling on 5/13/2008 collected at site 7A (1), 7A+1 (7) and 6A (1). Seven whitefish were collected in 2008. Sampling on 5/13/2008 collected at site 6A (4) and site 4A (1). One whitefish was collected at site 1A on 5/28/2008. Mainstem Cook Slough site 7A sampling collected one whitefish on 6/12/2008.

In 2009, among 9 sampling dates March – August, 2214 fish (629 salmonid) were collected with seine nets. A total of 239 Chinook were collected in the North Meander and 30 in Cook Slough. Chinook were collected in each sample effort 3/3/09 until 06/11/09. Sixty seven were adipose fin clipped indicating hatchery origin. Hatchery Chinook were first collected 4/28/09.

For coho salmon, 144 yearling and 12 first year fry were collected in the North Meander, while 7 fry and 8 yearlings were collected in the comparison site on Cook Slough. No coho were collected during the two sampling efforts in March. Coho were first collected on 4/16/09 and each sample effort through 06/11/09.

Sixty chum salmon, were collected, 7 in the mainstem. On 4/28/09, forty three chum salmon were collected in the North Meander, 38 at site 4A, near the project center. Fifteen steelhead and 1 cutthroat were collected in the North meander and 2 steelhead and 3 cutthroat trout in Cook Slough. One hatchery steelhead was collected on 5/13/09. Steelhead were collected 4/16/09 through 6/11/09, with one parr (60mm) collected 9/4/09. One bull trout was collected in the North Meander on 6/11/09. For mountain whitefish, 55 yearling or older and 38 fry or parr were collected in the North Meander and 14 yearling or older were caught in Cook Slough.

Table 2-2. Species presence and fish count by location, North Meander “Project” or Cook Slough “Mainstem,” among years (trap and seine sampling results are combined). Catch data among years and between sites does not represent equal sampling effort.

<table>
<thead>
<tr>
<th>Species</th>
<th>Location</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chinook</td>
<td>Project</td>
<td>18 (5H)</td>
<td>124 (83H)</td>
<td>239 (64H)</td>
</tr>
<tr>
<td></td>
<td>Mainstem</td>
<td>7 (2H)</td>
<td>2 (2H)</td>
<td>30 (3H)</td>
</tr>
<tr>
<td>Coho</td>
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<td>156</td>
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<td></td>
<td>Mainstem</td>
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<td>3</td>
<td>7</td>
</tr>
<tr>
<td>Pink</td>
<td>Project</td>
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<td>1</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Mainstem</td>
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<td>5</td>
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<td>1</td>
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<td>0</td>
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<td>121</td>
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<td><strong>Project</strong></td>
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<tr>
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<td><strong>Mainstem</strong></td>
<td>46</td>
<td>69</td>
<td>135</td>
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</table>

* indicates an estimated count of fish collected while performing project maintenance fish exclusion on 9/4/2009 using similar seining methods at site 6A.

**Fish Densities**

Chinook and coho salmon densities were estimated for each sample date based on the pooled catch among sites and pooled area sampled (by beach seine). As mentioned, generally, we did not conduct depletion sampling to estimate sampling efficiency or to produce an abundance estimate. In several instances, a second beach seine set at a single site caught more fish, but the sample area was not isolated (closed) and as stated efficiency was not known (but assumed to be less than 1.00). Therefore, total catch and density estimates are likely an underestimate of total Chinook and coho abundance. Furthermore, because we sampled free flowing habitats in a downstream direction, it is possible fish escaped being sampled from the target area because they moved downstream. However, sampling in an upstream direction, given the force of river currents (and depth in some places) was not possible. Although ideally we would have sub-sampled all habitats representative of the North Meander, this was infeasible (as was snorkeling) as well. In particular, we excluded habitat units with woody debris from beach seine sampling for obvious reasons. Additionally, we did not sample locations with complex bank edge habitat. In particular, natural bank edge habitat with woody debris has been observed to contain higher densities of Chinook salmon Parr in the Skagit River compared to gravel bars or modified streambanks (Hayman et al. 1996). Although deployment of baited minnow traps in woody debris jams failed to trap Chinook parr, higher densities of Chinook and coho salmon may have been supported in North Meander at these non-sampled habitat-specific locations. That being the
In this case, Chinook and coho densities reported here likely represents an underestimate of use and overall production.

Chinook salmon densities for wild and hatchery fish (and the combined density) for all sample dates is shown in Figure 2-2. Wild Chinook salmon were present on 11 out of 12 sample dates - hatchery Chinook were present on 8 out of 12 sample dates. On all dates in 2007 and 2009, wild fish outnumbered hatchery fish in the North Meander. The opposite was true in 2008 when hatchery fish outnumbered wild fish at all locations. Overall, total Chinook density in the North Meander was calculated to be greater than Chinook density in Cook Slough on 8 out of 12 dates. In 2009, mean Chinook densities in North Meander and Cook Slough for all sample dates were 0.059 fish/m² and 0.019 fish/m², respectively – a three-fold difference. Among all dates, Chinook density never exceeded 0.12 fish/m². On these dates, the inlet gates were always fully open, thus the gates could not have affected fish entrainment. This density threshold may be real, may be affected by absolute flow entrainment through the culvert, may represent a maximum rearing density for the North Meander (thus maximum capacity), or may be an artifact of our sampling frequency (with higher density not-observed). Additional monitoring will aid in determining whether higher Chinook densities are supported.

![Chinook densities, 2007-2009](image)

**Figure 2-2.** North Meander (Project) and Cook Slough comparative densities for wild and hatchery Chinook among all sample dates, 2007-2009.

Nevertheless, project densities appear to be consistent with densities reported from elsewhere, notwithstanding potential annual and watershed differences. For example in the Skagit River, Hayman et al. (1996) reported peak Chinook parr densities varied from 0.05-1.225 fish/m² among the following lower mainstem river edge habitat types; bars, armored banks, natural banks, and backwaters. Hayman et al. (1996) also described Chinook use of off-channel habitat areas in 1995 in the Skagit River system and noted migration timing from off-channel areas appeared to be later than the mainstem. Trapped fish from off-channel habitats were also larger.
Reported densities ranged from 192-486 Chinook parr per hectare, lower when compared to the Mainstem Skagit River. Based on North Meander sampling, our peak density of approximately 0.12 fish/m² is equivalent to 1,200 fish/hectare, a favorable comparison. Elsewhere, in British Columbia, Swales and Levings (1989) reported Chinook salmon parr in off-channel ponds ranged from 0.008-0.079 fish/m² in spring (one day sample). Locally, in the Port Susan estuary of the Stillaguamish River, the Stillaguamish Tribe conducted beach seine sampling of the following habitat types between 2004-2007; Blind tidal channel, Distributary slough, Intertidal beach, and Pocket estuary. Wild origin Chinook salmon were caught in the greatest sample proportions among Distributary slough habitats. Fish density ranged up to 1000 fish/hectare (in May, 2006), but mostly fell below 300 fish/hectare among all years and months (Feb-August) (Stillaguamish Tribe of Indians 2009). Of course, most habitat types, years, populations and watersheds are not directly comparable, but observed Chinook salmon rearing in North Meander and our conservative abundance estimates suggests use of this habitat is consistent with results from other research, and rearing densities may in fact be higher than reported elsewhere for “off-channel” habitat.

Densities of coho salmon fry and yearling are shown in Figure 2-3. Coho salmon density by date was always greater in North Meander than Cook Slough, consistent with the expectation, based on life history habitat preferences, that coho would favor off-channel rearing habitats over mainstem river locations. In 2008, the presence (or capture) of coho yearlings was restricted to one date and we observed low density (0.04 fish/m²). However, in 2008, coho fry density and abundance was much higher. In 2009, in turn, coho yearlings were most abundant, presumably related to the higher abundance of coho fry the previous year (same population cohort). However, we did not observe coho yearlings in either North Meander or Cook slough in March samples, suggesting the higher densities observed later were due to fish immigration and not overwintering (at least at higher density) in North Meander. Overall, observed coho density of fry and yearlings was low.

Reeves et al. (1989) reviewed limits to coho production and described rearing densities for population modeling. Potential carrying capacity of side-channels for summer parr was estimated to be 1.7 fish/m² and rearing density of spring coho fry was estimated to 5.0 fish/m²; both considerably higher than our observations. Elsewhere, Swales and Levings (1989) reported coho fry and yearling use of off-channel ponds in British Columbia. They observed spring densities ranged from 0.026-0.372 fish/m² and 0.061-0.632 fish/m² for coho fry and yearlings, respectively. Morley et al. (2005) reported on fish use of constructed and natural off-channel habitats in summer and winter in the Pacific Northwest. Coho density in summer (August) was 2.07 fish/m² and 1.18 fish/m² for constructed and natural channels, respectively (not significant). Coho density in winter (Feb.-March) was 0.77 fish/m² and 0.21 fish/m² for constructed and natural channels, respectively (significant difference). As previously mentioned, we observed no coho in North Meander in Feb.-March, 2009 and otherwise density, by comparison was relatively low. Higher density observed by Morley et al. (2005) in constructed channels may have been due to coho spawning in constructed channels, or higher emigration into constructed channels (from mainstem habitats), but neither were directly tested. Otherwise constructed channels studied by Morley et al. (2005) appeared to have significantly greater water depth and a higher proportion of slow-water habitats (e.g., no riffles), which is also true of the North Meander, suggesting high quality habitat for coho in summer and winter.
Fish Abundance Estimates
For Chinook (wild and hatchery) salmon and other species, density values by date for 2009 were expanded for North Meander based on the estimate of total project rearing area. Each sample date provides a point estimate for Chinook (wild and hatchery) and other species (Table 2-3). For Chinook, because average residence period is not known, total North Meander production can only be estimated based on other information sources. In the Skagit River for example, Hayman et al. (1996) used a residence time of 25 days (based on Healey 1980) to estimate total Chinook production from various Skagit River habitat types. This residence time suggests Chinook observed in mid-April at North Meander were different fish from those observed in mid-May. By integrating across the entire sample period in 2009 (111 days), we estimate the total fish-days at a mean sample density of 0.059 fish/m² is 65,490 fish-days/ hectare. Dividing by 25 days estimated residence time suggests 2009 annual Chinook salmon production was 2,620 fish/hectare or 4,715 total Chinook from the North Meander (based on 1.8 hectares total). We did not apply a different residence time for larger hatchery Chinook that demonstrate narrower outmigration timing than wild origin Chinook. Shorter residence time would produce a higher estimate of total fish use. Therefore, these estimates are preliminary and need to be investigated relative to Stillaguamish River total production estimates from the Stillaguamish Tribe. Nevertheless, the production potential is comparable to other Chinook parr rearing environments in the lower Skagit River, for which such estimates have been developed; in other words, blind tidal sloughs and blind tidal channels (Hayman et al. 1996).
Table 2-3. North Meander species abundance estimates by date from expanded 2009 sample data.

<table>
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<th></th>
</tr>
</thead>
<tbody>
<tr>
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<td>181</td>
<td>1120</td>
<td>922</td>
<td>1338</td>
<td>1220</td>
<td>553</td>
</tr>
<tr>
<td>Chinook (Hatchery)</td>
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<tr>
<td>Coho (yearling)</td>
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<td>1664</td>
<td>1109</td>
<td>221</td>
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<td>Coho (fry)</td>
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<td>130</td>
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<td>88</td>
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<td>44</td>
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<td>0</td>
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<td>1A</td>
<td>6A, 1A</td>
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For 2007 and 2008, sample dates do not sufficiently capture either the beginning (2007) or end (2008) of the outmigration timing in each year. In 2007, the wild Chinook 50% cumulative outmigration date was near March 31st and 90% cumulative outmigration was near May 1st. The 2008 out-migration was approximately 5 weeks later with 50% wild Chinook out-migration near May 8th and 90% near June 12th. For these years (and 2009), densities from similar fish sampling efforts in mid-May, late-May, and mid-June were expanded to estimate North Meander wild and hatchery juvenile Chinook abundance (Figure 2-4). For 2007, our abundance estimates show a diminishing population in mid-May to mid-June with the maximum wild Chinook estimate of 880 in mid-June corresponding with 94% of the wild Chinook out-migration. In 2008, similarly timed sample dates and subsequent abundance estimates show an increasing population with the maximum wild Chinook estimate of 731 in mid-June corresponding with 90% of the wild Chinook out-migration (Stillaguamish Tribe, unpublished data). As mentioned, data from Mainstem smolt trapping as well as these data indicate highly variable inter-annual out-migration timing.
Figure 2-4. North Meander wild and hatchery Chinook expanded abundance estimates by date, 2007-2009.

Juvenile Chinook length was measured during each sample event to use for potential comparison analysis to smolt trap, annual, and/or other identified rearing characteristics associated with the North Meander Project. Figure 2-5 shows the average Chinook length from each of the collection efforts separating wild and hatchery Chinook by year (sample size ranges 3-68 fish). Mean hatchery Chinook length for each sample date was greater than wild Chinook among all years. Average Chinook size was variable by year for both hatchery and wild fish, but more so for wild fish at later sample dates, as apparently affected by growth rate among years. Size and growth may be affected by temperature or other factors such as off-channel rearing residence (length of time). For example, Skagit River Chinook salmon parr using off-channel habitat, emigrated from those sites later than the mainstem population and had greater length, suggesting significant growth in that habitat (Hayman et al. 1996). Therefore, an important comparison to be made will be between North Meander fish and those trapped and measured at the mainstem smolt trap (at comparable times).
Other Fish Use
Chum and Pink Use Juvenile chum salmon were found in the North Meander from March - May in low numbers with one exception. On 4/28/09, near the center of the project (Site 4), 38 were collected, representing a density of 0.37 fish/m². Otherwise, few chum salmon were caught at all sites including the mainstem comparison sites densities of no more than 0.02 fish/m². Pink salmon, as expected, were not collected in 2007 and 2009 sampling. In 2008, only one pink was collected in the project channel, while 11 were collected at the mainstem comparison sites.

Steelhead were present in low densities in the North Meander from April through June in 2008 and 2009. In 2008, Steelhead densities were slightly higher at the mainstem Cook Slough site (a maximum of 0.03 fish/m²) than within the project area (0.01 fish/m²). Conversely, in 2009, Steelhead densities were slightly higher in the project channel (0.01 fish/m²) than at the comparison sites (0.003 fish/m²). In 2007, only one steelhead was collected in the Stillaguamish Mainstem near the project outflow. One hatchery steelhead was collected in both 2008 and 2009 sampling efforts, May 13th of each year. The average fork length of all steelhead collected was 150mm. Cutthroat have been collected in sampling efforts 2007 and 2009; three in the channel and three in mainstem comparison sites. One bull trout was collected at site 1A, in the project channel, on June 11th 2009.
Sculpines appear to be the only species captured in greater abundance in the Stillaguamish Mainstem, Cook Slough and near the outlet of the North Meander than within the North Meander project itself. Mean catch density among sample dates in 2009 was 0.032 fish/m² in Cook Slough and 0.0055 fish/m² in North Meander - a nearly 6-fold difference. Because of their low mobility and affinity for bottom habitats, they typically are found in larger gravel or cobble substrates, where they have cover, refuge, and a substrate (cobble) for spawning (White and Harvey 1999). Based on our observations and relevant literature, the North Meander may provide some refuge from sculpin predation based on lower sculpin density and (presumed) local abundance and predominately sandy/silty bottom habitats, but there does not appear to be a possible benefit based on sculpin size differences between North Meander and Cook Slough among years (Table 2-4). The larger size in 2007 may have resulted from sampling predominately with baited minnow traps. Overall, predation by sculpins, if important at all, may be variably affected by possible interannual differences in population size characteristics, which may be driven by year-class recruitment phenomena affecting multi-aged populations.

Table 2-4. Sculpin catch and size characteristics between North Meander and Cook Slough sites.

<table>
<thead>
<tr>
<th>Year</th>
<th>North Meander</th>
<th>Cook Slough</th>
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<tr>
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<td>Count</td>
<td>Mean size</td>
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<tr>
<td>2007*</td>
<td>42</td>
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<tr>
<td>2008</td>
<td>22</td>
<td>94 mm</td>
</tr>
<tr>
<td>2009</td>
<td>19</td>
<td>67 mm</td>
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*Mostly from baited minnow traps.

Finally, both adult and juvenile peamouth, dace, and sucker fishes were found in the North Meander channel. Stickleback fish were common along the bank edge in the center of the project channel. Salamanders collected in 2007 were adult northwestern salamanders. Egg clusters were in the same locations during the next sample effort and again in 2009. At site 5, near the center of the channel, in 2007 an unidentified sunfish and yearling bullfrog tadpoles were found; these are invasive species.

Conclusions

The North Meander Project is being used by salmonid and non-salmonid species during the typical spring salmonid smolt outmigration period at a location where side-channel habitats have been historically lost. At the North Meander, we observed 15 different fish species and various larval, juvenile and adult life stages. Juvenile Chinook were observed using the North Meander at densities that are comparable to other studies investigating similar habitat types. Based on North Meander sampling, our 2007, 2008, and 2009 peak density of approximately 0.12 fish/m² is equivalent to 1,200 fish per hectare. By comparison, in the Skagit River, Hayman et al. (1996) reported peak Chinook parr densities varied from 0.05-1.225 fish/m² (500-12,250 fish per hectare) among lower Skagit River mainstem edge habitat types. Additionally, they reported juvenile Chinook salmon density among off-channel habitats ranged from 192-486 fish per hectare. In the Port Susan estuary of the Stillaguamish River, the Stillaguamish Tribe collected wild origin Chinook salmon in the greatest sample proportions among distributary slough habitats where Chinook density ranged up to 1000 fish/hectare (in May, 2006), but mostly fell...
below 300 fish/hectare among all years and months (Feb-August) (Stillaguamish Tribe of Indians 2009). Finally, by applying a method developed for Skagit River Chinook salmon production estimation, we estimate Chinook salmon parr production from North Meander in 2009 was 4,715 fish during the 111 day sample period. This production estimate is based on using an assumed residence time of 25 days. If average residence time within the North Meander was less, then total production was higher.

In addition to Chinook salmon, we caught Coho salmon (yearling and fry), steelhead, chum, cutthroat, and pink salmon within the North Meander channel. Coho salmon density by date was always greater in North Meander than Cook Slough, consistent with the expectation, based on life history habitat preferences, that coho would favor off-channel rearing habitats over mainstem river locations. In 2009, coho yearlings’ abundance and density were presumably related to the higher abundance of coho fry the previous year (same population cohort). However, we did not observe coho yearlings in either North Meander or Cook slough in March 2009 samples, suggesting the higher densities observed later were entirely due to fish immigration and not overwintering in North Meander. Overall, observed coho density of fry and yearlings was low, consistently less than 0.1 fish/m². Reeves et al. (1989), in Oregon, estimated potential carrying capacity of side-channels for summer parr was 1.7 fish/m² and rearing density capacity of spring coho fry was estimated to be 5.0 fish/m²; both considerably higher than our observations. Morley et al. (2005) observed coho density in summer (August) was 2.07 fish/m² and 1.18 fish/m² for constructed and natural side channels, respectively.

Collection efficiency was not determined for our sampling, so observed densities are considered to be conservative estimates of fish use. Although ideally we would have sub-sampled all habitats represented in the North Meander, this was infeasible (as was snorkeling). In particular, we excluded habitat units with woody debris from beach seine sampling for obvious reasons. Additionally, we did not sample locations with complex bank edge habitat that would have precluded beach seine retrieval. In particular, natural bank edge habitat with woody debris has been observed to contain higher densities of Chinook salmon parr in the Skagit River compared to gravel bars or modified streambanks (Hayman et al. 1996). Although deployment of baited minnow traps in woody debris jams failed to trap Chinook parr, it’s conceivable that higher densities of Chinook and coho salmon are supported in North Meander at these other habitat–specific locations. That being the case, Chinook and coho densities reported here likely represents an underestimate of use and overall production.

While identifying salmonid presence, relative timing, and estimated project abundance is instructive; overall project benefit has yet to be determined, and obviously could vary annually and change over time. The proportional entrainment of migrating salmonids, and the duration of rearing are important questions that remain unanswered. Identifying the percent and origin of migrating salmon smolts entering the project area will help highlight project success and rearing duration could identify habitat and life history benefits that could be used to project potential project and population benefits at other (proposed) projects.

For example, beneficial use of lower river floodplain off-channel habitats by smaller, earlier migrating Chinook salmon fry may accrue disproportionately to populations where the availability of such habitat near spawning areas is naturally scarce or historically degraded. In
the South Fork Stillaguamish, where large expanses of side-channel and off-channel habitats (oxbows, ponds, lakes) are naturally sparse due to the geomorphologically incised setting (relative to the North Fork Stillaguamish), a life history strategy dependent upon such down-river rearing opportunities may benefit most.

Monitoring Recommendations

For fish monitoring, we recommend implementing monthly monitoring (August-February) and bi-monthly monitoring (March-July) of 3 North Meander site locations and 1 off-site comparison location (Cook Slough). We propose to test entrainment flow in spring to determine proportion of flow and estimate fish entrainment based on flow, using test drogues, or mark-re-capture (pending discussions with Stillaguamish Tribe). We plan to estimate trapping efficiency to possibly calibrate past catch results to new efficiency data. Depending upon 2010 water quality observations of low dissolved oxygen, we may conduct fish sampling to evaluate site specific fish use under these water quality conditions.

Project Management Recommendations

- Culvert inlet opening operation
  - For fish access management - The flow through the project channel, when limited by the intake gate, may reduce the potential entrainment of fish into the channel throughout the out-migration period. The operation of the gate should be timed to lengthen entry opportunity time to the channel potentially increasing early Chinook salmon fry-migrant use and prolong rearing time within the project. We recommend closing the inlet gate prior to potential fall/winter flooding and no later than November 1. We recommend opening the center slot no later than March 1, based on observed fish use in North Meander and long-term mainstem river outmigration timing documented by the Stillaguamish Tribe (e.g. Griffith et al. 2006). We recommend opening the full inlet no later than April 1.
  - For water quality management – Water quality does not appear to be degraded within the North Meander during critical outmigration periods. During summer low flow, the open culvert would not hinder, but also would not likely help water quality.
  - For fish entrainment or attraction – pending 2010 (or later) analysis of fish entrainment, the culvert inlet area may be enhanced with additional large woody debris placement in order to create more “backwater” habitat and local refuge at the point of North Meander flow entrainment.

- Sediment maintenance
  - For flow connectivity management – Sediment accumulation within the over-excavated inlet channel is evident. Bedform (sand) elevations appear to be increasing based on topographic survey. In the absence of any significant thalweg formation within the sand bed, flow connectivity may be disrupted at base flows, which will affect water quality and fish movement and dispersal. Removal of accumulated sediment at times when flow connectivity is disrupted (3-5 years) will be needed.
Literature Cited


APPENDIX A. North Meander Photo Point Survey and Aerial Oblique or Orthophotos.

Also available at:
http://www1.co.snohomish.wa.us/Departments/Public_Works/Divisions/SWM/Library/Publications/Aquatic_Habitat/Inventory_Assessment_Restoration/
APPENDIX A cont. North Meander Photo Point Survey and Aerial Oblique or Orthophotos.

Photopoint Dates

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Photopoint Map.
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Site 3

Downstream 2007 2008 2009

Upstream 2007 2008 2009
45° Downstream 2007

2008

2009

45° Upstream 2007

2008

2009
Site 4

90° Across 2007 2008 2009

Downstream 2007 2008 2009
Site 5

Downstream 2007 2009

Upstream 2007 2008 2009
Inlet Gate from Cook Slough (facing upstream).
Aerial Oblique Photos or Orthophotos by Date.

2005 (September) – Oblique aerial view prior to inlet channel construction. Note new bridge construction at Hevly Rd (circled).
2006 (February) – Note new inlet channel construction (bottom) and new outlet connection near Hevly Rd bridge.
2007 Orthophoto – Note inlet culvert connection (circled) is complete.
2009 Orthophoto – Note increasing vegetation growth (compared to 2007) from new plantings along excavated inlet channel (circled).