2016 Vedder River Gravel Excavation
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Habitat Changes and Environmental Impacts

(Revised) January 2018

Prepared for:

Vedder River Management Area Committee

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Executive Summary

Sediment removal is a key part of the ongoing floodway management program to maintain the Design Flood Conveyance Capacity of the floodway that is implemented by the Vedder River Management Area Committee (VRMAC). Typically, several excavations are conducted at strategic locations every two years to correspond with non-pink salmon years. In 2016, six removal sites were completed for a total removal of 92,485m^3, or 88% of the target volume approved by the regulatory agencies and the VRMAC.

This report describes the results of an environmental assessment undertaken to determine fish habitat changes and other impacts and is a snapshot of the river during low flow conditions immediately prior to excavation and again one year later. Naturally occurring changes in habitat due to sediment transport and erosion are significant and present challenges in ascertaining the extent to which the sediment removal program influences fish habitat value.

Detailed maps of habitat conditions form the basis for the assessment of the impact of gravel removal on fish habitat. Habitat maps have been created using ArcGIS software and custom aerial photography of the Vedder River from Vedder Crossing to the Highway 1 bridge. Polygons were created to map habitat and were assigned to 14 different habitat types. Individual polygons are rated in accordance with their contribution to fish habitat value. Each excavation site was assessed as an area that included the footprint plus one additional XS upstream and one downstream to allow for the influence of the excavation upstream and downstream as river changes. Summing the value of the polygons provides a numerical habitat rating and a percent change for each excavation area. An overall score is included for each site to allow inclusion of habitat effects not captured by the mapping.

Bar by Bar Point Form Summary

Giesbrecht Bar:

- Main purpose of excavation was to intercept gravel upstream of the area of freeboard limitation.
- The initial excavation design was converted to a scalp at the time of implementation due to concerns relating to the relatively high slope of the site.
- Following the excavation, more flow is directed at higher water levels away from the hardened right bank providing more natural bank conditions downstream.
- One small area of pink salmon spawning was observed although sediment in this area is generally too coarse to support good spawning habitat.
- Habitat rating has decreased slightly by 2% and the overall score was positive (+).

Lickman Bar:

- The purpose of this excavation was to trap gravel at the downstream end of the Upper Reach before it enters the narrower Middle Reach.
- The excavation has mostly filled, and the surrounding habitat characteristics are similar.
- Habitat channel constructed was still connected to flow and functioning as planned.
- Chum salmon observed spawning through the study area and pink salmon spawning concentrated in the main channel along the excavation.
- Habitat rating has increased by 2% and the overall score was positive (+).

Bergman Bar:

- Primary objective was to prevent sediment from moving downstream into the freeboard limited reach of the river.
- Thalweg now passes through the pit leaving a sinuous and deep channel with a substantial eddy pool at the upstream end.
- Upstream portion of habitat channel has surface flow and exits into the main channel at the excavation site. The downstream portion of habitat channel remains connected to the main channel at the downstream end, fed by sub-gravel flow.
- Heavy chum spawning in habitat channel and eddy pool.
- Habitat rating has increased by 30% and the overall score was strongly positive (++).

Railway Bar:

- The main purpose was to trap gravel upstream of Railway Bridge and reduce the amount of gravel moving downstream into the reach of the river that is most freeboard limited.
- The excavation has partly refilled and only the outlet remains connected to the main channel.
- Downstream end of enhanced right bank microchannel supports heavy chum spawning including some in the remnant of the excavation.
- Pink salmon spawning occurred across the full width of the channel at the downstream of the excavation.
- Habitat rating has increased by 11% and the overall score was neutral (0).

Yarrow Bar:

- The purpose of the excavation was to trap sediments and contribute to increased floodway capacity in freeboard-limited zone.
- Constructed inlet of excavation filled in, but excavation remnant has significant sub-gravel flow which is connected to the main channel by a downstream secondary channel.
- Upstream portion of habitat channel lacked surface flow at the time of the assessment, but downstream portion is fed by groundwater and is connected downstream.
- Extensive pink salmon spawning along main channel and chum spawning observed in habitat channel and pit remnant.
- Habitat rating has increased by 7% and the overall score was neutral (0).

Keith Wilson Bar:

- The main objective was to lower the backwater profile upstream and reduce the risk of dyke overtopping.
- The excavation has not fully refilled, but the outlet remains deep and wide.
- Right bank constructed habitat channel is connected to surface flow and functions as planned.
- No salmon spawning was observed.
- The habitat rating has increased by 15% and the overall score was positive (+).

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1.0 Introduction

The purpose of this report is to assess habitat changes in the Vedder River between August 2016 and September 2017 related to six sediment excavations along the river. The sites are located between Vedder Crossing and the Highway 1 bridge in Chilliwack, British Columbia. From upstream to downstream the excavation sites were identified as Giesbrecht Bar, Lickman Bar, Bergman Bar, Railway Bar, Yarrow Bar, and Keith Wilson Bar. These bars were excavated on behalf of the Vedder River Management Area Committee (VRMAC) flood risk reduction program as part of an ongoing floodway management program to maintain Design Flood Conveyance capacity of the channel.

Excavations on the Vedder River typically proceed every two years and target an amount intended to offset natural deposition and maintain flow capacity of the floodway for a projected 1 in 200-year flood event. The selection of sites and design of individual excavations focuses on avoiding significant environmental impacts and optimizing fish habitat by retaining and encouraging formation of desirable habitat configurations. For 2016, site selection and design were intended to effectively lower water levels where freeboard is limited, trap gravel upstream of freeboard limited areas and provide optimum habitat outcomes while meeting flood control objectives.

Two reports are prepared for each two-year excavation cycle, an Environmental Monitoring Report and an Environmental Assessment Report that summarize the results of these excavations. This report is the latter of these documents.

2.0 Methods

2.1 Habitat Mapping

Detailed maps of habitat conditions form the basis for the assessment of the impact of gravel removal on fish habitat. Habitat maps have been created using ArcGIS software and custom aerial photography of the Vedder River from Vedder Crossing to the Highway 1 bridge. For each of these six excavations mapping was completed to include upstream and downstream areas with a reasonable likelihood of being affected by the excavation. In practice this is at least one full survey cross-section both upstream and downstream of the location.

Aerial photos were taken on August 15, 2016 when the river discharge was 27 m^3/s and were repeated on September 2, 2017 when the discharge was 18 m^3/s.[1] Timing of flights is based on discharge levels and weather conditions. Flows are monitored regularly to provide as close a match as possible to facilitate pre- and post- excavation comparison. In 2017, the timing of the flight was delayed due to persistent smoky conditions in the Fraser Valley due to wildfires burning in British Columbia and Washington. In relative terms these flows are quite different, however both represent typical low flow conditions. Notation is provided in text and tables where flow levels affect the outcome of the analysis. The August 15, 2016 flight captures pre-excavation conditions although it should be noted excavation work was already underway at Giesbrecht Bar. Any excavated areas shown in the photos are mapped according to their pre-excavation conditions which in almost all cases is unvegetated gravel bar. As in previous years, we have evaluated the outcomes from each individual excavation through onsite observations and through mapping of habitat types before and after each excavation. Due to the difficulty in obtaining ortho-correct photos under correct flow and

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[1] Due to ongoing concerns about the reliability at low flows of the WSC gauge at Vedder Crossing, discharge data is calculated using water levels recorded at WSC gauges Chilliwack River above Slesse Creek and Slesse Creek near Vedder Crossing using the following calculation: (Chilliwack River above Slesse Creek + Slesse Creek near Vedder Crossing) x 1.5. The WSC gauge at Vedder Crossing reported 25 m^3/s and 17 m^3/s for 2016 and 2017 respectively.

weather conditions polygon mapping is based on photographs that have been fitted to a base map. A detailed description of the mapping process can be found in Appendix 1.

Mapping has been improved by switching the principal software for the work from AutoCAD, as used in previous years, to ArcGIS. The new software provides improved fitting of aerial photos to the base map as well as improved data manipulation and presentation properties. The total area mapped was constant between the two years as shown in the summary tables for each bar. This helps ensure that the comparisons between the two years are an accurate reflection of the changes in the assessment area.

The boundaries and classification of each polygon includes a ground-truthing component and an interpretive component. Ground-truthing provides information for the mapping process, particularly where habitat types such as large woody debris (LWD), deeper riffles, temporary channels, glide edges and tails and pools can be misclassified or missed during air photo interpretation.

The habitat types and habitat ratings applied during the mapping and assessment in 2016 and 2017 were the same as in 2014. Definitions of habitat types and habitat ratings applied to individual polygons are provided in Appendix 2 and 3, respectively. The habitat rating values are based on the relative contribution to key drivers of fish habitat value and when multiplied by the area of each polygon and summed, provide a score for each excavation assessment area. The rating system provides an objective means for comparison of habitat conditions pre- and one-year post excavation, however it should be noted that they are not actual measures of fish habitat value. Appendix 4 summarizes offsetting measures implemented and follow up monitoring of these measures one year later and Appendix 5 provides a listing of guidelines and criteria used in designing the excavations.

To ensure that potential habitat concerns not covered by the mapping are addressed, an overall score for each excavation site is also provided. Each excavation is evaluated on six additional factors that are not directly addressed by the habitat rating alone. The habitat rating remains the primary factor in evaluating any excavation while the other factors modify the habitat rating to determine an overall score. The modifiers also include our knowledge of any changes throughout the one-year time period not just at the assessment times. As such, the modifiers are subjective but ensure that potentially significant alterations are not ignored. The six modifying factors are defined as follows:

- Habitat Artifact or Anomaly: applies to remnants of the excavation that do not provide habitat of equivalent value to natural habitats as defined. Typically, this is an unfilled excavation that shows up as a pool or backwater but does not provide the same habitat value due to its large size or unusual configuration.
- Stranding Risk: conditions remaining at the excavation present a potential for adult or juvenile salmon to be isolated.
- Spawning Observed: post-excavation spawning occurs within the excavation or adjacent areas that may be unstable in the aftermath of the excavation.
- Stability: habitat conditions as mapped are subject to substantial change that could be detrimental to fish or fish habitat, typically this is an unfilled excavation but can also apply to complex atypical habitat features.
- Functional Changes: changes that are not reflected by low flow mapping that could provide significant change at higher flows, an example would be at Giesbrecht where the split of flow expected at higher flows has been significantly altered by the excavation.
- Non-excavation Related Changes: changes to habitat types can result from upstream changes unrelated to the excavation, for example aggradation at the inlet to a microchannel can eliminate the value of the feature from the downstream area.

The habitat rating for each excavation forms the basis for evaluating each excavation. The habitat rating provides a starting point for the overall score as follows:

Habitat rating change (%)	Overall Score	
>15%	(++)	Strongly positive
5 to 15%	(+)	Positive
5 to -5%	(0)	Neutral
-5 to -15%	(-)	Negative
<-15%	(--)	Strongly negative

Where the modifiers have a small effect, the changes are net. However, in the event of the substantial change a single modifier may shift or dominate the entire score. Appendix 6 provides an outcome summary of key attributes that are used to determine the score for each excavation and Appendix 7 shows how the modifiers were applied to provide an overall score for each excavation.

2.2 Assessment of Spawning Distribution

The 2016 chum salmon spawning assessment was conducted on October 26th and 31st following excavations in the summer of that year. 2016 was a non-pink spawning year. Spawning distribution was assessed only in the vicinities of the six gravel extraction sites. Each of the sites and surrounding area were evaluated.

2017 was a pink salmon spawning year so assessments were completed to observe chum and pink spawning. The pink spawning assessment was conducted on October 2, 2017 and the chum spawning assessment was conducted later in the season on November 1 and 2, 2017.

NPE biologists walked the areas of the excavated bars noting active spawning and presence of redds. Each site was visited at least once during the peak spawning time of each of the two species of salmonids being assessed. Chinook salmon also spawn in this reach, however, they spawn in deeper water and are sparse so only seen and mapped occasionally. Spawning was defined as heavy (redds are contiguous or over-lapping), medium (unused portions of substrate within an area) or light (only a few redds within an area). The main interest is in the distribution of spawning and not in numbers. Spawning areas noted are marked as accurately as possible on field maps. This information is then transferred to the relevant base maps.

3.0 Results

The six gravel bars excavated on the Vedder River in 2016 are shown in Figure 1, which also shows the locations of key features and the reach boundaries. A total of 92,485 m^3 of material was removed, comprising 88% of the total proposed removal volumes (Table 1). Fourteen gravel bars were proposed to the VRMAC for consideration. The sites selected were those that best met the VRMAC mandates to reduce flood risk and protect fish habitat and cumulatively met the volume target for 2016.

Table 1: 2016 Vedder River excavation sites and gravel removal volumes

Site	Code	Area of excavation (m^2)	Expected Volume (m^3)	Actual Volume (m^3)	Percent Obtained (%)
Giesbrecht Bar	16-41L	7,040	12,700	11,714	92
Lickman Bar	16-35M	6,960	21,500	28,668	133
Bergman Bar	16-23L	4,185	9,600	14,433	150
Railway Bar	16-19R	1,862	3,200	4,160	130
FLNRO Total		**20,047**	**47,000**	**58,975**	**125**
Yarrow Bar	16-13L	5,525	14,300	16,566	116
D/S Rail Bridge Bar		0	26,850	0	0
Keith Wilson Bar	16-C26R	7,480	17,200	16,944	99
City Total		**13,005**	**58,350**	**33,510**	**57**
TOTAL		**33,052**	**105,350**	**92,485**	**88**

The following sections provide summaries of changes in habitat that occurred in the vicinity of each excavation typically including one cross-section upstream and downstream in each assessment area. It should be noted that the water level of the Vedder River was slightly lower at the time of the 2017 aerial photography which could have the effect of increasing the area of dry habitats such as unvegetated gravel bar and thereby lowering overall habitat ratings.

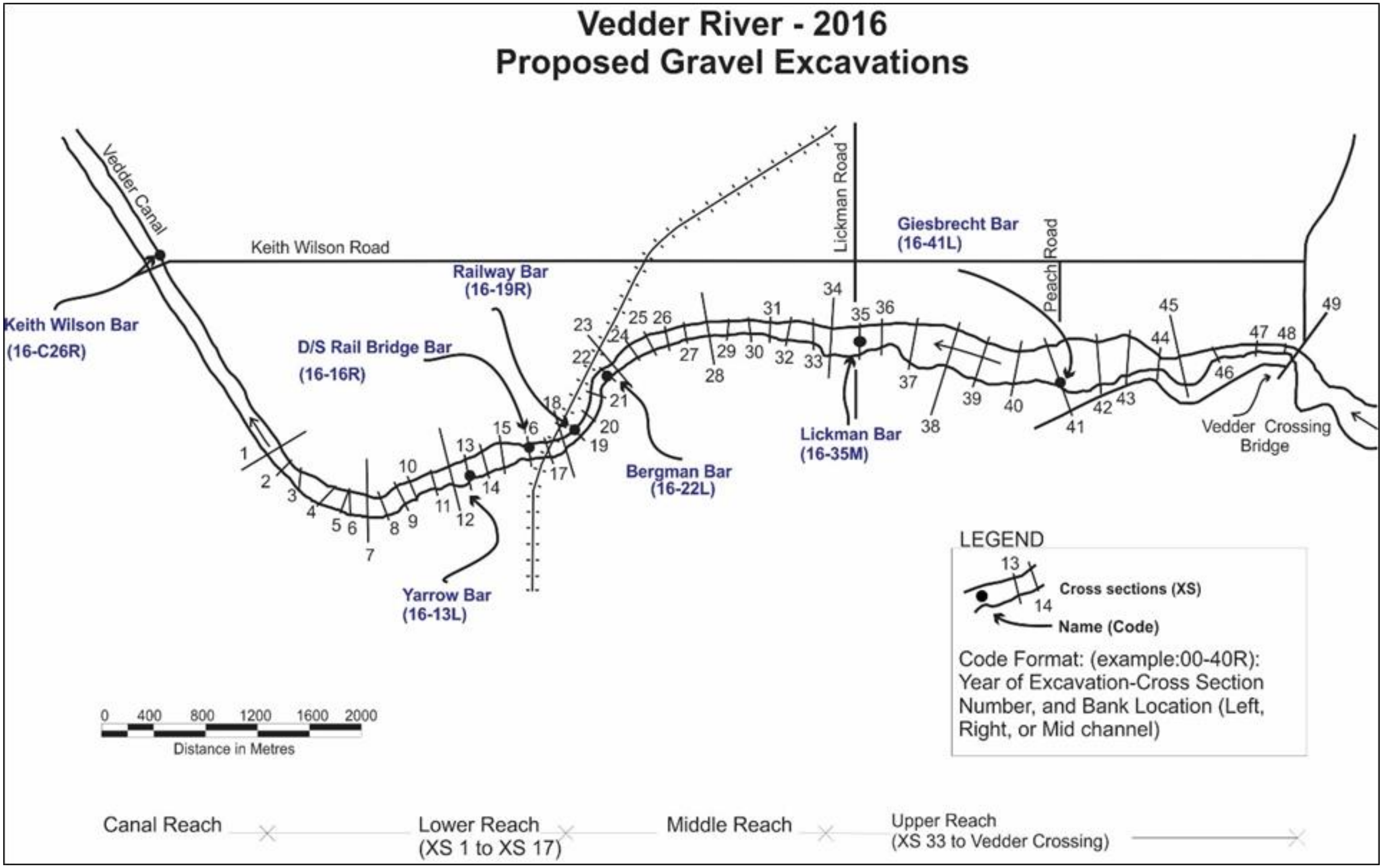


Figure 1: 2016 Vedder River gravel removal sites.

3.1 Giesbrecht Bar (16-41L)

3.1.1 Plan and Implementation

The Giesbrecht Bar excavation was located on the left side of the main channel, approximately 200m downstream from Peach Road. Figure 2 shows an aerial view of the Giesbrecht Bar excavation plan. The main purpose of this project was to intercept gravel upstream of the area of freeboard limitation. The initial excavation design was converted to a scalp at the time of implementation due to the significantly greater amount of material above the expected excavation site water level and concerns that the original design could induce head-cutting and capture too much of the river flow.

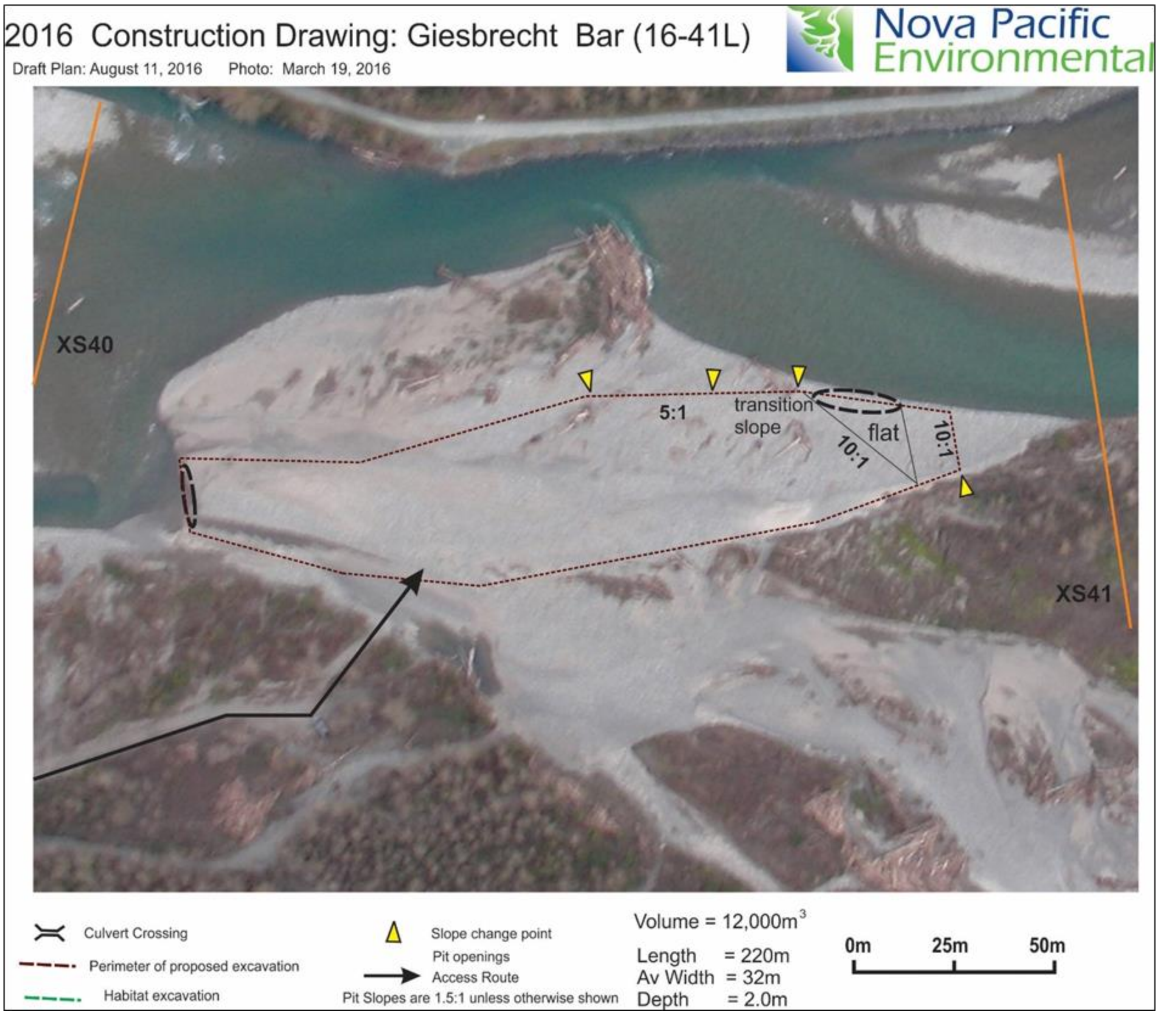


Figure 2: Aerial view of the Giesbrecht Bar excavation plan. Photo taken March 19, 2016, drawing rendered on August 11, 2016.

3.1.2 Observed Changes

Giesbrecht Bar has re-filled in a similar configuration as existed previously. However, the bank on the main channel is lower so that flow continues to the left at much lower flows. Previously there was a high bank at the upstream end. Several braided channels now cross the bar surface at low flows, providing riffle habitat with small pools between. In higher flows, more water would be directed to the left than previously. This direction of flow to the left provides additional benefit by directing the flow away from the hardened right bank providing more natural bank conditions downstream.

The secondary channel on the left side of the excavation was observed to be dry on September 12, 2017 but at moderately higher flow would provide connectivity to the left bank riparian zone and the large woody debris (LWD) features that were placed. The secondary channel on the right had good flow that lends functionality to LWD pieces along that side of the excavation.

This excavation appears to have sequestered a substantial amount of gravel and improved habitat conditions within the footprint of the excavation. The continuing presence of some LWD complexes and other features demonstrates that after the excavation the site was stable and then partially refilled.

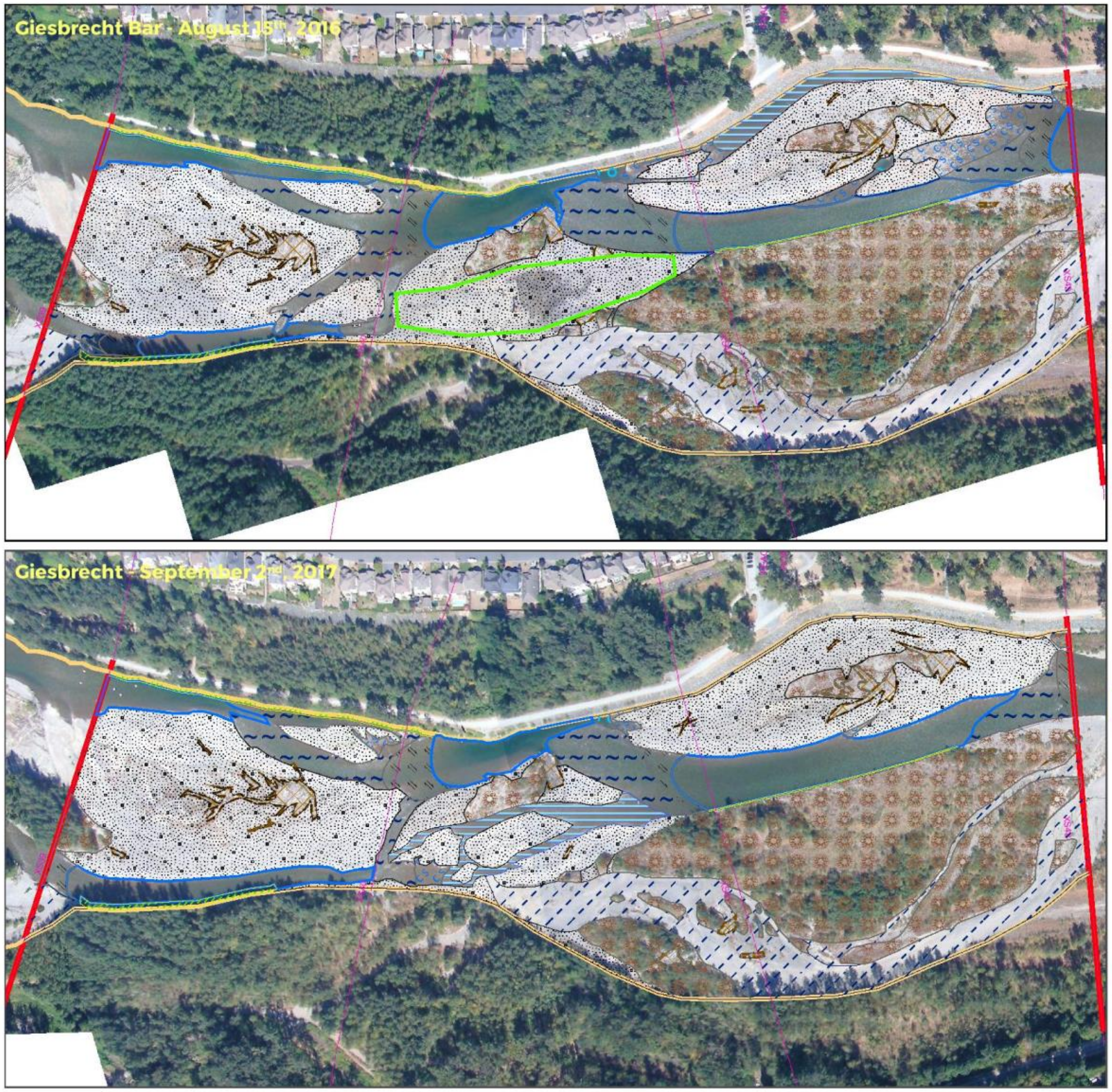
Three LWD structures were added at Giesbrecht Bar excavation area in 2016 to provide bank complexity and two platforms of boulders were created near the bank-side LWD structures to enhance fish habitat in the area. However, only the LWD structure placed along the river side remained after the 2017 spring freshet. The boulder platforms were covered by the channel infilling. These were intended to be effective only if a channel formed along that bank.

3.1.3 Habitat Mapping

The assessment area for the Giesbrecht Bar excavation covered cross sections 39 to 42 (Figure 3). Table 2 indicates the area of each habitat type and the corresponding habitat ratings calculated for the two study years. Table 3 presents the change in area and habitat ratings, the percentage change in area, and comments for the different habitat types.

The largely vegetated bar along the left bank at the upstream end of the study area shows a small amount of erosion while the mapped area of temporary channels crossing this area has increased slightly. The flow of the river is concentrated in one channel between XS 42 and XS 41. The split near the upstream end of the excavation at XS 41 diverts more of the flow toward the left channel in 2017. The channel splits again at the gravel bar between XS 40 and XS 39. The main river channel includes two glide tail/riffle sequences as it passes along Giesbrecht Bar and transitions into two channels.

The habitat mapping assessment showed a 2% decrease in overall habitat rating for this study area. Review of the maps and calculated habitat ratings shows an increase in unvegetated gravel bar and losses in vegetated gravel bar, complex shallows and the one small pool along the right bank. Secondary channel habitat has increased overall, with the increase within the excavation footprint offset by a decrease upstream of the excavation. The upstream habitat losses may be due in part to aggradation, however, with limitations on achieving perfectly matched flows for comparison purposes, a final determination would be dependent on pending survey data. Regardless, this change should not be seen as an effect of the excavation. It is possible the reduction in complex shallow, pool and secondary channel habitat upstream of the excavation could be attributed to the water flow being lower at the time of the aerial photo in 2017.



PROJECT

2016 Vedder River Gravel Excavation Assessment - Habitat Changes and Environmental Impacts

Nova Pacific Environmental

STUDY AREA

Giesbrecht Bar

DATE

2018/01/12

HABITAT ANALYSIS

Habitat Type	2016 (m^2)	2017 (m^2)	Δ
Unvegetated Gravel Bar	58,221	60,031	3%
Vegetated Gravel Bar	51,168	49,598	-3%
Temporary Channel	21,586	22,009	2%
Large Woody Debris	3,720	3,702	0%
Glide/Run	15,651	18,365	17%
Glide Tail	3,646	3,694	1%
Glide Edge	-	-	n/a
Complex Shallows	4,073	1,067	-74%
Riffle	12,259	11,040	-10%
Habitat Edge	1,932	1,944	1%
Backwater	-	-	n/a
Micro-Channel	-	-	n/a
Secondary Channel	2,676	3,735	40%
Pool	378	125	-67%
Excavation Outline (2016)	n/a	n/a	n/a
Total	175,311 m²	175,311 m²	0%

KEY MAP - SCALE 1:50,000

Map No.

0 60 120 180 240

Meters

1:3,250 when printed on 11" x 17" size paper

3,600 sq. m

Figure 3: Habitat mapping of the Giesbrecht Bar location prior to excavation in 2016 (top) and one year later in 2017

Table 2: Giesbrecht Bar areas and habitat ratings, 2016-17

Giesbrecht Bar: Areas and Habitat Ratings 2016-2017 XS 39-42						
Habitat Type	**Pre-Excavation (Aug. 2016)**			**Post-Excavation (Sep. 2017)**		
	Area (m^2)	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
Dry Habitats	134,696	76.8	510,360	135,341	77.2	504,685
Unvegetated Gravel Bars	58,222	33.2	58,222	60,032	34.2	60,032
Vegetated Gravel Bars	51,168	29.2	307,008	49,598	28.3	297,588
Temporary Channel	21,586	12.3	107,930	22,009	12.6	110,045
LWD	3,720	2.1	37,200	3,702	2.1	37,020
Wet Habitats	40,615	23.2	272,171	39,970	22.8	261,260
Run & Glide	15,651	8.9	62,604	18,365	10.5	73,460
Glide Tail	3,646	2.1	29,168	3,694	2.1	29,552
Glide Edge	0	0	n/a	0	0	n/a
Shallows	4,073	2.3	24,438	1,067	0.6	6,402
Riffle	12,259	7.0	110,331	11,040	6.3	99,360
Habitat Edge	1,932	1.1	17,388	1,944	1.1	17,496
Backwater	0	0	n/a	0	0	n/a
Microchannel	0	0	n/a	0	0	n/a
Secondary Channel	2,676	1.6	24,084	3,735	2.2	33,615
Pool	378	0.2	4,158	125	0.1	1,375
Total	175,311	100	782,531	175,311	100	765,945
Wetted:Dry Ratio	0.3			0.3		

Table 3: Giesbrecht Bar changes in areas and habitat ratings, 2016-17

Giesbrecht Bar: Changes in Area and Habitat Rating 2016-17 XS 39-42						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	645	1	-5,675	65.2	66	
Unvegetated Gravel Bar	1,810	3	1,810	7.4	7.8	The secondary channel along the right bank is dry and expansion of the associated bar has caused an increase in area of this habitat
Vegetated Gravel Bar	-1,570	-3	-9,420	39.2	38.9	Small area of vegetated gravel bar eroded along the left bank at XS 42
Temporary Channel	423	2	2,115	13.8	14.4	Temporary channel has increased despite the loss of channel between XS 42 and 41 due to the increase of this habitat within the excavation site
LWD	-18	0	-180	4.8	4.8	
Overall Wet Habitats	-645	-1.6	-10,911	34.8	34	
Run & Glide	2,714	18	10,856	8	9.7	Increase due to widening of glides between XS 42 and 41 and downstream along the left bank
Glide Tail	48	1	384	3.7	3.9	
Glide Edge	0	n/a	n/a	n/a	n/a	No significant glide edge observed during either year
Shallows	-3,006	-74	-18,036	13.1	0.8	Complex shallows around bar on the right bank near XS 42 were dry at time of assessment in 2017
Riffles	-1,219	-10	-10,971	14.1	13	Loss of some riffle habitat just down stream of Giesbrecht Bar
Habitat Edge	12	1	108	2.2	2.3	
Backwater	0	n/a	n/a	n/a	n/a	No backwater habitat observed during either year
Microchannel	0	n/a	n/a	n/a	n/a	No microchannel habitat observed during either year
Secondary Channel	1,059	40	9,531	3.1	4.4	New secondary channel network across excavation area more than offsets loss of channel along the right bank
Pool	-253	-67	-2,783	0.5	0	
Total	0	0	-16,586 (-2%)	100	100	

3.1.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 4)

Chum 2016

No redds or active spawning of chum salmon was observed at Giesbrecht Bar during the survey conducted in 2016. No carcasses were observed in this area either although active spawning was observed occurring at other bars and areas along the Vedder River at the same time as this survey.

Chum 2017

Again, during the 2017 survey no redds, carcasses or active spawning of chum salmon was observed at Giesbrecht Bar although active spawning was observed occurring at other bars and areas along the Vedder River at the same time.

Pink 2017

Pink salmon spawning (light) was observed in a small area along the outer, downstream edge of the excavated bar. Pink salmon on the Vedder River have been consistently observed to spawn in glide tail areas above riffles. The area where these spawners were observed is located within the only glide tail mapped in this study area.

Spawning of chum and pink salmon is not expected to occur in the vicinity of Giesbrecht Bar as the pitch of the river in this area is relatively steep which results in velocities being too high and sediment too coarse to support good spawning habitat. This is consistent with observations from previous years contained in NPE sediment removal assessment reports from 1995 through 2015.

3.1.5 Summary

The geomorphology of the Giesbrecht Bar study area has been altered due to erosion on the left bank and apparent aggradation along the right gravel bar upstream of the excavation. This has resulted in lowering of habitat ratings in the area upstream of excavation. These changes are not likely attributable to the excavation. These habitat losses have been offset by habitat gains within the exaction itself. Thus, despite the neutral habitat rating the overall assessment score is positive (+).

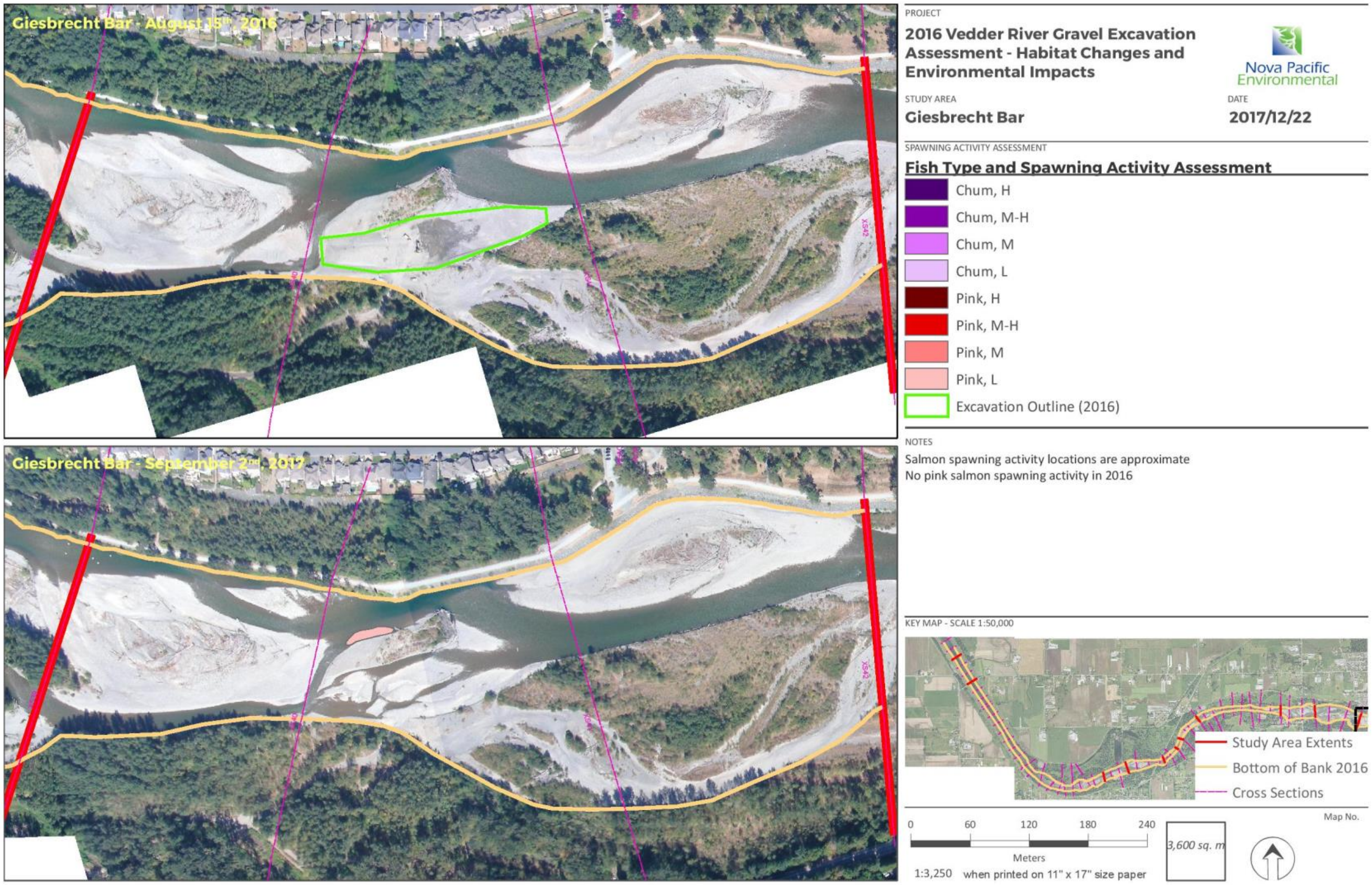


Figure 4: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Giesbrecht Bar in 2016 (top) and 2017 (bottom).

3.2 Lickman Bar (16-35M)

3.2.1 Plan and Implementation

The Lickman Bar sediment removal site was located mid-channel at XS-35. Figure 5 shows an aerial view of the Lickman Bar excavation plan. The purpose of this excavation was to trap gravel at the downstream end of the Upper Reach before it enters the narrower Middle Reach. The site was laid out as originally planned with no significant modifications between the initial and construction layout drawings.

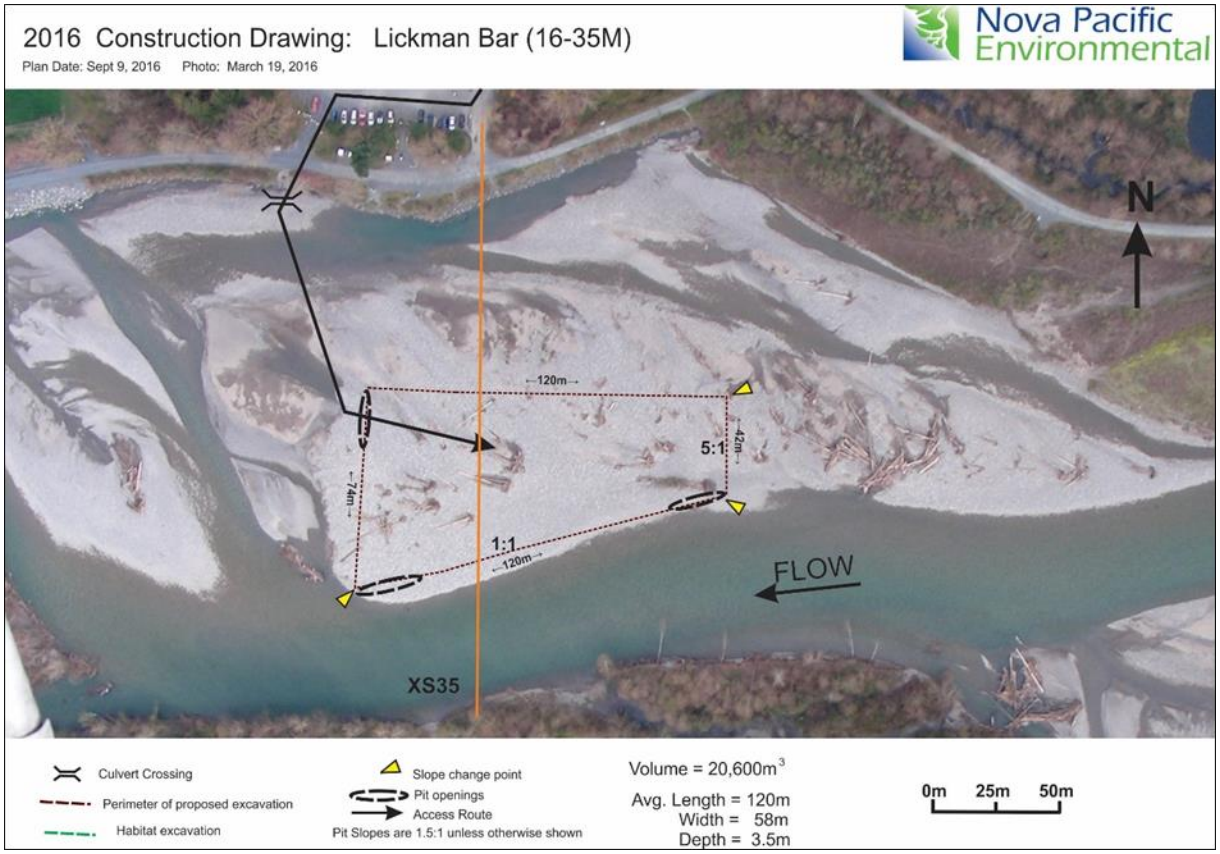


Figure 5: Aerial view of the Lickman Bar excavation plan. Photo taken March 19, 2016, drawing – September 9, 2016.

3.2.2 Observed Changes

Lickman Bar is mostly filled and the surrounding characteristics have not changed significantly. There is some flow across the upstream end of the bar into the remnant pit as well as some sub gravel water entering this feature. The remnant pit connects to the outlet that was directed towards the right bank. Both the inlet and the outlet along the main channel have filled in. Although the pit has mostly refilled the bar elevation is approximately one meter lower. The pre-existing microchannels crossing the bar from left to right also appear to have filled in. The majority of flow continues to be directed toward the left bank past the campground. At higher flows the lower bar elevation should benefit the flow characteristics in this reach by splitting the flow more evenly toward both banks.

This excavation was relatively wide and short, and this appears to have created a potential risk for fish trapping because it has left a remnant pool midway along a relatively minor channel. Consideration should be given to defining an additional guideline that limits excavations that are too wide relative to their length. This would ensure flow and refilling and avoid potential stranding. (also see Section 3.5 of Yarrow Bar)

During the excavation, an unusually high and unstable looking riffle was observed upstream of the bar outside of the study area. This wedge of gravel appears to have moved downstream, widening the channel at the upstream end of the excavation and assuming a lower profile.

The habitat channel constructed downstream of excavation remains connected to the flow at upstream and downstream ends. The excavated habitat channel was functioning well and providing a diversity of habitats.

Seven LWD structures were placed at Lickman Bar excavation area to provide bank complexity, including three placed along the bank side of the excavated pit, one in a small microchannel downstream of southwest outlet of the pit, and three placed along excavated habitat channel, During the assessment of the offsetting measures in 2017 it was found that the only two LWD structures remained, one placed along excavated habitat channel and the one placed in the microchannel immediately downstream of the pit.

3.2.3 Habitat Mapping

The habitat mapping assessment area for the Lickman Bar excavation covered cross sections 33 to 36 (Figure 6). Table 4 shows the area of each habitat type and the corresponding habitat ratings calculated for the two study years. Table 5 presents the change in area and habitat ratings, the percentage change in area, and comments for the different habitat types.

One of the key changes at Lickman Bar is the net reduction in glide habitat. This includes a narrowing of the main channel along the left bank and reduction of the branch of the wide channel that flowed across the bar toward the right bank at XS 34 in 2016 to a secondary channel. A new tail and riffle sequence leading in to the excavation area, a large pool within the excavation remnant and the outlet channel provide new higher habitat rated polygons in the excavation area. This also resulted in relatively significant increases is glide tail and riffle habitat. Changes in microchannels across the study area that resulted in a loss of about a third of this habitat type. Other changes to higher value habitats observed in 2017 include conversion of a pool along the right bank at XS 35 to shallows and filling of another pool along the left bank at XS 36. Pool habitat increased by 5% because of the pool within the excavation area.

The habitat mapping assessment showed a 2% increase in overall habitat rating for this study area. Review of the maps and calculated habitat ratings shows small increases in both unvegetated and gravel bar habitats and a large decrease in glide habitat. The positive habitat rating arises from increases in secondary and temporary channels, glide tail, glide edge, riffle, pool and complex shallow habitats. Loss of some LWD was observed primarily at the upstream end of bar and in the excavation area.

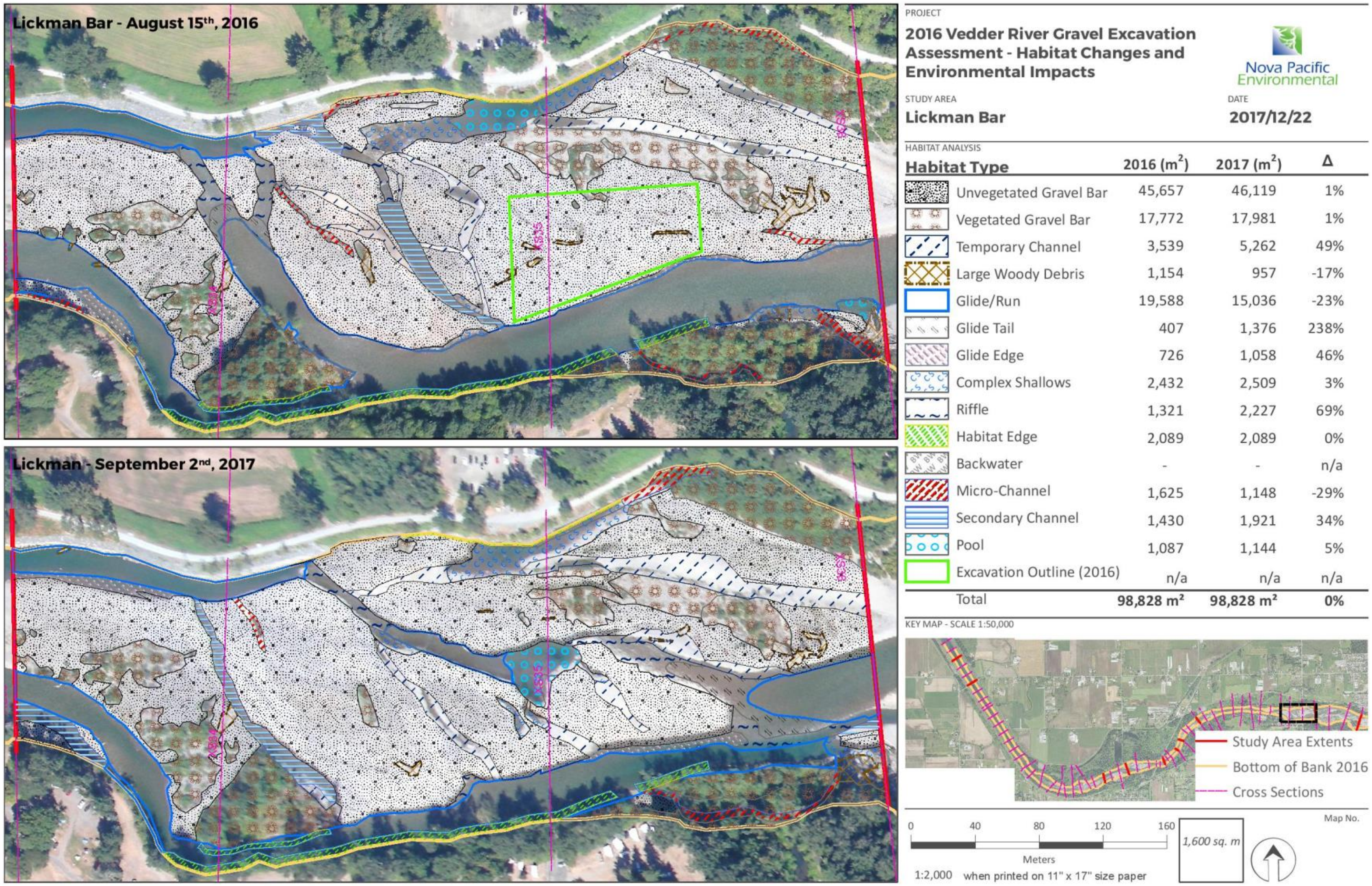


Figure 6: Habitat mapping of the Lickman Bar location prior to excavation in 2016 (top) and one year later in 2017 (bottom).

Table 4: Lickman Bar areas and habitat ratings, 2016-17

Lickman Bar: Areas and Habitat Ratings 2016-2017 XS 33-36						
Habitat Type	**Area (m^2)**	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
	Pre-Excavation (Aug. 2016)			**Post-Excavation (Sep. 2017)**		
Dry Habitats	68,122	68.9	181,524	70,319	71.2	189,885
Unvegetated Gravel Bars	45,657	46.2	45,657	46,119	46.7	46,119
Vegetated Gravel Bars	17,772	17.9	106,632	17,981	18.2	107,886
Temporary Channel	3,539	3.6	17,695	5,262	5.3	26,310
LWD	1,154	1.2	11,540	957	1	9,570
Wet Habitats	30,705	31.1	174,674	28,508	28.8	174,957
Run & Glide	19,588	19.8	78,352	15,036	15.2	60,144
Glide Tail	407	0.4	3,256	1,376	1.4	11,008
Glide Edge	726	0.7	5,082	1,058	1.1	7,406
Shallows	2,432	2.5	14,592	2,509	2.5	15,054
Riffle	1,321	1.3	11,889	2,227	2.2	20,043
Habitat Edge	2,089	2.1	18,801	2,089	2.1	18,801
Backwater	0	0	n/a	0	0	n/a
Microchannel	1,625	1.7	17,875	1,148	1.2	12,628
Secondary Channel	1,430	1.5	12,870	1,921	1.9	17,289
Pool	1,087	1.1	11,957	1,144	1.2	12,584
Total	98,828	100	356,198	98,828	100	364,842
Wetted:Dry Ratio	0.5			0.4		

Table 5: Lickman Bar changes in areas and habitat ratings, 2016-17

Lickman Bar: Changes in Area and Habitat Rating 2016-17 XS 33-36						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	2,197	3.2	8,361	51	52	
Unvegetated Gravel Bar	462	1	462	12.8	12.6	Reconfiguration of channels and creation of a new riffle/pool sequence crossing excavation results in a small net increase of this habitat area
Vegetated Gravel Bar	209	1	1,254	29.9	29.6	Vegetation near XS 34 has continued to grow
Temporary Channel	1,723	49	8,615	5.1	7.2	Widening of large temporary channel between XS 36 and XS 35 and formation of new channels in excavation area
LWD	-197	-17	-1,970	3.2	2.6	Loss of LWD at upstream end of bar and in excavation area
Overall Wet Habitats	-2,197	-7.2	283	49	48	
Run & Glide	-4,552	-23	-18,208	22.0	16.5	Narrowing of the main channel along the left bank exceeded increases elsewhere in the study area
Glide Tail	969	238	7,752	0.9	3.0	Migration of gravel wedge from upstream moves this habitat feature into the study area
Glide Edge	332	46	2,324	1.4	2.0	See glide tail comment
Shallows	77	3	462	4.1	4.1	Complex shallow habitat increased due to filling of two small pools on left and right bank
Riffles	906	69	8,154	3.3	5.5	Habitat channel and downstream migration of gravel wedge provide increase. Some loss of riffle from small channels crossing the bar downstream.
Habitat Edge	0	0	0	5.3	5.2	
Backwater	n/a	n/a	n/a	n/a	n/a	No backwater habitat observed during either year
Microchannel	-477	-29	-5,247	5.0	3.5	Less flow to microchannels due to configuration changes in the main channel as well as some effect due to lower water levels in 2017
Secondary Channel	491	34	4,419	3.6	4.7	Configuration changes of secondary channels crossing the bar downstream of the excavation
Pool	57	5	627	3.4	3.5	Increase in pool habitat due to new pool in excavation area
Total	0	0	8,644 (+2%)	100	100	

3.2.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 7)

Chum 2016

Heavy spawning of chum salmon was noted in the pool and complex shallows along the right bank below the public parking area and at the outlet of the microchannel on the left bank. Medium and light spawning was observed in the secondary channel downstream of the pool on the right bank and along both sides of the main channel between XS 36 and XS 35 and then into the secondary channel that crosses the main bar. The areas where chum spawning was occurring are influenced by perched water and sub-gravel flow.

Chum 2017

Heavy spawning of chum salmon was noted in the complex shallows and pools again in 2017 including a large area just downstream of the pool within the excavation area. A mix of heavy and medium spawning was also observed in the pool and shallows complex along the right bank downstream of the microchannel. Medium spawning was seen along the small channel connecting the main channel to the pool in the excavation area and along other channels. The most intense spawning activity was noted in areas influenced by perched water and sub-gravel flow.

Pink 2017

Pink salmon spawning was observed to be concentrated in the main channel along the excavation area and downstream which was a relatively shallow glide. This area is immediately downstream of where the gravel wedge has migrated to creating new glide tail, glide edge and riffle habitat within the study area.

3.2.5 Summary

The geomorphology of the area around Lickman Bar remains relatively similar between 2016 and 2017. The habitat rating for this excavation site is slightly positive (2%). The overall assessment score is positive (+) based on the increase in habitat rating and observed changes.

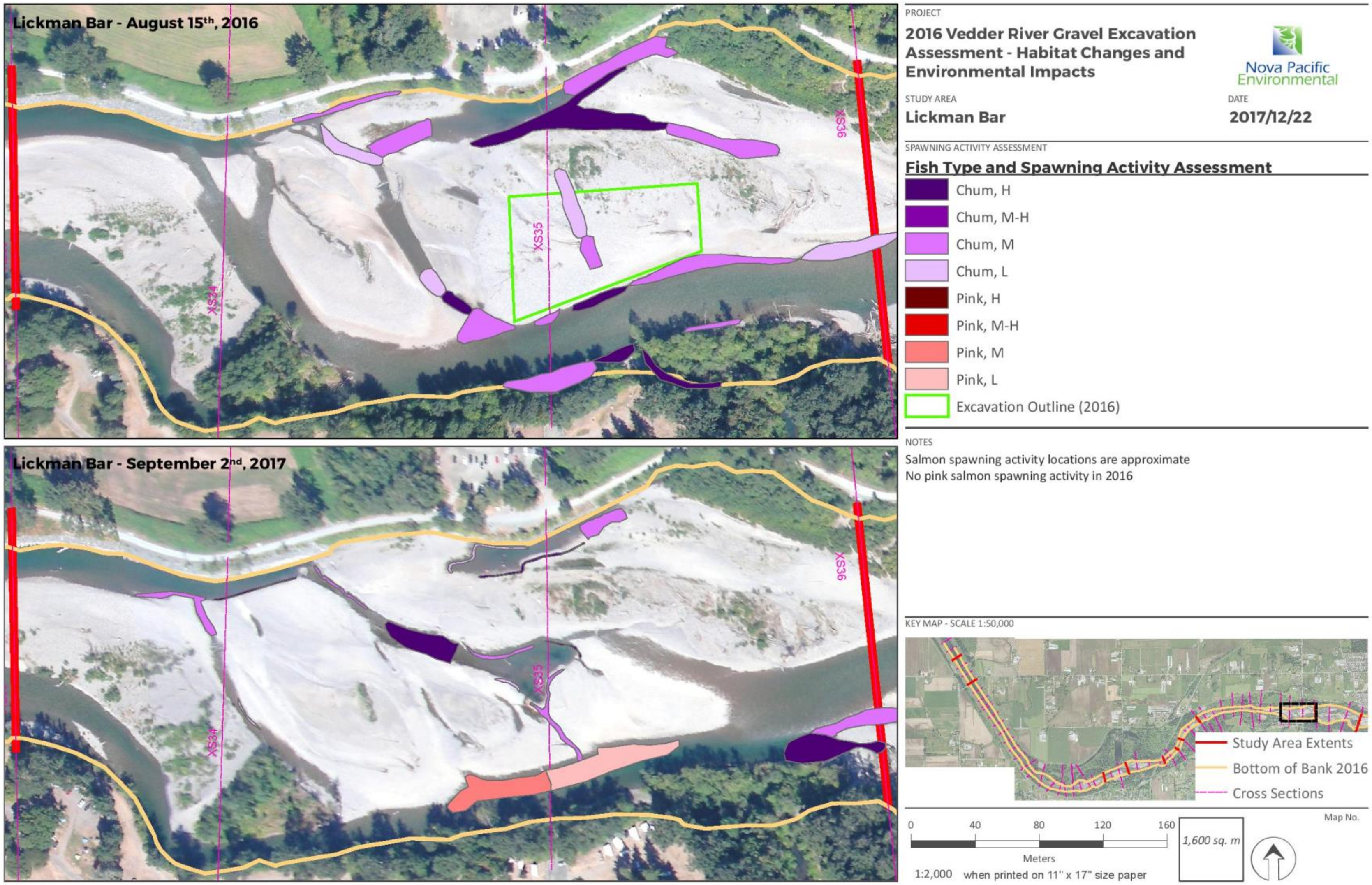


Figure 7: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Lickman Bar in 2016 (top) and 2017 (bottom).

3.3 Bergman Bar (16-22L)

3.3.1 Plan and Implementation

The Bergman Bar sediment removal site was located on the left side of the main channel at XS-23. Figure 8 shows aerial view of the Bergman Bar excavation plan. The intent of the design was to prevent sediment from moving downstream into the freeboard limited section of the river. Conditions at the site provided for a wider excavation than originally planned which contributed to the volume increase for this site.

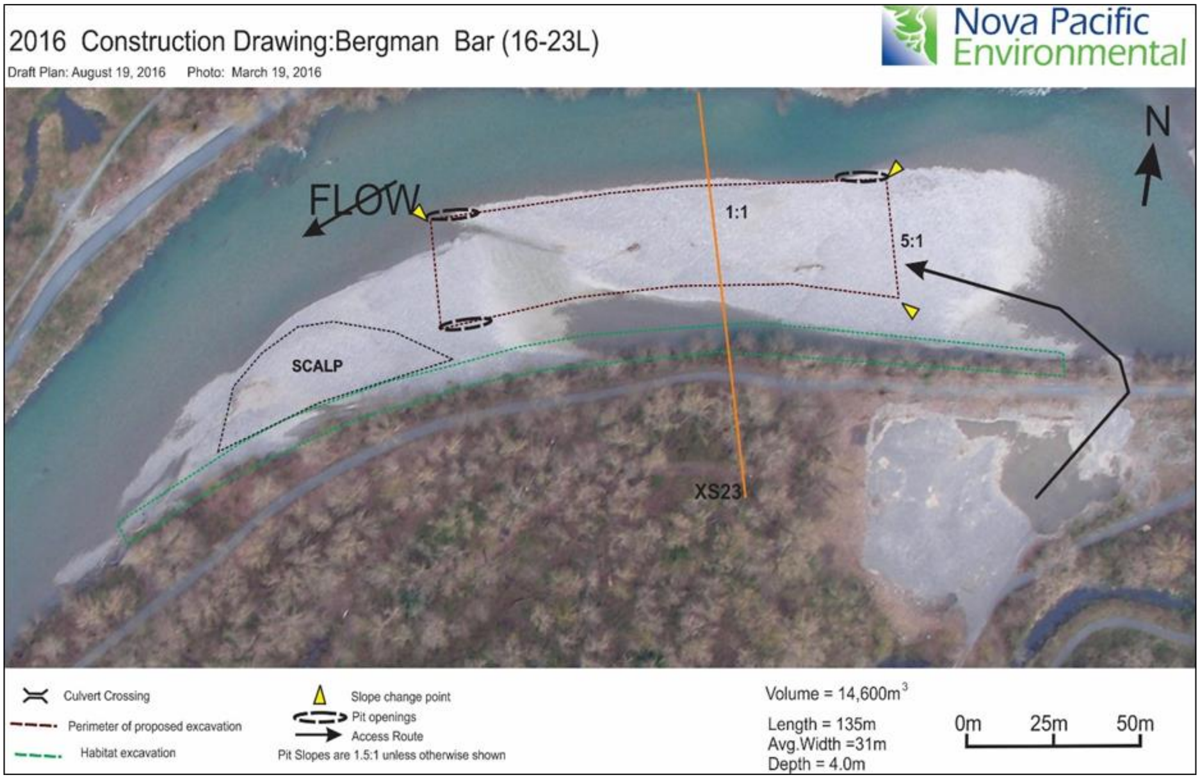


Figure 8: Aerial view of the Bergman Bar excavation plan. Photo taken March 19, 2016, drawing – August 19, 2016.

3.3.2 Observed Changes

The thalweg of the channel is now through the pit leaving a sinuous and deep channel with a substantial pool at the upstream end. The channel of the old thalweg along right bank has much less flow but still provides a good mix of riffle and pool habitat along the bank. A new gravel bar (Relief Bar) has formed between the two channels.

The microchannel constructed at Bergman Bar has divided into two sections with the upstream section exiting into the main channel about halfway along the original excavation footprint. The upstream section of the microchannel is straight and appears uniform in width and depth. It has excellent riparian vegetation characteristics due to the well-established overhanging trees at this location. The inlet appears optimal and is expected to provide flow to the channel at all river levels. Heavy chum spawning was noted near the upstream end in 2017, notably near the area where the channel above the riffle would be expected to contribute sub-gravel flow. The greater benefit from this channel, however is likely due to increased rearing opportunities for salmonid fry. The midsection of the channel has been replaced with a substantial section of gravel, likely due to deposition at this location.

The downstream section of microchannel extends from approximately 50m downstream from XS 22 to the upstream tip of Railway Bar. This section of the channel is fed by sub-gravel flows during low flow conditions. It has supported significant amounts of chum spawning in both 2016 and 2017. The comparison of chum spawning in the two sections serves to well illustrate the importance of the emergent sub-gravel flows for spawning site selection.

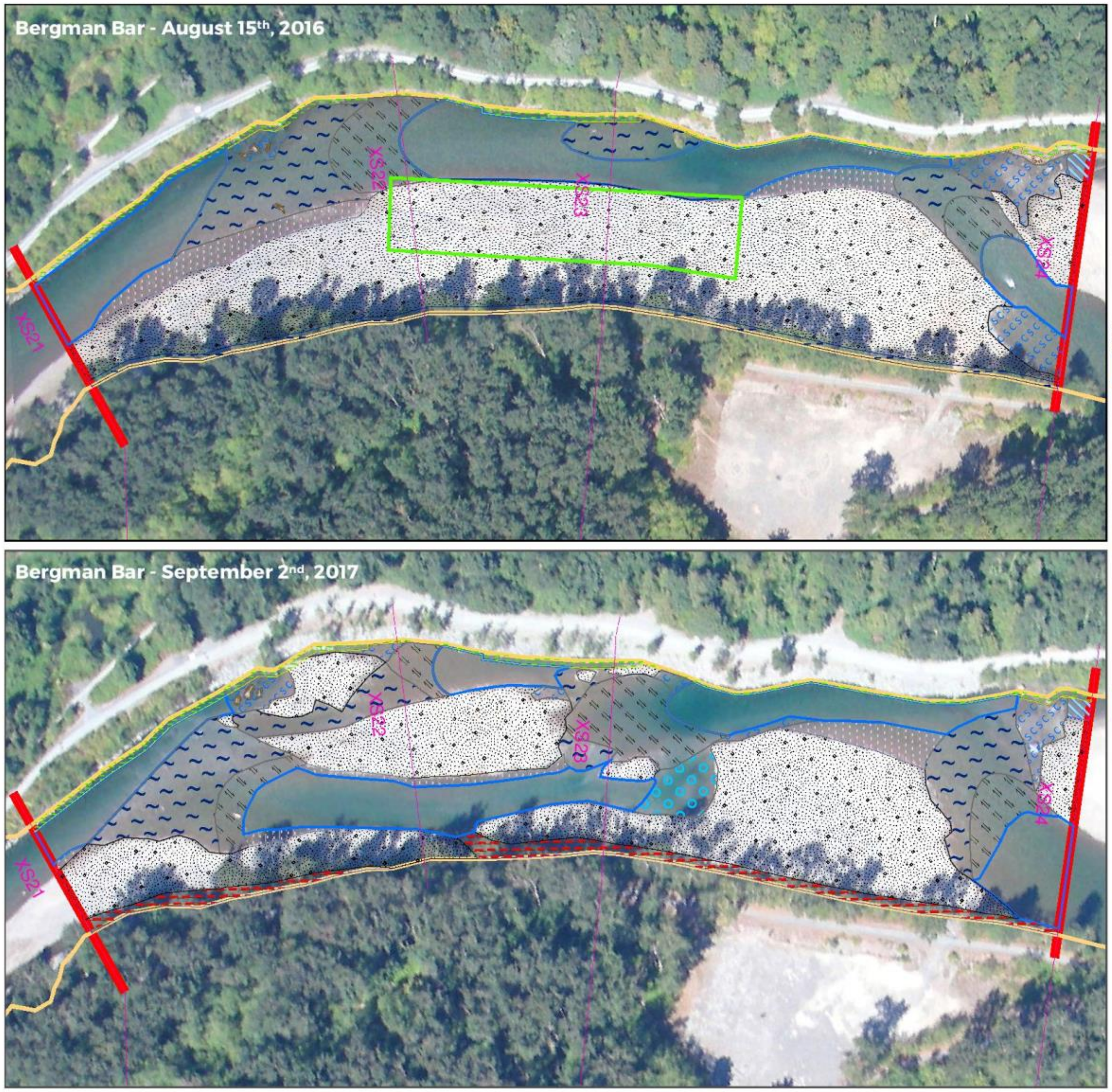
The primary offsetting measure implemented at Bergman Bar excavation area in 2016 was the excavation of a habitat channel along the left bank to improve the rearing capacity and provide additional chum salmon spawning habitat as well as to reduce the potential for fry stranding. Three LWD structures were placed along this excavated habitat channel.

During the assessment of the offsetting measures in 2017 it was found that the excavated habitat channel was functioning well. It was filled part way along but remains connected to the main flow at both upstream and downstream ends. The downstream end is fed by sub-gravel flows and is open to the main flow. All three LWD structures placed along excavated habitat channel were gone, however there were other LWD which had been deposited downstream within the habitat channel present at the time of this assessment.

3.3.3 Habitat Mapping

The assessment area for the Bergman Bar excavation covered cross sections 21 to 24 (Figure 9). The habitat mapping assessment showed a significant increase in overall habitat rating of 30%. Table 6 indicates the area of each habitat type and the corresponding habitat values calculated for the two study years. Table 7 presents the change in area and habitat value, the percentage change in area, and comments on the causes and interactions where those have been identified for the different habitat types.

The biggest change observed at Bergman Bar is that the main channel now forks and passes through the bar in the area of the excavation replacing unvegetated gravel bar with higher rated habitat polygons and greater habitat diversity. The upstream end of the excavation has not refilled but provides high habitat value as a large eddy pool. This pool and the enhancement of the microchannel along the left bank during the excavation have improved the habitat rating in the study area. Other changes include a wider glide edge upstream of the excavation, a new glide tail/riffle sequence at XS 23 and some expansion of unvegetated gravel bar areas near the downstream end of the study area.



PROJECT

2016 Vedder River Gravel Excavation Assessment - Habitat Changes and Environmental Impacts

Nova Pacific Environmental

STUDY AREA

Bergman Bar

DATE

2018/01/19

HABITAT ANALYSIS

Habitat Type	2016 (m^2)	2017 (m^2)	Δ
Unvegetated Gravel Bar	18,238	14,435	-21%
Vegetated Gravel Bar	66	7	-90%
Temporary Channel	1,002	-	-100%
Large Woody Debris	19	24	25%
Glide/Run	6,479	7,354	13%
Glide Tail	1,591	2,922	84%
Glide Edge	1,361	1,110	-18%
Complex Shallows	1,428	995	-30%
Riffle	3,121	4,317	38%
Habitat Edge	967	972	1%
Backwater	-	-	n/a
Micro-Channel	-	1,572	n/a
Secondary Channel	93	71	-24%
Pool	-	587	n/a
Excavation Outline (2016)	n/a	n/a	n/a
Total	34,365 m^2	34,365 m^2	0%

KEY MAP - SCALE 1:50,000

0 30 60 90 120

Meters

1:1,600 when printed on 11" x 17" size paper

1,000 sq. m

Map No.

Figure 9: Habitat mapping of the Bergman Bar location prior to excavation in 2016 (top) and one year later in 2017 (bottom).

Table 6: Bergman Bar areas and habitat ratings, 2016-17

Bergman Bar: Areas and Habitat Ratings 2016-2017 XS 21-24						
Habitat Type	**Area (m^2)**	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
	Pre-Excavation (Aug. 2016)			**Post-Excavation (Sep. 2017)**		
Dry Habitats	19,325	56.2	23,834	14,465	42.1	14,717
Unvegetated Gravel Bars	18,238	53.1	18,238	14,435	42.0	14,435
Vegetated Gravel Bars	66	0.2	396	7	0.02	42
Temporary Channel	1,002	2.9	5,010	0	0	n/a
LWD	19	0.06	190	24	0.07	240
Wet Habitats	15,040	43.8	94,368	19,900	57.9	138,521
Run & Glide	6,479	18.9	25,916	7,354	21.4	29,416
Glide Tail	1,591	4.6	12,728	2,922	8.5	23,376
Glide Edge	1,361	3.9	9,527	1,110	3.2	7,770
Shallows	1,428	4.2	8,568	995	2.9	5,970
Riffle	3,121	9.1	28,089	4,317	12.6	38,853
Habitat Edge	967	2.8	8,703	972	2.8	8,748
Backwater	0	0	n/a	0	0	n/a
Microchannel	0	0	n/a	1,572	4.6	17,292
Secondary Channel	93	0.3	837	71	0.2	639
Pool	0	0	n/a	587	1.7	6,457
Total	34,365	100	118,202	34,365	100	153,238
Wetted:Dry Ratio	0.8			1.4		

Table 7: Bergman Bar changes in areas and habitat ratings, 2016-17

Bergman Bar: Changes in Area and Habitat Rating 2016-17 XS 21-24						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	-4,859	-25	-9,117	20.2	9.6	
Unvegetated Gravel Bar	-3,803	-21	-3,803	15.4	9.4	New thalweg passes through the main gravel bar. Former thalweg provides a diversity of wetted habitats
Vegetated Gravel Bar	-59	-89	-354	0.3	0.03	
Temporary Channel	-1,002	-100	-5,010	4.2	n/a	Temporary channels were not observed during either year
LWD	5	26	50	0.1	0.2	Increase attributed to lower water levels around LWD complex on right bank
Overall Wet Habitats	4,859	32	44,153	79.8	90.4	
Run & Glide	875	14	3,500	21.9	19.2	New channel through the bar has increased the amount of glide habitat
Glide Tail	1,331	84	10,648	10.8	15.3	Channel change has created a new tail/riffle sequence and increased the area of glide tail habitat
Glide Edge	-251	-18	-1,757	8.0	5.1	Glide edge at downstream end of the bar has decreased while glide edge at upstream end of bar has increased
Shallows	-433	-30	-2,598	7.2	3.9	Reduction of complex shallows at the outlet of the secondary channel along right bank at the upstream end of the study area
Riffles	1,196	38	10,764	23.8	25.3	Channel change has created a new tail/riffle sequence and increased the area of riffle habitat
Habitat Edge	5	1	45	7.4	5.7	
Backwater	n/a	n/a	n/a	n/a	n/a	No backwater habitat observed during either year
Microchannel	1,572	n/a	17,292	n/a	11.3	Increase in microchannel is due to habitat excavation along the left bank
Secondary Channel	-22	-24	-198	0.7	0.4	Small change in secondary channel upstream of the excavation
Pool	587	n/a	6,457	n/a	4.2	Eddy pool has formed within the excavation footprint
Total	0	0	35,036 (+30%)	100	100	

3.3.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 10)

Chum 2016

Chum spawning was observed in the temporary channel along the left bank. This temporary channel is fed by sub-gravel percolation and despite periods of no surface flow still successfully supports chum spawners. Spawning also occurred within the excavation, encouraged by the head differential between the channel upstream of the riffle at XS 24 and the outlet of the pit. Lower slopes are employed to limit risk to spawners using this area. Given the stable configuration this likely allowed these redds to be successful.

Chum 2017

Chum spawning patterns were repeated in the channel along the left bank this included the downstream groundwater fed section as well as the upstream surface water fed section. The pattern was also repeated at the upstream end of the excavation. Again, this would be related to the sub-gravel percolation. Guidelines used in designing the excavations stress maintenance of these attributes within the channel. Heavy spawning was also observed in the secondary channel upstream of the excavation. This would be related to conditions upstream at Peach Bar.

Pink 2017

Pink salmon spawning was observed at the upstream end of the bar near cross-section 24 and along the downstream end of the left channel which passes through Bergman Bar. Both of these areas are associated with glide tail habitat.

3.3.5 Summary

Substantial changes associated with the excavation at Bergman Bar have resulted in habitat rating gains of 30%. The habitat excavation has provided microchannel habitat along much of the length of the bar which continued to support spawning activity and provides a significant increase in available rearing habitat. A new glide tail/riffle sequence has been formed in association with a split in the main channel near the excavation site. Additionally, a new pool has been created in the excavation area where the newly created left for of the channel moves through the former bar. Accordingly, the overall score for this site is strongly positive (++).

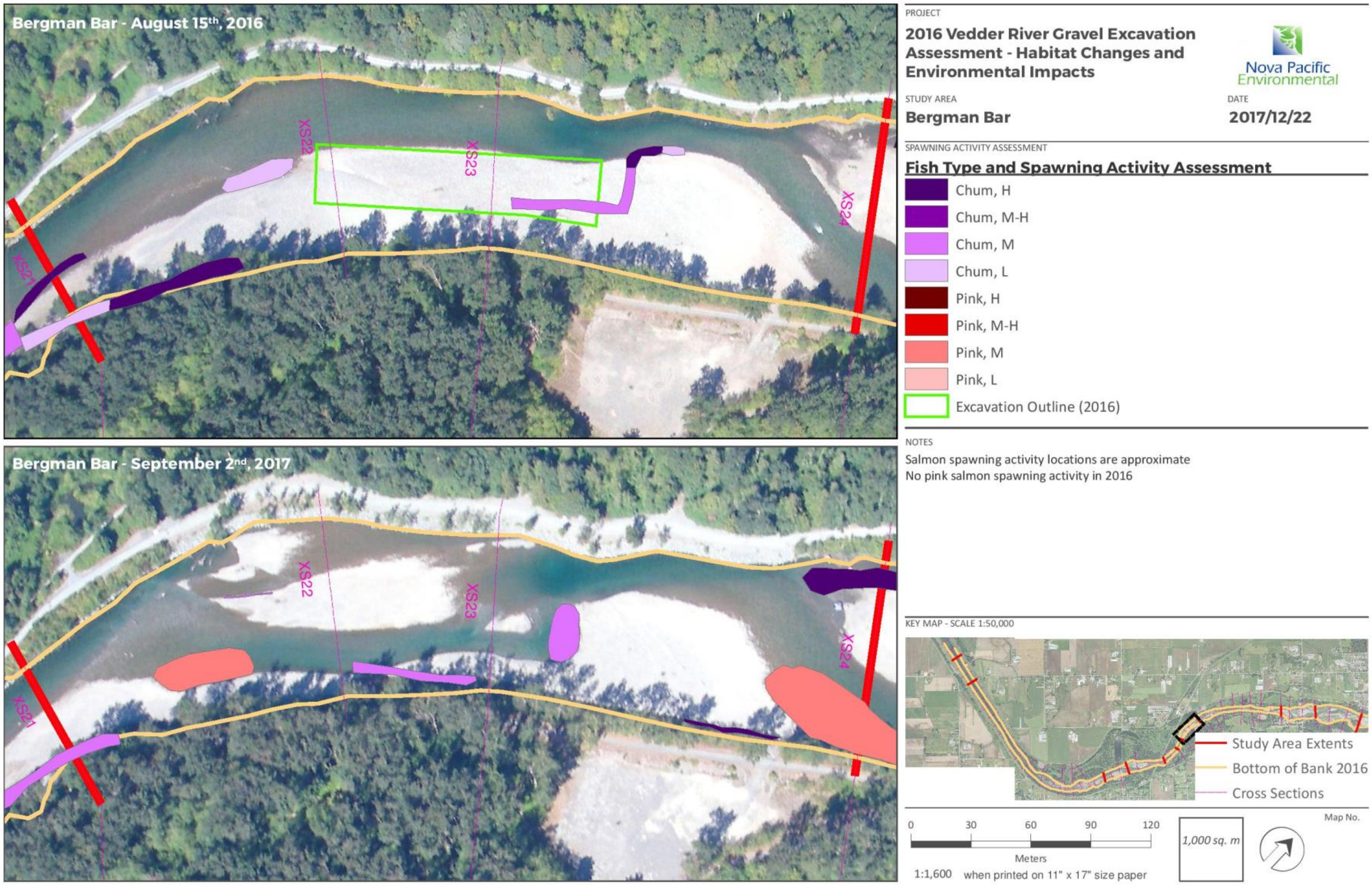


Figure 10: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Bergman Bar in 2016 (top) and 2017 (bottom).

3.4 Railway Bar (16-19R)

3.4.1 Plan and Implementation

Railway Bar is a narrow point bar located on the right bank on an inside bend of the river, upstream of the BC Southern Railway Bridge. The Railway Bar sediment removal footprint in 2016 extended from about 20 m downstream to about 70m upstream of XS-19. Figure 11 shows an aerial view of the Railway Bar excavation plan. The intent of the design was to trap gravel upstream of the bridge and reduce the amount of gravel moving downstream into the reach of the river that is most freeboard limited. A secondary purpose was to increase channel capacity upstream of the bridge. The excavation was laid out as originally planned with a small increase in length which resulted in a volume increase from design estimate. These changes were made to ensure that the field fit excavation meets key design criteria. Continued aggradation of the gravel bar during the spring freshet prior to the excavation necessitates this approach to meet the habitat objectives originally set for this location.

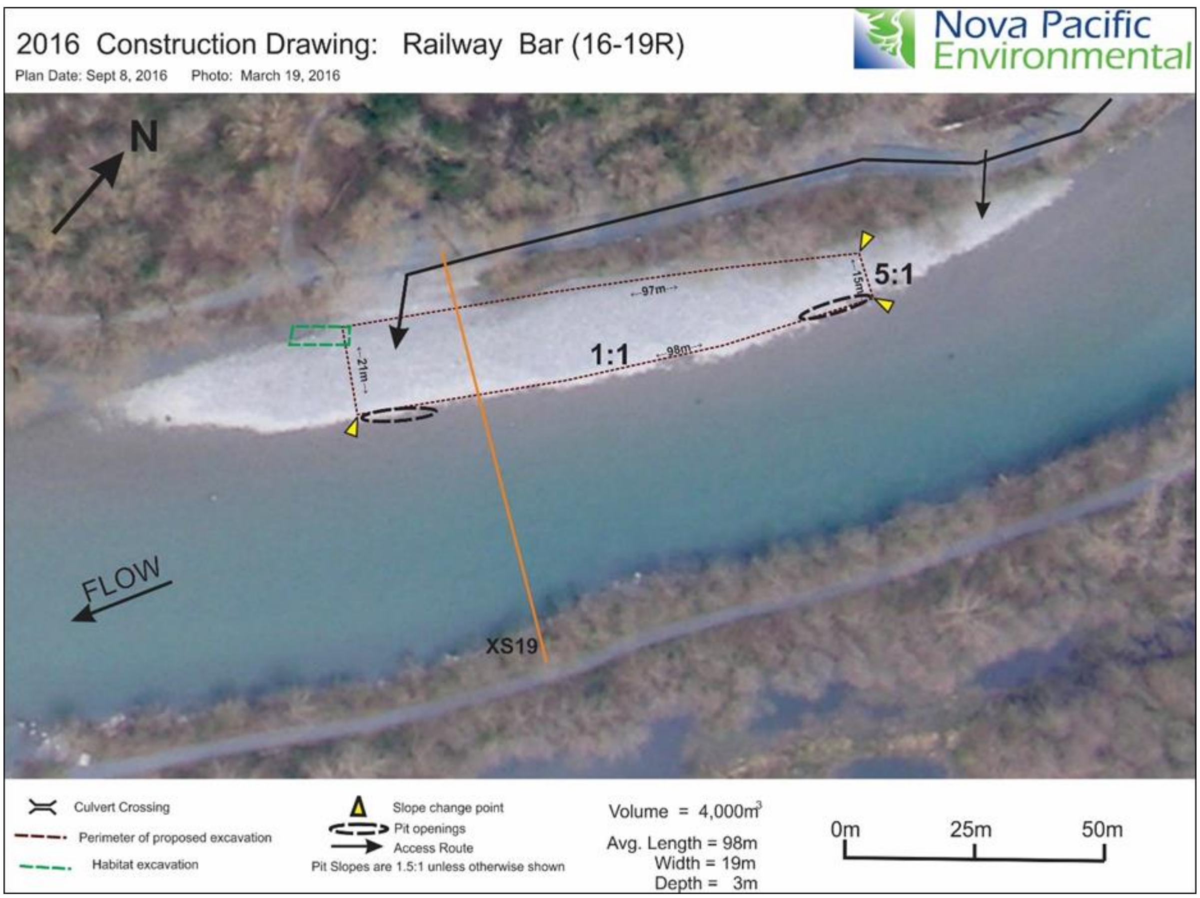


Figure 11: Aerial view of the Railway Bar excavation plan. Photo taken March 19, 2016, drawing – September 8, 2016.

3.4.2 Observed Changes

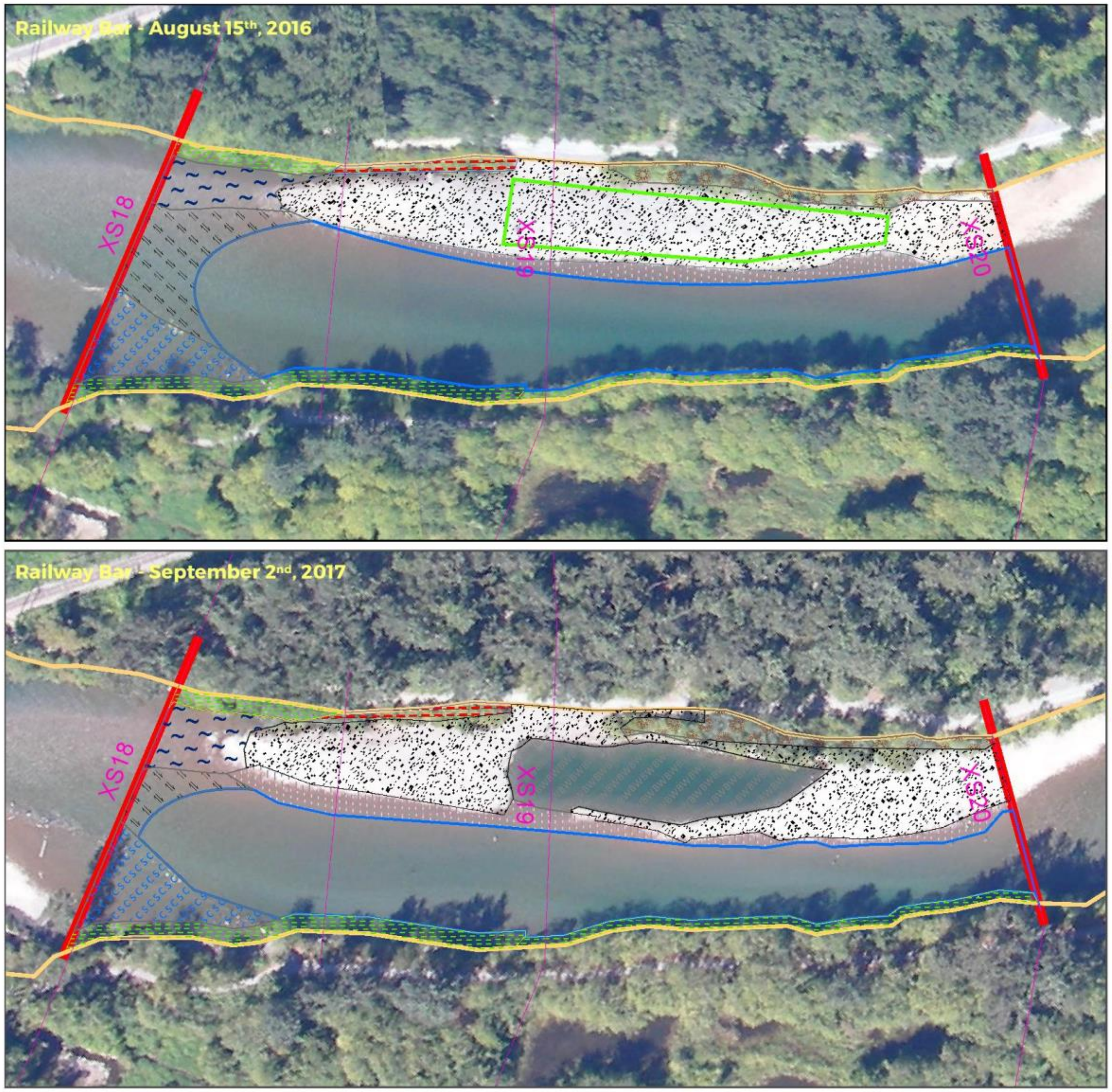
Railway bar excavation has filled only at the upstream end however, this filling has blocked the inlet. The outlet is shallow but still provides a very wide connection. The connection to the microchannel downstream was also blocked under these very low flow conditions, however there was still evidence of flow input from ground water. Upstream at Bergman the main channel appears to have filled in as the thalweg diverted through the pit. This may have limited the amount of gravel contributed to Railway Bar.

3.4.3 Habitat Mapping

Table 8 indicates the area of each habitat type and the corresponding habitat values calculated for the two study years. Table 9 presents the change in area and habitat value, the percentage change in area, and comments for the different habitat types.

The assessment area for the Railway Bar excavation covered cross sections 18 to 20 (Figure 12). The habitat mapping assessment showed an increase in overall habitat value of 11%. The total area mapped did not change between the two years which helps ensure that the comparisons over the two years are an accurate reflection of the changes in this area.

The biggest change at Railway Bar was replacement of unvegetated gravel bar habitat with backwater habitat remaining within the footprint of the excavation. The glide tail downstream of the excavation appears to have migrated downstream leading to a reduction within the study area. There was also an increase in glide edge along the bar downstream of the excavation.



PROJECT

2016 Vedder River Gravel Excavation Assessment - Habitat Changes and Environmental Impacts

Nova Pacific Environmental

STUDY AREA

Railway Bar

DATE

2017/12/28

HABITAT ANALYSIS

Habitat Type	2016 (m²)	2017 (m²)	Δ
Unvegetated Gravel Bar	4,661	4,247	-9%
Vegetated Gravel Bar	517	524	1%
Temporary Channel	-	-	n/a
Large Woody Debris	-	-	n/a
Glide/Run	8,189	7,053	-14%
Glide Tail	981	318	-68%
Glide Edge	811	1,152	42%
Complex Shallows	767	821	7%
Riffle	519	560	8%
Habitat Edge	1,411	1,406	0%
Backwater	-	1,758	n/a
Micro-Channel	187	202	8%
Secondary Channel	-	-	n/a
Pool	-	-	n/a
Excavation Outline (2016)	n/a	n/a	n/a
Total	18,043 m²	18,043 m²	0%

KEY MAP - SCALE 1:50,000

0 25 50 75 100

Meters

1:1,200 when printed on 11" x 17" size paper

625 sq. m

Map No.

Figure 12: Habitat mapping of the Railway Bar location prior to excavation in 2016 (top) and one year later in 2017 (bottom).

Table 8: Railway Bar areas and habitat ratings, 2016-17

Railway Bar: Areas and Habitat Ratings 2016-2017 XS 18-20						
Habitat Type	**Pre-Excavation (Aug. 2016)**			**Post-Excavation (Sep. 2017)**		
	Area (m^2)	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
Dry Habitats	5,178	28.7	7,763	4,773	26.5	7,393
Unvegetated Gravel Bars	4,661	25.8	4,661	4,249	23.6	4,249
Vegetated Gravel Bars	517	2.9	3,102	524	2.9	3,144
Temporary Channel	0	0	n/a	0	0	n/a
LWD	0	0	n/a	0	0	n/a
Wet Habitats	12,865	71.3	70,310	13,270	73.5	79,484
Run & Glide	8,189	45.4	32,756	7,053	39.1	28,212
Glide Tail	981	5.4	7,848	318	1.8	2,544
Glide Edge	811	4.5	5,677	1,152	6.4	8,064
Shallows	767	4.3	4,602	821	4.6	4,926
Riffle	519	2.9	4,671	560	3.1	5,040
Habitat Edge	1,411	7.8	12,699	1,406	7.8	12,654
Backwater	0	0	n/a	1,758	9.7	15,822
Microchannel	187	1.0	2,057	202	1.1	2,222
Secondary Channel	0	0	n/a	0	0	n/a
Pool	0	0	n/a	0	0	n/a
Total	18,043	100	78,073	18,043	100	86,877
Wetted:Dry Ratio	2.5			2.8		

Table 9: Railway Bar changes in areas and habitat ratings, 2016-17

Railway Bar: Changes in Area and Habitat Rating 2016-17 XS 18-20						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	-405	-8	-370	9.9	8.5	
Unvegetated Gravel Bar	-412	-9	-412	6.0	4.9	Reduction in area of unvegetated gravel bar due to remnant of excavation now being backwater habitat
Vegetated Gravel Bar	7	1	42	3.9	3.6	
Temporary Channel	n/a	n/a	n/a	n/a	n/a	No temporary channels observed during either year within study area
LWD	n/a	n/a	n/a	n/a	n/a	No LWD observed during either year within study area
Overall Wet Habitats	405	3.2	9,174	90.1	91.5	
Run & Glide	-1,136	-14	-4,544	42.0	32.5	Glide area reduced due to more mapped glide edge
Glide Tail	-663	-68	-5,304	10.1	2.9	Glide tail downstream of excavation appears to have migrated partially out of the study area
Glide Edge	341	42	2,387	7.3	9.3	Glide edge has widened along the bar downstream of the excavation
Shallows	54	7	324	5.9	5.7	
Riffles	41	8	369	6.0	5.8	Increase due to growth of riffle at downstream end of the bar
Habitat Edge	-5	0	-45	16.3	14.6	
Backwater	1,758	n/a	15,822	n/a	18.2	Backwater habitat created within the remnant of the excavated area
Microchannel	15	8	165	2.6	2.6	Minor changes in microchannel on right bank
Secondary Channel	n/a	n/a	n/a	n/a	n/a	No secondary channels observed during either year within the study area
Pool	n/a	n/a	n/a	n/a	n/a	No pools observed during either year within the study area
Total	0	0	8,804 (+11%)	100	100	

3.4.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 13)

Chum 2016

Heavy spawning of chum salmon was observed within the microchannel along the right bank and a few spawners were observed within the excavation.

Chum 2017

Heavy spawning of chum salmon was observed within the microchannel along the right bank extending downstream into the riffle area and beyond the study area. It appears that this area of spawning has expanded from 2016. Spawning activity was also observed within the remnant of the excavation.

The spawning within the pit is a concern due to the risk of refilling during the incubation period. This has not been an issue as this excavation has not previously attracted chum spawners and has normally filled within the first year regularly. One potential difference may have arisen from the need to return to the ramp via the outside berm. Future excavations at this site should leave a very narrow berm that can be expected to disintegrate in the first freshet. To accomplish this, it is recommended that the excavation be completed upstream to downstream but the secondary access at the upstream end be used. Alternatively, if appropriate a narrower excavation with an access route along the inside edge can be used.

Pink 2017

A significant area of pink salmon spawning was observed in the main channel downstream of the excavation area. This activity is associated with a glide tail/riffle sequence. The complex shallows habitat on the left bank is located above the riffle downstream so it also functions like a glide tail in attracting pink spawners.

3.4.5 Summary

Changes mapped at Railway Bar have resulted in habitat rating gains of 11%. As well, the enhancement of the microchannel along the right bank downstream, seems to have allowed a big increase in chum spawning. The backwater habitat as a remnant of the excavation is of lesser value. Much of the gain in habitat rating is due to the replacement of gravel bar habitat with backwater habitat within the excavation footprint. This gain is somewhat offset by the risk to chum spawners within the footprint of the excavation resulting in an overall neutral outcome (0).

The primary offsetting measure implemented at Railway Bar excavation area in 2016 was excavation of the downstream corner on the right bank of the pit to maintain habitat value of the small microchannel downstream of the excavation. This simple enhancement has again been successful in maintaining habitat value on a regular basis at this site.

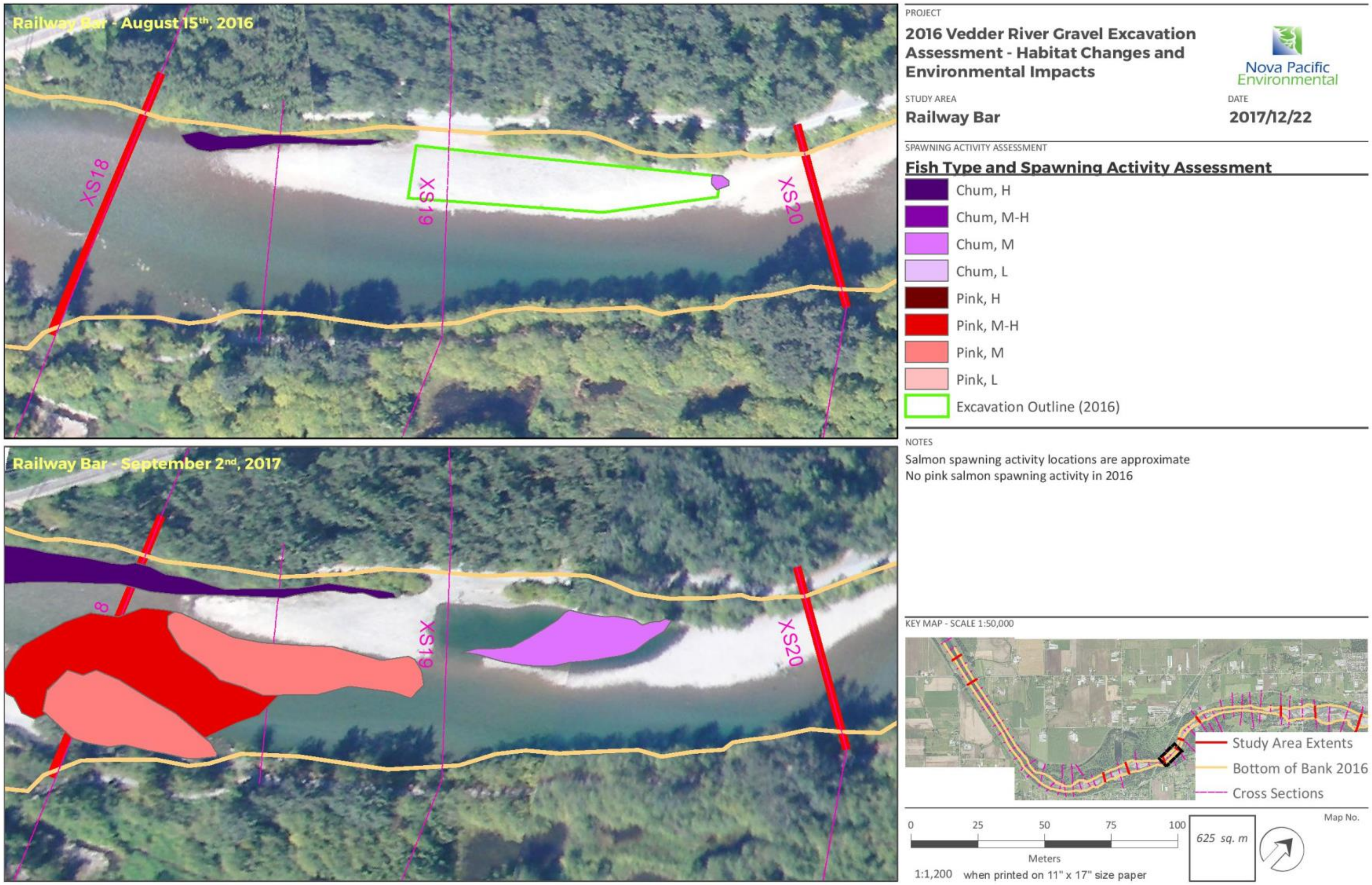


Figure 13: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Railway Bar in 2016 (top) and 2017 (bottom).

3.5 Yarrow Bar (16-13L)

3.5.1 Plan and Implementation

The Yarrow Bar excavation was positioned on the left side of the main channel between XS-13 and XS-12. Figure 14 shows an aerial view of the Yarrow Bar excavation plan. This site is excavated regularly and is just upstream of the area where freeboard limitation is typically an issue. Thus, this excavation served a dual purpose of trapping sediments and contributing to increased floodway capacity in freeboard-limited zone. Previous excavations here have also been effective at mitigating bank erosion concerns downstream by directing flow more centrally within the channel instead of towards the left bank. In order to field fit the key excavation features identified in the original plan, a small modification to the perimeter was required.

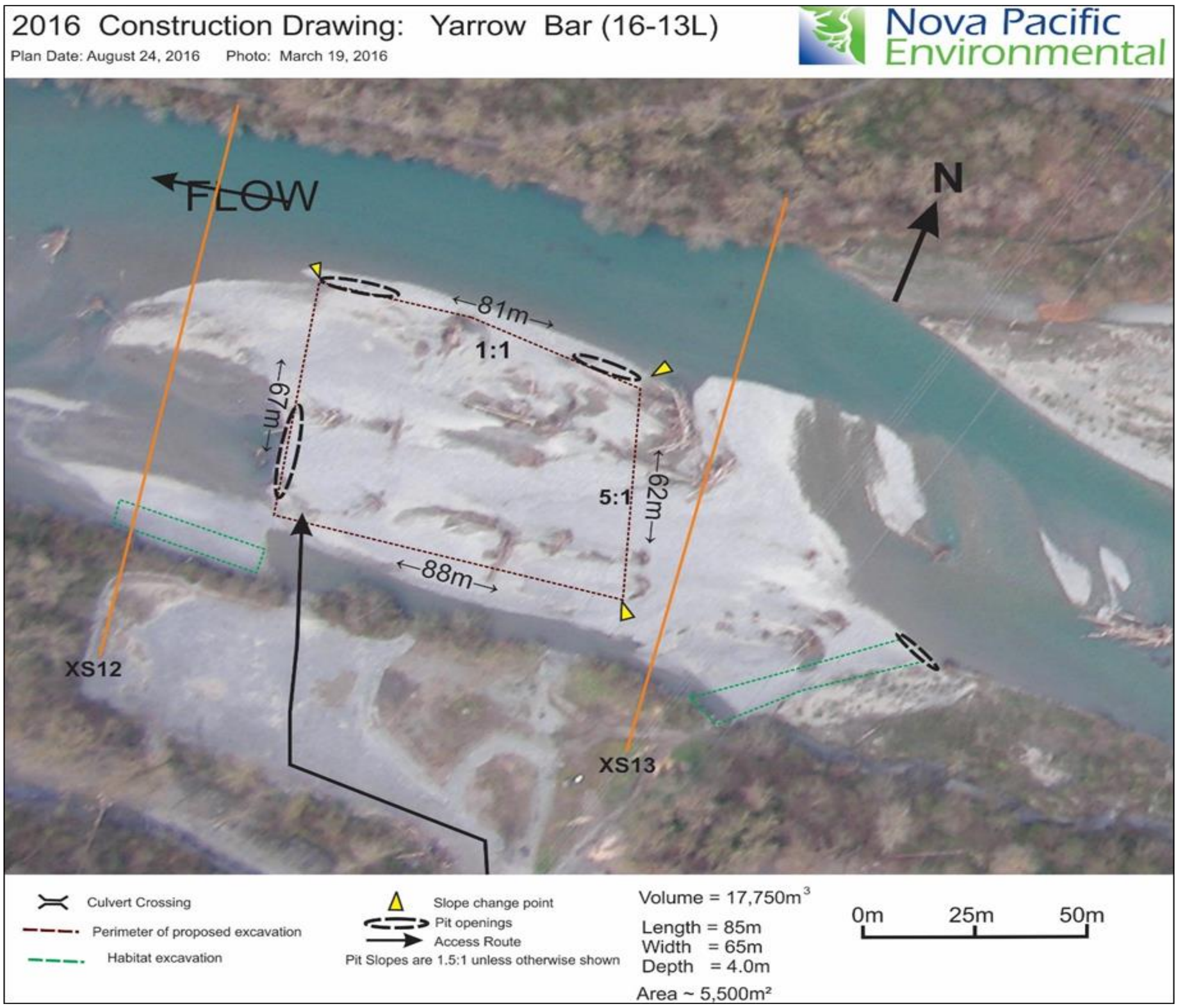


Figure 14: Aerial view of the Yarrow Bar excavation plan. Photo taken March 19, 2016, drawing – August 24, 2016.

3.5.2 Observed Changes

The pit at Yarrow Bar has filled in laterally from the right. The upstream opening has been blocked as the bar upstream of the excavation has extended downstream. The broader area around the bar remains largely unaffected by the excavation with lots of LWD complexing downstream. The split of flow and the glide tail/riffle complex remain.

As noted in the discussion of Lickman Bar above, the relatively high proportion of width to length of this excavation has led to a relatively poor pattern of refilling. Based on this outcome it is recommended that a minimum 2:1 ratio of length to width be considered as a rough guideline for future excavations.

The outlet channel downstream of the excavation is very similar to the pre-excavation conditions. The remnant of the excavation provides a large infiltration pond. In essence, this has created a blind channel with good flow and a large backwater at the upstream end. While this is good habitat for rearing it poses a risk for trapping of returning spawners. No remedial action is required but a post freshet follow-up is recommended.

Offsetting measures implemented at Yarrow Bar excavation area in 2016 included excavation of two habitat channel segments, one upstream and one downstream of the site and placement of seven LWD structures. The habitat channel segments excavated were intended to provide improved connectivity and maintenance of microchannel habitat.

During the assessment of the offsetting measures in 2017 it was found that the upstream habitat channel had no surface flow. There appears to have been some aggrading at the upstream end of this bar and possibly some filling of the channel. Without this surface flow, the downstream habitat excavation was partially dry and had returned to the conditions that were present prior to the excavation. The downstream segment of the channel remains connected to the main flow. Remaining habitat values within this microchannel were similar to pre-existing conditions however six out of seven LWD structures, mostly within the microchannel remained in place.

3.5.3 Habitat Mapping

The assessment area for the Yarrow Bar excavation covered cross sections 11 to 14 (Figure 15). The habitat mapping assessment showed an increase in overall habitat value of 7%. Table 10 indicates the area of each habitat type and the corresponding habitat values calculated for the two study years. Table 11 presents the change in area and habitat value, the percentage change in area, and comments for the different habitat types.

Downstream of the excavation complex shallows, which were the remnant of the 2014 excavation, are smaller in area. As well, as a result of increased flow this complex shallow habitat has converted to secondary channel. Upstream configuration has changed with decreased riffle habitat, more complex shallows as the upstream end of the bar has appeared to be subject to deposition. It also appears the linear pool has lengthened along the head of the bar. These changes would not be a direct effect of the excavation. Finally, the remnant of the excavation provides a large area of backwater habitat.

PROJECT

2016 Vedder River Gravel Excavation Assessment - Habitat Changes and Environmental Impacts

Nova Pacific Environmental

STUDY AREA

Yarrow Bar

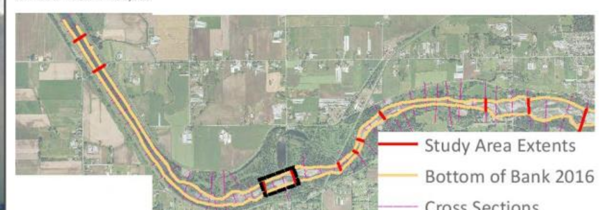
DATE

2018/01/24

HABITAT ANALYSIS

Habitat Type	2016 (m^2)	2017 (m^2)	Δ
Unvegetated Gravel Bar	19,899	19,266	-3%
Vegetated Gravel Bar	6,335	5,281	-17%
Temporary Channel	1,705	2,199	29%
Large Woody Debris	937	870	-7%
Glide/Run	9,598	8,468	-12%
Glide Tail	2,653	2,433	-8%
Glide Edge	786	922	17%
Complex Shallows	3,855	2,987	-23%
Riffle	3,939	2,946	-25%
Habitat Edge	1,256	1,298	3%
Backwater	1,052	3,646	246%
Micro-Channel	775	1,036	34%
Secondary Channel	-	1,132	n/a
Pool	442	749	70%
Excavation Outline (2016)	n/a	n/a	n/a
Total	53,232 m²	53,232 m²	0%

KEY MAP - SCALE 1:50,000



0 30 60 90 120

Meters

1:1,600 when printed on 11" x 17" size paper

1,000 sq. m

Map No.

Figure 15: Habitat mapping of the Yarrow Bar location prior to excavation in 2016 (top) and one year later in 2017 (bottom).

Table 10: Yarrow Bar areas and habitat ratings, 2016-17

Yarrow Bar: Areas and Habitat Ratings 2016-2017 XS 11-14						
Habitat Type	**Area (m^2)**	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
	Pre-Excavation (Aug. 2016)			**Post-Excavation (Sep. 2017)**		
Dry Habitats	28,876	54.2	75,804	27,616	51.9	70,647
Unvegetated Gravel Bars	19,899	37.4	19,899	19,266	36.2	19,266
Vegetated Gravel Bars	6,335	11.9	38,010	5,281	9.9	31,686
Temporary Channel	1,705	3.2	8,525	2,199	4.1	10,995
LWD	937	1.8	9,370	870	1.6	8,700
Wet Habitats	24,356	45.8	157,858	25,616	48.1	178,545
Run & Glide	9,598	18	38,392	8,467	15.9	33,872
Glide Tail	2,653	5.0	21,224	2,433	4.6	19,464
Glide Edge	786	1.5	5,502	922	1.7	6,454
Shallows	3,855	7.2	23,130	2,987	5.6	17,922
Riffle	3,939	7.4	35,451	2,946	5.5	26,514
Habitat Edge	1,256	2.4	11,304	1,298	2.4	11,682
Backwater	1,052	2.0	9,468	3,646	6.8	32,814
Microchannel	775	1.5	8,525	1,036	1.9	11,396
Secondary Channel	0	0	n/a	1,132	2.1	10,188
Pool	442	0.8	4,862	749	1.4	8,239
Total	53,232	100	233,662	53,232	100	251,214
Wetted:Dry Ratio	0.8			0.9		

Table 11: Yarrow Bar changes in areas and habitat ratings, 2016-17

Yarrow Bar: Changes in Area and Habitat Rating 2016-17 XS 11-14						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	-1,260	-4	-5,157	32.4	28.4	
Unvegetated Gravel Bar	-633	-3.2	-633	8.5	7.7	Reduction of unvegetated gravel bar is a result of riffle and complex shallows evident on the bar head and the remnant pool within excavation area
Vegetated Gravel Bar	-1,054	-16.6	-6,324	16.3	12.7	Some loss of vegetation at downstream end of the bar due to erosion
Temporary Channel	494	29	2,470	3.6	4.4	Minor changes in temporary channel configuration
LWD	-67	-7	-670	4.0	3.5	Erosion within the bar removed some LWD
Overall Wet Habitats	1,260	5	20,687	67.6	71.6	
Run & Glide	-1,130	12	-4,520	16.4	13.6	Conversion of some riffle habitat upstream of excavation to glide
Glide Tail	-220	-8	-1,760	9.1	7.8	Minor changes in mapped glide tail habitat
Glide Edge	136	17	952	2.4	2.6	Glide edge appears wider along channel near excavation area
Shallows	-868	-23	-5,208	9.9	7.2	Conversion of complex shallows habitat downstream of excavation to secondary channel offset by increase at head of bar
Riffles	-993	-25	-8,937	15.2	10.6	Conversion of some riffle habitat upstream of excavation to glide
Habitat Edge	42	3	378	4.8	4.7	
Backwater	2,594	246	23,346	4.1	13.2	Backwater habitat at the downstream end of left bank microchannel reduced due to extension of the microchannel
Microchannel	261	34	2,871	3.6	4.6	Expansion of downstream end of bar has effectively extended the microchannel along the left bank
Secondary Channel	1,132	n/a	10,188	n/a	4.1	Gains due to conversion of shallows habitat downstream of excavation
Pool	307	70	3,377	2.1	3.3	Some lengthening of linear pool along upstream end of the bar
Total	0	0	15,530 (+7%)	100	100	

3.5.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 13)

Chum 2016

Spawning of chum salmon was observed within the microchannel along the left bank and along the outer edges of the bar. A few spawners were also observed within the excavation. Sub gravel percolation from the main channel into the excavation remnant as well as in the microchannel/temporary channel along the left bank supports this activity.

Chum 2017

Again chum salmon spawning was observed within the microchannel along the left bank and within the remnant of the excavation. Chum spawning was also noted along the secondary channel immediately downstream of the excavation.

Pink 2017

Pink salmon spawning was observed above the glide tail/riffle sequence upstream and downstream of the excavation. The downstream area provided a significant contiguous area of spawning that extended downstream beyond the end of the study area.

3.5.5 Summary

The 2016 Yarrow Bar excavation, as in 2014, has a persistent remnant of the excavation extending past the first fall freshet. While incomplete filling is not necessarily a concern the closure of the two openings along the thalweg creates risks to spawners. The habitat rating for this excavation while positive (7%) is offset by the risk of stranding and the isolation and incomplete filling of the pit. Accordingly, the overall assessment score is neutral (0).

Two recommendations for the next excavation at this site are to ensure the berm left along the main channel is as narrow as possible and the openings are as deep and wide as possible and secondly to ensure the length to width ratio is at least approaching 2:1.

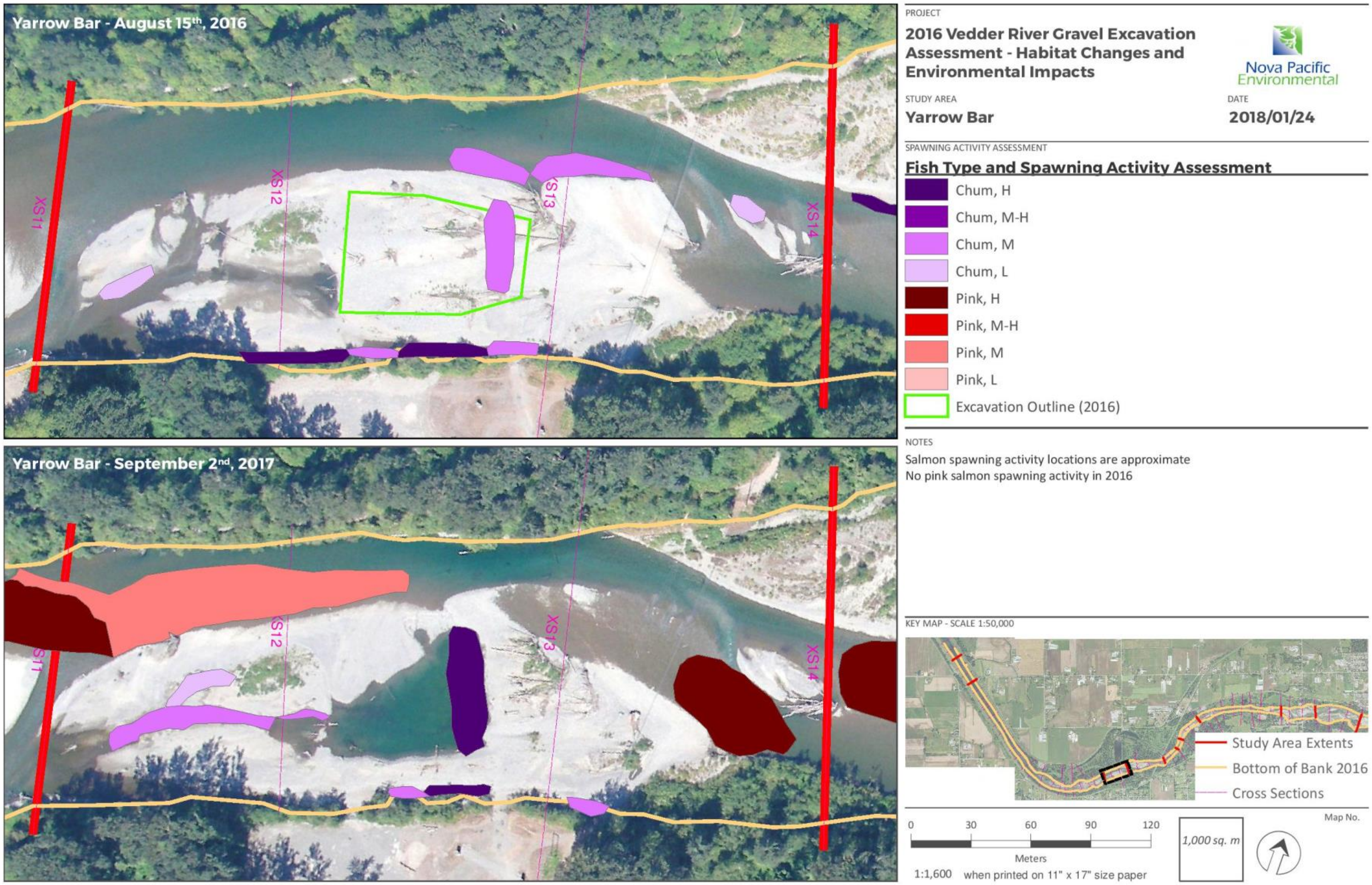


Figure 16: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Yarrow Bar in 2016 (top) and 2017 (bottom).

3.6 Keith Wilson Bar (16-C26R)

3.6.1 Plan and Implementation

The Keith Wilson Bar sediment removal site was located on the right side of the Vedder Canal, approximately 150m downstream of Keith Wilson Bridge. Figure 17 shows an aerial view of the Keith Wilson Bar excavation plan. The main objective of the excavation project was to reduce the risk of dyke overtopping upstream by improving the backwater profile. Habitat benefits were expected from an improved outflow channel for the pump station and from the right bank habitat channel excavation. The site was laid out as originally planned however, the field fit layout was approximately 30m longer than estimated.

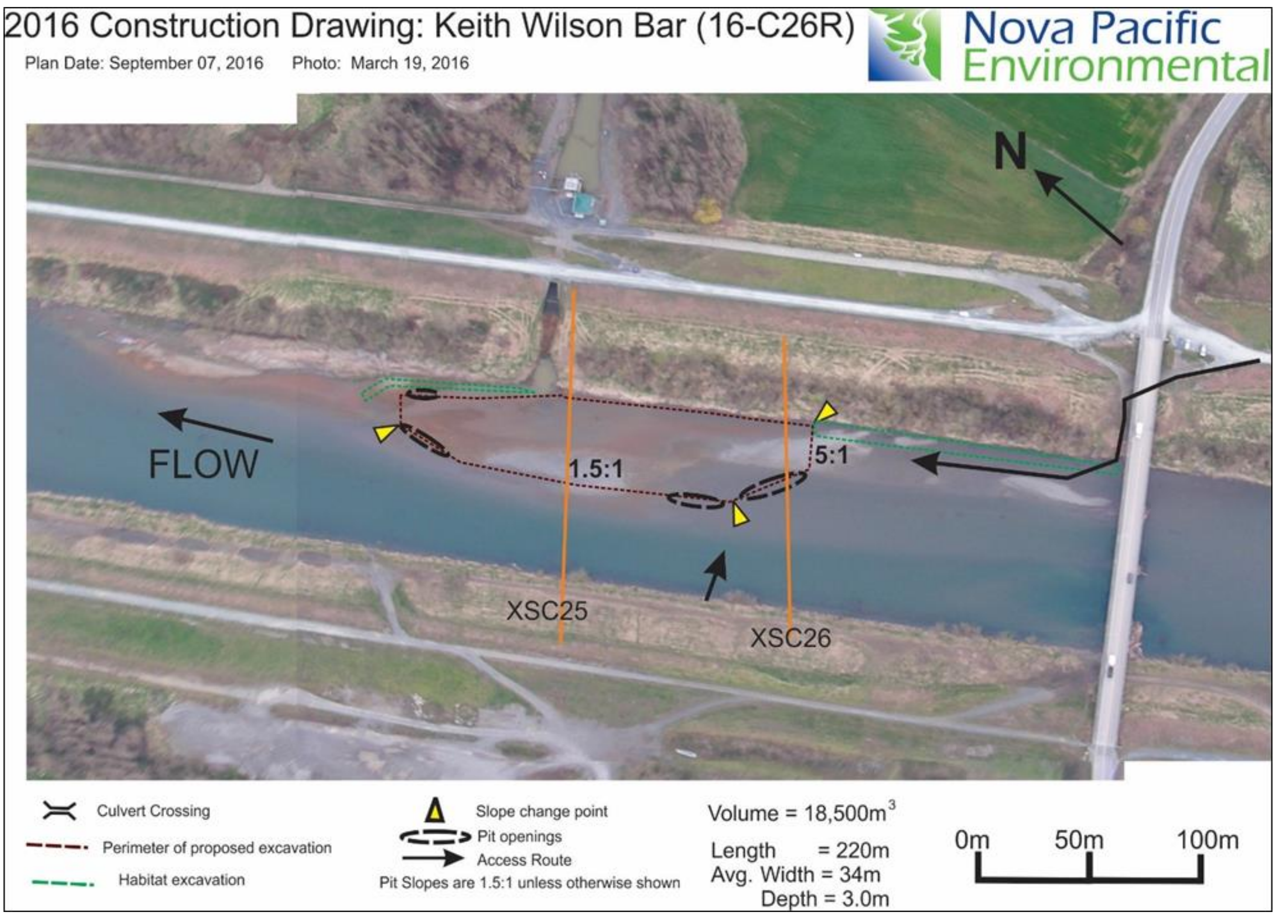


Figure 17: Aerial view of the Keith Wilson Bar excavation plan. Photo taken March 19, 2016, drawing – September 7, 2016.

3.6.2 Observed Changes

The right bank habitat channel excavated at Keith Wilson Bar has good flow and is performing as expected. The pit itself has filled at the upstream end which has led to a closing off of the upstream inlet. The downstream outlet remains deep and wide, so stranding is not an issue and no corrective action is recommended. The outlet channel from the pump station remains open and separate from the pit with the exception of a small gap as excavated originally into the pit proper. Habitat complexity around the site is high, especially the upstream end of the bar where turbulence from the bridge pilings provides a mix of pools, complex shallows and riffles. The remnant of the berm is fairly substantial and is an example of where a thinner berm would provide a better outcome. Achieving a thinner berm at this site would have required a greater risk of excavation containment loss during the excavation.

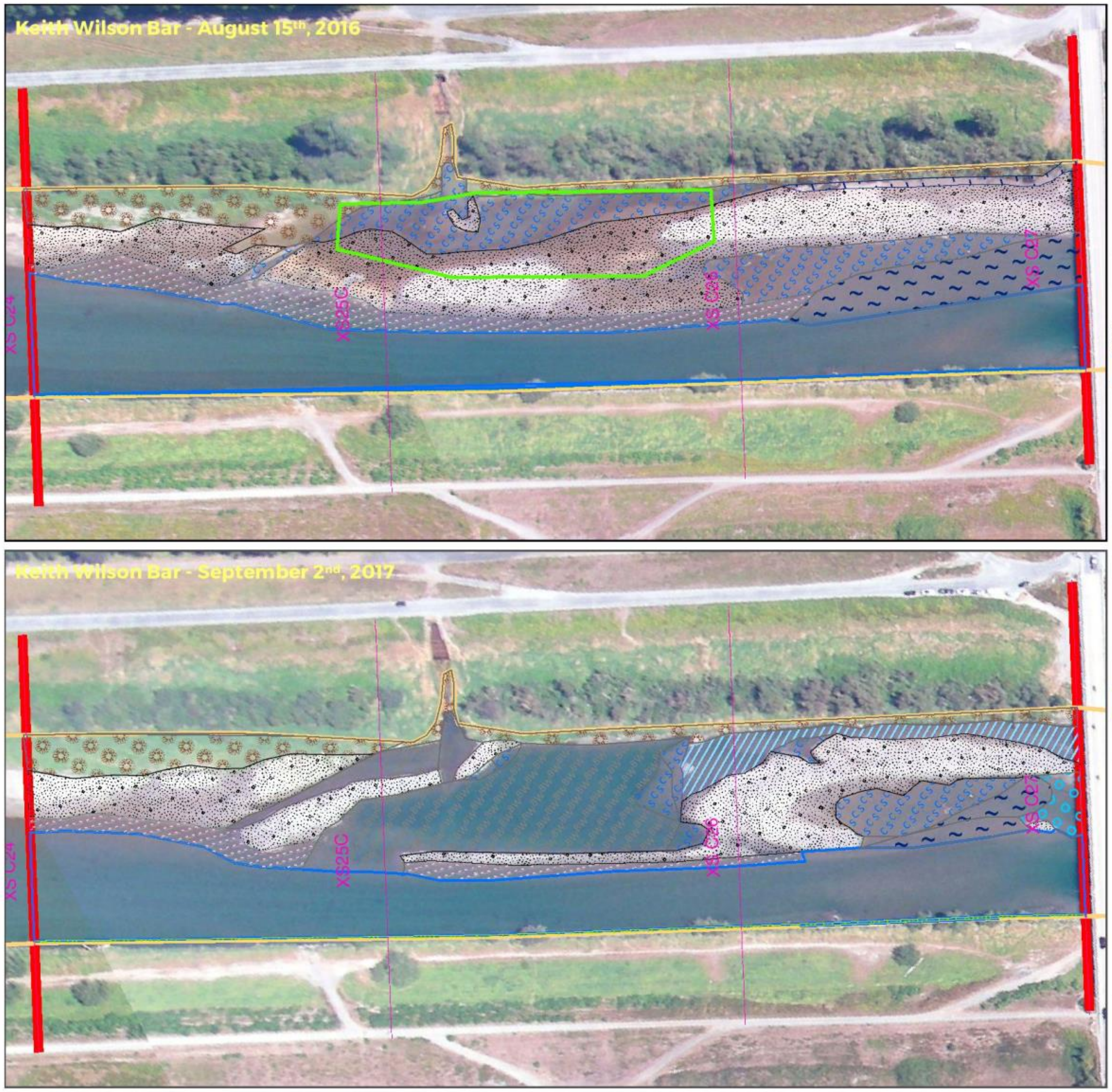
The offsetting implemented at Keith Wilson Bar in 2016 was the enhancement of an existing habitat channel along the right bank. The objectives for this enhancement were to improve flow and maintain edge habitat along the bank.

During the assessment of the offsetting measures in 2017 it was found that the excavated right-bank side channel is functioning as planned and remains connected to substantial surface flow at the upstream end. Discharge is into the remnant of the 2016 excavation.

3.6.3 Habitat Mapping

The assessment area for the Keith Wilson Bar excavation covered cross sections C24 to C27 (Figure 18). The habitat mapping assessment showed an increase in overall habitat value of 14%. Table 12 indicates the area of each habitat type and the corresponding habitat values calculated for the two study years. Table 13 presents the changes in area, percent change and habitat value, by polygon type. Where appropriate, comments on the causes and interactions of those changes for the different habitat types have been included.

The major habitat changes at Keith Wilson Bar include the addition of a large backwater habitat within the excavation area and addition of secondary channel habitat along the right bank upstream of the excavation. Most other mapped changes were upstream of the excavation and are likely associated with the structure of Keith Wilson Bridge rather than the excavation.



PROJECT

2016 Vedder River Gravel Excavation Assessment - Habitat Changes and Environmental Impacts

Nova Pacific Environmental

STUDY AREA

Keith Wilson Bar

DATE

2018/01/24

HABITAT ANALYSIS

Habitat Type	2016 (m²)	2017 (m²)	Δ
Unvegetated Gravel Bar	11,863	8,872	-25%
Vegetated Gravel Bar	3,868	3,551	-8%
Temporary Channel	431	-	-100%
Large Woody Debris	-	-	n/a
Glide/Run	13,641	14,221	4%
Glide Tail	-	-	n/a
Glide Edge	2,909	1,842	-37%
Complex Shallows	4,722	1,979	-58%
Riffle	2,392	922	-61%
Habitat Edge	453	453	0%
Backwater	-	6,436	n/a
Micro-Channel	-	-	n/a
Secondary Channel	-	1,582	n/a
Pool	-	420	n/a
Excavation Outline (2016)	n/a	n/a	n/a
Total	40,279 m²	40,279 m²	0%

KEY MAP - SCALE 1:50,000

Map No.

0 30 60 90 120

Meters

1:1,700 when printed on 11" x 17" size paper

900 sq. m

Figure 18: Habitat mapping of the Keith Wilson Bar location prior to excavation in 2016 (top) and one year later in 2017 (bottom).

Table 12: Keith Wilson Bar areas and habitat ratings, 2016-17

Keith Wilson Bar: Areas and Habitat Ratings 2016-2017 XS C24-C27						
Habitat Type	**Area (m^2)**	**%Total Area**	**Habitat Rating**	**Area (m^2)**	**%Total Area**	**Habitat Rating**
	Pre-Excavation (Aug. 2016)			**Post-Excavation (Sep. 2017)**		
Dry Habitats	16,162	40.1	37,226	12,423	30.8	30,178
Unvegetated Gravel Bars	11,863	29.5	11,863	8,872	22.0	8,872
Vegetated Gravel Bars	3,868	9.6	23,208	3,551	8.8	21,306
Temporary Channel	431	1.0	2,155	0	0	n/a
LWD	0	0	n/a	0	0	n/a
Wet Habitats	24,117	59.9	128,864	27,855	69.2	170,809
Run & Glide	13,641	33.9	54,564	14,221	35.3	56,884
Glide Tail	0	0	n/a	0	0	n/a
Glide Edge	2,909	7.2	20,363	1,842	4.6	12,894
Shallows	4,722	11.7	28,332	1,979	7.2	11,874
Riffle	2,392	5.9	21,528	922	2.3	8,298
Habitat Edge	453	1.1	4,077	453	1.1	4,077
Backwater	0	0	24,849	6,436	13.7	57,924
Microchannel	0	0	n/a	0	0	n/a
Secondary Channel	0	0	n/a	1,582	3.9	14,238
Pool	0	0	n/a	420	1.0	4,620
Total	40,279	100	166,090	40,279	100	200,987
Wetted:Dry Ratio	1.5			2.2		

Table 13: Keith Wilson Bar changes in areas and habitat ratings, 2016-17

Keith Wilson Bar: Changes in Area and Habitat Rating 2016-17 XS C24-C27						
Habitat Type	**Change in area (m^2)**	**Change in area (%)**	**Change in habitat rating**	**% of total value 2016**	**% of total value 2017**	**Comments**
Overall Dry Habitats	-3,739	-23	-7,048	22.4	15.0	
Unvegetated Gravel Bar	-2,991	-25	-2,991	7.1	4.4	Reduction in gravel bar due to backwater habitat within excavation remnant and secondary channel along right bank
Vegetated Gravel Bar	-317	-8	-1,902	14.0	10.6	Reduction of vegetation on the right bank downstream of the excavation
Temporary Channel	-431	-100	-2,155	1.3	n/a	No temporary channels observed during either year within the study area
LWD	n/a	n/a	n/a	n/a	n/a	No LWD observed during either year within the study area
Overall Wet Habitats	3,739	16	41,945	77.6	85.0	
Run & Glide	580	4	2,320	32.9	28.3	Apparent widening of glide upstream of excavation
Glide Tail	n/a	n/a	n/a	n/a	n/a	No glide tail habitat observed during either year within the study area
Glide Edge	-1,067	-37	-7,469	12.3	6.4	Reduction of glide edge at the outflow of excavation area
Shallows	-2,743	-58	-16,458	17.1	5.9	Reduction of complex shallows at upstream end of bar and at outlet of pump station
Riffles	-1,470	-61	-13,230	13.0	4.1	Riffle upstream of excavation reduced due to widening of the glide and possible aggradation of upstream end of bar
Habitat Edge	n/a	n/a	n/a	2.5	2.0	
Backwater	6,436	n/a	57,924	n/a	28.8	Backwater habitat within excavation footprint
Microchannel	n/a	n/a	n/a	n/a	n/a	No microchannels observed during either year within the study area
Secondary Channel	1,582	n/a	14,238	n/a	7.1	Secondary channel created along right bank upstream of excavation
Pool	420	n/a	4,620	n/a	2.3	As above changes at the upstream end of the bar, probably unrelated to the excavation, have resulted in a pool at the upstream end of the study area
Total	0	0	34,897 (+21%)	100	100	

3.6.4 Spawning Assessment

Chum and Pink Salmon Spawning (Figure 13)

Chum 2016

No redds or active spawning of chum salmon was observed at Keith Wilson Bar during the survey conducted in 2016. No carcasses were observed in this area either although active spawning was observed occurring at other bars and areas along the Vedder River at the same time as this survey.

Chum 2017

During the 2017 survey no redds or active spawning of chum salmon was observed at Keith Wilson Bar. although active spawning was observed occurring at other bars and areas along the Vedder River at the same time.

Pink 2017

No pink salmon active spawning or redds was observed at Keith Wilson Bar although a few carcasses were observed. Pink salmon on the Vedder River have been consistently observed to spawn in glide tail areas above riffles and none of this habitat type was observed in the study area.

3.6.5 Summary

The enhancement of the secondary channel along the right bank has provided a significant area of new rearing habitat. The backwater habitat as a remnant of the excavation is of lesser value and much of the gain in habitat rating is due to the replacement of gravel bar habitat with this backwater habitat within the excavation footprint. Changes at the upstream end of the study area, probably not related to the excavation, have decreased riffle and glide edge habitat. While there were small gains in gravel bar and pool habitat, these apparently non-excavation related changes appear to have negatively impacted the habitat rating. Accordingly, while the offsetting measure has been successful the increased value arising from the backwater is lessened

The habitat rating for this excavation is positive (21%) however, the large area of backwater that is a remnant of the excavation offers less habitat value than a natural backwater habitat would. The overall assessment score is positive (+).

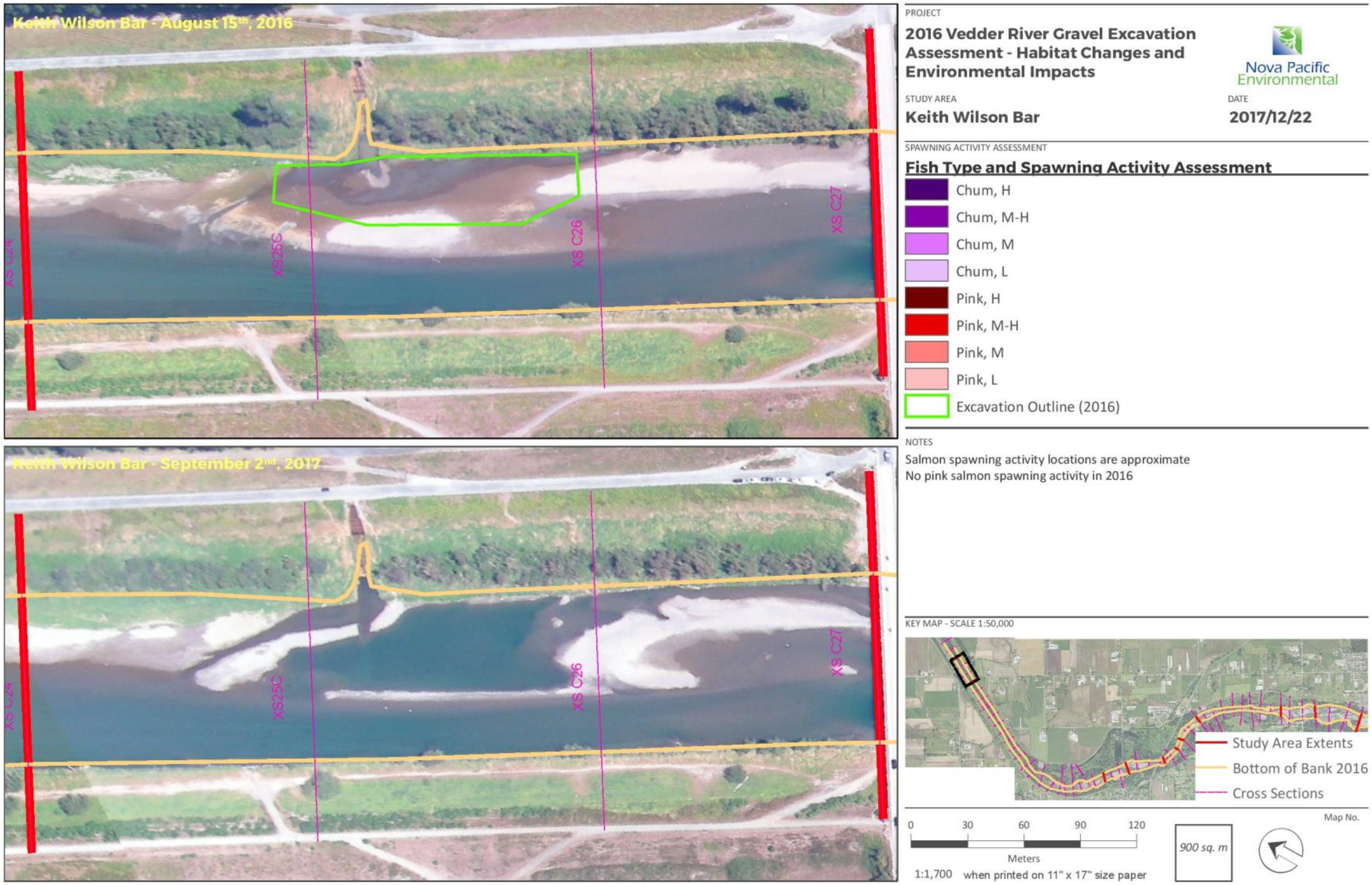


Figure 19: Spawning distribution of Chum Salmon and Pink Salmon in the vicinity of Keith Wilson Bar in 2016 (top) and 2017 (bottom).

3.7 Offsetting

All excavations yielded habitat ratings in 2017 that were neutral or positive. Giesbrecht had a slightly negative rating (-2%) which is still considered neutral based on the study methodology (refer to Section 2.1). This is within normal geomorphic fluctuations and in this case, can be seen to have arisen independent of the excavation. Of the five positive habitat ratings two exceeded 20% in gains thus resulting in an overall habitat gain from the excavations.

A further review of each excavation addressed changes that were not captured by the mapping alone. These changes were used as modifiers to the habitat rating to provide an overall score for each excavation. Overall scores were two neutral, three positive and one strongly positive which again demonstrates an overall gain. To offset any residual losses habitat channels were constructed or enhanced and LWD were placed. A detailed summary of the offsetting measures implementation can be found in the Environmental Monitors Report[2] and the follow-up monitoring is provided in Appendix 4.

Habitat channels were constructed or enhanced at all excavations except Giesbrecht. The habitat channels constructed at Lickman, Bergman and Keith Wilson in 2016 were observed to be functioning as planned in 2017. The channel at Bergman was subject to some filling in the middle section. The upstream section functions effectively with surface and sub-gravel flow while the downstream section functions with sub-gravel flow. The habitat channel at Yarrow was affected by aggradation at the upstream end and was not connected to surface flow and the time of assessment. The downstream portion of this channel which is fed by groundwater was still functioning. The habitat channel at Railway Bar was enhanced and although the upstream portion was dry at the time of assessment, the downstream portion of this channel which is fed by groundwater was still functioning.

Of the 20 LWD features placed in 2016, 10 were present in 2017 providing an overall gain of 10 habitat features. Until now the approach to LWD placement has been informal using as much of the onsite wood resource as possible and creating as many potential LWD features as possible. However, this means that sub-optimal locations and in some cases materials have been employed. An alternative approach with fewer LWD structures in optimal locations might be considered by some as a preferred approach. If it is determined that the objective should be to increase the persistence of these features, then a more careful approach could be taken. This could include clarity under the contractor’s terms of references with respect to LWD placement, provide environmental monitors with time and opportunity to plan and implement these installations, only place LWD at optimal locations and allow limited use of cable to secure pieces of LWD to each other or wooden ballast. This alternative approach would likely result in better persistence but may yield fewer overall LWD features.

[2] Wright, B.F. & Kozlova, T. (2016). 2016 Vedder River Sediment Removal – Environmental Monitors Report. Prepared for the Vedder River Management Area Committee.

3.8 Sediment Analysis

Particle size distribution prior to excavation in 2016 and after excavation in 2017

Surface sediment sampling was used to estimate grain-size parameters in August-September 2016 and September 2017 following a photographic method described in Church et al. (2000)[3]. A number of descriptive parameters were then determined including median size (D_{50}) and two distribution percentiles that indicate the size of the coarse (D_{95}) and fine (D_5) material present (see Table 14). This method is based on the inverse relationship between the size of the stones that occur on a surface and the number of those stones present per unit area. The photographic method has the advantage of rapid data collection over large areas in the field.

Table 14: Particle size distribution before and after excavation in 2016-17

	2016 (before excavation)				2017 (after excavation)			
Location	**D5 (mm)**	**D50 (mm)**	**D95 (mm)**	**Avg (cm^2)**	**D5 (mm)**	**D50 (mm)**	**D95 (mm)**	**Avg (cm^2)**
Giesbrecht Bar	13.11	33.57	71.65	5.64	14.99	47.62	87.82	7.96
Lickman Bar	11.26	28.49	56.53	4.68	14.65	45.66	84.51	7.62
Bergman Bar	11.52	29.90	57.30	4.90	12.04	32.14	61.27	5.28
Railway Bar	12.51	34.68	65.61	5.72	13.57	39.91	74.69	6.62
Yarrow Bar	11.41	29.55	56.63	4.85	10.06	23.37	45.76	3.79
Keith Wilson Bar	6.03	13.10	31.21	2.09	7.04	14.60	31.68	2.33

Commencing in 2008, particle size distribution has been determined at each excavation. Following the 2008 report recommendations, new data has been collected annually since 2010 once prior to excavation and then during the one year follow up monitoring. All data collected since 2010 for the six bars excavated in 2016 is shown on Figure 20. Because the location of excavations changes from year to year there is not a continuous record for all bars excavated in 2016. Generally, it has been observed the gravel size is larger during the follow up monitoring.

Due to flow events during the 2016/17 winter and 2017 spring, most of the gravel bars showed an increase in the average particle size between the 'before' and 'after' excavation data. In 2017 the average size of gravel at all bars increased after freshet except at Yarrow Bar. Bars further upstream (Giesbrecht and Lickman) showed the greatest increase in average particle size and Keith Wilson Bar showed the smallest increase in average particle size.

[3] Church, M., Rempel, L., & Rice, S. (2000). Morphological and Habitat Classification of the Lower Fraser River Gravel-Bed Reach. Submitted to The Fraser Basin Council Suite 1257 – 409 Granville St. Vancouver, British Columbia, V6C 1T2

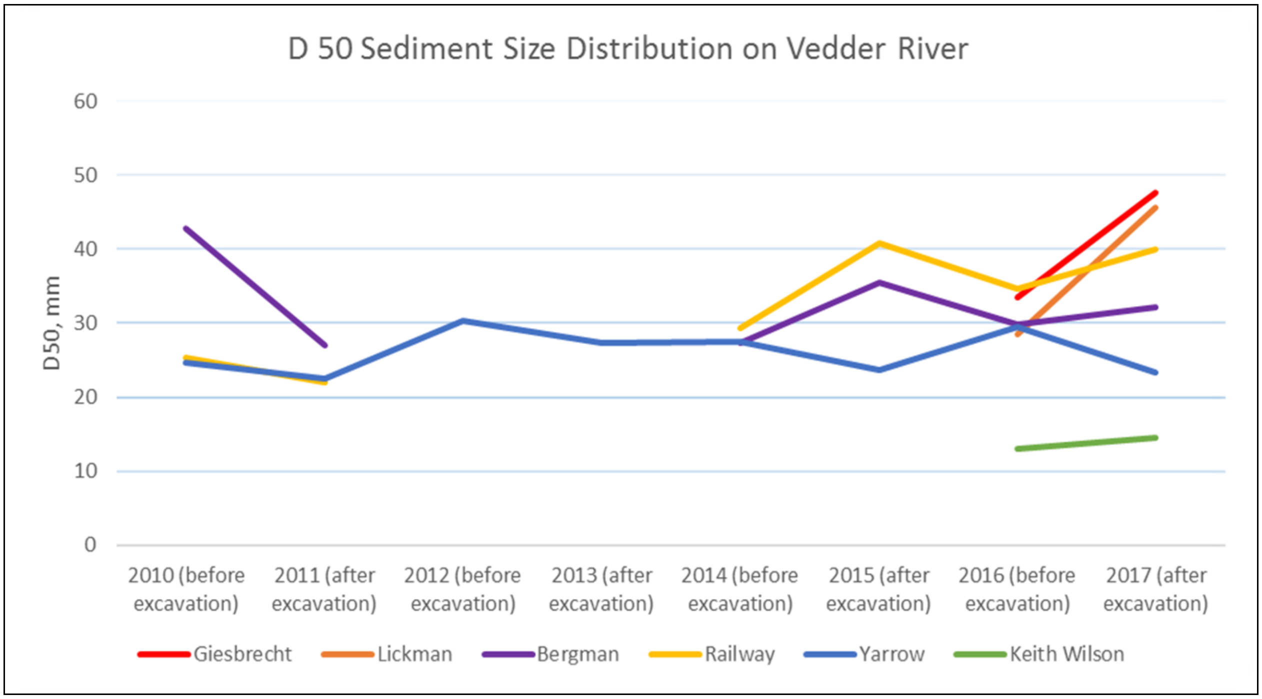


Figure 20: D50 sediment size distribution on Vedder River (2010, 2012, 2014, and 2016 excavations)

Over the eight years that sediment size has been recorded as part of this effort, only Yarrow Bar provides a continuous record of this analysis and thus can be used as a longer-term estimate of particle size deposition change. At Yarrow Bar the average gravel size has not fluctuated more than 10 mm over this period. The data from Railway Bar may indicate a trend to coarser sediments over time while other data could be explained by local geomorphic changes. Additional analysis of all data that includes sites not excavated in this cycle may provide evidence of longer-term change.

4.0 Conclusions and Recommendations

The volume of sediment removed in 2016 was 92,485 m^{3}. This is 88% of the target volume (Table 1). The shortfall is primarily due to the cancellation of D/S Rail Bridge Bar. Because each excavation is ultimately field fit in accordance with key design objectives, some individual excavations exceeded expected volumes.

Site selections and designs included a balance of gravel traps located in the Upper Reach and Middle Reach of the Vedder River, removals from the freeboard deficient area (Lower Reach) and areas that benefit the freeboard deficient section through improved downstream conveyance (Canal Reach). The six sites, listed from upstream to downstream, are presented in Table 15.

Table 15: Summary of assessment areas and habitat changes between 2016 and 2017

Excavation Site	Assessment Area (m^2)	Footprint (m^2)	Ratio (%)	Change in Habitat Rating (%)	Overall Score
Giesbrecht Bar	175,311	7,040	4	-2	+
Lickman Bar	98,828	6,960	7	+2	+
Bergman Bar	34,365	4,185	12	+30	++

Railway Bar	18,043	1,862	10	+11	0
Yarrow Bar	53,232	5,525	10	+7	0
Keith Wilson Bar	40,279	7,480	19	+21	+

Overall scores are strongly positive (+ +), positive (+), neutral (0), negative (-), or strongly negative (- -).

Habitat ratings improved at five of the six excavation sites with only a minor decrease at Giesbrecht Bar. These ratings were subjected to review based upon six modifying characteristics that were not fully reflected by the mapping methodology. A simple overall score has been included to reflect this review. The overall scores included one strongly positive outcome, three positive outcomes, one neutral outcome and one negative outcome. The negative outcome, at Railway Bar, does not reflect a permanent loss of habitat but rather a delay in refilling with associated risk to fish. The strongly positive outcome at Bergman Bar is due to a substantially improved habitat rating plus generally positive modifying characteristics.

Enhancement projects are typically confined to the bar being excavated or adjacent areas and are subject to field fit design modifications as this work can be affected by post-planning freshet changes and the effects of the main excavation on the enhancement project setting. As well, because of the dynamic nature of the river and the frequent interventions necessary to maintain floodway capacity enhancements tend to be simple and non-permanent in nature. For example, LWD placement is always made by keying pieces into the substrate without anchors. Some wash out in the first freshet while others last indefinitely. Habitat enhancement completed in 2016 included LWD placements and enhancement of microchannels.

Giesbrecht Bar enhancements included LWD placements and construction of boulder platforms. Lickman Bar enhancements included construction of a third outlet to provide flow to a secondary channel. At Bergman Bar and Yarrow Bar microchannels were excavated all along the left bank. Railway Bar was enhanced through the restoration of the small channel to downstream habitats. Excavations habitat improvements included placement of LWD typically within the secondary adjacent habitats at all bars except Railway Bar and Keith Wilson Bar. Microchannels proved to be successful including contribution to mapped habitats. Retention of LWD provided mixed results. A full analysis of the success of these offsetting measures is included in Appendix 4.

The study provides habitat comparisons between low flow conditions observed at representative times approximately one year apart. The mapping and habitat comparisons reflect pre-excavation conditions with conditions one year later. It is important to note that changes in habitat at each excavation site are influenced by a wide potential array of natural hydrological conditions over the duration of the year. Excavation design has focused on presenting geomorphological conditions that through careful planning and experience have been found to yield positive habitat outcomes. The influence of the excavation site may include a direct geomorphic change, cause secondary changes by its effect on natural flow and depositional patterns or it may be overwhelmed in the face of large scale natural change. Understanding the relationship between the natural and anthropogenic activities presents a challenge to the interpretation of results and to the ongoing assessment of the program.

Summary List of Recommendations:

1. Ensure the length to width ratio of excavations is at least approaching 2:1 to avoid uneven filling of the excavation.
2. Ensure the berms left along the main channel are as narrow as possible to help ensure that excavations remain open to the main channel.

3. Ensure the openings to the excavations are deep and wide. Typically, this means 15-20 meters in length and a depth similar to the main channel at the limit of the reach of the excavator and sloping down into the pit.
4. At Railway Bar it is recommended that the secondary access be used to ensure the upstream opening is excavated properly and not limited by the requirement for the excavator to return to the main access ramp. Alternatively, if appropriate a narrower excavation with an access route along the inside edge can be used.
5. Consideration should be given to approach the LWD placement.

Appendix 1. Habitat Mapping Methodology

Aerial photography of the entire river for the 2016 base year was completed during a low flow period to maximize the visibility of key habitat features. As the requirement for precise water levels for comparative purposes prevents utilization of orthophotography, photos were taken with a conventional camera, from a plane flown at a consistent altitude. Thus, aerial photography for 2017 was flown at a point in time where water levels and flows where matched as closely as possible to facilitate comparisons between the two years. Aerial photos were georeferenced to the same ground control points (such as monuments, road lines, light standards) which did not change year-to-year. This effort both minimized the effects of lens distortion as well as aligned photo sets from both years to the same ground control (again to facilitate a more precise year-over-year comparison). The air photos were then cropped to remove edge distortion and combined into photo mosaics that could be used for habitat delineation.

Study area edges were defined roughly as the bottom of bank of the 2016 photos. LiDAR from the City of Chilliwack was used to supplement the identification of the toe of the dykes. This edge was then validated through ground-truthing as well as reference photographs taken by field crews. Ground-truthing was completed between mid-August of 2016 and again in September of 2017 to determine the extent of each habitat type.

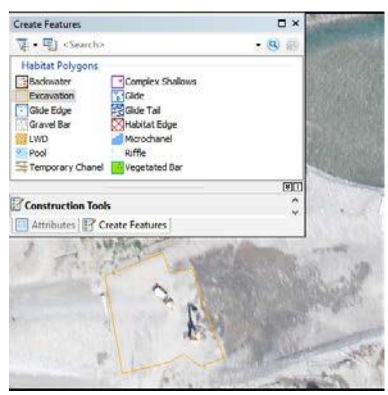
Habitat delineation was completed in a “heads-up” digitization environment (i.e. tracing a mouse over features displayed on a computer monitor which is used as a method of vectorizing air photo data). Polygons were identified using a combination of air photo interpretation and field notes. Where the two appear to disagree, the field notes are taken to be correct. The resulting polygons were assessed for topological errors (i.e. overlapping polygons, or holes between polygons), attribution errors (incorrect habitat identification) and consistency errors (similar habitats should have the same types between sub-reaches and years). Resulting areas by habitat type were totalled by study area and were validated against common rules regarding fluvial hydrogeomorphology (i.e. vegetated areas could not increase dramatically between 2016 and 2017). Resulting areas and habitat polygons were combined into the reference maps presented in this report.

A summary of the habitat delineation process is presented below for reference:

Figure 1 – Control Imagery (30cm)

Figure 2 – Orthorectified Air Photo

Figure 3 – Templated Digitization Environment



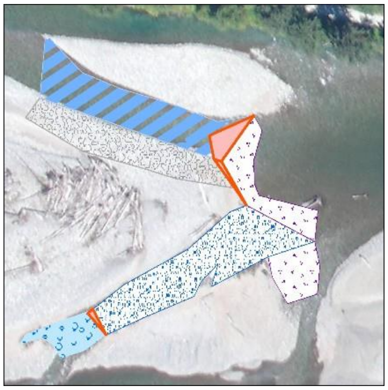


Figure 4 – Habitat Polygons with Data Errors Identified in Red

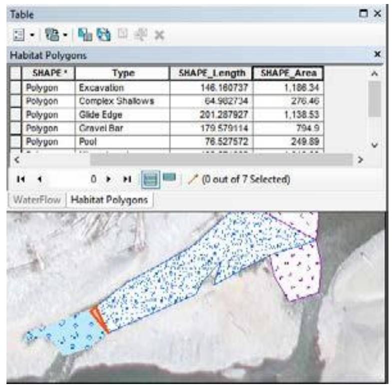


Figure 5 - Area Calculations

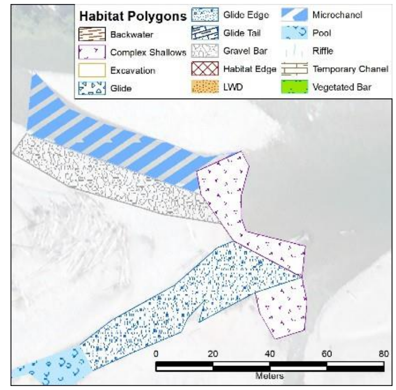


Figure 6 – Sample Figure Output

(1) Download pertinent control imagery and data (Figure 1)
(2) Orthorectify images using a 2nd or 3rd order polynomial transformation (Figure 2)
(3) Develop a templated digitization environment (Figure 3)
(4) Conduct GIS quality control including checks on polygon topology (overlaps, voids etc.) and feature attribution (Figure 4)
(5) Complete area calculations using standard GIS processes (areas are inherent attributes in GIS), as required (Figure 5).
(6) Create summary figures for the area calculations as well as for additional pink and chum spawning activities where required (figure 6).

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Appendix 2. Habitat Types

The habitat types applied during the mapping and assessment are defined according to the following parameters:

Habitat Type	Definition
Unvegetated Gravel Bar	Dry gravel bars with no significant vegetation have little habitat value other than their morphological influence on adjacent habitats. At higher flows, these habitats provide productivity and refugia.
Vegetated Gravel Bar	Dry, vegetated gravel bar areas are those with established perennial vegetation (>2 yrs) covering more than 10% of the bar. They are a source of invertebrate food for fish, provide cover, and eventually contribute LWD. As vegetation matures, it also shades and influences the temperature regime of the river.
Temporary Channel	Distinct channel that may be dry much of the time, but will convey flow when the river discharge exceeds 25m^3/s. A channel which does not convey flow until the river discharge exceeds 100 m^3/s is not placed in this classification as it does not provide the benefits attributed to a temporary channel. A temporary channel will typically flow during the freshet and during periods of heavy rainfall, providing important habitat for rearing salmonids and for aquatic invertebrates.
LWD	Large Woody Debris (LWD) complexes are the highest rated of the “dry” habitat types. The small scale complexity of LWD provides valuable refuge and foraging opportunities for salmon fry, as well as other small fish and invertebrates.
Glide/Run	A glide is fast-flowing, non-turbulent water, deeper than 30cm, usually flowing over relatively flat river bottoms. Runs are fast flowing and slightly turbulent, and for the purpose of this assessment are included in the glide habitat type. Glides and runs typically contain the thalweg and are the primary route for upstream and downstream migration.
Glide Tail	A glide tail is the most downstream limit of a glide, immediately above a riffle. They are usually shallow crescent-shaped areas with laminar flow. These areas have been sub-categorized because of their particular value to food production and to spawning.
Glide Edge	A glide edge is an area adjacent to a glide/run that is less than 30cm deep, and associated with an area of gravel, usually a bar edge. These areas have been sub-categorized because of their particular value to food production.
Complex Shallows	Areas of many riffle channel and small island features or an area of shallow, slow moving water is classified as complex shallows. The expected depth is <50 cm at 25 m^3/s. These areas are important for food production and spawning. A micro-channel or secondary channel with very little depth would be classified as shallows.
Riffle	Riffles are shallow turbulent, fast flowing habitats which form as the flow descends a moderately increased gradient. The well oxygenated riffle is an excellent environment for algal production particularly when there is abundant sunlight. The high primary production and coarse substrate make riffles a valuable habitat for aquatic invertebrate production and juvenile fish. Sub-gravel flow characteristics and the interactions of riffles with pools and glides, has an influence on spawning and feeding behaviour.
Habitat Edge	Habitat edge refers to high complexity river edge habitat. The habitat is characterized by over-hanging vegetation, LWD, and small pools. When mapped, the habitat is assigned a width of 1m where low riparian and/or riprap sits along the bank, 3 m for medium riparian, and 5m for considerably tall or overhanging vegetation and/or shore-based LWD. This habitat type can provide excellent rearing habitat beneath the cover of the overhanging vegetation. The adjacent vegetation also provides opportunity for contribution to the river ecology from an external source. Small pools may also be holding areas for migrating adults.
Backwater	An area that is not isolated from the main channel, but with no significant inflow from upstream. Backwater areas are often deep, with no current through the habitat. Although

Habitat Type	Definition
	temperature and oxygen levels can be a deterrent, a backwater can provide opportunities for food production and for rearing and migrating salmonids.
Micro-channel	A complex, narrow channel that has low flow. Micro-channels have significant cover and/or considerable habitat complexity, while secondary channels do not. Micro-channels are used by spawning and rearing salmonids. The presence of groundwater is an additional benefit since it tends to maintain flow and provide spawning opportunity.
Secondary Channel	A channel that is approximately <1 m deep, contains less than 10% of the total flow of the river, and is flowing when the discharge of the Vedder is $10 m^3/s$ or higher. While a micro-channel provides significant cover and/or considerable habitat complexity, a secondary channel does not. Very shallow secondary channels (less than 30-40 cm) are treated as shallows.
Pool	Relatively slow deep water, with a concave bottom profile. Plunge pools are found at points of heavy flow convergence, usually in the thalweg at the base of a steep riffle. Thalweg pools can be caused either by scouring around or deflection from an obstruction, or be residual effects of earlier topography. Eddy pools can be shallow, against a bank, and circulate opposite to flow (eddy). Pools act as a holding and resting place for migrating and rearing fish.

Appendix 3. Values of Mapped Habitats Categorized According to Relative Contribution

	Primary Production	Food Contribution	Support Migration	Support Spawning	Cover	Rearing Space	**Total Value**
Unvegetated gravel bar	0	0	0	1*	0	0	**1**
Vegetated gravel bar	2	2	0	0	2	0	**6**
LWD	1	1	1	0	3	3	**10**
Glide or Run	0	0	1	1	1	1	**4**
Glide Edge	2	2	0	2	0	1	**7**
Glide Tail	2	2	0	3	0	1	**8**
Complex Shallows	2	2	0	1	0	1	**6**
Backwater	1	2	2	0	2	2	**9**
Habitat Edge	1	2	1	1	2	2	**9**
Riffle	2	3	1	1	1	1	**9**
Micro-channel	2	2	1	2	2	2	**11**
Secondary Channel	2	1	1	2	1	2	**9**
Temporary Channel	1	1	1	0	1	1	**5**
Pool	0	2	3	2	2	2	**11**

* - A score of 1 indicates a contribution; 2 indicates an important contribution; 3 indicates a paramount contribution

To provide a basis for comparing pre- and post-excavation conditions, each habitat type is assigned a value from 1 to 11 based on its perceived relative value for salmonids. This assigned value is then multiplied by the area of the given habitat to determine the habitat rating. The habitat ratings are not a measure of absolute habitat value but rather, they provide a quantitative value for comparison of pre and post habitat conditions relative to aspects considered of key importance to fish.

Taken together with the mapping and habitat type classifications, this method provides a consistent and repeatable means to quantify changes in the river following sediment removal activities. Additional interpretation is provided for each instance of sediment removal to ensure that transitory impacts, water levels, and occasional mapping anomalies are considered in the evaluation of each sediment removal site.

Appendix 4. Offsetting Measures Implemented and Follow-up Monitoring

Following the Paragraph 35(2)(b) Fisheries Act Authorization No. 16-HPAC-00518, clause 5.1.1.3, the inspection of the offsetting measures was completed on September 12th and 13th, 2017.

Ground conditions for the area assessed at the time of visit were dry, and it was overcast on the 12th and sunny on the 13th. River discharge at Vedder Crossing was 16 m^3/s. The offsetting measures assessment was conducted along the Vedder River for the gravel bars excavated in September of 2016. The six bars were assessed to determine if there are any functional concerns with the offsetting measures and their survival after major freshets. The inspection found more LWD complexes were still in place in Lower Reach excavations compared to the Upper Reach. Summaries by location are found below.

1: Giesbrecht Bar

G1(a): LWD structure (LWD #G2016-1) placed in scalped pit along the channel-side in 2016 is still. The boulder platform constructed at this location may have contributed to riffle formation. Part of the river now flows through the scalped area. Picture taken on August 13, 2017.

G2(a): LWD structure (LWD #G2016-2) placed in scalped pit along the bank-side is gone. Some other LWD have collected near the area. A platform of boulders created upstream of LWD complex to enhance fish habitat is covered with gravel. Picture taken on August 13, 2017.

G3(a): LWD structure (LWD #G2016-3) placed in scalped pit along the bank-side is gone. A platform of boulders created downstream of LWD complex to enhance fish habitat is covered with gravel. Picture taken on August 13, 2017.

LWD Identifiers and GPS locations

LWD ID	GPS location
G2016-1 (Picture G1(a))	10U 0573714 5438680
G2016-2 (Picture G2(a))	10U 0573799 5438662
G2016-3 (Picture G3(a))	10U 0573772 5438652

Summary

The following offsetting measures were implemented at Giesbrecht Bar excavation area in 2016:

1. Three LWD structures were placed at Giesbrecht Bar excavation area to provide bank complexity. One LWD structure was placed in the excavation along the river side and two were placed along the bank side. Two platforms of boulders were created near the bank-side LWD structures to enhance fish habitat in the area.

During the assessment of the offsetting measures in 2017 it was found that only the LWD structure on the river side remained after spring freshet. The two LWD structures on the bank side were gone and the platforms of boulders were covered with gravel. Interestingly, new LWD was present at the same location of one of the washed out LWD.

2: Lickman Bar

L1(a): LWD structure (LWD#L2016-1) placed along the bank-side of the pit in 2016 is gone. The excavated pit is mostly filled in. Picture taken on August 13, 2017.

L2(a): LWD structure (LWD#L2016-2) placed along the bank-side of the pit upstream of LWD#L2016-1 in 2016 is gone. Picture taken on August 13, 2017.

L3(a): LWD structure (LWD#L2016-3) placed along the bank-side of the pit upstream of LWD#L2016-2 in 2016 is gone. Some LWD are present on top of the bank. Picture taken on August 13, 2017.

L4(a): LWD structure (LWD#L2016-4) placed in microchannel downstream of southwest outlet in 2016 is still in place. Microchannel was dry at the time of the assessment. Picture taken on August 13, 2017.

L5(a): LWD structures (LWD#L2016-5, LWD#L2016-6, and LWD#L2016-7) were placed along excavated habitat channel in 2016. Only LWD#L2016-7 is still in place. Channel attributes have improved as bed gravel has replaced previously sandy substrate. Picture taken on August 13, 2017.

LWD Identifiers and GPS locations

LWD ID	GPS location
L2016-1 (Picture L1(a))	10U 0572489 5438874
L2016-2 (Picture L2(a))	10U 0572500 5438874
L2016-3 (Picture L3(a))	10U 0572514 5438875
L2016-4 (Picture L4(a))	10U 0572466 5438797
L2016-5 (Picture L5(a))	10U 0572460 5438876
L2016-6 (Picture L5(a))	10U 0572448 5438867
L2016-7 (Picture L5(a))	10U 0572428 5438883

Summary

The following offsetting measures were implemented at Lickman Bar excavation area in 2016:

1. Seven LWD structures were placed at Lickman Bar excavation area to provide bank complexity; three LWD structures were placed along the bank side of the excavated pit, three LWD structures were placed along excavated habitat channel, and one LWD structure was placed in microchannel downstream of southwest outlet of the pit, and
2. A habitat channel was constructed downstream of excavation to connect flow from the main channel through the pit to the secondary channel to maintain it flow toward the right bank.

During the assessment of the offsetting measures in 2017 it was found that the only two LWD structures, one placed along excavated habitat channel and the one placed in microchannel, remain. The excavated habitat channel was connected to the main flow at upstream and downstream ends, showed improved substrate and supported spawning.

3: Bergman Bar

B1(a): LWD structures (LWD#B2016-1, LWD#B2016-2, and LWD#B2016-3) placed along left bank habitat channel in 2016 are gone. The habitat channel excavated along the left bank has retained both surface and groundwater flow, has supported spawning and offers a significant gain of rearing habitat. Picture taken on August 12, 2017.

B2(a): The upstream connection of habitat channel to the main flow. Picture taken on August 12, 2017.

B3(a): Downstream the habitat channel connects to the main flow. Note that this section of the main channel is the former excavation footprint. With this flow diverted here the downstream portion of habitat channel (on the left in the distance of this photo) relies on sub-gravel flow for its continuing function. Picture taken on August 12, 2017.

LWD Identifiers and GPS locations

LWD ID	GPS location
B2016-1 (Picture B1(a))	10U 0570619 5438437
B2016-2 (Picture B1(a))	10U 0570625 5438445
B2016-3 (Picture B1(a))	10U 0570727 5438583

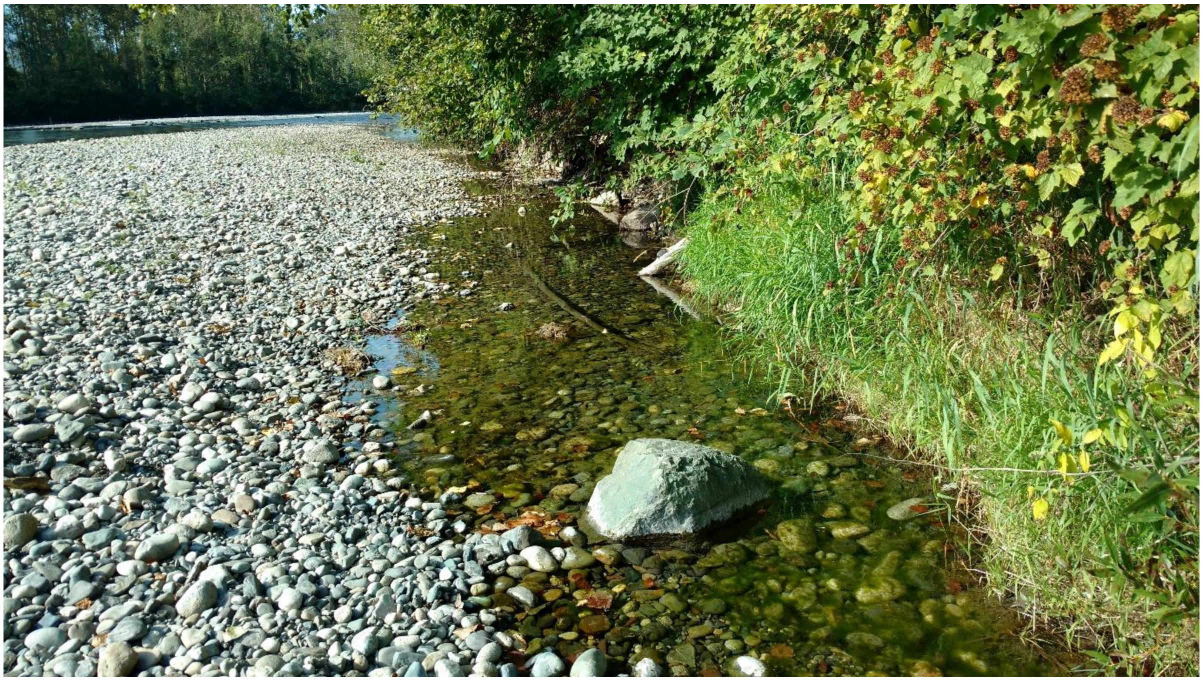
Summary

The following offsetting measures were implemented at Bergman Bar excavation area in 2016:

1. A habitat channel was excavated along the left bank to improve the rearing capacity, provide additional Chum Salmon spawning habitat and reduce the potential for fry stranding, and
2. Three LWD structures were placed along excavated left bank habitat channel.

During the assessment of the offsetting measures in 2017 it was found that the upstream portion of the excavated habitat channel supported spawning and rearing and exhibited both surface and sub-gravel flow. The channel appears to have filled part way along, but the downstream portion is fed by sub-gravel flows and is open to the main channel at the downstream end. All three LWD structures placed along excavated habitat channel were gone. Some other LWD was present in the downstream part of the channel.

4: Railway Bar



R1(a): Right-bank microchannel is groundwater-fed and remains connected to the main channel at downstream end. Picture taken on August 13, 2017.

Summary

The following offsetting measures were implemented at Railway Bar excavation area in 2016:

1. A downstream corner of the pit was excavated along the right bank to maintain habitat values of the microchannel downstream of the excavation and provide a simple enhancement that can be maintained on a regular basis.

The right-bank microchannel remains connected to the main channel at the downstream end and with sufficient sub-gravel flow is functioning as intended. The upstream surface connection to the excavated pit is filled in and dry at current flow conditions but the sub-gravel flow continues.

5: Yarrow Bar

Y1(a): LWD structure (LWD# Y2016-1) placed along the bank side at downstream end of the pit in 2016 is still in place. Picture taken on August 12, 2017.

Y2(a): LWD structure (LWD# Y2016-2) placed downstream of the pit near the third opening in 2016 is still in place. Picture taken on August 12, 2017.


Y3(a): LWD structure (LWD# Y2016-3) placed along left-bank channel downstream of access ramp in 2016 has infilled and this part of the channel was dry at the current low flow conditions. Picture taken on August 12, 2017.


Y4(a): LWD structure (LWD# Y2016-4) placed along left-bank channel downstream of LWD# Y2016-3 in 2016 is in place. Picture taken on August 12, 2017.

Y5(a): LWD structure (LWD# Y2016-5) placed along left-bank channel downstream of LWD# Y2016-4 in 2016 is still in place but some pieces of the structure are gone. Picture taken on August 12, 2017.

Y6(a): LWD structure (LWD# Y2016-6) placed along left-bank channel upstream of access ramp in 2016 is still in place. Picture taken on August 12, 2017.

Y7(a): LWD structure (LWD# Y2016-7) placed along left-bank channel upstream of LWD# Y2016-6 in 2016 is still in place. Picture taken on August 12, 2017.

Y8(a): Habitat channel upstream of the site has partially filled and is dry. Picture taken on August 12, 2017 looking toward the river.

Y9(a): Habitat excavation downstream shows some infilling but still has sub-gravel flow downstream and remains connected to the main channel at the downstream end. Picture taken on August 12, 2017.

LWD Identifiers and GPS locations

LWD ID	GPS location
Y2016-1 (Picture Y1(a))	10U 0569562 5437851
Y2016-2 (Picture Y2(a))	10U 0569546 5437846
Y2016-3 (Picture Y3(a))	10U 0569556 5437835
Y2016-4 (Picture Y4(a))	10U 0569534 5437828
Y2016-5 (Picture Y5(a))	10U 0569521 5437822
Y2016-6 (Picture Y6(a))	10U 0569634 5437865
Y2016-7 (Picture Y7(a))	10U 0569663 5437876

Summary

The following offsetting measures were implemented at Yarrow Bar excavation area in 2016:

1. Two segments of habitat channel were excavated upstream and downstream of the site to improve flows along the left bank, and
2. Seven LWD structures were placed at Yarrow Bar excavation area to provide site complexity; one LWD structure was placed along the bank side at downstream end of the pit, one LWD structure was placed downstream of the pit near the third opening, and five LWD structures were placed along left bank channel.

During the assessment of the offsetting measures in 2017 it was found that there was no surface flow in the upstream habitat channel. The downstream habitat excavation has been partially filled in and returned to the conditions that were present prior to the excavation. The downstream segment of the channel remains connected to the main flow. All seven LWD structures remained in place.

6: Keith Wilson Bar

KW1(a): Excavated right-bank channel remains connected to the main flow, looking downstream from bridge. Picture taken on August 12, 2017.

KW2(a): Upstream view of the right bank channel connected to the main flow. Picture taken on August 12, 2017

Summary

The following offsetting measures were implemented at Keith Wilson Bar excavation area in 2016:

1. A habitat channel along the right bank was excavated to improve flow and maintain edge habitat along the bank.

During the assessment of the offsetting measures in 2017 it was found that the excavated right-bank channel is functioning as planned and remains connected to the main flow at the upstream end and discharges into the remnant of the 2016 excavation.

Appendix 5. Guidelines and Constraints Followed during 2016 Excavations

Since 1994, eighteen guidelines or constraints have been considered in planning each year's excavation. To analyze the efficacy of these guidelines, all past excavations from 1994 to 2010 have been reviewed to see if the guidelines were followed. Correlations have been drawn between successful outcomes and adherence to the guidelines[4].

Table below summarizes how the guidelines were followed during 2016 excavations at Giesbrecht, Lickman, Bergman, Railway, Yarrow, and Keith Wilson bars.

Guidelines	Criteria Adherence 1=yes, 0=no					
	Giesbrecht Bar	Lickman Bar	Bergman Bar	Railway Bar	Yarrow Bar	KW Bar
1. No excavations in pink spawning years in the reach where most pink salmon spawn	1	1	1	1	1	1
2. Avoid excavating in areas of sub-gravel percolation as this may impact chum spawning and water levels in enhanced off-channel habitat	1	1	1	1	1	1
3. Work only in isolation from flowing water	1	1	1	1	1	1
4. Leave the upstream third of bars	0	1	1	1	1	1
5. Adherence to the fisheries windows	1	1	1	1	1	1
6. Avoid digging consecutive bars because of potential interaction between them	1	1	1	1	1	1
7. Excavate channels to replicate natural streambed shape to minimize post-excavation changes	1	0	0	0	0	0
8. Protect areas adjacent to points where secondary channels branch off from the main flow	1	1	1	1	1	1
9. Avoid excavating in areas adjacent to sensitive habitat	1	1	1	1	1	1
10. Avoid digging long pits associated with elevation drops or which can affect long sections of the river	0	1	1	1	1	1
11. Leave gently sloped inside edges on upper end of cuts to prevent head cutting and to leave stable habitat for chum spawners	1	1	1	1	1	1
12. Open the upstream end of deep gravel pits so that headcutting can occur, and to encourage gravel flow into the pits	0	0	0	0	0	0
13. Construct internal, cross channel berms in long pits or where there is a significant elevation drop	0	0	0	0	0	1
14. Leave the downstream ends of bars since this will preserve tailouts which provide rearing and spawning opportunities	1	1	1	1	1	1
15. Ensure riffles are not bypassed by excavation	0	1	1	1	1	1
16. Adjacent dry channels should be deepened and stabilized with flow control structures such as LWD complexes	1	1	1	1	1	1
17. Leave pits with large head differences closed to prevent chum spawning within them or fish trapping	1	1	1	1	1	1
18. Open excavations thoroughly to avoid creating fish traps. Two deep openings adjacent to the main channel should prevent this problem	1	1	1	1	1	1
Number of Criteria Followed	**13**	**15**	**15**	**15**	**15**	**16**
Assessment Outcome (Net Impact)	Positive (+)	Positive (+)	Strongly positive (++)	Neutral (0)	Neutral (0)	Neutral (0)

[4] Vedder River Management Area Plan Update Analysis Report. (2012). Prepared for the Vedder River Management Area Committee. Work in progress.

Appendix 6. 2016 Outcome Summary

Site	Excavation characteristics	Impact Summary	Spawning Effects	Habitat Rating Change*	Number of criteria followed	Guidelines not followed	Outcome (--, -, 0, +, ++)**
Giesbrecht Bar	Scalp excavation Partially refilled.	The scalped area provides a better split in flow which modifies score upward. No loss in habitat value due to excavation.	Some pink salmon were observed spawning but generally salmon spawning is not expected to occur in this section of the river.	-2%	13	4,10,12,13, 15	Positive (+)
Lickman Bar	Deep pit excavation, mostly refilled	Remnant pit connected to both upstream and downstream flow. Glide tail/riffle complex migrated into study area upstream of the pit. Other characteristics have not changed significantly.	Chum spawning abundantly both years including within the pit. Pink salmon were only observed to be spawning in the channel along the left bank.	+2%	15	7,12,13	Positive (+)
Bergman Bar	Deep pit excavation, now has become the thalweg	Split in channel at excavation creates new glide tail/riffle habitat. Excavated microchannel on left bank functions well. Large increase in habitat value.	Chum spawning in microchannel and eddy pool within excavation. Pink spawning upstream and downstream of excavation.	+30%	15	7,12,13	Strongly positive (++)
Railway Bar	Deep pit excavation, partially refilled	Filling has blocked inlet, but outlet still provides a very wide connection. Potential for stranding modifies score downward. Very little change in surrounding area.	Extensive chum spawning in microchannel downstream of excavation and some within pit. Large area of pink spawning downstream of excavation.	+11%	15	7,12,13	Neutral (0)
Yarrow Bar	Deep pit excavation, partially refilled	Filling has blocked inlet but some connection to downstream flow. Potential for stranding modifies score downward.	Chum spawning in microchannel and within pit Extensive pink spawning in main channel along entire bar continuing downstream.	+7%	15	7,12,13	Neutral (0)
Keith Wilson Bar	Deep pit excavation, partially refilled.	Filling has blocked inlet, but outlet still connected to flow. Score modified downward to reflect low habitat value of pit remnant.	No chum or pink salmon spawning observed either year.	+21%	16	7,12	Positive (+)

*Habitat rating change is between 2016 pre-excavation conditions and similar low flow conditions approximately one year later.
**Strongly negative (- -), negative (-), neutral (0), positive (+), strongly positive (++)

Appendix 7. Overall Rating Summary

GIESBRECHT	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)				comments
Habitat Rating from Mapping						-2%	(0)		less than 5% decrease
Habitat Artifact or Anomaly			x				(0)		no anomaly
Stranding Risk			x				(0)		no stranding risk
Spawning Observed			x				(0)		minor pink salmon spawning only
Stability		x					(-)		habitat features subject to elimination as filling continues
Functional Changes				x			(+)		improved split of flow away from armoured right bank
Non-excavation Related Changes					x		(++)		reduction of riffle habitat due to effects upstream of the excavation
						rating	score		
						-2%	(+)		neutral habitat rating with improved flow pattern

LICKMAN	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)				comments
Habitat Rating from Mapping						2%	(0)		less than 5% increase
Habitat Artifact or Anomaly			x				(0)		pit remnant connected at both ends at time of obervation
Stranding Risk			x				(0)		no stranding risk
Spawning Observed				x			(+)		increase in spawning habitat
Stability			x				(0)		no stability issues
Functional Changes				x			(+)		reduced higher flows along left eroding bank
Non-excavation Related Changes		x					(-)		migration of tail/riffle into study area
						rating	score		
						2%	(+)		small habitat rating increase and improved flow pattern

BERGMAN	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)			comments
Habitat Rating from Mapping						30%	(++)	greater than 15% increase
Habitat Artifact or Anomaly			x				(0)	armouring repair on right bank
Stranding Risk			x				(0)	no stranding risk
Spawning Observed		x					(-)	spawning in head of pit
Stability			x				(0)	no stability issues
Functional Changes				x			(+)	new thalweg location
Non-excavation Related Changes			x				(0)	no non-excavation realted changes
						rating	score	
						30%	(++)	large habitat rating increase and new thalweg

RAILWAY	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)			comments
Habitat Rating from Mapping						11%	(+)	increase between 5 and 15%
Habitat Artifact or Anomaly	x						(--)	unfilled pit shows as large backwater
Stranding Risk			x				(0)	no stranding risk
Spawning Observed		x					(-)	some spawning in pit
Stability			x				(0)	no stability issues
Functional Changes			x				(0)	no functional changes
Non-excavation Related Changes			x				(0)	no non-excavation realted changes
						rating	score	
						11%	(0)	revaluing backwater polygon offsets mapped gains

YARROW	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)				comments
Habitat Rating from Mapping						7%	(+)		increase between 5 and 15%
Habitat Artifact or Anomaly			x				(0)		unfilled pit shows as backwater, supports flow to secondary channel
Stranding Risk			x				(0)		despite pit remnant site expected to retain downstream outlet
Spawning Observed		x					(-)		small risk (see comment above)
Stability		x					(-)		unfilled pit
Functional Changes			x				(0)		no functional changes
Non-excavation Related Changes				x			(+)		unrelated filling (or lower water levels)
						rating	score		
						7%	(0)		revaluing backwater polygon offsets mapped gains

KEITH WILSON	strongly negative (--)	negative (-)	neutral (0)	positive (+)	strongly positive (++)				comments
Habitat Rating from Mapping						21%	(++)		greater than 15% increase
Habitat Artifact or Anomaly	x						(--)		unfilled pit shows as large backwater
Stranding Risk			x				(0)		pit remnant is connected at both ends to flow
Spawning Observed			x				(0)		no spawners observed
Stability			x				(0)		typically this site fills slowly
Functional Changes			x				(0)		no functional changes
Non-excavation Related Changes				x			(+)		lower habitat values upstream likely due to lower water
						rating	score		
						21%	(+)		revaluing backwater polygon offsets mapped gains

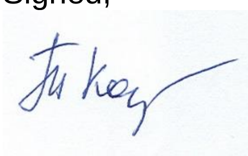
Date and Signature Page

The effective date of this report titled “2016 Vedder River Gravel Excavation-Habitat Changes and Environmental Impacts” is January 8, 2020.

Signed,

Bruce F. Wright, B.Sc. MBA, RPBio

Signed,



Tatiana Kozlova, PhD, RPBio

Signed,

Michael Richard, B.Sc. Geo/Env Sci