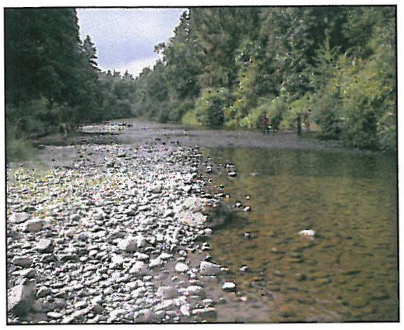

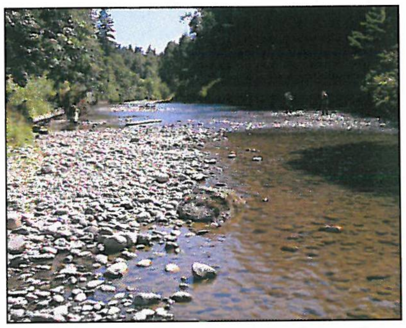

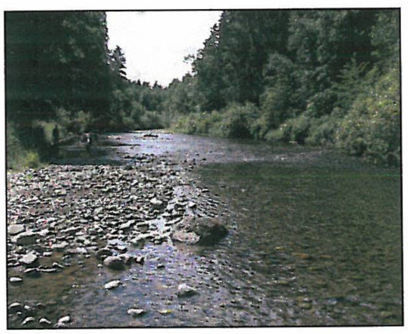

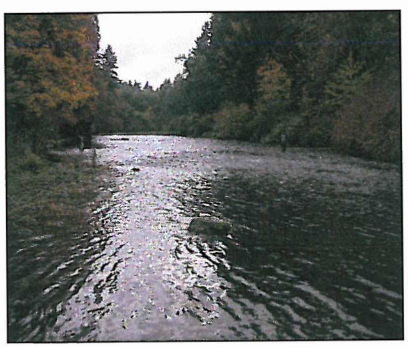

LITTLE QUALICUM RIVER FLOW-HABITAT STUDY 2009

PREPARED FOR
TOWN OF QUALICUM BEACH
MINISTRY OF ENVIRONMENT
FISHERIES & OCEANS CANADA

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MARCH 2010

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1.0 Introduction

1.1 Background

In 2003 the BC Ministry of Environment initiated multi-year feasibility work on a stream flow improvement project for the Little Qualicum River near Qualicum Beach, Vancouver Island. The project examined the existing water storage weir at Cameron Lake (headwaters) and potential downstream benefits to stream-rearing fish of upgrading the facility and increasing the amount of licensed storage.

In 2006 with habitat benefits identified and support of MoE and weir/license owner DFO, BC Conservation Foundation (BCCF) undertook maintenance and upgrades at the weir to re-establish full hydraulic access to existing licensed storage (2,400 ac-ft) and enable efficient summer releases to increase/improve downstream rearing habitat. Upgrades included installation of a low-level gate for incremental releases and an 8-chamber submerged orifice fishway to improve resident fish passage. A storage shed was installed on site in 2007 to accommodate weir supplies, safety equipment and automation instrumentation for the low-level gate.

In 2008, having addressed the provincial application process including all agency requirements and outstanding stakeholder issues, a new water license was issued to DFO for an additional 1,355 ac-ft of conservation storage on Cameron Lake[1]. The weir height was subsequently extended 15 cm and full storage matching total licensed volumes was achieved July 10, 2008. .26 m

1.2 Storage Management

Enhanced storage management is required to realize the full potential of investments to date and maximize rearing period streamflows, habitat conditions and fish production. Though the Cameron weir gate is now remotely operated by staff at the Big Qualicum River Hatchery, operators are challenged to meet flow targets on the lower Little Qualicum River because no hydrometric station currently measures flow there. To date, BCCF staff have manually measured discharge at regular intervals through the flow augmentation season to inform DFO's management of conditions in the Little Qualicum River. Without the ability to monitor stream flows on the lower river, operators risk releasing too much and wasting valuable storage or releasing too little and compromising habitat quality and availability. There is also a reduced ability to take advantage of in-season precipitation and to adaptively manage storage during unusual or extreme climate conditions.

A hydrometric station on the lower Little Qualicum River would enable Cameron Lake weir operators to consistently meet standardized, agency-determined flow targets. Linked to a web-based system, such a station would be able to generate real-time river stage, discharge and water quality data that weir operators could easily monitor and use daily to inform storage management decision-making. In September 2007, BCCF and Water Survey of Canada (WSC) staff briefly toured the lower river and identified a likely station site immediately upstream of District Lot 10 owned by the Town of Qualicum Beach (TQB). Typically client-initiated, WSC-style hydrometric stations can be set up relatively simply, but do require one-time installation and annual maintenance costs of approximately $25,000 and $10-15,000, respectively.

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[1] Conditional water license no. 120794 issued June 16, 2008.

The fisheries agencies (MoE, DFO) are each experiencing budget constraints that make such financial commitments very difficult to achieve, particularly those with recurring annual costs. Though DFO operates the Little Qualicum spawning channel, management is already seeking to reduce costs and run this facility with staff from the Big Qualicum River Hatchery, as much as possible.

While there might be other potential clients for funding a WSC station, the TQB may be the most appropriate. The TQB operates well fields adjacent to the lower river and has a direct community interest in the state of the river's water supply, its habitat and the fish stocks supported by it.

Accordingly, discussions have occurred regarding a possible agreement between DFO and TQB to establish and operate a suitable hydrometric station. In exchange for a reserve on DFO's newly licensed storage at Cameron Lake, TQB would operate the station and commit to habitat mitigation in lieu of losses associated with a domestic water withdrawal on the lower river. Currently, the TQB has no rights on Cameron Lake or the Little Qualicum River, and relies on groundwater wells exclusively. The reserve would afford the TQB rights to a future domestic consumption license based on the new Cameron storage. Extraction would be limited to the lower river only, likely at a location adjacent to the TQB's existing water infrastructure on District Lot 10, so that storage releases would continue to benefit most fish populations (at least 10.3 of the 11.6 km of anadromous mainstem habitat). Based on conservative groundwater production estimates and an ultimate population of 16,000 people in the Qualicum Beach service area, TQB estimates a maximum instantaneous withdrawal rate of 170 l/s might be sought from the Little Qualicum River.

Following meetings in March and May 2009, DFO and MoE advised a study was needed to document changes to habitat quality/quantity at various low flow levels to estimate impacts of potential domestic withdrawal. This report describes the methods used and results of the study which examined habitats in the 855 m reach between the downstream end of TQB's District Lot 10 (DL10) property and tidewater (Highway 19a bridge).

2.0 Methods

To better understand the study area, mesohabitats in the potential diversion reach (PDR) and along side the DL10 property were documented using hip-chain, clinometer, a measuring tape and camera. Channel and wetted perimeter dimensions, depths, slopes and substrates were recorded. Criteria used to classify each mesohabitat type were based on the *Fish Habitat Assessment Procedures* (Johnston and Slaney 1996).

To assess impacts that may result from withdrawals of up to 170 l/s, habitat quantity and quality was documented at several sites and discharges over the range of moderate to low summer flows. A typical range of flows studied for such assessments would include 2.5, 5, 10, 20 and 40% of mean annual discharge[2] (MAD). To focus on the potential impact range and in light of the low probability of discharges less than 10% MAD occurring in this flow-augmented river, the following target flows were selected with support of DFO and MoE:

- 8-10% MAD (0.96-1.20 m^3/s);
- 14-16% MAD (1.68-1.92 m^3/s);
- 18-20% MAD (2.16-2.40 m^3/s); and
- 30-40% MAD (3.60-4.80 m^3/s).

[2] MAD for the Little Qualicum River at the mouth is 12.0 m^3/s (Chilibeck 2004).

These targets were judged to most effectively cover the likely range of summer flows and would allow adequate interpretation to assess impacts to habitat quality and quantity stemming from 170 l/s changes in discharge.

DFO and MoE fisheries staff reviewed the suggested study outline and clarified the type of analysis they wished to see. Of additional interest were instances where, at certain percentages of MAD (e.g., long-term summer targets), streambed benches or gravel bars might become de-watered or habitat feature connectivity might be significantly reduced or eliminated altogether. The reviewers reasoned that should such a scenario be the case, extractions of 170 l/s might be particularly impactful to habitat quantity or quality.

Assessment techniques employed aspects of the instream flow incremental methodology (IFIM; Bovee *et al.* 1997) as well as more recent standardizations in procedures used and metrics assessed (Hatfield *et al.* 2007, Lewis *et al.* 2004). Water depth and velocity data were collected for discharge calculations using recently calibrated Swoffer velocity meters (models 2000 and 3000) and following RIC Standards (Province of BC 2001) for site selection and procedure.

Transects were established in representative riffle, pool and glide habitats selected for sampling in the PDR. Transects were flagged, marked with rebar on both banks and photographed. Channel widths, cover components and substrate criteria (D_{90}, D_{max}) were documented at each transect.

When periodic discharge measurements through the summer season confirmed flows were at target levels, depth and velocity measurements were then taken at a minimum of 20 wetted stations along each riffle transect, and wetted widths were measured at all transects. Riffle site data were subsequently analyzed using BC Hydro WUP-derived habitat suitability index (HSI) curves (Appendix A) to determine site fitness for juvenile fish and generic aquatic insects. Because depths and velocities of pools and glides were generally anticipated to change so little with flow alterations of 170 l/s (R. Ptolemy, MoE, Victoria, pers. comm.), habitat suitability in these mesohabitats was not measured.

Where possible, photo-points were established and upstream, downstream and cross-stream photographs of all transects were taken at each of the four target flows to provide a visual record of how habitat conditions changed with water levels.

3.0 Results

Field data collection occurred between June 6 and October 19, 2009. The summer season in Qualicum Beach was generally drier and hotter than normal[3], with several air temperature records set in late July. With about 70% of normal snowpack on the South Island[4], area stream flows declined quickly in June. Due to operational challenges, full storage at Cameron Lake was not achieved in June as usual. However, lake levels corresponding to the storage rule curve were essentially achieved by July 10 (Appendix B).

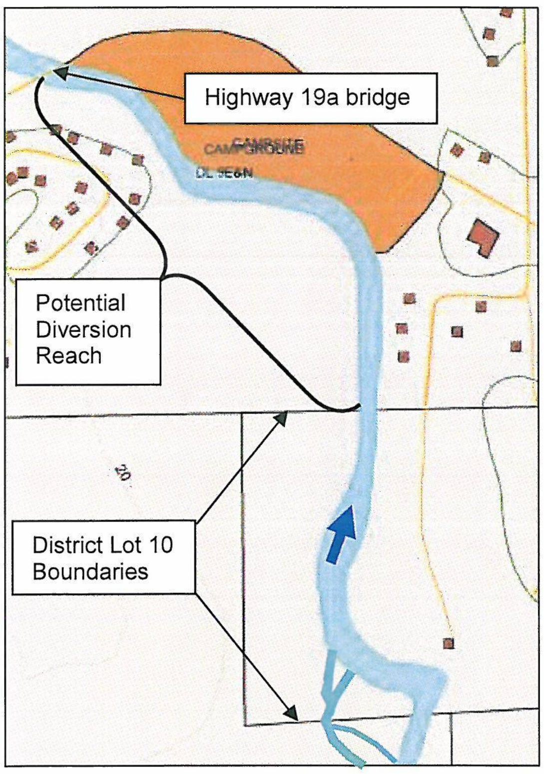
On July 9, mesohabitats in the PDR and the stream section flowing through District Lot 10 (Figure 1) were inventoried (Appendix C). Overall results indicate a relatively even proportion of riffles (38.7%), pools (31.8%) and glides (29.5%). Discharge appeared stable and was measured in the morning, prior to

[3] Monthly precipitation was 16.1, 23.7, 22.1, 42.7 mm for June, July, August and September, respectively, (UVic School-Based Weather Station Network, http://victoriaweather.ca) compared to 1971-2000 mean monthly values of 47.3, 28, 36.9, 51.7 mm (Environment Canada, http://www.climate.weatheroffice.gc.ca/). Mean daily air temperatures from July 25 through August 2 averaged 24.2°C. A maximum air temperature of 35.3°C was recorded on July 28, 2009.

[4] http://www.al.gov.bc.ca/rfc/river_forecast/graphs/spd3b23p.html

the inventory, to be 2.59 m^3/s (21.6%MAD)[5]. Because the inventory occurred at levels slightly greater than base flow, minor changes in mesohabitat composition were expected (and noted) by summer's end. Channel typology was riffle-bar-pool as defined by Johnson and Slaney (1996) and habitat unit gradients ranged from <0.5 to 3.5%. Typically, dominant substrates were gravel, with cobble or sand subdominant. Channel widths averaged 30.5 m (range 22-46 m) while stability was judged to be moderate (eroding banks along cleared private property) to high (rip-rap). Examples of both stable and transient LWD were noted throughout the surveyed reaches. No tributaries entered this reach.

The PDR was defined as that portion of the river that would definitely be affected should any diversion to TQB's infrastructure on DL10 occur, regardless of where the point of diversion was located along the property. Accordingly, the PDR extended from the glide opposite the downstream DL10 property line[6], to the riffle that commenced beneath the Highway 19a bridge (Figure 1). With the exception of one riffle unit split ~50/50 by a mid-channel gravel bar, the PDR was single thread and contained five riffles, five glides and four pools totalling 855 m in length. Tides are known to regularly affect Little Qualicum River water levels up to the Highway 19a bridge, and further upstream in some high flow events. The riffle immediately downstream of the bridge was intentionally included in the PDR to include some assessment of tidal reach habitat.



In contrast, the stream section immediately upstream and flowing through DL10 was 525 m long and contained five riffles and four glides in its primary (historic) channel. This section was defined as extending from the upstream end of the right (east) bank revetments protecting DL10, downstream to the top of the PDR. The four uppermost habitat units (combined length=178 m) in this section were paralleled to the west by ~100 m of natural, braided side-channel that, at the time of survey, was conveying ~65% of total flows. Because of the side-channel's orientation (80° from the mainstem), its multiple entry points (4-5) and its protection (stable log jams at most entrances), it was clear that the primary channel remains the largest conveyor of water during moderate to high flow events. This section also had no tributaries. The presence of a side-channel and relative lack of stability in this section are presumably factors that would influence point of diversion (PoD) location and dictate it be further downstream in the DL10 property.

Figure 1. Overview of the Little Qualicum River study area showing the 855 m PDR and the 525 m section flowing through DL10.

With no real-time gauge measurements with which to coordinate habitat measurements, capturing the four target flow conditions was challenging. The lower three targets were essentially met, with measurements occurring at 11.2, 15.7 and 19.8% MAD. The lowest flow during which habitat measurements were taken, 11.2% MAD (1.343 m^3/s), occurred on August 5, 2009, while the lowest flow measured during the

[5] Throughout the study and on each occasion, discharge was measured within the study area, typically at a hydraulically stable glide or pool tailout, following RIC standards.
[6] On the ground, DL10's downstream property line was assumed to be at the southern end of Waters Road, identified by the fence between the intact forest and the first private home on the river's right (east) bank.

entire season[7] was 9.8% MAD (1.174 m^3/s; occurred August 27). Between successive measurements on June 6 and 17, spring flows on the lower river receded quickly from 57% MAD to 21% MAD, due partly to aggressive storage acquisition by DFO at Cameron Lake. As a result, the fourth target of 30-40% MAD was missed in the early season. Elevated by the eventual onset of fall rains, stream flows rapidly passed the fourth target range, though habitat conditions at a stable 50.2% MAD (6.02 m^3/s) were eventually documented on October 21.

Because only five riffle mesohabitats exist in the PDR below the DL10 property, each one became the site of wetted width and habitat suitability transects (Figure 2; Appendix D, photos 1-40). This "census" approach reduced the need for statistical analysis to compare variation across riffles. Labelled R1 through R5 in a downstream direction, the five riffles were 99, 80, 98, 18 and 36 m in length, totalling 331 m (39%) of the PDR. A mid-channel gravel bar split riffle R3 in two, with roughly equal flow in each channel. Because the right (east) braid was choked with LWD, wetted widths and habitat suitability were only documented in the left hand braid.

Simple wetted width transects were established at two pools and two glides in the PDR (Figure 2; Appendix D, photos 41-88). In one pool 84 m in length, two transects were set up for a total of three sites in pools (P1, P2, P3). Similarly, two transects were set up in one representative glide 82 m in length, for a total of three sites in glides (G1, G2, G3).

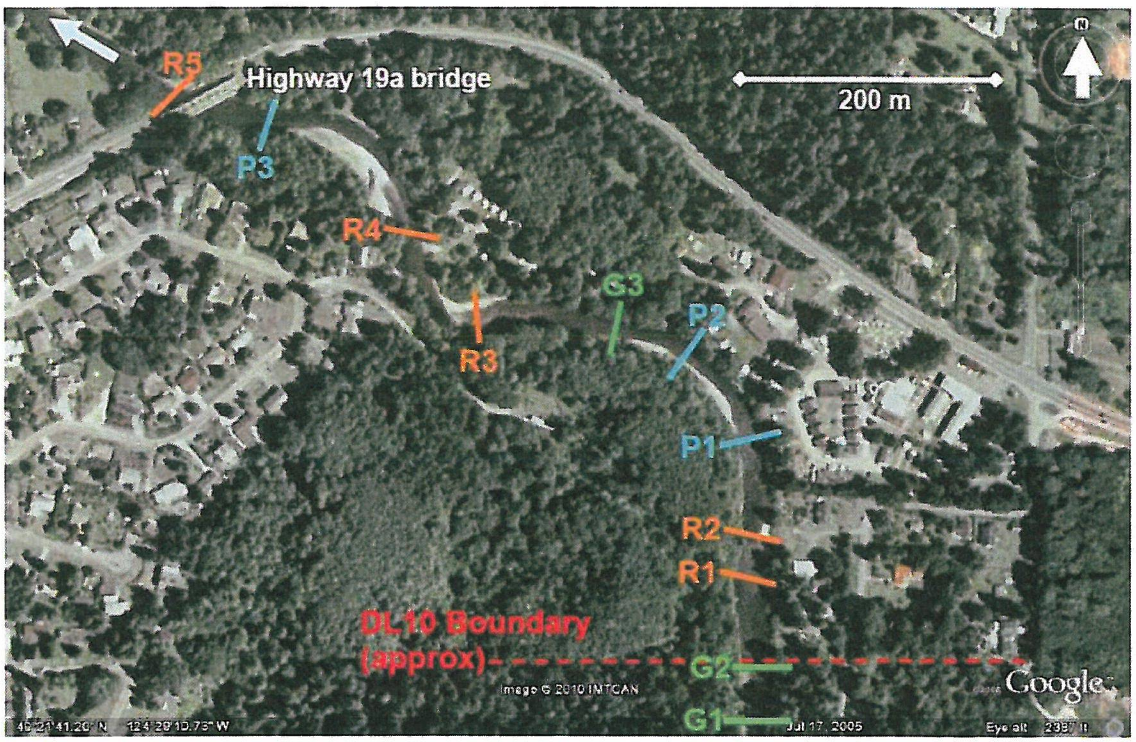


Figure 2. The potential diversion reach in the lower Little Qualicum River, showing riffle, pool and glide mesohabitats studied June to October 2009.

[7] While this was the lowest flow <u>measured</u> during the season, it was also thought to be the lowest flow that <u>occurred</u> during the season, based on adjacent gauged watersheds, observed weather conditions during August and DFO's management of storage and releases at Cameron Lake during the month.

3.1 Wetted Width – Riffles

The degree of change in net wetted widths at each of the five riffle transects varied significantly over the range of flows documented (Figure 3). Change was most significant at riffles R1 and R5, particularly between flows of 19.8%MAD and 11.2%MAD. Situated along a relatively straight section of stream channel and having the lowest gradient of the five riffles, R1 lost the greatest amount of wetted area through the range of flows (Appendix D, photos 1-8). For example, applying habitat unit length data collected July 9 and assuming the R1 transect is representative of the unit as a whole, riffle R1 lost 485 m^2 of wetted area as flows declined from 19.8 to 11.9%MAD, slightly more than the aggregate wetted area lost at the other four riffle sites (Table 1).

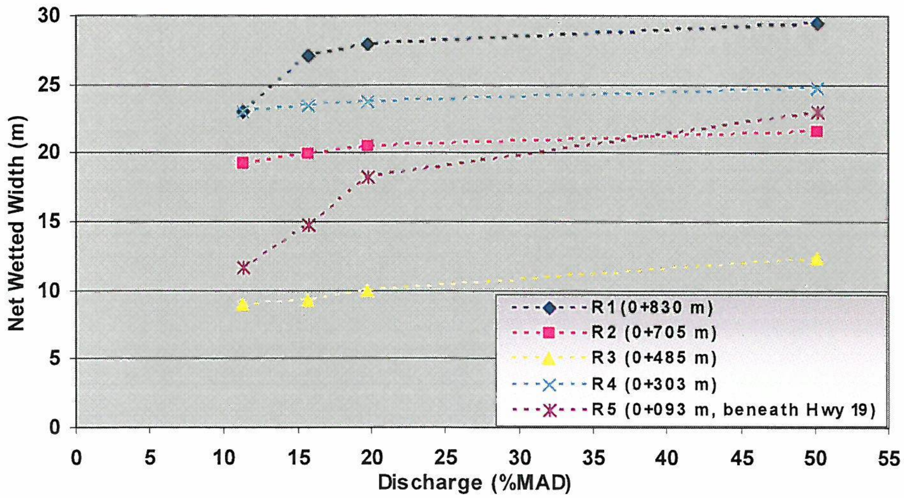


Figure 3. Discharge versus wetted widths at five riffle sites in the PDR.

Fitting a logarithmic curve to wetted width results for the <u>three lowest data sets only</u> (11.2, 15.7 and 19.8%MAD) and calculating area using habitat unit length data, we can predict wetted area losses at PDR riffles individually or in aggregate for reductions in flow of 170 l/s (1.42%MAD), the maximum instantaneous diversion estimated by TQB. While estimates of change associated with flows between 19.8 and 11.2%MAD have a fairly high confidence, predictions of wetted area losses when flows recede below 11.2%MAD would be less reliable because no data were collected in that range in 2009. Theoretically, as discharges decrease toward zero, so would wetted widths in riffles. This is in contrast to pools and glides that can remain largely wetted even with little to no flow through a reach.

Table 1. Available riffle habitat in the potential diversion reach at the four discharges examined.

%MAD	Area (m^2)					
	R1 (98.8 m)	**R2 (79.8 m)**	**R3 (98.9 m)**	**R4 (18.0 m)**	**R5 (35.8 m)**	**Total**
11.2	2,271	1,537	883	415	419	5,525
15.7	2,675	1,585	921	421	524	6,126
19.8	2,756	1,636	991	426	651	6,459
50.2	2,903	1,720	1,226	445	824	7,119

Riffle habitat losses resulting from a 170 l/s diversion when flows are greater than 20%MAD would be less than 121.5 m^2 (e.g., ~35 m^2 lost when flows = 50.2%) and become virtually inconsequential as flows increase from 50 to 100%MAD.

Table 2 shows examples of riffle habitat wetted width losses occurring in the PDR with diversions of 170 l/s. Base flow values are in the range most likely to occur given the system's historic hydrograph and the capacity of new storage at Cameron Lake to augment flows. The examples give scope to the degree of change that might be associated with TQB's estimated peak withdrawal in the potential diversion reach.

Table 2. Riffle area lost in the PDR with diversions of 170 l/s from a range of base flows most likely to occur during summer assuming proper management of Cameron Lake storage.

Base Flow (%MAD)	Base Flow less 170 l/s Diversion (%MAD)	PDR Riffle Area Lost (m^2)
20	18.58	121.5
15	13.58	164.1
12	10.58	207.7

Losses indicated would be the minimum – additional habitats would be impacted depending upon the ultimate location of the point of diversion. These estimates only predict losses downstream of the lowest DL10 boundary line.

For the purposes of examining a drought scenario, we attempted to predict riffle area losses that might occur if, despite storage at Cameron Lake, lower river flows were to recede below 11.2%MAD, to as low as 8%MAD. Extending the log curve (discussed above) toward zero flow acknowledges that as stream flow drops, riffle habitat in the PDR would also shrink to zero. The result (Figure 4) appears logical, with flows less than 5%MAD resulting in riffle habitat losses in excess of 1,000 m^2. Predicted riffle habitat losses in the PDR for 170 l/s diversions when base flows decline from 10 to 8%MAD range from 265 to 399 m^2, respectively.

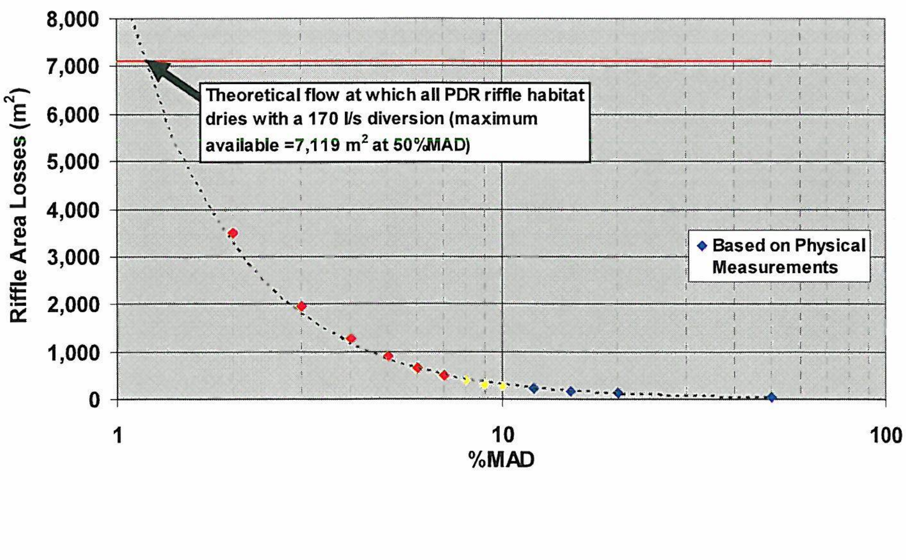


Figure 4. A predicted relationship between flows below 11.2%MAD and riffle habitat losses in the PDR with 170 l/s diversions. Yellow diamonds predict losses of 265 to 399 m^2 as base flows decline from 10 to 8%MAD.

3.2 Wetted Width – Pools & Glides

As stream flow approaches zero, pools and glides would be expected to remain largely wetted. Study results confirmed that as flows decreased on the Little Qualicum River, wetted widths in pools and glides decreased at a much slower rate than riffle mesohabitats and in a linear fashion (Figure 5a/b).

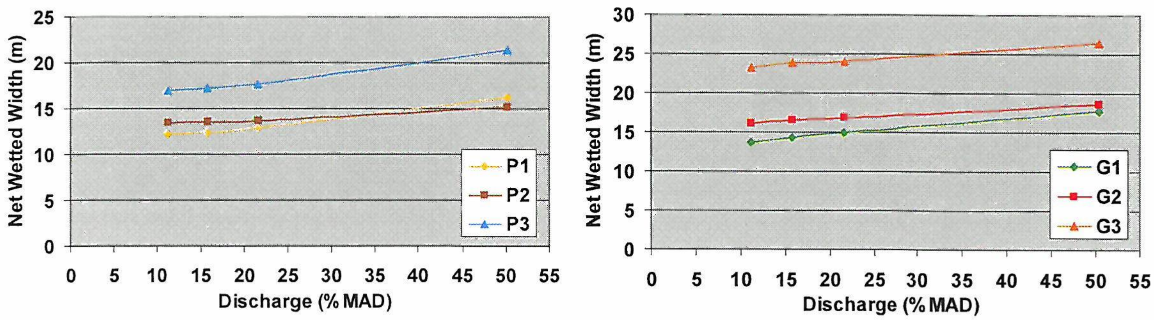


Figure 5a/b. Wetted widths of pools (left) and glides (right) versus discharge in the PDR.

Interpolation is straightforward for changes in pool and glide wetted widths with diversions of 170 l/s when flows are between 11.2 and 50.2%MAD. Trends shown in Figure 5a/b suggest that when stream flow approaches zero (i.e., intersect the y-axis), pools and glides would retain from 10 to 20 m of wetted width, as expected.

Assuming the observed linear relationship of flow versus wetted width for pools and glides continues to zero discharge, we predicted changes that would occur when base flows are less than 11.2%MAD and a 170 l/s diversion takes place. In doing so, we applied the mean rate of change observed at pool transect sites to the two PDR pools not studied. Individual habitat unit length data collected on June 9 (with flows at 21.62%MAD) were then used to generate available pool area and the widths and areas that would be lost with diversion (Table 3). The same procedure was used to assess effects on PDR glides[8].

Table 3. PDR pool and glide parameters and predicted wetted area losses with 170 l/s diversions. Results are applicable for any discharge less than 50%MAD. Shaded losses are for unsampled habitats and were estimated using trends observed in measured habitats.

Habitat Unit	Length (m)	Area when Q=21.62%MAD (m^2)	Habitat Lost with 170 l/s Diversion	
			Wetted Width (m)	Area (m^2)
Pool 0+625	115.8	1,552	0.13	14.5
Pool 0+387 (P1, P2)	84.1	1,430	0.10	8.8
Pool 0+285	16.1	200	0.13	2.0
Pool 0+186 (P3)	55.8	984	0.17	9.3
Glide 0+912 (G1, G2)	82.1	1,305	0.11	9.4
Glide 0+731	26.5	477	0.11	3.0
Glide 0+509 (G3)	24.0	564	0.11	2.6
Glide 0+268	82.4	939	0.11	9.3
Glide 0+130	37.4	804	0.11	4.2
Totals	**524**	**8,255**		**63**

[8] Assumes that the two pools and two glides sampled during the study were representative of the aggregate pools (n=4) and glides (n=5) in the PDR.

At 21.62%MAD the PDR supports an estimated 8,255 m^2 of pool and glide rearing area. With diversions of 170 l/s from any base flow less than 50%MAD, the aggregate loss of pool and glide habitat area in the potential diversion reach was estimated to be 63 m^2. To provide further perspective, this loss ranges from 0.76% of available pool and glide habitat when flows equal 21.62%MAD, to 0.87% of available habitat should flows recede to 8%MAD.

3.3 Habitat Suitability – Riffles

Riffles are known to be the most sensitive mesohabitat with respect to changes in flow. Though stream rearing juveniles are commonly found in pools, growth rates and densities of steelhead and coho are likely correlated with invertebrate production in riffles (Hartman *et al.* 1996). Reiser and Bjornn (1979) described good fish food production areas for juvenile salmonids as "mostly riffles with water depths of 0.15-0.91 m and water velocities of 0.30-0.46 m/s". Both depth and velocity in a riffle must meet species specific threshold values before the habitat functions optimally for a given species. In most BC streams, optimum threshold levels for fish rearing and insect production in most mesohabitats often occur when streams are at or near 20%MAD (Ptolemy and Lewis 2002).

3.3.1 Generic Insects

Depth/velocity transect data collected in 2009 show that as flows decreased from 50%MAD, generic aquatic insect suitability in riffles also decreased (Figure 6). Applying a logarithmic trend line to the data allows interpolation of changes in generic insect suitability within the range of flows studied and predictions of suitability at flows below the lowest discharge documented. Changes appear most severe at flows below 10%MAD.

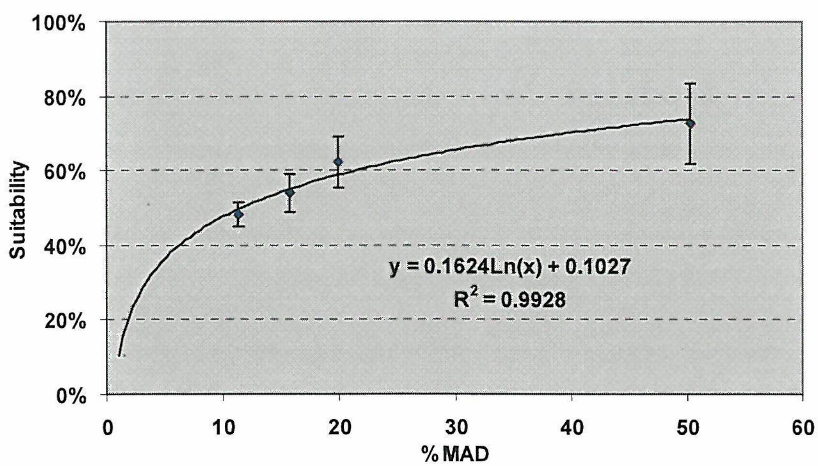


Figure 6. Flow versus mean generic insect suitability (95% C.I.) measured in PDR riffle sites (n=5). The relationship has been extended below 11.2%MAD, the lowest discharge examined during the study.

As would be expected, the trend suggests zero suitability for generic insects in riffles when flows reach zero. Depending on species and how quickly a riffle dries, macro invertebrates would either perish or migrate to other habitats remaining wetted, though many species only thrive in riffles.

Using weighted usable widths[9] and corresponding habitat unit lengths, we estimated losses, expressed as riffle area 100% suitable for generic insects, that would occur with diversions of 170 l/s (Table 4). Required assumptions are that transects established in riffles are representative of the unit as a whole, and that habitat unit lengths measured on June 9 remained constant through declining flows. As with loss estimates generated for simple wetted widths (Section 3.1), estimated losses of riffle area 100% suitable for generic insects would be the minimum – additional habitats would be impacted depending on the location of the point of diversion.

Table 4. PDR losses, expressed as equivalent riffle area 100% suitable for generic insects, with diversions of 170 l/s from a range of base flows most likely to occur during summer.

Base Flow (%MAD)	Base Flow less 170 l/s Diversion (%MAD)	Equivalent riffle area (100% suitable for generic insects) lost (m^2)
20	18.6	122
18	16.6	136
16	14.6	154
14	12.6	177
12	10.6	209
10	8.6	254
8	6.6	324

3.3.2 Rainbow Trout Fry and Parr

For the purposes of reporting, we generically refer to *Oncorhynchus mykiss* juveniles rearing in the Little Qualicum River as "rainbow trout". The vast majority of the river's juvenile rainbow are in fact progeny of wild steelhead trout, the ocean-going version of rainbow trout. As with most Vancouver Island stocks, Little Qualicum River steelhead rear for two to three years before migrating to sea as smolts between April and June. Juveniles less than one year old are called fry, while those with one to three years of rearing are parr.

Observed trends (Figure 7) in riffle habitat suitability for rainbow parr and fry in the PDR were similar to those expected. In the case of parr, mean suitability of the five riffle transects appeared highest when flows were in the range of 15-20%MAD, and declined slightly with higher flows of 50.2%MAD. This trend seemed logical as site mean velocities during the higher flows ranged from 0.72 to 1.36 m/s, values well in excess of those preferred by parr (0.25 to 0.55 m/s according to HSI curves; Appendix A).

[9] Weighted usable widths generated from individual site suitability and corresponding habitat unit wetted widths.

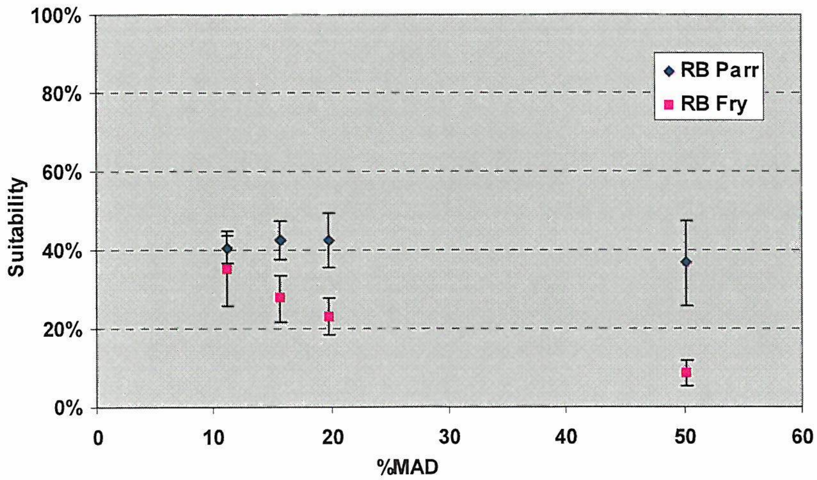


Figure 7. Flow versus mean rainbow parr and fry suitability (95% C.I.) measured in PDR riffle sites (n=5).

Using data only from the lowest three flows documented and assuming suitability trends to zero as flows further decline, we estimated losses, expressed as riffle area 100% suitable for rainbow parr, that would occur with diversions of 170 l/s (Table 5). Required assumptions are similar to those stated previously: that transects established in riffles are representative of the unit as a whole, and that habitat unit lengths measured on June 9 remained constant through declining flows. Additional habitats would be impacted if the point of diversion is located upstream of the lower DL10 boundary.

Table 5. PDR losses, expressed as equivalent riffle area 100% suitable for rainbow parr, with diversions of 170 l/s from a range of base flows most likely to occur during summer.

Base Flow (%MAD)	Base Flow less 170 l/s Diversion (%MAD)	Equivalent riffle area (100% suitable for rainbow parr) lost (m^2)
20	18.6	69
18	16.6	77
16	14.6	87
14	12.6	100
12	10.6	118
10	8.6	143
8	6.6	183

Mean suitability for rainbow fry in PDR riffles declined with higher flows, significantly so as flows reached 50.2%MAD. This reflects the preference of this species/age class for slower velocities ranging from 0.07 to 0.20 m/s. In spite of the trend suggesting habitat fitness for rainbow fry increases as flows recede (Figure 7), suitability would soon peak at a flow between 11.2%MAD and zero, and then decline to zero. Though predicting changes in habitat suitability for flows in this lower range is not possible, we estimated losses that might occur with diversions of 170 l/s within the range of flows measured. Losses, expressed as riffle area 100% suitable for rainbow fry, ranged from 25 m^2 at base flows of 50.2%MAD to 117 m^2 at base flows of 11.2%MAD.

3.3.3 Coho Fry

The vast majority of Little Qualicum coho juveniles spend one year rearing in fresh water before smolting and migrating to sea. The Little Qualicum's stock is not enhanced and essentially wild – a small portion of the Big Qualicum River Hatchery's coho production is known to stray and return as adults to the Little Qualicum.

Compared to rainbow trout, coho fry prefer habitats with much lower velocities. Provided temperature and food supply are not issues, coho fry find pools or glides with velocities of 0.0 to 0.12 m/s 100% suitable (Appendix A). As velocities increase from 0.13 to 0.44 m/s, suitability for coho fry steadily decreases from 100 to 0%. With respect to water column depths, any values in excess of 0.25 m are 100% suitable for coho fry. As depths decrease from 0.25 m, usability also steadily decreases, eventually to zero as habitat dries.

Because riffle mesohabitats are inherently fast, they are generally not suitable for, or preferred by, coho fry. Exceptions are riffle margins at each stream edge where velocities are slowest. As summer flows decline, riffle margin habitat with velocities preferred by coho generally remains constant or increases, until water depth becomes limiting and shrinks available habitat.

Study results confirmed that Little Qualicum River PDR riffles were not well suited for coho fry rearing (Figure 8). As stream flow declined suitability appeared to increase, but not significantly. It is probable that, as flows (and therefore mean velocities) decreased below 11.2%MAD, overall suitability for coho would continue to increase until depth becomes limiting. At 50.2%MAD, mean depths were 100% suitable at three out of five riffle sites. Even at relatively low flows of 11.2%MAD, mean riffle depths remained at least 66% suitable for coho.

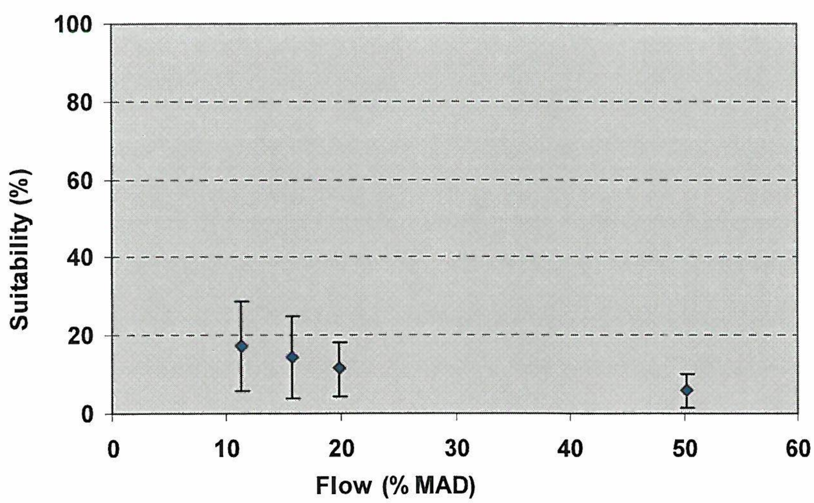


Figure 8. Flow versus mean coho fry suitability (95% C.I.) measured in PDR riffle sites (n=5).

Though riffles are not nearly as suitable for coho fry than are slower pool and glide habitats, their contribution to stream health through food supply production and distribution is significant if not critical. Compared to pool habitats, riffles generally produce greater numbers of aquatic invertebrates (Gippel and Stewardson 1998) and velocities through riffles have been shown to be positively correlated with quantity of invertebrate drift (Stalnaker and Arnette 1976). Riffles also serve to oxygenate the stream flow. Accordingly, diversion related changes described above for riffle wetted area and generic insect suitability (sections 3.1 and 3.3.1) could be used to infer probable changes to coho productivity in the PDR and are likely more significant than measures of suitability for this species in riffle habitats.

3.3.4 Chinook Fry

Little Qualicum Chinook have been enhanced by DFO for decades, with current releases of 2.25 to 2.5 million smolts annually (T. Forrest, DFO, pers. comm.). Though records suggest there were several hundred wild Chinook returning prior to the 1977 Salmon Enhancement Program starting, three decades of hatchery production has essentially created a hatchery run. Released in May, hatchery smolts are generally thought to leave the system by the end of June though no studies have confirmed outmigration timing. Recent snorkel observations, by the primary author, of outplanted Chinook smolts persisting in high numbers through mid-September in the nearby Englishman River suggest that a small portion of hatchery production might rear in freshwater during summer.

From the freshwater habitat suitability perspective, juvenile Chinook have depth and velocity preferences that are very similar to rainbow parr (Appendix A) and would therefore be affected similarly by diversions of 170 l/s. There is virtually no difference between *depths* 100% suitable for Chinook fry and depths preferred by rainbow parr. Though suitability for the two is similar for *velocities* up to 0.33 m/s, Chinook suitability in velocities higher than 0.33 m/s steadily drops from 100 to 20% by 0.86 m/s, while suitability for rainbow parr continues at 100% until velocities reach 0.55 m/s, whereby it then drops to 20% by 1.06 m/s. This lower tolerance by Chinook fry for higher velocities preferred by rainbow parr reflects the species' typical size, which is more similar to rainbow fry (i.e., same age cohort). Accordingly, impacts to PDR riffle suitability for Chinook fry are estimated to be slightly less than those identified for rainbow parr (Figure 7; Table 5) and slightly more than those identified for rainbow fry (Section 3.3.2).

3.4 Potential Diversion Impacts to Specific Channel Habitat Features

Both fisheries agencies expressed interest in whether a particular base flow, or range of flows, existed whereby specific habitat features (e.g., streambed benches, gravel bars, braids, etc.) in the PDR might be particularly impacted with diversions of 170 l/s.

Only one area of concern was identified in the PDR: the secondary braid flowing parallel to riffle site R3. The proportion of total discharge entering this LWD-choked braid varied significantly over the range of flows studied. At 20%MAD, flows were split fairly evenly (Figure 9). However, as flows receded the secondary braid received an increasingly smaller proportion of total discharge. At 11.2%MAD, the braid received little if any flow. Though the secondary braid's riffle areas were mainly dry, a number of large scour pools beneath LWD persisted and offered reasonable pool depth and cover for the braid's juvenile fish.

Figure 9. Panorama looking upstream at riffle R3 (at far right) and the LWD-choked secondary braid (at left) flowing parallel to it. Taken July 9, 2009 at a discharge of 21.6%MAD, the photo shows flows were evenly split between the braids.

This observed drying of the secondary braid over the study period seemed to occur evenly as flows dropped, with no evidence of accelerated de-watering within a particular range of flows.

As no tributaries enter the PDR, there were no tributary connectivity issues identified.

4.0 Summary

- Field work occurred between June 6 and October 19, 2009.
- Under flows of 21.6%MAD (2.59 m^3/s), the 855 m potential diversion reach (PDR) was defined as the portion of river downstream of the lower District Lot 10 (DL10) boundary line and consisted of fourteen mesohabitats: five riffles (39%), four pools (32%) and five glides (29%).
- Immediately upstream of the PDR, the stream section running through DL10 was 525 m long and contained five riffles, four glides and no pools. The uppermost 178 m of this section were paralleled to the west with 100 m of natural side-channel conveying 65% of total flows. The presence of a side-channel and relative lack of stability in this section are presumably factors that would influence the location of a domestic withdrawal, making it more likely to be situated further downstream in DL10, just above the PDR.
- Flows documented during this study were 50.2, 19.8, 15.7 and 11.2% of mean annual discharge, very close to target flows identified in consultation with DFO and MoE. Sites selected for transect analysis were exclusively within the PDR. All five riffle units were studied, as were two pools and two glides. Results were modelled to predict changes that might occur with diversions of 170 l/s from a range of likely base flows.
- Habitat suitability was measured at each riffle site, and wetted widths at all sites. Because depth/velocity of pools and glides were anticipated to change so little with diversions of 170 l/s, suitability of these mesohabitats was not measured. At each target flow, all sites were photographed from photo points looking upstream and downstream.
- Riffle habitat losses resulting from a 170 l/s diversion when flows are greater than 20%MAD were estimated to be no greater than 121.5 m^2 (e.g., ~35 m^2 lost when flows = 50.2%) and become virtually inconsequential as flows increase from 50 to 100%MAD and higher.
- As base flows decline from 20 to 12%MAD, 170 l/s diversions were estimated to result in PDR riffle area losses ranging from 121.5 to 207.7 m^2. Additional habitats upstream of the PDR would be affected depending on where a PoD was located. Should base flows recede to 8%MAD, predicted losses of riffle habitat due to diversion amounted to 400 m^2.
- For any base flow less than 50%MAD, habitat lost in PDR pool and glide habitats with diversions of 170 l/s was estimated to be 63 m^2.
- PDR habitat losses from 170 l/s diversions were identified and expressed as equivalent riffle area 100% suitable for the specific fish species and/or age class being considered (Figure 9).

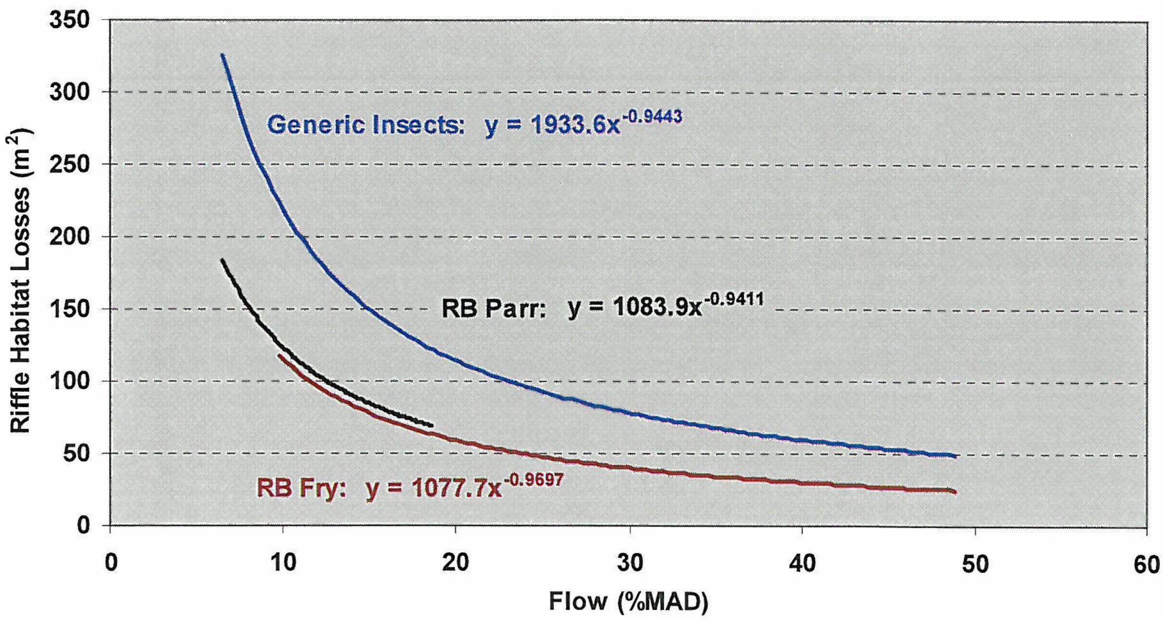


Figure 10. PDR losses, expressed as equivalent riffle area 100% suitable for specific species/age classes, predicted to occur with diversions of 170 l/s. Data showed that suitability for RB parr became less predictable with higher flows of 50.2%MAD. Suitability for RB fry was also less predictable with flows below 11.2%MAD.

- Suitability of PDR riffles for coho fry was very low, as expected. As stream flow declined (and therefore mean velocities), suitability for coho in riffles appeared to increase somewhat (but not significantly), reflecting the species' tendency toward slower habitats. However, as flows recede and velocities decrease, water column depth would eventually become limiting for coho.

- Because Chinook fry preferences are similar to rainbow parr, suitability results for the latter may be used to infer effects of diversion. Impacts to PDR riffle suitability for Chinook fry were estimated to be slightly more than those identified for rainbow fry and slightly less than those identified for rainbow parr.

- No sensitive flow or range of flows were identified at which extraordinary impacts to habitat occurred with diversions of 170 l/s. One site, riffle R3, contained a braid that tended to de-water evenly over the range of flows studied.

5.0 References

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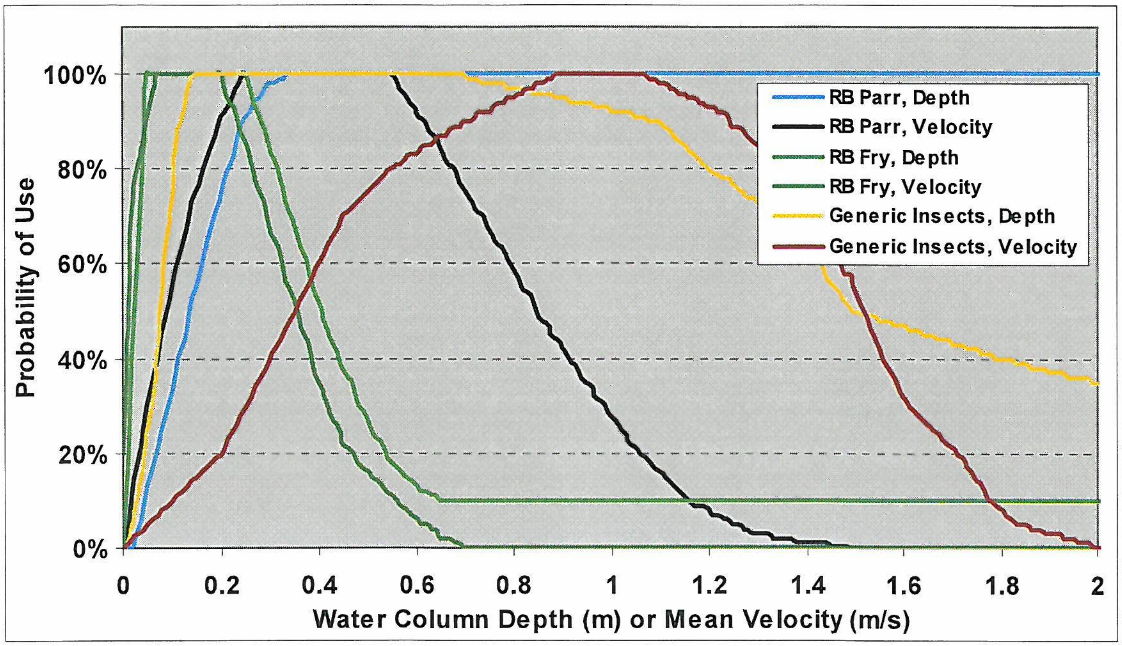
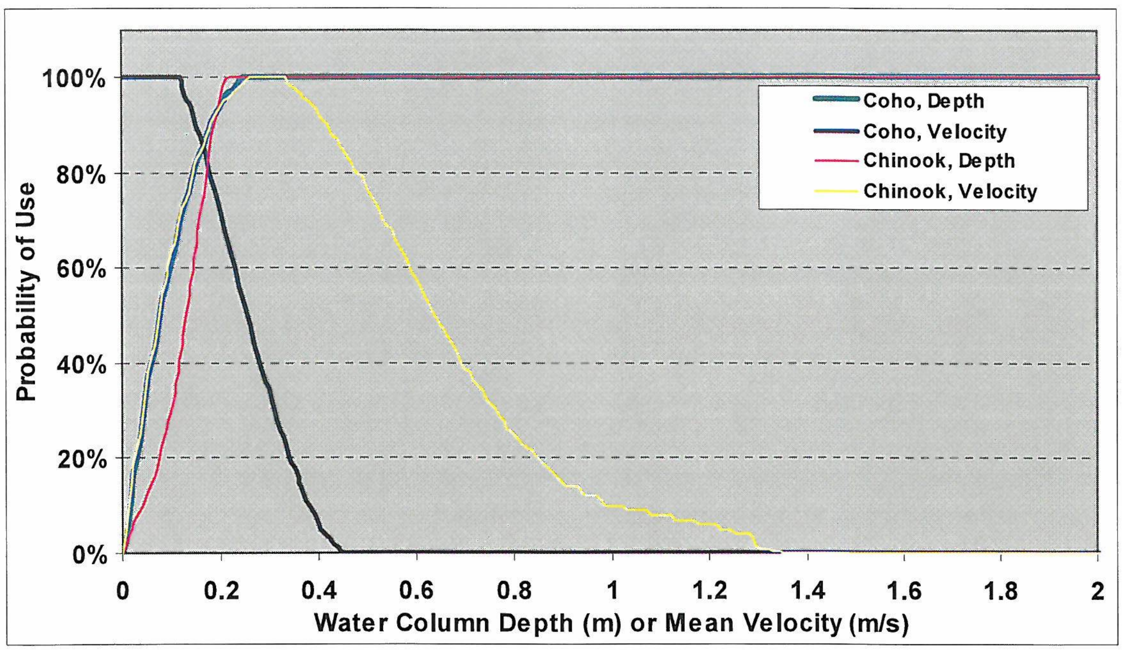
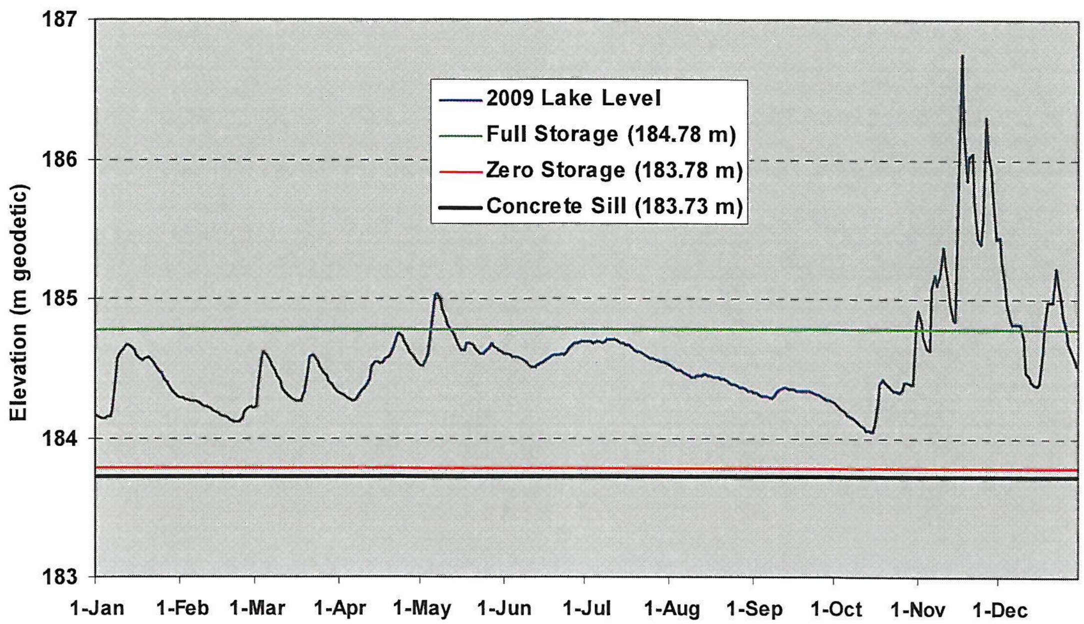
Appendix A. Habitat suitability index curves for rainbow trout (fry and parr) and generic insects (top) and coho and Chinook fry (bottom). Developed for BC Hydro for the Campbell River Water Use Planning process.





Appendix B. Cameron Lake elevation targets and levels, 2009.



Appendix C. Mesohabitats inventoried in the Potential Diversion Reach and in the stream section flowing through DL10.

Stream: Little Qualicum River **Date:** July 9, 2009 **Weather:** Sun & cloud, clearing up

H_2O Temp: 15.7°C @ 0930 h **Air Temp:** 16.3°C @ 0930 h **Discharge:** 2.59 m^3/s (21.6%MAD) **Crew:** MK/JD

Section	Chainage (m)	Hab. Unit Type	Trans. Site #	Unit Length (m)	Unit Grad. (%)	Depths (m)				Bankfull Width (m)	Wetted Width (m)	Substrate		D_{90} (m)	D_{max} (m)	Comments
						1	2	3	mean			Dom.	Sub.			
	0+000	Chainage commenced from a point 93 m downstream of Highway 19a Bridge (tidal influence at time of survey)														
Potential Diversion Reach	0+058	G		57.5		0.40	0.60	0.70	0.57	36.0	21.5	Cobble	Gravel			Survey started 5 m u/s of lowest riffle showing at moderate tide.
Potential Diversion Reach	0+093	R	R5	35.8	2	0.50	0.35	0.35	0.40	37.0	21.0	Gravel	Sand	0.16	1.10	Riffle ends under the hwy 19a bridge, end of tidal influence. Rip rap on LB.
Potential Diversion Reach	0+131	G	G1	37.4	0.5	0.60	0.55	0.55	0.57	29.0	21.5	Gravel	Sand			
Potential Diversion Reach	0+187	P	P3	55.8		2+			2+		17.6	Sand	Gravel			Large downed tree crosses the river, pool up to large rootwad
Potential Diversion Reach	0+269	G		82.4	1	1.10	0.60	0.45	0.72	36.0	11.4	Gravel	Sand			Gravel bar on LB, adjacent lowermost campsites, some fast water at top
Potential Diversion Reach	0+285	P		16.1		1.20	1.00	1.10	1.10	31.0	12.4	Gravel	Sand			Small pool directly after R4
Potential Diversion Reach	0+303	R	R4	18.0	3.5	0.15	0.10	0.20	0.15	36.0	23.0	Gravel	Cobble	0.16	0.25	
Potential Diversion Reach	0+387	P	P1, P2	84.1	1	1.10	1.30	2+	1.47	29.0	17.0	Gravel	Sand			Shallow zone in middle but defined as one large pool, gravel bar on RB.
Potential Diversion Reach	0+485	R	R3	98.3	2	0.30	0.25	0.32	0.29	39.0	21.5	Gravel	Cobble	0.14	0.25	Riffle braided, with RB (east) braid full of LWD
Potential Diversion Reach	0+509	G	G3	24.0	<0.5	0.55	0.90	0.27	0.57	25.0	23.5	Gravel	Sand			Adjacent to rip rap & campground
Potential Diversion Reach	0+625	P		115.8		1.18	1.40	1.50	1.36	26.0	13.4	Gravel	Sand			Large pool, close to glide characteristics
Potential Diversion Reach	0+705	R	R2	79.8	2.5	0.20	0.32	0.25	0.26	25.5	22.5	Gravel	Cobble	0.15	0.40	Lower end at Dashwood intake, upper end adjacent to cement stairs on RB
Potential Diversion Reach	0+732	G		26.5	<0.5	0.65	0.75	0.90	0.77	27.0	18.0	Gravel	Cobble			
Potential Diversion Reach	0+830	R	R1	98.8	1.5	0.15	0.35	0.22	0.24	27.0	25.0	Gravel	Cobble	0.12	0.31	
Potential Diversion Reach	0+912	G	G1, G2	82.1	1	0.52	1.15	0.55	0.74	31.0	13.0	Gravel	Cobble			U/S extent is at the bottom boundary of the DL10 property
Section Thru DL10	0+937	R		25.0	3.5	0.35	0.50	0.75	0.53	23.0	13.8	Cobble	Gravel			Confined riffle above typical Q-site
Section Thru DL10	1+102	G		164.9	1	0.55	0.67	0.70	0.64	32.0	12.5	Gravel	Cobble			Alternative Q-site under the large cedar
Section Thru DL10	1+114	R		12.1	1.5	0.25	0.25	0.17	0.22	46.0	17.4	Gravel	Cobble			Extends from the glide below to the windfalls over the river
Section Thru DL10	1+211	G		96.9	<0.5	1.10	1.15	0.80	1.02	43.0	12.5	Gravel	Cobble			
Section Thru DL10	1+258	R		46.8	2	0.45	0.30	0.42	0.39	29.0	8.7	Gravel	Cobble			Two side-channel braids (65% of total flows) join mainstem here.
Section Thru DL10	1+295	G		36.9	1	1.10	0.80	0.45	0.78	22.0	10.0	Gravel	Cobble			
Section Thru DL10	1+328	R		33.5	2	0.40	0.43	0.40	0.41	23.0	5.6	Gravel	Cobble			
Section Thru DL10	1+393	G		64.5	<0.5	0.45	1.10	1.00	0.85	22.0	13.0	Cobble	Gravel			Adjacent "TQB Corner" revetments
Section Thru DL10	1+438	R		45.1	3	0.15	0.20	0.15	0.17	28.0	16.0	Gravel	Boulder			Adjacent "TQB Corner" revetments, survey ends at uppermost rip rap

Appendix D. Photo Documentation.


Photo 1. 11.2% MAD – Riffle 1 LDS

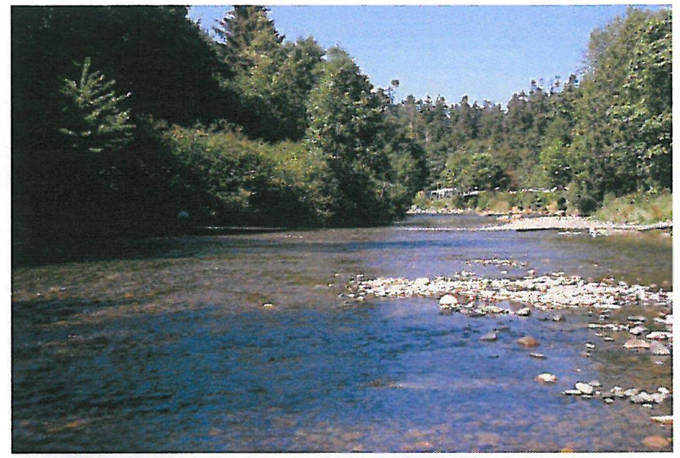


Photo 2. 15.7% MAD – Riffle 1 LDS

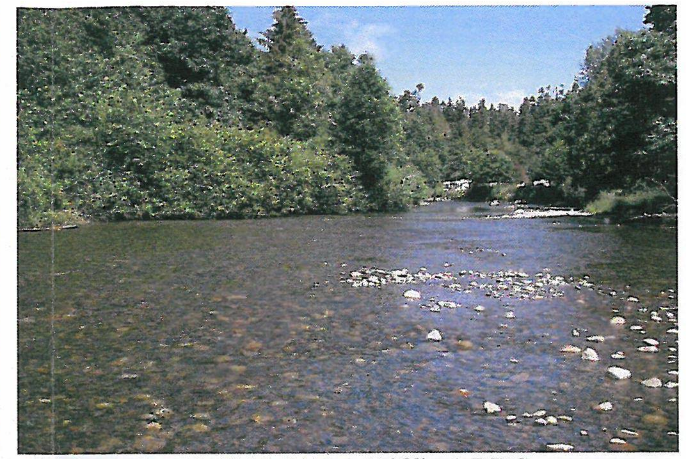


Photo 3. 19.8% MAD – Riffle 1 LDS


Photo 4. 50.2% MAD – Riffle 1 LDS

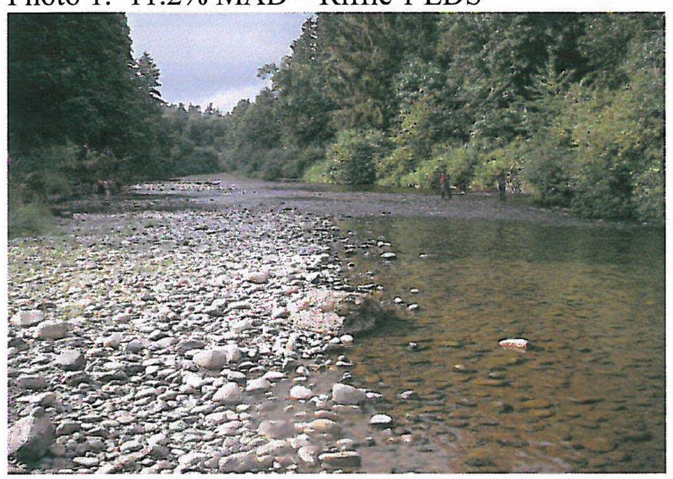


Photo 5. 11.2% MAD – Riffle 1 LUS

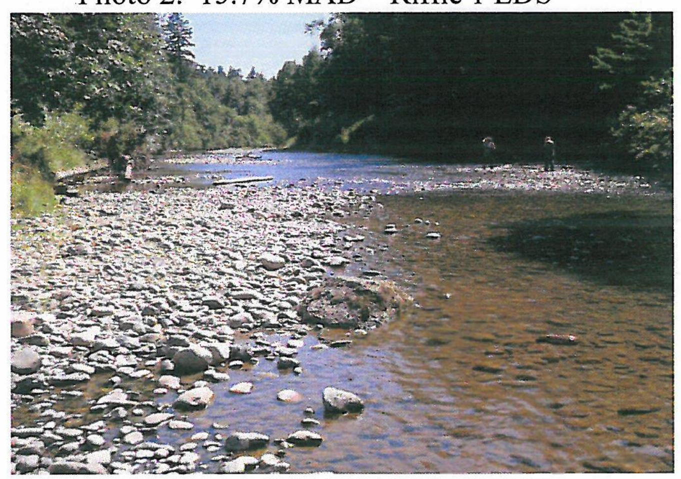


Photo 6. 15.7% MAD – Riffle 1 LUS

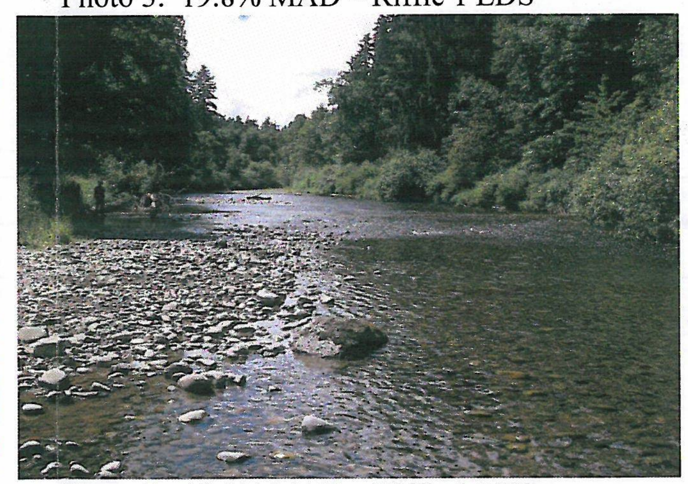


Photo 7. 19.8% MAD – Riffle 1 LUS

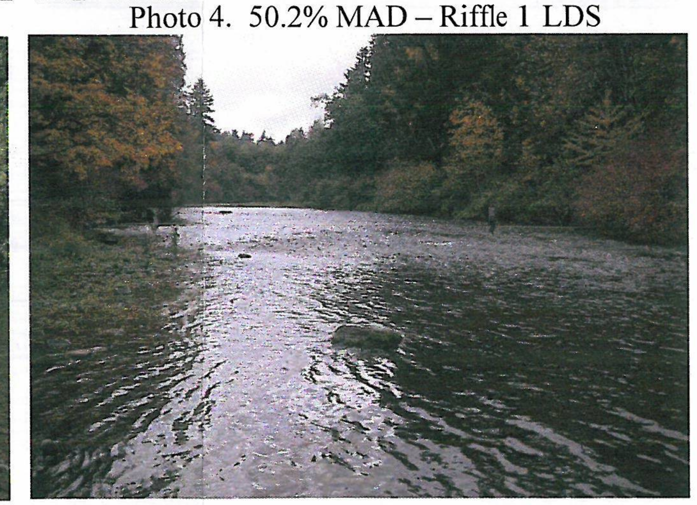


Photo 8. 50.2% MAD – Riffle 1 LUS

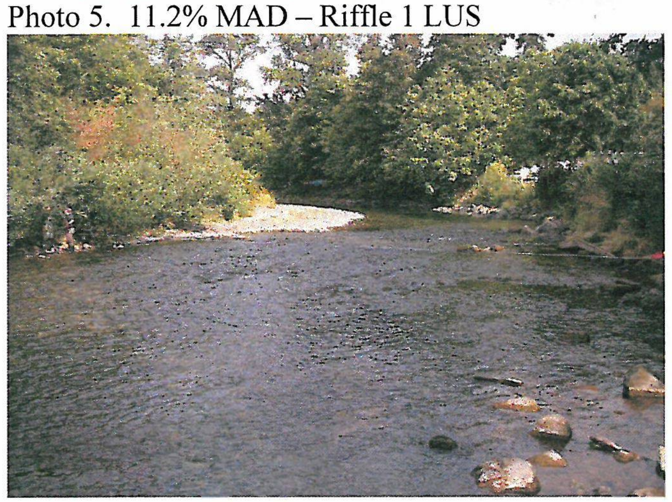


Photo 9. 11.2% MAD – Riffle 2 LDS

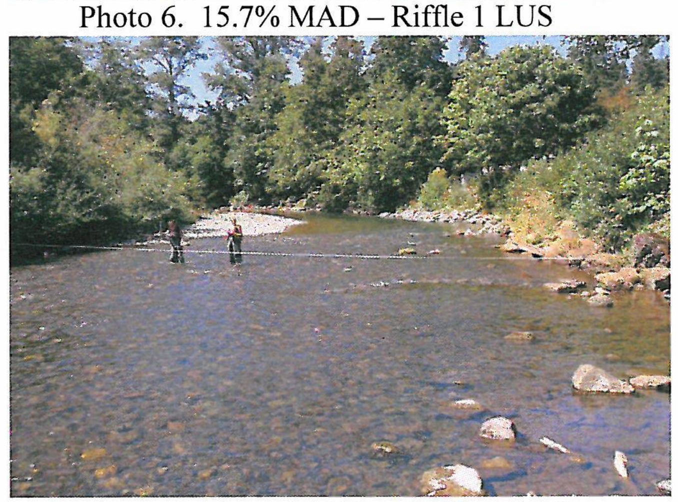


Photo 10. 15.7% MAD – Riffle 2 LDS

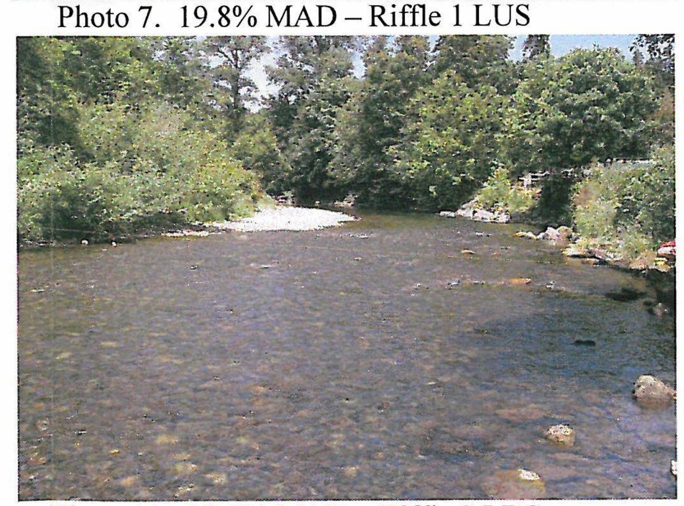


Photo 11. 19.8% MAD – Riffle 2 LDS


Photo 12. 50.2% MAD – Riffle 2 LDS


Photo 13. 11.2% MAD – Riffle 2 LUS

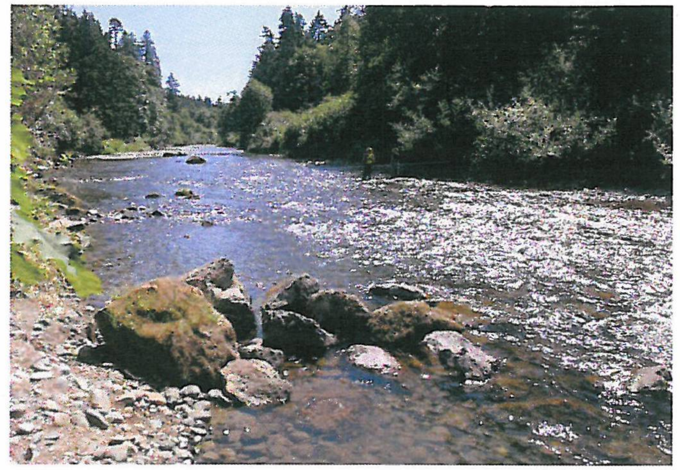


Photo 14. 15.7% MAD – Riffle 2 LUS

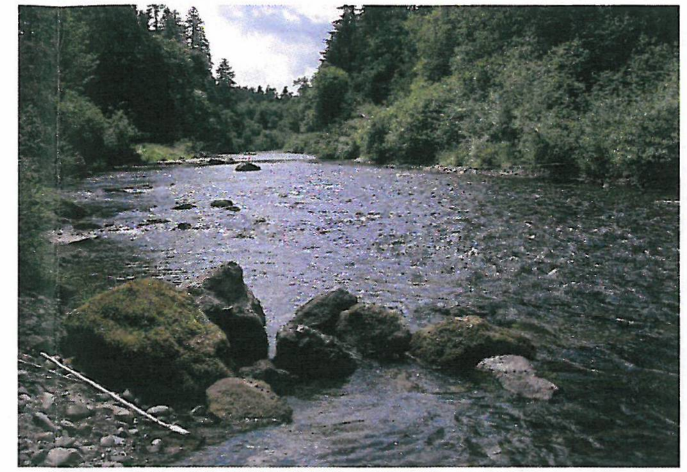


Photo 15. 19.8% MAD – Riffle 2 LUS

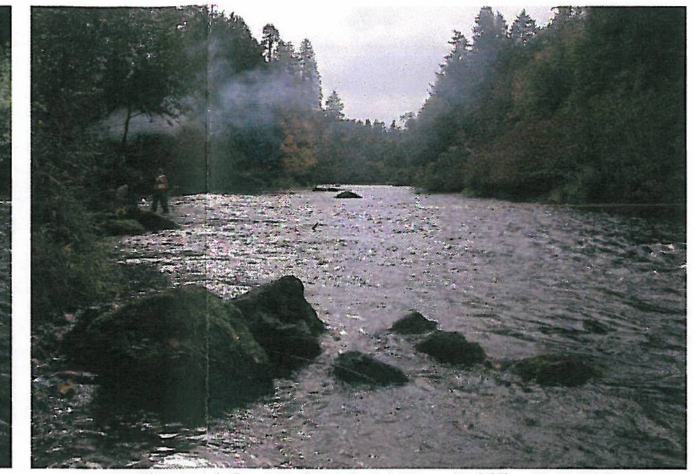


Photo 16. 50.2% MAD – Riffle 2 LUS


Photo 17. 11.2% MAD – Riffle 3 LDS

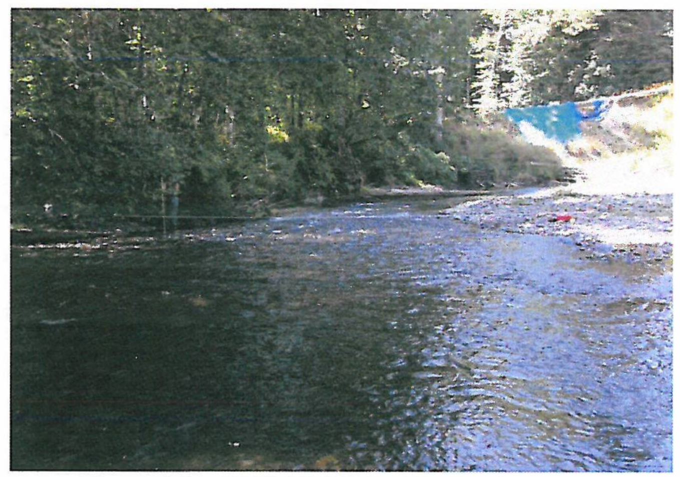


Photo 18. 15.7% MAD – Riffle 3 LDS

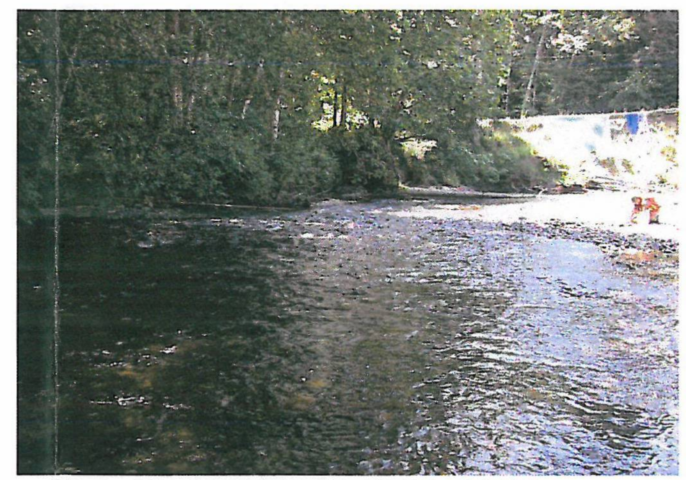


Photo 19. 19.8% MAD – Riffle 3 LDS

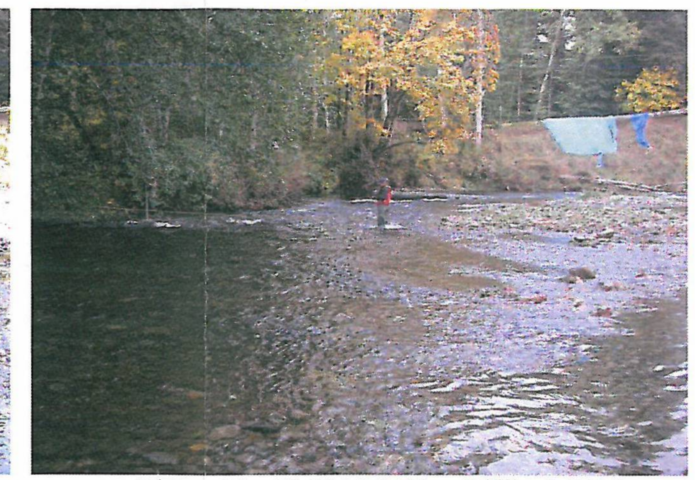


Photo 20. 50.2% MAD – Riffle 3 LDS

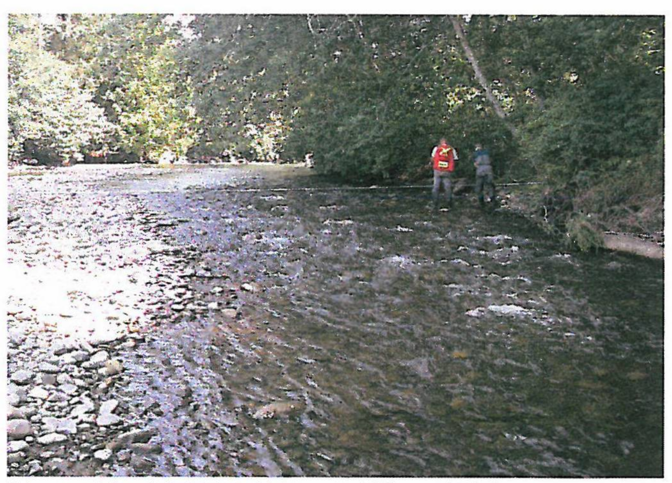


Photo 21. 11.2% MAD – Riffle 3 LUS


Photo 22. 15.7% MAD – Riffle 3 LUS

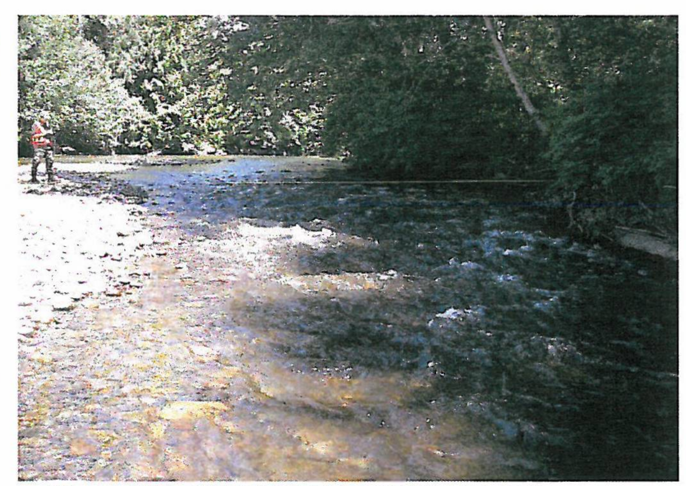


Photo 23. 19.8% MAD – Riffle 3 LUS

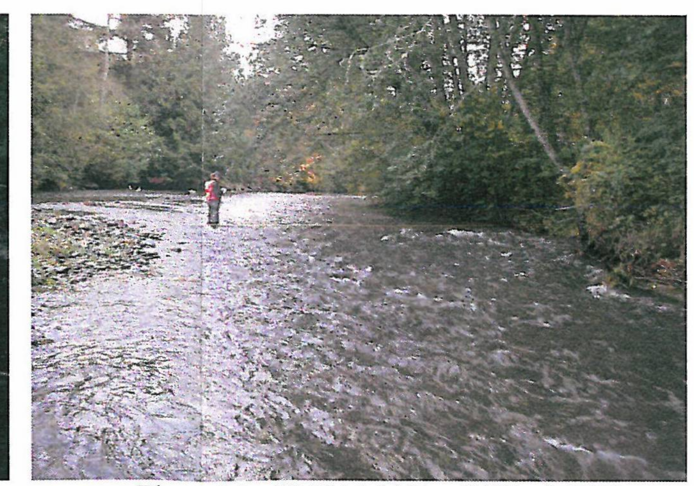


Photo 24. 50.2% MAD – Riffle 3 LUS


Photo 25. 11.2% MAD – Riffle 4 LDS


Photo 26. 15.7% MAD – Riffle 4 LDS

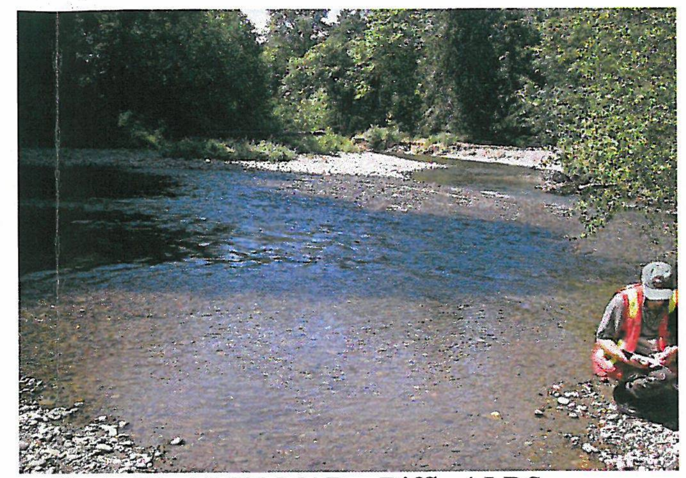


Photo 27. 19.8% MAD – Riffle 4 LDS

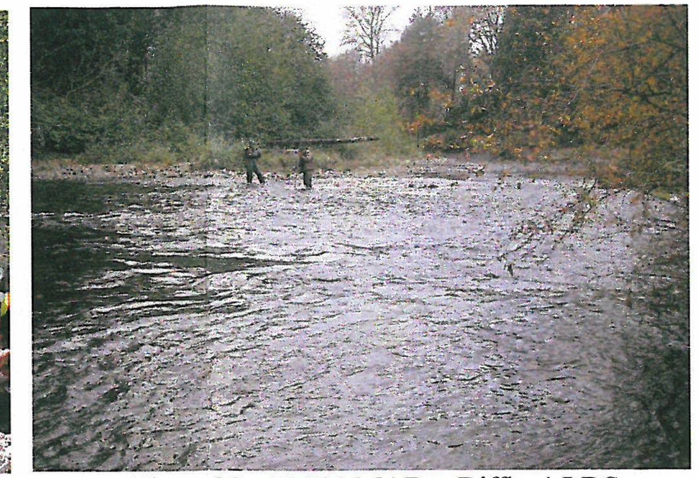


Photo 28. 50.2% MAD – Riffle 4 LDS

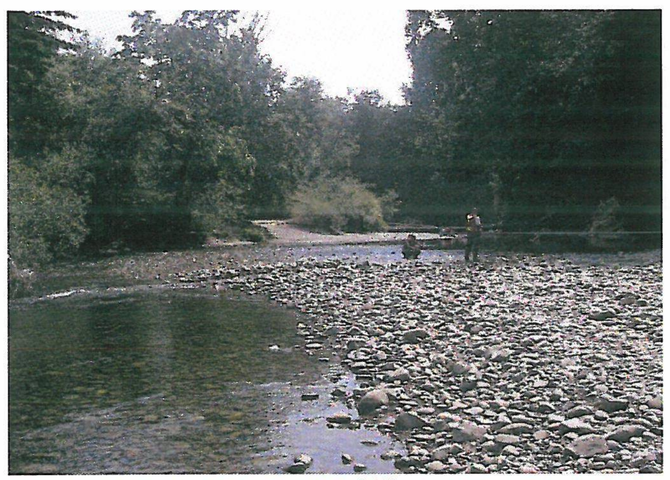


Photo 29. 11.2% MAD – Riffle 4 LUS


Photo 30. 15.7% MAD – Riffle 4 LUS

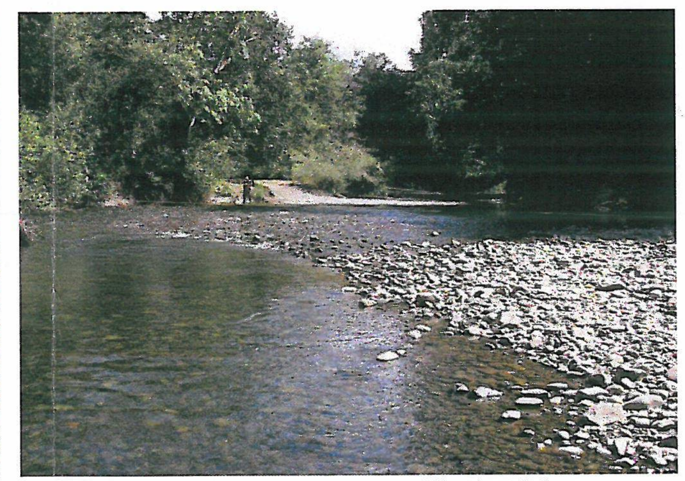


Photo 31. 19.8% MAD – Riffle 4 LUS

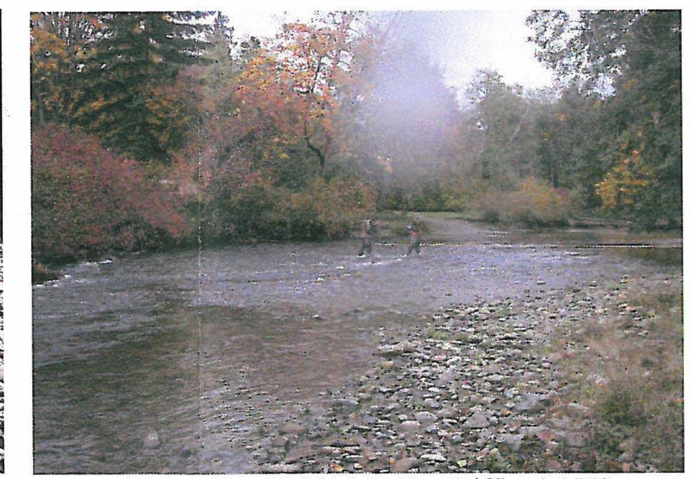


Photo 32. 50.2% MAD – Riffle 4 LUS

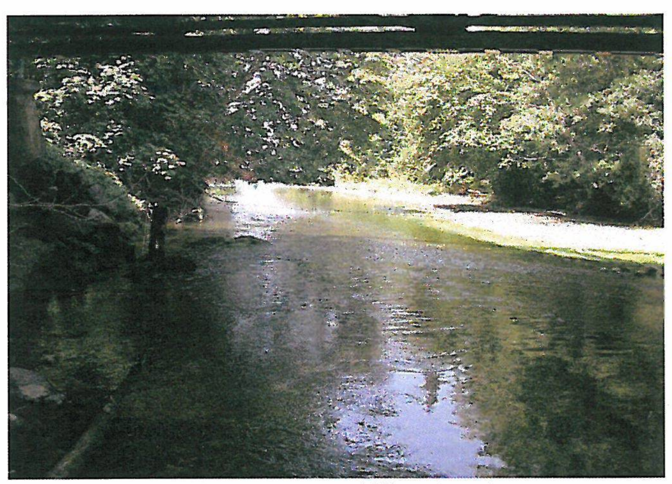


Photo 33. 11.2% MAD – Riffle 5 LDS

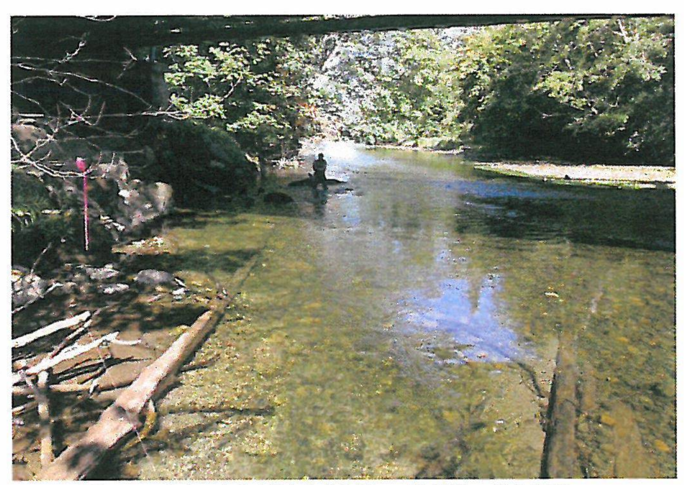


Photo 34. 15.7% MAD – Riffle 5 LDS

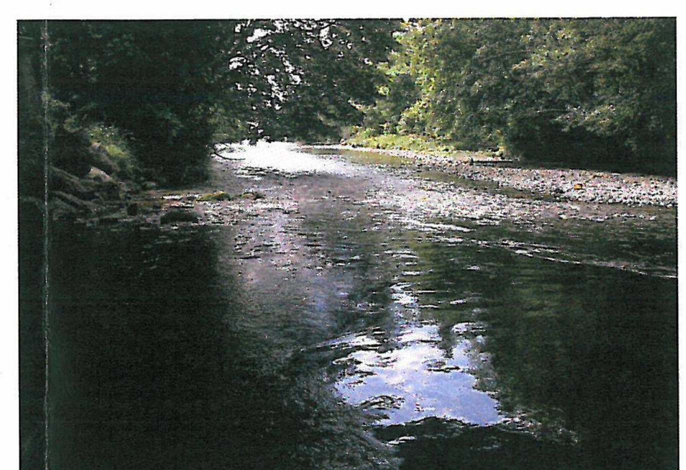


Photo 35. 19.8% MAD – Riffle 5 LDS

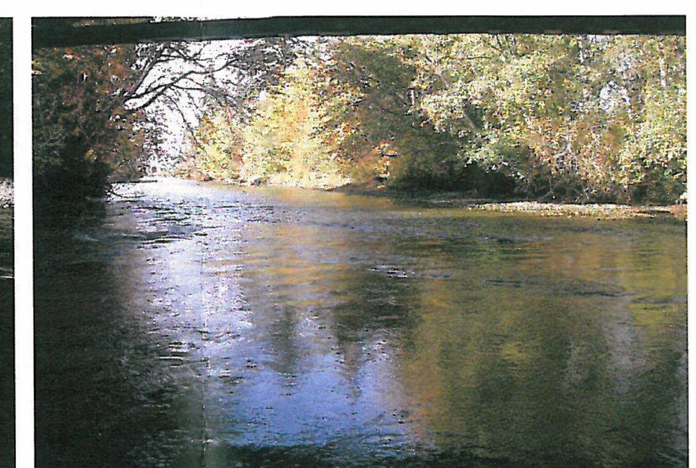


Photo 36. 50.2% MAD – Riffle 5 LDS


Photo 37. 11.2% MAD – Riffle 5 LUS


Photo 38. 15.7% MAD – Riffle 5 LUS

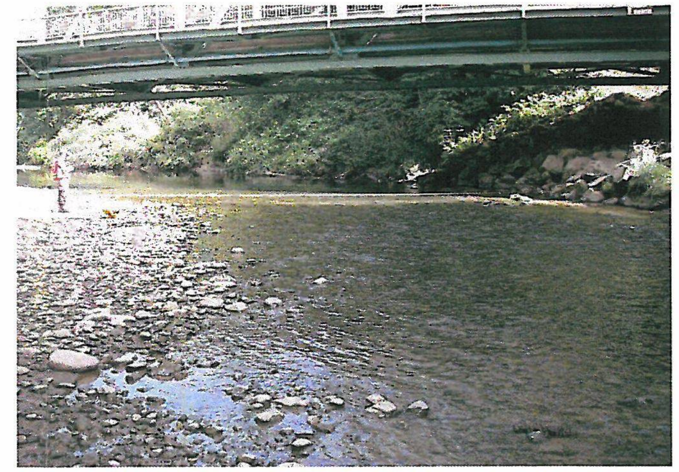


Photo 39. 19.8% MAD – Riffle 5 LUS


Photo 40. 50.2% MAD – Riffle 5 LUS


Photo 41. 11.2% MAD – Glide 1 LDS

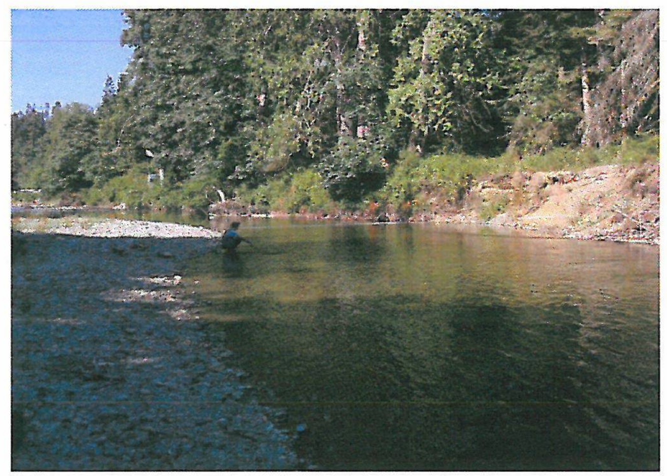


Photo 42. 15.7% MAD – Glide 1 LDS


Photo 43. 19.8% MAD – Glide 1 LDS


Photo 44. 50.2% MAD – Glide 1 LDS

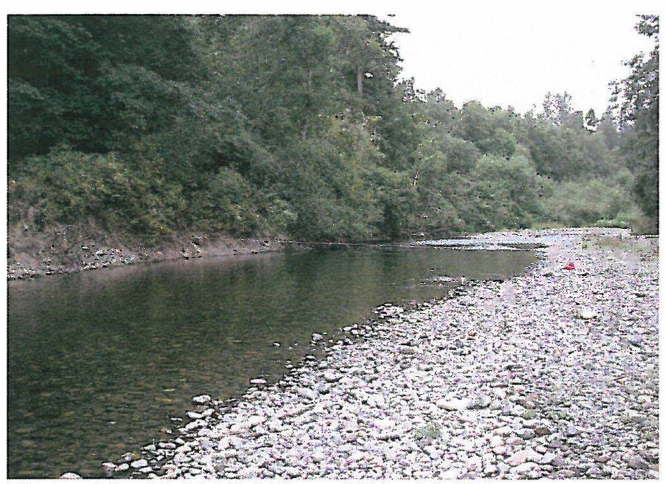


Photo 45. 11.2% MAD – Glide 1 LUS

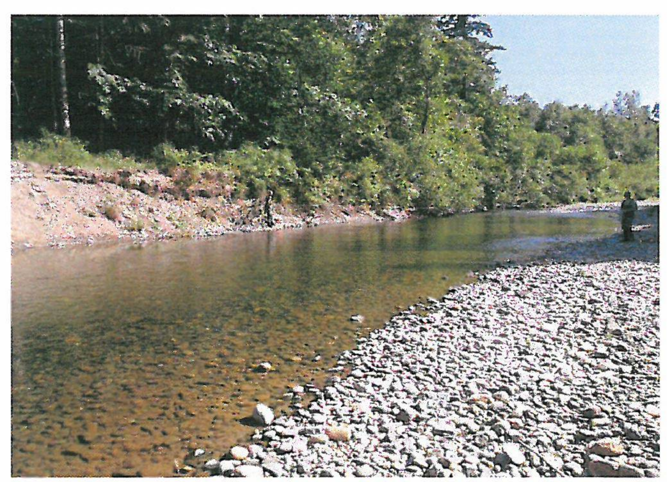


Photo 46. 15.7% MAD – Glide 1 LUS

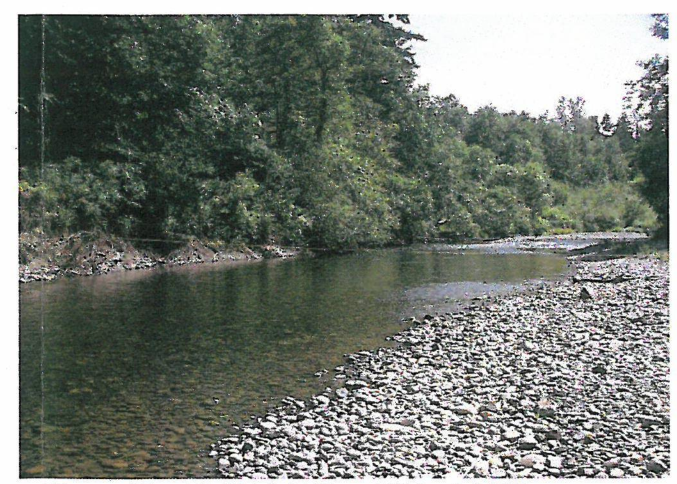


Photo 47. 19.8% MAD – Glide 1 LUS

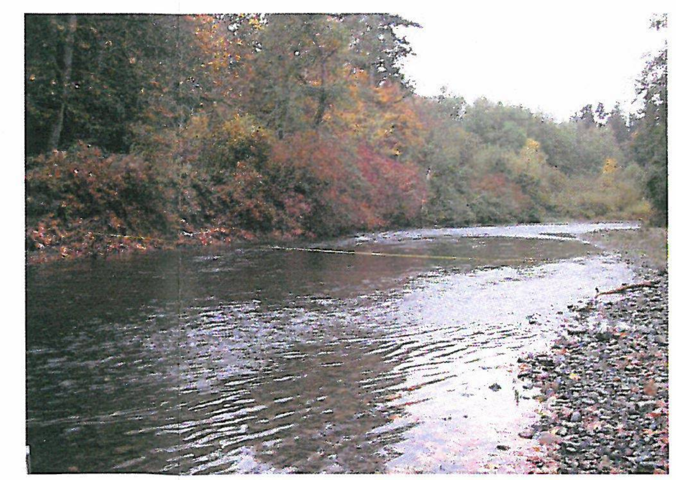


Photo 48. 50.2% MAD – Glide 1 LUS

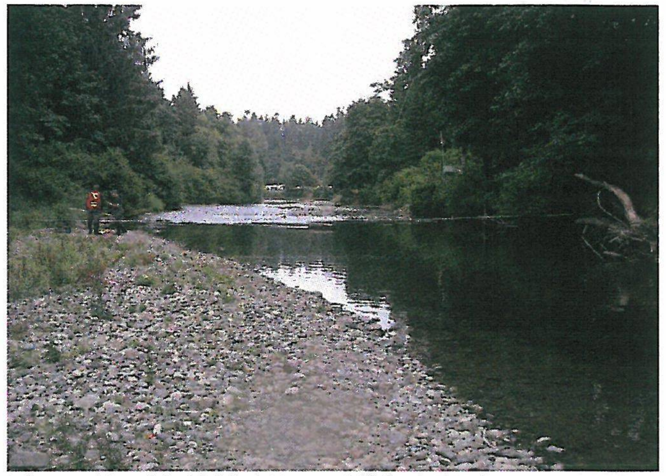


Photo 49. 11.2% MAD – Glide 2 LDS

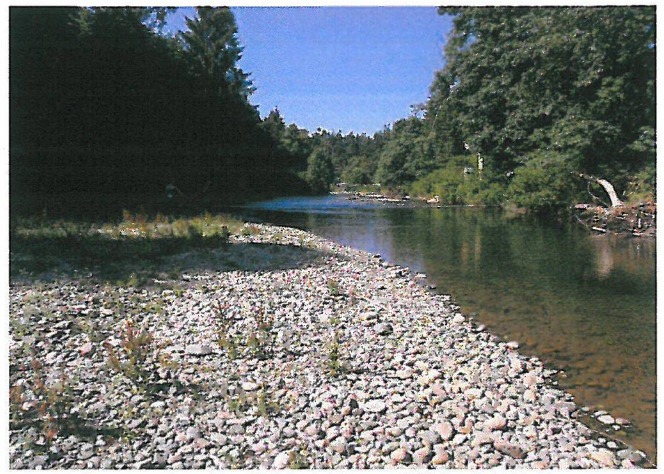


Photo 50. 15.7% MAD – Glide 2 LDS


Photo 51. 19.8% MAD – Glide 2 LDS

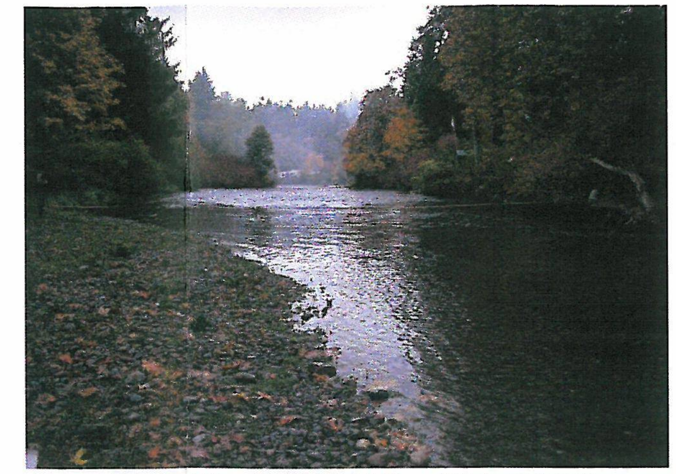


Photo 52. 50.2% MAD – Glide 2 LDS


Photo 53. 11.2% MAD – Glide 2 LUS

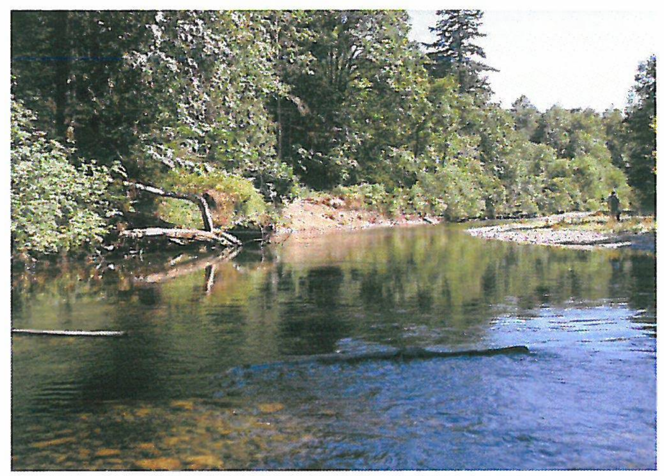


Photo 54. 15.7% MAD – Glide 2 LUS

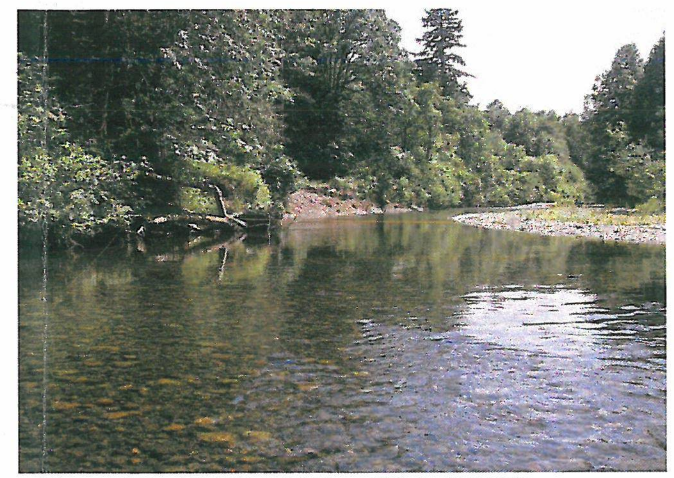


Photo 55. 19.8% MAD – Glide 2 LUS

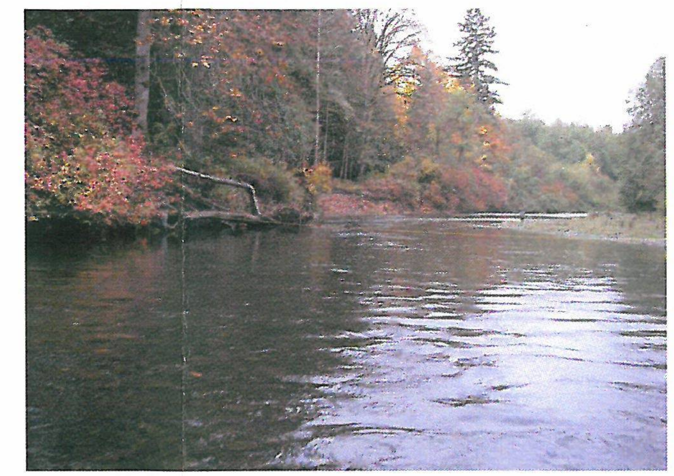


Photo 56. 50.2% MAD – Glide 2 LUS

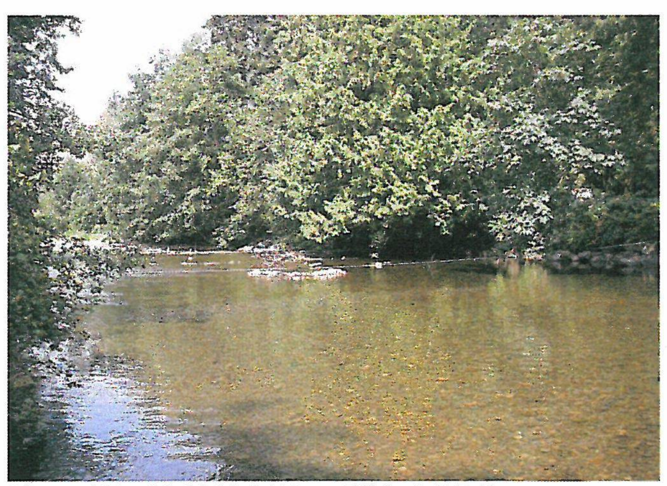


Photo 57. 11.2% MAD – Glide 3 LDS

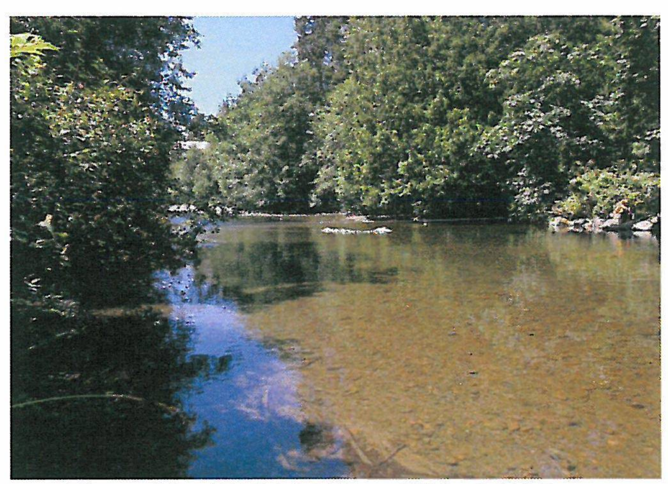


Photo 58. 15.7% MAD – Glide 3 LDS

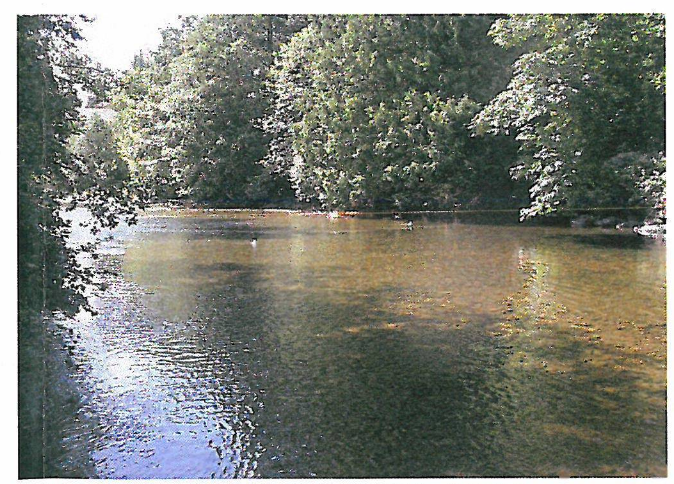


Photo 59. 19.8% MAD – Glide 3 LDS

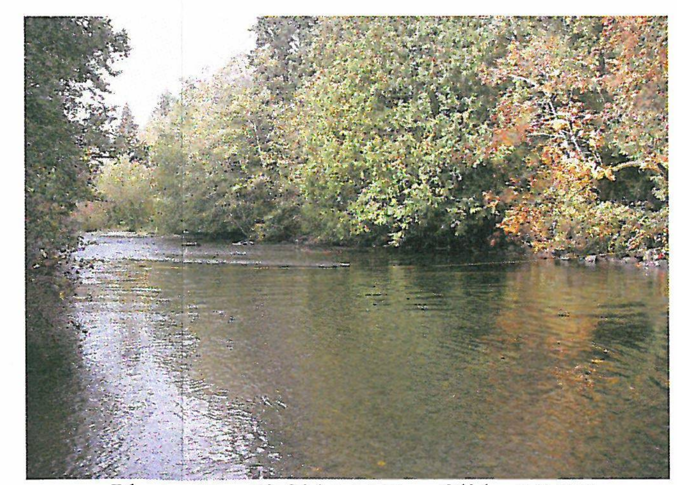


Photo 60. 50.2% MAD – Glide 3 LDS


Photo 61. 11.2% MAD – Glide 3 LUS

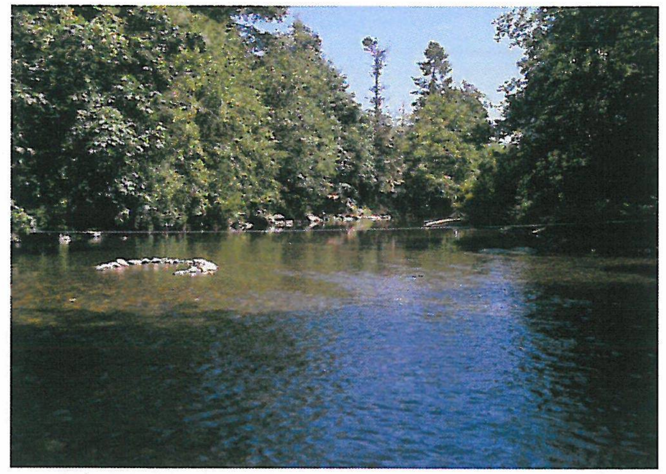


Photo 62. 15.7% MAD – Glide 3 LUS


Photo 63. 19.8% MAD – Glide 3 LUS


Photo 64. 50.2% MAD – Glide 3 LUS


Photo 65. 11.2% MAD – Pool 1 LDS

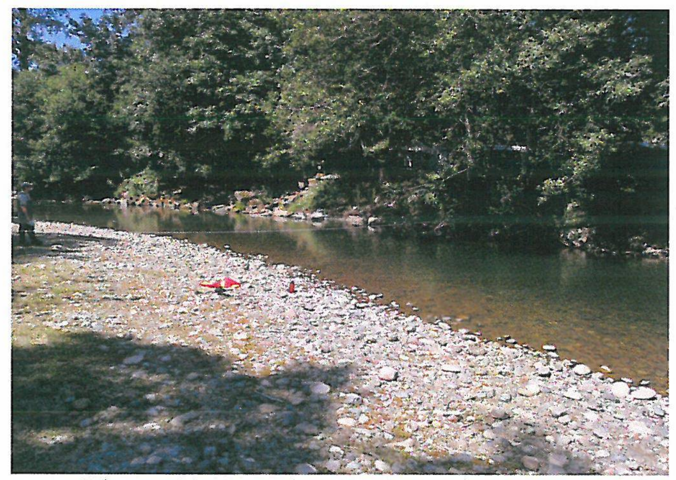


Photo 66. 15.7% MAD – Pool 1 LDS


Photo 67. 19.8% MAD – Pool 1 LDS


Photo 68. 50.2% MAD – Pool 1 LDS


Photo 69. 11.2% MAD – Pool 1 LUS

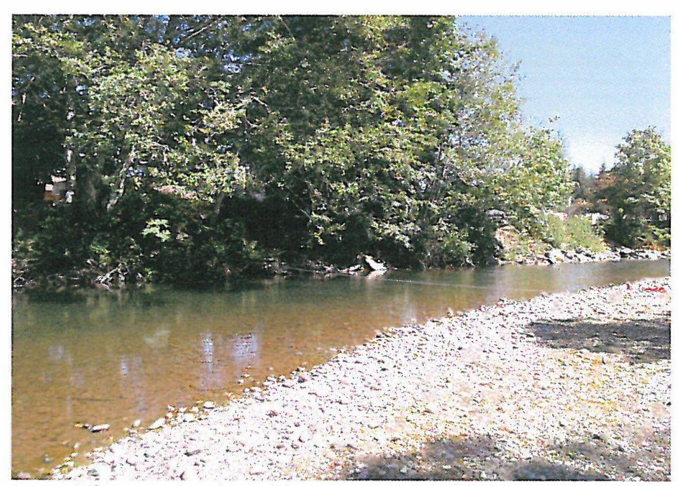


Photo 70. 15.7% MAD – Pool 1 LUS


Photo 71. 19.8% MAD – Pool 1 LUS

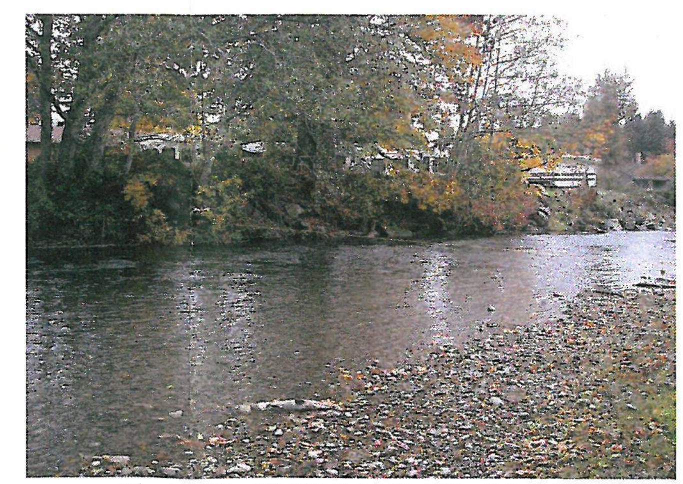


Photo 72. 50.2% MAD – Pool 1 LUS


Photo 73. 11.2% MAD – Pool 2 LDS


Photo 74. 15.7% MAD – Pool 2 LDS


Photo 75. 19.8% MAD – Pool 2 LDS


Photo 76. 50.2% MAD – Pool 2 LDS


Photo 77. 11.2% MAD – Pool 2 LUS

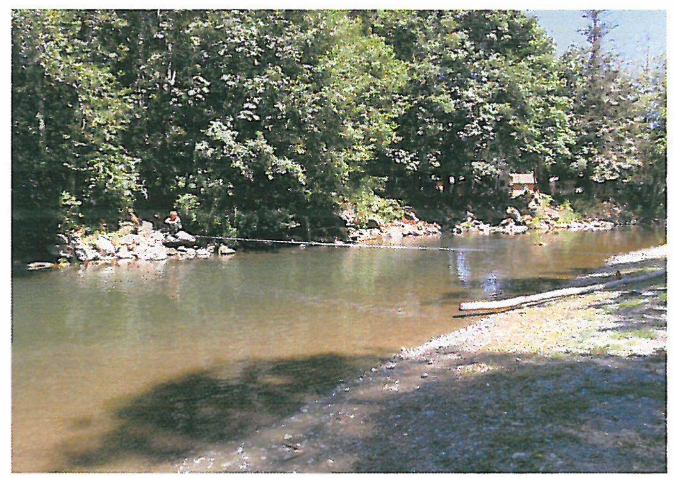


Photo 78. 15.7% MAD – Pool 2 LUS

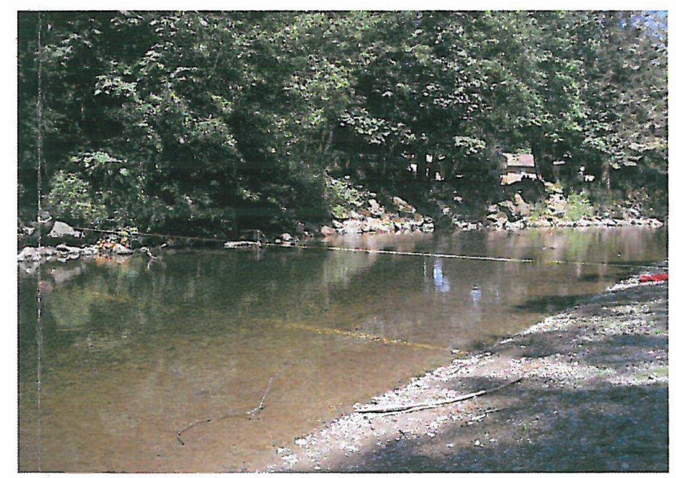


Photo 79. 19.8% MAD – Pool 2 LUS

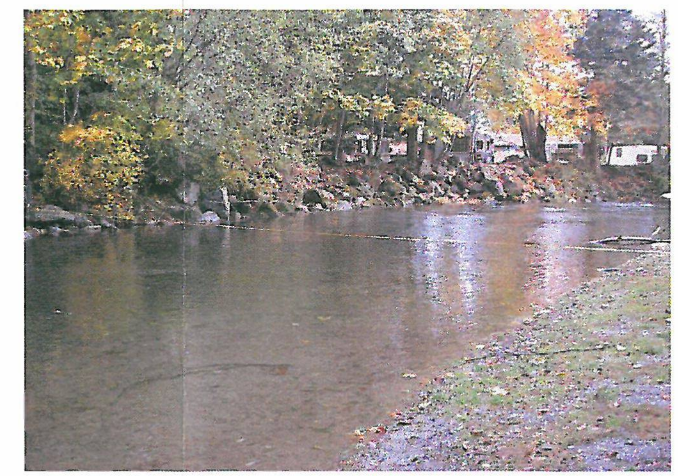


Photo 80. 50.2% MAD – Pool 2 LUS


Photo 81. 11.2% MAD – Pool 3 LDS

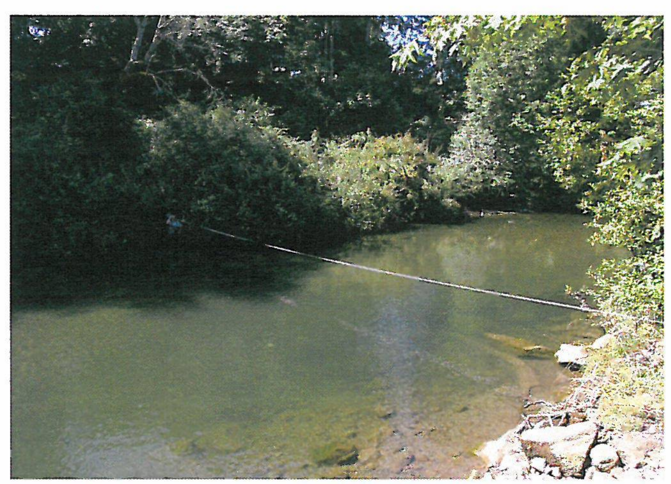


Photo 82. 15.7% MAD – Pool 3 LDS

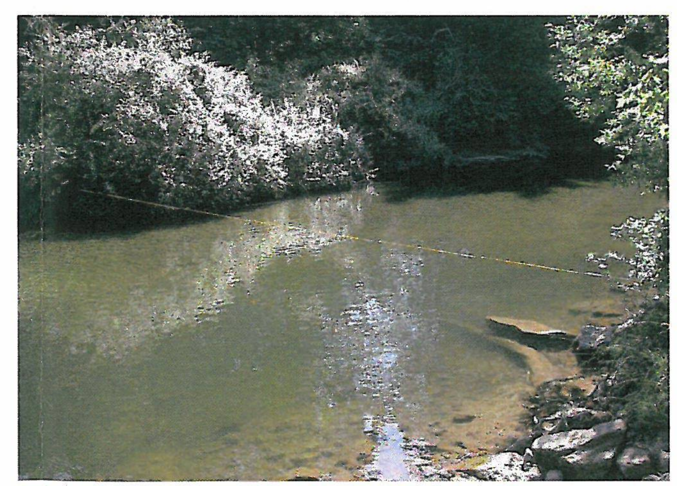


Photo 83. 19.8% MAD – Pool 3 LDS


Photo 84. 50.2% MAD – Pool 3 LDS

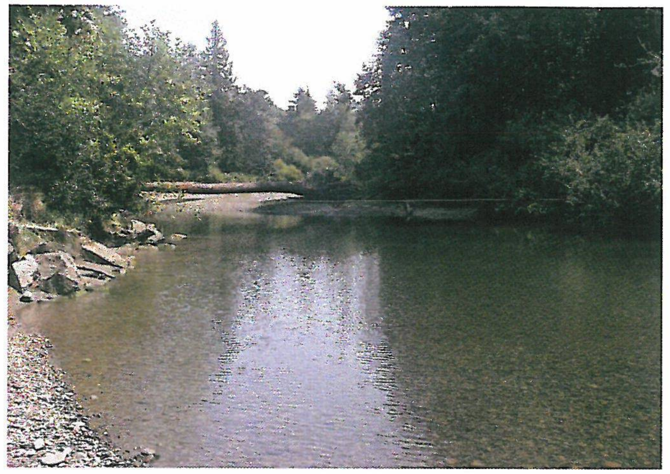


Photo 85. 11.2% MAD – Pool 3 LUS

Photo 86. 15.7% MAD – Pool 3 LUS

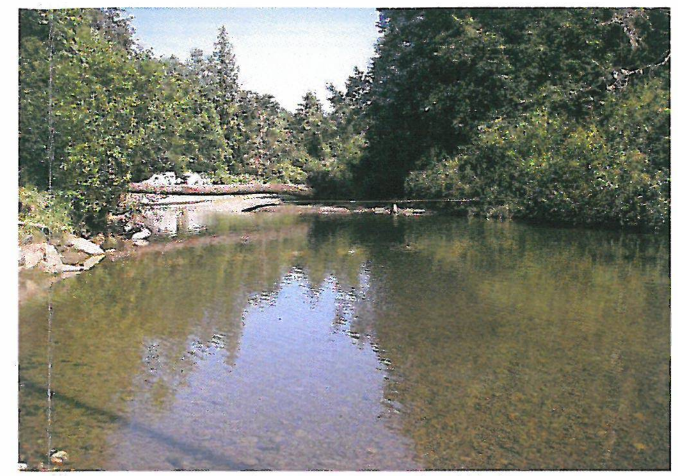


Photo 87. 19.8% MAD – Pool 3 LUS

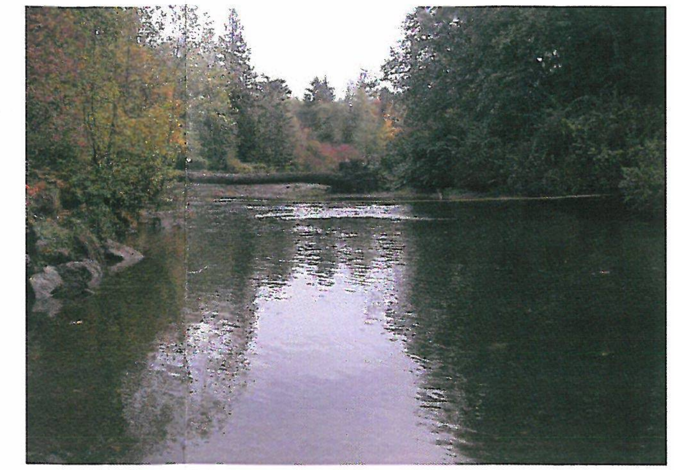


Photo 88. 50.2% MAD – Pool 3 LUS