The Feasibility of Acoustic Telemetry for Juvenile Salmonid Entrainment Studies at Wilsey Dam 16.SHU.01

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Prepared for:  
White Valley Community Resource Centre  
and  
Fish and Wildlife Compensation Program

This Project was funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.

February 2016

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Citation: McGrath, E. The Feasibility of Acoustic Telemetry for Juvenile Salmonid Entrainment Studies at Wilsey Dam. Prepared for the Wilsey Dam Fish Passage Committee and Fish and Wildlife Compensation Program.
EXECUTIVE SUMMARY

We conducted a feasibility study for using acoustic telemetry to verify passage route (spillway versus turbines) of outmigrating juvenile salmonids at Wilsey Dam. The study consisted of testing detection rate and detection range in three different configurations in the main Shuswap River channel, the forebay, and spillway of Wilsey Dam. A further component examined if acoustic equipment could be configured to conclusively determine passage route of tagged fish.

Three telemetry systems were tested, including Lotek tags and receivers, as well as two different transmission systems from Vemco. Results indicate that detection rates were generally sufficient for a smolt survival study at the dam. Detection rates near intake No.2 were generally >90% (Lotek) and >73% (Vemco). Detection rates in the spillway were on average 53% (Lotek) and 39% (Vemco). The Lotek system also had relatively high detection rates extending across the entire width of the spillway (~80%), whereas the Vemco system had detection rates <60% past 16 m, which is less than the width of the spillway (approx. 35 m). Detection rates in the main channel upstream of the spillway were likely impacted by large rip rap that blocked line of sight between some receiver-tag pairs, but were acceptable (55% Lotek, 50% Vemco). Some receivers showed high detection rates (~78%) at distances of 150 m (Lotek) and 118 m (Vemco).

During a future entrainment study, passage route of a tagged fish through Wilsey Dam would be inferred from the location of last detection in the spillway or near Intake No.2. Receivers near Intake No.2 were unable to detect tags in the spillway and vice versa. Therefore, a key conclusion from this test is that receivers can be configured to definitively determine fish passage route. Detection rates seemed to be impacted by large rip rap present in the main river channel and spillway. Thus, care will have to be taken to position receivers away from large rocks and rip rap.
ACKNOWLEDGEMENTS

The authors would like to thank Richard Bussanich and Skyeler Folks of Okanagan Nation Alliance, and Robyn Laubman of Splatsin for providing input in the test design and review of this report. Dale Webber of Vemco provided input in the test design and assisted with analysis of the Vemco acoustic data. Michelle Walsh, Stuart Lee, Keith Louis, Chelsea Mathieu, and Nicholas Yaniw provided field assistance, and Ryan Benson led the deployment of the acoustic telemetry equipment.

This Project was funded by the Fish and Wildlife Compensation Program (FWCP). The FWCP is partnership between BC Hydro, the Province of B.C., Fisheries and Oceans Canada, First Nations and public stakeholders to conserve and enhance fish and wildlife impacted by the construction of BC Hydro dams.
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1.0 INTRODUCTION

1.1 Project Background

The Shuswap River Watershed is one of the most important salmon-producing systems in British Columbia supporting a diversity of anadromous and resident fish species. Salmon produced in the Shuswap River provide the basis for First Nations Food, Social, and Ceremonial Fisheries along their entire migration route including the marine, Fraser River, and local area. In addition, they contribute significantly to marine and freshwater recreational and commercial fisheries.

In 1928, salmon runs in the Middle Shuswap River were completely obstructed from migrating upstream of Shuswap Falls with the construction of Wilsey Dam, now operated by BC Hydro. This prevents fish access to approximately 32 kilometers of Middle Shuswap River. Initial plans for the dam included a fish ladder for salmon and other species; however, the ladder was never built. There is considerable support and efforts to this day to restore fish passage at Wilsey Dam.

The Wilsey Dam Fish Passage Committee (WDFPC) recently received a Biological Feasibility Report for restoring fish passage at Wilsey Dam (McGrath et al., 2014). The report supports Step 3 of BC Hydro’s 7 step framework for restoring fish passage at its dams (BC Hydro, 2008). The report concluded that there were no serious impediments to re-establishing fish passage above Wilsey Dam; however, entrainment mortality was identified as a critical knowledge gap. Specifically, there was uncertainty around fish entrainment mortality during smolt outmigration as they pass through the turbines. In the Middle Shuswap River this would primarily affect outmigrating juvenile Chinook (Oncorhynchus tshawytscha), Coho (O. kisutch), and Sockeye Salmon (O. nerka), as well as adfluvial Rainbow Trout (O. mykiss) and Bull Trout (Salvelinus confluentus) from Mabel Lake.

If entrainment rates are a cause for concern, then further studies into entrainment mortality and/or entrainment mortality mitigation strategies may be warranted (e.g., scheduled turbine shut downs, increased spillage, bypass systems, screens) under Step 4 of BC Hydro’s Fish Passage Framework. Ultimately, the knowledge of fish entrainment rates and mortality will assist resource managers in determining whether reintroduction of salmonids upstream of Wilsey Dam will be beneficial to salmon stocks in the Shuswap River Basin.

Due to site and design variations, each hydroelectric dam system is unique and the extrapolation of entrainment data and studies between sites carries with it inherent assumptions. Thus, site-specific studies are needed to respond to this uncertainty at Wilsey Dam. In 2014, we trialled the use of split-beam hydroacoustic equipment to study entrainment at Wilsey Dam (Walsh and McGrath, 2015). While the method was successful at observing pulses of (likely) released Chinook smolts moving through the intake and spillway, the cost of data processing by 3rd parties and the difficulty with required concurrent fish sampling prevent us from recommending a full-scale entrainment study using this approach at the current time. This recommendation may be revised as we build more cost-effective processing capabilities in-house.
An alternative to hydroacoustic methodology is the use of acoustic telemetry. Acoustic telemetry is used to track fish movement via electronic transmitters implanted in fish that emit a series of pings, which are then heard and recorded by strategically positioned receivers. Acoustic telemetry has been used extensively at hydropower dams and flood control projects throughout North America for investigating anadromous fish passage and estimating fish entrainment. The method has been intensively used to study smolt entrainment and survival at Columbia River hydropower dams, including yearling and sub-yearling Chinook Salmon, Sockeye and Steelhead (Skalski et al., 2014; McMichael et al., 2010; Ransom et al., 2007; ). Due to site-specific “noise” conditions that have a bearing on the feasibility of using acoustic gear, it was necessary to approach the study in a phased manner:

- Year 1 (2015) – conduct a feasibility test with range testing and testing of various configurations of the acoustic receivers around key locations of the dam.
- Year 2 (2016) – if the method appears feasible, pursue a full entrainment study using acoustic telemetry, using results from Year 1 to inform the study design.

The feasibility test conducted in 2015 was a partnership project led by White Valley Community Resource Centre, and delivered by Okanagan Nation Alliance Fisheries Department, Okanagan Indian Band, Secwepemc Fisheries Commission and Splatsin. In-kind contributions were received by University of Alberta Department of Civil & Environmental Engineering and BC Hydro, Secwepemc Fisheries Commission, and Okanagan Nation Alliance with the primary funding source from the Fish &Wildlife Compensation Program.

1.2 Project Objectives
The goal of the study was to complete range and configuration testing of several brands of acoustic telemetry receivers and transmitters ("tags") in the vicinity of Wilsey Dam to explore their suitability for a juvenile salmon entrainment study at this site. Specific objectives were to:

- Determine detection rates of acoustic transmitters in the area of the active Intake No.2, the spillway, and the main river channel upstream of the dam as a function of distance, under high and low flow conditions.
- Determine the optimal configuration of receivers around the intake and spillway to detect the passage route of tagged fish.
- Produce detailed bathymetric maps of the forebay area and determine flow rates and velocities in areas adjacent to the spillway and intakes to better inform future hydroacoustic and acoustic telemetry gear deployment.

2.0 METHODS

2.1 Study Area
The Shuswap River originates from Joss Pass in the Sawtooth Range of the Monashee Mountains. It flows approximately 150 km down into the Shuswap Highlands and through two large lakes, Sugar Lake and Mabel Lake, before discharging into Mara
Lake, which is a tributary lake of Shuswap Lake (Figure 1). The Shuswap River is located within the traditional territory of the Secwepemc Nation and Okanagan Nation.

The current Wilsey Dam is located approximately 22.4 km upstream of the Mabel Lake inlet at an elevation of 418 m and with a crest elevation of 448.54 m. The facility consists of a concrete arch dam, a spillway, and two generation units (Figure 2). Intake No.1 is on the left abutment, and Intake No.2 is on the right abutment (nhc and ecofish, 2002). Wilsey Dam only has a small headpond (~ 7 ha), because most of the water for generation is stored at Sugar Lake dam approximately 32 km upstream. These two structures make up the Shuswap generating station (BC Hydro, 2003).

Wilsey Dam has a non-gated spillway located on the right bank, and constructed at a crest elevation of 444.5 m. The spillway can be raised approximately 1 m by adding flashboards to create a higher head for power generation during low flows. This is typically done in winter to reduce the occurrence of frazil ice. The flashboards are not in use during freshet due to possible damage from debris during high water (BC Hydro, 2003). The spillway discharges for approximately 300 m through a rock chute into the lower river opposite the tailrace of the generating station.

Power releases from the dam pass through the 5 MW powerhouse, located 140 m downstream of Wilsey Dam. There are two penstocks to supply the generating units, each with trash racks on the intake (BC Hydro, 2002). The unit No.2 penstock has a bypass valve that allows up to 19.2 m³/s of flow to bypass the turbine and enter downstream waters during power outages (BC Hydro, 2003). Two Francis turbines are used for power generation; one with a maximum capacity of 16.4 m³/s and another with a maximum capacity of 15.2 m³/s (BC Hydro, 2002). A single turbine unit operates when flows are less than 17 m³/s, and both units are shut down when inflows are less than 8 m³/s. Any inflows that exceed the maximum turbine capacities of the generating station (31.6 m³/s) are spilled (nhc and ecofish, 2002). The dam typically spills from April to August. Over the past three years, unit No.1 has been down due to maintenance requirements, with no immediate plans to bring it back into operation. As a result, during our study there was only flow through unit No.2 and while unit No.1 is down, the dam spills year-round. Further, silt build-up in the forebay and in front of Intake No.2 has reduced flows through the intake substantially.
Figure 1: Location of Shuswap River Watershed and Wilsey Dam (nhc 2005)

Figure 2: Wilsey Dam site layout (nhc and ecofish, 2002).
2.2 Acoustic Telemetry Deployment

Acoustic telemetry is used to track fish movement via electronic tags that are implanted in fish and emit a series of pings. These pings are heard by receivers as the fish swim by, and the date and time, as well as the individual tag code is stored in the receiver’s memory. This enables researchers to determine the presence of individual tagged fish near a particular receiver, and hence its location. Range testing is typically completed prior to implementation of a full study to determine if a particular location is conducive to using acoustic technology.

Initial plans for our study included a high water test (May/June) and a low water test (July/August) to assess the performance of acoustic equipment across the full range of potential flow conditions encountered by salmon smolts. However, scheduling of the high flow test was unsuccessful due to delays in obtaining the necessary equipment; a dredging project BC Hydro was planning to complete in the forebay during our proposed May/June study period; and earlier than normal reduction in river flows due to the 2015 drought conditions and installation of flash boards at Sugar Lake Dam. As a result, the equipment was only tested during low flow conditions (approx. 36 m³/s).

Three different acoustic telemetry systems were trialed during our study (Table 1). Juvenile Salmon Acoustic Telemetry System (JSATS) AMT tags (Figure 3a) are produced by Lotek Wireless Inc. and were trialed with their WHS4000 receivers (Figure 4a). The JSATS AMT tags transmit a uniquely coded 31-bit binary phase-shifted (BPSK) signal that is transmitted over 744 µs. Due to this rapid code transmission rate, the receivers can detect many nearby tags at once (reduced tag collision). The tags transmitted at a rapid pulse rate of 3 s, which allowed for frequent detection of passing tags. The WHS4000 receivers were deployed with one lithium battery and employed a false code detection filter.

Vemco V5 tags (Figure 3b) were trialed with their VR2W receivers (Figure 4a) and with a new prototype High Residency (HR2) receiver (Figure 4b; Table 1). The V5 tags use two separate approaches to signal encoding – they emit a pulse-interval-coding signal over 1.5 seconds in which the time between pulses is used to identify a unique tag code. This pulse position modulation (PPM) signal is then detected by the VR2W receivers. The V5 tags also emit a second code using a high residency (HR) transmission system that transmits the tag code in a few milliseconds, similar to the JSATS tags. This signal is detected by the HR2 prototype receivers. The HR2 receivers can be installed with synch tags placed in a tripod (Figure 4b) to enable their use as a Vemco positioning system (VPS), if needed, enabling 3-D positioning of a particular tag by triangulation. The synch tags serve to synch the receiver’s internal clock which is necessary for the VPS. It should be noted that the PPM technology alone is unsuitable for a potential entrainment survival study at Wilsey Dam due to the slower pulse rate (nearly 1 minute between pings; Table 1), and higher susceptibility for tag collision (and thus non-detection) when multiple tags are present near a receiver due to the slower signal transmission speed. However, this technology is available within the standard V5 tags and can provide a “safety” mechanism of sorts, to increase the probability of detection of a tag over the HR capabilities alone. The HR system is new to Vemco and the HR2 prototype receivers and VR2W receivers were generously loaned by Vemco for trialing the technology in the Wilsey Dam environment.
We installed a total of three Lotek JSATS tags and four Vemco V5 tags in each of the three configurations tested. Both tag types trialed in this study have been used for studying Chinook salmon smolt survival and movement. For example, outmigration survival through Columbia River hydroelectric dams of subyearling Chinook salmon as small as 95 mm fork length and 7.6 g in weight was estimated using AMT tags that were almost identical to the JSATS tags described above (Skalski et al., 2014). JSATS were used to study survival of juvenile Chinook between 86 mm and 121 mm (average weight 11.4 g) on the San Joaquin-Sacramento Delta (Cavallo et al., 2013). Vemco V7 and V9 tags (older and larger version of the V5 tag) were used to study outmigration survival of >125 mm fork length spring Chinook salmon in the Fraser River (Welch et al., 2008) and in California streams (Chapman et al., 2012).

Table 1: Technical specifications of transmitters and receivers tested at Wilsey Dam.

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Lotek (3 x) WHS4000</th>
<th>Vemco HR2 (3 x) HR2 Prototype&lt;sup&gt;a&lt;/sup&gt;</th>
<th>Vemco PPM (3 x) VR2W</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimensions (mm)</td>
<td>440 x 60</td>
<td>308 x 73</td>
<td>1190</td>
</tr>
<tr>
<td>Weight in air (g)</td>
<td>1100</td>
<td>1190</td>
<td>50</td>
</tr>
<tr>
<td>Weight in water (g)</td>
<td>NA</td>
<td>50</td>
<td>NA</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tag</th>
<th>Lotek (3 x) JSAT L- AMT-1.421</th>
<th>Vemco V5 (4 x) V5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency (kHz)</td>
<td>416.7 ± 0.5%</td>
<td>180</td>
</tr>
<tr>
<td>Weight in air (g)</td>
<td>0.32</td>
<td>0.65</td>
</tr>
<tr>
<td>Weight in water (g)</td>
<td>NA</td>
<td>0.38</td>
</tr>
<tr>
<td>Dimensions (mm)</td>
<td>11.1 x 5.5 x 3.7</td>
<td>12.7 x 4.3 x 5.6</td>
</tr>
<tr>
<td>Pulse rate (s)</td>
<td>3</td>
<td>4.5</td>
</tr>
<tr>
<td>Power output (dB)</td>
<td>158</td>
<td>45 - 55</td>
</tr>
</tbody>
</table>

<sup>a</sup> dimensions not provided
NA not available

Figure 3: (a) JSATS L- AMT-1.421 and (b) Vemco V5 tags used in this study.
Ancillary data collected during each deployment included weather conditions, start and end time of each test, depth of water and of installation, a description and sketch of configuration and positioning of the equipment in relation to obstacles and the shoreline, and GPS location. GPS location was recorded using a handheld Garmin GPSmap 78s unit, using WGS84 datum. The estimated accuracy and number of satellites was recorded for each point.

This acoustic telemetry feasibility study had two distinct objectives: (1) determine the detection rate and detection range for the different tag-receiver combinations in the vicinity of the forebay, the spillway and the main channel; and (2) determine the optimal configuration of receivers for a future entrainment study. Three different configurations were tested (A, B, C). Each brand of tags and receivers were deployed at the same time in as close to the same configuration as possible to ensure that the same conditions would be encountered during each test. While Configurations A and B were mainly aimed at determining detection rate and range, Configuration C was also aimed at determining the optimal configuration of receivers for a future entrainment study. The installation depth of tags under the water surface was chosen to mimic the distribution of Chinook smolts in the water column.

2.2.1 Test A - Forebay

Receivers and tags for Test A were placed in and around the active Intake No.2 to determine detection rate and range in the forebay. Details of the configuration of receivers and tags are provided in Figure 5 and Table 2. Water depths in this area are generally >2m and therefore all receivers were suspended at the water surface with their hydrophones pointing downward. The HR2 receivers were installed with tripod-mounted synch tags in place to enable their use as a VPS (Figure 4b).
Table 2: Details of receiver and tag deployment for Test A.

<table>
<thead>
<tr>
<th>Receiver</th>
<th>Location</th>
<th>Depth below water surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>~1-2 m right of Intake No.2</td>
<td>0.45</td>
</tr>
<tr>
<td>A2</td>
<td>In forebay area between sediment island and forebay log boom</td>
<td>0.3 (WHS4000 &amp; VR2W) 0.45 (HR2)</td>
</tr>
<tr>
<td>A3</td>
<td>Between 3\textsuperscript{rd} and 4\textsuperscript{th} log in mainstem log boom</td>
<td>0.3</td>
</tr>
<tr>
<td>A4</td>
<td>(V5 tag only); on river right bank 20 m upstream of spill crest</td>
<td>0.15</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Tag</th>
<th>Location</th>
<th>Depth below water surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1</td>
<td>~1 m right of Intake No.2</td>
<td>0.9</td>
</tr>
<tr>
<td>A2</td>
<td>In forebay area between sediment island and forebay log boom</td>
<td>1.2</td>
</tr>
<tr>
<td>A3</td>
<td>Between 2\textsuperscript{nd} and 3\textsuperscript{rd} log in mainstem log boom</td>
<td>0.6</td>
</tr>
<tr>
<td>A4</td>
<td>(V5 tag only); on river right bank 20 m upstream of spill crest</td>
<td>0.15</td>
</tr>
</tbody>
</table>

Figure 5: Test A - forebay and Intake No.2 area (yellow arrows show direction of flow).
**A1 – Intake No.2**

The installation of equipment at location A1 was completed via boat. The receivers and tags were suspended from a rope tied between the ladder above Intake No.2 and the main channel log boom (Figure 6). Water depth in front of Intake No.2 was 7.3 m. The receivers were zap-strapped to ropes that were weighed with a piece of metal (HR2) or cannonball sinkers (VR2W and WHS4000) in order to remain as vertical as possible. A buoy was attached to the HR2 receiver due to its substantial weight, to keep it near the surface. One JSATS and one V5 tag were suspended from thin nylon rope weighed down by a cannonball sinker (Figure 7) and installed nearest to the intake. All tags were attached to the nylon rope by inserting their battery end into heat-shrink tubing which was then tied to the rope. Care was taken not to obstruct the transmitter end of the tag. All pieces of equipment were spaced approximately 0.5 m apart.

![Figure 6: Installation of receivers and tags at location A1](image1)
![Figure 7: Configuration of tags.](image2)
**A2 – Forebay Area**

The installation of equipment at location A2 was completed via boat between the tip of the (dismantled) forebay log boom and a sediment island (Figure 8). Water depth in the area was 4.0 m. The HR2 receiver was zap-strapped to a rope suspended from a buoy that was weighed down with a piece of metal to remain vertical. The VR2W and WHS4000 receivers were installed in a similar fashion on a second buoy but zap-strapped side-by-side to one rope that was weighed down with cannonball sinkers. Their hydrophones were positioned at the same depth to ensure that one was not blocking reception of the other. One JSATS and V5 tag were suspended from a thin nylon rope tied between the two buoys and weighed with a cannonball sinker, similar to installation at location A1 (Figure 7).

![Figure 8: Configuration of equipment at location A2.](image)

**A3 – Main Channel Log Boom**

The installation of equipment at location A3 was completed via boat along the main channel log boom (Figure 9). The intention was to trial the equipment in the observed travel path of hatchery Chinook smolts that were released above the dam in 2014 during a hydroacoustic feasibility study (Walsh and McGrath, 2015). Some of the fish were observed to move down the left bank of the main channel and swim left toward the forebay at the downstream end of the gravel island. Water depth in this area was 5.0 m. The HR2 receiver was zap-strapped to a rope between the 3rd and 4th logs (from the intake) in the main channel log boom and weighed down with a piece of metal to remain vertical. The VR2W and WHS4000 receivers were installed in a similar fashion but were zap-strapped side-by-side to one rope that was weighed down with cannonball sinkers. Their hydrophones were positioned at the same depth to ensure that one was not blocking reception of the other. One JSATS and V5 tag were suspended from a thin nylon rope tied from the log boom between the 2nd and 3rd log from Intake No.2, and weighed down with a cannonball sinker, similar to installation at location A1 (Figure 7).
A4 – River Right Bank

One V5 tag was installed on the river right bank directly across from Intake No.2 to determine what the detection range would be across the main channel. The tag was suspended from thin nylon rope tied to a piece of rebar that had been inserted into a concrete block and affixed with concrete adhesive to form and anchor (Figure 10). The rope was attached to a bobber so the tag would remain suspended in the middle of the water column.
2.2.2 Test B – Main Channel

Receivers and tags for this test were placed on the right and left bank of the main channel upstream of the spillway and forebay to determine detection rates of tags as fish approach the dam. Details of the configuration of receivers and tags are provided in Figure 11 and Table 3. All receivers were placed on the river right bank and all tags were placed on the river left bank. Installation was completed from shore using safety harnesses. Exact location of the receivers was determined by finding a spot where they would not be knocked over by the strong current. Placement of equipment in the thalweg was considered but not possible for safety reasons.

![Figure 11: Test B – main channel.](image)

**Table 3: Details of receiver and tag deployment for Test B.**

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth below water surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Receiver</strong> B1 On river right bank across and a bit upstream from downstream tip of mid-channel gravel island</td>
<td>0.6 (WHS4000 &amp; VR2W)</td>
</tr>
<tr>
<td></td>
<td>0.45 (HR2)</td>
</tr>
<tr>
<td>B2 On river right bank across from mid-island</td>
<td>0.9 (WHS4000 &amp; VR2W)</td>
</tr>
<tr>
<td></td>
<td>0.45 (HR2)</td>
</tr>
<tr>
<td>B3 On river right bank across from upstream end of island (near canoe portage take out)</td>
<td>0.9 (WHS4000 &amp; VR2W)</td>
</tr>
<tr>
<td></td>
<td>0.6 (HR2)</td>
</tr>
<tr>
<td><strong>Tag</strong> B1 On river left bank Downstream end of gravel island, 50 m upstream of spillway</td>
<td>0.15 (JSATS)</td>
</tr>
<tr>
<td></td>
<td>0.3 (V5)</td>
</tr>
<tr>
<td>B2 On river left bank on gravel island, mid-island, straight across from B2 receiver</td>
<td>0.2 (JSATS)</td>
</tr>
<tr>
<td></td>
<td>0.35 (V5)</td>
</tr>
<tr>
<td>B3 On river left bank at upstream end of gravel island, across from B3 receiver</td>
<td>0.15 (JSATS)</td>
</tr>
<tr>
<td></td>
<td>0.4 (V5)</td>
</tr>
<tr>
<td>B4 On river left bank upstream of the island, near Mabel Lake Road bridge.</td>
<td>0.1 (V5)</td>
</tr>
</tbody>
</table>
The receivers were zap-strapped to a piece of rebar that was inserted into a concrete block and affixed with concrete adhesive to form and anchor (Figure 12). Also attached was a carabiner so that ropes could be used to tie the anchor to shore. At each location (B1 to B3), the VR2W and WHS4000 receivers were attached side-by-side to one anchor and the HR2 receiver was attached to another anchor. The HR2 receivers were installed with tripod-mounted synch tags in place to enable their use as a VPS (Figure 4b). The hydrophone end of all receivers was pointed upward due to deployment on the river bottom.

At each location on the river left bank (gravel island), staff waded into the stream to water depths of approximately 0.45 - 0.8 m and pounded rebar into the streambed. One JSATS and one V5 tag were suspended from thin nylon rope tied to the rebar. The rope was weighed down by a cannonball sinker similar to installation at location A and attached to a bobber so that tags would remain suspended in the water column (Figure 13).
2.2.3 Test C – Spillway and Intake No.2

Receivers and tags for this test were placed in and around the spillway and active Intake No.2 to determine optimal configuration of receivers for a future entrainment study. The goal was to configure receivers in a fashion that would allow us to determine the final passage route of tagged fish. Final passage route is inferred by last detection – if a tag was last detected at a spillway receiver it would be concluded that the fish passed down the spillway. If a tag was last detected at a receiver near the intake it would be concluded that the fish passed through the intake. In order for this to work it is essential that the spillway receiver cannot detect fish entering the intake and vice versa so that the test is unambiguous (i.e., if a tag is last detected at both receivers at the same time it is unknown which route the fish passed). If it is not possible to place receivers in an unambiguous way, a positioning system like the VPS tested in our study has to be employed, leading to increased complexity (and cost) in data analysis, interpretation and logistics of installation.

Details of the configuration of receivers and tags are provided in Figure 14 and Table 4. The HR2 receivers were installed without the tripod-mounted synch tags in place due to insufficient water depths in the spillway (Figure 4b).

![Figure 14: Test C - spillway and Intake No.2](image)

Table 4: Details of receiver and tag deployment for Test C.

<table>
<thead>
<tr>
<th>Location</th>
<th>Depth below water surface (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Receiver C1</td>
<td>In spillway on river right bank approx. 7 m upstream of spillcrest</td>
</tr>
<tr>
<td>C2</td>
<td>Suspended from rope between Intake No.2 ladder and forebay log boom</td>
</tr>
<tr>
<td>C3</td>
<td>In spillway on river left bank across from C1 receivers</td>
</tr>
<tr>
<td>Tag C1</td>
<td>In spillway on river right bank, approx. 5 m upstream from spillcrest</td>
</tr>
<tr>
<td>C2</td>
<td>Suspended from the tip of the ladder above Intake No.2</td>
</tr>
<tr>
<td>C3</td>
<td>Suspended in center of spillway approx. 3 m upstream from spillcrest</td>
</tr>
<tr>
<td>C4</td>
<td>Between 1st and 2nd log in main channel log boom</td>
</tr>
</tbody>
</table>
**C1 – Spillway Right Bank**

Equipment at location C1 was installed by wading into the water from the shore. Water depth at this location was approximately 1 m and staff were secured by safety harnesses. Receivers were zap-strapped to concrete anchors similar to Configuration B. The VR2W and WHS4000 receivers were attached to the same anchor and the HR2 receiver was attached to a separate anchor, approximately 1 m upstream (Figure 15). Exact location of the receivers was determined by finding a spot where they would not be knocked over by the strong current. The hydrophone end of all receivers was pointed upward due to deployment on the river bottom.

A piece of rebar was pounded into the streambed approximately 5 m upstream of the spillcrest and one JSATS and one V5 tag were suspended from thin nylon rope tied to the rebar (Figure 16). The rope was weighed down by a cannonball sinker similar to Test A and B, and attached to a bobber so that tags would remain suspended in the water column.

![Figure 15: Installation of receivers at location C1.](image1)

![Figure 16: Receivers and tags at location C1.](image2)

**C2 – Intake No.2**

Equipment at location C2 was installed via boat. The receivers were suspended from a rope tied between the ladder above Intake No.2 and the forebay log boom (Figure 17). This positioned them approximately 3 m to the river left of Intake No.2 so that they would not have a direct line of sight to (and presumably would not detect) tags in the spillway (Figure 14). This is important to ensure that in future entrainment studies, the passage route of a tagged fish based on last detection is unambiguous. The receivers were zap-strapped to two ropes that were weighed with a piece of metal (HR2) or cannonball sinkers (VR2W and WHS4000) in order to remain as vertical as possible. Two buoys were attached to the HR2 receiver due to its substantial weight, to keep it near the surface. The hydrophone end of all receivers was pointed downward. The receivers were positioned approximately 1 m off a rock wall.
One JSATS and one V5 tag were suspended from thin nylon rope tied to the ladder directly above Intake No.2 (Figure 18). These tags were to simulate fish immediately prior to entering the intake.

![Figure 17: Installation of receivers and tags at location C2.](image1)

![Figure 18: Installation of tags above Intake No.2 (location C2).](image2)

**C3 – Spillway Centre & Left Bank**

Equipment at location C3 was installed by wading into the water from the left shore of the spillway. Water depth at this location was approximately 1 m and staff were secured by safety harnesses. Receivers were zap-strapped to concrete anchors similar to Configuration B. The VR2W and WHS4000 receivers were attached to the same anchor and the HR2 receiver was attached to another anchor, placed approximately 1 m upstream (Figure 19). Specific position was determined by finding a spot where strong current would not knock the receivers over and where large rip rap would not block the receivers. The hydrophone end of all receivers was pointed upward due to deployment on the river bottom.

The tags at location C3 were installed in the centre of the spillway to simulate tagged fish passing over the spillway. A cable crossing was set up between each bank of the spillway approximately 10 m upstream of the spillcrest, and one JSATS and one V5 tag were suspended from thin nylon rope tied to the cable crossing (Figure 20), in the centre of the spillway. The rope was weighed down by fishing weights to ensure the tags would remain below the water surface.
C4 – Intake No.2 Approach

One V5 tag was installed between the 1st and 2nd log in the main channel log boom to simulate tagged fish approaching the intake from the main channel (Figure 14). Previous years’ studies showed that in this location, Chinook smolts were following strong surface flows from the main channel toward Intake No.2 and the forebay (Walsh and McGrath, 2015). The tag was suspended from thin nylon rope tied to the log boom and weighed down by a cannonball sinker.
2.3 Acoustic Telemetry Data Processing and Analysis

Analysis of data from the Vemco VR2W receivers and V5 tags was completed using Vemco Range Test software version 1.9.22.0 (AMIRIX Systems Inc., 2014). Data from the Vemco HR2 receivers as well as the Lotek receivers and tags was processed and analyzed manually in excel. As a first step, the Lotek data was validated for false detections by Blueleaf Consulting. The primary objective of data analysis was to determine the detection rate and detection range for the three different receiver/tag configurations (A, B, C), and to compare the three different systems (Vemco HR and PPM vs. Lotek). Detection rate of a particular receiver/tag combination is the ratio of observed detections / expected detections at a known tag pulse rate. Detection range is the relationship between detection probability and distance of the receiver and tag (Kessel et al., 2013). Detection range in this report is always described in relation to detection rate at a given location.

2.4 Bathymetry Surveys

Bathymetry surveys were completed by staff from the University of Alberta, ONA, OKIB and Splatsin using a SonTek Acoustic Doppler Profiler (ADP) during typical low flow conditions (19.48 m$^3$/s) in early August 2015. The proportion of flow passing through Intake No.2 at the time of survey was 28% of total river flow (5.46 m$^3$/s). A copy of the final report is provided in Appendix A. The primary conclusions from the report relevant to acoustic studies and entrainment at Wilsey Dam are summarized below:

- As flow approaches the dam, the flow splits between the spillway and toward Intake No.2.
- The influence of turbine withdrawal was observed up to 14 m upstream of Intake No.2.
- The uppermost 2 m of the water column at 1 m upstream of Intake 2 showed transverse flows on the order of 0.08 m/s, whereas strong currents were measured at large depths (below 4.5 m)
- Maximum measured flow velocities in the spillway were 0.74 m/s and near Intake No.2 were 0.64 m/s.
3.0 RESULTS

3.1 Environmental Conditions

The weather was hot (>30°C) and sunny during Test A and B and overcast with rain showers during Test C. The water was generally clear and water temperature measured between 21.4°C and 21.8°C. The scheduled timing of the high flow test was based on median river flows for early July (approximately 100 m³/s), which are similar to those observed during the onset of freshet in mid-May when subyearling Chinook migration typically occurs (Figure 21). Unusual drought conditions in the summer of 2015 and installation of flashboards at Sugar Lake Dam by BC Hydro rapidly reduced river flows to levels substantially below normal by early July. Unfortunately, a proposed dredging project in the forebay during May and June made shifting the high flow test to an earlier time impossible; therefore, only the low flow test was completed. Flows during the study period were representative of pre- and post-freshet levels when the yearling component of the Middle Shuswap Chinook stock typically migrates.

![Graph showing water flow](image)

Figure 21: Median Shuswap River discharge (dashed blue) and observed 2015 discharge (green) at Water Survey Canada station 08LC003 (study period outlined in red).

River flows declined from 39.97 m³/s at the beginning of the study period (July 2nd) to 28.65 m³/s on the last day (July 14th, 2015) (Figure 22). A rain event on July 11th led to a small rise in water and subsequent loss of one tag suspended in the center of the spillway, cutting Test C short to 24 hrs instead of the planned 96 hrs. Turbine flows ranged from a low of 3.5 m³/s (9% of river flow) on July 9th to a high of 11.9 m³/s (35% of river flow) on July 10th through Intake No.2 (Intake No.1 was not operational).
3.2 Acoustic Range Testing Results

This section provides results for tests A-C. For each test, we present summary statistics and comparisons between the systems for tags 1 to 3 only, since 4 tags were only available for the Vemco system. The fourth Vemco tag was used to test further distances beyond what would be required or additional configurations that were not critical to each test.

3.2.1 Test A - Forebay

Test A lasted from 16:11:00 on July 2, 2015 to 10:10:59 on July 6, 2015, (91 hrs) when all equipment was removed from the test location. Mean hourly detection rates in the forebay ranged from 34% to 96% (tag A1-A3 average = 65%) for Vemco HR tags and 3% to 100% (average = 38%) for Lotek JSATS tags. Both Vemco HR and Lotek JSATS detection rates were variable between receiver/tag combinations and declined noticeably with distance (Figure 23). However, Lotek detection rates declined more rapidly and, at 20 m distance from the receiver, were generally below 30% whereas Vemco HR remained around 50%. Standard deviations between the two systems were comparable at means of 8.8% (Lotek) and 6.6% (Vemco HR). Some tag-receiver combinations (e.g., Lotek A3-A3) were possibly affected by placing multiple receivers immediately next to each other, and blocking clear “view” of the tag, leading to low detection rates. Some fluctuating patterns and trends over time can be seen in the detection rates of both systems at this location (Figure B1 and Figure B2, Appendix B), particularly in those tags and receivers near the sediment island and main channel log boom, as well as the A4 Vemco tag across the main channel. It is unknown what caused these patterns but some appear to follow a daily (24-hr) cycle, particularly in the Vemco HR data.

Detection rates of the Vemco PPM technology were generally higher (60% to 80%, mean standard deviation of 7.6%) (Table 5) and remained higher at greater distances

Figure 22: Observed Shuswap River discharge over the study period at Water Survey Canada station 08LC003.
Detection rates for some tag-receiver combinations show more short-term fluctuation than the other systems, but the system appears less prone to trends over the test duration of several days (Figure B3 in Appendix A).

Table 5: Detection Rates for Test A.

<table>
<thead>
<tr>
<th>Test A</th>
<th>Lotek JSATS</th>
<th>Vemco HR2</th>
<th>Vemco PPM</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>Receiver</td>
<td>Distance</td>
<td>Mean Detection Rate</td>
<td>Mean Detection Rate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>(m)</td>
<td>% (Std. Dev.)</td>
<td>% (Std. Dev.)</td>
</tr>
<tr>
<td>A1</td>
<td>A1</td>
<td>1.0</td>
<td>100 (0.7)</td>
<td>0.4</td>
</tr>
<tr>
<td>A1</td>
<td>A2</td>
<td>26.2</td>
<td>28 (4.7)</td>
<td>26.0</td>
</tr>
<tr>
<td>A1</td>
<td>A3</td>
<td>19.6</td>
<td>27 (7.9)</td>
<td>19.5</td>
</tr>
<tr>
<td>A2</td>
<td>A1</td>
<td>26.2</td>
<td>3 (1.3)</td>
<td>26.5</td>
</tr>
<tr>
<td>A2</td>
<td>A2</td>
<td>0.4</td>
<td>60 (7.6)</td>
<td>0.4</td>
</tr>
<tr>
<td>A2</td>
<td>A3</td>
<td>39.9</td>
<td>17 (11.9)</td>
<td>39.8</td>
</tr>
<tr>
<td>A3</td>
<td>A1</td>
<td>12.3</td>
<td>65 (4.9)</td>
<td>11.8</td>
</tr>
<tr>
<td>A3</td>
<td>A2</td>
<td>35.5</td>
<td>18 (18.9)</td>
<td>35.3</td>
</tr>
<tr>
<td>A3</td>
<td>A3</td>
<td>8.0</td>
<td>22 (21.1)</td>
<td>7.9</td>
</tr>
<tr>
<td>A4</td>
<td>A1</td>
<td>-</td>
<td>-</td>
<td>50.6</td>
</tr>
<tr>
<td>A4</td>
<td>A2</td>
<td>-</td>
<td>-</td>
<td>76.7</td>
</tr>
<tr>
<td>A4</td>
<td>A3</td>
<td>-</td>
<td>-</td>
<td>47.8</td>
</tr>
</tbody>
</table>

Figure 23: Mean hourly detection rate of Vemco and Lotek equipment over distance during Test A (forebay and near Intake No.2).
3.2.2 Test B – Main Channel

Test B lasted from 15:00:00 on July 6, 2015 to 10:38:59 on July 10, 2015, (92 hrs) when all equipment was removed from the test location. Mean hourly detection rates in the main channel ranged from 0% to 85% (tag B1-B3 average = 50%) for Vemco HR tags and 1% to 92% (average = 55%) for Lotek tags (Table 6). Lotek (Figure 24) and Vemco HR (Figure 25) detection rates were highly variable between receiver/tag combinations but did not show a clear declining trend with distance. Mean standard deviations between the two systems were slightly higher for Vemco HR equipment (20%) than Lotek equipment (15%). It is suspected that the variability in detection rates observed in this test is at least in part caused by site-specific conditions like large rip rap boulders, which were present along the entire right bank where the receivers were installed. Further, in some cases detection was likely affected by placing multiple receivers immediately next to each other, thus blocking line of sight to a tag (e.g., Lotek tag B2-receiver B2, Vemco PPM tag B1-receiver B2). Detection rates of the Vemco PPM system were generally higher (0% to 84%, mean = 68%, standard deviation = 10.2%) (Table 6) and less variable over short distances up to 100 m (Figure 26), but became variable beyond that. Some receivers showed high detection rates (~80%) at distances of 150 m (Lotek) and 118 m (Vemco HR) indicating that it is possible to achieve sufficient range across the channel at this location.

Similar to Test A, some distinct patterns and trends can be seen in the detection rates of the Lotek and Vemco HR systems over time (Figure B4 and Figure B5, Appendix B). A distinct short-term drop in detection rate is evident for both systems on July 8 for tag B3. On that day, BC Hydro strung a boom across the main channel through the test area via boat. The boom extended from approximately receiver B3 to tag B3. It is assumed that the observed low detection rates in tag B3 at that time are due to boat activity disturbing the range test. Further, both Vemco VR2W (PPM) and Lotek WHS4000 receivers at location B3 were found laying on their side upon retrieval on July 10, which likely impacted detection rates for the remainder of Test B. Similar to Test A, detection rates for the PPM technology appear more stable and less prone to trends over time (Figure B6, Appendix B).
Table 6: Detection Rates for Test B.

<table>
<thead>
<tr>
<th>Test B</th>
<th>Lotek JSATS</th>
<th>Vemco HR2</th>
<th>Vemco PPM</th>
<th>Note</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Distance (m)</td>
<td>Mean Detection Rate % (Std. Dev.)</td>
<td>Distance (m)</td>
<td>Mean Detection Rate % (Std. Dev.)</td>
</tr>
<tr>
<td>B1</td>
<td>B1</td>
<td>56.1</td>
<td>79 (10.5)</td>
<td>55.8</td>
</tr>
<tr>
<td>B1</td>
<td>B2</td>
<td>98.4</td>
<td>92 (3.9)</td>
<td>98.3</td>
</tr>
<tr>
<td>B1</td>
<td>B3</td>
<td>159.4</td>
<td>78 (19.5)</td>
<td>159.3</td>
</tr>
<tr>
<td>B2</td>
<td>B1</td>
<td>52.0</td>
<td>83 (18.1)</td>
<td>52.0</td>
</tr>
<tr>
<td>B2</td>
<td>B2</td>
<td>26.5</td>
<td>1 (3.0)</td>
<td>26.8</td>
</tr>
<tr>
<td>B2</td>
<td>B3</td>
<td>68.5</td>
<td>12 (12.8)</td>
<td>68.3</td>
</tr>
<tr>
<td>B3</td>
<td>B1</td>
<td>118.3</td>
<td>26 (23.9)</td>
<td>118.4</td>
</tr>
<tr>
<td>B3</td>
<td>B2</td>
<td>74.9</td>
<td>54 (23.4)</td>
<td>75.2</td>
</tr>
<tr>
<td>B3</td>
<td>B3</td>
<td>29.5</td>
<td>69 (17.8)</td>
<td>28.9</td>
</tr>
<tr>
<td>B4</td>
<td>B1</td>
<td>-</td>
<td>-</td>
<td>186.2</td>
</tr>
<tr>
<td>B4</td>
<td>B2</td>
<td>-</td>
<td>-</td>
<td>144.5</td>
</tr>
<tr>
<td>B4</td>
<td>B3</td>
<td>-</td>
<td>-</td>
<td>92.6</td>
</tr>
</tbody>
</table>
Figure 24: Mean hourly detection rate of Lotek equipment over distance during Test B (main channel).

Figure 25: Mean hourly detection rate of Vemco HR equipment over distance during Test B (main channel).

Figure 26: Mean hourly detection rate of Vemco PPM equipment over distance during Test B (main channel).
3.3.3 Test C – Spillway and Intake No.2

The objectives for Test C are described in Section 2.2.3. The equipment was configured to simulate a future entrainment study; therefore, there was no direct line of sight between some tag-receiver pairs (Table 7). This was intended to provide definitive information on the passage route of tagged fish inferred from last detection. Test C lasted from 18:03:00 on July 10, 2015 to 17:04:59 on July 11, 2015, (24 hrs) when Tag C3 was lost down the spillway following a rain event and subsequent increase in water level (Figure 22). The test was only 24 hrs in length compared to 91 and 92 hrs for tests A and B, respectively. All remaining equipment was removed on July 14.

Mean hourly detection rates ranged from 0% to 87% for Vemco HR tags and 0% to 90% for Lotek tags (Table 7). Average detection rate for tag-receiver pairs with direct line of sight (tags C1- C3 only) was 42% for Vemco HR tags and 63% for Lotek JSATS tags, with similar mean standard deviations (9.1% and 12.9%, respectively). Lotek detection rates were relatively high (>60%) and quite stable over distance (Figure 27), with good (60%-80%) detection across the width of the spillway (approx. 35 m). Vemco HR detection rates were very high at short distances (>80% up to 16 m) but were consistently lower than Lotek beyond that (Figure 28). Similar to the previous two tests, detection rates of the Vemco PPM system were slightly higher (0% to 93%, mean = 72%; Table 7) and less variable over short distances up to 30 m (Figure 29) than the other systems, but the Lotek system performed similar or better at distances beyond that (Figure 27).

Across the spillway, three of four Lotek tag-receiver pairs had good detection rates (56%-83%, mean = 67%). The exception was tag C1 - receiver C1, located within 3 m of each other on the right side of the spillway (Figure 16), with a detection rate of only 10%, which lowered the average for the spillway to 53%. The low detection rate between this pair was likely caused by a large piece of rip rap between the tag and receiver at this location. Vemco HR equipment, which was situated slightly away from the rip rap, did not seem to be affected by this particular piece of rip rap and had a high detection rate for this pair (69%), illustrating the influence of site specific streambed conditions on detection rates. Nonetheless, Lotek detection rates were higher than Vemco HR for all other tag-receiver pairs in the spillway (Table 7). In particular, the tag C1 - receiver C3 pair, which measured across the width of the spillway, showed high detection rates for Lotek (83%) but not Vemco HR (2%).

Figure B7 and Figure B8 (Appendix B) show that detection rates were quite stable over time for tags C1 and C2. Tag C3, however, showed some distinct trends: Lotek detection rate increased over the duration of the test whereas Vemco HR detection rate fluctuated in the low range (spillway right bank receiver C1), or decreased over the test (spillway left bank receiver C3). The trends seen for this tag may have been caused by possible changes in depth of the tag over the test duration. The tag was suspended from a cable crossing near the spill crest in relatively shallow water (visual estimate was 30 cm), and was observed to be bouncing around slightly due to the strong current and shallow depth at this location. It is possible that floating debris accumulated on the line it was fastened to over time, slowly weighing it down and possibly lowering the tag in between rocks at the bottom (Vemco HR tag, which was attached lower), or lowering it from near the surface to the center of the water column (Lotek tag, which was attached higher). It is likely that the trends in detection rate over time observed for this tag were the result of the unsteady nature of the tag. A tagged fish would have the benefit of moving around in
the spillway, increasing the chances of being detected by a receiver even if the line of sight is blocked by a rock at a particular instance. Ultimately, a rain event led to rising water levels, causing the line to break and the loss of the C3 tag.

Detection rates at Intake No.2 (tag C2-receiver C2) were consistently very high (>87%) for Lotek and both Vemco systems (Table 7), and there were no trends over time (Figure B7 – B9; Appendix B).

Aside from detection rates and range, Test C was laid out to determine if it would be possible to provide definitive information on the passage route of tagged fish, inferred from last detection. To do so, it is critical that receivers in the spillway do not detect tags that approach Intake No.2, and vice versa. Specifically, no detections were wanted between the following tag-receiver pairs: tag C1 and C3 (spillway) – receiver C2 (Intake No.2); tag C2 (Intake No.2) – receiver C3 (and ideally, C1) (spillway). The configuration was successful in getting no detections between these pairs for all three technologies trialed, with the exception of tag C2-receiver C1 (right bank of spillway). The Lotek C2 tag showed high (77%) and consistent detection at the C1 receiver, whereas detection was low for the Vemco HR (9%) and PPM (18%) (Table 7). In contrast, the right bank spillway tag (C1) was not detected at the Intake No.2 (C2) receiver by any system - likely because the C2 receiver was placed to the left of the intake toward the forebay to avoid detecting spillway tags.

Table 7: Detection Rates for Test C.

<table>
<thead>
<tr>
<th>Test C</th>
<th>Lotek JSATS</th>
<th>Vemco HR2</th>
<th>Vemco PPM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tag</td>
<td>Receiver</td>
<td>Mean Detection Rate % (Std. Dev.)</td>
<td>Distance (m)</td>
</tr>
<tr>
<td>C1</td>
<td>C1</td>
<td>10 (4.2)</td>
<td>4.2</td>
</tr>
<tr>
<td>C1</td>
<td>C2</td>
<td>0 (0.0)</td>
<td>55.7</td>
</tr>
<tr>
<td>C1</td>
<td>C3</td>
<td>83 (17)</td>
<td>33.6</td>
</tr>
<tr>
<td>C2</td>
<td>C1</td>
<td>77 (4.5)</td>
<td>47.9</td>
</tr>
<tr>
<td>C2</td>
<td>C2</td>
<td>90 (2.3)</td>
<td>8.9</td>
</tr>
<tr>
<td>C2</td>
<td>C3</td>
<td>0 (0)</td>
<td>18.4</td>
</tr>
<tr>
<td>C3</td>
<td>C1</td>
<td>62 (17.5)</td>
<td>16.0</td>
</tr>
<tr>
<td>C3</td>
<td>C2</td>
<td>0 (0)</td>
<td>40.1</td>
</tr>
<tr>
<td>C3</td>
<td>C3</td>
<td>56 (31.9)</td>
<td>18.3</td>
</tr>
<tr>
<td>C4</td>
<td>C1</td>
<td>-</td>
<td>39.2</td>
</tr>
<tr>
<td>C4</td>
<td>C2</td>
<td>-</td>
<td>17.9</td>
</tr>
<tr>
<td>C4</td>
<td>C3</td>
<td>-</td>
<td>14.6</td>
</tr>
</tbody>
</table>

1 RB = right bank; LB = left bank
Figure 27: Mean hourly detection rates of Lotek equipment over distance during Test C.

Figure 28: Mean hourly detection rates of Vemco HR equipment over distance during Test C.

Figure 29: Mean hourly detection rates of Vemco PPM equipment over distance during Test C.
Testing of three acoustic telemetry systems at Wilsey Dam under low flow conditions (approx. 30 m³/s) was completed successfully. Average detection rate throughout the forebay area of the dam (Test A) was higher for the Vemco HR (average 65%) than for the Lotek system (average 38%). However, in the two receiver-tag configurations that simulated tags going into Intake No.2 (location A1 in Test A and location C2 in Test C) the Lotek system performed better (100% and 90%, vs. 73% and 87% for Vemco HR). Some tag-receiver combinations were possibly affected by positioning of multiple receivers immediately next to each other, and blocking clear “view” of the tag. This would not be the case in a future entrainment study where only one brand receiver would be placed at each location.

Average detection rate in the main channel upstream of the dam (Test B) was similar between the Vemco HR (average 50%) and the Lotek system (average 55%). Of note were some very low detection rates between particular tag-receiver pairs, which were likely affected by large rip rap along the river right bank blocking line of sight between tags and receivers in some cases, as well as boating activity and disturbance of some receivers during the test. Overall, performance of both systems was much more variable at this location and there was no clear declining trend with distance. In some cases, very good (~80%) detection rates was achieved at distances of 150 m (Lotek) and 118 m (Vemco HR).

The last configuration (Test C) simulated a future entrainment study. Equipment was placed in the spillway and near Intake No.2 to determine if unambiguous information on the passage route of tagged fish could be collected, and if detection rates would be sufficient to detect tagged fish in those areas. Average detection rate in the spillway was higher for Lotek tags (53%) than Vemco HR (39%), and the Lotek system also showed further detection ranges (77% detection rate at 48 m). Detection range was shorter for the Vemco HR system at detection rates <60% past 15 m, which is less than the width of the spillway (approx. 35 m). A key conclusion from this test was that receivers can be configured to explicitly determine fish passage route, as Intake No.2 receivers were unable to detect tags in the spillway and vice versa.

The Vemco PPM technology, which was also trialed during this study and is included in Vemco’s V5 tags, generally had higher detection rates over further ranges, and appears more stable than the Vemco HR and Lotek systems. Due to limitations on pulse rate and tag collisions this system is not suitable on its own for a future entrainment study at Wilsey Dam, but would be a useful “backup” should the Vemco HR system be used.

The following are the primary conclusions from this feasibility test with respect to a future entrainment study:

- Lotek equipment performed equal to or better than Vemco HR equipment in key areas (spillway and near Intake No.2), and slightly poorer in the forebay area.
- Detection of tags is susceptible to being blocked by large rip rap located in some areas of the spillway and along the river right bank. This effect was observed in all systems trialed. This would likely also affect receivers placed downstream of the dam where rip rap and boulders are present.
• In some locations, detection rate was variable over the duration of the test with increasing or decreasing trends or fluctuations observed. Some of these could be explained by disturbances through boat traffic and the placement of a logboom, or by changes in the position of the tag. In other cases (e.g., Test A), the cause of the fluctuations is unknown and may be related to dam operations or environmental factors that were not immediately obvious.

• Detection range in the spillway and near Intake No.2 was sufficient to detect tagged fish during a future entrainment study. In some instances, detection range is much further than would be required. This would lead to increased chances of detecting a tagged fish because it would spend a longer period of time (and thus emit more pings) in a “detectable” area. However, most important is that fish are detected in the key areas that definitively determine passage route.

• It is possible to configure equipment to definitively determine fish passage route through the dam. Key locations for this are a receiver placed slightly to the left of Intake No.2 (C2 in this study) and a receiver placed on the left bank of the spillway (C3 in this study). Figure 30 illustrates this concept. The spillway right receiver (C1) was able to detect all tags and thus cannot be used to determine passage route. This may possibly be improved by moving the receiver closer to the spill crest to eliminate direct line of sight to Intake No.2, but shallow water depths become a problem. This receiver would still be useful as a “check” for the other receivers.

• The window of opportunity for detecting tagged fish in key areas of Wilsey Dam may be as short as 15 seconds (at a minimum), which is an estimate of minimum travel time of a tagged fish through areas A or B (Figure 30) based on distance and flow velocity measured during the bathymetry survey (Appendix A). It is therefore critical that pulse rates of the tags used are very rapid (every 2 or 3 seconds) to ensure that there are at least a few detections for each tag.

• The more rapid the pulse rate, the higher the likelihood that a tag is detected. The number of times that a tagged fish is expected to be detected at a given receiver is a function of the detection rate, the tag’s pulse rate, and the duration that the fish remains in the receiver’s detection range (Equation 1). For example, at a detection rate of 60%, a tagged fish that is within the detection range for 15 seconds and pings every 3 seconds would get detected 3 times. 15 s is estimated to be the absolute minimum time that a tagged fish would be within the detection range of receivers, based on flow velocities and distance of travel through the spillway and toward Intake No.2.

\[
\text{# detections} = \frac{\text{time spent in detection range}}{\text{pulse rate}} * \text{detection rate} \quad \text{(Equation 1)}
\]
Several recommendations for a future entrainment study were developed from this feasibility study:

- Placement of receivers in the forebay should take into account the locations of sediment islands which may lead to reduced detection rates.
- Placement of receivers in the main channel up- and downstream of the dam and spillway should be away from large rip rap and boulders which may lead to reduced detection rates. Overall, micro-scale conditions at the site can have a large effect on detection rates.
- Deploy “sentinel tags” at each detection site to monitor variations in detection rate throughout the study period.
- Test detection rates of sentinel tags prior to the release of test fish, and adjust receiver position if necessary. This could also include moving a test tag through a receiver gate via boat.
- Tags need to have a high pulse rate due to the potential for short travel times of tagged fish between Intake No.2 and the spillway (recommendation is <3 s). Tagged fish are unlikely to remain in the area of the dam for long periods of time so there is little concern with battery life (battery life decreases at more rapid pulse rates).
- The logistics of installing receivers in strong current and away from large rip rap needs to be considered with respect to anchoring mechanisms to keep receivers upright. Receivers should not be braced against large rocks that may block line of sight to tags. Alternative installations could include cable crossings.
- A site visit during clear water conditions is necessary to determine best placement of receivers.

Figure 30: Estimated detectability of tags by receivers in various areas of Wilsey Dam, based on observed tag locations and estimated by detection range.
5.0 REFERENCES


Walsh M., and E. McGrath. 2015. Feasibility of Assessing Fish Entrainment at Wilsey Dam: Towards Re-Establishing Fish Passage. Prepared for Whitevalley Community Resource Centre and the Wilsey Dam Fish Passage Committee.


Appendix A – Bathymetry and Flow Survey Report
Appendix B – Hourly Detection Rates
Figure B1: Lotek Hourly Detection Rates for Tag-Receiver Combinations during Test A (ID indicates hour from start of test).
Figure B2: Vemco HR2 Hourly Detection Rates for Tag-Receiver Combinations during Test A (ID indicates hour from start of test).
Figure B3: Vemco PPM Hourly Detection Rates for Tag-Receiver Combinations during Test A (ID indicates hour from start of test).
Figure B4: Lotek Hourly Detection Rates for Tag-Receiver Combinations during Test B (ID indicates hour from start of test).
Figure B5: Vemco HR2 Hourly Detection Rates for Tag-Receiver Combinations during Test B (ID indicates hour from start of test).
Figure B6: Vemco PPM Hourly Detection Rates for Tag-Receiver Combinations during Test B (ID indicates hour from start of test).
Figure B7: Lotek Hourly Detection Rates for Tag-Receiver Combinations during Test C (ID indicates hour from start of test).
The Feasibility of Acoustic Telemetry for Juvenile Salmonid Entrainment Studies at Wilsey Dam

Test C - Vemco HR2

Figure B8: Vemco HR2 Hourly Detection Rates for Tag-Receiver Combinations during Test C (ID indicates hour from start of test)
Figure B9: Vemco PPM Hourly Detection Rates for Tag-Receiver Combinations during Test C (ID indicates hour from start of test).