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Fish and Wildlife Service
Mid-Columbia Fish and Wildlife Conservation Office

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MEMORANDUM **May 5, 2016**

To: Interested Parties
From: Hayley Potter

RE: Assessing Fish Passage at Leavenworth National Fish Hatchery using DIDSON Sonar

Leavenworth National Fish Hatchery (LNFH) has operated several water diversion structures since its construction in 1939. One of these structures, Structure 2, is a channel-spanning diversion dam consisting of two, 5ft x 16ft radial gates (Figure 1, 2). Using one or both of the steel radial gates, water can be diverted away from the Historical Channel and into the Hatchery Channel (Figure 3). Structure 2 has been operated in the previous years for multiple reasons, including, seasonal flood control through the Historical Channel, groundwater aquafer recharge and to generate attraction flows for broodstock collection. (Anglin, 2013). However, Structure 2 can impede fish passage under high and low flow conditions (high velocity and inadequate depths, respectively (Anglin, 2013)).

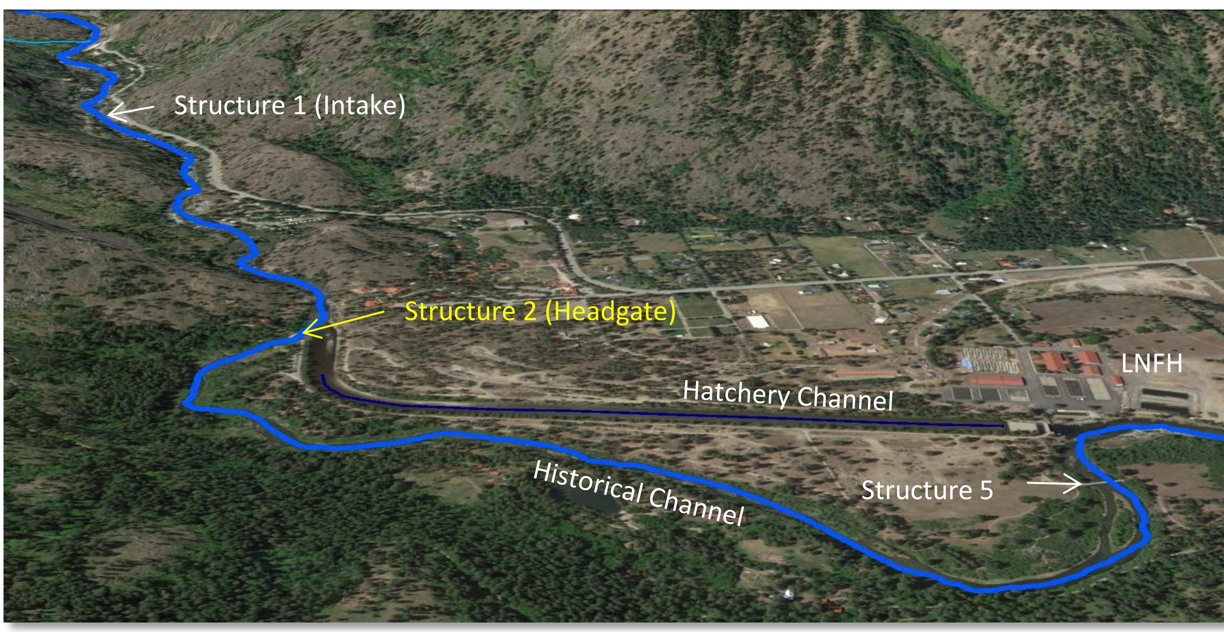

Figure 1 Leavenworth National Fish Hatchery

Figure 2. Structure 2 radial gates in a closed position.

Methods

DIDSON

In response to adaptive management guidelines and to monitor fish passage through the Historical Channel, the Mid-Columbia Fish and Wildlife Conservation Office (MCFWCO) acquired a Dual-frequency Identification SONAR (DIDSON^{TM}), manufactured by Sound Metrics Corp. The DIDSON acoustic camera insonifies the water at a high frame rate providing a "video like" recording. When an object passes through the insonified field an "echo" is returned back to the camera, creating an image. The software of the DIDSON then interprets and rotates the images 90^{o} to give the viewer a "from above" perspective (Figure 3). An obvious swimming motion or upstream movement makes determining an object as a fish relatively straightforward.

From 2011 through 2015, the DIDSON was located in the river left (i.e North) abutment above Structure 2 (Figure 3) where it has the ability to insonify the complete span of Structure 2 (Figure 4). The sonar was operated 24 hours a day on solar battery power from May through July to encompass the entire adult spring Chinook salmon return for all years. Data were recorded in hourly increments and evaluated using the DIDSON software features, Echogram or CSOT (Convolved Sample over Threshold), and trained personnel. Fish lengths were determined using the Mark Fish tool in the DIDSON software following the methods outlined in Hall, 2014.

Discharge / Velocities

To measure water stage height, a cantilevered wire-weight gage was installed at Structure 2 in 2010. This stage height measurement calculates both discharge and velocity. Accurately calculating discharge and velocity through the structure can be difficult at times, depending on flow and radial gate configurations.

When Icicle Creek is under free flow conditions, a drawdown occurs as the water flows over the crest of Structure 2. As the drawdown progresses over the structure the water depth decreases, the narrowest point just prior to free fall is referred to as critical depth (Figure 5a). It is at that point where velocity is the highest. The maximum/critical velocity is calculated by multiplying the width of the structure by the critical depth. To calculate minimum velocity the width of Structure 2 was multiplied by the water stage height before drawdown occurred (i.e. above Structure 2). The difference in velocities at these two points increases as discharge increases (Figure 6). In this “weir scenario”, discharge is calculated using the water stage height and a broad crested weir equation.

When the radial gates are in the path of flow, either lowered to block flow or the river stage height is above 5 feet different equations were used to calculate discharge and velocity. Under this “radial gate” scenario, flows pass under the gate and form a jet of water on the downstream side (Figure 5b). This jet has a constricted area, thus causing the velocities to be much higher than when the creek is under free flow conditions at the same discharge. Determining discharge and velocities under these conditions requires accurate gate opening measurements and stage height above drawdown.

Prior to 2015, there was no accurate way to measure the gate opening when the radial gates were lowered. During this time period, when radial gates were lowered, flow measurements were shifted to an instream flow gage near Structure 5, however, there was no way to accurately determine velocities during those time periods. (M. Lindenberg, pers. comm.).

Data Analysis

Average discharge and velocity are hourly measures derived from stage height measurements taken every 15 minutes by an automated system. These hourly averages were then linked to the corresponding fish passage events.

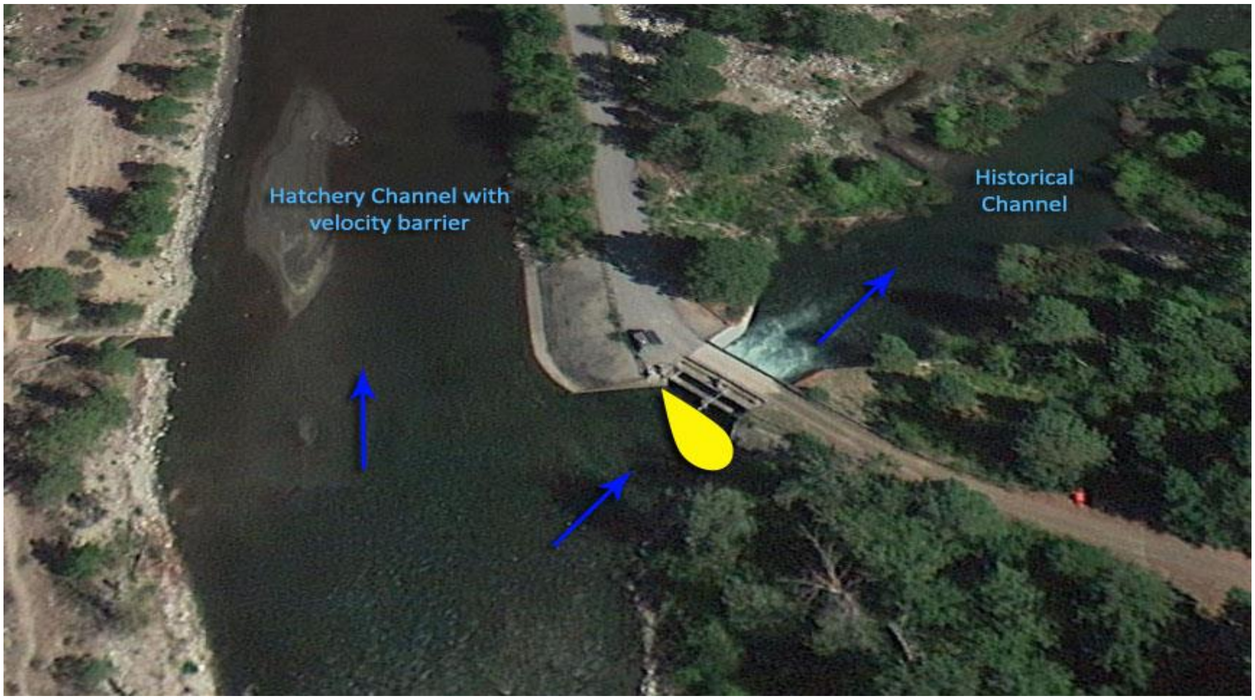

Figure 3. Aerial photo of Structure 2 with DIDSON insonified area in yellow

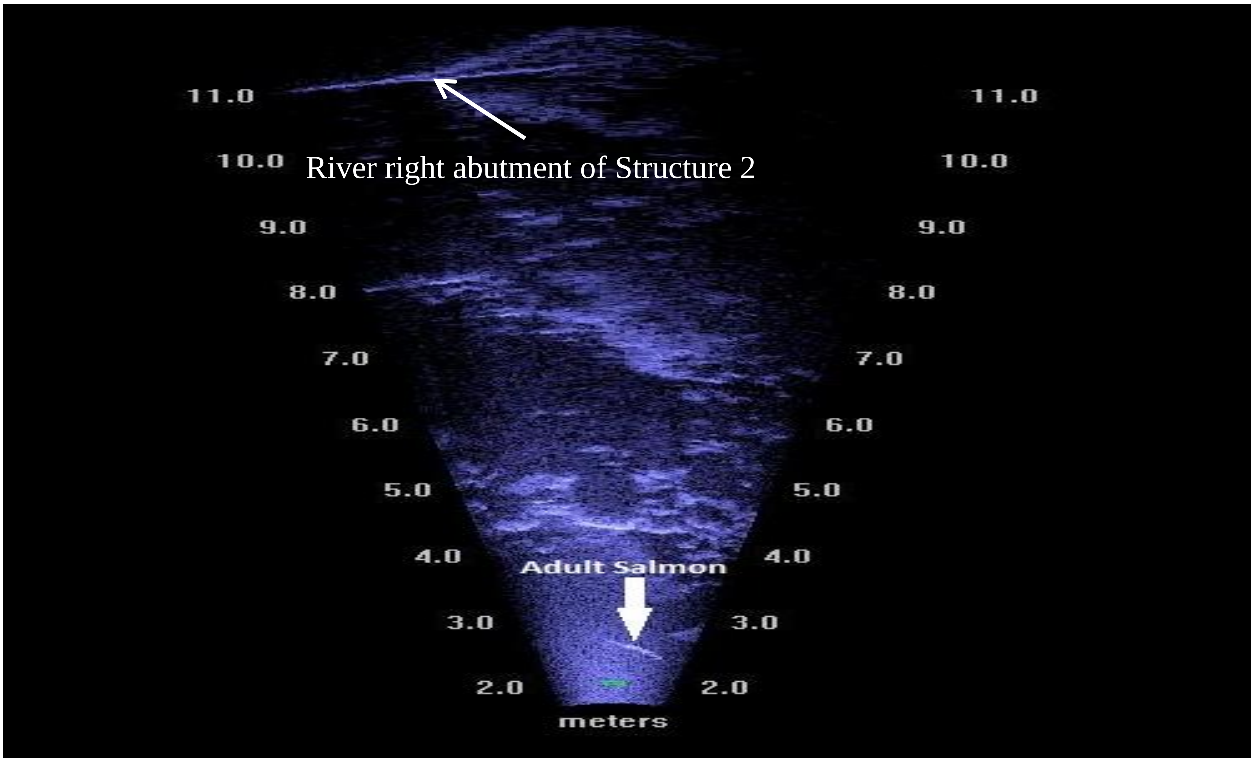

Figure 4. DIDSON video still depicting adult salmon above Structure 2.

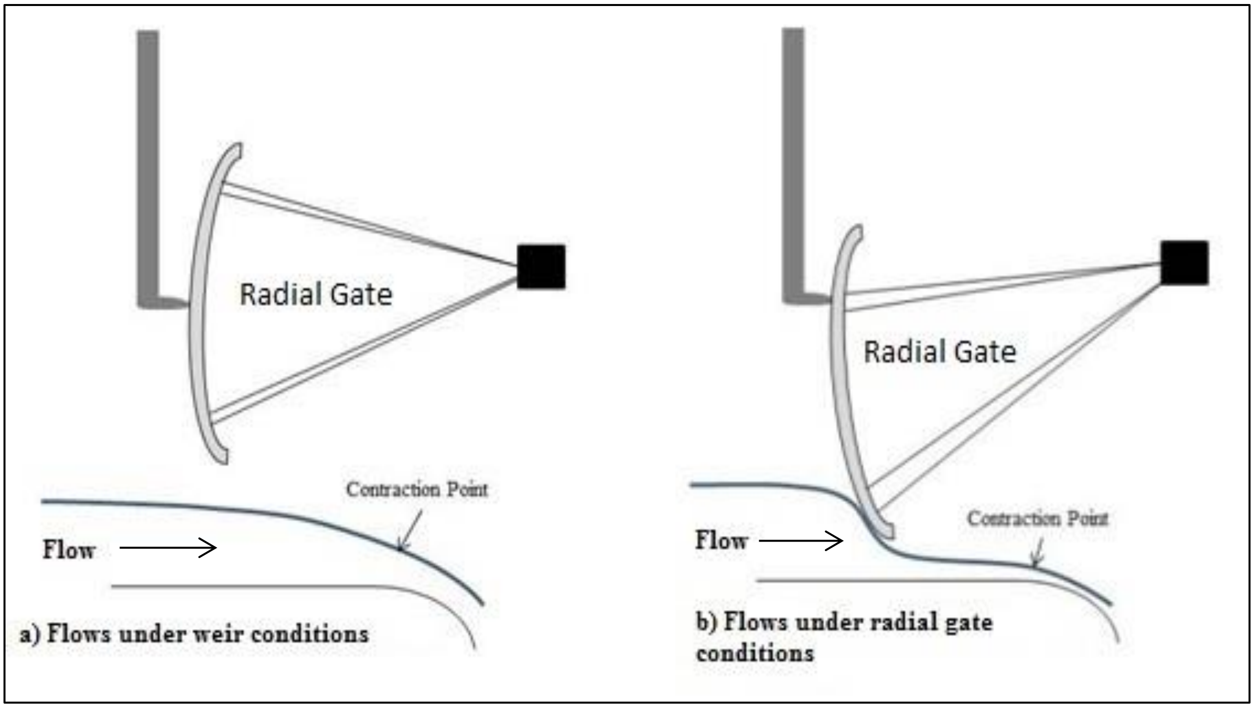

Figure 5. Diagram of the radial gates at Structure 2, under different flow regimes.

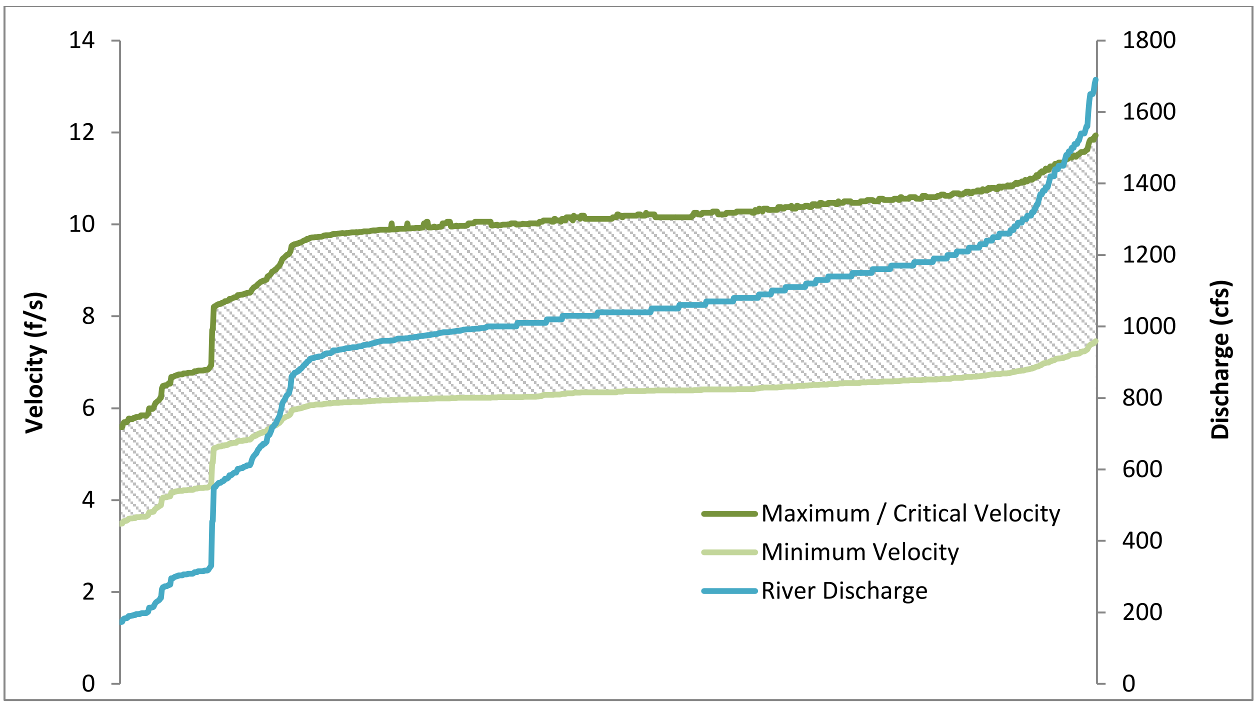

Figure 6. Relationship between minimum and maximum/critical velocities (ft/s) and discharge (cfs) through Structure 2.

Results

Since 2011, a total of 7,518 DIDSON video hours have been recorded and processed by the MCFWCO staff. From this, we have documented 4,120 salmon-sized (>24 inches, 60cm) fish migrating upstream of Structure 2. Successful upstream passage at Structure 2 in the weir scenario occurred with discharge ranging between 36 and 1690 cfs, (maximum/critical velocity of 4.2 and 11.9ft/s, respectively), with 50% of all passage occurring with discharges between 900 and 1200 cfs (Figure 7). Although the DIDSON operated when flows were greater than 1,690 cfs, there was no upstream passage documented.

During 2015, both gates remained open during the early portion of the spring Chinook Salmon run (April 28th thru June 1st) allowing 630 fish to migrate past Structure 2. On June 1st, to provide decreased flows through the historical channel for the installation of pickets at Structure 5, both gates were incrementally lowered to an opening of 11 inches, which decreased flows from 900cfs to 320cfs by June 3rd forcing the remaining water through the hatchery channel. During this time 3 salmon- sized fish were observed passing the structure. On June 4th, the gate on the south side of the structure was completely closed while the other gate was opened to 22 inches to aid in fish passage. While in this configuration (June 4th thru June 23rd), 370 salmon-sized fish were observed passing the structure with hourly average flows ranging from 140 to 287 cfs (Figure 8). Both gates were then completely opened on June 24th as directed by permitting agencies.

By early July the drought conditions in Icicle Creek and subsequent low flows of 72 cfs over Structure 2 were of concern. To provide sufficient water depth over Structure 2, the south gate was completely closed on July 13th effectively doubling the water depth through the north gate. In 2015 the DIDSON was shut down on July 22nd due to inadequate water depth at the camera site (Figure 8).

During the 2012 and 2013 monitoring period, lengths of 1,268 detected fish were measured using the DIDSON software (Hall 2014). Of these, 105 (8%) were less than 40 centimeters (16inches) in length with 68 traveling downstream and 37 migrating upstream of Structure 2. The smallest measured fish that was able to pass upstream of Structure 2 was 14.4 cm (5.6 inches) at an estimated discharge of 325 cfs (4.3-6.9 f/s, Figure 9). The remaining 1,163 fish were comparable in size to that of returning spring Chinook Salmon (mean length 30in, 76cm) measured at LNFH.

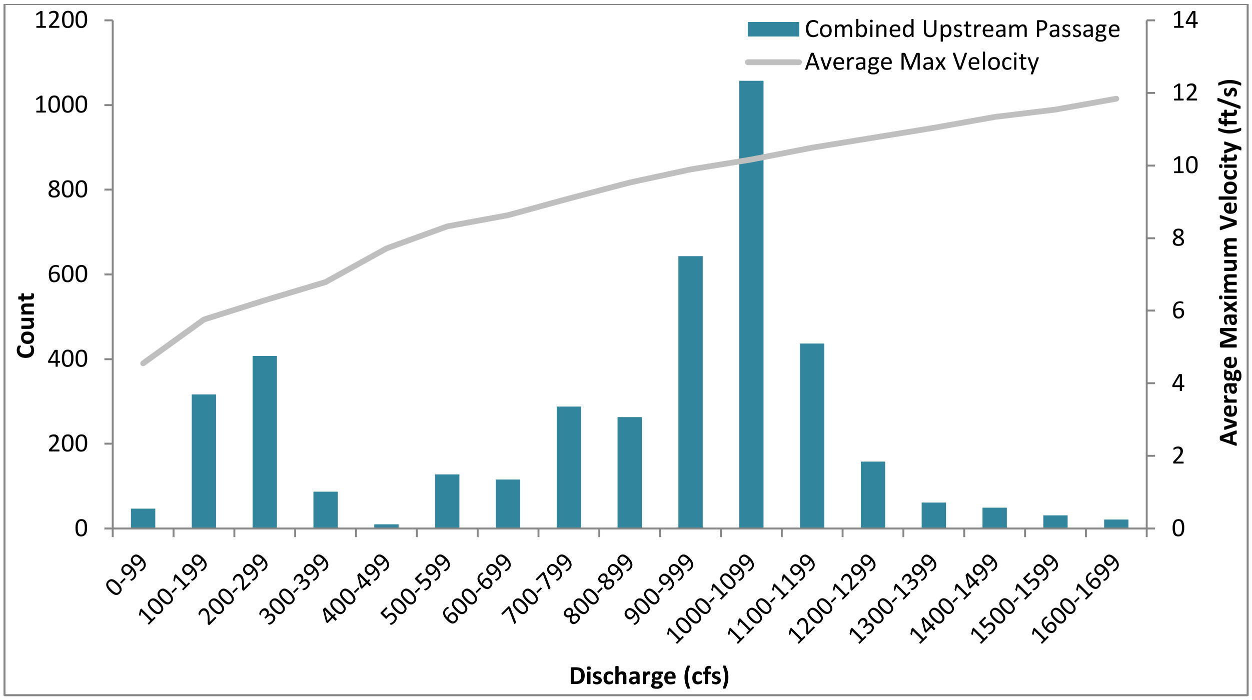

Figure 7. Combined count of upstream passage events of salmon-sized fish with binned discharge (cfs) and the average maximum/critical velocity (ft/s) at Structure 2, 2011-2015.

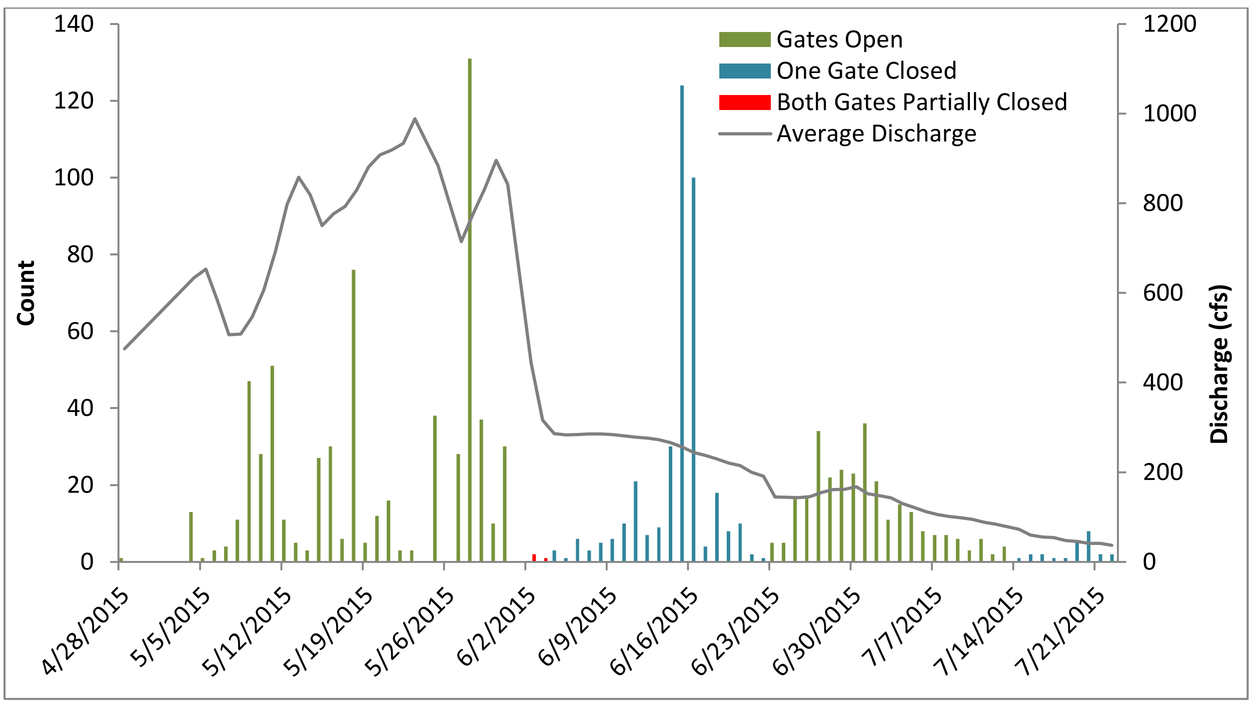

Figure 8. Fish passage events and discharge (cfs) at Structure 2 under multiple gate configurations, 2015.

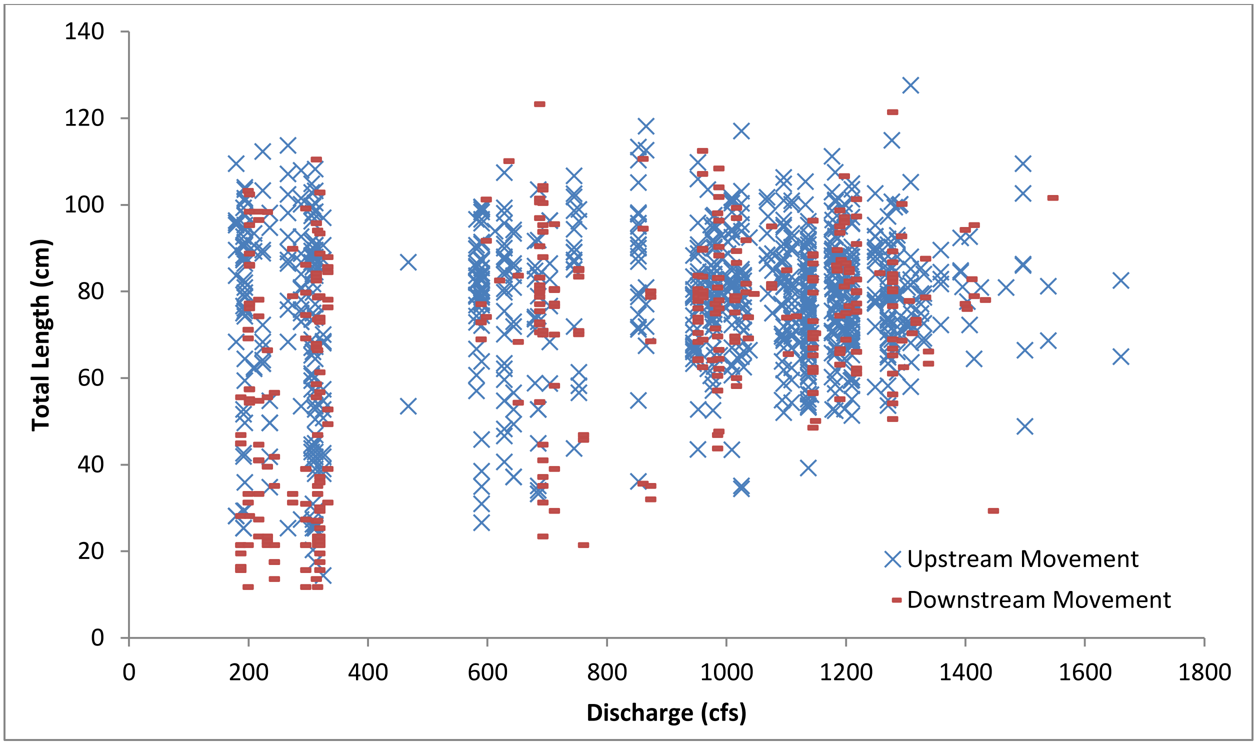

Figure 9. Distribution of movement events for length (cm) and discharge (cfs), 2012-2013.

Discussion

Even though fish passage through Structure 2 has only been monitored for a few months out of the year since 2011, the DIDSON camera has provided valuable insight into fish passage at Structure 2. Most passage events occurred at water velocities exceeding criteria commonly used in fish passage evaluations (Anglin 2013). One plausible explanation for this is based on observations of fish leaping over much of the high velocity area.

While the timing, size, and movement lends us to believe that we are monitoring adult spring Chinook salmon migration, determining species with the DIDSON is often difficult given the "from above" angle produced. It can be assumed however that a majority of the adult salmon-sized fish detected are spring Chinook Salmon since they heavily dominate the watershed during the annual monitoring periods. Other species may include adult fluvial Bull Trout (*Salvenlinus confluentus*) or steelhead (*Oncorhynchus mykiss*). Throughout the monitoring period numerous smaller (20 -40cm) fish were also observed migrating up and downstream through Structure 2. There is also a likelihood that juvenile fish are migrating through Structure 2 undetected due to small size.

Due to low snow pack during the 2014/2015 winter, the spring/summer of 2015 was exceptionally dry. This lack of discharge in Icicle Creek resulted in a lack of spill into the pool through hatchery channel flow as virtually all discharge was routed into the historical channel. It is apparent that fish did not hold in the spillway pool, as in average runoff years, but instead migrated into and through the historical channel to Structure 2. During the time period when pickets were installed at Structure 5 (June 1st- June 24th), all fish that were in the historical channel were trapped upstream of the Structure 5 pickets. Those fish had no option but to stay in the historical channel or to move through Structure 2. In prior years, the radial gates were operated simultaneously; however, modifications to Structure 2 in 2015 allowed LNFH to operate the gates independently. This modification allowed managers to address the low flow conditions in Icicle Creek and provide adequate water depth for fish passage over Structure 2.

References

Anglin, D.R., J.J. Skalicky, D. Hines, and N. Jones. 2013. Icicle Creek Fish Passage Evaluation for The Leavenworth National Fish Hatchery. U.S. Fish and Wildlife Service, Columbia River Fisheries Program Office, Vancouver, WA.

Hall, M.R. 2014. Spring Chinook Salmon Passage at the Leavenworth National Fish Hatchery, 2013, with Summary of Data from 2011-2013. U.S. Fish and Wildlife Service, Leavenworth WA.