KOOTENAI RIVER WHITE STURGEON CRITICAL HABITAT WITH FREE FLOWING AND BACKWATER CONDITIONS, BOUNDARY COUNTY, IDAHO: EVALUATION OF WATER DEPTH AND FLOW VELOCITY DURING 2006-09 SPAWNING SEASONS

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The U.S. Geological Survey has developed multidimensional-flow models of the Kootenai River between river kilometer 222 and 258 as tools to aid understanding of the physical factors affecting quality and quantity of spawning habitat used by the endangered Kootenai River white sturgeon (*Acipenser transmontanus*). Model simulations were used to compute the percentage of longitudinal profiles through a sub reach of the Kootenai River white sturgeon critical habitat that meet U.S. Fish and Wildlife Service 2006 Biological Opinion water depth and streamflow velocity criteria, on a daily interval during the 2006-09 spawning seasons. The Kootenai River flows through designated critical habitat composed of a braided, straight, and meandering reach between river kilometers 228 and 252.7 near Bonners Ferry, Boundary County, Idaho. Kootenay Lake, British Columbia, Canada, creates backwater conditions in the river that can extend throughout most of the critical habitat depending on lake elevation. Flow in the Kootenai River is regulated by Libby Dam in Montana, between the dam and critical habitat is a free flowing river. Channel geometry and the extent of backwater create a complex relation between stream discharge, depth and velocity. The Biological Opinion specifies a depth and streamflow velocity criteria for a sub reach of the critical habitat between RKMs 244.6 and 252.7, it includes the straight reach and lower three-fifths of the braided reach. Depth criteria were established in the Biological Opinion to provide target depths for Libby Dam sturgeon augmentation flows that would provide adequate depth for white sturgeon to swim upstream from the sandy meander reach–where sturgeon currently spawn and eggs are suffocated–to the braided reach where gravel and cobble are the dominant substrates and favorable for sturgeon egg incubation. The streamflow velocity criterion is intended to provide adequate velocity to reduce the ability of other fish species to prey upon sturgeon eggs, aid egg incubation, and enhance downstream dispersal of sturgeon. Our evaluation showed that the 5-m depth criterion was met on about half of the days during peak flow augmentation during the 2006-09 spawning seasons. The 7-m water depth criterion was never met. The 1 meter per second stream velocity criterion was met daily during peak flow augmentation of the 2006-09 spawning seasons.

BACKGROUND

The endangered Kootenai white sturgeon (*Acipenser transmontanus* is a naturally landlocked, locally adapted population that has been isolated since the last glacial age approximately 10,000 years ago. The Kootenai sturgeon was listed as endangered under the Endangered Species Act (ESA) in 1994. A recent population assessment concluded that the wild population was between 800 and 1,000 adults with the population declining by approximately 4 percent a year (Ray Beamesderfer, Cramer Fish Sciences, written commun., 2009). At this rate there will be no remaining wild population by approximately 2080, although functional extinction could occur well before that time.

Kootenai white sturgeon spawn near Bonners Ferry, Idaho. A graph of spawning events per unit of monitoring effort during 1994-2001 shows that the sturgeon spawn in the meander reach between river kilometer (RKM) 228 and 240, with a few events observed in the straight reach between RKMs 245.0 and 245.8 (fig. 1). A series of research investigations determined that sturgeon were spawning over unsuitable incubation and rearing habitat—sand–in the meander reach, and that survival of eggs and larvae was negligible (Paragamian and others, 2002). Sedimentation has been presented as a likely source of mortality for white sturgeon embryos (Kock and others, 2006). Currently, less than 30 percent of tagged sturgeon spawners swim upstream into the braided reach, only to briefly inhabit the lowermost part of the reach, before swimming back downstream to the meander or straight reach to spawn (Pete Rust, Idaho Department of Fish and Game, oral commun., 2008).

There has been a well-documented decline in Kootenai sturgeon recruitment over the past 50 years (Partridge, 1983; U.S. Fish and Wildlife Service, 1999; Paragamian and others, 2005). There has been no significant recruitment of young sturgeon observed since the early 1970s and consistent annual recruitment has not been observed since the 1950s (U.S. Fish and Wildlife Service, 1999; Paragamian and others, 2005). In 1989, the Kootenai Tribe of Idaho (KTOI) initiated a conservation aquaculture program as a stopgap measure designed to ensure an adequate demographic and genetic basis for a healthy future Kootenai sturgeon population pending completion of appropriate habitat restoration actions. The KTOI's conservation aquaculture program, which is funded by Bonneville Power Administration (BPA) through the Northwest Power and Conservation Council's Fish and Wildlife Program, currently provides the only consistent source of recruitment for Kootenai River white sturgeon.

Flow regulation at Libby Dam is thought to be one of the major reasons for the continued decline of Kootenai sturgeon. Historically, the annual Kootenai River hydrograph consisted of minimum flows during the winter, followed by a rise in discharge in the spring, a peak in the late spring or early summer, and a recession for the remainder of the summer, fall and winter. Regulated spring peak flows are less than the pre-Libby Dam peak flows, while winter flows have increased by 300% relative to the pre-dam period (U.S. Fish and Wildlife Service, 1999). High spring flows similar to pre-dam conditions have not occurred during the May-July spawning season since Libby Dam began operating in 1974 .

The U.S. Fish and Wildlife Service (USFWS) updated the 2000 Biological Opinion (BiOp; U.S, Fish and Wildlife Service, 2000; 2006) due to litigation over the 2000 BiOp and the designation of critical habitat for Kootenai sturgeon in 2001. In a 2008 final ruling (73 FR 39505), a small portion of the Kootenai River meander reach, the entire straight reach, and a portion of the braided reach, RKM 228 -252.7, was designated as white sturgeon critical habitat (WSCH). The BiOp specifies a depth and streamflow velocity criteria for a sub reach of the WSCH between RKMs 244.6 and 252.7, it includes the straight reach and lower three-fifths of the braided reach. This habitat criteria sub reach is referred to here as the HCR. The BiOp calls for releases of water from Libby Dam to augment streamflow during the spawning season. The median streamflow with flow augmentation during the spawning season is about one-half that of the pre-Libby Dam era (Barton and others, 2009). The habitat criteria and streamflow augmentation is summarized here and details are included in the 2006 Kootenai River BiOp, which addressed how the U.S. Army Corps of Engineers and the Bonneville Power Administration operate Libby Dam in Montana and the effect of dam operation on the endangered Kootenai River white sturgeon and its critical habitat. The BiOp specifies a minimum water depth of 5–7 m or greater for 60 percent of the thalweg longitudinal profile of the HCR, during peak-flow augmentation. Peak-flow augmentation is based on a full-powerhouse discharge of about 708 m^3/s at Libby Dam, which generally occurs in mid–late May to mid June during the white sturgeon spawning season. The depth criterion was established to ensure adequate depth for white sturgeon to swim upstream from the sandy meander reach to the braided reach where gravel and cobble substrate conditions are favorable for the incubation of sturgeon eggs. The BiOp also specifies a minimum streamflow velocity criterion of 1 m/s in 60 percent of the maximum-velocity longitudinal profile in the HCR during post-peak flow augmentation, for as many as 21 days. Post peak-flow augmentation occurs in mid–late June and early–mid July, spawning is generally over by the end of June. The velocity criterion is intended to provide high enough streamflow velocity to increase the likelihood of white sturgeon recruitment. Higher velocities reduce the ability of other fish species from preying on sturgeon eggs and aid egg incubation and downstream dispersal of sturgeon during early life stages.

GEOLOGY, CHANNEL MOPHOLOGY, AND FREE FLOWING AND BACKWATER CONDITIONS

The Kootenai River WSCH consists of a braided, straight, and meander reaches (fig. 1). The braided reach is actively changing course and flows over gravel, cobbles, some sand, and a few areas bedrock. This 11.1 kilometer reach extends from RKM 257 below the Moyie River to RKM 245.9 at Bonners Ferry. This reach is mostly a multi-threaded channel with about 3 kilometers as a single-threaded channel (fig.1). The channel has many gravel bars, sloughs, and islands. Many of the side sloughs are dry during periods of low flow. Scour pools form at 2 locations above Crossport where bedrock crops out along the river and water depths in the pools exceed 15 m; here bedrock rubble is strewn on the riverbed. When stream flow is 850 cubic meters per second (m^3/s), the average water depth in the braided reach is about 3 m (meters) is generally less than other parts of the river, and the average and maximum velocity is about 1.2 and 2.8 meters per second (m/s; Barton and others, 2009)

Downstream of the braided reach is a short straight reach that lies completely in the WSCH between RKMs 245.9 and 244.5 and forms a transition zone between the braided reach and the meander reach. Here, the river substrate consists of gravel, sand, and traces of cobble and bedrock. This bedrock crops out at several small areas along the right bank. Ambush Rock, a large outcrop along the left bank with a deep scour hole, is at the downstream end of this reach. The channel is single threaded except the upstream half of the reach during low flow when gravel bars are exposed. When stream flow is 850 m^3/s the average and maximum depth and velocity in the straight reach are about 4 and 23 m and 0.9 and 1.3 m/s (Barton and others, 2009).

The meander reach is located downstream of the straight reach. This reach is mostly a sand riverbed entrenched in the lacustrine clay valley. This sand forms a mobile streambed consisting mainly of dune bedforms with amplitudes that sometimes are greater than 1 m (Barton and others, 2006). Lacustrine clay-silt generally forms steep steps and flat lying shelves mostly in meander bends. At the base of clay steps is clay rubble with the appearance of gravel and cobble. At a few locations there are bedrock outcrops into the channel and along the riverbank with rock rubble on the riverbed. Small patches of gravel-cobble lag deposits form the riverbed below the mouth of select tributaries. Discontinuous lenses of gravel lag deposits are buried by 1-3 m of sand. Rip-rap consisting of shot rock, boulders and cobble placed on dikes in select locations form armoring. When stream flow is 850 m^3/s the average and maximum depth and velocity in the meander reach is about 7 and 23 m and 0.6 and 1.1 m/s (Barton and others, 2009).

Flow in the Kootenai River is regulated by Libby Dam in Montana, and between the dam and WSCH the river is free flowing. Kootenay Lake, British Columbia, Canada, creates backwater conditions in the Kootenai River that can extend several kilometers upstream of Bonners Ferry into the braided reach (fig. 1). In the backwater region the flow is subcritical, depth is greater and stream velocity is lower than would be under unconstricted, free flowing conditions. During periods of low streamflow Kootenay Lake levels decline and backwater conditions diminish, then free-flowing water may extend throughout the braided reach and downstream into the straight reach. Extent of backwater in the WSCH is a function of river flows and lake level induced backwater which creates a complex relation between streamflow, depth and velocity. An analysis of the location of transition between the free-flowing river and backwater under a range of streamflow conditions is presented in Berenbrock (2005).

STREAMFLOW MODEL FOR SIMULATING DEPTH AND VELOCITY

The U.S. Geological Survey has developed multidimensional-flow models of the Kootenai River between RKM 222 and 254 as tools to aid understanding of the physical factors affecting quality and quantity of spawning and rearing habitat used by the endangered Kootenia sturgeon (Barton and others, 2005 and 2009). These models include all observed white sturgeon spawning sites and the designated WSCH (fig. 1). Model simulations have proved useful in linking streamflow velocities and water depths to spawning location and other habitat data (Barton and others, 2006; McDonald and others, 2006). We selected the braided-straight reach model to simulate depth and velocity in the HCR, this model extends from RKMs 242.9 to 254 and includes the lower three-quarters of the braided reach, the straight reach, and 1.6 river kilometers of meander reach. Output from model runs were used to report on depth and velocity criteria in the HCR for the 2006-09 spawning seasons. In addition, this model was extended four kilometers upstream using highly detailed 2009 bathymetry so it includes the entire braided reach. Model output was used to develop maps showing where water depth meets the 5-m and 7-m criteria over a range of streamflows. Construction, calibration, and validation of the braided-straight reach model used in this study to simulate depth and velocity is described in Barton and others (2009). The USGS Multi-Dimensional Surface-Water Modeling System (MD_SWMS) was used in this study and has a graphical user interface (GUI) developed by the USGS (McDonald and others, 2005) for hydrodynamic models. FaSTMECH is one computational model within MD_SWMS that was developed at the USGS and was used in this study (Nelson and others, 2003).

PERCENTAGE OF KOOTENAI STURGEON CRITICAL HABITAT IN THE STRAIGHT AND BRAIDED REACHES MEETING DEPTH AND VELOCITY CRITERIA DURING THE 2006-09 SPAWNING SEASONS

Barton and others (2009) used output from the braided-straight reach model to compute the percentage of a longitudinal profile through the sturgeon HCR, through the straight and braided reaches that meet U.S. Fish and Wildlife Service 2006 BiOp minimum criteria for depth and streamflow velocity (U.S, Fish and Wildlife Service, 2006). The simulation was executed on a daily interval during the 2006-07 white sturgeon spawning seasons and this analysis is extended herein to include the 2008-09 spawning seasons. The model was run for each day of the spawning seasons by specifying the mean daily discharge measured at the Tribal Hatchery gaging station (12310100). Mean daily water-surface elevations for the downstream model boundary were computed by interpolating measured water-surface elevations from the Bonners Ferry (12309500) and the Tribal Hatchery gaging stations. Mean-daily stage at eight stream gages located throughout the model reach were compared to the simulated surface-water elevations, thereby assuring the simulated water depths are correct. Water-depth criterion was evaluated by analyzing simulated depth for the period of peak flow augmentation: May 18-June 5, 2006, and May 22-June 5, 2007, June 7-21, 2008, and June 11-24, 2009 (fig. 2). Streamflow at Bonners Ferry during peak flow augmentation during the 2006-09 white sturgeon spawning seasons ranged from 651 m^3/s on June 24, 2009 to 1,311 m^3/s on May 20, 2006. Streamflow velocity criterion was evaluated by analyzing simulated velocity for the period of post-peak flow augmentation on June 6–30, 2006 and 2007, June 22-July 10, 2008, and June 25-July 12, 2009 (fig. 2). Streamflow at Bonners Ferry during post-peak flow augmentation during the 2006-09 white sturgeon spawning seasons ranged from 595 m^3/s on July 10, 2008 to 1,759 m^3/s on June 18, 2006.

The thalweg longitudinal water-depth profile and maximum velocity longitudinal profile are in different locations. The horizontal location of the thalweg longitudinal water-depth profile was fixed. Simulations of flow velocity over the range of streamflows during the 2006-09 post peak flow augmentation show the maximum-velocity longitudinal profile—high velocity corridor—shifts laterally with different streamflows and backwater conditions. The high-velocity corridor is more coincident with the thalweg longitudinal profile at smaller flows of 595 and 766 m^3/s (fig. 3a and b) compared to the higher flows ranging from 972 to 1,759 m^3/s (figs. 3c-e). As flow increase and more of the channel is inundated, then the high velocity corridor is less likely to be coincident with the thalweg.

The longitudinal-probe tool available in MD_SWMS was used to extract simulated water depth for every model node along the thalweg longitudinal profile. These data were used to compute the length and percentage of the river's longitudinal profile that were within the depth criterion. MD_SWMS was used to develop maps of simulated depth-averaged water velocity to evaluate the velocity criterion. A mapping approach was used to extract velocity from model simulations because the location of the maximum velocity longitudinal profile shifts laterally with different streamflows and backwater conditions. Color-coded maps of simulated water velocity with 0.10 km markings along the river were used to evaluate the velocity criterion along a maximum-velocity longitudinal profile in the sturgeon HCR. Data from these maps were manually extracted to compute the length and percentage of the river's maximum velocity longitudinal profile in compliance with the velocity criterion.

Relation between streamflow and percentage of thalweg longitudinal profile in the sturgeon HCR meeting the water depth criteria during 2006-09 is shown in figure 4. The 5-m depth criterion was met every day from May 18 to June 5, 2006 except for June 1 when streamflow was the lowest at 986 m^3/s. Mean daily streamflows from May 18 to June 5, 2006 ranged from 986 to 1,310 m^3/s, during this period 58 to 91 percent of the thalweg longitudinal profile met the BiOp 5-m criterion. During May 22 to June 5, 2007, water depth did not meet the 5-m criterion. Mean daily streamflow during this period ranged from 878 to 980 m^3/s, and 46 to 59 percent of the daily thalweg longitudinal profile met the 5-m criterion. During June 7-21, 2008, the sturgeon HCR did meet the 5-m depth criterion except on June 7 and 21. Mean daily streamflow during this period ranged from 986 to 1054 m^3/s, and during this period 59 to 74 percent of the thalweg longitudinal profile met the 5-m criterion. During June 11-24, 2009, the water depth did not meet the 5-m criterion. Mean daily streamflow during this period ranged from 651 to 954 m^3/s, and during this period 35 to 55 percent of the thalweg longitudinal profile met the 5-m criterion. During 2006-09, water depth along the thalweg longitudinal profile never met the 7-m habitat criterion.

The streamflow velocity criterion in the sturgeon HCR was met each day during post peak-flow augmentation during the 2006-09 spawning seasons (fig. 5). The percentage of the maximum-velocity longitudinal profile meeting the velocity criterion varied for specific streamflows due to the day-to-day variability in the location of the transition zone between the free-flowing river and backwater.

EVALUATE DEPTH CRITERIA THROUGHOUT THE BRAIDED REACH

The 2006 BiOp states that the lack of insufficient depth is an obstacle preventing fish from swimming to areas with suitable spawning substrate. Our research shows that the braided reach within the sturgeon HCR often does not meet the 5-m depth criterion: the braided reach is on average much shallower than the canyon, straight and meander reaches. Based on the aforementioned discussion, we choose to simulate water depth throughout the entire braided reach. The model was extended four kilometers upstream to include the entire braided reach. The bathymetry of the entire braided reach was mapped by the USGS during 2009 using a 480 channel multibeam echo sounder. A 1-m digital elevation model was developed from the 2009 bathymetry and the 2005 LIDAR survey of the valley floor. The 2009 survey is a much higher resolution survey than that conducted by the USGS during 2005; this previous survey was conducted using a single-channel echo sounder and did not include the upper three kilometers of the braided reach. The braided reach model by Barton and others (2009) is based on the 2005 bathymetry. Five streamflows ranging from 623 to 1,760 m^3s were modeled. Boundary conditions for these simulations are based on instantaneous streamflow and stage measurements at gaging stations during the 2006 record Libby Dam era high flow event and during 2008. For each model run, the simulated water-surface elevation drop through the modeled reach matched the measured stage at the gaging stations shown in figure 6. Maps showing simulated water depths exceeding 5-m and 7-m for the five streamflow simulations are provided in figures 6 and 7. Model simulations show that the thalweg in the braided reach upstream of the sturgeon HCR also has reaches not meeting the 5-m depth criterion.

DISCUSSION

Depth and velocity criteria were evaluated over a range of hydraulic conditions as evidence by the large range of streamflow and stage during the 2006-09 spawning seasons, and that is in part due to the 2006 record high flows for the Libby Dam era (fig. 2). These high flows were due to flood control operations and not sturgeon augmentation flows, and as a result largely occurred after sturgeon had spawned. Our evaluation showed the 5-m depth criterion during peak-flow augmentation was met on about half the days during the 2006-09 spawning seasons (fig. 4) for the HCR however these results are skewed by the 2006 high flows. During 2006, only 17 percent of the tagged adult fish went upstream of the Route 95 Bridge and 7 percent went above upstream of RKM 246.6 into the multichannel braided reach, and yet spawning was still recorded downstream in the meandering reach. During these four years, 33 to 91 percent of the thalweg longitudinal profile in the sturgeon HCR had met the 5-m depth criterion during the BiOp specified period. For a typical spawning season flow of 909 m^3s, the extended braided-straight model shows that less than half of the braided reach meets the 5-m depth criterion (fig. 6). The 5-m depth criterion is generally met for flows greater than about 1,000 m^3s. However, depth criterion exceedance varies for a specific streamflow (fig. 3) because (1) water depth in the HCR is also a function of Kootenay Lake levels and associated backwater, and (2) streamflow measurement error of 5 percent at the Tribal Hatchery gaging station (12310100). Simulation of the 2006 record peak flow of 1760 m^3s shows that about a kilometer of the thalweg in the braided reach, upstream of the HCR have depths less than 5-m. We found that during 2006-09 the 7-m water depth criterion was never met; 7 to 48 percent of the thalweg longitudinal profile had a depth of 7-m or greater and is well short of the 60 percent goal (fig. 4). Likewise, the thalweg in more than half of the braided reach upstream of the sturgeon HCR also does not meet the 7-m depth criterion (fig. 7).

The streamflow velocity criterion was met each day during post peak-flow augmentation during the 2006-09 spawning seasons. The maximum velocity longitudinal profile of the river meeting the 1 m/s velocity habitat criterion during this period ranged from 70 to 96 percent and far exceeded the 60 percent goal (fig. 4). As streamflow increases from about 280 to about 1,000 m^3/s, the percentage of the longitudinal profile meeting the velocity criterion decreases. This condition results from filling of Kootenay Lake, which increases lake levels causing backwater conditions to extended father upstream into the braided reach and thereby decreasing velocity and to changes in channel geometry within the braided reach. The percentage of the maximum-velocity longitudinal profile meeting the criterion increases for streamflow greater than about 1,000 m^3/s (Barton and others, 2009).

The sturgeon HCR can be sub divided into three reaches based on stream velocity and channel geometry. In the upstream part of the HCR between RKM's 251and 252.7, the river consist of a single channel and free flowing conditions generally prevail. The width-depth ratio near RKM 252.3 is about 39 and 22 during flows of 595 and 1,759 m^3/s (fig. 3). Here, streamflow velocity increased with increasing streamflow during post peak-flow augmentation during the 2006-09 spawning seasons (fig. 3a-e). Downstream of this reach, between RKMs 246.8 and 251, the river has multiple channels, is much wider, and during post peak-flow augmentation part or most of this reach is in backwater from Kootenay Lake. The width-depth ratio near RKM 248.8 is about 570 and 110 during flows of 595 and 1,759 m^3/s. Here, as streamflow increased the velocity within the thalweg decreased and velocity in other parts of the channel remained about constant or increased slightly (fig. 3). Between RKMs 246.8 and 244.6 in the downstream part of the HCR, the river consist of a single channel, and during post peak-flow augmentation this reach is in backwater from Kootenay Lake. The width-depth ratio is somewhat similar to the upper reach, near RKM 245.3 the ratio is about 33 and 21 during flows of 595 and 1,759 m^3/s. Here, velocity generally increased with increasing streamflow but the backwater conditions affect that relationship (fig. 3). Our simulations on figure 3 show that the middle reach had lower velocities compared to the upstream and downstream reaches for simulated flows of 927, 1,277, and 1,759 m^3/s, this velocity pattern reflects the larger width-depth ratio in this reach. The variable backwater conditions also influence velocity in this subreach of the HCR.

The 2009 depth and velocity analysis of the HCR should be re-analyzed using an updated multidimensional model based on the most current braided reach bathymetry and new stage measurements. The USGS mapped the braided reach bathymetry in 2009 with much greater detail than mapped in 2005 and since then the channel has migrated laterally in select areas.

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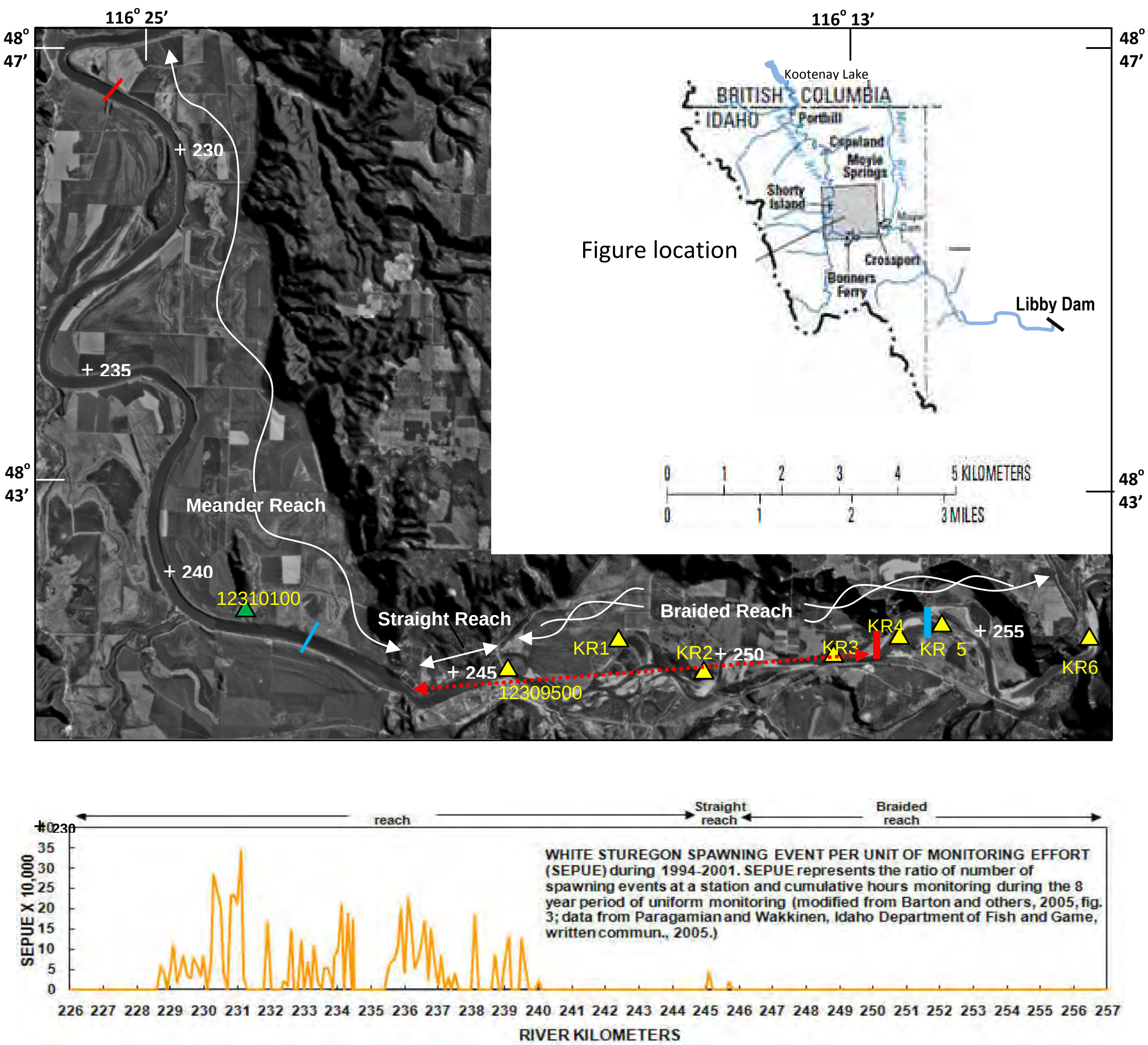


EXPLANATION

River kilometer

Upstream boundary for braided-straight reach multidimensional flow model, downstream boundary shown as thinner line

Upstream boundary for Kootenai River white sturgeon critical habitat reach, downstream boundary shown as thinner line. Dashed red line shows extent of critical habitat sub reach with a depth and velocity criteria.

12310100
U.S. Geological Survey permanent gaging station, streamflow, velocity, and temperature, and identifier. Yellow triangle indicates stage only gaging station

KR1 U.S. Geological Survey temporary gaging station (stage) and identifier

Figure 1. Location of critical habitat, sturgeon spawning events during 1994-2001, model boundaries, and stream-gaging stations, Kootenai River near Bonners Ferry, Idaho.

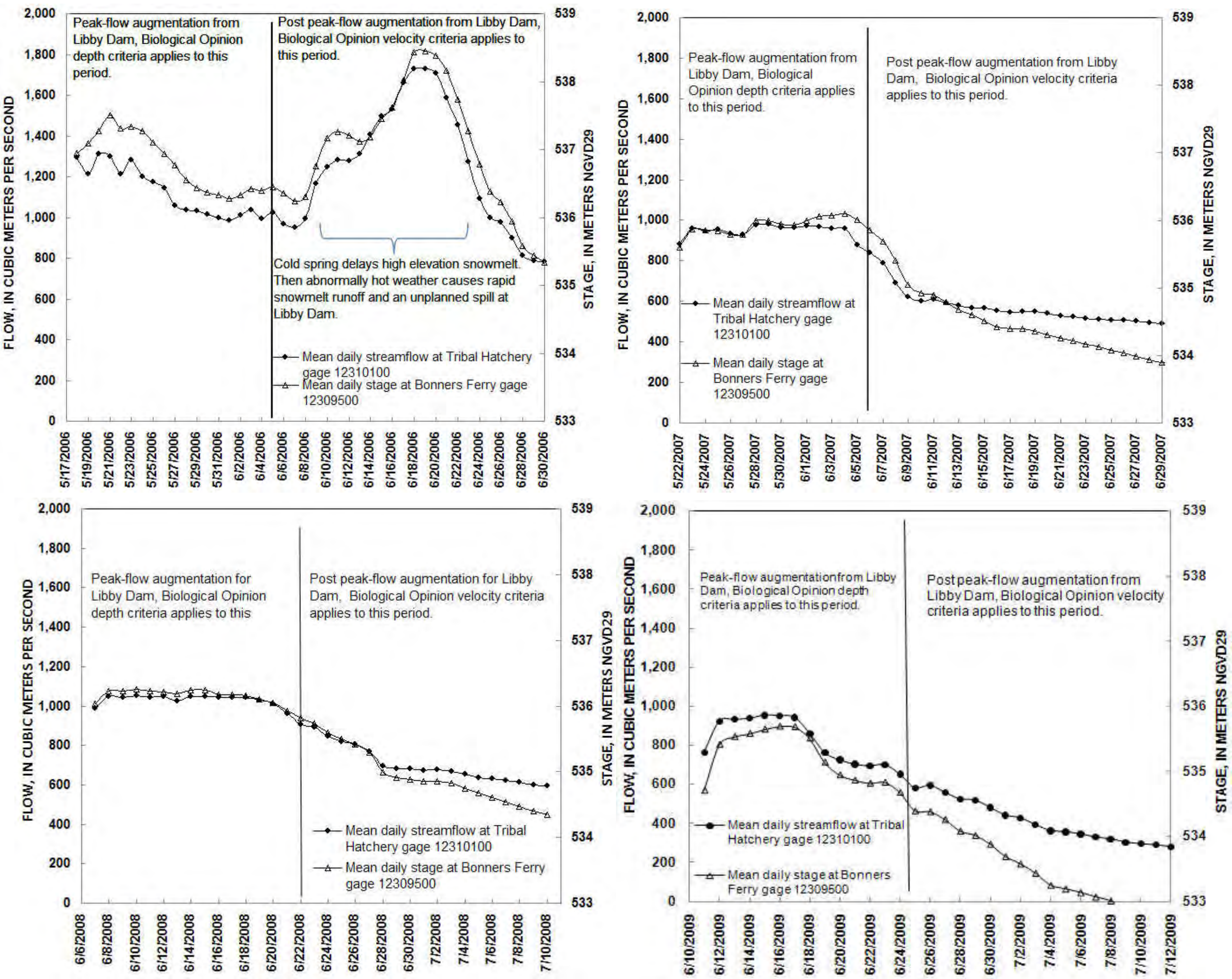


Figure 2. Mean daily streamflow and stage on the Kootenai River at Bonners Ferry, Idaho during the 2006-09 white sturgeon spawning seasons when streamflow is augmented by flow release from Libby Dam to help re-establish natural recruitment of new year classes of the endangered white sturgeon.

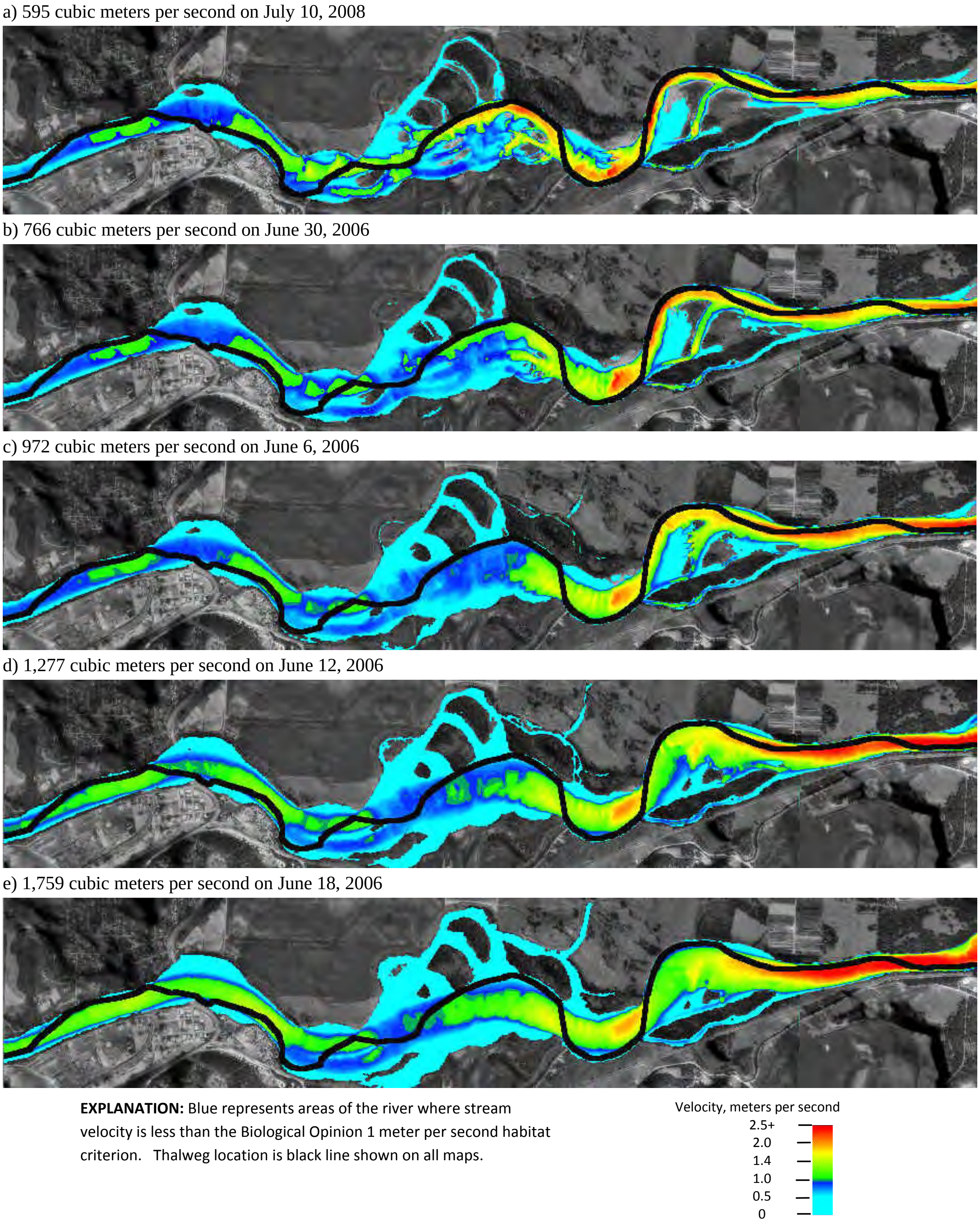


Figure 3. Simulated velocity over the range of streamflows during the white sturgeon spawning season post-peak flow augmentation 2006-09, Kootenai River white sturgeon habitat criteria sub reach, Idaho: as flow increases the contact between backwater and free flowing river moves farther up this reach and the zone of maximum velocity shifts laterally from the thalweg.

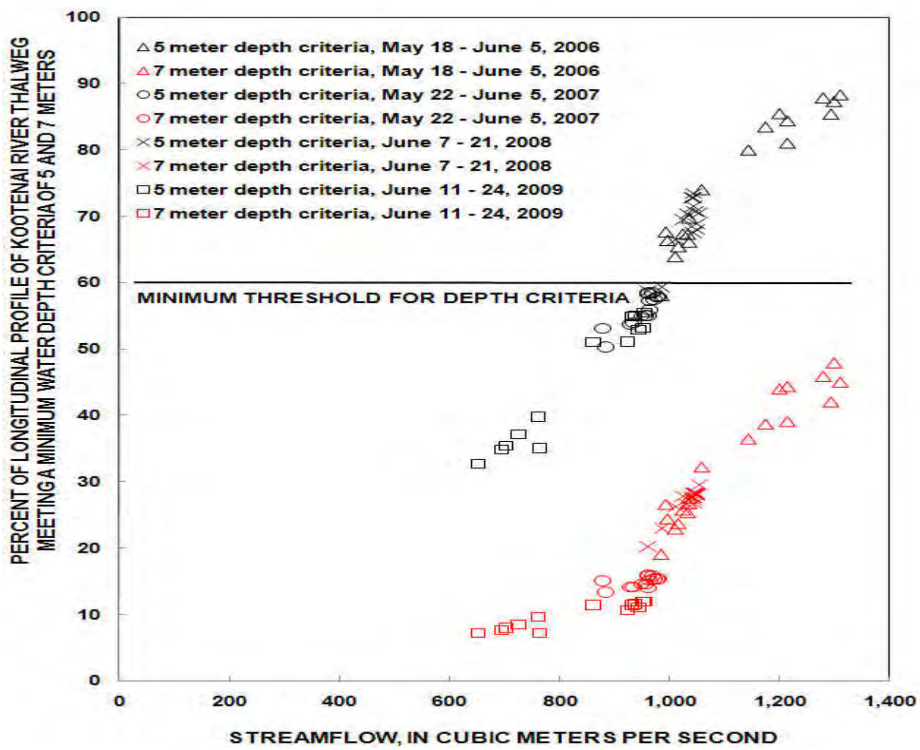


Figure. 4 Streamflow and percent of longitudinal profile of Kootenai River thalweg in the habitat criteria sub reach between river kilometer 244.6 and 252.7 meeting a minimum water-depth criteria of 5 and 7 meters during peak-flow augmentation, 2006-09 sturgeon spawning seasons.

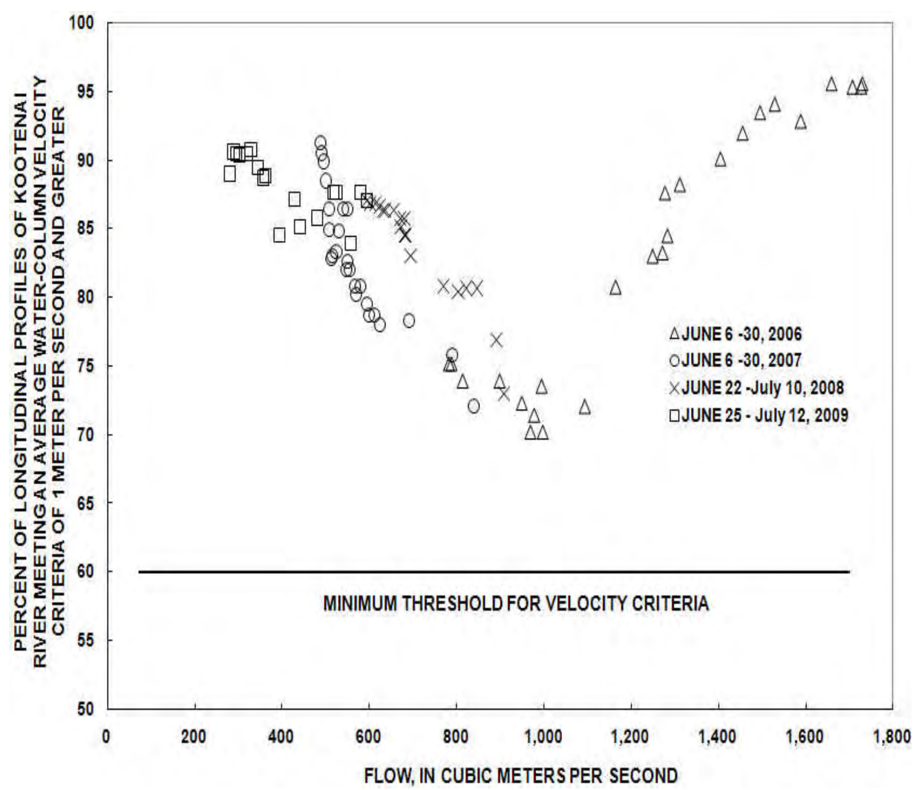
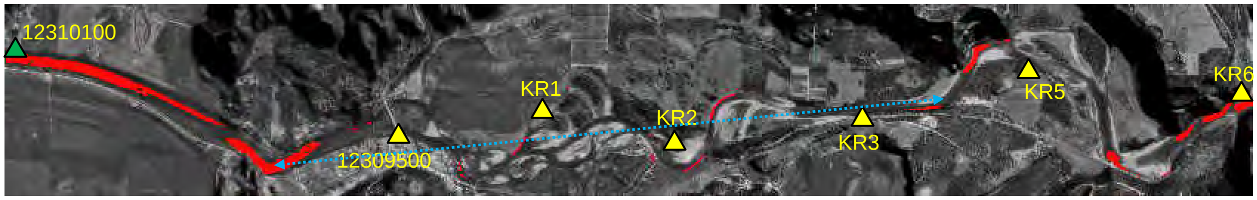
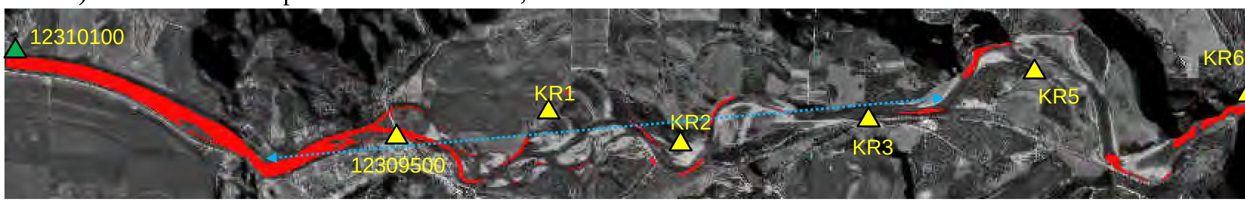


Figure 5. Streamflow and percent of longitudinal profile of the Kootenai River in the habitat criteria sub reach between river kilometer 244.6 and 252.7 meeting a minimum water-velocity criteria of 1 meter per second during post-peak flow augmentation, 2006-09 sturgeon spawning seasons.

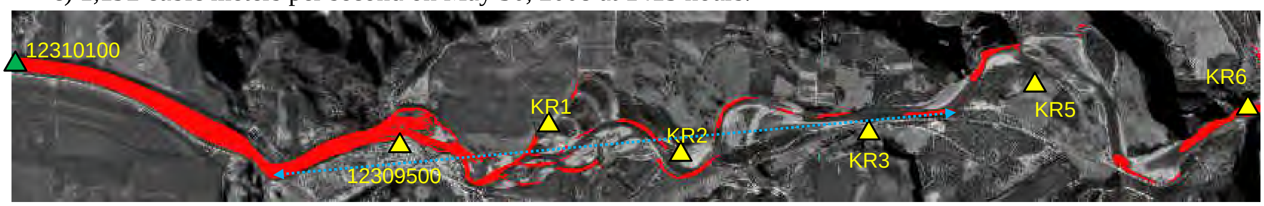
a) 623 cubic meters per second on July 7, 2008 at 0100 hours.



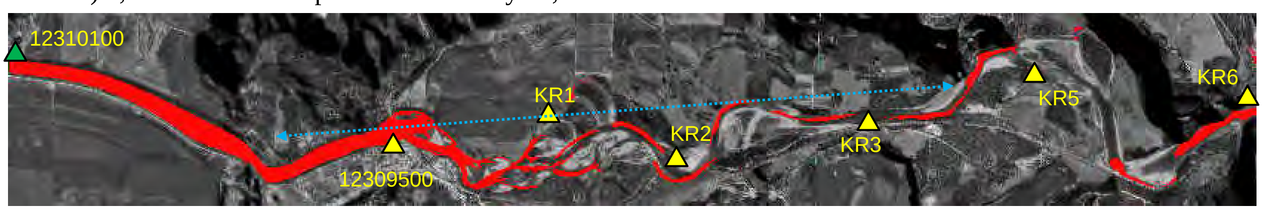
b) 909 cubic meters per second on June 23, 2008 at 0100 hours



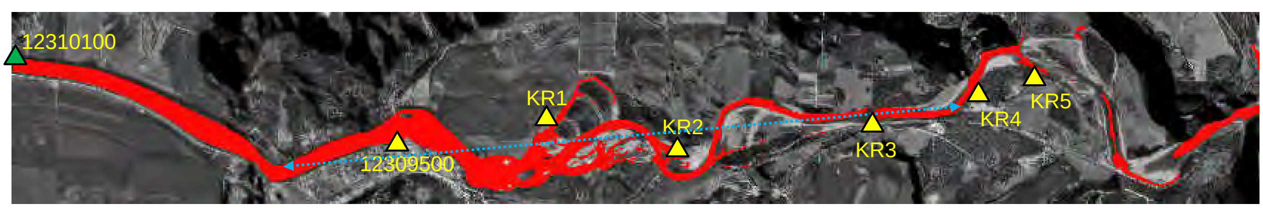
c) 1,192 cubic meters per second on May 30, 2008 at 1415 hours.



d) 1,420 cubic meters per second on May 19, 2008 at 1010 hours.



e) 1,760 cubic meters per second on June 18, 2006 at 1400 hours.



EXPLANATION:

12310100 U.S. Geological Survey permanent gaging station (streamflow, velocity, and temperature) and identifier

12309500 U.S. Geological Survey permanent gaging station (stage) and identifier

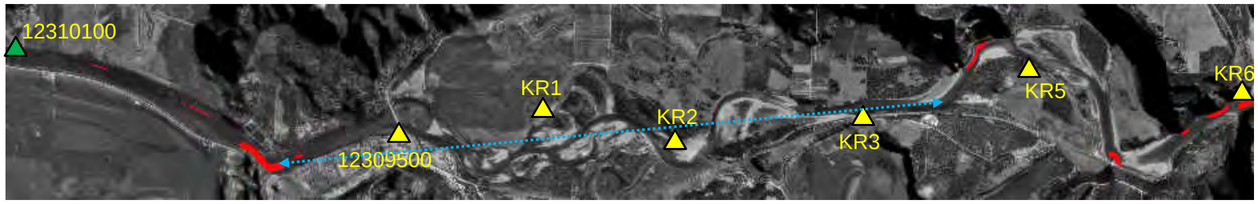
KR1 U.S. Geological Survey temporary gaging station (stage) and identifier

Extent of critical habitat with a depth and velocity criteria

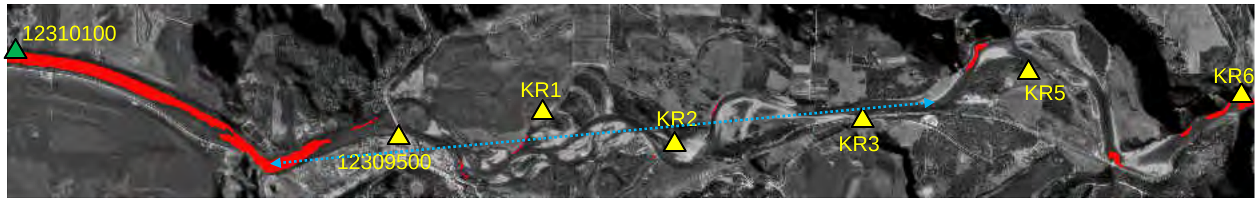
Red riverbed represents simulated water depths that equal or exceed 5 meters

Figure 6. Simulated water depths that equal or exceed five meters for a range of streamflows during the 2006 and 2008 white sturgeon spawning seasons, Kootenai River near Bonners Ferry, Idaho. Simulated water-surface elevation drop through the modeled reach match the measured stage at the gages shown on each map.

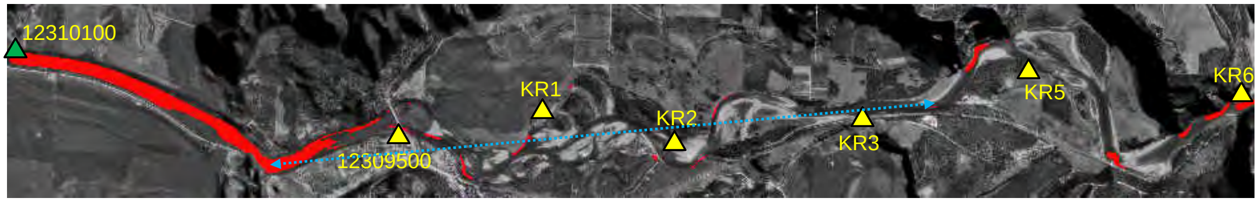
a) 623 cubic meters per second on July 7, 2008 at 0100 hours.



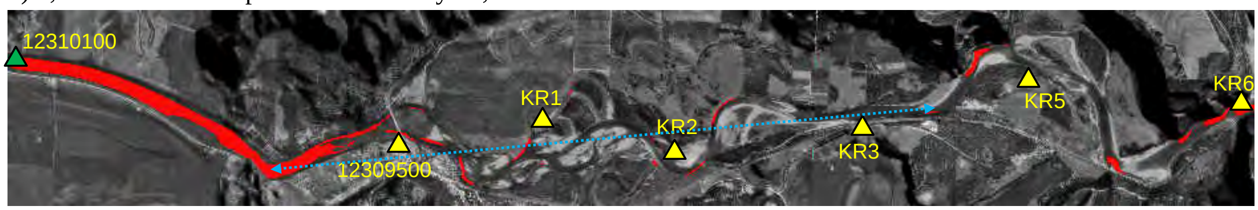
b) 909 cubic meters per second on June 23, 2008 at 0100 hours.



c) 1,192 cubic meters per second on May 30, 2008 at 1415 hours.



d) 1,420 cubic meters per second on May 19, 2008 at 1010 hours.



e) 1,760 cubic meters per second on June 18, 2006 at 1400 hours.

EXPLANATION:

12310100 U.S. Geological Survey permanent gaging station (streamflow, velocity, and temperature) and identifier

12309500 U.S. Geological Survey permanent gaging station (stage) and identifier

KR1 U.S. Geological Survey temporary gaging station (stage) and identifier

Extent of critical habitat with a depth and velocity criteria

Red riverbed represents simulated water depths that equal or exceed 7 meters

Figure 7. Sirnulated water depths that equal or exceed seven meters for a range of streamflows during the 2006 and 2008 white sturgeon spawning season, Kootenai River near Bonners Ferry, Idaho. Simulated water-surface elevation drop through the modeled reach match the measured stage at the gages shown on each map.