A Hydrologic Monitoring Plan for Oregon Chub Ponds at Big Island on the McKenzie River

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Ecohydrology West

A Hydrologic Monitoring Plan for Oregon Chub Ponds at Big Island on the McKenzie River

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1 Introduction

Oregon chub population estimates for ponds[1] on Big Island along the McKenzie River have been declining significantly over the past three years. Measurement of one pond's water surface elevation over the same time period has also shown substantial decrease. The correlation in time between these declines has lead to the conjecture that there may be a causal link. The purpose of this report is to compile existing information relevant to the status and condition of Big Island's Oregon chub population, develop a conceptual model of chub pond hydrology and propose future data collection measurements and a hydrologic monitoring plan in order to relate mainstem McKenzie River flow to chub pond water levels.

Figure 1 shows the McKenzie River watershed and the location of Big Island. Big Island is located from river mile (RM) 16-18 from the present confluence of the McKenzie and Willamette Rivers. There are two major storage reservoirs above Big Island that greatly affect flow. Roughly 22% of the total watershed area of 1360 square miles drains into the Corps' reservoir system. The currently active USGS gage at Vida (14162500) is located at river mile 47.7 and has an upstream drainage area of 930 square miles. The USGS Walterville gage (14163900) is closer to Big Island at RM 27.7 but its utility is compromised by the fact that the Walterville power canal diverts a substantial fraction of the total flow around the gage.

Figure 1: The McKenzie River Basin showing the location of Big Island, the drainage network and Army Corps reservoirs. An aerial photograph shows Big Island as it appeared on 3/15/04.

2 Background Data: Oregon Chub Populations and Pond Water Surface Elevations

2.1 Oregon Chub Population Data

Since 2002 Oregon chub populations have been sampled annually at Big Island. Several distinct ponds have been found to support chub. Table 1 shows the raw data for the chub populations within each pond (Paul Scheerer, ODFW, personal communication, 2004). The locations of the ponds on the Big Island site are shown in Figures 2 and 3.

McKenzie River Trust Site Number	2002 Abundance	2003 Abundance	2004 Abundance	Percent Remaining
1	242	258	185	76
2	79	65	4	5
3	Not Sampled			
4	90	78	62	69
5	0	0	0	

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[1] Ponds are deeper sections of abandoned channels. See section 5 on pond formation for a discussion and terminology.

6	461	167	42	9
7	48	49	19	40
8	24	7	0	0
Total	**944**	**624**	**312**	**33**
95% Confidence Interval	790-1180	490-860	220-550	

Table 1: Oregon chub population data (Paul Scheerer, ODFW, personal communication, 2004).

Figure 2: Oregon chub have been found in several ponds located within the red rectangle. The region containing chub ponds is enlarged in Figure 3 and the ponds identified by site number.

Figure 3: Oregon chub pond locations with McKenzie River Trust site number shown on a 2004 aerial photograph.

Using the population data from Table 1 two graphs were constructed to show population trends for each pond. Pond 1 has sustained populations best overall and may be stable given sampling errors and natural variability of a group of fish in a small pond. Pond 6 has sustained the greatest loss in total numbers and the population is only 9% of what it was in 2002.

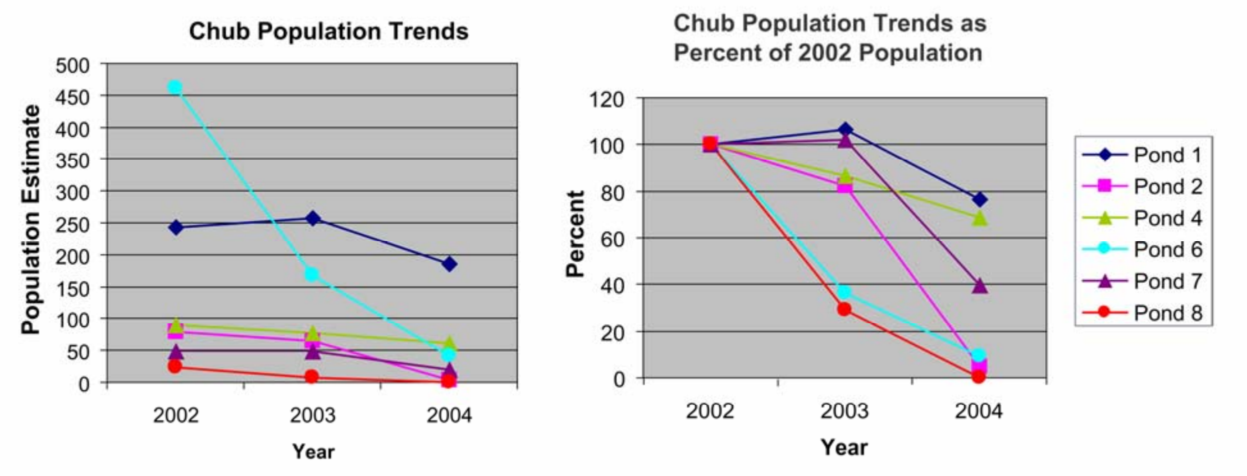

Figure 4: Oregon chub population trends by pond for years 2002, 2003 and 2004. Data is from Table 1.

2.2 Pond 1 Water Surface Elevation Data

Table 2 shows the data collected for pond 1 water surface elevation. Reported measurements were made by reading a staff gage attached to a metal stake that was pounded into the pond's bed. The bottom of the staff gage touched the bed surface at the time of original installment.

Measurement Date	Pond 1 Staff Gage Reading (ft)
5/29/2002	4.50
5/14/2003	3.60
5/16/2004	1.85

Table 2: Pond 1 water surface elevations obtained from reading a staff gage on three dates (Paul Scheerer, ODFW, personal communication, 2004).

3 Ecohydrology

The seasonal distribution, depths and velocities of riverine water on a floodplain within secondary channels and hyporheic zones are key environmental factors regulating ecosystem function and organizing habitat structure. Differing habitat functions and their functional capacities are related to—even determined by—these parameters of floodplain hydrology.

Riverine water distribution on a floodplain may be characterized in terms of its seasonal timing, frequency, amount, duration, depth and velocity. Based on conversations with Paul Scheerer (Fisheries Biologist, Oregon Department of Fish and Wildlife) attention is focused on two parameters of floodplain hydrology deemed important for sustaining chub populations within a pond. These are

1. Pond water depth - Maintain sufficient water depths through the dry summer.
2. Pond water velocity – High flows in winter can flush out fish and the shear force can remove aquatic vegetation.

A recommended monitoring design will include a means for annually gaining information on these two hydrologic parameters.

4 Preliminary Hydrologic Analysis of Pond 1 Water Surface Elevation Data

Change in river stage can explain a portion of the change in the pond 1's water surface elevation. Natural mainstem flow variations during the measurement month of May have been variable (Figure 5). The measurements of pond 1's water surface elevation were made at differing river flows and thus differing river stages. Table 3 shows pond 1's water surface elevation data along with river flow and stage at Vida for the measurement days.

Measurement Date	Pond 1 Staff Gage Reading (ft)	Flow at Vida Gage (cfs)	Gage Height at Vida (ft)	Accumulated Rainfall at Eugene for 2 weeks before measurement date (in)
5/29/2002	4.50	5,550	3.04	2.07
5/14/2003	3.60	3,830	2.23	0.56
5/16/2004	1.85	3,469	1.96	1.08

Table 3: Pond 1 water surface elevations obtained from reading a staff gage on three dates. Included in this table are the flows and gage heights at the USGS flow gage at Vida, and accumulated rainfall at Eugene for the weeks prior to a measurement date.

The Walterville gage is closer to Big Island and we use the rating table from this gage to estimate how the differences in river flow between the measurement dates could affect the water surface elevation in pond 1. If we use the same flow as Vida then we can use the rating table to find river stage. All elevations are referenced to their respective heights on the 2004 measurement day so change in elevation above the 2004 level is clear. Table 4 shows these heights.

Measurement Date	Change in Staff Gage Reading Compared to 5/16/04 (ft)	Change in Gage Height at Vida Compared to 5/16/04 (ft)	Change in Gage Height at Walterville Compared to 5/16/04 (ft)	Percent of Change in Staff Gage Reading Possibly Due to Higher River Stage
5/29/2002	2.65	1.46	1.33	50%
5/14/2003	1.75	0.27	0.26	15%
5/16/2004	0.00	0.00	0.00	-

Table 4: Pond 1 water surface elevations and gage heights referenced to their respective elevations on date of lowest elevation, 5/16/2004. The gage height in Walterville assumes the same flow as that in Vida (gage height was obtained from the Walterville rating table).

This analysis suggests that a significant portion of pond 1's water surface elevation decline could be due to natural variability in river stage and may be an artifact of the day a staff gage measurement happened to be made. The staff gage was read in May the last three years but the flow in the river each time was different. On measurement day in 2002 the river stage might have been about 1.3 ft higher than measurement day 2004, so one would expect the pond water surface elevation to reflect that via surface water connections and/or hyporheic connections to the mainstem river. To see if the pond water surface elevation is declining (or rising) one would have to make measurements in the pond at the same mainstem river flow each year while keeping other variables roughly equal like evaporation and local rainfall. It is possible that the observed "decline" in pond water surface may be partly explained by the happenstance of measuring on successively lower river flows each year.

Further, in 2002 and 2003 high flows (great than 10,000 cfs) occurred near the measurement date as shown in the hydrographs of Figure 5. The trailing limb of these peaks extends to the measuring date. Whereas in 2004 the last peak occurred almost 5 months before and the flows were a fairly constant 4,000 cfs until the measurement date. These differing conditions could also contribute to a lower pond water surface elevation by a comparative reduction in the natural water flows feeding the pond.

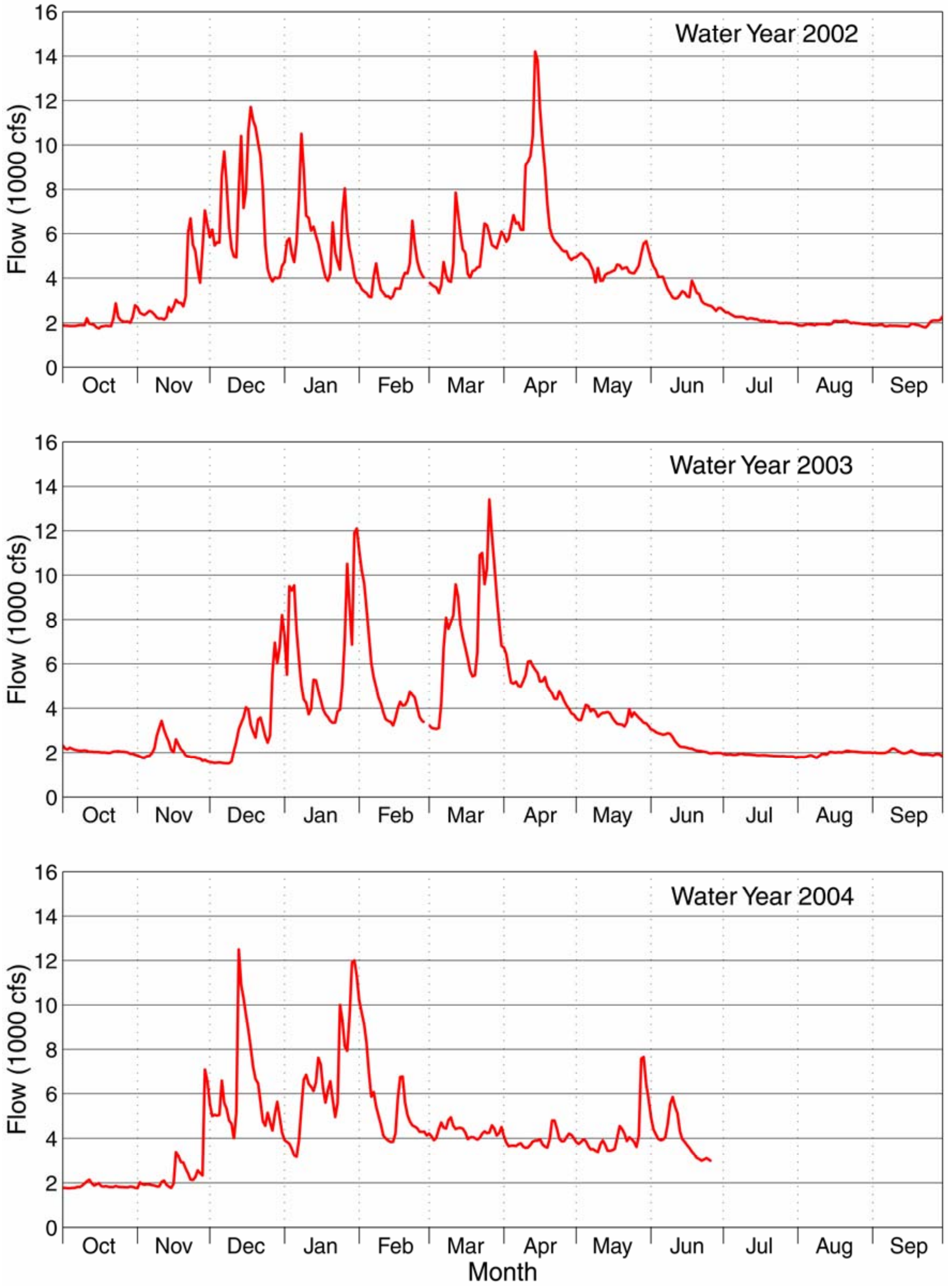

Figure 5: Flow at the USGS gage at Vida (station number 14162500) for the past three years when measurements were made at pond 1 staff gage.

5 Hydrogeomorphic Analysis of Pond Formation

Understanding how the chub ponds formed can aid in locating surface and subsurface water flow paths to the ponds, and help identify trends in pond geomorphology such as sedimentation and stability of a feature through time. We use historical aerial photographic interpretation to understand pond formation and water flow path connections.

5.1 Scientific Background

Floodplains are composed of a dynamic mosaic of distinct landforms or geomorphic elements. Geomorphic elements comprise the physical substrate upon which the diversity of all river-floodplain habitat rests. Geomorphic elements, together with the processes responsible for their formation, are the building blocks for habitat. At any particular location, a geomorphic element is shaped by a prevailing combination of hydrogeomorphic processes--such as erosion, deposition, and flooding. These processes determine in large part the distribution of species upon and between landforms by both building the habitat and establishing the environmental conditions there.

The lower McKenzie River is a medium energy gravel bed stream. Within-channel barforms are the predominant incipient floodplain landform and habitat for primary succession on the McKenzie River[2]. Interlinked development of bar(s) and erosion of near banks, filling of channels, and establishment and growth of pioneering trees results in coalescence with older floodplain. Floodplain appears constructed from coalesced bars and islands. Colonization of bars by pioneering trees (mainly cottonwoods and willows) enhances the island- and floodplain-building process by filtering finer sediment and increasing erosional resistance of gravel bars. Floodplain matures as the active channel migrates away by repetition of the bar formation and near-bank erosion process, or is progressively abandoned by infilling and/or constriction with a bar. Other parts of the floodplain are recycled as eroding banks provide the coarse sediment and large woody debris for building new bars.

Characteristic geomorphic elements for the unconstrained reaches of the McKenzie River are:

1. **Main Channel** - Channel routing dominant portion of flow.
2. **Secondary Channel** - A channel smaller than main delivering a portion of flow. Secondary channels may be active all year or only seasonally at higher flows.
3. **Backwater** - An abandoned channel filled at its upstream end, and open and connected to an active channel at its downstream end.
4. **Island** - A central bar stabilized by vegetation sufficiently long for matures trees to develop.
5. **Crescentric Lake** - Results from incomplete island coalescence with river margin, and is land-locked at low river stage.
6. **Central Bar** - A bar forming entirely within channel.
7. **Point Bar** - Contiguous depositional landform forming on the inside (convex) of a river curve.

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[2] B. B. Dykaar and P. J. Wigington, Jr, 2000. Floodplain Formation and Cottonwood Colonization Patterns on the Willamette River, Oregon, USA. Environmental Management vol. 25, no. 1 pp87-104.

8. **Oxbow Lake** - Results from a meander bend cutoff, and is land-locked at low river stage.

5.2 Aerial Photographic Analysis

Historical aerial photographic interpretation is used to determine the origins, ages and geomorphic trends of chub ponds and secondary channels at Big Island. Seventeen aerial photo dates were obtained and analyzed, they are: 4/10/36, 8/9/44, 9/11/47, 8/21/52, 7/17/60, 6/20/62, 4/18/64, 6/20/65, 7/26/69, 4/14/77, 5/14/79, 5/29/84, 5/10/87, 8/10/90, 6/18/93, 8/10/98 and 3/15/04. From each aerial photograph, or set of them, roughly the same geographic location was "cut-out" and is displayed in Figures 6-10.

1936
In 1936 Big Island, was in fact, an island. Big Island appears as two separate landforms, each likely composed of coalesced islands as evidenced by forest structure. The north/south flowing secondary channel separating the pieces of Big Island is labeled 1 in the 1936 frame of Figure 6. The main channel was in roughly the same position as it is today. The southern sides of the pieces of Big Island are separated from the mainland by a large secondary channel labeled 2. None of the chub ponds exist yet. Most of the fluvial geomorphic action relevant to pond formation and subsequent maintenance will occur as secondary channel 2 develops to its current configuration. The emergent gravel labeled 3 and forming as a distinct piece of a meander lobe will comprise an important part of the structure of pond 1 as it develops.

1944
The upstream end of the main secondary channel fills at 1 and a new entrance alignment is created. The filling extends all the way to what will be roughly the southern end of pond 1. The mainstem river reopens abandoned channels to split flow through Big Island, water in the channel at 2 flows north while the narrower channel at 3 directs flow south. The beginning of pond 1 formation is evident as a crescentric lake at 4 as within channel sediments fill at the upstream end blocking flow at 5.

1947
The primary secondary channel along the southern edge of Big Island at 1 approximates its current alignment amid the deposition of substantial amounts of large woody debris on bar tops and channel constrictions.

1952
Large flows again deposit substantial amounts of large woody debris and sediment in the southerly secondary channel. The gross channel alignment is about the same and what are likely to become the two major hyporheic flow paths to the chub pond region appear to be established by the deposition of substantial amounts of gravels and cobbles (paths are labeled 1 and 2). The secondary channel has made smaller changes significant for chub pond formation. The genesis of pond 6 appears at 3, the consequence of a point bar cut-off.

1960
The entrance to the main secondary channel has filled at 1 and will remain plugged through time to the present. These sediments will form a hyporheic flow path. While the secondary channel will be reopened later via another path, this route will remain filled. The configuration of pond 1

at 2 appears established and remains relatively stable to the present. The narrow side channel that will eventually form pond 6 is at 3.

1962
The secondary channel is reopened at 1.

1964
The secondary channel at 1 is substantially cleared.

1965
Large flows deposit substantial sediment in the secondary channel at 1, beginning the latest filling and plugging of this large secondary channel. The capacity of the secondary channel is greatly reduced by the deposition and the channel continues to fill to the present allowing the remaining chub ponds to form and achieve stability by protection from the force of high winter flows. Chub pond 3 begins to form in the sediment at 1 and pond 8 is at 2. The small channel connecting these two ponds is visible, a part of which, ultimately becomes pond 6.

1969-2004
By 1969 the features within the secondary channels that become the chub ponds are largely in place. The relict network of secondary channels feeding the ponds is in place and the subsurface cobbles and gravels forming the two (likely) primary hyporheic flow paths have been laid down. Through the intervening years what was once a very active and large secondary channel fills with sediment and is colonized by a variety of woody species. Broadly, surface channels feeding the ponds have likely continued to fill with finer sediments. Since 1969 in terms of pond hydrologic function, the most significant natural geomorphic activity has likely occurred at the upstream ends of surface channels feeding ponds where they intercept mainstem flow. These secondary channel inlets can become blocked or opened by geomorphic processes.

5.3 Fluvial Geomorphic Characterization of the Ponds

The origins of the chub ponds have been gleaned from the aerial photographic record discussed above. The ponds are relict features of typical fluvial geomorphic processes operating in the McKenzie River. Generally, the ponds are deeper portions of relict secondary channels left isolated in the process of the river building central bars and islands, and point bars. In terms of geomorphic origin the name “pond” is a misnomer but suffices to describe the landforms function during summer low flow periods. Ponds 2 and 4 appear to have somewhat different origins and look like relatively deep scour areas. The next sections show and discuss pond formation in more detail.

Figure 6: Historical aerial photo series.

Figure 7: Historical aerial photo series.

Figure 8: Historical aerial photo series.

Figure 9: Historical aerial photo series.

Figure 10: Aerial photo date 3/15/04.

6 Pond 1 Hydrogeomorphology

The basic configuration of pond 1 appears set by 1960. Pond 1has been a relatively stable geomorphic feature of a very dynamic Big Island Since 1960, and it's planimetric form appears little changed to the present.

Pond 1 hydrology is unique and derives from its geomorphic construction. All of the other ponds appear to have "flow-through" hydrology. That is, flow enters at an upstream inlet and flows to a single downstream outlet. In contrast, pond 1 appears to have one primary inlet and two primary outlets. This fortuitous circumstance creates pond hydrology that enhances chub survival.

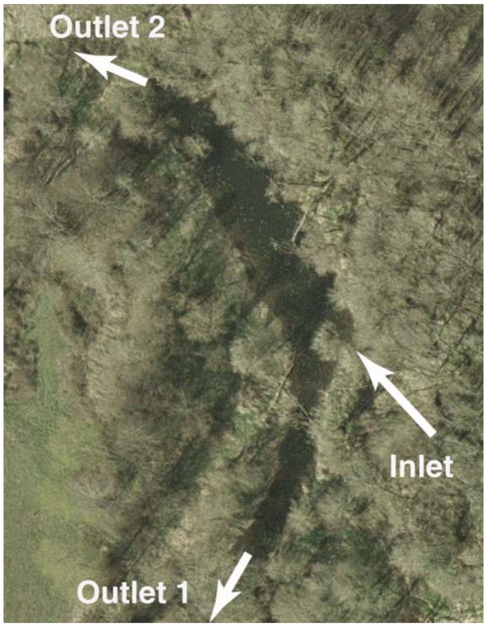

Figure 11: Pond 1 flow diagram.

A diagram of pond 1 hydrology is shown in Figure 11. A single inlet is located roughly at pond center and there is an outlet at each end. The outlet crests above the pond's water surface was surveyed on 6/17/04 when the staff gage in the pond read 2.0 ft. Table 5 gives the elevations of the outlet crests above the pond surface and the elevations of pond 2 and 3's water surface relative to pond 1 water surface. The data show that outlet 1 will become active at a lower flow than outlet 2.

Feature	Relative Elevation (ft)
Pond 1 water surface	0.0
Pond 1 south outlet crest	0.8

Pond 1 north outlet crest	0.9
Pond 2 water surface	-1.1
Pond 3 water surface	-0.9

Table 5: Relative elevation survey data on 6/17/04. Elevations are relative to pond 1 water surface elevations. Pond 1 staff gage read 2.0 ft and flow at Vida was 3,570 cfs.

At higher flows when both outlets are active and the direction of outflow in pond 1 is difficult to predict. The outflow direction will be determined by water surface elevations at the outlets, which in turn is determined by the drainage capacity of nearby channels receiving water from the pond and elsewhere. Hence, the outflow direction could well be a function of mainstem river stage, with direction changing over the course of a rising or falling hydrograph. While at least at some modest mainstem river stage both outlets will be active and outflow will be bidirectional.

The hydrology of pond 1 leads to more gentle flows even during higher flow events. These two outlets work to keep the pond water surface slope at a shallow angle (roughly horizontal) so water velocities and hence shear stress in the pond remains low. During higher flow events, the inflow arrives at the pond's midsection, and probably for a significant range of flows, water flows toward both outlets. Therefore aquatic plants in the pond can escape the shear forces of high flow events and avoid being removed. Pond 1 is the only pond inhabited by floating lily (Nuphar lutea ssp. polysepala).

Figure 12: Pond 1 formation photographic series.

The hydrology of pond 1 was created by a particular set of geomorphic circumstances. Referring to Figure 12, pond 1 formation begins with the central bar labeled 1 in the 1936 frame. This central bar becomes a point bar in 1944 where the arrow labeled 2 locates the center of the point bar. Lateral point bar growth in combination with deposition of another central bar at 3 erodes the southern bank so that at 4 the channel almost joins a long relict secondary channel, which joins the mainstem upstream. This process is responsible for forming outlet 1 of pond 1. The southern end of pond 1 begins to form at 5. The inlet to the pond forms at 6 and appears to be a consequence of the fact that the point bar (2) originally developed from the mid-channel bar shown in the 1936 frame (1). The inlet to pond 1 is a flow path across the top of the point bar. The inlet is highlighted again at 7 in the 1947 frame. In 1952 the northern end of the pond has been blocked with sediment deposits at 8. By 1960 pond 1 has stabilized and is in roughly the same position today. Over time deposition of fines has likely occurred reducing overall pond depth.

7 Other Pond Formation

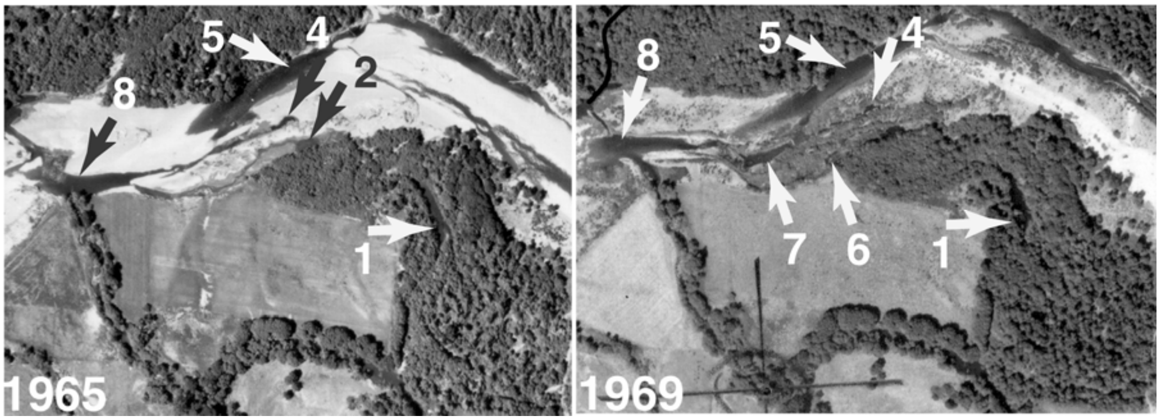

Figure 13: By 1965-1969 the other ponds had formed.

By 1965 the remaining ponds had mostly taken shape as shown in Figure 13. Pond 2 appears to be a scour area. Important pond 6 with high chub populations in 2002 was originally part of a narrow channel formed along the edge of a side bar (see Figure 14). In the 1969 vegetation is colonizing and stabilizing the cobbles and gravel landforms in which the ponds are embedded.

Figure 14: Enlargement of 1965 photograph of pond region.

In terms of total numbers of individuals, pond 6 has had biggest decline of chub through 2004. Compared to pond 1, pond 6 lies in a position more vulnerable to the force of higher winter flows. Higher winter flows generate intense shear stress (high water velocity gradients) sufficient to scour aquatic plants and sediment. This likely explains the absence of floating lily as seen in pond 1.

8 Analysis of Water Sources to the Ponds

Water entering the ponds may come from the following sources.

1. Precipitation.
2. Groundwater.
3. Hyporheic Flow
4. Surface Water Flow

To understand the magnitude of each mechanism we need at least a simple assessment of upland contributing area. Since there is virtually no relevant data, a simple analysis of upland contributing area is given next.

Figure 15: Upland contributing area for the ponds.

Water may reach the ponds by surface runoff from rainfall and/or hyporheic flow from areas physically above the ponds and whose flow paths then can reach the ponds. Such regions are upland contributing areas for the ponds. Upland contributing area can be estimated if we make a reasonable simplifying assumption that secondary channels within the floodplain capture any surface runoff or hyporheic flow path that reaches them. Said another way, no flow path will cross a secondary channel.

Figure 15 shows potential upland contributing area for the ponds. Figure 15 shows in red the secondary channels that will capture the bulk of flow from upland areas. The blue arrows represent flow paths from upland floodplain regions intercepted by the secondary channels. The yellow arrows show flow paths from upland areas that could arrive at the ponds. Evident from Figure 15 is the small potential upland contributing area for the ponds. Because the area is small, water sources derived from the upland contributing region will likewise be small.

8.1 Precipitation

Precipitation can arrive at the ponds directly by landing in the ponds or from upland contributing areas. Direct rainfall input has negligible impact, particularly since it coincides with high stream flows. Precipitation landing south of the secondary channel labeled A in Figure 15 cannot get to the ponds. Since the upland contributing area is small this source is therefore deemed negligible.

8.2 Groundwater

There is no data concerning groundwater flow from the floodplain and/or uplands to the ponds. It is unlikely that there is an appropriately placed impermeable clay layer that allows groundwater to feed the ponds.

8.3 Hyporheic Flow

Hyporheic flows almost certainly supplies some nontrivial portion of the ponds water annually and may be most important during the dry summer months. Secondary channels near the ponds have been observed to be dry upstream from sections carrying flowing surface water. As a first approximation from aerial photographic analysis we assume that the main hyporheic flow paths follow the most recently deposited large cobble and gravel secondary channels leading to or near the ponds. This was discussed above in reference to the 1952 frame of Figure 6.

Accurately discerning hyporheic flow paths requires installing wells to measure hydraulic head gradients and then adaptively redesigning the well network depending on what is learned from prior monitoring. It is assume that hyporheic flow originating upstream of point 1 on Figure 15 can not get to the pond region since that flow would be intercepted by secondary channel A.

While this report raises doubts about concluding pond water depths are receding, it is interesting to note that in the spring and summer of 2002 the Army Corps drew down Cougar Reservoir releasing large quantities of fine sediment[3]. These fines have potential to externally clog riverbank and bed sediments, and deeper into the interstitial pore spaces of the framework cobbles and gravels forming the hyporheic conduits to the ponds[4]. The retention of fine particles will reduce the hydraulic conductivity of the sediment layers thereby reducing water flows under a given hydraulic gradient.

The increased sediment load from the reservoir draw down may have increased deposition within the ponds. Sedimentation raising pond bed elevation of the ponds would reduce, in particular, summer water depth. Shallower ponds will have increased summer water temperatures and thus increased evaporation further reducing water depths compared to historic levels. Monitoring pond bed topography and elevations over time is recommended.

8.4 Surface Water Flow

Surface water flow can arrive at the ponds through a network of secondary channels and by overtopping mainstem channel banks and then flowing across floodplain. Floodplain flow inundating most of Big Island will occur at only the highest and relatively infrequent flows. For this study, we are primarily interested in the wide range of mainstem flows that feed surface water to the pond region within the banks of the secondary channel network. The activity level of any particular secondary channel path to a pond will depend on mainstem stage (or flow). A central objective of the monitoring program is to gain understanding into how surface flow is

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[3] Stewart, G., Glasmann, J.R., Grant, G.E., Lewis, S.L. and Ninneman, J., 2002. Evaluation of Fine Sediment Intrusion into Salmon Spawning Gravels as Related to Cougar Reservoir Sediment Releases. Unpublished report prepared for U.S. Army Corps of Engineers, Portland District Office, dated October 4, 2002. Appendices A (Methods), B (Grainsize Data) and C (Photographs)

[4] N. Tufenkji, J.N. Ryan and M. Elimelech, 2002. Bank Filtration. Environmental Science and Technology pp423-428.

routed in the secondary channels to the pond region as a function of mainstem flow. Specifically, what are the flow paths and at what mainstem flows do routes become active.

A preliminary model of secondary channel flow paths to the ponds and mainstem flow levels required for their activation was developed to guide monitoring activities. The preliminary model is based on casual observation by ODFW and MRT (McKenzie River Trust) personnel during a limited range of mainstem flows, and aerial photograph interpretation. Figure 16 shows the preliminary model of the network of secondary flow channels routing water to the pond region. The secondary channels are color coded to indicate the estimated mainstem flow (measured at the Vida gage) at which a channel becomes active. Three hydrologic stages are identified and the estimated levels for activation are given in Table 6.

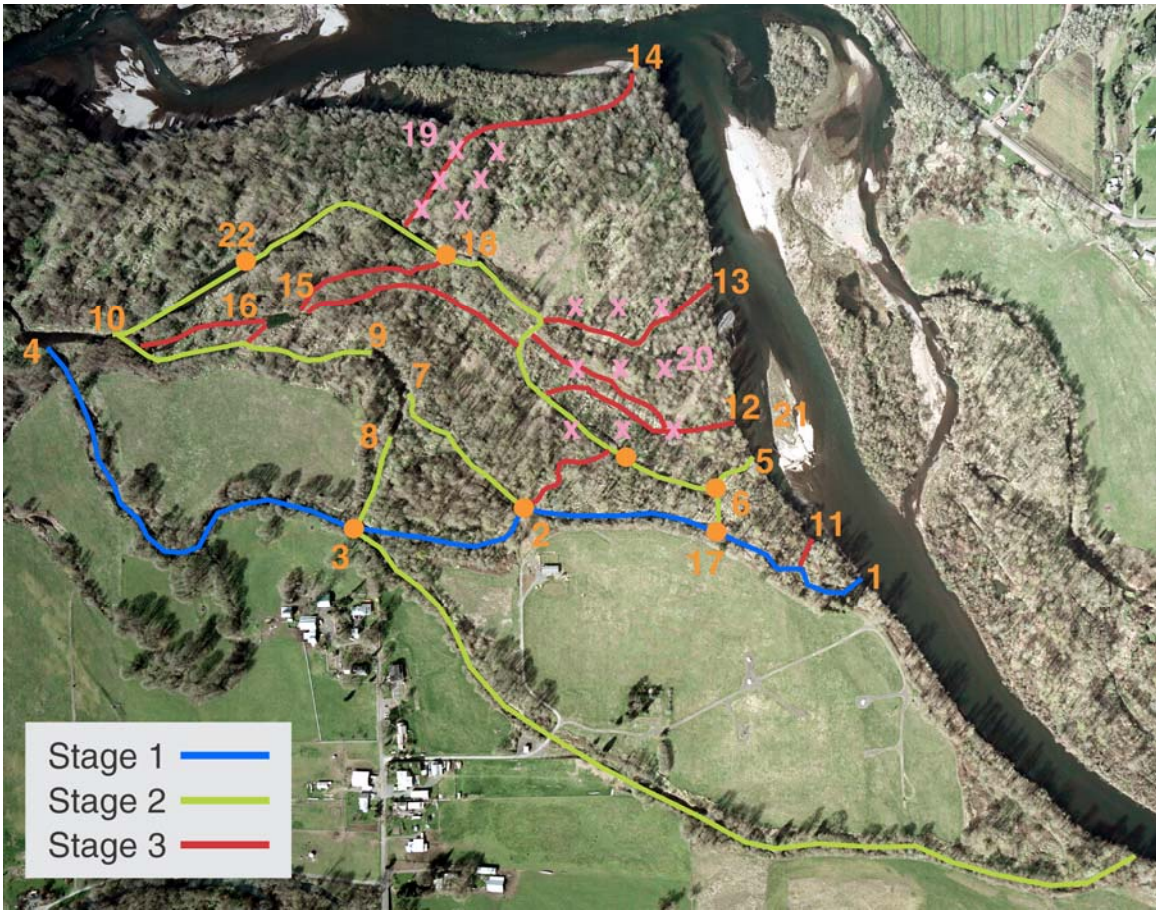

Figure 16: A preliminary model of the network of secondary channels routing water to the pond region.

Hydrologic Stage	Vida Gage Height (ft)	Flow at Vida (cfs)
Stage 1	2.0 – 2.5	3,500 – 4,500
Stage 2	2.5 – 3.5	4,500 – 6,700
Stage 3	3.5 – 4.7	6,700 – 10,000

Table 6: Definitions for preliminary hydrologic stages of the secondary channel network routing surface water to the pond region.

At this point, a note about stage-discharge relationships, commonly called rating curves, is in order. The most recent rating curve for the Vida gage was obtained from the USGS office in Portland, OR[5]. The table of rating curve data is shown as a graph in Figure 17. A rating curve is used to convert gage height readings into the desired streamflow measurement. The USGS periodically updates rating curves to maintain accuracy since channel geometries at a gage can, and do, change. Over time, a given gage height may associate to different streamflows. For the purpose of this study therefore, potential confusion may be avoided by using flows at Vida, not gage heights, to define and analyze hydrologic stages on Big Island.

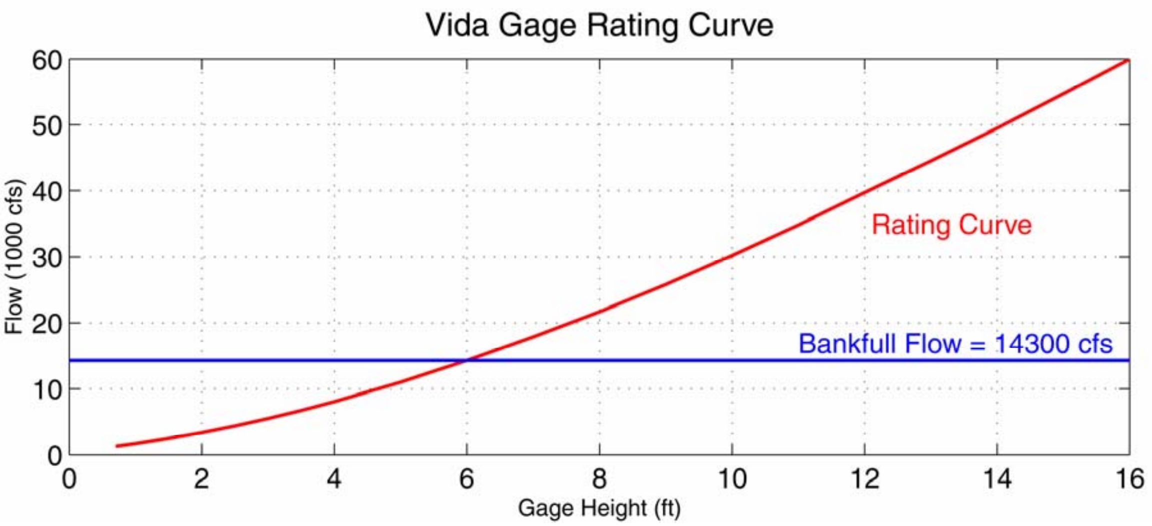

Figure 17: Stage-discharge function (rating curve) for the gage at Vida. From a rating table dated 11/10/99. The blue line marking bankfull flow was obtained from the National Weather Service, Portland, OR.

The surface water connection active at the lowest mainstem McKenzie River flow was identified by ground investigation by MRT personnel (George Grier, personal communication, 2004). Referring to Figure 16, the lowest flow entry point is labeled 1 and is coded as a blue secondary channel (hydrologic stage 1). On 6/17/04 flow at Vida was 3570 cfs and surface water could be seen slowly flowing into the secondary channel (pond 1 staff gage reading of 2.0 ft). Identifying the lowest flow surface connection is important for designing a monitoring plan and understanding water connection mechanisms to the ponds. Below the mainstem stage at which the surface water connection at 1 first becomes inactive, water feeding the ponds is likely mainly

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[5] Suzanne Jo Miller, Technical Information Spec., U.S. Geological Survey, 10615 S.E. Cherry Blossom Drive, Portland, OR 97216, (503) 251-3201, sjmiller@usgs.gov

derived from hyporheic flow. The monitoring plan will include a staff gage installed at the readily accessible secondary channel entry point 1.

The lowest flow path reaches a junction at 2 (Figure 16). A road crossing complicates understanding flow direction and resistance at this juncture. The crossing does not have a culvert. At hydrologic stage 1, surface water generally flows to junction 3 and so may circumvent the pond region to some degree. A hyporheic connection is likely still active, and how much flow the road redirects or how much resistance to subsurface flow the crossing causes is unclear. The lowest flow route then continues to an outlet at 5, which is chub pond 8. MRT personnel have observed that the lowest flow path (blue path in Figure 16) does not have a continuous surface water connection along its entire length during the lower values of mainstem flows encompassed by hydrologic stage 1. At the lower range of hydrologic stage 1, some sections convey water subsurface (hyporheic), which reemerges downstream.

At hydrologic stage 2, a second inlet to a secondary channel becomes active at 5 in Figure 16. Flow splits at 6 and can either contribute water to the blue route to the south or flow north-west toward the northerly edge of the pond region. Interesting and important flow patterns in secondary channels and pond 1 likely occur during the range of mainstem flows categorized as stage 2. Flow arriving at junction 2 can now reach pond 1 via the pond’s main inlet at 7. Somewhere in the lower range of stage 2 flows, it is hypothesized that outlet 1 of pond 1 becomes the first active outlet at 8 (also see Figure 11). Flows from pond 1 outlet 1 can drain to junction 3. At some point within stage 2, higher flow rates will elevate pond 1’s water surface sufficiently to activate outlet 2 at 9 (also see Figure 11). When this occurs, a channel connecting pond 1 to ponds 3, 6 and (probably) 7 is active and water can flow through to junction 10 and pond 8.

At hydrologic stage 3 more inlets to secondary channels at 11-14 in Figure 16 become active. The locations of these inlets are approximate and others likely exist. It is particularly challenging to delineate the stage 3 (red) routes, as ground truthing is absent due to the difficulty in accessing the site. Of particular importance to chub survival is likely the additional flow paths that become active at 15 and 16 (Figure 16). These paths allow high flows to enter pond 3 and 6 with substantial force. Topography at pond 3 allows water to drop rapidly down into the pond likely creating very high velocities, which may continue into pond 6. High shear stresses caused by high water velocities are implicated in chub population diminishment.

It is conjectured that at the higher range of stage 3 flows and beyond, pond 1 empties through outlet 2. At high flows the capacity of secondary channels to convey water depends more strongly on their geometry. Pond 1 outlet 1 connects to the blue route from junction 3 to 4 (Figure 16), which is a confined steep banked channel. To convey a given high discharge, water in the blue channel must rise higher than water that can spread out across the relatively wider open marshy region containing the green channel from junctions 9 to 10. Hence, the hydraulic gradient across the pond likely depends on mainstem flow and may change direction as water levels in the area rise or fall.

Beyond stage 3 the myriad channels and floodplain regions that become active flow paths is very uncertain. As far as chub survival, what is likely most important at these elevated water levels is the force of flowing water moving through the ponds.

9 A Monitoring Plan and Conclusions

Effective monitoring is necessarily an adaptive procedure. At present, the hydrologic system at Big Island is poorly understood (essentially no quantifiable data) and so substantial information will likely be learned as incoming data from monitoring is analyzed. Changes should be made to the monitoring design to integrate what is learned in order to better capture the hydrology affecting the chub ponds. The monitoring plan proposed here is based on very limited data and should be critically evaluated within one year.

The ecological basis for recommendations for a hydrogeomorphic monitoring plan are driven by the criteria discussed in section 3 on ecohydrology. Pond water depths become crucial during the dry summer but understanding their hydrology will require monitoring during the entire receding and baseflow sections of an annual hydrograph, roughly April through the end of October. Observing and measuring higher flow water velocities requires monitoring during December through April.

9.1 Hydrologic Monitoring

Hydrologic monitoring includes the placement and reading of water level gages at certain intervals, measuring high flow velocities, and observation of flow patterns. All water level gages should be surveyed relative to a fixed reference point so that gage readings can be used to find elevation differences between the gages. This will allow the computation of hydraulic head gradients and therefore give information on the direction of water flow at a larger scale.

A choice of water level gage will depend on funding and access issues at higher flows. For example, Global Water Instrumentation's WL15 automatic water level data recorder is ~$800. Simple staff gages can suffice for most locations, and may be a prudent choice in most locations until more quantifiable data is obtained. Automatic water level data loggers can increase the range of observable mainstem flows due to site accessibility difficulties of reading manual gages during higher flows.

It is recommended the water level gages be placed at the following locations. (Numbered locations refer to Figure 16.)

1. In all ponds sampled for chub (7 gages).
2. Lowest flow secondary channel inlet at 1. (The other inlets are inaccessible on the ground.)
3. Junction 17 (Junction 6 is desirable but assumed inaccessible.)
4. Junction 2 above (west) of the road crossing.
5. Junction 2 below (east) of the road crossing.
6. Junction 3.
7. Points 18 and 22 within large crescentric lakes.
8. Edge of mainstem channel near 14 and 19, depending on accessibility.

Water level gages in the ponds and inlet 1 will provide the basic information and an historical record for relating water surface level of the ponds to mainstem river stage. If water levels in the pond have dropped due to a one-time event, such as the Cougar Reservoir sediment slug, this after-the-fact monitoring will not shed much light into whether sediment pore clogging occurred.

If the water level gages selected for monitoring are manual, such as staff gages, they should be read almost daily during the first year. Consistent and relatively frequent readings will allow pond water surface elevation response to mainstem flow changes to be analyzed. In particular, monitoring (at least) daily during rainfall events when there are spikes in the hydrograph could yield valuable insight into flow mechanisms to the ponds. Analyzing pond water surface change response times to mainstem stage change can likely distinguish between a more rapid surface water connection and slower hyporheic connection. The spikes in the April 2002 and May 2004 hydrographs are examples that can be readily measured with manual gages, as accessibility is probably not an insurmountable issue at these flows.

If manual water level gages are used, the consistent and frequent monitoring period during the first year should extend from the time the site is accessible (roughly April) through November, the beginning of the raining season. Monitoring regularly during the dry summer will yield valuable information about the pond water source transition from primarily secondary channel surface flow to hyporheic flow.

Mainstem water surface slope should be surveyed to determine the slope. This can be done over a single reasonable length (several hundred feet) of channel. It is reasonable to assume that the mainstem water surface slope is constant around Big Island. It is possible that the 2 ft contour digital terrain model from the 2004 Digital Ortho Imagery Acquisition Project may provide a sufficiently accurate mainstem water surface slope.

Monitoring at junction 17 will yield a hydraulic gradient between this point and the inlet at 1. Monitoring at junction 17 is intended to give information about the resistance to flow at and near the inlet. Could the deposition of sediments near the inlet have contributed to the hypothesized drop in pond 1’s water surface level?

Monitoring on either side of the road, at junction 2 above (west) of the road crossing and junction 2 below (east) of the road crossing can test a theory about water circumventing pond 1 and therefore contributing to the hypothesized diminishment of water in pond 1. Further, this monitoring will gage the resistance to flow across the road crossing, and give another data point for the computation of the lowest flow secondary channel’s water surface slope (blue channel in Figure 16).

Monitoring at junction 3 will give information about how that channel’s water surface elevation changes with discharge. It will provide heights for determining water surface slope to pond 1’s outlet 1 (and so flow direction).

Monitoring at 18 and 22 within the large crescentric lakes could help in determining direction of large scale hyporheic flows on Big Island. What is the hydraulic gradient from the mainstem to point 18? What are the gradients from 18 to the chub pond at 15?

Monitoring at the edge of mainstem channel near 14 and 19 can provide information about the large scale surface and subsurface flows across Big Island. Accessing these sites at anything other than lower flows is unlikely and information gained here may be redundant with determining mainstem water surface slope discussed below.

Field personnel should also make regular observations. Regular hydrologic observations to record as field notes are listed below.

1. Observe direction of pond 1 outlet flow over a wide range of mainstem flows. Discern what mainstem flow outlet 1 and then outlet 2 first become active. If pond 1 is accessible at stage 3 flows, determine direction of flow.
2. Pond 1’s outlet 1 has a twin “v” shape. At the lowest outlet flows, water is flowing out through a narrower “v” shaped gap, like a v-notch weir. At higher flows water empties out through a wider “v” shaped opening. Observe what mainstem flows this transition occurs.
3. Observe flow patterns at road crossing at 2. This observation along with the two staff gages on either side of the road will aid in understanding if water is being circumvented around pond 1.
4. Observation of pond 6 during winter high flow events may be possible. Personnel familiar with the site should explore options for how that can be done safely. Observation would provide useful subjective information about how high flows are directed through pond 6 and where velocity meters (if desired) might be located.

In all the ponds sampled for chub, water velocities should be measured. Measurement will need to be made during very high flows in order to assess shear stress. If only a few ponds can be instrumented it is suggested that emphasis be placed on ponds 1, 4 and 6.

Placement of subsurface monitoring wells to measure hyporheic flows will require a more iterative process of learning and fine tuning the design than the measurement of surface flows. Establishment of well locations without prior information about hyporheic flow paths is generally not possible. As a first approximation it is suggested that well fields be located along the hypothesized main relict channel paths identified in historical aerial photographic analysis earlier in this report. For easier analysis of results wells should be placed on a regular grid roughly aligned with the presumed hydraulic gradient. Two subsurface monitoring well fields are suggested and shown conceptually at 19 and 20 (pink x’s). A survey will be required to fix water depth in a well to a common reference point so that a gradient (water surface slope) can be determined. Funding will determine the number of wells.

9.2 Geomorphic Monitoring

Geomorphic monitoring should include two main activities.

1. Monitor pond bed cross sections.
2. Secondary channel inlets at mainstem, particularly lowest flow inlet.

Ponds may be filling with sediment over time due to natural deposition rates of fines and/or augmented rates due to human activities. It is likely too late to assess what impact the sediment slug released by the draw down of Cougar reservoir has had on the pond sedimentation rates. A regular program of measuring pond bed cross section topography should be instituted to determine if water depths are decreasing due to infilling.

The other most likely geomorphic process to impact pond hydrologic function is deposition of cobbles and gravels in the mainstem that could alter secondary channel inlets. There is significant fluvial geomorphic activity near inlets at present. Figure 16 at 21 shows a mid-channel bar in the early stages of development. This bar will likely build, extending laterally causing mainstem bank erosion. The bar may eventually coalesce with the mainland, blocking inlets 5 and 12. Root wades are present near inlets 1 and 11 that may affect inlet function. Monitoring geomorphic activity near the inlets would include subjective observation recorded as field notes and photographs.