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Memo

TO: **Mr. Llewellyn Matthews** **DATE: 5 December, 2007**

FROM: **Mr. Larry Hildebrand, R.P.Bio** **Our File No:** 06-1480-001

RE: Recommendations for Outlet Velocities and Exclusion Screen Sizes at WEP

INTRODUCTION

In response to your request, I have prepared the following summary of information regarding information on white sturgeon that is relevant to their potential presence in the draft tubes of the proposed Waneta Expansion Powerplant (WEP). The specific issues addressed are: 1) the sizes of white sturgeon that could be excluded using differing screen spacing and the risks of various age-classes of sturgeon being present in the area of the draft tubes, 2) the swimming speeds of white sturgeon as related to their potential entry into the draft tubes when the unit is shut down and risks of subsequent impingement on the screen following unit start-up, and 3) the volume of water necessary to maintain the health of sturgeon that may become trapped in the draft tube during dewatering events. Each of these topics is addressed below and an opinion is provided as to design criteria for draft tube screen sizing and outlet velocities.

Screen Spacing

Provision of a physical screen to exclude white sturgeon has been proposed for use at WEP. The bar spacing of the screen will determine the size of sturgeon that can enter the draft tubes but also can have substantial effects on power production and therefore, the final design of the structure will have to consider both these factors.

The Waneta Eddy area, which is situated about 200 m downstream from the proposed WEP outlet, supports large numbers of white sturgeon, both adults and juveniles. To assess the ability of a white sturgeon to pass through a particular screen spacing the following body characteristics were considered (Plate 1):

- white sturgeon have a slightly ovoid body form, with width typically being slightly greater than height;
- sturgeon have large pectoral fins that are relatively fixed and cannot be folded flat against the body as in other fish species;
- the widest part of the body is located at the insertion of the pectoral fin rays;
- when the fish is in typical upright swimming mode, the extended pectoral fins can double or triple the effective width; and,
- the minimum diameter of the fish would be presented when the fish turns sideways.

Plate 1 Photos show the typical pectoral fin orientation and size (left) and the body form (right) of juvenile white sturgeon.

The relative sizes (length, weight, and girth) of juvenile hatchery reared white sturgeon in the Columbia River were obtained from the Upper Columbia White Sturgeon Recovery Initiative database (Table 1). The age-1 fish in Table 1 are juveniles that have been recaptured 5 to 6 months after release. When released, these fish were approximately 14-16 cm in fork length (FL) and represent the smallest juveniles that would likely be present in the Project area. Girth data for these fish are not available, but based on the girths of recaptured age-1 fish (Table 1), estimated average girth of the post-release juveniles would be approximately 10 cm, equivalent to an average diameter of about 3 cm.

Table 1 Average fork length, average weight, and average girth-at-age for hatchery released white sturgeon recaptured in the Lower Columbia River.

Parameter	**Age**					
	1	**2**	**3**	**4**	**5**	**6**
Average Fork Length (cm)	35	46	53	61	64	63
Standard Deviation	6	5	7	9	10	7
Range	22 - 66	31 - 62	40 - 74	44 - 85	45 - 89	53 - 80
n	331	422	281	256	115	60
Average Weight (g)	300	639	1059	1728	2126	1859
Standard Deviation	144	284	517	942	1259	780
Range	64 - 710	160 - 1850	414 - 3123	550 - 5000	650 - 6000	1000 - 4200
n	328	421	270	255	112	60
Average Girth (cm)	15	19	19	22	24	26
Standard Deviation	2	2	2	3	4	2
Range	11 - 20	15 - 25	15 - 26	18 - 28	22 - 31	23 - 28
n	69	51	48	23	5	6
Average Fish Diameter - cm (in)	4.8 (1.9)	6.0 (2.4)	6.2 (2.4)	6.9 (2.7)	7.7 (3.0)	8.2 (3.2)
Min. Fish Diameter - cm (in)	3.5 (1.4)	4.8 (1.9)	4.8 (1.9)	5.7 (2.2)	7.0 (2.8)	7.3 (2.9)
Max. Fish Diameter - cm (in)	6.4 (2.5)	8.0 (3.2)	8.3 (3.3)	8.9 (3.5)	9.9 (3.9)	8.9 (3.5)

The juvenile sturgeon diameter at-age data in Table 1 was used as the basis for an assessment of what fish age-classes would be excluded by a range of vertical bar screen spacing. For this type of screen the minimum body diameter would be the factor determining possible entry into the draft tube. The following assignments of vertical bar screen exclusion efficiency were determined for juvenile white sturgeon:

- 1 inch (2.5 cm): would exclude all age-classes;
- 2 inch (5.1 cm): would exclude age-4 to age-6;
- 3 inch (7.6 cm): would not exclude any of the age-classes.

Therefore, a 1 inch vertical bar is the only spacing that would exclude all white sturgeon juveniles from potentially entering the draft tubes of WEP. Anything larger would potentially allow access by some age-classes.

If a square mesh screen was used at WEP, the body shape and pectoral fin ray extension of juvenile white sturgeon would play a much larger role in their exclusion. To account for the ovoid body shape and the influence of the pectoral fins on the ability of sturgeon to pass through the bar spacing regardless of swimming orientation, the minimum diameters of the fish provided in Table 1 were increased by a factor of 1.75, which is considered as a conservative adjustment. This resulted in the following assignments of exclusion efficiency for square mesh screens:

- 1 inch (2.5 cm): would exclude all age-classes
- 2 inch (5.1 cm): would exclude all age-classes
- 3 inch (7.6 cm): would exclude age-2 to age-6
- 4 inch (10.2 cm): would exclude age-5 and age-6
- 5 inch (12.7 cm): would not exclude any of the age-classes.

White Sturgeon Swimming Speeds

Information on swimming speeds of juvenile white sturgeon is needed to determine: 1) the likelihood that juvenile white sturgeon would be in the immediate vicinity of the draft tubes when the turbines are shut down, 2) whether they could move upstream from the eddy and into the area either over the period of the shutdown or during WEP operations, and 3) if a sturgeon did enter the draft tubes through a screen when the unit was down, what would be the risk that that fish would be impinged on the inside of the screen when the unit was started up.

The following materials were reviewed to obtain information on sturgeon swimming speeds:

- Graham, J.B., H. Dewar, N.C. Lai, W.R. Lowell, and S.M. Arce. 1990. Aspects of Shark Swimming Performance Determined Using a Large Water Tunnel. Journal of Experimental Biology 151,175-192 (1990).

- Adams, S.R., J.J. Hoover, K.J. Killgore. 1999. Swimming Endurance of Juvenile Pallid Sturgeon, Scaphirhynchus albus. Copeia, Vol. 1999, No. 3, pp. 802-807.

- http://www.fsl.orst.edu/geowater/FX3/help/9_Fish_Performance/Fish_Length_and_Swim_Speeds.htm

For most fish species, absolute swimming speed (distance per time) and fish length are positively related through the categories of sustained, prolonged and burst swimming speeds. Although swimming speeds for juvenile white sturgeon are not available, a reasonable surrogate would be pallid sturgeon (*Scaphirhynchus albus*) which have a similar body form and also inhabit large river systems and sharks, which have similar swimming characteristics and body form.

For juvenile pallid sturgeon (17.0 to 20.5 cm FL), the maximum observed sustained swimming speed (no fatigue after 480 min) was 25 cm/sec, prolonged speed was 30 cm/s, and burst speeds of 55-70 cm/sec were measured. Similar to other lotic, benthic fish, sturgeon could use their pectoral fins and overall body morphology to maintain station against velocity without swimming. Fish typically swam with the ventral body surface in contact with the tunnel bottom during tests, rarely swimming in the water column.

The pallid sturgeon tested were smaller than the average 35 cm FL of age-1 white sturgeon in the Columbia River. Since larger fish are capable of faster swimming speeds, the swimming speeds of all age-1 and older white sturgeon would be greater than the values provided for juvenile pallid sturgeon.

The critical swimming velocity (U_{crit}, an index of aerobically sustainable swimming speed) of a 70 cm long lemon shark (*Negaprion brevirostris*) was determined to be 1.1 Ls^{-1}, where L is total length (TL). The U_{crit} of the leopard shark (*Triakis semifasciata*) was found to vary inversely with body size; from about 1.6Ls^{-1}in 30-50cm sharks to 0.6LS^{-1} in 120cm sharks. Applying this relationship to 30-50 cm TL white sturgeon provides U_{crit} values (using the1.6Ls^{-1} conversion) of 66 cm/s for age-1 (41 cm TL) and 91 cm/s for age-2 (57 cm TL).

Using the data from pallid sturgeon and sharks, a reasonable estimation of swimming speeds for age-1 juvenile white sturgeon would be a sustained speed of 30 to 40 cm/s, a prolonged speed of 40 to 60 cm/s, and a burst speed of 60 to 90 cm/s. Older fish would be capable of faster swimming speeds in all three categories.

The near-bottom velocities in the Pend d'Oreille channel near the highway bridge crossing are predicted to always exceed 2 m/s, (i.e., at lower discharges from WEP and the existing Waneta plant of about 280 cms) and at higher discharges will commonly exceed 4 m/s (ASL Numerical Modeling of Flows at the Confluence of the Columbia and Pend d'Oreille Rivers: Phase 2 Report, May 2002; Appendix D, Figure D.1.21). The burst speed of age-5 and age-6 juveniles could exceed 2 m/s, meaning these age-classes could potentially access the WEP tailrace during low discharge periods. Younger white sturgeon juveniles would have lower burst speeds and this, combined with their high degree of selection for relatively low velocity habitats (typically less than 50 cm/s), is expected to reduce the likelihood of their presence in the WEP tailrace area during periods of WEP operation. However, during periods of minimum flow operations (i.e., 34 cms at speed-no-load flow), most juvenile age-classes would be capable of accessing the WEP tailrace area and potentially could do so. As well, juveniles that resided in the plungepool of

Waneta Dam during non-spill periods could potentially access the WEP outlet at any time; whether they would choose to do so during periods of operation of either powerplant is unknown.

White Sturgeon Stranding During Draft Tube Dewatering

Stranding of sturgeon in draft tubes during unit shutdowns for maintenance has been reported at several facilities on the Columbia River. Therefore, it is reasonable to expect that if the screen size selected does not exclude all white sturgeon, then there is the possibility that some sturgeon will be trapped in the draft tube after the stoplogs have been installed and the unit isolated from the tailwater. The main factors that will determine potential risk to trapped sturgeon are the amount of water that remains in the draft tube, the DO and temperature of the water, and the number of fish present (including other species). Based on the base concept design, dewatering the unit to the point where an inspection of the runner can occur will result in approximately 300 m^3 of water remaining in the draft tube. This will be the scenario in most shut-downs. This volume of water combined with the provision of fresh water from leakage through stop log seals should easily support several juvenile sturgeon over the typical one to two week duration of the shutdown period. The number of sturgeon that can be supported will be dependent on water temperature (warmer waters hold less oxygen and increase fish metabolic rates which results in higher oxygen consumption rates), leakage rates (how much fresh water is added), the number of fish trapped, and the activity level of the fish.

Oxygen consumption rates of white sturgeon under commercial culture conditions were available from :

> Thomas S.L. and R.H. Piedrahita. 1997. Oxygen consumption rates of white sturgeon under commercial culture conditions. Aquacultural Engineering Volume 16, Issue 4, November 1997, Pages 227-237.

Mean fish size tested ranged from 0.09 to 3.8 kg which encompasses the range of age-1 to age-6 juveniles in the Columbia River. Mean daily values of oxygen consumption rates for the cultured fish ranged from 70–330 mg kg $fish^{-1}$ h^{-1}at 18°C. Using the highest oxygen consumption rate and applying this to a 300 m^3 volume of water at 18°C with a DO concentration of 10 mg/L, the draft tube would support 260 kg of fish (approximately equivalent to 260 age-3 sturgeon juveniles) for a period of 14 days before DO levels declined to 6 mg/L (a minimum target level used in other instances where sturgeon have been trapped in draft tubes). This calculation also assumes no additional DO would be provided over this period from inflow of fresh water (leakage) or through the interchange of oxygen from the water surface. In the infrequent cases where the draft tube has to be completely dewatered for inspection and maintenance, the water will be drawn down to about 1 m in depth with a volume of approximately 30 m. At this point, any fish present can be easily identified, captured and removed. Development of a standard protocol for monitoring of these events and conducting the salvage activities should provide adequate protection for sturgeon.

Recommendations

If a decision is made to use a vertical bar screen, then a 1 inch vertical bar spacing will be required to exclude all white sturgeon. A 2 inch vertical spacing would protect larger juveniles and if combined with a target velocity at the screen of 0.3 to 0.5 m/s, could be suggested for use based on the following considerations:

- Younger juveniles are less likely to use the WEP outlet area based on their preference for deep water low velocity habitats with fine substrates;

- Younger age-classes that do enter into the draft tube must be able to escape when the unit starts up or risk impingement against the screen. A larger spacing would allow safer egress for any juveniles that do manage to enter the draft tube. Velocities at the screen face of 0.3 to 0.5 m/s should be sufficient to prevent any juveniles that are present in the draft tube at start-up from swimming further up into the runner but low enough to increase the chances for juveniles to successfully exit through the screen bars.

- From a biological perspective, the greatest protection should be afforded to the older individuals (i.e., fish that have already survived the early years when mortality rates are naturally high). For example, mortality rates for age-1 hatchery juveniles after the first six months at-large are about 70%. Screens that prevent the entry and possible damage to age-1 juveniles at Waneta are unlikely to have any detectable effect on this value.

If a mesh screen was selected, then a 2 inch mesh screen would achieve much the same exclusion effectiveness as a 1 inch vertical bar screen and a 4 inch mesh screen would be roughly equivalent to a 2 inch vertical bar screen. The same considerations provided above for the vertical bar screen would also apply to the mesh screen. Note that these assessments for both screen types are based on the minimum diameters of the fish recorded, and as such, the exclusion assessments represent conservative estimates as is warranted for an endangered species.

The 300 m^3 volume of water remaining in the draft tubes during most turbine maintenance shut downs would be ample for the maintenance of any sturgeon that become trapped for the 1 to 2 week duration of a typical shutdown. One exception might be for shutdowns conducted in the warmest water periods when additional monitoring of DO conditions would be warranted.

Please do not hesitate to contact me if you have any questions or require additional information.

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