Effects of Water—Borne Pollutants on Salmon—Passage at John Day Dam, Columbia River (1982 – 1986)

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COASTAL ZONE AND ESTUARINE STUDIES

CONTENTS

BACKGROUND

John Day Dam, completed in 1968 and operated by the U.S. Army Corps of Engineers (COE), is located at Columbia River Mile (RM) 216; the John Day Reservoir extends 76 miles upstream to McNary Dam (RM 292). The John Day River enters the Columbia River about 2 miles above John Day Dam. Like other hydroelectric projects on the Columbia River, John Day Dam has facilities for passage of migratory adult salmonids. These facilities include a fish collection system along the downstream face of the powerhouse and a fishway with auxiliary water-supply systems on both sides of the river (Fig. 1).

John Day Dam had been associated with inordinate delays in the upstream migration of adult spring chinook salmon, *Oncorhynchus tshawytscha*. During the 1979 and 1980 spring migration periods, the average passage time for radio-tagged fish was 158 and 156 h (Johnson 1981). This compared unfavorably to less than 2 days for fish passing the first Columbia River Dam at Bonneville (RM 145) and to less than 1 day for fish passing the second dam at The Dalles (RM 192). The delay of nearly 1 week at John Day Dam was believed to be a particularly harmful and, perhaps, unnecessary addition to the cumulative delay and other stresses salmonids must endure as they migrate up the Columbia River during this critical and closely-timed part of their life history. Individual fish tracked below John Day Dam spent most of the time in the tailrace area, just below the dam. Although the fish apparently located the collection system entrances, they were reluctant to enter and remain in the system. In addition, passage times for radio-tagged salmonids were twice as long at John Day Dam in fall 1982 as they were at The Dalles and McNary Dams (Liscom and Stuehrenberg 1983).

Within the limits of the John Day Dam's structural design, altered flows and configurations did not improve fish passage. Delays were not

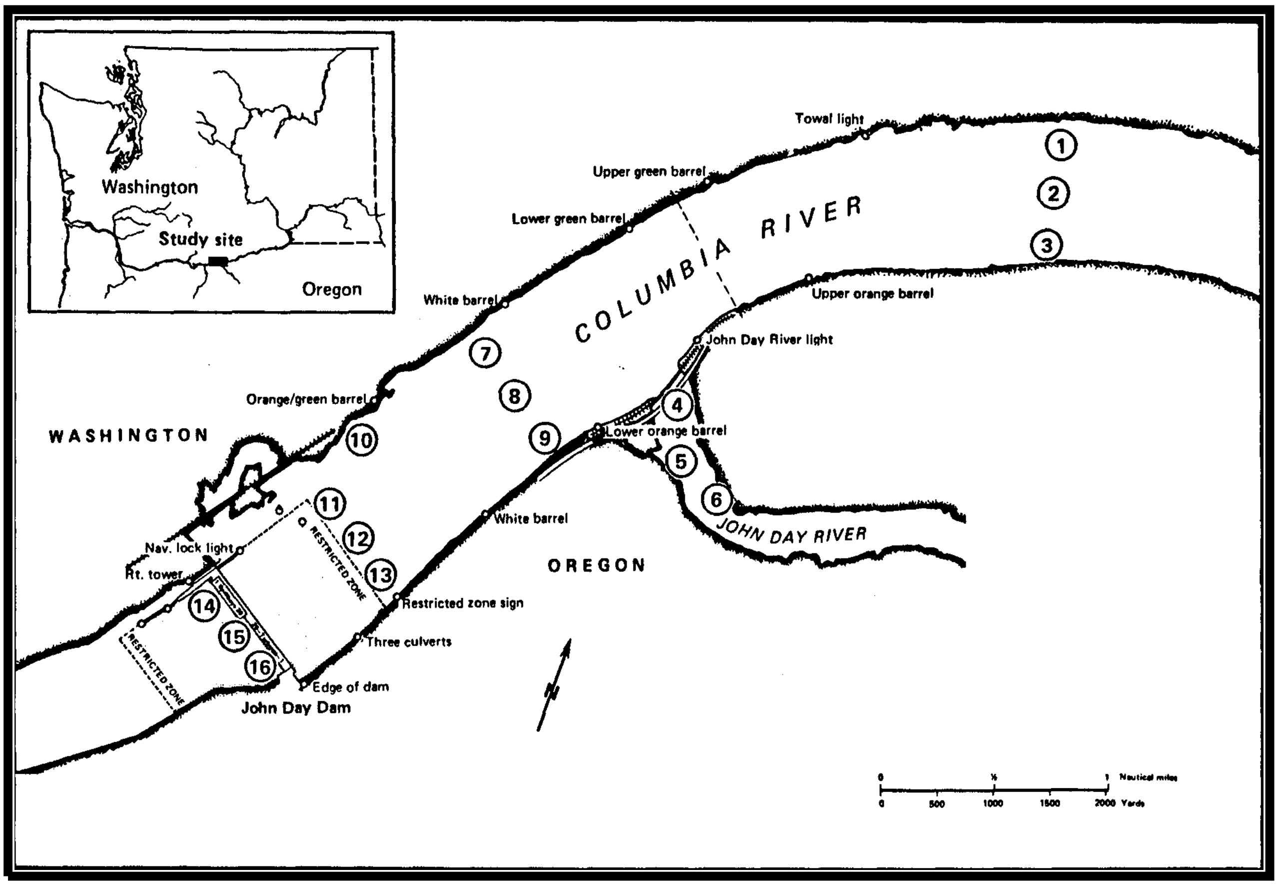

Figure 1.--Study area for adult salmonid passage-delay program, John Day Dam region, Columbia River. Circled numbers indicate sampling sites (sampling sites on downstream side of The Dalles and Bonneville Dams not shown).

significantly decreased by changing entrance locations, water discharge volumes, or turbine operating conditions (Johnson et al. 1980). Also, there was usually a distinct preference for fish to use the south fishway, which was not a problem in itself; initially this was thought to be related to the cause of the general delay (Fig. 2). Because there was evidence that the delay at John Day Dam had caused increased adult mortality and reduced spawning success (Jungel/), this study was undertaken to identify and, if possible, moderate causes of delay.

Describing the water-borne pollutant gradients in the John Day Dam region and relating these pollutants to behavior of salmonids are not simple problems. If the river were free-flowing, the time and space distributions of pollutants would be much less complex. But the pollution field, because of the dam and its reservoir, is modified greatly by wind and the vacillating trajectory of the John Day River plume. During the frequent strong westerly winds, it is apparent that pollutants are moved upstream. From aerial photographs, it is apparent that the John Day River plume can sweep across the Columbia River to the Washington side and then either continue through the north fishway or cross again to the Oregon side before passing the south fishway. During non-spring periods of low flow in the John Day River, pollutants originating on the upstream Columbia River north shore would tend to persist within north shore flows. A secondary effect of the John Day River is the probable influence of its high suspended particulate load, which could alter the toxicity of many pollutants, especially heavy metals.

1[1] C. Junge, Oregon Department of Fish and Game, Clackamas, OR 97015; pers. commun.

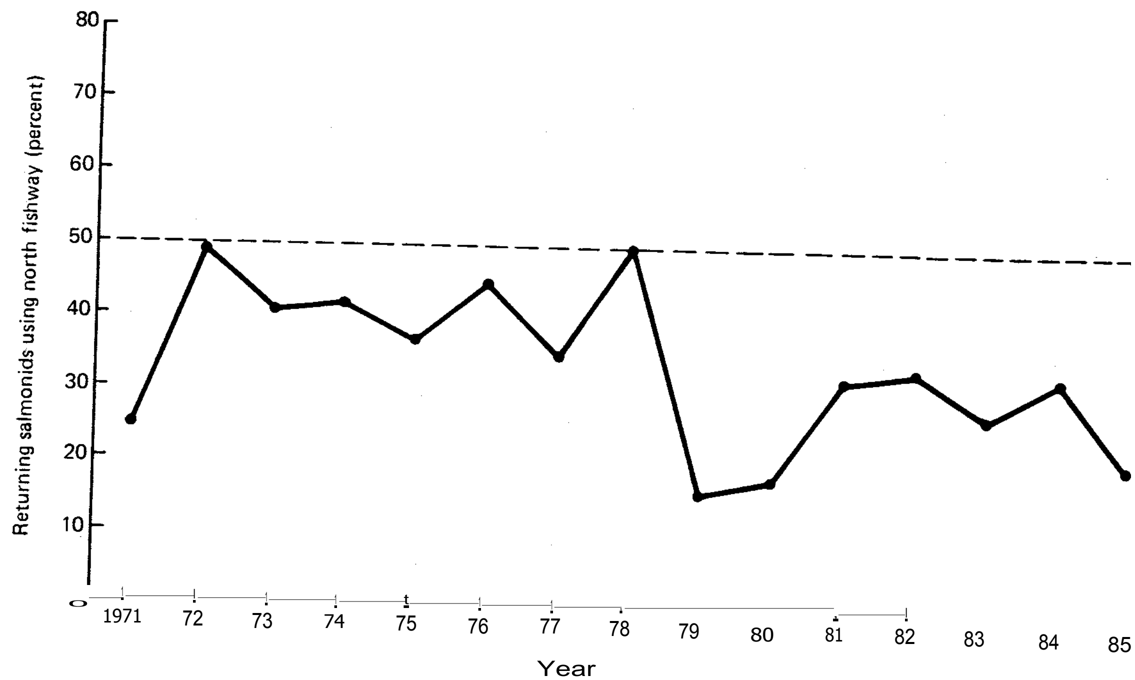

Figure 2.--Returning adult salmonids using north fishway at John Day Dam, Columbia River (1971 through 31 October 1985).

Many of the monitored elements and compounds did not appear to have gradients within the John Day Dam region, and therefore the observed delays of salmonids would not likely be attributable to these constituents. Some of these elements were not investigated beyond the first two or three sampling cruises. Although of little value in the present study, observations on these constituents provide a useful chemical background to this middle stretch of the Columbia River and to the mouth of the John Day River. In view of the expense of such intensive chemical analyses, especially of the organic components, it is not likely that a comparable broad assay would be repeated soon.

If behavior-altering pollutants are present in critical concentrations, it is likely that the migrating adult salmonids would respond to them in a short time-frame. Brown et al. (1982), Cooper and Hirsch (1982), and Kleerekoper (1982) have reviewed numerous laboratory studies demonstrating that salmonids have an acute sense of smell, with threshold values for many chemicals of at least 10^{-6} ppm. Pollutants may cause avoidance or preference, overwhelm biologically relevant odors, or damage chemoreceptive mechanisms. Complete avoidance of pollutants may prevent deleterious exposures. However, serious hazards to fish could arise through unperceived or unavoidable low-level pollutants, in particular altering predator or food detection, reproduction, or migration. Research into this area has received little attention because of the difficulties of quantitative assessment and the variability among individuals in time and space.

That the migrating salmonids at John Day Dam are responding to short-term events is suggested by the changes in preference of fishways during 1982 (Fig. 3) and subsequent years. These daily changes do not appear to be random. Except for 8 days, the majority of fish after 1 June 1982 used the

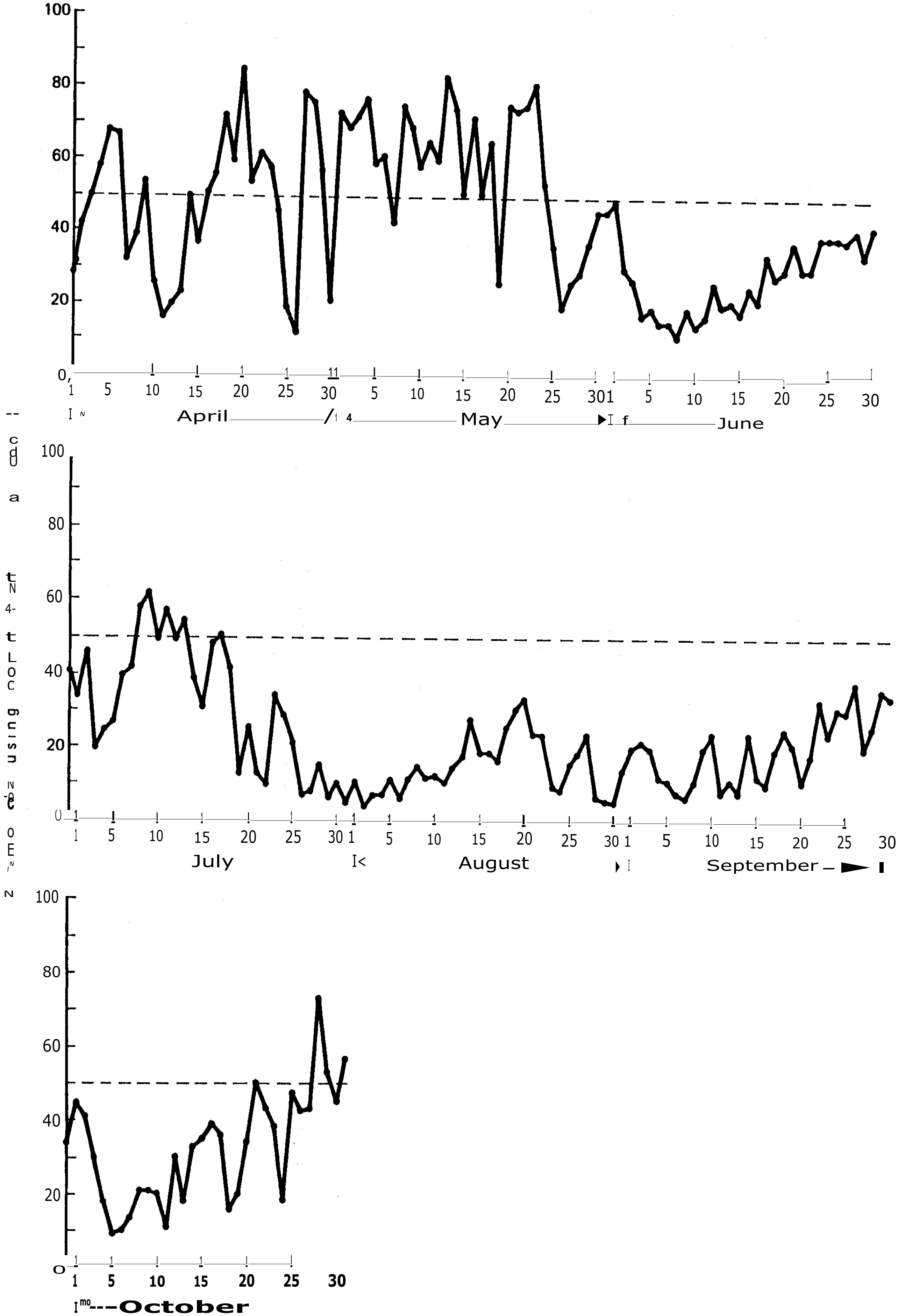

Figure 3.--Returning adult salmonids using north fishway at John Day Dam, Columbia River, 1982; through 31 October, 33% passed north fishway and 67% passed south fishway.

south fishway. Before June 1982, the majority of salmonids used one fishway or the other for 4 days, on the average, before switching fishways. Therefore, what factors cause them to prefer one fishway or the other probably operate on this time-scale. Such a time-scale is not inconsistent with a variable pollution gradient established perhaps in part by the variable trajectory of the John Day River plume in the forebay of John Day Dam.

In 1982, it was determined from studies of the distributions of a large number of pollutants that the reported fish-passage delays might be caused in part by fluorides, free heavy metals (cadmium, copper, lead, and zinc), and/or aromatic hydrocarbons. Each of these pollutants, especially the first and third categories, appeared to be related to activities at the primary aluminum-production plant located on the north shore of the reservoir just upstream from John Day Dam. Because of the apparent relationship of fluoride concentrations around John Day Dam to the reported discharges of fluoride from the aluminum plant, and because of the relative intractability of experimentation with heavy metals and hydrocarbons, it was decided to intensify our sampling to determine the fluoride concentrations and gradients in the John Day Dam region and to focus research on the effects of fluoride on the migratory behavior of adult salmon. Bioassay studies on the effects of low levels of fluoride were added in the second and third years of the investigation and are described in this report.

METHODS

A standard station-grid was established with three boat-sampled transects in the Columbia River and one in the mouth of the John Day River (Fig. 1). Each of these transects consisted of three sampling sites, numbered from roughly north to south. A single station (Station 10) was over the approximate location of the aluminum plant outfall. Additional routine observations were made at two stations in the lagoon on the Washington shore between Station 10 and John Day Dam. This lagoon, which is at the base of the hill upon which the aluminum plant is located, is directly connected to the Columbia River only by a large culvert near the upstream end. Also, several stations were later added covering the river up to one-half mile below John Day Dam. At each station, physical characteristics were recorded generally at 5-m intervals from the surface to the bottom, and water samples were collected at the surface, mid-depth, and near-bottom. Water samples were also collected from the surface at three downstream locations at both John Day and The Dalles Dams (the Washington-shore fishway, the central powerhouse area, and the Oregon-shore fishway) and at four downstream locations at Bonneville Dam (both ends of the new powerhouse, south end of the spillway, and south end of the old powerhouse). Beginning in 1983, water samples for fluoride and turbidity analysis were collected daily from the north and south fishways at John Day Dam, April through October. Because of the danger to the analytical probe, environmental factors were generally not measured directly off the dams. Other locations from which surface water samples were regularly collected included the "pre-outfall pond" uphill from the aluminum plant outfall, and two rivulets freely flowing down the hill from the aluminum plant to the large lagoon described previously.

Basic physical characteristics at each station were measured using a Montedoro-Whitney Mark VA Water Quality Analyzer®.?[i] This is a self-contained portable system for in situ measurements of depth and up to five factors as

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[2-] Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

functions of depth: in this study (1) temperature, (2) dissolved oxygen, (3) pH, and (4) conductivity. Further information regarding specifications and capabilities of this instrument is in Damkaer (1983).

Water samples for inorganic analyses and turbidity measurements were collected using Niskin® 1.2- and 2.5-1 closing water-bottles, constructed of teflon-lined PVC. Sediments for both inorganic and organic analyses were collected at some stations, using a 6-1/2-inch OD by 6-inch long cast-iron pipe with a cleaned cloth bag clamped over one end. This sampler was dragged along the bottom until filled with sediment.

Turbidity measurements were made with an HF Instruments® portable turbidimeter (Model DRT-15). This instrument uses a dual photo-diode system oriented at 90° to the incident light beam (tungsten lamp) and is factory calibrated against formazin solutions. The instrument was field-calibrated daily, against a factory-supplied standard.

All inorganic chemical analyses were performed by the Water Quality Laboratory, Fisheries Research Institute, University of Washington. A description of analytical methods and instrumentation is in Damkaer (1983).

Surface samples for organic analyses were collected in a specially prepared 4-1 glass bottle; subsurface samples for organic analyses were collected with the Niskin (teflon-lined) closing water-bottle. All organic chemical analyses were done by the National Analytical Facility, Northwest and Alaska Fisheries Center. Water samples were stored at 4°C until extracted for analysis (within 96 h of collection). Sediments were stored similarly until received at the laboratory, where they were frozen until extraction. Analytical methods and instrumentation for organic analyses are discussed in Damkaer (1983).

The principal bioassay tests were conducted at Big Beef Creek, the University of Washington's experimental station on Hood Canal (Fig. 4). Preliminary tests with adult chum salmon, Oncorhynchus keta, were done in late fall 1982. From September through December 1983, over 400 tests were conducted using returning chinook, O. tshawytscha; coho, O. kisutch; and chum salmon. From September through December 1984, 178 tests were conducted using returning chinook and coho salmon.

One of two branches of Big Beef Creek was furnished with a two-choice flume (Fig. 5). An 8-m partition longitudinally divides this flume. Upstream migrants can choose to proceed into the left or right arms, which are otherwise equivalent. Once a few meters into either side, fish are kept there by a funnel-trap. At the head of this two-choice flume, about 15 m from the starting point (fish acclimating area), a 55-l carboy empties into the flowing creek water at each of the two arms of the flume. The flow-rates are identical from each carboy, adjusted to empty in about 1 h. Control tests were conducted using no fluoride in either carboy. Most of the other tests were conducted using sodium fluoride in only one carboy (randomly chosen each day). In 1982 and 1983, the fluoride concentration was established to result in approximately 0.5 ppm fluoride in the treatment arm of the flume. This concentration was equivalent to the highest fluoride level we observed in the Columbia River at John Day Dam in 1982. In 1984, a fluoride concentration of approximately 0.2 ppm was established in the treatment arm of the flume, similar to fluoride levels observed in the Columbia River in 1983, 1984, and 1985.

Fish were tested one at a time and were allowed to acclimate about 10 min in the holding area downstream from the two-choice flume. A gate was

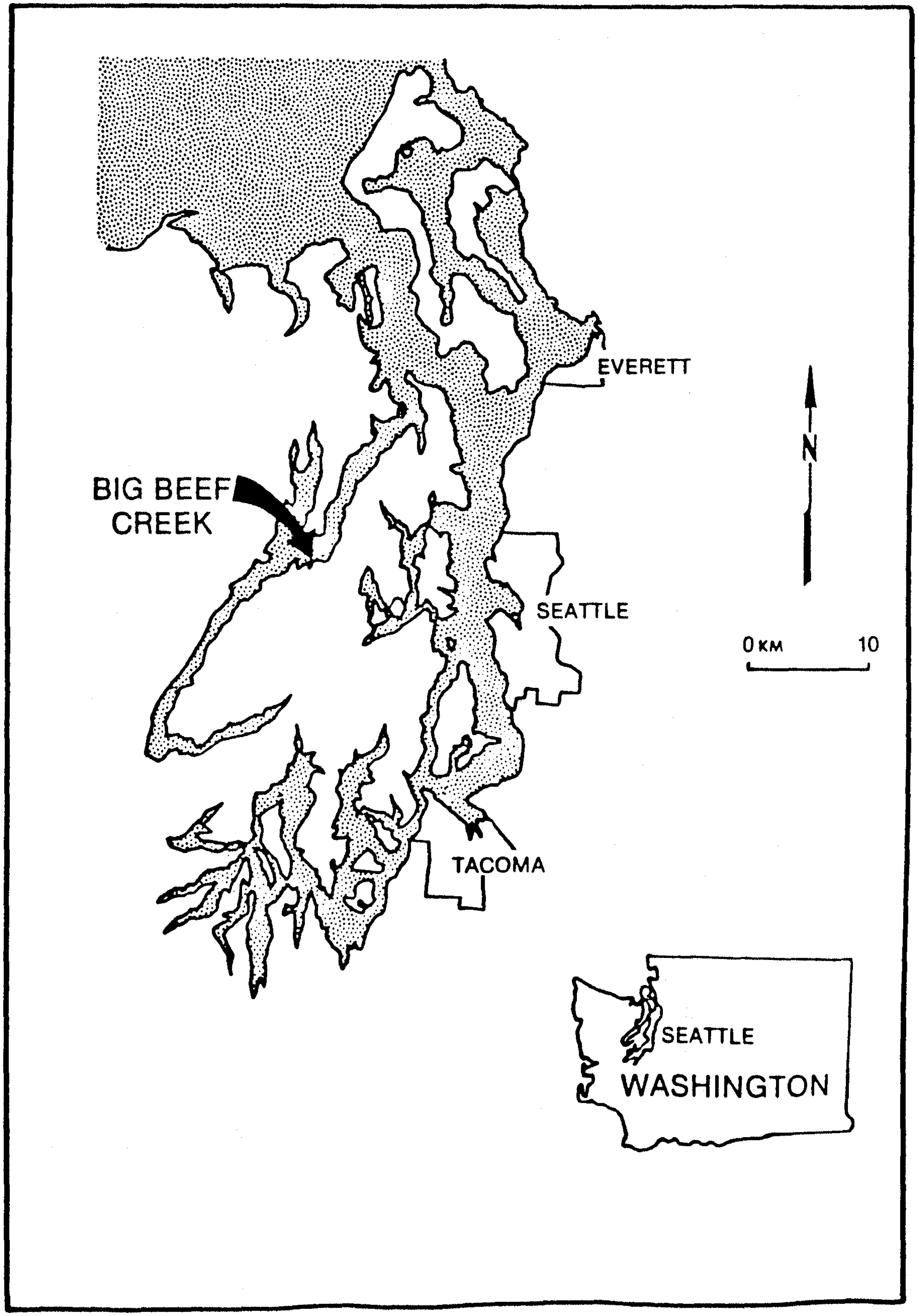

Figure 4.--Big Beef Creek study site for fluoride bioassays with returning salmon.

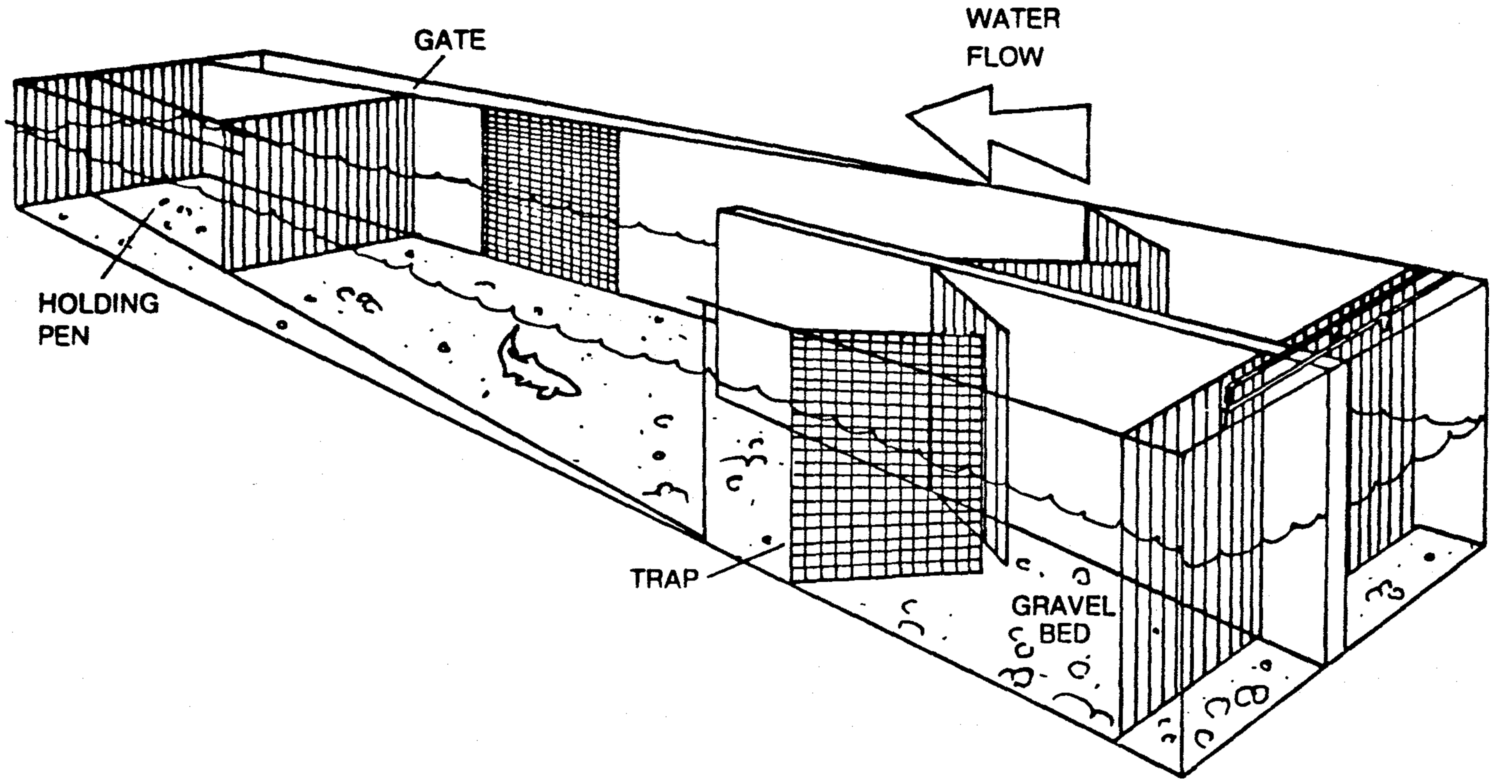

Figure 5.-Two-choice flume for fluoride-gradient salmon-behavior tests, diagramatic view.

then carefully raised from behind a concealed observation area, and each fish was allowed 1 h (1982 and 1983) or 20 min (1984) to move upstream or not.

Small-scale experiments, using juvenile salmonids (chinook and coho salmon and steelhead/rainbow trout hybrids, *Salmo gairdneri)* were conducted when adult salmonids were not available. These bioassays were conducted at NMFS' Seattle or Manchester, Washington, laboratories. Several tests were carried out to determine effects of fluoride and industrial effluent gradients on the behavior (avoidance) of these juveniles in 5-ft long troughs. The treated water flowed into one end of the trough at the same rate as untreated water at the other end. The two water types mixed and left the trough at the center. Fish were introduced singly into the center of the trough and observed for about 0.5 h. Tests were conducted with 0, 0.3, 0.5, and 1.0 ppm fluoride, and with an aluminum-plant industrial effluent diluted to contain 0.5 ppm fluoride.

Groups of juveniles were also held for several weeks in fluoride concentrations of 0, 0.3, 0.5, and 1.0 ppm. Then swimming performance (stamina) was observed for each fish in an adjustable-flow chamber. At the beginning of the bioassay and at the conclusion of the swimming test, blood was taken from each fish for thyroxine hormone (T_4) analyses.

RESULTS

Physical Characteristics

Dates, times, locations, depths of measurement, and corresponding physical characteristics of river water in the John Day Dam region for 1982-1984 are available in tabulated form in Damkaer (1983) and Damkaer and Dey (1984, 1985) and for 1985 in this report, Appendix Table 1. Because of mixing due to the frequent strong winds in the area, and the variability of river flow (and thus spill rate) at the dam through the year, very few patterns of monitored environmental factors were uncovered. Measurements of pH indicated only small differences in time or space in this region and there were no clean horizontal or vertical patterns in conductivity of the river water, reflecting a uniform distribution of major ionic materials [for components analyzed individually, mostly chloride, sodium and sulfate, see Damkaer (1983)]. Of considerable interest, however, were strong indications of the influence of the generally warmer (and therefore, less oxygen rich) and the more turbid John Day River on the Columbia River near John Day Dam. Physical data clearly corroborate photographic evidence of how important the John Day River could be to returning salmonids as they approach John Day Dam.

Inorganic Chemical Analyses

Concentrations of the target inorganic elements (Table 1) by station and depth in 1982 are reported in Damkaer (1983). There were no significant gradients of <u>total</u> inorganics present for any of the analyzed factors, except for fluoride.

1982 Fluoride Levels

It is believed that the primary source of fluorides near John Day Dam is the outfall from the aluminum plant on the Washington shore above the dam. This is borne out by monthly discharge records submitted by the plant to the Washington State Department of Ecology (DOE). The fluoride discharges by the aluminum plant were relatively high in 1982, continuing a several-year pattern. The average daily fluoride discharge in 1982 was 846 lbs, with an

Table 14--Target inorganic elements and compounds analyzed in water and sediment samples from the John Day Dam region, Columbia River.

Aluminum	Lead
Arsenic	Manganese
Barium	Mercury
Cadmium	Nitrate
Chloride	Selenium
Chromium	Silver
Copper	Sodium
Cyanide	Sulfate
Fluoride	Zinc
Iron	

average monthly maximum discharge of 1,792 lbs. From April to June 1982, fluoride concentrations in the John Day Dam forebay, particularly along the north shore, were generally above 0.2 ppm, against a likely Columbia River background of 0.1 ppm or less (Fig. 6). The maximum fluoride concentrations were usually along the forebay's north shore, close to the aluminum plant outfall, and ranged between 0.3 and 0.5 ppm, although high fluoride concentrations could be rather uniform within the area under the influence of strong westerly winds (Fig. 7).

1983 Fluoride Levels

The aluminum plant located near John Day Dam was required to modify its pollution-discharge system and began using a pollutant landfill-storage system in January 1983. As a result, the 1983 fluoride discharges to the Columbia River were about one-fourth those of previous years. Disregarding September and October, when the new treatment system malfunctioned, the average daily fluoride discharge in 1983 was 235 lbs, with an average monthly maximum of 635 lbs.

Probably as a consequence of reduced fluoride discharge by the aluminum plant, the 1983 fluoride concentrations in the John Day Dam region were significantly <u>less</u> than in 1982. The general fluoride levels in the forebay were 0.10-0.15 ppm, and even near the aluminum-plant outfall they did not exceed 0.17 ppm.

1984 and 1985 Fluoride Levels

The 1984 and 1985 studies involved monitoring fluorides at critical areas above and below John Day Dam from spring through fall. As in 1983, daily

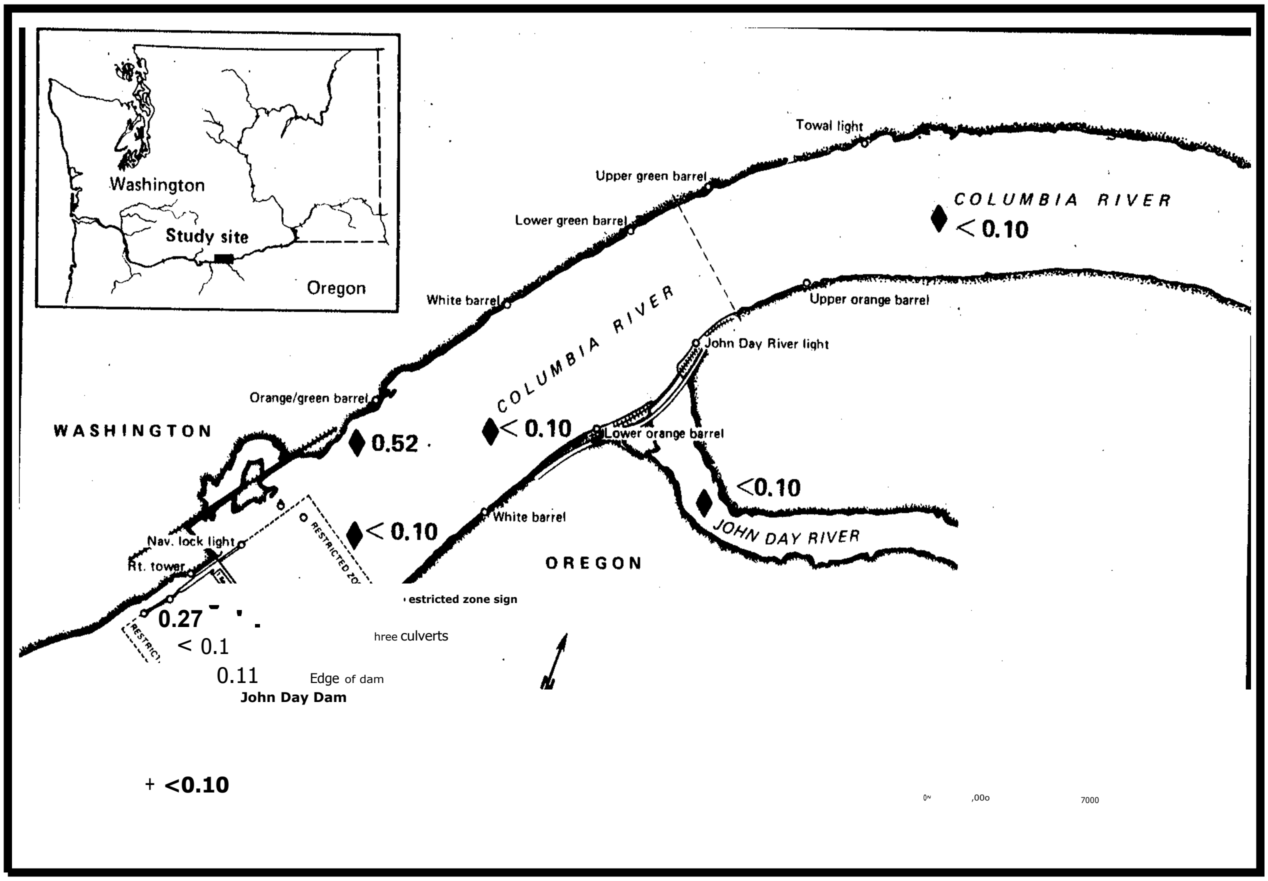

Figure 6.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 1-4 April 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

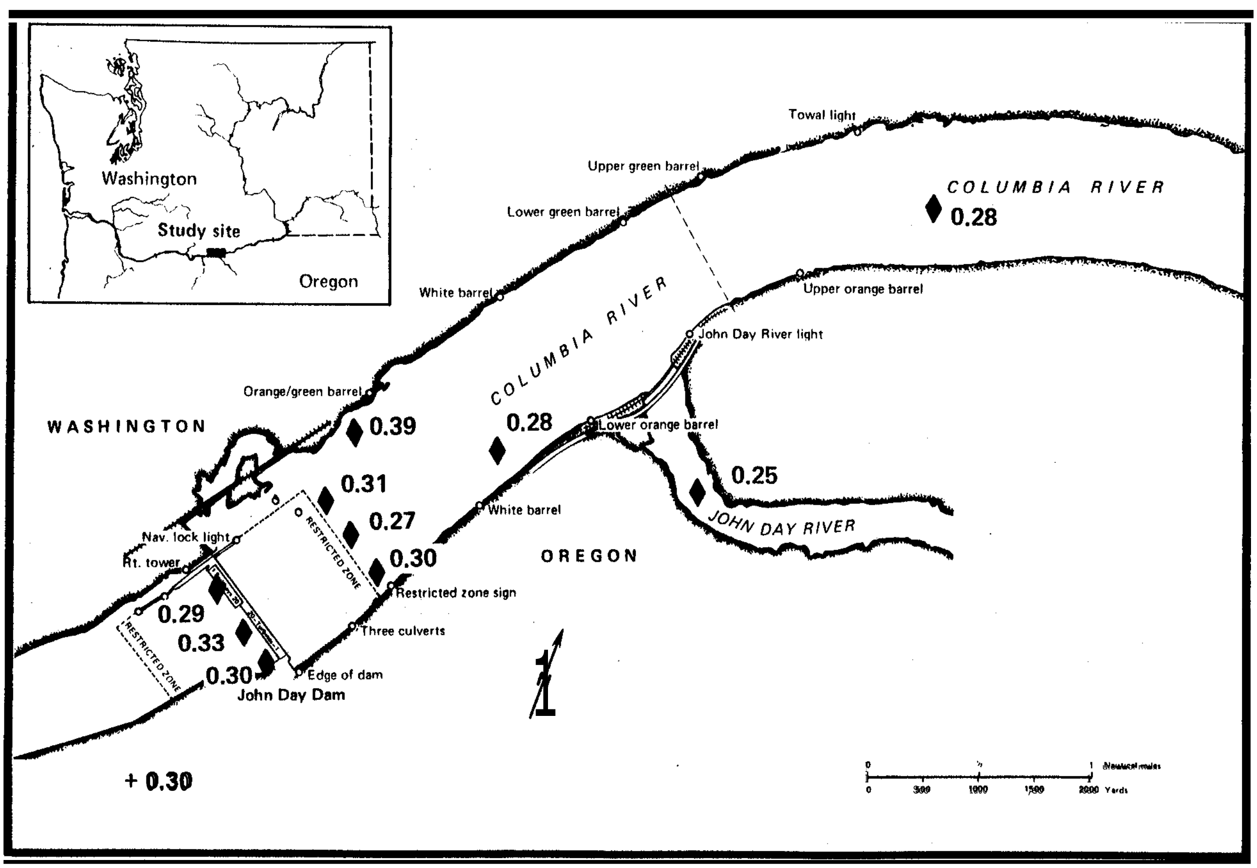

Figure 7.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 23-25 April 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

fluoride and turbidity measurements were taken in the adult fishways at John Day Dam (to mid-November).

The fluoride discharges from the aluminum plant at John Day Dam continued to be low during 1984 and were lower still in 1985. The average daily fluoride discharge was 282 lbs in 1984 and 109 lbs in 1985, with an average monthly maximum of 676 lbs in 1984 and only 185 lbs in 1985. The low fluoride discharges were reflected in the continued low fluoride concentration in the main Columbia River. The surface fluoride concentrations rarely approached 0.3 ppm, and were generally 0.1 to 0.2 ppm, even near the aluminum-plant outfall. The highest fluoride concentration in the fishways was about 0.3 ppm, but by far most observations there also indicated a range of 0.1 to 0.2 ppm fluoride. On nearly all days there was no significant difference in fluoride concentrations between fishways. Results of all fluoride analyses for 1982-1984 are reported in Damkaer (1983) and Damkaer and Dey (1984, 1985); and for 1985 in this report, Appendix Tables 2 and 3. It should be noted that the fluoride content of the two rivulets entering the large lagoon, on the north shore upstream from the dam, was extraordinarily high (up to 10 ppm). This appeared to be unreported, fugitive fluoride, leaking from the aluminum plant on the slope above. These concentrations are higher than generally noted in the outfall discharge settling ponds. While the total daily fluoride additions through these rivulets are estimated at only 10 lbs/day (ca. 5 to 10% of the routine plant discharges), this fluoride enters an area of low flushing and low dispersion. It is expected that the lagoon fluoride concentration, already nearly twice that of the main river, will continue to increase. An equilibrium will be reached that may lead to a significantly high fluoride concentration at the north fishway. This fugitive fluoride discharge, and presumably the associated organic compounds reported from 1982, may also have significant impacts on the COE public park at the lagoon, since one of the rivulets flows through this recreation area. In addition to the regularly monitored stations near John Day Dam, a number of samples were taken at various key locations adjacent to or within the facilities of the aluminum plant during Cruise I in 1985 (Appendix Table 2).

1986 Fluoride Levels

In March, the aluminum plant reported a problem with its pollutant-storage system which resulted in the discharge of up to thousands of pounds per day of fluoride into the Columbia River for an indefinite period. Because these discharges would apparently coincide with spring runs of adult salmonids, surface water samples were collected for fluoride analysis in the John Day Dam area in mid-April (Appendix Table 4). A fluoride concentration of 1.21 ppm for a sample taken from shore near the aluminum plant outfall (Station 10) was the highest we have recorded for Columbia River water. Fluoride in the outfall pond ("D" pond) was close to 8 ppm, the highest we have measured at this site. Finally, fluoride concentrations were all above 0.20 ppm along the Washington shore near the aluminum plant and John Day Dam. Thus, there were clear indications that the very recent, greatly increased fluoride discharge from the aluminum plant outfall had already begun to raise, at least temporarily, the fluoride concentration in the Columbia River near John Day Dam just as the early, upstream migrating spring chinook salmon and steelhead were moving into the area. It is not known how long this situation may persist or how often it may arise in the future.

Metals

The aluminum plant outfall may also be a source of free heavy metals which could influence the behavior of migrating salmonids. Of particular significance with respect to potential effects on fish behavior are copper, zinc, lead, and cadmium. The toxicity to fish of metals in general varies considerably depending on species, temperature, water hardness, pH, and other dissolved materials. If the metals are in a particulate phase (adsorbed to suspended matter, chelated by other compounds, or in insoluble compounds) the metals may not be toxic to fish. Initial observations in the John Day region indicated no spatial gradients with respect to the _total_ concentrations of these four metals. However, special analyses revealed gradients in the study area with respect to the _free_ (ionic) form of the metals (Table 2). It is the free form that is most likely toxic to fish. With the high suspended matter of the Columbia River, and especially of the John Day River, free metals probably have a short existence. This is reflected in the very high metal concentrations in the sediments (Table 2). Also, some metal salts, especially of zinc, lead, and cadmium, are insoluble in water, and some free metals are quickly precipitated by formation of these salts.

Literature pertaining to the _behavioral_ effects of these metal ions is sparse, although the _lethal_ properties are fairly well documented for fish in general. For free copper, ranges of 100-1,000 ppb are not toxic to most fishes (McKee and Wolf 1963). The USEPA (1980) criterion for protecting freshwater aquatic life is 5.6 ppb free copper over a 24-h average. Note that nearly three times this concentration was found in the John Day Dam fishways (Table 2). McKim and Benoit (1971) reported maximum acceptable copper concentrations for brook trout, _Salvelinus fontinalis,_ lie in the range of 9.5

Table 2.--Concentrations of total and free copper, zinc, lead, and cadmium in the John Day Dam region, Columbia River, 1982.

	Total metal (ppb)			Free metal (ppb)		
	River water	Lagoon water	Outfall & lagoon sediments	Outfall area	**North** fishway	South fishway
Copper	<50	<50	1000-2000	31	13.5	14.8
Zinc	20-30 (**John Day River** 10-17)	10	6000-8000	9	41.5	10.4
Lead	<10	<10	1000	8.8	2.0	2.1
Cadmium	<10	<0.5	100-200	1.3	0.7	1.4

to 17.4 ppb, while Drummond et al. (1973) found altered behavior in the same species with 6 to 15 ppb copper. Giattina et al. (1982) observed that rainbow trout avoided copper in excess of 6.4 ppb. Hara et al. (1976) noted depressions of olfactory responses in rainbow trout to occur above 8 ppb copper, and irreversible damage above 50 ppb. Folmar (1976) observed that trout avoid copper concentrations as low as 0.1 ppb. Even the hardy goldfish, *Carassius auratus,* avoids copper concentrations in excess of 5 ppb (Westlake et al. 1974). Sprague (1964) reported that Atlantic salmon, *Salmo salar,* avoided copper concentrations above 2 ppb. Sprague et al. (1965) observed that Atlantic salmon changed migration patterns in a river in response to 17 ppb copper (together with 210 ppb zinc). Mixtures above 38 ppb copper and 480 ppb zinc *prevented* upstream migration.

Lethal concentrations of zinc for trout are reported between 10 and 3,000 ppb under various experimental conditions (McKee and Wolf 1963), and between 130 and 150 ppb for chinook salmon fry (Hublou et al. 1954). These authors also report synergistic effects with zinc in the presence of other metals. Black and Birge (1980) reported that trout avoid concentrations of zinc in excess of 47 ppb. Note that this concentration was nearly reached in the John Day Dam fishways (Table 2).

There have also been wide lethal limits of lead reported for trout, 1,600 to 4,000 ppb (McKee and Wolf 1963), but narrower limits for coho salmon, 340 to 410 ppb (Gill et al. 1960). Apparently no behavior studies have been done for salmonids exposed to lead.

Lethal limits of cadmium for fish vary from 10 to 10,000 ppb (McKee and Wolf 1963). Black and Birge (1980) reported trout avoiding cadmium concentrations above 52 ppb.

The limited data available indicate that avoidance of some of these metals does occur under natural stream conditions, and that this behavior can be an important factor influencing the migration, distribution, and survival of salmonids.

Organic Chemical Analyses

In addition to the analysis of inorganic components, water and sediment samples collected above John Day Dam and at the downstream entrances to the fishways were analyzed for non-polar aromatic and chlorinated organic compounds (Table 3). None of these compounds was detected in the river-water samples. However, a water sample from the pre-outfall pond contained a number of the target aromatic hydrocarbons (Table 4) as well as many others not yet reported. Analyses of the sediment samples showed that, of the chlorinated hydrocarbons, only hexachlorobenzene and the DDT-related pesticides were present at measurable concentrations of up to 3.1 ppb (Table 5). The concentrations of aromatic hydrocarbons were higher in the sediment collected near the aluminum plant outfall and in the nearbly lagoon than from the upriver stations (Table 4). For example, the concentration of chrysene was as much as 260 times higher in sediment collected near the outfall than in sediment from upstream. These distributions implicate the aluminum plant as a source of aromatic hydrocarbons, and although these organic compounds were not detected in the river water, their concentrations in the sediments of this region are reason for concern. Some of these compounds, which may enter the aquatic food chain from interstitial water through benthic organisms, are potentially carcinogenic and also have the potential to accumulate in organisms, to be metabolically transformed and to be transferred through successive trophic levels.

Table 3.--Target organic compounds analyzed in water and sediment samples from the John Day Dam region, Columbia River. Detection limits for 800-ml water samples are noted in ppb after the compound.

Aromatic hydrocarbons (AHs):		Chlorinated pesticides:	
1. **Isopropylbenzene**	0.08	Hexachlorobenzene (HCB)	0.002
2. n-Propylbenzene	0.09	Lindane (1 - BHC)	0.002
3. Indan	0.09	Heptachlor	0.002
4. 1,2,3,4-Tetramethylbenzene	0.08	**Aldrin**	0.002
5. Naphthalene	0.07	o,2'-DDE	0.004
6. Benzothiophene	0.10	si..-Chlordane	0.002
7. 2-Methylnaphthalene	0.08	trans-Nonachlor	0.002
8. 1-Methylnaphthalene	0.07	P,g'-DDE	0.002
9. **Biphenyl**	0.08	o,g'-DDD	0.004
10. 2,6-Dimethylnaphthalene	0.08	m,p'-DDD	0.004
11. Acenaphthene	0.07	E,2'-DDD	0.003
12. 2,3,5-Trimethylnaphthalene	0.08	o,p'-DDT	0.003
13. Fluorene	0.08	R,p'-DDT	0.003
14. Dibenzothiophene	0.08		
15. Phenanthrene	0.07	Dichlorobiphenyls)	
16. Anthracene	0.07	Trichlorobiphenyls)	
17. 1-Methylphenanthrene	0.08	Tetrachlorobiphenyls)	
18. 3,6-Dimethylphenanthrene	0.21	**Pentachlorobiphenyls**)	PCBs 0.017
19. Fluoranthene	0.08	**Hexachlorobiphenyls**)	
20. Pyrene	0.10	**Heprachlorobiphenyls**)	
21. Benz[a]anthracene	0.08	Octachlorobiphenyls)	
22. Chrysene	0.10	**Nonachlorobiphenyls**)	
23. Benzo[e]pyrene	0.09		
24. **Benzo[a]pyrene**	0.08	Dichlorobutadienes	
25. Perylene	0.07	Trichlorobutadienes (3CBD))	
26. Dibenzanthracene	0.16	Tetrachlorobutadienes (TCBD))	CBDs .017
27. Benzofluoranthene		Pentachlorobutadienes (PCBD))	
		Hexachlorobutadienes (HCBD))	
		RonneL1/	
		Endosulfan1/	
		Heptachlorepoxide1/	
		Methoxychlor1/	
		2,4-D1/	
		2,4,5-TP1/	

1/ Only water samples were analyzed for these compounds.

Table 4.--Concentrations of aromatic compounds in sediment and water collected from the John Day Dam region, Columbia River.

		Sediment [illegible] dr wei•ht							
Compound	Settling pond water (ng/ml) 6/11/82	Station 2 4/24/82	Station 4 4/24/82	Station 10 4/24/82-1	Station 10 4/24/82-2	Station 10+ 6/11/82	Station 10 6/11/82	L1 6/11/82	L2 6/11/82
isopropylbenzene	(.08	<.83	<.83	<.83	<.83	<.5	3.0	13	<1.0
n-propylbenzene	<.09	<.92	<.92	<.92	<.92	<.5	1.5	<1.1	<1.0
indan	<.09	<.87	<.87	<.87	<.87	<.5	1.2	3.7	1.4
tetramethylbenzene	<.08	<.83	<.83	<.83	<.83	<.5	<.5	<1.0	<1.0
naphthalene	(.07	<.76	<.76	13	12	<.5	<.5	42	29
benzothiophene	<.10	<1.1	<1.1	<1.1	<1.1	4.0	10	3.4	4.7
2-methylnaphthalene	(.08	<.85	<.85	5.7	6.1	18	13	20	9.7
1-methylnaphthalene	<.07	<.40	<.70	2.9	3.2	6.6	11	19	33
biphenyl	<.08	<.80	<.80	<.80	<.80	<.5	<.5	.8	6.3
2,6-dimethylnaphthalene	<.08	<.82	(.82	<.82	<.82	<.5	0.8	2.9	<.7
acenaphthene	<.07	<.73	<.73	16	13	8.0	5.6	110	55
trimethylnaphthalene	<.08	<.72	3.4	<.72	<.72	<.5	4.4	<.7	<.7
fluorene	<.07	<.82	<.82	23	20	13	8.2	78	44
dibenzothiophene	<.08	<.80	<.80	10	10	1.1	<.5	39	22
phenanthrene	<12	16	14	230	230	100	66	830	460
anthracene	<.07	C.85	C.85	140	140	37	16	200	88
1-methylphenanthrene	0.64	<.5	<.84	30	30	27	22	59	43
3,6-dimethylphenanthrene	0.25	<2.3	<2.3	25	25	11	11	53	26
fluoranthene	0.69	49	13	1100	1200	340	140	2000	1400
pyrene	0.51	49	14	1100	1200	360	150	2300	1500
benz[ajanthracene	0.52	20	4.3	1500	2000	280	100	1200	720
chryeene	1.5	39	12	4000	5800	780	310	2100	1500
benzo[ejpyrene	0.93	23	6.9	1800	2400	330	180	1300	770
benzo[ajpyrene	0.37	19	4.7	1700	2100	270	150	1200	720
perylene	<0.07	28	13	400	460	83	78	320	180
dibenzanthracene	0.10	7.4	<1.9	630	700	140	94	430	280

Table 5.-Concentrations of chlorinated compounds in sediment collected from the John Day Dam region, Columbia River.

Compound		Station 2 4 24/82	Station 4 4/24/82	Station 10 4/24/82-1	Station 10 4/24/82-2	Station 10 6/:1/82	L1 6/11/82	L2 6/11/82	Station 10+ 6/11/82
		(ng/g, dry weight)							
hexaehlorobenzene (HCB)		.48	.64	.28	.77	1.6	.64	.40	**.69**
Lindane (Y-BHC)		<.08	<.08	<.08	<.08	<.08	<.08	<.08	<.08
Heptachlor		<.04	(.04	<.04	<.04	<.04	<.04	<.04	<.04
Aldrin		<.03	<.03	<.03	<.03	<.03	<.03	<.03	<.04
'1-Chlordane		<.09	<.09	<.09	<.09	<.09	<.09	<.09	<.09
trans-Nonachlor		<.05	(.05	<.05	<.05	<.05	(.05	<.05	<.05
2,g'-DDE	DDTs	<.13	<.13	<.13	<.13	<.13	<.13	<.13	<.13
2,E'-DDE	DDTs	**2.4**	.76	**2.4**	2.3	3.1	1.9	1.4	1.9
2,E'-DDD	DDTs	.28	.16	.29	.22				
2,g'-DDD	DDTs	<.21	C.21	<.21	<.21	<.21	<.21	(.21	<.21
2,g'-DDD	DDTs	1.3	.28	1.6	1.3	1.5	1.2	.83	1.1
2,E'-DDT	DDTs	.17	.09	.11	.10				
2,g'-DDT	DDTs	.70	.41	.78	.70	1.7	1.2	1.4	.44
dichlorobiphenyls	PCBs	<.67	<.67	<.67	<.67	<.67	(.67	C.67	<.67
trichlorobiphenyls	PCBs	<.17	<.17	<.17	<.17	<.17	<.17	<.17	<.17
tetrachlorobiphenyis	PCBs	<.09	C.09	(.09	<.09	<.09	<.09	<.09	<.09
'entachlorobiphenyis	PCBs	<.10	<.10	<.10	<.10	(.10	<.10	<.10	<.10
'iexachlorobiphenyls	PCBs	(.26	<.26	<.26	<.26	<.26	<.26	<.26	<.26
heptachlorobiphenyis	PCBs	(.09	(.09	<.09	<.09	<.09	<.09	<.09	<.09
Ictachlorobiphenyis	PCBs	<.06	<.06	(.06	<.06	<.06	<.06	(.06	<.06
nonachlorobiphenyls	PCBs								
dichlorobutadienes		<.67	<.67	<.67	<.67	<.67	<.67	<.67	(.67
trichlorobutadienes	(3CBD)	(.17	<.17	<.17	C.17	<.17	<.17	<.17	(.17
tetrachlorobutadienes	(TCBD)	(.09	<.09	<.09	(.09	<.09	<.09	(.09	<.09
;entachlorobutadienes	(PCBD)	<.10	<.10	<.10	<.10	<.10	<.10	<.1U	<.10
hexachlorobutadienes	(HCBD)	<.26	C.26	<.26	<.26	<.26	<.26	<.26	(.26

Behavior Experiments

Because most of the experimentation was conducted under semi-natural conditions in the field, the intractability and general environmental risks of working with the necessary concentrations of heavy metals and aromatic hydrocarbons, as well as the steep analytical costs, precluded their use to any great extent. Attention was instead focused on the behavioral effects of fluoride.

Fluorides are known to be toxic to trout and other fish. The median toxic limits (concentration required to kill 50% of the test fish) in trout have been reported between 2.3 and 7.5 ppm fluoride (Neubold and Sigler 1960; Angelovic et al. 1961), or only about an order of magnitude higher than found in the study area in 1982. Apparently, there is very little information regarding the effect of fluorides on fish behavior. However, fluorides are known to be enzyme inhibitors and would, therefore, have the potential to reduce activity at sublethal concentrations.

Bioassay experiments conducted in fall 1983 at Big Beef Creek indicated that adult salmon react rather quickly to fluoride concentrations of around 0.5 ppm. To demonstrate that observations reflect behavior due to fluoride alone, test fish were allowed to react to the two-choice flume without fluoride in either carboy's effluent. In over 40 tests each with chinook and coho salmon and over 30 tests with chum salmon there was no significant channel preference (Appendix Tables 5-7). Only one of these test fish failed to move upstream out of the holding area, although at the end of the test this fish was still active.

In over 100 tests with returning male chinook salmon with fluoride entering one channel or the other, about half of the fish failed to make a choice. Their behavior was subdued, and very different from that of fish not exposed to fluoride. Of the chinook salmon moving upstream into one arm or the other, nearly 75% chose the non-fluoride side (Appendix Table 5).

In 97 fluoride tests with returning adult coho salmon, 64% moved upstream; of those, 66% chose the non-fluoride side. The experimental coho salmon generally appeared to be in better physical condition and were more active and decisive than the earlier-returning chinook salmon. However, while coho salmon seemed less subdued by the presence of fluoride in the water, they chose to avoid fluoride at nearly the same frequency as did the chinook salmon (Appendix Table 6).

During December 1983, 77 fluoride tests were conducted with returning adult chum salmon. Of the 78% entering the two-choice flume, nearly 60% chose the non-fluoride side. The results with chum salmon did not indicate as strong an avoidance response as with chinook or coho salmon, but the variability of experimental conditions in December, in particular the large fluctuations in water temperature and the periods of extremely cold water (1°C), may have had some influence on the sensitivity of chum salmon (Appendix Table 7).

Bioassay tests on juvenile salmonids have shown there is no preference for either end of the test apparatus when no pollutant is present. Strong statistically significant avoidance (chi-square test) was observed when 1.0 ppm fluoride was introduced to one end of the test chamber. A lesser avoidance, but still significant, was recorded with 0.5 ppm fluoride stress. Though there was a tendency for the juveniles to avoid 0.3 ppm fluoride, enough tests were not completed to determine statistical significance. However, the juveniles' general behavior (other than choice, no-choice) suggests a clear response even to this lowest test level of fluoride.

With dillution indexed to give 0.5 ppm fluoride, the juveniles avoided the aluminum-plant industrial effluent in every case.

The swimming-performance tests suggested that increasing, but low, fluoride concentrations will decrease the stamina of juvenile salmonids. There were also significant alterations in levels of blood-T_4 in smolting juveniles kept in fluoride concentrations of 0, 0.3, 0.5, and 1.0 ppm. With the juvenile rainbow/steelhead trout hybrids, there was an elevation of plasma T_4 at 0.3 and 0.5 ppm fluoride but not at 1.0 ppm. However, while T_4 has been implicated in migratory behavior of juvenile salmonids (Godin et al. 1974), its influence has not been established on the migratory behavior of adults.

In fall 1984, bioassay experiments were again conducted at Big Beef Creek but with the fluoride concentration reduced to about 0.2 ppm or approximately the fluoride level observed in the Columbia River at John Day Dam during 1983 and 1984. As in 1983, tests <u>without</u> fluoride in either side of the flume indicated no preference for one side or the other among either the returning chinook or coho salmon. These data from 1984 were therefore combined with the no-fluoride data for each species from 1983 (Appendix Tables 8 and 9).

The observations on returning chinook salmon faced with a 0.2 ppm fluoride level suggested that a significant number (54%) delayed even at that low concentration (Appendix Table 8). It is possible that a number of chinook salmon were sensitive to 0.2 ppm fluoride, but this observation might also have resulted from the shorter observation times for each fish in 1984 (20 min vs about 1 h). Of the chinook salmon which continued upstream within the 20 min (46%), there was no statistically significant difference between their choices of the fluoride and non-fluoride arms of the flume. It is believed, therefore, that 0.2 ppm fluoride is at or below the threshold level for fluoride sensitivity in returning chinook salmon at Big Beef Creek.

The observations on returning coho salmon faced with an approximately 0.2 ppm fluoride concentration suggested that they reacted as they would have been expected to if there had been no fluoride at all (Appendix Table 9). Therefore, it is believed that 0.2 ppm fluoride is below the threshold concentration for fluoride sensitivity in returning coho salmon at Big Beef Creek.

DISCUSSION

The greatly reduced fluoride discharges from the aluminum plant near John Day Dam beginning in 1983 and continuing through 1985 have provided a remarkable opportunity to test the hypothesis that industrial fluorides (on the order of 0.3 to 0.5 ppm) may be implicated in passage delay of adult salmonids. The 1982 fluoride concentrations of 0.3 to 0.5 ppm at the dam were probably representative of fluoride levels of at least the previous several years, judging from the reported discharges from the aluminum plant. Fluoride concentrations in this range were observed as far back as 1971 by the aluminum plant and in 1971 and 1972 by the National Marine Fisheries Service. Unfortunately, while radio-tagging and tracking studies from 1980 to 1982 determined that fish-passage times were unacceptably high at John Day Dam, there were no studies on salmonid delays at John Day Dam conducted in 1983. However, fish counts at the dams revealed that from 1980 to 1982 there was an average "unaccountable loss" of 55% of the upriver-bright fall chinook salmon passing Bonneville Dam and expected to reach McNary Dam (DeVore3/). In 1983, coincident with the fluoride discharge reduction, this loss was only

3/ J. DeVore, Washington Department of Fisheries, P.O. Box 999, Battleground, WA 98604; pers. commun.

11%, the lowest since 1972. In addition, substantially fewer salmonid carcasses were observed below John Day Dam in 1983 than in 1982.

In 1984 the proportion of salmon reaching McNary Dam was comparable to the high value of 1983. Moreover, radio-tracking was resumed at John Day Dam, and the median passage time for spring chinook salmon was slighty less than 2 days (Shew et al. in prep). In 1985, median passage time for spring chinook salmon at John Day Dam was 28 hours (Peters et al. 1985).

There is no doubt that on the average, returning salmonids "prefer" the south fishway at John Day Dam. The north/south fishway preference pattern at John Day Dam remained generally stable from 1982 to 1985. In each of these years, an early short-term fluctuation in preference between the two fishways became a strong and steady preference for the south fishway in spring, and continued in this fashion through summer and early fall when again the fishway preference began to fluctuate (Fig. 3). The daily pattern of fishway preference does not appear to be related either to total Columbia River flow, to total spill at John Day Dam, or to the spill-to-flow ratio. Also, daily fluoride and turbidity measurements in the fishways do not indicate a relationship with passage preference nor does water temperature in the fishways. Of course, whether or not the various factors monitored at the dam are among those determining the salmonids choice of fishway, it is the passage delay and not the <u>choice</u> of fishway that has been the problem at John Day Dam.

There is evidence, both empirical and theoretical, that fluoride from the aluminum plant at John Day Dam has a very significant impact on adult salmon passage time and survival at the dam. In 1982, fluoride concentrations at the dam were in the range of 0.3 to 0.5 ppm, and fish-passage times and interdam losses were unacceptably high. Bioassay experiments, on the behavior of returning salmon, suggest that fluoride concentration ca. 0.5 ppm adversely affect the migration of adult salmon and that 0.2 ppm fluoride is near the threshold for fluoride sensitivity in chinook and coho salmon. Subsequent to the reduction in the aluminum plant fluoride discharge in 1983, fluoride concentrations in the main river have been reduced nearly 50%, fish-passage times at John Day Dam have been lowered to parity with times at near-by dams, and interdam losses are lower than they have been in over a decade.

There are indications, however, that the present fluoride situation at John Day Dam could be only temporary. First of all, the low discharges of fluoride over the last 3 years are the result of precipitation and storage of fluoride in adjacent land-fills. However, the spring 1986 breakdown of the pollutant-storage system and the subsequent large increases in fluoride discharged to the river suggests that this is not a permanent solution. Also, the continuing extraordinarily high fluoride concentrations in the free rivulets flowing from the aluminum plant will likely raise fluoride levels in the large lagoon near the north fishway, and ultimately the fluoride concentrations at the fishway could reach previous high levels. There is hope this situation can be avoided, however, as the DOE has recently reviewed the aluminum plant's wastewater discharge permit. Several items in the new permit reflect the active interest DOE has shown in the results of our water-quality and sediment investigations near the plant and the related salmonid behavioral studies: (1) effluent limitations for the discharge of fluoride into the river are one-third the previously allowed limits; (2) all surface and groundwater sources near the plant must be identified and the water analyzed and treated if necessary; (3) sediments in the lagoon system, in the vicinity of the outfall, and in the pool upstream from John Day Dam must be analyzed for heavy metals and toxic organic pollutants; and (4) a study must be conducted to determine the feasibility of installing a totally enclosed system for the discharge of wastewater. There is every reason to believe that the aluminum plant will be able to comply with the new regulations without undue hardship.

In fall and winter 1985, the aluminum plant conducted the first required surveys of water and sediment near their facilities (J-U-B Engineers, Inc. 1986a, 1986b). In general, concentrations of fluoride, metals, and organic compounds were within or below the range of concentrations reported during our study. However, there are differences in interpretation of the effects of the aluminum plant activity on the river. In the aluminum-plant study, frequent reference is made to finding no significant differences between stations sampled near the plant outfall and the "upstream, background Station 7NMFS" (i.e., our Station 7). Because of the pool-like reservoir conditions above John Day Dam, aided by frequent, strong westerly winds (particularly during periods of low river flow or when very little water is spilled at the dam), the proximity of Station 7 to the outfall makes it unsuitable as a background reference point. A Columbia River background station for this area should be located well upstream from the confluence with the John Day River (See Fig. 1).

In view of the apparent critical role of fluoride in salmonid passage and survival, it would be appropriate and fruitful to expand the recent studies and prepare a <u>fluoride budget</u> for the entire Columbia River system. There are natural sources of fluoride, but the "natural" fluoride level cannot be determined without extensive sampling. It is obvious that the natural fluoride regime is overwhelmed by the industrial sources, of which there are several, generally in conjunction with hydroelectric projects. The possibilities, then, that fluoride interacts at other fishways are great, although it may prove to be that it is <u>relative</u> position of discharge and fishway that is most important. For example, at John Day Dam, the aluminum plant discharge is just upstream from the fishways. For the aluminum plant at The Dalles Dam, the discharge is downstream from the fishways, and the returning salmonids need contend with only one obstacle at a time. There is another aluminum plant in conjuction with a dam at Wenatchee, Washington, and there are aluminum plants alone at Spokane, Vancouver, and Longview, Washington, and Troutdale, Oregon. It is not known what the relative impacts of these sources are on the fluoride concentration of the Columbia River, nor what might be the impact on the salmonids.

The motivation for these investigations is the protection of the salmonid resource. However there is another aspect that has never been explored nor even raised. That is, it is likely, with an understanding of the sources, fate, and effects of fluoride in the Columbia River, that discharge standards could be flexible and related to seasonal fish migrations. It is possible, for example, that high discharge only in winter may have no effect on fish passage, but might ensure low fluoride levels during critical migrations. The information from this investigation could optimize relationships between point-source pollution-discharges and dams, and contribute considerably to planned construction of new industrial/hydroelectric complexes.

One must note that while direct fluoride discharges have in general decreased markedly near John Day Dam, the possible heavy-metal activations and hydrocarbon accumulations remain a concern. For example, the aromatic hydrocarbon content of sediments near John Day Dam (average 8,300 ppb) approaches that found in the Duwamish Waterway (Seattle, Washington) (range 4,100-22,000 ppb) and the Hylebos Waterway (Tacoma, Washington) (range 5,000-39,000), which are classed among the most-polluted areas in the U.S. (Table 6). There is no information yet on the role these organic compounds

Table 6.--The <u>sums</u> of concentrations of selected 1- through 5-ring aromatic compounds in sediment samples from Columbia River and Puget Sound (ng/g dry weight).

	Columbia R. stations			Puget Sound sites		
	2	4		Duwamish Waterway	Hylebos Waterway'	Port Madison
<u>Sums</u> of concentrations of selected 1-5 ring aromatic compounds listed in Table 3.	250	86	8,300 [range 1,300- 16,000]	11,000 [range 4,100- 22,000]	18,000 [range 5,000 39,000]	480 [range 200- 640]
<u>Sums</u> of concentrations of 3-, 4-, and 5-ring compounds listed in Table 3.	240	82	8,000 [range 2,600- 16,000]	10,000 [range 3,700- 20,000]	13,000 [range 3,800- 33,000]	340 [range 160- 510]

a/ Average for four samples (Damkaer 1983).

b/ Duwamish Waterway, Seattle, WA, average for four samples (Malin et al. 1980, 1982).

c/ Hylebos Waterway, Tacoma, WA, average for six samples (Malins et al. 1980, 1982).

d/ Port Madison, Puget Sound, WA, average for two samples (Malin et al. 1980, 1982).

might have in fish passage, but the existence of the compounds in the area, and their association with the aluminum-production process, is documented. What fraction of salmonid passage-delay, if any, is due to hydrocarbons and/or heavy metals has yet to be determined. Future work, therefore, should continue to have both pollutant-monitoring and bioassay/behavior components aimed at the specific problem of Columbia River adult salmonid passage-delay.

SUMMARY AND CONCLUSIONS

1. There is evidence, both empirical and theoretical, that fluoride from the aluminum plant at John Day Dam has a very significant impact on adult salmon passage time and survival over the dam. The 1982 floride concentrations of 0.3 to 0.5 ppm at the dam were probably representative of fluoride levels of the previous several years. During those years, the fish-passage times and interdam losses were unacceptably high. Bioassay experiments, on the behavior of returning salmon, suggested that fluoride concentrations ca. 0.5 ppm would adversely affect the migration of adult salmon. Subsequent bioassay experiments indicated that 0.2 ppm fluoride was at or below the threshold for fluoride sensitivity in chinook salmon and below the threshold for fluoride sensitivity in coho salmon. In 1983, the aluminum plant fluoride discharge was significantly reduced, and the fluoride concentrations in the main river were nearly half of those in 1982. Although no passage times were measured at John Day Dam in 1983, the interdam loss was the lowest since 1972. Low fluoride concentrations in the main river continued through 1985. Median passage times near 2 days and 1 day were observed for spring chinook salmon in 1984 and 1985, and the proportion of salmon reaching McNary Dam in each of these years was comparable to the high value of 1983.

2. There are indications, however, that the present fluoride situation at Jonn Day Dam is only temporary. The low discharges of fluoride over the last 3 years are the result of precipitation and storage of fluoride in adjacent land fills. However, because the pollutant-storage system is subject to periodic failure and because of the continued presence of high-fluoride rivulets flowing from the aluminum plant, fluoride concentrations in the large lagoon, the river, and the fishways could reach previous high levels for indefinite periods.

3. In view of the apparent critical role of fluoride in salmonid passage and survival, it would be fruitful to expand the recent studies and prepare a fluoride budget for the entire Columbia River system. There are natural sources of fluoride, but the "natural" fluoride level cannot be determined without extensive sampling. It is not known what the relative impacts of other aluminum plants in Washington and Oregon are on the fluoride concentrations of the Columbia River, nor what might be the impact on the salmonids.

4. Besides fluoride there are low and apparently increasing levels of some organic compounds (chlorinated and aromatic hydrocarbons) in the water and sediments around John Day Dam. The aromatic hydrocarbon content of the sediments approaches that found in some of the most polluted areas in the U.S. The existence of the compounds in the area, and their association with the aluminum-production process has been established.

5. The greatly reduced fluoride discharges near John Day Dam have provided a remarkable opportunity to test the early hypothesis that industrial fluorides (on the order of 0.3 ppm) may be implicated in the passage delay of adult salmonids. Field observations of passage times in 1984 and 1985, coupled with surveys of the continuing lower-level fluoride, have given the

best evaluation of this research to date. One must note that while direct fluoride discharges have decreased markedly near John Day Dam, the possible heavy-metal activations and hydrocarbon accumulations may be unchanged. What fraction of salmonid passage-delay, if any, is due to heavy metals and hydrocarbons has yet to be determined. Future work, therefore, should continue to have both pollutant-monitoring and bioassay/behavior components aimed at the specific problem of Columbia River adult salmonid passage-delay.

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APPENDIX

Tables 1—9

Appendix Table 1.--Physical characteristics of river water and other aquatic sites in the John Day Dam region, Columbia River, April-September 1985 (see Figure 1 for station locations). During Cruise I, in March, only fluoride samples were collected (see Appendix Table 2).

1985 Cruise II
April 15-17
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
1	15 Apr	1710	35.0	0	10.30	8.0	0.21	8.2	9.0
				5	9.82	7.9	0.21	8.4	-
				10	9.81	7.9	0.21	8.5	-
				15	9.79	7.9	0.21	8.7	10.0
				20	9.81	7.9	0.21	8.8	-
				25	9.86	7.9	0.21	8.9	-
				30	10.01	8.0	0.21	9.3	10.0
2	15 Apr	1640	35.0	0	10.47	8.0	0.21	8.7	10.0
				5	10.10	7.9	0.21	8.8	-
				10	10.00	7.9	0.21	8.9	-
				15	9.72	7.9	0.21	9.1	9.0
				20	9.73	7.9	0.21	9.2	-
				25	9.74	8.0	0.21	9.3	-
				29	9.80	8.0	0.20	9.6	10.0
3	15 Apr	1740	35.0	0	11.43	8.1	0.21	8.2	8.0
				5	9.69	8.1	0.21	8.8	-
				10	9.60	8.1	0.21	8.9	-
				15	9.59	8.1	0.21	9.1	10.0
				20	9.58	8.1	0.21	9.3	-
				25	9.58	8.1	0.21	9.5	-
				30	9.79	8.0	0.21	9.6	10.0
	16 Apr	0950	22.0	0	13.23	7.7	0.11	8.9	44.0
				5	13.05	7.8	0.11	9.0	-
				10	12.89	7.9	0.11	9.1	44.0
				15	10.44	7.8	0.19	10.0	-
				20	10.34	7.8	0.19	10.1	21.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
6	16 Apr	1010	25.0	0	13.34	7.8	0.11	8.8	45.0
				5	13.25	7.7	0.11	8.9	-
				10	13.23	7.8	0.11	9.1	48.0
				15	13.16	7.8	0.11	9.2	-
				20	9.67	7.9	0.12	10.4	49.0
	16 Apr	0900	35.0	0	10.86	7.7	0.18	11.0	23.0
				5	10.66	7.7	0.18	11.4	-
				10	10.30	7.8	0.20	11.8	-
				15	10.06	7.8	0.21	12.1	11.0
				20	**9.99**	7.8	0.21	12.4	-
				22	9.94	7.8	0.21	12.6	-
				30	-	-	-	-	10.0
8	16 Apr	0930	35.0	0	10.73	7.8	0.18	10.2	23.0
				5	10.73	7.8	0.18	10.4	-
				10	10.64	7.8	0.19	10.5	-
				15	10.52	7.8	0.19	10.8	19.0
				20	10.38	7.8	0.19	11.1	-
				27	10.31	7.9	0.18	11.3	11.0
9	16 Apr	1050	35.0	0	-	-	-	-	29.0
10	15 Apr	1615	35.0	0	10.60	8.0	0.19	9.2	20.0
				5	9.71	8.0	0.21	9.4	-
				10	9.67	8.0	0.21	9.5	-
				15	9.67	8.0	0.21	9.6	9.0
				20	9.68	8.1	0.21	9.7	-
				25	9.70	8.1	0.21	**9.9**	-
				29	9.75	8.1	0.21	10.1	9.0

1985 Cruise II (cont.)

Station		Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
11		16 Apr	1205	35.0	0					15.0
12		16 **Apr**	1210	35.0	0					15.0
13		16 Apr	1216	35.0	0					17.0
14	John Day Dam N. Fishway	16 Apr	1305	-	0					11.0
16	John Day Dam S. Fishway	16 Apr	1315	-	0					16.0
17	The Dalles Dam N. Fishway	15 Apr	1320	-	0					12.0
19	The Dalles Dam S. Fishway	15 **Apr**	1340	-	0					12.0
	Bonneville Dam	15 Apr								
	N. Fish trap		1158	-	0					11.0
	S-end new powerhouse		1155	-	0					11.0
	S-end spillway		1145	-	0					11.0
	S-end old powerhouse		1140	-	0					12.0

1985 Cruise II (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mhos)	Dissolved oxygen (ppm)	**Turbidity (NTU)**
Additional Stations									
1. **W. rivulet (L-2)**	16 Apr	1145	<1.0	0					2.0
2. E. rivulet (L-1/L-2)	16 Apr	1155	<1.0	0					3.0
3. W. lagoon (L-2)	16 Apr	1130	10.0	0	10.18	8.3	0.20	9.8	6.0
				5	10.07	8.3	0.20	**9.9**	
				9	8.23	8.2	0.20	10.6	4.0
4. E. lagoon (L-1)	16 Apr	1105	12.0	0	11.57	8.6	0.20	11.0	8.0
				5	11.43	8.5	0.20	11.3	
				10	9.42	8.2	0.20	-	4.0
5. Outfall pond (D)	15 Apr	1930		0	-	-		-	6.0
6. N-shore, J.D. Dam, nav-lock	16 Apr	1245	-	0					11.0
7. N-shore, below J.D. Dam, at tower	16 Apr	1250		0	-	-	-	-	11.0
8. S-shore, below J.D. Dam, opposite nav-lock	16 Apr	1320		0	-	-	-	-	14.0
9. S-shore, below J.D. Dam, opposite tower	16 Apr	1325		0	-	-	-	-	13.0
10. Creek near Bonneville Dam, OR side	15 Apr	1220		0	-	-	-	-	1.0

1985 Cruise III
May 15-16
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (Mm)
1	15 May	1800	35.0	0	12.56	8.4	0.15	10.0	4.0
				5	12.42	8.5	0.15	10.2	-
				10	12.32	8.5	0.15	10.5	-
				15	12.13	8.6	0.15	10.7	5.0
				20	12.07	8.6	0.15	11.0	-
				25	11.91	8.6	0.15	11.3	-
				30	11.98	8.6	0.15	11.7	6.0
2	15 May	1813	35.0	0	11.96	8.2	0.15	10.1	4.5
				5	11.81	8.3	0.15	10.5	-
				10	11.67	8.3	0.15	10.9	-
				15	11.68	8.4	0.15	10.6	8.0
				20	11.72	8.4	0.15	11.1	-
				25	11.75	8.5	0.15	11.6	-
				30	11.89	8.6	0.15	11.6	5.0
3	15 May	1830	35.0	0	11.76	8.3	0.15	10.6	5.0
				5	11.68	8.3	0.15	10.6	-
				10	11.65	8.3	0.15	10.7	-
				15	11.67	8.3	0.15	10.7	6.0
				20	11.63	8.3	0.15	10.7	-
				25	11.68	8.4	0.15	10.9	-
				30	11.73	8.4	0.15	10.9	7.0
4	15 May	1910	25.0	0	14.95	8.1	0.14	10.3	9.0
				5	14.35	8.2	0.14	10.4	-
				10	12.61	8.3	0.14	10.8	5.0
				15	11.91	8.4	0.15	11.3	-
				20	11.94	8.4	0.15	11.3	7.0

1985 Cruise III (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	**Turbidity** (NTU)
6	15 May	1852	25.0	0	15.52	8.1	0.14	10.5	8.0
				5	14.83	8.1	0.14	11.1	-
				10	12.92	8.2	0.14	11.3	10.0
				15	11.89	8.3	0.15	11.4	-
				20	11.96	8.3	0.15	11.9	11.0
7	15 May	2000	35.0	0	12.59	8.2	0.15	**9.9**	7.0
				5	12.15	8.2	0.15	10.0	-
				10	11.84	8.3	0.15	10.2	-
				15	11.73	8.3	0.15	10.7	6.0
				20	11.73	8.3	0.15	10.9	-
				25	11.78	8.4	0.15	11.0	-
				30	11.90	8.5	0.15	11.2	6.0
8	15 May	1942	35.0	0	12.69	8.2	0.14	10.6	6.0
				5	12.08	8.2	0.15	10.8	-
				10	11.68	8.3	0.15	10.9	
				15	11.64	8.3	0.15	11.1	6.0
				20	11.65	8.3	0.15	11.2	-
				25	11.70	8.4	0.15	11.3	-
				30	11.80	8.5	0.15	11.3	6.0
9	15 May	1926	35.0	0	13.16	8.1	0.14	**9.6**	6.0
				5	11.85	8.2	0.15	10.4	-
				10	11.61	8.2	0.15	10.8	-
				15	11.59	8.3	0.15	11.2	6.0
				20	11.61	8.3	0.15	11.0	-
				25	11.68	8.3	0.15	11.8	-
				30	11.76	8.3	0.15	11.8	8.0

1985 Cruise III (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
10	15 May	1453	35.0	0	13.18	8.3	0.14	10.0	6.0
				5	12.79	8.4	0.14	10.2	-
				10	11.84	8.3	0.14	10.3	-
				15	11.64	8.4	0.14	10.5	6.0
				20	11.70	8.4	0.14	10.6	-
				25	11.69	8.4	0.14	10.7	-
				30	11.65	8.3	0.15	10.9	6.0
11	15 May	1618	35.0	0	13.17	8.1	0.14	10.3	5.0
				5	12.85	8.2	0.15	10.8	-
				10	12.61	8.2	0.15	10.5	-
				15	12.41	8.2	0.15	11.0	5.0
				20	12.38	8.3	0.15	11.2	-
				25	12.40	8.2	0.15	11.6	-
				30	12.06	8.2	0.15	11.2	7.0
12	15 May	1558	35.0	0	12.23	8.2	0.15	10.8	5.0
				5	12.14	8.3	0.14	10.9	-
				10	11.95	8.3	0.15	11.2	-
				15	11.67	8.3	0.15	11.2	5.0
				20	11.65	8.5	0.15	11.3	-
				25	11.65	8.5	0.15	11.8	-
				30	11.76	8.5	0.15	11.5	7.0
13	15 May	1530	35.0	0	12.15	8.1	0.15	10.7	5.0
				5	11.51	8.1	0.15	10.9	-
				10	11.49	8.1	0.15	10.9	-
				15	11.50	8.3	0.15	11.3	6.0
				20	11.51	8.3	0.15	11.5	-
				25	11.50	8.3	0.15	11.8	-
				30	11.63	8.4	0.15	11.7	7.0

1985 Cruise III (cont.)

Station		Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NT[3)
14	John Day Dam									
	N. Fishway	16 May	0840							5.0
16	John Day Dam									
	S. Fishway	16 May	0855		0					5.0
17	The Dalles Dam									
	N. Fishway	15 May	1235	-	0					4.0
19	The Dalles Dam									
	S. Fishway	15 May	1255		0					4.0
	Bonneville Dam	15 May								
	N. Fish trap		1110	-	0					4.0
	S-end new powerhouse		1105	-	0					4.0
	S-end spillway		1055	-	0					5.0
	S-end old powerhouse		1045	-	0					5.0
Additional Stations										
1.	**W. rivulet (L-2)**	15 May	1705	-	0	-	-	-	-	1.0
2.	E. rivulet (L-1/L-2)	15 May	1730	-	0	-	-	-	-	1.0
3.	W. lagoon (L-2)	15 May	1651	15.0	0	14.38	8.5	0.17	10.4	3.0
					5	12.70	8.4	0.17	10.5	-
					10	11.71	8.4	0.18	10.8	-
					14	11.70	8.5	0.18	10.7	4.0

1985 Cruise III (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
4. E. lagoon (L-1)	15 May	1642	12.0	0	12.06	8.6	0.17	10.4	4.0
				5	11.85	8.5	0.18	10.7	-
				10	11.93	8.6	0.18	10.5	5.0
5. Outfall pond (D)	15 May	2100		0	-	-	-	-	2.0
6. N-shore, J.D. Dam, nav-lock	16 May	0810		0	-	-	-	-	5.0
7. N-shore, below J.D. Dam, at tower	16 May	0820		0	-	-	-	-	4.0
8. S-shore, below J.D. Dam, opposite nav-lock	16 May	0900		0					5.0
9. S-shore, below J.D. Dam, opposite tower	16 May	0910	-	0					5.0

1985 Cruise IV
June 18-19
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
1	18 Jun	1600	35.0	0	19.64	7.5	0.12	11.3	1.0
				5	17.52	7.7	0.12	10.7	-
				10	17.47	7.7	0.12	10.8	-
				15	17.41	7.8	0.12	10.7	3.0
				20	17.31	7.8	0.12	10.7	-
				25	17.14	7.9	0.12	10.7	-
				30	16.98	7.9	0.12	10.8	3.0
2	18 Jun	1632	35.0	0	19.17	7.8	0.12	9.7	3.0
				5	17.31	7.9	0.12	9.9	-
				10	17.24	8.0	0.12	10.2	-
				15	17.18	8.1	0.12	10.5	4.0
				20	17.10	8.1	0.12	10.5	
				25	17.10	8.1	0.12	10.6	-
				30	17.23	8.2	0.12	10.6	3.0
3	18 Jun	1647	35.0	0	21.89	7.6	0.12	8.5	2.0
				5	17.44	7.6	0.12	9.3	
				10	17.08	7.6	0.12	9.5	-
				15	16.93	7.7	0.12	9.9	5.0
				20	16.91	7.7	0.12	10.2	-
				25	16.98	7.8	0.12	10.2	-
				30	17.09	7.8	0.13	10.5	3.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	**pH**	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
4	18 Jun	1720	25.0	0	21.32	7.6	0.14	9.3	2.0
				5	17.30	7.7	0.12	9.5	-
				10	16.86	7.8	0.11	10.0	3.0
				15	16.90	7.9	0.11	10.0	-
				20	17.00	7.9	0.11	10.3	3.0
6	18 Jun	1708	25.0	0	21.45	7.6	0.14	9.4	2.0
				5	17.28	7.8	0.12	9.1	
				10	16.83	7.9	0.12	9.7	3.0
				15	16.74	7.9	0.11	10.2	
				20	16.73	8.0	0.11	10.2	3.0
7	18 Jun	1811	35.0	0	19.12	7.7	0.12	9.5	2.0
				5	17.66	7.6	0.12	9.8	
				10	17.35	7.7	0.12	10.0	
				15	17.26	7.8	0.12	10.0	4.0
				20	17.23	7.8	0.12	10.3	
				25	17.21	7.8	0.12	10.6	
				30	17.26	7.9	0.12	11.1	3.0
8	18 Jun	1751	35.0	0	19.14	7.6	0.12	10.9	2.0
				5	17.39	7.5	0.12	10.9	
				10	17.05	7.6	0.12	10.4	
				15	16.91	7.7	0.12	**9.9**	4.0
				20	16.88	7.7	0.12	10.1	
				25	16.92	7.8	0.12	10.4	
				30	17.15	7.9	0.12	10.6	3.0

1985 Cruise IV (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NTU)
9	18 Jun	1738	35.0	0	20.72	7.5	0.12	9.7	1.0
				5	17.27	7.5	0.12	9.8	-
				10	**16.99**	7.6	0.12	**9.9**	**-**
				15	16.84	7.6	0.12	10.1	4.0
				20	16.82	7.7	0.12	10.2	-
				25	16.83	7.7	0.12	10.2	-
				30	16.96	7.7	0.12	10.3	4.0
10	18 Jun	1826	35.0	0	19.36	7.6	0.12	8.9	3.0
				5	17.71	7.6	0.12	9.0	-
				10	17.41	7.8	0.12	9.0	-
				15	17.32	7.8	0.12	9.4	4.0
				20	17.11	7.8	0.12	9.4	-
				25	17.15	7.8	0.12	9.6	-
				30	17.27	7.8	0.12	10.6	3.0
11	18 Jun	1843	35.0	0	20.38	7.6	0.12	8.7	2.0
				5	17.88	7.7	0.12	9.6	-
				10	17.53	7.7	0.12	9.7	-
				15	17.38	7.8	0.12	10.0	4.0
				20	17.18	7.8	0.12	**9.9**	**-**
				25	17.09	7.8	0.12	10.2	-
				30	17.20	7.8	0.11	10.1	3.0
12	18 Jun	1900	35.0	0	20.55	7.6	0.12	9.2	1.0
				5	17.58	7.6	0.12	9.3	
				10	17.35	7.8	0.12	9.6	
				15	17.23	7.8	0.12	9.7	3.0
				20	17.13	7.8	0.12	10.0	
				25	17.08	7.8	0.12	10.2	
				30	17.20	7.8	0.11	10.4	3.0

1985 Cruise IV (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	**Turbidity** (NTU)
13	18 Jun	1918	35.0	0	21.84	7.6	0.12	8.3	1.0
				5	17.65	7.6	0.12	9.0	-
				10	17.13	7.8	0.11	9.3	-
				15	16.85	7.8	0.11	9.3	3.0
				20	16.89	7.7	0.11	9.7	-
				25	16.94	7.8	0.11	10.3	-
				30	17.02	7.8	0.11	10.3	3.0
14 John Day Dam N. Fishway	18 Jun	0845	-	0					3.0
16 John Day Dam S. Fishway	18 Jun	0854	-	0					3.0
17 The Dalles Dam N. Fishway	18 Jun	1235	-	0	-	-	-	-	2.0
19 The Dalles Dam S. Fishway	18 Jun	1250		0	-	-	-	-	2.0
Bonneville Dam	18 Jun								
N. Fish trap		1110	-	0					2.0
S-end new powerhouse		1115	-	0					3.0
S-end spillway		1120	-	0					3.0
S-end old powerhouse		1125	-	0					3.0

Additional Stations

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
1. W. rivulet (L-2)	18 Jun	2000		0	-	-	-	-	1.0
2. E. rivulet (L-1/L-2)	18 Jun	1950		0	-	-	-	-	5.0

1985 Cruise IV (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	**Turbidity (NTU)**
3. W. lagoon (L-2)	18 Jun	1955	12.0	0	23.70	7.8	0.13	8.9	1.0
				5	17.56	7.9	0.13	9.1	
				10	14.98	8.0	0.16	10.0	1.0
4. E. lagoon (L-l)	18 Jun	1933	12.0	0	21.79	7.7	0.12	8.2	1.0
				5	17.75	7.8	0.12	9.7	-
				10	16.54	7.8	0.13	10.6	1.0
5. Outfall pond (D)	18 Jun	2040	-	0					8.0
6. N-shore, J.D. Dam, nav-lock	18 Jun	0815		0					3.0
7. N-shore, below J.D. Dam, at tower	18 Jun	0830		0					2.0
8. S-shore, below J.D. Dam, opposite nav-lock	18 Jun	0900		0					2.0
9. S-shore, below J.D. Dam, opposite tower	18 Jun	0910	-	0					2.0

19 85 Cruise V
July 26-27
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NTU)
1	26 Jul	1542	35.0	0	24.02	6.8	0.12	10.3	2.0
				5	22.73	7.6	0.12	10.4	-
				10	22.65	7.6	0.12	10.4	-
				15	22.63	7.6	0.12	10.4	3.0
				20	22.63	7.6	0.12	11.2	-
				25	22.64	7.7	0.12	11.5	-
				30	22.65	7.7	0.12	11.5	4.0
2	26 Jul	1600	35.0	0	24.48	6.9	0.13	10.0	2.0
				5	22.83	7.5	0.12	10.3	-
				10	22.75	7.5	0.12	10.4	-
				15	22.61	7.6	0.12	10.8	3.0
				20	22.62	7.6	0.12	11.2	
				25	22.64	7.7	0.12	11.4	
				30	22.72	7.8	0.12	11.4	4.0
3	26 Jul	1618	35.0	0	24.62	7.0	0.13	9.8	2.0
				5	23.11	7.7	0.12	10.0	-
				10	22.84	7.7	0.12	10.4	-
				15	22.63	7.8	0.12	10.8	3.0
				20	22.80	7.8	0.12	11.2	-
				25	22.72	7.8	0.13	11.4	-
				30	22.71	7.9	0.13	11.4	6.0
4	26 Jul	1715	25.0	0	24.68	7.5	0.15	9.7	2.0
				5	23.36	7.5	0.17	**9.9**	**-**
				10	23.00	7.6	0.14	10.0	5.0
				15	22.72	7.8	0.13	10.4	-
				20	22.75	7.8	0.13	10.4	5.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NM)
6	26 Jul	1700	25.0	0	24.15	7.7	0.16	9.4	2.0
				5	23.54	7.5	0.19	9.5	-
				10	22.77	7.7	0.14	10.0	3.0
				15	22.74	7.7	0.13	10.3	-
				20	22.70	7.8	0.13	10.4	6.0
7	26 Jul	1810	35.0	0	23.06	7.6	0.13	10.0	1.0
				5	22.96	7.7	0.13	10.3	-
				10	22.73	7.7	0.13	10.7	-
				15	22.69	7.8	0.13	10.9	2.0
				20	22.72	7.8	0.13	11.1	-
				25	22.76	7.9	0.13	11.1	-
				30	22.84	7.9	0.13	11.2	4.0
8	26 Jul	1748	35.0	0	23.29	7.5	0.13	10.1	2.0
				5	23.13	7.6	0.13	10.1	-
				10	22.80	7.6	0.13	10.3	
				15	22.63	7.7	0.13	10.9	3.0
				20	22.65	7.8	0.13	11.0	-
				25	22.73	7.8	0.13	11.3	-
				30	22.78	7.9	0.13	11.3	5.0
9	26 Jul	1725	35.0	0	24.12	7.6	0.13	9.3	1.0
				5	23.15	7.5	0.14	9.9	-
				10	22.81	7.6	0.13	10.2	-
				15	22.68	7.7	0.13	10.3	3.0
				20	22.64	7.8	0.13	10.8	-
				25	22.67	7.9	0.13	11.1	-
				30	22.76	7.9	0.13	11.3	6.0

1985 Cruise V (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
10	26 Jul	1830	35.0	0	22.95	7.5	0.13	9.8	2.0
				5	22.76	7.7	0.13	10.3	-
				10	22.70	7.7	0.13	10.3	-
				15	22.72	7.8	0.13	10.5	2.0
				20	22.75	7.8	0.13	10.6	-
				25	22.78	7.9	0.13	10.9	-
				30	22.83	7.9	0.13	10.9	3.0
11	26 Jul	1850	35.0	0	22.82	7.5	0.13	9.6	2.0
				5	22.81	7.6	0.13	10.2	-
				10	22.70	7.7	0.13	10.7	-
				15	22.68	7.7	0.13	10.9	3.0
				20	22.63	7.8	0.13	11.1	-
				25	22.64	7.8	0.13	11.2	-
				30	22.64	7.9	0.13	11.2	4.0
12	26 Jul	1912	35.0	0	22.85	7.6	0.13	9.2	1.0
				5	22.87	7.8	0.13	**9.9**	**-**
				10	22.86	7.9	0.13	10.2	-
				15	22.68	7.9	0.13	10.4	3.0
				20	22.70	7.9	0.13	10.8	-
				25	22.72	8.0	0.13	10.9	-
				30	22.76	8.0	0.13	10.9	4.0
13	26 Jul	1930	35.0	0	23.82	7.6	0.13	**9.9**	1.0
				5	23.17	7.7	0.13	10.2	-
				10	22.90	7.8	0.13	10.2	-
				15	22.91	7.8	0.13	10.6	3.0
				20	22.90	7.8	0.13	10.7	-
				25	22.79	7.9	0.13	10.8	-
				30	22.68	8.0	0.13	10.9	7.0

1985 Cruise V (cont.)

Station		Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
14	John Day Dam N. Fishway	27 Jul	0940	-	0					3.0
16	John Day Dam S. Fishway	27 Jul	0955	-	0					4.0
17	The Dalles Dam N. Fishway	26 Jul	1226	-	0					3.0
19	The Dalles Dam S. Fishway	26 Jul	1238		0	-	-	-	-	3.0
	Bonneville Dam	26 Jul								
	N. Fish trap		1100	-	0					3.0
	S-end new powerhouse		1105	-	0					3.0
	S-end spillway		1112	-	0					4.0
	S-end old powerhouse		1120	-	0					3.0
Additional Stations										
1.	W. rivulet (L-2)	27 Jul	0850		0					1.0
2.	E. rivulet (L-1/L-2)	27 Jul	0830		0					5.0
3.	W. lagoon (L-2)	27 Jul	0840	12.0	0	22.13	7.8	0.13	**9.9**	2.0
					5	21.24	7.9	0.13	10.5	
					10	20.52	7.9	0.13	10.9	2.0
4.	E. lagoon (L-1)	27 Jul	0818	17.0	0	22.39	7.9	0.13	10.3	1.0
					5	19.90	8.0	0.13	10.5	
					10	12.03	8.1	0.19	10.8	
					15	11.44	8.1	0.20	10.9	1.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NM)
5. Outfall pond (D)	26 Jul	2033		0	-	-	-	-	5.0
6. N-shore, J.D. Dam, nav-lock	27 Jul	0930	-	0					3.0
7. N-shore, below J.D. Dam, at tower	27 Jul	0920	-	0					3.0
8. S-shore, below J.D. Dam, opposite nav-lock	27 Jul	1000		0					3.0
9. S-shore, below J.D. Dam, opposite tower	27 Jul	1010	-	0					3.0
10. Forebay (restricted zone), J.D. Dam	26 Jul	1950	40.0	0	23.55	7.7	0.13	9.2	1.0
				5	22.87	7.6	0.13	9.7	-
				10	22.84	7.6	0.13	**9.9**	-
				15	22.61	7.7	0.13	10.2	4.0
				20	22.57	7.7	0.13	10.5	-
				25	22.57	7.7	0.13	10.8	-
				30	22.55	7.7	0.13	10.9	6.0
				35	22.53	7.8	0.13	11.2	-
				38	22.57	7.9	0.13	11.2	-

1985 Cruise VI
August 20-21
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
1	21 Aug	0808	35.0	0	20.83	7.2	0.15	9.3	3.0
				5	20.82	7.3	0.15	9.4	-
				10	20.81	7.3	0.15	9.5	-
				15	20.80	7.3	0.15	9.6	4.0
				20	20.79	7.3	0.14	9.8	-
				25	20.79	7.3	0.14	9.8	-
				30	20.77	7.3	0.14	10.0	4.0
2	21 Aug	0827	35.0	0	20.86	7.3	0.15	9.8	3.0
				5	20.84	7.4	0.15	9.9	-
				10	20.83	7.4	0.15	9.7	-
				15	20.81	7.4	0.15	9.7	5.0
				20	20.80	7.4	0.15	9.7	-
				25	20.78	7.4	0.15	9.8	-
				30	20.72	7.5	0.14	9.8	4.0
3	21 Aug	0845	35.0	0	20.85	7.2	0.15	9.4	3.0
				5	20.81	7.2	0.15	9.5	-
				10	20.79	7.2	0.15	9.5	-
				15	20.77	7.3	0.15	9.7	4.0
				20	20.76	7.4	0.15	9.7	-
				25	20.74	7.4	0.15	9.9	-
				30	20.70	7.5	0.15	9.8	5.0

1985 Cruise VI (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	**Turbidity** (NTU)
4	21 Aug	0920	25.0	0	20.84	7.3	0.15	**9.9**	4.0
				5	20.73	7.3	0.15	9.8	-
				10	20.67	7.2	0.15	9.7	6.0
				15	20.61	7.3	0.15	9.8	-
				20	20.52	7.4	0.15	9.6	7.0
6	21 Aug	0905	22.0	0	20.62	7.2	0.15	9.3	6.0
				5	20.52	7.1	0.15	9.3	-
				10	20.49	7.0	0.15	9.4	7.0
				15	20.41	7.1	0.16	9.8	-
				20	20.30	7.0	0.16	**9.9**	7.0
7	21 Aug	1005	35.0	0	20.92	7.2	0.15	9.5	4.0
				5	20.82	7.3	0.15	9.6	-
				10	20.80	7.4	0.15	9.6	-
				15	20.79	7.4	0.15	9.7	5.0
				20	20.78	7.5	0.15	9.7	-
				25	20.76	7.5	0.15	9.8	-
				30	20.74	7.5	0.15	9.7	4.0
8	21 Aug	0950	35.0	0	20.89	7.2	0.15	9.3	5.0
				5	20.81	7.2	0.15	9.3	-
				10	20.75	7.2	0.15	9.4	-
				15	20.75	7.3	0.15	9.5	5.0
				20	20.74	7.4	0.15	9.8	-
				25	20.73	7.4	0.15	9.8	-
				30	20.70	7.6	0.15	**9.9**	10.0

1985 Cruise VI (cont.)

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	**pH**	**Conductivity** (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NTH)
9	21 Aug	0934	35.0	0	20.90	7.2	0.15	9.3	4.0
				5	20.78	7.3	0.15	9.5	-
				10	20.77	7.3	0.15	9.8	-
				15	20.76	7.5	0.15	10.0	5.0
				20	20.76	7.4	0.15	10.1	-
				25	20.74	7.4	0.15	10.2	-
				30	20.69	7.5	0.15	10.3	7.0
10	20 Aug	1615	35.0	0	20.94	7.6	0.15	9.5	4.0
				5	20.94	7.6	0.15	9.8	-
				10	20.95	7.7	0.15	10.2	-
				15	20.96	7.7	0.15	10.0	5.0
				20	20.96	7.7	0.15	10.2	-
				25	20.96	7.7	0.15	10.3	-
				30	20.95	7.7	0.15	10.5	4.0
11	20 Aug	1740	35.0	0	20.91	7.4	0.15	9.1	1.0
				5	20.92	7.4	0.15	9.4	-
				10	20.93	7.5	0.15	9.3	-
				15	20.92	7.5	0.15	9.3	1.0
				20	20.93	7.5	0.15	9.5	-
				25	20.92	7.5	0.15	9.7	-
				30	20.90	7.6	0.15	**9.9**	1.0
12	20 Aug	1810	35.0	0	20.90	7.4	0.15	9.5	1.0
				5	20.93	7.4	0.15	9.5	-
				10	20.92	7.4	0.15	9.7	-
				15	20.92	7.3	0.15	**9.9**	1.0
				20	20.92	7.3	0.15	10.0	-
				25	20.92	7.3	0.15	10.0	-
				30	20.90	7.3	0.15	10.2	1.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
13	20 Aug	1820	35.0	0	20.90	7.4	0.15	9.5	4.0
				5	20.92	7.4	0.15	9.5	-
				10	20.91	7.4	0.15	9.6	-
				15	20.92	7.4	0.15	9.9	1.0
				20	20.92	7.4	0.15	9.7	-
				25	20.91	7.4	0.15	9.9	-
				30	20.89	7.5	0.15	9.8	2.0
14 John Day Dam N. Fishway	20 Aug	2000	-	0					1.0
16 John Day Dam S. Fishway	20 Aug	2020	-	0					1.0
17 The Dalles Dam N. Fishway	20 Aug	1330	-	0					1.0
19 The Dalles Dam S. Fishway	20 Aug	1340		0	-	-	-	-	1.0
Bonneville Dam	20 Aug								
N. Fish trap		1155	-	0					1.0
S-end new powerhouse		1202	-	0					2.0
S-end spillway		1211	-	0					2.0
S-end old powerhouse		1215	-	0					2.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	Turbidity (NTU)
Additional Stations									
1. W. rivulet (L-2)	20 Aug	1720	-	0	-	-	-	-	< 1.0
2. E. rivulet (L-1/L-2)	20 Aug	1655	-	0	-	-	-	-	< 1.0
3. W. lagoon (L-2)	20 Aug	1705	12.0	0	19.21	7.6	0.14	9.5	1.0
				5	19.40	7.7	0.14	9.9	-
				10	19.14	7.9	0.14	10.1	3.0
4. E. lagoon (L-1)	20 Aug	1645	12.0	0	19.79	7.7	0.14	9.6	3.0
				5	19.70	7.7	0.14	10.0	-
				10	18.90	7.8	0.14	10.2	5.0
5. Outfall pond (D)	20 Aug	1945		0	-	-	-	-	1.0
6. N-shore, below J.D. Dam, nav-lock	20 Aug	1910		0	-	-	-	-	1.0
7. N-shore, below J.D. Dam, at tower	20 Aug	1920		0	-	-	-	-	1.0
8. S-shore, below J.D. Dam, opposite nav-lock	20 Aug	2025		0	-	-	-	-	1.0
9. S-shore, below J.D. Dam, opposite tower	20 Aug	2030							

1985 Cruise VII
September 24-25
General Physical Characteristics

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen (ppm)	**Turbidity** (NTU)
1	24 Sep	1607	35.0	0	17.95	7.5	0.16	10.2	2.0
				5	17.54	7.6	0.16	10.2	-
				10	17.52	7.5	0.16	10.3	
				15	17.48	7.7	0.16	10.4	3.0
				20	17.48	7.7	0.16	10.6	-
				25	17.47	7.7	0.16	10.6	-
				30	17.48	7.7	0.16	10.7	3.0
2	24 Sep	1628	35.0	0	18.22	7.8	0.16	10.0	2.0
				5	17.65	7.8	0.16	10.1	-
				10	17.49	7.7	0.16	10.2	-
				15	17.48	7.7	0.16	10.4	2.0
				20	17.49	7.7	0.16	10.6	-
				25	17.50	7.7	0.16	10.6	-
				30	17.57	7.7	0.16	10.6	4.0
3	24 Sep	1645	35.0	0	18.31	7.7	0.16	**9.6**	2.0
				5	17.58	7.7	0.16	9.8	-
				10	17.45	7.7	0.17	**9.9**	**-**
				15	17.46	7.7	0.17	**9.9**	6.0
				20	17.47	7.7	0.17	10.0	-
				25	17.49	7.7	0.17	10.5	-
				30	17.57	7.6	0.16	10.5	6.0
4	24 Sep	1730	22.0	0	18.54	7.7	0.16	9.8	2.0
				5	17.70	7.7	0.16	**9.9**	**-**
				10	17.70	7.6	0.17	10.0	3.0
				15	17.71	7.6	0.17	10.3	-
				20	17.73	7.8	0.17	10.4	14.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	**pH**	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NTU)
6	24 Sep	1705	24.0	0	18.44	7.6	0.17	9.5	2.0
				5	17.80	7.7	0.17	9.4	-
				10	17.73	7.6	0.17	9.8	3.0
				15	17.74	7.5	0.19	**9.9**	**-**
				20	17.76	7.7	0.21	10.3	4.0
7	24 Sep	1808	35.0	0	18.05	7.6	0.16	9.6	2.0
				5	17.98	7.6	0.16	10.0	-
				10	17.85	7.6	0.17	10.0	-
				15	17.60	7.6	0.16	10.0	2.0
				20	17.60	7.6	0.17	10.1	-
				25	17.62	7.5	0.17	10.2	-
				30	17.65	7.7	0.17	10.2	3.0
8	24 Sep	1755	35.0	0	18.20	7.6	0.16	**9.9**	2.0
				5	17.62	7.6	0.16	10.3	-
				10	17.54	7.6	0.17	10.4	
				15	17.51	7.6	0.17	10.2	3.0
				20	17.53	7.6	0.17	10.1	-
				25	17.54	7.6	0.17	10.3	-
				30	17.57	7.7	0.17	10.3	4.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity (NTU)**
9	24 Sep	1740	35.0	0	17.80	7.7	0.16	9.6	2.0
				5	17.62	7.7	0.16	9.6	-
				10	17.54	7.7	0.17	9.8	-
				15	17.50	7.7	0.17	10.2	4.0
				20	17.51	7.7	0.17	10.3	-
				25	17.53	7.7	0.17	10.4	-
				30	17.57	7.8	0.17	10.4	5.0
10	24 Sep	1825	35.0	0	18.29	7.7	0.16	9.5	2.0
				5	18.18	7.7	0.16	9.6	-
				10	17.93	7.7	0.16	10.1	-
				15	17.64	7.7	0.16	10.1	3.0
				20	17.63	7.6	0.16	10.2	-
				25	17.62	7.6	0.16	10.2	-
				30	17.65	7.7	0.16	10.2	3.0
11	25 Sep	0820	35.0	0	17.69	7.6	0.16	9.8	2.0
				5	17.63	7.6	0.16	**9.9**	**-**
				10	17.57	7.6	0.16	**9.9**	**-**
				15	17.50	7.7	0.16	**9.9**	2.0
				20	17.46	7.7	0.16	10.0	-
				25	17.39	7.6	0.16	10.3	-
				30	17.33	7.8	0.16	10.3	3.0
12	25 Sep	0800	35.0	0	17.49	7.5	0.16	9.0	2.0
				5	17.50	7.6	0.16	10.0	-
				10	17.46	7.7	0.16	10.1	-
				15	17.44	7.7	0.16	10.3	3.0
				20	17.40	7.7	0.16	10.3	-
				25	17.33	7.8	0.16	10.4	-
				30	17.26	7.8	0.16	10.4	3.0

Station		Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	Turbidity (NTU)
13		25 Sep	0725	35.0	0	17.45	7.6	0.16	9.8	3.0
					5	17.42	7.6	0.16	10.0	
					10	17.41	7.6	0.16	10.0	
					15	17.39	7.7	0.16	10.2	4.0
					20	17.37	7.7	0.16	10.2	
					25	17.32	7.7	0.16	10.3	
					30	17.28	7.7	0.16	10.3	5.0
14	John Day Dam N. Fishway	25 Sep	0940		0					3.0
16	John Day Dam S. Fishway	25 Sep	0950	-	0					4.0
17	The Dalles Dam N. Fishway	24 Sep	1345		0					2.0
19	The Dalles Dam S. Fishway	24 Sep	1355	-	0					2.0
	Bonneville Dam	24 Sep								
	N. Fish trap		1234	-	0					3.0
	S-end new powerhouse		1240	-	0					3.0
	S-end spillway		1245	-	0					3.0
	S-end old powerhouse		1250	-	0					4.0

Station	Date 1985	Time (PST)	Total depth (m)	Sample depth (m)	Temperature °C	pH	Conductivity (mmhos)	Dissolved oxygen **(ppm)**	**Turbidity** (NTU)
Additional Stations									
1. W. rivulet (L-2)	25 Sep	0900	-	0					2.0
2. E. rivulet (L-1/L-2)	25 Sep	0830	-						1.0
3. W. lagoon (L-2)	25 Sep	0845	12.0	0	17.29	7.9	0.15	10.2	1.0
				5	17.00	7.9	0.15	10.4	-
				10	16.67	7.9	0.15	10.4	1.0
4. E. lagoon (L-1)	25 Sep	0822	12.0	0	17.22	7.6	0.15	10.5	2.0
				5	17.06	7.8	0.15	10.4	-
				10	16.70	7.9	0.15	10.5	1.0
5. Outfall pond (D)	24 Sep	1930		0					5.0
6. N-shore, J.D. Dam, nav-lock	24 Sep	1850	-	0					3.0
7. N-shore, below J.D. Dam, at tower	24 Sep	1855							3.0
8. S-shore, below J.D. Dam, opposite nav-lock	25 Sep	1000		0					2.0
9. S-shore, below J.D. Dam, opposite tower	25 Sep	1005		0					2.0

Appendix Table 2.--Fluoride concentrations of river water and other aquatic sites in the John Day Dam region, Columbia River, March-September 1985 (see Figure 1 for station locations). Additional sampling sites reported for Cruise I were at or adjacent to aluminum plant facilities near John Day Dam.

1985 Cruise I
March 12-13
Fluoride (ppm)

Station	Date	Time	Surface
West sludge pond	12 Mar	1418	9.18×10^{2}
Treatment plant, line to W. sludge pond		1433	3.20×10^{3}
East sludge pond		1450	2.80×10^{3}
"D" pond (outfall pond)		1506	1.46
Stream above "C" pond		1514	1.30
"B" pond		1531	6.52
"A" pond		1540	3.45
West rivulet (L-2)		1600	5.56
East rivulet (L-1/L-2)		1610	7.51
Lagoon, off float		1625	0.27
Culvert, road above E. rivulet		1630	0.88
Boiler plant		1640	0.21
Pond west of boiler plant		1645	4.41
Industrial storm collection pond		1700	3.04
John Day River, Lepage Park	13 Mar	0850	0.12
John Day Dam, boat basin	12 Mar	1740	0.17
John Day Dam, N-fishway		1840	0.16
John Day Dam, S-fishway		1855	0.16
John Day Dam, nav-lock		1723	0.17
N-shore, below J.D. Dam at tower		1730	0.17
S-shore, below J.D. Dam opposite nav-lock	13 Mar	0835	0.17
S-shore, below J.D. Dam opposite tower		0830	0.17
The Dalles Dam, N-fishway		1120	0.17

Station	Date	Time	Surface
The Dalles Dam, S-fishway		1130	0.16
Bonneville Dam, N-fish trap	13 Mar	1250	0.17
Bonneville Dam, S-end new powerhouse		1255	0.17
Bonneville Dam, S-end spillway		1300	0.17
Bonneville Dam, S-end old powerhouse		1310	0.17

1985 Cruise II
April 15-17
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.23	0.23	0.24
2		0.24	0.24	0.25
3		0.25	0.22	0.25
4		0.20	0.08	0.29
6		0.06	0.07	0.07
		0.23	0.23	0.17
8		0.24	0.19	0.19
9				0.17
10		0.25	0.26	0.18
11				0.23
12				0.21
13				0.21
14	John Day Dam N. Fishway			0.26
16	John Day Dam S. Fishway			0.18
17	The Dalles Dam N. Fishway			0.22
19	The Dalles Dam S. Fishway			0.23
	Bonneville Dam:			
	N. Fish trap			0.22
	S-end new powerhouse			0.23
	S-end spillway			0.22
	S-end old powerhouse			0.22

1985 Cruise II (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. West rivulet (L-2)			5.59
2. East rivulet (L-1/L-2)			8.91
3. West lagoon (L-2)	0.26		0.26
4. East lagoon (L-1)	0.27		0.27
5. Outfall pond (D)			1.32
6. N-shore, John Day Dam, nav-lock			0.23
7. N-shore, below John Day Dam, at tower			0.22
8. S-shore, below John Day Dam, opposite nav-lock			0.20
9. S-shore, below John Day Dam, opposite tower			0.22
10. Creek adjacent to Bonneville Dam, OR side			0.03

1985 Cruise III
May 15-16
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.14	0.14	0.15
2		0.14	0.15	0.14
3		0.15	0.14	0.14
4		0.14	0.13	0.07
6		0.14	0.08	0.07
7		0.14	0.15	0.13
8		0.14	0.14	0.11
9		0.14	0.16	0.13
10		0.15	0.15	0.14
11		0.14	0.15	0.14
12		0.15	0.16	0.12
13		0.15	0.15	0.15
14	John Day Dam N. Fishway			0.15
16	John Day Dam S. Fishway			0.14
17	The Dalles Dam N. Fishway			0.12
19	The Dalles Dam S. Fishway			0.14
	Bonneville Dam:			
	N. Fish trap			0.14
	S-end new powerhouse			0.14
	S-end spillway			0.15
	S-end old powerhouse			0.14

1985 Cruise III (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. West rivulet (L-2)	-	-	5.71
2. East rivulet (L-1/L-2)	-	-	9.95
3. West lagoon (L-2)	0.22	-	0.22
4. East lagoon (L-1)	0.23	-	0.24
5. Outfall pond (D)	-	-	1.36
6. N-shore, John Day Dam, nav-lock	-	-	0.15
7. N-shore, below J.D. Dam, at tower	-	-	0.14
8. S-shore, below J.D. Dam, opposite nav-lock	-	-	0.14
9. S-shore, below J.D. Dam, opposite tower	-	-	0.15

1985 Cruise IV
June 18-19
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.12	0.12	0.11
		0.12	0.11	0.08
3		0.13	0.13	0.14
4		0.13	0.12	0.12
6		0.09	0.08	0.08
7		0.14	0.12	0.16
8		0.14	0.11	0.14
9		0.14	0.12	0.16
10		0.14	0.15	0.15
11		0.14	0.15	0.14
12		0.15	0.15	0.15
13		0.14	0.14	0.13
14	John Day Dam N. Fishway			0.14
16	John Day Dam S. Fishway			0.14
17	The Dalles Dam N. Fishway			0.14
19	The Dalles Dam S. Fishway			0.16
	Bonneville Dam:			
	N. Fish trap			0.14
	S-end new powerhouse			0.14
	S-end spillway			0.14
	S-end old powerhouse			0.14

1985 Cruise IV (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. West rivulet (L-2)			5.24
2. East rivulet (L-1/L-2)			6.73
3. West lagoon (L-2)	0.23		0.22
4. East lagoon (L-1)	0.23		0.21
5. Outfall pond (D)			1.35
6. N-shore, John Day Dam, nav-lock			0.15
7. N-shore, below J.D. Dam, at tower			0.15
8. S-shore, below J.D. Dam, opposite nav-lo ck			0.13
9. S-shore, below J.D. Dam, opposite tower			0.13

1985 Cruise V
July 26-27
Fluoride (ppm)

Station		Bottom	Mid-depth	-Surface
1		0.12	0.12	0.12
2		0.12	0.13	0.13
3		0.12	0.12	0.12
4		0.13	0.11	0.13
6		0.11	0.13	0.14
7		0.13	0.13	0.13
8		0.08	0.13	0.11
9		0.11	0.13	0.14
10		0.13	0.13	0.15
11		0.13	0.13	0.13
12		0.13	0.13	0.13
13		0.12	0.12	0.13
14	John Day Dam N. Fishway			0.17
16	John Day Dam S. Fishway			0.14
17	The Dalles Dam N. Fishway			0.12
19	The Dalles Dam S. Fishway			0.12
	Bonneville Dam:			
	N. Fish trap			0.12
	S-end new powerhouse			0.12
	S-end spillway			0.12
	S-end old powerhouse			0.12

1985 Cruise V (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. Forebay (restricted zone), John Day Dam	0.12	0.13	0.13
2. West rivulet (L-2)			5.69
3. East rivulet (L-1/L-2)			7.28
4. West lagoon (L-2)	0.20		0.21
5. East lagoon (L-1)	0.24		0.20
6. Outfall pond (D)			1.70
7. N-shore, John Day Dam, nav-lock			0.12
8. N-shore, below J.D. Dam, at tower	-		0.12
9. S-shore, below J.D. Dam, opposite nav-lock			0.12
10. S-shore, below J.D. Dam, opposite tower			0.11

1985 Cruise VI
August 20-21
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.14	0.15	0.15
2		0.15	0.15	0.15
3		0.14	0.13	0.14
4		0.13	0.15	0.15
6		0.12	0.15	0.15
7		0.16	0.15	0.16
8		0.14	0.14	0.15
9		0.15	0.15	0.15
10		0.16	0.15	0.16
11		0.16	0.16	0.16
12		0.16	0.15	0.15
13		0.16	0.15	0.15
14	John Day Dam N. Fishway			0.16
16	John Day Dam S. Fishway			0.14
17	The Dalles Dam N. Fishway			0.14
19	The Dalles Dam S. Fishway			0.14
	Bonneville Dam:			
	N. Fish trap			0.14
	S-end new powerhouse			0.13
	S-end spillway			0.14
	S-end old powerhouse			0.14

1985 Cruise VI (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. West rivulet (L-2)			5.11
2. East rivulet (L-1/L-2)			6.42
3. West lagoon (L-2)	0.22		0.22
4. East lagoon (L-1)	0.22		0.21
5. Outfall pond (D)			1.42
6. N-shore, John Day Dam, nav-lock			0.15
7. N-shore, below John Day Dam, at tower			0.15
8. S-shore, below John Day Dam, opposite nav-lock			0.14
9. S-shore, below John Day Dam, opposite tower			0.15

1985 Cruise VII
September 24-25
Fluoride (ppm)

Station		Bottom	Mid-depth	Surface
1		0.16	0.17	0.18
2		0.17	0.17	0.19
3		0.16	0.16	0.18
4		0.16	0.15	0.15
6		0.15	0.15	0.16
7		0.16	0.17	0.17
8		0.17	0.18	0.18
9		0.17	0.17	0.17
10		0.19	0.18	0.16
11		0.18	0.18	0.18
12		0.17	0.18	0.18
13		0.18	0.16	0.16
14	John Day Dam N. Fishway			0.17
16	John Day Dam S. Fishway			0.17
17	The Dalles Dam N. Fishway			0.17
19	The Dalles Dam S. Fishway			0.17
	Bonneville Dam:			
	N. Fish trap			0.16
	S-end new powerhouse			0.16
	S-end spillway			0.16
	S-end old powerhouse			0.16

1985 Cruise VII (cont.)

	Bottom	Mid-depth	Surface
Additional Stations			
1. West rivulet (L-2)	-	-	5.69
2. East rivulet (L-1/L-2)	-	-	5.39
3. West lagoon (L-2)	0.23	-	0.23
4. East lagoon (L-1)	0.23	-	0.22
5. Outfall pond (D)	-	-	4.89
6. N-shore, John Day Dam, nav-lock	-	-	0.17
7. N-shore, below John Day Dam, at tower	-	-	0.16
8. S-shore, below John Day Dam, opposite nav-lock	-	-	0.16
9. S-shore, below John Day Dam, opposite tower	-	-	0.16

Appendix Table 3.-- Daily fluoride concentration and **turbidity** in John Day Dam north (N) and south (S) fishways, 1985.

Date (1985)	Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU) (N)	Turbidity (NTU) (S)
Apr 2	0.19	0.18	6.0	8.0
3	0.21	0.20	8.0	2.0
4	0.23	0.21	-	-
5	0.21	0.19	-	-
6	0.22	0.21	-	-
7	0.20	0.19	-	-
8	0.20	0.20	2.0	2.0
9	0.20	0.17	2.0	2.0
10	0.21	0.18	2.0	3.0
11	0.23	0.19	2.0	2.0
12	0.24	0.21	2.0	3.0
13	0.22	0.21	2.0	3.0
14	0.24	0.21	-	-
15	0.21	0.21	10.5	11.5
16	0.24	0.21	10.0	16.0
17	0.26	0.25	9.0	14.0
18	0.27	0.26	9.0	13.0
19	0.30	0.25	9.0	16.0
20	0.30	0.23	12.0	17.0
21	0.28	0.25	12.0	13.0
22	0.21	0.21	12.0	14.0
23	0.24	0.23	12.0	12.0
24	0.22	0.21	11.0	11.0
25	0.23	0.22	10.0	11.0
26	0.23	0.21	6.0	9.0
27	0.22	0.20	8.0	8.0
28	0.21	0.22	8.0	8.0
29	0.21	0.20	8.0	9.0
30	0.20	0.18	6.0	6.0
May 1	0.20	0.20	7.0	8.0
2	0.20	0.19	7.0	8.0
3	0.18	0.18	7.0	8.0
4	0.18	0.18	6.0	6.0
5	0.20	0.19	5.0	6.0
6	0.20	0.19	8.0	6.0
7	0.20	0.19	7.0	8.0
8	0.21	0.20	-	-
9	0.18	0.19	6.0	7.0
10	0.18	0.19	-	-
11	0.19	0.18	-	-
12	0.20	0.16	-	-
13	0.20	0.17	-	-
14	0.20	0.19	5.0	6.0
15	0.18	0.19	-	-
16	0.16	0.16	-	-
17	0.17	0.17	-	-

Appendix Table 3.--cont.

Date (1985)	Fluoride (ppm) (N)	(S)	Turbidity (NTU) (N)	(S)
May 18	0.16	0.14		
19	0.16	0.17		
20	0.15	0.15		
21	0.14	0.14		
22	0.13	0.14		
23	0.12	0.12		
24	0.13	0.12		
25	0.11	0.11		
26	0.12	0.10		
27	0.14	0.12		
28	0.12	0.12		
29	0.11	0.13		
30	0.12	0.12		
31	0.14	0.13		
Jun 1	0.15	0.13		
2	0.14	0.14		
3	0.14	0.12		
4	0.14	0.14		
5	0.12	0.12		
6	0.12	0.11		
7	0.11	0.13		
8	0.11	0.11		
9	0.11	0.11		
10	0.12	0.10		
11	0.12	0.11		
12	0.11	0.11		
13	0.14	0.11		
14	0.14	0.12		
15	0.13	0.12		
16	0.13	0.12		
17	0.13	0.13		
18	0.13	0.12		
19	0.13	0.12		
20	0.12	0.12		
21	0.13	0.13		
22	0.12	0.12	2.0	3.0
23	0.13	0.13		
24	0.12	0.12	2.0	2.0
25	0.13	0.12	2.0	2.0
26	0.11	0.11	2.0	2.0
27	0.11	0.11	2.0	2.0
28	0.12	0.11	2.0	2.0
29	0.12	0.12	1.0	1.0
30	0.12	0.11	2.0	1.0
Jul 1	0.12	0.12	2.0	3.0
2	0.12	0.12	2.0	3.0
3	0.12	0.11		

Appendix Table 3.--cont.

Date (1985)		Fluoride (ppm) (N)	(S)	Turbidity (NTU) (N)	(S)
Jul	4	0.12	0.12	-	-
	5	0.12	0.11	2.0	2.0
	6	0.11	0.12	-	-
	7	0.12	0.12	-	-
	8	0.13	0.12	1.0	2.0
	9	0.13	0.12	1.0	2.0
	10	0.13	0.13	1.0	2.0
	11	0.12	0.12	2.0	2.0
	12	0.12	0.12	2.0	2.0
	13	0.12	0.12	-	-
	14	0.12	0.12	-	-
	15	0.12	0.11	-	-
	16	0.12	0.13	-	-
	17	0.13	0.12	-	-
	18	-	-	-	-
	19	-	-	-	-
	20	0.12	0.12	-	-
	21	0.12	0.12	-	-
	22	0.12	0.12	1.0	2.0
	23	0.13	0.12	1.0	2.0
	24	0.13	0.13	2.0	3.0
	25	-	-	-	-
	26	0.13	0.12	2.0	3.0
	27	0.12	0.12	1.0	3.0
	28	-	-	-	-
	29	0.13	0.12	1.0	2.0
	30	0.12	0.12	-	-
	31	0.13	0.13	4.0	4.0
Aug	1	0.13	0.12	4.0	4.0
	2	0.13	0.12	4.0	4.0
	3	0.13	0.13	-	-
	4	0.13	0.13	-	-
	5	0.12	0.12	5.0	6.0
	6	0.13	0.12	6.0	6.0
	7	0.14	0.13	5.0	7.0
	8	0.13	0.13	6.0	7.0
	9	0.12	0.12	6.0	6.0
	10	0.13	0.12	-	-
	11	0.12	0.12	-	-
	12	0.12	0.11	5.0	6.0
	13	0.13	0.12	4.0	5.0
	14	0.13	0.12	3.0	4.0
	15	0.14	0.12	4.0	6.0
	16	0.13	0.13	4.0	5.0
	17	0.13	0.13	2.0	<1.0
	18	0.14	0.14	<1.0	<1.0
	19	-	-	-	-

Appendix Table 3.--cont.

Date (1985)	Fluoride (ppm) (N)	Fluoride (ppm) (S)	Turbidity (NTU) (N)	Turbidity (NTU) (S)
Aug 20	-	-	-	-
21	0.15	0.14	4.0	6.0
22	0.15	0.14	6.0	6.0
23	0.15	0.15	4.0	4.0
24	0.14	0.15	<1.0	<1.0
25	0.16	0.15	<1.0	<1.0
26	0.15	0.14	6.0	6.0
27	0.15	0.14	4.0	6.0
28	0.15	0.15	5.0	4.0
29	0.14	0.15	4.0	7.0
30	0.14	0.13	4.0	5.0
31	-	-	-	-
Sep 1	-	-	-	-
2	0.16	0.14	4.0	6.0
3	0.15	0.13	4.0	6.0
4	-	-	-	-
5	0.15	0.14	4.0	6.0
6	0.14	0.14	4.0	4.0
7	0.15	0.14	-	-
8	0.15	0.15	-	-
9	0.16	0.15	4.0	4.0
10	0.15	0.14	4.0	4.0
11	0.15	0.15	4.0	6.0
12	0.14	0.14	3.0	5.0
13	0.15	0.14	4.0	4.0
14	0.15	0.15	-	-
15	0.15	0.15	-	-
16	-	-	-	-
17	0.14	0.14	4.0	8.0
18	0.15	0.14	4.0	8.0
19	0.15	0.15	4.0	4.0
20	0.15	0.15	4.0	4.0
21	0.16	0.15	-	-
22	0.16	0.15	-	-
23	0.16	0.15	4.0	4.0
24	0.15	0.15	4.0	4.0
25	0.17	0.17	3.0	4.0
26	0.20	0.19	4.0	4.0
27	0.18	0.18	-	-
28	-	-	-	-
29	-	-	-	-
30	-	-	-	-
Oct 1	-	-	-	-
2	0.18	0.18	4.0	4.0
3	0.19	0.19	4.0	5.0
4	0.19	0.18	4.0	4.0
5	0.18	0.18	4.0	4.0

Appendix Table 3.--cont.

Date (1985)	Fluoride (ppm) (N)	(S)	Turbidity (NTU) (N)	(S)
Oct 6	0.18	0.17	4.0	-
7	0.18	0.18	4.0	5.0
8	0.19	0.18	4.0	5.0
9	-	0.18	-	4.0
10	0.18	0.17	4.0	5.0
11	0.17	0.17	4.0	4.0
12	0.18	0.18	3.0	3.0
13	0.17	0.16	3.0	3.0
14	0.18	0.17	4.0	4.0
15	0.17	0.17	4.0	4.0
16	0.17	0.17	4.0	4.0
17	0.17	0.16	4.0	4.0
18	0.18	0.18	-	-
19	0.17	0.16	-	-
20	0.16	0.17	-	-
21	0.16	0.16	4.0	6.0
22	0.17	0.17	4.0	6.0
23	0.17	0.16	4.0	4.0
24	0.17	0.17	4.0	4.0
25	0.16	0.16	4.0	4.0
26	0.16	0.15	2.0	2.0
27	0.16	0.16	-	-
28	0.17	0.16	4.0	4.0
29	0.17	0.17	4.0	4.0
30	-	-	-	-
31	0.17	0.17	4.0	4.0
Nov 1	0.18	0.16	4.0	4.0

Appendix Table 4.--Fluoride concentrations of river water and other aquatic sites in the John Day Dam region, Columbia River, April 1986 (see Figure 1 for station locations).

Station		1986 Cruise I April 15-16 Fluoride (ppm) Surface
1		0.22
4		0.10
5		0.09
9		0.18
10		1.21
14	John Day Dam N. Fishway	0.24
16	John Day Dam S. Fishway	0.20
17	The Dalles Dam N. Fishway	0.19
19	The Dalles Dam S. Fishway	0.19
	Bonneville Dam: N. Fish trap	0.17
	S-end new powerhouse	0.19
Additional Stations		
1.	West rivulet (L-2)	5.63
2.	East rivulet (L-1/L-2)	8.96
3.	West lagoon (L-2)	0.33
4.	Outfall pond (D)	7.91
5.	N-shore, John Day Dam, nav-lock	0.22
6.	N-shore, below John Day Dam, at tower	0.20
7.	S-shore, below John Day Dam, opposite nav-lock	0.19
8.	S-shore, below John Day Dam, opposite tower	0.20
9.	N-shore, between Station 10 and John Day Dam	0.24
10.	S-shore, forebay of John Day Dam	0.18

Appendix Table S.--Choices made by chinook salmon when exposed to fluoride (0.50 ppm) in a two-choice flume.

Experimental conditions	Total tests	Results		
		Fluoride side	Non-Fluoride side	No choice
Fluoride right side	53	7	21	25
Fluoride left side	59	9	21	29
TOTALS	112	16	42	54
No fluoride either side (control)	43	19 (right side)	13 (left side)	11

X^2 analysis

1. To test for fluoride avoidance among chinook making a choice,

$$X2 = \frac{(16-29)^2}{29} + \frac{(42-29)2}{29} = 11.7;\ P < 0.001;\ H0 \text{ rejected.}$$

Conclusion: Chinook salmon avoided fluoride side.

2. To test preference for one side or the other among chinook salmon making a choice (no fluoride either side).

$$X2 = \frac{(19-16)^2}{16} + \frac{(13-16)^2}{16} = 1.1;\ P = 0.30;\ H_0 \text{ accepted.}$$

Conclusion: No preference.

3. To test effects of fluoride on proportion of "No choices" (delays), [with no fluoride on either side (control), 74% (32 of 43) of the chinook salmon made a choice. It would therefore be expected that 83 chinook salmon of the 112 tested with fluoride present would also make a choice, if fluoride had no delaying effect, and 29 would not].

$$x2 = \frac{(58-83)^2}{83} + \frac{(54-29)^2}{29} = 29.1;\ P < 0.001;\ HO \text{ rejected.}$$

Conclusion: Significantly more "No choices" (delays) occurred when fluoride was present.

Appendix Table 6.--Choices made by coho salmon when exposed to fluoride (0.50 ppm in a two-choice flume.

Experimental conditions	Total tests	Results: Fluoride side	Non-Fluoride side	No choice
Fluoride right side	44	14	17	13
Fluoride left side	53	7	24	22
TOTALS	97	21	41	35
No fluoride either side (control)	42	13 (right side)	17 (left side)	12

X^2 analysis

1. To test for fluoride among coho salmon making a choice,

$$X2 = \frac{(21-31)^2}{31} + \frac{(41-31)^2}{31} = 6.5; P=0.01; HO \text{ rejected.}$$

Conclusion: Coho salmon avoided fluoride side.

2. To test preference for one side or the other among coho salmon making a choice (no fluoride either side),

$$X2 = \frac{(13-15)^2}{15} + \frac{(17-15)^2}{15} = 0.5; P > 0.30; HO \text{ accepted.}$$

Conclusion: No preference.

3. To test effects of fluoride on proportion of "No choices" (delays), [with no fluoride on either side (control), 71% (30 of 42) of the coho salmon made a choice. It would therefore be expected that 69 coho salmon of the 97 tested with fluoride present would also make a choice, if fluoride had no delaying effect, and 28 would not].

$$x^2 = \frac{(62-69)^2}{69} + \frac{(35-28)^2}{28} = 2.5; 0.20 > P > 0.10; H_o \text{ accepted.}$$

Conclusion: Significantly more "No choices" (delays) did not occur when fluoride was present.

Appendix Table 7.--Choices made by chum salmon when exposed to fluoride (0.50 ppm) in a two-choice flume.

Experimental conditions	Total tests	Results		
		Fluoride side	Non-Fluoride side	No choice
Fluoride right side	40	17	13	10
Fluoride left side	37	8	22	7
TOTALS	77	25	35	17
No fluoride either side (control)	34	16	14	4

$x2$ analysis

1. To test for fluoride avoidance among chum salmon making a choice,

$$X2 = \frac{(25-30)^2}{30} + \frac{(35-30)^2}{30} = 1.7;\ P = 0.20;\ H_o \text{ accepted.}$$

Conclusion: Chum salmon did not avoid fluoride side.

2. To test preference for one side or the other among chum salmon making a choice (no fluoride either side),

$$X2 = \frac{(16-15)^2}{15} + \frac{(14-15)^2}{15} = 0.1;\ P >> 0.30;\ H_0 \text{ accepted.}$$

Conclusion: No "natural" preference.

3. To test effects of fluoride on proportion of "No choices" (delays), [with no fluoride on either side (control), 88% (30 of 34) of the chum salmon made a choice. It would therefore be expected that 68 chum salmon of the 77 tested with fluoride present would also make a choice, if fluoride had no delaying effect, and 9 would not].

$$X^2 - \frac{(60-68)^2}{68} + \frac{(17-9)^2}{9} = 8.1;\ .01 > P > 0.001;\ HO \text{ rejected.}$$

Conclusion: Significantly more "No choices" (delays) occurred when fluoride was present.

Appendix Table 8.--Choices made by chinook salmon when exposed to low concentrations (0.20 ppm) of fluoride in a two-choice flume.

Experimental conditions	Total tests	Results: Fluoride side	Non-Fluoride side	No choice
Fluoride right side	32	5	6	21
Fluoride left side	65	20	14	31
TOTALS	97	25	20	52
No fluoride either side (control)		(right side)	(left side)	
1984	19	5	4	10
1983	43	19	13	11
TOTALS	62	24	17	21

x^2 analysis

1. To test preference for one side or the other among chinook salmon making a choice (no fluoride either side),

$$x^2 = \frac{(5-4.5)^2}{4.5} + \frac{(4-4.5)^2}{4.5} = 0.11;\ P > 0.30;\ H_0 \text{ accepted.}$$

Conclusion: No preference.

2. To test effects of fluoride on proportion of "No choices" (delays) [Combining 1983 and 1984 data for chinook tests without fluoride (because of small sample size in 1984), 66% (41 of 62) of the chinook salmon made a choice. It would therefore be expected that 64 chinook salmon of the 97 tested with fluoride present would also make a choice, if fluoride had no delaying effect, and 33 would not.],

$$X^2 = \frac{(45-64)^2}{64} + \frac{(52-33)^2}{33} = 16.58;\ P < 0.001;\ H0 \text{ rejected.}$$

Conclusion: Significantly more "No choices" (delays) occurred when fluoride (0.20 ppm) was present.

3. To test for fluoride avoidance among chinook making a choice,

$$x^2 = \frac{(25-22.5)^2}{22.5} + \frac{(20-22.5)^2}{22.5} = 0.56;\ P > 0.30;\ H_0 \text{ accepted.}$$

Conclusion: Chinook salmon did not avoid fluoride (0.20 ppm) side.

Appendix Table 9.--Choice made by coho salmon when exposed to low concentrations (0.20 ppm) of fluoride in a two-choice flume.

Experimental conditions	Total tests	Results Fluoride side	 Non-Fluoride side	 No choice
Fluoride right side	30	11	8	11
Fluoride left side	21	8	7	6
TOTALS	51	19	15	17
No fluoride either side (control)		(right side)	(left side)	
1984	11	3	2	6
1983	42	13	17	12
TOTALS	53	16	19	18

x^2 analysis

1. To test preference for one side or the other among coho salmon making a choice (no fluoride either side),

$$x^2 = \frac{(3-2.5)^2}{2.5} + \frac{(2-2.5)^2}{2.5} = 0.20;\ P > 0.30;\ HO \text{ accepted.}$$

Conclusion: No preference.

2. To test effects of fluoride on proportion of "No choices" (delays) [Combining 1983 and 1984 data for coho tests without fluoride (because of small sample size in 1984), 66% (35 of 53) of the coho salmon made a choice. It would therefore be expected that 34 coho salmon of the 51 tested with fluoride present would also make a choice, if fluoride had no delaying effect, and 17 would not.],

$$x^2 = \frac{(34-34)^2}{34} + \frac{(17-17)^2}{17} = 0;\ P > 0.30;\ H_o \text{ accepted.}$$

Conclusion: Significantly more "No choices" (delays) did not occur when fluoride (0.20 ppm) was present.

3. To test for fluoride avoidance among coho making a choice,

$$x2 = \frac{(19-17)^2}{17} + \frac{(15-17)^2}{17} = 0.47;\ P > 0.30;\ HO \text{ accepted.}$$

Conclusion: Coho salmon did not avoid fluoride (0.20 ppm) side.