# Effects of Water-borne Pollutants on Fish-passage at John Day Dam, Columbia River

by
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COASTAL ZONE AND ESTUARINE STUDIES

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## BACKGROUND

John Day Dam, completed in 1968, is at Columbia River Mile 216; the John Day Reservoir extends 77 miles upstream to McNary Dam. The John Day River enters the Columbia River about a mile 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 (Figure 1).

John Day Dam has been shown to cause 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 h and 156 h, respectively. This compares unfavorably to less than 2 days for fish passing the first dam (Bonneville) and to less than 1 day for fish passing the second dam (The Dalles). Individual fish tracked below John Day Dam spent most of the time in the tailrace area, just below the dam. Although the fish apparently locate the collection system entrances, the fish are reluctant to enter and remain in the system. Radio-tagged salmonids also delayed at the face of the dam in Fall 1982 (Stuehrenberg[1/]).

Within the limits of project design, altered flows and configurations have not improved fish passage. Delays have not been significantly decreased by changing entrance locations, water discharge volumes, or turbine operating conditions. There has always been a distinct preference for fish to use the south fishway, which is not a problem in itself, but which may ultimately suggest reasons for the general delay (Figure 2).

1/ L. Stuehrenberg, Northwest and Alaska Fisheries Center, National Marine Fisheries Service, Seattle, WA 98112, pers. commun.

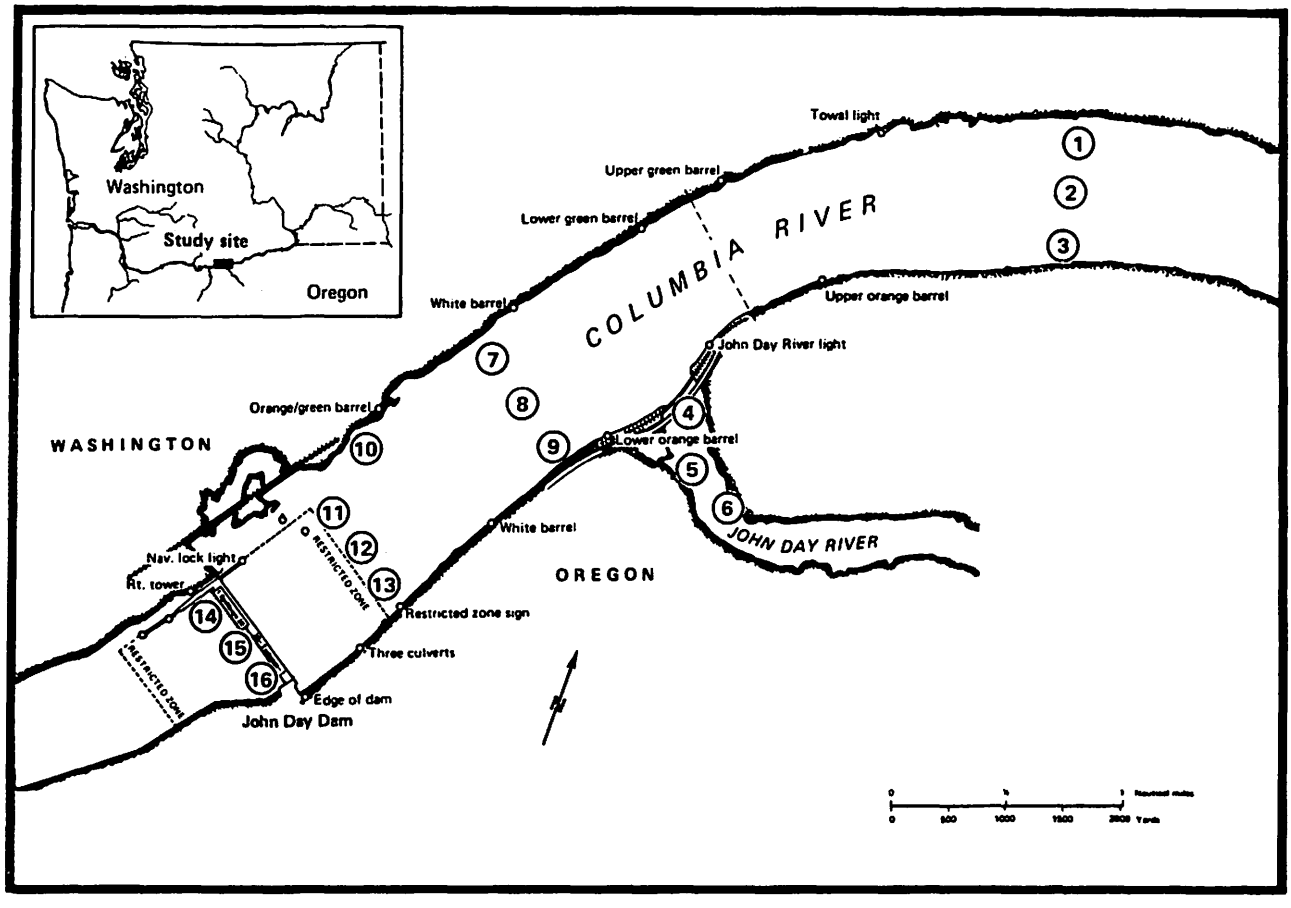


Figure 1.--Study area for adult salmonid passage delay program, John Day Dam region, Columbia River. Circled numbers indicate sampling sites (three sites on downstream side of The Dalles Dam not shown).

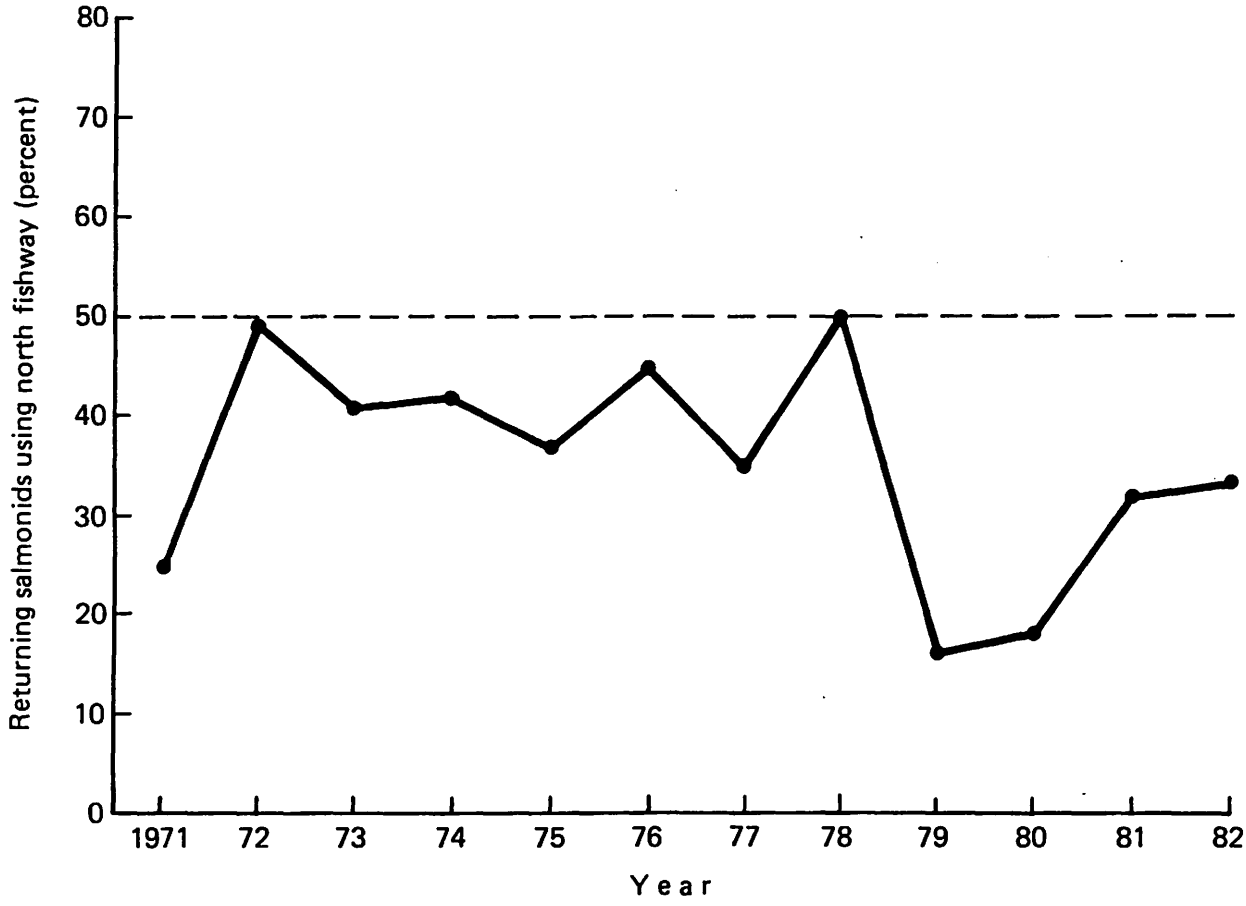


Figure 2.--Returning adult salmonids using north fishway at John Day Dam, Columbia River (1971 through 31 October 1982).

## RESEARCH OBJECTIVES

Because there is evidence that the delay at John Day Dam has caused increased adult mortality and reduced spawning success (Junge[2/]), it is necessary that additional efforts be made to identify and moderate causes of delay. It is believed that water-borne pollutants, especially fluorides, may have a potentially negative influence on fish passage.

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 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.

Describing the pollutant gradients in the waters of the John Day Dam region and relating these pollutants to behavior of salmonids are not simple problems. If the river was 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 altered trajectory of the John Day River plume. During the frequent strong winds, it is apparent that pollutants are moved upstream. From aerial photographs it is apparent that the John Day River plume can sweep the outfall area on 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

2/ C. Junge, Oregon Department of Fish and Game, Clackamas, OR 97015, pers. commun.

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.

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, altering in particular 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 (Figure 3) and previous years. These daily changes do not appear to be random. Except for 8 days, the majority of fish after 1 June 1982, used the south fishway. Before June, in 1982, the majority of salmonids used one fishway or the other for 4 days, <u>on the average</u>, 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

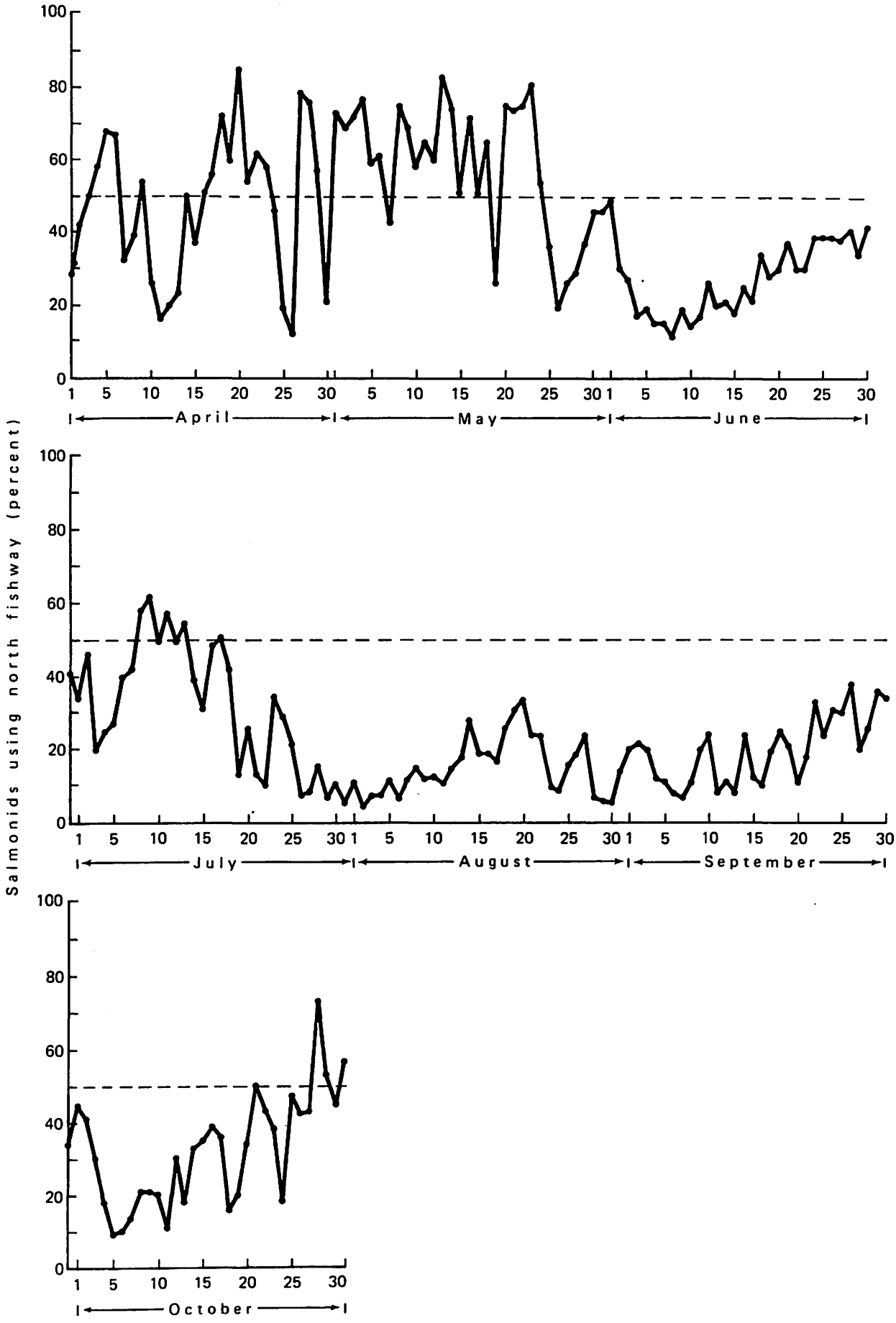


Figure 3.--Returning adult salmonids using north fishway at John Day Dam, Columbia River, 1982; through 31 October 33% passed north fishway and 67% passed south fishway.

gradient perhaps determined in part by the variable trajectory of the John Day River, in the forebay of John Day Dam.

## METHODS

A standard station-grid was established with three transects in the Columbia River and one in the mouth of the John Day River (Figure 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. 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 from both the John Day Dam and The Dalles Dam: the Washington-shore fishway, the central powerhouse area, and the Oregon-shore fishway. Because of the danger to the *in situ* analytical probe, environmental factors were generally not measured at these six stations.

Basic physical characteristics at each station were measured using a Montedoro-Whitney Mark V Water Analyzer®[3/]. This is a self-contained portable system for *in situ* measurements of depth and up to five factors as functions of depth: in this study (1) temperature, (2) dissolved oxygen, (3) pH, and (4) conductivity. The system consists of a power/control unit with liquid crystal display panel, individual sensor calibration controls and sensor selector switch, a multiconductor cable supplying power to the sensor amplifiers and carrying signals back to the surface unit, and the underwater probe containing the sensor signal conditioning amplifiers and sensors. All sensors are

3/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

temperature and pressure compensated. The depth sensor consists of an absolute pressure transducer which reads pressure with respect to a vacuum. A zero control corrects for changes in elevation and atmospheric pressure; accuracy of this sensor is well within 1/2% of full scale with a standard resolution of 1 cm. A linearized thermistor mounted inside the conductivity sensor is used for temperature measurement over a range of 0-50°C. The dissolved oxygen sensor is a polarographic membrane unit containing a gold cathode and a silver anode; a pump constantly circulates ambient water in contact with the sensor membrane. The pH sensor consists of a glass electrode, a silver/silver chloride reference electrode, and a thermistor temperature compensation element. The conductivity sensor is a three-electrode type that operates over a range of 10 mhos to 65 mmhos.

Water samples for inorganic analyses and turbidity measurements were collected using a Niskin® 2.5-l closing water-bottle, 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). The instrument is factory calibrated against internationally accepted formazin solutions; standard reference solutions allow routine one-point standardizations for the full range capability of 0-200 nephelometric turbidity units (NTU). Linearity, precision, and range congruence are ± 1% of full scale, and sensitivity is 0.02 NTU.

All inorganic chemical analyses were performed by the Water Quality Laboratory, Fisheries Research Institute, University of Washington. The most sophisticated instrumental techniques available were used to identify and quantify the target elements and compounds in the water and sediment samples. Depending on analyses, water and sediment subsamples were treated in various ways upon collection: subsamples for metal analyses were acidified with glass-distilled Ultrex® nitric acid, pellets of sodium hydroxide were added to subsamples for cyanide analyses, nitrate/nitrite subsamples were frozen in dry ice, subsamples for fluoride analyses were cooled in an ice chest and then refrigerated, other subsamples were not treated.

The following elements were determined by flameless atomic absorption: aluminum, arsenic, barium, cadmium, chromium, copper, iron, lead, manganese, mercury, selenium, silver, sodium, and zinc. The procedures followed were those described in EPA's Manual 600/4-79-020. The method involves a nitric acid--hydrogen peroxide digestion of the samples to reduce any matrix effects. In the digestion procedure, Ultrex (J.T. Baker Co., Phillipsburg, N.J.) grade of nitric acid was used for the hydrolysis. This acid contains less than 0.001 mg of heavy metals per liter and does not contribute to the metal concentrations in the river water.

The instrument used in the metal analyses was a Zeaman effect atomic absorption spectrophotometer (ZEAAS), which analyzes metals directly in aqueous or organic hydrolysates without costly extraction. A polarographic analyzer,

which is capable of distinguishing bound, labile, and total forms of metals, was used for confirmational analyses. Mercury was analzyed on the same instrument utilizing a cold vapor technique as described in the 15th edition of Standard Methods for the examination of water and wastewater. Cyanide and fluoride were determined by ion-specific electrodes as described in Standard Methods, utilizing an appropriate buffer to prevent interference by cations such as Al 111, Fe 111, or Si 111. Nitrate was determined by cadmium reduction to nitrite and assayed colorimetrically using the Standard Methods procedure with the sulfanilamide reagent (p. 380, 15th ed., Standard Methods). Sulfate and chloride ion were assayed colorimetrically in an autoanalyzer as described in the 15th edition of Standard Methods. The sulfate ion was determined by the methylthymol blue method and the chloride ion by the ferricyanide method. Standard additions were used in all tests, and comparison was made with Environmental Protection Agency (EPA) and National Bureau of Standards (NBS) standards.

Surface samples for organic analyses were collected in a specially prepared 4-l glass bottle; subsurface samples for organic analyses were collected with the Niskin 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; water samples (800-1000 ml) were acidified to pH 1-3 and extracted three times with 50 ml of dichloromethane. The extract from each sample was concentrated to about 1 ml for gas chromatographic (GC) analysis for all compounds except 2, 4-D, and 2, 4, 5-TP.

For analysis of the latter two, the extracts were heated with boron trifluoride-methanol to methylate them for GC analysis.

Sediment samples were extracted using the procedure reported by Malins et al. (1980). The extraction involves removal of water with methanol and extraction with dichloromethane/methanol on a ball-mill tumbler. Column chromatography on $SiO_2$ and Sephadex LH-20 was used to isolate the fraction containing the compounds for GC analysis.

The prepared extracts were analyzed for the compounds by GC, using flame ionization, electron capture, and mass spectrometer detectors (Malins et al. 1980). Added internal standards were used for quantification and the results were corrected for losses during sample preparation.

## RESULTS AND CONCLUSIONS

### Physical Characteristics

Dates, times, locations, depths of measurement, and corresponding physical characteristics of river water in the John Day Dam region are given in Tables 1-7. Often, Station 10 (at the aluminum plant outfall) was sampled more than once during a cruise, and the multiple observation times are indicated by consecutive numbers. Some chemical analyses from Station 10 samples were composite samples taken over several hours during some cruises; these are indicated by "10-C." During Cruise IV (10-11 June), observations were made in the lagoon on the Washington shore between Station 10 and the John Day Dam (Figure 1). This lagoon is directly open to the Columbia River only by a culvert near the upstream end. The culvert is just large enough to pass the 24-foot Bayliner® boat used as a sampling platform. Station L-1 is just inside the lagoon from this entrance; Station L-2 is at the southwest end of the

Table 1.--Physical characteristics of river water in the John Day Dam region, Columbia River, 1-4 April 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 2 Apr | 1020 | 36.6 | 0 | 6.60 | 8.9 | 0.15 | 13.4 | 9.0 | |
| | | | | 5 | 6.61 | 8.9 | 0.14 | 13.4 | - | |
| | | | | 10 | 6.57 | 8.9 | 0.15 | 13.4 | - | |
| | | | | 15 | 6.56 | 8.8 | 0.14 | 13.4 | 10.0 | |
| | | | | 20 | 6.54 | 8.8 | 0.14 | 13.5 | - | |
| | | | | 30 | 6.54 | 8.7 | 0.14 | 13.5 | - | |
| | | | | 35 | 6.54 | 8.6 | 0.14 | 13.6 | 17.5 | |
| 2 | 2 Apr | 1130 | 31.1 | 0 | 6.48 | 9.0 | 0.15 | 13.3 | 10.0 | |
| | | | | 5 | 6.50 | 8.9 | 0.15 | 13.4 | - | |
| | | | | 10 | 6.48 | 8.8 | 0.15 | 13.4 | - | |
| | | | | 15 | 6.47 | 8.8 | 0.15 | 13.4 | 10.5 | |
| | | | | 20 | 6.47 | 8.7 | 0.15 | 13.4 | - | |
| | | | | 30 | 6.48 | 8.6 | 0.15 | 13.6 | 10.0 | |
| 3 | 2 Apr | 1200 | 20.1 | 0 | 6.55 | 8.8 | 0.15 | 13.4 | 11.0 | |
| | | | | 5 | 6.51 | 8.7 | 0.15 | 13.4 | - | |
| | | | | 10 | 6.52 | 8.7 | 0.15 | 13.4 | 11.0 | |
| | | | | 20 | 6.52 | 8.6 | 0.15 | 13.5 | 13.0 | |
| 4 | 2 Apr | 1620 | 18.0 | 0 | 8.57 | 9.1 | 0.16 | 11.6 | 17.5 | |
| | | | | 5 | 8.58 | 9.2 | 0.16 | 11.4 | - | |
| | | | | 10 | 8.18 | 9.0 | 0.16 | 11.4 | 18.5 | |
| | | | | 15 | 7.90 | 8.9 | 0.16 | 11.9 | 17.0 | |
| | | | | 17 | 7.91 | 8.8 | 0.16 | 12.2 | - | |
| 5 | 2 Apr | 1715 | 19.0 | 0 | 8.34 | 9.0 | 0.16 | 11.5 | 22.0 | |
| | | | | 5 | 8.11 | 9.1 | 0.16 | 11.6 | - | |
| | | | | 10 | 7.93 | 8.9 | 0.16 | 11.9 | 18.0 | |
| | | | | 15 | 7.70 | 8.9 | 0.16 | 11.9 | - | |
| | | | | 18 | 7.26 | 8.7 | 0.15 | 12.7 | 15.5 | |

Table 1.--continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 2 Apr | 1750 | 19.0 | 0 | 8.29 | 8.9 | 0.16 | 11.5 | 20.0 | |
| | | | | 5 | 8.28 | 8.9 | 0.16 | 11.5 | - | |
| | | | | 10 | 8.26 | 8.9 | 0.16 | 11.8 | 19.0 | |
| | | | | 15 | 8.15 | 8.9 | 0.16 | 11.8 | - | |
| | | | | 18 | 8.06 | 8.8 | 0.16 | 11.8 | 18.0 | |
| 7 | 3 Apr | 1115 | 31.0 | 0 | 6.8 | - | - | - | 10.0 | Equip. failure; |
| | | | | 15 | - | - | - | - | 9.5 | all water samples |
| | | | | 30 | - | - | - | - | 11.0 | collected. |
| 8 | 3 Apr | 1150 | 30.0 | 0 | 6.9 | - | - | - | 11.0 | |
| | | | | 15 | - | - | - | - | 11.0 | |
| | | | | 27 | - | - | - | - | 10.5 | |
| 9 | 3 Apr | 1220 | 29.0 | 0 | 7.0 | - | - | - | 13.0 | |
| | | | | 15 | - | - | - | - | 14.0 | |
| | | | | 28 | - | - | - | - | 13.0 | |
| 10-1 | 1 Apr | 1645 | 40.0 | 0 | 7.3 | 8.8 | 0.13 | 13.6 | - | |
| | | | | 5 | 6.9 | 8.8 | 0.13 | 13.6 | - | |
| | | | | 10 | 6.8 | 8.8 | 0.13 | 13.6 | - | |
| | | | | 15 | 6.8 | 8.7 | 0.13 | 13.6 | - | |
| | | | | 20 | 6.8 | 8.8 | 0.13 | 13.6 | - | |
| | | | | 25 | 6.7 | 8.7 | 0.13 | 13.6 | - | |
| | | | | 30 | 6.7 | 8.7 | 0.13 | 13.6 | - | |
| 10-2 | 2 Apr | 0850 | 30.5 | 0 | 6.7 | 8.8 | 0.14 | 13.4 | 9.0 | |
| | | | | 5 | 6.7 | 8.8 | 0.14 | 13.4 | - | |
| | | | | 10 | 6.7 | 8.7 | 0.14 | 13.4 | 9.4 | |
| | | | | 20 | 6.6 | 8.7 | 0.14 | 13.5 | - | |
| | | | | 25 | 6.6 | 8.7 | 0.14 | 13.5 | 9.4 | |
| 10-3 | 2 Apr | 1440 | 30.0 | 0 | 6.71 | 8.8 | 0.15 | 13.4 | 9.5 | High winds |
| | | | | 5 | 6.68 | 8.7 | 0.15 | 13.5 | - | |
| | | | | 10 | 6.70 | 8.7 | 0.15 | 13.6 | - | |
| | | | | 13 | 6.70 | - | - | - | 11.0 | |
| | | | | 30 | - | - | - | - | 9.8 | |

Table 1.--continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10-4 | 3 Apr | 1030 | 40.0 | 0 | - | - | - | - | 8.8 | Equip. failure; all water samples collected. |
| | | | | 15 | - | - | - | - | 10.0 | |
| | | | | 30 | - | - | - | - | 9.4 | |
| 10-5 | 3 Apr | 1400 | 30.0 | 0 | 6.9 | - | - | - | 10.0 | |
| | | | | 15 | - | - | - | - | 10.0 | |
| | | | | 30 | - | - | - | - | 11.0 | |
| 10-6 | 4 Apr | 0845 | 30.0 | 0 | 6.8 | - | - | - | 10.0 | High winds |
| | | | | 15 | - | - | - | - | 10.0 | |
| | | | | 30 | - | - | - | - | 10.5 | |
| 11 | 3 Apr | 1420 | 30.0 | 0 | 6.8 | - | - | - | 11.0 | High winds |
| | | | | 15 | - | - | - | - | 11.0 | |
| | | | | 30 | - | - | - | - | 11.0 | |
| 12 | 3 Apr | 1444 | 36.6 | 0 | 6.9 | - | - | - | 11.0 | High winds |
| | | | | 15 | - | - | - | - | 11.0 | |
| | | | | 30 | - | - | - | - | 11.0 | |
| 13 | 3 Apr | 1520 | 36.6 | 0 | 7.0 | - | - | - | 12.0 | High winds |
| | | | | 15 | - | - | - | - | 12.5 | |
| | | | | 30 | - | - | - | - | 13.0 | |
| 14 | 3 Apr | 1730 | - | 0 | - | - | - | - | 9.7 | |
| 15 | 3 Apr | 1650 | - | 0 | - | - | - | - | 10.0 | |
| 16 | 3 Apr | 1640 | - | 0 | - | - | - | - | 12.0 | |
| 17 | 4 Apr | 1220 | - | 0 | - | - | - | - | 11.0 | |
| 18 | 4 Apr | 1245 | - | 0 | - | - | - | - | 12.5 | |
| 19 | 4 Apr | 1310 | - | 0 | - | - | - | - | 12.0 | |

Table 2.--Physical characteristics of river water in the John Day Dam region, Columbia River, 23-25 April 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 24 Apr | 1010 | 30.5 | 0 | 8.86 | - | 0.17 | 13.3 | 26.0 | Equip. failure |
| | | | | 5 | 8.75 | - | 0.17 | 13.3 | - | (pH); all |
| | | | | 10 | 8.70 | - | 0.17 | 13.4 | - | water samples |
| | | | | 15 | 8.70 | - | 0.17 | 13.4 | 27.0 | collected |
| | | | | 20 | 8.71 | - | 0.17 | 13.4 | - | |
| | | | | 25 | 8.71 | - | 0.17 | 13.5 | - | |
| | | | | 30 | 8.77 | - | 0.17 | 13.8 | 26.0 | |
| 2 | 24 Apr | 1045 | 33.5 | 0 | 8.90 | - | 0.17 | 13.4 | 25.0 | |
| | | | | 5 | 8.75 | - | 0.17 | 13.3 | - | |
| | | | | 10 | 8.74 | - | 0.17 | 13.3 | - | |
| | | | | 15 | 8.69 | - | 0.17 | 13.3 | 27.0 | |
| | | | | 20 | 8.70 | - | 0.17 | 13.4 | - | |
| | | | | 25 | 8.70 | - | 0.17 | 13.5 | - | |
| | | | | 30 | 8.74 | - | 0.17 | 13.7 | 28.0 | |
| 3 | 24 Apr | 1210 | 21.3 | 0 | 8.91 | - | 0.17 | 13.4 | 29.0 | |
| | | | | 5 | 8.70 | - | 0.17 | 13.3 | - | |
| | | | | 10 | 8.67 | - | 0.17 | 13.4 | 30.0 | |
| | | | | 15 | 8.67 | - | 0.17 | 13.5 | - | |
| | | | | 20 | 8.78 | - | 0.17 | 13.7 | 29.0 | |
| 4 | 24 Apr | 1715 | 18.0 | 0 | 13.48 | - | 0.16 | 10.6 | 22.0 | |
| | | | | 5 | 13.40 | - | 0.16 | 10.6 | - | |
| | | | | 10 | 10.42 | - | 0.16 | 11.5 | 23.0 | |
| | | | | 15 | 9.20 | - | 0.17 | 13.2 | 22.0 | |
| 5 | 24 Apr | 1830 | 27.0 | 0 | 13.32 | - | 0.16 | 10.4 | 22.0 | |
| | | | | 5 | 13.10 | - | 0.16 | 10.5 | - | |
| | | | | 10 | 10.74 | - | 0.16 | 11.5 | - | |
| | | | | 15 | 9.54 | - | 0.16 | 12.5 | 29.0 | |
| | | | | 20 | 9.00 | - | 0.17 | 12.8 | - | |
| | | | | 25 | 8.91 | - | 0.17 | 13.2 | 32.0 | |

Table 2.--continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 6 | 24 Apr | 1930 | 15.2 | 0 | 13.20 | - | 0.16 | 10.5 | 22.0 | |
| | | | | 5 | 13.15 | - | 0.16 | 10.5 | - | |
| | | | | 10 | 11.93 | - | 0.15 | 10.9 | 24.0 | |
| | | | | 15 | 9.69 | - | 0.16 | 12.4 | 28.0 | |
| 7 | 24 Apr | 0705 | 35.0 | 0 | 8.65 | - | 0.17 | 13.4 | 27.0 | |
| | | | | 5 | 8.63 | - | 0.16 | 13.4 | - | |
| | | | | 10 | 8.63 | - | 0.16 | 13.4 | - | |
| | | | | 15 | 8.63 | - | 0.16 | 13.4 | 27.0 | |
| | | | | 20 | 8.64 | - | 0.16 | 13.5 | - | |
| | | | | 25 | 8.64 | - | 0.16 | 13.5 | - | |
| | | | | 30 | 8.66 | - | 0.16 | 13.7 | 27.0 | |
| 8 | 24 Apr | 0755 | 26.0 | 0 | 8.88 | - | 0.17 | 13.2 | 26.0 | |
| | | | | 5 | 8.83 | - | 0.16 | 13.2 | - | |
| | | | | 10 | 8.76 | - | 0.16 | 13.3 | - | |
| | | | | 15 | 8.70 | - | 0.17 | 13.4 | 28.0 | |
| | | | | 20 | 8.67 | - | 0.17 | 13.6 | - | |
| | | | | 25 | 8.68 | - | 0.17 | 13.8 | 28.0 | |
| 9 | 24 Apr | 0830 | 35.0 | 0 | 9.05 | - | 0.17 | 12.7 | 28.0 | |
| | | | | 5 | 9.06 | - | 0.16 | 12.7 | - | |
| | | | | 10 | 9.00 | - | 0.16 | 12.7 | - | |
| | | | | 15 | 8.86 | - | 0.16 | 12.7 | 30.0 | |
| | | | | 20 | 8.81 | - | 0.16 | 12.8 | - | |
| | | | | 25 | 8.81 | - | 0.16 | 13.0 | - | |
| | | | | 30 | 8.80 | - | 0.16 | 13.1 | 31.0 | |
| 10-1 | 23 Apr | 1830 | 30.0 | 0 | 8.60 | 8.4 | 0.16 | 13.5 | 25.0 | High winds; equip. failure |
| | | | | 5 | 8.58 | 8.3 | 0.16 | 13.6 | - | |
| | | | | 10 | 8.58 | 8.2 | 0.16 | 13.8 | 26.0 | |
| | | | | 15 | 8.57 | 7.9 | 0.16 | 14.1 | 26.0 | |
| 10-2 | 24 Apr | 0615 | 30.0 | 0 | 8.61 | - | 0.17 | 13.5 | 26.0 | |
| | | | | 5 | 8.61 | - | 0.16 | 13.5 | - | |
| | | | | 10 | 8.61 | - | 0.16 | 13.5 | - | |
| | | | | 15 | 8.61 | - | 0.16 | 13.5 | 27.0 | |
| | | | | 20 | 8.61 | - | 0.16 | 13.5 | - | |
| | | | | 25 | 8.62 | - | 0.16 | 13.5 | - | |
| | | | | 30 | 8.63 | - | 0.16 | 13.8 | 28.0 | |

Table 2.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10-3 | 24 Apr | 1340 | 26.0 | 0 | 9.06 | - | 0.17 | 13.6 | 26.0 |
| | | | | 5 | 9.50 | - | 0.17 | 13.7 | - |
| | | | | 10 | 8.84 | - | 0.17 | 13.9 | - |
| | | | | 15 | 8.83 | - | 0.17 | 13.4 | 26.0 |
| | | | | 20 | 8.82 | - | 0.17 | 13.5 | - |
| | | | | 25 | 8.96 | - | 0.17 | 13.8 | 26.0 |
| 10-4 | 24 Apr | 2030 | 35.0 | 0 | - | - | - | - | 25.0 |
| | | | | 15 | - | - | - | - | 25.0 |
| | | | | 30 | - | - | - | - | 25.0 |
| 10-5 | 25 Apr | 0900 | 35.0 | 0 | 9.45 | - | 0.17 | 12.9 | 21.0 |
| | | | | 5 | 9.19 | - | 0.16 | 12.9 | - |
| | | | | 10 | 9.06 | - | 0.16 | 13.0 | - |
| | | | | 15 | 8.98 | - | 0.16 | 13.1 | 22.0 |
| | | | | 20 | 8.95 | - | 0.16 | 13.2 | - |
| | | | | 25 | 8.94 | - | 0.16 | 13.2 | - |
| | | | | 30 | 8.93 | - | 0.16 | 13.3 | 23.0 |
| 10-6 | 25 Apr | 1150 | 35.0 | 0 | 9.45 | - | 0.17 | 13.0 | 21.0 |
| | | | | 5 | 9.23 | - | 0.17 | 13.0 | - |
| | | | | 10 | 8.99 | - | 0.17 | 13.2 | - |
| | | | | 15 | 8.99 | - | 0.17 | 13.2 | 23.0 |
| | | | | 20 | 8.95 | - | 0.16 | 13.3 | - |
| | | | | 25 | 8.96 | - | 0.17 | 13.3 | - |
| | | | | 30 | 8.99 | - | 0.17 | 13.4 | 23.0 |
| 11 | 25 Apr | 1000 | 22.0 | 0 | 9.15 | - | 0.17 | 13.1 | 21.0 |
| | | | | 5 | 8.99 | - | 0.17 | 13.1 | - |
| | | | | 10 | 8.95 | - | 0.17 | 13.1 | 22.0 |
| | | | | 15 | 8.95 | - | 0.17 | 13.1 | - |
| | | | | 20 | 8.97 | - | 0.17 | 13.2 | 22.0 |
| 12 | 25 Apr | 1045 | 21.0 | 0 | 9.55 | - | 0.17 | 13.0 | 20.0 |
| | | | | 5 | 9.37 | - | 0.17 | 12.9 | - |
| | | | | 10 | 9.02 | - | 0.17 | 13.2 | 24.0 |
| | | | | 15 | 8.90 | - | 0.17 | 13.3 | - |
| | | | | 20 | 8.91 | - | 0.17 | 13.5 | 24.0 |

Table 2.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 25 Apr | 1110 | 22.0 | 0 | 9.98 | - | 0.17 | 12.8 | 22.0 |
| | | | | 5 | 9.58 | - | 0.17 | 12.9 | - |
| | | | | 10 | 9.45 | - | 0.17 | 12.7 | 25.0 |
| | | | | 15 | 8.85 | - | 0.17 | 13.2 | - |
| | | | | 20 | 8.85 | - | 0.17 | 13.2 | 26.0 |
| 14 | 24 Apr | 1540 | - | 0 | - | - | - | - | 28.0 |
| 15 | 24 Apr | 1600 | - | 0 | - | - | - | - | 31.0 |
| 16 | 24 Apr | 1610 | - | 0 | - | - | - | - | 30.0 |
| 17 | 23 Apr | 1455 | - | 0 | - | - | - | - | 33.0 |
| 18 | 23 Apr | 1420 | - | 0 | - | - | - | - | 32.0 |
| 19 | 23 Apr | 1437 | - | 0 | - | - | - | - | 38.0 |

Table 3.--Physical characteristics of river water in the John Day Dam region, Columbia River, 14-15 May 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 15 May | 0930 | 32.9 | 0 | 12.01 | 8.9 | 0.14 | 12.9 | 9.0 | |
| | | | | 5 | 11.53 | 8.8 | 0.14 | 12.9 | - | |
| | | | | 10 | 11.50 | 8.8 | 0.14 | 12.9 | - | |
| | | | | 15 | 11.48 | 8.8 | 0.14 | 13.0 | 10.0 | |
| | | | | 20 | 11.53 | 8.8 | 0.14 | 13.0 | - | |
| | | | | 25 | 11.57 | 8.8 | 0.14 | 13.1 | - | |
| | | | | 30 | 11.60 | 8.8 | 0.14 | 13.3 | 11.0 | |
| 2 | 15 May | 1000 | 31.1 | 0 | 11.74 | 8.9 | 0.14 | 12.9 | 9.0 | |
| | | | | 5 | 11.45 | 8.7 | 0.14 | 12.9 | - | |
| | | | | 10 | 11.41 | 8.7 | 0.14 | 12.9 | - | |
| | | | | 15 | 11.41 | 8.8 | 0.14 | 12.9 | - | |
| | | | | 20 | 11.40 | 8.7 | 0.14 | 13.0 | - | |
| | | | | 25 | 11.41 | 8.8 | 0.14 | 13.1 | - | |
| | | | | 30 | 11.42 | 8.8 | 0.14 | 13.3 | 11.0 | |
| 3 | 15 May | 1030 | 32.9 | 0 | 11.81 | 8.8 | 0.14 | 12.9 | 9.0 | |
| | | | | 5 | 11.65 | 8.9 | 0.14 | 12.8 | - | |
| | | | | 10 | 11.45 | 8.8 | 0.14 | 12.8 | - | |
| | | | | 15 | 11.38 | 8.8 | 0.14 | 12.8 | 12.0 | |
| | | | | 20 | 11.37 | 8.8 | 0.14 | 12.9 | - | |
| | | | | 25 | 11.38 | 8.8 | 0.14 | 13.0 | - | |
| | | | | 30 | 11.41 | 8.8 | 0.14 | 13.3 | 12.0 | |
| 4 | 15 May | 1410 | 18.0 | 0 | 15.73 | 8.5 | 0.13 | 10.6 | 18.0 | |
| | | | | 5 | 14.21 | 8.6 | 0.13 | 10.8 | - | |
| | | | | 7.5 | 13.94 | 8.6 | 0.13 | 10.9 | 21.0 | |
| | | | | 10 | 13.54 | 8.6 | 0.13 | 11.1 | - | |
| | | | | 15 | 11.96 | 8.7 | 0.14 | 12.6 | 15.0 | |

Table 3.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 5 | 15 May | 1500 | 27.4 | 0 | 16.01 | 8.5 | 0.14 | 10.6 | 18.0 |
| | | | | 5 | 14.17 | 8.6 | 0.13 | 10.8 | - |
| | | | | 10 | 13.27 | 8.6 | 0.13 | 11.2 | - |
| | | | | 15 | 11.98 | 8.7 | 0.14 | 12.7 | 14.0 |
| | | | | 20 | 11.70 | 8.8 | 0.14 | 12.7 | - |
| | | | | 25 | 11.92 | 8.8 | 0.14 | 12.9 | 16.0 |
| 6 | 15 May | 1530 | 25.6 | 0 | 15.95 | 8.6 | 0.14 | 10.7 | 19.0 |
| | | | | 5 | 14.51 | 8.6 | 0.13 | 10.9 | - |
| | | | | 10 | 13.09 | 8.7 | 0.13 | 11.4 | - |
| | | | | 15 | 11.85 | 8.8 | 0.14 | 12.7 | 14.0 |
| | | | | 20 | 11.92 | 8.8 | 0.14 | 13.0 | - |
| | | | | 25 | 12.00 | 8.8 | 0.14 | 13.3 | 15.0 |
| 7 | 14 May | 1820 | 35.0 | 0 | 11.53 | 8.6 | 0.14 | 13.1 | 9.0 |
| | | | | 5 | 11.46 | 8.7 | 0.14 | 13.1 | - |
| | | | | 10 | 11.43 | 8.6 | 0.14 | 13.1 | - |
| | | | | 15 | 11.44 | 8.6 | 0.14 | 13.2 | 10.0 |
| | | | | 20 | 11.43 | 8.6 | 0.14 | 13.3 | - |
| | | | | 25 | 11.43 | 8.6 | 0.14 | 13.7 | - |
| | | | | 30 | 11.54 | 8.6 | 0.14 | 13.7 | 12.0 |
| 8 | 14 May | 1900 | 27.4 | 0 | 11.63 | 8.6 | 0.14 | 12.9 | 10.0 |
| | | | | 5 | 11.56 | 8.6 | 0.14 | 12.9 | - |
| | | | | 10 | 11.43 | 8.5 | 0.14 | 13.0 | - |
| | | | | 15 | 11.38 | 8.5 | 0.14 | 13.0 | 11.0 |
| | | | | 20 | 11.38 | 8.6 | 0.14 | 13.3 | - |
| | | | | 25 | 11.36 | 8.6 | 0.14 | 13.0 | 12.0 |
| 9 | 14 May | 1940 | 31.1 | 0 | 11.63 | 8.7 | 0.14 | 12.9 | 10.0 |
| | | | | 5 | 11.61 | 8.6 | 0.14 | 12.9 | - |
| | | | | 10 | 11.44 | 8.6 | 0.14 | 13.0 | - |
| | | | | 15 | 11.33 | 8.6 | 0.14 | 13.0 | 12.0 |
| | | | | 20 | 11.35 | 8.6 | 0.14 | 13.1 | - |
| | | | | 25 | 11.37 | 8.6 | 0.14 | 13.2 | - |
| | | | | 30 | 11.39 | 8.6 | 0.14 | 13.3 | 12.0 |

Table 3.--continued

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 10-1 | 14 May | 1750 | 31.0 | 0 | 11.99 | 8.7 | 0.14 | 13.1 | 9.0 | |
| | | | | 5 | 11.76 | 8.7 | 0.14 | 13.1 | - | |
| | | | | 10 | 11.67 | 8.7 | 0.14 | 13.2 | - | |
| | | | | 15 | 11.57 | 8.6 | 0.14 | 13.2 | 10.0 | |
| | | | | 20 | 11.60 | 8.7 | 0.14 | 13.3 | - | |
| | | | | 25 | 11.57 | 8.7 | 0.14 | 13.3 | - | |
| | | | | 30 | 11.60 | 8.6 | 0.14 | 13.4 | 10.0 | |
| 10-2 | 15 May | 1110 | 33.8 | 0 | 12.01 | 9.0 | 0.14 | 12.8 | 9.0 | |
| | | | | 5 | 11.62 | 8.9 | 0.14 | 12.8 | - | |
| | | | | 10 | 11.55 | 8.9 | 0.14 | 12.8 | - | |
| | | | | 15 | 11.56 | 8.8 | 0.14 | 12.8 | 10.0 | |
| | | | | 20 | 11.58 | 8.8 | 0.14 | 12.8 | - | |
| | | | | 25 | 11.65 | 8.8 | 0.14 | 12.8 | - | |
| | | | | 30 | 11.76 | 8.8 | 0.14 | 12.8 | 10.0 | |
| 10+ | 15 May | 1210 | 40.0 | 39.5 | - | - | - | - | 11.0 | Deep hole near 10 |
| 11 | 15 May | 0700 | 32.9 | 0 | 11.47 | 8.7 | 0.14 | 13.0 | 10.0 | |
| | | | | 5 | 11.45 | 8.7 | 0.14 | 13.1 | - | |
| | | | | 10 | 11.46 | 8.7 | 0.14 | 13.1 | - | |
| | | | | 15 | 11.46 | 8.6 | 0.14 | 13.1 | 10.0 | |
| | | | | 20 | 11.46 | 8.6 | 0.14 | 13.2 | - | |
| | | | | 25 | 11.46 | 8.6 | 0.14 | 13.2 | - | |
| | | | | 30 | 11.46 | 8.7 | 0.14 | 13.4 | 10.0 | |
| 12 | 15 May | 0800 | 31.1 | 0 | 11.63 | 8.7 | 0.14 | 12.9 | 10.0 | |
| | | | | 5 | 11.54 | 8.7 | 0.14 | 12.9 | - | |
| | | | | 10 | 11.46 | 8.6 | 0.14 | 13.0 | - | |
| | | | | 15 | 11.51 | 8.7 | 0.14 | 13.1 | 11.0 | |
| | | | | 20 | 11.45 | 8.7 | 0.14 | 13.2 | - | |
| | | | | 25 | 11.44 | 8.7 | 0.14 | 13.3 | - | |
| | | | | 30 | 11.44 | 8.7 | 0.14 | 13.4 | 11.0 | |

Table 3.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 13 | 15 May | 0830 | 32.9 | 0 | 11.88 | 8.8 | 0.14 | 12.3 | 11.0 |
| | | | | 5 | 11.76 | 8.7 | 0.14 | 12.5 | - |
| | | | | 10 | 11.70 | 8.7 | 0.14 | 12.6 | - |
| | | | | 15 | 11.63 | 8.6 | 0.14 | 12.8 | 12.0 |
| | | | | 20 | 11.42 | 8.6 | 0.14 | 13.0 | - |
| | | | | 25 | 11.42 | 8.6 | 0.14 | 13.3 | - |
| | | | | 30 | 11.42 | 8.7 | 0.14 | 13.4 | 12.0 |
| 14 | 15 May | 1233 | - | 0 | - | - | - | - | 11.0 |
| 15 | 15 May | 1255 | - | 0 | - | - | - | - | 12.0 |
| 16 | 15 May | 1305 | - | 0 | - | - | - | - | 13.0 |
| 17 | 14 May | 1455 | - | 0 | - | - | - | - | 14.0 |
| 18 | 14 May | 1420 | - | 0 | - | - | - | - | 12.0 |
| 19 | 14 May | 1435 | - | 0 | - | - | - | - | 12.0 |

Table 4.--Physical characteristics of river water in the John Day Dam region, Columbia River, 10-11 June 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 11 Jun | 0745 | 43.9 | 0 | 14.09 | 9.2 | 0.11 | 12.2 | 7.0 | |
| | | | | 5 | 13.87 | 9.2 | 0.11 | 12.1 | - | |
| | | | | 10 | 13.88 | 9.2 | 0.11 | 12.1 | - | |
| | | | | 15 | 13.78 | 9.1 | 0.11 | 12.1 | 8.0 | |
| | | | | 20 | 13.75 | 9.1 | 0.11 | 12.3 | - | |
| | | | | 25 | 13.78 | 9.2 | 0.11 | 12.5 | - | |
| | | | | 30 | 13.81 | 9.3 | 0.11 | 12.7 | - | |
| | | | | 35 | 13.86 | 9.3 | 0.11 | 13.6 | 9.0 | |
| 6 | 11 Jun | 0830 | 25.6 | 0 | 18.68 | 9.1 | 0.14 | 9.3 | 14.0 | |
| | | | | 5 | 18.21 | 9.2 | 0.13 | 9.6 | - | |
| | | | | 10 | 13.61 | 9.2 | 0.11 | 11.6 | 11.0 | |
| | | | | 15 | 13.51 | 9.2 | 0.11 | 11.5 | - | |
| | | | | 20 | 13.57 | 9.2 | 0.11 | 11.7 | 10.0 | |
| 7 | 10 Jun | 1800 | 35.0 | 0 | 16.33 | 9.4 | 0.11 | 12.0 | 7.0 | |
| | | | | 5 | 14.20 | 9.2 | 0.11 | 12.1 | - | |
| | | | | 10 | 13.77 | 9.1 | 0.11 | 12.0 | - | |
| | | | | 15 | 13.71 | 9.1 | 0.11 | 12.2 | 10.0 | |
| | | | | 20 | 13.65 | 9.1 | 0.11 | 12.9 | - | |
| | | | | 25 | 13.71 | 9.2 | 0.11 | 13.1 | - | |
| | | | | 30 | 13.86 | 9.2 | 0.11 | 13.3 | 11.0 | |
| 9 | 10 Jun | 1730 | 32.9 | 0 | 15.36 | 9.0 | 0.12 | 11.0 | 12.0 | |
| | | | | 5 | 13.73 | 8.9 | 0.11 | 11.4 | - | |
| | | | | 10 | 13.56 | 8.9 | 0.11 | 11.6 | - | |
| | | | | 15 | 13.55 | 8.9 | 0.10 | 11.7 | 12.0 | |
| | | | | 20 | 13.55 | 8.9 | 0.10 | 11.9 | - | |
| | | | | 25 | 13.55 | 9.0 | 0.10 | 12.7 | - | |
| | | | | 30 | 13.72 | 9.1 | 0.10 | 13.0 | 11.0 | |

Table 4.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 10 | 11 Jun | 0920 | 31.0 | 0 | 14.32 | 9.4 | 0.11 | 11.9 | 7.0 |
| | | | | 5 | 14.02 | 9.4 | 0.11 | 11.9 | - |
| | | | | 10 | 13.94 | 9.3 | 0.11 | 12.0 | - |
| | | | | 15 | 13.93 | 9.3 | 0.11 | 12.0 | 9.0 |
| | | | | 20 | 13.89 | 9.3 | 0.11 | 12.0 | - |
| | | | | 25 | 13.91 | 9.3 | 0.11 | 12.1 | - |
| | | | | 30 | 13.94 | 9.4 | 0.11 | 12.2 | 9.0 |
| L-1 | 11 Jun | 1230 | 16.5 | 0 | 19.18 | 9.6 | 0.13 | 10.8 | 3.0 |
| | | | | 5 | 14.14 | 9.1 | 0.13 | 10.0 | - |
| | | | | 10 | 13.67 | 9.0 | 0.14 | 9.7 | 4.0 |
| | | | | 15 | 13.52 | 9.1 | 0.15 | 9.6 | 4.0 |
| L-2 | 11 Jun | 1315 | 25.6 | 0 | 18.88 | 9.7 | 0.14 | 10.9 | - |
| | | | | 5 | 14.17 | 9.1 | 0.14 | 10.1 | - |
| | | | | 10 | 13.62 | 9.0 | 0.15 | 9.4 | - |
| | | | | 15 | 13.41 | 9.0 | 0.16 | 9.2 | - |
| | | | | 20 | 9.61 | 8.8 | 0.17 | 5.6 | - |
| | | | | 24 | 9.55 | 9.0 | 0.17 | 4.9 | 5.0 |
| 11 | 10 Jun | 1600 | 31.5 | 0 | 15.33 | 9.0 | 0.10 | 12.3 | 7.0 |
| | | | | 5 | 14.02 | 8.9 | 0.10 | 12.0 | - |
| | | | | 10 | 13.96 | 8.8 | 0.10 | 11.9 | - |
| | | | | 15 | 13.61 | 8.8 | 0.10 | 11.9 | 9.0 |
| | | | | 20 | 13.60 | 8.8 | 0.10 | 11.9 | - |
| | | | | 30 | 13.66 | 8.9 | 0.10 | 12.0 | 10.0 |
| 13 | 10 Jun | 1645 | 32.9 | 0 | 15.41 | 8.9 | 0.11 | 11.2 | 12.0 |
| | | | | 5 | 13.50 | 8.8 | 0.10 | 11.7 | - |
| | | | | 10 | 13.43 | 8.8 | 0.10 | 11.8 | - |
| | | | | 15 | 13.43 | 8.8 | 0.10 | 11.8 | 11.0 |
| | | | | 20 | 13.44 | 8.7 | 0.11 | 11.9 | - |
| | | | | 25 | 13.46 | 8.8 | 0.11 | 12.4 | - |
| | | | | 30 | 13.52 | 8.9 | 0.11 | 13.0 | 12.0 |
| 14 | 11 Jun | 1100 | - | 0 | 14.22 | 8.9 | 0.11 | - | 8.0 |

Table 4.--continued

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 15 | 11 Jun | 1115 | - | 0 | - | - | - | - | 9.0 |
| 16 | 11 Jun | 1120 | - | 0 | 14.24 | 8.8 | 0.12 | - | 10.0 |
| 17 | 10 Jun | 1330 | - | 0 | 14.03 | 8.2 | 0.10 | - | 10.0 |
| 18 | 10 Jun | 1400 | - | 0 | - | - | - | - | 10.0 |
| 19 | 10 Jun | 1415 | - | 0 | 13.93 | 8.3 | 0.10 | - | 10.0 |

Table 5.--Physical characteristics of river water in the John Day Dam region, Columbia River, 1 July 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 1 Jul | 1115 | 30.0 | 0 | 16.42 | 9.1 | 0.09 | - | 12.0 | High winds; all |
| | | | | 5 | 16.41 | 9.1 | 0.09 | - | - | all water samples |
| | | | | 10 | 16.41 | 9.2 | 0.09 | - | - | collected |
| | | | | 15 | 16.40 | 9.0 | 0.09 | - | 12.0 | |
| 10 | 1 Jul | 1230 | 30.0 | 0 | - | - | - | - | 14.0 | |
| 14 | 1 Jul | 1000 | - | 0 | 16.75 | 8.2 | 0.09 | - | 14.0 | |
| 16 | 1 Jul | 1028 | - | 0 | 16.74 | 8.0 | 0.09 | - | 15.0 | |

Table 6.--Physical characteristics of river water in the John Day Dam region, Columbia River, 13 August 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 2 | 13 Aug | 1330 | 30.0 | 0 | 20.40 | - | - | - | 5.0 | High winds; all water samples collected |
| 10 | 13 Aug | 1245 | 35.0 | 0 | 19.80 | - | - | - | 5.0 | |
| 14 | 13 Aug | 1150 | - | 0 | 20.35 | 9.3 | - | - | 5.0 | |
| 16 | 13 Aug | 1130 | - | 0 | 20.45 | 9.4 | - | - | 6.0 | |
| 17 | 13 Aug | 1000 | - | 0 | - | - | - | - | 5.5 | |
| 19 | 13 Aug | 1120 | - | 0 | - | - | - | - | 5.0 | |

Table 7.--Physical characteristics of river water in the John Day Dam region, Columbia River, 16 September 1982 (see Fig. 1 for station locations).

| Station | Date 1982 | Time (PST) | Total depth(m) | Sample depth(m) | Temperature C° | pH | Conductivity (mmhos) | Dissolved oxygen (ppm) | Turbidity (NTU) | Remarks |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 16 Sep | 1100 | 35.0 | 0 | 19.50 | - | - | - | 4.0 | All water samples collected |
| 10+ | 16 Sep | 1115 | 30.0 | 0 | 19.80 | - | - | - | 5.0 | |
| 14 | 16 Sep | 1130 | - | 0 | - | - | - | - | 7.0 | |
| 16 | 16 Sep | 1150 | - | 0 | - | - | - | - | 5.0 | |
| 17 | 16 Sep | 1240 | - | 0 | - | - | - | - | 5.0 | |
| 19 | 16 Sep | 1245 | - | 0 | - | - | - | - | 6.0 | |

lagoon. Also during Cruise IV, samples were collected in the settling pond (Station P) uphill from the aluminum plant outfall. Effluent is gravity fed from this pond through the outfall pipe and diffuses into the river about 75 m from shore and at about 10 m depth. Station 10+ is about 300 m downstream from Station 10. Bottom profiles of the three Columbia River transects routinely sampled and Station 10 are shown in Figure 4.

Temperature

During Cruise I (2-4 April), observations with depth were obtained only at the upriver transect because of equipment failure. Temperatures at Stations 1-3 were low and rather uniform with depth (Figure 5). The greatest mass of Columbia River water at that time was 6.5°C. Surface temperatures at the downstream Columbia River stations during this time of moderately low river flow (257 kcfs passing John Day Dam) were 6.8°-7.0°C. These somewhat higher temperatures probably resulted from admixture of John Day River water, which ranged from 8.5°C at the surface to 7.3°-8.0°C at the bottom (Stations 4-6).

By Cruise II (23-25 April), Columbia River waters had warmed by over 2°C; even though there were suggestions of slightly higher temperatures at the surface, the temperatures still indicated a rather well mixed situation (Figure 6). The greatest upriver (background) water mass was 8.7°C. This was a period of strong and persistent easterly winds, though still of moderately low Columbia River flow (273 kcfs). Very distinctive high temperatures were found in the John Day River mouth, from 13.5°C at the surface to 9°C near the bottom. That these high, intruding temperatures influenced the physical characteristics of the water in the forebay is indicated in Figure 6 (B and D). The isotherms on the Oregon side indicate John Day River water in a nearly stratified situation.

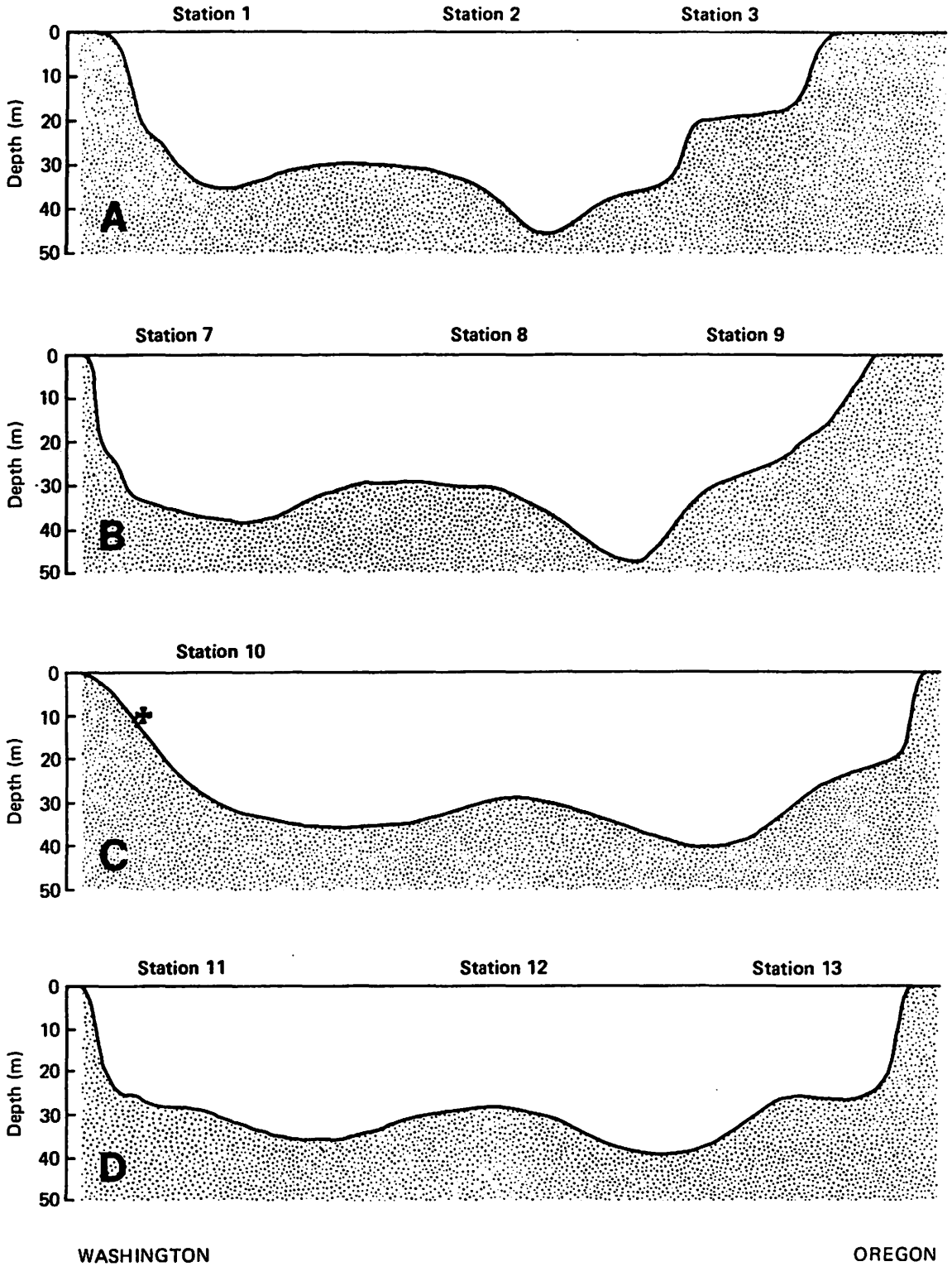


Figure 4.-- Bottom profiles of three routinely sampled transects and station 10, John Day Dam region, Columbia River (see Fig. 1 for station locations). Maltese cross indicates location of aluminum plant outfall.

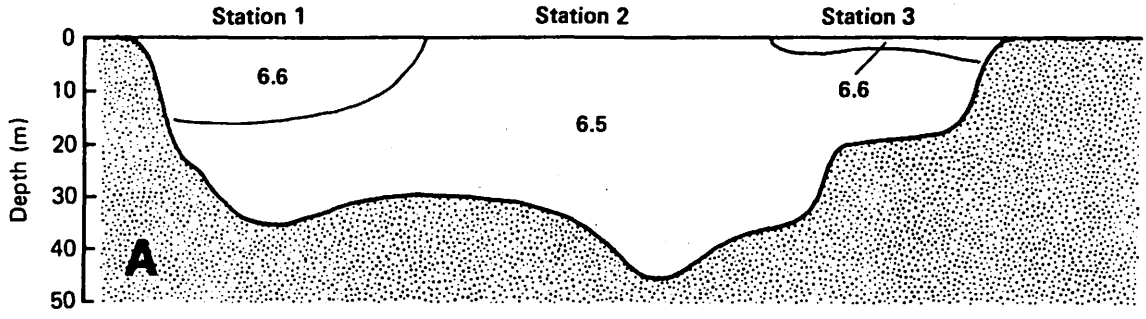


Figure 5.--Temperature contours ($^{o}C$), 1-4 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

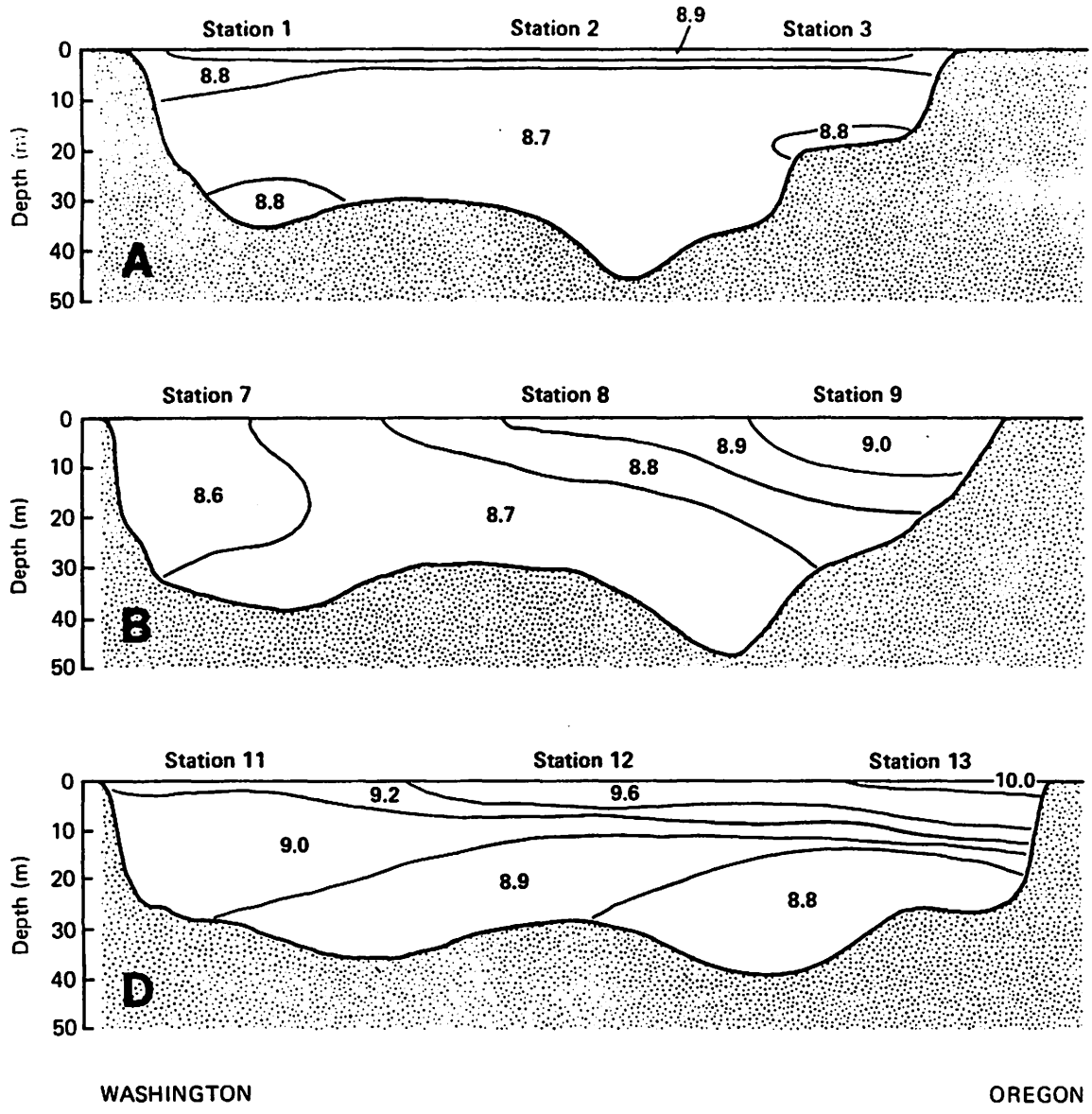


Figure 6.--Temperature contours ($^{o}$C) 23-15 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

The water on the Washington side remained fairly well mixed, although a John Day River influence was seen even there at the surface.

During Cruise III (14-15 May), the upriver transect indicated that temperatures below about 5 m were still fairly uniform but much warmer (11.4°-11.5°C) than before (Figure 7A). Lenses of even warmer water (up to 12°C) were observed at the surface. The Columbia River flow at this time was considerably greater than before (388 kcfs). Stations 7-10, and to a large extent even Stations 11-13, showed similar temperature patterns (Figure 7, B and D). The influence of the much warmer John Day River water (16.0°C at the surface to about 12°C at the bottom) was not particularly noticed, probably because of the high Columbia River flow, although the oxygen distribution suggested some John Day River water at Station 13 (see below).

By Cruise IV (10-11 June), there had been continued warming at all depths, and the Columbia River flow remained high (378 kcfs). The Columbia River background surface temperature was about 14°C, decreasing to 13.8°C below 15 m (Figure 8A). John Day River bottom water appeared to be about the temperature of deep Columbia River water, but the surface temperature of this tributary was 18.7°C. This warm water was detected above 5 m at Stations 7, 9, 11, and 13, although deep temperatures there were similar to Columbia River background (Figure 8, B and D). The temperature profile at Station 10 was similar to the Columbia River background. The temperatures in the John Day Dam fishways indicated surface water (14.2°C), as did those at The Dalles Dam (ca. 14°C).

Few temperature measurements were made on subsequent dates. On 1 July, the background temperature of the upper 15 m was about 16.4°C, and the temperature in both John Day Dam fishways was slightly above 16.7°C. Surface temperatures, including fishways, on 13 August were generally just above 20°C, the maximum

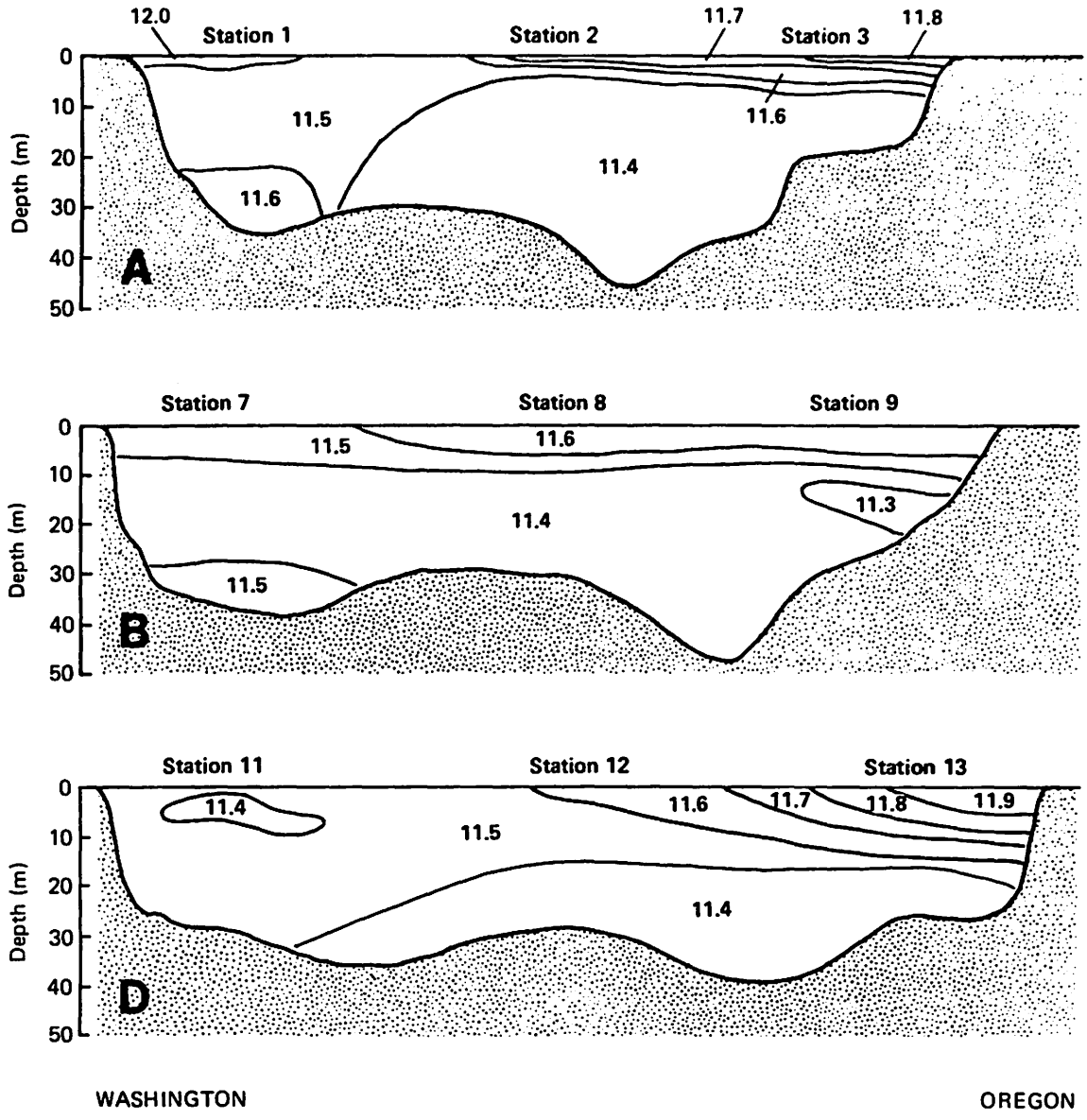


Figure 7.--Temperature contours ($^{o}$C) 14-15 May 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

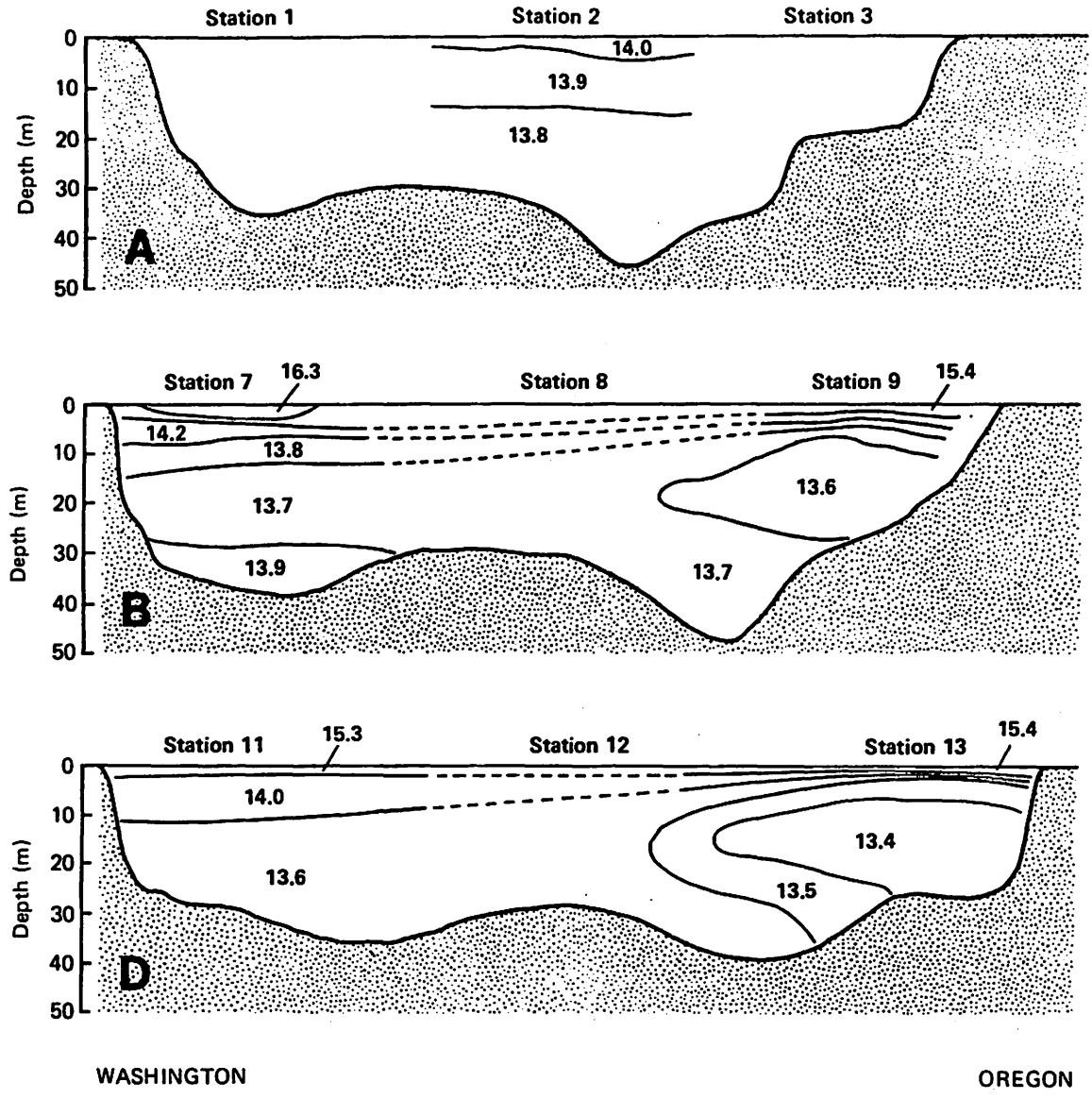


Figure 8.--Temperature contours (°C) 10-11 June 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

Columbia River temperature during this study. By 16 September, the surface temperature at Station 10 had fallen below 20°C.

Dissolved Oxygen

The entire sampling field was not measured during the first cruise because of equipment failure. The upriver transect appeared to be somewhat stratified with respect to oxygen, although the vertical range (13.3-13.6 ppm) was not great (Figure 9A). The Station 10 oxgyen profile was similar. In the John Day River, with higher temperatures, dissolved oxygen was lower (11.5-12 ppm).

The background oxygen distribution was similar during Cruise II. Below about 20 m at all stations the oxygen content reflected background values (Figure 10). The Oregon shore, however, downstream of the John Day River, showed the influence of the low surface oxygen concentration (ca. 10.5 ppm) of this tributary. The linkage with temperature is obvious.

Surface oxygen concentrations continued to fall with increasing temperature. During Cruise III, there may have been a general surface influence of the low oxygen content of the John Day River, but this influence was clearest at Station 13 (Figure 11). Below about 15 m there was not much reduction in oxygen.

By Cruise IV, there was a greater range between surface (12.2 ppm) and deep background (13.6 ppm) oxygen concentrations (Figure 12A). The oxygen content in the John Day River (9.3-11.7 ppm) was much lower than the Columbia River background, and admixture of this water was detected at the surface on the downstream Oregon shore (Figure 12, B and D) and perhaps even at Station 10 near the aluminum plant outfall.

pH

The pH component of the environmental monitoring system failed for most of Cruise I and all of Cruise II. On other cruises there were no apparent

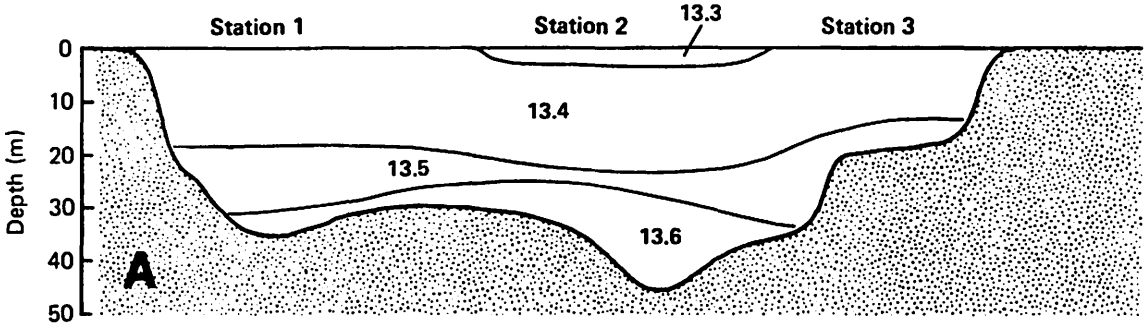


Figure 9.--Dissolved oxygen contours (ppm), 1-4 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

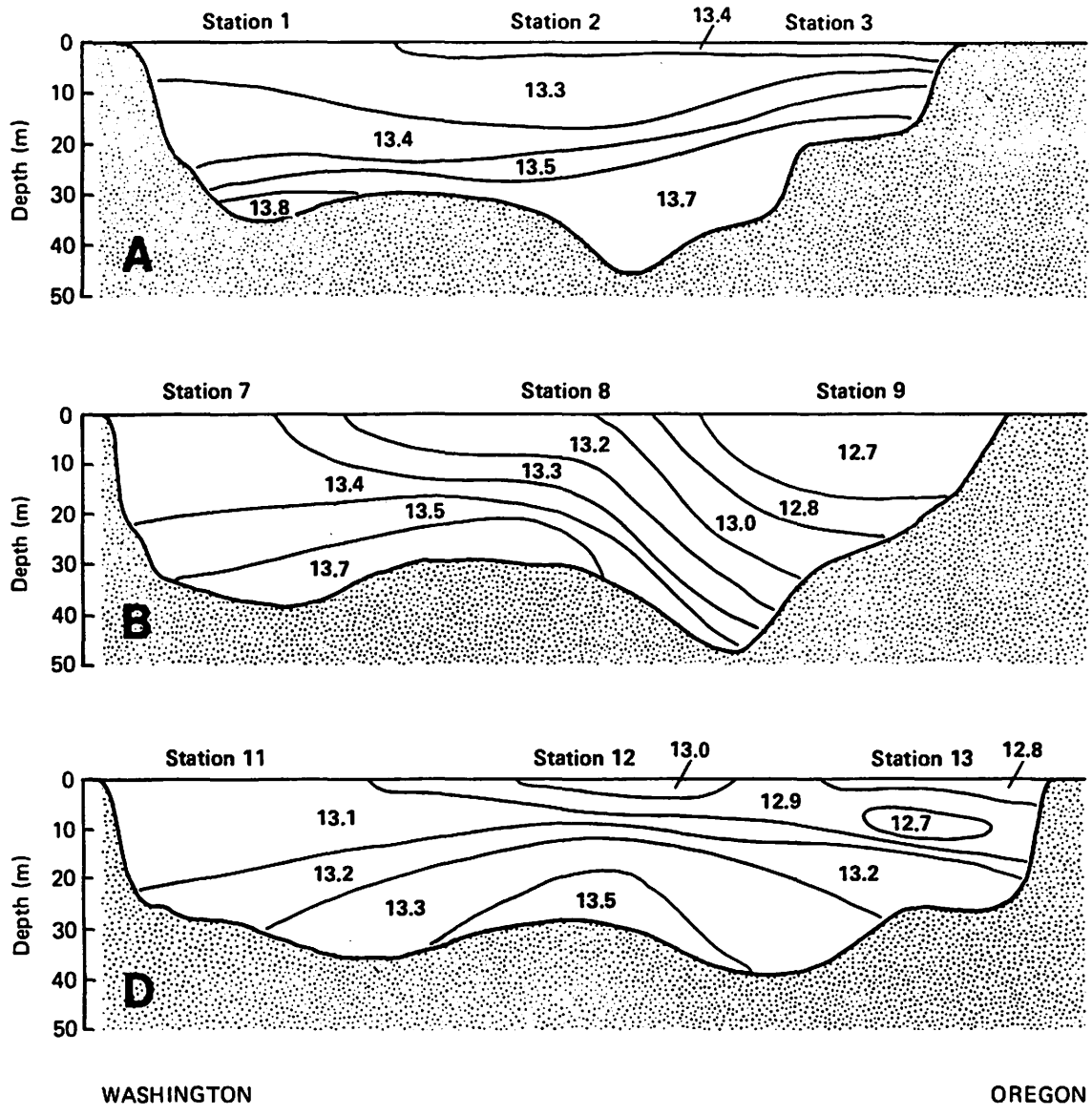


Figure 10.--Dissolved oxygen contours (ppm), 23-25 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

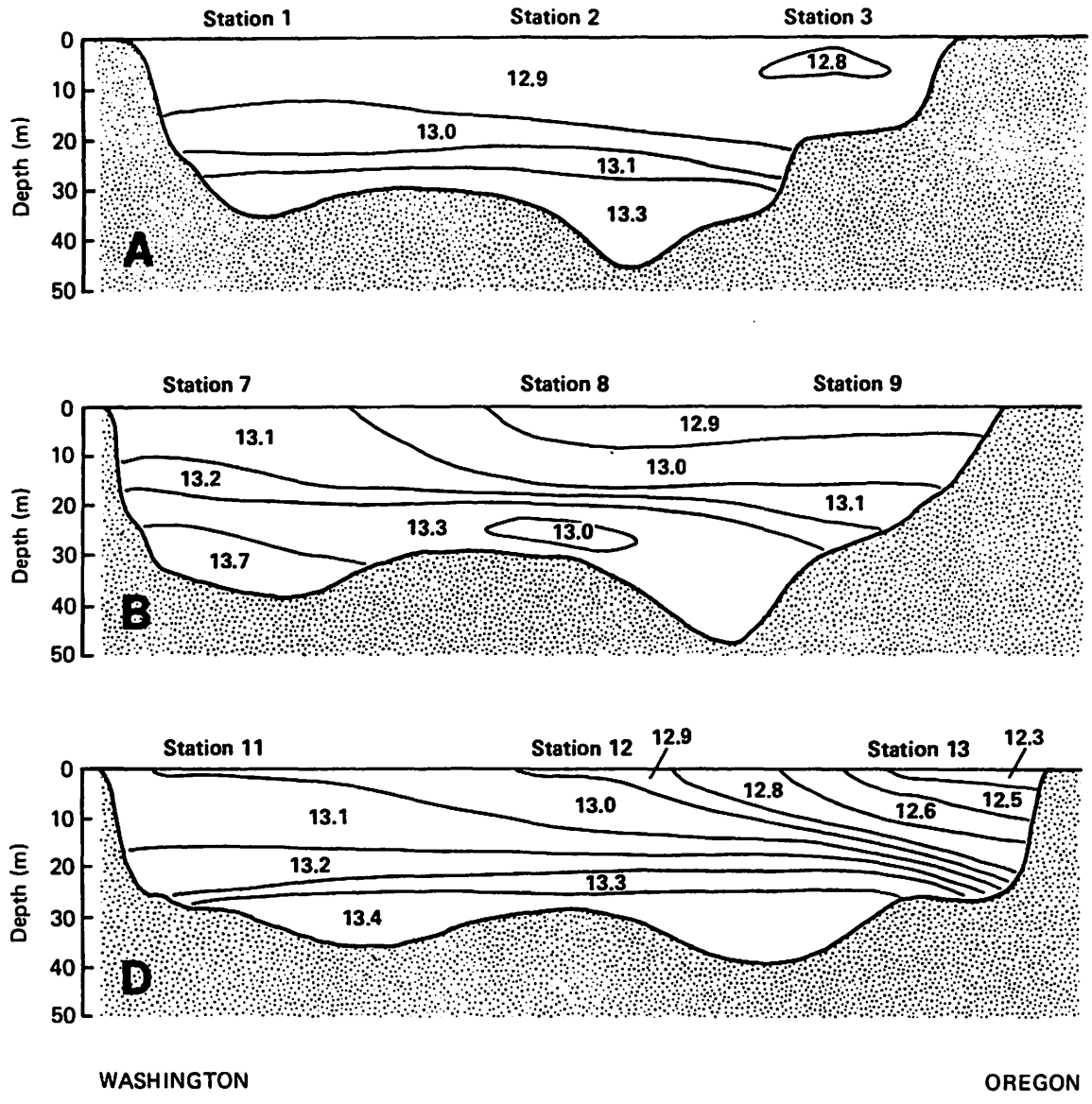


Figure 11.--Dissolved oxygen contours (ppm), 14-15 May 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

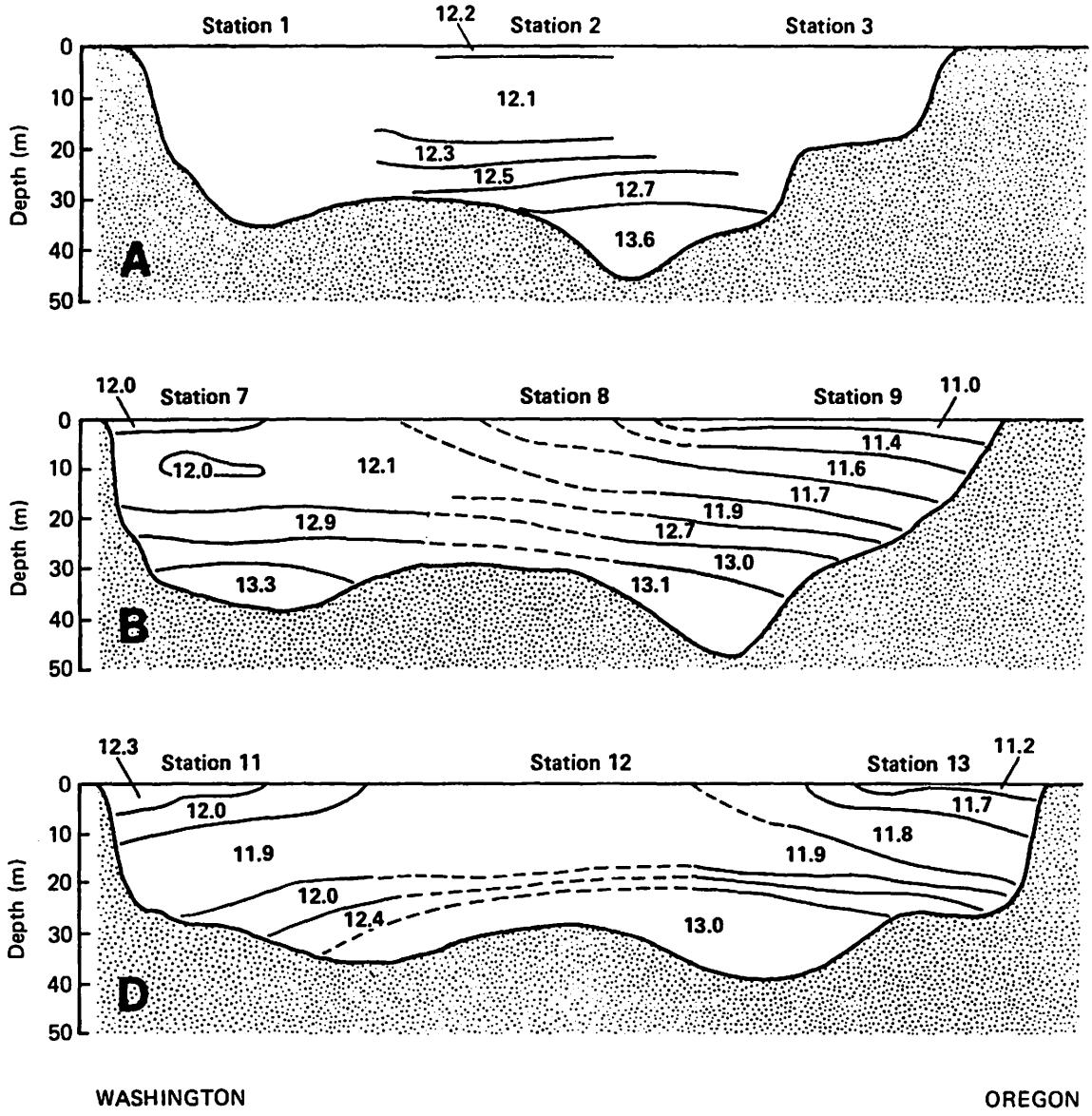


Figure 12.--Dissolved oxygen contours (ppm), 10-11 June 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

interesting time or space patterns in pH. Surface pH in both the Columbia River and the John Day River was everywhere about 9, decreasing to about 8.6 near the bottom.

Conductivity

There were no clear horizontal or vertical patterns in conductivity of the river water, reflecting a uniform distribution of major ionic materials (of components analyzed, mostly chloride, sodium, and sulfate; see below). In April and May, Columbia River conductivity was 0.13-0.17 mmhos; John Day River values were within this range (0.15-0.16 mmhos). In June and July, conductivity decreased in both rivers (0.09-0.11 mmhos).

Turbidity

Relatively low turbidity was found during the low river flow of Cruise I although with somewhat higher turbidity at all stations on the Oregon side of the Columbia River (Figure 13). It is likely that these higher turbidities reflected the much higher John Day River turbidity (17-20 NTU).

The relative pattern was essentially the same during Cruise II, although the turbidity was much increased everywhere (25-30 NTU), probably due to the strong wind mixing (Figure 14). The highest surface values were again found on the Oregon shore, although now the lowest surface values were mid-river.

With the higher flow and lessened wind mixing by Cruise III, turbidity had decreased markedly in the Columbia River (Figure 15), equaling the background values of Cruise I. John Day River turbidity remained much higher than that in the Columbia River, and some admixture was noted at Station 13 (Figure 15D).

The lowest Columbia River turbidity was observed during Cruise IV, where

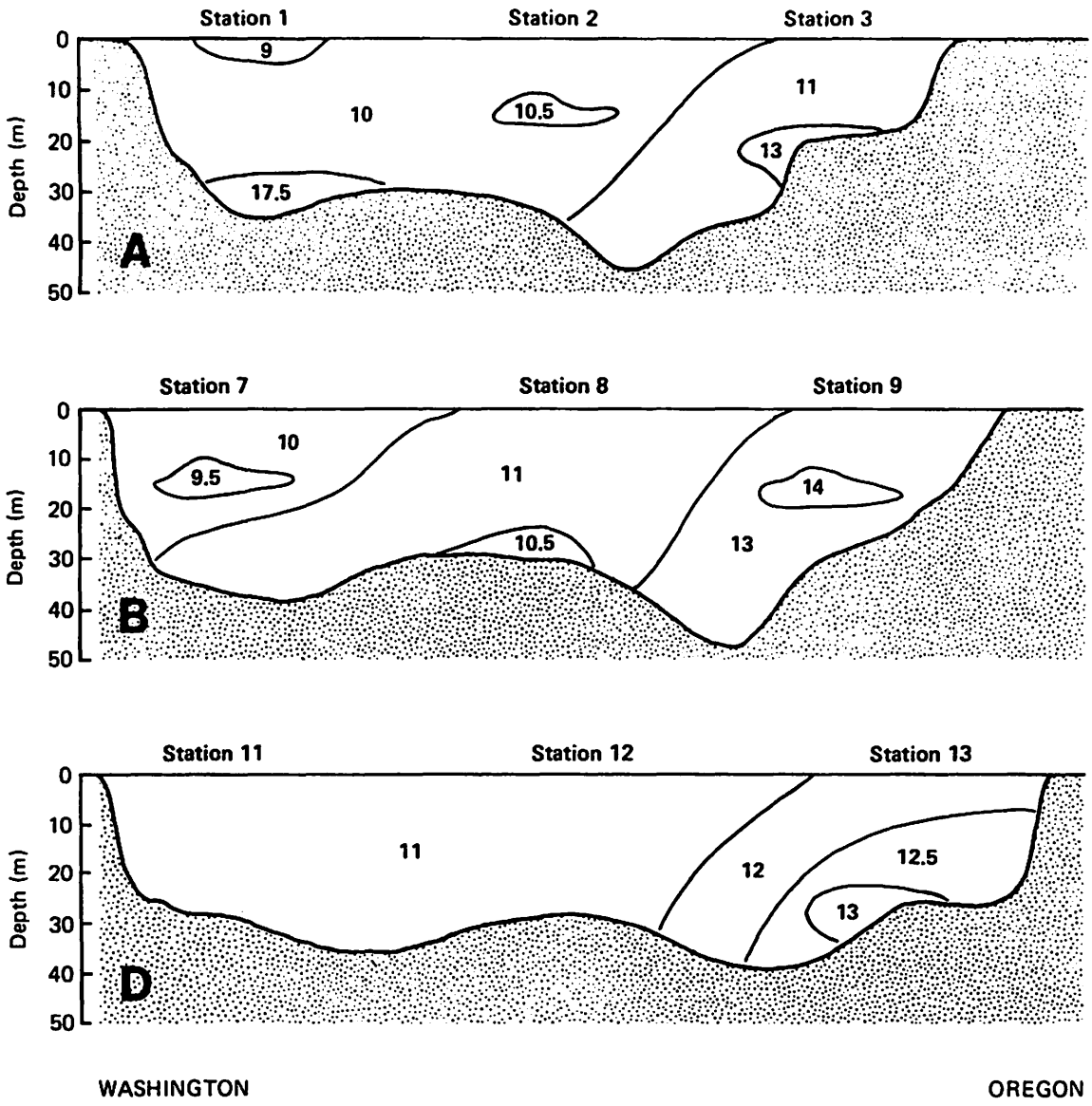


Figure 13--Turbidity contours (NTU), 1-4 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

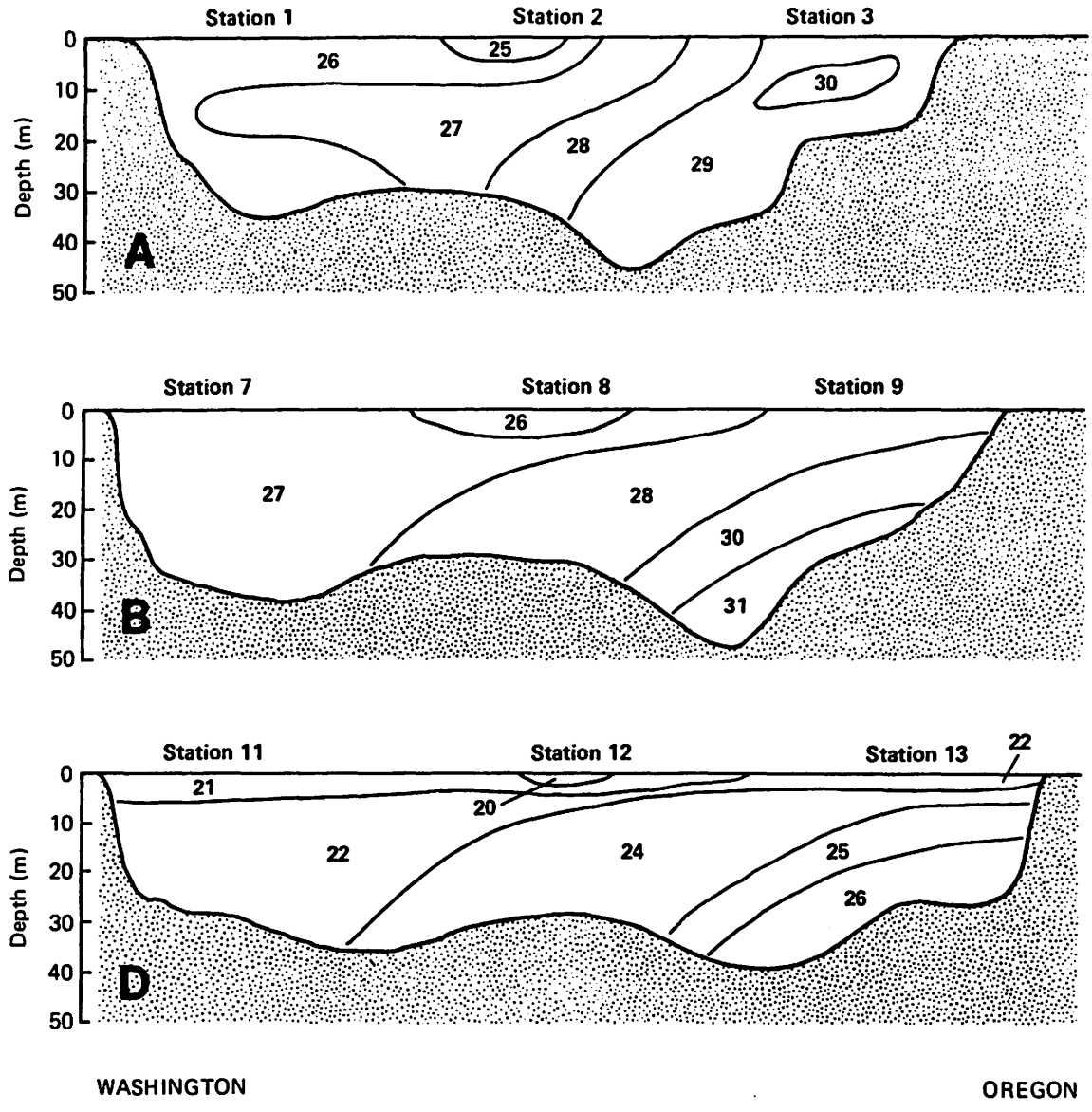


Figure 14.--Turbidity contours (NTU), 23-25 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

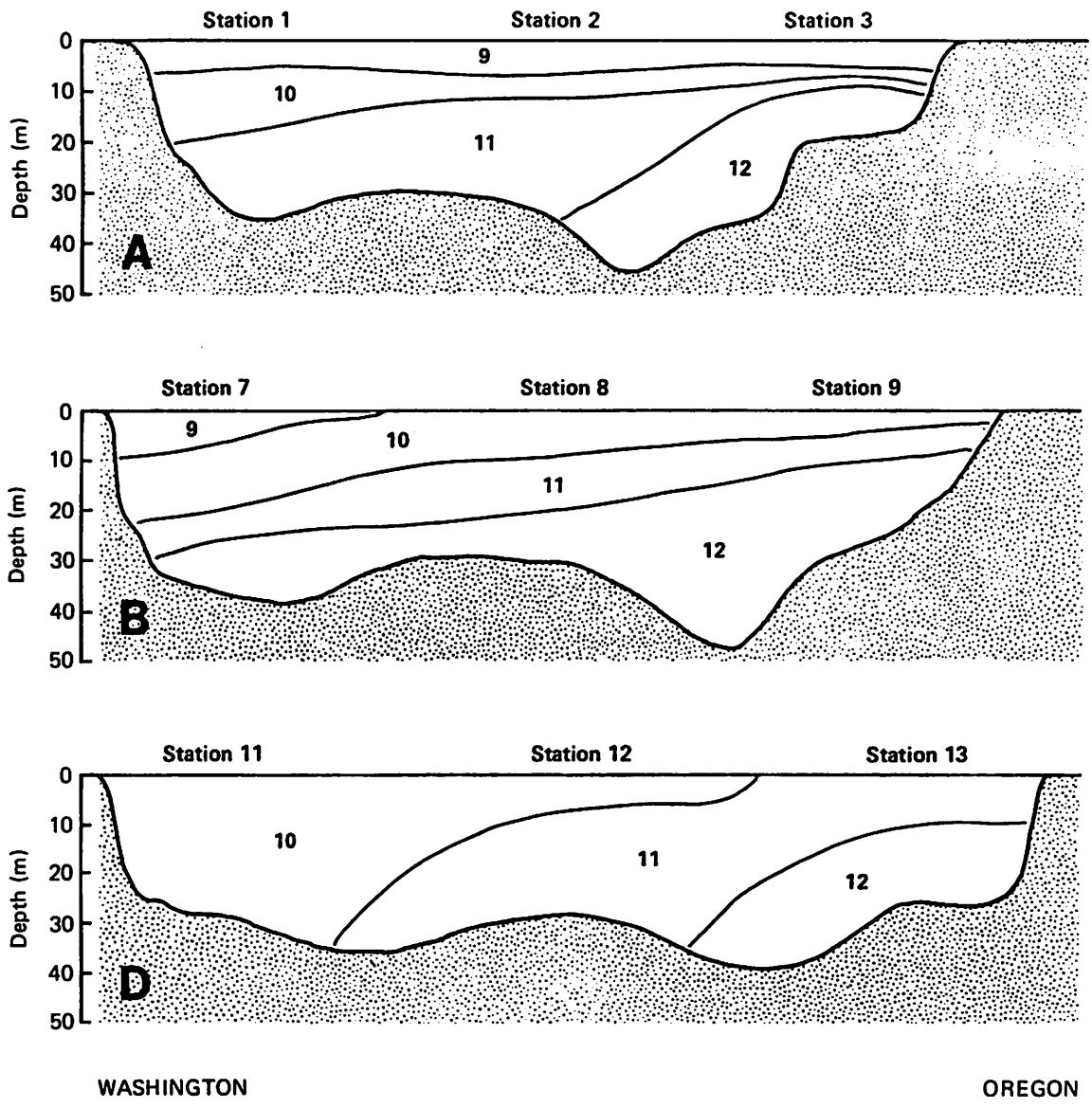


Figure 15.--Turbidity contours (NTU), 14-15 May 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

the surface was only 7 NTU and the near bottom layer 9 NTU (Figure 16A). This background generally persisted on the Washington shore, but the admixture of the decreased turbidity of John Day River water (10-14 NTU) was obvious on the Oregon side (Figure 16, B and D).

## Inorganic Chemical Analyses

Concentrations of the target elements (Table 8) at each station and depth are given in Tables 9-15. Though the FY82 survey of possible water-borne pollutants is not yet completed, it appears (tentatively) that there are no significant gradients of total inorganics present for any of the analyzed elements, except for fluoride. Typical fluoride concentrations during the first four surveys are indicated in Figures 17-24. It is assumed that the primary source of fluorides is the outfall from the aluminum plant on the Washington shore above the dam. This is borne out by monthly discharge records submitted to the Washington State Department of Ecology (Mix[4/]). Observations during the present study found the highest fluoride concentrations in the vicinity of the aluminum plant outfall. That there was not always a clear relationship between the fluoride concentration at the outfall vicinity and at the "downstream" fishways is most likely due to strong wind-mixing in the reservoir.

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 (Neuhold and Sigler 1960; Angelovic et al. 1961), or only about an order of magnitude higher than found in the study area. There are suggestions that the fluoride distributions in the present study relate to the choice of fishway used by the majority of returning adult salmonids (Table 16).

4/ T. J. Mix, Washington State Department of Ecology, Olympia, WA 98504, pers. commun.

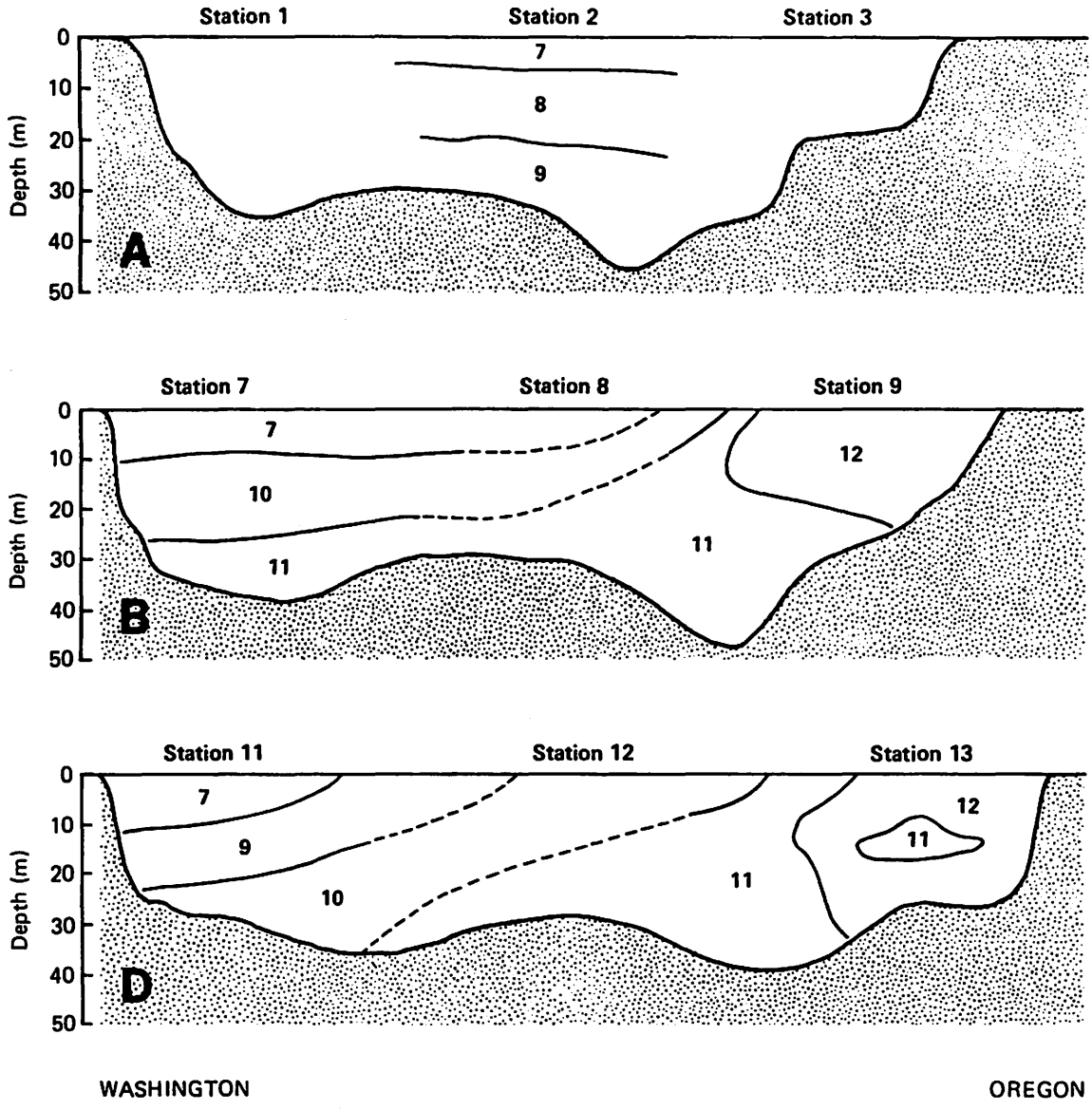


Figure 16.--Turbidity contours (NTU), 10-11 June 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

Table 8.--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 | |

Table 9.--Concentrations of target elements in the John Day Dam region, Columbia River, 1-4 April 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 1 | 0 | 0.33 | <50 | <50 | <0.20 | 2.68 | <5 | <2.5 | 4. | <0.10 | 0.45 | <2.5 | 21 | 1.10 | 0.38 | <5.0 | <0.5 | 5.11 | 4.63 | 23 |
| | 15 | 0.34 | " | " | " | 2.60 | " | " | 6 | " | 0.24 | " | 24 | 0.30 | 0.42 | " | " | 5.18 | 4.67 | 23 |
| | 35 | 0.29 | " | 76 | " | 2.63 | " | " | 6 | " | 0.13 | " | 18 | <0.20 | 0.38 | " | " | 5.23 | 4.67 | 23 |
| 2 | 0 | 0.48 | " | <50 | " | 2.76 | " | " | 6 | " | 0.29 | " | 18 | <0.10 | 0.42 | " | " | 5.78 | 4.69 | 29 |
| | 15 | 0.46 | " | " | " | 2.83 | " | " | 6 | " | 0.27 | " | 19 | " | 0.41 | " | " | 6.37 | 4.70 | 29 |
| | 30 | 0.45 | " | " | " | 2.72 | " | " | 5 | " | 0.25 | " | 18 | 0.13 | 0.41 | " | " | 5.79 | 4.68 | 34 |
| 3 | 0 | 0.42 | " | 62 | " | 2.81 | " | " | 6 | " | 0.20 | " | 32 | <0.20 | 0.50 | " | " | 5.69 | 4.69 | 26 |
| | 10 | 0.33 | " | 50 | " | 2.83 | " | " | 6 | " | 0.22 | " | 24 | 0.50 | 0.51 | " | " | 5.48 | 4.69 | 25 |
| | 19 | 0.63 | " | 68 | " | 2.74 | " | " | 6 | " | 0.53 | " | 46 | <0.20 | 0.52 | " | " | 5.63 | 4.69 | 31 |
| 4 | 0 | 0.67 | " | <50 | " | 1.85 | " | " | 9 | " | 0.43 | " | 27 | 0.90 | 0.20 | " | " | 7.92 | 1.99 | <10 |
| | 7.5 | 0.74 | " | " | " | 1.82 | " | " | 10 | " | 0.45 | " | 23 | <0.20 | 0.20 | " | " | 7.70 | 1.98 | " |
| | 15 | 0.73 | " | " | " | 2.17 | " | " | 9 | " | 0.41 | " | 29 | " | 0.32 | " | " | 6.88 | 2.82 | " |
| 5 | 0 | 0.76 | " | " | " | 1.83 | " | " | 8 | " | 0.39 | " | 32 | " | 0.22 | " | " | 7.44 | 2.03 | " |
| | 9 | 0.80 | " | " | " | 1.84 | " | " | 9 | " | 0.50 | " | 28 | " | 0.24 | " | " | 7.44 | 2.12 | " |
| | 18 | 0.63 | " | " | " | 2.47 | " | " | 8 | " | 0.32 | " | 33 | 0.70 | 0.42 | " | " | 6.93 | 3.82 | 10 |
| 6 | 0 | 0.53 | " | " | " | 1.81 | " | " | 10 | " | 0.53 | " | 21 | <0.10 | 0.20 | " | " | 7.64 | 1.99 | <10 |
| | 9 | 0.52 | " | " | " | 1.78 | " | " | 10 | " | 0.57 | " | 27 | " | 0.20 | " | " | 8.21 | 1.99 | 14 |
| | 18 | 0.57 | " | " | " | 1.82 | " | " | 10 | " | 0.57 | " | 24 | " | 0.21 | " | " | 7.09 | 2.01 | 17 |
| 7 | 0 | 0.38 | " | 50 | " | 5.41 | " | " | 5 | " | 0.08 | " | 21 | <0.20 | 0.41 | " | " | 5.20 | 4.67 | 20 |
| | 15 | 0.41 | " | 76 | " | 2.56 | " | " | 6 | " | 0.08 | " | 23 | " | 0.38 | " | " | 5.21 | 4.68 | 20 |
| | 30 | 0.39 | " | 50 | " | 2.56 | " | " | 5 | " | 0.06 | " | 23 | " | 0.31 | " | " | 5.04 | 4.73 | 23 |
| 8 | 0 | 0.29 | " | <50 | " | 2.67 | " | " | 6 | " | 0.29 | " | 16 | <0.10 | 0.31 | " | " | 5.45 | 4.72 | 26 |
| | 15 | 0.24 | " | " | " | 2.62 | " | " | 6 | " | 0.24 | " | 21 | 0.34 | 0.27 | " | " | 5.65 | 4.74 | 26 |
| | 27 | 0.22 | " | " | " | 2.67 | " | " | 6 | " | 0.24 | " | 19 | 0.14 | 0.27 | " | " | 5.43 | 4.71 | 26 |

Table 9.--continued

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 9 | 0 | 0.40 | <50 | 104 | <0.20 | 2.58 | <5 | <2.5 | 7 | <0.10 | 0.17 | <2.5 | 28 | <0.20 | 0.25 | <5.0 | <0.5 | 6.08 | 4.30 | 17 |
| | 15 | 0.38 | " | 50 | " | 2.62 | " | " | <2 | " | 0.22 | " | 33 | " | 0.26 | " | " | 5.81 | 4.49 | 20 |
| | 28 | 0.38 | " | 80 | " | 2.75 | " | " | 7 | " | 0.22 | " | 29 | " | 0.31 | " | " | 5.90 | 4.62 | 23 |
| 10-1 | 0 | 0.42 | " | <50 | " | 3.84 | " | " | 6 | 0.52 | 0.27 | " | 17 | <0.10 | 0.30 | " | " | 5.39 | 4.84 | 29 |
| | 15 | 0.40 | " | " | " | 2.63 | " | " | 6 | 0.10 | 0.25 | " | 20 | " | 0.30 | " | " | 5.28 | 4.80 | 26 |
| | 30 | 0.38 | " | " | " | 2.70 | " | " | 6 | <0.10 | 0.25 | " | 15 | " | 0.30 | " | " | 5.46 | 4.82 | 29 |
| 10-C | 0 | 0.22 | " | 118 | " | 2.58 | " | " | 2 | " | 0.29 | " | 17 | 0.11 | 0.31 | " | " | 5.18 | 4.78 | 29 |
| | 15 | 0.32 | " | 76 | " | 2.58 | " | " | 4 | 0.10 | 0.27 | " | 18 | 2.50 | 0.31 | " | " | 5.10 | 4.77 | 26 |
| | 30 | 0.32 | " | 68 | " | 2.56 | " | " | 4 | <0.10 | 0.27 | " | 18 | 0.30 | 0.31 | " | " | 4.55 | 4.76 | 31 |
| 11 | 0 | 0.25 | " | <50 | " | 2.54 | " | " | 5 | " | 0.18 | " | 19 | 0.18 | 0.70 | " | " | 5.12 | 4.78 | 23 |
| | 15 | 0.24 | " | " | " | 2.49 | " | " | 6 | " | 0.22 | " | 20 | 0.11 | 0.31 | " | " | 5.05 | 4.79 | 29 |
| | 30 | 0.27 | " | " | " | 2.49 | " | " | 5 | " | 0.18 | " | 18 | 0.24 | 0.31 | " | " | 5.04 | 4.64 | 26 |
| 12 | 0 | 0.25 | " | 50 | " | 2.57 | " | " | 6 | " | 0.18 | " | 19 | 0.26 | 0.38 | " | " | 5.23 | 4.69 | 20 |
| | 15 | 0.31 | " | <50 | " | 2.63 | " | " | 7 | " | 0.20 | " | 21 | 0.43 | 0.39 | " | " | 5.32 | 4.63 | 20 |
| | 30 | 0.24 | " | " | " | 2.67 | " | " | 6 | " | 0.20 | " | 26 | <0.10 | 0.40 | " | " | 5.58 | 4.64 | 23 |
| 13 | 0 | 0.26 | " | 111 | " | 2.50 | " | " | 5 | " | 0.25 | " | 23 | <0.20 | 0.31 | " | " | 5.87 | 4.31 | 17 |
| | 15 | 0.22 | " | 80 | " | 2.59 | " | " | 7 | " | 0.27 | " | 22 | " | 0.33 | " | " | 5.90 | 4.52 | 20 |
| | 30 | 0.30 | " | 50 | " | 2.63 | " | " | 6 | " | 0.25 | " | 26 | " | 0.34 | " | " | 5.57 | 4.59 | 26 |
| 14 | 0 | 0.27 | " | 62 | " | 2.48 | " | " | 5 | 0.27 | 0.17 | " | 18 | 0.70 | 0.31 | " | " | 5.61 | 4.70 | 26 |
| 15 | 0 | 0.32 | " | <50 | " | 2.61 | " | " | 7 | <0.10 | 0.20 | " | 26 | <0.20 | 0.36 | " | " | 5.64 | 4.70 | 23 |
| 16 | 0 | 0.51 | " | " | " | 4.44 | " | " | 5 | 0.11 | 0.25 | " | 22 | " | 0.33 | " | " | 5.71 | 4.57 | 20 |
| 17 | 0 | 0.36 | " | " | " | 2.59 | " | " | 5 | <0.10 | 0.20 | " | 18 | " | 0.33 | " | " | 5.63 | 4.62 | 31 |
| 18 | 0 | 0.38 | " | 76 | " | 2.49 | " | " | 6 | " | 0.20 | " | 29 | 0.80 | 0.34 | " | " | 5.57 | 4.63 | 26 |
| 19 | 0 | 0.40 | " | 68 | " | 2.53 | " | " | 6 | " | 0.22 | " | 21 | <0.20 | 0.34 | " | " | 5.67 | 4.62 | 26 |

Table 10.--Concentrations of target elements in the John Day Dam region, Columbia River, 23-25 April 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 1 | 0 | 0.36 | 50 | <100 | <0.50 | 3.68 | <5.0 | <2.5 | 5 | 0.26 | 0.87 | <2.5 | 51 | <0.20 | 0.33 | <5.0 | <2.5 | 9.8 | 5.28 | 21 |
| | 15 | 0.59 | 44 | " | " | 3.75 | " | " | 3 | 0.27 | 0.90 | " | 54 | " | 0.42 | " | " | 10.3 | 5.32 | 25 |
| | 30 | 0.56 | 38 | " | " | 3.71 | " | " | 2 | 0.26 | 1.57 | " | 55 | " | 0.48 | " | " | 10.3 | 5.33 | 21 |
| 2 | 0 | 0.44 | 56 | " | " | 3.83 | " | " | - | 0.27 | 0.85 | " | 37 | " | 0.39 | " | " | 10.0 | 5.36 | 13 |
| | 15 | 0.51 | 31 | " | " | 3.88 | " | " | 5 | 0.28 | 1.30 | " | 43 | " | 0.38 | " | " | 10.3 | 5.36 | 13 |
| | 30 | 0.42 | 63 | " | " | 3.87 | " | " | <2 | 0.32 | 1.07 | " | 46 | " | 0.32 | " | " | 10.5 | 5.37 | 13 |
| 3 | 0 | 0.86 | 25 | " | " | 4.03 | " | " | 5 | 0.27 | 0.88 | " | 38 | " | 0.32 | " | " | 10.7 | 5.44 | 10 |
| | 10 | 0.73 | 56 | " | " | 4.10 | " | " | 5 | 0.26 | 1.07 | " | 43 | " | 0.40 | " | " | 10.8 | 5.46 | " |
| | 20 | 0.75 | <20 | " | " | 4.03 | " | " | 3 | 0.29 | 1.05 | " | 44 | 0.30 | 0.40 | " | " | 10.5 | 5.46 | " |
| 4 | 0 | 0.77 | 38 | " | " | 1.65 | " | " | 10 | 0.20 | 0.93 | " | 28 | <0.20 | 0.09 | " | " | 10.9 | 2.16 | " |
| | 7.5 | 0.61 | 25 | " | " | 1.63 | " | " | 3 | 0.18 | 0.97 | " | 29 | " | 0.10 | " | " | 10.8 | 2.20 | " |
| | 15 | 0.83 | 56 | " | " | 1.64 | " | " | 3 | 0.20 | 0.98 | " | 29 | " | 0.11 | " | " | 10.1 | 2.20 | " |
| 5 | 0 | 0.57 | 25 | " | " | 1.57 | " | " | 5 | 0.25 | 0.90 | " | 29 | " | 0.09 | " | " | 10.4 | 2.14 | " |
| | 15 | 0.94 | 56 | " | " | 3.47 | " | " | 7 | 0.29 | 1.02 | " | 43 | 0.40 | 0.34 | " | " | 9.9 | 4.68 | " |
| | 25 | 0.68 | 44 | " | " | 3.60 | " | " | 2 | 0.26 | 1.08 | " | 50 | <0.20 | 0.40 | " | " | 10.4 | 4.94 | " |
| 6 | 0 | 0.39 | <20 | " | " | 1.57 | " | " | 7 | 0.22 | 0.97 | " | 26 | " | 0.10 | " | " | 10.7 | 2.15 | 13 |
| | 7.5 | 0.76 | " | " | " | 1.49 | " | " | 5 | 0.20 | 0.98 | " | 28 | " | 0.10 | " | " | 9.4 | 2.13 | 13 |
| | 15 | 0.64 | 25 | " | " | 1.64 | " | " | 5 | 0.21 | 1.47 | " | 33 | " | 0.13 | " | " | 10.4 | 2.25 | 13 |
| 7 | 0 | 0.53 | 69 | " | " | 3.82 | " | " | 7 | 0.28 | 0.93 | " | 42 | " | 0.40 | " | " | 10.3 | 2.55 | 18 |
| | 15 | 0.55 | 38 | " | " | 3.76 | " | " | 7 | 0.28 | 0.95 | " | 43 | " | 0.40 | " | " | 10.2 | 5.42 | 21 |
| | 30 | 0.62 | 56 | " | " | 3.83 | " | " | 2 | 0.31 | 1.22 | " | 44 | " | 0.39 | " | " | 10.3 | 5.49 | 18 |
| 8 | 0 | 0.46 | 50 | " | " | 3.51 | " | " | 3 | 0.28 | 1.18 | " | 38 | " | 0.39 | " | " | 10.2 | 5.15 | 17 |
| | 15 | 0.61 | 25 | " | " | 3.75 | " | " | 3 | 0.33 | 0.98 | " | 41 | " | 0.38 | " | " | 11.1 | 5.16 | 17 |
| | 25 | 0.56 | 25 | " | " | 3.80 | " | " | 7 | 0.22 | 1.13 | " | 44 | " | 0.36 | " | " | 11.0 | 5.23 | 17 |

Table 10.--continued

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 9 | 0 | 0.72 | 56 | <100 | <0.50 | 3.31 | <5.0 | <2.5 | 7 | 0.26 | 1.38 | <2.5 | 40 | <0.20 | 0.36 | <5.0 | <2.5 | 10.2 | 4.55 | 21 |
| | 15 | 1.08 | 100 | " | " | 3.51 | " | " | 8 | 0.29 | 1.05 | " | 43 | " | 0.34 | " | " | 10.6 | 4.70 | 18 |
| | 30 | 0.74 | 38 | " | " | 3.58 | " | " | 5 | 0.30 | 1.05 | " | 50 | " | 0.36 | " | " | 10.7 | 4.84 | 18 |
| 10-6 | 0 | 0.37 | <20 | " | " | 3.18 | " | " | 7 | 0.30 | 0.75 | " | 30 | " | 0.38 | " | " | 9.6 | 4.60 | 21 |
| | 15 | 0.37 | 69 | " | " | 3.49 | " | " | 7 | 0.30 | 0.92 | " | 34 | " | 0.34 | " | " | 9.6 | 5.00 | 28 |
| | 30 | 0.46 | 25 | " | " | 3.57 | " | " | 7 | 0.32 | 0.80 | " | 34 | " | 0.38 | " | " | 8.9 | 5.06 | 25 |
| 10-C | 0 | 0.43 | 38 | " | " | 3.62 | " | " | 7 | 0.39 | 0.78 | " | 35 | " | 0.36 | " | " | 10.6 | 4.98 | 21 |
| | 15 | 0.38 | 106 | " | " | 3.65 | " | " | 8 | 0.22 | 0.85 | " | 36 | " | 0.36 | " | " | 9.5 | 5.11 | 25 |
| | 30 | 0.41 | 63 | " | " | 3.67 | " | " | 10 | 0.29 | 0.87 | " | 35 | " | 0.38 | " | " | 10.0 | 5.11 | 25 |
| 11 | 0 | 0.42 | 31 | " | " | 3.40 | " | " | 7 | 0.34 | 1.10 | " | 32 | " | 0.42 | " | " | 10.3 | 4.83 | 17 |
| | 10 | 0.40 | 38 | " | " | 3.49 | " | " | 8 | 0.30 | 1.15 | " | 36 | " | 0.37 | " | " | 9.8 | 5.10 | 20 |
| | 20 | 0.41 | 31 | " | " | 3.51 | " | " | 8 | 0.30 | 0.97 | " | 37 | " | 0.38 | " | " | 9.4 | 5.13 | 20 |
| 12 | 0 | 0.37 | 25 | " | " | 3.13 | " | " | 8 | 0.28 | 0.80 | " | 31 | " | 0.32 | " | " | 10.2 | 4.55 | 10 |
| | 10 | 0.36 | <20 | " | " | 3.49 | " | " | 7 | 0.27 | 0.98 | " | 38 | 0.20 | 0.38 | " | " | 10.2 | 5.11 | 14 |
| | 20 | 0.37 | 44 | " | " | 3.54 | " | " | 8 | 0.27 | 1.15 | " | 42 | <0.20 | 0.38 | " | " | 10.2 | 5.20 | 18 |
| 13 | 0 | 0.32 | 55 | " | " | 3.14 | " | " | 7 | 0.29 | 1.18 | " | 34 | " | 0.34 | " | " | 10.4 | 4.48 | 14 |
| | 10 | 0.56 | <20 | " | " | 3.61 | " | " | 7 | 0.26 | 0.97 | " | 41 | " | 0.36 | " | " | 10.0 | 5.09 | 18 |
| | 20 | 0.59 | 69 | " | " | 3.66 | " | " | 7 | 0.32 | 0.93 | " | 45 | " | 0.39 | " | " | 10.2 | 5.20 | 18 |
| 14 | 0 | 0.66 | 38 | " | " | 3.75 | " | " | 8 | 0.29 | 0.95 | " | 43 | " | 0.36 | " | " | 10.3 | 5.24 | 18 |
| 15 | 0 | 0.73 | 63 | " | " | 3.66 | " | " | 8 | 0.33 | 1.08 | " | 43 | " | 0.39 | " | " | 11.0 | 4.83 | 18 |
| 16 | 0 | 0.77 | 31 | " | " | 3.55 | " | " | 8 | 0.30 | 1.18 | " | 41 | " | 0.38 | " | " | 10.8 | 4.83 | 18 |
| 17 | 0 | 0.44 | 25 | " | " | 3.39 | " | " | 10 | 0.37 | 1.02 | " | 54 | " | 0.39 | " | " | 10.1 | 4.94 | 25 |
| 18 | 0 | 0.56 | 56 | " | " | 3.38 | " | " | 10 | 0.27 | 1.18 | " | 56 | " | 0.40 | " | " | 9.5 | 4.92 | 21 |
| 19 | 0 | 0.80 | 75 | " | " | 3.48 | " | " | 8 | 0.34 | 1.38 | " | 57 | " | 0.39 | " | " | 10.1 | 4.86 | 25 |

Table 11.--Concentrations of target elements in the John Day Dam region, Columbia River, 14-15 May 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | Al | Cl | Cr | CN | F | Hg | $NO_3$ $NO_2$ | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppm | ppb | ppb | ppm | ppb | ppm | ppm | ppm | ppb |
| 1 | 0 | - | 2.39 | <10 | 3.5 | 0.32 | <0.20 | 0.121 | 8.4 | 3.82 | 14 |
| | 15 | - | 2.42 | " | 6.0 | 0.28 | " | 0.097 | 8.2 | 3.88 | 16 |
| | 30 | - | 2.38 | " | 3.5 | 0.24 | " | 0.099 | 6.3 | 3.84 | 18 |
| 2 | 0 | 0.30 | 2.44 | " | 4.0 | 0.28 | " | 0.098 | 6.7 | 3.83 | 14 |
| | 30 | 0.32 | 2.44 | " | 4.0 | 0.30 | " | 0.095 | 6.3 | 3.85 | 14 |
| 3 | 0 | - | 2.45 | " | 3.0 | 0.31 | " | 0.094 | 6.7 | 3.88 | 14 |
| | 15 | - | 2.42 | " | 3.5 | 0.24 | " | 0.096 | 6.5 | 3.84 | 14 |
| | 30 | - | 2.43 | " | 3.0 | 0.24 | " | 0.095 | 6.8 | 3.88 | 18 |
| 4 | 0 | - | 1.33 | " | 3.0 | 0.19 | " | 0.078 | 9.0 | 1.82 | 9 |
| | 7.5 | - | 1.31 | " | 5.5 | 0.17 | " | 0.073 | 8.7 | 1.90 | 9 |
| | 15 | - | 2.36 | " | 4.0 | 0.16 | " | 0.085 | 7.0 | 3.62 | 14 |
| 5 | 0 | - | 1.23 | " | 4.5 | 0.15 | " | 0.067 | 7.2 | 1.85 | 9 |
| | 15 | - | 2.20 | " | 4.0 | 0.17 | " | 0.080 | 7.0 | 3.35 | 14 |
| | 25 | - | 2.37 | " | 4.0 | 0.17 | " | 0.085 | 6.5 | 3.66 | 16 |
| 6 | 0 | 0.31 | 1.28 | " | 5.0 | 0.13 | " | 0.073 | 9.0 | 1.85 | 7 |
| | 15 | 0.33 | 2.32 | " | 3.5 | 0.19 | " | 0.056 | 7.2 | 3.51 | 14 |
| | 25 | 0.29 | 2.46 | " | 2.0 | 0.22 | " | 0.097 | 9.5 | 3.83 | 18 |
| 7 | 0 | - | 2.50 | " | 3.0 | 0.22 | " | 0.091 | 7.0 | 3.98 | 11 |
| | 15 | - | 2.42 | " | 3.0 | 0.25 | " | 0.105 | 6.8 | 4.00 | 14 |
| | 30 | - | 2.50 | " | 3.0 | 0.19 | " | 0.097 | 6.7 | 3.99 | 16 |
| 8 | 0 | 0.32 | 2.44 | " | 3.0 | 0.24 | " | 0.097 | 6.7 | 3.91 | 16 |
| | 15 | 0.33 | 2.44 | " | 3.0 | 0.25 | " | 0.107 | 6.7 | 3.96 | 14 |
| | 25 | 0.35 | 2.45 | " | 3.5 | 0.26 | " | 0.096 | 6.8 | 3.99 | 16 |
| 9 | 0 | - | 2.76 | " | 3.0 | 0.19 | " | 0.119 | 7.7 | 4.00 | 14 |
| | 15 | - | 2.73 | " | 3.0 | 0.26 | " | 0.097 | 8.3 | 3.98 | 14 |
| | 30 | - | 2.75 | " | 3.0 | 0.29 | " | 0.098 | 6.7 | 4.05 | 18 |
| 10-1 | 0 | 0.37 | 2.60 | " | 3.5 | 0.23 | " | 0.090 | 5.9 | 3.89 | 18 |
| | 15 | 0.32 | 2.61 | " | 3.0 | 0.26 | " | 0.093 | 6.7 | 3.99 | 16 |
| | 30 | 0.33 | 2.64 | " | 3.5 | 0.24 | " | 0.090 | 6.3 | 4.00 | 14 |
| 10-2 | 0 | 0.28 | 2.59 | " | 7.5 | 0.25 | " | 0.095 | 6.9 | 3.94 | 11 |
| | 15 | 0.32 | 2.57 | " | 5.5 | 0.22 | " | 0.095 | 6.4 | 4.00 | 7 |
| | 30 | 0.32 | 2.58 | " | 4.0 | 0.33 | " | 0.097 | 7.3 | 4.02 | 11 |
| 10+ | 39.5 | 0.31 | 2.47 | " | 4.5 | 0.22 | " | 0.092 | 6.7 | 3.93 | 16 |
| 11 | 0 | 0.32 | 2.59 | " | 3.5 | 0.23 | " | 0.100 | 8.4 | 4.10 | 14 |
| | 15 | 0.32 | 2.53 | " | 2.5 | 0.23 | " | 0.092 | 8.2 | 4.04 | 14 |
| | 30 | 0.34 | 2.56 | " | 3.5 | 0.26 | " | 0.089 | 6.3 | 3.72 | 14 |
| 12 | 0 | 0.20 | 2.47 | " | 3.5 | 0.21 | " | 0.094 | 6.9 | 3.69 | 11 |
| | 15 | 0.22 | 2.46 | " | 3.0 | 0.19 | " | 0.093 | 6.5 | 3.79 | 14 |
| | 30 | 0.22 | 2.49 | " | 4.0 | 0.27 | " | 0.096 | 6.7 | 3.81 | 14 |
| 13 | 0 | 0.28 | 2.40 | " | 4.0 | 0.17 | " | 0.095 | 6.9 | 3.53 | 14 |
| | 15 | 0.20 | 2.39 | " | 4.0 | 0.25 | " | 0.093 | 6.6 | 3.74 | 14 |
| | 30 | 0.25 | 2.48 | " | 3.5 | 0.23 | " | 0.094 | 6.6 | 3.79 | 16 |
| 14 | 0 | 0.20 | 2.62 | " | 3.5 | 0.31 | " | 0.097 | 6.5 | 3.86 | 11 |
| 15 | 0 | 0.22 | 2.46 | " | 4.5 | 0.15 | " | 0.094 | 6.6 | 3.77 | 14 |
| 16 | 0 | 0.24 | 2.59 | " | 5.0 | 0.31 | " | 0.092 | 6.9 | 3.62 | 14 |
| 17 | 0 | - | 2.88 | " | 5.0 | 0.27 | " | 0.090 | 7.3 | 3.90 | 14 |
| 18 | 0 | - | 6.42 | " | 15.0 | 0.26 | " | 0.091 | 7.1 | 3.90 | 16 |
| 19 | 0 | - | 2.87 | " | 5.0 | 0.24 | " | 0.092 | 7.4 | 3.88 | 16 |

Table 12.--Concentrations of target elements in the John Day Dam region, Columbia River, 10-11 June 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 2 | 0 | | | | | 2.06 | | | <2.0 | 0.13 | | | | <0.20 | 0.017 | | | | 2.96 | <10 |
| | 15 | | | | | 1.88 | | | " | 0.14 | | | | " | 0.125 | | | | 2.87 | " |
| | 35 | | | | | 1.88 | | | " | 0.15 | | | | " | 0.027 | | | | 2.88 | " |
| 6 | 0 | | | | | 1.27 | | | " | 0.09 | | | | " | 0.062 | | | | 1.72 | " |
| | 10 | | | | | 1.59 | | | " | 0.18 | | | | " | 0.042 | | | | 2.62 | " |
| | 20 | | | | | 1.58 | | | " | 0.17 | | | | " | 0.047 | | | | 2.76 | " |
| 7 | 0 | | | | | 1.73 | | | 2.3 | 0.19 | | | | " | 0.013 | | | | 2.82 | " |
| | 15 | | | | | 1.70 | | | <2.0 | 0.18 | | | | " | 0.033 | | | | 2.74 | " |
| | 30 | | | | | 1.64 | | | " | 0.20 | | | | " | 0.032 | | | | 2.76 | " |
| 9 | 0 | | | | | 1.33 | | | " | 0.37 | | | | " | 0.042 | | | | 2.41 | " |
| | 15 | | | | | 1.80 | | | " | 0.23 | | | | " | 0.043 | | | | 2.74 | " |
| | 30 | | | | | 1.83 | | | " | 0.17 | | | | " | 0.100 | | | | 2.78 | " |
| 10 | 0 | | | | | 1.89 | | | " | 0.15 | | | | " | 0.033 | | | | 2.78 | " |
| | 15 | | | | | 1.89 | | | " | 0.16 | | | | " | 0.031 | | | | 2.78 | " |
| | 30 | | | | | 1.93 | | | " | 0.16 | | | | " | 0.056 | | | | 2.83 | " |
| P | 0 | 0.170 | <20 | <50 | <0.5 | 4.78 | <2 | <2.5 | 3.9 | 1.25 | 0.11 | <1 | 8.9 | <1.00 | 0.267 | <5 | <1 | 97 | 12.7 | 12 |
| L-1 | 0 | 0.072 | " | " | " | 2.87 | " | " | <2.0 | 0.29 | <.05 | " | 7.0 | " | <.010 | 5 | " | 10.0 | 3.88 | 10 |
| | 7.5 | 0.090 | " | " | " | 2.92 | " | " | " | 0.24 | 0.09 | " | 8.6 | " | 0.062 | 6 | " | 11.6 | 4.09 | <10 |
| | 15 | 0.093 | " | " | " | 3.20 | " | " | " | 0.26 | 0.11 | " | 9.4 | " | 0.289 | <5 | " | 11.1 | 4.36 | 10 |
| L-2 | 24 | 0.082 | " | " | " | 3.72 | " | " | 3.1 | 0.31 | 0.10 | " | 300 | " | 0.089 | <5 | " | 10.5 | 5.15 | 12 |
| 11 | 0 | | | | | 1.87 | | | <2.0 | 0.13 | | | | <0.20 | 0.056 | | | | 2.78 | <10 |
| | 15 | | | | | 1.83 | | | " | 0.15 | | | | " | 0.062 | | | | 2.79 | " |
| | 30 | | | | | 1.82 | | | " | 0.16 | | | | " | 0.058 | | | | 2.83 | " |

Table 12.--continued

| Station | Depth (m) | Al | As | Ba | Cd | Cl | Cr | Cu | CN | F | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Ag | Na | $SO_4$ | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppm | ppb | ppb | ppb | ppm | ppb | ppb | ppm | ppm | ppb |
| 13 | 0 | | | | | 1.62 | | | " | 0.11 | | | | " | 0.078 | | | | 2.42 | " |
| | 15 | | | | | 1.85 | | | " | 0.14 | | | | " | 0.089 | | | | 2.80 | " |
| | 30 | | | | | 1.82 | | | " | 0.15 | | | | " | 0.078 | | | | 2.75 | " |
| 14 | 0 | | | | | 1.95 | | | " | 0.17 | | | | " | 0.044 | | | | 2.80 | " |
| 15 | 0 | | | | | 1.96 | | | " | 0.15 | | | | " | 0.011 | | | | 2.83 | " |
| 16 | 0 | | | | | 1.85 | | | " | 0.17 | | | | " | 0.020 | | | | 2.73 | " |
| 17 | 0 | | | | | 1.73 | | | " | 0.16 | | | | " | 0.022 | | | | 2.80 | " |
| 18 | 0 | | | | | 1.69 | | | " | 0.16 | | | | " | 0.022 | | | | 2.87 | " |
| 19 | 0 | | | | | 1.74 | | | " | 0.15 | | | | " | 0.013 | | | | 2.78 | " |

Table 12.--continued (Sediments)

| Station | Al | As | Ba | Cd | Cr | Cu | Fe | Pb | Mn | Hg | $NO_3$ $NO_2$ | Se | Zn |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | ppm | ppb | ppb | ppb | ppb | ppb | ppm | ppb | ppb | ppb | ppm | ppb | ppb |
| 10 | 879 | 296 | 9,600 | 212 | 1,220 | 2,000 | 200 | 1,306 | 1,240 | 18 | 0.39 | 20 | 5,700 |
| L-1 | 451 | 204 | 7,600 | 99 | 1,070 | 1,160 | 105 | 902 | 1,240 | 9.6 | 0.71 | 20 | 8,300 |

based on sample dry weight

Table 13.--Concentrations of target elements in the John Day Dam region, Columbia River, 1 July 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | F | Total dissolved metal Cd | Cu | Pb | Zn | Ionized metal Cd | Cu | Pb | Zn |
|---|---|---|---|---|---|---|---|---|---|---|
| | | ppm | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb |
| 2 | 0 | 0.17 | 0.36 | 1.70 | 0.11 | 28.5 | 0.04 | 0.76 | 0.13 | 11.58 |
| 10 | 0 | 0.34 | 0.25 | 1.75 | 0.24 | 29.1 | 0.08 | 0.31 | 0.11 | 11.81 |
| 14 | 0 | 0.18 | 0.32 | 2.15 | 0.30 | 27.7 | 0.06 | 0.32 | 0.19 | 12.34 |
| 16 | 0 | 0.17 | ND | 2.00 | 0.35 | 21.5 | 0.07 | 0.22 | 0.08 | 8.92 |

| | | Particulate metals: Dry weight (mg/kg) Cu | Zn | Percent free metal Cd | Cu | Pb | Zn |
|---|---|---|---|---|---|---|---|
| 2 | 0 | 5,525 | 781 | 11 | 45 | 100 | 41 |
| 10 | 0 | 3,444 | 60 | 32 | 18 | 46 | 41 |
| 14 | 0 | 2,819 | 71 | 19 | 15 | 63 | 45 |
| 16 | 0 | 3,597 | 191 | ND | 11 | 23 | 41 |

Table 14.--Concentrations of target elements in the John Day Dam region, Columbia River, 13 August 1982 (see Fig. 1 for station locations).

| Station | Depth (m) | Total dissolved metal | | | | Ionized metal | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Cd | Cu | Pb | Zn | Cd | Cu | Pb | Zn |
| | | ppb | ppb | ppb | ppb | ppb | ppb | ppb | ppb |
| 2 | 0 | 0.32 | 1.54 | ND | 27.3 | 0.05 | 0.05 | 0.13 | 11.91 |
| 10 | 0 | 0.23 | 1.65 | 0.22 | 27.3 | 0.01 | 0.16 | 0.03 | 9.24 |
| 14 | 0 | 0.39 | 2.80 | 0.37 | 28.8 | 0.03 | 0.08 | 0.02 | 10.10 |
| 16 | 0 | ND | 2.06 | 0.32 | 12.0 | 0.02 | 0.49 | 0.07 | 2.02 |
| 17 | 0 | ND | 1.22 | 0.32 | 19.2 | 0.04 | ND | 0.27 | 11.95 |
| 19 | 0 | ND | 1.36 | ND | 21.3 | 0.04 | 0.04 | 0.04 | 11.64 |

Particulate metals

| | | Dry weight (mg/kg) | | Percent free metal | | | |
|---|---|---|---|---|---|---|---|
| | | Cu | Zn | Cd | Cu | Pb | Zn |
| 2 | 0 | 105 | 1,774 | 16 | 3 | ND | 44 |
| 10 | 0 | 72 | 1,762 | 4 | 10 | 14 | 34 |
| 14 | 0 | 95 | 2,487 | 8 | 3 | 5 | 35 |
| 16 | 0 | 54 | 1,020 | ND | 24 | 22 | 17 |
| 17 | 0 | 73 | 1,125 | ND | ND | 84 | 62 |
| 19 | 0 | 58 | 1,507 | ND | 3 | ND | 55 |

Polarographic results

measuring 200 pptrillion of each metal

| Metal | SD | CV(%) | n |
|---|---|---|---|
| Cd | 2.22 | 3 | 5 |
| Cu | 3.20 | 3 | 5 |
| Pb | 4.36 | 10 | 5 |
| Zn | 4.79 | 9 | 5 |

Table 15.--Concentrations of target elements in the John Day Dam region, Columbia River, 16 September 1982 (see Fig. 1 for station locations).

| Station | Sample | Depth (m) | F |
|---|---|---|---|
| | | | ppm |
| 10 | a | 0 | 0.16 |
| | b | 0 | 0.15 |
| 10+ | a | 0 | 0.12 |
| | b | 0 | 0.13 |
| 14 | a | 0 | 0.14 |
| | b | 0 | 0.12 |
| 16 | a | 0 | 0.16 |
| | b | 0 | 0.10 |
| 17 | a | 0 | 0.13 |
| | b | 0 | 0.13 |
| 19 | a | 0 | 0.13 |
| | b | 0 | 0.12 |

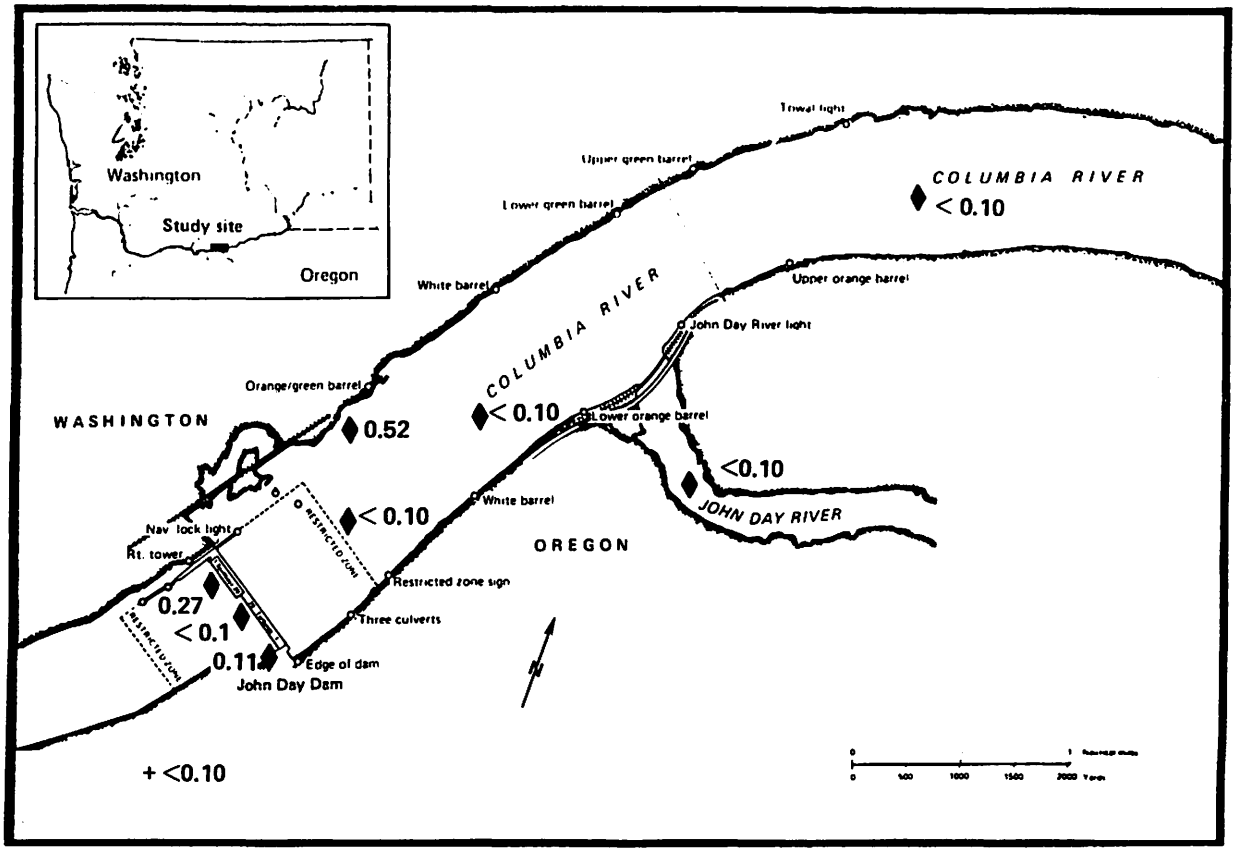


Figure 17.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 1-4 April 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

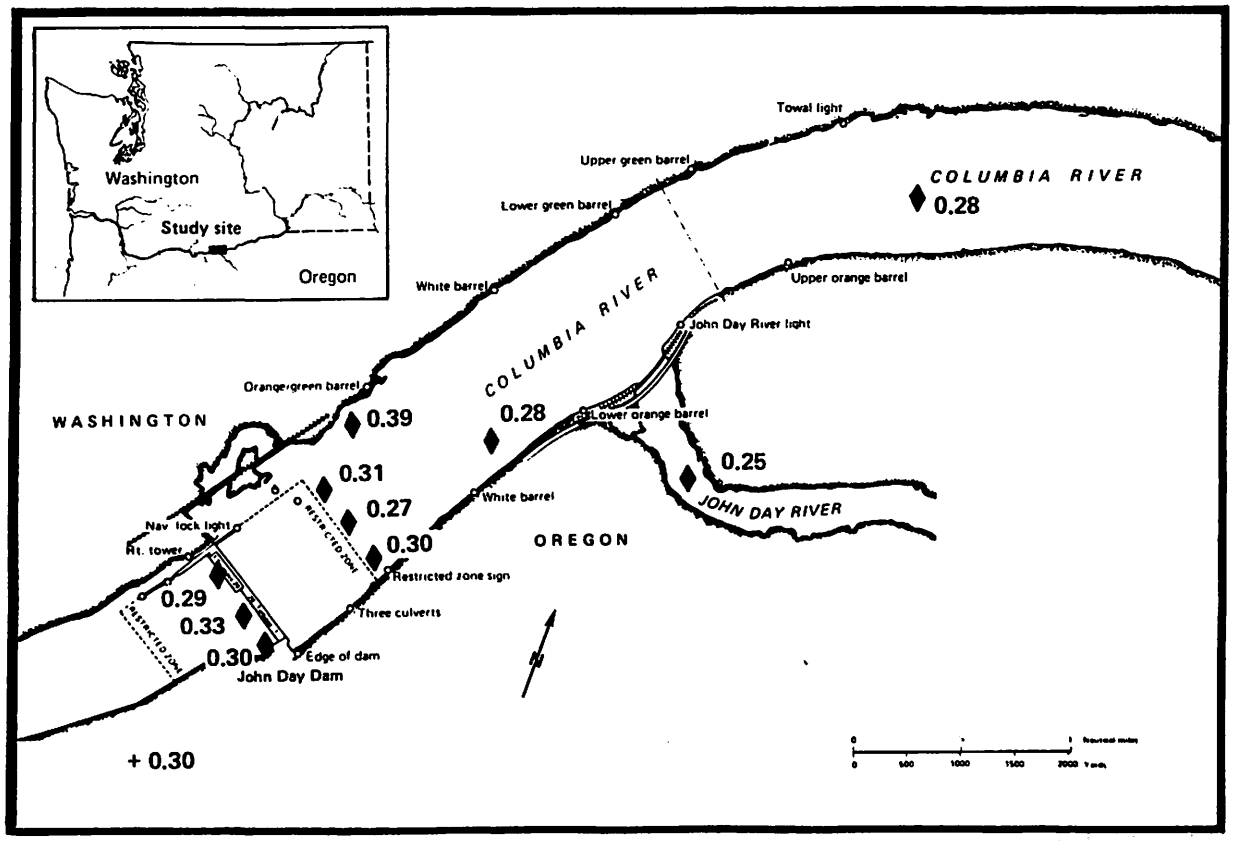


Figure 18.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 23-25 April 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

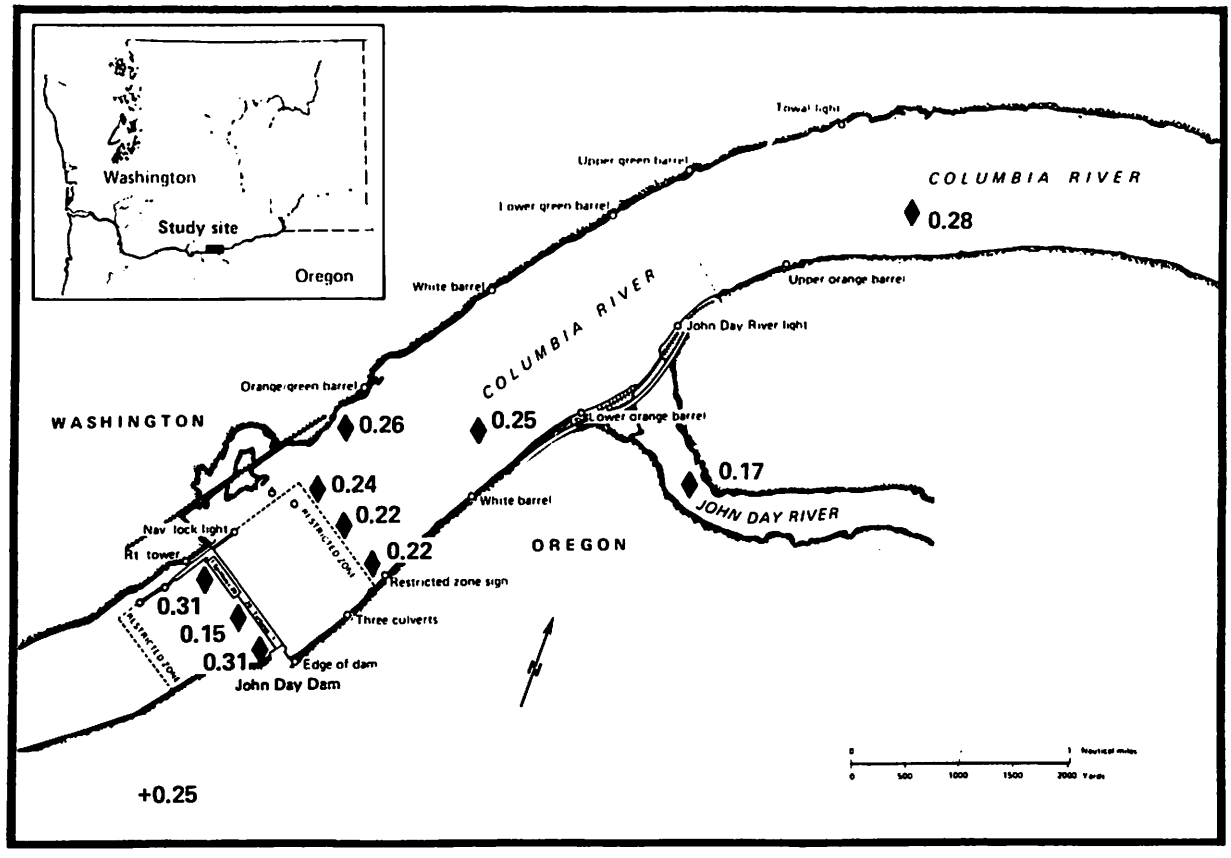


Figure 19.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 14-15 May 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

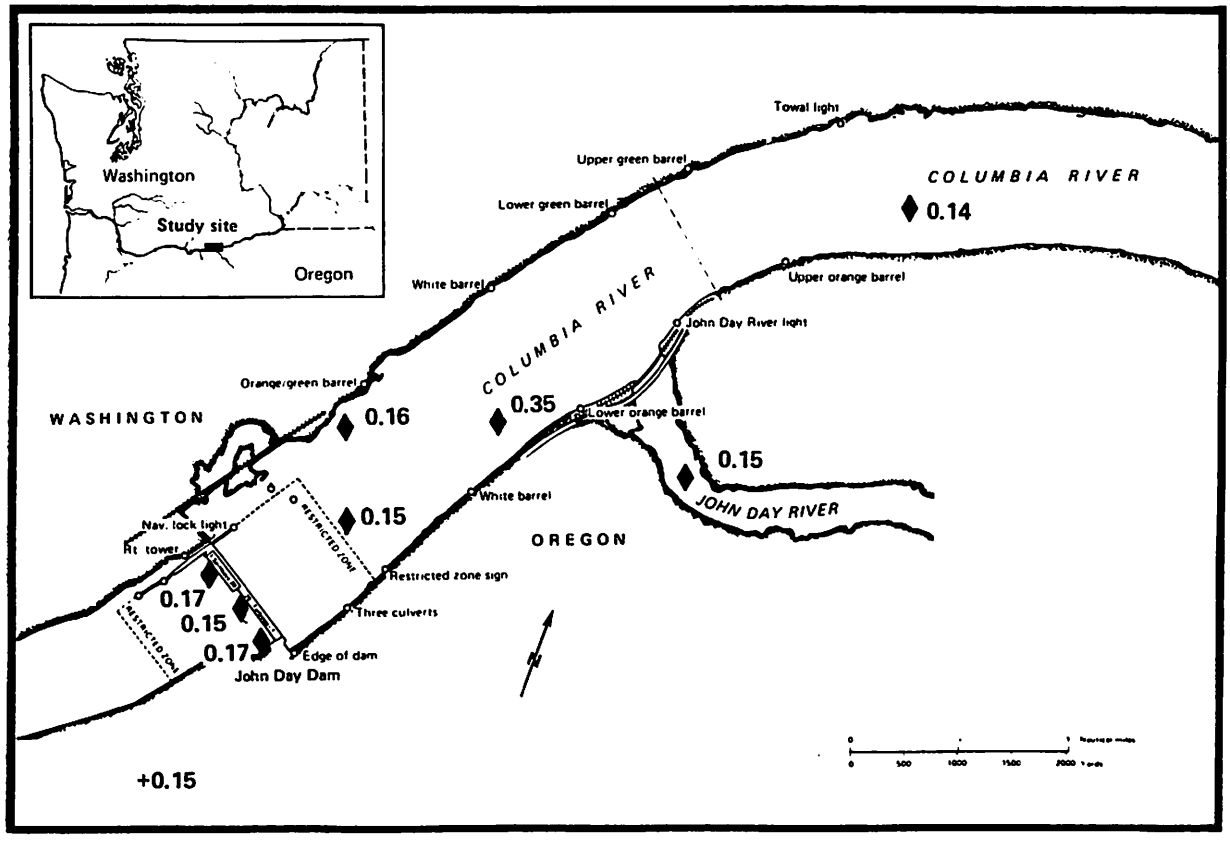


Figure 20.--Fluoride concentrations (ppm) at water sampling sites in the John Day Dam region, Columbia River, 10-11 June 1982. Fluoride concentrations below The Dalles Dam are indicated by +.

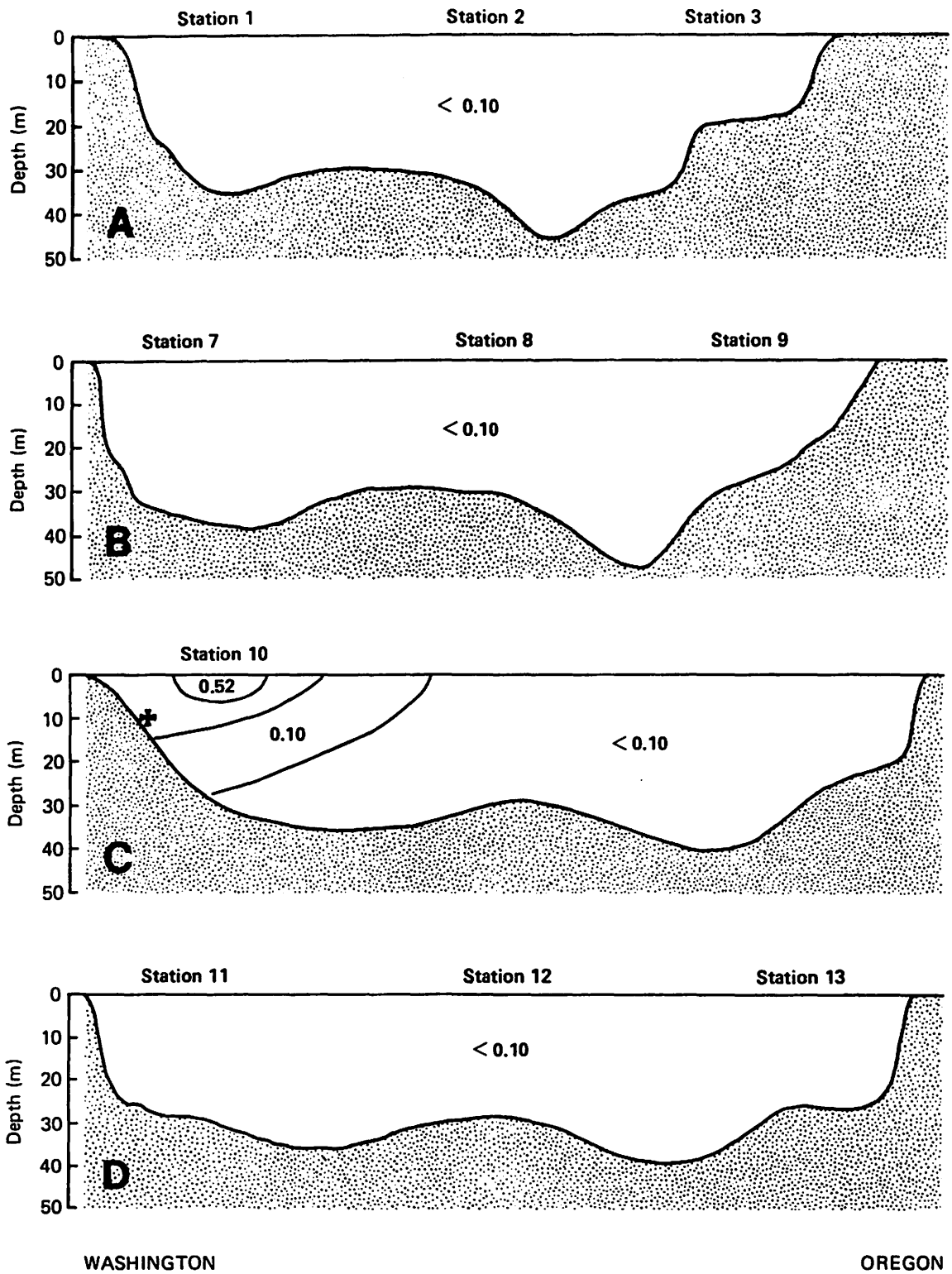


Figure 21.--Fluoride contours (ppm), 1-4 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations). Maltese cross indicates location of aluminum plant outfall.

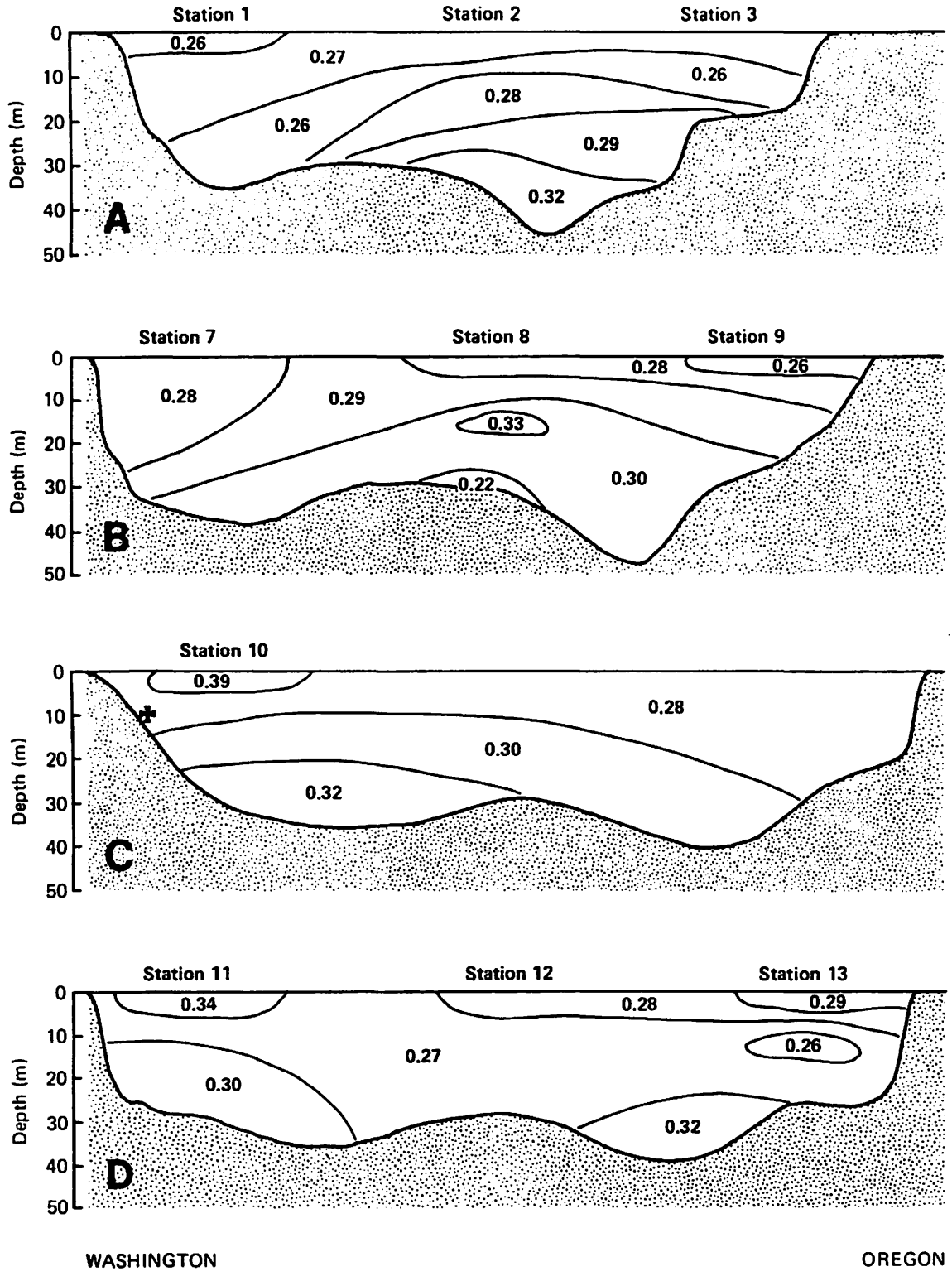


Figure 22.—Fluoride contours (ppm), 23-25 April 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations). Maltese cross indicates location of aluminum plant outfall.

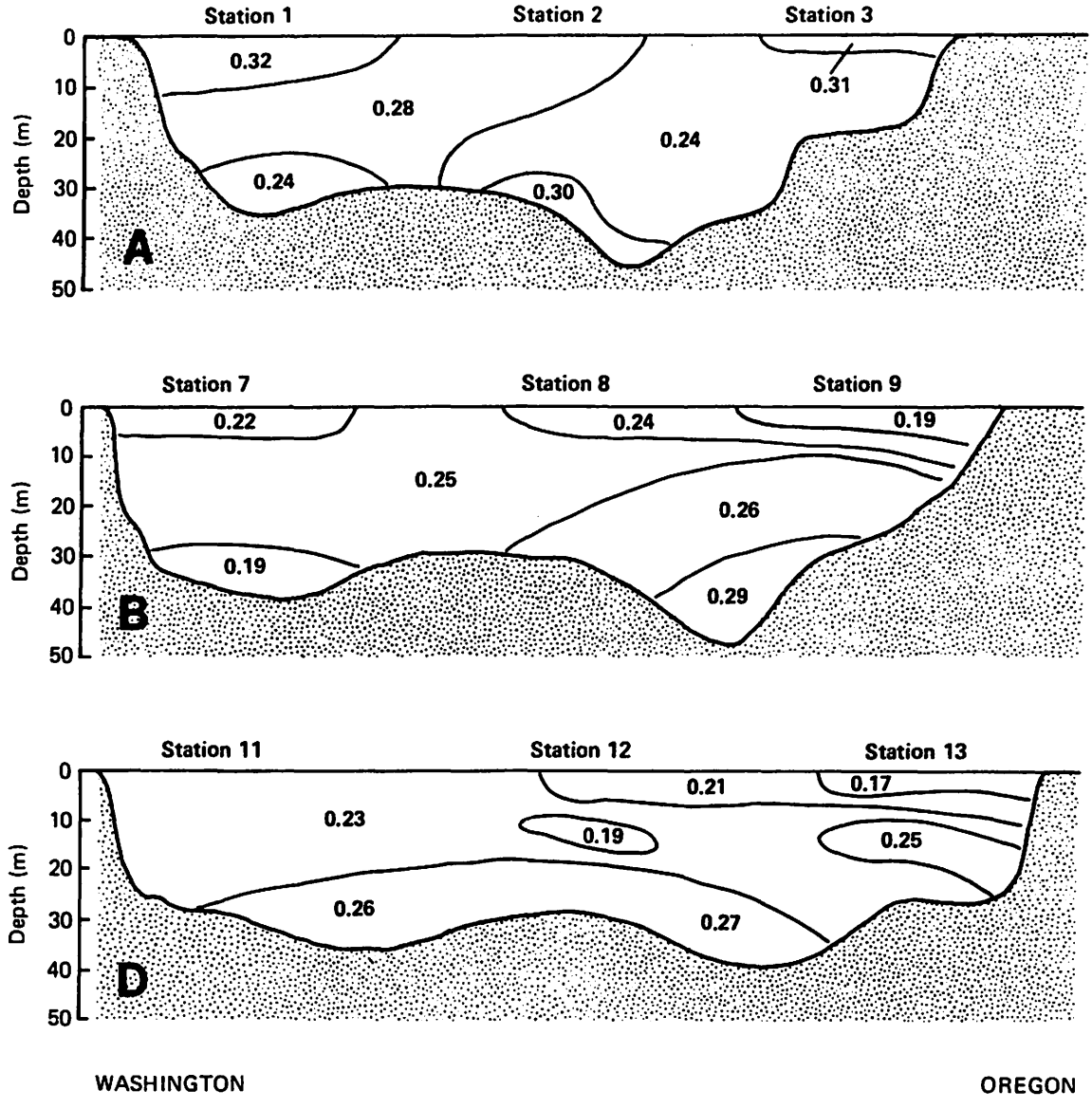


Figure 23.--Fluoride contours (ppm), 14-15 May 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

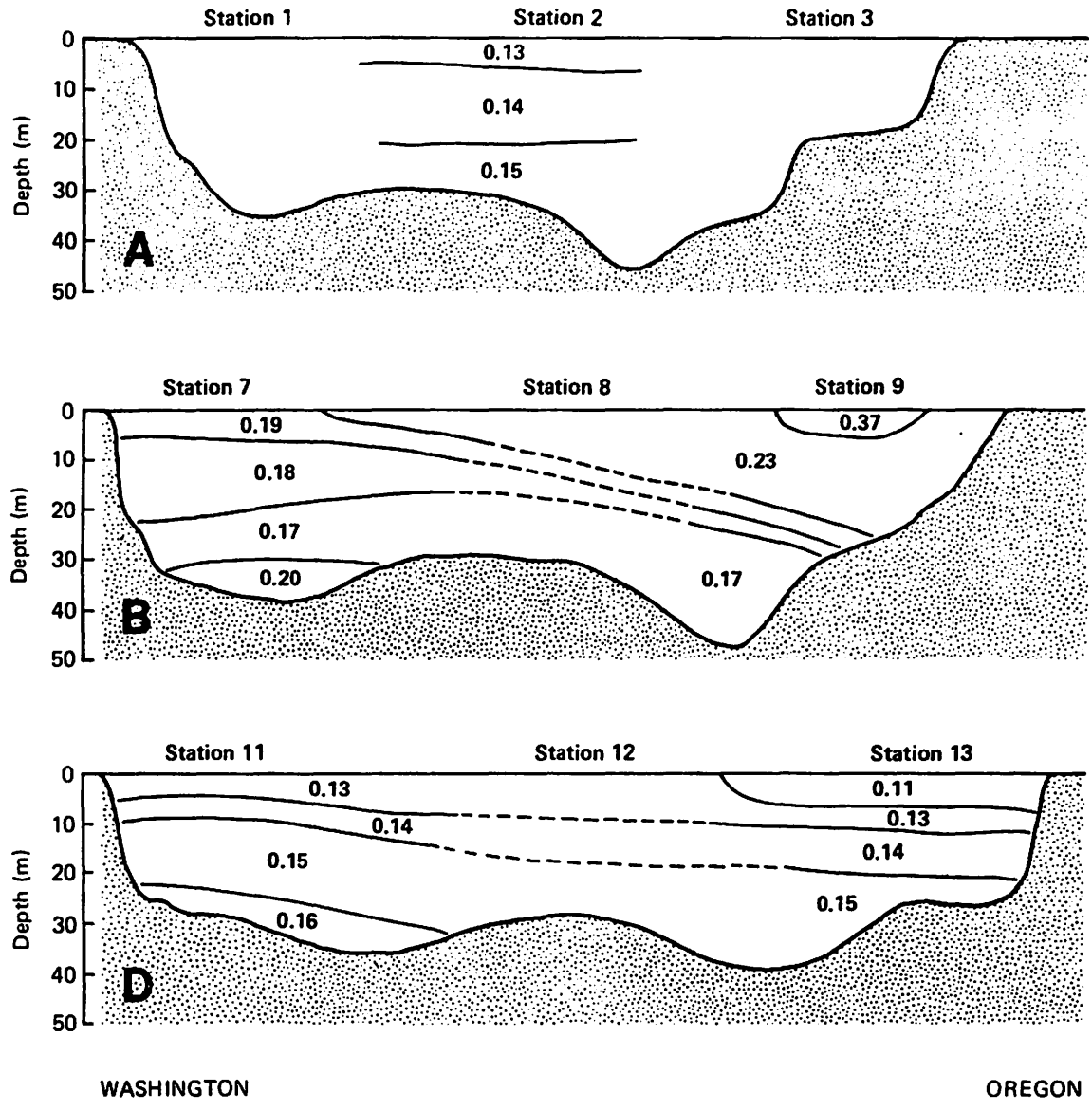


Figure 24.--Fluoride contours (ppm), 10-11 June 1982, John Day Dam region, Columbia River (see Fig. 1 for station locations).

Table 16.--Fluoride concentrations in the John Day Dam region, Columbia River, 1982. Average total discharge (John Day Dam) and average salmonids using north fishway during week after cruise.

| Cruise | Date | Fluorides (ppm) | | | | | | Salmonids using north fishway | Total discharge (kcfs) |
|---|---|---|---|---|---|---|---|---|---|
| | | Col. River background | Outfall area | Forebay | North fishway | South fishway | The Dalles | | |
| I. | 1 - 4 Apr | < 0.10 | 0.52 | < 0.10 | 0.27 | 0.11 | < 0.10 | 34% | 257 |
| II. | 23 - 25 Apr | 0.28 | 0.39 | 0.30 | 0.29 | 0.30 | 0.30 | 55% | 273 |
| III. | 14 - 15 May | 0.28 | 0.26 | 0.23 | 0.31 | 0.31 | 0.25 | 63% | 388 |
| IV. | 10 - 11 June | 0.14 | 0.35 | 0.15 | 0.17 | 0.17 | 0.15 | 24% | 378 |

During Cruise I, relatively high concentrations of fluoride were seen off the outfall and in the north fishway, while low, presumably background levels, were found at all other stations (Figures 17 and 21). During the subsequent week, the majority of adult salmonids passed through the south fishway (Table 16).

The fluoride concentrations were moderately high at all stations during Cruise II (Figures 18 and 22). Presumably this was the result of relatively low river flows and strong west winds. There was probably no significant difference in fluoride concentration in the two fishways. There was probably also no significant preference by salmonids for one fishway over the other during the subsequent week (Table 16). It was interesting to find that fluoride concentrations at The Dalles Dam were equally high at this time. This was also probably the result of upstream wind-driven flow carrying pollutants from the downstream aluminum plant outfall at that site.

The fluoride field was not much different by Cruise III, but suggested some movement of fluorides out of the upstream region (Figures 19 and 23). This movement was probably the result of considerably increased river flow, as reflected by total discharge over John Day Dam (Table 16). Even though no differences were found in fluoride concentrations at the two fishways, the adult salmonids slightly favored the north fishway during the subsequent week.

By Cruise IV, with continued high river flows, the fluoride concentrations at most stations were approaching the presumed background levels, although there were still pockets of high concentrations in the outfall area (Figures 20 and 24). Even though the fishways had similar fluoride concentrations at the time of Cruise IV, during the subsequent week, the majority of migrating salmonids preferred the south fishway (Table 16).

Apparently there is no information regarding the effect of fluorides on fish behavior. Fluorides are known to be enzyme inhibitors, thus having a potential to reduce activity at sublethal concentrations. It would be surprising if the migrating adult salmonids were indifferent to the fluoride concentrations seen in the John Day Dam region. Behavioral studies on the effects of fluorides, at comparable concentrations, would be a logical extension of this survey. Ultimately it will be necessary to observe the daily changes in the pollution field while concurrently radio-tracking individual salmonids. No tracking could be done in 1982, but because fish delays were recognized as a serious problem at John Day Dam in past years, it was assumed that delays also occurred in 1982. The continued preference for the south fishway suggests this.

## Metals

The aluminum plant outfall may also be a source of heavy metals which could influence 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 significantly depending on species, temperature, water hardness, pH, other dissolved materials, etc. 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 Dam region indicated no spatial gradients with respect to the total concentrations of these four metals. However, recent special analyses have revealed gradients in the study area with respect to the free (ionic) form of the metals (Table 17). It is the free form that is most probably toxic to fish. With the high suspended matter content of the Columbia River, and especially of the John Day River, free metals

Table 17.--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 |

probably have a short existence. This is reflected in the very high metal content of the sediments (Table 17). 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 17). McKim and Benoit (1971) reported maximum acceptable copper concentrations for brook trout, *Salvelinus fontinalis*, to lie in the range 9.5-17.4 ppb, while Drummond et al. (1973) found altered behavior in the same species with 6-15 ppb copper. Giattina et al. (1982) observed that rainbow trout, *Salmo gairdneri*, avoided copper in excess of 6.4 ppb. Hara et al. (1976) noted depressions of olfactory responses in rainbow trout to occur obove 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 avoided copper concentrations above 2 ppb. Sprague et al. (1965) observed that Atlantic salmon, *Salmo salar*, 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 10-3,000 ppb under various experimental conditions (McKee and Wolf 1963), and between 130-150 ppb for chinook salmon fry (Hoblou et al. 1954). These authors also report

increased toxicity of zinc in the presence of other metals (synergistic effects). 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 17).

There have also been wide lethal limits of lead reported for trout, 1,600-4,000 ppb (McKee and Wolf 1963), but narrower limits for coho salmon, O. kisutch, 340-410 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 10-10,000 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.

## Organics

In addition to the analyses 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 18). 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 19) 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 3.1 ppb or lower (Table 20). The concentrations of aromatic hydrocarbons were higher in the sediment collected near the aluminum plant

Table 18--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 (γ - 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,p'-DDE | 0.004 | |
| 6. | Benzothiophene | 0.10 | α-Chlordane | 0.002 | |
| 7. | 2-Methylnaphthalene | 0.08 | trans-Nonachlor | 0.002 | |
| 8. | 1-Methylnaphthalene | 0.07 | p,p'-DDE | 0.002 | |
| 9. | Biphenyl | 0.08 | o,p'-DDD | 0.004 | |
| 10. | 2,6-Dimethylnaphthalene | 0.08 | m,p'-DDD | 0.004 | |
| 11. | Acenaphthene | 0.07 | p,p'-DDD | 0.003 | |
| 12. | 2,3,5-Trimethylnaphthalene | 0.08 | o,p'-DDT | 0.003 | |
| 13. | Fluorene | 0.08 | p,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 | Heptachlorobiphenyls ) | | |
| 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) ) | | |
| | | | Ronnel[1/] | | |
| | | | Endosulfan[1/] | | |
| | | | Heptachlorepoxide[1/] | | |
| | | | Methoxychlor[1/] | | |
| | | | 2,4-D[1/] | | |
| | | | 2,4,5-TP[1/] | | |

1/ Only water samples were analyzed for these compounds.

Table 19.--Concentrations of aromatic compounds in sediment and water collected from the John Day Dam region, Columbia River.

| Compound | Settling pond water (ng/ml) 6/11/82 | Sediment (ng/g, dry weight) 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 | <.85 | <.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[a]anthracene | 0.52 | 20 | 4.3 | 1500 | 2000 | 280 | 100 | 1200 | 720 |
| chrysene | 1.5 | 39 | 12 | 4000 | 5800 | 780 | 310 | 2100 | 1500 |
| benzo[e]pyrene | 0.93 | 23 | 6.9 | 1800 | 2400 | 330 | 180 | 1300 | 770 |
| benzo[a]pyrene | 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 20.--Concentrations of chlorinated compounds in sediment collected from the John Day Dam region, Columbia River.

| Compound | | (ng/g, dry weight) | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 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 | L1 6/11/82 | L2 6/11/82 | Station 10+ 6/11/82 |
| hexachlorobenzene (HCB) | | .48 | .64 | .28 | .77 | 1.6 | .64 | .40 | .69 |
| Lindane ( γ-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 |
| α-Chlordane | | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 |
| trans-Nonachlor | | <.05 | <.05 | <.05 | <.05 | <.05 | <.05 | <.05 | <.05 |
| o,p'-DDE | | <.13 | <.13 | <.13 | <.13 | <.13 | <.13 | <.13 | <.13 |
| p,p'-DDE | | 2.4 | .76 | 2.4 | 2.3 | 3.1 | 1.9 | 1.4 | 1.9 |
| o,p'-DDD | DDTs | .28 | .16 | .29 | .22 | | | | |
| m,p'-DDD | | <.21 | <.21 | <.21 | <.21 | <.21 | <.21 | <.21 | <.21 |
| p,p'-DDD | | 1.3 | .28 | 1.6 | 1.3 | 1.5 | 1.2 | .83 | 1.1 |
| o,p'-DDT | | .17 | .09 | .11 | .10 | | | | |
| p,p'-DDT | | .70 | .41 | .78 | .70 | 1.7 | 1.2 | 1.4 | .44 |
| dichlorobiphenyls | ) | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 |
| trichlorobiphenyls | ) | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 |
| tetrachlorobiphenyls | ) | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 |
| pentachlorobiphenyls | ) PCBs | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 |
| hexachlorobiphenyls | ) | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 |
| heptachlorobiphenyls | ) | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 |
| octachlorobiphenyls | ) | <.06 | <.06 | <.06 | <.06 | <.06 | <.06 | <.06 | <.06 |
| nonachlorobiphenyls | ) | | | | | | | | |
| dichlorobutadienes | | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 | <.67 |
| trichlorobutadienes | (3CBD) ) | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 | <.17 |
| tetrachlorobutadienes | (TCBD) ) | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 | <.09 |
| pentachlorobutadienes | (PCBD) ) | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 | <.10 |
| hexachlorobutadienes | (HCBD) ) | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 | <.26 |

outfall and in the nearby lagoon than from the upriver stations (Table 19). 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.

Even though these organic compounds have not yet been detected in the river water, some are undoubtedly present and may influence the behavior of returning salmonids.

## SUMMARY

The results of this first year's investigation are preliminary. There is some evidence to link pollutants from the aluminum production plant to the delay of salmonids at John Day Dam, but this is not conclusive. Better real time observations on fluoride content, particularly, to correlate with fish-passage through the fishways are planned for 1983. Also, it will be essential to consider the behavior of adult and juvenile salmonids while in gradients of fluoride comparable to gradients found in the John Day Dam region. Such bioassay studies are proposed for next year and will be conducted at the University of Washington's experimental hatchery at Big Beef Creek, on Hood Canal. Investigations into the possible effects of the organic pollutants from the aluminum plant should be undertaken, especially in view of their buildup in the sediments upstream from the dam. Additional studies on the effects of these organic compounds are not planned for next year, but we do intend to look further into the extent, persistence, and influence of heavy metal ions, particularly copper, zinc, and cadmium.

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