Radio Tracking of Juvenile Salmonids in John Day Reservoir, 1982

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COASTAL ZONE AND ESTUARINE STUDIES

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INTRODUCTION

Salmon (*Onchorynchus* spp.) and steelhead (*Salmo gairdneri*) populations in the Columbia River system have been adversely affected by the growth of agriculture, general population, and hydroelectric production (Raymond 1979). Fishery agencies are concerned with the large losses of seaward migrating smolts—sometimes as high as 98% (Sims et al. 1978). Even with collection and transportation operations at upriver dams designed to minimize losses (Basham et al. 1982), large numbers of smolts remain in the river for a volitional outmigration. As agriculture and power demands grow, spill is no longer readily available at the dams and more of these smolts are forced to pass through the powerhouse. Consequently, protection of the nontransported smolts is a major concern, especially at John Day Dam. Special flows, spills, and sequential load dropping have been used in conjunction with the bypass system at John Day Dam, but the bypass system is still not efficient enough (Sims and Johnsen 1976), and more forebay behavior information is needed to efficiently move the fish to the spillway.

In 1979, development of a radio tag suitable for smolting salmon allowed observation behavior as they approached These radio tags were used in 1980 and again in 1981 to observe smolt behavior at John Day Dam (Sims et al. 1981; Faurot et al. 1982). In 1982, the National Marine Fisheries Service (NMFS) under contract to the U.S. Army Corps of Engineers (CofE), used radio tags to expand the knowledge of the behavior of smolting salmonids in the forebay of John Day Dam. The objectives of the study were as follows: (1) determine the effects of various modes of spill and powerhouse operation on juvenile chinook salmon behavior as they

migrated downstream, (2) correlate the observed chinook salmon behavior to metered flow data obtained from a Bonneville Power Administration (BPA) funded flow-net study (Sims and Giorgi 1982), and (3) monitor the relationship between diel behavior of smolts in the forebay and passage time at the dam.

METHODS

Site

Radio-tagged juvenile salmonids were tracked in the immediate vicinity of John Day Dam--River Kilometer (RKm) 347 to 353 (Figure 1). In this area, the river is about 1 km wide, and a major tributary, the John Day River, enters on the Oregon side at RKm 351.

The John Day project has three paths that smolts may follow to pass downstream: through the spillway, through the turbines, or through the bypass system. Passage through the turbines produces smolt mortality as high as 33% (Raymond 1979), and the design operational efficiency of the juvenile bypass system still needs improvement (Swan et al. 1982). The mortality for fish passing through the spillway is approximately 3% (Bell et al. 1972). Flows through the John Day project ranged from 130 to >500 kcfs during the spring outmigration, and involuntary spill began at about 300 kcfs.

Equipment

The juvenile radio tag was developed by NMFS electronics personnel to provide a means of monitoring movements of individual smolts. The radio tags are battery powered transmitters operated on a carrier frequency of approximately 30 megahertz (MHz). The transmitter and batteries are coated

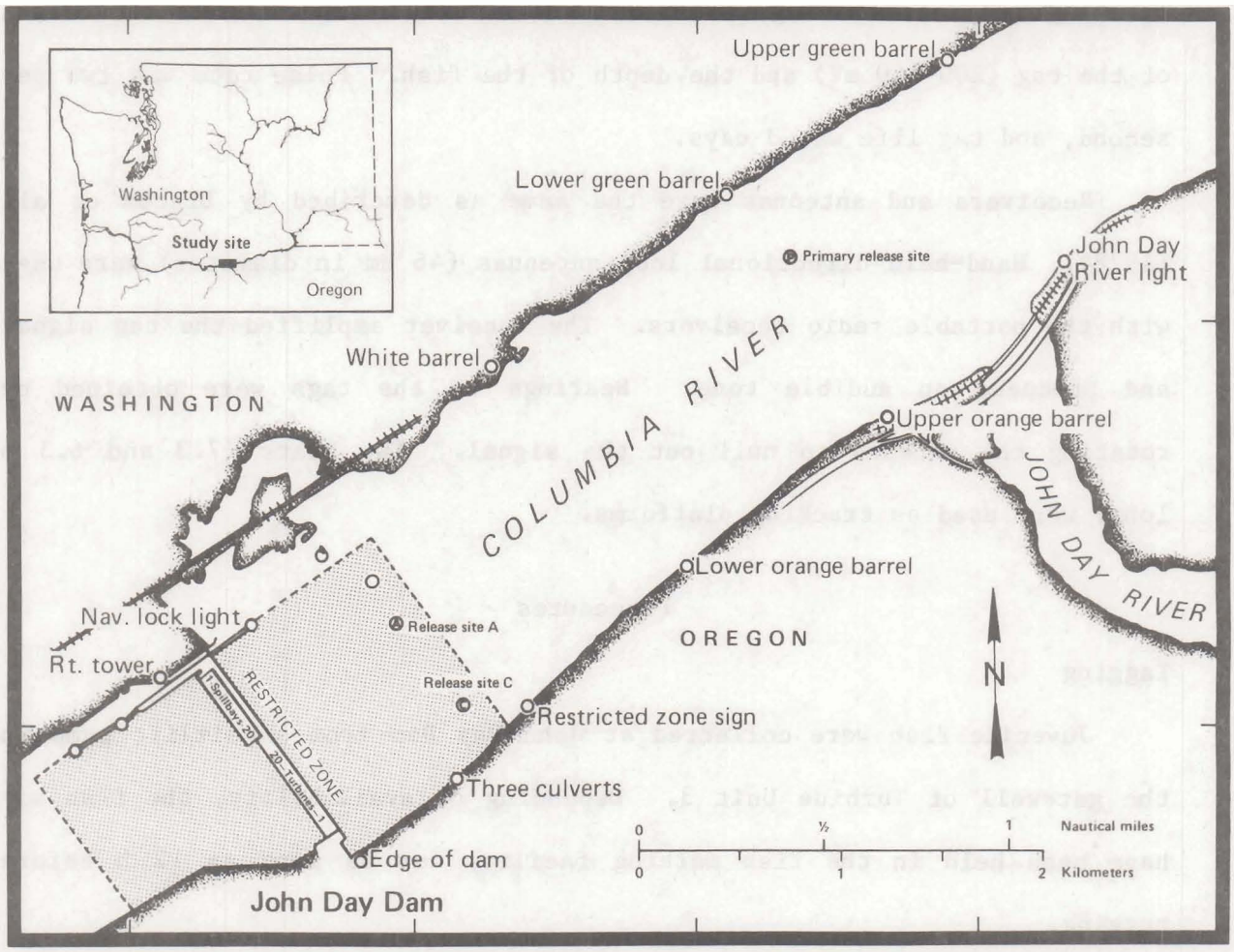

Figure 1.--Study area for radio tracking of juvenile salmonids at John Day Dam, 1982.

with acrylic and a mixture of paraffin and beeswax to form a flattened cylinder 26 x 9 x 6 mm, which weighs approximately 2.9 g in air. For identification purposes, each tag transmitted on one of nine specific frequencies spaced 10 kilohertz (KHz) apart (30.17 through 30.25 MHz). Tracking range of the tag varied from 50 to 300 m depending on the output of the tag (200-640 mV) and the depth of the fish. Pulse rate was two per second, and tag life was 3 days.

Receivers and antennas were the same as described by Liscom et al. (1978). Hand-held directional loop antennas (46 cm in diameter) were used with the portable radio receivers. The receiver amplified the tag signal and produced an audible tone. Bearings to the tags were obtained by rotating the antenna to null out the signal. Two boats (7.3 and 6.3 m long) were used as tracking platforms.

Procedures

Tagging

Juvenile fish were collected at John Day Dam from an airlift pump in the gatewell of Turbine Unit 3. Depending on availability, the fish may have been held in the fish marking facility for as long as 12 h before tagging.

The smolts used were longer than 152 mm and showed a minimum amount of descaling. The first two fish used in the study were anesthetized before tagging, but because of a fish death and a tag failure during the holding period before the third track, the third fish was tagged without anesthetic. The recovery time for this fish was almost immediate, and this fish was the first that reached the dam during the 1982 season. For tracks

4 through 7, we dummy-tagged fish (without aneshtetic), at the same time we radio tagged the test fish (with anesthetic). The nonanesthetized fish always recovered faster than the anesthetized fish, and the effects of stress did not appear to be different. Consequently, from release number 8 on, the fish were tagged without anesthetic.

After a fish was measured, the radio tag was dipped in glycerin and inserted into the fish's mouth. A plastic drinking straw was used to push the tag through the esophagus into the stomach. The flexible antenna extended out of the fish's mouth. Care was taken during tagging to ensure the fish was completely immobilized, as any movement during insertion of the tag could rupture the heart. If the tag was not inserted far enough, it was regurgitated by the fish, usually within an hour. The time required to tag and place the fish in the recovery tank was usually no more than 30 s.

Tagged fish were held in a recovery tank for at least 2 h before they were released into the river. This provided a test of the tag and allowed the fish to adjust to carrying the extra weight. After recovery, tagged fish were placed in a livewell on the tracking boat, transported to the release site, released into the river, and tracking began. Chinook salmon were the primary species studied, but steelhead were used late in the study when chinook salmon were not available.

Release Sites

Radio-tagged fish were released at three locations in the John Day forebay. The primary site (P) was approximately one-fourth of the river width directly out from the lower green barrel on the Washington shore (Figure 1). When poor weather conditions prevented tracking in this

vicinity, fish were released in the restricted zone at Site A near Buoy A on the north edge of the forebay restricted zone, or at Site C near Buoy C on the south edge of the restricted zone. This area was protected from wind by the dam, and tracking was always possible. Fish releases were generally made within an hour of 1900 h, except when diel behavior was being studied.

Tracking

The tracking range (50->300 m) and large size of the study area (5 km long by 1 km wide) required tracking by boat rather than from shore stations. Two boats, each with a two-man crew, were used for tracking the tagged fish. One person operated the boat while the second person operated the antenna and receiver. To stay within range of the tagged fish, one boat was deployed upwind from the fish, and the other boat was deployed to one side of the fish's expected location. As the relative position of the boats and fish changed, the boats would change position, one at a time, in anticipation of the relative movement.

Fixes for plotting the fish's location on tracking maps were made by placing a boat directly over the fish's location and then fixing the location of the boat on the map. The boat was judged to be directly over a fish when a strong signal was received throughout the entire 360° rotation of the antenna. Fixes to determine the location of the boat were made by measuring, with a sextant, the horizontal angle between fixed navigational aids and/or brightly colored and lighted markers placed at known positions on the river bank. The angles, when plotted with a three-arm protractor, provided a very accurate and fast method of locating fish positions on a navigational chart (Dunlap and Schufeldt 1969).

Short tracking ranges and high winds required that constant cross bearings be taken to stay with the fish. If the signal was lost, a marker buoy was dropped at the point of last contact, and the area was searched until the tagged fish was relocated. During the 1980 and 1982 tracking seasons, more steelhead tracks were terminated because of signal strength irregularities than chinook salmon tracks. We believe this is the result of a difference in depth behavior, and that frequent and deeper dives made by steelhead is the reason that the signal is lost.

RESULTS AND DISCUSSION

From 12 April to 26 June 1982, 43 juvenile salmonid smolts (37 chinook salmon, 6 steelhead) were radio tracked (Table 1). The mean length of the chinook salmon was 168 mm (152-192 mm) and the steelhead 169 mm (157-181 mm). Of the fish released, 26 were tracked until they passed the dam.

The increase in the number of fish tracked successfully during the 1982 season was due to the increased output of the radio tag and the use of chinook salmon as the primary test species. The increased range was obtained by decreasing tag life from 10 to 3 days and increasing pulse width.

River flows were varied in the vicinity of the dam by changing the spill and turbine loading conditions. Various combinations of spill and turbine loading were used during periods of peak passage (2100 to 0200 h). During tracking, total flows ranged from a low of 236.6 kcfs with 99.7 kcfs spill (42%) to a river flow of 448 kcfs with involuntary spill of 151.1 kcfs (34%). Set flow conditions originally designed by the CofE for their

Table 1.--Radio tracking summary.

Fish Number	Species	Lgth (mm)	Ms-222	Release site	Release time	Duration of track (h)	Cause of termination	Passage Location	Passage Time (h)	Discharge (kcfs) Spill	%	(Bays	Open)	Turbine
1	Chinook	169	yes	Abv. J.D. Rv.	1324	6.2	Lack of movement							
2	Chinook	171	yes	P	1843	1.8	Lost							
3	Chinook	166	no	P	1914	5.5	Nav. lock pasage							
4	Chinook	156	yes	P	1901	0.4	Lost							
5	Chinook	170	yes	A	2002	0.6	Lost							
6	Chinook	170	yes	P	1847	4.9	Passage	Spill 6	2343	102.1	31	(2-4)	(9-14)	228.3
7	Chinook	154	yes	P	2036	0.7	Lost							
8	Chinook	156	no	P	1902	0.3	Lost							
9	Chinook	170	no	P	1919	3.7	Passage	Turb 17B	2303	99.7	40	(11-20)		148.0
10	Chinook	182	no	P	1358	5.9	Day track only							
11	Chinook	172	no	P	2045	4.2	Passage	Spill 20	0059	99.7	36	(15-20)		108.6
12	Chinook	164	no	P	1844	1.0	Lost							
13	Chinook	165	no	P	1745	6.7	Lost							
14	Chinook	152	no	P	1846	0.5	Lost							
15	Chinook	168	no	A	1805	1.1	Passage	Turb 7B	1908	120.3	37	(1-20)		207.1
16	Chinook	164	no	P	1811	4.5	Passage	Turb 7C	2240	120.3	37	(13-15)	(17-20)	207.3
17	Chinook	160	no	P	1807	2.6	Lost							
18	Chinook	170	no	P	1729	3.5	Passage	Spill 17	2056	120.3	36	(14-20)		217.0
19	Chinook	162	no	P	0024	4.4	Lost							
20	Chinook	171	no	A	1822	0.8	Passage	Turb 12B	1910	80.7	27	(14-16)	(18-20)	215.3
21	Chinook	162	no	A	1946	0.9	Passage	Turb 10C	2038	80.7	30	(16-20)		192.0
22	Chinook	165	no	P	1839	2.9	Lost							
23	Chinook	174	no	P	1307	3.1	Passage	Spill 13	1611	134.1	30	(1-14)		311.5
24	Chinook	152	no	P	1829	2.0	Passage	Spill 19	2030	134.2	30	(14-20)		310.1
25	Chinook	155	no	P	1801	5.3	Passage	Spill 13	2318	150.4	40	(14-20)		227.7
26	Chinook	163	no	A	1948	1.1	Passage	Spill 14	2056	150.4	40	(14-20)		224.2
27	Chinook	160	no	P	1750	3.1	Passage	Spill 19	2057	150.4	40	(14-20)		224.2
28	Chinook	154	no	C	2106	1.2	Passage	Turb 8A	2215	150.4	36	(1-5)	(12-20)	265.7
29	Chinook	167	no	C	2110	1.1	Passage	Turb 8B	2218	150.4	37	(1-5)	(12-20)	258.6
30	Sthd	174	no	P	1903	5.7	Passage	Spill 2	0045	150.4	42	(1-5)	(12-20)	205.2
31	Chinook	192	no	P	1753	5.5	Lack of movement							
32	Sthd	181	no	P	1750	2.9	Passage	Turb 7C	2043	81.1	30	(14-20)		209.5
33	Chinook	168	no	A	2000	1.4	Passage	Turb 11B	2122	150.4	44	(1,2)(4,5)	(12-20)	192.7
34	Chinook	160	no	P	1733	5.1	Passage	Turb 1	2239	150.4	38	(1-5)	(12-20)	242.1
35	Chinook	166	no	P	2325	3.0	Passage	Spill 15	0225	150.4	45	(1-5)	(12-20)	186.4
36	Chinook	162	no	P	1714	4.2	Passage	Turb 11C	2124	100.1	29	(1-5)	(12-20)	249.5
37	Chinook	159	no	P	1737	4.6	Passage	Spill 17	2211	117.7	36	(14-20)		213.4
38	Sthd	158	no	P	1848	2.8	Lost							
39	Chinook	163	no	P	1735	4.3	Passage	Turb 7C	2152	161.5	37	(1-5)	(14-20)	270.8
40	Sthd	169	no	P	1742	4.6	Lack of movement							
41	Sthd	157	no	P	1740	3.8	Passage	Turb 4A	2130	151.1	34			296.3
42	Sthd	172	no	P	0435	5.4	Lack of movement							
43	Chinook	157	no	P	2127	1.7	Passage	Spill 16	2311	143.1	32	(1-5)	(12-20)	299.3

Release Site P - 250 m off shore at the lower green marker barrel.
Site A - At bouy A (near mid-dam at upper edge of restricted zone).
Site C - In restricted zone closer to Oregon shore than Site A.

sonar evaluation were not available because of high flow conditions. This limited the number of radio tracks that could be obtained during any one flow condition.

For the 26 fish tracked to the dam, passage locations were evenly split between the powerhouse and the spill sides of the dam. Thirteen fish passed through the powerhouse, and twelve fish passed through the spillway. One fish is believed to have gone downstream through the navigation lock. Passage locations for just those fish released at the primary release site near the Washington shore, approximately 3 km upstream from the dam, were not evenly split. Eleven fish passed through the spillway, one through the navigation lock, and seven through the powerhouse. Fish released within the restricted zone (Sites A and C) also passed through the powerhouse and spillway in a disproportionate manner. One fish passed through the spillway, and six fish passed through the powerhouse.

Primary Releases

Even though the number of tracks from the primary release site during any given flow condition was small, we believe that the tracks indicated that timing and rate of spill can be controlling factors for moving smolts to the spillway for passage. Of the 18 fish tracked to the dam from the primary release site (Table 2), 11 (61%) stayed on the spill side of the river as they approached the restricted zone whereas 7 (39%) moved to the powerhouse side. Of the 11 fish that moved down the spill side of the river 9 (82%) passed through the spillway and 5 (71%) of the 7 fish that crossed to the powerhouse side of the river passed through the powerhouse. During the tracks when fish stayed on the spill side of the river, the spill rate was 34% of the total river flow or greater in all but two cases.

Table 2.--Summary of the effects of various spill levels on the approach to the resticted zone and eventual passage location of radio tagged salmonid smolts tracked in 1982.

	Approach to restricted zone					
	Spill side			Powerhouse side		
		Passage location			Passage location	
% of river flow being spilled	Total	Spill	Powerhouse	Total	Spill	Powerhouse
0-20	1	1	-	1	-	1
21-33	1	-	1	4	1	3
34-45	9	8	1	2	1	1
Total	11	9	2	7	2	5

When the fish moved to the powerhouse side during their movements to the dam, the rate of spill was greater than 34% during only two of the seven tracks.

Restricted Zone Releases

No apparent effects of spill were seen on the fish released within the restricted zone. The two fish released on the Oregon side of the restricted zone (Site C) passed through the powerhouse and four of the five fish released on the mid-dam line (Site A) passed through the powerhouse. The rate of spill during the tracks of fish released at Buoy A ranged from 27 to 43% of the total river flow. The one passage through the spillway (Bay #14) was made when the spill rate was 40% of the river flow, and the flow was concentrated on the powerhouse end of the spillway.

The data from the BPA flow-net study are not yet available for an evaluation of behavior with known flow direction and velocities.

Spill Configurations

Of the factors that cause fish to move to the spillway for passage, configuration of the spill does not appear to be as important as the amount of river flow being spilled. Three spill configurations were tested in 1982: equal spill across the entire spillway; a concentrated spill next to the powerhouse, usually at Gates 14-20; and a split spill, with a low flow at Gates 1-5 on the north end of the spillway and the majority of the flow through Gates 12-20. During the equal spill, seven radio tagged fish passed the dam, five (71%) on the spill side and two (29%) on the powerhouse side. During concentrated spill near the powerhouse, 10 fish passed the dam, 5 (50%) through the spillway and 5 (50%) through the

powerhouse. During split spill, eight fish passed the dam, three (38%) through the spillway and five (62%) through the powerhouse. The percent of the total river flows being spilled during each spill configuration covered the full range of the flows tested. With the limited sample sizes available no differences were observed between configurations.

Concentrating the flow near the powerhouse creates problems for adult salmonid passage and barge traffic. Moving the spill away from the north end of the spillway reduces the attraction flow into the north fishway. There may be a period of the day, however, when adult passage is low enough that moving the spill closer to the powerhouse would have little or no effect on overall adult passage. Concentrating high flows near the powerhouse creates eddy currents below John Day Dam that make barge navigation difficult. When this condit was present, some barge operators delayed passage at John Day Lock until the flow configuration was changed.

Diel Behavior

Tests in 1980 and 1981 indicated that the majority of the smolts passed our primary release site on their way to the dam. There were also indications that the release area is a holding area for fish that approach the dam during daylight periods. The sample size for that assumption is small, and fish released at the upstream site in 1982, (also a small sample 2) tended to move randomly downstream during the holding period with no obvious effect from any rate of spill. An exception to the pattern of fish holding up until darkness was fish #23. It was released during a daylight period at the peak of the outmigration and it moved without delay to the dam for passage. Spill during its approach to

the dam was 37% and the fish stayed on the spill side of the river for passage through the spillway. In 1982, two fish were released after dark at the primary release site. Both fish moved directly down to the restricted zone. One was lost just inside the restricted zone and the other passed through the spillway 3 h after its release.

Radio Tracks 1980-1982

When the 1982 data are combined with data from 1980 and 1981, the effects of spill rates between zero and 45% of the total river flow can be observed. During the 3 years of juvenile tracking studies, 36 smolts were monitored as they moved from release sites upstream from the restricted zone to eventual passage at the dam (four smolts in 1980 and one in 1981 were released 1 km upstream from our 1981, 1982 primary release site). Table 3 gives a breakdown on which side of the river the fish approached the dam, what the spill rate was during the approach, and where the fish passed through the dam.

When the spill rate was 20% of the river flow or less, 14 fish were tracked to the dam from upstream (primary) release sites; 6 (43%) moved down the Washington side of the river and 8 (57%) moved down the Oregon side. All of the fish from the Oregon side (eight) plus four fish from the Washington side passed through the powerhouse; only two fish (14%) passed downstream through the spillway.

Ten fish were observed as they aproached the dam during spill that ranged from 21 to 33% of the total river flow. Seven fish (70%) moved down the Oregon side of the river, and three fish (30%) moved down the Washington side. The passage locations for these fish were evenly split between the powerhouse and the spillway, five fish each.

Table 3.--Summary of the effects of various spill levels on the approach to the restricted zone and eventual passage location of radio tagged salmonid smolts tracked in 1980 through 1982.

	Approach to restricted zone					
	Spill side			Powerhouse side		
		Passage location			Passage location	
% of river flow being spilled	Total	Spill	Powerhouse	Total	Spill	Powerhouse
0-20	6	2	4	8	-	8
21-33	3	3	0	7	2	5
≥34	10	8	2	2	1	1
Total	19	13	6	17	3	14

During periods when the spill rate was greater than 33%, 12 fish were observed as they approached the dam. Ten fish (83%) moved down the Washington side of the river and two fish (17%) moved down the Oregon side. Of the 12 fish, 9 (75%) passed the dam via the spillway and 3 (25%) passed via the powerhouse.

If these figures are used without further input, it would appear that 75% of the spring outmigration could be passed through the spillway with a spill rate of 34%. That passage rate may be biased by the time of day that tagged fish were released and the location of release--neither factor has been quantitatively studied. Smolt tracks in 1980 and 1981 indicated that the majority of the fish moving downstream passed through our primary release area, but the release location of these fish may have biased the data.

Data from purse seine operations indicated that fish move in the reservoir during the day and heldup during periods of darkness (Sims 1976). Smolt monitoring data at John Day Dam indicated that smolts entered the dam during periods of darkness and not during the day. With no passage during the day, the fish must holdup above the dam until dark. The radio tracks indicated that the fish released upstream from the John Day River spent the holding period near our primary release area, and that fish released into that holding area moved further downstream before holding up. Information from purse seining indicated there were large numbers of fish in the area between the restricted zone and the mouth of the John Day River.

To determine the portion of the migrating population that can be expected to benefit from any given spill condition, further tests are needed to determine where smolts hold during daylight periods, what the effects of spilling during the holding period are, and the distance upstream from the dam that fish are holding during darkness.

Movement Rate

The rates of movement for chinook salmon in 1982 (Table 4) were within the rates reported in 1980 and 1981. The average rates of movement reported are net rates from release point to the point the track was terminated and do not take into account meanders that fish might take. For chinook salmon, the 1980 and 1981 average rates were 0.52 and 0.59 km/h, respectively. In 1982, the average rate for chinook salmon was 0.58 km/h.

For steelhead, our assessment of movement rates has been complicated by their meandering behavior. In 1982, only six steelhead were tracked, and the average rate of movement was 0.47 km/h. In 1980, six steelhead had an average rate of 0.40 km/h, and in 1981 a year that included more daytime tracks, nine steelhead averaged 0.20 km/h. In general, steelhead tend to meander more than chinook salmon and that is the reason for the slower travel rates for steelhead from the release point to the point the track was terminated.

SUMMARY AND CONCLUSIONS

During the spring of 1982, radio-tracking studies were conducted to monitor the approach and passage behavior of salmonid smolts under various modes of spill and powerhouse operation at John Day Dam. Forty-three radio tagged smolts (37 chinook salmon and 6 steelhead) were released into the John Day Dam forebay, and 26 were tracked to the dam. Of the 26 fish tracked to the dam, 13 passed through the powerhouse, 12 through the spillway, and 1 through the navigation lock.

Of the factors that influence the passage location of smolts, the percentage of the total river discharge being spilled appears to have the greatest effect. Spill rates of over 33% are needed to keep the fish on the Washington side of the river, and the higher spill rates tend to keep

Table 4.--Net downstream movement rates of radio-tagged salmonid smolts in John Day Dam forebay, spring 1982.

Fish number	Species	Duration of track (h)	Net downstream movement: Distance (km)	Rate of travel (km/h)	Travel per day (km/day)
1	Chinook	6.2	1.7	0.27	6.58
2	Chinook	2.5	1.6	0.64	15.36
3	Chinook	5.5	3.1	0.56	13.53
4	Chinook	0.4	-	-	-
5	Chinook	0.6	-	-	-
6	Chinook	4.9	3.2	0.65	15.67
7	Chinook	0.7	-	-	-
8	Chinook	0.3	-	-	-
9	Chinook	3.7	3.1	0.84	20.11
10	Chinook	5.9	0.2	0.03	0.81
11	Chinook	4.2	3.3	0.79	18.86
12	Chinook	1.0	0.1	0.10	2.40
13	Chinook	6.7	1.7	0.25	6.09
14	Chinook	2.3	0.2	0.09	2.09
15	Chinook	1.1	0.7	0.64	15.27
16	Chinook	4.5	3.1	0.69	16.53
17	Chinook	2.6	1.8	0.69	16.62
18	Chinook	3.5	3.1	0.89	21.26
19	Chinook	4.4	2.6	0.59	14.18
20	Chinook	0.8	0.7	0.88	21.00
21	Chinook	0.9	0.7	0.78	18.67
22	Chinook	4.4	1.2	0.27	6.55
23	Chinook	3.1	3.1	1.00	24.00
24	Chinook	2.0	3.0	1.50	36.00
25	Chinook	5.3	3.0	0.57	13.58
26	Chinook	1.1	0.7	0.64	15.27
27	Chinook	3.1	3.0	0.97	23.22
28	Chinook	1.2	0.6	0.50	12.00
29	Chinook	1.1	0.6	0.55	13.09
30	Steelhead	5.7	3.1	0.54	13.05
31	Chinook	5.5	1.3	0.23	5.67
32	Steelhead	2.9	3.1	1.07	25.66
33	Chinook	1.4	0.7	0.50	12.00
34	Chinook	5.1	3.1	0.61	14.59
35	Chinook	3.0	3.0	1.00	24.00
36	Chinook	4.2	3.1	0.74	17.71
37	Chinook	4.6	3.1	0.67	16.17
38	Steelhead	2.8	0.8	0.29	6.86

Table 4.--cont.

Fish number	Species	Duration of track (h)	Net downstream movement: Distance (km)	Net downstream movement: Rate of travel (km/h)	Net downstream movement: Travel per day (km/day)
39	Chinook	4.3	3.0	0.70	16.74
40	Steelhead	4.6	1.1	0.24	5.74
41	Steelhead	3.8	3.1	0.82	19.58
42	Steelhead	5.4	0.7	0.13	3.11
43	Chinook	1.7	2.9	1.71	40.94
	Total	139.0	78.2	x=0.56	
	Chinook	113.8	66.3	0.58	
	Steelhead	25.2	11.9	0.47	

the fish from crossing from the spill side of the river to the powerhouse once they are within the restricted zone.

Based on the three spill shapes tested in 1982 (flat, split, and concentrated at the powerhouse end of the spillway) and the passage locations of the radio tagged smolts, no spill configuration was noteably better than the others. Slightly more fish passed through the spillway under flat and concentrated spills than when the spill was split. The concentrated spills that were tested caused barge navigation problems and possible adult passage problems.

Our study of diel behavior in the forebay has shown that smolts holdup in the forebay and pass through the dam at night. We have not however, addressed specific holding locations and the effect of spill on those locations. Consequently, we do not know what portion of the general population that our test fish represent. Further studies are needed in this area. In 1982, two of the three fish tracked during daylight periods held up upstream from the restricted zone. The third fish, released during the peak of the run, moved directly to the dam and passed through the spillway during the day.

In 1982, the net movement rate for chinook salmon from release to last heard location was 0.58 km/h. The net rate for steelhead was 0.47 km/h.

Conclusions determined from these tracks and their significance come from rather small samples. Patterns are beginning to emerge, but further replicates of conditions are necessary to develop firm spill recommendations. Based on our present level of knowledge, our conclusions are as follows:

1. The majority of the fish that can benefit from water being spilled are those that stay on the Washington side of the river as they approach the dam.

2. To keep migrating smolts on the Washington side of the river, spill should be greater than 34% of the total river flow.

3. The diel behavior patterns of radio tagged smolts in the forebay supports data based on diel sampling at the dam.

4. Further studies are needed on the location of daylight holding areas and the effects of spill on the smolts in these locations.

5. An evaluation of radio tagged smolt behavior in relation to the flow-net will be made when the flow-net data becomes available.

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APPENDIX

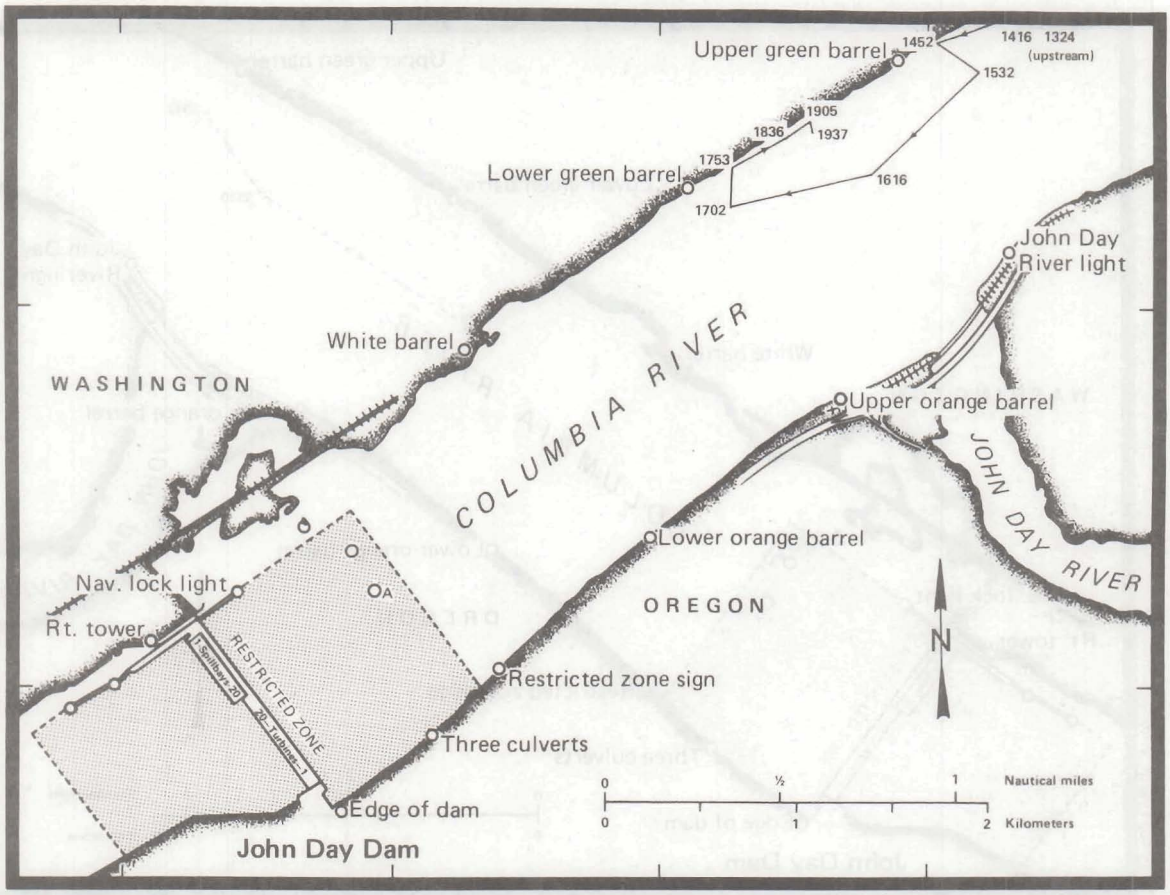
Individual radio tracks of juvenile salmonids, 1982.

Fish Number 1
Chinook salmon 169 mm
10 April 1982

Track number 1 was a training activity for the crew, but it also shows daylight behavior. When the fish moved upstream and then remained stationary the track was terminated. The effective tracking range was 500 feet.

Flow Kcfs

Time	1300	1400	1500	1600	1700	1800	1900	
Total	237.4	237.9	239.8	239.0	239.1	239.7	258.3	
Turbine	158.1	156.5	156.7	157.6	157.8	158.4	176.9	
Spill	76.9	80.7	80.7	80.7	80.7	80.7	80.7	
% spill	32	34	34	34	34	34	31	

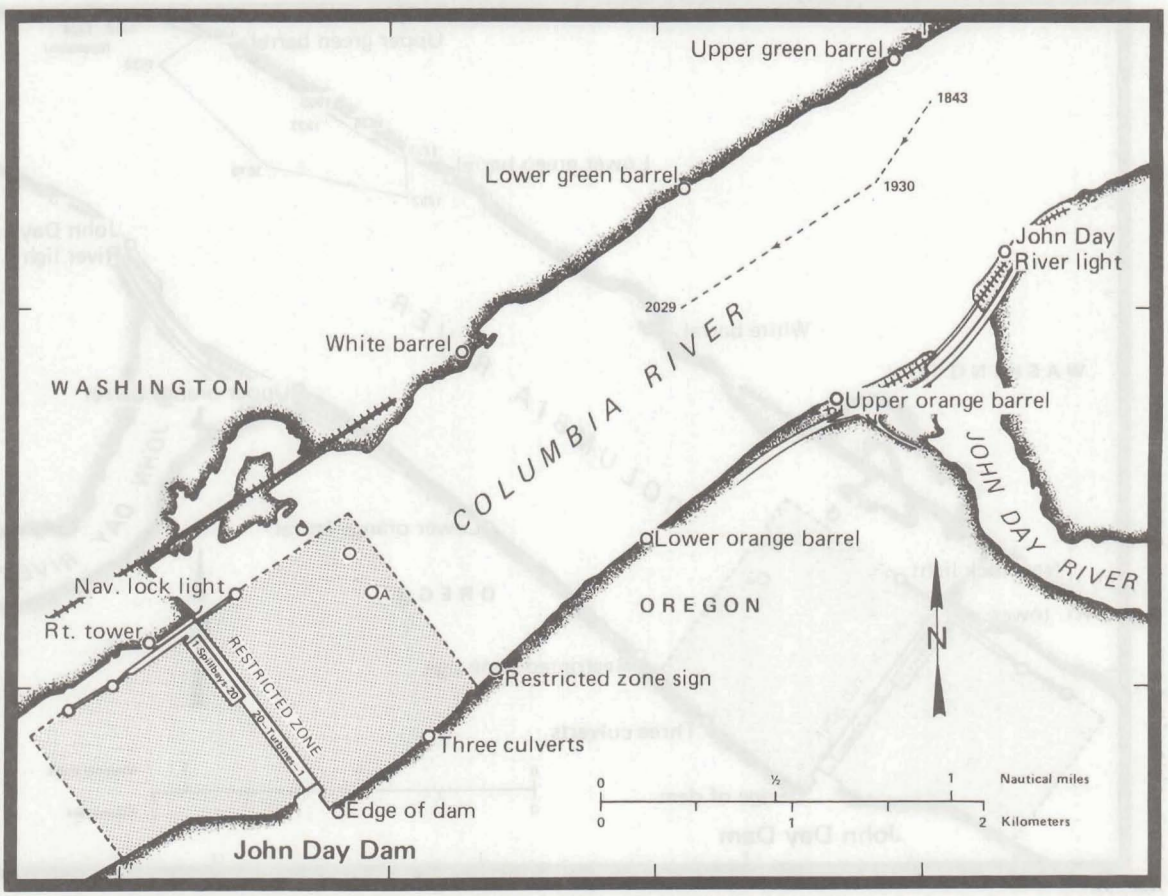


Fish Number 2
Chinook salmon 171 mm
11 April 1982

Fish number 2 was hard to follow. During the 2.5 hours that we worked with this fish, we had radio signals for less than 60 minutes. The track was terminated an hour after the last signal was los

Flow Kcfs

Time	1800	1900	2000					
Total	239.2	258.3	278.5					
Turbine	158.4	176.9	195.4					
Spill	80.7	80.7	80.7					
% spill	34	31	29					

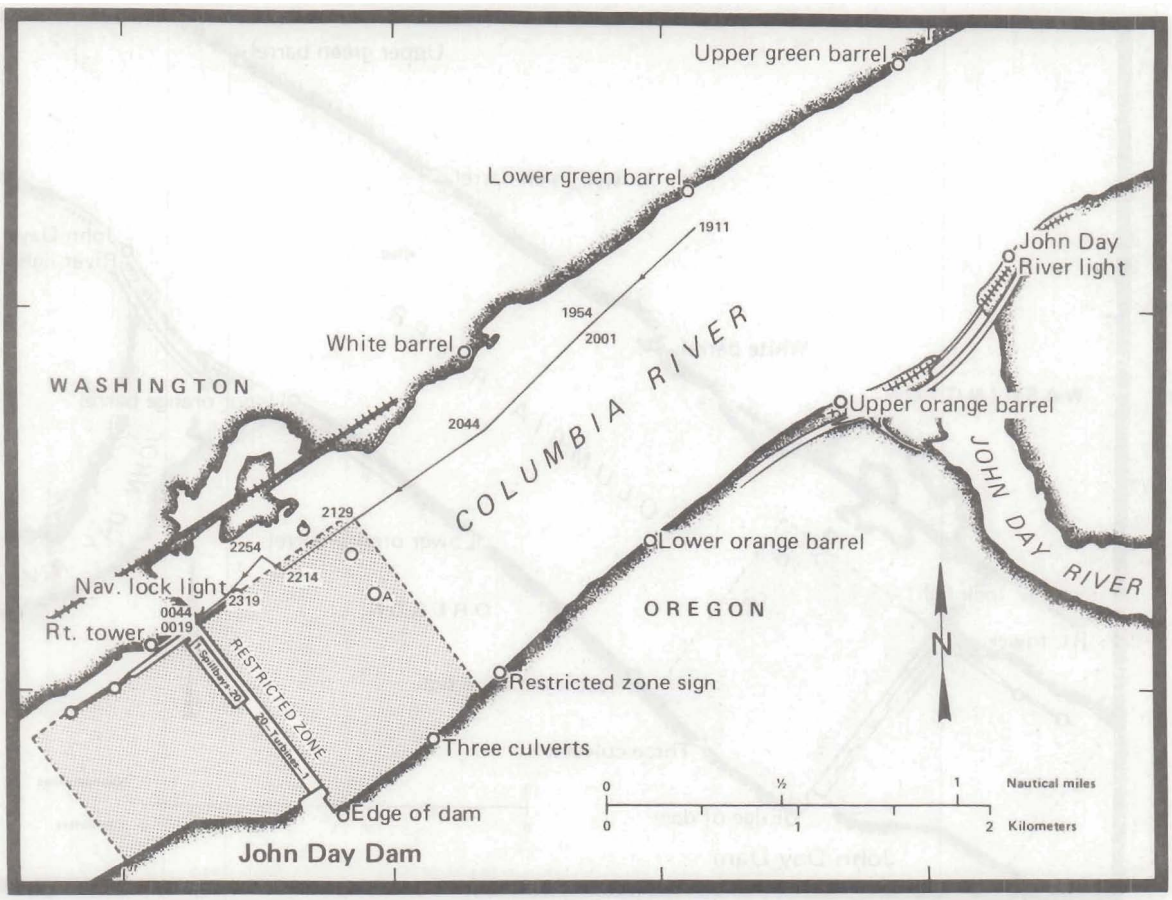


Fish Number 3
Chinook salmon 166 mm
12 April 1982

Fish Number 3 moved at a steady rate until it got to the upstream gate of the navigation lock. When the fish had not moved for an hour, the track was terminated. A check of the lockage report showed a downstream lockage one hour after the track ended, and a check for tag signals later in the morning showed no fish present at the dam.

Flow Kcfs

Time	1900	2000	2100	2200	2300	2400	0100	
Total	302.2	296.1	317.7	290.0	268.6	309.7	286.4	
Turbine	277.5	272.3	266.7	237.8	183.6	171.2	146.5	
Spill	22.3	23.2	50.2	52.5	84.4	137.9	139.3	
% spill	7	8	16	18	31	45	49	

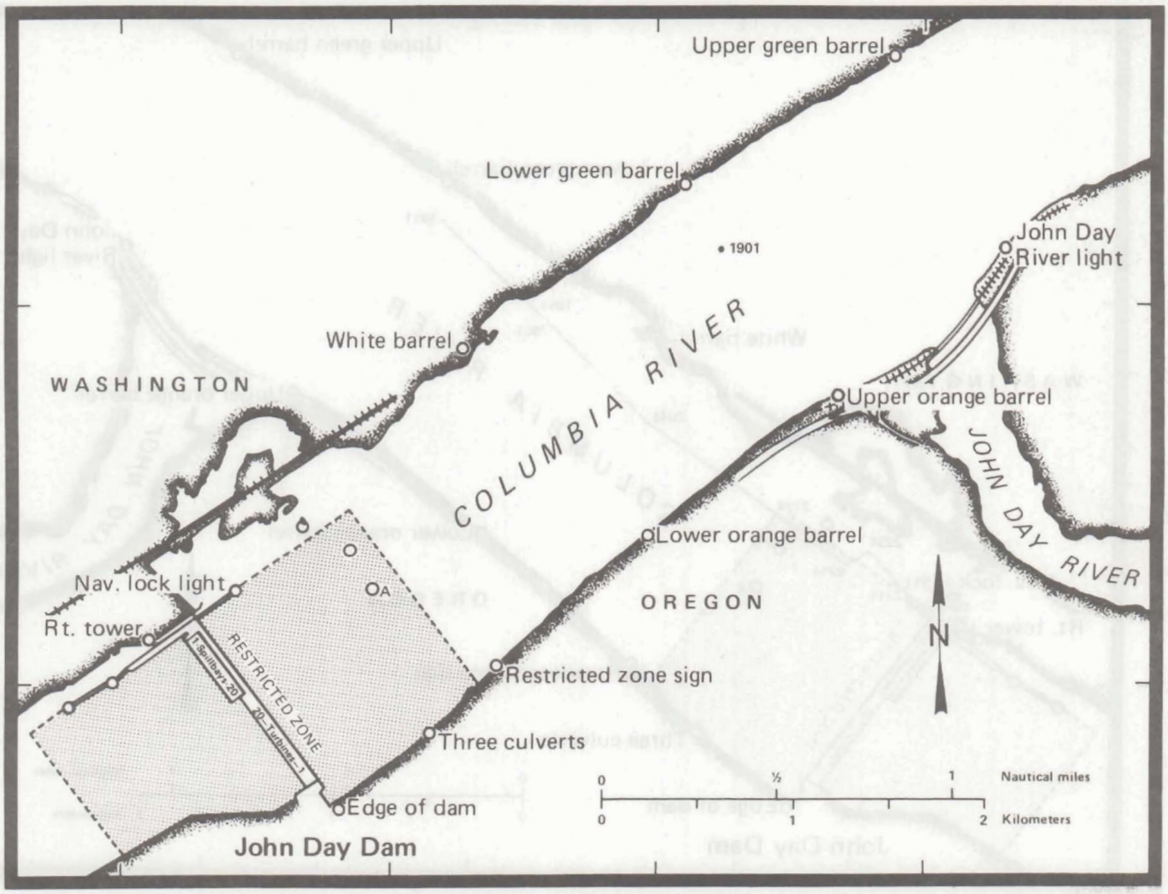


Fish Number 4
Chinook salmon 182 mm
14 April 1982

Tracking range for this fish was less than 50 feet. When the rough weather was added to the short range, it was very hard to stay with this fish. After the fish was lost, we searched for one-half hour before terminating this track to start tracking fish number 5.

Flow Kcfs

Time	1900							
Total	360.4							
Turbine	326.3							
Spill	31.7							
% spill	9							

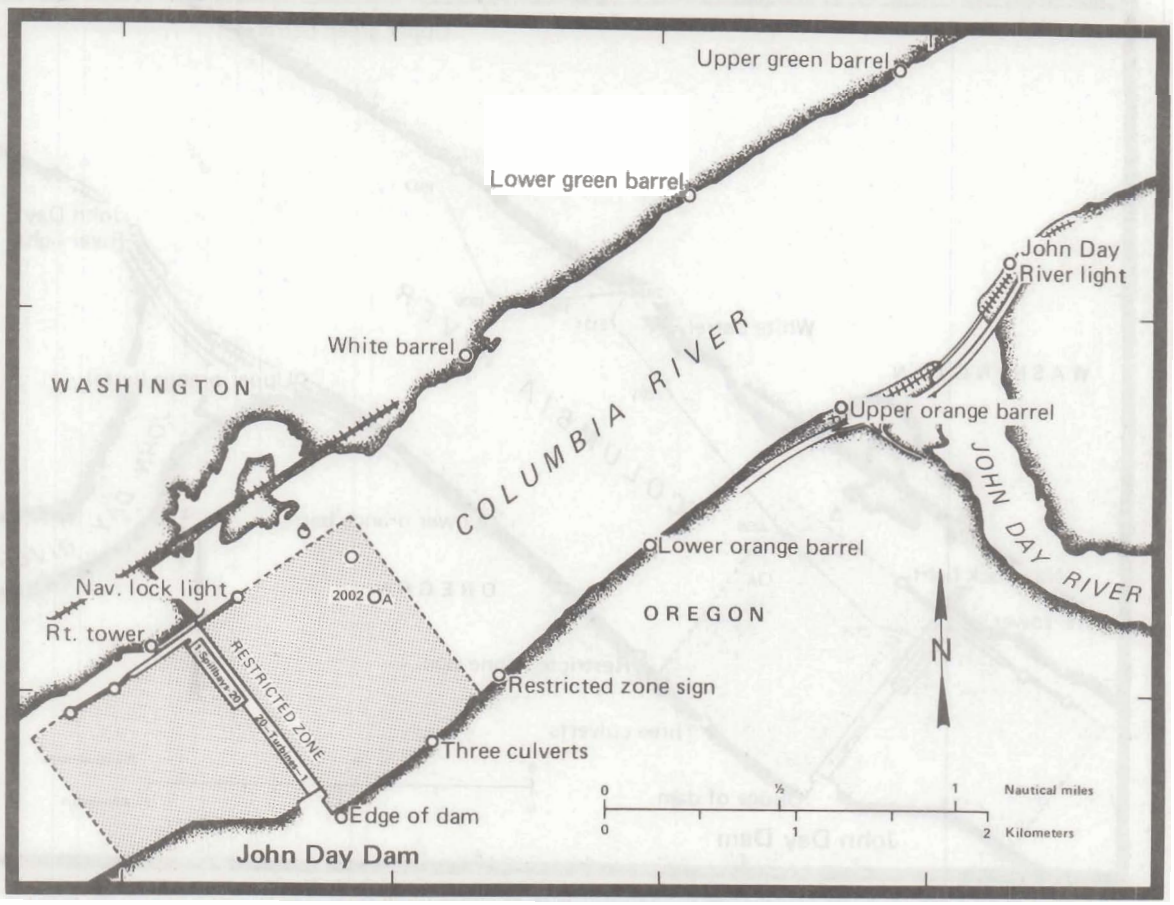


Fish Number 5
Chinook salmon 252 mm
14 April 1982

The weather got worse as the night progressed and fish number 5 was released at Buoy A. The signal from this fish was lost after two minutes and the track was terminated after an unsuccessful search.

Flow Kcfs

Time	2000							
Total	351.6							
Turbine	319.5							
Spill	31.5							
% spill	9							

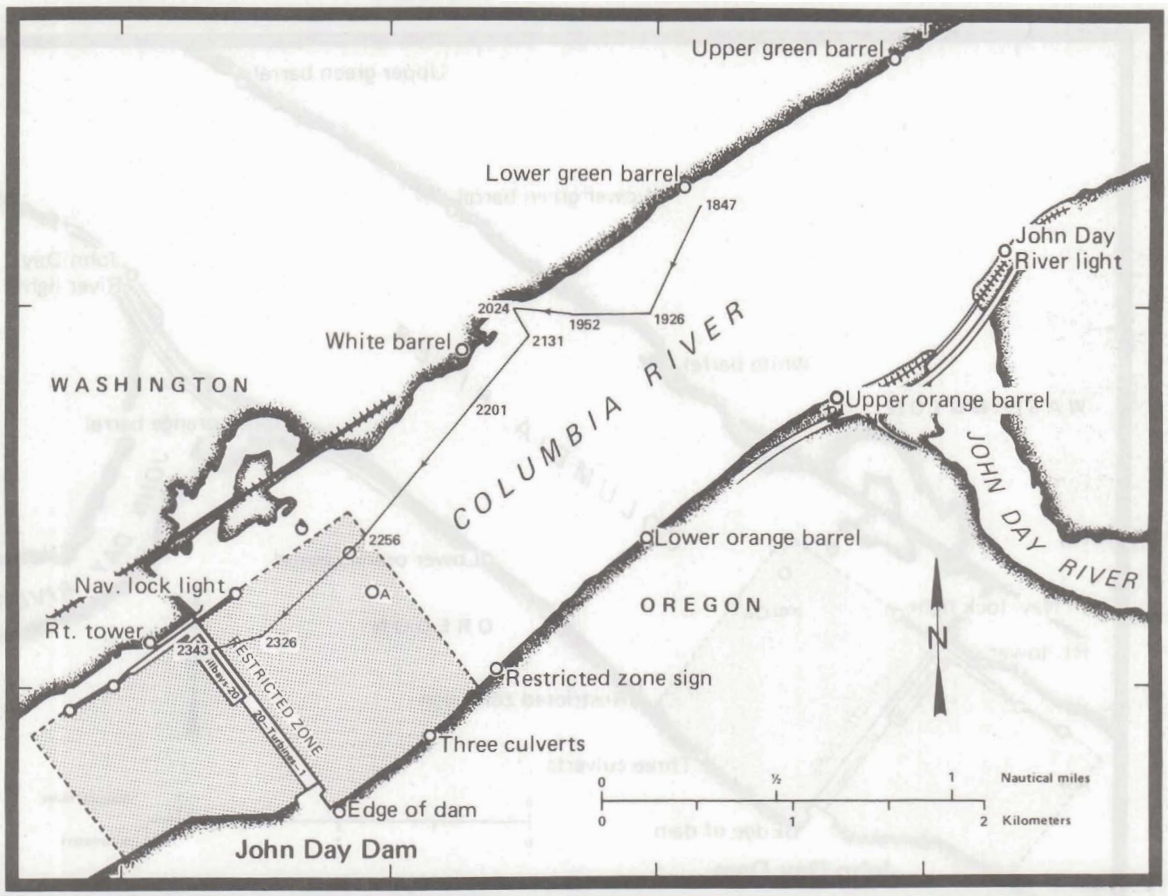


Fish Number 6
Chinook salmon 170 mm
20 April 1982

During track number 6, the radio signal varied from very good to poor, but the signal was never lost. After holding in a cove on the Washington shore until after sunset, the fish moved steadily to the dam for passage through Spill Gate 6.

Flow Kcfs

Time	1800	1900	2000	2100	2200	2300		
Total	284.5	297.3	298.3	273.2	298.9	332.8		
Turbine	211.1	222.1	271.8	264.5	250.4	228.3		
Spill	72.8	72.8	25.9	6.3	47.9	102.1		
% spill	26	25	9	2	16	31		

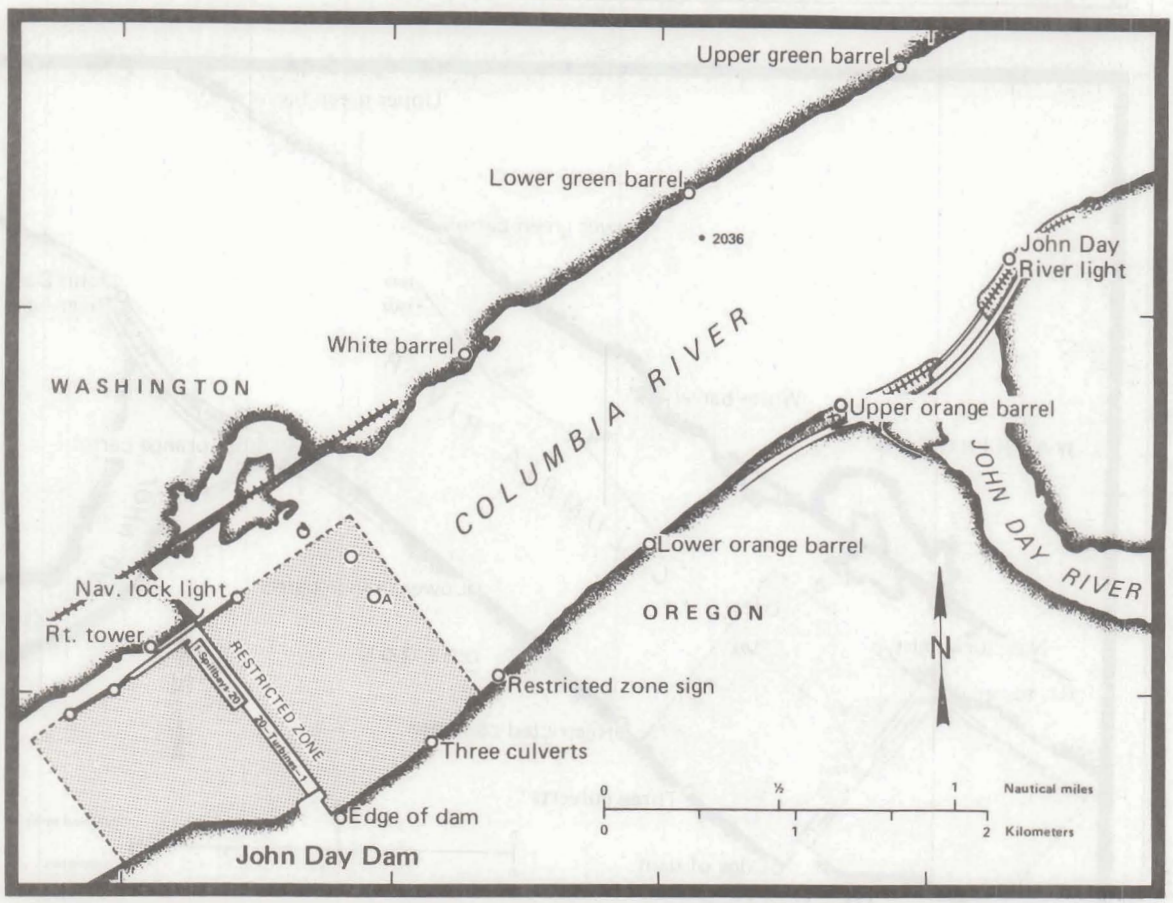


Fish Number 7
Chinook salmon 154 mm
21 April 1982

Fish number 7 was lost after two minutes of tracking. The track was terminated when searching did not relocate the signal. The tracking range at release was 100 feet.

Flow Kcfs

Time	2000							
Total	334.9							
Turbine	258.3							
Spill	76.0							
% spill	23							



Fish Number 8
Chinook salmon 156 mm
25 April 1982

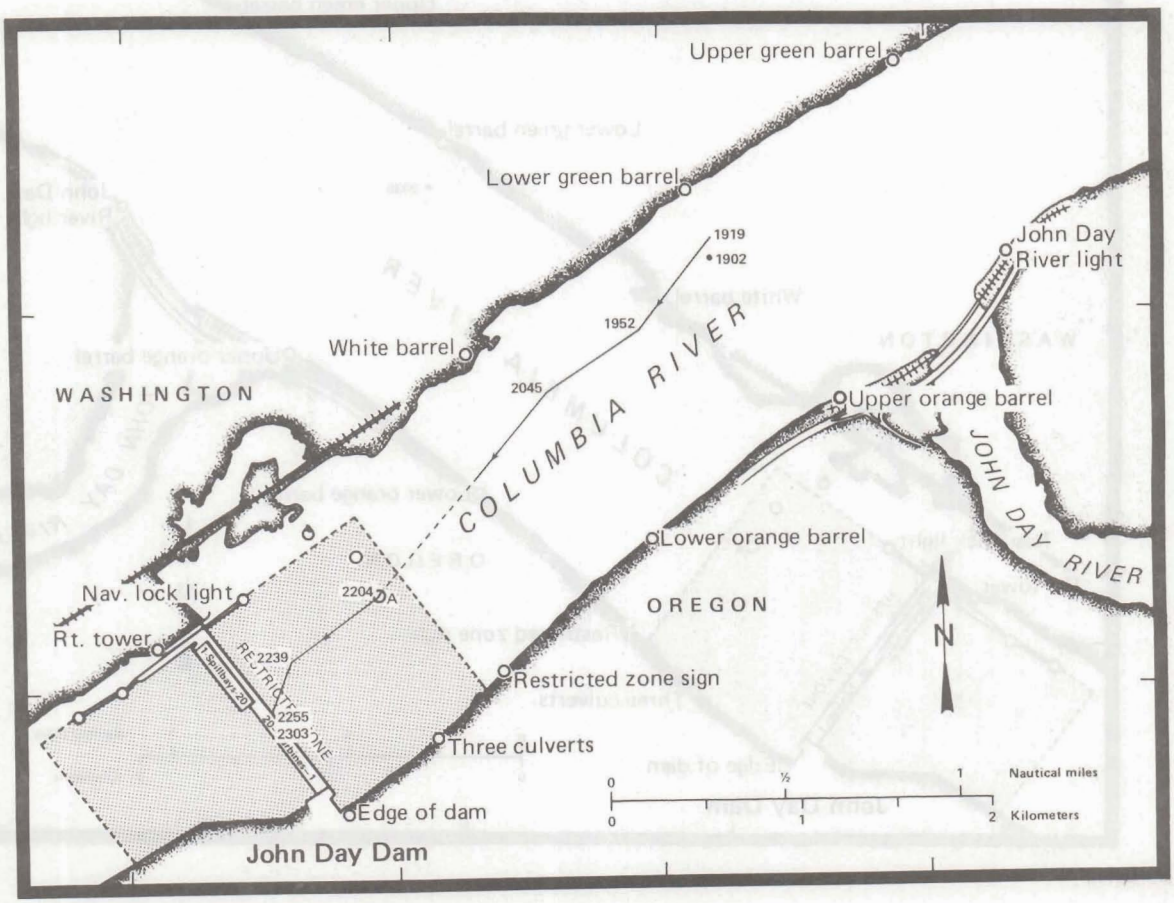
This was the first fish released that had not been anesthetized before tagging. It was lost immediately upon release, and the track was terminated after an unsuccessful search.

Fish Number 9
Chinook salmon 170 mm
25 April 1982

Tracking range from this fish was estimated to be 250 yards. As the fish approached the restricted zone, the signal fluctuated and the track became broken. The track was terminated when the fish passed through Turbine Unit 17.

Flow Kcfs

Time	1900	2000	2100	2200	2300			
Total	248.4	260.5	279.8	283.9	250.1			
Turbine	146.3	160.3	179.5	183.6	148.0			
Spill	99.7	99.7	99.7	99.7	99.7			
% spill	40	38	36	35	40			

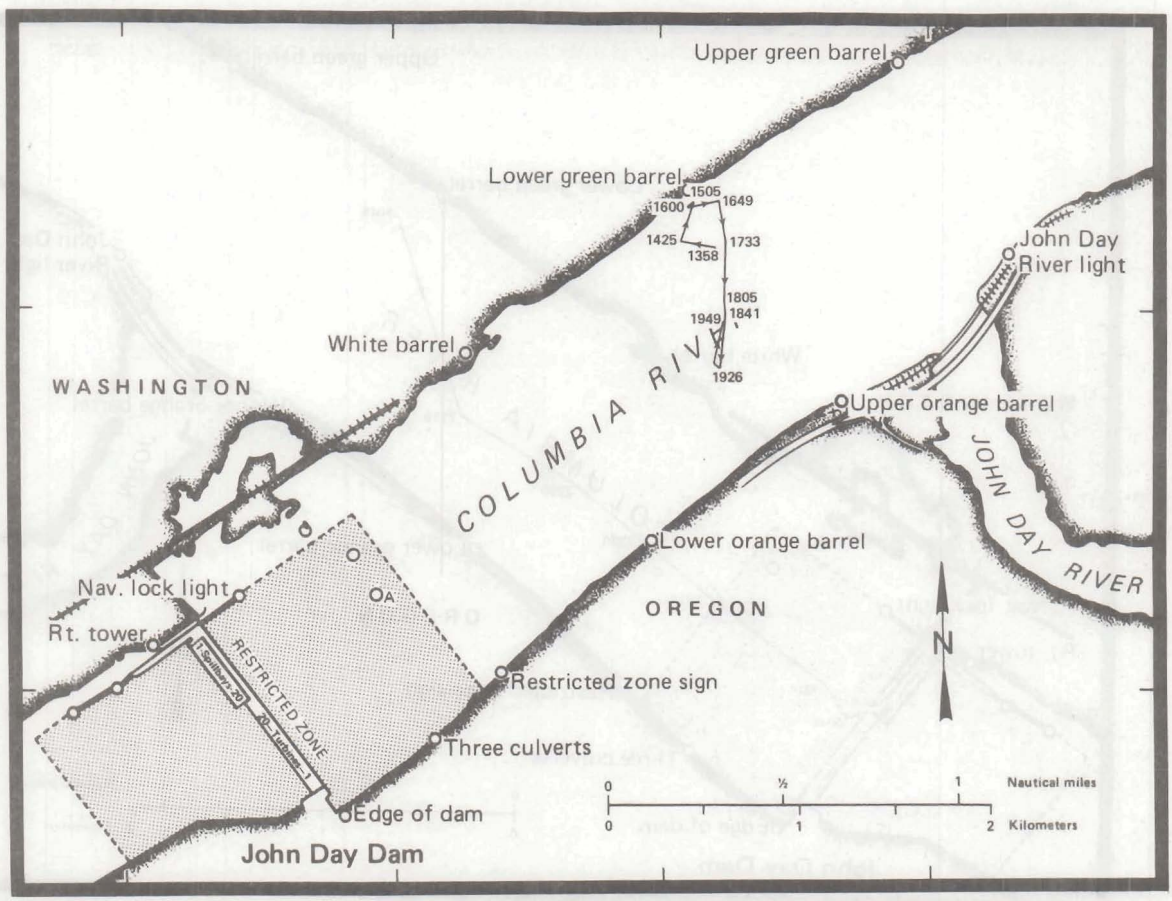


Fish Number 10
Chinook salmon 182 mm
26 April 1982

This track was made to observe daytime behavior. Tag output provided an estimated 250 yard tracking range. The track was terminated when there was no downstream movement near sunset.

Flow Kcfs

Time	1300	1400	1500	1600	1700	1800	1900	
Total	259.0	258.6	243.3	240.8	246.1	246.6	247.0	
Turbine	158.7	158.3	143.0	140.1	142.2	146.3	146.7	
Spill	99.7	99.7	99.7	100.0	99.7	99.7	99.7	
% spill	39	39	41	42	41	40	40	

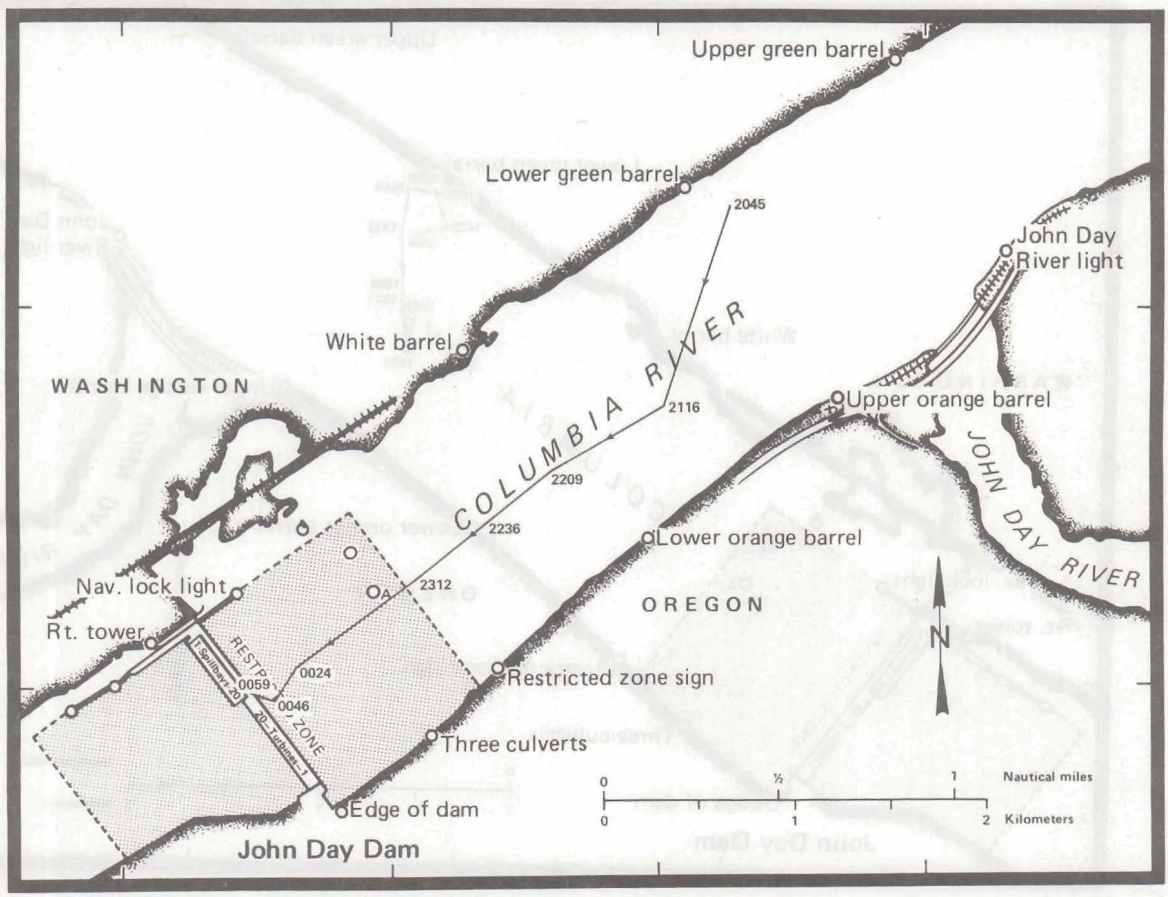


Fish Number 11
Chinook salmon 172 mm
27 April 1982

Fish number 11 was released after sunset. It moved directly downstream. As the fish approached the dam, it entered the area above the empty turbine bay and then toward the spillway where it passed through Spill 20. At the time of passage, all of the spill was concentrated on the powerhouse end of the spillway and 36% of the total river flow was being spilled.

Flow Kcfs

Time	2000	21000	2200	2300	2400			
Total	254.0	268.0	258.3	277.3	280.9			
Turbine	202.7	214.9	198.5	196.0	180.6			
Spill	50.7	50.7	57.4	80.7	99.7			
% spill	20	19	22	29	36			

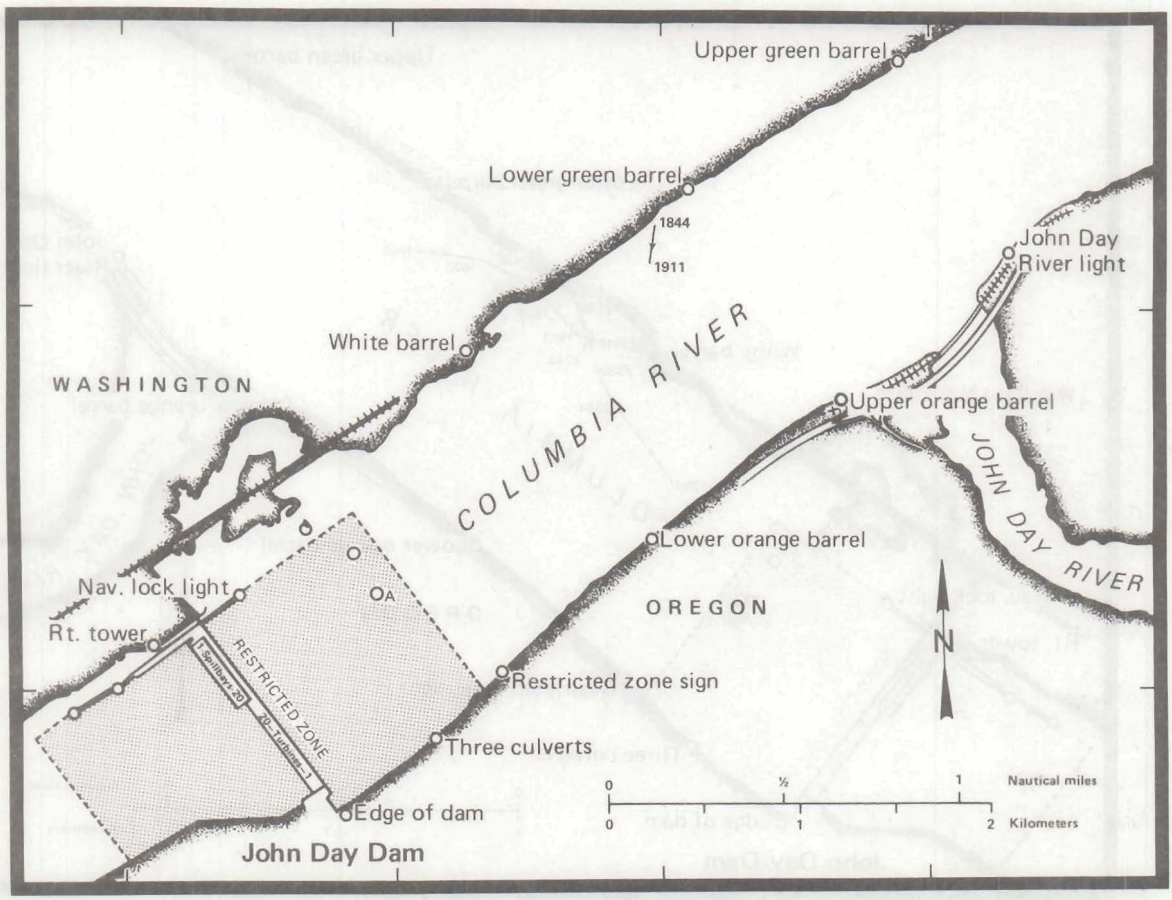


Fish Number 12
Chinook salmon 164 mm
4 May 1982

At the beginning of the track, the range was considered good. After 22 minutes of tracking the signal abruptly stopped, leading us to believe that the tag had failed. The track was terminated after an unsuccessful search.

Flow Kcfs

Time	1800	1900						
Total	345.2	345.6						
Turbine	243.3	245.3						
Spill	99.7	99.7						
% spill	29	29						

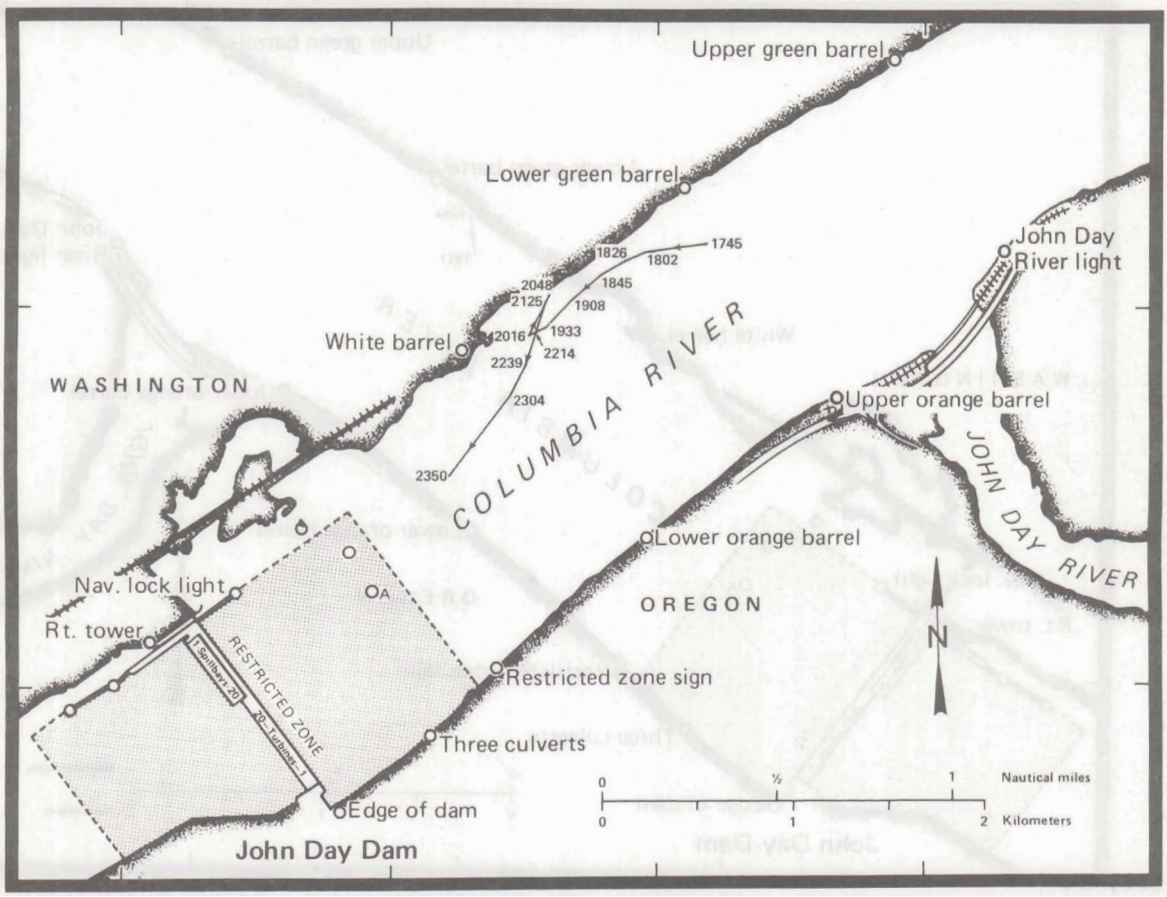


Fish Number 13
Chinook salmon 165 mm
5 May 1982

Upon release, fish number 13 moved downstream to a cove on the Washington shore. It stayed in the cove until well after dark. The track proceeded well until the fish was downstream of the Washington white barrel. At that point the signal began to fluctuate. The signal was last heard at 0009 h just upstream of the restricted zone, but an accurate fix was not possible. The track was terminated after an unsuccessful search.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	
Total	362.8	344.6	354.9	343.6	359.6	363.7	318.4	
Turbine	240.1	223.7	232.2	222.6	236.4	242.8	197.5	
Spill	120.3	120.3	120.3	120.3	120.7	120.3	120.3	
% spill	33	35	34	35	34	33	38	

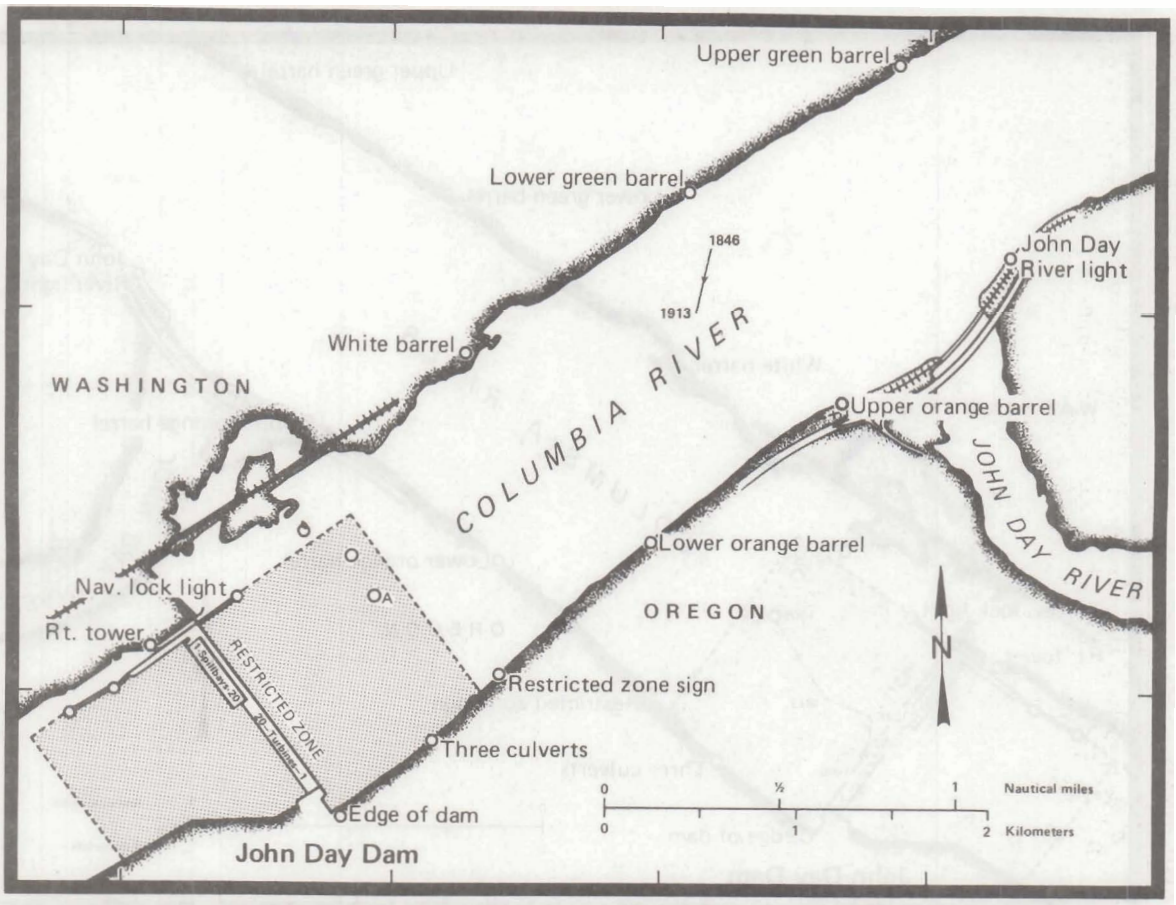


Fish Number 14
Chinook salmon 152 mm
6 May 1982

Strong winds and a tracking range of less than 100' made this track difficult. When the signal abruptly stopped at 2006 h, tag failure was thought to be the reason. The track was terminated after an unsuccessful search.

Flow Kcfs

Time	1800	1900						
Total	344.4	335.0						
Turbine	250.9	254.2						
Spill	90.2	80.2						
% spill	26	24						

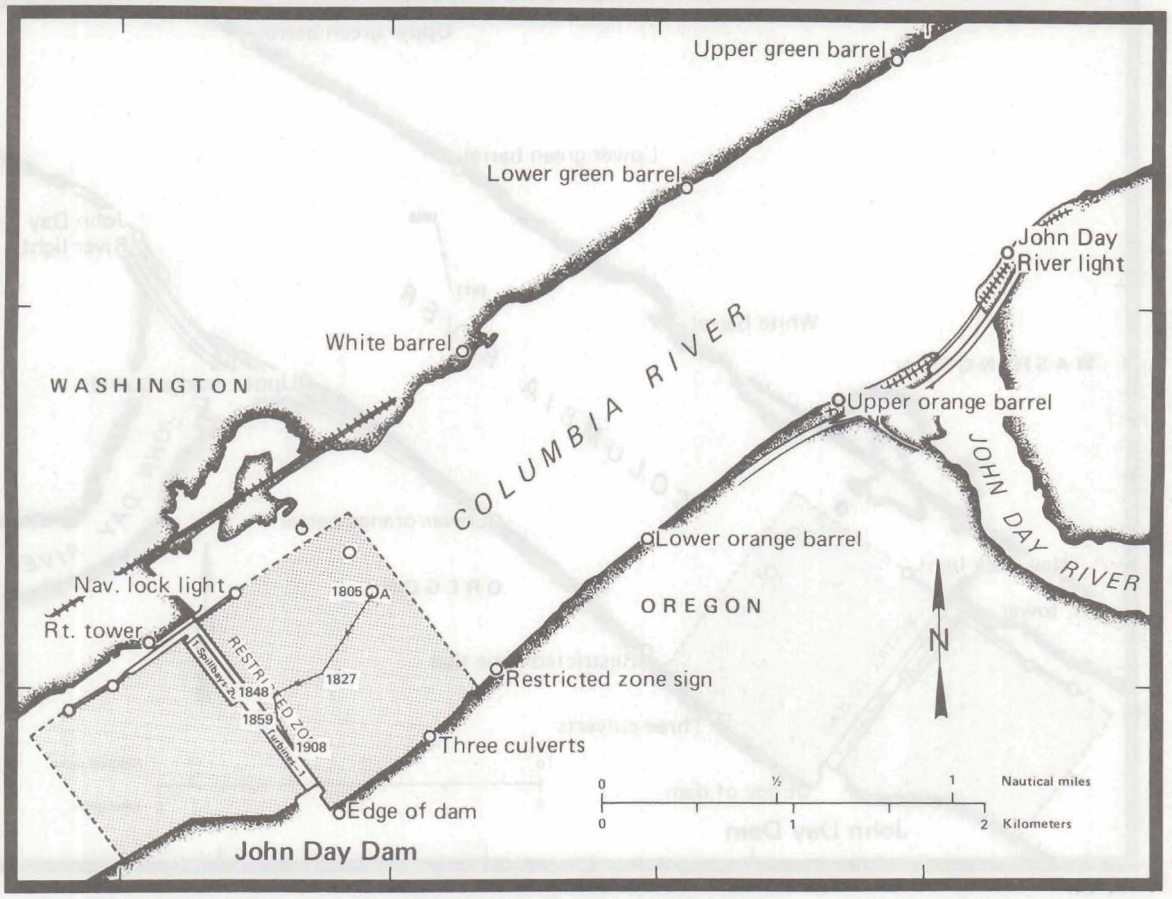


Fish Number 15
Chinook salmon 168 mm
7 May 1982

Because of wind gusts of over 40 mph, the release uoy A. Fish number 15 stayed on the powerhouse side of the river and passed through Turbin 7B.

Flow Kcfs

Time	1800	1900						
Total	323.8	329.8						
Turbine	202.9	207.1						
Spill	120.3	120.2						
% spill	37	37						

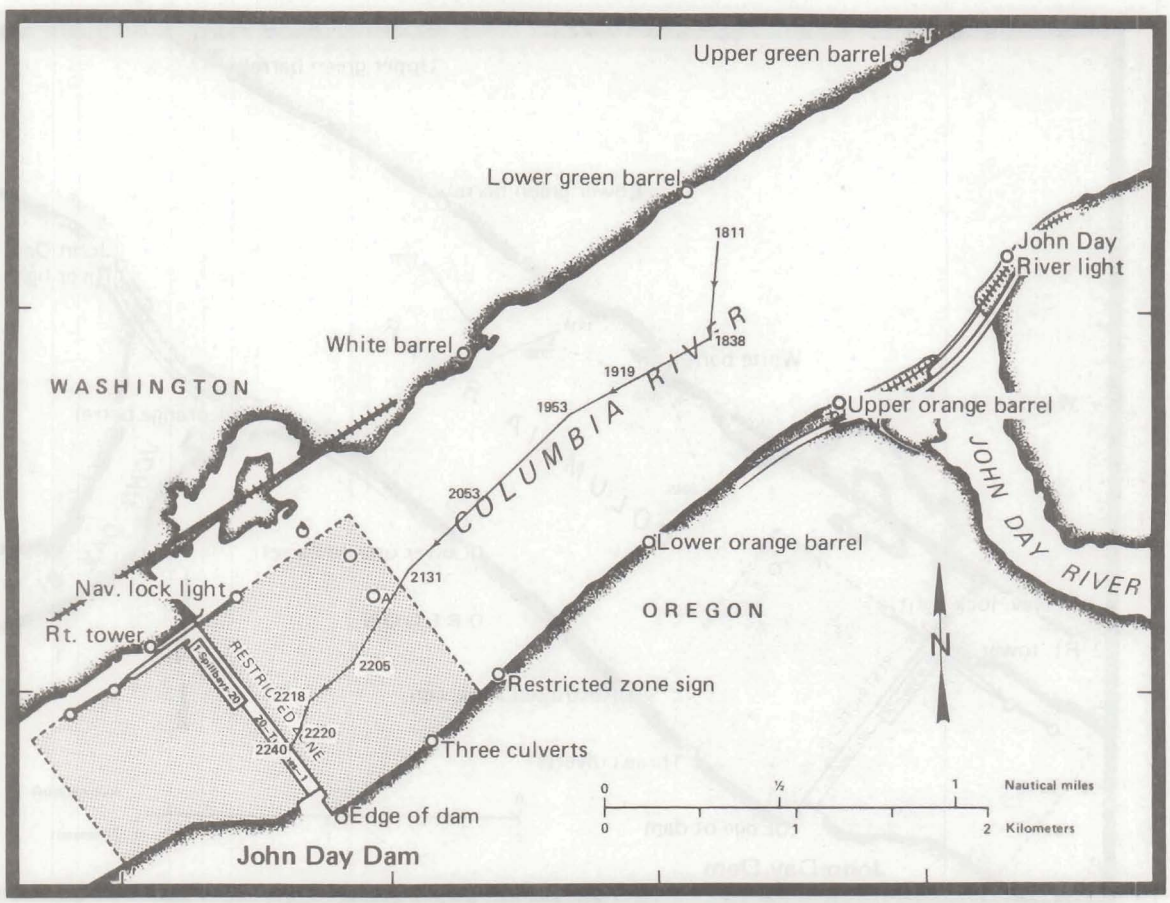


Fish Number 16
Chinook salmon 164 mm
8 May 1982

Fish number 16 moved to the center of the river and then steadily downstream. While it stayed on the Washington (spill) side of the river until it was in the restricted zone, it crossed to the powerhouse side inside the area and passed through Turbine 13.

Flow Kcfs

Time	1800	1900	2000	2100	2200			
Total	272.7	265.1	297.1	327.5	328.2			
Turbine	150.0	144.2	174.2	206.2	207.3			
Spill	120.3	120.3	120.3	120.7	120.3			
% spill	44	45	41	37	37			

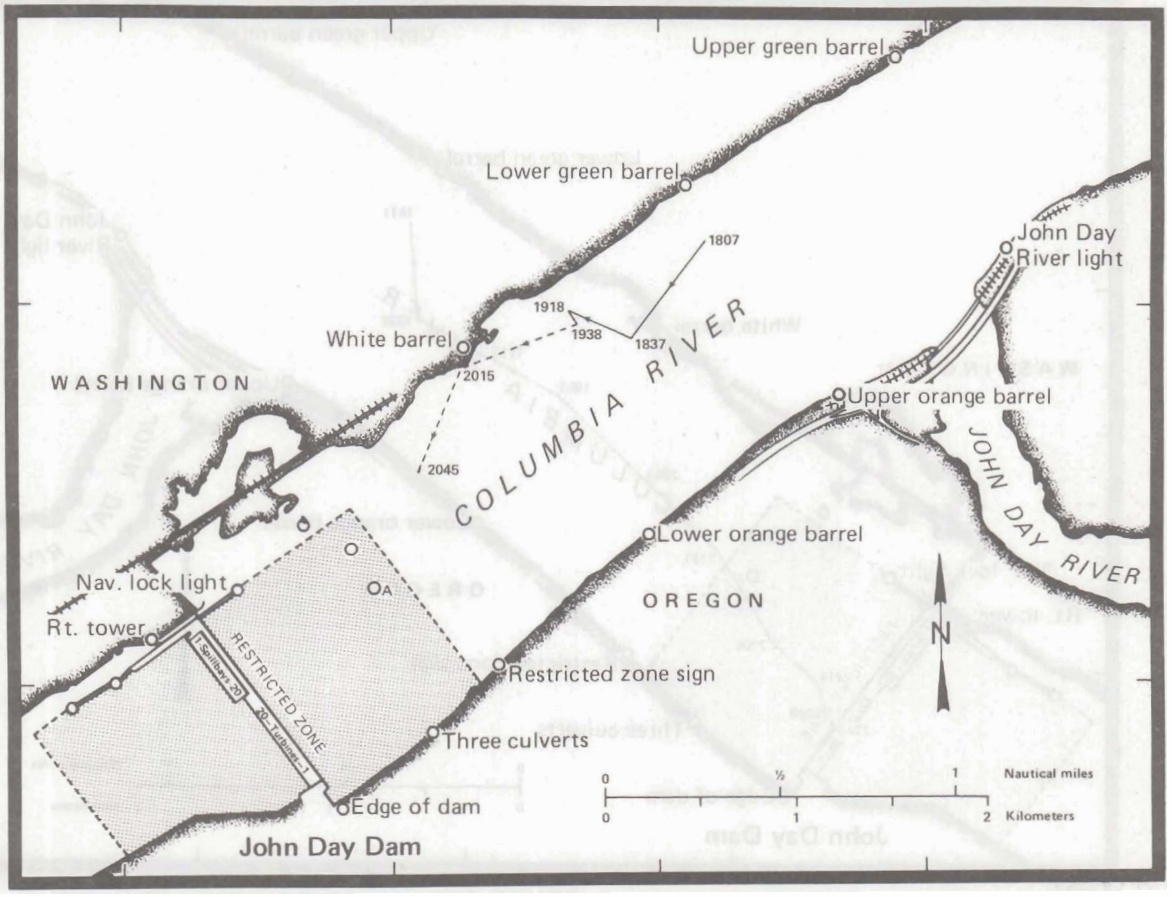


Fish Number 17
Chinook salmon 160 mm
9 May 1982

The signal from fish number 17 was good for the first 90 minutes, but then, the signal began to fluctuate. At 1938 h the signal was lost. Extensive searches found the fish twice before the track was terminated. The length of time the signal was heard, each time it was located, was only enough to fix a location.

Flow Kcfs

Time	1800	1900	2000					
Total	337.2	329.4	341.4					
Turbine	214.5	228.5	220.7					
Spill	120.3	120.3	120.2					
% spill	36	37	35					

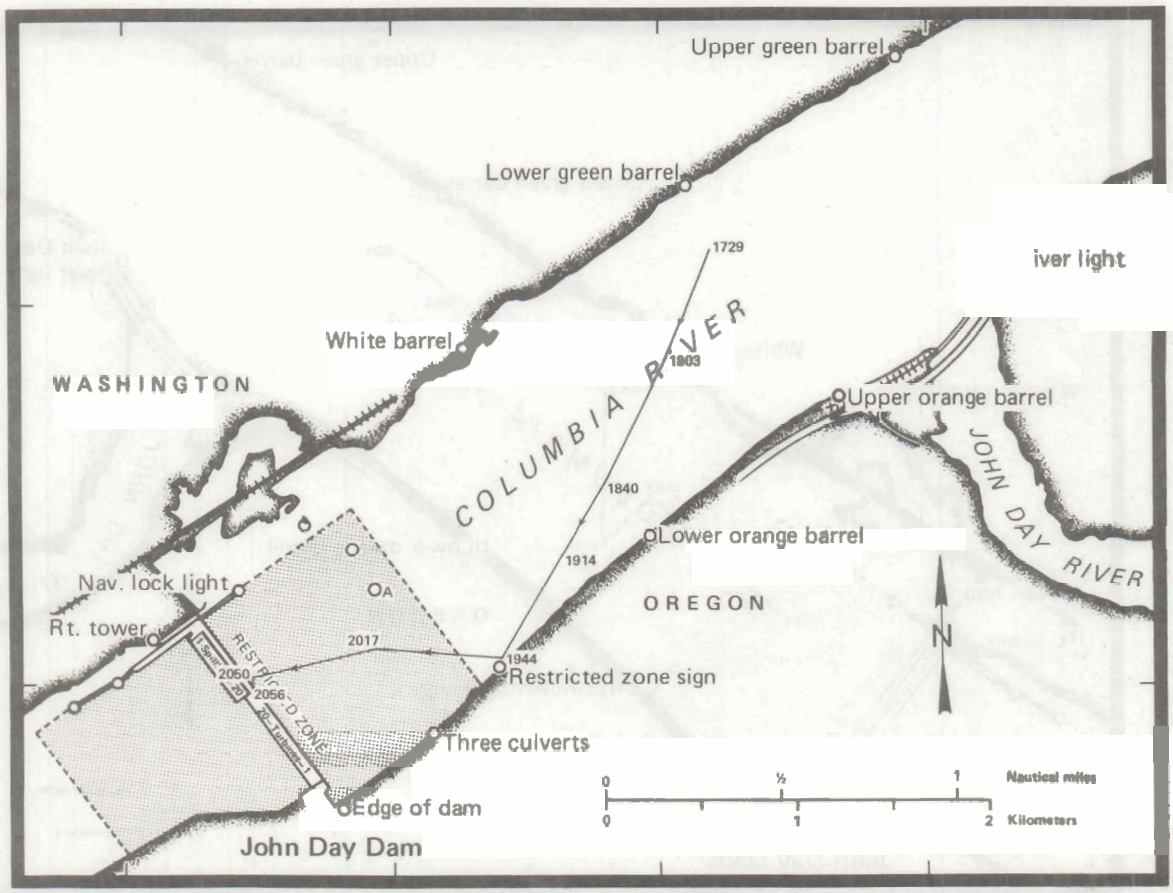


Fish Number 18
Chinook salmon 170 mm
10 May 1982

Except for a short holdup at the restricted zone sign on the Oregon shore, fish number 8 moved steadily until passage through Spill 20. This fish is part of a small group that have crossed from the powerhouse side of the river to the spill side of the river for passage.

Flow Kcfs

Time	1700	1800	1900	2000	21000			
Total	326.0	336.3	336.8	339.7	349.5			
Turbine	203.3	213.6	214.1	217.0	228.5			
Spill	120.3	120.3	120.3	120.3	120.4			
% spill	37	36	36	35	34			

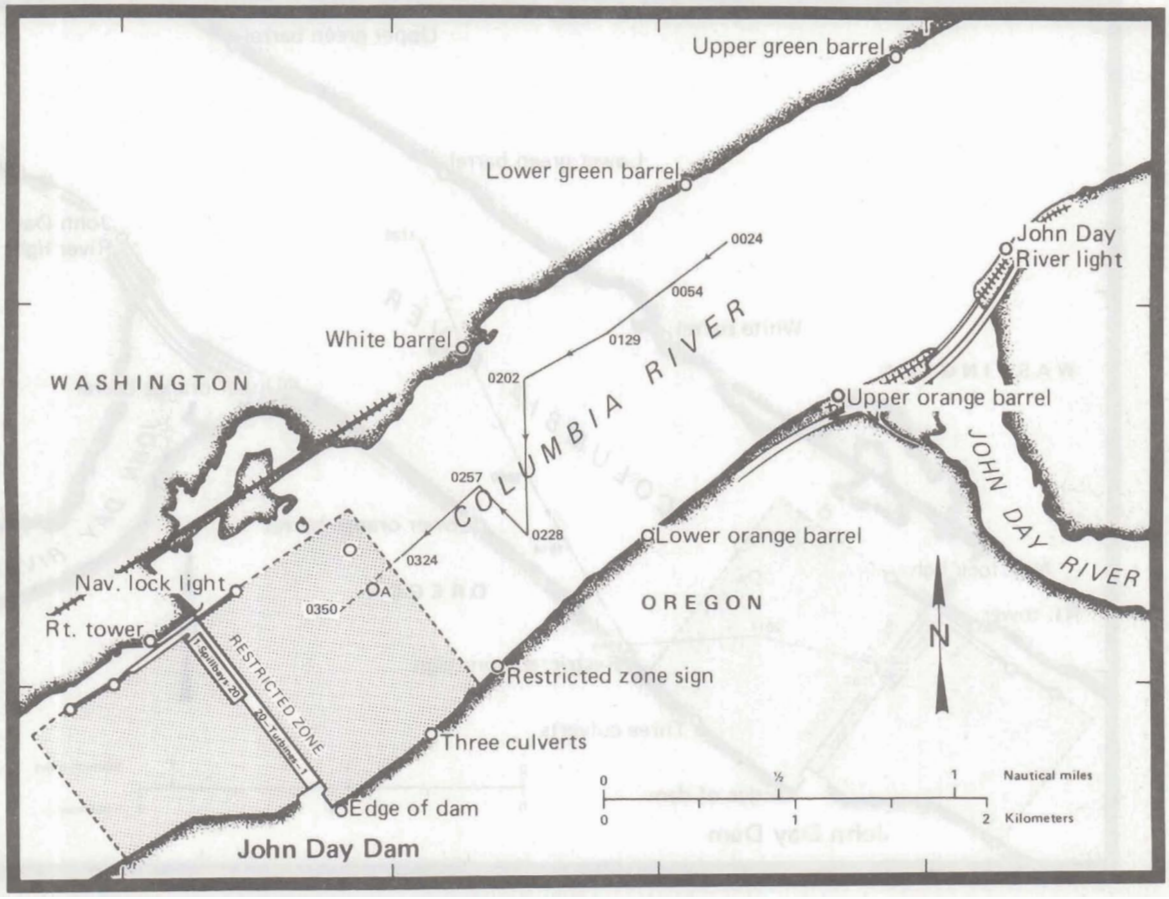


Fish Number 19
Chinook salmon 162 mm
11 May 1982

This fish was released after dark to observe behavior during darkness. It began to move downstream immediately and kept on moving at a moderate rate until we lost the signal inside the restricted zone. Signal fluctuation led us to believe that this fish regularly moved up and down in the water column. The track was terminated after an unsuccessful search.

Flow Kcfs

Time	2400	0100	0200	0300	0400			
Total	282.7	290.7	340.3	317.9	380.5			
Turbine	161.8	169.8	219.4	256.1	257.8			
Spill	120.3	120.3	120.3	120.3	120.3			
% spill	43	41	35	38	32			

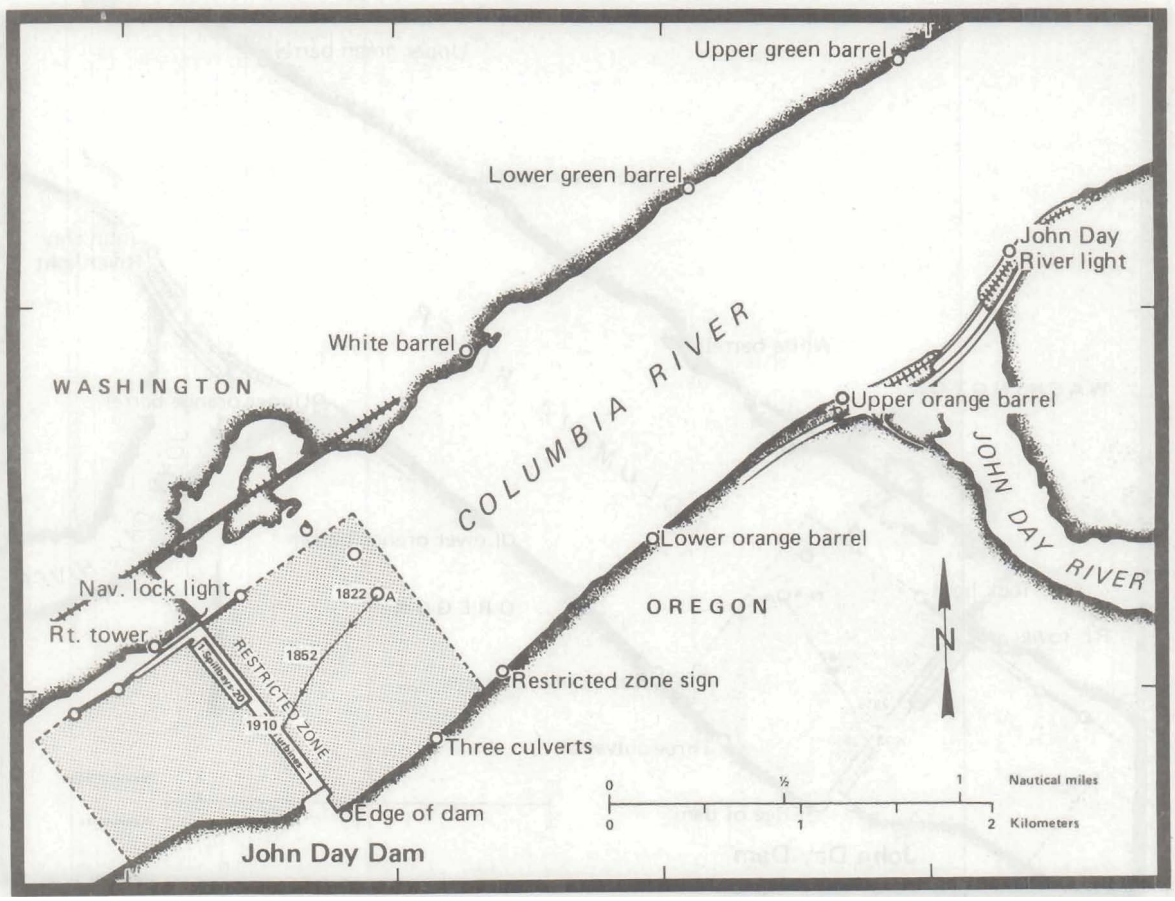


Fish Number 20
Chinook salmon 171 mm
12 May 1982

Fish number 20 was released at Buoy A because of rough weather. The fish began moving immediately toward the powerhouse where it passed through Turbine 18.

Flow Kcfs

Time	1800	1900						
Total	287.0	298.4						
Turbine	206.0	215.3						
Spill	80.4	80.7						
% spill	28	27						

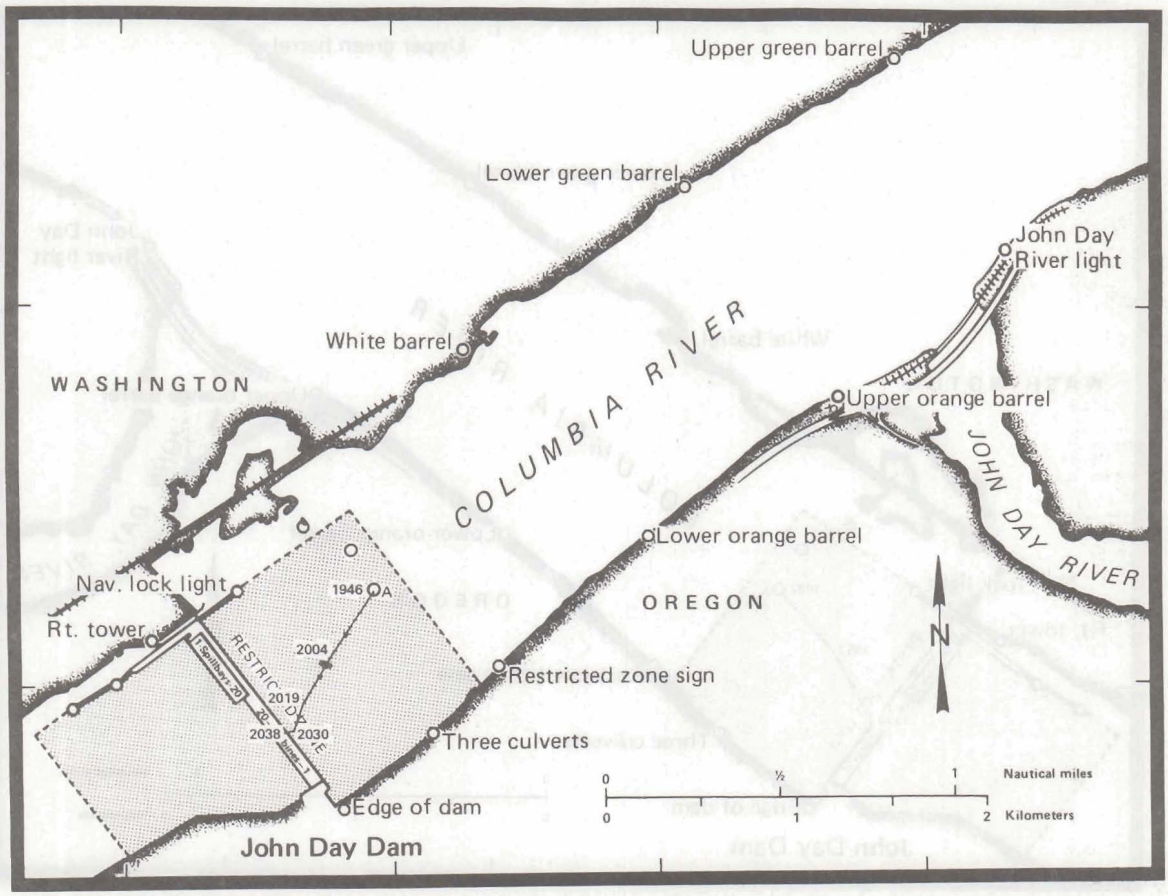


Fish Number 21
Chinook salmon 162 mm
12 May 1982

Fish number 21 was the second fish for the day. When released at Buoy A, it immediately began to move toward the powerhouse. After steady movement downstream, it delayed for a short period at the face of the dam before passing through Turbine Unit 10.

Flow Kcfs

Time	1900	2000						
Total	298.4	273.3						
Turbine	215.3	192.0						
Spill	80.7	80.7						
% spill	27	30						

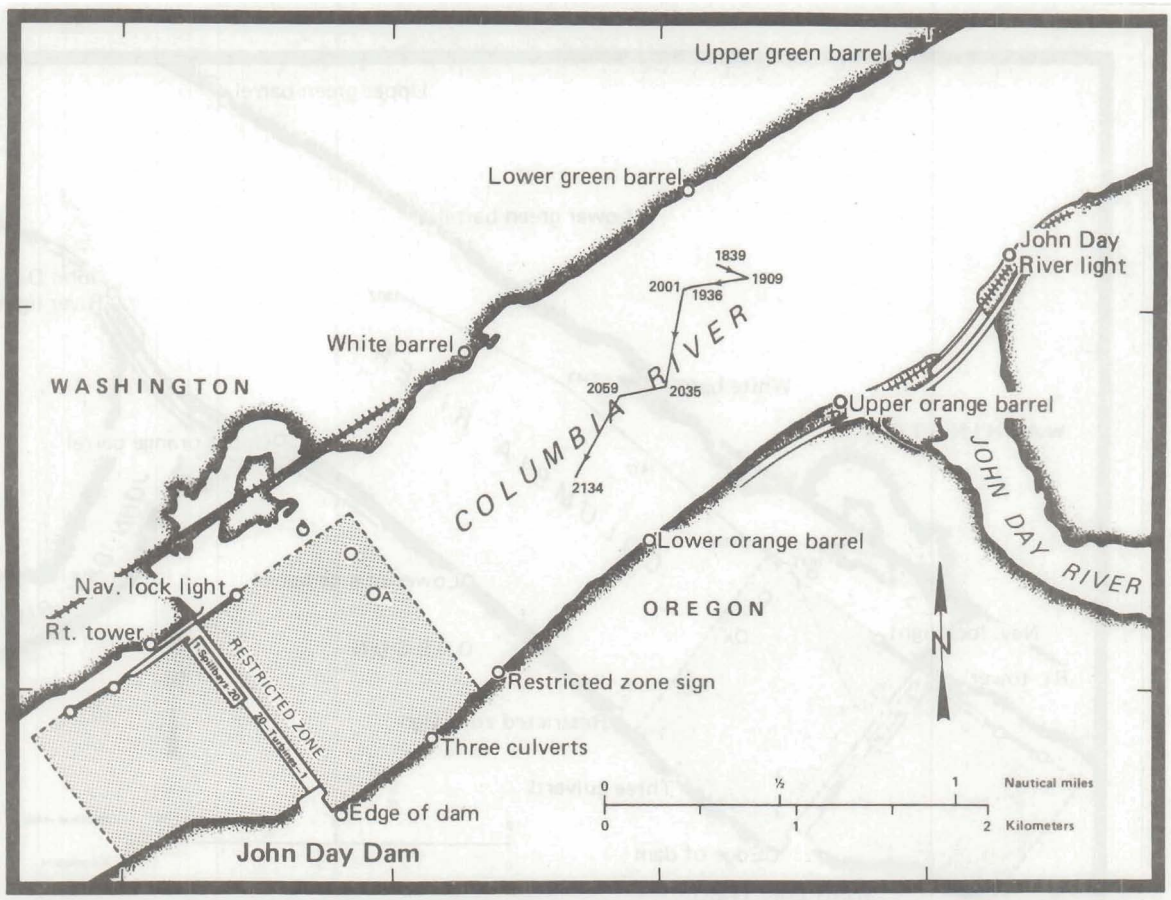


Fish Number 22
Chinook salmon 165 mm
18 May 1982

Fish number 22 was in poor physical condition and recovered slowly after tagging. It made little or no movement upon release, but started downstream after 1/2 h. After 2 h of tracking, the signal began to fluctuate and was then lost. The track was terminated after unsuccessful search.

Flow Kcfs

Time	1800	1900	2000	2100				
Total	444.3	439.6	426.6	427.1				
Turbine	293.3	286.8	275.6	278.7				
Spill	150.4	150.4	150.4	147.9				
% spill	34	34	35	35				

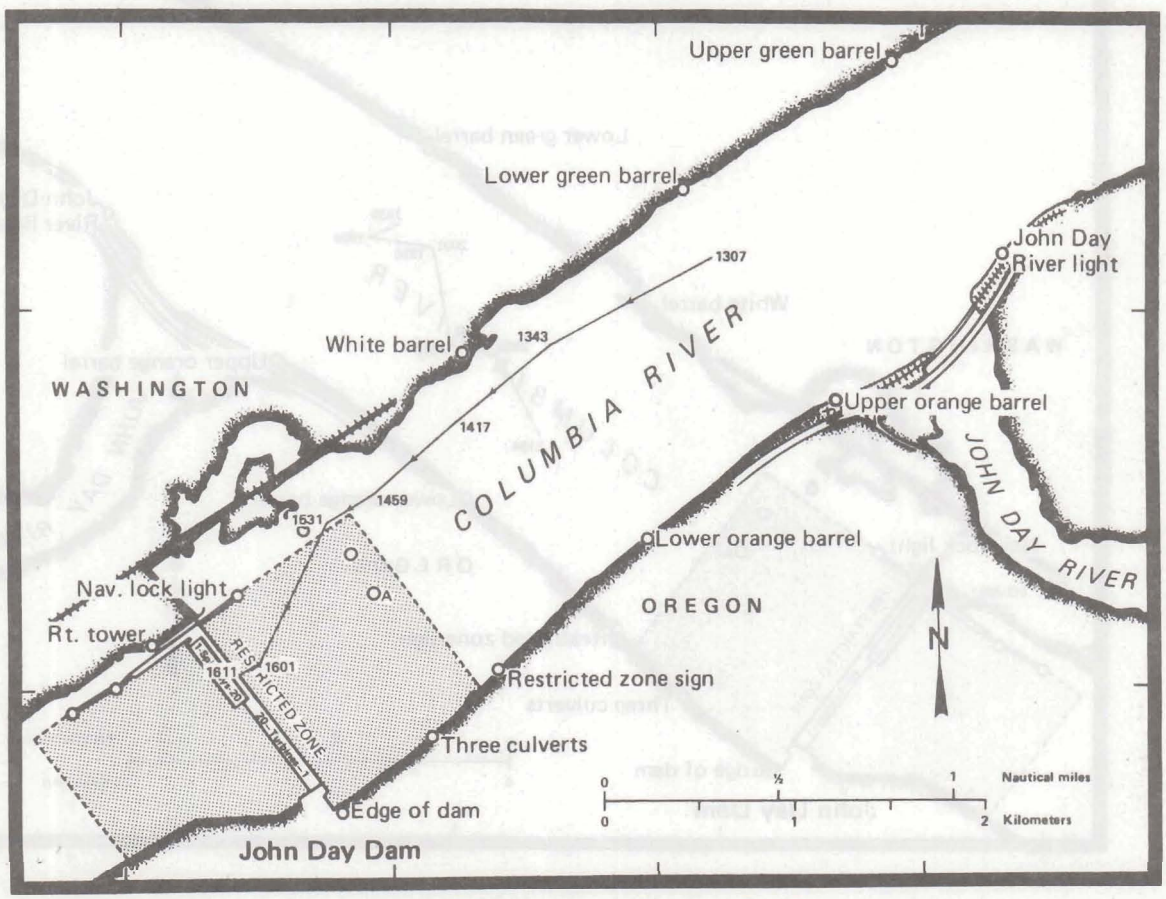


Fish Number 23
Chinook salmon 174 mm
19 May 1982

Fish number 23 was released to observe daylight behavior during the peak of the outmigration. It moved downstream at a steady rate until it reached the restricted zone, where it held up for almost 1/2 h before moving down to the spillway for passage through Spill Unit 13.

Flow Kcfs

Time	1300	1400	1500	1600				
Total	407.1	443.2	432.5	446.2				
Turbine	254.3	292.2	181.6	311.5				
Spill	150.5	150.4	150.3	134.1				
% spill	37	34	35	30				

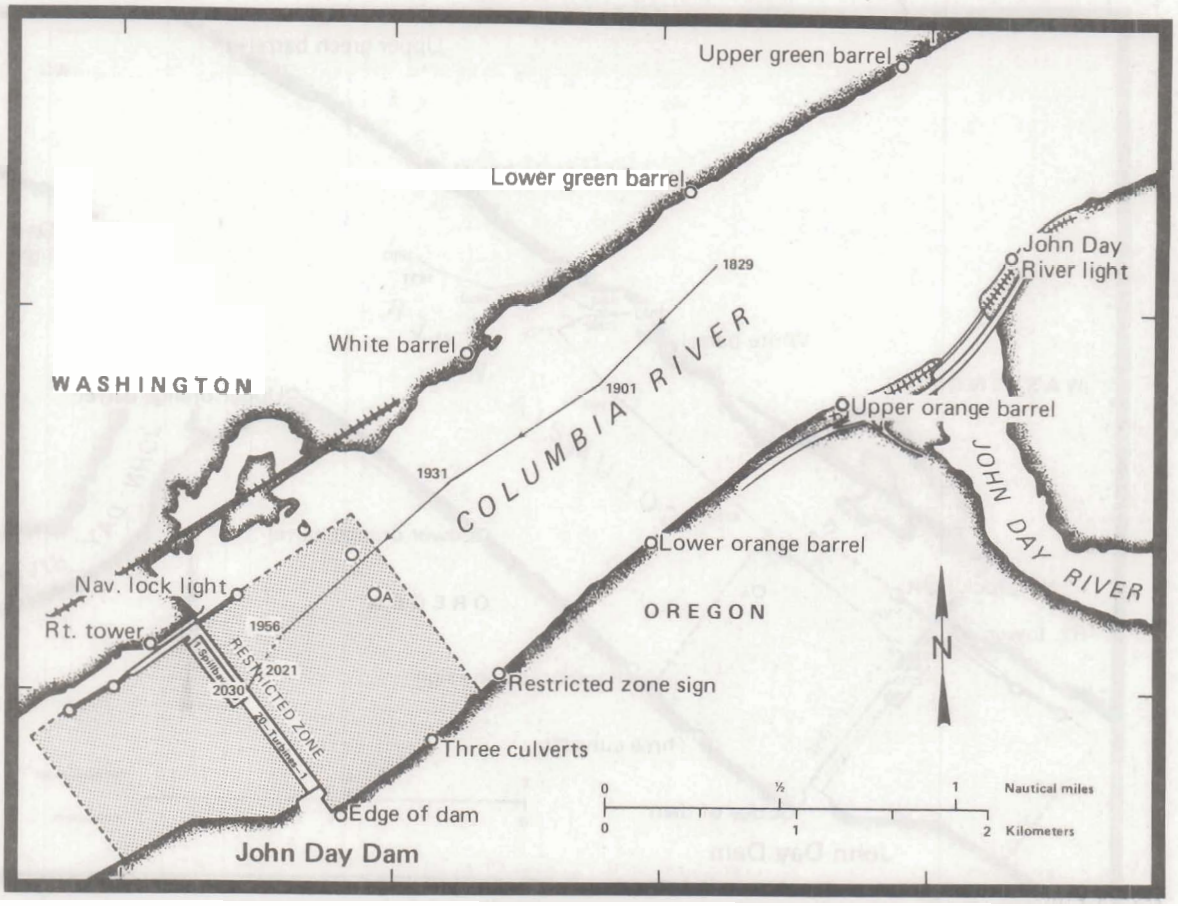


Fish Number 24
Chinook chinook 152 mm
20 May 1982

This track was conducted on a clear evening with no wind. Fish number 24 moved with the drifting track boats until 375 yards from the spillway. There it sounded and the signal could only be heard by the crew directly over its position. When the signal picked up, the track proceeded to Spill Unit 19 where the fish passed through the spillway.

Flow Kcfs

Time	1800	1900	2000					
Total	446.3	446.3	446.7					
Turbine	293.5	293.5	310.1					
Spill	150.4	150.4	134.2					
% spill	34	34	30					

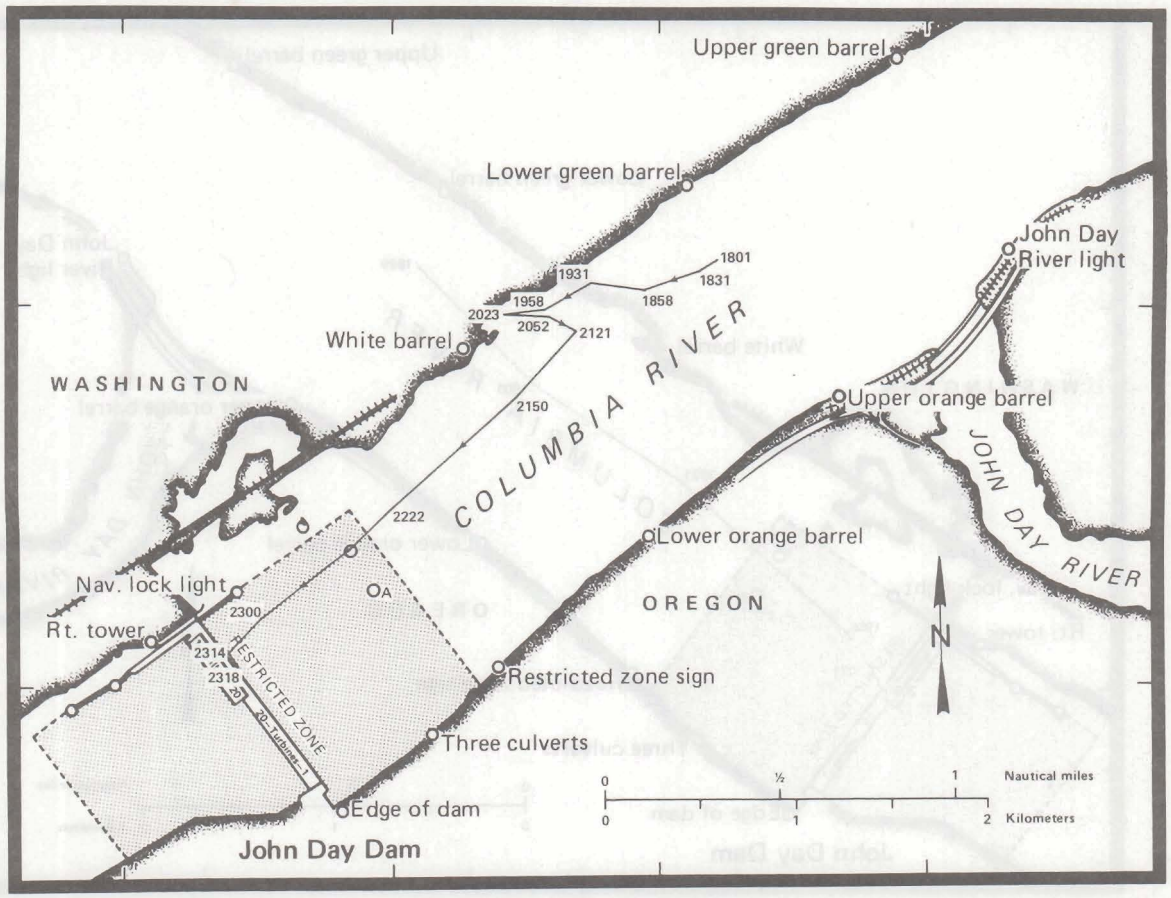


Fish Number 25
Chinook salmon 155 mm
21 May 1982

Upon release this fish moved slowly down to the cove on the Washington shore. After 1-1/2 h in the cove, it moved back into the river for rapid movement down to and through Spill Bay number 13.

Flow Kcfs

Time	1800	1900	2000	2100	2200	2300		
Total	415.0	388.1	379.8	386.6	404.0	380.5		
Turbine	264.0	253.3	226.9	235.3	253.0	227.7		
Spill	150.4	150.4	150.4	150.7	150.4	150.4		
% spill	36	39	40	39	37	40		

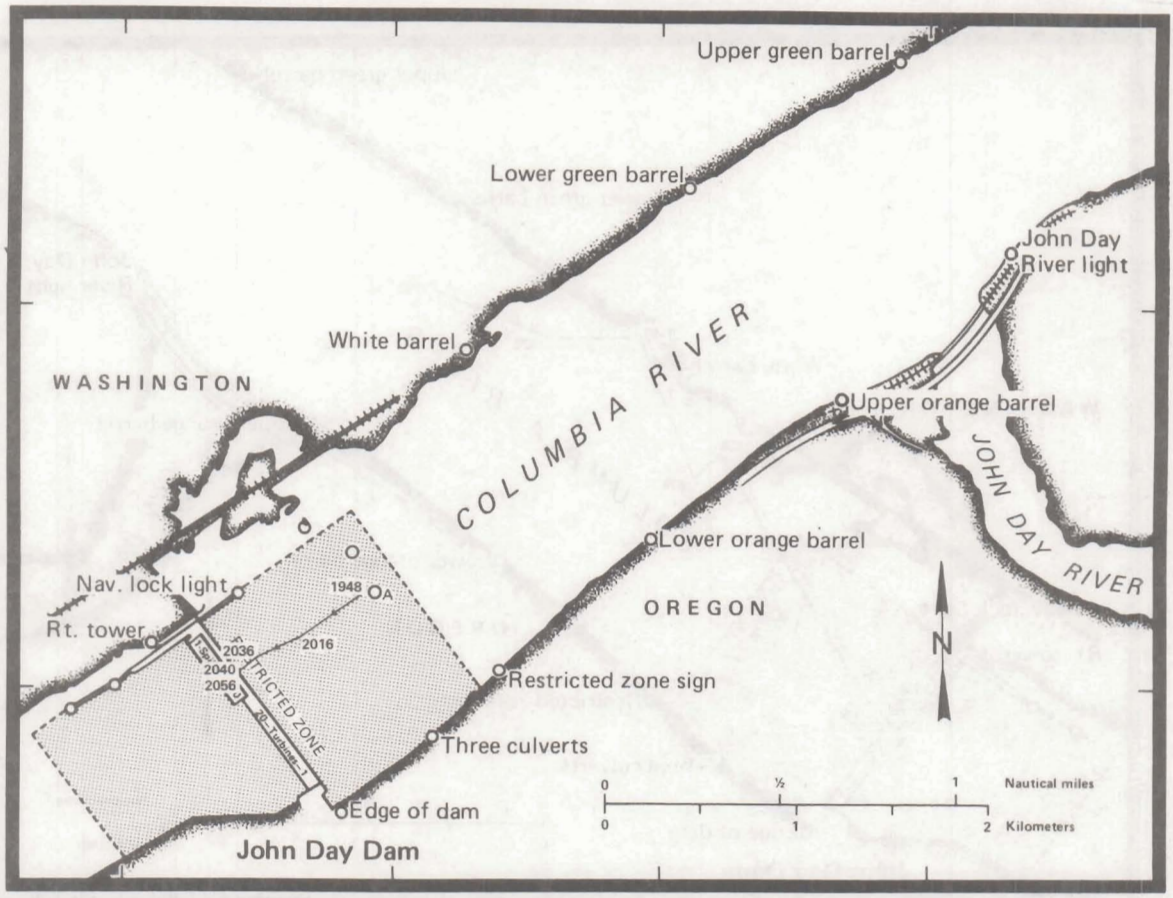


Fish Number 26
Chinook salmon 163 mm
22 May 1982

Because of bad weather conditions this fish was released at Buoy A. As the fish approached the dam, the spill was concentrated to the powerhouse end of the spillway. The fish moved directly to the spillway for passage through Unit 13.

Flow Kcfs

Time	1900	2000						
Total	376.4	375.2						
Turbine	225.4	224.2						
Spill	150.4	150.4						
% spill	40	40						

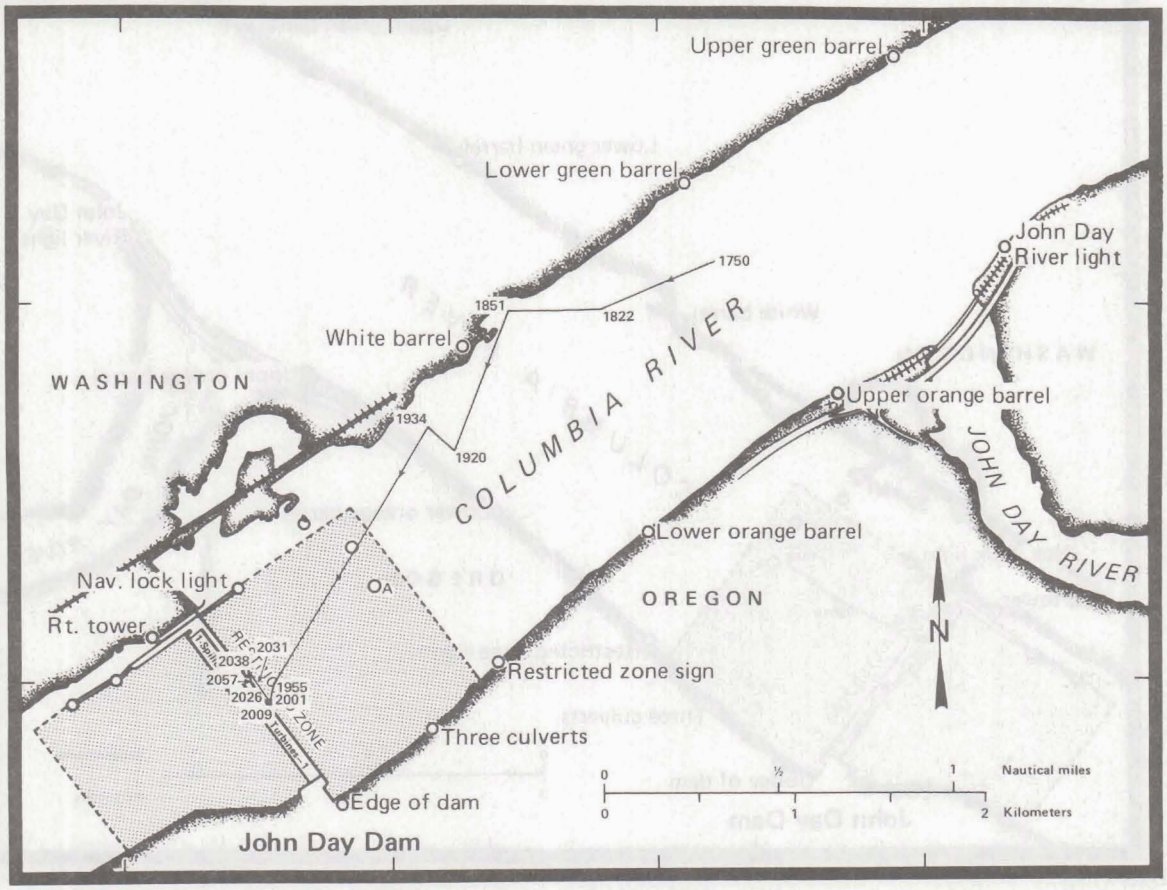


Fish Number 27
Chinook salmon 160 mm
23 May 1982

Fish number 27 made regular progress down to the dam except for a short stop in the cove on the Washington shore. It first approached the dam in the area above the empty turbine bays, then moved across the powerhouse to Turbine Bay 12. The fish then turned back toward the spillway and moved to Spillbay 17 where it turned back toward the powerhouse. When the fish was above Spillbay 19 it fell through the spillbay.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	361.9	383.5	376.4	375.2	352.8			
Turbine	209.1	232.5	225.4	224.2	201.6			
Spill	150.4	150.4	150.4	150.4	150.7			
% spill	42	39	40	40	43			

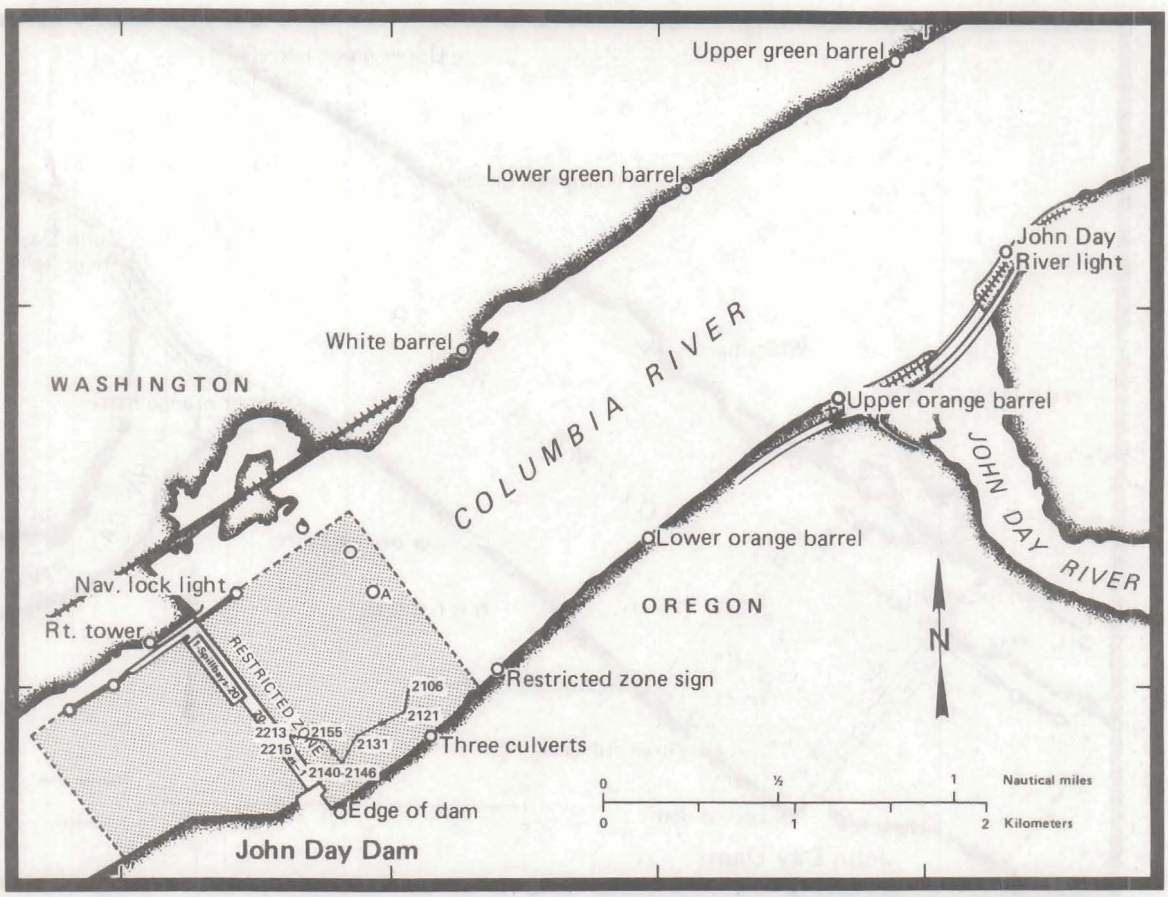


Fish Number 28
Chinook salmon 154 mm
25 May 1982

Fish number 28 was released in the restricted zone well into the powerhouse flow to check the pulling effect of a concentrated spill on the powerhouse end of the spillway. The spill was not concentrated and the fish passed through the powerhouse at Turbine 8.

Flow Kcfs

Time	2100	2200						
Total	416.8	418.5						
Turbine	276.2	264.0						
Spill	150.4	150.4						
% spill	36	36						

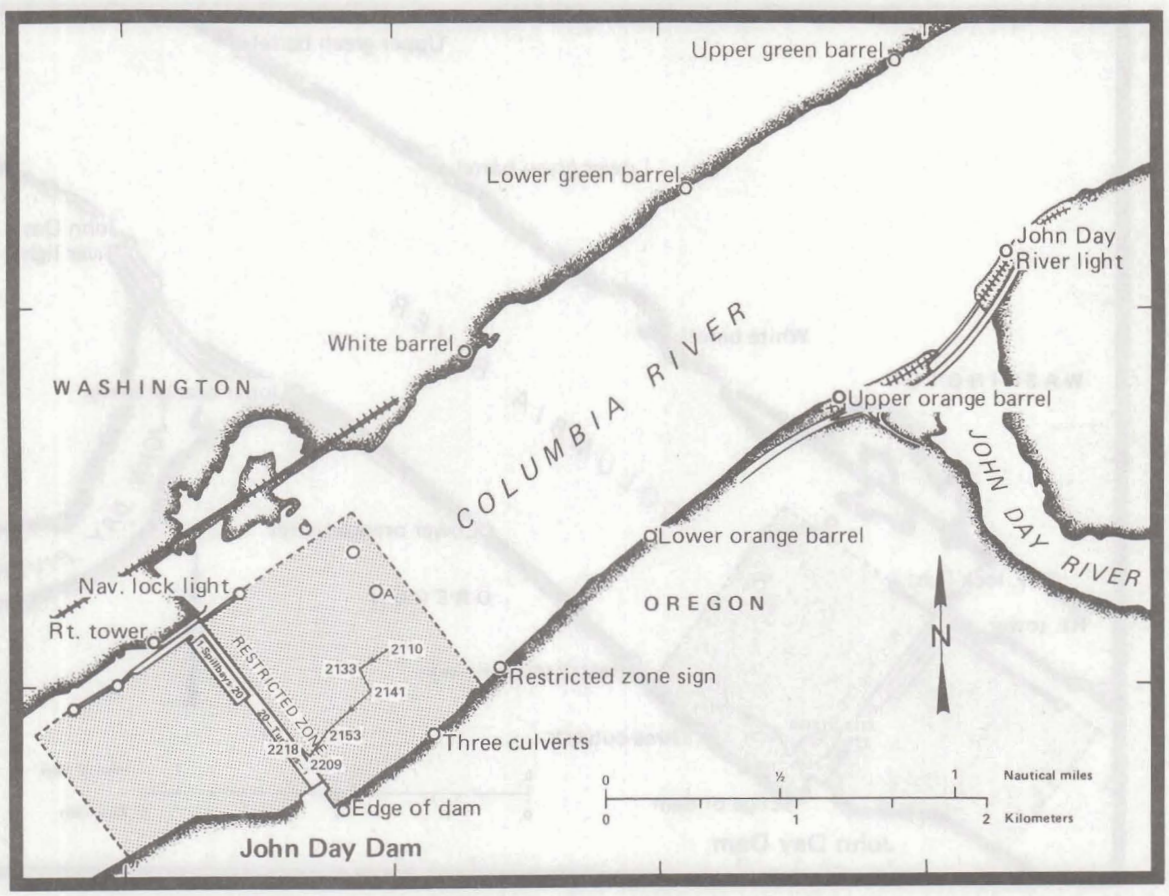


Fish Number 29
Chinook salmon 167 mm
26 May 1982

Fish number 29 was released in the restricted zone halfway across the powerhouse. With 36% of the river flow split between the ends of the spillway, the fish was not moved to the spill but passed through Turbine Unit 8.

Flow Kcfs

Time	2100	2200						
Total	412.6	409.6						
Turbine	260.4	258.6						
Spill	151.6	150.4						
% spill	37	37						

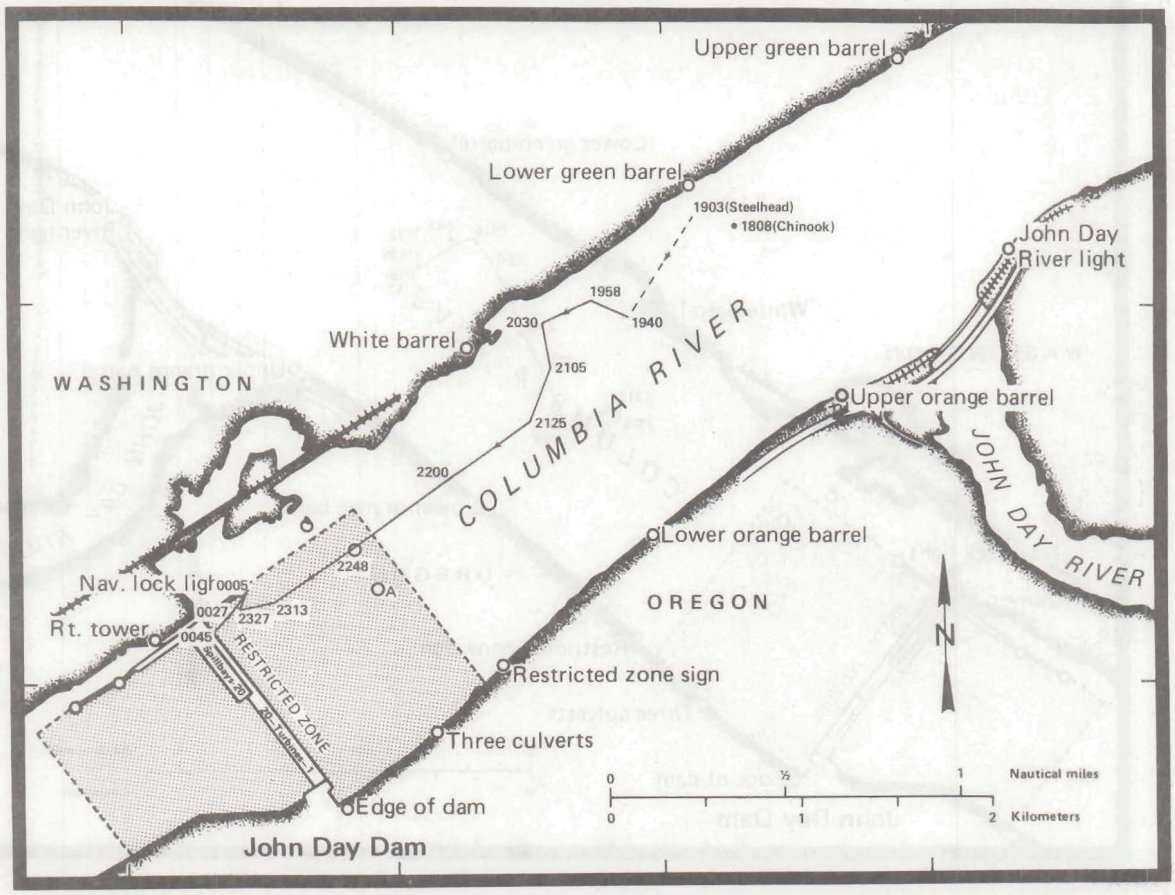


Fish Number 30
Steelhead 174 mm
2 June 1982

Fish number 30 moved downstream on the Washington side of the river after a 1/2 h rest at the Washington shore cove. After reaching the north end of the spillway, the fish heldup 2 hours before passing downstream through Spill Bay 2.

Flow Kcfs

Time	1900	2000	2100	2200	2300	2400		
Total	351.7	348.9	356.8	366.7	355.3	361.0		
Turbine	218.5	210.4	205.8	213.9	205.2	205.2		
Spill	139.8	136.1	150.4	150.4	150.4	150.4		
% spill	37	39	42	41	42	42		

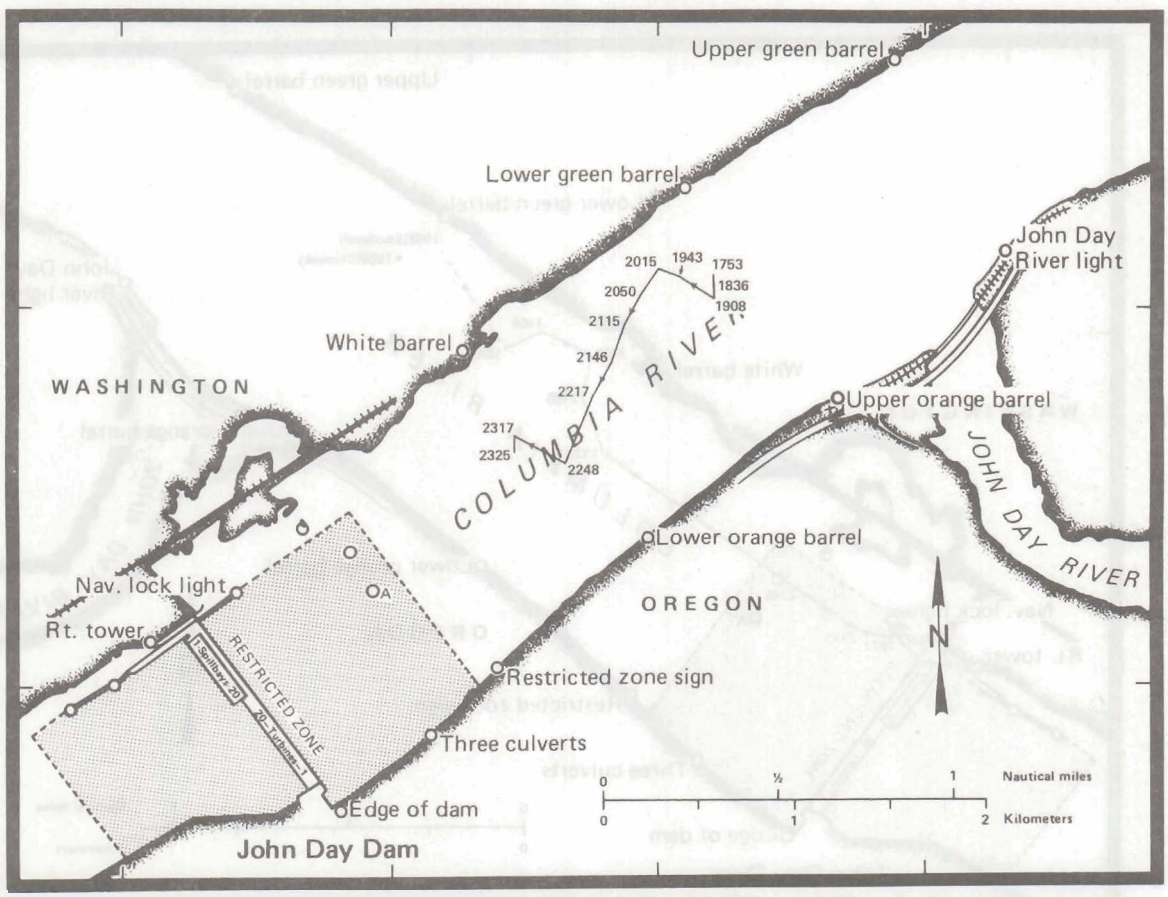


Fish Number 31
Chinook salmon 192 mm
3 June 1982

Fish number 31 was a slow moving fish. The track was terminated at 2325 h because of a lack of movement and worsening weather conditions.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200	2300	
Total	353.7	351.7	348.9	348.9	356.8	366.7	355.3	
Turbine	221,5	221,3	218.5	210.4	205.8	213.9	205.9	
Spill	129.8	129.8	129.8	136.1	150.4	150.4	150.4	
% spill	36	36	37	39	42	41	42	

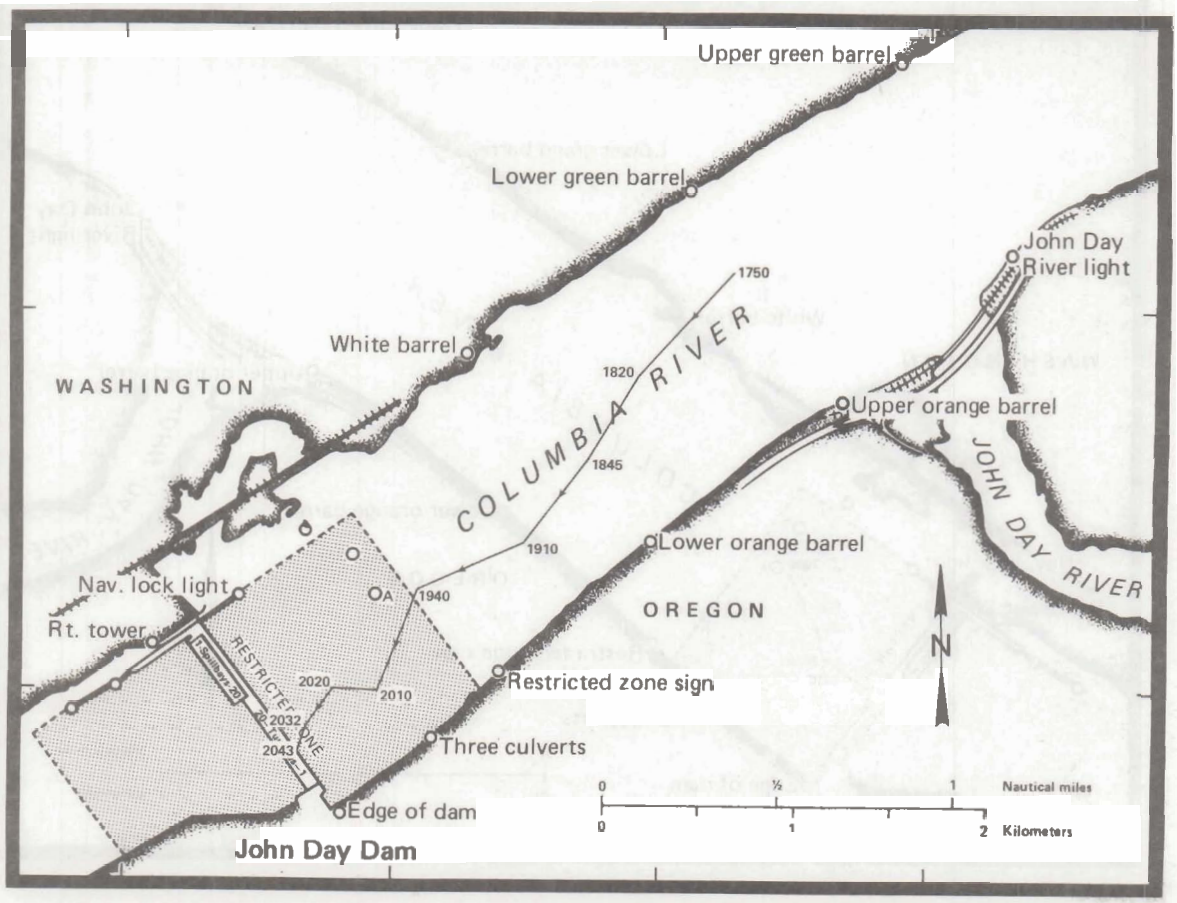


Fish Number 32
Steelhead 131 mm
4 June 1982

Fish number 32 moved rapidly down to the powerhouse with crossover to the Oregon side of the river about a km above the restricted zone. The track was terminated when the fish passed through Turbine Unit 7.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	299.9	303.4	315.3	291.2	288.2			
Turbine	218.6	222.1	234.0	209.5	204.7			
Spill	80.7	80.7	80.7	81.1	81.3			
% spill	26	26	25	27	28			

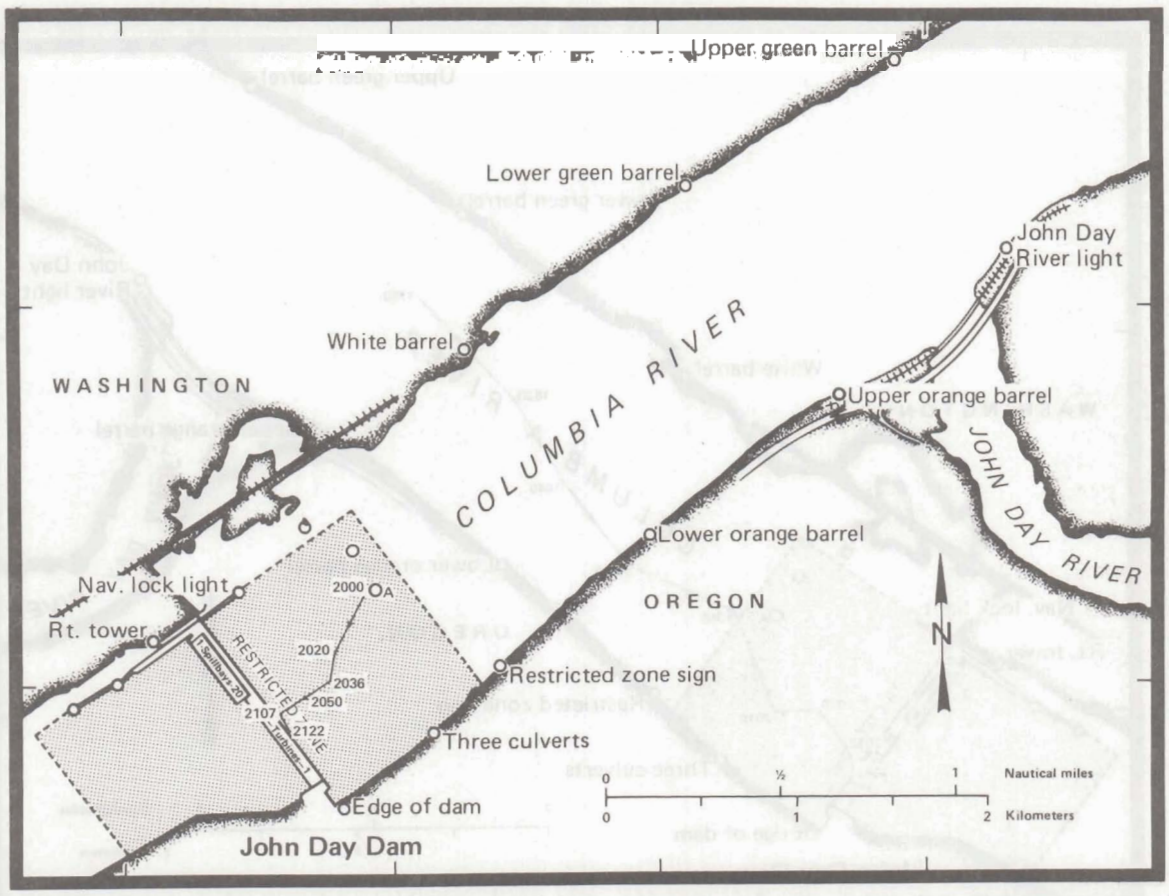


Fish Number 33
Chinook salmon 168 mm
5 June 1982

Because of rough weather, fish number 33 was released at Buoy A. Fourty-three percent of the total river flow was being spilled through seven gates on the powerhouse end of the spillway as the fish moved to Unit 15 and then to Unit 11 for passage.

Flow Kcfs

Time	2000	2100						
Total	345.7	345.5						
Turbine	194.4	192.7						
Spill	150.7	150.4						
% spill	43	43						



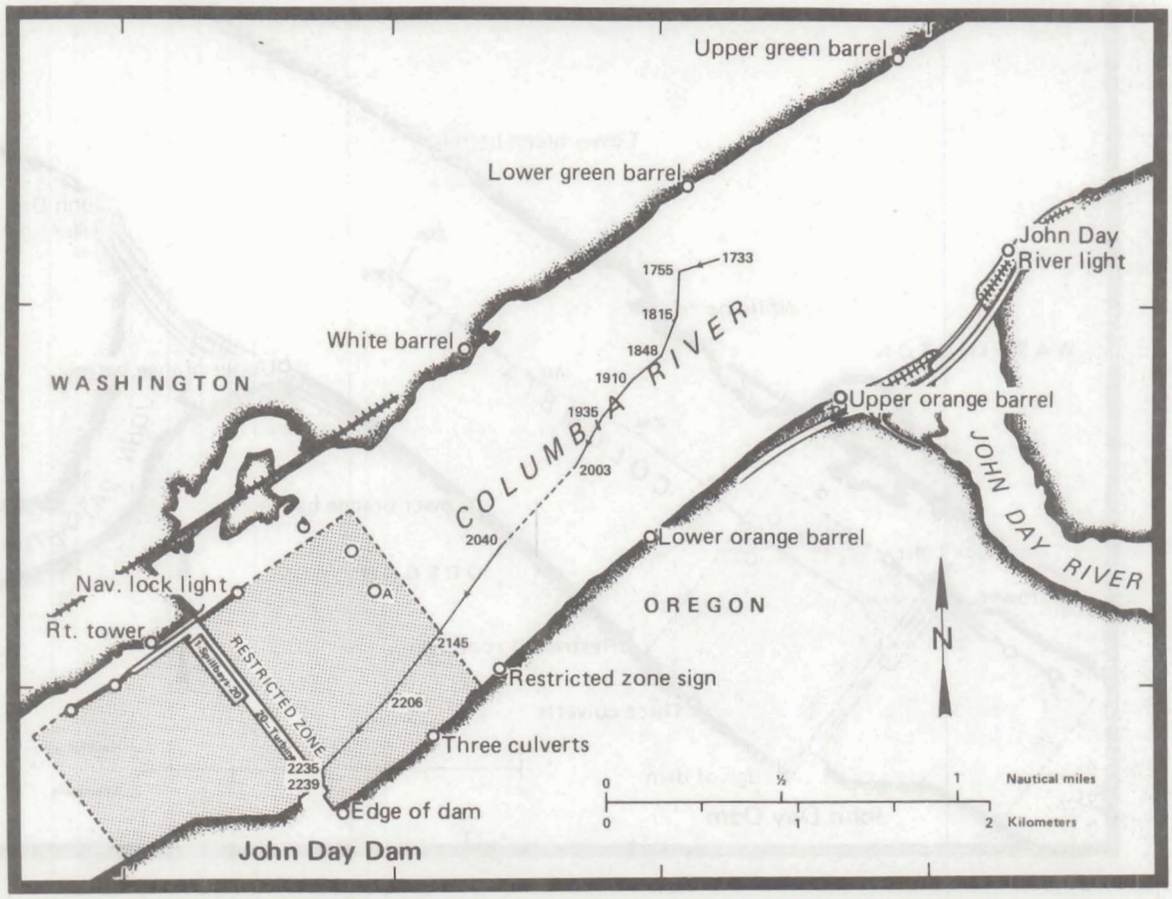
Fish Number 34

Chinook salmon 160 mm
6 June 1982

Fish number 34 was one of the fish that crossed from the Washington side of the river to the Oregon side during a period when the spill was greater than 40% of the total river flow. The track was terminated when the fish passed through Turbine Unit 1.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200		
Total	361.2	349.7	357.3	350.5	386.0	393.1		
Turbine	208.4	196.9	206.3	199.9	235.0	242.1		
Spill	150.4	150.4	150.4	150.0	150.4	150.4		
% spill	41	43	42	42	38	38		

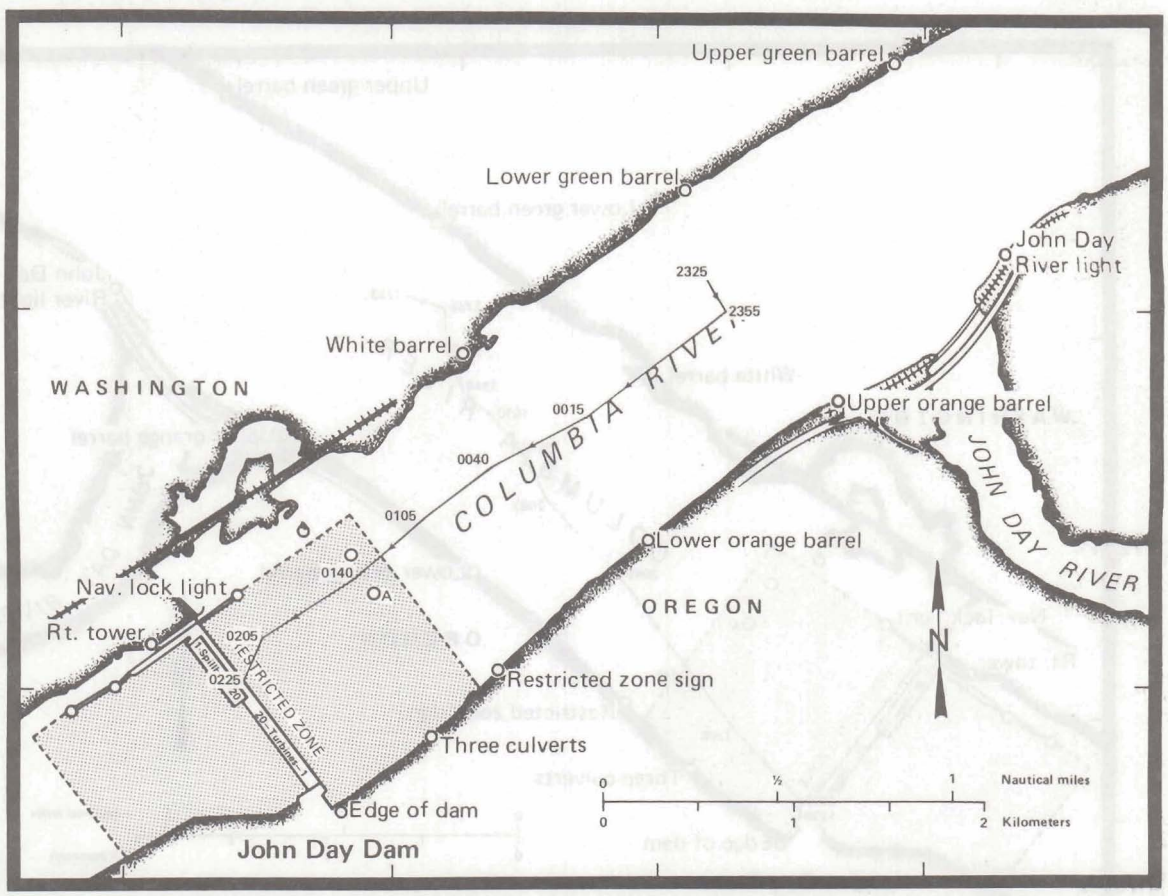


Fish Number 35
Chinook salmon 166 mm
7 June 1982

Fish number 35 was released after dark to test night behavior. Spill at the time of release was greater than 40% of the total river flow. After moving downstream with no delay, the fish passed through Spill Bay number 15.

Flow Kcfs

Time	2300	2400	0100	0200				
Total	346.1	337.4	346.9	342.6				
Turbine	195.1	186.4	194.1	191.6				
Spill	150.4	150.4	150.4	150.4				
% spill	43	45	43	44				

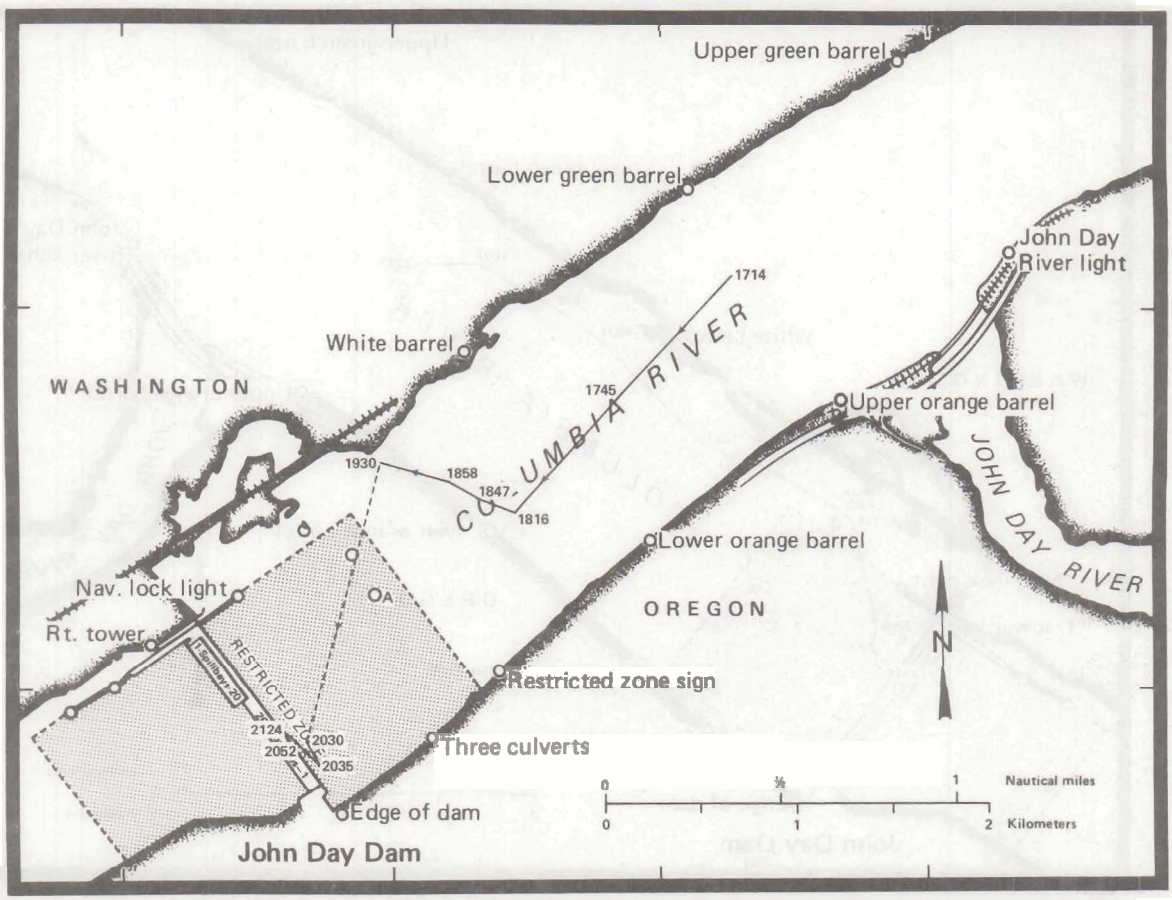


Fish Number 36
Chinook salmon 162 mm
8 June 1982

The track proceeded normally until the fish got down to the restricted zone. There the signal was then lost for 1 h. The fish was found at the face of the dam, and after spending 1 h at the face of the powerhouse the fish passed through Turbine Unit 11.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	366.4	335.1	305.7	329.1	350.2			
Turbine	283.3	253.8	224.4	240.8	249.5			
Spill	80.7	80.7	80.7	80.7	100.1			
% spill	22	24	26	26	28			

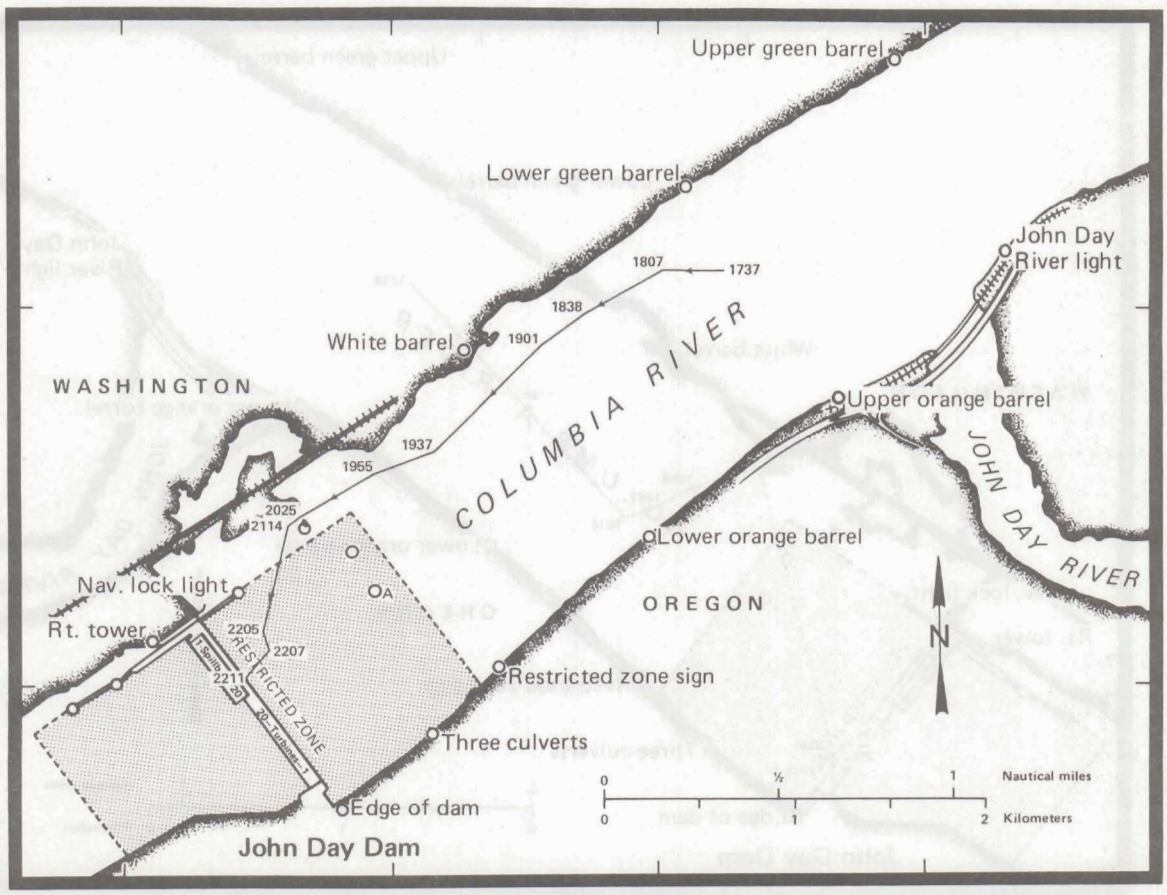


Fish Number 37
Chinook salmon 159 mm
9 June 1982

After proceeding normally down to the restricted zone this fish delayed of an hour near the Washington shore. At the time the fish passed through Spill Bay 17 the spill was concentrated at 6 gates on the powerhouse end of the spillway.

Flow Kcfs

Time	1700	1800	1900	2000	2100	2200		
Total	269.7	298.7	325.4	329.8	331.7	346.8		
Turbine	188.4	216.8	224.2	226.9	213.4	242.7		
Spill	80.7	80.7	98.7	100.5	117.7	101.7		
% spill	29	27	30	30	35	29		

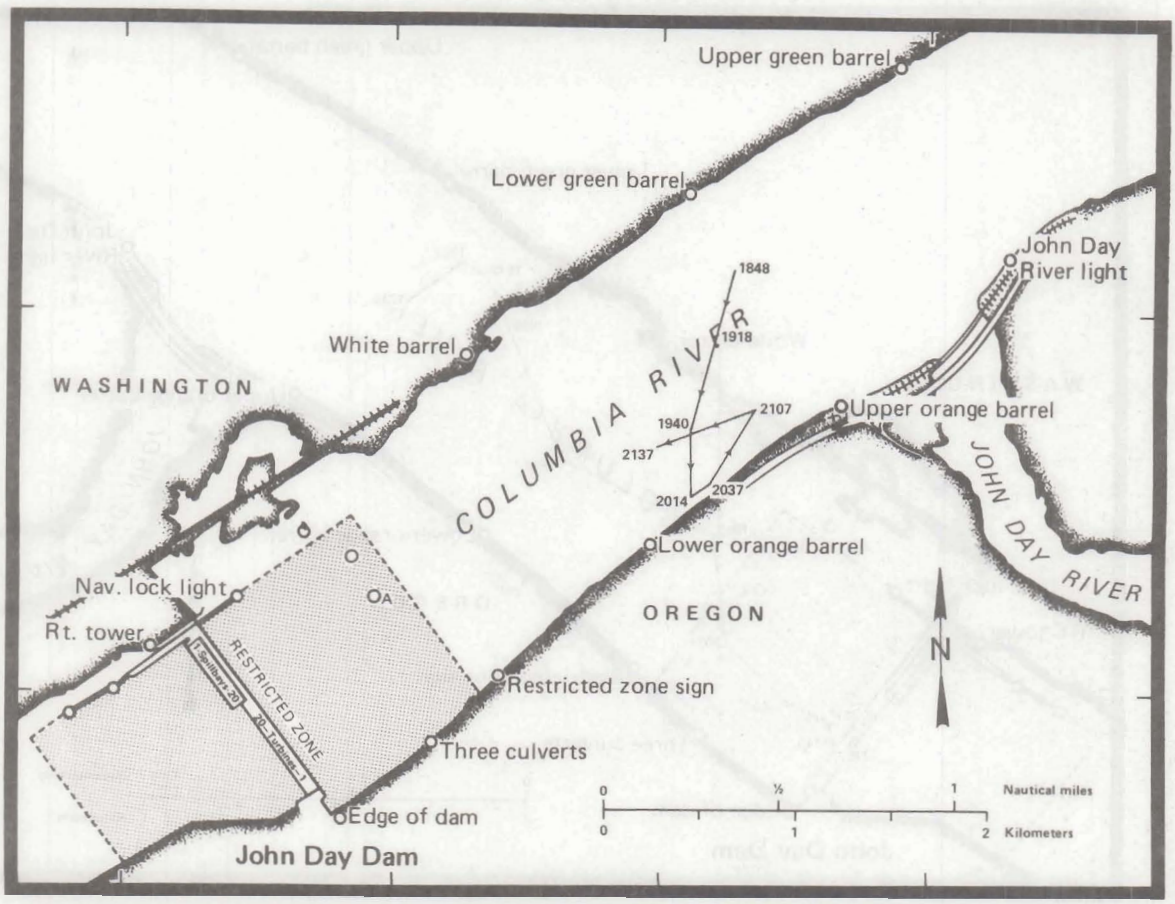


Fish Number 38
Steelhead 158 mm
15 June 1982

This track demonstrated the reasons that chinook salmon were the primary species studied this year. After the fish crossed the river and moved upstream, the signal strength fluctuated and was eventually lost. The track was terminated after an unsuccessful search.

Flow Kcfs

Time	1800	1900	2000	2100				
Total	405.8	401.7	393.0	407.0				
Turbine	304.3	291.9	260.6	261.2				
Spill	100.9	107.4	131.8	145.2				
% spill	25	27	34	36				

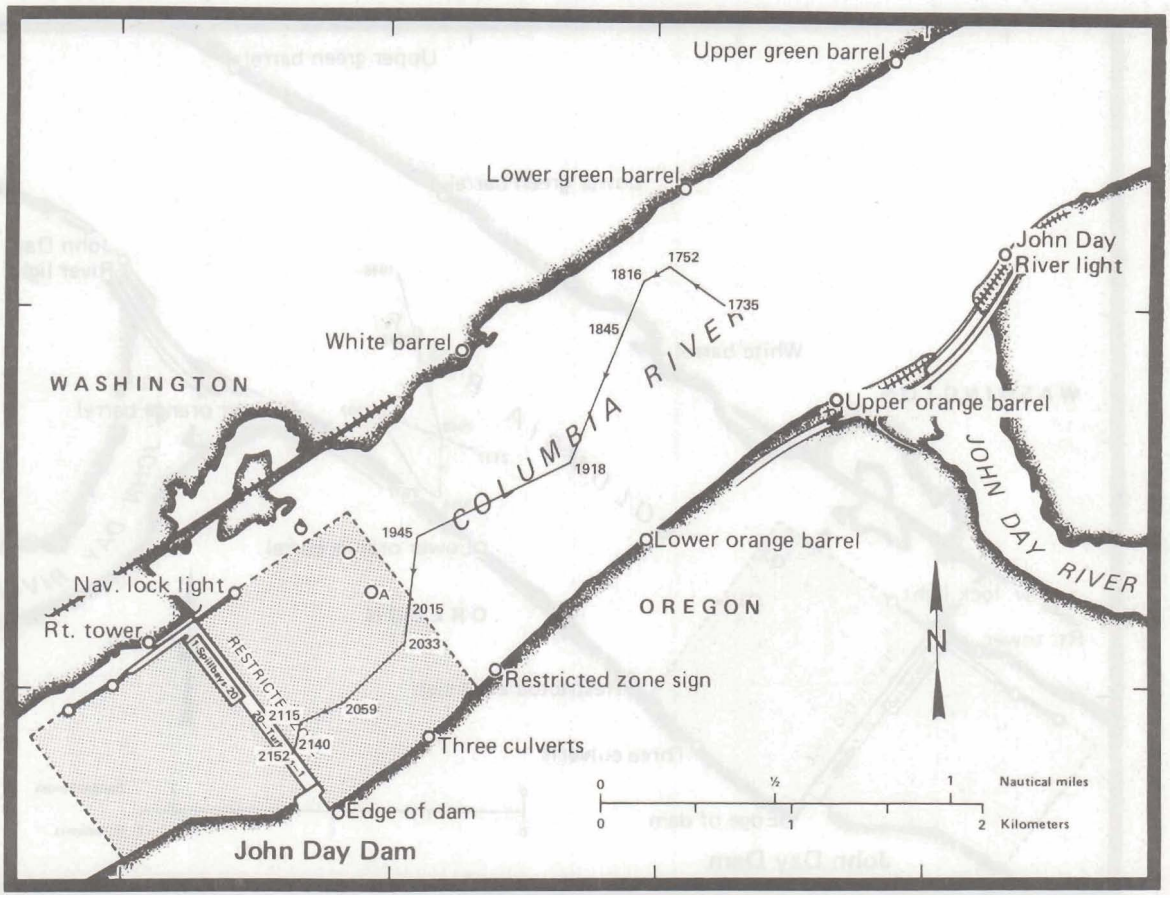


Fish Number 39
Chinook salmon 163 mm
16 June 1982

This fish moved to the dam during a period with less than 20% spill. The track was terminated when the fish passed through Turbine Unit 7.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	443.1	443.6	418.7	414.9	432.8			
Turbine	318.0	332.8	338.6	253.8	270.7			
Spill	124.5	110.2	79.5	160.5	161.5			
% spill	28	25	19	39	37			

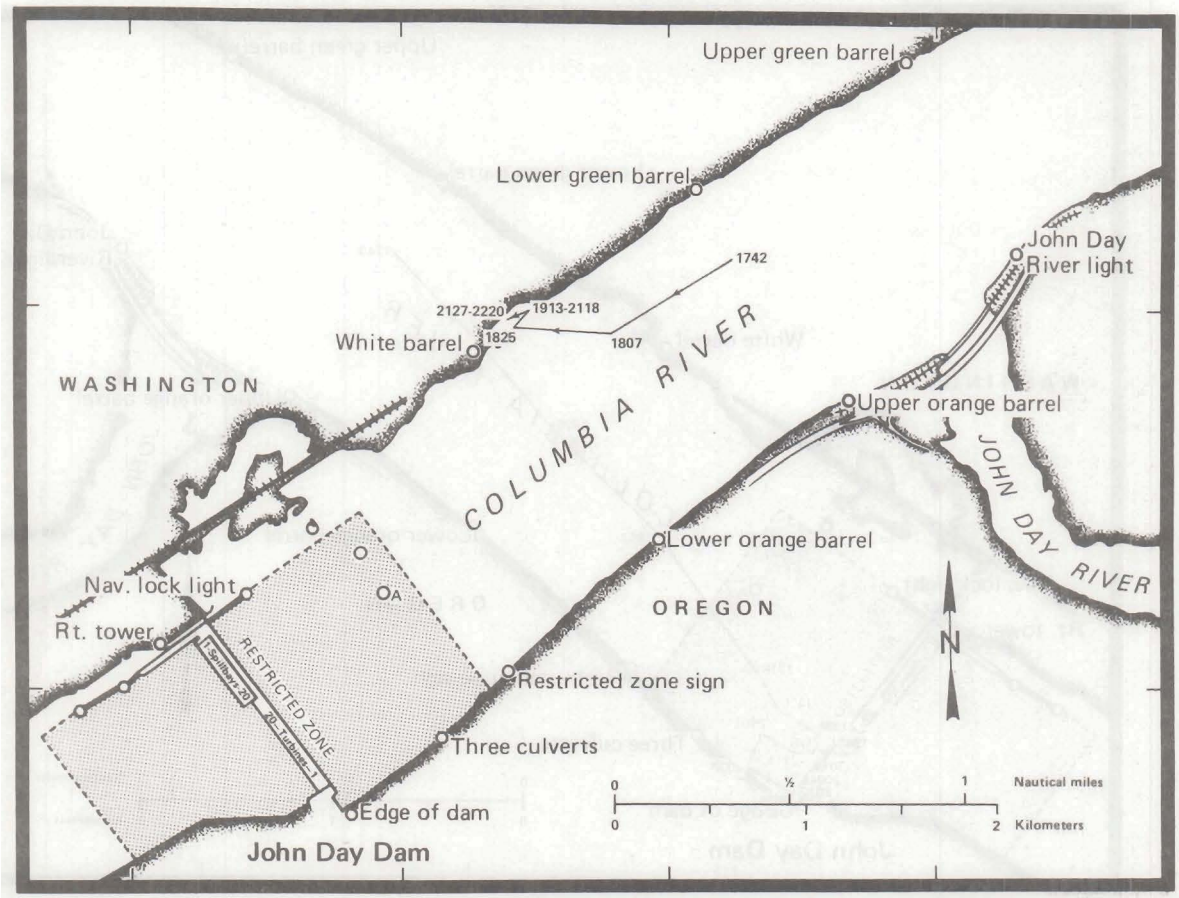


Fish Number 40
Steelhead 169 mm
17 June 1982

Fish number 40 moved to the cove on the Washington shore where it stayed until the track was terminated because of no movement.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	416.2	441.2	426.5	418.9	419.9			
Turbine	294.4	302.3	298.1	260.6	244.4			
Spill	121.2	138.2	127.8	157.8	174.9			
% spill	29	31	30	38	42			

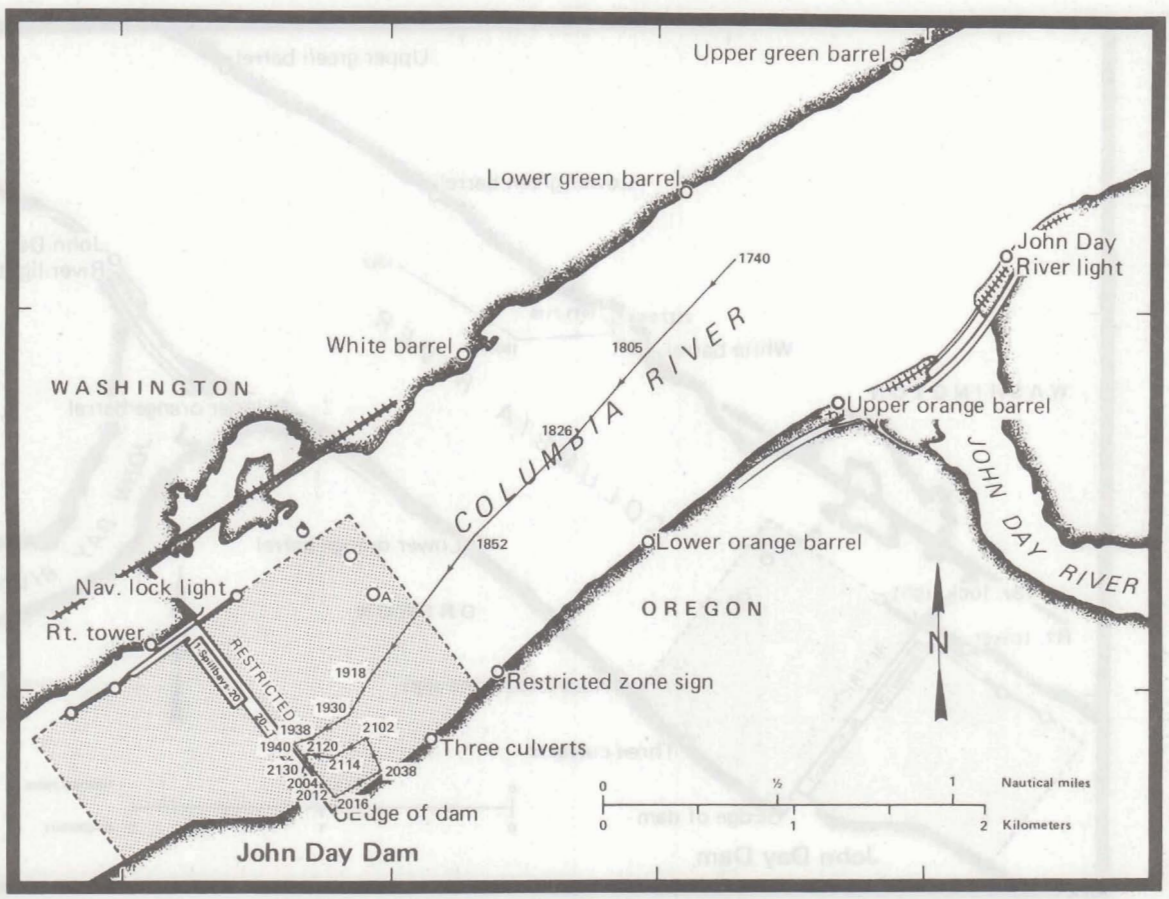


Fish Number 41
Steelhead 151 mm
17 June 1982

This steelhead moved to the powerhouse at Unit 9, then to the Oregon shore and upstream before returning to the powerhouse to pass through Turbine Unit 4. The powerhouse flow during the time the fish was at the dam was nearly 300 kcfs.

Flow Kcfs

Time	1700	1800	1900	2000	2100			
Total	432.4	450.1	448.3	443.6	448.0			
Turbine	289.3	291.2	296.0	294.2	296.3			
Spill	142.5	158.3	151.7	148.8	151.1			
% spill	33	35	34	34	34			

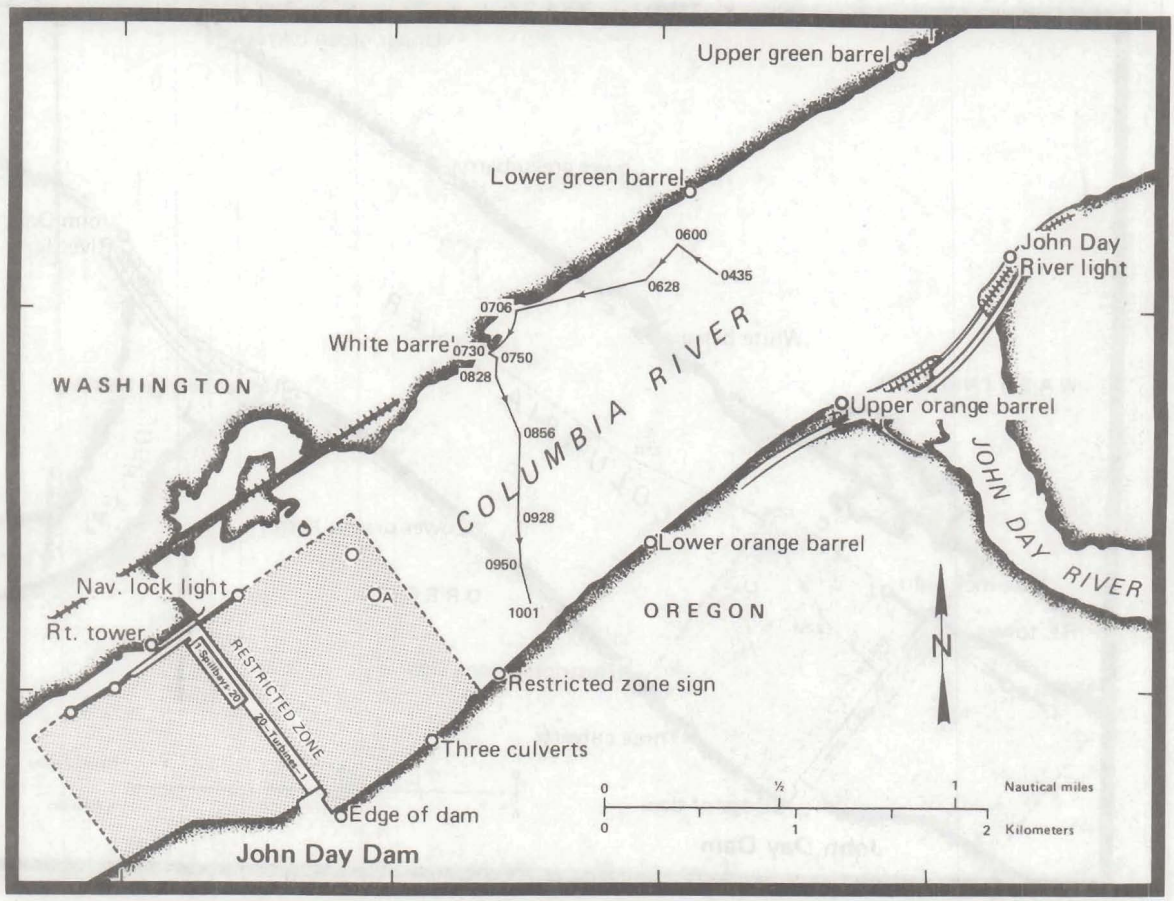


Fish Number 42
Steelhead 172 mm
19 June 1982

This fish was released to observe daylight behavior, and the track was terminated due to the lack of downstream movement. A monitor on the dam indicated that the fish passed through the powerhouse on the morning of 20 June.

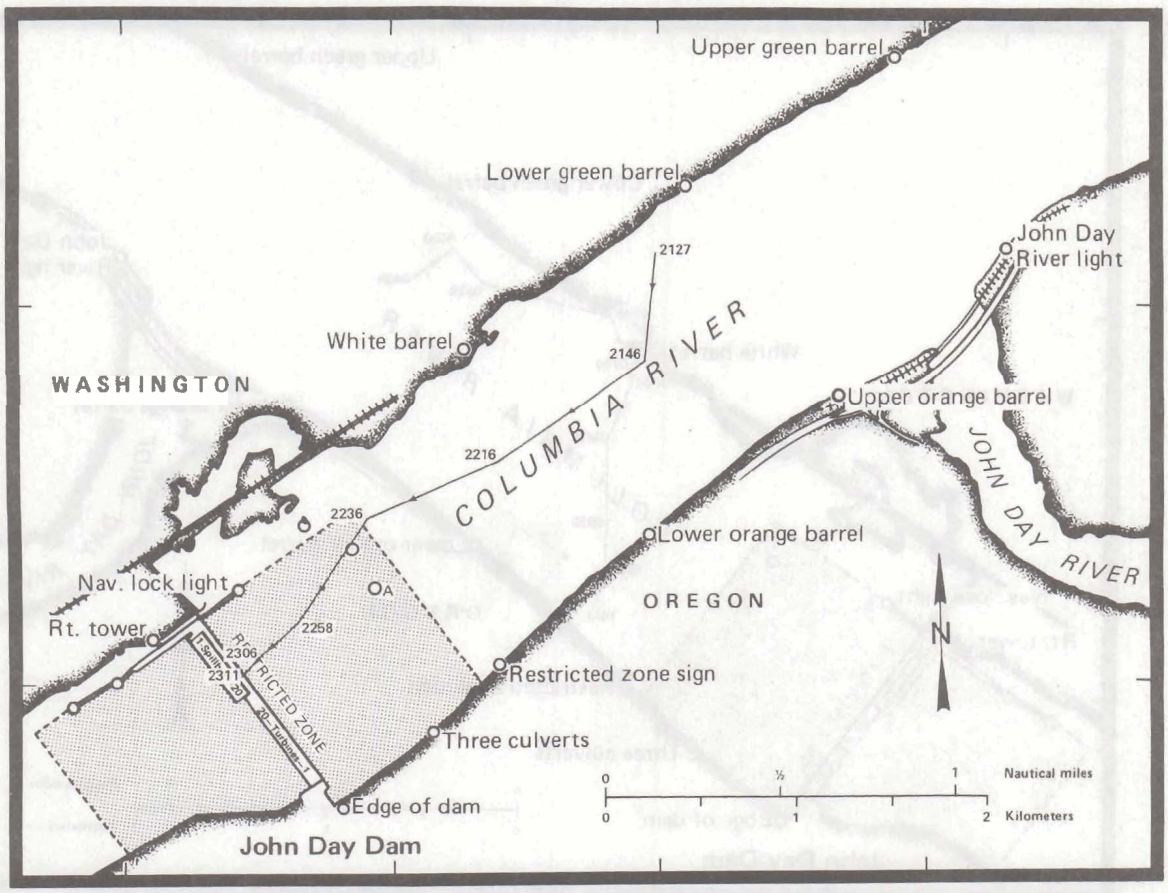
Flow Kcfs

Time	0400	0500	0600	0700	0800	0900	1000	
Total	439.0	435.8	437.6	436.9	446.3	444.7	444.6	
Turbine	288.0	284.8	284.8	285.9	293.5	293.7	293.6	
Spill	150.4	150.4	150.4	150.4	150.4	150.4	150.4	
% spill	34	35	34	34	34	34	34	



Fish Number 43
Chinook salmon 157 mm
20 June 1982

y to the dam for passage through the spillway. when the fish passed through Bay 16.

Flow Kcfs

Time	2100	2200	2300					
Total	432.9	439.0	443.0					
Turbine	287.7	288.0	299.3					
Spill	150.6	150.4	143.1					
% spill	34	34	32