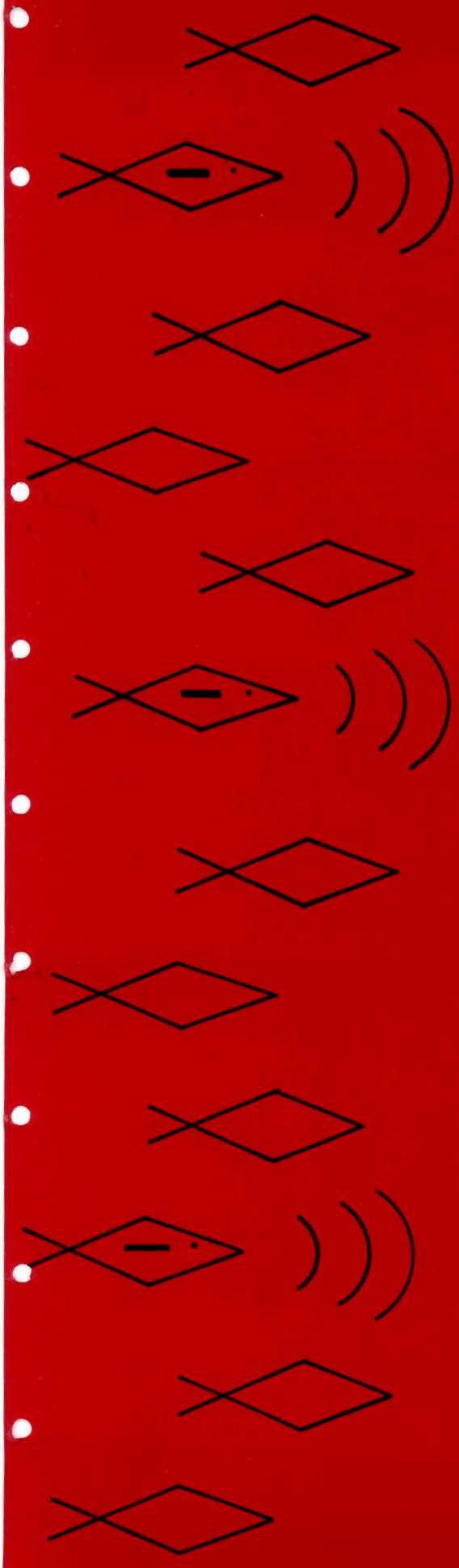

FINAL REPORT

RADIO TRACKING STUDIES OF SPRING CHINOOK SALMON IN RELATION TO EVALUATING POTENTIAL SOLUTIONS TO THE FALLBACK PROBLEM AND INCREASING THE EFFECTIVENESS OF THE POWERHOUSE COLLECTION SYSTEM AT BONNEVILLE DAM, 1976

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INTRODUCTION

Two areas of immediate concern have developed in relation to adult fish passage at Bonneville Dam (Figure 1) on the Columbia River. One is the problem of fish falling back over the spillway after they ascend the dam (Monan and Liscom, 1975; Junge and Carnegie, 1976). The second involves the apparent inefficiency of the powerhouse collection system (Junge and Carnegie, 1976).

Radio tracking studies have shown that as fish enter the forebay from the Bradford Island fishway, many tend to orient to the Bradford Island shore--swimming to the upstream end of the island, around the end, and down to the spillway (Monan and Liscom, 1974, 1975, 1976). Most of these fish swim across the channel in front of the spillway to the Washington shore and continue upstream. However, during periods of spill many fall back over the spillway.

Fallback has three deleterious effects on adult salmon passage: (1) direct mortality at time of fallback, (2) delayed mortality due to added delay in reentry and reascension of fishways, and (3) inflated fish counts which hamper management of the runs.

A committee, made up of representatives of the Corps, Oregon Department of Fish and Wildlife (ODFW), and National Marine Fisheries Service (NMFS), was formed to develop a means to break up the pattern of fish swimming around Bradford Island to the spillway. Many things were considered; but because of time restrictions for construction, the only practical device suitable for installation during the 1976 spring chinook salmon run was a deflector net extending at an angle from the Bradford Island shore, just upstream from the fishway, to an area about 150 feet out into the powerhouse channel.

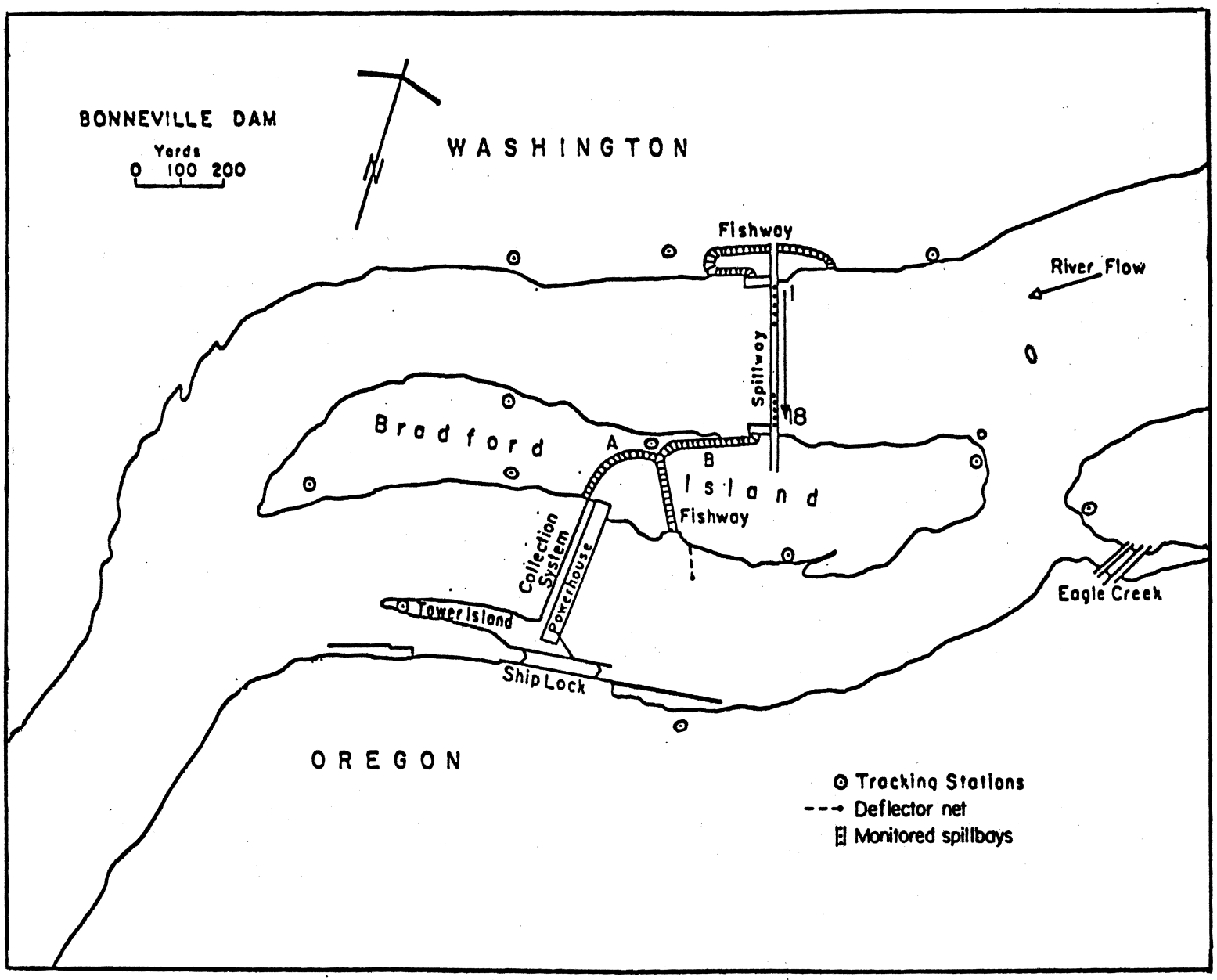

Figure 1.--Diagrammatic sketch of Bonneville study area and location of stationary tracking sites.

Recent decreases in the numbers of fish using the "A" branch of the Bradford Island fishway are thought to be a result of a decrease in the efficiency of the collection system for adult salmonids located across the downstream face of the powerhouse. To study this problem under various flow conditions, personnel from the Corps installed electronic fish counting tunnels in the orifices of the collection system. The tunnel study can provide information on the number of entries and exits made by fish at the orifices, but it cannot show how flow manipulations, etc., effect fish approaching the system. Tracking studies carried out in conjunction with the tunnel studies could provide this additional information.

Radio-tracking studies of chinook salmon at Bonneville Dam during the spring of 1976 were primarily designed to study the reaction of tagged fish to the deflector net located near the exit to the Bradford Island fishway and to obtain information on specific areas of fallback. In addition, tracking information obtained on radio-tagged fish in the powerhouse channel below the dam would supplement data obtained by the Corps in their electronic tunnel studies.

Specifically, there were five objectives: (1) evaluate the effectiveness of the deflector net in reducing fallback and monitor the reactions of fish to the net, (2) determine if fish released into the forebay at different distances across the powerhouse channel fell back at different rates from those exiting the Bradford Island fishway, (3) determine which specific spill gates radio-tagged fish fell back through, (4) determine swimming depths of tagged fish as they swam around the deflector net and Bradford Island, and (5) monitor radio-tagged fish as they approached the powerhouse fish collection system.

EXPERIMENTAL SITE AND EQUIPMENT

Bonneville Dam is located on the Columbia River, 145 miles from the Pacific Ocean. As it is the first dam encountered by returning adult salmonids, fish counts taken there are instrumental in managing the runs. At Bonneville Dam, the spillway is separated from the powerhouse by Bradford Island (Figure 1) creating two channels. Fishway entrances are located at the north and south ends of the spillway and a fish collection system runs across the face of the powerhouse with a fishway entrance at the north end. The south end spill entrance ("B" Branch) and the powerhouse entrance ("A" Branch) connect and form a single fishway over the dam. The exit to the north fishway is on the Washington shore approximately 387 feet upstream from the spillway. The Bradford Island fishway exit is on the south side of the island about 465 feet upstream from the powerhouse.

Radio Tags

The conventional radio tag is a small battery powered radio transmitter operating on a carrier frequency of approximately 30 megahertz (MHz). Transmitter and batteries are sealed in a plastic capsule about 3.5 inches long and 0.75 inch in diameter. The batteries power the transmitter for about 12 days. Each tag is frequency coded, weighs about 1 ounce in water, and is carried in the stomach of the fish except for a small wire antenna extending from the tag, through the fish's esophagus, to the roof of the mouth where it is attached by means of a small plastic anchor. Use of frequencies 30.17, 30.18, 30.19, 30.20, 30.21, 30.22, 30.23, 30.24, and 30.25 MHz gives us nine separately identifiable tag codes.

The pressure tag is also a small battery operated radio transmitter on a carrier frequency of about 30 MHz. The battery life of the pressure tag is approximately 6-1/2 days. The plastic capsule is 4-1/4 inches long and 1 inch in diameter with the pressure transducer mounted on the forward end. This tag also weighs approximately one ounce in water and is carried in the stomach of the fish, the same as the beacon tag. The tag transmits 30.21 MHz pulses 30 milliseconds long. The pulse interval or period varies with pressure (depth). The period for pressure was set to vary over a range of from 0 to 60 feet.

Direction Finder-Receiver and Antennas

The direction finder-receiver used by trackers is a self-contained battery-operated unit that receives the radio signal from the antenna, amplifies it, and converts it to an audible tone. The operator can monitor any one of the nine frequencies at any time. To eliminate as much extraneous noise as possible, each operator uses earphones to listen to the signal.

Two types of directional antennas were used for tracking: the loop antenna used in previous years and the two element vertically polarized directional beam antenna (Adcock). The loop antennas were mounted on vehicles used as mobile units. The Adcock antennas were used at the fixed tracking stations and because of their size, were not adaptable to the mobiles. The horizontal boom of the Adcock is 6 feet 4 inches long. The two vertical elements are 15 feet 9-3/4 inches long and are attached to the boom at their centers. The antennas were mounted on 16 foot masts making the height of the upper tip of the elements about 24 feet from the ground. Guy lines stabilized the mast, and trackers easily turned the unit by hand while tracking tagged fish.

Pressure Tag Receiver

Pressure tag signals require a sophisticated receiving system consisting of five main components: (1) a quarter-wave whip antenna, (2) a broad band receiver, (3) a phase-lock loop demodulator with pulse conditioner, (4) an electronic digital counter, and (5) a clamp-bar direct current strip chart recorder.

The strip chart recorder was used for the first time and enabled us to keep a permanent and continuous record of the fish's swimming depth. Signals from the tag were recorded on pressure sensitive paper as a measurement of the pulse interval. Each pressure tag was calibrated just before being inserted in the fish and the appropriate graphs were used to easily convert the pulse interval to depth. Depth information was accurate to within plus or minus 6 inches.

Fishway Monitoring Units

Movement of fish in the fishways was monitored by two different systems. One was a simple unit to alert fish counters to the presence of a tagged fish in a specific area. The other was a sophisticated telemetry unit that transmitted data on the movements of tagged fish in the fishways to the data collection center.

The simple alert system was a battery-powered receiver placed in the counting house and a standard 18-inch loop antenna positioned over the fishway pool just below the counting house. This system did not distinguish between specific tag codes. The gain controls on the receivers were set so they would give an audible beeping sound only when fish were in the immediate vicinity of the counting station.

Telemetry units monitored the fishway entrances and determined when specific tagged fish entered the fishway. Each telemetry unit had two underwater antennas suspended from floats--one just inside the entrance and the other about 100 feet upstream. The underwater antenna was developed by our electronic unit for use in fishways and other areas where reduced range is desirable. The underwater unit is a dipole antenna resonant underwater at 30.21 MHz. Its range is less than a loop antenna and provides more accurate data on fish movement into the fishways.

As tag signals came into the receiver unit (located adjacent to the fishway), it determined the tag frequency, converted the information to a tone code, and transmitted the appropriate code via radio transmitter to the receiver in the data control center. The tone code was automatically decoded and a flashing light on a panel array indicated the frequency and location. By viewing the light panel and clock, observers determined the time each tagged fish moved into each specific fishway, and whether the fish was near the upstream or downstream antenna. By noting the sequence of events, the observers could determine if the fish was moving upstream, holding, or moving down the fishway.

Spillgate Monitoring Units

Fallback was monitored at the spillway section of the dam by underwater antennas, counting house-type receivers, and strip chart recorders. The antennas were weighted and lowered to a depth of about twenty feet in the upstream side of the spillgate slots (two antenna per spill bay).

The antennas were positioned in gate slots to minimize damage to the antennas by swirling logs and other debris that collect above the spill gates. A receiver was attached to the safety railing above each gate being monitored and relayed tag signals received by the antennas to one of the multi-channel strip chart recorders. One recorder was housed at the north end of the spillway and one at the south end. When a fish fell back, the appropriate pen in the recorder indicated on the chart paper which gate the fish fell back through. The moving chart was calibrated so the time an event occurred could be determined. Identifying the proper tag code was done by checking central control room charts for the code of the fish that had been tracked as a fallback at the time indicated on the recorder chart.

GENERAL EXPERIMENTAL PLAN

Plans called for tagging and tracking as many individually identifiable spring chinook salmon as possible between April 23 and May 27, 1976. Fish were to be released at various locations below and above Bonneville Dam. Tracking would be most intense above the dam in the powerhouse channel, around Bradford Island, and at the spillway. Fish continuing around Bradford Island and swimming toward the spill would be carefully monitored, and special efforts would be made to ascertain the exact spillgate where any fallback occurred.

Radio-tagged fish would be tracked below the dam prior to their entry into the fishways. Special emphasis would be placed on tracking fish as they approached the powerhouse collection system. Because of manpower restraints, tracking below the dam would only be done when there were no radio-tagged fish in the forebay.

Data on swimming depths of migrating chinook salmon were to be obtained by releasing fish tagged with a pressure tag. Continuous monitoring would be done from the point of release until the tagged fish left the Bonneville Dam study area.

EXPERIMENTAL PROCEDURES

Trapping and Tagging

Chinook salmon for tagging were diverted from the fishway on the north side of the Bonneville spillway into a trapping facility in the Fisheries-Engineering Research Laboratory. Fish to be tagged ascended a twenty-foot Denil type fishway to a short holding area. From the holding area, they swam over a false weir and down a slide into a tank of water containing anesthetic (MS-222). Chinook salmon were tagged as they came, except those under 660 mm in length were rejected.

Individual anesthetized fish were placed into a tagging rack belly up and the lower jaw was raised to fully open the mouth. The tagger then took the radio tag from an antiseptic solution of zephiran chloride, dipped the posterior end (that portion entering the fish first) in glycerin, and inserted the tag into the stomach of the fish through the esophagus.

The short antenna lead attached to the anterior end of the tag extended from the esophagus to the roof of the mouth where it was attached with a plastic anchor. The main purpose of the anchor was to prevent the fish from swallowing the antenna. The fish was then turned over, and a color coded spaghetti flag tag was attached near the base of the dorsal fin. Tagging procedures were the same for the conventional radio tag and the pressure sensitive tag.

After tagging, fish were placed in a fish hauling truck, driven to the release point, and released directly into the Columbia River or placed in a live box or pen. Our first releases for this study were made into the river at the entrance to Hamilton Slough on the Washington shore about 0.9 of a mile downstream from the powerhouse. Later releases were made at Dodson, approximately four miles below the dam on the Oregon side. During previous studies at Bonneville Dam, we released our tagged fish below the dam at the boat ramp at Beacon Rock State Park. However, this year the bridge entering the park was damaged by high water and was impassable to vehicular traffic. Releases above the dam were made from the ODFW recovery pen located immediately upstream from the deflector device, from a live box midway across the powerhouse channel, and from the fish lock at the south end of the powerhouse. To expose more fish to the deflector net, tagged fish were also released into the Bradford Island "A" Branch fishway at the steep slope experimental facility. Table 1 shows the number of fish released at each location.

A total of 67 spring chinook salmon were tagged and released in the vicinity of the dam, and we attempted to have at least nine separately identifiable tagged fish in the study area at all times. On occasion, a duplicate code was released when one or more tag codes were downstream and out of the tracking area. These duplicate releases were always made at upstream locations. Releases below the dam were not made until a fish with a particular code left the study area (Bridge of the Gods) and continued upstream. The data on fish tagged and released are detailed in Table 2.

Table 1.--Release sites and number of radio-tagged fish released.

LOCATION	NUMBER OF FISH
Hamilton Slough	21
Dodson	7
Bradford Island "A" Branch	12
Recovery Pen	14
Fish Lock	9
Mid-Channel	4
TOTAL	67

Table 2.--Tagging data for chinook salmon used in the study at Bonneville Dam, April 23-May 27, 1976.

Date Released	Location	Flag Color	Radio Tag Code	Fish Length mm
April 23	Hamilton Slough	Blue/Orange	D6A	720
April 23	Hamilton Slough	Blue/Orange	E6B	980
April 23	Hamilton Slough	Blue/Orange	F6A	950
April 23	Hamilton Slough	Blue/Orange	L6C	690
April 23	Hamilton Slough	Blue/Orange	K6A	800
April 23	Hamilton Slough	Blue/Orange	H6D	830
April 23	Hamilton Slough	Blue/Orange	J6D	760
April 23	Hamilton Slough	Blue/Orange	G6E	730
April 23	Hamilton Slough	Blue/Orange	I6E	880
April 26	Hamilton Slough	Pink/White	D6B	760
April 26	Pen	Pink/White	H6G	680
April 26	Pen	Yellow/Green	H6K	680
April 27	"A" Branch	Pink/White	F6I	820
April 28	"A" Branch	Pink/White	E6S	720
April 28	Hamilton Slough	White/Blue	D6C	810
April 30	Hamilton Slough	Pink/White	I6N	730
April 30	Hamilton Slough	Pink/White	G6G	750
May 1	Pen	White/Blue	I6G	850
May 1	Hamilton Slough	Pink/White	L6L	750
May 2	Pen	Pink/White	K6I	730
May 2	Hamilton Slough	Pink/White	J6O	850

Table 2.-- Continued

Date Released	Location	Flag Color	Radio Tag Code	Fish Length mm
May 2	Hamilton Slough	White/Blue	G6M	670
May 3	Hamilton Slough	White/Blue	K6L	850
May 4	Hamilton Slough	White/Blue	E6J	670
May 4	"A" Branch	White/Blue	L6G	830
May 5	"A" Branch	Orange/Green	L6B	860
May 5	"A" Branch	White/Blue	J6A	730
May 6	Fish Lock	Orange/Green	D6G	970
May 7	"A" Branch	White/Blue	HD17	800
May 7	Fish Lock	Pink/Orange	D6D	670
May 9	Hamilton Slough	Green/White	D6F	720
May 9	Pen	Orange/Green	E6E	660
May 10	Hamilton Slough	Orange/Green	I6L	880
May 10	"A" Branch	Orange/Green	K6H	880
May 10	Fish Lock	Pink/Orange	L6J	690
May 12	Pen	Green/White	L6H	710
May 12	Dodson	Orange/Green	G6F	740
May 14	Dodson	Pink/Orange	E6A	870
May 14	Fish Lock	Pink/Orange	K6G	940
May 15	Pen	Green/White	F6G	760
May 15	Pen	Yellow/Pink	D6E	700
May 16	"A" Branch	Orange/Green	HD13	770
May 16	Fish Lock	Yellow/Pink	J6M	720

Table 2.--Continued

Date Released	Location	Flag Color	Radio Tag Code	Fish Length mm
May 16	Dodson	Orange/White	K6E	760
May 17	Pen	Orange/White	F6H	900
May 18	Dodson	White/Blue	F6D	830
May 18	Hamilton Slough	Green/White	K6B	920
May 19	"A" Branch	Pink/Orange	J6K	980
May 19	Fish Lock	Pink/Orange	I6H	710
May 20	Pen	Yellow/Pink	L6I	850
May 21	Fish Lock	Green/White	E6G	900
May 21	"A" Branch	Green/White	I6A	740
May 21	Dodson	Orange/Green	J6B	840
May 22	"A" Branch	Pink/Orange	H14	920
May 22	Fish Lock	Orange/Green	F6J	840
May 22	Pen	Yellow/Pink	E6C	660
May 22	Mid-Channel	Yellow/Pink	K6J	940
May 22	Dodson	Pink/Orange	G6D	770
May 23	Dodson	Yellow/Pink	I6B	820
May 24	"A" Branch	Green/White	H15	800
May 24	Mid-Channel	Pink/Blue	K6F	900
May 25	Mid-Channel	Blue/Yellow	K6C	770
May 26	Mid-Channel	Yellow/Pink	G6H	780
May 26	Fish Lock	Orange/White	J6H	830

Table 2.--Continued

Date Released	Location	Flag Color	Radio Tag Code	Fish Length mm
May 26	Pen	Pink/Orange	F6B	950
May 27	Pen	Blue/Yellow	J6G	770
May 27	Pen	Orange/White	G6J	810

Tracking and Plotting

Fish tagged with conventional radio-tags and released into the river below Bonneville Dam were monitored only intermittently from the release point until they entered the study area adjacent to the dam. Trackers equipped with mobile tracking gear traveled along the highways on either side of the river periodically and listened for tagged fish to alert staff at the dam when tagged fish were approaching the tracking area.

Tracking fish near the dam was done from 0600 hours to 2230 hours each day primarily from fixed tracking stations located throughout the area (Figure 1). Because we did not have sufficient trackers to cover the total area at any one time, we had to set priorities for tracking coverage when there were fish in more than one area of interest. Since the fallback problem was of primary interest, tracking above the dam was given top priority. Therefore, when a tagged fish entered a fishway, all trackers were alerted to be ready to be taken to the upstream stations. When the fish reached the area in the fishway where the tag activated the receiver in the counting house, trackers were informed and prepared for immediate transport by mobile units to designated stations above the dam. Tracking below the dam was discontinued except for periodic checks by mobile units. One lower station near the "B" branch was kept active to verify any fallback and to keep track of any fish that might be near the fishway entrances. Trackers remained above the dam until all tagged fish left the forebay area, either by swimming upstream or by falling back. Trackers were then re-deployed to

resume tracking below the dam in the appropriate areas. Tracking stations above the dam always were manned previous to releases in the forebay. Some days little or no tracking was done below the dam. All tracking was under the direction of the plotter located in the control center. When tagged fish were in the area, the plotter determined where the trackers should be located and which trackers could best monitor the fish's location.

Each tracking station consisted of a wooden shelter equipped with a fixed antenna mount, compass rose, and Adcock antenna. The antenna was mounted above the shelter and coupled into the mount so the null point of the antenna corresponded to a pointer that rotated with the antenna over the compass rose. The tracker established a bearing to the tagged fish by tuning his receiver to the frequency of the tag, rotating the antenna until the null point was determined, and then noting the location of the pointer on the compass rose. Simultaneously, a second and perhaps a third tracker did likewise, and the bearings were radioed to the plotter.

Locations of fish were established by triangulation and plotted in real-time on charts made from an aerial photograph showing the position of tracking stations and corresponding compass roses. A time-sequence series of these plots provided details on the route taken by the fish. The interval between plots depended upon how fast a fish was moving and the number of fish in the area.

Anomalies of radio-wave transmission were immediately apparent with this plotting system. Because bearings were so closely coordinated, false bearings were readily noticeable. When this occurred, the plotter immediately called for additional bearings from other tracking stations or mobile units.

Tracking procedures for fish carrying a pressure tag were slightly more complex. When these fish were near the dam, they were tracked by the regular tracking crews in the same way as conventional radio-tagged fish. This provided exact patterns of movement of the fish within the immediate area. In addition, a tracking crew operating in a specially outfitted van-type truck followed the tagged fish and recorded the pressure (depth) data. The two-person crew in the truck was rotated each shift, as we kept the pressure tagged fish under continuous surveillance from the time of its release until it left the study area. When the pressure tagged fish traveled away from the dam and during the hours when no trackers were on duty in the fixed stations, the fish locations were only approximations; but accurate depth of travel information was recorded continuously.

DEFLECTOR NET AND FISH BEHAVIOR

The seine net used to deflect migrating adult salmon away from the shore was installed approximately 200 feet upstream from the Bradford Island fishway exit (Figure 2). The 150-foot long net was made of 3-inch stretched mesh and extended from shore into the forebay at a slight angle upstream. It created a barrier from the surface to the river bottom over a distance of 150 feet. The water was 18 feet deep at the outer end of the net when the forebay water level gauge indicated 74 feet (above sea level). Piling driven offshore held the outer end of the net in place. Installation of the deflector net was done by the U.S. Army Corps of Engineers for the ODFW.

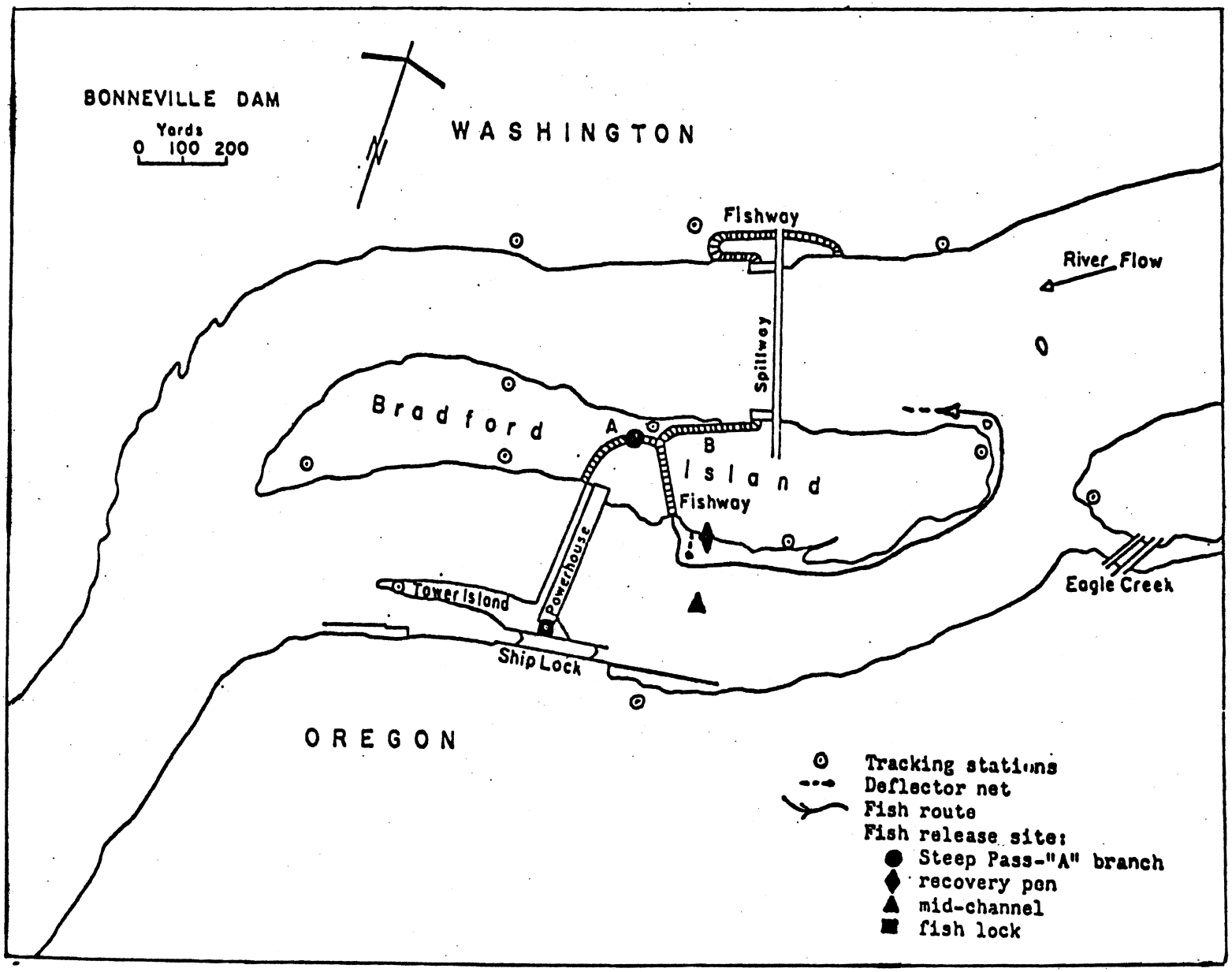

Figure 2.--Diagrammatic sketch of Bonneville study area showing the relative position of the deflector net and release sites above the dam. Also shown is the general route tagged fish took to swim around the net, along Bradford Island, to the spill.

The net appeared ineffective or at best only marginally effective in discouraging fish from following the shoreline of Bradford Island around to the spillway. A total of 14 radio-tagged chinook salmon were exposed to the deflector net, and tracking showed that only two fish (15 percent) were deflected by the net. Past tracking studies have shown a natural tendency for some fish to cross to the Oregon shore even without the net. Three previous tracking studies indicated an average of twenty-eight percent crossed over (Monan and Liscom, 1973, 1974, 1975).

There was no indication that fish were delayed by or fought the net. Tracks showed fish approaching the net, then moving away, but repeated movement into the net was not seen. Milling below the net was not extensive nor was there a tendency for tagged fish to drop back toward the powerhouse. Generally, fish moved along the net, around the end, then swam upstream to intercept the Bradford Island shore (Figure 2). The swimming pattern for most fish was the same as observed in previous years--follow along the shore, go around the tip of the island, and swim back to the spillway.

Swimming depth of one chinook salmon carrying a pressure tag was recorded as it swam around the deflector net (Figure 3). Average swimming depth was 4.1 feet with a range from zero feet (surface) to about ten feet. Figure 4 shows the entire depth recording of the fish as it swam from the Bradford Island fishway exit to where it fell back over the spillway.

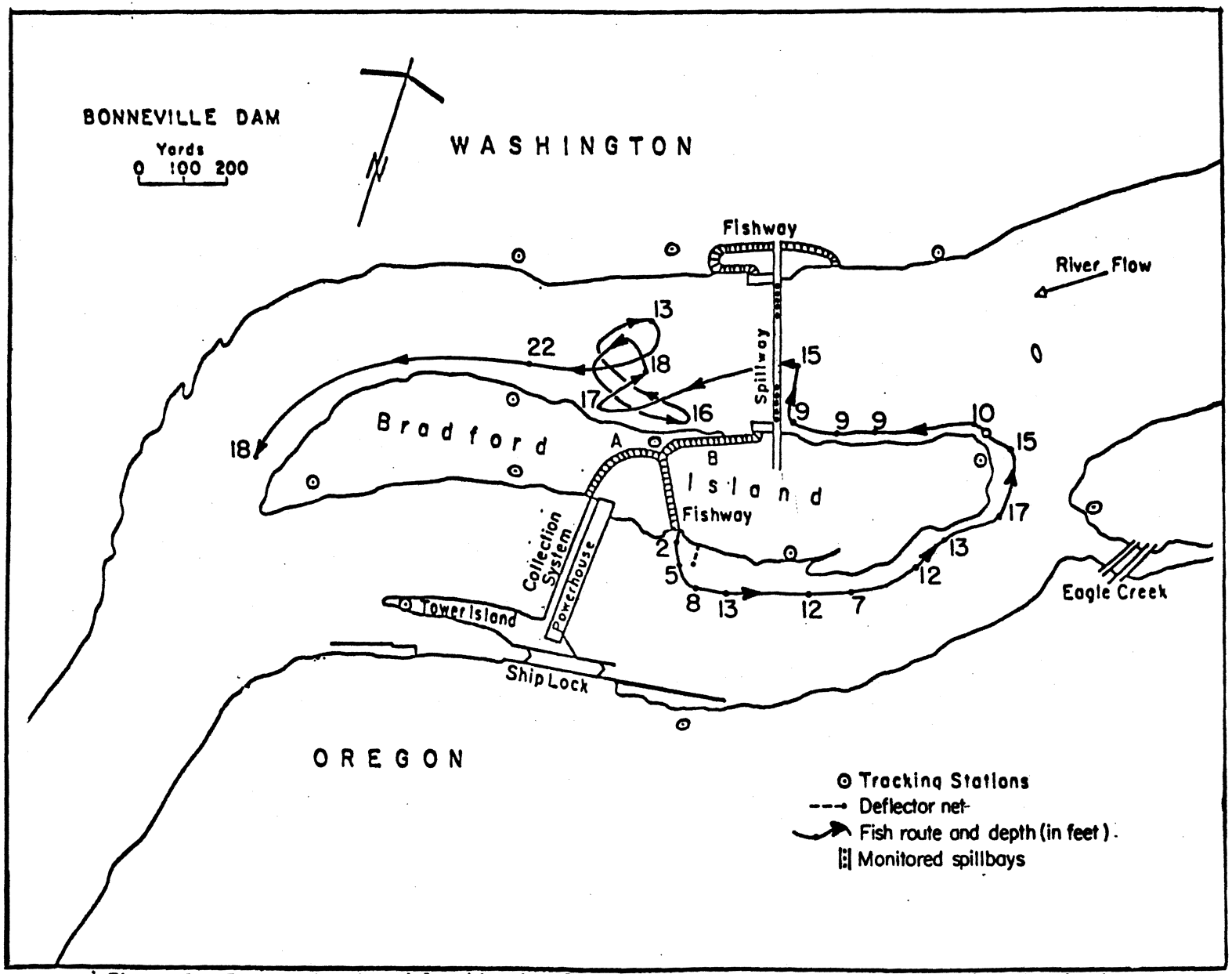

Figure 3.--Route taken by adult chinook salmon carrying a pressure-sensitive radio tag showing representative depths (in feet) at approximate locations. Monitored spillbays are indicated.

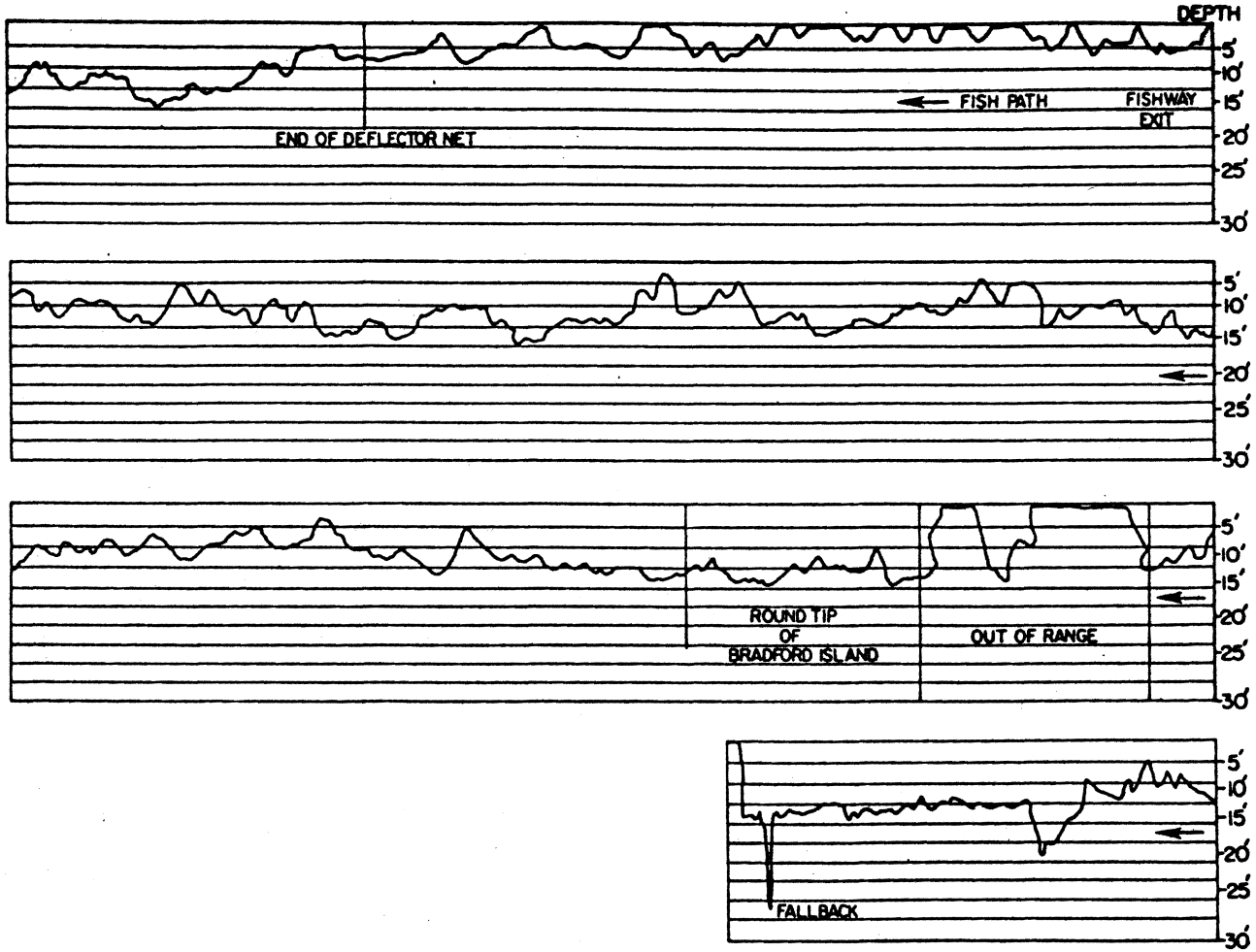

Figure 4.--Record of the swimming depth for a chinook salmon carrying a a pressure sensitive telemetry tag. The period from the time the fish exited the Bradford Island fishway until it fell back over the dam is shown. The figure reads from right to left.

BEHAVIOR OF FISH RELEASED IN POWERHOUSE CHANNEL

The behavior of tagged fish released at three different locations in the powerhouse channel was monitored (Figure 2). One release site was in the ODFW recovery pen just upstream from the deflector net. These releases were made to increase the number of potential fallbacks for the study of fallback location. A second release site was off the tip of the net in mid-channel to simulate a longer net and the third was in the fish lock at the south end of the powerhouse to test displacement of fish to the Oregon shore.

Recovery Pen Releases

Of the 14 fish released, 10 were tracked beyond the tip of the island during the study and 9 (90 percent) swam around the tip and back to the spill. Four of these fell back. A single fish crossed to the Oregon shore above the mouth of Eagle Creek and went upstream. Most tagged fish released in the pen milled about before moving on.

Mid-Channel Releases

Data from forebay releases in mid-channel above the powerhouse showed three out of four tagged fish swimming upstream without apparent orientation to Bradford Island. However, the other fish swam around the tip of the island to the spill but did not fall back.

Fish Lock Releases

Nine radio-tagged chinook salmon were released into the fish lock. The tag signal from one fish was lost before it exited the lock. The other eight fish were all tracked leaving the lock and went on upstream

without going near the spillway. In fact, only one fish swam close to the tip of Bradford Island. The others went upstream close to the Oregon shore or near mid-channel. None of these fish swam immediately in front of the powerhouse or made a move to go into the navigation lock when the upstream gates were open or to swim near the gates while they were closed.

FALLBACK THROUGH THE SPILLWAY

Each radio-tagged fish that swam into the spill area was closely observed for fallback so that, when such an event occurred, the specific spillbay could be determined. Recording monitors were placed in bays 2, 3, 4, 5, and 6 at the north end of the spillway; and in bays 13, 14, 15, 16, and 17 at the south end (Figure 3). We found that fallback occurred across the entire spillway (Table 2) with no definite pattern other than fish from Bradford Island fishway tended to fall back through spill gates at the south end of the spillway, and fish from the Washington fishway tended to fall back through spill gates at the north end of the spillway.

A higher rate of fallback (24%[1/]) was observed for fish exiting the Washington fishway than from those exiting the Bradford Island fishway (18%[1/]). Previous studies (Monan and Liscom, 1975) indicated fish from the Bradford Island fishway were more prone to fall back. Nothing was observed to explain the change. Total fallback was 19% for the total of 64[1/] fish tracked above the dam. More multiple fallbacks occurred than have been observed before; one fish fell back three times and another fell back twice.

1/ Includes fish which fell back more than once.

Table 2.--Distribution of fallback through the spillway at Bonneville Dam, April 23-May 27, 1976.

Fish Exited	SPILL GATES[1/]																Unk[2/]	Total
	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17		
Washington	1	1			1		1							1				5
Bradford Island					1			1		1		1			1	1	1	7
TOTAL	1	1			2		1	1		1		1		1	1	1	1	12

1/ Bay 8, 9, 11, fallback determined from active tracking.

2/ Specific spill bay unknown but at the south end.

The chinook salmon carrying the pressure-sensitive tag fell back, and an excellent record of the event was obtained (Figure 4). The track shows the fish approach the spill area, swim in close to the dam, then begin swimming across the spillway. The depth of travel increased to 27 feet (approximate depth of the bottom of the spill gate at that time) and then the chart indicated zero feet (surface). The time and location correlated well with fixed tracking station plots being taken at the time.

FISH BEHAVIOR BELOW BONNEVILLE DAM

A total of 28 chinook salmon were radio-tagged and released below Bonneville Dam. A high proportion of tagged fish (17 or 77%) ascended the Washington shore fishway, while only 53% of the regular run used that fishway during the same period. It is believed that the release site at Hamilton Slough may have been the reason for the higher north shore passage, but fish released at Dodson also used the Washington shore fishway to a greater degree--five out of seven fish. Even though many fish used the Washington fishway to cross the dam, a good number of fish spent part of their time in the powerhouse channel while below the dam. Of the 21 fish released at Hamilton Slough, ten (48%) spent some time below the powerhouse. Five fish entered the "A" Branch fishway and two stayed in and crossed over the dam.

Of the fish released at Dodson, five of the seven fish entered the powerhouse channel; one entered the "A" Branch fishway and continued up to cross the dam.

Limited tracking below the powerhouse indicated the fish behaved much the same as in previous years (Monan and Liscom, 1973, 1974, 1975). Because of insufficient data, it was impossible to correlate data from fish tracks obtained this year and data from the Corps' tunnel studies.

RECOVERIES OF TAGGED FISH

Recoveries of tagged fish were widespread with tags from 21 fish (31% of the total fish tagged) subsequently recovered (Table 3). The Snake River system accounted for 50% of the recoveries.

One interesting recovery was made in Catherine Creek, a tributary to the Grande Ronde River. The tag came from a fallback that had reascended the dam, reached the spawning grounds, spawned successfully, and died with the radio tag in its stomach and the flag tag still attached to its back.

GENERAL OBSERVATIONS

Of 67 chinook salmon tagged with radio tags, 19 had not been tracked upstream away from the dam by the end of the study: signals quit on three tags soon after release, nine fish were still below the dam--four out of the study area and five near the dam, four fish were still above the dam in the powerhouse channel, one fish remained in the "A" Branch fishway and two tags were shed[2/]. We learned later that

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2/ The shed tags were lost at the release site in the Bradford Island ladder. Modifications were made in our fish handling procedures at that site and no further instances of tags being shed were experienced.

Table 3.--Recoveries of radio-tagged chinook salmon released in the vicinity of Bonneville Dam, April 23-May 27, 1976.

Recovery Location	Number of tag recoveries
Lower Granite Dam	2
Little Goose Dam	7
Little White Salmon Hatchery	4
Carson National Fish Hatchery	1
Sunnyside Dam (Yakima River)	1
Klickitat River	2
South Prong of Catherine Creek	1
Columbia River (Bonneville Forebay)	2
Longview	1
TOTAL	21

eight of the nineteen fish subsequently swam on upstream. At the time of the report, all but three of the nine tagged fish that were below the dam at the end of the study were known to have crossed the dam.

Individual fish spent varying amounts of time below the dam before crossing and continuing their migration upstream; however, for the most part, average times appeared to be similar to previous years. Dodson released fish, once they reached the study area, spent an average of 56 hours below the dam before crossing. This compared with the 60 hours average time spent by spring chinook in 1974 (Monan and Liscom, 1975). Those fish released at Hamilton Slough averaged 95 hours in the study area below the dam. This longer time is due to the close proximity of the release site to the study area, and probably includes time for the fish to reorient after tagging and handling.

If we examine the average time spent by fish in traveling from the release site to exiting a fishway, the times compare closely to other years. Dodson released fish spent an average of 4 days, 4 hours, and 18 minutes; while Hamilton Slough releases averaged 4 days, 3 hours, and 36 minutes. By comparison, spring chinook salmon in 1974 (Monan and Liscom, 1975) spent an average of 4 days, 21 hours, and 36 minutes from time of release at Beacon Rock until they exited a fishway.

There were nine fallbacks from original crossings, and seven of these fish were known to have reascended the dam; one three times and another twice. Of the known reascents, four used the Bradford Island "B" Branch fishway, two the Washington fishway, and one crossed without being tracked. One of the remaining two fallbacks was last located

near Skamania Landing and the other approximately one-half mile below the spillway along the Washington shore.

It is of interest to note that four of the seven reascending fallback fish were subsequently recovered. The fish that fell back three times was recaptured in the adult separator at Lower Granite Dam and was reported in good condition. An Indian dip net at the Sunnyside Irrigation Diversion Dam caught the fish that fell back twice. Another fallback was subsequently reported as a dead spawned out female chinook found in Catherine Creek. The fourth fish was recovered at the Little White Salmon Hatchery during spawning operations.

CONCLUSIONS

1. The deflector net, as installed, is not effective in changing the swimming pattern of migrating adult chinook salmon so as to reduce their exposure to the spillway and possible fallback over the spillway.

2. The net did not cause fish to delay or drop back to the powerhouse.

3. Releasing fish on or deflecting fish to the Oregon shore shows good potential for influencing migrating fish to swim directly upstream in mid-channel or nearer the Oregon shore and thus decrease the danger of fallback.

4. Fallback takes place over the width of the spillway and is not localized to any particular section.

5. Tracking below the dam was insufficient to adequately describe the behavior patterns of spring chinook salmon in the powerhouse channel.

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