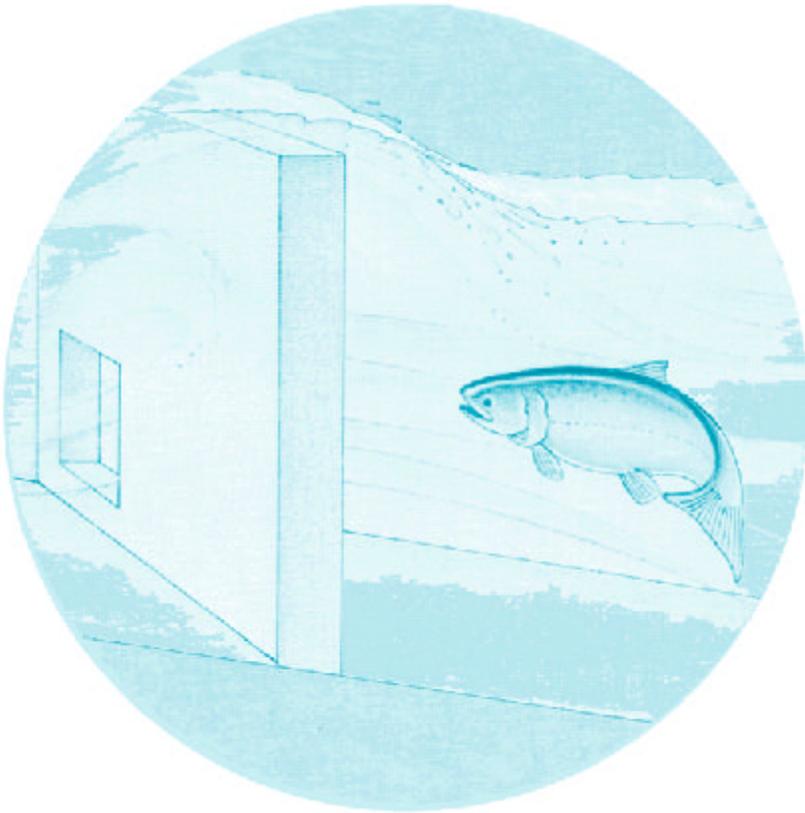


March 1990

**A FISHERIES EVALUATION OF THE RICHLAND AND  
TOPPENISH/SATUS CANAL FISH SCREENING FACILITIES,  
SPRING 1986**



DOE/BP-01830-2



This report was funded by the Bonneville Power Administration (BPA), U.S. Department of Energy, as part of BPA's program to protect, mitigate, and enhance fish and wildlife affected by the development and operation of hydroelectric facilities on the Columbia River and its tributaries. The views of this report are the author's and do not necessarily represent the views of BPA.

This document should be cited as follows:

*Neitzel, Duane A., C. Scott Abernethy, E. William Lusty, The Bonneville Power Administration under a Related Services Agreement with the U.S. Department of Energy Contract DE-AC06-76RL0 1830, Pacific Northwest Laboratory, 76 electronic pages (BPA Report DOE/BP-01830-2)*

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**A FISHERIES EVALUATION OF THE  
RICHLAND AND TOPPENISH/SATUS  
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**Duane A. Neitzel  
C. Scott Abernethy  
E. William Lusty**

**March 1987**

**Prepared for  
The Bonneville Power Administration  
under a Related Services Agreement  
with the U.S. Department of Energy  
Contract DE-AC06-76RLO 1830**

**Pacific Northwest Laboratory  
Richland, Washington 99352**

## PREFACE

The Bonneville Power Administration (BPA) is funding fish passage and protection facilities at 20 irrigation diversions in the Yakima River Basin, Washington. Construction implements section 904(d) of the Northwest Power Planning Council's Columbia River Basin Fish and Wildlife Program. The program addresses natural propagation of salmonids to help mitigate the impact of irrigation in the Yakima River Basin and provides offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin.

The fish screening facilities at the Richland and Satus canals (Richland Screens and Toppenish/Satus Screens) are two of the protective facilities funded by BPA. The Richland Screens divert fish entering the Richland Canal back to the Yakima River. The Toppenish/Satus Screens divert fish entering the Satus Canal back to Toppenish Creek. This report is a fisheries evaluation of the effectiveness of the Richland and Toppenish/Satus Screens. Fish were released upstream of or within the screen facilities and captured in the diversion that transfers them back to the river. Results indicate that both screens safely divert fish from the canals back to the river or creek.

The study focused on salmonids. Test fish were steelhead, Salmo gairdneri, smolts; spring chinook salmon, Oncorhynchus tshawytscha, smolts; and fall chinook salmon fingerlings. Testing was limited to one set of conditions at each site because of construction delays. Near minimum flow capacity was tested at the Richland Screens and near full flow capacity was tested at the Toppenish/Satus Screens.

## ACKNOWLEDGMENTS

The involvement and cooperation of many people contributed to the success of this project. Tom Clune was the Bonneville Power Administration Project Manager. Bob Tuck and Dave Fast of the Yakima Indian Nation, Gary Malm of the U.S. Fish and Wildlife Service (USFWS), and John Easterbrooks of the Washington State Department of Fisheries contributed to the review of the 1985 annual report and refinement of the study plan. John Easterbrooks, Dave Fast and Bob Pearce of the National Marine Fisheries Services reviewed this report and provided comments. Ed LaMott of the USFWS Spring Creek National Hatchery, Bill Walsdorf and Ralph Malson of the USFWS Leavenworth National Hatchery, and Joe Steele of the Washington State Department of Game Naches Trout Hatchery helped rear and procure the test fish.

We very much appreciate the counsel and guidance provided by Duane H. Fickeisen in assuring that this effort met the needs of Bonneville Power Administration. The manuscript was reviewed by Kathy A. Borgeson, C. Dale Becker, and Robert H. Gray. C. Dale Becker, Dennis D. Dauble, R. William Hanf, Jr., Donald C. Klopfer, John P. McDonald, Rodney Pharness, Theodore M. Poston, and Alan J. Scott assisted with the field tests. Leslie A. Prohammer and Mary Ann Simmons helped design the mark/capture tests and did the statistical analysis of the data. Anita K. Baldwin typed the manuscript.

## ABSTRACT

Fish diversion facilities at the Richland and Satus canals are part of a joint project funded by the Bonneville Power Administration (BPA) and the Bureau of Reclamation to construct fish passage and protection facilities at existing irrigation diversions in the Yakima River Basin. The facilities are part of the Northwest Power Planning Council's (NPPC) Columbia River Basin Fish and Wildlife Program Construction implements Section 904 (d) of the NPPC plan to address natural propagation of salmon.

This is our second annual report describing the fisheries evaluation phase of diversion screen effectiveness. It summarizes the results of our work at the Richland and Toppenish/Satus Fish Screening Facilities (Richland Screens and Toppenish/Satus Screens) during 1986. More than 10,000 steelhead, Salmo gairdneri, and chinook salmon, Oncorhynchus tshawytscha, were released at the screen diversions. At the Richland Screens, 61% of the released steelhead were recovered and 1.1% were descaled; 93% of the spring chinook salmon were recovered and less than 1% were descaled. At the Toppenish/Satus Screens, only steelhead were evaluated for descaling; 88.9% were recovered and 23.94 were descaled. Only steelhead were evaluated because the Yakima River fisheries managers did not expect any other smolts to occur in Toppenish Creek. Because of the acclimation conditions and the amount of time the fish had to be held before testing, some of the test population were descaled during holding and transportation. The 23.9% descaling for the test fish was compared to 26.4% for the controls.

The time required for fish to bypass the screens and reach the river varied with species. At Richland, about half the spring chinook salmon smolts we caught, were caught in 1 hr and practically all in less than 6 hr. Steelhead smolts did not readily exit from the Richland Screens; only half the steelhead we caught, were caught within 24 hr. In contrast, half the fall chinook salmon fingerlings we caught occurred within 8 hr. At the Toppenish/Satus Screens, nearly 100% of the spring chinook salmon smolts were caught after less than 1 hr. About half our catch occurred within

**12 hr for steelhead smolts and less than 0.5 hr for fall chinook salmon fingerlings.**

**The Richland Canal headgates are located at Yakima River km 29 [river mile (RM) 18]. The Richland Screens divert fish entering the Richland Canal back to the Yakima River. The headgates of the Satus Canal are located at river km 6 (RM 3.5) on Toppenish Creek. The Toppenish/Satus Screens divert fish entering the Satus Canal back to Toppenish Creek. The methods used for this evaluation and the 1985 results were reviewed by the BPA, Washington State Department of Fisheries, U.S. Fish and Wildlife Service, National Marine Fisheries Service, NPPC, and the Yakima Indian Nation.**

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## INTRODUCTION

The Yakima River Basin has historically supported significant salmonid runs. During the late 1800s, between 500,000 and 600,000 adult salmon, Oncorhynchus spp., and steelhead, Salmo gairdneri, returned to the Yakima River and its tributaries (Bureau of Reclamation 1984). Salmon runs included spring, summer, and fall chinook salmon, O. tshawytscha; coho salmon, O. kisutch; and sockeye salmon, O. nerka.

Some runs are now extinct or near extinction. Spawning escapement averaged about 2000 salmonids in the early 1980s (Bureau of Reclamation 1984). There are currently no sockeye salmon in the Yakima River Basin and only 37 coho salmon passed the Prosser Diversion Dam in 1983 (Hollowed 1984). Improvements in salmon management and enhancement efforts have increased spawning escapement to 8000 adults in 1986 (Fast et al. 1986).

The decline in salmonid runs to the Yakima River basin is the result of many factors. Spawning and rearing habitat have been reduced as a result of the construction and operation of diversion dams. Stream flows have been inadequate for fish because of irrigation withdrawals. Ineffective fish passage facilities for adults and juveniles at diversion dams have resulted in mortality during migration. Additionally, many Yakima River fish are killed while passing hydroelectric dams on the mainstem Columbia River.

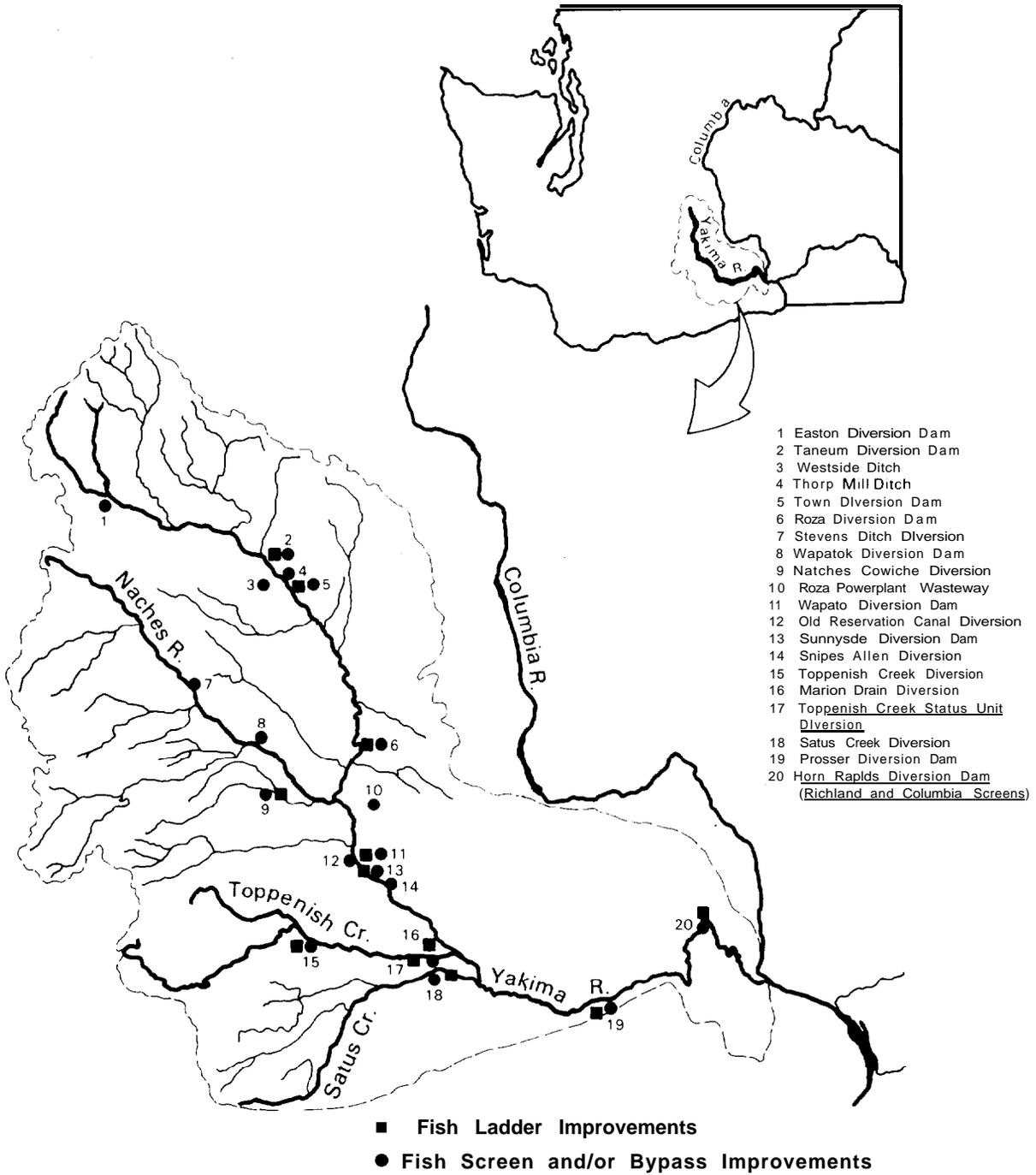
The Pacific Northwest Electric Power Planning and Conservation Act (Public Law 96-501) was passed and a regional Conservation and Electric Power Plan was prepared by the Northwest Power Planning Council (NPPC 1984). The NPPC administers the plan, and is charged with developing a program to protect and enhance fish and wildlife populations and to mitigate the effects of development, operation, and management of hydroelectric facilities.

The Yakima River Basin was selected as one site for enhancement of salmon and steelhead runs in the Pacific Northwest. The Bonneville Power Administration (BPA) and the Bureau of Reclamation (BR) are funding the

**construction of fish passage and protection facilities at 20 irrigation diversions in the Yakima River Basin (Figure 1). The BPA is also providing funds to the Yakima Indian Nation to increase production of spring chinook salmon in the Yakima River Basin.**

**The BPA and BR are constructing screen facilities in the Yakima Basin to protect outmigrating salmonids. The Richland and Toppenish/Satus Canal Fish Screening Facilities (Richland and Toppenish/Satus Screens) are two of the protection facilities being constructed. Construction of the screens was completed in the spring of 1986. The BPA asked the Pacific Northwest Laboratory (PNL) to evaluate the effectiveness of these diversion facilities in returning fish that had entered the Richland Canal and the Satus Canal back to the river.**

**This report describes each screening facility, methods used to evaluate the effectiveness of the screens, and study results. Results of the studies at the Richland and Toppenish/Satus Screens are compared with those from the Sunnyside Screens (Neitzel et al. 1985).**



**FIGURE 1. Yakima River Basin, Including Locations of the Richland and Toppenish/Satus Fish Screening Facilities and Other Fish Protection and Passage Facilities**

## DESCRIPTION OF STUDY AREAS

The study areas included the canal from the trash rack to the screening facility, the fish bypass system within the screening facility, the terminus of the fish bypass system and the canal downstream of the screening facility. Our description of the study areas includes the range of conditions in which the sites are operated. Specific conditions tested during the evaluations are reported in the results and discussion of the results.

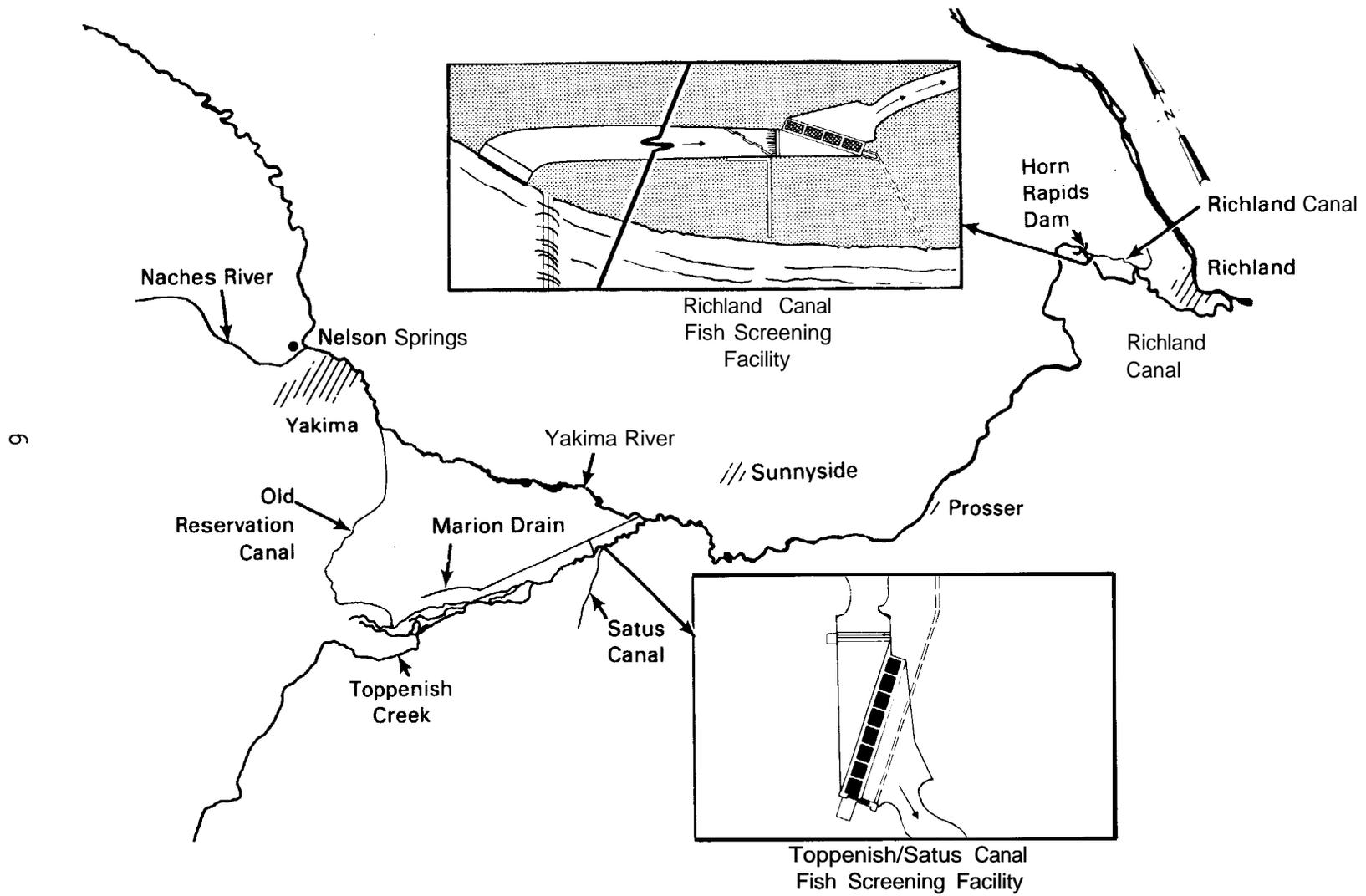
### RICHLAND CANAL FISH SCREENING FACILITY

The headgates of the Richland Canal are located at the Horn Rapids Diversion Dam on the Yakima River (Figure 7) at river km 29 (RM 18). The carrying capacity of the Richland Canal is about  $2.5 \text{ m}^3/\text{sec}$  [90 cubic feet per second (cfs)]. Canal flow is maintained at  $0.8$  to  $1.4 \text{ m}^3/\text{sec}$  (30 to 50 cfs) during the irrigation season (April to October) and at about  $0.6 \text{ m}^3/\text{sec}$  (20 cfs) during the rest of the year.

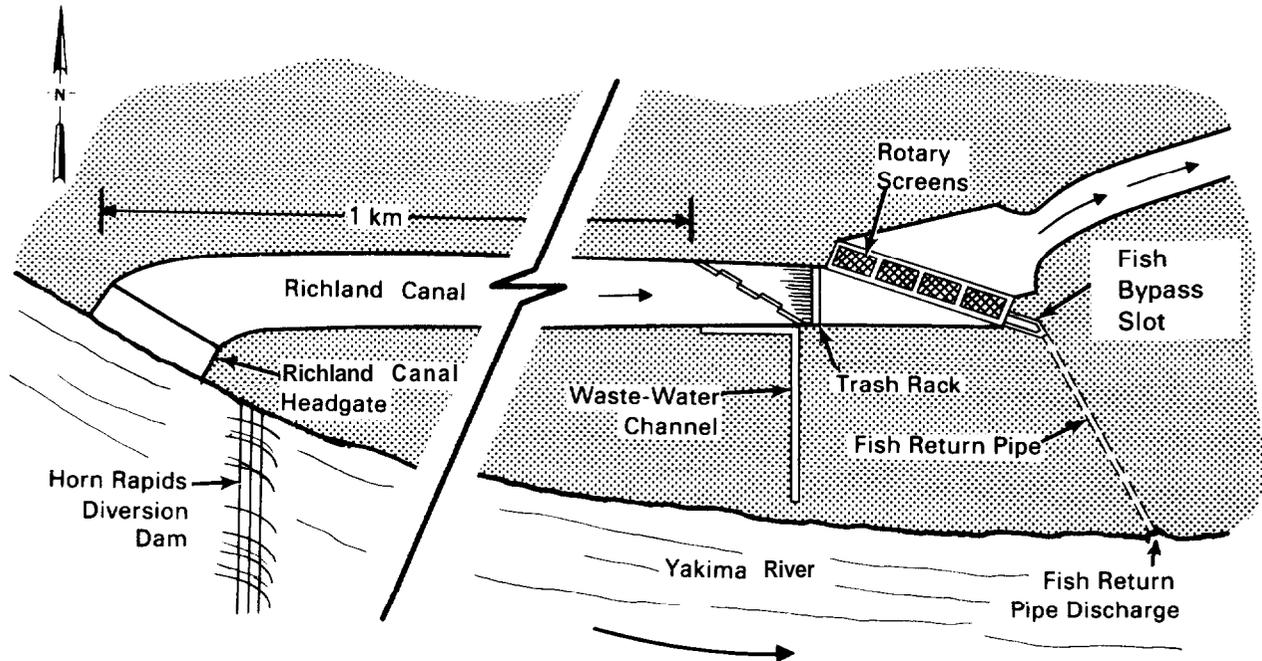
Canal flow is regulated at the canal headgates about 1 km upstream of the Richland Screens. The screening facility diverts fish that have entered the canal and directs them back to the Yakima River. A trash rack placed in the canal upstream of the screening facility (Figures 2 and 3) "filters" out large debris that could damage the screens or interfere with flow control through the screening facility.

A waste-water channel is immediately upstream of the trash rack. The channel runs perpendicular to the canal and discharges into the Yakima River. Excess water spills into the waste-water channel when the canal flow exceeds the combined flows through the screens and fish return pipe. Waste-water flow can be regulated to help keep debris from accumulating on the trash rack and helps prevent flooding of the screening facility during the winter when ice forms at the screens.

The screening facility houses four rotary drum screens with axes parallel to the length of the structure (Figure 3). Each screen is about 3 m (10 ft) wide and 1.8 m (6 ft) in diameter. The screen mesh openings are 3.18 mm (1/8 in.). Water depth at the screens varies with canal flow.



**FIGURE 2. Yakima River Basin Showing Location of Richland and Toppenish/Satus Canal Fish Screening Facilities**



**FIGURE 3. Flow Control Structure and the Bypass System in the Richland Canal Fish Screening Facility**

However, average depth across the face of the screens is about 1.7 m (6 ft). Water depth in the screen forebay is nearly as great as screen diameter because the screens are installed on a curb about 0.5 m (1.5 ft) above the forebay floor.

The screening facility also has a fish bypass slot at the downstream end (Figure 3). Water and fish that are diverted past the front of the screens pass through the fish bypass slot and out the fish return pipe. About 0.6 m<sup>3</sup>/s (30 cfs) of water are diverted into the fish return pipe.

The rotary screens are installed at a 26-degree angle to canal flow. This orientation is designed to provide a sweeping velocity to approach velocity ratio equal to or exceeding 2:1 (Easterbrooks 1984). The maximum allowable approach velocity is 0.15 m/sec (0.5 fps). Screen orientation and flow velocity differential help direct fish toward the fish return pipe and back to the river.

**TOPPENISH/SATUS CANAL FISH SCREENING FACILITY**

The Toppenish/Satus Unit Diversion is located at river km 6 (RM 3.5) on Toppenish Creek, just downstream of the confluence of Toppenish Creek

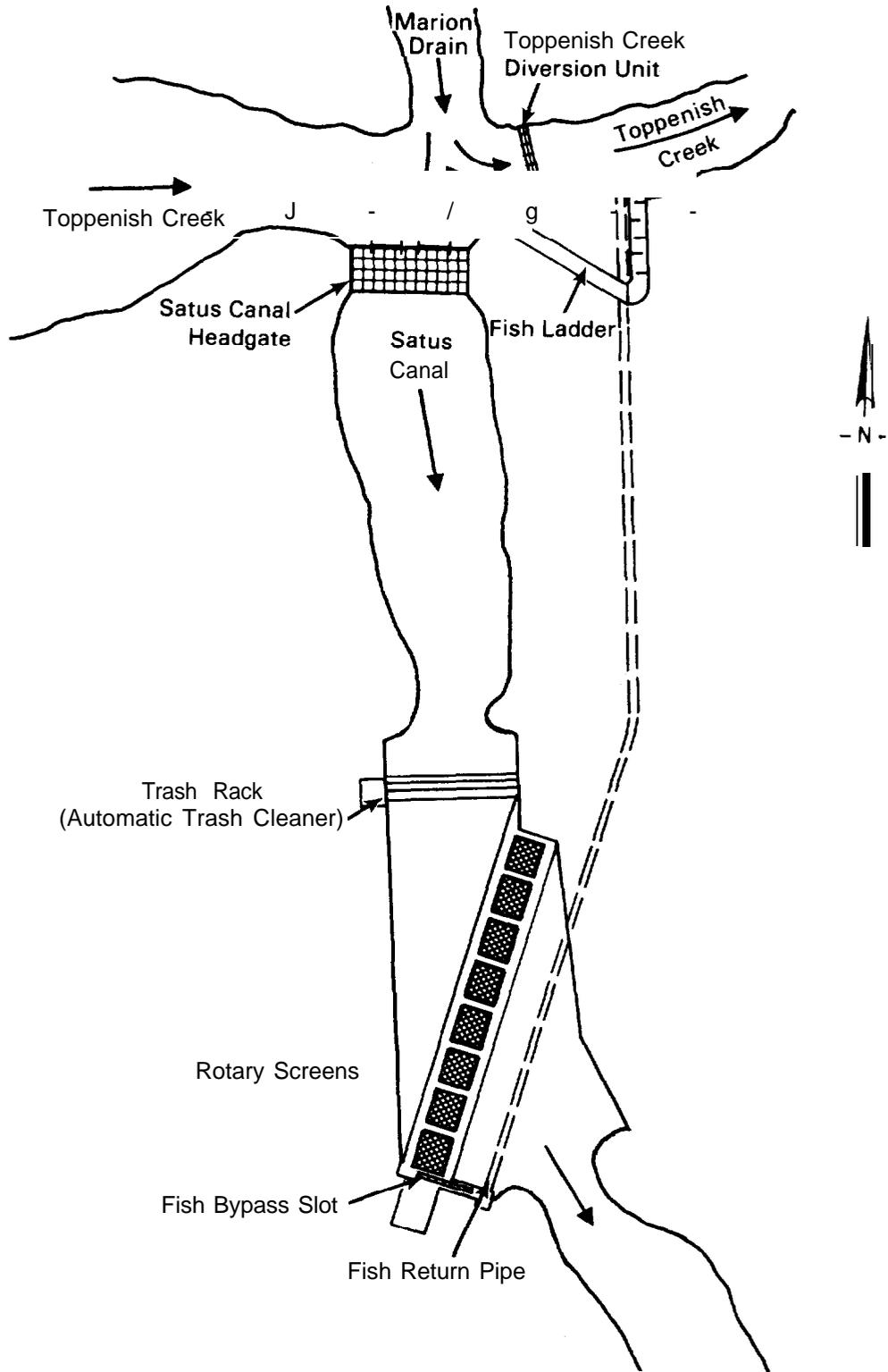
and Marion Drain (Figure 4). The diversion directs water from Marion Drain and Toppenish Creek to the Satus Canal. Canal operation begins in late March or early April and continues through the irrigation season, usually to mid-October. Canal capacity is about  $18 \text{ m}^3/\text{sec}$  (650 cfs).

The Toppenish/Satus Screens are located about 200 m (650 ft) downstream of the headgates of Satus Canal. The facility (Figures 2 and 4) diverts fish entering the canal and directs them back to Toppenish Creek.

A trash rack, installed immediately upstream of the screening facility (Figures 2 and 4), "filters" out debris entering the canal such as large logs or tree branches that may damage the screens or interfere with flow through the facility. The rack is equipped with an automated trash removal system designed to clean the upper 2 m (6 ft) of the trash racks. This system is especially important at Toppenish/Satus because of the large quantity of aquatic macrophytes that enter the canal from Marion Drain and Toppenish Creek during the summer.

The screening facility houses eight rotary drum screens (Figure 4) with axes parallel to the length of the structure. Each screen is about 5.5 m (18 ft) wide and 3.7 m (12 ft) diameter. The screen mesh openings are 3.18 mm (1/8 in). Water depth at the screens varies with canal flow. The average depth across the face of the screens is about 2.4 m (8 ft). The rotary drum screens are installed in the canal at a X-degree angle to the canal flow. This orientation is designed to provide a sweeping velocity to approach velocity ratio of 2:1. The maximum allowable approach velocity is  $0.15 \text{ m}/\text{sec}$  (0.5 ft) (Easterbrooks 1984). This orientation guides fish toward the fish return pipe and back to the river.

The fish bypass slot (Figure 4) is located at the downstream end of the screening facility. About  $0.6 \text{ m}^3/\text{sec}$  (20 cfs) of water pass through the fish bypass slot and out the fish return pipe. A fish sampling screen has been installed in the fish bypass slot at the Toppenish/Satus Screens, although it cannot be used because it does not include any means for cleaning.



**FIGURE 4. Flow Control Structure and Bypass System in the Toppenish/Satus Canal Fish Screening Facility**

## WORK PLAN

The work plan for BPA-funded screen evaluations includes four phases. Phases I through III involve release/capture studies to determine changes in fish condition after the fish have moved through the screening facility, and to estimate the time required to divert fish from the screening facility to the river. Phase IV involves a monitoring study to determine the presence of predators near the screening facilities, to determine if fish pass through the screens into the canals, and to estimate arrival times of outmigrating salmonid populations at the screening facilities.

The work plan addresses a generic facility (i.e., a facility with headgates, a trash rack, screens, a fish return-water pumpback system a separation chamber, and a fish return pipe). Although some components may be different or absent at a given facility, the four-phase concept is flexible and can be applied to all the facilities in the Yakima Basin. It is not always necessary to implement all phases at all sites. The most important data necessary to evaluate a specific site are determined by the BPA and the fisheries management agencies in the Yakima Basin. Identification of needs determines which phases of the work plan are implemented at each site.

### PHASE I

Phase I tests are conducted to determine the condition of juvenile salmonids after they pass through components of the diversion facility. Phase I tests are accomplished by releasing branded fish at the entry to the fish bypass system. Released fish are collected near the terminus of the fish return pipe. The percent of fish that are descaled, the number of fish killed (both immediately and after 4 days), and the rate and extent of other injuries are recorded.

Several collection systems may be used, including a net at the terminus of the primary fish return pipe or a modified inclined plane placed near the terminus of the diversion system. Collection systems are chosen after a site-specific evaluation of each screening facility. Collection systems are tested to ensure their effectiveness and to verify

that fish are not injured or stressed by the equipment. These tests are conducted by releasing fish in and near the collection system. Efficiency and handling tests are conducted throughout the evaluation.

Collection of released fish begins immediately after their release. Recovery duration varies depending on the site and the test objective. If the primary objective is to estimate the proportion of released fish that are killed or descaled, we continue collecting until an acceptable 95% confidence estimate is obtained. When estimating travel time through a component of the screening facility, a similar criterion is used to determine sample duration. Whenever possible, samples are collected continuously during the first 24 to 48 hr after release. If, after 48 hr, the total catch is insufficient to obtain an accurate estimate, the collection period is extended up to 96 hr.

Phase I will help develop a hypothesis about the fate of noncollected fish from each release. The hypothesis will be based on catch efficiency data that we collect during the control tests, duration of the sample effort, and data from replicate tests.

Expected results from Phase I tests include determination of the percent of fish that are killed or descaled during passage through the fish bypass system, the change in condition of fish that survive passage through the bypass, suspected fate of noncollected fish, effects of sampling equipment, and handling effects from marking, release, and capture techniques.

## PHASE II

Phase II tests evaluate the change in condition of fish by comparing the condition of fish released upstream of the trash rack to the condition of fish that have passed through the bypass system (Phase IIa) or through individual fish passage components of the screening facility (Phase IIb). Whether Phase IIa or IIb tests are conducted depends on whether fish are killed or injured during Phase I. If no mortalities or injuries occur

after passage through the bypass system during Phase I, Phase IIa follows Phase I. If there are mortalities or injuries during Phase I, Phase IIb follows Phase I.

#### Phase IIa

If no effect is observed in Phase I, the condition of fish that pass through the screening facility (from upstream of the trash rack through the bypass) is determined. Fish are released at the trash rack and collected at the terminus of the fish return pipe. The percentage of fish descaled, number of fish killed (immediately and after 4 days), and rate and extent of injuries are noted. Releases are made in and near the collection system to determine collection efficiency and handling effects.

Phase IIa studies evaluate the condition of fish that have been diverted into a canal and returned to the river through the primary fish return pipe. Additionally, the transit time of fish from the trash racks to the fish return pipe discharge is determined.

Expected results from Phase IIa tests include determination of the change in condition of fish that travel through the entire fish diversion and are returned to the river, suspected fate of noncollected fish, transit time for fish traveling through the diversion facility, and collection efficiency and handling effects.

#### Phase IIb

If a detrimental effect is observed in Phase I tests, the condition of fish that pass through or by specific components of the fish bypass system (i.e., the intermediate bypass pipe, secondary separation chamber, traveling screens, and the fish return pipe) is determined. The number of fish released is determined by the same criteria used in Phase I. Fish are released into specific components of the bypass system and collected at the terminus of the component or fish return pipe, depending on the data needed and the probability of successfully sampling within the component.

The study evaluates the condition of fish after they have passed through the bypass and secondary separation chambers and at the fish return

pipe discharge, the transit time of fish through specific components of the screening facility, and the transit time of fish through the entire facility.

Expected results include the determination of bypass components that adversely affect the condition of fish passing through the screening facility, suspected fate of noncollected fish, and possible changes to the screening facility that may reduce identified effects.

### PHASE III

Phase III tests evaluate screen operating conditions and canal flow changes that may affect the screen efficiency. Test design, test species, and most of the study objectives are the same as in Phases I and IIa. The study evaluates operating conditions that maximize screen efficiency, the effectiveness of the screens over a range of flows, and factors that affect fish transit time through the facilities.

Expected results include determination of any change in the facility effectiveness over a range of canal flows and examination of operating conditions that may change transit time of fish through the facility.

### PHASE IV

Phase IV has two segments (Phase IVa and IVb); Phase IVa is designed to monitor the presence and temporal distribution of predators and other fish populations near the screens, and Phase IVb is designed to examine rates of fish impingement on the screens, and to determine if fish can pass through, around, under, or over the screens and be lost in the irrigation canal.

#### Phase IVa

Phase IVa includes use of an inclined plane, fyke nets, beach seines, or electroshocker to monitor the presence and temporal distribution of natural fish populations near the screening facility. Proposed locations for monitoring are downstream of the headgates, in the fish bypass slot of the screening facility, and in the river downstream of the fish return pipe discharge. Sampling equipment and techniques will be chosen to prevent

interference with our evaluation efforts in other work phases. In most cases, collection can be conducted concurrently with other phases. However, collection that might affect other evaluations, such as sampling between a release point and collection point, will have to be conducted independently. Collection efforts will be determined by consulting with the RPA, Yakima Basin fisheries agencies, and by the priority placed on Phase IV work. Phase IVa monitoring of the occurrence of native outmigrant salmonid and predatory fish populations will be conducted during all release/capture tests in Phases I, II, and III.

The study evaluates the presence of predatory fish populations and native and hatchery-released outmigrant salmonids at each screening facility.

Expected results include a qualitative determination of fish predator populations near the facility and expected arrival time of native and hatchery-released outmigrant salmonid populations at the screening facility.

#### Phase IVb

Phase IVb monitoring evaluates the rotary and vertical traveling screens. Visual observations will be made to determine if fish are impinged on or can pass over the screens. In addition, some Phase IVb objectives may require the release of fish. For example, screen integrity may be determined by releasing marked fish upstream of the screens and monitoring for their presence in the irrigation canal downstream of the screens. Marked fish would also be released behind the screens to evaluate gear and sampling efficiency.

The study evaluates the rate of impingement on the rotary and traveling screens, and the rate of passage through the screens.

Expected results include determination of the rate of fish impingement on rotary screens, rate of fish impingement on traveling screens, effectiveness of the screens in preventing fish from entering the canal downstream of the screens, and the operating conditions that might result in fish impingement.

## METHODS

Fish were released upstream of the screening facility and captured at the terminus of the fish bypass slot or the primary fish return pipe. Some test fish were held for post-test observation. Nontest fish were also collected during release/capture tests.

### TEST FISH

The species of test fish used at the Richland and Toppenish/Satus Screens were recommended by fisheries biologists from the Washington State Department of Fisheries, United States Fish and Wildlife Service (USFWS), and the Yakima Indian Nation. Salmonid smolts and fry of both hatchery and natural origin migrate down the Yakima River and its tributaries each year during the spring and early summer.

Young steelhead, spring and fall chinook salmon, and coho salmon migrate from upriver rearing habitats and could be impacted by the Richland Screens on the lower Yakima River. Spring chinook salmon and steelhead smolts were selected to evaluate descaling so that results could be compared to previous evaluations at the Sunnyside Screens. In addition, fall chinook salmon fingerlings (<60 mm) were selected to evaluate impingement frequency and the effectiveness of rotary screens at preventing small salmonids from entering the irrigation canal.

Steelhead and fall chinook salmon use the Toppenish Creek drainage. Steelhead spawn in the headwaters of Toppenish Creek and fall chinook salmon spawn in Marion Drain, which enters Toppenish Creek near the headgates of Satus Canal. Thus, steelhead smolts and fall chinook salmon fingerlings (<60 mm) were selected to evaluate the Toppenish/Satus Screens.

### Steelhead

Yearling steelhead were obtained from the Washington State Department of Game (WDG) and came from stocks designated for release in the upper Yakima Basin. The steelhead were hatched, reared, and adipose-fin-clipped at the WDG Naches Trout Hatchery in Naches, Washington. They weighed about 28 fish/kg when transferred to PNL on March 18 and 19, 1986. The fish were

held outdoors at 12°C in a mixture of Columbia River and well water until they weighed 18 to 22 fish/kg (40 to 50/lb) and were 15- to 23-cm (6 to 9 in.) fork length (FL). Test fish were acclimated to test-site temperature at least 1 week prior to release.

#### Spring Chinook Salmon

Yearling spring chinook salmon were obtained from the USFWS Leavenworth National Hatchery in Leavenworth, Washington. The fish weighed about 46 fish/kg (100/lb) when transferred to PNL on March 26, 1986. They were reared outdoors in ambient Columbia River water (7°C to 13°C) until smolting occurred. Test groups were acclimated to test-site temperature at least 1 week prior to testing. The fish weighed 25 to 33 fish/kg (55 to 75/lb) and were 12- to 16-cm (5 to 6 in) FL when released.

#### Fall Chinook Salmon

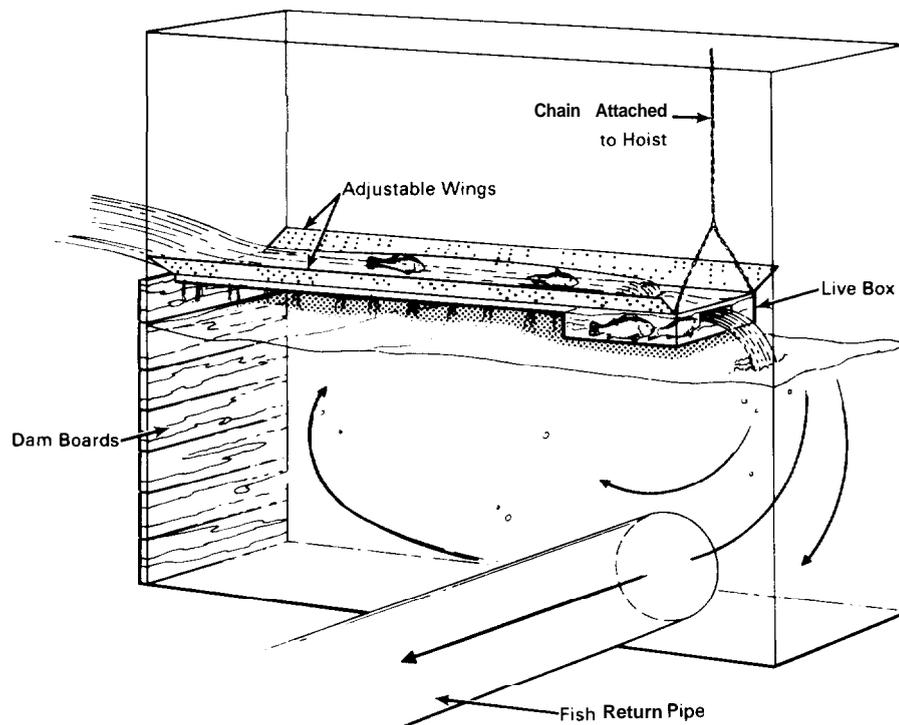
Fall chinook salmon were obtained from the USFWS Spring Creek Hatchery in Underwood, Washington. The fish were 1500 fish/kg (3300/lb) when transferred to PNL on March 6, 1986. They were held indoors in chilled well water (8°C) and acclimated to test-site temperature at least 1 week prior to testing. Fall chinook salmon fingerlings weighed 385 fish/kg (850/lb) and were 55- to 70-mm FL (20 to 30 in.) when released.

#### SAMPLING EQUIPMENT

Released fish had to be captured within the screening facility and at the terminus of the primary fish return pipe. Fish were collected with an inclined plane and fyke net that were custom fit to the structures at the Richland and Toppenish/Satus Screens. Temporary fish-holding facilities were installed at each test site.

#### Inclined Plane

Fish were captured by placing an inclined plane in the fish bypass slot between the most downstream rotary screen and the fish return pipe (Figure 5). The inclined plane used at the Richland Canal was 2.5 m (8 ft) long and 0.76 m (2 ft) wide. Adjustable wings, 2.5 m (8 ft) long and 0.15 m (0.5 ft) wide, were fastened to the sides of the inclined plane to



**FIGURE 5. Inclined Plane System Used at Richland and Toppenish/Satus Canal Fish Screening Facilities, Spring 1986**

compensate for irregularities in the walls of the fish bypass slot. A live-box [0.37 m (1 ft) long by 0.75 m (2 ft) wide, 45-l (12 gal) volume] was fastened at the end of the inclined plane. The inclined plane had an aluminum framework covered with a perforated aluminum sheet [0.32-cm (1/8 in.) diameter holes, staggered centers, 40% open]. Water flow was directed over the plane surface by placing dam boards in the upstream end of the fish bypass slot. The height of the dam boards relative to water depth determined the water volume through the fish bypass slot.

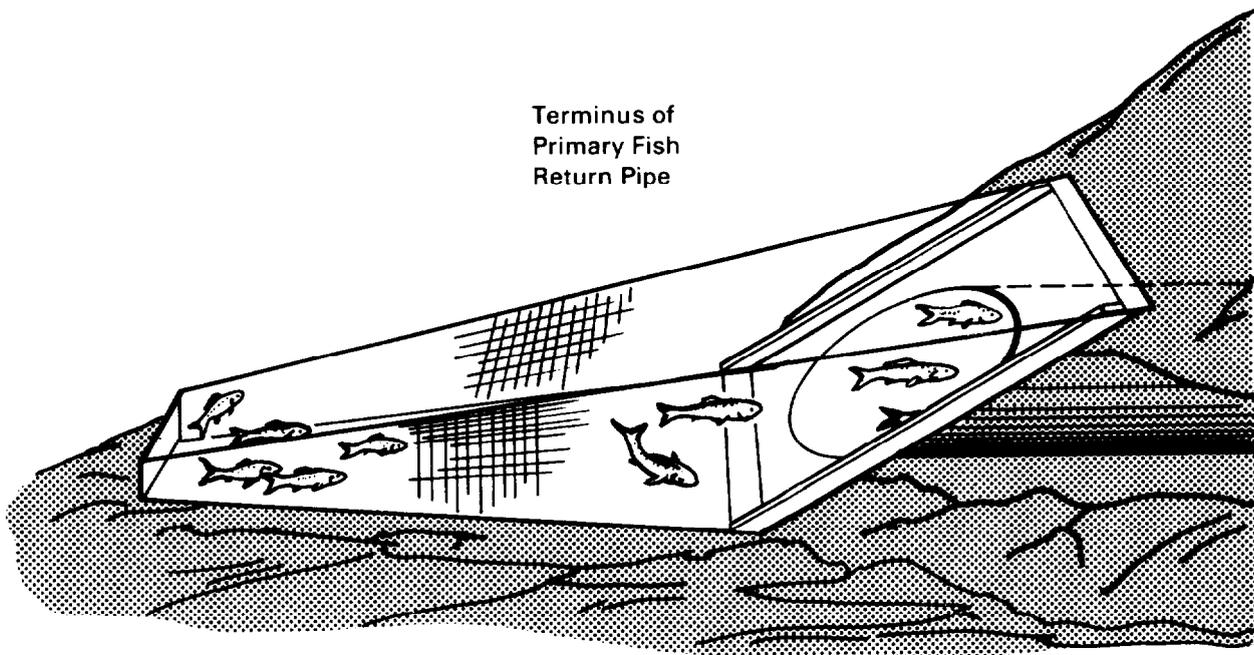
The inclined plane at Toppenish/Satus was similar to that used at Richland, differing only in plane dimension and live-box size. The plane was 4.25 m (15 ft) long and 0.46 m (2 ft) wide. The live-box was 0.61 m (2 ft) long and 0.46 m (2 ft) wide, with a 57-l (15 gal) volume. Flow rate was controlled by placing dam boards in the upstream end of the fish bypass slot.

The inclined planes were lowered into position with an electric winch or hand hoist. Planes were brushed periodically to prevent the perforated sheet from becoming clogged with vegetation and debris.

#### Fyke Nets

At Richland, fish were captured at the terminus of the fish return pipe using a 6.0-m (20 ft) long fyke net. The fyke net was set in the river with the mouth of the net as close to the terminus of the fish return pipe as possible (Figure 6). The net mouth was 1 m x 3. m (3 ft x 3 ft), tapering to a 25 cm x 25 cm (50 in. x 50 in.) cod end. A zipper was installed at the cod end for fish removal. Two fyke nets with 4 m x 1 m (12 ft x 3 ft) wings (Figure 6) were placed in the irrigation canals behind the screen structure during Phase IV tests.

Fyke nets and frames were built to sample the end of the fish return pipe at the Toppenish/Satus Screens, and in the waste-water channel at Richland, but were not used during the 1986 tests.



**FIGURE 6.** Fyke Net Used at Richland Canal Fish Screening Facilities, Spring 1986

### Electrofishing Gear

An electroshocker (Smith-Root Model Type VI Electrofisher) was used at the terminus of the fish return pipe at Richland. The probes were placed in the water, one on either side of the pipe. Fish were shocked as they exited the pipe. Electroshocked fish were dipped from the river. At Richland and Toppenish/Satus, a Smith-Root Model Type VII backpack electrofisher was used in the irrigation canal behind the rotary screens. When sampling behind the screens, the backpack electrofisher was used from a 4 m aluminum boat. Electrofishing served as an alternative to fyke net collection at the end of the fish return pipe and supplemented fyke net catch data in tests where fish were released in the canal behind the rotary screens.

### Holding Facilities

After fish were netted from the live-box they were placed in holding facilities at the site. The holding facilities were set up to hold fish for evaluation of injury and descaling, and to retain some fish for 96 hr after capture. Four metal troughs [1.5 m (5 ft) x 0.3 m (1 ft) x 0.2 m (1 ft) deep, 90-l (25 gal) volume] and one fiberglass circular tank (1.2 m (4 ft) diameter x 0.75 m (2 ft) deep, 725-l (190 gal) volume) were installed at Richland, and 4 fiberglass troughs [3 m (10 ft) x 0.56 m (2 ft) x 0.75 m (1 ft) deep, 540-l (150 gal) volume] were installed at Toppenish/Satus. All tanks were supplied with canal water that was pumped from behind the screens.

### DESCALING EVALUATION

The evaluation system developed by the U.S. Army Corps of Engineers (Basham et al. 1982) was used to monitor fish condition at both test sites. Evaluation criteria included modifications established in 1985 (Neitzel et al. 1985). Baseline descaling was determined by randomly sampling the groups of test fish prior to their release. Descaling was evaluated in each of ten areas, five on each side of the fish. When 40% or more scale loss was observed in any two areas on one side of a fish, the fish was classified as descaled.

## TEST PROCEDURE

At the Richland and Toppenish/Satus Screens branded groups of test fish were released into the canal systems and captured as they moved through the screening facility. Fish were released in the canal behind the trash racks or at the head of the fish return pipe, depending on the test objective. Fish were released in the canal to quantify descaling and mortalities resulting from passage in front of the rotary drum screens (Phase IIa tests). At the Richland Screens, fish were released at the head of the fish return pipe to determine if fish that safely entered the fish bypass slot returned to the river unharmed (Phase IIb tests). Fall chinook salmon were released behind the rotary screens in Phase IV tests at both the Richland and Toppenish/Satus Screens to evaluate screen integrity.

### Test Stock Identification

Steelhead, fall chinook salmon, and spring chinook salmon were cold branded to identify specific test groups. Fish were marked in one of four locations: right anterior, left anterior, right dorsal, and left dorsal. Brands were applied at least 1 week prior to release. Brands were approved by the National Marine Fisheries Service and were unique from other brands used in the Columbia River Basin. Releases of test fish were reported to the Fish Passage Center in Portland, Oregon, for entry into their computer files. Thus, our test fish could be identified by U.S. Army Corps of Engineers biologists as they arrived at dams on the lower Columbia River.

### Fish Transport and Release

Test fish were transported at acclimation temperature in an insulated tank [400-l (100 gal) volume] supplied with oxygen. Transit time from PNL to the Richland and Toppenish/Satus Screens was 0.3 hr and 1.0 hr, respectively. Loading densities did not exceed 120 g of fish/l. Water temperature in the transporter changed less than 1°C during transit. Test fish were netted from the transporter into buckets for release into the canal. There were no losses attributable to transporting.

### Fish Release Locations

Test fish were released uniformly across the canal downstream of the trash rack during Phase IIa tests at Richland and Toppenish/Satus. During Phase IIb tests at Richland, fish were released in the fish return structure within 1 m of the head end of the fish return pipe. Fall chinook salmon used during Phase IV tests at Richland and Toppenish/Satus were released at two locations: uniformly along the downstream side of the trash rack and uniformly along the downstream side of the rotary screens.

### Release Controls

The condition of test fish at the time of release (baseline condition) was estimated by sampling fish from the transporter. For Phase IIa tests, 100 fish were sampled for baseline condition and 200 to 500 fish were released into the canal. During Phase IIb tests, groups of 10 to 20 test fish were serially removed from the transport tank and released. Release controls were similarly removed and evaluated throughout the test series.

### Fish Capture and Evaluation

Fish captured during Phase IIa tests were dip netted from the live-box at the end of the inclined plane and placed in a holding tank before evaluation. Evaluations were made at half-hour intervals. Fish were anesthetized in K-222, examined to determine the extent of scale loss, and returned to a holding tank. Some fish were held for 96 hr to determine possible delayed mortality. After fish recovered from the anesthetic, they were released to the river via the fish return pipe.

Fish were captured either by fyke net or electrofishing in Phase IIb tests. Fish were removed from the cod end of the net 10 minutes after their release at the head of the fish return pipe. When the electroshocker was used, stunned fish were dip netted at the end of the fish return pipe. Fish were anesthetized with MS-222, examined, held in a cage at the river bank to recover, and released into the river.

## STATISTICAL ANALYSIS

The percent of fish descaled or killed was estimated based on the number of test fish caught. Descaled fish, defined by Basham et al. (1982), were considered dead for evaluation of the data. Confidence intervals for these estimates were calculated from Mainland's Tables (Mainland et al. 1956). Data for replicate tests were combined to obtain a mean estimate. The estimate assumes each fish behaved independently (i.e., fish within a test did not behave more similarly than fish between tests, and there were no interactions among fish within a test). Although some interaction is expected among fish, the assumption that each fish behaved independently is necessary for the analytical methods used. All tests were conducted in the same manner to reduce nonindependent behavior of fish.

The time required for planted fish to move out of the screening facility was estimated from the total number of fish recovered and the recovery times. Median passage times were calculated and represent the time when 50% and 95% of the recovered fish were captured.

## RESULTS

Fish passed through the fish bypass systems in the Richland and Satus Canals without being descaled or killed. The results of the tests are shown below as they relate to the objectives of each phase outlined in the work plan. Appendix A contains a detailed summary of the catch data and estimates for percent of test fish descaled or killed.

### PHASE I TESTS

Phase I tests were designed to evaluate components within the fish diversion system other than the rotary screens. Fish return structures at the Richland and Toppenish/Satus Screens are simple in design and do not include pumpback systems, multiple fish return pipes, or traveling screens. Therefore, Phase I tests were not conducted at these sites.

### PHASE II TESTS

Phase II tests were designed to evaluate either the entire fish bypass system from the trash rack through the fish return pipe (Phase IIa), or to evaluate specific components of the fish return system (Phase IIb). At the Richland and Toppenish/Satus Screens, we initiated our evaluations with Phase IIa testing. We released fish at the trash rack and captured them before they entered the fish return pipe. We also conducted Phase IIb tests at the Richland Screens to evaluate the potential effects of passage through the fish return pipe. We also determined how long released fish remained upstream of or within the fish screening facilities.

#### Phase IIa, Richland Screens

Of the three groups of steelhead and spring chinook salmon released behind the trash rack (200 fish/group; 1200 fish total), 363 (61%) steelhead and 560 (93%) spring chinook salmon were captured. About 1% of the steelhead and 0.7% of the spring chinook salmon were descaled or dead (Tables 1 and 2). Of 157 steelhead and 154 spring chinook salmon held for 96-hr observation, 2 steelhead and no spring chinook salmon died. Combined losses from descaling and delayed mortality were within the 95% confidence interval for the condition controls (Appendix A; Tables A.10 and A.11).

TABLE 1. Descaling and Mortality Data from Release and Capture Tests with Steelhead, Salmo gairdneri, Smolts at the Richland Canal Fish Screening Facility, Spring 1986

TEST GROUP	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1	200	129	1	0.8	0.2-4.2
2	200	132	2	1.5	0.2-5.4
3	200	102	1	1.0	0-5.3
TOTAL	600	363	4	1.1	0.3-2.8

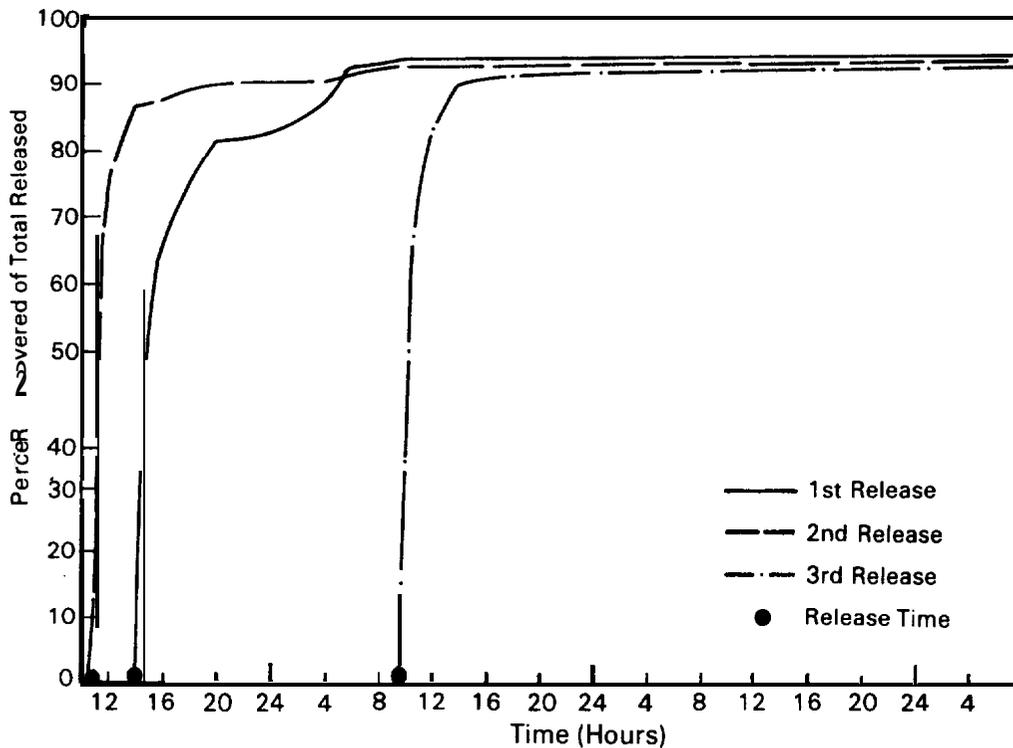
TABLE 2. Descaling and Mortality Data from Release and Capture Tests with Spring Chinook Salmon, Oncorhynchus tshawytscha, Smolts at the Richland Canal Fish Screening Facility, Spring 1986

TEST GROUP	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1	200	186	2	1.1	0.1-3.8
2	200	189	2	1.1	0.1-3.8
3	200	185	0	0.0	0-2.0
TOTAL	600	560	4	0.7	0.2-1.8

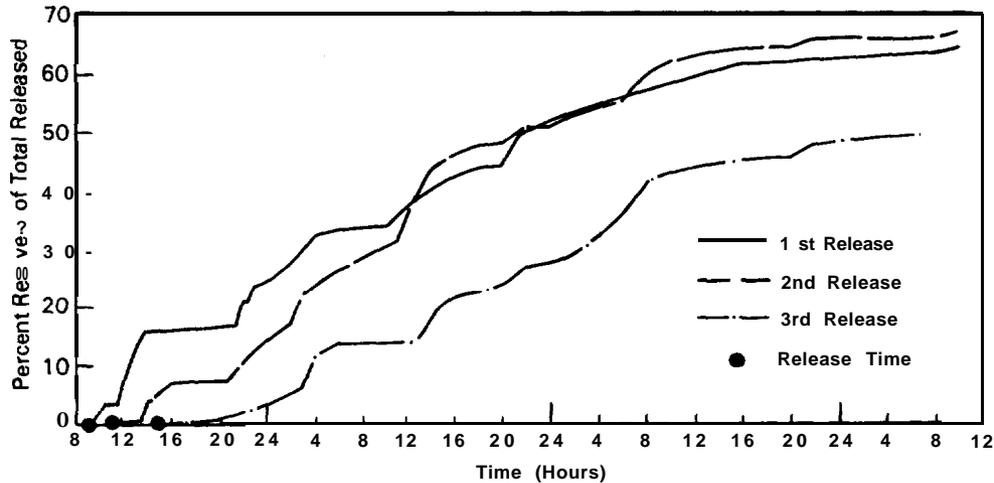
Test fish moved through the Richland Screens forebay of their own volition. Spring chinook salmon migrated rapidly through the screen forebay; mean migration time was less than 1 hr (Table 3), and virtually all the fish were caught in less than 6 hr (Figure 7). Steelhead migrated more slowly, with most movement occurring in darkness. Steelhead were captured throughout the 72-hr sampling period; 50% were caught in less than 24 hr (Table 3), and few were caught after 48 hr (Figure 8).

**TABLE 3. Estimated Time (hr) to Catch 50% and 95% of the Test Fish Captured at Richland Canal Fish Screening Facility, Spring 1986**

SPECIES	TIME TO CATCH		NUMBER OF FISH		PERCENT RECOVERY
	50%	95%	RELEASED	CAUGHT	
Steelhead	18.0	52.5	200	129	64.5
Steelhead	21.0	48.0	200	132	66.0
Steelhead	29.0	54.5	200	102	51.0
Chinook Salmon	0.5	6.5	200	186	93.0
Chinook Salmon	1.0	5.0	200	189	94.5
Chinook Salmon	1.0	3.5	200	185	92.5



**FIGURE 7. Movement of Spring Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Based on the Capture of Test Fish at the Richland Canal Fish Screening Facility, Spring 1986**



**FIGURE 8. Movement of Steelhead, *Salmo gairdneri*, Smolts Based on The Capture of Test Fish at the Richland Canal Fish Screening Facility, Spring 1986**

In Phase IV tests at Richland, we released 3300 fall chinook salmon fingerlings downstream of the trash rack and caught over 2000 of the fish in the next 48 hr. The fish were fingerlings and, therefore, were not expected to move quickly from the canal. Additionally, the flow at the Richland Screens was near low flow during our tests. Although the fingerlings were not "flushed" from the screen forebay, many were captured in the fish return structure shortly after their release. The remainder of the test fish seemed to move out of the canal through the fish return structure of their own volition. Estimated time to catch 50% of the fall chinook salmon captured was about 8 hr (Table 4). Peak migration occurred after sunset (Figure 9).

**Phase IIa, Toppenish/Satus Screens**

The tests at Toppenish/Satus were started in June, 2 months after the canal was filled. We did not start our tests when the canal was filled because the screens were not ready. Because of the late start date for the tests the steelhead had to be held in water at 17°C. The scales were easily dislodged and many fish lost scales during acclimation and transport. To evaluate fish descaling after passage through the diversion facility, the condition of fish captured on the inclined plane was compared to that of fish in the control group (fish that were transported to the site with the test fish but were not placed in the canal).

TABLE 4. Estimated Time (hr) to Catch 50% to 95% of Fall Chinook Salmon, *Oncorhynchus tshawytscha*, Fingerlings Captured at Richland Canal Fish Screening Facility, Spring 1986

TEST	TIME TO CATCH		NUMBER OF FISH		PERCENT CAPTURED
	50%	95%	RELEASED	CAPTURED	
1	9.5	34.5	1000	638	63.8
2	8.5	32.0	1150	682	59.3
3	7.0	31.0	1150	809	70.3

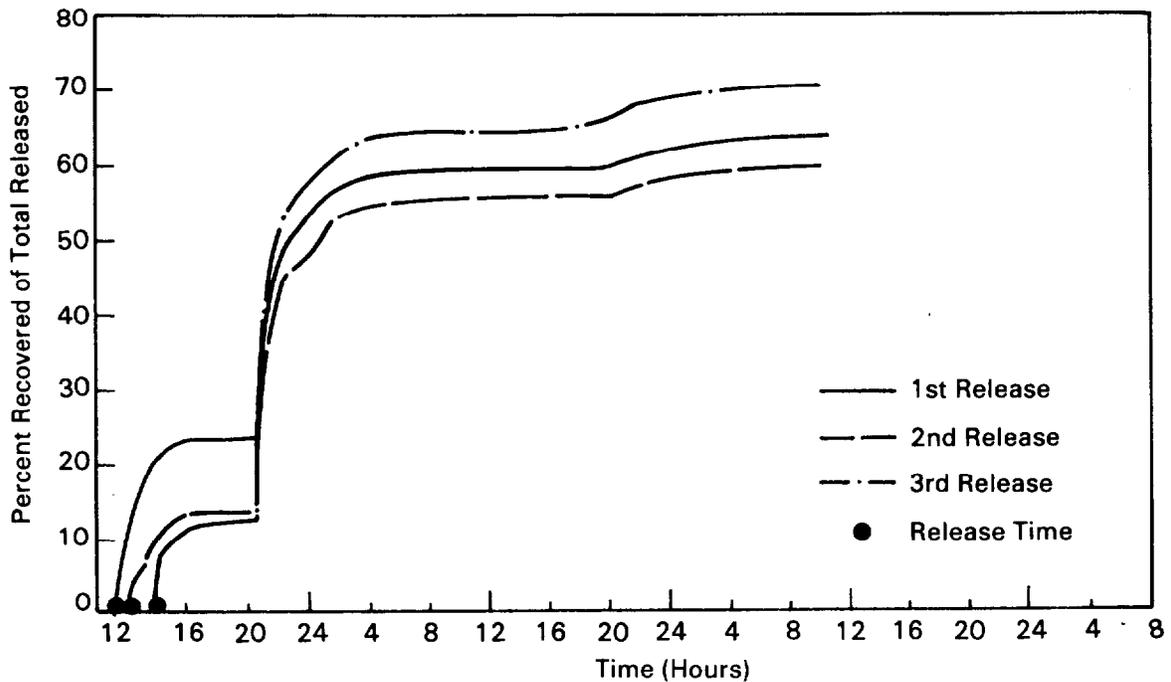


FIGURE 9. Movement of Fall Chinook Salmon, *Oncorhynchus tshawytscha*, Fingerlings Based on the Capture of Test Fish at the Richland Canal Fish Screening Facility, Spring 1986

Of three groups of steelhead smolts released behind the trash rack (520-fish/group; 1560 fish total), 1388 (89%) were captured during the 96-hr sampling period. The descaling rate for captured steelhead was 18.9% (Table 5) based on all steelhead that were captured, and 23.9% (Table 5) based on steelhead captured and evaluated during daylight hours, compared to a descaling rate of 26.4% for the control group (Appendix A, Table A.16). There was no significant change in the condition of the fish that passed through the diversion system (Tables 5 and A.16). We made our assessment using the data for fish that were evaluated in the daylight because all of the control fish were evaluated in natural daylight.

Spring chinook salmon smolts were released in the canal, but only to compare their movement with movement trends observed for spring chinook salmon smolts released at the Richland and Sunnyside Screens. We did not examine the spring chinook salmon smolts for descaling because no native or hatchery-released spring chinook salmon stocks had previously been reported

TABLE 5. Descaling and Mortality Data from Release and Capture Tests with Steelhead, *Salmo gairdneri*, Smolts at the Toppenish/Satus Canal Fish Screening Facility, Spring 1986

TEST GROUP	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1	520	462	120	26.0	23.1-31.3
2	520	463	102	22.0	19.4-27.1
3	520	463	40	8.6	6.2-11.6
TOTAL	1560	1388	262	18.9	17.4-21.6
1 (a)	520	224	73	32.6	28.2-40.7
2 (a)	520	236	60	25.4	21.5-33.0
3 (a)	520	154	14	9.1	5.1-14.8
TOTAL (a)	1560	614	147	23.9	13.6-24.1

(a) Steelhead caught during daylight only.

in Toppenish Creek or Marion Drain. Fall chinook salmon fingerlings released in the Toppenish/Satus Screens forebay in Phase IV tests were monitored as they moved through the fish return structure.

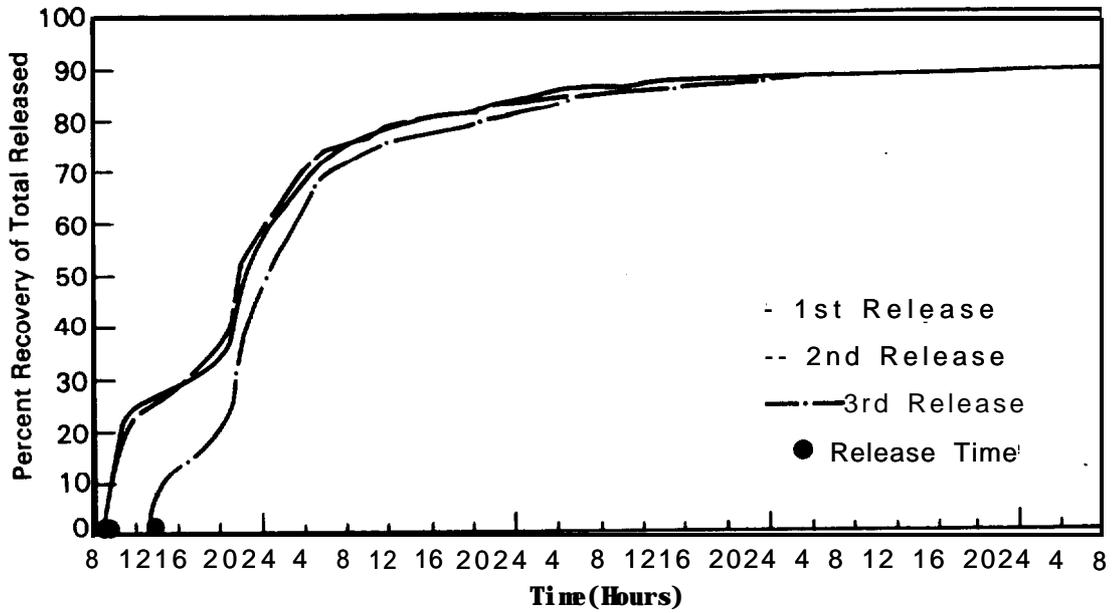
Steelhead were not flushed from the Toppenish/Satus Screens. Mean clearance time through the fish bypass system was about 12 hr (Table 6). Many test fish were captured on the inclined plane shortly after their release; however, peaks in fish movement occurred at night (Figure 10).

Of 2460 fall chinook salmon fingerlings and 1030 spring chinook salmon smolts released, 1760 (72%) and 999 (97%), respectively, were captured in the fish return structure. Fall chinook salmon fingerlings were "flushed" from the screen forebay, with 95% of the captures occurring in 0.5 hr or less (Table 6). Although the inclined plane was operated continuously for 72 hr after fish were released, none of the fall chinook salmon we released were captured after 14 hr (Figure 11).

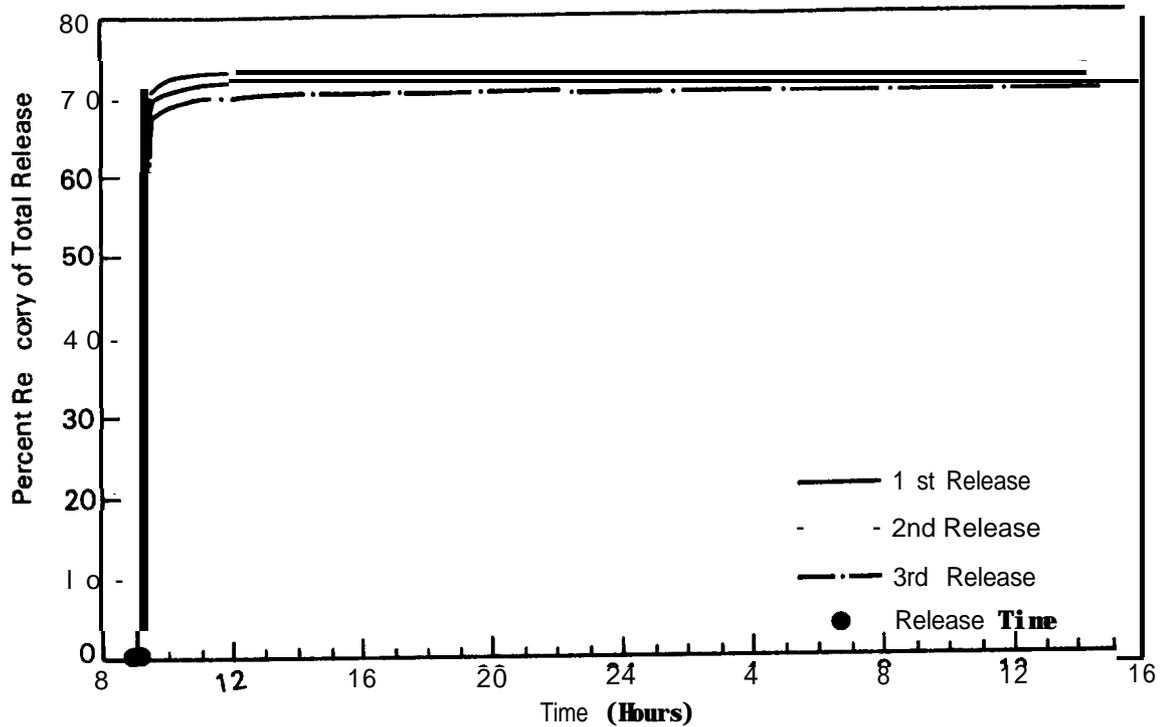
Spring chinook salmon smolts migrated quickly through the screen forebay. Mean clearance time was about 0.5 hr and 95% were caught within 1.5 hr (Table 6). No spring chinook salmon were caught after 6 hr (Figure 12).

**TABLE 6.** Estimated Time (hr) to Catch 50% and 95% of the Test Fish Captured at the Toppenish/Satus Canal Fish Screening Facility, Spring 1986

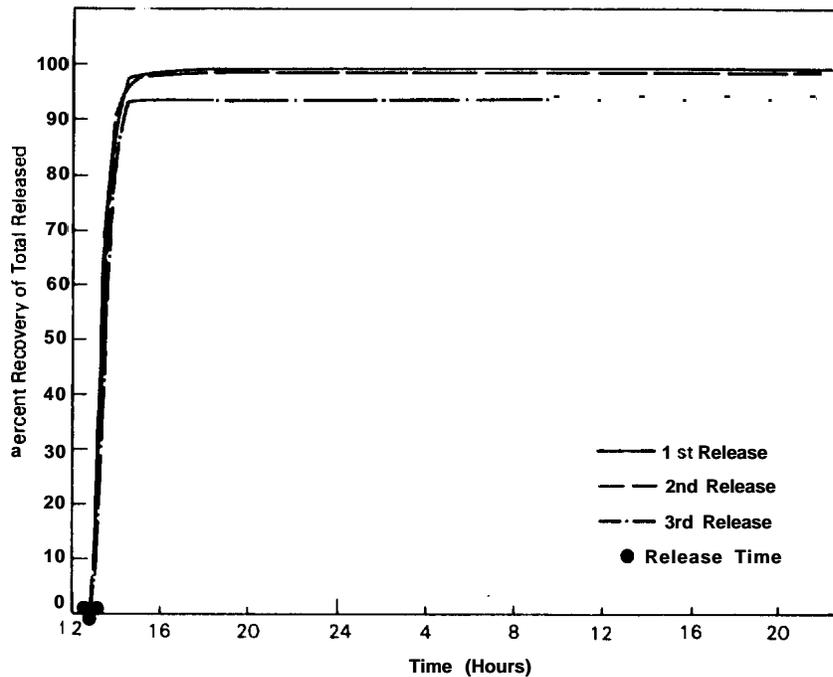
SPECIES	TIME TO CATCH		NUMBER OF FISH		PERCENT RECOVERY
	50%	95%	RELEASED	CAUGHT	
Steelhead	12.5	41.0	520	462	88.8
Steelhead	12.0	46.5	520	464	89.2
Steelhead	10.0	42.5	520	463	89.0
Spring Chinook Salmon	0.5	1.5	360	356	98.9
Spring Chinook Salmon	0.5	1.5	335	329	98.2
Spring Chinook Salmon	0.5	1.5	335	314	93.7
Fall Chinook Salmon	<0.5	<0.5	1000	728	72.8
Fall Chinook Salmon	<0.5	<0.5	1000	702	70.2
Fall Chinook Salmon	<0.5	<0.5	460	330	71.7



**FIGURE 10.** Movement of Steelhead, *Salmo gairdneri*, Smolts Based on the Capture of Test Fish Toppenish/Satus Canal Fish Screening Facility, Spring 1986



**FIGURE 11.** Movement of Fall Chinook Salmon, *Oncorhynchus tshawytscha*, Fingerlings Based on the Capture of Test Fish at Toppenish/Satus Canal Fish Screening Facility, Spring 1986



**FIGURE 12.** Movement of Spring Chinook Salmon, uncornyncnus  
pture of Test  
 Fish at Toppenish/Satus Canal Fish Screening  
 Facility, Spring 1986

**Phase IIb**

The potential effect of passage through the fish return pipe was evaluated separately because test fish were more easily captured in the fish bypass slot. Tests involving the fish return pipe were only conducted at the Richland Screens. Construction delays prevented us from conducting fish return pipe tests at Toppenish/Satus.

Spring chinook salmon smolts survived passage through the fish return pipe at the Richland Screens. Two groups of fish were tested; 360 were released and collected with the fyke net and 320 were released and collected by electroshocking. The net collected 199 fish and the 213 were collected by electrofishing. Less than 3% of the test fish captured by net were descaled under low flow conditions (0.3 m<sup>3</sup>/sec, 10 cfs) through the

return pipe. At high flow (0.6 m<sup>3</sup>/sec, 20 cfs), 18.7% of the test fish were descaled; however, descaling was caused by the collection gear (Appendix A, Table A.9) and not by passage through the fish return pipe. Descaling was not observed at either low or high flow when test fish were collected by electrofishing (Table 7).

### PHASE III TESTS

Phase III tests were not conducted, except for the pipe tests at the Richland Screens. Those tests, in which the condition of fish passing through the fish return pipe was examined under two different flows, are described above. Tests to determine how different operating conditions affect fish passage could not be conducted due to delays in facility construction and start-up at both the Richland and Toppenish Screens.

TABLE 7. Descaling and Mortality Data for Spring Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts After Passage through the Fish Return Pipe at the Richland Canal Fish Screening Facility, Spring 1986. E.S. = electroshocker

TEST GROUP	CAPTURE METHOD	FLOW (m <sup>3</sup> /sec, cfs)	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
			RELEASED	CAPTURED	DESCALED		
1	Fyke	0.3, 10	90	58	2	3.5	0.4-11.9
2	Fyke	0.3, 10	90	37	1	2.7	0.1-14.2
3	Fyke	0.3, 10	90	29	0	0.0	0.0-12.0
TOTAL			270	124	3	2.4	0.5- 6.9
	Fyke	0.6, 20	90	75	14	18.7	10.6-29.3
	E.S.	0.3, 10	110	107	2	1.9	0.2- 6.6
	E.S.	0.6, 20	210	106	0	0.0	0.0- 3.4

## PHASE JV TESTS

The inclined plane was used during release and capture tests to note the presence of predators, and the occurrence and condition of native and hatchery-released salmonids. Rotary screens were monitored during the tests to determine if fish were impinged. These observations were qualitative, as required by the work plan. Fall chinook salmon fingerlings were released up stream and downstream of the Richland and Toppenish/Satus Screens to test for possible passage through, around, or over the rotary screens. Downstream releases were made to monitor sampling efficiency and effectiveness.

### Phase IVa, Richland Canal

Few predacious fish (smallmouth bass, Micropterus dolomieu; and squawfish, Ptychocheilus oregonensis) were caught in the fish return pipe. However, predacious feeding activity was observed in the canal upstream of the trash rack. Two salmonids were found in the gut of a 38-cm (15 in.) smallmouth bass.

Seagulls, Larus spp., were feeding downstream of Horn Rapids Dam during our studies. The birds frequently flew over the shoreline or perched on exposed boulders in the river. Releases of disoriented fish resulted in increased feeding activity downstream of the fish return pipe. Gull activity near the fish return pipe did not appear to be different from activity in the surroundino area at other times.

Based upon visual observations, salmonids were not impinged on the rotary screens. Fall chinook salmon fingerlings and steelhead smolts were frequently observed in the screen forebay along the outer wall or downstream of the trash rack piers. Some fish were observed near the screens at night; however, they were oriented parallel to the screen surface and facing upstream

The occurrence and condition of upriver salmonid stocks was monitored throughout our sampling period at the Richland Screens. Hatchery (fin-clipped) and native salmonid smolts were observed but were not segregated in our descaling evaluation (Table 8). Steelhead and spring chinook salmon smolts were more prevalent in our catches than coho salmon smolts.

**TABLE 8. Descaling and Mortality Data for Upriver Salmonids Captured at the Richland Canal Fish Screening Facility, Spring 1986**

SPECIES	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	CAUGHT	DESCALED		
Chinook Salmon (a)	17	3	4.7	1.0-11.0
Coho Salmon	51	3	17.6	3.8-48.0
Steelhead			5.9	1.3-18.9

(a) Primarily spring chinook salmon (>10 cm 4 in.), but includes some fall chinook salmon (<10 cm 4 in.).

Descaling of some fish was apparently caused by bird or fish bites, as indicated by scale loss patterns in a "V"-shape (bird bites) or a curved arc (fish bites) on both sides of the fish.

**Phase IVa, Toppenish/Satus Canal**

Few predacious fish (largemouth bass, M. salmoides; and squawfish) were caught on the inclined plane during our studies, and they contained no salmonids. Although the canal had been operating for 8 weeks, the rotary screens had been in place for only 1 week, allowing little time for predators to accumulate in the screen forebay. No predacious feeding activity was observed in the canal during our studies. Seagulls were not common at the site.

Forage fish, mostly red-sided shiners, Richardsonius balteatus; chiselmouth, Acrocheilus alutaceus; and bridgelip suckers, Catostomus columbianus, were the most commonly caught fish at the Toppenish/Satus Screens. Three species of juvenile salmonids were observed: chinook salmon, coho salmon, and steelhead. Descaling was rare among hatchery and wild salmonids originating from upstream of the sample sites. Fish generally were in excellent condition (Table 9).

Most chinook salmon outmigrants appeared to be yearlings, presumably spring chinook salmon smolts, that averaged 13 cm to 15 cm (5 to 6 in.) in length. We did not expect to catch spring chinook salmon at the Toppenish/Satus Screens. Yakima Basin fisheries management personnel stated that no

**TABLE 9. Descaling and Mortality Data for Upriver Salmonids Captured During Tests at Toppenish/Satus Canal Fish Screening Facility, Spring 1986**

SPECIES	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	CAUGHT	DESCALED		
Steelhead (1-age)	20	0	0	0.0-16.8
Steelhead (0-age)	69	0	0	0.0-5.2
Coho Salmon (1-age)	29	0	0	0.0-12.0
Chinook Salmon	25	1	4	0.1-20.4

spring chinook salmon spawned upstream of the Toppenish Creek Diversion Unit. One spring chinook salmon smolt caught was a hatchery released fish, as indicated by an adipose fin clip. We speculate that the outmigrant spring chinook salmon smolts we caught may have originated in the Yakima River above the Old Reservation Canal (Figure 2) and could have been diverted into the Old Reservation Canal and subsequently into Toppenish Creek.

Some outmigrant chinook salmon were 7 cm to 10 cm (3 to 4 in.) long and were probably fall chinook salmon. Coho salmon outmigrants were 13 cm to 15 cm (5 to 6 in.) long. Steelhead smolts were 12 cm to 20 cm (5 to 8 in.) long; however, one steelhead was over 25 cm long and may have been a native rainbow trout. We also caught 69 0-age rainbow trout (possibly steelhead) that were 2.5 to 7.5 cm (1 to 3 in.) long.

**Phase IVb, Richland**

A total of 3300 fall chinook salmon fingerlings were released in front of the screens and 3150 were released behind the screens to evaluate the effectiveness of rotary screens in preventing fish from entering the irrigation canal behind the screens. During the 48-hr period following release, 3129 fish (65%) of the fish planted in front of the screens were captured in the fish return structure. Only 15 (0.5%) of the fish planted behind the screens were captured in the irrigation canal (12 were captured by fyke net and 3 by electrofishing). None of the fish planted in front of the screens were captured in the canal.

**Phase IVb, Toppenish/Satus**

A total of 2460 fall chinook salmon fingerlings were released upstream of the screens and 2600 were released downstream of the screens in Satus Canal. During the subsequent 72-hr period, 1760 (72%) of the fish we released upstream of the screens were captured in the fish bypass slot. Two fyke nets were fished in the canal for 12 hr following release of the fish, and none of the fish that were planted downstream the screens were captured in these nets. Because no fish were captured in the fyke nets, we fished with the electroshocker from the screen structure downstream to the utility pipe that crosses Satus Creek. Two fish were captured by electrofishing, both of which had been released downstream of the screens. None of the fish released upstream of the screens were captured in the canal.

## DISCUSSION

Fish screening facilities in the Yakima River Basin are designed to direct fish that have been diverted from the river and into irrigation canals back to the river without killing or injuring them or delaying their migration. The work plan for this study was designed to determine if the diverted fish can be safely and expeditiously returned to the river. Tests following the work plan are conducted to: 1) evaluate the conditions or circumstances that affect fish survival as the fish pass through the screening facility; 2) determine if a screening facility provides conditions under which diverted fish may become more susceptible to predation; 3) evaluate whether fish are delayed at or upstream of the screening facilities; and 4) determine if fish pass through, around, or over rotary screens and become trapped in the irrigation canal.

Operating conditions at each facility vary, resulting in different conditions for bypassing or diverting fish. The work plan included tests to determine the potential for adverse conditions resulting from changes in operating conditions.

### FISH SURVIVAL AT THE SCREENING FACILITY

Based on the condition of juvenile salmonids released upstream of or into the screening facilities and captured as they returned to the river, diverted fish are not injured or descaled. The condition of native or hatchery-released salmonids captured during our tests supports this conclusion in that less than 4% of more than 500 salmonids checked during our tests were descaled. We obtained similar results at three screening facilities: Sunnyside (Neitzel et al. 1985), Richland, and Toppenish/Satus.

At each of the three screening facilities, we collected juvenile salmonids in the fish bypass slot at the head of the fish return pipe. Sampling in the fish bypass slot ensured more stable conditions and allowed evaluation of the screening facilities under any river flow. Sudden fluctuations in river flow could have affected gear efficiency and

jeopardized our evaluations if fish were collected at the terminus of the fish return pipe. All three screening facilities have both flow control slots and fish return pipes. However, the flows through the fish return pipe and the dimensions of the fish return pipes varied. By collecting juvenile salmonids within the fish bypass slot, the common aspects of the three screening facilities were evaluated and compared. Separate tests were conducted at Sunnyside and Richland to evaluate passage through the fish return pipes. These test data indicate that fish are returned safely through the pipes to the river.

At Richland, juvenile salmonids enter the Richland Canal from the Yakima River through the headgates at Horn Rapids Dam. Fish encounter the Richland Screens after passing downstream through about 1 km (0.6 mile) of canal. Fish pass in front of four screens before entering the 4-m (12 ft)-long fish bypass slot, then into the fish return pipe, and back to the river. The Richland Screens include a waste-water channel that can be used to return water to the river before it passes through the trash rack in the canal. The volume of water wasted is dependent on the volume of water entering the canal versus the volume of water passing through the screens and the fish return system. Fish could be diverted from the canal into the waste-water channel. The proportion of fish and the potential fate of fish passing from the canal to the river through the waste-water channel was not evaluated during our study because the use of the channel in operating the screens has not been determined.

At the Toppenish/Satus Screens, the Satus Canal originates at the confluence of Toppenish Creek and Marion Drain. An adjustable barrier dam across Toppenish Creek creates a reservoir that supplies Satus Canal. Fish diverted into the Satus Canal travel downstream about 130 m (430 ft) to the Toppenish/Satus Screens where they are diverted through the fish bypass slot into a fish return pipe. The pipe empties into Toppenish Creek just downstream of the Toppenish Creek Diversion Unit.

#### POTENTIAL FOR PREDATION AT THE SCREENING FACILITIES

We observed no increase in susceptibility to predation because of the screening facilities. Predatory fish and birds occur throughout the Yakima

River Basin. Screening facilities could affect the predator/prey relationship if the screens concentrate the prey or increase the exposure of prey to predators due to stress, injury, or delay in migration. The mere presence of predators at a screening facility does not necessarily indicate an increase in predation.

At Richland, few predacious fish were captured during our evaluation. However, the canal had been dewatered for several months prior to our tests. Because the Richland Canal normally operates year-round, predacious fish could accumulate in the screen forebay over an extended period. The presence of predacious fish in the forebay might represent only a shift in predation activity, as predators move from the Horn Rapids Diversion Dam to the canal, and not an overall increase in predation within the lower Yakima River. A survey of predatory fish populations in the screen forebay after 1 or more years of continuous operation might provide information about predator populations. Both the Sunnyside and Satus Canals are operated seasonally, which provides an opportunity to survey predacious fish populations when the canals are drained in the fall.

Seagulls are abundant in the lower Yakima River near the Richland Screens, but are relatively rare at the Sunnyside and Toppenish/Satus Screens. Seagulls did not feed in the Richland Canal or in the screen forebay. However, seagulls actively fed in the river downstream of the fish return pipe during some of our tests. The fish return pipe enters the Yakima River in a riffle area less than 0.3 m (1 ft) deep during low river flows, making fish emerging from the pipe highly visible to seagulls perched on boulders or hovering above the water. Although predation by seagulls at the end of the fish return pipe did not appear to be greater than predation throughout the area below Horn Rapids Dam, placing the opening of fish return pipes in deeper water could reduce predation by birds.

#### POTENTIAL FOR FISH DELAY AT THE SCREENING FACILITIES

We observed no delay in the movement of test fish at or within the screening facilities that could be attributed to the design or construction of the Richland, Toppenish/Satus, and Sunnyside Screens. However, there

are many factors that can influence the rate at which fish move or migrate within a river (e.g., fish species, smolting stage, fish size, canal flow, and time of day). Few of these factors have been specifically tested at the diversion screens. Movement of fish through a screening facility can also be active or passive. Active movement is especially evident in salmonids when juveniles undergo smolt transformation and migrate downstream. Smolt outmigrants move through a screening facility quickly, while fish that are not migrating may hold their position. Nonmigrating fish can be "flushed" from a screening facility if there are no resting areas (structure or eddies) in the screen forebay and the water velocity in the canal exceeds the swim speed of the fish.

Steelhead smolts appeared to migrate from the screen forebay slower than spring chinook salmon smolts. The mean migration time was longer and the percent of test fish captured was lower for steelhead. The trend was the same at all three sites regardless of time of release, type of test, or rearing and handling conditions. After release, we sampled continuously for up to 96 hr and the catch amounted to 26%, 64%, and 88% of the total fish released. Although we cannot account for every steelhead released, the uncaptured steelhead may have remained in the forebay of the screening facility.

We compared the movement of steelhead released at the Sunnyside, Richland, and Toppenish/Satus Screens with the movement of hatchery releases of steelhead at Nelson Springs and Ringold. Nelson Springs and Ringold are steelhead-rearing facilities on the Naches and Columbia Rivers, respectively. Herman Stilwater of the Yakima Chapter of the Northwest Steelheader's Association in Yakima, Washington, kept records of steelhead releases and concluded that most fish migrating out of Nelson Springs do so during the first week after the gate from the rearing pond to the river is opened. However, some steelhead have to be "forced" from the rearing pond after 2 weeks. During 1986, the rearing pond gates were opened on March 31 and April 13, and about 25% of the steelhead were forced from the pond.

Similar observations were made by Bruce Walters, manager of the Ringold Steelhead Rearing Facility. Mr. Walters reported that he normally

opens the gates from the rearing pond to the river on April 1. Usually the fish move out of the pond sometime between April 15 and April 25. Most fish move during a 2-day period after movement starts. Normally, about 1% to 10% of the steelhead have to be forced from the ponds. This movement behavior is consistent with our observations at the Sunnyside, Richland, and Toppenish/Satus Screens. We would not expect to capture 100% of the steelhead released into the diversion canals after 96 hr unless each steelhead was actively migrating.

Smolting stage affected the migration rate and percent of test fish captured. At Sunnyside, the recovery rate of both steelhead and spring chinook salmon was less than at Richland and Toppenish/Satus. Many test fish released at Sunnyside had lost the silvery sheen associated with smolting, while a higher percentage of the test fish released at Richland and Toppenish/Satus displayed strong smolt characteristics.

Differences in migration rates of chinook salmon depended on fish size and smolting condition. At Richland, spring chinook salmon smolts migrated after release, while fall chinook salmon fingerlings did not migrate until after sundown. Fall chinook salmon fingerlings were observed holding in the screen forebay. At nightfall, the fingerlings moved out, either voluntarily or because they became disoriented in the darkness. However, at Toppenish/Satus, fall chinook salmon fingerlings moved out of the screen forebay quickly. Increased water velocities at the Toppenish Canal apparently "flushed" the fingerlings from the structure, whereas the slower velocities in the Richland Canal did not.

Steelhead smolts migrated at night at all three study sites. Catches of both test fish and native steelhead increased at sundown. Catch rate declined in early morning and few steelhead were caught in the afternoon. Coho and spring chinook salmon migrated primarily at daybreak. At Sunnyside, catches of hatchery-released coho salmon were high at daybreak, while few were caught in the afternoon or at night. Although spring chinook salmon smolts released at Richland and Toppenish/Satus were

**captured shortly after release, peak chinook salmon catches at Sunnyside occurred just before sunrise.**

**Although total flow affects the number of salmonids entering a canal, it does not appear to affect their migration rate. The fastest movement and highest recovery rate for all test species occurred at the Toppenish/Satus Screens, at a flow of about 18 m<sup>3</sup>/sec (650 cfs). Tests at the Sunnyside Screens were conducted when flows were about 34 m<sup>3</sup>/sec (1200 cfs); but migration was slower and recovery rates were lower. At the Richland Screens, canal flow was about 1.4 m<sup>3</sup>/sec (50 cfs), but the recovery rate was higher and migration rate faster than at the Sunnyside Screens.**

**Water velocities in the canal are important in moving fish through the screen forebay. Water velocity is a function of canal flow and cross-sectional area. Canal depth may also be important in maintaining uniform flow within the canal. The Sunnyside Canal has a deep forebay (5 m 15 ft), and countercurrents were evident both in front of and behind the trash rack. Salmonid smolts were able to hold their position in these eddies. At Richland, steelhead smolts and fall chinook salmon fingerlings held and fed in the screen forebay (1.7 m deep, 6 ft), but current velocity was less than 0.3 m<sup>3</sup>/sec (1 fps) with a 1.4 m<sup>3</sup>/sec (50 cfs) flow. Flow at the Toppenish/Satus Screens, with a screen forebay about 2.5 m (8 ft) deep, appeared more uniform which may have accounted for the rapid movement of both the spring and fall chinook salmon. However, some steelhead smolts held at the entrance to the fish bypass slot at the Toppenish/Satus Screens.**

#### **FISH PASSAGE THROUGH OR OVER THE ROTARY SCREENS**

**One aspect of our evaluation is to determine if screening facilities prevent fish from getting into the irrigation canal behind the screens. We initiated tests at the Richland, Toppenish/Satus, and Sunnyside Screens to address this question. The work plans for the Sunnyside, Richland, and Toppenish/Satus screens included a qualitative evaluation of screen integrity. Our research effort has been directed towards descaling**

evaluations. Consequently, we have not developed the sampling equipment to quantitatively evaluate screen integrity. Additionally, vandalism thwarted our efforts at Richland this year and negated the data we collected. Because of the heightened interest in evaluating screen integrity, we have recommended new collection techniques be used during the 1987 sampling (see Recommendations section).

#### POTENTIAL EFFECTS OF CHANGING SCREEN OPERATION

Operating conditions at a screening facility are important when evaluating the relevance of fisheries evaluation data. Screen efficiency may vary with flow, water temperature, amount of debris in the water, other conditions that affect the screens, and the condition of the fish that enter the screening facility. Normal operating conditions must be clearly defined at each screening facility in order to properly evaluate screen effectiveness.

Tests at the Richland Canal were conducted in mid-May. Peak migration of salmonids at Horn Rapids Diversion Dam occurs in April and early May, when water temperature is near 10°C. Capture rate of wild and hatchery salmonids released upriver decreased throughout the sampling period, indicating that migration had already peaked at Horn Rapids Dam. Temperatures ranged from 13°C to 17°C during our tests.

The Richland Canal is a small irrigation diversion. Water usage varies from 2.3 m<sup>3</sup>/sec (80 cfs) during the summer to about 0.8 m<sup>3</sup>/sec (30 cfs) during the winter. The facility was designed for a maximum flow of 2.5 m<sup>3</sup>/sec (90 cfs) through the screens. Our evaluation was conducted under low flow conditions, with a flow of about 0.9 m<sup>3</sup>/sec (30 cfs) passing through the screens, 0.3 to 0.4 m<sup>3</sup>/sec (10 to 15 cfs) through the fish return pipe, and no spill at the waste-water channel.

Normal operating flow through the fish return system and the waste-water channel is not defined. Flow through the fish return pipe can be regulated from 0 to about 0.7 m<sup>3</sup>/sec (0 to 25 cfs) by using dam boards in the fish bypass slot. The waste-water channel was set to be used only for the emergency return of water to the river in case of screen failure during our tests. However, water may be spilled continuously to prevent the

buildup of debris on the trash rack and to increase water flow and velocity to the screen structure. Outmigrant salmonids would probably move into the channel if it were operated continuously. If the waste-water channel is operated so that fish might routinely utilize it during migration, the concrete channel should be extended to reach the the Yakima River at low flow. Additionally, the continuous discharge of large volumes of water out the waste-water channel could attract migrating adult salmonids, which could cause them to move away from the fish ladders at Horn Rapids Dam

Satus Canal is operated from late March through early October. The canal was filled in early April during 1986 but the fish screens were not put into service until the end of Flay. Our evaluation was conducted during the first week of June, when water temperatures were high for salmonids-- 24°C in Toppenish Creek and 17°C in Marion Drain. Water temperature in the canal ranged from 18.5°C to 20°C during our evaluation, indicating that most of the water entering the canal was from Marion Drain. The barrier dam across Toppenish Creek was diverting all water and outmigrant fish into the canal. The small catches of chinook and coho salmon and steelhead indicate that very few salmonids migrate out of Toppenish Creek or Marion Drain as late as June.

Water flow through the fish bypass slot and fish return pipe was restricted by the BR's fish sampling plane, which was plugged with debris and lodged in the fish bypass slot. Our tests were conducted with about 0.4 m<sup>3</sup>/sec (15 cfs) of water running through the fish return pipe, the maximum flow available with the incapacitated plane in place. The assumed normal operating flow through the fish return pipe (0.7 m<sup>3</sup>/sec, 25 cfs) was not attainable during our evaluation.

The accumulation of aquatic vegetation and debris is a serious problem at the Toppenish/Satus Screens in June. Our sampling equipment was scrubbed at 10-minute intervals to prevent clogging. The debris can also inhibit flow at the trash rack, causing the water level at the screens to fluctuate. Debris that washes through the trash racks during cleaning can accumulate at the head end of the fish bypass slot and restrict flow through the fish return pipe. Automatic trash rack cleaners were not

effective at keeping the trash rack clean. The cleaners do not clean the lower half of the trash rack. When the trash rack is partially plugged, fish could be injured or killed at the trash rack. However, the aquatic vegetation problem is probably more severe in the summer than it is in the spring when most salmonids are expected to migrate through the system

Tests at Sunnyside Canal were also conducted in June under near-maximum flow conditions. Peak runs of native and hatchery-released salmonids had already passed Sunnyside Dam except for a late release of coho salmon smolts. Delays in start up and problems with screening facility equipment prevented us from testing more than one canal flow condition. Impingement velocities at the screens are probably greater at maximum flow operation than during low flow operation of the canal. However, during low canal flows, reduced velocities might affect the efficiency of the fish bypass system or delay migration.

## SUMMARY

Release and capture tests and other monitoring studies have been conducted at three diversion screening facilities in the Yakima Basin: Sunnyside Screens (Neitzel et al. 1985), Richland Screens, and Toppenish/Satus Screens. Objectives were to determine if fish that enter an irrigation canal are safely and expeditiously diverted back to the river. The objective is met by determining: 1) if fish that pass through the diversion are killed, injured, or eaten by predators, 2) if fish are delayed at the screen structure extend their downstream migration, and 3) if fish are prevented from passing through or over the screens.

### PHASE I

Phase I tests were conducted at the Sunnyside Screens using chinook salmon and steelhead smolts. Test data indicate that fish safely pass through all components of the fish bypass system. Phase I tests were not conducted at the Richland or Toppenish/Satus Screens because the fish bypass systems did not incorporate intermediate and terminal bypasses, a separation chamber, traveling screens, or pumpback systems in their designs.

### PHASE II

Phase IIa tests were conducted at the Sunnyside, Richland, and Toppenish/Satus Screens. At the Sunnyside Screens, fish were released at either the trash rack or the headgates. Fish captured after moving through the screen forebay and diversion system were not injured or killed. At the Richland and Toppenish/Satus Screens, fish were released at the trash rack. Captured fish were not killed or injured. Tests at the Sunnyside Screens were conducted with chinook salmon and steelhead smolts, and tests at the Richland and Toppenish/Satus Screens were conducted with chinook salmon fingerlings as well as chinook salmon and steelhead smolts.

Phase IIb tests were conducted at Sunnyside and Richland. At Sunnyside, tests were conducted to evaluate the intermediate bypass system, the terminal bypass system, the secondary separation chamber, and the primary fish return pipe. At Richland, the fish return pipe was evaluated.

### **PHASE III**

Phase III tests were not conducted at the screening facilities with the exception of fish return pipe tests at Richland, where tests were conducted at two flows. Opportunities to conduct tests under different canal flows were limited because of delays in construction and start up at each of the three sites. The Sunnyside and Toppenish/Satus Screens were evaluated at full flow condition. The Richland Screens were evaluated at minimum flow conditions expected during the outmigration of juvenile salmonid.

### **PHASE IV**

Fish other than test fish were collected during all release/capture tests. The gut contents of predacious fish were examined. Birds were observed feeding near the screen structures and in the river near the terminus of the fish return pipe. Rotary drum screens were examined during release/capture tests to determine if any fish were impinged on or passed over the screens. Although screen integrity tests were initiated at all screens, no conclusive data have been collected.

## RECOMMENDATIONS

Fish are safely diverted by the screening facilities. Similar tests should be conducted at all future diversion sites to assess potential site-specific problems. Unless data from future tests suggest otherwise, no further testing of the bypass systems at the Sunnyside, Richland, and Toppenish/Satus Screens is necessary.

We have not observed increased predation on juvenile salmonids in or near the screening facilities that could be attributed to the screens. At Richland, seagulls caught test fish as they exited the fish return pipe. Such predation seemed to occur only when many disoriented fish were released together. Predation by birds at the terminus of the fish return pipe could be reduced if the pipe entered the river in a pool instead of a riffle area. However, there is no indication that predation at the Richland Screens was greater for upriver juvenile salmonids diverted through the screen structure than for salmonids passing over Horn Rapids Dam. Any potential for increased predation at the end of the fish return pipe might be reduced if the pipe terminated in deeper water and further from the shore. Qualitative observations on predacious fish populations made to date could be supplemented by surveys conducted when canals are dewatered after the irrigation season. At the Richland Canal and other systems that operate year-round, predator surveys should be conducted after at least one season of continuous operation.

The data are not conclusive regarding the potential for delay at the screens. Data collected up to 96 hr after release have not documented the clearance of all test fish from the screening facility. Test fish released at the Richland and Toppenish/Satus Screens were monitored as they arrived at McNary and John Day Dams. The relatively small number of fish released in our tests is not adequate to analyze these data. However, releases of larger numbers of salmonids in and near the screening facilities could provide the amount of fish necessary to analyze data from the dams to determine if juvenile salmonids are delayed by the screening facilities.

Testing of screen integrity should be given a high priority during 1987 tests. Determining screen integrity was a secondary priority behind descaling tests during 1985 and 1986. Future evaluations must emphasize collecting data to quantitatively evaluate the efficiency of screening facilities in preventing juvenile salmonids from entering the irrigation canals downstream of the screening facilities. For tests during 1987, we have designed an electroshocking system to increase the efficiency of our collection facility in the canal. A similar electroshocking system is being used successfully at hatcheries in Western Oregon to guide adult fish. We are planning to use the electroshocking system to increase net efficiency and net retention; we do not expect to guide the juvenile salmonids toward our collection facility. This system is designed to provide us with an adequate sample to quantitatively estimate the number of fish passing through the screens. We will release branded fish to test the effectiveness of our sampling gear.

Operating standards for each screening facility must be established, including minimum flow through the fish bypass, conditions for implementation of auxiliary systems like the waste-water channel at the Richland Screens or the secondary fish return pipe at the Sunnyside Screens, and pumping schedules for fish-water return systems. Operating standards should require a log of screen operations (e.g., screen downtime, screen removal, screen clogging, flow volume through various bypass components). Practically all tests at the Sunnyside, Richland, and Toppenish/Satus Screens were conducted under one set of operating conditions for each site. Evaluations may be recommended for a range of operating conditions (i.e., lowest canal flow to highest flow, lowest water temperature to highest, maximum to minimum flow through the fish bypass system). Whether or not we recommend more tests will depend on the results of tests at Wapato and Town and the standard operating procedures that are established for Sunnyside, Richland, and Toppenish/Satus. Further tests may be required at Richland when the operating procedures for the waste-water channel are established. Additionally, the potential for the waste-water channel to attract adult salmonids should be evaluated.

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**APPENDIX A**

**RELEASE AND CAPTURE DATA FROM THE SUNNYSIDE, RICHLAND,  
AND TOPPENISH/SATUS CANAL FISH SCREENING FACILITY EVALUATIONS**

## APPENDIX A

### RELEASE AND CAPTURE DATA FROM SUNNYSIDE, RICHLAND, AND TOPPENISH/SATUS CANAL FISH SCREENING FACILITIES EVALUATIONS

This appendix contains data collected during the evaluations of Sunnyside (Neitzel et al. 1985), Richland, and Toppenish/Satus Fish Screening Facilities. Data presented in the Results sections are sometimes combined (i.e., individual trials within a test series were combined for a single estimate). Descaled fish were considered dead for these estimates. Combining of dead and descaled fish was also used to evaluate screen performance.

Data from the Sunnyside Screens indicate that fish are safely diverted from the canal to the river. Data are presented in seven tables (Tables A.1-A.7).. The data in Tables A.1 and A.2 are from the evaluation of the inclined plane and fyke net. Both samplers collected fish without killing or descaling the fish. Data in Tables A.3 and A.4 are evaluations of the condition of test fish prior to releasing in the canal or screen facility. Test fish were in good condition prior to their release. Data in Tables A.5 and A.6 are the results of the screening facility evaluations. Descaling data from upriver hatchery and native fish are presented in Table A.7.

Data from the Richland Screens evaluation indicate that fish are safely diverted from the canal to the river. Data are presented in seven tables (Tables A.8-A.15). Data in Tables A.8 and A.9 are from the evaluation of the inclined plane and the fyke net. The inclined plane safely collected fish. The fyke net descaled too many fish to be used as an effective collection device at the terminus of the Richland Canal fish return pipe during flows of 0.6 m<sup>3</sup>/sec (20 cfs). Therefore, we used an electroshocker to collect fish during the evaluation of the fish return pipe. Data in Tables A.10 and A.11 are evaluations of the condition of the test fish prior to their release in the canal. Fish were in good condition prior to release. Data in Tables A.12 and A.13 are the results of

screening facility evaluations. Data in Table A.14 are the estimated times for test fish to move through the Richland Screen Facility. Descaling data from upriver hatchery and native fish are presented in Table A.15.

Data from the Toppenish/Satus Screens evaluation indicate that fish are safely diverted from the canal to the river. Data are presented in four tables (Tables A.16-A.19). Data in Table A.16 are evaluations of the condition of the test fish prior to release in the canal. The fish were in marginal condition prior to testing. The water temperature at the canal during testing was near 20°C, therefore we acclimated the test to near 20°C. The scales were loose on the test fish and many of them became descaled during acclimation and transport; however, the test data are useful. The condition of the test fish as a population was not degraded by passage through the screen diversion. This conclusion is based on the change of condition between test and control populations. Data in Table A.17 are the results of screening facility evaluations. Data in Table A.18 are the estimated times for test fish to move through the Toppenish/Satus Screen Facility. Descaling data from upriver hatchery released and native fish are in Table A.19.

**TABLE A.1. Percentage of Coho Salmon, *Oncorhynchus kisutch*, Smolts Descaled or Killed during Tests of the Inclined Plane at Sunnyside Canal Fish Screening Facility, Spring 1985**

TEST REPLICATE	NUMBER OF FISH			FISH %	95% CONFIDENCE INTERVAL
	ON PLANE	CAPTURED	DESCALED	DESCALED	
1	10	7	0	0	0-41.0
2	10	9	0	0	0-33.6
3	10	10	0	0	0-30.8
4	10	10	0	0	0-30.8
5	10	10	0	0	0-30.8
6	10	8	0	0	0-37.0
7	10	10	0	0	0-30.8
8	10	10	0	0	0-30.8
<b>TOTAL</b>	80	74	0	0	0-04.8

**TABLE A.2. Percentage of Steelhead, *Salmo gairdneri*, and Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled or Killed during Tests of the Fyke Net at Sunnyside Canal Fish Screening Facility, Spring 1985**

SPECIES, TEST REPLICATE	NUMBER OF FISH			FISH %	95% CONFIDENCE INTERVAL
	IN NET	CAPTURED	DESCALED	DESCALED	
<b>Steelhead 1</b>	50	8	0	0	0-36.0
<b>Steelhead 2</b>	50	28	0	0	0-12.3
<b>Steelhead 3</b>	55	21	0	0	0-16.1
<b>TOTAL</b>	155	57	0	0	0-06.3
<b>Chinook Salmon 1</b>	50	21	0	0	0-16.1

**TABLE A.3. Percentage of Steelhead, *Salmo gairdneri*, Smolts Descaled Before Being Used in Tests at Sunnyside Canal Fish Screening Facility, Spring 1985**

TEST SITE	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	EVALUATED	DESCALED		
<b>Intermediate Bypass</b>	24	0	0	0-14.3
<b>Terminal Bypass</b>	13	0	0	0-24.7
<b>Trash Rack</b>	<b>19</b>	<b>0</b>	<b>0</b>	<b>0-17.7</b>
<b>Canal Headgates</b>	20	0	0	0-16.8

**TABLE A.4. Percentage of Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled Before Being Used in Tests at Sunnyside Canal Fish Screening Facility, Spring 1985**

TEST SITE	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	EVALUATED	DESCALED		
<b>Primary fish Return pipe</b>	36	0	0	0-09.7
<b>Intermediate Bypass</b>	<b>20</b>	<b>0</b>	<b>0</b>	<b>0-16.8</b>
<b>Terminal Bypass</b>	<b>20</b>	<b>0</b>	<b>0</b>	<b>0-16.8</b>
<b>Trash Rack</b>	<b>20</b>	<b>0</b>	<b>0</b>	<b>0-16.8</b>
<b>Canal Headgates</b>	32	0	0	0-09.7

**TABLE A. 5. Percentage of Steelhead, Salmo gairdneri, Smolts Descaled or Killed in Each Test at the Sunnyside Canal Fish Screening Facility, Spring 1985**

RELEASE SITE	TEST REPLICATE	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
		RELEASED	CAPTURED	DESCALED		
<b>Primary fish Return pipe</b>	1	50	8	0	0	O-36.8
	2	50	166	00	00	O-20.69
<b>Intermediate Bypass</b>	1	275	139	0	0	O-02.6
<b>Terminal Bypass</b>	1	200	112	0	0	O-03.2
<b>Trash Rack</b>	1	500	126	0	0	O-02.9
<b>Canal Headgates</b>	1	500	100	0	0	O-03.6

TABLE A.6. Percentage of Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled or Killed in Each Test at the Sunnyside Canal Fish Screening Facility, Spring 1985

RELEASE SITE	TEST REPLICATE	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
		RELEASED	CAPTURED	DESCALED		
Primary fish Return pipe	1	100	83	0	0.0	0.0-04.4
	2	100	64	2	3.1	0.4-10.8
	3	100	75	0	0.0	0.0-04.8
	4	100	60	1	1.7	0.0-08.9
	5	100	89	0	0.0	0.0-04.1
Intermediate	1	100	82	2	2.4	0.3-08.5
	2	100	95	0	0.0	0.0-03.8
	3	100	99	0	0.0	0.0-03.7
	4	100	95	2	2.1	0.3-07.4
	5	100	97	0	0.0	0.0-03.7
Terminal Bypass	1	100	98	2	2.0	0.3-07.2
	2	100	96	1	1.0	0.0-05.7
	3	100	98	0	0.0	0.0-03.7
	4	100	98	3	3.1	0.6-08.7
	5	92	86	1	1.2	0.0-06.3
Trash Rack	1	1000	856	20	2.3	1.4-03.6
Canal Headgates	1	1000	729	6	0.8	0.2-01.6
	2	1000	725	21	2.9	2.0-04.7

TABLE A.7. Scale Loss for Hatchery-Released and Native Salmonids Captured During Tests at the Sunnyside Canal Fish Screening Facility, Spring 1985

SPECIES	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	COLLECTED	DESCALED		
Chinook Salmon	214	9	4.2	2.0-07.7
Steelhead	36	1	2.8	0.2-14.7

**TABLE A. 8. Percentage of Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled or Killed During Tests of the Inclined Plane at Richland Canal Fish Screening Facility, Spring 1986**

RACE	TEST REPLICATE	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
		RELEASED	CAPTURED	DESCALED		
Spring	1	25	21	0	0	0-16.1
	Control		19	0	0	0-17.7
Fall	1	25	16	0	0	0-20.6
	Control		20	0	0	0-16.8
	2	500	156	0	0	0-02.3

**TABLE A. 9. Percentage of Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled or Killed During Tests of the Fyke Net at Richland Canal Fish Screening Facility, Spring 1986 (The L designation indicates tests at 0.6 m<sup>3</sup>/sec flow through the fish return pipe and the H designation indicates tests at 1.6 m<sup>3</sup>/sec flow through the fish return pipe)**

TEST REPLICATE	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1-L	50	26	0	0.0	0.0-13.2
L-control	50	50	0	0.0	0.0-07.1
1-H	90	75	14	18.7	10.6-29.3
H-control	50	42	17	40.5	25.6-56.7

**TABLE A. 10. Percentage of Steelhead, *Salmo gairdneri*, Smolts Descaled Before Being Used in Tests at Richland Canal Fish Screening Facility, Spring 1986**

	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
	100	100	0	0.0	0-3.6
	100	100	0	0.0	0-3.6
	101	101	1	1.0	0-5.4
<b>TOTAL</b>	<b>301</b>	<b>301</b>	<b>1</b>	<b>0.3</b>	<b>0-1.8</b>

**TABLE A. 11. Percentage of Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts Descaled Before Being Used in Tests at Richland Canal Fish Screening Facility, Spring 1986**

TEST GROUP	NUMBER OF FISH			FISH % DESCALD	95%
	RELEASED	CAPTURED	DESCALD		CONFIDENCE INTERVAL
	100	100	0	0	<b>0-3.6</b>
	100	100	0	0	<b>0-3.6</b>
	<b>102</b>	<b>102</b>	<b>0</b>	<b>0</b>	<b>0-3.6</b>
<b>TOTAL</b>	<b>302</b>	<b>302</b>	<b>0</b>	<b>0</b>	<b>0-1.2</b>

**TABLE A. 12. Descaling and Mortality Data from Release and Capture Tests with Steelhead, *Salmo gairdneri*, Smolts at the Richland Canal Fish Screening Facility, Spring 1986**

TEST GROUP	NUMBER OF FISH			FISH % DESCALD	95%
	RELEASED	CAPTURED	DESCALD		CONFIDENCE INTERVAL
1	200	129	1	0.8	<b>0.2-4.2</b>
2	200	132	2	1.5	<b>0.2-5.4</b>
3	200	102	1	1.0	<b>0.0-5.3</b>
<b>TOTAL</b>	<b>600</b>	<b>363</b>	<b>4</b>	1.1	<b>0.3-2.8</b>

**TABLE A.13. Descaling and Mortality Data from Release and Capture Tests with Spring Chinook Salmon, *Oncorhynchus tshawytscha*, Smolts at the Richland Canal Fish Screening Facility, Spring 1986 (E. S. = electroshocker and I. P. = inclined plane)**

TFST SITE	CAPTURE METHOD	FLOW (m <sup>3</sup> /sec, cfs)	NUMER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
			RELEASED	CAPTURED	DESCALED		
Pipe	Fyke	0.3, 10	90	58	2	3.5	0.4-11.9
Pipe	Fyke	0.3, 10	90	37	1	2.7	0.1-14.2
Pipe	Fyke	0.3, 10	90	29	0	0.0	0.0-12.0
<b>TOTAL</b>			270	124	3	2.4	0.5-06.9
Pipe	Fyke	<b>0.6</b> , 10	90	75	14	18.7	10.6-29.3
Pipe	E. S.	0.3, 10	110	107	2	1.9	0.2-06.6
Pipe	E. S.	0.6, 10	210	106	0	0.0	0.0-03.4
Trash rack			200	186	2	1.1	0.1-03.8
Trash rack			<b>200</b>	189	2	1.1	0.1-03.8
Trash rack			200	185	0	0.0	0.0-02.0
<b>TOTAL</b>			<b>600</b>	<b>560</b>	4	0.7	0.2-01.8

**TABLE A. 14. Estimated Time (hr) to Catch 50% and 95% of Test Fish Captured at Richland Canal Fish Screening Facility, Spring 1986**

SPECIES	GROUP	TIME TO CATCH		NUMBER OF FISH		PERCENT RECOVERY
		50%	95%	RELEASED	CAUGHT	
<b>Steelhead</b>	1		52.5	200	129	64.5
<b>Steelhead</b>	2	<b>21.0</b>	48.0	200	134	67.0
<b>Steelhead</b>	3	29.0	54.5	200	102	51.0
<b>Spring Chinook</b>	1	0.5	6.5	200	186	93.0
<b>Spring Chinook</b>	2	1.0	5.0	200	188	94.0
<b>Spring Chinook</b>	3	1.0	3.5	200	185	92.5
<b>Fall Chinook</b>	1	<b>9.5</b>	34.5	1000	638	63.8
<b>Fall Chinook</b>	2	8.5	32.0	1150	682	59.3
<b>Fall Chinook</b>	3	7.0	31.0	1150	809	70.3

**TABLE A. 15. Scale Condition of Upriver Salmonids Captured at the Richland Canal Fish Screen Facility, Spring 1986**

SPECIES	NUMBER OF FISH		FISH % DESCALED	95%
	CAUGHT	DESCALED		CONFIDENCE INTERVAL
<b>Chinook Salmon</b> <sup>(a)</sup>	<b>64</b>	3	4.7	1.0-11.0
<b>Coho</b>	<b>17</b>	3	17.7	3.8-48.0
<b>Steelhead</b>	<b>51</b>	3	5.9	1.3-18.9

(a) **Primarily spring chinook salmon (>10cm), but includes some fall chinook salmon (<10 cm).**

TABLE A.16. Percentage of Steelhead, *Salmo gairdneri*, Smolts Descaled Before Being Used in Tests at Toppenish/Satus Canal Fish Screening Facility, Spring 1986

TEST REPLICATE	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1	103	103	37	35.9	26.7-46.0
2	103	103	29	28.2	19.7-37.9
3	105	105	16	15.2	9.0-23.6
TOTAL	311	311	82	26.4	22.0-32.9

TABLE A.17. Descaling and Mortality Data from Release and Capture Tests with Steelhead, *Salmo gairdneri*, Smolts at the Toppenish/Satus Canal Fish Screening Facility, Spring 1986

TEST GROUP	NUMBER OF FISH			FISH % DESCALED	95% CONFIDENCE INTERVAL
	RELEASED	CAPTURED	DESCALED		
1	520	462	120	26.0	23.1-31.3
2	520	463	102	22.0	19.4-27.1
3	520	463	40	8.6	6.2-11.6
TOTAL	1560	1388	262	18.9	17.4-21.6

**TABLE A.18. Estimated Time (hr) to Catch 50% and 95% of Test Fish Captured at Toppenish/Satus Canal Fish Screening Facility, Spring 1986**

SPECIES	GROUP	TIME TO CATCH		NUMBER OF FISH		PERCENT RECOVERY
		50%	95%	RELEASED	CAUGHT	
<b>Steelhead</b>	1	<b>12.5</b>	41	520	462	88.8
<b>Steelhead</b>	2	12	46.5	520	464	89.2
<b>Steelhead</b>	3	10	42.5	520	463	89.0
<b>Spring chinook</b>	1	0.5	1.5	360	356	<b>98.9</b>
<b>Spring chinook</b>	2	0.5	1.5	335	329	<b>98.2</b>
<b>Spring chinook</b>	3	0.5	1.5	335	314	<b>93.7</b>
<b>Fall chinook</b>	1	<0.5	<0.5	<b>1000</b>	728	72.8
<b>Fall chinook</b>	2	<0.5	<0.5	<b>1000</b>	702	70.2
<b>Fall chinook</b>	3	<0.5	<0.5	460	330	71.7

**TABLE A.19. Descaling Condition of Upriver Salmonids Captured During Tests at Toppenish/Satus Canal Fish Screening Facility, Spring 1986**

SPECIES	NUMBER OF FISH		FISH % DESCALED	95% CONFIDENCE INTERVAL
	CAUGHT	DESCALED		
<b>Steelhead (1-age)</b>	20	0	0	0.0-16.8
<b>Steelhead (0-age)</b>	<b>69</b>	<b>0</b>	<b>0</b>	0.0-05.2
<b>Coho (1-age)</b>	29	0	0	0.0-12.0
<b>Chinook Salmon</b>	25	1	4	0.1-20.4

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