A FISHERIES EVALUATION OF THE WESTSIDE DITCH AND WAPATO CANAL FISH SCREENING FACILITIES

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Annual Report

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PREFACE

The Bonneville Power Administration, the United States Bureau of Reclamation, and the Washington State Department of Ecology are funding the construction and evaluation of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin, Washington State. This construction implements Sections 903 (d) and 803 (b) of the Northwest Power Planning Council's 1984 and 1987 Columbia River Basin Fish and Wildlife Programs.[1] The programs provide offsite enhancement to compensate for fish and wildlife losses caused by hydroelectric development throughout the Columbia River Basin, and they address natural propagation of salmon to help mitigate the impact of irrigation in the Yakima River Basin.

The Westside Ditch and Wapato Screens are two of the juvenile screening facilities. This report evaluates the effectiveness of the screens facilities for intercepting and returning juvenile salmonids unharmed to the Yakima River from which they were diverted. Studies were conducted in which fish were released upstream of or within the screen facilities and captured in the diversion that transfers them back to the river. Results indicated that the screens safely diverted fish from the canals to the river.

The study emphasized salmonids. Test fish were steelhead Oncorhynchus mykiss smolts, spring chinook salmon *O. tshawytscha* smolts, and rainbow trout *O. mykiss* fry. Evaluations were conducted during typical spring flows in the diversion.

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[a]NPPC (Northwest Power Planning Council). 1984. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.
NPPC (Northwest Power Planning Council). 1987. Columbia River Basin Fish and Wildlife Program. Northwest Power Planning Council, Portland, Oregon.

ACKNOWLEDGMENTS

The involvement and cooperation of many people during these studies were greatly appreciated. Thomas J. Clune, Bonneville Power Administration, was the Project Manager. Chuck Keller and Ed Spegler, Bureau of Reclamation, and their operations and maintenance staffs provided critical support and assistance during site preparation and data collection. Jack Whitehurst, Westside Irrigation Company, helped with the flow adjustments and maintenance we needed at Westside. Jim Cummins and Jim Lee, Washington Department of Wildlife, and Bill James, Washington Department of Fisheries helped with the procurement of test fish. Jeanne Simpson and Sally Wampler helped with the statistical analysis. Bill Hanf, Dennis Dauble, and Pete Test helped conduct the field tests. The manuscript was reviewed by Andy Plymale and Dennis Dauble.

ABSTRACT

We evaluated the effectiveness of new fish screening facilities in the Westside Ditch and Wapato Canal in south-central Washington State. The screen integrity tests indicated that test fish released in front of the screens could enter the canal behind the screens. At Westside Ditch, between 6% and 25% of the zero-age fry passed through the rotary drum screens. The 6% estimate is based on tests with rainbow trout Oncorhynchus mykiss fry. The 25% estimate is based on monitoring chinook salmon O. tshawytscha fry that were diverted from the river into the irrigation ditch.

At Westside Ditch, we estimated that 1.8% of steelhead O. mykiss smolts and 0.3% of chinook salmon smolts

released during tests were descaled. The time required for 50% of the test fish to exit from the Westside Ditch Screen forebay was 3 to 8 h for chinook salmon smolts and up to 28 h for steelhead smolts.

Methods used in 1988 were first used at Sunnyside in 1985 and were used in subsequent years at Richland, Toppenish/Satus, Wapato, and Toppenish Creek. The methods and 1985 through 1987 results have been reviewed by the Washington State Department of Fisheries, U.S. Fish and Wildlife Service, National Marine Fisheries Service, Northwest Power Planning Council, and the Yakima Indian Nation.

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INTRODUCTION

The Yakima River Basin historically has supported significant runs of salmonids. During the late 1800s, between 500,000 and 600,000 adult salmon and steelhead *Oncorhynchus* spp. returned to the Yakima River and its tributaries (Bureau of Reclamation 1984). Runs of salmon included several races: spring, summer, and fall chinook salmon *O. tshawytscha*, coho salmon *O. kisutch*, sockeye salmon *O. nerka*, and steelhead *O. mykiss*.

Some of the runs now are extinct or near extinction. Spawning escapement averaged about 2000 salmonids in the early 1980s (Bureau of Reclamation 1984). There is no sockeye run in the Yakima River Basin today, and only 37 coho salmon passed the Prosser Diversion Dam in 1983 (Hollowed 1984). Recent improvements in efforts to manage and enhance salmonid runs in the Yakima River increased the total spawning escapement to between 5,000 and 10,000 adults in the mid-1980s (Fast et al. 1986).

Reduced numbers of salmonids returning to the Yakima River Basin result from many factors. Spawning and rearing habitat is less because reduced in-stream flow downstream of irrigation diversion dams. Ineffective fish passage facilities for adults and juveniles at diversion dams cause high 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 to enable preparation and implementation of a regional Conservation and Electric Power Plan. The Northwest Power Planning Council administers the Plan, and is charged with developing a program to protect and enhance fish and wildlife populations and to mitigate adverse effects from development, operation, and management of hydroelectric facilities.

The Yakima River Basin was selected as one site for enhancement of salmon and steelhead runs. Under the Plan, the Bonneville Power Administration (BPA) and the Bureau of Reclamation (BR) are funding the construction of fish passage and protection facilities at irrigation and hydroelectric diversions in the Yakima River Basin (Figure 1). BPA is also providing funds to the Yakima Indian Nation to increase production of spring chinook salmon in the Yakima River Basin.

The Westside Ditch and Wapato Canal Fish Screening Facilities (Westside and Wapato Screens) are part of the passage and protection facilities being constructed in the Yakima River Basin by BPA and BR. Construction of the Wapato and Westside Screens was completed in 1985 and 1989, respectively. BPA asked the Pacific Northwest Laboratory (PNL) to evaluate the effectiveness of these diversion facilities in returning to the river fish that had entered the canals.

This report covers work by PNL fisheries staff at the Westside and Wapato Screens in 1989. It describes each screen facility, methods used to evaluate the effectiveness of the screens, and test results. Our findings are discussed and compared with results from previous tests at the Sunnyside Screens (Neitzel et al. 1985), at the Richland and Toppenish/Satus Screens (Neitzel et al. 1986), at the Richland and Wapato Screens (Neitzel et al. 1988), and at the Toppenish Creek, Wapato, and Sunnyside Screens (Neitzel et al. 1990). The report includes two appendices. Appendix A is a description of the work plan prepared to guide the evaluations and to associate specific objectives with the methods used during the evaluations. Appendix B lists tables of the data collected at the Sunnyside Screens in 1985, the Richland and Toppenish/Satus Screens in 1986, the Richland and Wapato Screens in 1987, the Wapato, Sunnyside and Toppenish Creek screens in 1988, and the Westside and Wapato Screens in 1989.

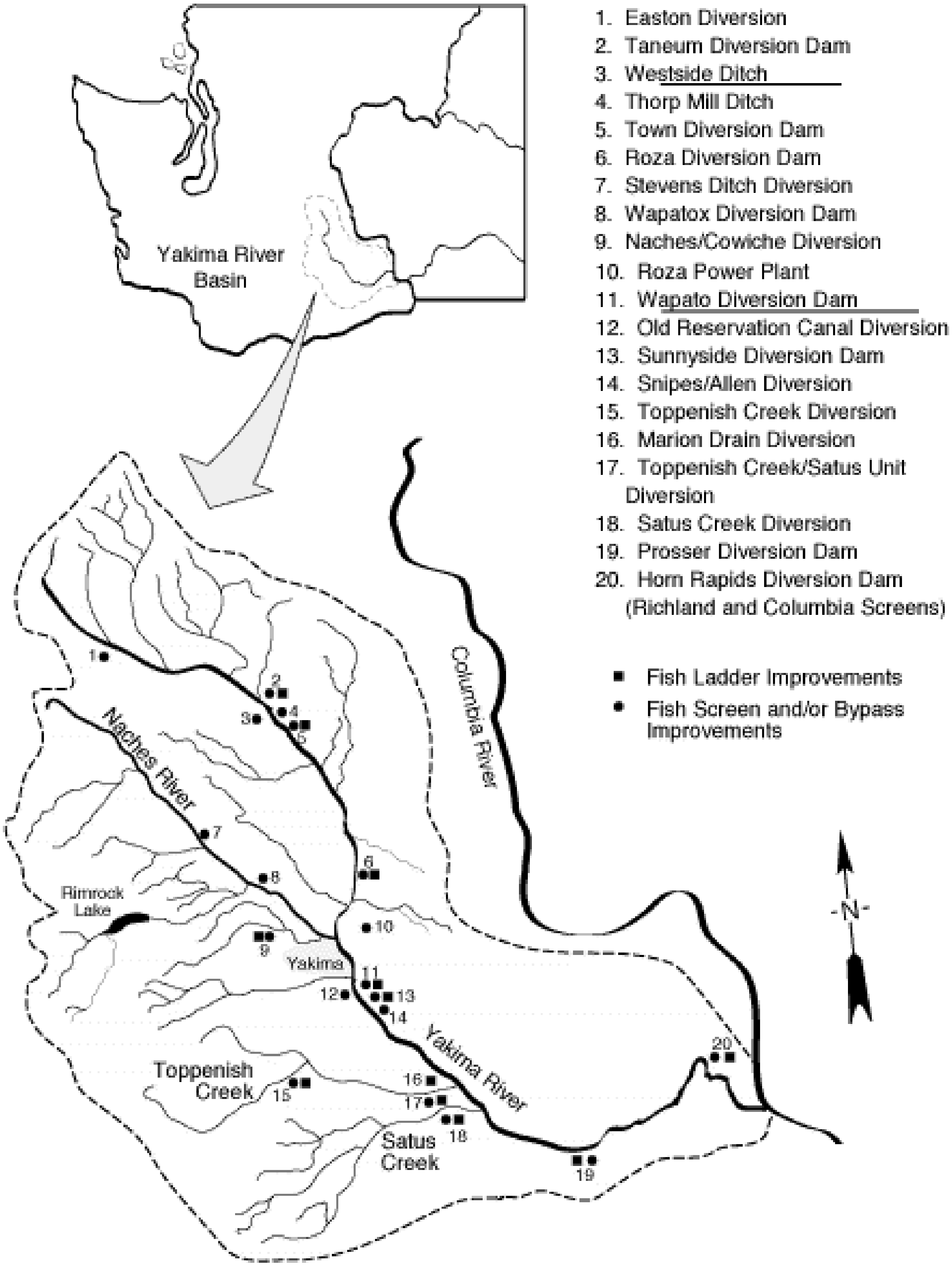


FIGURE 1. Yakima River Basin, Including Locations of the Westside Ditch and Wapato Canal Fish Screening Facilities and Other Fish Protection and Passage Facilities

DESCRIPTION OF THE STUDY AREAS

During 1989, studies were conducted at the Wapato and Westside Ditch screening facilities. Tests were conducted on the fish return pipe at the Wapato Screens. The study area for the Westside Ditch Screens included the canal upstream of the screens, the screens forebay, and the canal behind the screens. Specific conditions tested during the evaluations are reported in the Results and Discussion sections.

WESTSIDE DITCH CANAL

The Westside Ditch Diversion is located on the Yakima River at river km 267.4 [river mile (RM) 166.2], near Thorpe, Washington. Water is diverted from the Yakima River into the Westside Ditch Canal. The carrying capacity of the canal is about 2.8 m3/s [100 cubic feet per second (cfs)]. Canal flow varies from 0.6 to 2.8 m3/s (20 to 100 cfs) and is regulated at the canal headgates located about 0.5 km upstream of the Westside Ditch Screens. The screening facility (Figures 2 and 3) diverts fish that have entered the canal and directs them back to the Yakima River. Trash racks located in front of the headgates "filter" out large debris that could damage the screens or interfere with flow control through the screen facility.

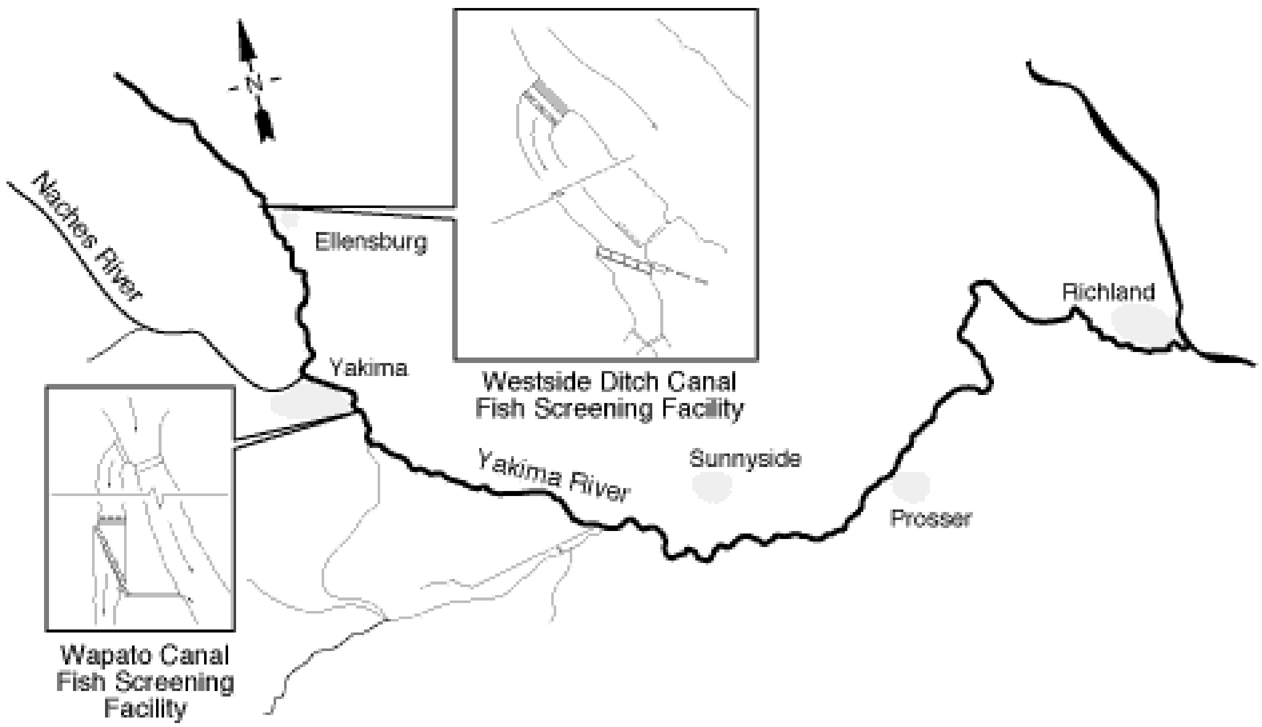


Figure 2. Yakima River Basin Showing Location of the Wapato Canal Fish Screening Facility and the Westside Ditch Canal Fish Screening Facility

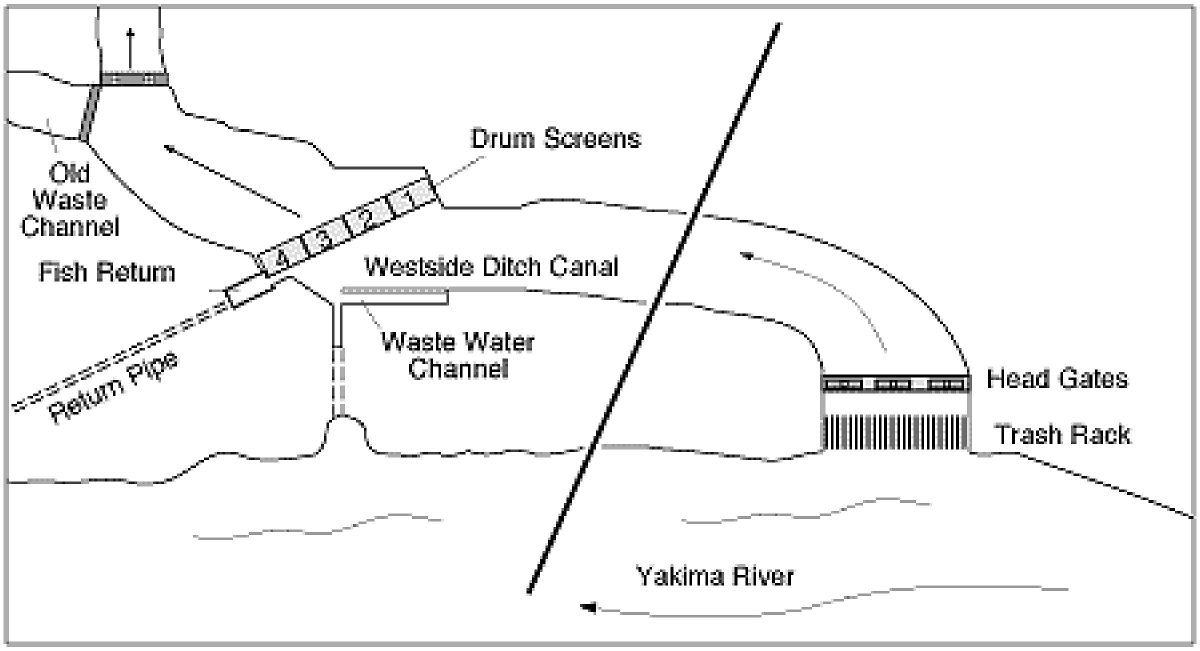


Figure 3. Flow Control Structure and Fish Bypass System in the Westside Ditch Canal Fish Screening Facility

The screening facility (Figure 3) houses four rotary drum screens with axes parallel to the length of the structure. Each screen is about 3.7 m (12 ft) long and 1.8 m (6 ft) in diameter. Screen mesh openings are 3.2 mm (1/8 in.). Water depth at the screens is maintained at about 1.6 m (5 ft). The fish bypass is located in the flow control structure at the downstream end of the screening facility. Water and fish diverted past the front of the screens pass through the fish bypass slot and out the fish return pipe. Flow through the fish return is 0.6 m^3/s (20 cfs). A waste water channel is installed along the forebay wall opposite the drum screens to prevent flooding and canal bank erosion. No water flows out the waste water channel at normal canal forebay level.

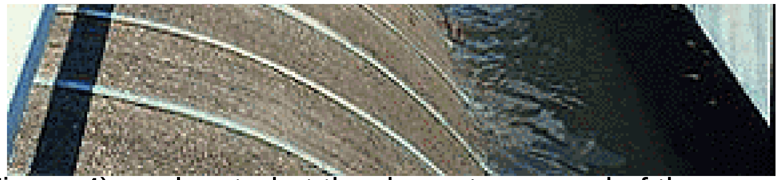
The rotary screens are installed at an angle of 26° to canal flow. This orientation is designed to provide a sweeping-velocity-to-approach-velocity ratio equal to or exceeding 2:1 (Easterbrooks 1984). The maximum allowable approach velocity is 0.15 m/s (0.5 fps). Screen orientation and flow velocity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

WAPATO CANAL

The Wapato Diversion (Figure 2) is located at river km 172 (RM 106.7) on the Yakima River. The diversion directs water from the Yakima River into the Wapato Canal. Canal operation begins in early March and continues through the irrigation season, usually until mid-October. Canal capacity is about 57 m3/s (2000 cfs).

The Wapato Canal Fish Screening Facility (Wapato Screens) is located about 1 km downstream of the headgates of the Wapato Canal. The screening facility (Figure 4) diverts fish entering the canal and directs them back to the Yakima River.

The trash racks from the old screening facility, immediately upstream of the new Wapato Screens, are used to "filter" out debris entering the canal. The screening facility houses 15 rotary drum screens (Figure 4) with axes parallel to the length of the structure. Each screen is about 7.3 m (24 ft) long and 4.6 m (15 ft) in diameter. Water depth at the screens varies with canal flow; however, the depth across the face of the screens at full canal level is normally about 3.7 m (12 ft).



The flow control structure and the separation chamber (Figure 4) are located at the downstream end of the screen facility. Two fish bypass pipes and the terminal bypass, each with a flow of about 1.4 m3/s (50 cfs), feed into the separation chamber. During normal operation, about 4.2 m3/s (150 cfs) of water enter the separation chamber. About 0.9 m3/s (30 cfs) of water and all fish that are diverted in front of the screens pass through the flow control structure and out the fish return pipe. Two bypass water return pumps, each with a pumping capacity of 1.4 m3/s (50 cfs), are located behind traveling screens near the terminus of the separation chamber. The traveling screens are equipped with screen washers to prevent fish and debris from being entrained in the pumpback system.

The pumpback system is not used during normal operation. Adequate flows are maintained in the fish bypass by discharging 3.4 m3/s (120 cfs) of water back to the Yakima River over adjustable weirs in the pump basin. When the pumps are operating, flow over the weirs is reduced. Thus, bypass flows are achieved by adjusting weirs in each fish bypass (Gates 1, 2, and 3), the fish return (Gate 4), and the two weirs behind the pump intakes (Gates 5 and 6).

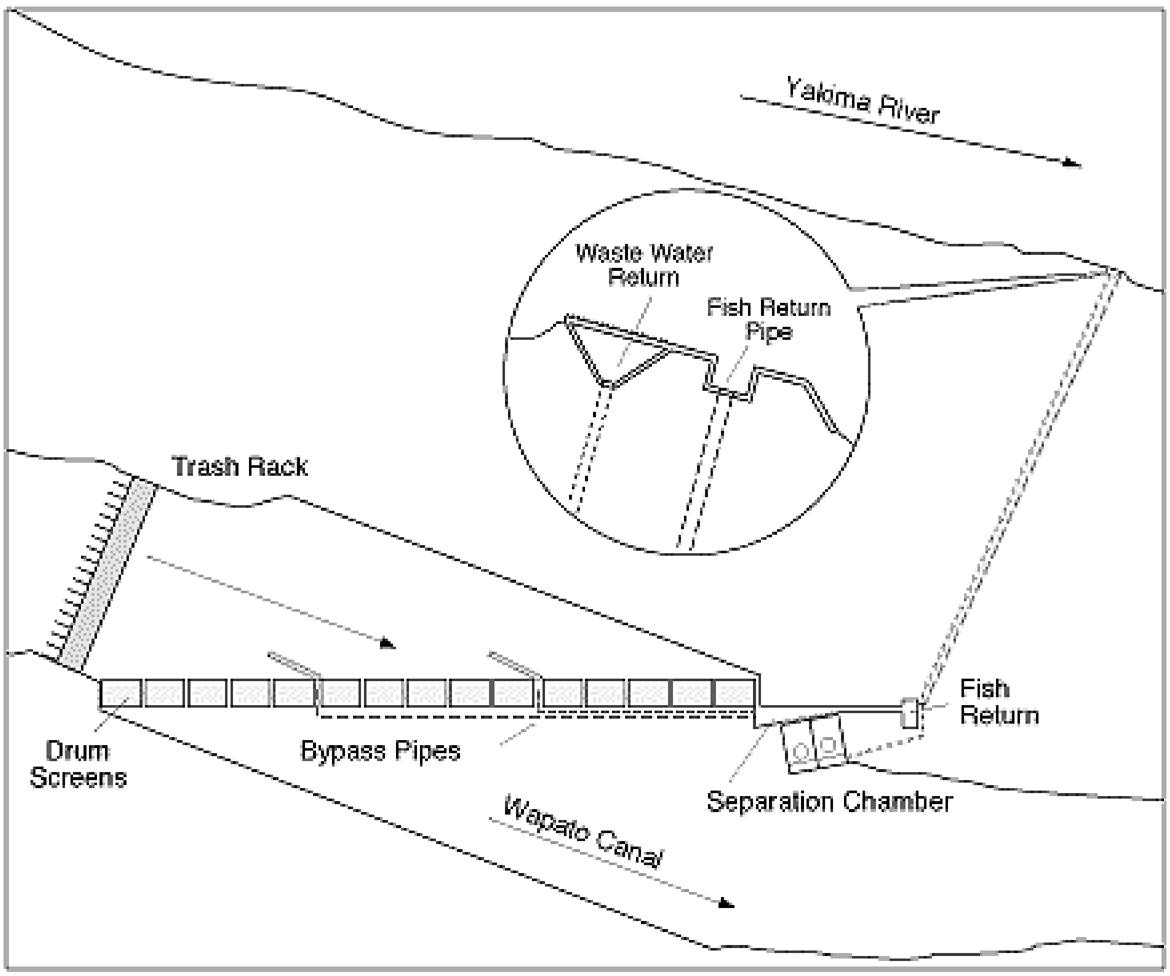


Figure 4. Flow Control Structure and Fish Bypass System in the Wapato Canal Fish Screening Facility

METHODS

Two types of tests were conducted in 1989: descaling (Phase II) tests and screen integrity (Phase IV) tests. In Phase IIb tests at the Wapato Screens, fish were released at the head of the fish return pipe and captured at the terminus of the pipe. In Phase IIa tests at the Westside Ditch, fish were released in the canal upstream of the screening facility and captured as they entered the fish return. Some test fish were held for post-test observation. Native salmonids entering the Westside Ditch Canal were monitored during release/capture tests. In Phase IV tests at the Westside Ditch Canal, fish were released both in front of and behind the screens and were captured as they appeared in the primary fish return or in fyke nets mounted behind the drum screens.

TEST FISH

The species of fish selected for tests were recommended by fisheries biologists from the Washington State Department of Fisheries (WDF), U.S. Fish and Wildlife Service (USFWS), and the Yakima Indian Nation (YIN). The species were selected based on the potential impact of an irrigation diversion on specific salmonid populations likely to encounter each screening facility during the rearing and outmigration period. Therefore, the selection was dependent on the species, race, and size of salmonids occurring in the Yakima River drainage upstream of each diversion.

Spring chinook salmon smolts were used in Phase IIb tests at the Wapato Screens. The pipe tests repeated previous work conducted at the Wapato Screens (Neitzel et al., 1988). Spring chinook salmon, resident rainbow trout, and possibly steelhead utilize the Yakima river upstream of the Westside Ditch diversion. Spring chinook salmon and steelhead smolts were selected for Phase IIa tests and rainbow trout fry (<50 mm) were used in Phase IV tests at the Westside Ditch Screens.

Steelhead

Juvenile steelhead were obtained from the Washington Department of Wildlife (WDW) Yakima Trout Hatchery in Yakima, Washington. The steelhead were progeny of native steelhead captured at the Prosser fish trap on the Yakima River. The fish were transported to PNL in November, 1988, and were reared throughout the winter in a mixture of ambient Columbia River water and well water. Fish were branded and acclimated to temperatures expected at the Westside Ditch Screens at least 1 week before release. The fish weighed about 22 fish/kg (10 fish/lb) when released in out tests.

Rainbow Trout

Rainbow trout fry, used in the Westside Ditch Screens integrity tests, were obtained from PNL brood stock spawned in December 1988. Eggs were hatched in vertical flow incubators supplied with 10°C well water. Fry were transferred to troughs and reared at 10°C until testing commenced. Rainbow trout fry used in tests at the Westside Ditch Screens averaged 49 mm fork length (FL) and were branded at least one week prior to release.

Spring Chinook Salmon

Yearling spring chinook salmon were obtained from the Leavenworth National Hatchery in Leavenworth, Washington. The fish were transported to PNL in February 1988, and held in ambient Columbia River water until used in pipe tests at the Wapato Screens. Fish used in Phase IIa tests at the Westside Ditch Screens were branded at least 1 week before release. The fish weighed about 35 fish/kg (16 fish/lb) when released.

SAMPLING EQUPIMENT

Fish were captured within the screening facility, at the terminus of the primary fish return pipe, and in the canal behind the screens, based on the objectives of each test. An inclined plane was custom-built to fit the fish bypass structure at the Westside Ditch Screens. A fyke net was used to collect fish at the terminus of the Wapato Screens fish return pipe, and fyke nets were mounted in stoplog slots behind the rotary drum screens to collect fish at the Westside Ditch Screens. Temporary fish-holding facilities were installed at the Westside Ditch Screens to acclimate and hold test fish.

Inclined Plane

Fish were captured by placing an inclined plane in the fish return between the last rotary drum screen and the head of the fish return pipe. The inclined plane used at the Westside Ditch Screens (Figure 5) was 2.1 m (7.0 ft) long and 1.0 m (3.3 ft) wide. The front face of the plane was hinged so that the slope of the plane could be changed to adjust the flow of water reaching the fish live box. Solid walls, tapering from 0.9 m (3 ft) at the entrance to 0.41 m (1.3 ft) at the live box, acted as splash guards to reduce fish loss from the plane. A live box [0.38 m (1.3 ft) long by 1.0 m (3.3 ft) wide, 100 l (26 gal) volume] was fastened at the end of the inclined plane. The inclined plane had an aluminum frame covered with a perforated aluminum sheet [0.32-cm- (1/8-in.-) diameter holes, staggered centers, 40% open]. Flow was directed over the plane surface by inserting dam boards in the upstream stoplog slot in the fish bypass slot. The height of the dam boards relative to the water depth determined the water volume through the fish bypass.

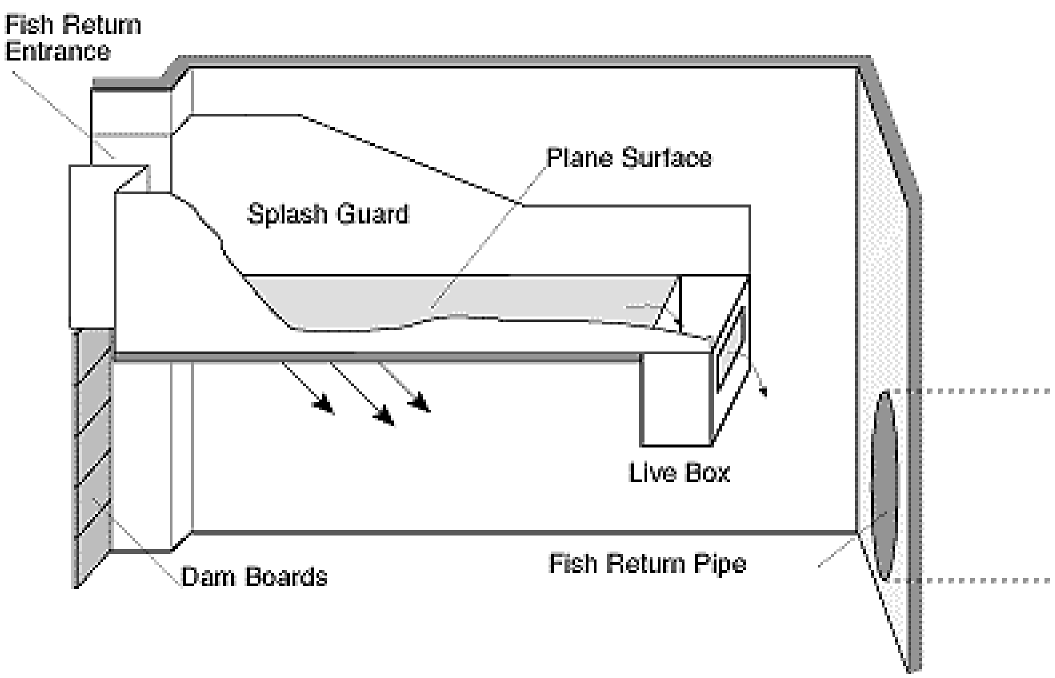


Figure 5. Inclined Plane Used at the Westside Ditch Canal Fish Screening Facility, Spring 1989

Fyke Net

The fyke net used for pipe tests at the Wapato Screens was attached to a frame that fit into slots in the concrete structure at the terminus of the fish return pipe (Figure 6). The frame was equipped with an adjustable solid metal wing that deflected flow from the waste water return and the Yakima River around the flow from the fish return pipe. The deflector was also used as an anchor point to prevent entanglement of the fyke net and to ensure that fish would not be harmed when exiting the fish return pipe. The net mouth was 1.0 m (3.3 ft) wide and 1.4 m (4.5 ft) tall and tapered to a 0.5-m-square cod end over a length of 4.9 m. A hoop net (1 m diameter, 4 m long) was fastened to the cod end net to provide additional holding area for fish, extending the length of the net to about 8 m (25 ft). The portion of the net attached to the deflector wing was constructed of solid vinyl sheeting to protect fish from net abrasion as they exited the fish return pipe.

Fyke nets were used behind each of the four drum screens in integrity tests at the Westside Ditch Screens. The mouths of the nets were 3.7 m (12 ft) wide and 1.8 m (6 ft) deep. The tops of the nets were above the water surface, and the bottoms of the nets settled into the mud on the canal floor. The net mouth tapered down to the 0.91-m- (3-ft) square mouth of the cod net over a length of 4.6 m (15 ft). The two sides of the net were of different lengths so that the net would hang parallel to canal flow without billowing on one side (Figure 7).

The cod net was 1.8 m (6 ft) long, resulting in an overall net length of 6.4 m (21 ft). The end of the cod net was tied shut. The nets were fished continuously during screen integrity tests, except for about 1 h intervals at the termination of each test, when the nets were raised from the water for fish retrieval and net cleaning.

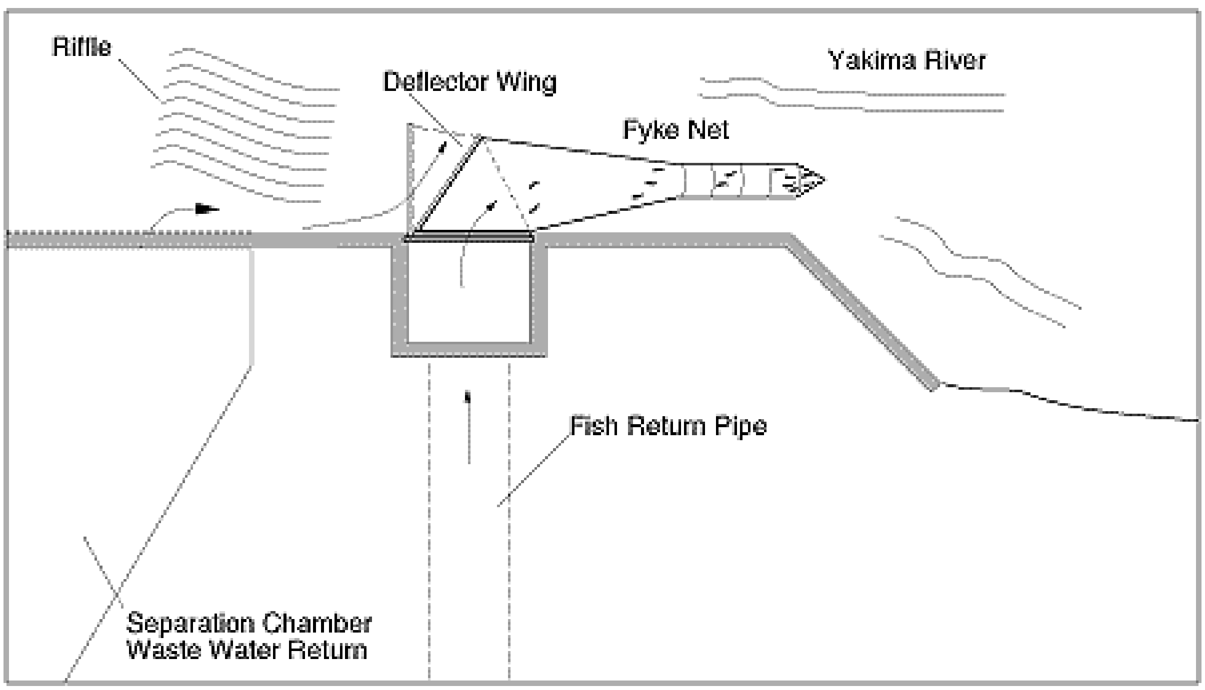


Figure 6. Fyke Net Used in Pipe Tests at the Wapato Screens, Spring 1989

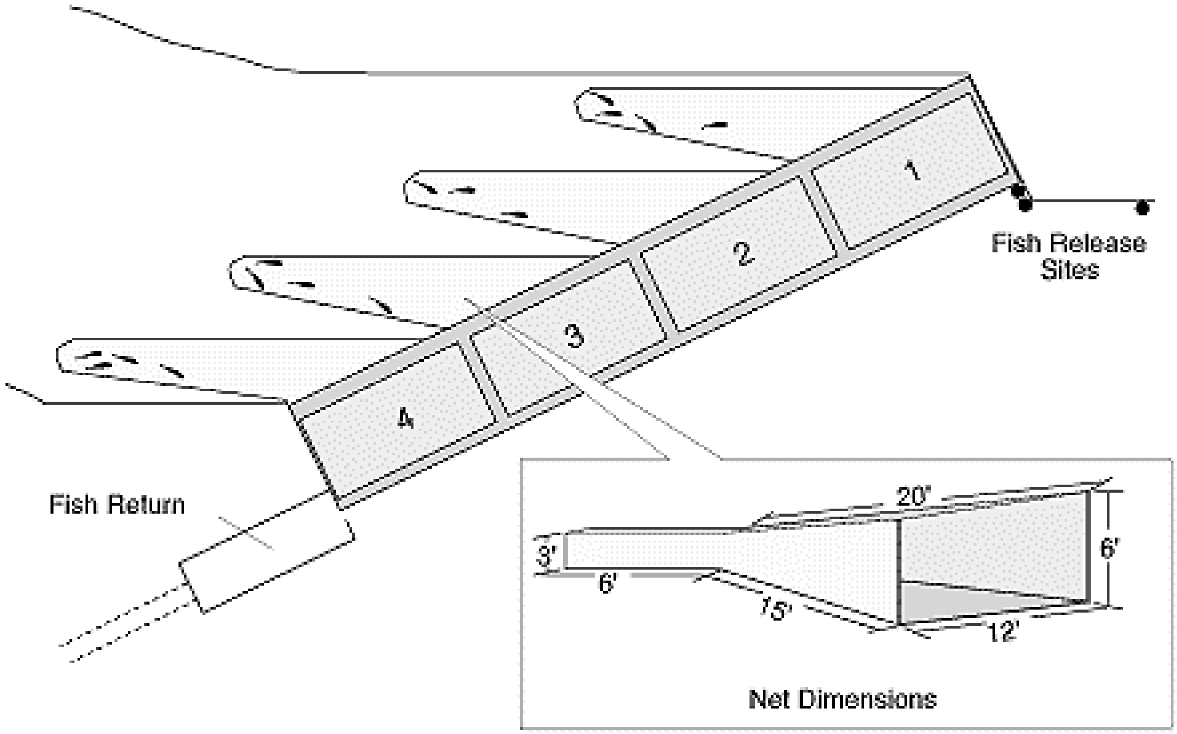


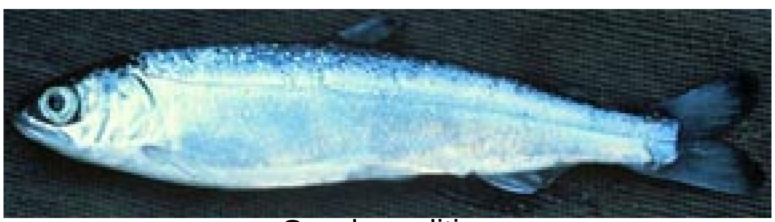
Figure 7. Fyke Nets Used in Integrity Tests at the Westside Ditch Screens, Spring 1989

HOLDING FACILITIES

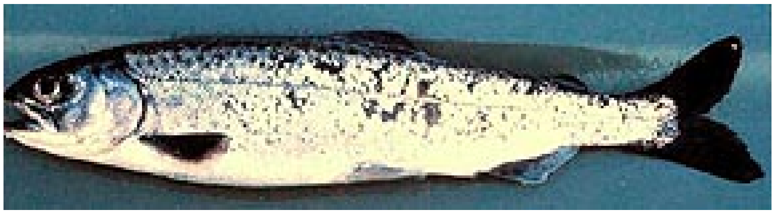
Temporary facilities were installed at the Westside Ditch Screens to hold fish during descaling evaluation and to retain some fish for 96 h after capture. A mobile laboratory containing three fiberglass troughs [3 m (10 ft) long by 0.6 m (1.8 ft) wide, 0.3 m (0.8 ft) deep, and 540 l (140 gal) in volume], and two fiberglass circular tanks [1.22 m (4 ft) in diameter by 0.6 m (2 ft) deep] was moved onto the site. All tanks were supplied with canal water that was pumped from behind the screens. The mobile lab was equipped with fluorescent lighting so that fish captured during both the day and night could be evaluated for descaling under similar light conditions.

DESCALING EVALUATION

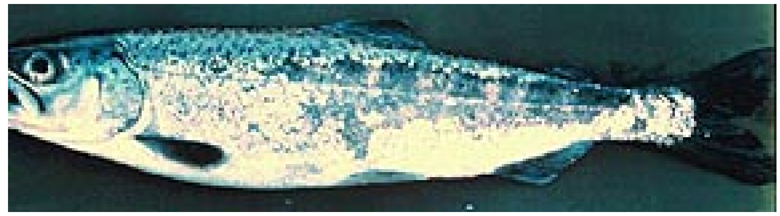
An evaluation system developed by the U.S. Army Corps of Engineers (Basham et al. 1982) was used to monitor the condition of fish at both sites. Evaluation criteria included modifications established in 1985 (Neitzel et al. 1985). Baseline descaling condition was determined by randomly sampling groups of test fish before their release. Descaling was evaluated in each of 10 areas, 5 on each side of the fish. When 40% or more scale loss was observed in any 2 areas on one side of a fish, the fish was classified as descaled.



Good condition



Partial descaling



Descaled

TEST PROCEDURE

Pipe tests at the Wapato Screens were accomplished by releasing spring chinook salmon smolts at the head of the fish return pipe and capturing them in a fyke net mounted on the terminus of the fish return pipe. The tests were conducted during the daytime when movement of native salmonids would not interfere with collection.

Descaling evaluations at the Westside Ditch Screens were made by introducing branded groups of steelhead and spring chinook salmon smolts into the canal upstream of the screening facility and capturing the fish when they appeared on the inclined plane in the primary fish return (Phase IIa, Appendix A). Tests were conducted during the last week in April. Flows were set and maintained near maximum canal flow. Native salmonid populations were monitored during tests at the Westside Ditch Screens (Phase IVa, Appendix A). Screen integrity tests were conducted at the Westside Ditch Screens by releasing branded groups of rainbow trout in front of and behind the rotary screens (Phase IVb, Appendix A). Fish were collected as they appeared either on the inclined plane in the fish return or in fyke nets placed in the canal behind the screens.

Test Stock Identification

Test fish were cold branded to identify specific test groups. Steelhead and spring chinook salmon were marked either in the right anterior or the right dorsal. The brands were applied at least 1 week before release. The brands used in our studies, approved by the National Marine Fisheries Service (NMFS), were distinguishable from all other brands used in the Columbia River Basin. Spring chinook salmon used in pipe tests at the Wapato Screens were not marked.

Fish Transport and Release

Test fish were transported at acclimation temperature in an insulated tank [400 l (125 gal) in volume] supplied with oxygen. Transit times from PNL to the Westside Ditch and Wapato screens were 2.5 h and 1.3 h, 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 and placed in holding tanks at the facility for acclimation before release into the canal for tests at the Westside Ditch Screens. Test fish used in pipe tests at the Wapato Screens were netted from the transport tank into buckets and poured directly into the head of the fish return pipe. No losses were attributable to transporting stress.

Fish Release Locations

Test fish for descaling evaluation at the Westside Ditch Screens were released from the north bank of the canal about 150 m upstream of the screening facility. Rainbow trout used in Phase IV tests at the Westside Ditch Screens were released just upstream of the first rotary screen near the structure wall (Figure 7) and uniformly across the mouth of the fyke nets positioned on the downstream side of the rotary screens. Fish were also released at the entrance to to the inclined plane to test gear efficiency and effect. In Phase IIb tests at the Wapato Screens, fish were released at the head of the fish return pipe, where the water falls over Gate 4 in the terminus of the fish return slot, and in the mouth of the fyke net mounted at the terminus of the fish return pipe.

Release Controls

The condition of test fish at the time of release (baseline condition) for fish used in Phase IIb tests at the Wapato Screens and in Phase IIa tests at the Westside Ditch Screens was estimated by sampling each group of test fish before release. Baseline condition evaluations were conducted under natural light conditions at the Wapato Screens, and inside the mobile laboratory under artificial light for Phase IIa tests at the Westside Ditch Screens. For Phase IIb tests at the Wapato Screens, 110 spring chinook salmon smolts were evaluated for baseline condition, 105 fish were evaluated to measure descaling caused by collection gear, and 150 were released at the head of the fish return pipe. For Phase II tests at the Westside Ditch Screens, 100 steelhead and 100 spring chinook salmon smolts were sampled for baseline condition, 60 steelhead and 70 spring chinook salmon were evaluated to measure descaling caused by collection gear, and 750 steelhead and 755 spring chinook salmon were released in front of the screens.

Fish Capture and Evaluation

Spring chinook salmon used in Phase IIb tests were recovered from the fyke net at the mouth of the Wapato Screens fish return 15 min after their release at the head of the fish return pipe. The cod end of the net was removed from the water, and the fish were transferred to a bucket and anesthetized in MS-222. The fish were examined to determine scale loss, then placed in another bucket to recover before being released into the Yakima River.

Fish captured during Phase IIa tests at the Westside Ditch Screens were netted from the live box of the inclined plane and placed in a holding tank before evaluation. Evaluations were made at half-hour intervals. The fish were anesthetized in MS-222, examined to determine the extent of scale loss, and returned to another holding tank. After fish recovered from the anesthetic, they were released into the fish return pipe. About 100 steelhead and 200 spring chinook salmon smolts were held for 96 h to monitor delayed mortality.

The purpose of Phase IVb tests was to determine the effectiveness of screening facilities in preventing fish from entering the canal behind the screens, and to monitor the rate at which fish moved through the fish bypass. Thus, fish captured in Phase IVb tests were not evaluated for descaling. Fish were identified by brand group and enumerated as they appeared on the inclined plane in the fish return. The brands identified when and where the fish were released within the screening facility.

The inclined plane was fished continuously during our tests at the Westside Ditch Screens. Groups of fish for Phase IVb tests were released in front of and behind the screens during the morning. The fyke nets were fished continuously for about 23 h following the release of test fish and then were raised for about 1 h to retrieve fish and to clean the nets. The nets were repositioned before the initiation of each test.

STATISTICAL ANALYSIS

Estimates are given for the percent of fish killed or descaled during the screen evaluations. The amount of time for test fish to move from their release point to the inclined plane is estimated from the hours required to capture 50% of a test group. The capture efficiency of the inclined plane and the fyke nets used during screen integrity tests are estimated using the number of fish captured during a test. The efficiency data are used to estimate the efficiency of the screen in preventing fish from passing from the screen forebay to the canal downstream of the screens.

Descaling and Mortality Estimates

Estimates of the percentage of fish descaled or killed were based on the number of test fish caught. Descaled fish were considered dead for evaluation of the results. The lower and upper confidence intervals, respectively, are estimated as

$$LCI = \frac{B}{B+(n-B+1)F}$$

and

$$UCI = 1 - \frac{n-B}{n-B[n-(n-B)+1]F}$$

where B equals the number of dead or descaled fish, n the number of fish caught, and F a ratio of the estimates for the mean sample variance and the individual sample variance. The 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 is necessary for the analytical methods used. All tests were conducted in the same manner to reduce non-independent behavior of fish.

Screen Efficiency Estimates

Three tests with four groups of fish were conducted at Westside Ditch. Screen efficiency estimates were computed for each test in addition to an overall estimate. Fyke nets were in place behind each screen for each test.

Two quantities are computed to estimate screen efficiency. They are inclined plane efficiency (EFF_{ip}) and net capture efficiency (EFF_{nc}). Net retention is assumed to be equal to net efficiency at Westside Ditch. Thus, net retention equals 1. Given this, the formula for computating of screen efficiency (EFF_{sc}) is

$$EFF_{sc} = 1 - \frac{X_{net}}{EFF_{nc}N}$$

where X_{net} equals the number of fish released upstream of the screens and caught in the nets, and N is defined as:

$$N = \frac{X_{net}}{EFF_{nc}} + \frac{X_{ip}}{EFF_{ip}}$$

where X_{ip} equals the number of fish released upstream of the screens and caught in the inclined plane. N represents of the total number of fish released into the section being estimated. For some estimates and the overall estimate, some fish are still not accounted for after the efficiencies (EFF_{ip} and EFF_{nc}) have been considered. To avoid making assumptions about what might have happened to these, an effective N has been computed that is smaller than the actual number released. It must be noted that N is not an actual accounting of all fish caught in different locations (inclined plane, fyke nets, bypass), but an estimate based on the actual numbers, adjusted by efficiencies for net losses and human error.

The efficiencies per set must now be defined. The input data for each section are as were explained, combining across relevant tests. The general forms are

$$EFF_{ip} = \frac{n_{ip}}{N_{ip}} \quad \text{and} \quad EFF_{nc} = \frac{n_{nc}}{N_{nc}}$$

where n_{ip} is the number of fish released in the bypass and caught in the inclined plane for the section being estimated, N_{ip} is the number released in the bypass, n_{nc} the number released in the net mouth and caught in the net, and N_{nc} the number released in the net mouth.

For the overall efficiency, it should be noted that individual test efficiencies are not simply averaged; rather, the efficiency is computed by combining all data. Averaging the separate tests would assume equal numbers were released in each test and weight them as such. By computing the overall estimates from all data lumped as one test, the varying N values are incorporated and differences in test size are compensated.

The confidence intervals were computed using the standard normal approximation method (Mood et al. 1974). For a 95% confidence interval

$$P\left[EFF_{sc} - 1.96\sqrt{var(EFF_{sc})} \leq \text{ true } [EFF_{sc}] \leq EFF_{sc} + 1.96\sqrt{var(EFF_{sc})}\right] = 0.95.$$

Here EFF_{sc} indicates our estimate while true [EFF_{sc}] indicates the true or actual value of the screen efficiency. EFF_{sc} is a binomial proportion, and the form for its variance is EFF_{sc} (1-EFF_{sc})/N. However, because we used efficiencies (EFF_{ip}, EFF_{nc}, EFF_{nr}) in the computation of EFF_{sc} with their own inherent errors, these errors must be propagated and incorporated into the variance of EFF_{sc}. If EFF_{ncr} is defined to be the combined catch and retain efficiency (EFF_{nc} x EFF_{nr}), then the variance of EFF_{sc} is

$$var\left[EFF_{sc}\right] = \left(\frac{\partial EFF_{sc}}{\partial Eff_{ncr}}\right)^2 var\left[EFF_{ncr}\right] + \left(\frac{\partial EFF_{sc}}{\partial EFF_{ip}}\right)^2 var\left[EFF_{ip}\right] + \left(\frac{\partial EFF_{sc}}{\partial X_{net}}\right)^2 var\left[X_{net}\right]$$

where all variables are as previously defined. This formula is the first term of a Taylor's series expansion (Holman 1971). Second-order and higher order effects have been neglected. The assumption is made that EFF_{ip} and X_{net} are independent of each other, which is reasonable in this case.

The variances of EFF_{ip} and EFF_{nc} were computed by assuming them to be binomial proportions and using the appropriate N for the section in the EFF(1-EFF)/N formula as stated previously. The variable X_{net}, the number of fish caught in the nets that were released upstream of the screens, is distributed binomial (N,EFF_{sc}), making its variance equal to N[EFF_{sc} (1-EFF_{sc})].

RESULTS

Fish that passed through the fish return pipe at the Wapato Screens or the fish bypass system at the Westside Ditch Screens were not descaled or killed. Fish were not "flushed" from the screen forebay at the Westside Ditch Screens, but moved out of their own volition. The angled rotary drum screen design prevented most fish from entering the canal behind the screens at Wapato. At Westside Ditch, chinook salmon fry were able to pass through, over, or around the screens. Data are presented as they relate to the objectives of each phase outlined in the work plan (Appendix A). A detailed summary of the catch data and estimates for percentage of test fish that were descaled or killed are presented in Appendix B.

PHASE I

Phase I tests are designed to evaluate components within the fish diversion system other than the rotary drum screens. The Westside Ditch Screens fish bypass system contains no structures other than the drum screens; therefore, no Phase I tests were conducted at the Westside Ditch Screens.

PHASE II

Phase II tests evaluated either the entire fish bypass system from the trash racks through the fish return pipe (Phase IIa) or specific components of the fish return system (Phase IIb). We initiated our evaluations with Phase IIa testing at the Westside Ditch Screens. We released fish into the canal upstream of the screening facility and captured them in the inclined plane before they entered the fish return pipe. In addition to collecting fish descaling and mortality data, we determined how long released fish remained upstream of or within the Westside Ditch Screens. Phase IIa and IIb tests were completed at the Wapato Screens in 1987 (Neitzel et al. 1988). Phase IIb tests were repeated at the Wapato Screens in 1989.

Phase IIa

Tests at the Westside Ditch Screens were conducted in late April. Two groups of branded steelhead and two groups of spring chinook salmon smolts were released in the canal upstream of the screens forebay. One group of steelhead and one group of spring chinook salmon (375 fish per group) were released during the morning, and two groups of fish (375 steelhead and 380 spring chinook salmon) were released in the evening. Of the groups released in the morning, 304 steelhead (81.1%) and 371 spring chinook salmon (98.9%) were captured on the inclined plane in the fish return during the next 96 h. Of the fish released in the evening, 321 steelhead (85.6%) and 379 spring chinook salmon (99.7%) were caught in the following 75 h. A total of 625 steelhead and 750 spring chinook salmon were examined for descaling, and 11 steelhead (1.8%) and 2 spring chinook salmon (0.3%) were descaled (Table 1). The descaling rates of 1.8% for steelhead and 0.3% for spring chinook salmon were well within the 95% confidence intervals for the condition controls (Appendix B). None of 104 steelhead and 204 spring chinook salmon held for 96 hr to monitor delayed mortality died.

TABLE 1. Descaling and Mortality Data from Release and Capture Tests with Steelhead *Oncorhynchus mykiss* and Spring Chinook O. *tshawytscha* Smolts at the Westside Ditch Fish Screening Facility, Spring 1989

SPECIES	GROUP	NUMBER RELEASED	NUMBER CAPTURED	NUMBER DESCALED	NUMBER DEAD	PERCENT CAPTURED	PERCENT DESCALED	95% CONFIDENCE INTERVAL
Steelhead	1	375	304	3	0	81.1	1.0	0-3
Steelhead	2	375	321	8	0	85.6	2.5	1-5
	TOTAL:	750	625	11	0	83.3	1.8	1-3
Chinook	1	375	371	0	0	98.9	0.0	1-0
Chinook	2	380	379	2	0	99.7	0.5	2-0
	TOTAL:	755	750	2	0	99.3	0.3	1-0
Rainbow	(Native)	-	16	0	0	-	0.00	0-21

The downstream movement of steelhead and spring chinook salmon released for descaling evaluations was monitored each half-hour as the fish appeared on our sampling plane in the fish return. The movement rate for steelhead (Figure 8, Table 2) indicates that salmonid smolts are not flushed from the Westside Ditch Screens forebay; rather, they move through the screen forebay of their own volition. Spring chinook salmon exited the screens forebay quickly (Figure 9, Table 2).

TABLE 2. Estimated Time to Capture 50% of Steelhead *Oncorhynchus mykiss* and Spring Chinook Salmon *O. tshawytscha* Smolts Released in Descaling Tests at the Westside Ditch Canal Fish Screening Facility, Spring 1989

SPECIES	GROUP	NUMBER RELEASED	NUMBER CAUGHT	PERCENT CAUGHT	TIME (h) TO CATCH 50%
Steelhead	1	375	304	81.1	12.5
Steelhead	2	375	321	85.6	28.1
Chinook	1	375	371	98.9	3.3
Chinook	2	380	379	99.7	7.8

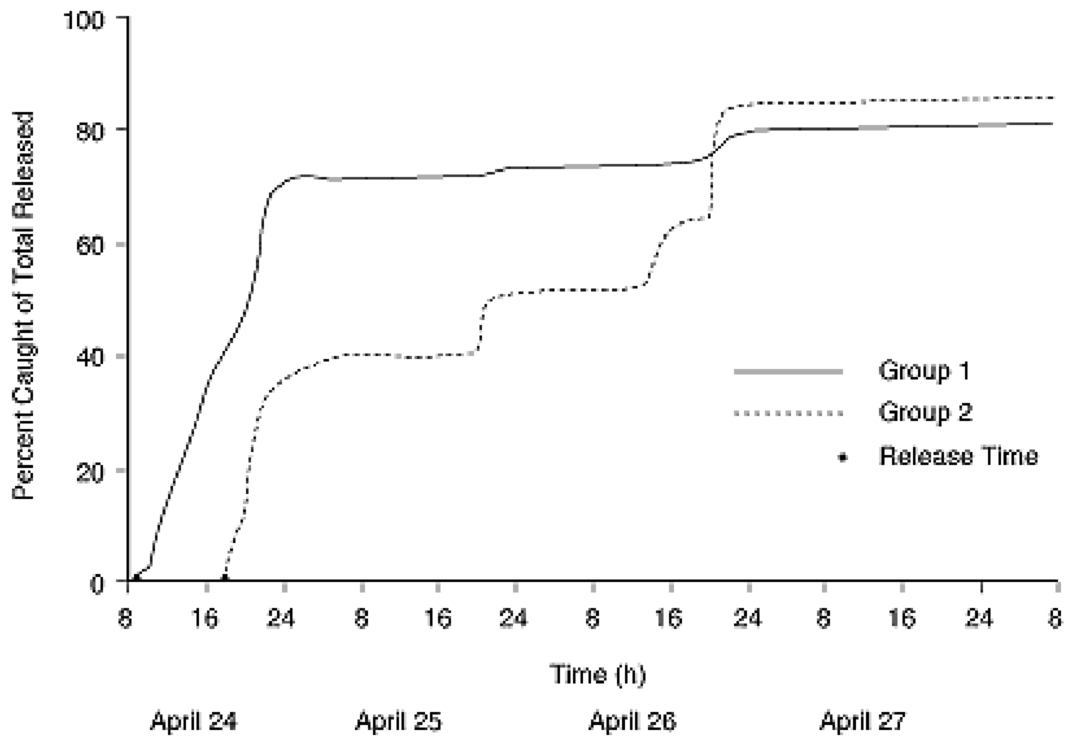


Figure 8. Movement of Steelhead *Oncorhynchus mykiss* Smolts Based on the Capture of Test Fish at the Westside Ditch Canal Fish Screening Facility, Spring 1989

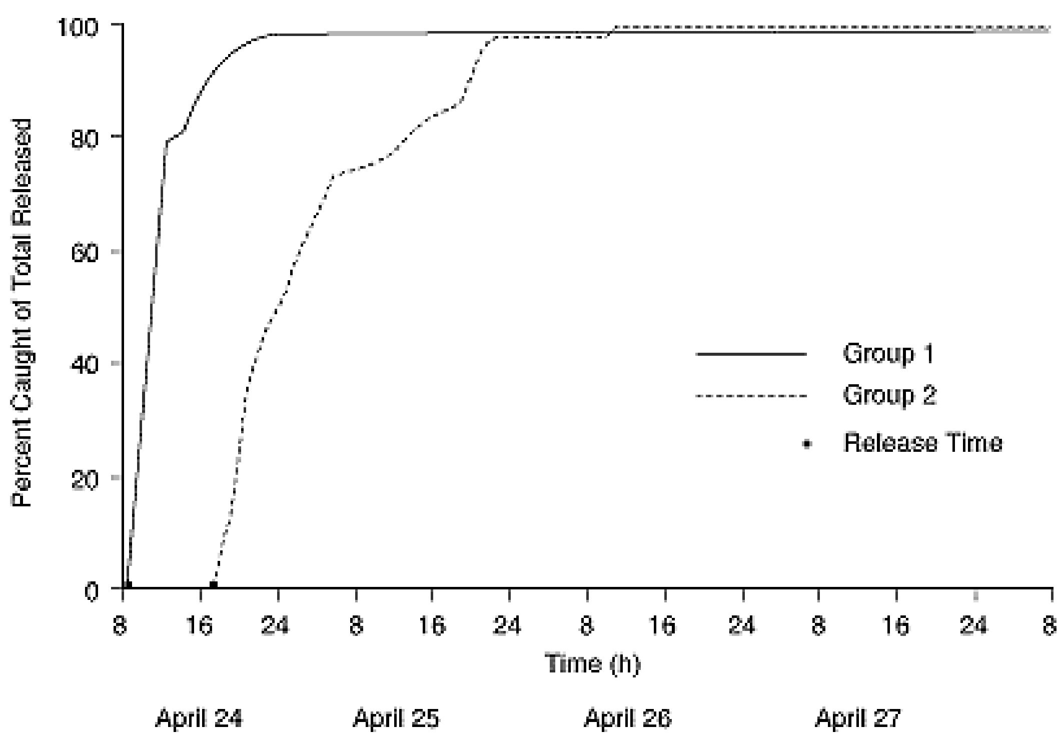


Figure 9. Movement of Spring Chinook Salmon *Oncorhynchus tshawytscha* Based on the Capture of Test Fish at the Westside Ditch Canal Fish Screening Facility, Spring 1989

Phase IIb

Because test fish were more easily captured at the flow control structure, the potential effect of passage through the fish return pipe was evaluated separately at the Wapato Canal. Because this was a test of a specific component of the fish return system, test results are presented as Phase IIb data.

Three groups of 50 spring chinook salmon were released at the head of the Wapato Screens fish return pipe. All of the fish were captured and evaluated for descaling, and none of the fish were descaled (Table 3).

TABLE 3. Percentage of Spring Chinook Salmon *Oncorhynchus tshawytscha* Smolts Descaled In Pipe Tests at the Wapato Canal Fish Screening Facility, Spring 1989

GROUP	NUMBER OF FISH RELEASED	NUMBER OF FISH CAPTURED	NUMBER OF FISH DESCALED	PERCENT DESCALED	95% CONFIDENCE INTERVAL
1	50	(a)	-	-	-
2	50	(a)	-	-	-
3	50	(a)	-	-	-
					-
TOTAL	150	152(b)	0	0	0-2

(a) Groups of 50 fish were released at the head of the fish return pipe at 3- to 6-min intervals. Because sampling at the end of the pipe was continuous, we were not able to determine capture or descaling rates for individual release groups.
(b) Two native chinook salmon were apparently captured that were indistinguishable from our test fish.

PHASE III

Phase III tests at the Wapato Screens were completed in 1987 (Neitzel et al. 1988) and were repeated this year. Tests at the Westside Ditch Screens were conducted about 1 week after the canal was filled, and flows were already near the maximum for the canal. No Phase III tests were conducted at the Westside Ditch Screens. Because operating criteria have not been formally submitted, we decided that the most meaningful data would result from tests where the canal is operated at near capacity.

PHASE IV

The inclined plane was used during release and capture tests to note the presence of predatory fish and the occurrence and condition of native salmonids. The drum screens were monitored to determine if fish were impinged. Rainbow trout fingerlings were released at the Westside Ditch Screens to test for possible passage through, around, or over the rotary drum screens. Additionally, passage of native chinook salmon fry was monitored.

Phase IVa

Few native juvenile salmonids were captured during tests at the Westside Ditch Screens; however, chinook salmon fry (<40 mm FL) were common. None of the 16 juvenile rainbow trout and/or steelhead and 1 spring chinook smolt we caught were descaled. The rainbow trout had not developed typical smolt characteristics and probably were not steelhead. Northern squawfish *Ptychocheilus oregonensis* and one yellow perch Perca flavescens were caught on the inclined plane during our tests, but no fish were found in their stomach contents.

Phase IVb

A total of 3143 rainbow trout fry (49.3 mm FL) were released in front of the screens and 2000 fry were released in the fyke nets behind the screens to evaluate screen effectiveness in preventing fish from entering the canal behind the screens. Of 3143 fish released in front of the screens, 508 (16.2%) were recovered in the fish return and 22 (0.8%) were recovered in fyke nets (Table 4). Of the 1200 branded rainbow trout fry (49.3 mm FL) and 800 unmarked fry (36.6 mm FL) released in fyke nets behind the drum screens, 714 (59.5%) and 523 (65.4%), respectively, were recovered from the fyke nets.

In addition to our test fish, 133 chinook salmon fry were caught in fyke nets behind the screens, compared to 650 fry caught on the inclined plane in the fish return during the same period (Table 5). Most of the chinook salmon fry caught on the inclined plane were captured at night. Fry were captured in fyke nets behind all four drum screens (Table 5).

The unmarked rainbow trout fry released in the mouths of fyke nets for the last two screen integrity tests were similar in girth but shorter than the chinook salmon fry. Capture rates for the small rainbow was similar to capture rates for the larger marked rainbow trout. Capture efficiency of the fyke nets varied from 56% to 79% (Table 6).

Based on the number of fish caught on the inclined plane and the capture efficiency of the fyke nets, about 6.0% (±0.35) of the rainbow trout released in front of the drum screens passed over, around, or through the drum screens. The 133 fall chinook fry captured in the fyke nets represented 17.0% of the total number of fry observed during our sampling period. When the fyke net capture efficiency for rainbow trout is applied to the chinook salmon capture data, we estimate 24.8% (±0.35) of chinook salmon fry in Westside Ditch passed over, around, or through the drum screens.

Approximately 83% of the rainbow trout fry that we planted in front of the screens were not recovered. Rainbow trout fry were not flushed from the Westside Ditch Screens forebay. Most of the fry held in the screens forebay; however, some fish were lost to predation by our test fish. Fish from each of the three release groups were caught throughout the duration of sampling, with movement increasing at sunset (Figure 10).

TABLE 4. Capture Data for Rainbow Trout Fry *Oncorhynchus mykiss* Released During Screen Integrity Tests at the Westside Ditch Canal Fish Screening Facility, Spring 1989

		Number of Control Fish				Number of Test Fish			
		Fyke Net		Plane			Captured In		
Test Group	Screen Number	Released	Captured	Released	Captured	Released	Plane	Fyke Net	Other
1	1-4	400	316	100	100	1047	140	6	5
2	1-4	800	448	100	99	1049	199	10	0
3	1-4	800	473	300	300	1047	169	6	6
Total		2000	1237	500	499	3143	508	22	11

TABLE 5. Capture Data for Chinook Salmon Fry *Oncorhynchus tshawytscha* Caught During Screen Integrity Tests at the Westside Ditch Canal Fish Screening Facility, Spring 1989

		CATCHES	
	SCREEN	FYKE NET	PLANE
TEST 1	1	2	227
	2	9	-
	3	14	-
	4	9	
TOTAL		34	227
TEST 2	1	4	217
	2	14	-
	3	16	-
	4	16	
TOTAL		50	217
TEST 3	1	5	206
	2	8	-
	3	23	-
	4	13	-
TOTAL		49	206
TOTAL NET 1:		11	
TOTAL NET 2:		31	
TOTAL NET 3:		53	
TOTAL NET 4:		38	
TOTAL		133	650

TABLE 6. Capture Efficiency of the Inclined Plane and Fyke Nets Used During Screen Integrity Tests at the Westside Ditch Canal Fish Screening Facility, Spring 1989

	CAPTURE PROBABILITY ESTIMATE		SCREEN	95% CONFIDENCE
TEST	INCLINED PLANE	FYKE NET	EFFICIENCY	INTERVAL
Rainbow Trout				
1	1.000	0.790	0.949	0.91-0.99
2	0.990	0.560	0.918	0.86-0.98
3	1.000	0.591	0.943	0.89-1.00
Total	0.998	0.619	0.935	0.90-0.97
Chinook Salmon				
1	1.000	0.790	0.841	0.79-0.89
2	0.990	0.560	0.711	0.65-0.78
3	1.000	0.591	0.713	0.65-0.78
Total	0.998	0.619	0.752	0.72-0.79

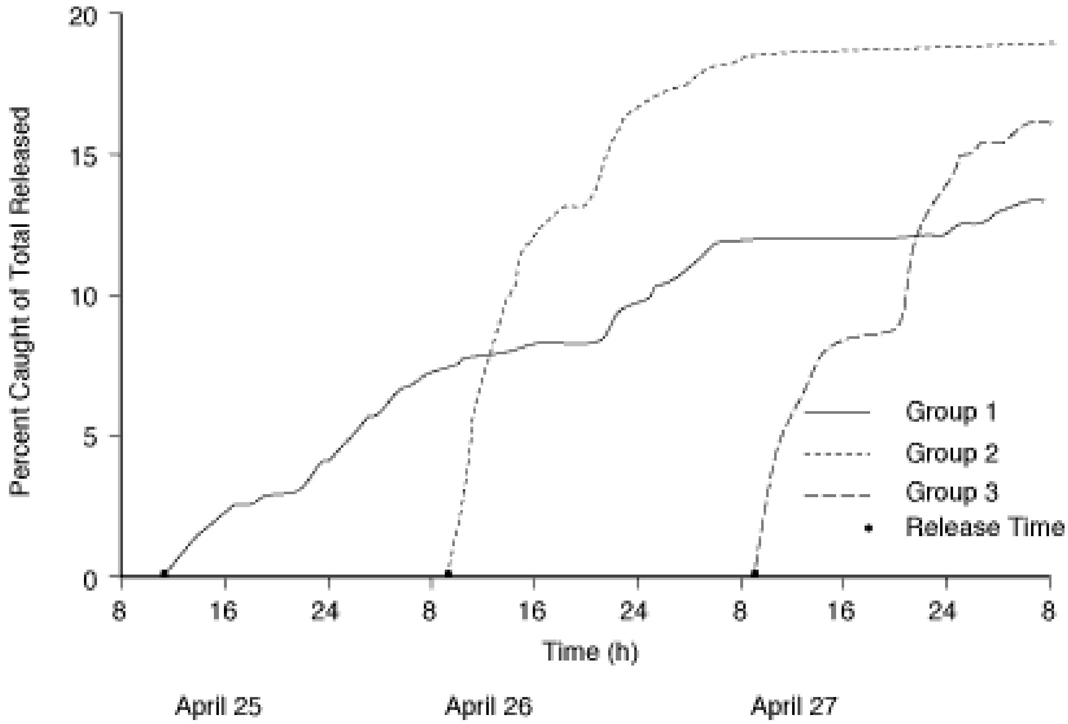


Figure 10. Movement of Rainbow Trout *Oncorhynchus mykiss* Fry Based on the Capture of Test Fish in the Bypass During Screen Integrity Tests at the Westside Ditch Canal Fish Screening Facility, Spring 1989

DISCUSSION

Fish screening facilities in the Yakima Basin are designed to direct fish that have been diverted from the river 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 were 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 drum screens and become trapped in the irrigation canal.

FISH SURVIVAL AT SCREENING FACILITIES

Based on release/capture tests at six screening facilities, fish are not descaled or killed during passage in front of the rotary drum screens or through the fish bypass systems. As in previous descaling evaluations at the Sunnyside, Richland, Toppenish/Satus, Toppenish Creek, and Wapato Screens, the descaling rate for test fish at the Westside Ditch Screens within the confidence limits for control fish.

Fish were not injured from passing through the fish return pipe at the Wapato Canal Fish Screening Facility. The small descaling rate observed in previous tests of the fish return pipe (Neitzel et al. 1988) was the product of the collection technique and equipment. No descaling was observed due to passage through the pipe or from the collection equipment in tests conducted this year.

POTENTIAL FOR PREDATION AT SCREENING FACILITIES

On the basis of the samples we have collected, loss to predation does not appear to be a problem at screening facilities when only native species are involved. However, hatchery-released salmonids that take up temporary residence in a screens forebay may increase predation pressure at screen sites. Screening facilities could affect the predator/prey relationship if the screens concentrate prey or increase the exposure of prey to predators because of stress, injury, or delay in migration.

Westside Ditch Screens

No predation was observed at the Westside Ditch Screens, although some rainbow trout fry released for Phase IVb tests were consumed by steelhead smolts we released for Phase IIb tests. Predation, therefore, appeared to be related to the artificial and temporary predator/prey population structure created by the release of our test fish. Although many chinook salmon fry were caught during tests at the Westside Ditch Screens, few smolt-size salmonids were caught, indicating that the smolts had already migrated from the reach of the Yakima River upstream of the Westside Ditch Canal or that juvenile salmon do not overwinter in the reach. Regardless, the natural predator/prey population structure in the screens forebay should be similar to that in the Yakima River because fish movement through the screens forebay is not impaired when adequate bypass flows are provided.

POTENTIAL FOR FISH DELAY AT SCREENING FACILITIES

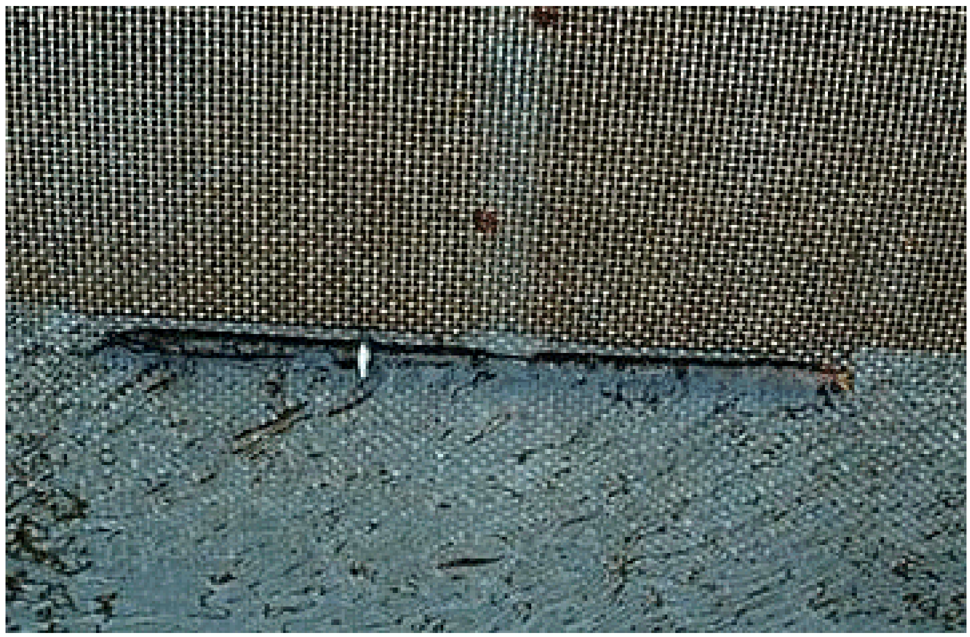
One of the basic objectives of redesigning and constructing new screens is to provide facilities that safely and rapidly return fish from diversion canals to the river (Easterbrooks 1984). Fish are not "flushed" from the screen forebay back to the river, although the screening facilities do not impede voluntary movement and migration under normal operating conditions. Conversely, inadequate bypass flows resulting from improper operation, inoperable components in the bypass system, low canal flows or forebay elevations, or blockages in the fish return can impair the movement of fish through the fish bypass system and contribute to delays in migration.

Flow through the fish return pipe at the Westside Ditch Screens was severely restricted before we initiated our tests. Normal fish bypass flows were not attainable because the fish return slot was backed up with water. In the week preceding our tests, we observed several small chinook salmon fry holding in the fish return slot. The head of the fish return pipe was plugged with debris that either washed into the fish return slot when the canal was filled or was not removed before startup. Besides restricting water flow and fish movement, a partially plugged pipe would injure fish.

FISH PASSAGE THROUGH OR OVER ROTARY DRUM SCREENS

The sweeping to approach velocity ratio designed into the facilities helps to guide fish into the fish bypass, and screen mesh openings (3.2 mm, 1/8 in.) are small enough to prevent most salmonid fry from passing through the drum screens. Tests were designed and accomplished at the Westside Ditch Screens to determine if any fish might be impinged by or passed over, around or through the drum screens.

Westside Ditch Screens



Fish released in the screens forebay were caught in fyke nets behind all four of the drum screens. Some of the fish caught behind the screens were the result of "rollover" of fish released at the water surface near the screen face. However, rollover accounted for only a small percentage of the total number of fish caught behind the screens. The passage rate for chinook salmon fry was four times greater than for our test fish, and was due either to the smaller size of the chinook salmon or to a difference in behavior. No rollover was observed for chinook salmon fry. However, the fish moved at night when rollover observations are difficult.

The 1/8-in. screen mesh used in the construction of the drum screens at the Westside Ditch Canal and most other screening facilities is believed to be small enough to prevent salmonid fry from passing through the mesh. However, the smaller chinook salmon fry captured in the fyke nets behind the drum screens could be "pushed" through the mesh without apparent injury. Chinook salmon fry 32 to 40 mm in length could not pass through a 5/32-in. screen opening (Fisher 1978); however, the tests were conducted with perforated plate, and not with the coarse woven wire mesh used in the construction of the drum screens.

Fish potentially can pass around the drum screens at Westside Ditch. Although the seals around the circumference at each end of the screens appear tight, small gaps around the end frames of the drum screens are evident.

SUMMARY

Release and capture tests and other monitoring studies have been conducted at six diversion screen facilities in the Yakima Basin: the Sunnyside Screens (Neitzel et al. 1985), the Richland and Toppenish/Satus Screens (Neitzel et al. 1986), the Wapato Screens (Neitzel et al. 1988), the Toppenish Creek Screens (Neitzel et al. 1989), and the Westside Ditch Screens. The objective of our evaluations was to determine whether or not fish that have entered a irrigation canal are safely diverted back to the river. The objective was met by determining if: 1) fish that pass through the diversion are killed, injured, or eaten by predators; 2) fish migration is delayed at the screen structure; and 3) fish are prevented from passing through or over the screens. These objectives are addressed in the various phases of the work plan.

PHASE I

Phase I tests conducted at the Sunnyside Screens in 1985 used chinook salmon and steelhead smolts. The test data indicated that fish safely pass through all components of the fish bypass system. No Phase I tests have been conducted at the Richland, Toppenish/Satus, Toppenish Creek, or Westside Ditch Screens, because the fish bypass systems did not incorporate intermediate and terminal bypasses, traveling screens, or fish water pumpback systems in their designs. No Phase I tests were conducted at the Wapato Screens, because none of the components of the fish passage facility differed significantly from components at the Sunnyside Screens, which were proven safe for fish passage.

PHASE II

Phase IIa tests have been completed at all six screening facilities. At the Sunnyside Screens, fish were released either at the trash racks or the headgates. Fish captured after moving through the screen forebay and diversion system were not injured or killed. At the Richland, Toppenish/Satus, Wapato , and Toppenish Creek Screens, fish were released only at the trash racks, and fish were released in the canal upstream of the screens at the Westside Ditch Screens. Captured fish were not killed or injured. Tests at the Sunnyside, Wapato, Richland, and Westside Ditch Screens were conducted with chinook salmon and steelhead smolts. Tests at the Toppenish/Satus and Toppenish Creek Screens were conducted with steelhead smolts only.

Phase IIb tests have been conducted at the Sunnyside, Richland, Toppenish Creek, and Wapato Screens. 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 the Richland, Toppenish Creek, and Wapato Screens, the fish return pipe was evaluated. Fish successfully passed through each of the components without injury or delay.

PHASE III

Phase III tests have been conducted at the Richland, Toppenish Creek, and Wapato Screens. Pipe tests were conducted under two bypass flows at the Richland Screens. Fish were not injured or killed at either bypass flow. Evaluations at the Toppenish Creek and Wapato Screens were conducted during low and full canal flow conditions. Fish were not injured or killed in either test; however, movement rate was slower during low canal flow conditions. Opportunities to conduct tests under different canal flows have been limited because of delays in construction and startup at the Sunnyside, Richland, and Toppenish/Satus Screens. The Sunnyside, Toppenish/Satus, and Westside Ditch Screens were evaluated only at full canal flow conditions and the Richland Screens only at minimum flow conditions.

PHASE IV

Native fish were collected during all bypass tests and the gut contents of predacious fish were examined. Predacious bird activity was also monitored in the vicinity of each screening facility. Increased predation does not occur at screening facilities, except that hatchery-released salmonids sometimes congregate in the screens forebay and prey on salmonid fry.

Rotary drum screens were examined during bypass tests to determine if any fish were impinged on or passed over the screens. Successful screen integrity tests have been completed at the Richland, Toppenish Creek, Sunnyside, Wapato, and Westside Ditch Screens. The Richland Screens are effective at preventing fish from entering the irrigation canal; however, some fish passed over the screens and through faulty screen seals at the Toppenish Creek, Sunnyside, Wapato, and Westside Ditch Screens. Screen integrity tests initiated at the Toppenish/Satus Screens were not completed because we did not have nets to capture fish downstream of the rotary screens.

RECOMMENDATIONS

Fisheries evaluations have been conducted at six diversion screen facilities: the Sunnyside, Richland, Toppenish/Satus, Wapato, Toppenish Creek, and Westside Ditch Screens. Data were collected to address five areas of concern: fish survival, predation, migration delays, screen passage, and effects of operating conditions. The results of tests addressing each concern were integrated to evaluate the effectiveness of the screens.

The data indicate that fish are not descaled or killed as they are diverted by the screening facilities; however, descaling tests should continue at future diversion sites to assess potential site-specific problems. Emphasis should be placed on correlating descaling to canal operations (Phase III). The periods when canal operating conditions are of greatest concern are 1) during canal startup and 2) during peak migration of native salmonid stocks in the vicinity of each screening facility.

Increased predation does not seem to occur at screening facilities, except when hatchery-released salmonids sometimes congregate in the screens forebay, and prey on salmonid fry. The potential impact of predation in the screen forebays can only be assessed if predation in the screen forebay is compared to predation in the river.

Fish successfully pass through the screen facilities of their own volition. Fish are not "flushed" from the screen forebays and can remain in the forebays. The potential impact of migration delay in the screen forebays can only be assessed when migration timing through the screen forebays is compared to migration timing in the river.

Tests to evaluate screen integrity should continue to have high priority. The screen integrity tests we completed at the Toppenish Creek, Sunnyside, Wapato, and Westside Ditch Screens indicate that screen seals play a vital role in preventing fish from entering the irrigation canal. Annual inspection and replacement of screen seals might reduce losses; however, a new seal design may be necessary if the present loss rate is not acceptable.

Monitoring of chinook salmon fry should be conducted at the Westside Ditch Screens after the problems with end seals have been resolved. The Department of Fisheries has suggested that the frames be "crowded" upstream in the structure blockouts and wedged to close the gaps before the canal is filled.

The wire mesh used for the construction of drum screens should be tested to verify that fish can not pass through the mesh. Chinook salmon fry captured in future screen evaluations could be used as test fish.

The fish bypass systems are operated following criteria for flows through the flow control gates, fish return pipes, and other bypass structures. These operating conditions are set to protect fish that move through the system. It is imperative that the operating conditions are adhered to when fish are moving through the diversions. Operating conditions need to be published and should cover all operating conditions for each facility. Facility structures, such as water elevation markers, must be installed at all facilities so operating criteria can be properly implemented.

The fish bypass system should be thoroughly checked and calibrated at each screening facility at the beginning of each irrigation season. Operating criteria should stress that fish bypass flow is very important in achieving effective fish bypass. Fish are not involuntarily delayed at or within the screening facilities when bypass flows are set according to the operating criteria and properly maintained. Debris that blocked the head of the fish return pipe at the Westside Ditch Screens resulted in reduced bypass flows and was a potential site for injury to fish.

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