THE FARMERS SCREEN PROJECT

Farmers Conservation Alliance (FCA)
Conservation Innovation Grants (CIG) Final Project Report
Agreement Number: NRCS 69-3A75-7-92

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Period of grant project: Sept 21, 2007 – December 31, 2011

The purpose of the Farmers Conservation Alliance (FCA) Farmers Screen Project is to stimulate the development and adoption of the innovative fish screen technology, as well as demonstrate its benefits for agricultural production, environmental enhancement, and environmental protection.

Target Deliverables:

1. Installation of 56 demonstration Farmers Screens, operating to keep fish and debris in rivers from entering irrigation systems.
2. Demonstrate and evaluate the benefits of Farmers Screens in various environments and region throughout Oregon (amended to include western U.S. states)
3. Provide landowners with an alternative for affordable irrigation.
4. Provide outreach, education, and demonstrations to landowners, managers, agencies, and Tribes.

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EXECUTIVE SUMMARY

Farmers and environmentalists want the same thing: to keep fish from being entrained in irrigation diversions. For decades, a practical solution did not exist. Over 300,000 water diversions in the western U.S. are either unscreened, or screened in a way that is not safe for fish. Farmers struggle with excessive operation and maintenance costs for screening, limited available screen technologies, limited funding for new projects, and complicated permitting processes. The result: in the words of the Oregon Department of Fish and Wildlife, "there are surely hundreds of thousands of fish that die each year due to unscreened diversions,"[1] in Oregon alone.

One solution to this issue is the Farmers Screen. The Farmers Screen is a new, innovative fish screen technology that can provide a win-win solution for both farmers and fish. Farmers Conservation Alliance (FCA) received a Conservation Innovation Grant in 2007 to stimulate the development and adoption of the Farmers Screen, as well as demonstrate its benefits for agricultural production, environmental enhancement, and environmental protection.

This Conservation Innovation Grant has had a powerful impact on the development of the Farmers Screen, with ancillary beneficial effects that go beyond, including greater awareness of the need for fish screens in general, and the development of opportunities to leverage the economic benefits of screening with the inclusion of off-stream, fish-friendly hydropower generation in previously existing irrigation infrastructure. Throughout the course of this grant period, FCA has found that CIG support plays an integral role in developing new technological solutions to water and energy resource issues while fostering a culture of optimistic cooperation, focused on achieving systemic solutions that benefit both the environment and agriculture.

About the technology:

In order to successfully screen the great diversity of surface water diversion types, site conditions, water uses, and hydraulic profiles throughout the west in a way that is safe for fish at all life stages, a diverse portfolio of screen technologies is required. The Farmers Screen is a new addition to that portfolio, and one that offers the unique combination of proven fish protection and lowered operation and maintenance costs. The Farmers Screen is an exciting opportunity to save farmers millions of dollars while at the same time saving the lives of millions of fish.

The Farmers Screen is a horizontal, flat-plate fish and debris screen. Designed to be installed in an off-stream channel, water, fish, and debris pass quickly over the screen material, which lies parallel to the water's surface, and return to the river. Diverted water travels slowly through fine perforations in the screen material, and the water carrying fish and debris moves quickly across the screen surface, cleaning it as it returns to the river. This combination of minimal downward velocity and high sweeping velocity is what manages debris and protects fish. Finally, taper and weir walls ensure uniform water depths and velocities.

About the organization and the grant project:

FCA is a 501(c)3 social enterprise nonprofit organization based in Hood River, Oregon. FCA used The Farmers Screen Project funds to conduct an extensive outreach campaign, develop a market-based distribution system for the Farmers Screen, contribute to the creation of a streamlined

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[1] Oregon Department of Fish and Wildlife *Backgrounder*, January 1996.

permitting process, and install 15 demonstration Farmers Screens in Oregon, Idaho, Montana, and Wyoming.

This Conservation Innovation Grant project helped FCA develop a market-based approach to distributing the Farmers Screen in various environments and regions throughout the western U.S., while providing landowners, managers and agencies with an affordable and simple irrigation and fish management solution.

Market sectors affected by the project:

Customers benefiting from the Farmers Screen Project CIG grant include irrigators of farm and rangeland; irrigation districts, with or without off-channel hydro facilities; Tribes; environmental advocacy groups; watershed groups; and river restoration professionals.

Results:

The Farmers Screen represents the culmination of years of field experience combined with knowledge gained from laboratory and field hydraulic and biological testing. The technology has been refined to provide consistent and predictable fish protection as well as debris management with minimal maintenance requirements. Permitting and distribution systems have been streamlined and refined. Environmental and economic benefits have been evaluated and shown to exceed expectations. Opportunities to further leverage these benefits have been identified, including packaging options that further incentivize screening. FCA is now assessing the feasibility of conducting a national-scale inventory of sites well suited to Farmers Screen installations and hopes to continue the CIG partnership in the future to further expand the adoption of the technology throughout the country.

FCA's CIG supported Farmers Screen installations have cumulatively:

- Converted a total of 256.7 cubic feet per second (cfs) of diverted water to fish-friendly status,
- Opened 107.7 river miles for safe fish passage,
- Supported the generation capacity of 3MW of fish-friendly, green hydropower ($1,024,920 in revenue at 65% capacity, $0.06 per kWh),
- Protected 18,255 acres of farmland with reliably screened, consistent, compliant irrigation water,
- Saved irrigators at least $115,250 annually in avoided operation and maintenance costs for their diversions.

Recommendations:

FCA recommends NRCS and USDA promote and encourage widespread adoption of the Farmers Screen technology, and utilize the full portfolio of approved screen technologies in a stepped-up approach to address the more than 300,000 unscreened diversions in the western U.S. states.

Funding for new Farmers Screen projects, in-depth training of NRCS Field Service personnel about the technology, and inclusion of Farmers Screen technical information in pamphlets and flyers disseminated by USDA and NRCS to irrigators and other water users throughout the western U.S. would be the three optimal methods for achieving this goal. A technical document on the Farmers

Screen is attached to this report, Appendix 1. Widespread distribution of the technical document to NRCS Field Service personnel, engineers, partners, landowners and other stakeholder groups via NRCS communication channels is encouraged.

This report will provide details on the full scope of work performed to achieve these objectives, in addition to the economic and ecological benefits realized from the results of this work.

INTRODUCTION

FCA was awarded an NRCS Conservation Innovation Grant (CIG) for The Farmers Screen Project in 2007. Work covered by the CIG grant was performed from November 2007 – December 2011. The purpose of the project was to stimulate the development and adoption of the Farmers Screen as well as demonstrate the benefits for agricultural production, environmental enhancement, and environmental protection.

CIG funding enabled FCA to hire two new staff people to increase marketing capacity and provide project management, as well as initiate in-depth metrics tracking and project evaluation systems. This CIG funding also proved critically important in allowing FCA to address systemic permitting complications that were hindering FCA's ability to install demonstration screens in sites with anadromous fish species present. Successful resolution of these permitting issues required additional biological testing and greater investment in staff time for outreach and collaboration with agency partners. Both on-the-ground and systemic results of this CIG funded work provide benefit to fish and farms, far beyond the scope of The Farmers Screen project itself.

Project goals and objectives:

1. Install 56 Farmers Screens to keep fish and debris in rivers from entering irrigation systems.
2. Demonstrate and evaluate the benefits of Farmers Screens in various environments and regions throughout the Pacific Northwest
3. Provide landowners with an alternative for affordable irrigation.
4. Provide outreach, education, and demonstrations to landowners, managers, agencies, and Tribes.

On the ground impact:

As a result of the CIG grant, FCA has installed 15 demonstration Farmers Screens. These Farmers Screens have cumulatively:

- Converted a total of 256.7 cubic feet per second (cfs) of diverted water to fish-friendly status,
- Opened 107.7 river miles for safe fish passage,
- Supported the generation capacity of 3MW of fish-friendly, green hydropower,
- Protected 18,255 acres of farmland with reliably screened, consistent, compliant irrigation water,
- Saved irrigators at least $115,250 annually in avoided operation and maintenance costs for their diversions.

Outreach impact:

Additionally, as a result of CIG support, FCA has conducted extensive outreach campaigns geared toward promoting the Farmers Screen and familiarizing key target markets with each features and benefits, and raising awareness about the need for fish screens in the general public. The Farmers Screen Project education and outreach campaign has resulted in:

- A total of 27 articles about the Farmers Screen in print and broadcast media that resulted in at least 1,321,606 "hard" impressions in the marketplace,
- The broadcast of a seven-minute segment titled "Building a Better Fish Screen" on Oregon Public Broadcasting's *Oregon Field Guide,* which as since re-run at least once. (Aired twice in Oregon and at least once in the Seattle Metro market and parts of Idaho.)
- A front-page article in *The Oregonian* newspaper, which ran on August 14, 2008 titled "Save crops, fish, and money all at once? Farmers design an answer," by Michael Milstein.
- 13,649 unique visits to FCA websites focused on the Farmers Screen.

Impact on permitting systems:

This Conservation Innovation Grant provided critical funding to be able to invest the time and money required to achieve improved efficiency in the permitting process. Particularly for "passive screens," a category that includes the Farmers Screen, the permitting process has been significantly improved. In 2011, the National Marine Fisheries Service (NMFS) created a new criteria document for passive screens that includes the Farmers Screen as a "NOAA Approved Technology."

Impact on distribution systems:

Finally, resulting from the CIG, FCA was able to develop a market-based distribution process for the Farmers Screen technology, which features the new option for a lower cost, pre-fabricated, modular design. Through this modular design, the screen can be shipped to the installation site in sections. These are then easily bolted together for a quick installation that requires no concrete. Modular Farmers Screens are typically small screens, suitable for diversions from 0.5 - 15 cfs, or dual configurations up to 30 cfs. FCA's modular design provides significant cost savings while simplifying delivery and installation.

Barriers to success:

One major barrier to the achieving FCA's goal of installing 56 Farmers Screen was the NMFS review process for the approval of the Farmers Screen that took significantly longer than expected. This process was FCA's greatest barrier to success of CIG grant goals and significantly slowed the growth to full scale Farmers Screen adoption throughout the Pacific Northwest marketplace. In order to accommodate the NMFS review process timeline, FCA requested a no-cost extension of FCA's CIG grant in 2010, which extended the grant period to December 31, 2011. The Farmers Screen received NMFS approval in the summer of 2011.

In the meantime, the designation of the Farmers Screen as "NOAA Approved Technology" allows FCA to:

- Provide customers with reliably shorter permitting timelines
- Provide potential customers, funders, and permitting partners with greater assurance of the Farmers Screen's proven performance in terms of fish protection
- Greatly expand the geographic territory in which we can actively market and sell the Farmers Screen, to include those areas within NMFS jurisdiction (all rivers and streams that carry anadromous fish species in the US)

Refining the technology:

Of course one of the major focuses during the project period was also technology refinement. With CIG funding support, FCA installed demonstration Farmers Screens in a variety of sites with varying cultural and political conditions. By doing so, FCA was able to refine the technology itself as well as its sales and customer vetting processes.

The Modular Farmers Screen

During this process of refining the technology and developing demonstrations sites, FCA designed a modular Farmers Screen system. The modular system was developed as a way to reduce the cost and complexity of screen installation for small, remote diversions. By eliminating the need for onsite fabrication, concrete, and individual screen engineering, the modular system reduces over all project costs as well as the time it takes to implement a small project.

Sediment Management System

FCA was fortunate to develop screening projects in basins with very high levels of organic material, as well as large sediment loads. As a result, an effective and simple sediment management system was developed to address a constant flow of glacial and other sediment into Farmers Screen installations.

Screen Process

Working with the Columbia Basin Fish and Wildlife Authority's (CBFWA) Fish Screening Oversight Committee (FSOC), FCA developed a detailed site selection process, operation manual, and monitoring process. These processes and documents are intended to provide a consistent method for properly siting the Farmers Screen technology and as well as providing guidance in operation and monitoring once the screen is installed.

ACTIVITY REPORT

To achieve the goals of the CIG grant, FCA set out the following project Objectives:

1. Work with staff, engineers, fabricators, agencies, and landowners to develop a streamlined, affordable screening process
2. Engage in an extensive outreach campaign to educate landowners, managers, agencies, and Tribes about the Farmers Screen
3. Work with state and federal agencies to develop streamlined permitting processes
4. Install at least 56 demonstration sites in 5 different basins throughout the West in order to introduce the Farmers Screen in other geographic areas, environments and sectors
5. Evaluate installation sites and processes to identify potential improvements in outreach efforts, installation packages, and affordability
6. Evaluate screen benefits for agricultural production as well as environmental protection and enhancement
7. Work with local, state, and regional NRCS staff to become a Technical Service Provider and receive EQIP approval for the Farmers Screen

The following is a detailed activity report on the full scope of work to achieve these goals and objectives.

Objective 1:

Work with staff, engineers, fabricators, agencies, and landowners to develop a streamlined, affordable screening process. To achieve this objective, throughout the course of the grant period, FCA staff:

- Conducted weekly and quarterly meetings with staff, engineers, and fabricators to make improvements and identify ways to lower costs and streamline sales/permitting/installation process
- Completed 15 screen evaluations on 15 screens post install and start-up
- Refined Farmers Screen technology
- Developed Modular Design
- Established set pricing for Farmers Screens based on size, measured in terms of cfs (cubic feet per second)
- Worked with USGS biologists to design and implement biological testing of the Farmers Screen and completed two separate tests, assisted in peer review and publication of study results[2]
- Received NMFS criteria approval for the Farmers Screen
- Improved and expanded operation manuals, required site condition guidelines, guides for surveyors, and other collateral to provide easy to use information resources to Farmers Screen operators
- Researched and interviewed fabricators outside of Oregon in an effort to reduce costs for out-of-state clients
- Evaluated performance of installed modular and custom screens with flow tests
- Conducted research and development on new sediment flush system designs

[2] Available online at: http://pubs.usgs.gov/of/2010/1042/

- Incorporated new sediment flush system into both modular and custom designs

The result of this work includes a more streamlined, affordable screening process for clients with sites suitable to a Farmers Screen installation. Customers purchasing a Farmer Screen for their diversion are assured reliably shorter permitting timelines due to the NMFS approval, (compared to when the Farmers Screen was considered an experimental technology). In addition, the extensive testing required provides assurance that the Farmers Screen is safe for fish at all life stages. FCA has greatly expanded the geographic area of our service market with new permitting and funding relationships as well as working demonstration Farmers Screens in states beyond Oregon.

Another result of the work conducted for this objective is that FCA is now positioned as a neutral, non-governmental expert in fish screening. FCA works to support broader acceptance of fish screening in general by actively working to educate landowners and the general public about the value and the need for fish screens. FCA enjoys a reputation as a company that is well networked, able and willing to refer customers to other screen technologies and manufacturers for sites not suitable to our technology, and one that is ultimately interested in providing a win-win solution for fish and farmers.

Objective 2:

Engage in an extensive outreach campaign to educate landowners, managers, agencies, and Tribes about the Farmers Screen. To achieve this objective, throughout the course of the grant period, FCA staff:

- Expanded education and outreach campaign with messaging tailored specifically to agency and project partners
- Conducted outreach tours throughout market region focused specifically on giving introductory and technical presentations to engineering firms, Tribes, state and federal agencies to increase broad familiarity with the Farmers Screen among these potential project partners
- Continuously performed outreach activities throughout the market region to give technical presentations to consultants, irrigation districts, watershed councils, resource conservation districts, soil and water conservation districts, and environmental advocacy groups to increase familiarity with the Farmers Screen among these potential client groups
- Conducted outreach campaign to potential project partners and clients announcing NMFS approval
- Held a total of 141 meetings that resulted in a total of at least 683 face-to-face interactions with individual agency representatives.
- Held a total of 50 meetings that resulted in a total of at least 429 face-to-face interactions with Soil and Water Conservation District and Resource Conservation District personnel.
- Gave a total of 30 presentations that included a total of at least 61 face-to-face interactions with landowners and agricultural producers about the Farmers Screen.
- Conducted a total of 32 tours of operating Farmers Screens with a total of at least 100 tour attendees.

- Attended a total of 25 fish screening industry or interest group conferences, with FCA staff recording at least 2,955 face-to-face interactions occurring with target audience individuals.
- Had a total of 27 articles about the Farmers Screen in print and broadcast media that resulted in at least 1,321,606 "hard" impressions in the marketplace.[3]

Objective 3:

Work with state and federal agencies to develop streamlined permitting process. To achieve this objective, throughout the course of the grant period, FCA staff:

- Worked with agencies to perform tests on modular Farmers Screen.
- Devised and refined new system to track and reduce hours and costs associated with permitting tasks.
- Completed biological testing to prove all Farmers Screen configurations meet criteria standards.
- Supported peer review process of USGS biological fish test study results.
- Continue to work with NMFS on evaluation of modular Farmers Screens with goal to achieve full acceptance into criteria document within two years.
- Continue to promote new NMFS criteria and raise awareness on how this approval streamlines the permitting process for custom Farmers Screens and those modular screens operating with at least 12 inches of depth over the screen surface.

The Farmers Screen is the first new technology to be added to the NMFS fish screening criteria document since it was created. Though these criteria only apply to anadromous streams in the Northwest, NMFS approval is widely regarded as the most rigorous fish screen design standard and, therefore, is the standard used for most national, and international, screen design.

Objective 4:

Install at least 56 demonstration sites in 5 different basins throughout the West in order to introduce the Farmers Screen in other geographic areas, environments, and sectors. To achieve this objective, throughout the course of the grant period, FCA staff:

- Installed 15 new Farmers Screens in 11 different basins Oregon, Montana, Idaho, and Wyoming:
    1. Fish Haven, Idaho #1 - 3 section modular design (5 cfs)
    2. Fish Haven, Idaho #2 - 3 section modular design (5 cfs)
    3. Glendale Ditch, Idaho - 2 section modular, (2 cfs)
    4. Wolf Creek, Oregon - 2 section modular, (2.5 cfs)
    5. Widows Creek, Oregon #1 - 1 section modular (1.5 cfs)
    6. Widows Creek, Oregon #2 - 1 section modular (1.5 cfs)
    7. Widows Creek, Oregon #3 - 2 section modular, (3 cfs)

[3] Full list available online at http://Farmerscreen.org/inthenews.

8. German Gulch, Montana - 3 section modular, (7 cfs)
9. Berry Creek, - custom design retrofit Farmers Screen, (1 cfs)
10. Jordan Ditch, Idaho - 3 section modular, (5 cfs)
11. Trout Creek, Wyoming - 1 section modular, (1 cfs)
12. Coe Creek, Oregon - dual design, (5-30 cfs range)
13. Deadpoint Creek, Oregon – 5 section modular (15 cfs)
14. Whychus Creek, Oregon – custom dual design (160 cfs)
15. Sixmile Creek, Montana – 2 section modular (3 cfs)

- The screens provide irrigation water to a total of at least 18,255 acres of farmland.
- These installations have converted a total of 256.7 cfs to fish-friendly diversions, opened 107.7 river miles to safe fish passage, and are saving their owners a total of at least $115,250 annually in avoided operation and maintenance costs.
- In addition, the Coe Creek, Deadpoint Creek, and Whychus Creek screens are supporting a total of 3MW generation capacity of fish-friendly, off-channel hydropower.
- FCA sales staff are continuing to pursue a total of 120 active sales leads for new Farmers Screens from throughout our market region, including Missouri, Colorado, Utah, Washington, New Hampshire, Massachusetts, Nevada, New Mexico, California, Vermont, and Hawaii. Also, international interest is coming from Canada, New Zealand, and locations in South America.

While FCA did not install the 56 screens that we set as our goal for the project, the benefits realized by these 15 installations did surpass the goals of total of affected river basins, acres of farmland protected, and total dollars saved annually in avoided operation and maintenance costs.

With the new NMFS criteria accepting the Farmers Screen as "NOAA Approved Technology" enabling streamlined permitting of Farmers Screens at 12" of depth, FCA feels confident in its projections of installing 45 new Farmers Screens by the end 2014. With a clear path toward full NMFS acceptance of 6" depth Farmers Screens in the next 2 years, FCA expects to install 346 screens by 2018.

For more information on the process of obtaining a Farmers Screen, please refer to the Technical Document, Appendix 1.

Objective 5:

Evaluate installation sites and processes to identify potential improvements in outreach efforts, installation packages and affordability. To achieve this objective, throughout the course of the grant period, FCA staff:

- Conducted 48 post-installation visits to meet with clients and assess screen performance, conduct flow surveys and record operational and monitoring data.
- Devised and refined new system to track and reduce FCA hours spent per project, thereby reducing costs of installation.
- Created and distributed new Farmers Screen Operation Manual to all screen operators.
- Conducted operation training to all operators and owners of the three Widows Creek Farmers Screens (in the John Day Basin in Oregon) to ensure proper operation, which

FCA deemed necessary due to the unique case of having multiple operators on the same system.

- Researched possible screen fabricators outside of Oregon in an effort to identify cost-saving opportunities for Idaho, Montana, and Wyoming customers.
- Developed, refined, and installed new sediment flush systems on the Coe Creek, Whychus Creek, and the three Widows Creek screens and assessed improvements in sediment management.
- Created underwater video of leaves and debris passing over the screen material at varying depths to illustrate how the screen handles heavy leaf and debris loading.
- Developed, refined, and installed new baffle systems to better regulate approach velocities at the leading edge of the screen, and assessed performance with flow surveys.
- Continuously gathered performance data from clients, especially after significant flooding events and during dry seasons to better evaluate screen performance in diverse operating conditions.

The result of this work includes a refined, standardized installation process, incorporating lessons learned from the demonstration site installs. For more detailed information on the installation processes for both the modular and the custom Farmers Screen systems, please refer to the Technical Document, Appendix 1.

Objective 6:

Evaluate screen benefits for agricultural production as well as environmental protection and enhancement. To achieve this objective, throughout the course of the grant period, FCA staff:

- Conducted hydraulic testing to assess agricultural and environmental benefits.
- Completed extensive biological testing, with results showing the Farmers Screen is safe for fish at all life stages, and that smolt stage salmon do not reject the screen. Supported the peer review of these USGS studies. Supported distribution of study results through presentations at conferences.
- Collected client testimonials reflecting the beneficial impacts of the screen on operations.
- Promoted client experience via articles in farming/ranching niche publications such as The Good Fruit Grower, Western Farmer Stockman, and the Capital Press.[4]

The result of this work is a greater understanding of the specific site conditions and operator training needed to ensure proper operation of the new Farmers Screen. Put in simple terms, the site must have elevation differential in both the conveyance and the source river or stream **and** constantly available by-pass flow in addition to the screened flow and in-stream flow. For more detailed information on the site conditions required, refer to the Technical Document, Appendix 1.

Objective 7:

Work with local, state, and regional NRCS staff to become a Technical Service Provider and receive EQIP approval for the Farmers Screen.

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[4] These articles available online at http://Farmerscreen.org/inthenews.

FCA did not pursue becoming a TSP because we don't fit the definition of a TSP. We are not a service provider like engineering or consulting firms would be. We provide a specific technology that fits specific types of surface water diversions. We would work with a TSP who was interested in applying our specific technology to a particular site.

The categories that we come closest to fitting within would be under Land Treatment – Surface Water Management: Diversion (362) and Structure for Water Control (587). The typical TSP in these categories would be a Licensed Engineer, not a supplier of a manufactured product.

PROJECT PARTNERS AND SUPPORTING ENTITIES:

FCA was fortunate to receive funding and other support from these and other entities, in varying capacities, to achieve completion of the Farmers Screen Project:

- National Resource Conservation Service
- U.S. Department of Agriculture
- U.S. Fish and Wildlife
- National Marine Fisheries Service
- Oregon Department of Fish and Wildlife
- Confederated Tribes of the Warm Springs Indian Reservation
- Oregon Governor's Office
- Senator Ron Wyden
- Senator Jeff Merkely
- Congressman Greg Walden
- Farmers Irrigation District
- Three Sisters Irrigation District
- Middle Fork Irrigation District
- Columbia Basin Fish and Wildlife Authority
- Oregon Department of Energy
- Fish Screening Oversight Committee
- Hood River Soil and Water Conservation District
- Hood River Watershed Group
- Upper Deschutes Watershed Council
- Deschutes River Conservancy
- Bonneville Power Administration
- Trout Unlimited
- Montana Fish Wildlife and Parts
- Wyoming Game and Fish
- Idaho Fish and Game
- Oregon Watershed Enhancement Board
- Oregon Water Resources Council

REVIEW OF METHODS

The biological testing was conducted under contract with the USGS Columbia River Research Laboratory. The full report including a detailed description of the methods used can be found in Appendix 5.

METRICS TRACKING

In order to accurately track metrics and provide a sound platform to determine future goals and work plans, FCA utilizes Salesforce's NonprofitForce. Because Salesforce is a highly customizable customer relations management (CRM) tool, FCA has developed a system that supports FCA staff in the collection and evaluation of FCA's social and economic metrics, marketing and outreach activities, and progress of individual Farmers Screen projects. Salesforce has proven to be invaluable for managing day-to-day operations as FCA is able to generate weekly, quarterly and yearly reports in a timely manner. The platform is provided to FCA from the Salesforce Foundation at no cost.

PROJECT METRICS DEFINED

What do we mean, exactly, when we say that Farmers Screen installations save farmers money, protect farming acres, and support hydropower generation capacity? FCA tracked these and other metrics in order to clearly communicate the social and environmental impact of the CIG grant. Here are the ways we define these metrics:

Dollars saved by landowners:
Reported in dollars saved annually, these are the total savings in avoided operation and maintenance costs for FCA clients as a result of a Farmers Screen installation. In instances where the new Farmers Screen replaces an older screening device or structure, these savings are actual, and typically significant. In instances where the diversion was not previously screened at all, these savings are avoided costs, and can vary depending on regulatory enforcement, plans for future upgrades, grants eligibility, or plans for future water rights transfers. Having brought their diversion into compliance with their Farmers Screen installation, FCA clients can realize economic benefits beyond simple savings in the operation and maintenance of their diversions, compared to other screen technologies. While benefits may also be realized for those previously unscreened diversions (such as debris and sediment screening to protect equipment and infrastructure further down the system), since the dollar value of these benefits is not reliably standard, nor the data easily collected, FCA does not report a dollar value for those instances.

Acres of farmland protected:
Reported in acres, this is the total number of acres of farmland served by the Farmers Screen installation. When these data are available from clients (almost always for completed screens), the exact number is used for the metric. For instances where the data is not available, a formula is used to determine the metric data value. The formula is based on the allowable water law allocation. For example, in Oregon, water law permits 5.6 gallons per minute per acre. There are 7.48 gallons per

cubic foot, which is 448.8 gallons per minute, which equal 81.6 acres per cfs. Usually, FCA will opt to use a value of 75 acres per cfs to ensure a conservative estimate.

Fish-friendly, green hydro megawatts capacity supported:
Reported in MW, this is the total number of off-channel hydropower generation capacity with the Farmers Screen technology providing fish protection. These are all off-stream hydro facilities, utilizing water diverted for other purposes, i.e. irrigation or municipal water supply. According to the U.S. Department of Energy, a one megawatt electric plant running continuously at full capacity can power 778 households each year. In contrast to in-stream hydro facilities, these off-stream facilities operate in a fish-free environment, utilizing water that is already enroute to another use. This is an exciting way in which the Farmers Screen helps to support lowering carbon emissions while also lessening the impact on fish.

CONCLUSIONS AND RECOMMENDATIONS

The Farmers Screen is a technology that is well suited to 15-25% of all surface water diversions in the west. It is particularly well suited to 60-75% of those diversions that could support hydropower generation. FCA is continues to build an inventory to assess applicability beyond the western U.S., and initial indications are that those percentages remain the same across the country.

FCA recommends NRCS and USDA promote and encourage widespread adoption of the Farmers Screen technology, and utilize the full portfolio of approved screen technologies to encourage a stepped-up approach to the more than 300,000 unscreened diversions in the western U.S. states. Funding for new Farmers Screen projects, in-depth training of NRCS Field Service personnel, and inclusion of Farmers Screen technical information in pamphlets and flyers disseminated by USDA and NRCS to irrigators and other water users throughout the northwest would be the three optimal methods for achieving this goal. A technical document on the Farmers Screen is attached to this report, see Appendix 1. Widespread distribution of the technical document to NRCS Field Service personnel, engineers, partners, landowners and other stakeholder groups via NRCS communication channels is encouraged.

HISTORICAL BACKGROUND

The Challenge: Keeping fish out of irrigation diversions

There are more than 300,000 unscreened diversions in the Western United States alone. These diversions are essential for food production, power generation, and municipal water needs. Yet, it is difficult to divert water without trapping fish and debris. The solution to this challenging issue is fish screens. Fish screens create one of the greatest opportunities to protect fish and ensure cost efficient, consistent water flow to diverters. However, 75-90% of all diversions are unscreened. Why?

Limited Technological Options
Since the late 1800s, farmers have been seeking the perfect water diversion screen. While some screening devices were improved over time, and most are better than nothing, these devices are, nevertheless, contraptions requiring constant cleaning, either by hand or via complex mechanical mechanisms that predictably fail. While many of the systems generally protect fish, they often break down or require constant maintenance, and, therefore, operation costs are high, and water delivery is sporadic.

Fish Screening Laws
In the early 1990's, when salmon became a listed species, federal rules were established requiring fish screens. In response, National Marine Fisheries Service (NMFS) developed screening criteria and grandfathered the most commonly used fish screening technologies into these criteria. The challenge was that there were only a handful of screening technologies allowed to address hundreds of thousands of diversions, each with different site conditions. The result: many landowners were required to install a screening device that did not work well on their site resulting in high operation and maintenance costs, an increasing belief that fish screens don't work, and often, as a result, fish screens being ripped out and landowners trying to keep their diversions "under the radar" to avoid screening.

Complicated Permitting
For landowners willing to install a screen, another complicating factor is that agencies, in a genuine effort to protect the environment and public interest, developed permitting processes that must be completed before the installation of a screen. But with each project requiring two to seven permits, each with different rules and with different agencies, the process is difficult to navigate. This takes considerable time and money, and the process can take months or even years to receive approval. Contrary to their intent, these permit requirements became a primary impediment to screen installations.

Fluctuating Prices
Further preventing landowners from installing a fish screen, screens do not have a set price. Because every site is unique, if a landowner orders a 5 cubic feet per second (cfs) screen, a relatively small screen, his or her liability could be anywhere from $5,000 to $75,000.

Agencies: the suppliers and the regulators of fish screens
In light of these chronic problems, private sector involvement has been limited. Consequently, the task of developing and installing screens fell to state and federal fish agencies where funds for research, development, and installation are at least available even if limited. But the agencies are overwhelmed. In Oregon, the leader in state screening programs with four screen shops, roughly 75

screens are installed annually. With somewhere between 30,000 and 50,000 unscreened diversions in each of the states of Oregon, Washington, and Idaho alone, state fish screen shops cannot begin to meet the demand for screens.

Trigger Events

Due to limited budgets, agencies often rely on trigger events for enforcement action. Landowners fear coming forward to get information about obtaining a fish screen for their diversion, as this the inquiry itself may be a trigger event. The fear is that once a farmer makes notice that he or she needs a screen, he or she will be then compelled to install one regardless of whether or not the technological options are acceptable. While many farmers consider themselves stewards of the environment, the fear of spending thousands of dollars on a screen, without assurance it will even work for their site, has kept many farmers from coming forward.

Lack of Public Awareness

Most people have never heard of a fish screen. Therefore, they have no idea about the benefits fish screens provide for both the fish and farmer. This lack of awareness has made it difficult to get public, and, therefore, political support, for legislation and funding that could dramatically improve the situation for both the environment and agriculture. Similarly, lack of public awareness has also affected the amount of investment in agrarian technologies despite the massive potential for resource conservation.

Solution: The Farmers Screen, a rare win-win solution for fish and farmers

Invention

Seeking a way to reduce the $90,000 in annual operation and maintenance costs, as well as prevent an estimated 250,000 fish trapped in their diversions, Farmers Irrigation District (FID) of Hood River, Oregon struggled with their thirteen points of diversion.

Then, in 1996, FID lost its irrigation infrastructure due to a severe flood event on the Hood River on the north side of Mount Hood. Left without a way to deliver water to their farmers or generate revenue with their hydroelectricity plants, the staff and farmers began brainstorming ways to restore their district without re-installing the same high maintenance fish screens they previously had.

Intrigued by the idea of horizontal fish screens, district staff and farmers worked to overcome the previously unresolved shortcomings of horizontal screens: early horizontal screens took far too much water through a very small surface area, thus trapping debris and killing fish. During this time of rebuilding, the farmers and staff went to state agencies, nonprofits and tribes and asked for their support in developing a new type of fish screen. After ten years of research and testing, FID created the Farmers Screen, a self-cleaning, horizontal screen that would soon be proven to protect fish and manage debris.

To honor the collaborative effort that made the screen possible, as well as to ensure that the screen would always be used to benefit the common good, FID patented the Farmers Screen technology. In 2005, FID licensed the Farmers Screen to the Farmers Conservation Alliance with the conditions that FCA take the screen to market, address institutional barriers to widespread screen installation, and use profits for other solutions that benefit both environment and agriculture.

Opportunity: FCA

FCA officially opened its doors in January 2006. In this initial phase, FCA sought to establish a proof of concept as well as become a criteria screen by receiving the essential NMFS approval. During this time, FCA's focused on:

- Marketing the Farmers Screen technology
- Developing demonstration sites
- Incorporating lessons learned to refine technology and sales process
- Creating a vast network of relationships and partnerships throughout the region
- Developing trust with the environmental and agricultural communities

Of course one of the major focuses during this period was also technology refinement. By installing twenty-three screens throughout the west in a variety of sites with varying cultural and political conditions, FCA was able to refine the technology itself as well as its sales and customer vetting processes.

In July 2011, after more than 16 years of testing and demonstration projects, the Farmers Screen received NMFS approval, and horizontal flat plate fish screens are now included in NMFS fish screening criteria. The Farmers Screen is the first new technology to be added to the criteria since it was created. Though these criteria only apply to anadromous streams in the Northwest, NMFS approval is widely regarded as the most rigorous fish screen design standard and, therefore, is the standard used for most national, and international, screen design. Hence, receiving NMFS approval is critical for widespread screen acceptance and, consequently, sales.

By 2018, FCA will install 314 Farmers Screens, open 2,100 of stream miles for safe fish passage, save landowners nearly $4 million in avoided operation and maintenance costs, and support the development of 91 MW of fish-friendly hydropower capacity.

THE FARMERS SCREEN

A Conservation Innovation Grant-Supported
Technological Innovation in Fish Screening

Technical Document
Submitted By: Les Perkins, Farmers Conservation Alliance

April 12, 2012

Introduction:

Water is diverted from rivers and streams for many different types of uses including agriculture, hydropower production, domestic and municipal water supplies, fish hatcheries, mining, and industrial applications. In most applications, there is a need to keep debris out of the diverted water. Beginning in the west, and now spreading throughout the country, there is an increasing need to exclude native fish species from water diversions without causing harm to the fish. While there are several traditional screening technologies available, these technologies have limitations that make operating in high gradient systems with high sediment and or organic debris loads problematic.

Development of new screening technologies to address the wide array of site conditions found at points of diversion has been hindered by a lack of economic incentive due to a complex web of regulatory requirements and a poorly defined and difficult to access market.

One screen design that offers an effective solution for traditionally difficult to screen high gradient sites is a horizontal flat plate design known as the Farmers Screen. The Farmers Screen is different from traditional screening technologies in several ways. First, the screen material itself is horizontal as opposed to vertical, allowing debris and fish to wash over the surface of the screen material. Second, the Farmers Screen has no moving parts, which eliminates the need for a power supply and greatly reduces the maintenance associated with the screen. Third, the Farmers Screen is substantially self cleaning, meaning that under normal operating conditions the screen will not accumulate debris on the screen surface which again reduces maintenance requirements and provides consistent fish protection. Finally, to operate correctly, the Farmers Screen requires by-pass flow, which provides protection from both injury and delay for fish as well as effective debris management.

The Farmers Screen design has been successfully implemented at 24 points of diversion in 4 states (OR, ID, MT, and WY). These sites span a wide range of flows (from 0.5 CFS maximum to 160 CFS maximum) and site conditions. All of the installed Farmers Screens are located off-channel and behind a functioning head gate that controls the rate of flow into the screen system.

How it works

The Farmers Screen uses hydraulics to effectively manage debris and protect fish. Water moves over the screen surface at a relatively high velocity (generally 2 to 8 feet per second) and moves through the screen at a relatively low velocity (maximum approach velocity of 0.25 feet per second). This combination of a high sweeping velocity and minimal downward velocity moves fish and debris over the screen and back to the river or stream. An oscillating velocity creates a pulsing action that also contributes to the self-cleaning characteristics of the screen. The combination of a weir wall and taper wall configuration keep water depths and velocities constant. The weir wall is essential for maintaining depth of water over the screen as well as consistent approach velocities. The taper wall is essential for maintaining velocities down the length of the screen by decreasing the cross sectional area of the screen flume as the volume of water in the flume decreases.

Testing

There have been numerous hydraulic and biological tests performed on the Farmers Screen both in the laboratory and in the field. Early hydraulic testing on the horizontal flat plate screen technology concept was performed by the Bureau of Reclamation in the Water Resources Research Laboratory in Denver, CO from 2000 to 2001 with a final report being published in February of 2005. The report can be found under the name "Hydraulic Performance of a Horizontal Flat-Plate Screen" Hydraulic Laboratory Report HL-2004-05, authored by Kathleen H. Frizell and Brent W. Mefford. A biological test was performed in the same laboratory using the same physical screen model by the Larval Fish Laboratory out of Colorado State University. The biological test report can be found under the title "Bull Trout Performance During Passage Over a Horizontal Flat Plate Screen" with a final report date of July 20, 2002 authored by Dr. Daniel W. Byers and Dr. Kevin R. Bestgen and identified as "Larval Fish Laboratory Contribution Number 128". This early laboratory testing of prototype designs provides a foundation for understanding the hydraulic performance of horizontal flat plate screens in relation to specific design components. The testing also points to some areas for improvement in the design to provide more favorable hydraulic characteristics for both fish protection and debris and sediment management.

More recent testing on installed Farmers Screens include biological testing performed by the United States Geological Survey (USGS), Western Fisheries Research Center, Columbia River Research Laboratory at a Farmers Screen installation at the Oxbow Fish Hatchery in Cascade Locks, OR. The final report was published in late 2010 under the name "Biological Evaluations of an Off-Stream Channel, Horizontal Flat-Plate Fish Screen – The Farmers Screen" Open-File Report 2010-1042 and authored by Matthew G. Mesa, Brien P. Rose, and Elizabeth S. Copeland. This biological testing examines the effects on juvenile Coho salmon and steelhead trout as they pass through a Farmers Screen system under various hydraulic and operating conditions, specifically analyzing injury and mortality rates as well as potential to cause delay in out migration for salmonids. The results of the testing show a very high level of protection that exceeds NMFS standards as well as a very low likely hood of delay with 99.6 % of test fish passing over the screen without hesitation or delay.

The Farmers Screen represents the culmination of years of field experience combined with knowledge gained from laboratory and field hydraulic and biological testing. The technology has been refined to provide consistent and predictable fish protection as well as debris management with minimal maintenance requirements. For specific site conditions, the Farmers Screen is an excellent choice to provide a high level of protection for aquatic species while reliably providing debris free water for beneficial use. The Farmers Screen design is described in US Patent numbers 6524028 and 6964541.






Background:

Farmers Irrigation District

Horizontal debris screens have been around for hundreds of years, but they have not been used for fish protection for the simple fact that they tend to be too efficient. Horizontal screens have historically tended to pin debris (and fish) against the screen surface, causing injury or death to aquatic species and a high level of necessary maintenance in order to maintain flows.

In the Hood River Valley in Oregon, on a glacially fed river system, Farmers Irrigation District (FID) developed a horizontal screening system that overcame the typical issues associated with earlier versions of the concept. The impetus for the development came from a high cost of maintenance associated with the District's existing vertical screens. In 2002, Farmers Irrigation District worked with federal and state resource agencies and the Confederated Tribes of the Warm Springs to permit and install a full-scale prototype of the Farmers Screen, a horizontal flat plate fish screen, on a diversion on the main stem of the Hood River. Upon becoming operational, the screen was subjected to hydraulic and biological testing. The testing showed a high level of fish protection as well as reliable debris management due to favorable and consistent hydraulic performance.

To honor the collaborative effort that made the screen possible, as well as to ensure that the screen would always be used to benefit the common good, FID patented the Farmers Screen technology. In late 2005, FID licensed the Farmers Screen to the Farmers Conservation Alliance (FCA) with the conditions that FCA take the screen to market, address institutional barriers to widespread screen installation, and use profits for other solutions that benefit both ecology and agriculture.

Farmers Conservation Alliance

FCA officially opened its doors in January 2006. In this initial phase, FCA sought to establish a proof of concept as well as become a criteria screen by receiving the essential NMFS approval. During this time, FCA's main focuses were:

- Developing demonstration sites
- Incorporating lessons learned to refine the technology and project development process
- Creating a vast network of relationships and partnerships throughout the region
- Developing trust with the environmental and agricultural communities

FCA was awarded an NRCS Conservation Innovation Grant (CIG) in 2007. The purpose of this award was to stimulate the development and adoption of the Farmers Screen as well as demonstrate the benefits for agricultural production, environmental enhancement, and environmental protection.

During the past six years, FCA has installed 23 Farmers Screens in Oregon, Idaho, Wyoming, and Montana. To date, these Farmers Screen installations have converted a total of 484.2 cubic feet per second of diverted water to fish-friendly diversions. A total of 10 MW of fish-friendly hydropower capacity has been optimized, and a total of 167.70 river miles have been opened for fish passage. Farmers Screen owners are saving a total of $493,700 each year in avoided operation and maintenance costs with their new fish screens.

By 2018, FCA expects to install By 2018, FCA will build a financially sustainable organization that will install 314 fish screens, open 2100 river miles for safe fish passage, save landowners $4,000,000 in reduced operation and maintenance costs, and support the production of $31,000,000 worth of fish-friendly, green hydropower production.

Refining the technology

By installing twenty-three screens throughout the west in a variety of sites with varying cultural and political conditions, FCA was able to refine the technology itself as well as its sales and customer vetting processes.

In the process of refining the technology and developing demonstrations sites, FCA designed a modular Farmers Screen system. The modular system was developed to reduce the cost and complexity of screen installation for small, remote diversions. By eliminating the need for onsite fabrication, concrete, and individual screen engineering, the modular system reduces overall project costs and the time it takes to implement a small project.

FCA was fortunate to develop screening projects in basins with very high levels of organic material, as well as large sediment loads. An effective and simple sediment management system was developed to address a constant flow of glacial and other sediment into Farmers Screen installations.

Working with the Columbia Basin Fish and Wildlife Authority's (CBFWA) Fish Screening

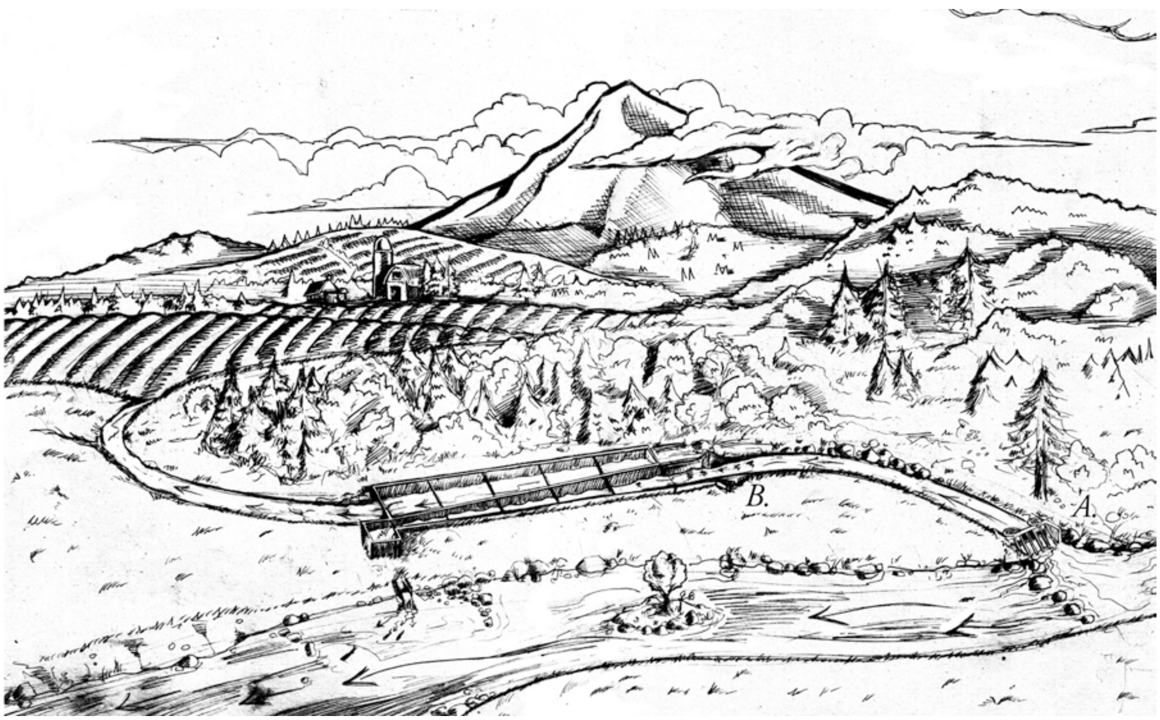
Oversight Committee (FSOC), FCA developed a detailed site selection process, operation manual, and monitoring process. These processes and documents are intended to provide a consistent method for properly siting the Farmers Screen technology and as well to provide guidance in operation and monitoring once the screen is installed.

In July 2011, after more than 16 years of testing and demonstration projects, the Farmers Screen received NMFS approval, and horizontal flat plate fish screens are now included in NMFS fish screening criteria. The Farmers Screen is the first new technology to be added to the criteria since these criteria were created. Though these criteria only apply to anadromous streams in the Northwest, NMFS approval is widely regarded as the most rigorous fish screen design standard and, therefore, is the standard used for most national, and international, screen design.

How It Works:

The Farmers Screen is a horizontal, flat-plate fish and debris screen. Designed to be installed in an off-stream channel, water, fish, and debris pass quickly over the Farmers Screen and return to the river. Inside the screen, the actual screening material lies parallel to the water's surface. Diverted water travels slowly through the screen material while the water carrying fish and debris moves quickly across the screen surface, cleaning the screen as the water returns to the river. This combination of minimal downward velocity and high sweeping velocity is what manages debris and protects fish. Finally, the taper and weir walls ensure uniform water depths and velocities.

Flow Control: The rate of flow into the screen system must be controlled upstream of the screen system, typically with a headgate (A). There are many types of headgates available, and each type has advantages and disadvantages for specific site conditions.

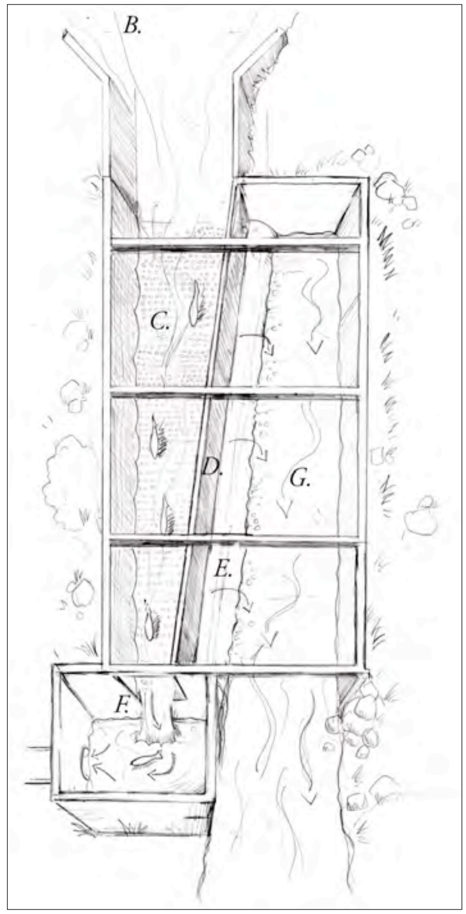


Components

The Farmers Screen has several components that work together to create the hydraulic conditions necessary for both fish protection and debris management without the need for a mechanical cleaning mechanism.

A. Flow Control: The rate of flow into the screen system must be controlled upstream of the screen system, typically with a headgate. There are many types of headgates available and each type has advantages and disadvantages for specific site conditions.

B. Inlet Flume: Typically there is a transition that creates turbulent flow as the diverted water moves from the diversion structure, through a headgate and into the conveyance structure. The Farmers Screen requires a sufficient length of straight flume prior to the leading edge of the screen to ensure steady state uniform flow when the water reaches the leading edge of the screen.



C. Screen Flume: The screen flume is where the actual screen material separates the screened flow from the by-pass flow. The screen flume must be perfectly level with smooth side walls to ensure proper hydraulic function.

D. Taper Wall: The taper wall reduces the cross sectional area of the screen flume as water volume decreases in the screen flume, therefore, keeping the sweeping velocities relatively constant down the length of the flume.

E. Weir Wall: The weir wall controls the water surface elevation over the screen material and provides a uniform approach velocity. The minimum depth over the screen surface depends upon the applicable regulatory agency criteria.

F. Screen Flume Outlet: The by-pass water must flow freely out the end of the screen flume. There must not be any backwater influence that could affect the hydraulic performance of the screen.

G. Attenuation Bay: The screened water must flow out of the attenuation bay at a rate that maintains a maximum water surface elevation that is below the crest of the weir wall. The water surface elevation in the attenuation bay must not influence the water surface elevation over the screen material.

These system components work in harmony to create consistent hydraulic conditions to effectively manage debris and protect fish. The system must be designed to maintain a maximum approach velocity of 0.25 ft/s and a sweeping velocity that is 30 to 60 times the approach velocity. The sweeping velocity automatically increases and decreases with a corresponding increase or decrease in approach velocity. The criteria developed specifically for horizontal fish screens by the National Marine Fisheries Service can be found in the “NMFS Anadromous Salmonid Passage Facility Design” document published in July of

2011. The relevant section pertaining to horizontal screens is 11.6.1.7 and can be found beginning on page 90.

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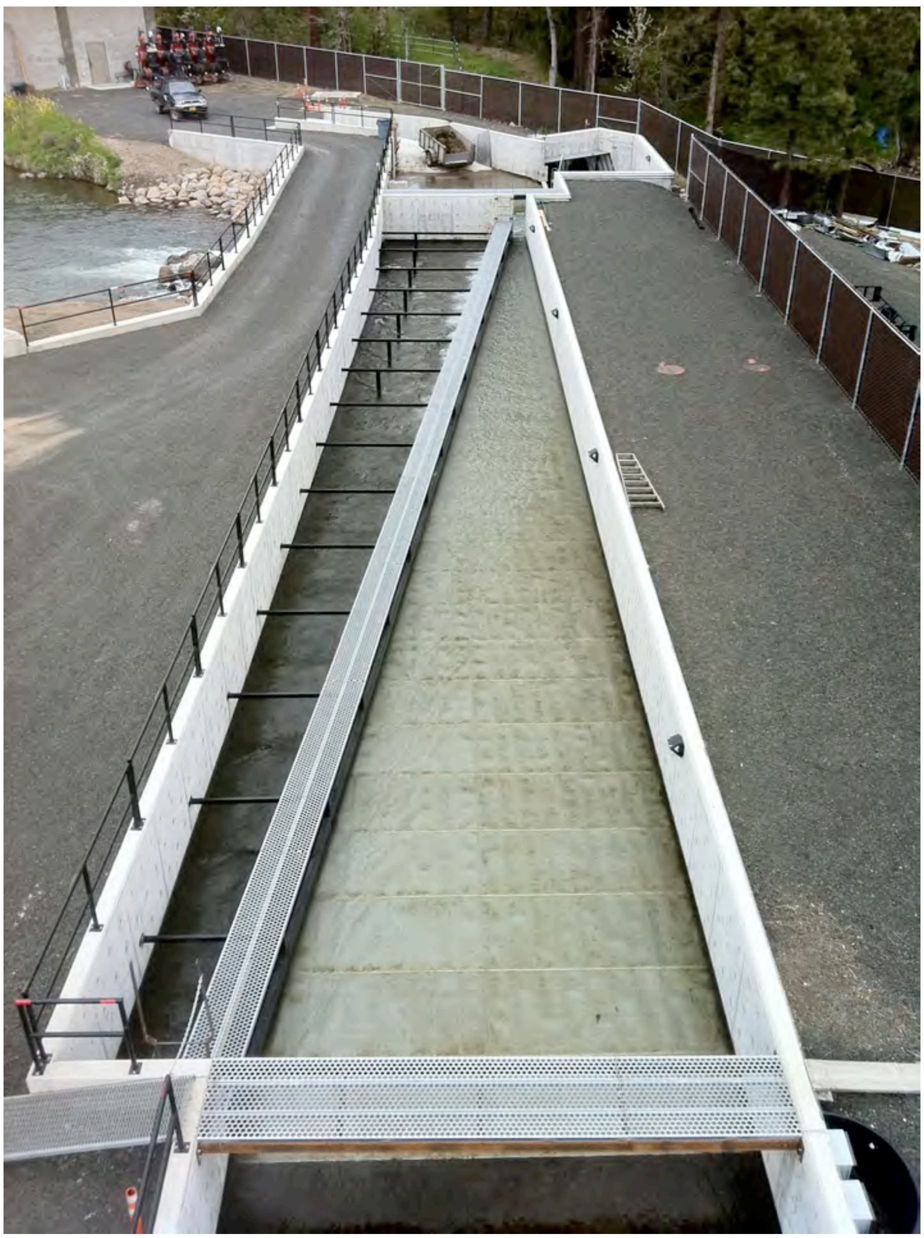


Where It Works:

The Farmers Screen requires specific site conditions in order to operate properly. Put in simple terms, the site must have elevation differential in both the conveyance and the source river or stream **and** constantly available by-pass flow in addition to the screened flow and in-stream flow.

Site Requirements

Screen Location: The site must be off-channel with flow to the screen regulated by a headgate. There must be adequate space to accommodate the screen structure in a place that is protected from high flow events.

Adequate Flow: There must be adequate flow in the source river or stream to ensure that the proper amount of by-pass flow (flow returning to the river or stream along with fish and debris) in addition to the screened flow and any necessary in-stream flow is available 100% of the time that the screen is operating. The necessary by-pass flow quantity is a function of screen design and is determined during the design process.

Elevation Differential: This is also sometimes referred to as required "head" or "fall." The Farmers Screen requires a drop in elevation from the point of diversion to the end of the screen structure. Typically, a total of 1 foot in water surface elevation differential from the point of diversion to the end of the screen structure is sufficient. The head generated by the elevation differential is needed in two places: the entrance to the inlet flume and at the leading edge of the screen. Head is required to drive the water into the inlet flume, and more head is required as water volume increases. There must be enough head to induce velocities of 3 to 7 feet per second across the screen flume. Head is also required to drive water through the screen structure itself. Approximately 0.3 feet is necessary to overcome the head loss through the screen (measured from the flume water surface elevation to the attenuation bay water surface elevation).

Stream or River Gradient: The slope of the source river or stream must exceed the slope of the diverted water conveyance such that the elevation differential between the screen surface elevation and the stream (at the point where the by-pass water return pipe enters the stream) is sufficient to prevent any backwater influence in the pipe and to meet NMFS criteria regarding by-pass flow hydraulics.

Operator: The screen owner/operator must be willing to agree to operate the screen as designed and as specified in the Operation Manual.

A siting criteria illustration is attached to this document as an appendix.

Common Limiting Site Conditions:

When deciding what type of fish screen technology to install at a particular site, it is important to understand and acknowledge all of the factors that can lead to project success and project failure. The following are examples of site conditions or information short falls that can easily lead to problems for a Farmers Screen:

Streamflow: Inaccurate, overestimated, or non-existent streamflow information can lead to serious problems. Knowing that the flow in the stream is adequate to support the screened water volume, the by-pass flow volume, and the necessary in-stream flow volume 100% of the time that the screen is operating is crucial to long term project success. Inadequate flows will lead to less-than-expected screened flow, increased maintenance due to loss of cleaning ability, and risk of stream de-watering.

Diverted Flow: Inaccurate, over- or under-estimated diverted flow volumes can cause serious problems in screen operation. The high and low diverted flow volumes must be known and can't be estimated or guessed at. Two of the most important design considerations for a screen are the maximum and minimum screened water volumes. Screened flow volumes higher than expected will lead to greater than expected head requirements, potentially causing issues at the point of diversion or in the conveyance system prior to the screen. Higher than expected screened flow volumes will also lead to greater than expected approach velocities, which can lead to problems with debris and fish impingement on the screen surface.

Elevation Differential: Proper siting of a screen requires a site survey to ensure the presence of adequate elevation differential to drive system hydraulics. Inadequate elevation differential in either the source stream or the conveyance system will lead to very low sweeping velocities, less than expected screened flow volumes, and increased maintenance.

Sediment Load: Characterizing the sediment load that the screen will be expected to process can be difficult but is very necessary. If planned for, a sediment management system can be designed and incorporated into the screen project. If not planned for, sediment can cause serious issues with screen operation including increased maintenance, loss of screen function, and decreased screened water volume.

Organic Debris: Characterizing the type and quantity of organic material expected to move through the diversion will help to determine what level of maintenance to expect. Most types of organic material will not pose a problem for a Farmers Screen. Algae and filamentous aquatic vegetation are two types of material that have not been extensively tested on a Farmers Screen.

Ice: If the diversion is to be operated in the winter months, it is important to know the low temperatures that will be encountered and what the duration of the low temperatures would be. Ice in the water column will clog the Farmers Screen. Several installations in Oregon operate throughout the winter months to supply hydropower water. These sites occasionally experience ice in the water column that eventually causes clogging at the screen and a shut down of the system until conditions improve.

Operator: The operator of the diversion to be screened must understand the operational requirements of the system and must be willing to follow the directions in the operation manual. The operator must also understand that any fish screen will require some level of maintenance. While the Farmers Screen has a low maintenance requirement when operated as designed, an operator must be aware that the head gate must be adjusted as stream flow changes and that the system should be inspected regularly to ensure proper operation.

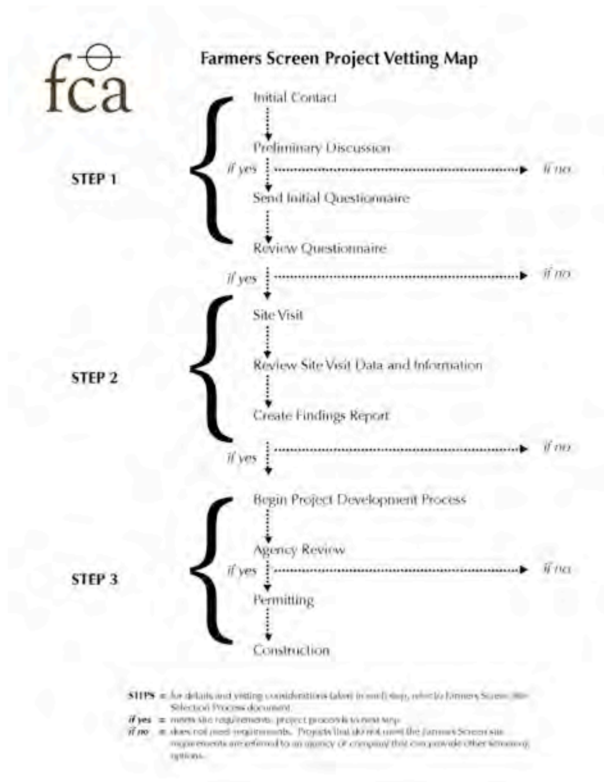
Siting a Famers Screen:

Process

FCA has developed a site selection process that is designed to gather information about a potential project with increasing levels of detail. Each step of the process allows for evaluation of the gathered information to determine if further investigation and investment of time and resources are warranted. At each stage, information gathered should be compared to the Farmers Screen site requirements. All site requirements must be met in order to proceed.

Step 1:

The first step of the process involves gathering information about the potential site such as high and low diverted flow, stream flow, and site topography. The initial questionnaire will provide enough information to determine if a site visit is warranted for further investigation.



Step 2:

The second step involves a site visit to gather more information. The site visit in this step should include the diverter and any potential project partners in order to be able to ask questions directly to those who might be able to provide good information. Photo and video documentation, a site sketch, detailed notes, a preliminary survey, and verification of previously gathered information should all occur in step 2. Following the review of all the information, a findings report should be generated with a recommendation regarding the suitability of the site for a Farmers Screen.

Step 3: Formal project development can occur at this point. All project partners should be engaged and design and permitting should proceed. It is still possible at this stage to discover information regarding the site that would make it a poor fit for a Farmers Screen. It is always better to stop at any point of the process and re-assess to ensure a good technology match for the given site than to proceed and end up with a project that doesn't meet expectations.

The tools that FCA has developed to move through the stages of site evaluation were developed with input from the members of the Columbia Basin Fish and Wildlife Authority's

Fish Screening Oversight Committee. The Initial Questionnaire and Site Evaluation Forms were designed to provide the information necessary to design a project with confidence. Copies of these forms can be obtained from FCA, and are attached to this document as appendices.

Site Survey

A site survey at some level is essential for developing a successful project. Whether using a Total Station to develop a detailed site plan or a simple laser level, there are some crucial pieces of information to gather. The following is a list of the most important survey points to obtain:

- Record top of water elevations and ordinary high water in host stream 100' above and below point of diversion. If possible, develop cross sections of the stream channel.
- Record the following elevations in the conveyance ditch: top of bank, ordinary high water, top of water, invert of ditch, and width of ditch at 10 foot intervals from point of diversion 100 feet upstream and downstream of proposed screen site location.
- Record the tops of all in-water structures such as a headgate, diversion structure, or an existing screen structure.
- Record all structures located on the project site.
- Survey surrounding area in order to provide sufficient information to develop a topographic map of the project site.
- Identify best route for a fish return pipe or channel back to the stream. Record the distance.
- Identify any trees that would need to be removed in order to gain access to proposed screen site or to install any infrastructure. Include the size and species of the tree.
- Identify access route to the site including grade, surface composition, and any potential hazards for access by cement trucks or other equipment.

Obtaining a Farmers Screen:

The Farmers Screen comes in two different formats: modular system and custom design. Site conditions and flow volumes will dictate which type of Farmers Screen is used.

Modular System:

The modular system was developed for remote sites and smaller diversions. The standard modular design can accommodate anywhere from 0.5 CFS to 15 CFS. The modular system is made of steel and is prefabricated and ready to be bolted together when it is delivered to the site. The modular system typically has the following components:

Inlet Flume: The inlet flume provides a smooth transition to the screen structure. The flume comes in two 10 foot sections which bolt to the screen structure. The inlet end of the flume can be configured to accept a pipe, an open canal, or butt to an existing flume.

Screen Sections: A modular system can have from 1 to 6 ten foot long sections, depending on the maximum flow. The sections will be either 3 feet or 5 feet wide, depending on the maximum flow.

Return Structure: A modular system can have several different return structures depending on the site conditions and the preference of the project partners. Typically, the system will have either a flume or a plenum box that connects to a pipe that carries the return flow back to the creek.

Sediment Management: A sediment management system can be built into the modular system if needed.

A modular system can be purchased directly from FCA by landowners, engineering firms, state and federal agencies, or any other project developers. FCA can provide any level of desired support during the development process.

Custom System:

Custom Farmers Screen systems are typically housed in a concrete structure. For all custom systems, FCA partners with an engineering firm. The engineering firm will provide all engineering for the concrete civil works into which the steel components of the Farmers Screen will be installed.

The custom design option can be used to screen any size diversion. Also, the custom system can be designed with multiple screens to accommodate wide flow ranges.

A custom screen system can be obtained by contacting FCA directly or by working through an engineering firm, state or federal agency, or any other project developer. FCA can provide any level of desired support during the development process.

Installing a Modular Farmers Screen:

Many small diversions are located in remote areas with poor site access. Field fabrication and pouring concrete can become extremely difficult and costly at many remote sites. The Farmers Screen Modular System was developed to provide for a relatively quick and cost effective installation. The Modular System consists of pre-fabricated steel sections and components that simply bolt together on site. The screen system rests on a bed of compacted gravel and is backfilled with native material. No concrete, welding, or electricity is required on site.

The process of installing a modular screen can be broken into the following components:

- Project Development
- Project Implementation
- Post-Project

Project Development:

1. Gather initial information about the project. This includes high and low water diversion rates, stream flow information, existing site conditions, and project proponent goals. This can be gathered by FCA, an engineering firm, or any other project developer.
2. Perform site visit and conduct survey. The site visit includes verifying any previously gathered information, interviewing operators, land owners, and field biologists as well as conducting a survey of the site. Again, this step can be performed by FCA, an engineer, or any other project developer. A full topographic survey of the site is preferred; however a simpler survey can suffice.
3. Analyze project information with particular emphasis on available stream flow in relation to desired screened flow. Using the survey data, analyze the hydraulic grade line in both the stream and the diversion. Head loss through the entrance flume and screen structure must be accounted for to ensure adequate head exists to allow for the screen installation and the associated by-pass/fish return structure.
4. Develop final project design and implementation plan. Include input from all project partners and ensure project goals and objectives will be met. Again, ensure all project information is accurate and expectations are realistic.

Project Implementation:

1. Apply for and obtain all relevant permits and approvals.
2. For a modular screen installation, plan on 1 to 3 days total construction time.
3. De-water the diversion. Ensure that the head-gate is sealed in order to provide as dry a construction site as possible. If a head-gate installation is part of the project, then sand bagging and dewatering of the installation point is necessary. Make sure the necessary fisheries biologists have been consulted and have given consent to this procedure.

4. Using a laser level or other method for accurate determination of elevation, excavate screen installation location. Typically, excavation must be deep enough to allow for a minimum of 6" of compacted gravel under the Farmers Screen Modular structure. Local soil conditions and types will dictate required site preparation. If high water table could be an issue, then ensure adequate drainage to eliminate the possibility of the screen structure floating (reduce the upward hydraulic pressure by giving an outlet to water that could accumulate under the screen).
5. Place Farmers Screen Modular sections. Each section weighs between 800 and 1000 pounds, so a machine capable of lifting and placing these components is required. Ensure that the screen structure is at the proper elevation and that it is level in all directions. Bolt together screen sections using supplied hardware. Lay a bead of 100% silicone caulk (provided) along attachment seams prior to attachment.
6. Place the intake flume. Ensure that the intake flume is at the proper elevation and that it is level in all directions. Attach the intake flume with the supplied hardware. Lay a bead of 100% silicone caulk along the attachment seams prior to attachment.
7. Place the fish return flume or plenum. Ensure that the return flume or plenum is at the proper elevation and is level in all directions. Attach the return flume with the supplied hardware. Lay a bead of 100% silicone caulk along the attachment seams prior to attachment.
8. Place fish return pipe or construct fish return channel. The design of the fish return will typically be determined by the local fisheries biologist from the relevant state or federal agency. Typically, the return will be in a pipe and will be set at a slope that provides in pipe velocities that meet National Marine Fisheries Service standards (1.3% slope is a good starting place).
9. If the Farmers Screen Modular system includes a sediment management system, then installation of the pipes and valve outside of the screen structure must occur prior to backfilling around the screen. Install the control valve on the exterior of the screen structure. Install the pipe for returning the sediment to the stream and connect it to the previously installed valve. Ensure that some type of an access box is installed to allow access to the valve.
10. Back fill around all components. Typically native material is adequate, however, in high water table applications, drain rock might be a good alternative.
11. If the conveyance between the headgate and the entrance flume is open channel, then providing some large rock armoring around the flume entrance is necessary. Using rock to shape an entrance to the flume that is roughly the same width as the flume will provide better entrance hydraulics and will reduce the chance of erosion around the entrance flume.
12. Open the head gate and test the screen through the expected range of flows. A flow measuring device such as a velocimeter is necessary to accurately determine actual flow. Ensure that the screen is operating properly and that the by-pass system is operating as expected.

13. Perform any planting or restoration activities necessary for the completion of the project.

Post Project:

1. Conduct any post-project site inspections/visits for project partners, permitting entities, or funders.
2. Distribute Farmers Screen operation manuals to project partners that will be operating, inspecting, or helping to maintain the project.
3. Provide monitoring forms to project partners who will be visiting the site periodically. Collecting monitoring data will help to identify any operational or design issues that need to be addressed to ensure a successful project.
4. Monitor the project at least through the first complete season of operation, and preferably for the first three seasons. It is important to ensure that the project operates as expected through the entire range of flows and conditions.
5. If an issue arises with screen performance or operation, contact FCA for input and review prior to making any changes to the screen system.

Installing a Custom Farmers Screen:

Custom Farmers Screens are typically designed for larger projects (greater than 15 CFS screened flow) or for sites where access is not an issue and a concrete structure is preferred. Custom Farmers Screens are always designed in partnership with an engineering firm. FCA provides the design of the fish screen, including the size and shape of the concrete structure that will house the screen components. The engineering firm is responsible for the structural engineering for the concrete structure, as well as the entrance and exit from the screen structure and any additional project components. FCA provides the steel screen components and is responsible for installing the screen components into the concrete structure. FCA will provide the engineering firm with the boundary conditions necessary for the screen to function properly. The engineering firm will be responsible for analyzing the hydraulic conditions of the entire project to ensure proper entrance and exit conditions of the final design.

The process of installing a custom Farmers Screen can be broken into the following components:

- Project Development
- Project Implementation
- Post-Project

Project Development:

1. Gather initial information about the project. This includes high and low water diversion rates, stream flow information, existing site conditions, and project proponent goals. This can be gathered by FCA, an engineering firm, or any other project developer.
2. Perform site visit and conduct survey. The site visit includes verifying any previously gathered information, interviewing operators, land owners, and field biologists as well as conducting a survey of the site. Again, this step can be performed by FCA, an engineer, or any other project developer. A full topographic survey of the site is necessary.
3. Analyze project information with particular emphasis on available stream flow in relation to desired screened flow. Using the survey data, analyze the hydraulic grade line in both the stream and the diversion. Head loss through the entrance flume and screen structure must be accounted for to ensure adequate head exists to allow for the screen installation and the associated by-pass/fish return structure.
4. Develop final project design and implementation plan. Include input from all project partners and ensure project goals and objectives will be met. Again, ensure all project information is accurate and expectations are realistic.

Project Implementation:

1. Apply for and obtain all necessary permits and approvals.
2. Hire contractors for the excavation and concrete work. Ensure that the contractors hired have experience working in and around rivers and streams.

3. For a custom Farmers Screen installation, plan on 2 weeks to 3 months for construction depending on the size and complexity of the project.
4. Ensure that all project components are placed at the design elevation and location on the site. It is essential to have an experienced project manager or construction engineer on site during all construction activities. Improper elevations will lead to a screen project that does not perform as designed.
5. Once the concrete has adequately cured, installation of the fish screen components can begin. Typically FCA will be responsible for installation of the screen components. Depending on the size of the screen, this will take between one and two weeks.
6. Once the screen component installation is complete and all other project components are complete, the screen system can be tested. The screen should be run through the entire expected flow range. Typically, FCA staff will be present for the initial calibration. Minor adjustments to the screen can be made to maximize performance through the entire design flow.
7. Perform any planting or site restoration activities necessary to complete the project.

Post-Project:

1. Conduct any post-project site inspections/visits for project partners, permitting entities, or funders.
2. Distribute Farmers Screen operation manuals to project partners that will be operating, inspecting, or helping to maintain the project.
3. Provide monitoring forms to project partners who will be visiting the site periodically. Collecting monitoring data will help to identify any operational or design issues that need to be addressed to ensure a successful project.
4. Monitor the project at least through the first complete season of operation, and preferably for the first three seasons. It is important to ensure that the project operates as expected through the entire range of flows and conditions.
5. If an issue arises with screen performance or operation, contact FCA for input and review prior to making any changes to the screen system.

Project Examples:

Deadpoint Creek: 15 CFS Modular Farmers Screen

• Location: Parkdale, Oregon
• Basin: Hood River
• Partners: Farmers Irrigation District, Crestline Construction
• Installation Date: October 2010

Project Description: Farmers Irrigation District diverts water from Deadpoint Creek (a tributary to the West Fork of the Hood River) for both irrigation and hydropower production. In October of 2010, FCA replaced an in-stream flat plate screen with a six section modular Farmers Screen with a maximum flow capacity of 16 CFS.

Deadpoint Creek is a high gradient stream with seasonally high amounts of organic debris. The point of diversion is remote and inaccessible during portions of the winter months. The diversion is monitored using telemetry. Low maintenance operation is a must at this site due to the remote location.

The new screen system consists of:

- New headgate
- Entrance flume
- 6 section modular Farmers Screen
- Screened water plenum (connects to conveyance pipe)
- Return water plenum (connects to fish return pipe)
- Drain curtain to manage ground water flows

Coe Creek: 5-30 CFS Dual Farmers Screen

- Location: Parkdale, Oregon
- Basin: Hood River
- Partners: USFS, USFW, DEQ, NMFS, ODFW, Hood River Watershed Group, The Confederated Tribes of the Warm Springs, OWEB, Middle Fork Irrigation District, Anderson Perry Engineering, and FCA
- Installation Date: December 2009

Project Description:
Coe Creek flows from the Coe Glacier on Mt. Hood and is a prime Bull Trout stream. Glacially fed streams flowing down the flanks of Mt. Hood tend to carry a large quantity of fine sediment as well as being prone to large debris flows in the spring and fall. Coe Creek is no exception.

In 2006, Middle Fork Irrigation District began the process of designing and permitting the removal of their dam on Coe Creek and the construction of a new fish screen. This diversion is located on the Mt. Hood National Forest and supplies irrigation water for agriculture and produces hydro power. The project included removing the dam (which was a passage barrier), installing rock weirs for grade control, restoring the stream channel, and installing a custom Farmers Screen with a sediment control system.

Construction began in the early fall of 2009 and was completed by the end of December of 2009. The restored stream allows for up and downstream passage in the stream channel. The new fish screen allows the district to manage sediment much more effectively while reducing their maintenance requirements.

This custom designed Farmers Screen is a dual design to accommodate a wide flow range. The district draws between 5 and 30 CFS from Coe Creek, depending on the time of year and water quality. The district operates one screen when flows are 15 CFS or less and then can operate both screens when flows exceed 15 CFS. Both screens are equipped with a sediment management system consisting of a slotted pipe system laying on the floor of the structure (in the screen underbay) just inside of the weir wall. The slotted pipe is used as a continuous flush mechanism which sucks any sediment which could settle out under the screen and sends it back to the creek. Water can be diverted with turbidity levels of over 1000 NTU's.

Whychus Creek: 30-160 cfs Farmers Screen

- Location: Sisters, Oregon
- Basin: Deschutes
- Owner: Three Sisters Irrigation District
- Installation Date: April, 2011
- Partners: USFS, NOAA/NMFS, ODFW, DEQ, USFWS, Three Sisters Irrigation District, Upper Deschutes Watershed Council, River Design Group, Anderson Perry and Associates, Specialty Metal Fabrication, and FCA.

Project Description:

This extensive restoration project on Whychus Creek in central Oregon includes in-stream fish passage, floodplain reconnection, and a low maintenance Farmers Screen. The project was fully operational for the 2011 irrigation season.

Three Sisters Irrigation District (TSID) diverts up to 160 CFS from Whychus Creek, a tributary to the Deschutes River. TSID has historically diverted water using a stream spanning low head dam and did not have a fish screen in place. The diversion is located on US Forest Service land in the National Forest where a re-introduction of summer Steelhead is occurring. The project goals included in-stream fish passage at the dam, reconnection of the flood plain, and installation of a fish screen capable of protecting fish while reliably supplying irrigation water through a wide range of stream flows and diverted flows in a system with high levels of glacial silt.

The 160 CFS maximum capacity fish screen is the largest Farmers Screen installed to date. The screen is a dual design which allows for a very wide range of diverted flows (30 to 160 CFS) while still meeting NMFS criteria. The TSID Farmers Screen has built in sediment management which allows continuous flushing of sediment from under the screen during the high sediment times of the year. The screened water leaves the screen structure and enters two pipelines that carry the screened water to a reservoir and directly to farmers and ranchers within the district. The by-pass flow carries fish and debris back to Whychus Creek through a pipeline.

The TSID Whychus Creek project is a great example of meeting the needs of both the agricultural community and the environment.

Farmers Screen Initial Questionnaire

This form is designed to gather preliminary information that will help FCA to determine how we can best serve your particular organization. The information will be confidential and will not be released to another party without your permission. If this information is provided to a government agency, it will no longer be confidential. We realize that some of the requested information may not be available, however providing as much information as possible early in the process will help us to save time and money for our organization and yours.

1. Organization name (owner of water right)
2. Is there more than one water user? If yes, how many?
3. Public or privately held?
4. Contact name and title
5. Address, phone, fax, email, web address
6. Location of diversion to be screened (city, county, state, water source diverting from, GPS coordinates if available)
7. Is the diversion on private or public land? If public, is it local, state, or federal?
8. Is the diversion currently screened and if so, what type of screen? Is it working? And, what problems have you encountered with the screen?
9. Does the diversion currently have a headgate?
10. Is there a dam associated with the diversion?

11. How is the water conveyed from the water source to the screen location? (canal or pipe)

12. Is there a hydroelectric project associated with this diversion?

13. Has a site survey been completed? If so, can you supply the survey?

14. What is the gradient in the conveyance (% slope)?

15. What is the gradient in the river or stream to be diverted from?

16. Basin, sub-basin located in:

17. Name of Watershed Group and Water Conservation District?

17. Water right (quantity, type of use, permit number, and date):

19. What is the maximum quantity of water diverted? How was this determined (estimate, gauging station, etc.)?

20. What is the minimum quantity of water diverted? How was this determined?

21. At any time during the year do you take 100% of the available water?

22. At any time of the year do you have difficulty getting your water right?

23. Is there stream flow data available?

24. Is water diverted year round?

25. What are your high and low water temperatures during the year? Do you ever experience freezing issues while diverting?

26. Do you have sediment, debris, or algae problems at this site? If so, what times of the year are of concern? Any details available will be helpful in determining scope of the project.

27. Is the diverted water transported in a canal or is it piped? This information helps with the initial design process.

28. Who do you work with at the state and federal agencies? (ODFW, DSL, USFW, Forest Service, NOAA Fisheries, etc.). FCA has positive relationships with all of the applicable agencies and will assist your organization in obtaining permits and in working for a positive outcome for all parties.

29. Are you interested in applying for grant funding and if so would you like FCA to apply on your behalf? Grant funding is dependent on many factors including species of fish present and the presence of threatened or endangered species. If you feel comfortable sharing information about all species present, we can use the information to determine what grant funds your organization might be eligible for. If an agency has taken an enforcement action against your organization, it would be important to disclose this information now because it has a large impact on the funding available for your project.

Please return the completed questionnaire to:

Les Perkins
fca
14 Oak Street, Suite 302
Hood River, OR 97031

Email: les.perkins@fcasolutions.org
Questions: 541.490.4062

fca

Farmers Screen Site Evaluation

The site evaluation is the second tier in evaluation of a potential project. The information gathered during the site visit is meant to provide enough information to either confirm that the site is appropriate for a Farmers Screen or to determine that another technology or solution would be necessary. It is essential that as much information is gathered during the site visit as possible. If acceptable to the landowner, state and federal agency representatives should be invited.

Equipment Checklist:

- ❍ Still Camera
- ❍ Video Camera
- ❍ Tape Measure
- ❍ Laser Level
- ❍ GPS Receiver
- ❍ Flow Meter

Site Information:
(include city, state, watershed, river or stream name, FCA project name)

Invited Attendees:

Actual Attendees:

Date:

GPS Coordinates:

Elevation:

Soil Type:

Describe existing infrastructure:

Conveyance: (canal or piped)

Photos:
- ❍ Point of Diversion
- ❍ Upstream
- ❍ Downstream
- ❍ Diversion structure
- ❍ Head gate
- ❍ Conveyance
- ❍ Potential screen site(s)
- ❍ Potential return flow point(s)
- ❍ Access
- ❍ Existing screen

Video:
- ❍ Stream conditions (up and down stream)
- ❍ Diversion function including head gate
- ❍ Conveyance
- ❍ Existing screen

Survey: (If possible, shoot and record the following elevations)
- ❍ Top of Diversion Structure
- ❍ Any other infrastructure (headgate, screen structure, weir, etc.)
- ❍ Top of water and high water mark in stream at diversion point
- ❍ Top of water and high water mark 100′ above diversion point
- ❍ Top of water and high water mark 100′ below diversion point
- ❍ Top of water, invert, and high water mark in conveyance:
- ❍ Just behind head gate or at beginning of diversion
- ❍ 50′ down conveyance
- ❍ 100′ down conveyance
- ❍ Any other relevant points

Sketch Site Plan Including:
- ❍ River or stream (up and downstream)
- ❍ Diversion Point
- ❍ Conveyance
- ❍ All existing structures
- ❍ Potential screen locations
- ❍ Potential return points

Questions to Ask:
(please identify who is answering the question)

1. What is the largest amount of water that is diverted during the year in CFS? How was this determined?

2. What is the smallest amount of water that is diverted during the year in CFS? How was this determined?

3. Is by-pass flow available at all times?

4. Is there any time of the year when 100% of the water is diverted?

5. Is there any time of the year when it is difficult to get your water right?

6. Characterize the sediment or bed load in the system including timing and duration.

7. Characterize organic debris in the system including timing and duration.

8. Are there any records or data available regarding stream flow, diverted quantities, sediment, or bed load?

9. What is the soil like on the site? Is it likely that the ditch will seal around the structure?

Notes:

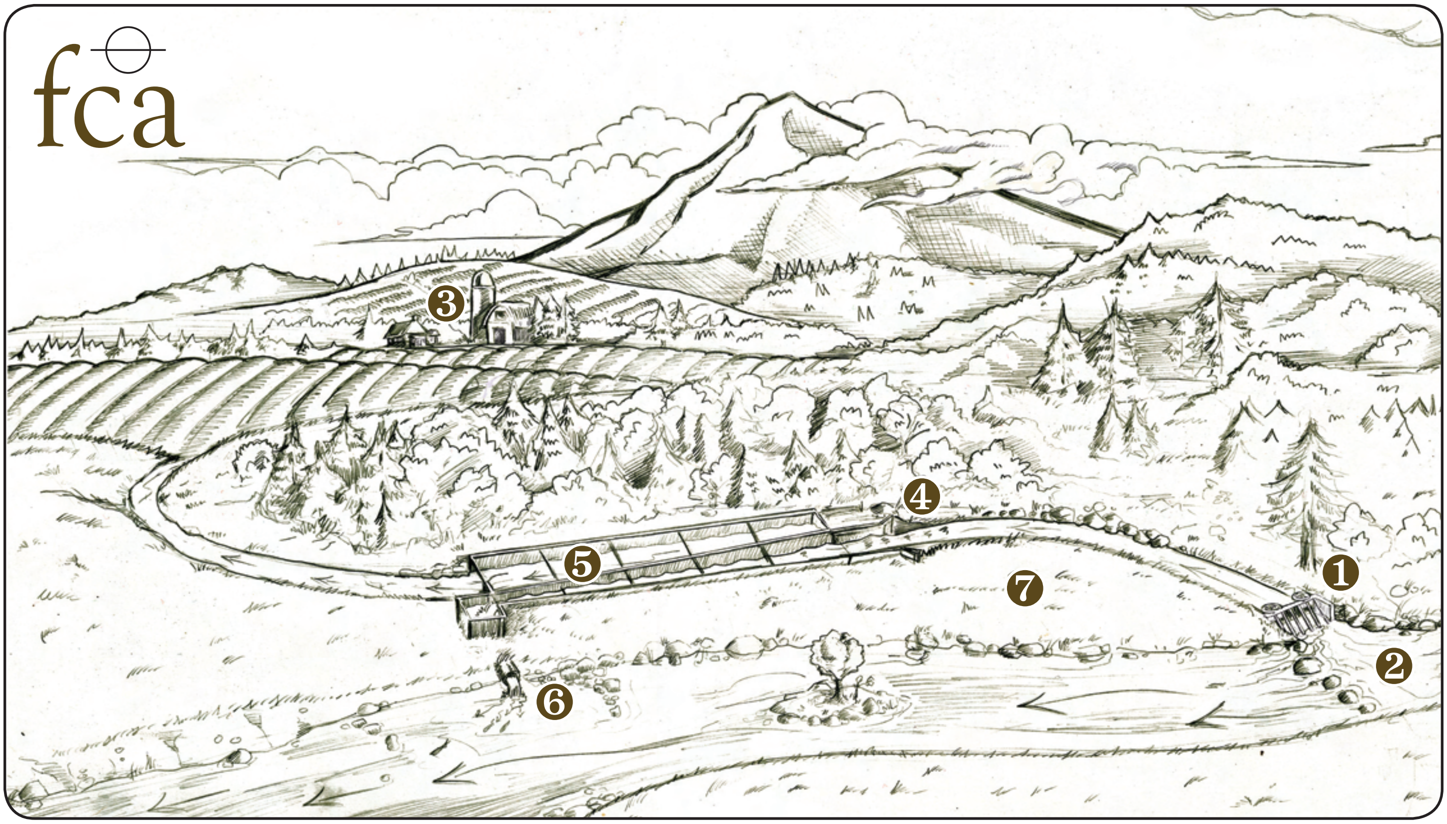


Illustration credit: Tommy Hood

FARMERS SCREEN SITING CRITERIA

❶ The proposed site must be located off-channel, and the flow to the screen must be controlled with a properly functioning head gate.

❷ There must be adequate flow in the stream to ensure that the proper amount of by-pass flow (necessary for the particular screen to operate properly), in addition to the desired screened flow, is available 100% of the time that the screen is operating. The by-pass flow required is a direct function of the screen design and will be determined when the flow range of the screen is determined.

❸ A screen owner/operator must be willing to agree to operate the screen as designed and as specified in the Operation Manual.

❹ The water at the leading edge of the screen must be of steady uniform flow at a velocity of between 3 and 7 feet per second. There must be sufficient gradient from the point of diversion to the leading edge of the screen to induce the required flow characteristics.

❺ A minimum total head differential (potential energy) of 0.3 feet, as measured from the flume water surface elevation to the attenuation bay water surface elevation is required for proper screen function in order to overcome head loss through the screen and into the attenuation bay.

❻ The slope of the source river or stream must exceed the slope of the diverted water conveyance such that the elevation differential between the screen surface elevation and the stream (at the point where the by-pass water return pipe enters the stream) is sufficient to meet NMFS criteria regarding by-pass flow hydraulics.

❼ There must be adequate land to locate the screen structure in a place that is protected from high flow events.

FOR MORE INFORMATION:

If your site meets these criteria, or if you would like help in evaluating your site conditions, FCA has an easy-to-use questionnaire that addresses these and all other relevant site issues.

Tours of existing Farmers Screen installations, model demonstrations, and in person presentations are available to people interested in learning more about this innovative fish screening technology.

CONTACT FCA:

Phone: 541.716. 6085 • Email: info@fcasolutions.org
FarmerScreen.org • FCASolutions.org

Biological Evaluations of an Off-Stream Channel, Horizontal Flat-Plate Fish Screen—The Farmers Screen

Open-File Report 2010–1042

U.S. Department of the Interior
U.S. Geological Survey

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U.S. Department of the Interior
KEN SALAZAR, Secretary

U.S. Geological Survey
Marcia K. McNutt, Director

U.S. Geological Survey, Reston, Virginia: 2010

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Conversion Factors

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
inch (in.)	25.4	millimeter (mm)
	Flow rate	
foot per second (ft/s)	0.3048	meter per second (m/s)
Multiply	**By**	**To obtain**
	Length	
centimeter (cm)	0.3937	inch (in.)
millimeter (mm)	0.03937	inch (in.)
meter (m)	3.281	foot (ft)
	Flow rate	
centimeter per second (cm/s)	0.0328	feet per second
cubic meter per second (m^3/s)	35.31	Cubic feet per second

Abbreviations and Symbols

Abbreviation and Symbol	Meaning
AV	approach velocity
CRRL	Columbia River Research Laboratory
FID	Farmers Irrigation District
FL	fork length
h	hour
mg/L	milligram per liter
NMFS	National Marine Fisheries Service
NV	normal velocity
s	second
SV	sweeping velocity
UV	ultraviolet
Z	water depth
<	less than
>	greater than

Biological Evaluations of an Off-Stream Channel, Horizontal Flat-Plate Fish Screen—The Farmers Screen

By Matthew G. Mesa, Brien P. Rose, and Elizabeth S. Copeland

Abstract

Screens commonly are installed at water diversion sites to reduce entrainment of fish. Recently, the Farmers Irrigation District (Oregon) developed a flat-plate screen design (that is, the Farmers Screen) that operates passively and may offer reduced installation and operation costs to irrigators. To evaluate the performance of this type of screen (its biological effect on fish), we conducted two separate field experiments in consecutive years. First, in 2009, two size classes of juvenile coho salmon (*Oncorhynchus kistuch*) were released over a small working version of this screen at Herman Creek, Oregon. The screen was evaluated over a range of inflow [0.02–0.42 cubic meters per second (m^3/s)] and diversion flows (0.02–0.34 m^3/s) at different weir wall heights. The mean approach velocities ranged from 0 to 5 centimeters per second and mean sweeping velocities ranged from 36 to 178 centimeters per second. Water depths over the screen surface ranged from 1 to 25 centimeters and were directly related to weir wall height and inflow. Passage of juvenile coho salmon over the screen under various hydraulic conditions did not severely injure the fish or cause delayed mortality. Injury or mortality did not occur even though many fish contacted the screen surface during passage. No fish were observed becoming impinged on the screen surface. Second, in 2010, we constructed a modular screen apparatus that had 34 meters of wooden flume connected to a 3.5-meter long section of the Farmers Screen to determine whether fish would refuse to pass over the screen and swim back upstream after encountering the leading edge of the screen under various hydraulic conditions. For these tests, smolting coho salmon and steelhead trout (*O. mykiss*) were released at the upstream end of the flume and allowed to volitionally move downstream and pass over the screen. Overall, 81 and 91 percent of the fish moved downstream through the entire apparatus within 5 and 25 minutes from their release and only 1 of the 275 fish released swam back upstream after encountering the screen. Collectively, our results indicate that when operated within its design criteria, the Farmers Screen provided safe and efficient downstream passage of juvenile salmonids under various hydraulic conditions. However, we do not recommend operating the Herman Creek screen at inflows less than 0.14 m^3/s because water depth can be quite shallow and the screen can completely dewater, particularly at low flows.

Introduction

Diversions from natural or manmade waterways are common in the United States and the water is used for many purposes. Many diversion structures are fitted with screens meant to prevent fishes and other aquatic life from becoming entrained in the diversion, injured, or killed. However, many thousands of water diversions remain unscreened. Some screening technology (for example, submersible traveling screens or rotary drum screens) and design criteria meant to protect fishes [National Marine Fisheries Service (NMFS), 2008] are relatively expensive and require frequent maintenance to operate properly (McMichael and others, 2004), which can limit the installation of screens in areas where screens are needed. Recently, the development of unique horizontal flat-plate fish screens offer designs that may be less expensive to install, offer simpler, more passive operation, and may have fewer detrimental effects on aquatic communities. Research on the hydraulic characteristics and biological effects of some flat-plate screens has been promising (Beyers and Bestgen, 2001; Frizell and Mefford, 2001; and Rose and others, 2008), but more work is needed to fully evaluate the performance of flat-plate screens. Evaluating different designs and sizes of horizontal flat-plate screens in the laboratory and in the field would allow further verification of screen performance, provide data for comparison with criteria for more traditional fish screens, and perhaps facilitate screen installation.

We evaluated the hydraulic and biological performance of a newly developed, off-stream channel horizontal flat-plate fish screen, also known as the Farmers Screen. These screens, designed over a 10-year period by personnel from the Farmers Irrigation District in Hood River, Oregon, have a higher rate of horizontal movement of water across the screen (sweeping velocity, SV) relative to the rate of movement of water through the screen (approach velocity, AV), good self-cleaning characteristics, the potential for reduced impingement, injury, and entrainment of fish, and may reduce installation and maintenance costs. The screens are manufactured in various sizes—a large version, designed to accommodate flows as large as 2.27 m^3/s, was subjected to hydraulic, debris-loading, and biological tests to evaluate injury and mortality to juvenile salmonids, including Chinook salmon (*Oncorhynchus tshawytscha*) and steelhead (*O. mykiss*). The test results showed that the large Farmers Screen did not cause injury or mortality to fish when operated in accordance with its design parameters (Craven Consulting Group, 2003). However, smaller versions of this screen have not been tested. Such evaluations would help to more fully evaluate the performance of these alternative technology screens.

The U.S. Geological Survey's Columbia River Research Laboratory (CRRL) conducted field experiments to assess the performance of this screen type during 2009 and 2010. The objectives of the study were to assess the hydraulic performance of the Farmers Screen and determine the effects of downstream passage of fish over the screen on their injury, delayed mortality, and behavior under various hydraulic conditions. This paper describes the study methods and results of those experiments.

Study Methods

Screen hydraulics and biological performance (2009)—The screen evaluated for its hydraulic and biological performance was located at the Oxbow Fish Hatchery in Cascade Locks, Oregon (fig. 1). The screen is on a side-channel of Herman Creek, a tributary of the Columbia River, and is designed to divert 0.28 m^3/s of water. The installation is similar to other Farmers Screens that have already been installed in the Pacific Northwest. For a complete description of this screen and of the Farmers Screen in general, see Farmers Conservation Alliance, 2006, *http://www.farmerscreen.org/*. For purposes of this report, we refer to this screen as the Herman Creek screen.

To assess the hydraulic performance of the Herman Creek screen, we adjusted the inflow entering the screen, measured the inflow and water depth (Z), diversion discharge, and bypass discharge, and calculated mean SV, AV, and normal velocity (NV, which is the AV multiplied by the percentage of open area of the screen, or AV × 0.5) under different weir wall heights. After most of these hydraulic conditions were measured, we experimentally released fish over the screen. We evaluated the screen under four weir wall heights (that is, 4, 11, 13, and 20 cm) and at inflows ranging from 0.02 to 0.42 m^3/s. We used multiple linear regression analysis to evaluate the influence of several continuous and discrete variables (for example, streamflow, weir wall height) on water depth over the screen, diversion discharge, and sweeping velocity. All coefficients are significant at the $P < 0.05$ level unless noted.

To assess the biological performance of the Herman Creek screen, we experimentally released groups of juvenile coho salmon (*O. kistuch*) over the screen under various hydraulic conditions and quantified any injuries to the integument of the fish and documented short-term delayed mortality. Our test fish were from the Oxbow Hatchery and we evaluated two size groups, large [85–145 mm FL (fork length)] and small (54–78 mm FL)], in two separate sets of trials. Fish that passed over the screen (treatment fish) were released in groups of 10, at a distance of 1–2 m above the upper edge of the screen, and were recaptured in a net beneath the bypass outfall. Control fish were released into the bypass outfall and captured in a net and held for several minutes to simulate the time it took most treatment fish to pass over the screen. We used a fluorescein dye method described by Noga and Udomkusonsri (2002) to determine the extent of ulceration on the skin, eyes, and fins of each fish. After capture, both groups of fish were euthanized in a lethal dose of MS-222 (200 mg/L), rinsed in a freshwater bath for 1 minute, and then placed in a solution of fluorescein dye (fluorescein disodium salt at 20 mg/L). After 6 minutes, fish were removed from the dye and rinsed in three separate freshwater baths over 3 minutes to remove excess dye. Images were taken of both sides of each fish in a dark box under ultraviolet (UV) light using a digital camera with a 200-mm macro lens. The UV lights were placed at 45° angles to the side of the fish and a yellow barrier filter was used to eliminate the blue auto-fluorescence. Images were imported into Adobe© Photoshop CS3 and the body surface area and area of fluorescence was measured on each side of a fish. The percentage of body surface area of a fish that was injured was derived by dividing the total area of fluorescence by the total body surface area. This included the two sides and most, but not all, of the dorsal and ventral surfaces of the fish. For each release group, we compared the percentage of body surface area of the fish that was injured for control and treatment fish using two-sample, Mann-Whitney *U* tests. We were interested in whether the levels of injury in treatment fish were significantly different than those of control fish. The level of significance was set at $P < 0.05$.

To assess delayed mortality after passage, additional fish were released in the same manner as described above but were transported to holding tanks after being collected in the bypass outfall. Fish were monitored for 24–48 h after passage and handling and the number of fish that died was compared between treatment and control groups. Mortality tests were conducted for most, but not all, of the same hydraulic conditions as injury tests.

To document the behavior of fish passing over the screen, treatment fish were videotaped using three underwater cameras mounted to one edge of the screen. The system was not designed to cover the entire screen area, and each camera provided only a partial, upstream view of the screen. Video files were reviewed in slow motion, and the approximate number of times fish contacted the screen, their orientation to the current during passage, and their general depth of passage were recorded. Control fish were not videotaped.

Behavioral responses of fish encountering the leading edge of a screen (2010)—To evaluate whether fish would refuse to pass over the screen after encountering the leading edge (a question we did not answer in 2009), we constructed a modular screen apparatus that had 34 m of wooden flume (46-cm wide by 36-cm deep) connected to a 3.1-m (long section of the Farmers Screen (fig. 2). The purpose of the long flume was to provide fish with plenty of distance between their release point (at the upstream end of the flume) and the upstream edge of the screen so the fish could orient themselves and move downstream somewhat naturally. The flume received water from the outflow of the Herman Creek Screen and was designed so that water velocities were slower in the upstream one-half of the flume than in the downstream one-half. We installed a trap on the downstream end of the screen to capture the fish.

We used yearling coho salmon (113–161 mm FL) from the Oxbow State Fish Hatchery (Oregon) and Skamania-stock steelhead (134–260 mm FL) from the Bonneville Fish Hatchery (Oregon) for tests. We used fish presumably undergoing the process of smoltification to maximize the probability that the fish would have a strong desire to migrate downstream. All the test fish were large and silvery with faint or non-existent parr marks. These fish should have had a relatively strong swimming ability (compared to smaller fish) and thus would be most likely to reject the screen if conditions posed a behavioral obstacle. Normally, these fish would have been released from the hatcheries during mid-April to early May. Prior to testing, all fish were held in large tanks at the Oxbow State Fish Hatchery and water temperatures were monitored daily.

On the day of testing, we first established the hydraulic conditions for the test, including inflow volume, water depth, AV, and SV over the screen, and water velocity and depths at several locations throughout the flume. Our intent was to test fish under various hydraulic conditions over the screen. We then removed 10 fish from their holding tank, placed them in a 19-L bucket with water, transported them from the hatchery to the test facility (about 2 km), and gently released them at the upstream end of the flume. Fish were allowed 20 minutes to volitionally migrate down the flume and pass over the screen. After 20 minutes, we gently prodded any fish that remained in the upper 3 m of the flume until the fish moved downstream. We conducted three to four releases of about 10 fish each, for a total release of 20–40 fish for each species under the various hydraulic conditions.

An observer was stationed on an elevated platform slightly upstream of the fish screen to record the behavior and passage timing of fish as they approached the screen. For each of five consecutive 5-minute periods, we recorded the number of fish that encountered the screen and whether the fish passed over the screen or refused to (that is, the fish turned and swam back upstream). For our analysis, we pooled data from the release groups for each species and hydraulic condition and determined the proportion of fish that passed over or rejected the screen for each time period. We also tallied data from each time period and determined the proportion of fish that passed over the screen within 25 minutes of their release.

Results of Field Experiments

Screen hydraulics and biological performance (2009)—Hydraulic conditions measured at the Herman Creek screen and the numbers of coho salmon released for injury and delayed mortality assessments are summarized in table 1. Diversion discharges (the volume of water collected from the screen and sent to the hatchery) comprised from 65 to 100 percent of the inflow rates. Mean AVs estimated for the entire screen ranged from 0 to 5 cm/s and for individual sections of the screen, mean AVs never exceeded 6 cm/s. Mean NVs ranged from 0 to 10 cm/s and varied along the length of the screen (fig. 3). Mean SVs ranged from 36 to 178 cm/s and generally were faster at the upstream edge and slower at the downstream edge of the screening panels. Mean SVs usually were at least 32 times higher than AVs for all conditions tested. The mean Z ranged from 1 to 25 cm and generally was deeper at the upstream end of the screen than at the downstream end. Mean depths were directly related to weir wall height and inflow and were inversely related to diversion discharge (R^2= 0.84; table 2), mean SVs were inversely related to weir wall height and diversion discharge and were directly related to inflow (R^2= 0.81; table 2), and diversion discharge was related to several variables (R^2= 0.99; table 2). "Hot spots" or localized areas of high AV with spiraling flow were not observed during any of our tests.

Overall, the injury rates of fish after passage over the Herman Creek screen were low, and severe injuries to the skin, eyes, and fins of both size cohorts were not observed. For large fish, the mean percentage of body surface area that was injured varied by release group and ranged from about 0.5 to 2.5 percent (fig. 4). The mean percentage of body surface area that was injured in treatment fish was significantly different than that of control fish for all test conditions (Mann-Whitney *U* tests, $P < 0.05$; fig. 4), but the magnitude of these differences was small (< 1 percent). For small fish, the mean percentage of body surface area that was injured ranged from about 0.4 to 3.0 percent (fig. 5). The mean percentage of body surface area that was injured in treatment fish was significantly different than that in control fish for three test conditions (fig. 5), but again, the magnitude of this difference was small (< 1 percent). One small fish, shown as an outlier in figure 5 with about 60 percent of its body surface area injured, probably was injured by something other than passage over the screen. For delayed mortality after passage, we tested 849 fish in total and none died within 24–48 h of passage or handling and only one control fish died.

The results of our video analysis revealed that for large fish, the mean number of times fish contacted the screen surface ranged from 0.15 to 0.72 per fish observed (table 3). During passage, most fish remained low in the water column near the screen surface (table 3). Fish were oriented either upstream or downstream during passage, with no clear relation to the hydraulic conditions (table 3). For small fish, the mean number of times fish contacted the screen surface ranged from 0.26 to 0.62 per fish observed (table 4). Again, most fish remained low in the water column and near the screen surface during passage. Most fish were oriented upstream during passage.

Behavioral responses of fish encountering the leading edge of a screen (2010)—To evaluate the behavioral responses of juvenile salmonids approaching and passing over the screen, we released a total of 173 coho salmon and 102 steelhead trout in the modular screen apparatus under various hydraulic conditions (table 5). In general, the hydraulic conditions in the modular screen system were similar to those recorded in the Herman Creek screen. For example, mean AVs estimated for the entire screen ranged from 1 to 3 cm/s or 2 to 6 cm/s after correcting for net open area (50 percent) and Z ranged from 15 to 25 cm. Mean SVs ranged from 102 to 150 cm/s and were at least 32 times higher than AVs for all tests. In the flume, mean water velocities ranged from 60 to 79 cm/s in the upstream one-half of the flume and from 85 to 104 cm/s in the downstream one-half of the flume. Mean values of Z in the flume ranged from 23 to 31 cm. For coho salmon, from 75 to 95 percent of the fish approached and passed over the screen within 5 minutes of their release, depending on hydraulic conditions (table 5). Within 20 minutes, the percentages of fish that quickly passed over the screen increased to 82–98 percent. After 20 minutes, 12 fish remained upstream in the flume and were gently prodded to move downstream; all these fish passed over the screen without hesitation. For steelhead trout, from 47 to 90 percent of the fish approached and passed over the screen within 5 minutes of their release, depending on hydraulic conditions (table 5). Within 20 minutes, the percentages of fish that quickly passed over the screen increased to 79–95 percent. After 20 minutes, 11 fish (11 percent) were coerced downstream of the upper 3 m of the flume and one fish turned and swam back upstream after it encountered the screen. However, this fish returned to the screen within 10 minutes and successfully passed. Overall, 99.6 percent of the fish we observed passed over the screen without hesitation or delay.

Biological Evaluation of Experimental Results

The results of our experiments in 2009 indicate that passage of juvenile coho salmon over the Herman Creek screen under various hydraulic conditions did not severely injure the fish, cause delayed mortality, or delay fish migration. These results occurred even though most fish passed over the screen near the screen surface, many contacted the screen during passage, and fish were oriented to the current in various directions. However, we did not observe fish becoming impinged on the screen surface (that is, >1 second contact with the screen). The screen showed good self-cleaning performance and never had problems with debris loading. Our results are similar to those of Rose and others (2008), who also reported minimal injuries and low mortality of rainbow trout after passage over backwatered and inverted-weir horizontal flat-plate screens in Oregon. Other studies evaluated various designs of vertically oriented screens and reported results similar to ours (Danley and others, 2002; Zydlewski and Johnson, 2002).

The injuries observed in our fish—both treatment and control groups—were minor and indicate that fish had some trauma to the integument prior to testing and that our holding and handling procedures probably caused more trauma. The fluorescein dye method was effective for detecting injuries to the integument of fish and revealed that all fish had some level of injury after testing. As stated previously, however, all injuries were minor and any differences in mean injury rates between treatment and control groups were small, which makes it difficult to ascribe any biological significance to the injuries we observed. Furthermore, and perhaps more importantly, none of our test results would have exceeded the performance standards for safe passage of fish over conventional screen systems as established by NMFS. For example, performance standards set by NMFS include less than 0.5 percent mortality and 2 percent injury rate (that is, the percentage of a sample that is injured) for salmonid smolts, and that at least 90 percent of salmonids that encounter a screened water diversion are bypassed within 24 h (Bryan Nordlund, National Marine Fisheries Service, written commun., 2010). The agency defines injury as visual trauma (including but not limited to hemorrhaging, open wounds without fungus growth, gill damage, bruising greater than 0.5 cm in diameter), loss of equilibrium, or greater than 20 percent descaling on one side (Bryan Nordlund, National Marine Fisheries Service, written commun., 2009). Because none of our fish showed such injuries, mortality was less than 0.5 percent, and most fish traveled over the screen without hesitation or delay, the Herman Creek screen would surpass these NMFS standards. Although the performance standards discussed here are for other types of screens, the standards do indicate that screens like the one at Herman Creek probably would, at a minimum, meet federal regulatory standards.

The ability of the Herman Creek screen to safely and efficiently pass fish at water depths ranging from 7 to 25 cm was largely due to achieving a high ratio of SV to AV (30:1–60:1) under various diversion conditions. These ratios were substantially higher than the SV recommendations established by NMFS for horizontal screens, which only suggest that downstream SVs be higher than AVs for the entire length of the screen (National Marine Fisheries Service, 2008). The combination of high SVs and low AVs facilitated quick downstream fish passage and eliminated impingements; results are similar to Beyers and Bestgen (2001). Because most fish passed over the screen near the screen surface—regardless of water depth—indicates that the 30 cm water depth recommendation established for horizontal screens (National Marine Fisheries Service, 2008) could be relaxed for smaller screens like the one at Herman Creek. Although fish safely passed over the screen at a depth of only 7 cm, the number of screen contacts per fish increased at this shallow depth for large, but not small, fish. Even though the screen contact rate was not related to the extent or severity of injuries, operating the screen at water depths near 7 cm seems too shallow, particularly under high-flow conditions. Thus, although our results suggest that the Herman Creek screen can be operated effectively at water depths less than 30 cm, we cannot unequivocally recommend a single, specific minimum depth for this screen. Rather, a range of minimum depths, perhaps from 15 to 20 cm, probably would provide safe passage of fish under most circumstances.

Despite the advantages of the Herman Creek screen for protecting fish populations, there are some things to consider when interpreting our results. First, we were unable to evaluate all possible hydraulic conditions on screen performance, fish injury, and mortality. Although we believe our evaluations were realistic because they encompassed typical diversion conditions, there may be other flow conditions we missed that are relevant to fish passage and safety. Second, only two species of fish were tested for the screen evaluations and our results may not be applicable to other species. The fishes used in our experiments probably were good surrogates for other salmonids of similar size. Extrapolation of our results to other fishes, such as juvenile lampreys or endangered suckers in the Klamath Basin, seems inappropriate and would require further testing. Next, our video analyses were not rigorous and our camera installation was meant to provide qualitative information on the behavior of fish as they passed over the screen. Even though we used three cameras, we had limited fields of view and it was often difficult to see because of water turbidity, sunlight, or other factors. Although we are confident that the data we did collect were representative of fish behavior during passage, more detailed analyses will require further work. Finally, we evaluated only the effects of downstream passage on juvenile fish. Further testing would be required to assess the effects of this screen type on fish migrating upstream across the screen surface.

The purpose of our testing in 2010 was to determine whether fish would reject or refuse to pass over the screen after encountering its leading edge—a notion that was a concern to fishery managers and something we did not evaluate in 2009. The concern was related to the changing hydraulic conditions at the flume-screen interface and whether fish would sense this change, turn around, and refuse to pass. Extended delays in passage over the screen could lead to excessive energy use in fish and violation of the NMFS standard that fish must be bypassed within 24 h. Our results, however, clearly indicate that the flume-screen interface was not an obstacle to passage for fish moving volitionally downstream, because high percentages of fish passed within 20 minutes. Even the small number of fish we had to manually coerce to move downstream readily passed over the flume-screen interface. We cannot state whether all fish encountering and passing through small versions of the Farmers Screen would be bypassed within 24 h because none of our tests were designed to answer this question. However, we think the possibility of fish not passing over these screens within 24 h would be remote.

Conclusions

When operated within its design criteria—diversion flows of about 0.28 m^3/s—the Herman Creek screen provided safe and effective downstream passage of juvenile coho salmon under various hydraulic conditions. We do not recommend operating the Herman Creek screen at inflows less than about 0.14 m^3/s because water depth can be quite shallow due in part to a weir wall that was not sealed and the screen can completely dewater, particularly at low flows. If the screen is operated at inflows less than 0.14 m^3/s, caution must be used to avoid diverting an excessive amount of water, which can lead to shallow depths, insufficient bypass flow, and perhaps screen dewatering. Finally, we do not know the fate of fish that pass over the screen, enter the bypass channel, and are diverted back to the Columbia River. It is possible that passage through these areas is a stressful and disorienting event for fish, which could make them vulnerable to hazards that exist downstream, such as predation by fish or birds. This idea is not unique to the Herman Creek screen, but is relevant for many types of diversions and obstacles fish may encounter in the wild. Further research would be necessary to address this issue.

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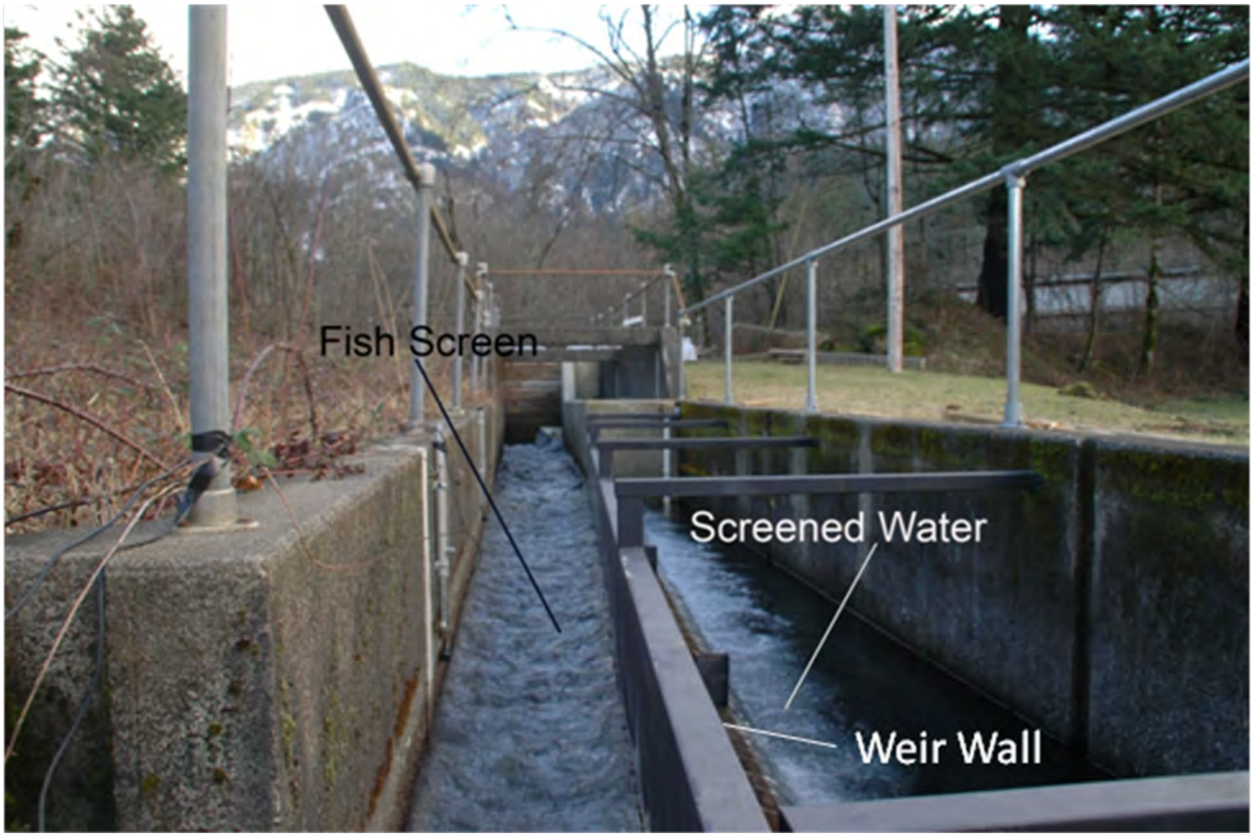

Figure 1. Photograph of the Herman Creek Screen, looking upstream, at the Oxbow Fish Hatchery, Cascade Locks, Oregon. Photograph taken by Brien P. Rose.

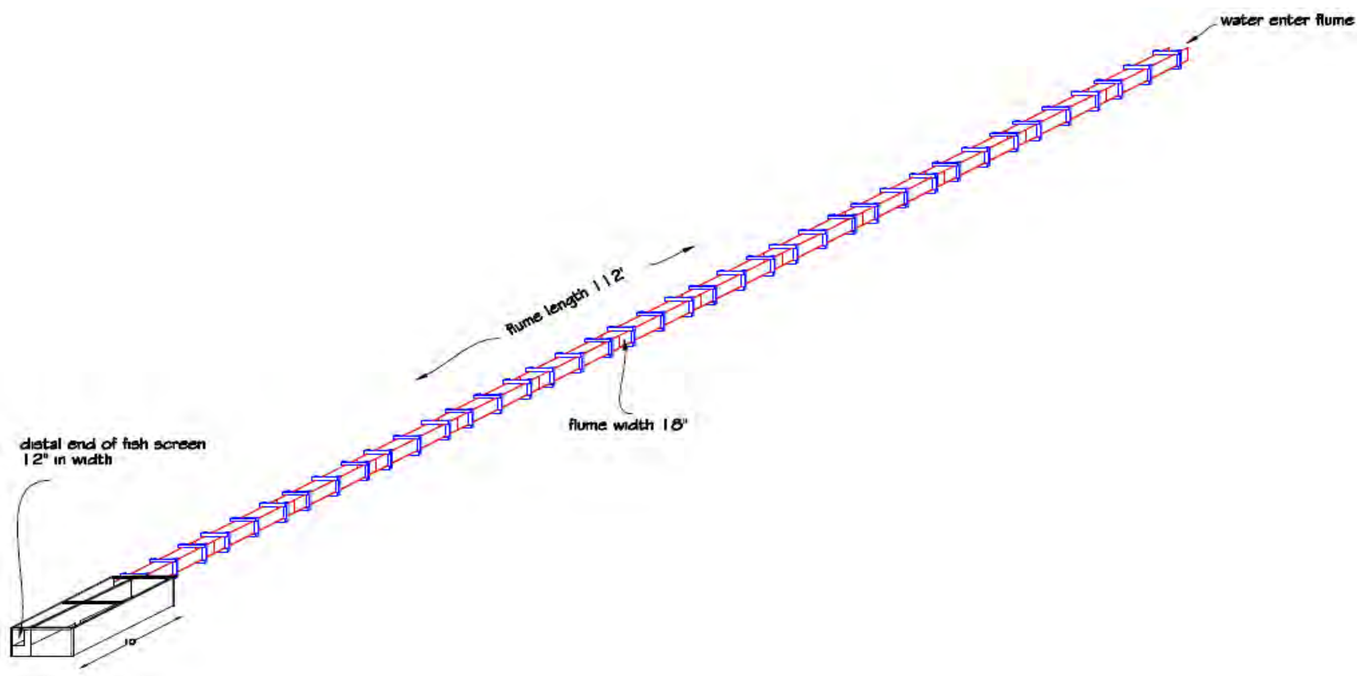

Figure 2. Schematic of the modular screen apparatus used to evaluate the behavioral responses of juvenile salmonids encountering the leading edge of the Farmers Screen, 2010. The modular screen apparatus consisted of a 34 m of wooden flume connected to a 3.1-m long section of the Farmers Screen.

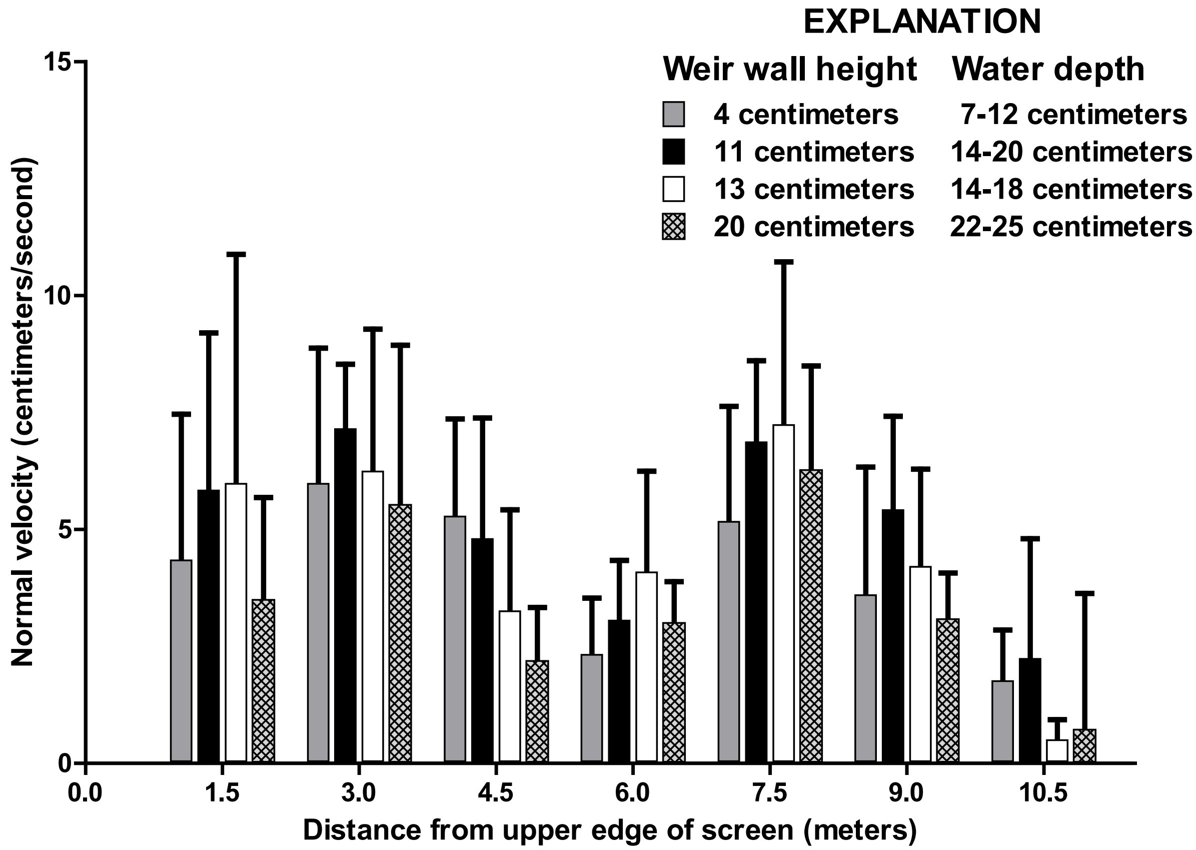

Figure 3. Mean normal velocities (approach velocities corrected for the net open area of the screen) estimated for different sections of the Herman Creek screen relative to weir wall height and water depth, 2009. The whiskers represent the standard deviations of the estimates.

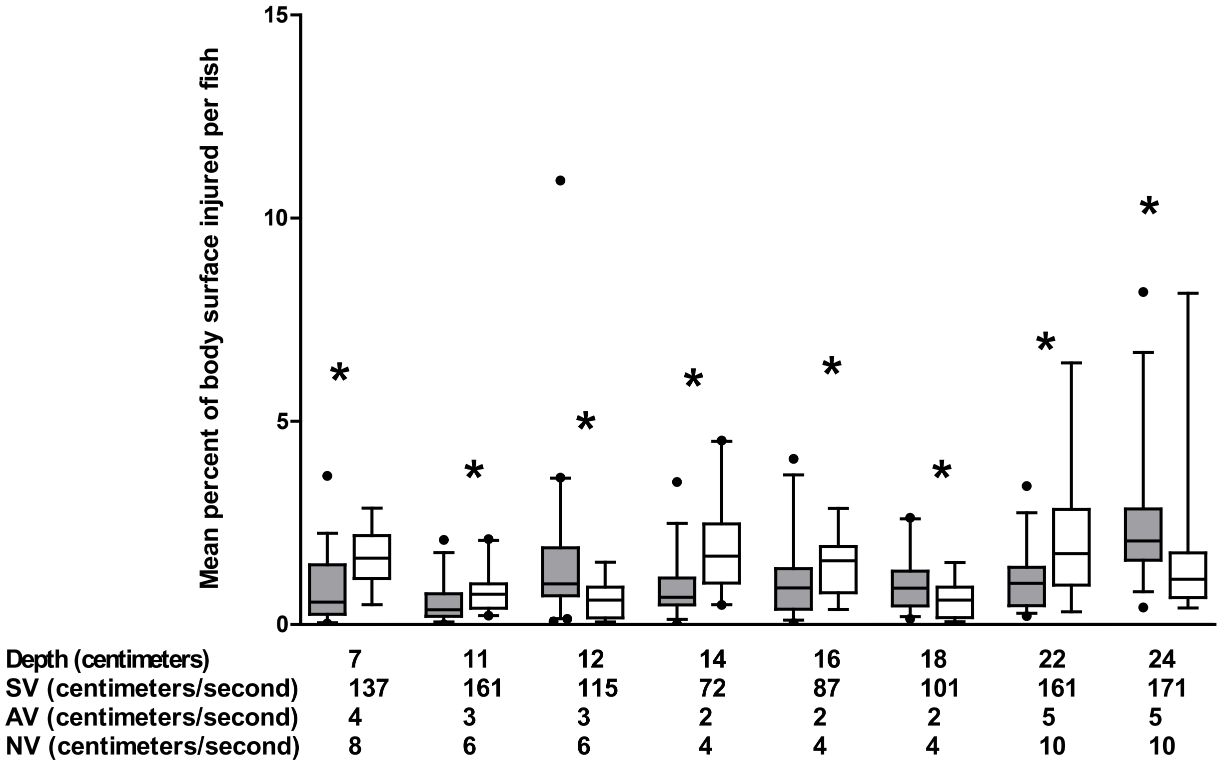

Figure 4. Distribution of the percentage of body surface area of large juvenile coho salmon injured when released over the Herman Creek screen (grey boxes) under various hydraulic conditions relative to control fish (white boxes). The upper and lower boundaries of the box represent the 25th and 75th quartiles, the line inside the box is the mean, the whiskers represent the 5- and 95-percent confidence intervals, and outliers are shown by solid points. The X-axis shows the water depth over the screen, the mean sweeping velocity (SV), the approach velocity (AV), and the normal velocity (NV) during each test. Asterisks denote a significant difference between medians within a group (Mann Whitney *U* test, $P < 0.05$).

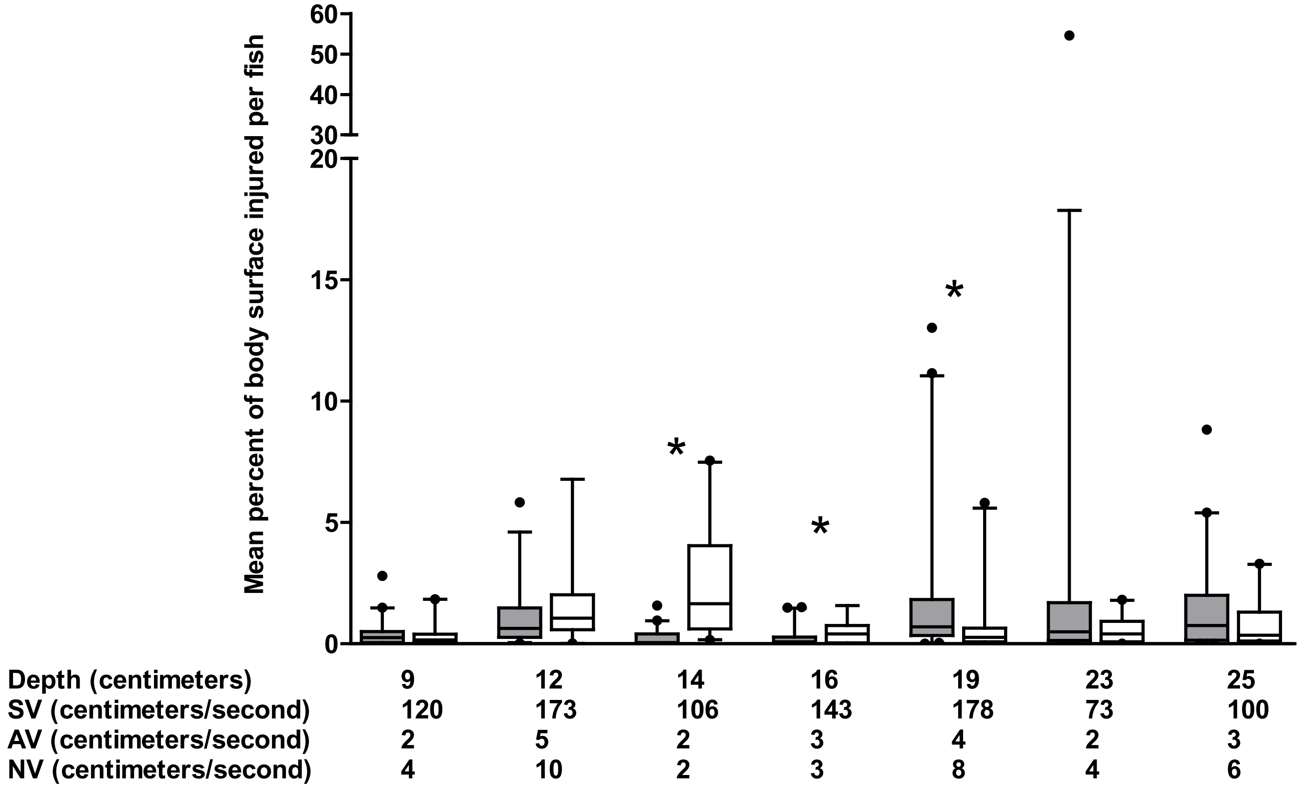

Figure 5. Distribution of the percentage of body surface area of small juvenile coho salmon injured when released over the Herman Creek screen (grey boxes) under different hydraulic conditions relative to control fish (white boxes). The upper and lower boundaries of the box represent the 25th and 75th quartiles, the line inside the box is the mean, the whiskers represent the 5- and 95-percent confidence intervals, and outliers are shown by solid points. The X-axis shows the water depth over the screen, the mean sweeping velocity (SV), the approach velocity (AV), and the normal velocity (NV) during each trial. Asterisks denote a significant difference between medians within a group (Mann Whitney *U* test, $P < 0.05$).

Table 1. Summary of hydraulic conditions at the Herman Creek screen and the numbers of two size groups of juvenile coho salmon used during injury and delayed mortality assessments.

[Trials were conducted on different days during February through May 2009. Q, discharge; SV, sweeping velocity; AV, approach velocity; Z, water depth over the screen; T, treatment fish; C, control fish. SD, standard deviation; cm, centimeters; cm/s, centimeters per second; m^3/s, cubic meters per second. Values in parentheses are data for delayed mortality tests. na, not available]

Inflow Q (m^3/s)	Diversion Q (m^3/s)	Bypass Q (m^3/s)	SV (cm/s; mean [SD])	AV (cm/s)	Z (cm; mean [SD])	Large fish		Small fish	
						T	C	T	C
4-cm weir wall height									
0.10	0.10	0.00	67 (34)	1	7 (1)				
0.14	0.13	0.01	87 (41)	2	7 (1)	37	17		
0.15	0.14	0.01	120 (50)	2	9 (1)			40 (44)	19 (15)
0.26	0.23	0.03	166 (52)	3	12 (1)				
0.27	0.25	0.02	137 (49)	4	11 (3)	38 (65)	20		
0.29	0.26	0.02	138 (73)	4	10 (1)				
0.31	0.28	0.02	130 (46)	4	12 (2)				
0.34	0.31	0.03	173 (45)	5	12 (1)			39 (51)	19 (17)
0.36	0.33	0.03	171 (41)	5	12 (1)	41 (60)	15 (30)		
11-cm weir wall height									
0.14	0.11	0.03	101 (30)	2	14 (1)	39	20		
0.15	0.12	0.03	106 (30)	2	14 (1)			40 (45)	20 (18)
0.29	0.23	0.05	161 (23)	3	16 (2)	40	20		
0.29	0.23	0.06	143 (30)	3	16 (1)			40 (45)	14 (15)
0.34	0.26	0.08	178 (32)	4	19 (1)			41 (36)	20 (15)
0.42	0.34	0.07	161 (30)	5	18 (1)	38 (61)	15 (42)		
13-cm weir wall height									
0.10	0.09	0.02	61 (20)	1	14 (0)				
0.20	0.13	0.07	170 (36)	2	16 (2)				
0.31	0.24	0.06	127 (25)	4	20 (1)				
20-cm weir wall height									
0.02	0.02	0.00	na	0	1 (1)				
0.04	0.03	0.01	36 (15)	0	8 (0)				
0.15	0.10	0.05	72 (12)	2	22 (1)	38	14		
0.15	0.10	0.05	73 (12)	2	23 (0)			36 (44)	20 (15)
0.27	0.20	0.07	100 (15)	3	25 (1)			35 (45)	20 (15)
0.28	0.22	0.06	115 (17)	3	24 (1)	39 (60)	15 (52)		
0.29	0.21	0.08	101 (25)	3	25 (1)				

Table 2. General linear models describing relation between hydraulic variables measured at the Herman Creek screen, 2009.

[All coefficients are significant (P < 0.05) unless noted. SV, sweeping velocity; Z, depth of water over screen; SQ, inflow discharge; DQ, diversion discharge; WW, weir wall height; *SEE*, standard error of estimate; cm, centimeters; m^3/s, cubic meters per second]

Dependent variable	Equation
Depth	Z = 2.592[1] + 0.572 (WW) + 89.673 (SQ) – 75.712 (DQ)
	$N = 24$, $R^2 = 0.84$, $SEE = 2.27$
Diversion discharge	WQ = 0.056 – 0.003 (WW) + 0.902 (SQ) + 0.000 (SV)
	$N = 24$, $R^2 = 0.99$, $SEE = 0.01$
Sweeping velocity	SV = 105.007 – 4.863 (WW) + 1,166.178 (SQ) - 1,063.394 (DQ)
	$N = 24$ $R^2 = 0.81$, $SEE = 17.82$

[1]*P*=0.25

Table 3. Mean number of fish contacts with the screen, their relative depth of travel during passage, and their general orientation to the water flow during passage for large juvenile coho salmon experimentally released over the Herman Creek screen, 2009.

[AV, approach velocity; SV, sweeping velocity; SD, standard deviation; cm, centimeter; cm/s, centimeter per second]

Date	Water depth (cm; mean [SD]))	AV (cm/s)	SV (cm/s; mean [SD])	Mean (SD) number of screen contacts per fish	Depth in water column (percentage of observed)			Orientation (percentage of observed)		
					low	mid	high	up stream	down stream	other
2/27	7	2	87 (41)	0.72 (0.58)	69	25	6	44	56	0
2/17	11	4	137 (49)	0.45 (0.23)	41	54	5	36	60	4
3/4	12	5	171 (41)	0.47(0.24)	53	35	12	55	45	0
3/2	14	2	101 (30)	0.26 (0.18)	58	35	6	35	65	0
2/18	16	3	161 (23)	0.41(0.23)	44	43	13	58	42	0
3/3	18	5	161 (30)	0.15 (0.18)	66	28	5	33	67	0
2/24	22	2	72 (12)	0.41 (0.34)	69	25	5	53	47	0
2/19	24	3	115 (17)	0.41 (0.33)	60	32	8	46	54	0

Table 4. Mean number of fish contacts with the screen, their relative depth of travel during passage, and their general orientation to the water flow during passage for small juvenile coho salmon experimentally released over the Herman Creek screen, 2009.

[AV, approach velocity; SV, sweeping velocity; SD, standard deviation; cm, centimeter; cm/s, centimeter per second]

Date	Water depth (cm; mean [SD])	*AV* (cm/s)	*SV* (cm/s; mean [SD])	Mean (SD) number of contact per fish	Depth in water column (percentage of observed)			Orientation (percentage of observed)		
					low	mid	high	up stream	down stream	other
5/19	9 (1)	2	120 (50)	0.32 (0.14)	57	40	3	56	40	4
5/20	12 (1)	5	173 (45)	0.50 (0.30)	63	33	4	61	15	24
5/15	14 (1)	2	106 (30)	0.56 (0.26)	58	32	10	55	41	4
5/13	16 (1)	3	143 (30)	0.42 (0.25)	49	37	14	44	38	18
5/14	19 (1)	4	178 (32)	0.62 (0.35)	65	23	12	53	35	12
5/8	23 (0)	2	73 (12)	0.26 (0.22)	69	24	7	70	30	0
5/12	25 (1)	3	100 (15)	0.35 (0.21)	53	28	19	61	37	2

Table 5. Summary of hydraulic conditions at the modular screen, the number and species of fish used for testing, and the percentage of fish that successfully passed over the screen during consecutive 5-minute periods, 2010. Only one steelhead refused to pass over the screen initially, but eventually did so within 10 minutes.

[Q, discharge; AV, approach velocity; SV, sweeping velocity; SD, standard deviation; cm, centimeter; cm/s, centimeter per second;

Inflow *Q* (m^3/s)	Water depth (cm; mean [SD])	AV (cm/s)	SV (cm/s; mean [SD])	Number of fish released	Percentage of observations where fish passed over the screen				
					0 – 5 min	5 – 10 min	10 – 15 min	15 – 20 min	>20[1] min
Coho Salmon									
0.06	15 (1)	2	111 (6)	40	91	0	0	0	9
0.09	15 (1)	3	150 (8)	20	75	10	10	0	5
0.09	19 (1)	2	132 (7)	33	82	0	0	0	18
0.07	20 (0)	1	102 (10)	40	88	0	0	0	12
0.08	25 (1)	1	102 (13)	40	95	3	0	0	3
Steelhead Trout									
0.06	15 (1)	2	111 (6)	40	90	3	0	0	8
0.09	15 (1)	3	150 (8)	22	62	5	0	29	5
0.08	25 (1)	1	102 (13)	40	47	12	0	21	21

[1]Values include fish that were prodded from the upper 3 m of the flume.

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