Fish Screening and Guidance at Water Diversions

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The “Design” Fish

Pacific Salmon and Steelhead
Downstream-migrating salmonids
Objectives

Practical Knowledge of:
1. Hazards for fish
2. Biological basis of design
3. Educate participants in project
4. Data requirements
5. Apply design data
6. Screen types
7. Screen materials
8. Perform calculations
9. Draw conceptual layouts
10. Expedite permit review process
Topics

1. The Typical Water Diversion
2. Swimming Capabilities of Juvenile Salmonids
3. Behavior of Juvenile Salmonids
4. Basic Methods of Guiding Juvenile Salmonids
5. Placeholder – Not Used
6. Facility Planning – Data Requirements
7. Design Objectives

Topics - continued

8. Selecting the Screen Structure Site
9. Facility Design
   Criteria
   Velocity
   Screen Materials
10. Types of Screen Facilities
11. Debris
12. Screen Velocity - Balancing
Topic 1. – Generic Water Diversion

On-Channel Screens
Topic 2. Swimming Capability of Juvenile Fish

University of Washington Fisheries Research Institute study (Smith and Carpenter, 1987) was used to develop fish screen criteria
USFWS Bull Trout studies

Factors Related to Swimming Capability

Approach velocity, sweeping velocity, and canal velocity
Water Temperature
Fish Size
Swimming Time Duration
Dissolved Oxygen Level
Swimming Speeds Classification

<table>
<thead>
<tr>
<th>Use</th>
<th>Cruising Speed</th>
<th>Sustained Speed</th>
<th>Darting Speed</th>
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<tbody>
<tr>
<td>Migration</td>
<td>Avoid Obstacles</td>
<td>Escape Predators</td>
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<tr>
<td>Duration</td>
<td>Hours</td>
<td>Minutes</td>
<td>Seconds</td>
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Juvenile Fish Swimming Speeds

* *Coho (1.33 in.)*
  Coho (3.5 in.)
  Coho (4.75 in.)
  Sockeye (5 in.)
  Brook Trout (3 - 5 in.)
  Grayling (2-4 in.)
  American Shad (1-3 in.)
  Herring (0.4-0.6 in.)
  Striped Bass (1 in.)
  * Chinook (1.5 in.)
  Steelhead (1.1 in.)

Data derived from Bell (1991) except (*) are from Smith and Carpenter 1987
Effect of Temperature on Cruising Velocity

Effect of Temperature on Critical Velocity
Effect of Fish Size on Critical Velocity

![Graph showing the effect of fish size on critical velocity.](image)

**EFFECT OF FISH SIZE ON CRITICAL SWIMMING VELOCITY OF SALMONID FRY AT 7°C (SMITH AND CARPENTER 1987)**

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**Topic 3. Behavior of Juvenile Salmonids**

- Physiology and Migration
- Design issues
- Dams and Water Diversions
- Reservoir Passage - turbulence
- Guidance in dam forebays
- Routes
Behavior of Juvenile Fish—contd.

Reluctance to enter small bypasses
Preference for day or night migration past screen structures
Migration corridors in lakes (shoreline? deep?)
Lateral line function
Dissolved Oxygen Level

Physiology
Smolt characteristics compared with parr

Body silvering (+)
Salinity tolerance (+)
Growth rate (+)
Weight per unit length (-)
Body total lipid content (+)
Blood glucose (+)
Gill microsome, Na, K, ATPase enzyme activity (+)
Migration Timing and Fish Size

Timing and Size of Juvenile Chinook
McKenzie River  Brood Years 1985-88

CHINOOK RUN TIMING
Temporal Pattern of Fry and Sub-Yearling Smolts in Two Rivers on Vancouver Island
A - Cowichan River - 1967
B - Nanaimo River - 1980
Source: Groot and Margolis 1991
Effect of River Flows

![Graph showing smolt index and outflow 1997, Lower Granite, Steelhead]

Effect of River Flows

![Graph showing smolt index and outflow 1999, Lower Granite, Steelhead]
Topic 4. Basic Methods of Guiding Juvenile Salmonids

A. Physical Barriers
   —1. Fish screen or rack to prevent fish entry into diversion
   —2. Preferred screen design - guide fish to bypass without contacting screen

B. Behavioral Devices

Examples of Physical Barriers

Vertical and Non-Vertical Fixed-Plate Screens
Traveling Screens
Cylindrical Screens
   —Rotating Drum Screens
   —Fixed Cylindrical Screen
Eicher Screens and Modular Inclined Screens
Pump Intake Screens
Examples of Behavioral Devices

- Sound
- Light
- Electric Fields
- Hydraulic Action

Topic 5. Prioritizing Screen Projects

- Number of fish entrained
- Existing level of protection
- Funding
- ESA
- Land ownership
- Proximity to other projects
- Frequency of diversion
- Type of diversion
Topic 6. Facility Planning
- Data Requirements

See Site Survey Form in Notebook

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Topic 7. Design Objectives

Guide Fish Past Screens:

— Without contacting screen - impingement
— Without entrainment through seals, mesh, other gaps
— Without delay - guidance
— Without injury or mortality
— Minimizing stress to fish
— Minimizing predation
Topic 8. Selecting the Screen Structure Site

Minimizing delay
O&M
On-River site
Off-River site
Hydraulics, Hydrology
Head
Bank characteristics
Data Collection – See Notebook

Off-Channel Diversion
On-Channel Diversion

Channel Configuration – Approach Flow Conditions
Other Site Considerations

Diversion Canal as Fish Habitat
Diversion Operations – Pitfalls
Starting and Stopping of Diversions

Topic 9. Facility Design

A. Recommend references included in Notebook
B. Design Features
   — Flow-Screen Angle
   — Uniform Approach Velocity
   — Channel Configuration
   — Trashracks
   — Seals
   — Cleaning System
Facility Design - Velocity

Sweeping Component of Velocity
— 45 degrees or less between flow and screen
— Smaller angles provide higher sweep component
— Fish move towards bypass by swimming and by sweeping component

Discharge, Q, calculations

\[ Q = (d)(w)(x) \]
\[ A = (d)(w) \]
\[ x = (V)(t) \]

where \( t \) = time (1 sec.)

\[ Q = \text{Volume flow rate} \]
\[ = \text{Volume/time} \]
\[ = A(V)(\frac{t}{t}) \]

\[ Q = VA \]
Velocity Components

- $V_a$: Approach velocity
- $V_s$: Sweeping velocity
- $V$: Actual water velocity

$V_a = V_{canal} \sin \Theta$

$V_s = V_{canal} \cos \Theta$
Fish Orientation in Front of Screens

- (A) When approach velocity exceeds swimming speed of fish.
- (B) When approach velocity is under or near the swimming speed of fish.

NOAA Fisheries Velocity Criteria (Northwest Region)

Salmonid Fry

- \( V_a < 0.4 \text{ fps} \)
- \( V_s > V_a \)
- Uniform Flow Distribution
- \( \frac{\text{Screen Length}}{V_s} < 60 \text{ seconds} \)
Screen Materials Criteria

NOAA Fisheries Screen Criteria included in Notebook
Screen Materials

Profile Bar
Profile Bar

Vee-Wire Profile Bar - Criteria

Salmonid Fry

Maximum Bar Spacing = 1.75 mm
Woven Wire

Woven Wire
Woven Wire Fabric - Criteria

Salmonid Fry

Max. Mesh Opening = 3/32 inch (2.38 mm)

Minimum Porosity = 27% Open Area

Perforated Plate
Perforated Plate - Criteria

Salmonid Fry

Maximum Opening = 3/32 inch (2.38 mm)

Minimum Porosity = 27% Open Area

Other Materials - Intralox
Topic 10. Types of Positive Barrier Screens

Rotary Drum
Fixed Vertical Plate
Vertical Traveling – belt and panel
Non-Vertical Fixed Plate
Horizontal Fixed Plate
Eicher Screen
Modular Inclined Screens
End-Of-Pipe (Pump) Intake Screens

Rotating Drum Screens
Rotary Drum Screens

Rotating Drum Screens
Rotating Drum Screens

Seals
Seals
Rotating Drum Screens - Advantages

- Proven fish protection
- Self-cleaning by rotation
- Passes debris downstream

Rotating Drum Screens - Disadvantages

- Susceptible to direct hits from large debris
- Large civil works are required.
- Seals require much maintenance.
- Susceptible to abrasions by sand - mesh requires periodic replacement.
Vertical Fixed Plate Screens

Vertical Fixed Plate Screens
Vertical Fixed Plate Screens

Easy to seal
Mechanically simple
Can be installed on river’s edge - small screens
  — No bypass required
  — Can use profile wire (very strong)
Mechanical/brush cleaning usually effective
Air burst cleaning system is on back side of screen.
Cleaning is started by timer or head loss.
**Vertical Fixed Plate Screens - Disadvantages**

- Must be cleaned mechanically
- Large bypass flows required
- Brush arms can be damaged by large debris.
- Circular air burst cleaners do not clean entire screen.
Traveling Screens

Traveling Screens
Traveling Screens

Traveling Screens
Traveling Screens - Advantages

Small screens can be installed on river.
Compact civil works
Self cleaned by rotation
Jet sprays provide additional cleaning.

Traveling Screens - Disadvantages

Mechanically complex
Seals can be a problem.
Make sure meets all NMFS criteria.
Non-Vertical Fixed Plate Screen

![Diagram of Non-Vertical Fixed Plate Screen]

Downward Sloping Flat Plate Screen

Upward Sloping Flat Plate Screen

Non-Vertical Fixed Plate Screen

![Diagram of Non-Vertical Fixed Plate Screen with additional elements]
Non-Vertical Fixed Plate

Non-Vertical Flat Plate Screens
Non-Vertical Fixed Plate Screens

Non-Vertical Fixed Plate Screens
Non-Vertical Fixed Plate Screens - Advantages

- No moving parts
- No bypass required if built in-river

Non-Vertical Fixed Plate Screens - Disadvantages

- Self-cleaning may not be reliable
- Risk of injury on screen during low flow
- Must raise water surface
- Tricky, unreliable flow rate control
- Adult concerns
Eicher Screens and Modular Inclined Screens

End-Of-Pipe Screens
**Fixed Cylinder Screens**

Source: Johnson Screens, Inc.

**Pump Screens (Active)**
Pump Screens (Active)

Pump Screens (Active)
### Fixed Cylindrical Screens - Advantages

- Good option for deep intakes
- Air burst cleaning system can be made to be effective
- Some off-the-shelf models with water backwash systems meet NMFS criteria for active screens.

### Fixed Cylindrical Screens - Disadvantages

- Out of sight, out of mind
- Need current to transport debris from screen site.
- Air burst systems on large installations don’t always clean entire screen - especially the bottom.
- Long, stringy vegetation is a problem on small pump screens.
Pump Screens

Pump Screens
Passive Screens

Passive Screens
Passive Screens

Passive Screens
Passive Screens

Passive Screens
Passive Screens

Passive Screens
Passive Screens

11. Debris Management

Trashracks
Screen Cleaning Systems
Trash racks - Criteria

“Open channel intakes shall include a trash rack which shall be kept free of debris.”

“In certain cases, a satisfactory profile bar screen can substitute for a trash rack.”

Comment - No trashrack would be rare situation - such as an on-river screen.

Trashracks
Trashracks

[Image of trashracks in a river]

Trashracks

[Image of another type of trashrack]

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Cleaning System

Head Loss

Screens w/Debris

12.5-14.5 in.

Fry Mortality Vs Head Loss

1993

% Fry Mortality

11.5 12.5 13.5 14.5

Head Loss Across Screen (in.)

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Cleaning Systems - Criteria

Screens shall have automatic cleaning system.
Effective, reliable, proven, approved by NMFS
Head differential to initiate cleaning = 0.1 ft

Cleaning System - ?
Cleaning System - ?

Cleaning System
Cleaning System

[Image]

Cleaning System

[Image]
Cleaning System

Cleaning System
Cleaning System

Cleaning System
12. Balancing Screen Velocities

Flat Plate Screens
Rotary Drum Screens
Cylindrical Screens
Case Study
Approach Flow Conditions

A) Poor Approach Conditions

- Non-uniform approach flow velocity distribution due to upstream bend in channel.
- Eddy from abutment offset.
- Eddies due to pier noses extending upstream.
- Eddy from abrupt channel wall transition.

Approach Flow Conditions

B) Good Approach Conditions

- Uniform approach flow velocity distribution due to straight upstream channel and gradual channel wall transitions.
- No abutment offset at screen face.
- Upstream pier noses flush with screen face.
- Straight and smooth wall.
Channel Configuration – Hydraulic Modeling

Channel Configuration – Hydraulic Modeling
Channel Configuration – Approach Flow Conditions

Balancing Screen Velocities

Balancing Flow Distribution in Vertical Plate Screens
No Flow "Tuning" Baffles

Plan View
Balancing Screen Velocities

Uniform Approach Velocity
Uniform Approach Velocity

Balancing Rotary Drum Screens
Cylindrical Screen Without Internal Baffles

Cylindrical Screen With Internal Baffles
Useful Link

Link to “Anadromous Salmonid Facility Design” document:
http://www.nwr.noaa.gov/Publications/Reference-Documents/Passage-Refs.cfm

Recent Innovative Projects

Rocky Reach Dam – Chelan Co. PUD - Columbia River, WA
Upper Baker Dam – Puget Sound Energy - Baker River, WA
Round Butte Dam – Portland General Electric – Deschutes River, OR
Rocky Reach Dam

Rocky Reach Dam
Upper Baker Lake

![Diagram of Upper Baker Lake](image)

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Upper Baker Lake

![Diagram of Upper Baker Lake](image)

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Upper Baker Lake

![Image of Upper Baker Lake](image1)

Upper Baker Lake

![Image of Upper Baker Lake](image2)
Upper Baker Lake

[Image of a water channel]

Upper Baker Lake

[Image of a structural support system]
Round Butte Dam
Supplemental Screen Slides

Rocky Reach Dam
Rocky Reach

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Rocky Reach
Entrance Horn / Fish Screen / Bypass Conduit
Looking D/S

Fish Pathway
(Representative)
Turbine Intake Screens

Screen Model

Turbine Intake Screens
Turbine Intake Screens

Turbine Intake Screens