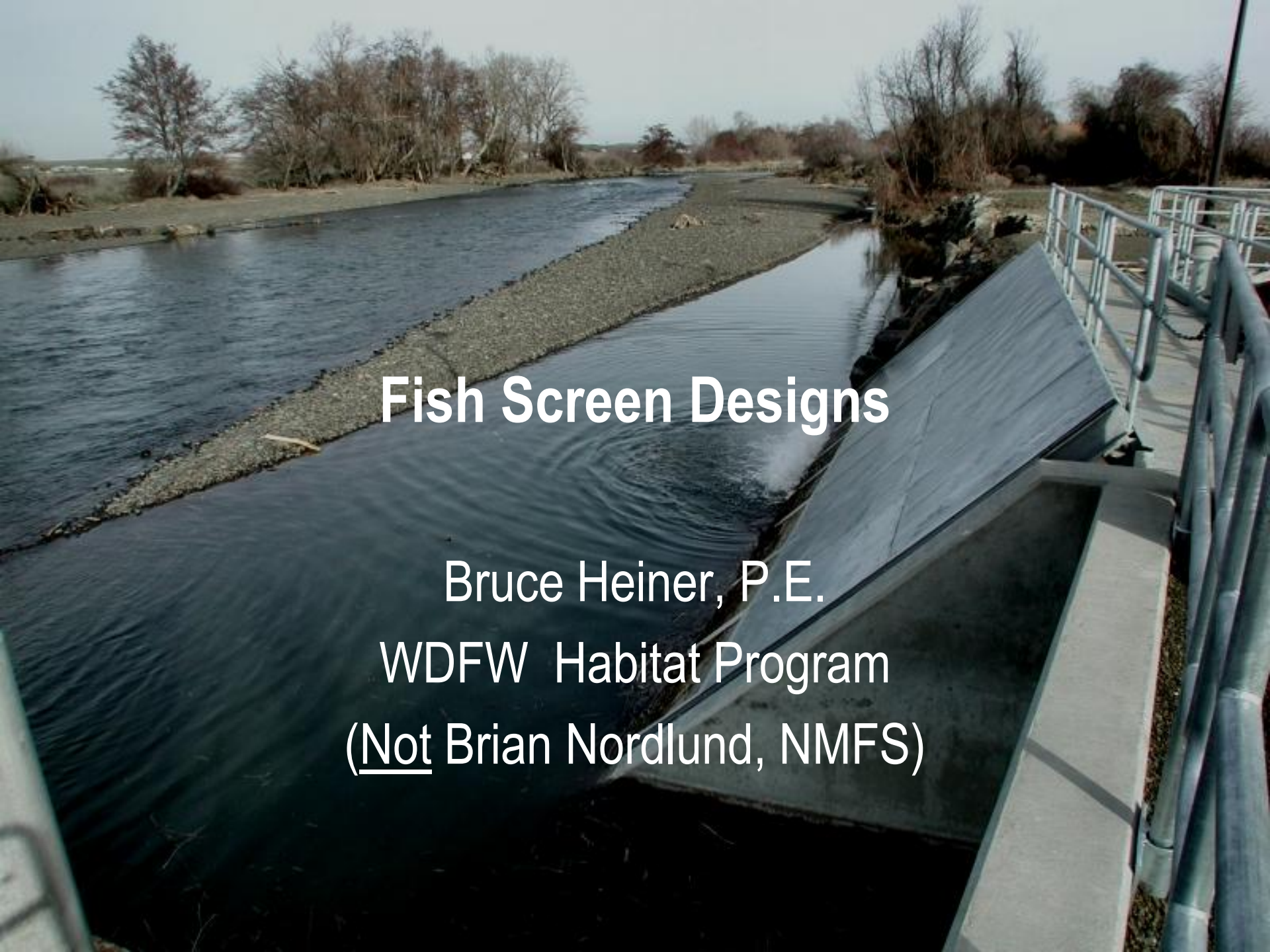


Fish Screen Designs

Bruce Heiner, P.E.
WDFW Habitat Program
(Not Brian Nordlund, NMFS)

Streamlining ESA consultations

- Early conceptual design development – contact NMFS Engineers (360-534-9338)
- Base designs on NMFS Fish Passage Criteria and Guidelines – click “Fish Passage Criteria” at: http://www.nwr.noaa.gov/hydropower/hydropower_northwest/hydropower_in_the_nw.html

Screen Permitting in Washington State

- Hydraulic Project Approval (HPA) is the permit for instream work.
- State screening criteria coordinated with federal agencies through FSOC
- Find WDFW guidelines at http://wdfw.wa.gov/publications/00050/

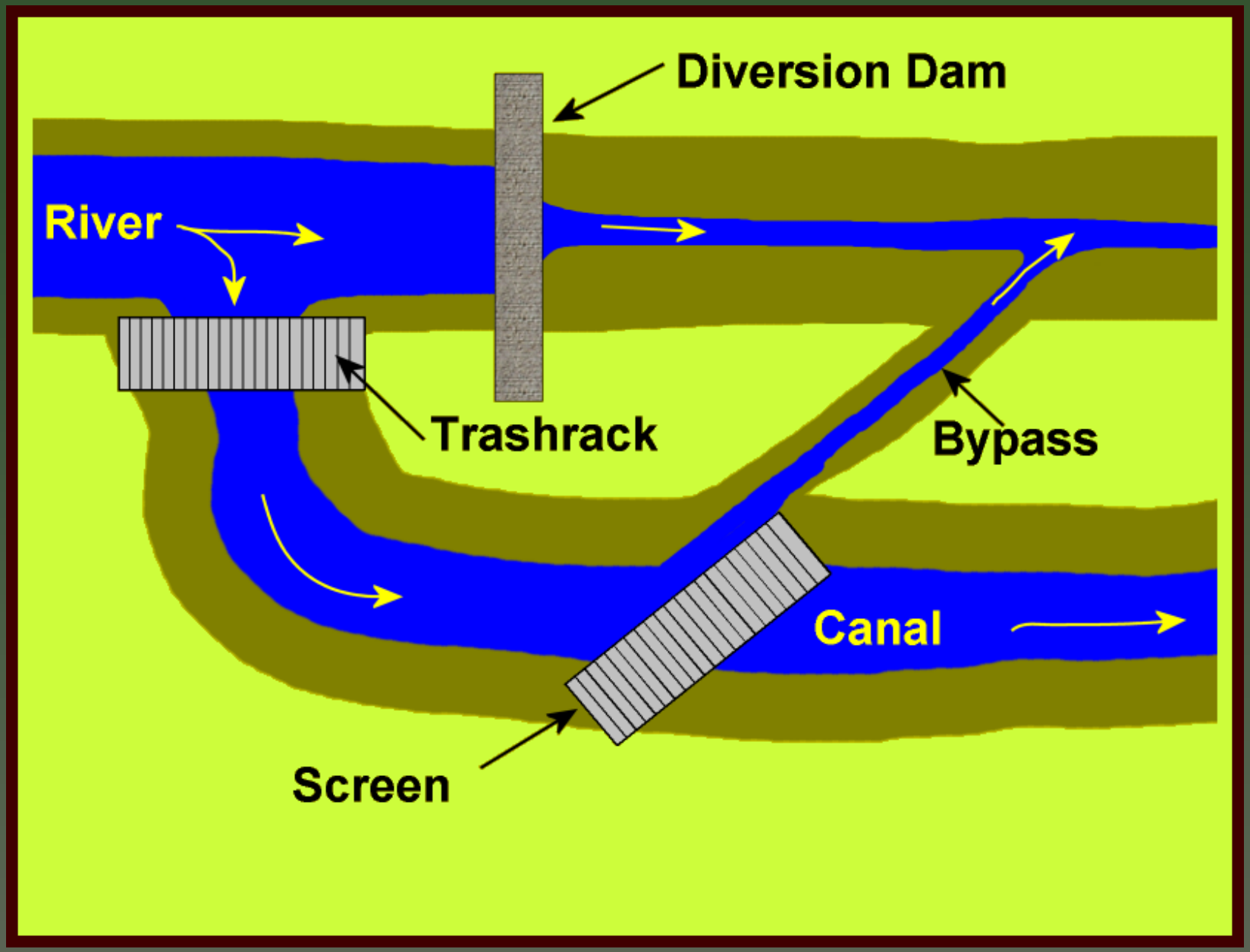
Screen Design Overview

1. The “Typical” Water Diversion
2. Swimming Capabilities of Juvenile Salmonids
3. Behavior of Juvenile Salmonids
4. Design Objectives
5. Basic Methods of Guiding Juvenile Salmonids
6. Prioritizing Screen Projects

Screen Design Overview - continued

7. Selecting the Screen Structure Site
8. Facility Design
    - Criteria
    - Velocity
9. Screen Velocity - Balancing
10. Types of Screen Facilities
11. Debris

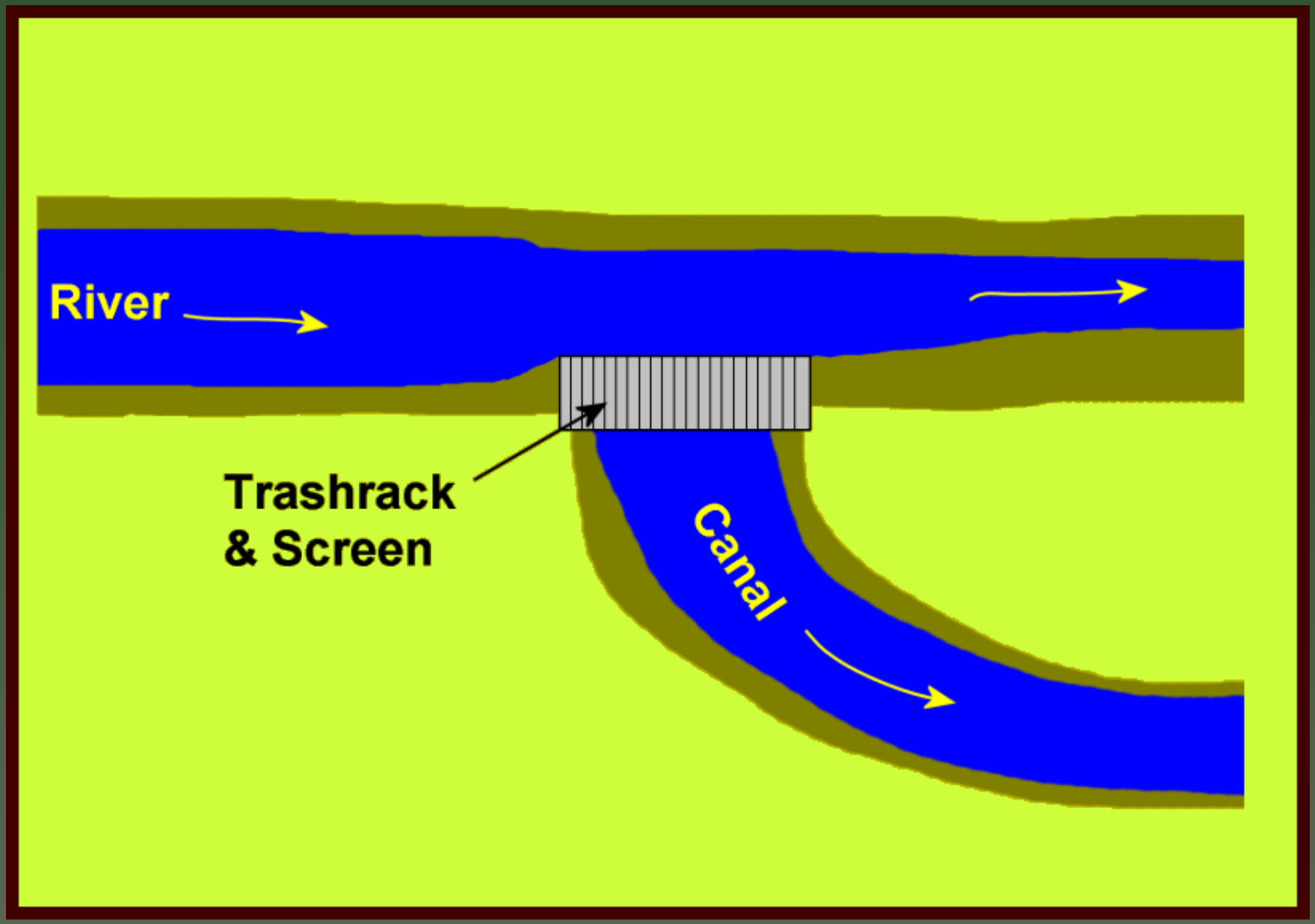
1. The Typical Diversion



Off-Channel Screen →

Pool and Chute Ladder →

On-Channel Diversion



On-Channel Screen

Design Fish - Juvenile Salmonid fry

40 mm fork length

Factors Influencing Swimming Capability

- Fish Species
- Water temperature
- Fish size
- Swimming time duration
- Dissolved oxygen

Behavior of Juvenile Salmonids

- Physiology and Migration
- Design issues
- Dams and Water Diversions
- Reservoir Passage - turbulence
- Guidance in dam forebays
- Passage Routes

Behavior of Juvenile Fish- contd.

- Reluctance to enter small bypasses
- Primary migration past screen structures at night
- Migration corridors in reservoirs
- Lateral line function
- Dissolved Oxygen Level

Screen and Bypass Design Objectives

- Guide fish past screens and into bypass:
  - Without contacting screen - impingement
  - Without entrainment through seals, mesh, other gaps
  - Without delay - guidance
  - Without injury or mortality
  - Minimizing stress to fish
  - Minimizing exposure to predation

Basic Methods of Guiding Juvenile Salmonids

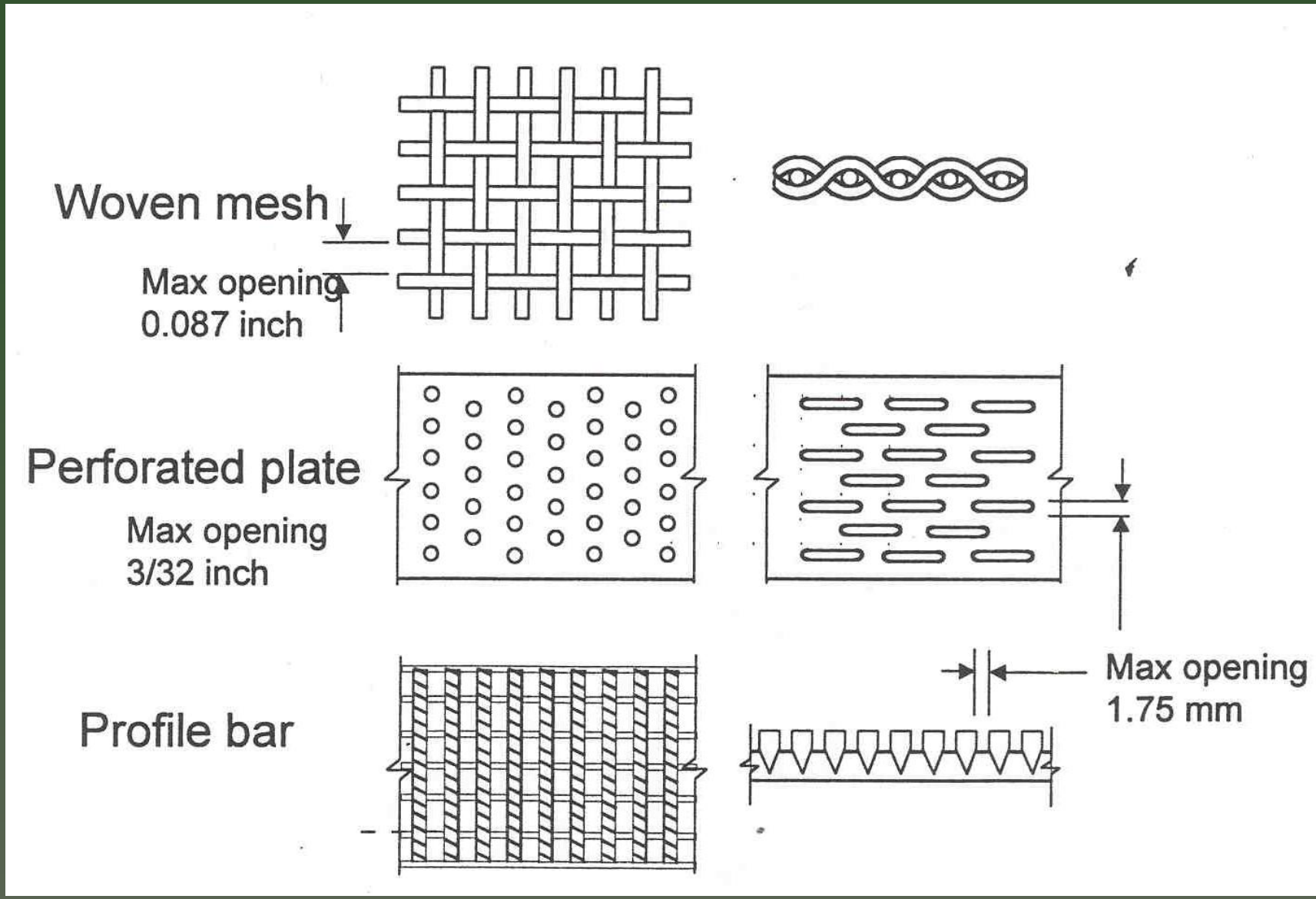
- **Physical Barriers**
  - Fish screen or rack to prevent fish entry into diversion
  - Preferred screen design - guide fish to bypass without contacting screen

- **Behavioral Devices**
  - In general, these don't provide consistent high levels of fish protection as a stand alone device

Examples of Physical Barrier Screens

- Vertical Fixed-Plate Screens
- Cylindrical Screens
  - Rotating Drum Screens
  - Fixed Cylindrical Screen
- End of Pipe or Pump Intake Screens
- Traveling Screens – belt and panel

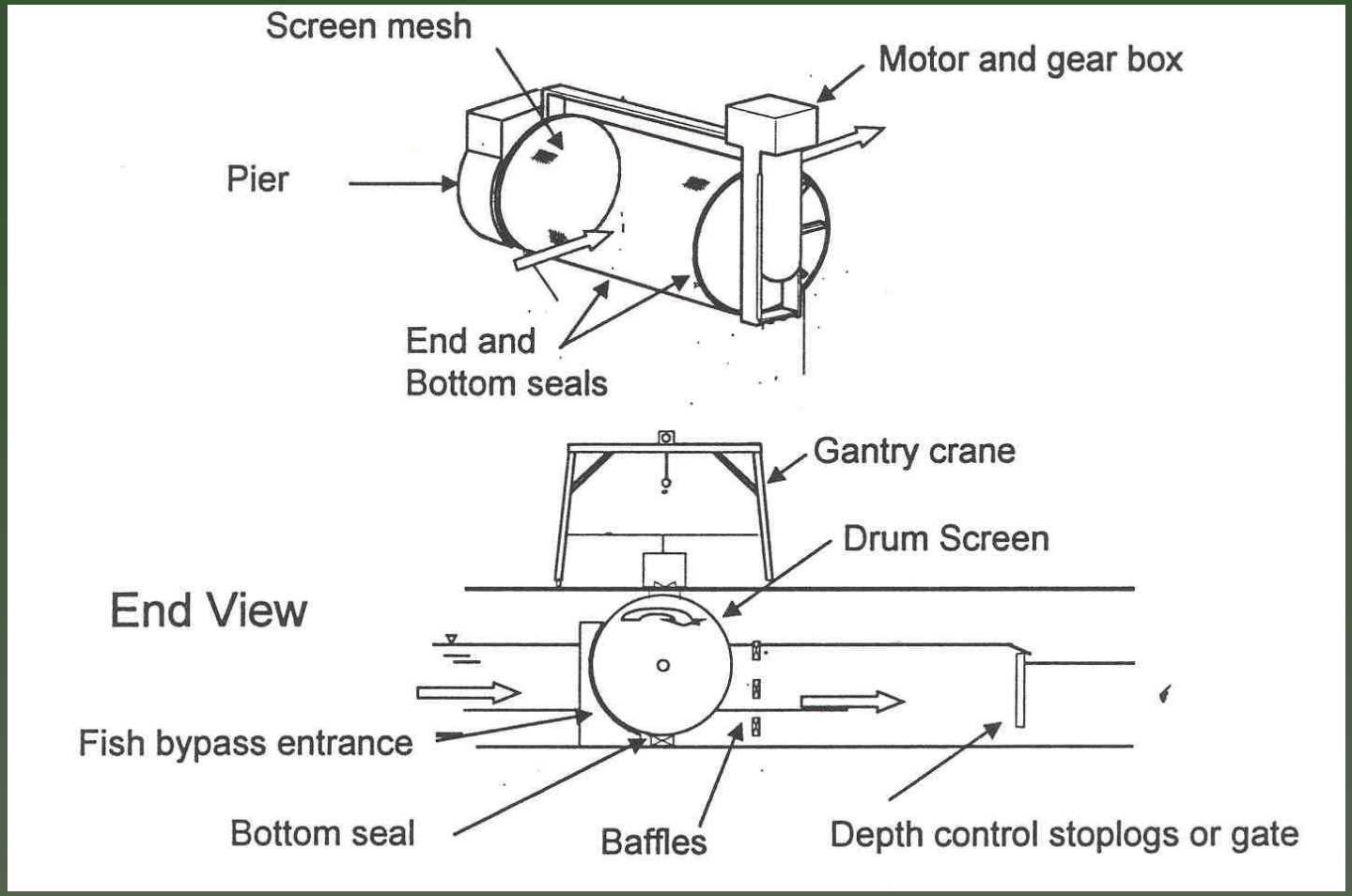
Screen Materials



Large Diversion - Rotating Drum Screens

Mid-Sized Diversion - Rotating Drum Screens

Schematic - Rotary Drum Screens



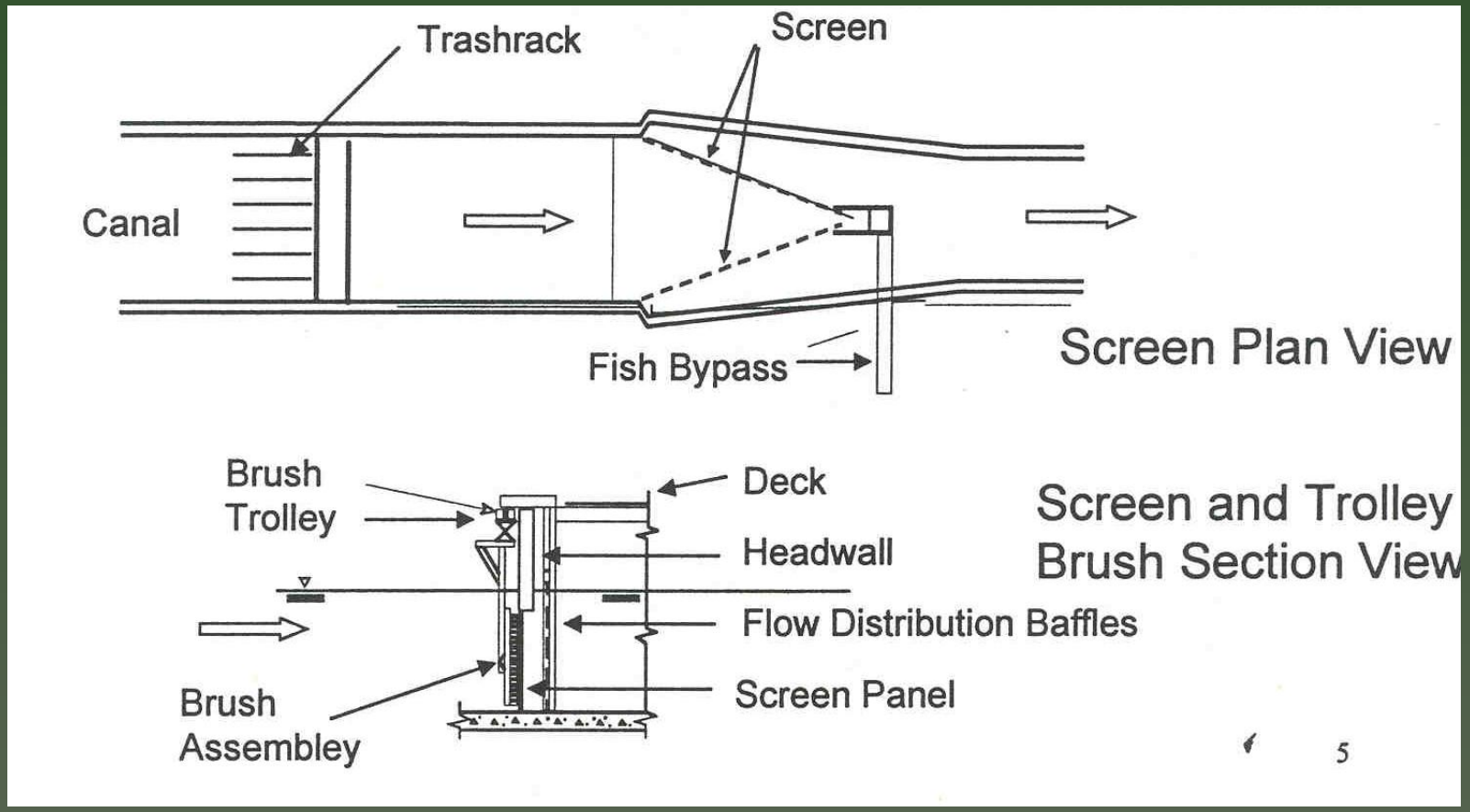
Rotating Drum Screens - Advantages

- 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.
- Mesh susceptible to abrasions by sand - mesh requires periodic replacement.
- Allowable water surface fluctuation is limited .

Schematic - Vertical Fixed Plate Screen



Large Diversion - Vertical Fixed Plate Screens

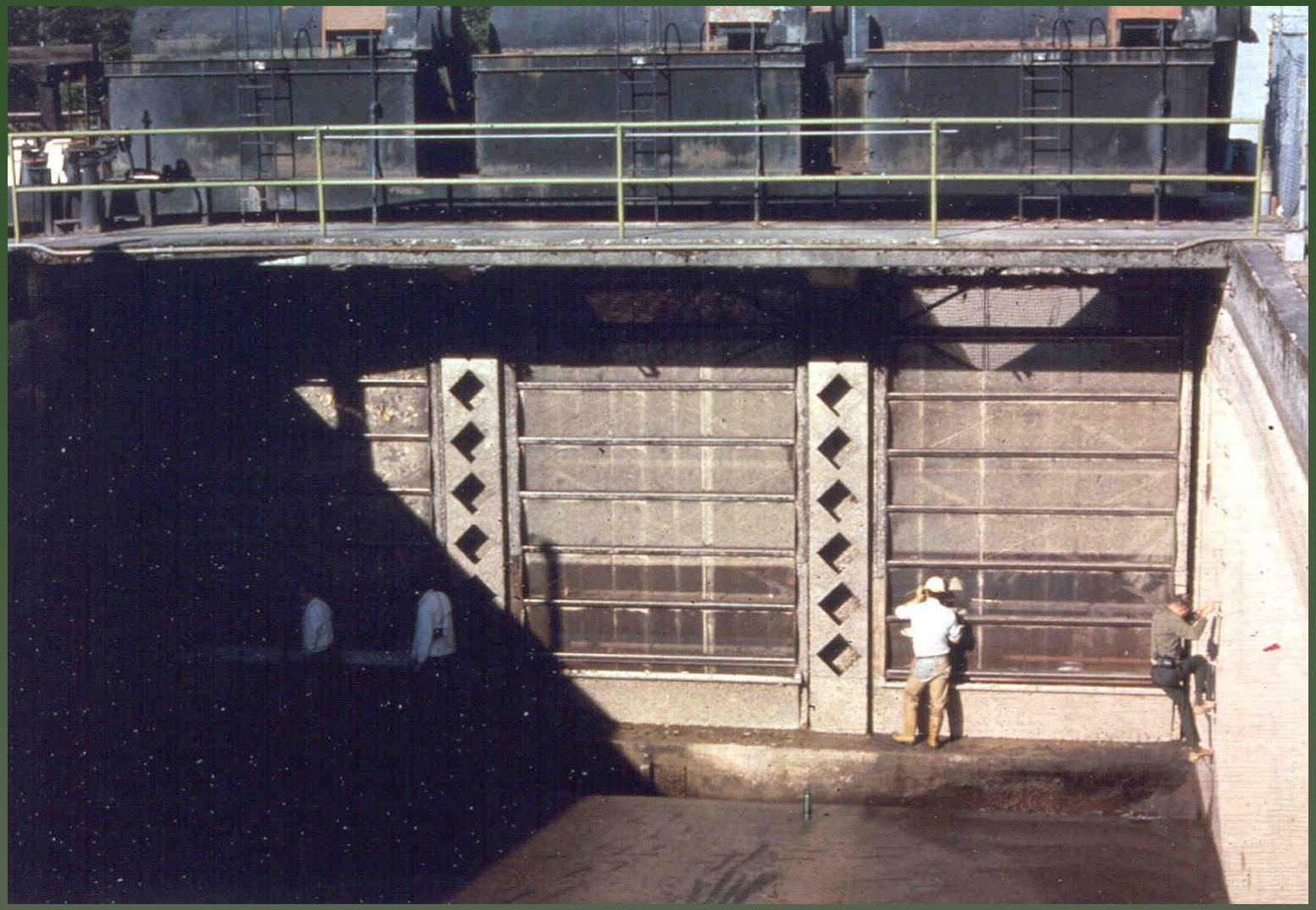
Vertical Fixed Plate Screens - Advantages

- Easy to seal
- Mechanically simple
- Small screens can be installed on river's edge
  - No bypass required
  - Can use profile wire (very strong)
- Mechanical/brush cleaning usually most 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.

Panel Type Traveling Screens



Belt Type Traveling Screens

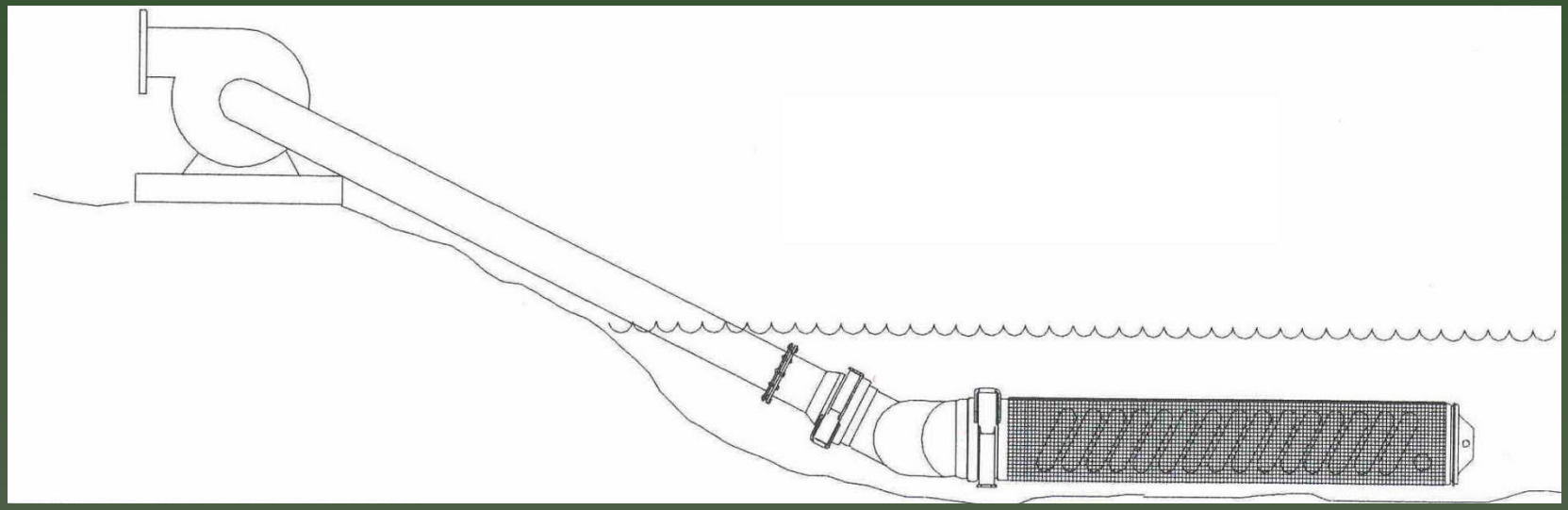
Traveling Screens - Advantages

- Small screens can be installed on river
- Compact civil works
- Function with large WSE fluctuation
- Self cleaned by rotation
- Jet spray can provide additional cleaning

Traveling Screens - Disadvantages

- Mechanically complex
- Seals can be a problem.
- Make sure meets all NMFS criteria.
- Can collect debris on the face, particularly weed mats
- High sediment loads can wear out moving parts

End-Of-Pipe Screens



Fixed Cylinder Screens

Source: Johnson Screens, Inc..

Fixed Pump (end of pipe) 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.

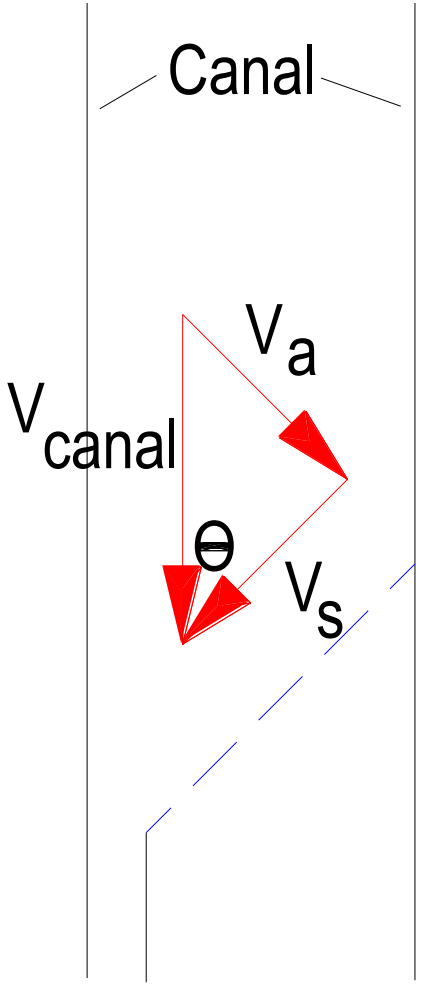
Fixed Pump Screens - Disadvantages

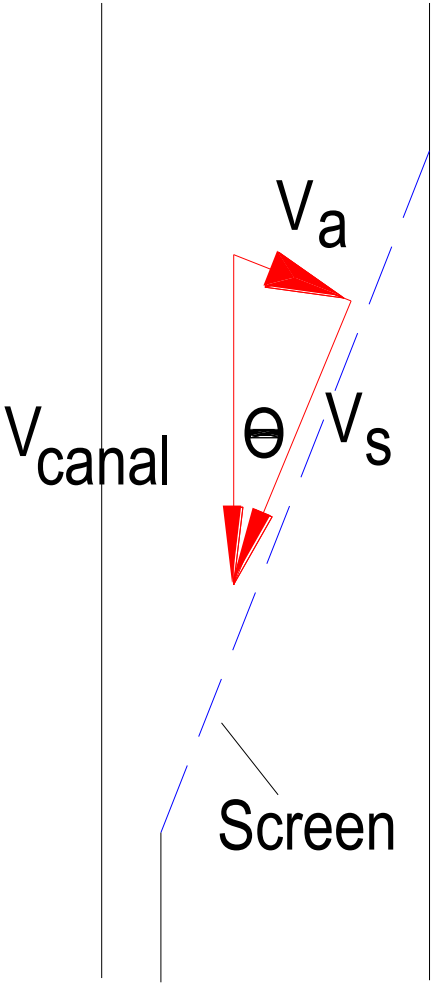
- Out of sight, out of mind
- Need current to transport debris from screen site.
- Air burst systems on large installations don’t always clean entire screen - especially the bottom.
- Long, stringy vegetation is a problem on small pump screens.

Screen Velocity Components

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

$$V_s = [V_{canal}] \cos\Theta$$





Basic Screen Design Features

- Flow-Screen Angle – determines Sweep Velocity (Vs) and Approach Velocity (Va)
- Va is uniform across face of screen
- Vs gradually increases toward fish bypass
- Screen face materials – wire mesh, perf plate, slots of specific size

Basic Screen Design Features (continued)

- Uniform approach channel geometry – uniform approach flow
- Trashrack sizing
- Side and bottom seals – maximum gap less than 1.75 mm
- Cleaning System – automated based on head differential and/or time interval

Screen Approach Velocity (Va) Criteria

- Based on assumed presence of Salmonid Fry
- Maximum Va < 0.4 fps (perpendicular to screen)
- Criteria: Vs > Va; Guideline: Vs > 2* Va
- Uniform flow distribution = Uniform Va – critical for fish protection and debris management
- Exposure Time: (Screen Length)/(Vs) < 60 seconds

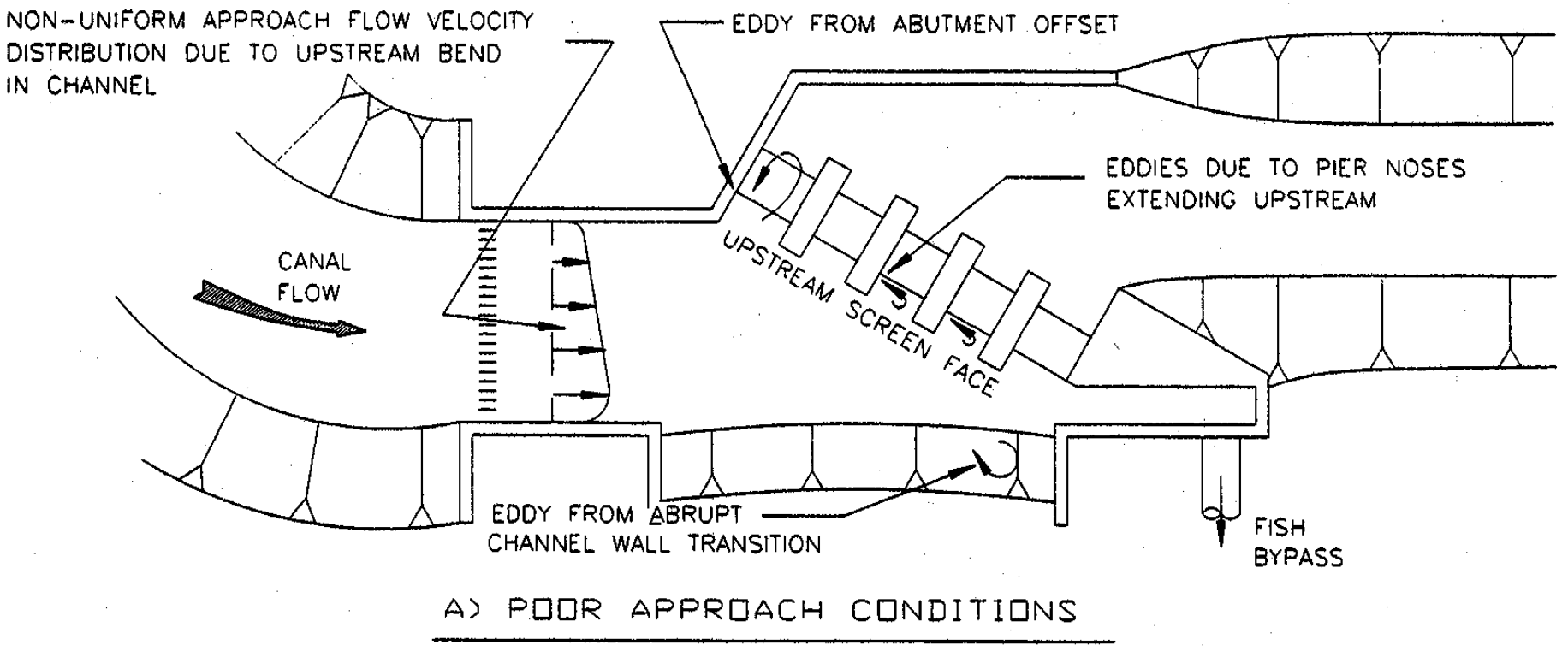
Screen Sweep Velocity (Vs)

- Sweeping Component of Velocity
  - Angle is 45 degrees or less between flow direction and screen face
  - Smaller angles provide higher Vs component
  - Fish move towards bypass “pushed” by Vs – need gradually increasing Vs (behavior)
  - Maximum 60 second exposure time to screen face, based on swim speed and screen length.

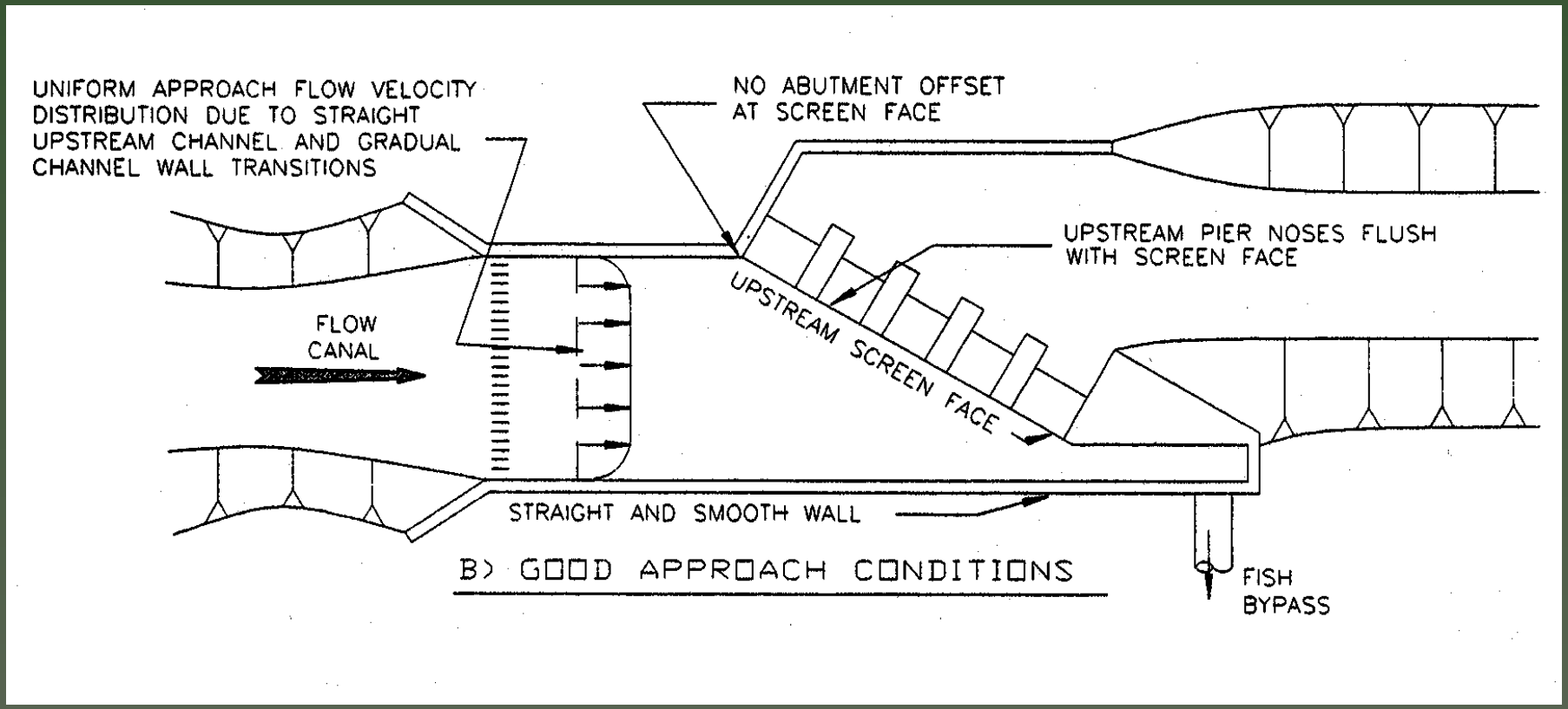
Flow Distribution and Approach Velocity (Va) Balancing

- Uniform Va is key for fish safety and debris management
- Uniform flow approaching the screen face provides best opportunity for uniform Va
- Adjustable porosity or baffle systems provide the ability to adjust screen flow and balance Va

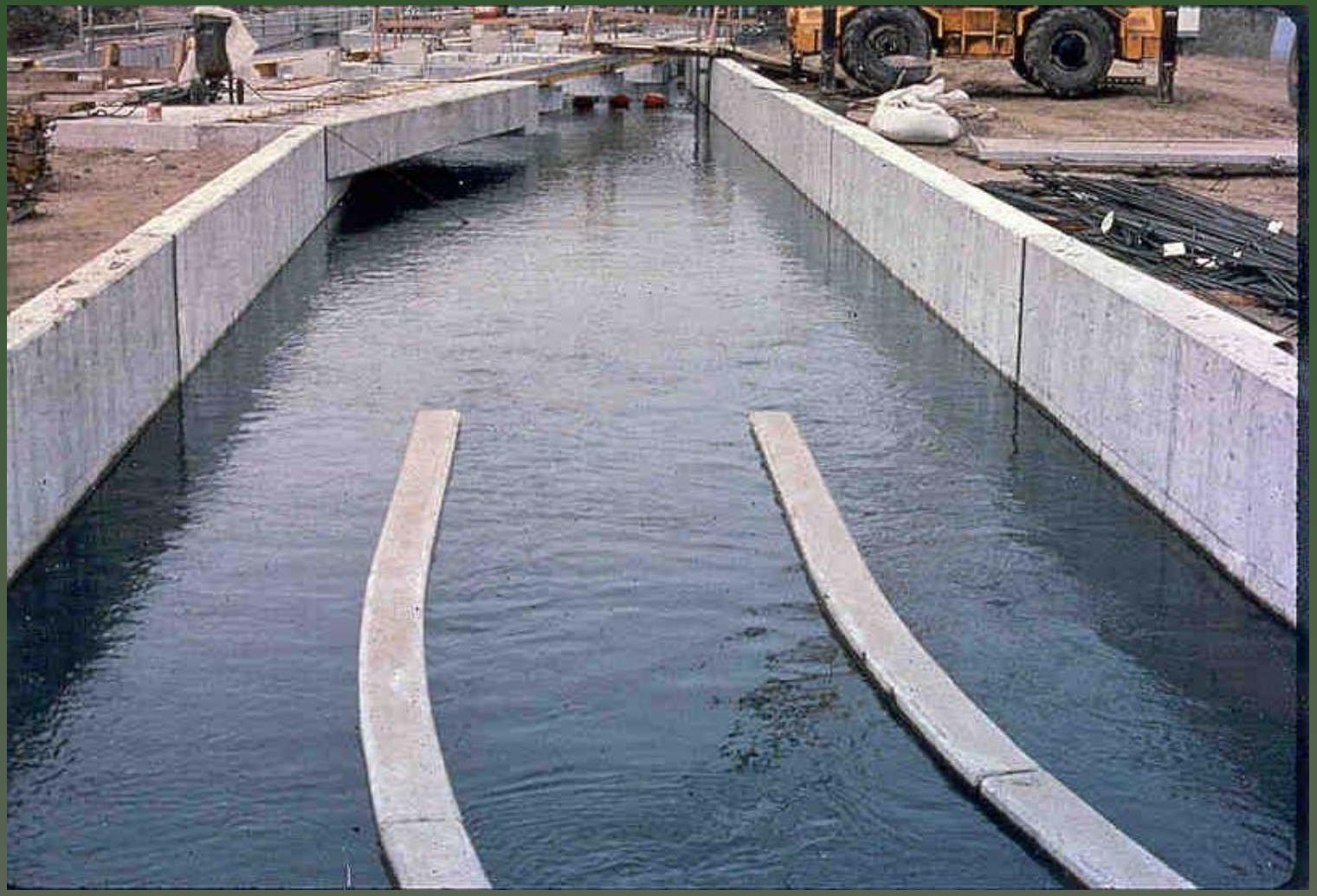
Approach flow – poor conditions



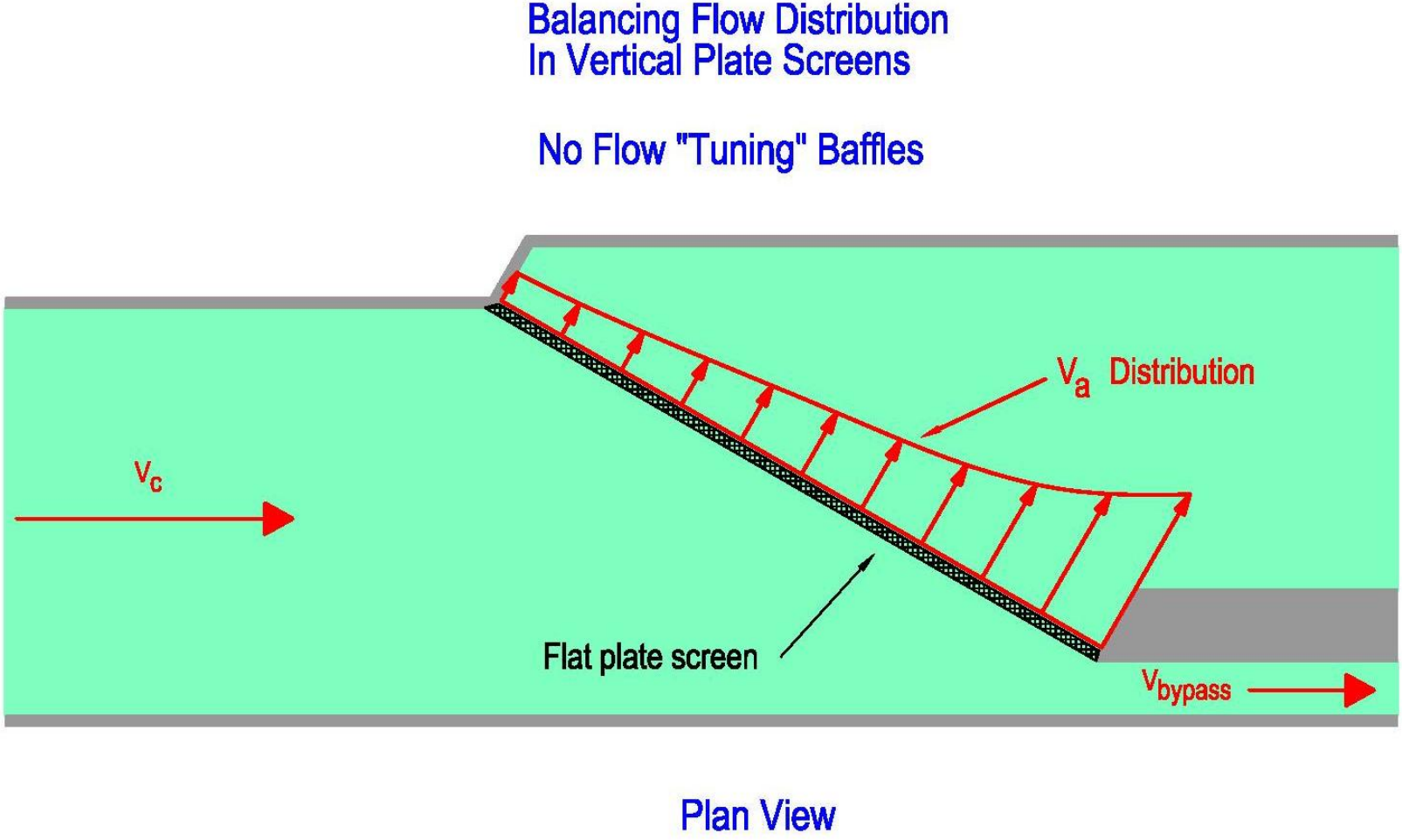
Approach flow - good conditions



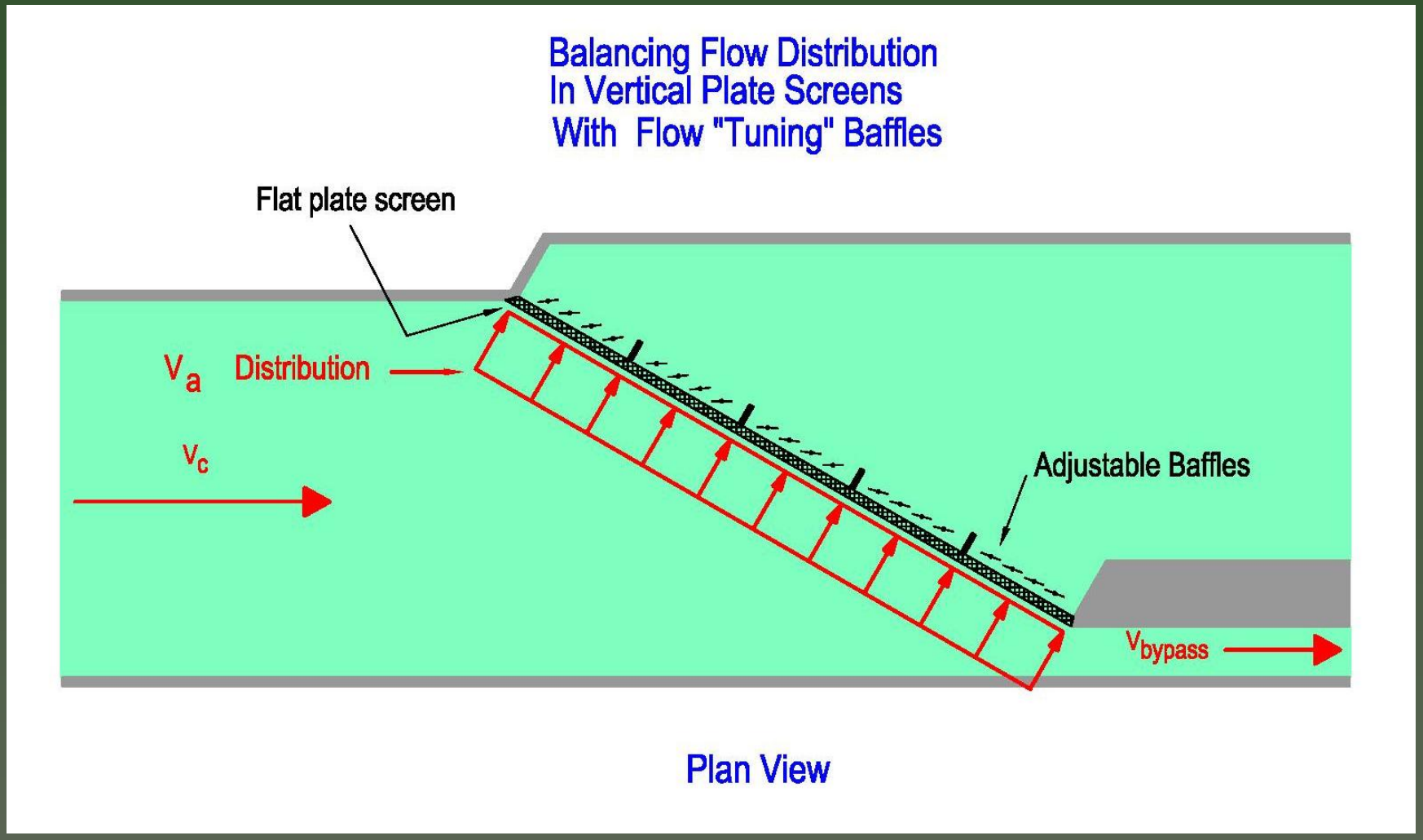
Channel Configuration – Correction for Approach Flow Conditions



Balancing Screen Approach Velocity

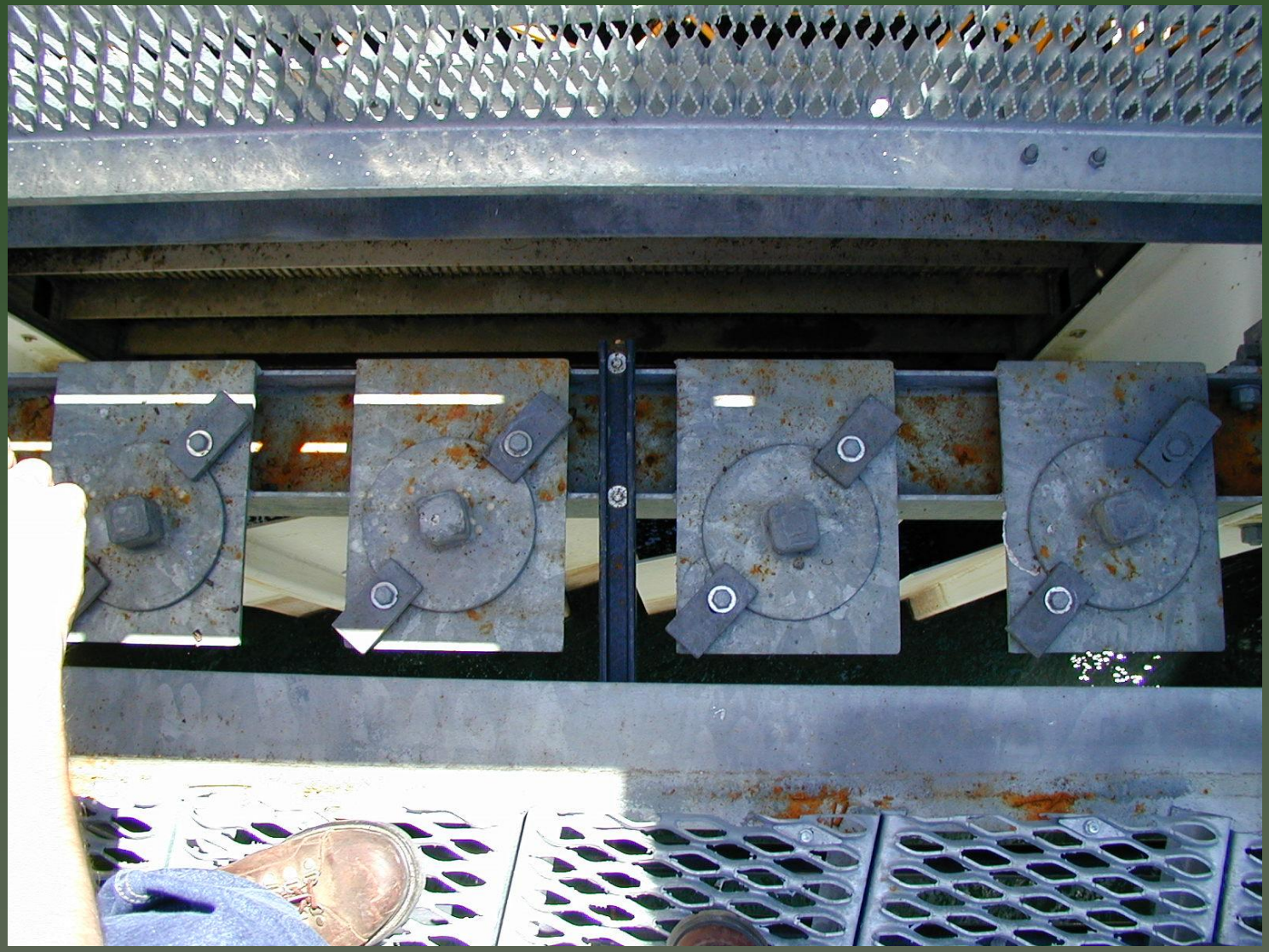


Balancing Screen Approach Velocity

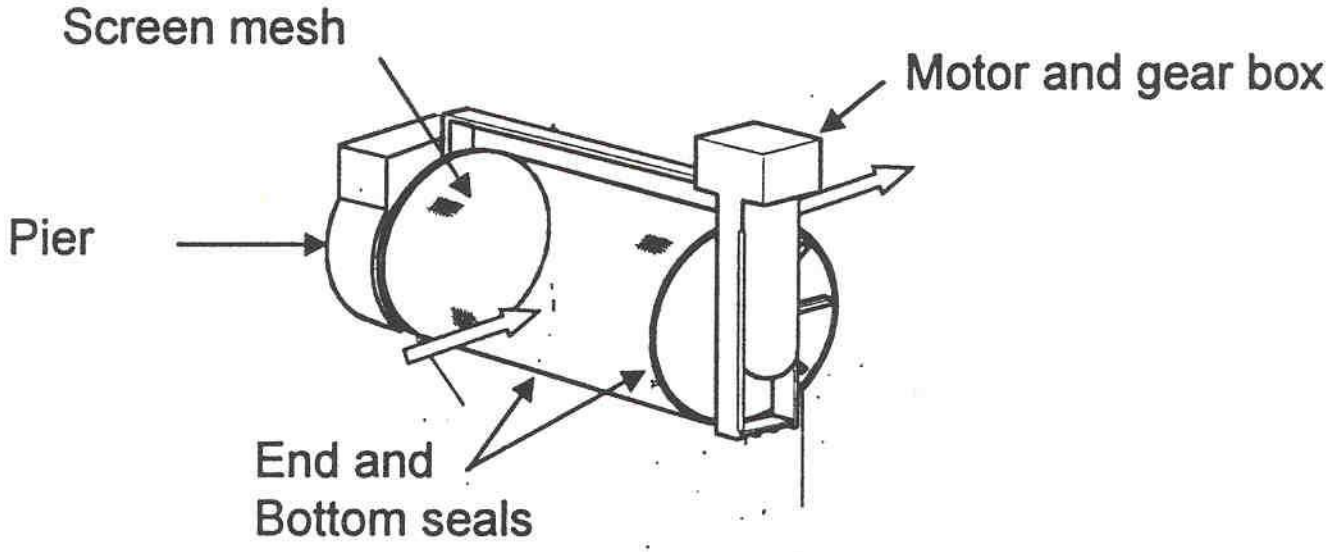


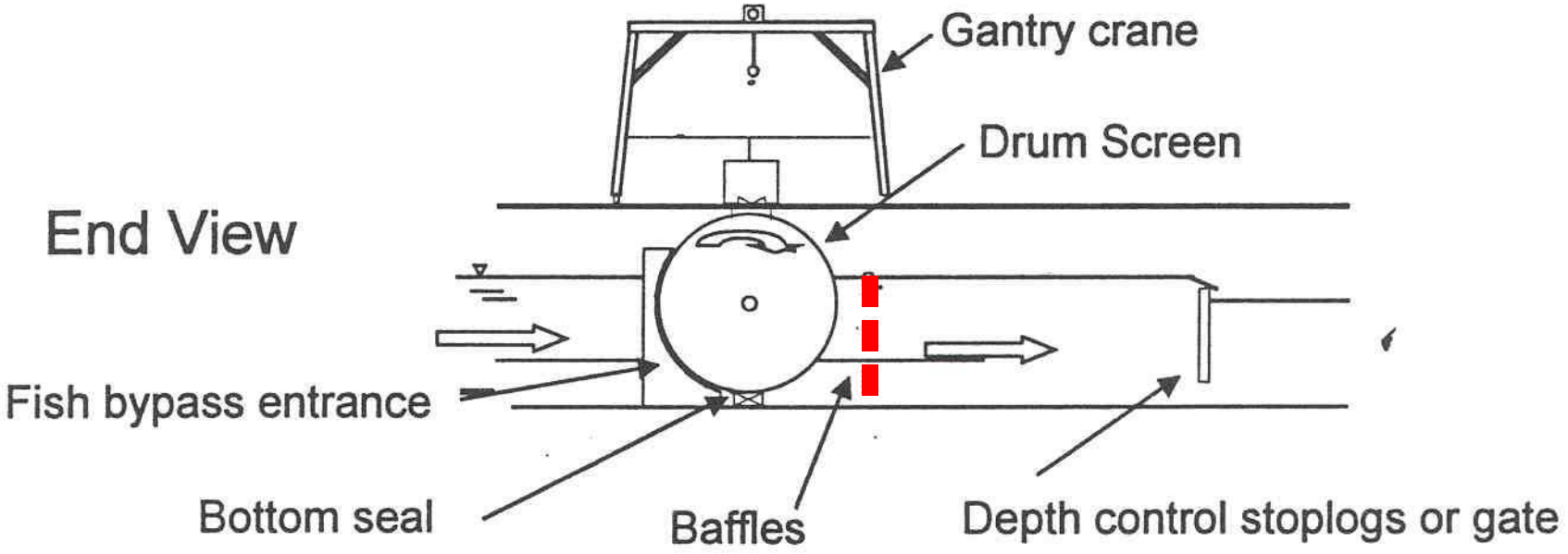
Baffles for Adjusting Approach Velocity

Baffles for Adjusting Approach Velocity



Balancing Rotary Drum Screens





Debris Management

- Trashracks
- Screen Cleaning Systems
- Sediment management *

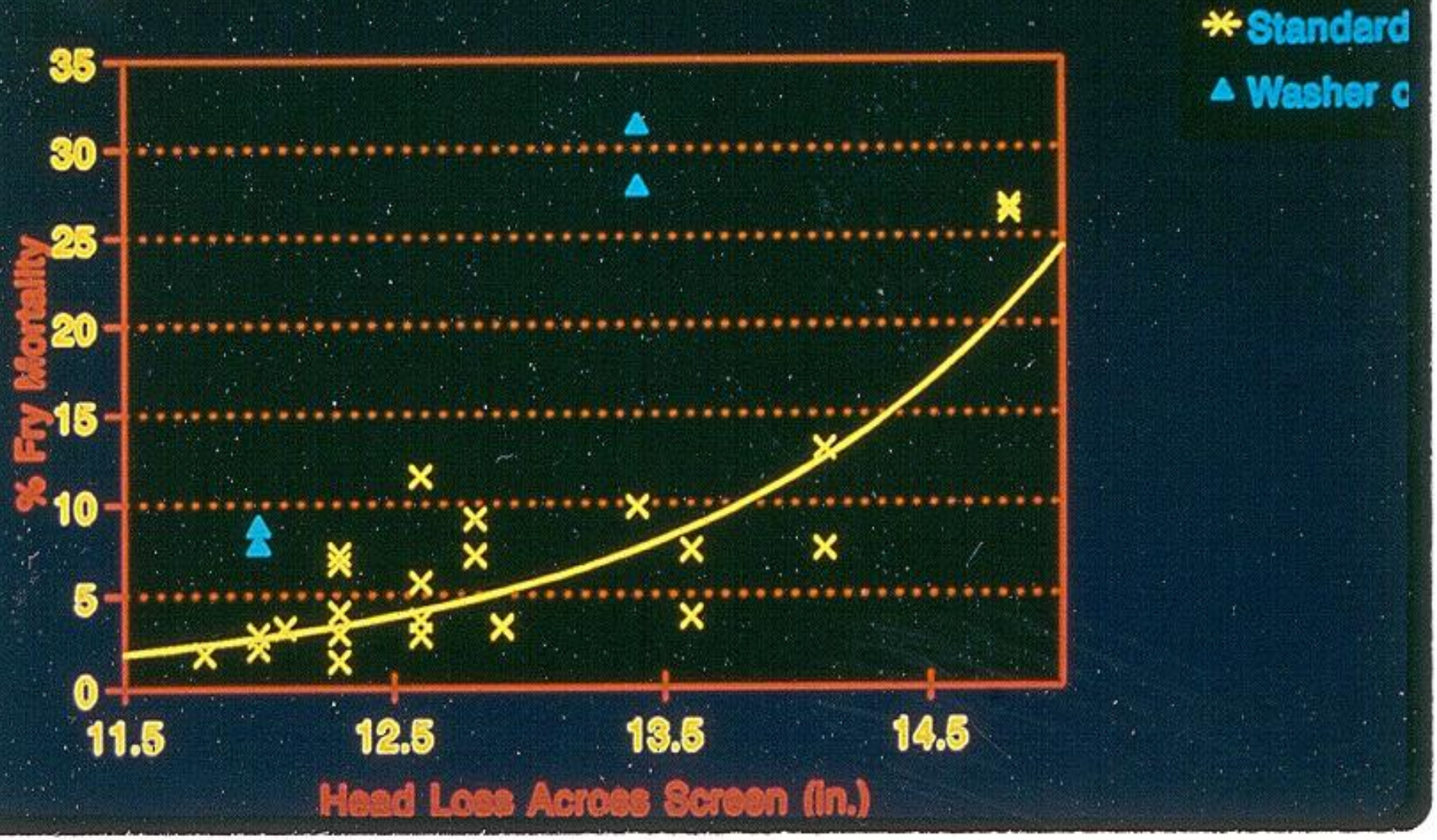
Sloped Trashrack – easier debris removal

Trashrack with automated cleaner

Cleaning Systems

Fry Mortality Vs Head Loss

1993



Main Criteria for Cleaning Systems

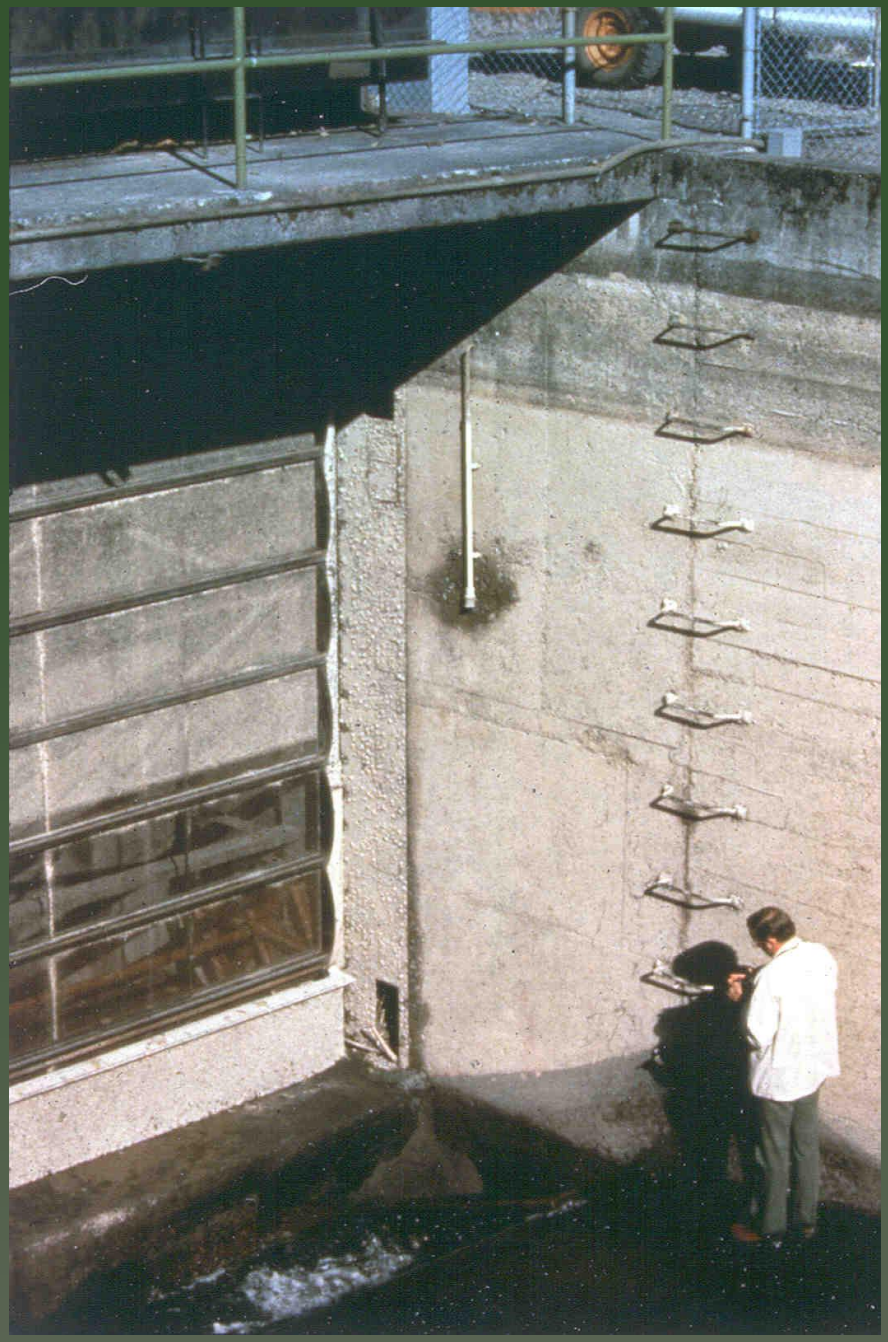
- Effective, reliable, proven, approved by NMFS
- Head differential to initiate cleaning = 0.1 ft
- Automated cleaning for most systems
- Time interval for cleaning – continuous to daily, depending on expected debris load.
- Ineffective cleaning system or underestimated debris – biggest cause of screen structural failures

Traveling Brush Cleaning System

Air Burst Cleaning System

Water Jet Cleaning System

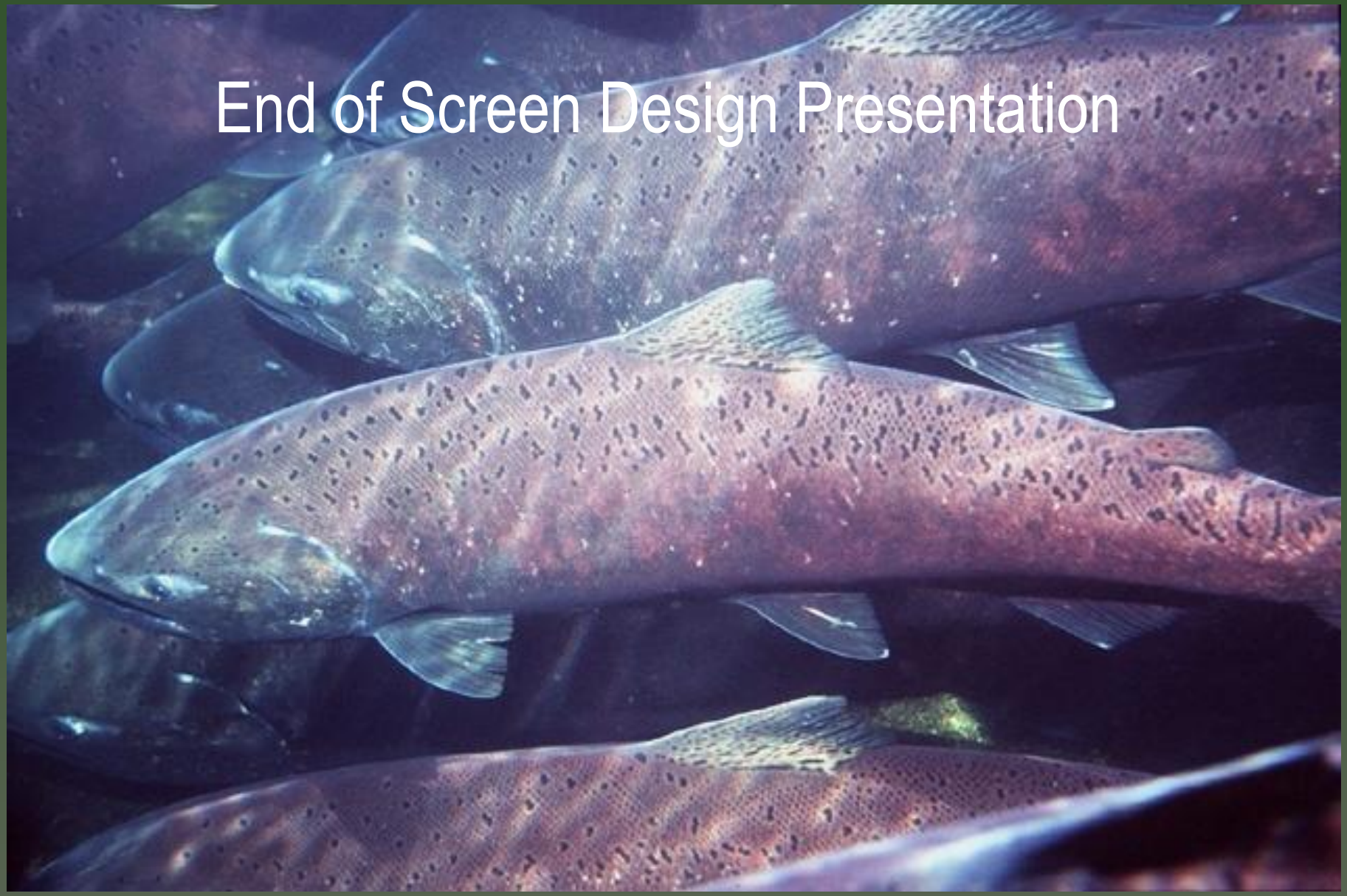
Rotation – Vertical Traveling Screens Cleaning System



Rotation – Drum Screen Cleaning System

Bypass Pipe Design

- 10” minimum diameter pipe – up to 9 foot diameter
- 4 ft/s to 8 ft/s generally works well for fish passage and debris transport
- Full pipe or open channel flow - avoid combination
- Generally 5% of diverted flow used as bypass flow
- Smooth joints are a must
- No pumping, hydraulic jumps or vertical transitions
- Bypass entrance – smooth hydraulics, weir or orifice


End of Screen Design Presentation