The Use of Angled Bar Racks and Louvers for Guiding Fish at FERC-Licensed Projects

FERC Fish Passage Workshop
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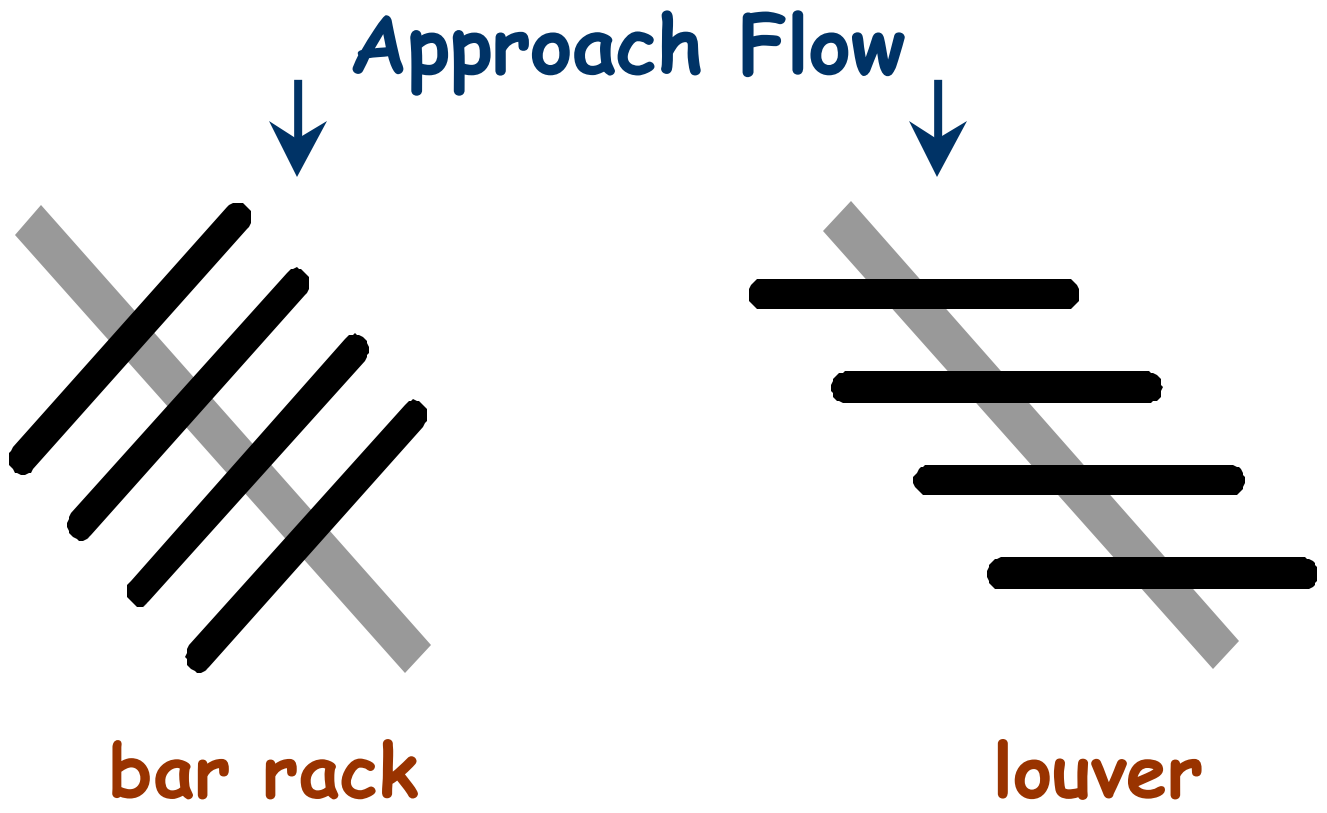
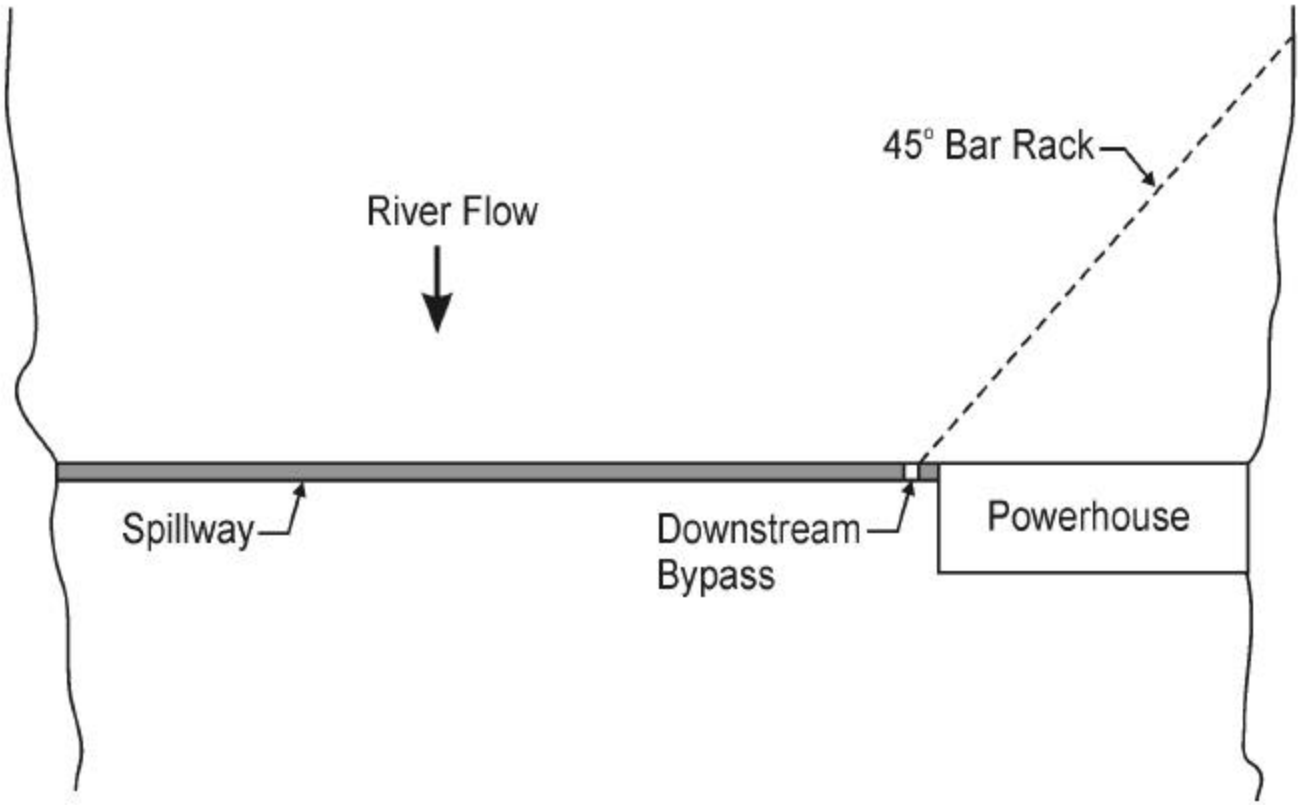
Use of Angled Bar Racks and Louvers for Guiding Fish at Hydro Projects

- Angled Bar Rack and Louver Design
- Development and Application of Angled Bar Racks
- Development and Application of Louvers
- EPRI Laboratory Evaluation of Bar Racks and Louvers
- Considerations for Successful Application
- Future Research Needs
- Conclusions

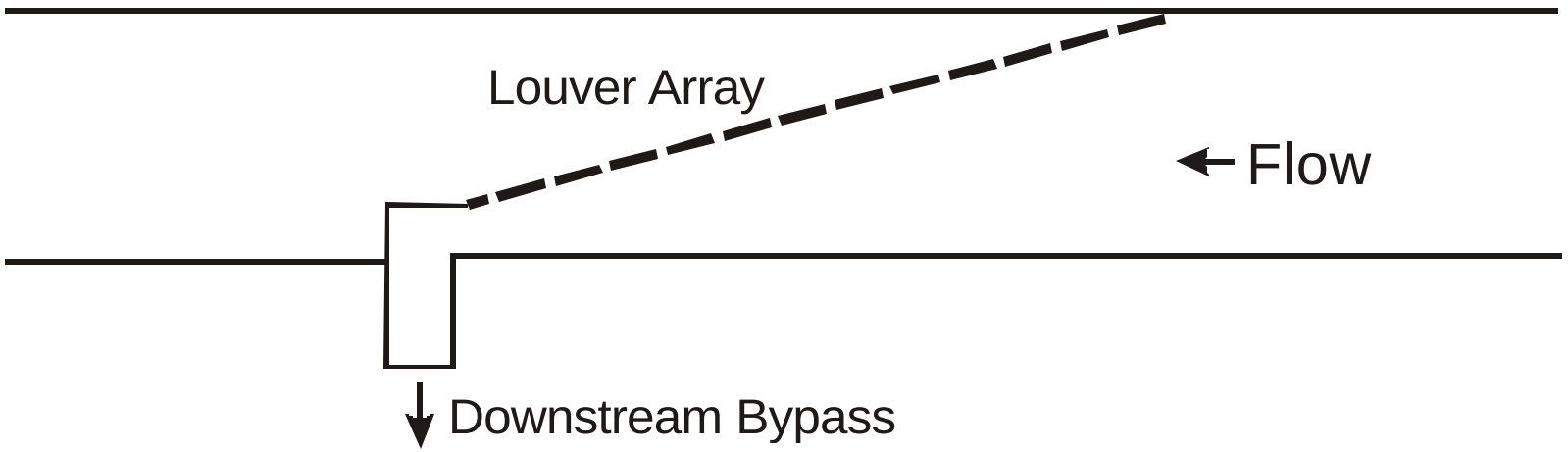
Angled Bar Rack and Louver Design



Angled Bar Rack Design



Louver Array Design



Angled Bar Rack and Louver Design

USFWS Design Criteria

- 3 ft minimum bypass width
- Bypass flow either 2% of total rated turbine capacity or 20 cfs, whichever is greater
- Maximum clear spacing of 1-inch (based on salmon smolt requirements)
- Bypass conduits with minimum diameter of 24 inches and minimum 10-ft radius bends.
- Discharge 6-10 ft above normal tailwater
- Discharge plunge pool depth at least 25% of total differential head

ANGLED BAR RACKS

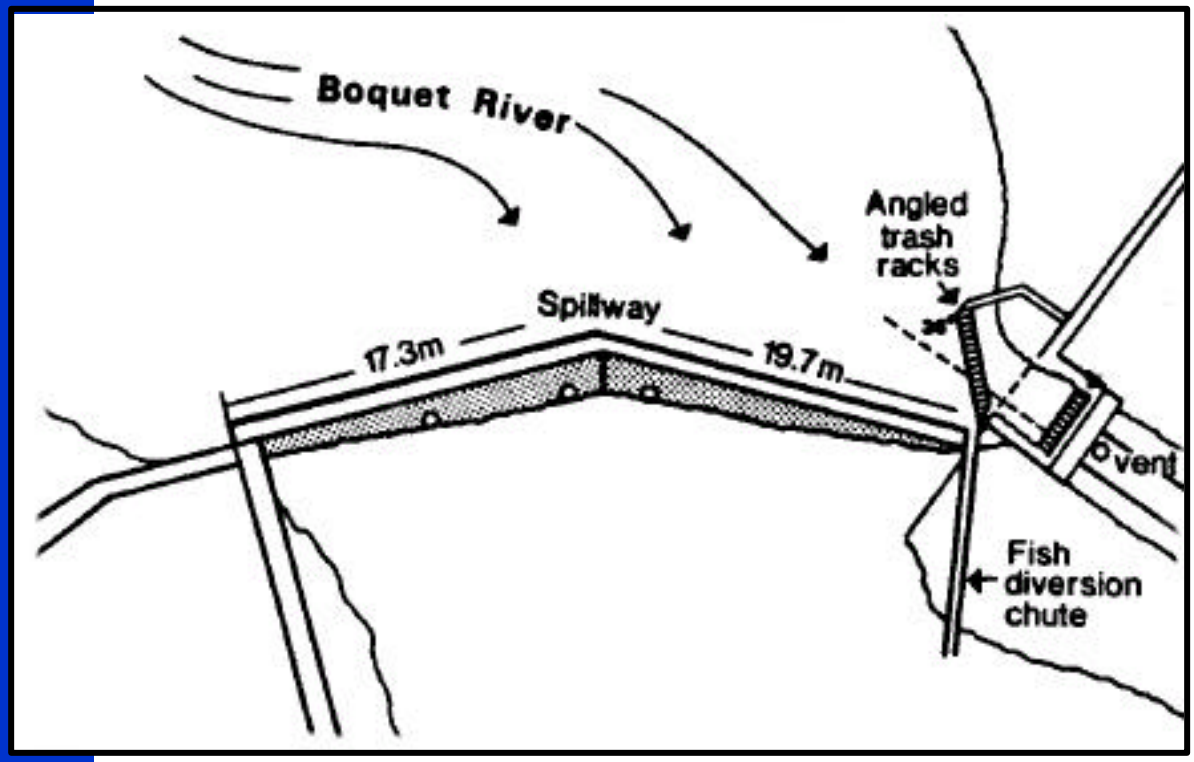
Guidance Mechanism and Design Considerations

- Primarily designed to physically exclude fish and guide them to a bypass; behavioral avoidance probably occurs.
- Most facilities have been installed at 45° to the flow and have clear bar spacings between 1 and 2 inches.
- Important hydraulic parameters include approach and bypass velocity.
- Important biological parameters include behavior and swimming capabilities of species and size classes targeted for protection.

ANGLED BAR RACKS
Concept Development

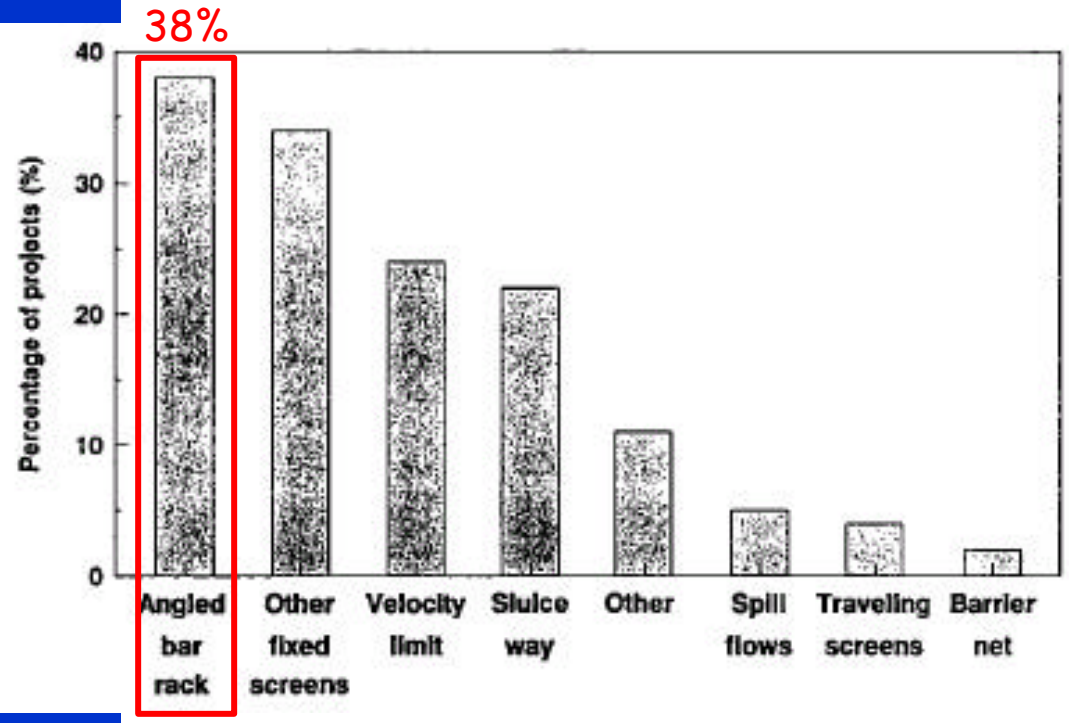
Migration of Landlocked Atlantic Salmon Smolts and Effectiveness of a Fish Bypass Structure at a Small-Scale Hydroelectric Facility

Nettles and Gloss (1987)



- Atlantic salmon
- 45 degrees
- 1-inch spacing

ANGLED BAR RACKS
Application at FERC-Licensed Projects



Cada and Sale (1993)

- 32 projects (38% of total examined) had angled bar racks

ANGLED BAR RACKS
Application at FERC-Licensed Projects

Number of Angled Bar Rack Installations in NE

(Data courtesy Curt Orvis, USFWS)

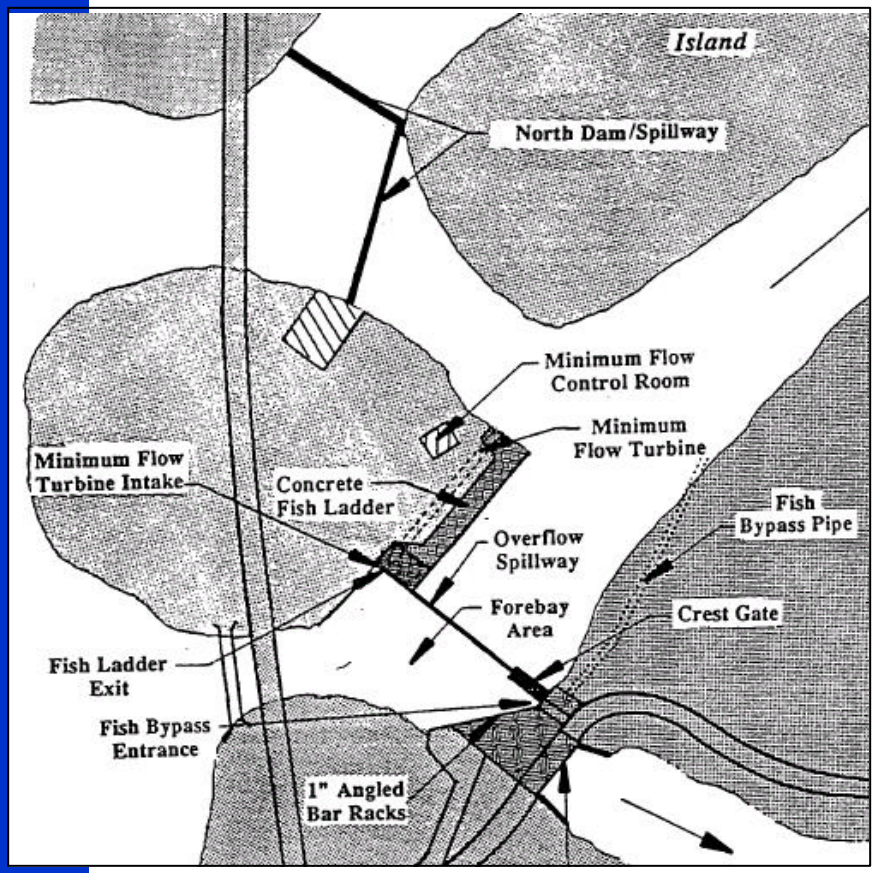
State	Number
CT	1
MA	3
ME	5
NH	3
NJ	3
NY	17
VA	1
VT	3
Total	36

FGE's have ranged From 20 – 100%

ANGLED BAR RACKS
Application at FERC-Licensed Projects

- Angled bar racks have been prescribed for use at many hydroelectric projects in the Eastern U.S.
- Most bar rack installations and have targeted anadromous species (Atlantic salmon, juvenile Alosa)
- Field results have been mixed; effectiveness is dependent on fish behavior and hydraulics
- Laboratory data suggest 45° bar racks may have FGE's <60% for American eel and riverine fishes

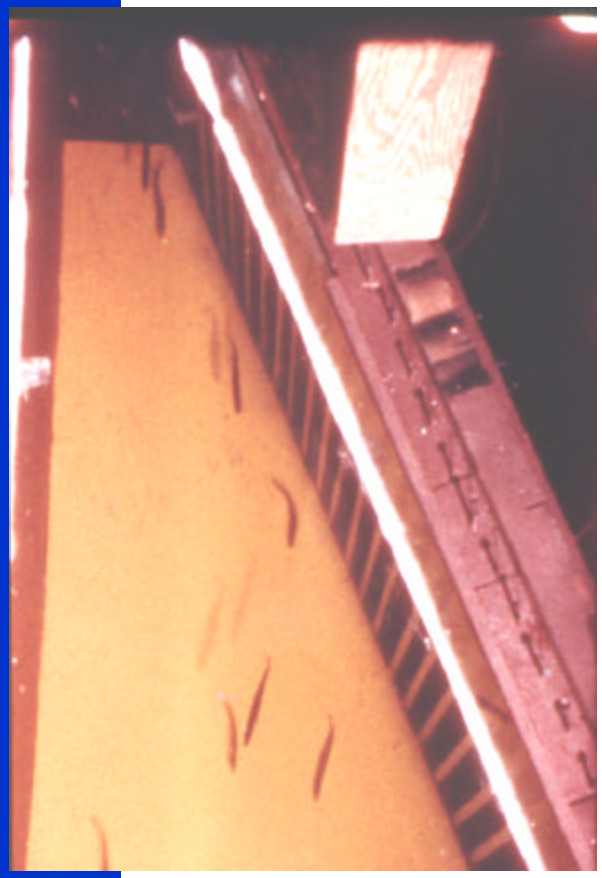
ANGLED BAR RACKS
Lower Saranac Hydroelectric Project



Simmons (2000); Normandeau Assoc. (1994, 1997)

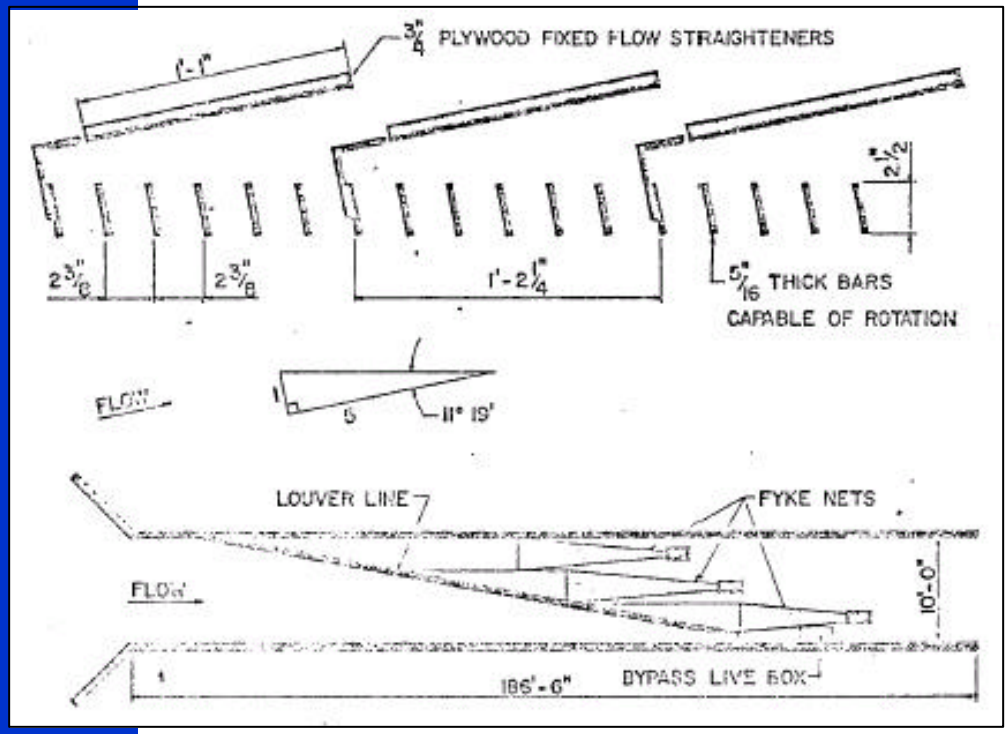
- 1-inch, 45-degree angled bar rack
- Atlantic salmon and steelhead smolts
- <50% FGE with bypass flow <2% of turbine capacity
- >80% FGE (97% for Atlantic salmon) with bypass flow >2% of turbine capacity

LOUVERS
Guidance Mechanism and Design Considerations



- Louvers create hydraulic conditions that elicit behavioral avoidance reactions from approaching fish
- Important design parameters include structure angle (15-30 degrees), slat spacing (1 to 12 inches), and bypass design
- Important hydraulic parameters include approach and bypass velocity
- Important biological parameters include behavior and swimming capabilities of species and size classes targeted for protection

LOUVERS
Concept Development



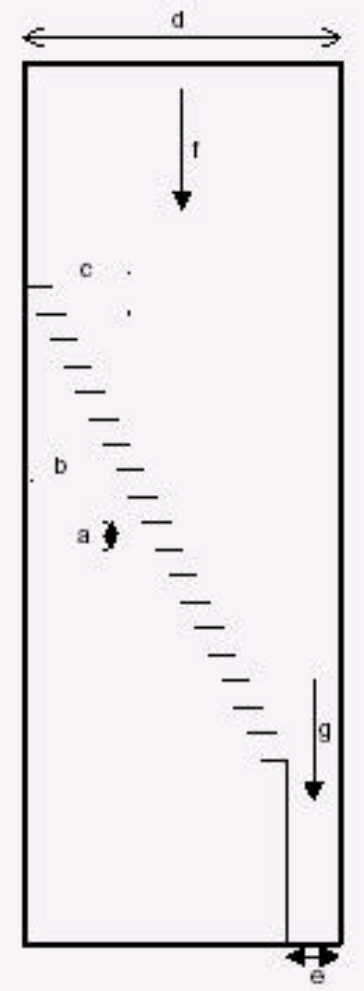
Bates and Vinsonhaler (1957)
- Tracy Pumping Plant
- Chinook salmon, striped bass

Bates and Jewett (1961)
- Maxwell Irrigation Canal
- Steelhead

Ruggles and Ryan (1964)
- British Columbia
- Pacific salmon

Ducharme (1972)
- Ruth Falls, NS
- Atlantic salmon

ANGLED BAR RACKS
Concept Development



Optimum Louver Design Criteria

Slat Spacing	>= 2 inches
Angle to Flow	15-30 degrees
Approach Velocity	<= 3 ft/s
Bypass Velocity Ratio	>= 1.5

Hanks and Haefner 1997

ANGLED BAR RACKS
Application at FERC-Licensed Projects

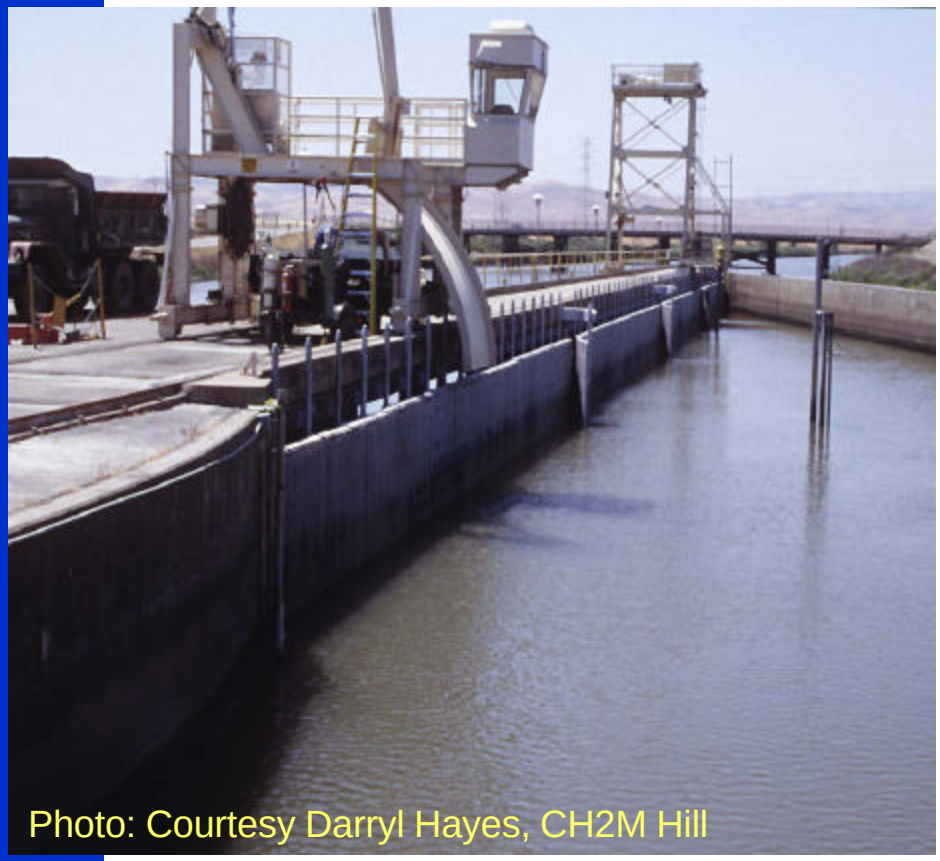


Photo: Courtesy Darryl Hayes, CH2M Hill

- Louvers have been effective at guiding anadromous species at several hydro projects
- Limited or no field information for most riverine species and American eel
- Laboratory data indicate that louvers could guide a wide range of species (> 2 inches in length) at rates greater than 80% (EPRI 2001)

ANGLED BAR RACKS
Application at FERC-Licensed Projects

Existing and Interim Facilities

- Holyoke Canal (Hadley Falls Project)
- Vernon
- Garvins Falls
- Eastman Falls
- Gardner Falls
- Cowlitz River (Mayfield Dam)

Guidance efficiencies generally have ranged from 50 to 90%

Application at FERC-Licensed Projects

Holyoke Canal Louver Facility

Original Design
Partial-Depth Louvers

Slat Spacing:	2 inches
Angle to Flow:	15 degrees
Approach Vel:	1 – 3 ft/s
Target Species:	Atlantic salmon juvenile Alosa
Size Range:	75 – 200 mm
Effectiveness:	80 – 95%

Application at FERC-Licensed Projects

Holyoke Canal Louver Facility

Photo: Courtesy Chris Tomichek, Kleinschmidt Associates

Modified Design
Full-Depth Louvers

Slat Spacing:	2 inches
Angle to Flow:	15 degrees
Approach Vel:	1 – 3 ft/s
Target Species:	Atlantic salmon juvenile Alosa riverine fishes shortnose sturgeon American eel
Size Range:	> 75 mm
Effectiveness:	??

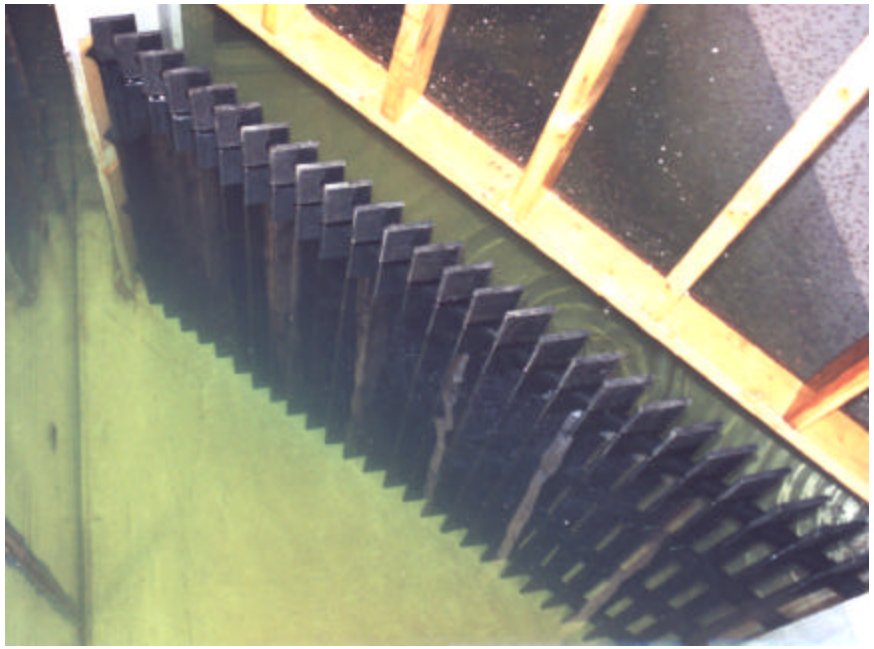
Application at FERC-Licensed Projects

Cowlitz River Hydroelectric Project

Mayfield Dam

Slat Spacing:	2.25 inches
Angle to Flow:	22 degrees
Approach Velocity:	2.5 – 3 ft/s
Target Species:	Salmon
Size Range:	100 - 200 mm
Effectiveness:	> 70%

ANGLED BAR RACKS AND LOUVERS
Laboratory Evaluation (EPRI 2001)



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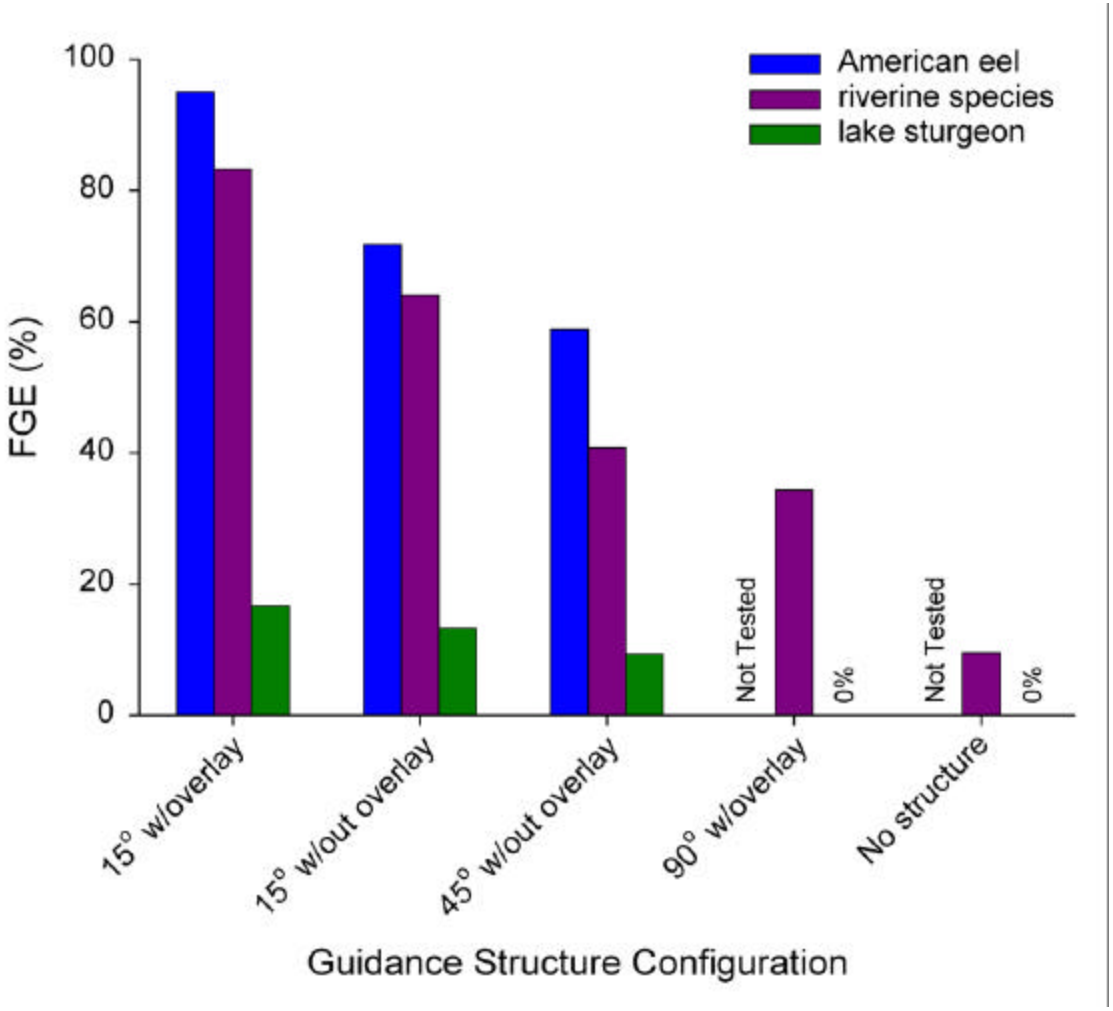
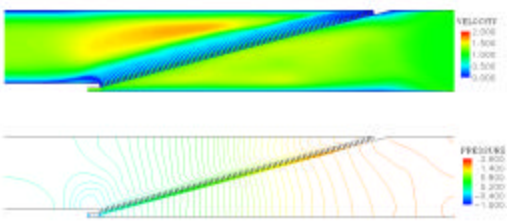


ANGLED BAR RACKS AND LOUVERS
Considerations for Successful Application

- Site Layout – location and orientation of spillway, bypass, and intake relative to one another and approaching flow
- Target Species – migration behaviors, reaction to flow fields, spatial and temporal distributions, swimming capabilities, and target size range
- Hydraulics – a thorough understanding of hydraulic conditions experienced by fish approaching a guidance structure is absolutely necessary for successful application
- Bypass – Fish may guide effectively, but will not enter a bypass that is poorly located or has sub-optimal hydraulic conditions

ANGLED BAR RACKS AND LOUVERS
Future Research Needs



- Design criteria for effective guidance of riverine species and American eel (laboratory data need to be supported by field studies)
- Better understanding of how fish respond to varying flow conditions and near-field hydraulics associated with guidance structures and bypasses
- Potential modifications to existing designs to improve guidance efficiency (e.g., bottom overlays, slat modifications, bypass design)
- More field data on effectiveness with respect to various design parameters (structure angle, slat spacing, approach velocity) and a wide range of species

ANGLED BAR RACKS AND LOUVERS
Conclusions

- Angled bar racks (45°) have been effectively applied for guiding salmon smolts and juvenile clupeids at some FERC-licensed projects.
- Limited field data available for riverine species and American eel; laboratory studies indicate angled bar racks may be ineffective (<60% FGE).
- Louvers have been employed at a limited number of sites, mainly due to engineering constraints.
- Most louver applications have been effective for anadromous species; laboratory data indicate louvers could be effective means for guiding riverine fishes and American eel.
- Better understanding and more analysis of existing data.
- More research needed to refine when, where, and how to use these technologies. Important tools include physical models (for engineering/biological testing), CFD, and field monitoring.