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Managing Water in the West

Rock Weir Design Guidelines

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http://www.usbr.gov/pmts/sediment/projects/RStructs

U.S. Department of the Interior
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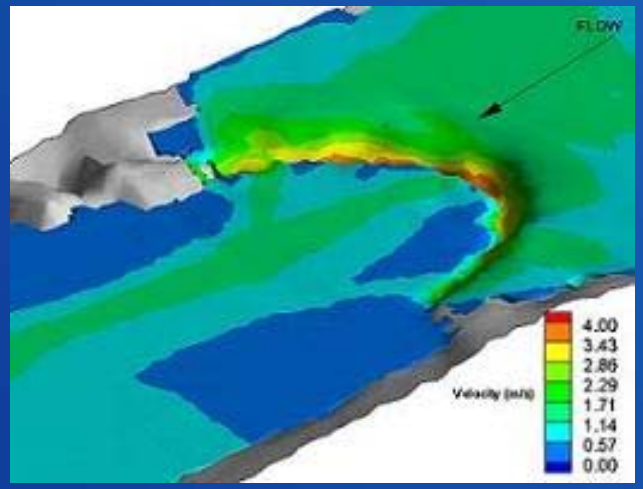
Overview

- Research need and background
- Research components
  - Field Evaluation
  - Physical Modeling
  - 3D Numerical Simulations
- Preliminary Results and Benefits
- Physical Model Details



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Background

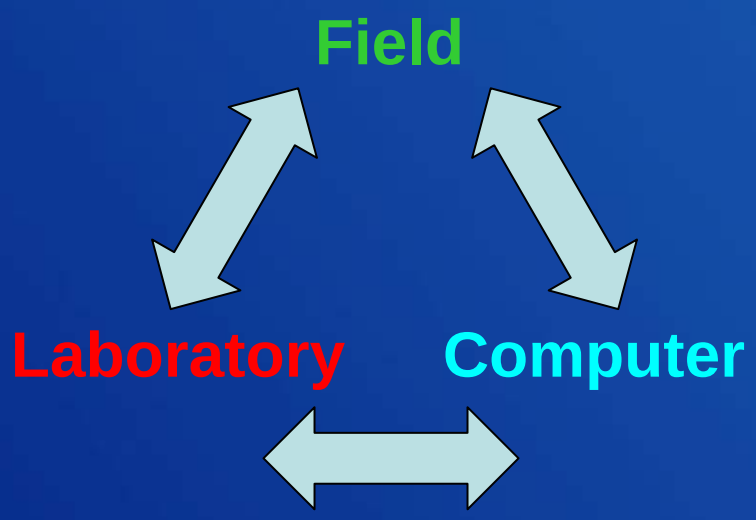
- Rock weirs capabilities include: fish passage, bank protection, channel profile stability, and improved aquatic habitat.
- Rock weirs are ideal structures for conditions of…steep slopes, bends, scalability, habitat, and aesthetics.
- Failures or loss of function can result in: disruption of service, expensive repairs, maintenance cost, failure to meet biological and geomorphic requirements, and loss of prestige.
- Initial laboratory results and qualitative field evaluations found widespread performance issues.
- We think this is a flaw in the designs, not in the concept.
- The Rock Weir Design Guidelines Project was developed to investigate failure mechanisms and provide methods for designing sustainable structures.

Research Components

The Rock Weir Research Project takes a multifaceted approach incorporating mutually supporting field, laboratory, and numerical studies.

- Evaluates current methods
- Hypothesizes successful techniques
- Identifies failure mechanisms
- Creates a practical link

- Provides a controlled setting
- Includes scour processes
- Physically replicates hydraulics



- Inexpensively simulates large numbers of cases
- Increases range of applicability
- Provides a design tool

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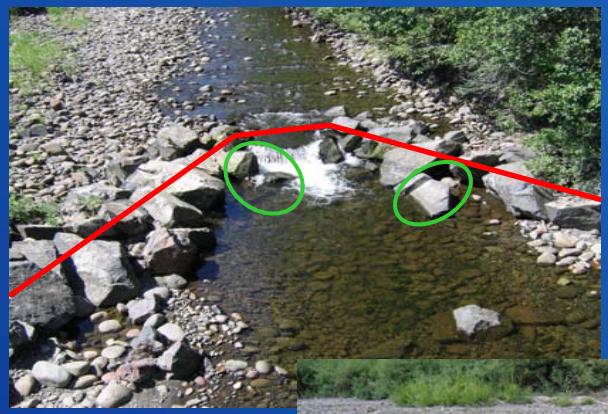
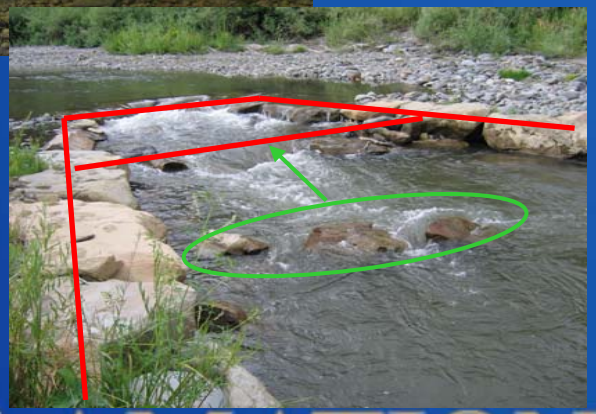
Evaluation of Field Performance

- Field evaluation collected information on many different design methods around the western United States.
- Field evaluations identified several failure mechanisms.
  - Scour and Slumping
  - Flanking
  - Loss of Pool Depth
  - Incipient Motion
- Identifying failure pathways allows design of countermeasures.
- Field measurements provide a practical link to guide and validate laboratory and numerical investigations.





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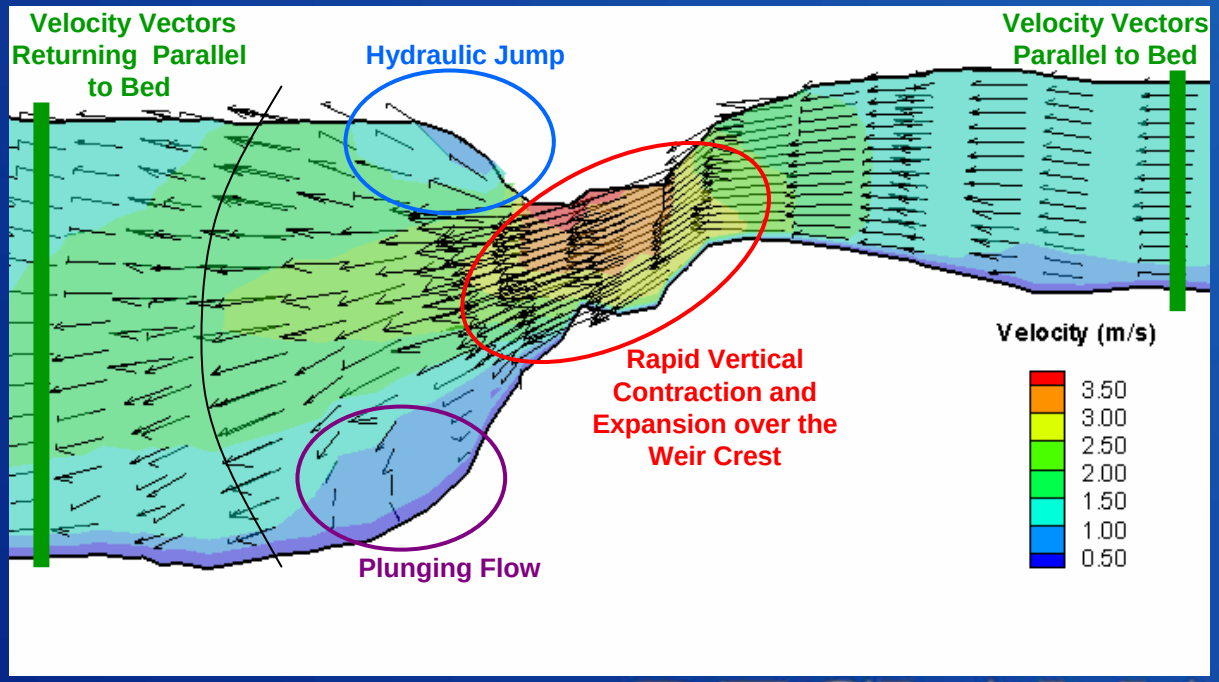
Laboratory Physical Modeling

- Field investigation identified growth of a scour hole causing geotechnical movement as the primary failure mechanism for rock weirs.
- Understanding the scour processes and quantities provides vital information on failure modes and potential counter measures required to design sustainable structures.
- Understanding failure modes in the field is COMPLICATED.
- Analyzing scour hole development is best answered in a controlled environment such as the laboratory.
- Benefits include
  - Scour prediction method
  - Potential counter measures and retrofits
  - Rating curves for flood elevations
  - Low flow depths and velocities for passage criteria

Need and Benefits of Numerical Modeling

- Field and laboratory provide data over a limited range of conditions.
- Narrower ranges of conditions limit the applicability of results.
- Numerical modeling provides opportunity to test numerous design parameters over large ranges for less money and in a shorter amount of time to extend the applicability.
- The complex flow patterns require 3-dimensional simulations .



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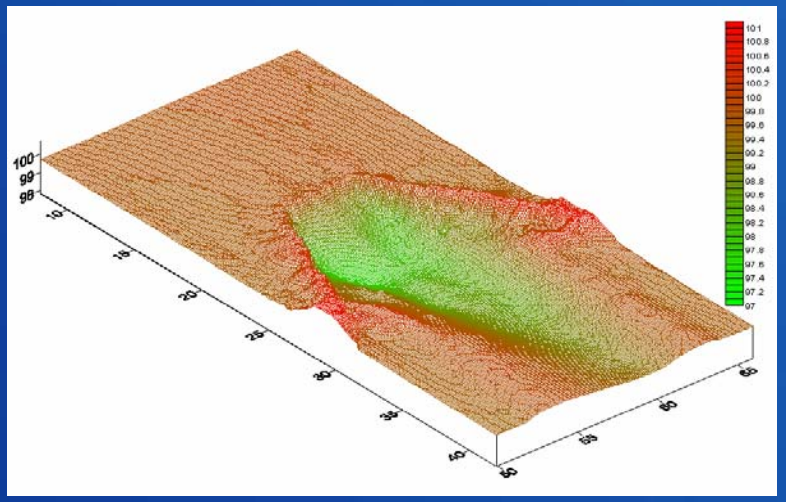
Design Guidelines Product

- The research produces tools and guidelines for structure design or retrofits based upon predictable engineering and hydraulic performance criteria.
- Existing structures may need retrofits in the future.
- Current solutions:
  - Deep foundations to protect against scour,
  - Grouted weir crests,
  - Using multiple structures in series, and
  - Using interlocking blocky shaped rocks.
- Future solutions:
  - Scour prediction method for foundation design,
  - Tools/Methods for numerical modeling rock weirs, and
  - Design guidelines based on field analysis, numerical modeling, and physical model results.

Physical Model

- Testing includes:
  - Average river geometries.
  - Mobile boundary.
  - Fine gravel, medium gravel, and very coarse gravel.
- Data collection includes:
  - Topographic bed surveys,
  - 3D velocities, and
  - Water surface data.
- Results will assist in developing a scour prediction method.



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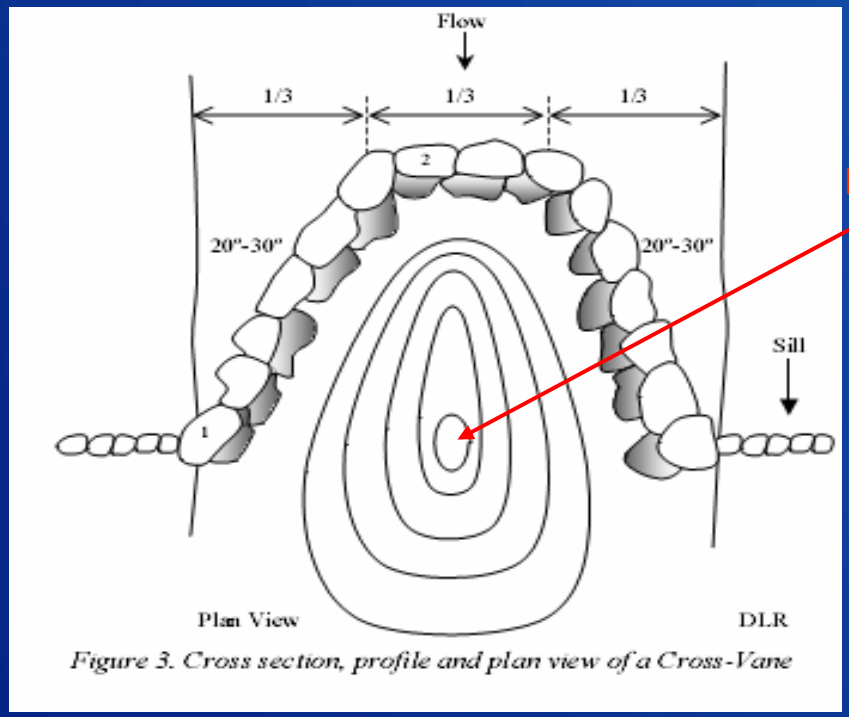
Physical Model Results

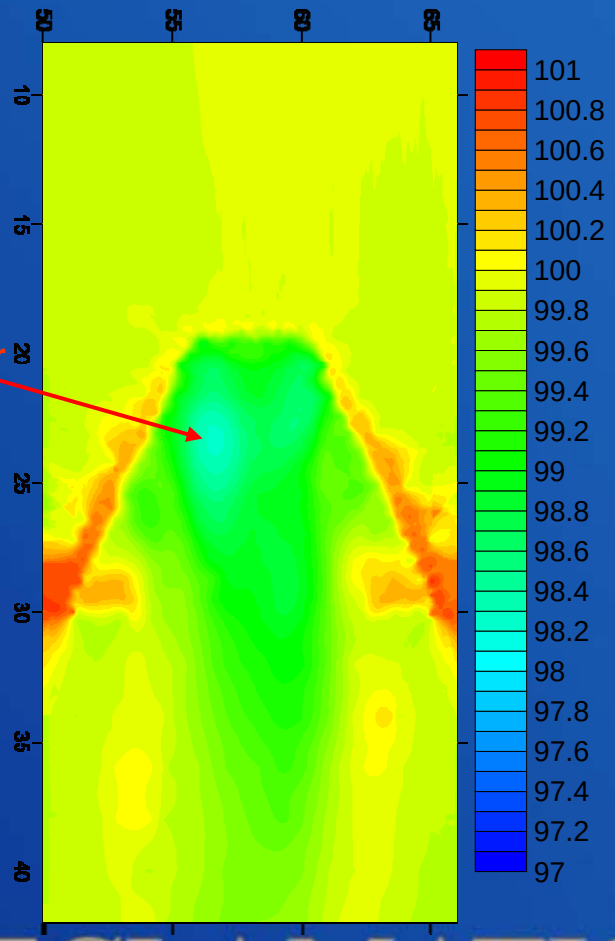
Difference in scour hole definition between theoretical and physical model

Theoretical



Physical Model

($Q_{bankfull}$, Small cobble)



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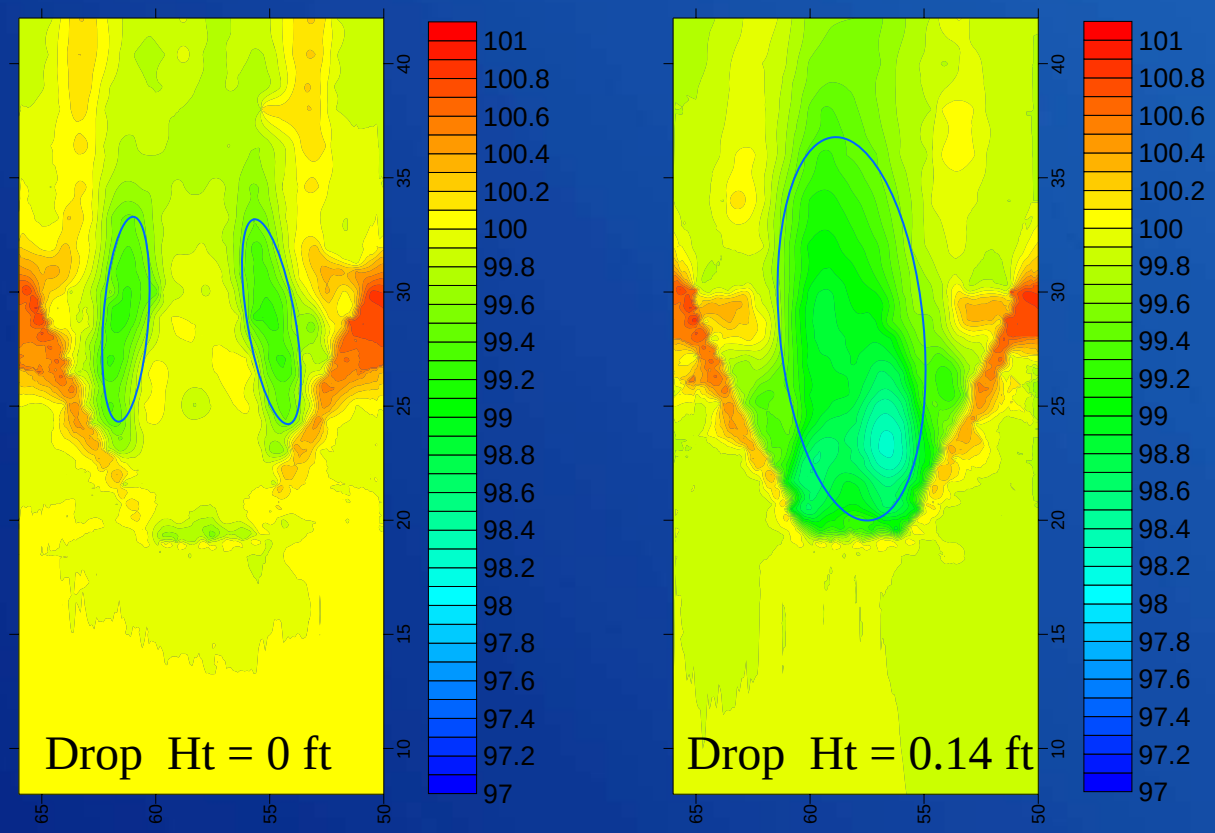
Physical Model Shakedown Results

Difference in scour hole definition between installing the throat crest: with no drop (level with the bed) vs. with a drop



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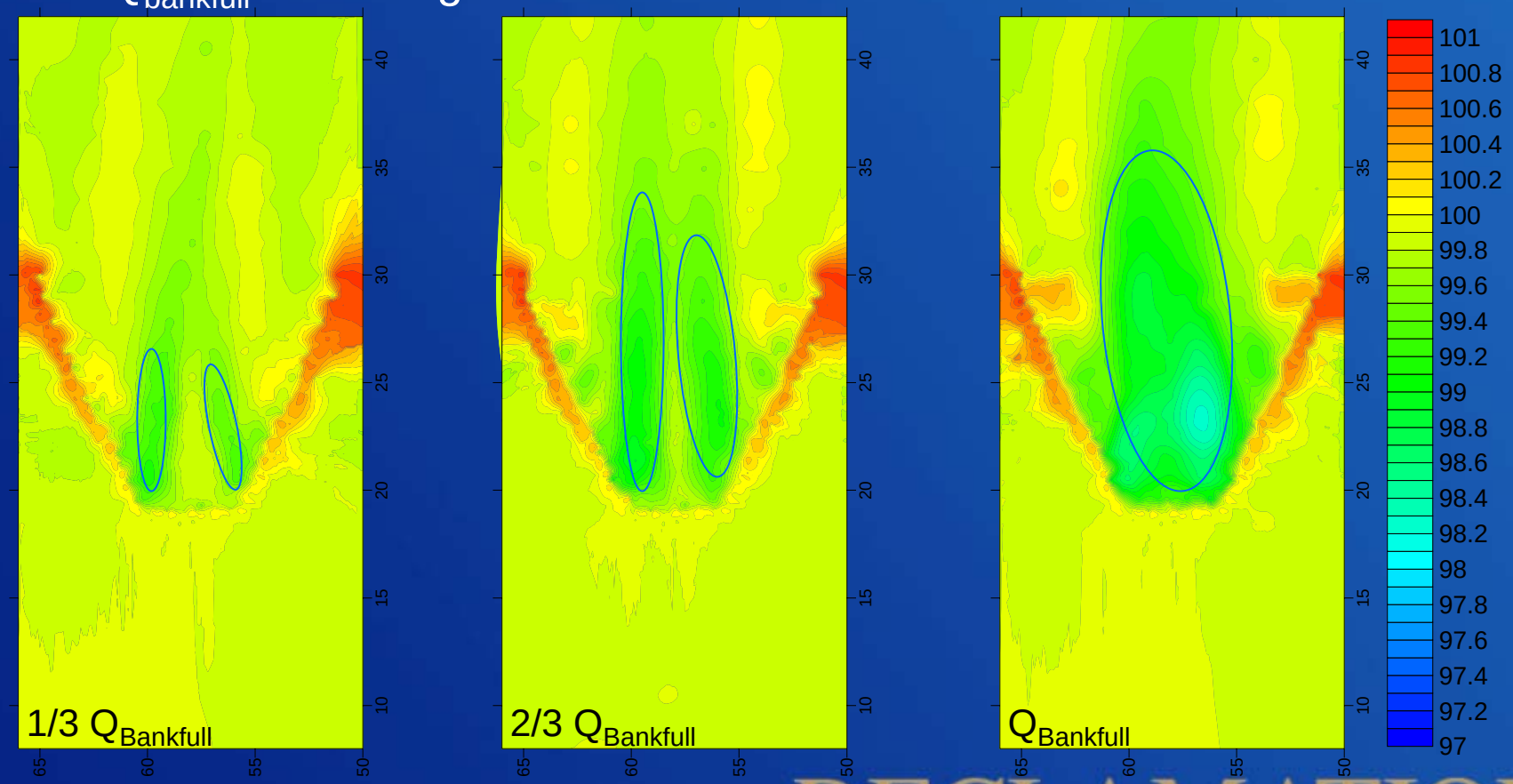
Physical Model Results

Scour Hole Evolution (15mm bed)

- 1/3 $Q_{Bankfull}$ - two separate scour holes located near the arms
- 2/3 $Q_{bankfull}$ - scour holes enlarge and move together
- $Q_{bankfull}$ - one large scour hole located below the throat



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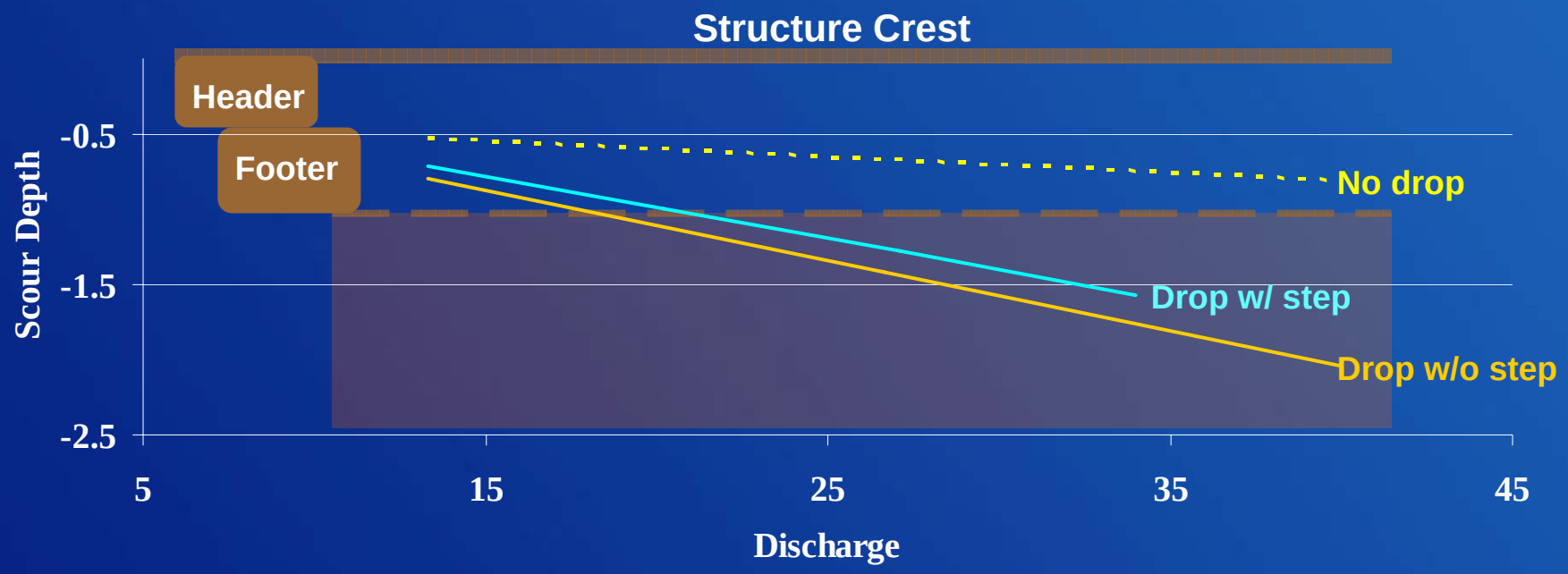
Physical Modeling Summary

- Structures are highly sensitive to drop height.
- A stair step approach to the header and footer rocks reduces the size of the scour hole.
- To minimize scour, the rocks comprising the weir should consist of blocky shapes spaced tightly together and carefully placed to form a smooth continuous crest.
- Scour prediction methods can be used to assist in designing sustainable structures while meeting project requirements.

Physical Modeling Summary

- Scour depth vs. Q
  - *Scour depth > foundation depth = potential failure*



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Research Summary

- The research produces tools and guidelines for structure design or retrofits based upon predictable engineering and hydraulic performance criteria.
- Understanding the processes governing success and failure allow designers to construct robust and sustainable structures requiring fewer repairs, less disruption of service, and lower maintenance costs.
- Guidelines simplify and reduce future design efforts while increasing the likelihood of successful structures.
- We hope that solidly developed criteria will simplify the regulatory permitting processes.

In the End

- Reliable structure designs reduce failures,
- Reduced failures results in fewer retrofits,

- Fewer retrofits saves money,
- Saving money while meeting regulatory requirements governing habitat and fish passage makes everyone happy

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