The Hydraulics of Flow Through Screens

Are we doing the hole thing wrong?

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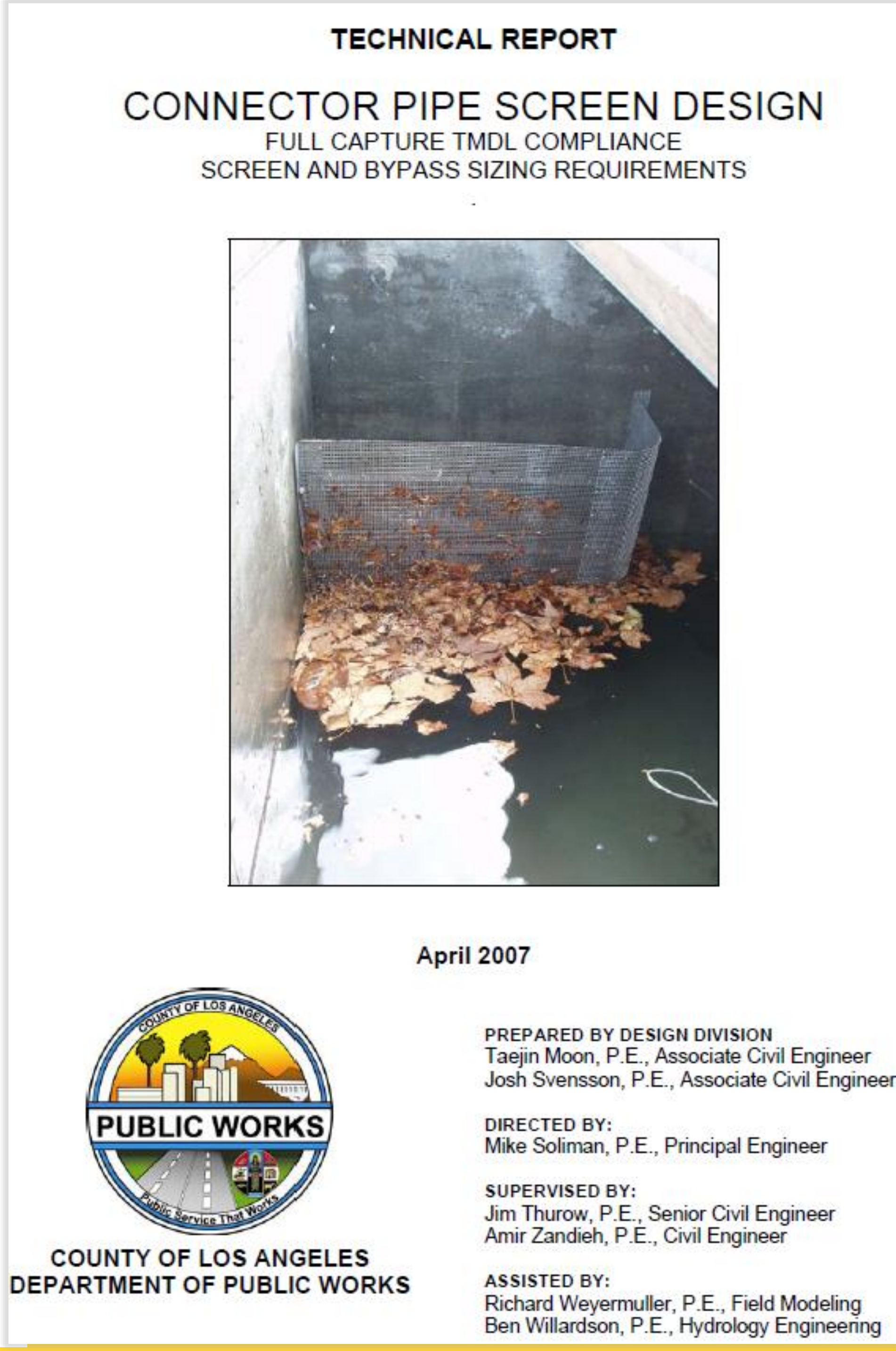
Introduction and Context

- California's statewide trash amendments and total maximum daily loads (TMDL) regulations impose strict requirements on **trash full capture**

Catch Basin Inserts

- Assumptions made within flow calculations using the single orifice approach may not provide the accuracy needed for trash capture compliance and flood prevention.

Single Orifice Approach – LA County 2007 Public Works Technical Report


TECHNICAL REPORT

CONNECTOR PIPE SCREEN DESIGN
FULL CAPTURE TMDL COMPLIANCE
SCREEN AND BYPASS SIZING REQUIREMENTS

April 2007

COUNTY OF LOS ANGELES
PUBLIC WORKS
Public Service That Works
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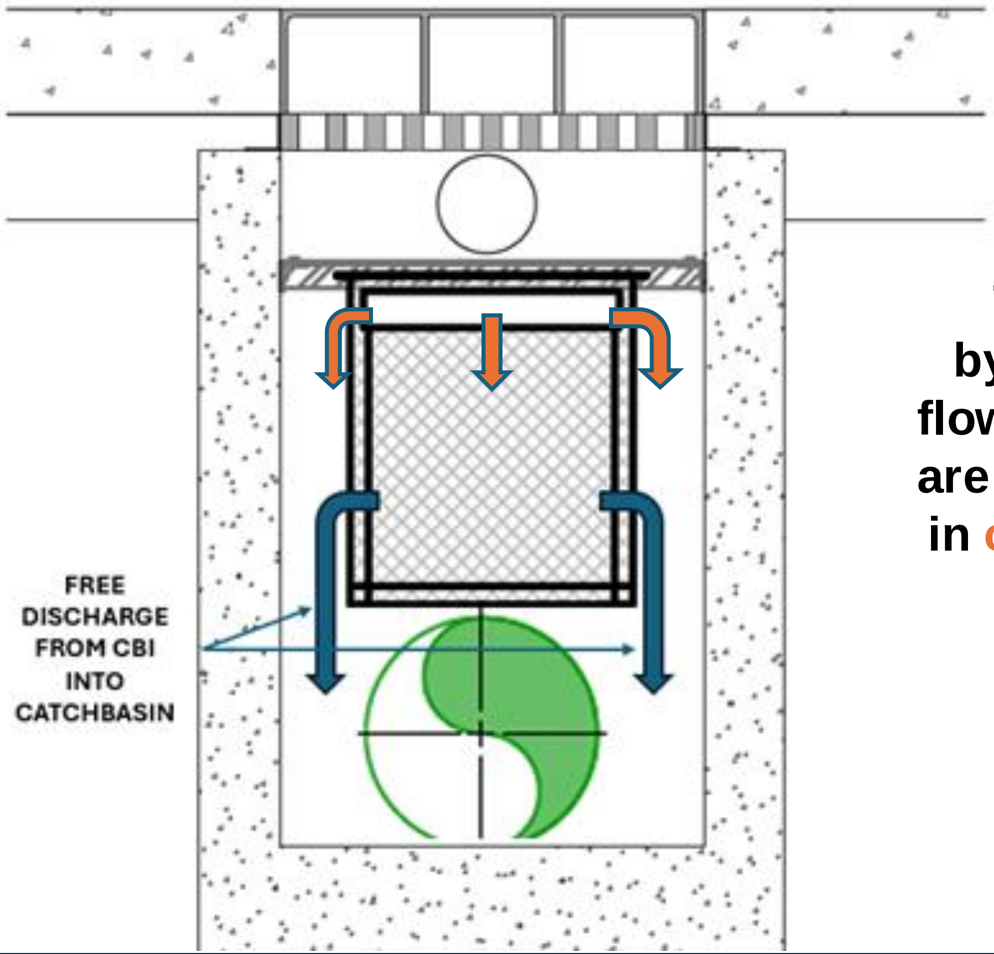
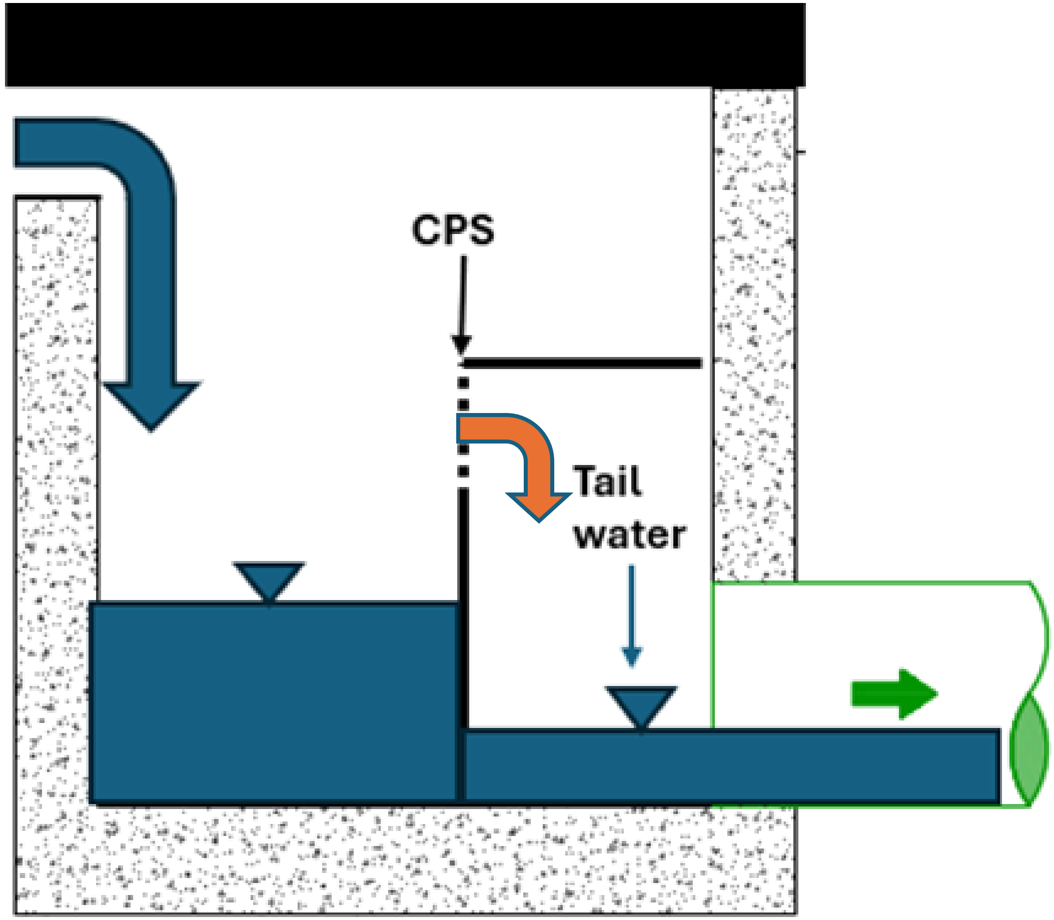
Types of Catch Basin Insert

Basket



The bypass flow paths are shown in orange

Connector Pipe Screen



Free Discharge Conditions

Tailwater Conditions

The Risks of Overestimation

- The widely-used single orifice method simplifies hydraulic design but the assumptions mean it can overestimate the flow capacity of catch basin inserts by up to 250%.

- Overestimation of treatment flow rates and bypass capacity leads to underperformance during high rainfall events, increasing the risk of environmental damage from trash and flooding.

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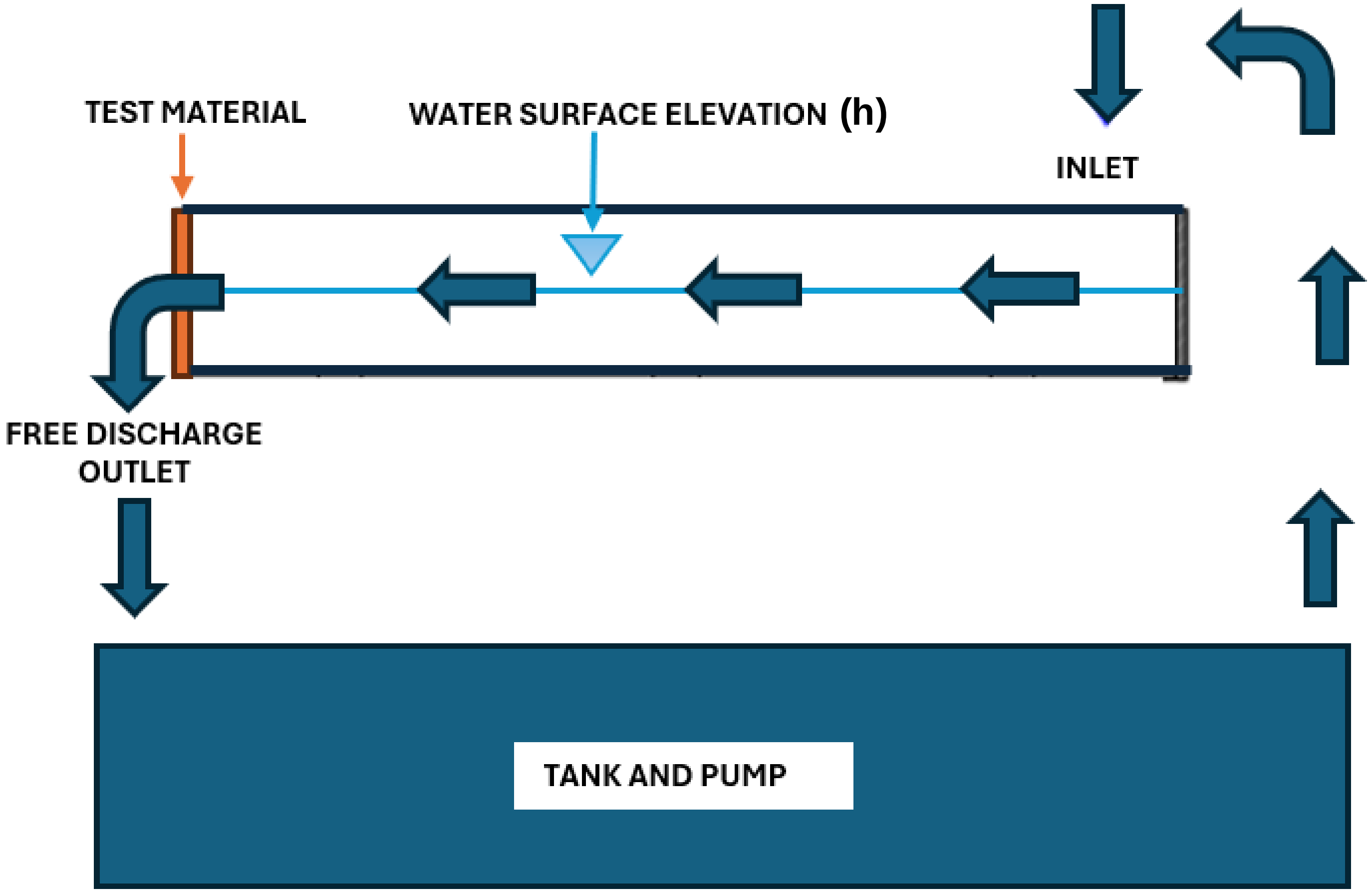
Outline of this Study

- Laboratory testing
  - Free discharge for application to baskets
  - Tailwater for application to connector pipe screens

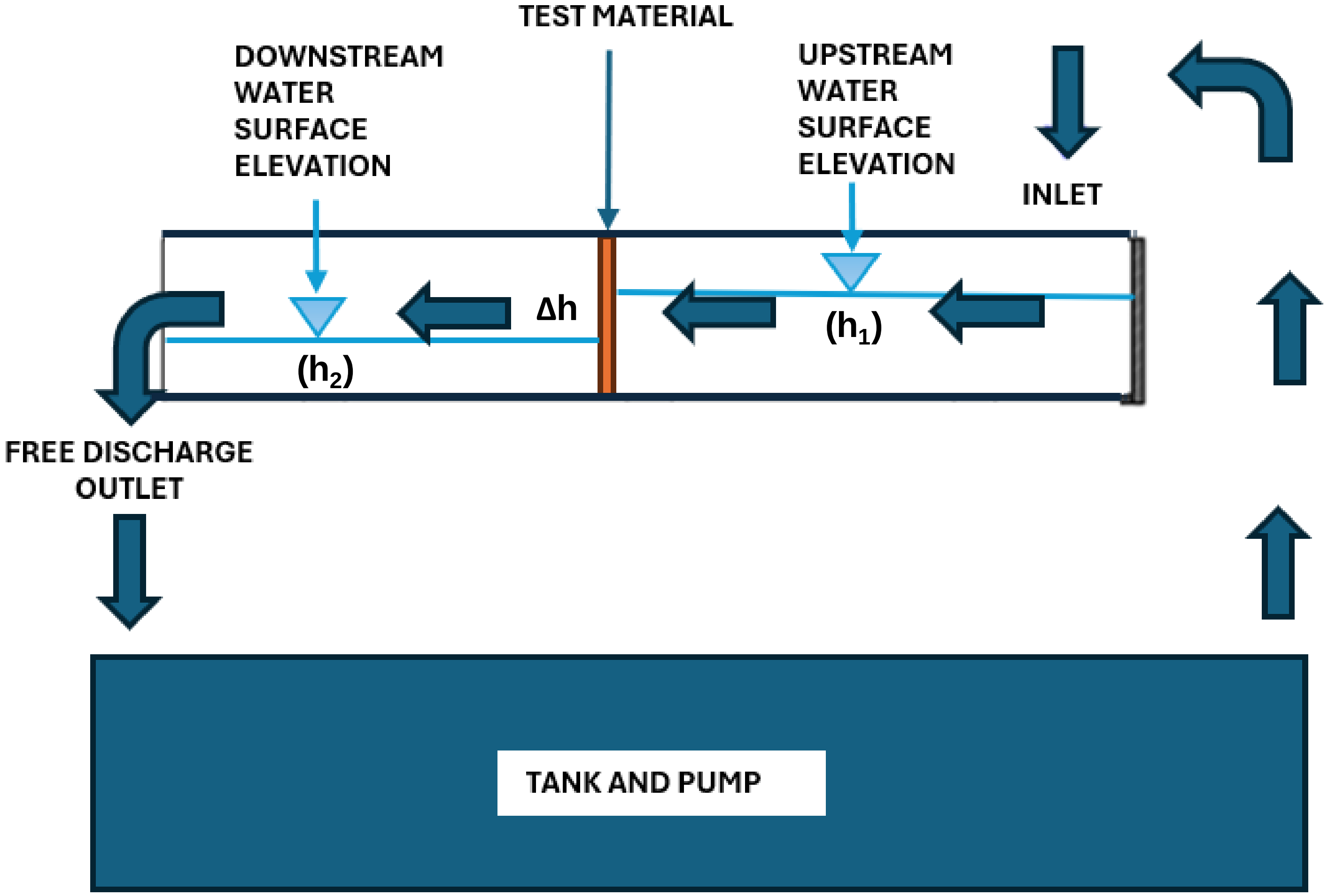
- Description of methods
  - Four methods applied to laboratory testing and baskets
  - Two of those methods applied to bypass capacity calculation
  - Methods for determining downstream tailwater acting on the screen

- Results
- Key takeaways
- Future work

Laboratory Testing – Free Discharge



Laboratory Testing – Tailwater



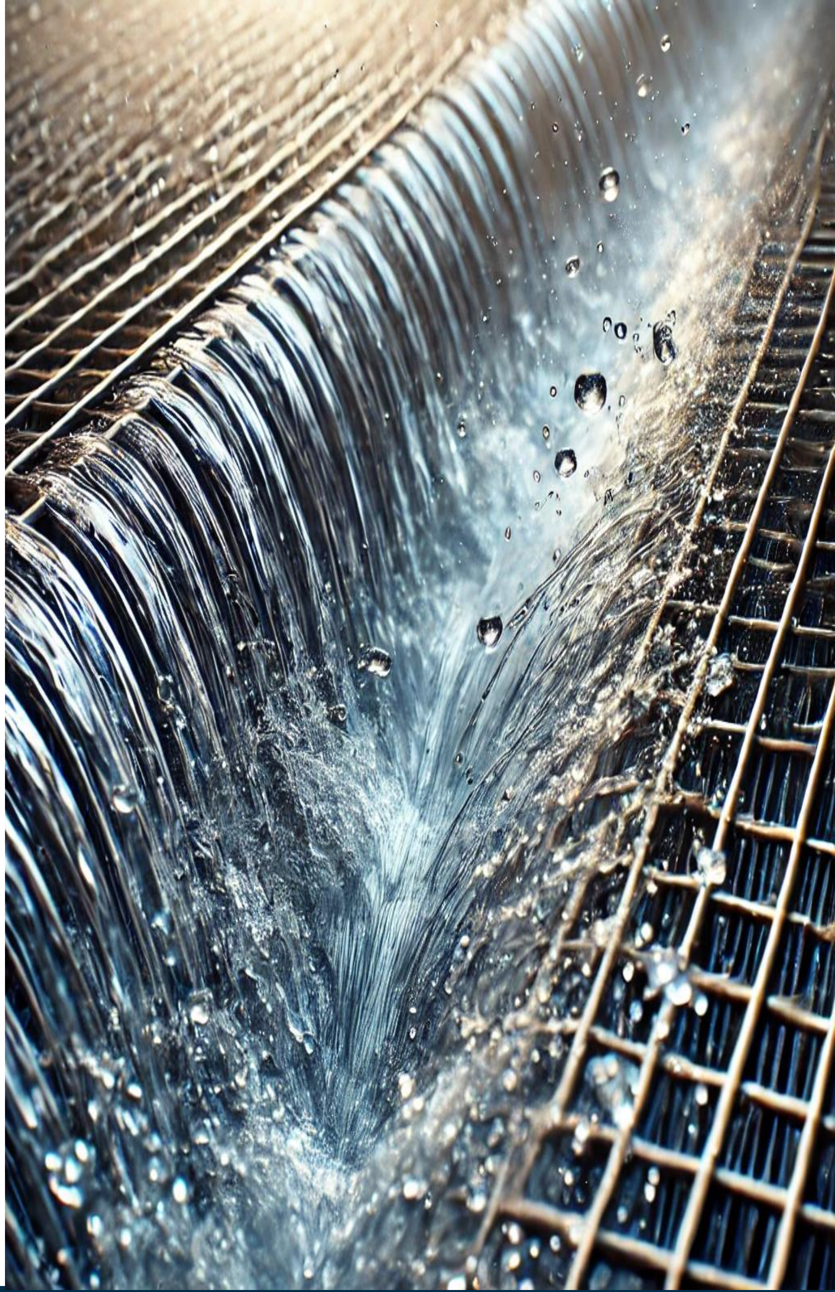
Methods Compared in This Study

- **Single Orifice Method (LA County Public Works Report):** The simplified approach uses an empirically derived discharge coefficient. Often assumed as 0.61 in the industry.

- **Integrated Orifice & Driving Head Model**: Considers individual orifices and varying driving heads, more representative of actual conditions.

- **Stage-Discharge Lab Testing**: Empirical lab data on flow through a screen, providing real-world validation.

- **Computational Fluid Dynamics (CFD) Modeling**: Simulates complex hydraulic interactions in catch basins, offering the most comprehensive analysis.



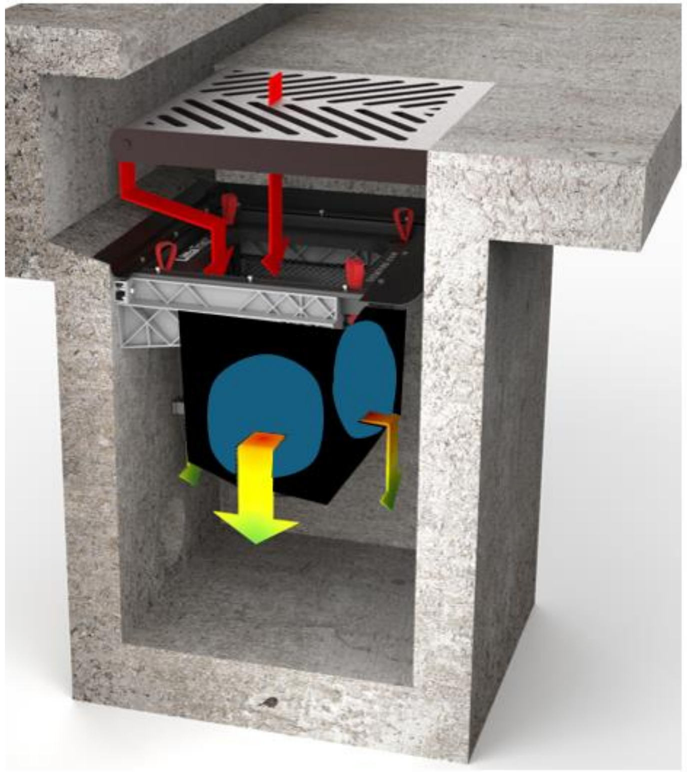
Single Orifice Method (LA County 2007 Technical Report)

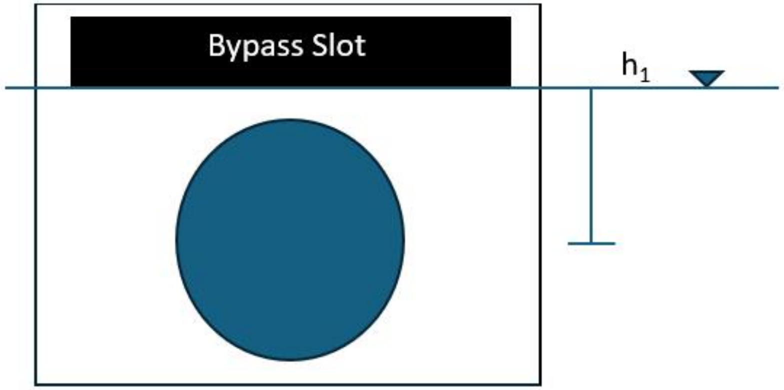
- Simplified approach – should be using an empirically derived discharge coefficient

$$Q_F = (C_d A_f \sqrt{2gh})$$

Assumed for screen →	$C_{assumed}$	**0.61**
Lab test on screen →	C_{Screen}	**0.41**

$$C_d = \frac{Q_{act}}{Q_{th}} = \frac{Q_{act}}{A\sqrt{2gH}}$$





"the screen coefficient, Cd, is unique to each orifice geometry and that orifice conditions for screen holes differ substantially from the conditions used to determine standard orifice coefficients" – LA, 2007

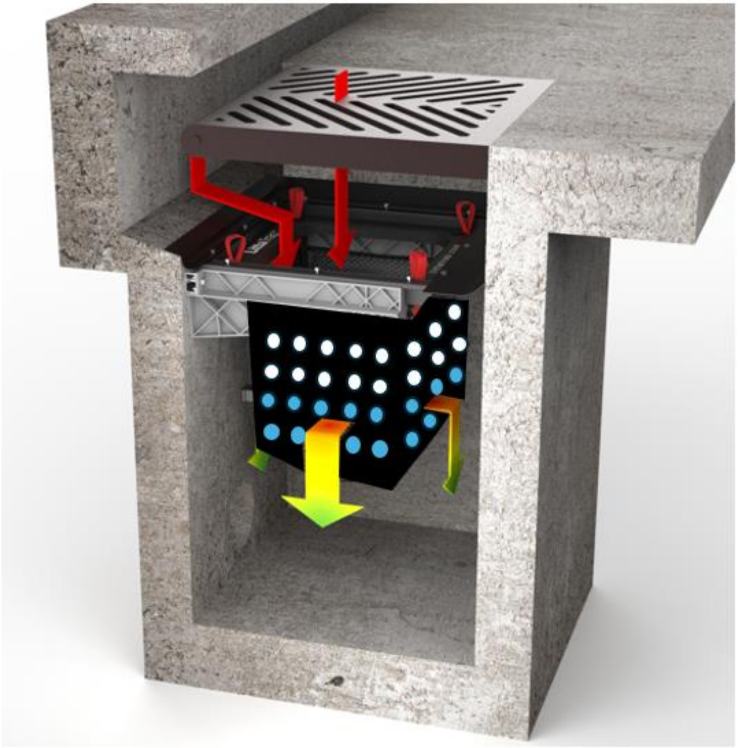
Integrated Orifice & Driving Head Model

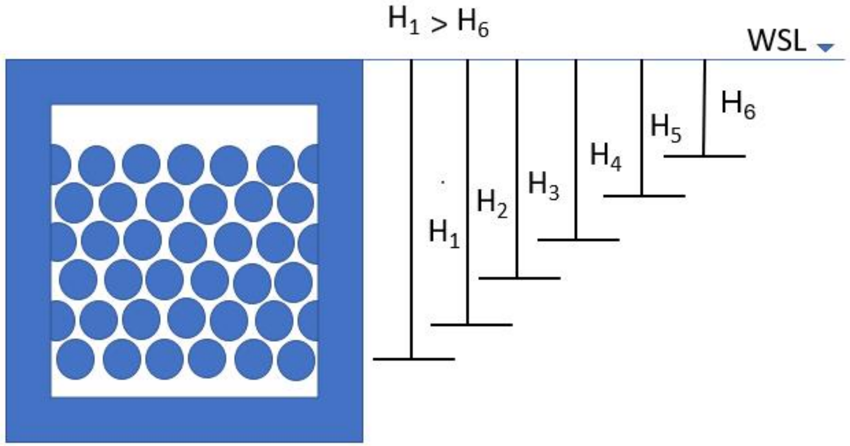
- **Integrated Orifice & Driving Head Model**: Considers individual orifices and varying driving heads, more representative of actual conditions.

$$Q_F = (C_d A_f \sqrt{2gh})$$

Per orifice → **$C_{orifice}$: 0.60**

Per row → **h: various**

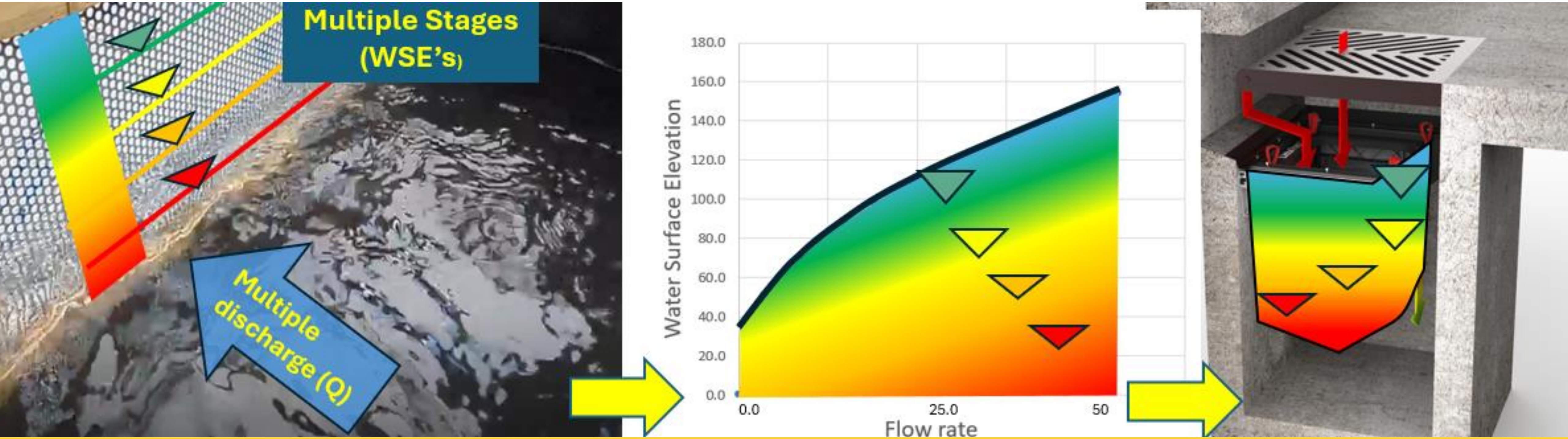




Stage-Discharge Lab Testing

- Similar to previous - considers the effects of driving head at each elevation within the device

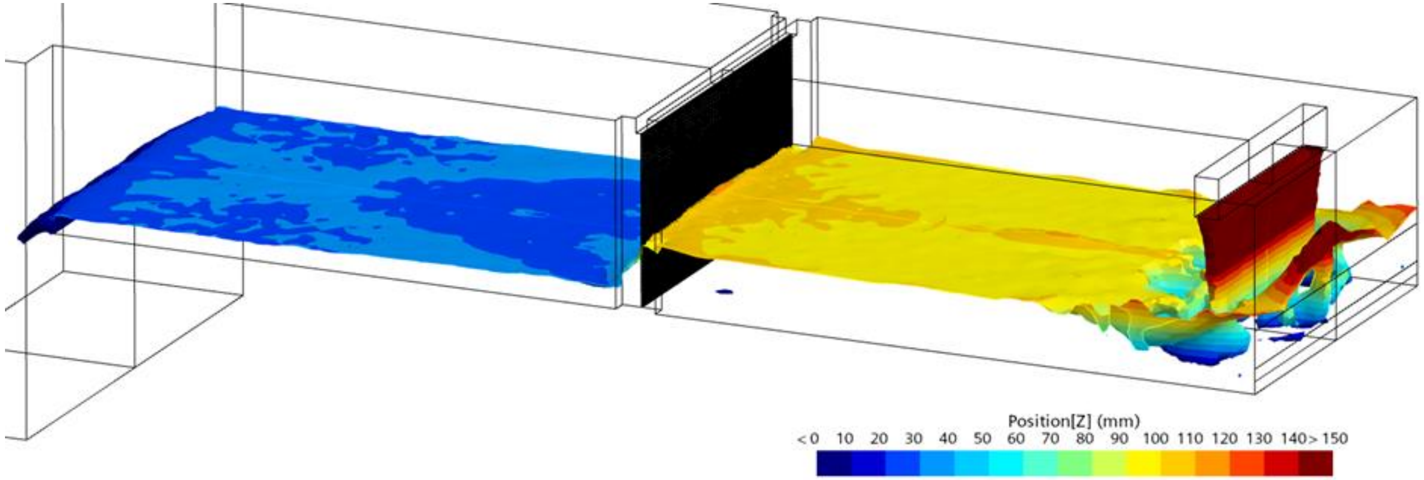
- Also calculated C_{screen} for the screen with 4.8mm holes and 51% open area from lab testing



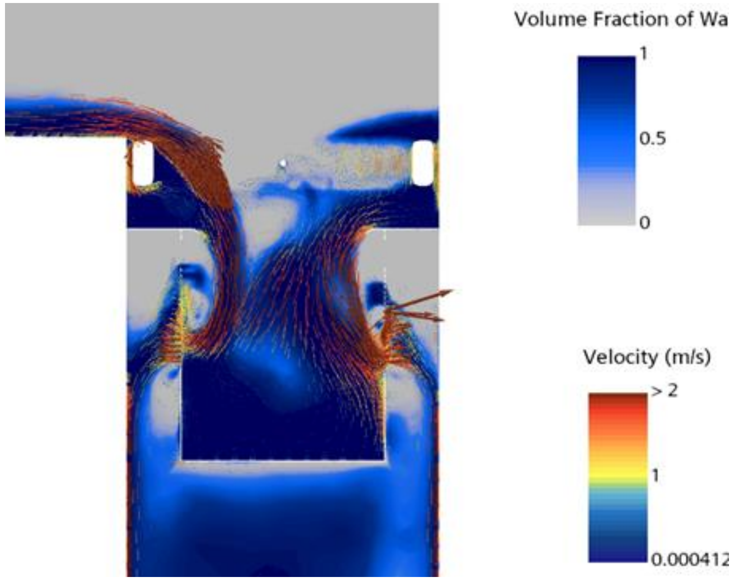
CFD Modelling

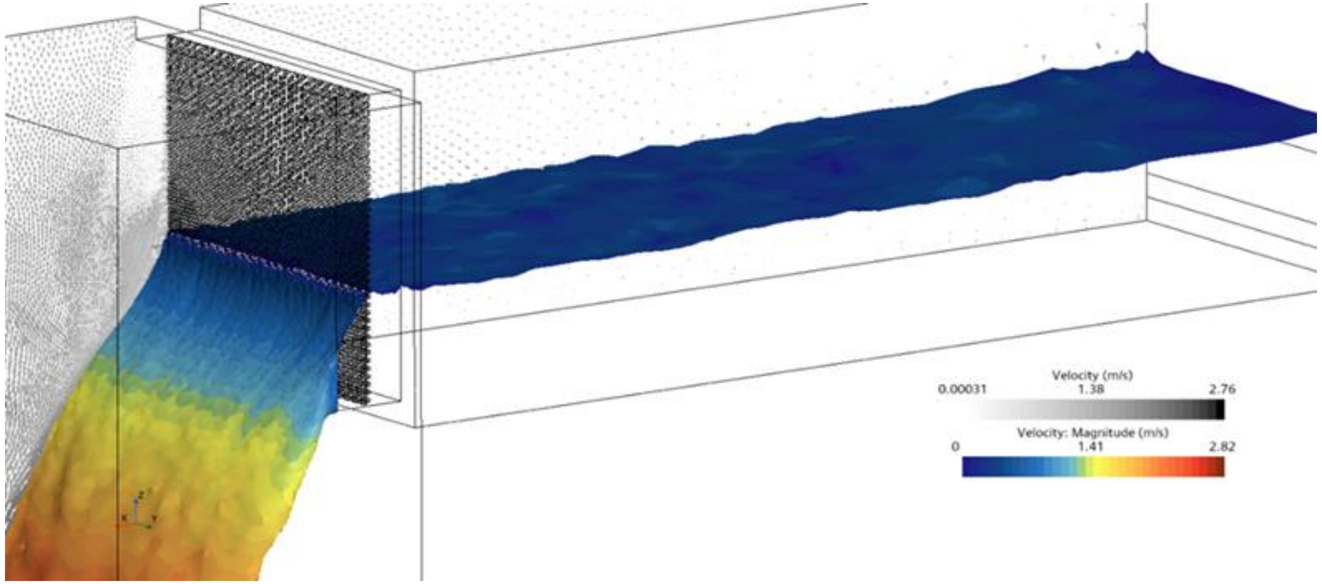
- Simulates complex hydraulic interactions in catch basins, offering the most comprehensive analysis.
- Uses $\frac{V}{V^2}$ and measures of pressure and resistance

Lab replication and model validation

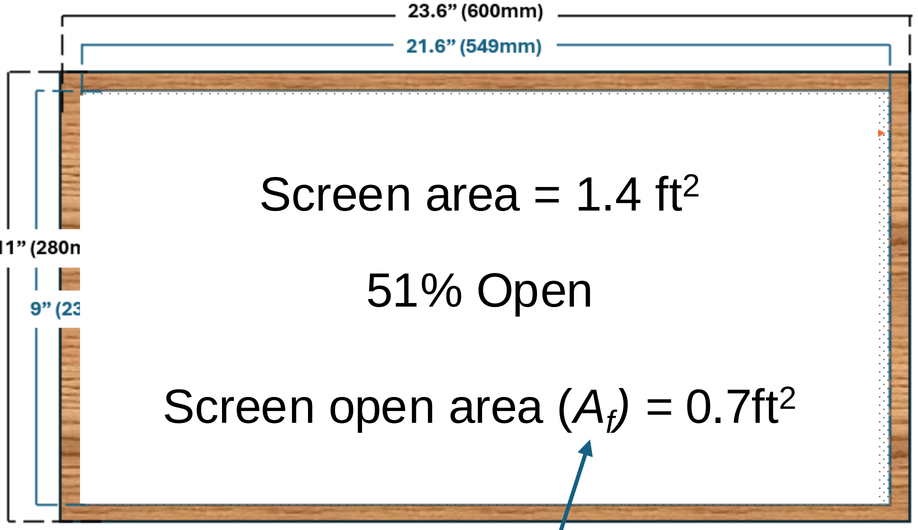


Basket and catchbasin interaction



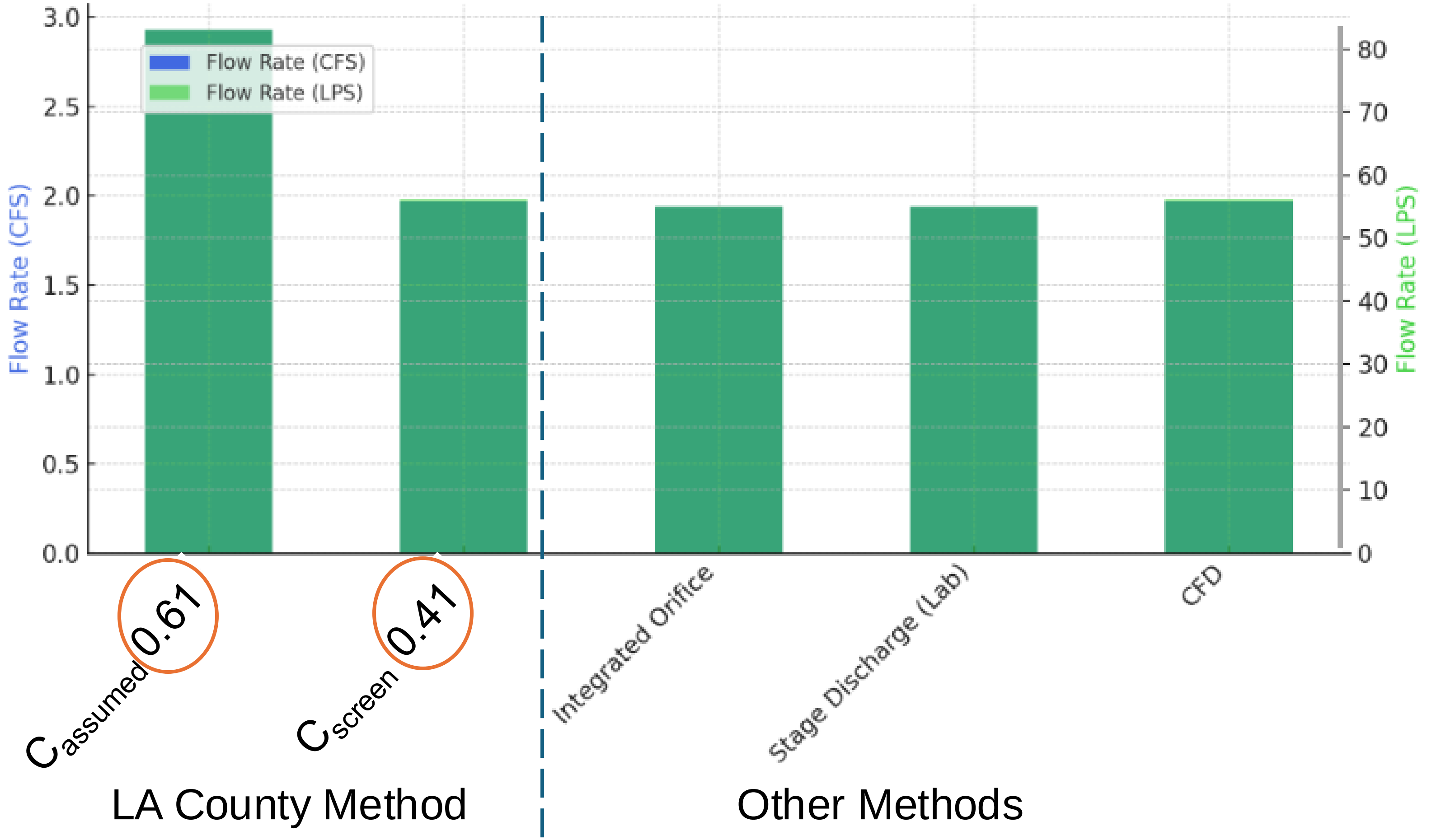


Results: Screen Q_{max} Free Discharge



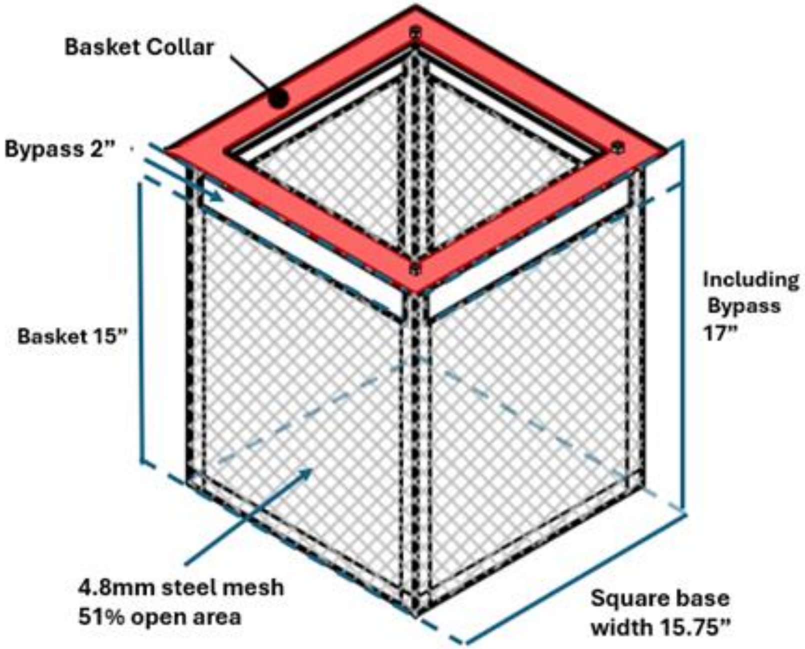
$$Q_F = C_d A_f \sqrt{2gh}$$

The maximum possible flow through the screen as defined by each method

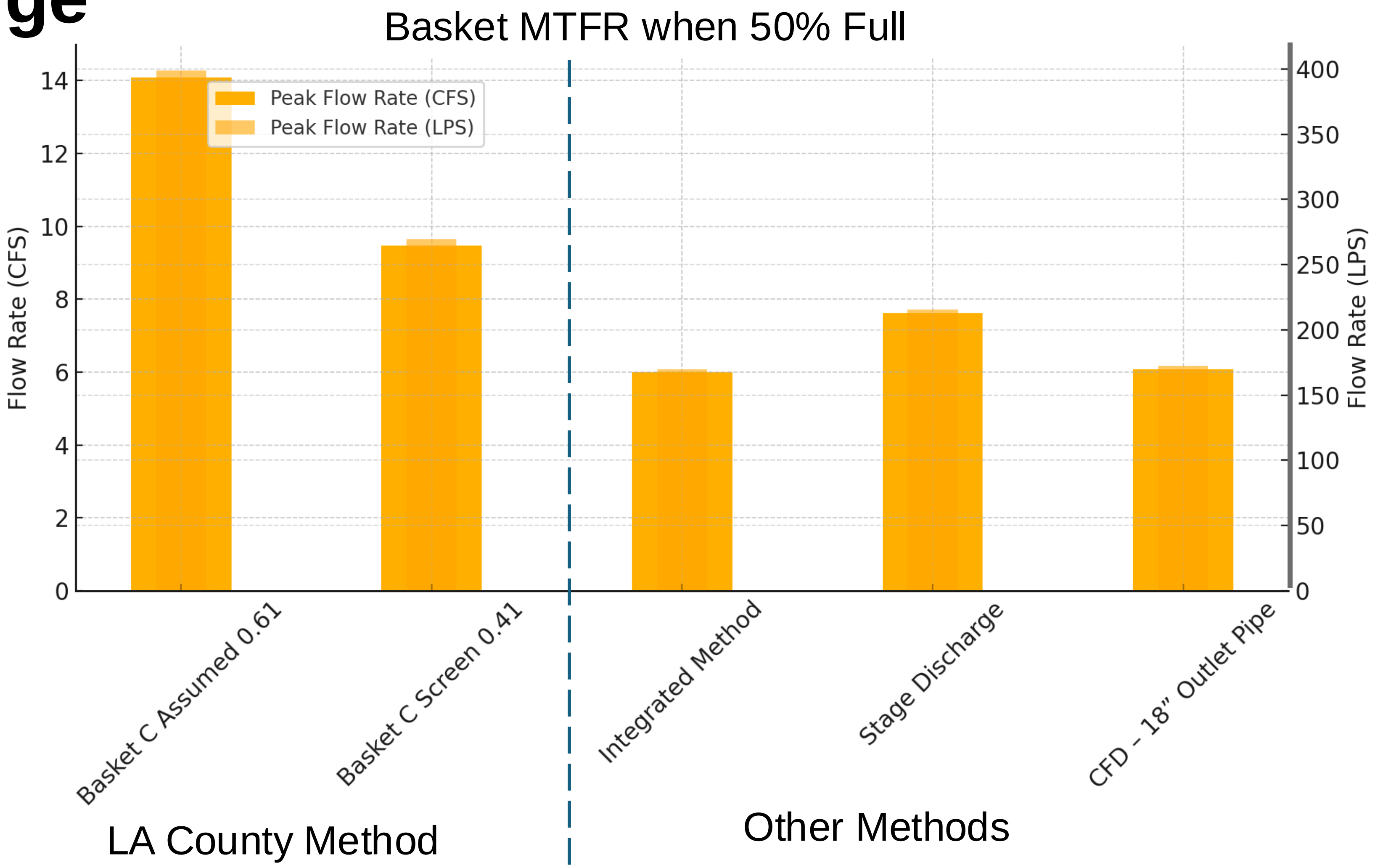


Results: Basket Q_{max} as 50% Full

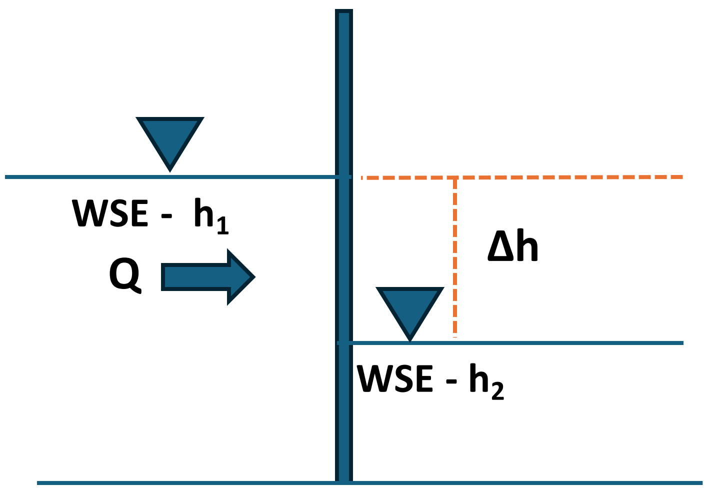
Applied Free Discharge



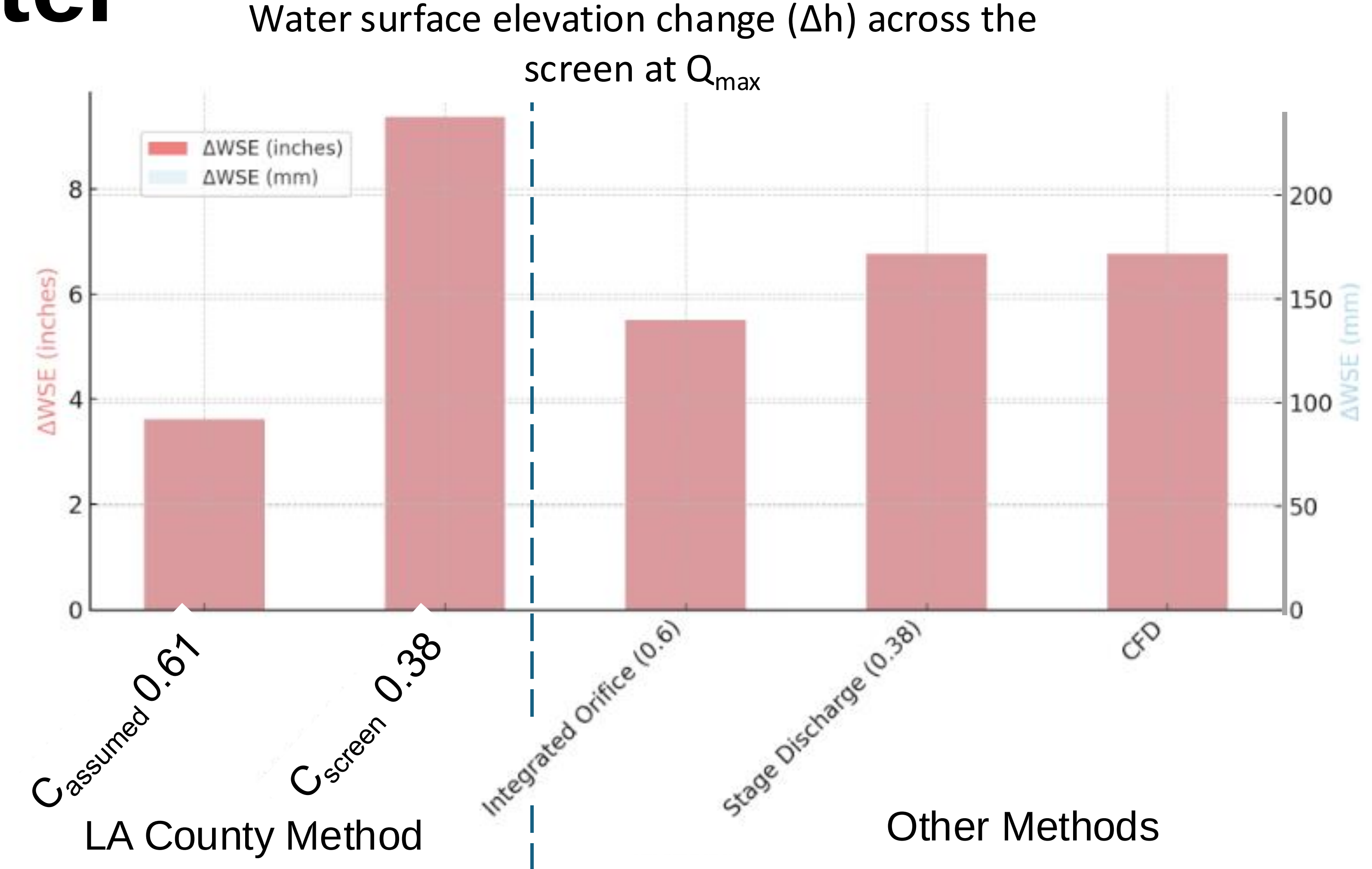
Schematic of the basket each method was applied to – for a 24" by 24" CB



Results: Δh, Screen Q_{max}: 1.9 CFS (55 LPS) Tailwater



- Lower Δh for same Q suggests a more efficient/less resistive screen



Additional Considerations

- **Bypass Capacity**
  - CFD and Single orifice method
    - Single orifice considered appropriate for a bypass therefore no other method is required

- **Connector Pipe Screen Tailwater Depth**
  - CFD
  - CPPA Design Manual
  - LA County critical Depth Method
    - Other methods are too complicated and onerous

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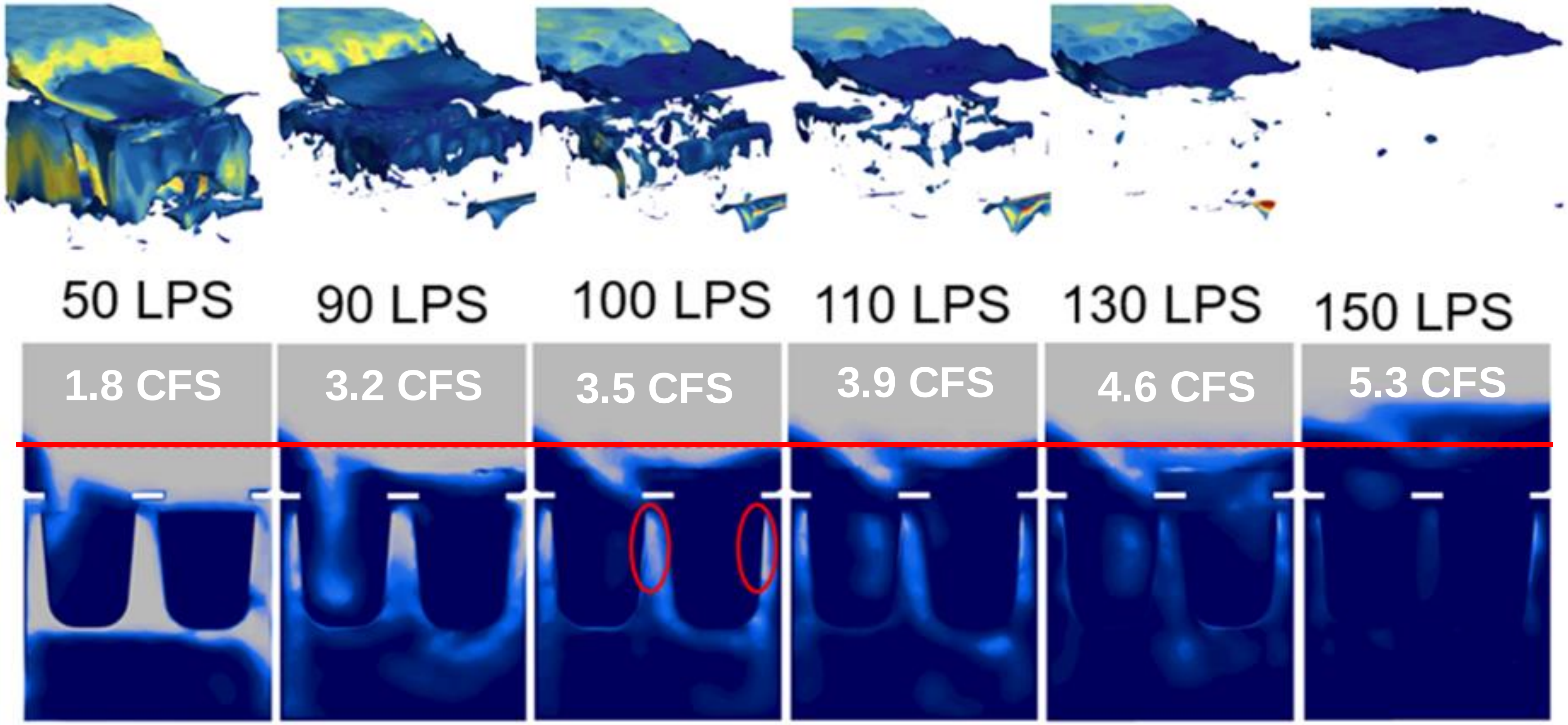
Results: CFD Bypass Capacity Full Scale Basket

- Single orifice method calculated 9 CFS (256 LPS)
- Surface flooding occurs 5.3 CFS (150 LPS)



Full Scale Connector Pipe Screen Methods: Tailwater Depths

Geometry and flows as recommended in the LA County Report

- $Q_{1\text{-}10}$ 2.9 CFS (82.1 LPS)
- CB Q_{max} 5.3 CFS (150 LPS)

- CFD

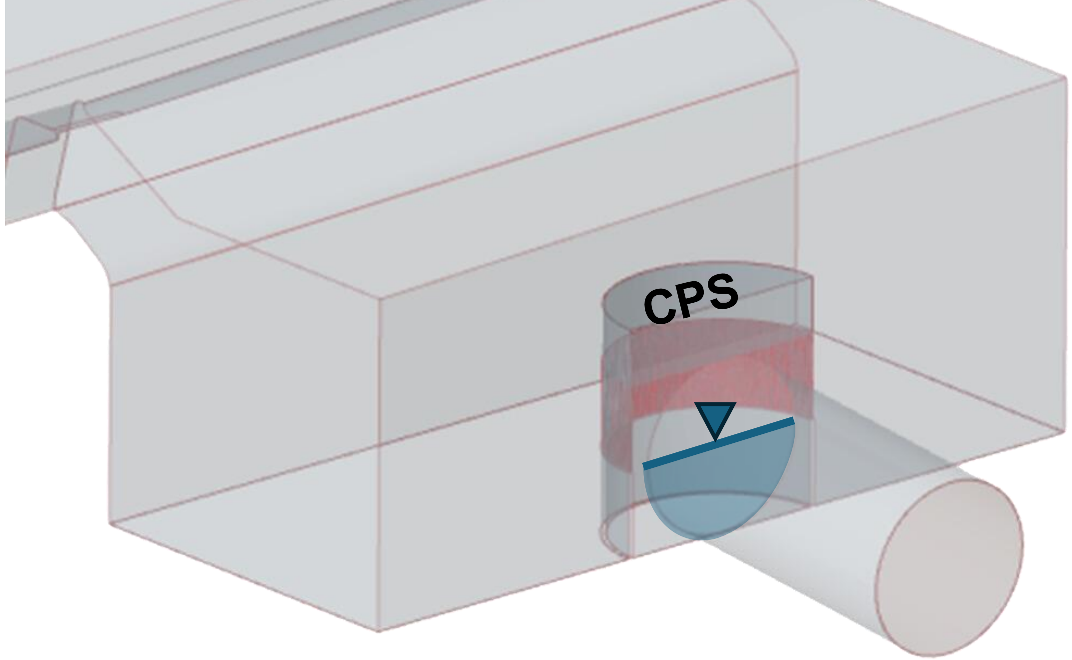
- LA County Critical Depth Method
  Downstream depth as a function of critical depth and outlet losses:

$$D_d = \mathrm{d}_C + 1 \cdot 2\frac{v^2}{2g}$$

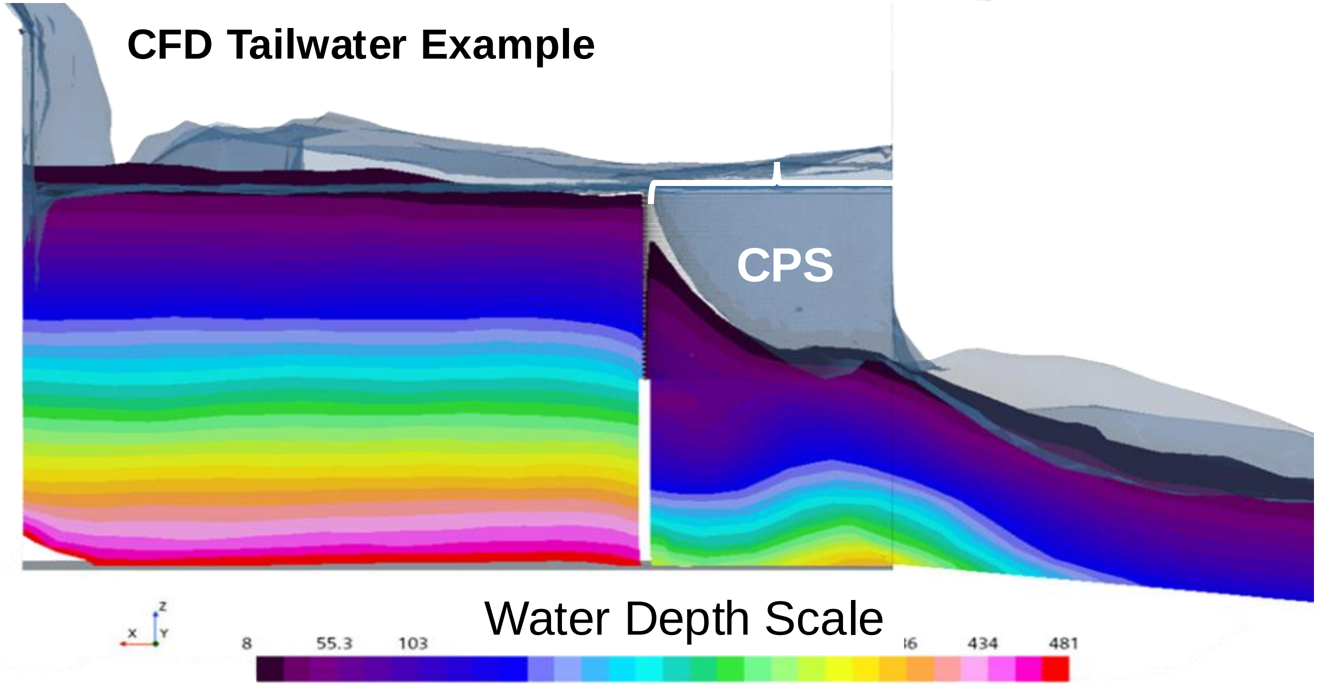
- CPPA Hydraulic Design Manual
  As a culvert inlet
  Assume inlet control and no tailwater
  Uses Figure 3.3

https://www.hynds.co.nz/wp-content/uploads/CPAAHydraulicsofPrecastConcreteConduits.pdf

Full Catch Basin Geometry (all methods)



CFD Tailwater Example

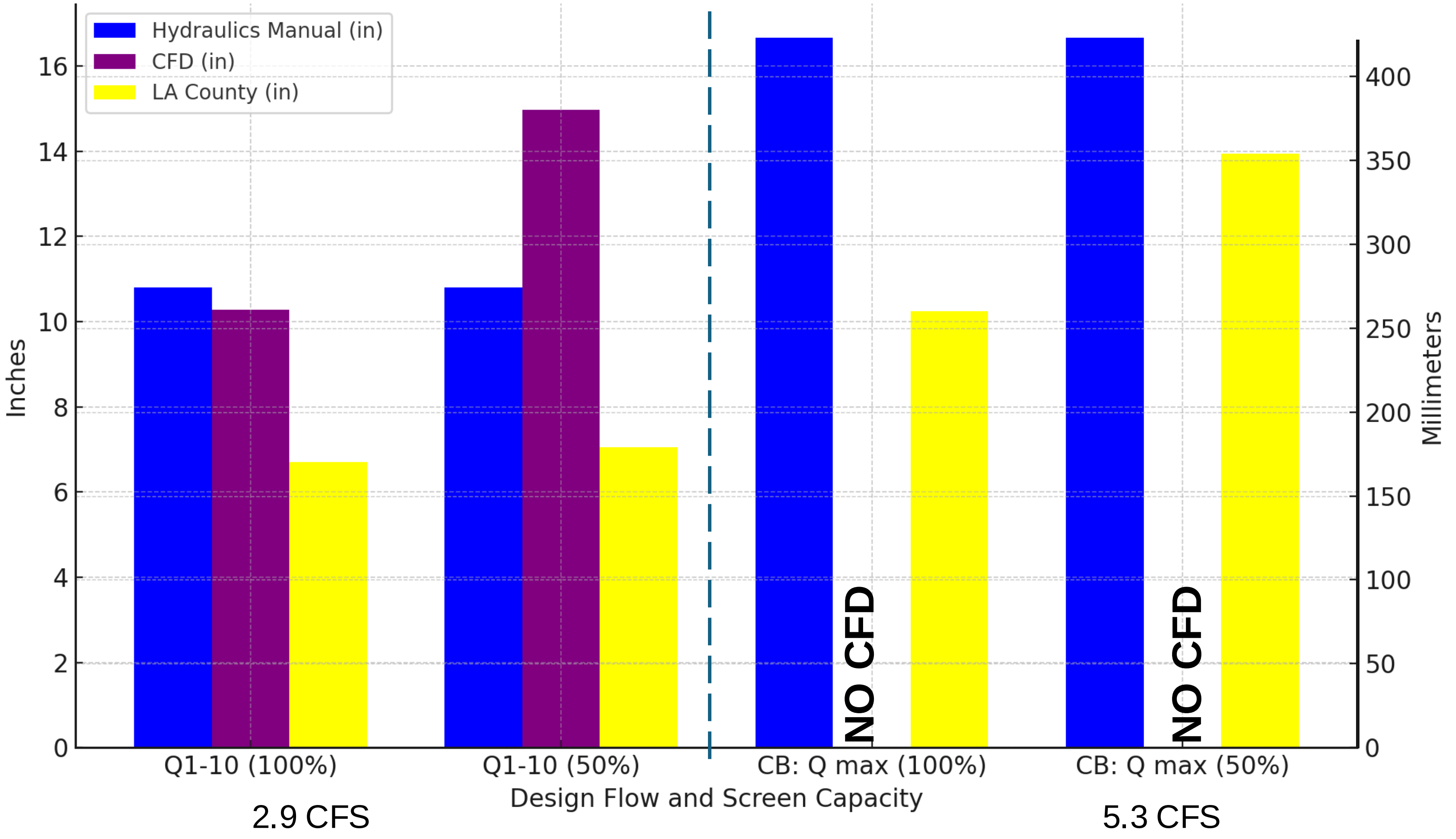


Results: Connector Pipe Screen Tailwater Depths

- LA County method consistently underestimates the depth of tailwater acting on the screen

- Tailwater reduces flow velocities through the screen

Depth of tailwater downstream of the CPS based on 50% or 100% of Screen Capacity for each Design Flow (2.9 CFS and 5.3 CFS)



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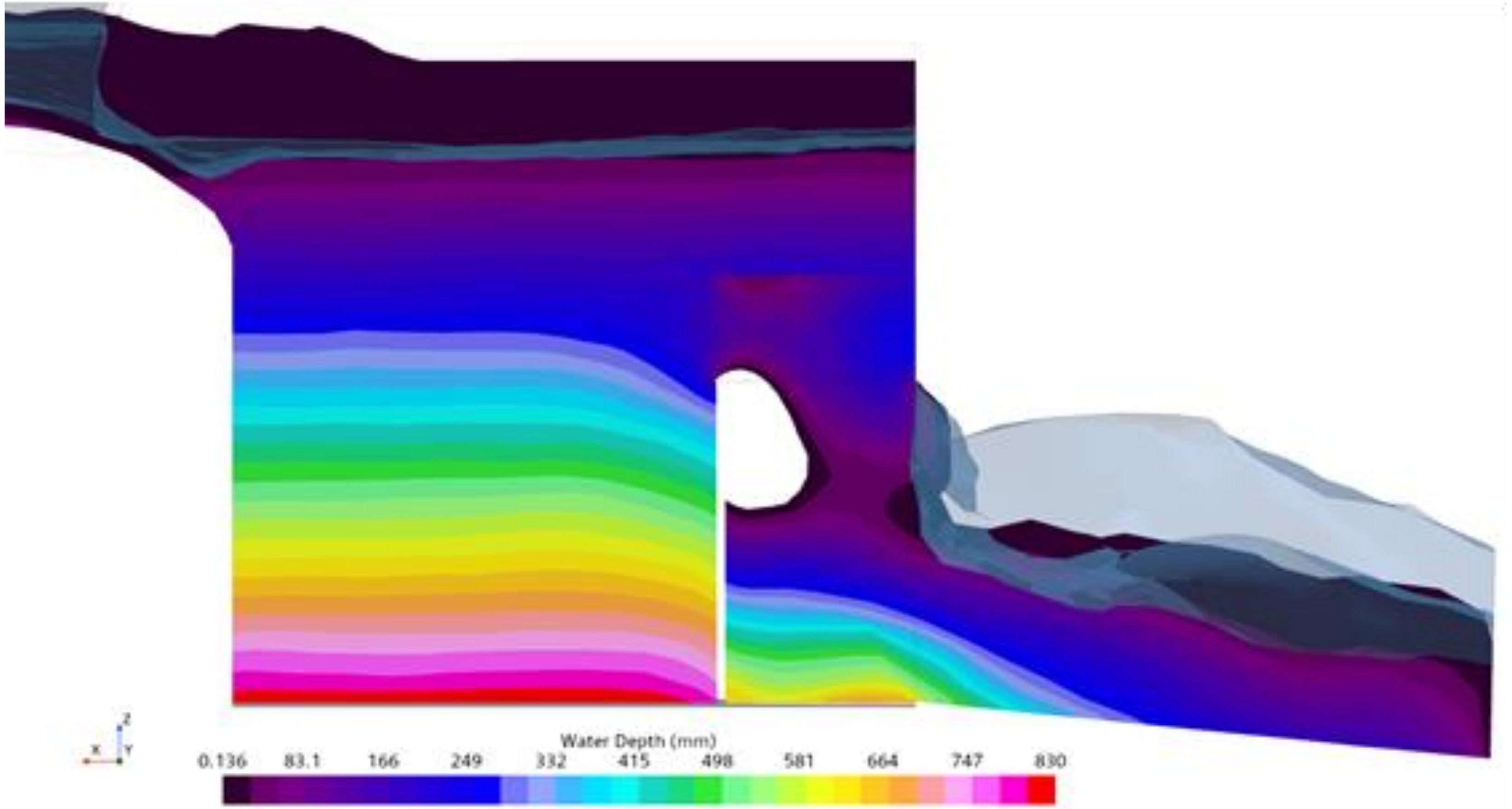
Results: CFD Bypass Capacity Connector Pipe Screen

- Conveying 5.3 CFS (150 LPS)
- Single orifice method calculated 6.14 CFS (173 LPS)



Results: Bypass Capacity

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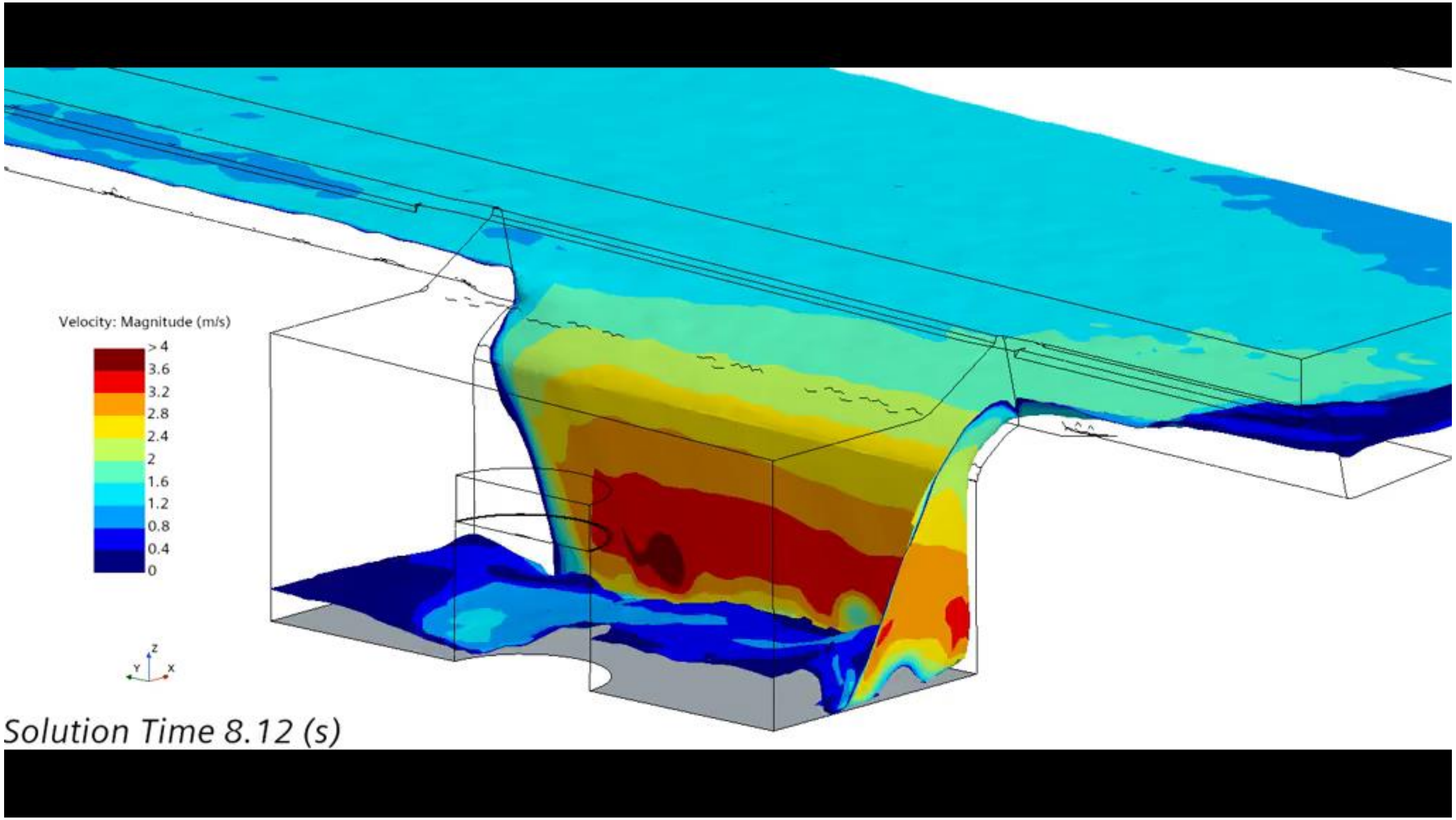
- Single orifice method calculated 6.14 CFS (173 LPS)
- Conveying 5.3CFS (150 LPS)



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Summary of Key Findings

- The LA County Report states:

"the screen coefficient, C_d, is unique to each orifice geometry and that orifice conditions for screen holes differ substantially from the conditions used to determine standard orifice coefficients"

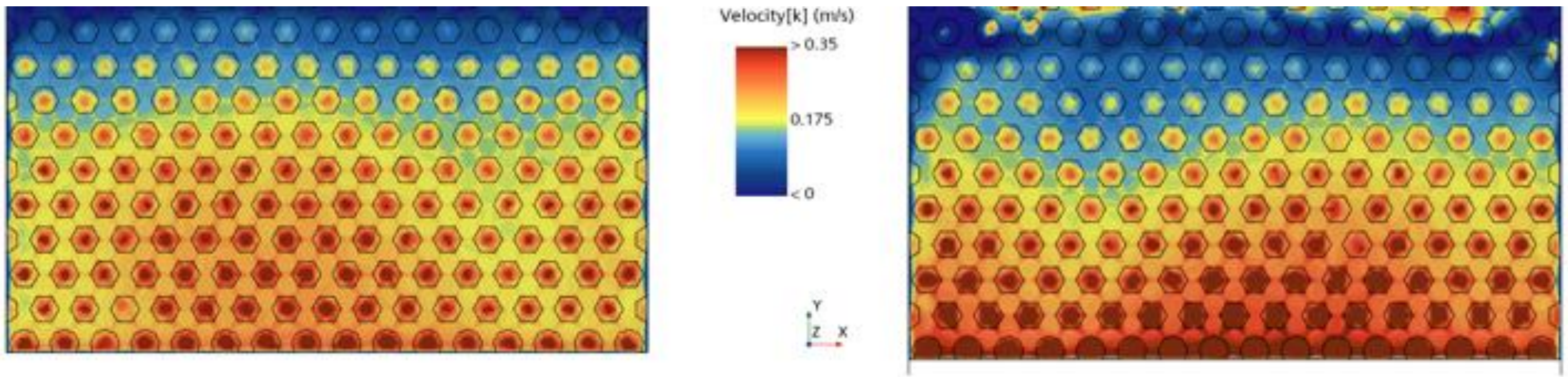
- The single orifice method is justified by empirical data for the CPS in that report
    - C_d of 0.53 the most conservative

- The industry has adopted the single orifice method with problematic assumption
    - C_d of 0.61 = overestimated screen capacity

Summary of Key Findings

- This study demonstrates basket flows can be overestimated by up to 250% using C_d of 0.61
- CPS tailwater conditions are difficult to calculate using the methods explored but tailwater is an important consideration
- Simplified methods are warranted BUT empirically derived C_d is required for better accuracy
- Bypass capacities can be largely reduced by air pockets induced by catch basin interactions and geometry
    - Consequences could be flooding

Tailwater Conditions | **Free Discharge Conditions**



Future Work

- The outcomes of this work are intended to be part of ASTM trash testing protocol to ensure full trash capture at the same time as flood mitigation

- Comparison of all the methods in the context of:

  - full-scale hydraulic testing
    - Basket in a 24” x 24” CB
    - pipe connector screen
  - full-scale hydraulic testing of bypass capacities
    - CFD validation.

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Thank you!

Questions?