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Modification of Folsom Dam Stilling Basin for Hydrodynamic Loading

Rick L Poeppelman, P.E. – USACE

Yunjing (Vicky) Zhang, P.E.
Peter J Hradilek, Ph.D., P.E., G.E.
HDR Engineering

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Overview

- Built in 1950s
- 340’ Conc.
- 5 operating gates
- 3 emergency gates
- Outlets
- Stilling basin
- Walls

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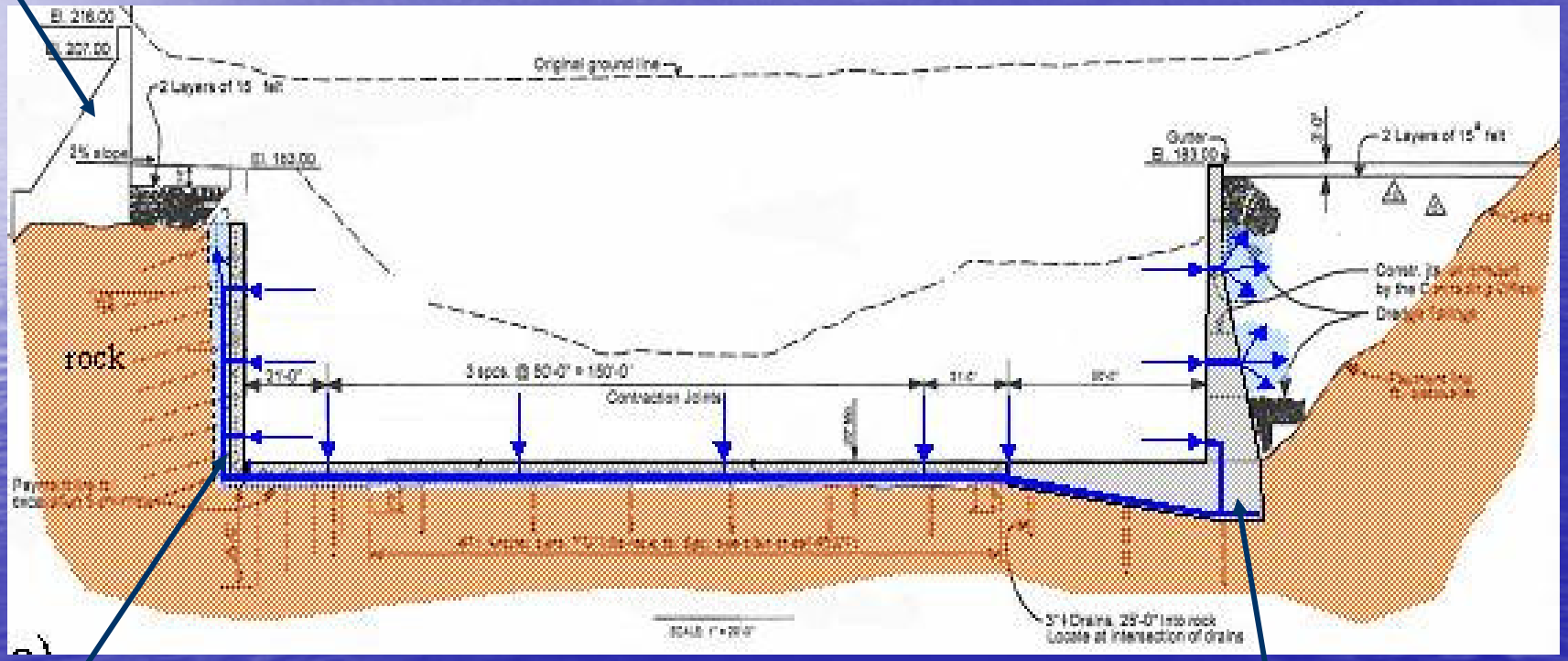
Introduction

- A multipurpose dam
- Reservoir capacity – 975,000 ac-ft
- Objective flood control release of 115,000 cfs

Transverse Cross-Section of Stilling Basin Geometry

Looking Upstream

Gravity Wall



Anchored Wall

L Wall

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Stilling Basin Floor

- 349’ long and 242’ wide, 5’ concrete slab
- #11 @ 5’ o.c, 7’ into rock
- Dental concrete to level slab

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Right Wall

- Hang-on type wall
- 372’ Long
- 43’ – 73’ tall
- #11 @5’ o.c, 25’ into rock
- Gravity Wall
- 164’ Long (total)
- 15’ – 32’ tall

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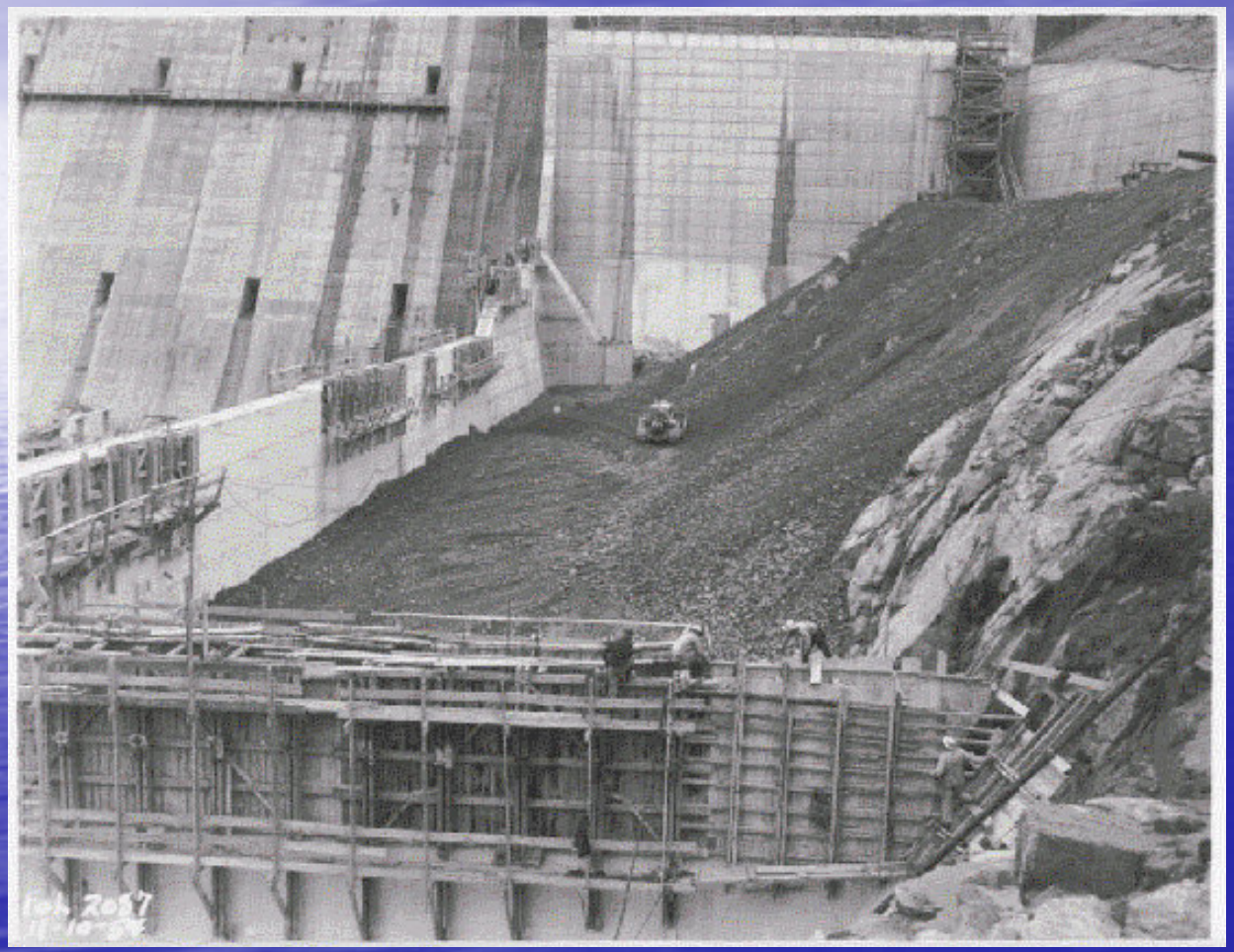
L - Wall



- Reinforced concrete L-type
- 372’ Long
- 76’ - 68’ tall
- Dredge tailings (cobbles)

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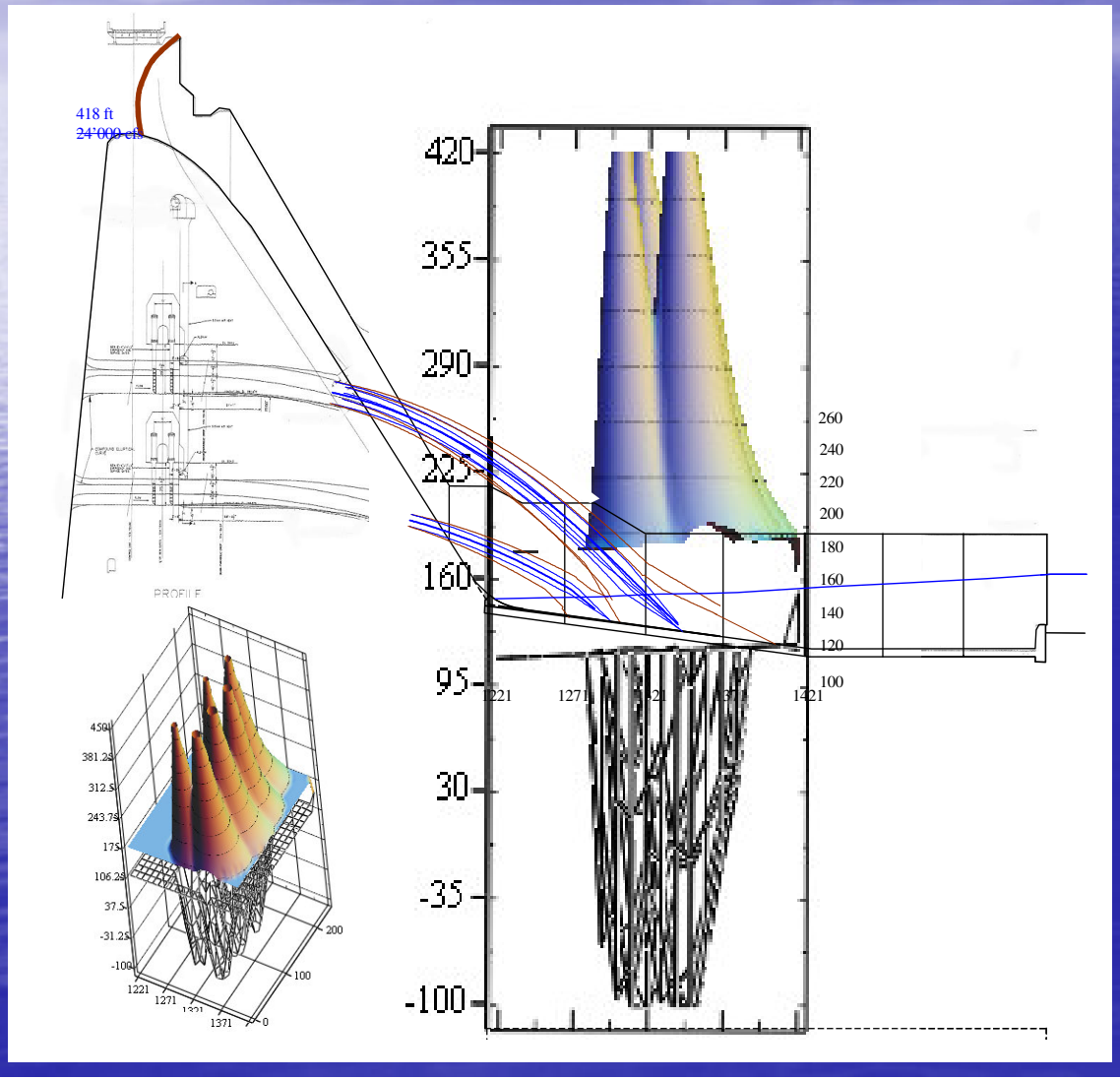
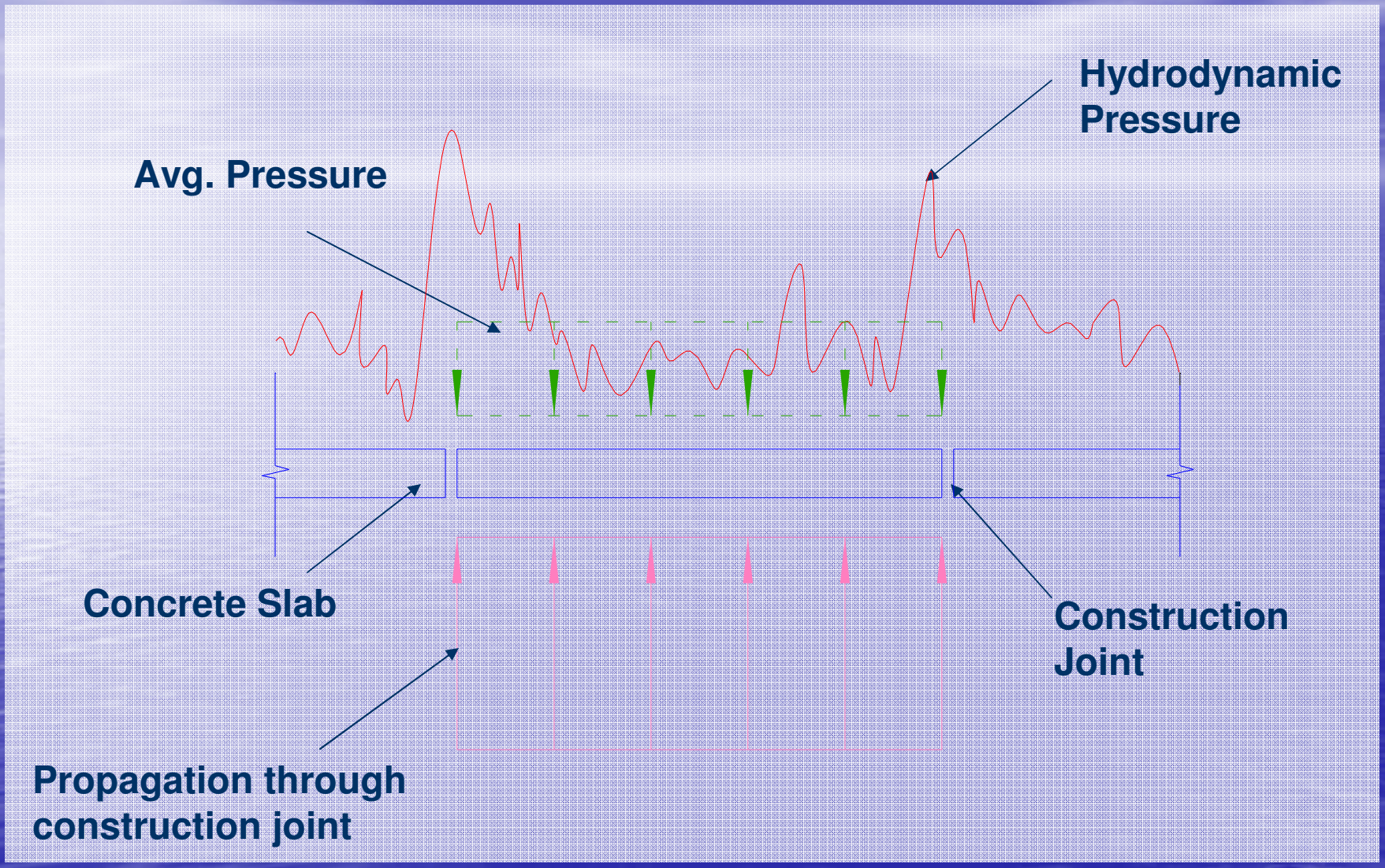
Design Concern - Extreme Dynamic Pressure



- **Failures** (Karnafuli and Malpaso Dams)
- **Background**
- **Propagation**
- **Numerical Model**
- **Physical Model**

Hydrodynamic Pressures



Dynamic pressure patterns on a concrete slab

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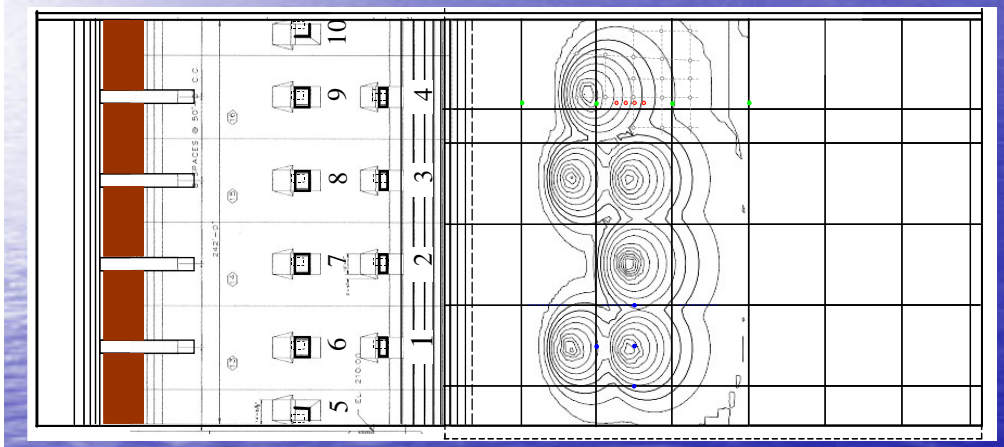
Extreme Dynamic Pressure
Probability



- Once in every 10 yrs (Continuous operation)
- Once in every 146,000 yrs (Real Life)
- Folsom dam – 1 in 3.75 days (continuous)
- Return periods of 150 years
- Spillway and outlet flows

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Physical Model

USBR - Denver Hydraulic Laboratory

Spillway Flows / Outlet Flows

Drain Modifications

Dewatering – Oct 10,2004

- Modify the drains to mitigate the propagation of hydrodynamic pressures into the drain system

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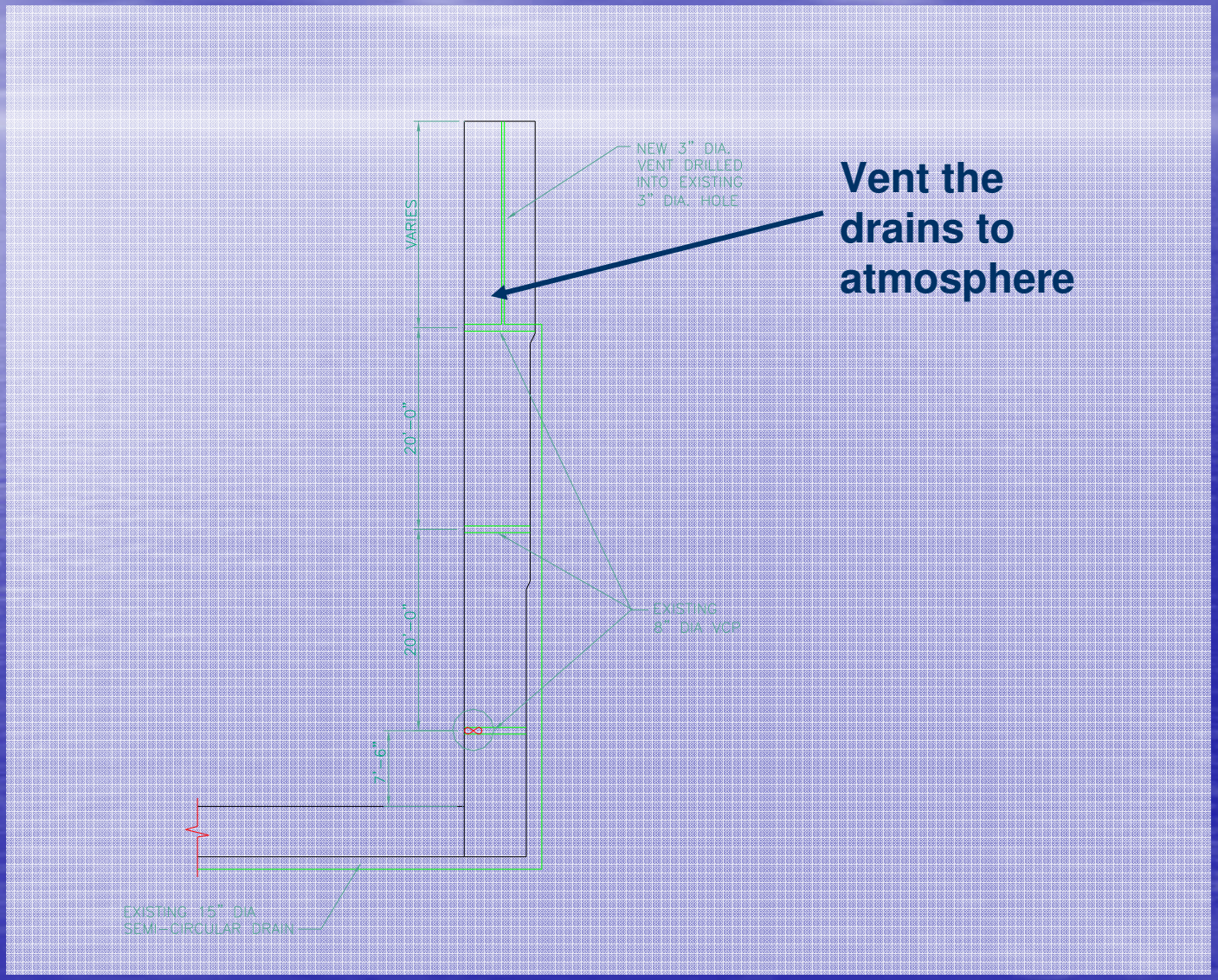
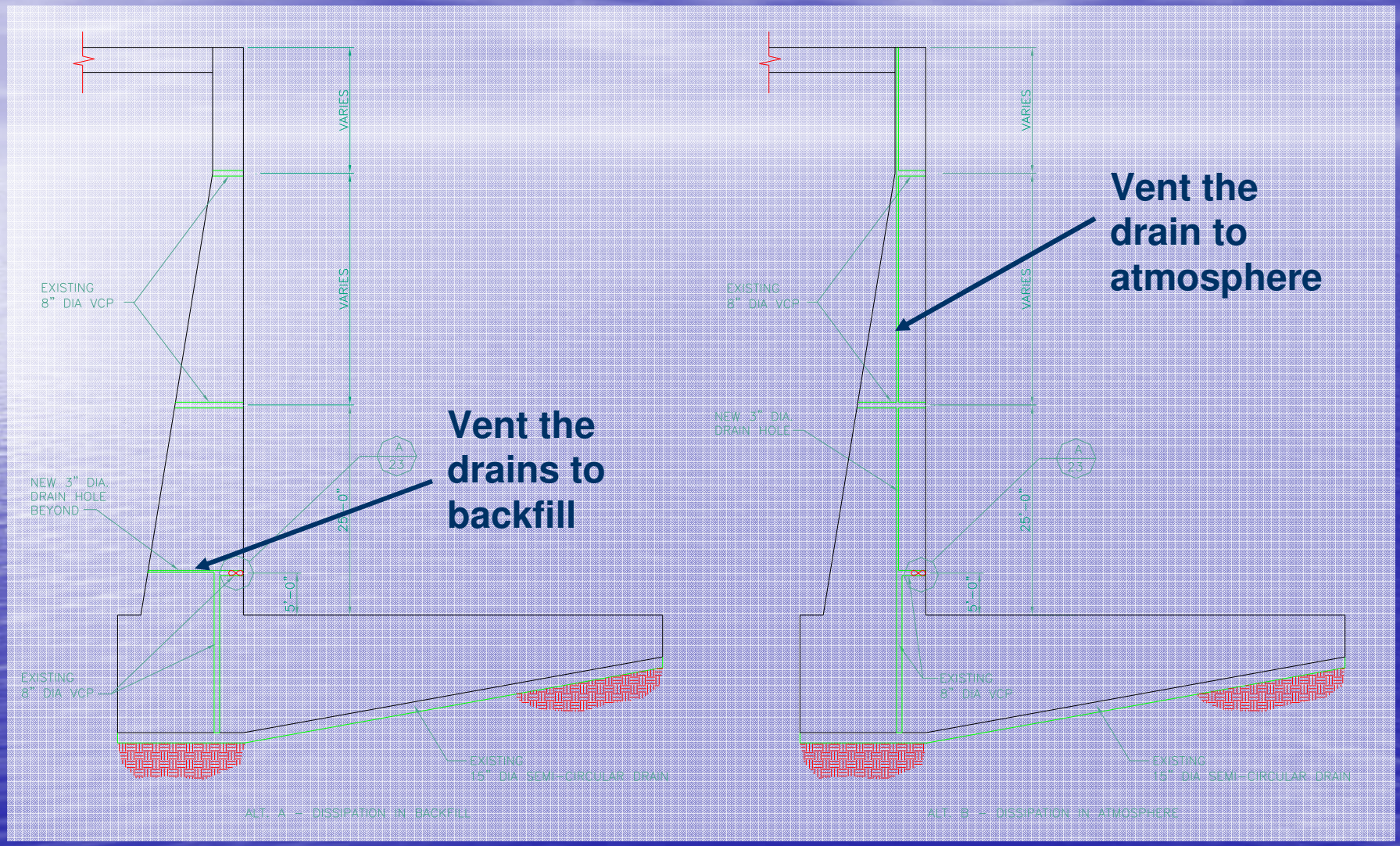
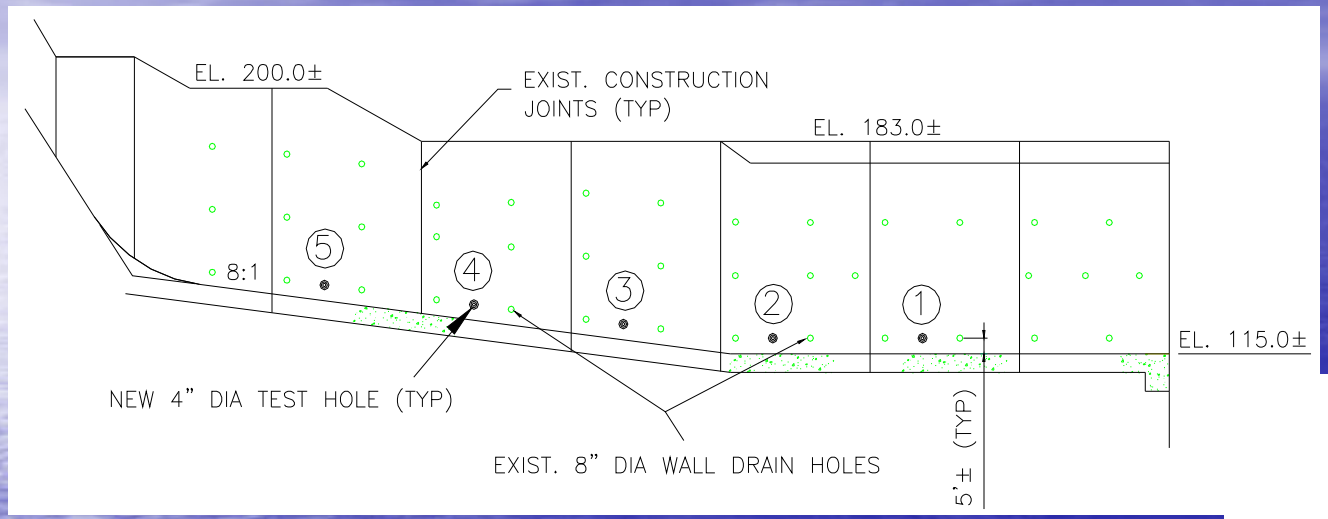
Right Wall Drainage



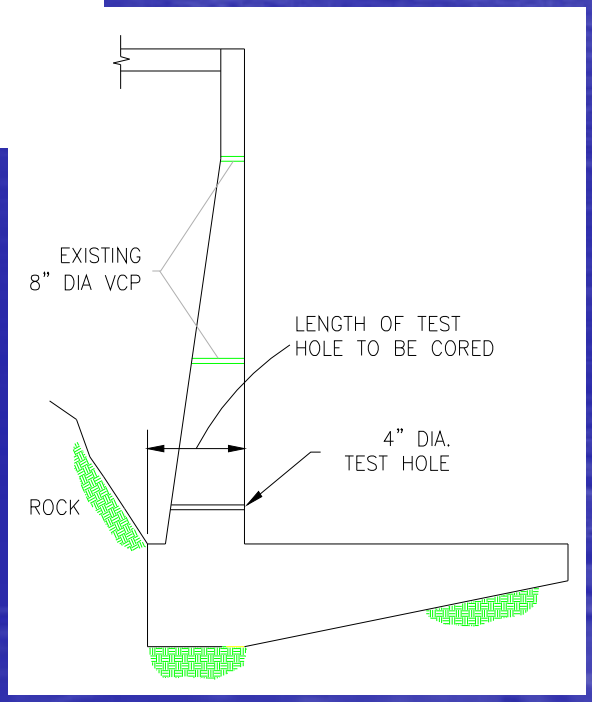
L-Wall Drainage Alternatives



L-Wall Backfill Pressure Dissipation Test



L-Wall Section



L - Wall Test Hole

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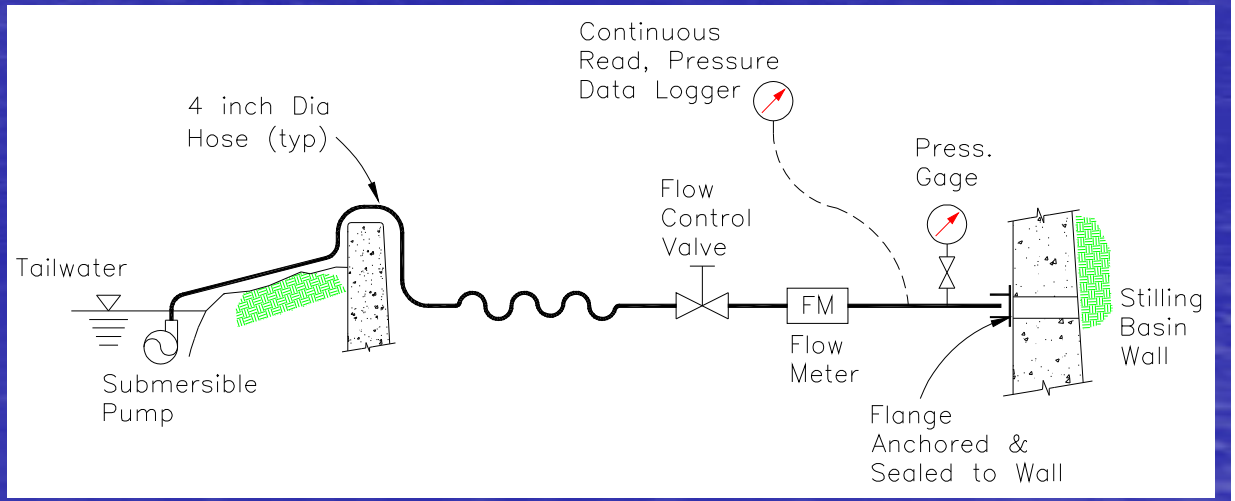
L-Wall Backfill Pressure Dissipation Test Equipments

- **Pressure**
- **Flow rate**
- **Duration of pump**



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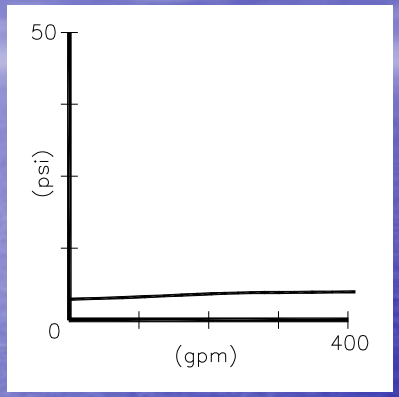
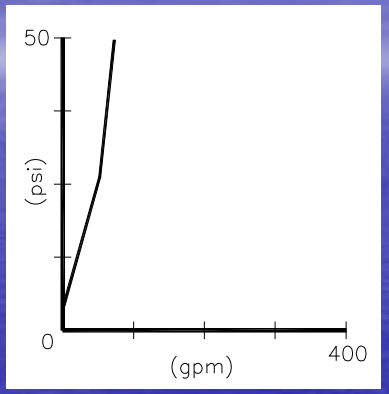
L-Wall Backfill Pressure Dissipation Test

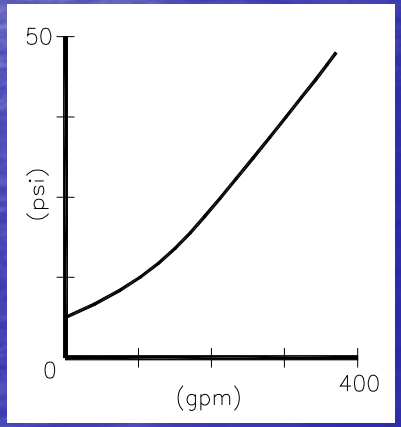
Potential Outcomes



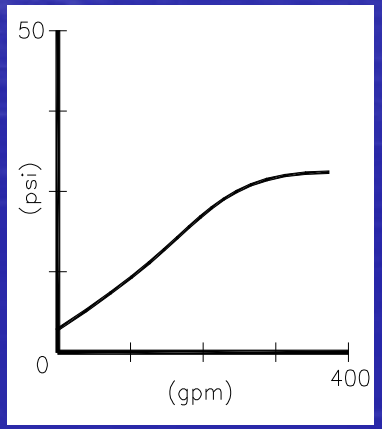
High flow v. low pressure graph



High pressure v. low flow graph



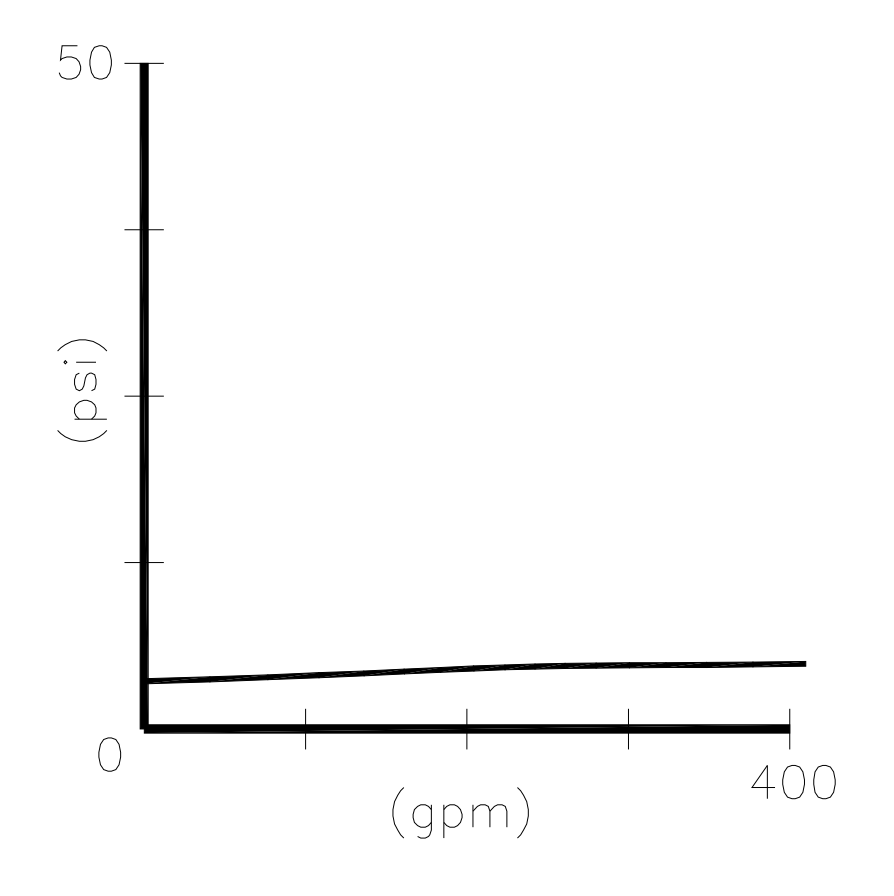
Linear flow v. pressure graph



Stabilized flow v. pressure graph

L-Wall Backfill Pressure Dissipation Test

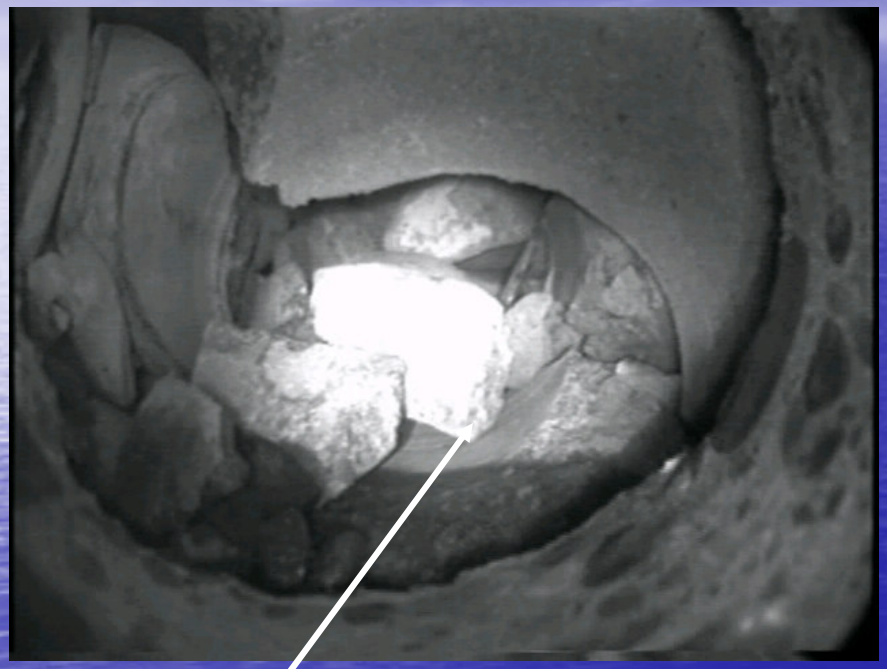
Actual Outcome



High flow v. low pressure graph

L-Wall Backfill Pressure Dissipation Test

Backfill from Hole Video Survey



Dredge Tailings (Cobble)

Stilling Basin Rehabilitation
Loading Cases

- Maintenance condition (stilling basin empty)
- Rapid closure of gates
- Operating case 1A (design outlet flows)
- Operating case 1B (design spillway flows)
- OBE (Operational Basis Earthquake) loading
- MCE (Maximum Credible Earthquake) loading

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Stilling Basin Rehabilitation
Criteria

- USACE criteria for hydraulic structures
  - ✓1.65 – Hydraulic load factor for tension
  - ✓1.70 – Single Load factor (Dead and live load)
  - ✓0.90 – Strength design factor for tension
  - ✓0.75 – Short duration/Low probability loading condition
- Working stress of 32% of ultimate anchor strength

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Stilling Basin Rehabilitation

- Hydrodynamic and hydrostatic loading cases
- Earthquake loading:
  - OBE: a_h= 0.07g and a_v=0.02g
  - MCE: a_h= 0.25g and a_v=0.08g
- Partial Blocks
  - Horizontal faults in the existing rock
- Gravity Wall Extensions
  - 25’ to 51’ long
  - 10’ spacing at U/S, 5’ spacing at D/S
  - Lock off loads: 12 – 71 kips

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Stilling Basin Rehabilitation
Tie-Downs and Tie-Backs

- Hydrodynamic pressure controls tie-down/tie-back strength
- Hydrostatic pressure controls length

- Tie-down - Prestressed 1-3/8" anchor bar 25’ long, 5’ (or 10’) on center
- Tie-back - Prestressed 1-3/8" anchor bar, 25’ – 43’ long, 5’ on center, lock-off load: 53-249 kips

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Conclusions

- Both hydrostatic and hydrodynamic design should be included
- Drain modifications will mitigate the extreme hydrodynamic pressure

Questions???