MANAGING INCREASED DAM SAFETY RISK DURING RECONSTRUCTION

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ASDSO

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Introduction and Objectives

- Identification of dam safety risks inherent in dam reconstruction
- Risk evaluation process

  (Construction Potential Failure Mode Analysis)
- Risk management strategies
  - Design-phase risk reduction measures
  - Construction-phase risk reduction measures
- Emergency response planning

Construction Risk Categories

- Categories of Risk
  - Technical Risks (i.e. site conditions differing from design)
  - Contracting and Construction Risks (i.e. schedule delays, cost risks, environmental impacts)
  - Dam Safety Risks
- This webinar will focus on dam safety risks during construction

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Increased Dam Safety Risk During Construction

- Dams are inherently more vulnerable during construction
  - Reduced cross section
  - Spillway or outlet out of service
  - New loading
- Reservoir may not be able to be fully drained
  - Water demand
  - Hydropower
  - Diversion requirements

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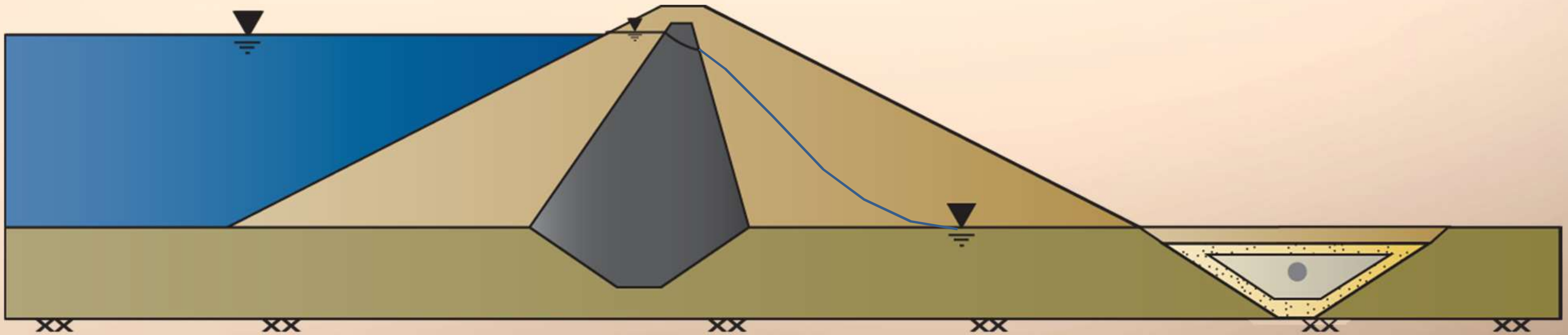
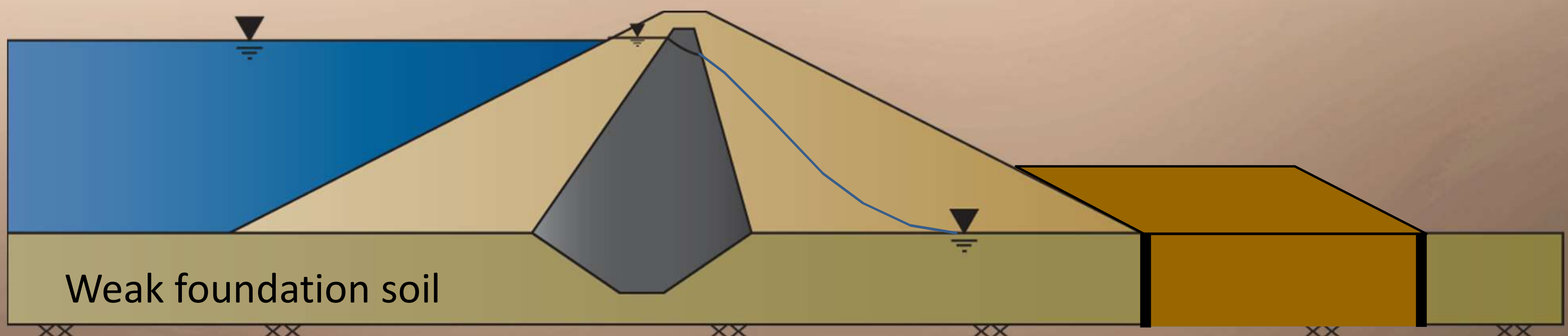
Toe Excavations

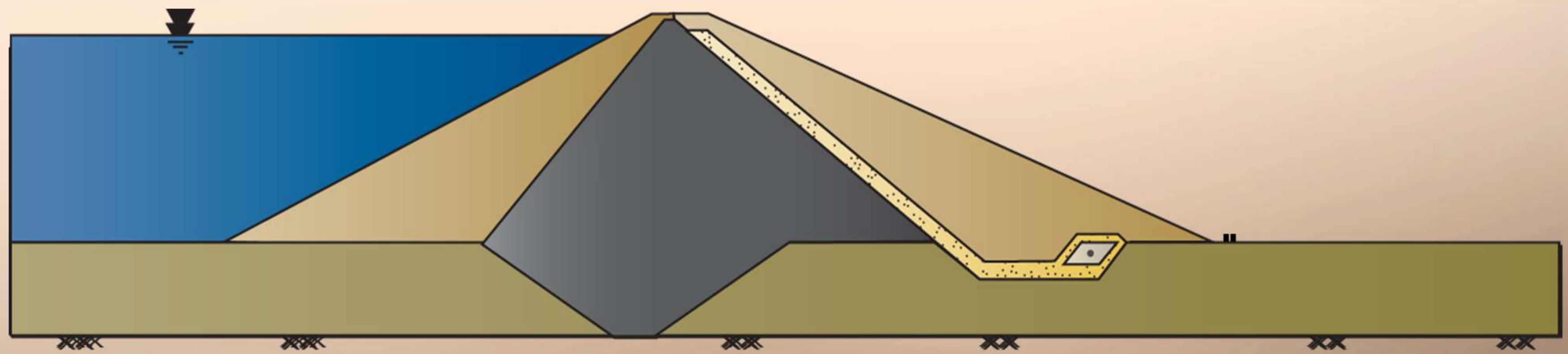


Drainage



Sloped/Shored Shear Key

Embankment Excavation for Chimney Filter



Downstream Excavations

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Downstream Excavations

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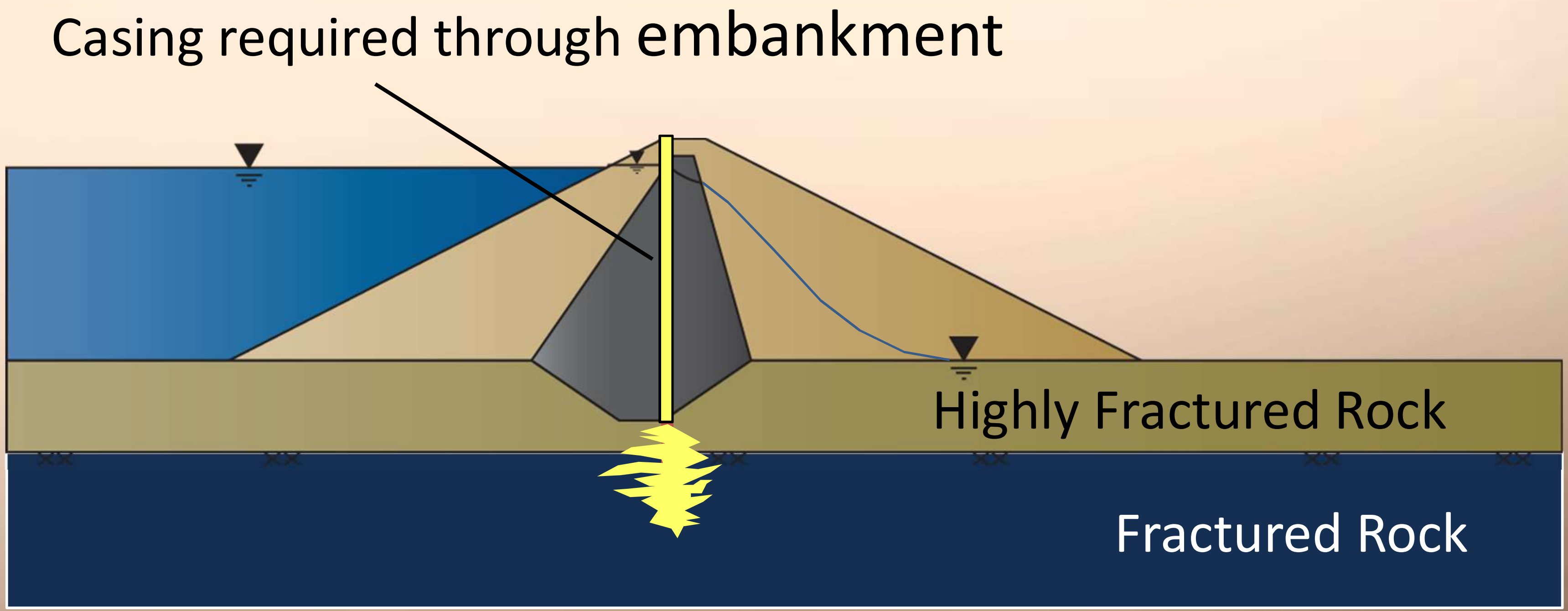
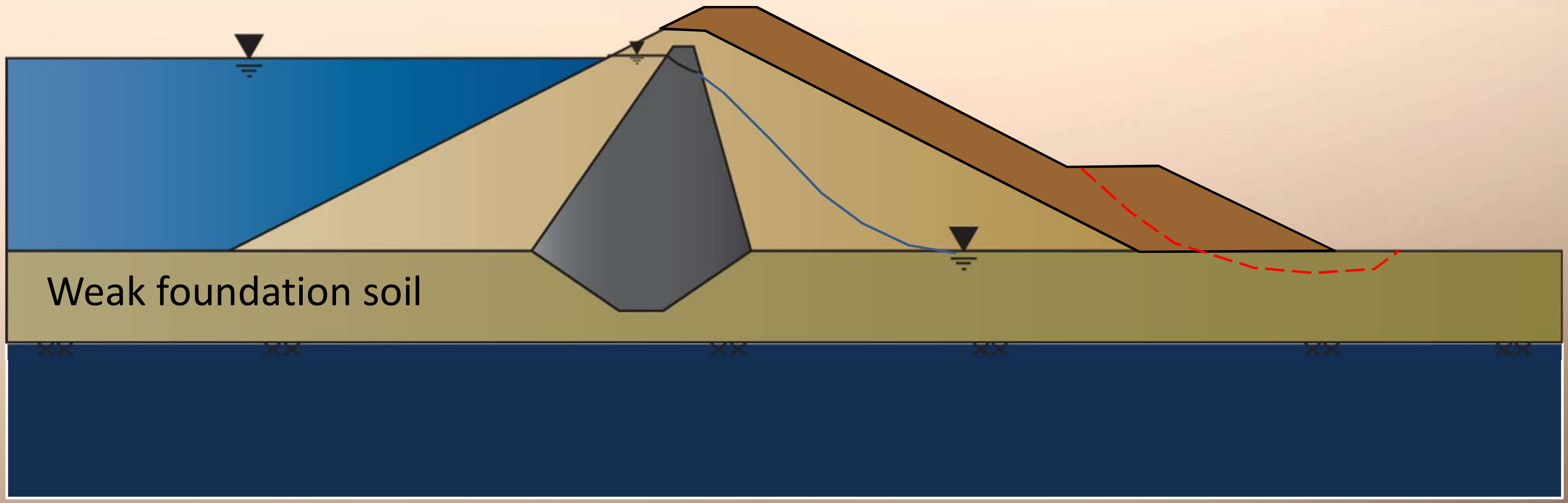
Grouting



Grouting in soils is NOT generally recommended due to potential hydraulic fracturing issues; caution needs to be exercised near top of rock and in weathered rock.

New Fill Placement



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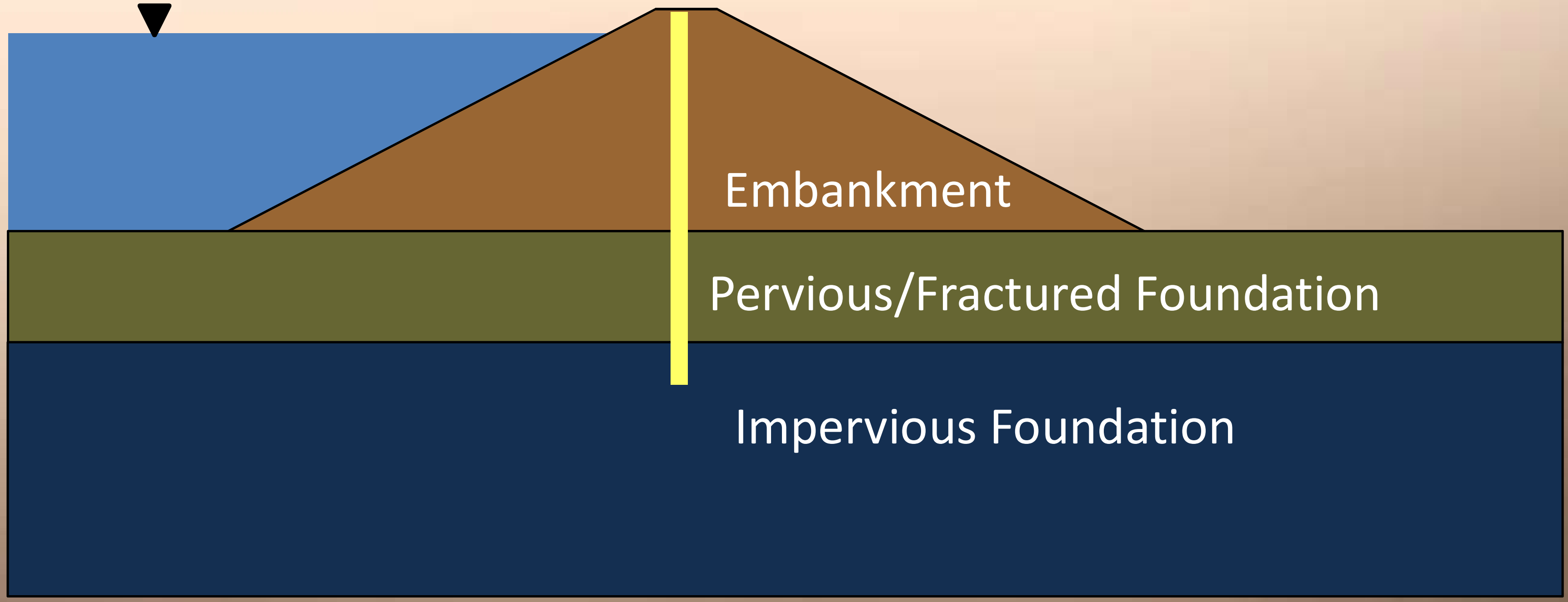
Cutoff Wall Construction: Slurry-Supported Excavation



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Cutoff Wall Construction

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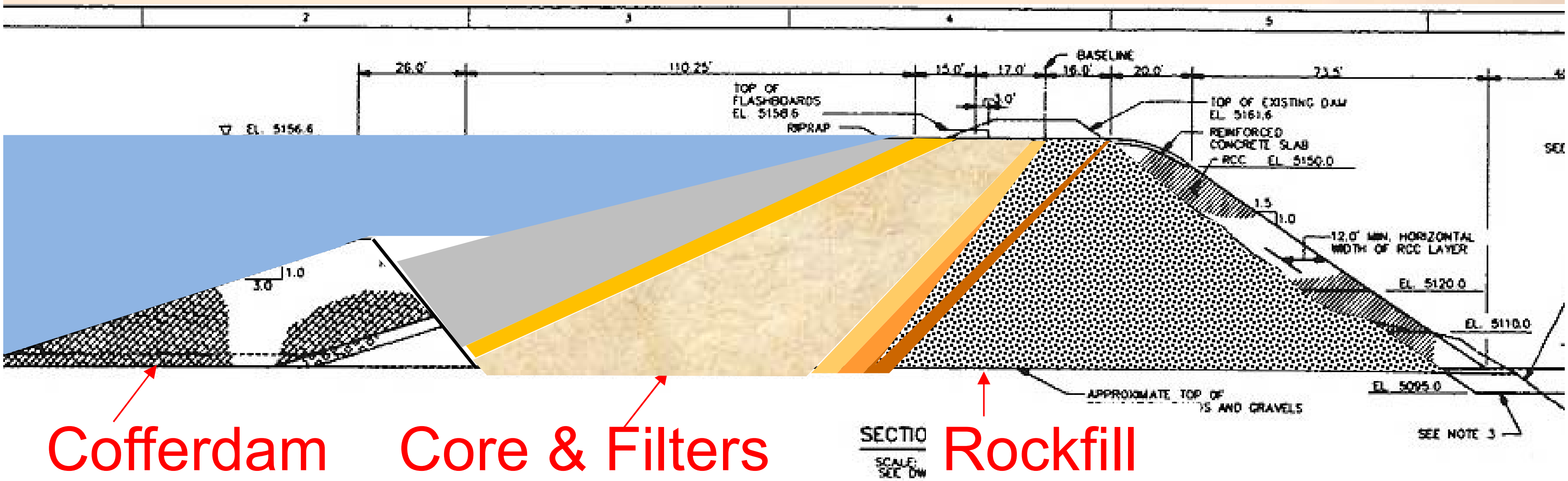
Cutoff Wall Construction

Upstream Excavation behind Cofferdam



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Upstream Excavation behind Cofferdam

Replacement of Outlet Conduit

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Spillway Repair/Replacement

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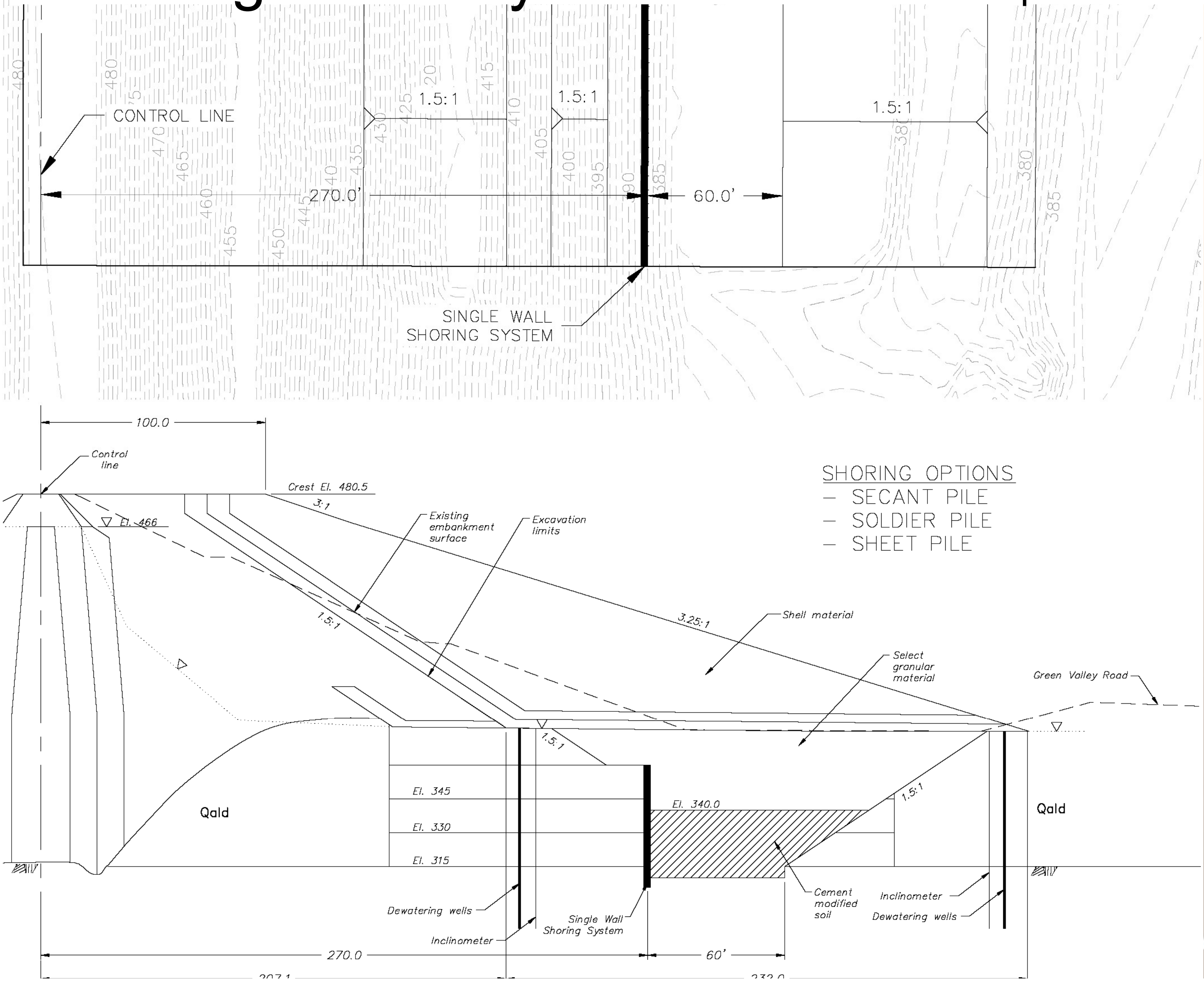
CONSTRUCTION RISK MANAGEMENT STARTING DURING DESIGN PHASE

Alternatives Evaluation

- Risk management starts at alternatives phase

- Alternative evaluation factors:
  – Technical criteria, risk reduction, cost, sensitivity to unknowns, precedent, environ and operational impacts, constructability, ….& construction risk

Single Wall System - Alternative 1A – Upstream Wall



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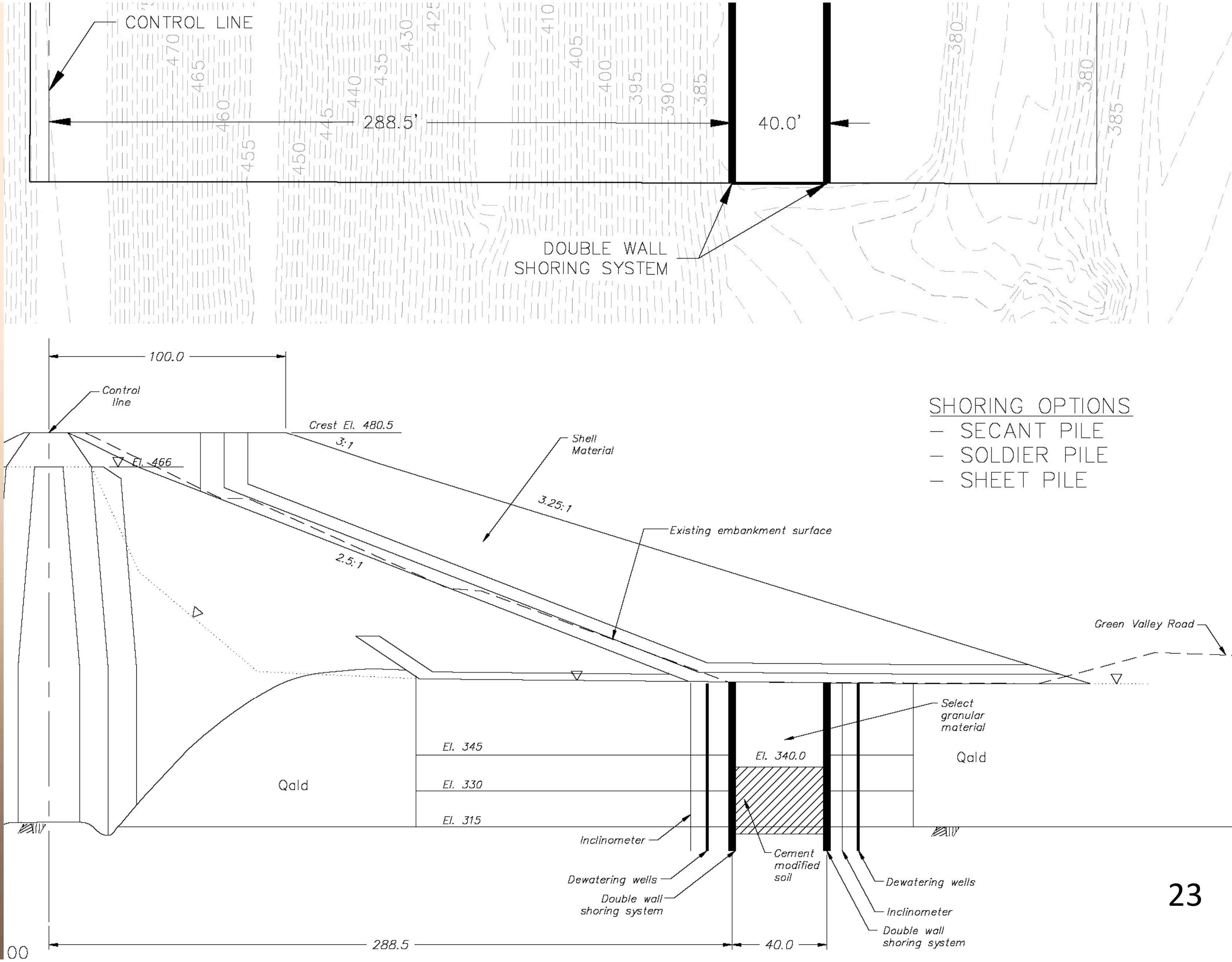
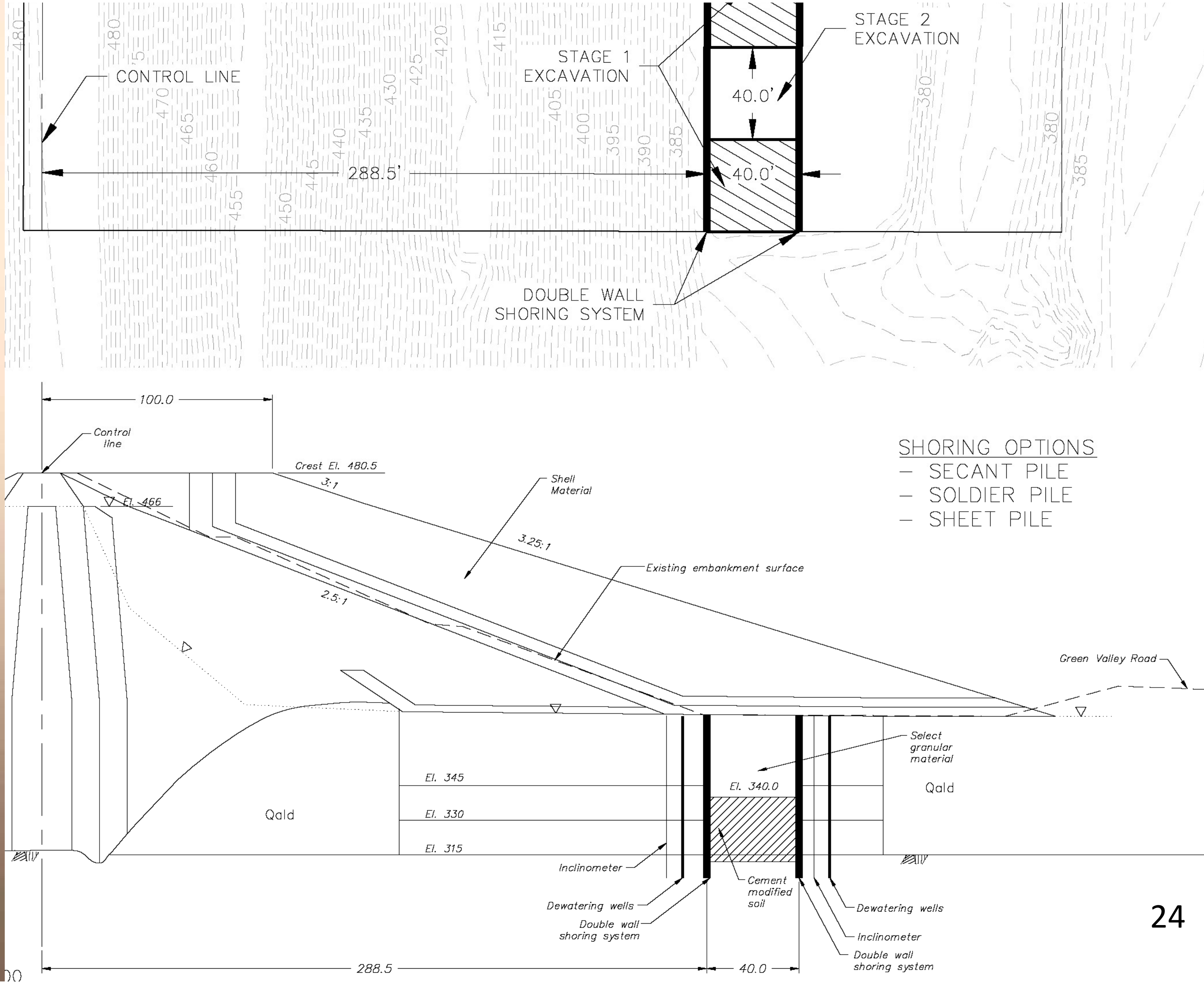
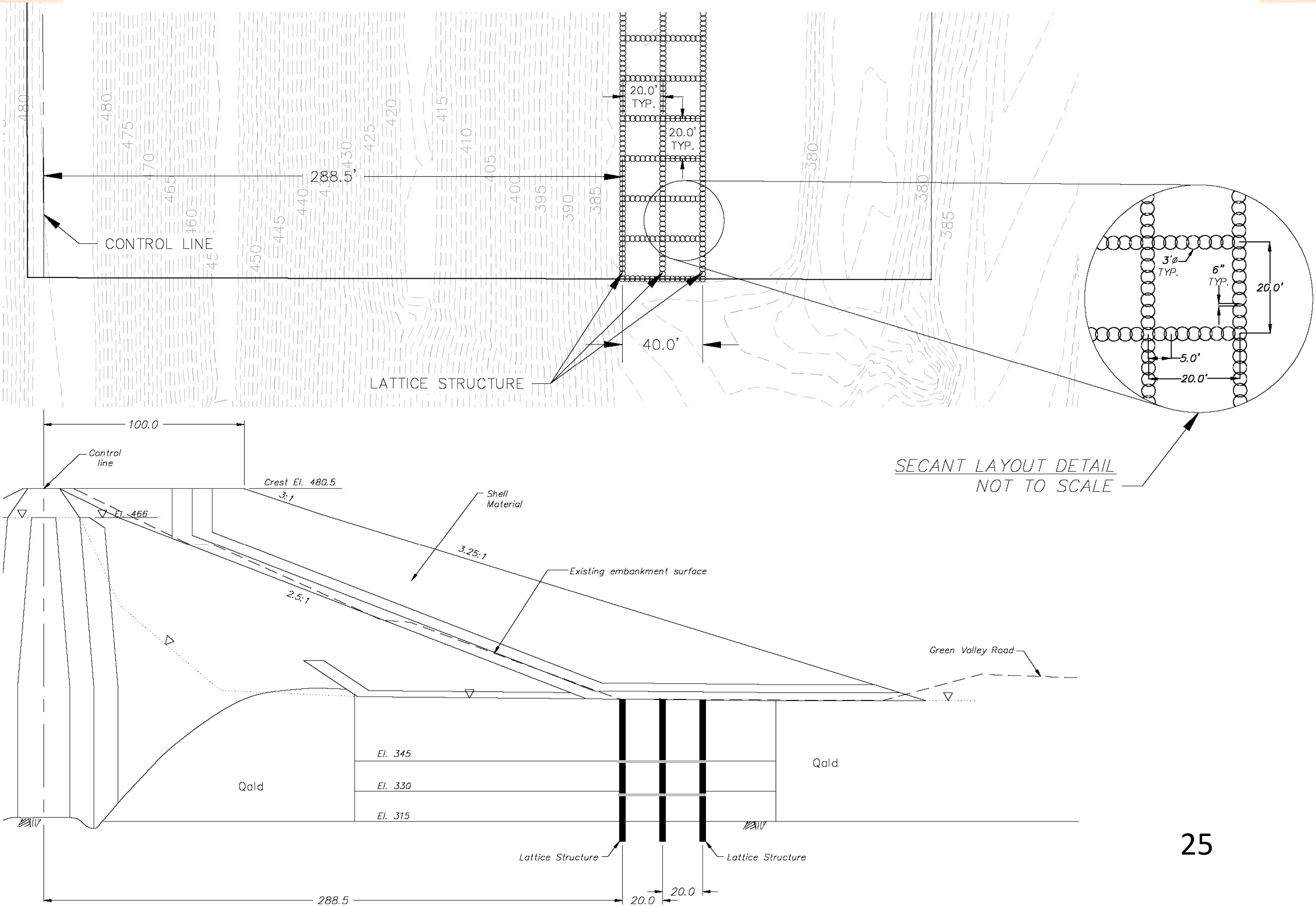
Double Wall System – Alternative 2A Full Height Shoring



Alternative 3 - Cellular Excavation



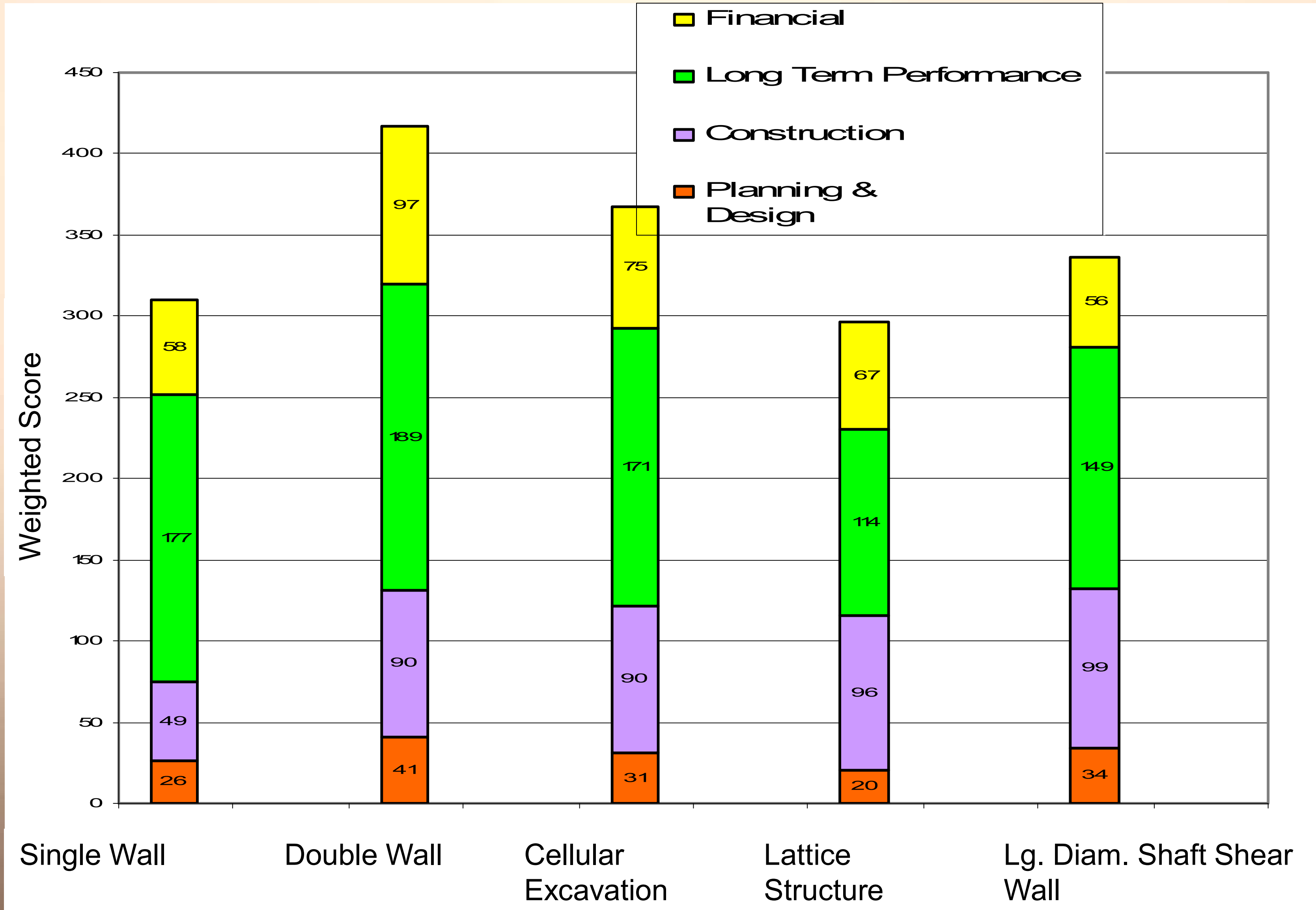
Alternative 4A - Lattice Structure



ALTERNATIVES EVALUATION MATRIX

Group Weighting (%)		Selection criteria	Criteria Weighting	Alt. 1 Raw Score	Alt. 1 Weighted Score	Alt. 2 Raw Score	Alt. 2 Weighted Score	Alt. 3 Raw Score	Alt. 3 Weighted Score	Alt. 4 Raw Score
15%	Planning & Design	Vulnerability to Unknowns	3	4	12	4	12	3	9	5
		Design Robustness	2	3	6	5	10	5	10	3
		Quantum of Risk Reduction	4	4	16	5	20	2	8	1
		Precedent	4	4	16	3	12	3	12	2
		Weighted Sub-Total	**14**	**58**		**61**		**45**		**39**
10%	Operation Impacts	Operation Impact	4	1	4	1	4	3	12	5
		Environmental	1	1	1	1	1	5	5	5
		Weighted Sub-Total	**8**	**10**		**10**		**36**		**50**
20%	Construction	Construction Risk	4	2	8	2	8	4	16	4
		Constructability	3	3	9	2	6	2	6	4
		Required contractor expertise	2	3	6	2	4	3	6	3
		QA/QC effectiveness	3	3	9	4	12	4	12	3
		Schedule Duration	4	3	12	2	8	4	16	5
		Weighted Sub-Total	**18**	**53**		**47**		**69**		**77**
25%	Long Term Performance	Long-term performance	4	4	16	5	20	2	8	1
		Risk of Defects	3	4	12	5	15	2	6	1
		Maintenance Requirements	2	4	8	4	8	2	4	1
		Weighted Sub-Total	**16**	**98**		**122**		**39**		**25**
30%	Financial	Contractual risk / Disputes	2	2	4	2	4	3	6	4
		Risk to Unknowns	2	2	4	2	4	1	2	3
		Construction Cost	4	4	16	3	12	2	8	5
		Weighted Sub-Total	**14**	**103**		**81**		**73**		**105**
100%		**Weighted Grand Totals**		**322**		**321**		**262**		**295**

Selection Matrix



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Alternatives Evaluation

- Features with a large degree of uncertainty of actual site conditions => pre-set design options to cover range of potential conditions.
  - Support/shoring for various ground conditions
  - Different potential excavation depths to reach "competent" criteria

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Risk Sharing
Engineer vs Contractor Designs

- Cofferdam and Diversion Design
  - Size, type, location and dimensions of cofferdam
  - Pump capacity and pipe sizes
- Dewatering Design
  - Type of dewatering, locations and capacity
- Excavation and Shoring Design
  - Selection and design (e.g. sheetpile, soil nails, soldier pile and lagging, etc.)
- Sequence of Construction

Risk Sharing
Engineer vs Contractor Designs

- Engineer provide Baseline Documents
  - Interpreted geologic and hydrologic conditions to be assumed in contractor design
- Minimum flood protection requirements
- Establish seasonal or reservoir pool restrictions for certain work tasks
- Submittal Reviews

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Geotechnical Investigation

- Invest money in geotechnical studies during the design to reduce risk of unexpected conditions during construction
  - cofferdam, grouting, cutoff design
- Consider range of potential conditions and be prepared with Contingency Designs
  - Excavations need to be deeper than anticipated,
  - Seepage is greater than estimated
  - Materials weaker than expected in excavation stability analyses

Hydrological Investigation

- Determine probabilistic analysis criteria (i.e. Should the coffer dam be designed for the 5-year, 10-year, or 25-year storm?)
- Define and share flood risk
- Recognize uncertainty

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Construction Risk Management during Design Phase

- Engineers should include contractors in the design phase for constructability reviews of the design.
- Include a third-party technical review board at the design stage to limit the chances of dealing with design issues/errors during construction
- Engage the regulator early in design
  - Improve their background understanding
  - Gain their insight
  - Facilitates design changes in real time during construction

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Constructability Reviews

- Reduces the number of change orders during construction
- A design with better constructability is less likely to run into safety issues during construction
- Gives contractor an opportunity to voice concerns about design aspects posing safety risks during construction

Risk Register

- What is a Risk Register?
  – A tool to help the project team document and proactively manage risks
  – Documents risks identified before and during the life of the project
  – Classifies likelihood of a particular risk occurring
  – Assesses the impact to the project if the risk comes to fruition
  – Assigns an "owner" to each risk
  – Proposes actions to mitigate a risk
  – Can be a formal document or informal risk evaluation process

Risk Register

- How to fully utilize the Risk Register
  - Prepare during the planning process
  - Share with all responsible parties
  - Treat as a "living document" through design and construction
  - Use to monitor and coordinate risk management strategies
  - Can be used to update policy makers on the safe progress of a project

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Risk Register

- The Risk Register is used during the Design Phase to;
  - Make appropriate design changes,
  - Enhance construction contract specifications,
  - Set a realistic schedule,
  - Liquidate damages for the construction contract

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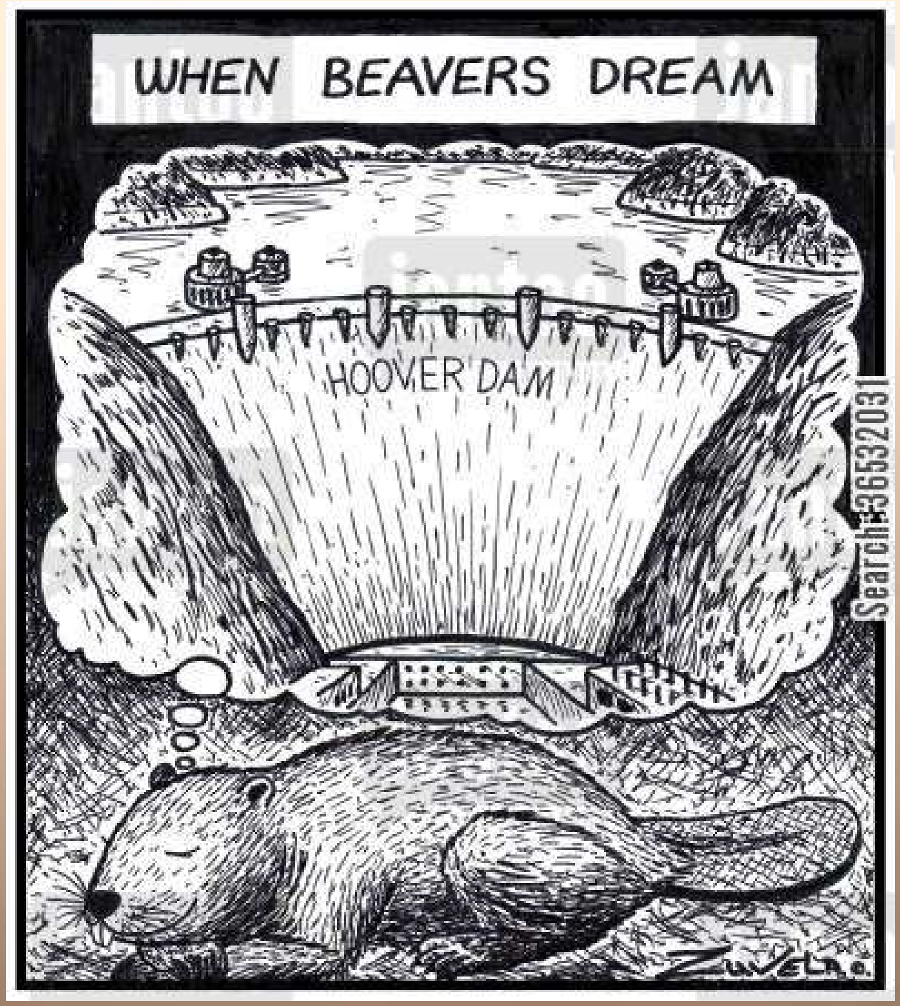
Questions?



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DAM SAFETY RISK MANAGEMENT

CONSTRUCTION PFMS AND EXAMPLE RISK REDUCTION

Construction Risk Identification

- *Identify* and *evaluate* risks during (1) design phase and (2) after contractor selected
- Schedule a formal project team workshop
  - Identify risks from several sources
  - Include lessons learned from similar projects
  - Project team experience
  - Technical expert experience
  - Current construction trends
  - Impacts to the current operation of the facility

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Construction Potential Failure Mode Analysis (PFMA)

- Identify work activities that induce a dam safety risk
- Consider series of events that *could* happen that would lead to a dam safety incident
- Identify site-specific risk factors that make the PFM more or less likely to occur
- Identify risk reduction measures for both design requirements and construction means/methods
  - Select which measures to be specified in contract documents and which to be left to contractor

Downstream Slope/Toe Excavation

Example Risk Factors / Initiators
Weak/saturated foundation or embankment soils
Unexpected weak seams or seepage paths
Required excavation is deeper than expected
Earthquake
Failure of dewatering system
Duration of excavated condition: increased risk of flood/earthquake, soil creep

Each of these may have their own Failure Event Tree

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Downstream Slope/Toe Excavation

Example: Static (sunny-day) slope stability failure

- Reservoir elevation
  - Dewatering fails
    - Phreatic level rises
      - Detection/Intervention Unsuccessful
        - Slope instability
          - Embankment deforms>freeboard
            - Reservoir is released

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Downstream Slope/Toe Excavation

Example: Seismic slope stability failure

- Reservoir elevation
  - Earthquake occurs
    - Strength loss in foundation soils occur
      - Slope instability
        - Embankment deforms>freeboard
          - Reservoir is released

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Downstream Slope/Toe Excavation

Example: Internal erosion of Embankment

- Increased gradient (dewatering, excavation decreasing seepage length, flood pool) initiates erosion
  - Unfiltered exit
    - Roof forms
      - Upstream zone fails to fill crack
        - Upstream zone fails to limit flows
          - Detection/Intervention Unsuccessful
            - Embankment breaches
              - Reservoir is released

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Downstream Slope/Toe Excavation

Example Risk Reduction
Sufficient geotechnical data to design depth/cutslope and expected seepage
Monitoring: Inclinometers, Piezometers, Reflective survey targets, automation, 24/7 monitoring ability
Advance (early) dewatering. Dewater embankment & liquefiable materials
Backup power (generators) and pumps
Excavation Sequence: Deepest excavation during lowest reservoir, limitation of open excavation duration/length
Stockpiled filter/drain material
Construction-case analyses; Risk-based evaluation for construction design seismic event; range of conditions

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Case History – Seismic Upgrade Downstream Shear Key Excavation

- 160-ft-tall zoned earthfill dam
- Founded on up to 60 ft of liquefiable soils
- Unacceptable deformations under design seismic event
- Water use requirements limited achievable reservoir drawdown

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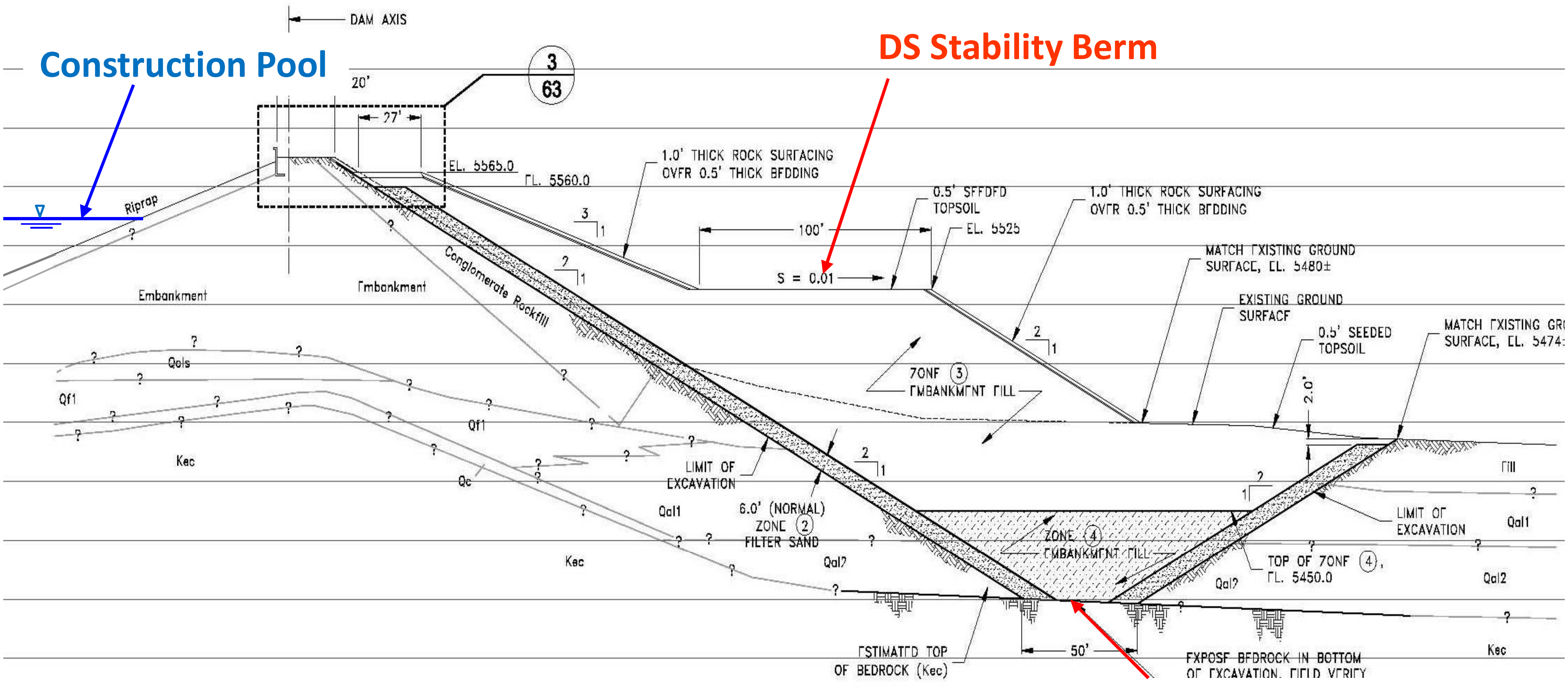
Case History – Seismic Upgrade Downstream Shear Key Excavation

- Alternatives analyses led to selection of preferred alternative:
  - Crest raise
  - 60-ft deep excavation at downstream toe for removal and replacement of fndn soils (downstream shear key)
  - Upstream & downstream stability berms
  - Full-height downstream chimney filter

Case History – Seismic Upgrade Downstream Shear Key Excavation



MODIFIED EMBANKMENT SECTION F-F' (58)

DAM STA. 3+00

0 15 30 60 90

SCALE IN FEET

Case History – Seismic Upgrade Downstream Shear Key Excavation

Excavation needed to be deeper than expected

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Case History – Seismic Upgrade Downstream Shear Key Excavation

- Risk Reduction Approach
  - Construction risk analysis
  - Additional instrumentation
    - Inclinometers read daily
    - Piezometers read daily
  - Excavation depth restrictions based on reservoir level

Case History – Seismic Upgrade Downstream Shear Key Excavation

- Risk Reduction Approach
  - Advance Dewatering
    - Ensure entire foundation and shell dewatered
    - Wells operated about a year prior to excavation
    - Allowed shear key excavation completed in 1 season.
    - Protected against liquefaction if an EQ occurred during construction
    - Increased gradient across cutoff trench
    - System modifications required after installation due to improved hydrogeologic understanding -> could have delayed construction

Case History – Seismic Upgrade Downstream Shear Key Excavation

- Risk Reduction Approach
  - Stockpiled filter/drain material
  - Backup power (generators) in case of power outage
  - Review of Contractor means and methods

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Foundation Grouting Through Emb

Injection water should also be considered

Example Risk Factors / Initiators
Improper isolation or verification of injection point leading to inadvertent grouting of embankment or fndn
Improper control of grout pressure/volume results in hydraulic fracturing leading to internal erosion or elevated pore pressures and instability
Windows or inadequately grouted zones leads to concentrated seepage
Multiple open grout holes connect seepage pathway
Grout flows downstream, clogging drains, blocking seepage exits and causes excessive uplift, high water pressures, and instability

Foundation Grouting Through Emb

Example: Internal erosion of Embankment due to Hydraulic Fracture

- Inadvertent grouting of embankment fractures fill
  - Gradient initiates erosion through fracture
    - Unfiltered exit
      - Roof forms
        - Upstream zone fails to fill crack
          - Intervention fails
            - Breach occurs

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Foundation Grouting Through Emb

Example Risk Reduction
Additional instrumentation: Inclinometers, Piezometers, Survey Prisms
Casings through embankment
MPSP (Multiple packer sleeved pipe) for target grouting
Grout mobility and pressure
Instrumented packers for live pressure monitoring

Slurry Trench Excavation

Example Risk Factors / Initiators
Slurry loss into high permeable foundation or embankment drainage zones increases downstream pore pressure leading to instability
Slurry loss leads to trench instability and progressive slope slumping/failure
High slurry loss into permeable features leads to internal erosion
Trench deformation leads to cracking and internal erosion
Adverse change in slurry properties leads to trench instability

Slurry Trench Excavation

Example: Slope Instability Due to Increase in Pore Pressure

- Slurry loss into permeable and drainage zones cause increased pore pressures within downstream slope
  - Increased pore pressures reduces effective stress and embankment strength
    - Slope instability
      - Detection and Intervention Unsuccessful
        - Embankment deforms>freeboard
          - Reservoir lost

Slurry Trench Excavation

Example Risk Reduction
Additional instrumentation and focused visual inspections: Inclinometers, Piezometers, Survey
Slurry QA/QC procedures
Internal Erosion response measures: filter/drain stockpiled material
Emergency buttressing fill

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Embankment Excavation Behind Cofferdam

Example Risk Factors / Initiators
Weak cofferdam foundation
Earthquake
Insufficient design of seepage barrier (sheetpile, geosynthetic liner, zoned embankment, etc)
Insufficient geotechnical information on cofferdam foundation
High-risk design in regard to flood level protection (i.e. designing for a high-frequent flood)

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Embankment Excavation Behind Cofferdam

Example: Flood Overtopping of Cofferdam

- Inflow exceeds diversion design capacity
  - Cofferdam overtops
    - Erosion & down-cutting of cofferdam occurs
      - Intervention is unsuccessful
        - Breach occurs
          - Reservoir is released

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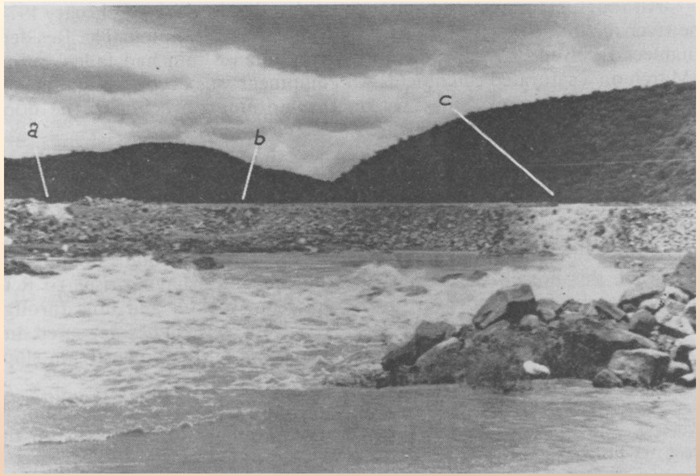
Embankment Excavation Behind Cofferdam

Example: Seepage Failure of Cofferdam

- Inadequate seepage/filter design leads to high seepage gradient through cofferdam
  - Cofferdam internal erosion initiates
    - Intervention is unsuccessful
      - Cofferdam breaches
        - Reservoir is released

Hans Strijdom Cofferdam (1977)

09h30 : wet patch



10h30: unravelling (right) & slip (left)

11h00: breach initiation

13h30: breach progression

Slide courtesy of Prof. Jean-Jacques Fry

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Embankment Excavation Behind Cofferdam

Example Risk Reduction
Risk-based evaluation to determine construction design flood event
Apply all modern design guidelines to cofferdams
Adequate geotechnical and geohydrology investigations
Hydrologic evaluation
Monitoring and inspections: added instrumentation for cofferdam (automated for access)
Design Reviews
Backup power (generators) and pumps if design reliance

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Spillway Repair/Replacement

Example Risk Factors / Initiators
Flood occurs in excess of construction-phase design event leading to
Outlet or diversion system is clogged or impeded causing pool to rise (leading to spillway operation of lower frequency flood)
Construction works cause embankment or abutment instability
Spillway has reduced capacity leading to embankment overtopping during rare flood

Spillway Repair/Replacement

Example: Flood Exceeds Available Passage Capacity

- Spillway chute is demolished for rehabilitation
  - Inflow exceeds available diversion passage capacity
    - Spillway operates
      - Erosion & head-cutting occurs of exposed foundation
        - Head-cutting progresses to control structure
          - Intervention fails
            - Spillway control structure fails
              - Reservoir is released

Spillway Repair/Replacement

Example Risk Reduction
Schedule constraints - work to be done during season with low flood risk
Evaluate critical flood pool that would allow storage of construction design flood event
Provisions for emergency flood passage (siphon)
Pre-defined spillway operation guidance in emergency

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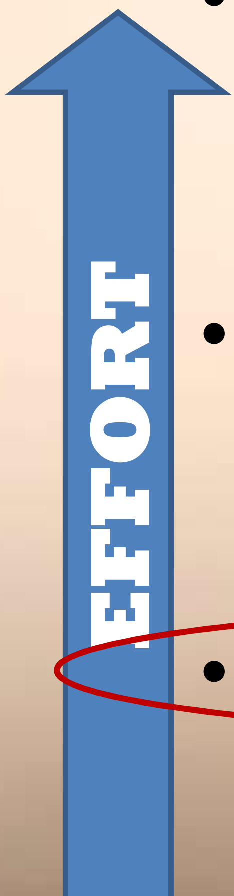
Construction PFMs – Risk Reduction

- Dam Safety Monitoring Plan:
  - Focused and frequent visual surveillance
  - Increased instrumentation monitoring
  - Automated instrumentation systems and alarms
- 24/7 staffing of construction sites if high risk
- Emergency material & equipment provisions
- Temporary Construction Emergency Action Plan

Construction Risk Analyses Framework



- **Quantitative Risk Analysis (RA)**
  - Quantitative estimate of probability of failure
  - Quantifying numeric impact/consequence
- **Semi-Quantitative Risk Analysis (SQRA)**
  - Estimating a range of likelihood of each PFM
  - Estimating a range consequence/impact
- **Potential Failure Mode Analysis (PFMA)**
  - Identifying list of PFMs
  - Qualitatively assessing significance of each PFM

All Methods: Identify risk reduction, monitoring, response

Construction Risk Review Documentation

Construction PFMA Report Contents

- Dam Safety Risk Criteria
- Issue/PFM Identification
- For each viable PFM
  - Description with initiator highlighted
  - Site-specific considerations
  - Construction-phase analyses
  - Risk reduction measures employed in design documents
  - Emergency response measures for each PFM
- Risk Category
  - Likelihood and consequence, if estimated
  - Qualitative judgement of significance (e.g. Highlighted, Viable, Remote)
- Risk Register

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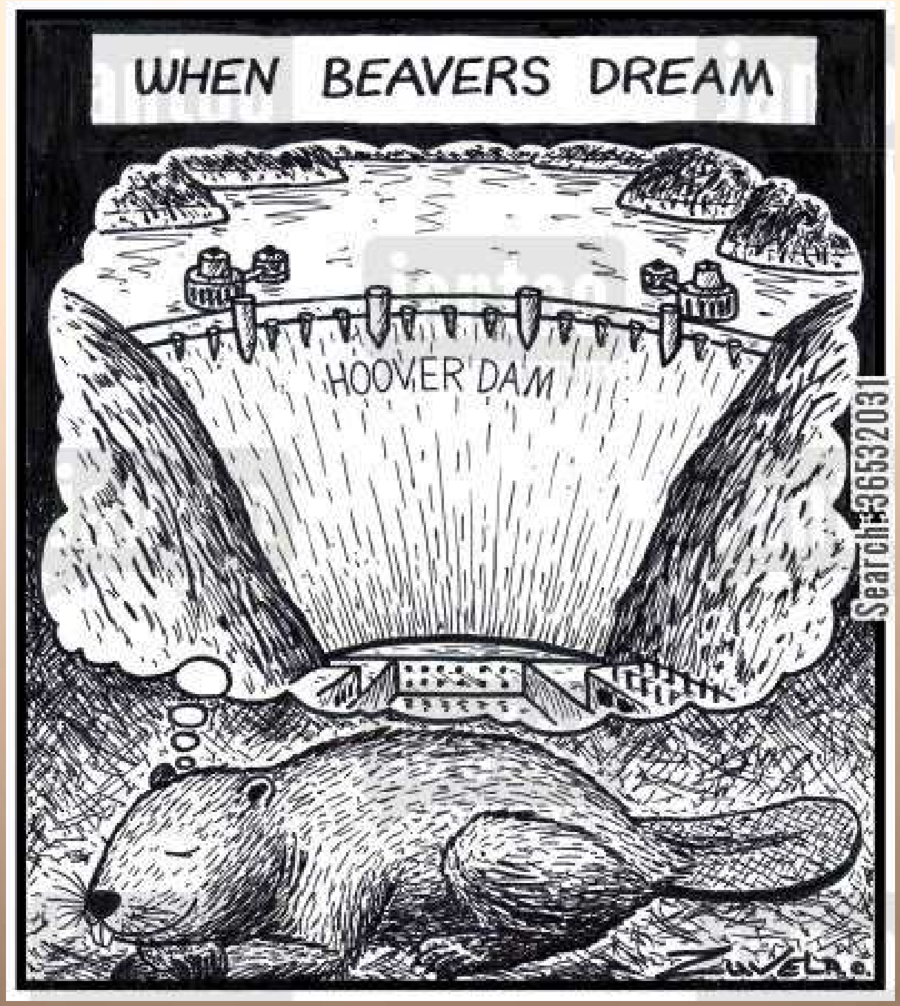
Questions?



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DAM SAFETY RISK MANAGEMENT DURING CONSTRUCTION

Construction Risk Register

- After bidding, hold a risk management workshop to engage the contractor in Risk Register process
- After construction begins, risks should be reviewed monthly
- As construction proceeds risks may need to be added or removed from the Risk Register

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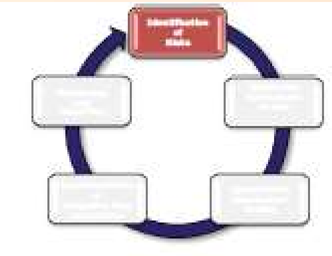
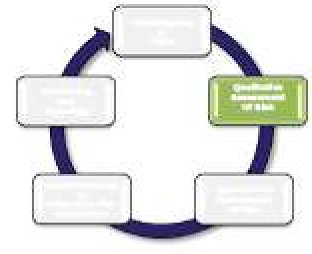
Identification
of
Risks
Qualitative
Assessment
Of Risk
Quantitative
Assessment
of Risk
Implementation
of
Mitigation Plan
and Actions
Monitoring
and
Reporting

Step 1 – Risk Identification



- Perform site visit
- Conduct risk assessment workshop to obtain information to develop a project risk register
- Begin planning for critical construction activities, schedule, sequencing and costs
- Key Participants
  - Owner (PM, operations, communications, technical staff, etc.)
  - Owner's engineer
  - Design Engineer
  - Contractor
  - Construction manager
  - Environmental personnel
  - Other key personnel



Step 2 – Qualitative Risk Assessment

- Probability of Occurrence
- Severity of Impact
- Develop Risk Register

Consequence					
5	5	10	15	20	25
4	4	8	12	16	20
3	3	6	9	12	15
2	2	4	6	8	10
1	1	2	3	4	5
	1	2	3	4	5
	Probability				

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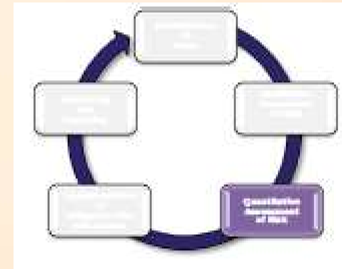
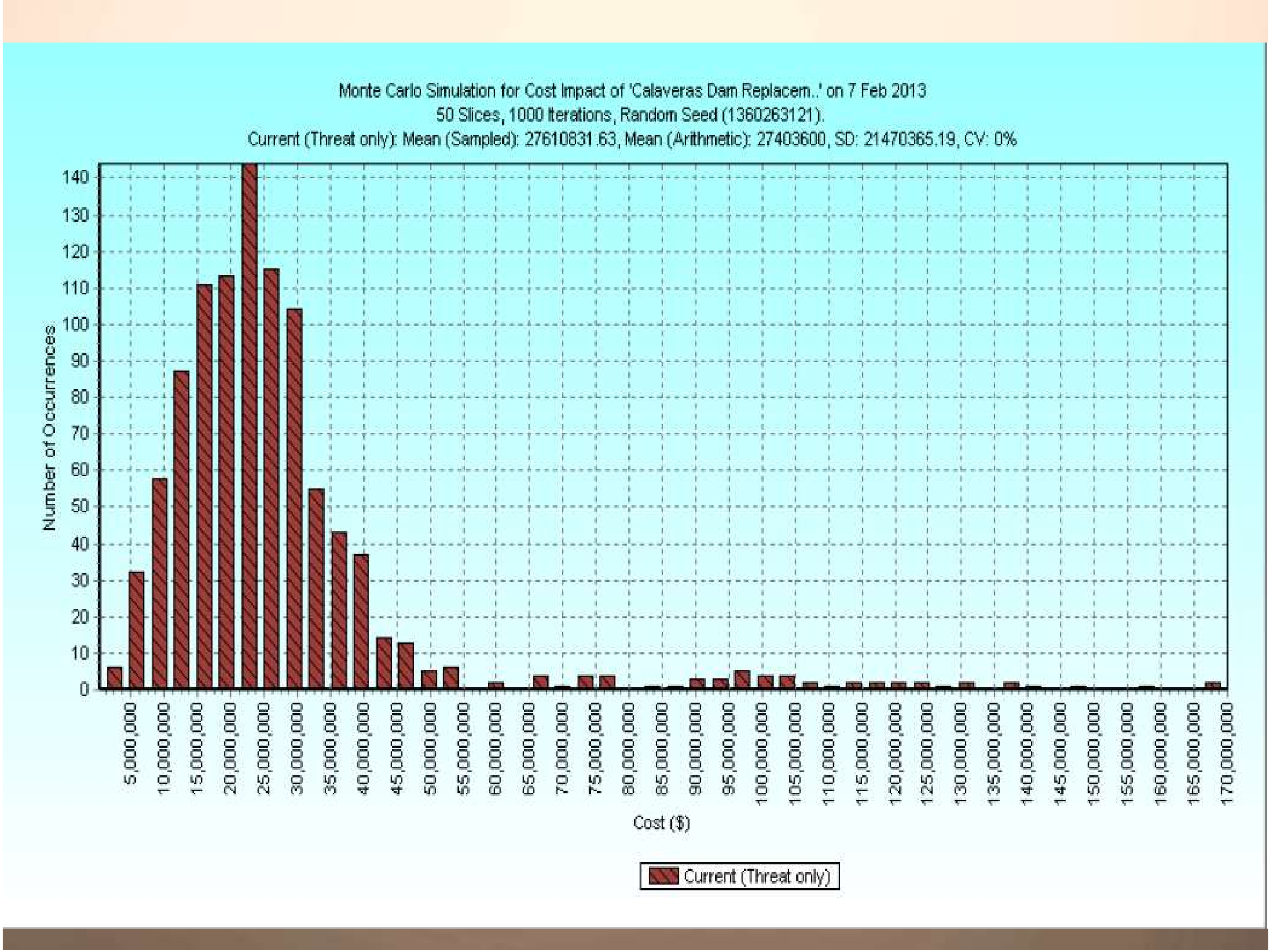
Calero Dam Seismic Retrofit Project - DSOD Coordination Risk Register

Risk Identification						Risk Consequence							
Risk Number	Hazard	Project Component	Cause of Hazard	Potential Consequence	**Risk Likelihood**	Financial	Schedule	Social	Regulatory/Legal	Safety	O&M	Environmental	**Risk Score**
1	DSOD												
1.1	Initial DSOD Coordination	DSOD preliminary design review	Failure to include DSOD of preliminary design	Construction delays	1	5	5		5			1	**2.3**
1.2	Minimize Review Duration	DSOD final design review	Failure to notify DSOD before final design submittal	Construction delays	1	5	5		5			1	**2.3**
1.3	Responding to DSOD Comments	DSOD approval of final design	Failure to timely address DSOD comments to final design	Construction delays	1	5	5		5			1	**2.3**
1.4	DSOD Inspections During Construction	DSOD onsite inspections of project during critical periods (foundation inspection, embankment placement, etc.)	Failure to appropriately prepare site for DSOD inspection	Construction delays	1	5	5	2	5	2		4	**3.3**

Step 3 – Quantitative Risk Assessment



- Three Point Estimates for:
  - Worst Case
  - Most Likely
  - Best Case
- Monte Carlo Simulation
- Risk Exposure Curve
- Severity of Impact



Monte Carlo Simulation for Cost Impact of 'Calaveras Dam Replacem..' on 7 Feb 2013
50 Slices, 1000 Iterations, Random Seed (1360263121).
Current (Threat only): Mean (Sampled): 27610831.63, Mean (Arithmetic): 27403600, SD: 21470365.19, CV: 0%
Number of Occurrences
0
10
20
30
40
50
60
70
80
90
100
110
120
130
140
5,000,000
10,000,000
15,000,000
20,000,000
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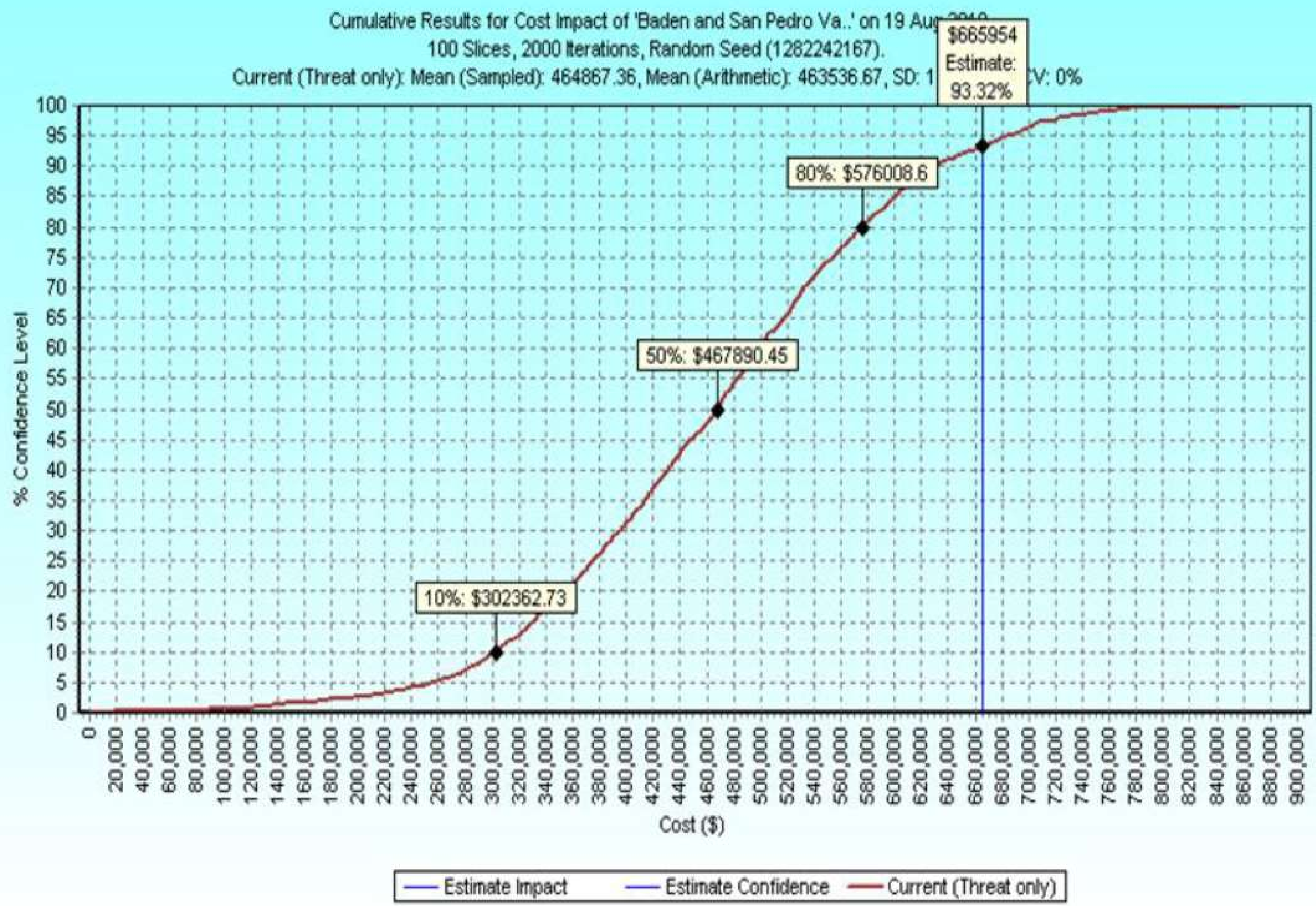
Cost ($)
Current (Threat only)



Cumulative Results for Cost Impact of 'Baden and San Pedro Va..' on 19 Aug
100 Slices, 2000 Iterations, Random Seed (1282242167).
Current (Threat only): Mean (Sampled): 464867.36, Mean (Arithmetic): 463536.67, SD: 1
CV: 0%
$665954
Estimate:
93.32%
80%: $576008.6
50%: $467890.45
10%: $302362.73
% Confidence Level
Cost ($)
Estimate Impact
Estimate Confidence
Current (Threat only)

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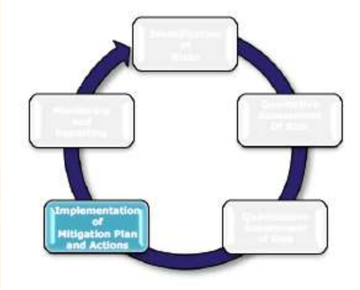
Step 4 – Implementation of Mitigation Risk Plans



- Develop Risk Mitigation Plan and Associated Actions
- Identify Action Dates and Ownership for Each Action
- Implement and Follow Up on Action Items

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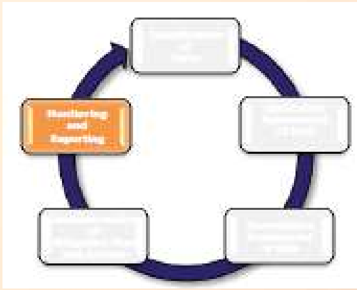
Step 5 – Monitoring and Reporting



- Ensure Mitigation Measures are Implemented
- Assess Project Risk Exposure and Continuously Plan for Contingency
- Monthly Review
- Quarterly Update
- Regular Reports to Monitor Risk Exposure

Care and Diversion of Water

- Cofferdams are one of the highest risk features during a dam rehabilitation
- Engineer vs Contractor Design
  - Selection of Flood Protection Level
    - Risk-based decision
    - Dependent on duration of construction
  - Hydrological and Geotechnical Baseline Conditions
  - Design Review

Care and Diversion of Water

Beaver Park Dam

Beaver Park Dam

Beaver Park Dam

Beaver Park Dam

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Beaver Park Dam

Buckhorn Dam

Buckhorn Dam – 45 days after substantial completion (Hurricane Floyd, ½ PMF)

Communication

- At an early stage, cultivate a good working relationship between the owner, contractor, designer, and regulator.
- The Risk Register is one tool to foster communication between the owner, contractor, designer, & regulator.
- Set up a framework for communication so everyone knows where to turn for answers and where to voice safety concerns
- Develop an environment where open communication about safety concerns is welcomed

Schedule and Construction Sequencing

- Construction schedule pressures could result in safety being set to the side.
- Safety should be a priority over meeting construction milestones.
- Plan float into the construction schedule to relieve time pressures that could result in higher risk activities
- Consider a phased construction schedule if uncertainties in early phases (e.g. foundation excavation, dewatering) will have a significant impact on later phases.

Schedule and Construction Sequencing

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Schedule and Construction Sequencing

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Schedule and Construction Sequencing

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Schedule and Construction Sequencing

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Cotter Dam

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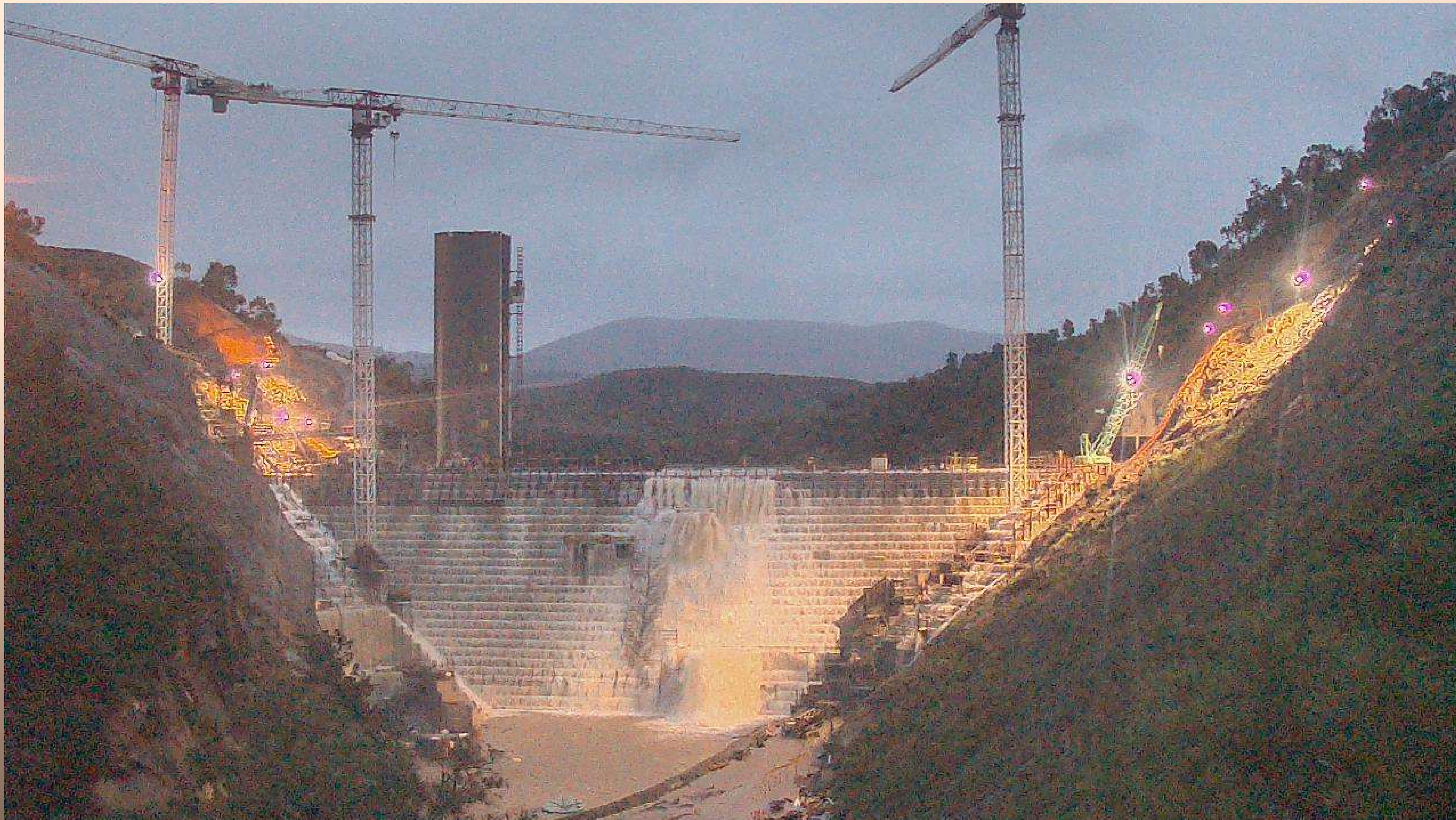
Cotter Dam



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Cotter Dam

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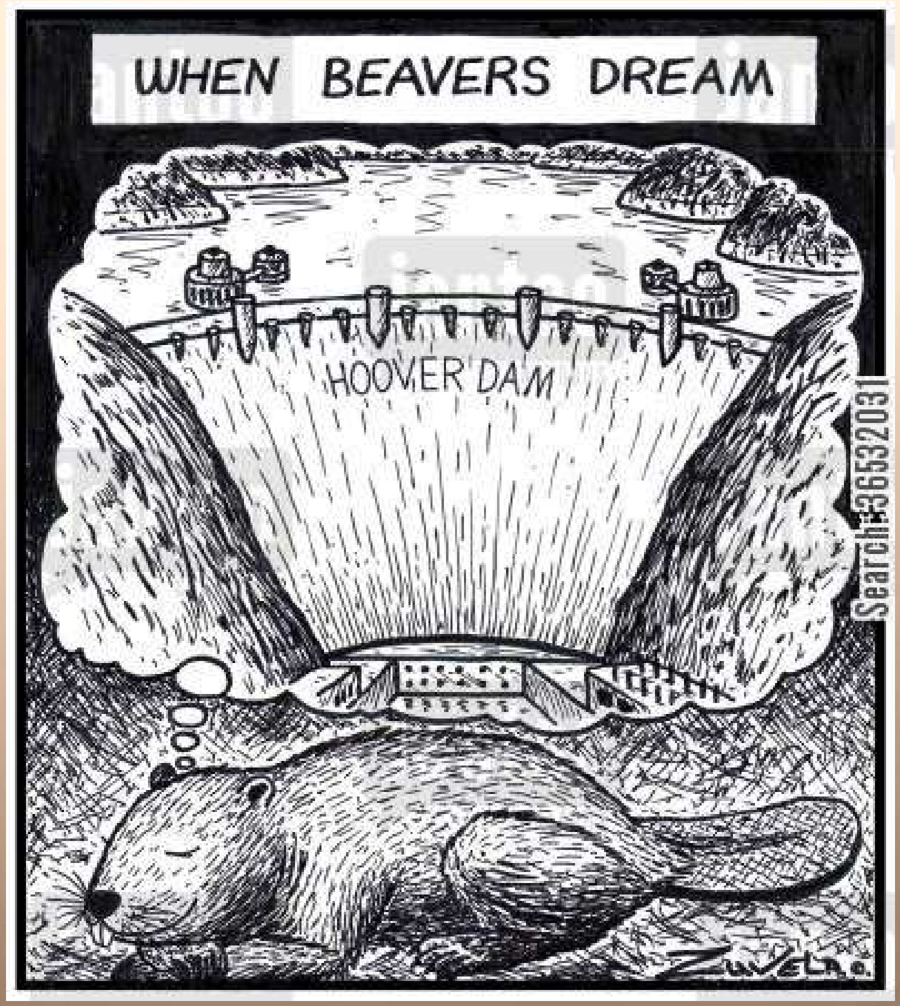
Cotter Dam

Questions?



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DAM SAFETY MONITORING &

EMERGENCY PREPAREDNESS / RESPONSE

Dam Safety Monitoring Plan

- “Dam Safety Monitoring Plan”, “Dam Safety Management Plan”, “Surveillance and Instrumentation Monitoring Plan”.....
- Informed by Construction Potential Failure Mode Analysis or Risk Assessment
- The Risk Register can also be used to ensure risks are monitored accurately
- Instrumentation
  - Install additional as warranted
  - Increase measurement frequency
  - Automated (frequency and physical access limitations)
- Targeted and frequent visual inspection

Dam Safety Monitoring Plan – Example Table of Contents

1. General
    - 1.1 Definitions
    - 1.2 Roles and Responsibilities
    - 1.3 Contact List
2. Description of Work
    - 2.1 Description of Dam and Construction Work
    - 2.2 Construction Sequence and Work Method Descriptions
    - 2.3 Construction Potential Failure Modes / Identified Risks
3. Monitoring During Construction
    - 3.1 Visual Inspection (daily, nightly, limited access, boat)
    - 3.2 Instrumentation Monitoring (description, frequency, procedure for each)
    - 3.3 Actionable / Incident Levels
4. Reporting Requirements (based on action/incident level)
5. Incident Declaration
6. Emergency Response

Dam Safety Monitoring Plan – Example Table of Contents

Key Data (Tables/Figures)

- Location Plan Figure
- Instrument Reading Procedure & Frequency
  - Survey, Piezometers, Inclinometers, Weirs
- Expected Instrument Reading Range (historic readings plots/tables)
- Visual Inspection Description, Location, and Frequency
- Actionable/Incident Levels
  - Visual Observations and Instrument Readings
  - Triggers and response
- Reporting Procedure, Review, and Frequency
  - Will vary by construction phase or action/incident level
- Inspection Checklist

Temporary Construction Emergency Action Plan

- Typically required when the public would be endangered from failure of the temporary construction work
- Differing regulator requirements
- Provide early warning of sudden release of water during construction caused by:
  - weather events
  - unanticipated failure of any facility component

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Temporary Construction Emergency Action Plan

Basic Contents:

1. Notification list of emergency response authorities, owner, engineer, regulator.
2. Plan drawing of proposed arrangement of the construction works.
3. Location of safety devices and escape routes.
4. Action levels (based on the Construction PFMA and Monitoring Plan)
    1. What triggers plan activation and when evacuation will occur.
5. Brief description of testing procedures for the plan.

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TCEAP – Example Contents

Table of Contents:

Information for Planholders

Sec **Page**

M

TCEAP

- Posted at a strategic location at the construction site visible to all workers
- Discussed during weekly safety meetings
- Periodic testing of the plan performed at least quarterly

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TCEAP Levels

LEVEL 1 *(Example)*

- Condition may occur when there is a significant event or an emergency localized only to the construction area and poses no life-threat issue.
- Examples include:
  - *Medical, Fire or Criminal Activity Emergency*
  - *Reservoir Elevation Reaches Threshold (e.g. 2 feet below cofferdam crest)*
  - *Free Water Accumulates within Excavation Area*
  - *Sinkhole Development in Excavation Area*
  - *Gate Operation is Difficult and/or Restricted*

TCEAP Levels

Level 2 *(Example)*

- Emergency exists and there may still be time to correct or modify an observed dam safety condition which could escalate into dam failure if left unattended, but which does not pose immediate danger.

TCEAP Levels

Level 3 *(Example)*

- Emergency exists and a dam failure is occurring or is imminent (will very soon occur), and there is no time to mitigate the failure. Evacuation response to both conditions should be the same since total failure could occur at any time.

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Emergency Preparedness Provisions Included in TCEAP

- Response plan identified for each significant PFM
- Pre-designed emergency filters, berms and backfill
- Stockpile material
- Maintain access to stockpiled materials
- Provisions for emergency flood passage
  - Siphons
  - Spillway operation guidelines

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Reservoir Refilling

- ~20% of dam safety failures occur within the first year of operation, including first filling
- First filling loads the dam for the first time and can find weaknesses in the structure
  - Seepage paths (low stress zones)
  - Windows in filters or cutoffs
- Refilling after a major rehabilitation should be treated as a first-filling warranting special care

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Reservoir Refilling Plan

- Limited rate of refilling
  - Typically 1-2 foot a day, with lower refill rates for the upper reaches of the dam as hydrostatic pressures increase.
- Hold Elevations
  - Typically a min. of 1-2 days
  - Allow embankment to stabilize to new load before continuing (Instrument stabilization)
- Inflow/Outflow requirements
- Schedule or chart daily reservoir targets

Reservoir Refilling Plan

- Increased Frequency of Surveillance & Monitoring
  - Reservoir level
  - Settlement Points
  - Piezometers
  - Weir/flume
- Verification of instrument functionality and initial readings prior to refill
- Frequent readings
  - Multiple times a day
  - Continuous (ADAS/SCADA)
- Convene review team daily to decide whether to continue

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Reservoir Refilling Plan

- Visual Surveillance
  - Physical changes
  - Settlement, Cracking, slumps
  - Seepage
  - Plumes
  - Boils

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Reservoir Refilling Plan

- Personnel Roles and Responsibilities
- Acceptance Criteria to Continue
- Action Levels to Cease Refill
- Emergency Response
- Procedure for Adjustments to Plan

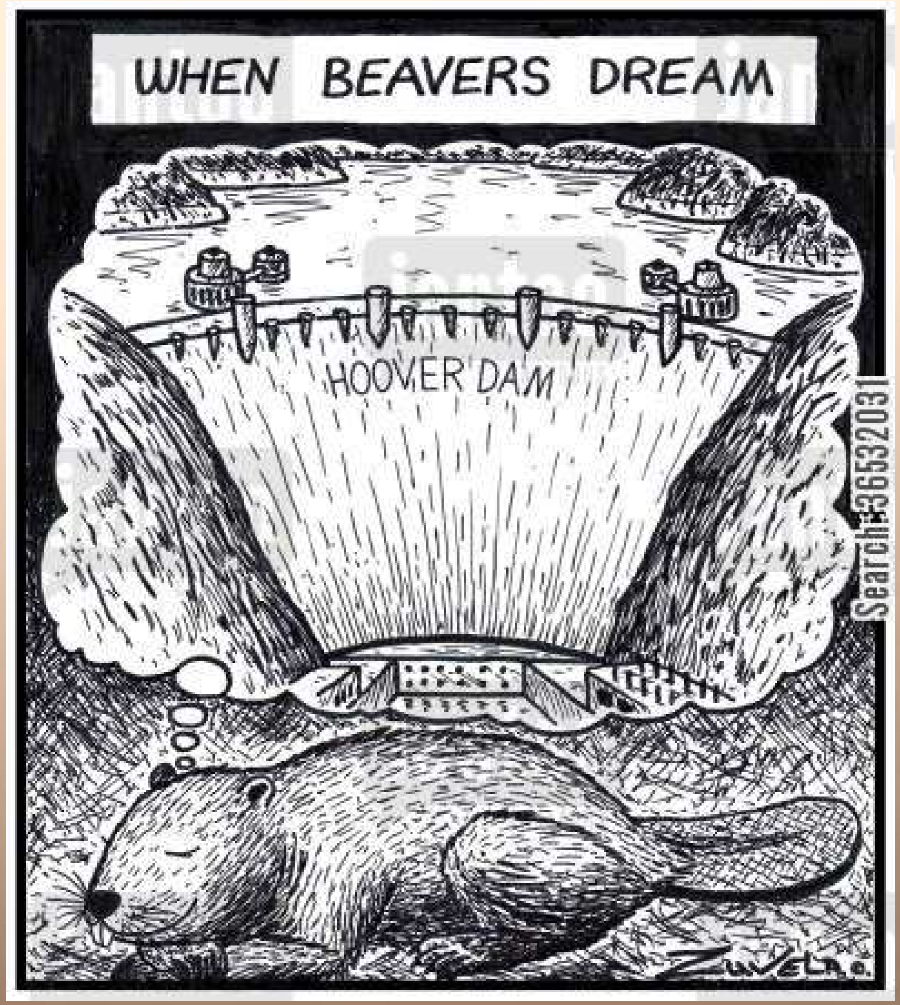
CLOSING REMARKS

Regulatory Review Considerations

Demonstrated that dam safety risks have been considered in a thoughtful and systematic manner?

– Construction failure modes for each work activity
– Risk reduction measures identified and implemented
– Construction conditions analyzed considering range of potential conditions/parameters
– Is degree of uncertainty acceptable for high risk activities (approached based on sufficient data)
– Contingency designs prepared
– Focused monitoring plan and emergency action plan

Questions?



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