US Army Corps of Engineers

Dam Safety Portfolio Risk Assessment

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Stewardship of National Infrastructure

- **Risk Assessment provides a defensible framework to support Performance Based Budgeting.**
- **Understanding degradation of system performance.**
- **Prioritization of Investments.**
- **Allows for allocation of limited funds for projects where potential for overall risk reduction is greatest**

Levels of Risk Analysis

Risk analysis for dam safety is performed at three levels:

- **<u>Screening</u> portfolio risk analysis (SPRA)**
- **<u>Portfolio</u> risk analysis (PRA) for safety improvement**
- **<u>Project or site specific</u> risk analysis for risk management actions or project improvements**

SPRA

- Probabilistic, Risk-Based Method of Determining Relative Risk
- Implemented Via 3 Multidiscipline National Technical Cadres
- 20% of Corps Dams Screened to Date.

SPRA

- Results used to shape the Budget
- Specific products delivered include:
  - Annualized Life Risk
  - Annualized Economic Risk
  - Index of Condition
  - Anticipated five year funding needs for each project
  - Sorting of risks by project feature (seepage and piping, stability, erodibility) and loading condition (hydrologic and seismic events).

SPRA Methodology

- Initiating event frequency
- Failure mode performance
- Breaching severity
- Consequence multipliers
- Fatality and loss rates

SPRA Methodology

Risk = (Hazard rate, H) (Conditional failure probability, Pf) (Conditional breach probability, Pb) (Exposure, X) (Loss rate, L)

1. R - Annual risk
2. H - Hazard rate is the initiating event rate
3. Pf - Conditional failure probability of a feature given the initiating event
4. Pb - Conditional dam breach probability (conditional breach probability per feature failure)
5. X - Exposure of developments due to breaching of the dam and uncontrolled flooding (population or property at risk per breach)
6. L is the loss rate of the uncontrolled flooding (lives or dollars lost per population, property at risk, economic loss of navigation).
7. The product of X L is called the consequences due to breaching of the dam and uncontrolled flooding (lives or dollars lost per breach).

Failure Mode Probability

Baseline Probabilities

- Evaluation of Major Components and Systems
- Comparisons made to a new structure
- Baseline failure probabilities:
  - Feature performance Multipliers
  - Breaching severity
- Design and construction USACE criteria and standards

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Feature Failure Mode Performance

- All features rated against a baseline
- Existing Data
- Numerical multipliers applied to baseline failure probabilities to model site conditions

Feature State According to Standards & Criteria	Modifier to New Dam Value	Variable Name
Adequate	1	A
Probably Adequate	10	PA
Probably Inadequate	100	PI
Inadequate	1000	I
Not applicable	0	NA

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Feature Failure Mode Performance

Breach Severity Factors

- Level of breaching resulting from feature failure mode performance.
- Adjusted to reflect linked failure modes and site specific conditions.

(a) Concrete Structures

Breach	Probability	Variable Name
None	0.830	Breach1
Minor	0.150	Breach2
Major	0.015	Breach3
Catastrophic	0.005	Breach4

(b) Embankment and Dikes

Breach	Probability	Variable Name
None	0.100	Breach5
Minor	0.150	Breach6
Major	0.250	Breach7
Catastrophic	0.500	Breach8

Consequences

- Project and event specific
- Loss of Life (LOL)/event
  - ✓ Population At Risk (PAR) within inundation zone
  - ✓ Fatality rate within PAR
- Economic damage/event
  - ✓ Property damage within inundation zone
  - ✓ Loss of Navigation
  - ✓ Loss of lifelines

Process

Districts give a presentation based on information request sent out by Headquarters

Process

Cadre then interviews (interrogates) District personnel to extract more information

Process

Review all relevant documents

- Pi's
- Foundation reports
- As-built drawings
- Construction photos
- Water control manuals
- Special studies

Economist works with District to develop consequences

Process

Cadre members then individually rate each feature.

Process

- Team then agrees on final ratings for each feature and any adjustments to release severity weighting.
- Loading info and ratings are then entered in spreadsheet.

Process

Consequences are then input and the spreadsheet is completed.

Process

Cadre will then prepare A report that documents:

- General description of the project
- All PI and I ratings
- Release severity adjustments
- Basis for PAR and LOL estimates
- Basis for economic damages
- 5 year funding need.

Process

When all projects at a location are complete the cadre will present a debriefing covering:

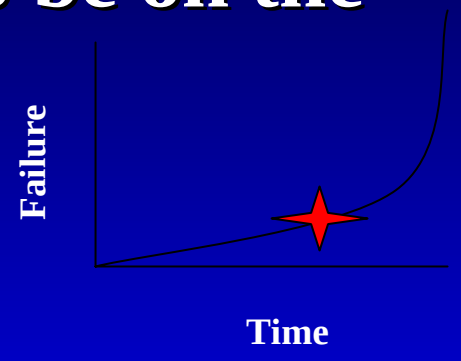
- Cadre members
- Purpose of SPRA
- Summary of the ratings for each project
- Relative ranking for each districts projects
- Address the Districts questions and concerns

Engineering Rating Summary

Feature Flood Control Dam	Normal Water Level	50% Exceedence Duration Normal Water Level with OBE	50% Exceedence Duration Normal Water Level with MDE	Unusual (300yr)	Extreme - (PMF)
Concrete Gravity Section					
External Stability	NA	NA	NA	NA	NA
Internal Stability	NA	NA	NA	NA	NA
Foundation Stability	NA	NA	NA	NA	NA
Foundation - Seepage & Piping	NA	NA	NA	NA	NA
.....Void	NA	NA	NA	NA	NA
Abutment Foundation Stability (Dam Structure)	NA	NA	NA	NA	NA
Spillway and/or Stilling Basin System					
Structural Stability	A	A	PA	A	PA
Structural Capacity	A	A	A	A	PA
Walls - Overtopping	A	A	A	A	I
Gates - Structural, Electrical and Mechanical	NA	NA	NA	NA	NA
Gate Piers - Structural Capacity	NA	NA	NA	NA	NA
Erodibility	A	A	A	PI	PI
.....Void	NA	NA	NA	NA	NA
Sill	A	A	A	PA	PA
Outlet Works and Conduits					
Embankment Piping at Conduit	PA	A	A	PA	PA
Gates - Structural, Electrical and Mechanical	A	A	A	A	I
Intake Tower Stability	A	PA	PI	A	A
Intake/Tunnel/Conduit Structural Failure	A	PA	PI	A	A
Tunnel/Conduit Joint Failure	PI	A	A	PI	PI
Embankment					
Embankment Seepage & Piping	PA	A	A	PI	PI
Erosion: Toe, Surface & Crest	A	A	A	A	I
Abutments Seepage & Piping	A	A	A	PA	PA
Abutments Stability and/or Liquefaction	A	PA	PA	A	A
Foundation Seepage & Piping	PI	A	A	I	I
Embankment Stability and/or Liquefaction	A	PI	I	A	A
Foundation Stability and/or Liquefaction	A	PI	I	A	A
Reservoir Rim					
Stability - Landslide	A	A	PA	A	A
Loss of Storage Capacity - Silt	A	A	A	A	A
Erosion	A	A	A	A	A
Mines	A	A	A	A	A
Other Features					
Feature 1	NA	NA	NA	NA	NA
Feature 2	NA	NA	NA	NA	NA
Feature 3	NA	NA	NA	NA	NA
Feature 4	NA	NA	NA	NA	NA

General Comments

- Several projects found to be on the continuum of failure



- Projects screened in 06 were mixed with 05 projects (i.e. we did not get top 10% in 05).
- Independent screening has identified significant safety issues

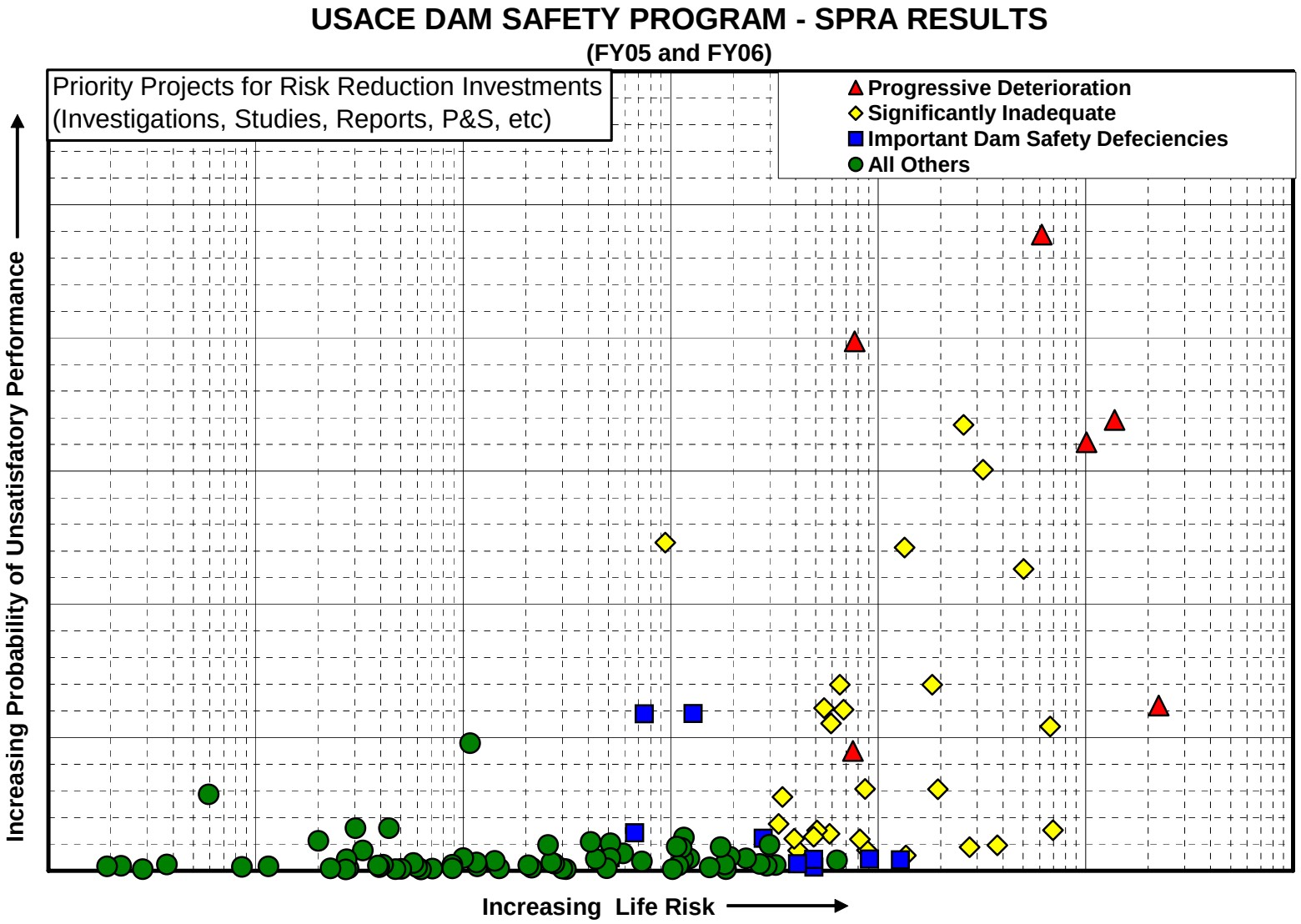
Basis of Ranking

- Flood Damage Reduction Projects
  - Annualized Life Risk
  - Relative Condition Ratio (Life Risk/Baseline Life Risk)
- Navigation Projects
  - Annualized Economic Risk
  - Ratio (Economic Risk/Baseline Economic Risk)

Priority Categories

- Active Failure Continuum (progressive deterioration)
- Significantly Inadequate
- Important Dam Safety Deficiencies
- All Others

05 and 06 Results



Review of Deficiencies

Due To Ageing And The State Of The Art At The Time Of Design And Construction Significant Dam Safety Deficiencies Exist At Many USACE Dams.

Review of Deficiencies

The top 25 projects from the initial round SPRA FY05 were reviewed and examples of deficiencies that were considered inadequate are presented.

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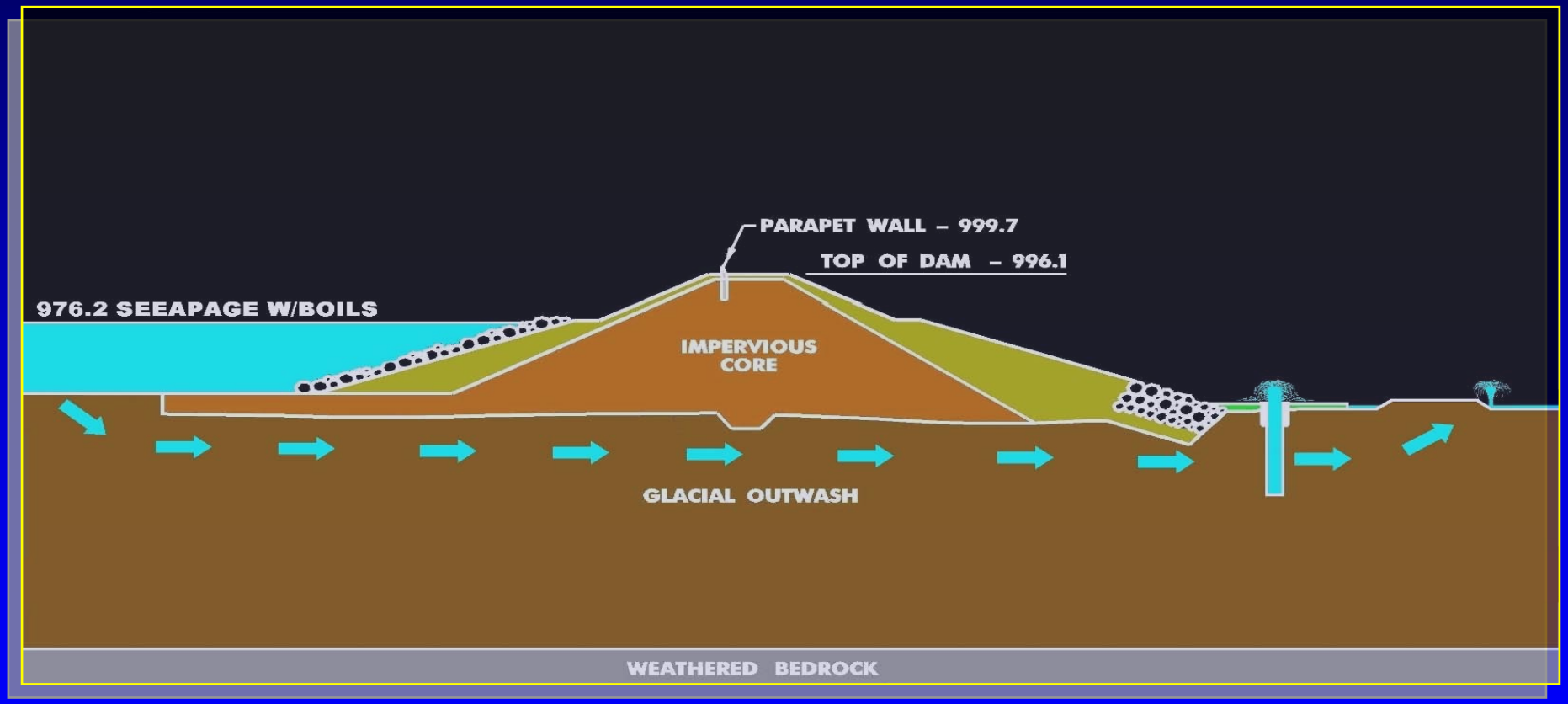
Foundation Seepage



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Inadequate Seepage Control

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High Toe Pressures

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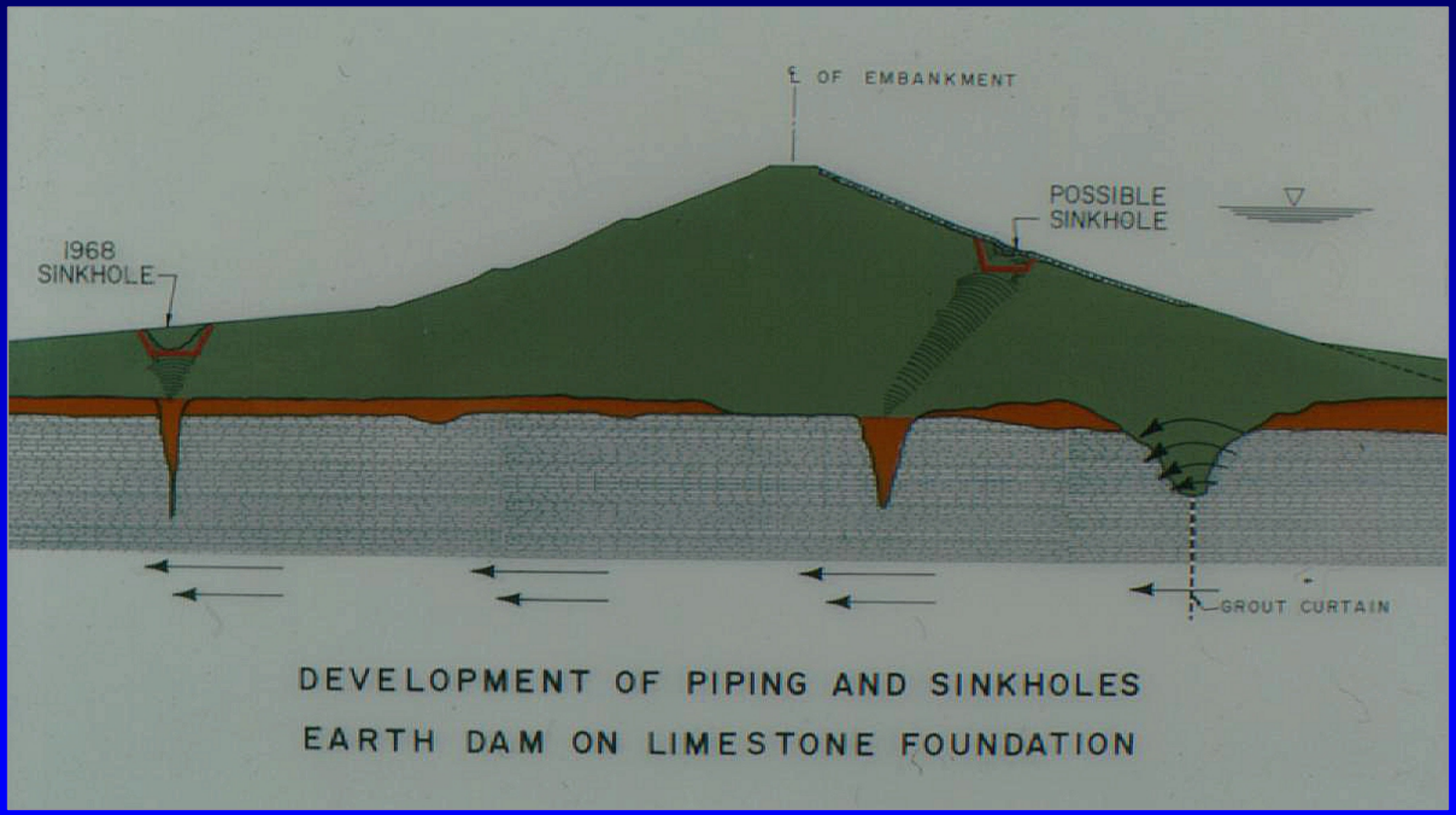
Foundations Seepage and Piping (Karst)



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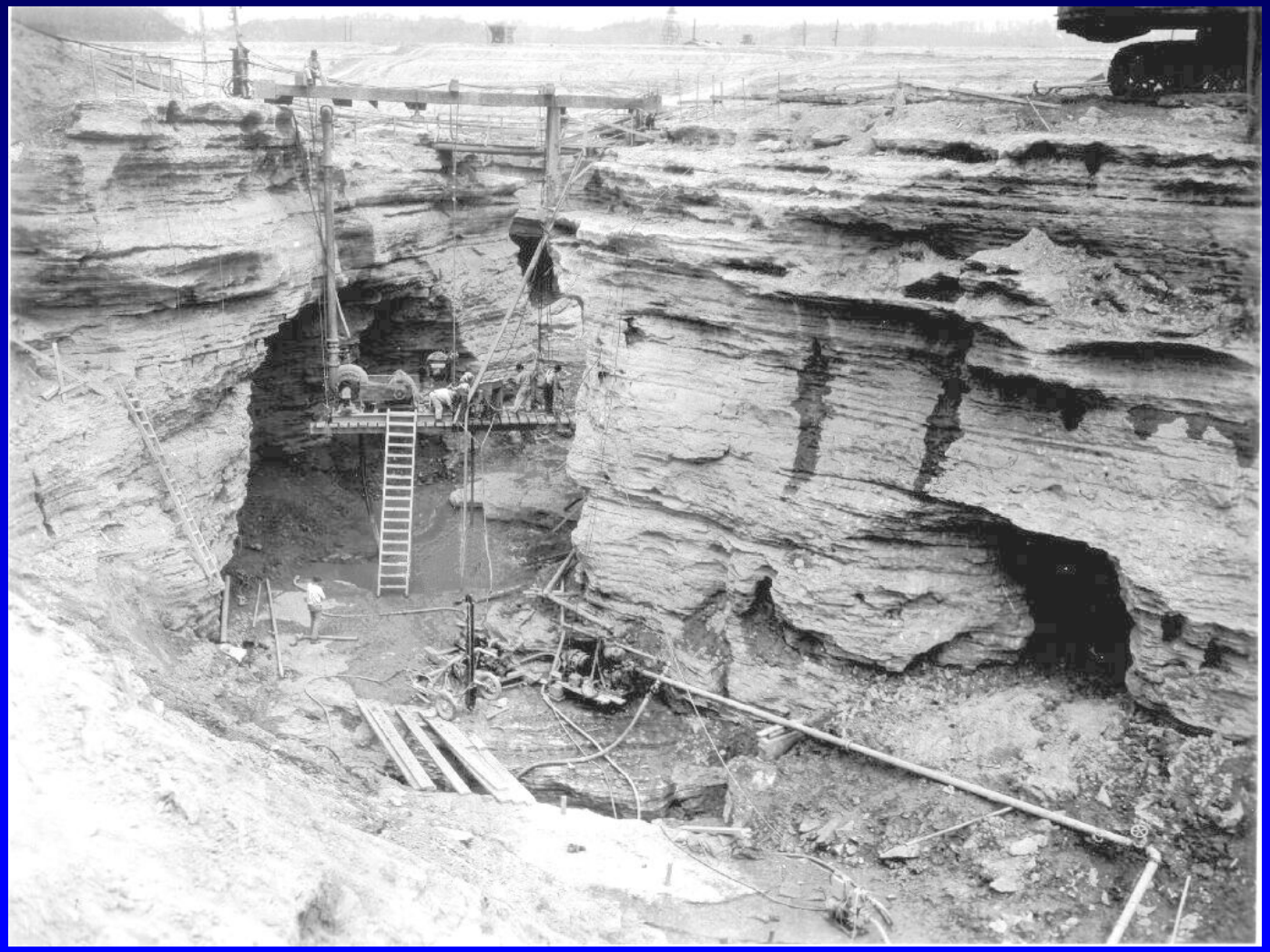
Foundations Seepage and Piping (Karst)



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Foundations Seepage and Piping (Karst)

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Abutment Seepage (Karst)

Abutment Seepage

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Inadequate Abutment Treatment

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Inadequate Filter

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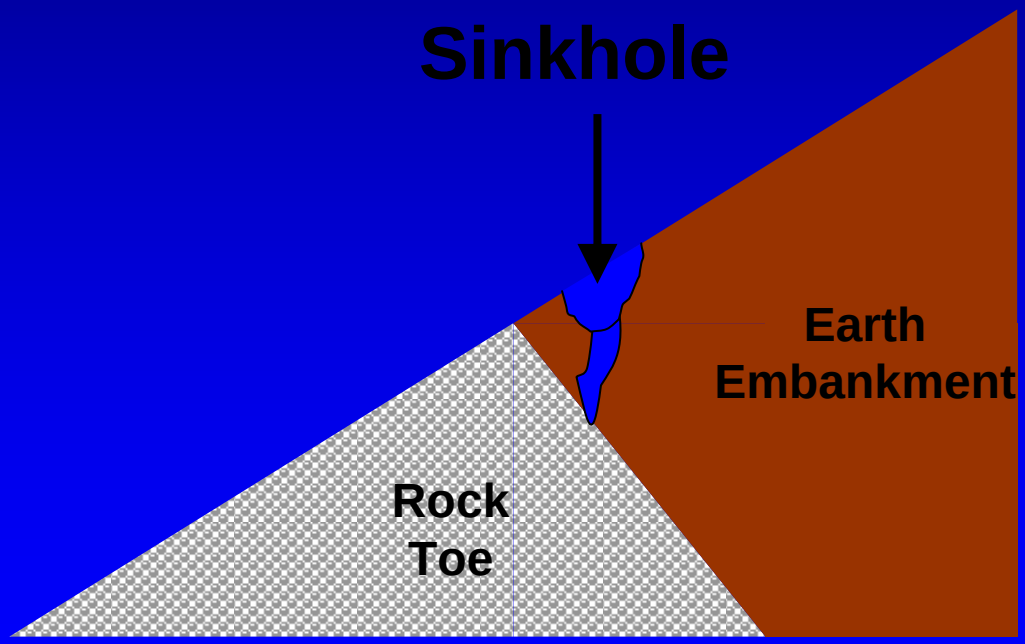
Inadequate Filter



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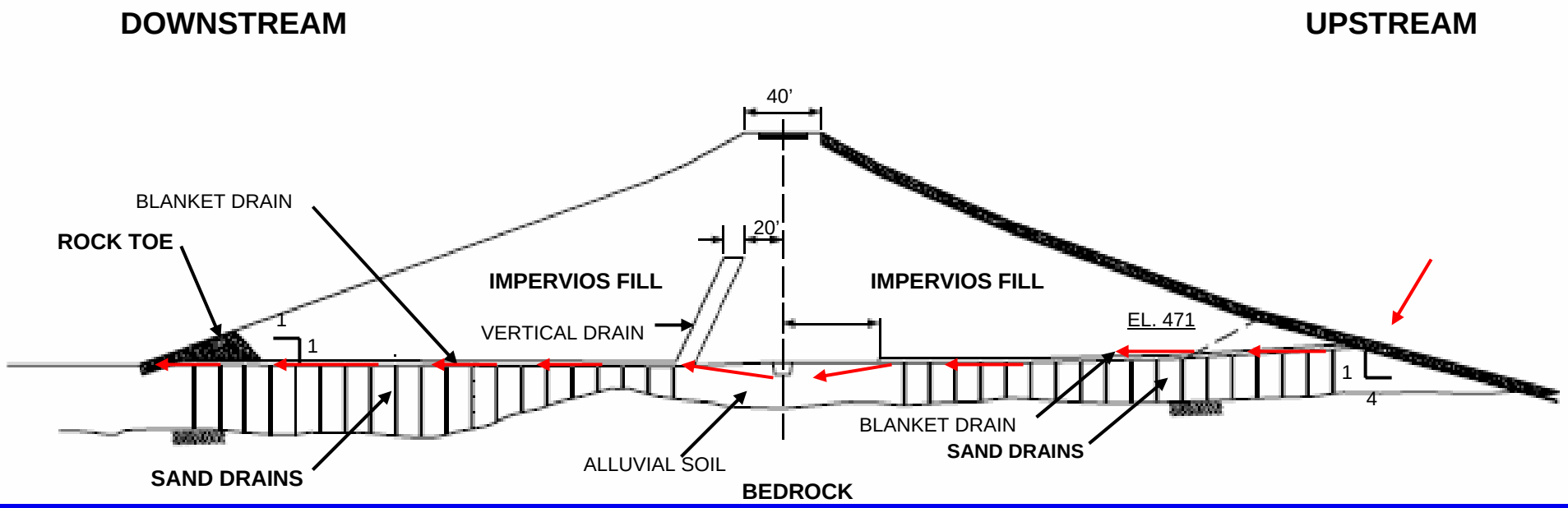
Blanket Drain Short Circuit



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PIPING INTO A CONDUIT

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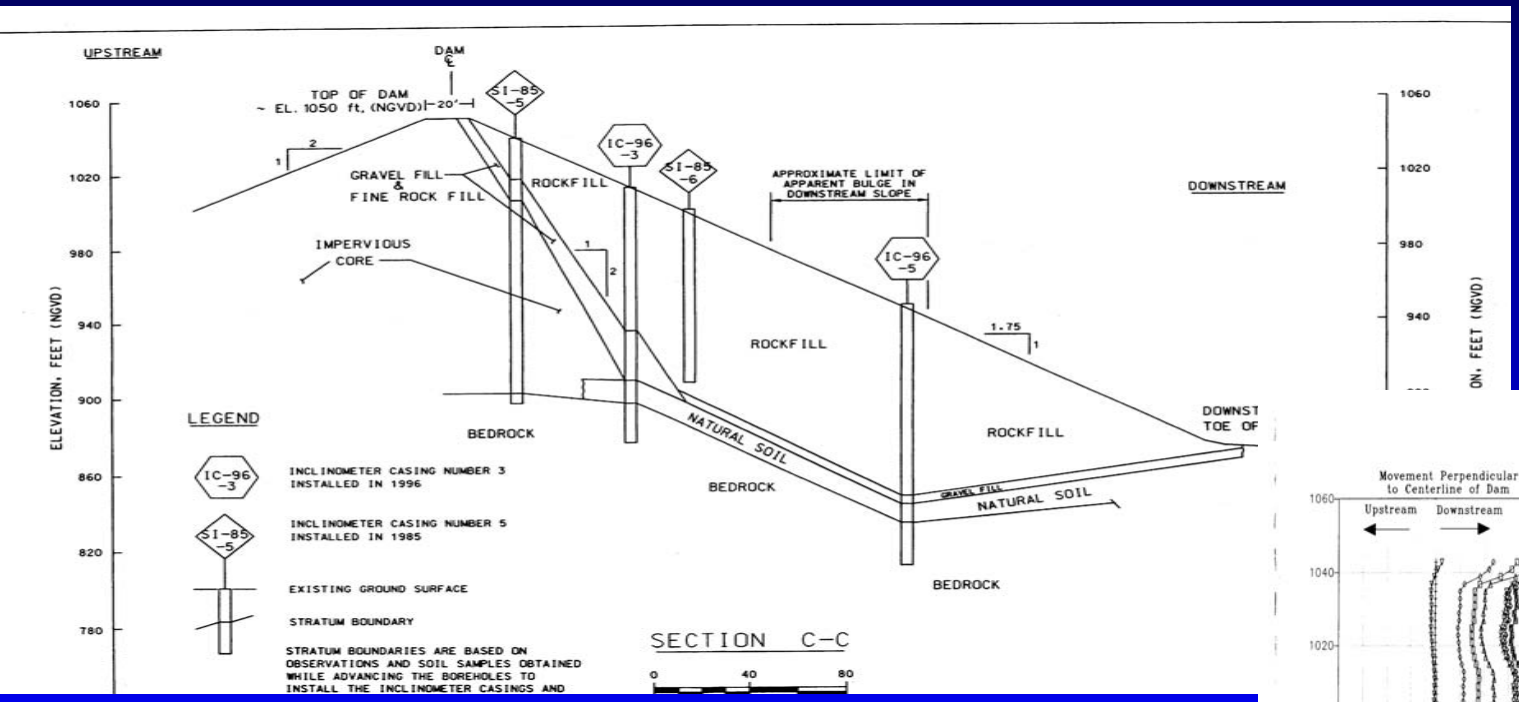
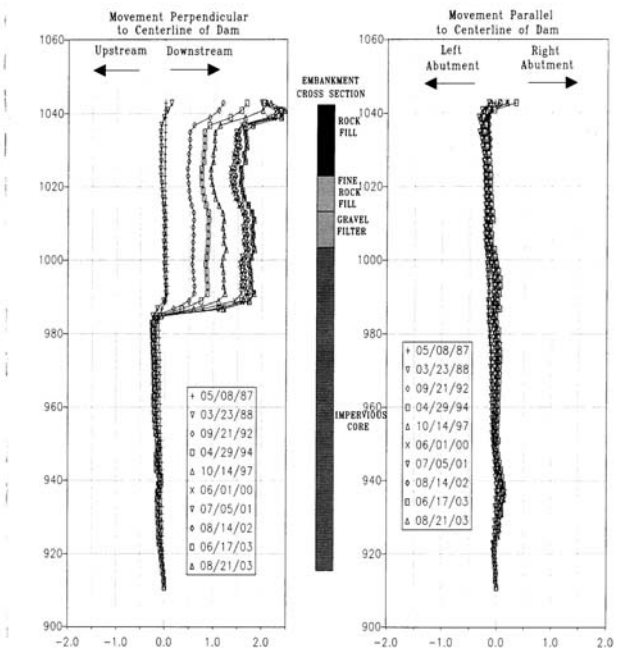
Slope Stability





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Spillway Erosion

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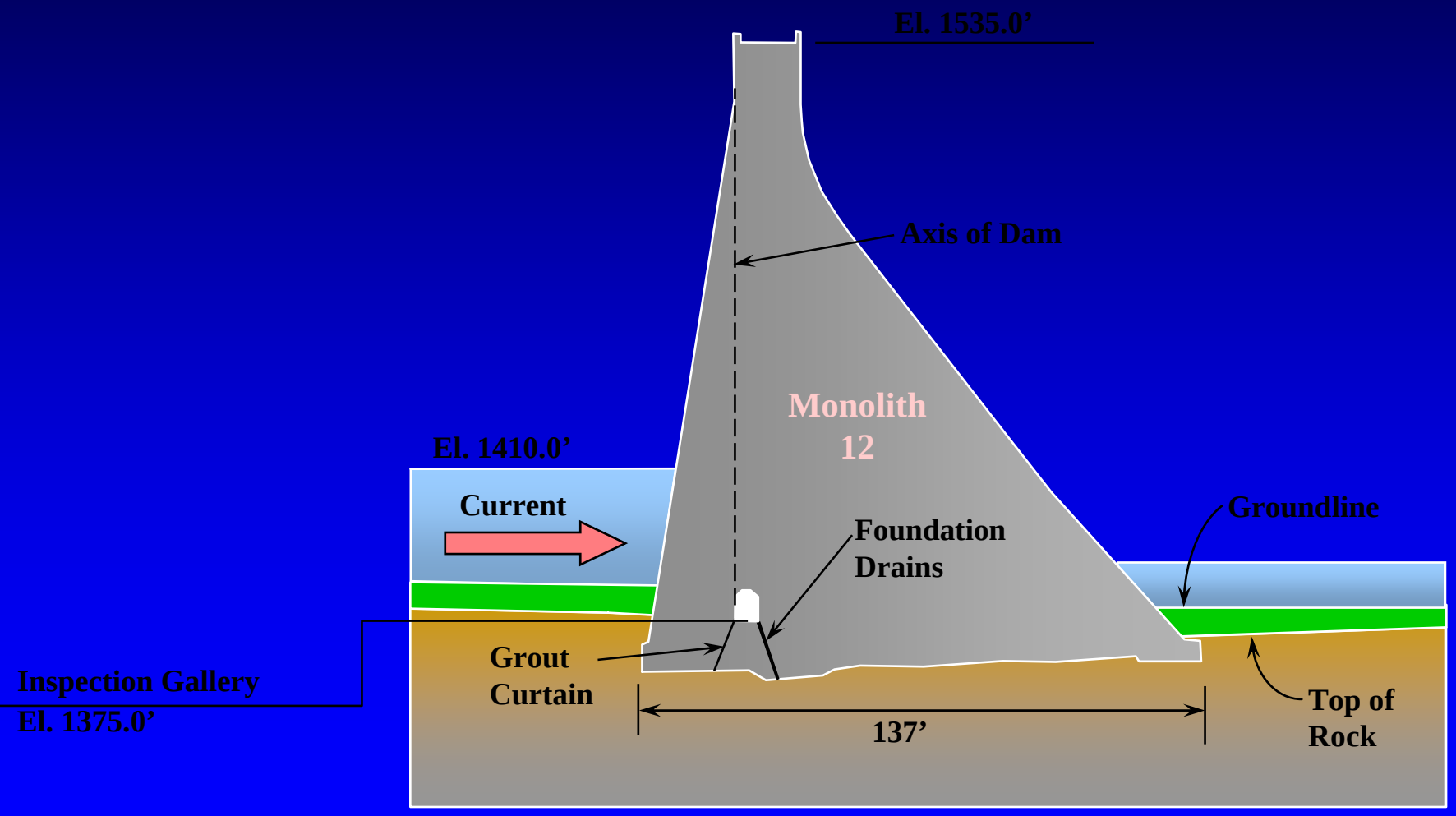
Spillway Erosion

Monolith Stability (PMF)



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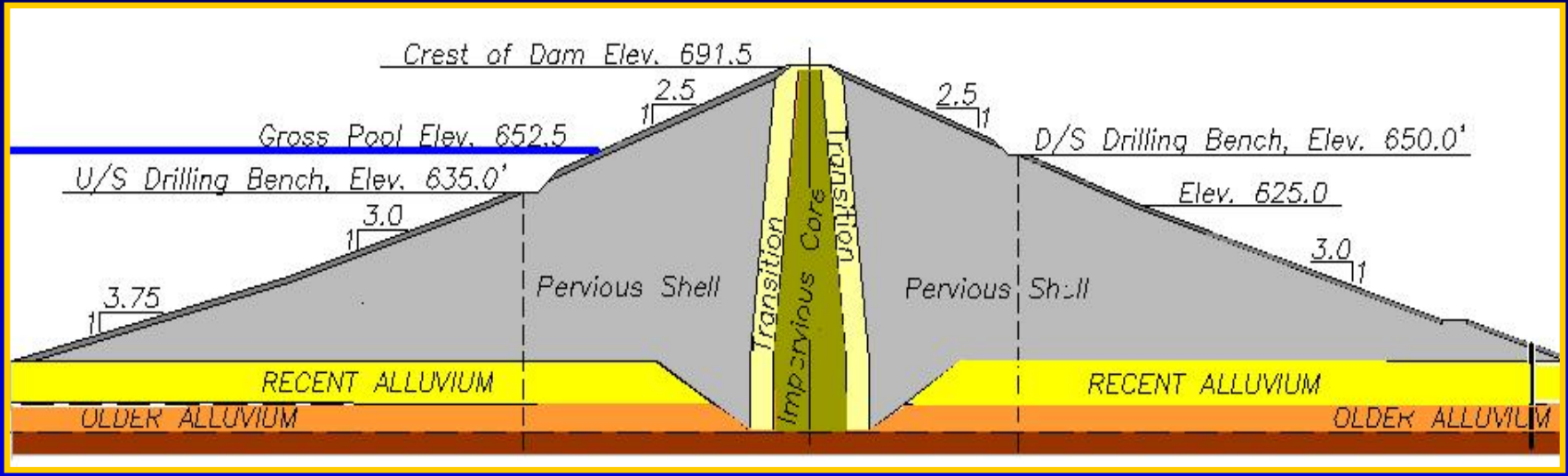
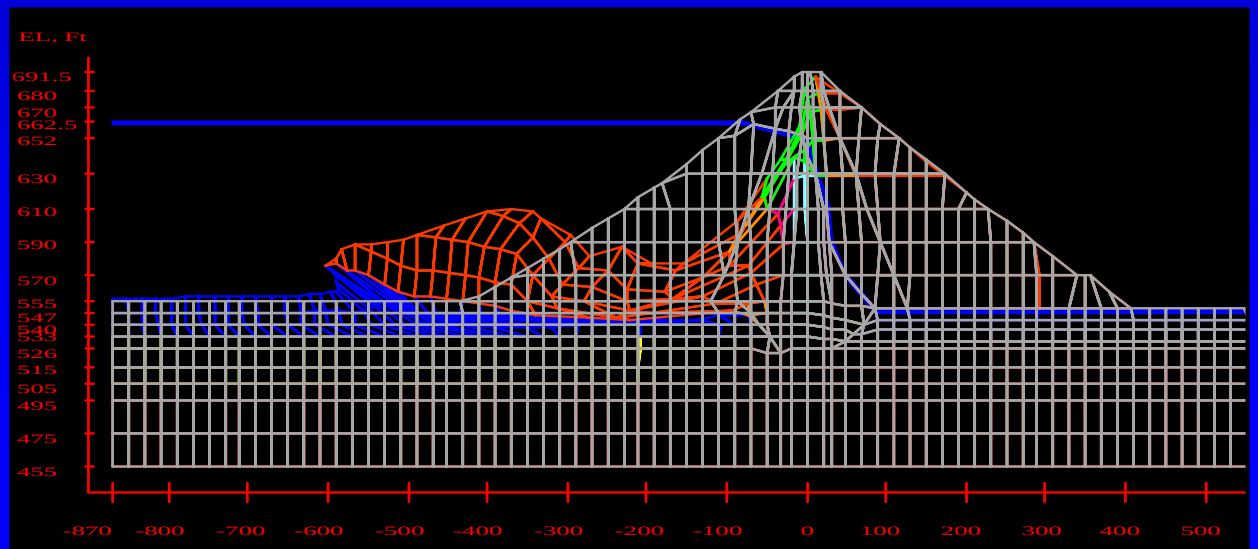
Seismic Deformation





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Spillway Stability

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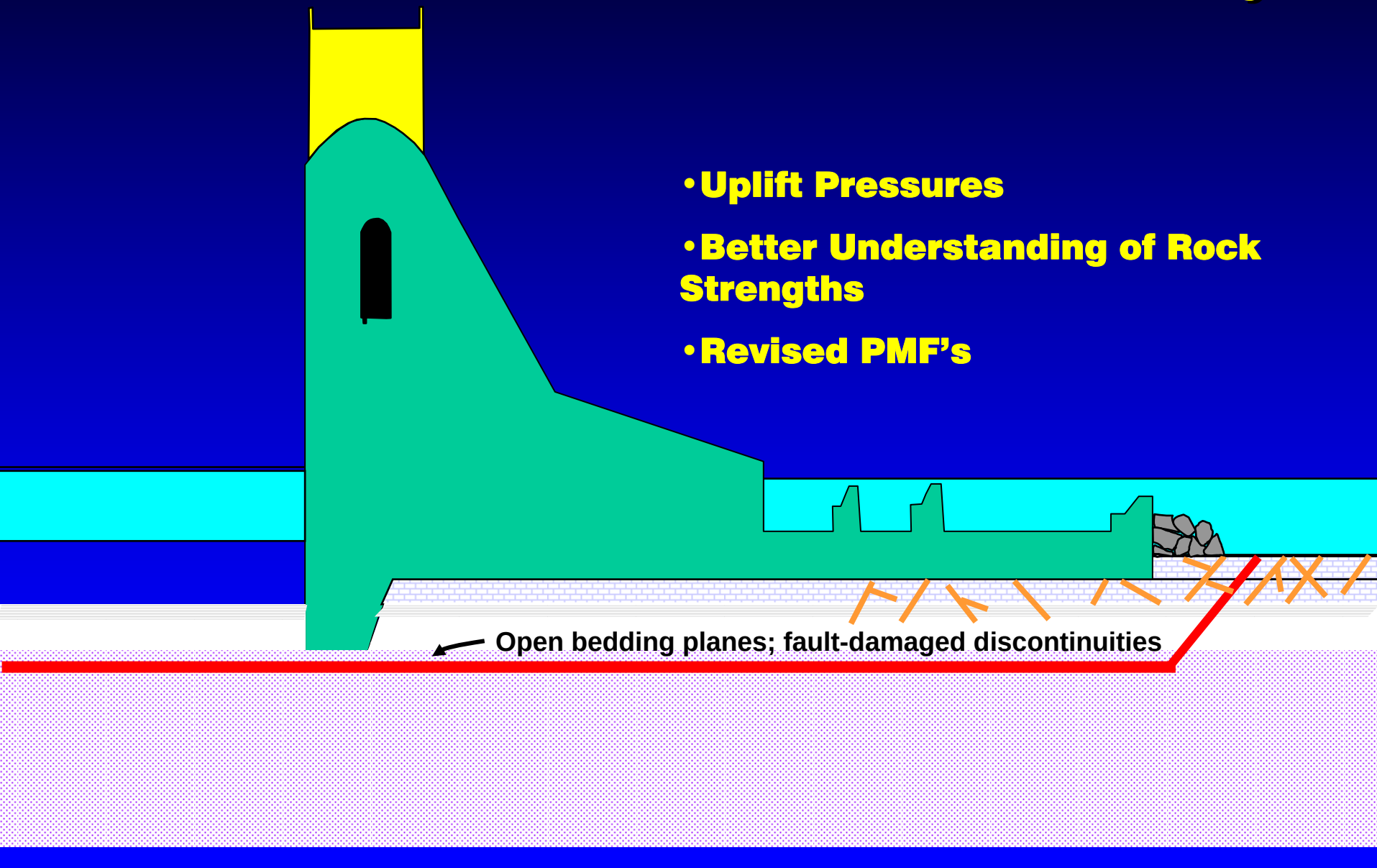
Foundation Stability

- Uplift Pressures
- Better Understanding of Rock Strengths
- Revised PMF's



Gate Deterioration

Gate Deterioration

A. Diaphragm: corrosion and holes developing in the steel.
B. End panel: corrosion and loss of structural support.

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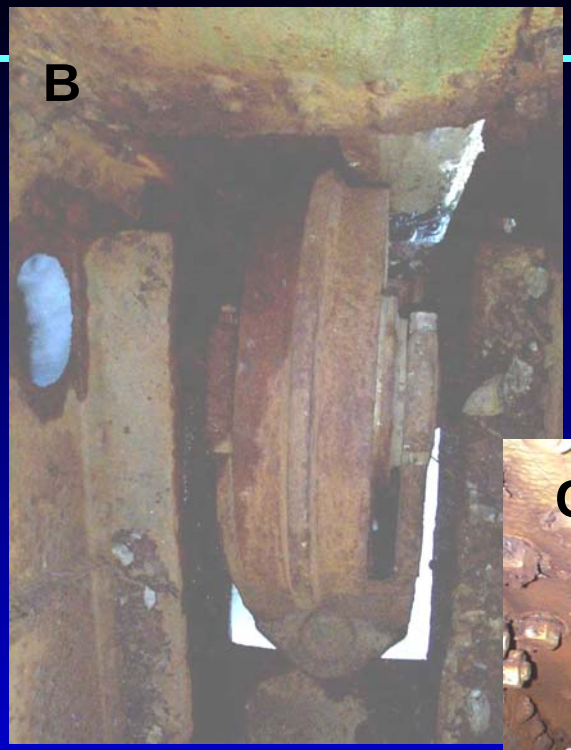

A. Gate pickup assembly.
B. Guide wheel truck assembly.
C. Truck assembly removed for repair.
D. Bolts, nuts, and rivets are beyond recognition.

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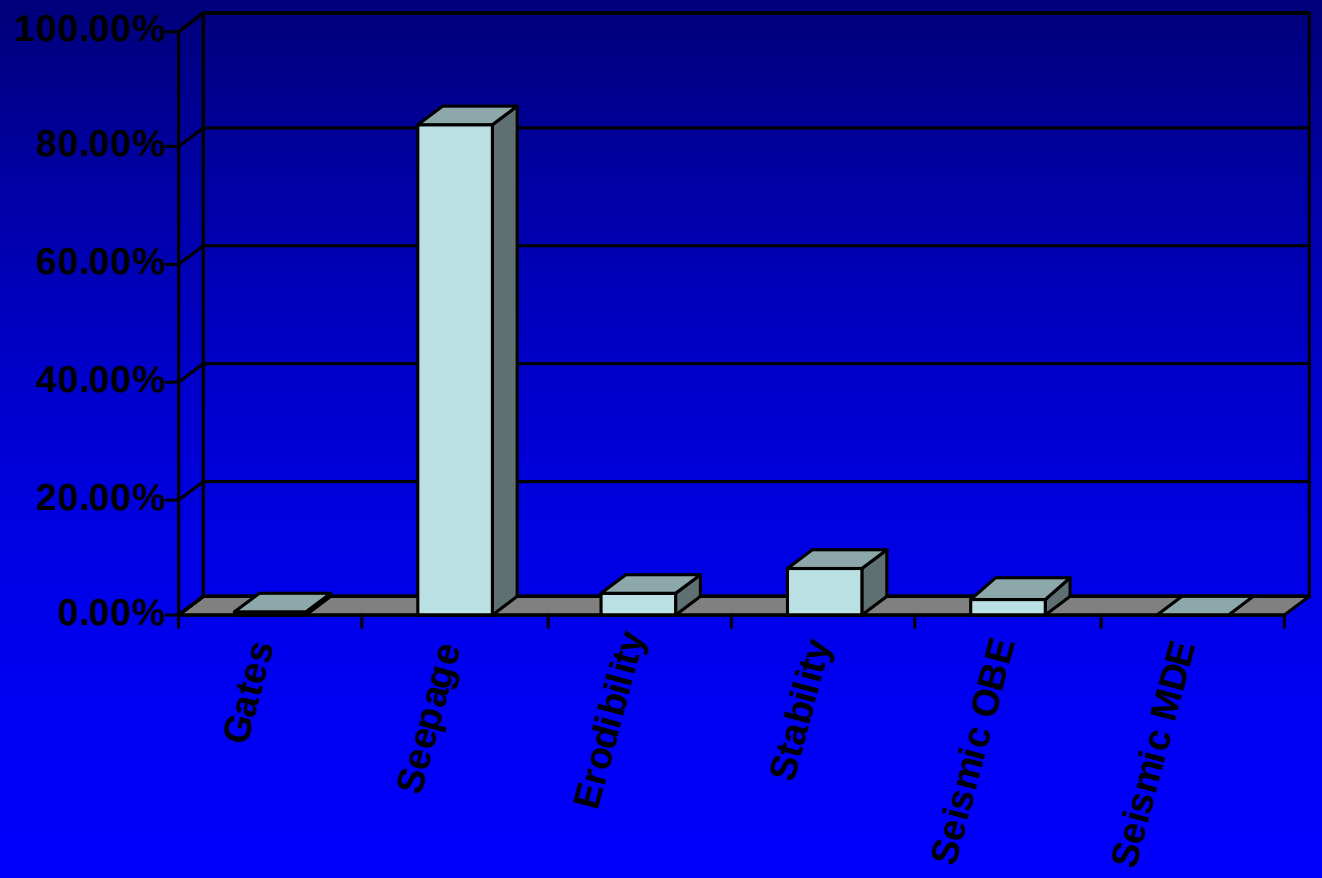
2005 SPRA TOTAL CONTRIBUTION TO RISK



Deficiencies That Could Lead to Breach and Are Present in Normal Load Conditions Generate the Highest Risk.

WHATS NEXT?

- Continue SPRA For The Next 10% (SPRA Team)
- Develop A Rigorous PRA Tool (Methodology Team) Will Be Incorporated Into PI Process
- Overhaul Dam Safety Program Based On Risk (Policy Team)