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:

- **Screening** portfolio risk analysis (SPRA)
- **Portfolio** risk analysis (PRA) for safety improvement
- **Project or site specific** risk analysis for risk management actions or project improvements
Probabilistic, Risk-Based Method of Determining Relative Risk

Implemented Via 3 Multidiscipline National Technical Cadres

20% of Corps Dams Screened to Date.
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
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
Feature Failure Mode Performance

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

<table>
<thead>
<tr>
<th>Feature State According to Standards &amp; Criteria</th>
<th>Modifier to New Dam Value</th>
<th>Variable Name</th>
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</table>
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.

<table>
<thead>
<tr>
<th>(a) Concrete Structures</th>
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<tr>
<td>Breach</td>
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<td>Minor</td>
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<td>Major</td>
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<table>
<thead>
<tr>
<th>(b) Embankment and Dikes</th>
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<td>Minor</td>
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<td>Major</td>
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</table>
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
Districts give a presentation based on information request sent out by Headquarters.
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
Cadre members then individually rate each feature.
• 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.
Consequences are then input and the spreadsheet is completed.
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.
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
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<th>Normal Water Level</th>
<th>50% Exceedence Duration Normal Water Level with OBE</th>
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<th>Extreme - (PMF)</th>
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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
USACE DAM SAFETY PROGRAM - SPRA RESULTS
(FY05 and FY06)

Priority Projects for Risk Reduction Investments
(Investigations, Studies, Reports, P&S, etc)

- Progressive Deterioration
- Significantly Inadequate
- Important Dam Safety Deficiencies
- All Others

Increasing Probability of Unsatisfactory Performance
Increasing Life Risk
**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.
The top 25 projects from the initial round SPRA FY05 were reviewed and examples of deficiencies that were considered inadequate are presented.
Inadequate Seepage Control
High Toe Pressures
Foundations Seepage and Piping (Karst)

Development of Piping and Sinkholes

Earth Dam on Limestone Foundation
Foundations Seepage and Piping (Karst)
Foundations Seepage and Piping (Karst)
Abutment Seepage (Karst)
Abutment Seepage
Inadequate Abutment Treatment
Inadequate Filter
Inadequate Filter

Sinkhole

Earth Embankment

Rock Toe
PIPING INTO A CONDUIT
Slope Stability
Spillway Erosion
Spillway Erosion
Monolith Stability (PMF)

- El. 1375.0’
- Axis of Dam
- Monolith 12
- Foundation Drains
- Groundline
- Top of Rock
- 137’

Inspection Gallery
El. 1375.0’

Current

Grout Curtain
Seismic Deformation

Crest of Dam Elev. 591.5

Gross Pool Elev. 652.5

U/S Drilling Bench, Elev. 635.0'

D/S Drilling Bench, Elev. 650.0'

Elev. 625.0

Pervious Shell

Transition

Recurrent Core Construction

Recurrent Alluvium

Older Alluvium

Recent Alluvium

EL, Ft
Foundation Stability

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

Open bedding planes; fault-damaged discontinuities
Gate Deterioration
A. Diaphragm: corrosion and holes developing in the steel.
B. End panel: corrosion and loss of structural support.
A. Gate pickup assembly.
B. Guide wheel truck assembly.
C. Truck assembly removed for repair.
D. Bolts, nuts, and rivets are beyond recognition.
Deficiencies That Could Lead to Breach and Are Present in Normal Load Conditions Generate the Highest Risk.
What's 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)