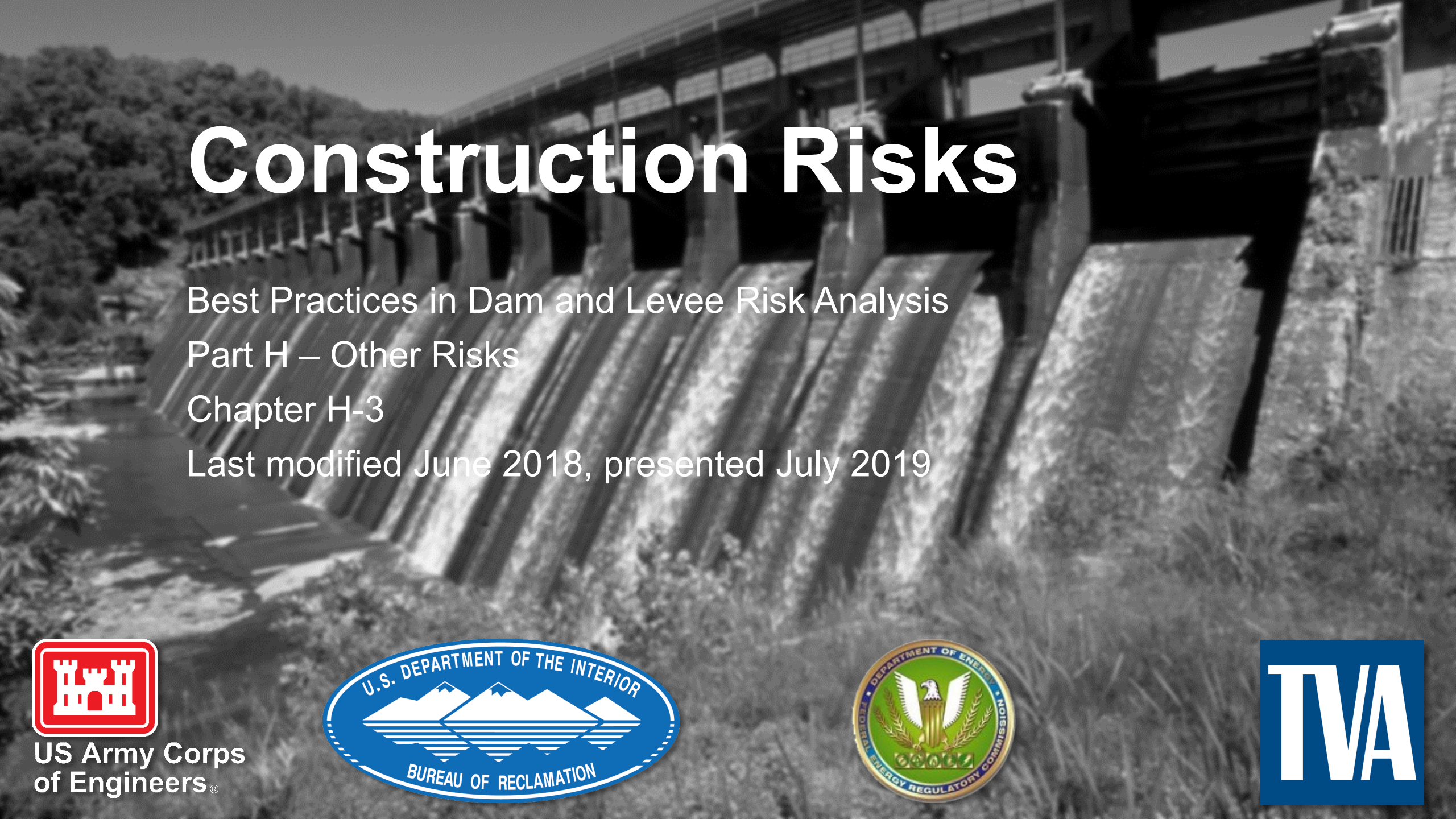


Construction Risks

Best Practices in Dam and Levee Risk Analysis

Part H – Other Risks

Chapter H-3

Last modified June 2018, presented July 2019

US Army Corps of Engineers®

U.S. DEPARTMENT OF THE INTERIOR BUREAU OF RECLAMATION

DEPARTMENT OF ENERGY FEDERAL ENERGY REGULATORY COMMISSION

TVA

Outline

- Objectives and Key Concepts
- Background and History
- General Conditions and Critical Considerations
- Spillway modifications
- Cofferdams

Objectives

- Understand conditions that could lead to increased risk during construction
- Understand how to construct an event tree to represent those construction risks

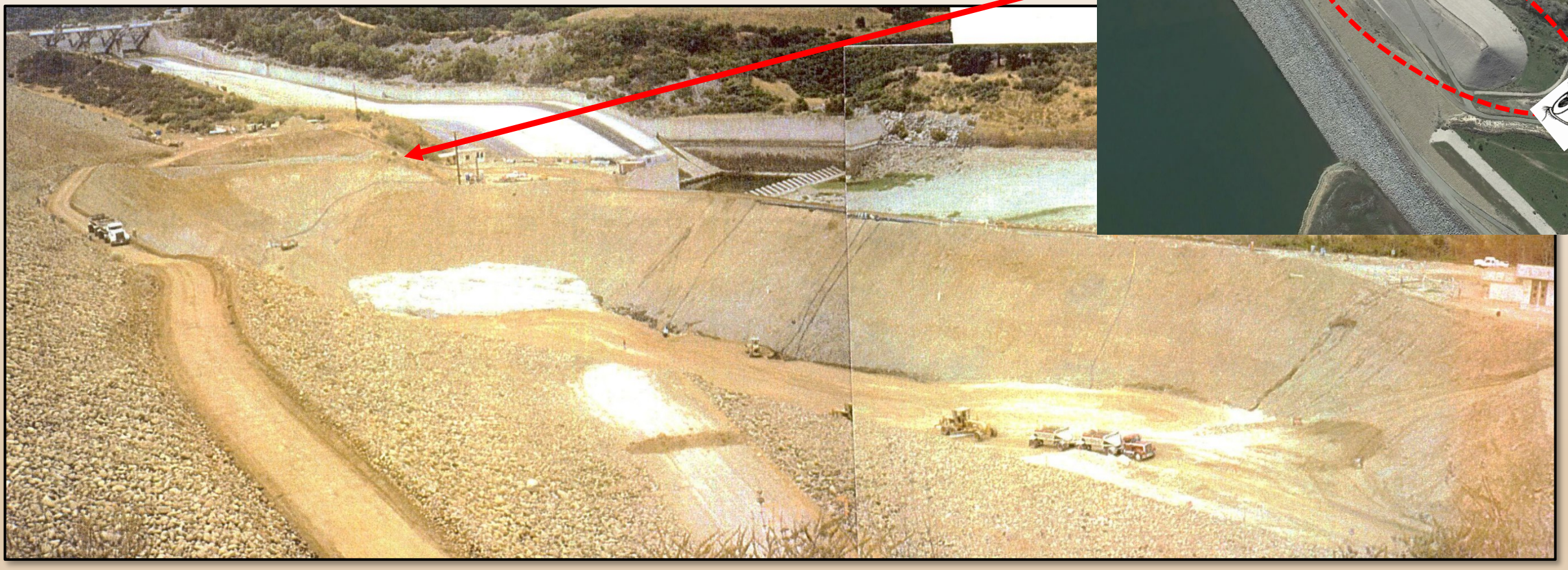
Key Concepts

- Construction “risk” can have different meanings, such as cost risk or schedule risk to construction. For Best Practices, construction risk refers to refers to the failure probability, annualized life loss, individual risk or societal risk that exists during the construction of risk reduction measures.
- Can be used to evaluate non-construction activities.
- Perhaps most important concept is for decision makers to understand construction risks and cost trade-offs.
- Do no harm.

Outline

- Objectives and Key Concepts
- **Background and History**
- General Conditions and Critical Considerations
- Spillway modifications
- Cofferdams

Example



More Examples

Outline

- Objectives and Key Concepts
- Background and History
- **General Conditions and Critical Considerations**
- Spillway modifications
- Cofferdams

General Conditions – Excavation

- Open excavations near the downstream or landside toe of the structure or within the structure can:
  - Reduce stability for normal conditions
  - Change the internal erosion potential
  - Reduce seismic stability potential
- The temporary risks can be much higher than the existing risks

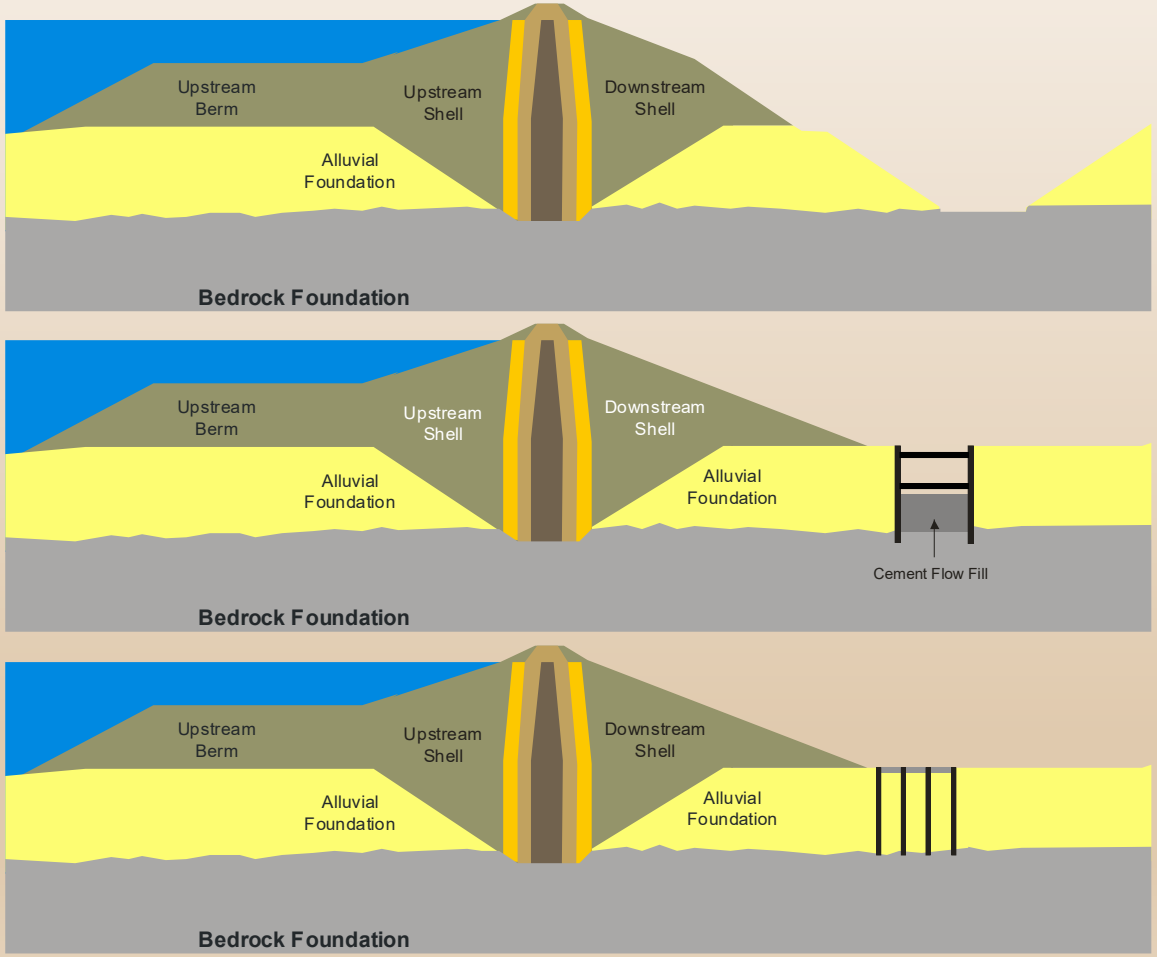
General Conditions – Gates, Structures, and Cofferdams

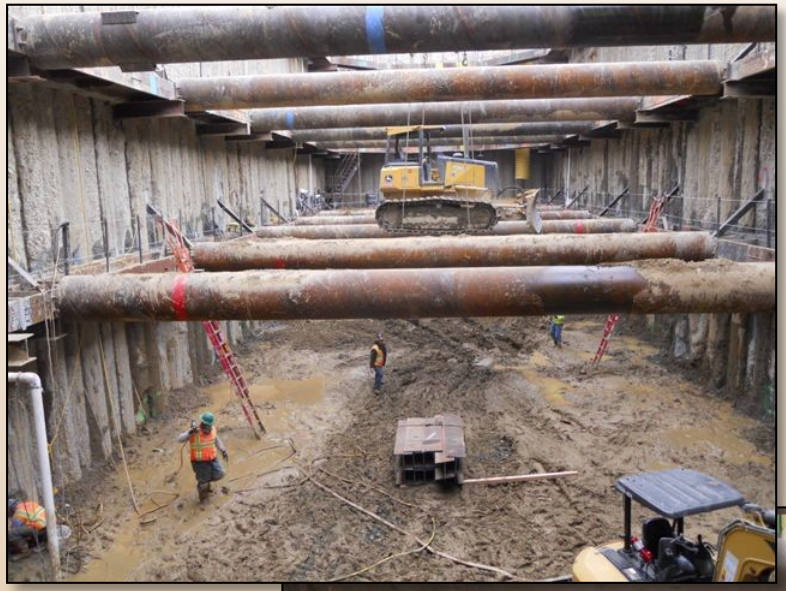
- Modifications to appurtenant structures that change the risks associated with a dam include:
  - Spillway and spillway wall modifications
  - Gate modifications
  - Outlet works modifications
- In some cases, we construct cofferdams to reduce risk during construction
  - Cofferdam stability is important
  - Cofferdam height is important

Critical Considerations

- Duration of Critical Construction Activities
- Magnitude of Impacts to the Existing Structure
- Overall Duration and Timing
- Evaluating Risks to the Structure
- Dewatering Reliability
- Construction Changes on Stability Factors
- Contingency Plans
- Warning Time
- Reservoir Restriction

Downstream Foundation Excavation Example





Downstream Foundation Excavation – Alternatives Considered

Alternatives

- Open Excavation (4 variants)
- Double Wall Excavation (3 variants)
- Cellular Excavation (2 variants)
- Lattice Cells (2 variants)
- Drilled Shafts (2 variants)
- Drilled Hexagonal Cells (2 variants)
- No Action

Considerations

- Field Construction Cost
- Ability to Meet Long Term Risk Reduction Objectives
- Risk During Construction
- Cost Uncertainty
- Schedule Delay Potential
- Technical Concerns or Lack of Concern

Downstream Foundation Excavation – Event Tree

- Loading (reservoir rises)
  - Dewatering System Works
    - Slope Becomes Unstable
      - Detection is Unsuccessful
        - Embankment Breaches
          - Consequences

- Loading (reservoir rises)
  - Dewatering System Fails
    - Slope Becomes Unstable
      - Detection is Unsuccessful
        - Embankment Breaches
          - Consequences

Downstream Foundation Excavation – Summary of Risks

	Duration	Field Cost ($ Million)	Additional Risk During Construction
1 – Open Excavation	8 Months	$36-43	5.0 – 16.0
2 – Double Wall	12-17 Months	$65-70	3.0 – 5.0
3 – Cellular	23-42 Months	$70	1.0 – 4.0
4 – Lattice Structure	N/A	$58-61	1.0
5 – Drilled Shafts	N/A	$104	1.0
6 – Hexagonal Cells	24-30 Months	$66-77	1.0 - 4.0
7 – No Construction	0 Months*	$0	1.0

The duration of increased risk (compared to the baseline) is a key consideration

Toe Foundation Excavation – Other Considerations

	Technical Concerns	Long Term Risk Reduction	Risk of Construction Delays
1 – Open Excavation	Significant	Yes	High
2 – Double Wall	Some to Significant	Yes	Moderate
3 – Cellular	Some	Yes	Low
4 – Lattice Structure	Very Significant	No	None
5 – Drilled Shafts	Significant	No	None
6 – Hexagonal Cells	Some	Yes	Very Low
7 – No Construction	None	No	None

The duration of increased risk (compared to the baseline) is a key consideration

During Construction

Picture during construction
with reservoir up

Outline

- Objectives and Key Concepts
- Background and History
- General Conditions and Critical Considerations
- **Spillway modifications**
- Cofferdams

Spillway Modification Construction

Spillway Mod. Construction – Alternatives Considered

Key Considerations

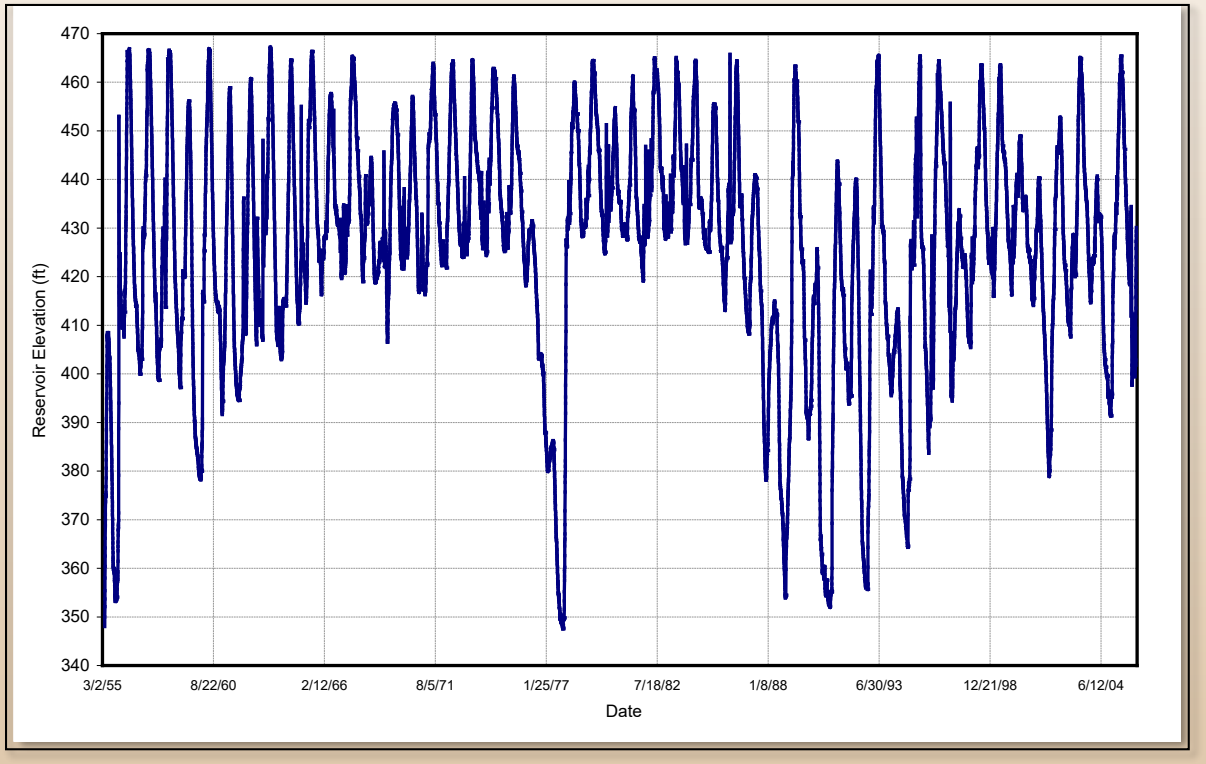
- Level of protection for the cofferdam
- Operational changes required during construction
- Construction duration

Alternatives Considered

- Replace Spillway Chute
- Replace Spillway Chute (Behind Cofferdam)
- Permanent Reservoir Restriction
- No Action

Spillway Modification – Example Event Tree

- Starting Reservoir Pool (reservoir restrictions are common)
  - Flood Loading
    - Cofferdam Overtops
      - Detection and Intervention Unsuccessful
        - Cofferdam Breaches
          - Consequences



There are many potential scenarios that would need custom event trees.

Spillway Modification – Summary of Risks

- Reducing spillway capacity or lowering dam crest may increase risk of dam overtopping during large floods
- Construction risks can be minimized by:
  - Schedule or stage work to reduce risk (minimize exposure during flood season)
  - Temporarily restrict reservoir during critical phases of work
- Costs of alternative construction schedules need to be identified and portrayed

Spillway Construction – Summary of Risks

- Seasonal floods and starting reservoir water surface elevations may need to be considered if construction activities are limited to certain months or periods
- May need to consider more remote floods if dam overtopping is an issue
- For construction only risks – need to portray potential for more frequent floods

Outline

- Objectives and Key Concepts
- Background and History
- General Conditions and Critical Considerations
- Risk Duration
- **Cofferdams**

Cofferdams

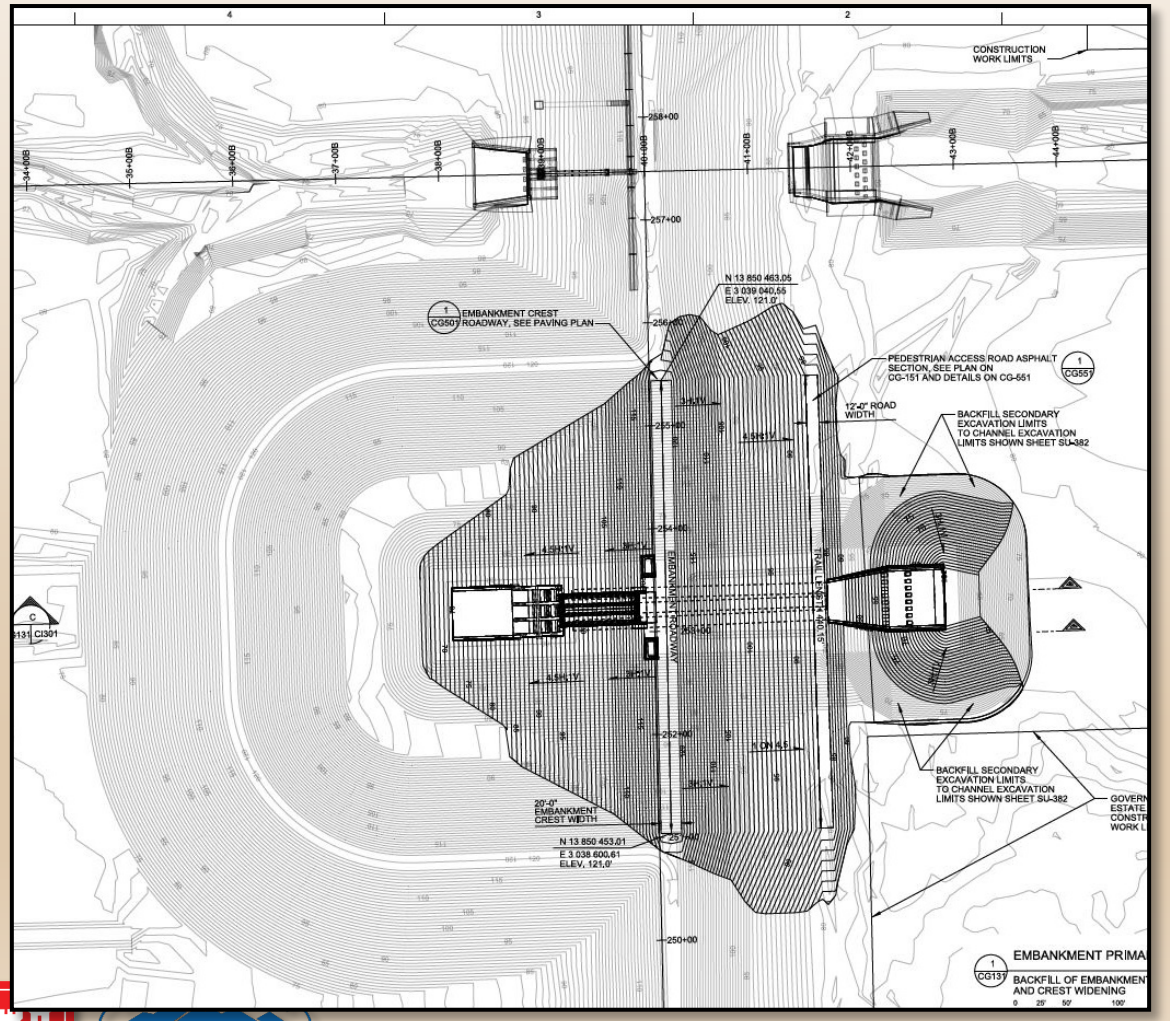
Historical Practice

- Cofferdams were constructed to protect the construction site from flooding for the duration of construction
- Typical historical practice has been ?? year level of protection for risks that impact construction (not dam failure.)
- Contractors are typically interested in reducing cofferdam costs – they are usually lump sum items in bid schedules

Key Concepts

- Cofferdam height should be commensurate with the risk and consequences
- Robustness should be explicitly considered
- For dams with high consequences, cofferdams will likely require the same level of design and attention as the dam itself

Cofferdams


CONSTRUCTION WORK LIMITS
EMBANKMENT CREST ROADWAY, SEE PAVING PLAN
PEDESTRIAN ACCESS ROAD ASPHALT SECTION, SEE PLAN ON CG-151 AND DETAILS ON CG-551
12'-0" ROAD WIDTH
BACKFILL SECONDARY EXCAVATION LIMITS TO CHANNEL EXCAVATION LIMITS SHOWN SHEET SU-382
20'-0" EMBANKMENT CREST WIDTH
BACKFILL OF EMBANKMENT AND CREST WIDENING

Cofferdams – Alternatives Considered

Some Key Considerations

- Level of Protection
- Flood Frequency, Duration, and Warning Time
- Construction Site Safety
- Redundancy
- Contingency Plans
- Reservoir Restriction

Potential Alternatives

- Partial Height Cofferdam
- Full Height Cofferdam
- Earthen Cofferdam with Cutoff Wall (concrete, steel)
- Cellular cofferdam
- Concrete Cofferdam

Cofferdam Failure – Event Tree

These are typical failure modes for cofferdams:

- Overtopping
- Instability
  - Scour can lead to instability
- Internal erosion through embankment or foundation
- Failure at the contact with existing structures or slopes

Typical event trees have been provided earlier in presentation or in other presentations. Customization will be needed.

Cofferdams – Summary of Risks

- Event tree will need to address if the cofferdam failure could lead to more severe event such as loss of additional pool due to down cutting during cofferdam breach discharge.
- Typically the consequences of cofferdam failure vary throughout the construction duration as the protected structure gets built.

Take Away

- There are many ways to deal with the increase in risk during construction, some of which involve additional funding to offset risk.
- Construction timing and schedule adjustments are evaluated for a given alternative.
- The duration of increased risk (compared to the baseline) is a key consideration
- Matrices are often used to evaluate the key information.
- A risk informed decision on construction risk can be made if all of the key information is considered and made available to the decision makers in a timely fashion.
- Do no harm.