US Army Corps
of Engineers

USACE Hydrologic Safety Assessment

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Presentation Topics

- **Overview**
- Hydrologic considerations
- Hydraulic considerations
- Typical alternatives used to correct deficiencies

INFLOW DESIGN FLOODS FOR DAMS AND RESERVOIRS

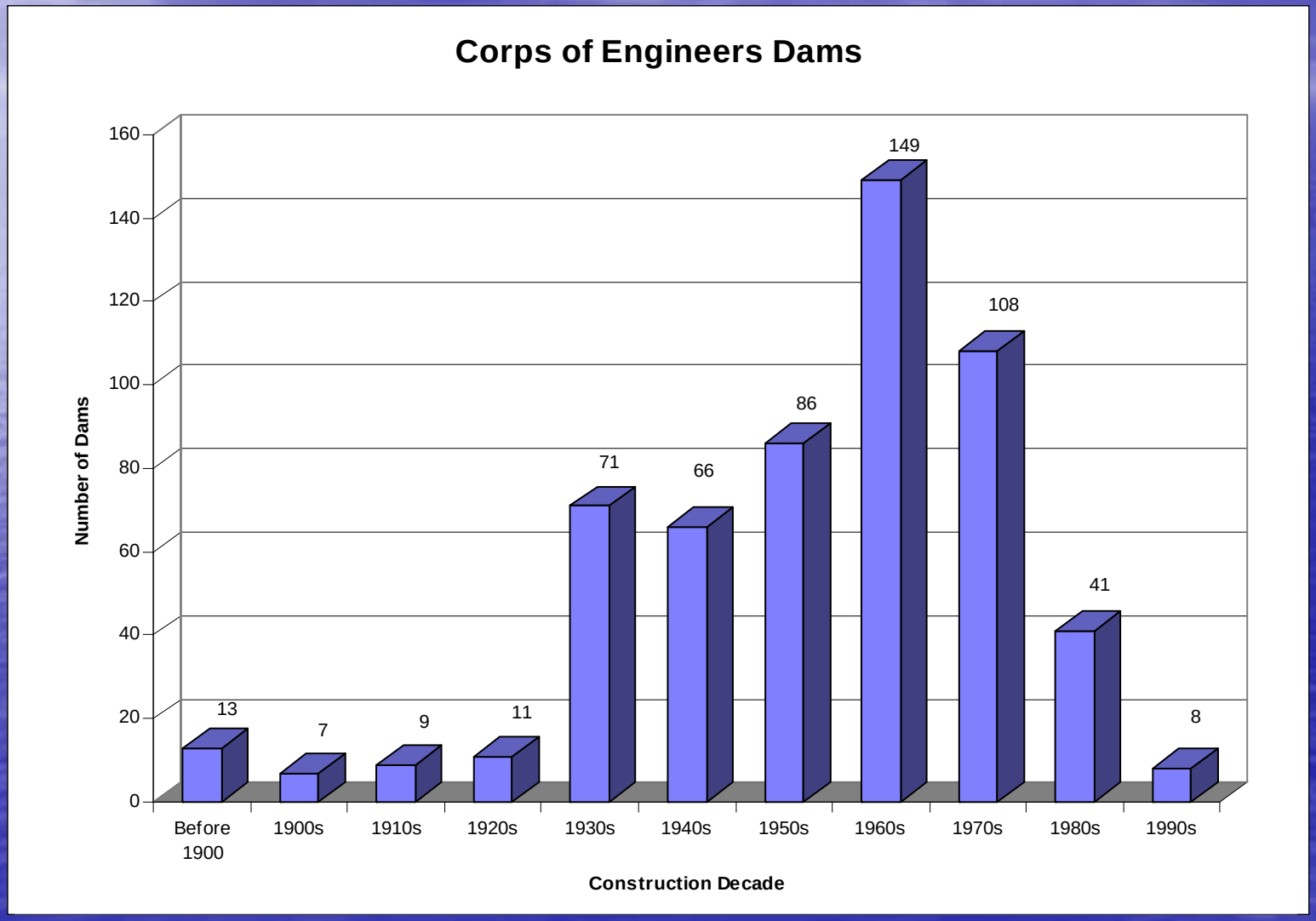
General Policy. **" It is the Corps of Engineers policy that dams designed, constructed, or operated by the Corps will not create a threat of loss of life or inordinate property damage. Departures from accepted policy or practice will not be made in the design of a dam simply to reduce cost. Every phase of the planning, design, construction, and operation of a dam will be accomplished to assure that it is safe, efficient, and reliable.**

ER 1110-8-2(FR) - Inflow Design Floods for Dams and Reservoirs
dated 1 March 1991

Purpose of Dam Safety Assurance

EC 1110-2-6061 Safety of Dams – Policy and Procedures which supercedes ER 1110-2-1155 Dam Safety Assurance (DSA) Program - "The Dam Safety Assurance Program provides for modification of completed Corps of Engineers dams and related facilities, when deemed necessary for safety purposes due to new hydrologic or seismic data or changes in state of the art design or construction criteria."

Corps Civil Works Dam Construction



Dam Safety Problem Identification

- 64% of Corps' Dams are over 30 years old
- 28% have reached or exceeded their 50-yr economic design life
- 11% (65) of the Corps' Dams have been identified as being hydrologically or seismically deficient, based on current methodologies & criteria
- Many are untested for a full pool condition
- The cost to fix these deficiencies ranges between $1.3 and $6.5 billion with limited funds available

Source: USACE Risk Analysis for Dam Safety Research Unit (2001)

Reasons for Dam Failures

- OVERTOPPING - 34% of all failures (nationally)
  - Inadequate Spillway Design
  - Debris Blockage of Spillway
  - Settlement of Dam Crest
- FOUNDATION DEFECTS - 30% of all failures
  - Differential Settlement
  - Sliding and Slope Instability
  - High Uplift Pressures
  - Uncontrolled Foundation Seepage
- PIPING AND SEEPAGE - 20%
  - Internal Erosion Through Dam Caused by Seepage-"Piping"
  - Seepage and Erosion Along Hydraulic Structures Such as Outlet
  - Conduits or Spillways, or Leakage Through Animal Burrows
  - Cracks in Dam
- CONDUITS AND VALVES - 10%
  - Piping of Embankment Material Into Conduit Through Joints or Cracks
- OTHER - 6%

Topics

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- **Hydrologic considerations**
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Hydrologic Considerations

- The Inflow Design Flood (IDF)
  - Inflow Design Flood is the flood hydrograph used in the design of a dam and its appurtenant works (particularly outlet works)
- Probable Maximum Flood (PMF)
  - The most severe flood that is considered reasonably possible at a particular location as a result of hydrologic and meteorological conditions. NOTE: For most Corps storage projects this used as the Inflow Design Flood.

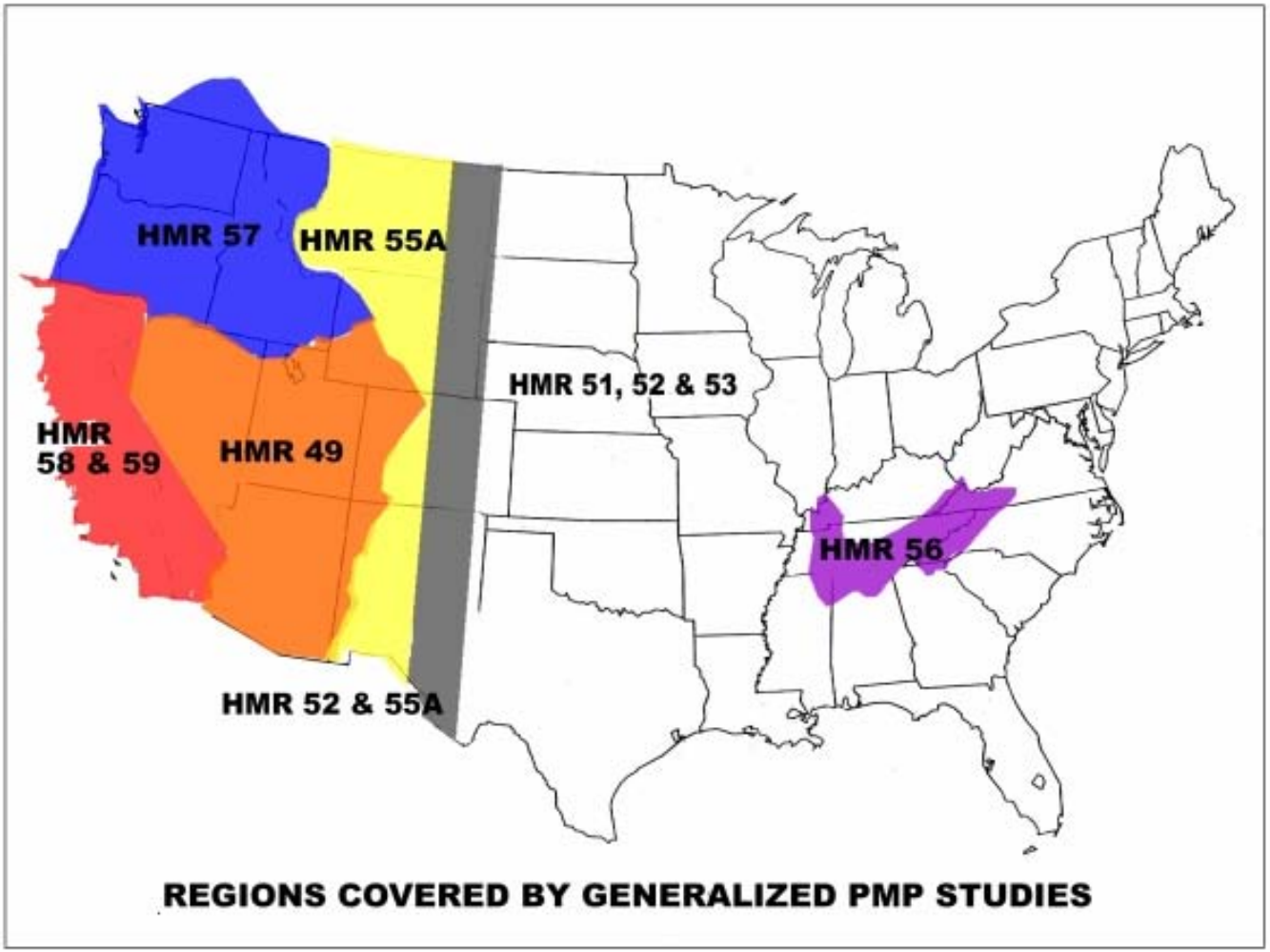
Hydrologic Standard for Corps Dams

Standard	Description	Inflow Design Flood
1	Risk to life and property	Probable Maximum Flood (PMF)
2	Run of river projects	Standard Project Flood (SPF)
3	Negligible incremental impacts due to failure	Base Safety Condition (minimum ½ PMF)
4	Small dams	1% Annual Exceedence

Hydrologic Criteria

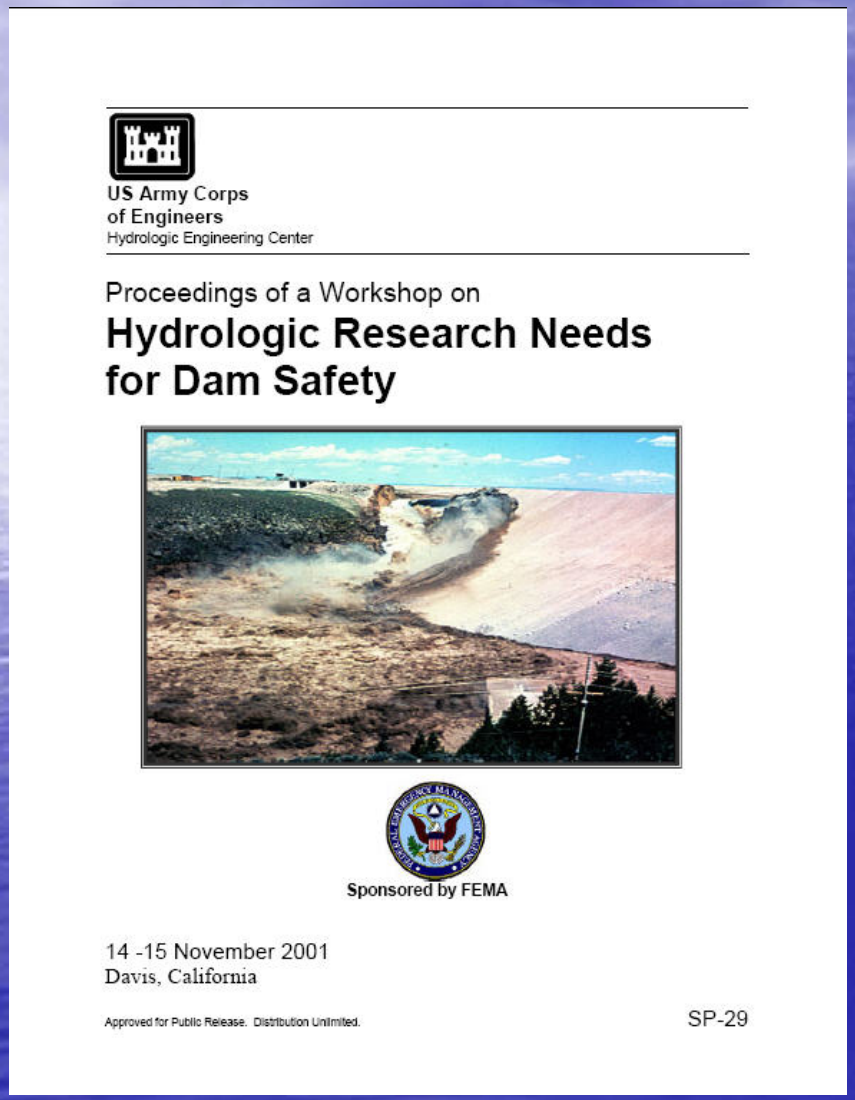
- Probable Maximum Precipitation
  - Greatest precipitation physically possible for a particular area
- Probable Maximum Flood
  - Flood resulting from the probable maximum precipitation
- Threshold Flood
  - Maximum flood a dam can safely pass
- Base Safety Condition
  - Flood for which loss of life is not different between with and without failure conditions

Probable Maximum Precipitation



http://www.nws.noaa.gov/oh/hdsc/currentpmp.htm

Background



US Army Corps
of Engineers
Hydrologic Engineering Center

Proceedings of a Workshop on
Hydrologic Research Needs for Dam Safety

Sponsored by FEMA

14 -15 November 2001
Davis, California

Approved for Public Release. Distribution Unlimited.

SP-29

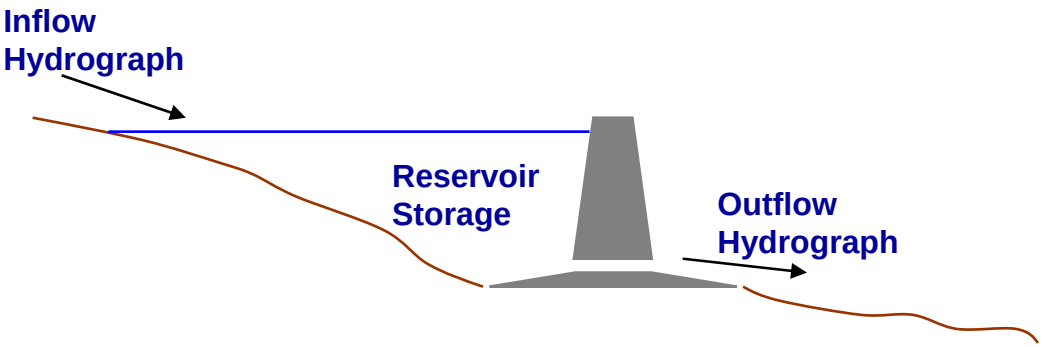
Workshop on Proposed Methods of Generating the Annual Exceedance Probability of the Probable Maximum Flood

26-27 July, 2005

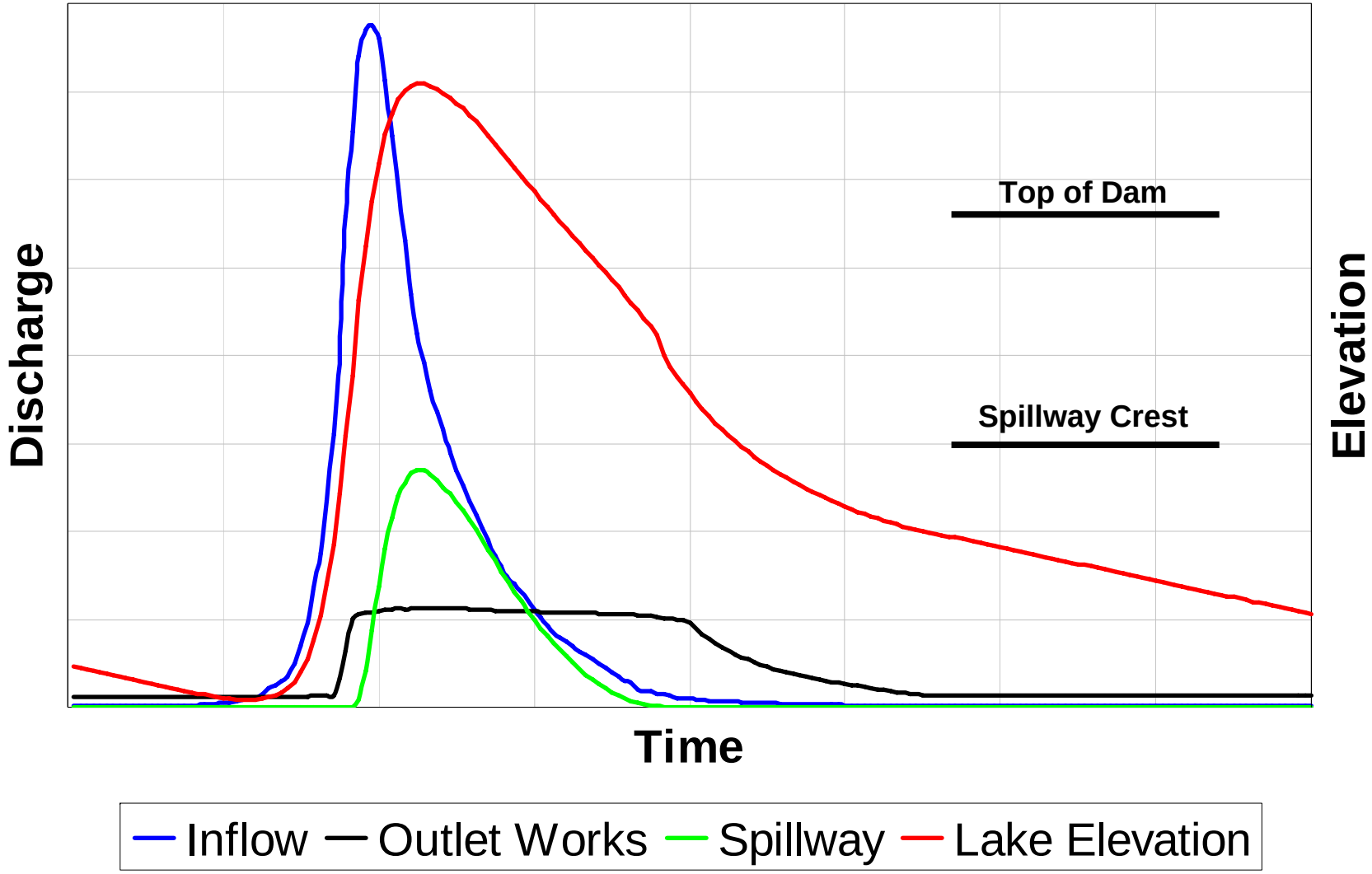
HEC, Davis CA

Hydrologic Routing

- Water control manual procedures
- Reservoir storage volume
- Outlet works and spillway capacity
- Antecedent conditions
- Pool elevation and outflow hydrographs



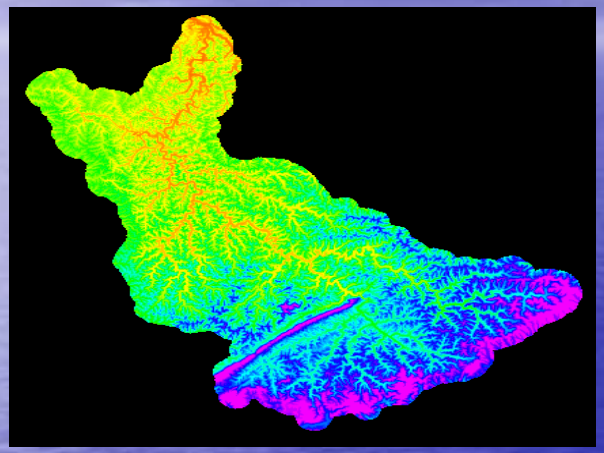
Hydrographs

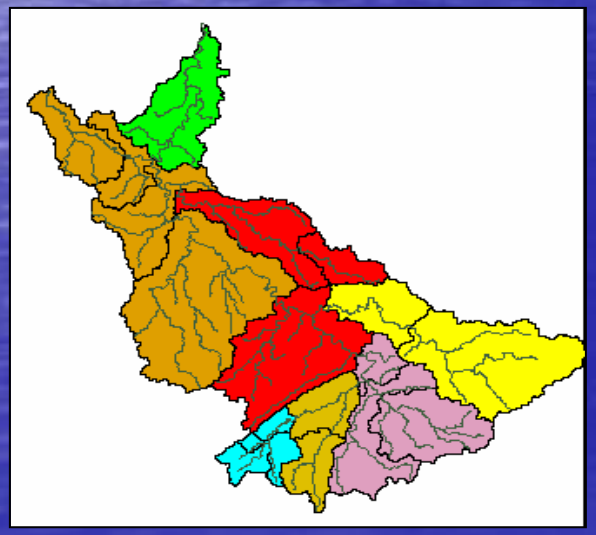


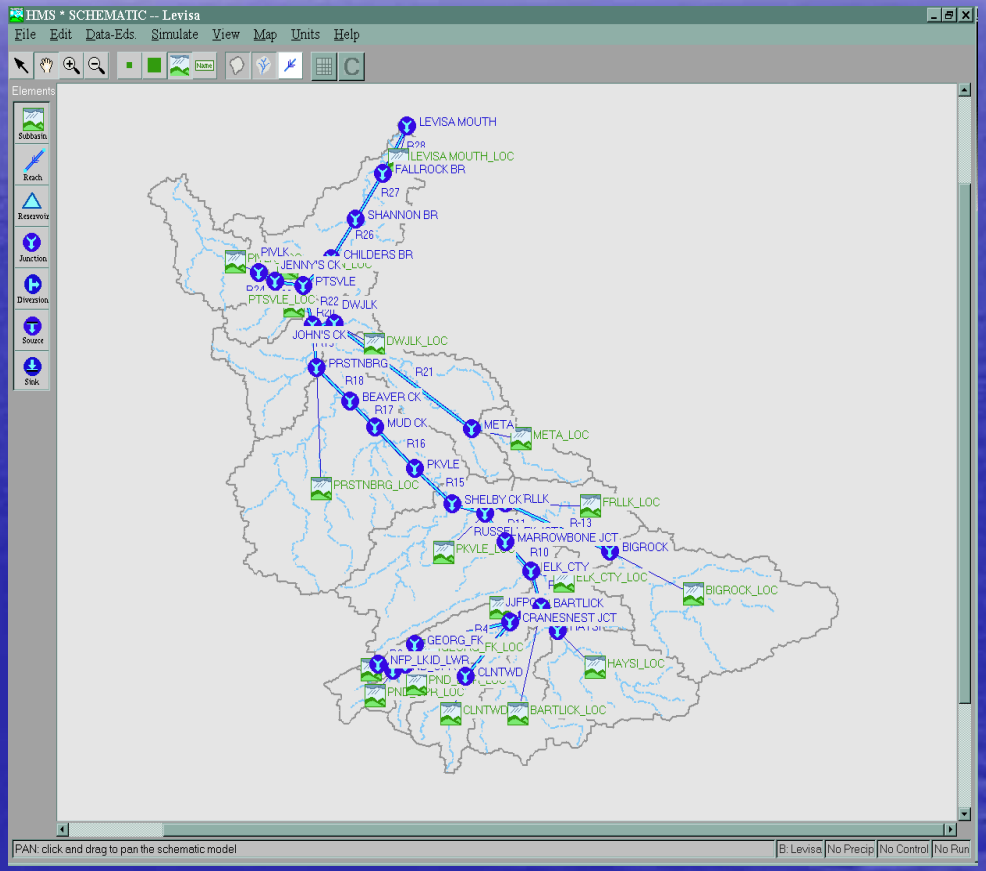
Hydrologic Evaluation

- Current design flood
- Are design limits exceeded?
  - Overtopping
  - Encroach on freeboard
  - Spillway capacity
  - Stilling basin
- What are the consequences?

Hydrologic Models



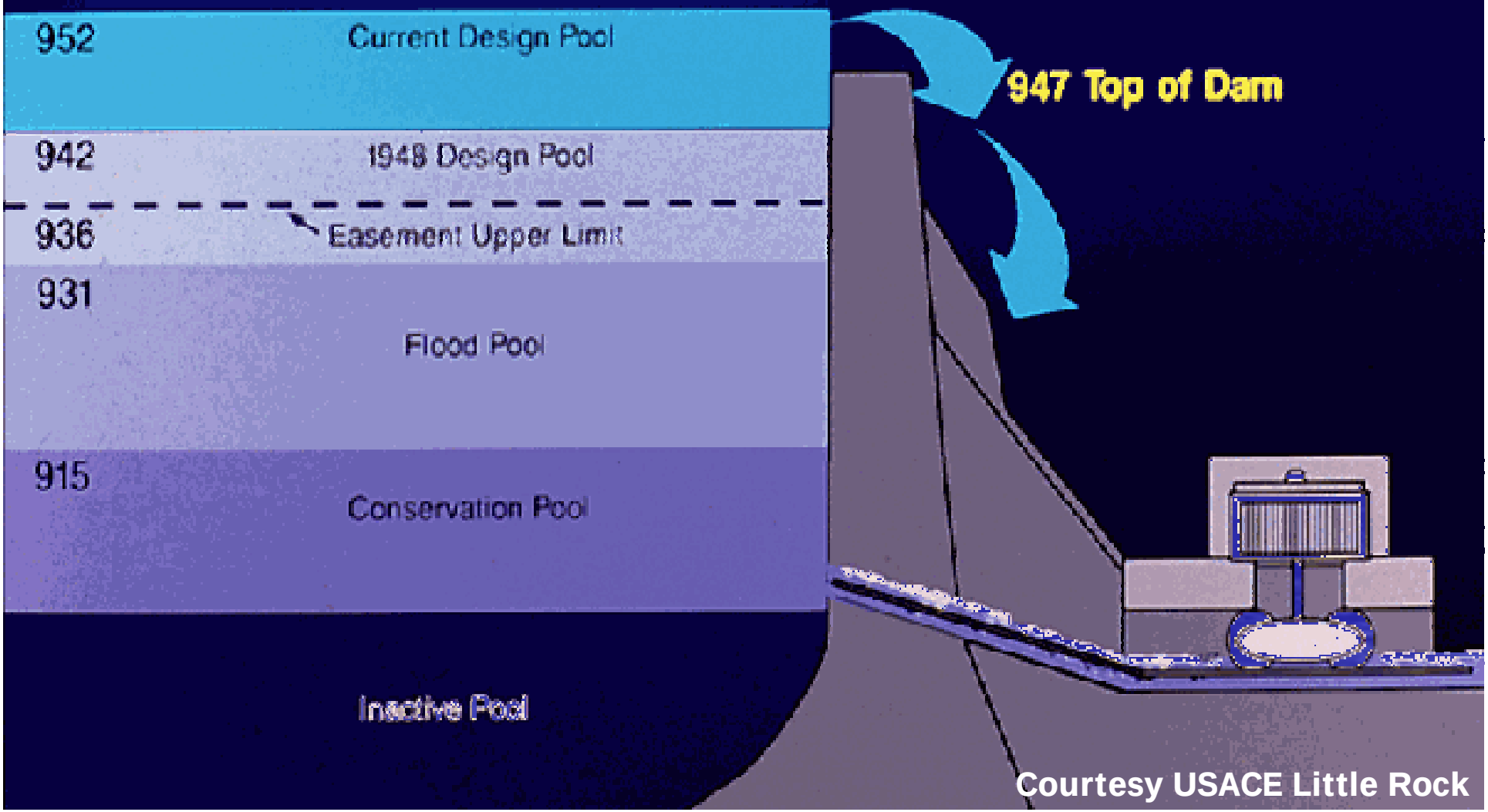




Hydrologic Considerations-DSA

- Has the IDF (PMF) changed?
- Has your elevation storage curve changed due to sedimentation ?
- D/S flow control limits might have changed; encroachment in the floodplain
- Operational constraints, can't go above a pool elevation due to Geotechnical concerns
- Other…

Table Rock Dam & Lake
Dam Safety Assurance



Courtesy USACE Little Rock

Topics

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- Hydrologic considerations
- **Hydraulic considerations**
- Typical alternatives used to correct deficiencies

Hydraulic Considerations

- Hydraulic Features
- Hydraulic Integrity!

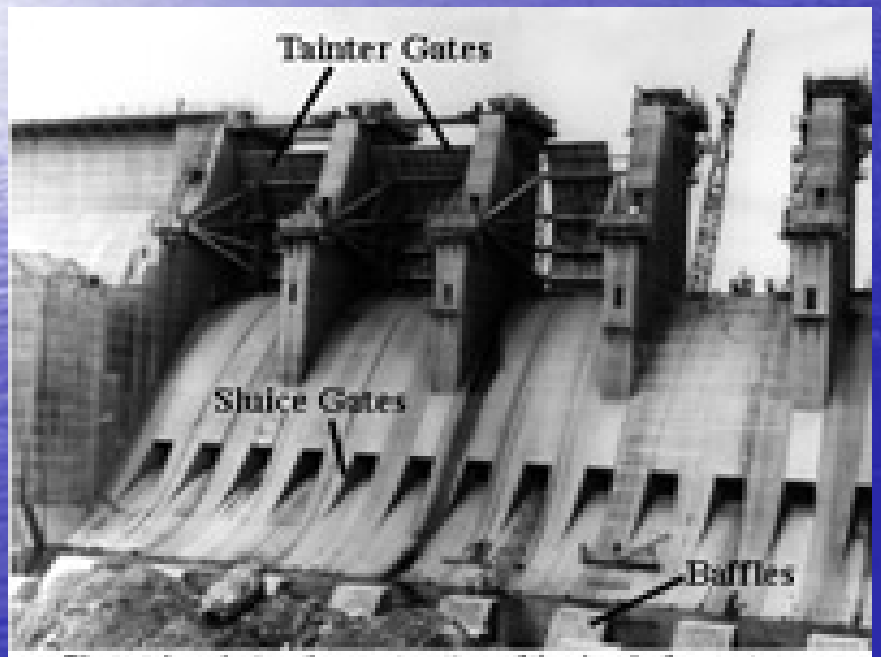


Photo taken during the construction of the dam before water filled the stilling basin and covered the baffles and sluice gates.

Hydraulic Considerations

- Spillway features, what do you have ?
  - Emergency or service spillway
- Spillway gates
  - Are they operational? Are you sure?
  - How are they operated? [staffing requirements]
  - When was the last time they were operated under load?

Hydraulic Considerations

- Spillway gates
  - During periodic inspections are they inspected?
  - Gate settings, how do you know the gate is really open 2 feet
  - Night time operations
  - Do you have vortex or cavitation problems?
  - Do you have any flow pattern requirements (this can often cause localized stilling basin erosion)

Hydraulic Considerations

- Spillway Channel
  - Lined (concrete) or unlined
  - Wave action in the chute
  - Crossover Waves
  - Erosion problems in the chute (increased roughness)
  - Joint Concerns
  - Vegetation may impede flows
    - flushing flows, sprays, vegetation removal

Water Management

- Project Operation
  - Failure of a project can be due to mis-operation
- Minimize mis-operation with documented procedures and plans
  - Periodic Inspections/Tests
  - Water Control Manuals

Hydraulic Considerations

Folsom Dam
July 1995

Hydraulic Considerations

Glen Canyon Dam

From DesertUSA.com. A monthly Internet-based magazine published by Digital West Media, Inc.

Glen Canyon Dam Erosion

Glen Canyon Dam, left spillway tunnel. Sept. 1983.

The “big hole” in the spillway invert was 11 meters deep.

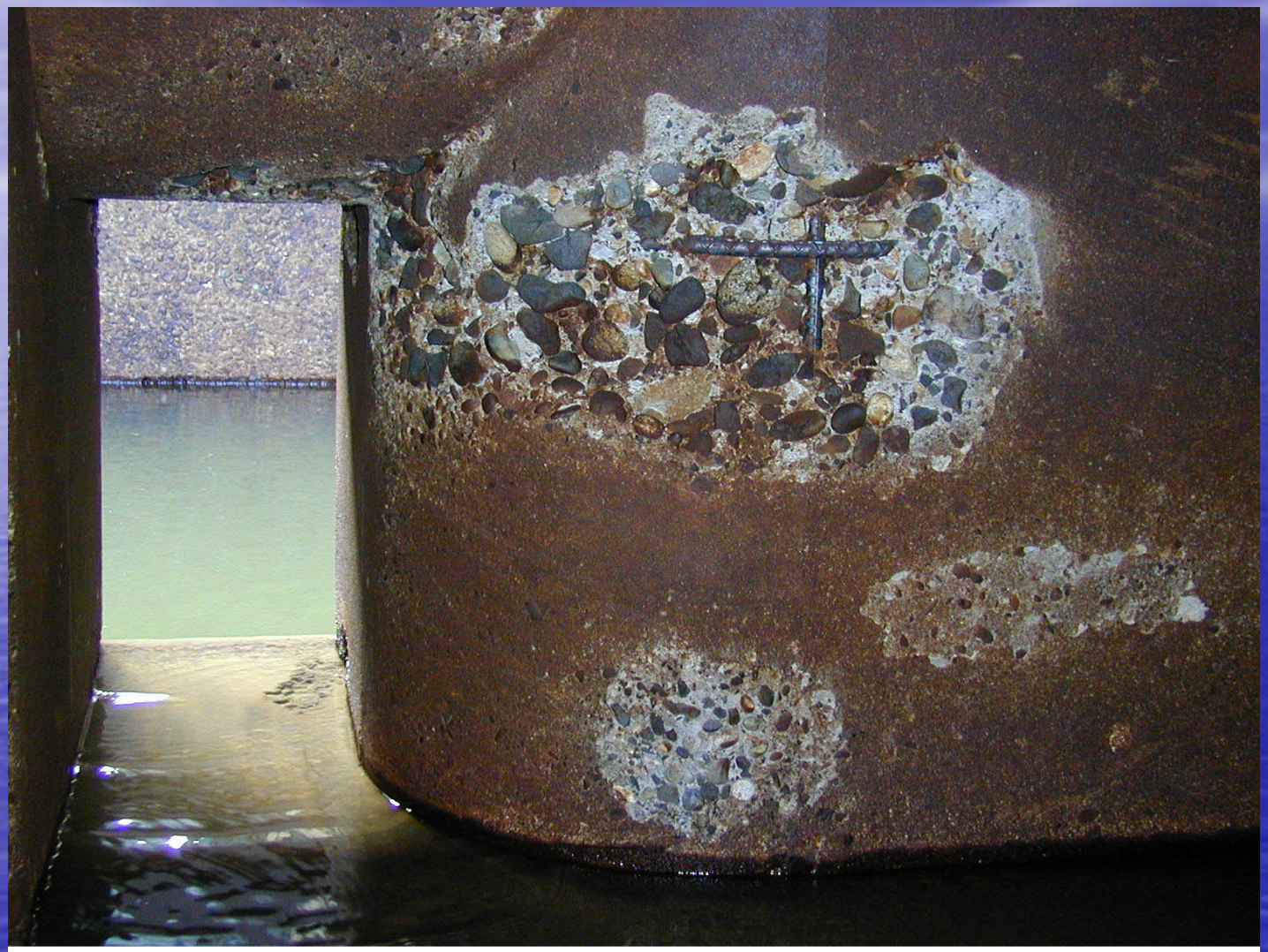
Hydraulic Considerations

- Stilling Basin
  - Erosion problems can result in the loss of your tailwater, which reduces energy dissipation
  - Erosion problems with Baffle Blocks
  - Undercutting problems at the downstream end of the stilling basin
  - Debris (boulders) in the basin can cause erosion problems

Hydraulic Considerations

- Regulating outlets
  - Cavitation can cause big problems
  - Minimum and maximum flow requirements
  - Transition zones (rough zones)
  - Brittle steel problems for older projects, problems for penstocks
  - Inlet problems, sediment & trash rack
  - Operations for temperature control

John Day Nav Lock Cavitation



Cavitation Damage in Navigation Lock Lateral Port, John Day Lock and Dam, 2000.

Tuttle Creek

Dam Safety Assurance
Spillway Erosion Repair

Courtesy of F. C. Walberg (Retired), KC District

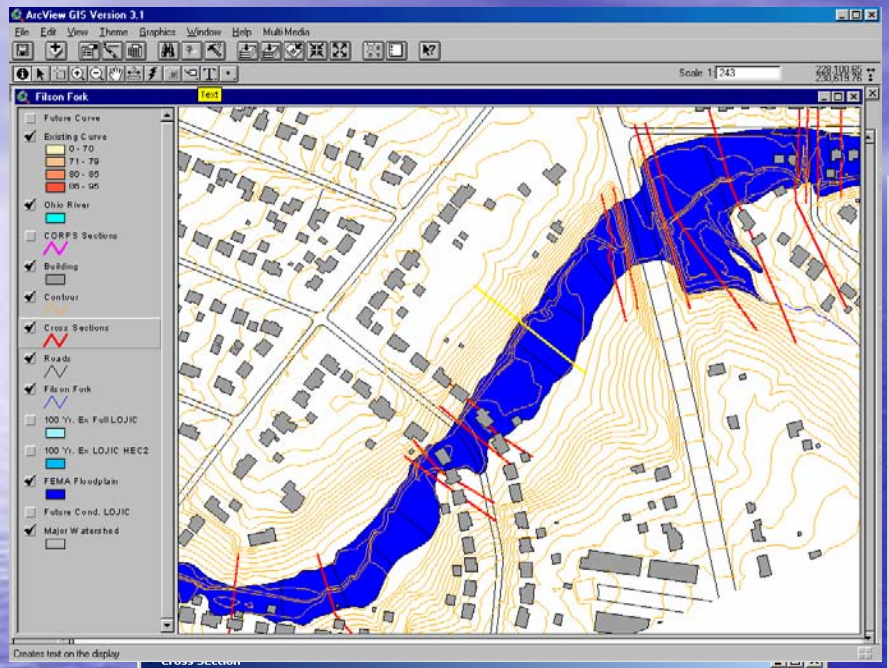
Hydraulic Evaluation

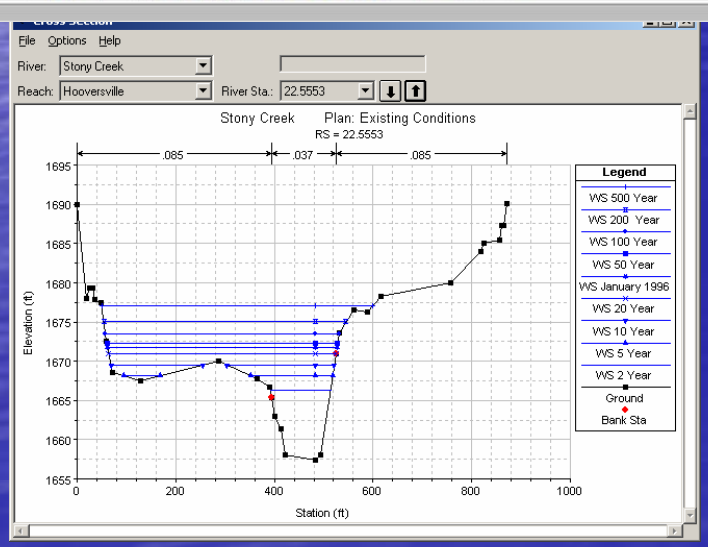
- Breach parameters
- Inundation
- Flood wave travel time
- Warning time
- Population at risk
- Loss of life

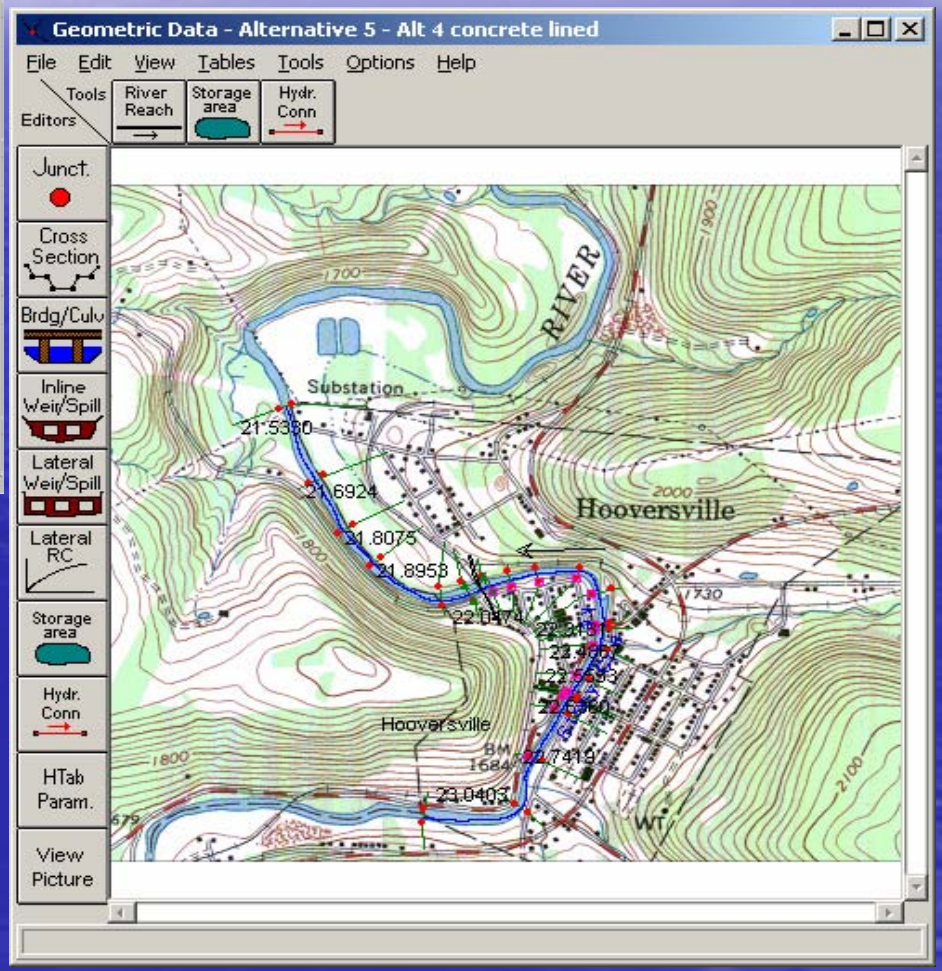
Evaluating Downstream Effects

- Discharge
- Channel geometry
- Roughness (Manning's n)
- Structures (bridges, dams, levees)
- Water surface profiles and inundation maps
  - Comparison with natural condition

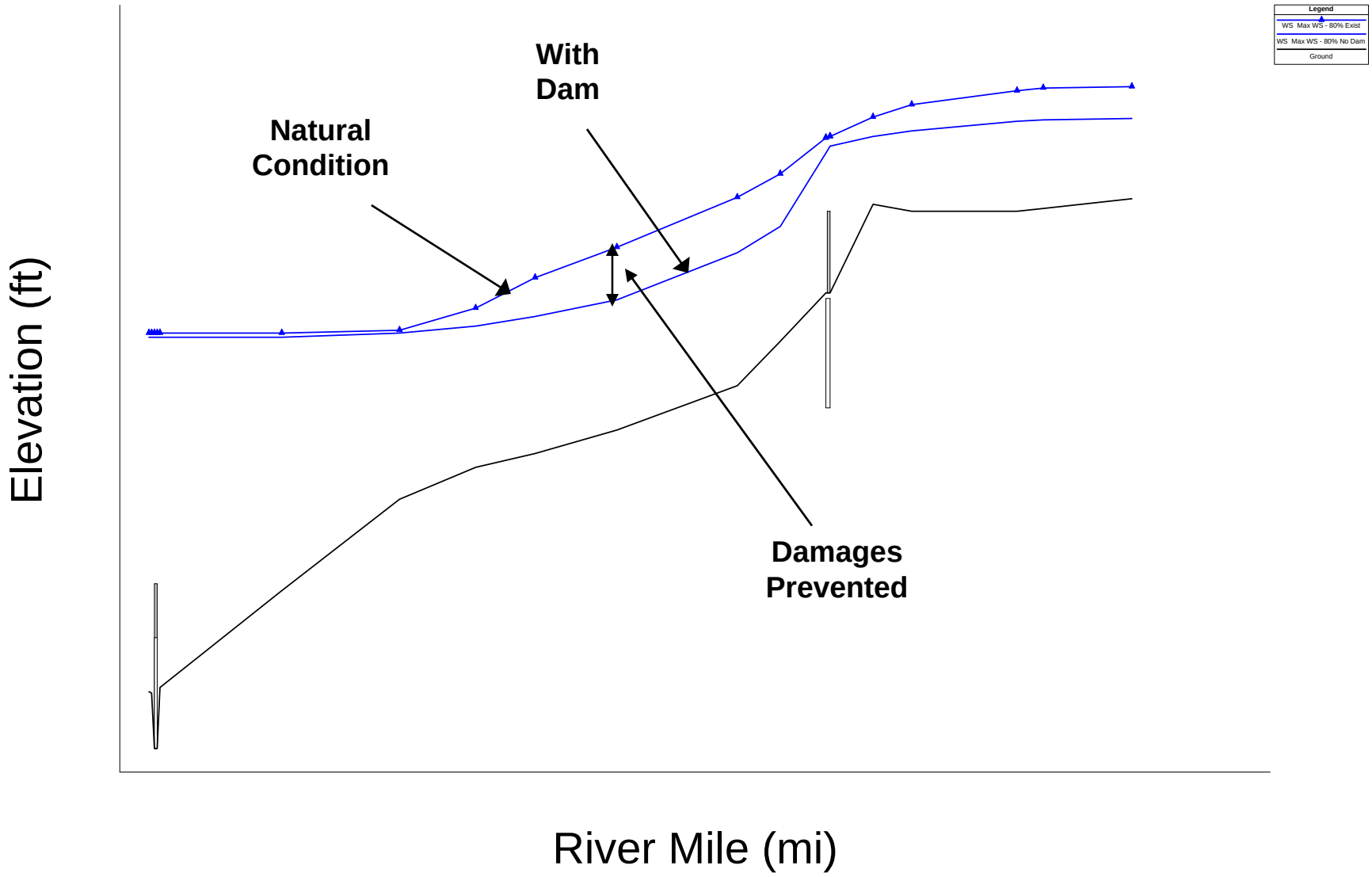
Hydraulic Models



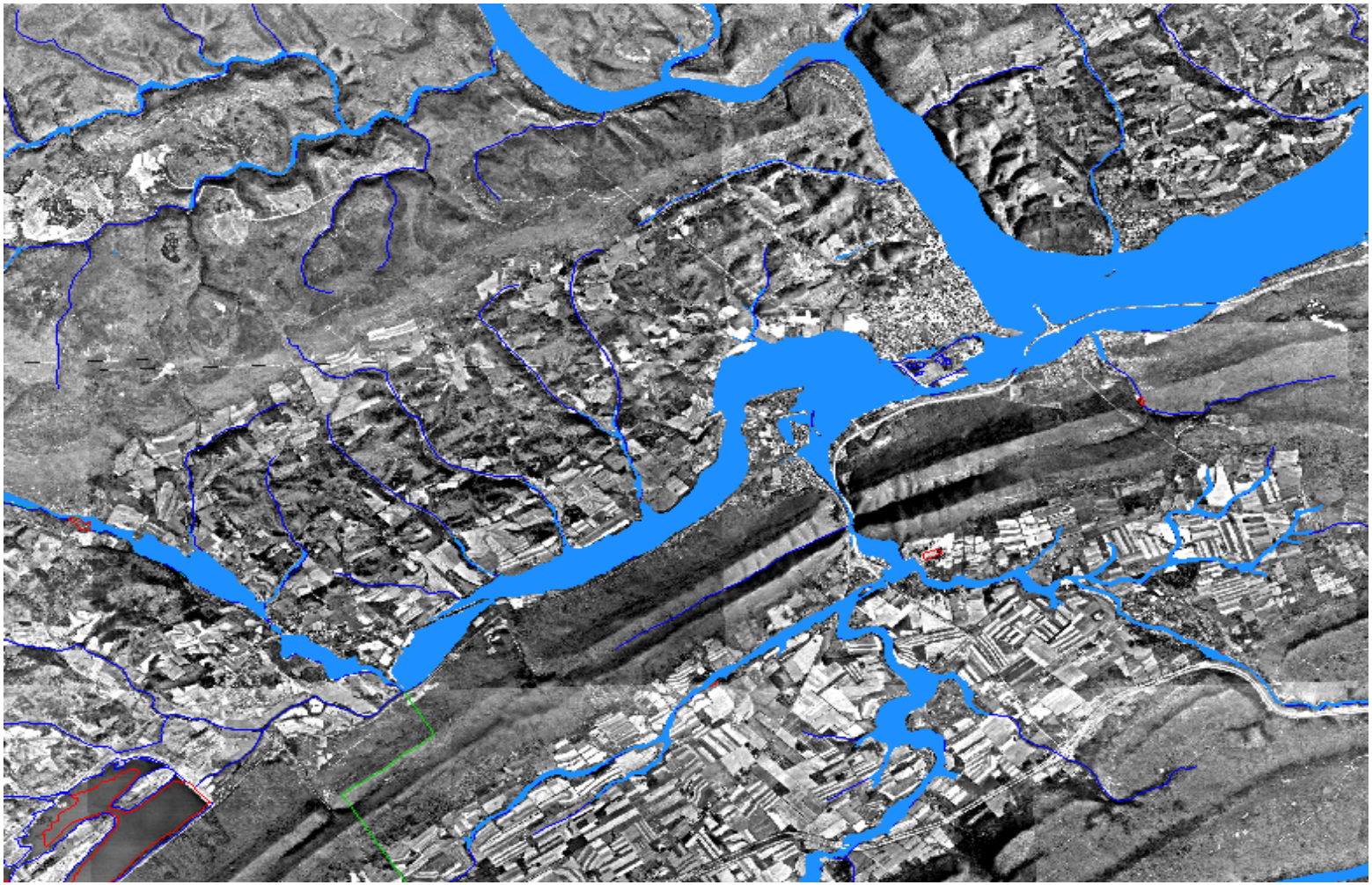




Water Surface Profiles



Inundation Maps



Topics

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- Hydrologic considerations
- Hydraulic considerations
- **Typical alternatives used to correct deficiencies**

Remediation

Fuseplug

Fusegate

Remediation

Overtopping

Inflatable Dam

DSA PROGRAM
TYPICAL ALTERNATIVES

Bolivar Dam, OH 27 June 1996

PARAPET WALL

DSA PROGRAM
TYPICAL ALTERNATIVES

SPILLWAY MOD

DSA PROGRAM
TYPICAL ALTERNATIVES

Combined Parapet & Spillway Modification

QUESTIONS