Tri Services ISC - Geotechnical Track 6
Wednesday, August 3, 2005
Room 227

State of the Art in Grouting

Dams on Solution Susceptible
or
Fractured Rock Foundations

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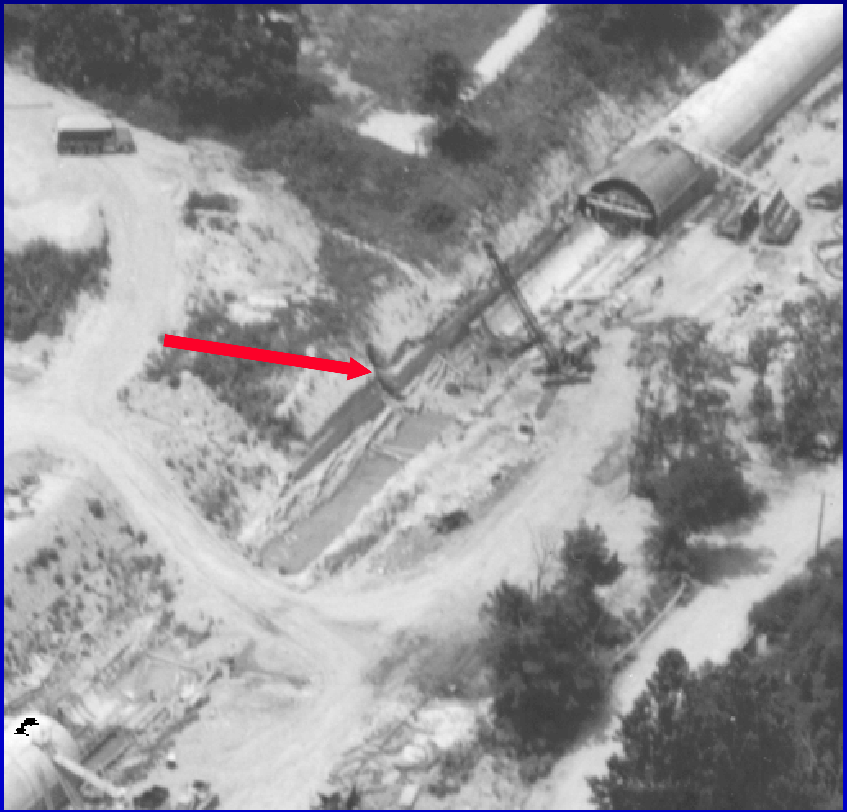
ENGINEERS AND PLANNERS

Track 6

- Overview of USACE dams on solution susceptible or fractured rock foundations
- Special drilling and grouting techniques for remedial work in embankment dams
- Composite grouting and cutoff wall solutions
- State of the art in grout mixes
- State of the art computer control, monitoring and analysis of grouting
- Quantitatively engineered grout curtains

Solution Susceptible Rock Foundation

Indiana Limestone



Solution Susceptible Rock Foundation

Indiana Limestone

Solution Susceptible Rock Foundation

Boone Formation
Beaver Dam, AK

Fractured Rock Foundation

Fractured Rock Foundation

Western Maryland

Rock Foundation at Clearwater Dam

Fractured Rock Foundation

Basic Technical Requirements
for an
Embankment Dam

- Must have sufficient spillway and outlet capacity as well as adequate freeboard to prevent over topping by the reservoir
- Must be stable under all loading conditions
- Dam and "foundation" must be sufficiently watertight and have adequate seepage control for safe operation

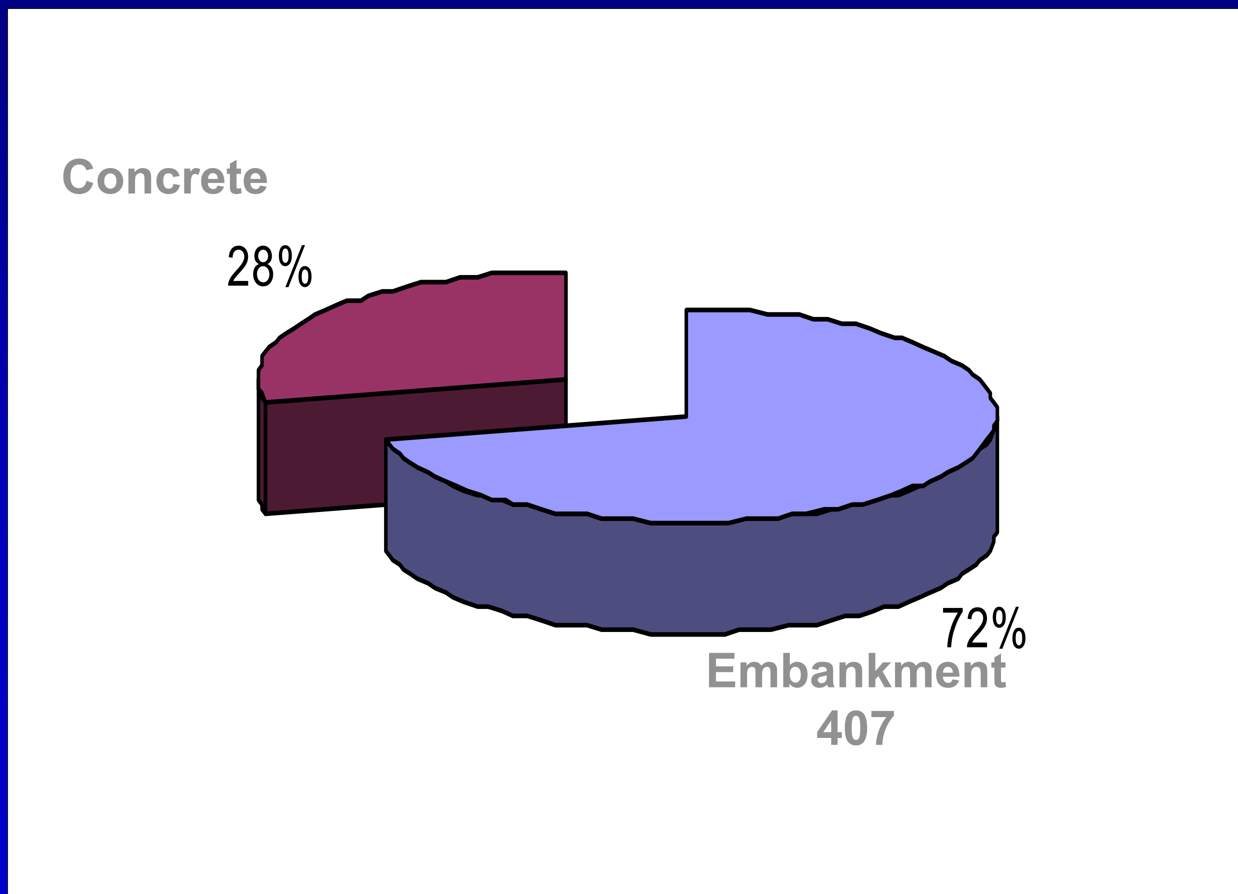
Causes of Dam Failures in the United States
Embankment Dams *

	Cause	1955	Current
1.	Inadequate spillway capacity	30%	40%
2.	Seepage/piping	25%	37%
3.	slides	15%	6%
4.	Conduit leakage	13%	
5.	Slope protection	5%	17%
6.	Unknown	12%	

* Source – National Inspection of Dams Program, Corps of Engineers survey and Bureau of Reclamation survey

Corps of Engineers Dams

569 Total dams (2000)



Corps of Engineers Embankment Dams
by
Hazard Classification & Spillway Operation

407 Embankment

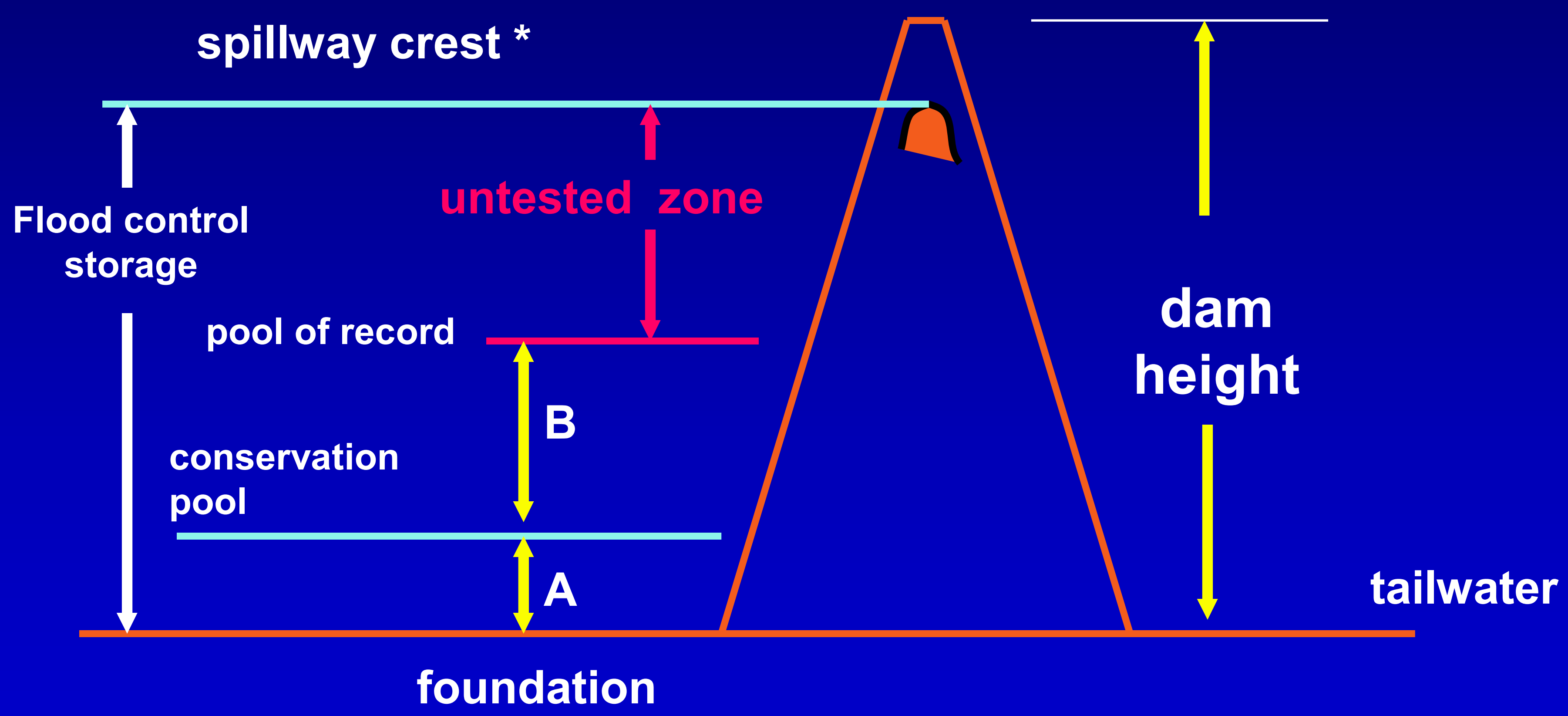
356 High hazard
243 ungated *
113 gated

36 Significant hazard
24 ungated *
12 gated

15 Low hazard

* Flood control loading in feet of head is greatest for ungated dams

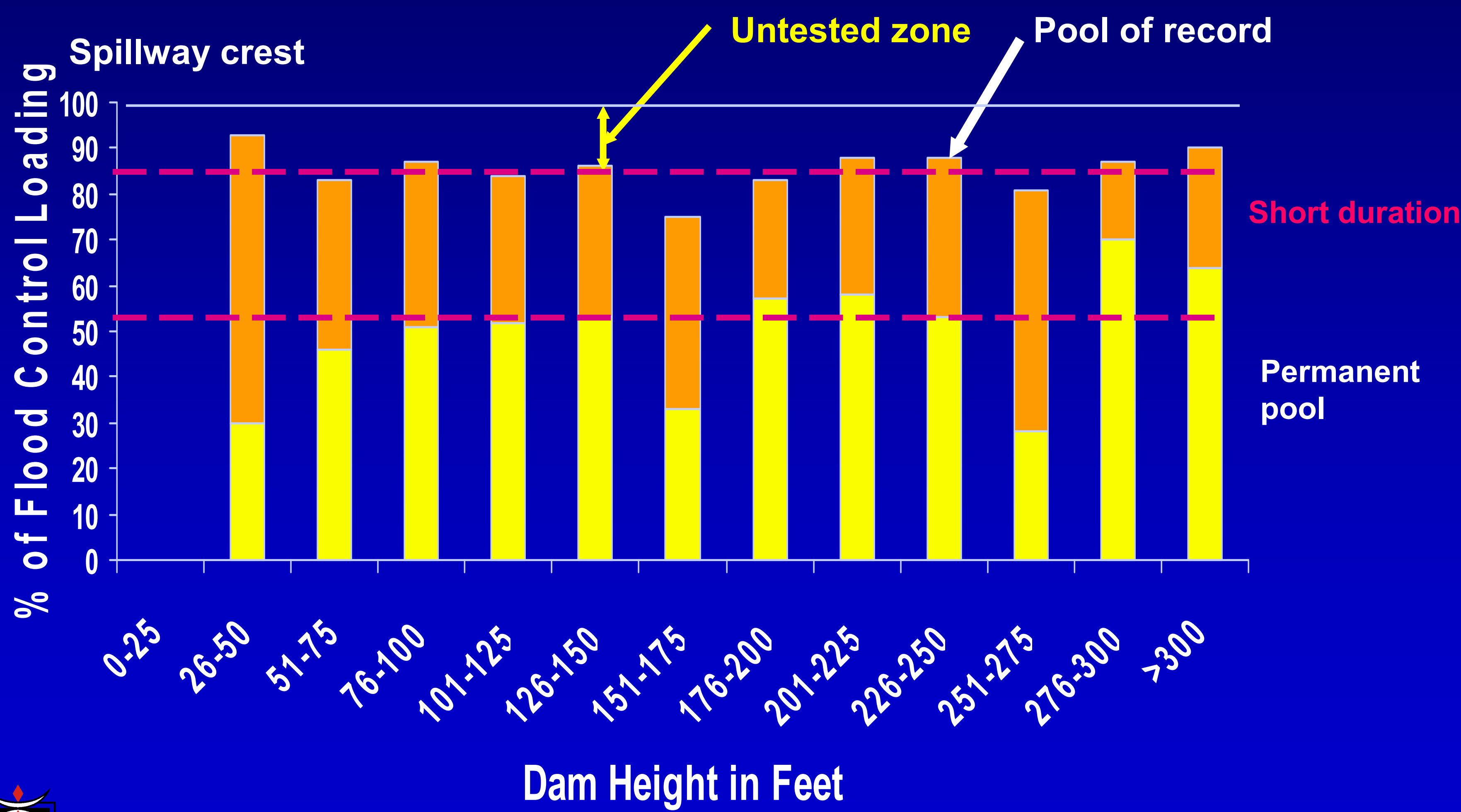
Schematic of an Ungated Flood Control Dam



Total Loading History

High Hazard Ungated Dams

as of 2000



41 0f the 243 have experienced spillway flow

Uplift in Rock and Seepage

Reservoir at 35% storage capacity

Summary of 1976 HQ Survey

MSC	Solution	Fractured	Both
LRD			
LRL	2		
LRN	5		
LRB		1	
NAD			
NAB			1
NAO	1		
MVD			
MVK	1		
MVR	1		
MVS	1		1
NWD			
NWK	5		1
NOW			3
NWW		1	

MSC	Solution	Fractured	Both
SAD			
SAJ	1		
SAM	1	1	
SPD			
SPA	1		
SPK	1	1	
SWD			
SWF	6		
SWL	5		
SWT	4		1

	Solution	Fractured	Both
USACE Total	35	4	7

Some Recent Corps Experiences with Existing Dams That Required or will Require Modification

- **Hartwell Dike, SC –** cutoff wall
- **Beaver Dam, AK –** secant pile cutoff
- **Patoka Dam, IN -** grouting
- **Mississineau Dam, IN –** grouting and then panel wall
- **Walter F. George, GA –** grouting with panel wall
- **Clearwater Dam, AK –** emergency grouting then permanent grouting and then cutoff wall
- **Wolf Creek, TN –** report with recommendations being submitted to headquarters

Considerations in Selecting the Type of Cutoff for Seepage Control

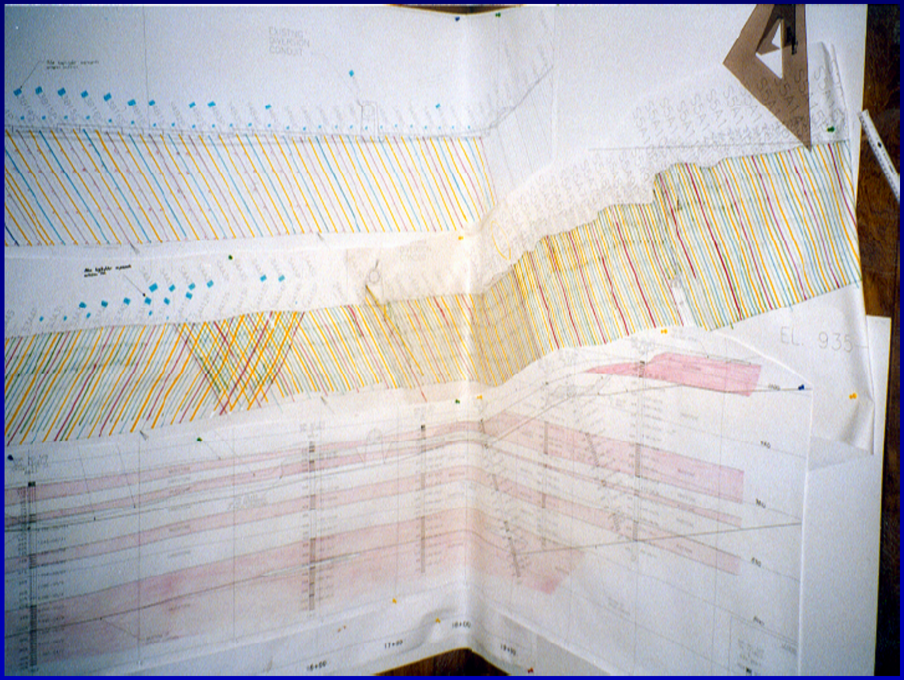
- Exploration and investigations
- Site characterization
- Physical properties of the fractured or solution susceptible rock foundation
- Establishing the depth and length of cutoff
- Contracting procedure

    IFB, RFP and Best Value

Conventional Grouting

Dipstick measurements

Mechanical gages and
manual monitoring

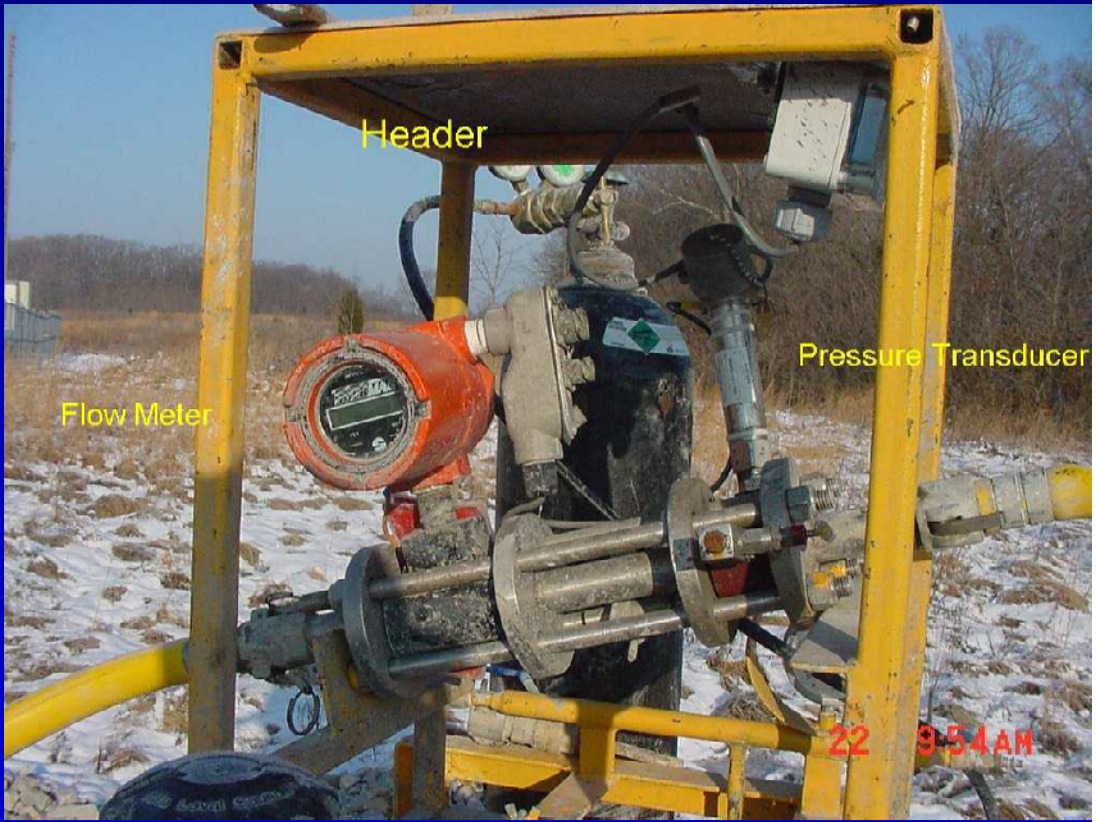


Time consuming
manually prepared charts


RESULTS ??
$$$
General Impression of Conventional Grouting

Recent Development in Grouting Materials, Equipment and Procedures

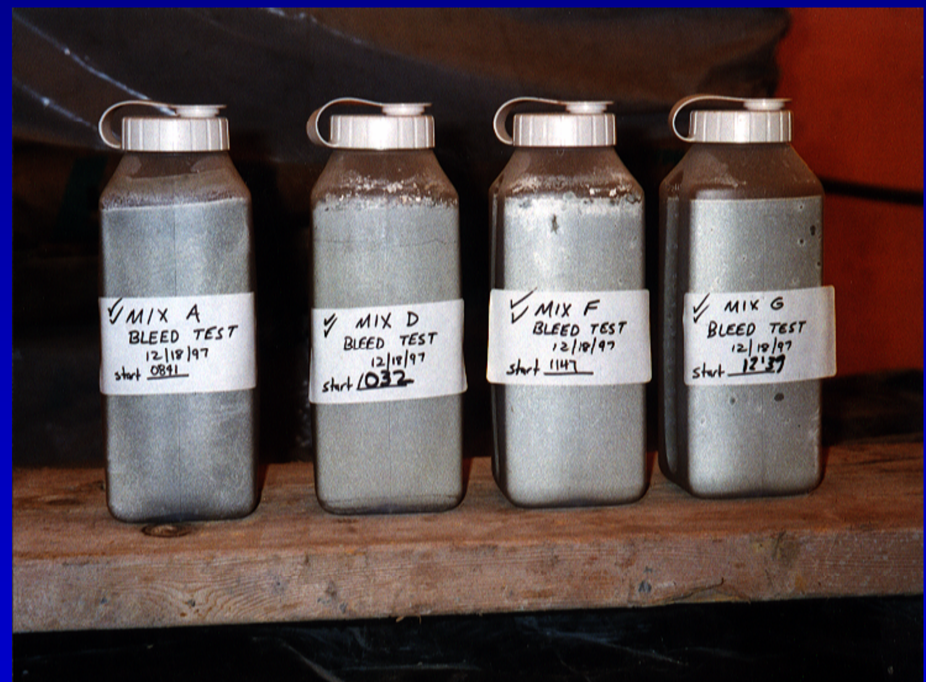
1. **Drilling and grouting techniques**



Recent Development in Grouting Materials, Equipment and Procedures

2. State of the art Grout mixes

Neat Cement



Balanced Stabilized

Recent Development in Grouting Materials, Equipment and Procedures

2. State of the art Grout mixes

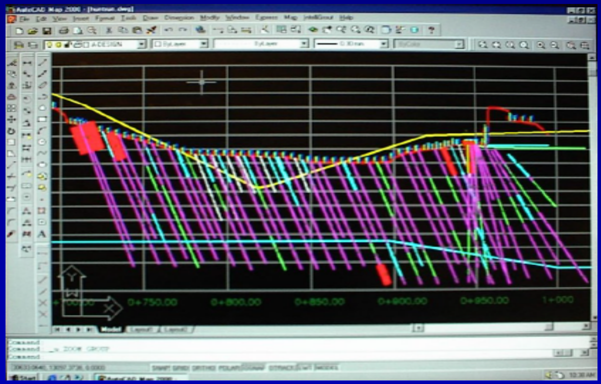
Computer controlled batch plant

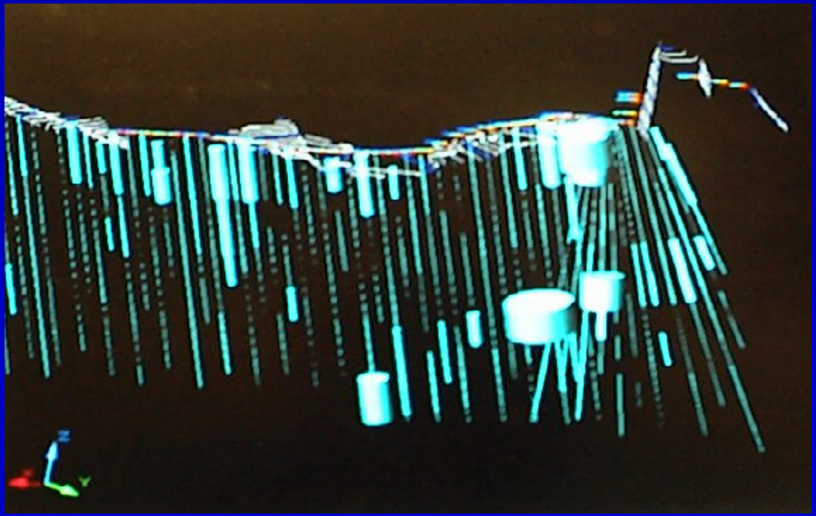
Recent Development in Grouting Materials, Equipment and Procedures

3. **Composite grouting and cutoff walls**

Recent Development in Grouting Materials, Equipment and Procedures

4. State of the art computer control, monitoring and analysis of grouting

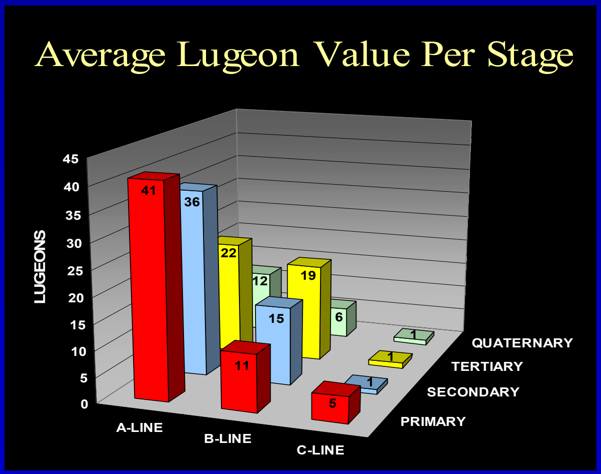




Recent Development in Grouting Materials, Equipment and Procedures

5. Quantitatively engineered grout curtains

- Evaluation of geologic conditions
- Detailed site characterization
- Design of grout curtains as an intergral part of the project to achieve specific results
- Best value contracting



Summary

Establishing the initial or remedial seepage cutoff for a water resources project can be difficult, expensive and requires monitoring and future evaluation

Recent advances in grouting technology, materials, practices and procedures have made multiple line grouting a reliable and cost effective method to control seepage or the flow of groundwater

Critical Information
for
Flood Control Operation of Dams

- Inflow predictions
- Projected reservoir levels
- Corresponding storage
- Predicted performance of the dam and structures
- Threshold for changes in monitoring program
- Threshold for potential operational changes due to structural performance
- Draw down capability
    - with full bank discharge capacity
    - with full discharge