RISK CHARACTERIZATION AND DAM SAFETY MODIFICATIONS TO ADDRESS ACTIVE FAULT RUPTURE BENEATH AN EMBANKMENT DAM

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US Army Corps of Engineers
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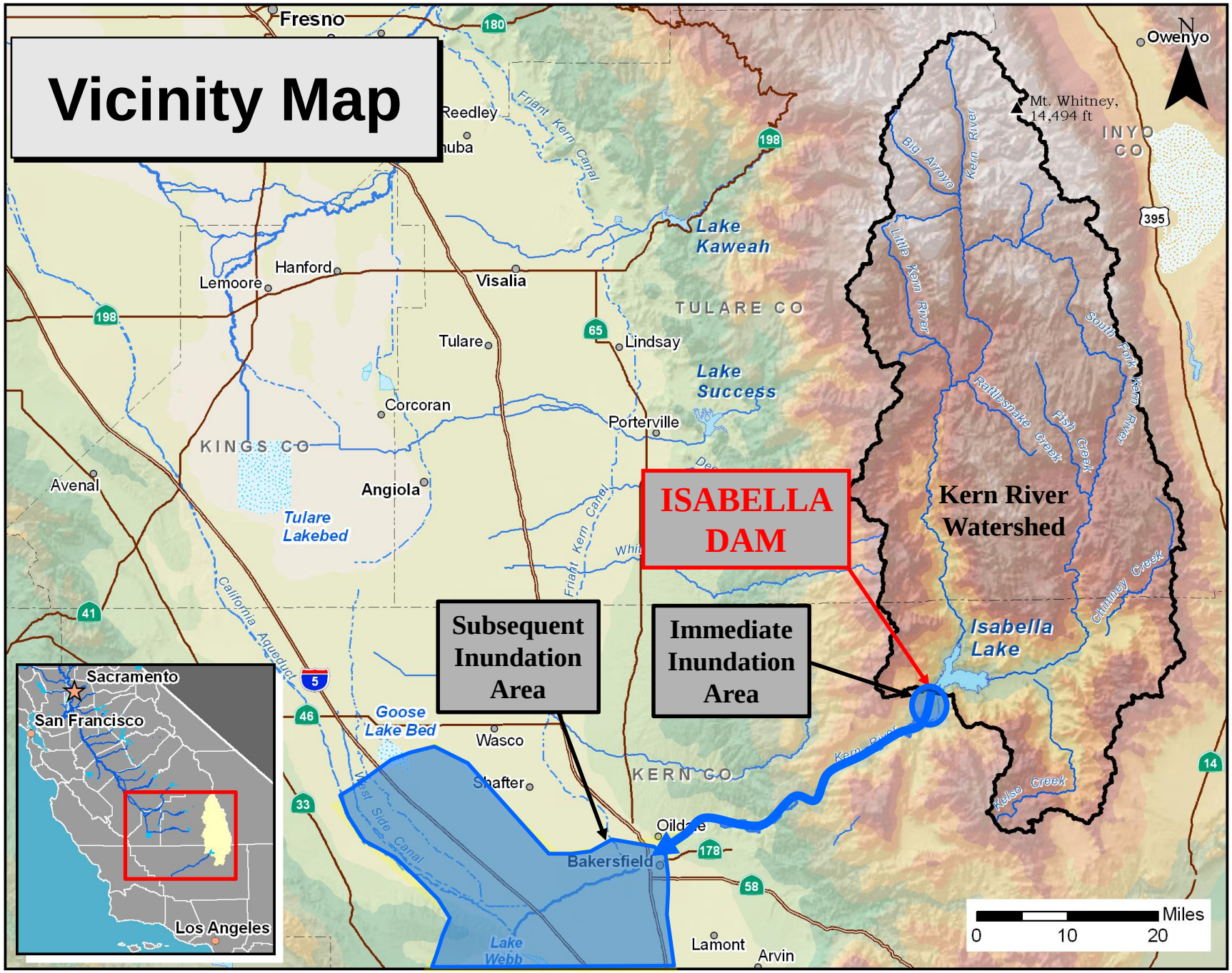
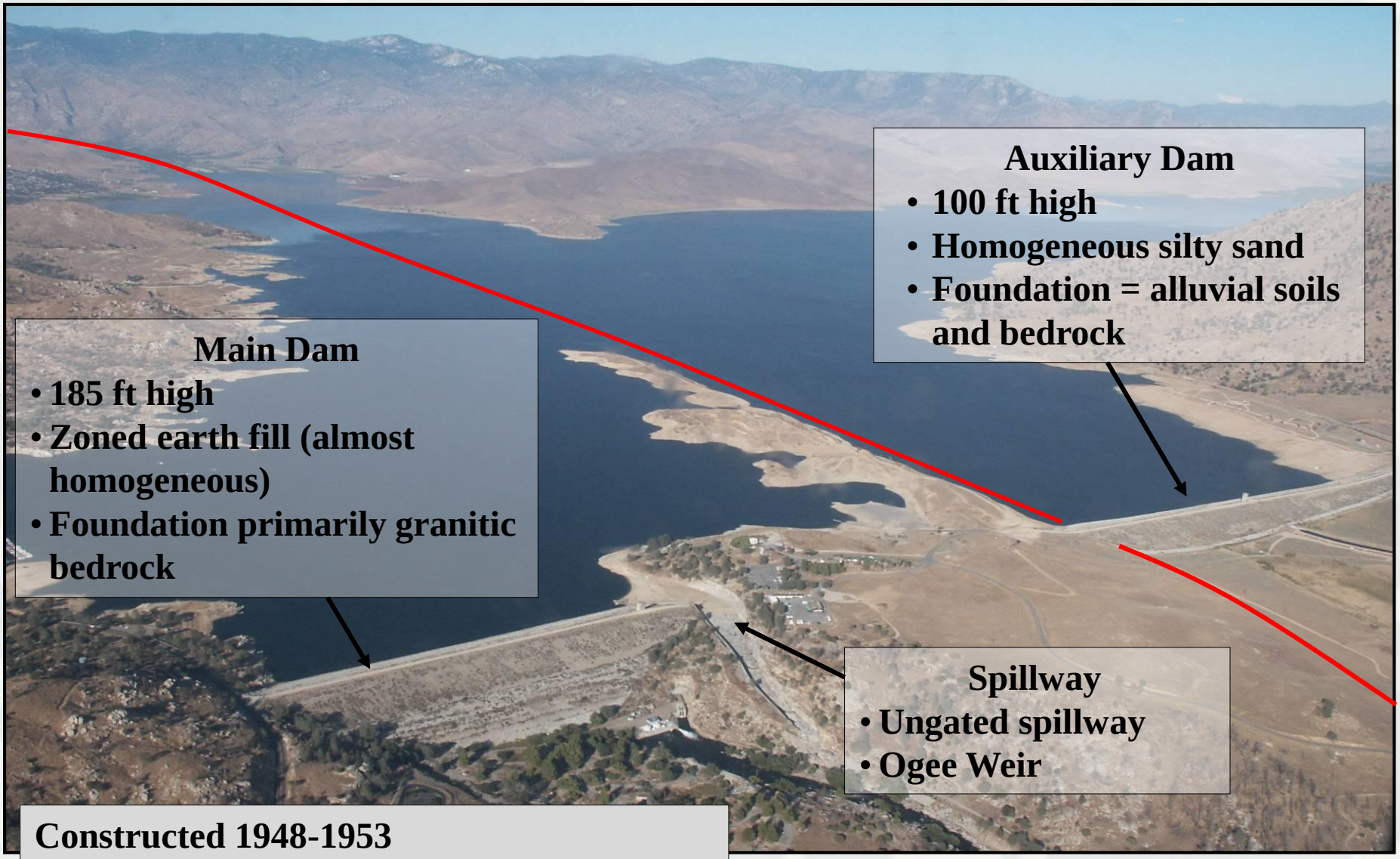
Outline

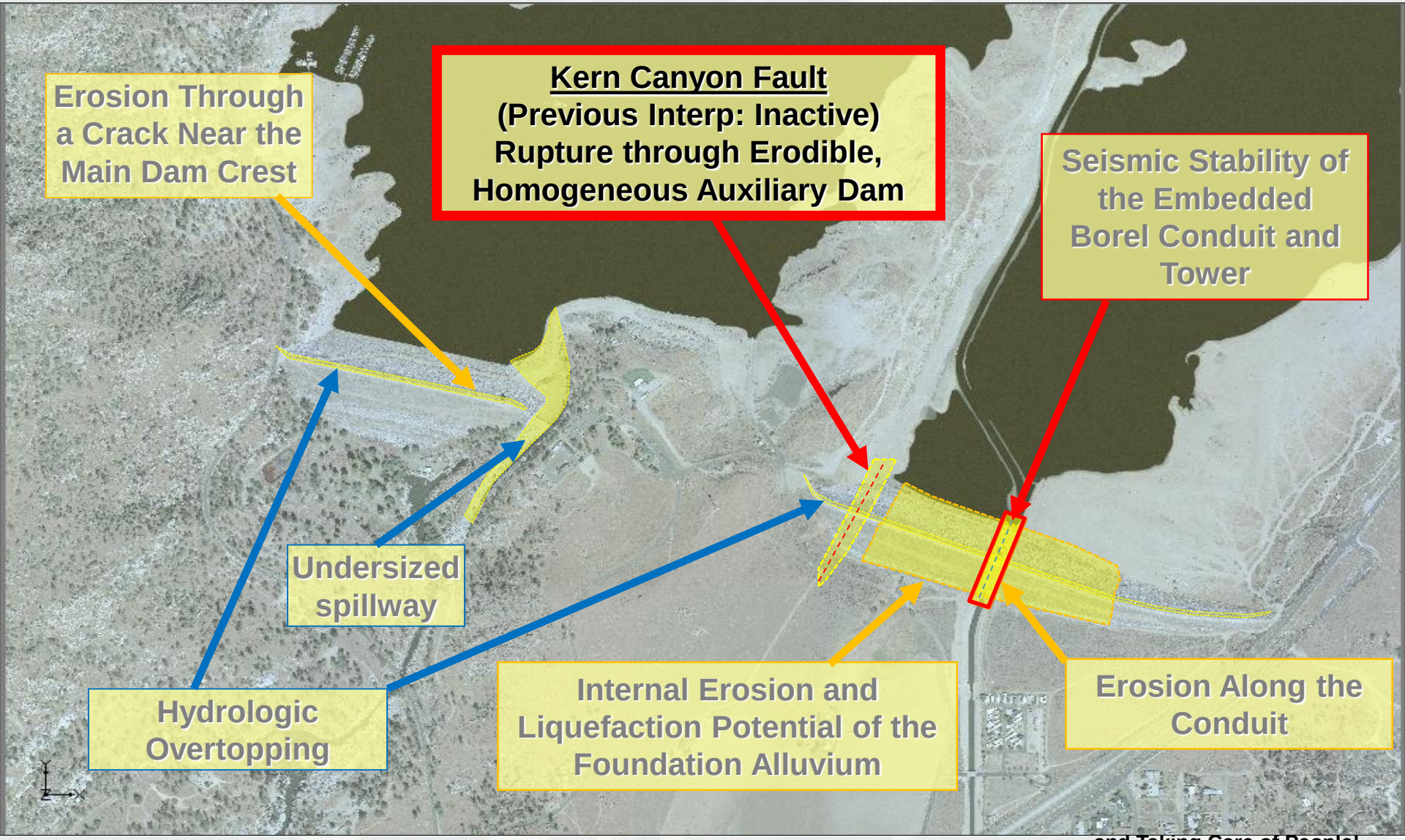
- Overview: Isabella Dam Modification Project
- Overview: Seismic Source Characterization (fault rupture)
  - Site-specific paleoseismic data
  - Scenario-based fault displacements using empirical relationships
- Overview: Design of the (size and location) of filter and drain zones for the downstream buttress modification of the Auxiliary Dam


Vicinity Map
ISABELLA DAM
Kern River Watershed
Subsequent Inundation Area
Immediate Inundation Area
Fresno
Reedley
Owenyo
Mt. Whitney, 14,494 ft
INYO CO
Lake Kaweah
Hanford
Lemoore
Visalia
TULARE CO
Tulare
Lindsay
Lake Success
Corcoran
Porterville
KINGS CO
Avenal
Angiola
Tulare Lakebed
Isabella Lake
Goose Lake Bed
Wasco
Shafter
KERN CO
Bakersfield
Oildale
Lamont
Arvin
Lake Webb
Friant Kern Canal
California Aqueduct
West Side Canal
Big Arroyo
Kern River
Little Kern River
South Fork Kern River
Rattlesnake Creek
Fish Creek
Chimney Creek
Kelso Creek
Sacramento
San Francisco
Los Angeles
Miles
0
10
20



Constructed 1948-1953
Primary Purposes: Flood control (~ 74%);
Irrigation (~21%);
Non-Federal Hydropower (~5%)
Reservoir Capacity = 568,100 ac ft

Primary Issues (Potential Failure Modes)
Isabella Dam Modification Study



Kern Canyon Fault Characterization

Data Needs (Fault Rupture PFM)

- Locations of Active Fault Strands
- Zone of Surface Deformation
- Amount of Surface Deformation
- Sense of Coseismic Slip
- Frequency of Coseismic Deformation

Kern Canyon Fault Characterization

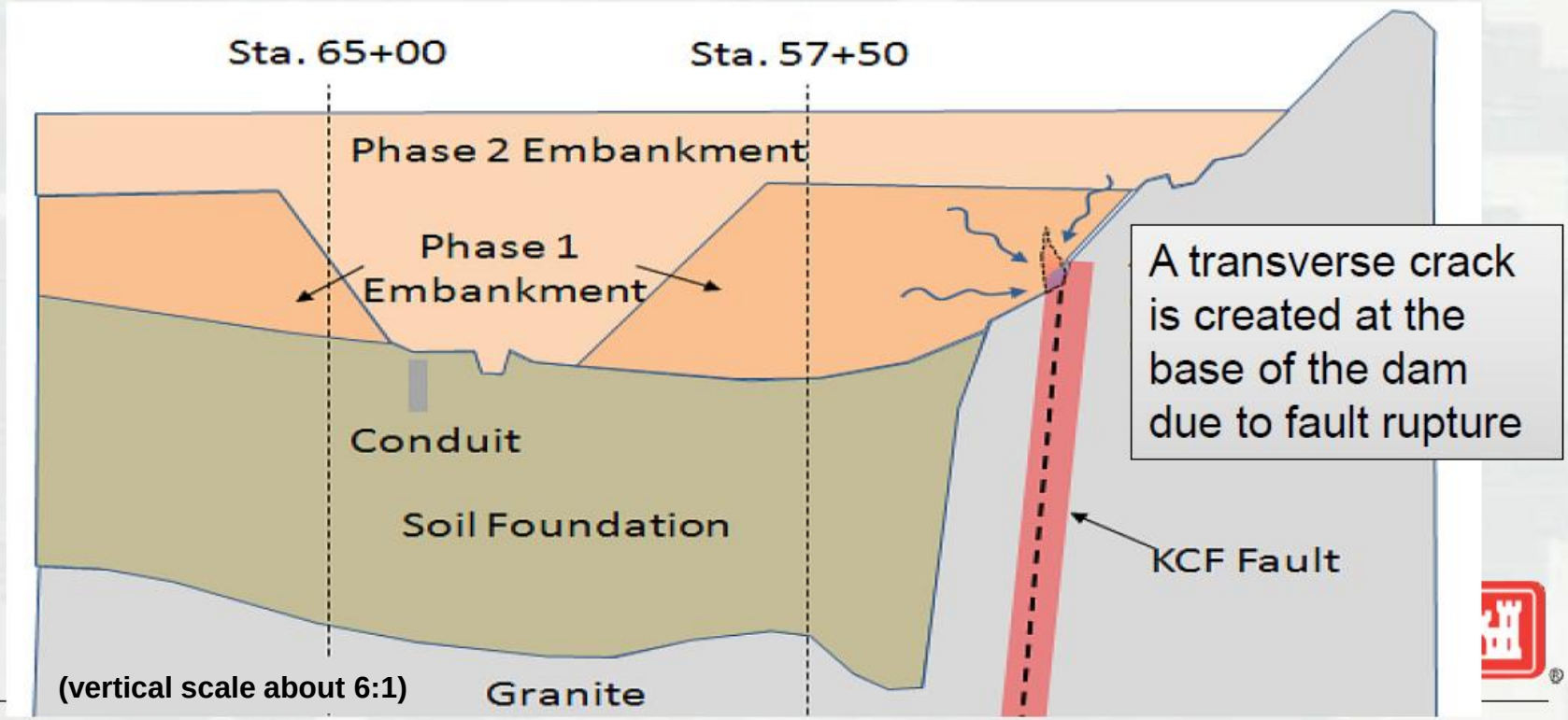
- **Starting from scratch**: KCF previously uncharacterized (inactive)
- Comprehensive program of fault evaluation (2005 to 2010)
  - Geologic, geomorphic, seismologic, paleoseismologic, age-dating analyses
  - Integrated with geotechnical and geophysical data

- **Active Fault**
- 140 km long; four sections
- Multiple Holocene surface ruptures
- Return period ca. 3ka
- Maximum magnitude: M_w7.5

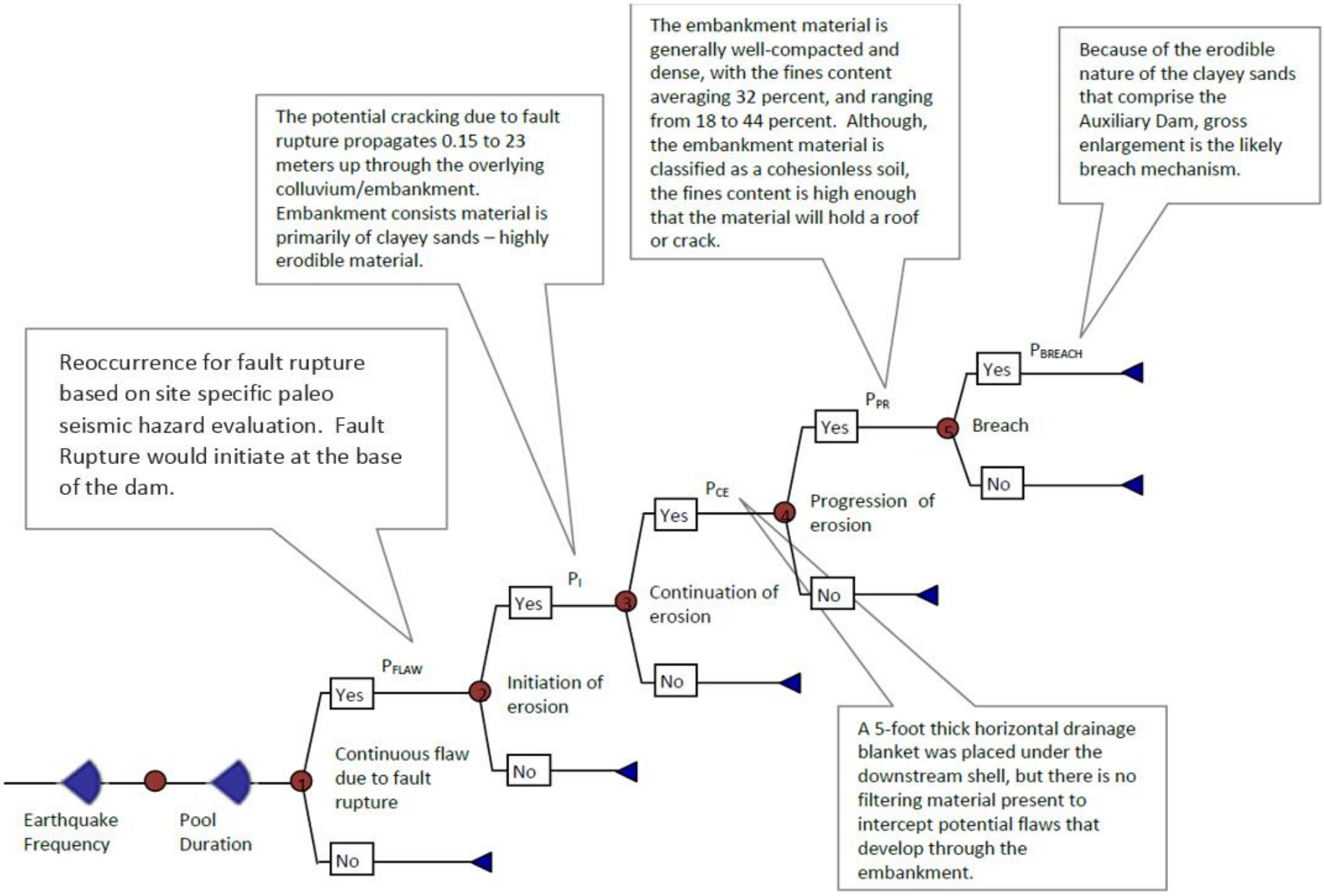
Potential Failure Mode: Fault Rupture Beneath Right Abutment

Kern Canyon Fault Rupture Summary:

- Normal (east-down) displacement
- **Design fault rupture displacement = 6.8 ft**
- Mean maximum displacement of 9.8 ft (unsegmented rupture scenario)



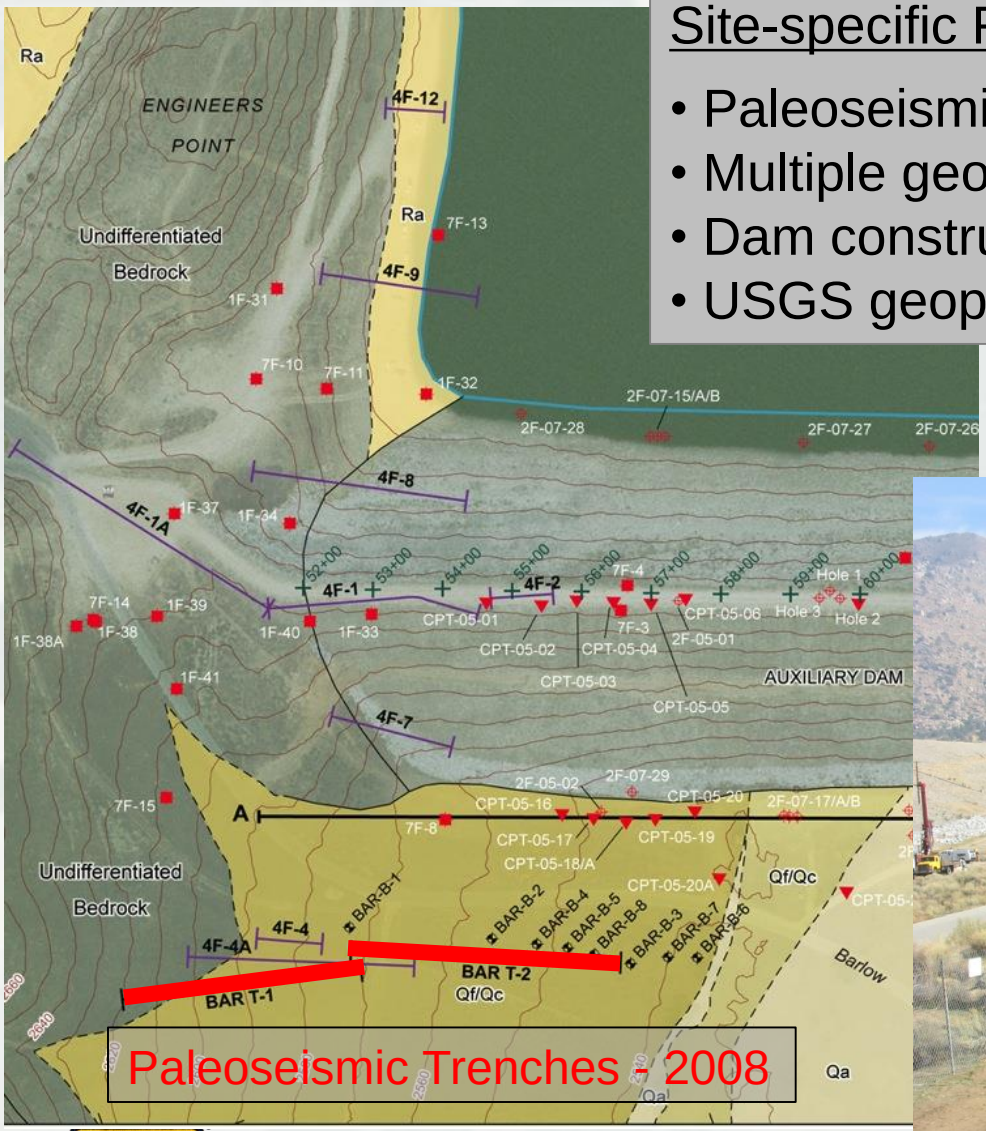
PFM #47 – Transverse Cracking Due to Fault Rupture



Kern Canyon Fault at Right Abutment

Site-specific Fault Data

- Paleoseismic trenches (16-ft-deep, 350-ft-long)
- Multiple geotechnical boreholes
- Dam construction trenches /exploratory shaft
- USGS geophysical data



Paleoseismic Trenches - 2008

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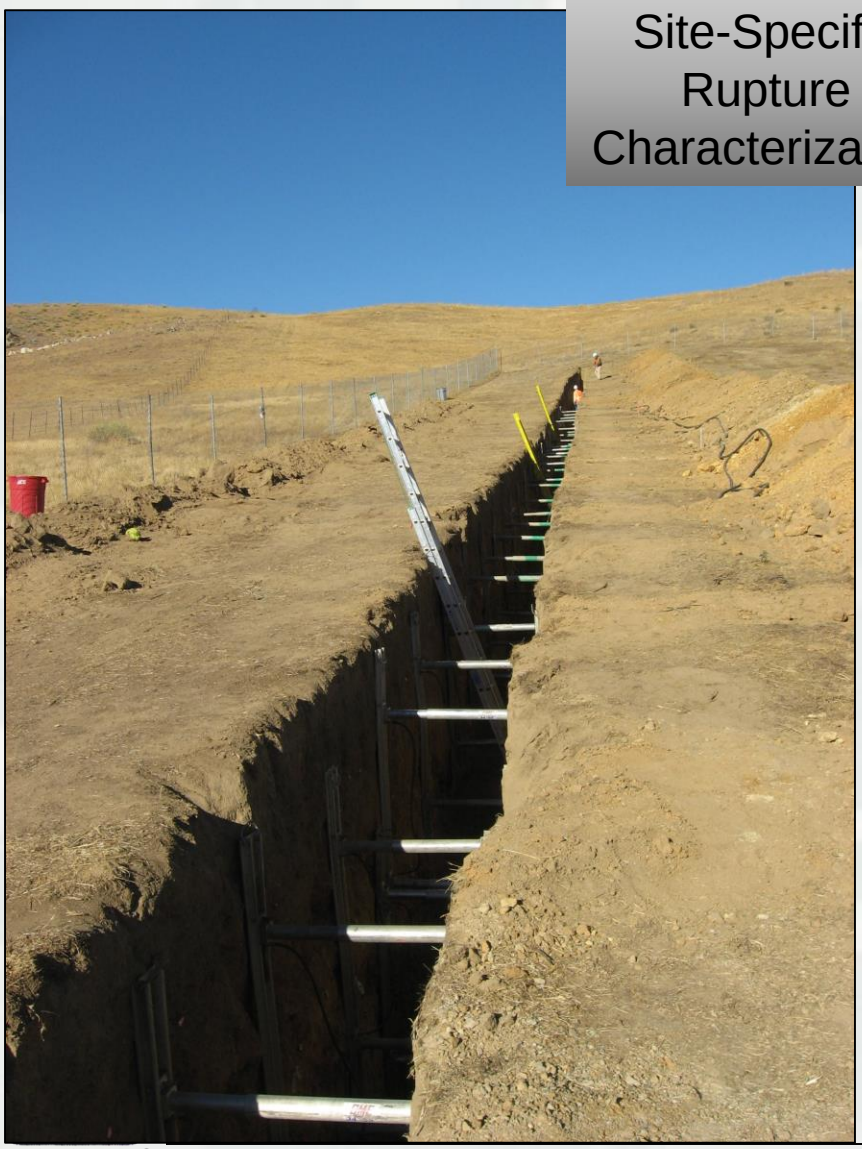
Dam Site Field Investigations



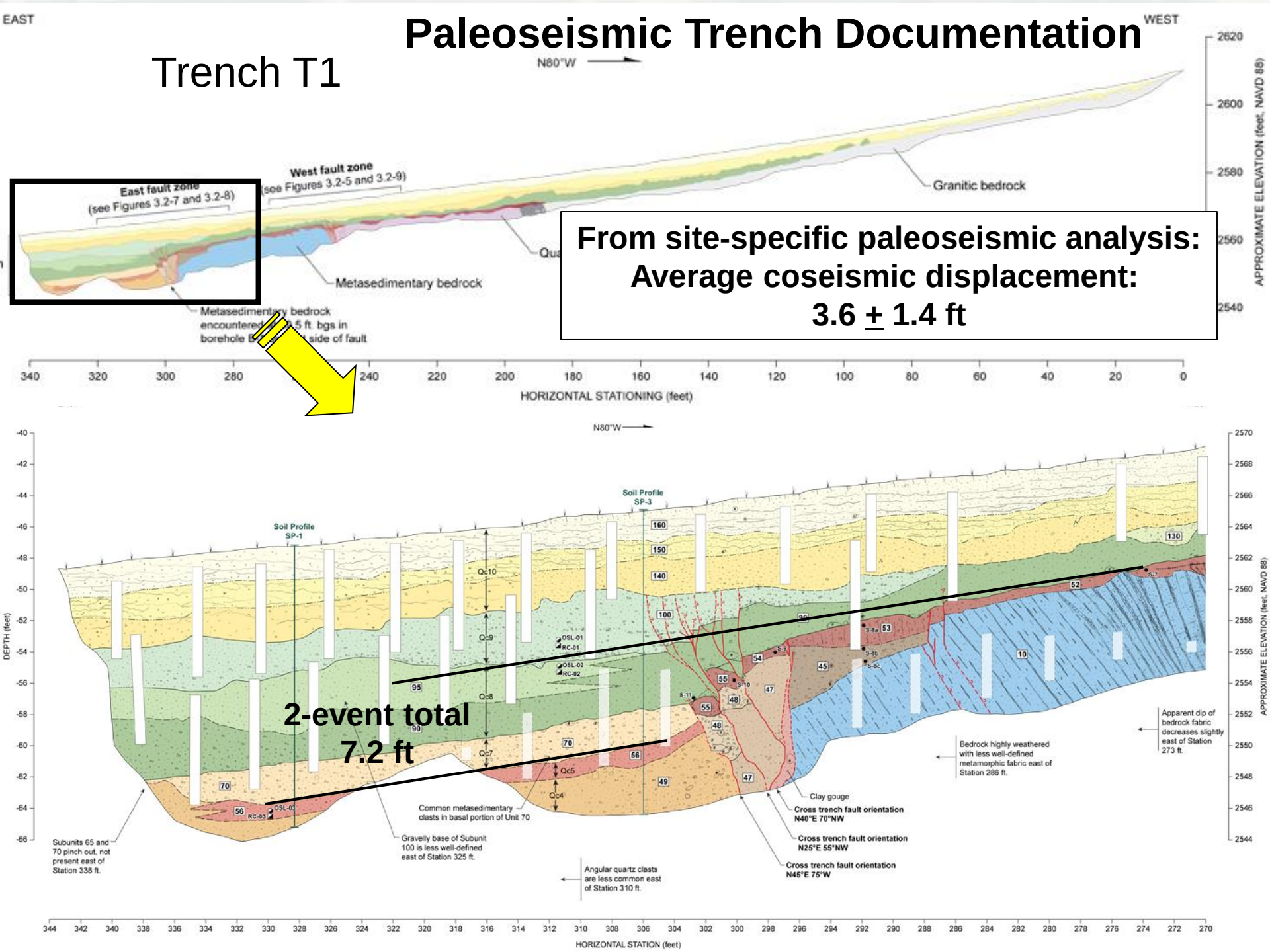
Site-Specific Rupture Characterization

Objectives:

- Define Rupture Characteristics
  - Location, Width, Sense of Slip
  - Amount of Coseismic
- Develop Recurrence Information

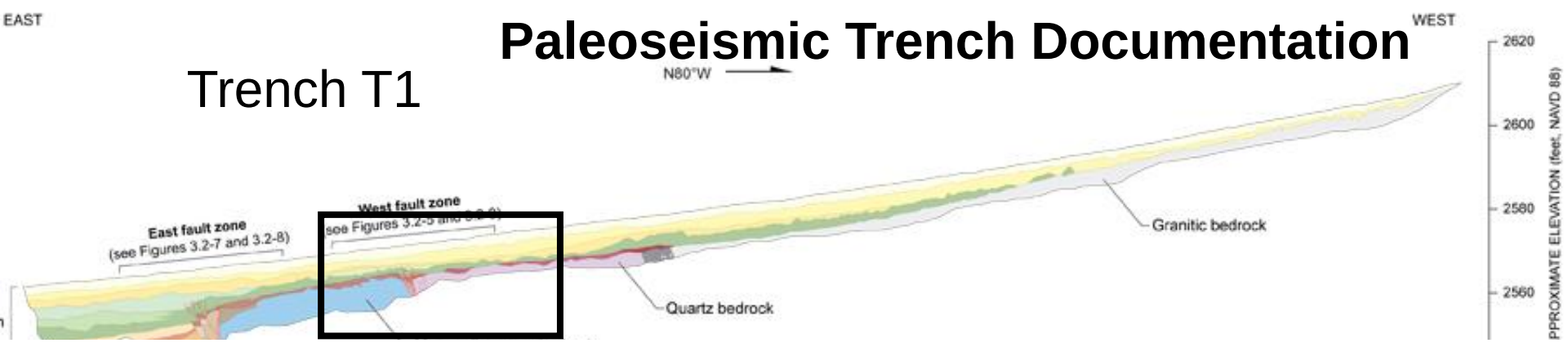
Paleoseismic Trench Documentation

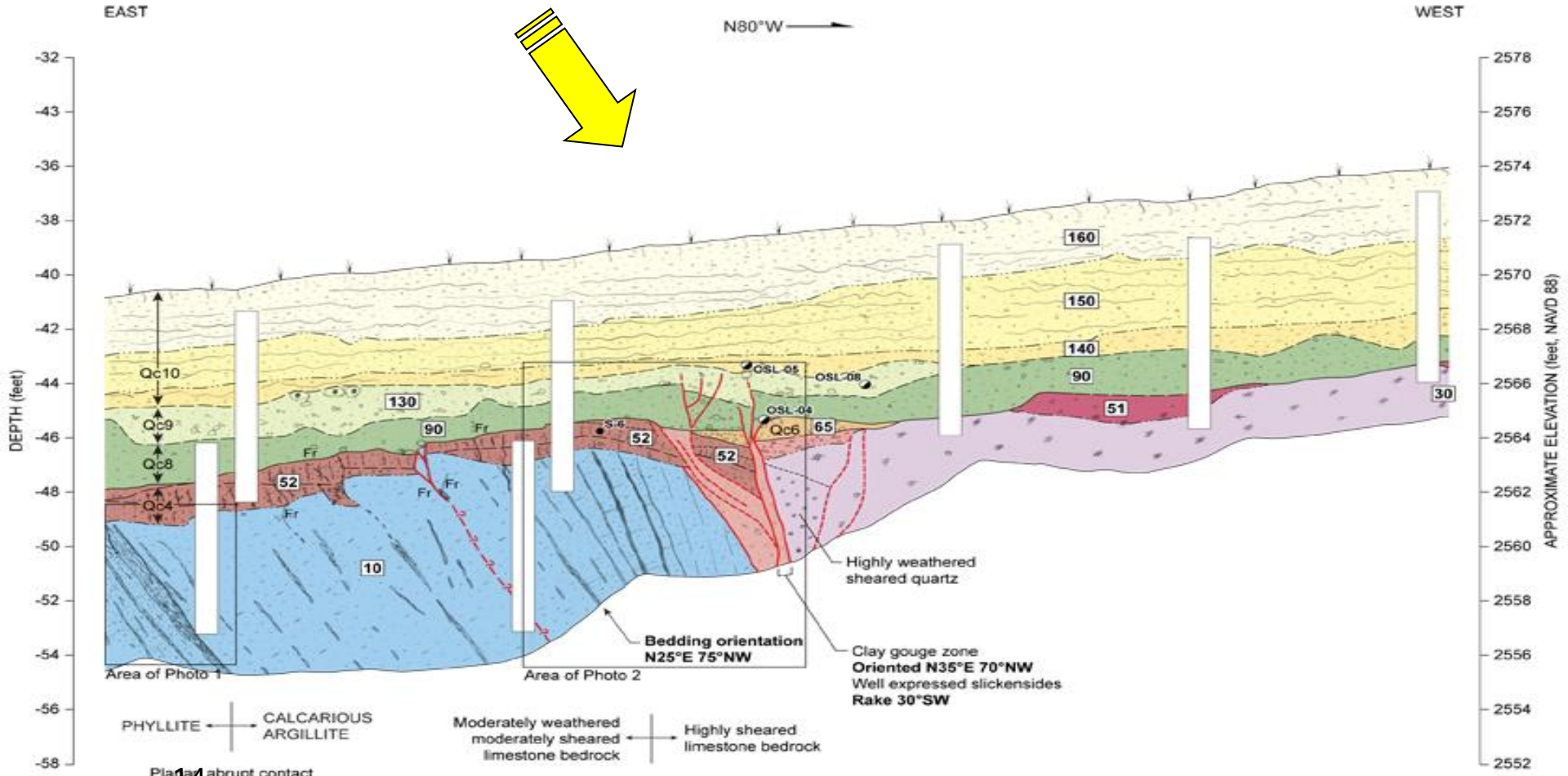
Trench T1



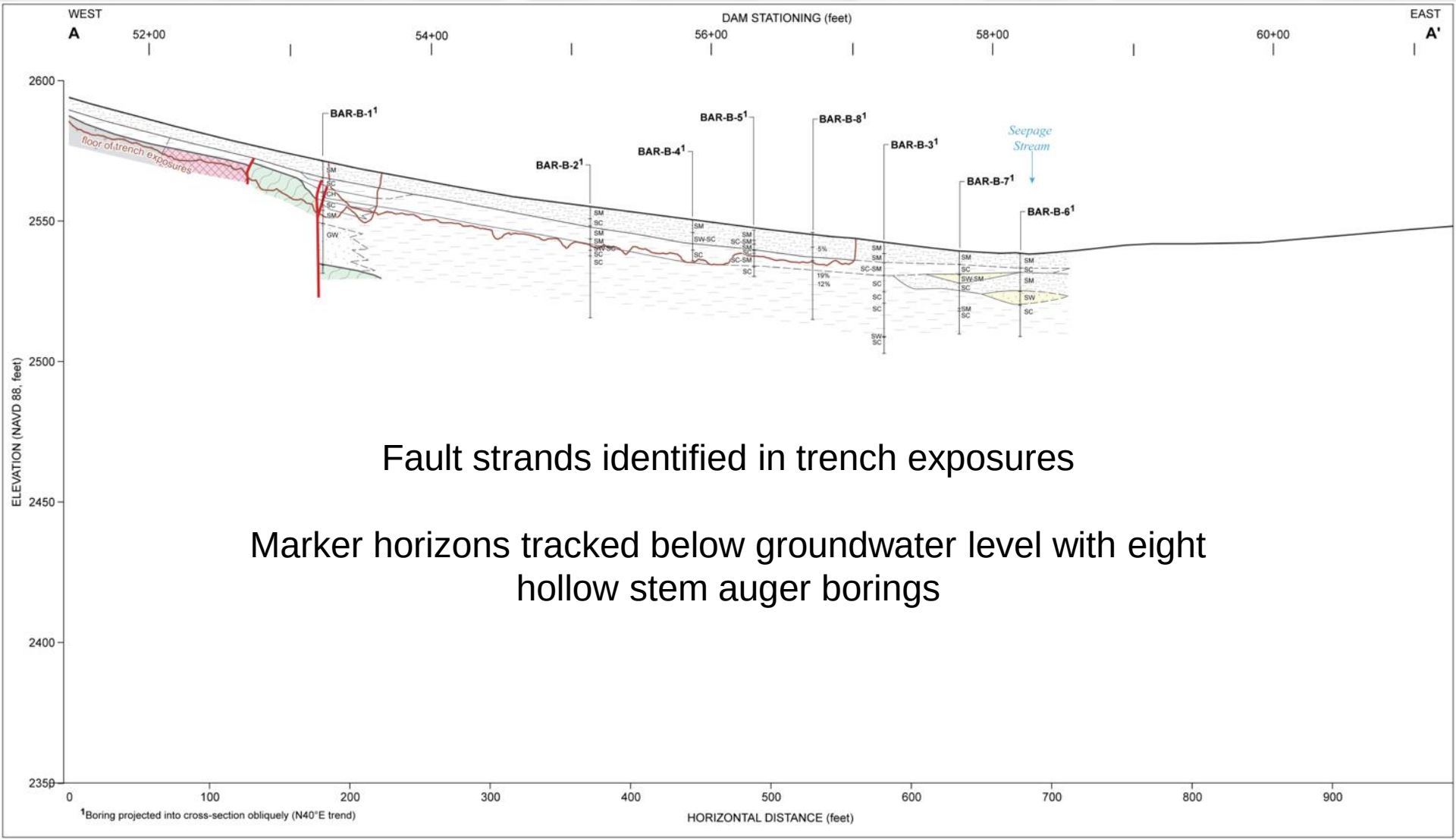
Paleoseismic Trench Documentation

Trench T1





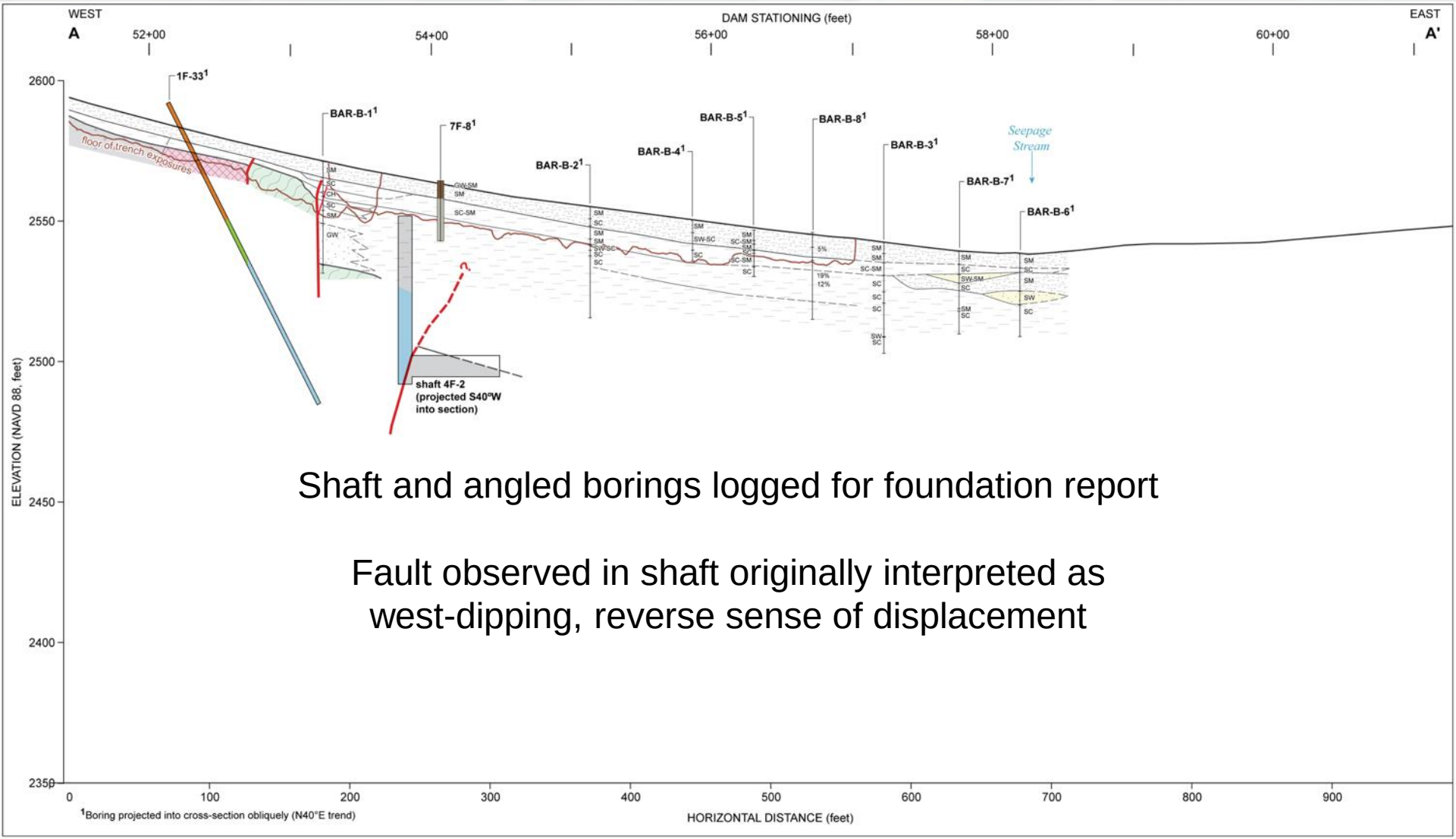
Cross Section: trenches and shallow borings



Fault strands identified in trench exposures

Marker horizons tracked below groundwater level with eight hollow stem auger borings

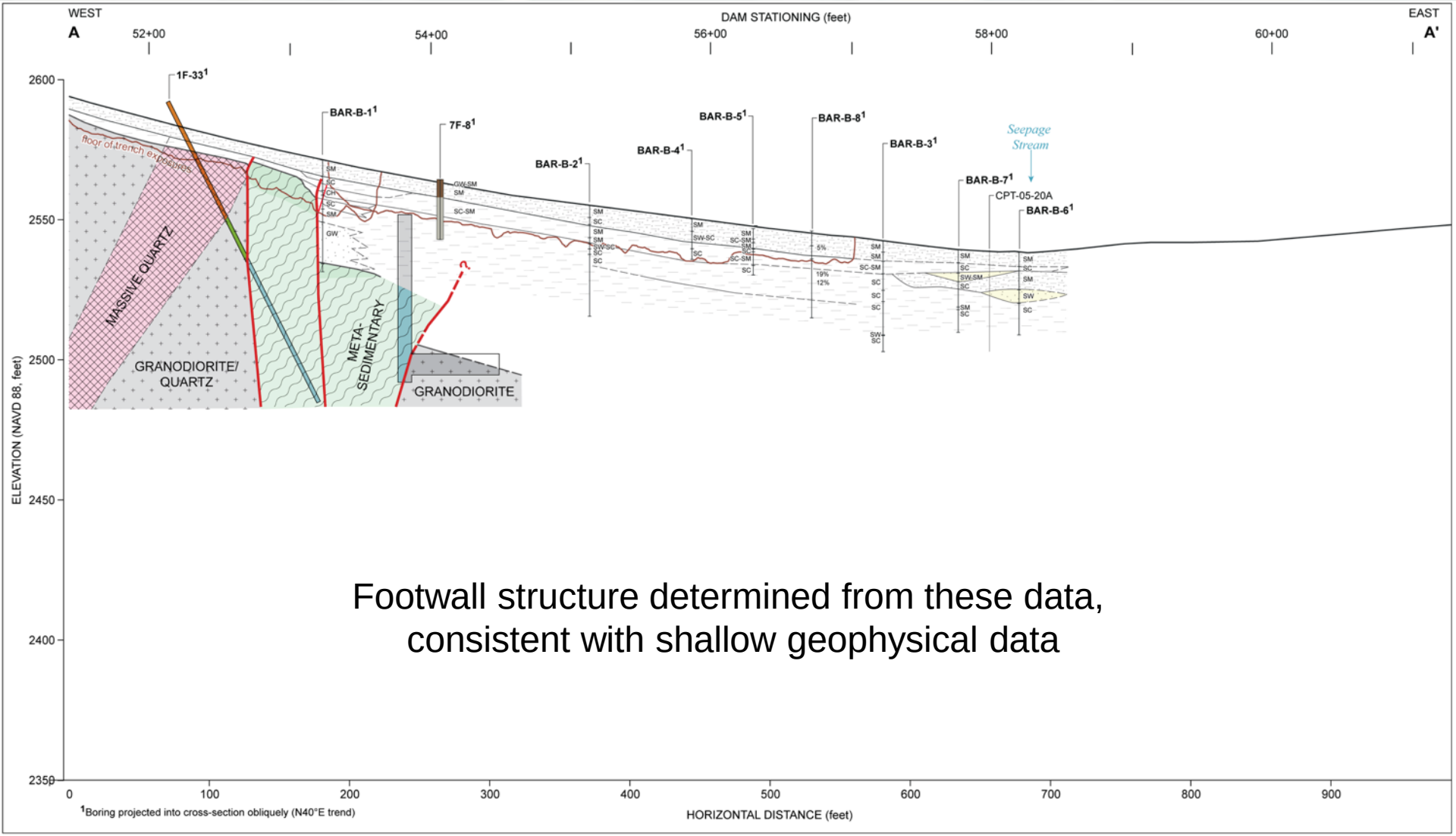
Cross Section: Trench data, USACE (1948)



Shaft and angled borings logged for foundation report

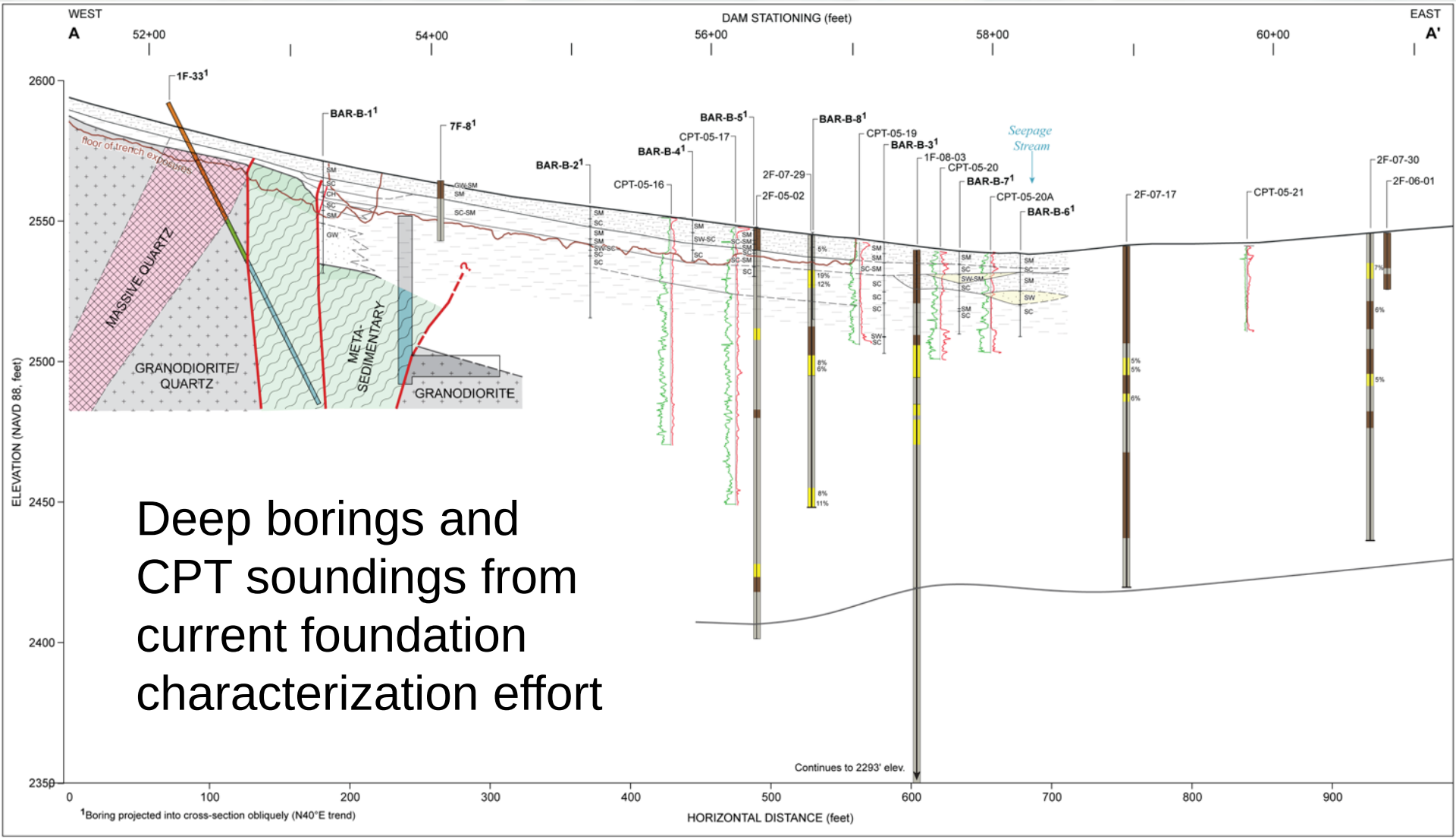
Fault observed in shaft originally interpreted as west-dipping, reverse sense of displacement

Cross Section: trench, USACE (1948)



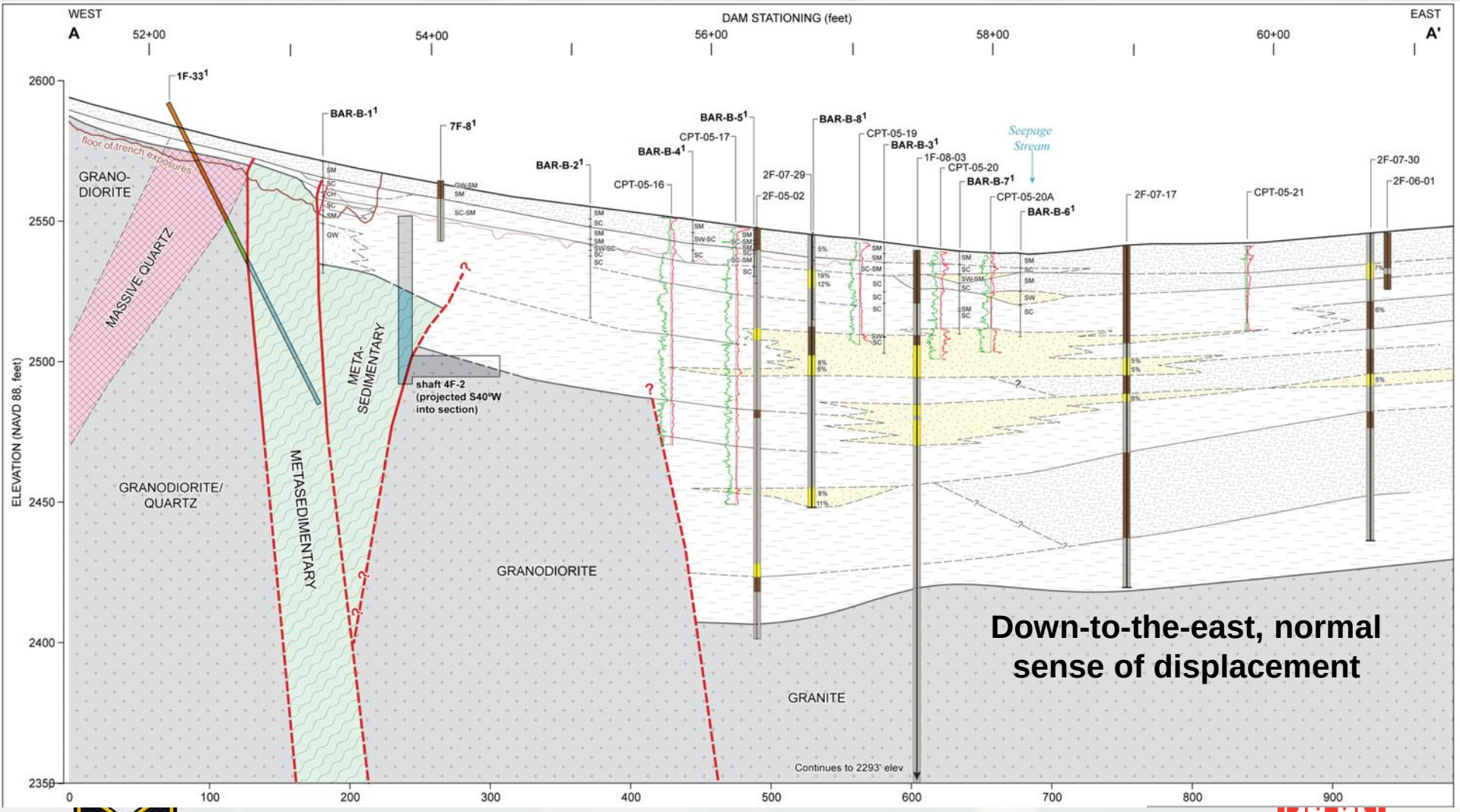
Footwall structure determined from these data, consistent with shallow geophysical data

Trench data, USACE (1948), URS (2008)

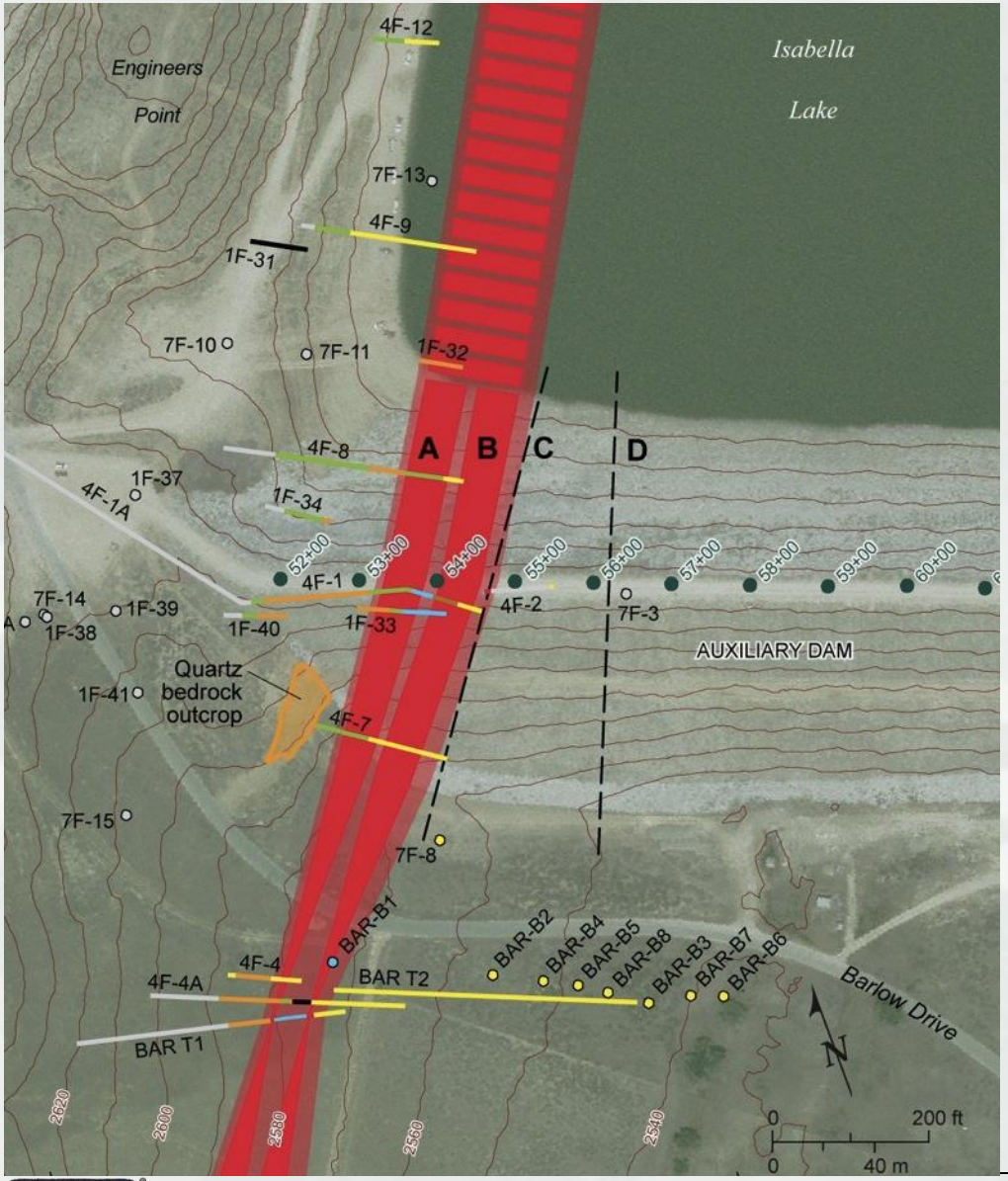


Deep borings and CPT soundings from current foundation characterization effort

Four fault strands, slightly asymmetric basin



Active Deformation on KCF



Tectonic displacement in 150-ft-wide zone

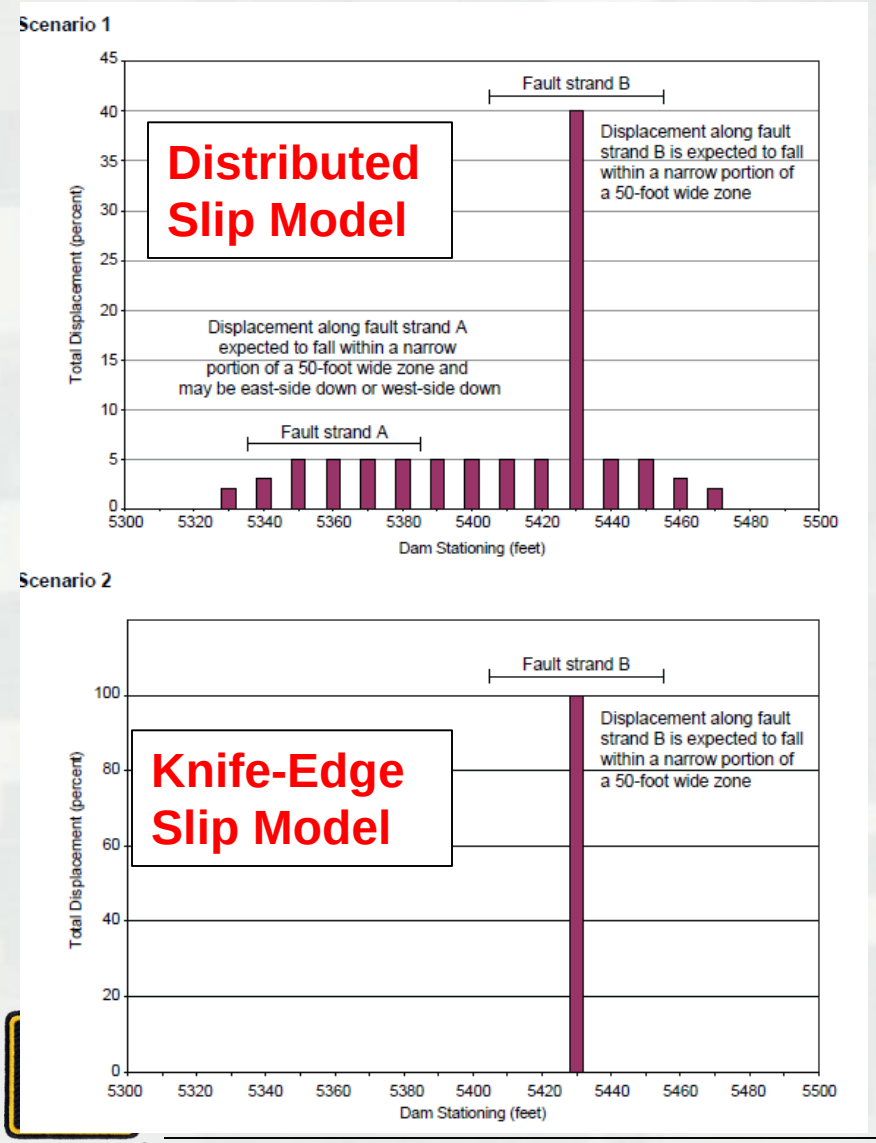
Two active fault strands, 50 ft apart; Secondary deformation between two primary strands

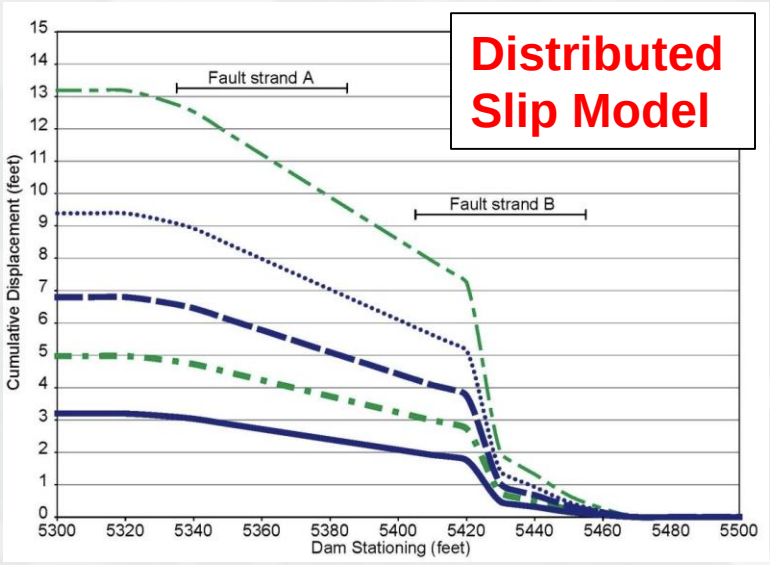
Overall displacement:
East-down normal

2 datable surface ruptures at Auxiliary Dam in past 10,000 yr **M**6.5-**M**7.1. Average 1.1m offset

Estimated recurrence on Lake Isabella section is 700 to 3600 yr, Most Recent Event:
3,600 years ago

Distribution of Slip Across the Fault Zone

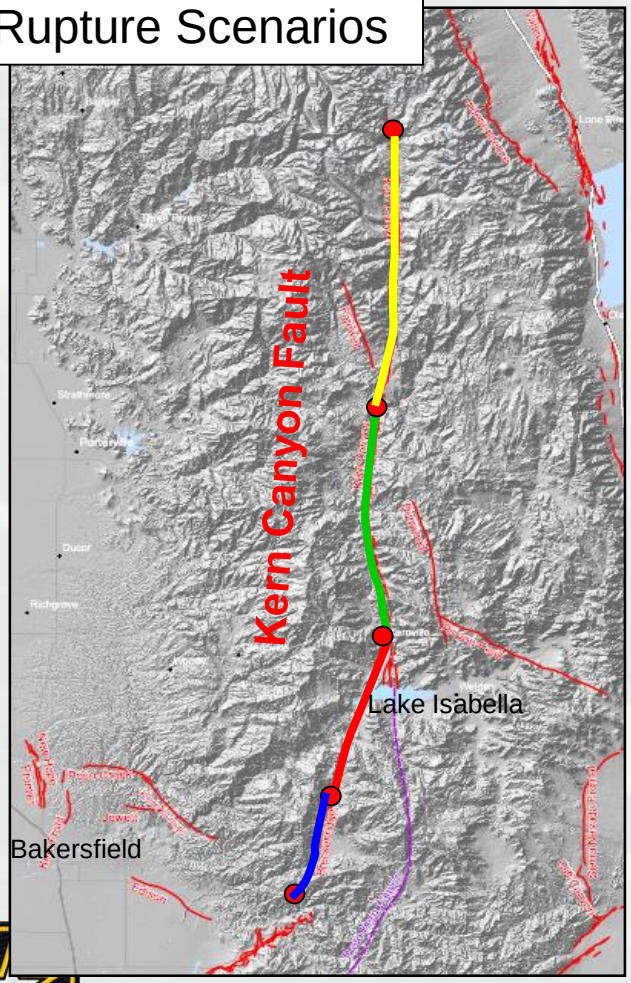


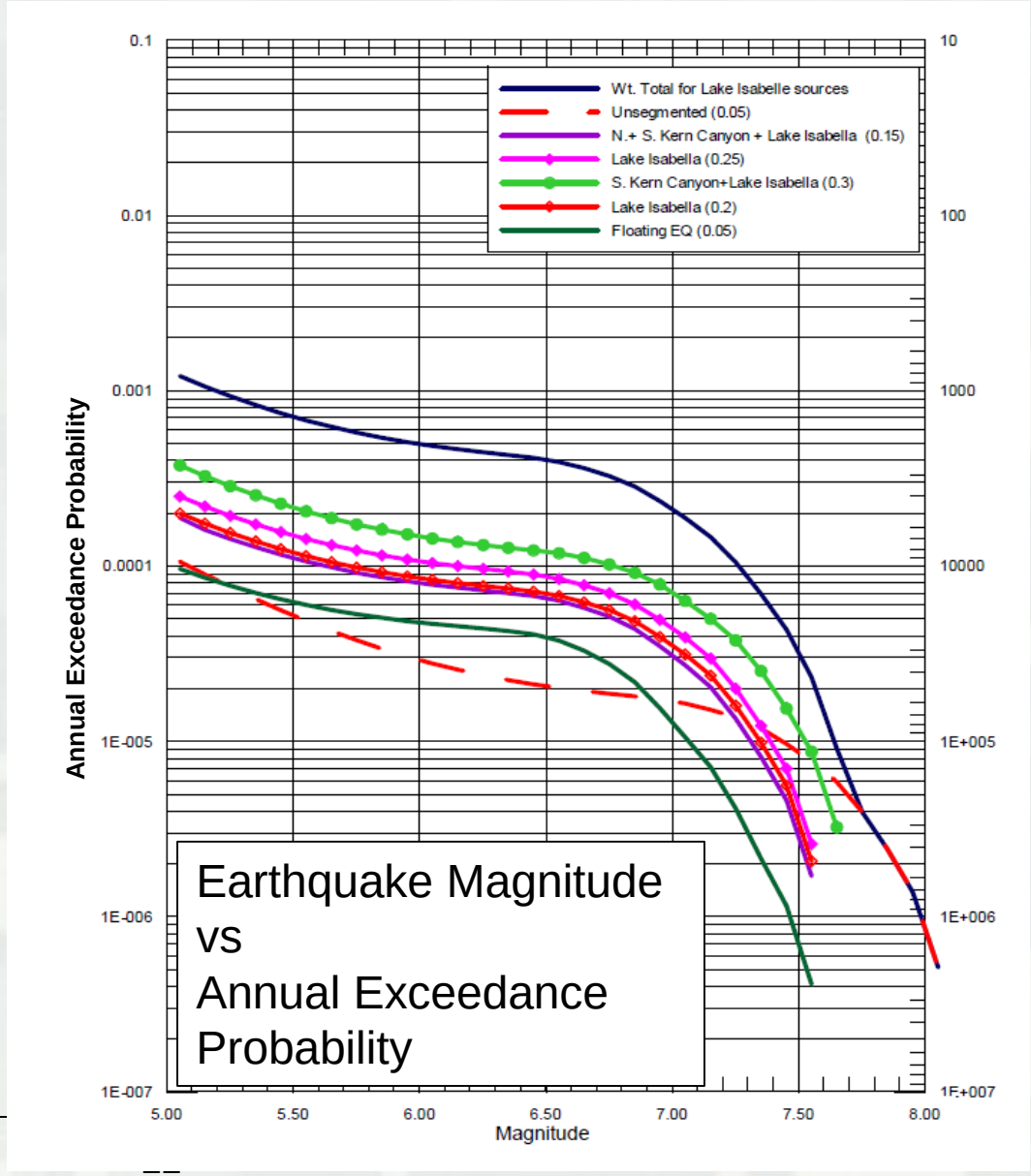


Must consider knife-edge model (more conservative)

Coseismic Rupture Estimation

Fault Segmentation and Rupture Scenarios





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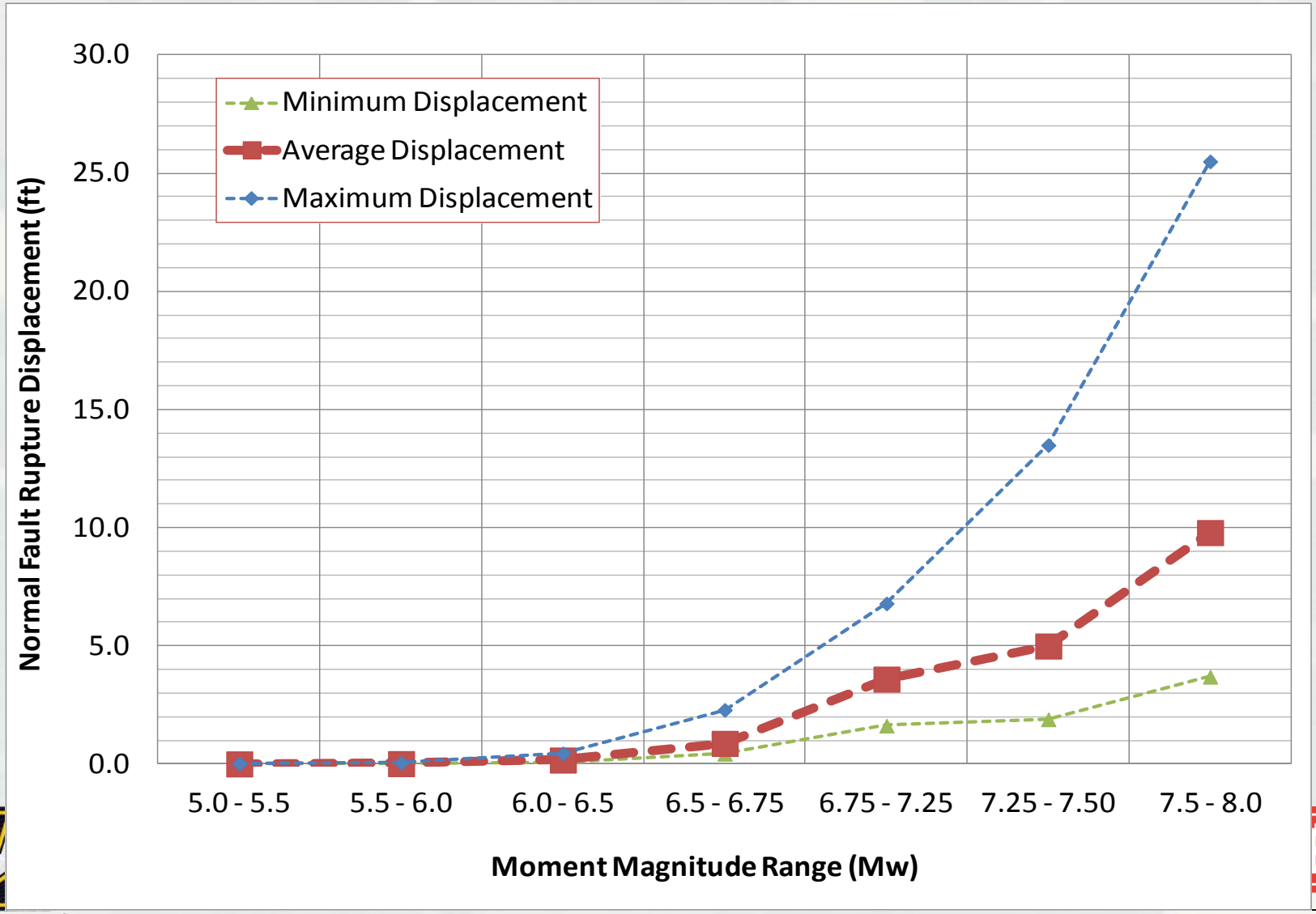
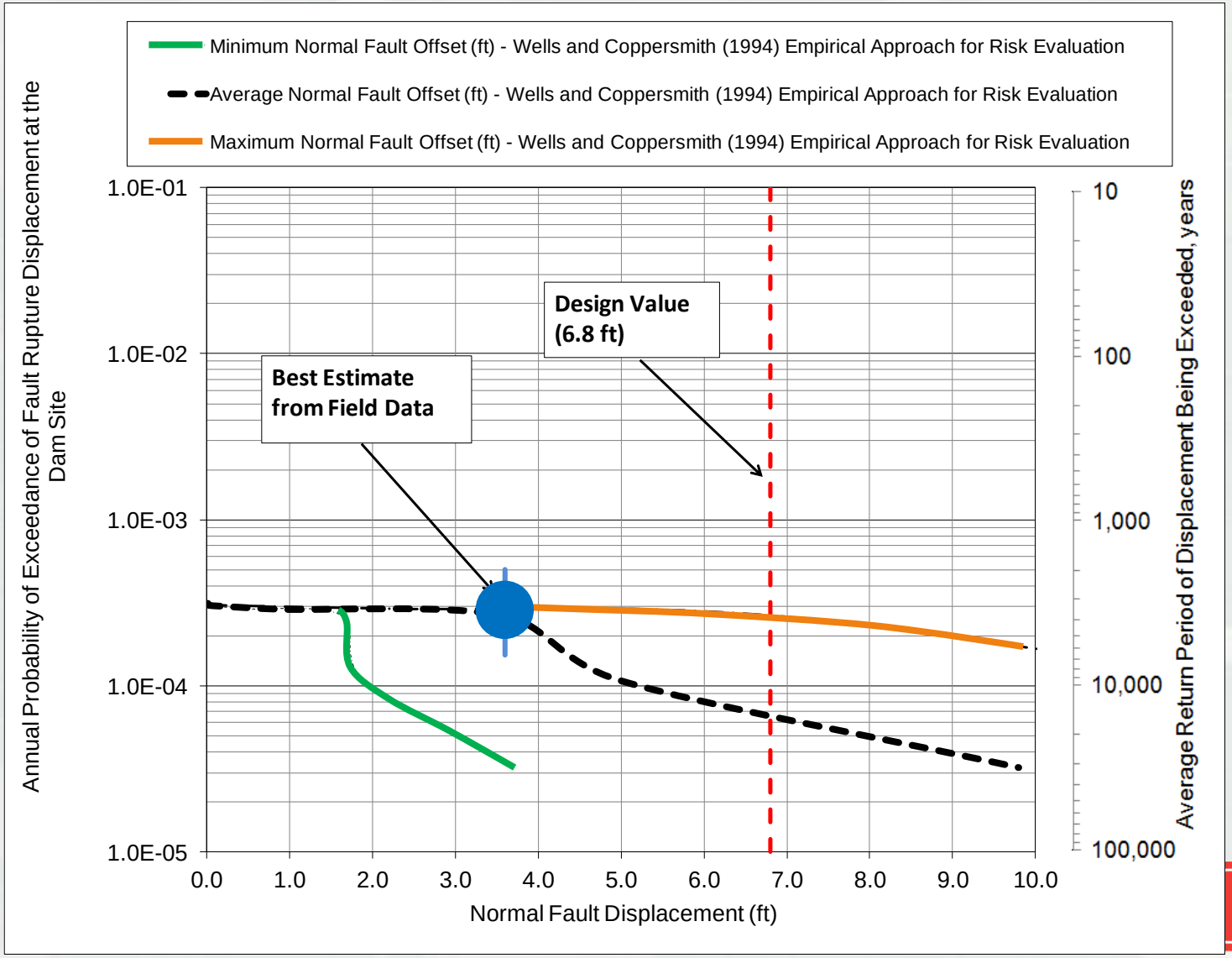
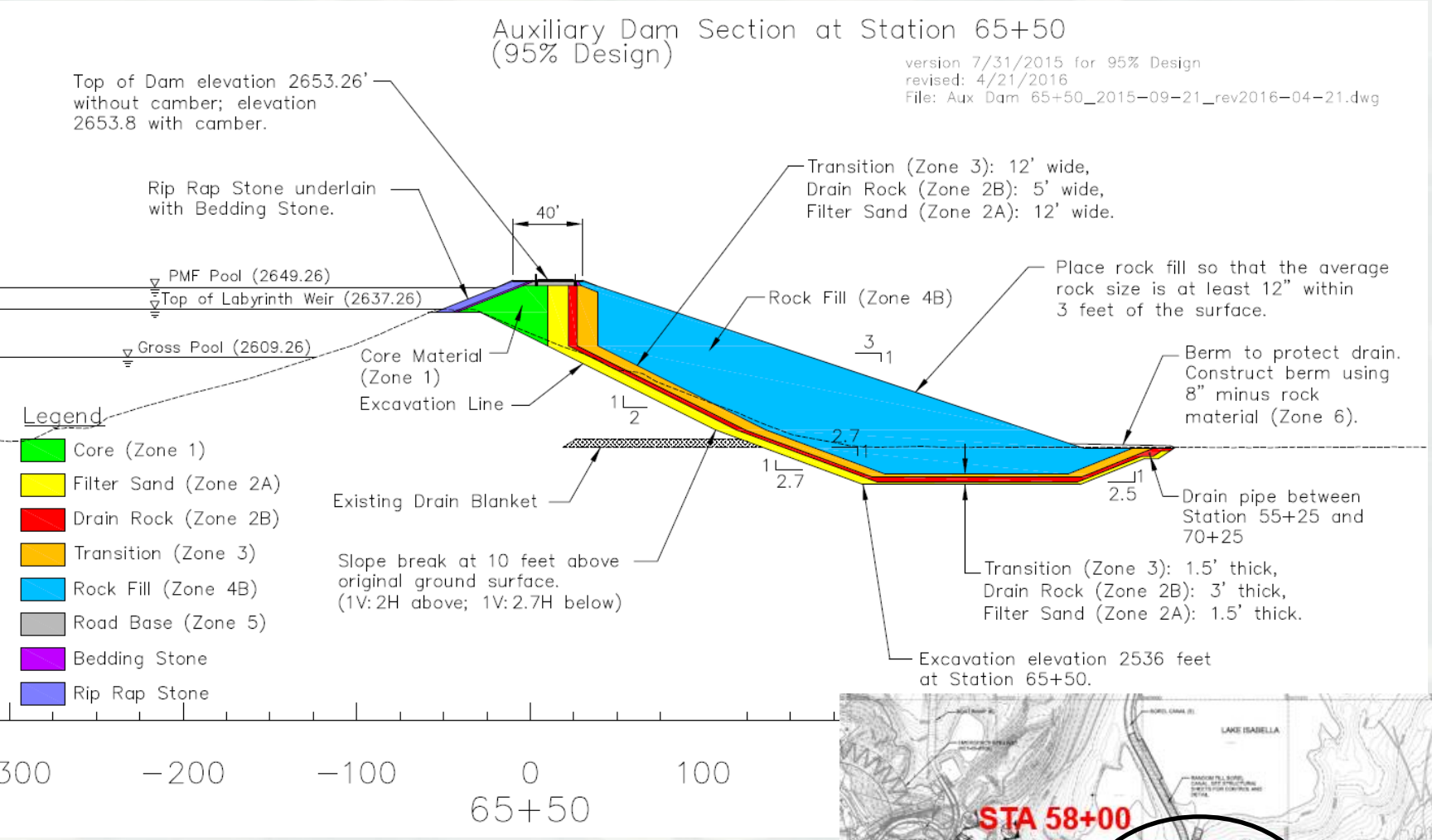
Coseismic Rupture Estimation

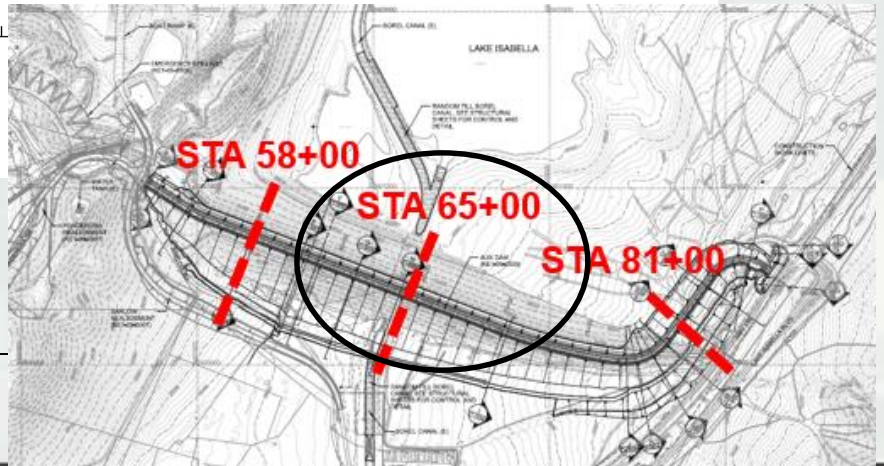


Coseismic Rupture Estimation

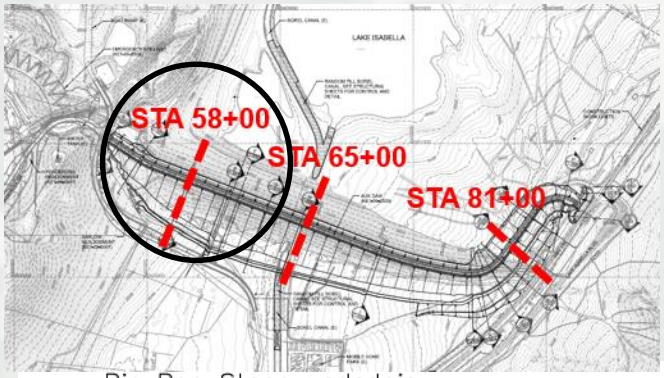


Auxiliary Dam STA 65+00





Auxiliary Dam STA 58+00



Filter Sand Layer 14 ft thick (vertical dimension)

Drain Rock layer 14 ft thick (vertical dimension)

Rip Rap Stone underlain with Bedding Stone

40'

PMF Pool (2649.26)

Top of Labyrinth Weir (2637.26)

Gross Pool (2609.26)

Core Material (Zone 1)

Excavation Line

Rock Fill (Zone 4B). Place rock fill so that the average rock size is at least 12" within 3 feet of the surface.

Berm to protect drain. Construct berm using 8" minus Rock Material (Zone 6).

Existing Drain Blanket

Slope break at 10 feet above original ground surface (1V: 2H above; 1V: 2.7H below).

Transition (Zone 3) thickness: 1.5',
Drain Rock (Zone 2B) thickness: 14'
Filter Sand (Zone 2A) thickness: 14'

Excavation elevation: 2522 feet at Station 58+00

0 100'

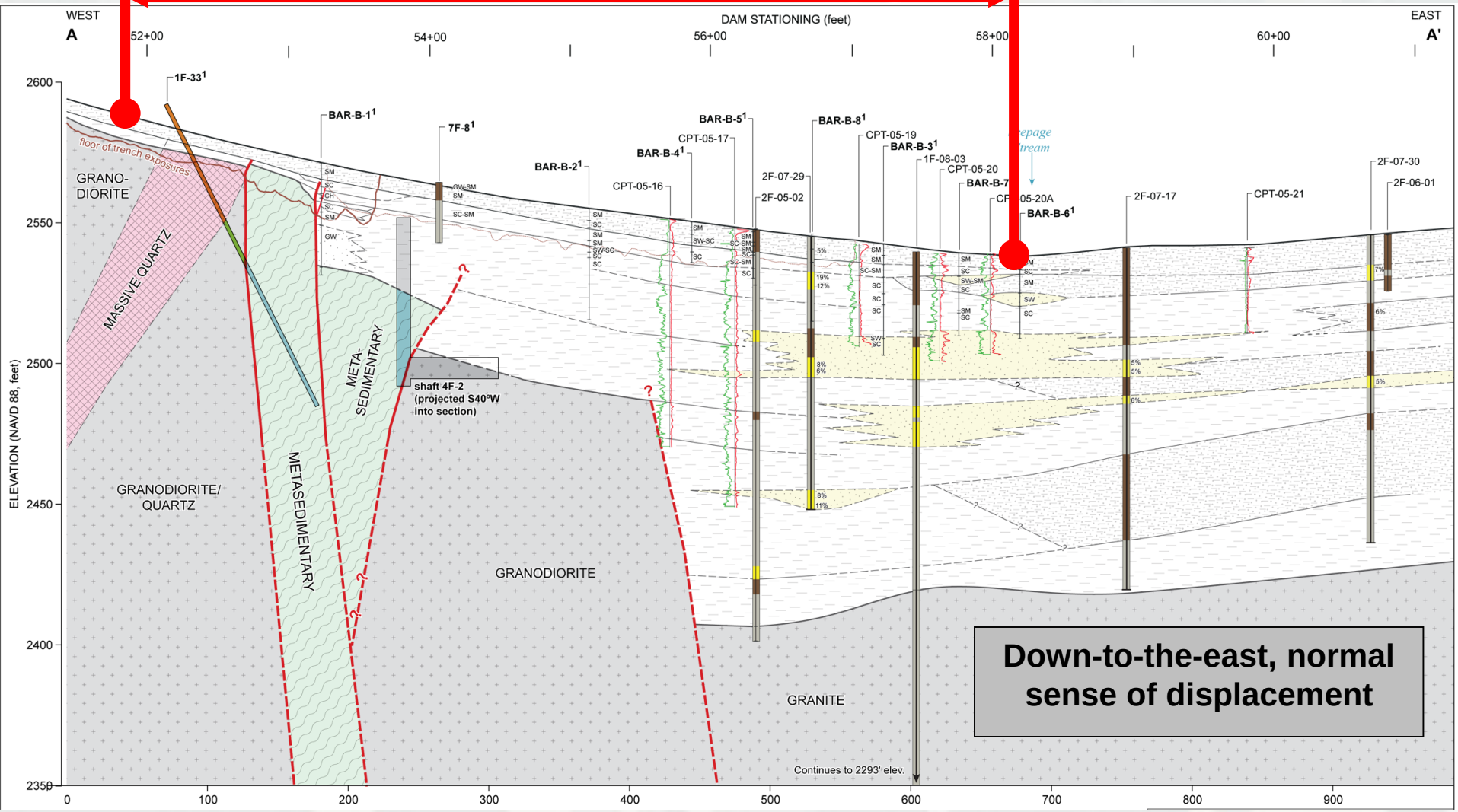
Legend

- Core (Zone 1)
- Filter Sand (Zone 2A)
- Drain Rock (Zone 2B)
- Transition (Zone 3)
- Rock Fill (Zone 4B)
- Road Base (Zone 5)
- Bedding Stone
- Rip Rap Stone

and Taking Care of People!

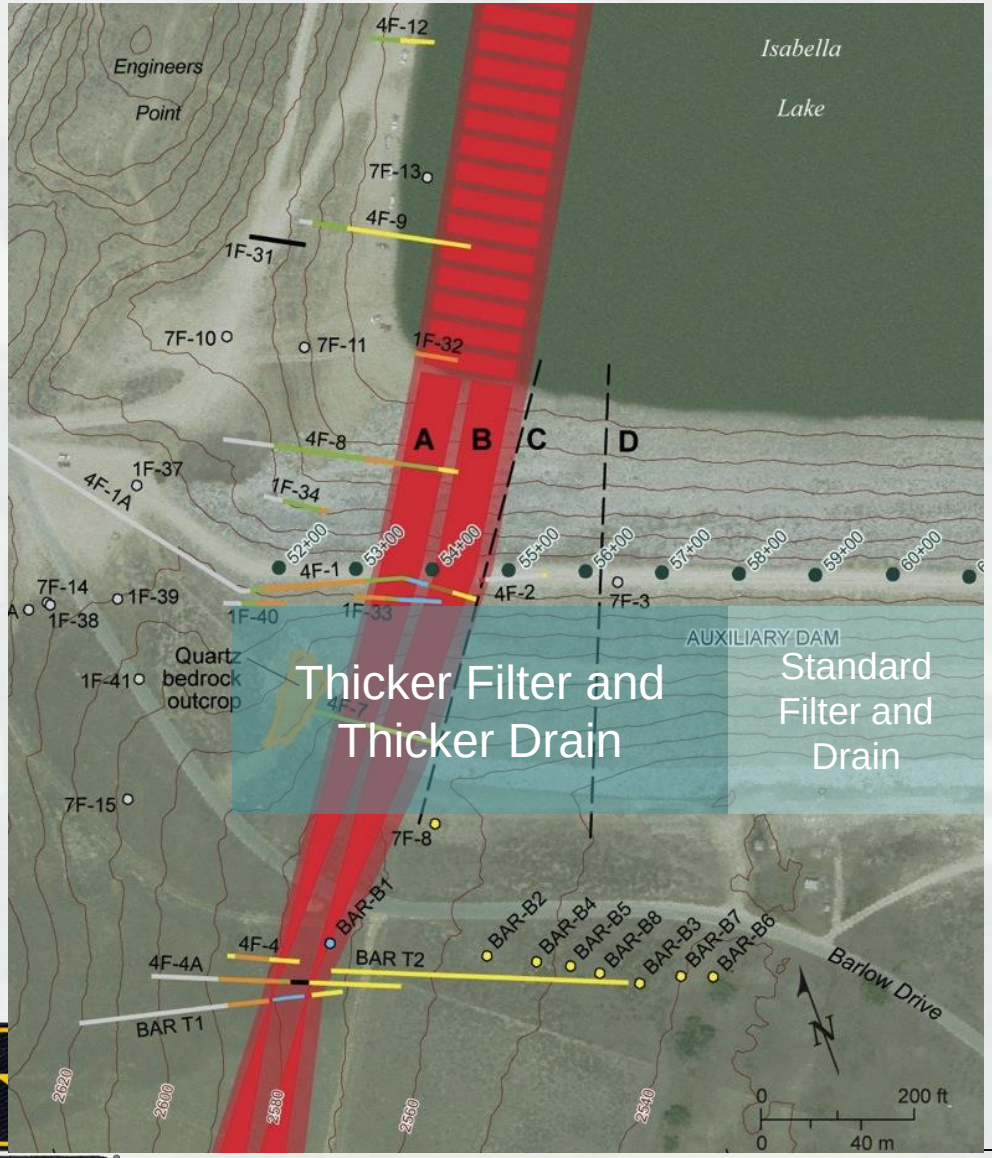
Auxiliary Dam Right Abutment

Filter and drain is thickest between Sta 52+00 and 58+00
to accommodate deformation from faulting



and Taking Care of People!

Kern Canyon Fault Rupture Mitigation



- Design value for fault rupture (6.8 ft normal offset) based on maximum estimated displacement from site-specific fault displacement
- Minimum and maximum fault rupture displacements from global empirical database
- To maintain filter compatibility, filter and drain layers designed to have same thickness over the fault zone area (2x design fault displacement)
- 7 x 2 = 14

Questions