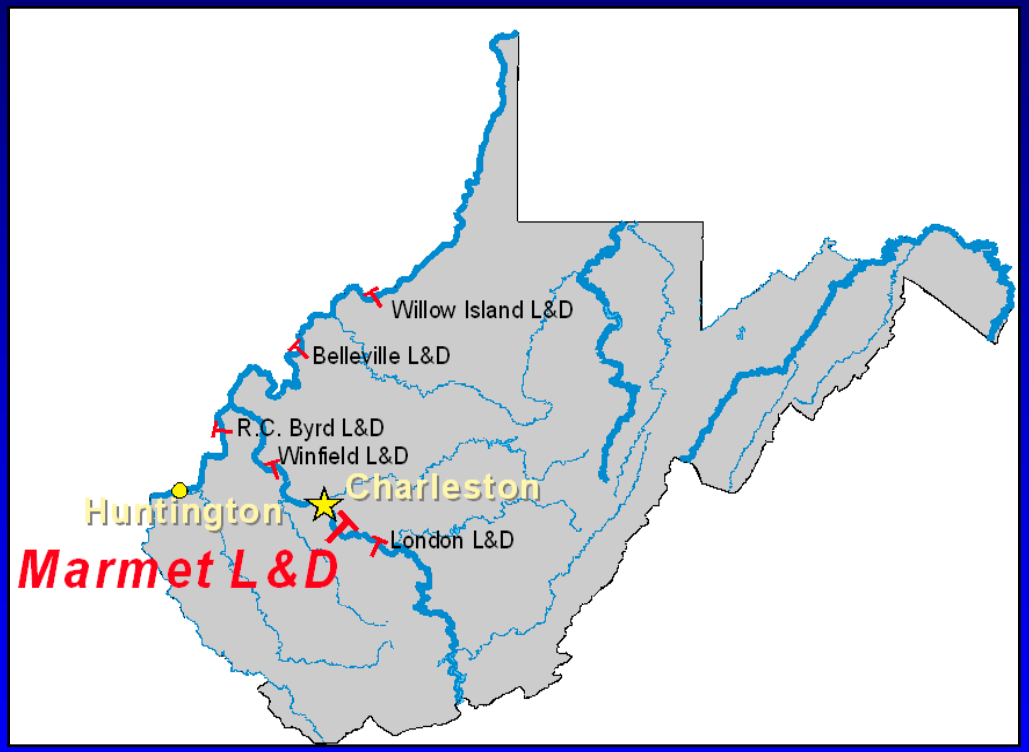
One Corps, One Regiment, One Team

US Army Corps of Engineers
Huntington District

Marmet Lock Replacement: Geotechnical Challenges



GEOHAZARDS IN TRANSPORTATION IN THE APPALACHIAN REGION

8th Annual Technical Forum:
Geohazards in Transportation in the Appalachian Region

Sean Carter, P.E.
USACE, Huntington District

Project Overview

- **Purpose is to alleviate traffic back ups on the Kanawha River**
- **Existing and smaller 56’ X 360’ lock chambers inhibit river traffic**
- **Project adds one larger 110’ X 800’ lock chamber and approach walls, located landward of old locks**
- **Construction started in summer 2002 with a contract cost of approximately $230 Million**

Project Overview

Existing Lock – Prior to Construction

Project Overview

New Lock – Photo taken 1 July 2008

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Project Overview : February 2007

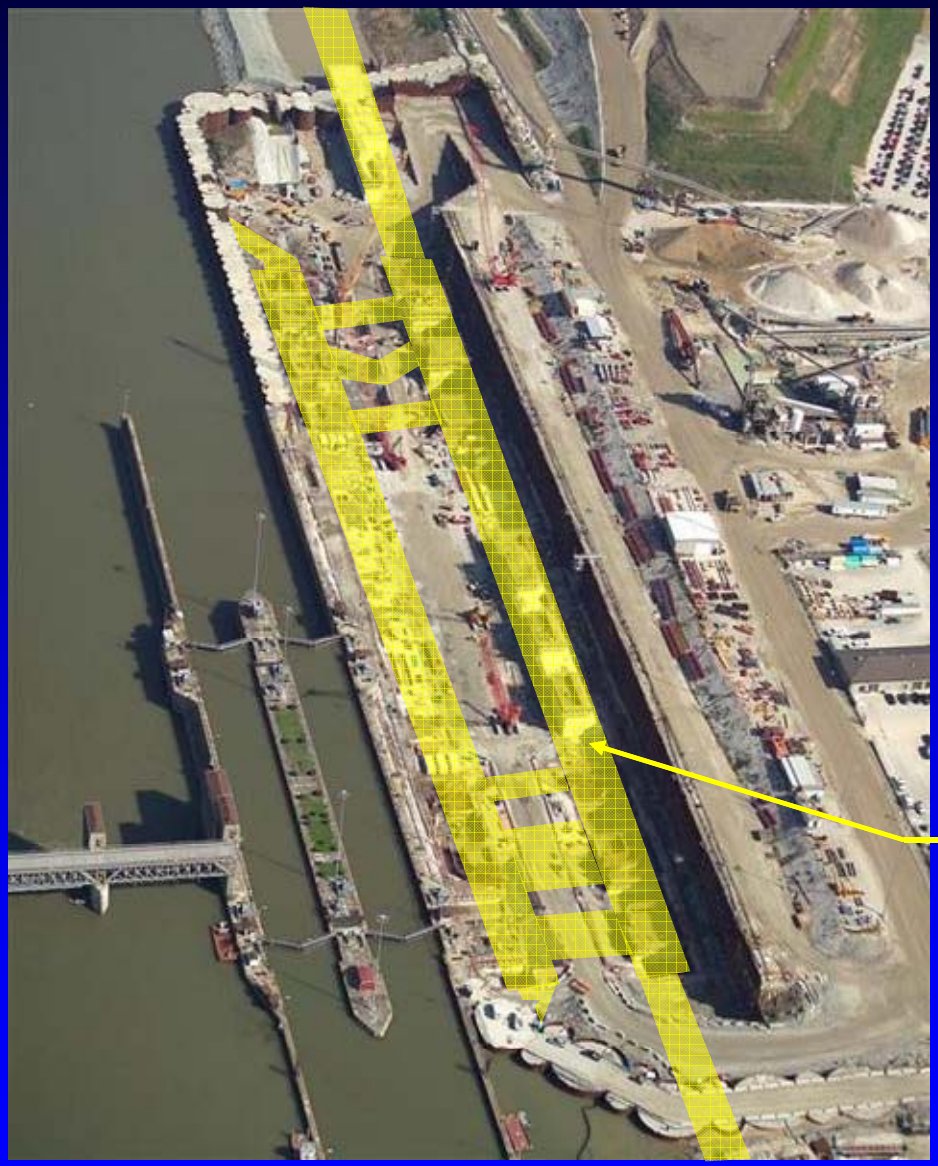
Project Overview

New Lock Chamber Under Construction

Existing Lock Chambers

New Lock Construction - Aerial View - May 2005

Project Overview



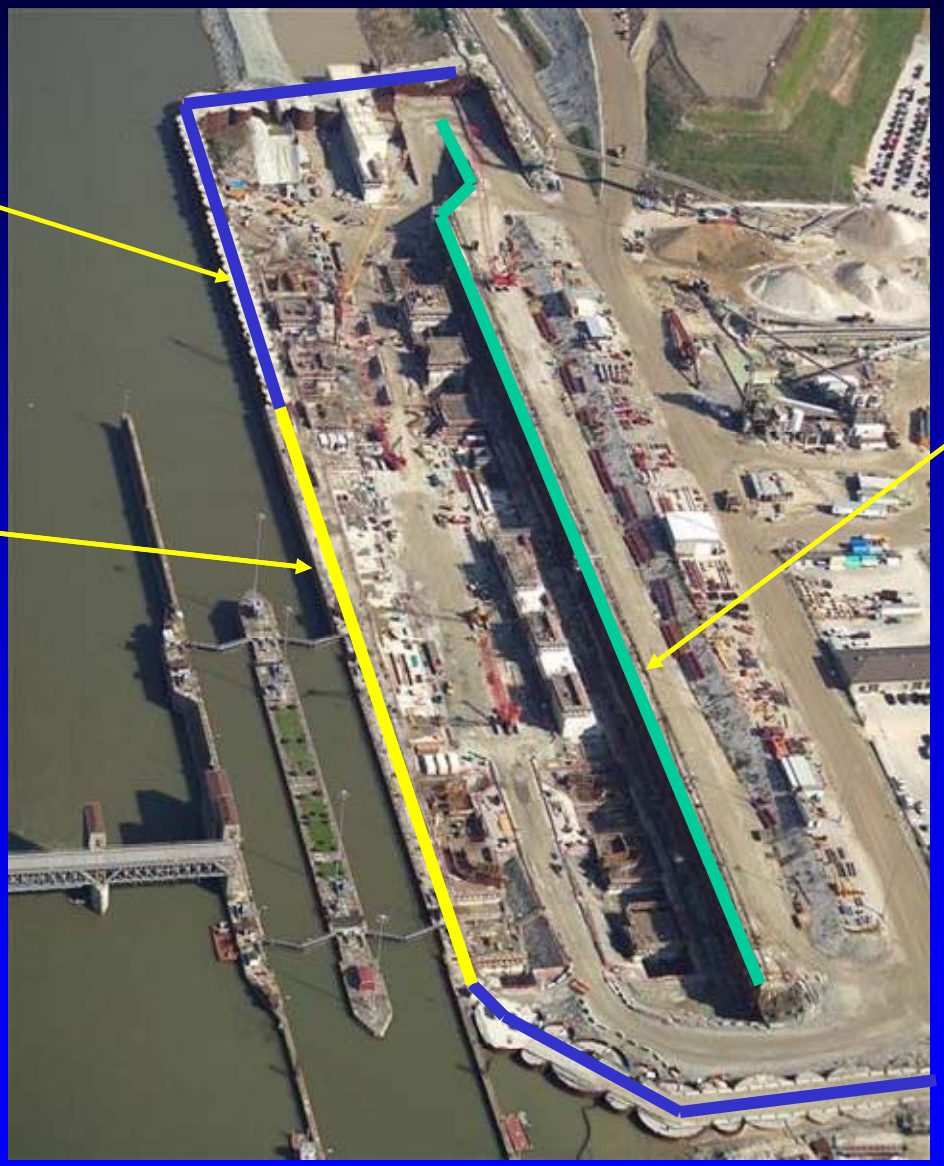
New Lock Chamber
and Approach Walls

New Lock Construction - Aerial View - May 2005

Project Overview

Sheet Pile Cell Cofferdam

Existing Landwall Portion of Cofferdam



Contractor Designed Anchored Retaining Wall

New Lock Construction - Aerial View - May 2005

Tied-back Flexible Wall

- **Contractor value-engineered construction of ~45 ft. tall tied-back wall in lieu of sloped excavation and two stage vacuum well system designed by government.**
- **Four rows of tie-backs with lower two socketed into rock and upper two utilizing soil anchors.**

- **Wall performed well throughout construction (approximately 4 years).**
- **Slurry trench was located landward of tied-back wall for excavation dewatering purposes.**

Geotechnical Concerns

- **Embankment Stability**
  - **Characterize Subsurface Conditions**
  - **Laboratory and Field Testing Program**
  - **Estimate Embankment Properties**
  - **Selection of Shear Strengths**
  - **Perform analyses**
  - **Construction Considerations**

- Slope Stability Analyses performed by USACE, Huntington District

- Placement Rate Analyses performed by FMSM Engineers (Lexington, KY)

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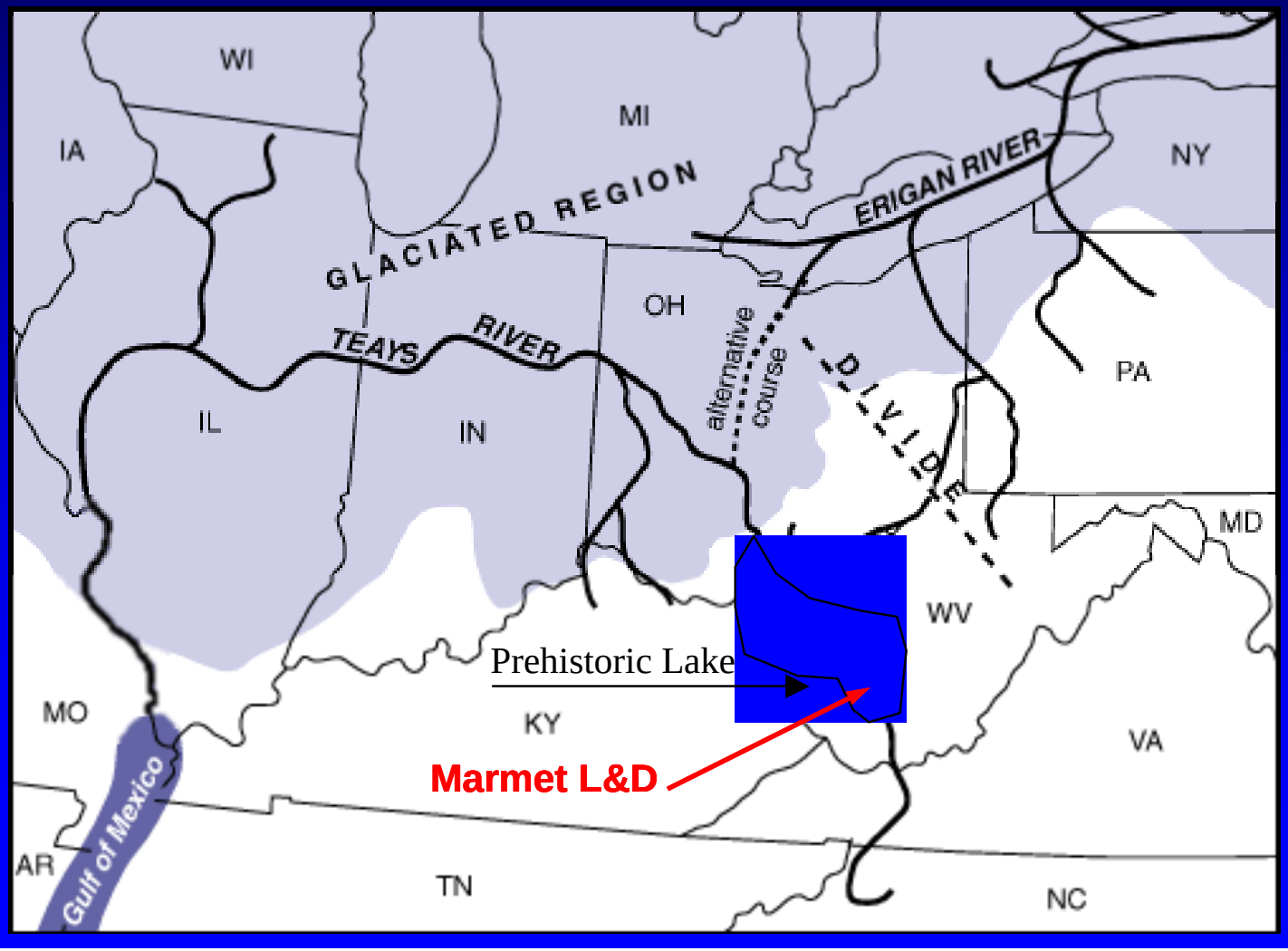
Deep Clay Deposits of the Prehistoric Teays Lake



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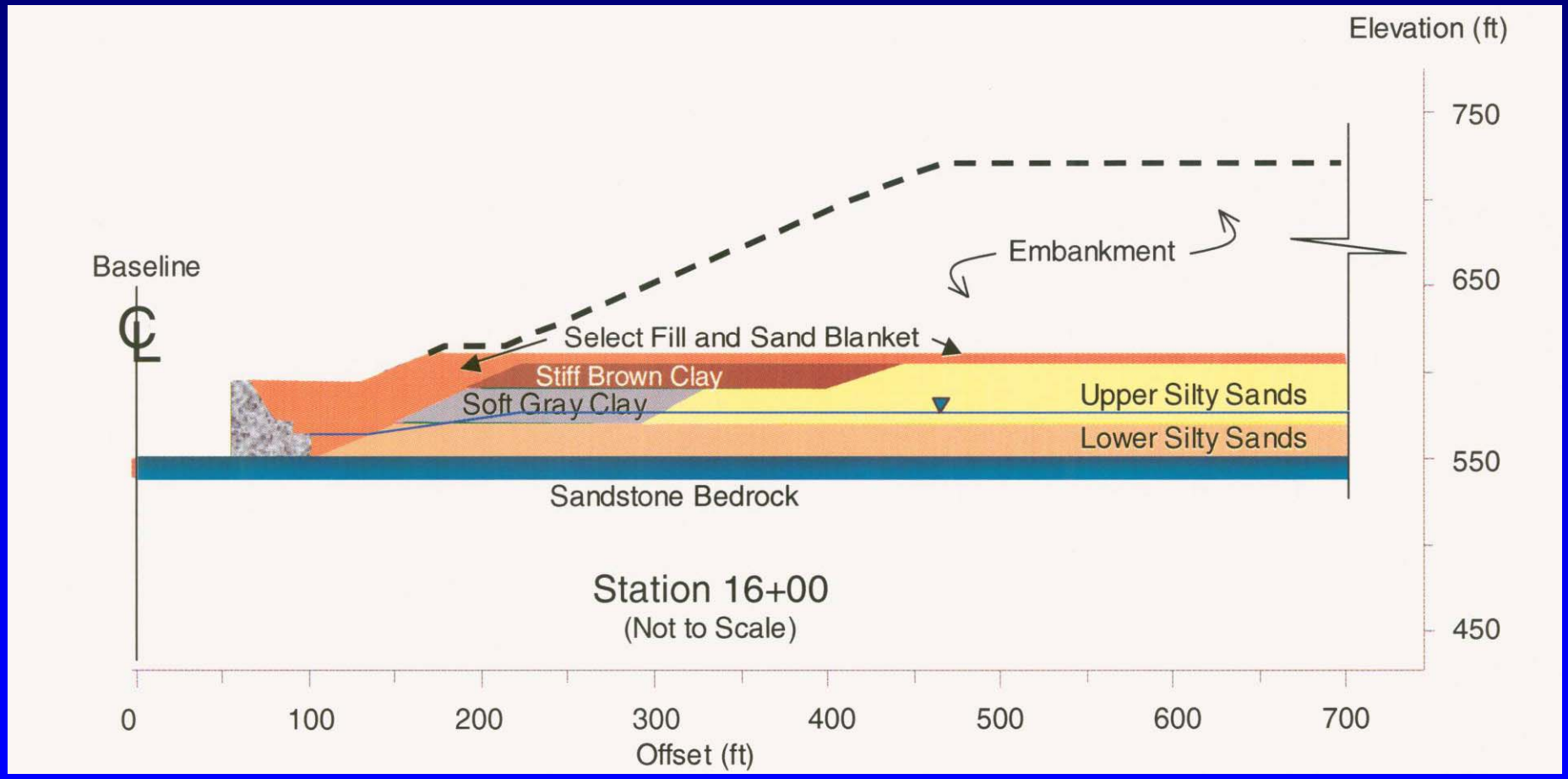
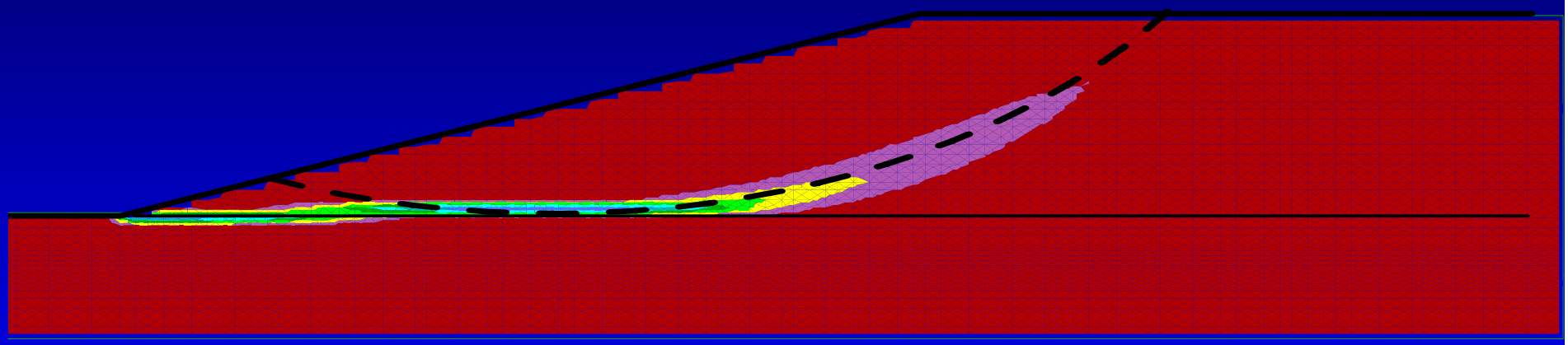
Mt. Marmet: ~120 ft. design height

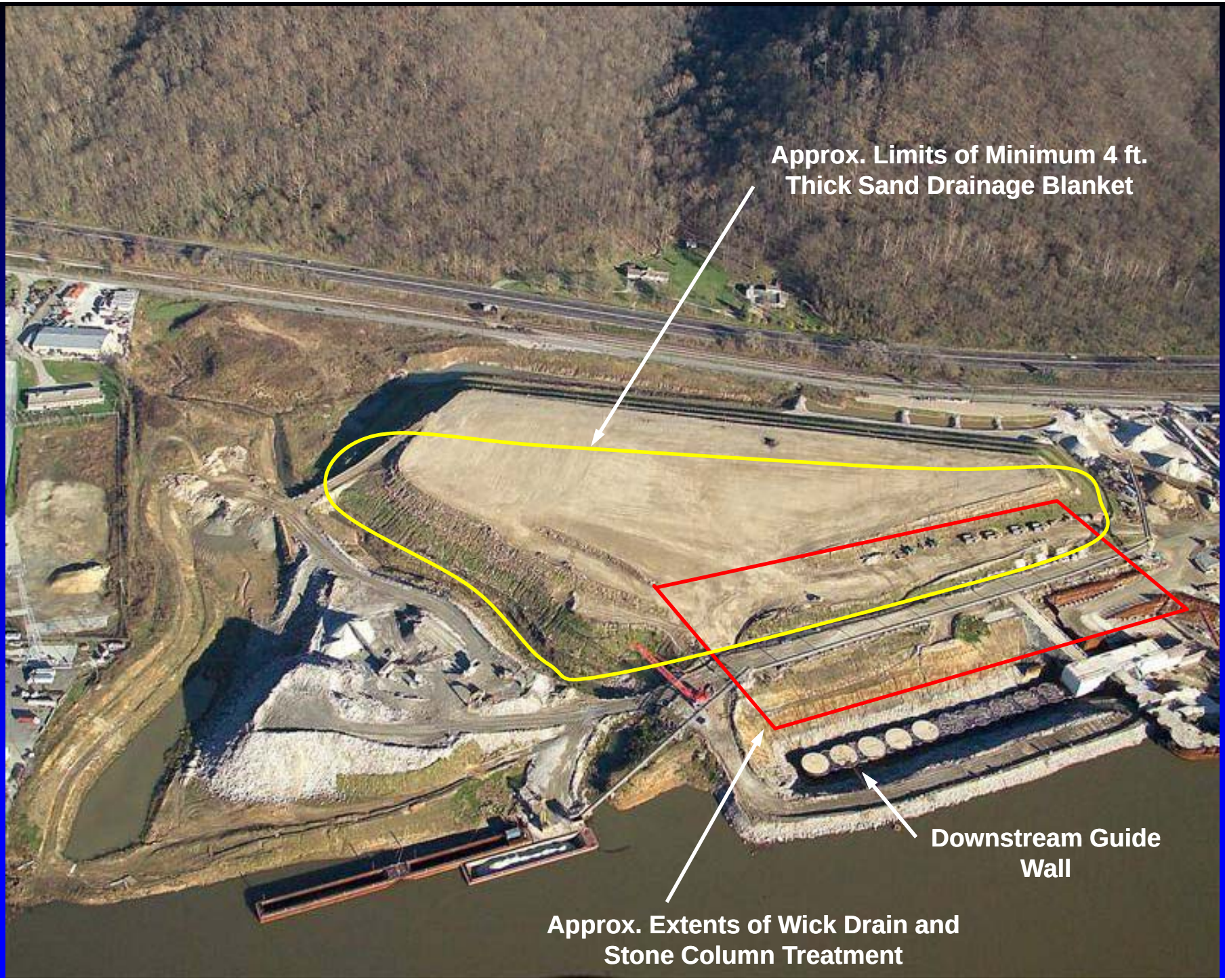


Typical Cross Section of Embankment

Slope Stability using FLAC



- **Factors of safety without foundation treatment were marginal.**
- **Even with wick drains installed to dissipate excess pore pressures, Contractor's flexibility of scheduling is limited due to additional lateral loads transmitted to the guidewall.**
- **Combination of wick drains and stone columns offer a solution that provides schedule flexibility for Contractor.**


Approx. Limits of Minimum 4 ft.
Thick Sand Drainage Blanket
Downstream Guide
Wall
Approx. Extents of Wick Drain and
Stone Column Treatment

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Wick Drains: 1,263 in 3 days

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Stone Columns: 1,081 in 3 months

Vibro-displacement Stone Columns

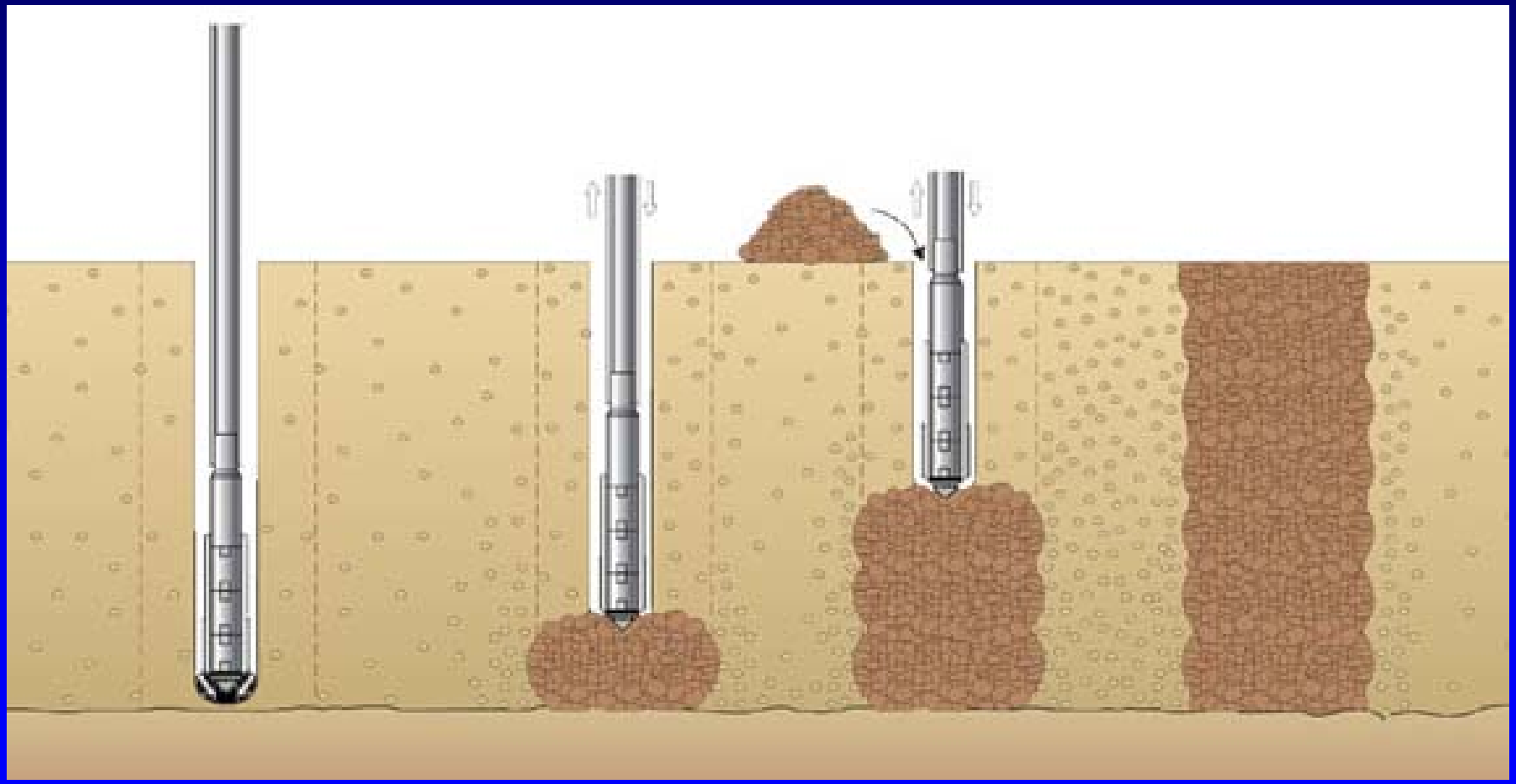

***Image from Hayward-Baker (http://www.haywardbaker.com)**

"Boils?"

- **Artesian pressures in lower aquifer.**
- **Excess pore pressure induced by fill placement or by vibration induced liquefaction.**

Confirm placement quality

Performed boring utilizing 2-inch and 3-inch split-spoons to verify that desired properties (free draining, relative densities) were actually being obtained.

Correlations to obtain N-value from 3-inch split-spoon and 300 lb. hammer did not work very well.

Instrumentation and Pore Pressure Measurement

After completion of the stone columns/wick drains, 24 vibrating wire piezometers and seven inclinometers were installed.

The piezometers were situated along the length of the embankment and measured pore pressures in four discreet intervals of the soft clay in the soil profile.

Lime Stabilization

The Contractor used lime in order to expedite placement of saturated clays. Generally, mixing 1.5-3% lime by weight has been successful depending on the water content of the clay and weather conditions.

Disposal Embankment

Photograph taken 27 April 2008

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Disposal Embankment

Photograph taken 2 June 2008

Summary

- **Subsurface soils included a very soft saturated clay.**
- **Proposed embankment foundation unstable for quick loading.**
- **To provide Contractor flexibility and ensure stability, combination of drainage blanket and stone columns/wick drains were installed at an overall cost of ~$2.4M.**
- **Automated piezometers installed to ensure excess pore pressures dissipate as embankment is placed.**
- **Inclinometers installed to monitor subsurface displacements.**
- **Since fill placement began in Summer 2002, no problems or concerns. (~$2.2X10^6$ CY placed out of a total ~$2.9X10^6$ CY estimated for completed embankment.)**

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Lock Operational

First Lockage: 22 January 2008

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Lock Operational

First Lockage: 22 January 2008

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Questions? – THANK YOU!

Grand Opening!

9/27/1932