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New York District

2005 Tri-Service Infrastructure Systems Conference
"Re-energizing Engineering Excellence"

BIOENGINEERING SLOPE STABILIZATION TECHNIQUES COUPLED WITH TRADITIONAL ENGINEERING APPLICATIONS –

THE RESULT IS A STABLE SLOPE

Waterbury Dam Mitigation

Thursday August 4th, 2005

St. Louis, Missouri

Presented By: Ms. Bethany Bearmore

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Waterbury Dam Mitigation

The objective of the project is to improve the water quality in the Waterbury Reservoir and Little River by implementing shoreline stabilization measures that reduce the sediment yield.

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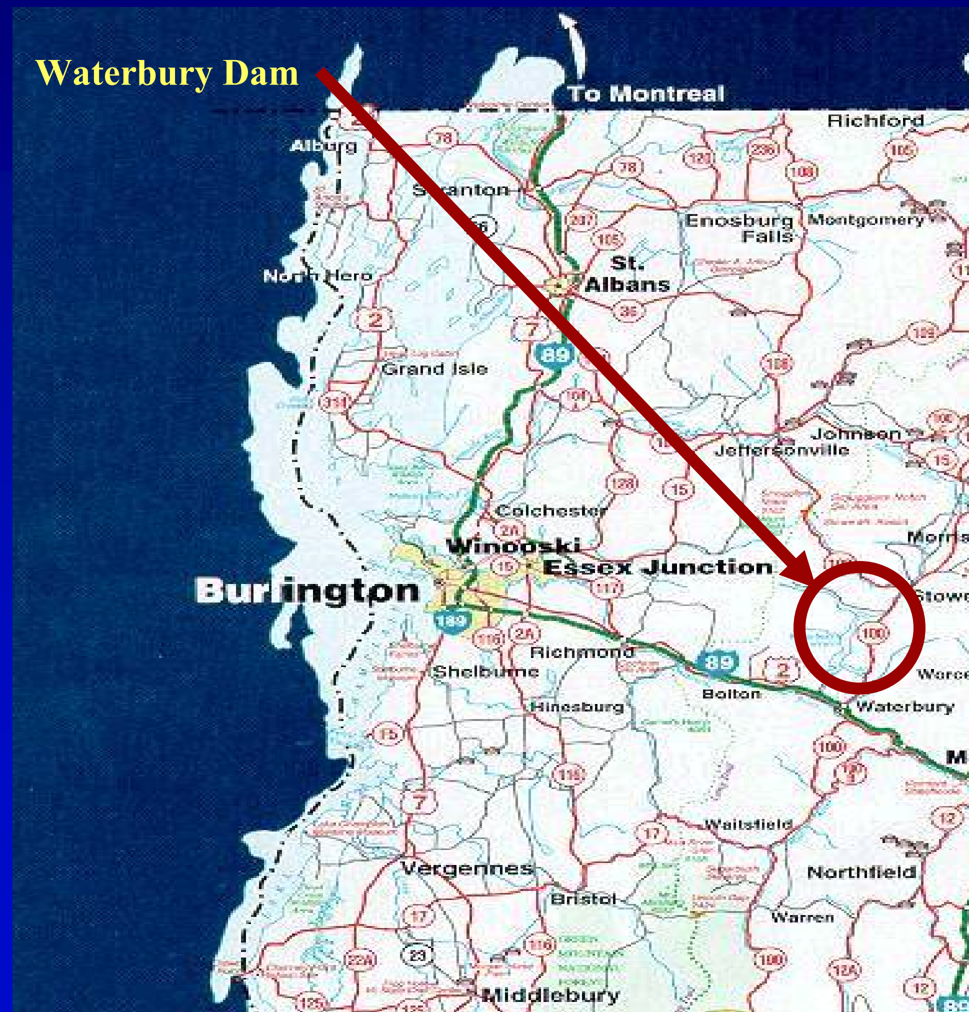
Waterbury Dam Mitigation
Vicinity Map

Background Information:

1. Winooski River Basin ~ 1,200.0 mi^2
2. Little River above Dam = 109.0 mi^2.
3. Built by Civilian Construction Corps
4. Operational in 1938
4. State of Vermont Owns & Operates

General Location



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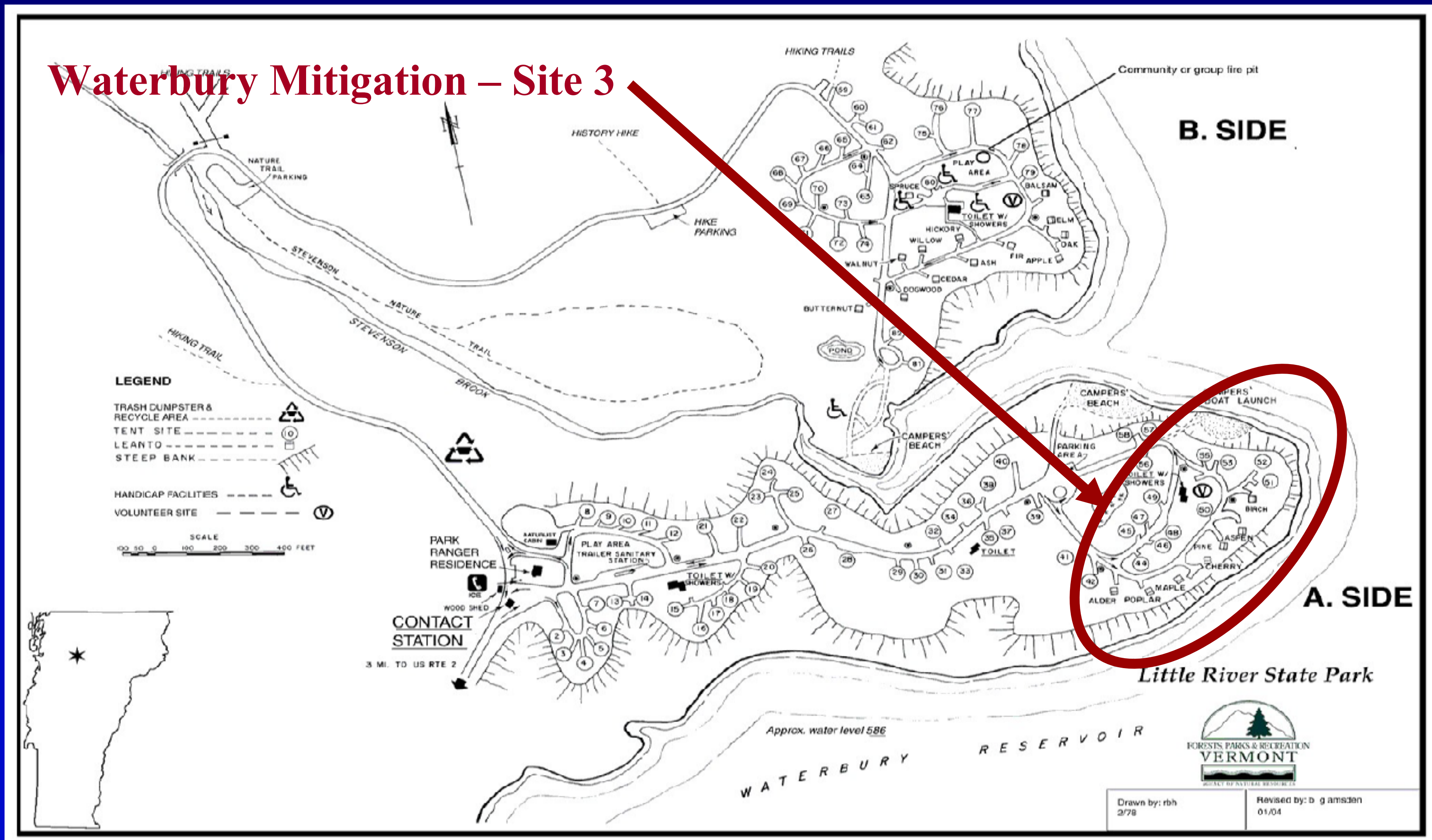
Waterbury Dam Mitigation Location Map



Waterbury Dam Mitigation Location Map

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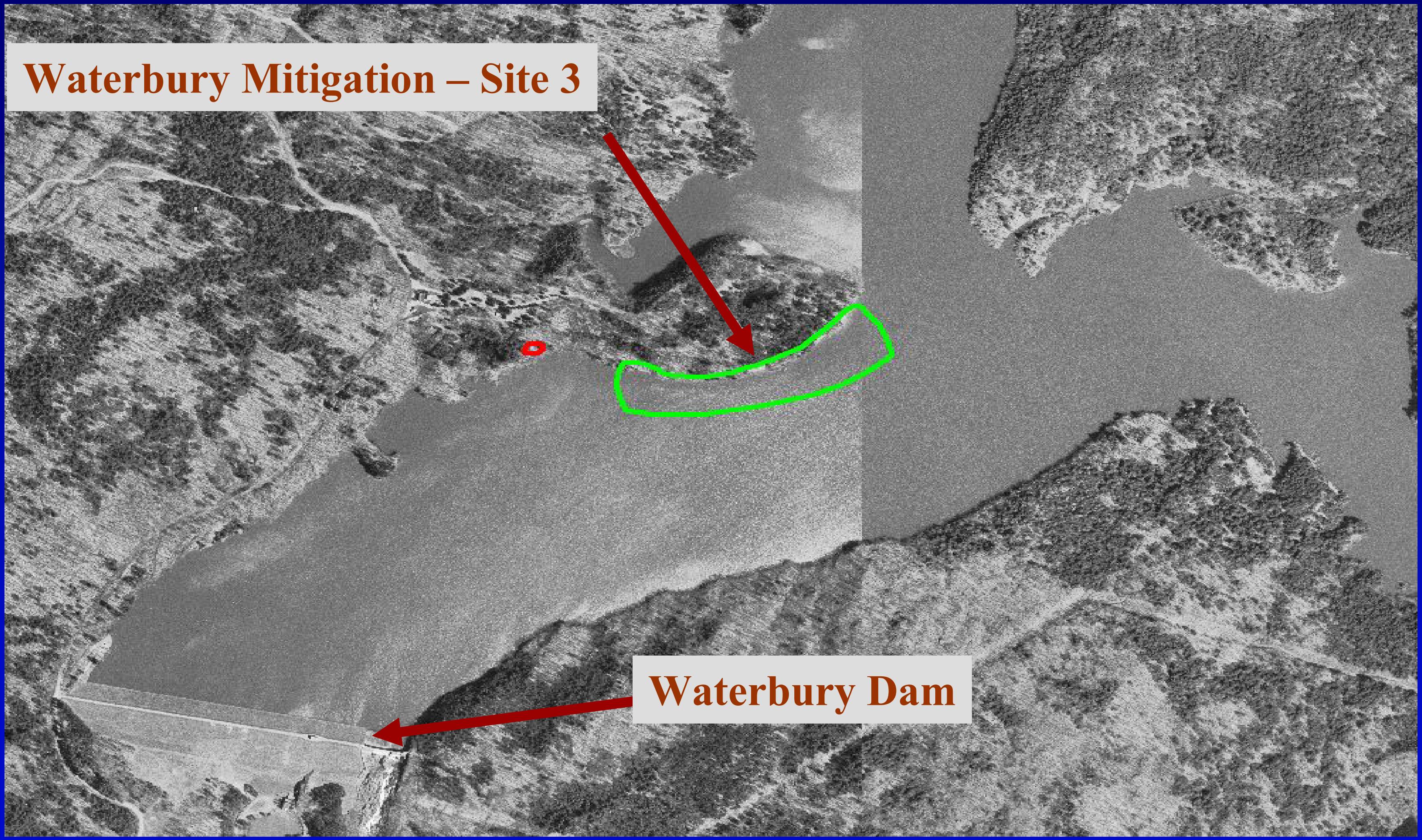

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Waterbury Dam Mitigation Construction History

- Original Construction (April 1935 - October 1938)
  - Built in response to 1927 Flood event
  - Project constructed by Civilian Conservation Corps; designed by Corps of Engineers
- Later Modifications to Dam with COE Involvement
  - 1957 Modification.
    - Embankment was raised 3 feet.
    - Added Third Tainter Gate.
  - 1985 Seepage Remediation.
    - Corrected terrace seepage.
    - Discovered and remediated gorge seepage.
  - 2002 Seepage Remediation.
    - Repair of conduit through dam
    - Lowering of Pool to Elevation 520, which resulted in slope instability along reservoir
    - Placement of Secant Piles

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Waterbury Dam Mitigation
Why Stabilization is Needed

- Slope erosion
  - Seepage forces generated from water level drawdown
  - Wind and wave energy from reservoir
  - Overland flow
  - Loss of soil tensile strength
    - Water quality
      - Increased turbidity down stream of the dam
    - Loss of habitat
      - Loss of vegetation due to bank failure
    - Potential loss of state park area

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Waterbury Dam Mitigation
What is Bioengineering?

Bioengineering is a technical term used to describe a variety of techniques that use dormant cuttings from woody plants to alleviate erosion. Cuttings are taken from species that root easily, such as willow and dogwood, then planted in a specific arrangement depending upon the technique. The beauty of these techniques is that they alleviate erosion, improve water quality, enhance wildlife habitat and look more natural than a pile of rock filled wire baskets or other such structures.*

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Waterbury Dam Mitigation
Why Use Bioengineering?

- Provides a more aesthetically pleasing site
- Allows the reintroduction of native plants species
- Encourages a more responsive approach to adaptive management
- Allows for a more rapid return to a “natural” setting
- Fosters the interaction of the biologist and engineer to produce a better project
- Reduce seepage forces and surface erosion
- Increase soil tensile strength
- Water quality improvement

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Waterbury Dam Mitigation
Existing Site

Location of campsite

Location of fire pit

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Waterbury Dam Mitigation
Existing Site

Current water level of reservoir 550’

Summer water level of reservoir 589.5’

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Waterbury Dam Mitigation Existing Site

Current Angle of Slope – 23º to 47º
Max stable slope - 41º
Colton gravelly, loamy sand

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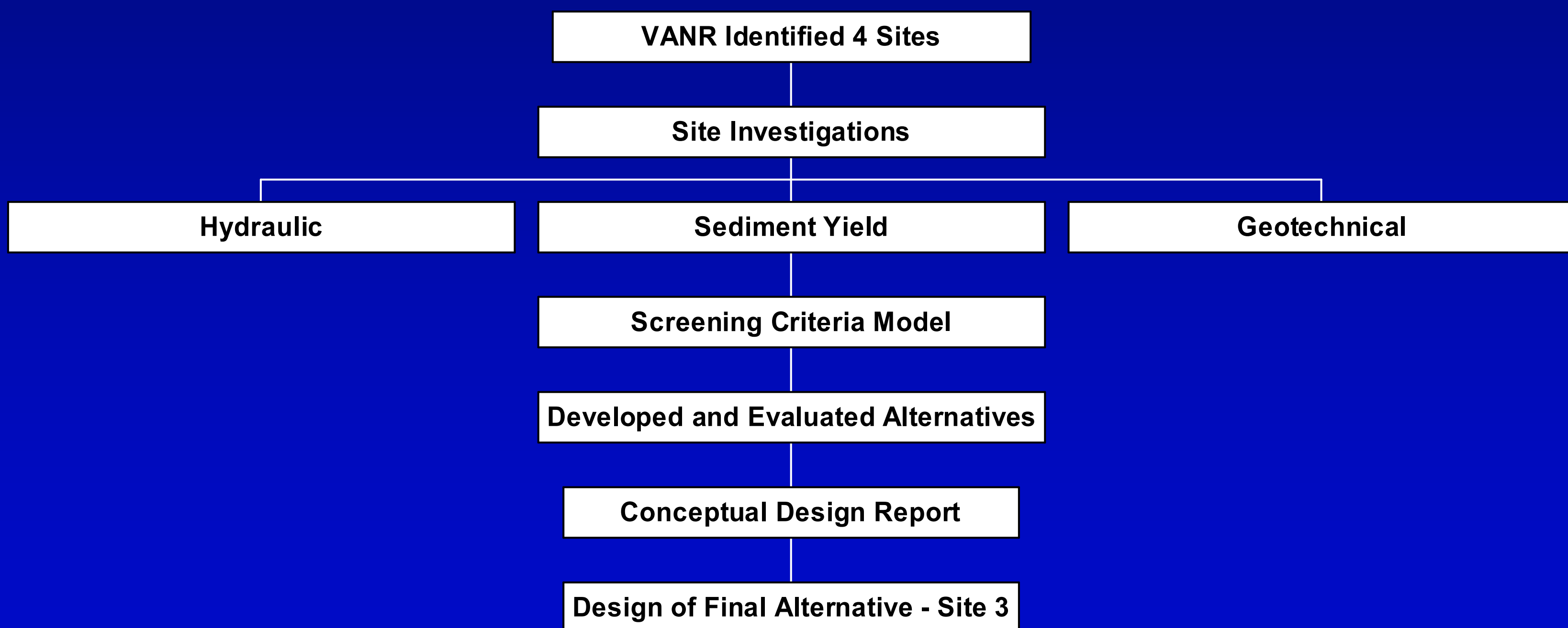
Waterbury Dam Mitigation Conceptual process

Conceptual Process



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Waterbury Dam Mitigation
Design of Final Alternative

- Three Components to the final design
  - Toe Protection
  - Transition Zone
  - Upland Slope

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Waterbury Dam Mitigation
Toe Protection

- Traditional Engineering Application
  - Wind Waves
    - USACE EM 1110-2-1414, Water Levels and Wave Heights for Coastal Engineering Design
    - Assumed waves would not be greater than 5 ft
    - Largest fetch at site is 3,360 ft

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Waterbury Dam Mitigation
Toe Protection

- Traditional Engineering Application
  - Vessel Waves
    - 3 recommended equations from the Interim Report for the Upper Mississippi River – Illinois Waterway System Navigation Study, ENV Report 4, December 1997
      - Used to determine vessel generated waves in deeper water
      - Sorrenson and Weggel 1984, Sorrenson and Weggel 1986 and PIANC 1987
    - PIANC was used to calculate vessel wave heights
    - The dispersion equation was used to determine the shallow water wave height

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Waterbury Dam Mitigation
Toe Protection

- Traditional Engineering Application
  - Quarry Stone
    - Stone from surrounding area
    - EM 1110-2-1614 – Revetment Design and the CEDAS version 2.01G Software (USACE WES, 2003)
    - Stone matches the natural rock outcrops that currently exist around the reservoir
    - Armor layer will extend 4 ft above maintained water surface to account for run-up
    - Armor layer will extend 5 ft below water surface to account for scour
  - Large woody debris from site will be used

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Waterbury Dam Mitigation
Toe Protection

- Revetment Design Input Parameters

Design Vessel Dimensions	8 ft wide, 20 ft long, 2 ft draft
Vessel Speed, Depth, Distance to Shore	10 knots, 30 ft depth, 50 ft from shore
Wave Height – Deep Water	3.0 ft
Wave Height at Toe of Revetment	3.72 ft
Wave Period	2.7 SECONDS
Unit Weight of Rock	170 lb/ft^3
Revetment Slope	1Vertical: 2Horizontal
Permeability Coefficient	0.1
Damage Level	2 (minimum)
Armor Layer Median Stone Size	206 lbs (1.07 ft)
Armor Layer Thickness	2.5 ft
Filter Layer Median Stone Size	0.38 lbs (0.13 ft)
Filter Layer Thickness	1 ft
Armor Layer Location	593.5 to 584.5 ft at 2.5 ft thickness
Bedding Layer Location	589.5 to 583.5 at 1.0 ft thickness
Linear Ft of Shoreline to be Armored	723 ft

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Toe Protection

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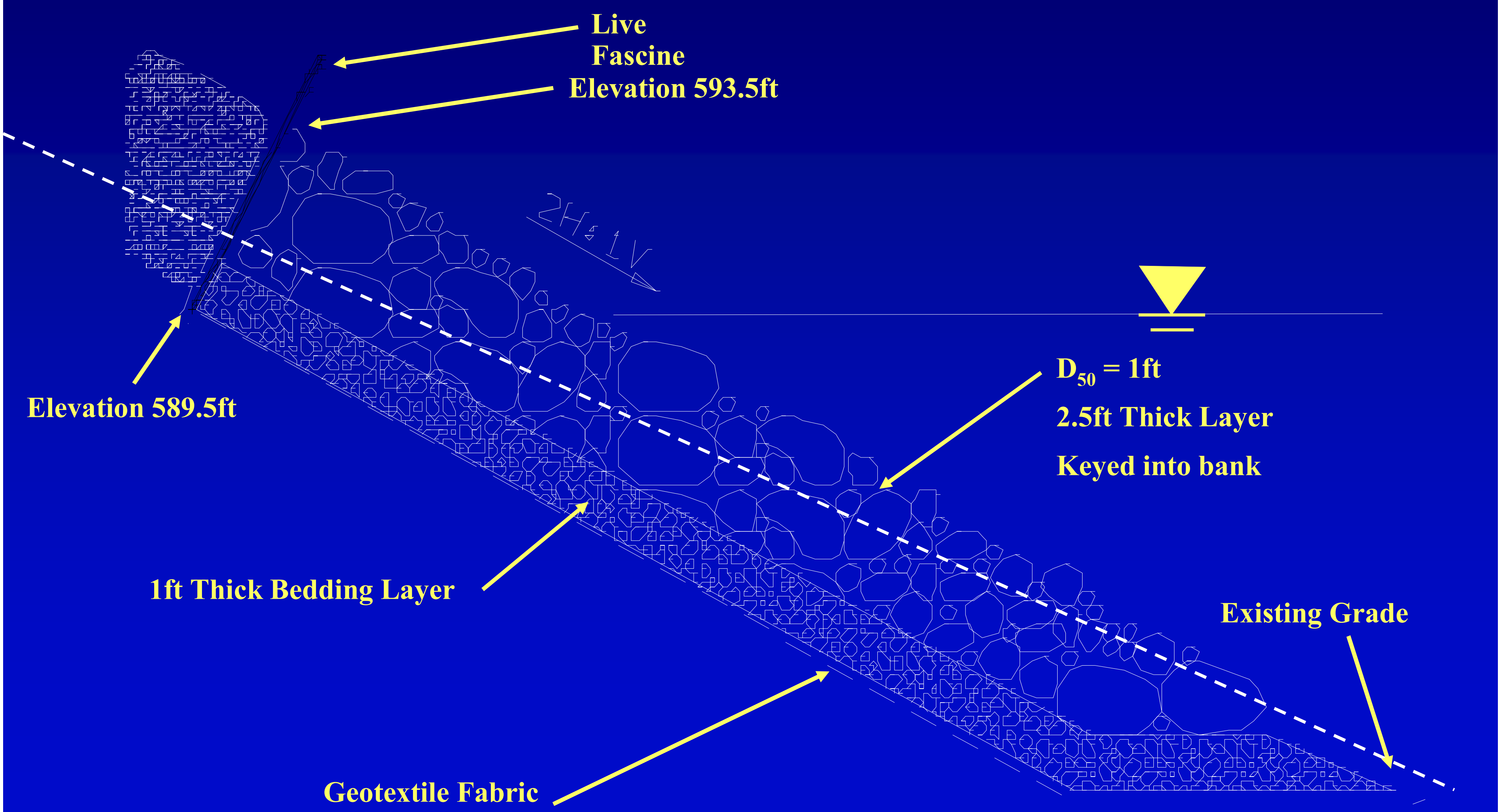

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Waterbury Dam Mitigation Transition Zone

- Bioengineering Application
  - Vegetated Geo-grid
    - Live cut branches interspaced between layers of soil
    - Stabilize slope and provide surface erosion protection
    - Retards runoff velocity and filters sediment out of the slope runoff
    - Brush layering – Red-osier Dogwood, Silky Dogwood, Pussy Willow and Purple Osier Willow
    - Vegetated soil lifts, after established should be able to withstand run-up form vessel waves
    - Material generally ranges ½” – 2” in diameter and 3 – 7 ft in length

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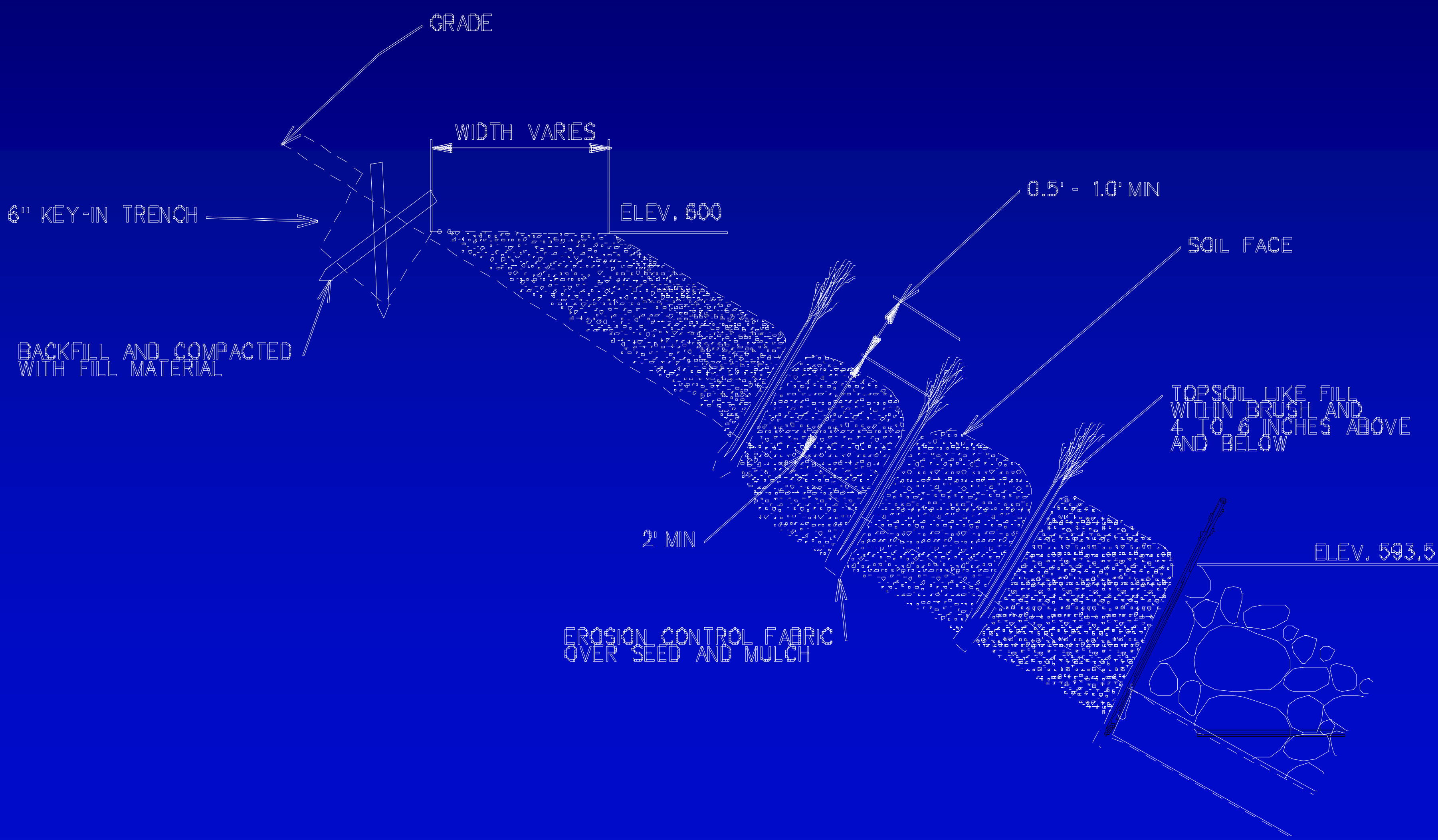
Waterbury Dam Mitigation
Transition Zone



Waterbury Dam Mitigation
Upland Slope Stabilization

- Bioengineering Application
  - Cutting back the slope
    - Maximum slope angle of 41 degrees
  - Branches
    - Woody, root able plant cutting inserted into ground
    - Alternate leaved Dogwood and Purple Osier Willow
    - Branches are usually ½ to 2 inches in diameter and 2 to 3 feet in length
    - Extract excess soil moisture which reduces the soil pore water pressure

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Waterbury Dam Mitigation
Upland Slope Stabilization

- Bioengineering Application
  - Tublings
    - Tree and shrub seedlings
    - White Pine, Eastern Hemlock, Bearberry and Buttonbush
    - Typically 2” in diameter and 6 ft in length
    - Increase the cohesion and integrity of the soil
  - Erosion Control fabric
    - Temporary degradable blankets used to enhance the establishment of vegetation
    - Provide tractive resistance and resist water velocity on slopes

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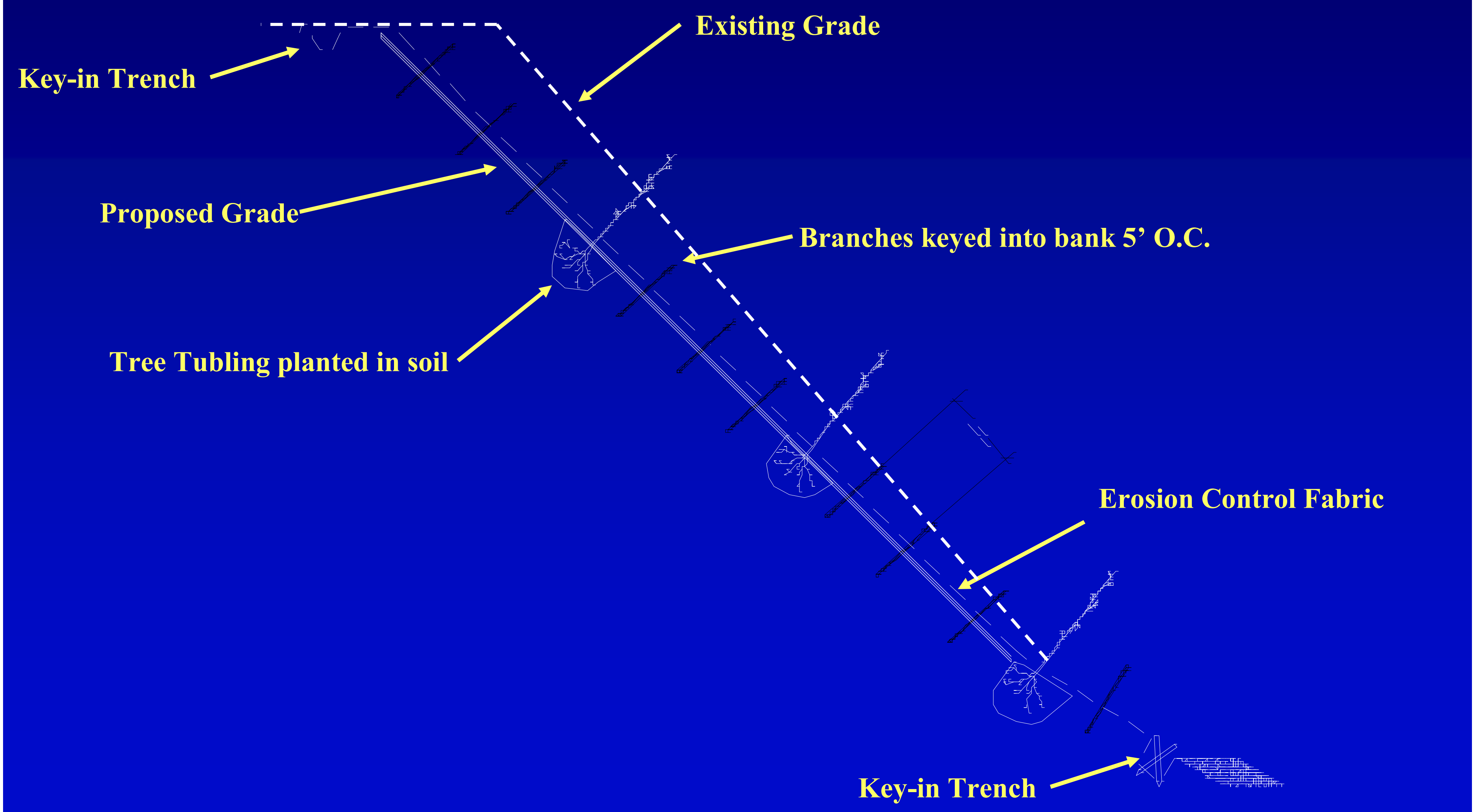
Waterbury Dam Mitigation
Upland Slope Stabilization



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Waterbury Dam Mitigation Monitoring

- VANR will monitor the site weekly from April to October.
- Monitoring period will be up to five years.
- The New York District will receive regular updates from VANR.
- The New York District will conduct site visits periodically through the monitoring period.

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Waterbury Dam Mitigation Conclusion

The USACE - New York District was able to work effectively with the Vermont Agency of Natural Resources (VANR) to promote bioengineering as a significant part of the mitigation. This "marriage" of bioengineering and traditional slope stabilization techniques had not been utilized by the New York District before this project and this project provided an opportunity to incorporate the Environmental Operating Principles into the project. The final mitigation design is a combination of bioengineering techniques for the slope stabilization and the placement of riprap for toe protection against wind and vessel waves.

- Costs for the project
  - Total Project Cost = $572,000
    - Toe Protection = $201,000
    - Transition Zone = $74,000
    - Upland Planting = $245,000
    - Other = $52,000

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Waterbury Dam Mitigation
Lessons Learned

- Partnerships
  - Involving the Local Sponsor, VANR early in the conceptual process
  - Corps understanding and incorporating the requests of VANR
  - Combining the the design goals of the biologist and engineers
- More research needs to be conducted on recreational vessel wave heights in reservoirs
- Think out of the box

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Waterbury Dam Mitigation Team Members

- Army Corps of Engineers – New York District
  - Paul Tumminello – Project Manager
  - Marty Goff – Project Engineer
  - Kerry Anne Donohue – Design Engineer
  - Bethany Bearmore – Design Engineer
  - Kimberly Rightler – Biologist
  - Emily Eng – Cost Engineer
  - Kevin Meranda - Constructability
- Vermont Agency of Natural Resources
  - Brian Fitzgerald – Hydrologist
  - Susan Warren – Biologist
  - Susan Baulmer – Parks
- Army Corps of Engineers – New England District
  - Kate Atwood – Cultural Resources
- A/E
  - Northern Ecological Associates

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Waterbury Dam Mitigation
Future Site and Questions