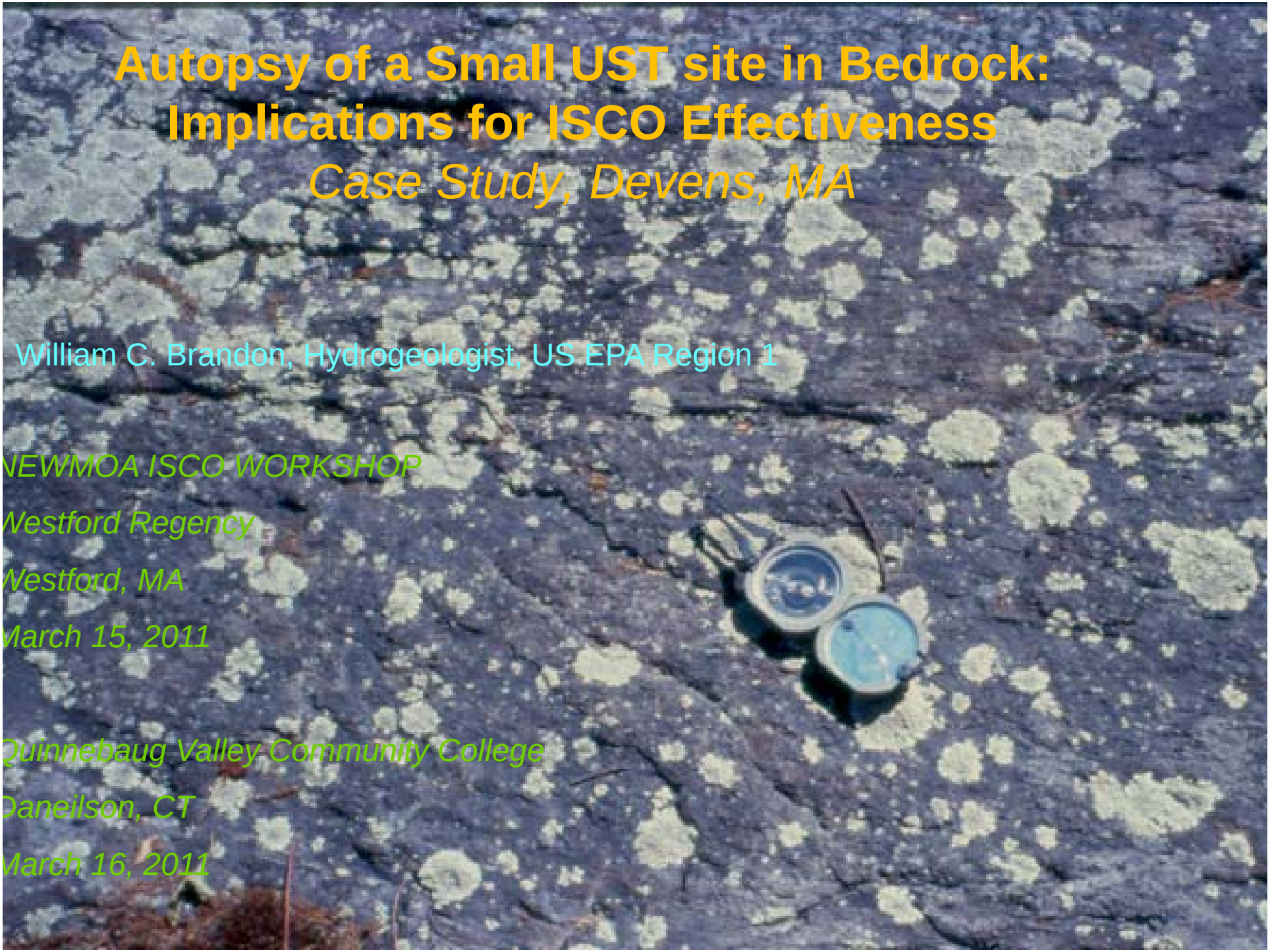


Autopsy of a Small UST site in Bedrock: Implications for ISCO Effectiveness

Case Study, Devens, MA

William C. Brandon, Hydrogeologist, US EPA Region 1

NEWMOA ISCO WORKSHOP

Westford Regency

Westford, MA

March 15, 2011

Quinnebaug Valley Community College

Danielson, CT

March 16, 2011

Acknowledgements

- Gannet Fleming Inc.
- Army BRAC Office
- HGL Inc.
- EPA Region 1 Federal Facilities
- EPA Region 1 OEME
- Mass Development

KEY THEMES

- Robust Geologic-Fracture Model (GFM) Essential
- DATA = Bedrock and Fracture Measurements and Observations
  - Outcrops not exposed at many sites
  - Need to consider if available
  - If you don’t understand this, hire a qualified geologist (or focus on overburden sites)
  - Remedial Efforts which do not adequately assess and account for bedrock are doomed to Failure

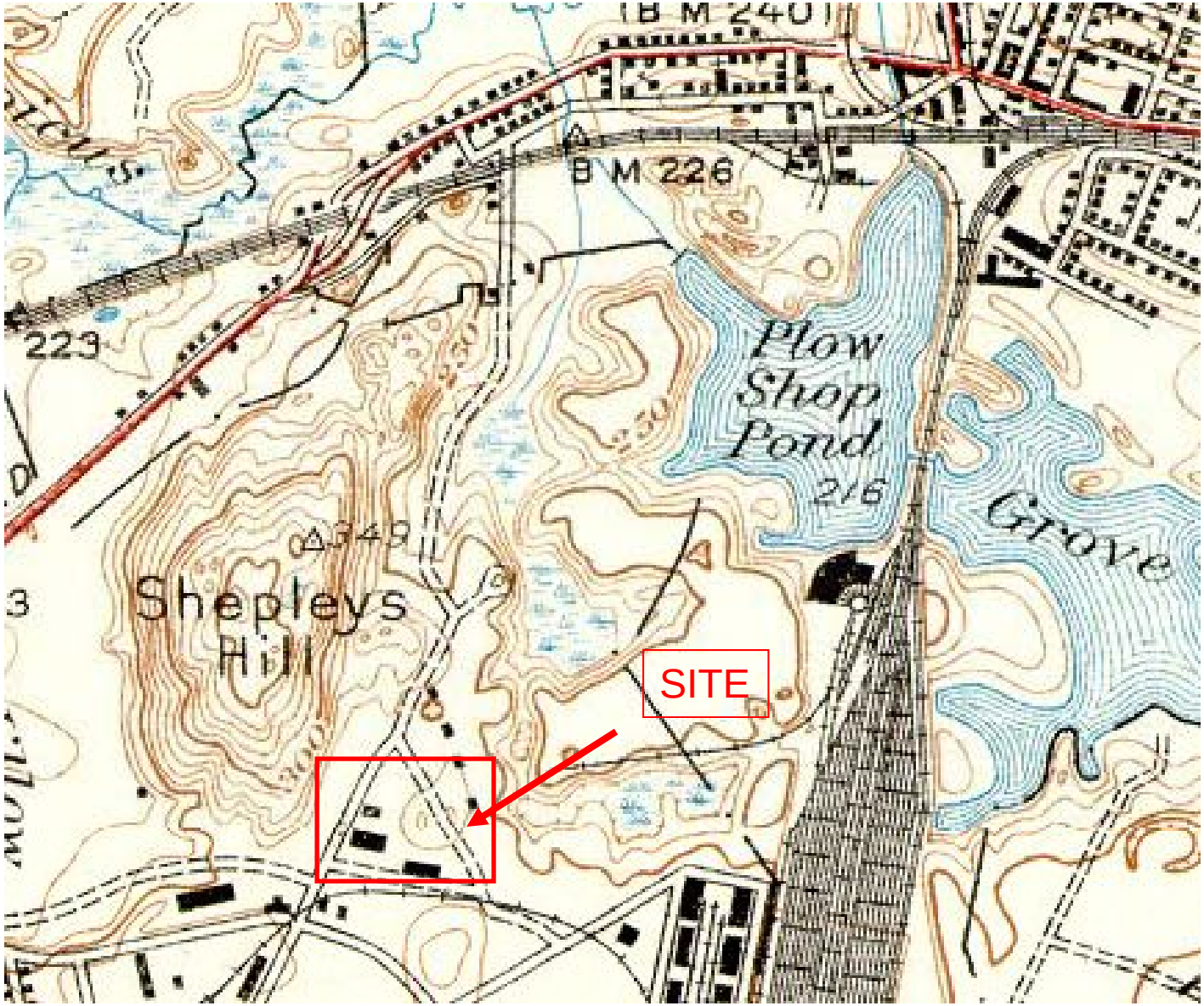
KEY THEMES (Continued)

- Numerical Modeling ? Save your $....Until you understand Fracture System (GFM)
- *CSM* requires robust *GFM*
- “Nuisance Site”: Mindset Drives unsuccessful approaches
- Just because you want it to “just go away” doesn’t mean it will be simple…

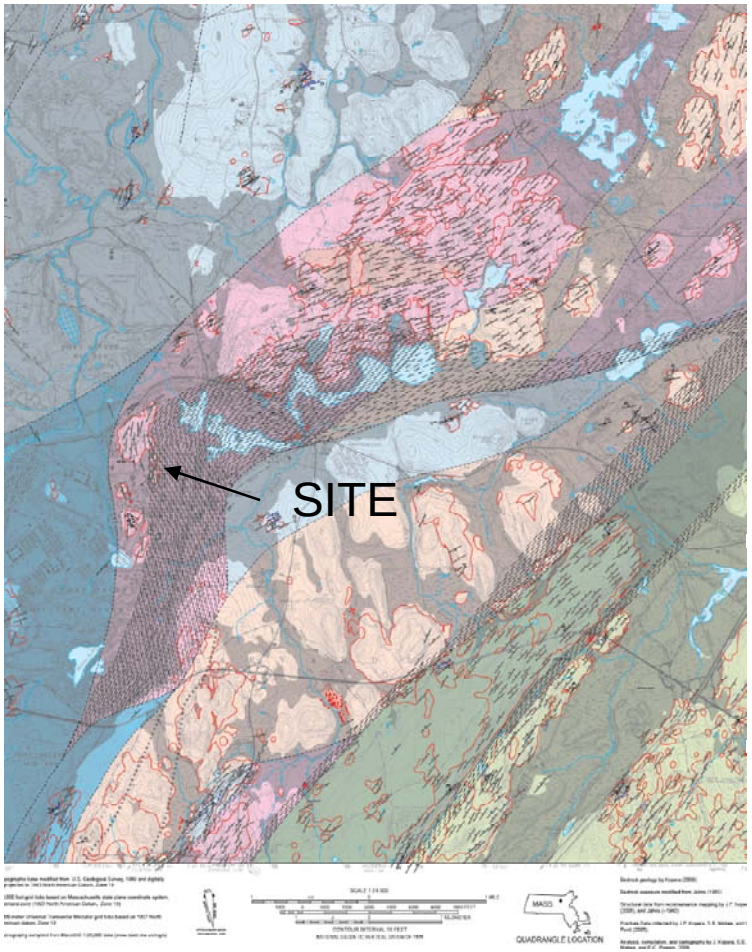
CSM Considerations

- Competing CSMs
- Residual NAPL distribution
  - “Pancake Model”
  - Vertical Equilibrium Model
- Fracture System – Simple GFM
  - Sub-horizontal “Sheeting Fractures”
  - West-Dipping Foliation Parallel Fractures
- GFM implications to CSM and ISCO effectiveness
  - CSM considers GFM
  - CSM does not consider GFM

Site Location



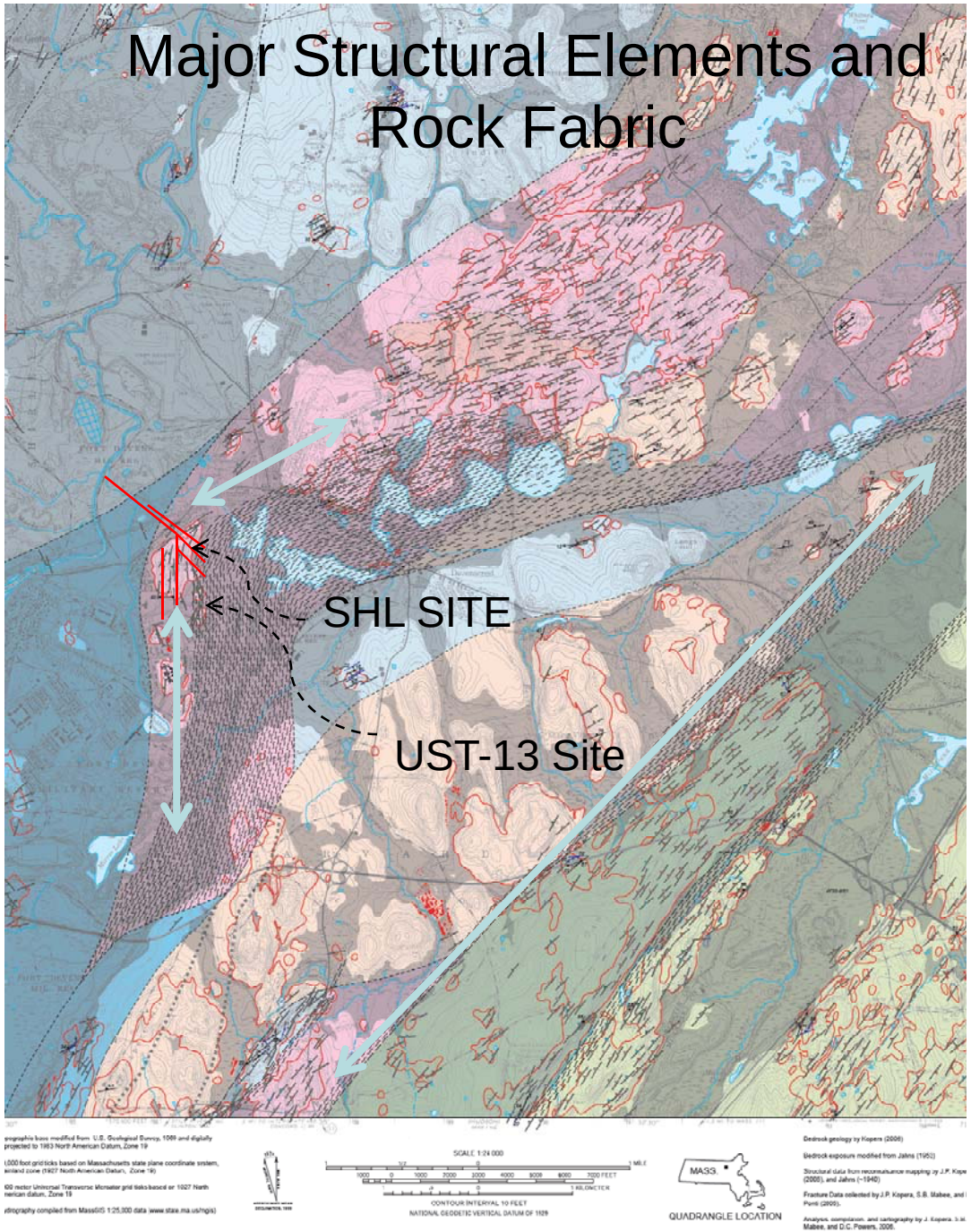
Geologic Setting



QUADRANGLE LOCATION

PRELIMINARY BEDROCK GEOLOGIC MAP
AYER QUADRANGLE, MASSACHUSETTS
M.O.S.G. OPEN FILE REPORT 06-03
SHEET 1 OF 4

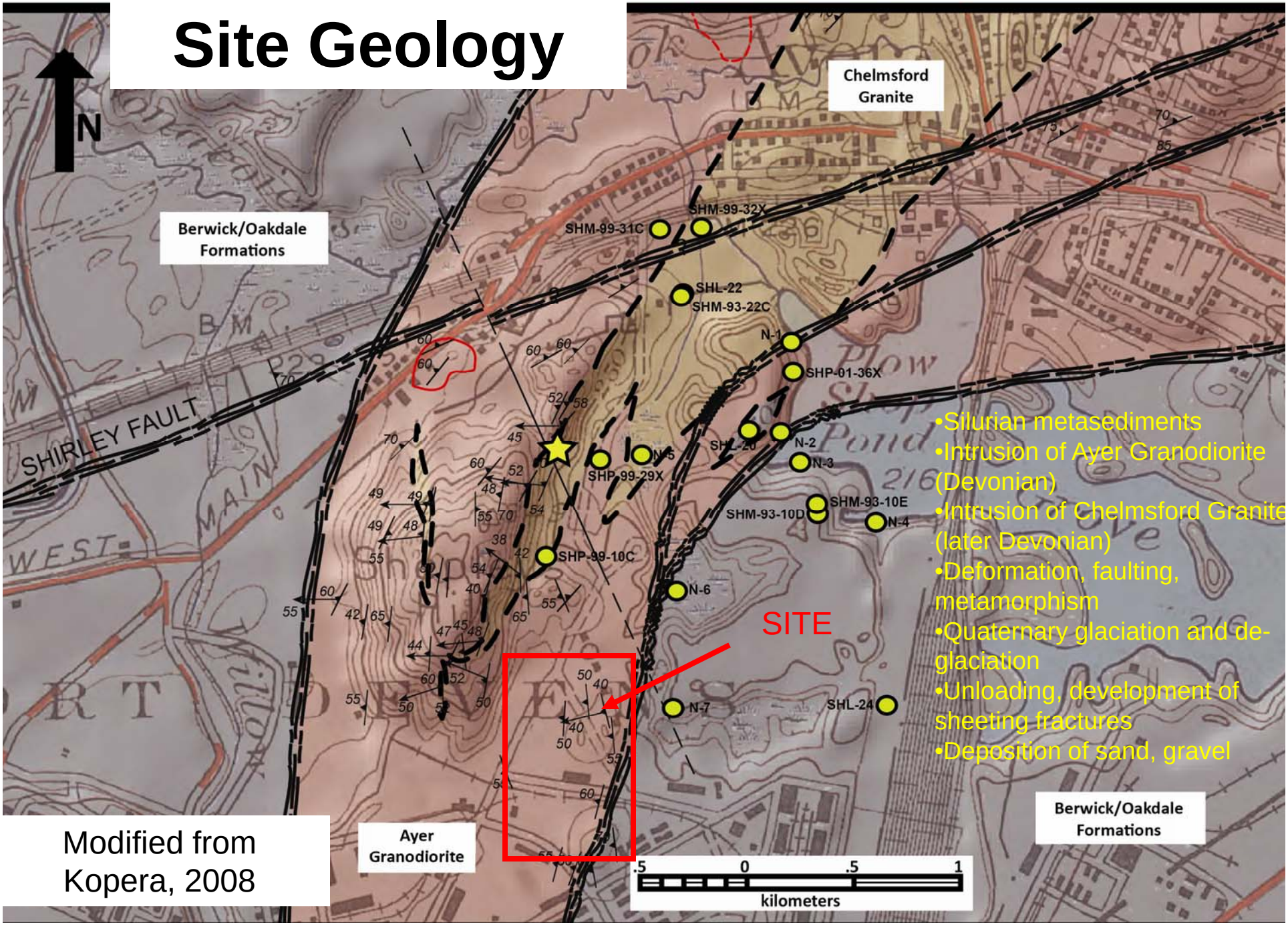
Major Structural Elements and Rock Fabric



QUADRANGLE LOCATION

PRELIMINARY BEDROCK GEOLOGIC MAP
AYER QUADRANGLE, MASSACHUSETTS
M.O.S.G. OPEN FILE REPORT 06-03
SHEET 1 OF 4

Site Geology



- Silurian metasediments
- Intrusion of Ayer Granodiorite (Devonian)
- Intrusion of Chelmsford Granite (later Devonian)
- Deformation, faulting, metamorphism
- Quaternary glaciation and de-glaciation
- Unloading, development of sheeting fractures
- Deposition of sand, gravel

Modified from Kopera, 2008

DRMO Site History

- Defense Reutilization and Marketing Office (DRMO)
- Equipment Recycling ~ 1964-1995

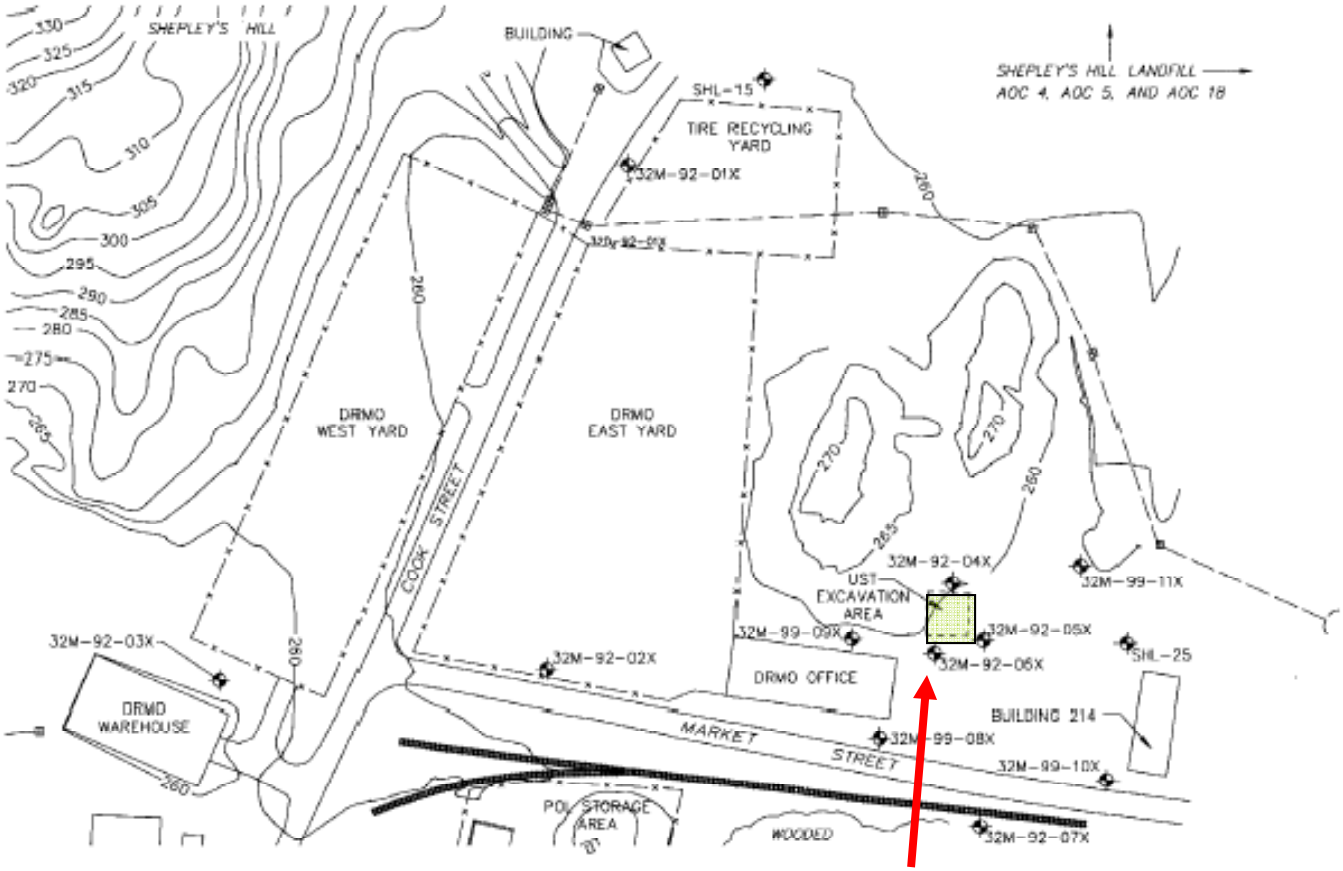
- 5000 gal Waste Oil UST

    - UST removed 1992
    - Limited soil removal
    - Tank grave partially in BR

- COCs: TCE, DCB, VPH, As, Mn

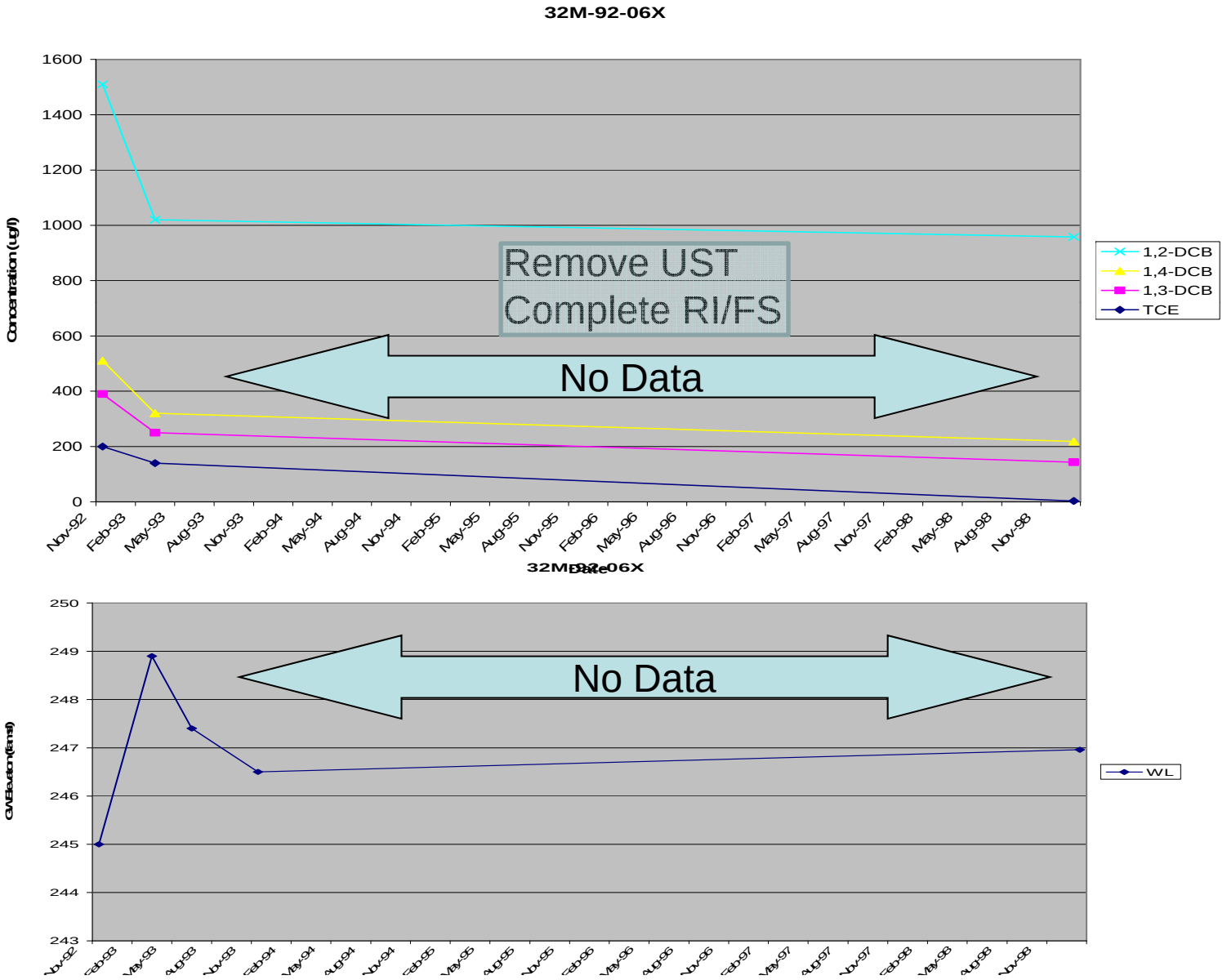
- 1998-1999; LTMP (V_1.0) Initiated

DRMO LTM Network
Pre-2000



One Bedrock MW
32M-92-06X

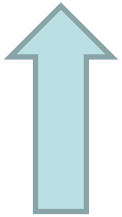
COC Trends (Pre-2000)



Site History (Part II)

- 2000-2001: Warehouse Construction/Large-scale site alterations
  - Bedrock Blasting/Cut-and-fill
  - Engineered Drainage (Storm sewers, Detention Basin)
  - Extensive area of impervious surface (Building, Parking lots)

- Site Hydrology Profoundly Altered
- SYSTEMATIC WATER LEVEL RISE BEGINS



- 2001-2002; LTMP Revised (v.2),
  - Numerous new monitoring wells installed.
  - New baseline
  - Ongoing LTM and data evaluation (2002-2006)

Site: Pre-construction (March 2000)

Fill Emplacement
SW of Building Footprint

Storm Drain Installation

LTM/CSM Issues (2002-2006)

- “Moving Target” - Site Hydrology Slowly Evolving Post-Construction
- “Down-gradient” directions uncertain
- Persistent Contamination in UST-13 Area
- Bedrock Affected, but Fracture Network not evaluated
- *Adequacy of LTM network called into question*

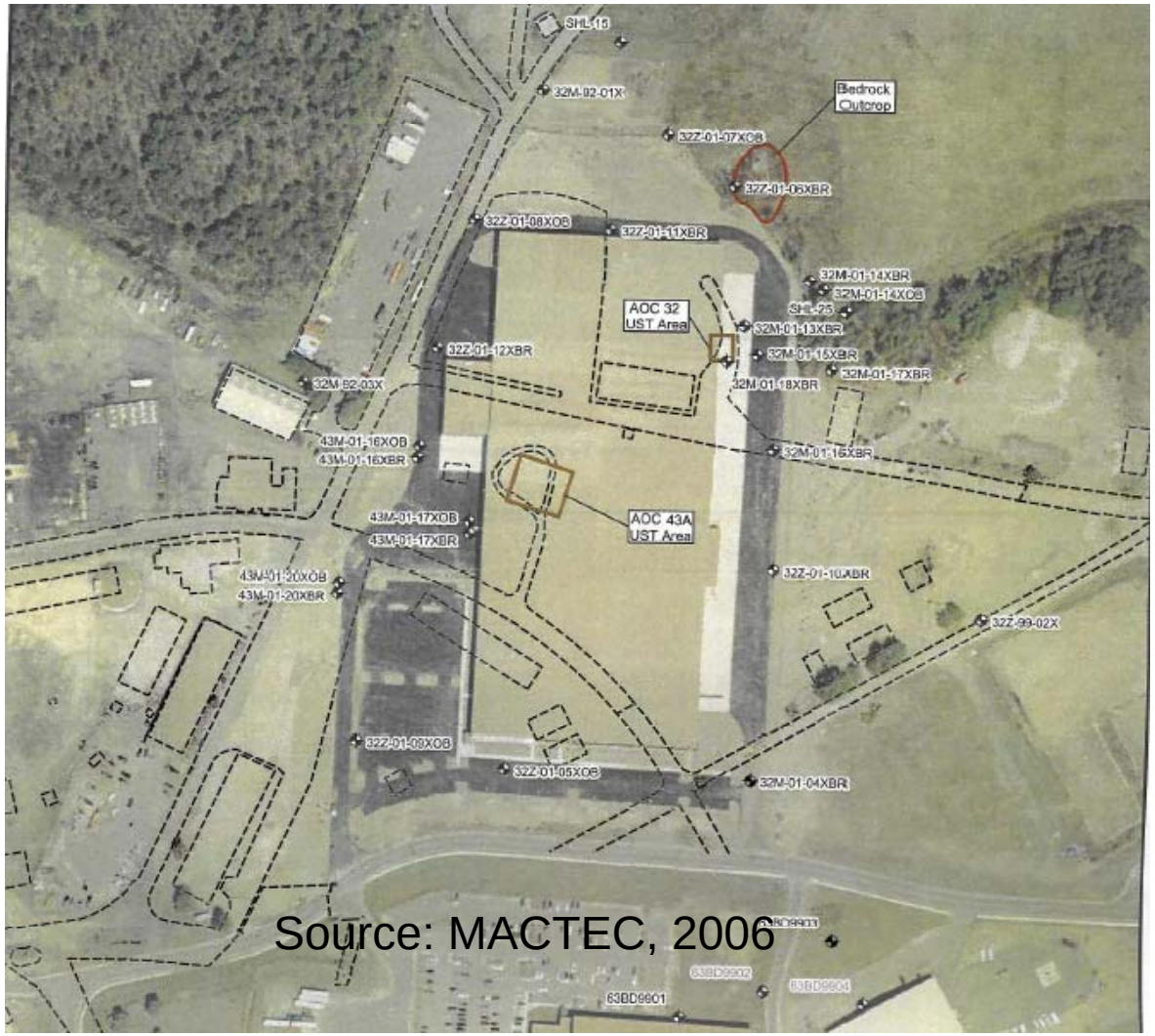
Near-Term Objectives

- UPDATE CSM IN CONSIDERATION OF BEDROCK DATA (GFM) and HYDRAULIC DATA
  - Bedrock Surface Map
  - Bedrock Fracture Data
  - Ground Water Flow Gradients
    - Lateral/vertical
    - Source Areas/Downgradient of Source Areas
    - Long-term water level trends
  - Configuration of Subsurface Hydrostratigraphic Units (2D/3D)
  - Detailed cross sections through each source area normal and parallel to hydraulic gradient
- Identify Data Gaps
- Recommend Adjustments to GW Monitoring Network

Longer-term Objectives

- Install New Monitoring Wells
- Decommission Unnecessary Wells
- New Baseline; Re-initiate Long-term Monitoring
- Evaluate time-series contaminant trends
- Determine whether additional remedial measures are needed
- **Site Closeout**

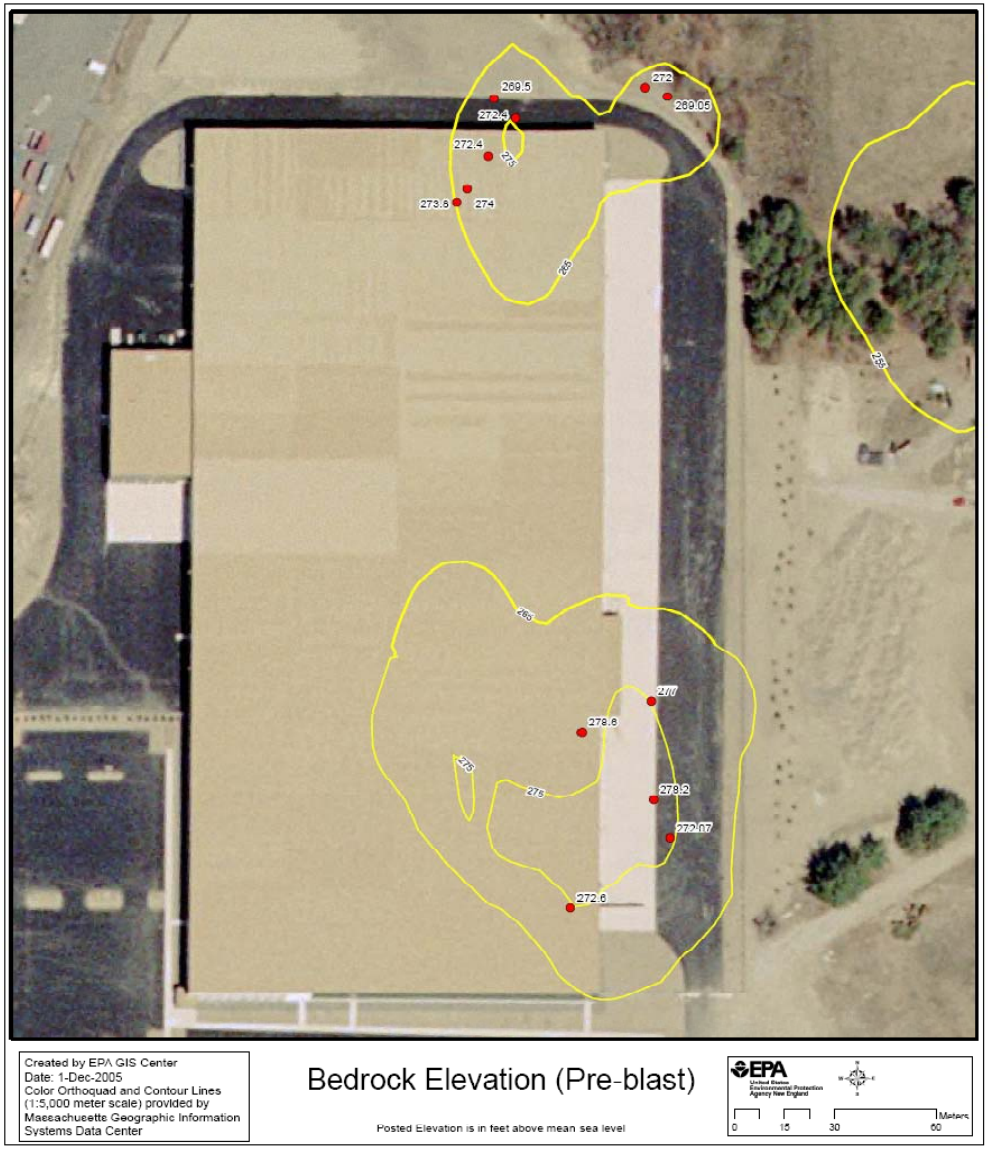
Site Plan with Existing Monitoring Well Locations



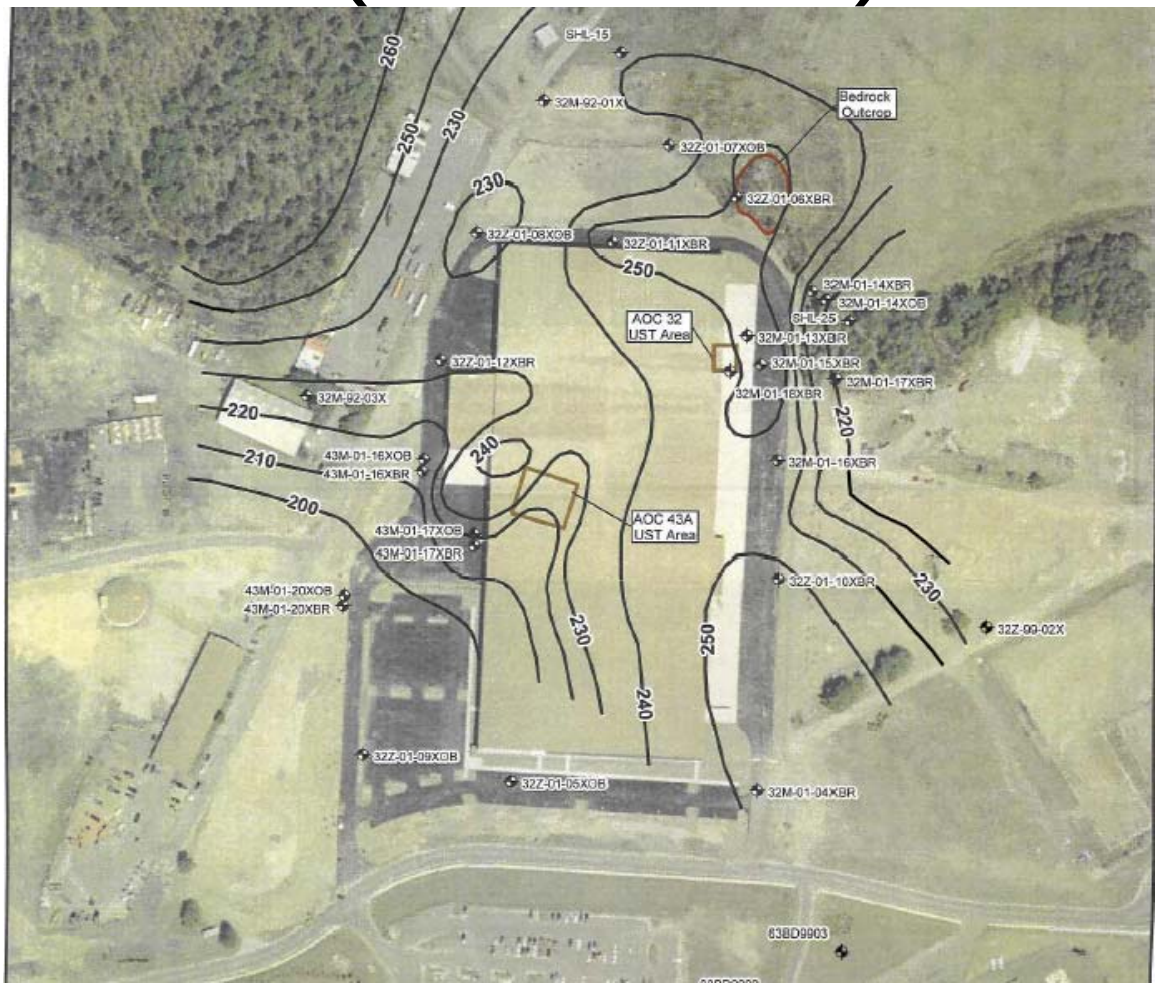
Source: MACTEC, 2006

Blasting Presents Fresh Exposures

Bedrock Elevation (Pre-Blast)



Elevation of Bedrock Surface (Post-Blast)

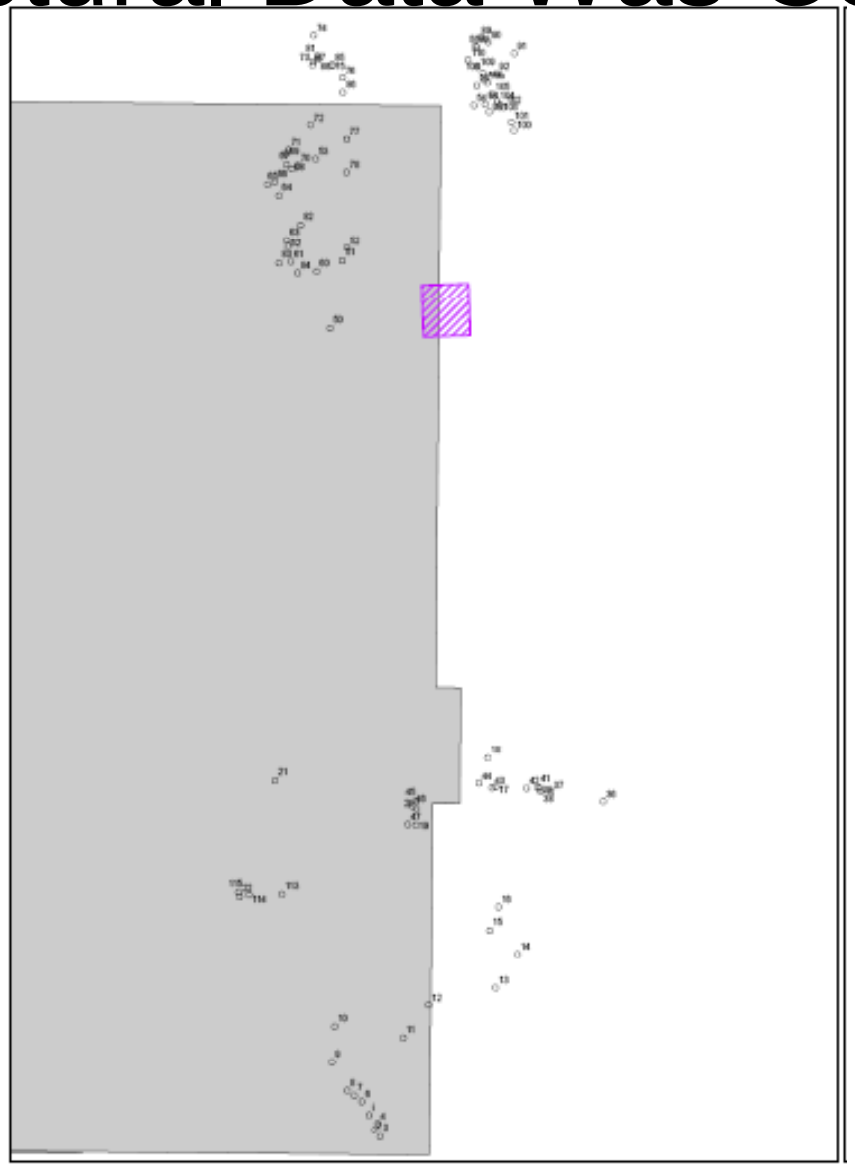


Source: MACTEC, 2006

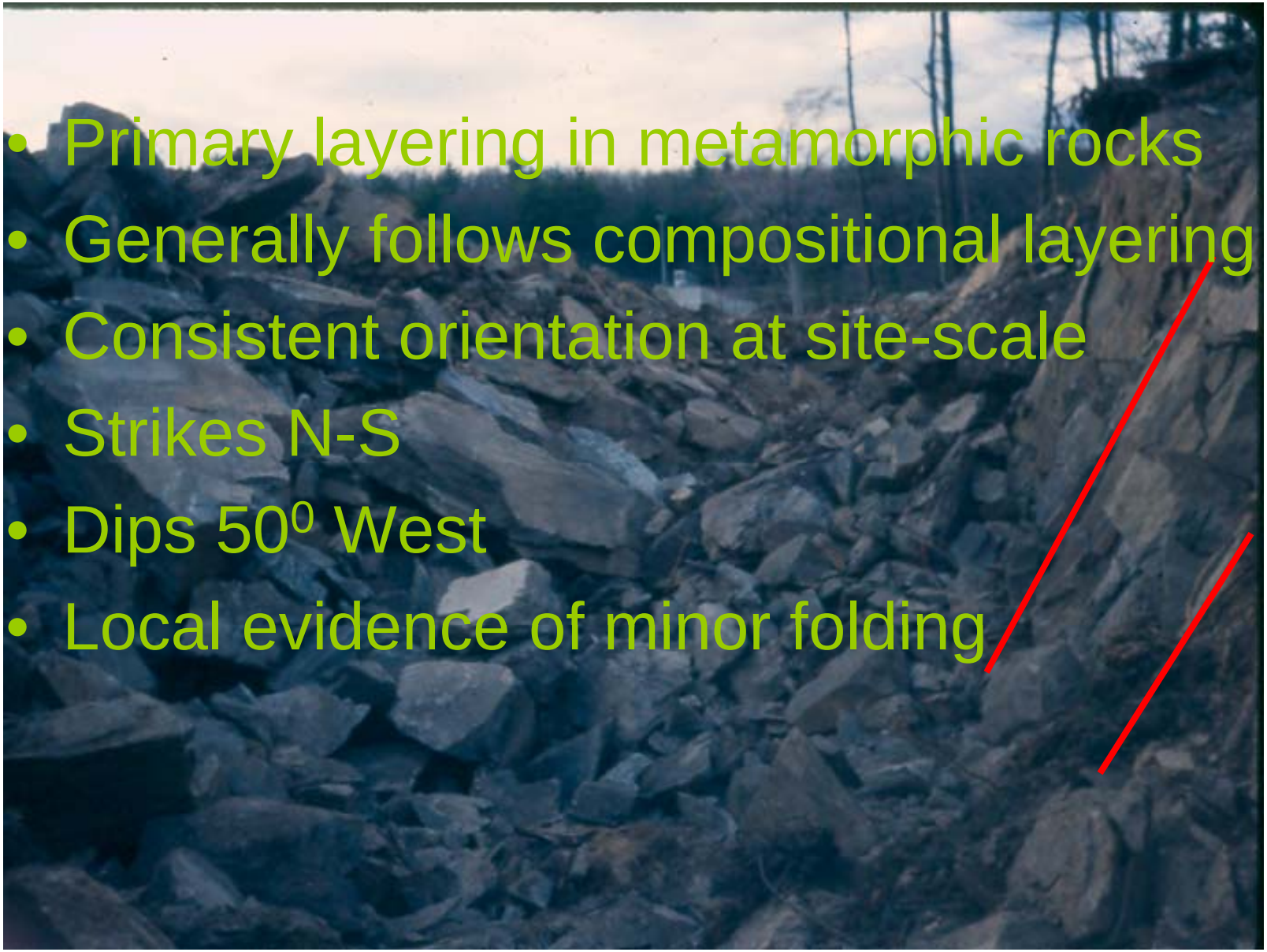
Elements of Bedrock Evaluation

- Configuration of top-of-bedrock surface
- Geologic Mapping
- Rock Type Identification
- Foliation orientation Data
- Joint Orientation Data
- Structural Analysis
  - Stereo-net analysis
  - Joint/Fracture Mapping

Overview of Locations Where Structural Data Was Collected

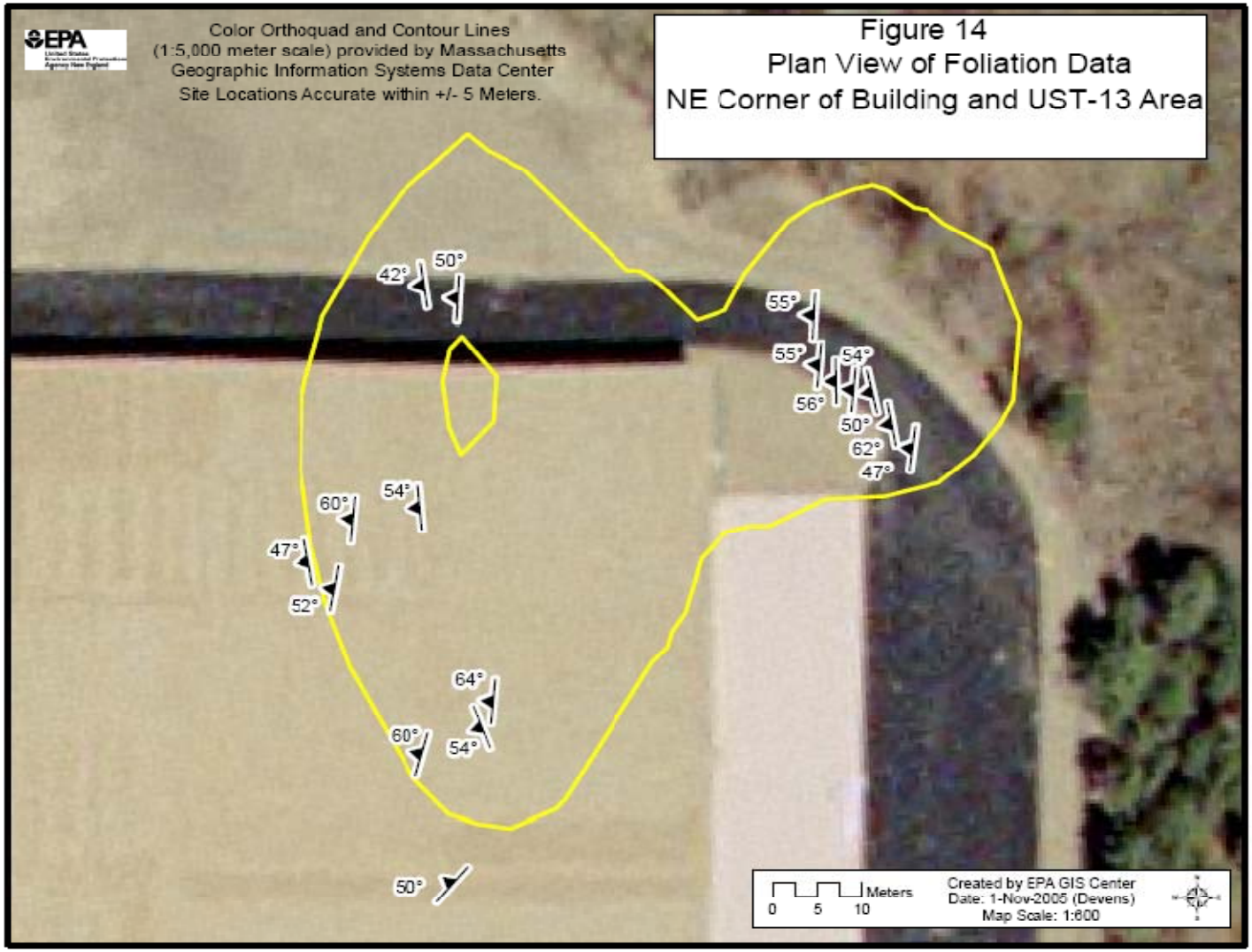


Foliation

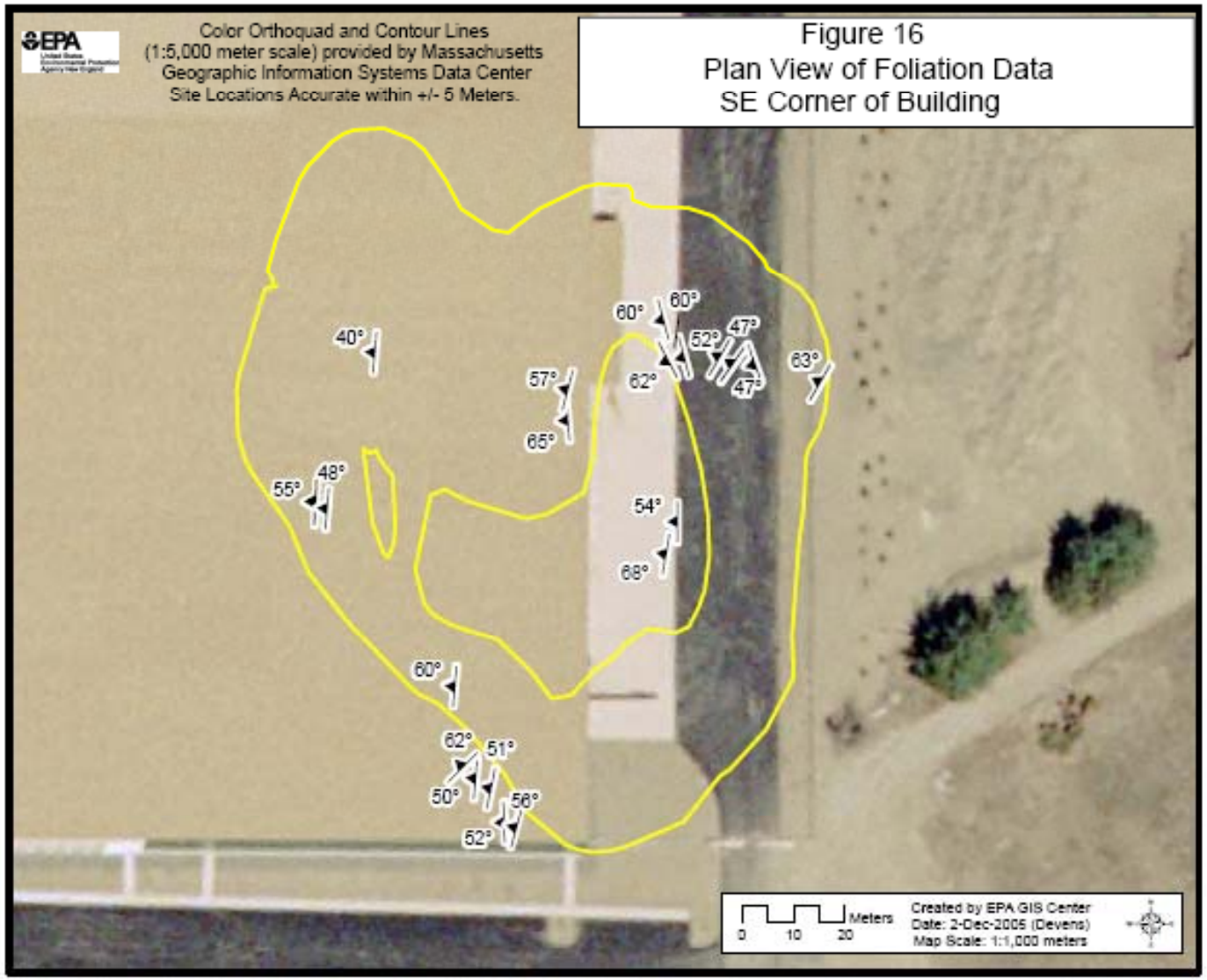


- Primary layering in metamorphic rocks
- Generally follows compositional layering
- Consistent orientation at site-scale
- Strikes N-S
- Dips 50^0 West
- Local evidence of minor folding

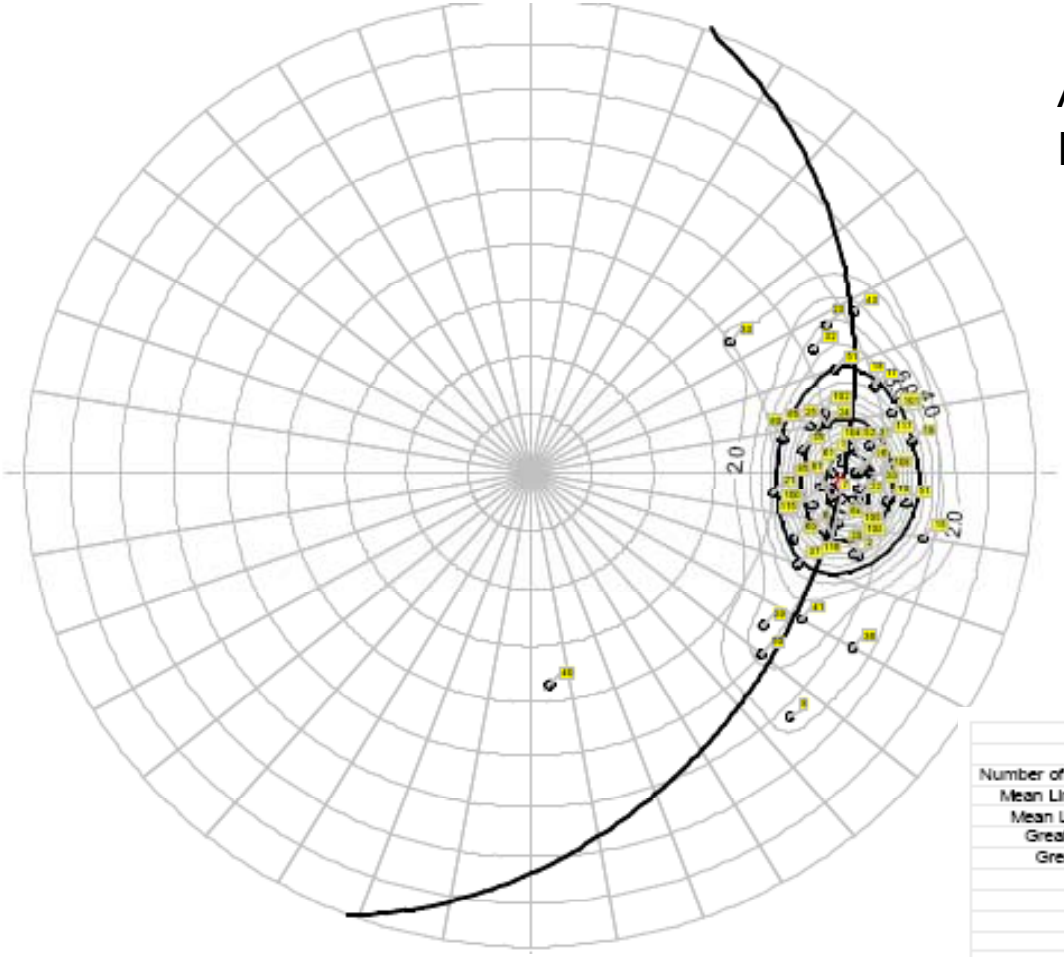
Plan View of Foliation Data NE Corner of Building



Plan View of Foliation Data SE Corner of Building



Stereoplot of Foliation indicating Fold Axis



Azimuth ~ N21E
Plunge ~ 40

Statistical Summary	
Projection:	Schmidt (Equal Area)
Number of Sample Points:	49
Mean Lineation Azimuth:	92.2
Mean Lineation Plunge:	38.2
Great Circle Azimuth:	20.8
Great Circle Plunge:	39.7
1st Eigenvalue:	0.926
2nd Eigenvalue:	0.057
3rd Eigenvalue:	0.017
LN (E1 / E2):	2.794
LN (E2 / E3):	1.181
(LN(E1/E2)) / (LN(E2/E3)):	2.366
Spherical Variance:	0.0404
Rbar:	0.9596

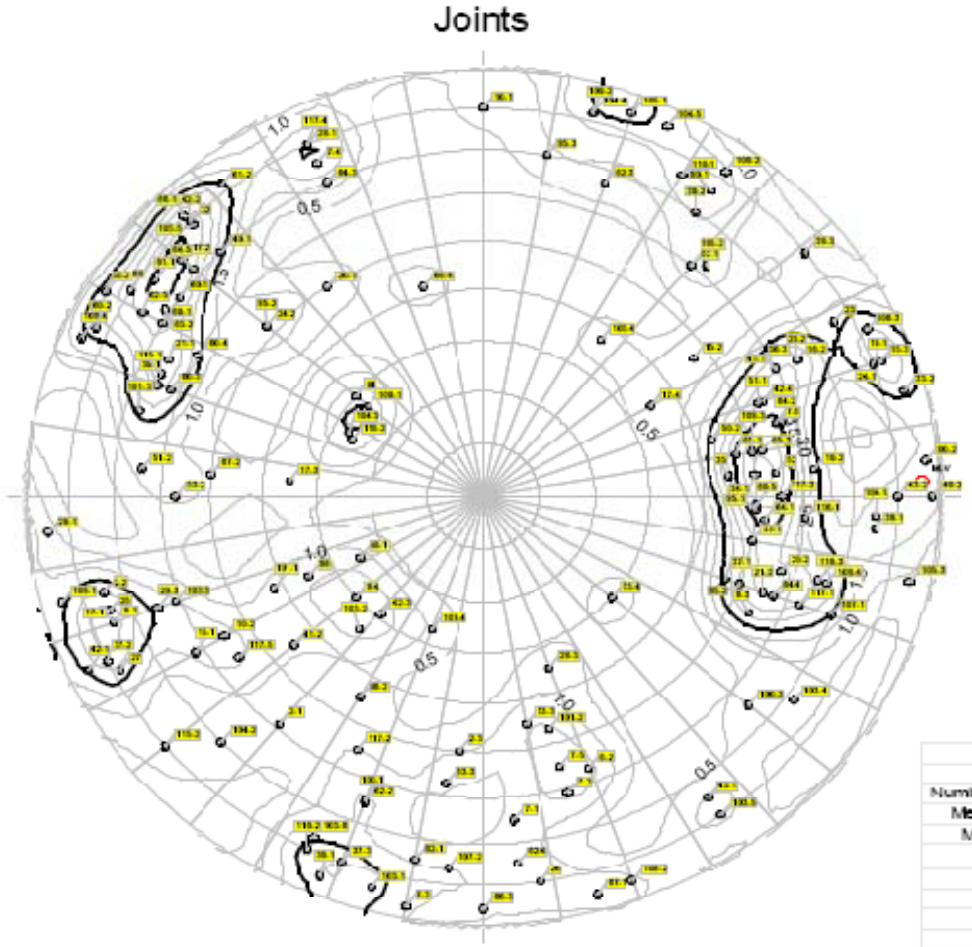
Joints

- Generic Term for Planar discontinuity in Rock Mass (e.g., crack)
- Open joints may transmit water (oxidation)
- Greater Variability than Foliation

Intersecting Joint Sets

Oxidized Fracture Plane

Stereo-plot of Joint Orientations



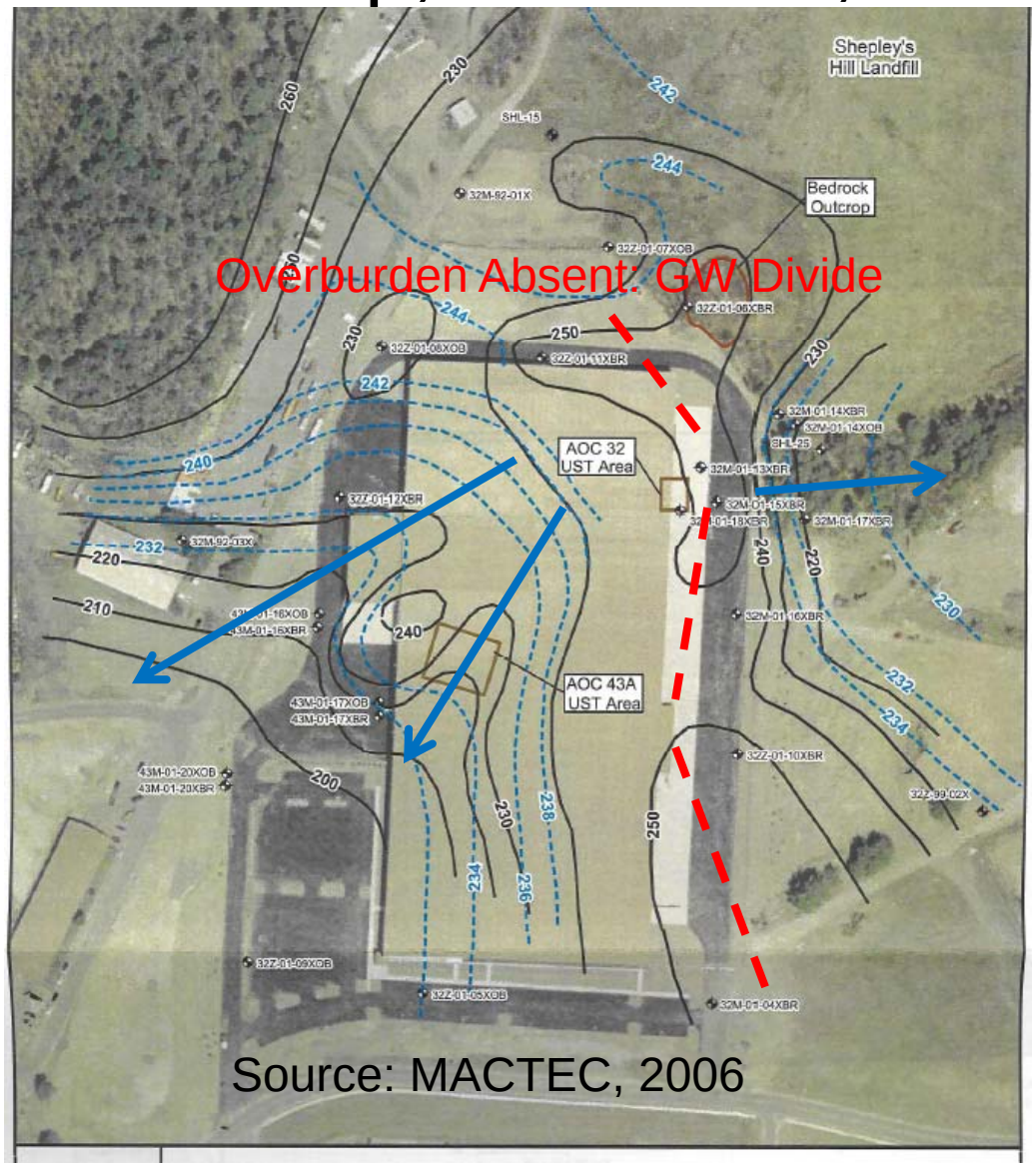
N=156
66 stations

Statistical Summary	
Projection:	Schmidt (Equal Area)
Number of Sample Points:	156
Mean Lineation Azimuth:	87.8
Mean Lineation Plunge:	4.2
Great Circle Azimuth:	66.3
Great Circle Plunge:	11.1
1st Eigenvalue:	0.452
2nd Eigenvalue:	0.321
3rd Eigenvalue:	0.226
LN (E1 / E2):	0.341
LN (E2 / E3):	0.351
(LN(E1/E2)] / (LN(E2/E3)]:	0.973
Spherical Variance:	0.5849
Rbar:	0.4151

Major and Minor Joint Sets

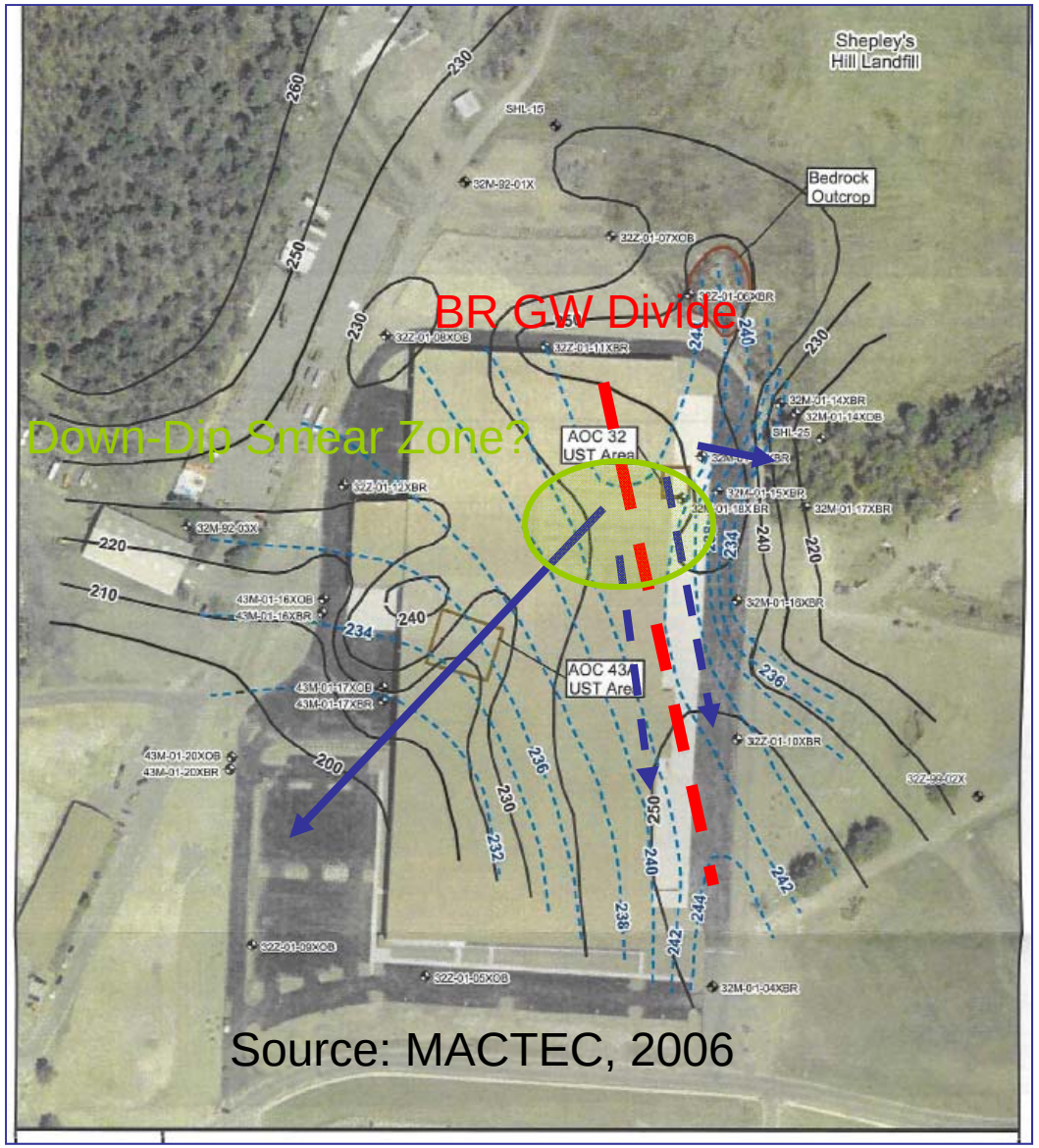
- N3E +/-, 50-60 W (parallel to foliation)
- N45E +/-, 65-85 SE
- Near-surface sheeting joints at various orientations, Sub-parallel to former topography
- ~ N70W, Subvertical (weak)
- ~ N30W, > 70-80 SE or SW Dips (weak)

Interpretive Overburden Groundwater Surface Map, October 7, 2004



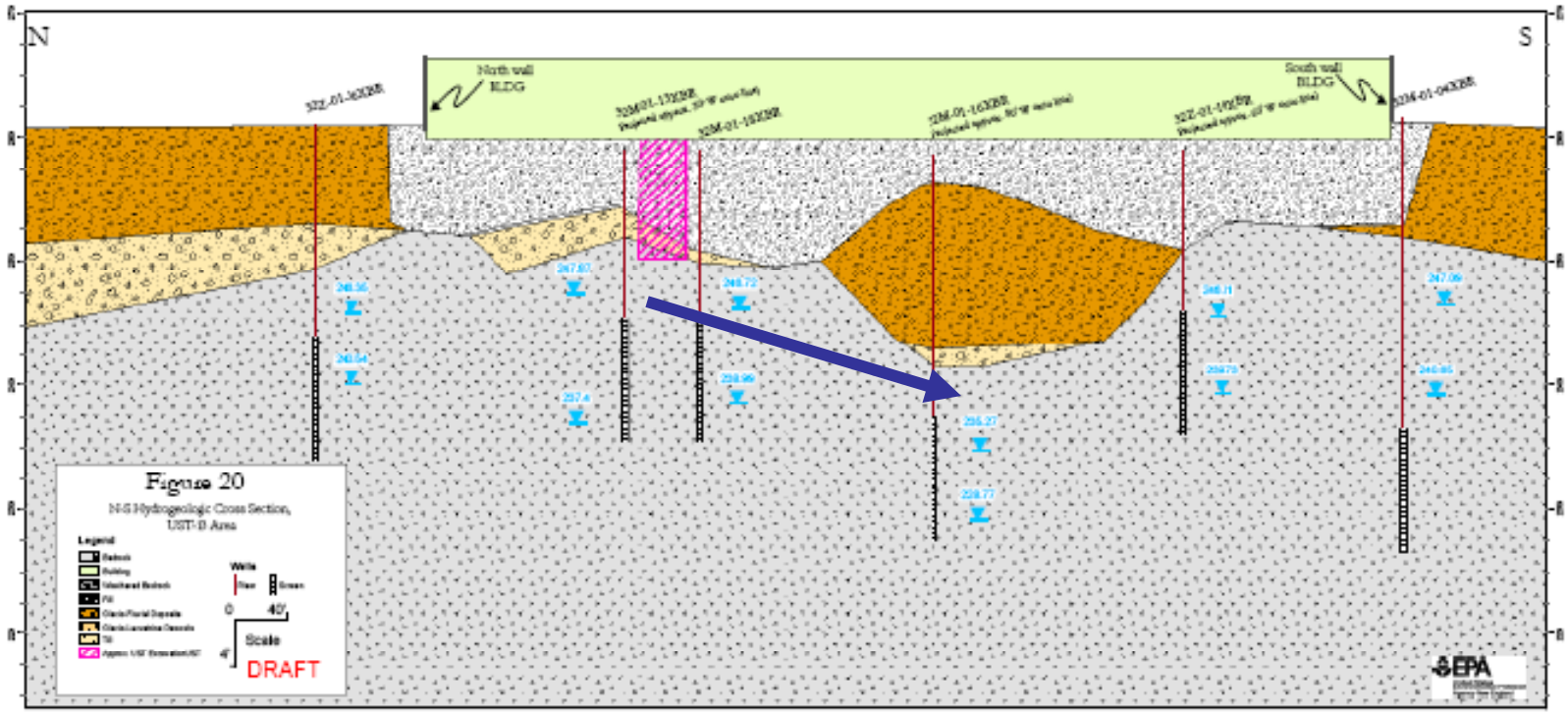
Source: MACTEC, 2006

Interpretive Bedrock Groundwater Surface Map, October 7, 2004

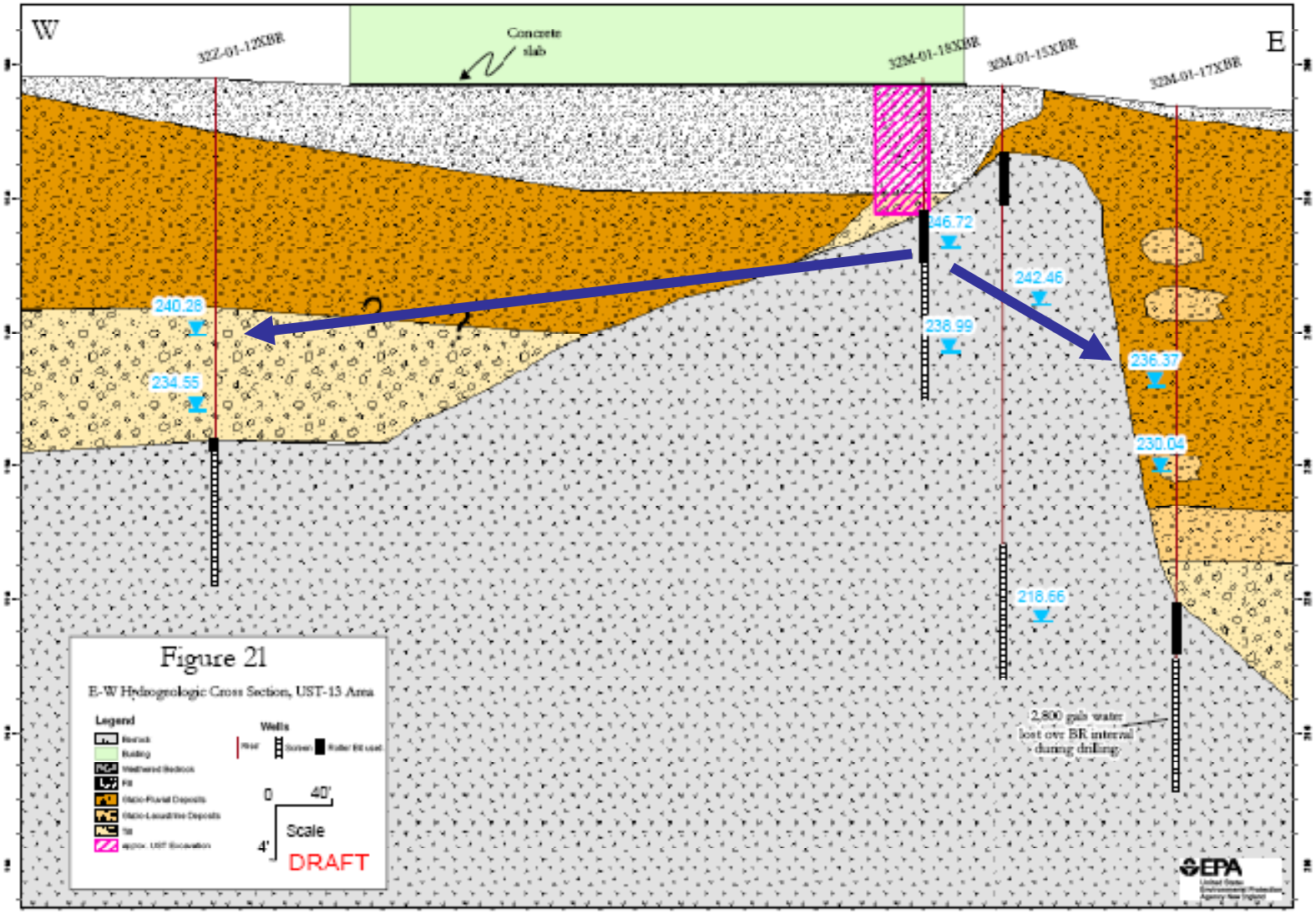


Source: MACTEC, 2006

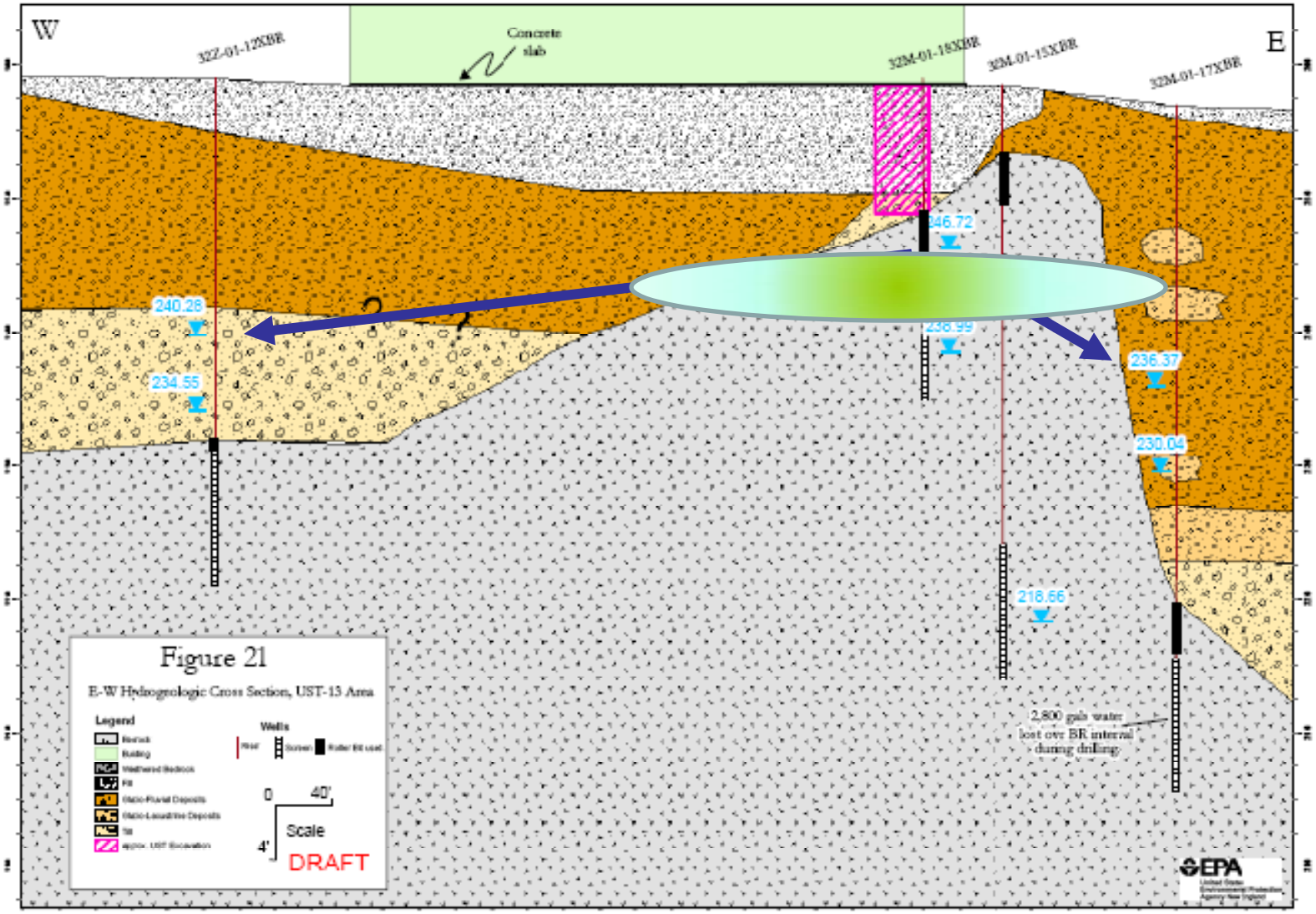
N-S Hydrogeologic Cross Section – UST 13

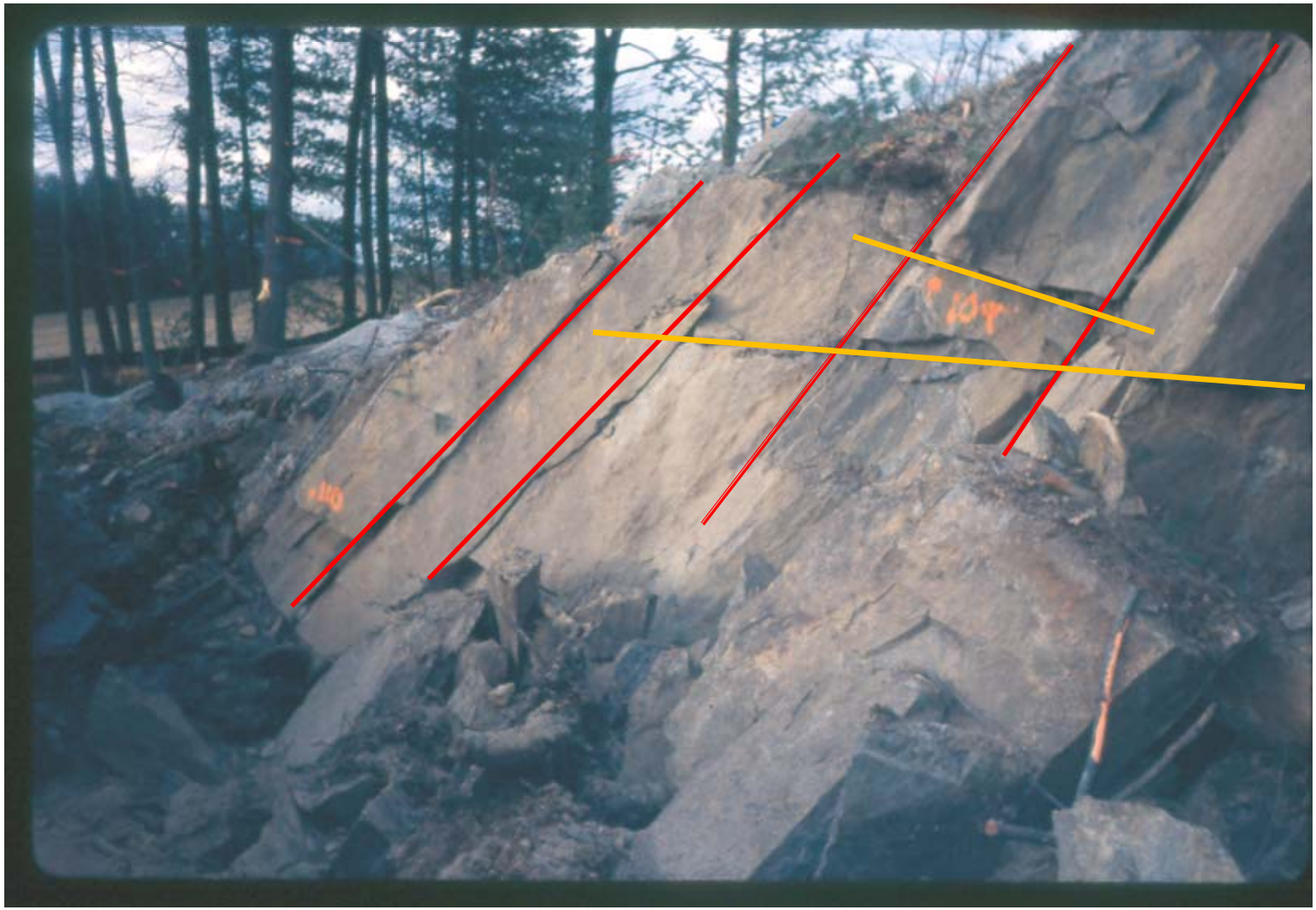


W-E Hydrogeologic Cross-Section
UST 13 Area

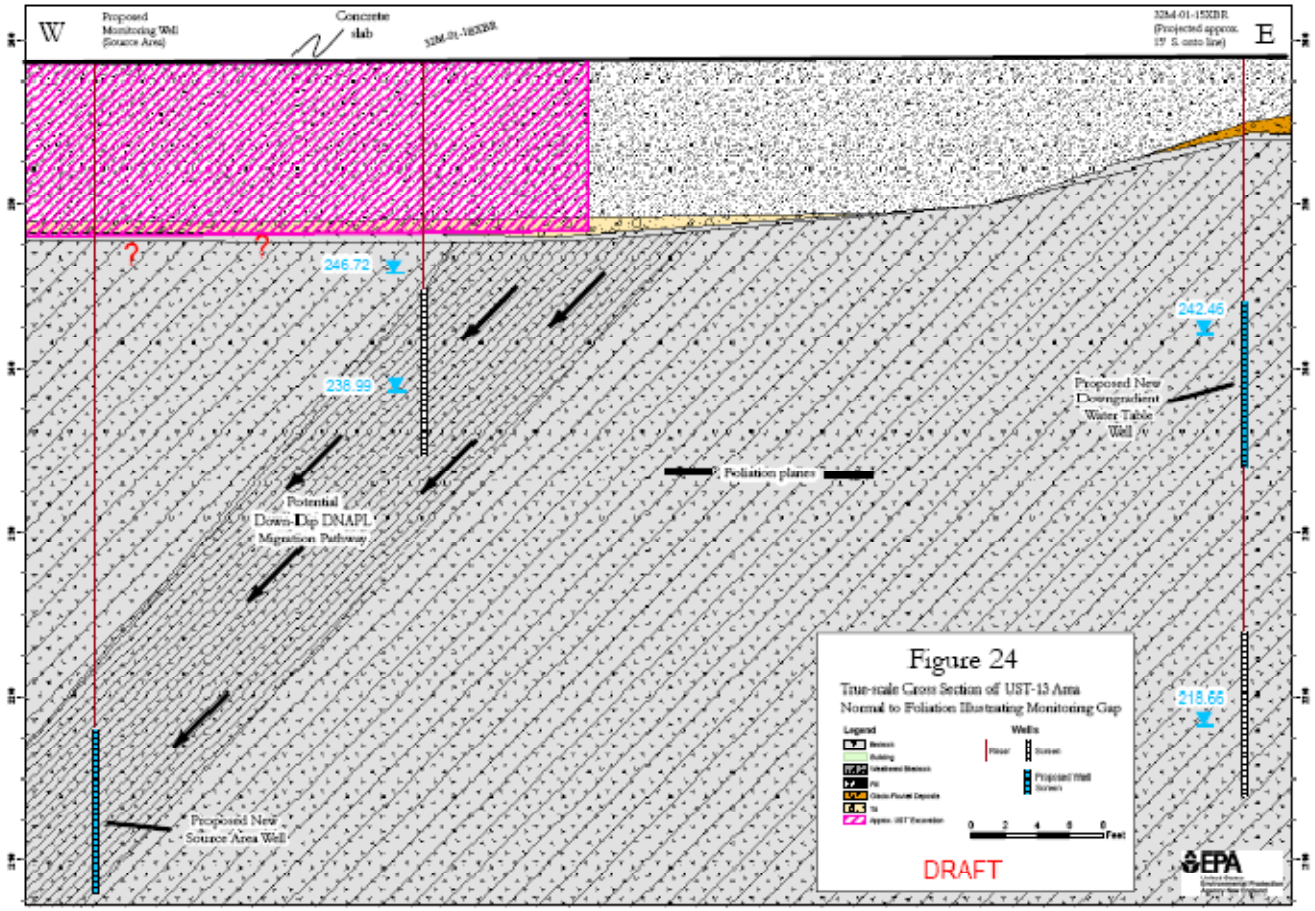


W-E Hydrogeologic Cross-Section
UST 13 Area – “Pancake Model”

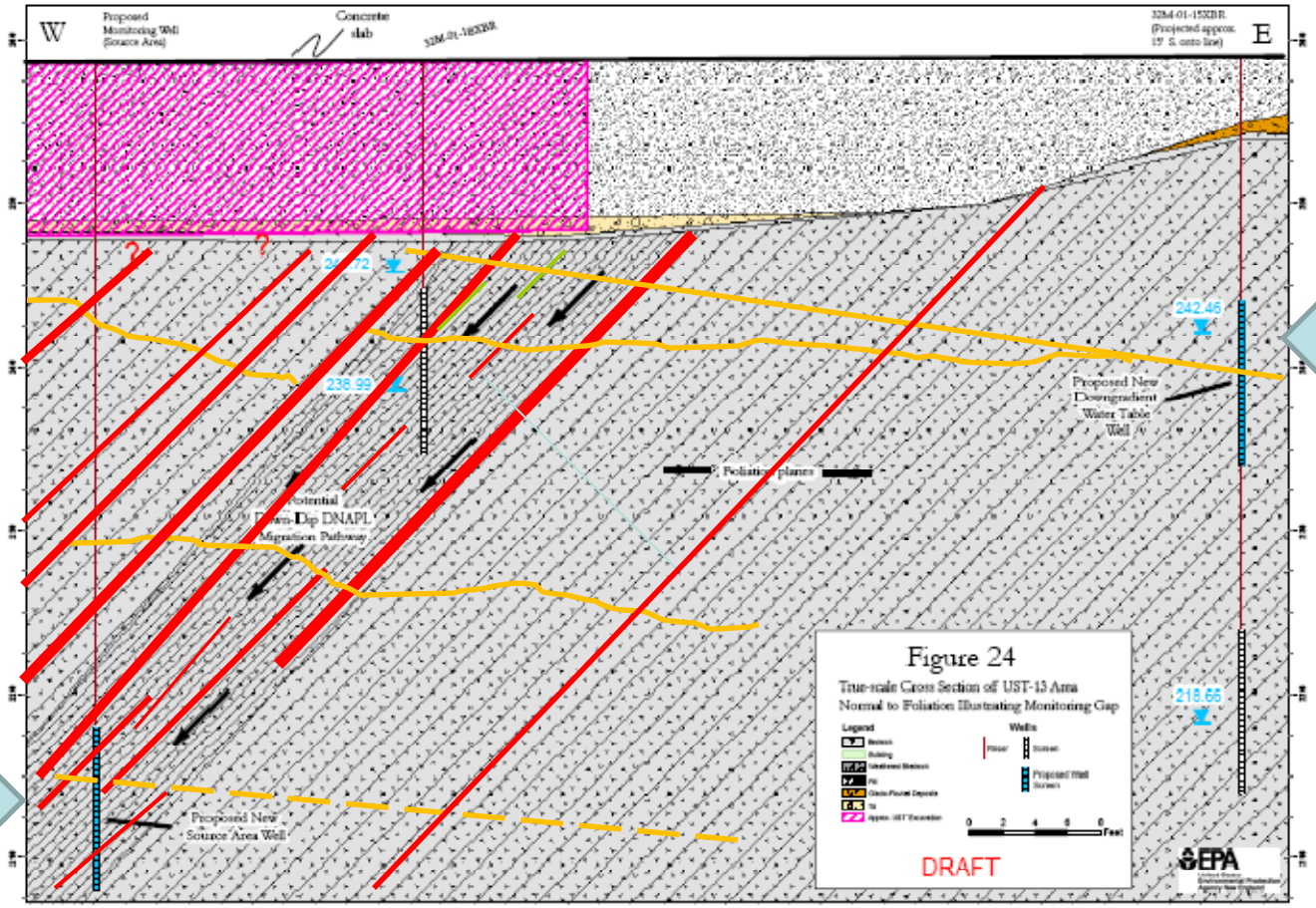




True-Scale Cross Section of UST-13 Area Normal to Foliation, Illustrating Monitoring Gap



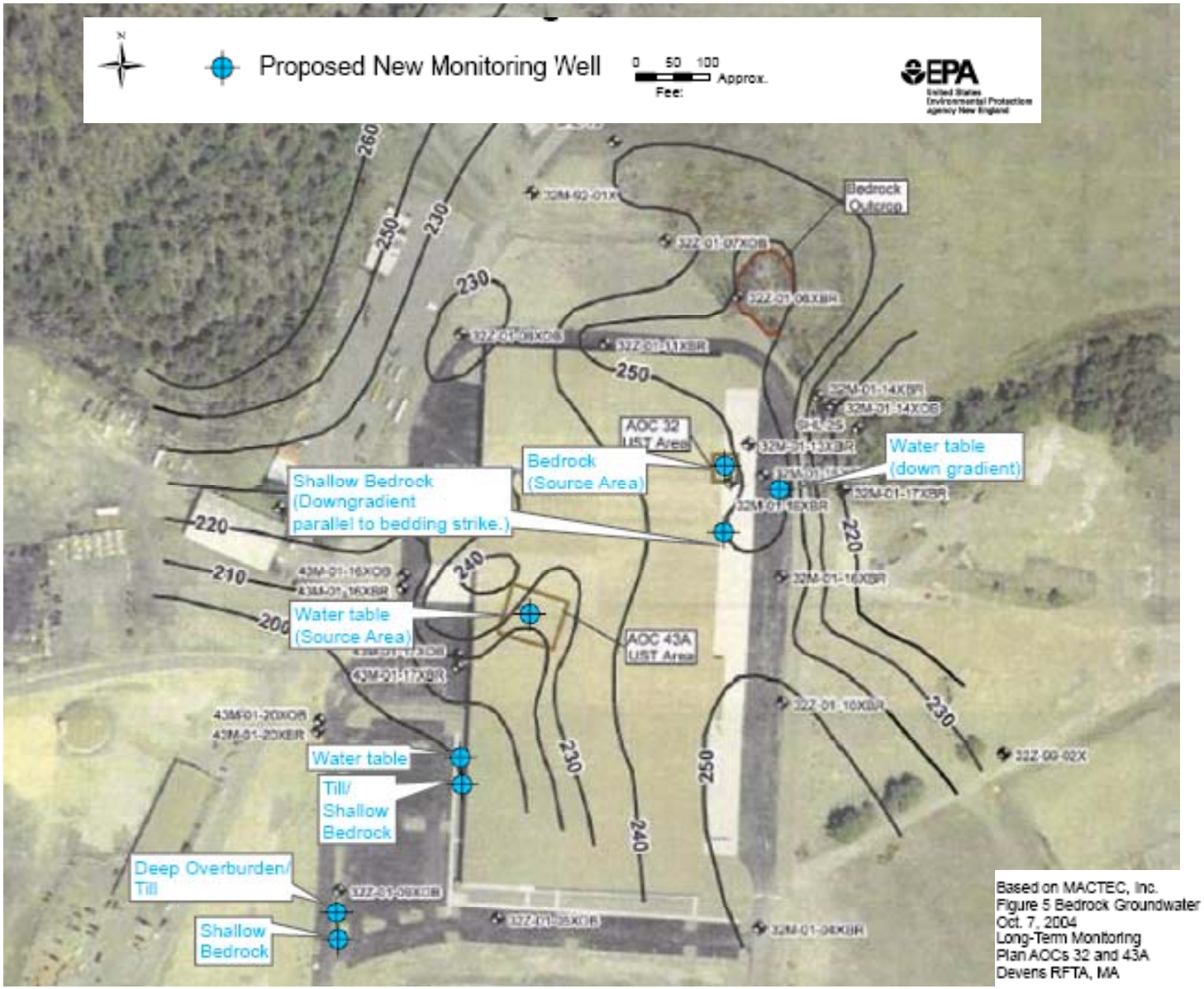
GFM: Conceptual Fracture Network



Proposed Source Area Well

Proposed 'DG' Water Table Well

Plan View of Site 32-43A Indicating Proposed Locations for New Monitoring Wells



Based on MACTEC, Inc.
Figure 5 Bedrock Groundwater Surface
Oct. 7, 2004
Long-Term Monitoring
Plan AOCs 32 and 43A
Devens RFTA, MA

Summary and Conclusions
CSM Considerations (sans GFM)

- Systematic water table rise in the POL area
- “Drowned Smear Zone”
- Many existing MWs no longer screened optimally for water table monitoring;
- UST-13 Area Requires several new MWs
  - Source area
  - True down-gradient directions
  - Water-table (BR/OB)

Summary and Conclusions

CSM Considerations (with GFM)

- Basic Geologic Analysis + Simple GFM: points to numerous opportunities for LTM Improvement
- Joints parallel to foliation may play a significant role in contaminant migration
  - Down-dip migration of NAPL in source zone(W/SW)
  - Dissolved COC migration along strike (S)
- Several MWs needed to South and SW of source area along primary flow pathways (SOB/DOB/BR)
- Target SW-striking Bedrock Structure

Recommendations and Outstanding Issues

- Install New Monitoring Wells
- Decommission Unnecessary Wells
- New Baseline
- Re-initiate Long-term Monitoring
- Evaluate time-series contaminant trends

NEXT STEPS

- Consensus on Competing CSMs
- CSM 1 (Simplistic):
  - Residual NAPL: ‘Pancake’ Model
  - Bedrock as Equivalent Porous Medium (EPM)
- CSM2 (More Complex)
  - Residual NAPL: Vertical Equilibrium Model (VEM)
  - Bedrock: CSM considers Bedrock Complexity (GFM)
- *Determine whether additional remedial measures are needed……..*