Establishment of Remote-Sensing Based Monitoring Program for Performance Limit State Assessment of the Sacramento Delta Levees

CRC 2nd Annual Meeting: February 1-3, 2017
Chapel Hill, NC

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Research Participants/Partners:
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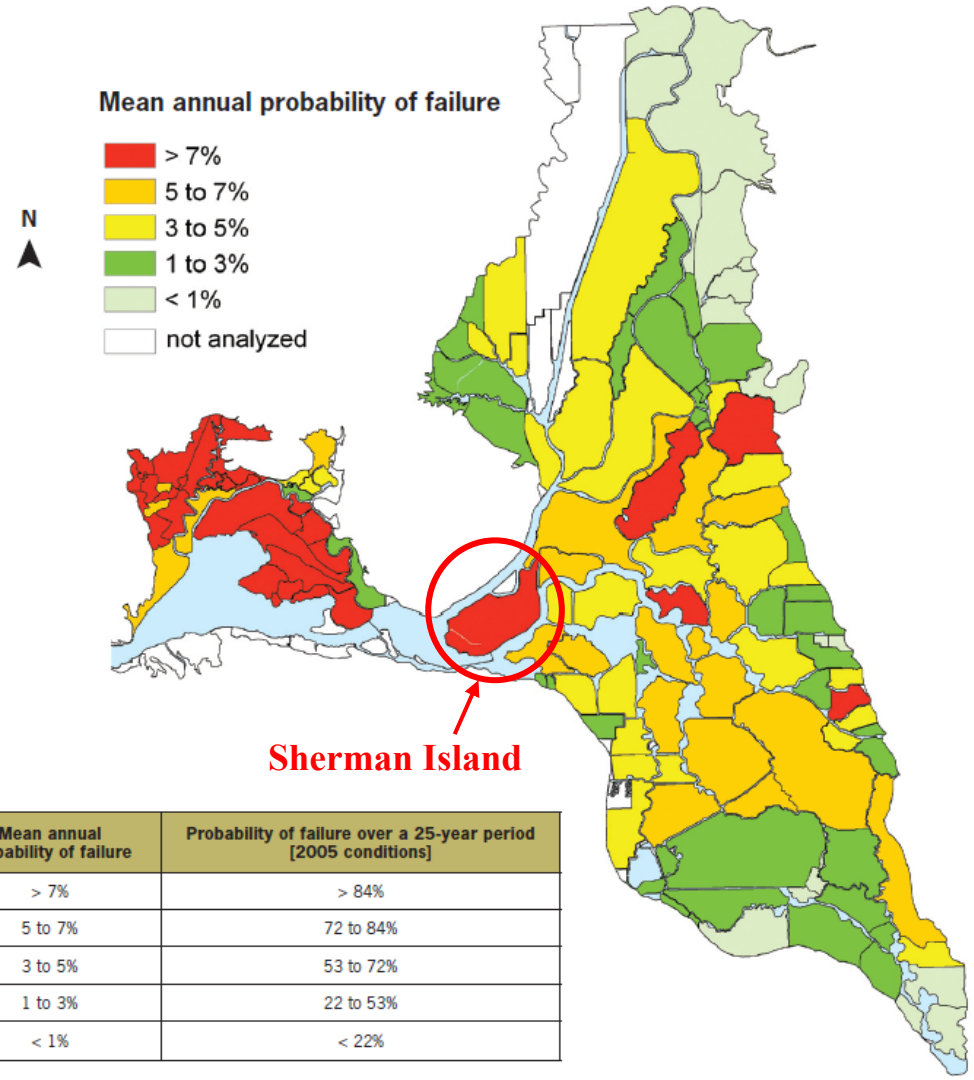
Joel Dudas, Department of Water Resources, Sacramento, CA;
USACE, Vicksburg, MS;
Amr Helal and Rowshon Jadid, Ph.D. Students, NCSU


HINDSIGHT

Project Overview

Scope: Enhancing Resiliency of the California Delta Levees

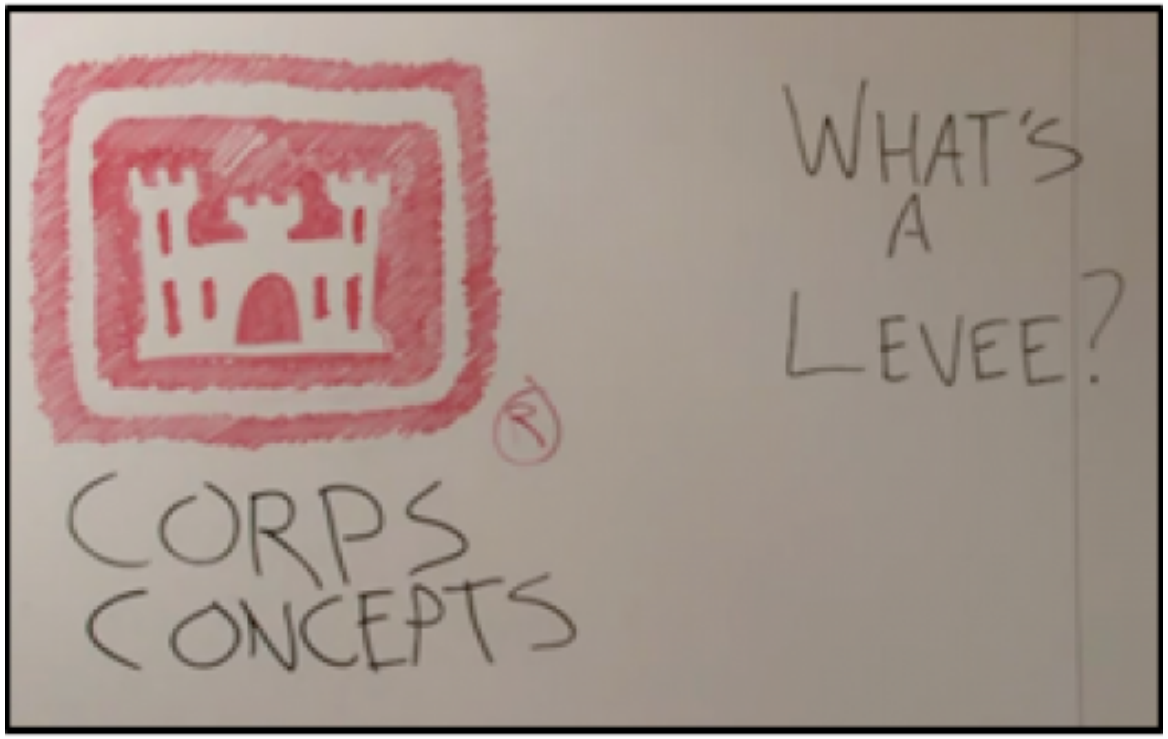
- Validated Remote-Sensing Based Monitoring Program
  - Sherman Island Monitoring – In Situ and Remote
- Assessment of Functionality Level Under Severe Storms
  - Incorporation of Peat Decomposition and Related Effect
  - Characterization of Resilience Response
- Dissemination
  - Levee Displacement Dataset
  - Updating of Software - Risk Estimator for Embankment Structures (REES)
  - Development of a User Manual for REES Software



Mean annual probability of failure	Probability of failure over a 25-year period [2005 conditions]
> 7%	> 84%
5 to 7%	72 to 84%
3 to 5%	53 to 72%
1 to 3%	22 to 53%
< 1%	< 22%

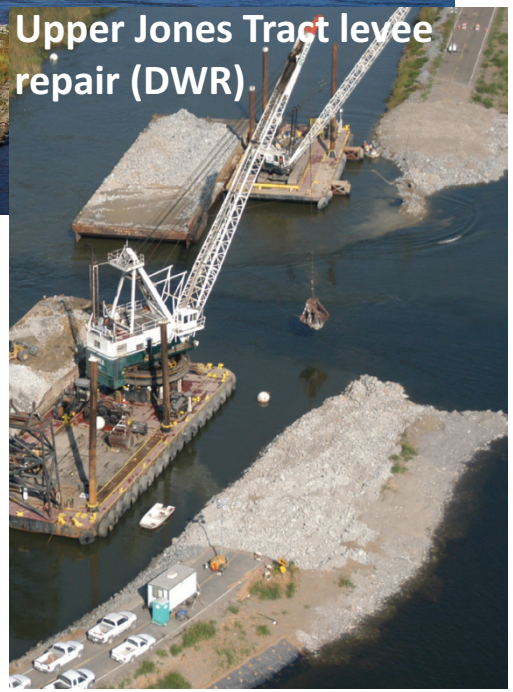
Figure 12 Mean annual probability of levee failure in the Delta Region from the combined risk of earthquakes, high water and dry-weather failures [2005 conditions]
Source: DRMS Risk Report [URS/JBA 2008c], Figure 13-16

Project Relevance to DHS S&T Mission / Impact of Project



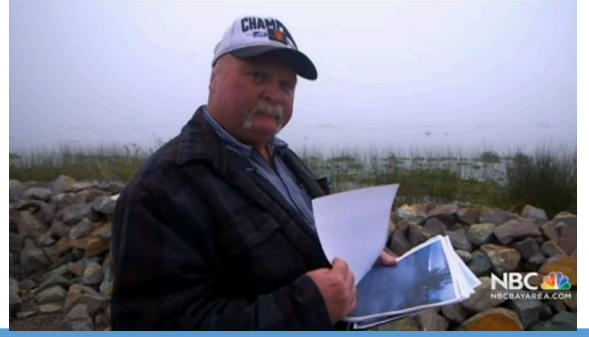
Project Progress


Upper Jones Tract levee failure (DWR)


Upper Jones Tract levee repair (DWR)

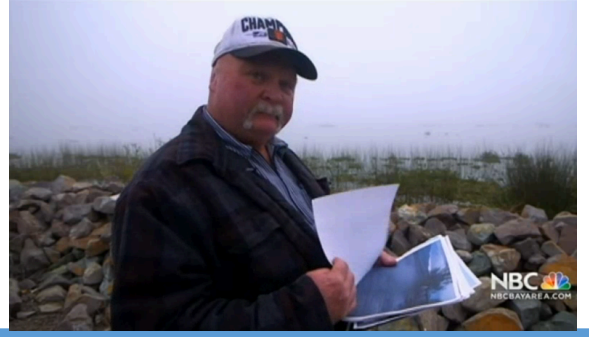
- ***Site Data Collection – Sherman Island***
  - *Installation of 3 autonomous GPS stations*
  - *Characterization of the subsurface properties*
  - *Geotechnical parameters and constitutive relationship*
- ***Model Calibration***
- ***Baseline Case***
- ***Probability of Exceeding Limit State and Uncertainty***
  - *Levee Section fragility in terms of probability of exceedance versus flood cycle and level*
- ***REES Comparison***
  - *Establish the coupled model-monitored data approach to identify vulnerabilities of the levee.*

End User Engagement



End User	Role in Project	Interactions to date	Interaction Outcome
California's Department of Water Resources (DWR) – **Joel Dudas, John Paasch, Kent Zenobia**	Levee Owner; Advisors; Delta Flood Emergency Preparedness, Response and Recovery Program	Many – Most recently Dec. 12 and 19, 2016	Review of geotechnical parameters and cross-section geometry used in model; Feedback on REES software and role of remote sensing in future work.
US Army Corps of Engineers (USACE)	Advisors; Leveraged support	Several – Most recently Sept. 2016	Funding for upgrading in situ instrumentation at one site in New Orleans

End User Engagement

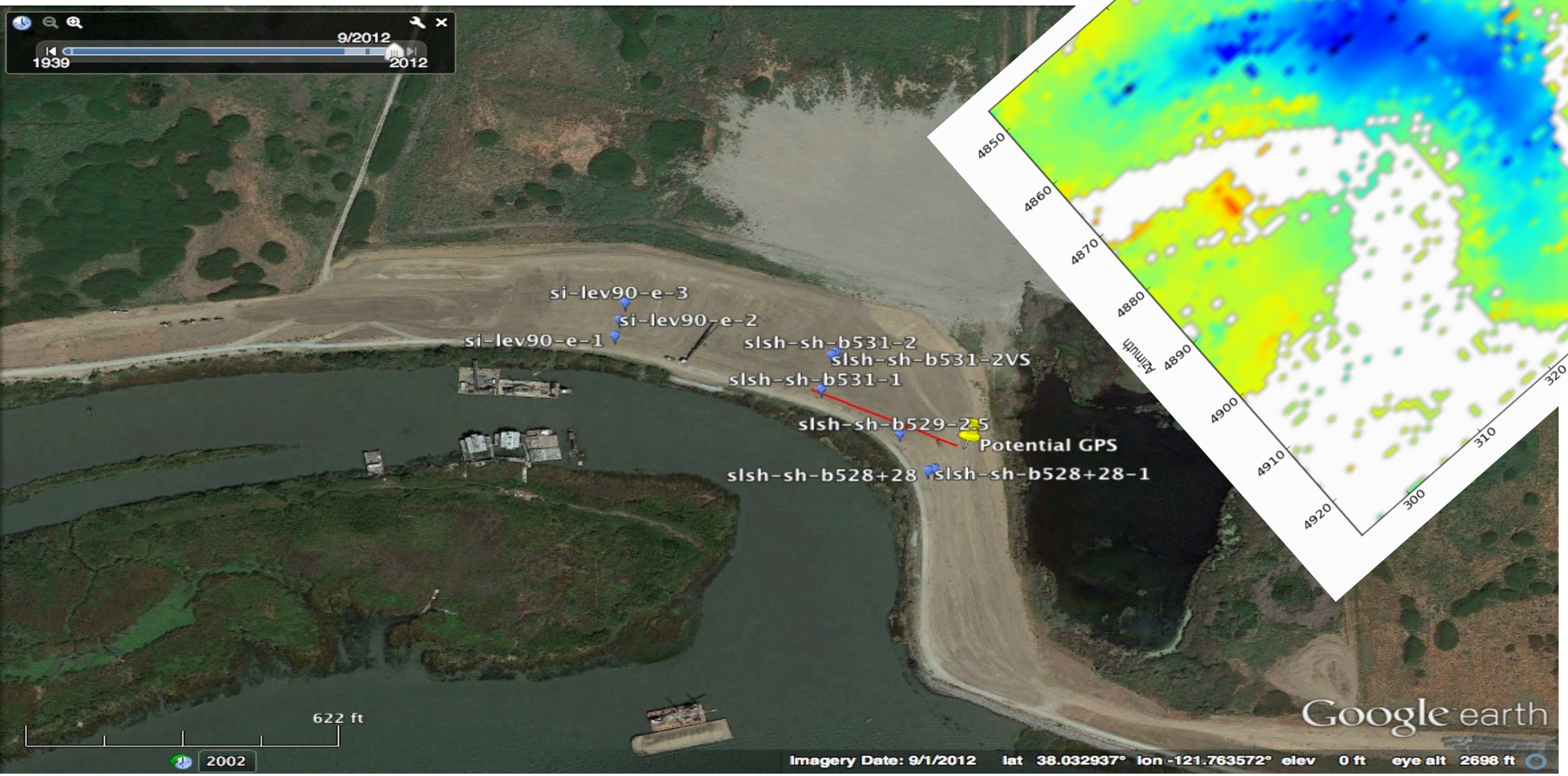


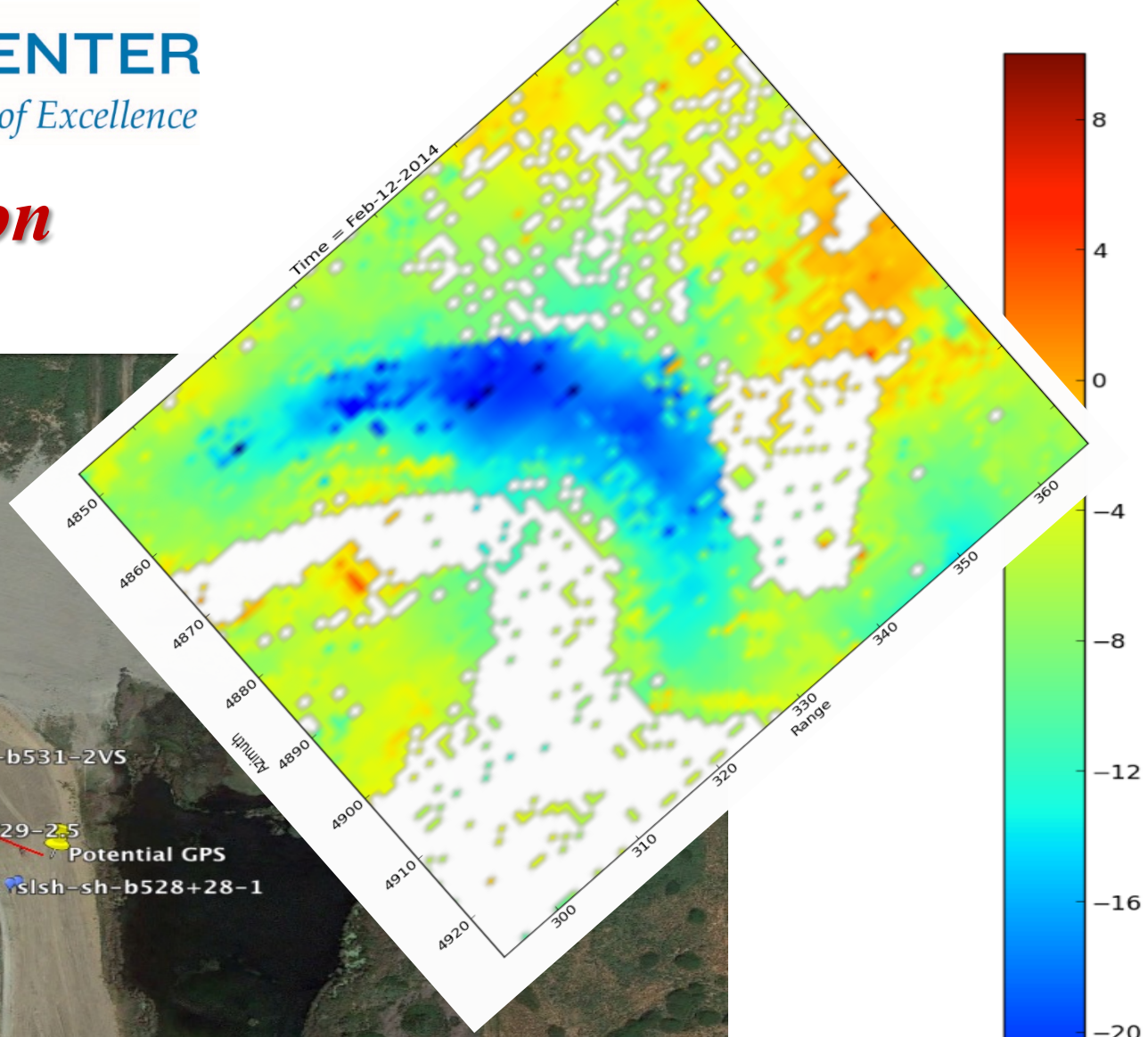
End User	Role in Project	Interactions to date	Interaction Outcome
California Governor's Office of Emergency Services, State Threat Assessment Center, Critical Infrastructure Protection (CIP) – **Brian Banning, Ted Johnson, Tom Ducker, Mark Johnson, Officer Tim Navarra (CHP); Protective Security Advisor, DHS**	Advisor; Interested in statewide levee performance	Emails & face-to-face meeting 12/15/16	Review of project objectives and discussion of this project's application to other areas in CA
CA Reclamation District #341 (Levee Safety Board) – **Joel McElroy**	First responder; Levee maintenance	Many – Most recently June 2016	Engagement of District in monitoring efforts

COASTAL RESILIENCE CENTER

A U.S. Department of Homeland Security Center of Excellence

Site Location and Instrumentation





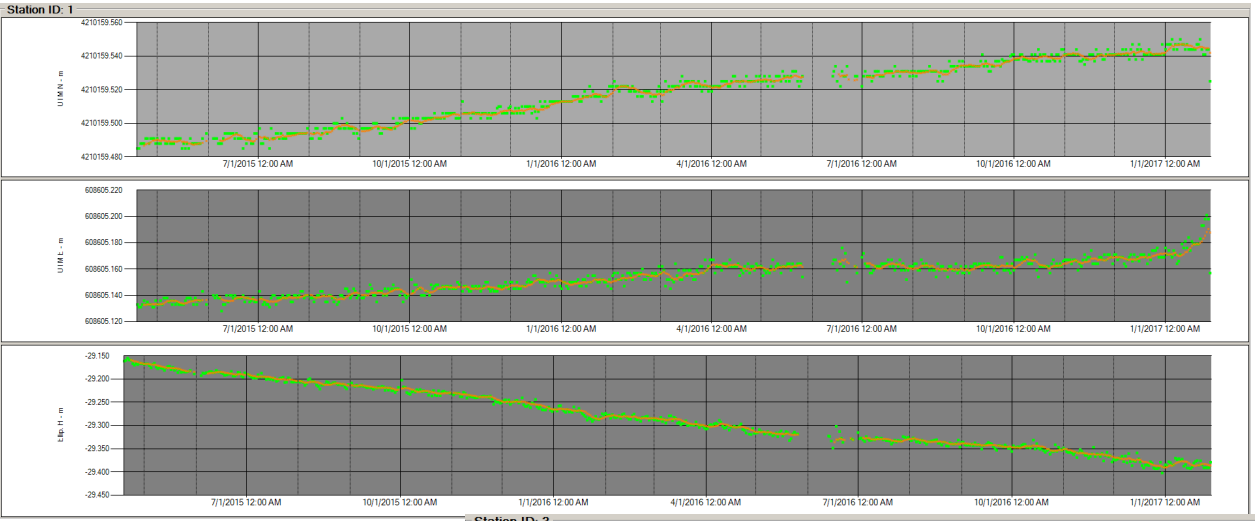
Cumulative Displacement in the Line-of-sight Direction [cm]


GPS_8003
GPS at W-2C_8002
GPS_8001
251 ft
2002
Google earth
Imagery Date: 10/30/2015 38°01'56.81" N 121°45'49.09" W elev 5 ft eye alt 1158 ft

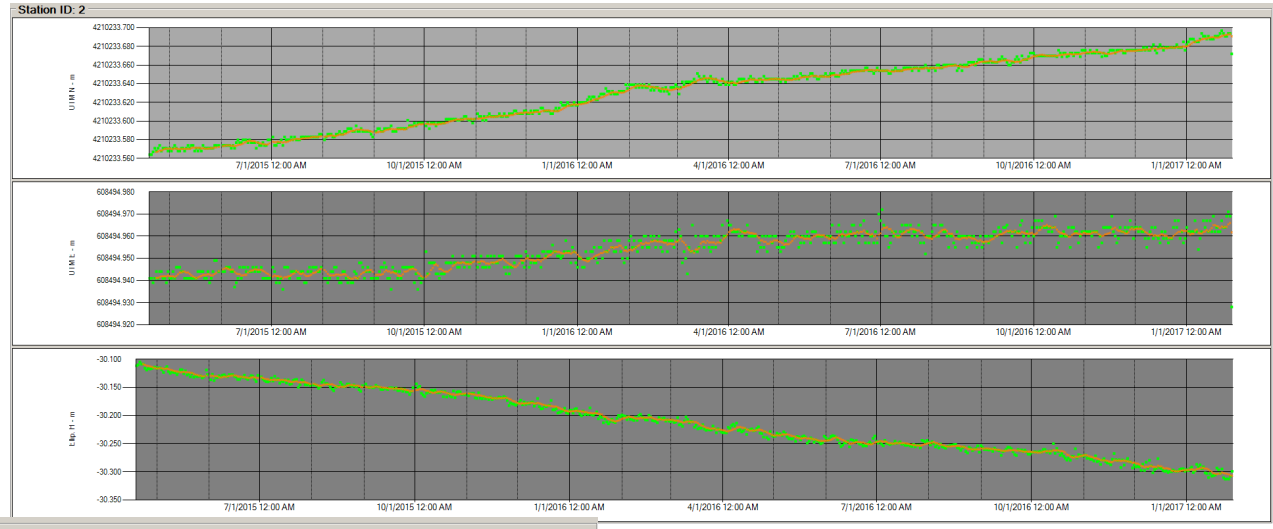

RPI

GPS Data
4/1/2015 – 1/30/2017

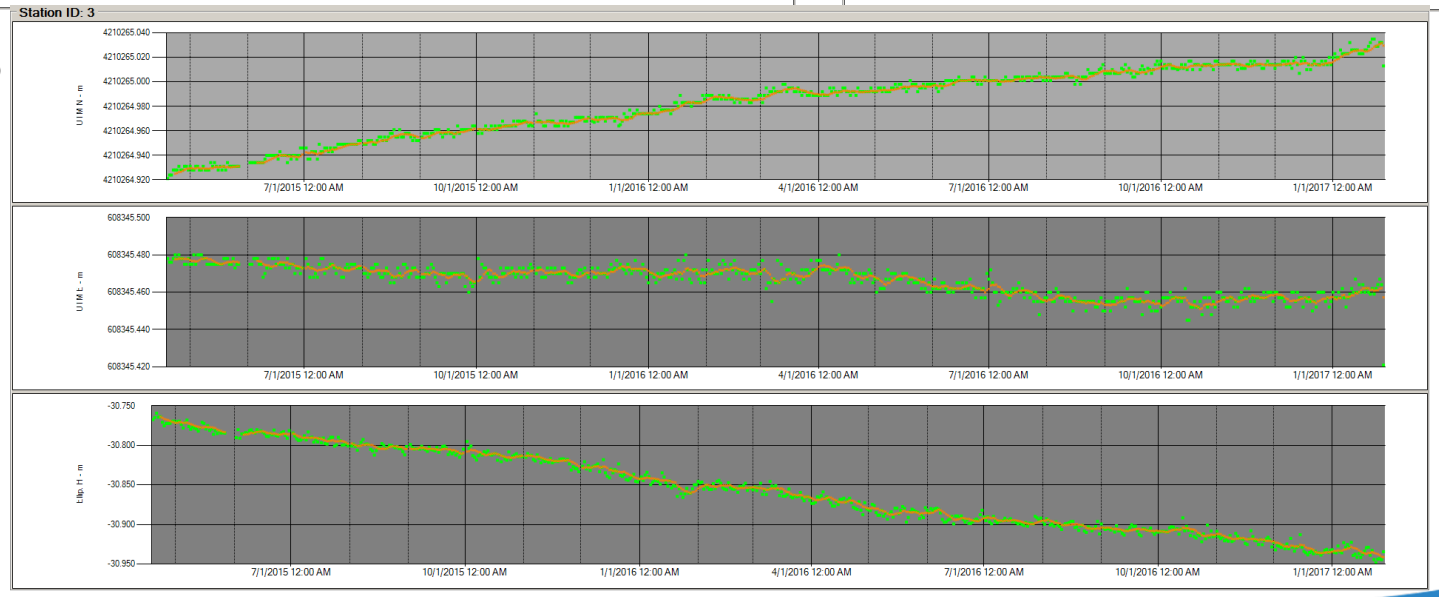
Station 8001



Station 8002

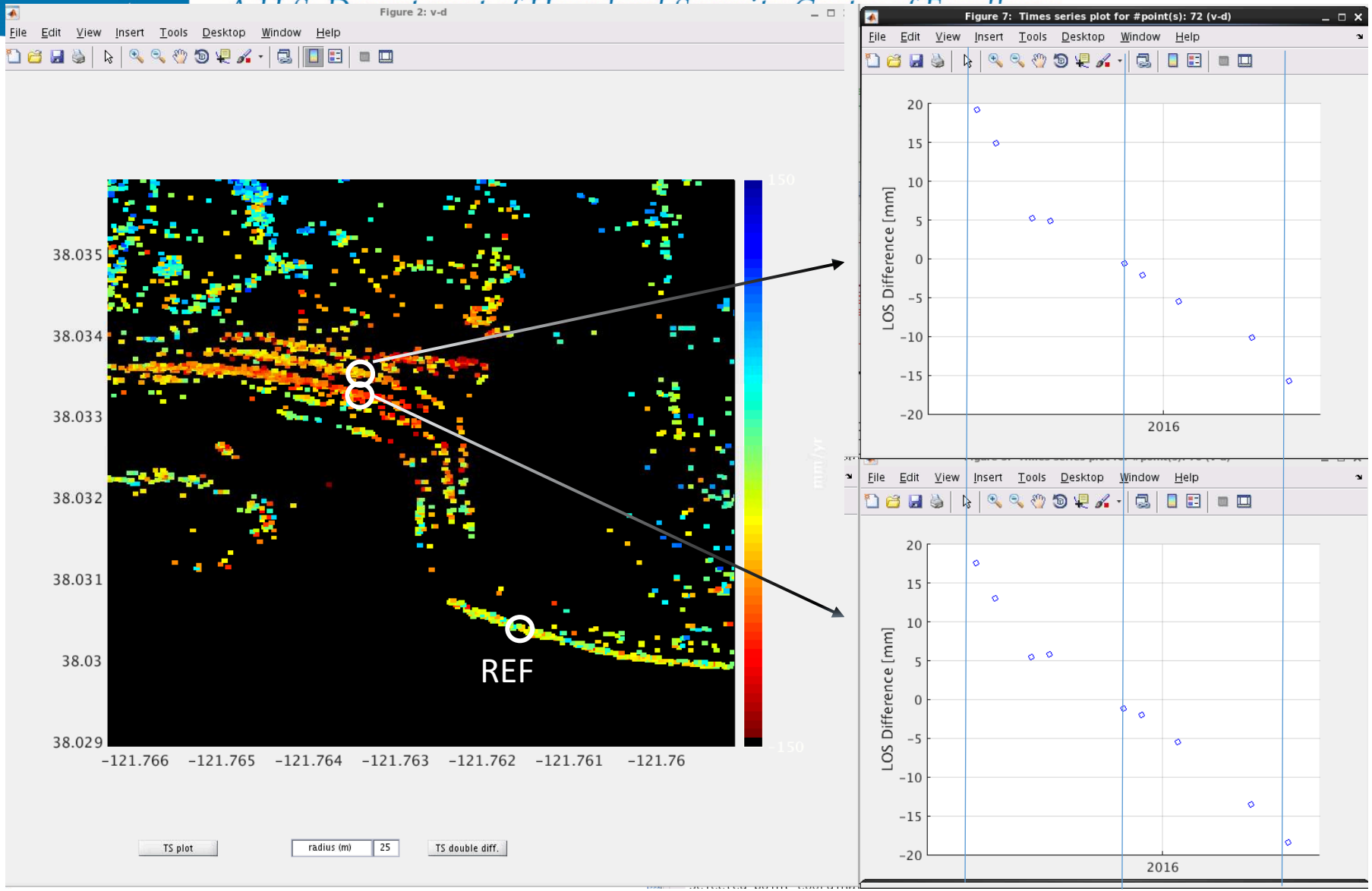


Station 8003



Settlement Rates:
Station 8001: 12.8 cm/yr
Station 8002: 11.7 cm/yr
Station 8003: 10.0 cm/yr

COASTAL RESILIENCE CENTER

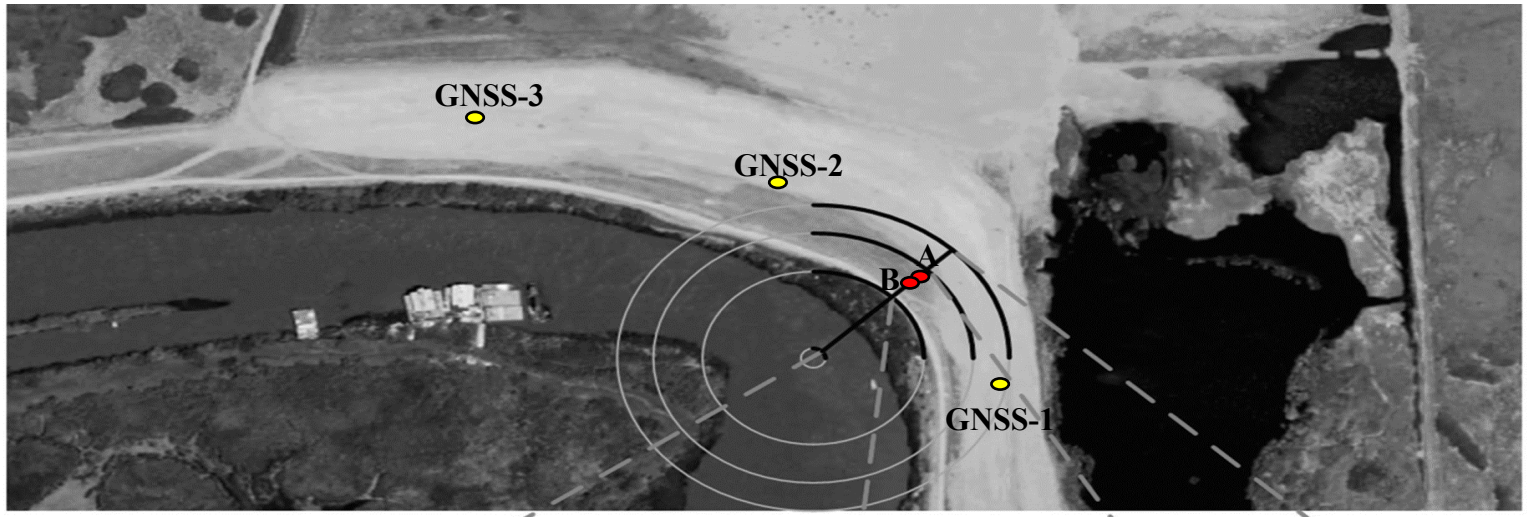


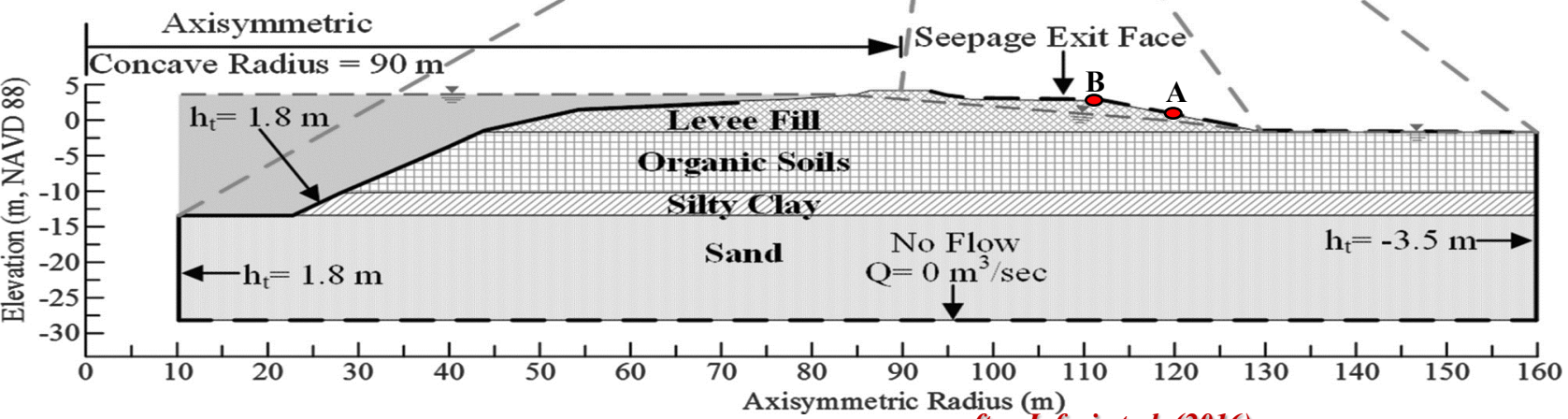
Settlement Rate:
~6 cm/yr LOS

Aug 2015 Dec April 2016

Incidence Angle = ~32-35 deg (cos = 0.83, sin = 0.55), descending track, looking ~100 deg from north (cos = 0.98, sin = 0.17)

Model of Sherman Island Levee Cross Section

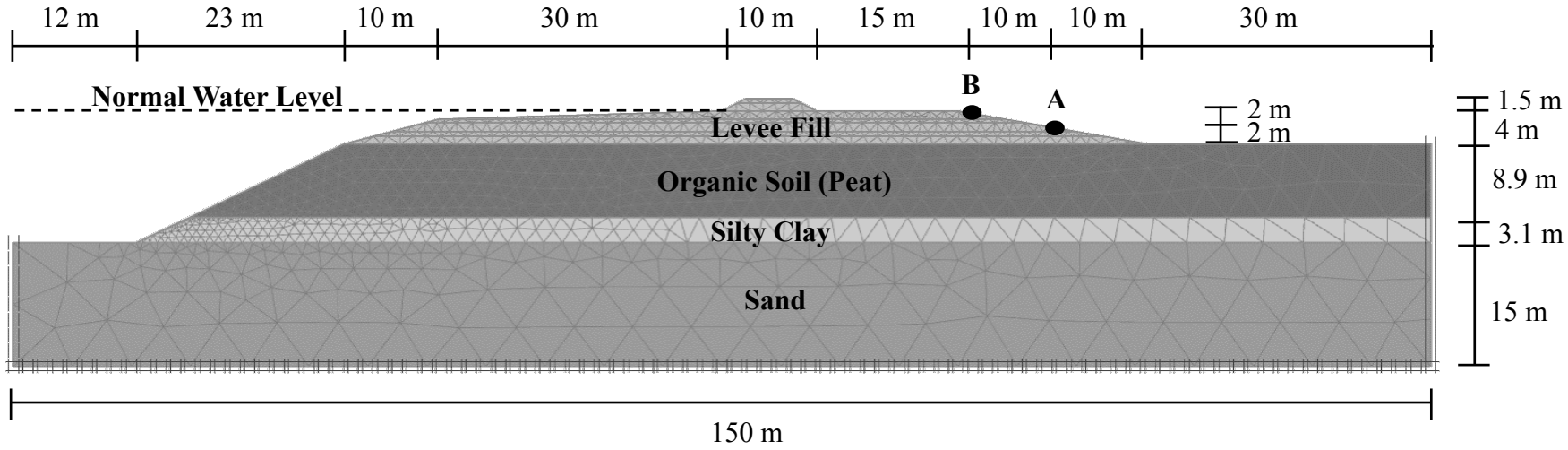




after Jafari et al. (2016).

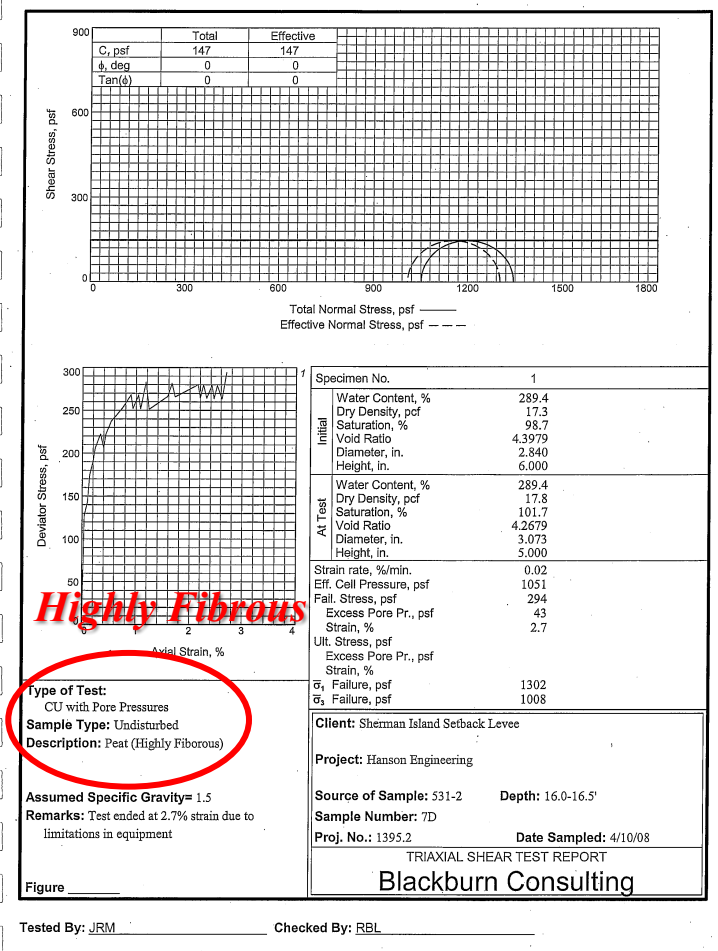
Numerical Model

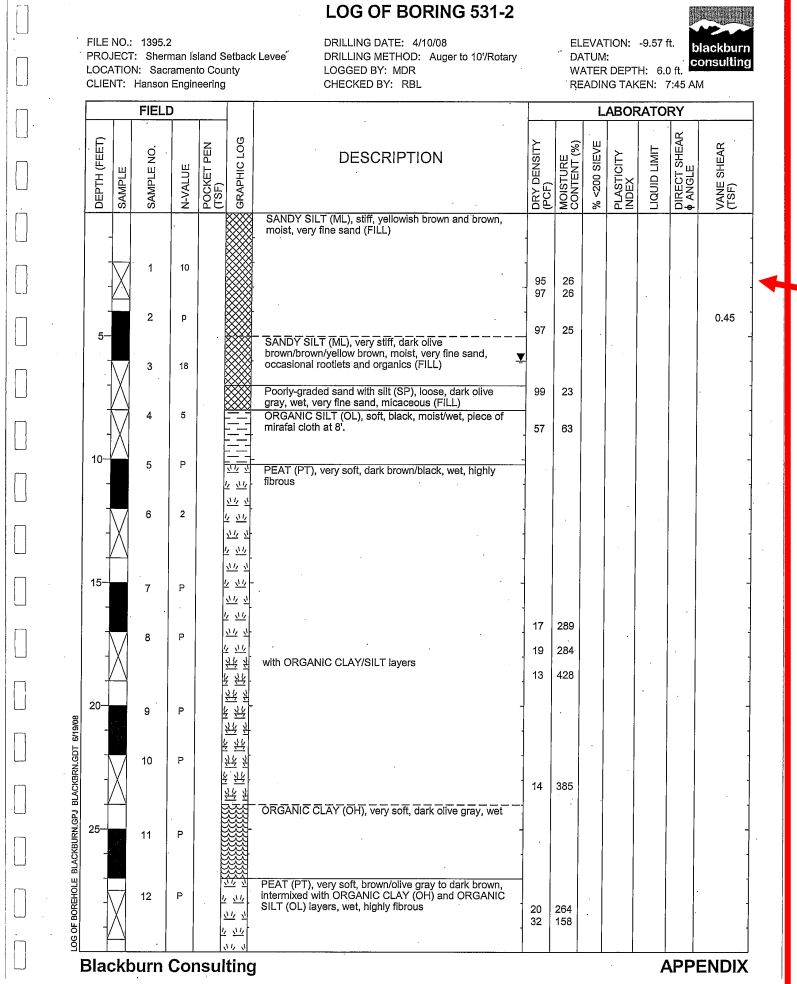
- Model levee section on Sherman Island
- Large deformation option in PLAXIS 2D
- A fine mesh with 15-node elements was used with the domain having 1961 elements and 15975 nodes
- Soft Soil Creep Model (SSC) in PLAXIS 2D



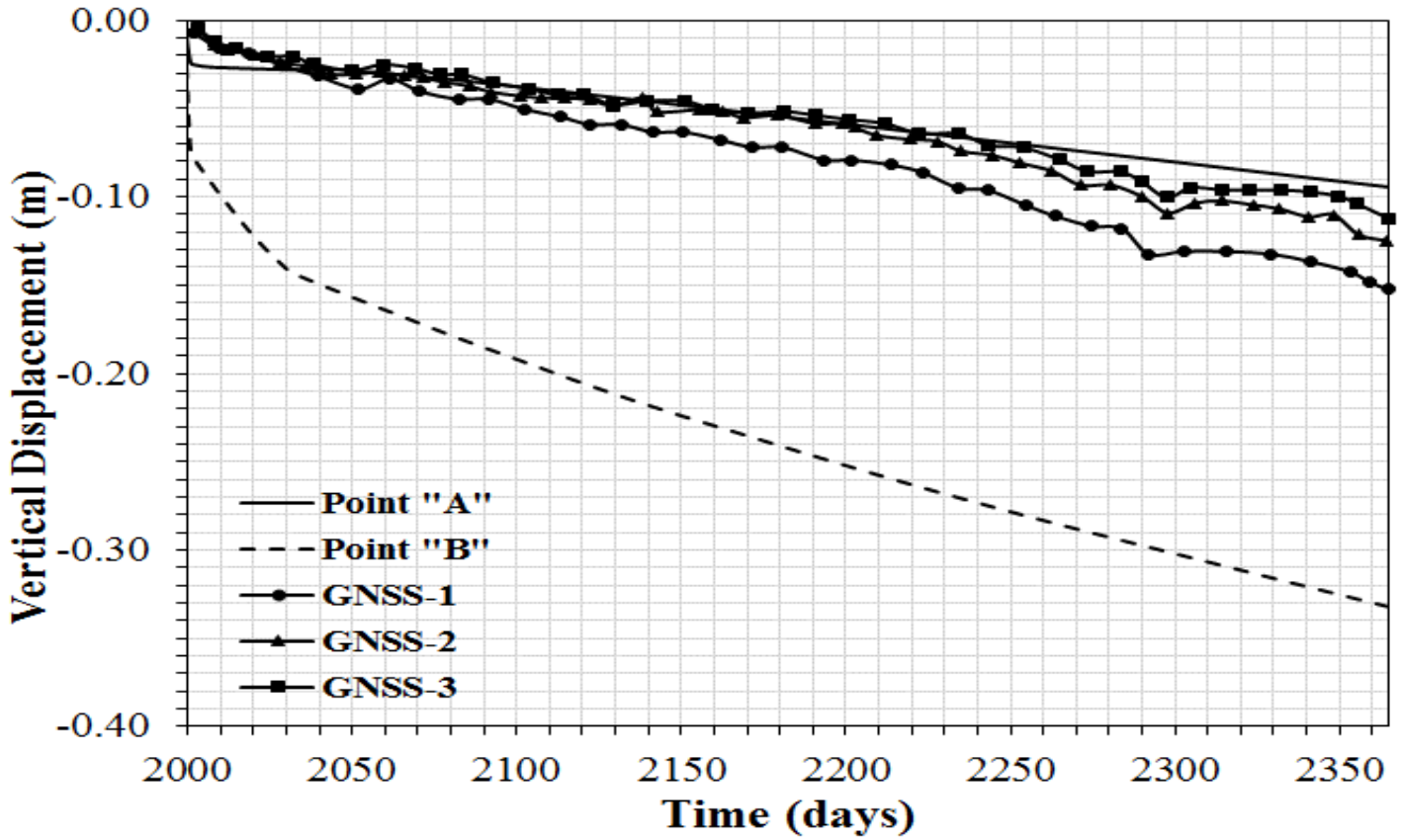
Finite element PLAXIS 2D levee mesh and boundary conditions

Borehole log for Sherman island setback levee project

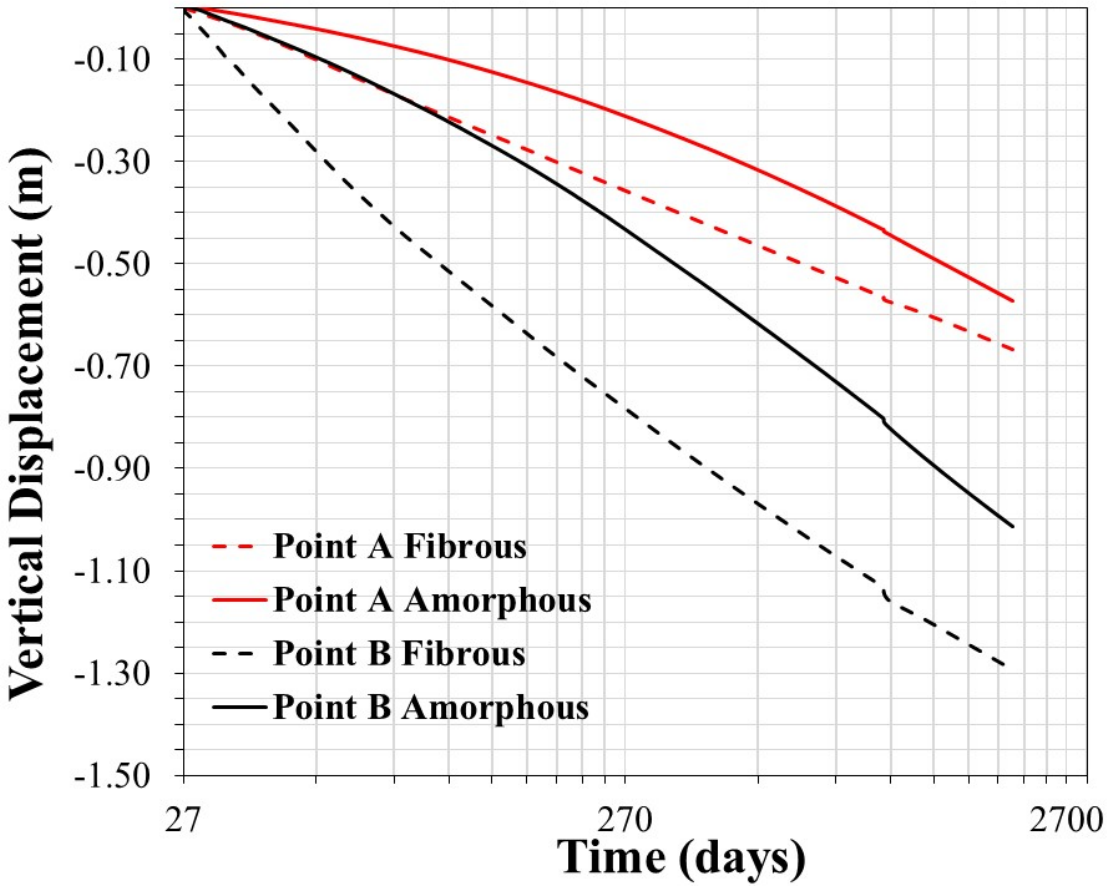




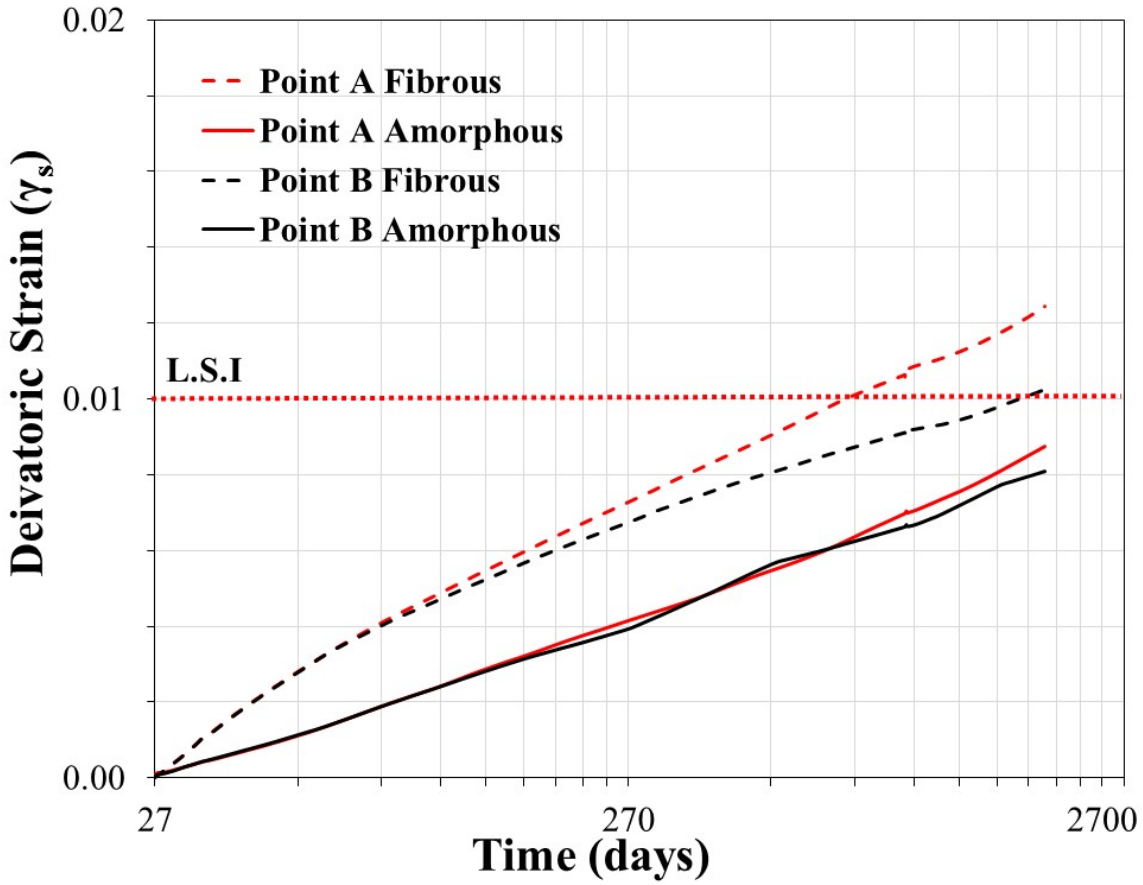
Displacement with time for fibrous peat versus GPS data (points A and B are indicated on the model cross-section)



Fibrous vs. Amorphous



Vertical Displacement with time for fibrous and amorphous peat.



Total Deviatoric Strain (γ_s) with time and limit state criteria for mean value of C_α/C_c=0.06.

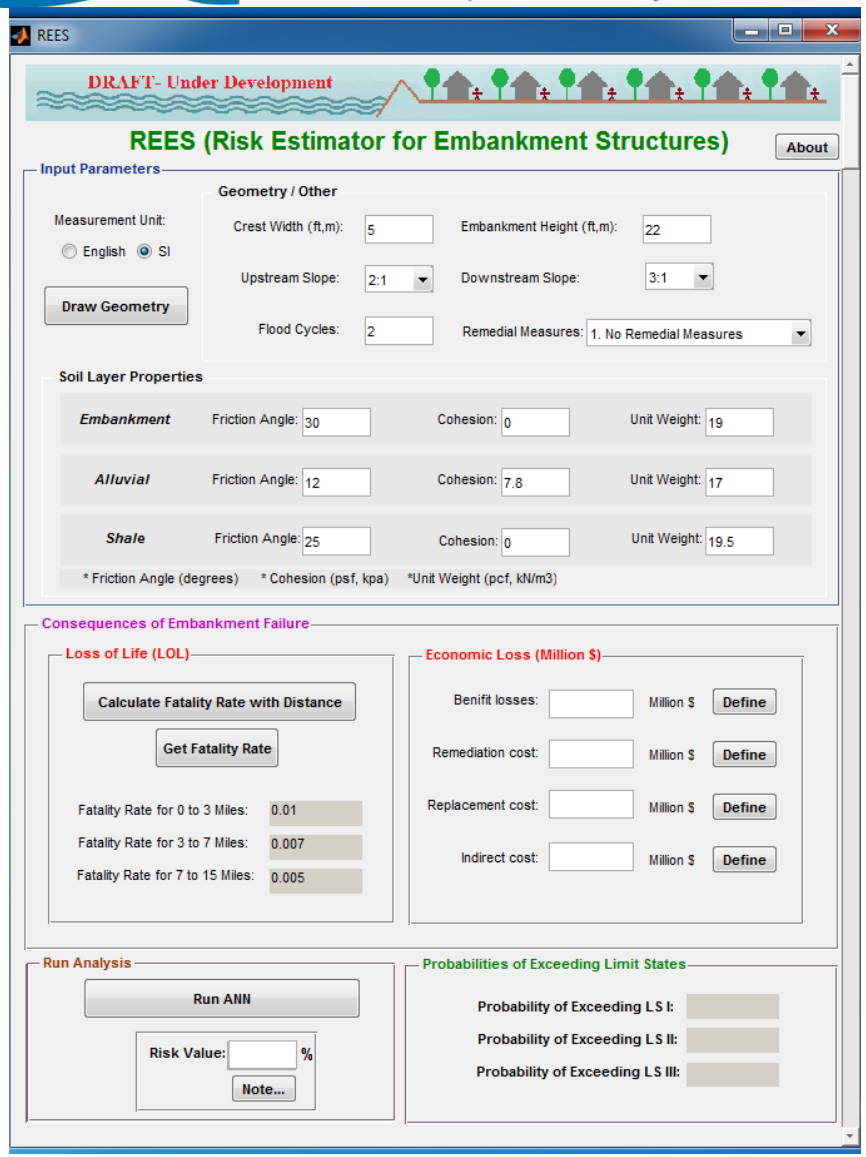
Observations from the Modeling

- **The use of amorphous peat properties shows stiffer response and lower compressibility than fibrous peat, which agrees with literature (Mesri et al., 2007). The assumption of amorphous peat led to lower computed displacements overall.**

- **The analyses indicated a relatively small mechanistic deformation induced by "extreme" water level under transient conditions. This is in comparison to the continuous and large deformation induced by the compression of the peat layer. The high-water level will however affect the exit hydraulic gradients and may lead to critical conditions, as was discussed by Jafari et al. (2016).**

- **The variability in the reported values for compression coefficients (C_c and C_α) for fibrous and amorphous peat suggests these values need to better defined as a function of fiber contents, state of decomposition, and water content. A parameter in terms of cellulose and lignin content can provide insight as to the chemical composition of the materials and the related shear strength with aging for more accurate performance assessment of the levee.**

REES: Risk Estimator for Embankment Structures



➢ Knowledge gap being addressed by project

❑ Peer-reviewed publications

"***Monitoring and Modeling of Peat Decomposition in Sacramento Delta Levees,***" Amr Helal, Victoria Bennett, Mo Gabr, Roy Borden and Tarek Abdoun. Submitted for Geotechnical Frontiers 2017, Orlando, Florida.

"Deformation Monitoring for the Assessment of Sacramento Delta Levee Performance," Victoria Bennett, Cathleen Jones, David Bekaert, Jason Bond, Amr Helal, Joel Dudas, Mo Gabr, and Tarek Abdoun. Accepted draft paper for Geo-Risk 2017 (Geotechnical risk from theory to practice), Denver, Colorado.

"Use of remote-sensing deformation monitoring for the assessment of levee section performance limit state," Victoria Bennett, Amr Helal, Cathleen Jones, David Bekaert, Joel Dudas, Mo Gabr, Chung Nguyen, Tarek Abdoun. Int'l Conference on Soil Mechanics and Geotechnical Engineering (ICSMGE) 2017, Seoul, S. Korea.

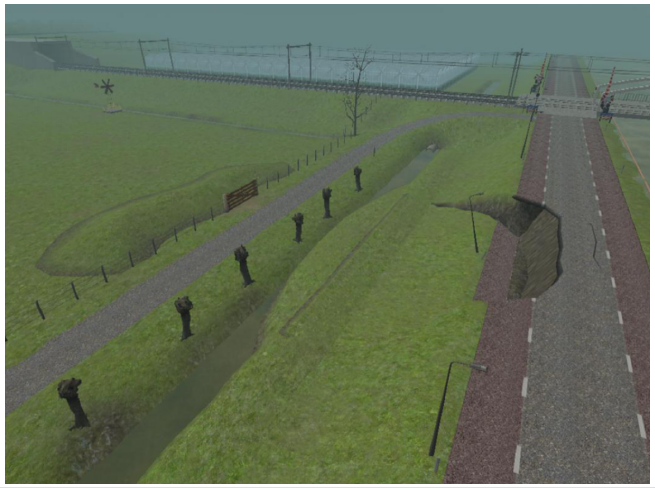
Geotechnical Frontiers
March 12–15, 2017 | Orlando, Florida USA

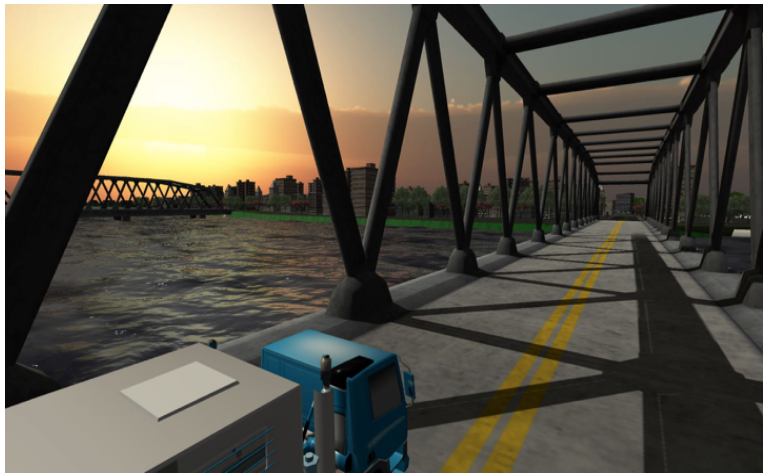
G-I ASCE
GEO-RISK 2017
DENVER, COLORADO | JUNE 4-7, 2017
Geotechnical Risk from Theory to Practice

19th International Conference on Soil Mechanics and Geotechnical Engineering
17 (Sunday) ~ 22 (Friday) September 2017
COEX Convention Centre, Seoul, Korea

CRC Education Project Integration

- "SUMREX" and "RETALK" programs
- Other opportunity:
  - Geo-Explorer: Mixed Reality & Mobile Game





Progress to Date

Reporting Period 1/1/2016 – 1/1/2017		
Research Activity	**Proposed Completion Date**	**% Complete**
Task a- Site Data Collection	6/30/2016	100%
Task b. Model Calibration	6/30/2017	80%
Task c. Baseline Case	6/30/2017	50%
Task d. Probability of Exceeding Limit State and Uncertainty	6/30/2017	50%
Task e. Field Comparison	12/31/2017	30%
Research Milestone		
Characterization of the subsurface properties and possible constitutive relationship to use in the modeling effort	6/30/2016	100%
Establishment of Levee Section fragility in terms of probability of exceedance versus flood cycle and level	6/30/2017	30%
Establish the coupled model-monitored data approach as a means to identify vulnerabilities of the levee section studied herein.	12/31/2017	20%

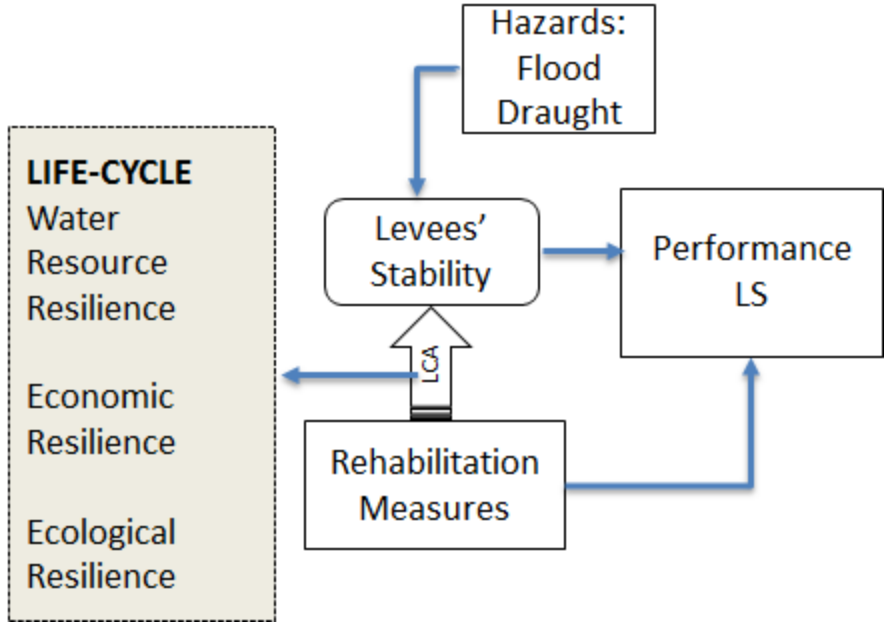
❑ *Plan to get research product/s into actual use*

Product Name	Product Type	Approx. Delivery Date	Recipient or Anticipated End Users
REES "Risk Estimator for Embankment Structures"	Software	June 2017	Dept. of Water Resources; FERIX
Monitoring of Sherman Island	Dataset	Ongoing	Dept. of Water Resources; FERIX

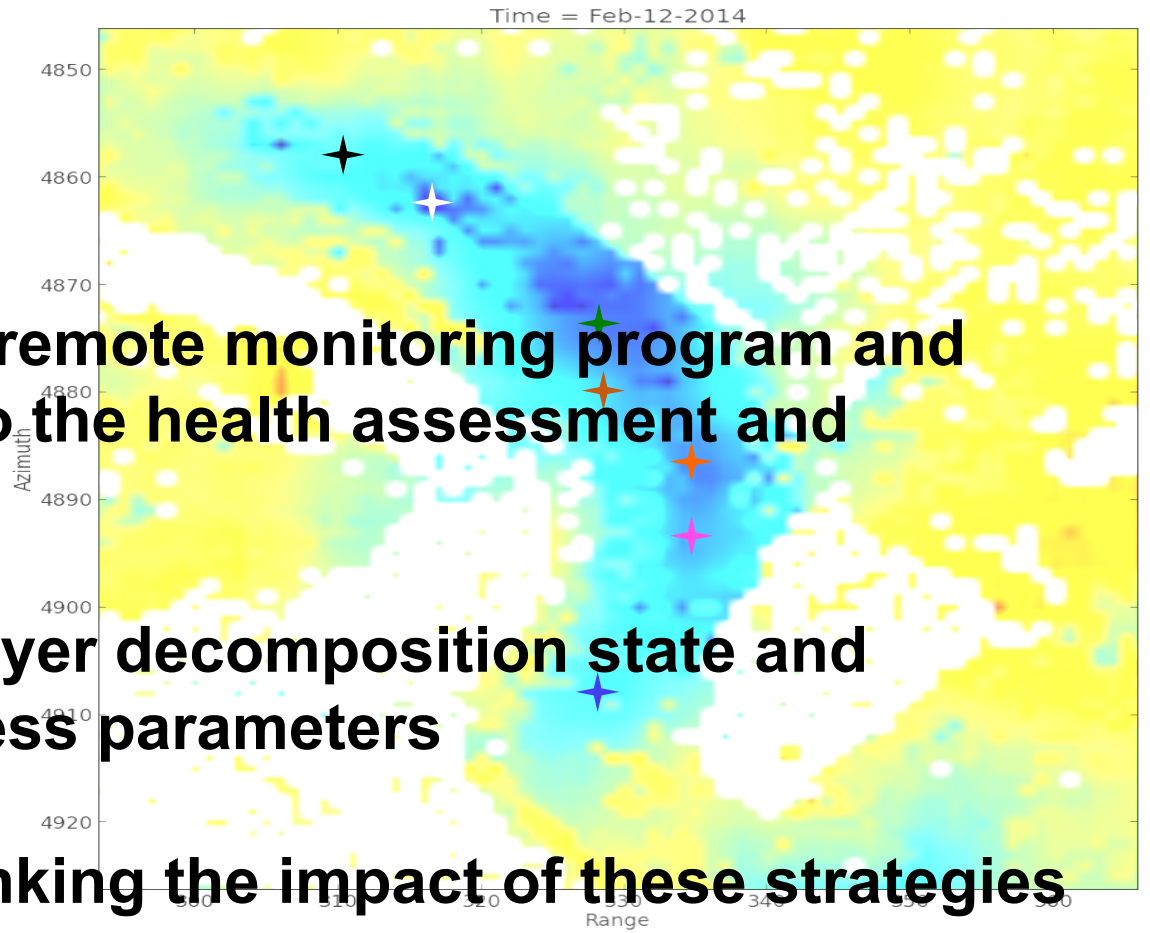
Department of Water Resources
FLOOD EMERGENCY RESPONSE INFORMATION EXCHANGE (FERIX)

Anticipated Project Impact

- **Effective means for remote damage-identification on a large scale**
- **Continuous assessment of remedial strategies and their impact on improving the levee condition and the corresponding system-level resiliency**
- **Availability of a tool for estimation of risk for various combinations of embankment geometry and cyclic flood loading without the need to run sophisticated numerical analyses**



Proposed Follow-on Work



- Continuation of and User Interface for the remote monitoring program and incorporation of the 3-D data collected into the health assessment and performance modeling
- Quantitative characterization of the peat layer decomposition state and associated changes in strength and stiffness parameters
- Development of remedial strategies and linking the impact of these strategies on resilience of water, ecological, and economical resources through system-level life cycle analysis
- Extension of the REES tool to include time-related aspects of peat degradation and stability in terms of flood and drought loading

Thank You!