U.S. Department of Transportation
Federal Highway Administration

Webinar Series

TRANSPORTATION CLIMATE CHANGE & EXTREME WEATHER VULNERABILITY ASSESSMENT

Session 2: System-Level Vulnerability Assessments

May 30, 2013

Missouri River flooding, Jefferson City, Missouri
Photo: Missouri DOT

Webinar Series

Session 1: Getting Started – Determining Assets to Study and Using Climate Information

Session 2: System-Level Vulnerability Assessments

Session 3: Applying the Results

Date: Wednesday, June 12, 2:00 – 3:30 pm EDT

Session 4: Hurricane Sandy - Lessons Learned

Date: Thursday, June 20, 2:00 – 3:30 pm EDT

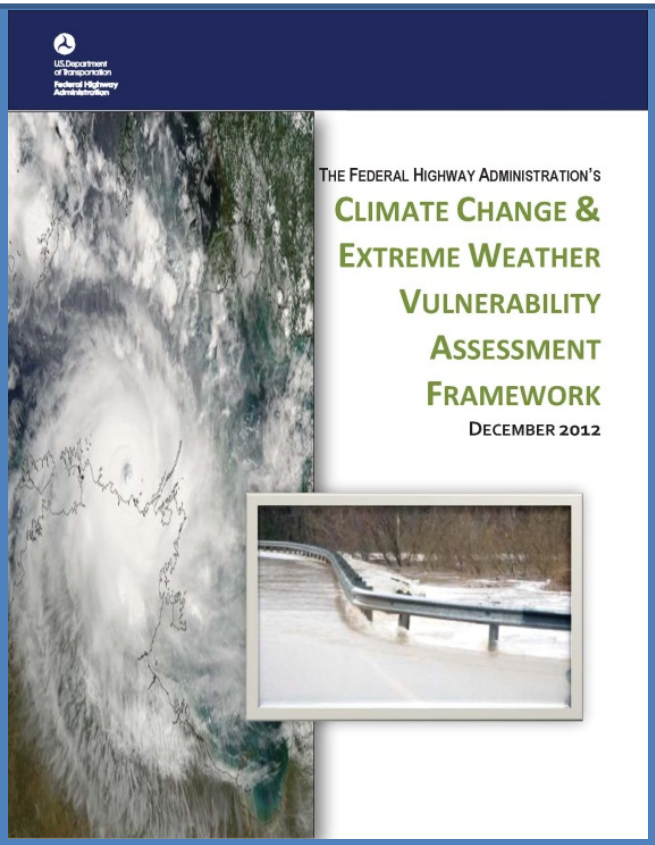
Agenda

Introduction	*Rob Kafalenos, FHWA*
Example Applications of System-Level Vulnerability Assessments	
Washington State DOT	*Carol Lee Roalkvam*
Metropolitan Transportation Commission	*Stefanie Hom, Carolyn Clevenger, & Sara Polgar*
New Jersey Transportation Planning Authority	*Jeffrey Perlman*
Q&As	

Vulnerability Assessments

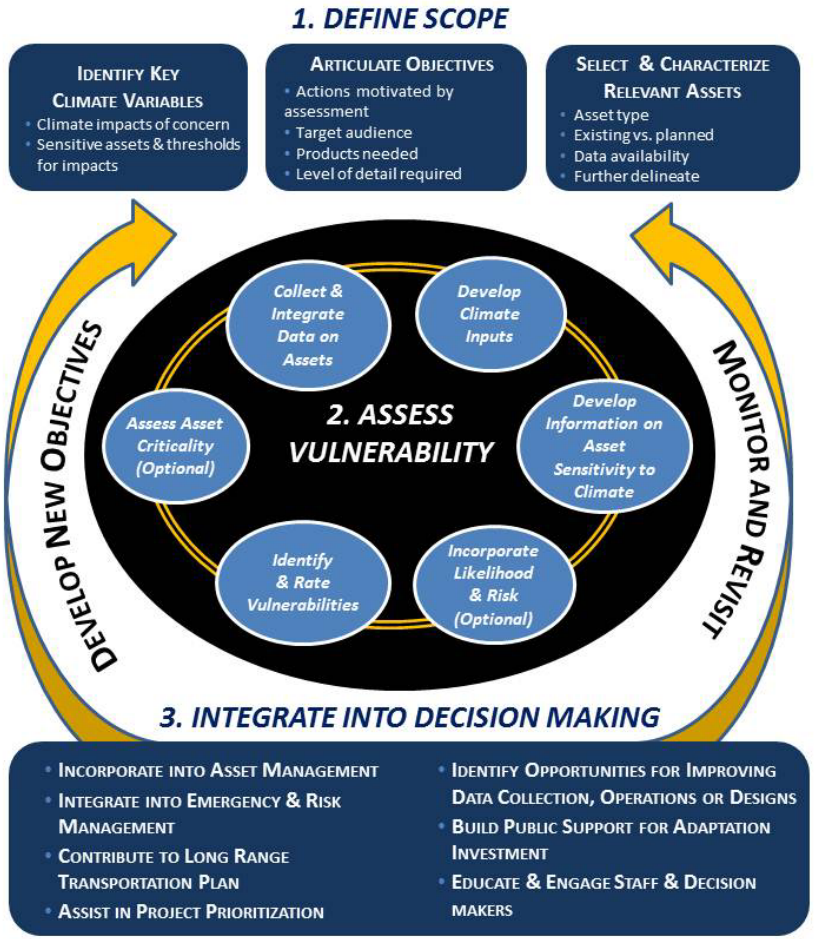
Understanding how climate change effects and extreme weather will affect your transportation network is key first step for climate change planning

FHWA's Climate Change and Extreme Weather Vulnerability Assessment Framework

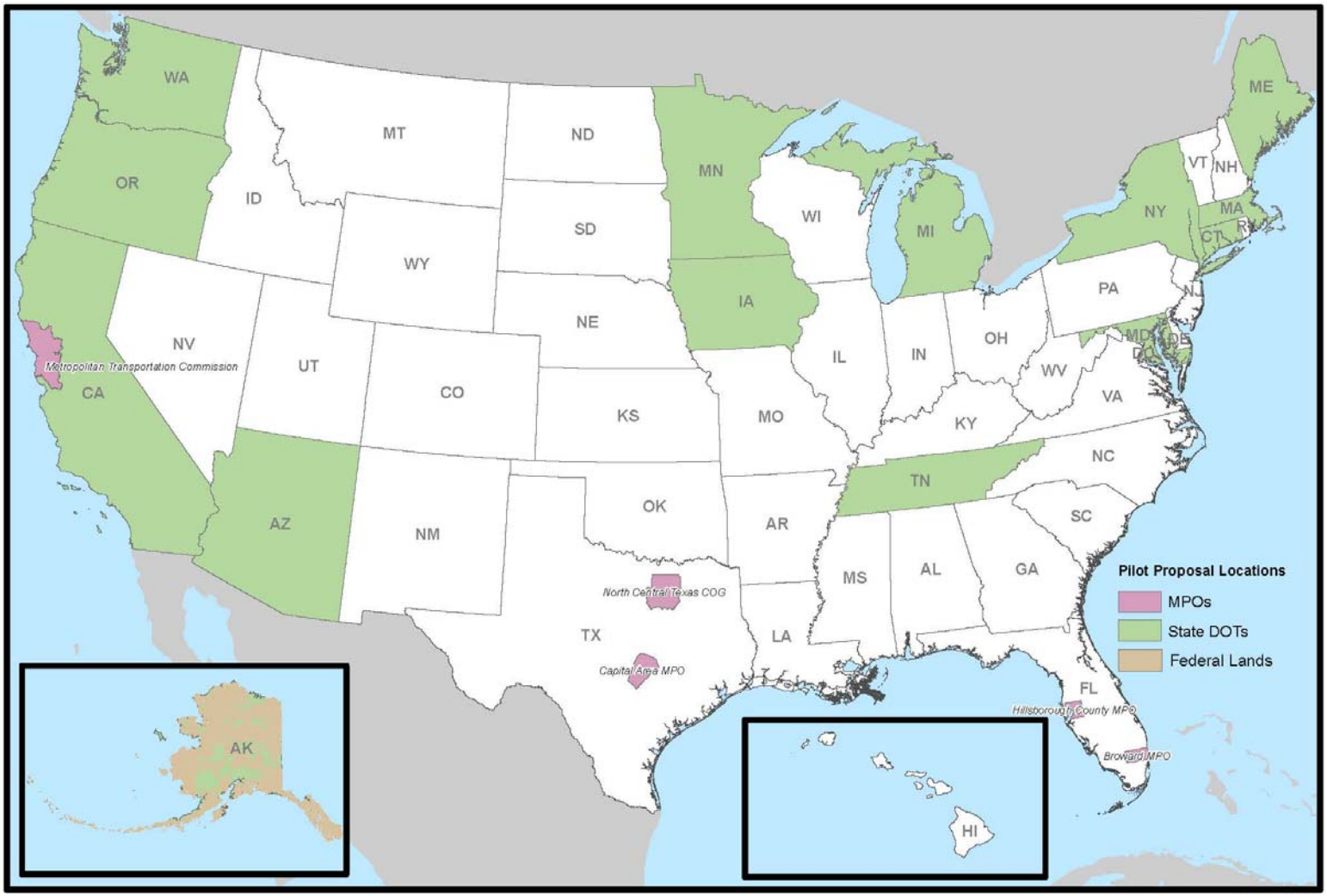


Climate Change & Extreme Weather Vulnerability Assessment Framework

1. Define Project Scope
   - Objectives
   - Relevant Assets
   - Climate Variables
2. Assess Vulnerability
   - Climate Inputs
   - Asset data, criticality, sensitivity
   - Vulnerabilities, risk
3. Integrate Vulnerability Into Decision Making



2013 – 2014 Pilot Locations



2013 – 2014 Pilot Locations

Vulnerability Assessments

- TN DOT
- CAMPO (Austin)
- North Central Texas COG
- Maine DOT
- Michigan DOT
- Arizona DOT
- Alaska

Adaptation Options

- Connecticut DOT
- MassDOT
- MNDOT
- NYSDOT
- Iowa DOT
- Maryland SHA
- MTC
- Broward MPO
- Oregon DOT
- CalTrans
- Hillsborough MPO
- WSDOT

Washington State DOT's Vulnerability Assessment:

Asking the "Climate Question"

Carol Lee Roalkvam
Environmental Policy Branch Manager

Lynn Peterson
Secretary of Transportation

Climate Change & Extreme Weather Vulnerability Assessment
FHWA & TRB Webinar Series

May 30,2013

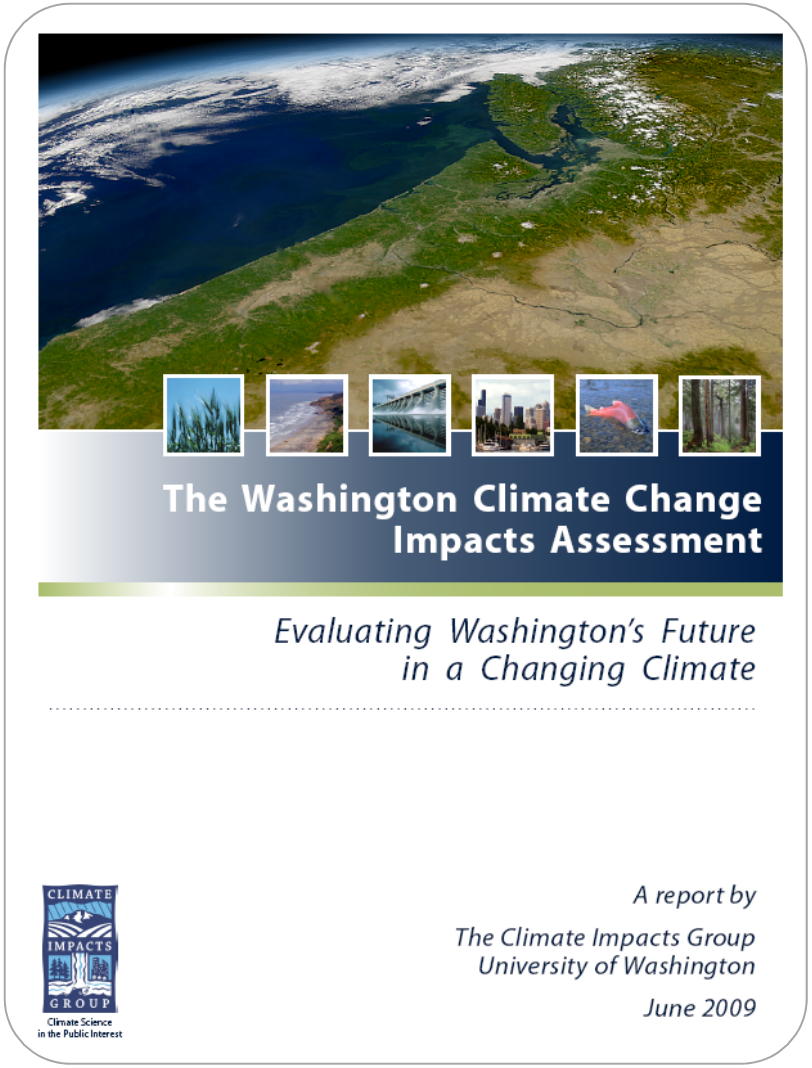
Washington State Department of Transportation

Washington State DOT's Pilot Facts

- FHWA $189,500 funds matched by state staff time
- State DOT test of the model leveraged:
  - Asset management & cost/risk assessment tools
  - Pacific Northwest climate change data
  - Field personnel intimate knowledge of threats
- Easily replicable process:
  - 14 Workshops across state
  - Microsoft Excel & GIS tools
- Qualitative rankings for all state-owned assets!

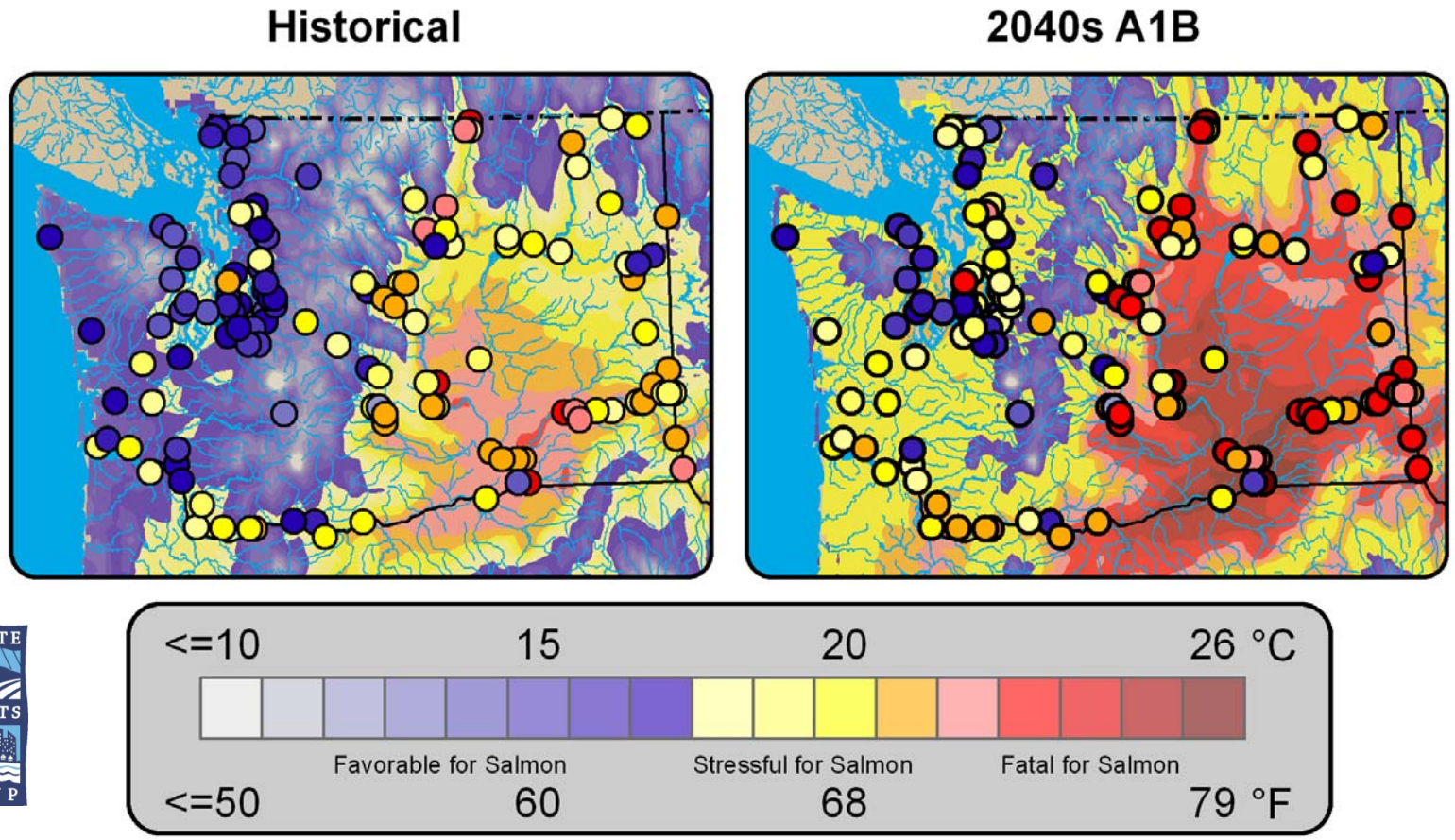
Washington Climate Change Impacts Assessment

- Funded by the Washington State Legislature
- Published in 2009
- Comprehensive report on climate change impacts in Washington
- Downscaled from global climate models
- Detailed data and technical support available



Changes in Air and Water Temperatures

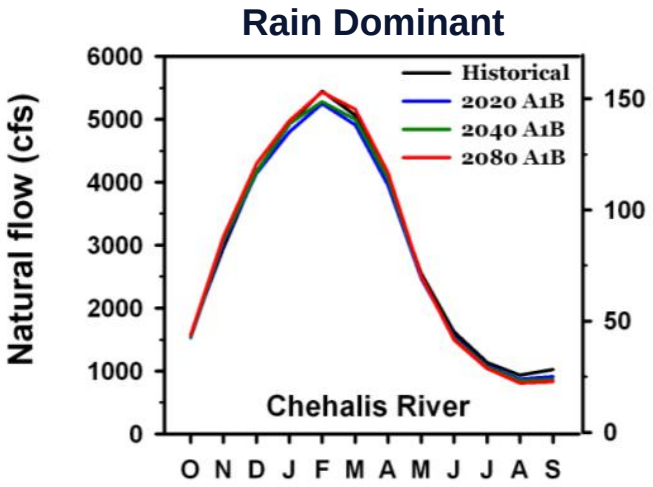
August Mean Surface Air Temperature and Maximum Stream Temperature
(Implications for Salmon)



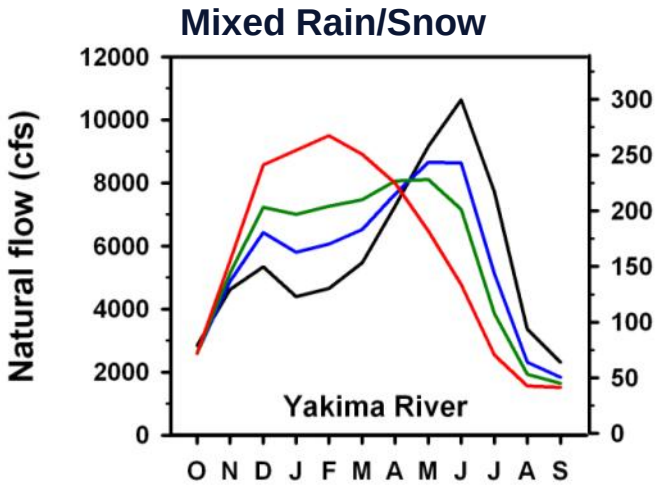
Source: Mantua et al. 2009, in press

Changes in Flood Risks

- Floods in western Washington will likely increase in magnitude due to the combined effects of warming and increasingly intense winter storms.
- In eastern Washington fall flood risks may increase; spring flood risks may decline due to loss of spring snow cover.



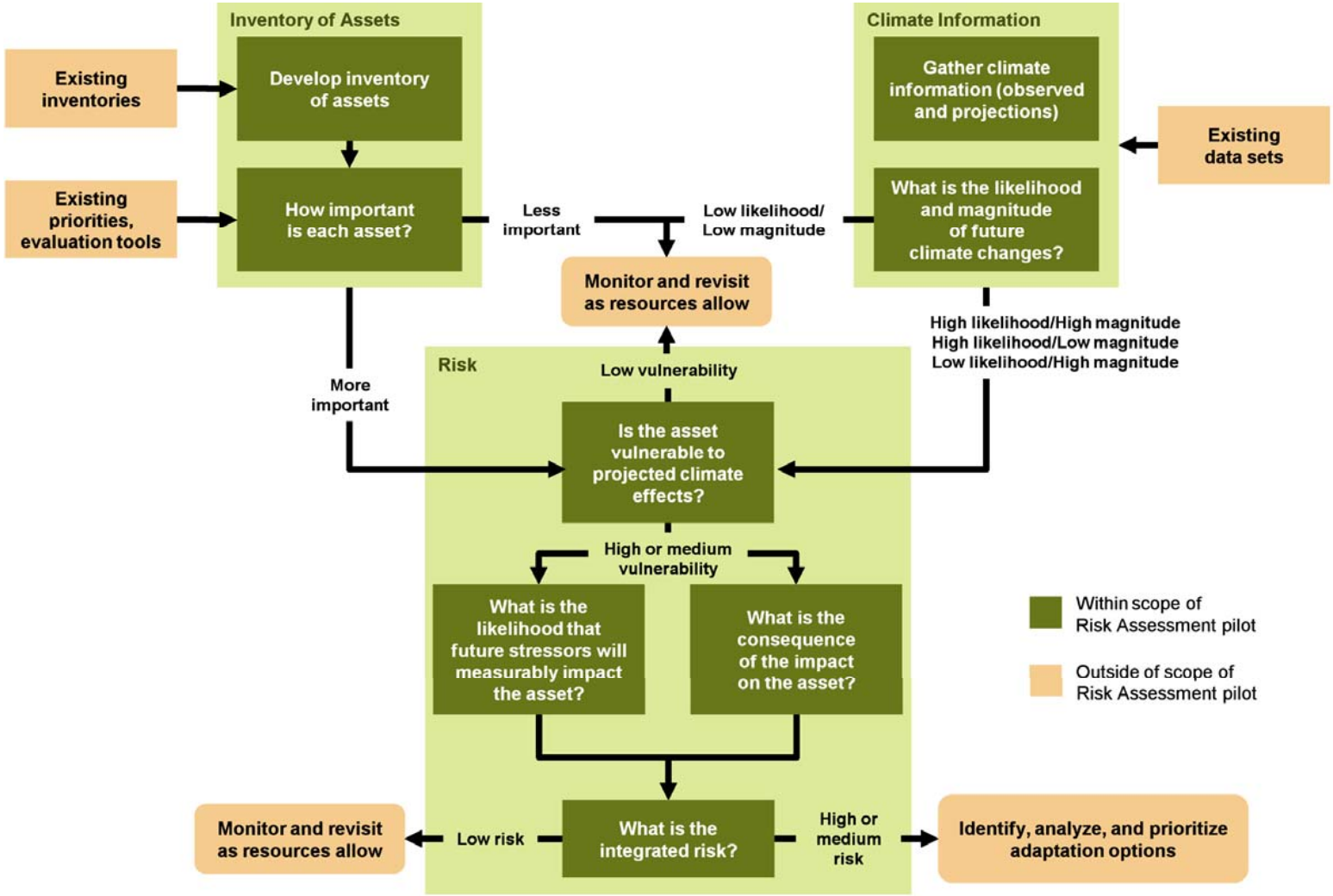
Chehalis River (Western WA)



Yakima River (Eastern WA)

Mantua et al. 2009, Elsner et al. 2009

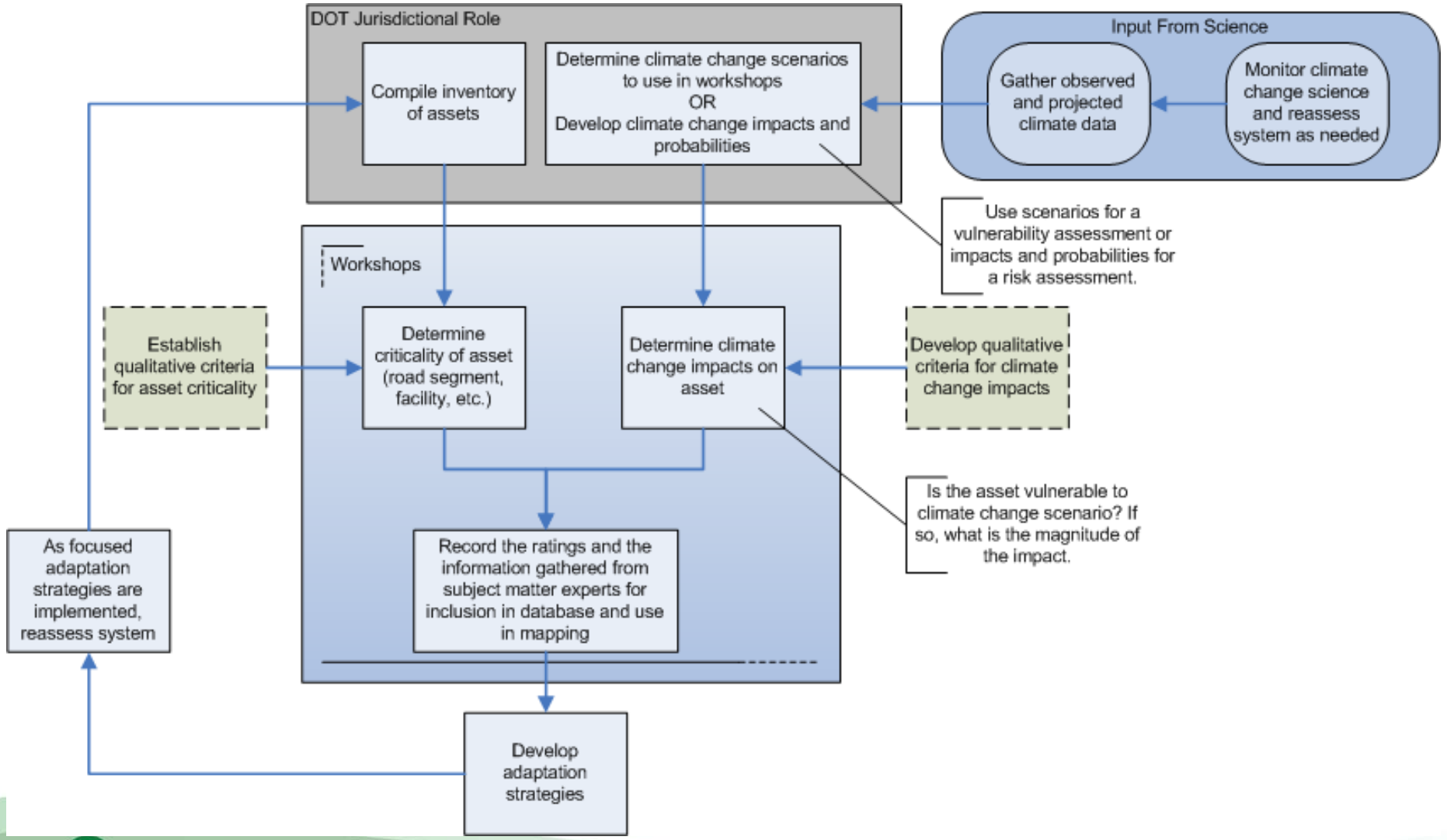
FHWA risk assessment model



Goal: Preserve assets in a changing environment

- FHWA $189,500 matched by state staff time
- WSDOT Approach:
  - Understand climate change within existing Asset Management framework
  - Create easily replicable process (leverage Cost/Risk Assessment tools)
  - Use internal knowledge and experience
  - Consider impacts on our all WSDOT assets (Highways, Ferries, State-owned Rail and Airports)


WSDOT pilot modifications to FHWA Process



Step 1 – How critical is the asset?

WSDOT Methodology

Very low to low			Moderate			Critical to Very Critical			
1	2	3	4	5	6	7	8	9	10
Criticality of asset									

Notice that along with the qualitative terms there is an associated scale of 1 to 10, this is to serve as a facilitation tool for some people who may find it useful to think in terms of a numerical scale - although the scoring by each individual is of course subjective. The scale is a generic scale of criticality where "1" is very low (least critical) and "10" is very critical.

Typically involves: non-NHS low AADT alternate routes available	Typically involves: some-NHS non-NHS low to medium AADT serves as an alternative for other state routes	Typically involves: Interstate Lifeline some NHS sole access no alternate routes

Step 2: What are the Climate Threats?

- Began with climate change forecast from UW Climate Impacts Group
- Talked about observed changes and extreme events – what is happening now
- WSDOT's internal experts ranked all WSDOT assets
- Key Questions:
  - **"What keeps you up at night?"**
  - **"What if it gets worse (given the scenario)?"**
  - **"How resilient is our existing system?**

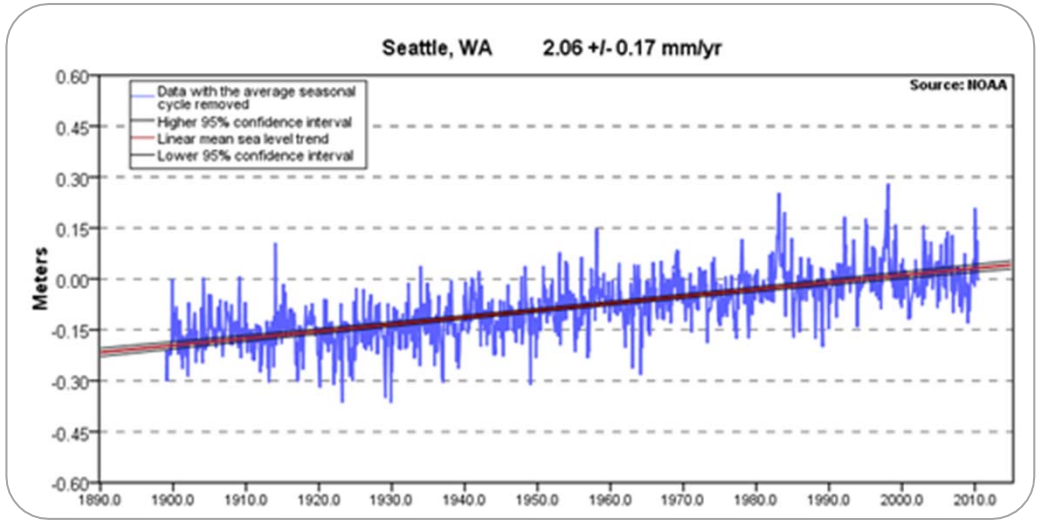
We used our experience to gauge future impacts

Scour and damage to structures - Just off US 12 Davis Creek

Oct. 4, 2009: Dust storm closes I-90 between Moses Lake and Ritzville

Washington State
Department of Transportation

We've seen a 9 inch rise over 110 years

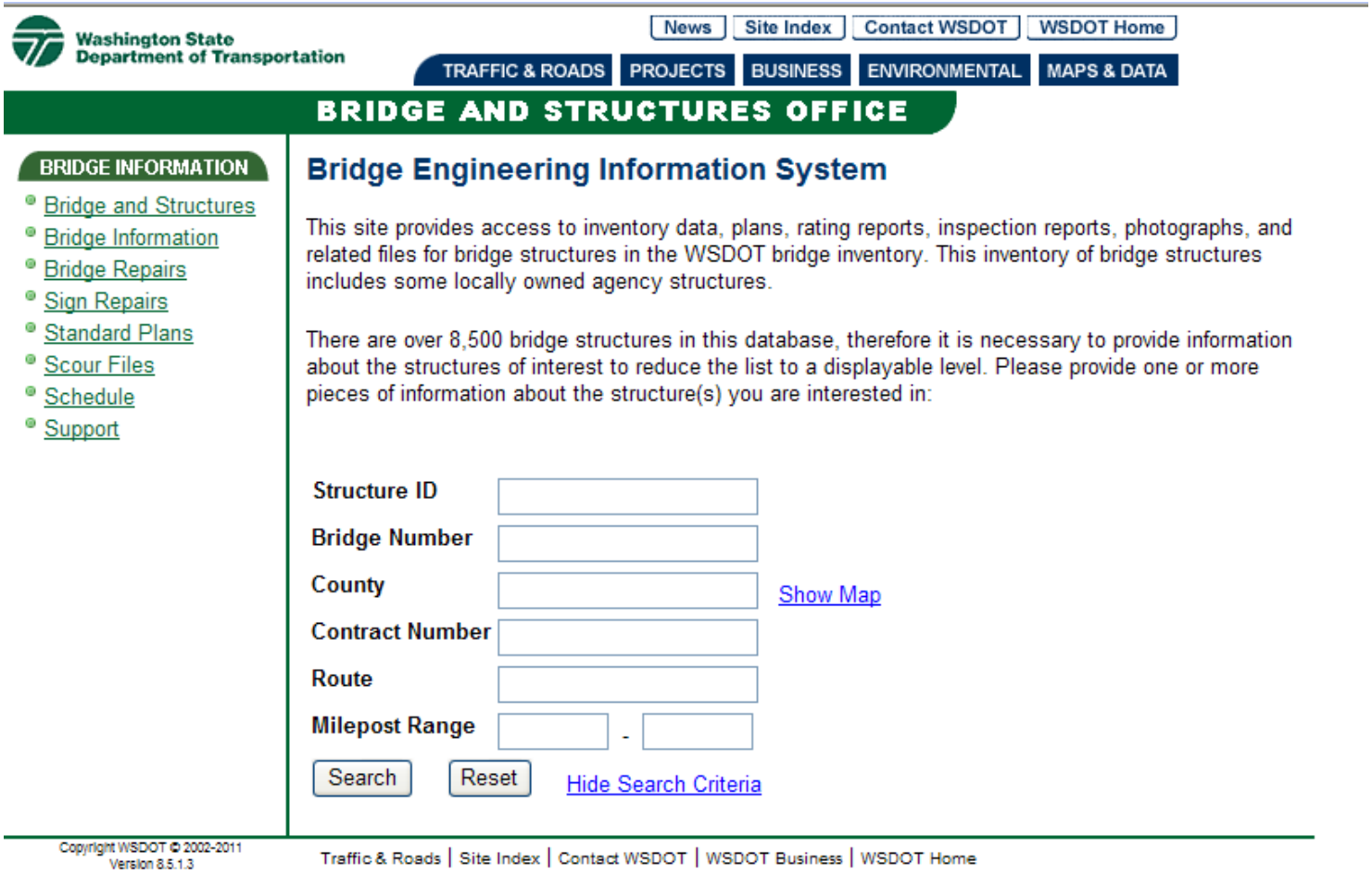


Washington State Department of Transportation

Workshops: How might climate impact assets?

Primary climate drivers		*Can lead to impacts on...*
Temperature	→	Expansion joints, pavement, rail tracks, construction periods, habitat projects, electrical equipment
Precipitation	→	Flooding of surface roads & tunnels, road washout, pump capacity, drainage
Hydrologic shifts	→	Soil instability, water supply, bridge and road support structures
Sea level rise, storm surge	→	Coastal erosion, coastal and upriver flooding, bridge footings, drainage, roadside stability, salt / corrosion

Bridge Engineering Information System (BEIS)



Mud Bay Bridge (101/508E)

Washington State Department of Transportation

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TRAFFIC & ROADS | PROJECTS | BUSINESS | ENVIRONMENTAL | MAPS & DATA

BRIDGE AND STRUCTURES OFFICE

BRIDGE INFORMATION

- Bridge and Structures
- Bridge Information
- Bridge Repairs
- Sign Repairs
- Standard Plans
- Scour Files
- Schedule
- Support

STRUCTURE DATA

- Current Bridge
- Plans
- Scour POA
- Contracts
- Inspection Photos
- Inspection Files
- Correspondence
- Inspection Reports
- Repairs
- Maintenance
- WS SI&A (English)
- WS SI&A (Metric)

MUD BAY

Hide current Bridge Information

Bridge Number	**101/508E**	Structure Type	**CS**
Structure Identifier	**0005677A**	Operating Rating Tons	**56**
Location	**1.3 S JCT SR 8**	Inventory Rating Tons	**34**
Route	**00101**	Min Over Deck	**99' 99"**
Mile Post	**362.83**	Min Under Bridge	**0"**
Feature Intersected	**MUD BAY**	Sufficiency Rating	**80.42**
Facilities Carried	**US 101**	Year Built	**1958**
Region	**OL**	Year Rebuilt	
Owner	**Washington State**	SD/FO	**N/A**
Open Close Posted Code	**A**		

Inspections Performed

Hide Current Inspections Performed

Report Type	Inspn Date	Inspn Freq	Insp Type
Routine	2010-05-12	24	
Equipment	2010-05-12	72	

MUD BAY Image

Hide Current Bridge Image

Record impact score

10 9 8 7 6 5 4 3 2 1

Complete catastrophic failure

Results in total loss or ruin of asset. Asset *may* be available for *limited* use after at least 60 days and would require major repair or rebuild over extended period of time. "Complete and/or catastrophic failure" typically involves:

- Immediate road closure;
- Disruptions to travel;
- Vehicles forced to re-route to other roads;
- Reduced commerce in affected areas;
- Reduces or eliminate.es access to some destinations;
- May sever some utilities located within right-of-way;
- May damage drainage conveyance or storage systems.

Temporary operational failure

Results in minor damage and/or disruption to asset. Asset would be available with either full or limited use within 60 days and may have immediate limited use still available.

"Temporary Operational Failure" typically involves:

- Temporary road closure, hours to weeks;
- Reduced access to destinations served by the asset;
- Stranded vehicles;
- Possible temporary utility failures.

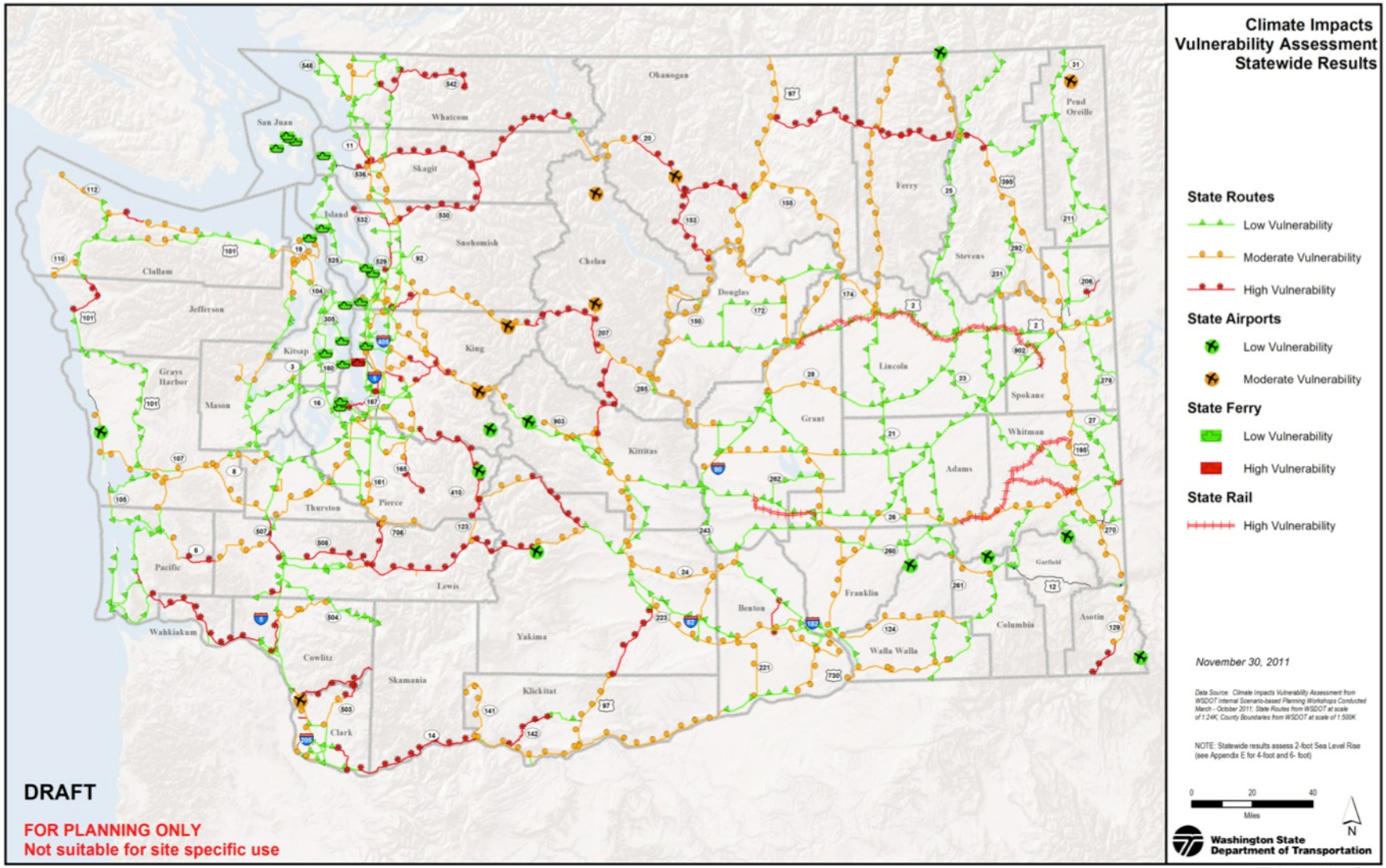
Reduced capacity

Results in little or negligible impact to asset. Asset would be available with full use within 10 days and has immediate limited use still available. "Reduced capacity" typically involves:

- Less convenient travel;
- Occasional/ brief lane closures, but roads remain open;
- A few vehicles may move to alternate routes;

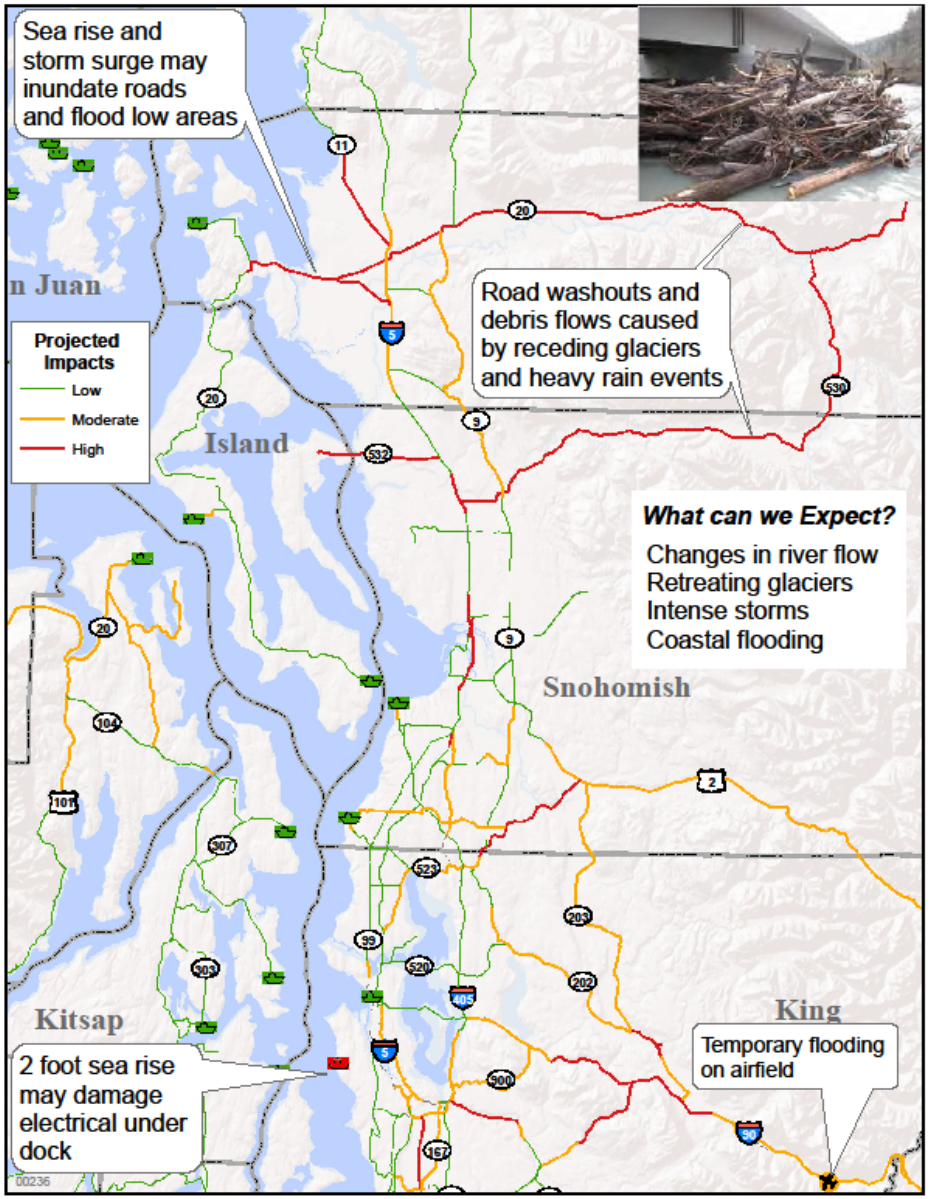
Figure 2.1 Photo depictions of qualitatively assessed climate change consequences

Statewide Results (map shows results with 2 foot sea-rise & all other threats)

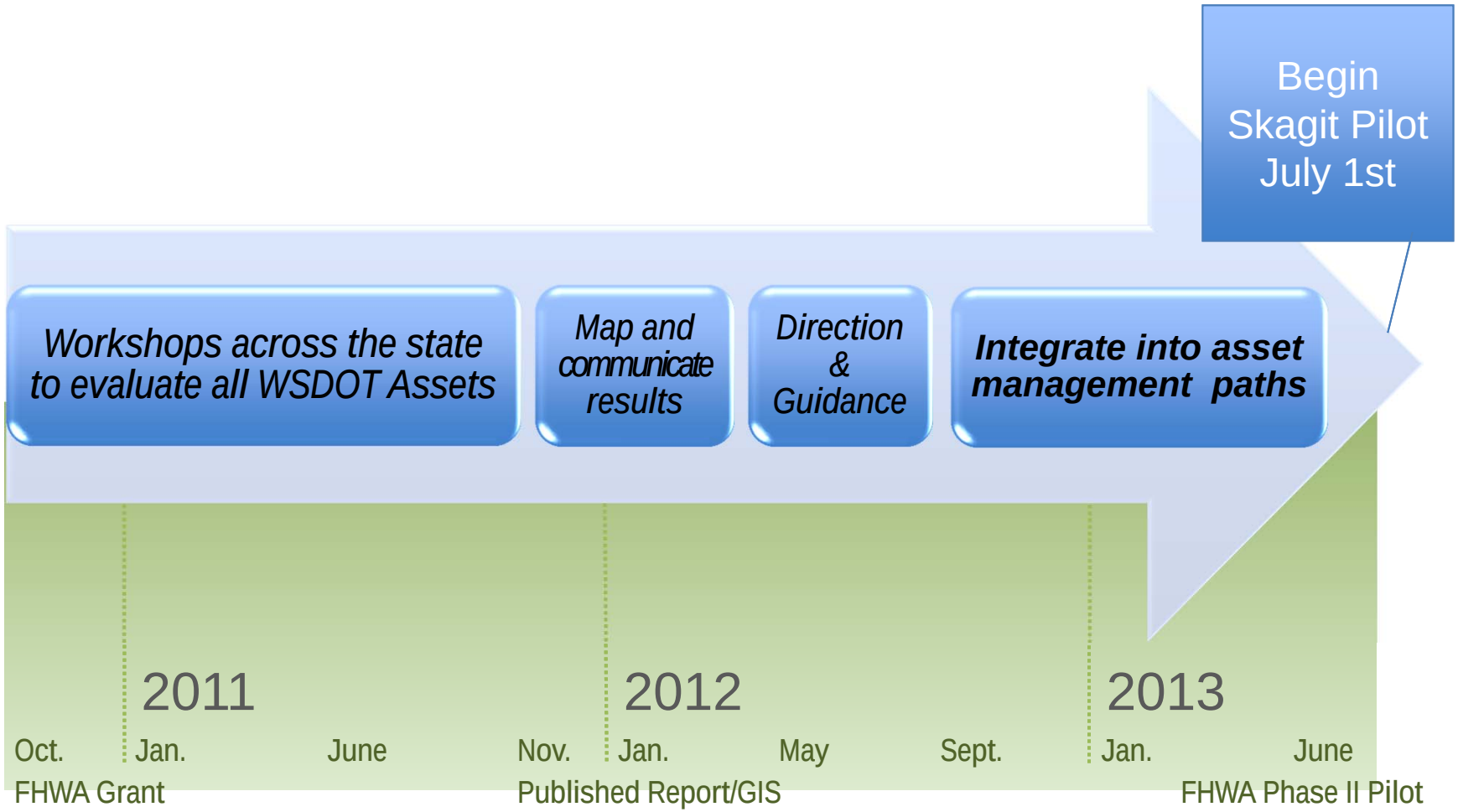


What did we find?

- Intensifies known threats
- Reinforces value of our current maintenance and retrofit programs
- Some surprises
- Unique way to capture knowledge of field staff

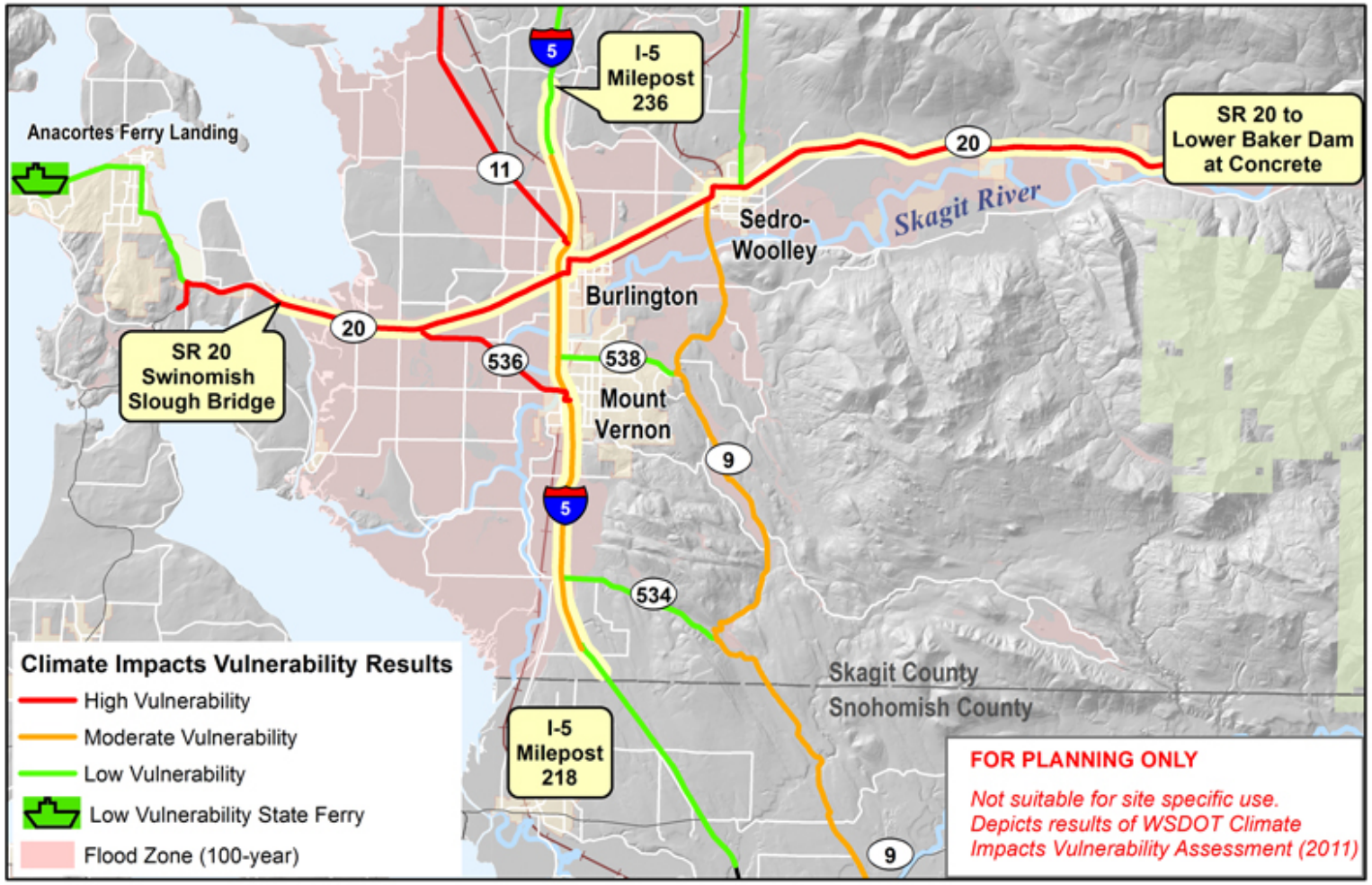


Timeline of WSDOT's Assessment



2011 WSDOT Climate Impacts Vulnerability

Assessment Results in Skagit Basin



Washington State Department of Transportation

Location of Skagit Bridge Collapse

Skagit Pilot Project Team Members

- WSDOT (Region Planning, HQ Environment, Design, Emergency Management, Public Transportation)
- FHWA – WA Division and HQ
- U. S. Army Corps of Engineers – Federal Lead for General Investigation
- Skagit County – Local Lead Agency www.skagitcounty.net/skagitrivergi

Task: Evaluate Corps Skagit study with preferred alternatives. Examine local options and evaluate potential risks and opportunities to improve / enhance resilience and preparedness

Task: Develop adaptation options for WSDOT managed infrastructure (Interstate 5, State Highways and Anacortes Ferry Terminal)

Washington State Department of Transportation

March 2012

Adapting to a changing climate

Statewide study of climate-related infrastructure risks

Our climate is changing. Demand for transportation resources continues to grow. Keeping state-owned and managed infrastructure safe and operational is key to a growing economy and building a more resilient and sustainable transportation system.

Protecting infrastructure, freight routes and keeping drivers safe for the long-haul

Our economy and quality of life can take serious hits when inclement weather floods interstates, closes critical bridges and brings relentless snow to our mountain passes. The past has shown how storms can wreak havoc on our daily lives and prevent goods and services getting to customers.

WSDOT's job is to keep the state's transportation system safe and operational. This means planning and preparing to protect and manage our vital roads, bridges, ferry terminals and other facilities that could be vulnerable to severe weather. We must be resilient and adapt to future environmental conditions. Thanks to a $189,500 Federal Highway Administration (FHWA) national pilot project grant, WSDOT was able to complete the groundwork on assessing how our state-owned and operated transportation assets may fare under extreme weather changes.

WSDOT pilots infrastructure vulnerability assessment

We conducted workshops with our field staff from across the state to assess the vulnerability of our highways, ferry terminals and other infrastructure to changes in our climate and weather extremes. We presented the participants with climate scenarios such as extreme temperatures and sea-level rise, asking "What would be the likely impact on our facilities?" The results from each workshop were used to create a series of planning-level maps.

USDOT Climate Change Policy

In addition to the federal dollars from the FHWA pilot project, United States Department of Transportation (USDOT) policy supports climate adaptation efforts. In a June 2011 policy statement, U.S. Transportation Secretary Ray LaHood directed USDOT agencies (such as the federal highway and transit administrations) to consider climate change impacts on current systems and future investments.

The USDOT climate change policy statement further states that "planning for climate adaptation assists State and local transportation agencies, and DOT, to identify how climate change is likely to impact their ability to achieve their mission, continue operations, and to meet policy and program objectives."

www.dot.gov/docs/climatepolicystatement.pdf

http://www.wsdot.wa.gov/SustainableTransportation/adapting.htm

For more information
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WSDOT Environmental Services
(360) 705-7126
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Adapting to Rising Tides

Transportation Vulnerability and Risk Assessment Pilot

The Metropolitan Transportation Commission
Thursday, May 30, 2013

Goal

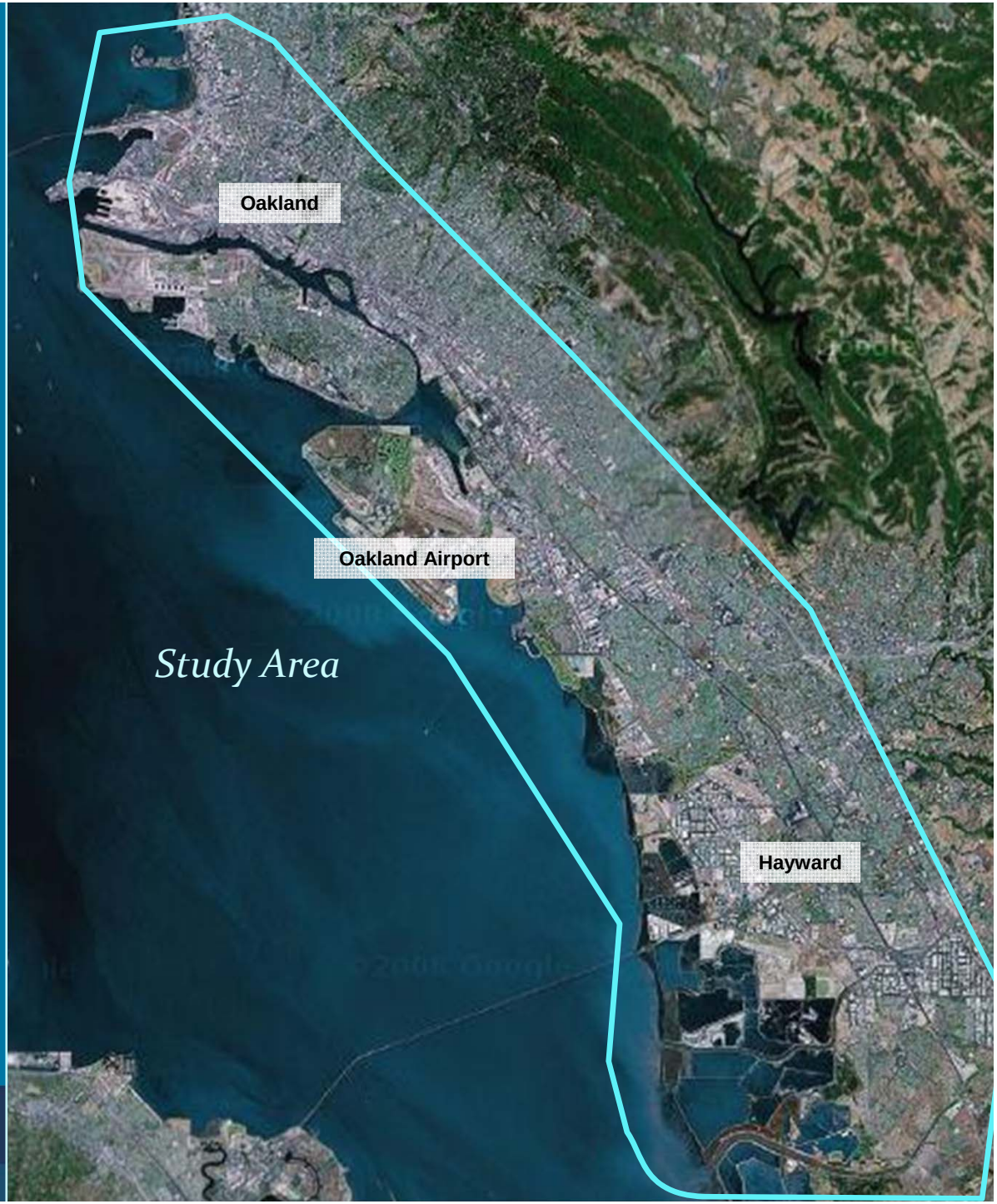
The goal of **Adapting to Rising Tides** is to increase preparedness and resilience of Bay Area communities to sea level rise and other climate change impacts while protecting ecosystem and community assets, such as transportation.

Photo: Ingrid Taylor

Partnerships

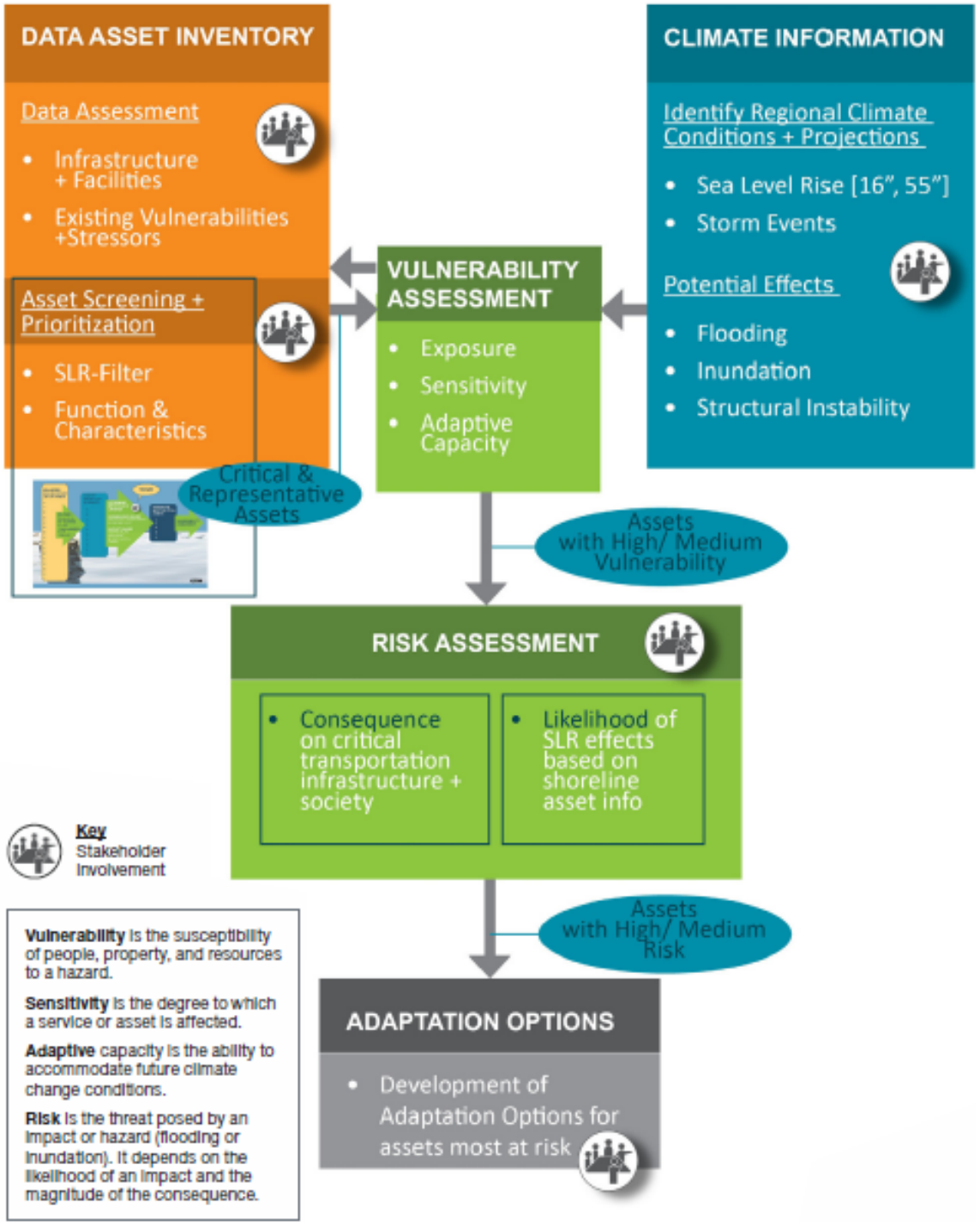
- **Project Management Team**
  - Metropolitan Transportation Commission, Bay Conservation and Development Commission, and Caltrans
- **Consultant Team**
  - AECOM, Arcadis, Geografika, 3D Visions
- **Federal Highway Administration**
- **Local Partnership**
  - Cities of Emeryville, Alameda, Oakland, San Leandro, Hayward, & Union City, and County of Alameda
  - BART, Capital Corridor, AC Transit
  - U.S. Geological Survey, National Oceanic and Atmospheric Administration, California Coastal Conservancy, East Bay Dischargers Authority, East Bay Municipal Utility District, East Bay Regional Park District, Hayward Area Rec. and Park, Port of Oakland, Association of Bay Area Governments, Alameda County Transportation Commission

Alameda County Sub-Region



Bay Area Refinements to Pilot Model

1. **Data Asset Inventory & Asset Screening and Prioritization**
2. **Climate and Shoreline Information**
3. **Vulnerability Assessment**
    1. **=Exposure + Sensitivity + Adaptive Capacity**
4. **Risk Assessment**
    1. **= Likelihood + Consequence**
5. **Adaptation Strategies**

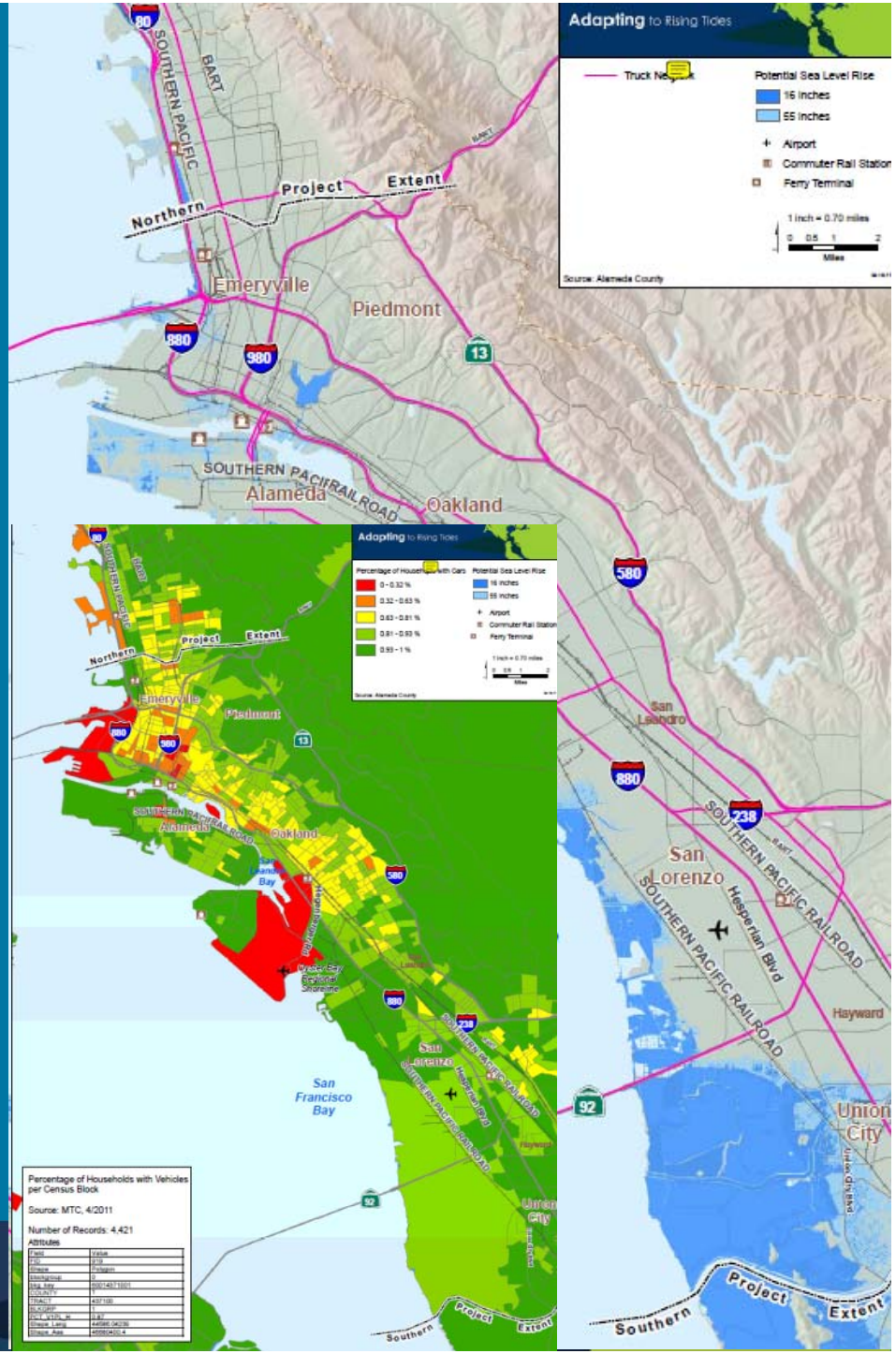


1a. Transportation Asset Inventory

- Interstates/Freeways
- Arterial, collector and local streets
- Road tunnels/tubes
- Bay bridges
- Alameda bridges
- BART stations
- BART alignments
- Amtrak stations
- Passenger/freight rail alignments
- Ferry terminals
- Transportation Management Centers
- Bus Maintenance Facilities
- BART System Assets
- Passenger and Freight Yards and Depots
- Pedestrian/ Bicycle Facilities
- Transit associated with all road assets

1b. Asset Selection

- **Physical Characteristics**
  built at-grade, below grade, or elevated on embankments or structures;
- **Functional Characteristics**
  lifeline routes, evacuation routes, goods movement routes, transit routes, and bike routes;
- **Jurisdiction**
  agency, city or other entity with ownership and/or management responsibility for the asset;
- **Social / Economic Functions**
  connecting to jobs, regional importance, and support of transit-dependent populations.

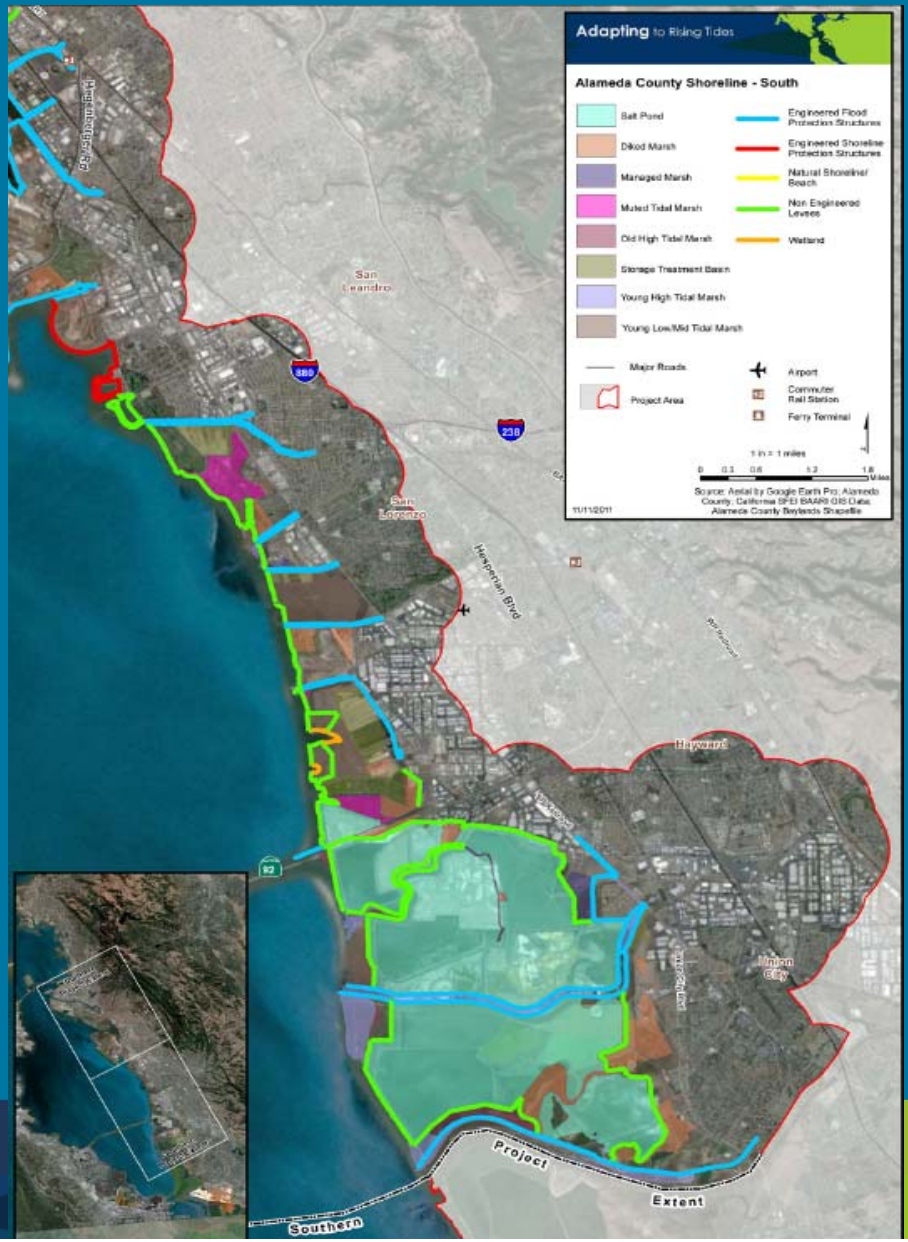


2. Climate Science & Shoreline Assets

- Developed simple, yet distinct, shoreline categories based on primary function and potential to protect against inland inundation
- Using shoreline categories in combination with new inundation maps to understand transportation vulnerability and risk

Shoreline Categories: North

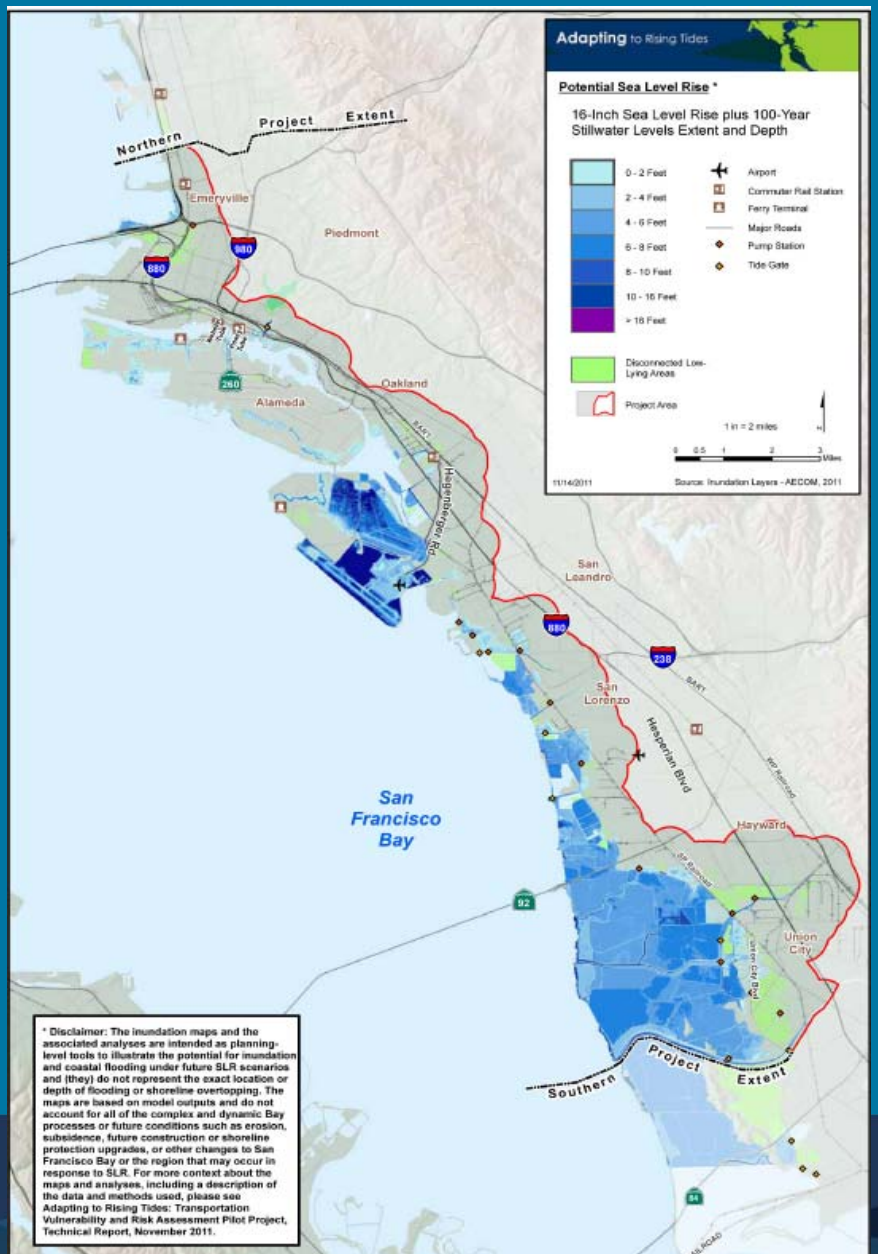
Shoreline Categories: South



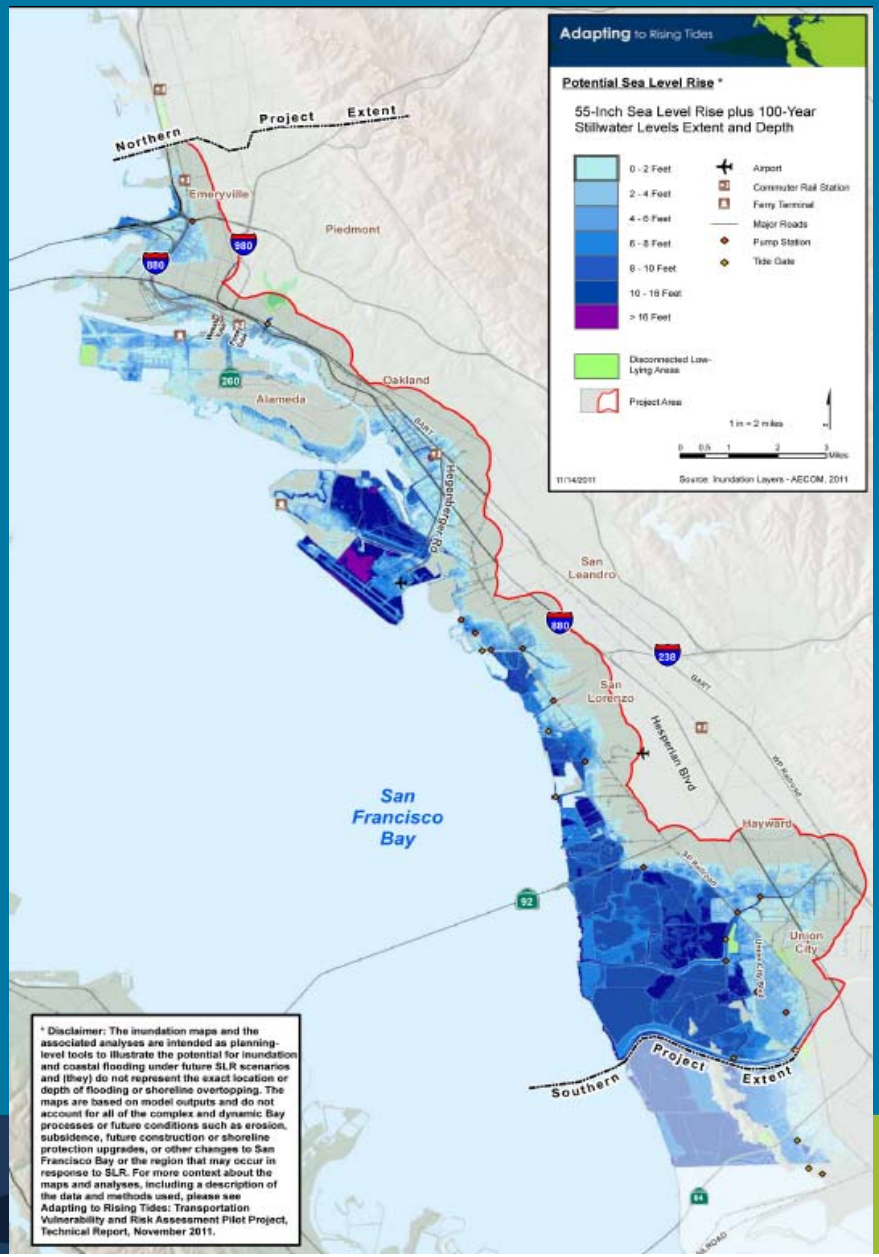
New Sea Level Rise Maps for Six (6) Climate Scenarios

- Two sea level rise projections
  - 16” (40 cm) of sea level rise ≈ mid-century
  - 55” (140 cm) of sea level rise ≈ end-century
- Three water level conditions
  - High tide (mean high high water, MHHW)
  - Extreme high tide (100-year stillwater level)
  - Extreme high tide + locally generated wind waves

16” SLR + 100-Year Stillwater Level



55” SLR + 100-Year Stillwater Level



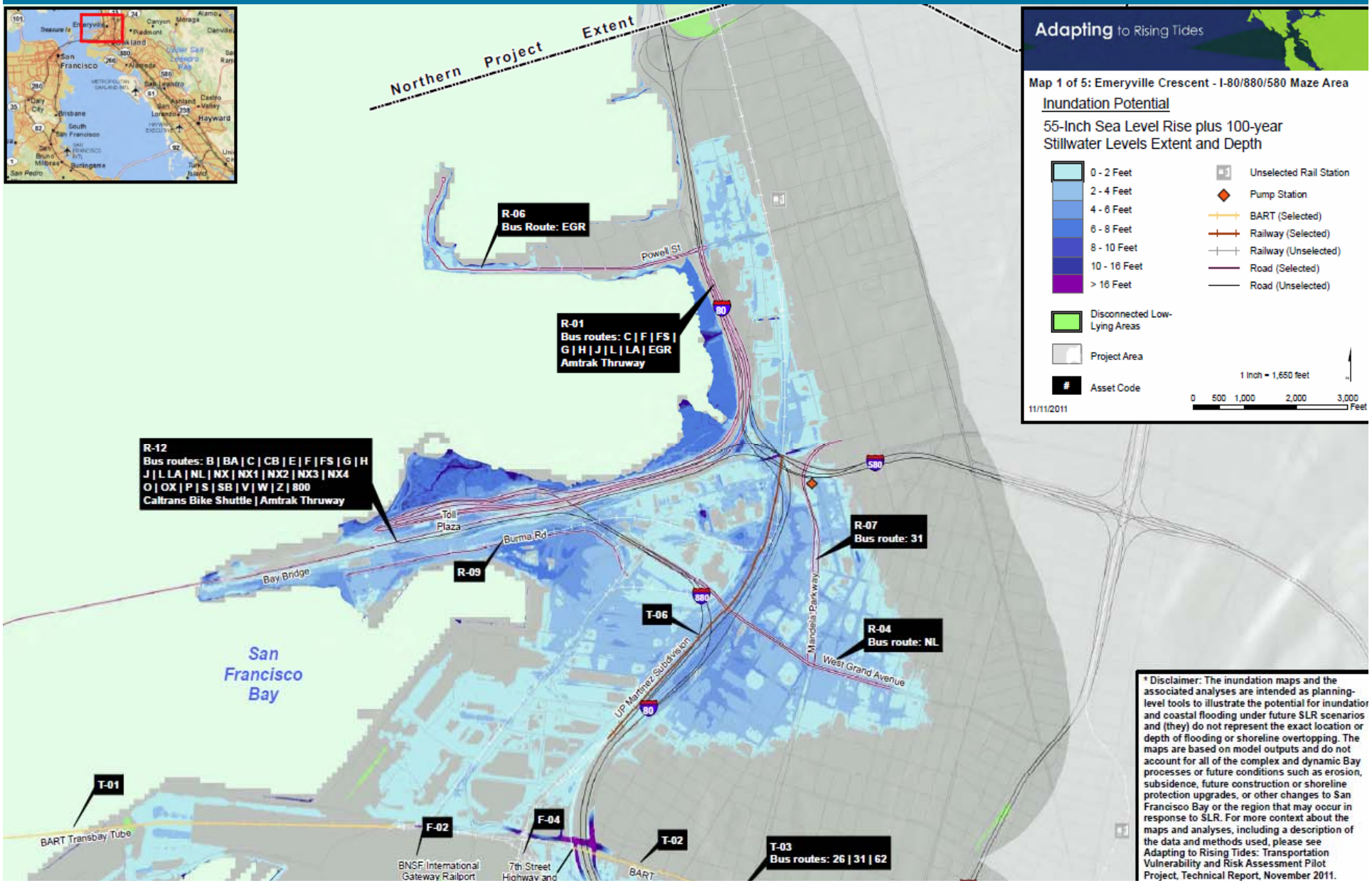
3. Vulnerability Assessment

- **Vulnerability:** "*is the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes.*" *(IPCC definition 2007)*

- **Vulnerability = exposure + sensitivity + adaptive capacity**
- Our definition: **Sea Level Rise exposure + condition of asset + ability to reroute, comparable facilities available**

Exposure to SLR

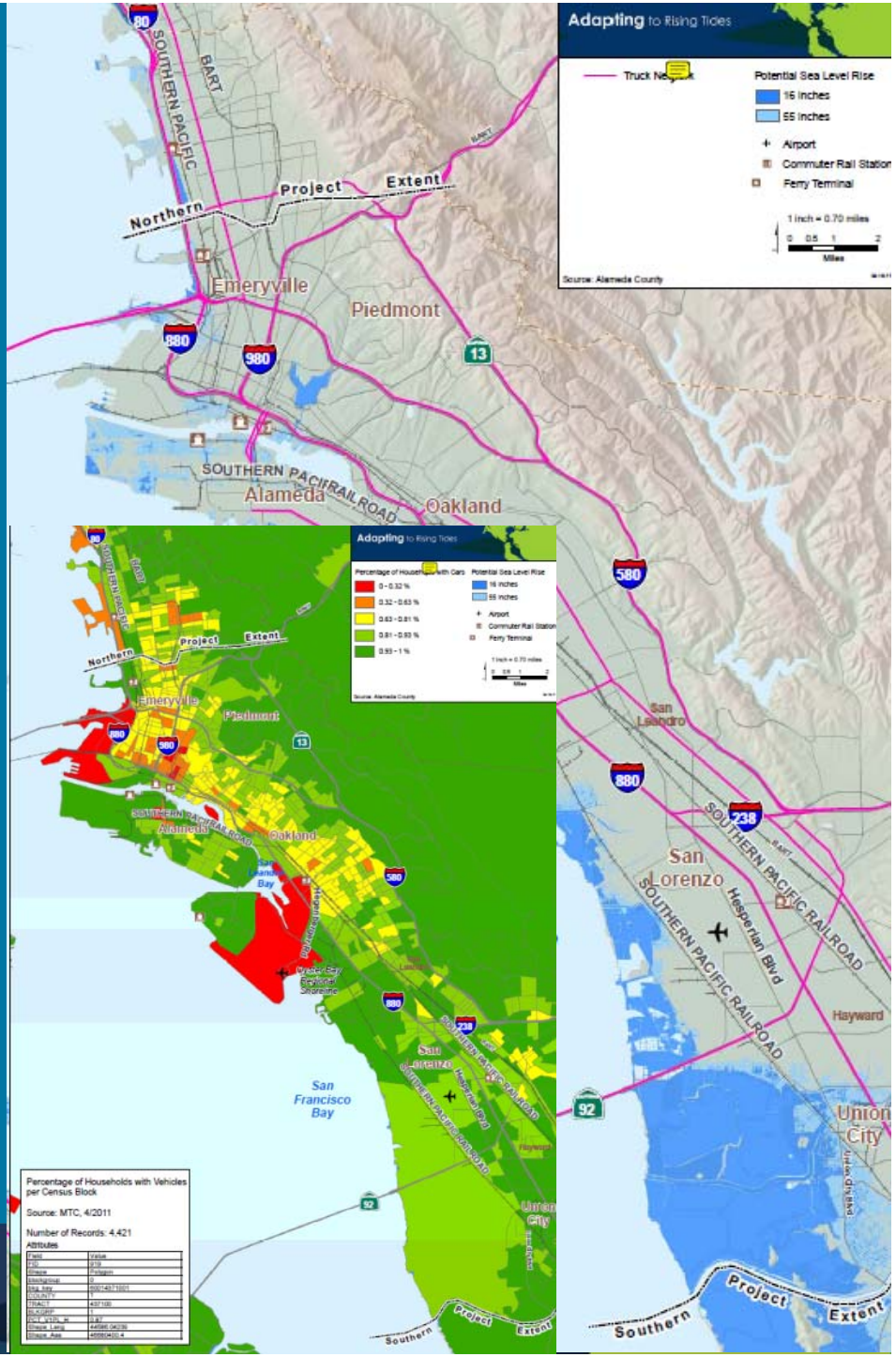
Measured by depth of inundation at midcentury and end of century



Asset Sensitivity

- Level of use - Average Daily Traffic (ADT) volume (cars / trucks) etc
- Age
- Seismically retrofitted
- Maintenance (Ongoing Operations and Maintenance [O&M]) Cost
- Foundation condition
- Liquefaction susceptibility

Exposure+Sensitivity+Adaptive Capacity = Vulnerability



Adaptive Capacity

- **Adaptive capacity**: "*is the ability of a system to adjust to climate change to moderate potential damages, to take advantage of opportunities or cope with the consequences.*" (*IPCC definition)*

- Our definition: **ability for rerouting or comparable available facilities to maintain all or part of the original functionality**

Photo: http://news.bbc.co.uk/2/hi/in_pictures/6237100.stm

4. Risk Assessment

Risk is the threat posed by an impact or hazard. It depends on the likelihood of an impact and the magnitude of the consequence.

What is the likelihood of the asset being impacted by sea level rise?

If so, what are expected consequences in terms of cost and time to replace asset, economic impact, socio-economic impact, public safety and degree of redundancy in the system?

Likelihood + Consequence = Risk

Likelihood and Consequence

- **Likelihood:** What is the likelihood that the asset will be impacted by SLR?
  - Mid century SLR scenario = 'highly likely'
  - End of Century SLR scenario = 'likely'
- **Consequence:** what is the expected impact or consequence to society if the asset is inundated? Criteria selected:
  - Cost of and time to replace asset
  - Economic impact (goods movement, commuter route)
  - Socio-economic impact (transit dependent communities, MTC Communities of Concern)
  - Public safety (lifeline, mass evacuation route)
  - Degree of redundancy in the system (ability to reroute)

Asset Risk Profile

- Asset Characteristics
- Vulnerability Rating
  - Exposure
  - Sensitivity
  - Adaptive Capacity
- Risk Rating
  - Likelihood
  - Consequence

Asset Risk Profile

Coliseum / Oakland Airport BART Station (T-04)

Asset Location / Jurisdiction
Oakland / BART

Summary
The Coliseum / Oakland Airport BART Station is a transit facility serving East Oakland neighborhoods and includes bus transfer and parking facilities. Pedestrian connections are available to Oakland Coliseum Amtrak Station, and frequent and direct bus service is provided from the BART station to Oakland International Airport. The future Oakland Airport BART Connector, currently under construction, will provide an automated guideway transit connection between the station and the airport. Due to lack of data, this asset was not rated with respect to sensitivity. Exposure is rated low, due to inundation under only 100-year SWEL + wind waves for both the 16" and 55" SLR scenarios. No adequate alternative station exists for the Coliseum / Oakland Airport BART Station, resulting in a medium vulnerability rating. Consequence is rated high for capital improvement costs, commuter use, and socioeconomic impact; moderate for time to rebuild; and low for public safety and goods movement, which does not apply. The overall consequence rating is 3.33, making this a medium-risk asset.

Characteristics:
- Elevated
- Commuter route
- Transit routes [3 BART Lines; AC Transit: 45, 46, 73, 98, 356, 805]

Sensitivity	
Data unavailable in project timeframe.	
Liquefaction Susceptibility	Medium
Exposure: Low	
Maximum Inundation Depths	
16" + MHHW	0 ft
16" + 100-yr SWEL	0 ft
16" + 100-yr SWEL + wind waves	YES
55" + MHHW	0 ft
55" + 100-yr SWEL	0 ft*
55" + 100-yr SWEL + wind waves	YES
Inadequate Adaptive Capacity (16" SLR): High No adequate alternative station	
Vulnerability Rating (mid century): Medium	

*The asset is inundated to 0.3 ft at 55" + 100-yr SWEL SLR scenario, which was rounded down to 0 ft due to resolution limitations of the mapping

Projected Inundation with 16 inch SLR + 100-yr SWEL

Projected Inundation with 55 inch SLR + 100-yr SWEL

5. Adaptation Strategies

- Explore potential range of near-term and long-term adaptation strategies
  - Structural Adaptation Measures
  - Nonstructural Adaptation Measures
  - Asset-Specific Adaptation Measures
  - Regional Adaptation Measures
- Evaluated risk profiles to identify appropriate adaptation measure for each asset – highest risk assets are to be addressed first
- Next Steps: more detailed adaptation planning needed

Lessons Learned

1. **Creating data inventory for transportation and shoreline assets was challenging due to inconsistent availability of data and high level of effort**
2. **Prioritizing assets was premature prior to consequence analysis and not acceptable to stakeholders,**
3. **Most important asset selection filter was exposure to flooding and inundation; asset characteristics and functionality were less important**
4. **Using existing climate science information is insufficient; further mapping of climate impacts is necessary to understand asset vulnerability**
5. **Need robust definitions or guidance on what exposure, sensitivity and adaptive capacity mean and how to use them for different project types**
6. **Need early input from stakeholders on how to define consequence impact criteria so that criteria are tailored to local context**

Adapting to Rising Tides Adaptation Options: Project Overview

- Focus Areas:
  - West Oakland/Emeryville/Bay Bridge Peninsula;
  - Oakland Coliseum Area; and
  - State Route 92 Corridor.

- Adaptation Strategies will Include:
  - Structural Measures
  - Non-Structural Measures
  - Asset-Specific Measures
  - Regional Measures

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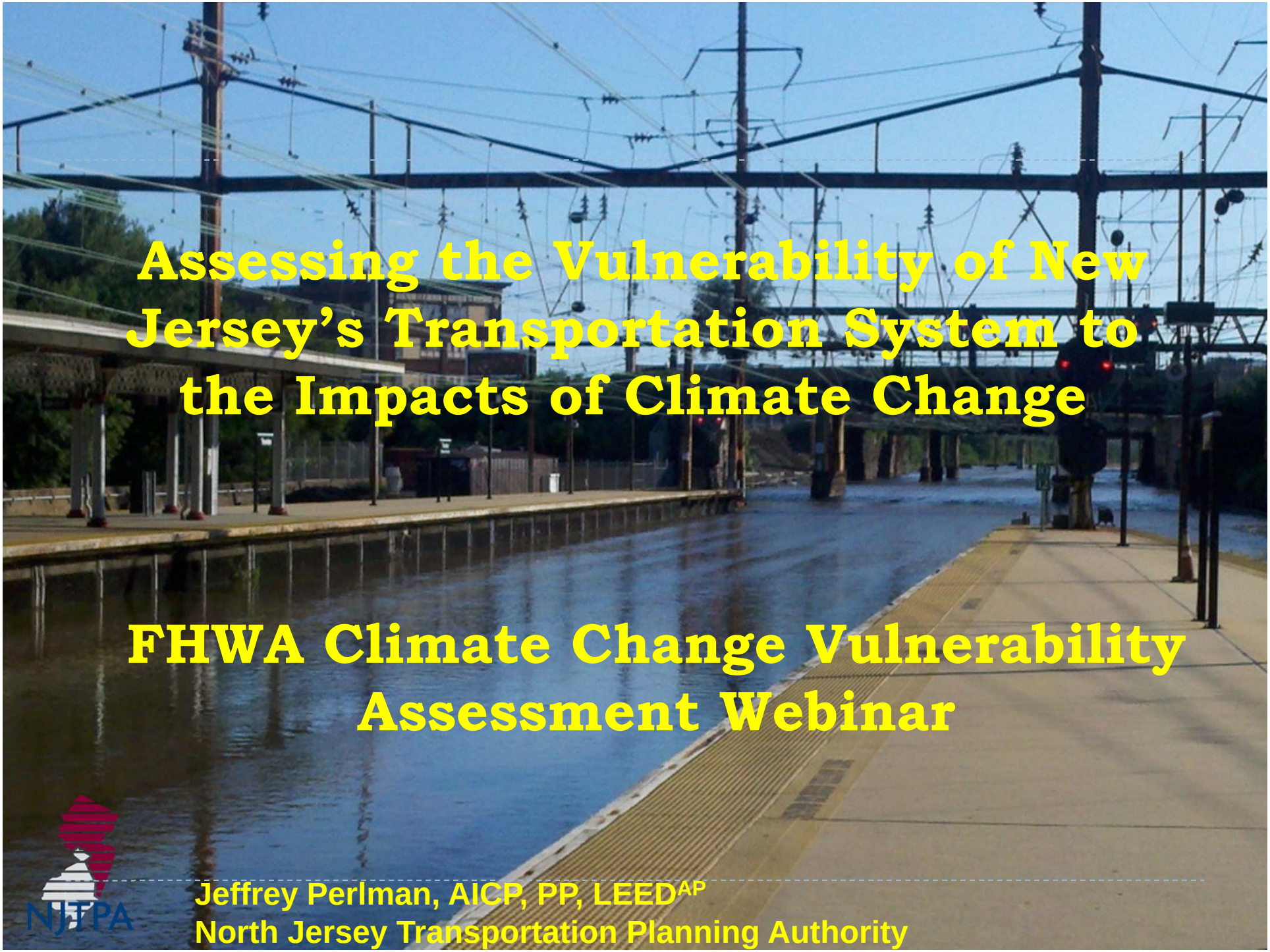
415.352.3654

For a report copy of Transportation Vulnerability and Risk Assessment Pilot Project, see:

http://www.mtc.ca.gov/planning/climate/Rising_Tides_Briefing_Book.pdf

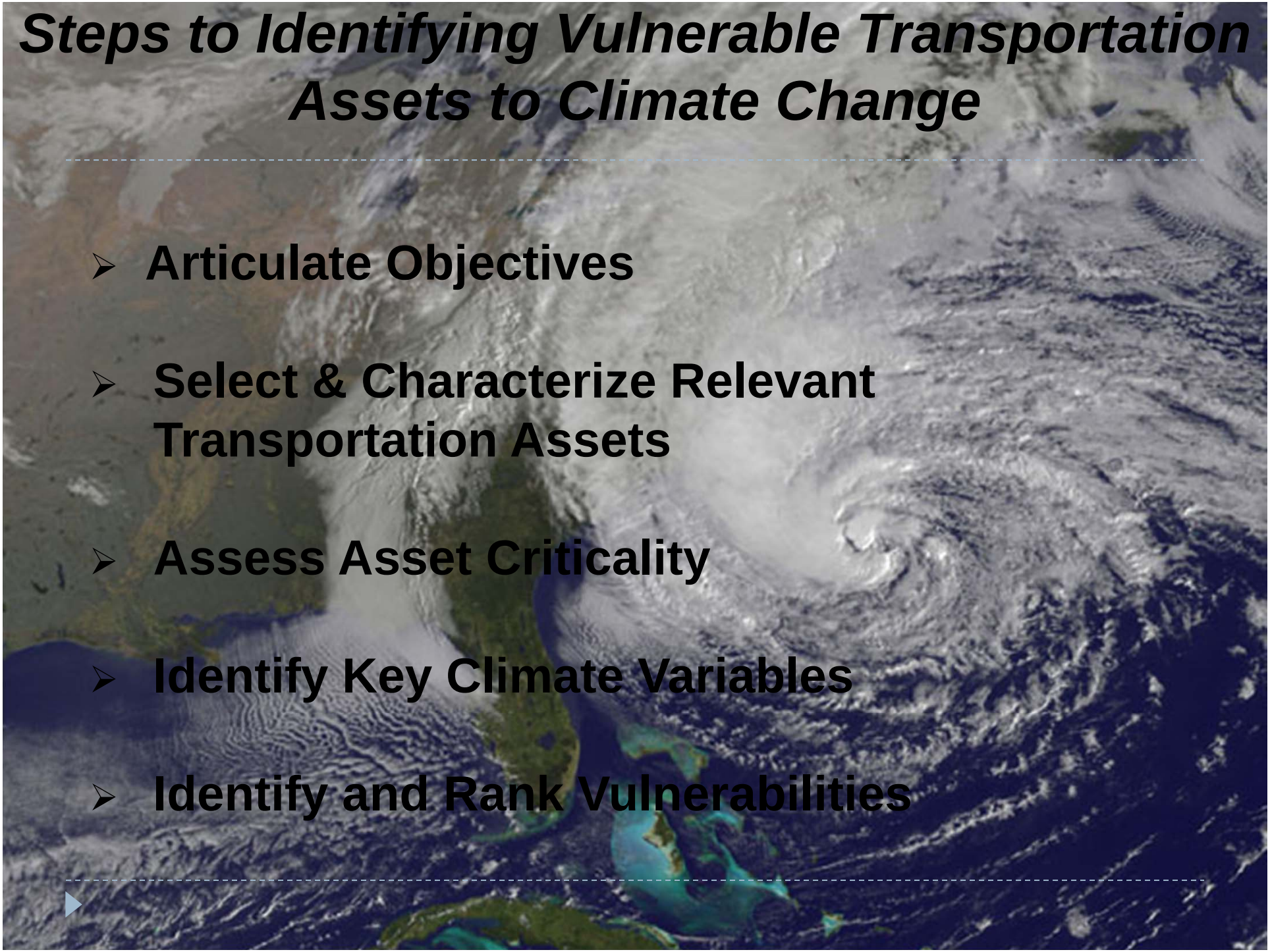
http://www.mtc.ca.gov/planning/climate/RisingTides-TechnicalReport.pdf



Assessing the Vulnerability of New Jersey's Transportation System to the Impacts of Climate Change

FHWA Climate Change Vulnerability Assessment Webinar

Jeffrey Perlman, AICP, PP, LEED^{AP}
North Jersey Transportation Planning Authority



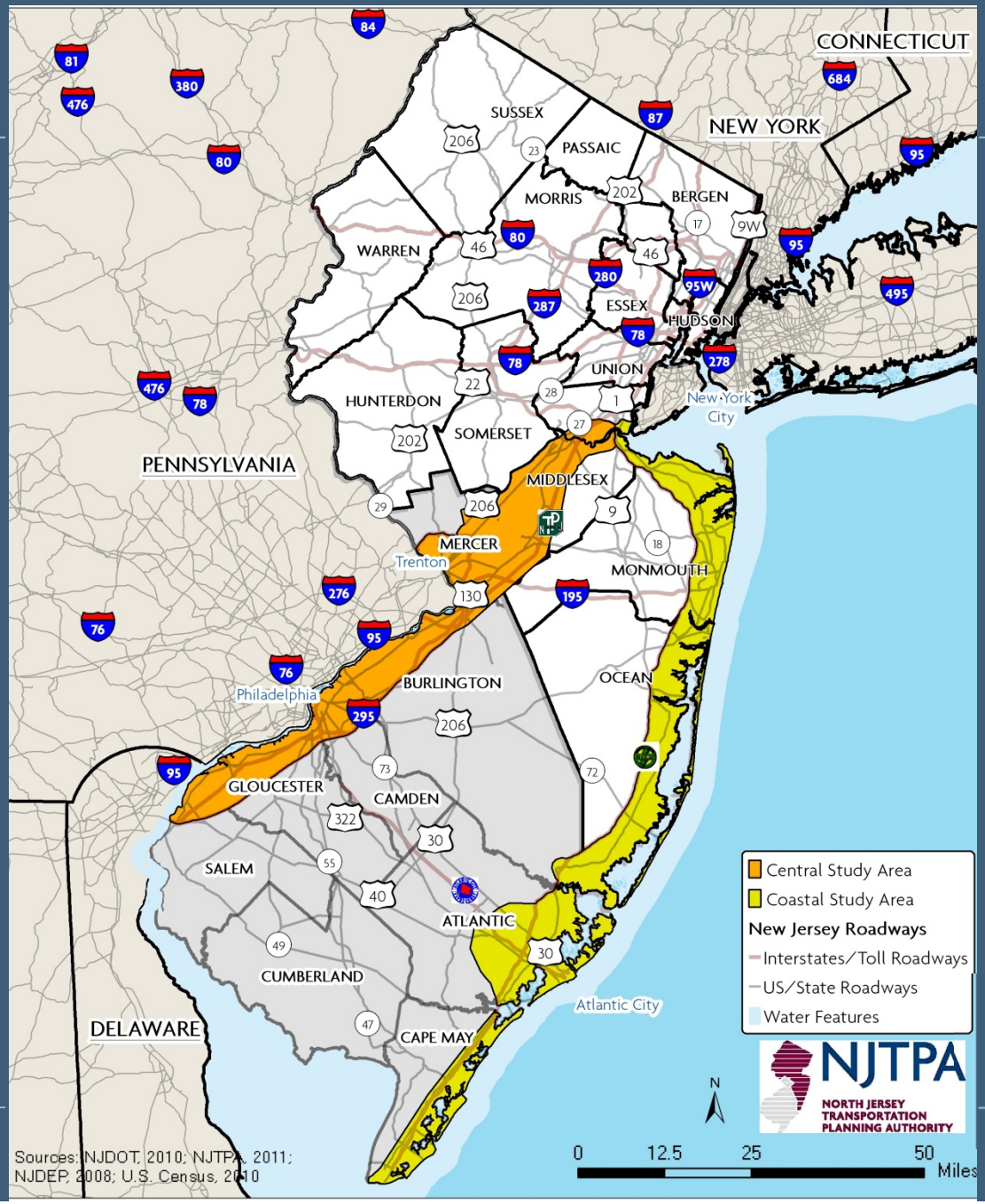
Steps to Identifying Vulnerable Transportation Assets to Climate Change

- **Articulate Objectives**
- **Select & Characterize Relevant Transportation Assets**
- **Assess Asset Criticality**
- **Identify Key Climate Variables**
- **Identify and Rank Vulnerabilities**

Climate Change Impacts on the Transportation System

Climate Stressor	Affected Asset
Drought & Extreme Precipitation	Roads and Bridges
More Frequent Storms	Rail
Temperature Increases	Aviation
Rising Sea Levels	Navigation

Project Study Area



Inventory of Assets & Criticality

Develop Inventory of Assets

- Roadways
  - from the CMS network
- Bridges
- Passenger Rail
  - Amtrak & NJ TRANSIT
- Freight Rail
  - NS and CSX, class 3
- Airports
- Wetlands
- Tunnels
  (Route 29 and Atlantic City Marina)

Determining Critical Assets

- Roadways & Bridges
  - Evacuation Routes
  - Access to Jobs
  - Volumes
- Passenger Rail
  - All Passenger Rail is Deemed Critical
- Freight Rail
  - Class-1 Very Critical
  - Class-2& -3 Less Critical

Determining Climate Impacts

Climate Threats

- Sea Level Rise and Storm Surge Impacts
- Temperature and Precipitation
- Inland flooding impacts

Scenario Development

- Three GHG Emissions Scenarios: Low, Medium, & High
- Projected climate impacts for 2050 and 2100
- Collected historic weather data from NJ weather stations

Threshold of Analysis

- Temperature
  - Days above 95 degrees
- Precipitation
  - Max within a five day period
  - Drought
  - Number of consecutive dry days
- Cold/Frost
  - Number of frost days

Climate Change Projections – select stations and emissions scenarios

Baseline and Projected for Select Stations from Average Grids						
	Precipitation (in)		Avg. Max Temp (F)		Avg. Min Temp (F)	
Station Name	Baseline	A1B 2100	Baseline	A1B 2100	Baseline	A1B 2100)
NEW BRUNSWICK 3 SE	48.7	52.8	62.78	69.44	42.8	49.28
ATLANTIC CITY INTL AP	41.7	45.3	63.14	69.62	44.42	50.54

Baseline and Projected for Select Stations from Average Grids								
	Days above 95F		Consec. dry days		Frost days		Days of <20F	
Station Name	Baseline	A1B 2100	Baseline	A1B 2100	Baseline	A1B 2100	Baseline	A1B 2100
MOORESTOWN	7.2	33.2	16	18	90	51	25.1	10.9
ATLANTIC CITY INTL AP	3.8	22.9	22	20	100	60	31.3	14.5

Vulnerability Analysis

Data Inputs

- Transportation Network
  - Roadway
  - Rail
- LiDAR (Digital Elevation Maps)
- Climate Projections
  - Sea Level Rise and Storm Surge
  - Temperature and Precipitation
  - Inland flooding impacts

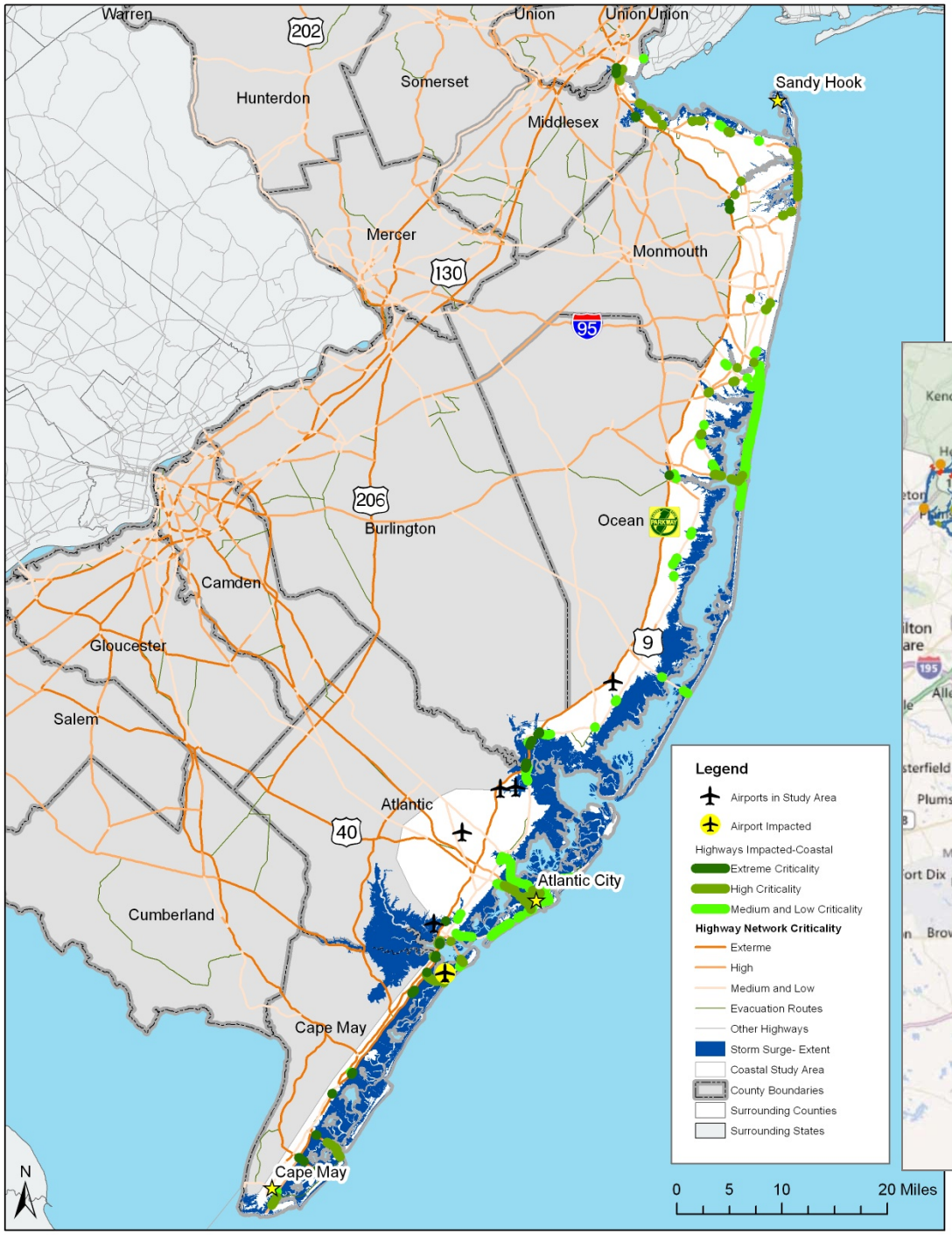
Outcomes

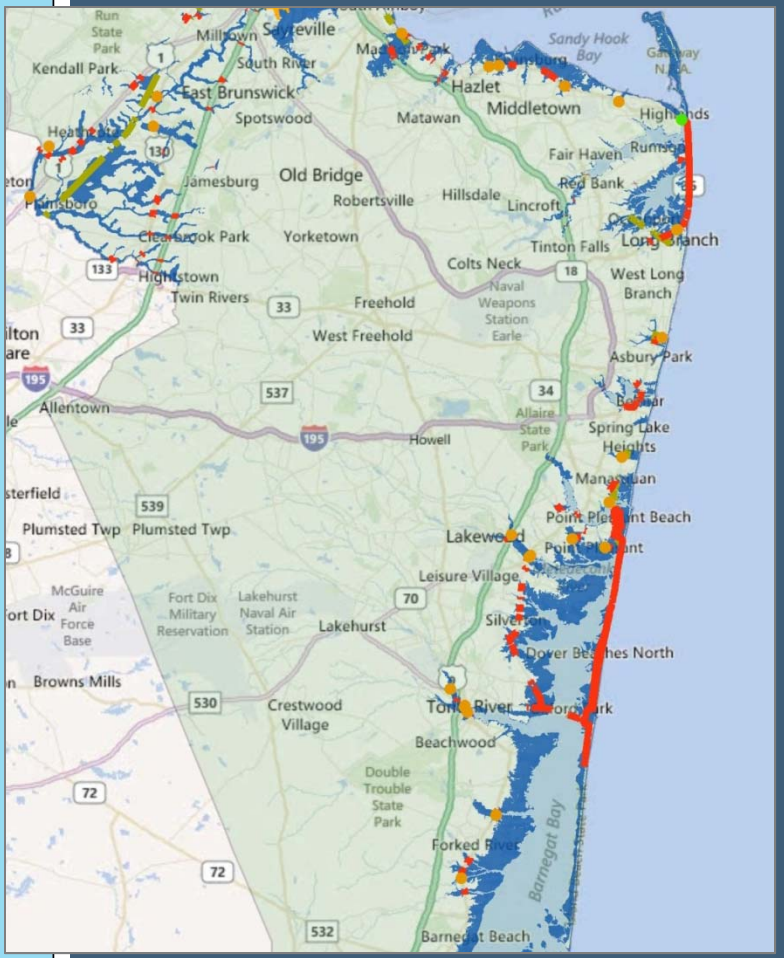
- Flooding of Transportation Assets
  - Roadways
  - Passenger Rail
  - Freight Rail
- Climate Extremes
  - More days above 95˚F
  - Increased storm intensity
  - Fewer frost days

Determining Infrastructure Vulnerable to Sea Level Rise and Storm Surge

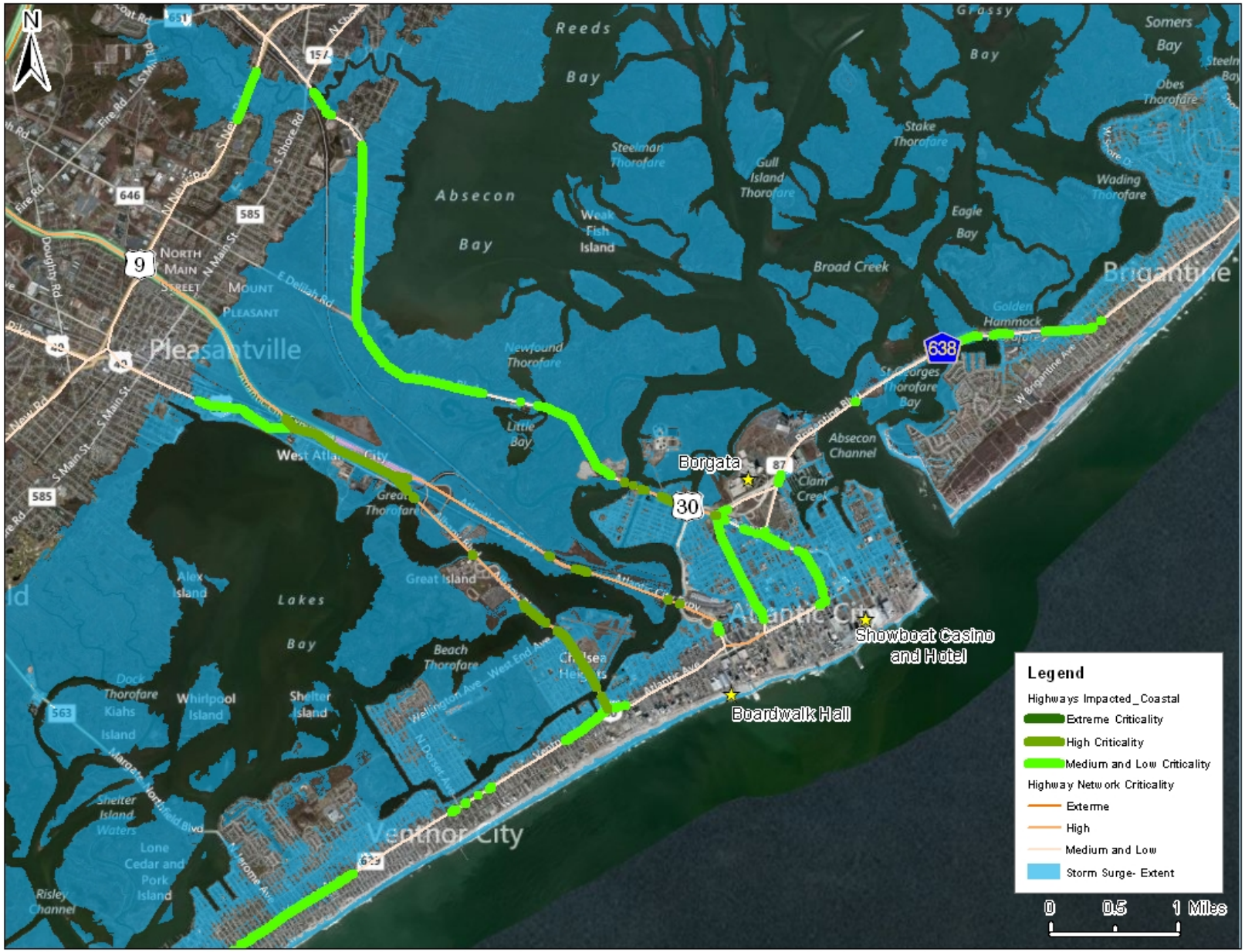
- Utilized three global sea level rise (SLR) scenarios - .5, 1, and 1.5 meters
- Applied high-resolution LiDAR data for ground elevations
- Obtained local subsidence data from NJDEP
- Projected SLR and storm surge impacts for 2050 and 2100 for each SLR scenario
- SLOSH Modeling to determine storm surge impacts from a Category 1 Hurricane

Highways Potentially Vulnerable to Sea Level Rise & Storm Surge – medium GHG scenario for 2100





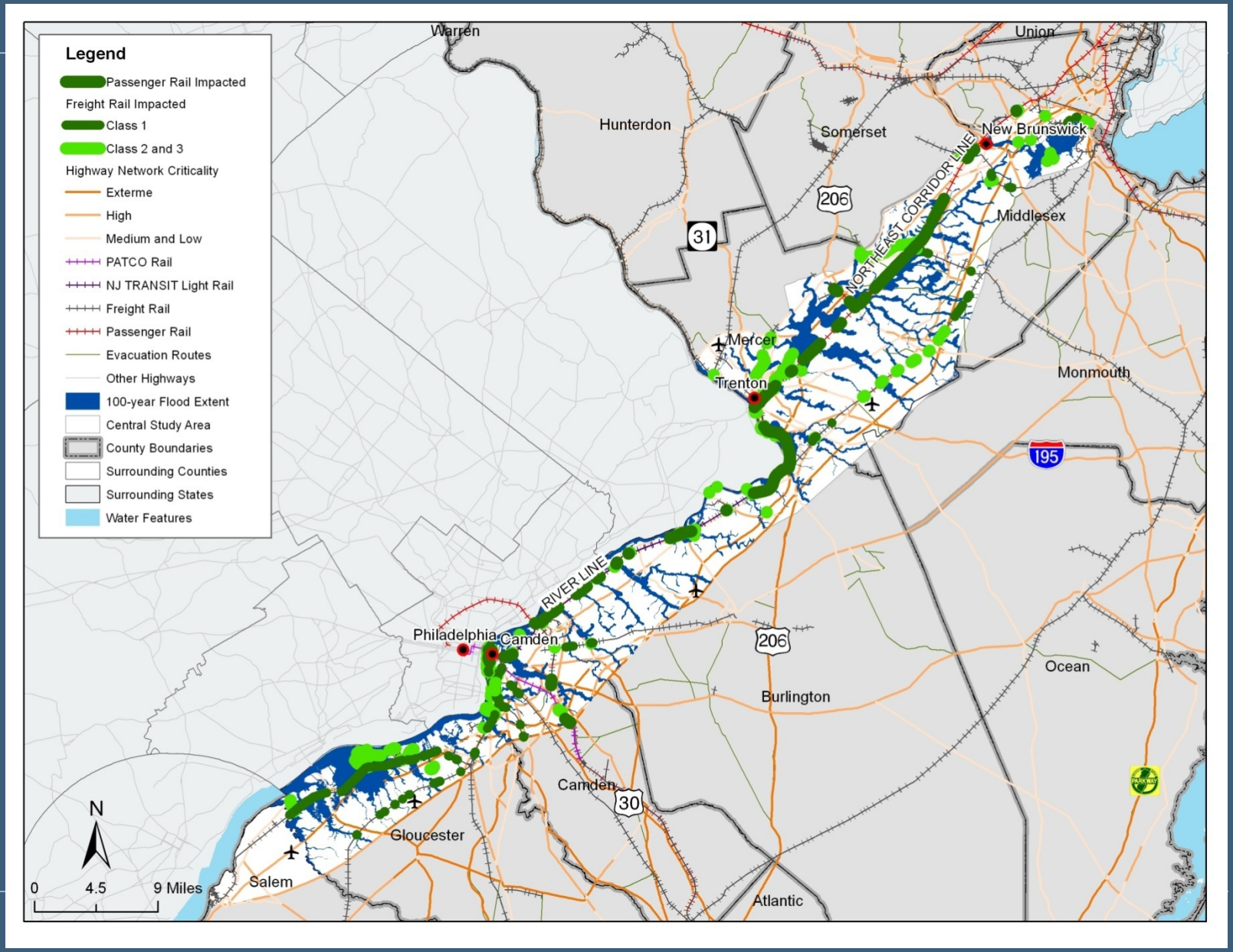
Highways Potentially Vulnerable to Sea Level Rise & Storm Surge – medium GHG scenario for 2100



Determining Infrastructure Vulnerable to Inland Flooding

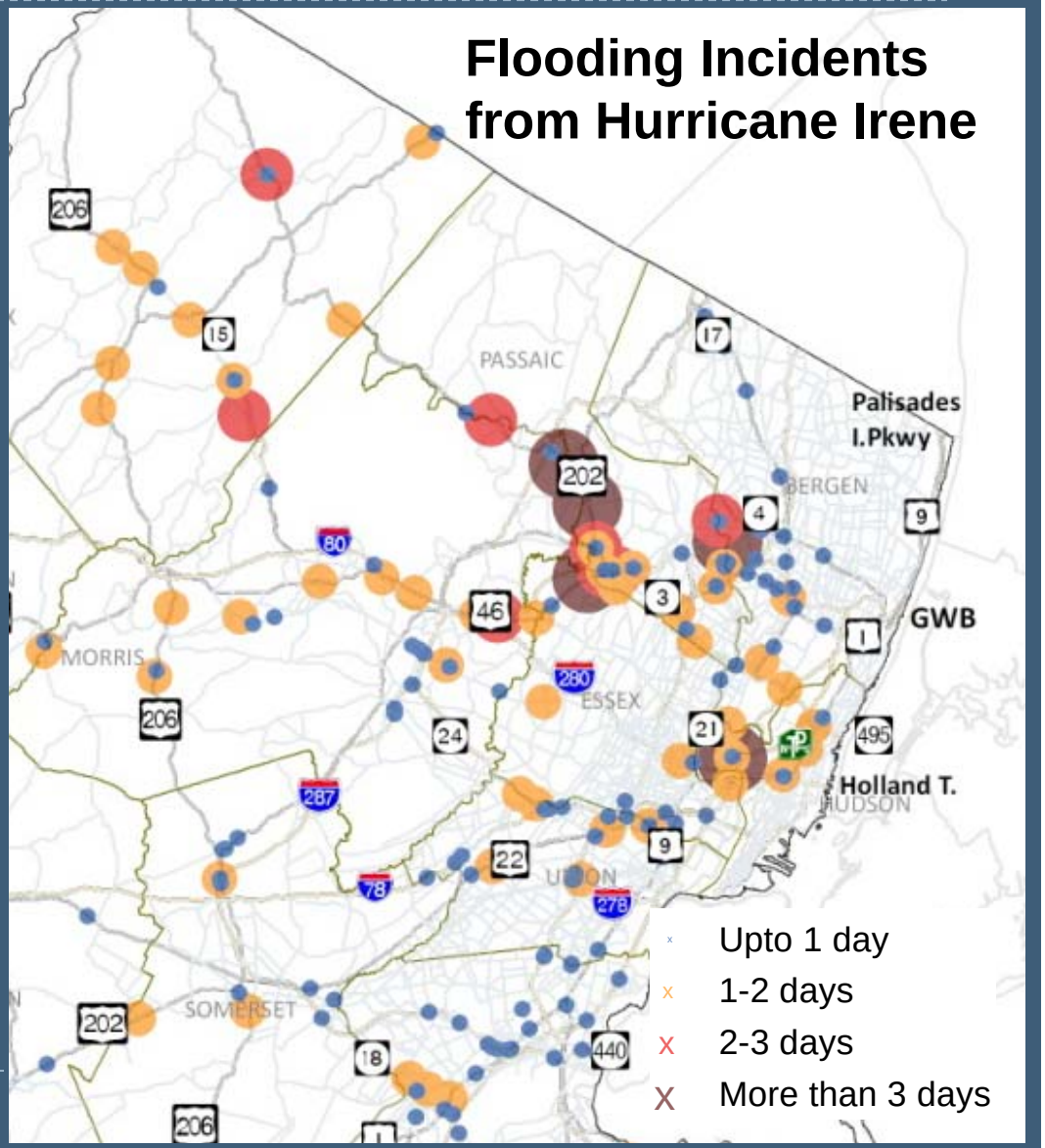
- Estimated potential changes in peak 100-year storm (1% annual storm event)
- Used climate change outputs as inputs for analysis
  - Frost days
  - Dry days
  - Rainfall
- Same timeframes and emissions scenarios for 2100
- Estimated changes to impervious coverage due to population growth
- Used updated Digital Flood Insurance Rate Maps from FEMA

Rail Infrastructure Potentially Vulnerable to 1% Storm Event – Medium GHG scenario for 2100

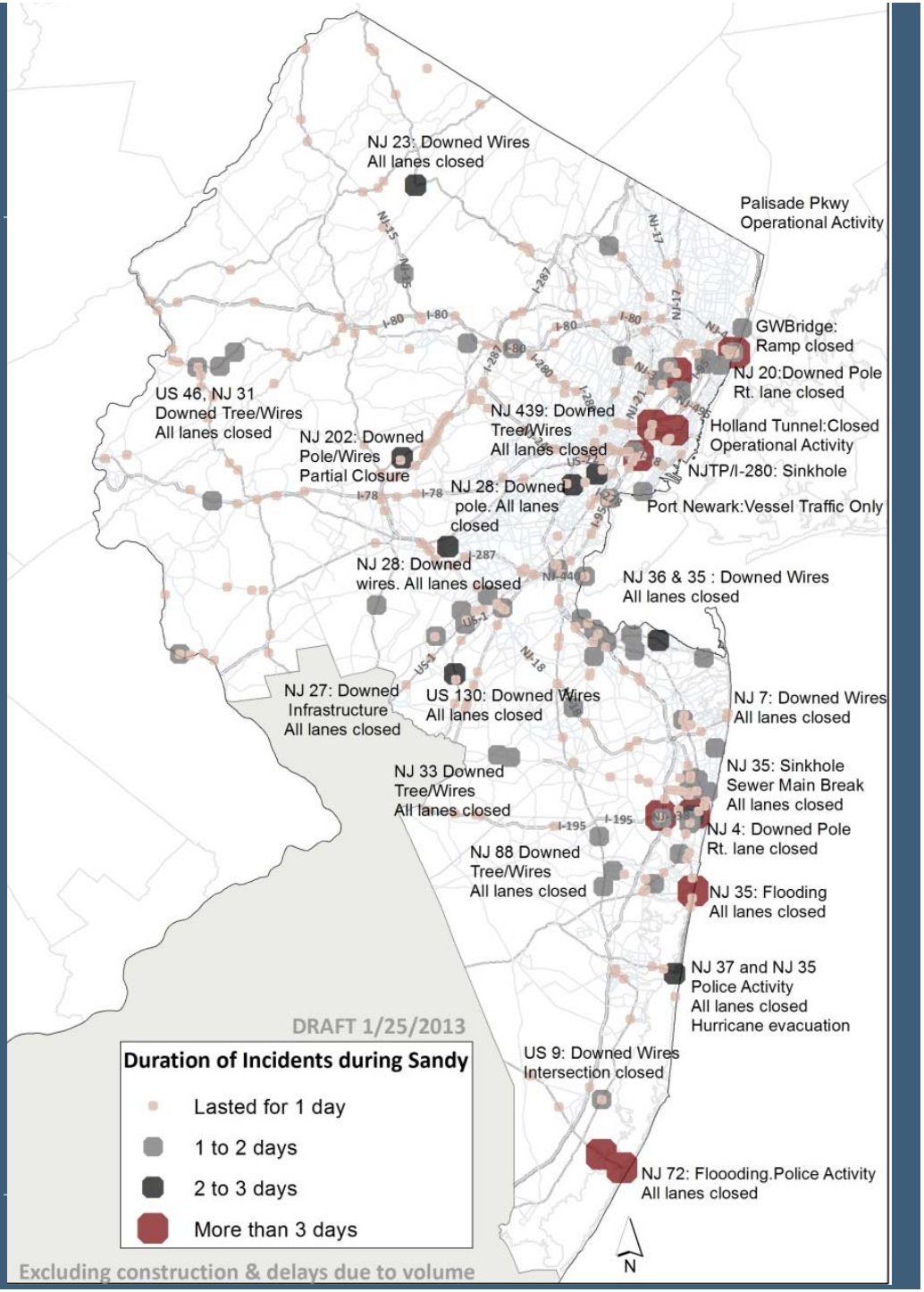


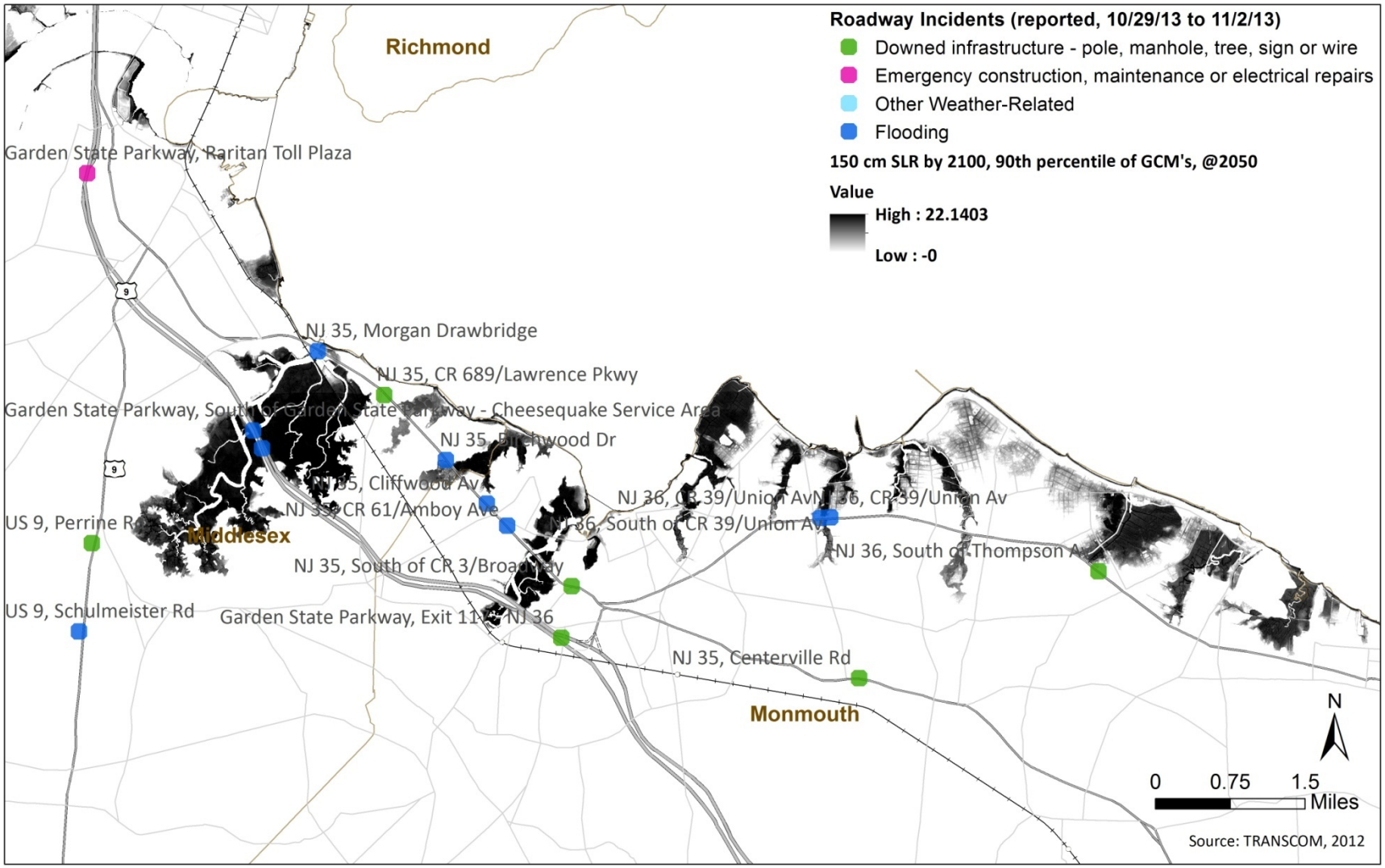
Recent Updates: Analyzing Flooding Impacts from Hurricane Irene and Sandy

- Used TRANSCOM data recorded from Hurricane Irene transportation incidents
- Coded incidents by location and duration
- State Highways and Major Arterials

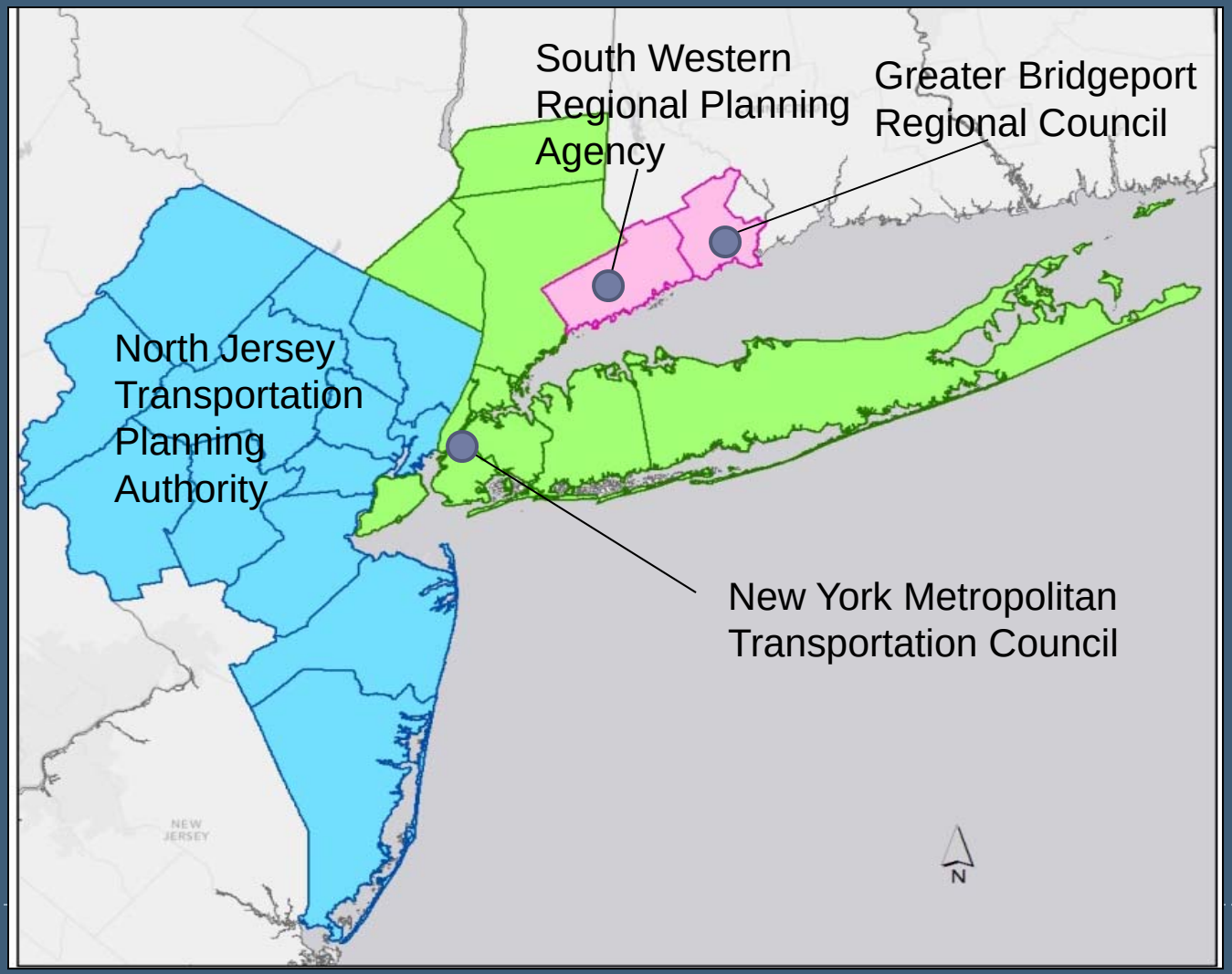


Impacts from Hurricane Sandy




Roadway Incidents (reported, 10/29/13 to 11/2/13)
Downed infrastructure - pole, manhole, tree, sign or wire
Emergency construction, maintenance or electrical repairs
Other Weather-Related
Flooding
150 cm SLR by 2100, 90th percentile of GCM's, @2050
Value
High : 22.1403
Low : -0
Richmond
Garden State Parkway, Raritan Toll Plaza
NJ 35, Morgan Drawbridge
NJ 35, CR 689/Lawrence Pkwy
Garden State Parkway, South of Garden State Parkway - Cheesequake Service Area
NJ 35, Birchwood Dr
NJ 35, Cliffwood Av
NJ 35, CR 61/Amboy Ave
US 9, Perrine Rd
Middlesex
NJ 35, South of CR 3/Broadway
US 9, Schulmeister Rd
Garden State Parkway, Exit 11
NJ 36
NJ 36, CR 39/Union Av
NJ 36, CR 39/Union Av
NJ 36, South of CR 39/Union Av
NJ 36, South of Thompson A
NJ 35, Centerville Rd
Monmouth
N
0
0.75
1.5
Miles
Source: TRANSCOM, 2012

Next Steps: New York – New Jersey – Connecticut Transportation Vulnerability Assessment and Adaptation Analysis



Further Reading

Visit the NJTPA Climate Initiative for more information

http://www.njtpa.org/Plan/Element/Climate/ClimateChangeInitiative.aspx

Thank you!