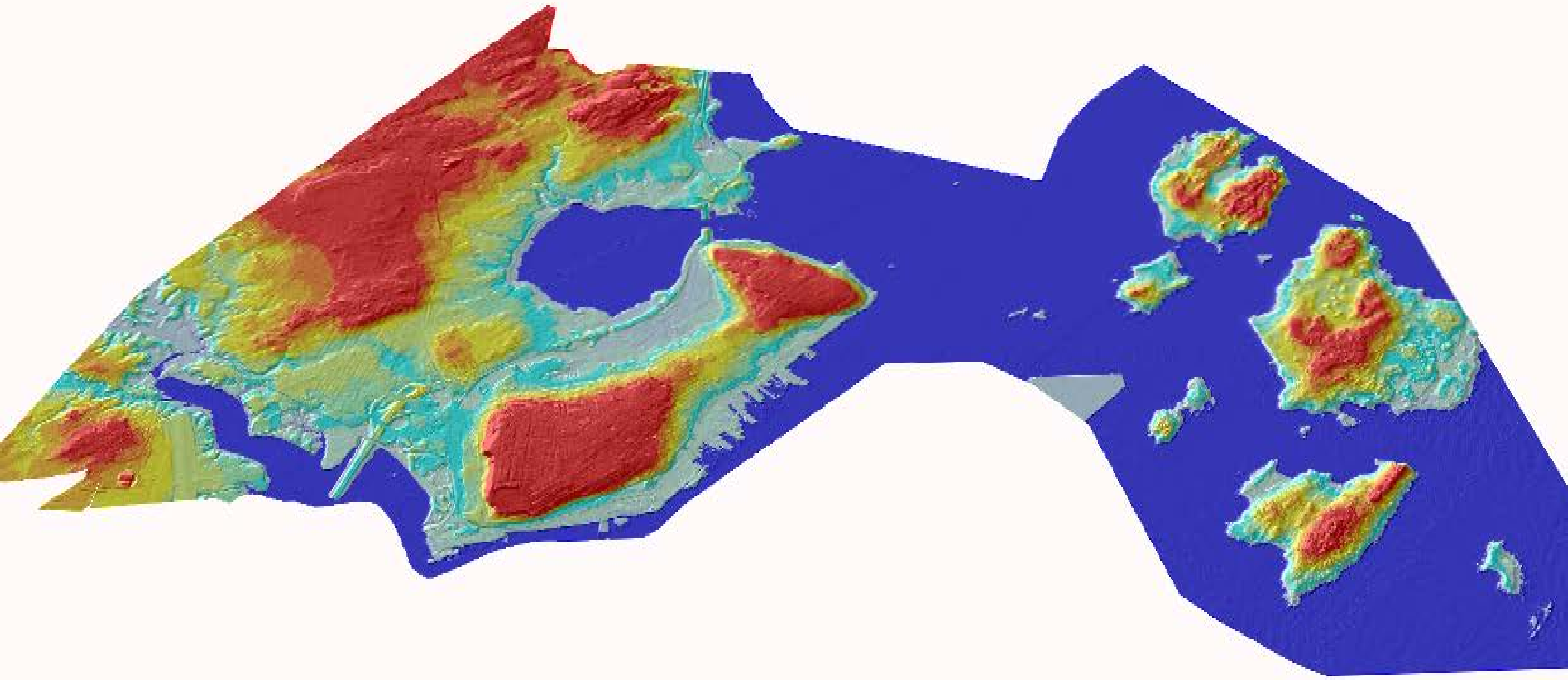
Base LiDAR Data



2006 LiDAR tiles (18 cm RMSE)

Mosaic and clip to municipal boundaries

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Buildings and Transportation Data

(overlain onto Base LiDAR)

Add Polygon layers for buildings and roads (municipal)

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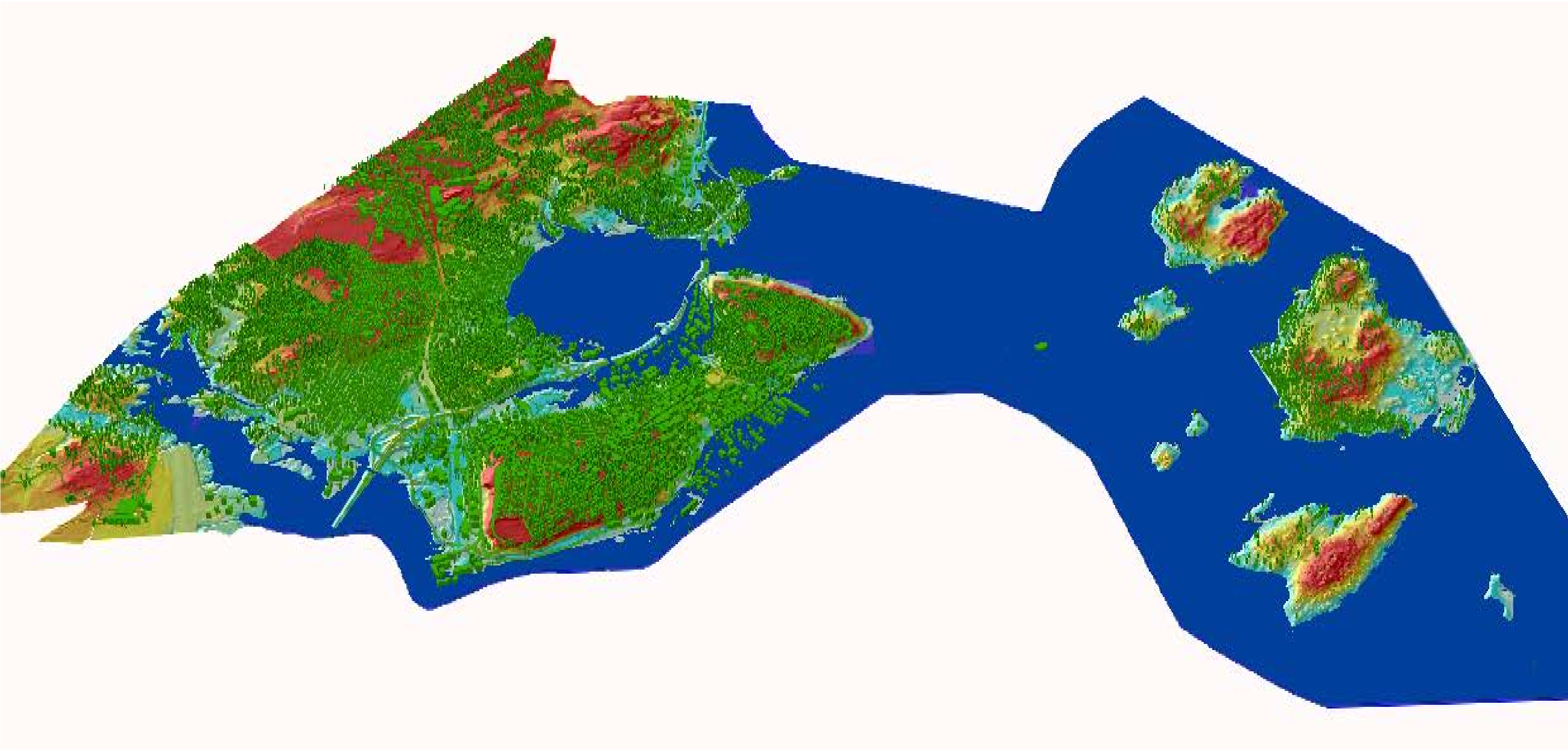
Simulate Flood Levels



Determine future inundation levels under different scenarios
Raster queries to determine areas below certain water levels

New England Environmental Finance Center

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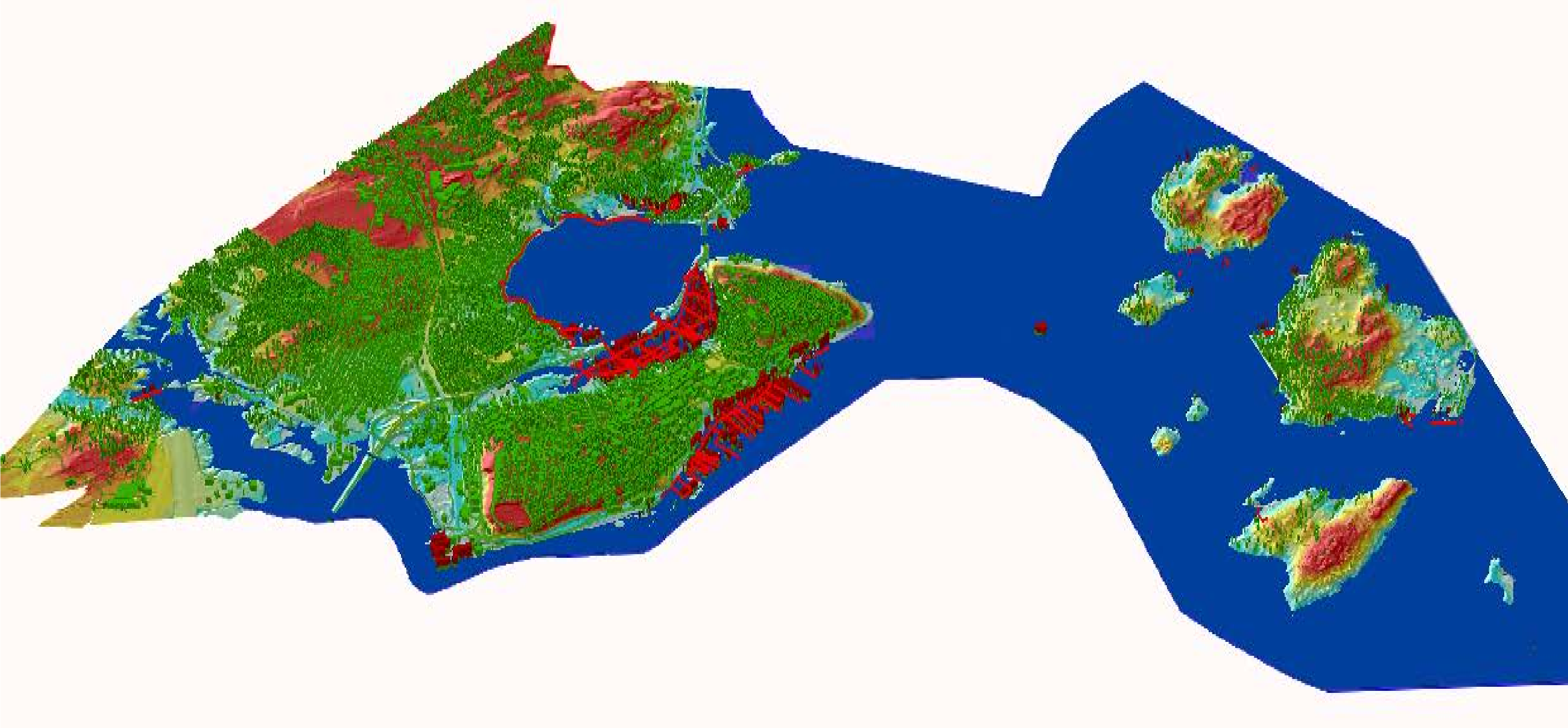
MAINE
GEOLOGICAL SURVEY

Identify Potentially Flooded Infrastructure



Determine inundation impacts to buildings and infrastructure
Analysis completed includes Islands

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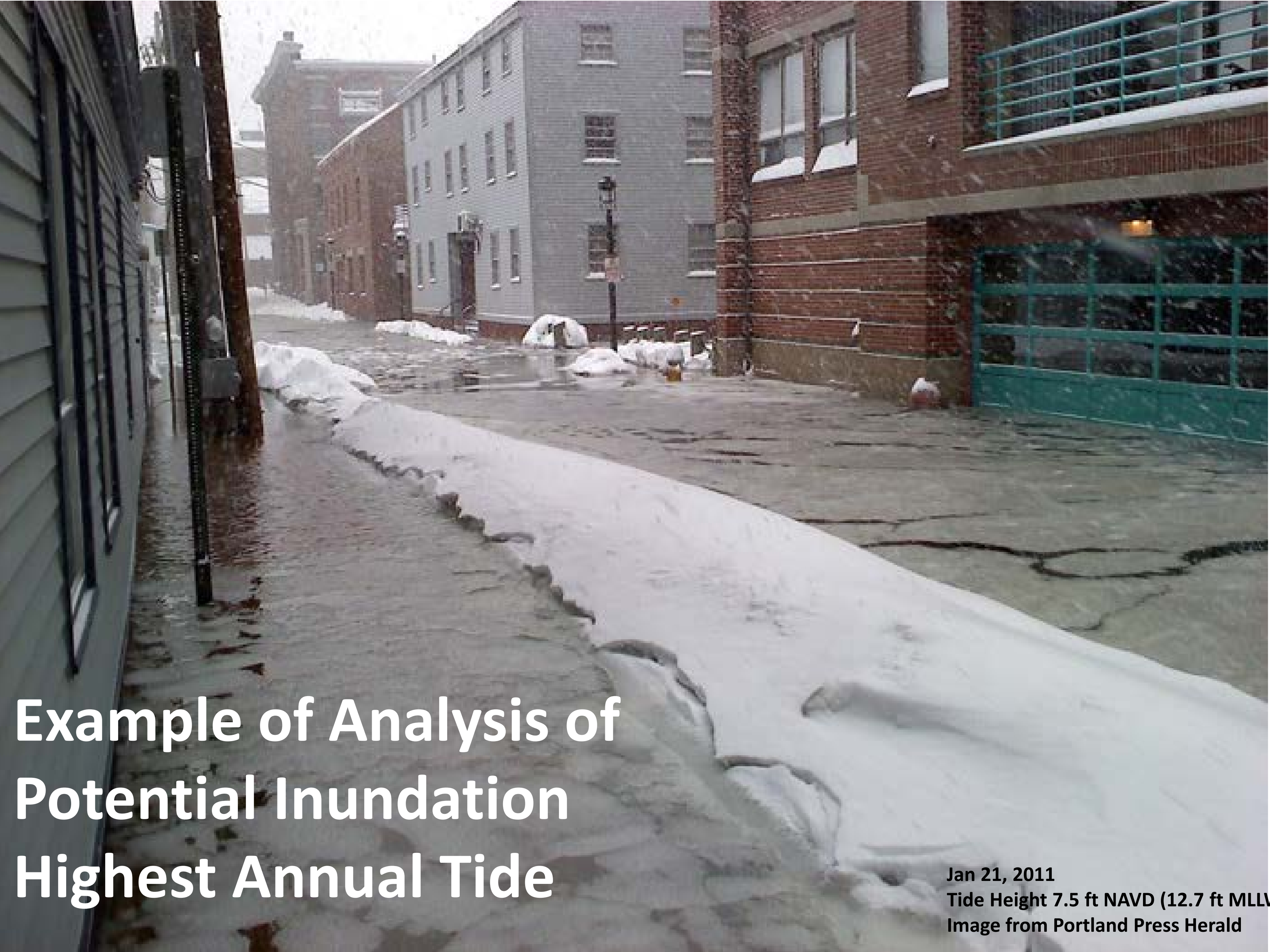
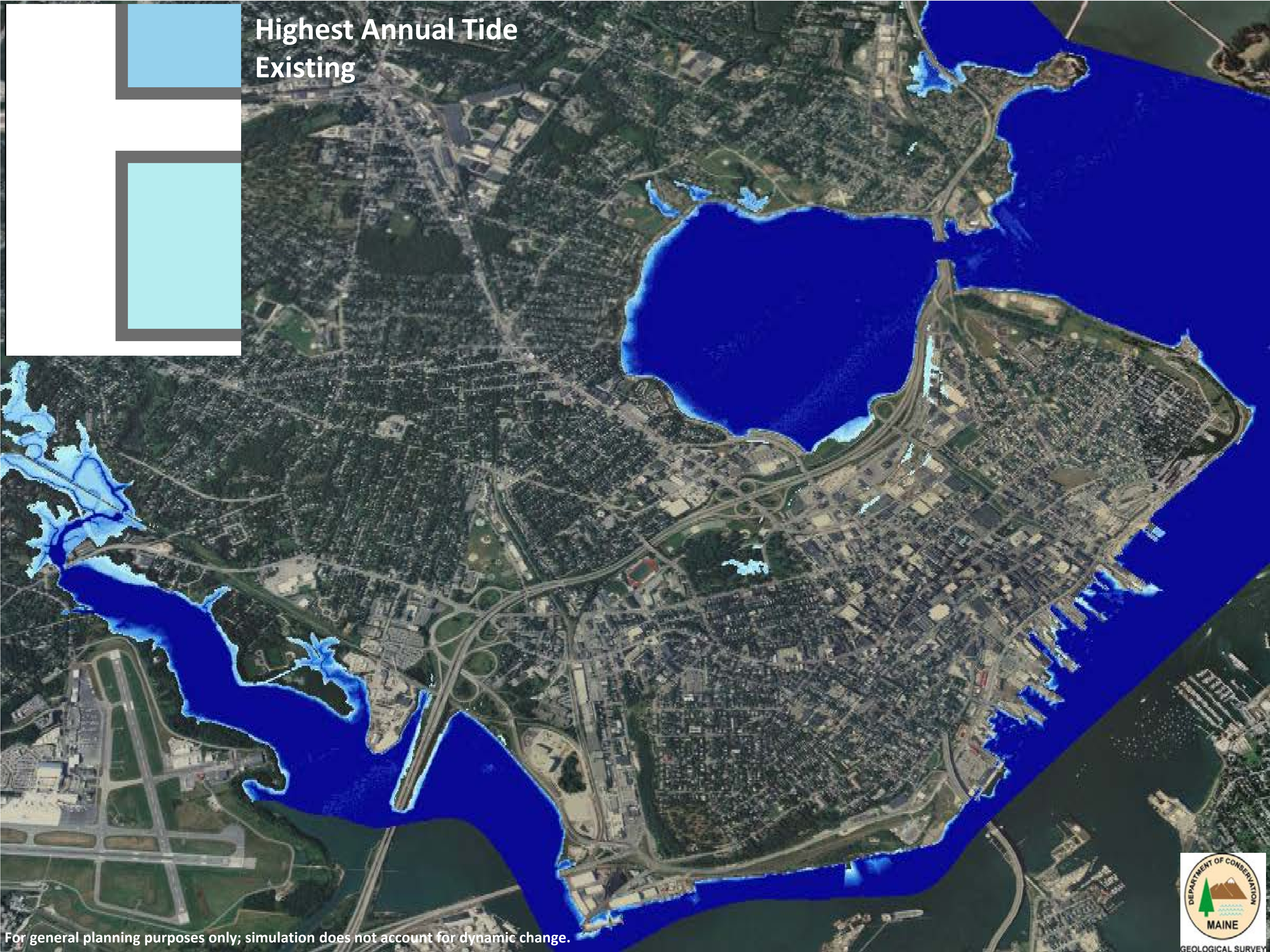


Example of Analysis of Potential Inundation Highest Annual Tide

Jan 21, 2011
Tide Height 7.5 ft NAVD (12.7 ft MLLW
Image from Portland Press Herald


Highest Annual Tide
Existing
For general planning purposes only; simulation does not account for dynamic change.
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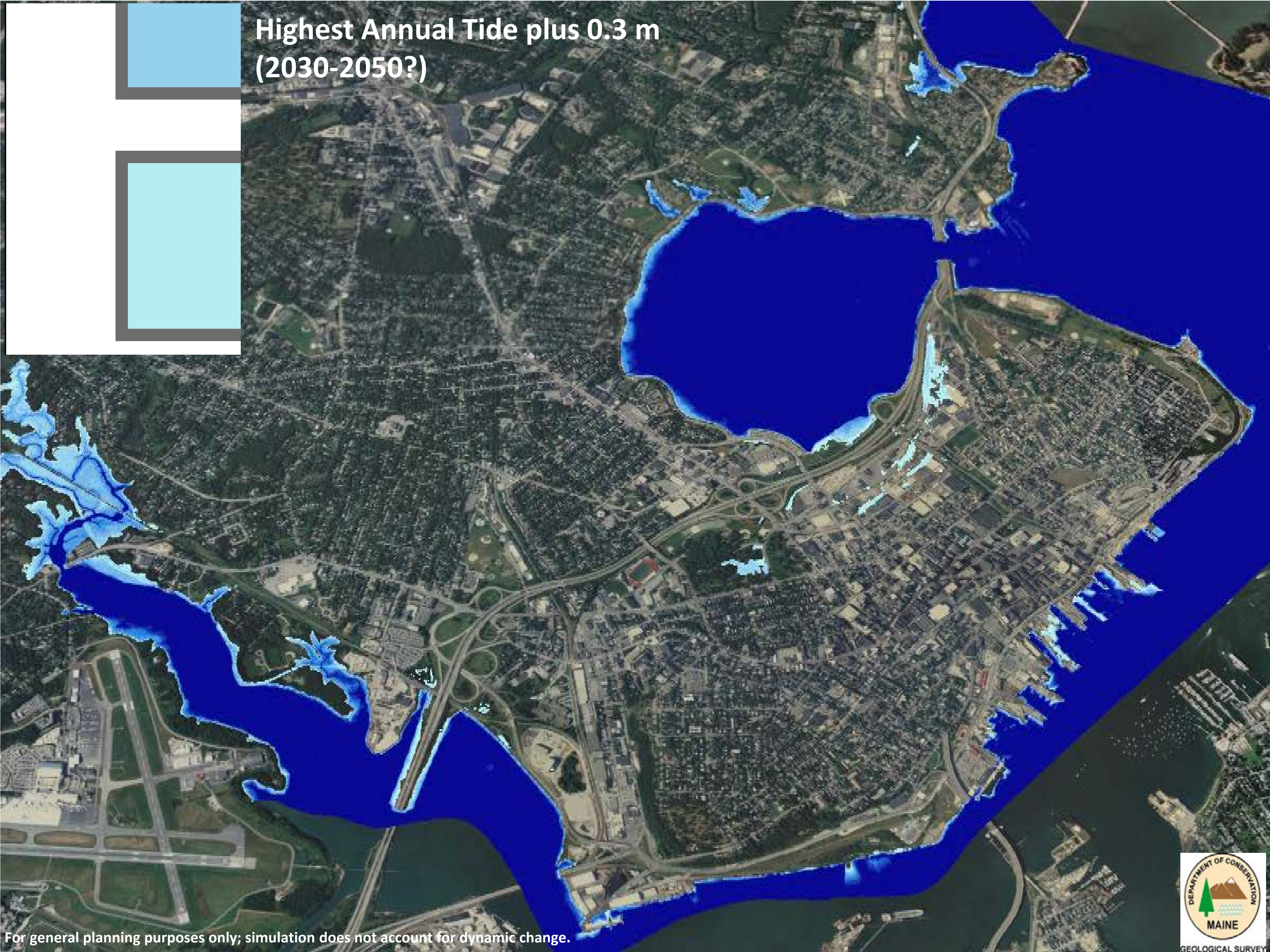
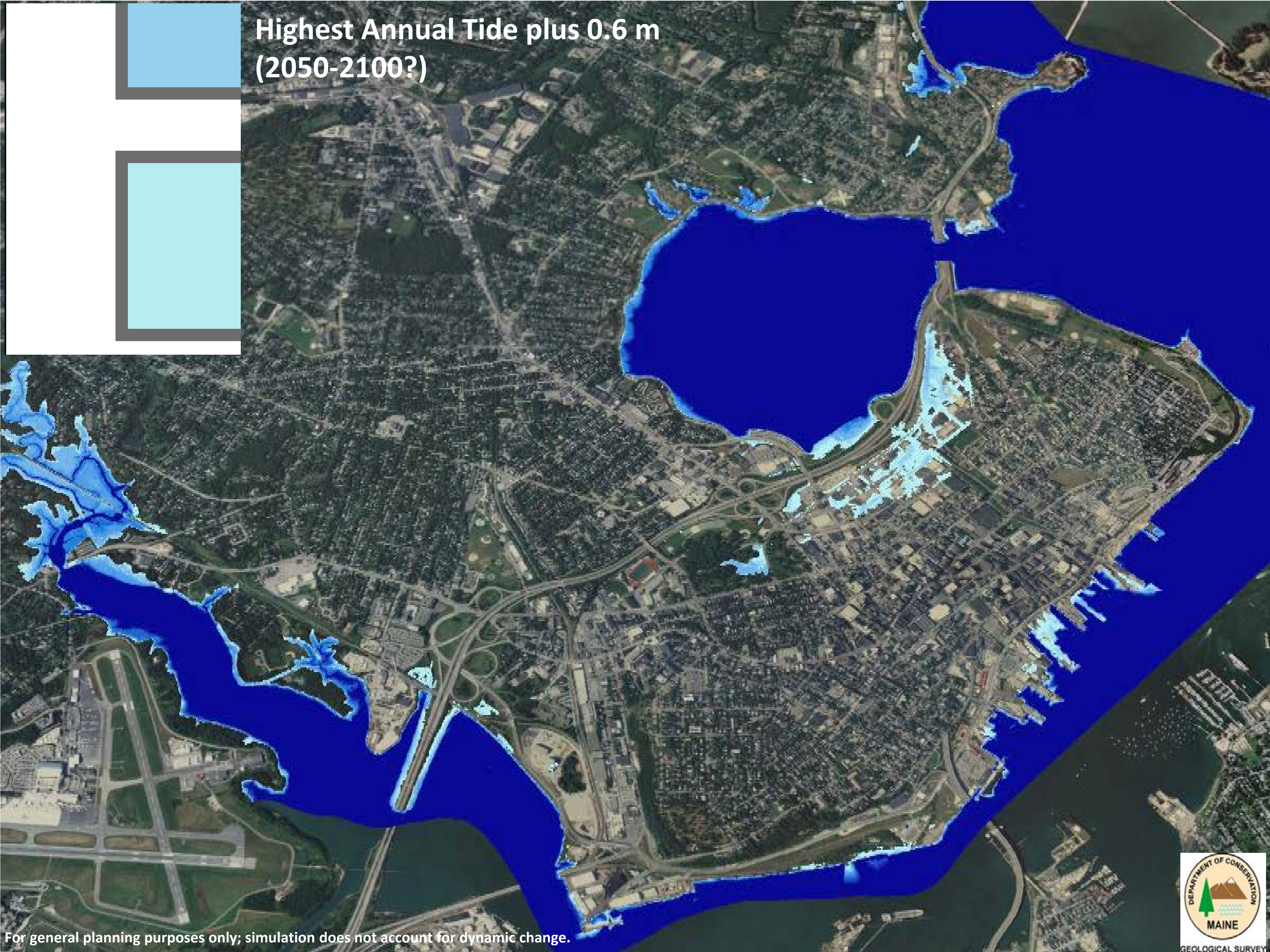
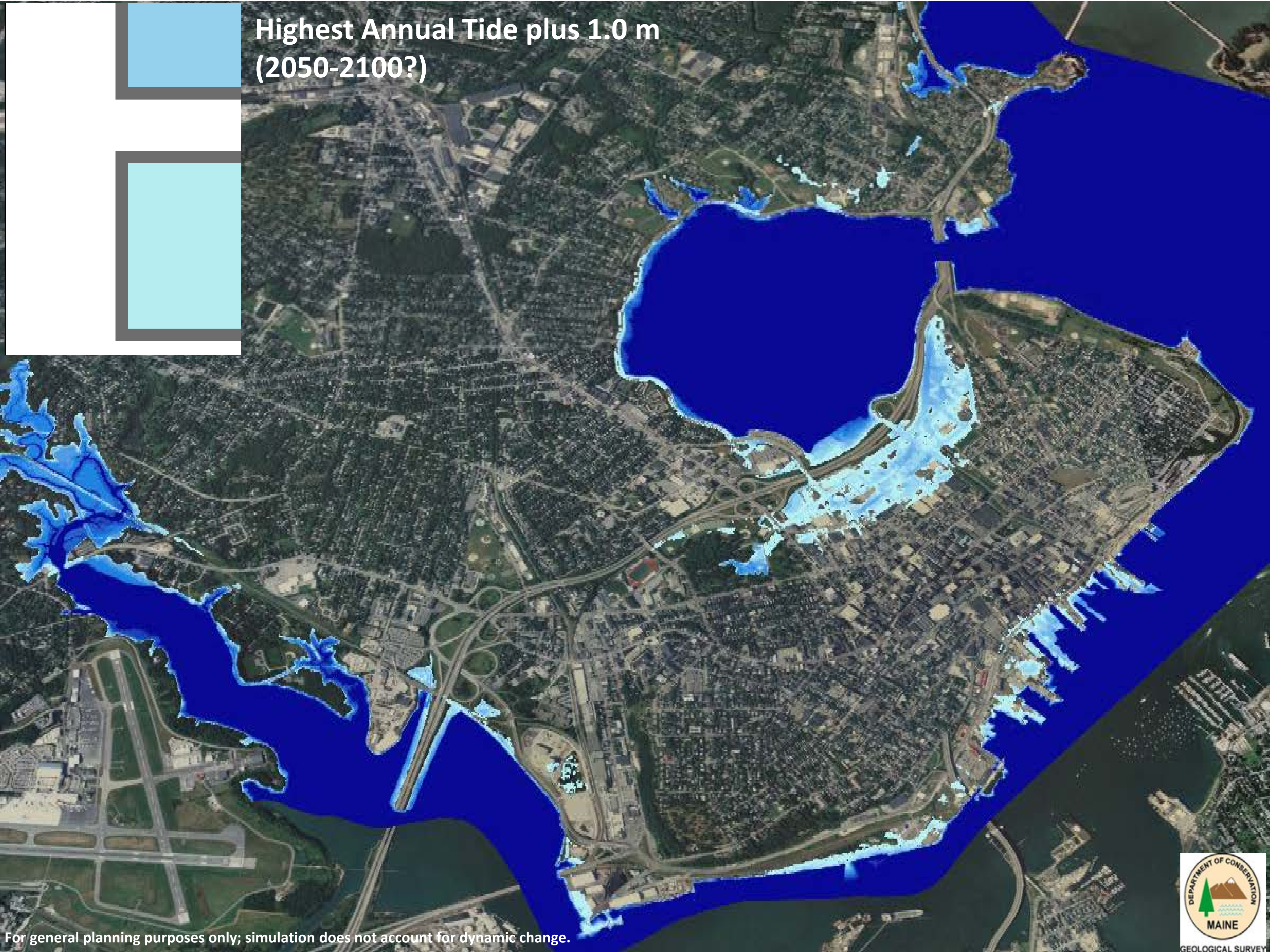
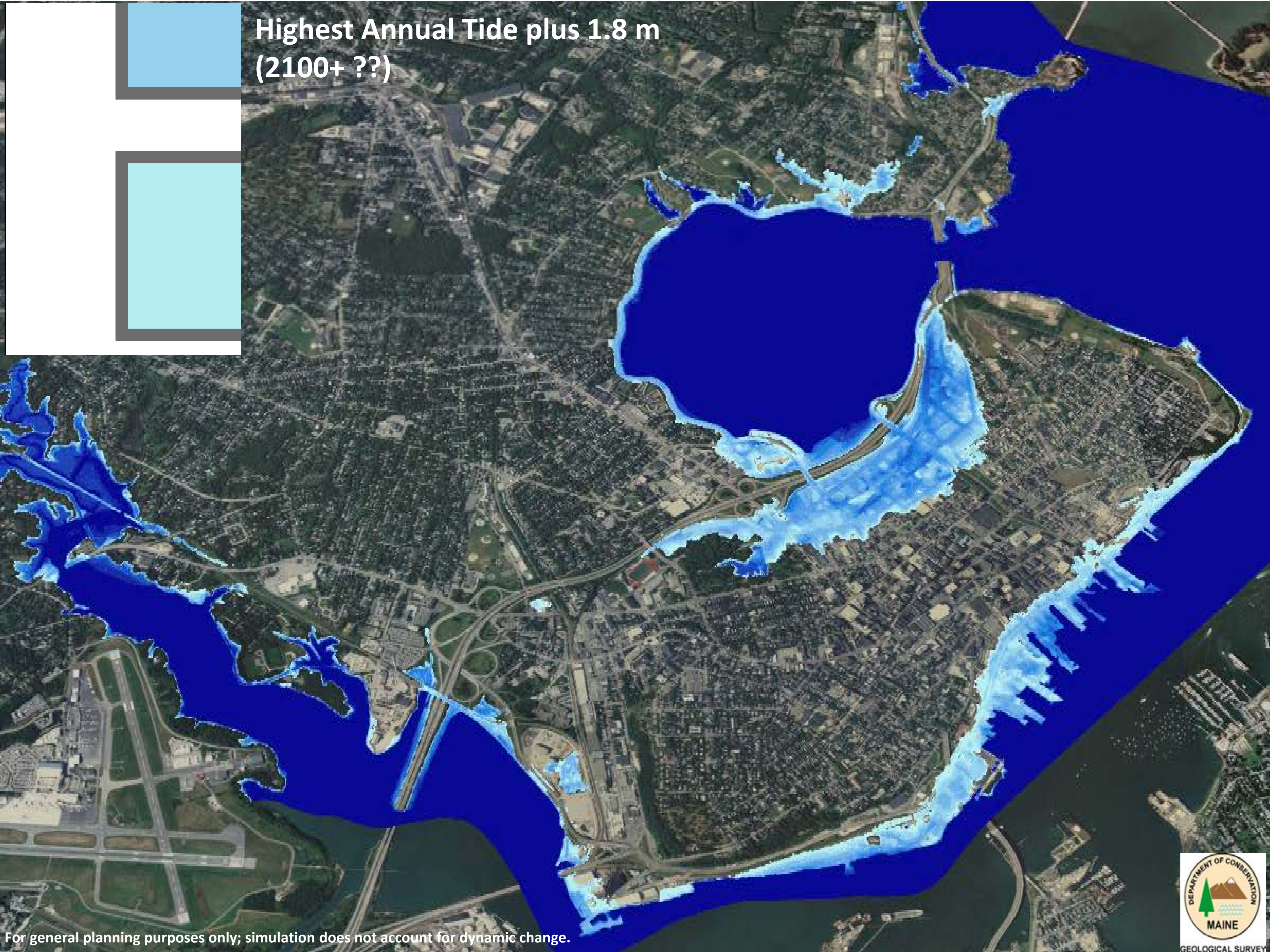

Highest Annual Tide plus 0.3 m
(2030-2050?)
For general planning purposes only; simulation does not account for dynamic change.

Highest Annual Tide plus 0.6 m (2050-2100?)



For general planning purposes only; simulation does not account for dynamic change.


Highest Annual Tide plus 1.0 m
(2050-2100?)
For general planning purposes only; simulation does not account for dynamic change.


Highest Annual Tide plus 1.8 m
(2100+ ??)
For general planning purposes only; simulation does not account for dynamic change.
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Existing and Potential Future Flooding in Portland

Based on Flood Stage

Scenario	Flood Stage Elevation (MLLW)	# times flood stage exceeded	% of Total High Tides	Hours of Inundation (above flood level)
2011 Year	12 ft	11	1.6%	8
+0.3 m (1 ft) SLR	11 ft	98	13.9%	141
+0.6 m (2 ft) SLR	10 ft	281	39.8%	570
+1.0 m (3.3 ft) SLR	8.7 ft	612	86.7%	1759
+1.8 m (5.9) ft SLR	6.1 ft	702	99.4%	3782

- Flood stage is indicated as 12 feet MLLW, including surge (source: NWS)
- Based only on data from 2011
- NOAA CO-OPs Inundation Analysis Tool

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Department of Conservation Maine Geological Survey

Potential Impacts to Buildings

Somerset St., October 28, 2011; Curtis Bohlen, CBEP

Highest Annual Tide
Existing Conditions
(6.6' NAVD, 11.8' MLLW)
Building Footprints

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For general planning purposes only, simulation does not account for dynamic change.

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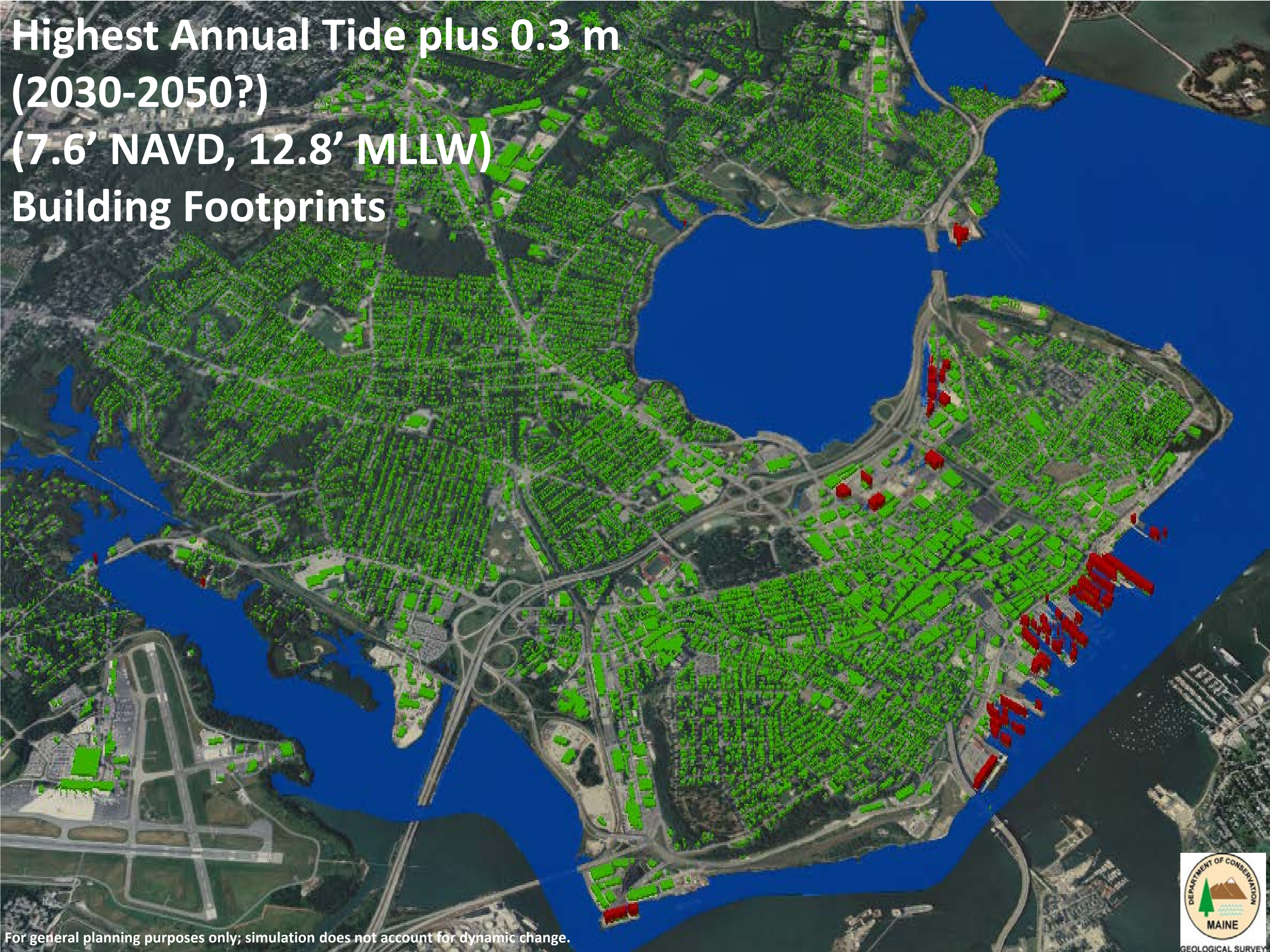
Highest Annual Tide plus 0.3 m
(2030-2050?)
(7.6' NAVD, 12.8' MLLW)
Building Footprints
For general planning purposes only; simulation does not account for dynamic change.
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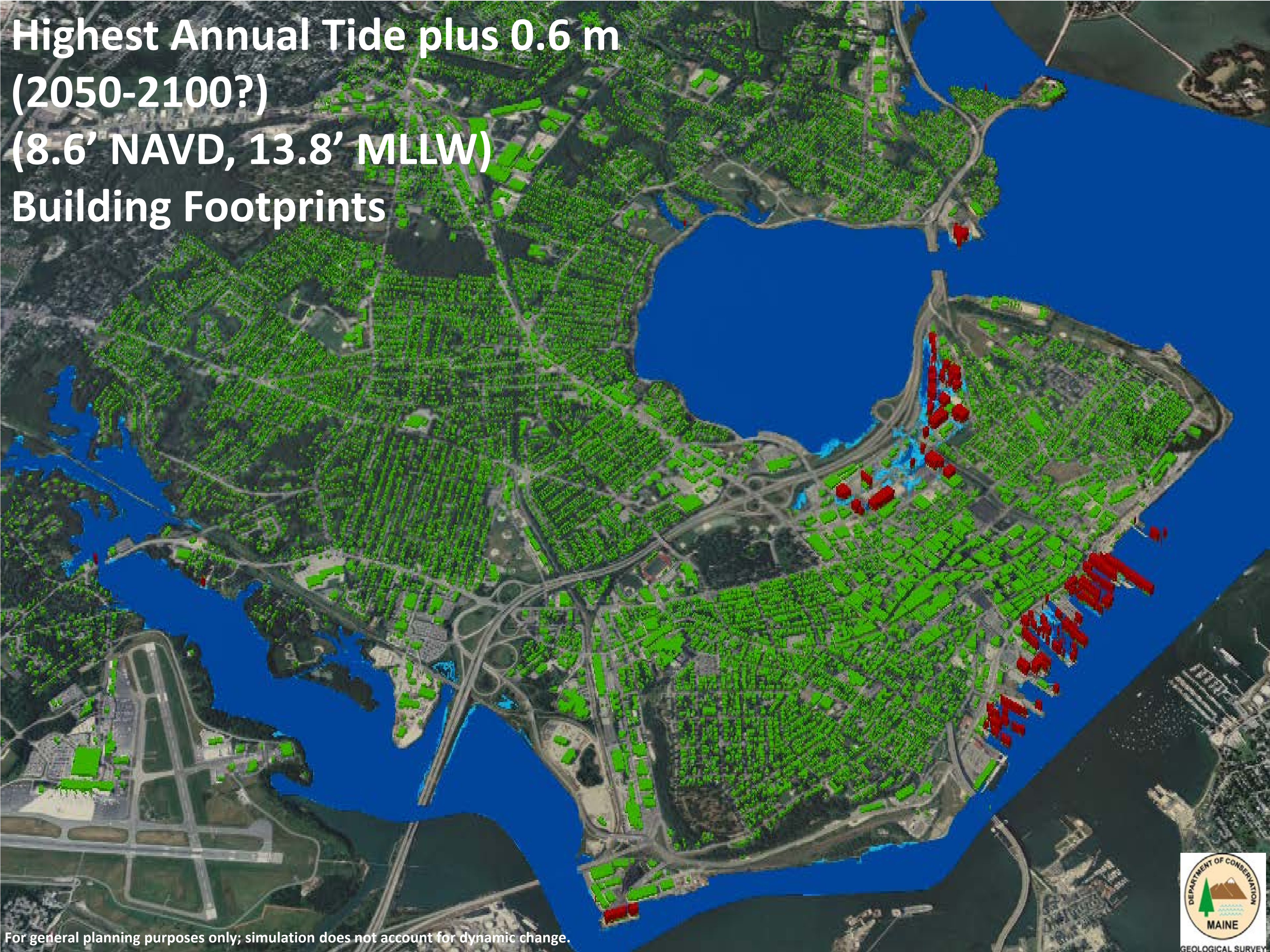
Highest Annual Tide plus 0.6 m (2050-2100?) (8.6’ NAVD, 13.8’ MLLW) Building Footprints



For general planning purposes only; simulation does not account for dynamic change.

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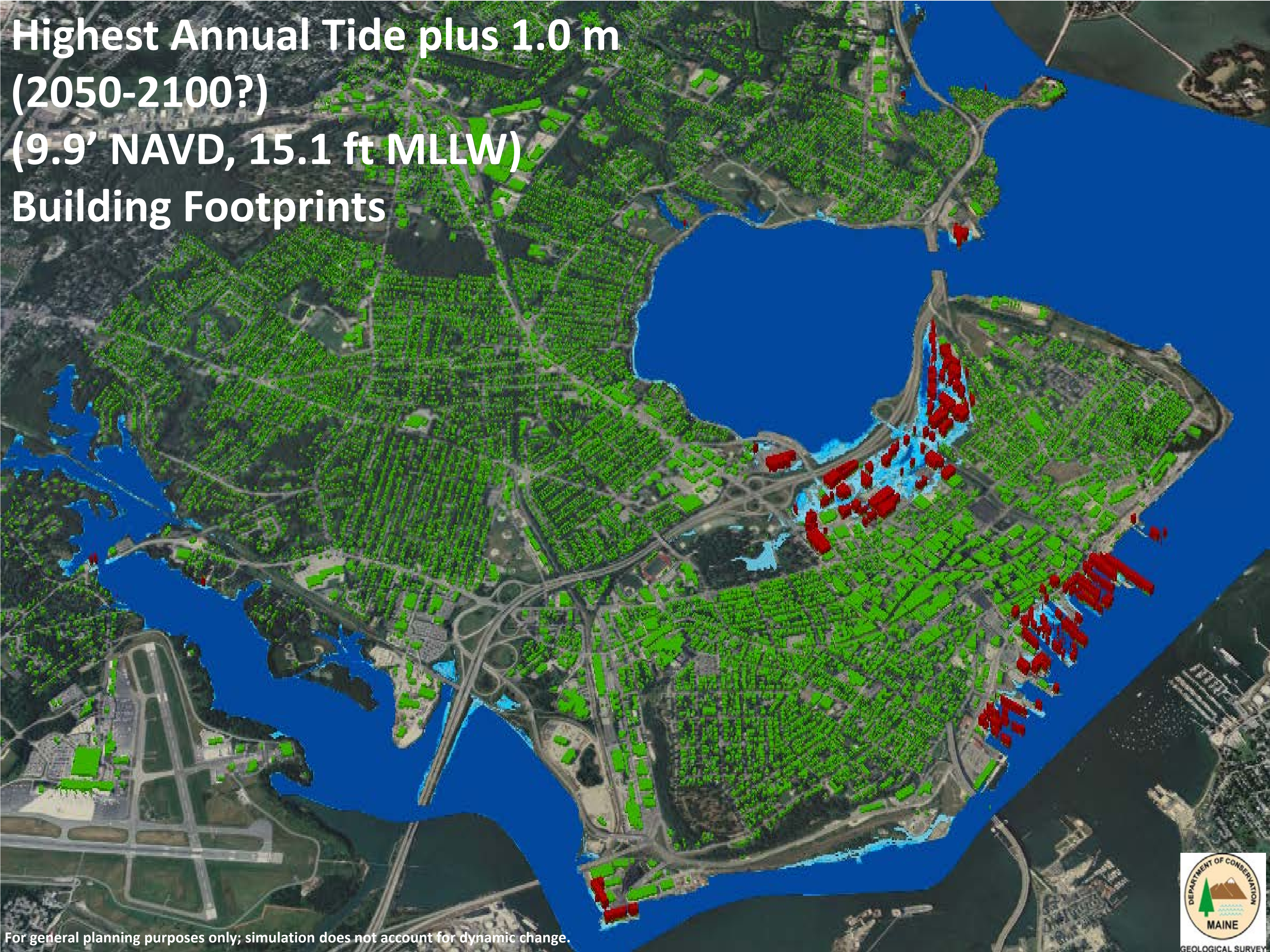
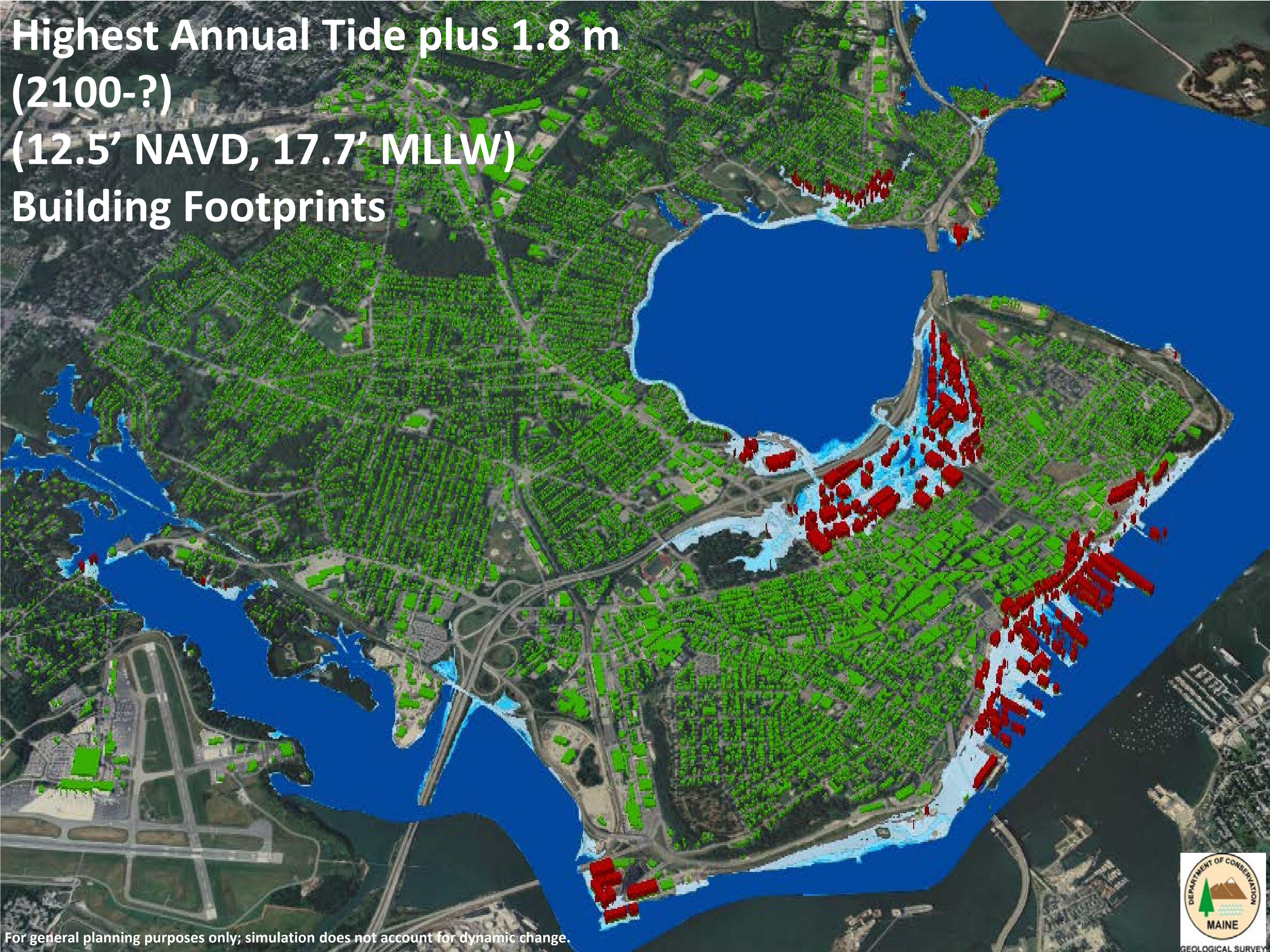
GEOLOGICAL SURVEY

Highest Annual Tide plus 1.0 m (2050-2100?) (9.9' NAVD, 15.1 ft MLLW) Building Footprints



For general planning purposes only; simulation does not account for dynamic change.


Highest Annual Tide plus 1.8 m
(2100-?)
(12.5’ NAVD, 17.7’ MLLW)
Building Footprints
For general planning purposes only; simulation does not account for dynamic change.
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Historic 1978 Storm
(8.9’ NAVD, 14.1’ MLLW)
Building Footprints

For general planning purposes only; simulation does not account for dynamic change.

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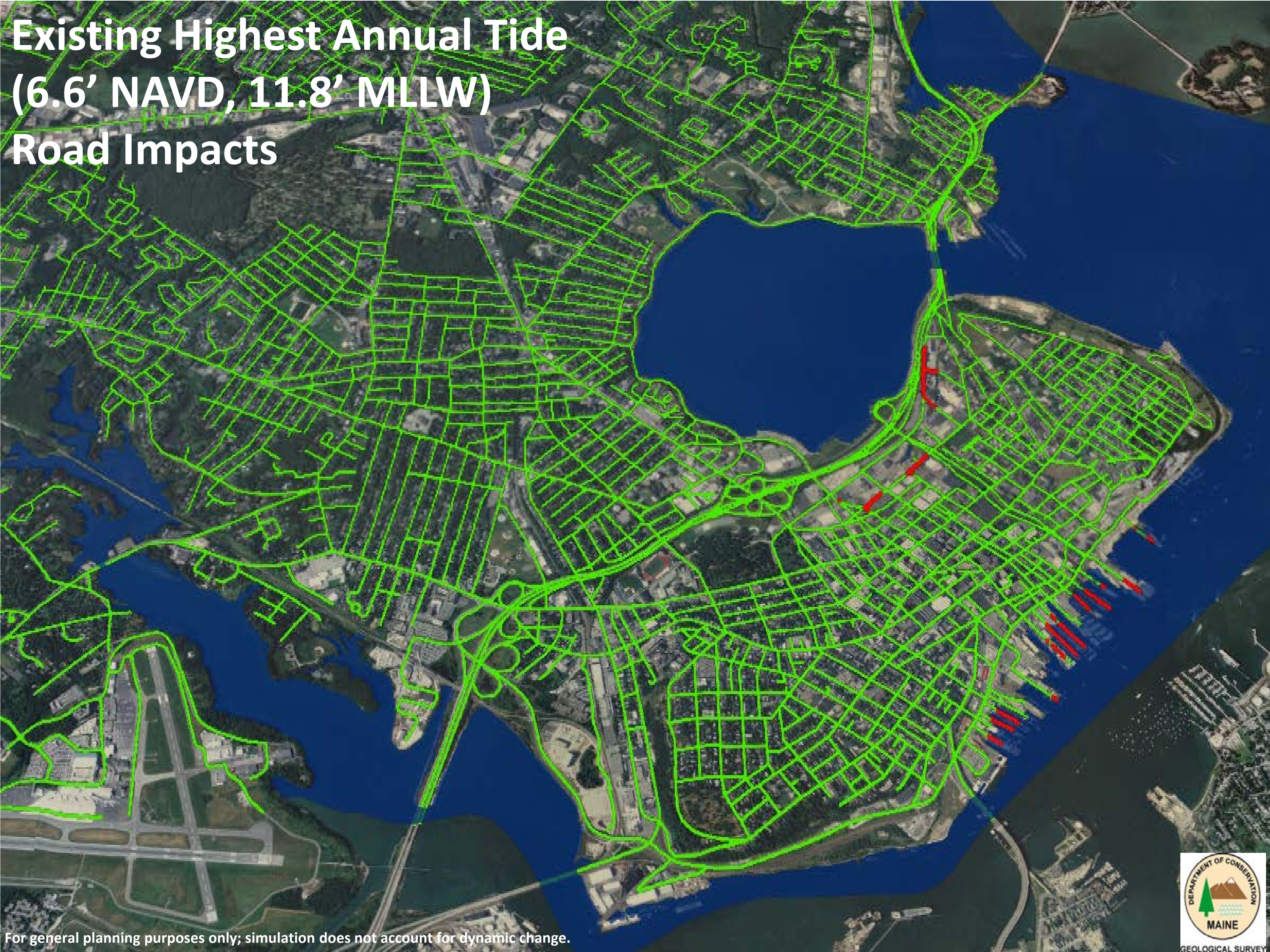
FedEx
PRIVATE PARKING
PRIVATE PARKING
RIPPLE
Potential Impacts to Roads
Assumption: “impacted” = flooded
C. Bohlen, CBEP

Existing Highest Annual Tide
(6.6’ NAVD, 11.8’ MLLW)
Road Impacts



For general planning purposes only; simulation does not account for dynamic change.

Highest Annual Tide plus 0.3 m (2030-2050?) (7.6' NAVD, 12.8' MLLW) Road Impacts

For general planning purposes only; simulation does not account for dynamic change.

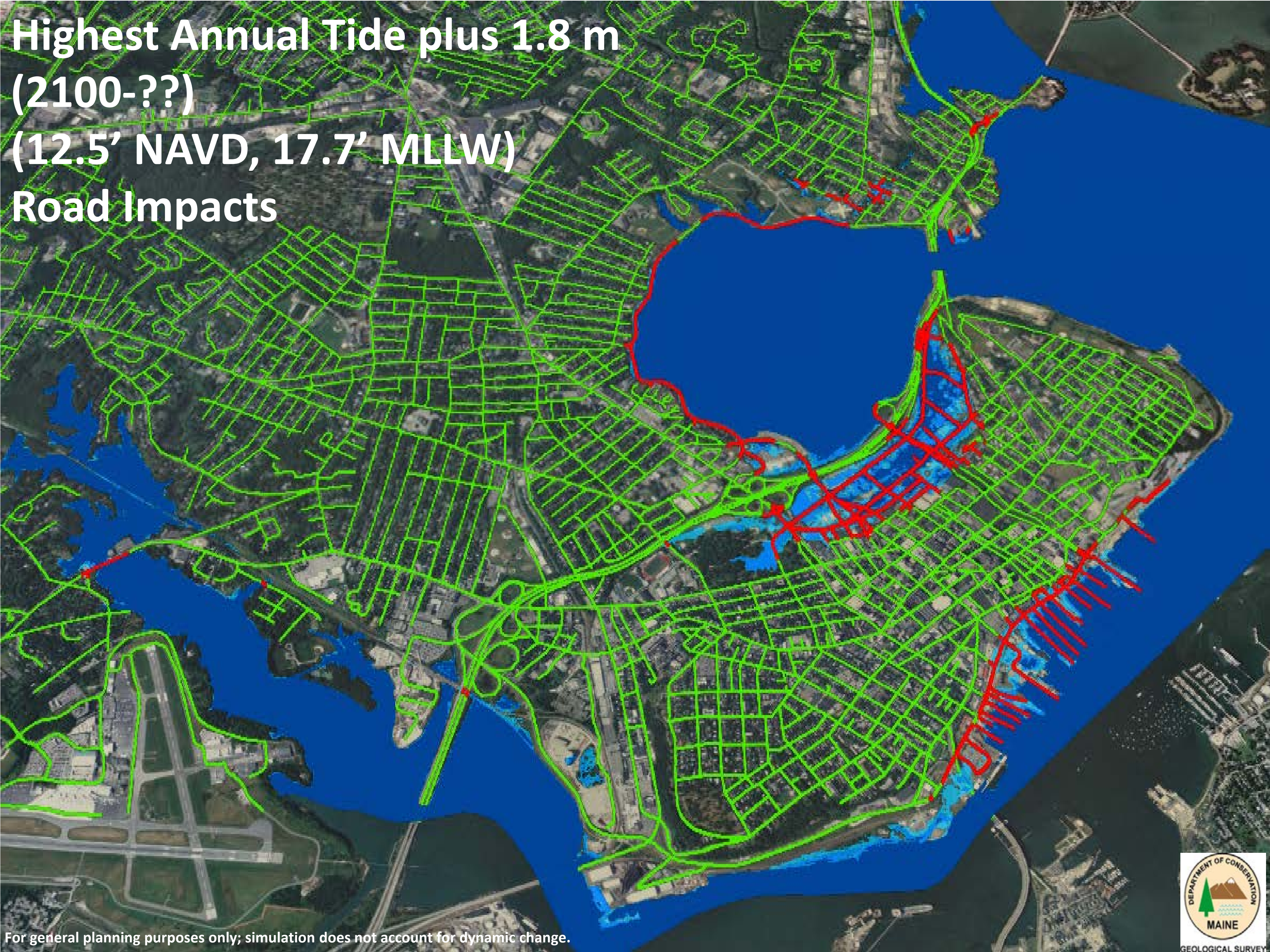
Highest Annual Tide plus 0.6 m (2050-2100?) (8.6’ NAVD, 13.8’ MLLW) Road Impacts

For general planning purposes only; simulation does not account for dynamic change.

Highest Annual Tide plus 1.0 m (2050-2100?) (9.9' NAVD, 15.1 ft MLLW) Road Impacts

For general planning purposes only; simulation does not account for dynamic change.

Highest Annual Tide plus 1.8 m (2100-??) (12.5’ NAVD, 17.7’ MLLW) Road Impacts



For general planning purposes only; simulation does not account for dynamic change.

Consider emergency access rerouting

Summary of Potentially Vulnerable Road* Infrastructure

Scenario	Highest Annual Tide	1978 Storm
Existing	1.1 miles	3.6 miles
+0.3 m (1 ft) SLR	1.4 miles	6.4 miles
+0.6 m (2 ft) SLR	2.8 miles	10.7 miles
+1.0 m (3.3 ft) SLR	6.2 miles	13.9 miles
+1.8 m (6.0 ft) SLR	14.5 miles	17.8 miles

* Assumes "bathtub" flooding, static topography, and that a road is "inundated" if the flooding scenario **covers** the entire road, regardless of the flooding depth. Does not assign any kind of damage function.

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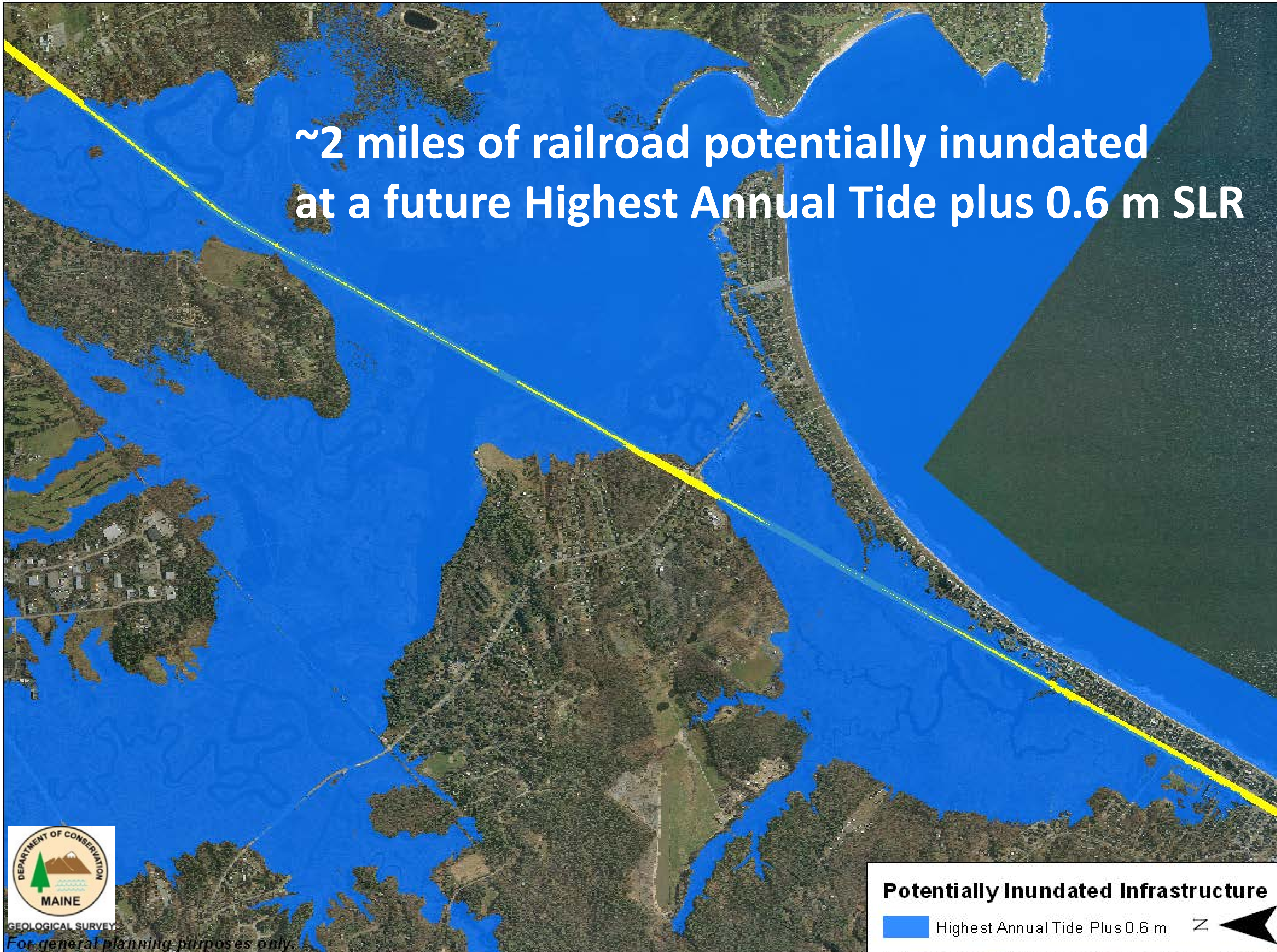
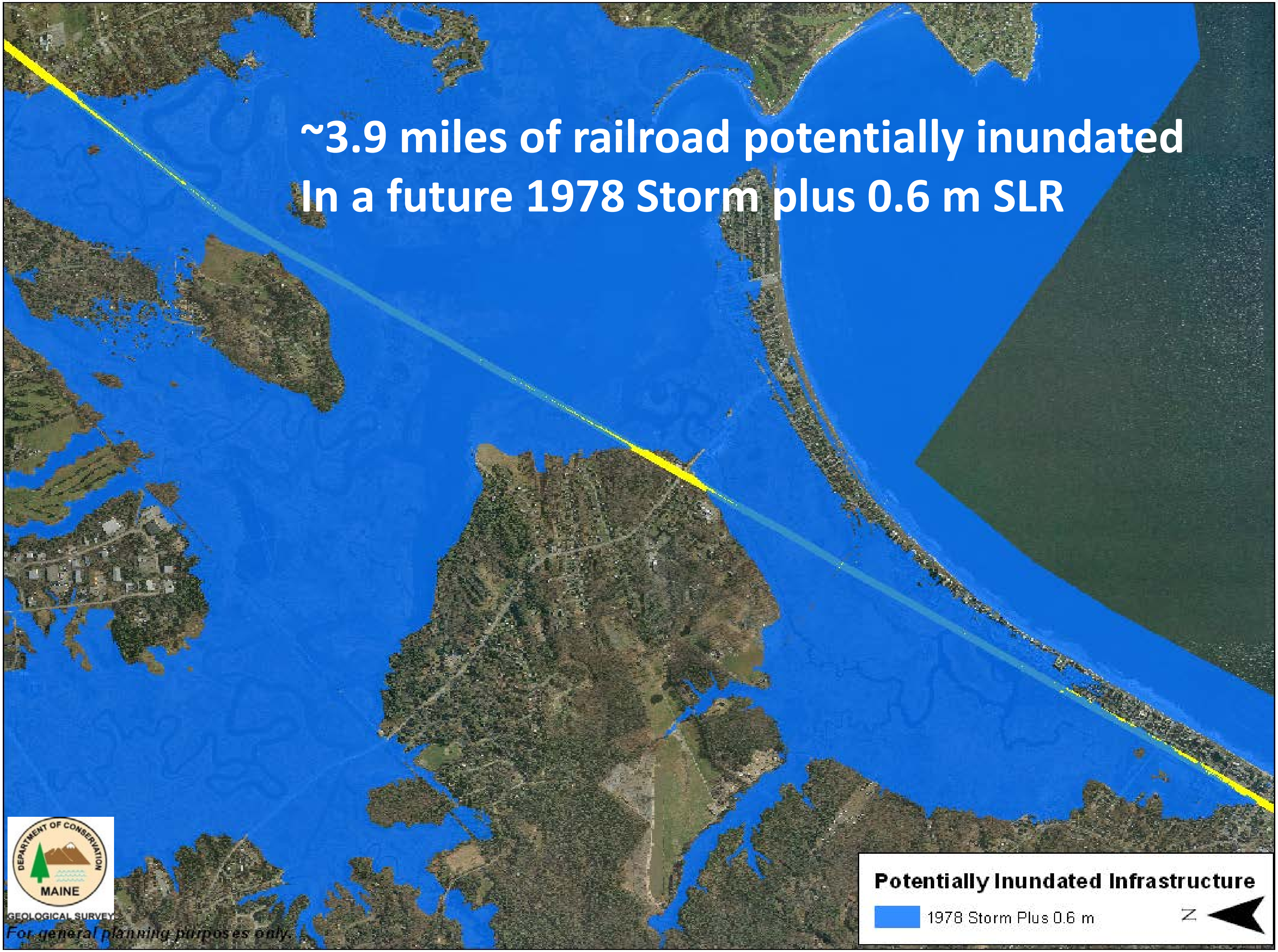
Downeaster Rail Line Scarborough/Old Orchard Beach

~2 miles of railroad potentially inundated at a future Highest Annual Tide plus 0.6 m SLR




~3.9 miles of railroad potentially inundated
In a future 1978 Storm plus 0.6 m SLR
Potentially Inundated Infrastructure
1978 Storm Plus 0.6 m
N
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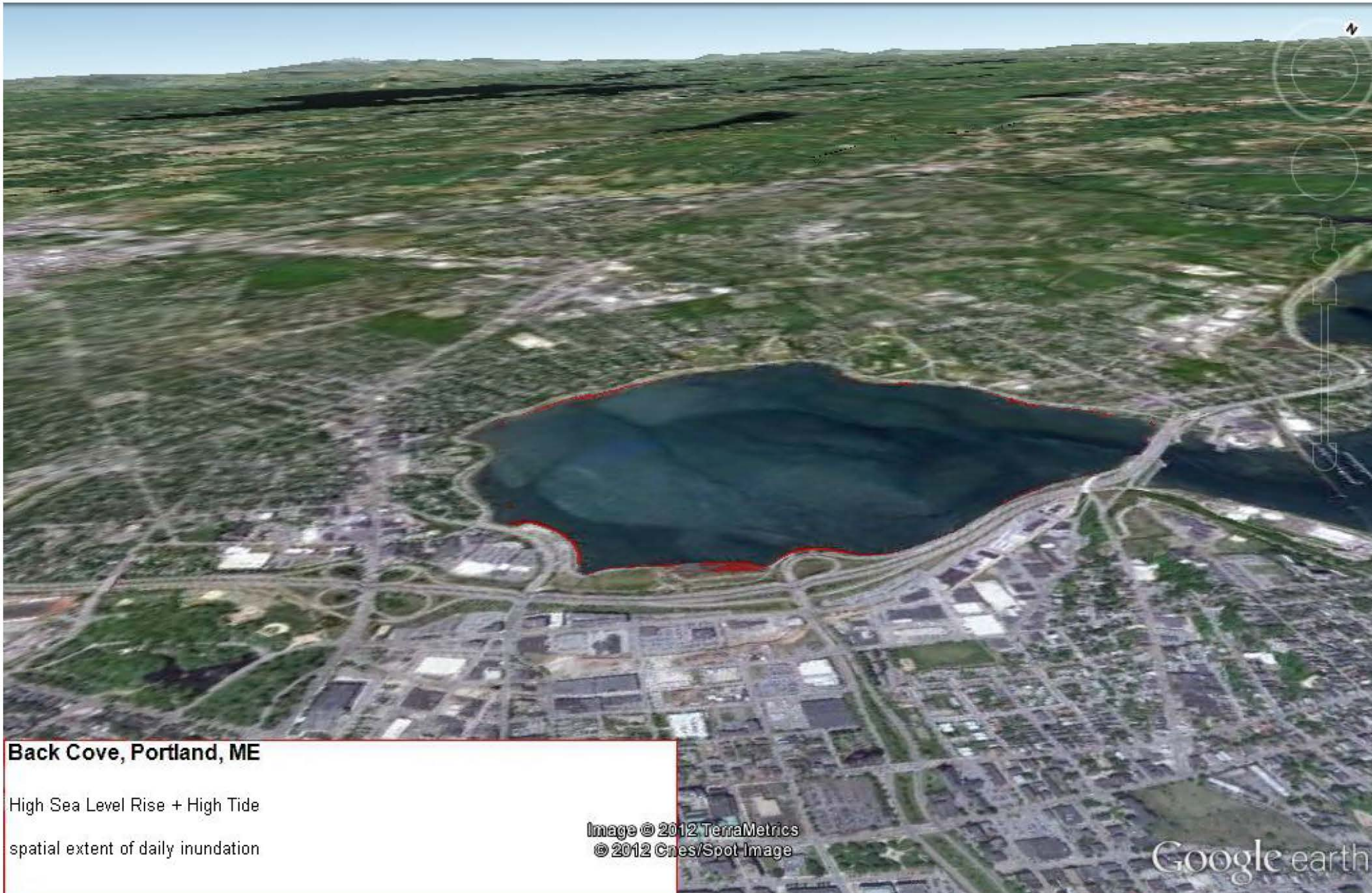
For general planning purposes only.

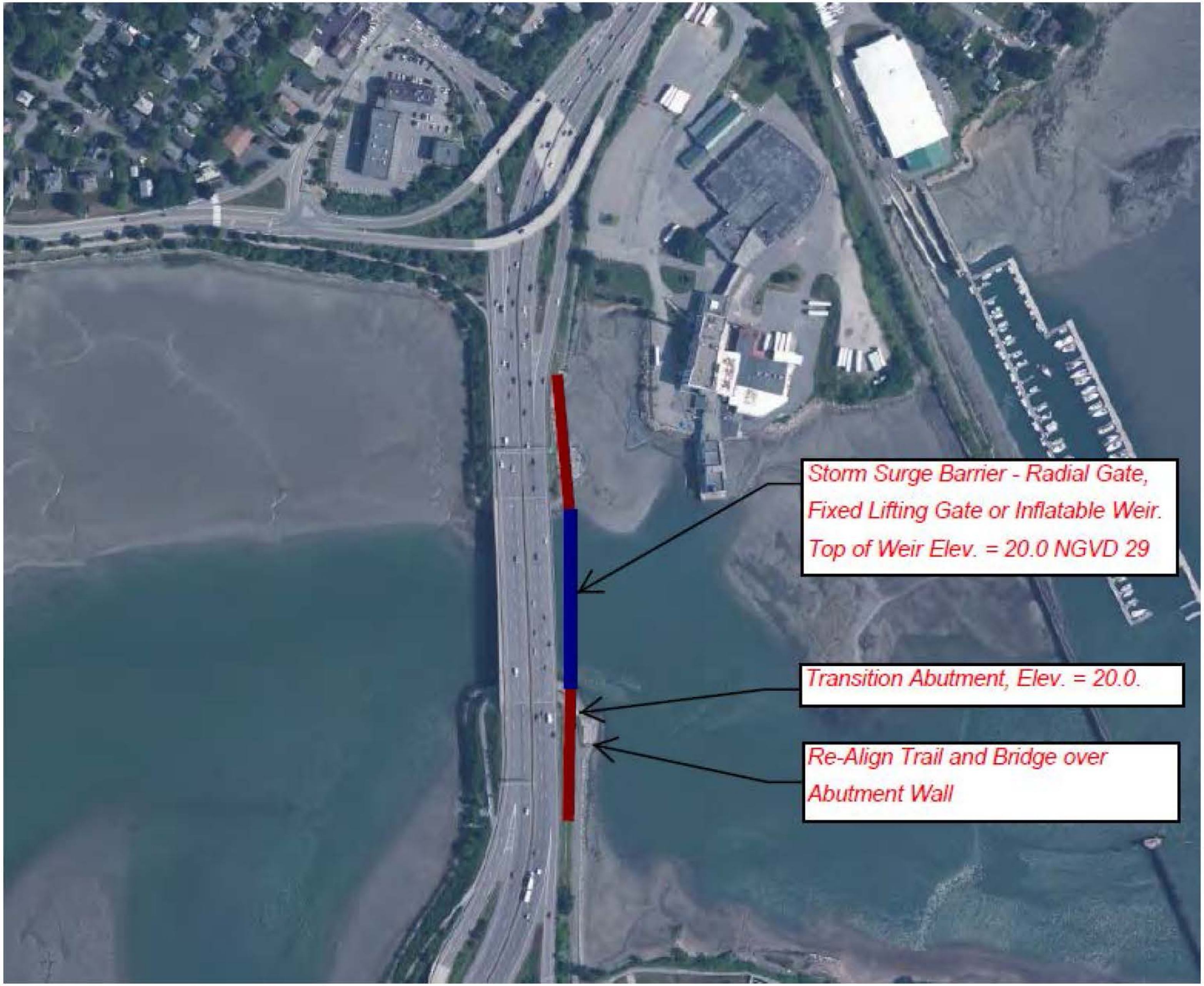
2050, high sea level rise and mean higher high water



2100, high sea level rise and mean higher high water

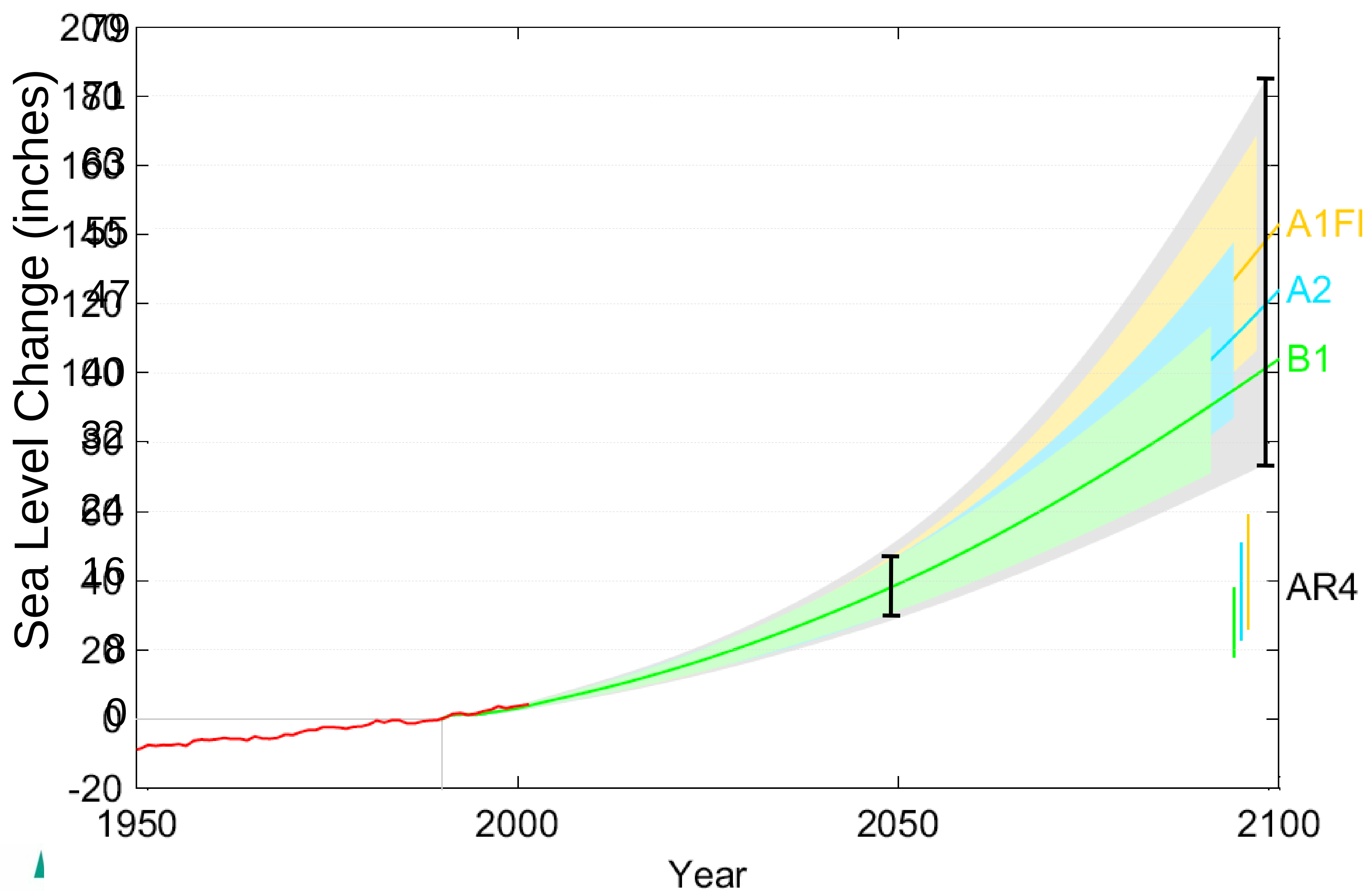
The four options:

1) Do nothing
2) Fortify assets
3) Relocate assets
4) Accommodate higher water levels


Storm Surge Barrier - Radial Gate,
Fixed Lifting Gate or Inflatable Weir.
Top of Weir Elev. = 20.0 NGVD 29
Transition Abutment, Elev. = 20.0.
Re-Align Trail and Bridge over
Abutment Wall

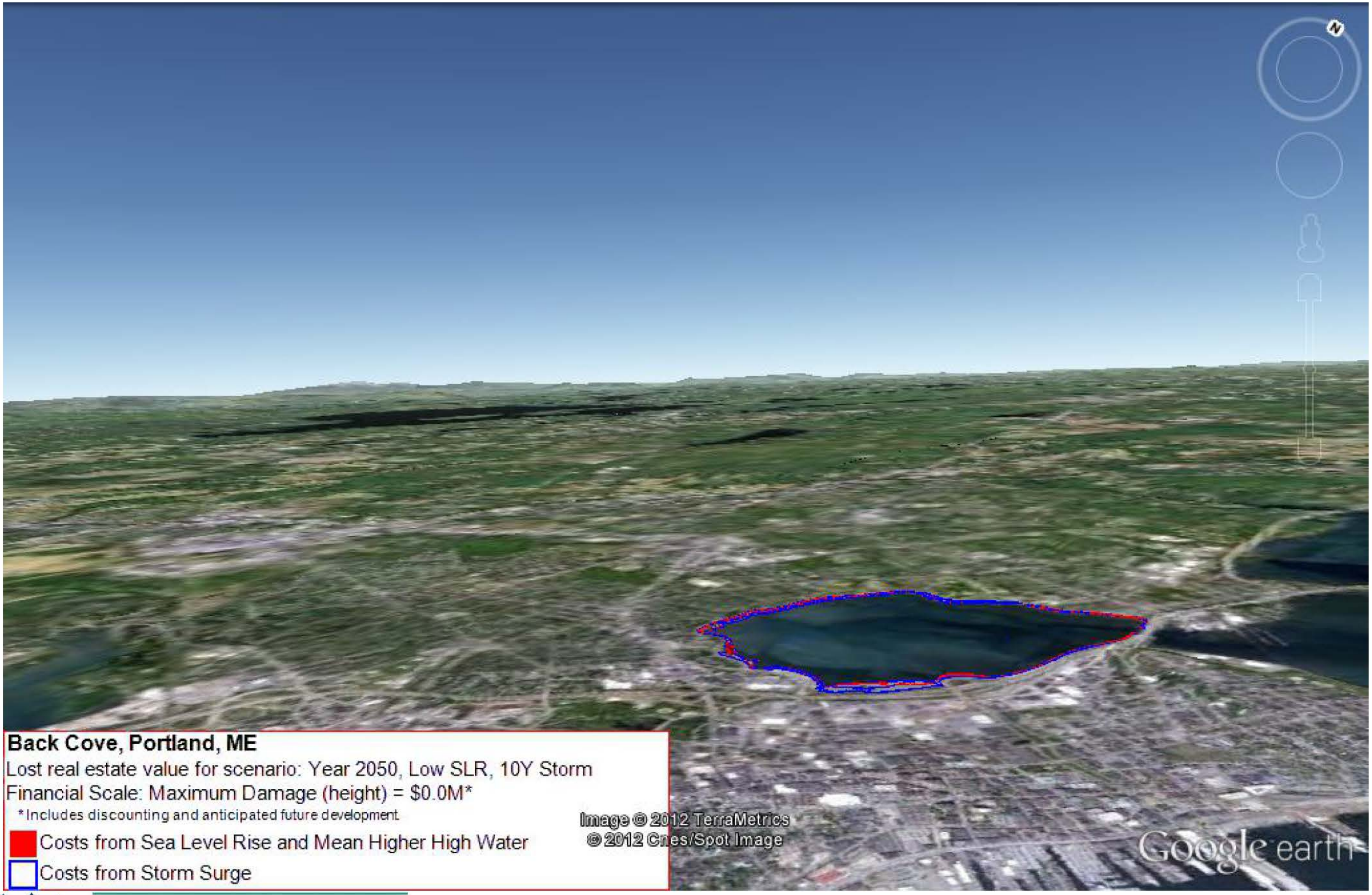
Levee Construction to Include Relocation of Back Bay Trail. Landside Stormwater Management System Also Required.
Storm Surge Barrier - Constructed at 2050 Condition
YEAR 2100 CONDITION
Levee Design Criteria - Mean High Higher Water (MHHW) + Sea Level Rise
Predicted Elevation = 7.85 to 11.30 feet NGVD 29
Levee Construction Expected Year 2100 Condition - Top of Berm Elevation = 14.0 (11.30 feet plus Wave Protection and Freeboard). Storm Surge Addressed at Tukey's Bridge Barrier

Projection of Sea Level Rise from 1990 to 2100

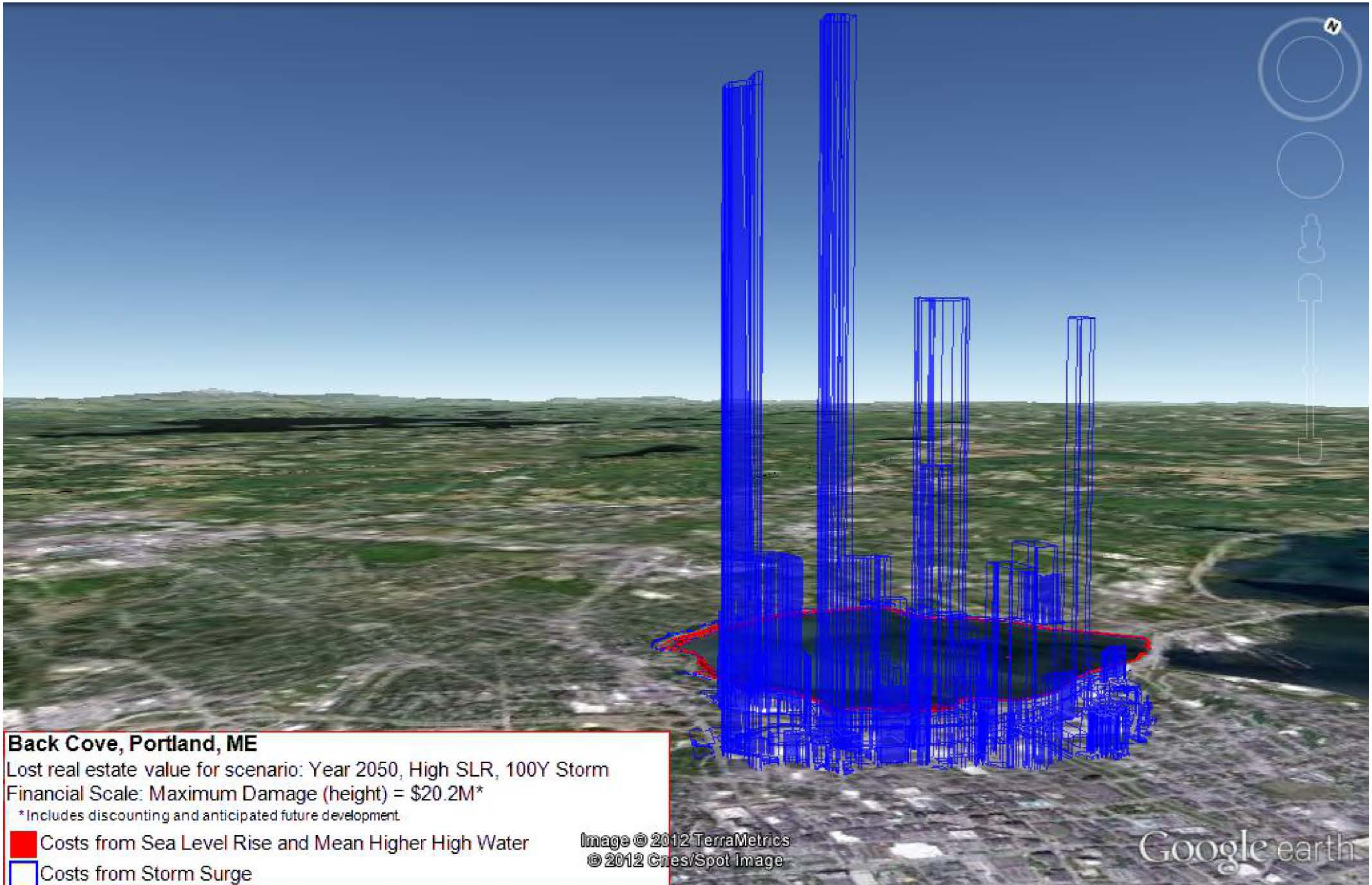


Vermeer and Rahmstorf (2009) Global sea level linked to global temperature. PNAS 106, 21527–21532.

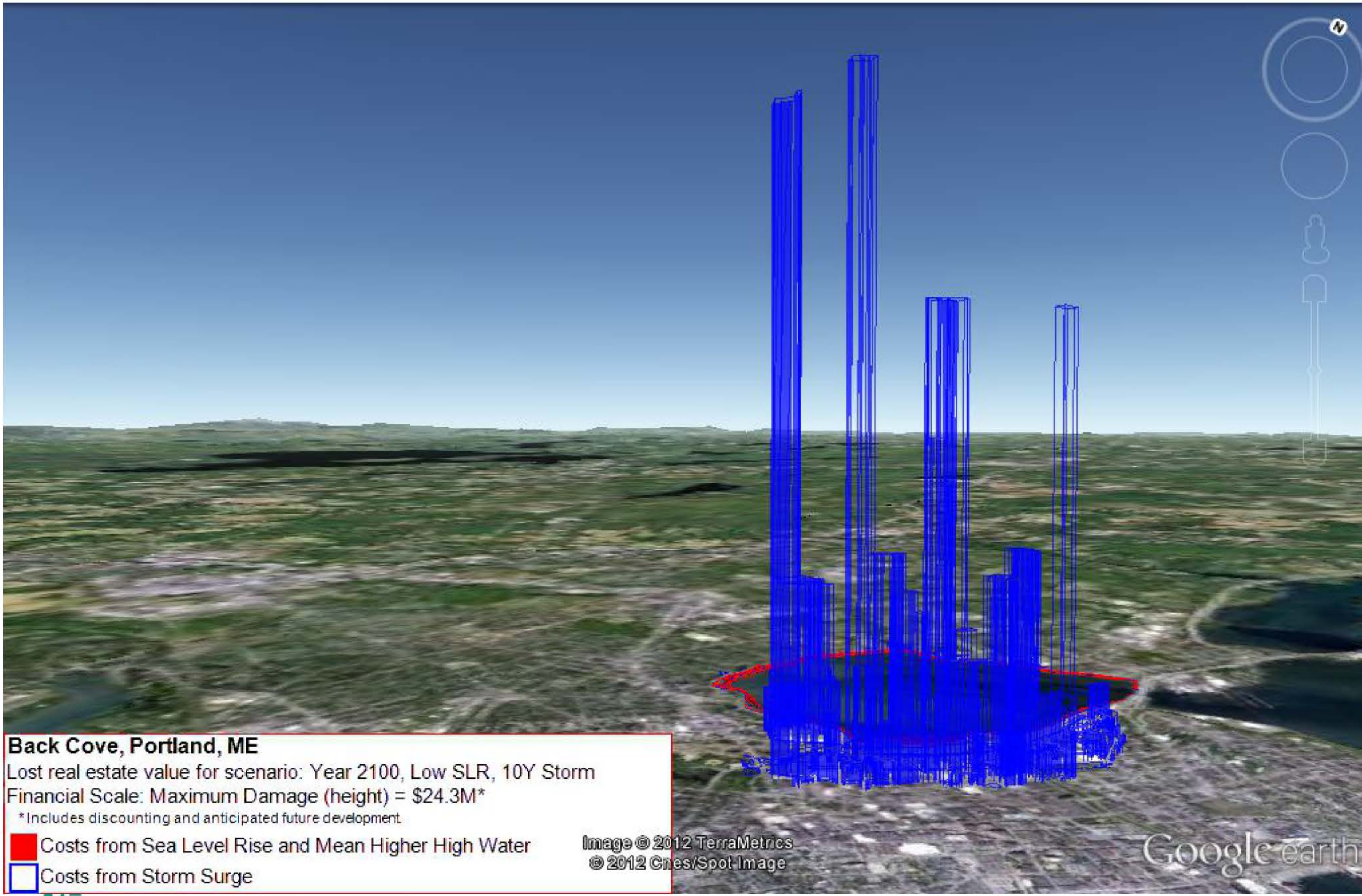
2050, low sea level rise, 10 year storm



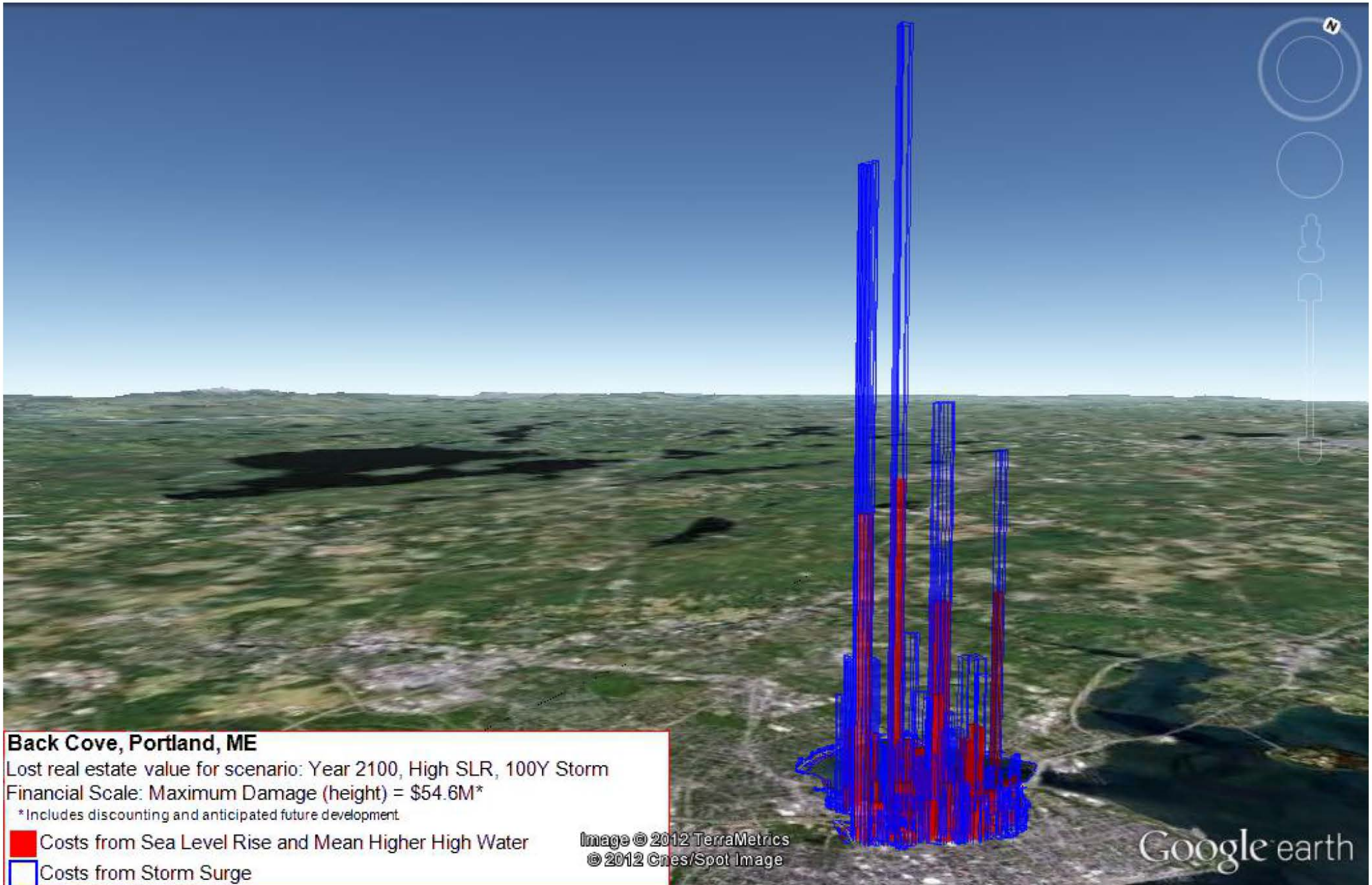
2050, high sea level rise, 100 year storm



2100, low sea level rise, 10 year storm



2100, high sea level rise, 100 year storm



Back Cove, Portland, Maine

Adaptation Costs and Cumulative Expected Damages, through 2050.

2050 SLR Scenario	Adaptation	Cost (M)	Real Estate Damage (M)	Percent of damage from Storm surge	Percent of damage from SLR
No SLR	No Action	$0	$356	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		
Low SLR (7.9")	No Action	$0	$407	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		
High SLR (19.7")	No Action	$0	$447	100%	0%
	Surge Barrier / Levee	$103 / $0	$0		

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Back Cove, Portland, Maine

Adaptation Costs and Cumulative Expected Damages, through 2100.

2100 SLR Scenario	Adaptation	Cost (M)	Real Estate Damage (M)	Percent of damage from Storm surge	Percent of damage from SLR
No SLR	No Action	$0	$1,791	100%	0%
	Surge Barrier / Levee	$0 / $40	$0		
Low SLR (27.6")	No Action	$0	$2,674	97%	3%
	Surge Barrier / Levee	$0 / $40	$0		
High SLR (70.9")	No Action	$0	$3,680	71%	29%
	Surge Barrier / Levee	$0 / $40	$0		

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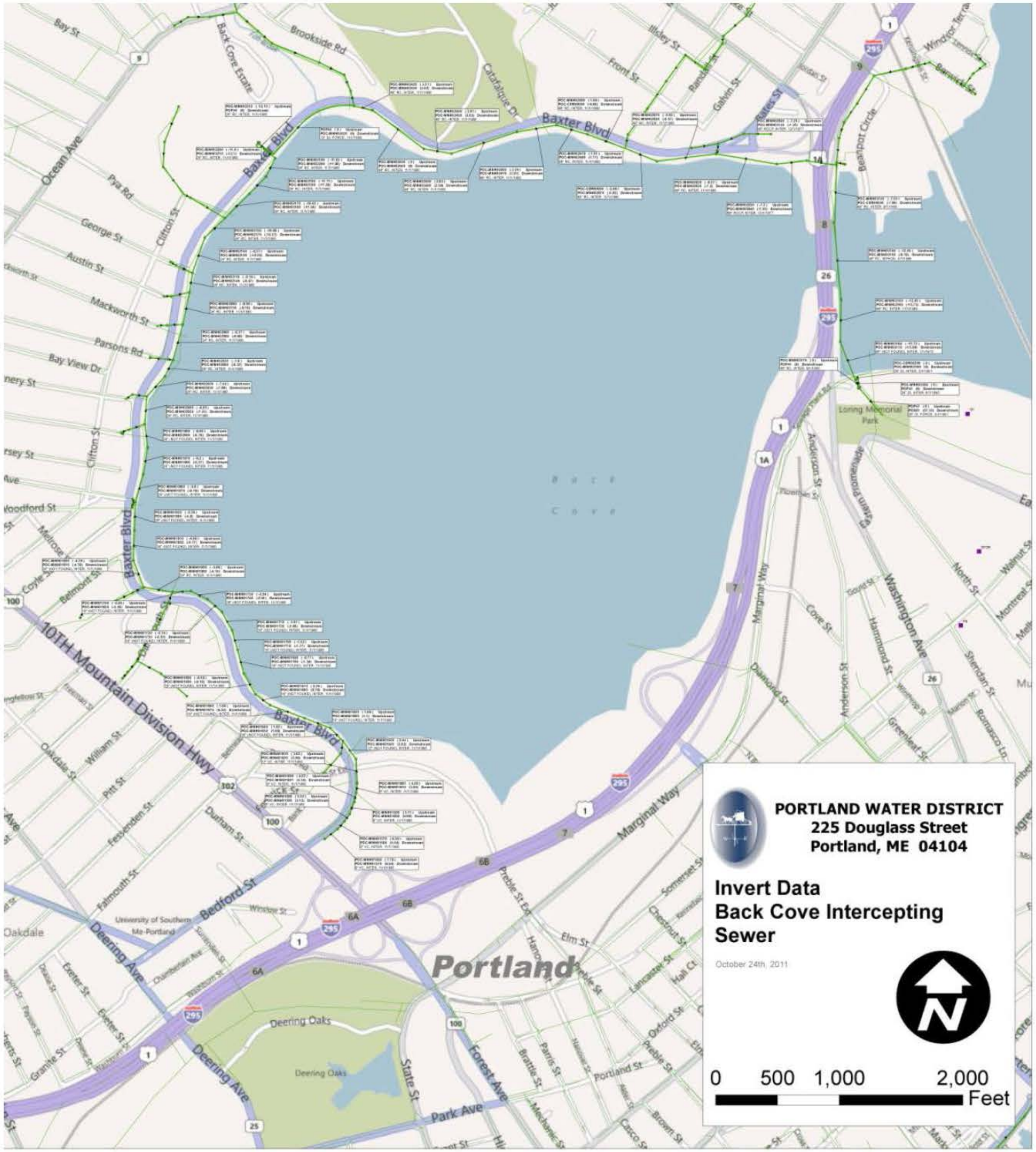
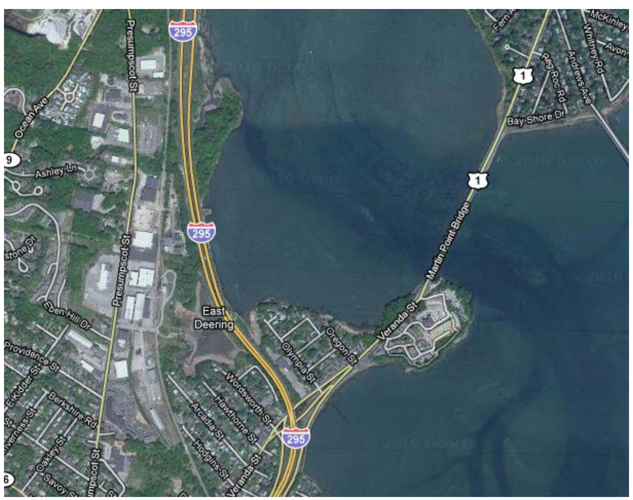

PORTLAND WATER DISTRICT
225 Douglass Street
Portland, ME 04104
Invert Data
Back Cove Intercepting
Sewer
October 24th, 2011
0 500 1,000 2,000
Feet
N
Baxter Blvd
Back Cove
Portland
10TH Mountain Division Hwy
Loring Memorial Park
Deering Oaks
Marginal Way
Washington Ave
Forest Ave
Park Ave
Bedford St
Deering Ave
State St
Ocean Ave
Brookside Rd
Bay St
Front St
Clifton St
Mackworth St
Parsons Rd
Bay View Dr
Woodford St
Elm St
University of Southern Me-Portland
Oakdale

Machias Bridge, Machias

(pressure transducer placed in 8/11)



Martin’s Point Bridge, Falmouth

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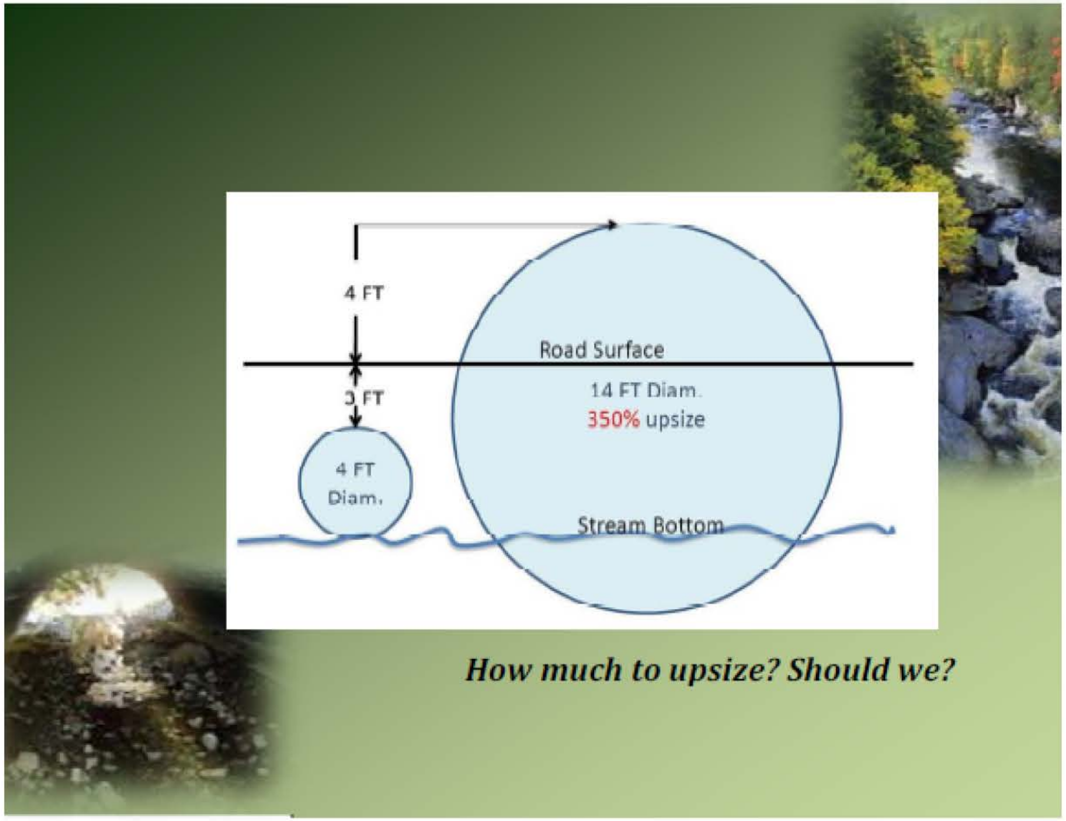
A Financial Impact Assessment of LD 1725: Stream Crossings



Prepared by: The New England Environmental Finance Center
For the Maine Department of Transportation Office of Environmental Planning

Some other potential Transportation Impacts

<u>Scarborough and Old Orchard Beach</u>

Downeaster Rail Line Scarborough/Old Orchard Beach

Wikipedia.com

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MAINE
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Downeaster Rail
Pine Point Rd.
Scarborough
Old Orchard Beach
East Grand Ave.
Eastern Trail
Route 1
Ross Rd.
Walnut St.
Ocean Park
Payne Rd.
DEPARTMENT OF CONSERVATION
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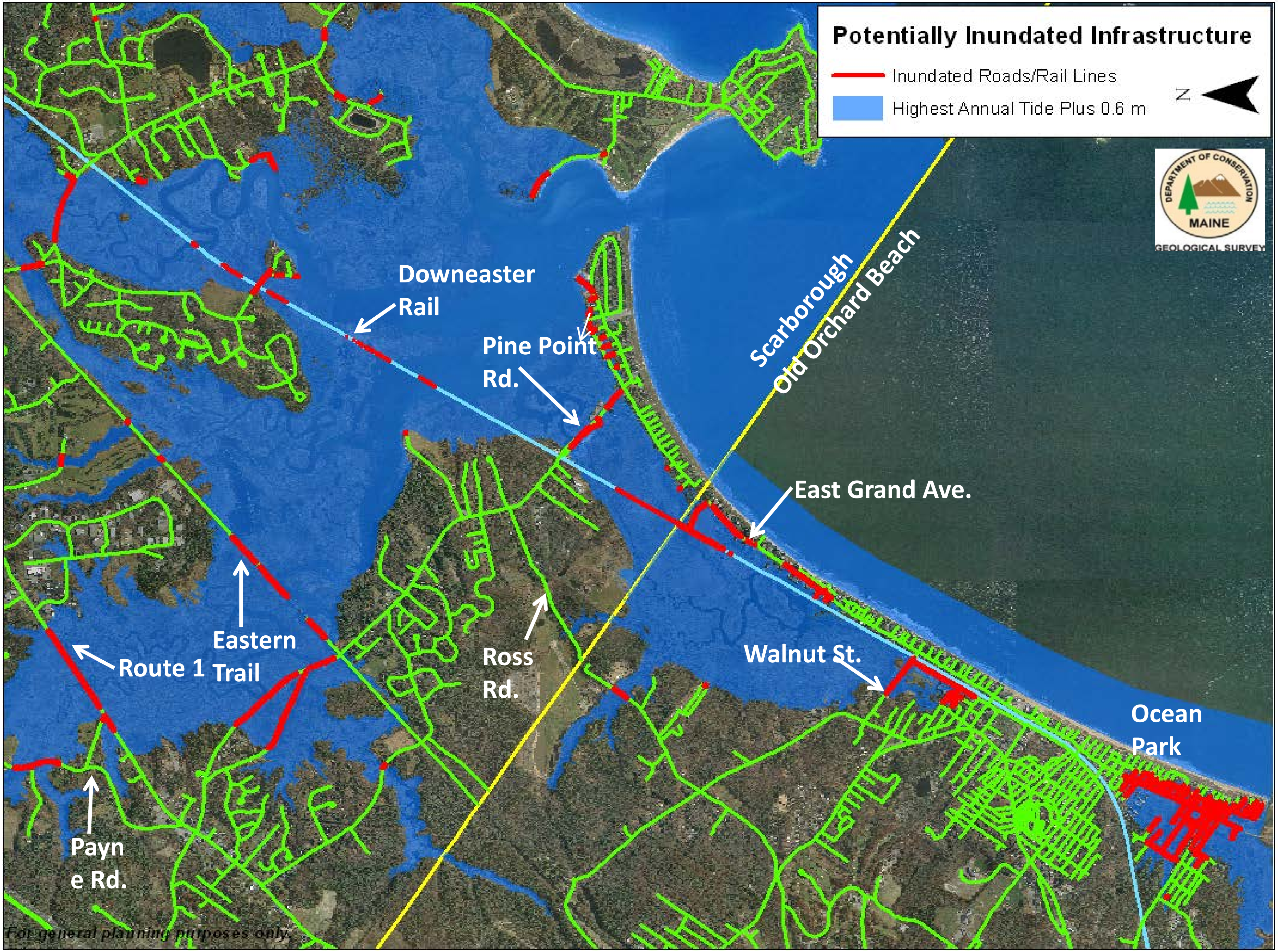
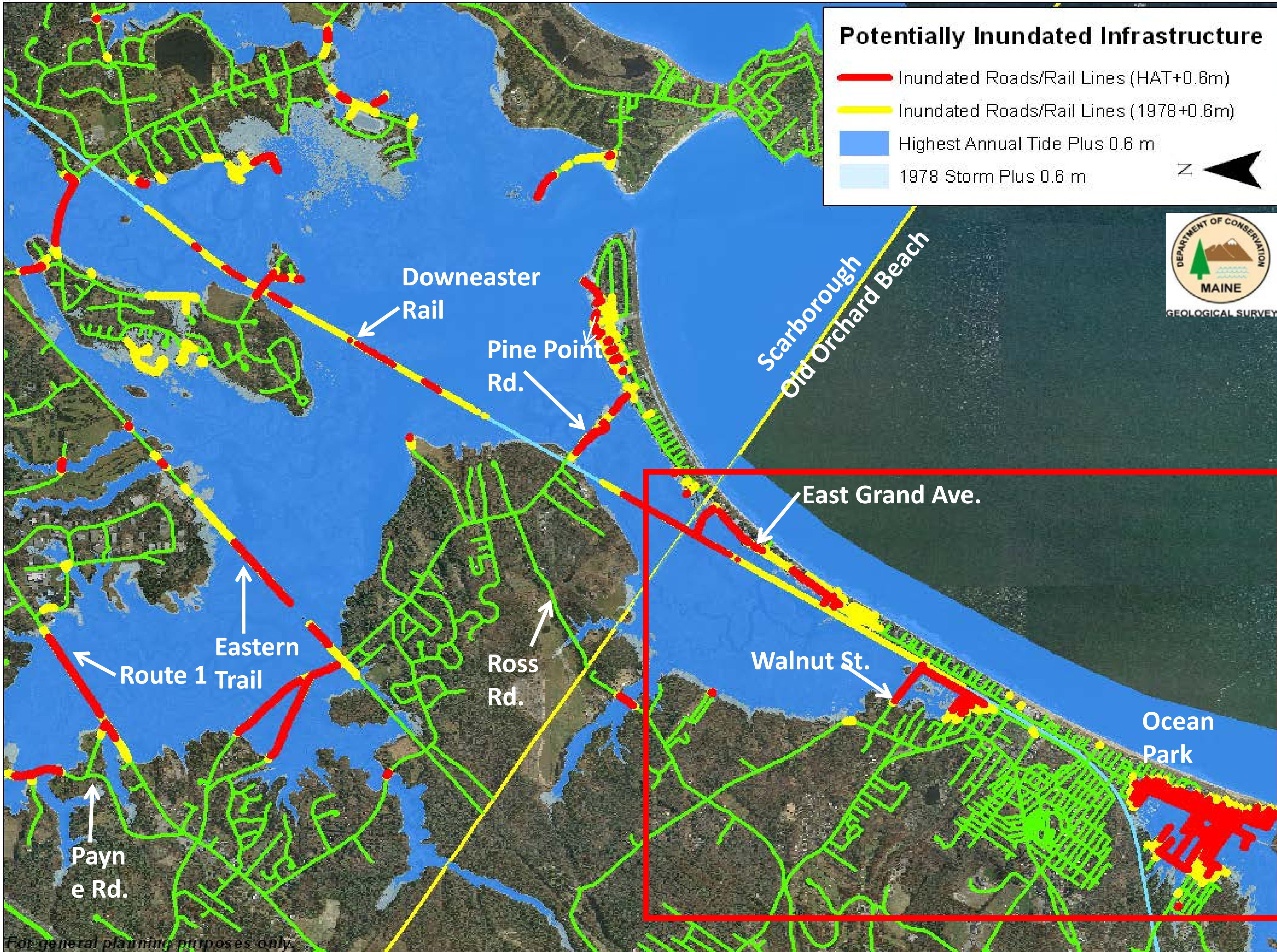
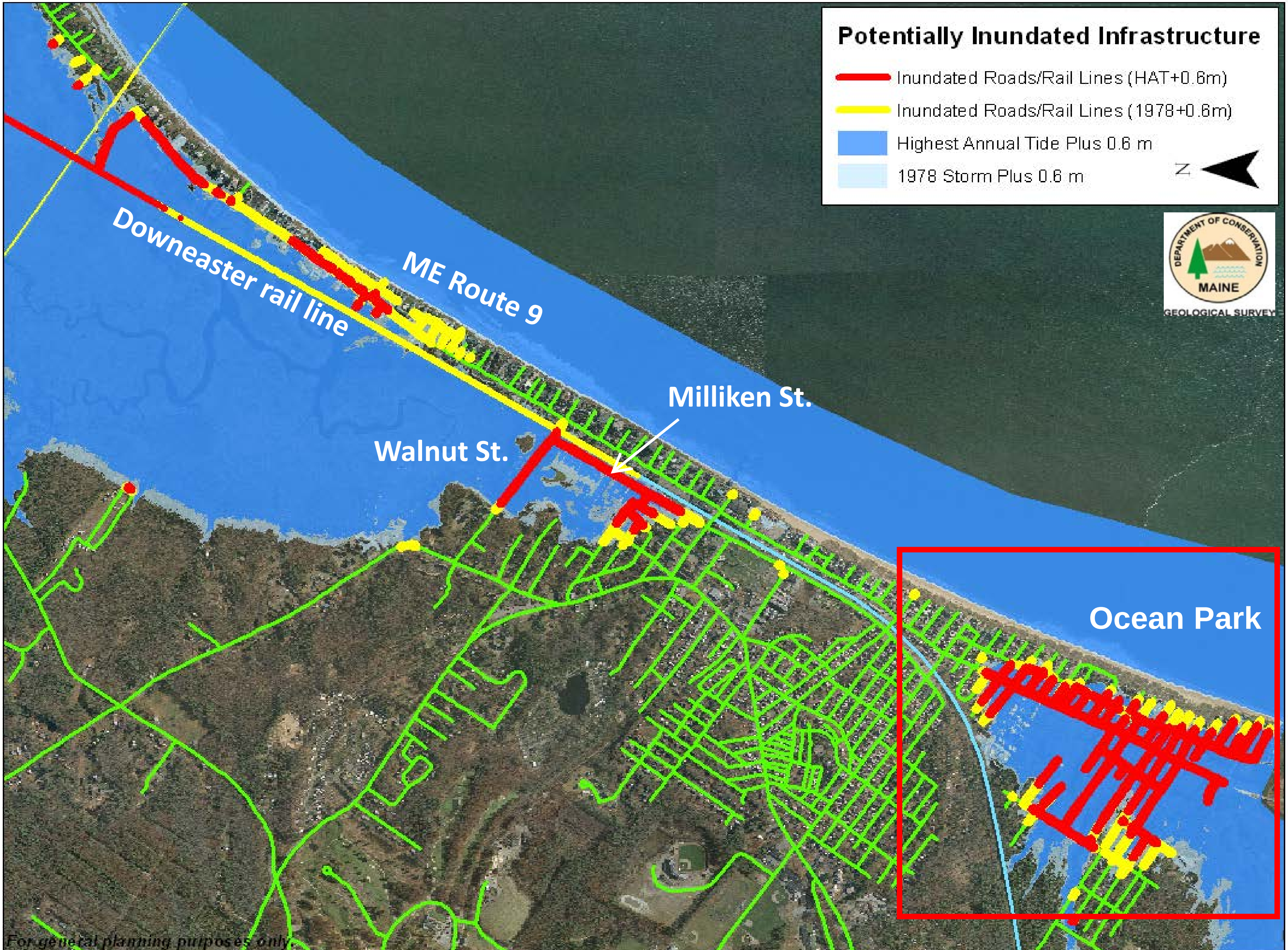
GEOLOGICAL SURVEY
For general planning purposes only.

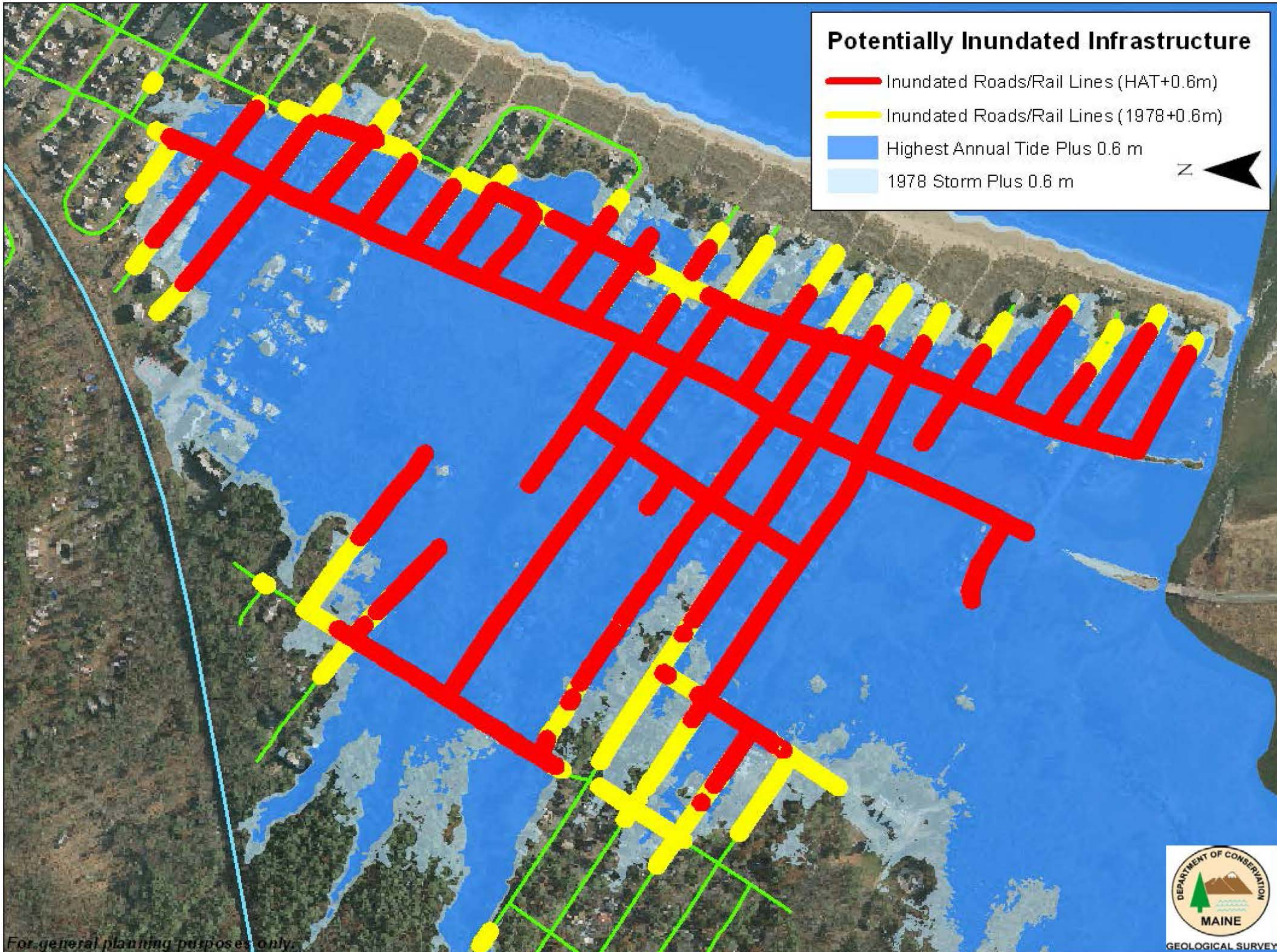


Potentially Inundated Infrastructure
Inundated Roads/Rail Lines
Highest Annual Tide Plus 0.6 m
N
DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY
Downeaster Rail
Pine Point Rd.
Scarborough
Old Orchard Beach
East Grand Ave.
Eastern Trail
Route 1
Ross Rd.
Walnut St.
Ocean Park
Payn e Rd.
For general planning purposes only.

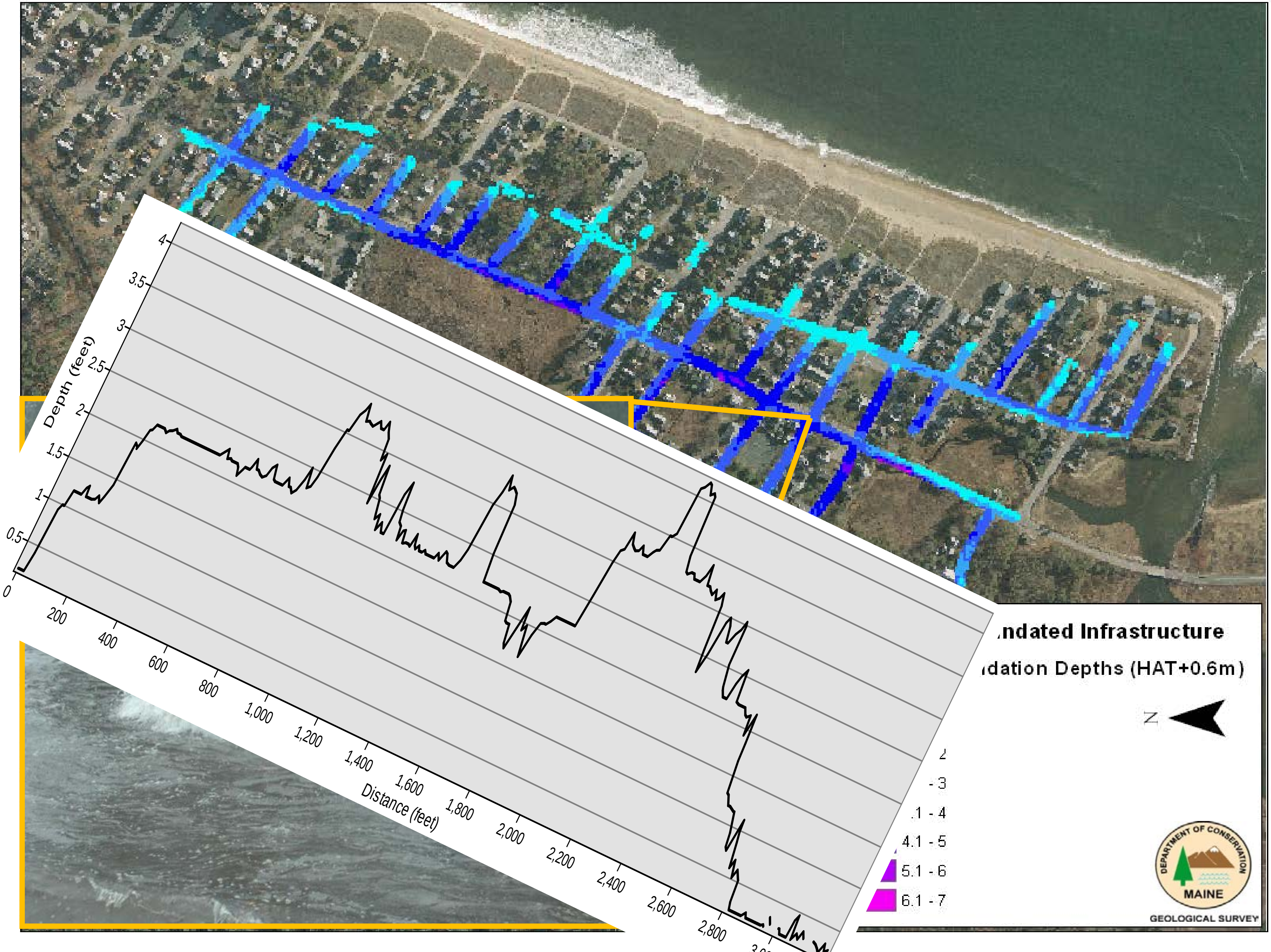

Potentially Inundated Infrastructure
Inundated Roads/Rail Lines (HAT+0.6m)
Inundated Roads/Rail Lines (1978+0.6m)
Highest Annual Tide Plus 0.6 m
1978 Storm Plus 0.6 m
N
DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY
Downeaster Rail
Pine Point Rd.
Scarborough
Old Orchard Beach
East Grand Ave.
Eastern Trail
Route 1
Ross Rd.
Walnut St.
Ocean Park
Payne Rd.
For general planning purposes only.



Potentially Inundated Infrastructure
Inundated Roads/Rail Lines (HAT+0.6m)
Inundated Roads/Rail Lines (1978+0.6m)
Highest Annual Tide Plus 0.6 m
1978 Storm Plus 0.6 m
N
DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY
Downeaster rail line
ME Route 9
Milliken St.
Walnut St.
Ocean Park
For general planning purposes only.


Potentially Inundated Infrastructure
Inundated Roads/Rail Lines (HAT+0.6m)
Inundated Roads/Rail Lines (1978+0.6m)
Highest Annual Tide Plus 0.6 m
1978 Storm Plus 0.6 m
N
For general planning purposes only.
DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY


Potentially Inundated Infrastructure
Potential Inundation Depths (HAT+0.6m)
feet
0 - 1
1.1 - 2
2.1 - 3
3.1 - 4
4.1 - 5
5.1 - 6
6.1 - 7
N
DEPARTMENT OF CONSERVATION
MAINE
GEOLOGICAL SURVEY
WEST GRAND


ndated Infrastructure
dation Depths (HAT+0.6m)
N
2
- 3
.1 - 4
4.1 - 5
5.1 - 6
6.1 - 7
DEPARTMENT OF CONSERVATION
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GEOLOGICAL SURVEY
Depth (feet)
0
0.5
1
1.5
2
2.5
3
3.5
4
Distance (feet)
200
400
600
800
1,000
1,200
1,400
1,600
1,800
2,000
2,200
2,400
2,600
2,800

Conclusions on Saco Bay Transportation Infrastructure

Under a future scenario of HAT + 2 feet…

- **Over 11 miles (1.9%) of roads would be potentially impassable**
- **About 2 miles of rail line would be potentially inundated**

Under a future scenario of 1978 storm + 2 feet…

- **Over 26 miles (4.5%) of roads would be potentially impassable**
- **Almost 4 miles of rail line would be potentially inundated**

* Assumes "bathtub" flooding, static topography, and that a road is "inundated" if the flooding scenario **covers** the entire road, regardless of the flooding depth. Does not assign any kind of damage function.

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<u>Some Potential</u>
Adaptation Strategies


Consider engineering methods for storm surge protection
New England Environmental Finance Center
Stamford, CT
USACE

Consider elevating or retrofitting vulnerable infrastructure, including roads, culverts and bridges

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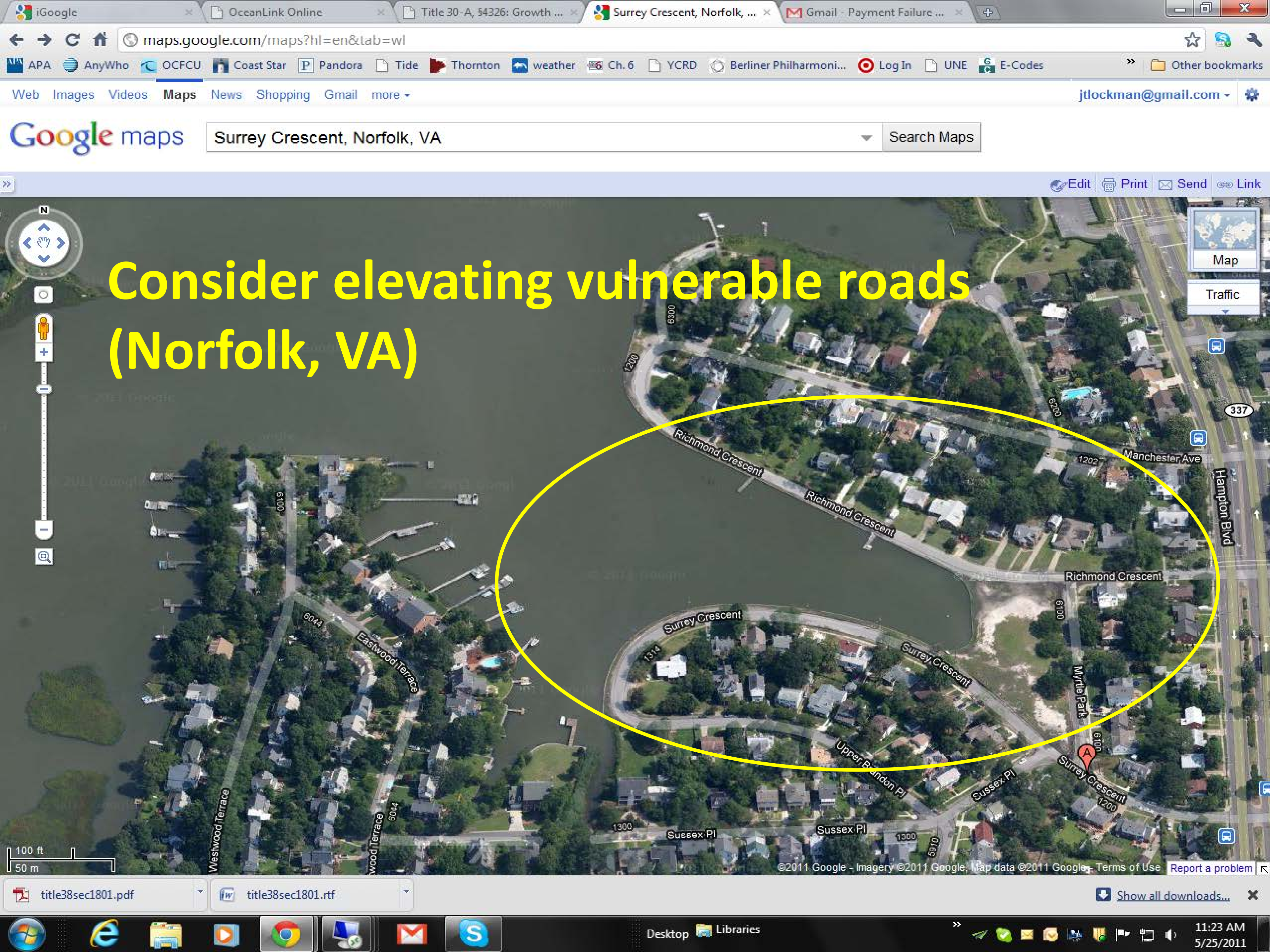
Consider elevating vulnerable roads (Norfolk, VA)



Customizing Depth Damage Functions, e.g.:

- Tiered costing, such as by road substrate and surface.
- Structured, probabilistic increases in failure rate.
- Use of other metrics instead of depth, such as asphalt temperature (inverse proxy for stiffness).

Consider the use of tidal flow control techniques

P.A. Slovinsky, MGS

Consider removing or enhancing tidal restrictions and ensure proper culvert sizing

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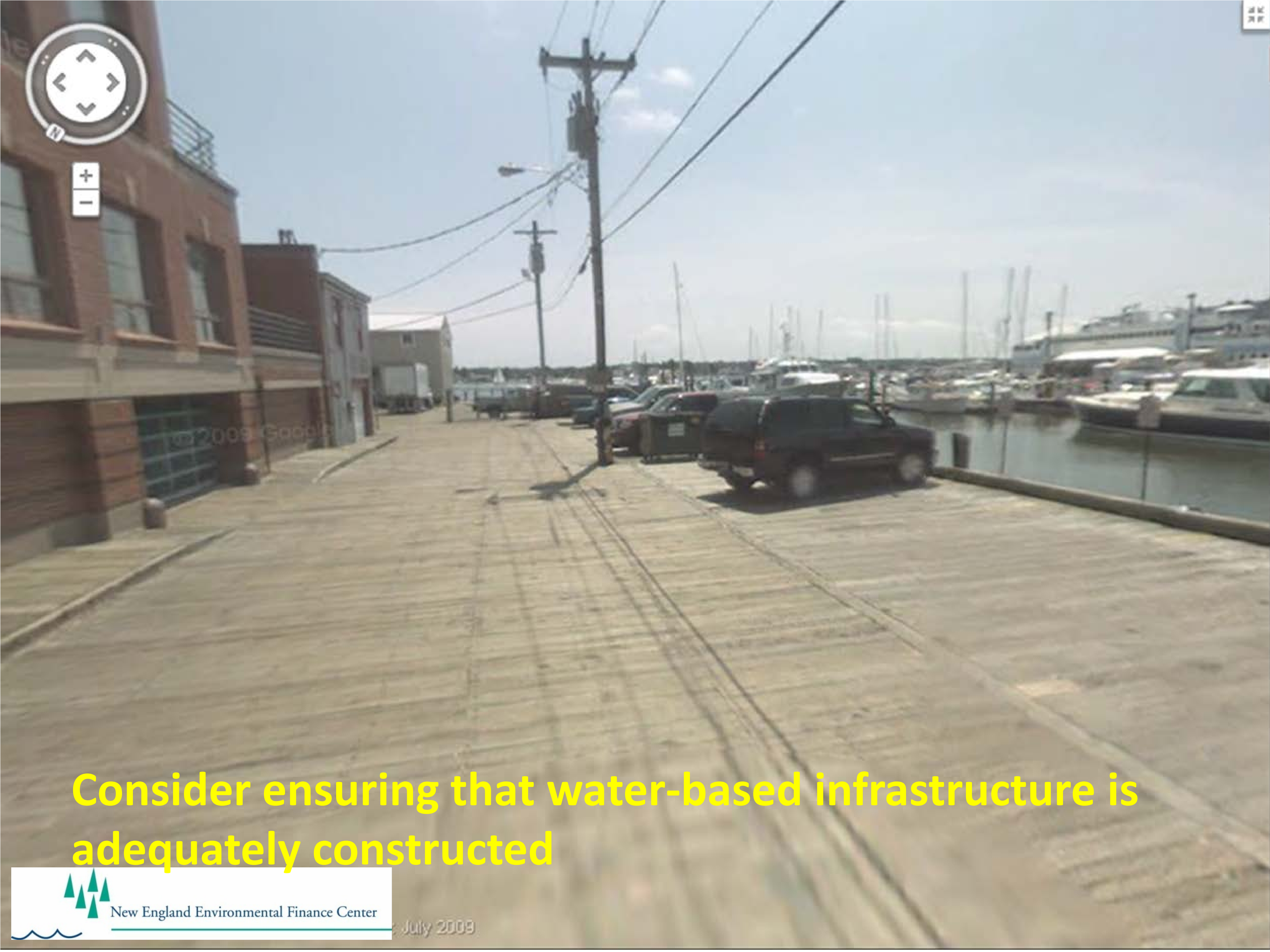
Consider retrofitting storm drains against tidal flow

Curtis Bohlen, CBEP


Levee Construction to Include Relocation of Back Bay Trail. Landside Stormwater Management System Also Required.
Storm Surge Barrier - Constructed at 2050 Condition
YEAR 2100 CONDITION
Levee Design Criteria - Mean High Higher Water (MHHW) + Sea Level Rise
Predicted Elevation = 7.85 to 11.30 feet NGVD 29
Levee Construction Expected Year 2100 Condition - Top of Berm Elevation = 14.0 (11.30 feet plus Wave Protection and Freeboard). Storm Surge Addressed at Tukey's Bridge Barrier

New



Consider ensuring that water-based infrastructure is adequately constructed

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P.A. Slovinsky, MGS

Consider increasing Minimum Floodplain Requirements

Consider increasing "freeboard" to include sea level rise (i.e., 3 feet above the 100 year BFE); results in lower insurance costs!

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Learn the alchemy
True human beings know.
The moment you accept
what troubles you’ve been given,
The door will open.

- Jalallabad Rumi, 13th Century Persia

Facing the bluntness of reality is the highest form of sanity and enlightened vision.

- Chogyam Trungpa Rinpoche