Coastal Flood Inundation Mapping and Climate Change

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Coastal Flood Inundation Mapping and Climate Change

Abstract:

Coastal flood inundation maps are valuable to both local and regional managers as well as individual property owners. It is generally well known now that the go-to dataset, FEMA Q3 flood maps, can be assumed to be both conservative in scope and spatially inaccurate. Equally importantly, this dataset is rapidly becoming temporally inaccurate due to climate-induced sea level rise (SLR).

In this presentation I summarize these constraints and discuss the basics of sea level rise science. I also present a compilation of DEM geoprocessing techniques use to generate coastal flood maps, and how well these techniques facilitate the modeling of coastal inundation phenomena.

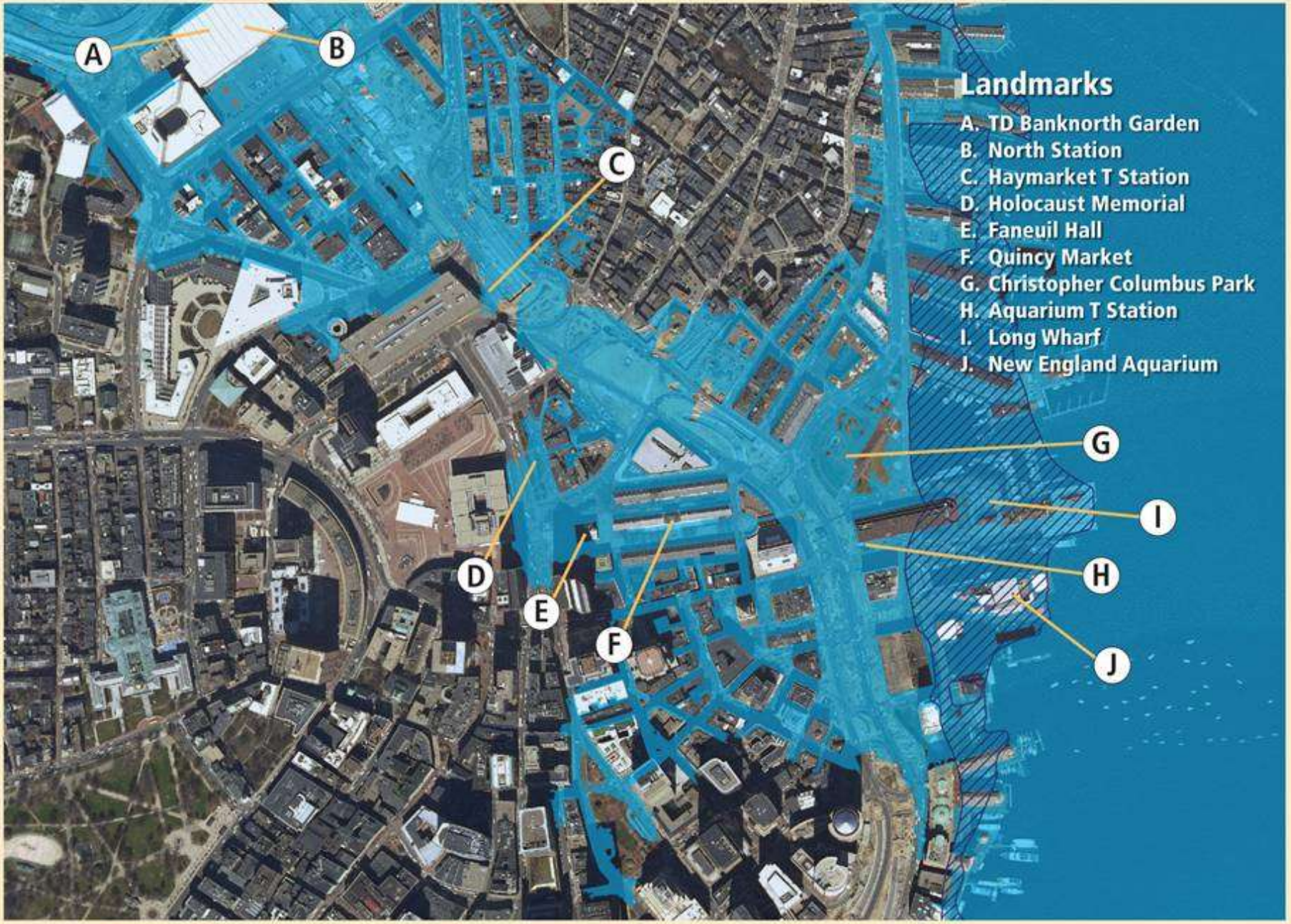
Coastal Flood Inundation Mapping and Climate Change

- Background and Current Research
- FEMA Q3 Flood Maps
- Sea Level Rise and Coastal Flooding
- DEMs and Coastal Flood Inundation Mapping
- Other Techniques and Datasets

Hyperlinks Included:
NorthEast Arc Users Group

Coastal Flooding and Climate Change

- **Northeast Climate Impacts Assessment**
  - www.northeastclimateimpacts.org
  - www.climatechoices.org/ne
  - **Kirshen, et al., 2008 (PDF)**
    - ***Coastal flooding in the Northeastern United States due to climate change*, Mitigation and Adaptation Strategies for Global Change, vol. 13, June 2008**
      - Special Issue: Assessment of Climate Change, Impacts, and Solutions in the Northeast United States
    - **Additional technical background (PDF)**

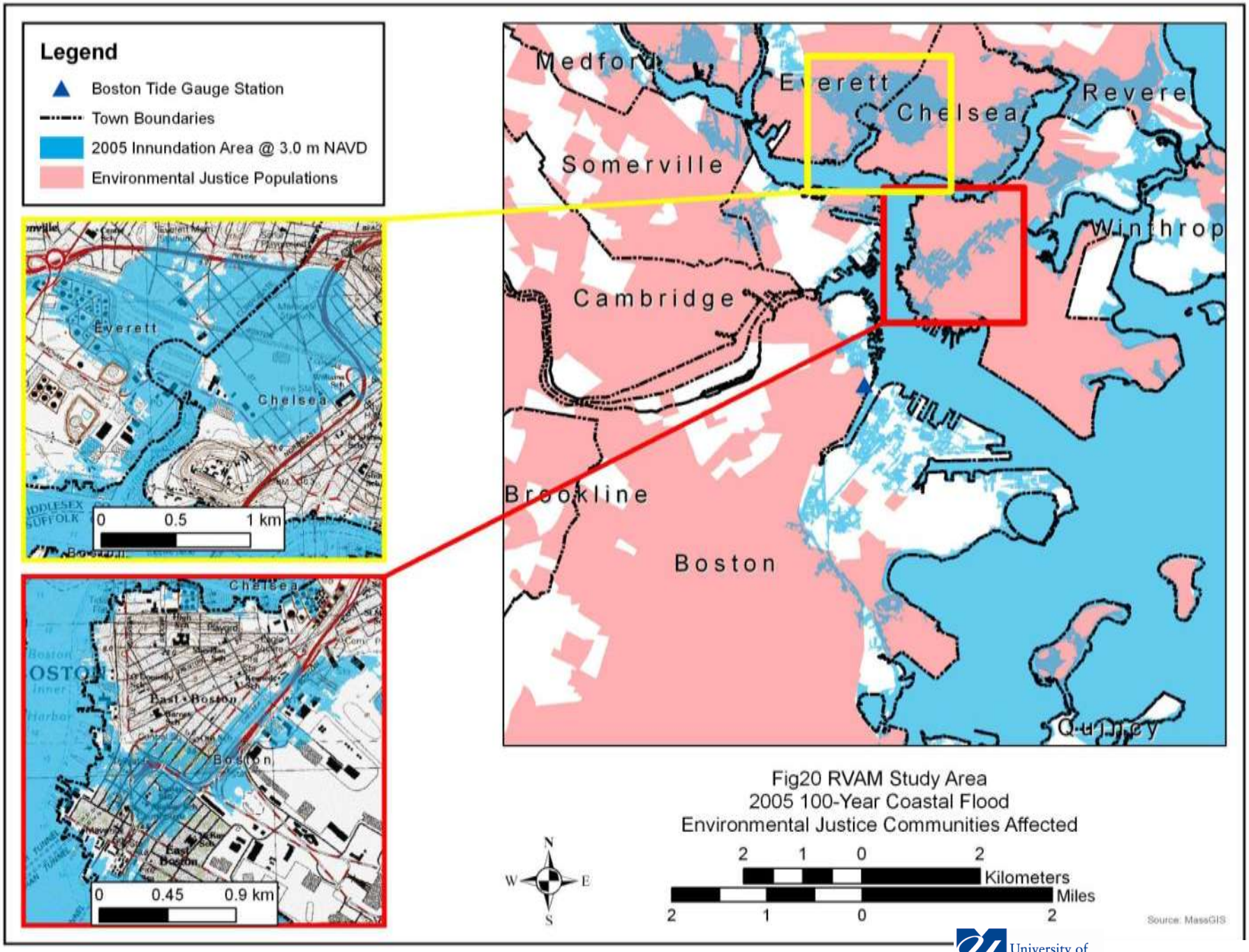


Union of Concerned Scientists

Source: NECIA, 2007 (see: www.climatechoices.org/ne)

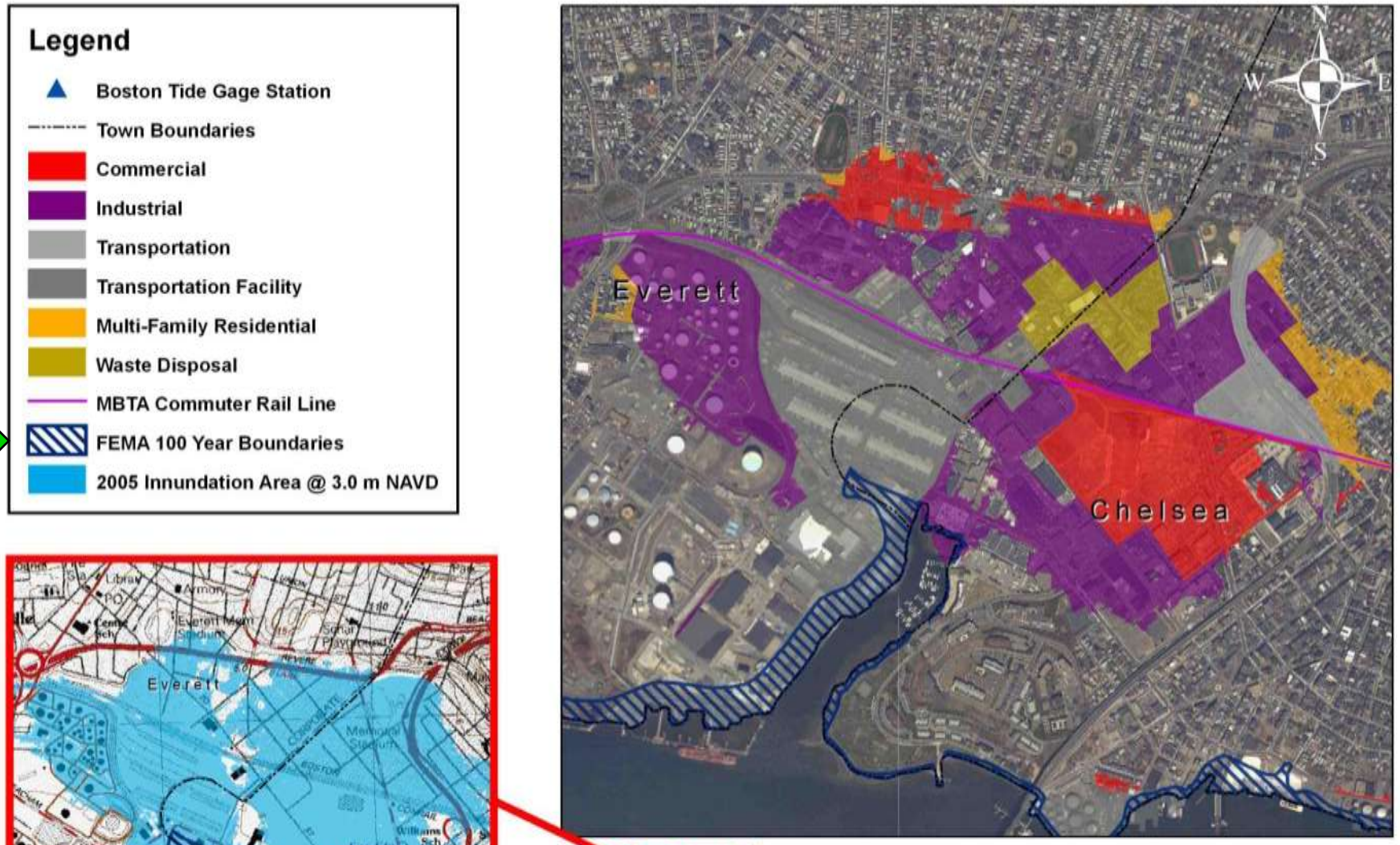
Coastal Flooding and Climate Change

- Watson, 2007
  - ***Assessing the Vulnerability of Metropolitan Boston to Increased Coastal Flooding due to Sea Level Rise***
    - Risk and Vulnerability Assessment Mapping (RVAM)
    - Master's Project, University of Massachusetts Boston
- Douglas, et al., to be published in 2010
  - ***Coastal Flooding and Environmental Justice: Developing Strategies for Adapting to Climate Change***
    - Two-year participatory research funded by NOAA Climate Program Office's Sectoral Applications Research Program
      - UMass Boston, Tufts and UMaryland College Park
      - Study Areas: Metro Boston and Maryland's Eastern Shore



University of Massachusetts Boston

Source: Watson, 2007



University of Massachusetts Boston

Source: Watson, 2007

FEMA Q3 Flood Maps

- FEMA Q3 Flood @ MassGIS

IMPORTANT NOTE: IT IS NOT APPROPRIATE TO USE THIS DATALAYER FOR LARGE-SCALE (DETAILED, E.G. PARCEL LEVEL) MAPPING AND ANALYSIS. PLEASE READ ALL DOCUMENTATION PROVIDED BY FEMA TO ENSURE YOU UNDERSTAND THE PROPER USE OF THESE DATA.

http://www.mass.gov/mgis/q3.htm, accessed 10-May-2009

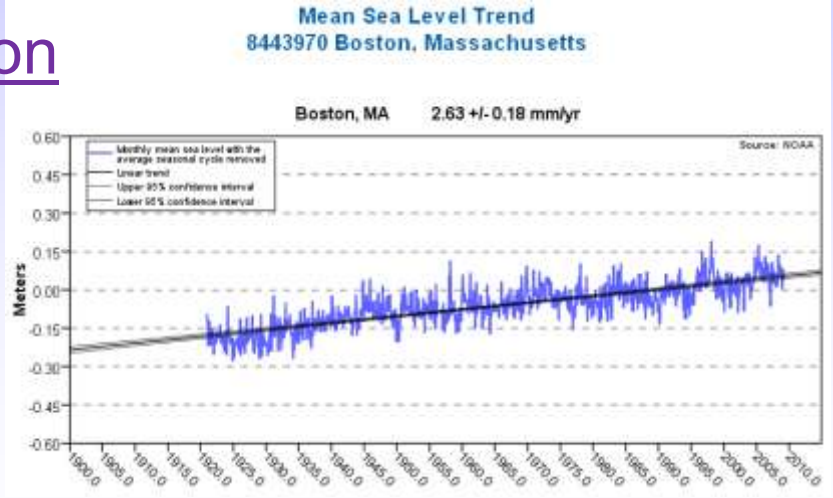
  - Polygon shapefiles representing horizontal boundaries of flood zones
    - Electronic version of Flood Insurance Rate Maps (FIRMs)
    - Available from some other state's GIS
      - Or, purchase directly from FEMA Map Service Center
  - FIRMs
    - Critical jurisdictional boundaries
    - Spatially inaccurate
    - Increasingly temporally inaccurate

FEMA Q3 Flood Maps

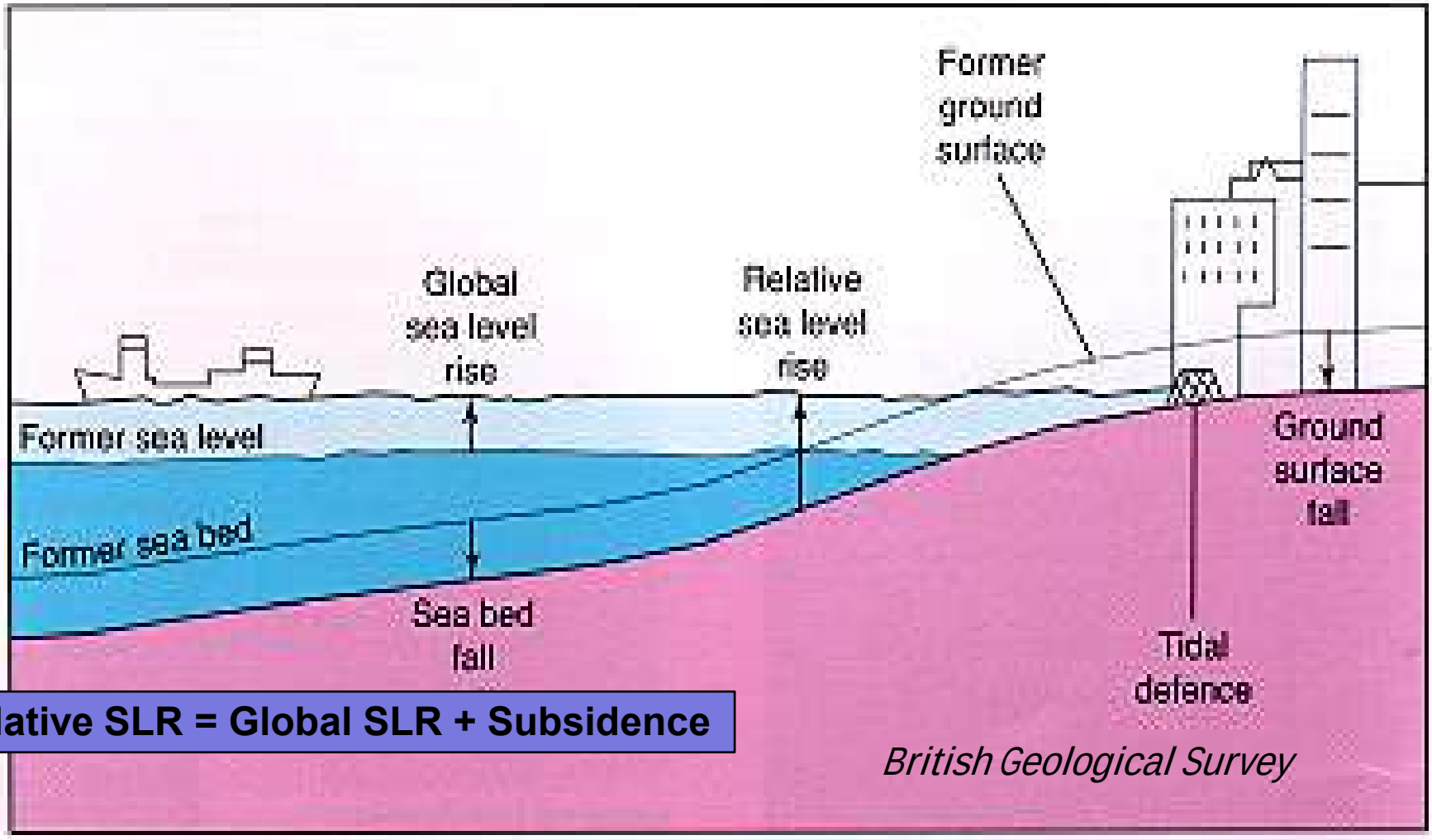
- Spatially Inaccurate
  - Digitized from paper source maps (FIRMs)
  - FIRMs based on topography published on paper USGS topo maps
    - Topography generated using stereophotogrammetry
- Digital FIRMs (DFIRMs) and FEMA Flood Map Modernization Program (recent MGIC seminar)
  - Enhancements in process but limited in availability
  - Mapping the Zone: Improving Flood Map Accuracy
    - Currently available as prepublication version only

FEMA Q3 Flood Maps

- Temporally Inaccurate
  - Inland riverine flood zones sensitive to increased flood frequency and intensity due to climate change
  - Coastal flood zones sensitive to SLR
    - Increases in coastal storm frequency and intensity are still uncertain
    - Historical Relative SLR in Boston
      - ~ 10 inches over past 100 years
        - ~ 4 inches due to subsidence
    - Future SLR in Boston
      - Interactive SLR Graphic
      - Climate Change @ Boston Globe



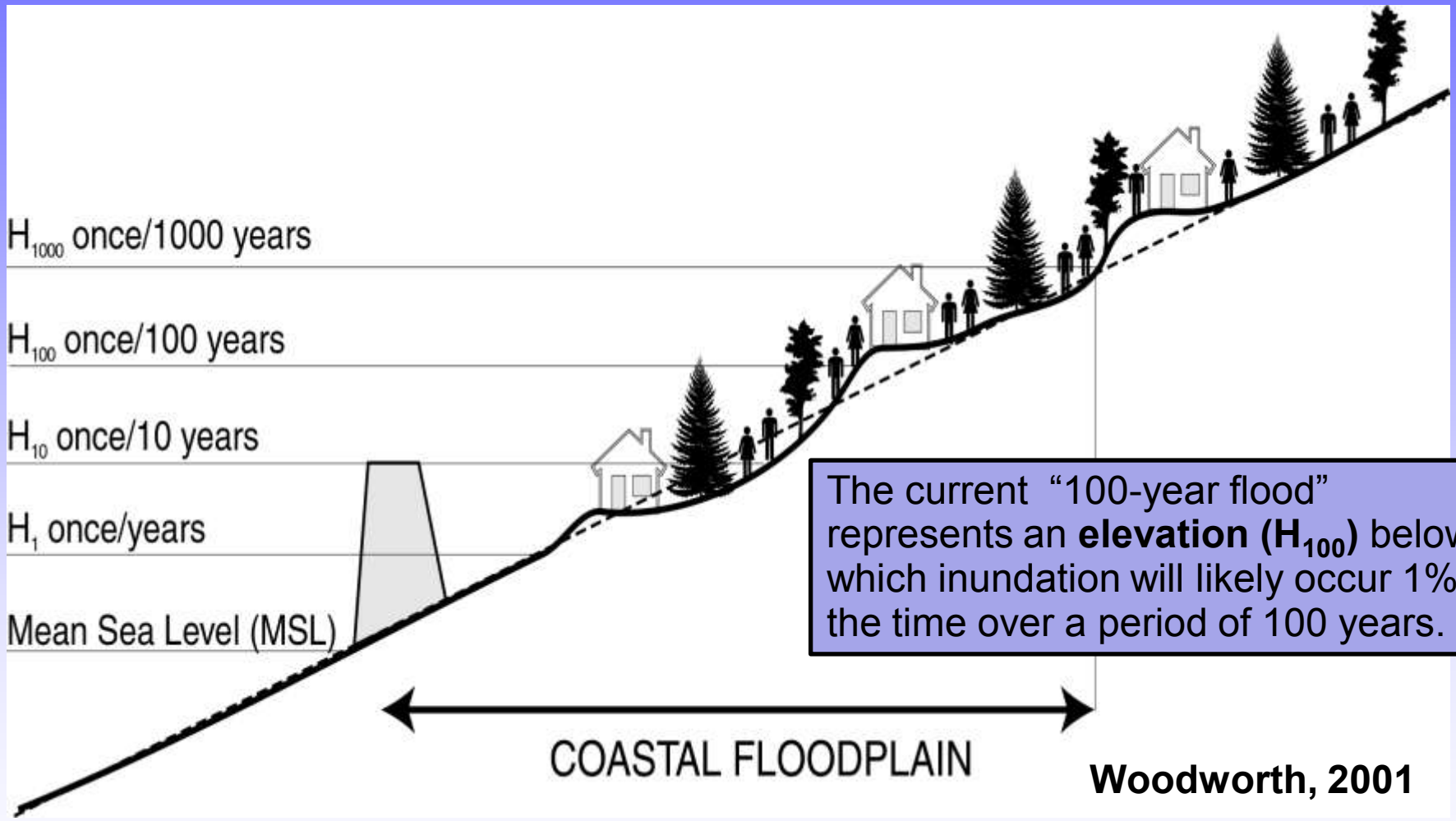
Sea Level Rise



Relative SLR = Global SLR + Subsidence

British Geological Survey

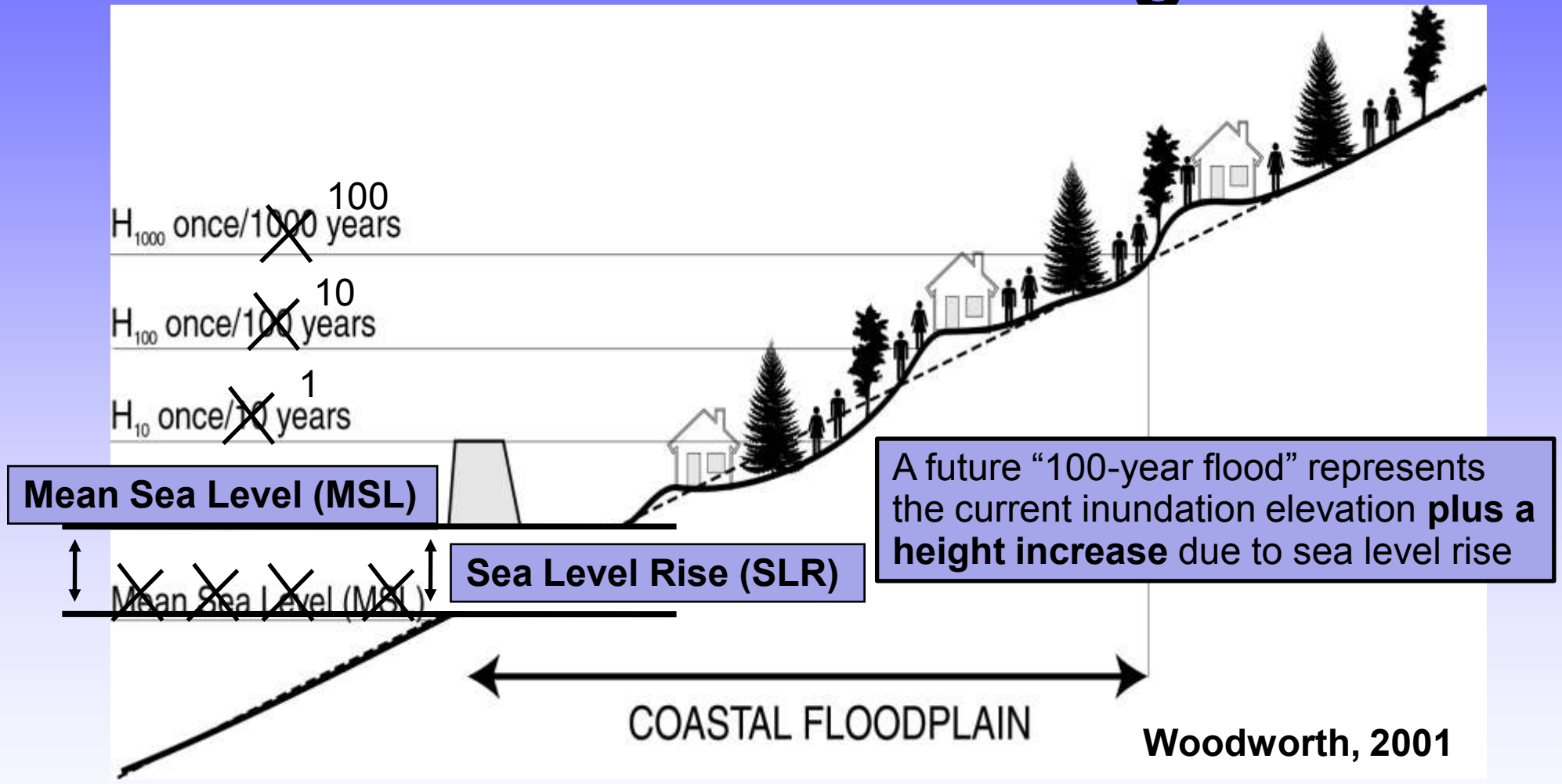
Coastal Flooding



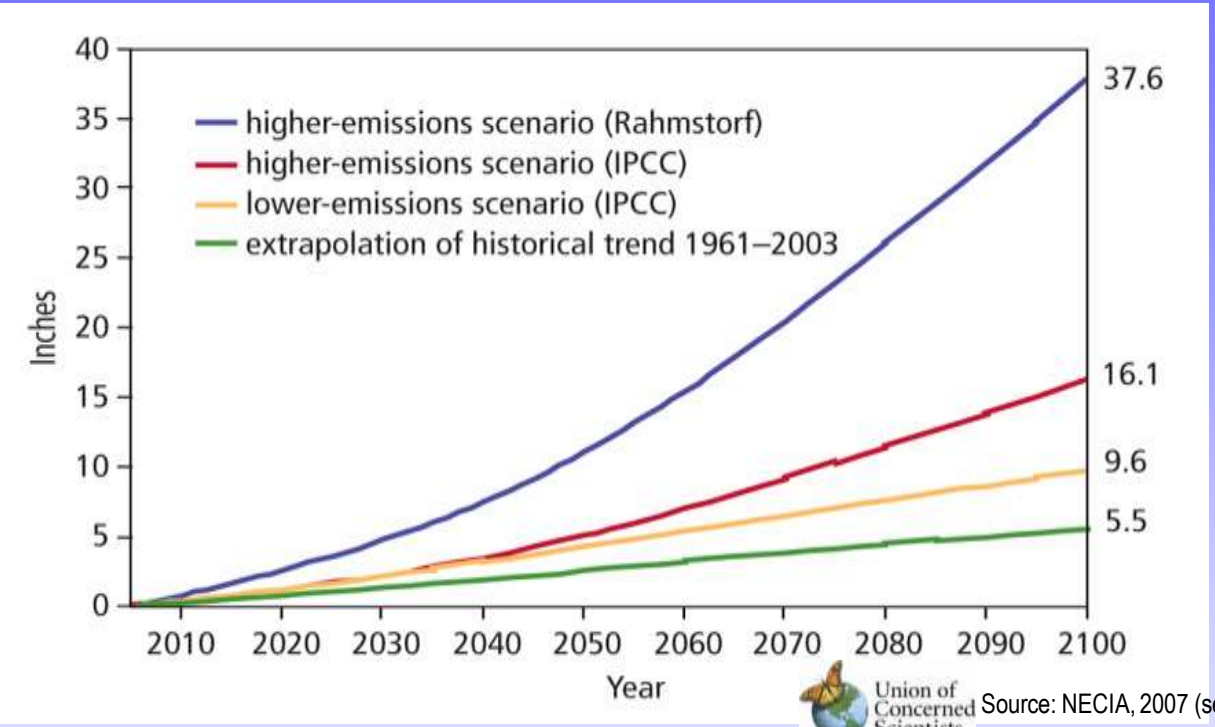
The current "100-year flood" represents an **elevation (H_{100})** below which inundation will likely occur 1% of the time over a period of 100 years.

Woodworth, 2001

Sea Level Rise and Coastal Flooding



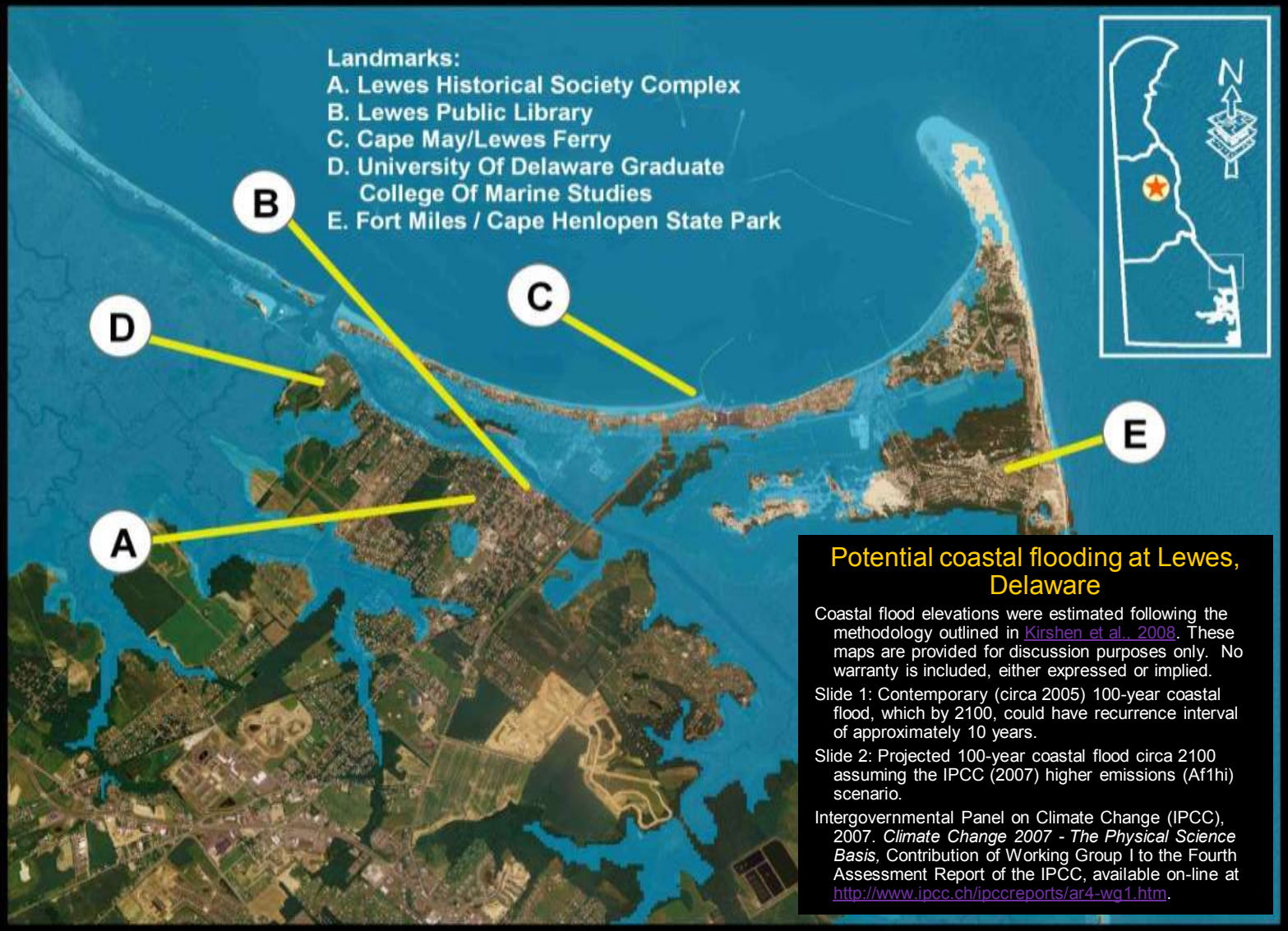
Future Sea Level Rise



Union of Concerned Scientists Source: NECIA, 2007 (see: www.climatechoices.org/ne)

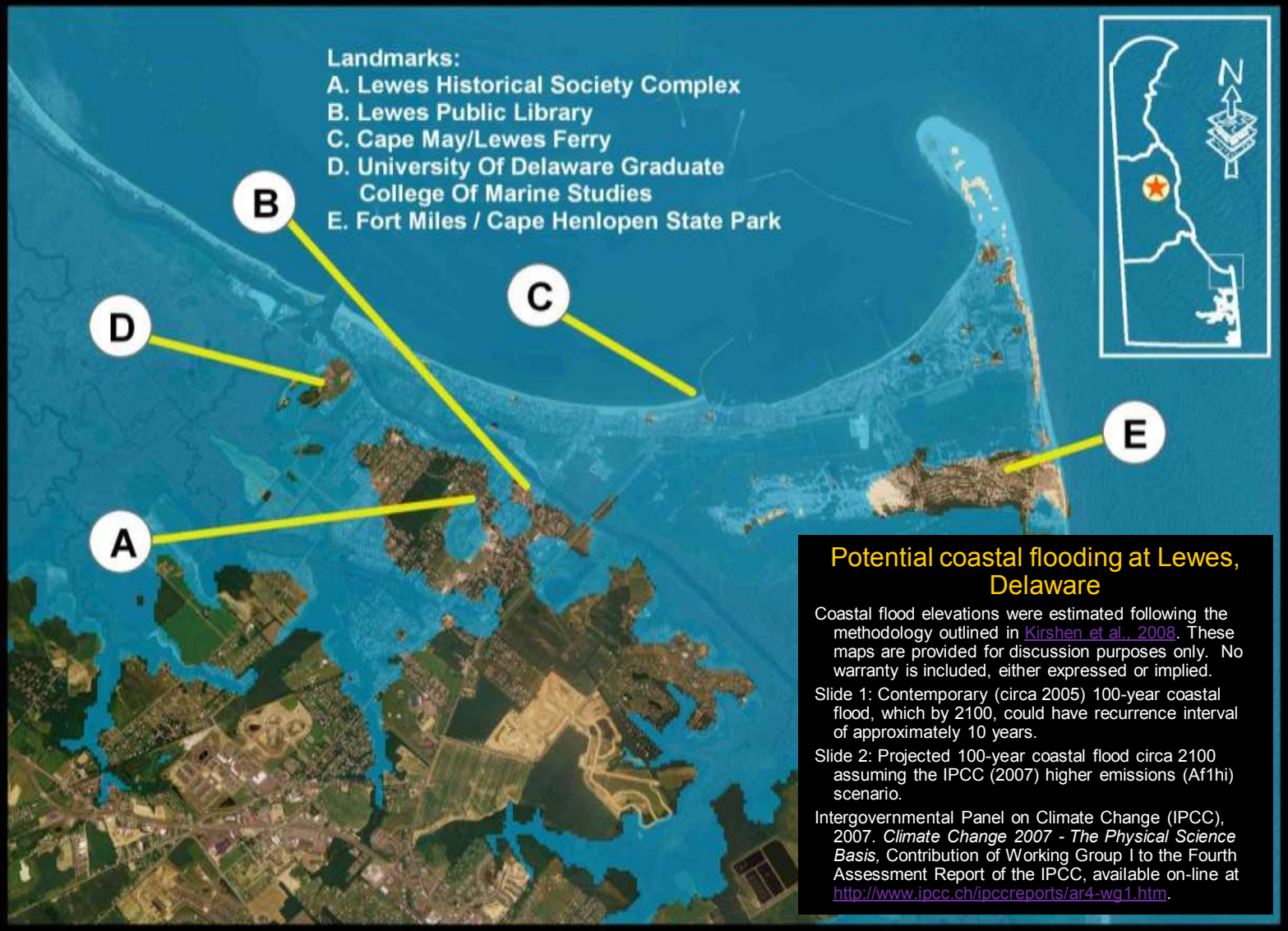
- Updated 2009 Projections
  - 6 to 13 inches by 2030
  - 3.5 to 7.5 feet by 2100
    - References: Pfeffer et al., 2008 & Yin et al., 2009

Lewes, Delaware: Today's 100-Year Flood Could Become a Ten-Year Flood by 2100



Credit: Chris Watson Sources: USDA, USGS, NOAA, ESRI, NECIA, 2007 (see: www.climatechoices.com/ne)

Lewes, Delaware: The Future 100-Year Flood under the Higher Emissions Scenario



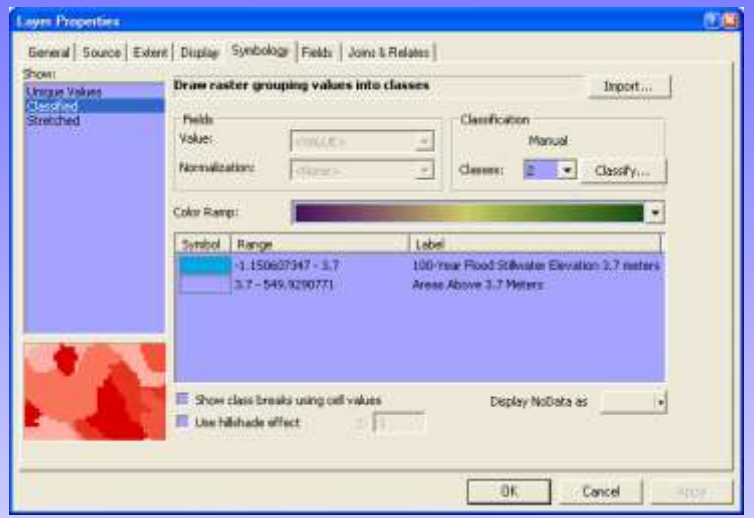
Some Publically Available DEMs

- National Elevation Dataset (NED)
  - 30 meter, 10 meter, 3 meter - available online
    - Seamless DEMs with a consistent datum, elevation unit, and projection
    - Source data vary (see the NED FAQ)
    - Higher resolution => less coverage nationally
- Mass GIS
  - 5 meter DEM
  - 2002 Metro Boston LiDAR
    - 1 meter grid / 0.15 meters (6 inches) vertical
    - Contact MassGIS directly to obtain (limited metadata here)

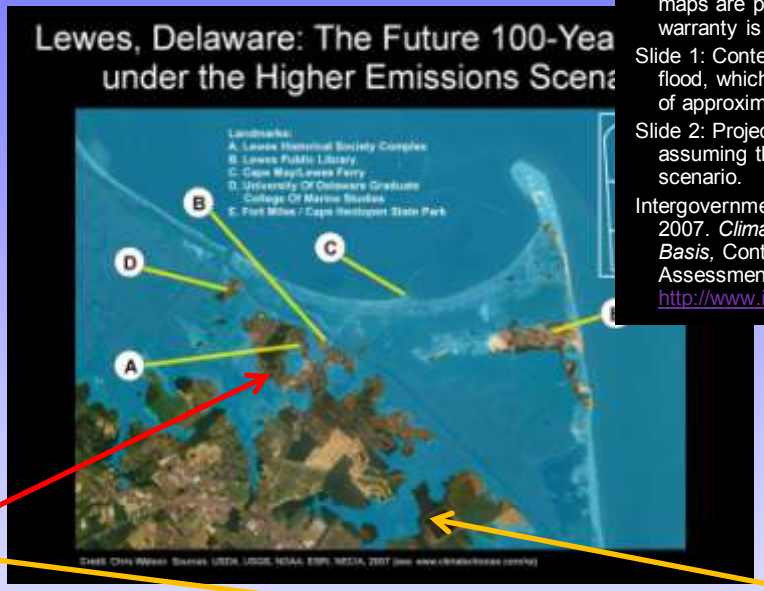
DEMs and Coastal Flood Inundation

(a work in process)

- Simple Raster Technique
  - Advantages
    - Spatial Analyst not required
    - Very simple
      - Classify raster into 2 classes
      - Adjust display to X% transparency
  - Disadvantage
    - No control over hydraulic connectivity/disconnectivity
      - Isolated topographic lows appear as ponds
        - These ponds may or may not have a hydraulic connection to ocean-based flooding
      - Unknown connectivity over/under infrastructure
        - Bridges, tunnels, sea walls, dams, etc.



Coastal Flood Inundation 30 meter NED



Potential coastal flooding at Lewes, Delaware

Coastal flood elevations were estimated following the methodology outlined in Kirshen et al., 2008. These maps are provided for discussion purposes only. No warranty is included, either expressed or implied.

Slide 1: Contemporary (circa 2005) 100-year coastal flood, which by 2100, could have recurrence interval of approximately 10 years.

Slide 2: Projected 100-year coastal flood circa 2100 assuming the IPCC (2007) higher emissions (Af1hi) scenario.

Intergovernmental Panel on Climate Change (IPCC), 2007. *Climate Change 2007 - The Physical Science Basis*, Contribution of Working Group I to the Fourth Assessment Report of the IPCC, available on-line at http://www.ipcc.ch/ipccreports/ar4-wg1.htm.

30 meter DEM was best available dataset, poor resolution

Pond?
Likely hydraulically disconnected from ocean

Bridge/causeway?
Hydraulically connected to ocean?

DEMs and Coastal Flood Inundation

(a work in process)

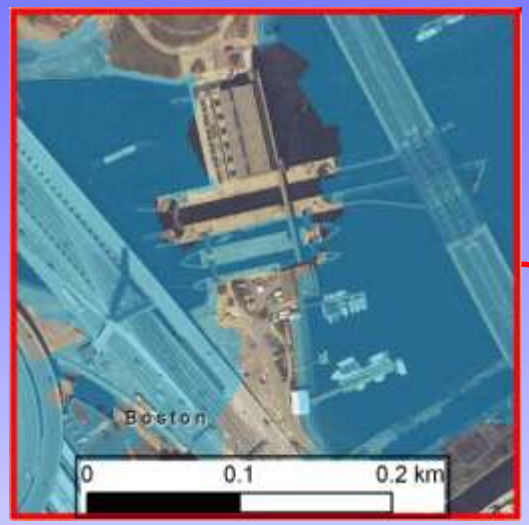
- Simple Vector Technique
  - (1) Spatial Analyst Map Calculator
    - gridshape(setnull([dem_raster] > M.MMM, 1))
      - M.MMM = flood elevation in meters NAVD
      - [dem_raster] = the DEM raster mosaic of the study area
    - Generates polygon feature class
      - Represents horizontal boundaries of inundation area
  - (2) Resolve hydraulic connectivity
    - Select polygon representing the ocean
    - Invert the selection
    - Delete the other polygons

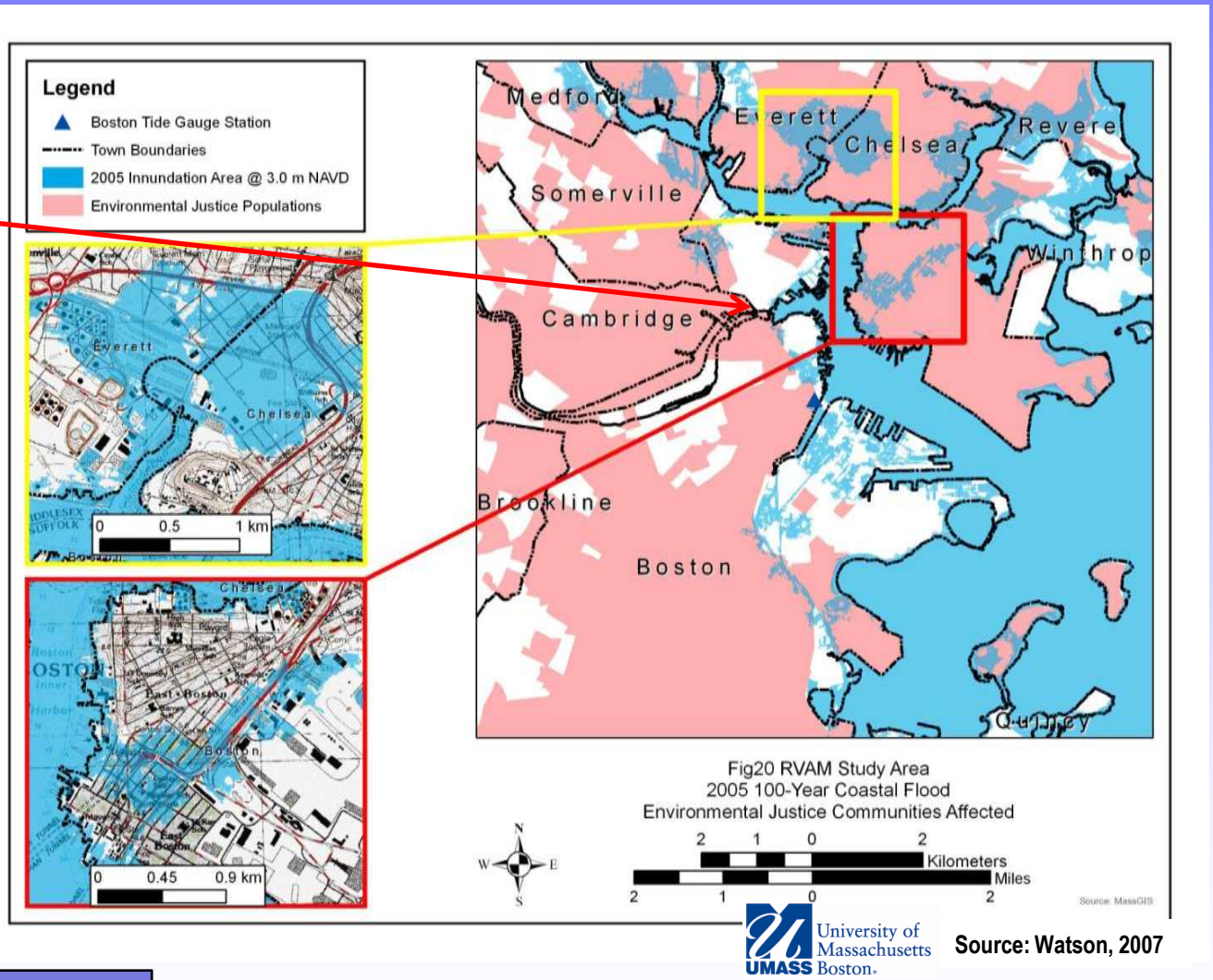
DEMs and Coastal Flood Inundation

(a work in process)

- Simple Vector Technique (continued)
  - Advantages
    - Simple spatial analysis
  - Disadvantages
    - Polygon is not topologically valid
      - Requires significant effort to clean
        - ArcToolbox: Explode, Repair Geometry, repeat!!
    - No ability to easily apply adjacency rules
      - Discontinuous polygons may be hydraulically connected
        - Polygons representing adjacent raster cells may not “touch”
        - Horizontal resolution (grid size) of source raster is critical
    - Does not resolve all connectivity issues

Coastal Flood Inundation MassGIS LiDAR





University of Massachusetts Boston

Source: Watson, 2007

Charles River Dam
Highly likely to be hydraulically disconnected from ocean
Solution: Editor => Split the polygon

DEMs and Coastal Flood Inundation

(a work in process)

- Simple Vector Technique (continued)
  - Buildings or no buildings?
    - ArcToolbox: Erase (ArcInfo license required)
      - Equivalent geoprocesses available @ ArcView
  - Advantages
    - Visual esthetics
    - More valid hydraulic connectivity
      - Water generally does not flow through buildings
  - Disadvantages
    - Need building polygons (available @ MassGIS)
    - Significant increase in topology problems
      - Recommendation: use Spatial Analyst

Union of Concerned Scientists

Source: NECIA, 2007 (see: www.climatechoices.org/ne)

Other Techniques and Datasets

- LIDAR for Northeast Proposal
  - The Maine Office of GIS, in cooperation with USGS, the State Planning Office, Maine Department of Transportation, the Maine GeoLibrary Board, and UNH, have developed a proposal for stimulus funding to collect LiDAR data for **all coastal counties in New England**.
  - The proposal (PDF) is currently (March 2009) being circulated to GIS contacts throughout the region and is receiving wide support.

Other Techniques and Datasets

- 3D Visualizations using Google Earth
  - Boston Animation
  - NEARC 2008
- Spatial Filters using Geostatistical Analyst
  - NEARC 2008
- Extrapolation to large spatial extents
  - Thiessen Polygons
    - Polygon boundaries manually altered to make the polygons cover areas likely influenced by tides

Other Techniques and Datasets

- FEMA's HAZUS-MH
  - MH = MultiHazard
    - Floods, hurricane winds and earthquakes
    - Primarily an economic analysis tool
  - Flood Analysis
    - Advantages
      - Generates coastal inundation polygons based on numerous input parameters, including bathymetry
    - Disadvantages
      - Labor, training, processor-speed & storage-capacity intensive
      - ArcView **9.2** required (also requires Spatial Analyst)
      - "Uncertainty/error are significant but not quantified"

Other Techniques and Datasets

- FEMA's HAZUS-MH (continued)
  - Flood Analysis
    - Level 1 (NEARC 2008)
      - Analysis based on FEMA datasets (ex. 30/10 meter NEDs)
    - Level 2
      - Allows for user-supplied datasets (ex. LiDAR)
      - Flood Information Tool (FIT)
        - ArcGIS extension
        - Testing of FIT @ Level 2 with Boston datasets in process
          - In coordination with Maine Geological Society
          - Results @ NEARC 2009
    - Level 3
      - Advanced economic analysis

Other Techniques and Datasets

- SLOSH
  - Sea, Lake and Overland Surges from Hurricanes
    - Estimates storm surge heights and winds resulting from historical, hypothetical, or predicted hurricanes by taking into account pressure, size, forward speed, track, and winds
    - Incorporates unique bay and river configurations, water depths, bridges, roads and other physical features
  - Advantages
    - Generally accurate within plus or minus 20 percent
  - Disadvantages
    - Highly complex model, limited access to output datasets

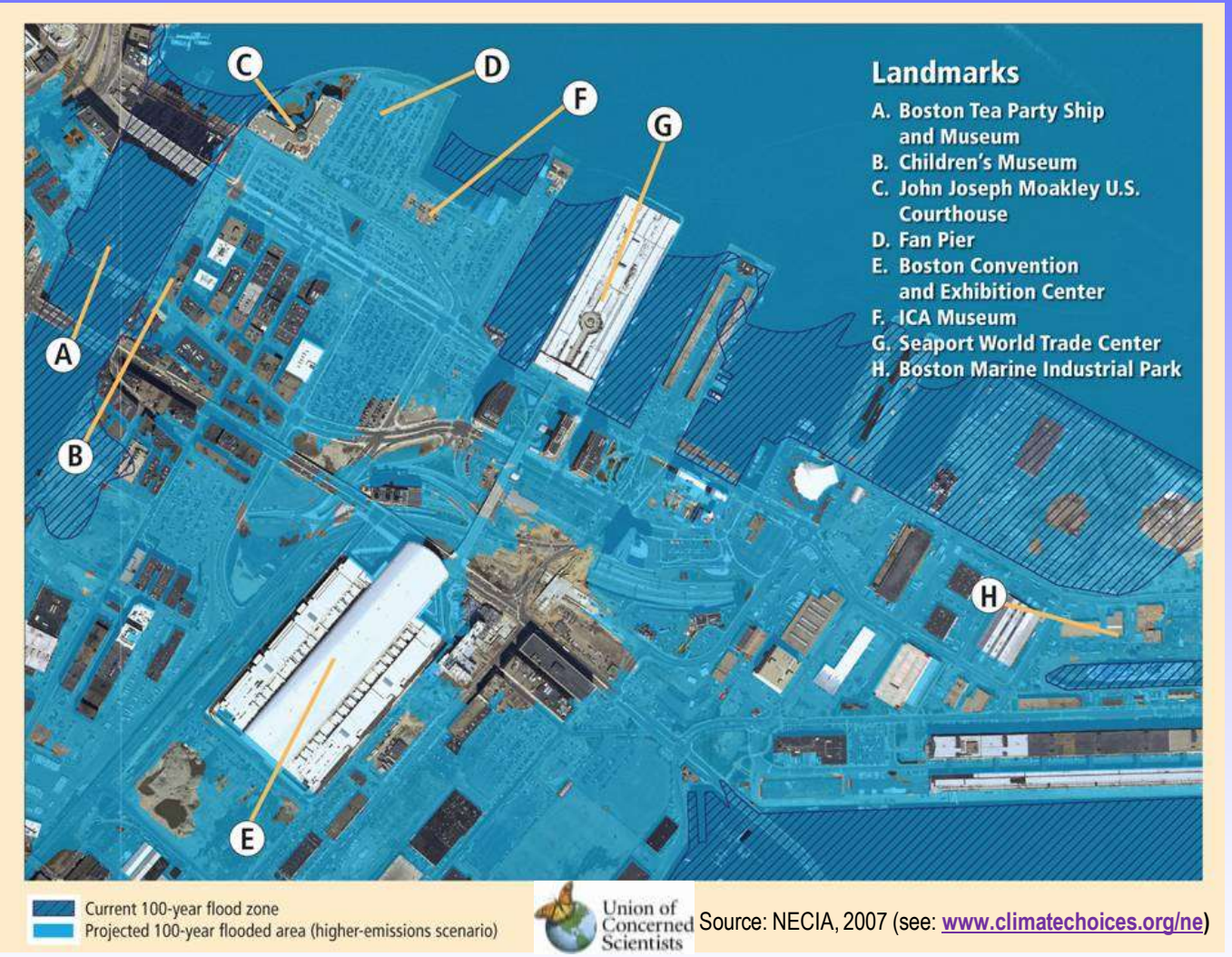
Other Techniques and Datasets

- Impact of climate change on the National Flood Insurance Program
  - "The Department of Homeland Security, Federal Emergency Management Agency, Headquarters is seeking a contractor under full and open competition to conduct studies on the impact of climate change on the National Flood Insurance Program and to determine whether policies and methodologies for mapping coastal special flood hazard areas should be revised."
  - Contract Awarded Sep 19, 2008

Coastal Flood Inundation Mapping and Climate Change

- Summary
  - FEMA Q3 Flood Maps are conservative in scope, spatially inaccurate, and rapidly becoming temporally inaccurate
  - Climate-induced sea level rise is creating increased risks associated with coastal flooding
  - Publically available DEMs and some relatively simple geoprocessing can be used to generate coastal flood inundation maps
  - Other techniques and better quality datasets are required generate higher-quality inundation maps

Questions?



Contact info: Chris Watson (email: **cwatson** at **gis** dot **net**), UMass Boston, EEOS