Geodesign and Sea Level Rise:

Linking Coastal Flooding, Ecosystem Models, Drone Mapping, and Green Infrastructure for Coastal Resilience

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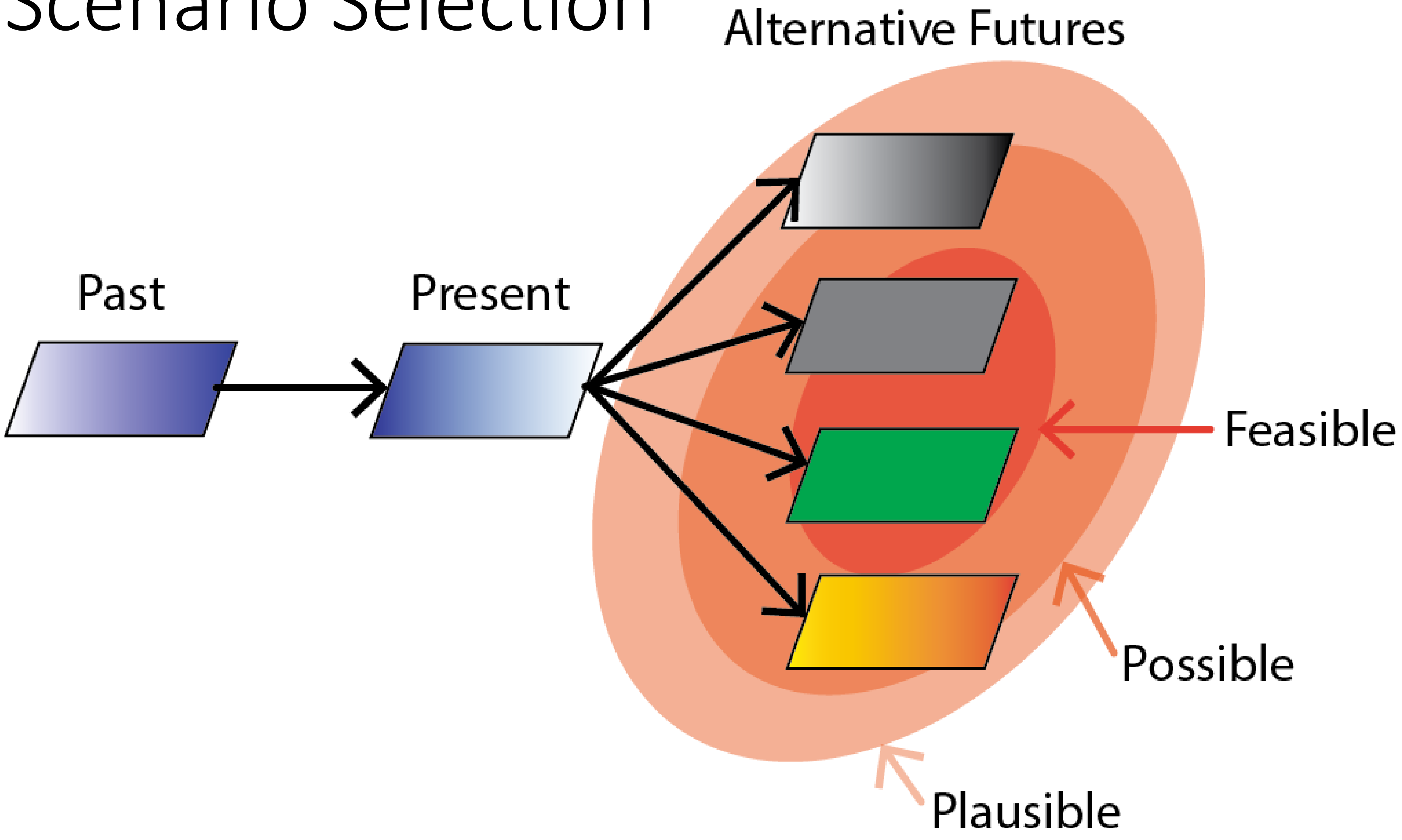
Current Situation

- Maturation of numerous environmental models (hydrodynamics, shoreline and geomorphic changes, wetland response to SLRise)
- Rapid evolution drone mapping technology (outpacing policy)
- High fidelity 3D geovisualization tools

Challenges and Questions

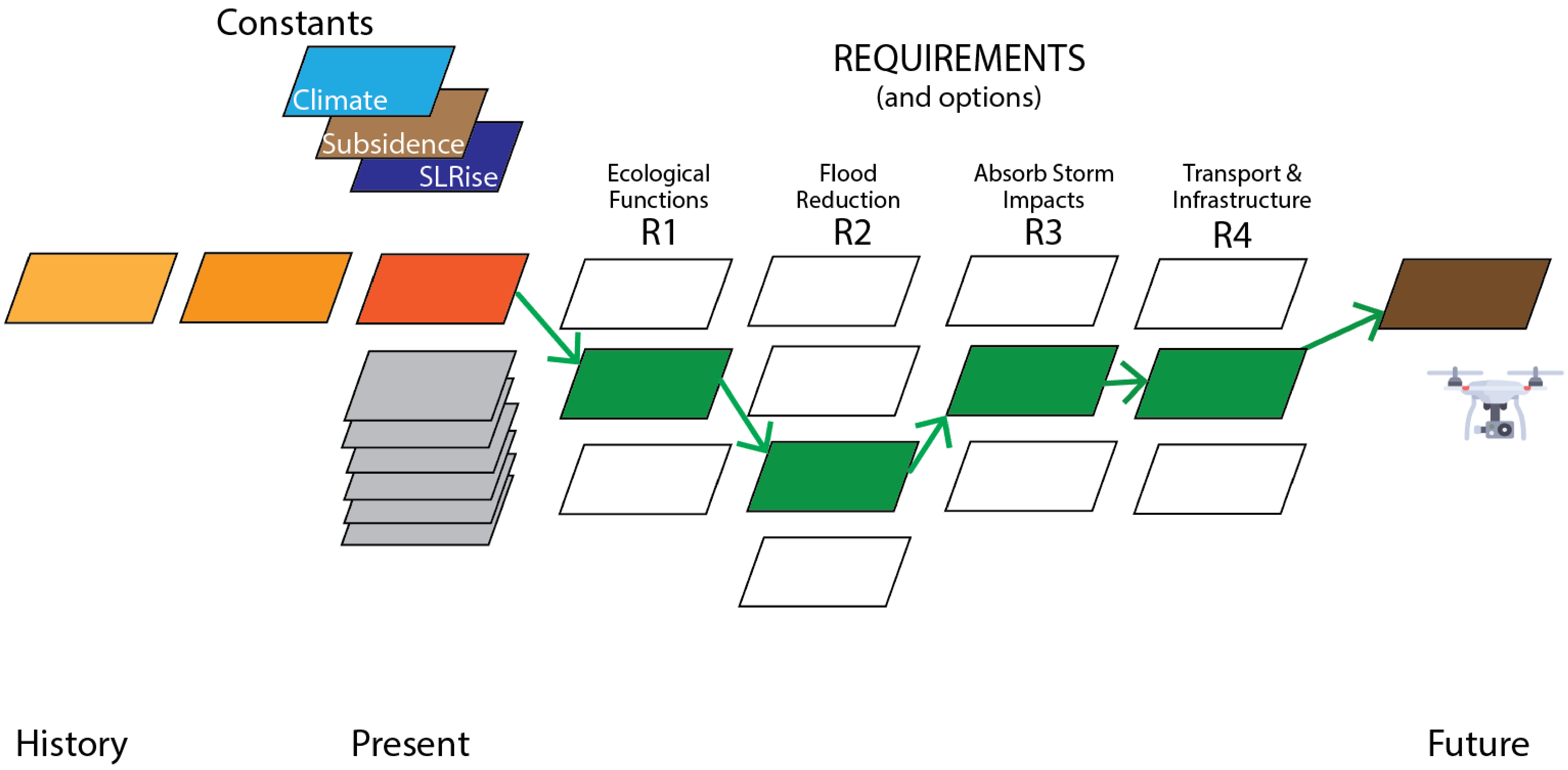
- How can environmental modeling, UAS, and geovisualization be integrated and applied to improve risk perception?
- What are the accuracy of UAS (and impediments) to scaling up?
- Can we produce science-based, salient, and feasible future scenarios of green infrastructure and resilient coastal communities?

Scenario Selection



After Steinitz (2012)

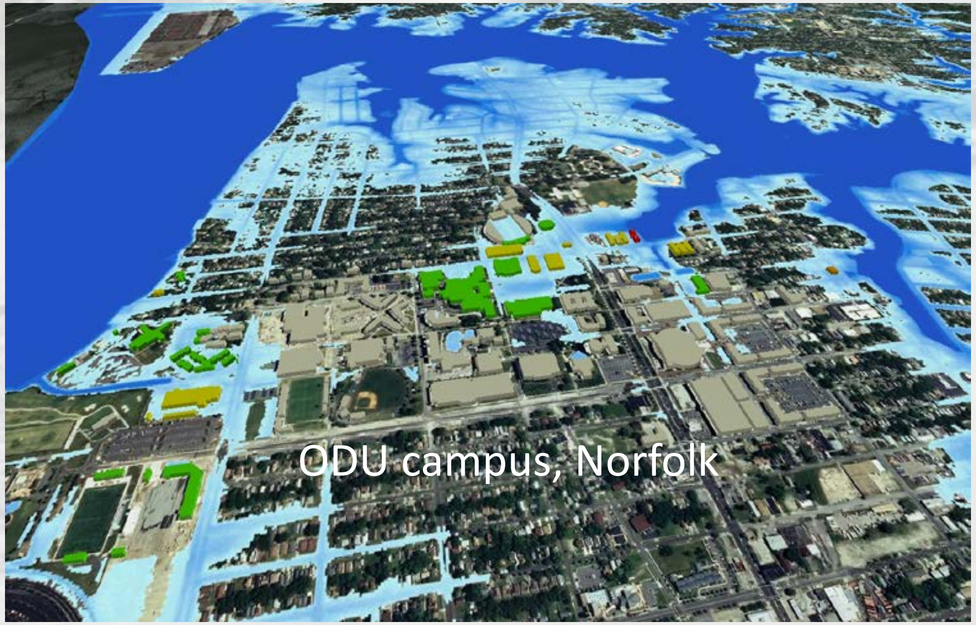
A Geodesign Approach after Steinetz (2012)



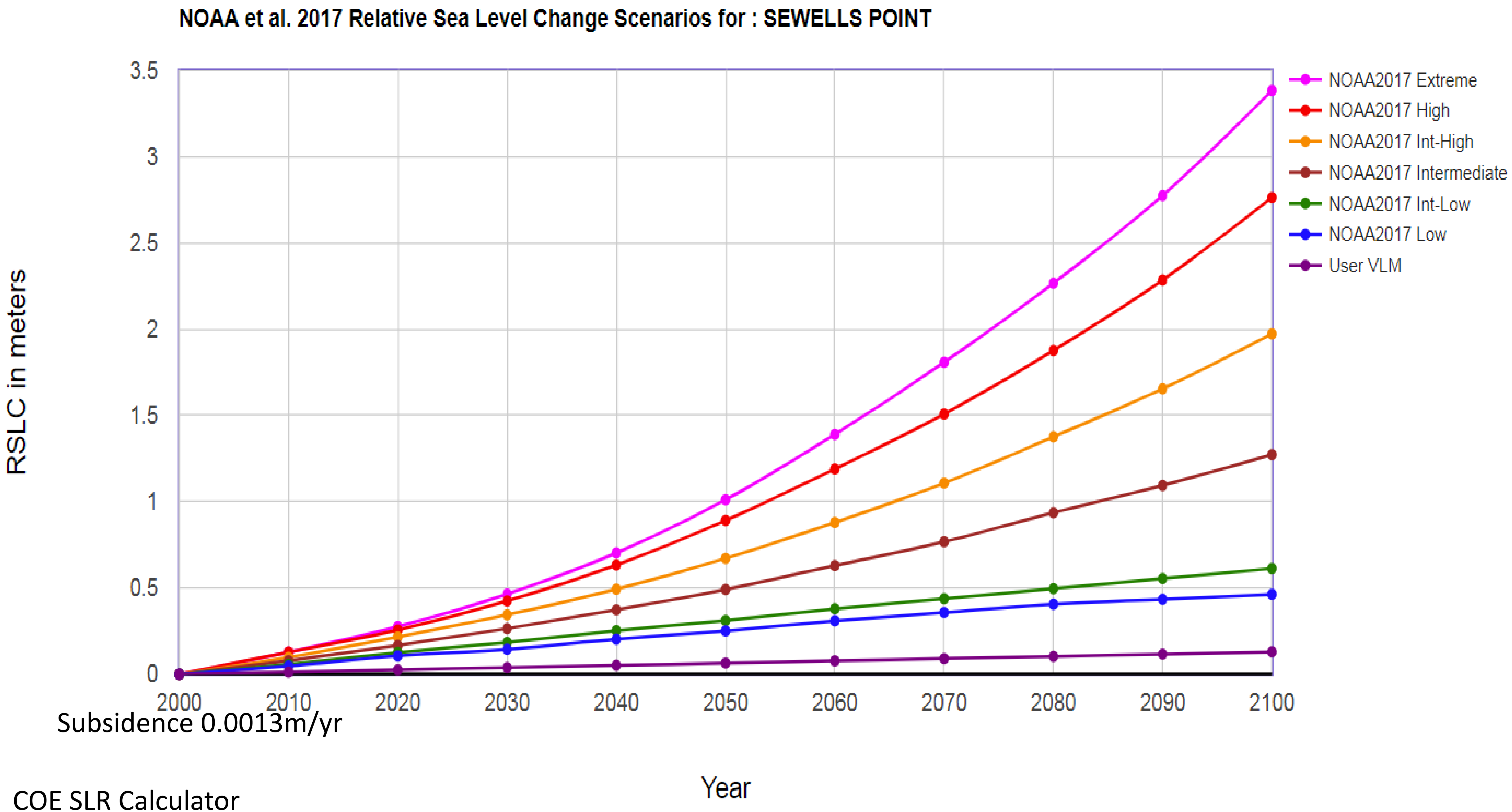
Sea Level Rise

- Hampton Roads NOAA Tide Gage nearby Sewells Point
- USACE SLR curve calculator
- Subsidence
- Impacts
  - Flooding
  - Habitat losses/gains
  - Landform and sedimentation changes
  - Land use and navigation changes

Colonial Place, Lafayette R., Norfolk



ODU campus, Norfolk



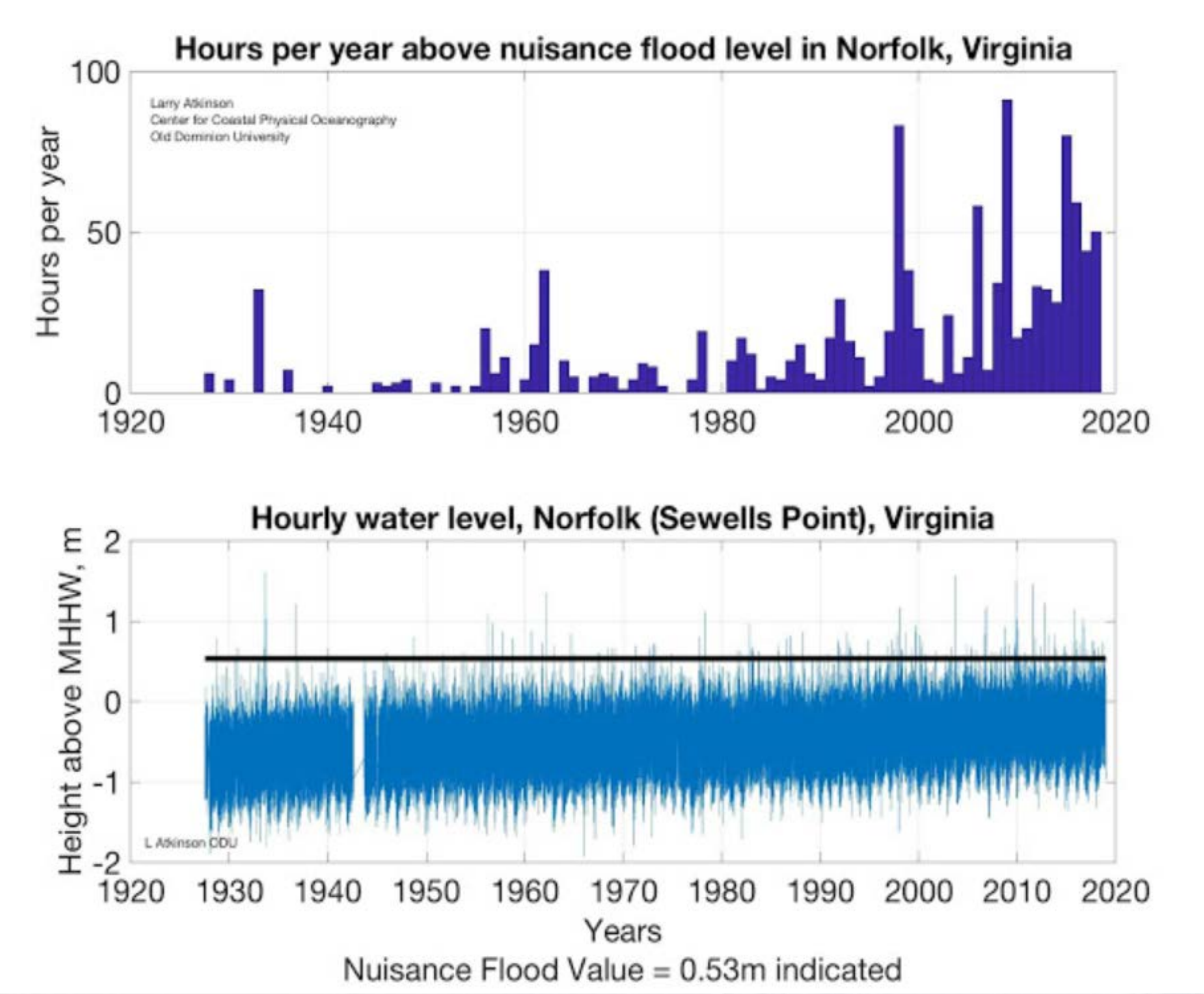
Subsidence 0.0013m/yr

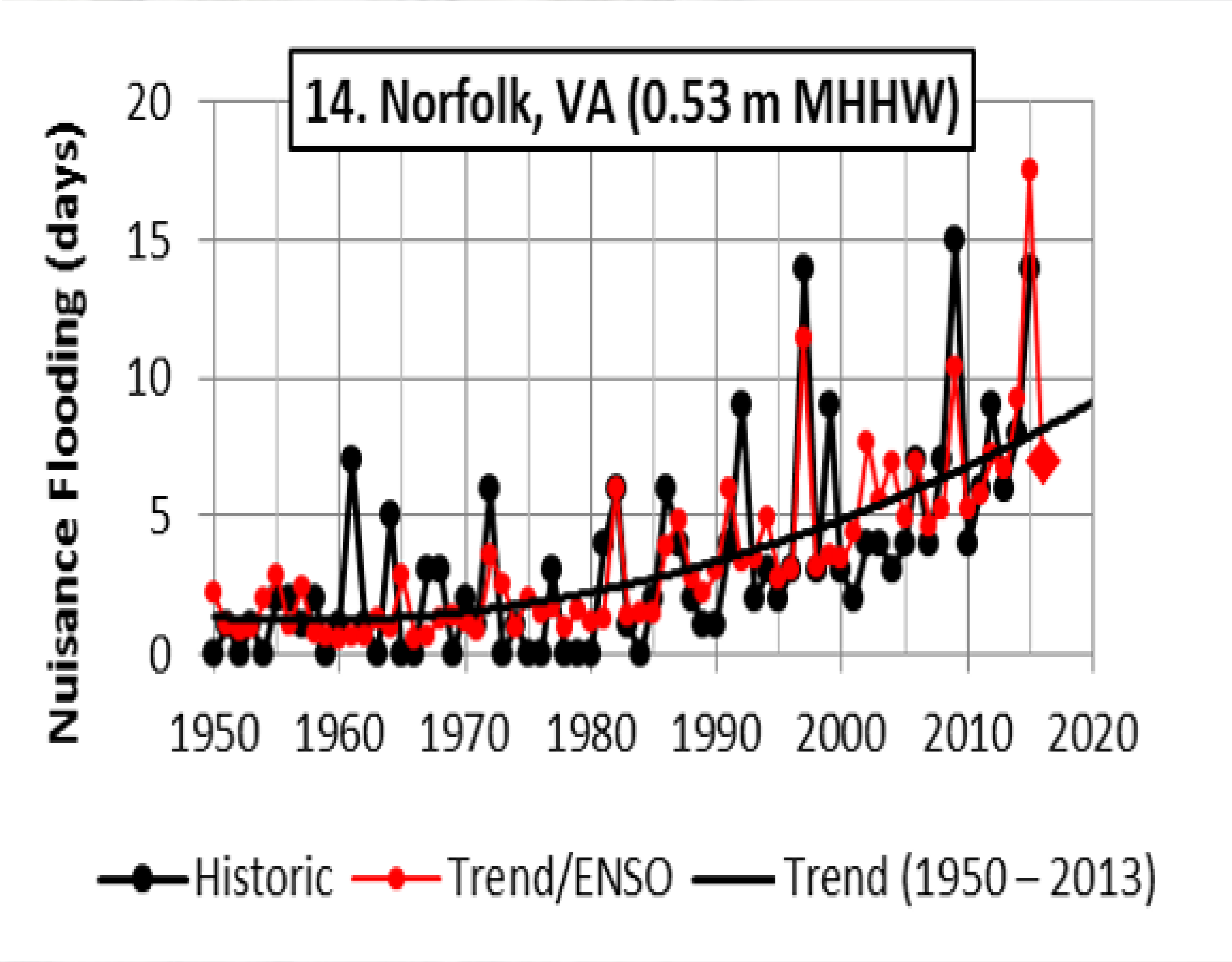
COE SLR Calculator

Modeling Potpourri

- VDATUM for topobathy and vertical datums
- SLOSH, SCHISM, ADCIRC for storm surges
- USGS WAVES Toolbox for wave and bed shear stress
- SLAMM for marsh response and future site suitability

SLR and Tidal Flooding

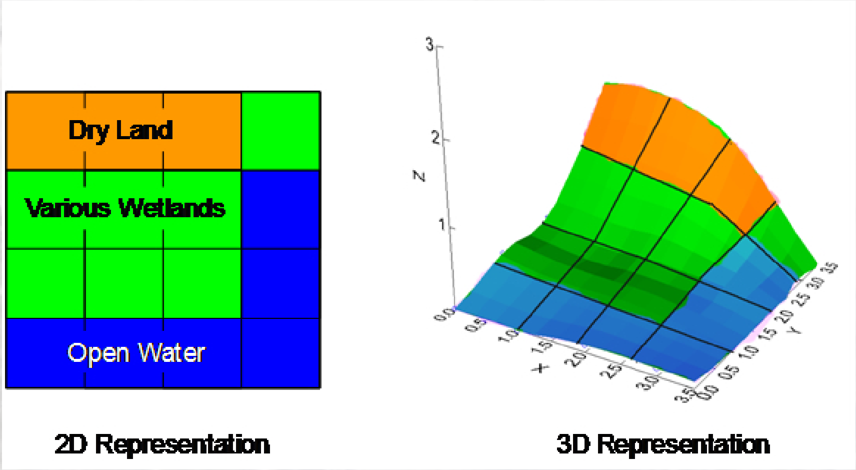




Sources: Sweet and Marra (2016); Larry Atkinson ODU (2019) http://coastalslr.blogspot.com/2019/01/sewells-point-2018.html

SLAMM and Wetland Response

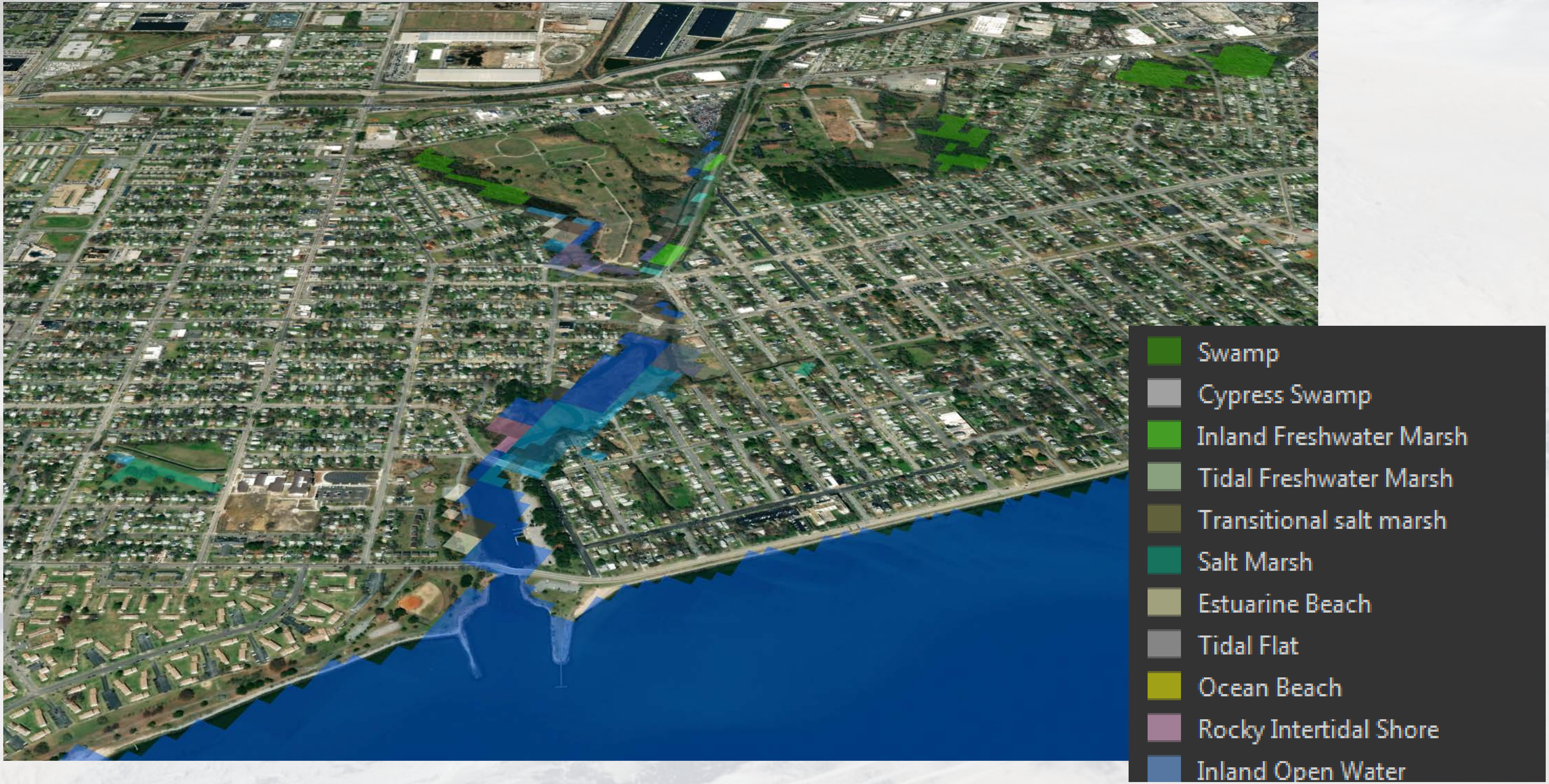
- Background
- Scenario and input data
- SLR scenarios
  - 1m and 1.5 m 2075 w/ and w/o protection
  - Restoration
- Assumptions
  - Salinity, climate, sedimentation



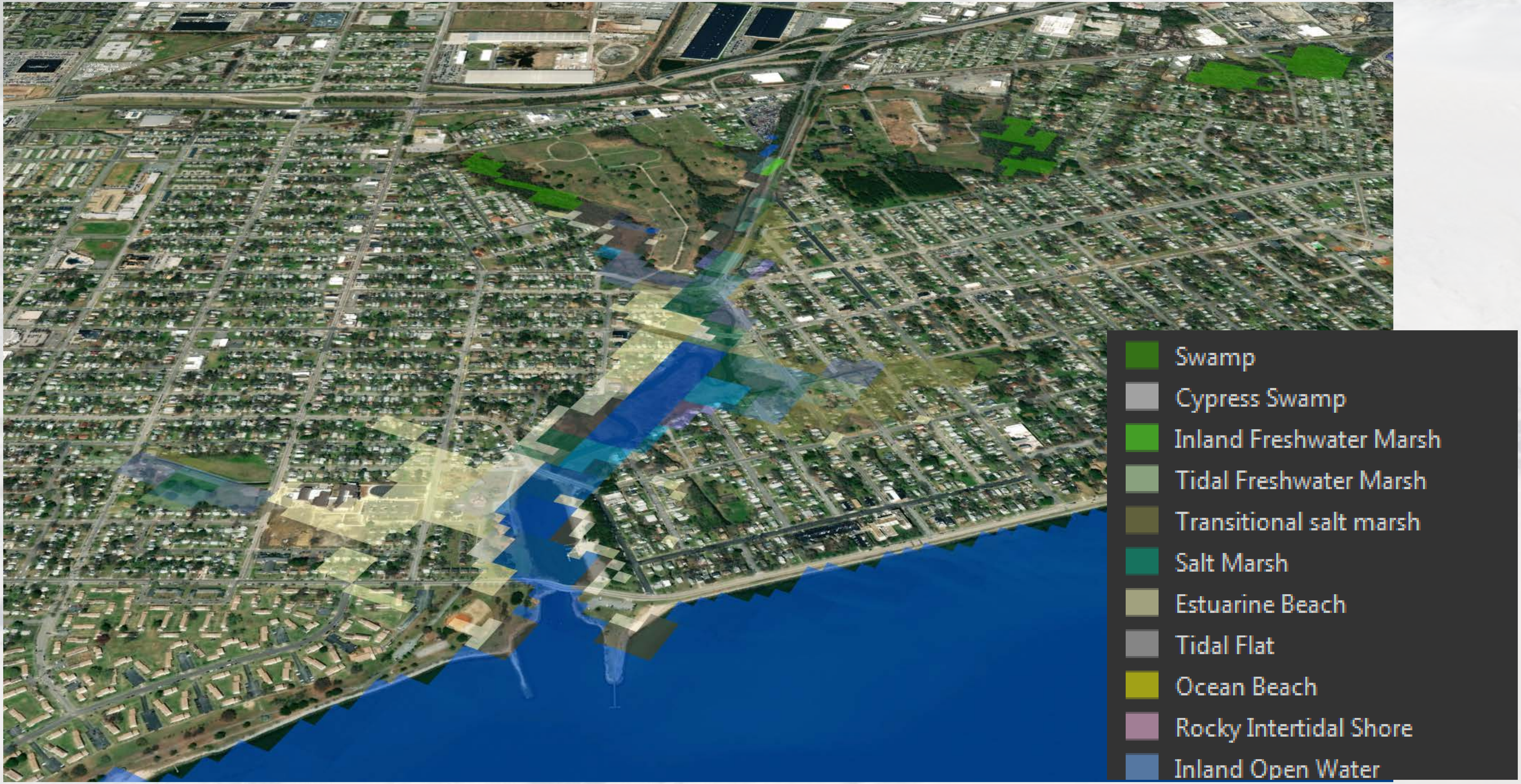
SLAMM 6 Warren Pinnacle Consulting


Tidal Flooding

SLAMM Protection



SLAMM No Protection

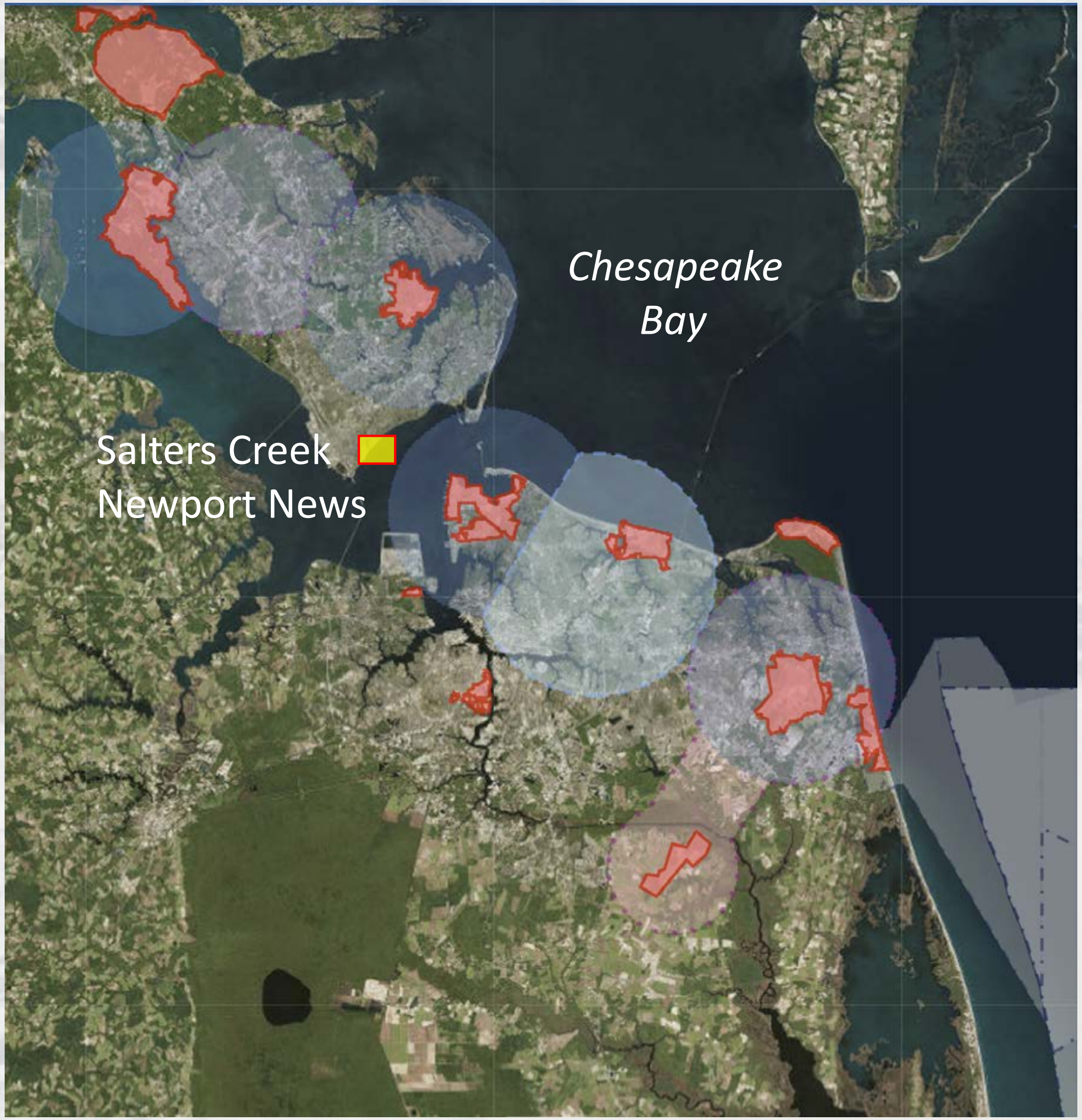


Drones in Coastal Mapping

- Digital surface model and elevation mapping and change
- Feature extraction for structures and digitization
  - Buildings
  - Shorelines
  - Dunes and other landforms
  - Vegetation and fine-scale covertypes
  - Historical cultural resources
  - Bird and other species monitoring
  - Rapid damage assessment

Drone Mapping Approach

- Purpose and method
- Local constraints
  - Airspace constraints/FAA
  - Tide
  - Weather
- Commercial off the shelf tech.
- Testbed approach (a small watershed)
  - Data volume
  - Seasonal snapshot



Drone DSM to DEM

- DSM from UAV with Pix4D SfM
- Sampling DEM and DSM
- Adjustment of DSM to NAVD88
- LiDAR RMSE vertical accuracy

  = 0.066 m (0.092 m spec.)

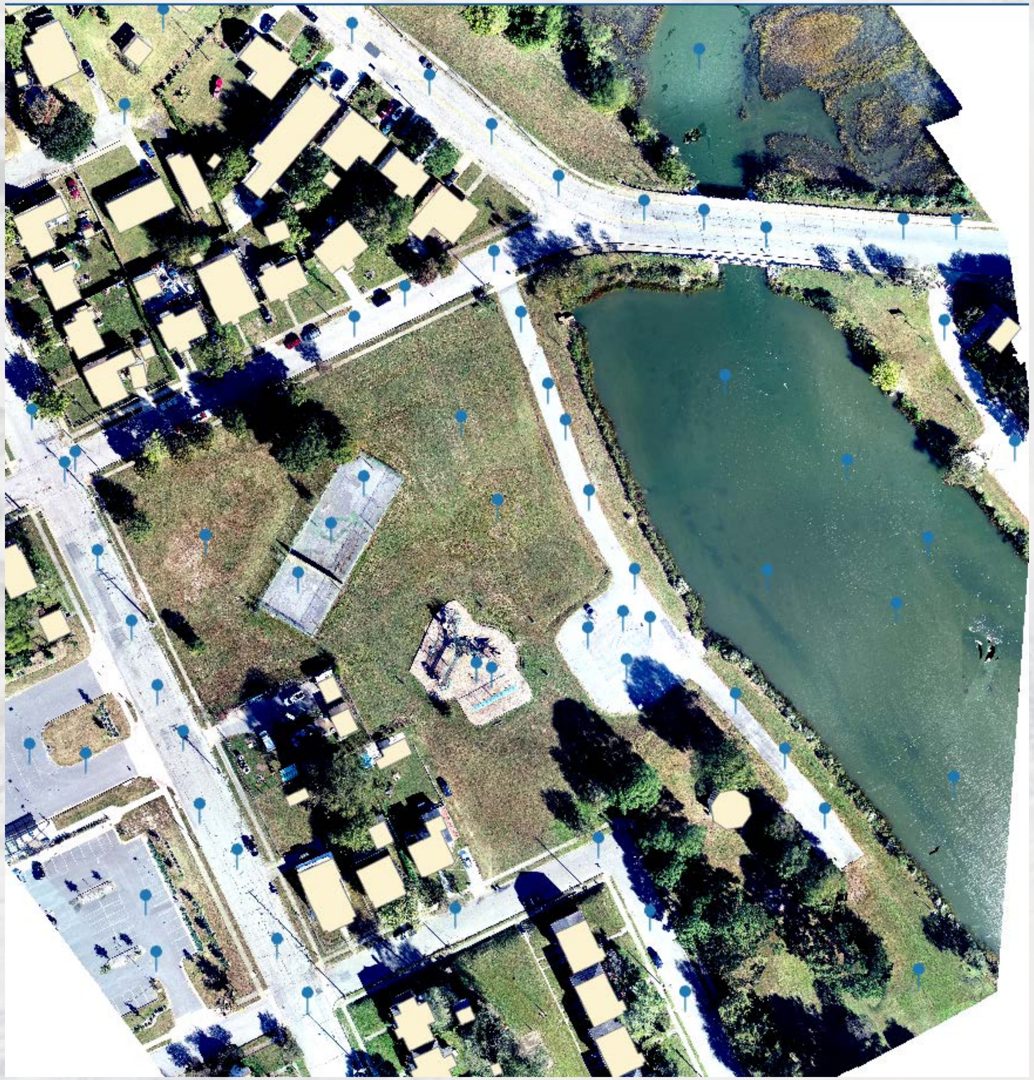
FVA of the classified LiDAR

RMSEz x 1.960 = 0.129 m (0.181 m spec.)

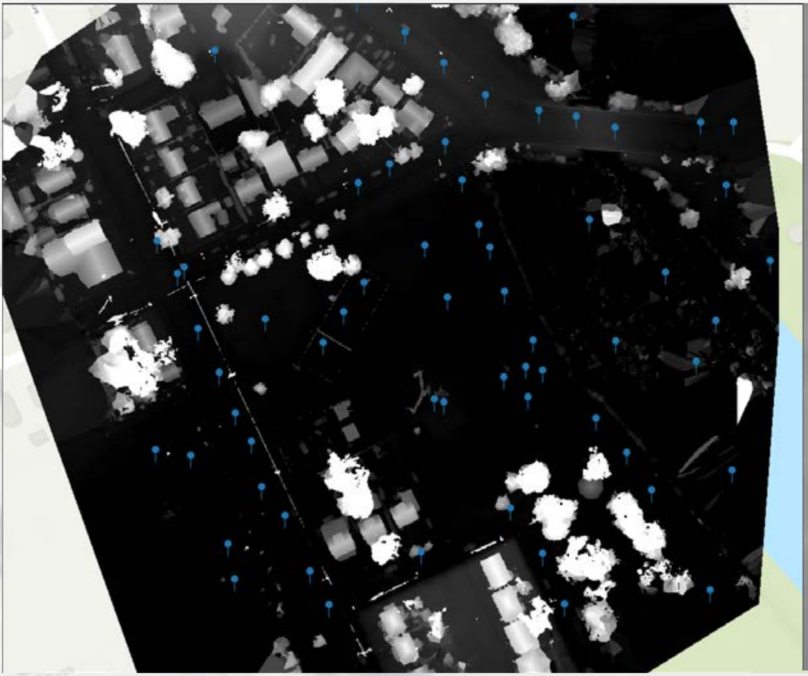
- Phantom 4 Pro specs.

  +/- 0.5m vertical with GPS positioning

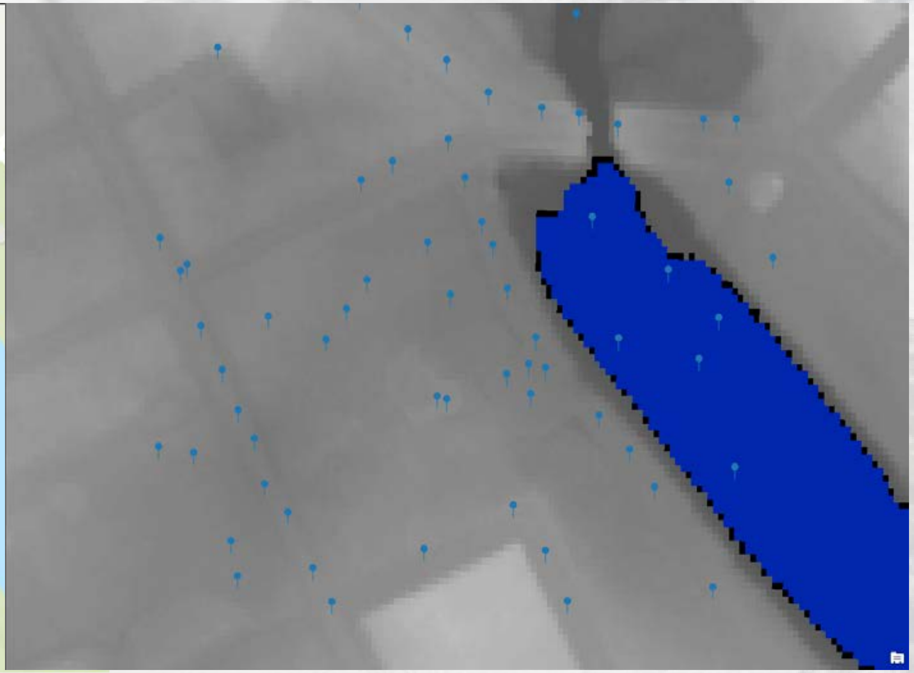
  +/- 0.1m Vision positioning
- Drone Derived DEM
  - Regression R^2 0.766 (<0.001)
  - RMSE of Drone DEM 0.0332m
  - 0.065m linear error at 95%
  - Min. SLR increment to model = 13cm
  - Min. Time to model SLR increment = 28.9 yrs



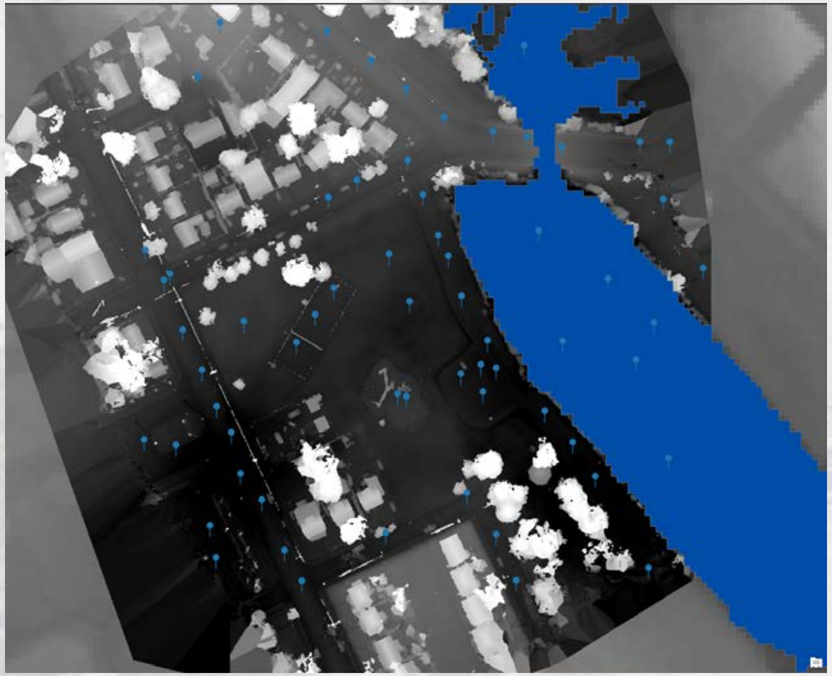
Raw DSM



LiDAR

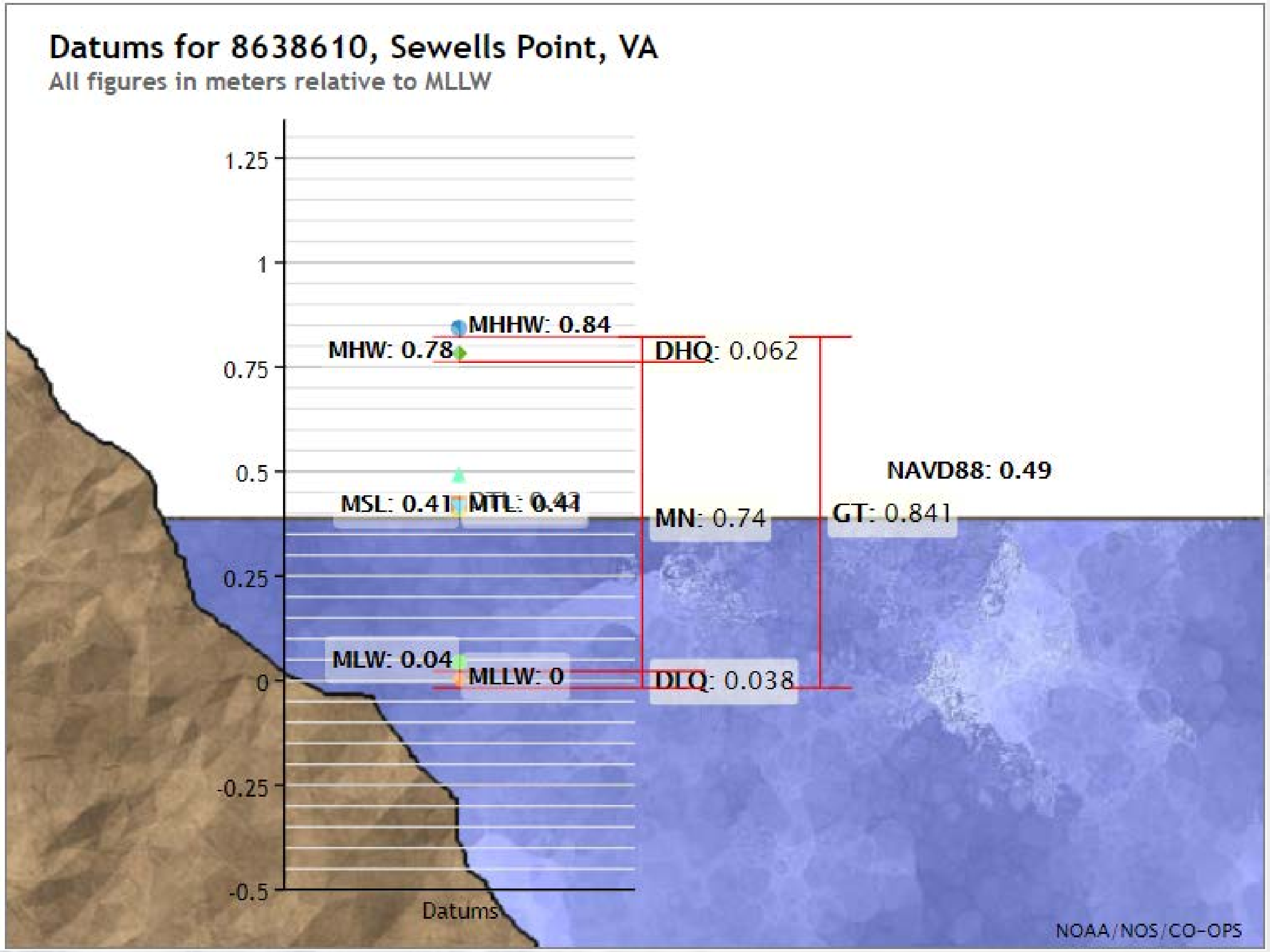


Drone DEM

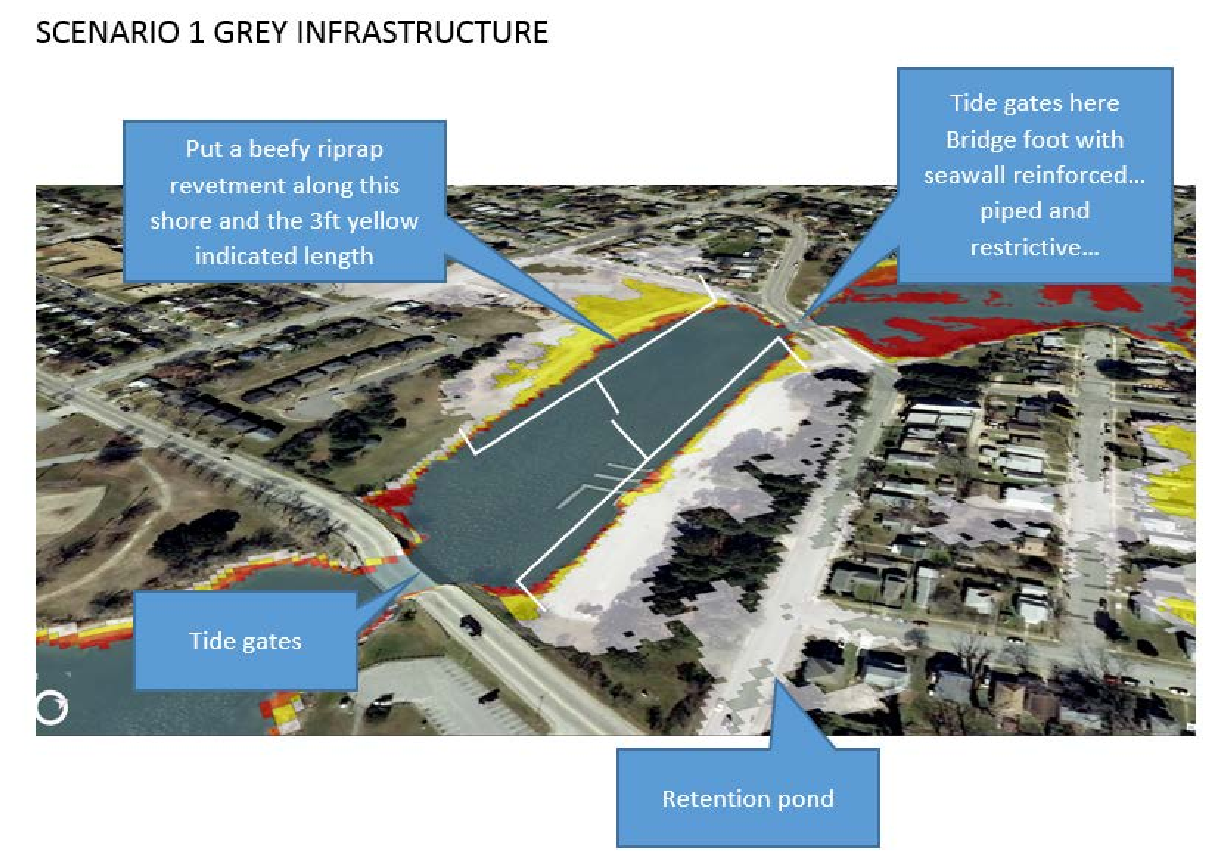


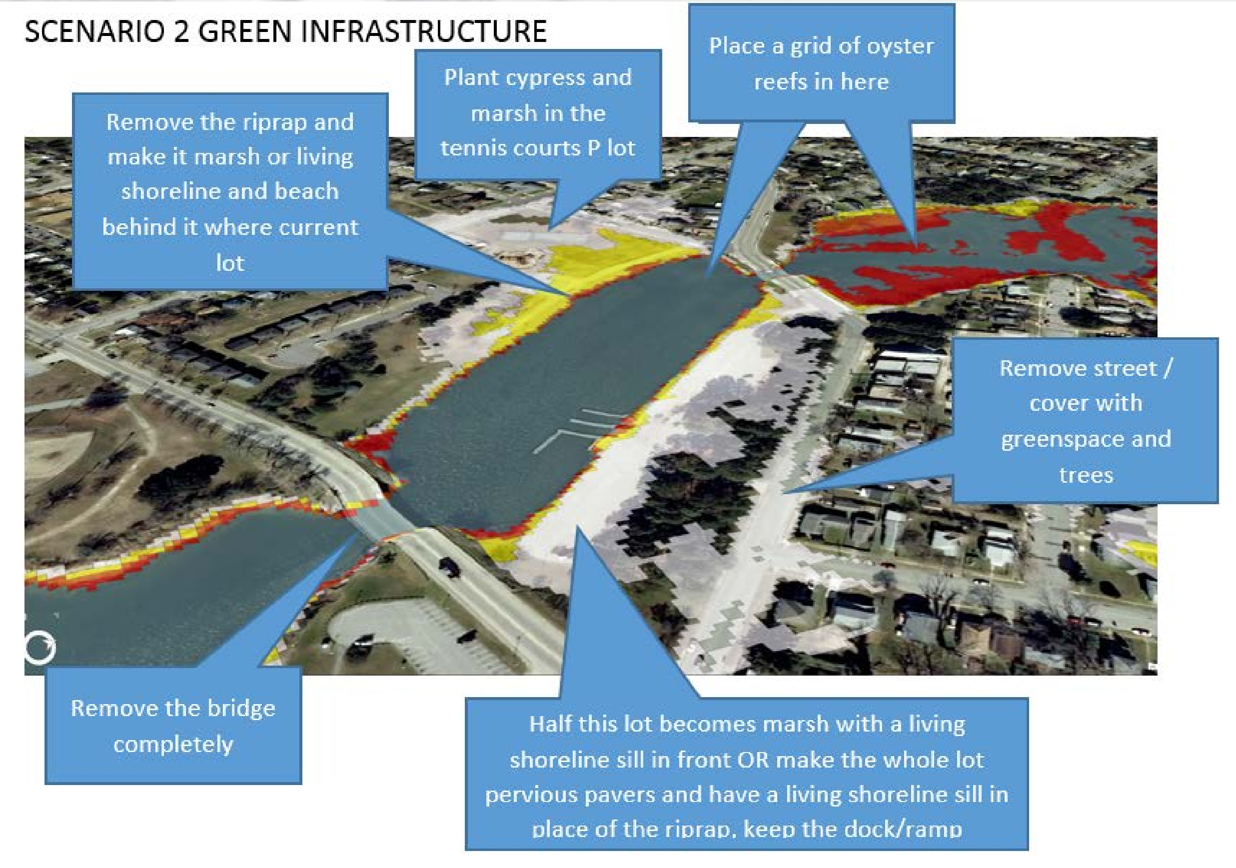
Derived Current and Future DEM Contours

- MaxSurge33-SLR (2.44m + 0.67m) = 3.11m 1933 storm 8/23/33
- MHHW-SLR2050 (0.84m + 0.67m) = 1.51m
- MHW-SLR2050 (0.778m + 0.67m) = 1.448m
- MTL-SLR 2050 (0.408m + 0.67m) =1.078m
- MHHW 0.84m
- MHW 0.778m
- MTL 0.48m



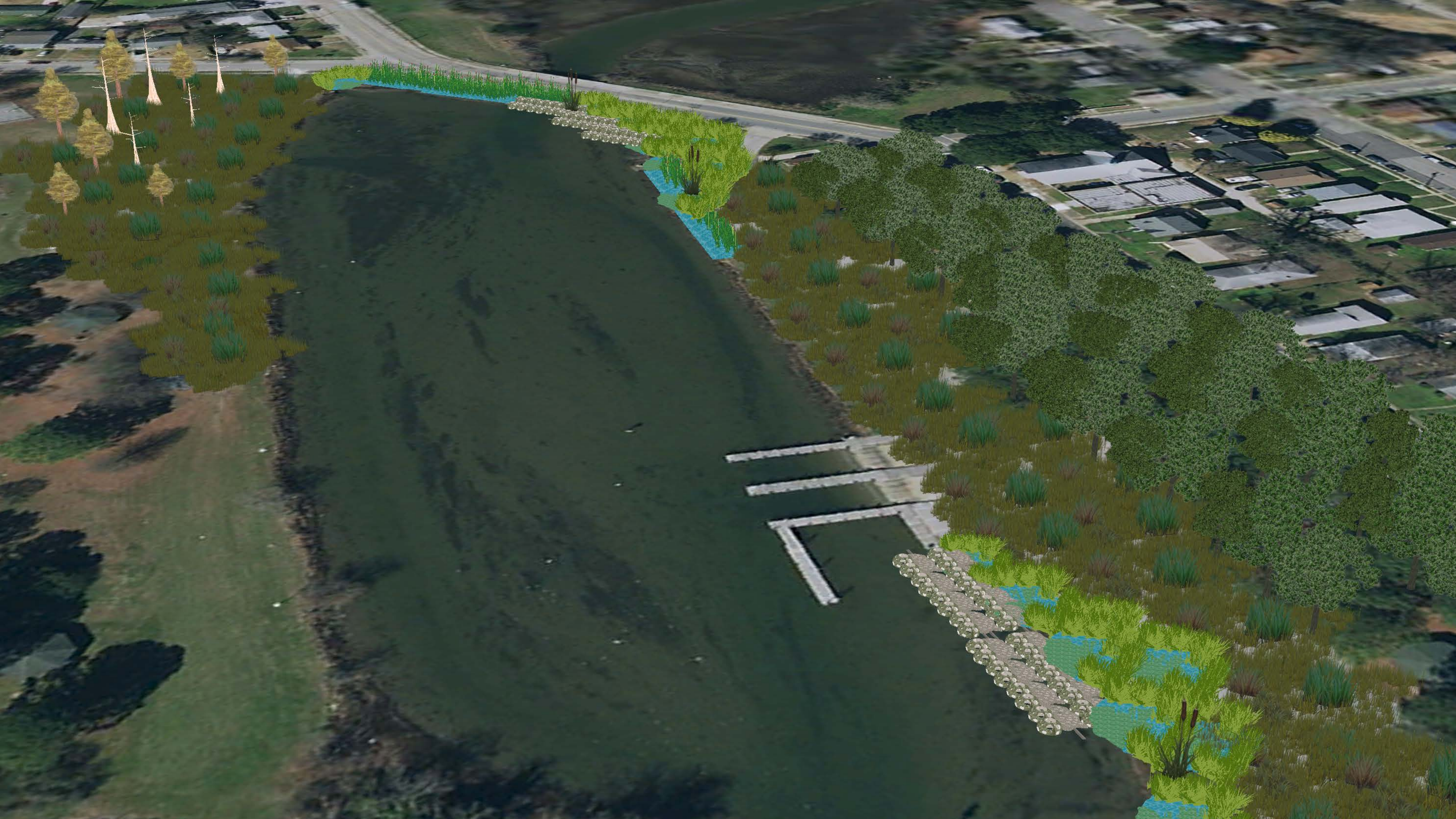
Visualization: Grey-Green Prescriptive Scenarios





Drone Visualization Results

- Set of structural grey infrastructure and natural/nature-based green infrastructure
- 3D models and COLLADA>ArcGIS Pro conversion
- Site selection and placement
- Final visualizations and future dissemination



Modeling Discussion

- Scenario and Modeling Challenges
    - SLRise scenarios continue to have wide uncertainty over time
        - But improving LiDAR and Drone DEMs are allowing more refined flood modeling
            - Hydrocorrection, ditches, nuisance flooding
            - Runoff and subwatershed delineation
    - SLAMM & other wetland spatial models
        - Marsh parameters imported from distant locations
        - Lacking feedbacks between structures, sedimentation, and marshes
        - Hybrid changes (e.g. marsh restoration, or sedimentary restoration)
    - Todays revetments and riprap as tomorrow's oyster reef/sill
        - Rolling or phased retreat approach
        - Apply Life Cycle Assessment (LCA) to NNB?
    - Sedimentation and landform changes highly uncertain
        - Dredging and protective structure stabilization vs. comprehensive planning
        - Coastal circulation and sediment transport under SLR

Drone Discussion

- Drone mapping challenges and discoveries
  - DSM is good quality for ideal surfaces
  - Effort to model structures, adaptations, and visualization (vs. alternatives, e.g., CityEngine, GoogleEarth, or Pictometry)
  - Airspace and other constraints limit portability
- Immediate potential for site analyses or event and long-term monitoring
- Bathymetry is a limiting data factor in the shallow turbid estuary (potential for ASV)

Geodesign Integration Discussion

- Integration and limitations to geodesign
  - More participatory to ensure feasibility and salience
- GIS can assimilate, but bottlenecks and scale & accuracy issues emerge
- Visualizations
  - Ought to be tested
  - Scenario embedded with local planning
  - Perceptions vs. preferences
  - Improve sharing, opendata, and dissemination

Conclusions

- **Geodesign** poses strong potential to combine hydrodynamic and SLR modeling, flooding and built environment, and green infrastructure planning for resilience
- Modeling and drone mapping remain quite **siloed**
- Geospatial data still require careful integration (especially **vertically**)
- 3D models and viz are **enhanced** by UAV mapping (but logistics and model production and viz remain limiting)
- **ASVs** could fill some data gaps
- Future research: Landform and marsh evolution, fate of grey infrastructure, and designing with **life cycle**.