20TH INTERNATIONAL CONFERENCE ON INFORMATION TECHNOLOGIES IN LANDSCAPE ARCHITECTURE
LANDSCAPE: INFORMED BY SCIENCE, SHAPED BY DESIGN
MAY 22 – 29, 2019
DESSAU, GERMANY

COMPUTATION AND VISUALIZATION OF COASTAL SEA LEVEL RISE MITIGATION STRATEGIES

SCIENTIFIC DATA TO FORMULATE DESIGN WORKFLOWS FOR CLIMATE CHANGE

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This research investigates a digital workflow for simulating and visualizing the impact of extreme storms on the coastal landscape, and for testing the effectiveness of landscape designs intended to mitigate the sustained damage caused by these storms.

In the coming decades, coastal areas will be exposed to accelerated sea level rise of up to 0.6 meters by the year 2100; increase of sea surface temperature up to 3°C; and larger ocean waves and storm surges.

Nichols et al. 2007

We are unable to perfectly model future rates of sea level rise based on current information: the underlying risks of sea level rise, already noticeable, may be significantly different in the future than they are today.

This adaptation necessitates technology which can respond quickly to complex parameters, incorporate them into every stage of the landscape architecture design process, and illustrate their potential outcomes in visually meaningful ways which can be interpreted by the public.

Brown et al. 2005

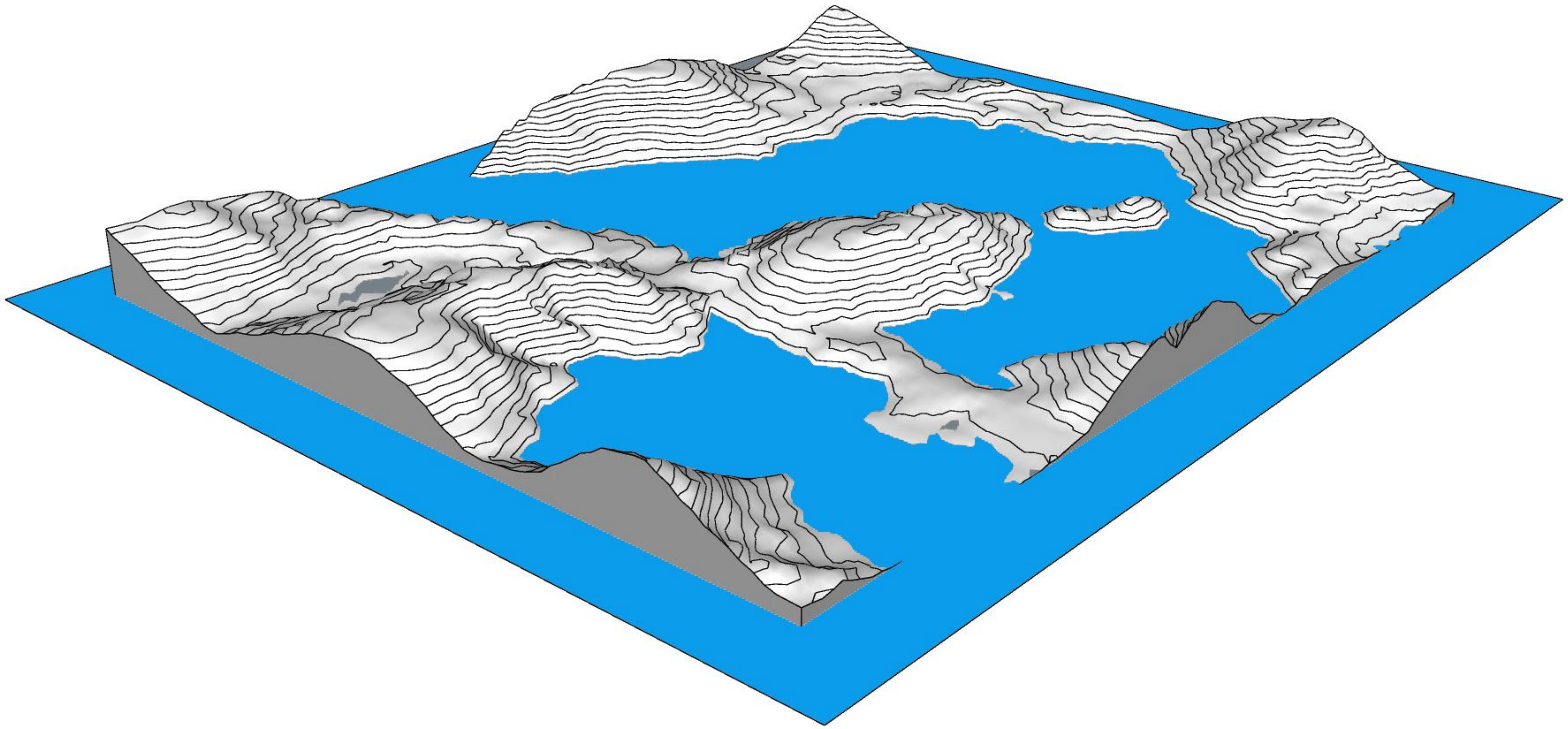
GOAL: one model to show:

erosion

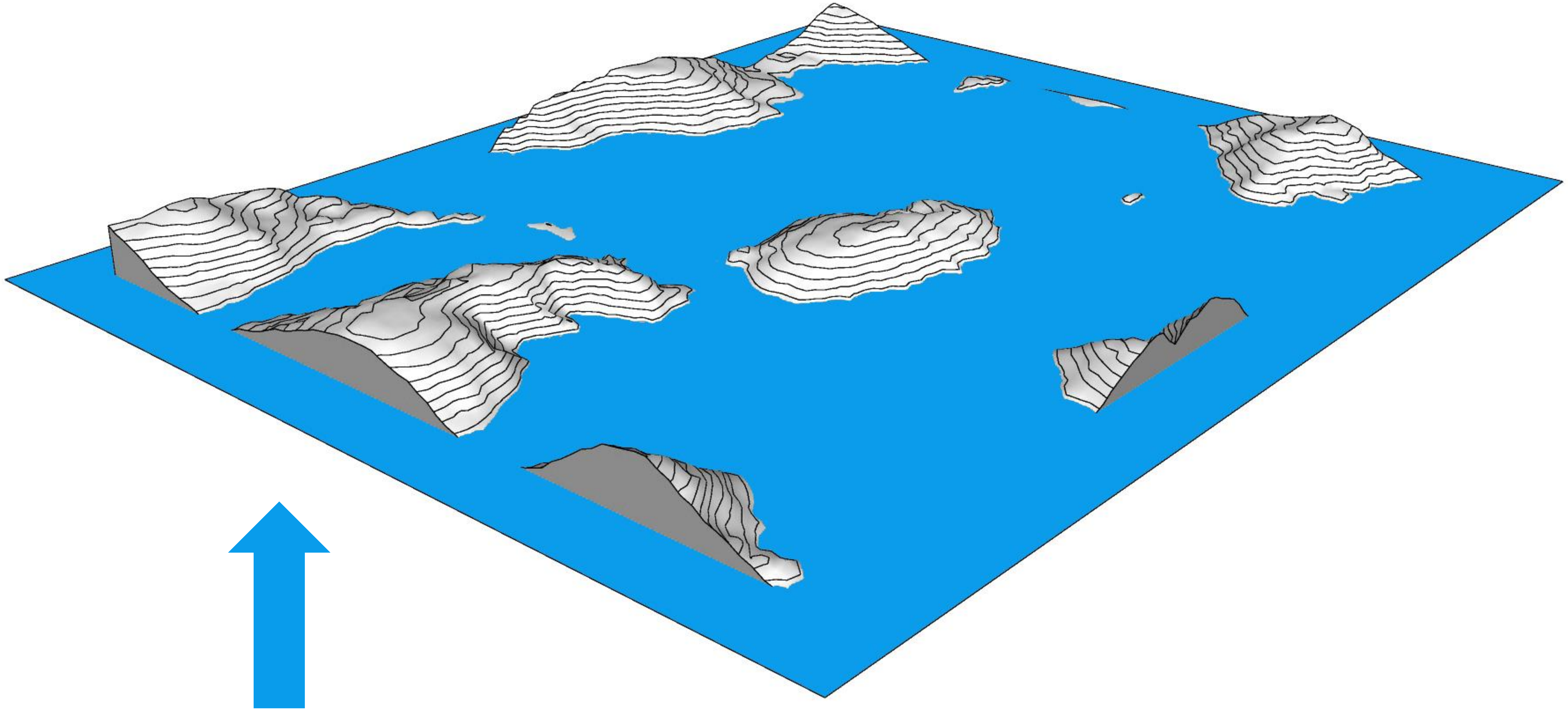
erosion
sea level rise

erosion
sea level rise
storm surge

COMMON “BATHTUB METHOD”



COMMON "BATHTUB METHOD"



ASSUMPTIONS

EROSION

- Erosion rates will remain constant
- low erosion rate of 0.25m/yr
- high erosion rate of 0.5m/yr
    - a greater erosion rate than the average erosion rates recorded in that area since 1939 (Boothroyd, 2015)
- Rising seas are predicted to increase erosion rates

ASSUMPTIONS

MATERIALS

- Material composition remained fixed, as there was too much uncertainty about future construction or demolition

- Absence of simulated coastal restoration strategies, as the high cost of nourishment programs in response to disaster caused their potential to be uncertain

THIS PROJECT ***IS NOT:***

A FORECASTING SYSTEM

This methodology should not be interpreted as a technique that can predict or forecast with exactitude how these coastal systems will evolve under climatic acute and long-term stresses.

AN ULTRA-PRECISE WORKFLOW

The complexity of these systems, the translation of their principles into a workflow more familiar for designers, and the process of working in multiple software programs all contribute to some loss of precision.

A PREDICTIVE MODELING TOOL

This workflow does not embed information that can be adjusted for re-calculation of specific, quantifiable project outcomes.

The systems being simulated are **variable** and **unpredictable**, therefore the simulations themselves cannot be exact.

Rather, the simulations express **one possibility** within the **predictable range** of outcomes.

INTRODUCTION

THIS PROJECT ***IS:***

A METHOD

An addition to a growing endeavor into the visualization of natural systems for design applications

A PROCESS

An ongoing examination of existing digital tools to improve how designers perceive environments, test design strategies, and understand spatial representations

A TECHNIQUE

A way of increasing how designers leverage the advances in computational power and efficiency to create relatively quick, iterative models of complex phenomena

METHODS

SITE | MISQUAMICUT, RI

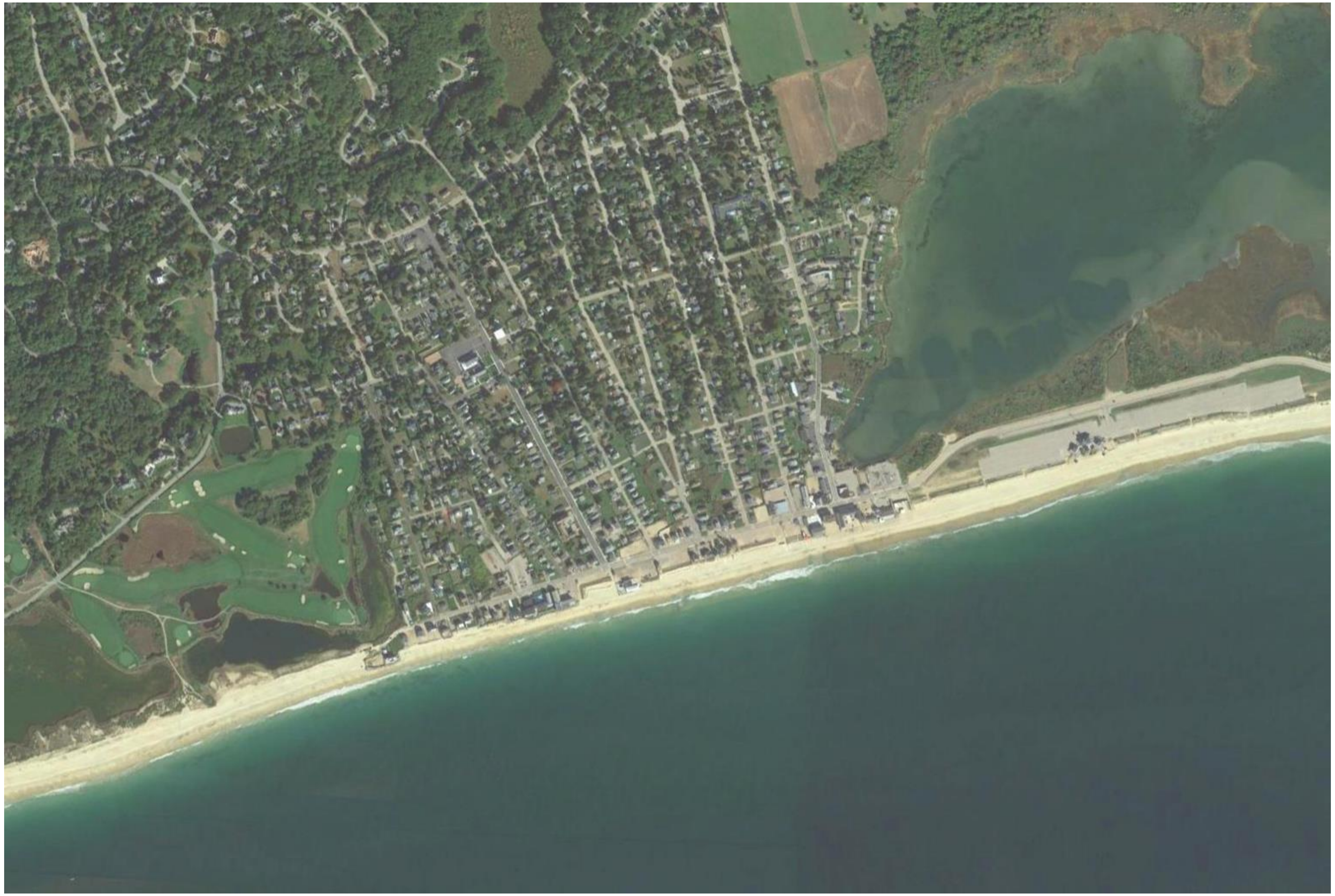
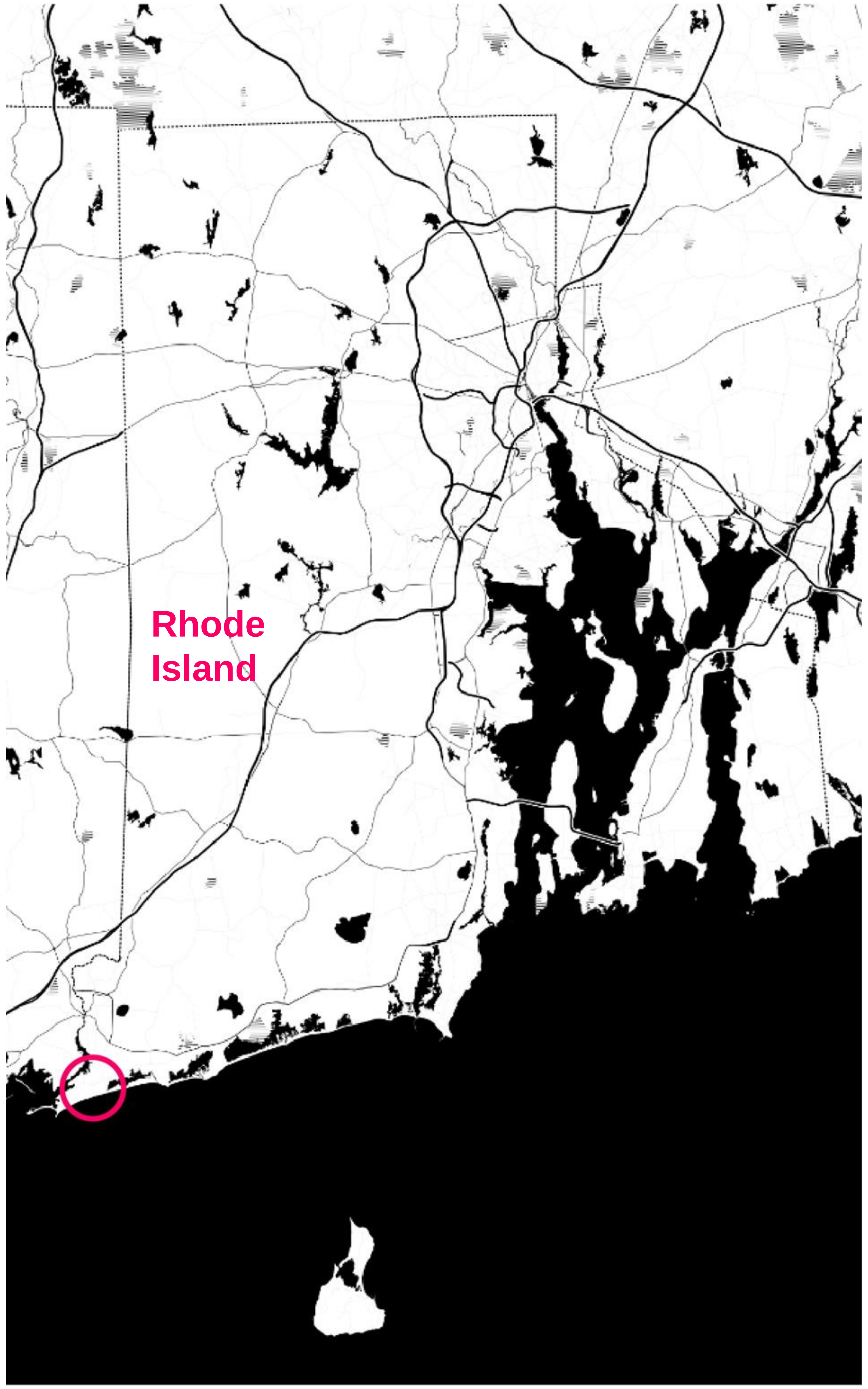


Image from Google Earth

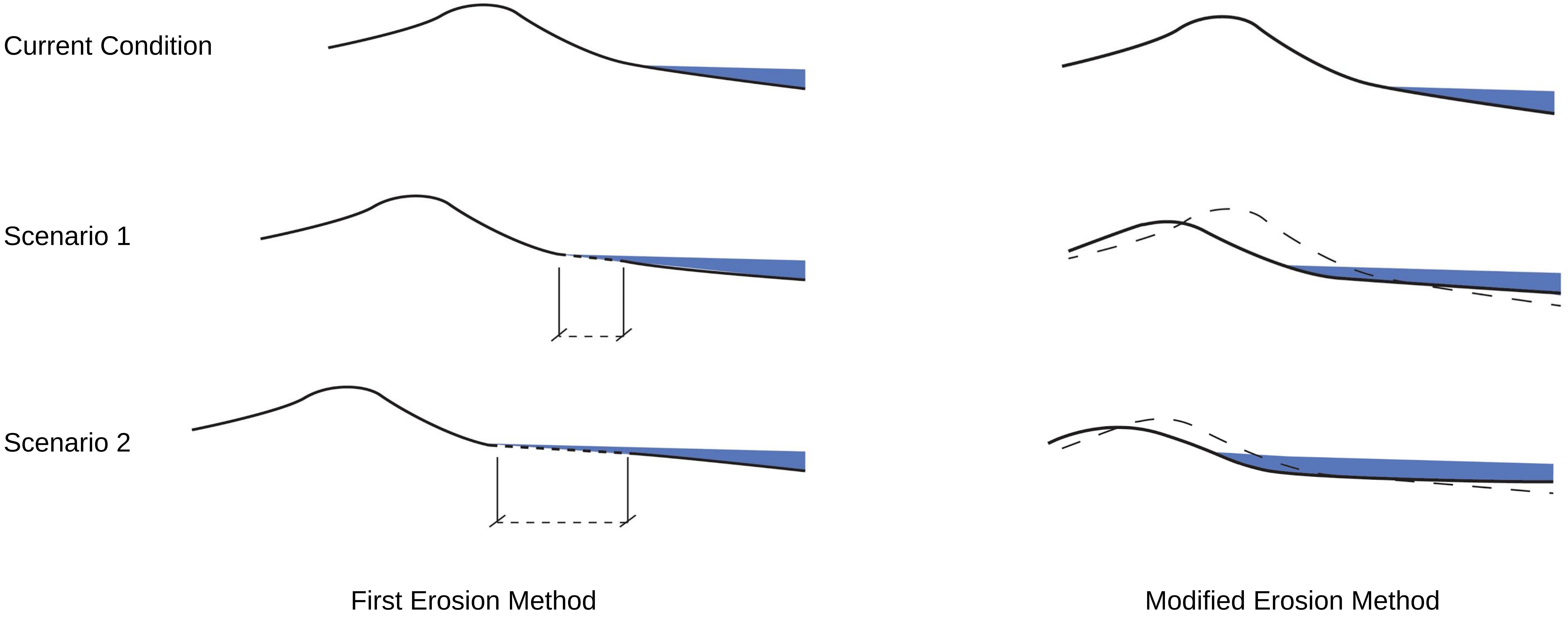


Misquamicut, Rhode Island is shown in the lower left side of the state

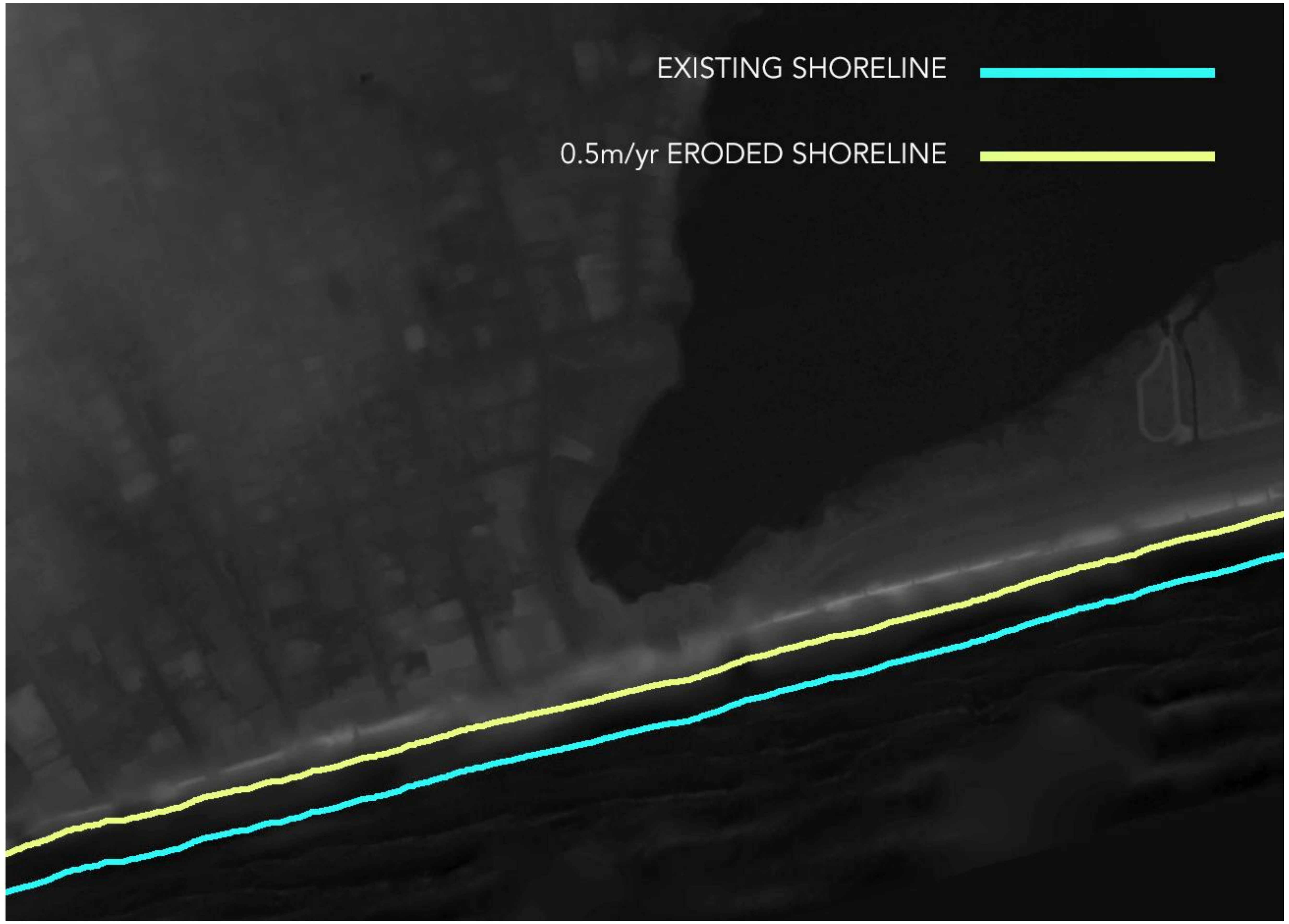
ECOLOGICAL DIVERSITY

CLOCKWISE | Salt marshes along Winnapaug Pond; Kayakers enjoying the brackish marshes of Little Maschaug Pond; Misquamicut State Beach; upland area between the ocean and the brackish marshes

MODELING EROSION



MODELING EROSION: GEOGRAPHIC IMAGER



HIGH EROSION RATE FOR SCENARIOS | 0.5m/yr

LOW EROSION RATE FOR SCENARIOS | 0.25m/yr

TIMELINE SCENARIOS| 100yrs & 50yrs

100-YEAR FLOODING SCENARIO AT .5m/yr

GEOGRAPHIC IMAGER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Foreground
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Opacity: 100%
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Anti-alias
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Adjustments
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TAKING MEASUREMENTS


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Reference File: today.asc
Coord System: UTM Zone 19N (72 W to 66 W)
Mode: Standard
Image Mode: Gray Scale | 16
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Survey
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PHOTOSHOP EDITING TERRAIN


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5/21/2019

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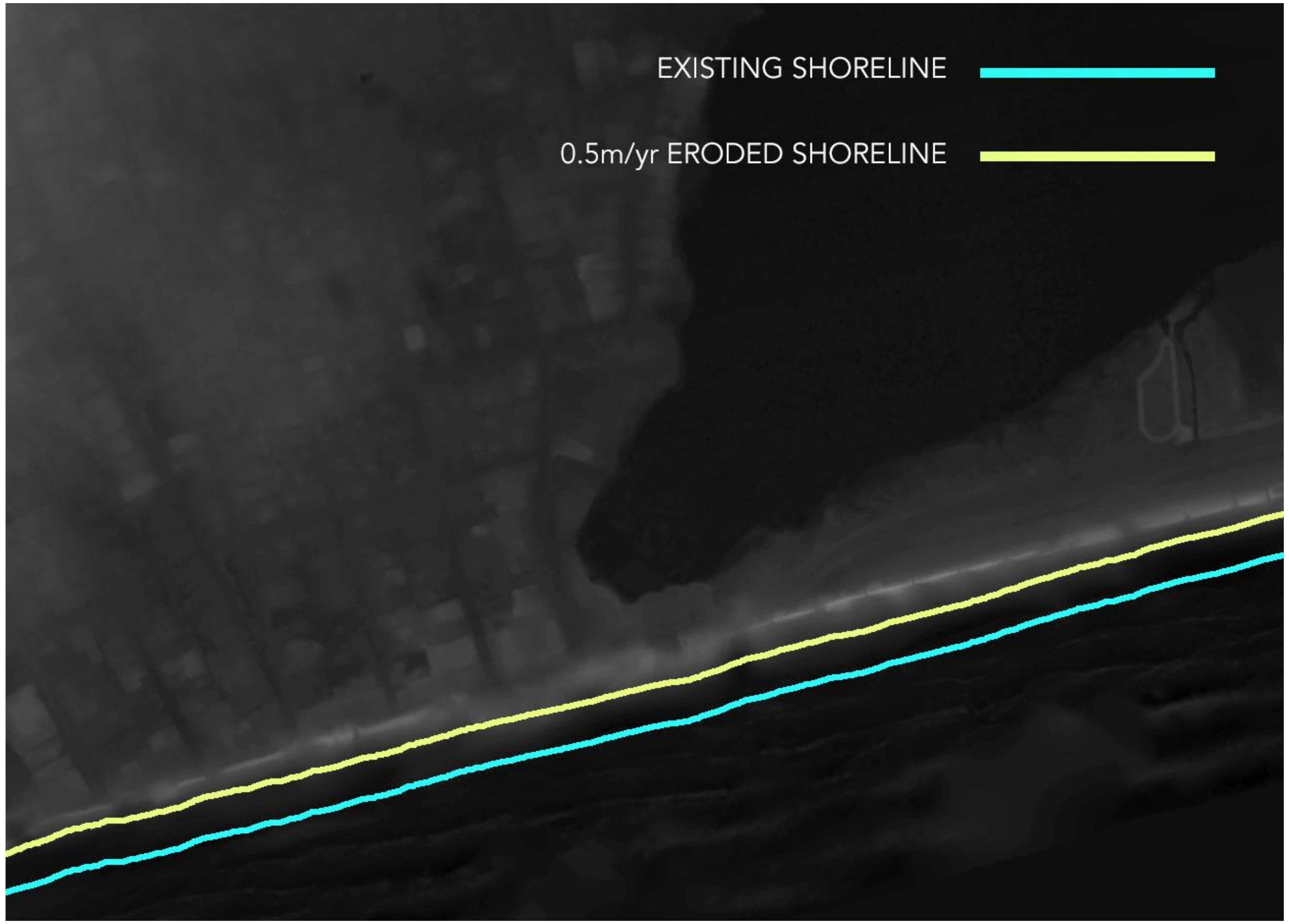
100-YEAR FLOODING SCENARIO AT .5m/yr



HIGH EROSION RATE FOR SCENARIOS | 0.5m/yr

LOW EROSION RATE FOR SCENARIOS | 0.25m/yr

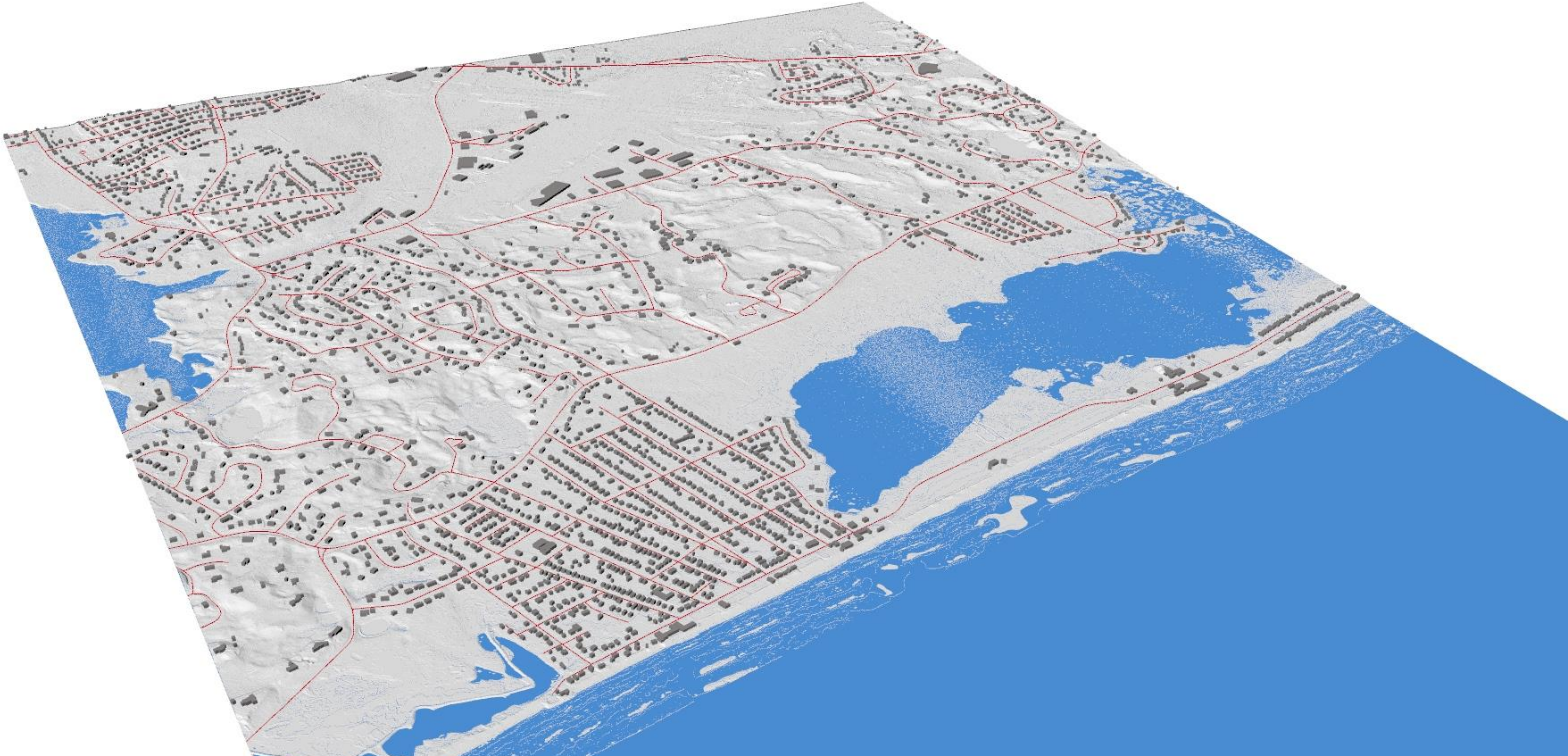
TIMELINE SCENARIOS| 100yrs & 50yrs

EROSION +
SEA LEVEL RISE

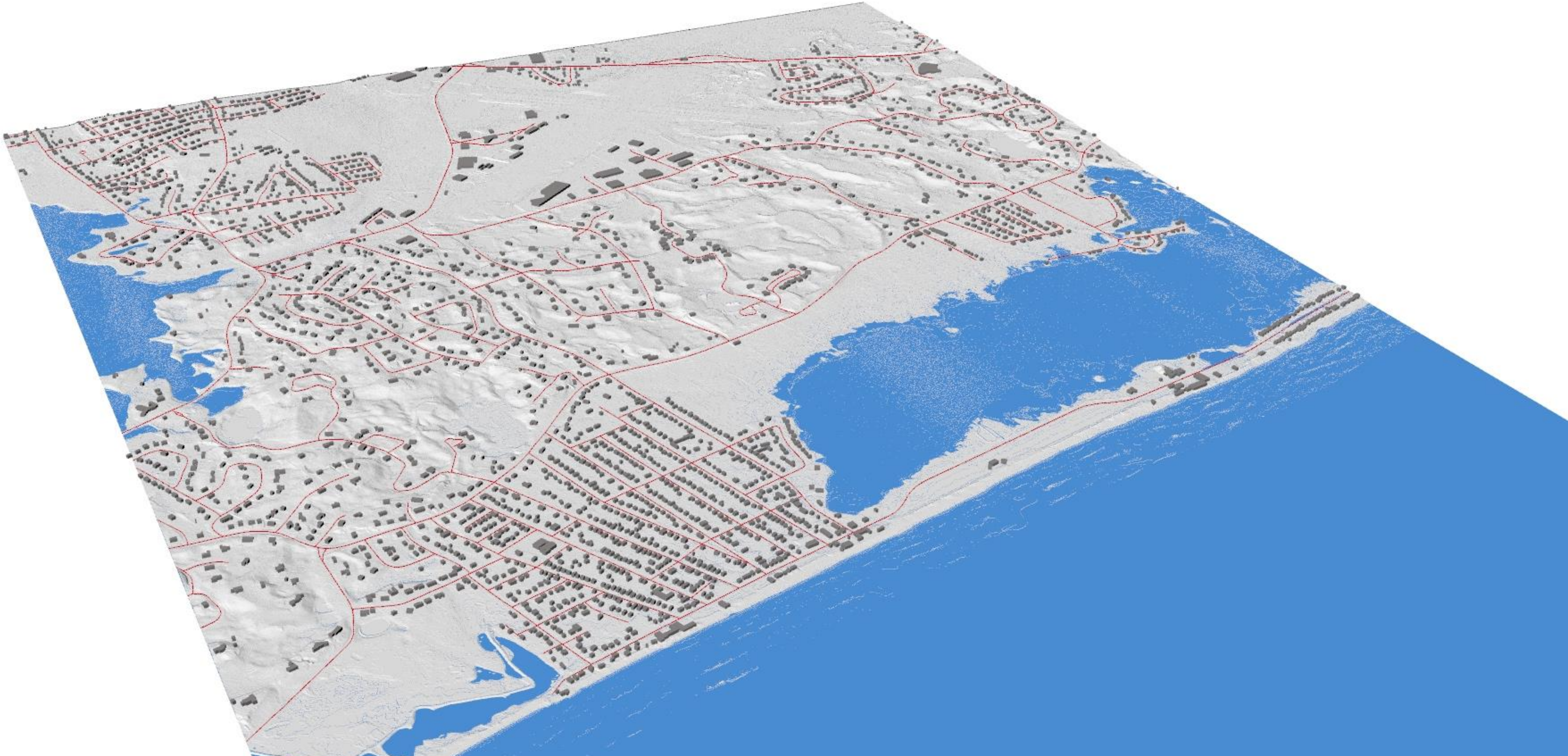
Sea level heights are projected to increase between 0.8 meters and 1.8 meters by 2100. We have used these approximations to create three scenarios, with 0.8 meters of sea level rise being the most conservative risk scenario, 1.3 meters of sea level rise being an intermediate risk scenario, and 1.8 meters of sea level rise being the most extreme risk scenario.

Hauer et al. 2016

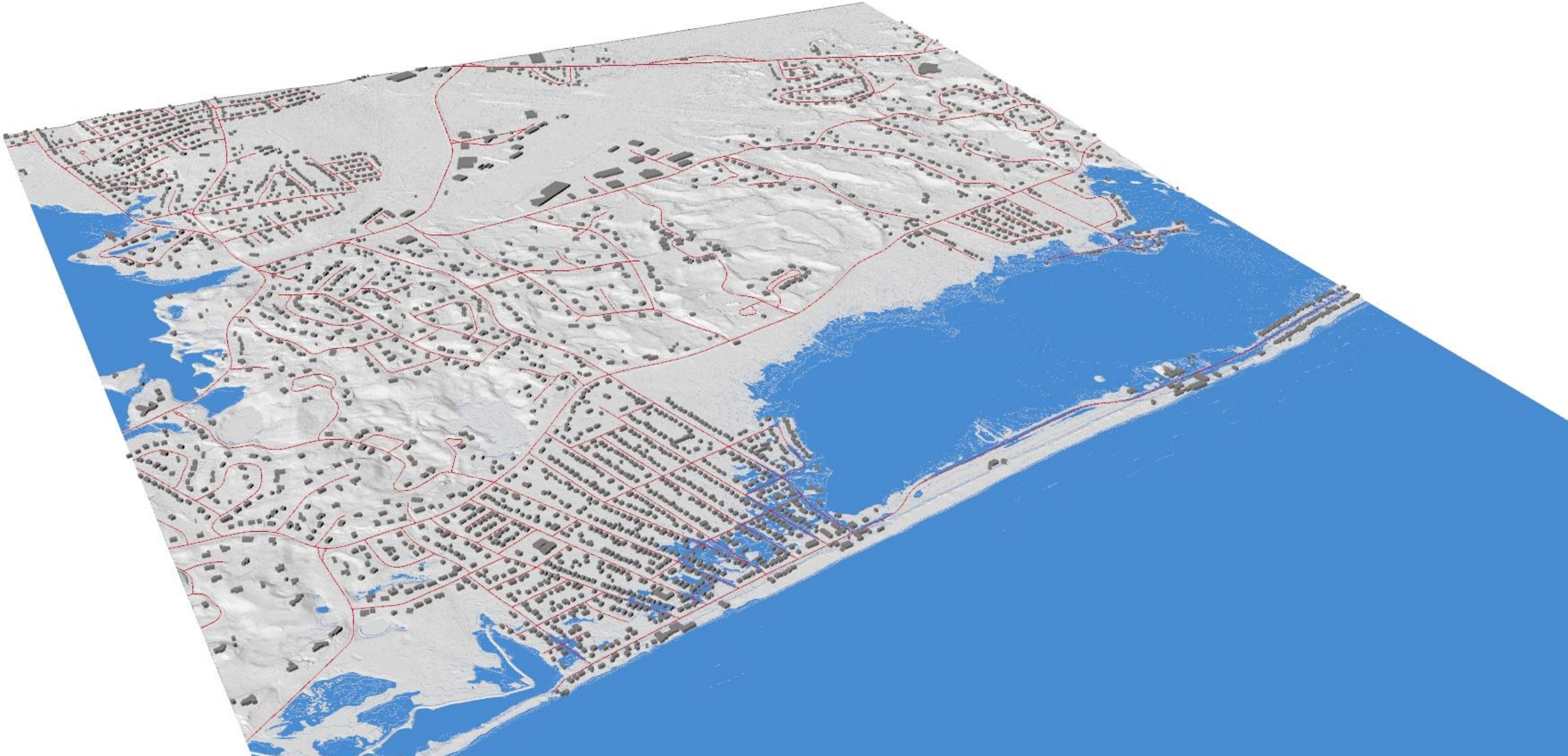
current condition



12.5m erosion + 0.8m sea level rise, 25-50yrs



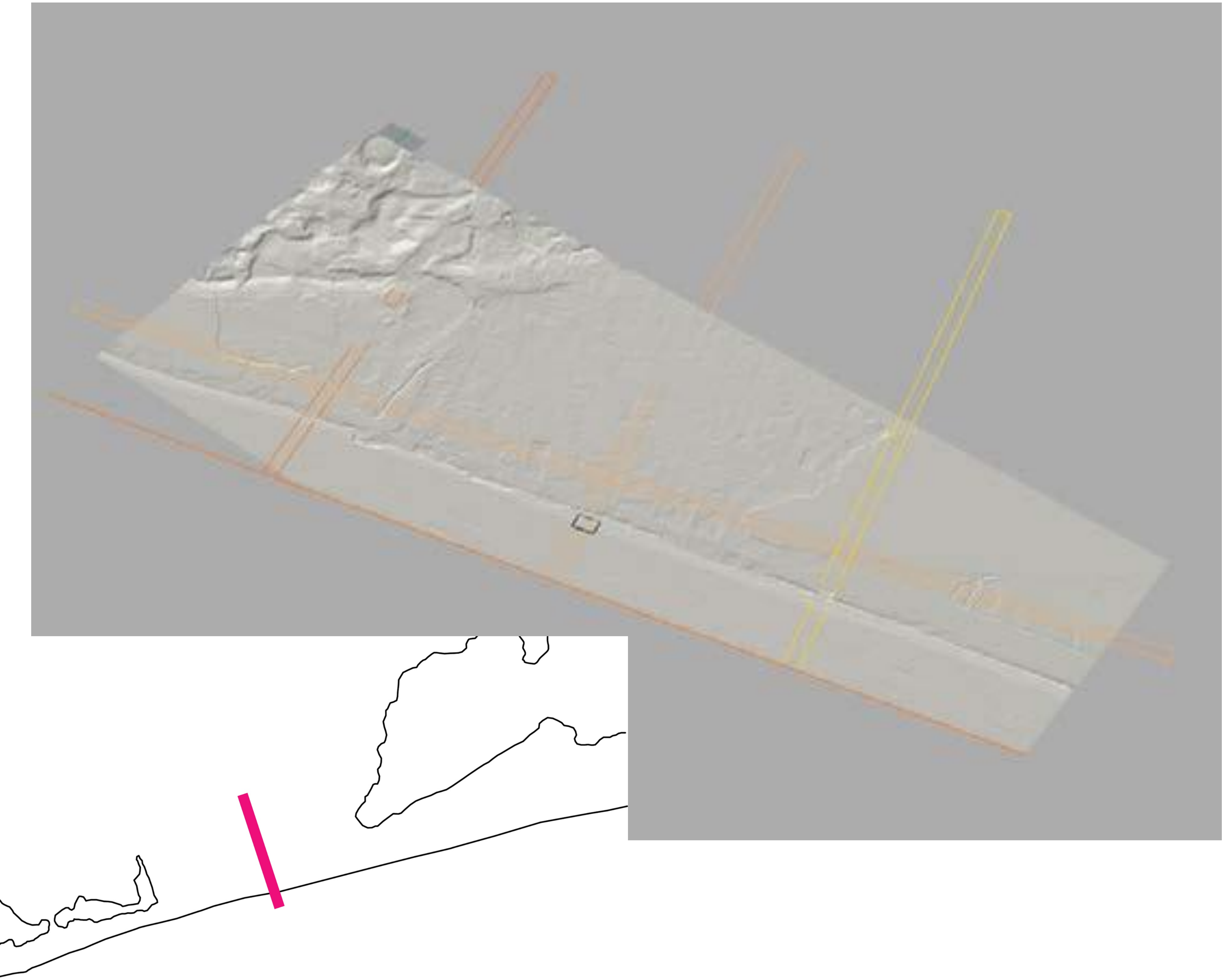
25m erosion + 1.3m sea level rise, 50-100yrs

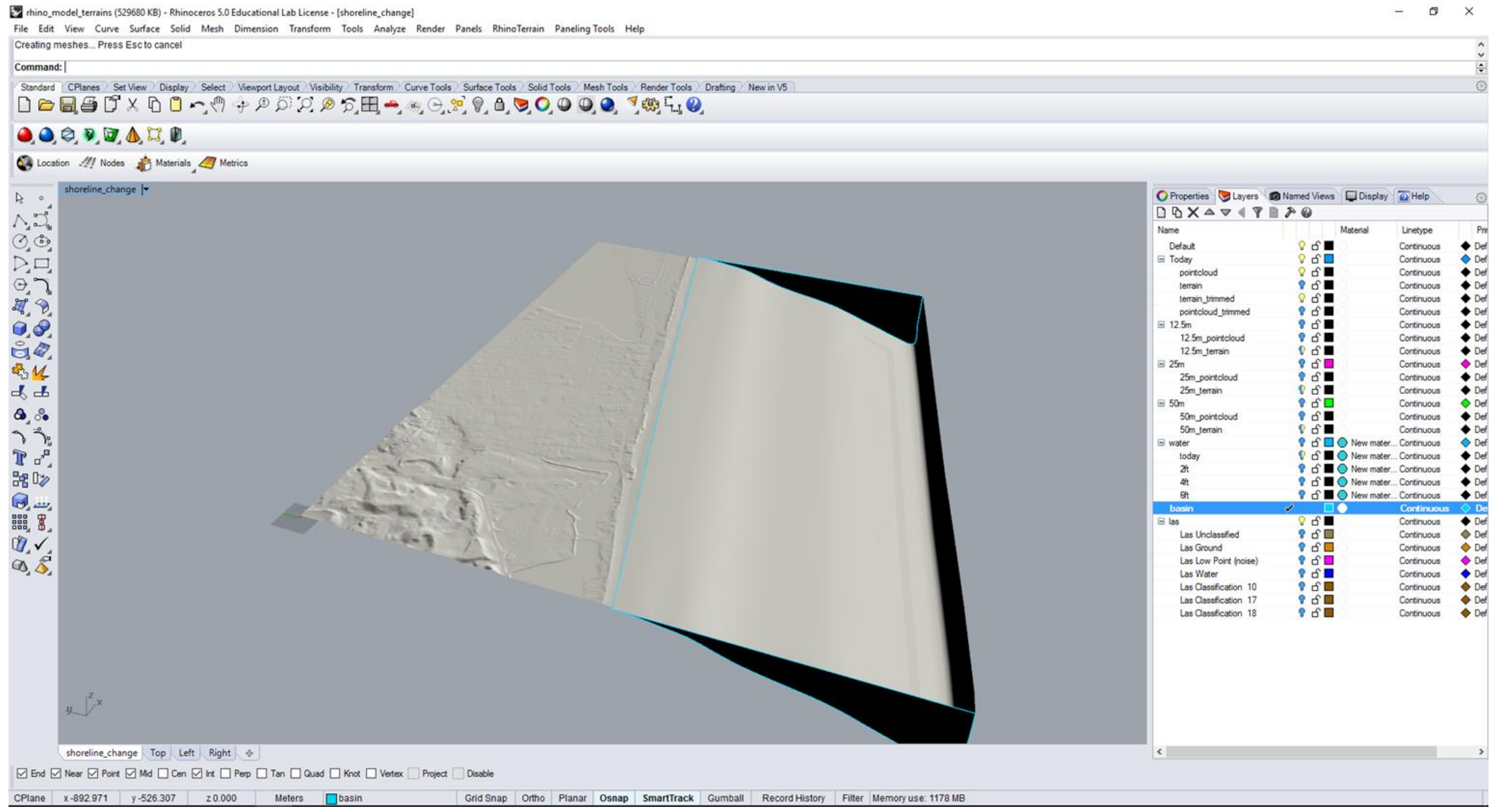


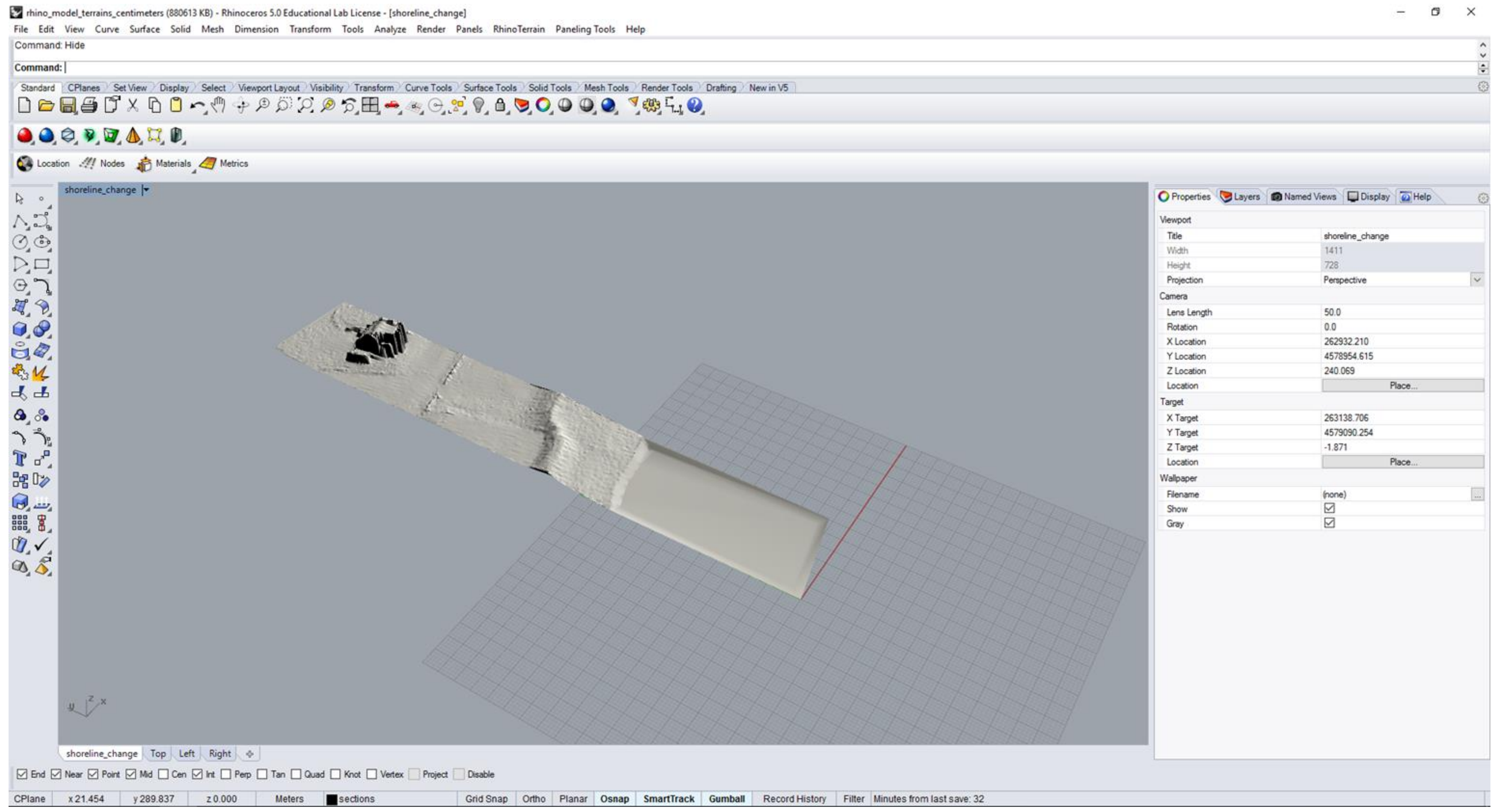
50m erosion + 1.8m sea level rise, 100yrs

EROSION +
SEA LEVEL RISE

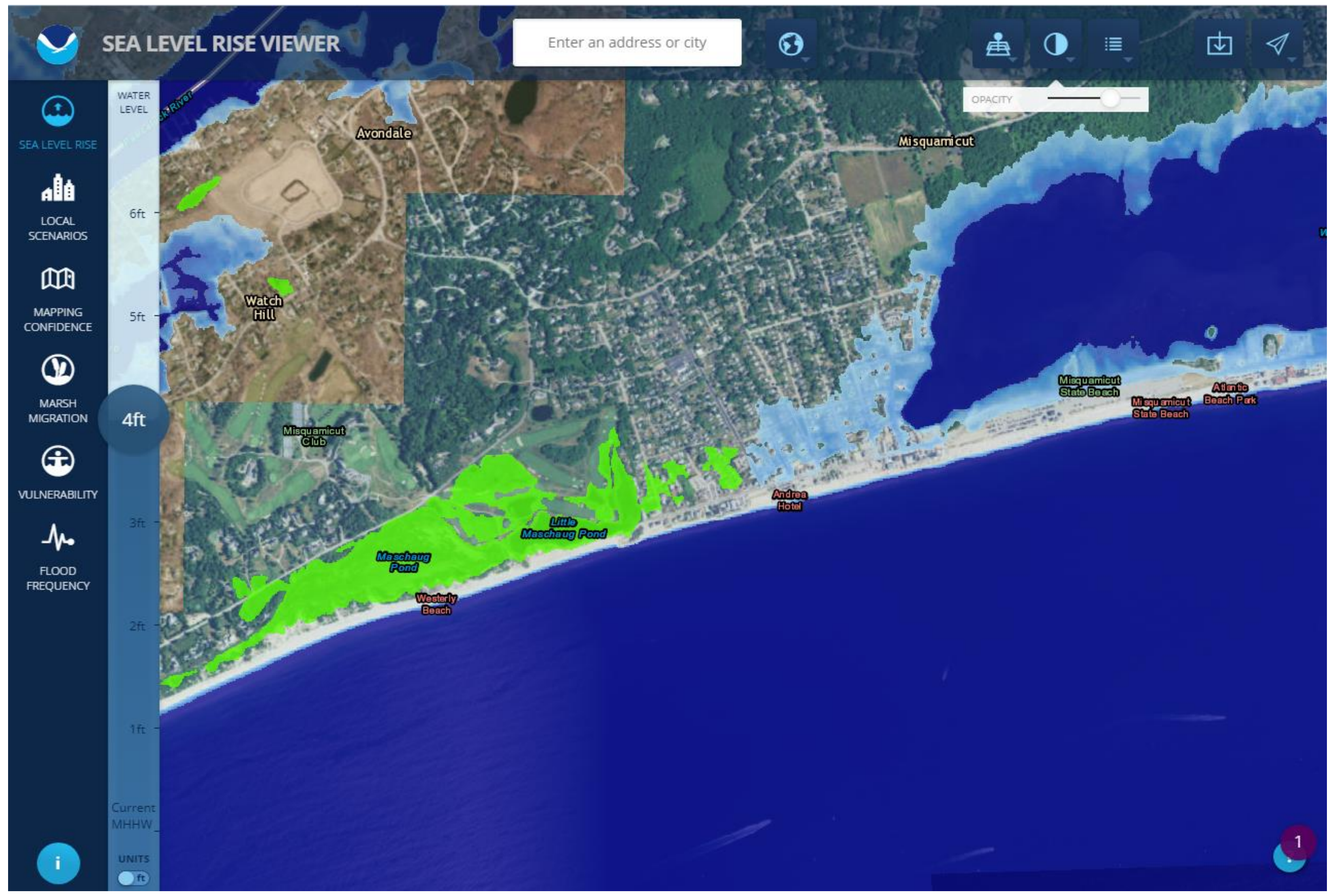
FLUID SIMULATION PREPARATION

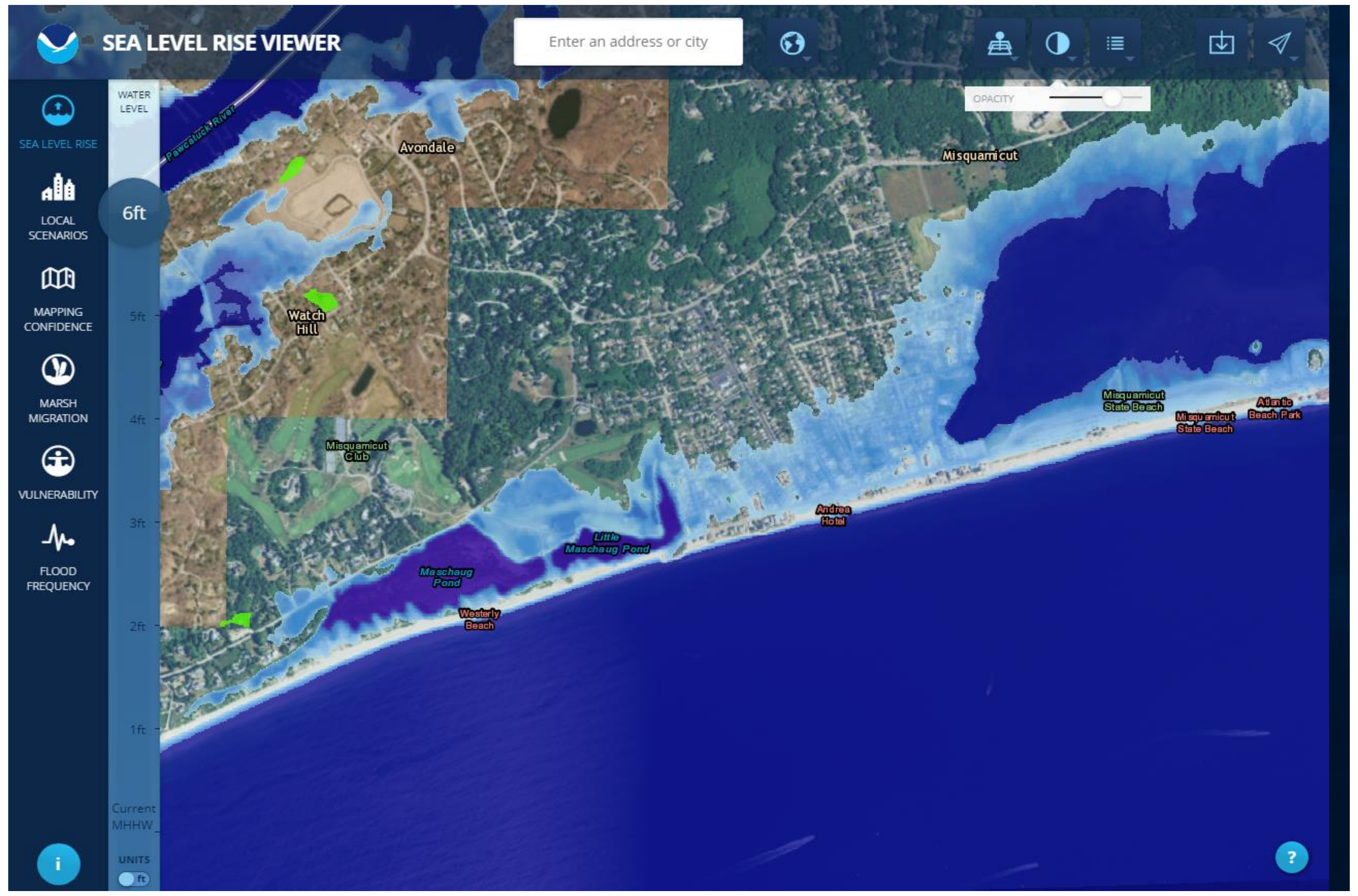


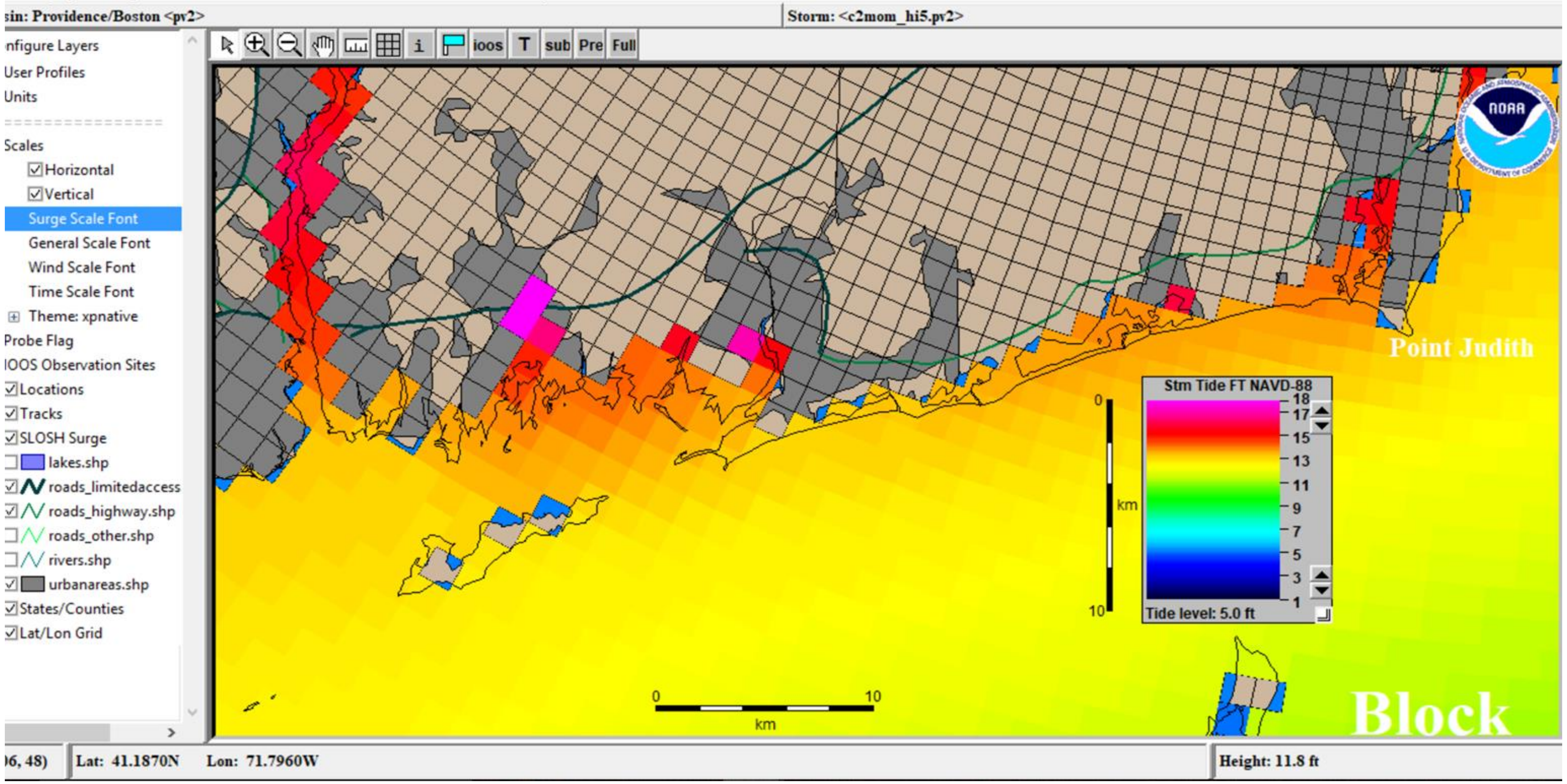




DEFINING COASTAL SCENARIOS







LEFT | Two sea level rise scenarios generated from NOAA's sea level rise viewer. The top image shows 4ft of sea level rise. The bottom image shows 6ft of sea level rise. RIGHT | A level 2 hurricane surge predictor for the area using NOAA's SLOSH program. Surges are shown between 13-16ft.

Maya includes a tool called Bifrost, a procedural framework which includes an Ocean Simulation System, which can create realistic ocean surfaces with waves, ripples, and wakes.

Bifrost relies upon a fluid implicit solver for the Navier-Stokes equations to simulate fluid motion, written here in pressure-velocity variables:

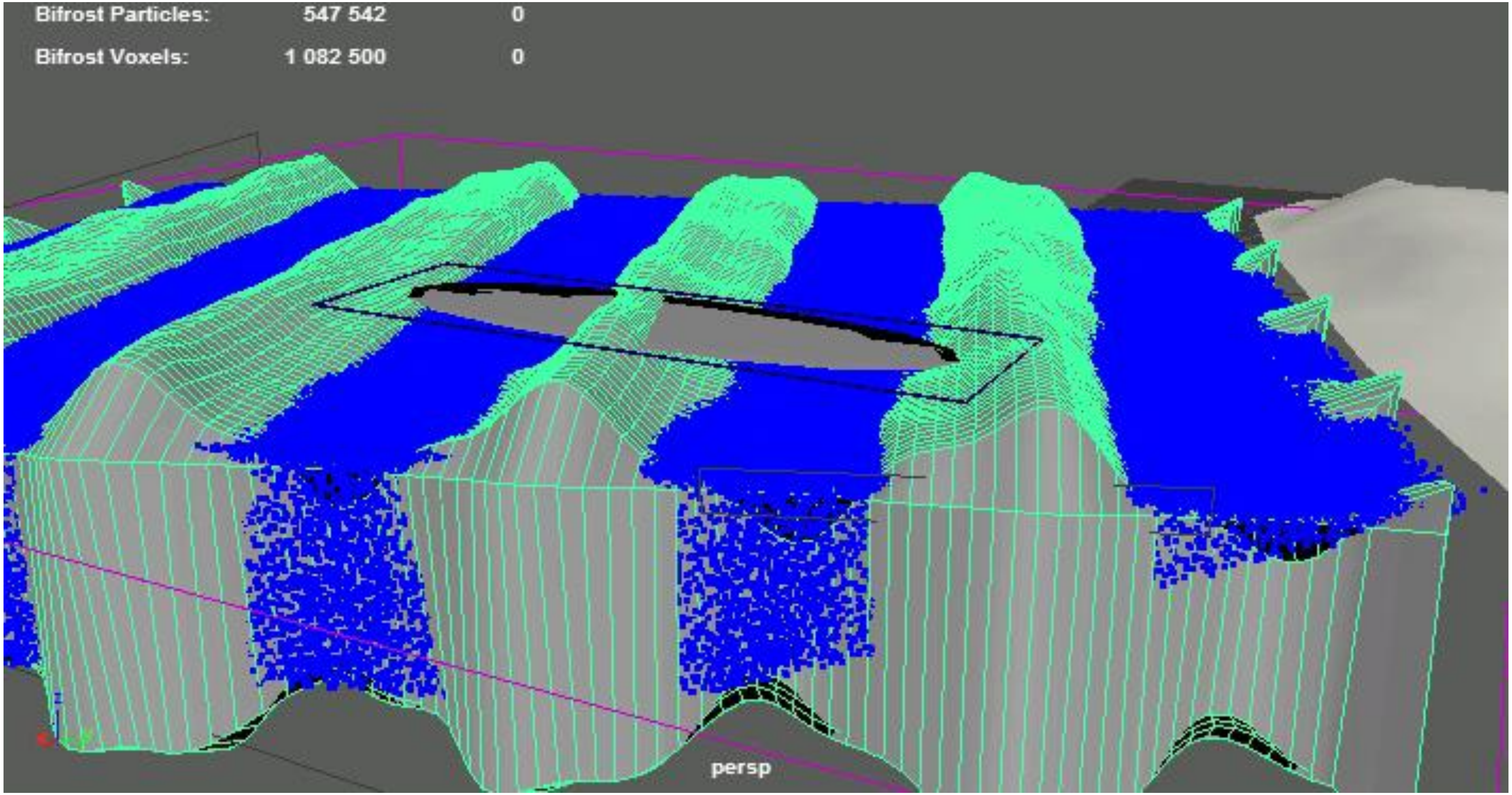
$$\nabla \cdot u = 0$$

$$\left(\frac{\partial}{\partial t} + u \cdot \nabla - v\nabla 2\right) u = g - \frac{1}{\rho}\nabla p + f$$

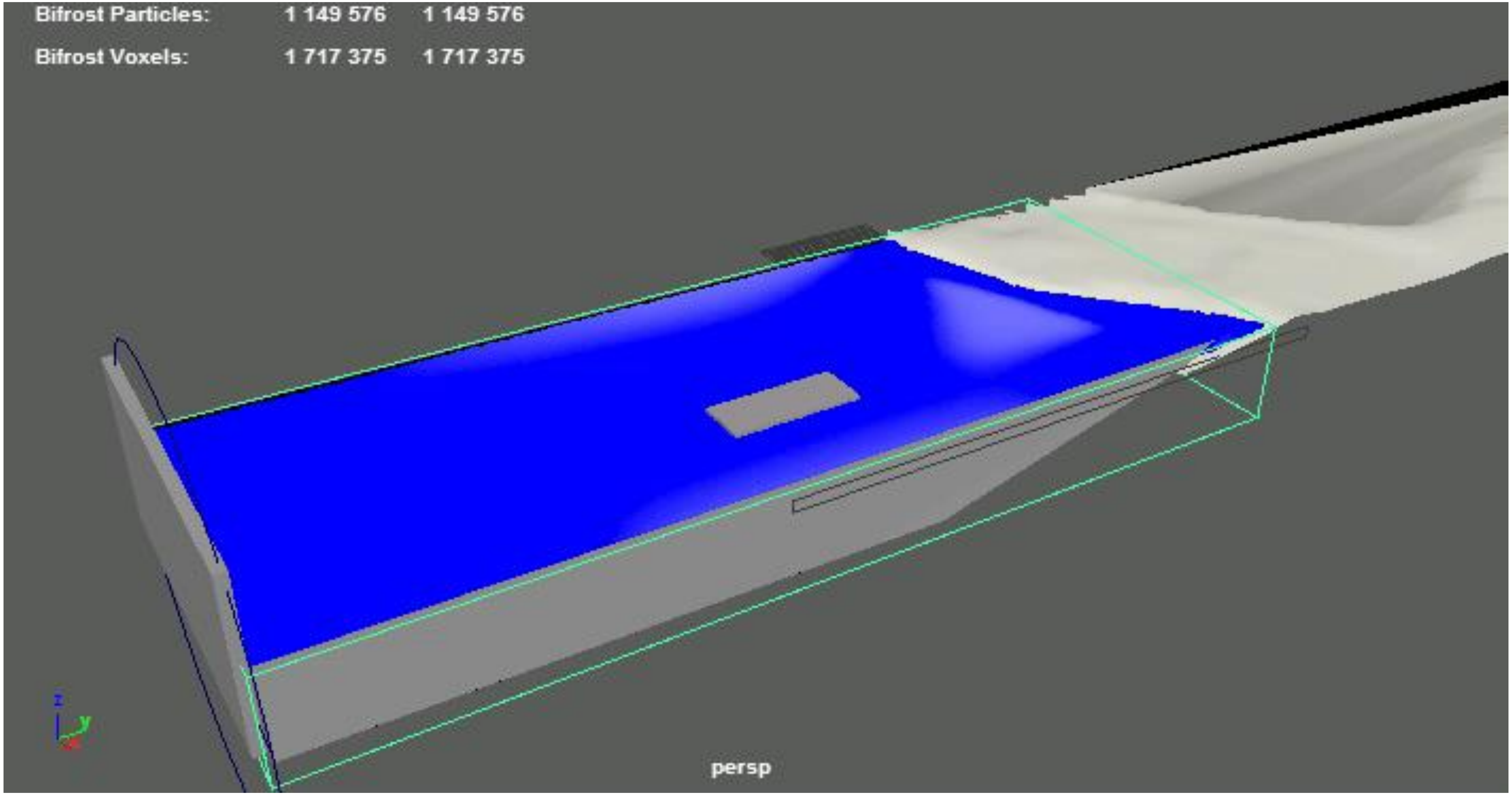
where $\nabla = (\partial/\partial x, \partial/\partial y, \partial/\partial z)$ is the gradient operator in 3-D,
$(\partial/\partial t + u \cdot \nabla - v\ \nabla 2)$ is the frequently-recurring convection-diffusion operator, and
f is an external force per unit mass.

Zaspel et al. 2011

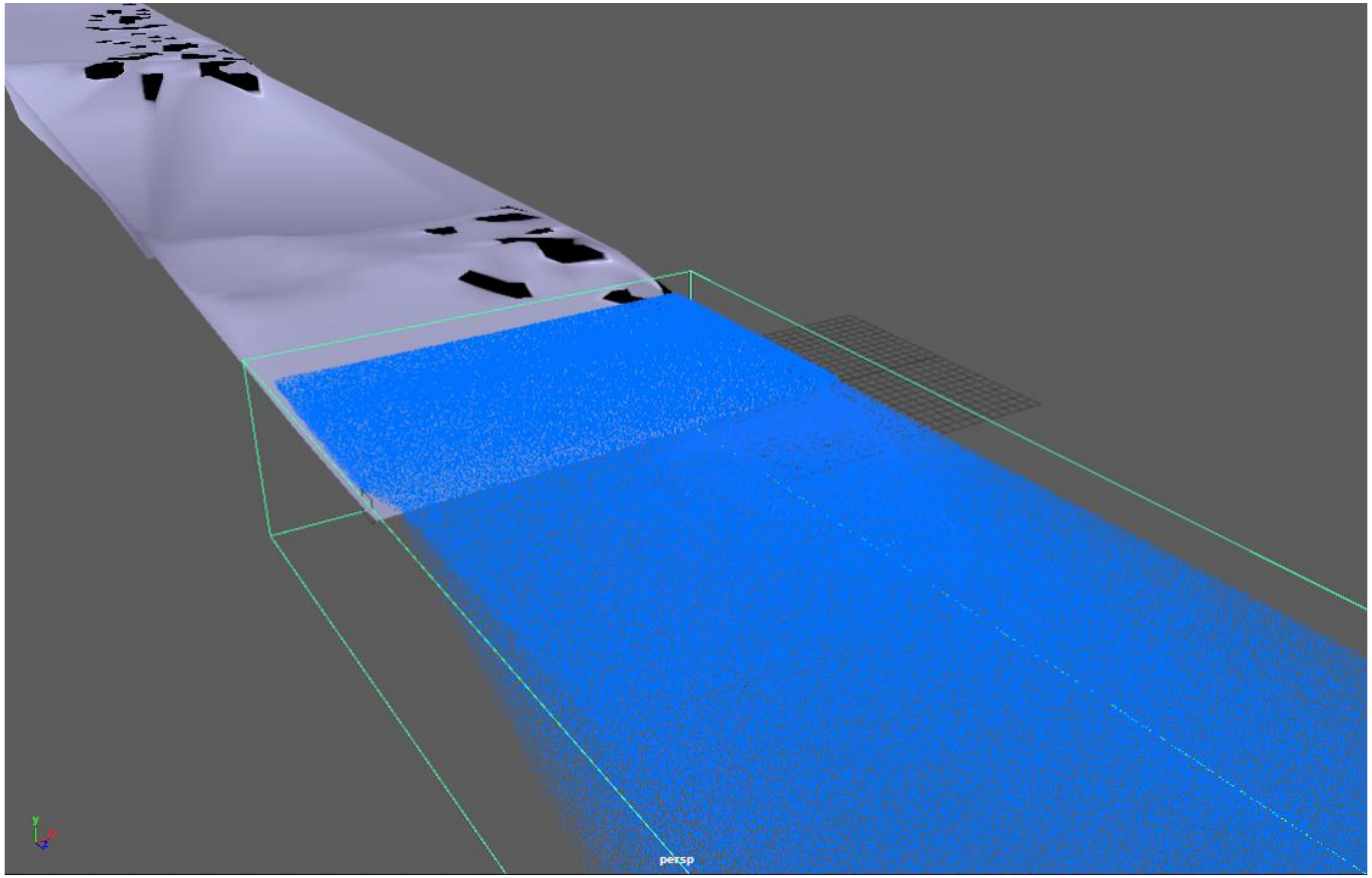
FLUID SIMULATION PROCESS – EARLY TRIALS

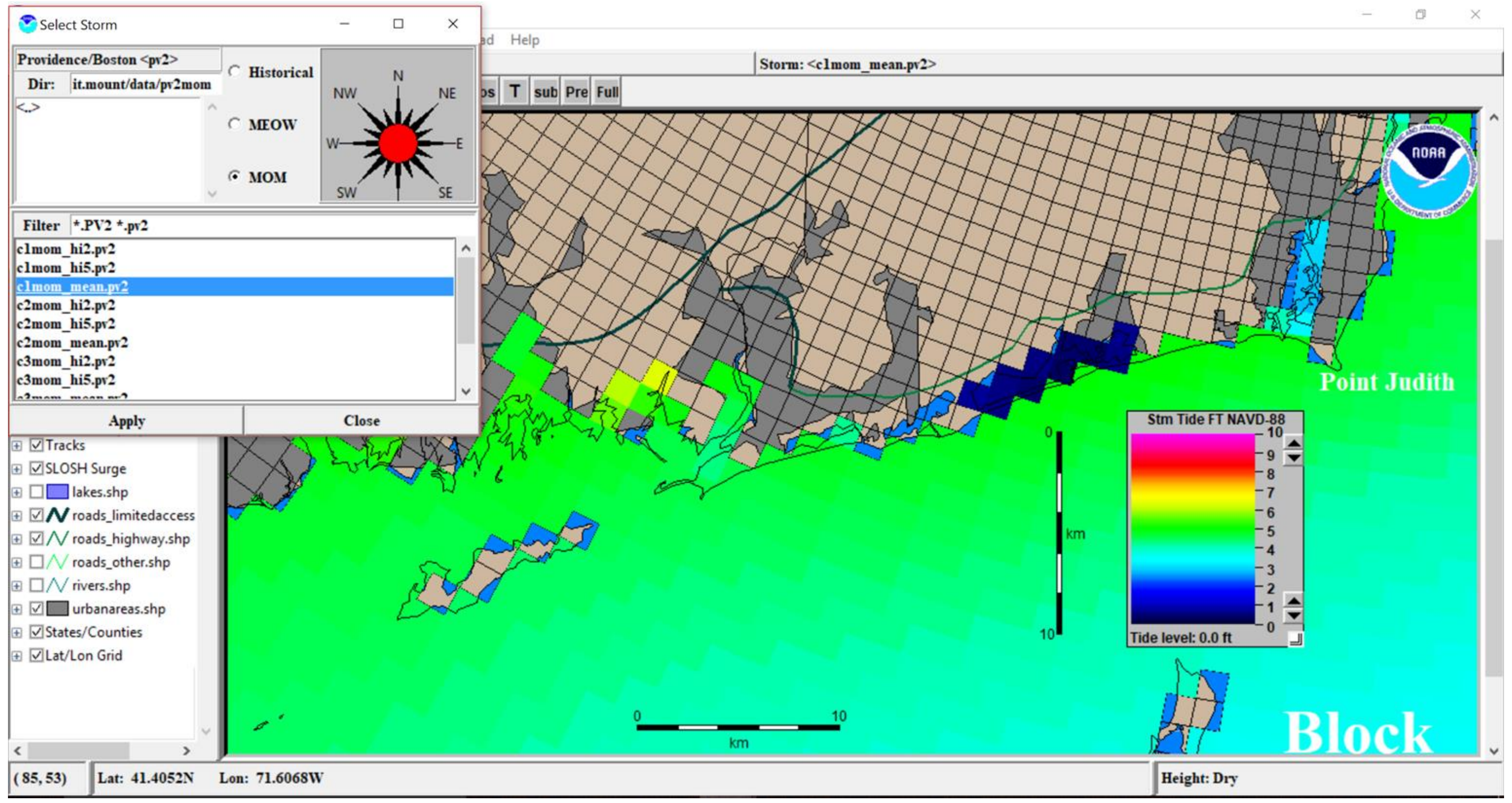


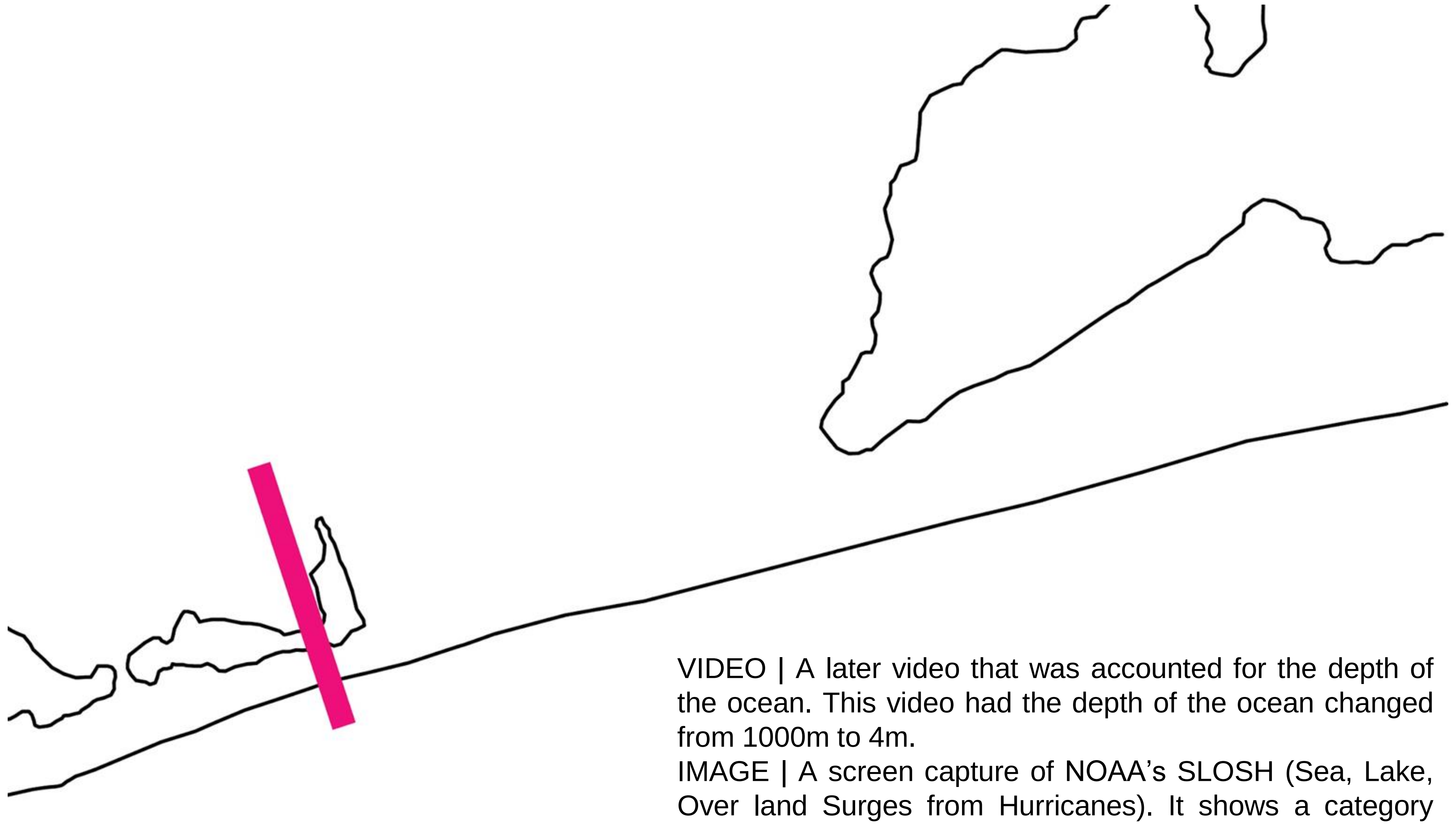
FLUID SIMULATION PROCESS – EARLY TRIALS



CURRENT BEACH SCENARIO | 1.8m storm surge

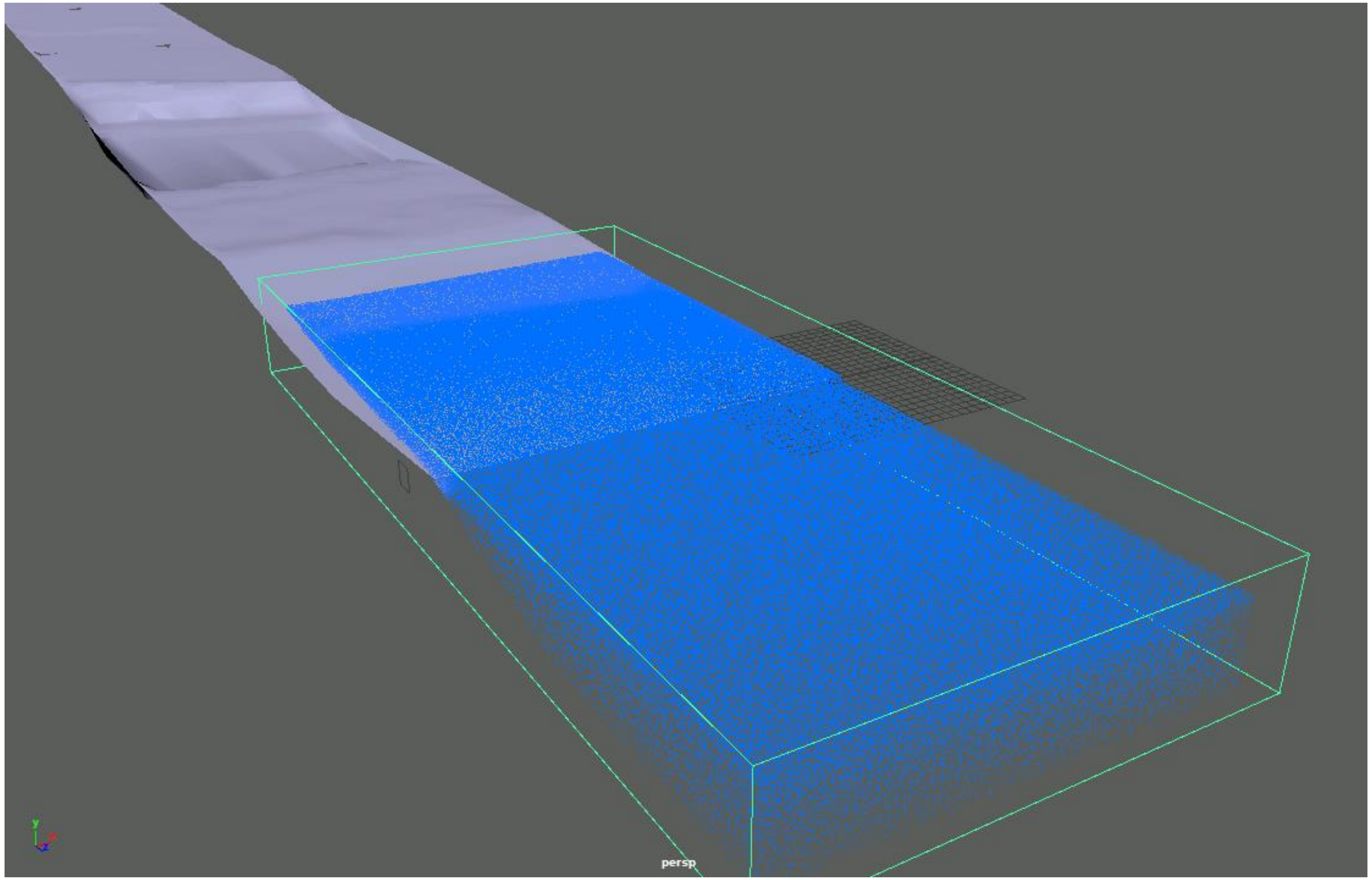


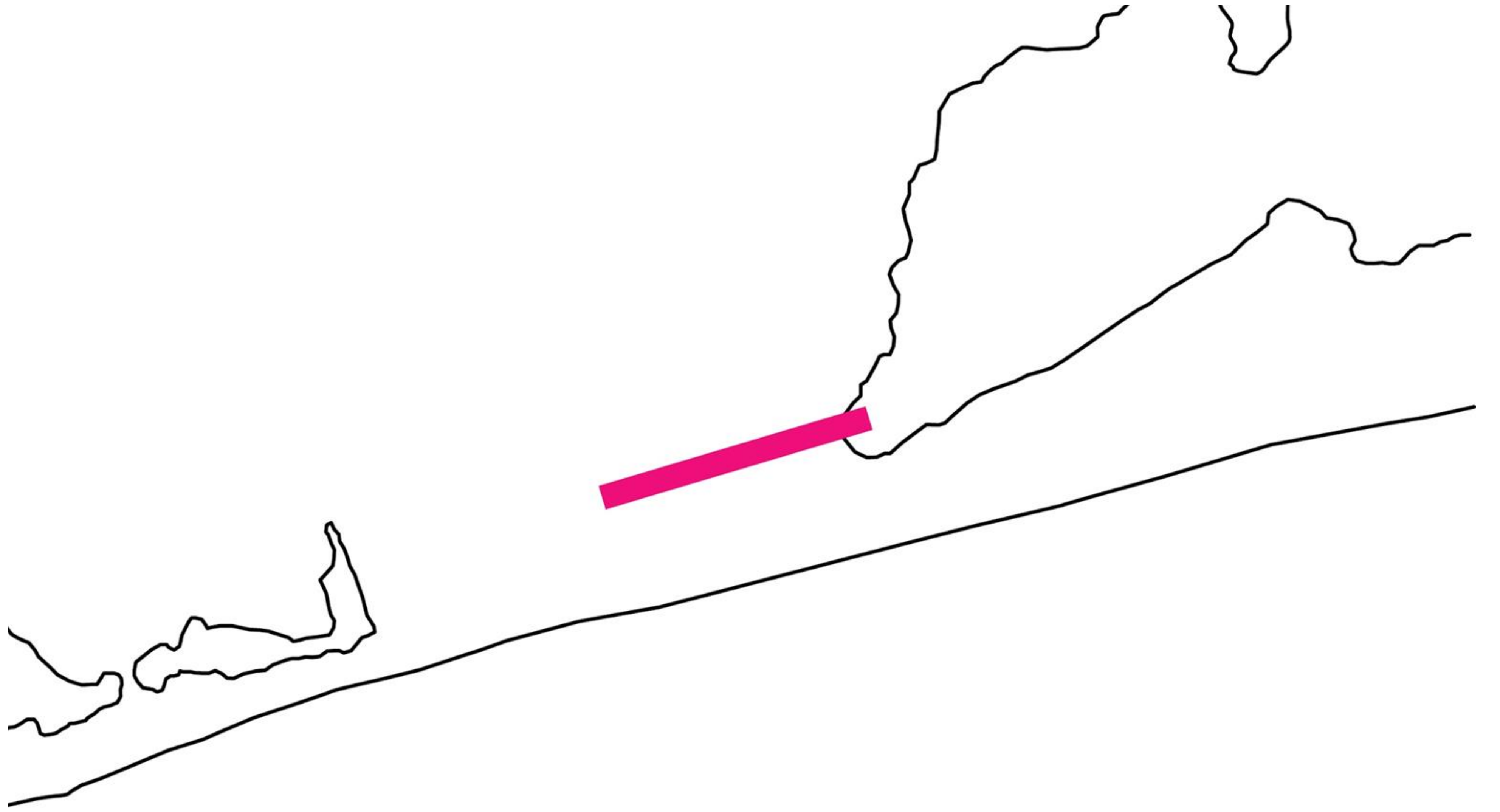




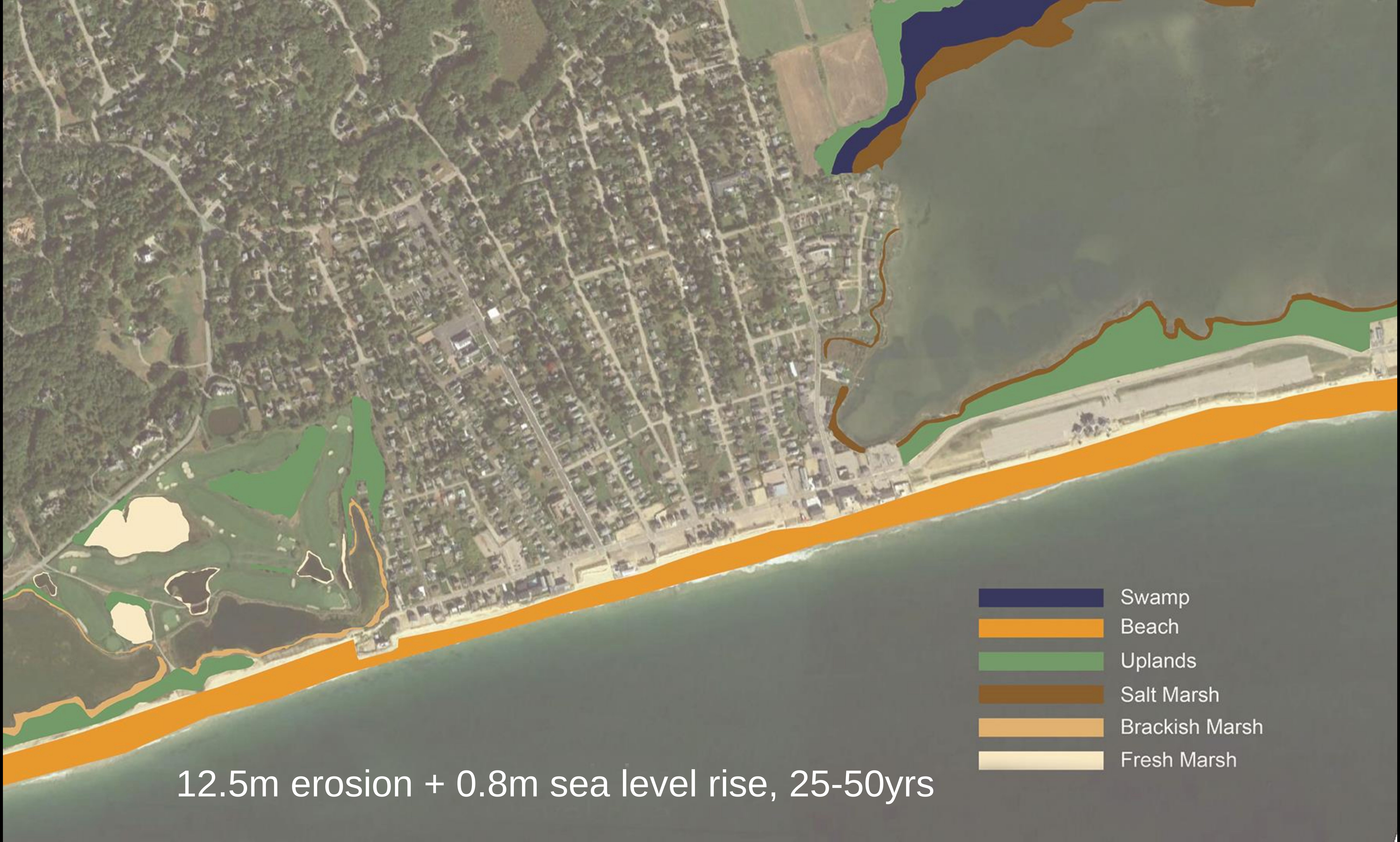
VIDEO | A later video that was accounted for the depth of the ocean. This video had the depth of the ocean changed from 1000m to 4m.
IMAGE | A screen capture of NOAA's SLOSH (Sea, Lake, Over land Surges from Hurricanes). It shows a category one hurricane surge around 5 to 6ft.

FUTURE SCENARIO | 25m erosion + 1.3m sea level rise

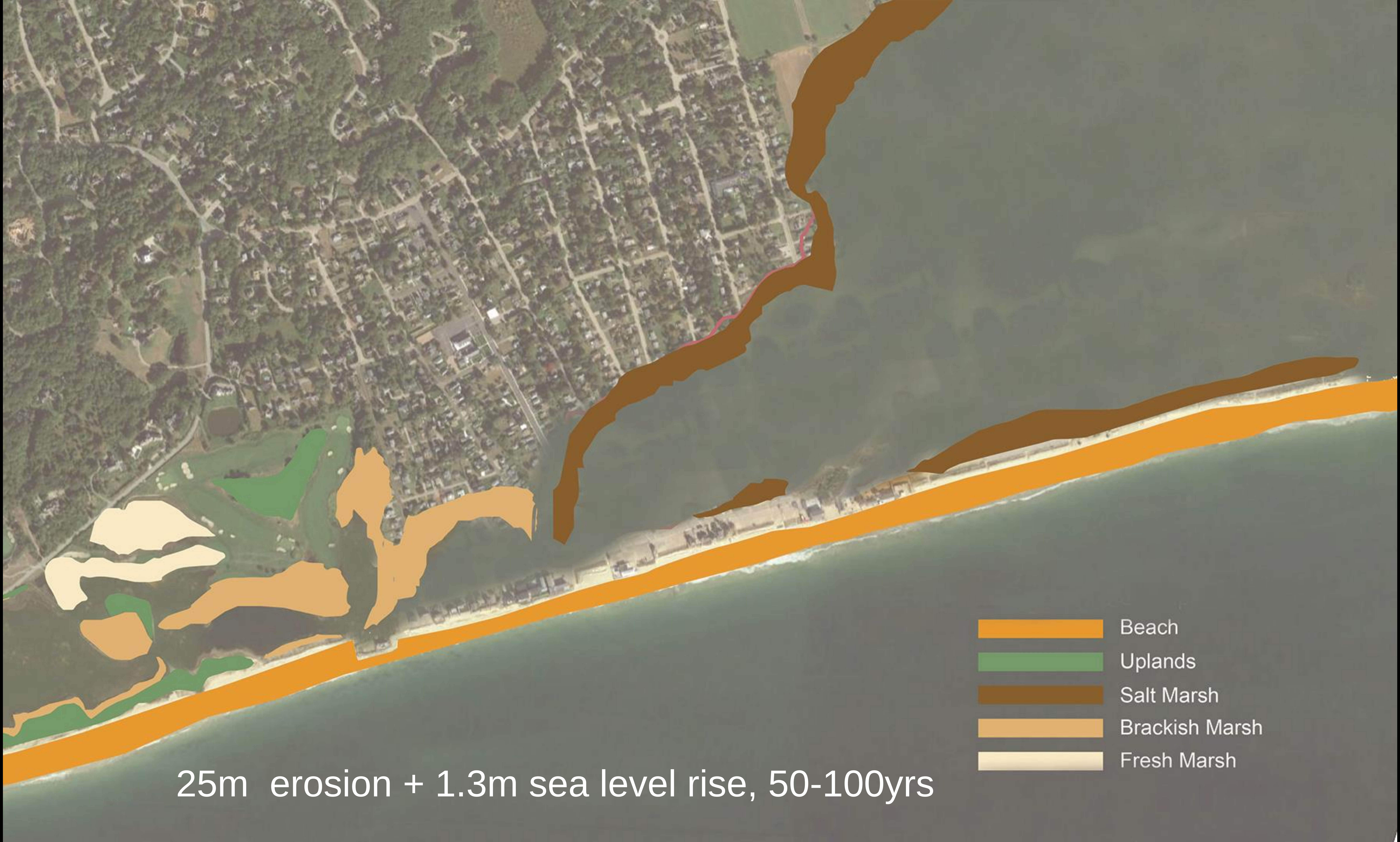





Swamp
Beach
Uplands
Salt Marsh
Brackish Marsh
Fresh Marsh
current condition



12.5m erosion + 0.8m sea level rise, 25-50yrs


Beach
Uplands
Salt Marsh
Brackish Marsh
Fresh Marsh
25m erosion + 1.3m sea level rise, 50-100yrs

50m erosion + 1.8m sea level rise, 100yrs

DESIGN INTERVENTION

The goals of an integrated approach to watershed protection include: reducing flooding during extreme events, providing healthy water for humans and nature, and restoring impaired waters such as the inland water bodies that appear to be threatened in our simulations.

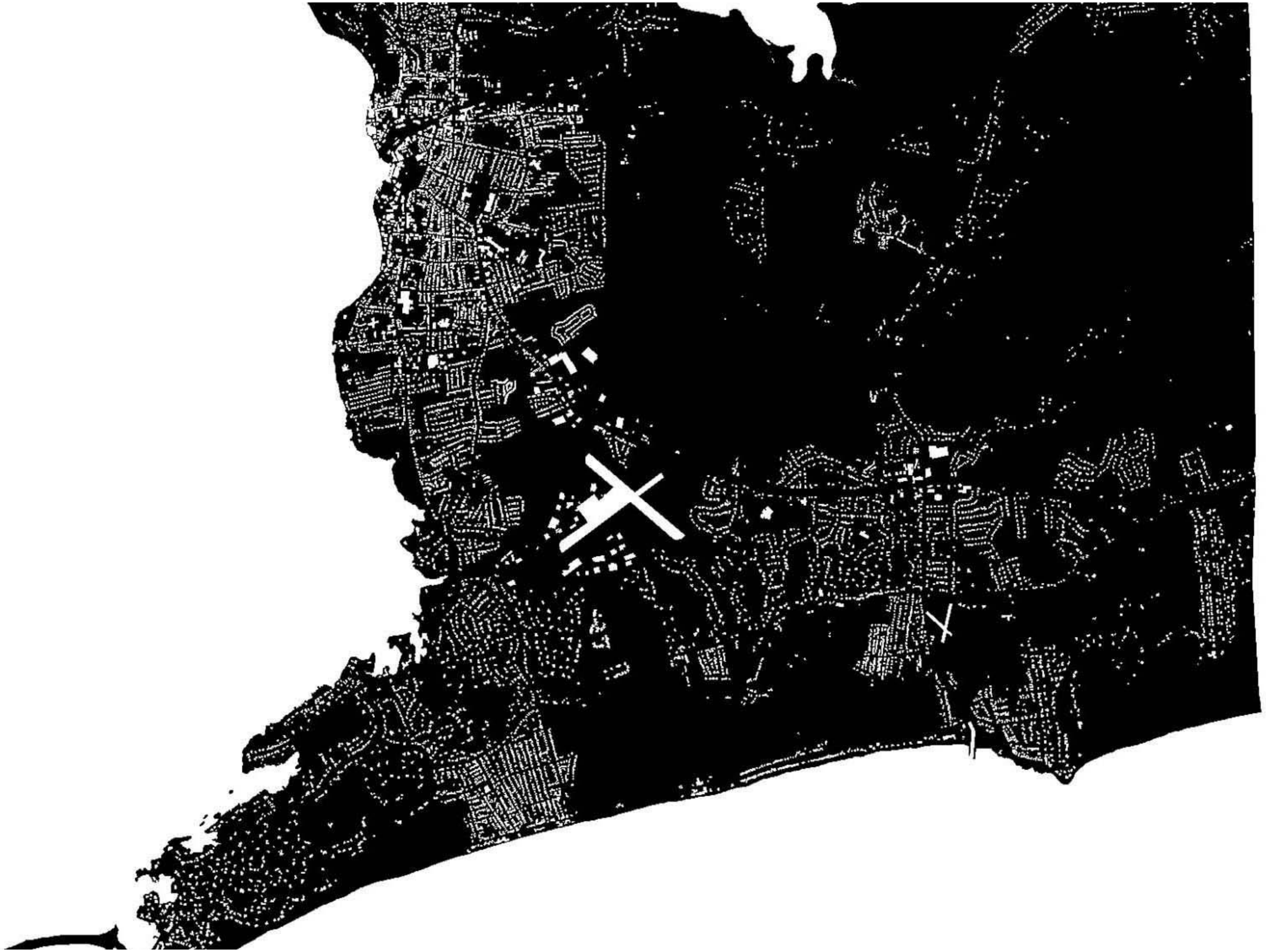
Watson, 2010

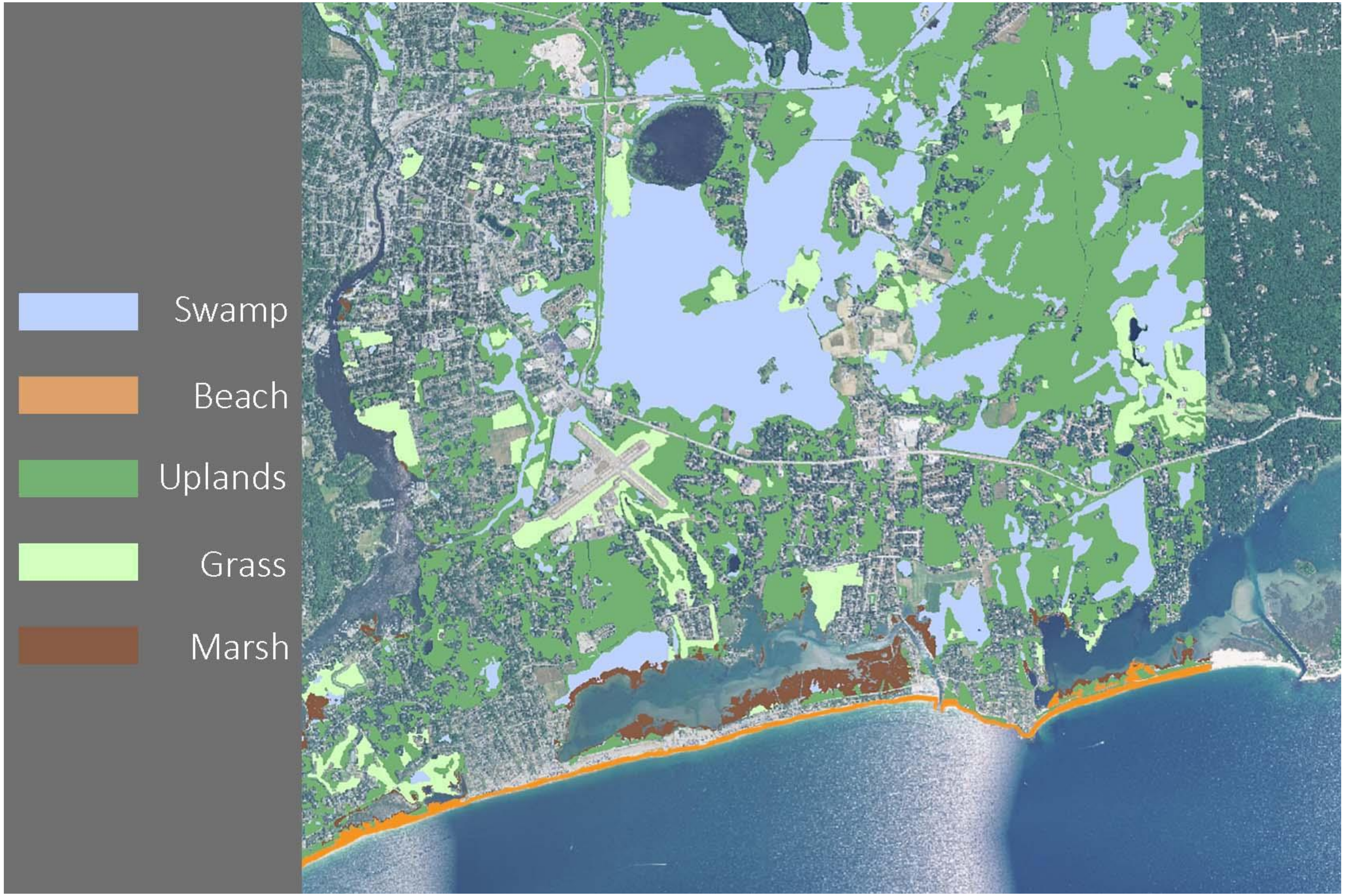
With these goals in mind, we asked the radical question:

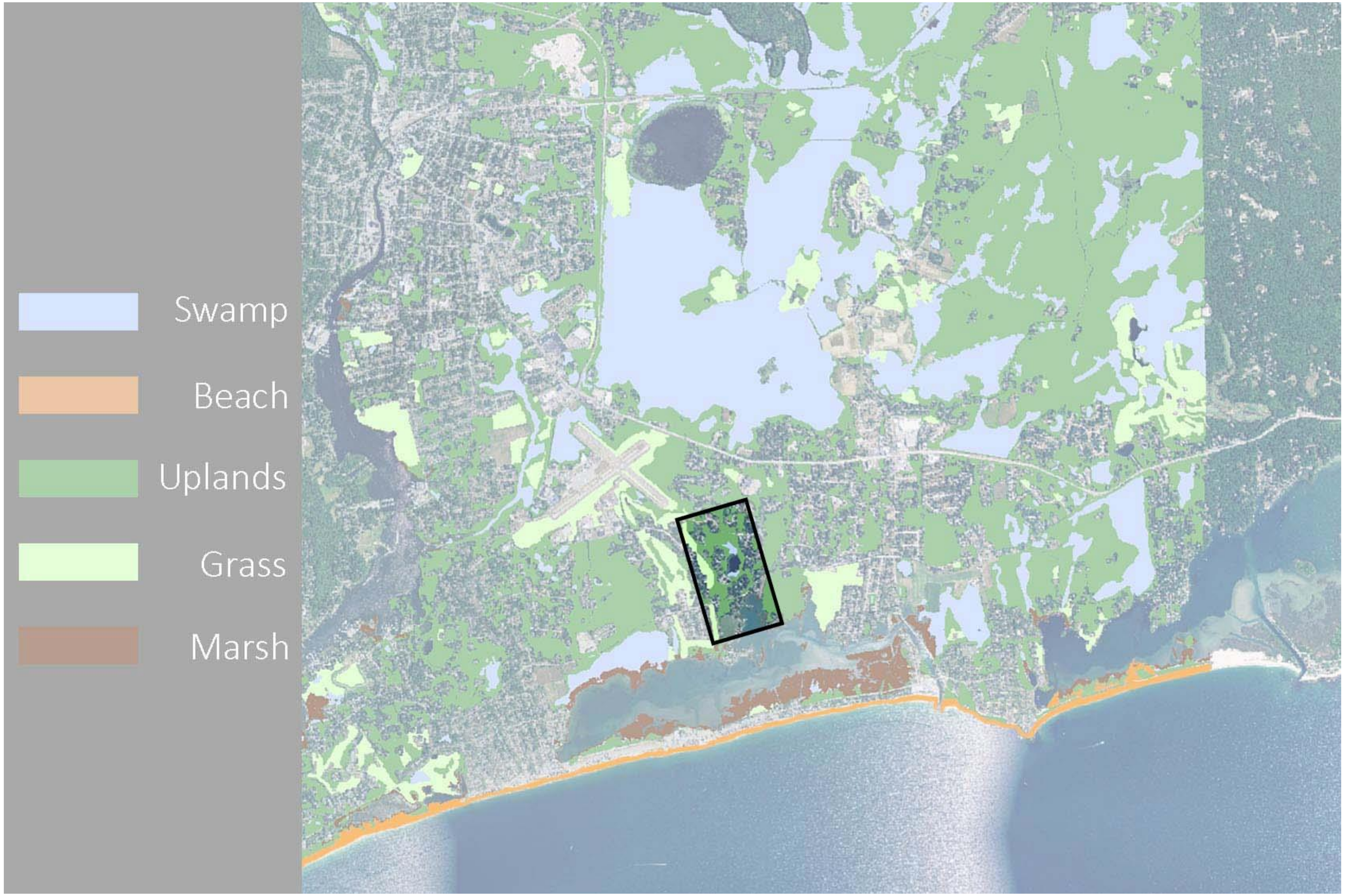
could a landscape design possibly recreate this lost coastal ecology through restoring it in an inland location?

Superpositions: Renaturalization of River L’Aire, Geneva, Switzerland.
Photo credit: Easytomap.

Superpositions: Renaturalization of River L’Aire, Geneva, Switzerland.
Photo credit: Easytomap.




Swamp
Beach
Uplands
Grass
Marsh


Swamp
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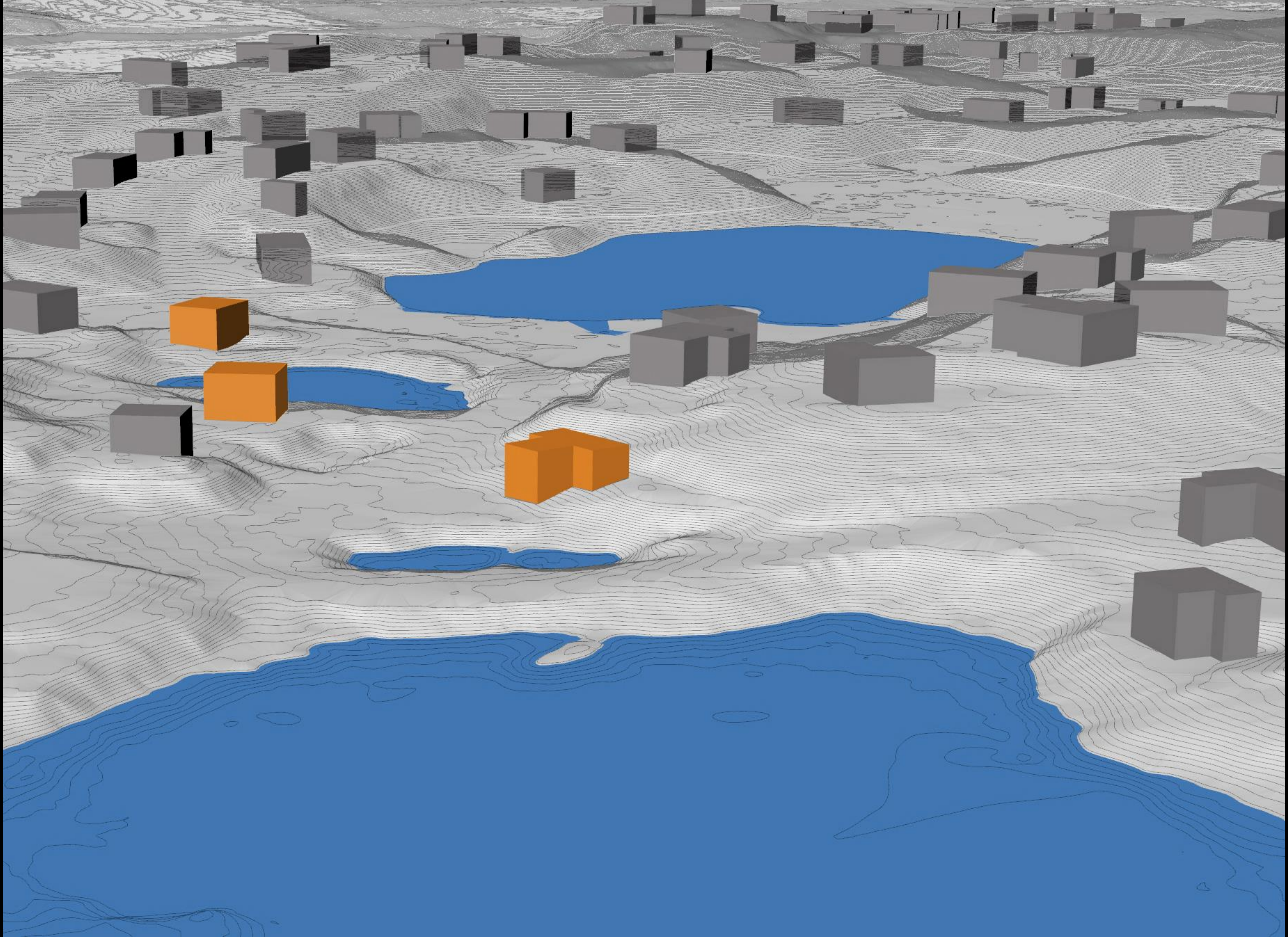
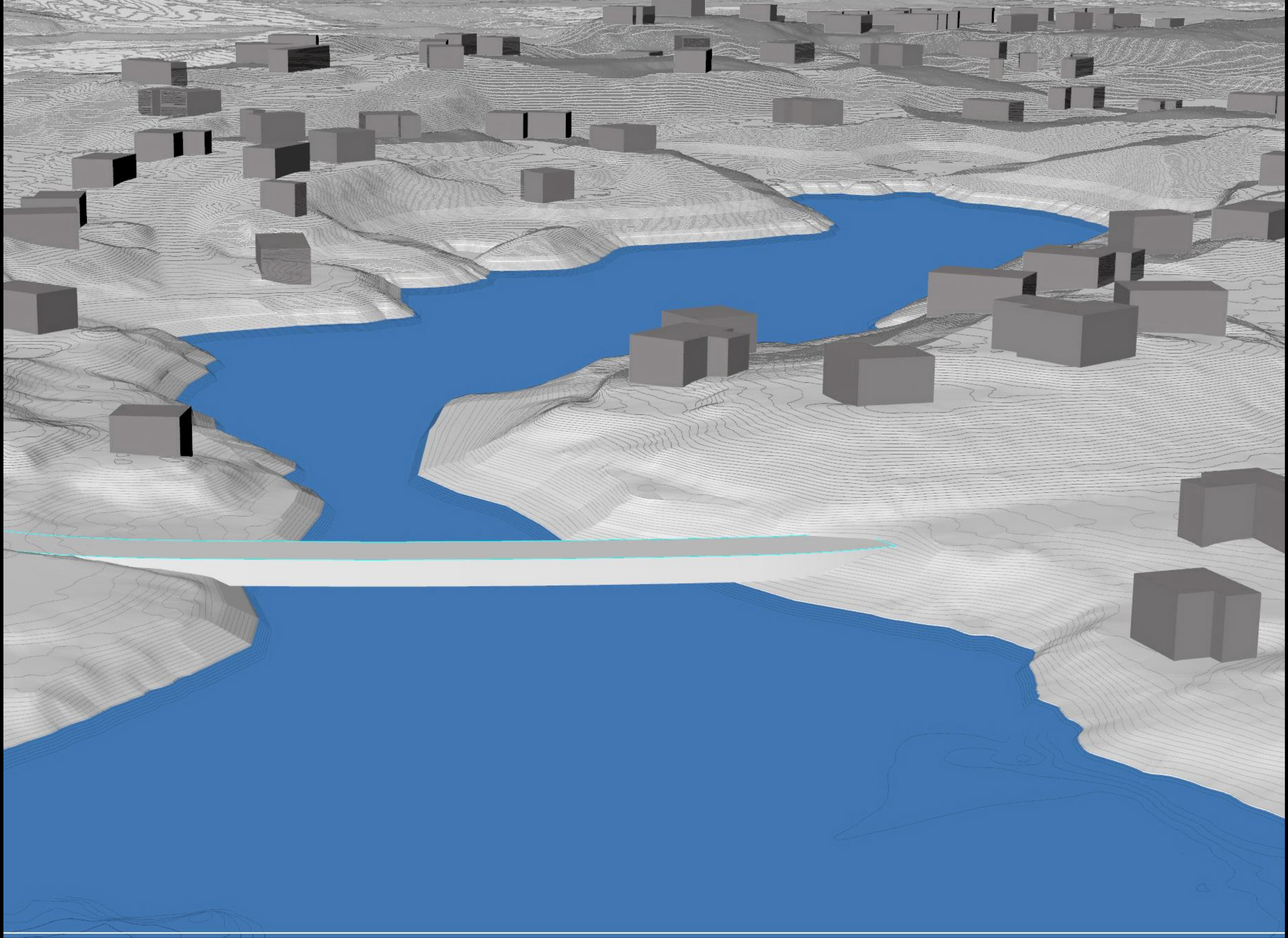
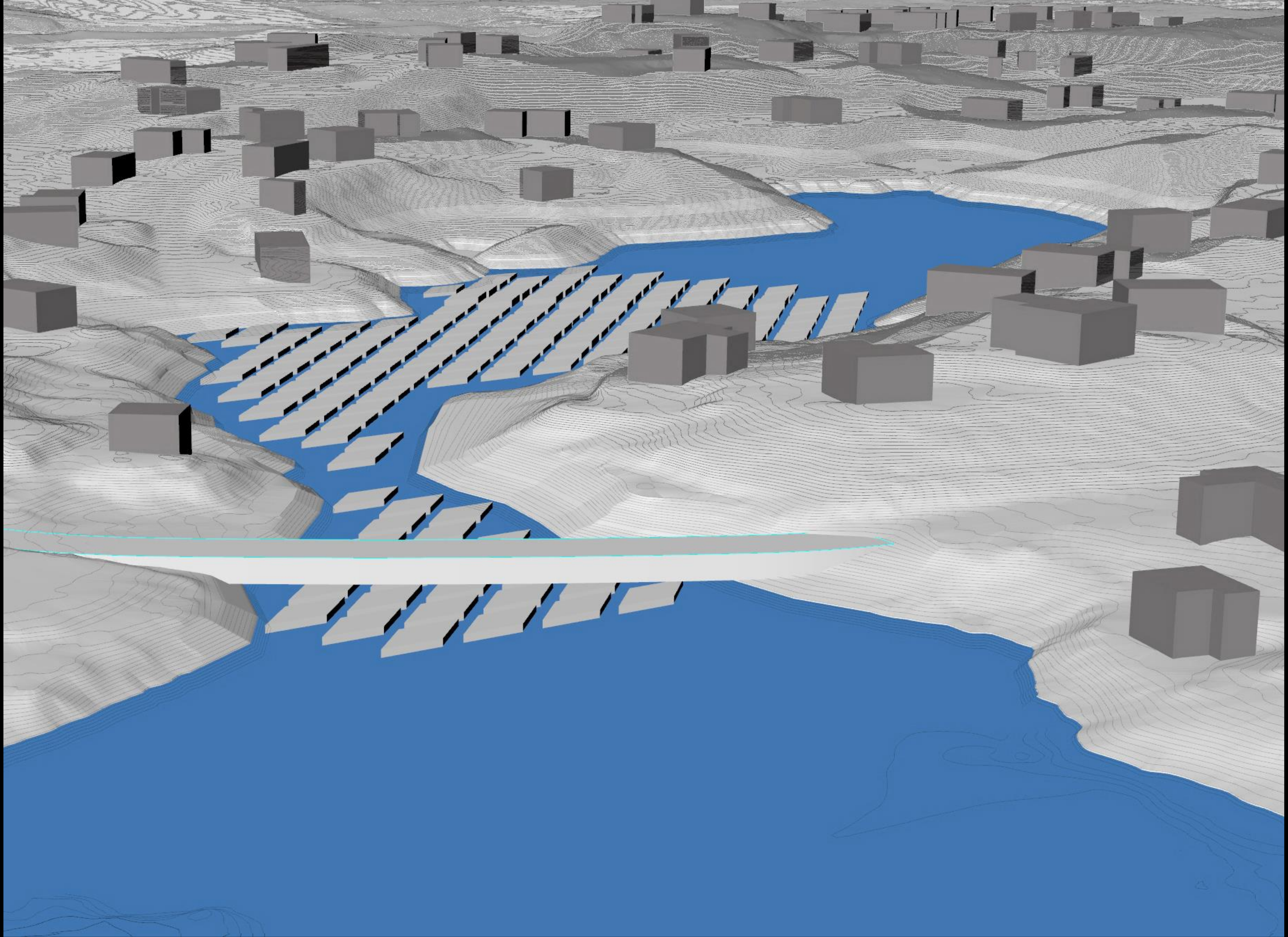
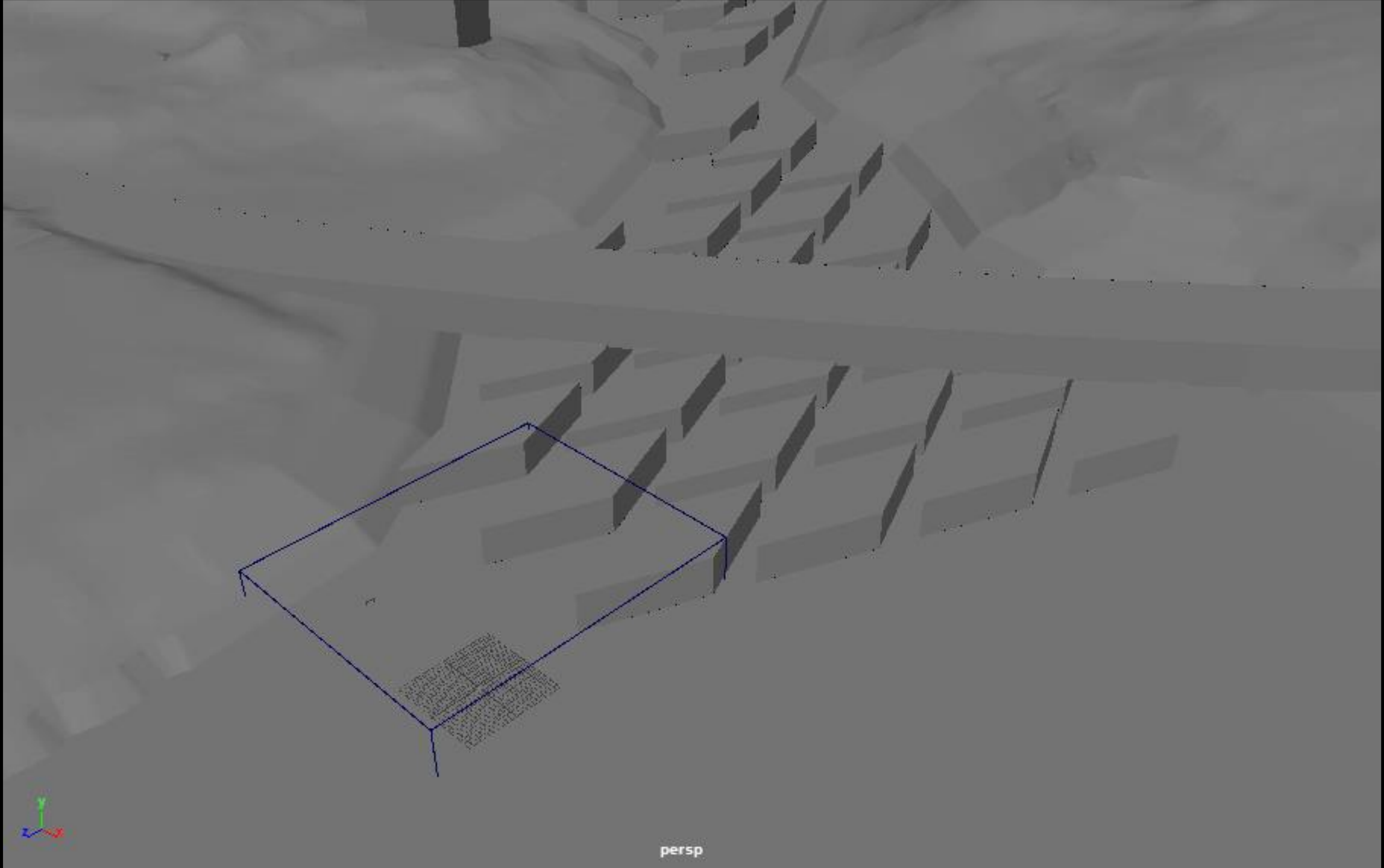
Marsh





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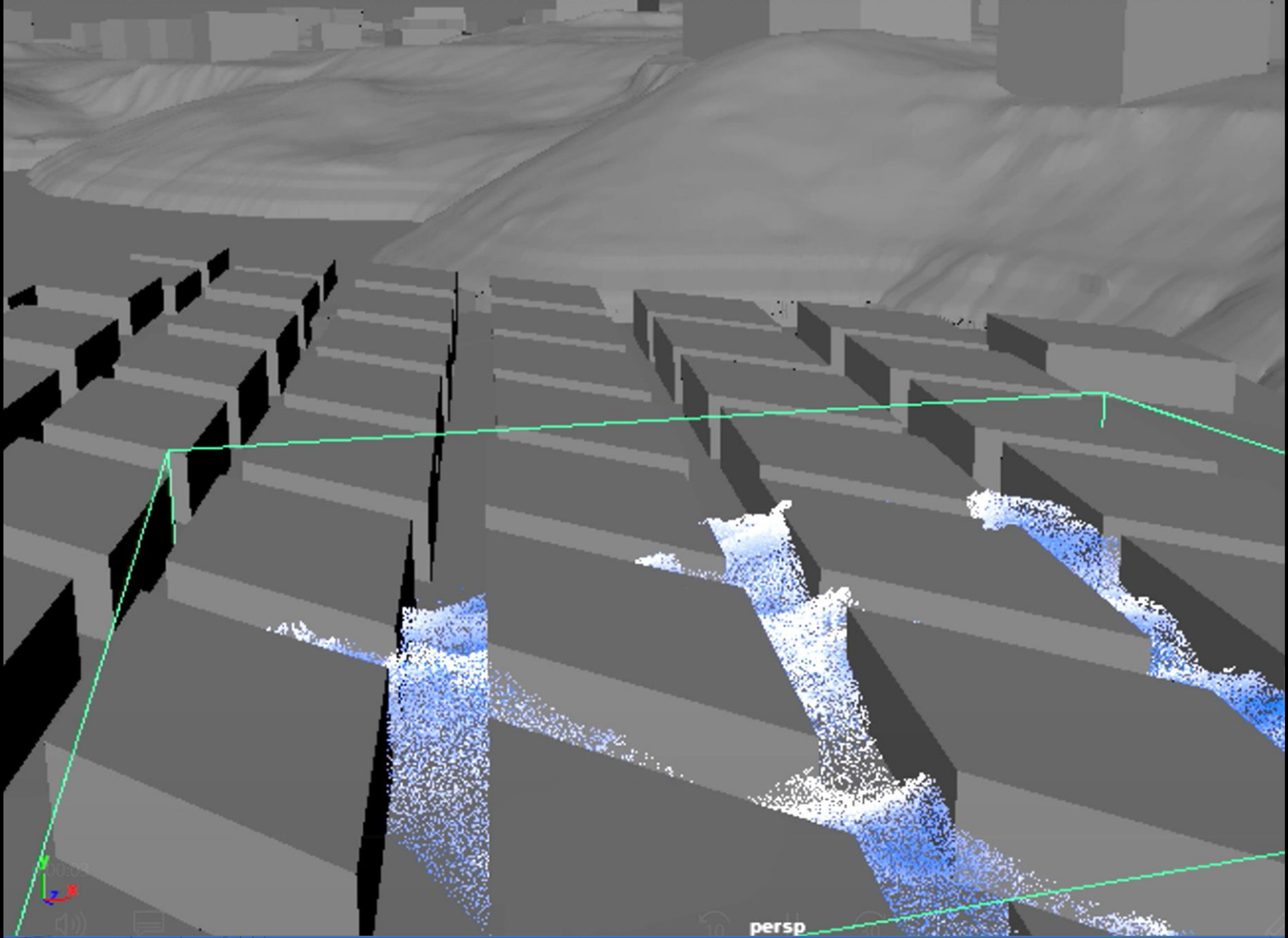
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QUESTIONS