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# Lake Mattamuskeet Watershed Restoration Plan: Design of Constructed Stormwater Wetlands

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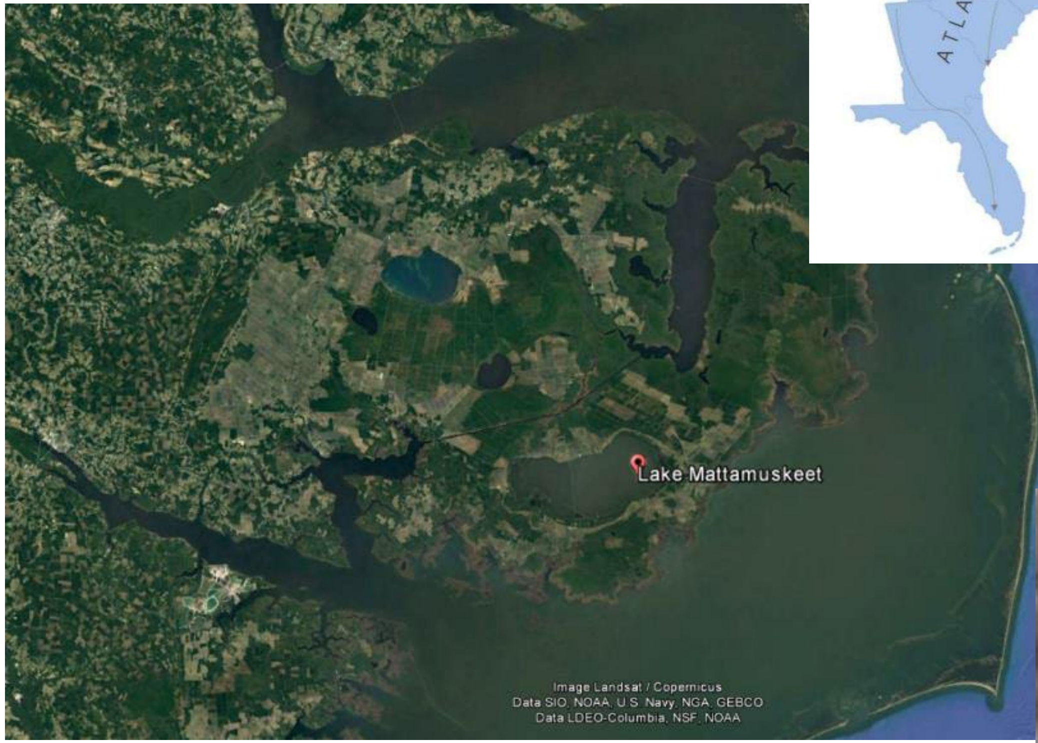
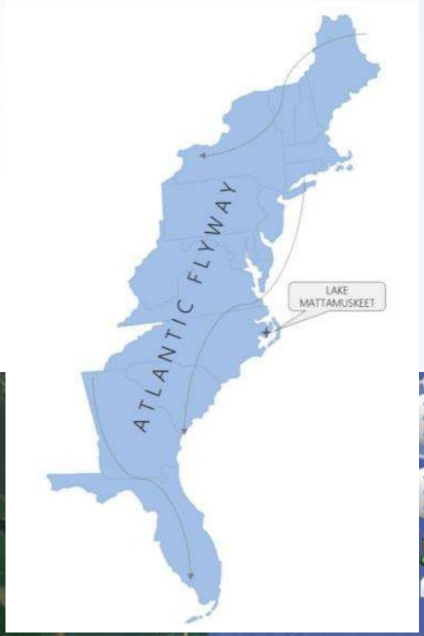
# Introduction to Lake Mattamuskeet

- North Carolina’s largest lake (40,000 acres; once 110,000 ac)
- Low relief: max 9 ft MSL in watershed
- Extensive hydrologic modifications (ditches/drains in area)
- 4 major canals cut to drain lake from 1800’s –1930’s
- Value of the lake

Lake Mattamuskeet Watershed Restoration Plan




# Present-Day Concerns for the Lake

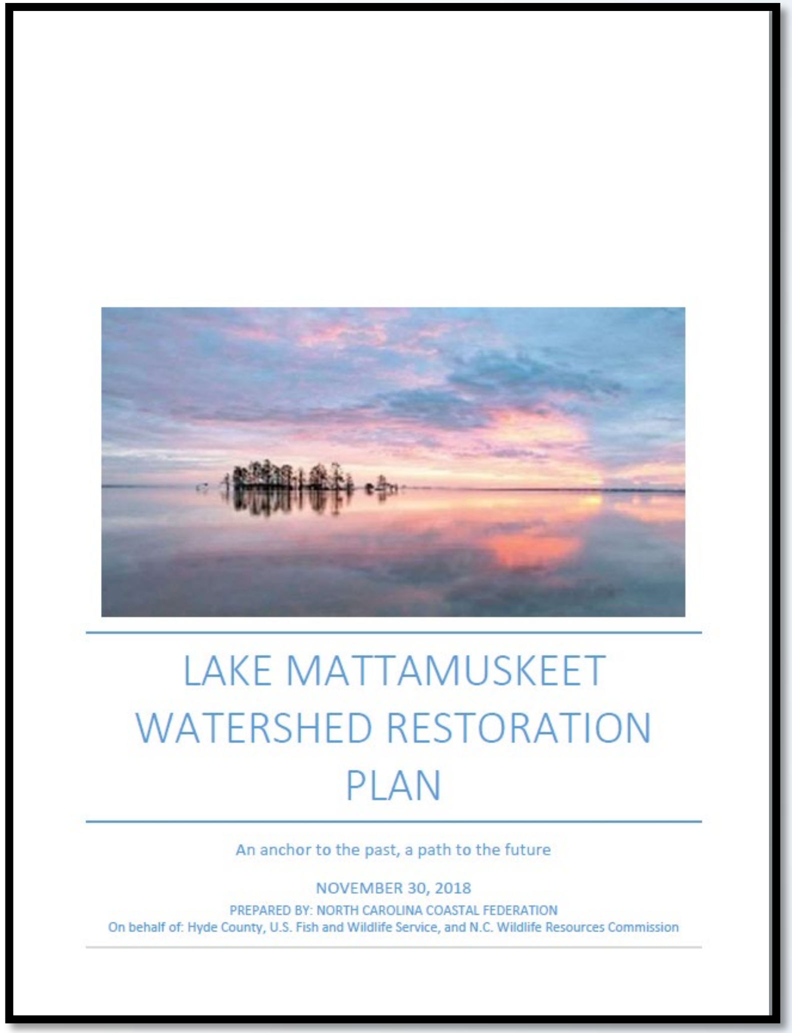
- Lake not actively managed – gravity/tide gate-controlled canal drainage system limited by encroaching sea levels
- Chronic flooding in residential and agricultural areas
- Oligotrophic, sandy bottom ➔ hyper-eutrophic, silty bottom
- Flora transition: submerged aquatic vegetation ➔ algae
  - Decreased light penetration, increased sedimentation and nutrients
  - Cyanobacteria
- Faunal changes: migratory waterfowl habitat affected
  - Lack of SAV and invasive carp contributing to water quality concerns
- All effects exacerbated by sea level rise
- 2016 state Clean Water Act 303(d) listing for pH and chlorophyll-α

# Science & Engineering to the Rescue!

- Partnership for Lake Mattamuskeet Watershed Restoration Plan (LMWRP):
  - Hyde County
  - NC Wildlife Resources Commission
  - U.S. Fish & Wildlife Service
- Developed by NC Coastal Federation for NCDEQ 319 approval
- 3 goals:
  - Protect Hyde Co. way of life
  - Actively manage lake water level
  - Restore water quality and clarity

**Focus of Phase 1 + 2**

**Focus of Phase 3**


LAKE MATTAMUSKEET WATERSHED RESTORATION PLAN

An anchor to the past, a path to the future

NOVEMBER 30, 2018

PREPARED BY: NORTH CAROLINA COASTAL FEDERATION

On behalf of: Hyde County, U.S. Fish and Wildlife Service, and N.C. Wildlife Resources Commission

# Lake Mattamuskeet – Project Overview

| Phase | Sub-tasks | 2020 | 2021 | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|---|---|---|
| Phase 1<br>Active Water Management | • Develop watershed-scale H&H model<br>• Alternatives Analysis<br>• Additional modeling + cost estimates for two (2) preferred alternatives<br>• Progress one (1) alternative to permit level plans and preliminary EIA | | | | | | |
| Phase 2<br>Outfall Canal Dredging Alternatives | • Outfall Canal Bathymetry<br>• Model Updates<br>• Dredging Alternatives | | | | | | |
| Phase 3<br>Constructed Wetland Design | • Detailed LiDAR topography<br>• H&H modeling for constructed stormwater wetlands<br>• Draft and Final Design | | | | | | |

- **Conclusion of Phase 1 of the Active Water Management evaluation resulted in further interest from stakeholders and Hyde County BOC in evaluating options and costs to dredge Outfall Canal in Phase 2**
- **Interest in progressing water quality initiatives led to progressing other preferred alternatives in Phase 3**

# Phase 1: Active Water Management Alternatives Analysis

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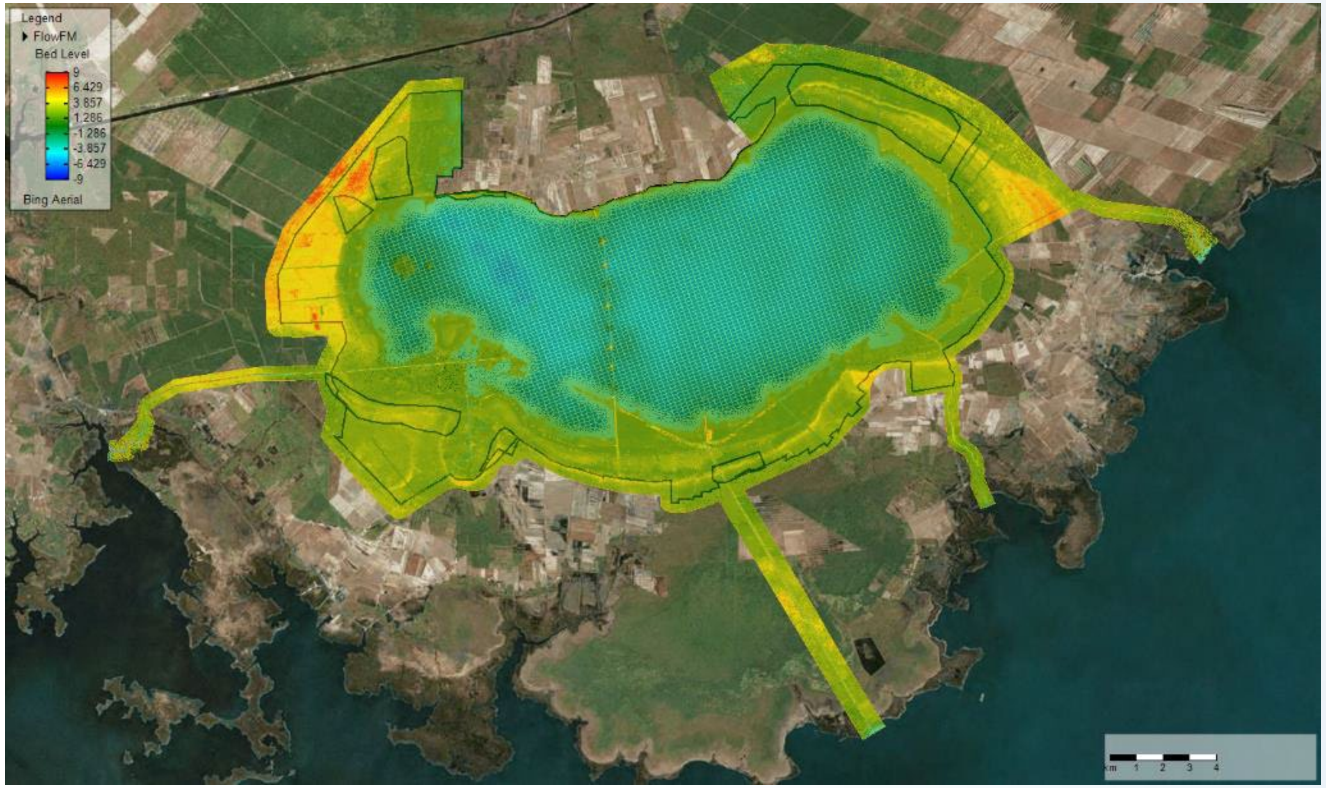
# Active Water Management Study Goals and Objectives

- Develop watershed-scale Hydrologic and Hydraulic (H&H) Model
- Calibrate model to Hurricanes Matthew and Joaquin
- Simulate calibrated model under various design storm scenarios in existing and future sea level rise
- Evaluate engineering options to actively manage lake levels during design storms
- Progress preferred alternative to permit-level plans

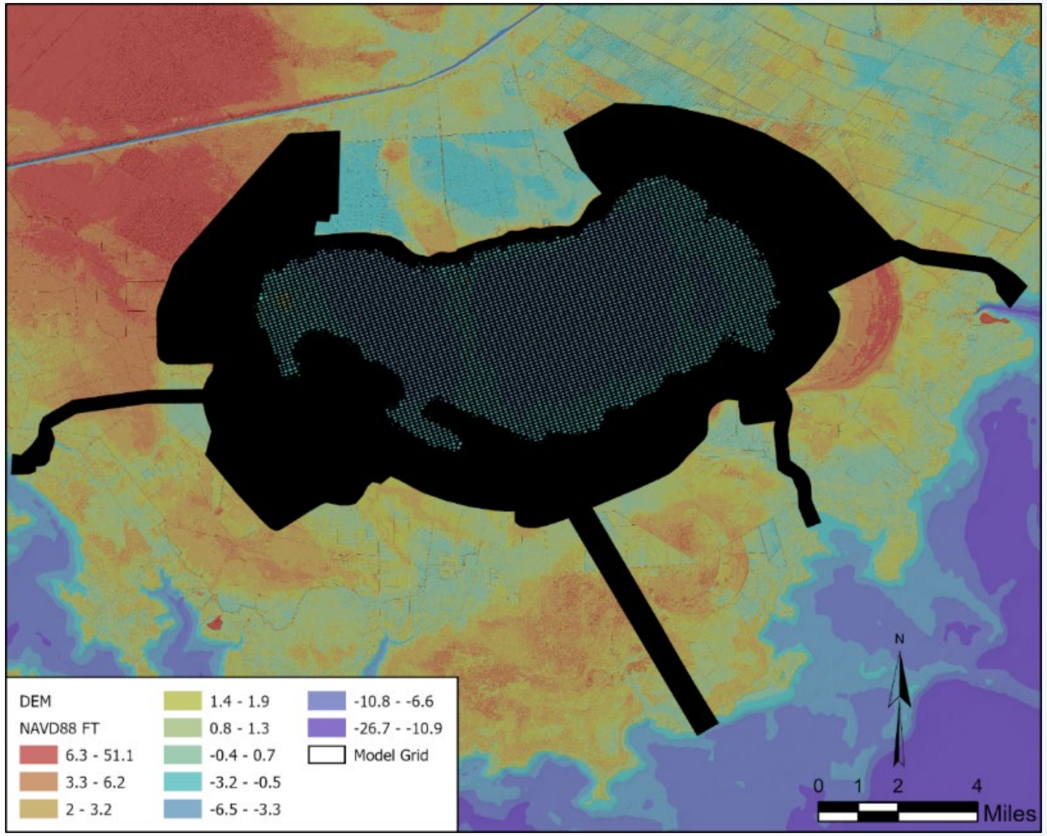
# Numerical Modeling Main Objectives

- Determine water levels that result in chronic flooding
- Calibrate to reproduce lake levels during Matthew and Joaquin
- Investigate options for increasing water discharge
- Evaluate impact of sea level rise projections in 2100 on drainage infrastructure
- Selected model: **Delft3D Flexible Mesh** which simulates the interaction of water, sediment, ecology, and water quality in time and space

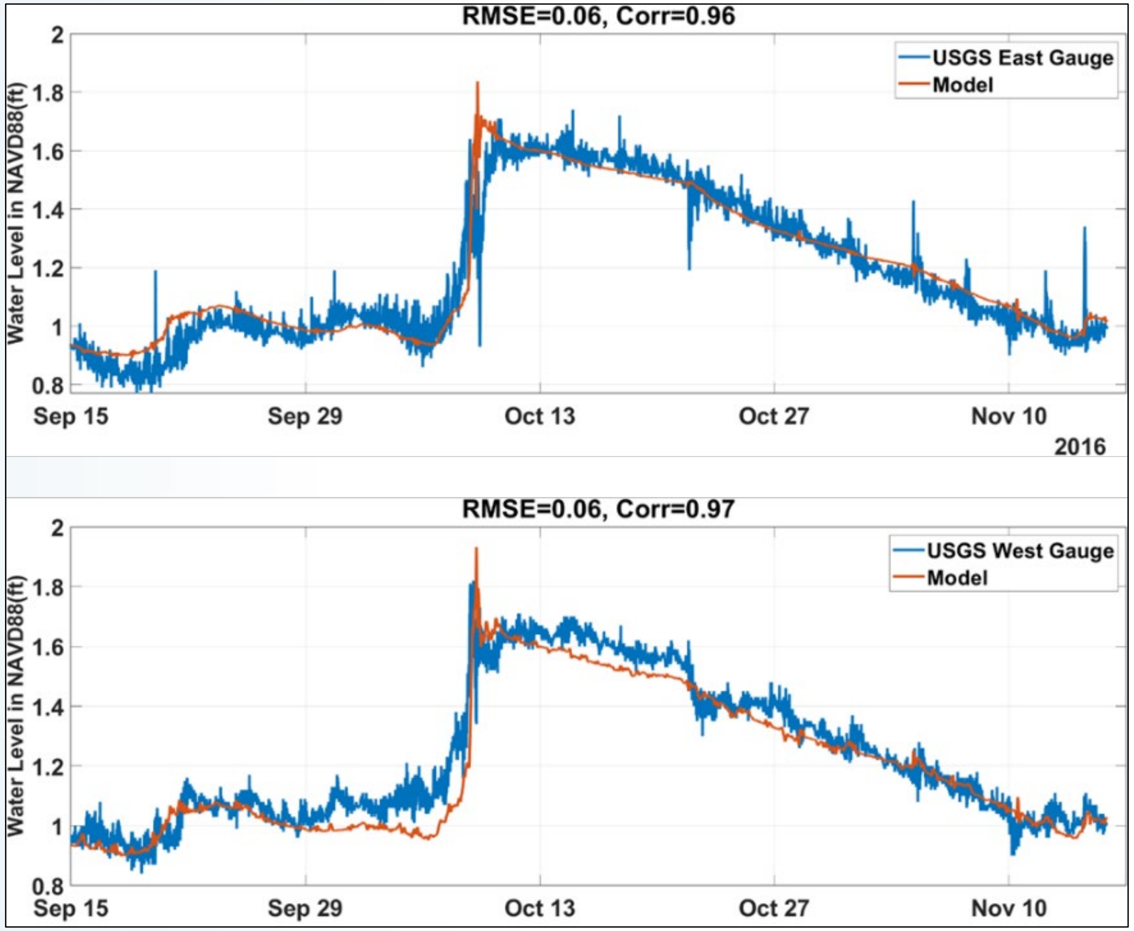


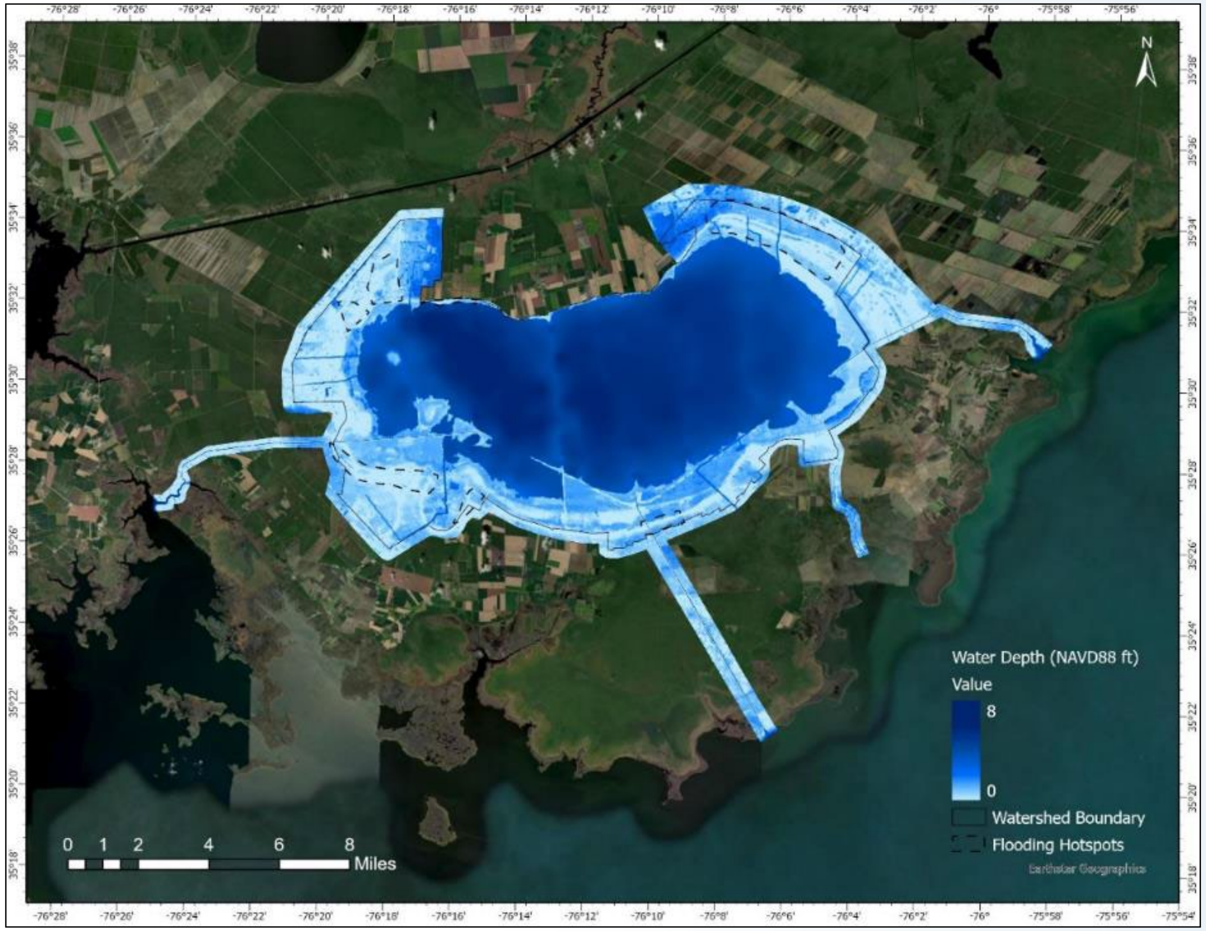
# Delft3D FM Lake Mattamuskeet Model Setup

- 300k cells; higher resolution in watershed and canals that link to Pamlico Sound
- Water level data: USGS Lake Stations and Bell Island Pier (Pamlico Sound)
- Precipitation and Evaporation data: NOAA - NCEP CFSv2 (hourly)
- Topo-bathy data: LiDAR from State Floodplain Mapping Program and locally collected bathymetry
- Gates resolved as gravity structures (open when positive lake/sound gradient)

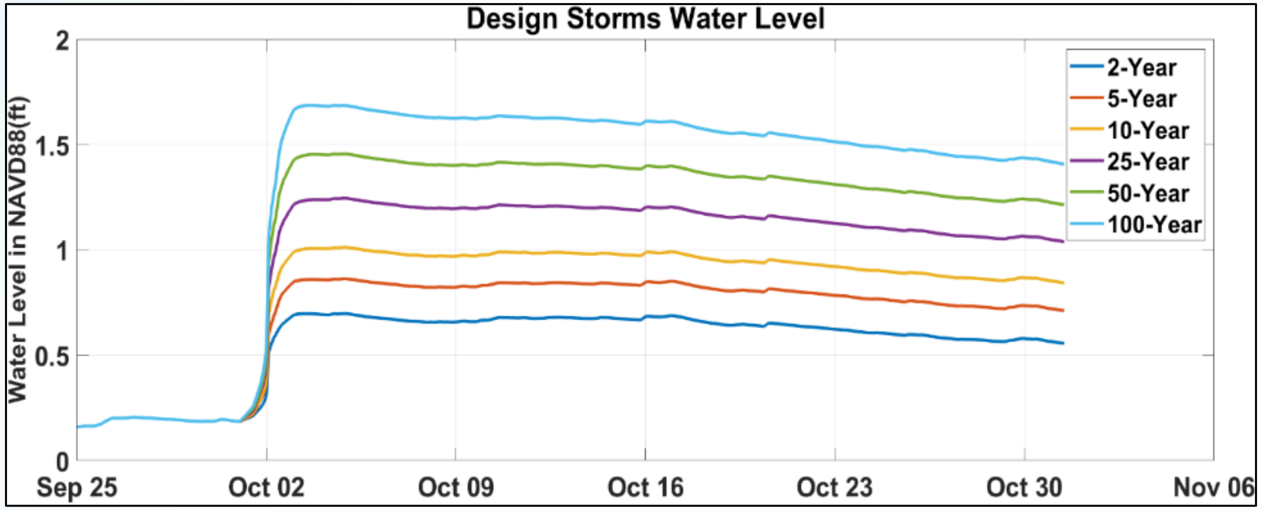


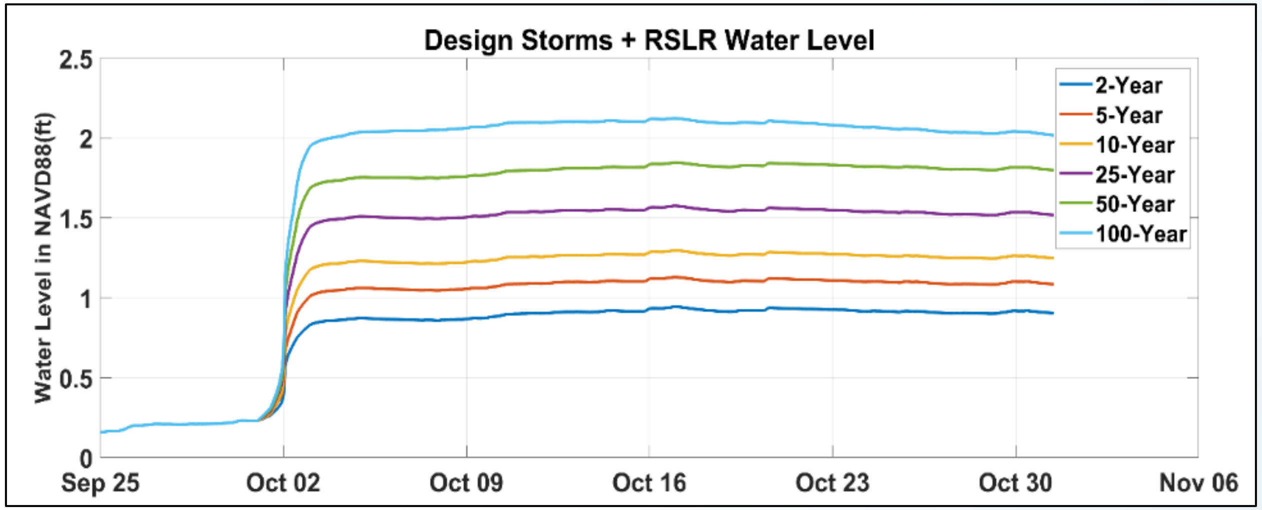
# Lake Mattamuskeet Model Calibration



# H&H Model: Existing Conditions and Sea Level Rise




**Lake drainage diminished due to SLR effect on canal outflows and gravity gates.**

# 10-year Design Storm Screening

## Simulate each alternative under 10-year design storm

- Starting water level of 2.17 ft (October average)
- Soundside boundary condition corresponding to Hurricane Matthew record with storm surge

## Evaluate performance metrics

- Peak water level
- No. of days pumping if option includes pumping
- No. of days to return to starting water level OR final lake level at end of simulation

## Select two alternatives to perform more detailed simulations

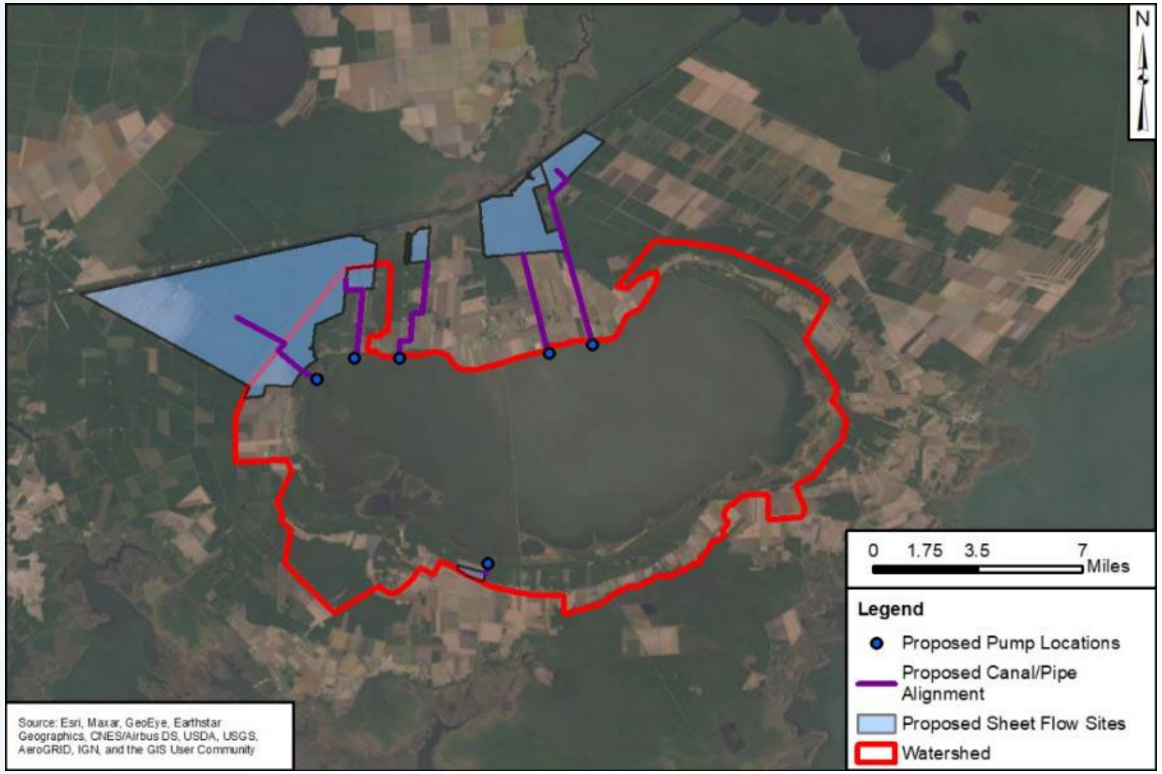
# List of Potential Engineered Alternatives

- Mid-sized pump station to drainage districts
- Large pump station to ICW
- Pump station with optimized pumping rate to ICW
- Sheet flow sites
- Dredge existing outlet canals
- Optimized outlet structures
- Dredge canals + optimized outlet structures
- Gravity-drained canals to drainage districts

**Selected by Hyde County BOC at May 2021 meeting for additional simulations**

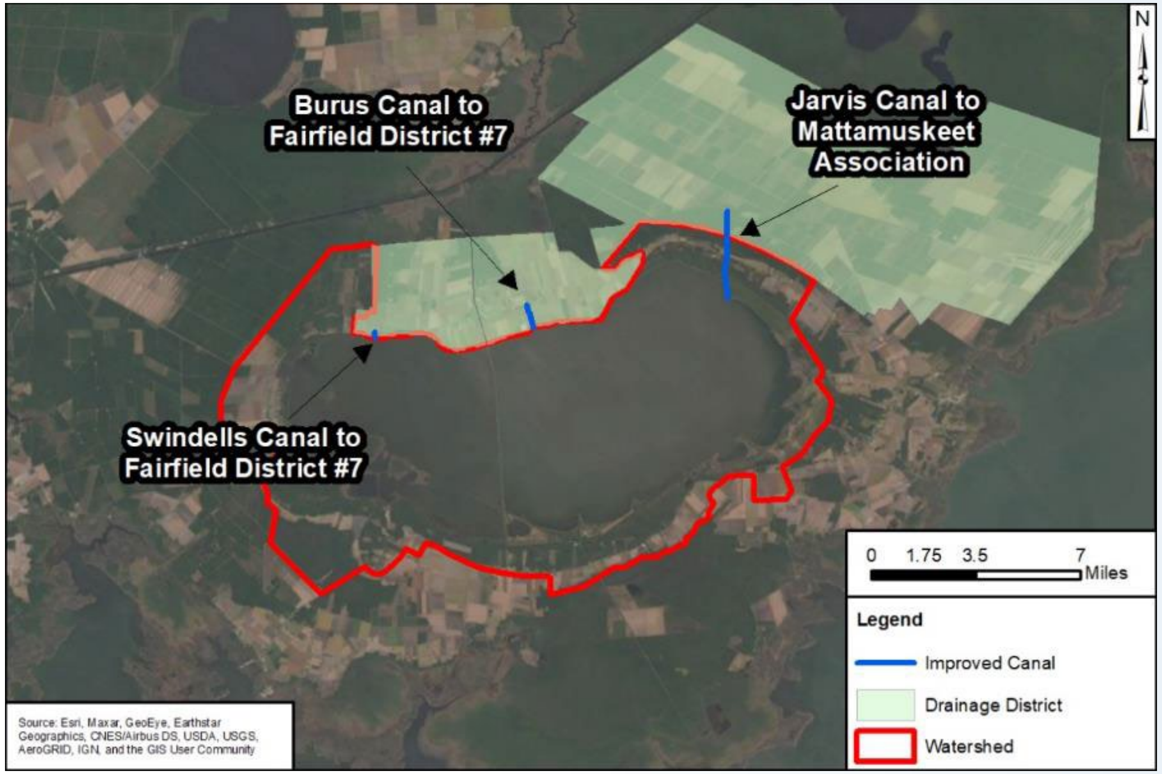
# Alternatives Selected for Additional Simulations + Costs

## Multiple Sheet Flow Sites




**Capital Costs (All Six Sites): $13MM to $23MM**
**Annual O&M Costs (All Six Sites) : $2.8MM**

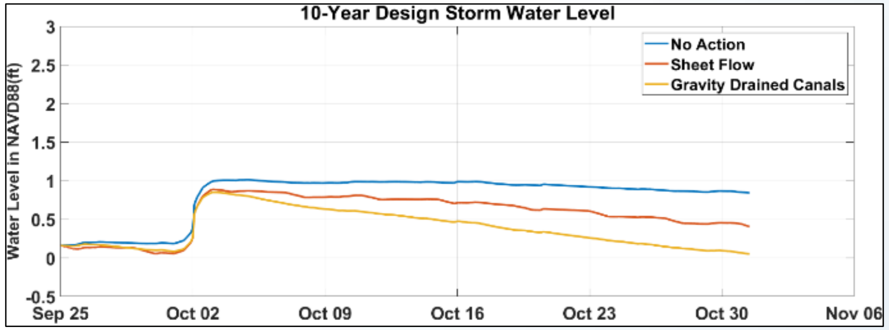
## Gravity-drained Canals



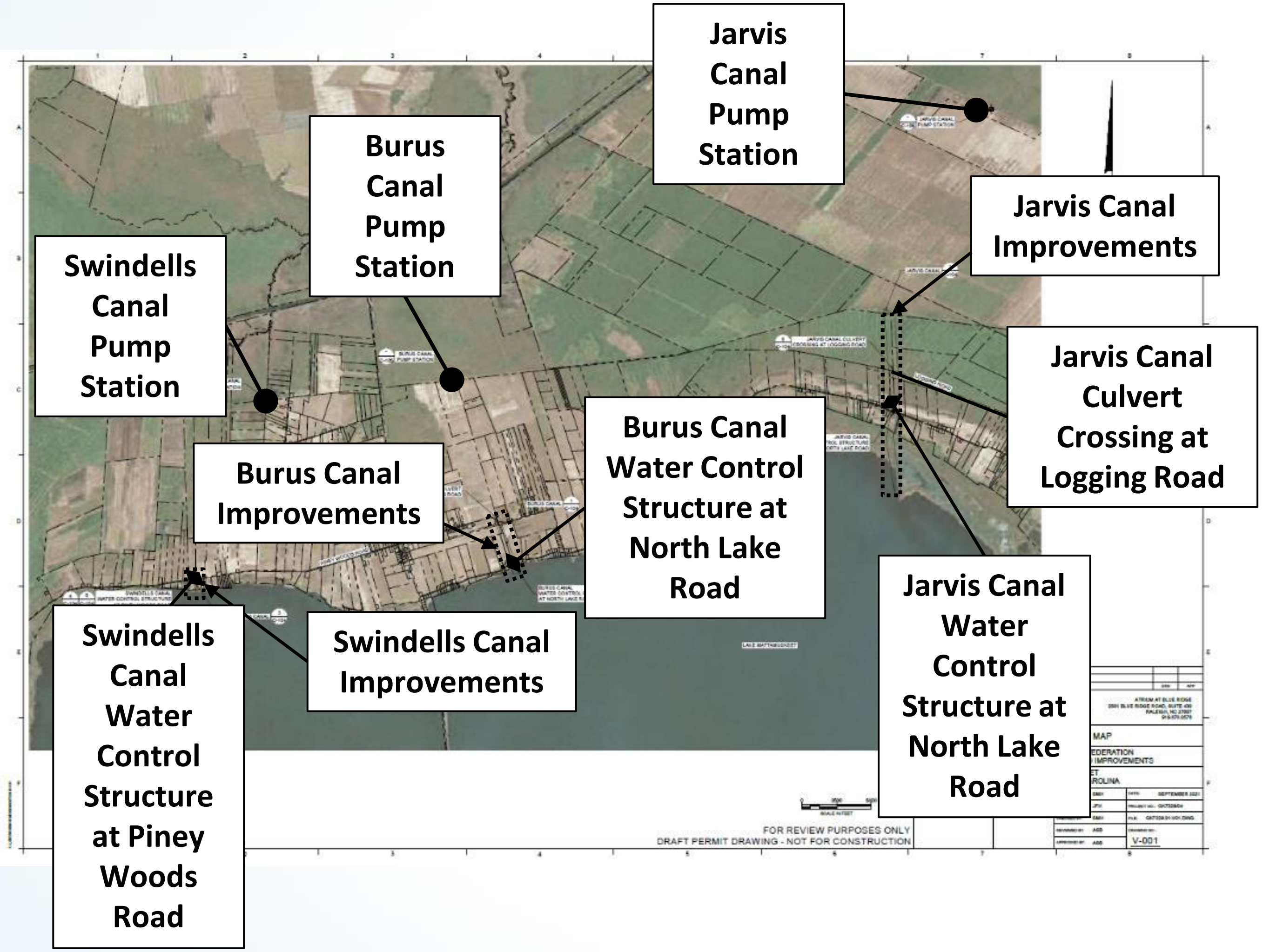

**Capital Costs: $6.5MM to $12MM**
**Annual O&M Costs: $1.0MM**

# Comparison of Alternatives: 10-year Design Storm

- Both options decreased time to drawdown, gravity drained canals more effective
- Sheet flow sites estimated to cost $500+ per acre managed per foot of water level drop during the 10-year storm
- Gravity drained canals estimated to cost $100 - $200 per acre managed per foot of water level drop during the 10-year storm
- Progressed the gravity drained canals alternative to permit-level plans including Preliminary EIA and Water Management Plan with input from Hyde County BOC



# Preliminary Engineering Design: Site Plan




- Canal Improvements
  - Burus Canal: ~ 3,500 LF
  - Jarvis Canal: ~ 13,000 LF
  - Swindells Canal: ~ 800 LF
- Water Control Structures
  - Series of adjustable weir gates, width based on canal and controlling flow to not exceed pump station capacity
- Pump Stations
  - Three (3) 48" axial flow pumps at each pump station

# Conclusion of the first phase of the Active Water Management evaluation resulted in further interest from stakeholders and Hyde County BOC in evaluating options and costs to dredge Outfall Canal

# Phase 2: Evaluation of Dredging of Outfall Canal

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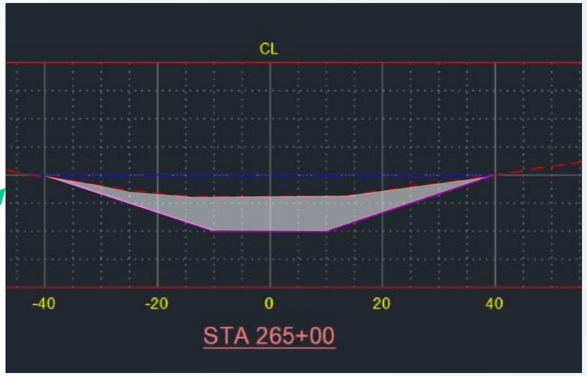
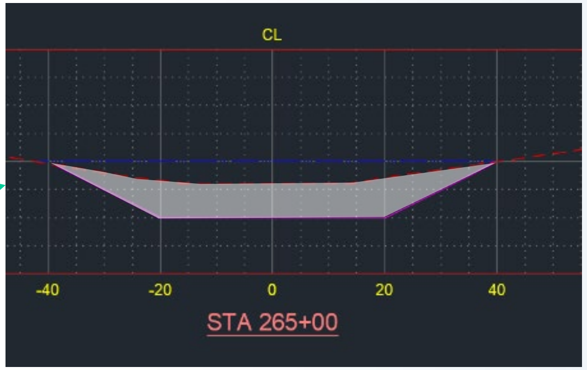
# Outfall Canal Bathymetry and Model Updates

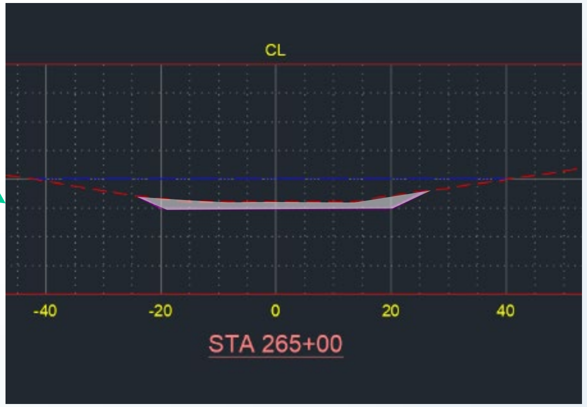
- Collection of topography and bathymetry for Outfall Canal
- Update Model Simulations with Refined DEM for Outfall Canal
- Screen Multiple Dredge Alternatives for Evaluation
- Preliminary Characterization of Outfall Canal Sediment
- AACE Class 5 Cost Estimates for Dredging Outfall Canal

# Dredging Alternative Screening Scenarios

| Scenario | Dredge Depth Below Water Level (ft) | Bottom Width (ft) | Quantity Estimate (cu. yd.) |
|---|---|---|---|
| 1 + 2 | 10 | 20 | 565,000 |
| 3 | 10 | 40 | 700,000 |
| 4 | 5 | 40 | 145,000 |
| 5 | 5/10 | Varies | 435,000 |

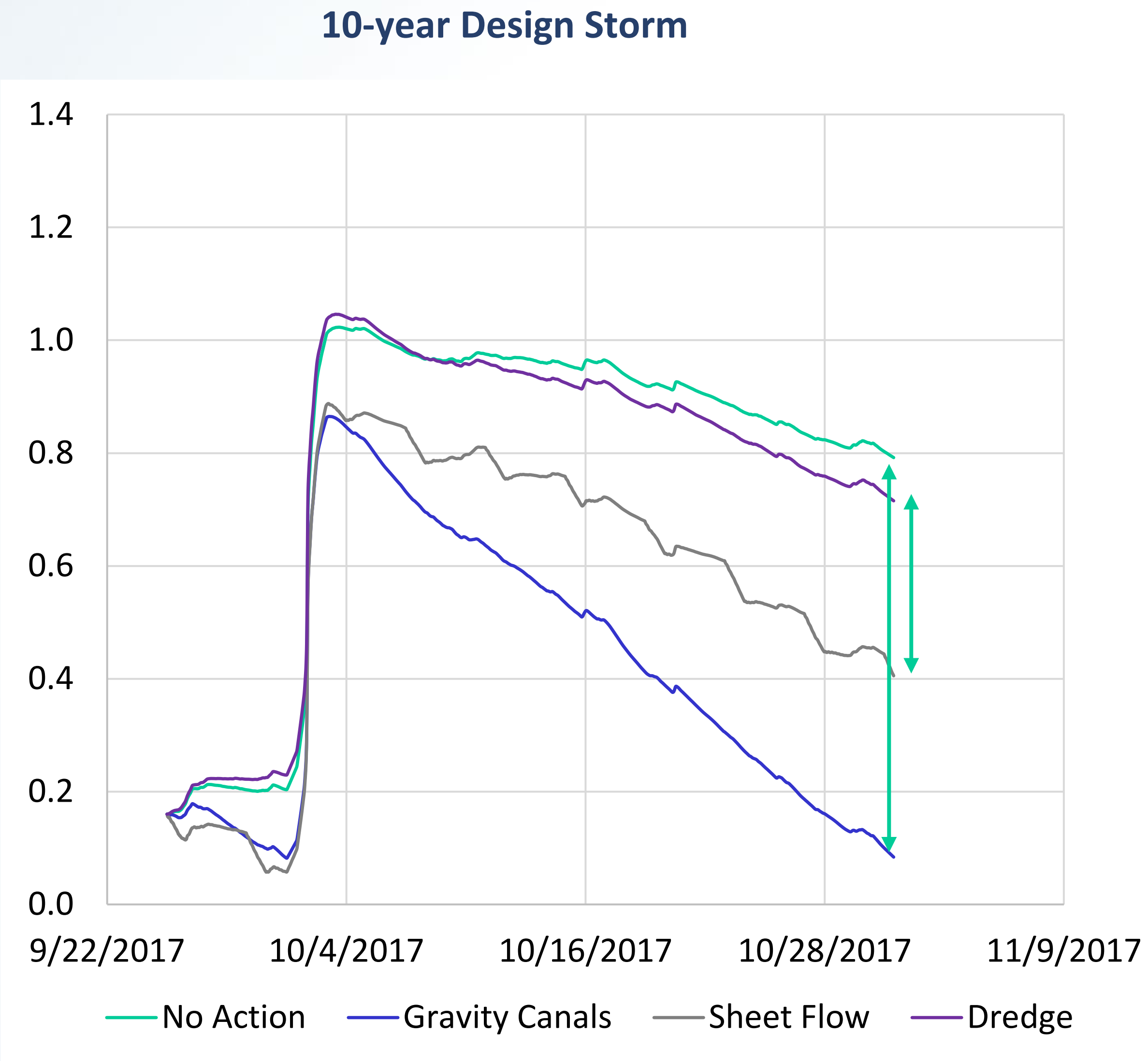


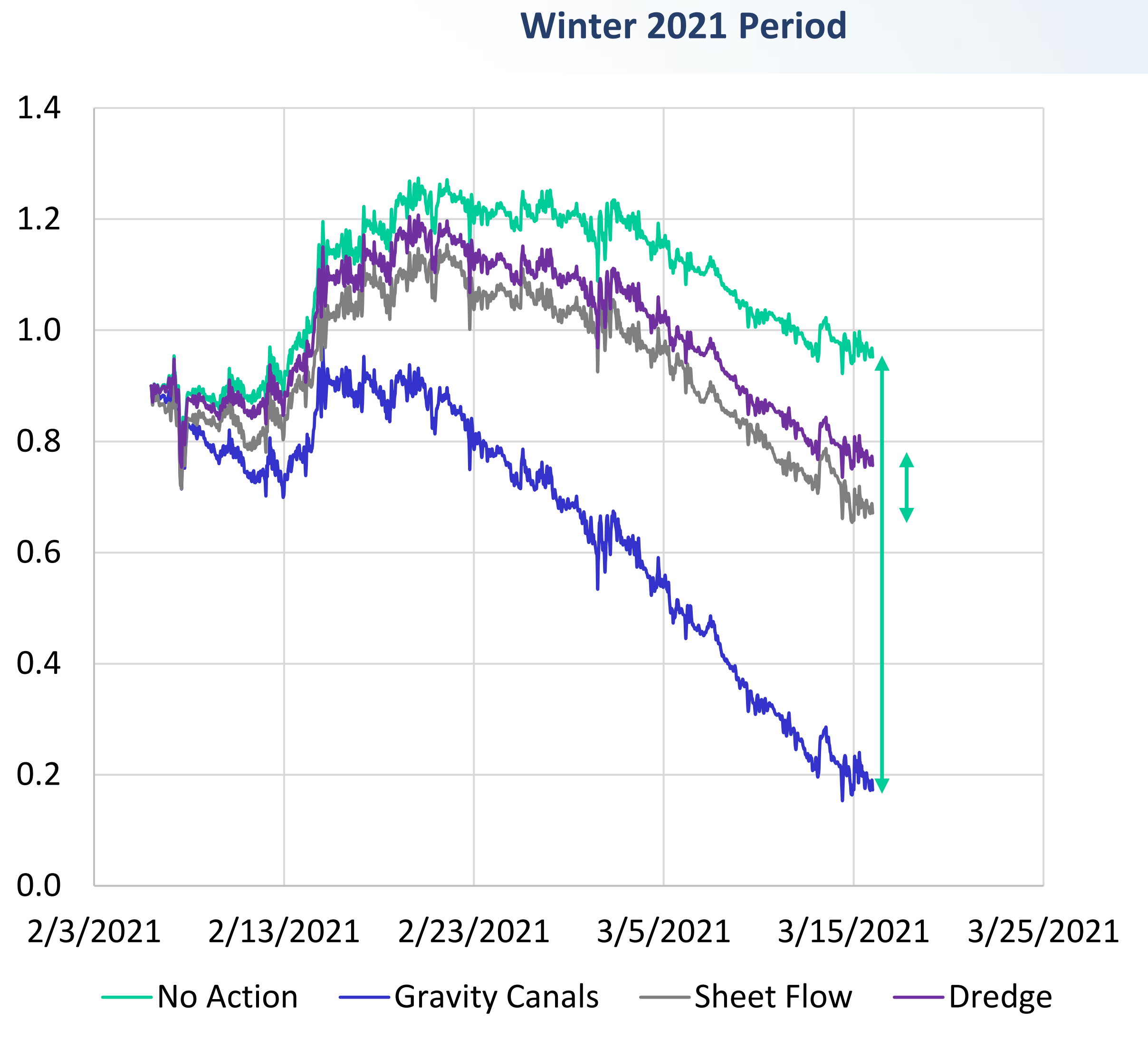




**Screening simulations indicated that despite large variations of dredged material removal, overall performance in lake water level drawdown was between +/- 0.1 ft across the scenarios due to drainage capacity being reduced when the sound water level is higher than the lake water level.**

# Comparison of Dredging to Gravity-Drained Canals + Sheet Flow



# Cost-Benefit Summary – Capital and Annual O&M Costs

| | Parameter | No Action | Gravity-Drained Canals | Sheet Flow Sites | Outfall Canal Dredging (Scenario 2) |
|---|---|---|---|---|---|
| **Capital Costs** | Capital Costs | - | \$6.5MM to \$12MM | \$13MM to \$23MM | \$8MM to \$17MM |
| **Annual O&M Costs** | Annual Operating and Maintenance Costs (\$) | - | \$1.0MM | \$2.8MM | \$493k |
| | Annual Additional Drawdown Volume (ac-ft) | - | 350,000 | 220,000 | 45,000 |
| | Cost per ac-ft of additional water managed (\$/ac-ft) | - | 2.9 | 12.8 | 11.0 |

**Progressing a combination of all three through various funding resources**

- All alternatives improve drawdown compared to existing conditions
- Hydraulic benefit (drawdown and water managed) highest for gravity-drained canals
- Gravity-drained canals are most cost-effective but come with other permitting challenges + higher operational costs – pilot projects and phased approach suggested

# Comparison to LMWRP Objectives

Progressing Pat Simmons and Burrus Canal Pilot Projects in Phase 3

| LMWRP Objectives | Gravity-Drained Canals | Sheet Flow Sites | Outfall Canal Dredging |
|---|---|---|---|
| Protects Hyde County Way of Life | ☑ | ☑ | ☑ |
| Manages Lake Water Levels | ☑ ☑ ☑ | ☑ ☑ | ☑ |
| Restores Water Quality and Clarity | ☑ | ☑ ☑ | ☑ |

$10MM awarded to NC Wildlife Resources Commission to be used towards dredging Outfall Canal

**Ongoing design for projects that contain elements of all three alternatives will result in progress towards the goals of the LMWRP**

# Phase 3: Design of Constructed Wetlands

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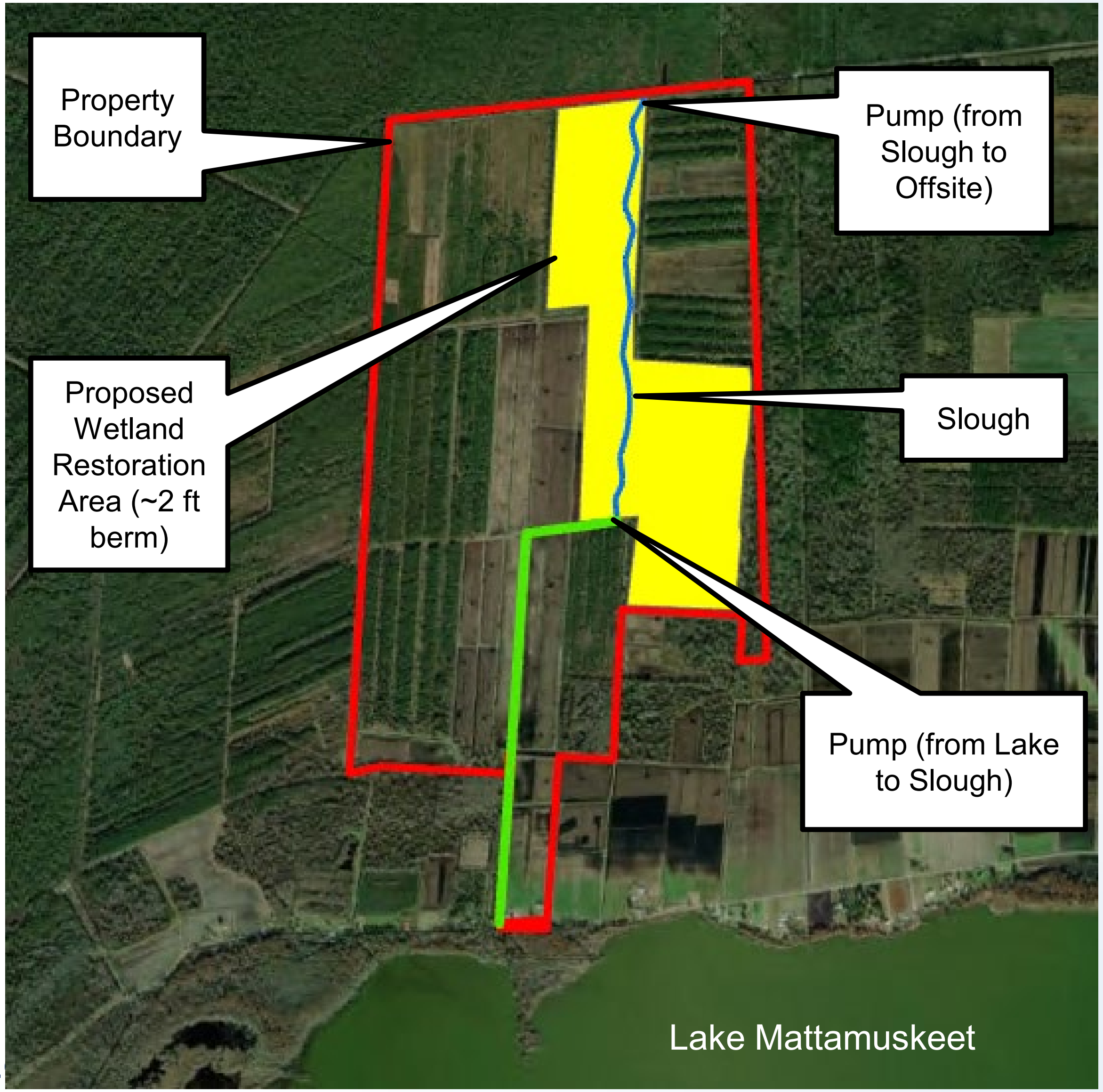
# Phase 3: Design of Constructed Wetlands

- Pat Simmons Site Layout + Project Components
- H&H Modeling Using the Interconnected Pond Routing (ICPR) Model
- Engineering Design Considerations
- Other Project Considerations
- Key Takeaways and Next Steps

# Pat Simmons Site Layout + Project Components

## Includes Approximately:

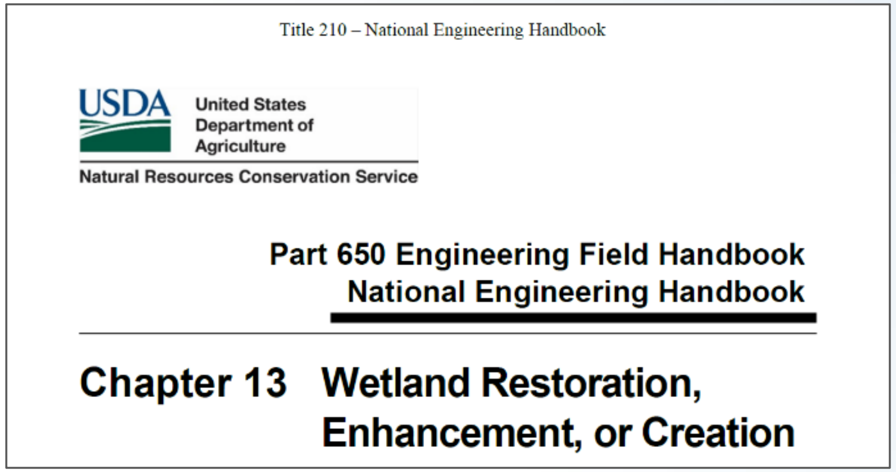
- 1 Pump Station
- 3 Water Control Structures
- 2 Tide Gates
- 6,500 LF of Canal Improvements
- 7,500 LF of Sloughs
- 36,000 LF of Dike Improvements



# H&H Modeling Objectives

**Support Design of a Constructed Wetland for the Pat Simmons property following NRCS Guidelines**

- Select and design water control structure for design storm runoff and water level control
- Evaluate hydraulic trespass
- Prepare Monthly Water Budget using continuous simulation model

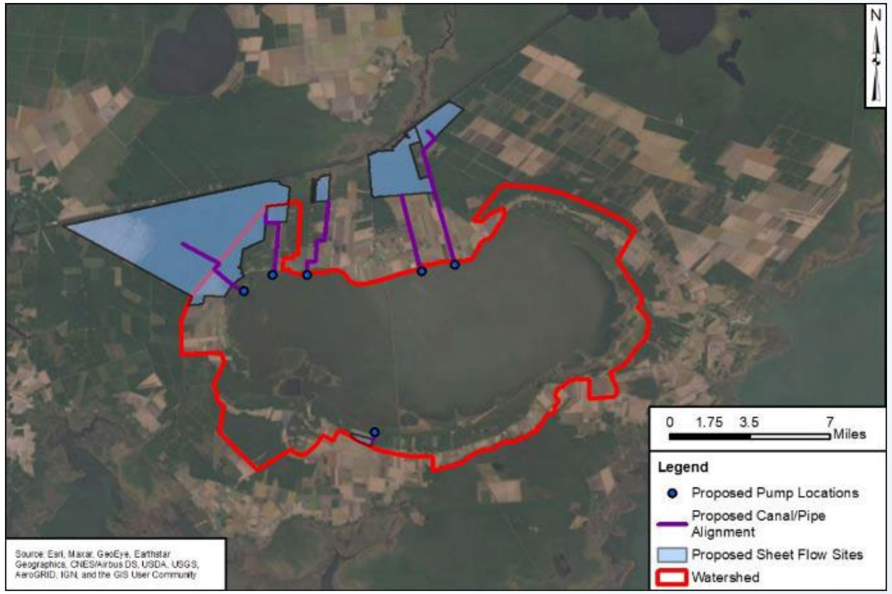

Title 210 – National Engineering Handbook

USDA United States Department of Agriculture

Natural Resources Conservation Service

Part 650 Engineering Field Handbook
National Engineering Handbook

Chapter 13 Wetland Restoration, Enhancement, or Creation



# Engineering Design Considerations

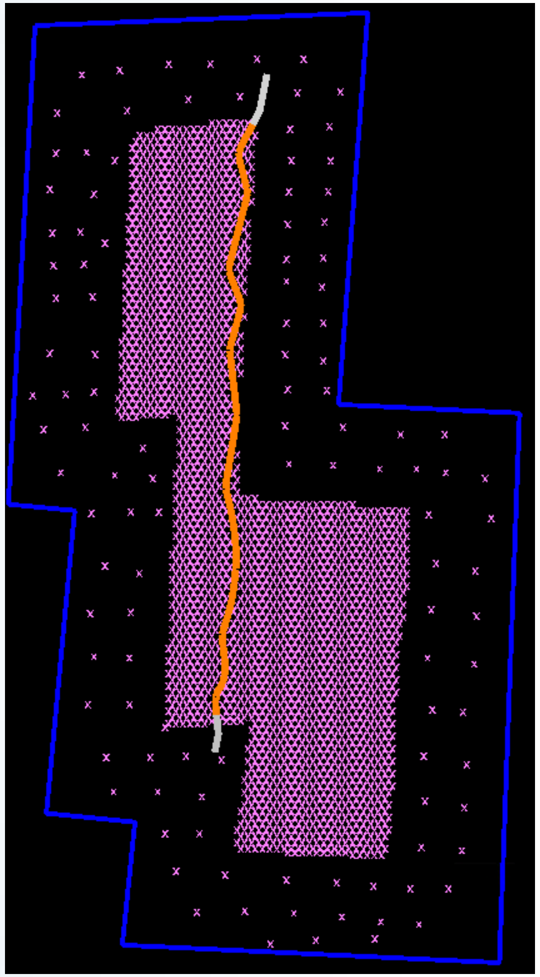
## Wetland Reserve Easement (WRE) Design Requirements

| Conservation Practice (CP) | Standard No. |
|---|---|
| Wetland Restoration | 657 |
| Water Control Structure | 587 |
| Dikes | 356 |
| Shallow Wetland Area for Wildlife | 646 |

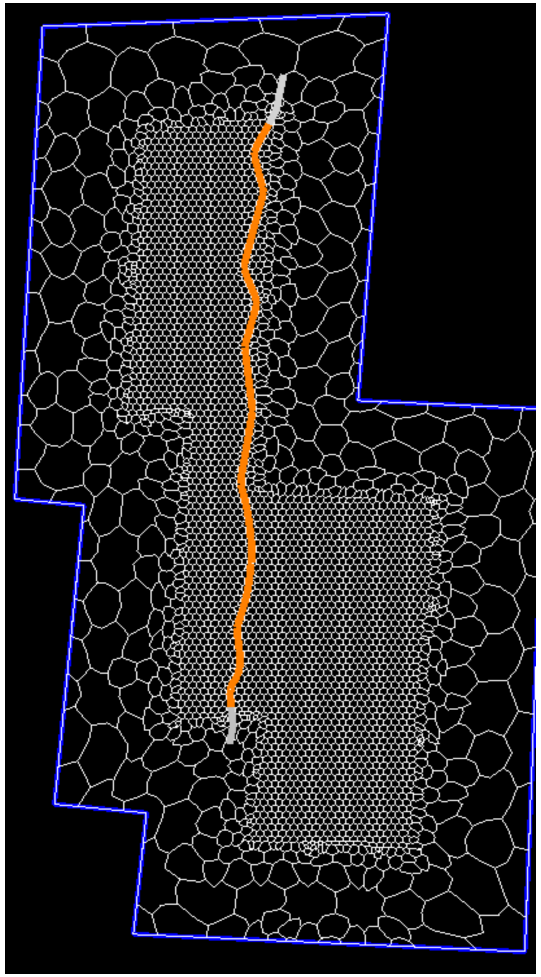
# H&H Model Selection: Interconnected Pond Routing Model

| Desired Capability | ICPR | HEC-RAS (2D) | PCSWMM (2D) | DRAINMOD | HydroCAD/ PondPack/ Similar Routing Models |
|---|---|---|---|---|---|
| Design Storm Simulation | ☑ | ☑ | ☑ | ⊗ | ☑ |
| Continuous Simulation | ☑ | ⊗ | ☑ | ☑ | ⊗ |
| 2D Modeling | ☑ | ☑ | ☑ | ⊗ | ⊗ |
| Surface Water and Groundwater Interaction | ☑ | ⊗ | 😐 | ☑ | ⊗ |
| Annual Water Balance | ☑ | ⊗ | ☑ | ☑ | ⊗ |
| ET/Infiltration/Pumps | ☑ | 😐 | 😐 | ☑ | ⊗ |
| Robust Graphics | ☑ | ☑ | ☑ | ⊗ | ⊗ |

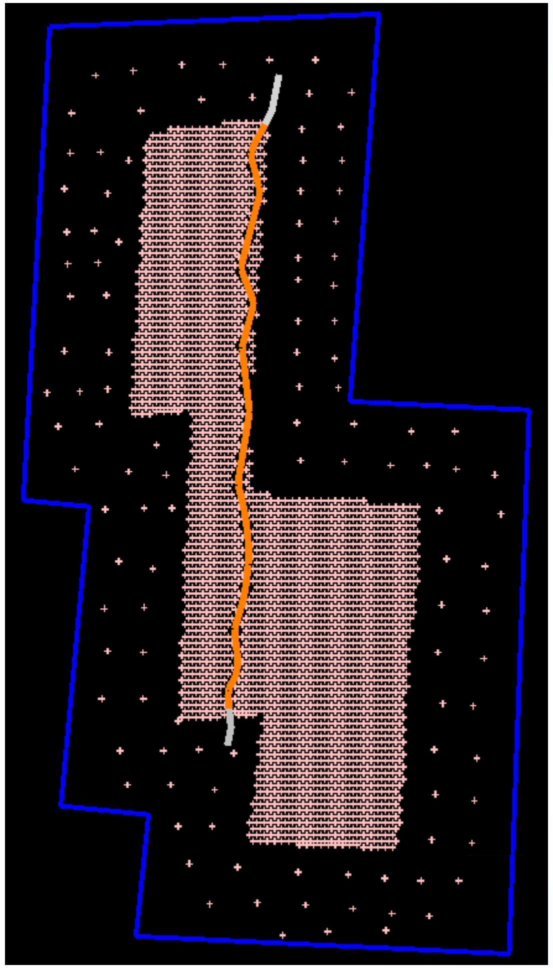
# ICPR Model Set-Up: Grid Network



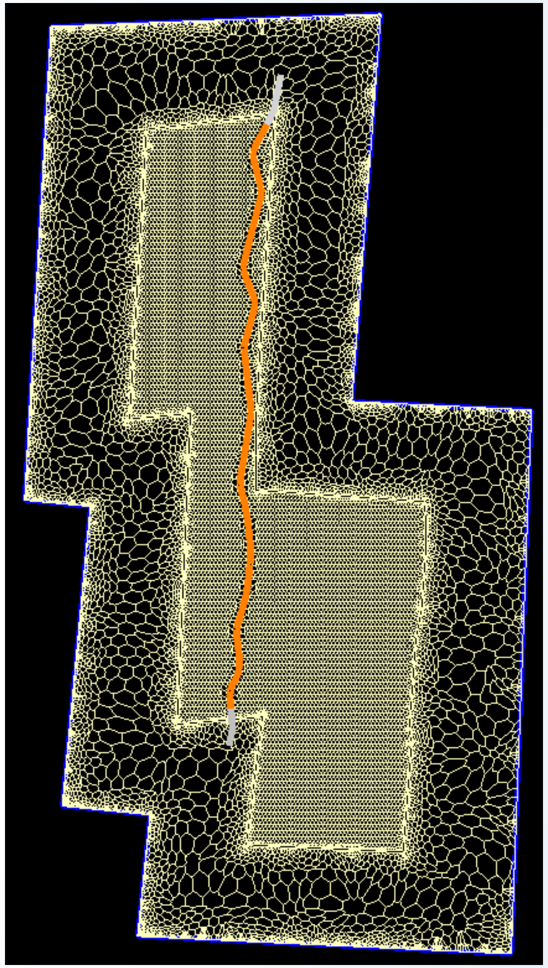
Overland Region Breakpoints



Overland Region Honeycombs



Groundwater Region Breakpoints



Groundwater Region Honeycombs

# ICPR Model Assumptions: Methods and Data Sources

| Parameter/Model Input | Assumption/Data Source |
| --- | --- |
| Land Use | 100% Pervious |
| Soil Characteristics | Web Soil Survey |
| Evapotranspiration | Thornthwaite Method to calculate monthly PET |
| Rainfall Excess Method | Green-Ampt Loss Model |
| Overland Flow Module | Represented slough as 1-D channel link |
| Groundwater Flow Module | Initial water table: - 2.5 ft<br>Confining layer top: - 12.5 ft<br>Clay exclusion around wetland perimeter |
| Pumping Rate | 135 cfs at inlet and outlet; controlled by water surface elevation |
| Simulation Manager | 5-min time step (hydrology + surface hydraulics)<br>60-min time step (groundwater) |
| Precipitation | USGS Rain Gage at Lake Mattamuskeet |
| Design Storm Simulation | 10-year, 25-year, and 100-year, 24-hour storms |
| Continuous Simulation | 2015 – 2021 |

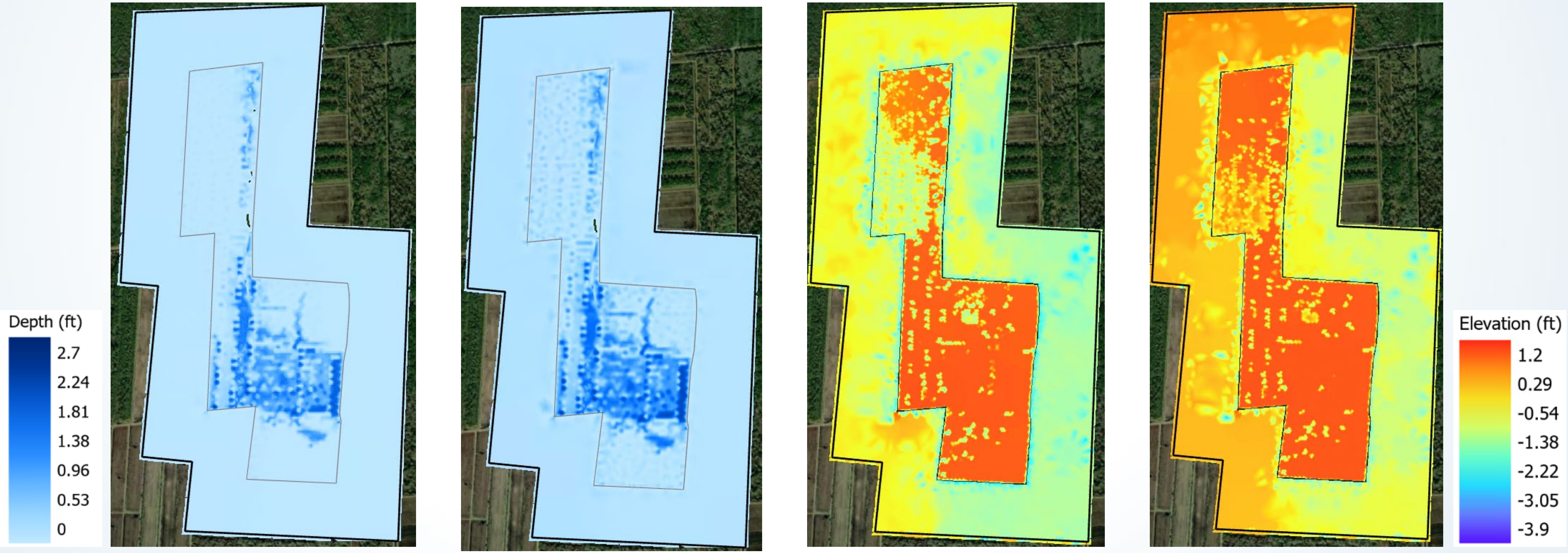
# Design Storm Results: Overland Flow and Groundwater Flow

**Overland Flow Region**
Hour: 12

**10-year** **100-year**

**Groundwater Flow Region**
Hour: 36

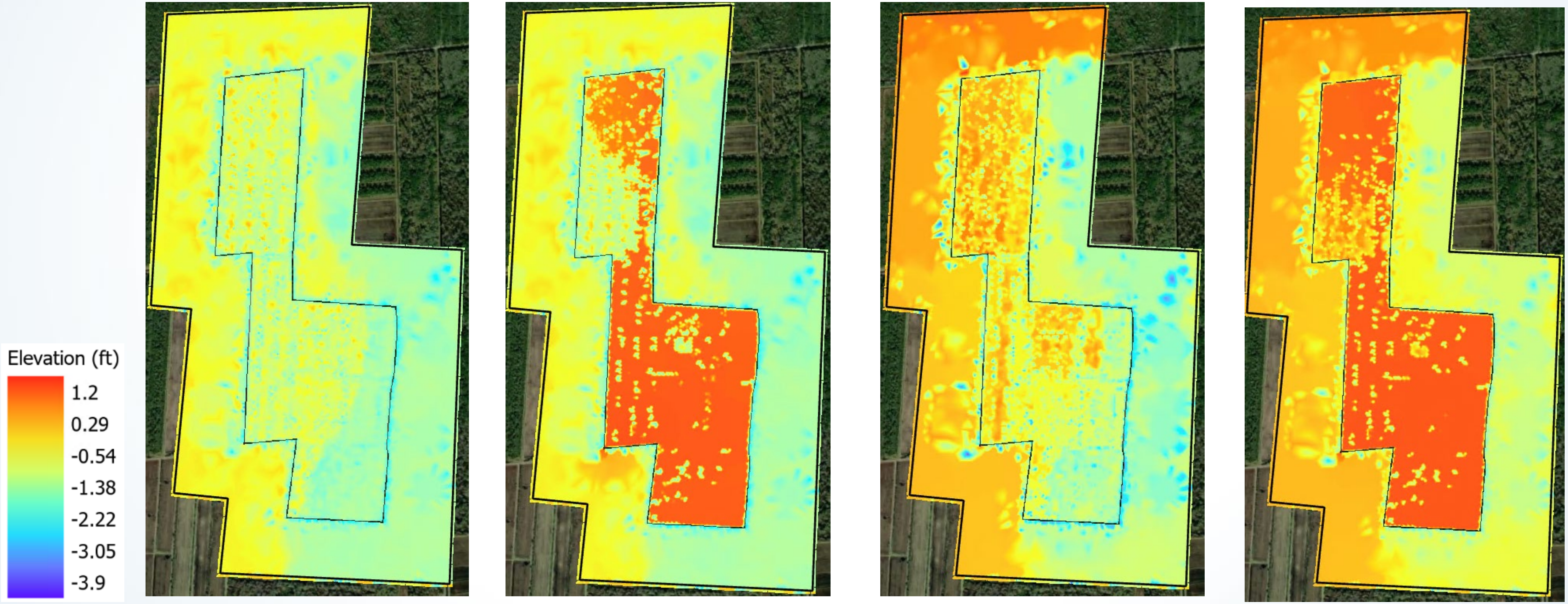
**10-year** **100-year**



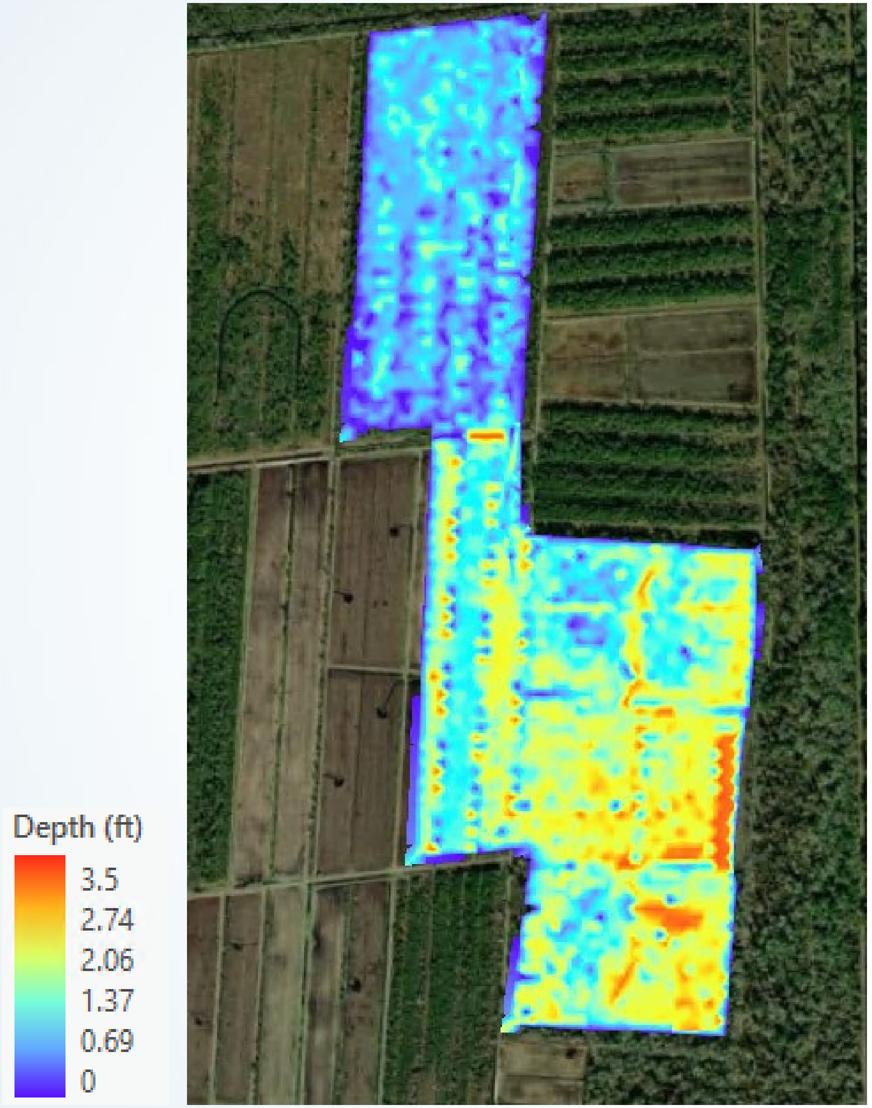
# Evaluation of Hydraulic Trespass: Groundwater at Hour 36

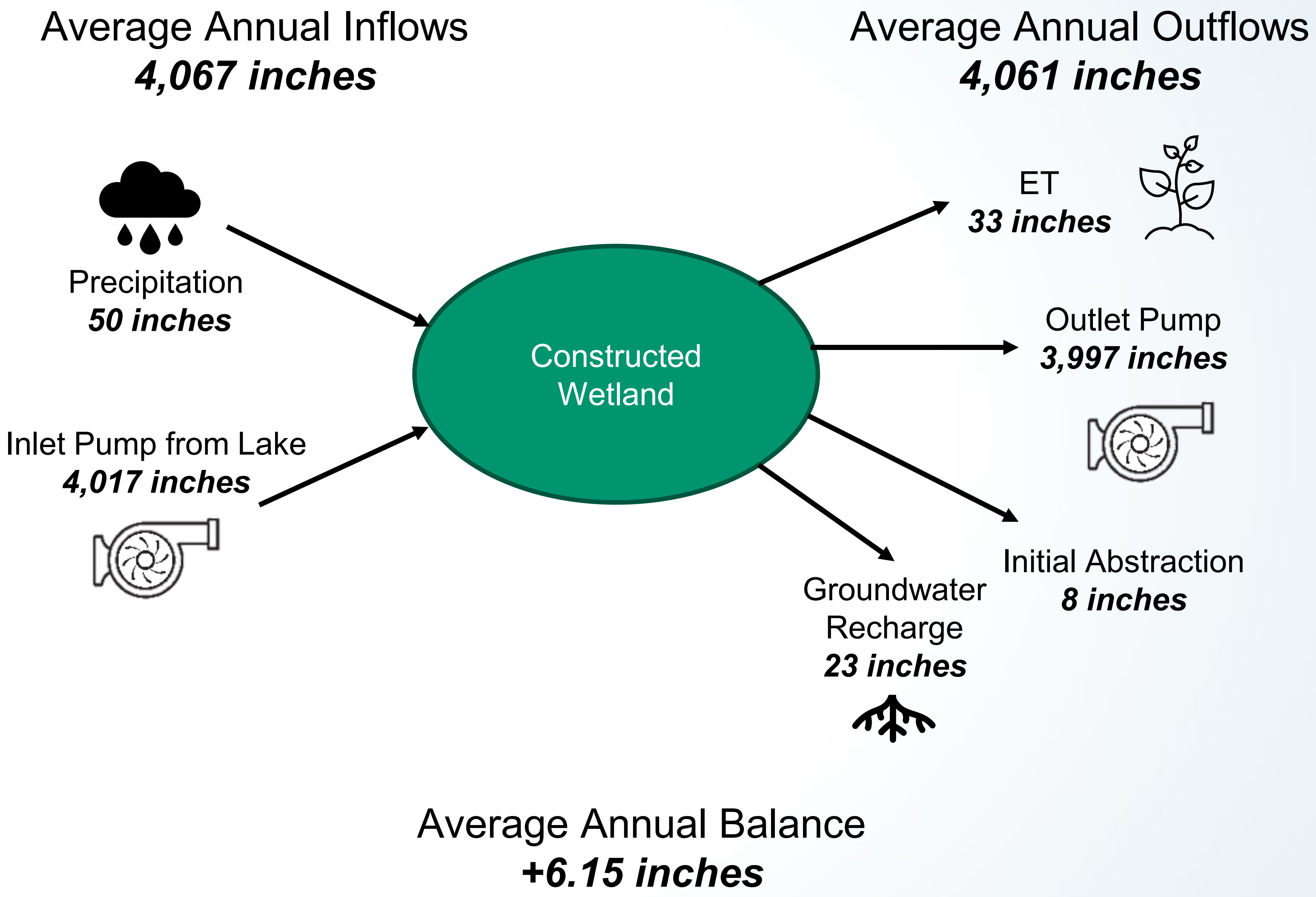
**10-year** | **100-year**

NO PUMP IN | PUMP IN | NO PUMP IN | PUMP IN



# Continuous Simulation with Continuous Pumping



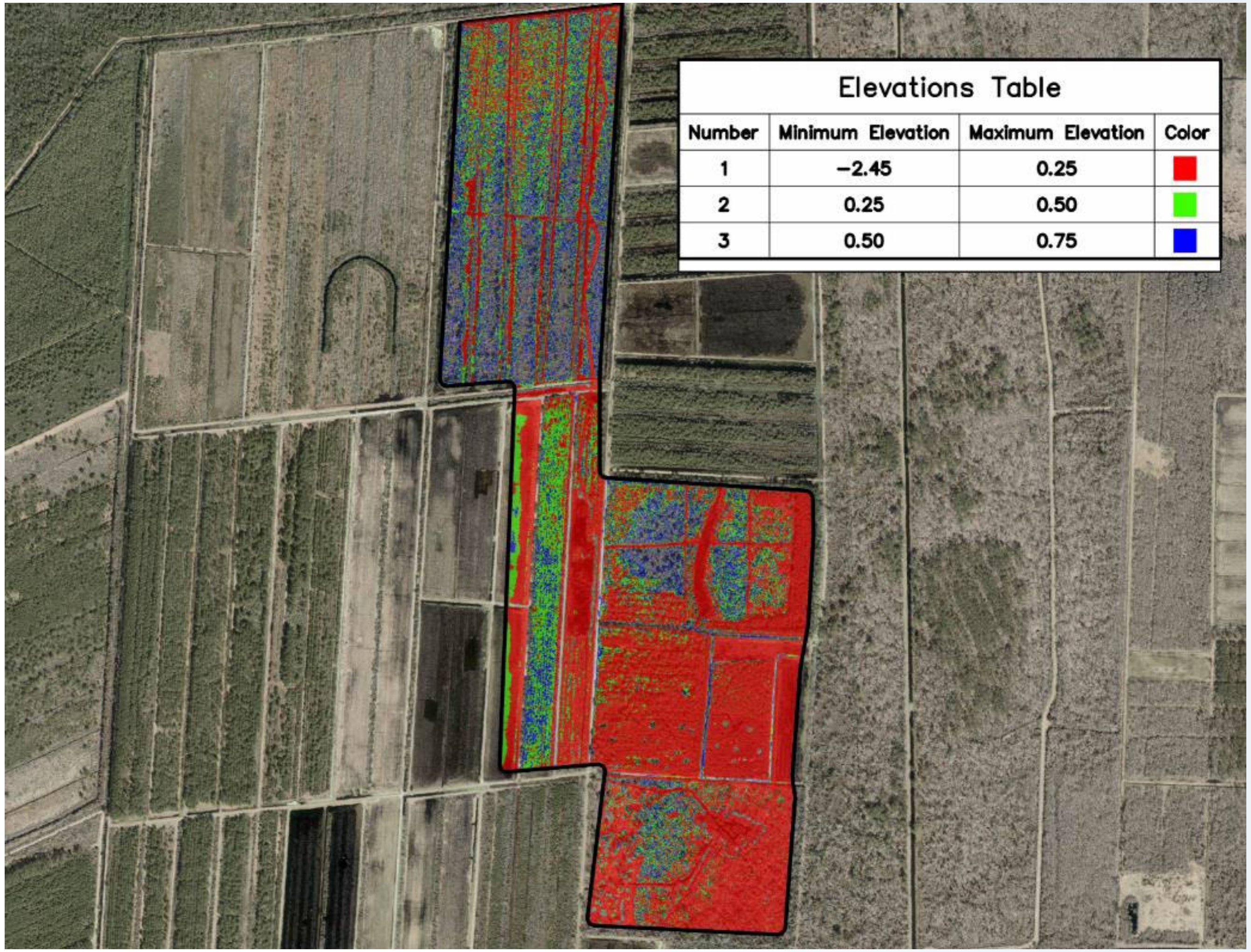
# Continuous Simulation – Preliminary Monthly Water Balance with Continuous Pumping

| Average Monthly Water Balance (inches) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan | Feb | Mar | Apr | May | Jun | July | Aug | Sep | Oct | Nov | Dec |
| -5.66 | +24.25 | -8.01 | +3.53 | -3.44 | +0.50 | -7.10 | -4.96 | +4.88 | -0.28 | +5.54 | -3.11 |

Average Annual Balance
***+6.15 inches*** → **Volume managed approximately 90,000 ac-ft or 1.5 ft of water drawdown in Lake Mattamuskeet**

# Other Project Considerations

- Minimum elevation
- Connection to the Lake
- Infiltration
- Ensuring wetland habitat
- Landowner considerations
- Multiple stakeholders
- Hydraulic trespass



# Key Takeaways + Next Steps

- Design storm runoff appropriately mitigated with 135 cfs pumps
- Minimal hydraulic trespass when pumping during design storms
- Potential for significant water removal from Lake Mattamuskeet… if continuously pumping to wetland, which has operational challenges
- Novel application of ICPR in North Carolina
- Progressing design and evaluating funding options


# Questions?

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