Coupled ADH and Ecological Modeling (CASM): Upper Mississippi Pool5 Island Restoration and Caernarvon Diversion

Charlie Berger, CHL/ERDC/USACE
Gaurav Savant, Contractor, CHL/ERDC/USACE
Jennifer N. Tate, CHL/ERDC/USACE
Steve M. Bartell, E2 Consulting Engineers
Tate O. McAlpin, CHL/ERDC/USACE

OUTLINE

- Hydrodynamic Model
- Ecological Model
- Integration
- Outputs
- Applications

ADaptive Hydraulics (ADH)

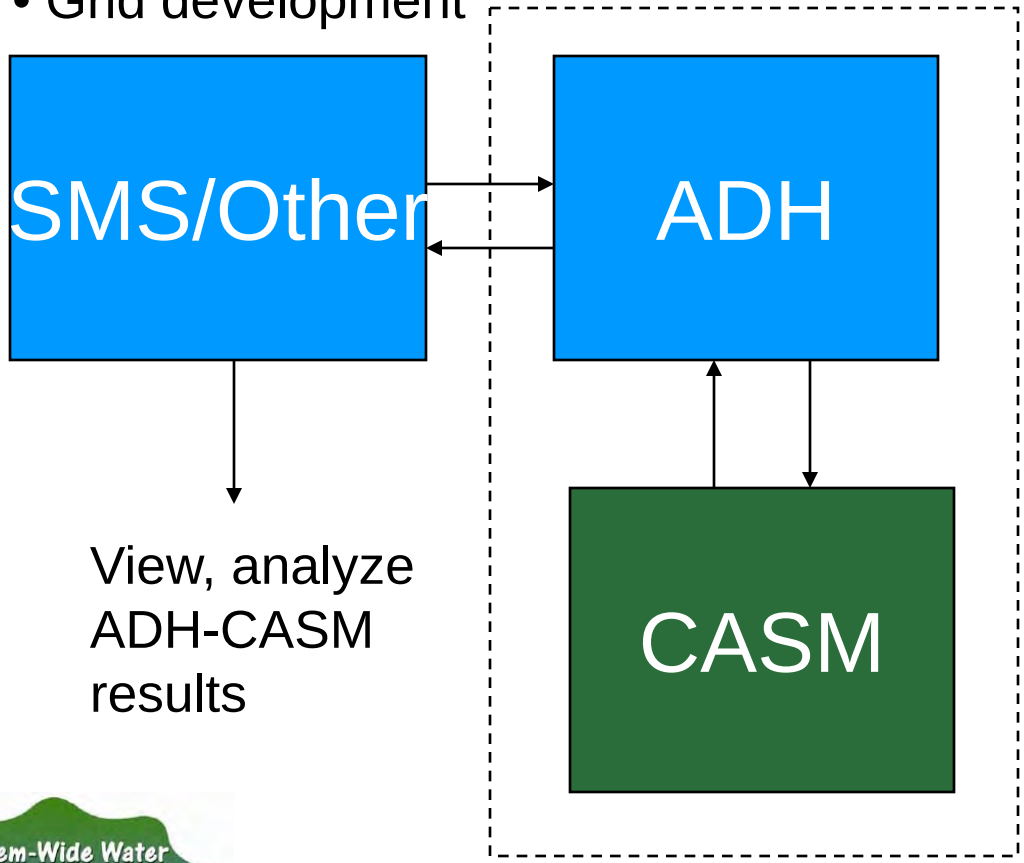
- ADH is a state of the art finite element hydrodynamic code.
- Features:
  - Adaptive – ADH has the ability to adapt in space. User generated mesh is adapted (refined or coarsened) depending upon error indicators.
  - Implicit Solver – Allows ADH to take large computational time steps.
  - Shallow Water (2D and 3D), Navier-Stokes, and Groundwater modules.
  - Multi-Processor.
  - Libraries – Sediment, Friction, Ice Impacts, Water Quality.

The Comprehensive Aquatic Systems Model (CASM)

- Ecological model developed by Dr. Steve M. Bartell, E2 consulting Engineers
- Features
  - Habitat
  - Biochemistry
  - Biota
  - 4 producer groups, each with 10 species: Phytoplankton, Periphyton, Macrophytes and Emergent Aquatic Plants.
  - 8 consumer groups- include benthic invertebrates, fish and bacteria.

ADH-CASM Integration

- Grid development



View, analyze ADH-CASM results

- Boundary conditions
- Flows, velocities
- Depths
- Transported constituents
- Non-transported

- Food web structure
- Bioenergetics parameters
- Trophic relationships
- Environmental functions

ADH-CASM Integration

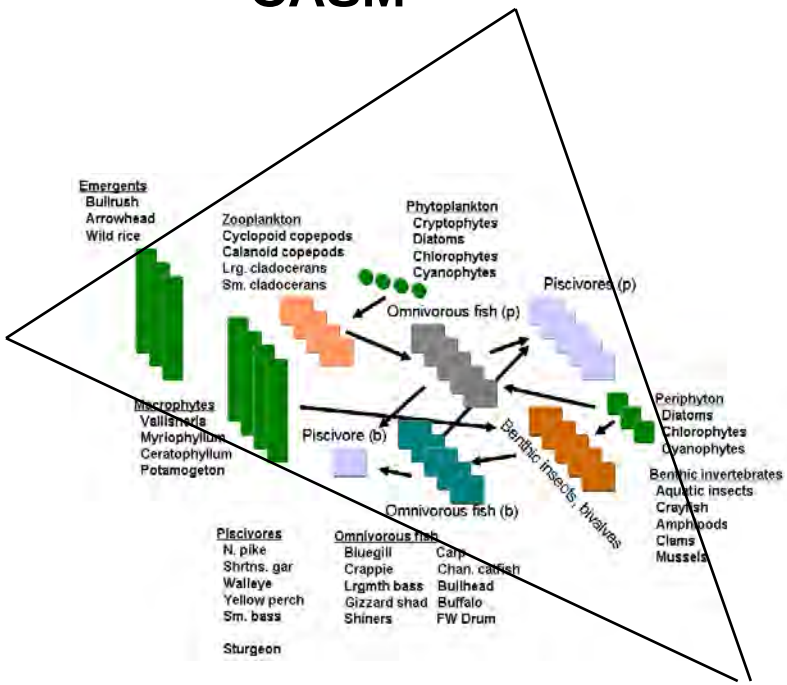
ADH

For node i,

Values of all CASM state variables
Time
Depth
Velocity

Derivatives of all CASM state variables

CASM



ADH-CASM Integration

- CASM can be called from ADH using a variety of options
  - A material can be designated as CASM material, doing so will call CASM for only this material
  - CASM can be called at each ADH hydrodynamic timestep
  - Or, CASM can be called every X time steps e.g. every 6000 sec or other user specified interval.
  - Integrated using a Runge-Kutta Level 4 scheme.
- Advantages
  - CASM can take advantage of ADH adaption in space: Better representation of known critical areas, and/or revelation of otherwise unknown critical areas.
  - Multiple processor

ADH-CASM Outputs

Hydrology
- velocity
- depth, elevation
-Salinity

Geomorphology
- sediment transport, deposition
- substrate variability
- channel structure

Biogeochemistry
- dissolved oxygen
- DIN, DIP
- particulate carbon, TSS
- water clarity

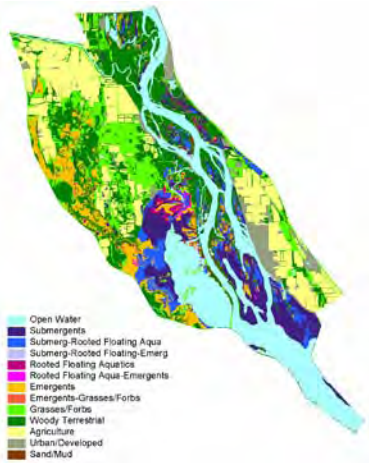
Habitat
- physical-chemical characteristics
- biological (e.g., SAV, emergents)

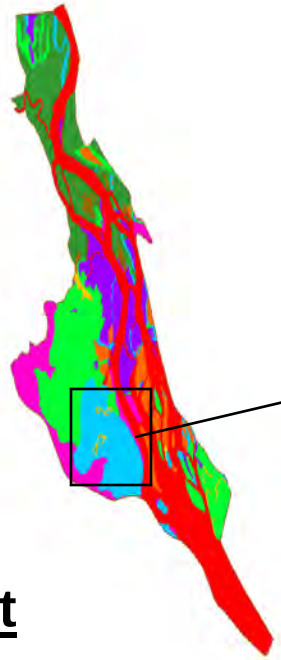
Biota
- phytoplankton
- periphyton
- SAV
- emergent aquatic plants
- zooplankton
- benthic invertebrates
- omnivorous fish
- piscivorous fish

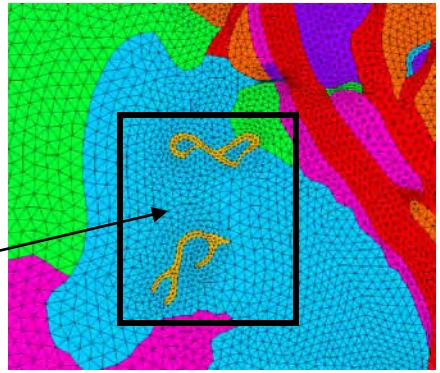
ADH-CASM Potential Applications

- Ecosystem Management: O&M
- Island Restoration
- Diversions

Upper Miss. Pool 5 Application Island Construction







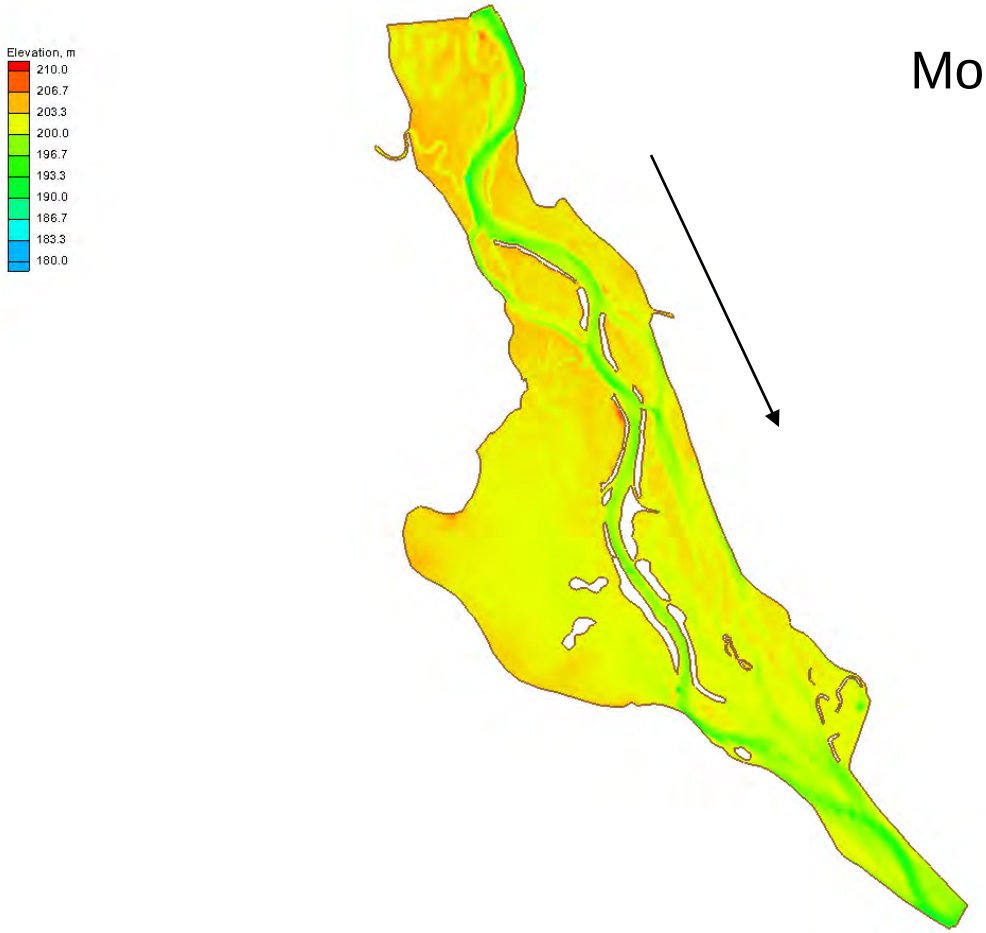
Physical environment

- current velocities
- water depths
- sediment concentrations

Evaluate ecological benefits

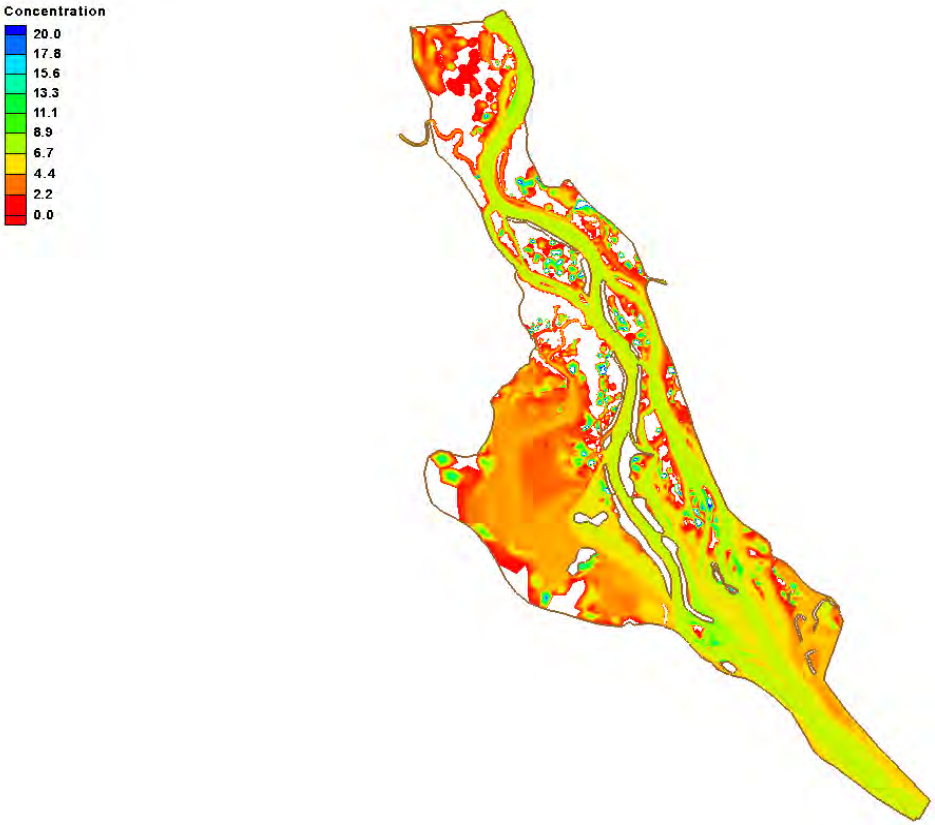
- SAV
- benthic invertebrates
- littoral fish
- water quality

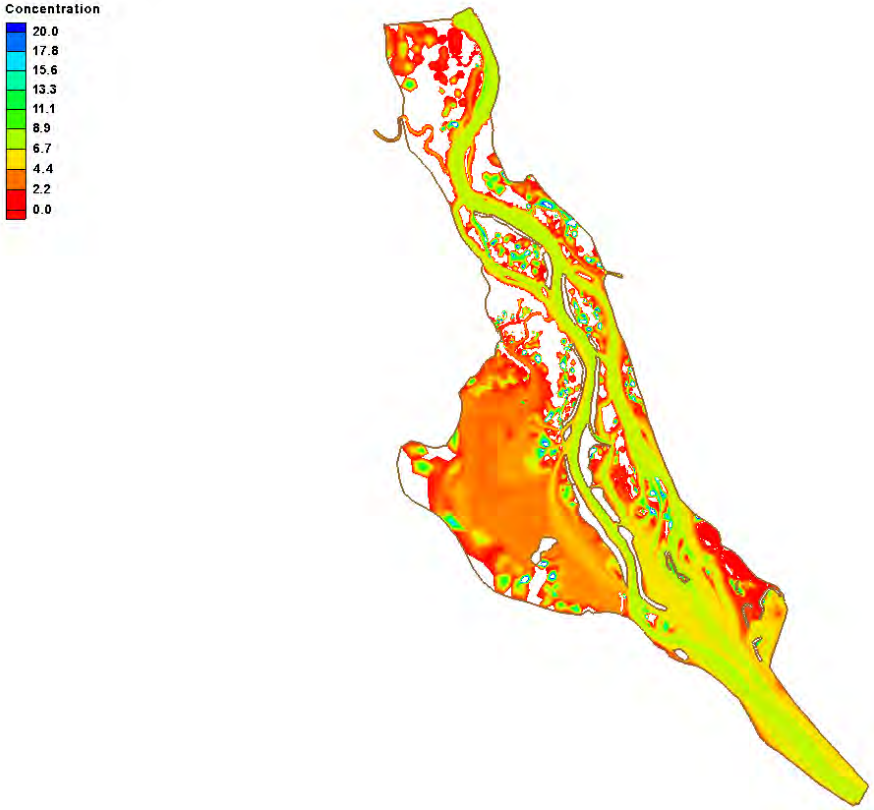
Upper Miss. Pool 5
Preliminary Results



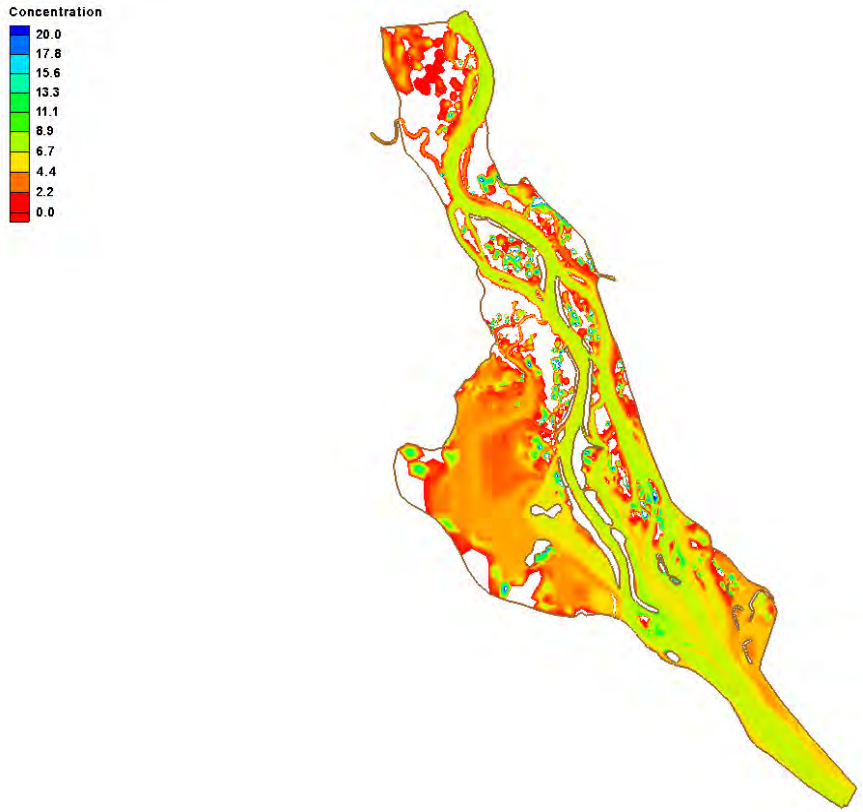
Model Domain

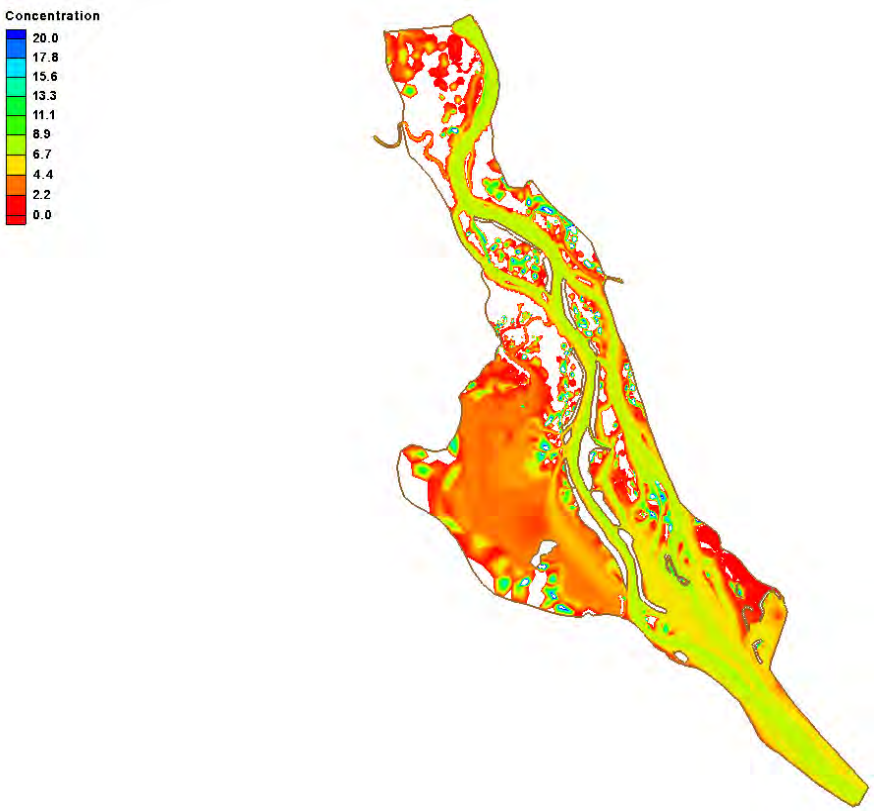
Upper Miss. Pool 5
Preliminary Results
Chlorophytes-Day 50



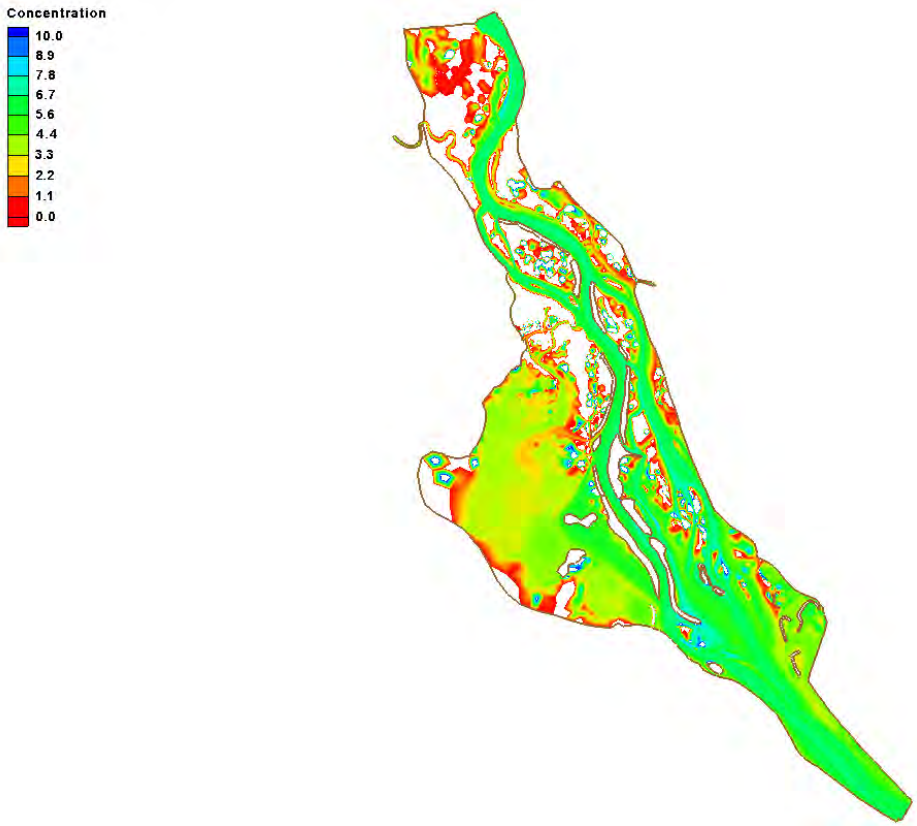


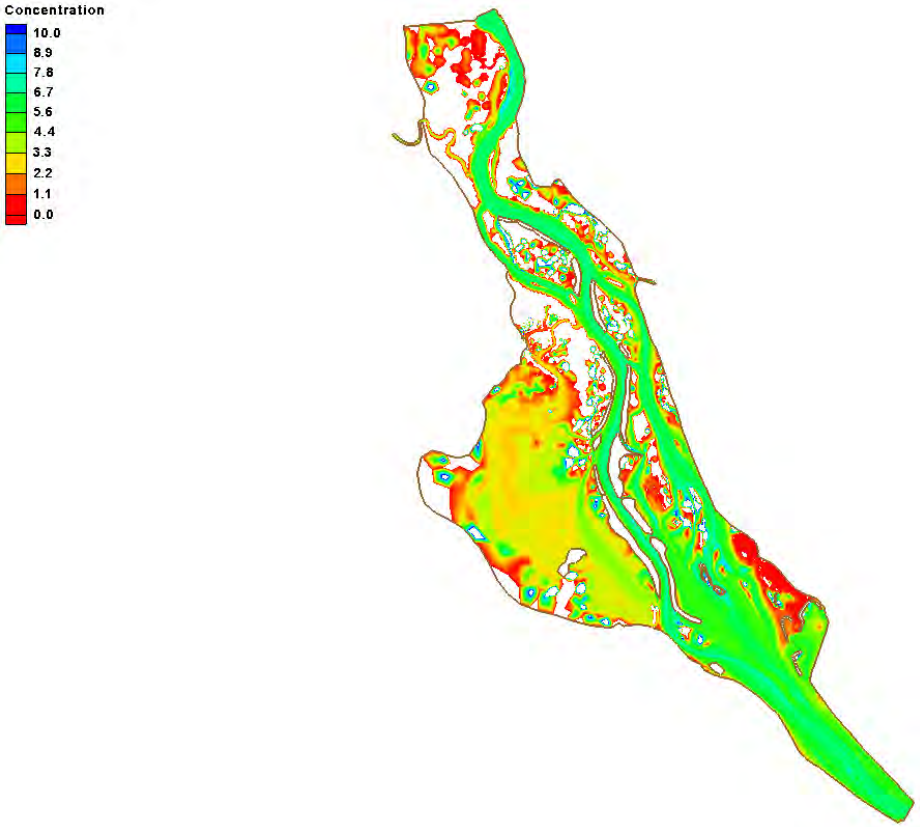
Upper Miss. Pool 5
Preliminary Results
Chlorophytes-Day 250



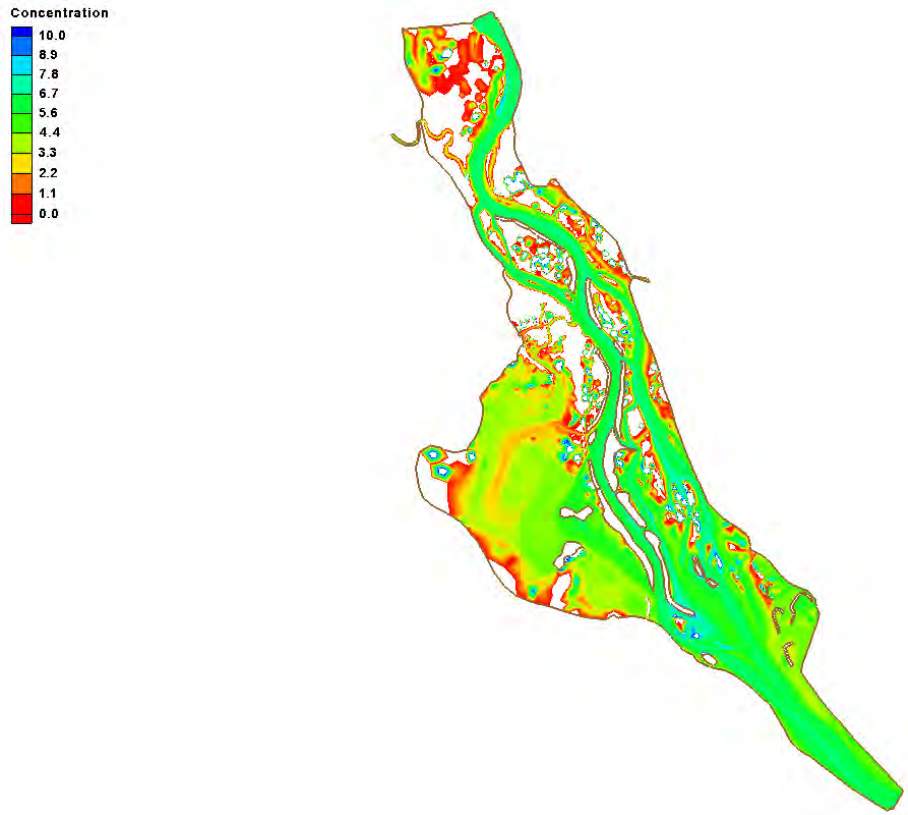


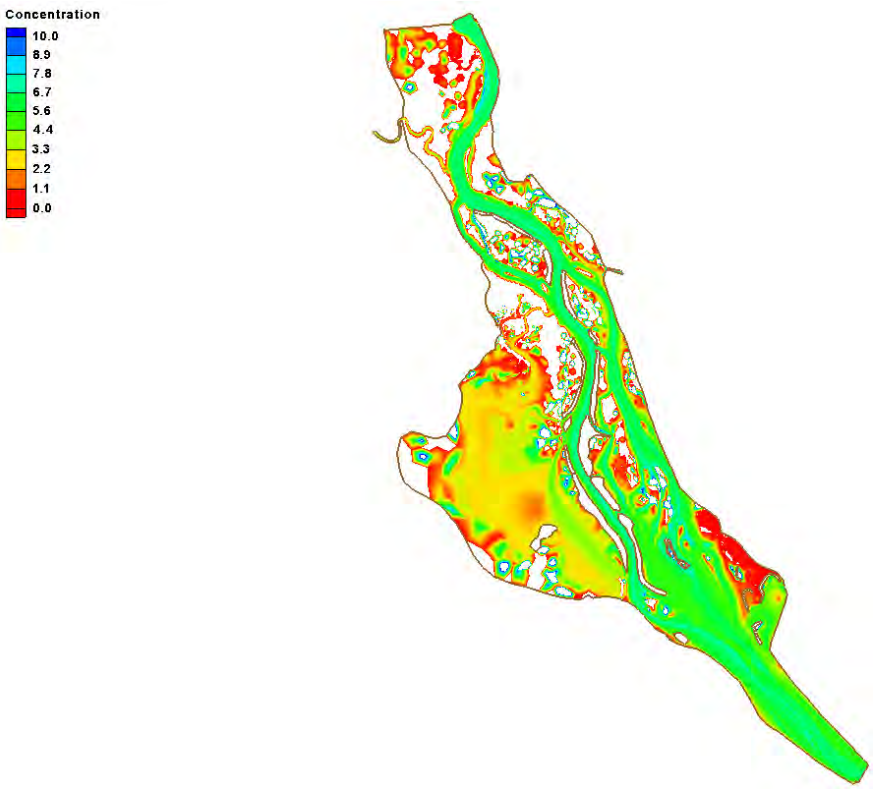
Upper Miss. Pool 5
Preliminary Results
Vallisneria-Day 50



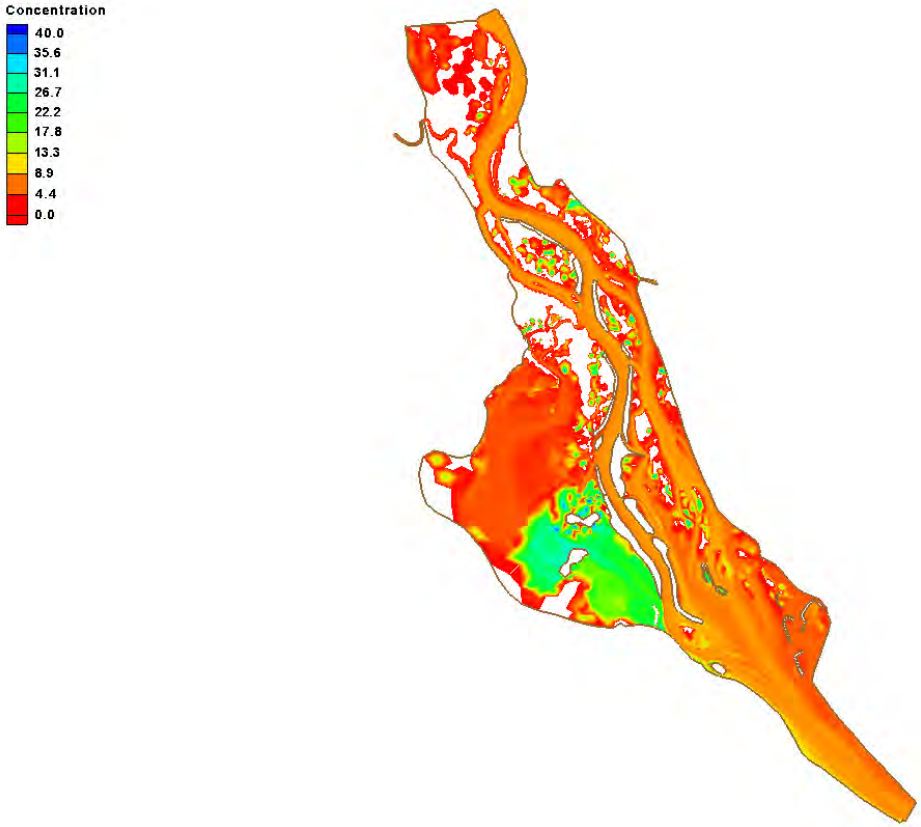


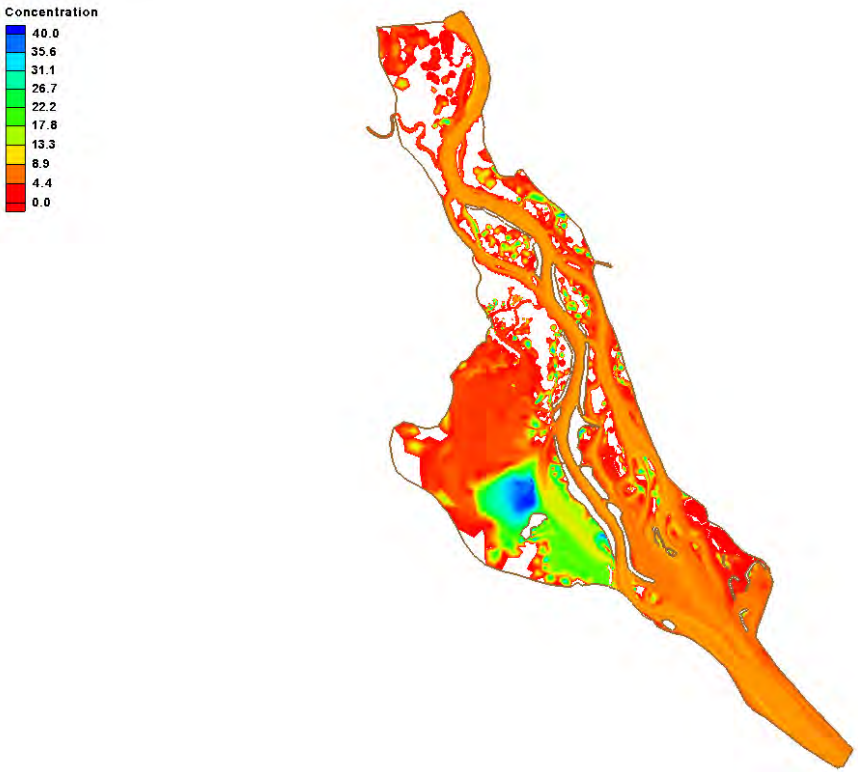
Upper Miss. Pool 5
Preliminary Results
Vallisneria-Day 250



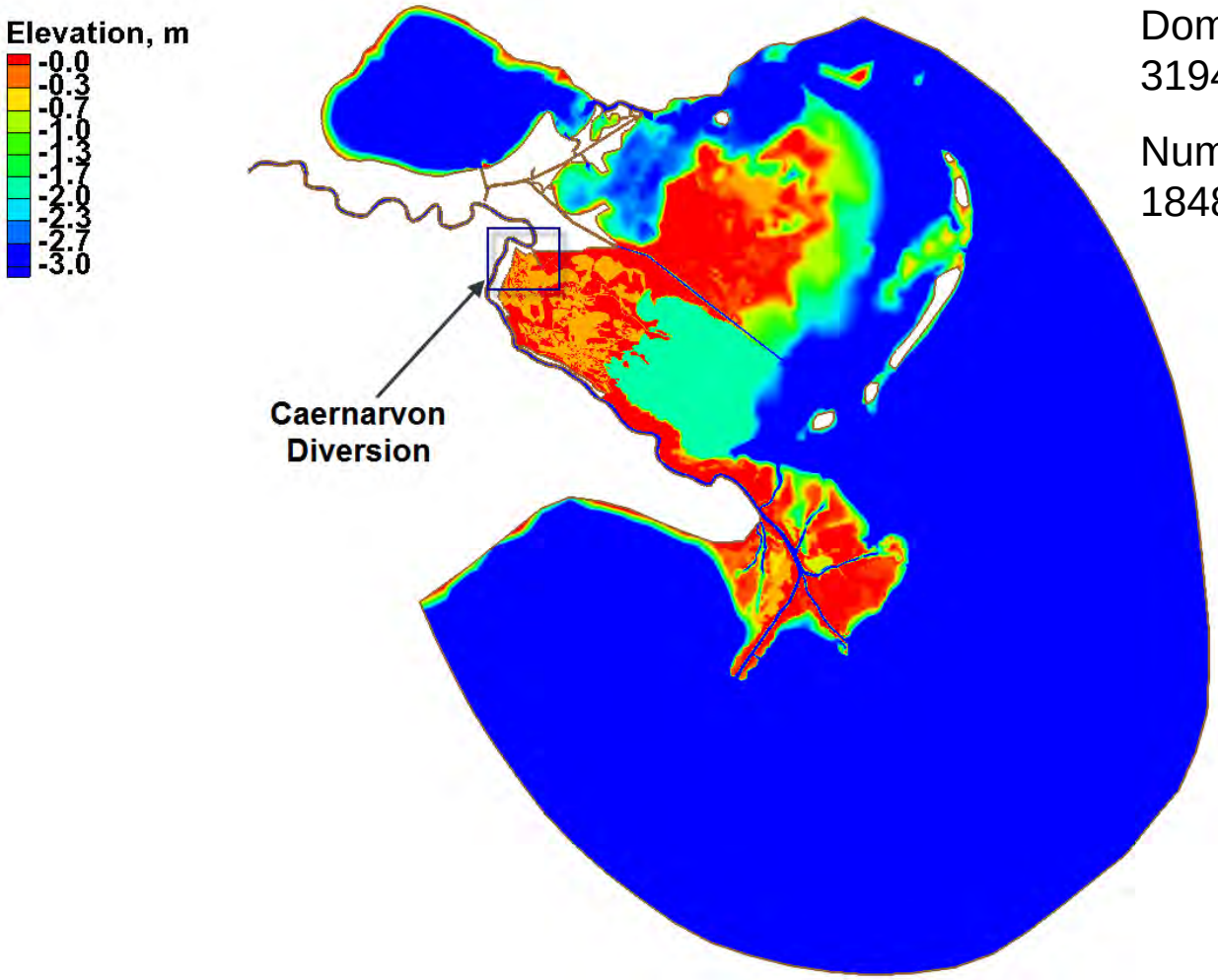


Upper Miss. Pool 5
Preliminary Results
BlueGill-Day 250





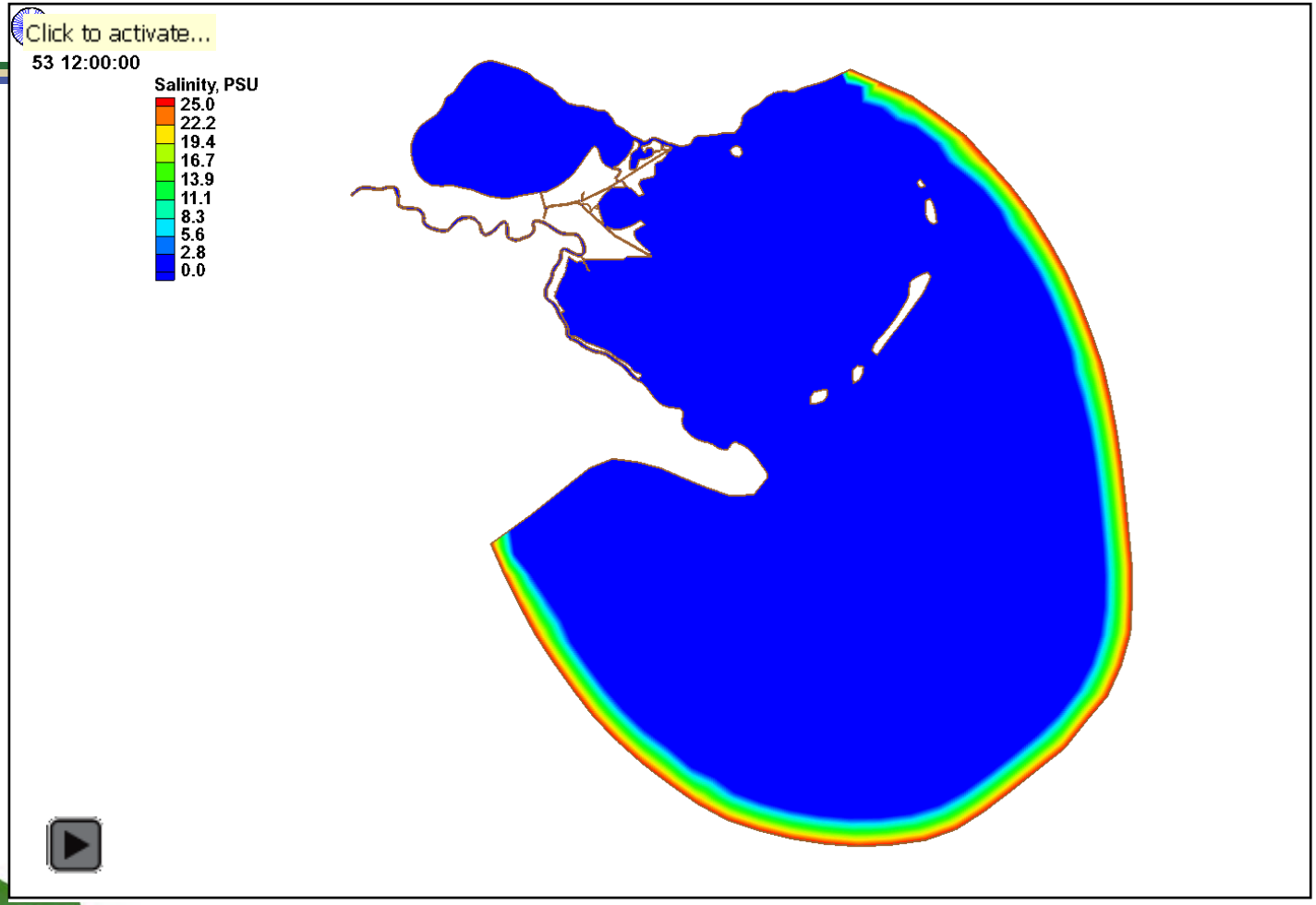
Caernarvon Diversion



Domain Area:
31948999280.1 m^2

Number of Elements:
184899

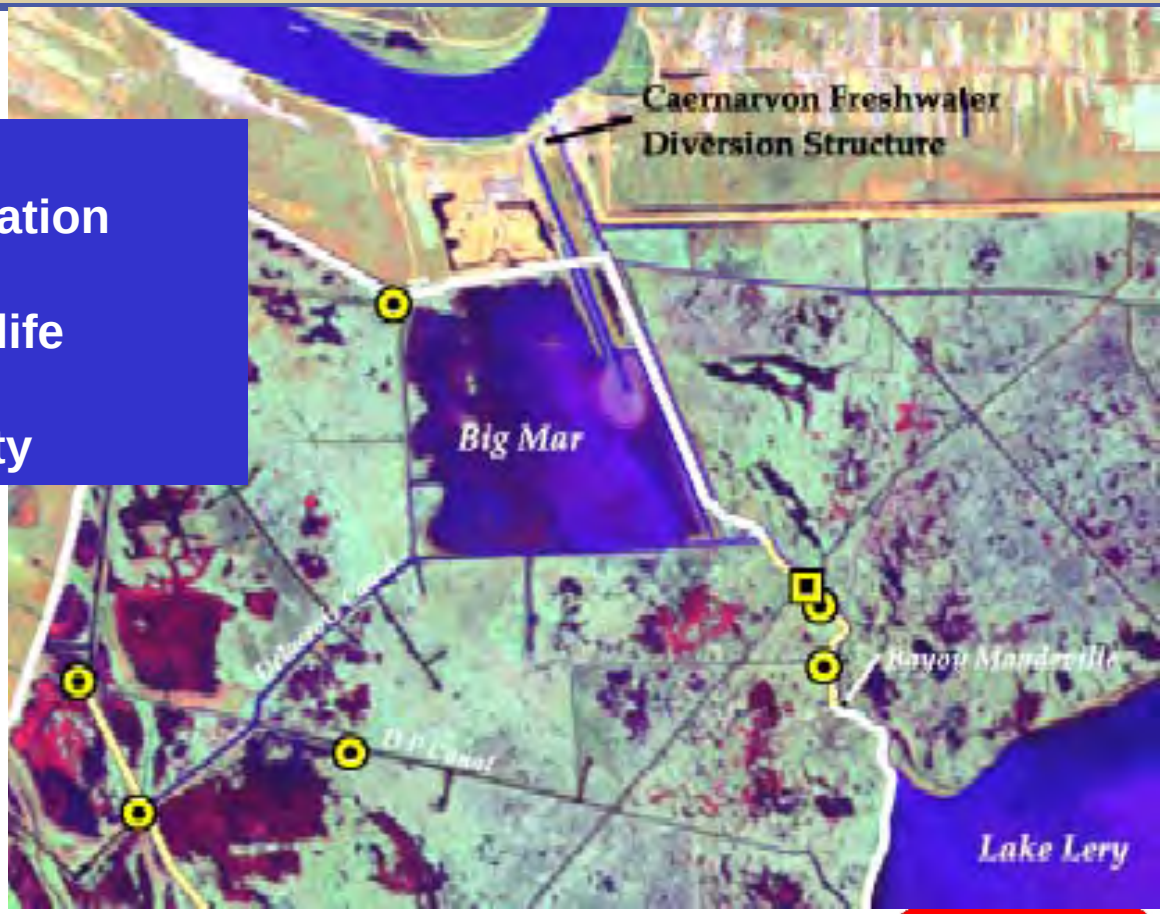
Caernarvon Diversion: Salt Simulation



Caernarvon Diversion

Restoration objectives

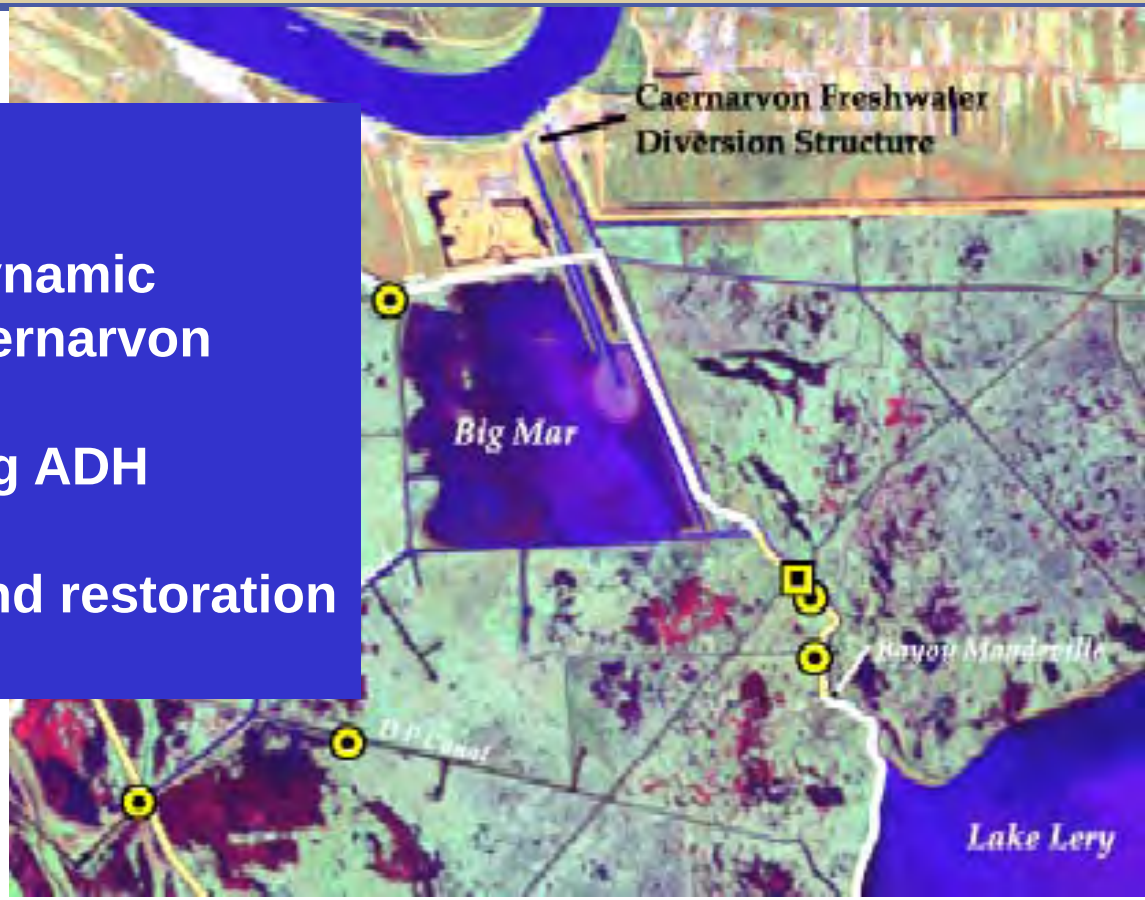
- Enhance emergent marsh vegetation
- Reduce marsh loss
- Increase estuarine fish and wildlife productivity
- Maintain or improve water quality



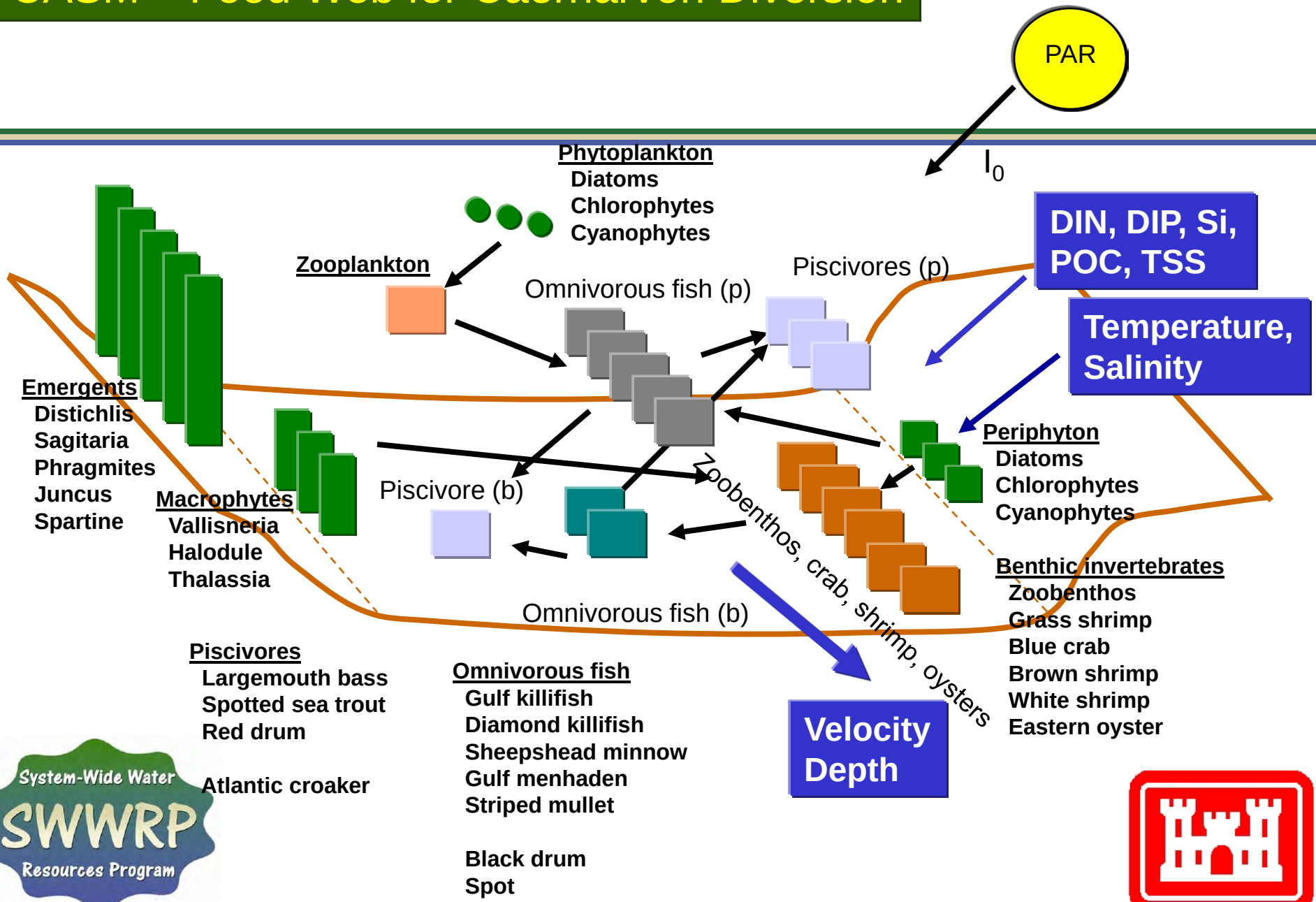
Caernarvon Diversion

<u>Modeling objectives</u>

- Develop spatially explicit, dynamic ecosystem model for the Caernarvon Diversion
- Integrate model with ongoing ADH development
- Forecast outcomes of wetland restoration actions



CASM – Food Web for Caernarvon Diversion



Governing equation

$$V_j \frac{dc_{ij}}{dt} = \sum_k Q_{kj} c_{ik} + \sum_k E'_{kj}(c_{ik} - c_{ij}) + \sum_k S_{ijk}$$

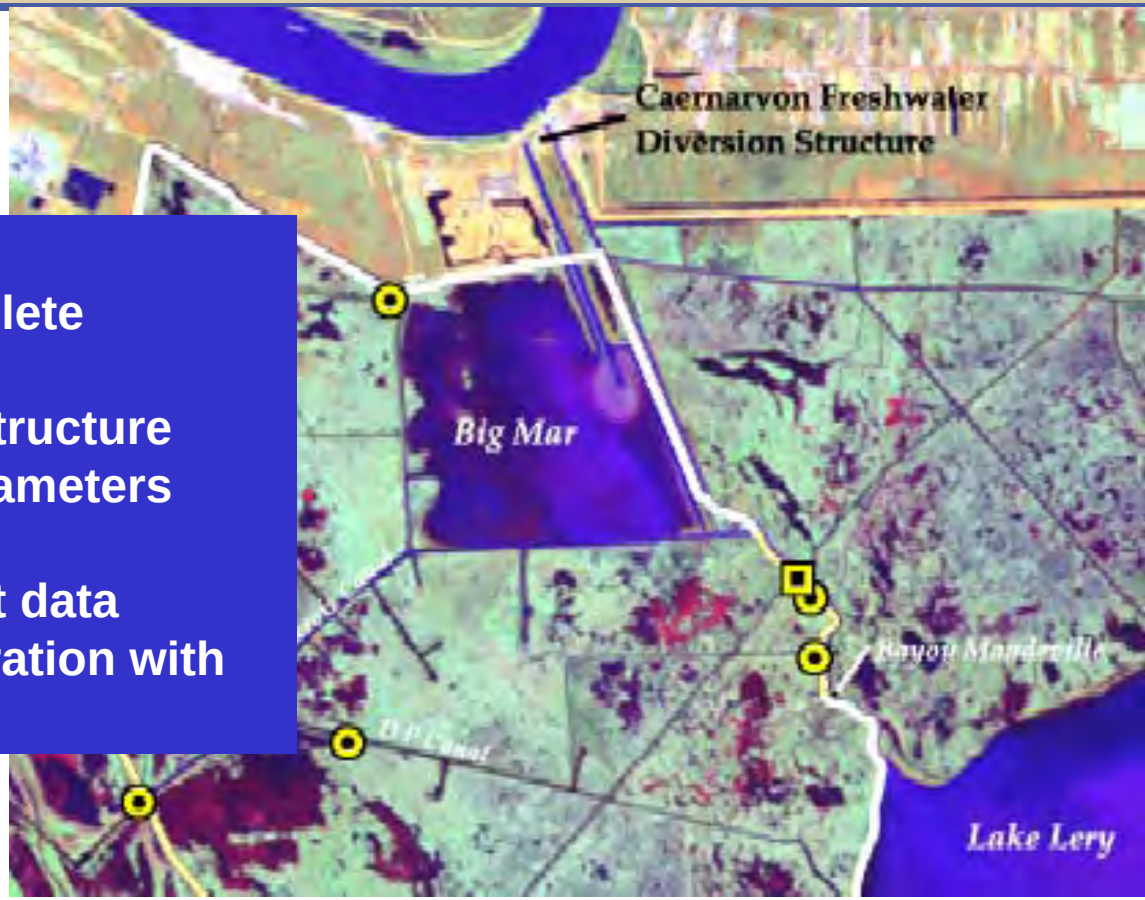
Vj volume of segment j
cij concentration of substance i in segment j
cik concentration of substance i in segment k
Qkj net advective flow rate between segment k and j
E'kj bulk transport rate between segment k and j
Sikj kth source or sink of substance i in segment j

<u>Data needs:</u>
Initial conditions (population biomass, water quality parameters)
Bioenergetics parameters
Food web interactions (e.g., diet composition)
Environmental inputs

Linking ADH-CASM Outputs to Restoration Objectives

Restoration objectives	ADH-CASM Outputs
Enhance emergent marsh vegetation	Emergent plant biomass
Reduce marsh loss	Marsh plant biomass
Increase fish and wildlife	Modeled populations of oysters, shrimp, crab largemouth bass, other modeled fish
Maintain or improve water quality	Dissolved oxygen, DIN, DIP, salinity

Caernarvon Diversion



Progress to date

- Hydrodynamic calibration complete
- Salinity runs ongoing
- Delineation of initial food web structure
- Estimation of bioenergetics parameters
- Specification of diets
- Collation of environmental input data
- Modification of casm.f for integration with Caernarvon ADH

ADH-CASM

- CASM has been incorporated within ADH as a callable library
- ADH-CASM has been applied to Pool5.
- ADH-CASM is currently being applied to the Caernarvon Diversion to study:
  - Hydrodynamics
  - Salinity Intrusion
  - Sedimentation and
  - Ecology