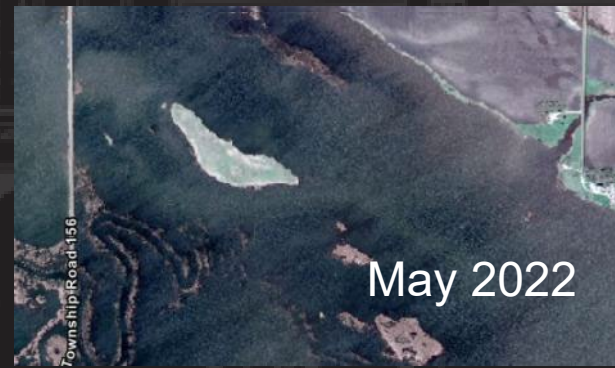


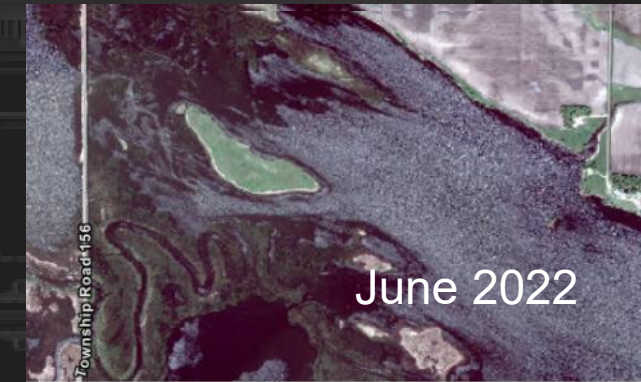
TASKING HIGH-RESOLUTION SATELLITE IMAGERY FOR MONITORING ECOSYSTEM PROJECTS

National Conference on Ecosystem Restoration
18 April 2024
Albuquerque, New Mexico

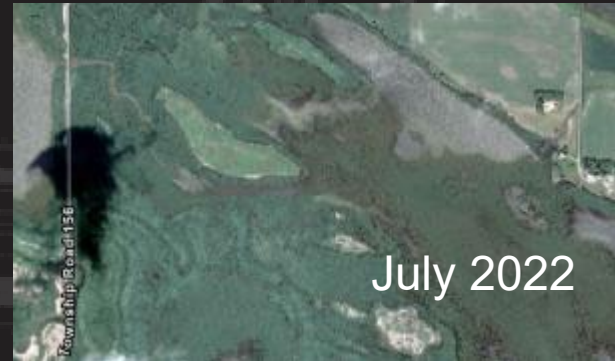
Kevin Hanson | Geographer/GIS Analyst
U.S. Army Corps of Engineers – St. Paul District



May 2022



June 2022



July 2022



August 2022



October 2022



November 2022

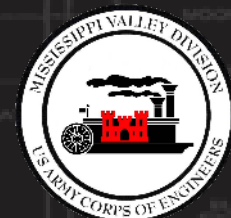
Marsh Lake 2022 | Pleiades Satellite Imagery
50cm Resolution



UPPER MINNESOTA RIVER
WATERSHED DISTRICT



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BACKGROUND

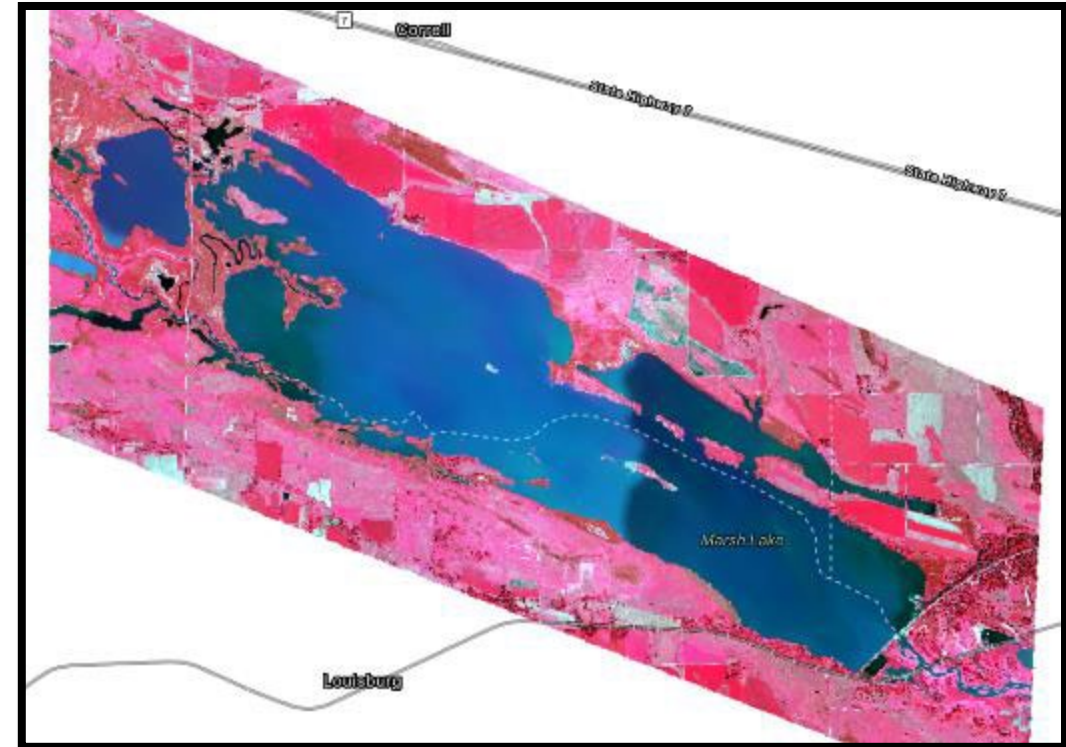
- Monitor the project after construction.
 - emergent and submergent aquatic vegetation
 - open water
 - wildlife

- Marsh Lake is a large area (4,500 acres).
 - Air photo on map is 14,000 ac/56 sq km.

- Adaptative management requires field monitoring and remote sensing.
 - MN DNR tasks with field monitoring.
 - USACE GIS tasked with remote monitoring.

- Monitor during the growing season (May-Sept).

- How to remotely monitor such a large area?**



Pre-Project Marsh Lake
FSA False Color Air Photo from August 14, 2015



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MONITORING OPTIONS FOR 14,000 ACRES

Aerial Orthophotography

- Free from FSA NAIP
- 4-Band
- 30cm-1m (ex.60cm)
- Every other year
- Summertime – July/Aug
- Nadir
- Contracting 15cm imagery cost estimated at \$30K



UAS Orthophotography

- 5 days minimum for one collection
- ~17K per collection
- ~100K for 6 collections
- 3-Band
- 3cm!
- Nadir/Top-Down
- Fly at max 400 ft



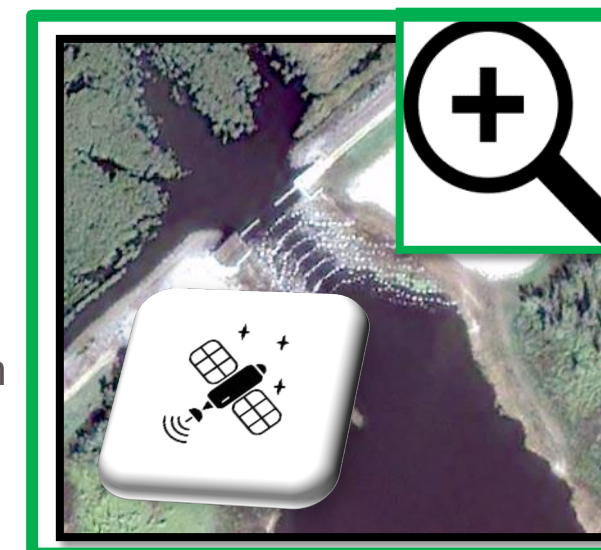
Low-Resolution Satellite Imagery

- Free Sentinel-2
- 4-Band
- 10-20m resolution
- Off-nadir
- All year
- 1-3 collects per month with less than 5% clouds



High-Resolution Satellite Imagery

- 2K per collection
- 4-Band
- 30-70cm
- Off-nadir
- Tasking satellites
- 1-3 collects per month with less than 5% clouds





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TASKING HIGH-RESOLUTION SATELLITE +/-

4

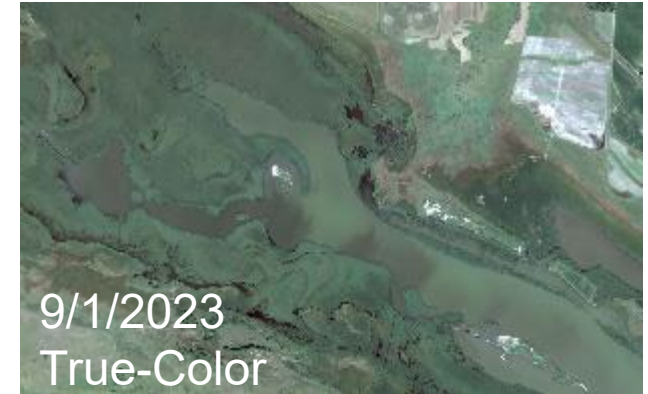
Advantages

- 4-band multispectral imagery (false color).
- Cloud free collections.
- 30-70 cm resolution compares to air photos.
- Georectified for GIS.
- Run GIS imagery analysis tools.
- Commercial vendor costs for 56 sqkm:
 - \$18.50 per sq km for past satellite data (~\$1,000/14K ac).
 - \$32.57 per sq km for tasking a satellite (~\$1,800/14K ac).

Challenges

- Can't choose a single date given weather & satellite path.
- The larger the area of interest the less chance of collection.
- May have clear day, but satellite picks up glint off water.

Next Step - Task a Satellite for the 2022 Growing Season



MARSH LAKE 2022 SATELLITE IMAGERY COLLECTION

PLEIADES SATELLITE

MAY – NOVEMBER

SIX 4-BAND 50CM IMAGES COLLECTED

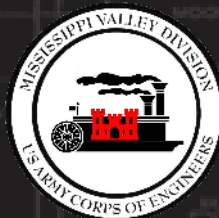
**SCREENSHOTS TAKEN FROM AN INTERACTIVE GIS DASHBOARD FOUND IN
THE MARSH LAKE STORYMAP**



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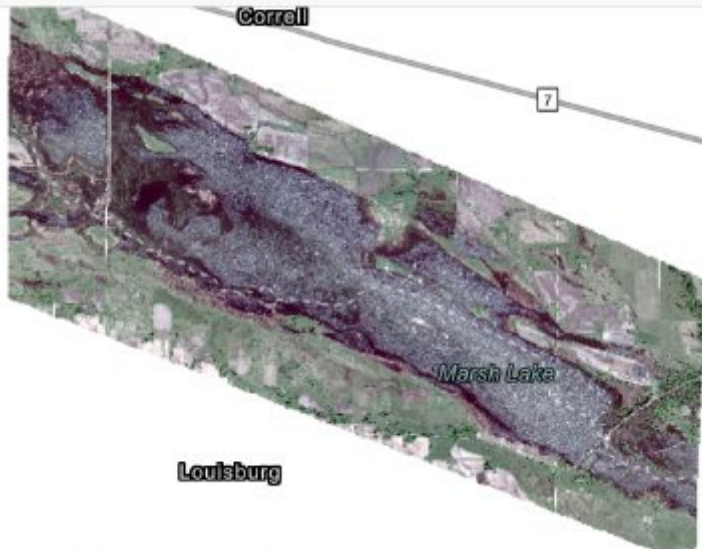




May 13, 2022 | 941.74 feet NGVD29



June 2, 2022 | 940.67 feet NGVD29



July 11, 2022 | 938.53 feet NGVD29



August 30, 2022 | 937.91 feet NGVD29



October 8, 2022 | 937.31 feet NGVD29



November 23, 2022 | 937.47 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

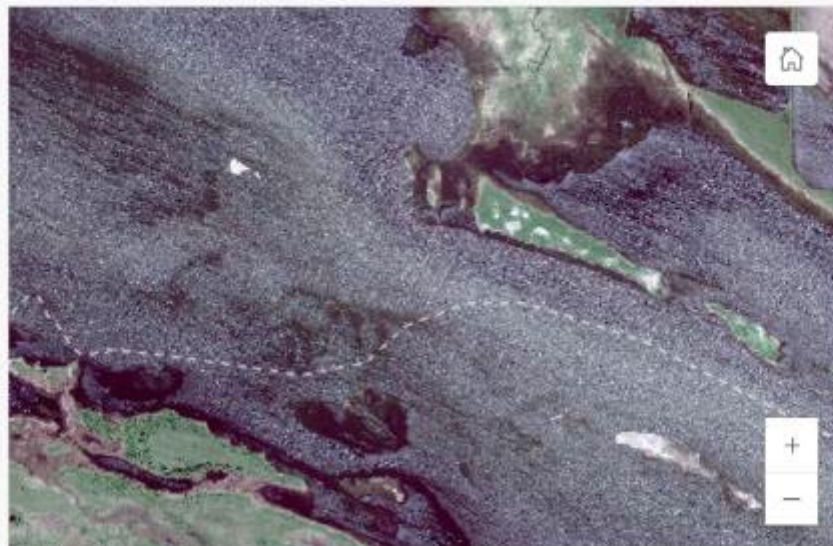


May 13, 2022 | 941.74 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

June 2, 2022 | 940.67 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

July 11, 2022 | 938.53 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

August 30, 2022 | 937.91 feet NGVD29



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October 8, 2022 | 937.31 feet NGVD29



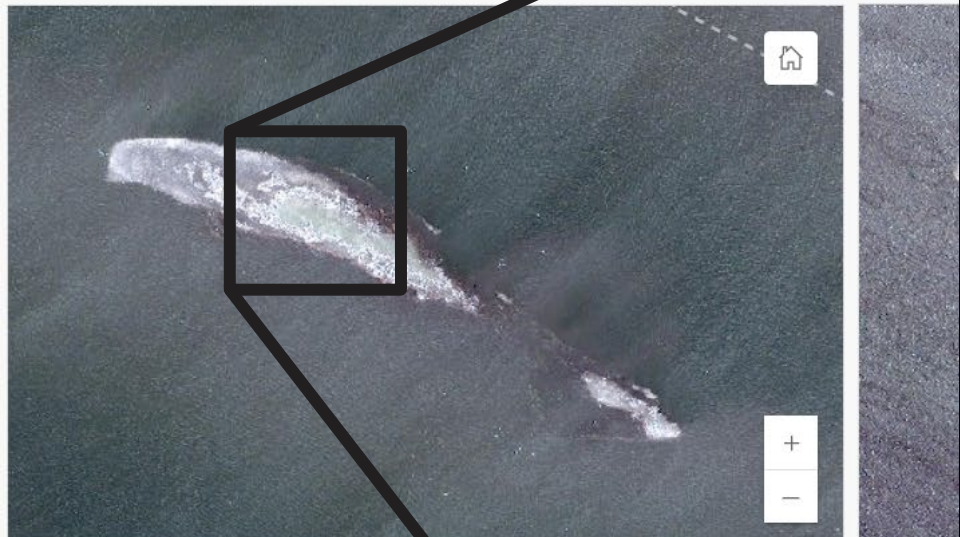
USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

November 23, 2022 | 937.47 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

May 13, 2022 | 941.74 feet NGVD29



USACE St. Paul District | Esri Community Maps Contributors, © OpenS... Powered by Esri USACE St...

August 30, 2022 | 937.9 feet NGVD29





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1:1,000

October 8, 2022 | 937.31 feet NGVD29



USACE St. Paul District, Community Maps Contributors, © OpenSt... Powered by Esri



MARSH LAKE 2023 SATELLITE IMAGERY COLLECTION

PLEIADES SATELLITE

MAY – NOVEMBER

SEVEN 4-BAND 50CM IMAGES COLLECTED

**SCREENSHOTS TAKEN FROM AN INTERACTIVE GIS DASHBOARD FOUND IN
THE MARSH LAKE STORYMAP**



U.S. ARMY

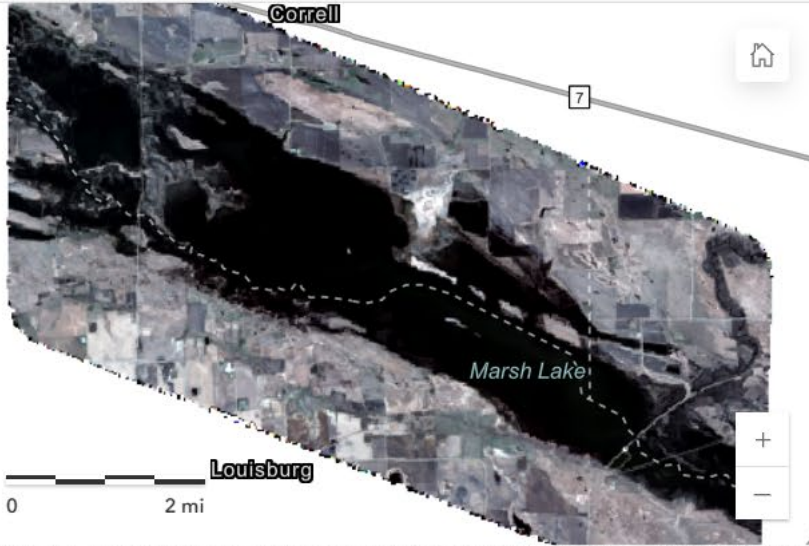


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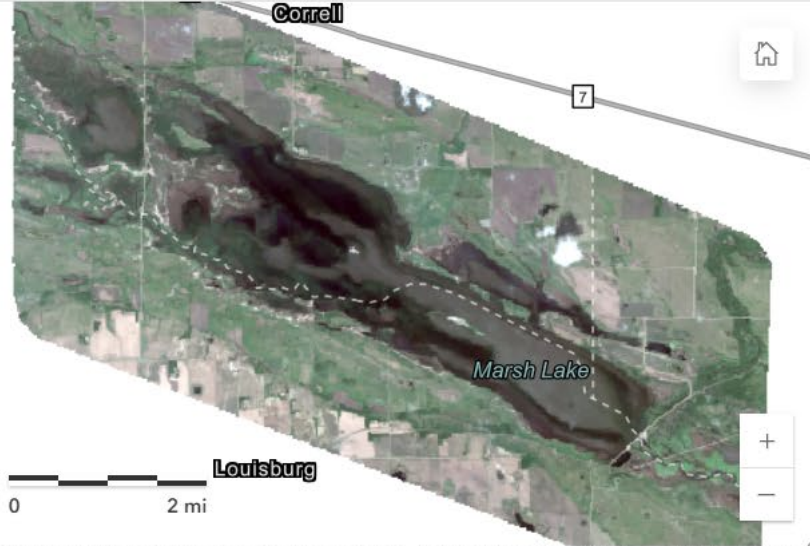




May 5, 2023 | 941.89 feet NGVD29



June 8, 2023 | 938.99 feet NGVD29



July 2, 2023 | 937.89 feet NGVD29 and August 12, 2023 | 937.14 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

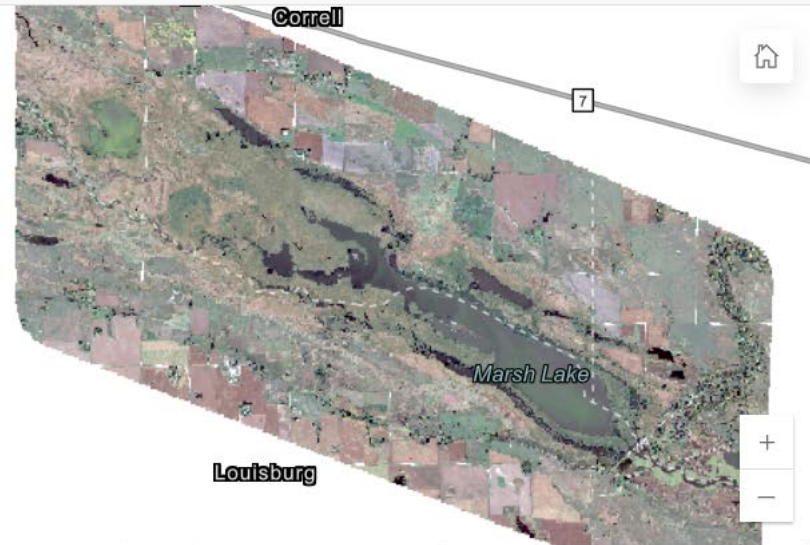
July 2, 2023

August 12, 2023

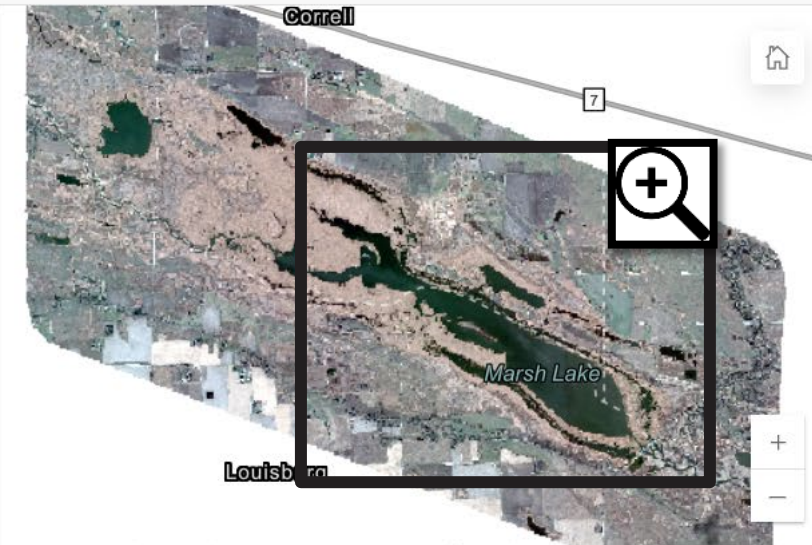
September 1, 2023 | 937.26 feet NGVD29



October 2, 2023 | 937.07 feet NGVD29



November 12, 2023 | 938.36 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri



May 5, 2023 | 941.89 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

June 8, 2023 | 938.99 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

July 2, 2023 | 937.89 feet NGVD29 and August 12, 2023 | 937.14 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

July 2, 2023

August 12, 2023

September 1, 2023 | 937.26 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

October 2, 2023 | 937.07 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri

November 12, 2023 | 938.36 feet NGVD29



USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri



May 5, 2023 | 941.89 feet NGVD29



USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

June 8, 2023 | 938.99 feet NGVD29



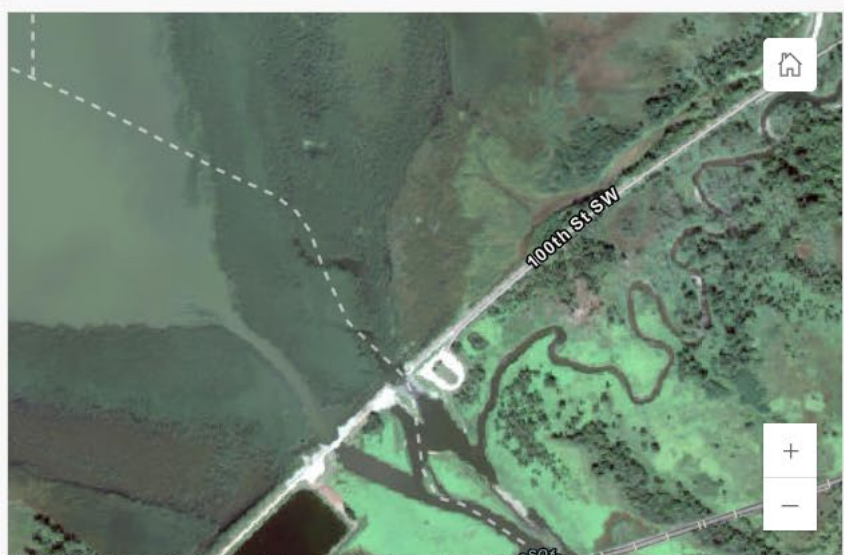
USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

July 2, 2023 | 937.89 feet NGVD29 and August 12, 2023 | 937.14 feet NGVD29



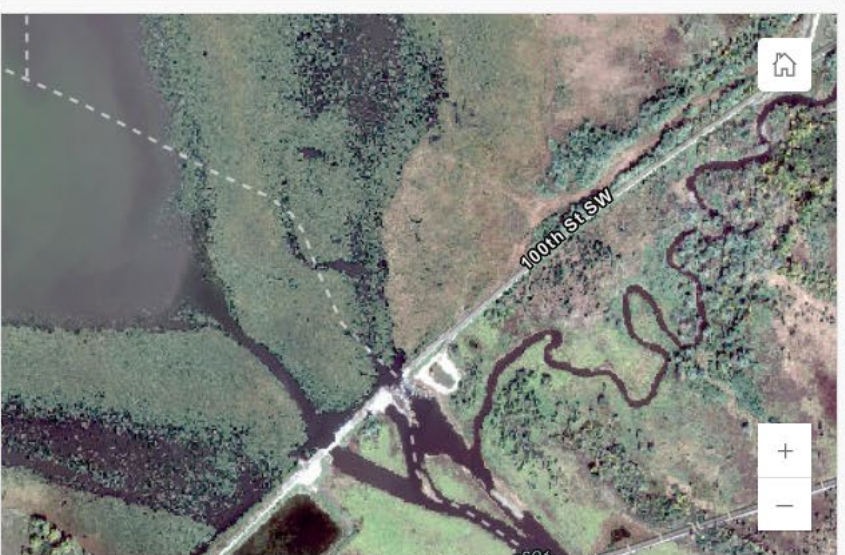
USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

September 1, 2023 | 937.26 feet NGVD29



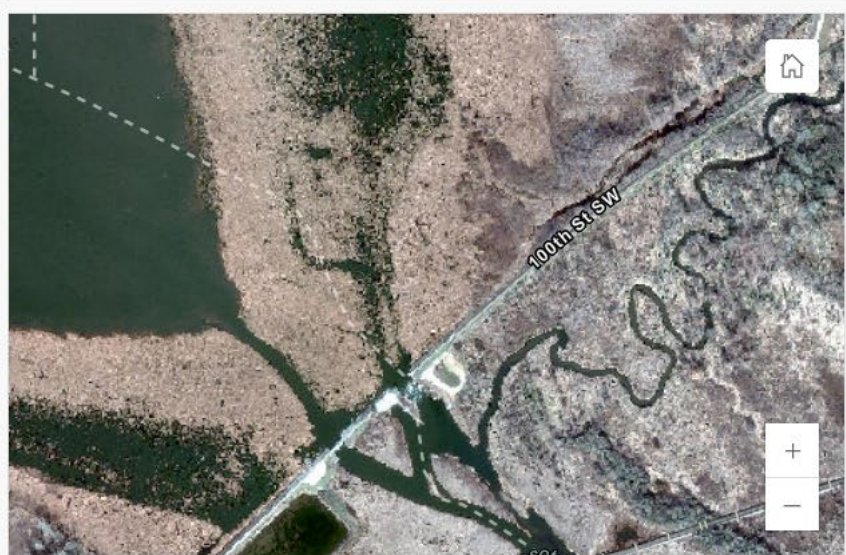
USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

October 2, 2023 | 937.07 feet NGVD29



USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

November 12, 2023 | 938.36 feet NGVD29



USACE St. Paul District | Esri Community Maps Contributors, Esri, TomT... Powered by Esri

MARSH LAKE IMAGERY COMPARISON

2015-2023

PRE-PROJECT TO POST CONSTRUCTION

SCREENSHOTS TAKEN FROM AN INTERACTIVE GIS DASHBOARD FOUND IN
THE MARSH LAKE STORYMAP



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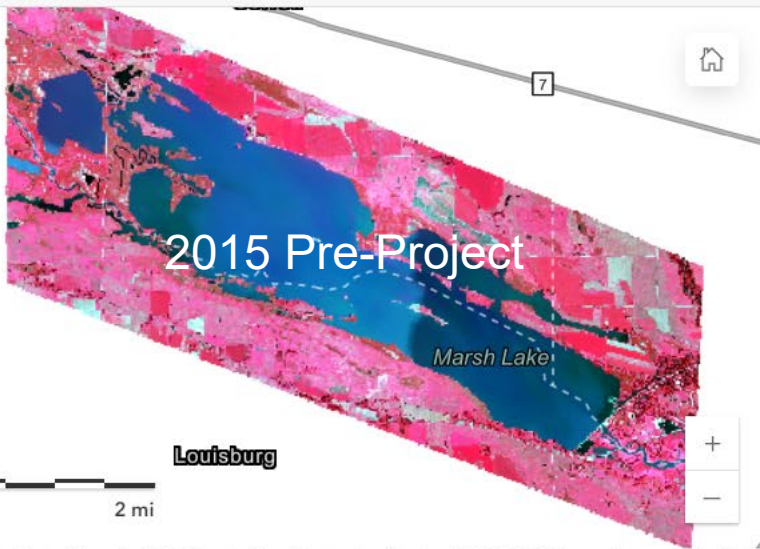


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August 14, 2015 (FSA Aerial) | 938.39 feet NGVD29

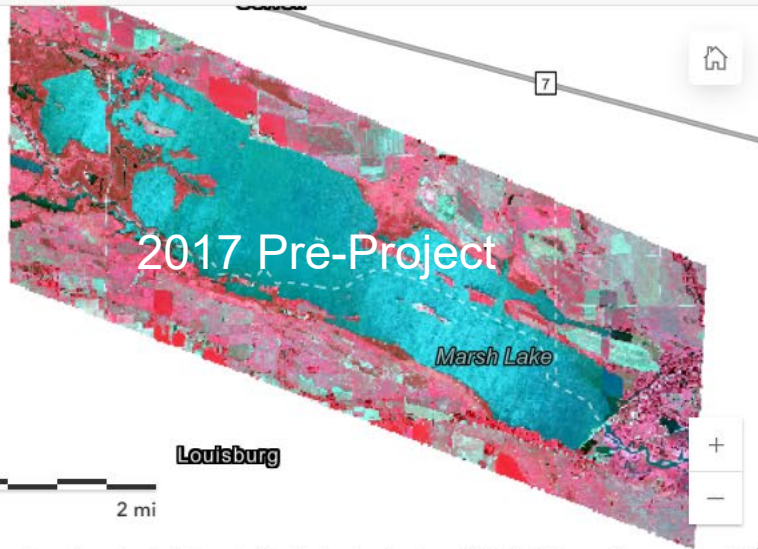


2015 Pre-Project

Marsh Lake

Louisburg

August 28, 2017 (FSA Aerial) | 940.10 feet NGVD29

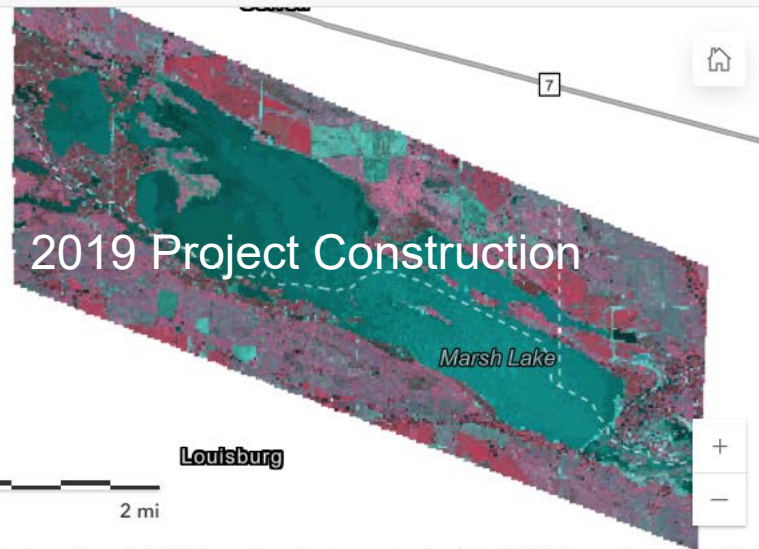


2017 Pre-Project

Marsh Lake

Louisburg

August 8, 2019 (FSA Aerial) | 937.37 feet NGVD29

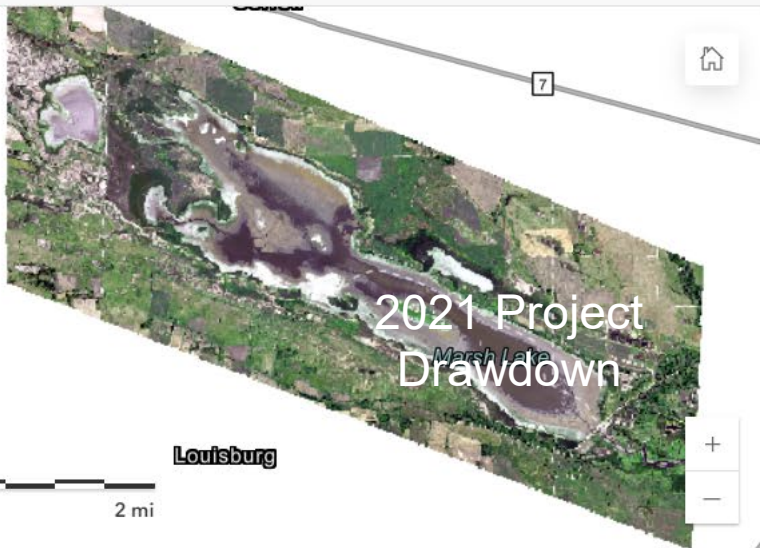


2019 Project Construction

Marsh Lake

Louisburg

June 19, 2021 (FSA Aerial) | ~935.40 ft (NGVD29)

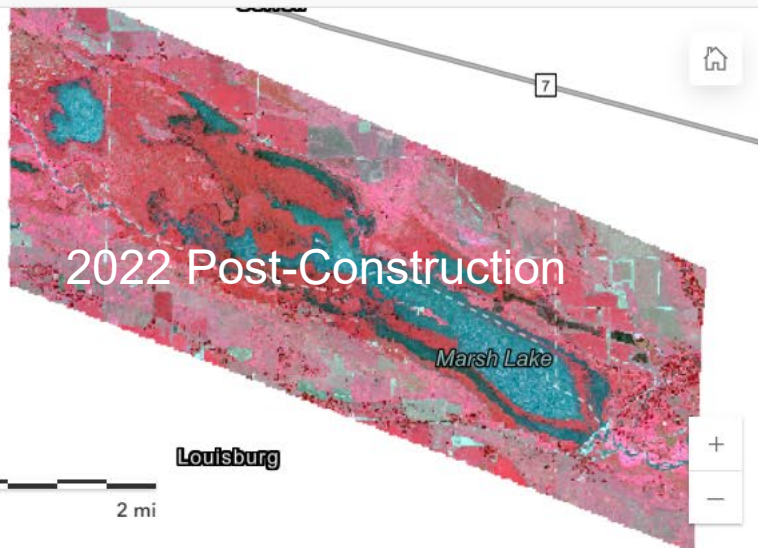


2021 Project Drawdown

Marsh Lake

Louisburg

August 30, 2022 (Pleiades Satellite) | 937.91 feet NGVD29

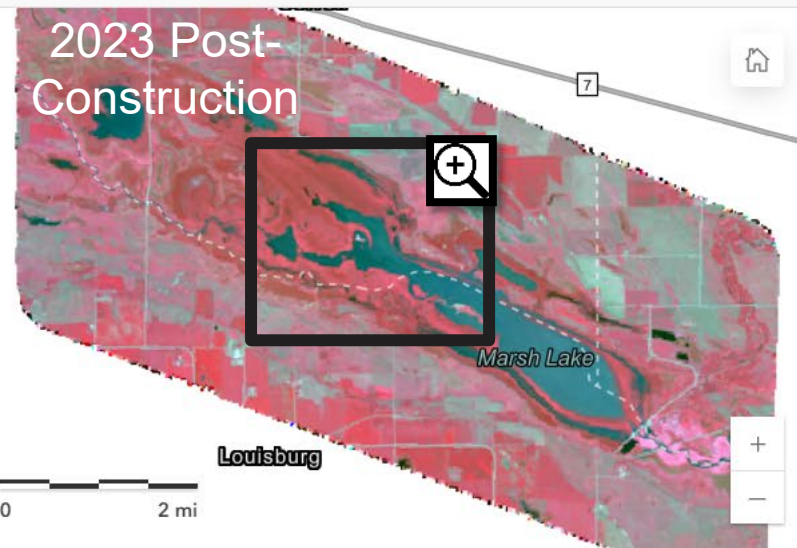


2022 Post-Construction

Marsh Lake

Louisburg

August 12, 2023 (Pleiades Satellite) | 937.14 feet NGVD29



2023 Post-Construction

Marsh Lake

Louisburg



August 14, 2015 (FSA Aerial) | 938.39 feet NGVD29

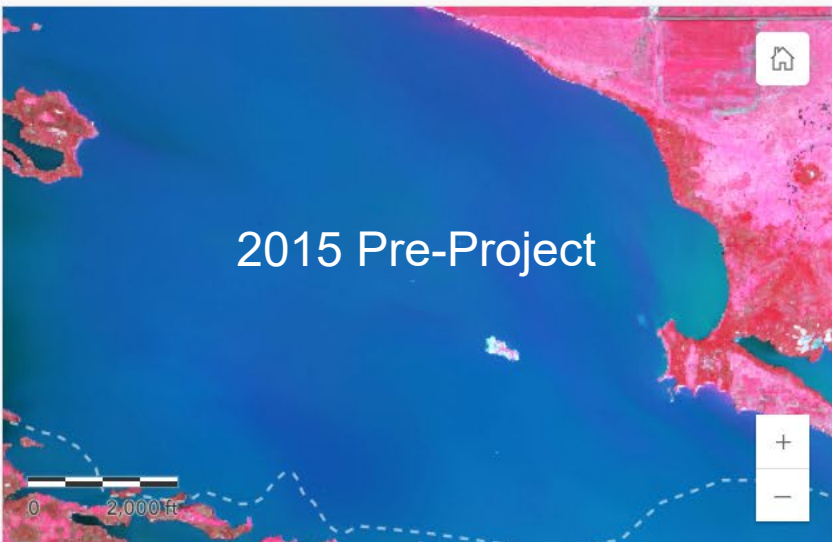
August 28, 2017 (FSA Aerial) | 940.10 feet NGVD29

August 8, 2019 (FSA Aerial) | 937.37 feet NGVD29

2015 Pre-Project

2017 Pre-Project

2019 Project Construction



Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, ... Powered by Esri

Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, ... Powered by Esri

Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, ... Powered by Esri

June 19, 2021 (FSA Aerial) | ~935.40 ft (NGVD29)

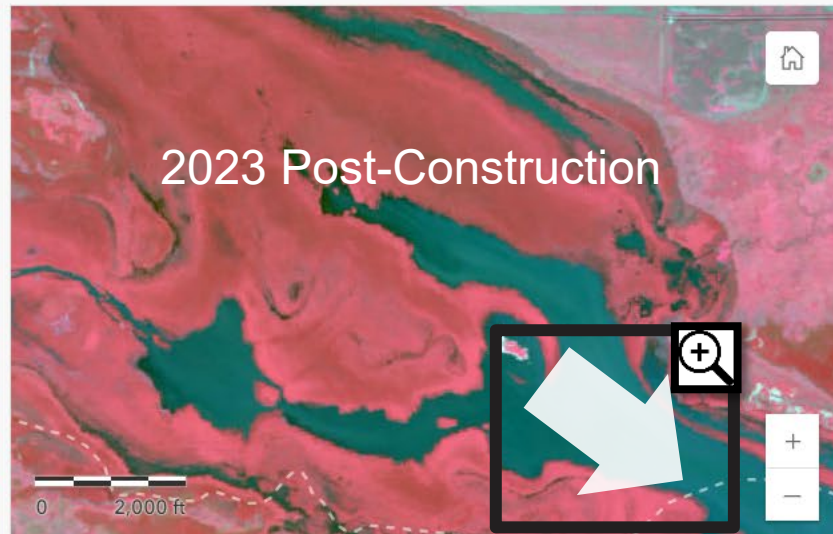
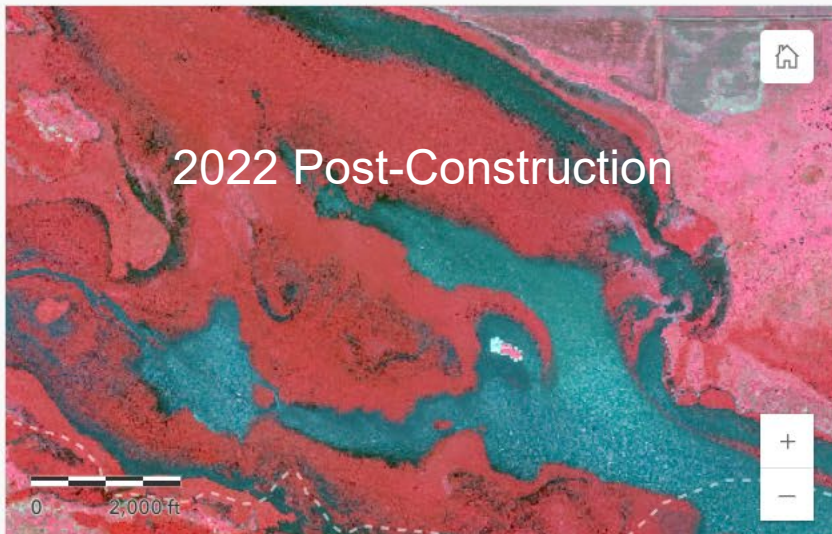
August 30, 2022 (Pleiades Satellite) | 937.91 feet NGVD29

August 12, 2023 (Pleiades Satellite) | 937.14 feet NGVD29

2021 Project Drawdown

2022 Post-Construction

2023 Post-Construction



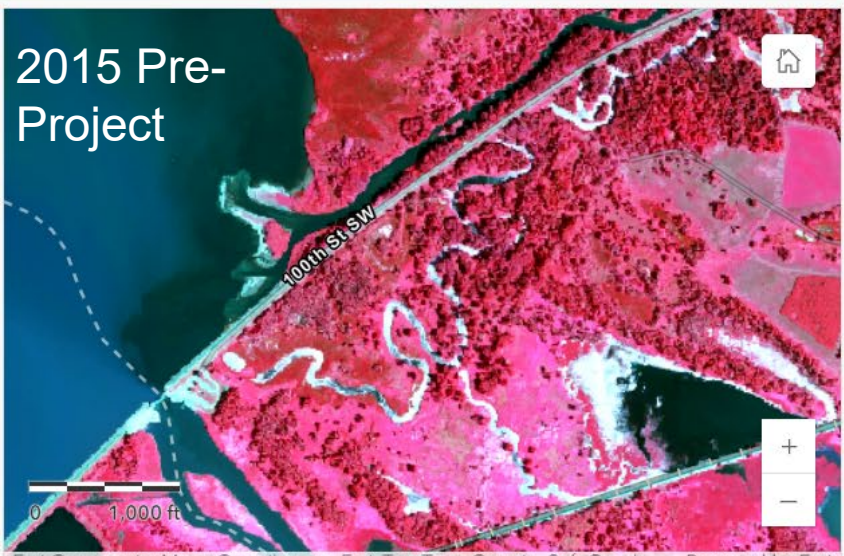
Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, ... Powered by Esri

Esri, TomTom, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, ... Powered by Esri

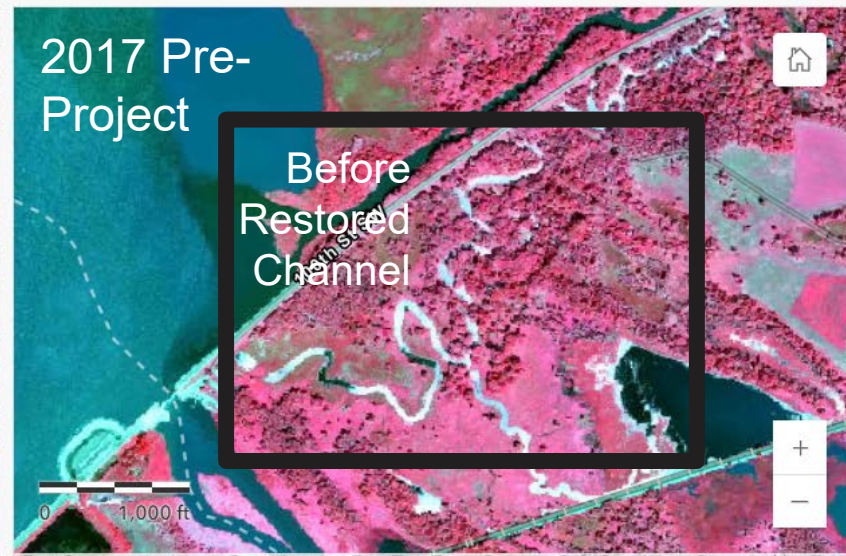
USACE St. Paul District | Esri, TomTom, Garmin, SafeGraph, GeoTechno... Powered by Esri



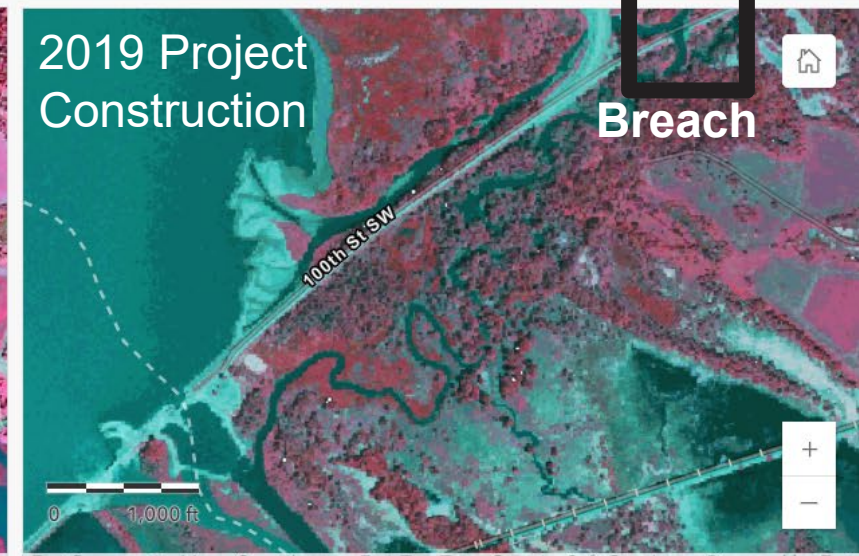
August 14, 2015 (FSA Aerial) | 938.39 feet NGVD29



August 28, 2017 (FSA Aerial) | 940.10 feet NGVD29



August 8, 2019 (FSA Aerial) | 937.37 feet NGVD29



June 19, 2021 (FSA Aerial) | ~935.40 ft (NGVD29)



August 30, 2022 (Pleiades Satellite) | 937.91 feet NGVD29



August 12, 2023 (Pleiades Satellite) | 937.14 feet NGVD29



GIS IMAGERY CLASSIFICATION ANALYSIS

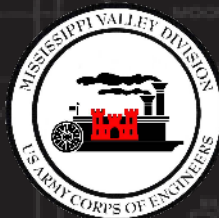
AUGUST 2015, 2022, AND 2023

PRE-PROJECT TO POST-CONSTRUCTION

OPEN WATER & EMERGENT AQUATIC VEGETATION



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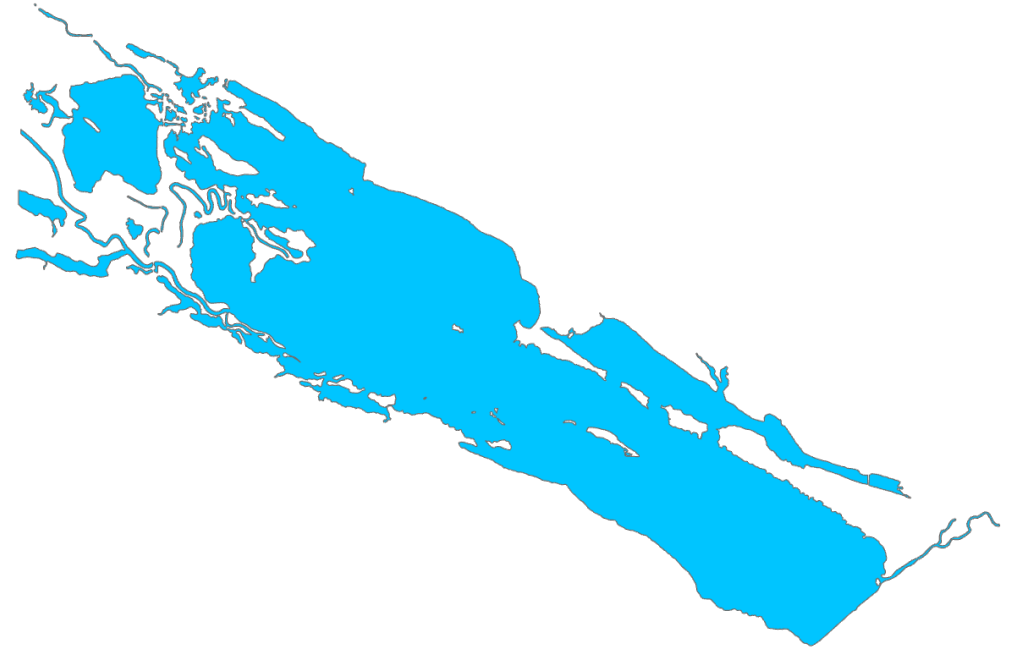


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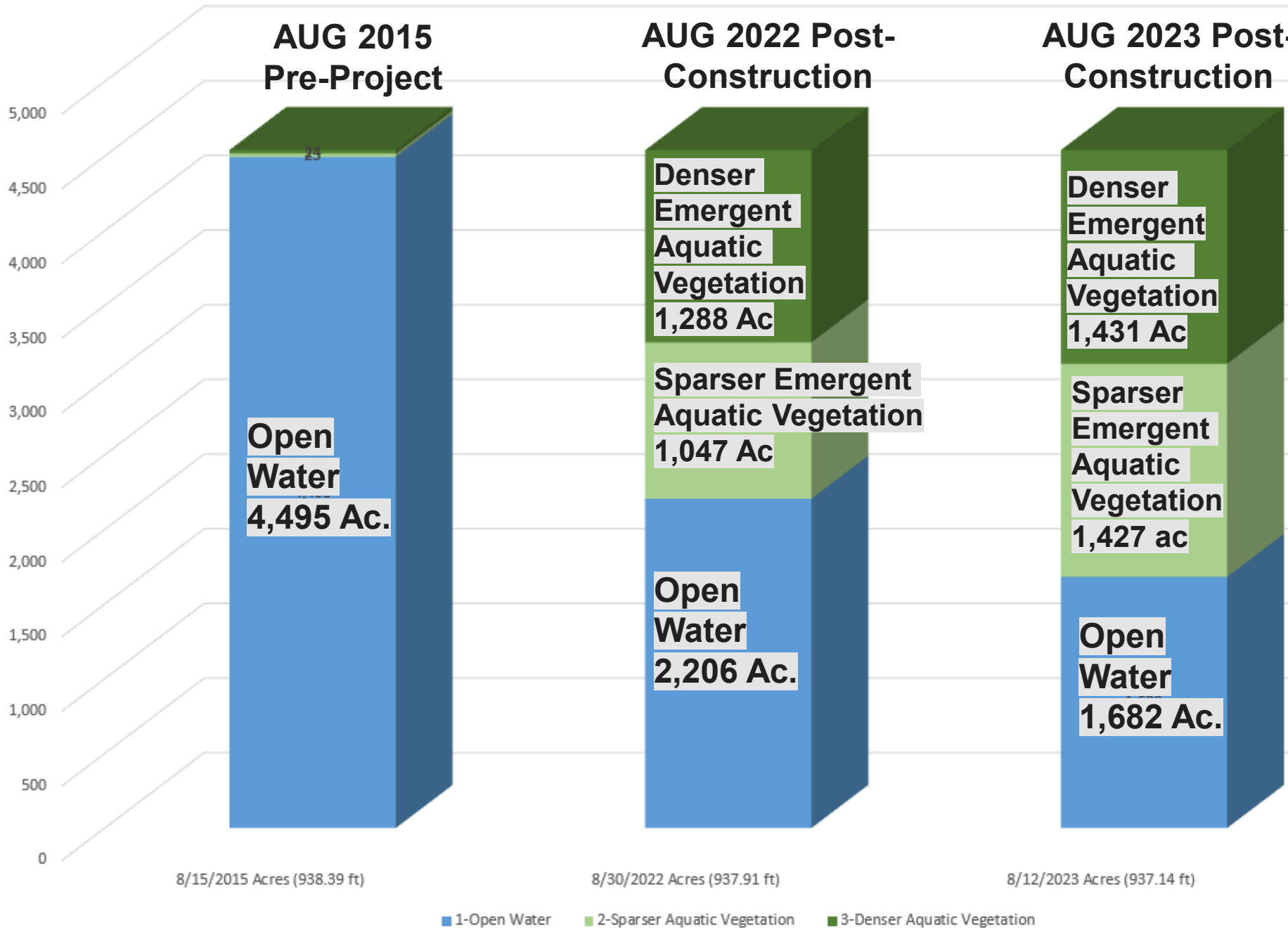


GIS IMAGERY CLASSIFICATION

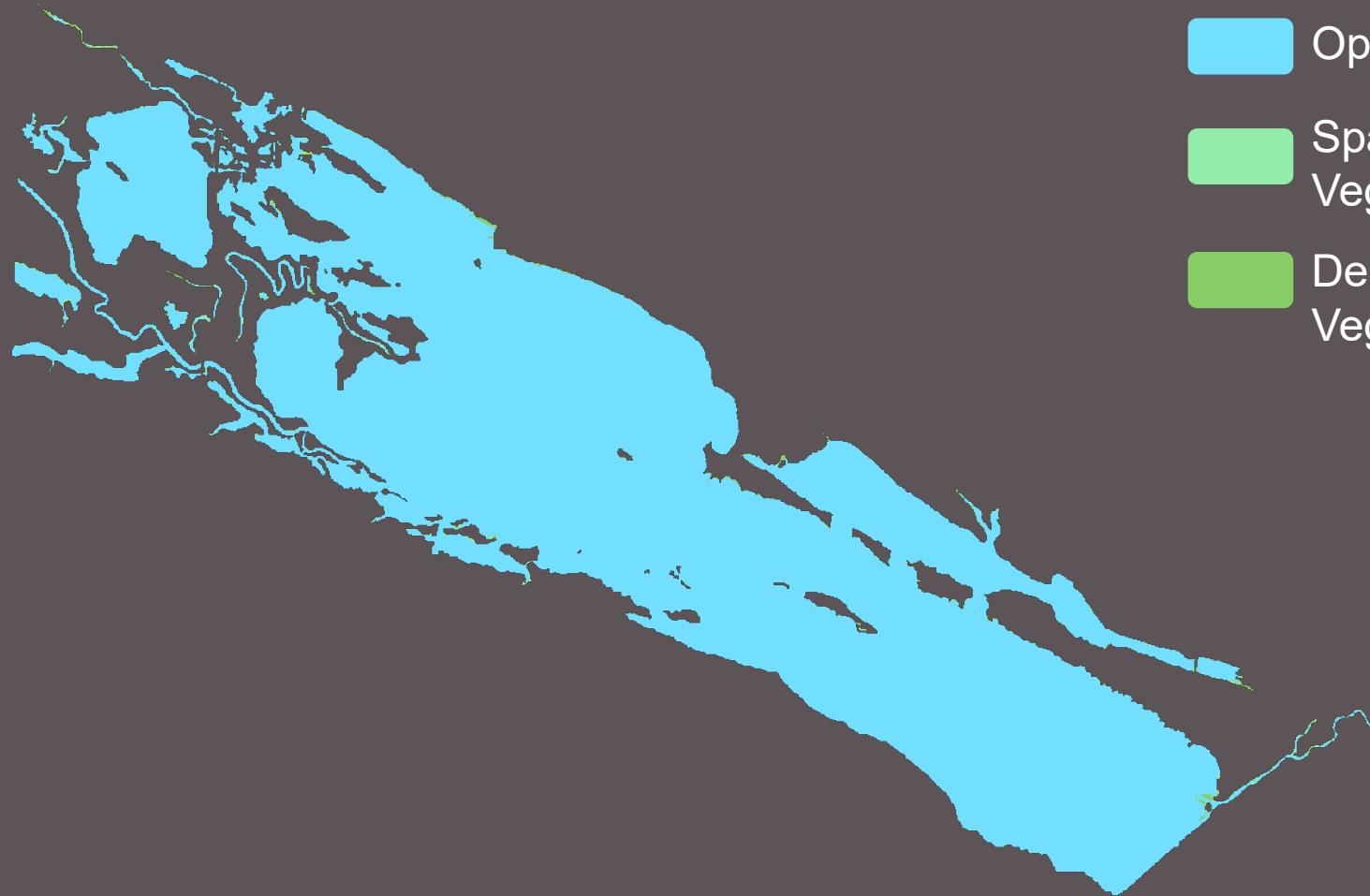
- Clip 2015, 2021, & 2022 imagery to Fall 2011 Marsh Lake Open Water boundary (4,541 acres).
- Use ArcGIS software to process satellite imagery to determine acres of:
 - open water
 - sparser emergent aquatic vegetation
 - denser emergent aquatic vegetation.
- Run Iso Cluster Unsupervised and/or Supervised Classification tool.
- Calculate results in acres.


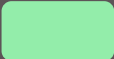



**Boundary of Open Water at
Marsh Lake from 2011 Leaf-Off
Aerial Photography. Digitized in
GIS as part of Level 1 2011
Vegetation Inventory.**

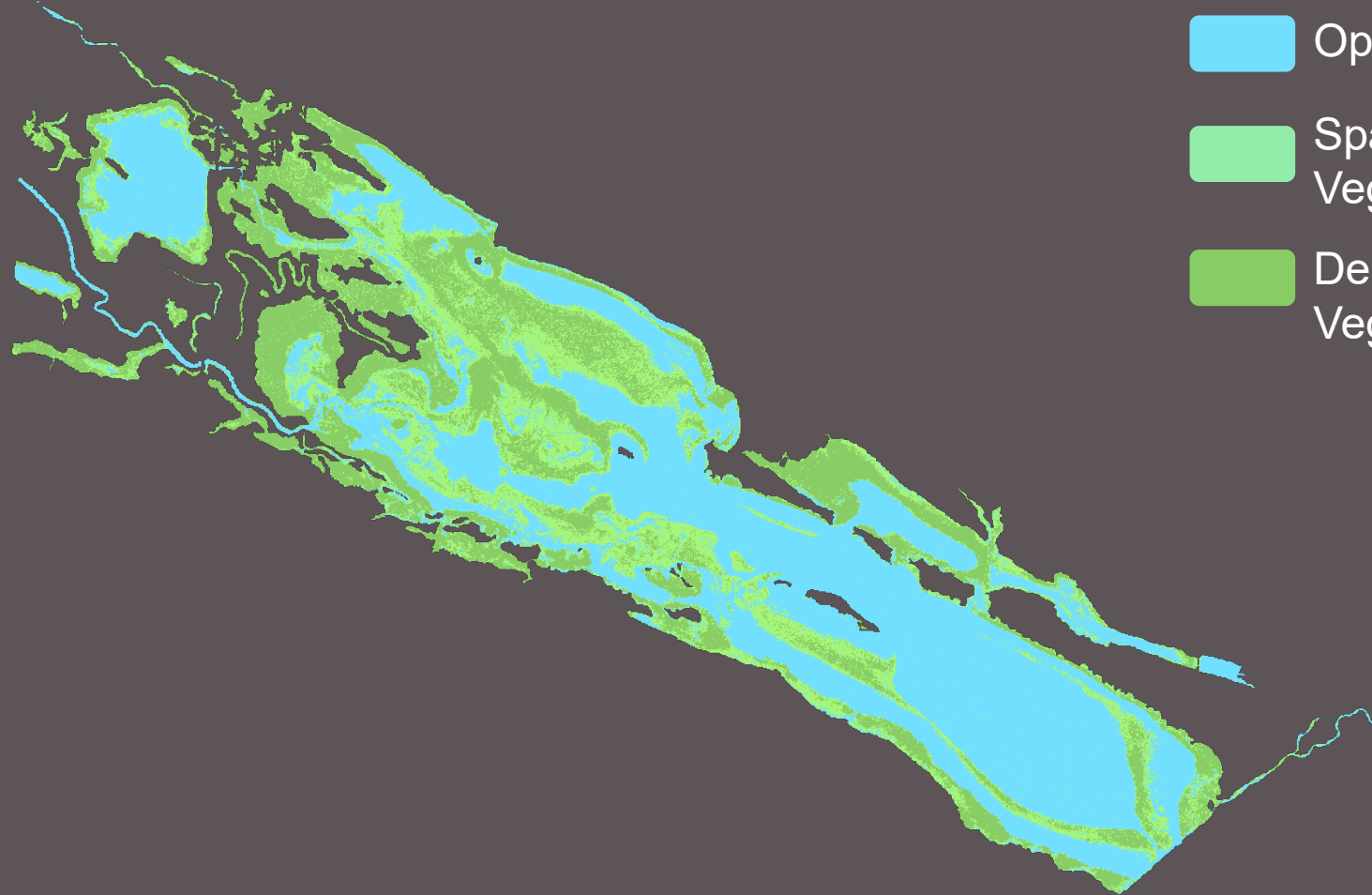


BEFORE PROJECT | 8/14/2015 | 938.39 FT²¹





-  Open Water-4,495 acres
-  Sparser Aquatic Vegetation – 23 acres
-  Denser Aquatic Vegetation – 24 acres

POST-CONSTRUCTION 2022 | 8/30/2022 | 937.91 FT²²

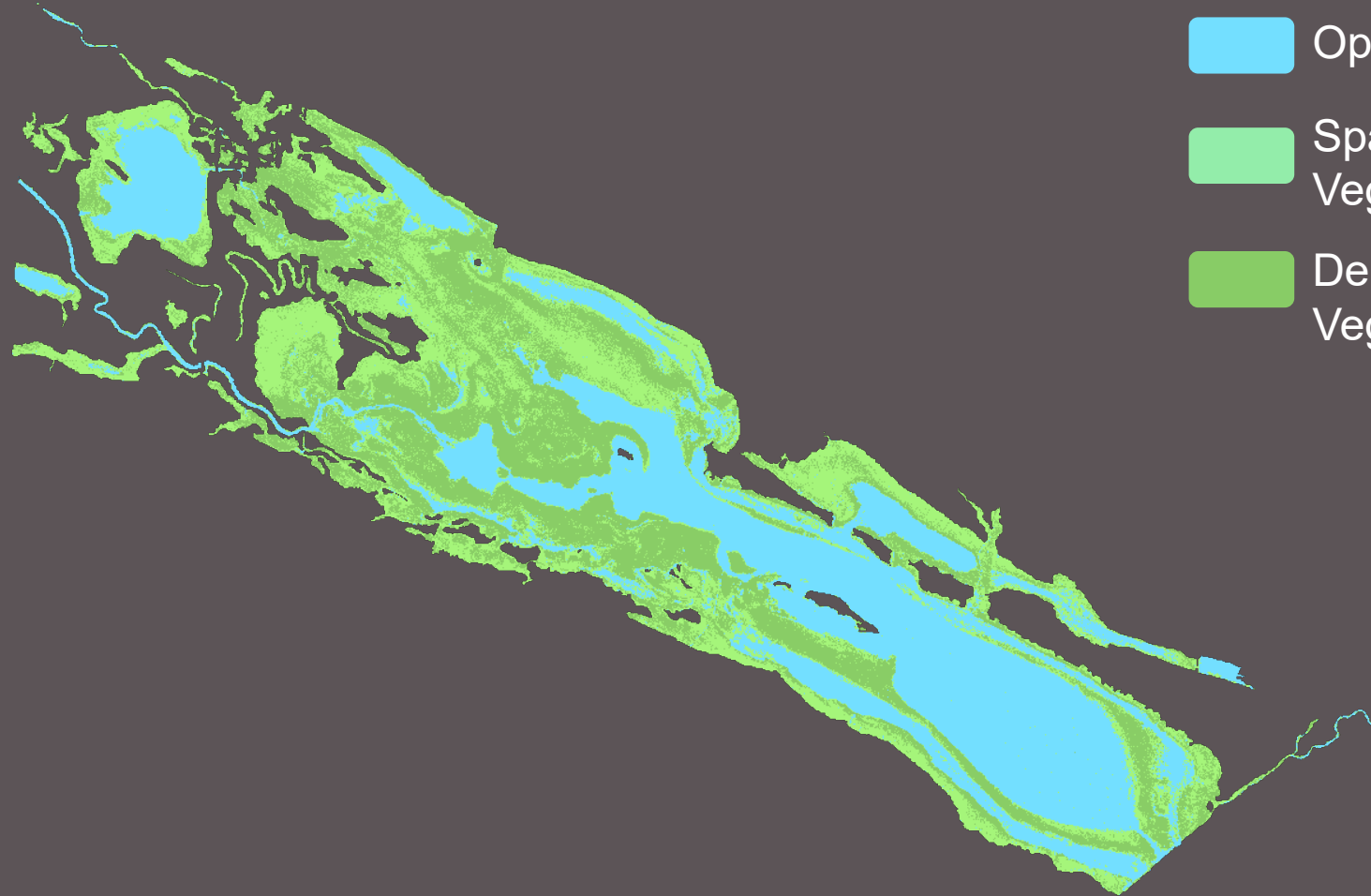


 Open Water-2,206 acres


 Sparser Aquatic
Vegetation – 1,047 acres


 Denser Aquatic
Vegetation – 1,288 acres

POST-CONSTRUCTION 2023 | 8/12/2023 | 937.14 FT²³



 Open Water-1,682 acres

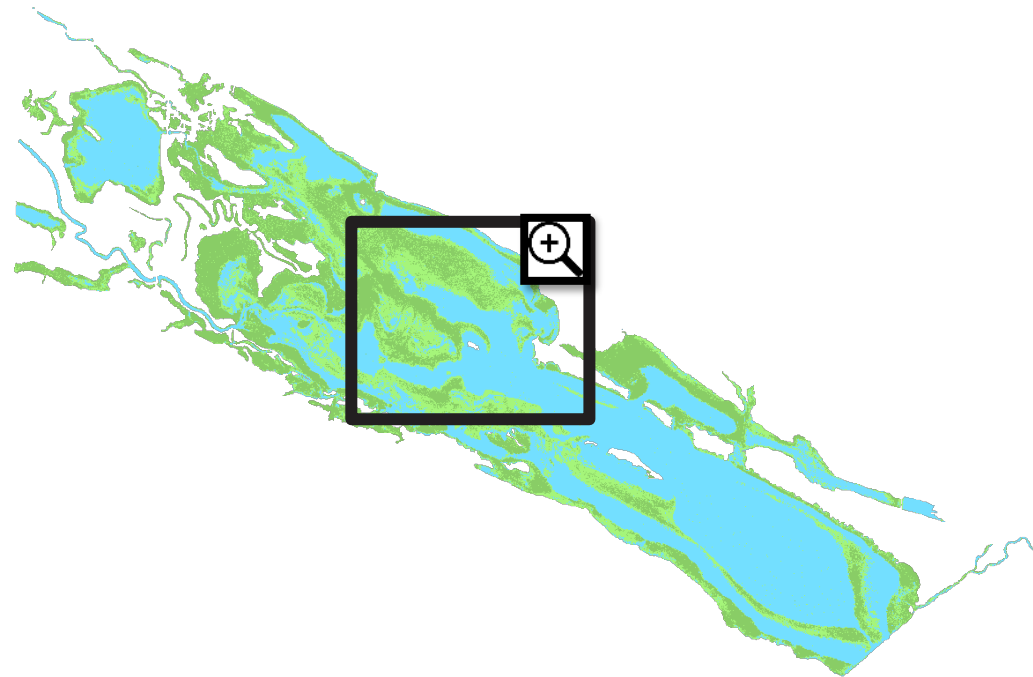
 Sparser Aquatic
Vegetation – 1,427 acres

 Denser Aquatic
Vegetation – 1,461 acres



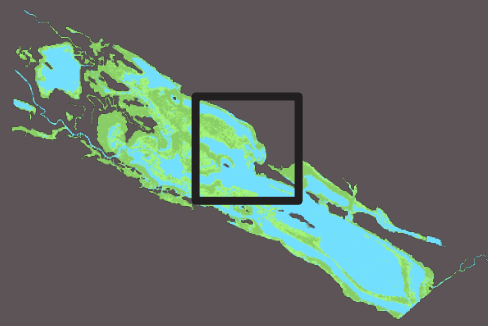
PRELIMINARY IMAGE CLASSIFICATION RESULTS

- ❑ Large increase in emergent aquatic vegetation between 2015 and 2022
- ❑ Slight increase in emergent aquatic vegetation between 2022 and 2023.
- ❑ Water Elevation Averages between May1-Oct1.
 - ❑ 2022 – 939.11 feet
 - ❑ 2023 – 938.15 feet (-0.96 ft)
- ❑ The following slides show image classification results versus satellite imagery.
- ❑ The two images are from end of the growing season and zoomed in to map location.
 - 10/8/2022 | 937.31 Feet
 - 10/2/2023 | 937.07 Feet

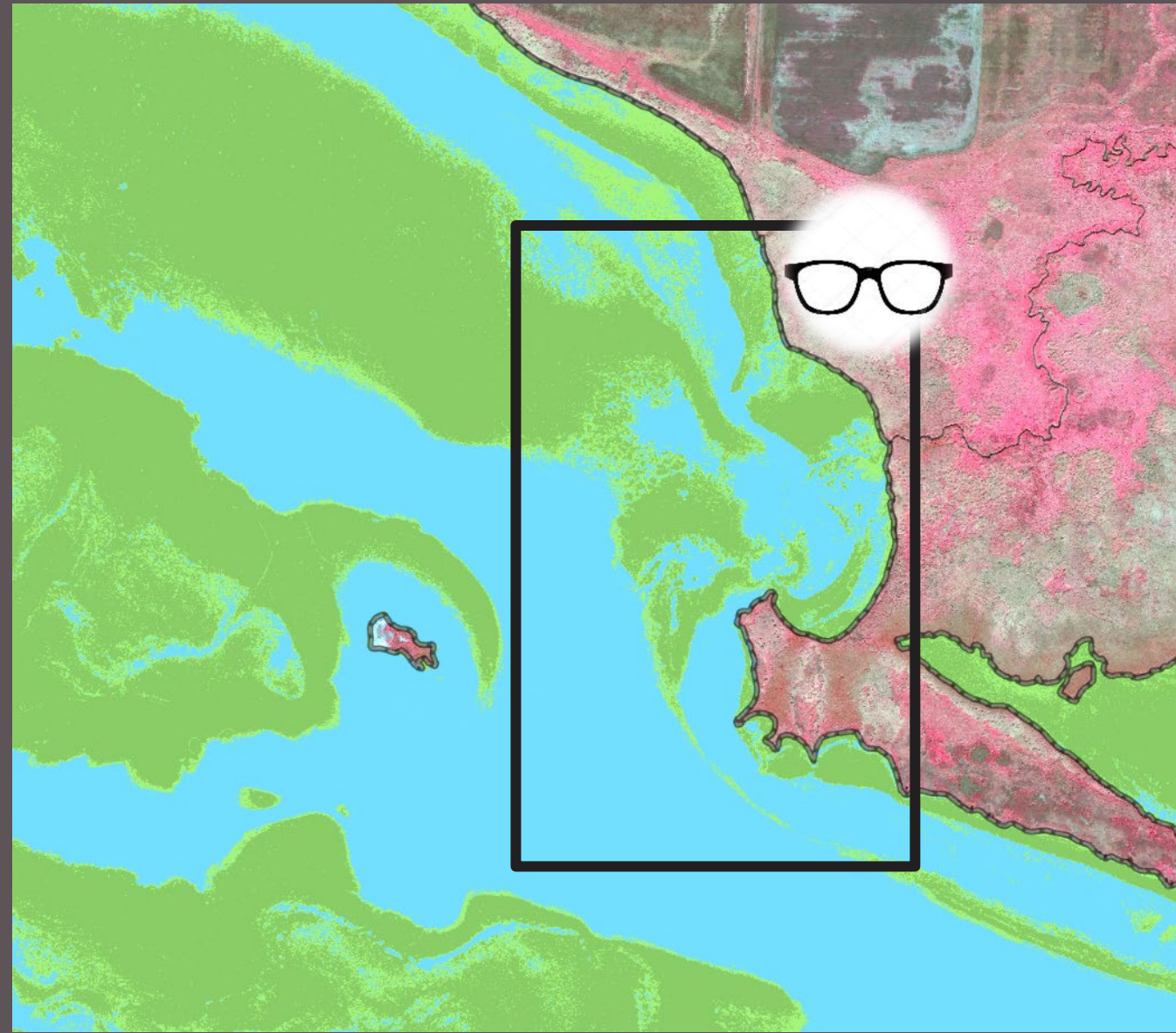


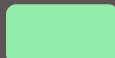
Location in Marsh Lake for following slides

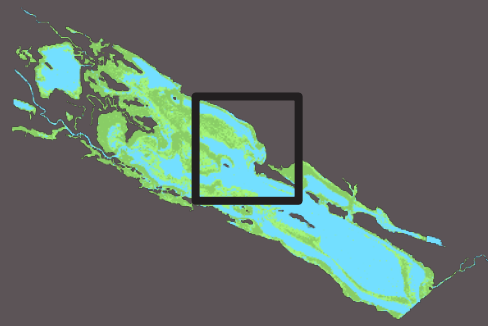
CLASSIFYING 2022 IMAGERY | 10/8/2022 – 937.31 FT



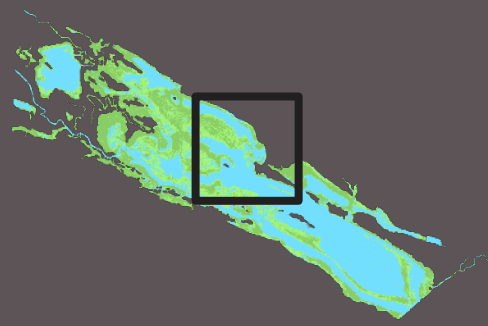
CLASSIFYING 2022 IMAGERY | 10/8/2022 – 937.31 FT



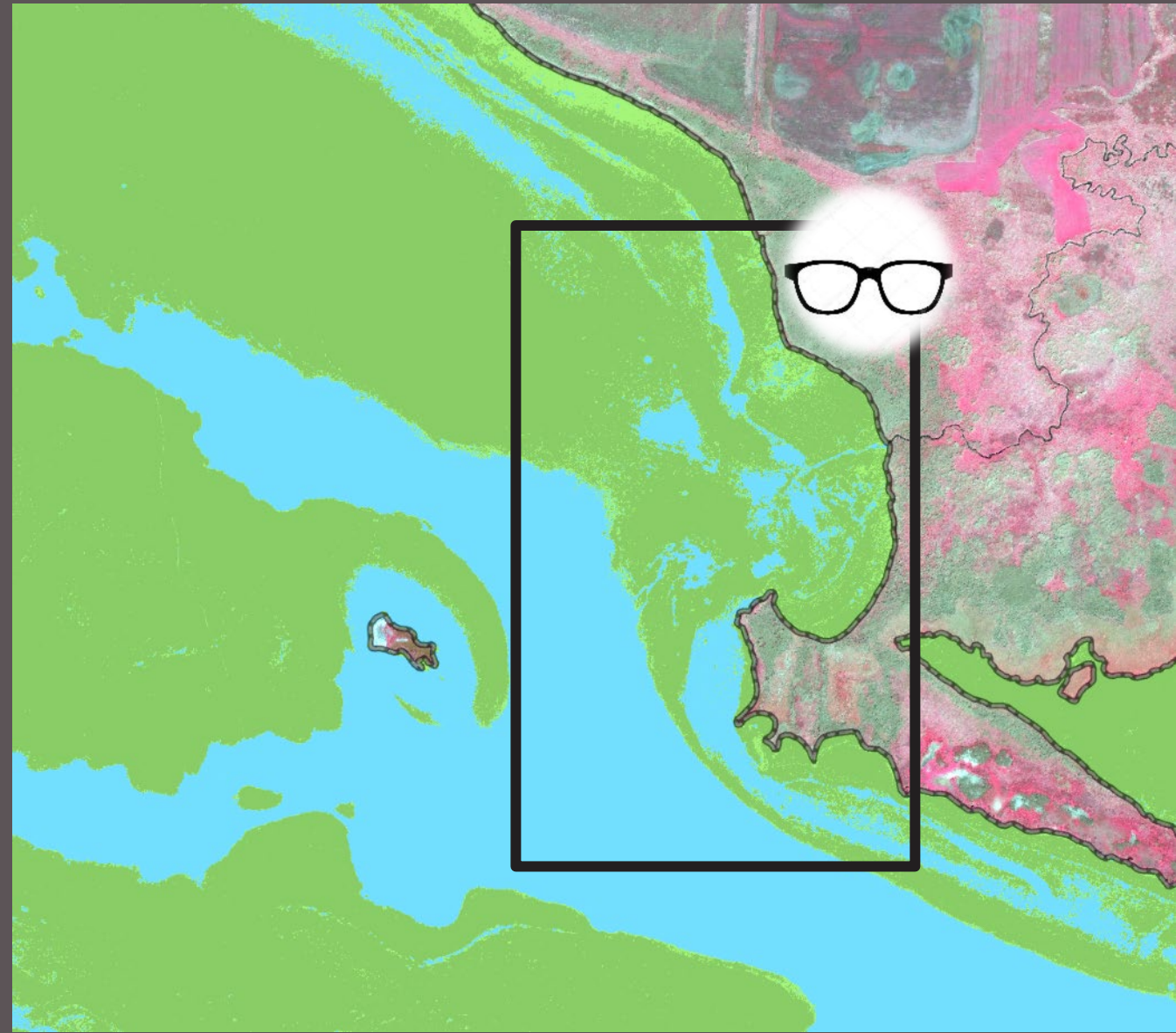
-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation




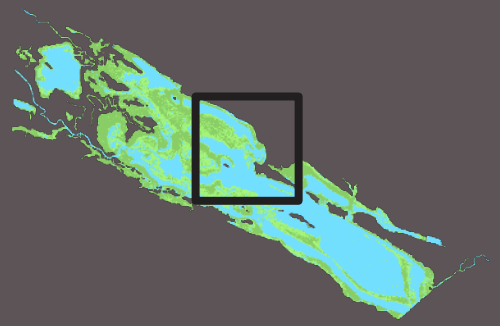
CLASSIFYING 2023 IMAGERY | 10/2/2023 – 937.07 FT



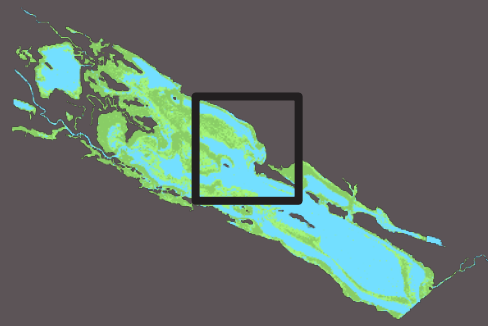
CLASSIFYING 2023 IMAGERY | 10/2/2023 – 937.07 FT



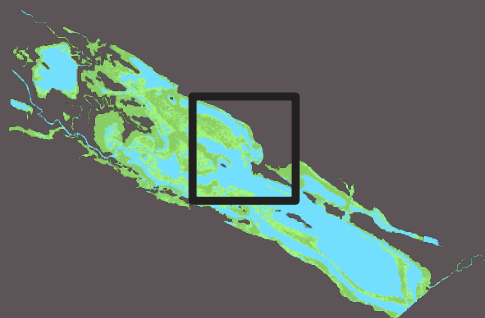
-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation



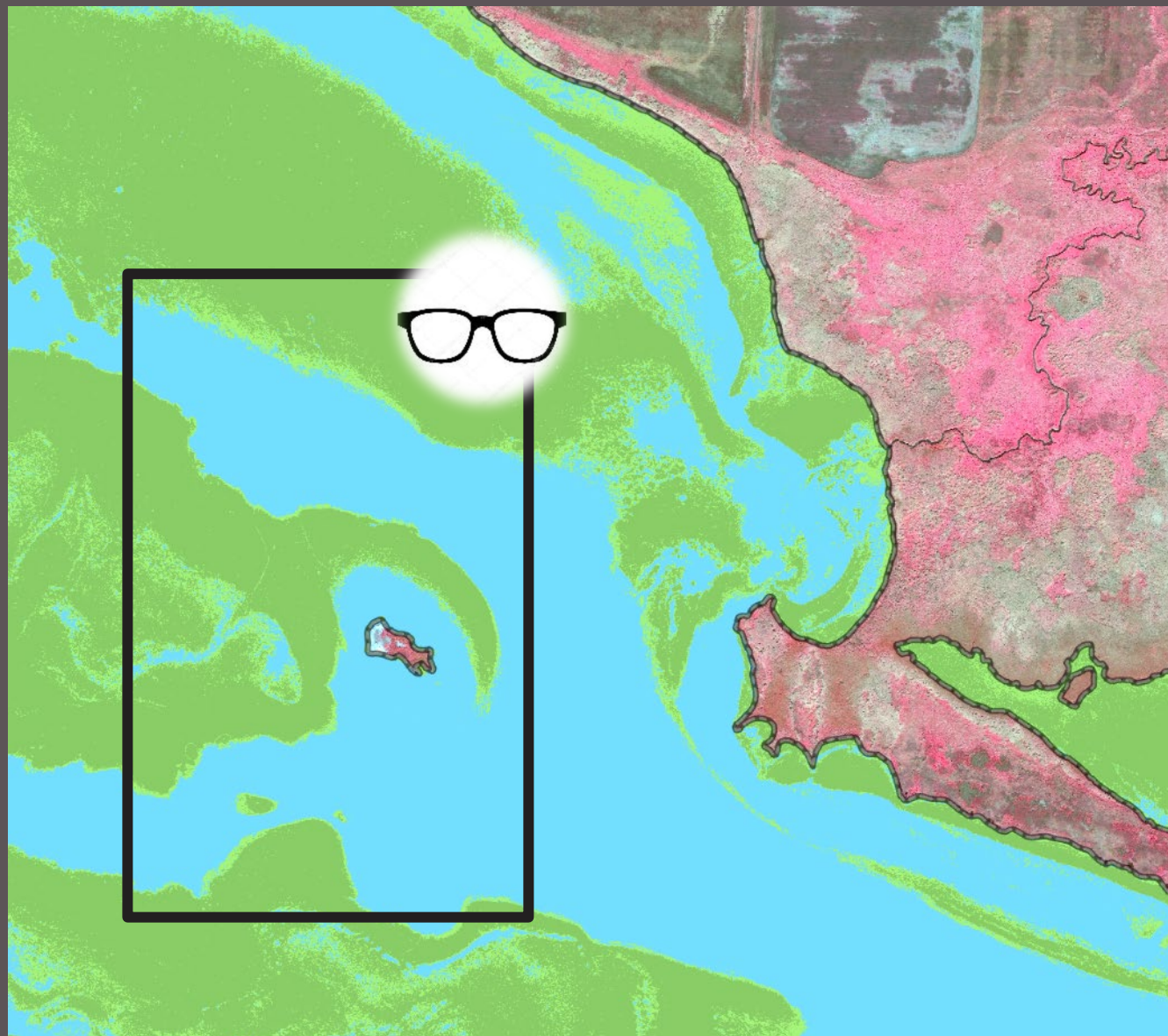
COMPARING 2022 IMAGERY | 10/8/2022 – 937.31 FT

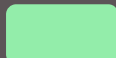


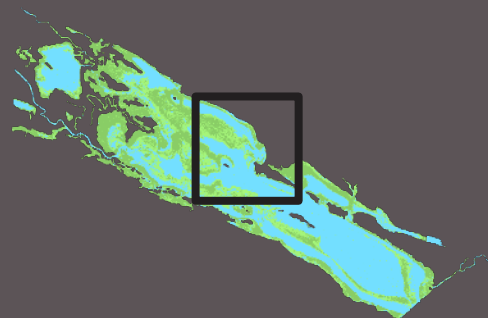
TO 2023 IMAGERY | 10/2/2023 – 937.07 FT



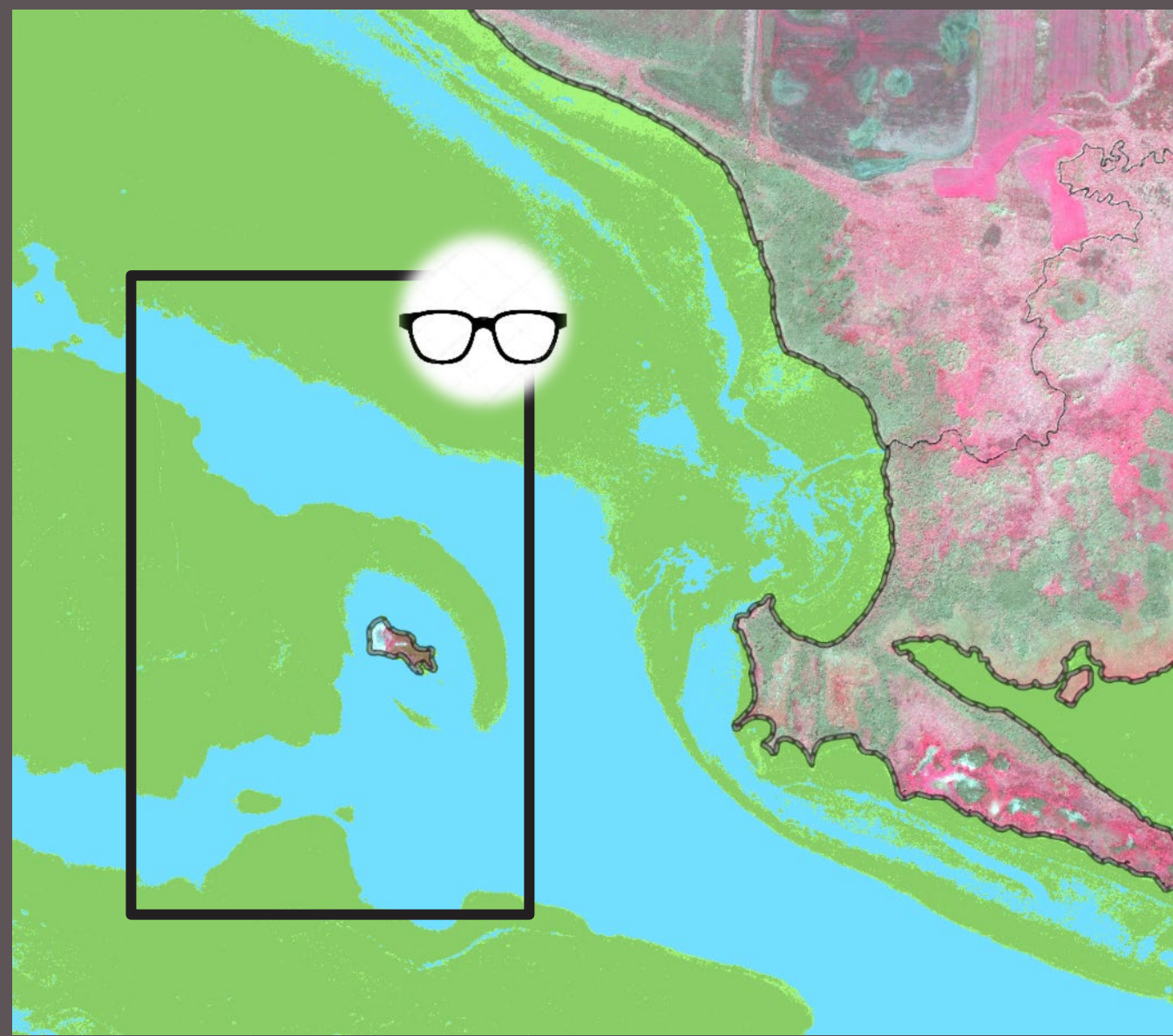
COMPARING 2022 CLASS | 10/8/2022 – 937.31 FT




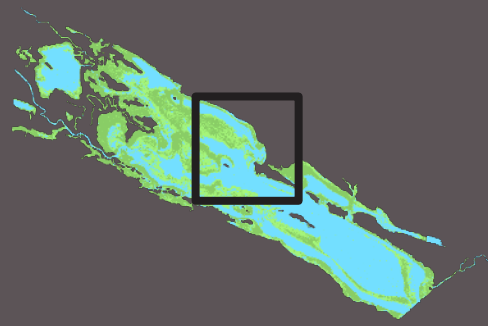
-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation



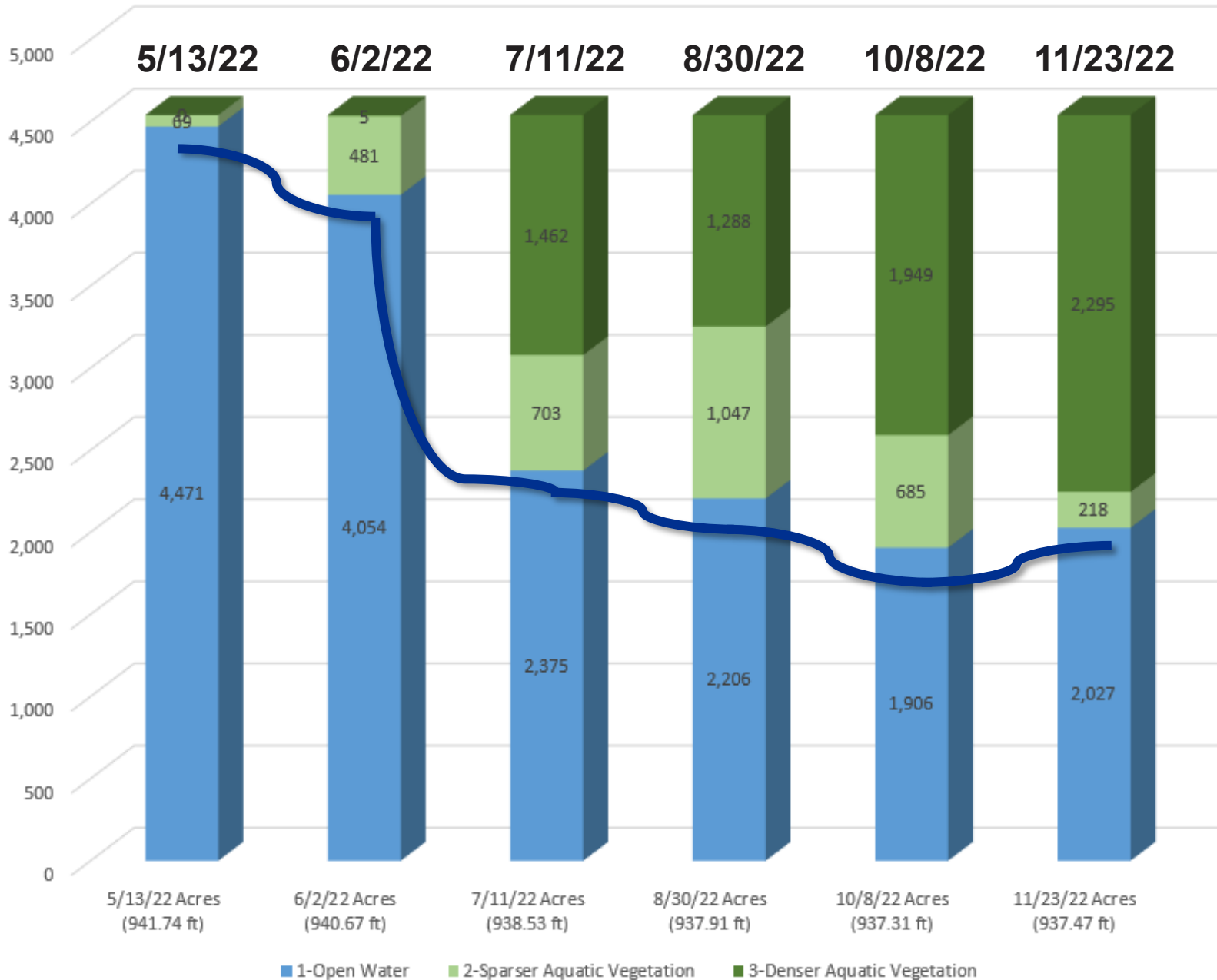
TO 2023 CLASS | 10/2/2023 – 937.07 FT



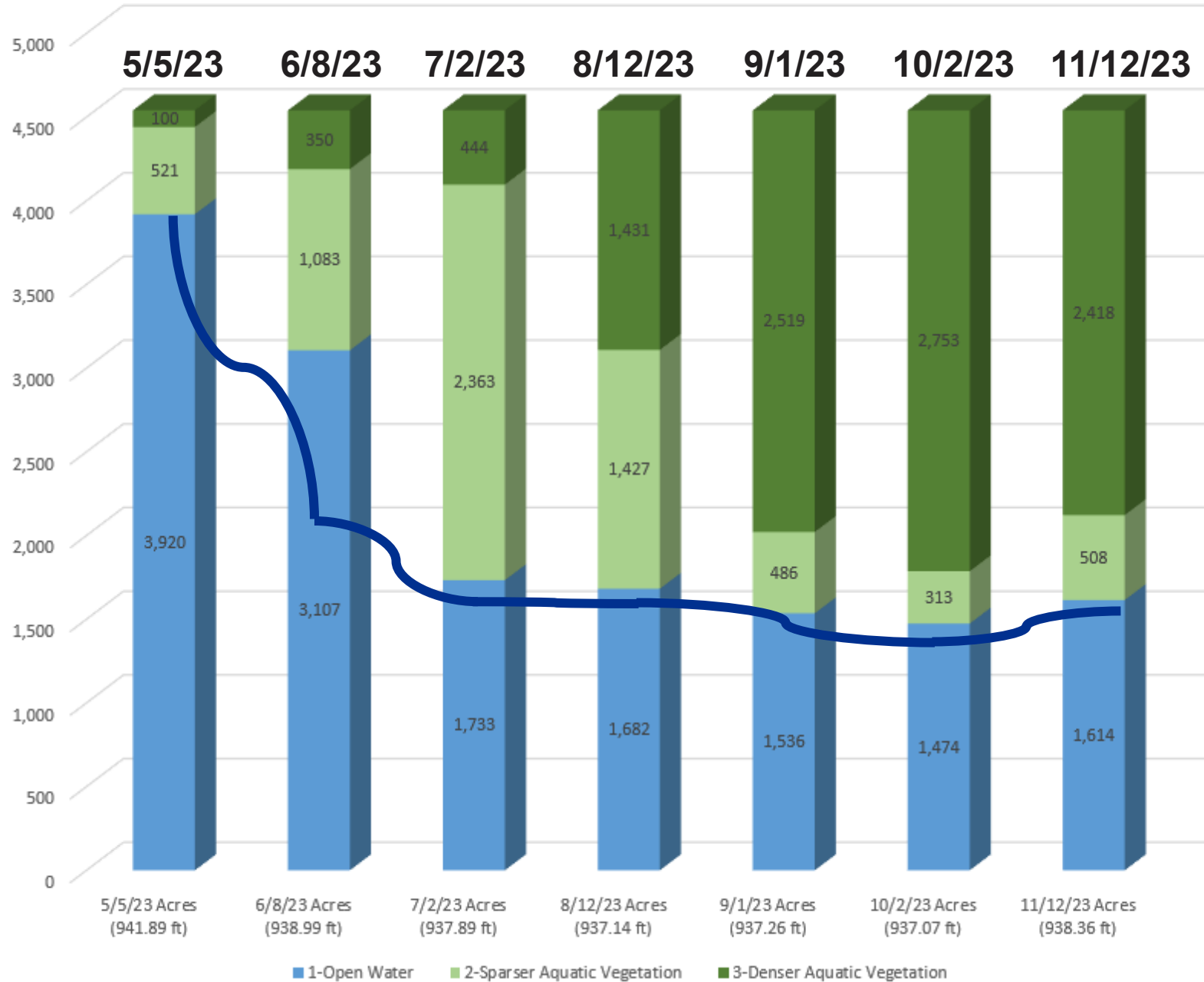
-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation



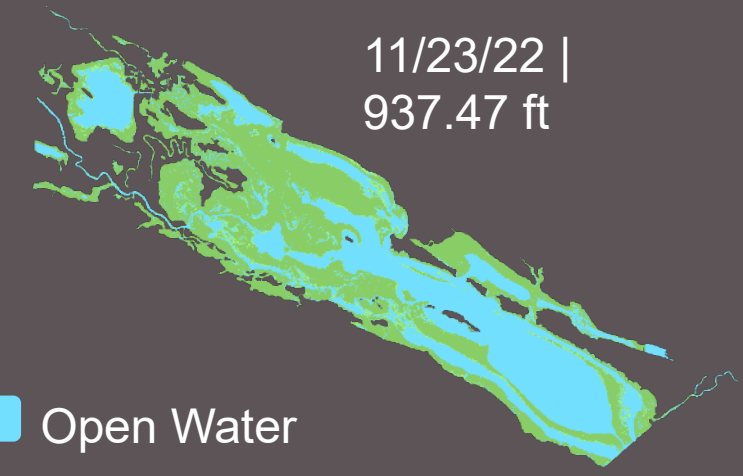
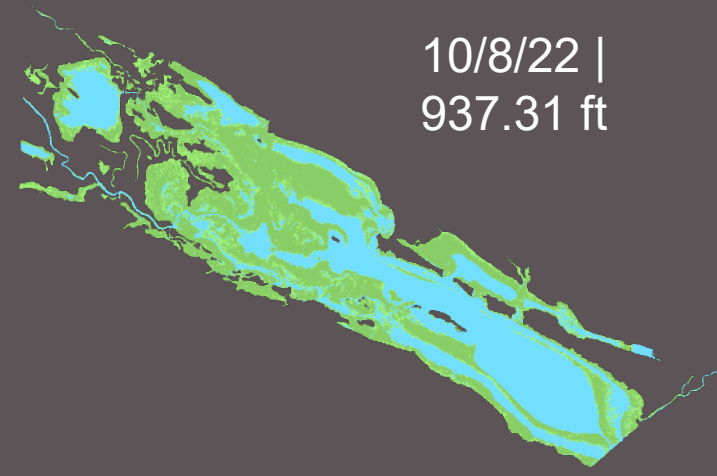
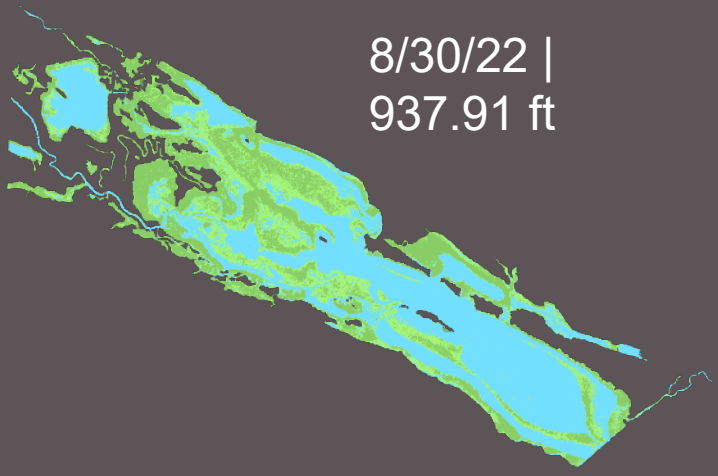
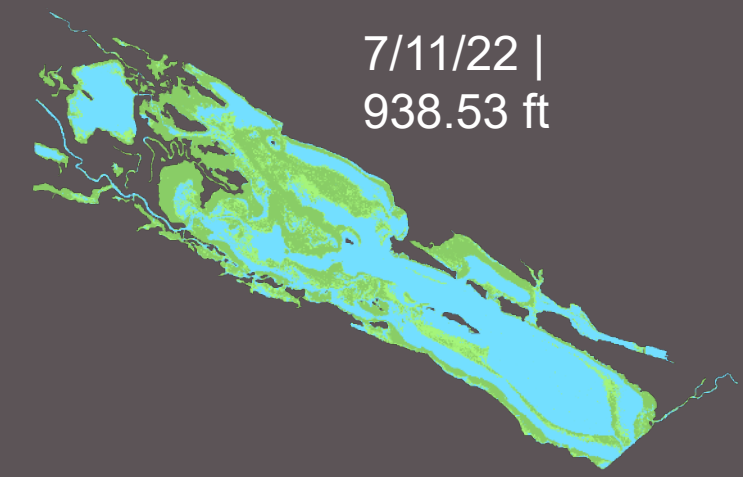
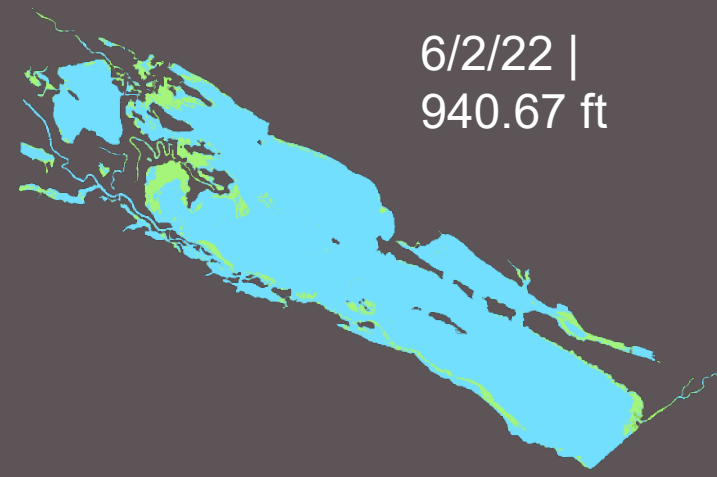
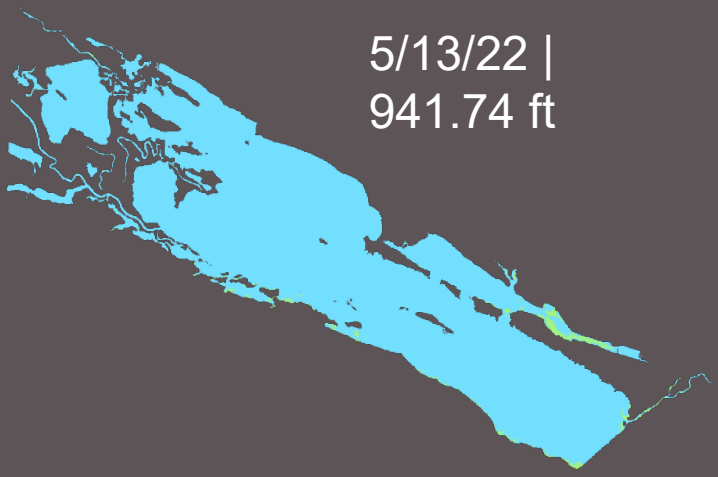
2022 Marsh Lake Imagery Classification of Open Water and Emergent Aquatic Vegetation in Acres






2023 Marsh Lake Imagery Classification of Open Water and Emergent Aquatic Vegetation in Acres

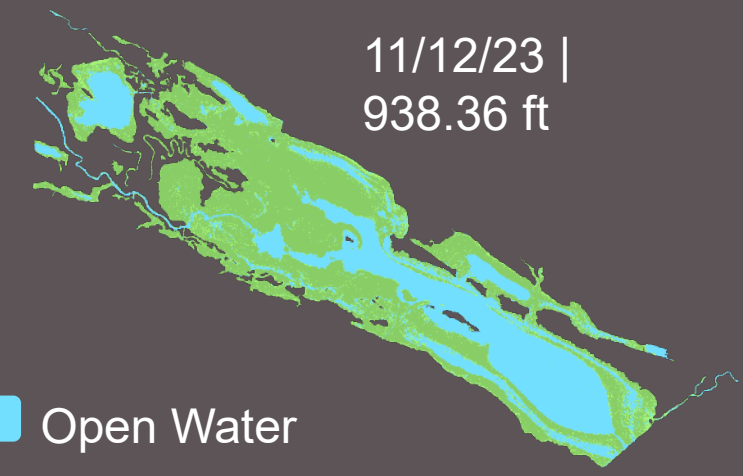
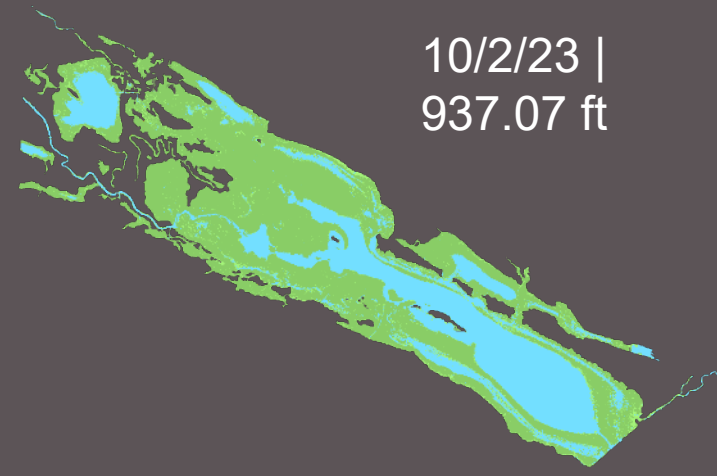
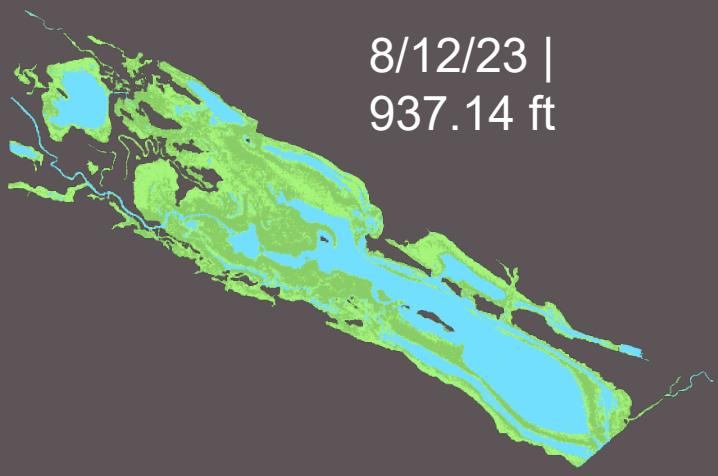
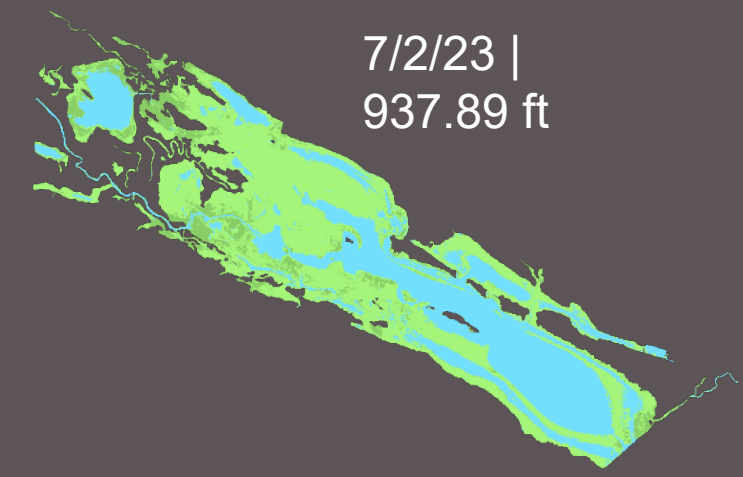
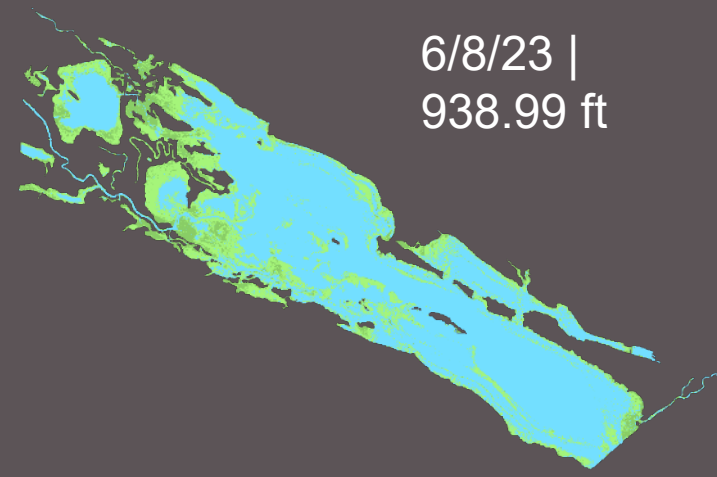
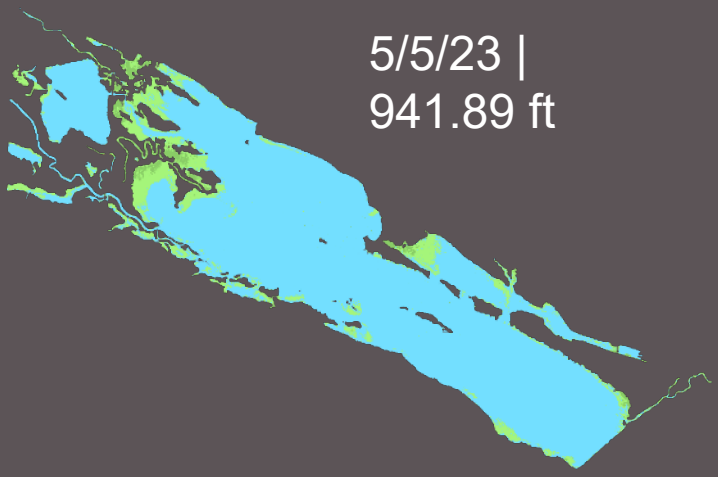





2022 Emergent Aquatic Vegetation Imagery Analysis Preliminary Results



-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation



2023 Emergent Aquatic Vegetation Imagery Analysis Preliminary Results






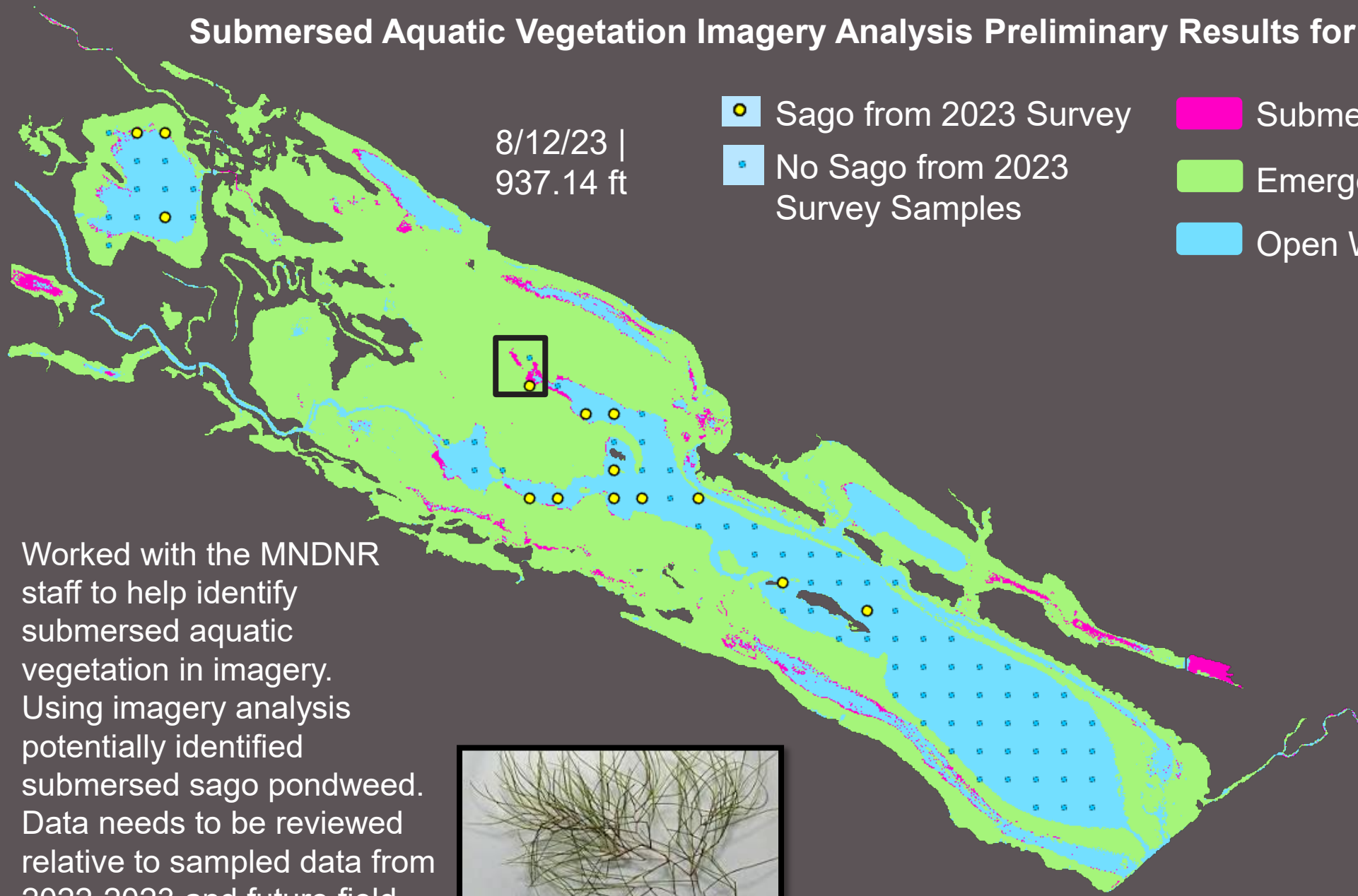
-  Open Water
-  Sparser Aquatic Vegetation
-  Denser Aquatic Vegetation

Submersed Aquatic Vegetation Imagery Analysis Preliminary Results for Sago Pondweed

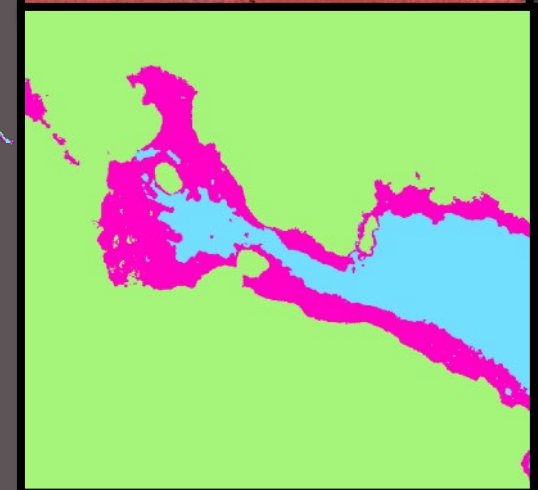
8/12/23 |
937.14 ft

-  Sago from 2023 Survey
-  No Sago from 2023 Survey Samples

-  Submersed Sago from Analysis
-  Emergent Aquatic Vegetation
-  Open Water






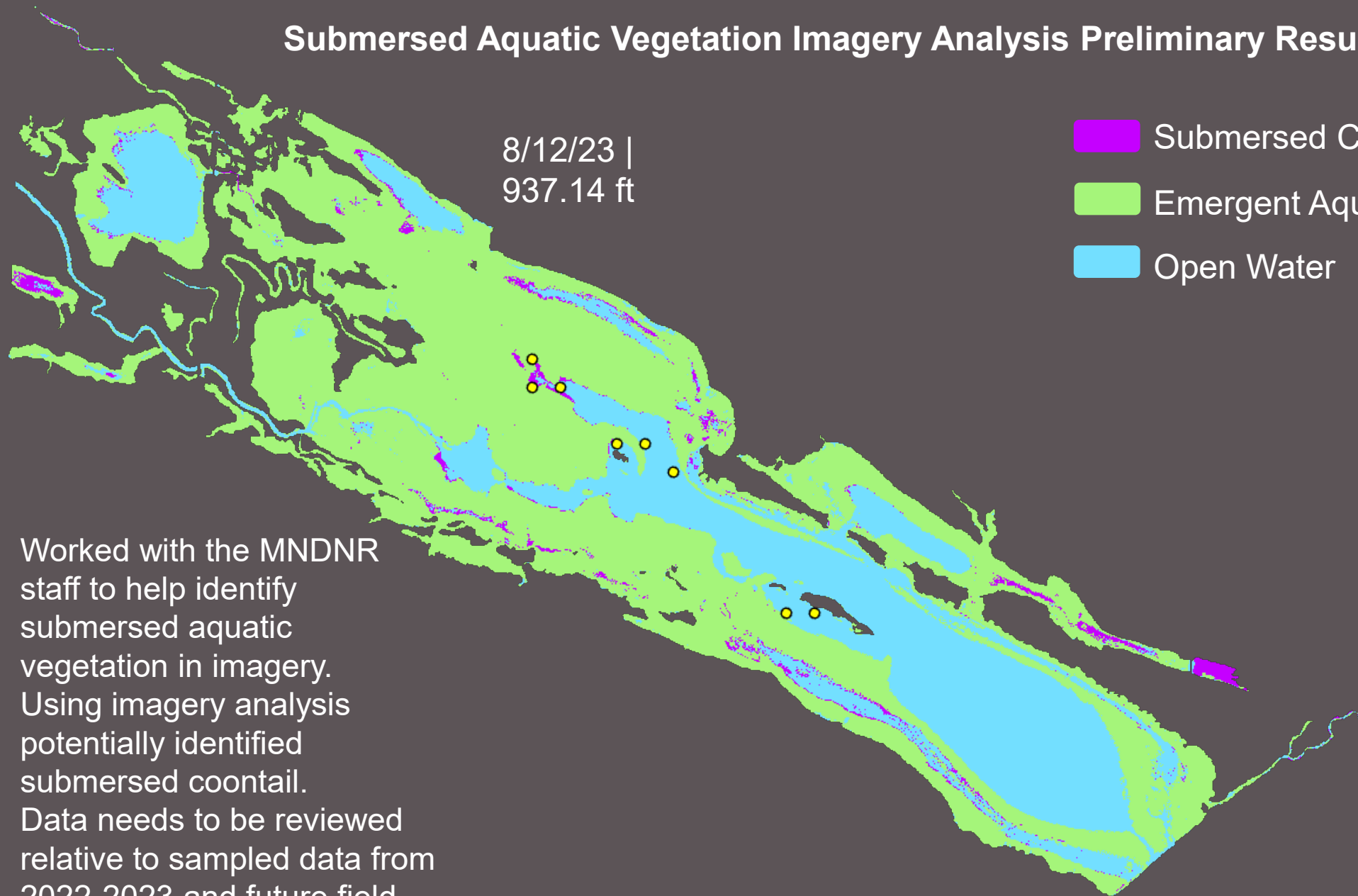
- Worked with the MNDNR staff to help identify submersed aquatic vegetation in imagery.
- Using imagery analysis potentially identified submersed sago pondweed.
- Data needs to be reviewed relative to sampled data from 2022-2023 and future field work.



Submersed Aquatic Vegetation Imagery Analysis Preliminary Results for Coontail

8/12/23 |
937.14 ft

-  Submersed Coontail from Analysis
-  Emergent Aquatic Vegetation
-  Open Water



- Worked with the MNDNR staff to help identify submersed aquatic vegetation in imagery.
- Using imagery analysis potentially identified submersed coontail.
- Data needs to be reviewed relative to sampled data from 2022-2023 and future field work.





U.S. ARMY



US Army Corps of Engineers



NEXT STEPS

- Continue to peer review the 2022 and 2023 imagery classification emergent and submersed vegetation results.
- Contract in place to collect seven satellite images for 2024 (May-Nov).
- Post imagery to Marsh Lake Story Map in late 2024.
- Run imagery analysis tools on 2024 imagery data and record results.

Questions?



Marsh Lake Habitat Enhancement Project

Restore the aquatic and riparian ecosystems in the Marsh Lake project area on the Minnesota River in Western Minnesota.

By U.S. Army Corps of Engineers and Minnesota Department of Natural Resources



About

Marsh Lake Dam is located on the Minnesota River in western Minnesota. The dam creates a 5,000-acre shallow impoundment that serves as habitat to fish and waterfowl.

Because the condition of the Minnesota River ecosystems affects migratory birds and a flyway of international importance, the geographic scope of the project extends in effect to the range of the many species of migratory birds that breed in, migrate through and stop to feed and rest in the Marsh Lake area. The project area is important to many species of migratory waterfowl with effects that extend beyond the immediate project area. In the fall, as many as 150,000 Canada geese use the management area at one time. Marsh Lake is also home to Minnesota's largest breeding colony of American white pelicans and several species of fish.

The purpose of the habitat enhancement project is to restore the aquatic and riparian ecosystems in the Marsh Lake project area. Impoundment of Lac qui Parle and Marsh Lake, diversion of the Pomme de Terre River into Lac qui Parle, and river regulation have significantly altered the ecosystem state. The intent is to increase variability in ecosystem processes, restore a more natural water level regime, aquatic habitat connectivity, and a vegetated lake ecosystem state.



Marsh Lake Location Map

Google **MARSH LAKE STORYMAP** | Best on Desktop
<https://storymaps.arcgis.com/stories/fed86ac1de824c12afb6bbaaa4a59917>