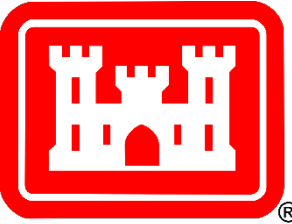




Remote Sensing Software Tools to Assist USACE Water Quality Monitoring



Harmful Algal Bloom indicator estimation in small inland waterbodies: The ArcGIS Pro waterquality toolbox and HAB Explorer online web application

Molly Reif¹, Christina Saltus², Richard Johansen², Erich Emery³

¹Research Geographer, Geospatial Data Analysis Team Lead, Project PI

²Research Geographer, Geospatial Data Analysis Team

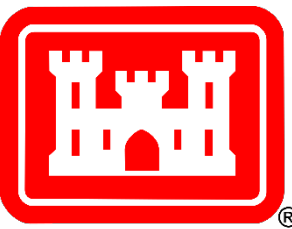
US Army Engineer Research and Development Center, Environmental Laboratory

³Water Quality Specialist, Great Lakes & Ohio River Division

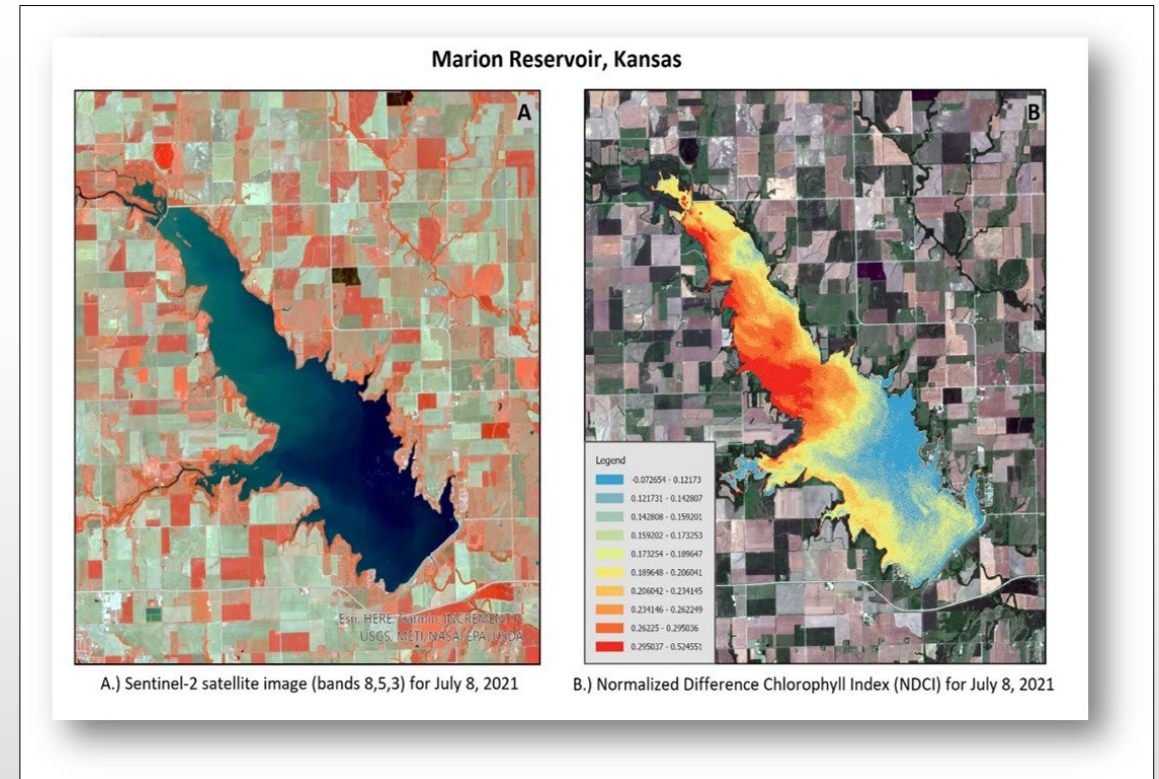
February 10, 2022

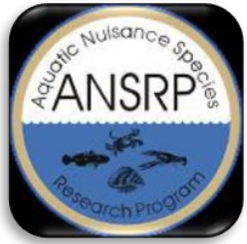


Outline

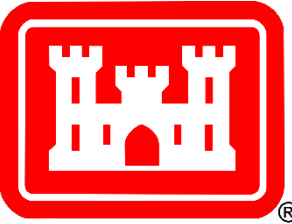


- Project Overview
- Sentinel Data Overview
- Toolbox Workflow
- Toolbox Requirements and Installation
- Exploring the Tools
- Harmful Algal Bloom (HAB) Explorer





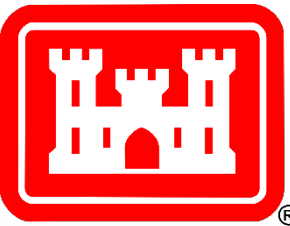
Project Overview



- **Purpose:** Software tools are needed to assist USACE with the challenge of monitoring hundreds of inland lakes and reservoirs that cover vast geographic areas, in which limited resources can lead to reactionary responses to HAB outbreaks
- **Goal:** Build on foundational research to develop remote sensing software tools to estimate water quality indicators of HABs, focusing on small, inland waterbodies in support of USACE water quality monitoring
- **Approach:** Develop satellite image-based tools to estimate potential HAB indicators: 1) chlorophyll-a, 2) phycocyanin, a proxy for cyanobacterial or blue-green algal biomass, and 3) turbidity

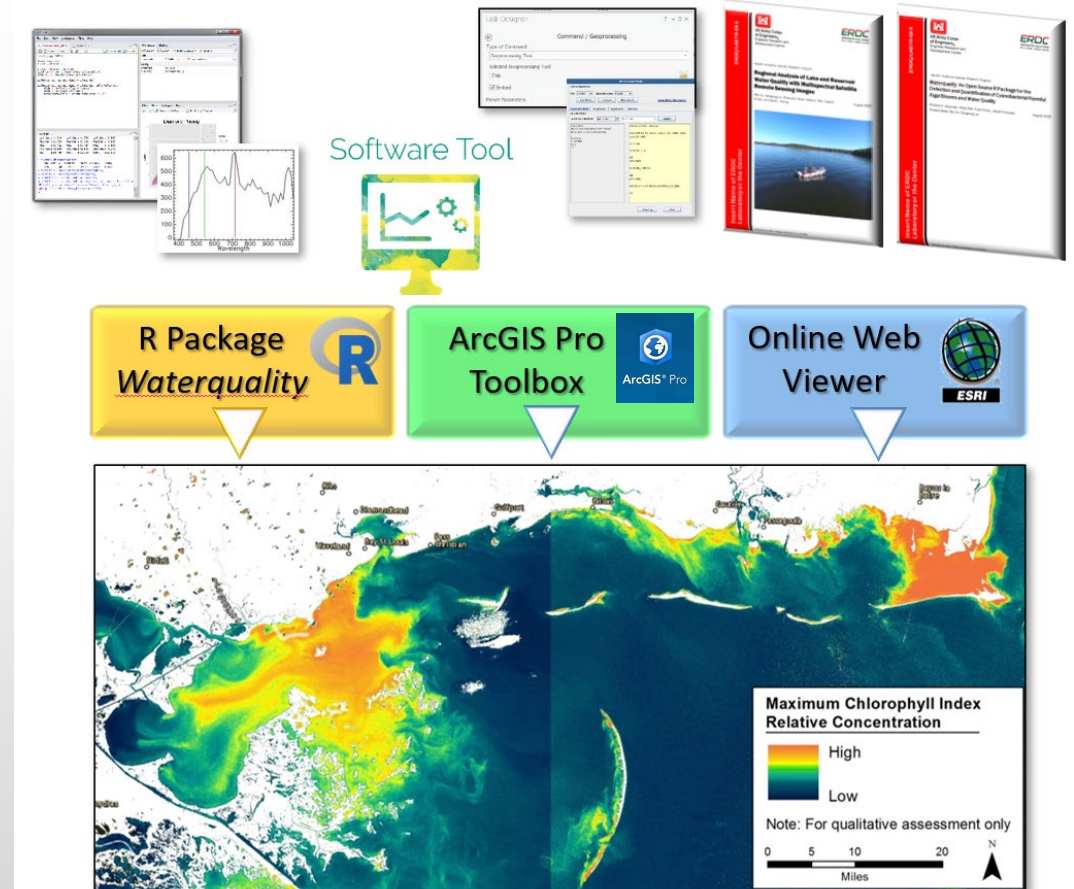


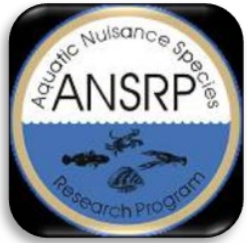
Project Overview



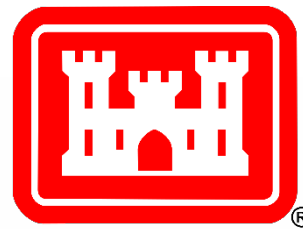
Array of software options to accommodate broad user base and skills:

1. Open-source [R software package](#), a U. of Cincinnati collaboration and most extensive option for developing image-based abundance maps of HAB indicators
2. Python-based [ArcGIS Pro toolbox](#) with pre-set menus and limited options to streamline HAB indicator estimation
3. Online ESRI [Web app](#) for constrained options to rapidly screen for potential HAB conditions

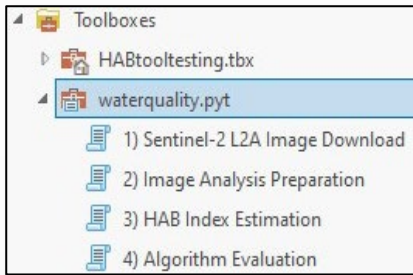




waterquality for ARCGIS Pro

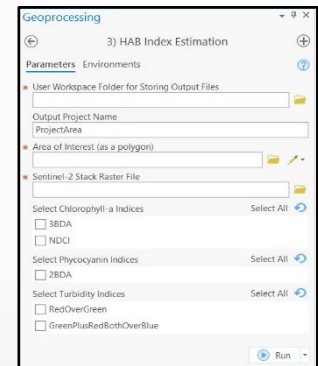


- ❖ A python-based *waterquality* toolbox developed in ESRI ArcGIS Pro desktop software using Sentinel-2 satellite imagery with pre-set menus to produce abundance maps. Four tool components help to streamline analysis and product development. Beta-tested by USACE Districts and external collaborators at NOAA.



Available Tools:

1. Sentinel-2 L2A image download
2. Automates creation of composite Sentinel-2 L2A image (cloud and land masks)
3. Estimates HAB water quality indicator using 5 well-known indices
4. Converts estimated values using a regression model and in situ measurements

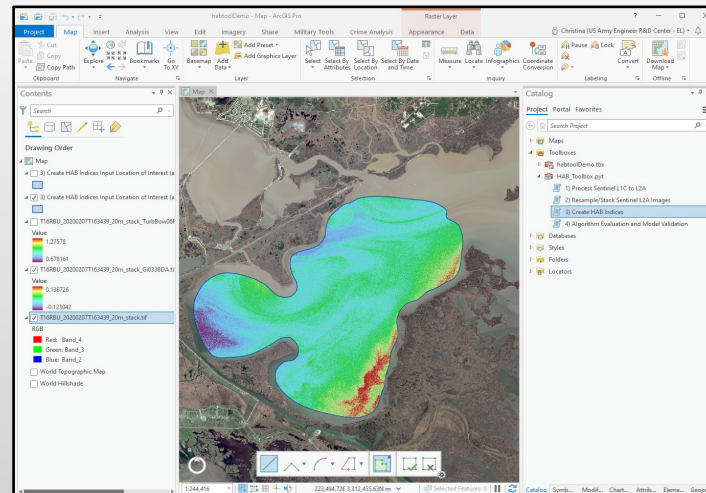


Tool Requirements:

- ArcGIS Pro 2.7
- Advanced License
- Spatial Analyst Extension
- Python 3.7
- Sentinelsat Python Library

Data inputs:

- Sentinel-2 satellite imagery
- Area of interest polygon
- Choice of 5 water quality algorithms
- In situ data – csv format

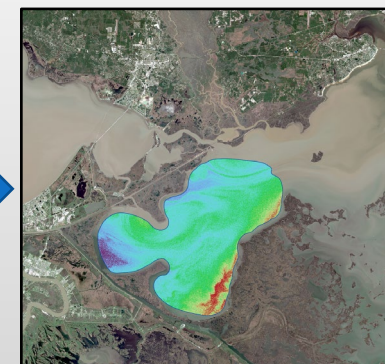


Output:

- Water quality index raster
- PDF report and raster of estimated concentrations



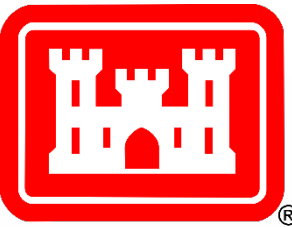
Sentinel-2
Lake Borgne, LA



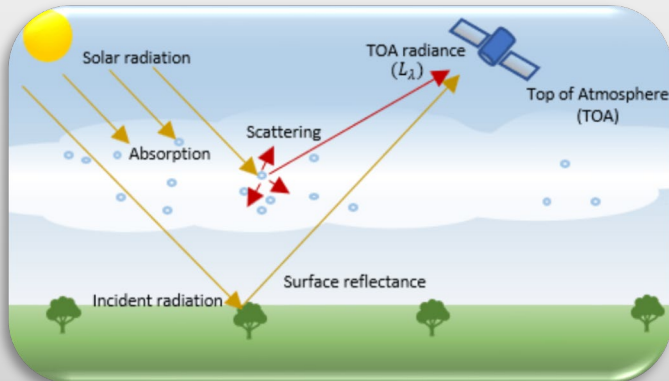
3BDA
Chlorophyll Index



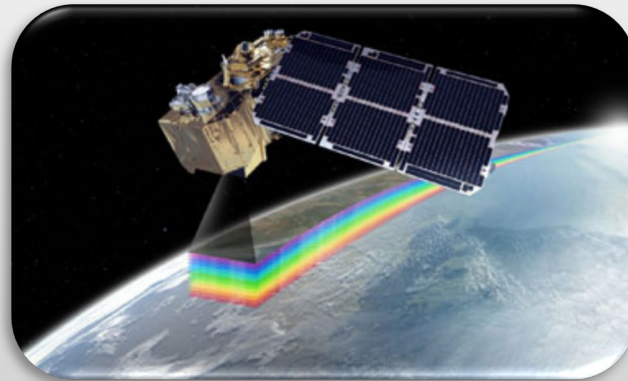
Sentinel-2 Satellite Imagery



- Imager:
 - Constellation of two satellites (2A and 2B) Multispectral imager
 - European Space Agency (ESA)
 - Global coverage and freely available
 - 5-10 day revisit time
 - 10-20-60 meter spatial resolution
 - Level-2A is atmospherically corrected



<https://de.mathworks.com/help/images/atmosphericcorrection.png>

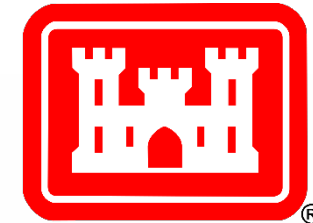


<https://www.ukspace.org/wp-content/uploads/2016/01/Sentinel-2-Airbus-DS.jpg>

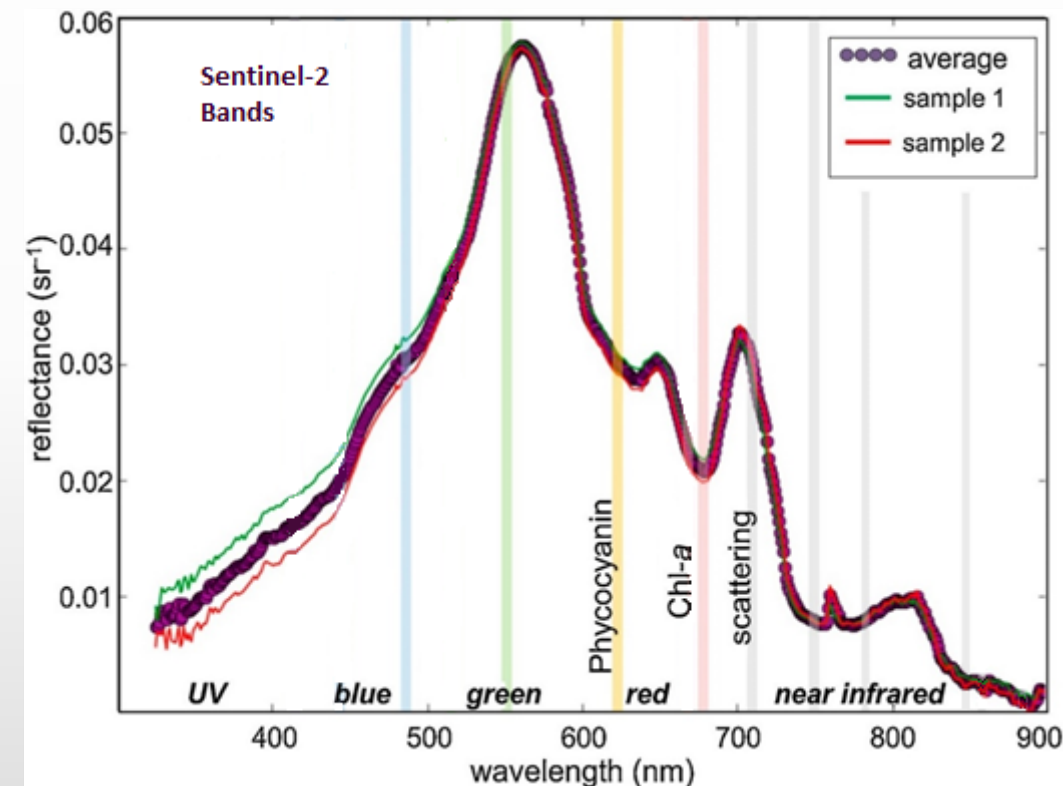
Spectral Band	Description	Center Wavelength (nm)	Initial Spatial Resolution (m)	Level-2A Available Product Spatial Resolution (m)
Band 1	Coastal Aerosol	443	60	60
Band 2	Blue	490	10	10; 20; 60
Band 3	Green	560	10	10; 20; 60
Band 4	Red	665	10	10; 20; 60
Band 5	Vegetation Red Edge	705	20	20; 60
Band 6	Vegetation Red Edge	740	20	20; 60
Band 7	Vegetation Red Edge	783	20	20; 60
Band 8	NIR	842	10	10
Band 8a	Narrow NIR	865	20	20; 60
Band 9	Water Vapor	940	60	60
Band 10	SWIR-Cirrus	1375	60	NA
Band 11	SWIR	1610	20	20; 60
Band 12	SWIR	2190	20	20; 60

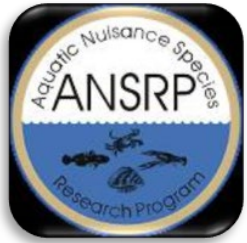


Remote Sensing & Water Quality Proxies

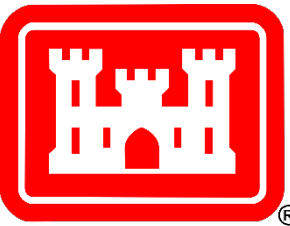


- Remote sensing HABs is possible because the photo-reactive pigments produced by algae can be 'sensed' by satellite imagers
- **Chlorophyll(s) (Chl_a)**
 - Ubiquitous phytoplankton pigment with absorption features around 433 nm and 686 nm and reflectance peaks at 550 nm and 715 nm.
- **Phycocyanin**
 - Cyanobacteria specific pigment with major absorption feature at 620 nm.
- **Turbidity**
 - General measure of water clarity
 - Effect of backscattering caused by suspended material in the water column



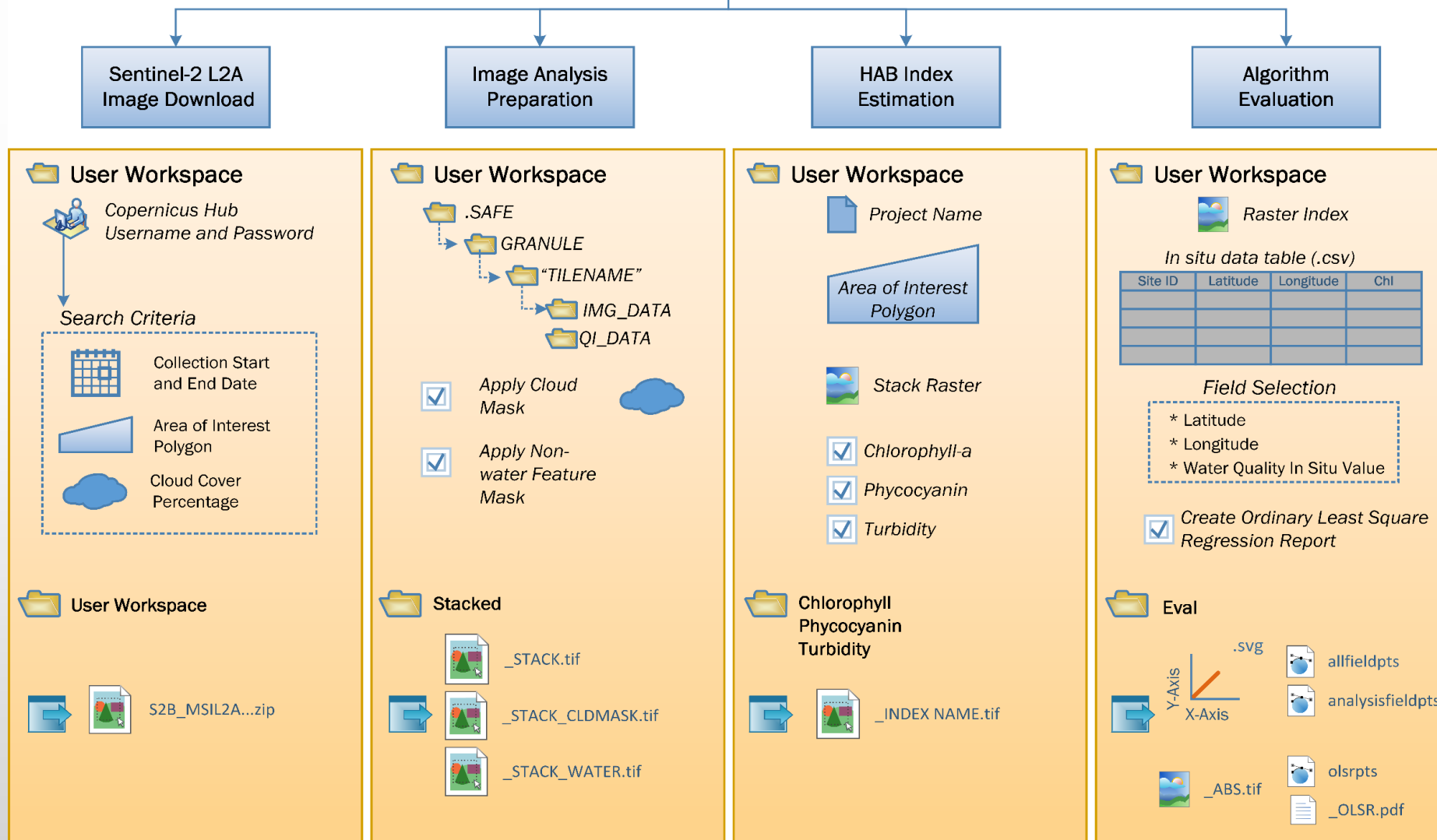
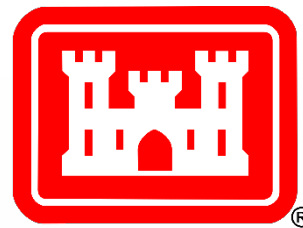


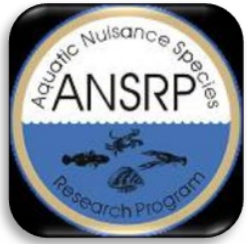
Water Quality Indices



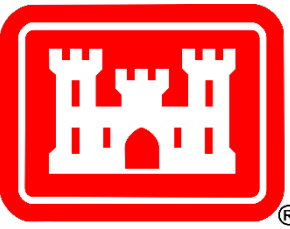
Water Quality Algorithm	Water Quality Parameter	Sentinel-2 Band Calculation wavelengths in nanometers (nm)	Reference
3BDA	Chlorophyll	$(1/665 \text{ nm}) / (1/705 \text{ nm}) * 740 \text{ nm}$	Gitelson et al 2003
NDCI	Chlorophyll	$(705 \text{ nm} - 665 \text{ nm}) / (705 \text{ nm} + 665 \text{ nm})$	Mishra and Mishra 2012
2BDA	Phycocyanin	705 nm/665 nm	Wynne et al 2008
RedOverGreen	Turbidity	665 nm / 560 nm	Bowers and Binding 2006
GreenPlusRedBothOverBlue	Turbidity	$(560 \text{ nm} + 665 \text{ nm}) / 490 \text{ nm}$	Frohn and Autrey 2009

Toolbox Workflow

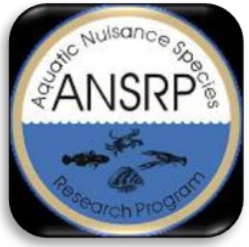




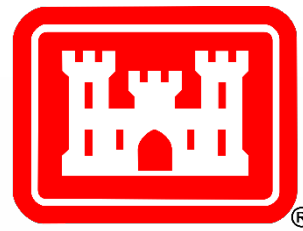
Toolbox Requirements



- ArcGIS Pro version 2.7 or greater
- Python version 3.7 or greater
- Advanced ArcGIS Pro and Spatial Analyst License
- Sentinelsat Python library

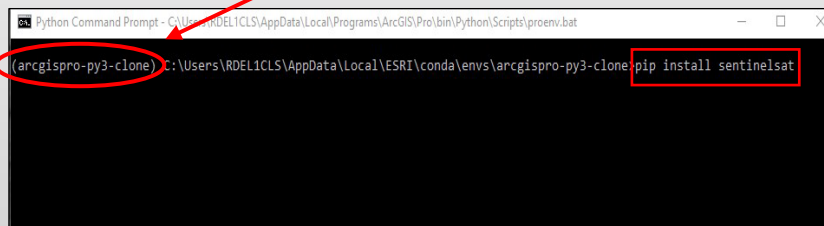
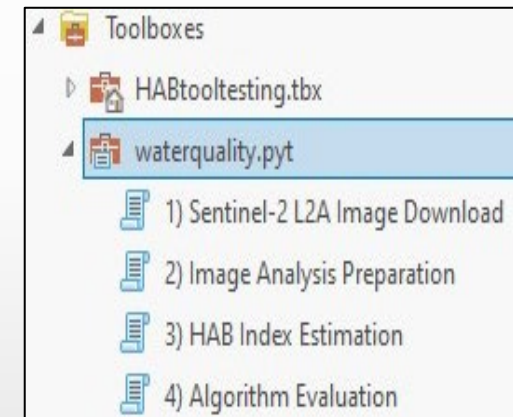
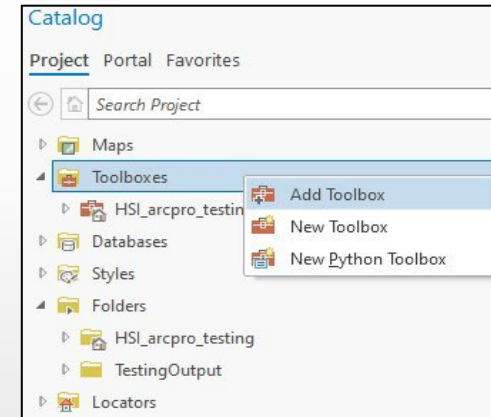
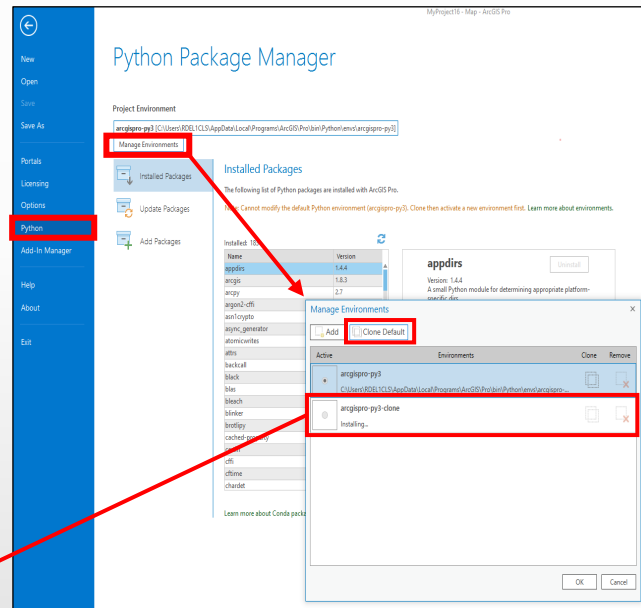
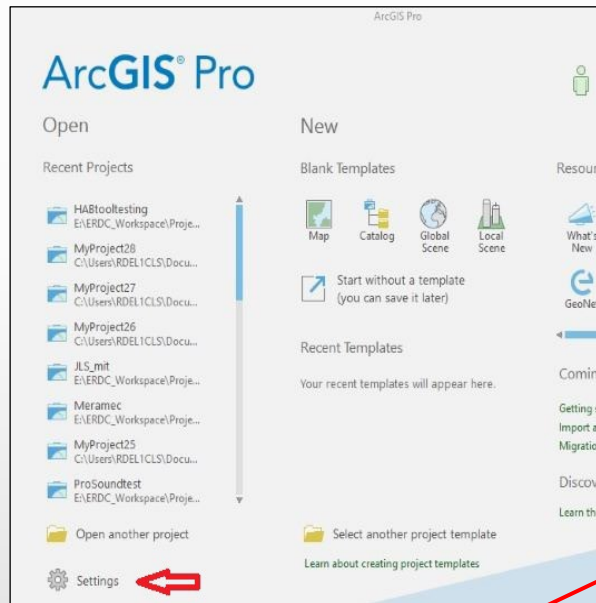


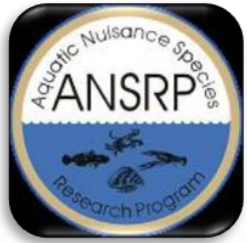
Toolbox Installation



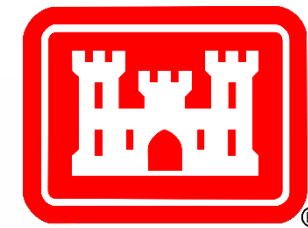
SentinelSat Python Library Installation

Waterquality Toolbox Installation





Sentinel-2 L2A Image Download Tool



Sentinel-2 L2A Image Download

User Workspace
Copernicus Hub Username and Password

Search Criteria

- Collection Start and End Date
- Area of Interest Polygon
- Cloud Cover Percentage

User Workspace

S2B_MSIL2A...zip

Geoprocessing

1) Sentinel-2 L2A Image Download

Parameters Environments

* User Workspace Folder for Storing Output Files

* Copernicus Open Access Hub username

* Copernicus Open Access Hub password

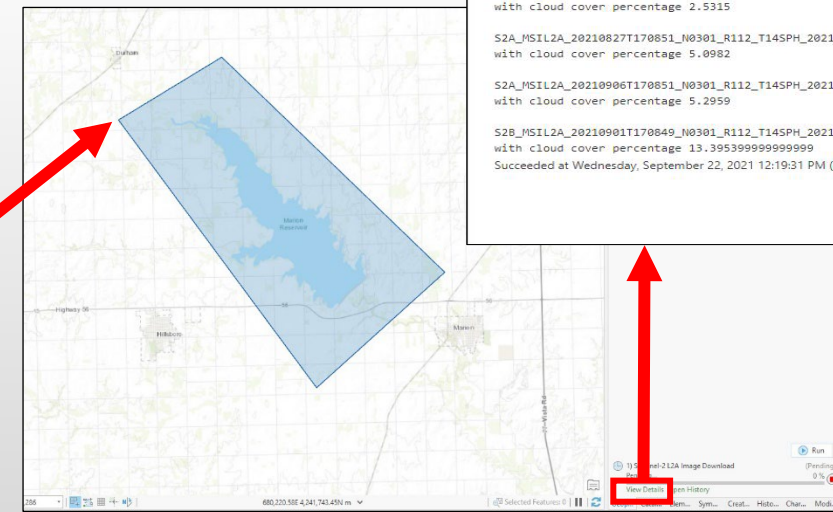
Image collection start date: 8/5/2021

Image collection end date: 8/19/2021

Generalized area of interest (as a polygon)

1) Sentinel-2 L2A Image Download Generalized ar

1) Sentinel-2 L2A Image Download Generalized a



1) Sentinel-2 L2A Image Download (waterquality)

Completed.

Started: Today at 12:10:09 PM
Completed: Today at 12:19:31 PM
Elapsed Time: 9 Minutes 22 Seconds

Errors and warnings

Parameters

User Workspace Folder for Storing Output Files	E:\ERDC_Workspace\Projects\2021\HAB-ARCGIS\HABtool\TrialT
Copernicus Open Access Hub username	csaltus
Copernicus Open Access Hub password	*****
Image collection start date	8/23/2021
Image collection end date	9/12/2021
Generalized area of interest (as a polygon)	1) Sentinel-2 L2A Image Download Generalized area of interest (a polygon) (Polygons)
Sentinel-2 cloud percentage coverage (as an integer)	35

Environments

Messages

Start Time: Wednesday, September 22, 2021 12:10:09 PM
The image collection START date is 8/23/2021
The image collection END date is 9/12/2021
The Maximum Cloud percentage is 35
There are 4 tiles that match your criteria.

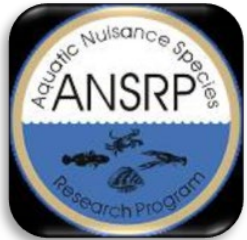
S2B_MSIL2A_20210911T170849_N0301_R112_T145PH_20210911T212132 is Downloading with cloud cover percentage 2.5315

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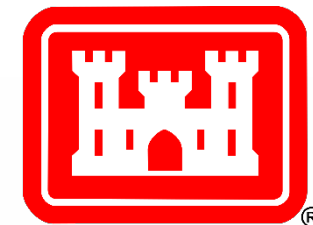
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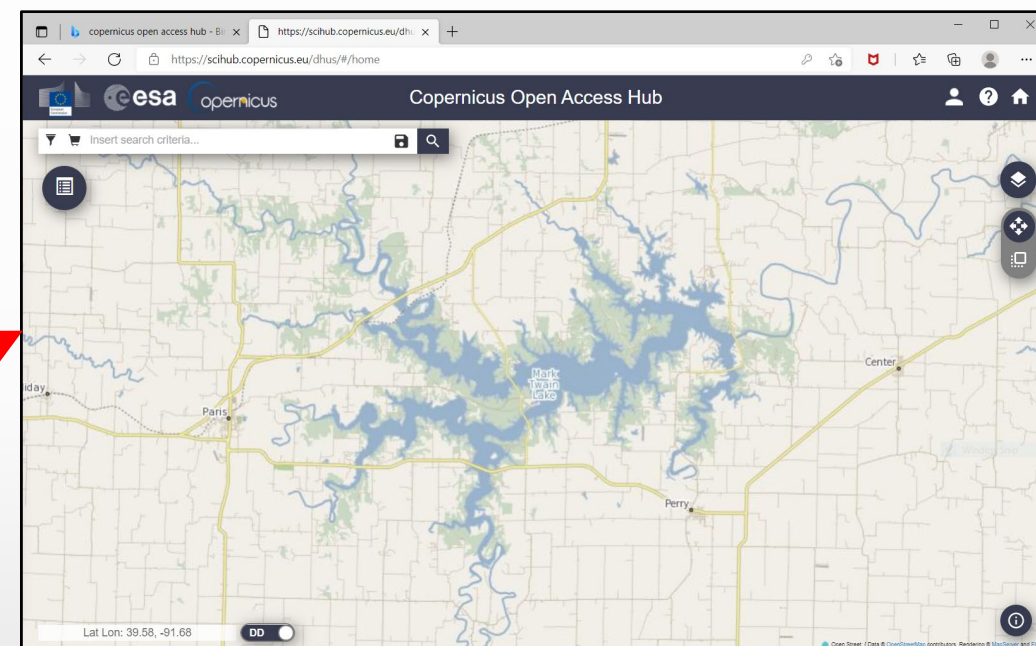
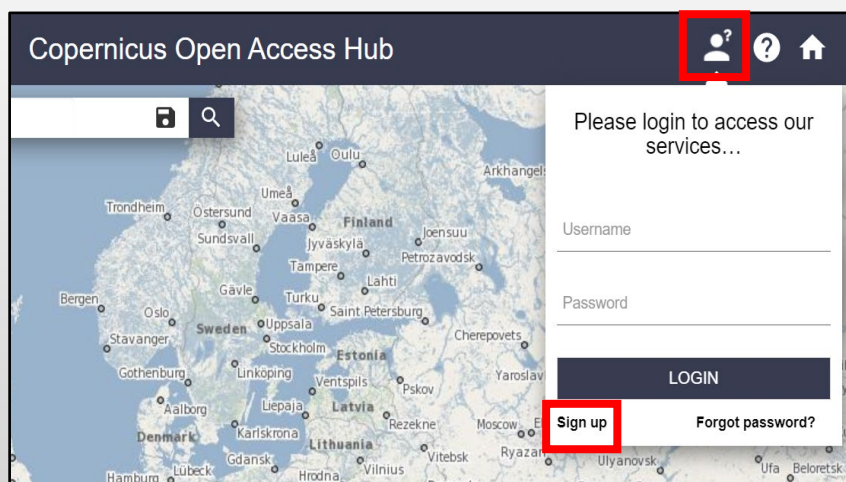
Succeeded at Wednesday, September 22, 2021 12:19:31 PM (Elapsed Time: 9 minutes 22 seconds)



How to Setup an Account

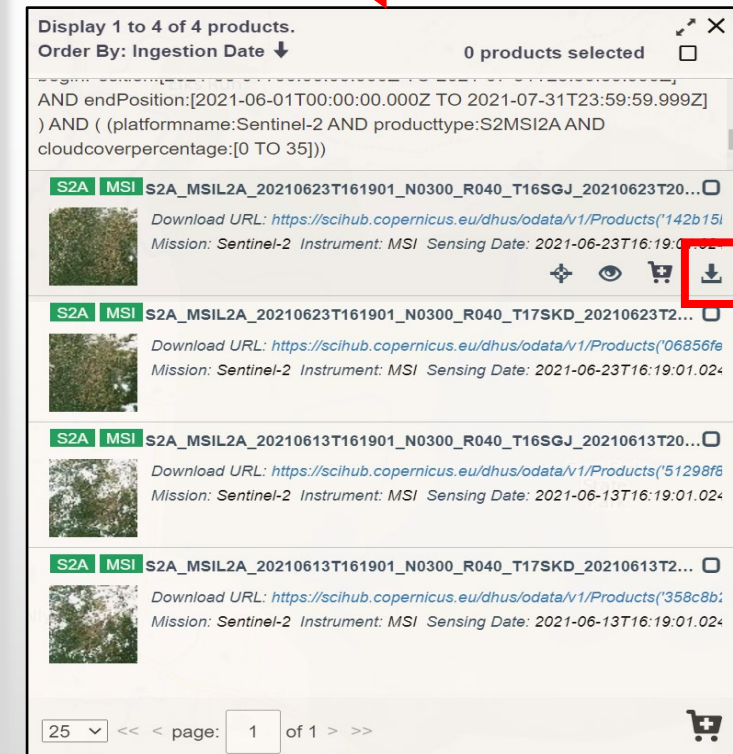
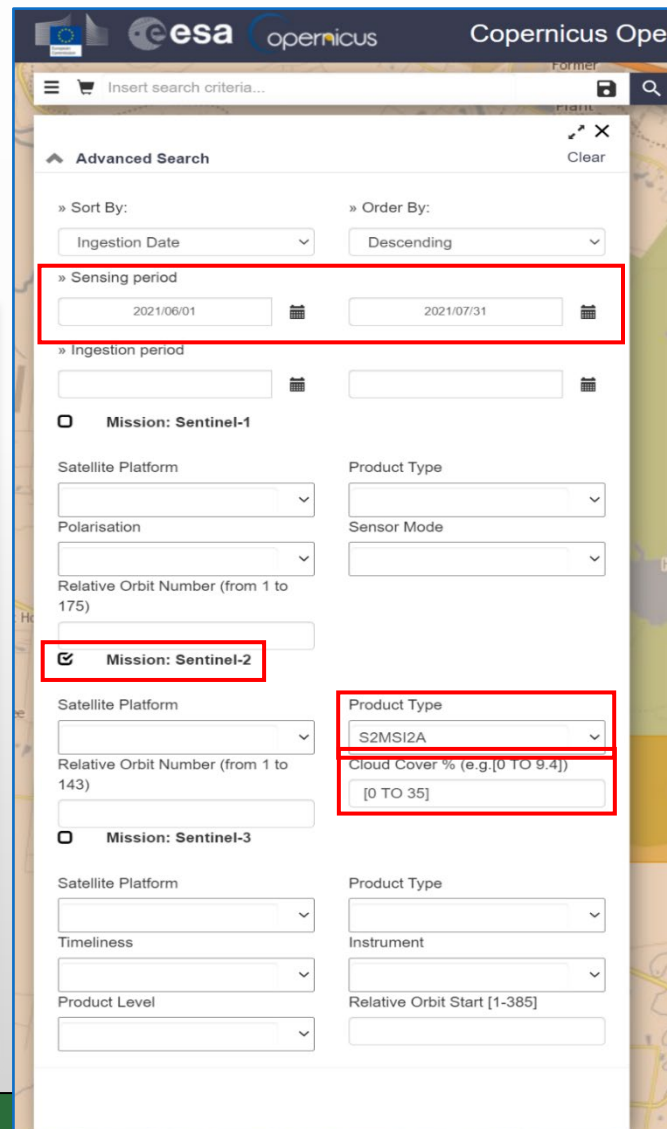
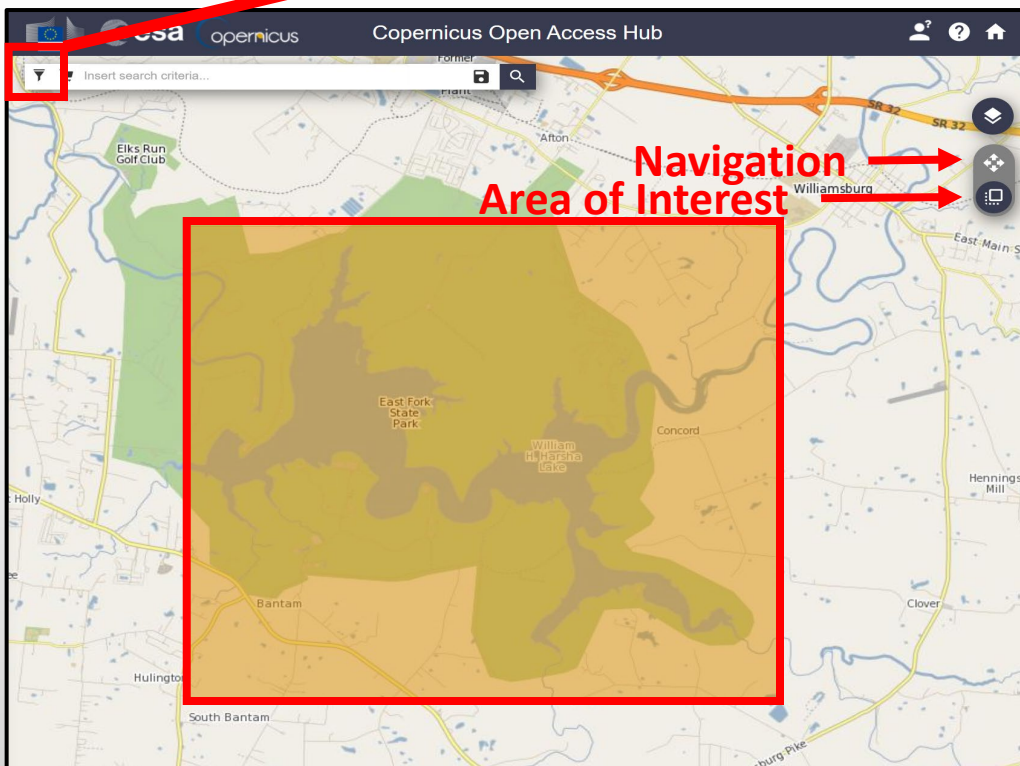
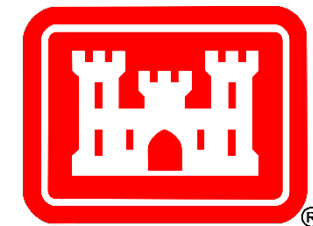


- Copernicus Open Access Hub website
<https://scihub.copernicus.eu/dhus/#/home>
- Create an account
<https://scihub.copernicus.eu/userguide>



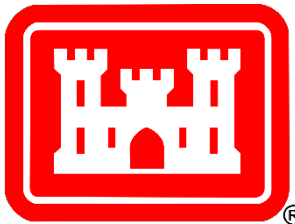


Sentinel-2 Image Download





SAFE File Naming Conventions and Directory Structure



MMM:
Mission ID
(S2A/S2B)

YYYYMMDDHHMMSS:
the datatake sensing time.

ROOO:
Relative Orbit number

Product Discriminator:
Used to distinguish between different end user products from the same datatake.

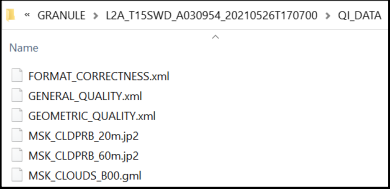
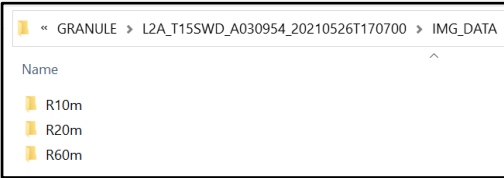
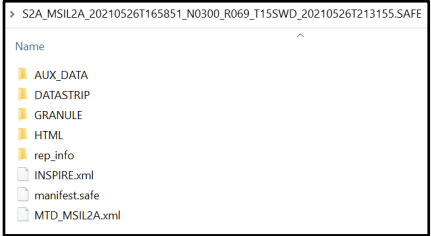
S2A_MSIL2A_20210526T165851_N0300_R069_T15SWD_20210526T213155.SAFE

MSIXXX:
Product Level
MSIL1C (Level-1C)
MSIL2A (Level-2A)

Nxyy:
PDGS Processing Baseline number

Txxxxx:
Tile Number

SAFE: Product Format (Standard Archive Format for Europe)



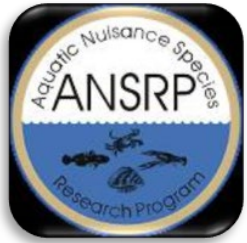


Image Analysis Preparation Tool

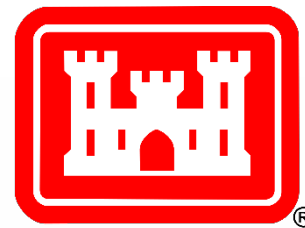


Image Analysis Preparation

User Workspace

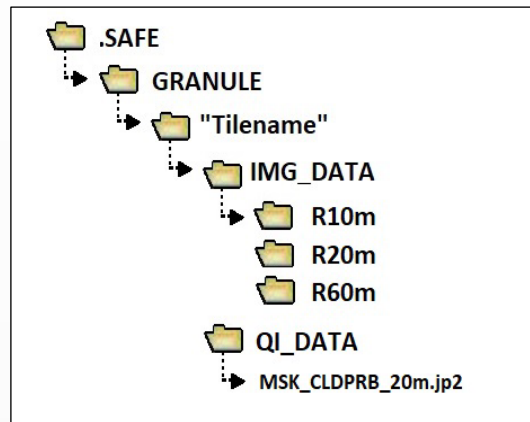
- .SAFE
 - GRANULE
 - "TILENAME"
 - IMG_DATA

Apply Cloud Mask

Apply Non-water Feature Mask

Stacked

- _STACK.tif
- _STACK_CLDMASK.tif
- _STACK_WATER.tif



Geoprocessing

2) Image Analysis Preparation

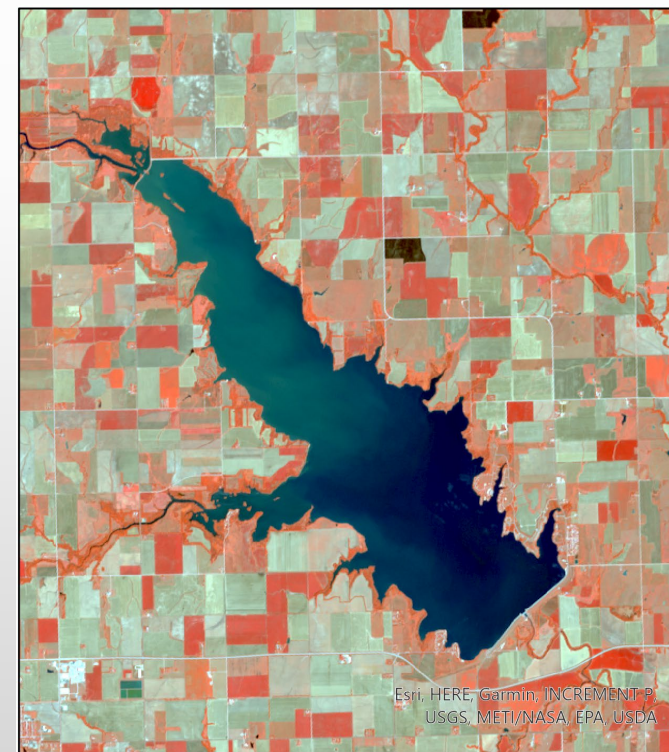
Parameters Environments

User Workspace Folder for Storing Output Files
HAB_Output

Select one or Multiple IMG_DATA Folder(s) Where Sentinel-2 L2A Raster Files are Located
IMG_DATA

Apply Cloud Mask

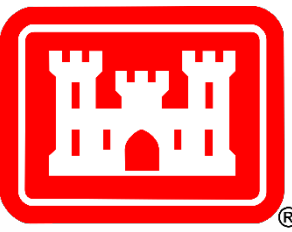
Apply Non-Water Feature Mask



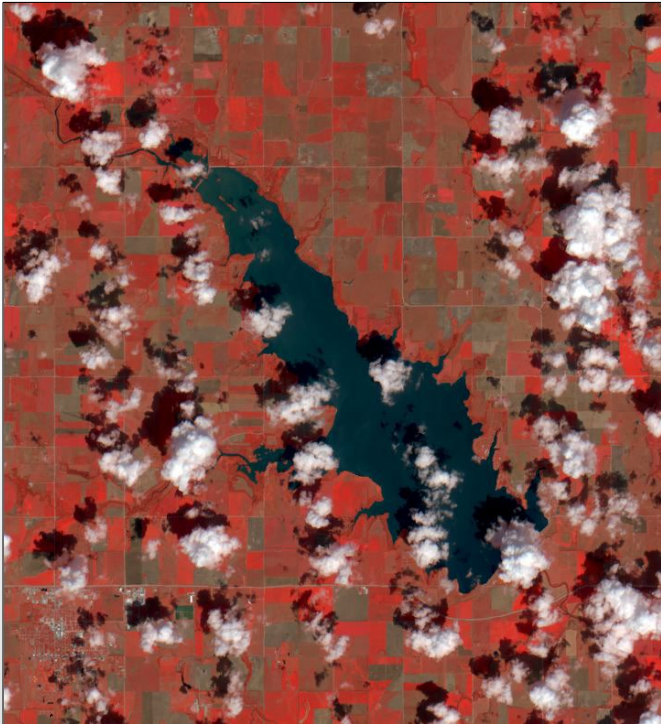
Esri, HERE, Garmin, INCREMENT P, USGS, METI/NASA, EPA, USDA



Image Analysis Preparation Tool Output

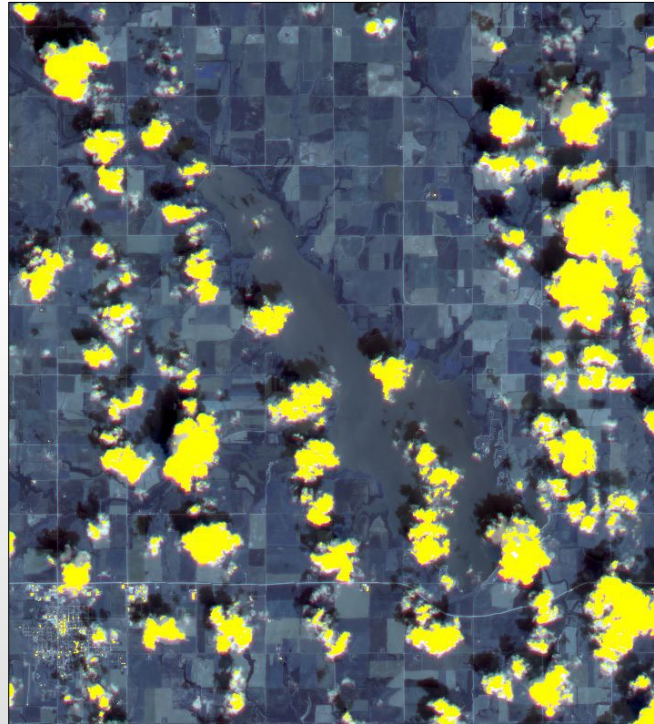


Marion Reservoir, KS
August 17, 2021



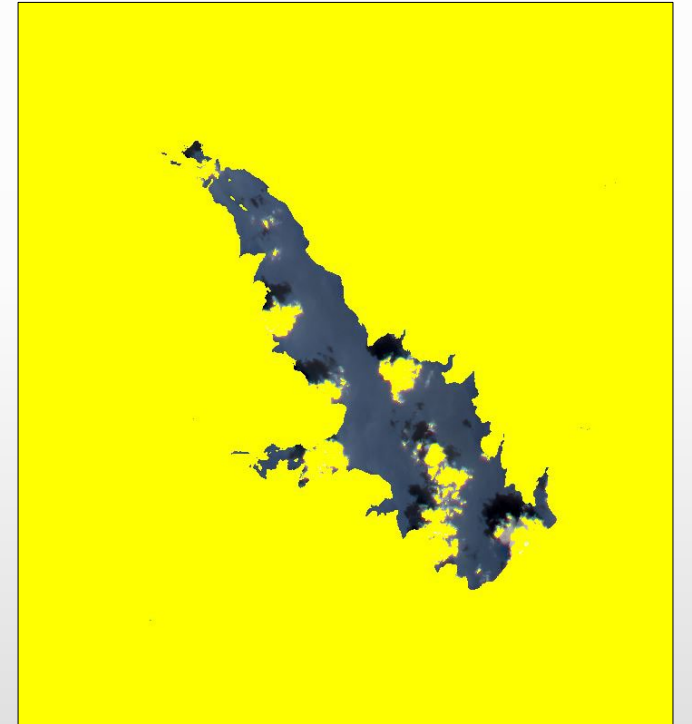
Stacked image

*_STACK.tif



Cloud Mask

*_STACK_CLDMASK.tif

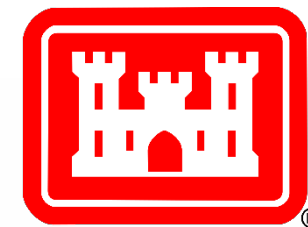


Only Water Features

*_STACK_WATER.tif



HAB Index Estimation Tool



HAB Index Estimation

User Workspace

- Project Name
- Area of Interest Polygon
- Stack Raster
- Chlorophyll-a
- Phycocyanin
- Turbidity

**Chlorophyll
Phycocyanin
Turbidity**

_INDEX NAME.tif

Geoprocessing

3) HAB Index Estimation

Parameters Environments

User Workspace Folder for Storing Output Files
HAB_Output

Output Project Name
Marion

Area of Interest (as a polygon)
3) HAB Index Estimation Area of Interest (as a polygo

Sentinel-2 Stack Raster File
T14SPH_20210708_STACK_WATER.tif

Select Chlorophyll-a Indices **Select All**

- 3BDA
- NDCI

Select Phycocyanin Indices **Select All**

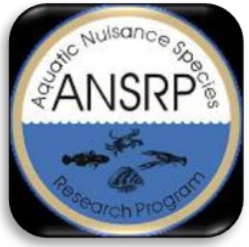
- 2BDA

Select Turbidity Indices **Select All**

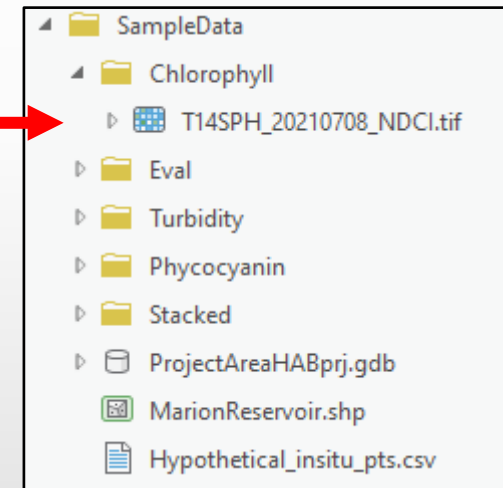
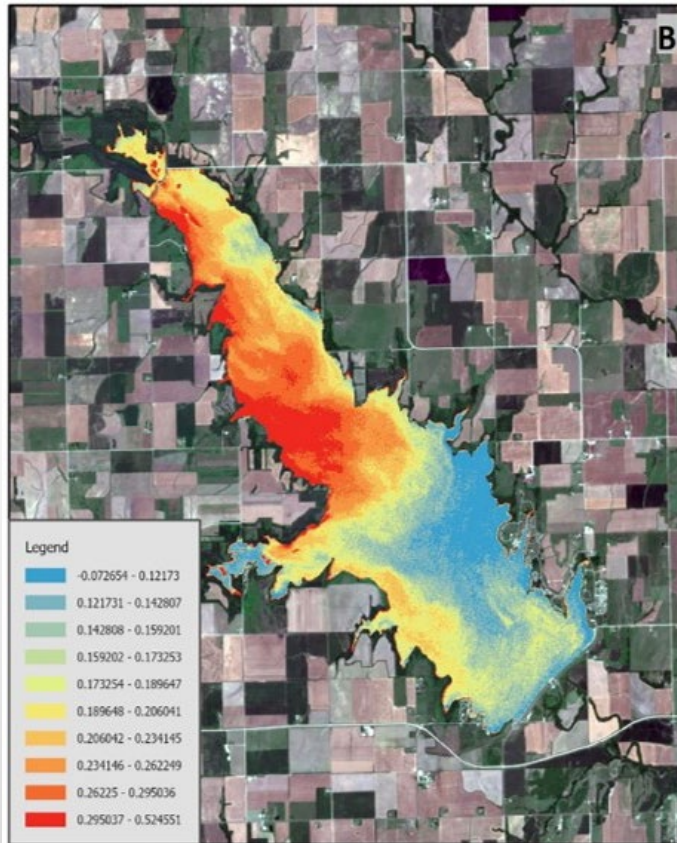
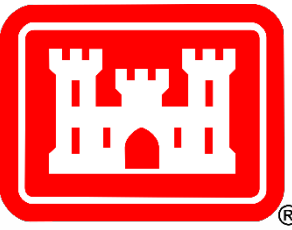
- RedOverGreen
- GreenPlusRedBothOverBlue

Run

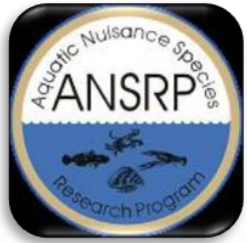
Water Quality Algorithm	Water Quality Parameter	Sentinel-2 Band Calculation wavelengths in nanometers (nm)	Reference
3BDA	Chlorophyll	$(1/665 \text{ nm}) / (1/705 \text{ nm}) * 740 \text{ nm}$	Gitelson et al 2003
NDCI	Chlorophyll	$(705 \text{ nm} - 665 \text{ nm}) / (705 \text{ nm} + 665 \text{ nm})$	Mishra and Mishra 2012
2BDA	Phycocyanin	705 nm/665 nm	Wynne et al 2008
RedOverGreen	Turbidity	665 nm / 560 nm	Bowers and Binding 2006
GreenPlusRedBoth OverBlue	Turbidity	$(560 \text{ nm} + 665 \text{ nm}) / 490 \text{ nm}$	Frohn and Autrey 2009



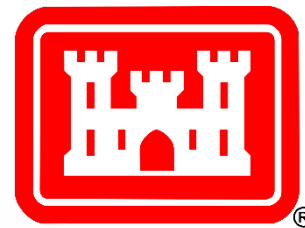
HAB Index Estimation Tool



NDCI Marion Reservoir, KS July 8, 2021



Algorithm Evaluation Tool



Algorithm Evaluation

User Workspace

Raster Index

In situ data table (.csv)

Site ID	Latitude	Longitude	Chl

Field Selection

- * Latitude
- * Longitude
- * Water Quality In Situ Value

Create Ordinary Least Square Regression Report

Eval

.svg

allfieldpts

analysisfieldpts

olsrpts

_OLSR.pdf

_ABS.tif

Geoprocessing

4) Algorithm Evaluation

Parameters Environments

User Workspace Folder for Storing Output Files
HAB_Output

Raster Index File
T14SPH_20210708_NDCI.tif

In Situ Sample Point data table (.csv)
210820_BetaTester\SampleData\Hypothetical_insitu_pts.csv

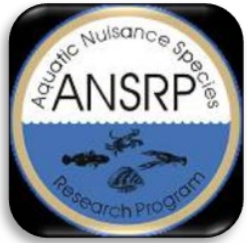
Field containing the latitude data values (in decimal degrees)
lat

Field containing
lon

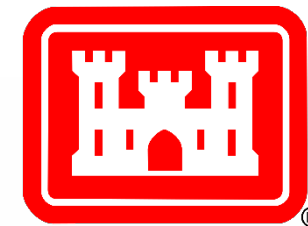
Field containing
Chl

Create Ord...

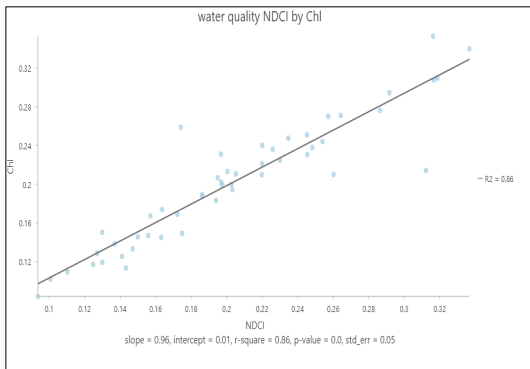
	A	B	C	D
1	SiteID	lat	lon	Chl
2	0	38.437	-97.158	0.244
3	1	38.447	-97.159	0.183
4	2	38.444	-97.154	0.231
5	3	38.442	-97.154	0.194
6	4	38.431	-97.146	0.225
7	5	38.429	-97.153	0.295
8	6	38.418	-97.146	0.271
9	7	38.419	-97.138	0.276
10	8	38.424	-97.137	0.238
11	9	38.425	-97.145	0.248
12	10	38.435	-97.150	
13	11	38.365		
	12	38.365		



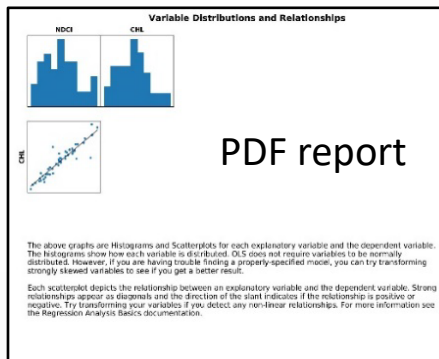
Algorithm Evaluation Tool Output



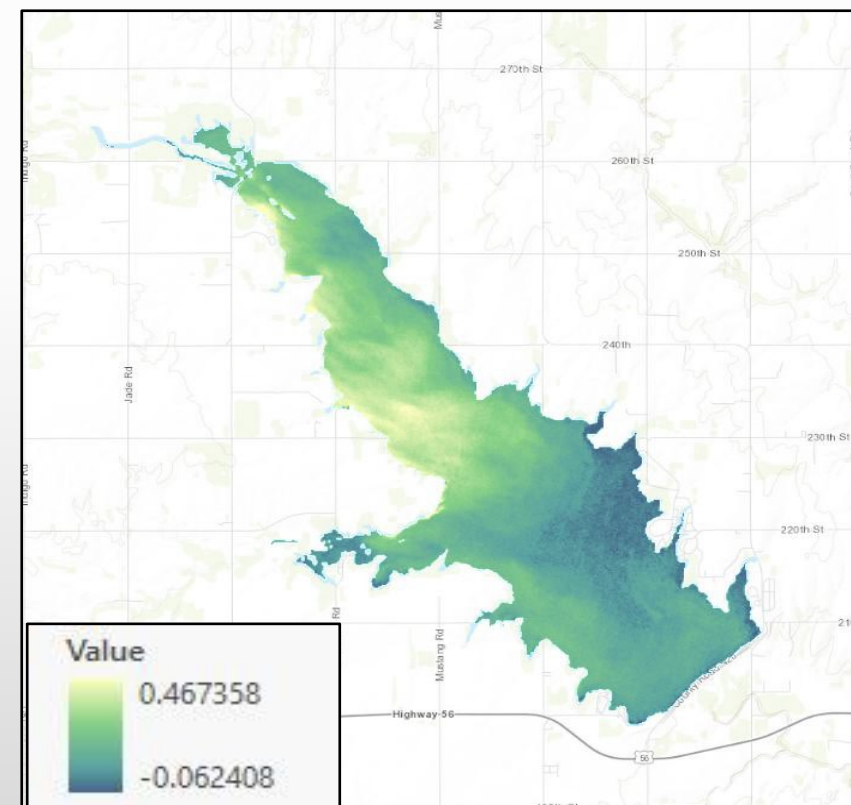
.svg file



OLRS Checkbox

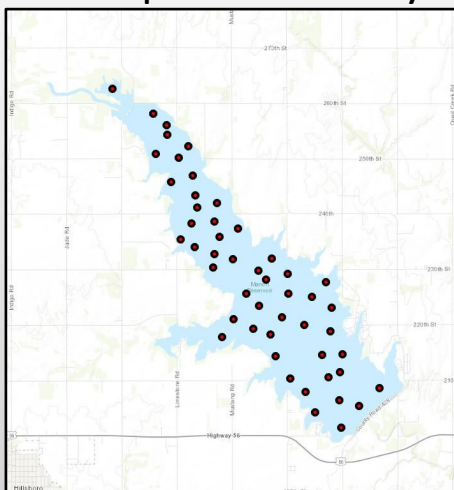


If $r^2 \geq .70$

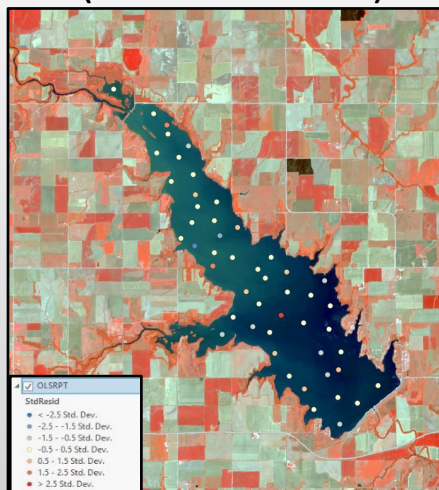


HAB concentrations (ABS)

Point Layers
(All Samples and Analysis)

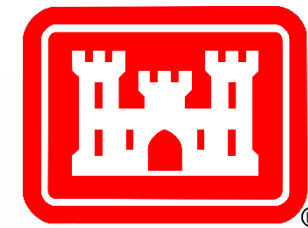


Point Layer
(OLSR statistics)



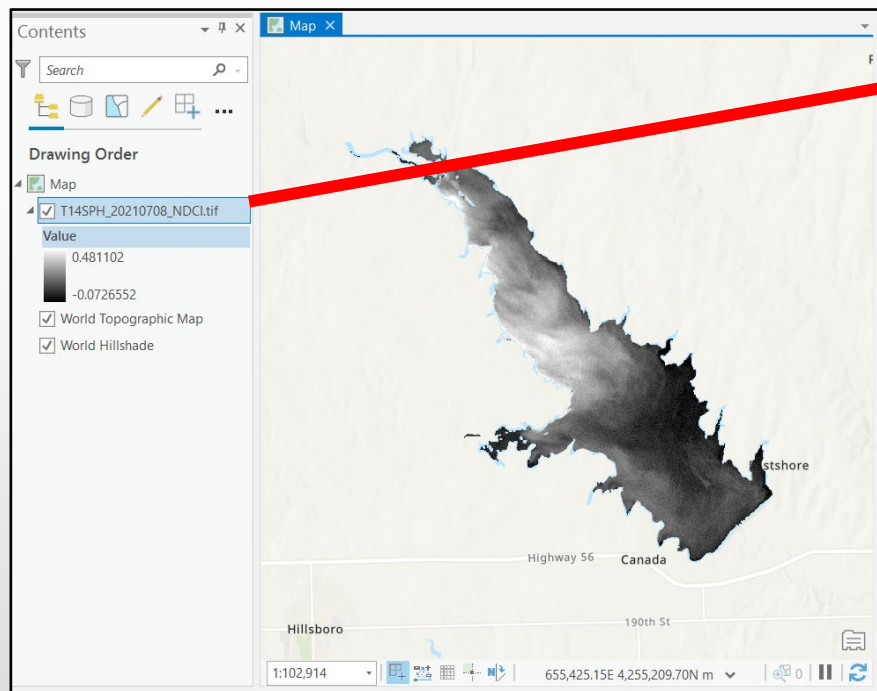


Explore the Data Symbology



Select Symbology

Default Tool Output



Primary symbology

Classify

Field: No fields

Normalization: No fields

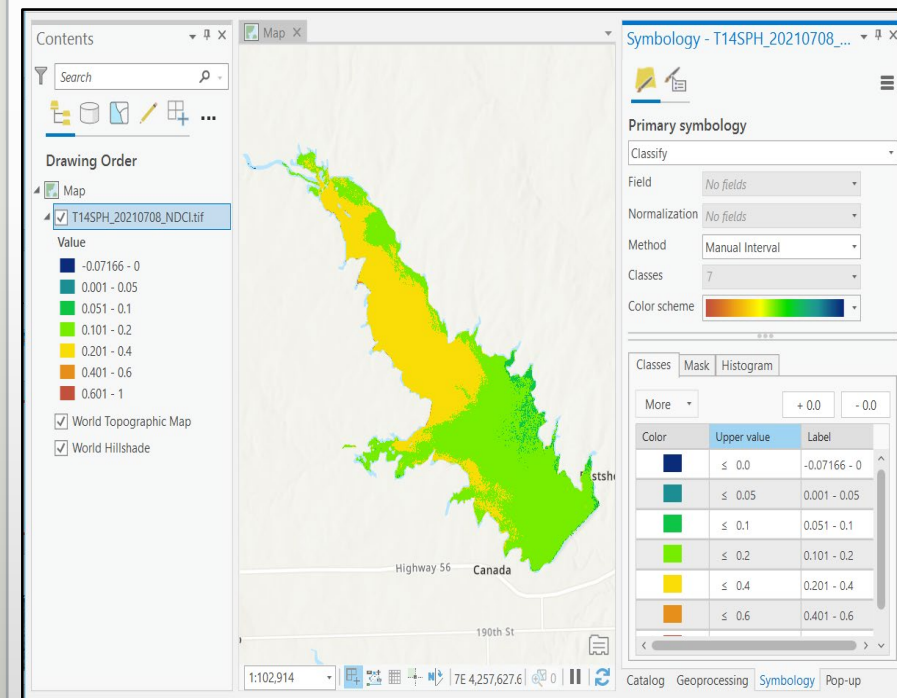
Method: Manual Interval

Classes: 7

Color scheme: Rainbow

Color	Upper value	Label
Dark Blue	≤ 0.0	-0.07166 - 0
Teal	≤ 0.05	0.001 - 0.05
Green	≤ 0.1	0.051 - 0.1
Light Green	≤ 0.2	0.101 - 0.2
Yellow	≤ 0.4	0.201 - 0.4
Orange	≤ 0.6	0.401 - 0.6

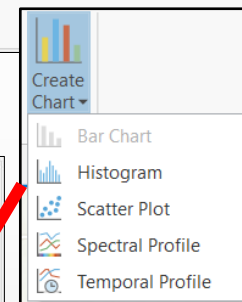
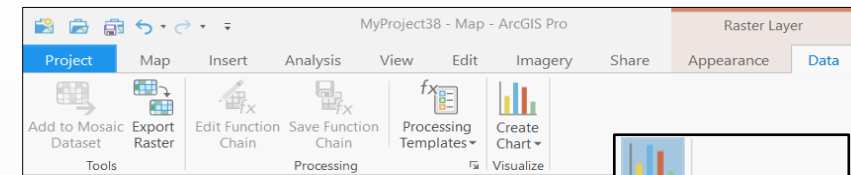
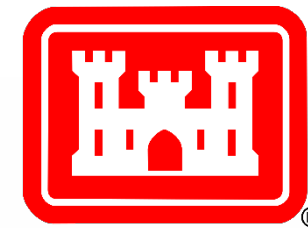
Output Symbology





Explore the Data

Histograms



Contents

Map X

Symbology - T14SPH_20210708_...

Primary symbology

Classify

Field: No fields

Normalization: No fields

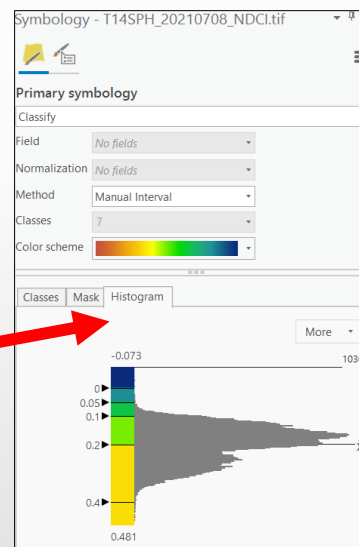
Method: Manual Interval

Classes: 7

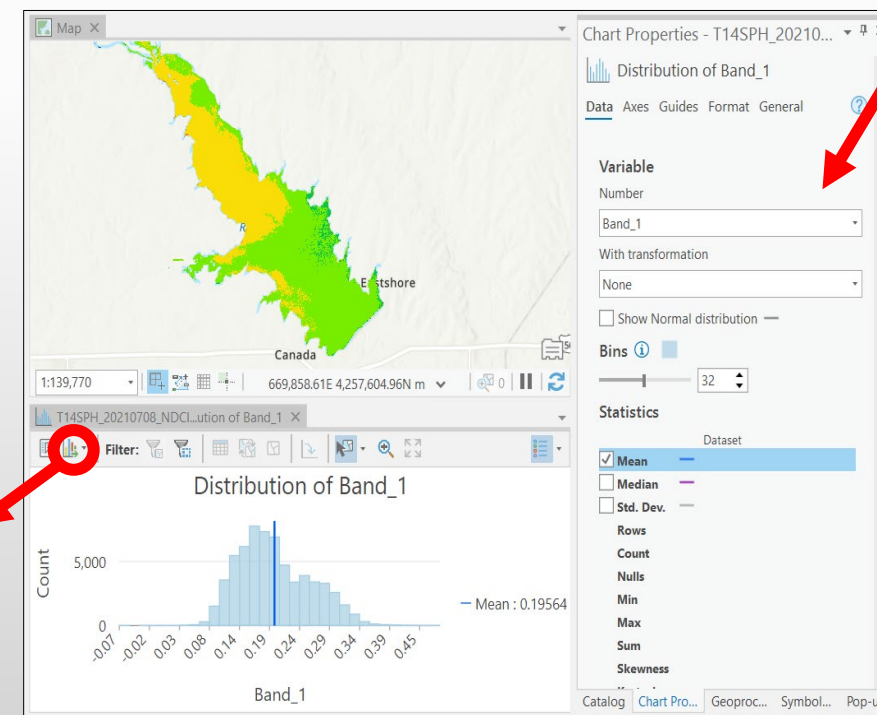
Color scheme

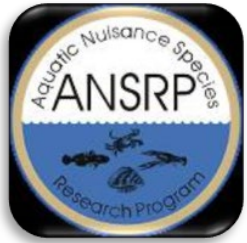
Classes Mask Histogram

Color	Upper value	Label
Dark Blue	≤ 0.0	-0.07166 - 0
Teal	≤ 0.05	0.001 - 0.05
Light Green	≤ 0.1	0.051 - 0.1
Green	≤ 0.2	0.101 - 0.2
Yellow-Green	≤ 0.4	0.201 - 0.4
Yellow	≤ 0.6	0.401 - 0.6
Orange	≤ 0.6	0.401 - 0.6

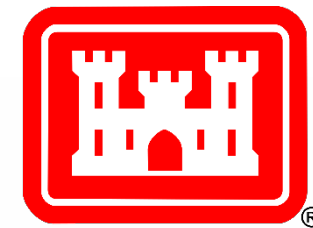


Export as
Table or Graphic



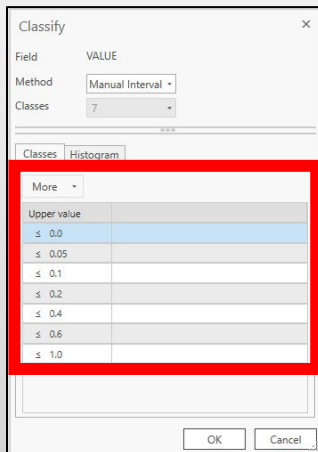
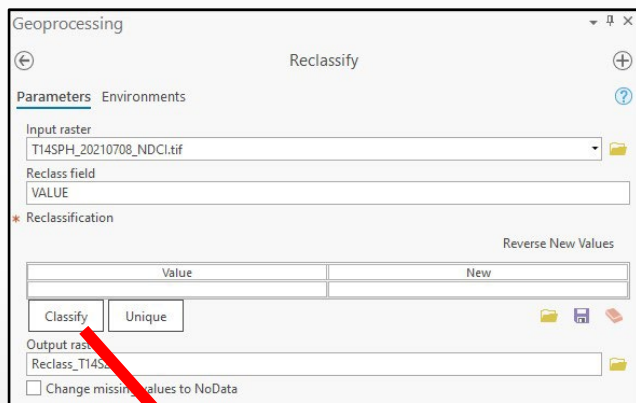
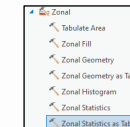
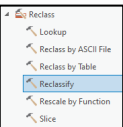


Explore the Data Statistics

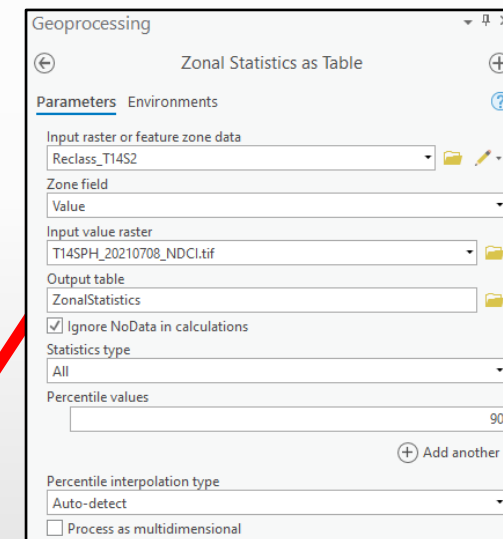
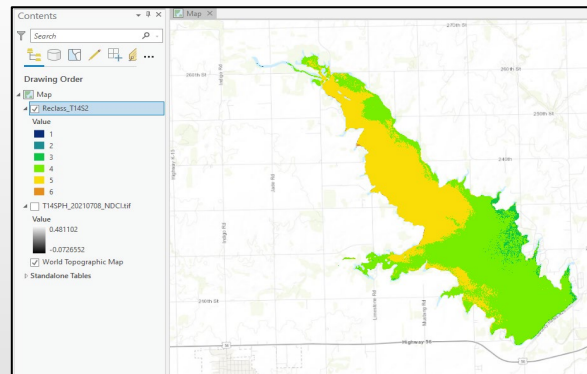
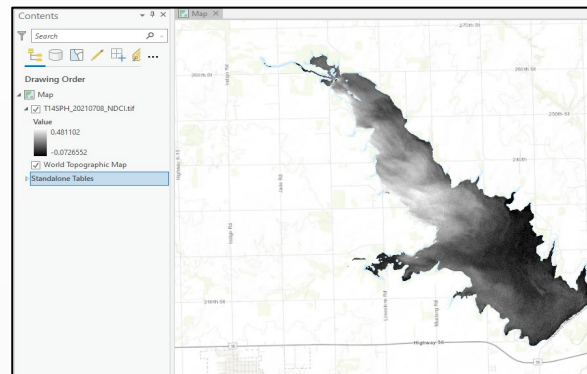


Spatial Analyst Tools>Reclass>Reclassify

Spatial Analyst Tools>Zonal>Zonal Statistics As Table



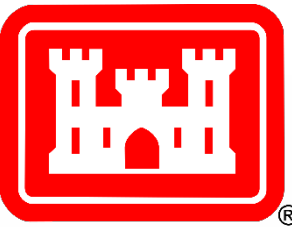
Start	End	New
-0.072655	0	1
0	0.05	2
0.05	0.1	3
0.1	0.2	4
0.2	0.4	5
0.4	0.6	6
0.6	1	7
NODATA	NODATA	NODATA



VALUE	COUNT	AREA	MIN	MAX	RANGE	MEAN	STD	SUM	MEDIAN	PCT90
0	1	400	-0.072655	-0.072655	0	-0.072655	0	-0.072655	-0.072655	-0.072655
1	7	2800	-0.057778	-0.006402	0.051376	-0.025259	0.014729	-0.17681	-0.020321	-0.013821
2	32	12800	0.007557	0.048159	0.040602	0.035099	0.01162	1.123174	0.037543	0.047589
3	1812	724800	0.050711	0.099893	0.049181	0.089489	0.009681	162.153743	0.092447	0.098782
4	35582	14232800	0.1	0.199731	0.099731	0.155891	0.026658	5546.901874	0.158392	0.191063
5	25958	10383200	0.2	0.399481	0.199481	0.257013	0.039701	6671.549666	0.253035	0.3116
6	89	35600	0.4	0.481102	0.081102	0.423887	0.019171	37.725969	0.420101	0.451294



Toolbox Updates Version 1.1



HAB Index Estimation Tool update:

Removal of the CI index from the Phycocyanin parameter and User's Guide Documentation

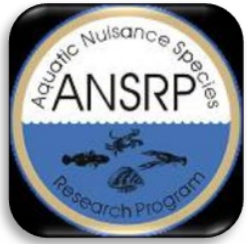
Anticipated Release Date:

March 2022

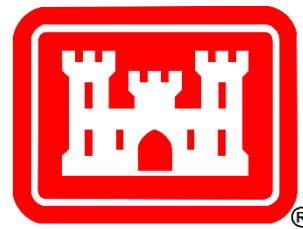
Request for feedback: Sentinel Hub connection issue (urllib3.py)

Christina Saltus:

Email: Christina.L.Saltus@erdc.dren.mil



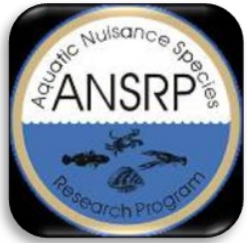
HAB Explorer



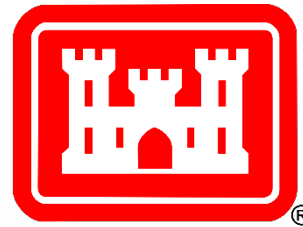
- ❖ Prototype developed by ESRI with design/input/testing from ERDC (Phase 1)
- ❖ Fast, simple way to assess inland lakes and reservoirs, in which constrained algorithm and visualization options allow for rapid screening of potential HAB conditions
- ❖ Hosted on the uCOP Production Portal (Corpsnet*); Best viewed in Google Chrome
 - *Requires VPN or USACE network access (to pull CAC credentials); RDE users via CANPC

HAB Explorer available on the uCOP!

<https://arcportal-ucop-corps.usace.army.mil/hab/>

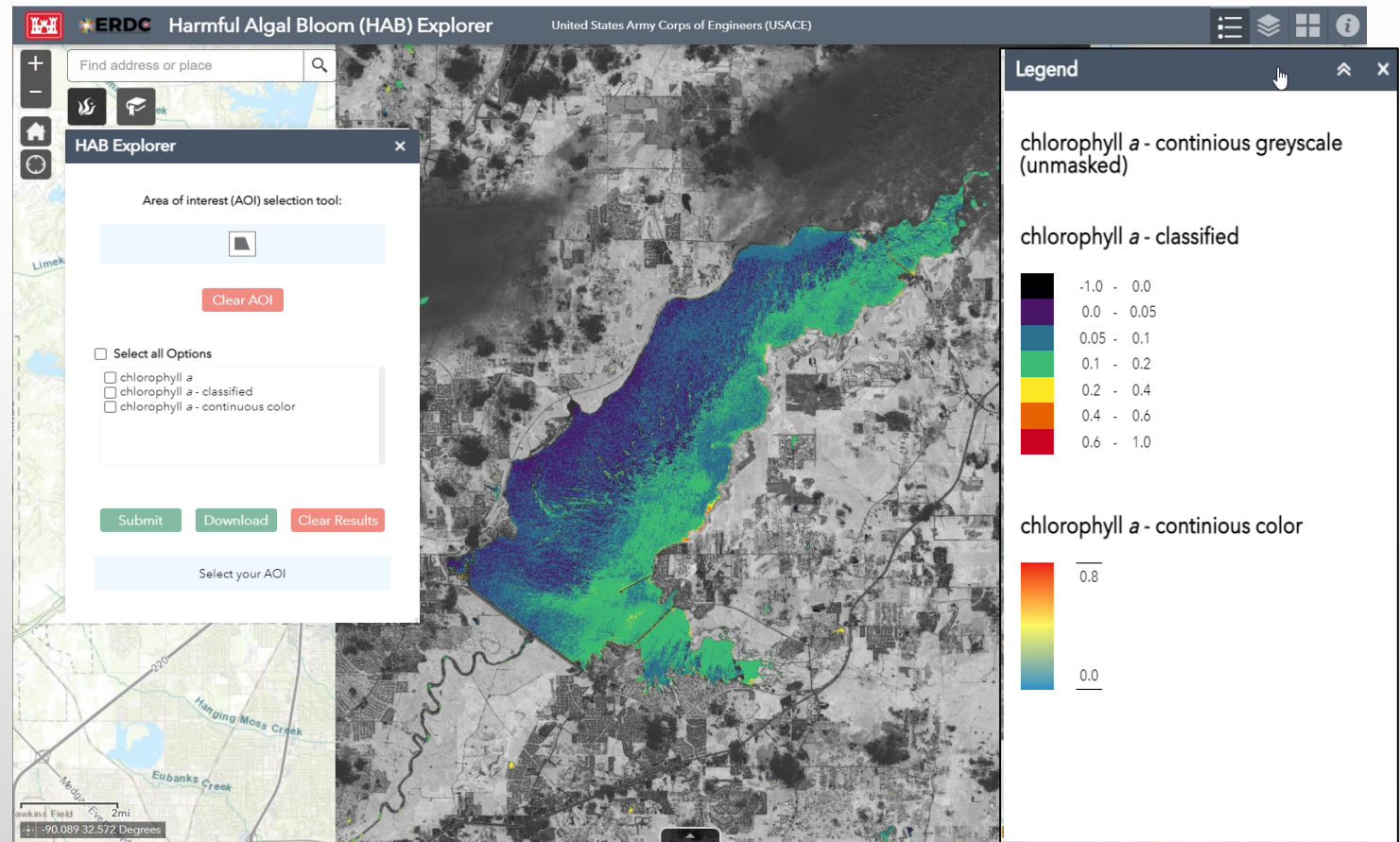


HAB Explorer

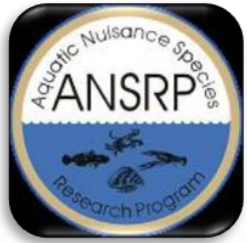


- Accesses ESA's Sentinel-2 L2A imagery via a cloud-based image service (most recent image meeting cloud threshold available)
- On-the-fly application of the Normalized Difference Chlorophyll Index (NDCI)
 $(B5-B4) / (B5+B4)$
- Two colored map products to help visualize the relative estimation of chl-a, HAB indicator
- Makes use of ESA scene classification to remove non-water pixels (i.e., land and clouds)

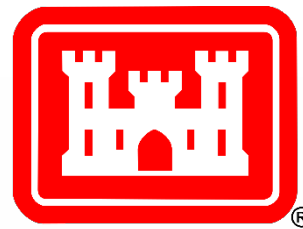
Ross Barnett Reservoir, MS Aug 2021



<https://arcportal-ucop-corps.usace.army.mil/hab/>



HAB Explorer



Five steps to produce & download a map illustrating relative estimation of chl-a

Milford Lake, KS Aug 2021



Classified

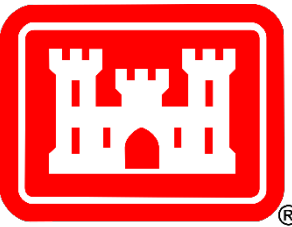
Continuous

1. Select AOI (extent is limited)
2. Check box for desired symbology option (all, continuous, or classified)
3. Submit options/AOI (wait ~30 – 45 seconds for algorithm processing)
4. View layer results – toggle on/off
5. Download geotagged tiffs and view in GIS desktop software with other spatial data*
*change color stretch type to None

<https://arcportal-ucop-corps.usace.army.mil/hab/>



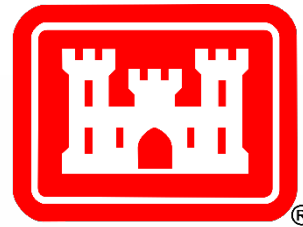
Use Considerations



1. **Area of interest** - size is limited to 750km² depending on the orientation of the area drawn; doesn't need to be detailed
2. **Clouds** - 35% threshold applied in the background, not adjustable; display in grey scale
3. **Symbology** - classified and continuous color options for water pixels only; 1 grey scale option for all pixels – all have same value ranges, -1 to 1
4. **Scene edges** - some lakes fall on scene boundaries; each scene is analyzed separately so scene edges may be apparent especially if they are from different dates
5. **Scene dates** - currently not listed in the web app
6. **Results** – dependent upon ESA scene classification (misclassifications of land/water/clouds may result in potential artifacts, such as land/clouds getting classified as water which may register as high in chl-a and/or water getting classified as clouds, which may result in omitted lake areas); artifacts tend to appear as “noise” or pixelated areas, which can occur near the shoreline, in dried up lakebeds, and/or near cloud edges
7. **Downloaded tiffs** - multiband images do not display in photo/paint or other graphics software; must be displayed in GIS software (change color stretch type to None to maintain color symbology)



Splash Screen




ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

Disclaimer

Welcome to the Harmful Algal Bloom (HAB) Explorer!



This application is meant to assist viewers with monitoring HABs in freshwater systems using readily available satellite imagery and was developed with support from the U.S. Army Corps of Engineers Aquatic Nuisance Species Research Program ([ANSRP](#)). The map products generated within the application show relative estimations of HAB water quality indicators and are intended as a cursory screening tool to quickly identify potential areas of concern that may require additional monitoring. The analytical methods used to generate the map products are based on current techniques available in the scientific literature and are subject to change as part of on-going research and development.

The user assumes and acknowledges the responsibility for determining accuracy, appropriateness for use, and acceptance of any data limitations.

I agree to the above terms and conditions

The recommended browser is Chrome.

Do not show this again

Ok

300mi

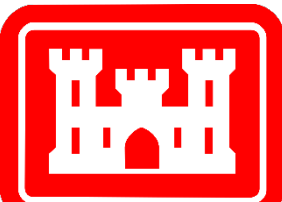
Move mouse to get coordinates

POWERED BY esri

Esri, HERE, Garmin, FAO, NOAA, USGS, EPA



Widgets and Tools



The screenshot shows the ERDC Harmful Algal Bloom (HAB) Explorer web application. The interface includes a search bar at the top left, a vertical toolbar with icons for home, refresh, and zoom, and a main map area. On the right side, there are panels for the legend, layer list, basemap gallery, and about page. Red arrows point from text labels to these specific UI elements.

ERDC Harmful Algal Bloom (HAB) Explorer
United States Army Corps of Engineers (USACE)

Find address or place

Search Bar

HAB Explorer and Bookmark Widgets

Basic map function tools

Legend

Layer List

Basemap Gallery

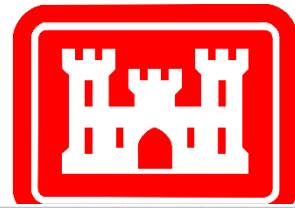
About

200mi
-117.807 44.822 Degrees

POWERED BY esri



HAB Explorer Widget



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

Select the HAB Explorer Widget

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

Submit Download Clear Results

Select your AOI

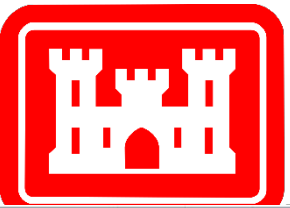
200mi -117.807 44.822 Degrees

POWERED BY esri

Esri, HERE, Garmin, FAO, NOAA, USGS, EPA



Area of Interest Selection




ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

 **Zoom to region or use the search bar. Draw AOI**

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

Submit Download Clear Results

Select your AOI

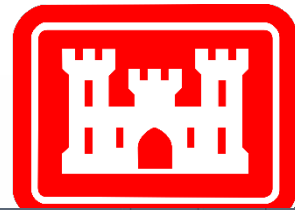
Map labels: Wakefield, Milford, Fort Riley Military Reservation, Ogden, Junction City, Grandview Plaza, Manhattan, Spillway State Park, Tuttle Creek State Park, POTTAWATOMIE, Fort-Rie Blvd, Sevenmile Creek, Wildcat Creek, Timber Creek, Milford Lake, Lark Rd, Talmage, 77, 24, 18, 40, 15, 177, 4mi, -97.140 39.352 Degrees

POWERED BY esri

Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS



Area of Interest Selection



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

Submit Download Clear Results

Your area of interest encompasses: 218.59 Km2

Wakefield Id, Milford Lake, Milford, Fort Riley Military Reservation, Manhattan, Ogden, Junction City, Grandview Plaza, Talmage

Timber Creek, Wildcat Creek, Spillway State Park, Tuttle Creek State Park, Colbert Hills, Fort Riley Blvd, Sevenmile Creek, 77, 24, 18, 40, 177

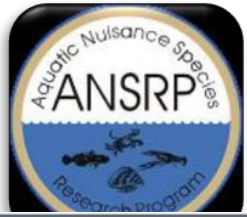
4mi -96.840 39.339 Degrees

POWERED BY esri

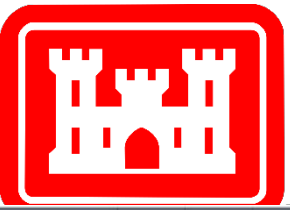
Esri, HERE, Garmin, USGS, NGA, EPA, USDA, NPS

You must select a symbology option in order to submit a request. If none are selected, it will not work. If you're unsure, select all.

Note that the area size is listed here once you draw an area



Area of Interest Selection



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

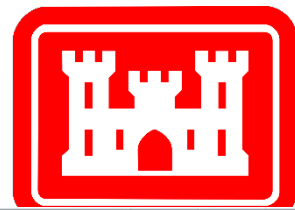
Submit Download Clear Results

The selected area (934.0) exceeds max (750 km2), please re-select

If the max extent is exceeded, a message will indicate that here



Area of Interest Selection



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

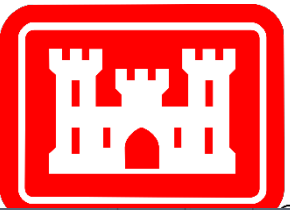
Submit Download Clear Results

Select your AOI

Clear the AOI if drawn in error or it exceeds the limit and redraw



Submit Request



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

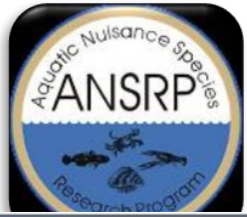
Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

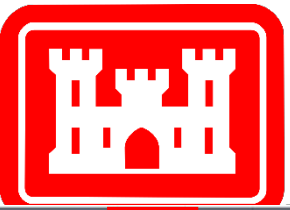
Submit Download Clear Results

Your area of interest encompasses: 218.59 Km²

Submit request



View Results



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

Submit Download Clear Results

Select your AOI

Layer List

Layers

- chlorophyll a - continuous color
- chlorophyll a - classified
- chlorophyll a

Zoom to

Transparency

Set visibility range

Move up

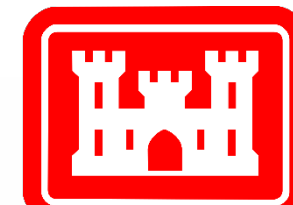
Move down

View in Attribute Table

Description



Download Results



ERDC Harmful Algal Bloom (HAB) Explorer United States Army Corps of Engineers (USACE)

Find address or place

HAB Explorer

Area of interest (AOI) selection tool:

Clear AOI

Select all Options

- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

Submit Download Clear Results

All done!

Download

- Select all
- chlorophyll a
- chlorophyll a - classified
- chlorophyll a - continuous color

OK Cancel

About

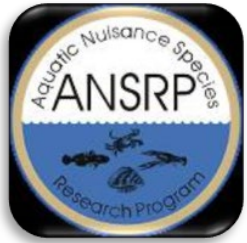
Harmful Algal Bloom (HAB) Explorer

Bloom Photo Credit Tulsa District USACE

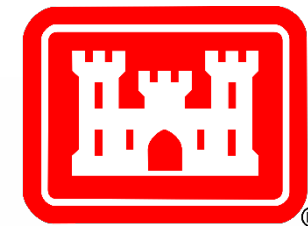
This viewer is part of research and development conducted at the U.S. Army Corps of Engineers (USACE), Engineer Research and Development Center's (ERDC) Environmental Laboratory with support from the USACE Aquatic Nuisance Species Research Program (ANSRP).

The goal of the project is to develop a series of remote sensing software tools (ranging in complexity and utility) to assist with water quality monitoring of HABs in small, inland waterbodies (primarily reservoirs and lakes managed by USACE Districts). These include: 1) an open-source R software package, [waterquality](#), 2) an ESRI ArcGIS Pro desktop software toolbox, and 3) an online ESRI-based web application.

The viewer utilizes the Normalized



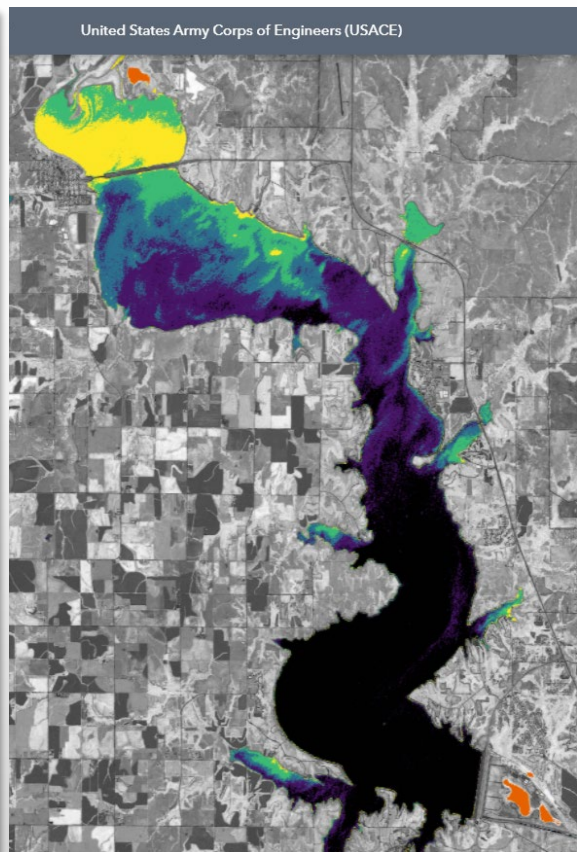
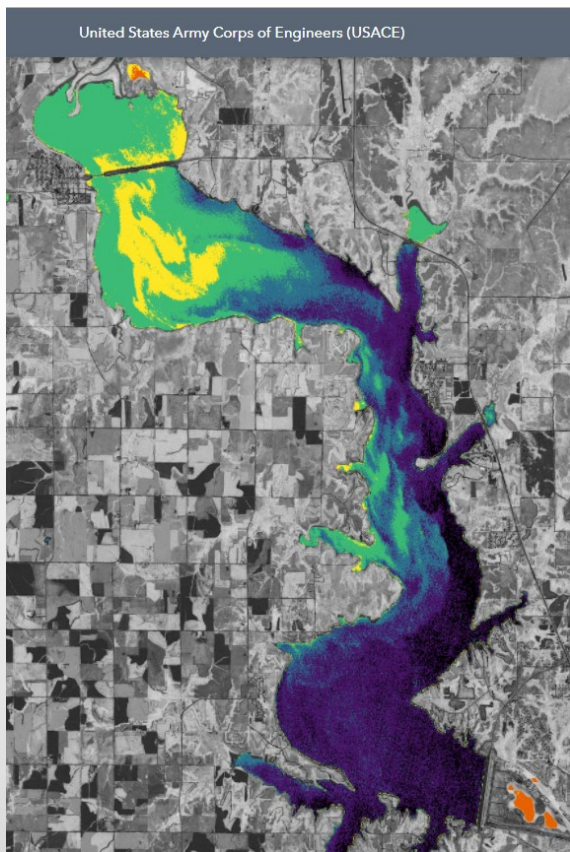
HAB Explorer Benefits



Aug, 2021

Milford Lake, KS

Sept, 2021

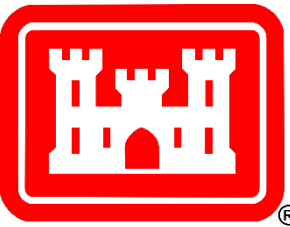


- Monitor whole-lake changes over time
- Visualize surface and near-surface phytoplankton biomass estimated through the NDCI
- Can help to initiate and prioritize location and timing of field-based sampling
- No GIS Desktop software required

<https://arcportal-ucop-corps.usace.army.mil/hab/>



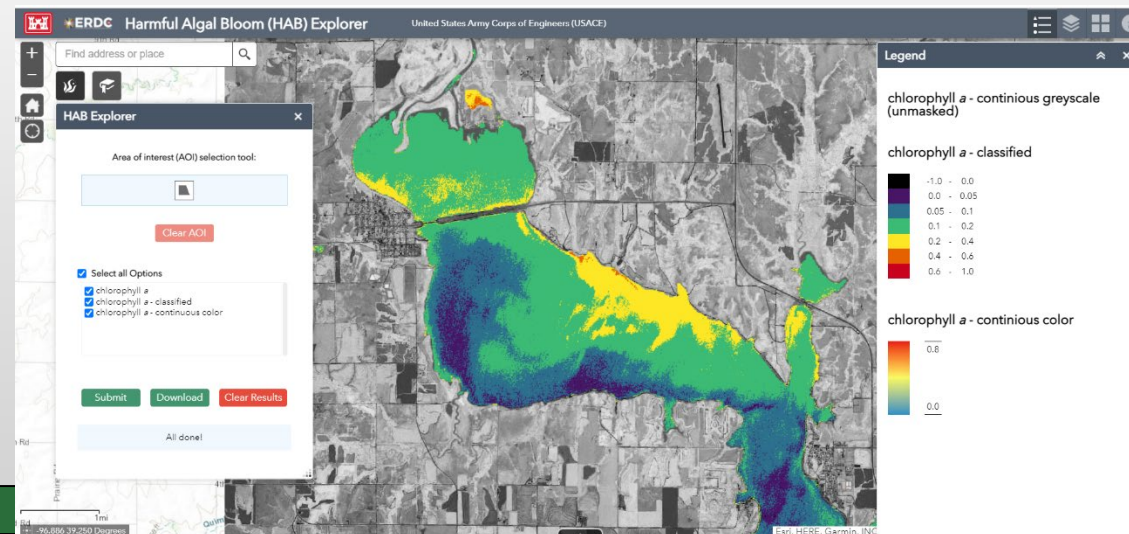
Phase 2 Development?

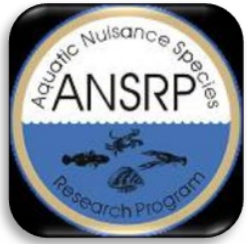


1. Display date of source image
2. Display the source image (RGB version)
3. Clean up legend values, spelling, orientation (consistency)
4. Increase the AOI extent limit (can't exceed 1600km²)
5. Return pixel value of results when hovering (info button)?
6. Include more algorithms?
7. Generate results for past imagery?

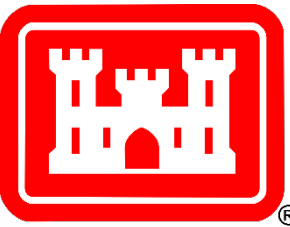


Milford Lake; Photo Credit USACE Kansas City District

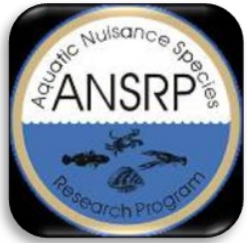




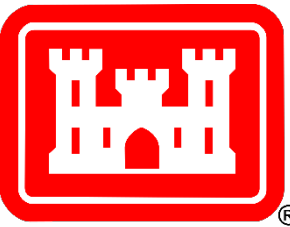
Interpreting Results...



1. **Algorithm estimations are locally-dependent**
 - Compare to in-situ data to better define what relative values mean in your area ... no hard/fast rules to define values for all datasets in all areas
2. **Algorithm accuracies are good, but every waterbody is unique**
 - The tools help streamline the process to explore/understand potential bloom trends in your area
3. **Start with NDCI if unsure or don't have in-situ data**
 - It's normalized/consistent similar to NDVI
 - GENERAL guidance: <0 = minimal/no chl-a; $0 - 0.2$ = low chl-a, and $> 0.2/0.3$ = higher chl-a with values approaching 1 to be the most consequential for HAB potential; anything more specific requires comparison to in-situ data
 - Watch values $>0.2/0.3$, pending movement/dynamics/persistence; could either be a HAB or be conducive for HAB development
4. **Use the tools to target field-based resources in space/time to increase monitoring efficiency**
 - The tools allow large area assessment in a matter of hours that would otherwise take days/weeks to sample
5. **New R&D to build confidence and understanding of the algorithms**
 - To help determine which ones work best in which waterbodies, environments, etc.



Follow-up & Contact List



These tools were specifically designed to assist the USACE monitoring of inland lakes and reservoirs to estimate water quality indicators of HABs. Your feedback is a critical component to the success and future development of these tools and ensuring that the capabilities and products generated are consistent with your priorities.

1. Need help? Please send us your in-situ measurements!
2. Provide feedback about the HAB Explorer!

- **Christina Saltus:**

Email: Christina.L.Saltus@erdc.dren.mil

- **Molly Reif:**

Email: Molly.K.Reif@usace.army.mil

- **Richard Johansen:**

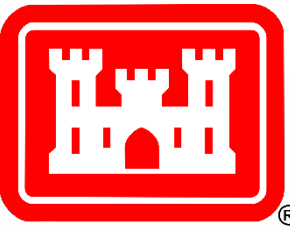
Email: Richard.A.Johansen@usace.army.mil

- **Erich Emery:**

Email: Erich.B.Emery@usace.army.mil



Tool Links



- Open Source R Package:
<https://github.com/RAJohansen/waterquality>
- ArcGIS Pro Toolbox:
<http://dx.doi.org/10.21079/11681/42240>
- HAB Explorer Web App:
<https://arcportal-ucop-corps.usace.army.mil/hab/>