DEMONSTRATION OF A LIGHT AVAILABILITY CALCULATOR FOR IDENTIFYING SUITABLE HABITAT FOR LIGHT-LIMITED AQUATIC VEGETATION

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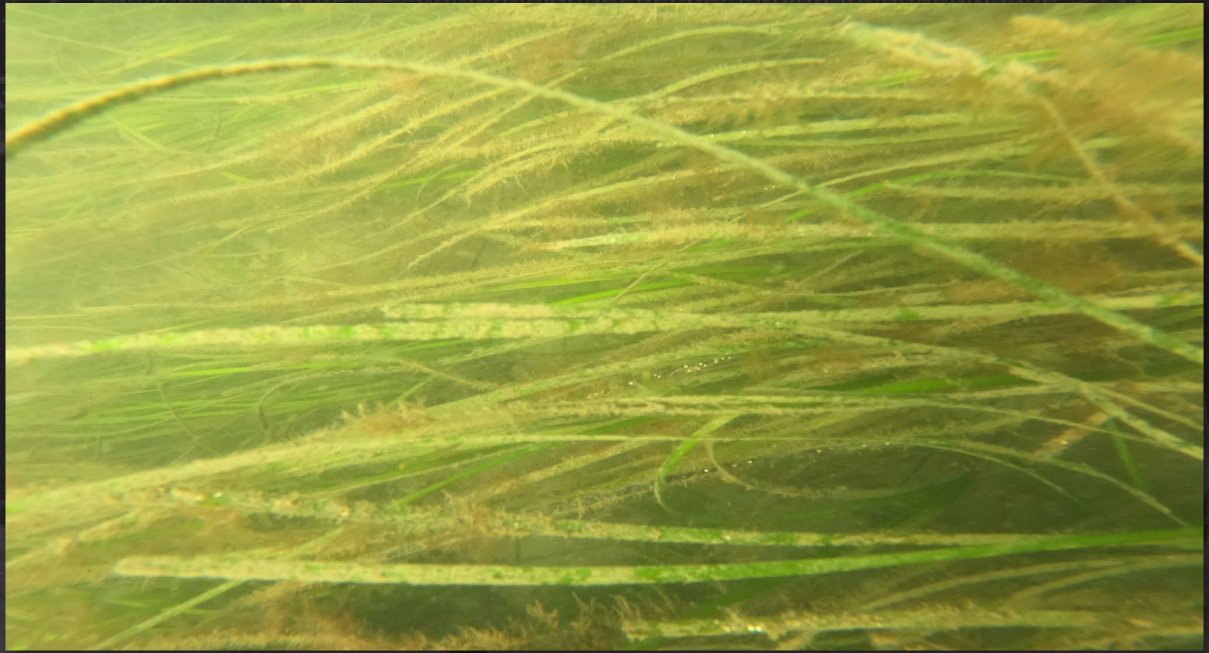
EMRRP Webinar Series



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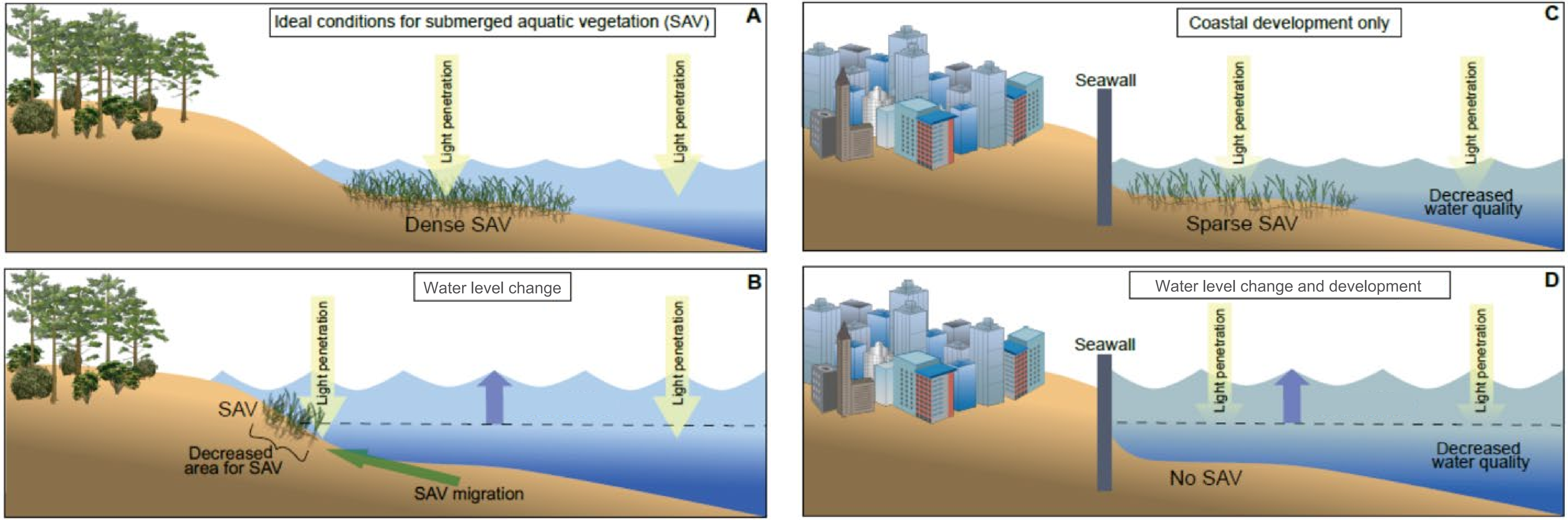
DREDGED MATERIAL CAN BENEFIT SAV

- SAV habitats declining due to environmental and anthropogenic stressors (Waycott et al. 2009)
- Expansion is hindered by developed shorelines (i.e., coastal squeeze)

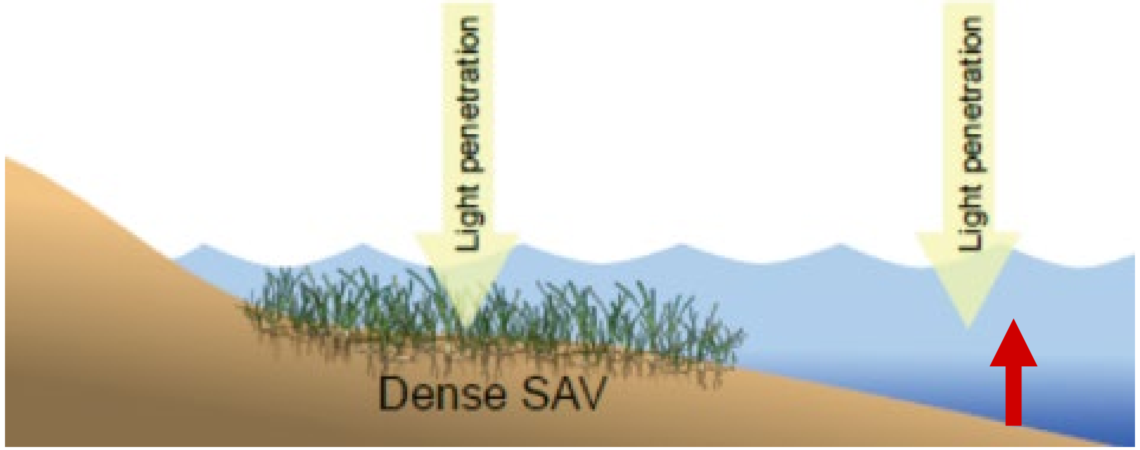
Source: Russ et al. 2023

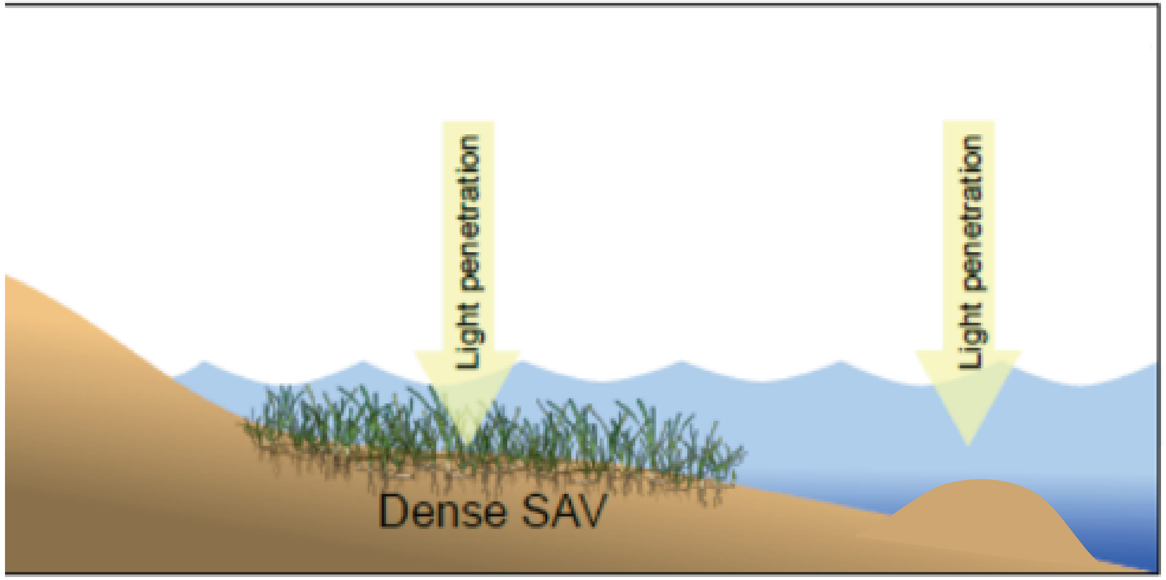


DREDGED MATERIAL CAN BENEFIT SAV

- Dredged material can elevate light-limited areas to support SAV if other suitability conditions met (Russ et al. 2023)

- SAV roots and rhizomes can stabilize sediment bed, limiting re-entry of BU back into navigation channel (Marin-Diaz et al., 2020)

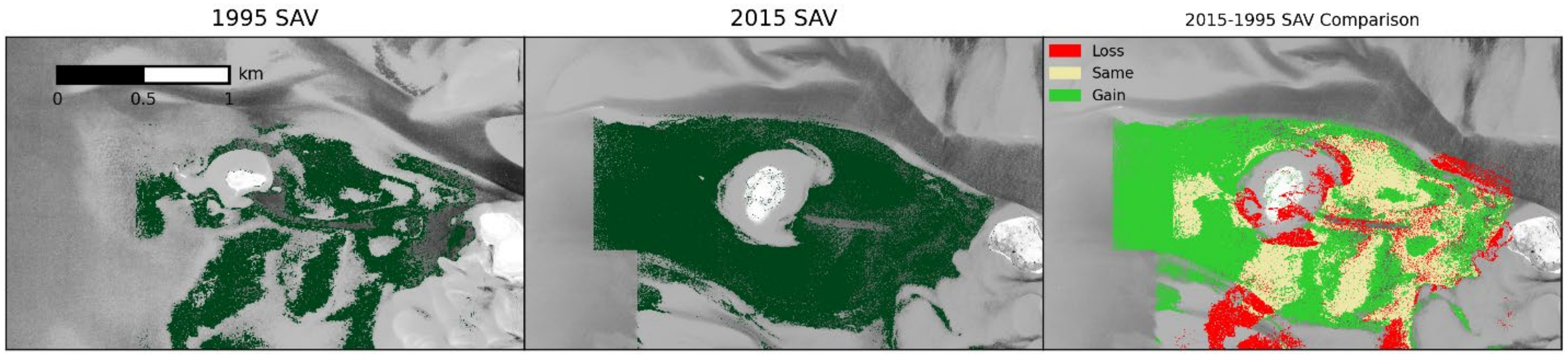




BUDM FOR SAV LIMITED BY NEGATIVE PERCEPTIONS

- **Perception:** Dredging and placement harms SAV habitats

- **Evidence:** SAV are resilient to/can recover from dredging, placement, and burial events (Russ et al., 2023; Duarte et al., 1997; Cabaço et al., 2008; Hirst et al., 2017)



Source: Russ et al. 2023

- Risk-averse resource management approach limits study/data collection

- Lack of guidance on planning, construction, and monitoring

- Need more tools, educational resources, monitoring support (Russ et al. 2025)

SIMPLE TOOL CAN HELP JUSTIFY BUDM FOR SAV

Using known relationships between water depth and light attenuation, we developed a geospatial calculator to help determine whether depths or depth changes (e.g., due to BU) can support SAV light requirements.

- User-adjustable light requirement for unique species needs (default taken from literature)
- Includes enhanced turbidity due to wave suspension (total = background + wave-derived)
- Additional assumptions*

Light availability calculator is designed to be:

- User friendly
- Easily interpretable
- Rapid calculator
- Scenario-planning tool

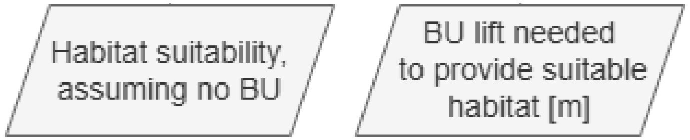
All of today's webinar content is in our forthcoming TN (mgmt. review)

CONCEPTUAL DIAGRAM

Calculator inputs

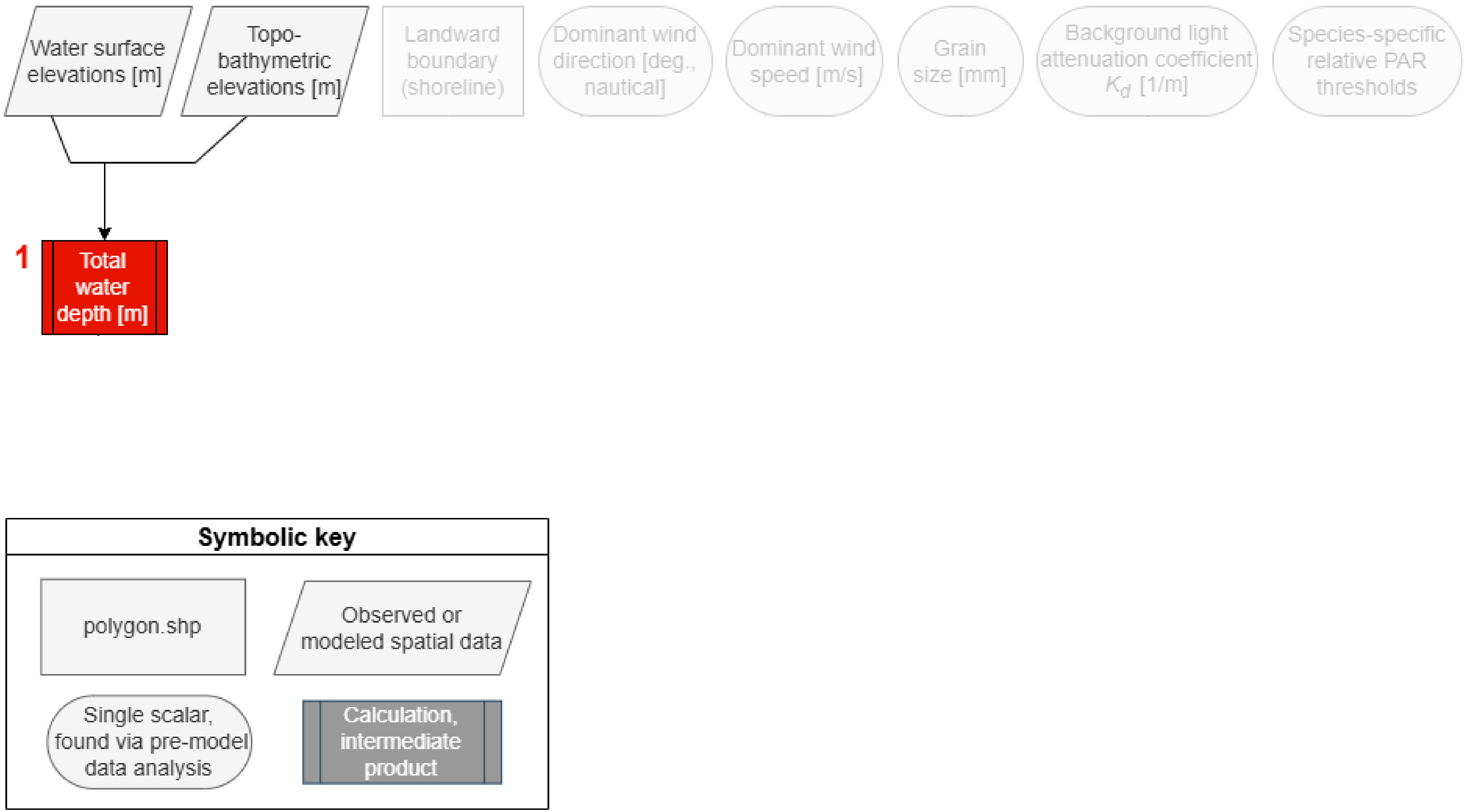
- **Raster files – developed using best-available data and/or numerical model output**
  - Water Surface Elevation [m], representative of time of interest (today, 2050, etc.)
  - Topo-bathymetric elevations [m], representative of time of interest
- **Shapefile/polygon**
  - Land/water boundary
- **Scalar value – user defined with default provided**
  - Grain size d50 [mm], background light attenuation coefficient K_d [1/m], species-specific PAR threshold, dominant* wind speed [m/s], dominant* wind direction [deg]
  - PAR – photosynthetically active radiation

- **Raster** – Habitat suitability, assuming no BU
- **Raster** – BU lift required to provide suitable habitat

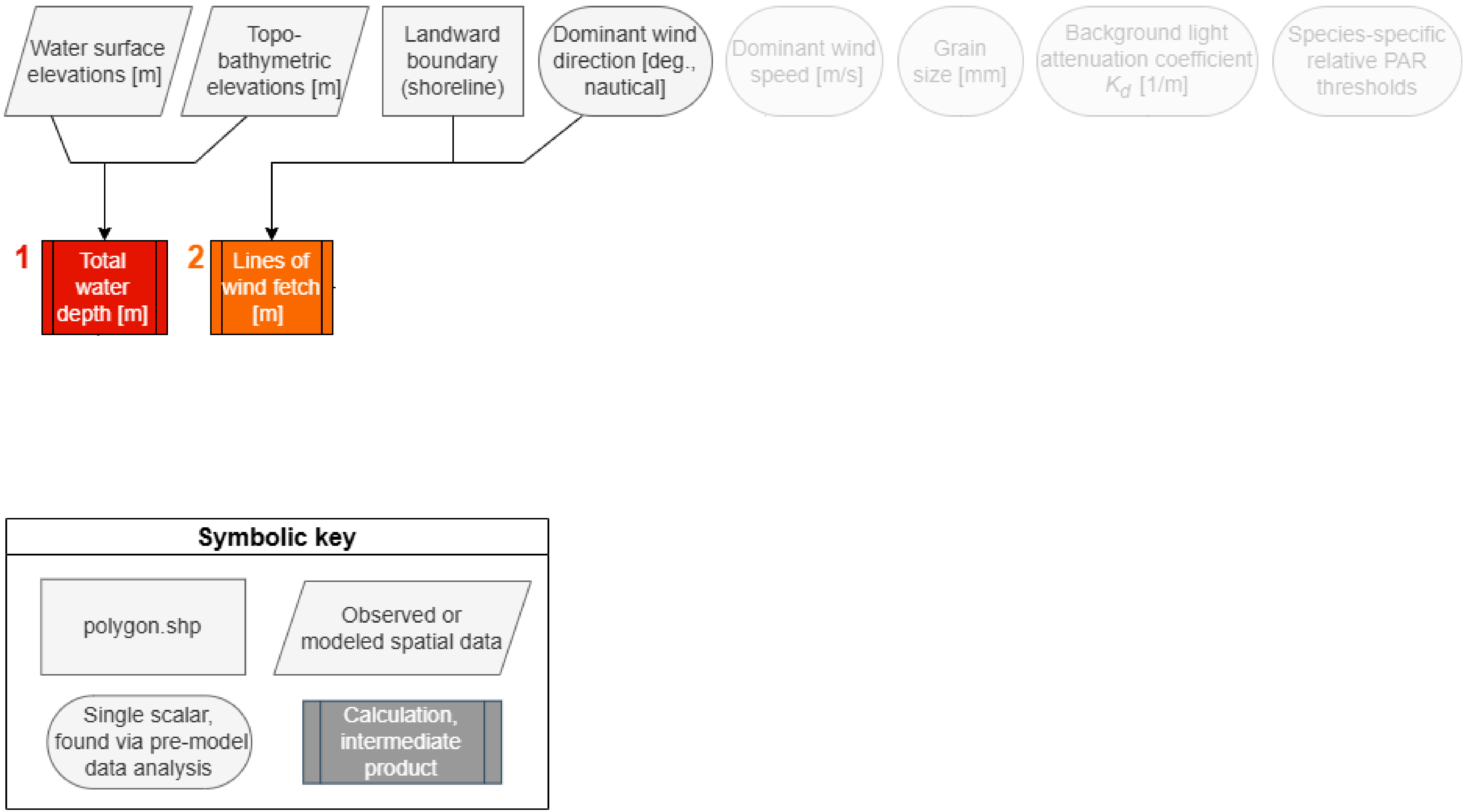


Calculator outputs

STEP 1 – CALCULATE TOTAL WATER DEPTH



STEP 2 – CALCULATE WIND FETCH LENGTH



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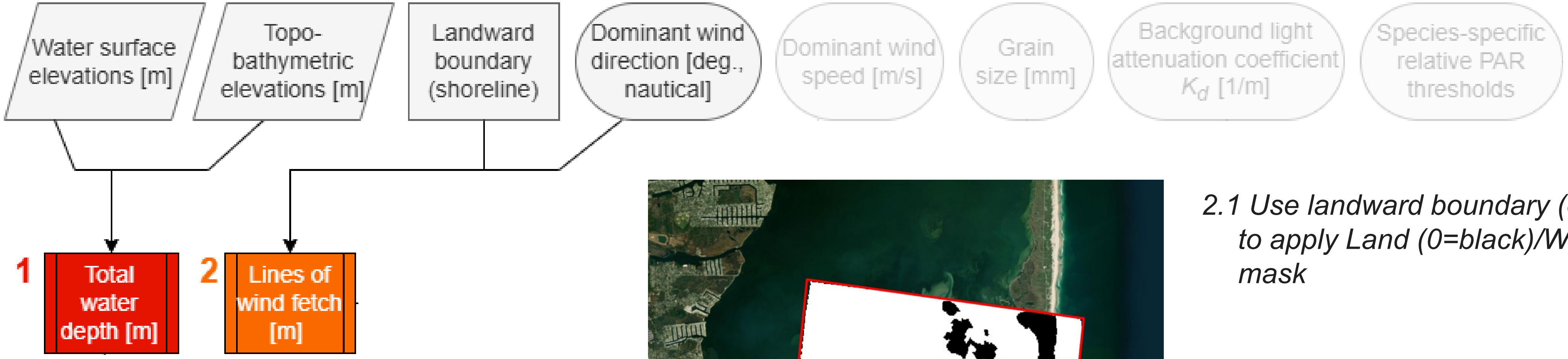
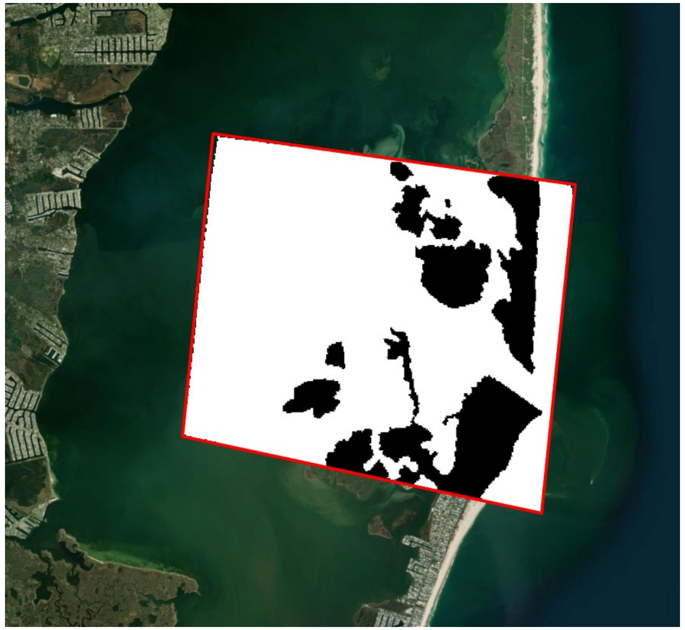
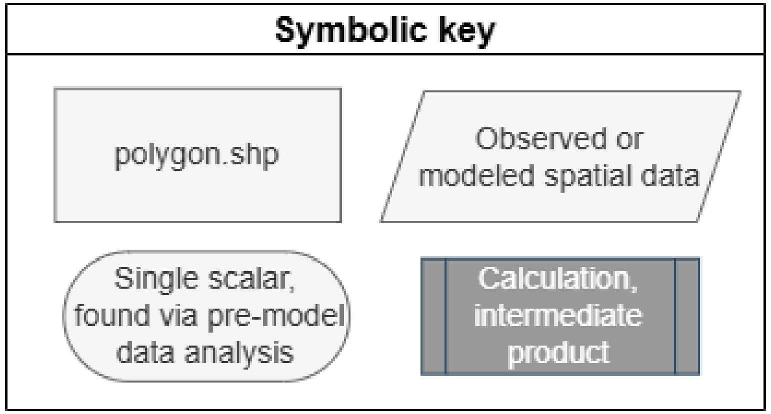




2.1 Use landward boundary (e.g., shoreline) to apply Land (0=black)/Water (1=white) mask



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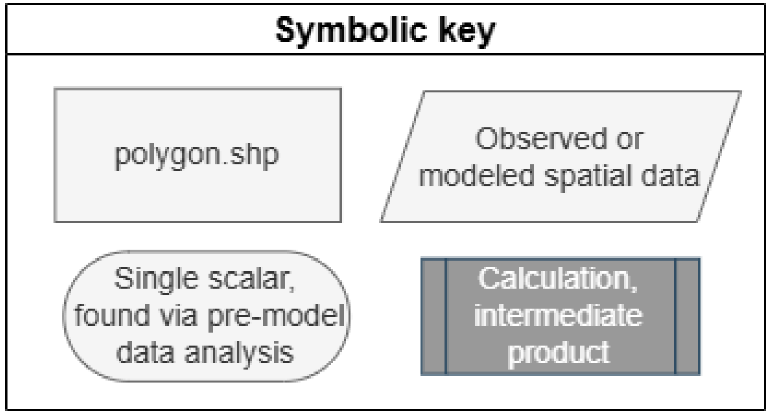
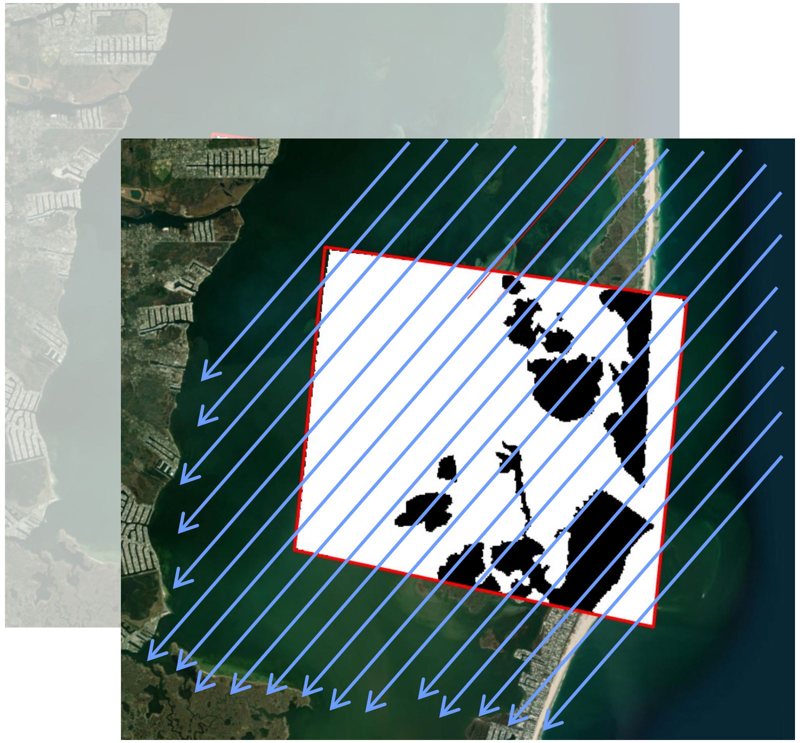
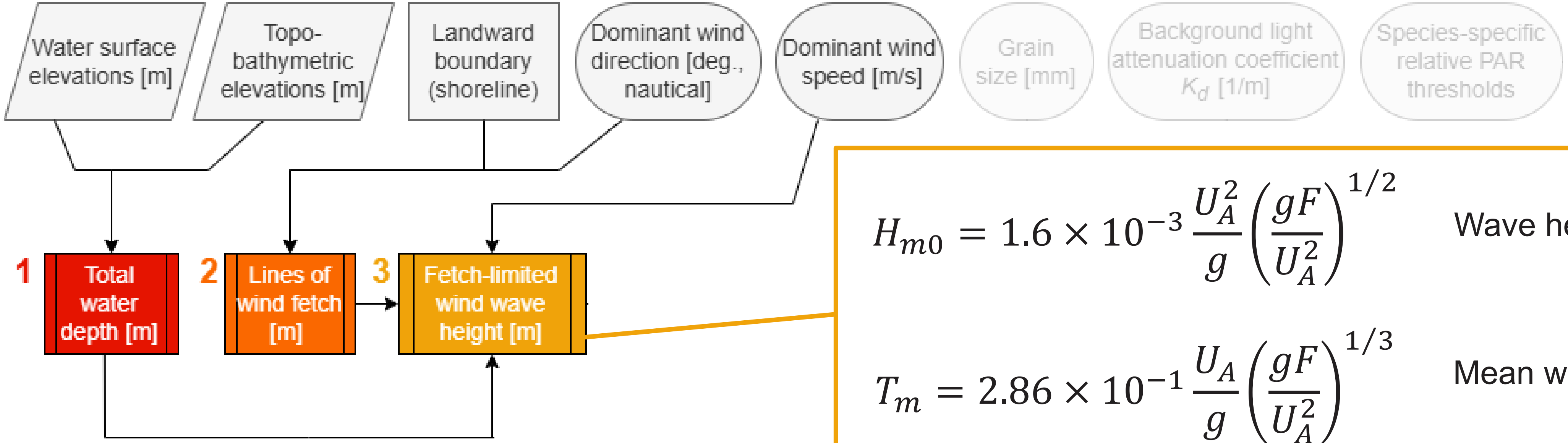




2.2 Create fetch lines corresponding to dominant wind direction, applied over entire ROI

STEP 3 – FETCH LIMITED WAVE HEIGHTS



$$H_{m0} = 1.6 \times 10^{-3} \frac{U_A^2}{g} \left(\frac{gF}{U_A^2}\right)^{1/2}$$ Wave height

$$T_m = 2.86 \times 10^{-1} \frac{U_A}{g} \left(\frac{gF}{U_A^2}\right)^{1/3}$$ Mean wave period

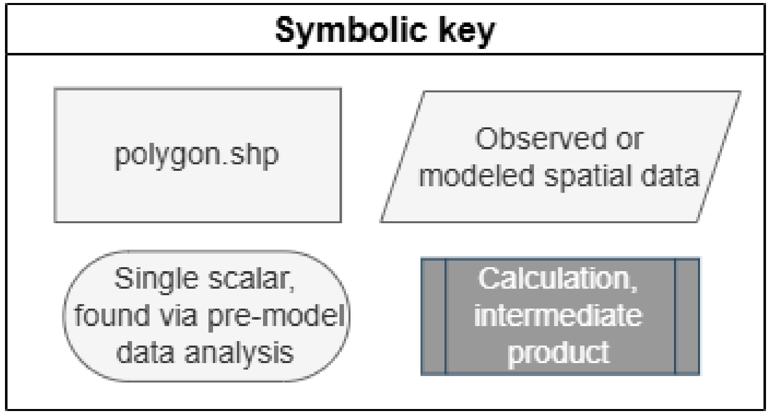
$U_A = 0.71U^{1.23}$ Wind stress factor

$T_p = 1.2T_m$ Peak wave period

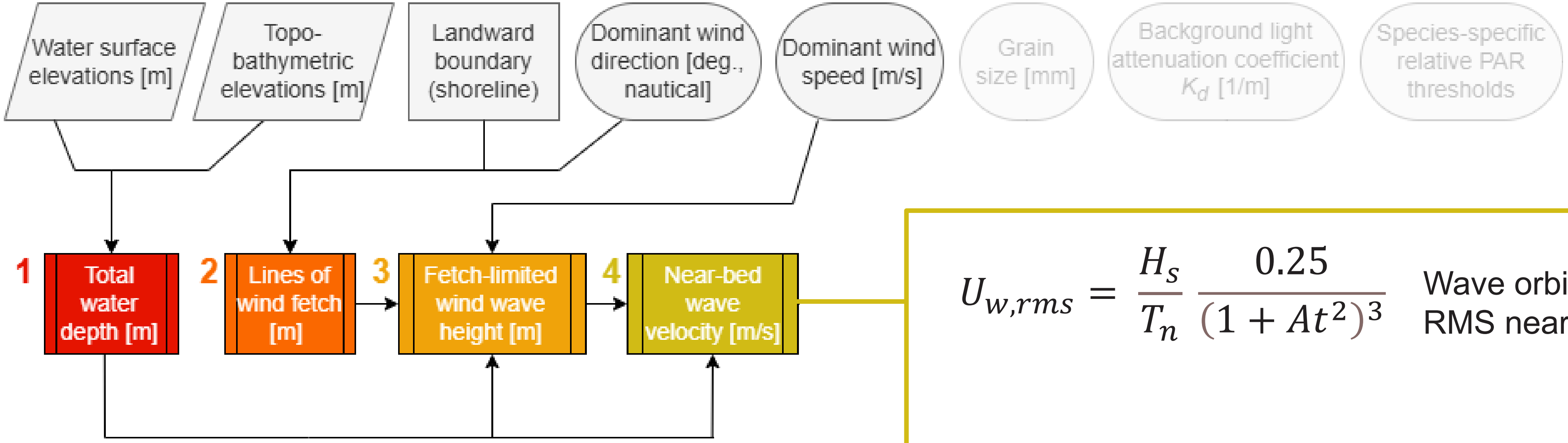
$H_s = H_{m0}/1.2$ Significant wave height

F – fetch length

U – wind speed (input)



STEP 4 – NEAR BED WAVE ORBITAL VELOCITY



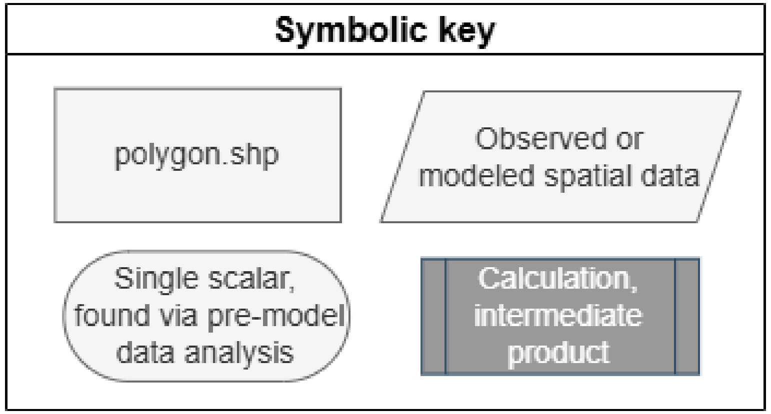
$$U_{w,rms} = \frac{H_s}{T_n} \frac{0.25}{(1 + At^2)^3}$$

Wave orbital velocity, RMS near bed

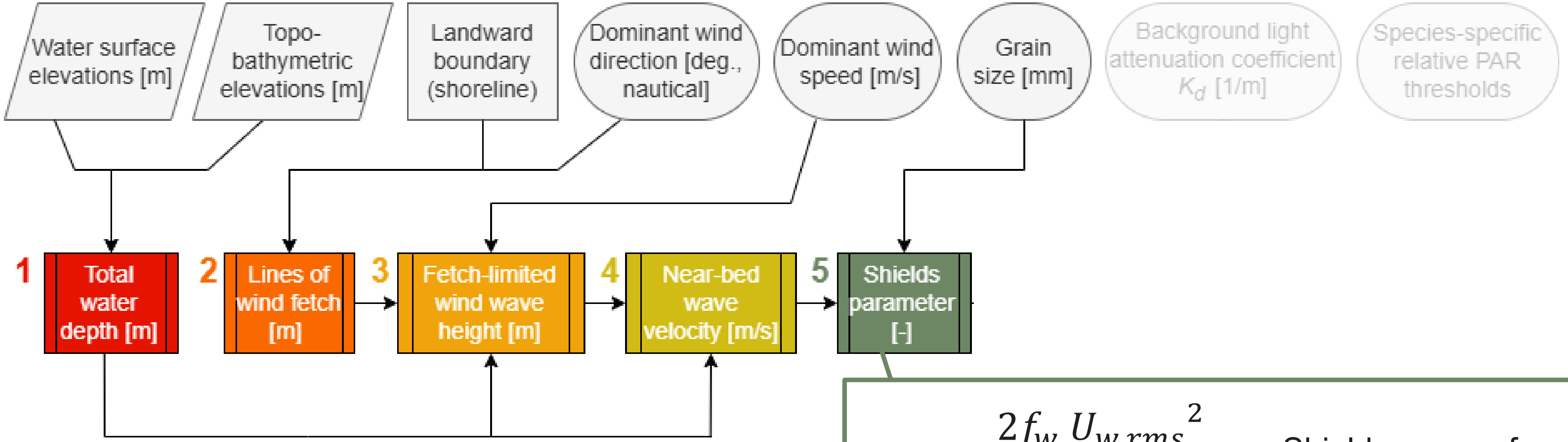
$$A = (6500 + (0.56 + 15.54t)^6)^{1/6}$$

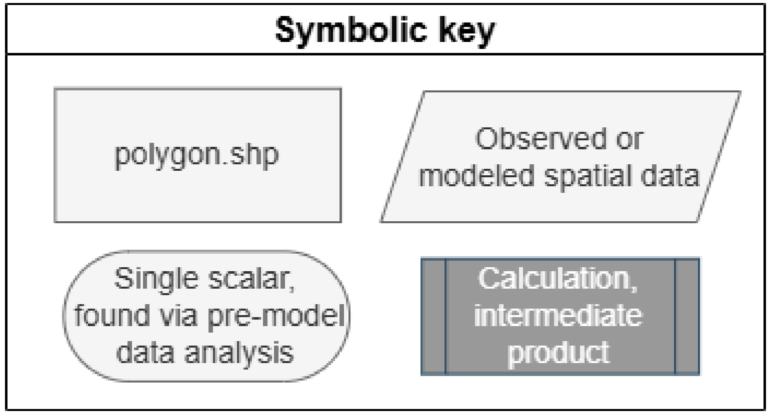
$$t = \sqrt{h/0.61\, gT_p^2}$$

$$T_n = \sqrt{h/g}$$



STEP 5 – DETERMINE SEDIMENT MOBILITY





$$\theta_w = \frac{2 f_w \, {U_{w,rms}}^2}{2g \, d_{50} \, (s-1)}$$

Shields param. from computed wave conditions

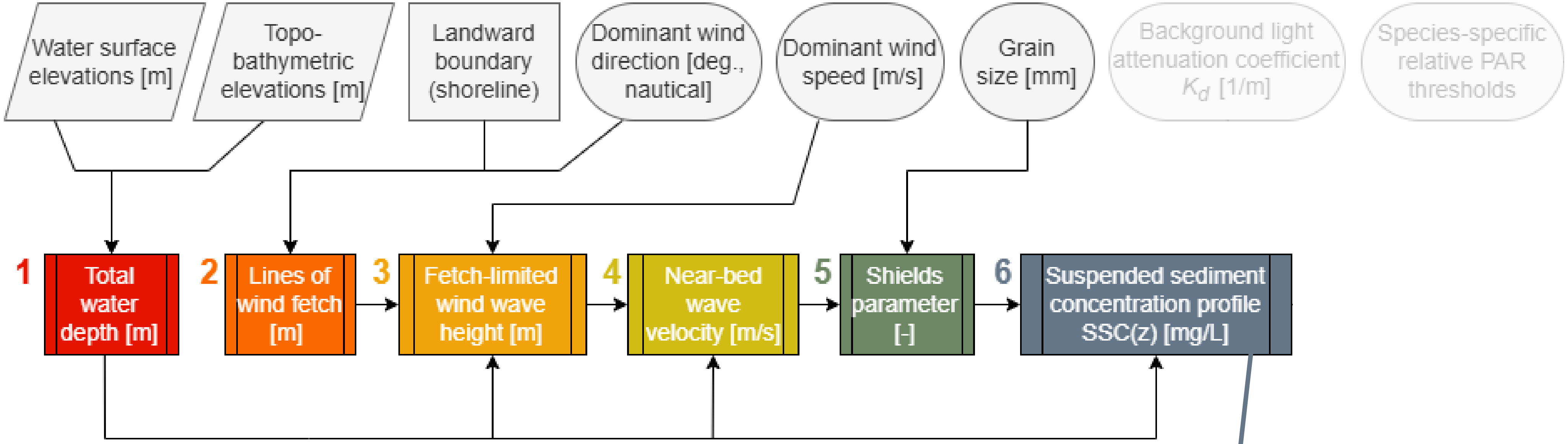
$$\theta_{cr} = \frac{0.30}{1 + 1.2 D_*} + 0.055[1 - \exp(-0.020 D_*)]$$

Minimum Shields param. required for sediment movement

$$D_* = d_{50} \left[\frac{g(s-1)}{\nu^2} \right]^{1/3}$$

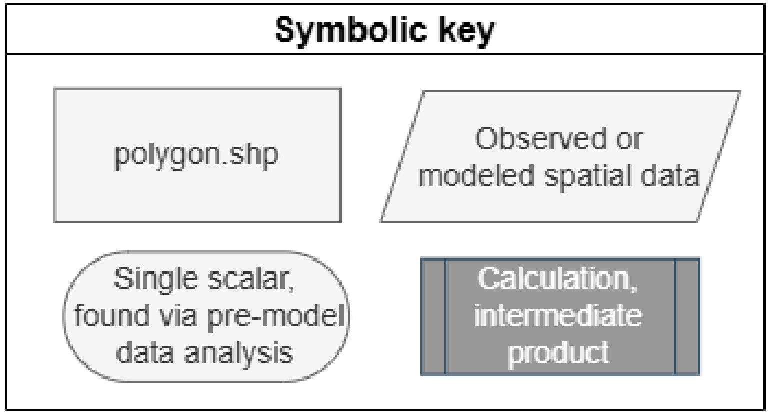
Dimensionless grain size

STEP 6 – SUSPENDED SEDIMENT CONCENTRATION

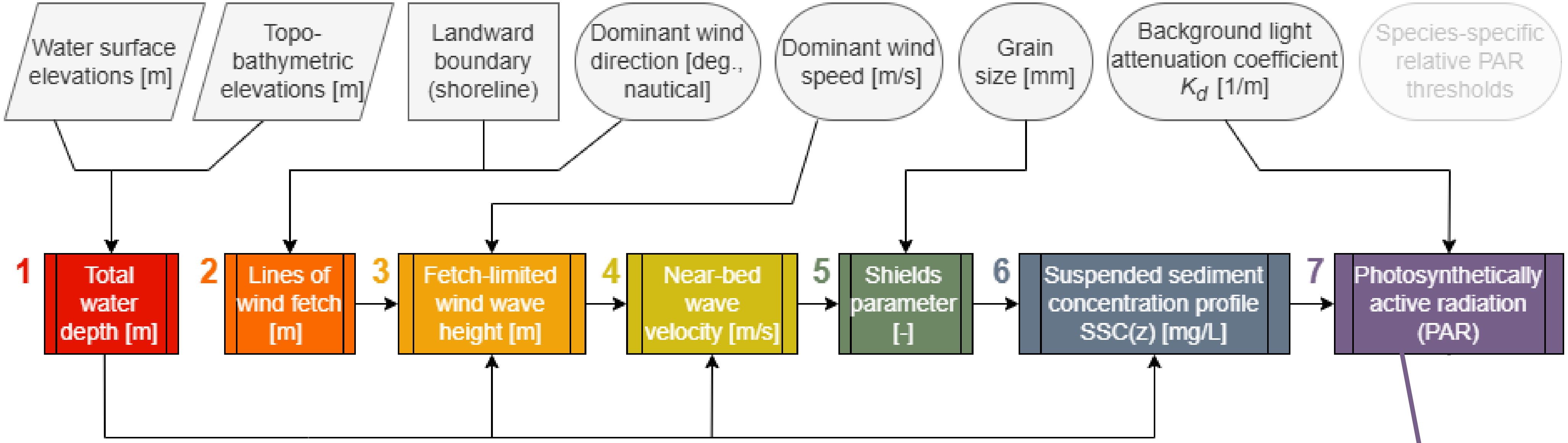


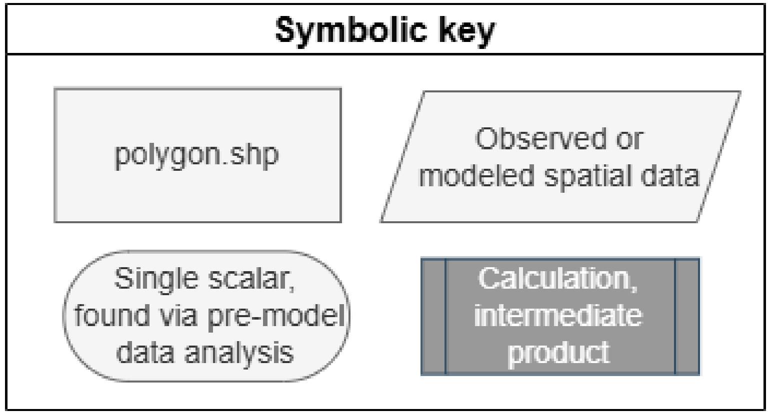
$$C_0 = 0.005\theta_w^3$$ Near bed sediment concentration

$$C_s(z_i) = C_0 \exp\left(\frac{-w_s}{\nu} z_i\right)$$ Sediment concentration profile



STEP 7 – LIGHT ATTENUATION COEFFICIENT & PAR

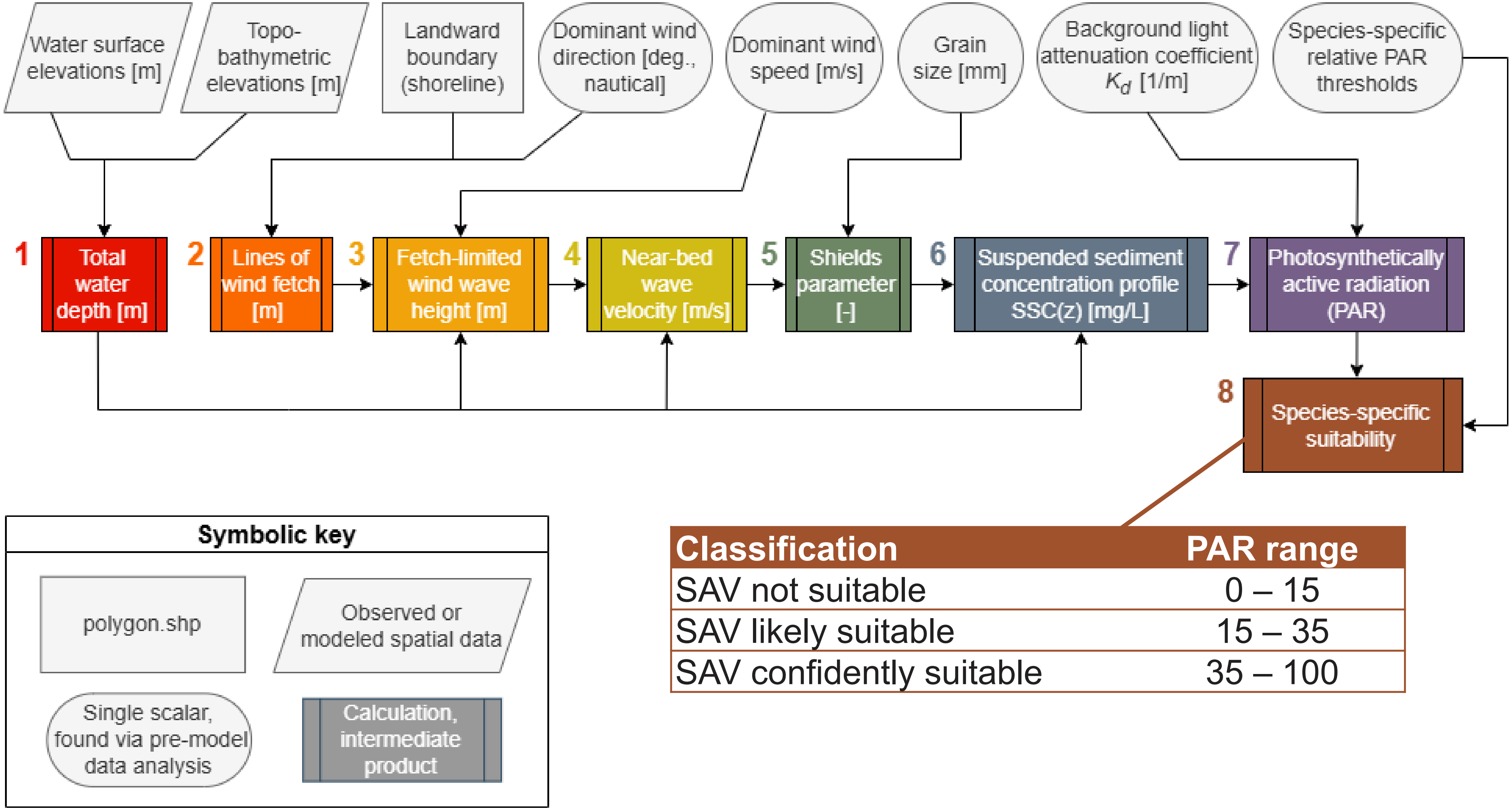




$$K_{d,w} = \sum_{i=1}^{N} 0.026 C_s(z_i)$$ Light attenuation due to sediment suspension by waves

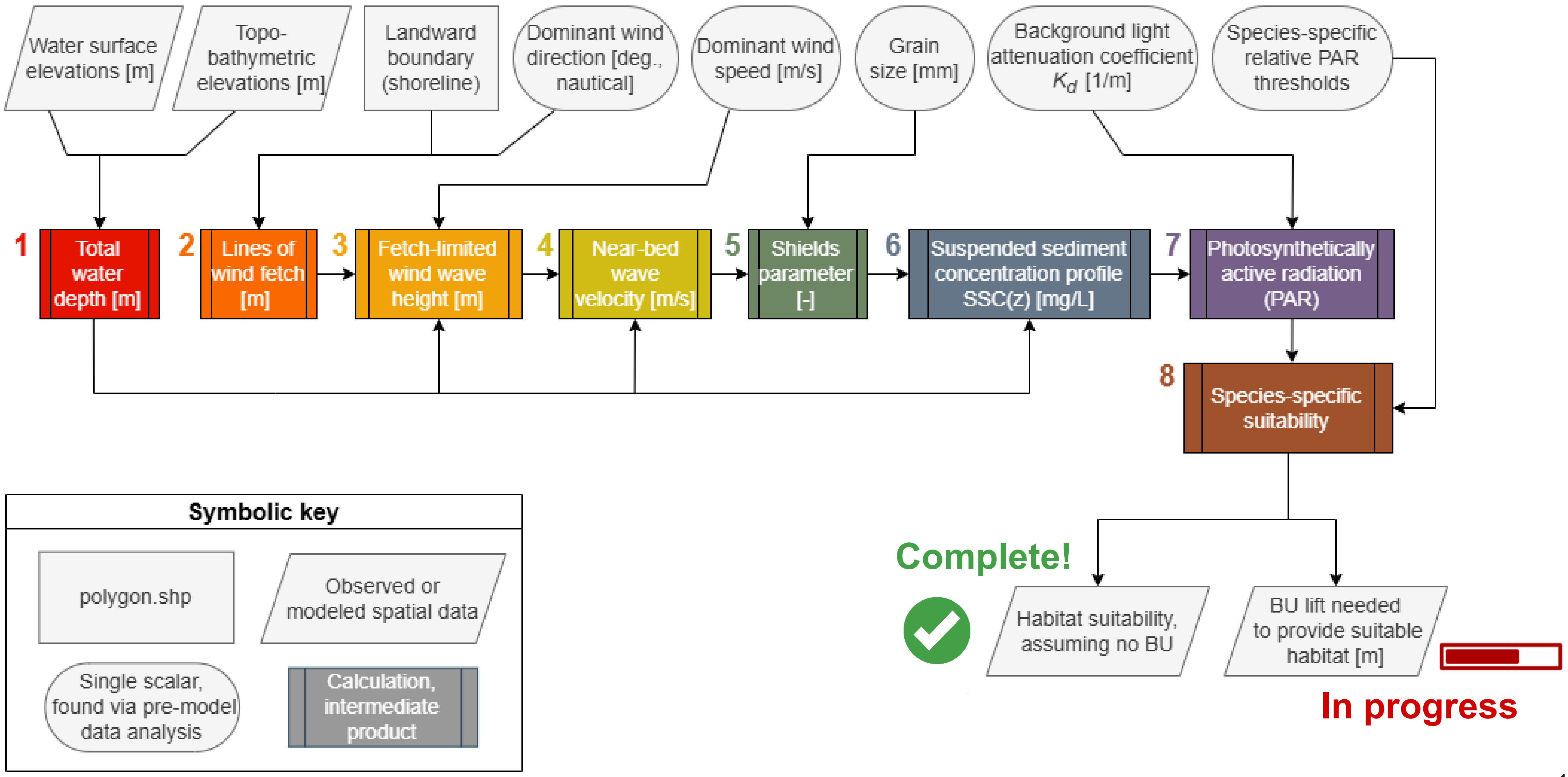
$$\frac{PAR_{bot}}{PAR_0} = \exp\left(-h\left(K_{d,w} + K_{d,bg}\right)\right)$$ PAR at seabed relative to surface

STEP 8 – CLASSIFY SUITABILITY FROM REL. PAR



Classification	PAR range
SAV not suitable	0 – 15
SAV likely suitable	15 – 35
SAV confidently suitable	35 – 100

OUTPUT PRODUCTS



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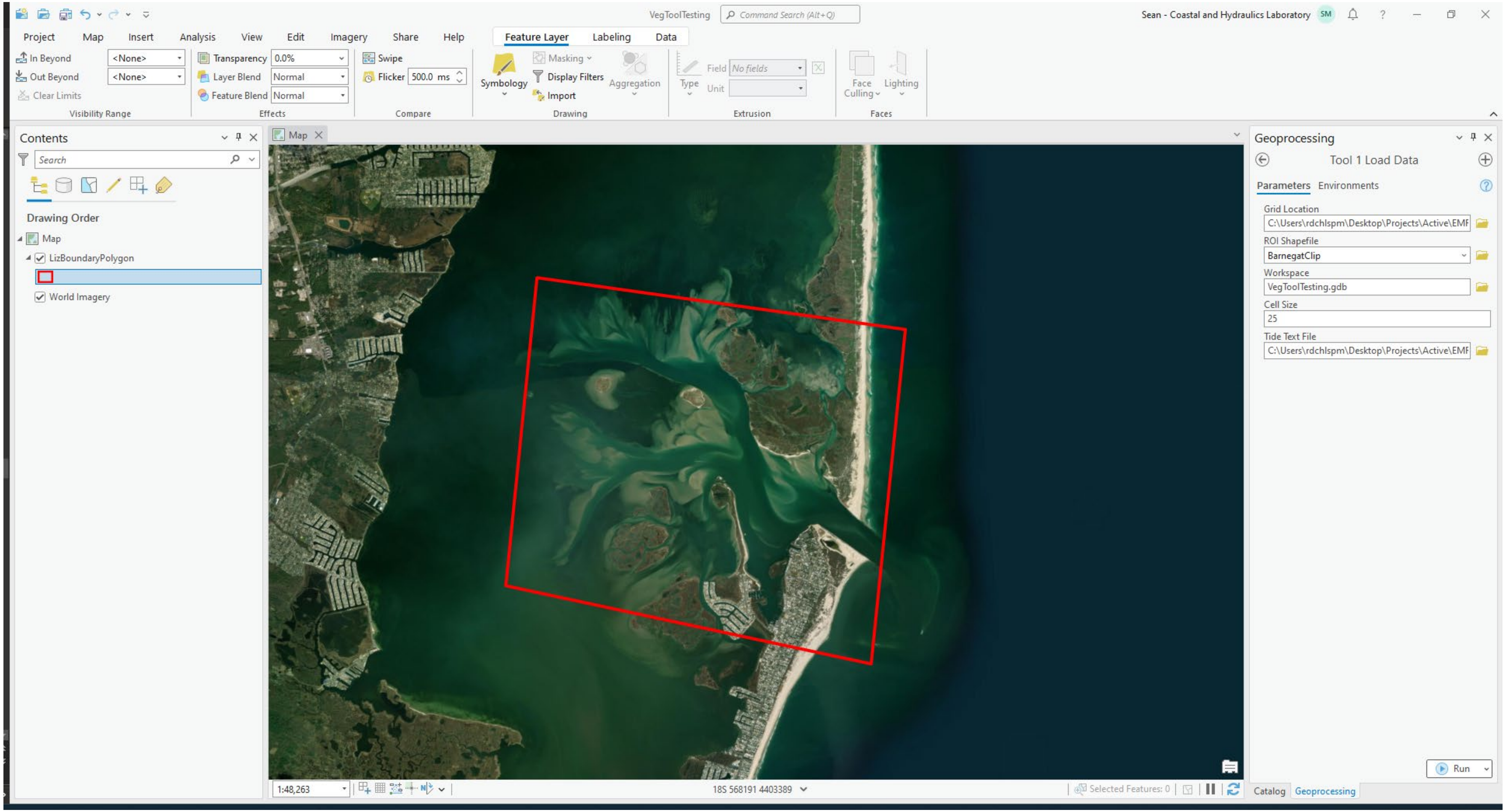
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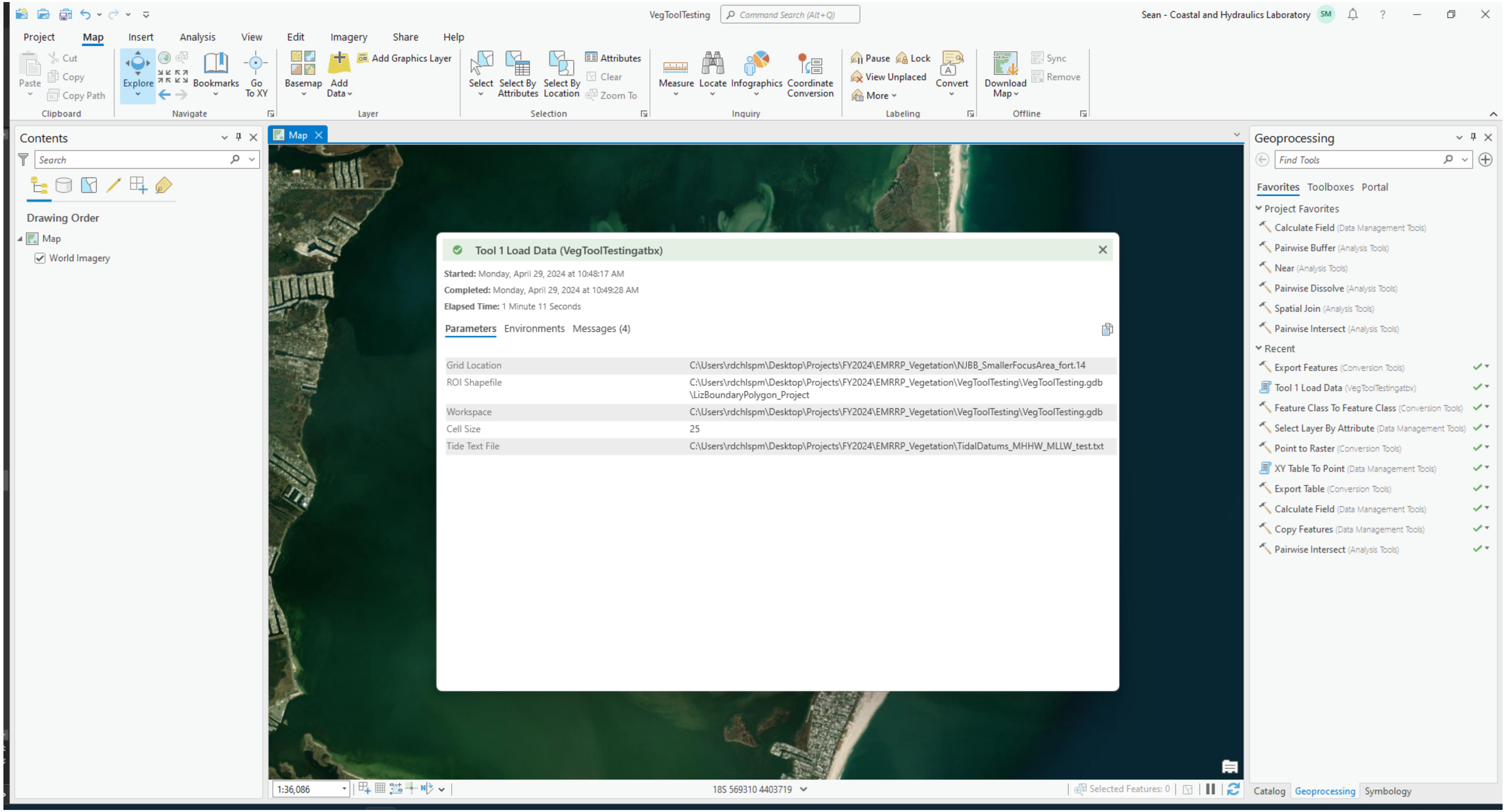
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Catalog Geoprocessing Symbology

UNCLASSIFIED

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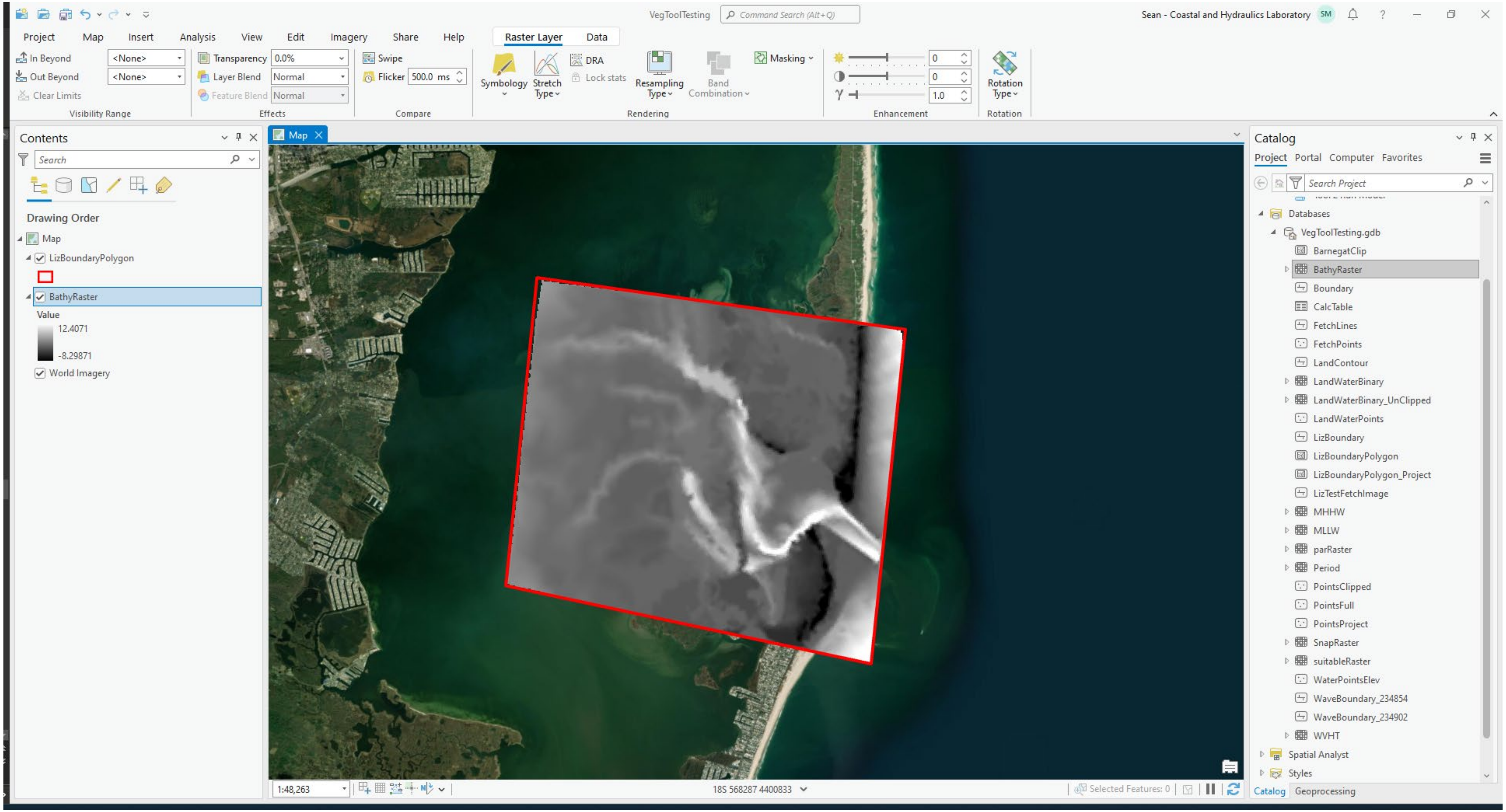

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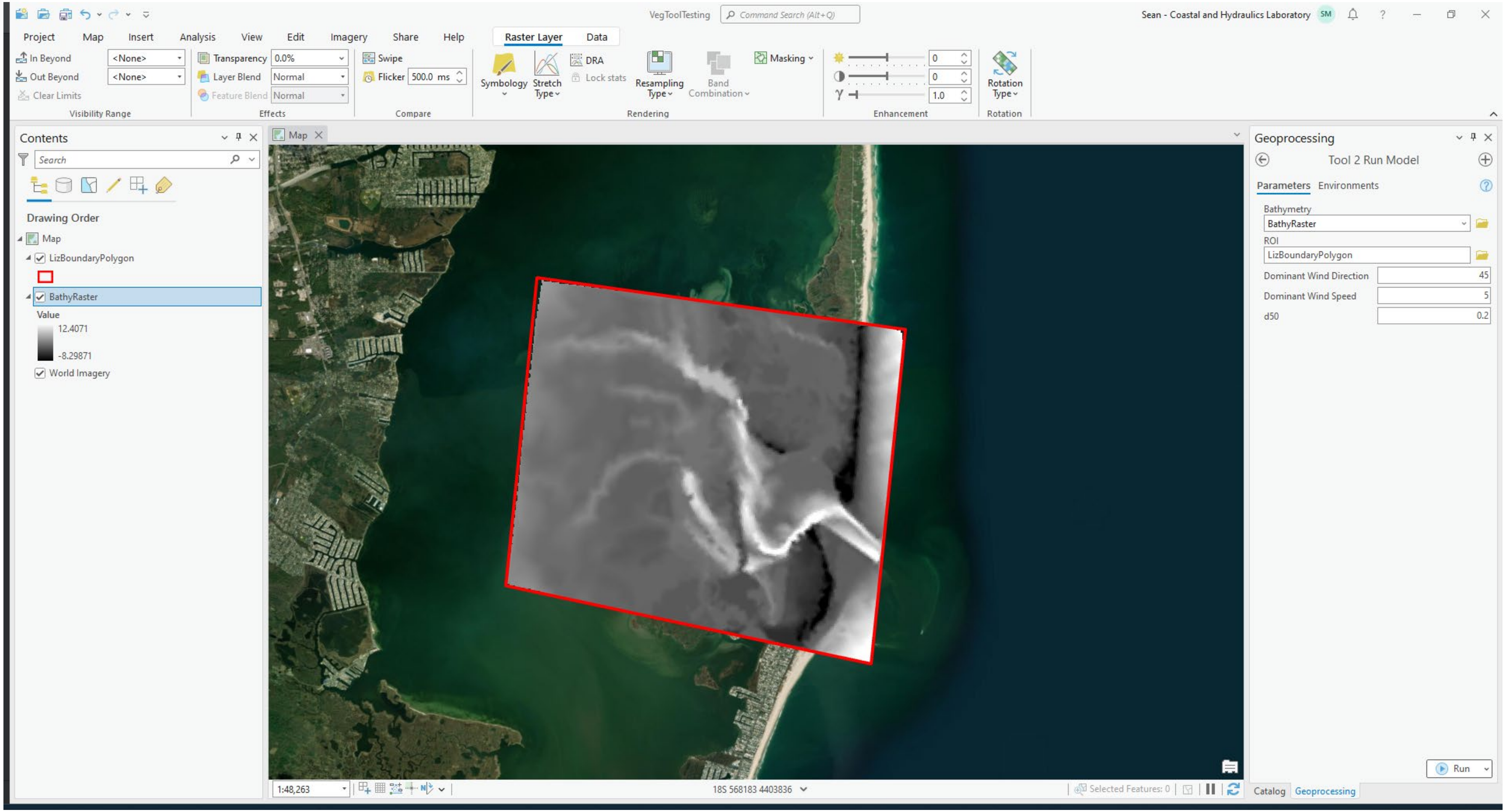
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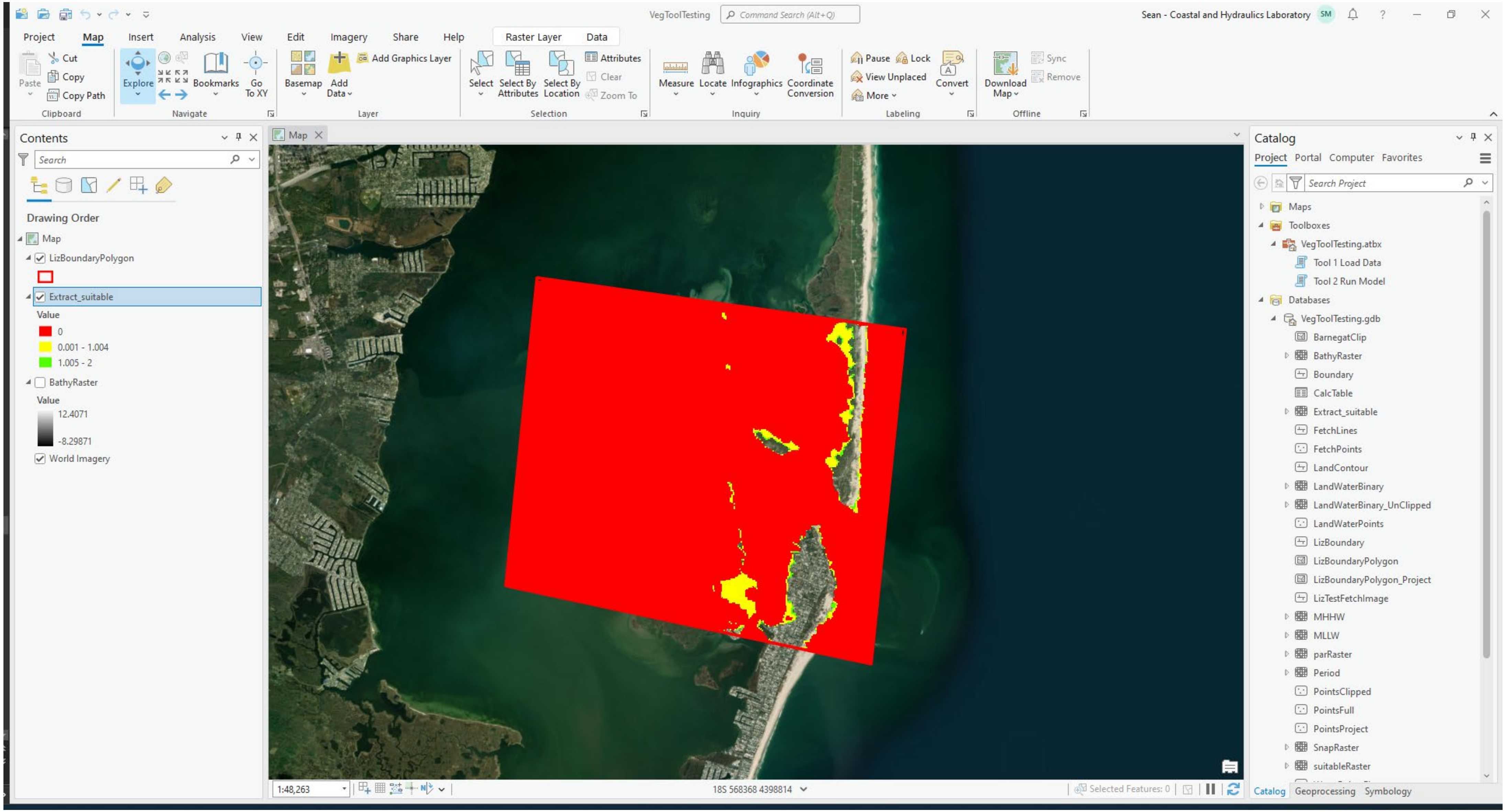

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ASSUMPTIONS

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1. SAV suitability is dominated by light availability, which is reduced by turbidity in the water column.
2. The only sources of turbidity are the static water column (e.g., background turbidity levels) and near-bed sediment suspension by waves.
3. All geophysical and biological processes are static in nature, meaning SAV habitat and/or community dynamics , time-varying hydrodynamics, and morphological changes are not included.
4. The geospatial tool is not meant to predict SAV habitat success following BUDM applications, but rather is an indicator of site suitability.
5. PAR at the water's surface is assumed to be adequate. SAV is not expected to be well-suited to waters with inadequate or infrequent solar radiation (i.e., chronically dark or shaded areas), so the calculator would not yield meaningful results in such areas.
6. Land/water boundary does not change in response to mean water levels (i.e., no change in infrastructure footprint).
7. SAV presence is not spontaneous; areas deemed suitable by the calculator must then be planted or close enough to existing habitats to spread.
8. Only one species, or multiple species with similar light requirements, can be evaluated for suitability at a time.

ASSUMPTIONS

9. Only area bounded within the provided ROI is calculated for suitability, even if larger input rasters are provided. Suitability can also only be calculated if the input rasters span the entire ROI.
10. Since SAV suitability is determined based on relative PAR availability, no specific datum is required, but all input rasters/spatial datasets must be relative to the same datum.
11. The sediment bed is assumed to be sandy (median grain size between 0.06 mm and 1 mm) with a bulk density of 1025 kg/m^3.
12. Current velocities (such as tidal currents and/or wave-induced currents) do not significantly contribute to sediment suspension.
13. Additional turbulence due to breaking waves does not significantly contribute to sediment suspension.
14. The simple cubed relationship for suspended sediment concentration does not account for advection of suspended sediment.
15. Waves are assumed to be locally generated by wind, but future releases of tool could allow users to provide wave height rasters (e.g., model output) to allow users to account for sea swell.
16. SAV-wave dynamics (e.g., attenuation, turbulence) not accounted for.

ADAPTIVE USE OF CALCULATOR

By changing the complexity of the inputs, users can adapt for appropriate level of risk/uncertainty.

For example, if future topo-bathymetric surface is anticipated (or estimated by numerical model),

- Use future anticipated/estimated topo-bathymetric elevation raster
- Use future anticipated/estimated water level raster
- Calculator will produce SAV suitability that reflects anticipated conditions

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- Use future anticipated/estimated topo-bathymetric elevation raster
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- Calculator will produce SAV suitability that reflects anticipated conditions

Current tool is geospatially based (i.e., ArcPro), but considering avenues for more rapid single-point calculator.

ADAPTIVE USE OF CALCULATOR

ERDC

By changing the complexity of the inputs, users can account for additional physical processes.

	Simplest	Moderate complexity	High complexity
Topo-bathymetric surface	Raster of range of values expected in study area.	DEM developed for project site or hydrodynamic model grid file (e.g., ADCIRC fort.14).	Topo-bathymetric results of morphodynamic modeling study evolving site to the time of interest.
Water surface elevation surface (WSE)	Static water level or projection based on local knowledge of water level trends.	Raster of MLLW calculated from water level time series output from hydrodynamic model of tides under variable water levels.	Raster of MLLW calculated from water level time series output from hydrodynamic model of combined tides, wind stress, wave radiation stress, and variable water levels.
Land/water boundary	Elevation contour corresponding to approximate time-averaged shoreline position.	Shapefile of wet-dry boundary prescribed in hydrodynamic model (e.g., series of boundary node X-Y positions).	Shapefile of boundary derived from combined methods, including contour extraction from DEM.
Dominant wind direction	Angle corresponding to anticipated cardinal direction (e.g., 0 for wind coming from the North).	Value computed from available historical records, such as from the WIS Portal.	Range of possible values computed from historical values to account for directional uncertainty.
Dominant wind speed	Default value or rough estimate based on local knowledge.	Value computed from historical record available.	Range of possible values computed from historical values to account for speed uncertainty.
Background K_d or SAV suitability thresholds	Default value or rough estimate based on local knowledge.	Site-specific value determined from review of published literature/data.	Site-specific value determined from local water sampling.

Level of complexity in today's demo

NEXT STEPS

Immediate term…

1. Calibration and validation against known SAV habitats
2. Statistical (ML) model for BU lift to meet SAV requirement

Then…

3. Adaptive complexity for calculator inputs
   - Single-point (or excel table) calculator
   - Spatially varying d_{50}, background K_d in geospatial calculator
   - Fine-grained material, floccs
4. Online knowledge hub for BU-SAV applications

Let us know where you want to see this work go!

REFERENCES

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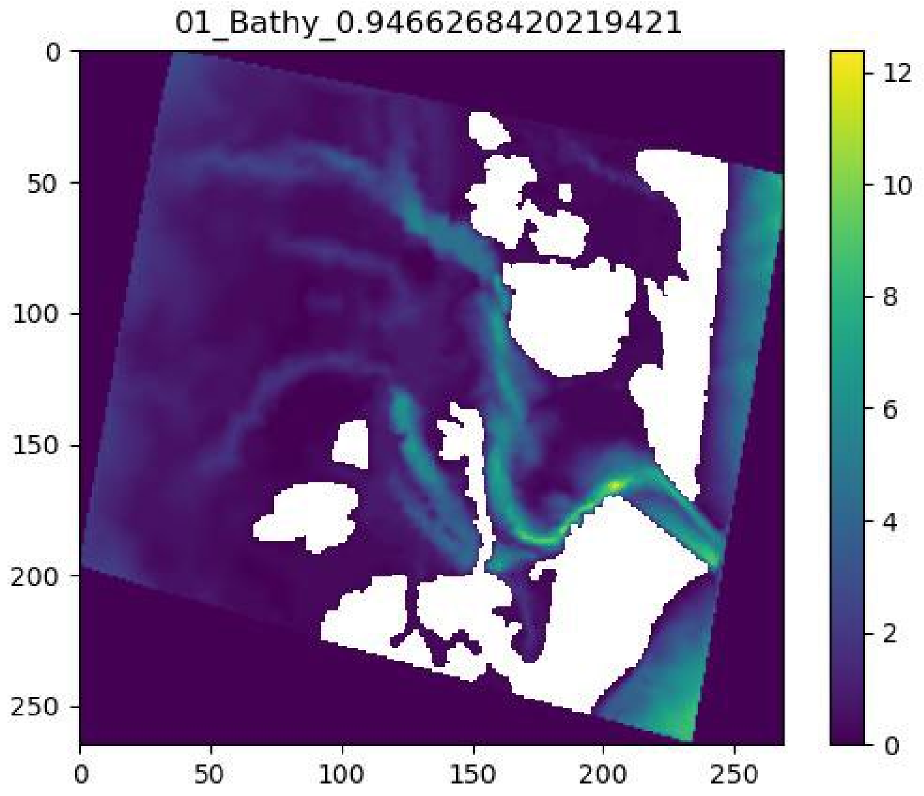
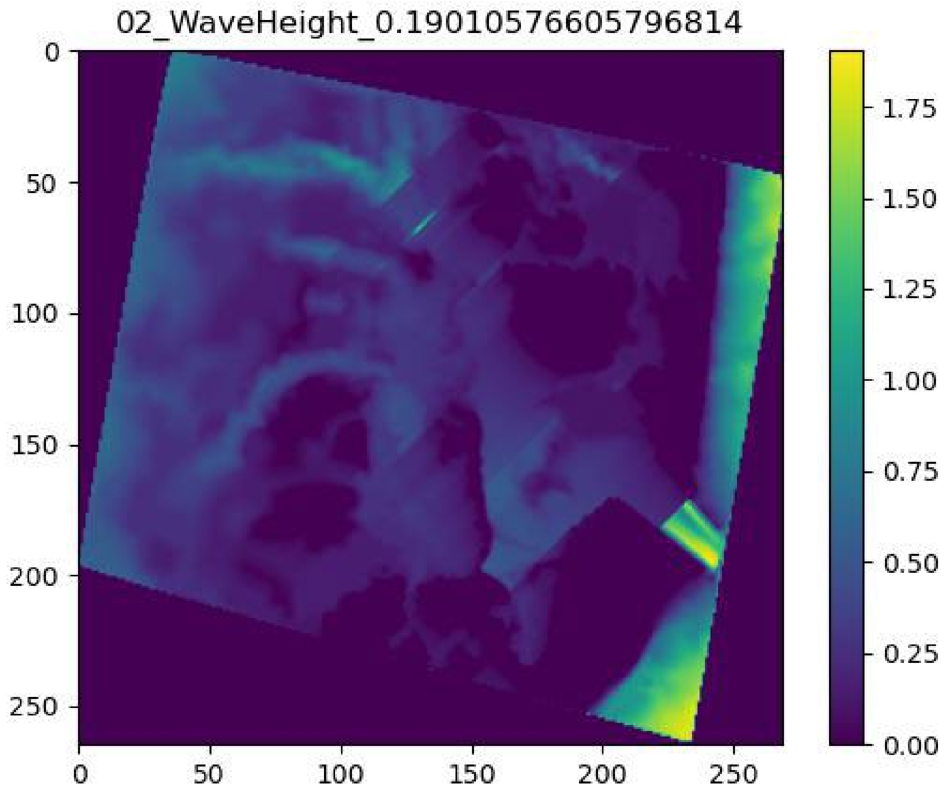
EXTRA SLIDES





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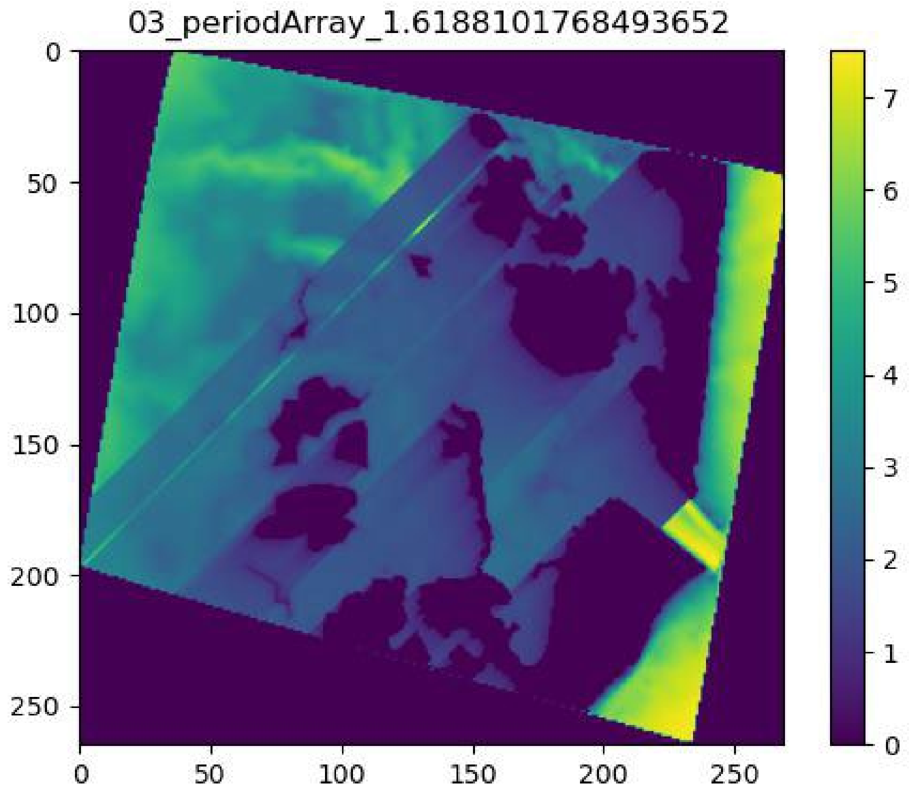

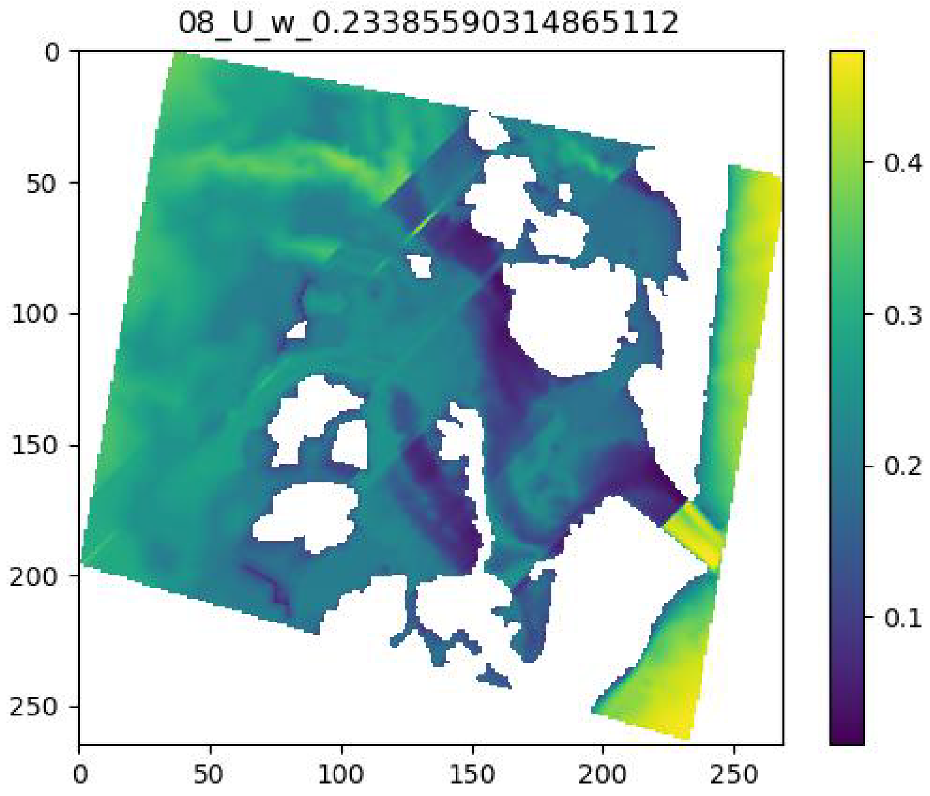

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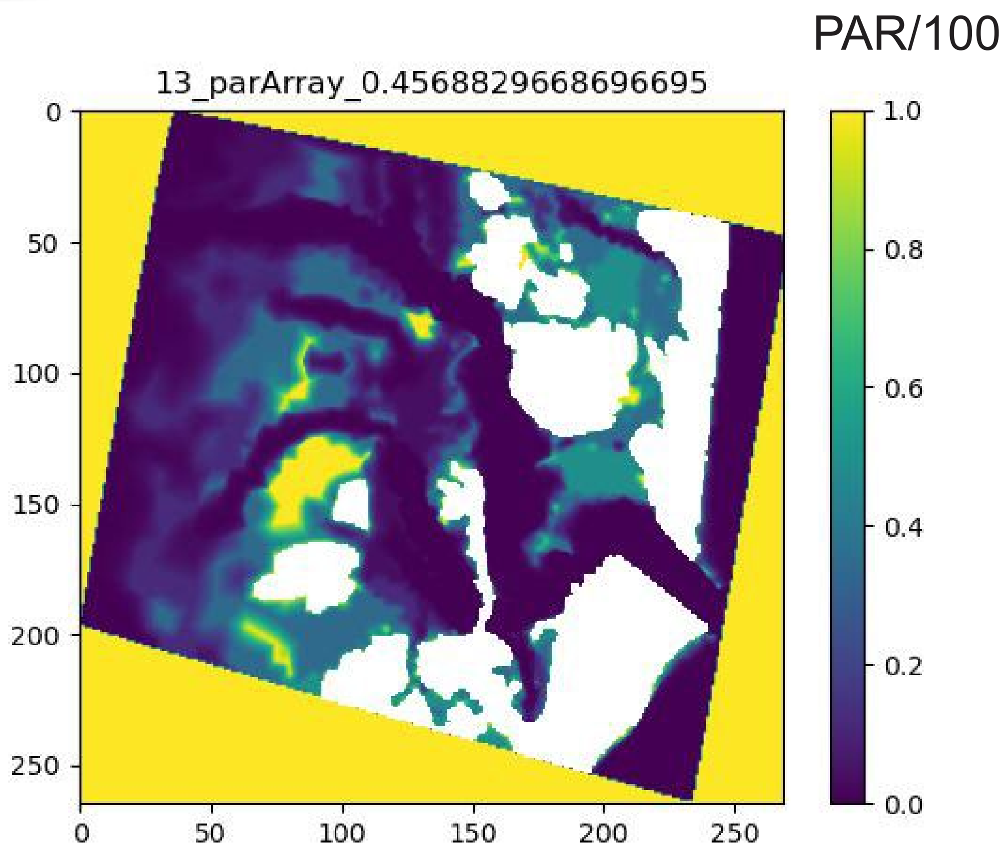

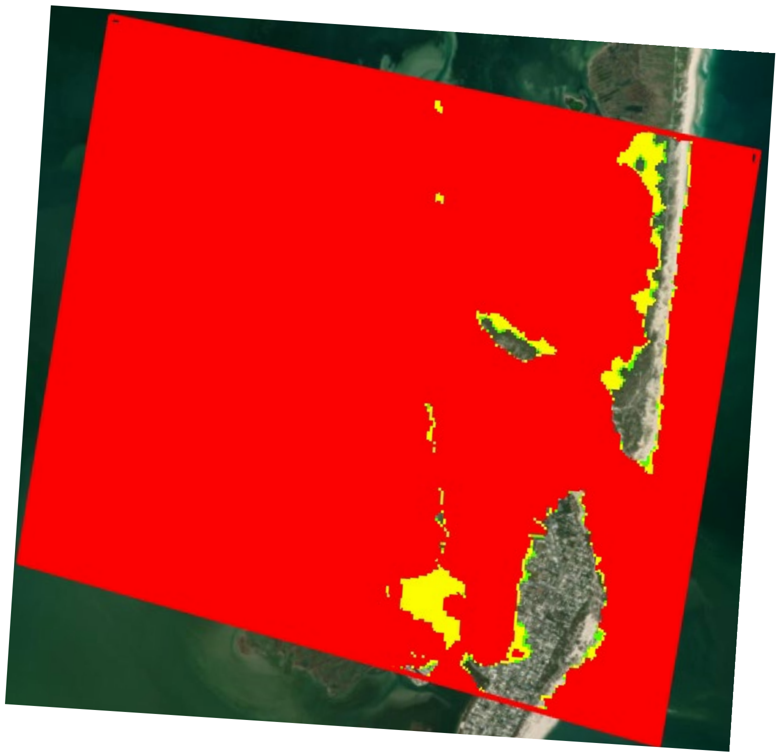

Classification	PAR range
SAV not suitable	0 – 15
SAV likely suitable	15 – 35
SAV confidently suitable	35 – 100

EXTRA SLIDES