Pouring Spatial Data Into Shellfishery Management Decision-Making

Bea Van Dam[1,2] and Sean Smith[1,2]

University of Maine

1. School of Earth and Climate Sciences 2. Senator George J. Mitchell Center for Sustainability Solutions

Introduction

Closures of Maine's coastal shellfish harvest areas due to bacteria pollution have substantial economic and social consequences for more than 1,500 licensed harvesters and their communities. Management of harvest areas to protect public health while avoiding unnecessary closures requires the use of spatial information to make science-based decisions related to land-sea connections along the state's ~5,600 km long, geographically varied coastline. Prior research demonstrates coastal river watersheds can be clustered into a limited number of coastal "settings" with self-similar physiographic and land cover conditions [Fig. 1]. The current project was undertaken to integrate near-coast "margin" watershed areas and estuarine waters into an expanded clustering and pollution vulnerability analysis of coastal embayment settings based on factors relating to bacteria landscape sources, delivery of polluted runoff to shellfish flats, and residence time of polluted water within tidal embayments.

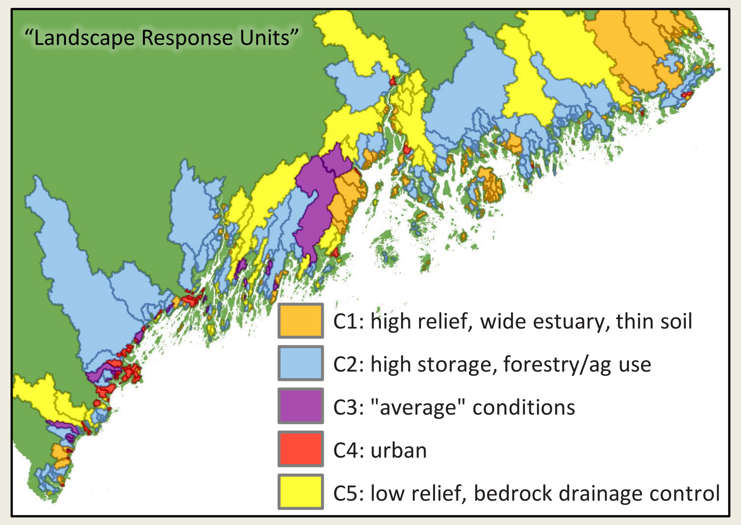

Figure 1. Clustering in a set of large non-tidal watersheds.

"Estuary Builder" GIS Tool

Unlike non-tidal watersheds, which have a single, well-defined outlet, the outlet of an estuary or other coastal embayment is not always simple to demarcate, particularly when dealing with the nested sub-embayments that are common along the Maine coast. In order to facilitate the data needs of the Maine Dept. of Marine Resources and other shellfishery management agencies, it became apparent that a more flexible solution than static maps of a fixed set of embayments was needed. The Estuary Builder GIS tool was first developed to give researchers a flexible platform to quickly aggregate landscape and estuary spatial data for any user-defined estuary outlet line, then modified to adapt it to the needs of shellfishery managers by incorporating the results of an expanded cluster analysis of coupled land-sea "estuary units." This poster describes the underlying data, user interface, and output of this powerful tool.

Tool Output

The Estuary Builder tool returns a shapefile containing a watershed polygon for each outlet line, consisting of the combined non-tidal watersheds and margin watershed areas contributing runoff to the estuary unit [Fig 8a]. The attribute table of this shapefile contains aggregated source, delivery, and residence time proxy metric data for each estuary unit [Fig 8b].

More importantly for end users, it also reports the cluster number for each unit [Fig 8c]. Clusters consist of self-similar groups of coupled land-sea units, and can be expected to have broadly similar vulnerabilities and responses to bacteria pollution following rain events, as compared to members of other clusters. As a result, knowing which cluster a delineated estuary unit belongs to allows managers to make sensible comparisons to well-monitored sites within the same cluster, guiding management strategies for poorly-monitored estuaries. The Estuary Builder tool is a flexible platform that allows users to quickly access relevant spatial data for any coastal embayment to make science-based management decisions.

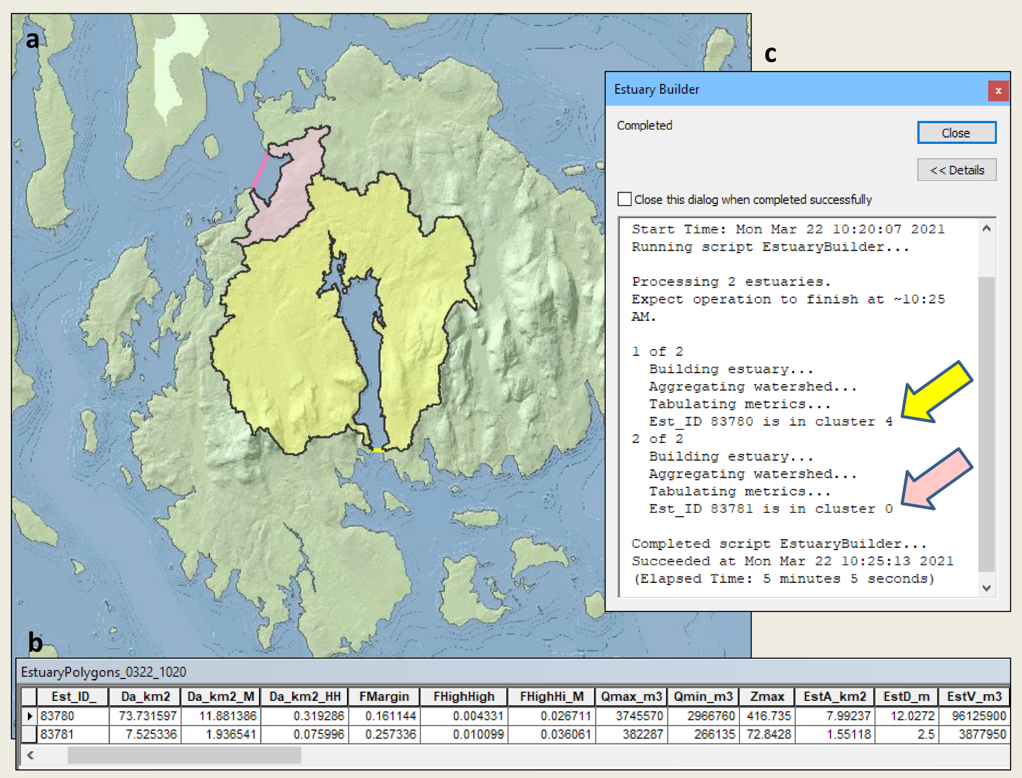

Figure 8. Estuary Builder tool output for two outlet lines. (a) Map view showing delineated watershed areas; (b) Attribute table showing selection of aggregated proxy metrics; (c) Tool dialog showing calculated cluster numbers for each estuary unit (highlighted with arrows).

Ongoing Work

The Estuary Builder tool currently operates on the ArcGIS desktop platform and is run locally – in order for a manager to use it, a copy of the tool and its underlying database (and a valid copy of ArcGIS) must be on a computer in their office. In order to increase accessibility, work is ongoing to migrate the tool to the UMaine Advanced Computing Group's cloud and provide access through an interactive online web portal. This should improve performance time as well as making the tool available to a wider audience, including organizations that cannot afford an ArcGIS license.

Reported clusters are currently calculated using a Gaussian Mixture Model, a type of probabilistic model that was trained with metric data from 500 coastal embayments and sub-embayments delineated by the Estuary Builder tool, from which eight clusters emerged. While this model is so far satisfactory, further investigations into more sophisticated clustering methods are being made before the final version of the tool is released.

For more information about coastal pollution vulnerability and other ongoing Watershed Process and Estuary Sustainability Research Group (WPES) projects, scan the QR code or visit umaine.edu/watershedresearch!

SCAN ME

Tool Design

Data

High-Resolution Elevation Data

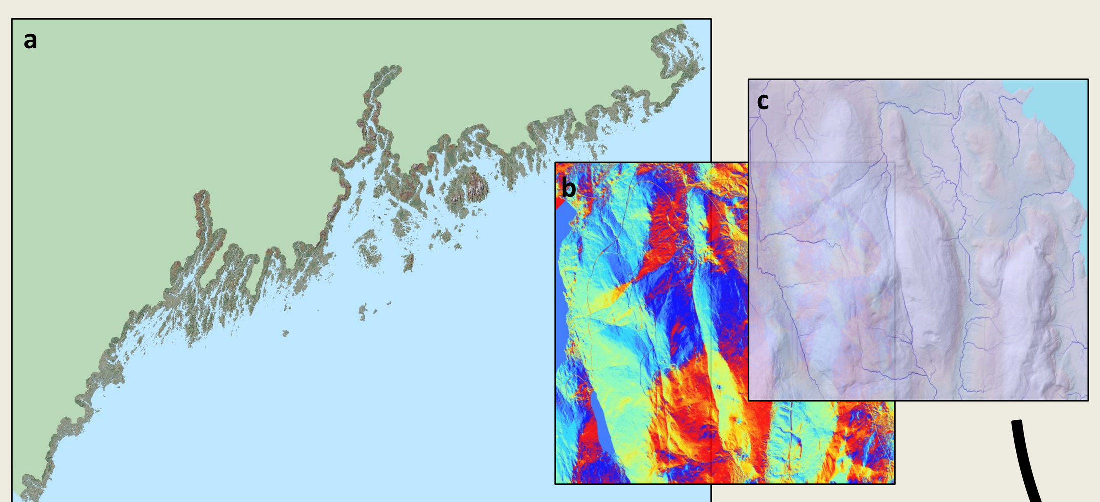

Figure 2. (a) 2 m LiDAR coverage for the Maine coast, with examples of derived (b) flow direction and (c) flow accumulation raster data.

Before the Estuary Builder tool could be developed, overland flow paths were delineated from 2 m resolution LiDAR elevation data for 5,200+ km^2 of coastal landscape [Fig. 2], a process that involved the placement of over 30,000 culvert lines to ensure proper routing from the landscape to coastal waters. The overland flow data were used to delineate watersheds for the 2,196 rivers and streams that reach Maine's tidal coastline, leaving 1,800 km^2 of "margin" area that falls between watershed boundaries and coastal waters [Fig. 4]. This area was split into more than 2.1 million gridded 30 m x 30 m cells, which the tool could later select and aggregate as needed.

To improve performance on less powerful computers, a lower resolution 10 m DEM was created to use as tool input. Flow direction and accumulation rasters derived from this DEM additionally incorporate bathymetric data for in-estuary flow routing [Fig 3].

Geodatabase - Incorporated Into Tool

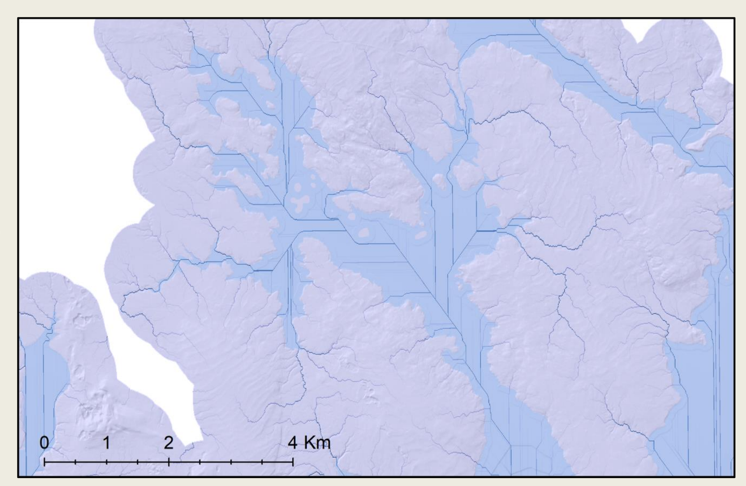

Figure 3. Flow accumulation raster incorporating bathymetry.

Coastal landscape/bathymetric flow direction and accumulation rasters and fully-attributed non-tidal watershed and margin polygons form the backbone of the spatial data the tool accesses for its operation.

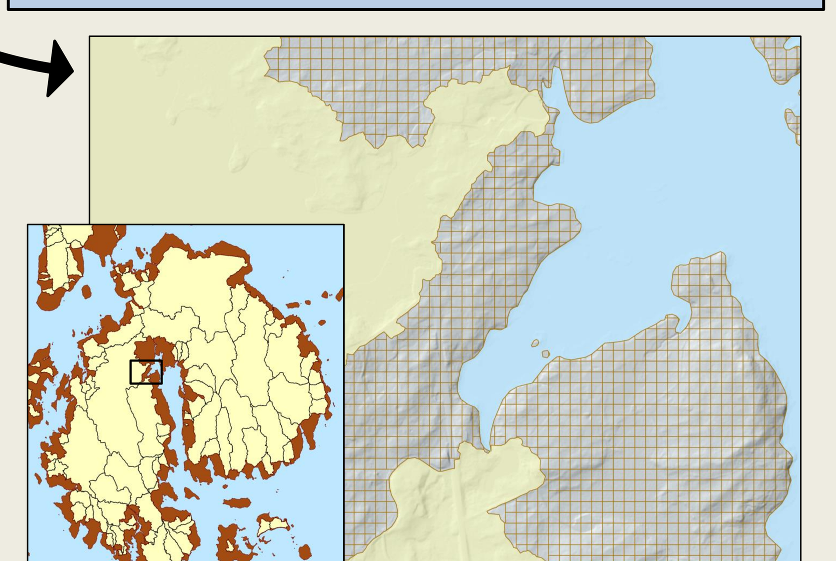

Figure 4. Nontidal watersheds (yellow) and margin watershed areas (brown). The latter are split into 30 m cells.

Proxy Metric Data

Delivery
- Total runoff – 2" storm
- Fraction margins
- Natural drainage density
- Engineered drainage density
- Soil storage and drainage
- Elevation change and slope

Source
- Fraction land covers: Developed, Farm, Rural, Storage
- Tidal Wetlands
- Population / Density
- Structures / Density
- OBDs / Density
- CSOs / Density
- PDESs / Density

Residence Time
- [Embayment area]
- [Embayment mean depth]
- [Embayment volume]
- [Drainage area / Embayment area ratio]
- [Runoff volume / Embayment volume ratio]
- [Embayment circularity]
- [Embayment openness]
- [Embayment outlet bearing]

Figure 5. Categories of source, delivery, and residence time metrics incorporated in the Estuary Builder tool.

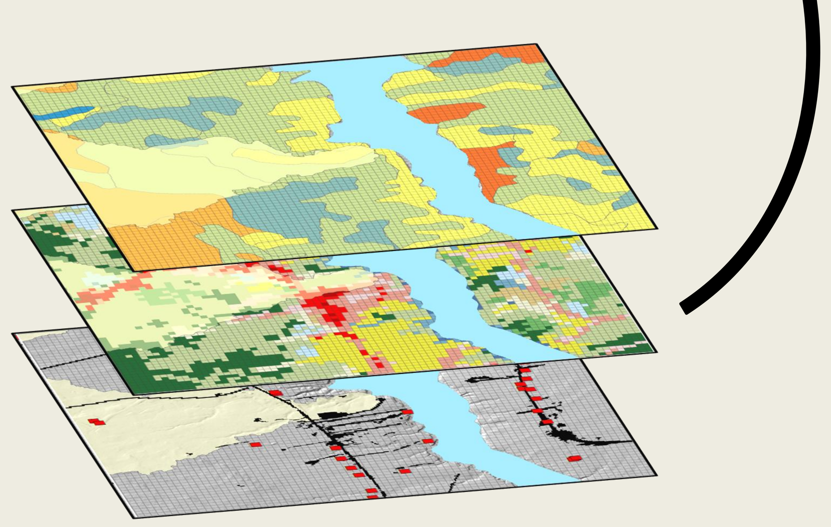

Figure 6. Cartoon illustrating metric data layers overlaid onto watershed polygons.

Because it is not possible to do detailed bacteria source tracking for the entire Maine coast, we use proxy metrics to look for relationships between available coastal spatial data and bacteria levels. High bacteria loads are often found adjacent to urban coastal areas, for example, making population density a useful metric even if the density itself is not the cause of the high loads (but perhaps household pet waste is!)

Source and delivery proxy metrics [Fig. 5] were calculated for all non-tidal watershed and margin cell polygons using USGS land cover data, USDA soils data, and point source pollution data from the State of Maine [Fig. 6], as well as metrics derived from the high-resolution elevation data. Estuary residence time metrics are calculated separately during the tool run (see **Behind the Scenes**).

User Interface

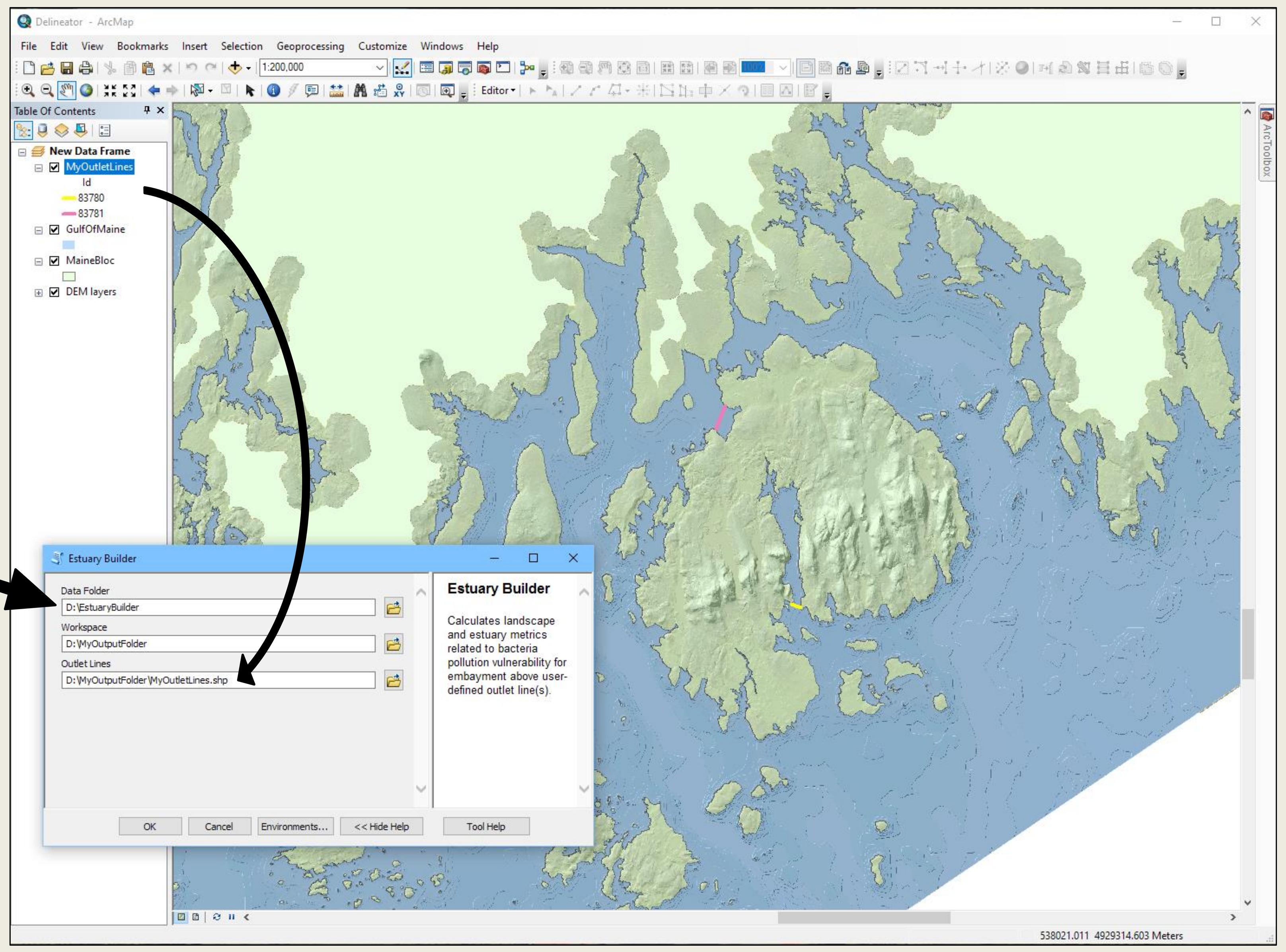

Figure 7. An example showing the use of the Estuary Builder tool in ArcGIS desktop. Two outlet lines for delineation are shown in pink and yellow.

Users begin by drawing an outlet line, or "pour line," across the mouth of any embayment, sub-embayment, or other coastal concavity of interest along Maine's tidal coastline [Fig 7]. Any number of embayments may be delineated in a single tool run.

When the user opens the Estuary Builder tool, they simply enter the location of the saved "Outlet Lines" shapefile and a "Workspace" folder into which the tool will save its output.

Behind the Scenes

When the user clicks "OK" to run the tool, the backend code goes to work. The Estuary Builder tool is written in the Python coding language and draws upon the Arcpy library, a Python package that accesses the same ArcToolbox tools as an ArcGIS desktop user would. This powerful functionality allows the development of custom code incorporating these tools to perform long or complicated series of operations on geographic and tabular data.

For each of the user's outlet lines, the Estuary Builder code uses the flow direction raster to find all landscape areas that contribute runoff to the embayment outlet. All non-tidal watersheds and margin cells that fall within these areas are selected and merged, and their area-weighted source and delivery metrics are aggregated and applied to the single landscape unit. Additionally, dimensions of the delineated embayment, including bathymetric data, are used to calculate residence time metrics.

Finally, a clustering algorithm (see **Ongoing Work**) uses the proxy metric data to assign the newly delineated unit to one of several clusters representing general coupled land-sea setting types.

Each estuary unit takes ~ 2.5 – 3 minutes to delineate, depending on available computing power.