Farm Runoff and Pollution Analysis Using ArcGIS Pro

CE 413 – Winter 2021 Final Project

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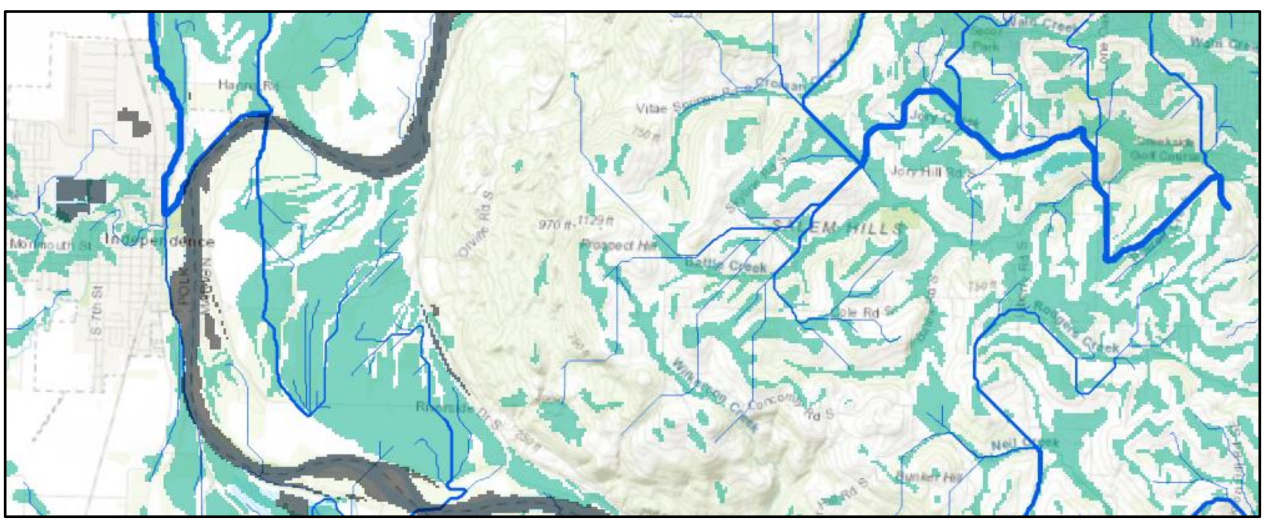


Contents

Introduction

This project aims to create a model that can applied to any area with the required GIS data to analyze the pollution from farm runoff that makes it into nearby rivers or wetlands. According to a report by the Department of Ecology, State of Washington, farm runoff is a major source of pollution in local water sources (WDoE, n.d.).

Major pollutants produced by farms are nitrates, nutrients, bacteria, and heat. Outside of formal treatment, the main ways to reduce this pollution include planting trees and shrubs to absorb the water, leaving stubble on farms to slow the water, and creating retention ponds to allow settlement and cooling of the water (WDoE, n.d.). Use of this model would allow farmers and water officials to determine problem areas for farm runoff and for designing capacity of a retention pond.

Site Description

An approximately 14 km by 14 km site was chosen for this project. The site begins at eastern Monmouth, Oregon and then heads 14 km east to Salem Hills, Oregon. The site extends 7 km both north and south from this midpoint.

This area is separated by the Willamette River and Willamette River Wetlands as shown in black in figure 1. To the east of the river is hilly forests with farmland dispersed at the top of the hill. To the far east of the site is southern Salem. West of the river is flat farmland with Independence, Oregon in the middle western area of the map.

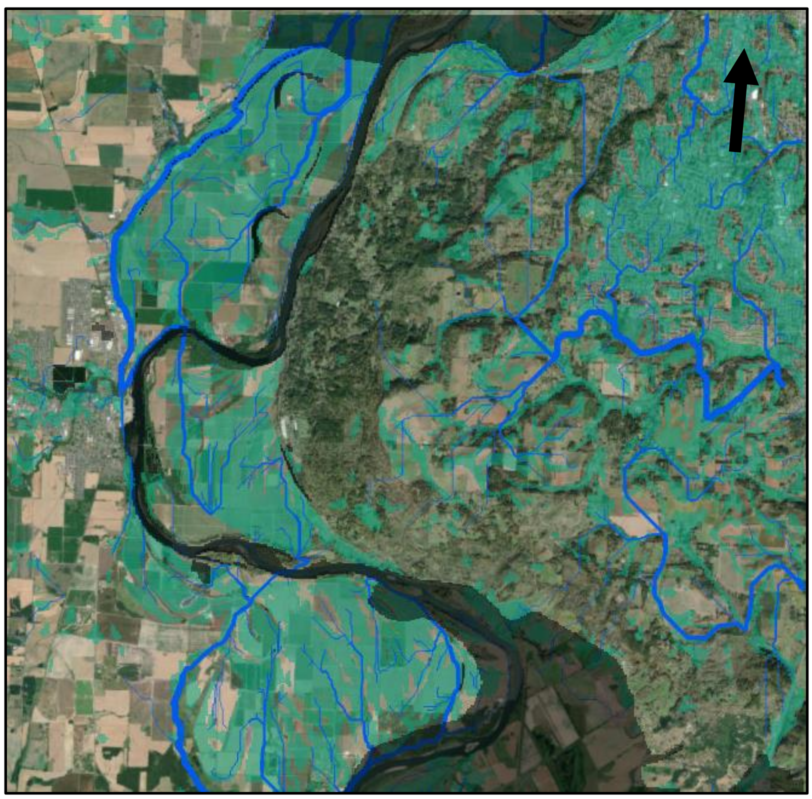


Figure 1: The final map area, it is largely flat farmland with some city. To the east is hilly forest mixed with farmland.

Data

This analysis requires four types of datasets to complete:

1. A target raster where the pollution is draining into, such as a river or wetlands. For this project two datasets are used, one that gives a major river and one that gives wetlands.
2. A digital elevation model, or DEM of the area spanning between the farmland and the target location. For this project a 10m DEM is used.
3. A raster of annual precipitation to determine peak runoff amounts.
4. A raster or polygon of the farmland whose pollution is being investigated.

For this project, the following dataset are used to fulfill these requirements:

Willamette Historic Channel 1995 WRB: This dataset comes from the Oregon Spatial Data Library and is called the _Channel_1995. It is a polygon using NAD 1983 HARN Oregon Statewide Lambert and shows the Willamette River. This fulfills the drainage target.

Willamette Valley Wetland Priority sites Oregon: This Dataset comes from the Oregon Spatial Data Library and is called Wetland_Priority_Site_WV. It is a polygon using OGIC default AG82 that shows the wetlands of the Willamette Valley. This is supplemental to the Willamette River to fulfill the drainage target requirement.

Shaded-relief and color Shaded-relief maps of the Willamette Valley, Oregon: This DEM comes from the United States Geological Survey, or USGS and is called Wil_hil_wil_hil. It is a DEM using NAD 1927 UTM Zone 10N that shows the elevation using 20 m by 20 m cells. This fulfills the DEM requirement.

Oregon Average Annual Precipitation, 1981-2010 (30 arc-second): This dataset comes from the Oregon Spatial Data Library and is called OR_PRISM_tmax_30yr_normal_800mM2_annual. It is a raster using NAD 1927 UTM Zone 10N that shows the maximum precipitation at each cell. The cell size is 20 m by 20 m. This fulfills the annual precipitation requirement.

Prime Farmland: This dataset comes from The Oregon Spatial Data Library and is called Wrb_prm_fmlnd. This is a raster using NAD 1983 Lambert that shows the ideal farmland in the Willamette valley. This dataset fulfills the farmland for this study.

Links to all used dataset are provided in the appendix.

GIS Methods

<u>Preparing the data:</u> First the datasets must be prepared so that they match in projection, scale, and type. This step will vary depending on the type of data available for the location. For this dataset the following step were used.

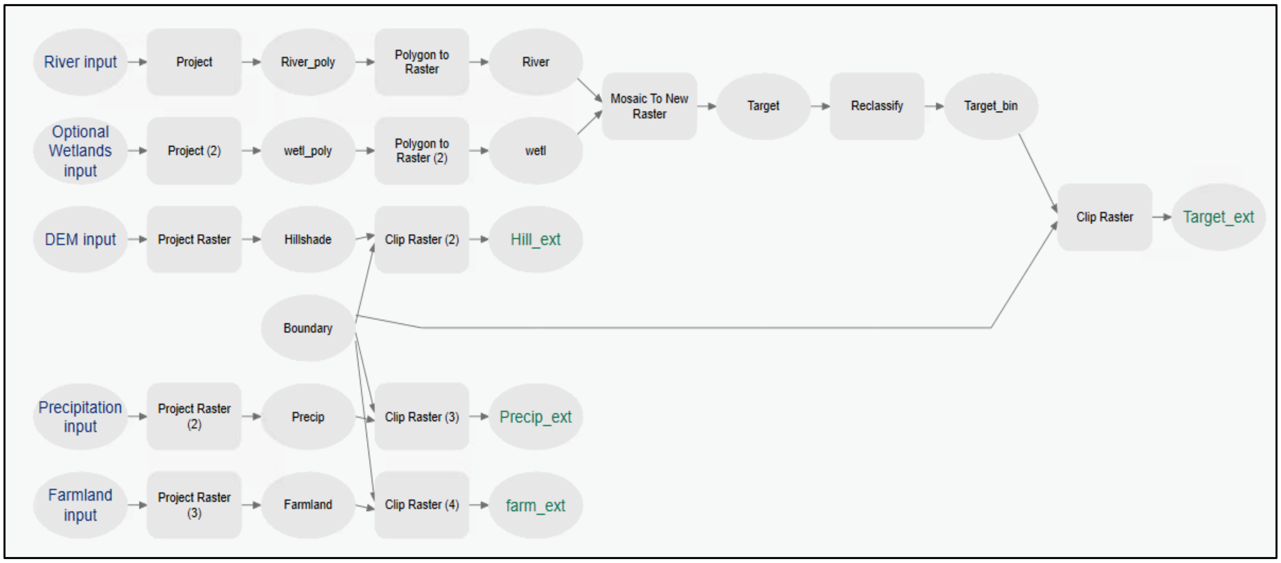
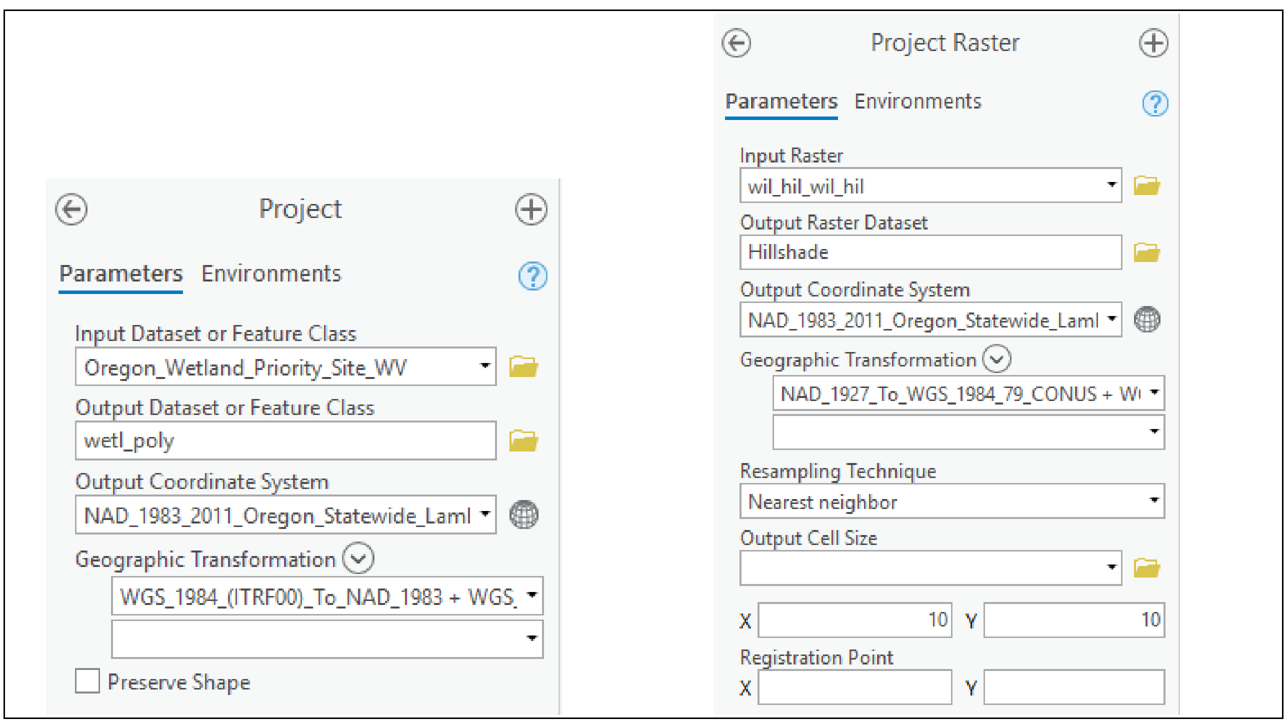
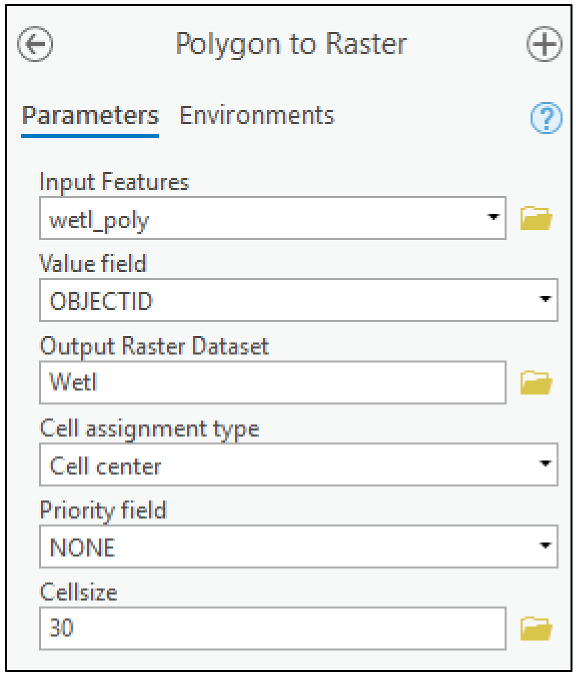


Figure 2: The steps required to prepare the datasets for use.

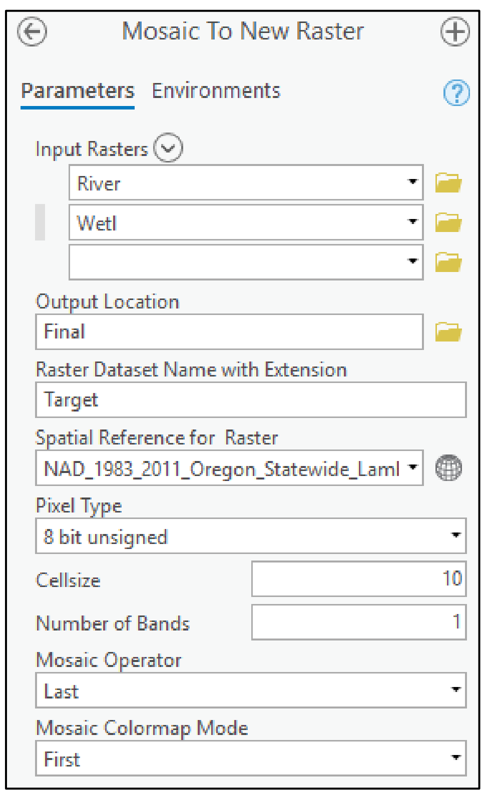
1. First, align all datasets to the same projection, in this case use Project for the polygons and Project Raster for the rasters. The raster was projected to NAD_1983_2011_Oregon_statewide_Lambert. All rasters were also resampled to 10 m cell size using nearest.



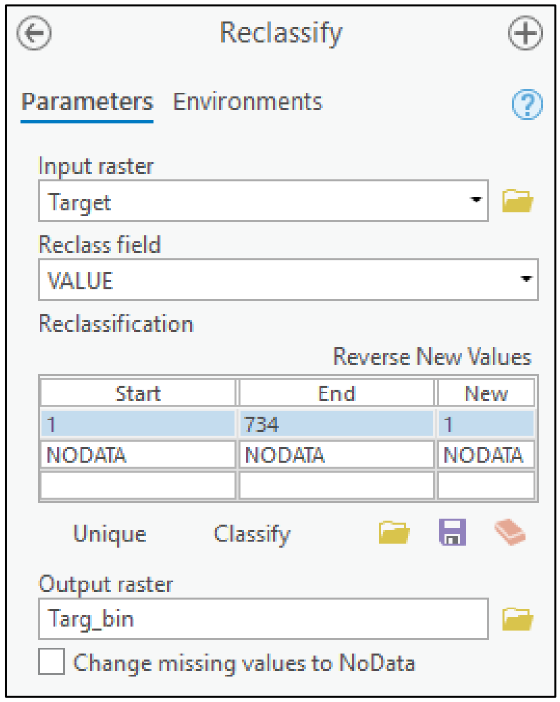
2. The polygons were converted to rasters. This was done with a larger cell size since it is only used as an end point. 30 m was chosen for this cell size and OBJECTID for the value field.



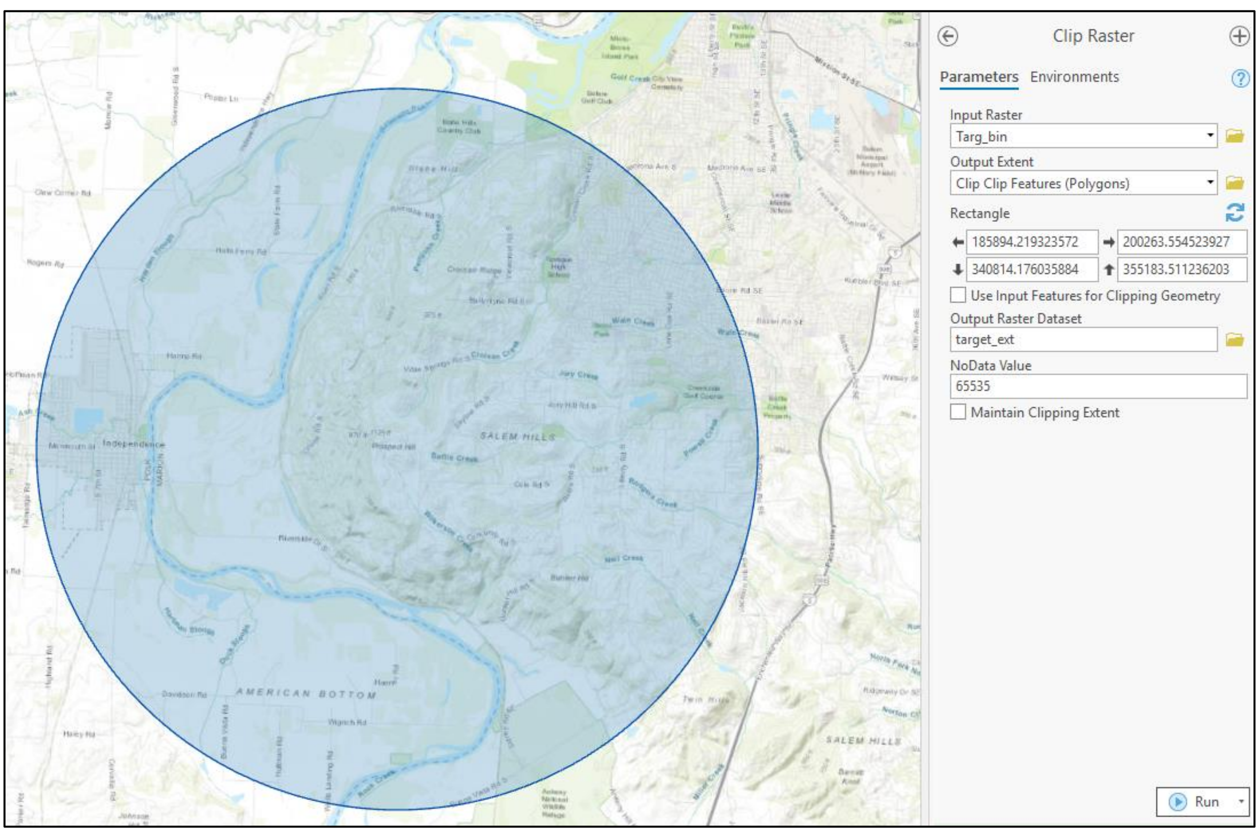
3. The wetland and river were combined to be a single raster. This was done with Mosaic to New Raster.



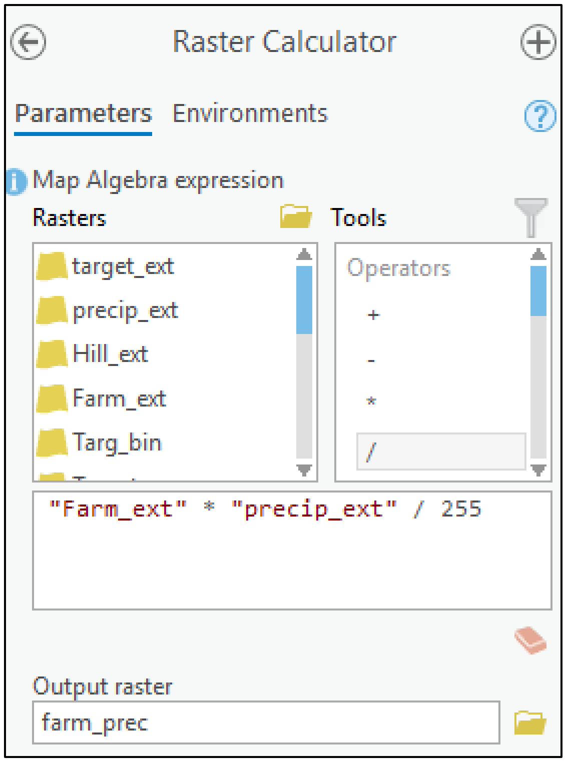
4. The target was recategorized to be binary. This is to create a single homogeneous raster.



5. The clip function was used to create a polygon that was then used with clip raster to select the study area. For this example a circular area was used.



6. The maximum rainfall was multiplied by the farmland. This gave a layer that contains the rainfall for croplands and no value for non-croplands. Note it was divided by 255, this is to counter the fact that the farm raster has a value of 255.



Using the data: Now that all four data types are 10m rasters with the same projection, the data is ready to be used to create the model. An overview of the steps is shown below.

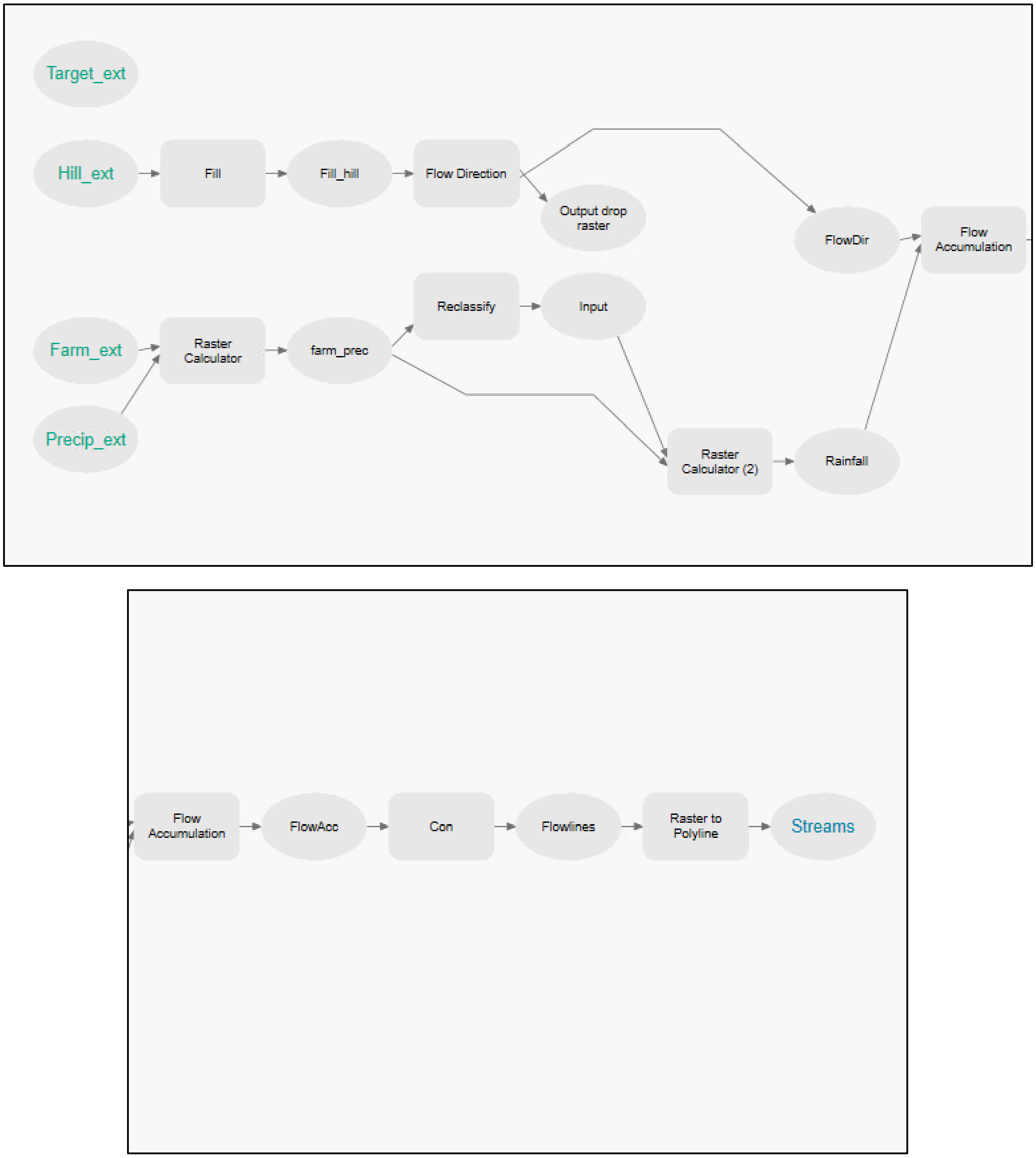
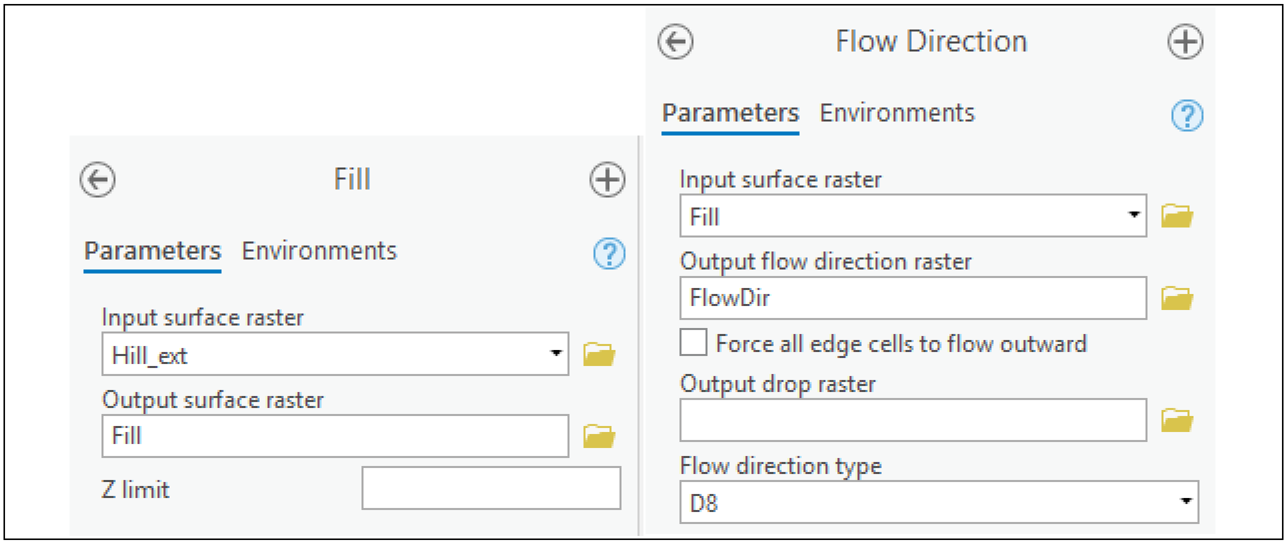
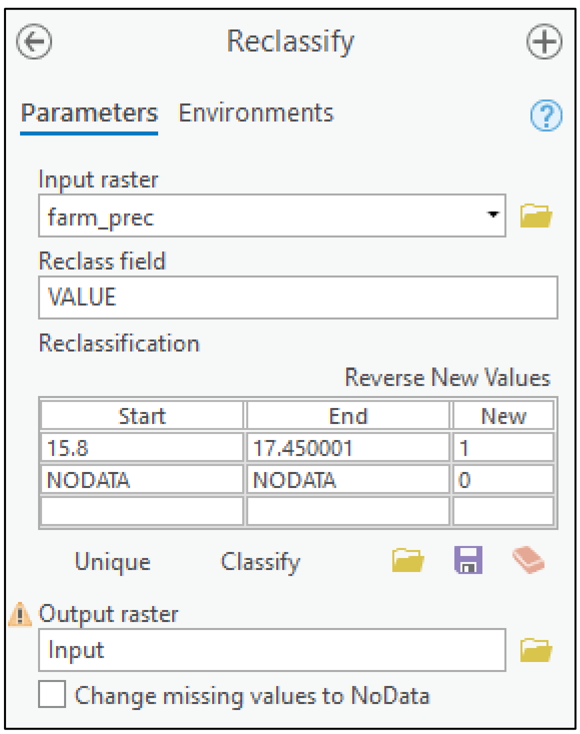


Figure 3: The steps to use the prepared datasets in making the desired map.

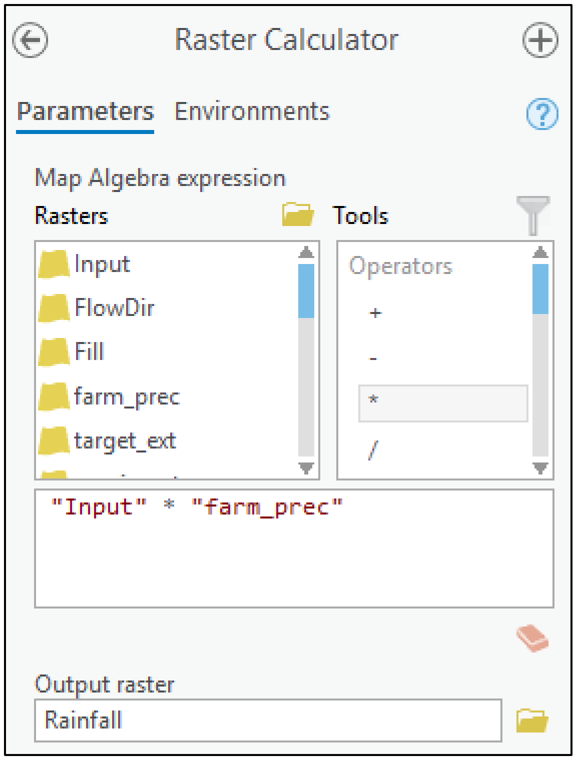
1. First, fill was used to fill in gaps in the data to reduce ponding in the final results. The fill raster was used to calculate flow direction using the D8 method.



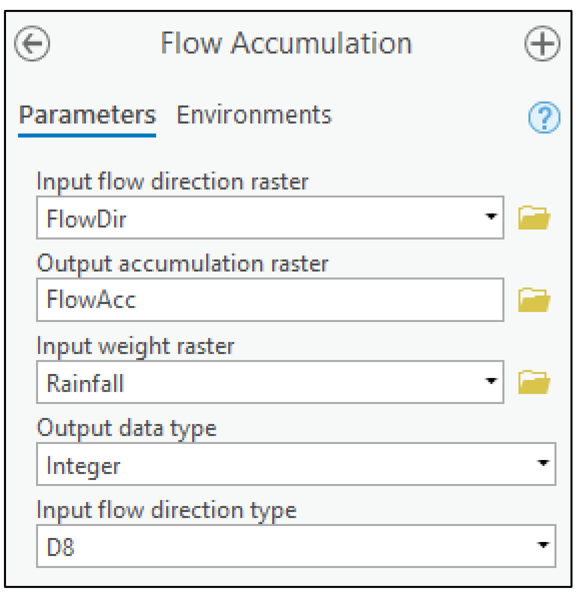
2. Next the farm precipitation raster was reclassified so that nodata is assigned to 0 instead for future calculations. This was done so that in the flow accumulation step will not calculate any flow from nodata cells.



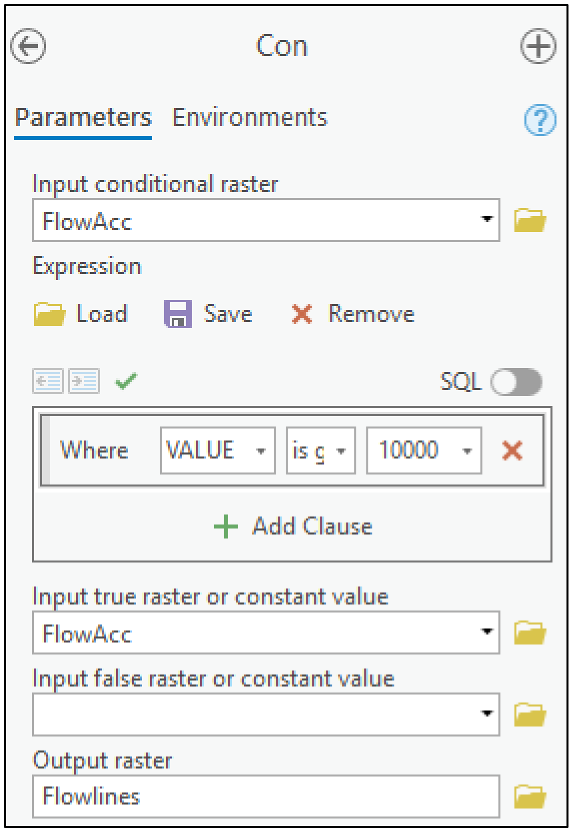
3. The farm precipitation is now binary, so the precipitation amount needed added back. The raster calculator was used to reinput the values in 1 by multiplying the original precipitation by the binary precipitation amounts.



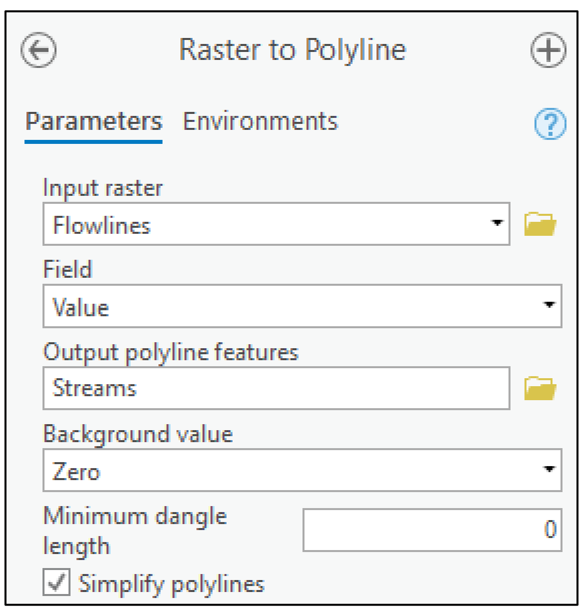
4. Flow accumulation was used to calculate the flow amount for the farmland. This created a layer that gives no visual information at first. Right click the layer and select symbology setting it to classify. Enter values into the upper limit until you can discern individual stream of importance. This may take trial and error.



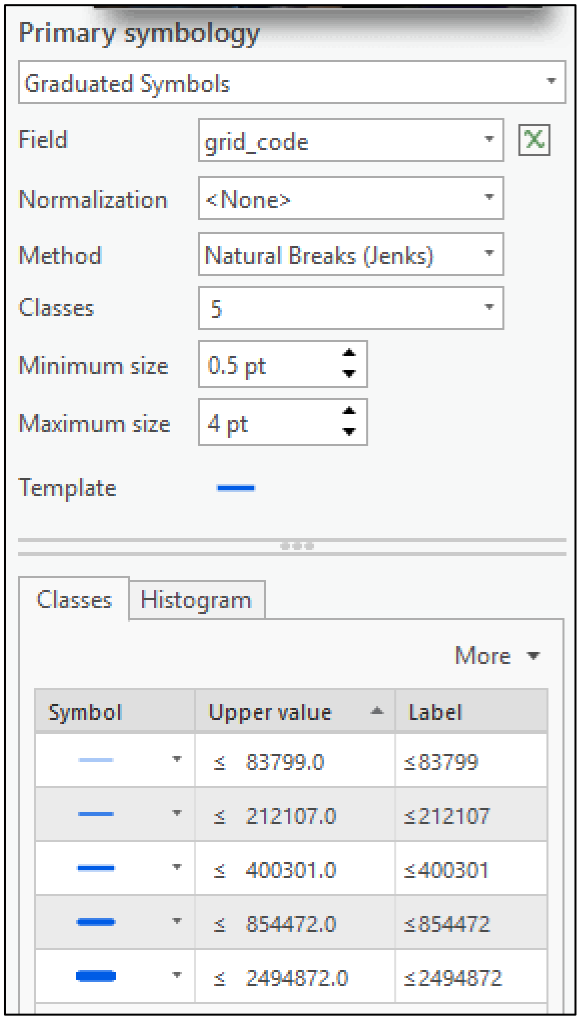
5. Using the minimum stream amount determined in the last step, con was used to remove values that fall below the chosen value. This gave rasters of streams greater than the value chosen.



6. Raster to polyline was used to turn the stream rasters into a polyline for ease of use and appearance.



7. Finally, the stream, target, and farm_ext layers were turned on. Symbology was used to create a visually pleasing map. For the streams layer select symbology and set it to a graduated symbol. This will show the stream polylines growing in size to reflect flow amount.

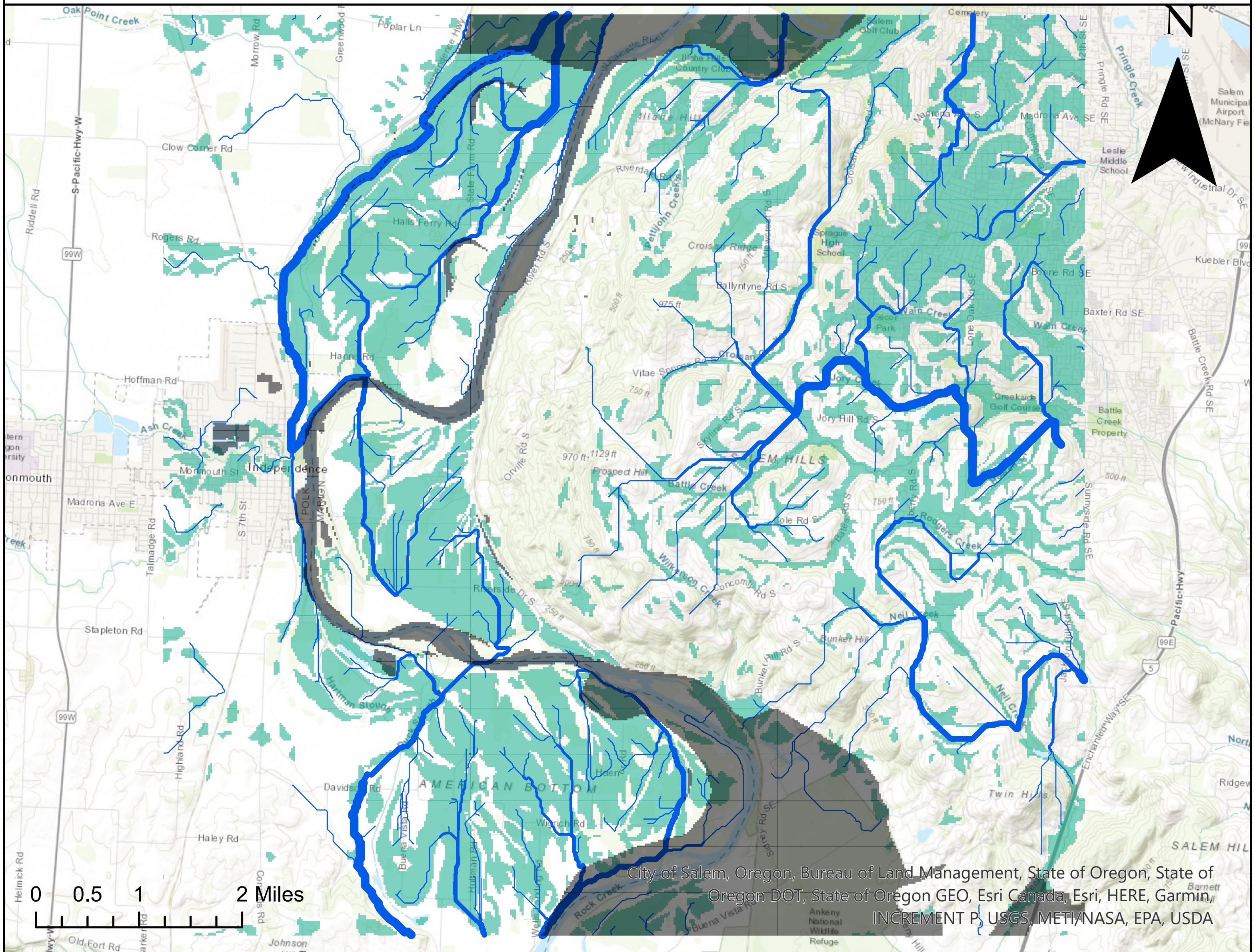


The map should now be ready for use in analysis.

Results

The final result is shown in the following two maps. The first map shows the entire site and describes the maps features. The second map shows an example usage of the data for determining flow on and off of a farm.

Pollution Flow Map



Legend

Rivers

Streams

Cubic inches

≤83799

≤212107

≤400301

≤854472

≤2494872

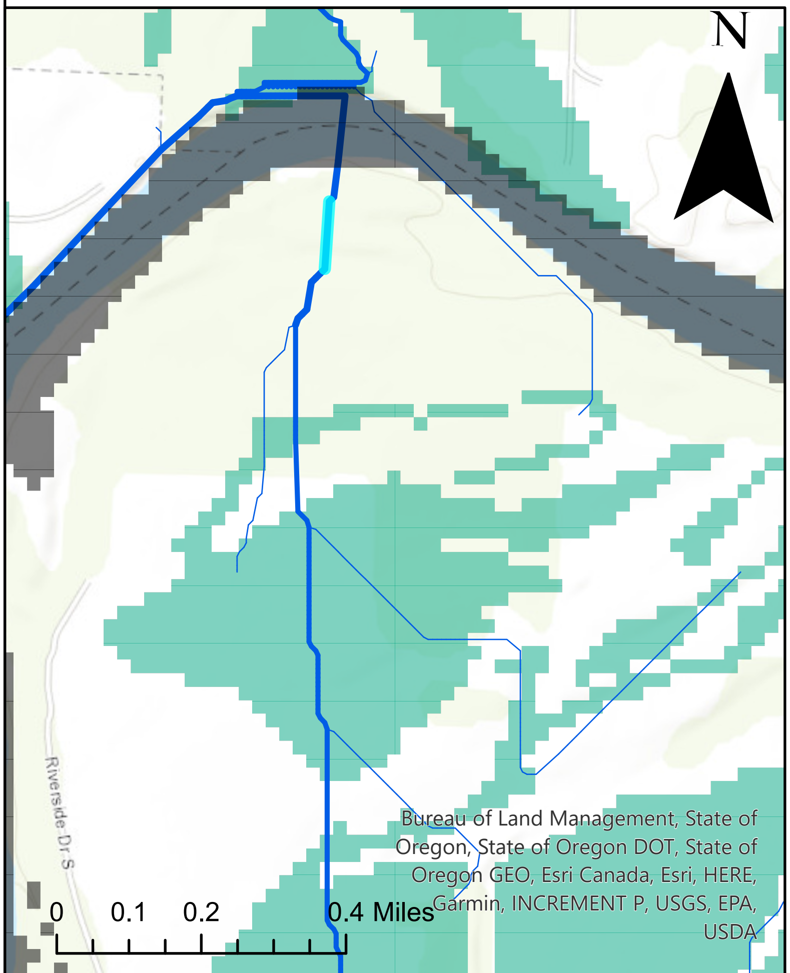
Farmland

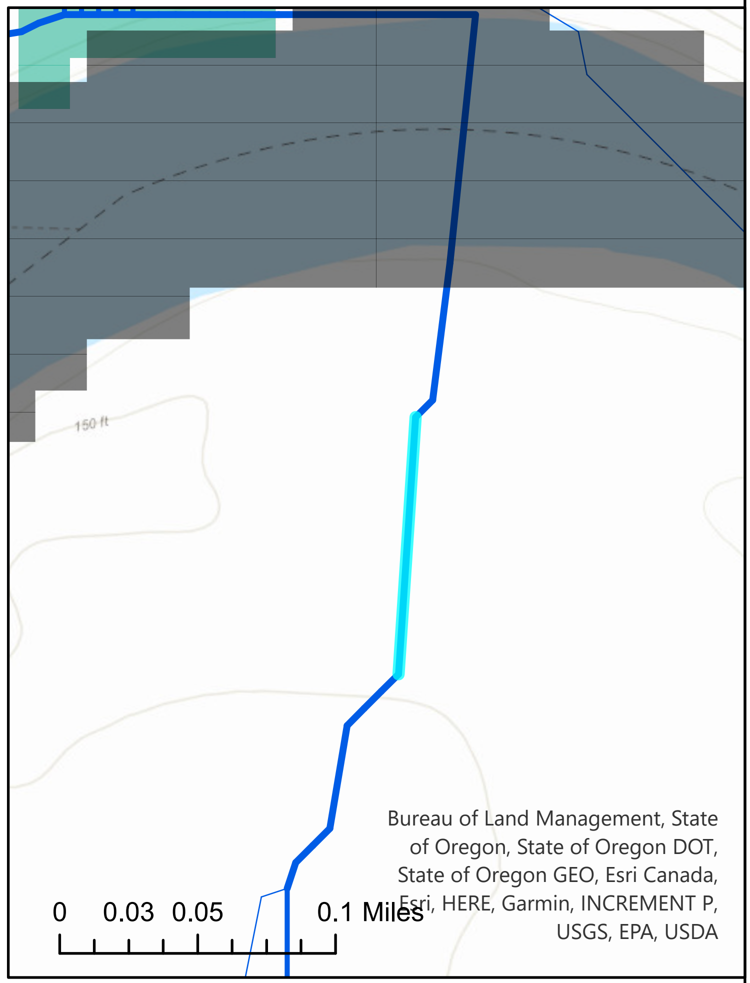
This map was created by OSU student Mark Philippi for use in modeling farmland polluted water volumes.

This map shows the farmlands in green. Streams coming from the farmland are in blue and grow larger the more volume they hold. Streams of volume under 5.8 cubic feet are ignored to reduce noise on the map. Wetlands and rivers are shown in black, these are the points where the polluted water is considered as river pollution.

This map can be used to investigate individual farmlands or collections of farmlands for use in planning water retention pond volumes.

Example usage of analysis





Legend

Rivers

Streams

Cubic inches

- ≤83799
- ≤212107
- ≤400301
- ≤854472
- ≤2494872

Farmland

These maps, which were created by OSU student Mark Philippi shows the polluted water runoff from farms. This water often contains pollutants that can be reduced by holding the water to let it settle.

This shows a theoretical application of this analysis. If a farmer or water official wanted to analyze the outflow from a particular farmland, such as the one shown on the left, they could navigate to the farm and select the outflow, as shown on the right. This would let them know the total amount of water passing leaving that farm, which was found to be 9262 cubic inches or 5.25 cubic feet of daily outflow in this case.

If only the output of one farmland was wanted then select the input to the farm and subtract the input from the output.

This analysis allows for determining the theoretical pollution from a farm for use in designing holding ponds.

Issues with this project are lack of usability for finding totals. This model is best used for a small collection of farms, a large grouping of farms would require hand calculations to find the total flow into streams. The model is useful in comparing outflow from multiple farms to determine problem areas.

When attempting to select polylines that intersect with the target raster, multiple polyline that feed into each other are selected. This makes it impossible to summarize total flow into the rivers with this model as it greatly overestimates volume.

Overall, while this model provided useful information, the largest issue is the lack of an easy way to analyze data.

Appendix

<u>Sources:</u>

"Agricultural runoff." (n.d.). *Agricultural runoff - Washington State Department of Ecology*, Washington State Department of Ecology, <https://ecology.wa.gov/Water-Shorelines/Water-quality/Runoff-pollution/Agricultural-runoff#:~:text=Agricultural%20runoff%20can%20pollute%20lakes,out%20of%20streams%20and%20rivers.> (Mar. 12, 2021).

"Managing Farm Runoff." (n.d.). *Waikato Regional Council*, Waikato Regional Council, <https://www.waikatoregion.govt.nz/environment/land-and-soil/managing-land-and-soil/managing-farm-runoff/> (Mar. 12, 2021).

"The Sources and Solutions: Agriculture." (2020). *EPA*, Environmental Protection Agency, <https://www.epa.gov/nutrientpollution/sources-and-solutions-agriculture> (Mar. 12, 2021).

<u>Data files:</u>

DEM:

https://data.doi.gov/dataset/shaded-relief-and-color-shaded-relief-maps-of-the-willamette-valley-oregon

Wetlands:

https://spatialdata.oregonexplorer.info/geoportal/details;id=d5244080c8b344b280c9f43ed6b48089

River:

https://spatialdata.oregonexplorer.info/geoportal/details;id=363d8857204e4b2f900895395f47310a

Annual Precipitation:

https://spatialdata.oregonexplorer.info/geoportal/details;id=3697813012da4982b34f93077f83a7a1

Farmland:

https://spatialdata.oregonexplorer.info/geoportal/details;id=d1a8122fe7954b0db3a943bf92179f65