Reducing Basin Energy Through Wetland Retainment: Applying GIS Methodology

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Introduction

This project is intended to aid in thesis research regarding hydrological connectivity of an actively managed riparian zone within an approximately 200-acre basin. Assessing the hydrological connectivity of this basin will aid in creating a comprehensible picture of the water's surface and subsurface influence on flood and erosion effects in perennial and intermittent attached streams. Using a top-down watershed management approach is ideal in analyzing cascading effects within a watershed. Within this management approach, water energy reduction in upstream reaches can lessen negative flood and erosion effects downstream.

Wetlands

Negative downstream effects can be the outcome of poor water retention in slopes due to soil degradation through deforestation or a lack of meandering and retention in tributaries causing increased water energy. Another key contributor to the effects of flooding and erosion are wetlands. Wetlands are valuable natural features that aid in flood protection, water quality, and erosion control. They excel in these roles by retaining water based upon low topographic locations and highly productive soil and vegetation characteristics. The sponge-like characteristics of wetlands absorb and slowly release water from surface flow, precipitation, runoff, and groundwater. Wetland soil types, such as clay, have small particle sizes which allows for very slow draining compared to that of larger particle size soils. Vegetation in wetlands is specially adapted to aquatic habitats and thrives off water that is held by soils. This gives vegetation a constant source of nutrients. Wetland absorption functions are important and can be used to mitigate downstream effects by slowing down channel flow, resulting in lower outflow energy into attached streams. Proper planning and management are key to this success.

Thesis Relevance

This project will be a key reference in my M.S. thesis study on hydrological connectivity. My thesis goal is to enhance restoration of an emerging wetland and riparian zone function to reduce flood risk and erosion in perennial attached streams. Furthermore, I would like to assess the groundwater and surface water runoff and their influence on the output of channel data. Through the evaluation and implementation of potential management practices, such as natural, mechanical, structural, and grazing treatments, we can work towards the goal of wetland and channel enhancement. Natural processes in watershed management and environmental planning should be emphasized in conjunction with constructed and man-made approaches to maximize ecological and function. Through these assessments and actions, we can reduce erosion and flood potential by lowering water energy into Oak Creek, the main tributary in the Oak Creek Watershed. In an area that experiences high precipitation and runoff, flooding is a common event and is of high management priority.

Objective

The objective of this project is to evaluate DEM models, tributary thresholds, drainage responses, slope, flow, calculations, and physical landscape characteristics to determine areas that would be of best interest for the installation or creation of wetland retainment structures. GIS applications can aid in boosting wetland hydrologic resonance and expansion. Evaluating connectivity of water in this area will give a better understanding of inflows and outflows in the riparian area. The outcome of this project can help in deciding management approaches to boost the overall basin functionality by slowing hydrologic movement on its way toward Oak Creek.

Site Description

The project study site is located within the small 8,300-acre Oak Creek Watershed of the larger 12,030-acre Lower Marys River sub-watershed, HUC ID: 170900030211, on Oregon State University property in Benton County, OR (USDA 2005). More specifically, the basin encompasses the Oregon State University Sheep Center on Oak Creek Drive. The basin is roughly 200 acres and is structured with slopes to the north, south, and east. The west edge of the site is bordered by Oak Creek, a tributary of the Marys River. The topography comprises of Oak Savannah, an emerging wetland, functioning intermittent tributary system, sedges, and grazing grasses. The riparian zone is near the center of the basin.

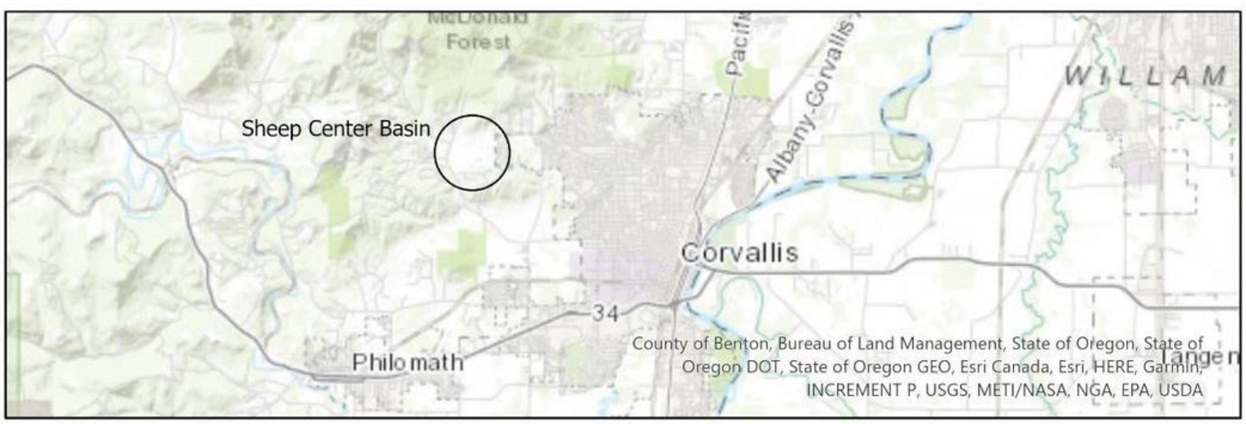

Fig. 1: Study site in reference to Corvallis

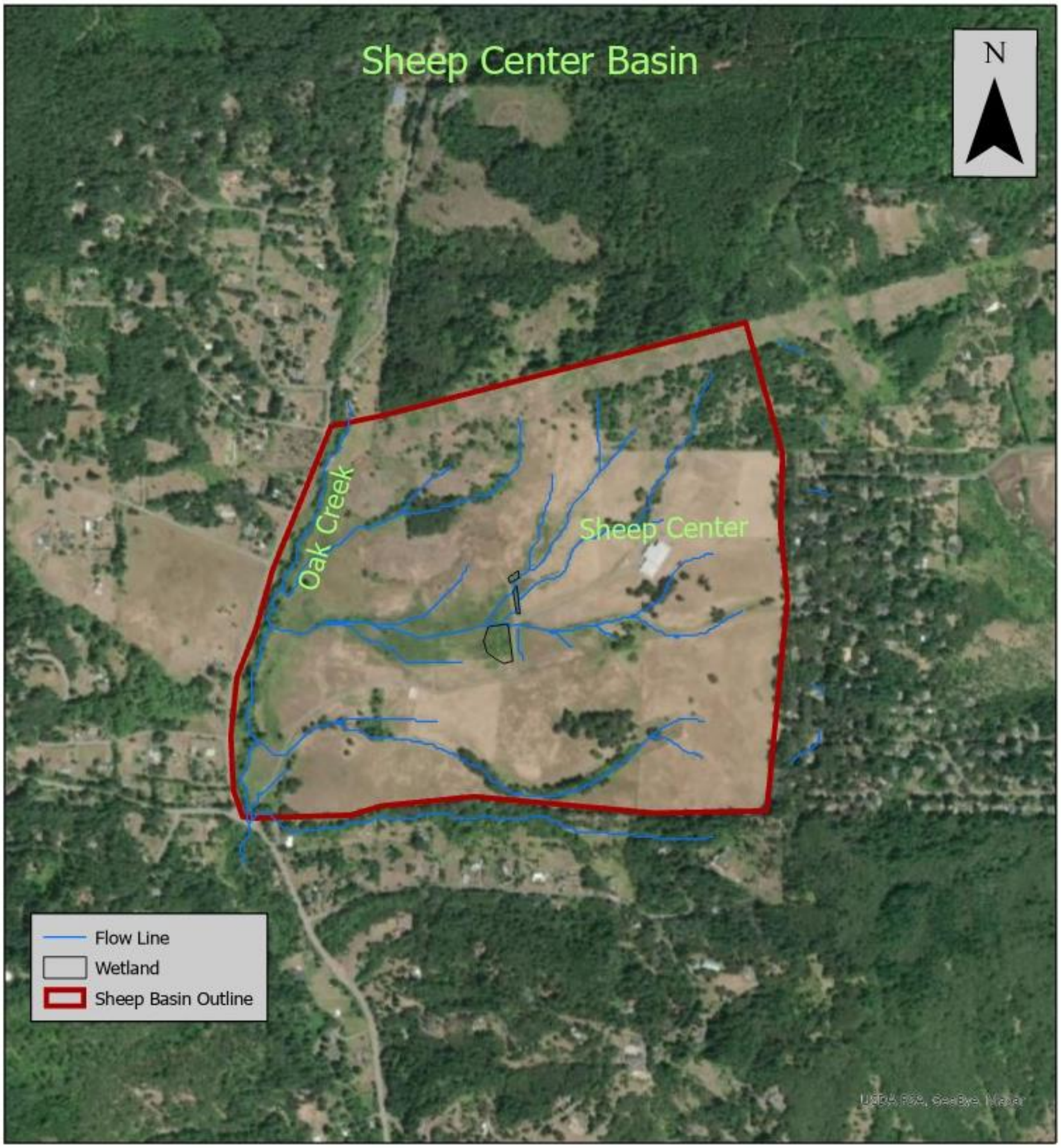

Fig. 2: Sheep Center Basin – study site

Data

Data	Type	Source	Projection	Resolution
DEM (Digital Elevation Model)	Raster: USGS_13_n45w124	USGS National Map Data Download	NAD 1983 UTM Zone 10N	1/3 Arc Sec
Watershed Borders (used in delineation)	Vector	Benton County GIS Data	NAD 1983 Contiguous USA Albers (not used in calculation steps)	1:100,000
Stream Network Data (used in comparison of calculated stream thresholds)	Vector	NHDPlus	NAD 1983 UTM Zone 10N	1:24,000
World Imagery	Base Layer Vector	ArcGIS Pro	NAD 1983 UTM Zone 10N	

Fig. 3: Data Sources

Methodology

ArcGIS Pro was used to locate areas that would help in assessing management techniques to increase resonance within the wetland areas. This was done through watershed delineation and landscape depression raster calculations.

Watershed Delineation

To display an understanding of the watershed functions of this basin, a coordinate was taken at the outflow of the basin's main channel at Oak Creek using a Geode.

Geode coordinate point: -123.3370632°W 44.5923682°N

This coordinate point helps create and display a watershed of flow of contribution to the Oak Creek Geode coordinate (Fig. 4). This indicates the many catchments and reaches that add to the flow of Oak Creek at this specific point in the watershed. The basin in which this study is taking place is one of many influences on Oak Creek and incorporates several small catchments. Although the study basin alone does not contribute mass flows to Oak Creek, this project will provide a modeled after approach to be used in other basins and catchments to analyze connectivity and possible flow reduction.

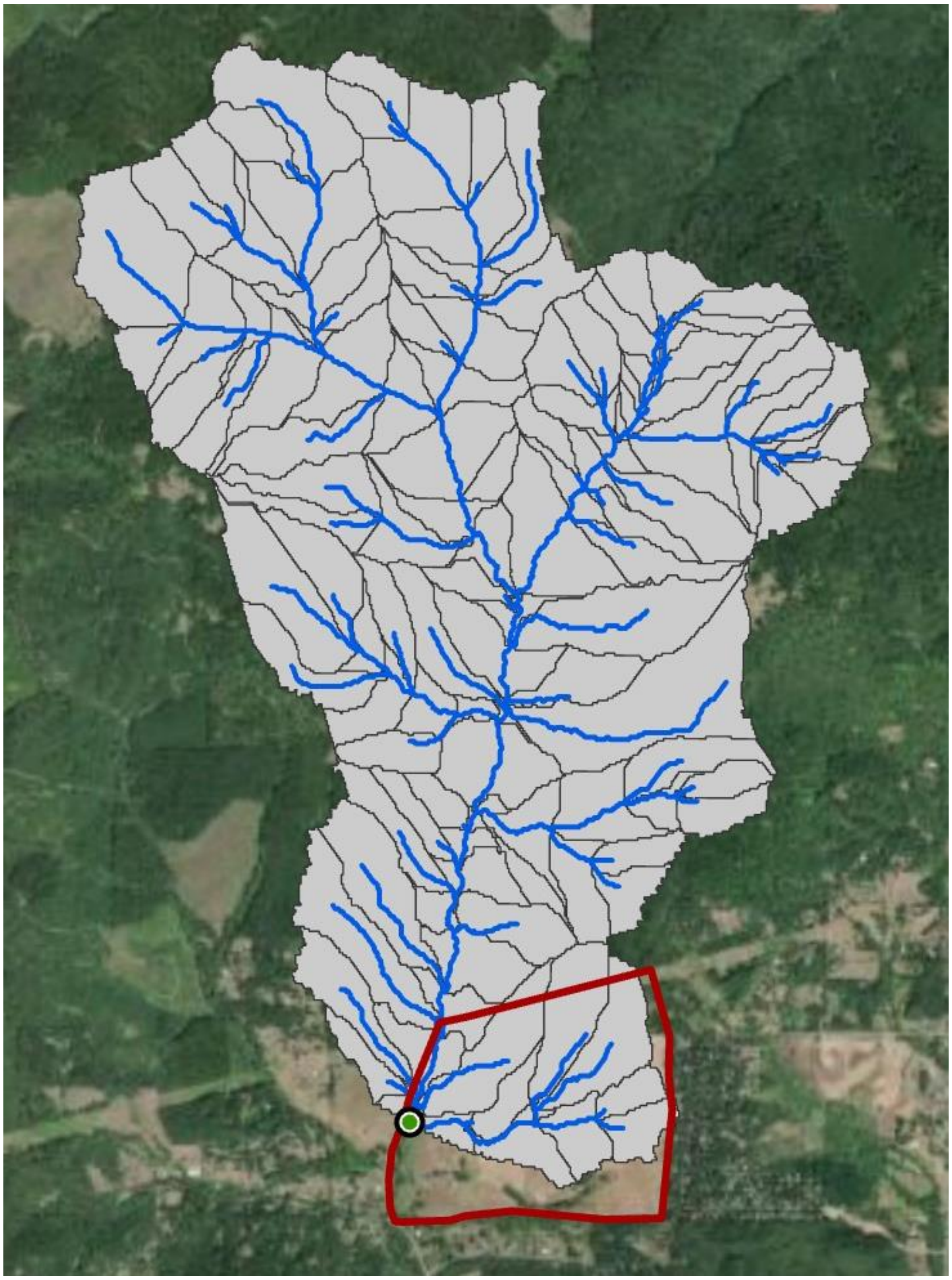

Fig. 4: Oak Creek Watershed

To delineate the specific area of the study and to use as a base map, the border of the Sheep Center basin was outlined by encompassing the highest and lowest areas of the property. World imagery and every layer passed this point was clipped to that of the Sheep Center basin border (Fig. 5). The USGS DEM layer (File: USGS_13_n45w124) was added and converted to the desired projected coordinate system of NAD 1983 UTM Zone 10N (Fig. 5).

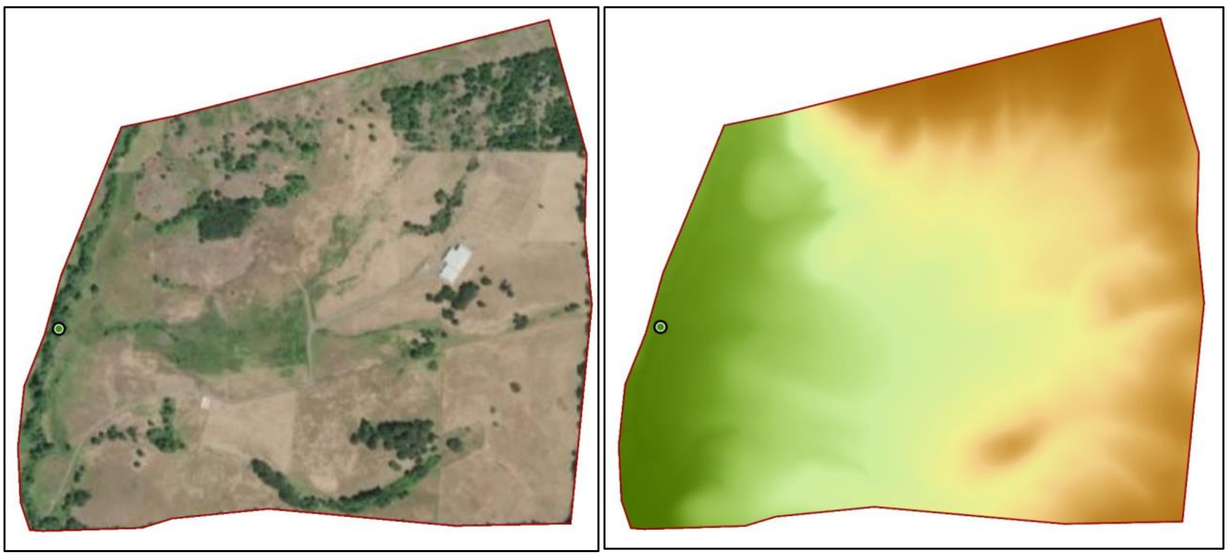

Fig. 5: Sheep Center outline (left) and addition of DEM (right)

Continuing the watershed delineation of the study area, spatial analysis operations were used to display, fill, flow direction, flow accumulation, and stream definition raster calculations of > 500 (Fig. 6).

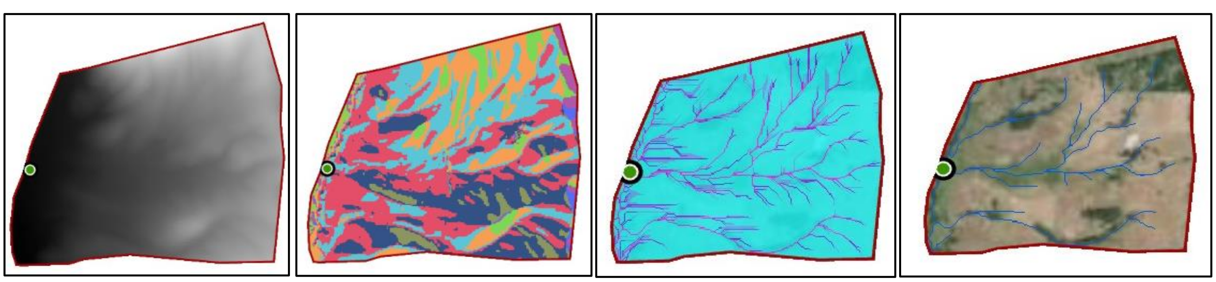

Fig. 6: In order: fill, flow direction, flow accumulation, stream definition.

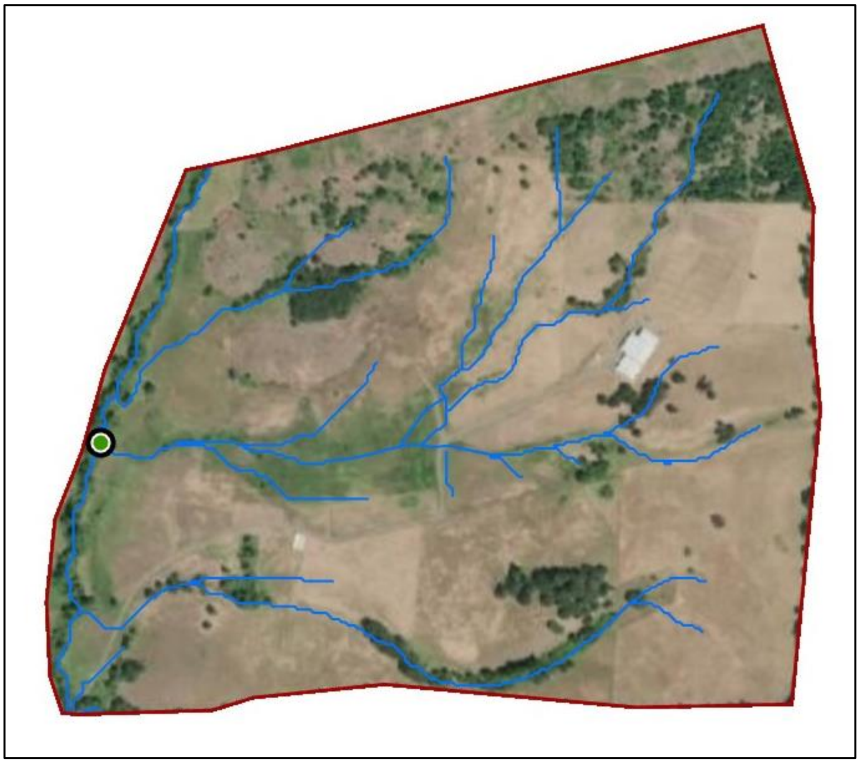

Fig. 7: Raster to Polyline of streams

Stream definition > 500 was converted to polylines using the Raster to Polyline conversion tool (Fig. 7). Watershed delineation in this project was important to show overall function in the study basin. By delineating the watershed, we can analyze flow patterns and topography. The most important step that will be addressed in the following section is flow direction, flow accumulation, and the use of the DEM in calculating depressions.

Finding Depressions

Using DEM raster calculations to locate depressions in the landscape was critical in the process of determining areas of wetland resonance management implementation. To accomplish this task, the following steps were taken:

1. Focal statistics using the DEM from USGS. The use of a 3x3 window and statistic type: MAX, evaluates the elevation within a 3x3 and emphasizes the maximum elevation variable in the center cell. From there, the process continues along each cell evaluating and placing the MAX DN as the identifiable variable. The

result is an output layer of the MAX focal statistic. This same process is then done using the MIN as the statistic type. The result of the second process is an output later of the MIN focal statistic for each cell.

2. Now that there are two layers created from focal statistics, MAX and MIN, these layers can be used in the raster calculator. MAX – MIN = Depression Output. This layer showing the differences between the MAX and MIN focal statistics will display depressions on the landscape.
3. After classifying the results from the raster calculations into a color scheme in the Depression Output, it is possible to see the depressions in the landscape about these surrounding cells.

Cells value corresponds to areas with the greatest depression. The lower the number value, the greater the depression. 0.01 indicates the lowest value and the greatest depression, while 8.33 indicates the max value and least depression. These depression outputs are not based on total basin elevation but rather elevation in reference to neighboring cells.

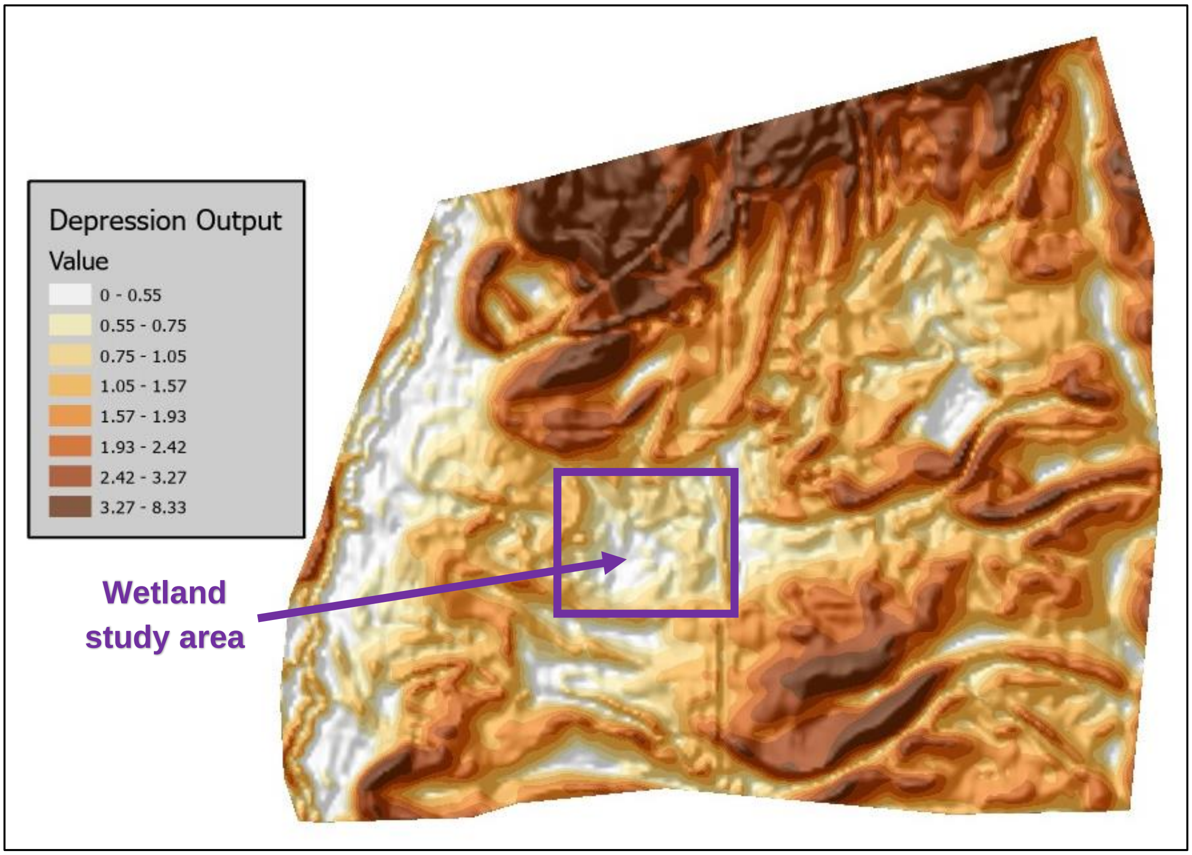

Fig. 8: Sheep Center basin depression output

Methodology Processing

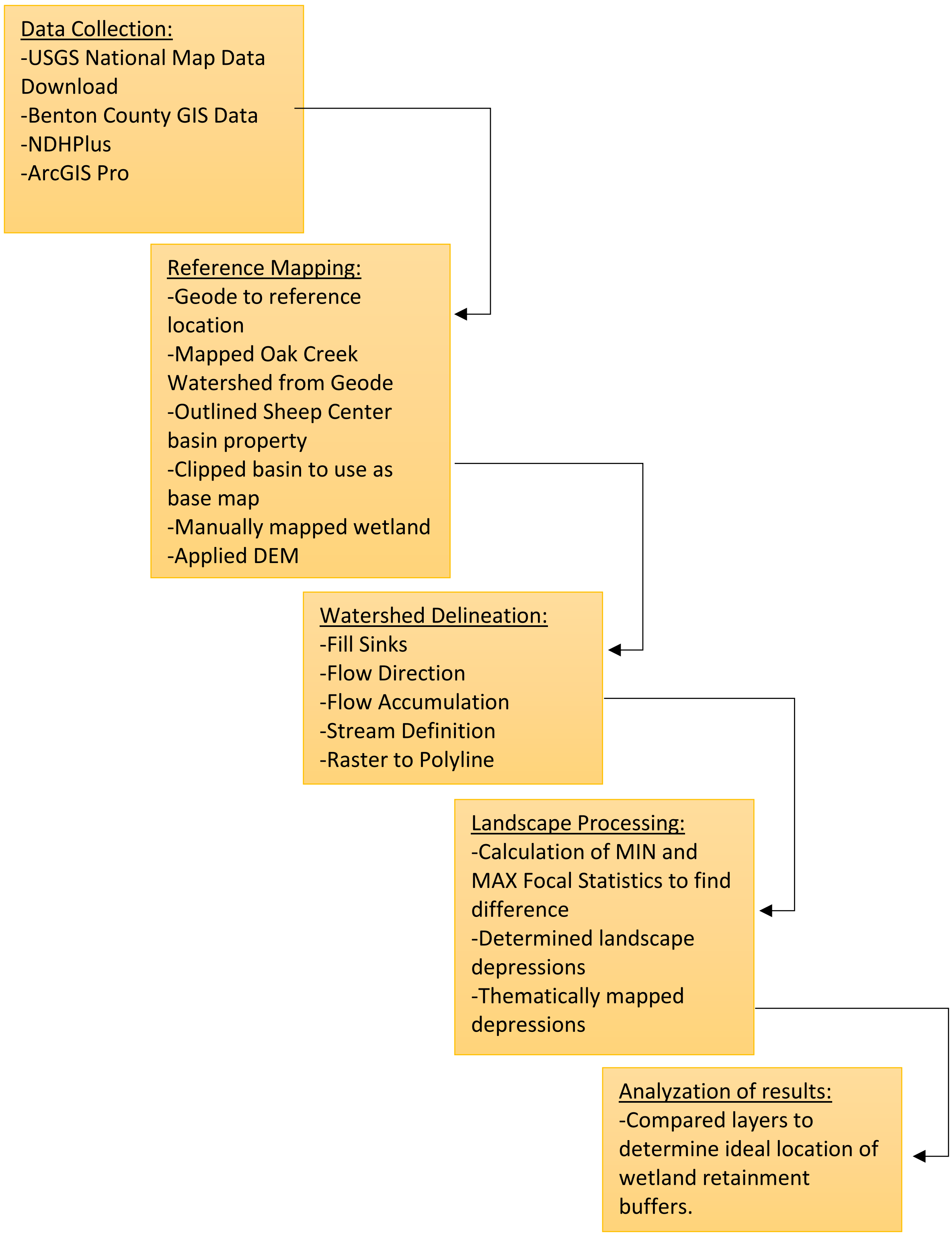

Fig. 9: Methodology

Results and Discussion

Within the area of the riparian zone, much of the surface hydrologic movement is high energy runoff from the wetland to the main channel. Due to the high water table, topography, and climate of the site, surface water movement during the fall, winter, and spring months is plentiful and leads to standing water causing depression inundation until mid-summer. Dense soils such as clays prevent draining of water until early summer when temperatures rise. We believe this system is dominated by deep groundwater movement into the main channel with the clay layer separating shallow subsurface flow from deep subsurface flow. The lack of draining deep into the groundwater zones and topography of the area allow for accumulation of water on the west edge of the wetland. Additionally, the wetland sits at a slope leading to water accumulation and westward flow.

Flow Accumulation

To show this in ArcGIS Pro, the flow accumulation function allows display of water movement based on elevation and flow direction (Fig. 10). Use of pre raster to flowline conversion allowed for greater analyzation of stream definition runoff. Showing a low enough threshold of flow accumulation helps in addressing the movement of surface runoff.

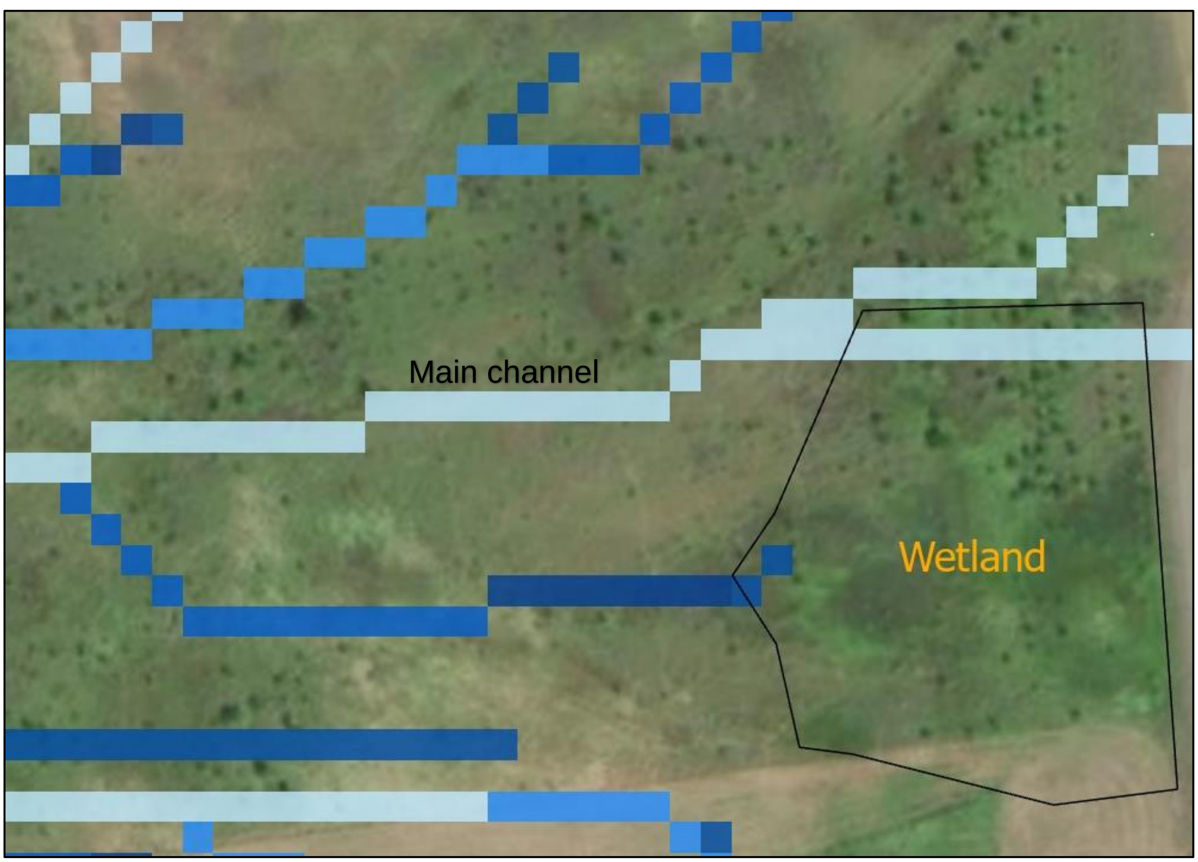

Fig. 10: Flow accumulation leaving wetland. Raster cell indicating flow.

Fig. 11: Flow accumulation leaving wetland through surface-subsurface interaction. Red circles indicate the start of accumulation. Low water levels due to minimal precipitation and runoff at the time the picture was taken.

Landscape Depression

The next step in determining the optimal locations for wetland retainment is to analyze the depression layer. Based on the value classifications of the output, the greatest depression is the area west of the wetland in white 0 – 0.55 (Fig. 12).

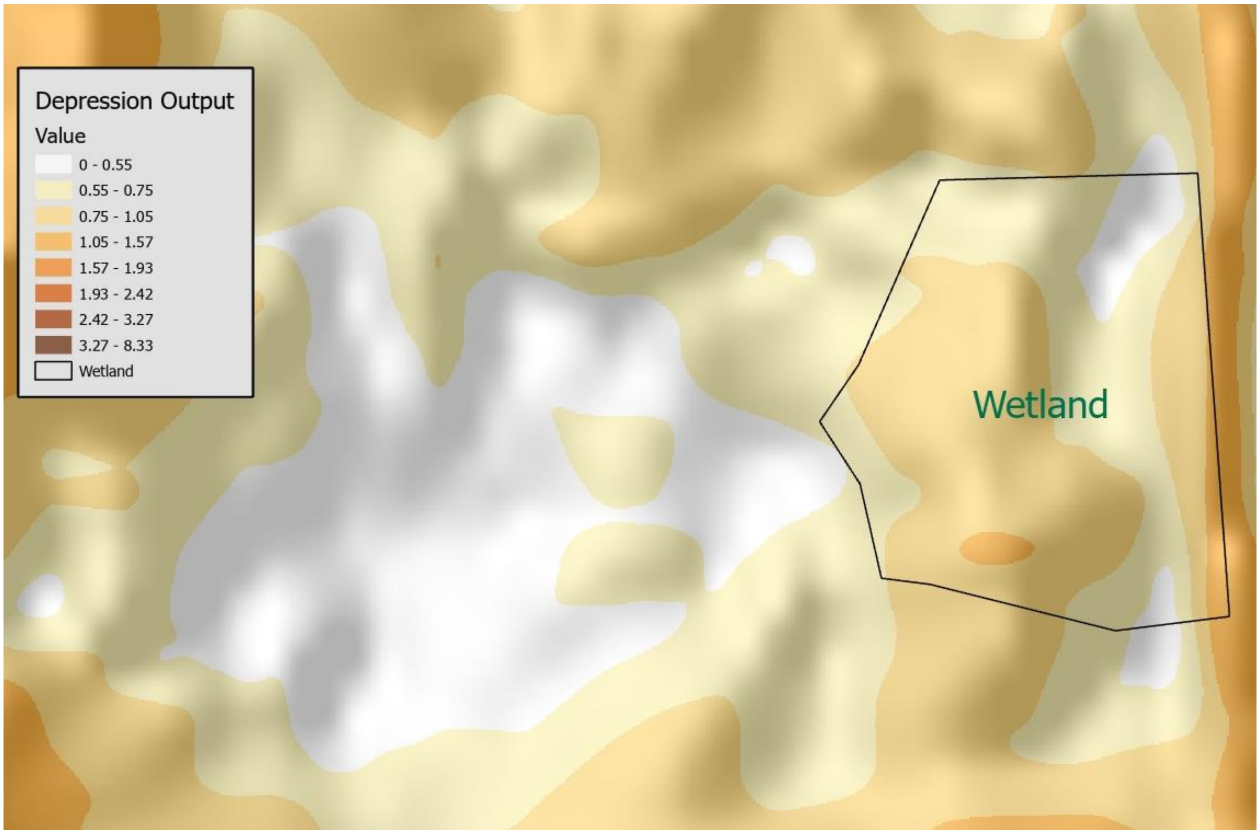

Fig. 12: Depression output near wetland

Within the white area of depression by classification, the purple indicates areas of depression less than 0.40m (Fig. 13). Areas of less than 0.40m have had greatest inundation since the study has begun in September.

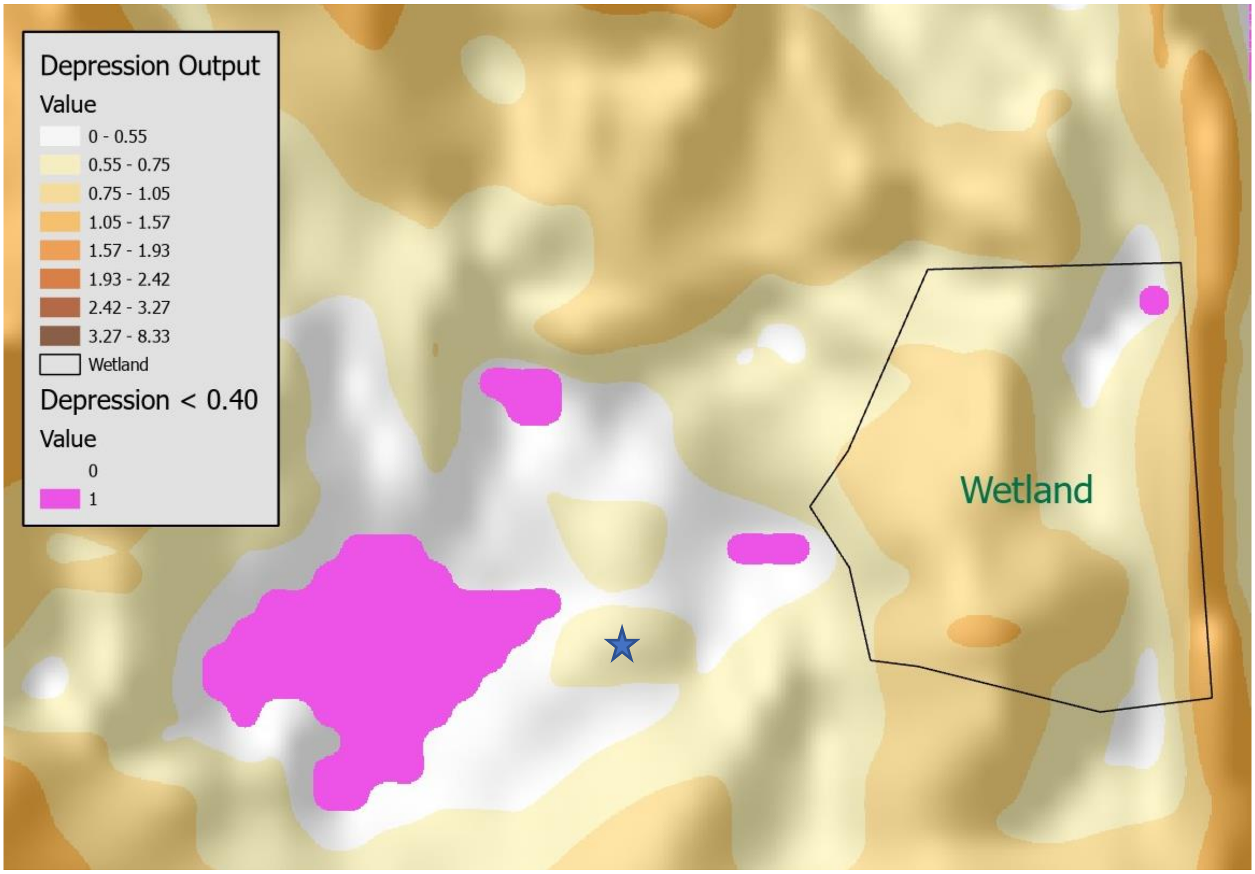

Fig. 13: Areas of inundation of less than 0.40 depression value. Star indicating below photo (Fig. 14)

Fig. 14 shows a photo of water flowing from the wetland between and around depression value 0.55 – 0.75, indicated by the star in Fig. 13, towards the inundated area. Flow from the inundated area in purple (Fig. 13) continues as runoff towards the main channel.

Fig. 14: Photo showing area of constant inundation, even during a dry point of the winter, represented by star on Fig. 13. Surface flow path on both sides of photo show landscape depression

Combining Functions for Analysis

To narrow down areas to increase resonance through retainment implementations, the flow accumulation layer and the depression output can be used in conjunction. This will help determine how the water patterns operate and provide locations to decrease flow.

In Fig. 15, the combination of raster flow accumulation and depressions share, or are bordered by, common cells. These common cells can help determine areas that can be considered for retainment. With the addition of the flow direction function, we can better assess how far the retainment needs to be in place (Fig. 15).

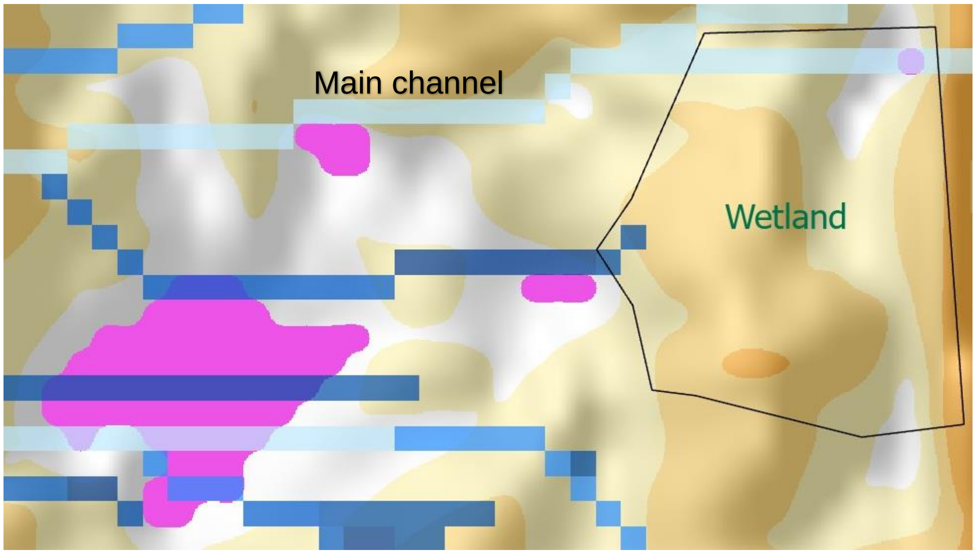

Fig. 15: Flow accumulation and depression output

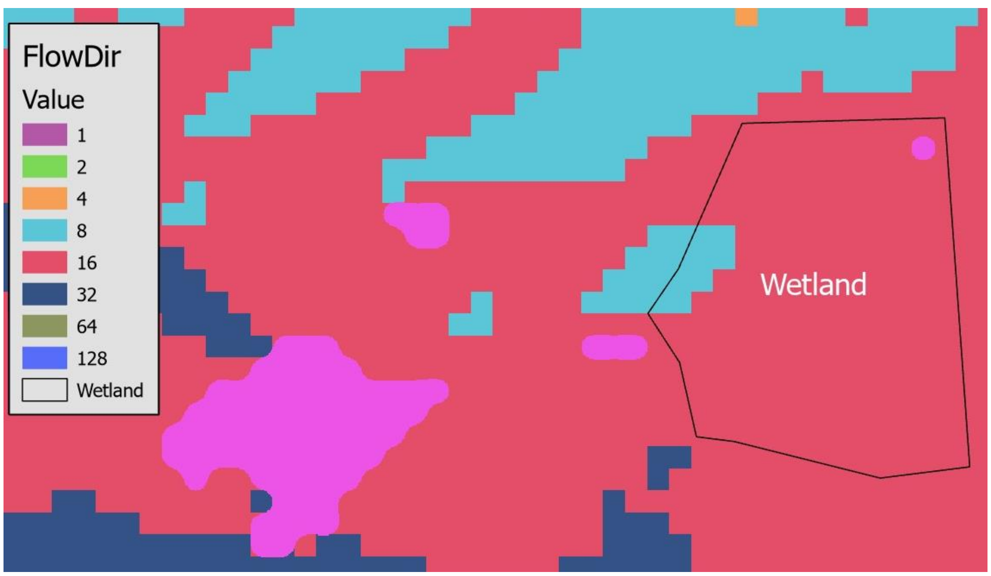

Fig. 16: Flow direction and depression < 0.40. For understanding how flow direction works, please refer to Fig. 17 (below)

32	64	128
16	X	1
8	4	2

Fig. 17: How flow direction works: the number corresponds to the direction of flow.

Once we understand where flow accumulates (Fig. 15), in which direction it is flowing (Fig. 16), and how depressions can work to our advantage, we can decide on potential locations for retainment structures.

Decision

After analyzing the different layers of accumulation, direction, and depression, there are two main locations that will be of ideal retainment structure emplacement. ‘A’ location incorporates the SW and W flow of water, indicated by the flow direction values of 8-SW and 16-W (Fig. 18). The flow direction is responsible for the flow accumulation based on topographical changes in elevation and slope. The flow direction and accumulation show surface water ponding at the main wetland water outflow point or point ‘A’. ‘B’ location indicates a NW and W flow on the outer edge of the wetland from depression ‘C’ (Fig. 18). ‘C’ is a depression on the south side of the wetland. Westward flow from ‘C’ occurs when surface water reaches its Fill and Spill point (Camporese 2019).

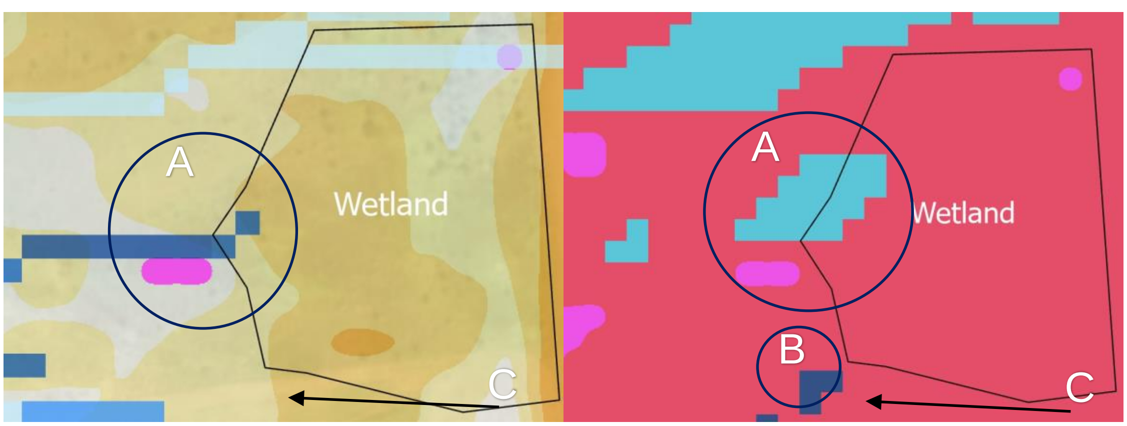

Fig. 18: Potential retainment points. Depression layer with flow accumulation (left) and flow direction layer (right)

Placing the retainment structure at this point will result in less inundation of area 'A' and utilization of land for other management options (Fig. 19). Red 'X' indicates former flow path of wetland outflow. Options could include strategic grazing strategies or planting of trees and other vegetation to boost overall riparian-basin health.

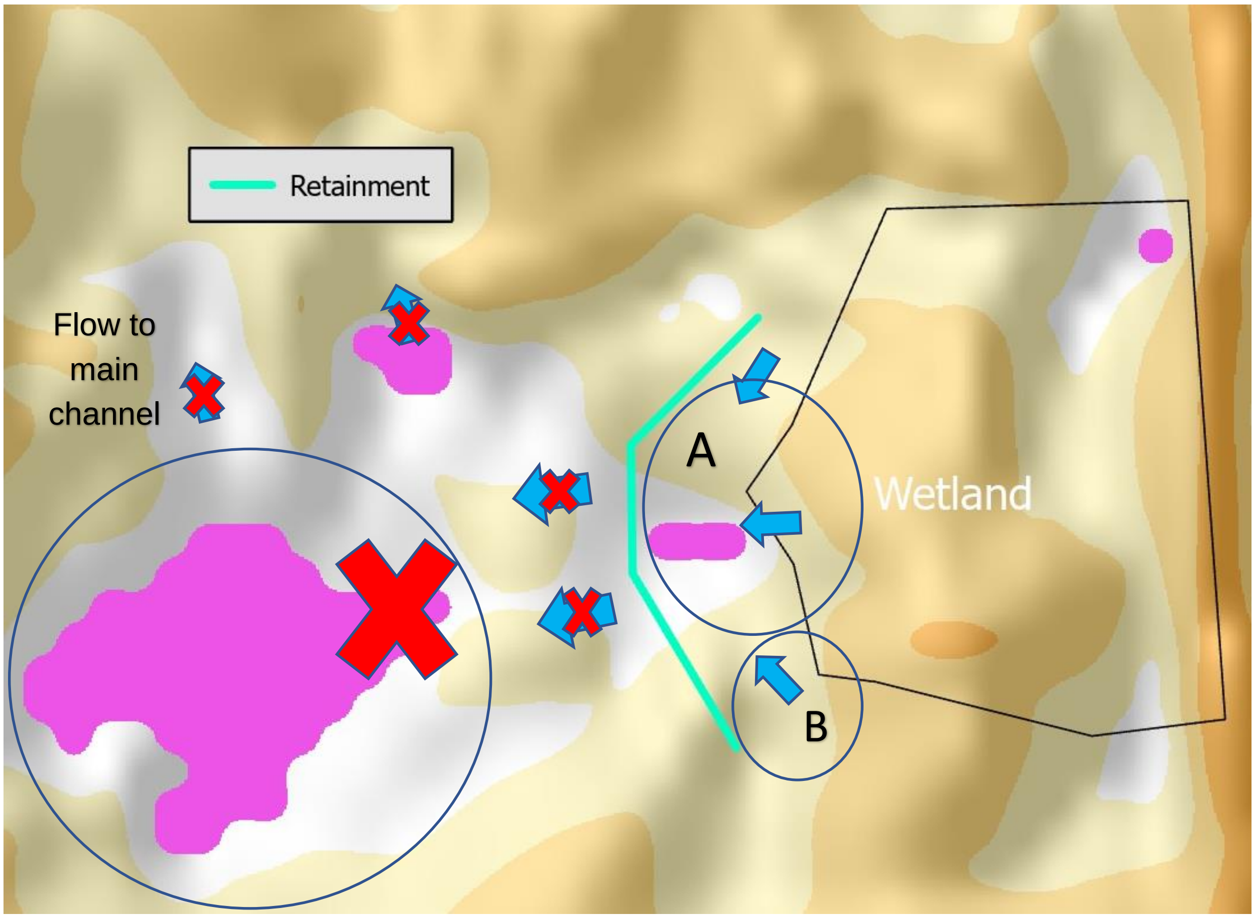

Fig. 19: Preventing water from leaving wetland, canceling inundation

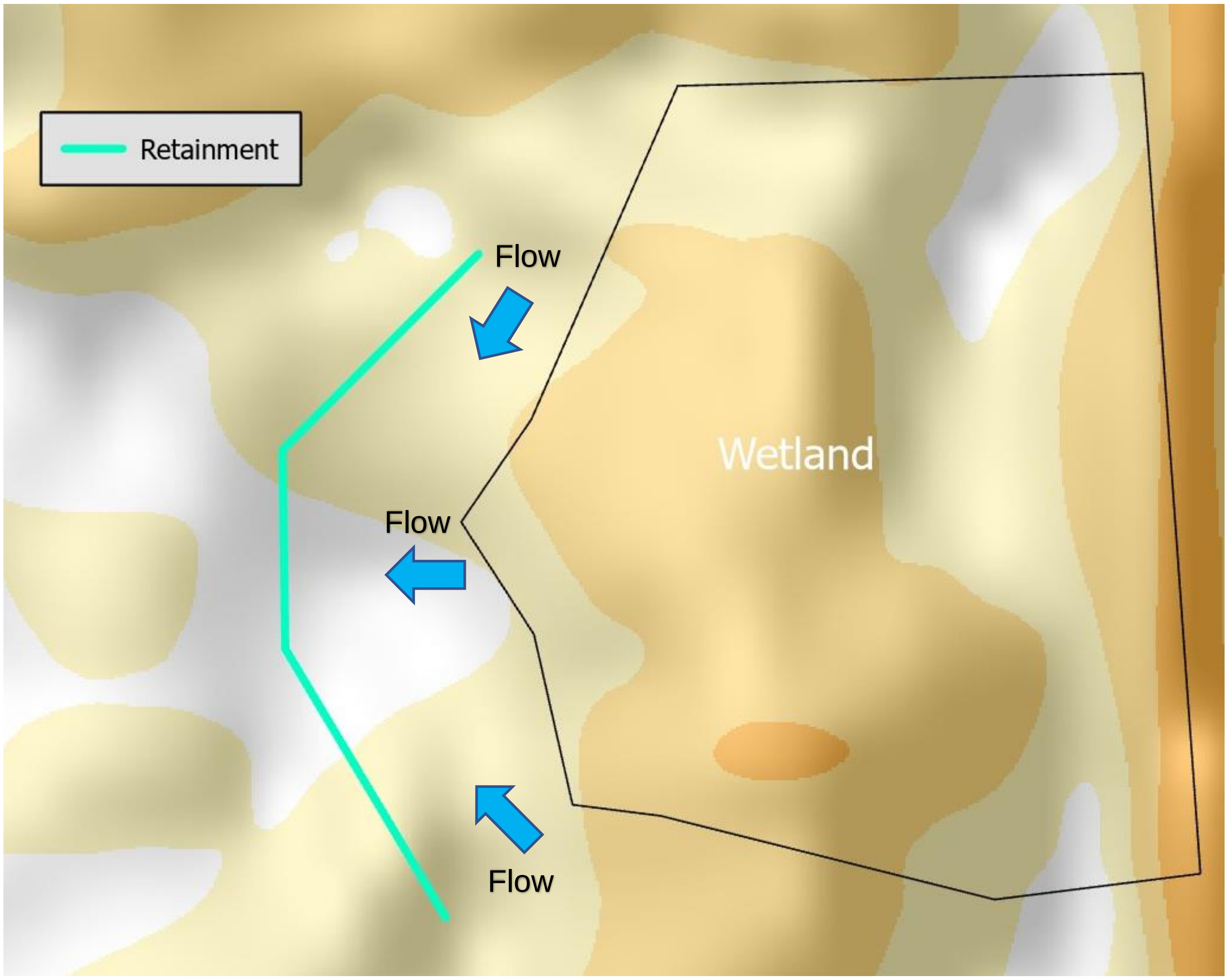

Fig. 20: Close-up of possible retainment location

Limitations

There are numerous tactics and strategies to employ if the goal is to retain water in the basin for as long as possible. This is only one technique and will be used in conjunction with other methods. A key limitation in this project was the period of time. If time was not an issue, water level measurements could have been taken over the course of the year to determine the exact of inundation within the areas of greatest depression. This would allow for more exact results for the retainment structure emplacement and ArcGIS Pro statistics analysis.

Conclusion

To boost wetland ecology and function of this site, decreasing flow from the wetland to the main channel will 1) increase resonance in the wetland thus boosting ecology and 2) decrease water energy flow to the main channel leading to less erosion and less potential flooding. Building natural retainment structures, such as soil-based berms or barriers, will help increase resonance in the wetland. Planting vegetation on berms will help maintain the berms structure and prevent erosion (Landers 2015). Strategically placing berms will create ponding around wetland outflow, retaining water in this portion of the wetland. Retainment via berms is one of many management strategies being used in this site to increase overall basin function. Others include, channel restoration morphological change, grazing techniques, vegetation enhancement, and check dams.

An alternative that has been presented was turning the site of the inundated non-wetland area into an additional or combined wetland. The issue with this is that the inundated area becomes dry in the late summer preventing the growth of wetland plants. Also, the soil composition is much different than that of the wetland. This option is not ruled out, and it will be reviewed for possible alternative solutions to increase function in the basin.

The analyzation of stream accumulation and the calculated depression layer were important in this project. The outcome allows a visual representation of data to use in conjunction with onsite knowledge. Development of this plan gives a better understanding of how hydrological connectivity works within the wetland area of the basin. This project is specific to reducing outflow from the basin into Oak Creek by increasing resonance in the wetland portion of the basin. Future projects include calculating surface runoff potential from inundated area, including the wetland, to the channel. This will further add to the understanding of how much water flows from the wetland, supporting the decision to add wetland retainment structures.

References

Camporese, M., C. Paniconi, M. Putti, and J. J. McDonnell. “Fill and Spill Hillslope Runoff Representation With a Richards Equation-Based Model.” *Water Resources Research* 55, no. 11 (2019): 8445–62. https://doi.org/10.1029/2019wr025726.

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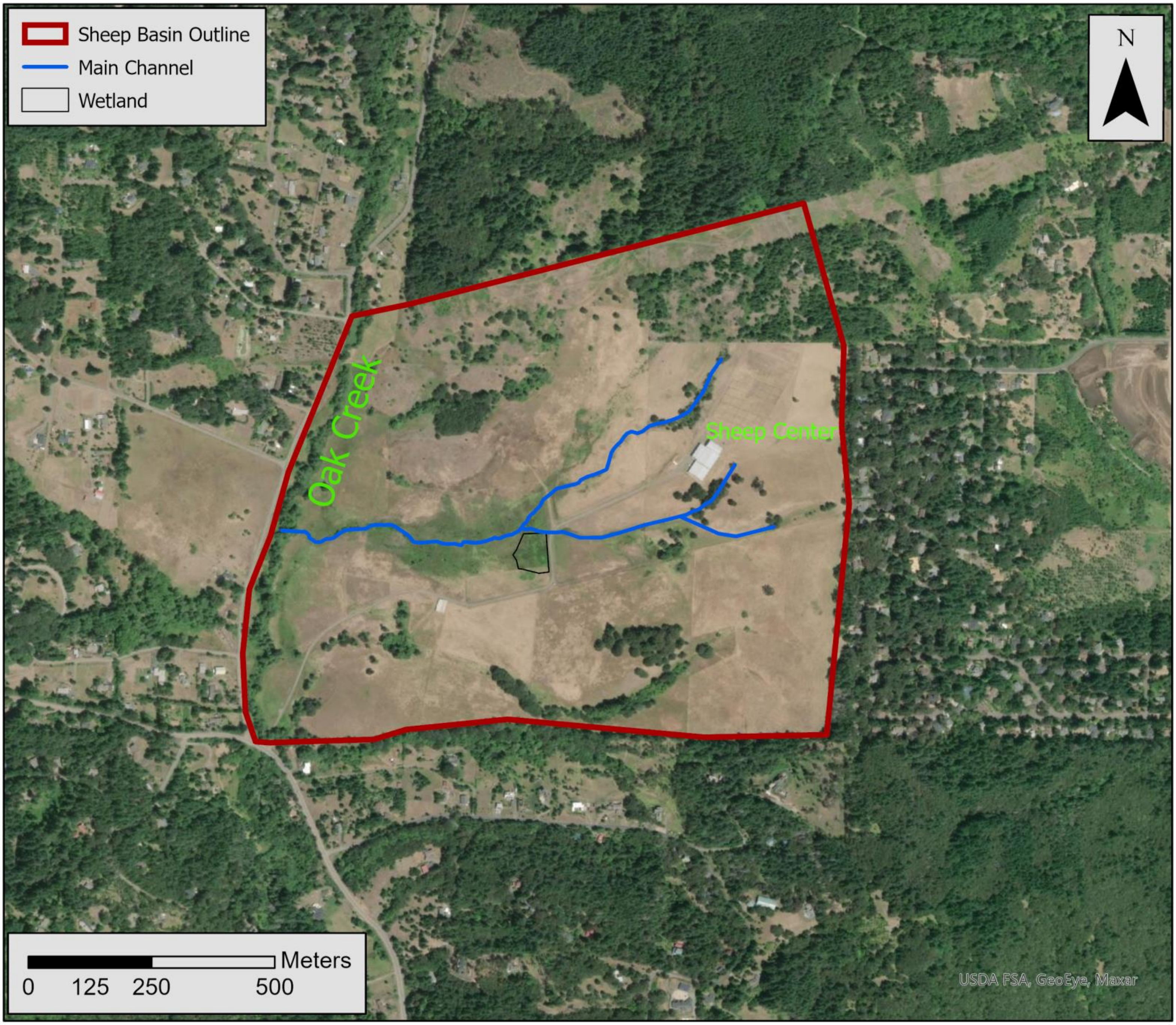
Sheep Center Basin

Drainage within Oak Creek Watershed, OR

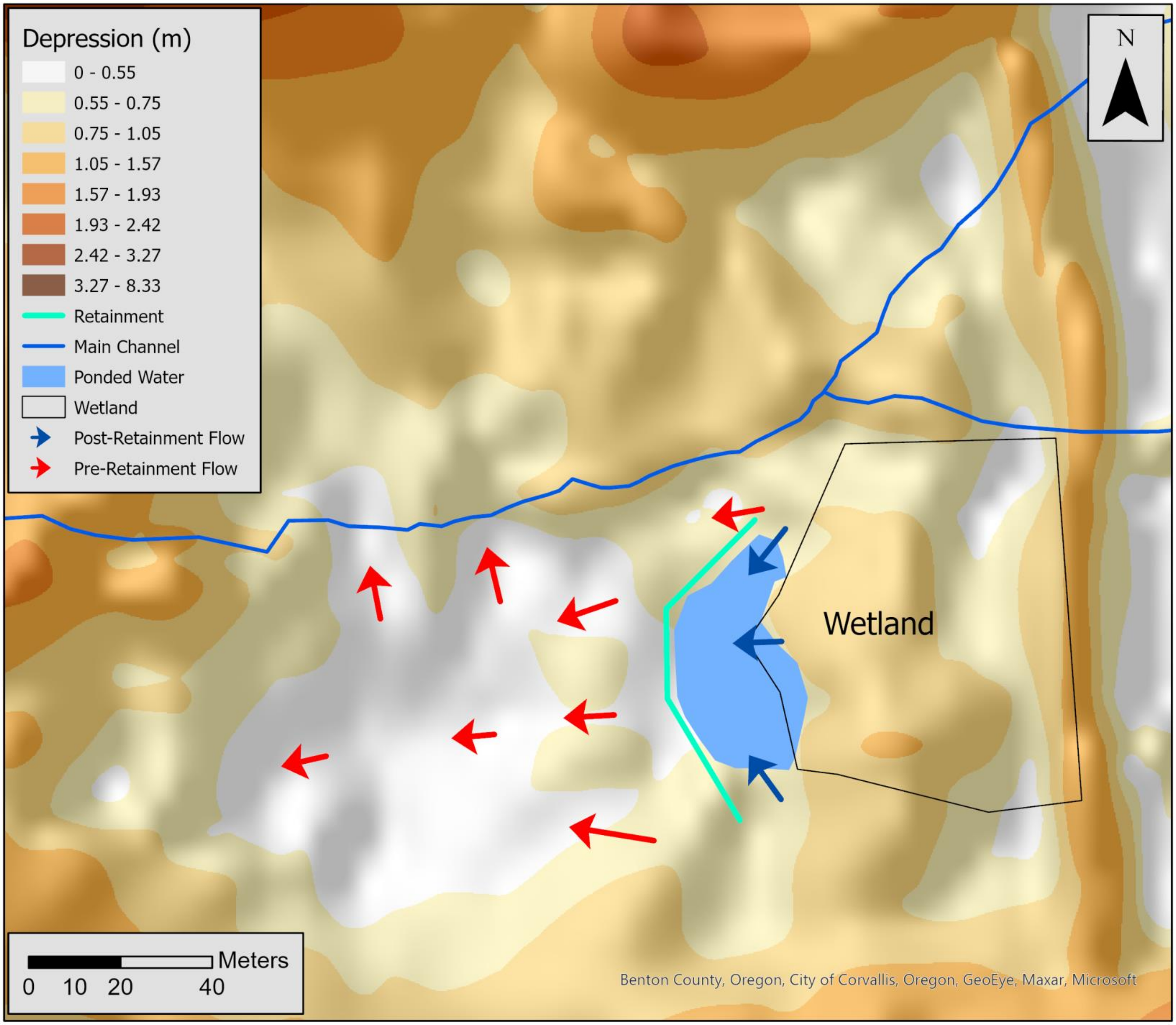


This map depicts the Sheep Center Basin in which this project takes place. The main channel of the basin flows into Oak Creek on the west edge of the basin border. This area is classified as Oregon State University property and is approximately 200 acres in size. It is currently being used for riparian, wetland, and watershed studies by the Ecohydrology Lab at Oregon State University. The basin also hosts sheep grazing operations in specific pastures of the site. The elevation of the site ranges from a high around 265 meters in the northeast corner of the border and a low around 110 meters at Oak Creek near the west border.

Created by Nick Colter
03/07/2021
Projection: NAD 1983 (2011)
UTM Zone 10N

Sheep Center Basin

Wetland Retainment Area



This map depicts an area of the study basin focused on a wetland retainment project. This project explores the use of depressions in the landscape and flow accumulation to determine an ideal location for wetland outflow retainment. Highlighted in teal, this retainment structure composed of soil-based material and supported by vegetative growth, will increase wetland resonance. By halting surface flow to the main channel and other areas of the basin, the retainment structure will result in ponding water leading to possible wetland expansion. Increased wetland function will aid in channel water energy dissipation due to less runoff from the seeping wetland.

Created by Nick Colter
03/07/2021
Projection: NAD 1983 (2011)
UTM Zone 10N