METHODS FOR DELIMITING WETLANDS

IN SLOCAN RIVER WATERSHED USING ARCGIS

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1 Abstract

The primary aim of this project proposal is to explore different methods for delimiting possible locations of wetlands in the Slocan River Watershed using Geographic Information Systems (GIS) techniques. The proposed GIS methodology consists of 3 different approaches (Difference Raster, Slope and Aspect method) using ArcMap and a Digital Elevation Model (DEM) obtained from the open source website: Geogratis. Additionally, a Python script and a Modelbuilder model were created to automate the detection of wetlands and flat areas in just 5 minutes using the Raster difference. Finally, the results from each methodology were represented in a web-map application using ArcGIS Online.

2 Introduction

Wetlands are important features in the landscape that provide numerous benefits for communities, fish and wildlife. They are also highly productive ecosystems that are important for flood control, water purification and habitat for different species. For example, during periods of flooding, they mitigate floods; meanwhile, during dry periods, they retain water.

Unfortunately, information on small potential wetlands across Canada is limited or not available, and this lack of knowledge can cause degradation in these ecosystems (Imran 2008). Activities resulting in wetlands loss and degradation include: pollution, invasive species, commercial and residential development, timber harvest, low dissolved oxygen, heavy metals, sulfurous oxides and other components that are released into the atmosphere by agricultural or industrial activities or vehicles.

Local governments play an important role for minimizing indirect or direct impacts to wetlands by identifying priority wetlands to be conserved, reducing disturbance thresholds or managing invasive plants. This particular project is focused in the Slocan River Watershed located in British Columbia where different societies have been monitoring wetlands in one project called the Slocan Wetlands Assessment and Monitoring Project (SWAMP).

In the Slocan River area, there are some wetlands that are not easily detectable using ground survey or remote sensing techniques, so for that reason this study aims to examine alternative methods for delimiting wetlands.

3. Objectives

The primary objective of this research was to create different methodologies that could be used by different professionals for delimiting potential wetlands using ArcGIS and digital elevation models that are available on open data sources such as Geogratis.

Secondary objectives:

- Detect what is the minimum number of pixels necessary to eliminate areas that are not wetlands.

- Automate each method using Modelbuilder and Python.

- Create a .kml file (Google Earth format) and web map application for comparing each methodology.

4. Study area

The study area comprises the Slocan River watershed that is located in the Kootenay Region, near the villages of Slocan, New Denver, Winlaw and Silverton. In this area there are approximately 189 wetlands that have been documented with an area of 557 hectares. (Durand 2015).

Since 2012 several organizations have been mapping the wetlands in Slocan River using the ranking system which consists in a combination of GIS analysis, remote sensing , field assessments, and analysis of vegetation and percent cover (Durand 2015). Figure 1 represents the boundary of Slocan River in black, the results obtained in yellow color and the provincial wetland layer in blue color. The provincial layer in this figure is vital because it is a reference of comparison for alternative GIS methods for delimiting wetlands.
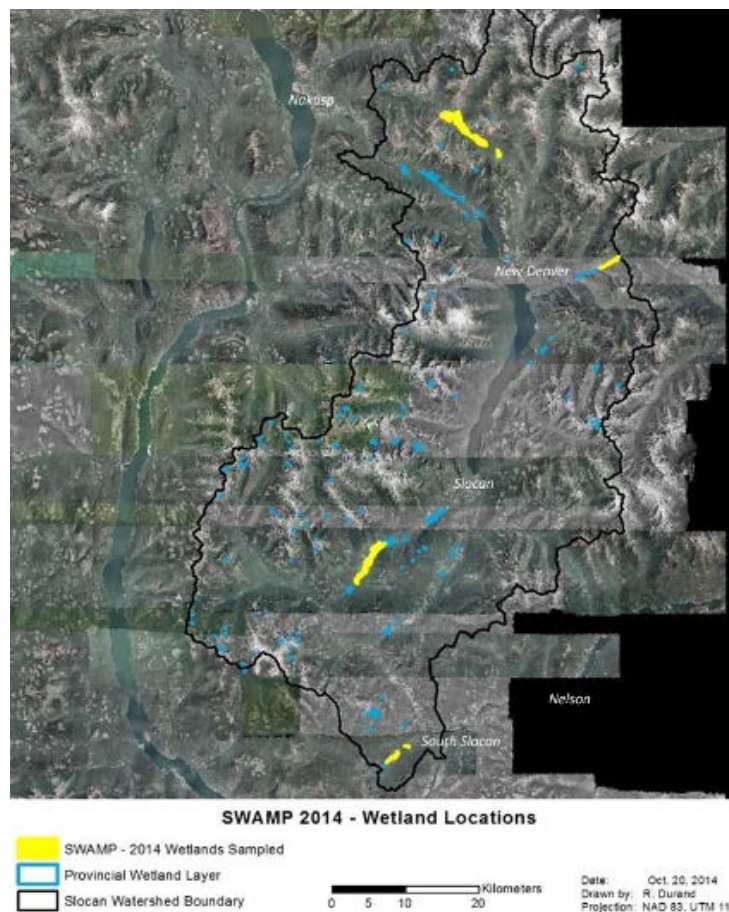
Figure 1 Representation of Slocan Watershed Boundary, previous wetlands obtained and the provincial wetland layer.

5. Data

The digital elevation model (DEM) was obtained using an Open Data portal called Geogratis (Website: http://geogratis.gc.ca/site/eng/extraction). The study area was clipped (Figure 1), and after 12 hours, the information was received by email. Figure 2 represents the DEM from Geogratis and the Slocan watershed boundary obtained by Slocan River Research Center for delimiting purposes.

The coordinate system of this DEM was GCS_North_American_1983_CSRS, and it was transformed to UTM with a cell size of 23 m by 23m in order to measure the area in real units (square meters instead degrees).

A Freshwater Atlas Wetlands dataset was also downloaded from DataBC for comparison purposes. This dataset is available in: https://catalogue.data.gov.bc.ca/dataset/freshwater-atlas-wetlands/resource/53dca277-90b4-44ab-829d-7657e44e8b90

Additionally, two shapefiles were provided, one that contains the Slocan watershed boundary and another one containing the wetlands sampled in 2014 by the Slocan Wetlands Assessment and Mapping Project (SWAMP) and the Slocan River Research Center.
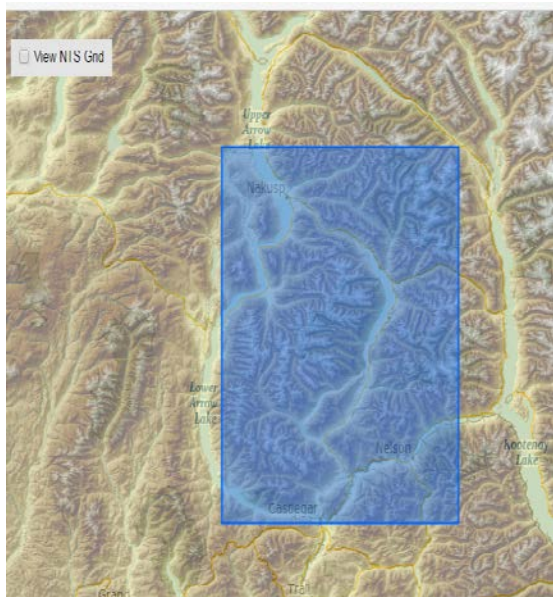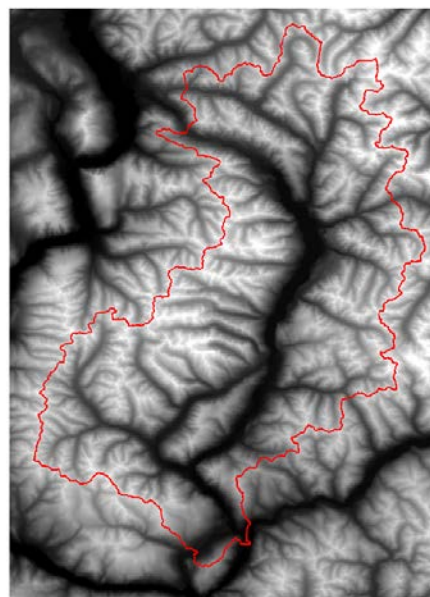

Figure 2: Area clipped from Geogratis portal

Figure 3: Original DEM and Slocan Watershed boundary

6. Methodology

One of the most important characteristics of wetlands is that they are present in flat areas, topographic depressions or sinks. In computer science, this concept could be visualized as follows: a wetland occurs if a pixel is at a lower elevation than all of the surrounding pixels (Doctor and Young 2013) because that area does not have a drain.

Sometimes this area only covers 1 pixel, or more pixels that means that it is necessary to know whether the area represents wetlands or just a dip in elevation caused by a stream bed. One of the approaches to answering this question is to set a lower limit on the number of pixels that helps to obtain real flat areas.

Figure 4 shows all the possible methods for detecting wetlands using Landsat images, SAR images or DEM data. The scope of this project is delimiting wetlands using DEM data and 3 different approach: Subtraction raster, Slope and Aspect method. Each scenario will be compared and analyzed with previous wetlands studies (SWAMP database) for choosing the best match option.
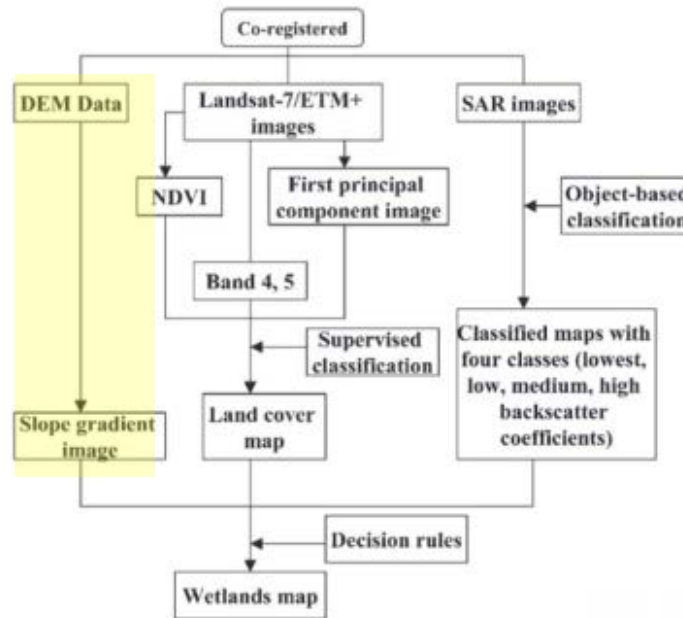
Figure 4: Different approaches for mapping Wetlands (Li and Chen 2005)

6.1 Difference or subtraction raster method

The automated generation of wetlands and flat areas by difference raster (using ArcGIS- ArcMap) primarily involves the following steps:

The automated generation of wetlands and flat areas by difference raster (using ArcGIS- ArcMap) primarily involves the following steps:

1) Clip DEM if a watershed boundary is available in the study.

2) Fill the original DEM using the Fill tool (Spatial Analysis). This tool detects cells with sinks and fills them for allowing a natural flow path in the hydrological model.

3) Subtract the original DEM from the Filled DEM to generate a fill-difference raster. This step generates cells with negative values representing cells that have changed (sinks) and values of 0 representing unchanged cells.

4) Reclassify pixels into 2 categories for a better understanding: 0 representing flat areas such as wetlands and lakes, and 1 representing areas with elevation.

5) Convert the DEM from raster to vector using the Raster to Polygon tool.

6) Start editing mode in ArcMap

7) Open attribute table and order the Shape_Area field ascending. Delete first record with the highest value in area because it represents area with elevations.

8) Query the following expressions and analyze the areas being selected:

   Shape_Area less than 529 s.q.m (that represents the area of one pixel – 23mx23m)

Shape_Area less than 1058 s.q.m (2 pixels together)

Shape_Area less than 1587 s.q.m (3 pixels together)

Shape_Area less than 2116 s.q.m (4 pixels together)

Shape_Area less than 2645 s.q.m (5 pixels together)

Shape_Area less than 3174 s.q.m (6 pixels together)

After analyzing each query, the conclusion was to consider areas of less than 3174 square meters.

9) Eliminate small areas that are not wetlands. Previous query shows that area less than 3174 sq.m are not representative of wetlands.

10) Export the model to kml using Layer to KML tool.

11) Open final result (kml file) in Google Earth Pro for generating conclusions.

6.2 Slope method

Flat areas have a value of 0 in the Slope tool in ArcMap. This method considers 3 types of scenarios during the reclassification: slope with 0 degrees, slope less than 1 and 3 degrees, and the results are compared for final conclusions.

1) Run Slope Tool in DEM.

2) Generate 3 results using Reclassify tool and the following criteria:

Option 1: Value 0 = Slope of 0 degrees, Value 1 = Slope between 1-45 degrees

Option 2: Value 0 = Slope less than 1 degree, Value 1 = Slope between 2-45 degrees

Option 3: Value 0 = Slope less than 3 degrees, Value 1 = Slope between 4-45 degrees

3) Each result is compared with previous wetlands detections (SWAMP database) for choosing the best match option.

4) Slope less than 1 degree (final option) is converted from raster to vector using the Raster to Polygon tool.

5) Start editing mode in ArcMap

6) Open the attribute table in each case and order the Shape_Area field ascending. Delete the first record with the highest value in area because it represents an area with elevations.

7) Eliminate area less than 3174 s.q.m because it is not representative of wetlands.

8) Compare the 3 results obtained.

6.3 Aspect method

Flat areas have a value of -1 in the Aspect tool in ArcMap, for that reason this is the value to be considered in the reclassification.

1) Run Aspect Tool in DEM.

2) Reclassify pixels into 2 categories: -1 representing flat areas such as wetlands and lakes, and 1 representing areas with elevation.

3) Convert result from raster to vector using the Raster to Polygon tool.

4) Start editing mode in ArcMap

5) Open the attribute table in each case and order the Shape_Area field ascending. Delete the first record with the highest value in area because it represents areas with elevations.

6) Eliminate areas less than 3174 s.q.m because it is not representative of wetlands.

7) Compare result with Slope methodology.

7. Results obtained for each method

Figure 9 illustrates the final result for the difference method where the attribute table shows 532 records after the query selection. Figure 10, 11 and 12 represent the final results for the slope method taking into account 3 degrees, 1 degree and 0 degree. The final result for the Aspect method was exactly the same obtained for the Slope method with 0 degree, the explanation for this is that Aspect with a value of -1 is equal to Slope with 0 degrees.

After comparing each method in detail, it was concluded that the difference raster method produces more possible wetlands than the slope with 0 degrees, however slope with 1 degree generates more records than 0 degree. For that reason, one of the final conclusions about this project is that a combination between difference raster method and slope with 1 degree generate all the possible scenarios for wetlands locations.
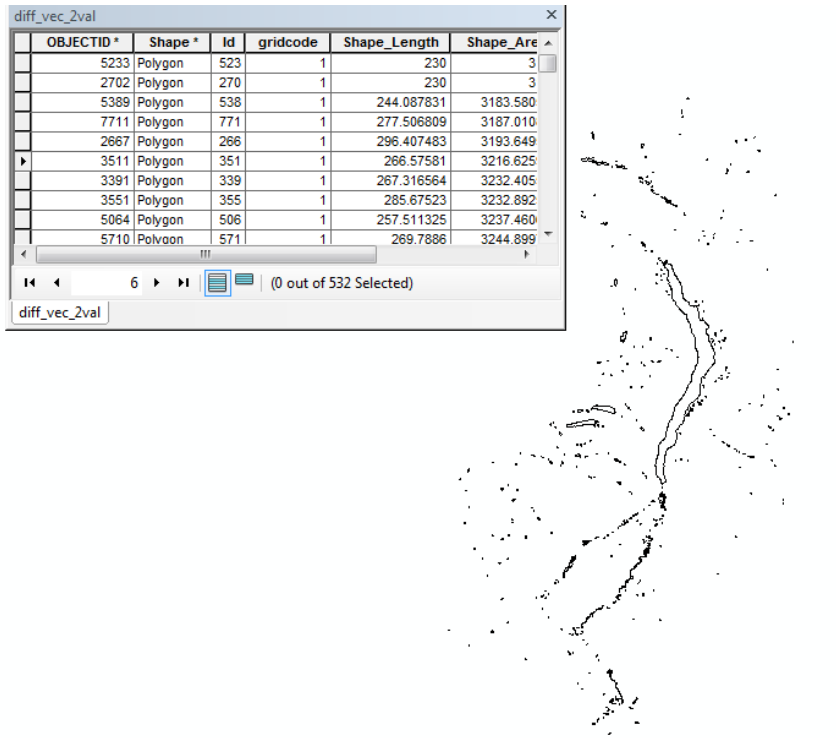
diff_vec_2val

OBJECTID *	Shape *	Id	gridcode	Shape_Length	Shape_Are
5233	Polygon	523	1	230	3
2702	Polygon	270	1	230	3
5389	Polygon	538	1	244.087831	3183.580
7711	Polygon	771	1	277.506809	3187.010
2667	Polygon	266	1	296.407483	3193.649
3511	Polygon	351	1	266.57581	3216.625
3391	Polygon	339	1	267.316564	3232.405
3551	Polygon	355	1	285.67523	3232.892
5064	Polygon	506	1	257.511325	3237.460
5710	Polygon	571	1	269.7886	3244.899

6 ▶ ▶| (0 out of 532 Selected)

diff_vec_2val

Figure 5 Final result Difference raster method – Records obtained: 532

slope_Vector_Query

OBJECTID *	Shape *	Id	gridcode	Shape_Length	Shape_Area
8867	Polygon	886	1	98507.895574	68435235.7719
12333	Polygon	123	1	99502.342179	9210884.64738
15014	Polygon	150	1	44398.723346	3523318.15040
6946	Polygon	694	1	11404.591962	2499069.88208
11741	Polygon	117	1	33308.71083	1975379.52823
6608	Polygon	660	1	8252.865159	1942530.79422
2221	Polygon	222	1	15385.447601	1876380.37738
828	Polygon	828	1	9818.651519	1246391.45419
16300	Polygon	163	1	17944.411368	1160094.01732
1452	Polygon	145	1	18343.570691	1112054.69084
12624	Polygon	126	1	15955.708443	1060410.21067
15368	Polygon	153	1	16394.058976	995770.92356
4989	Polygon	498	1	5778.757964	765453.094285
16969	Polygon	169	1	13014.482321	723706.156827

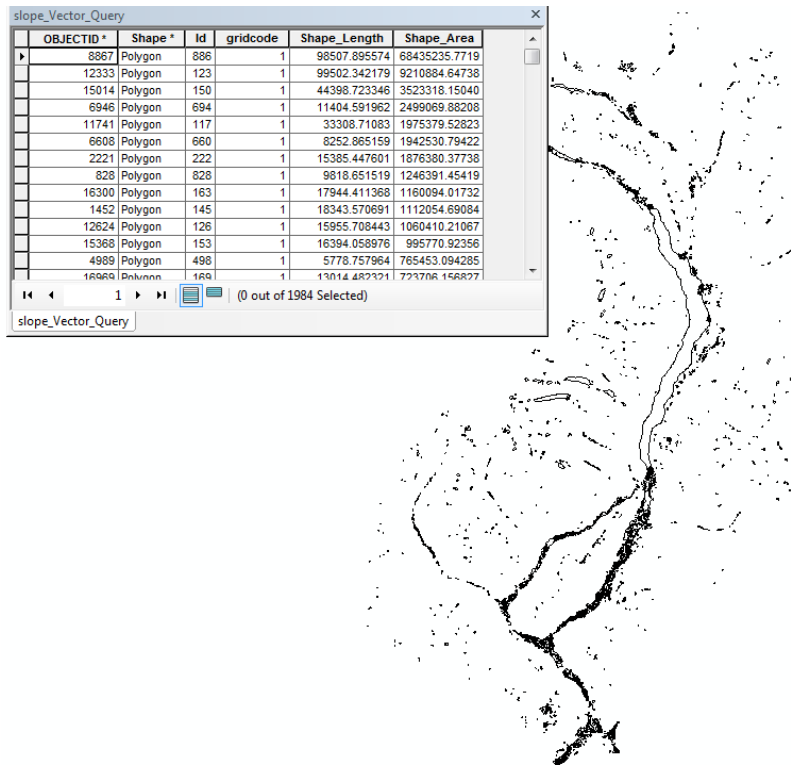1 ▶ ▶| (0 out of 1984 Selected)

slope_Vector_Query

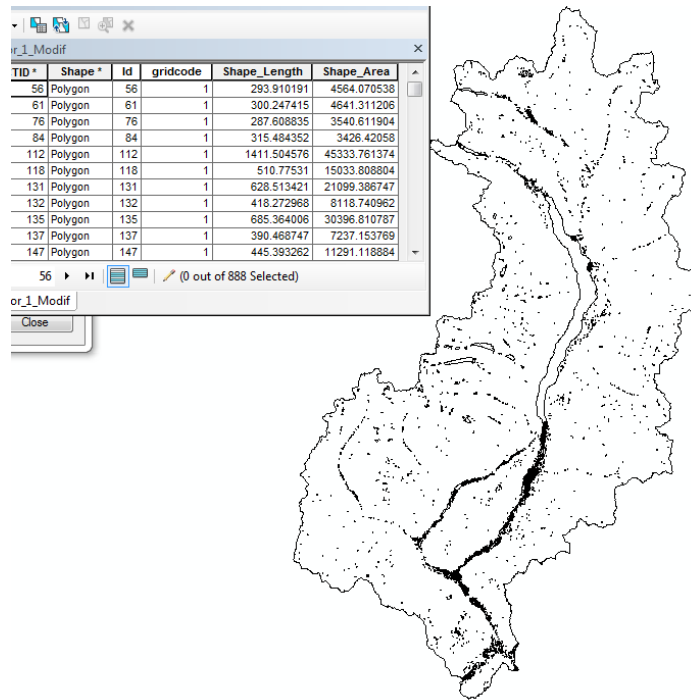Figure 6 Final result: Slope 3 degrees – Records obtained: 1984

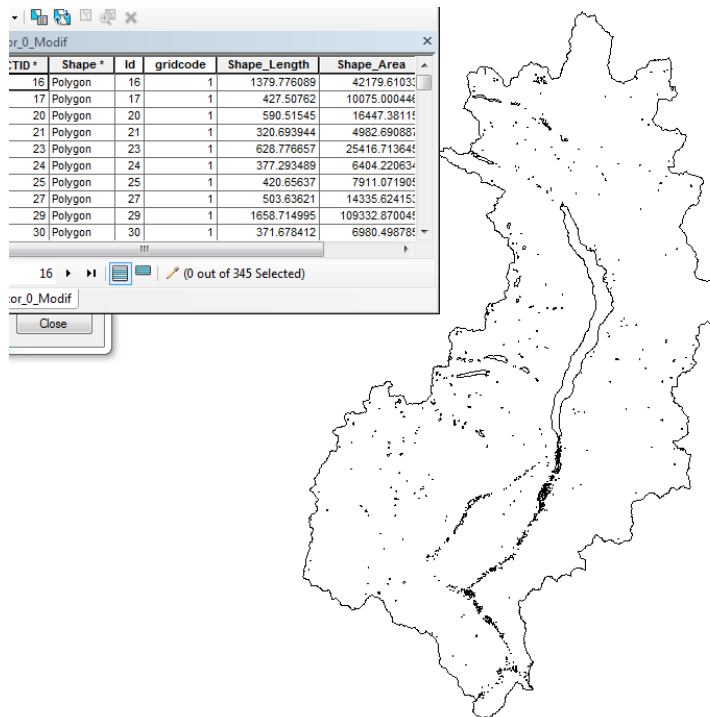Figure 7 Final result: Slope 1 degrees– Records obtained: 888

Figure 8 Final result: Slope 0 degrees – Records obtained: 345

Table 1 represents a summary about how many records were deleting in the Slope method for each scenario (0 degree, 1 degree and 3 degrees) respecting the original DEM without applying a query selection.

Table 1: Summary of Slope method after query 6 Pixel condition

	Original	Final
Slope 0 degree	2229	345
Slope 1 degree	9778	888
Slope 3 degrees	17086	1985

On the other hand, figure 10 illustrates one example about how accurate the model could be in different situations. Areas in black represent the final wetlands detected with the difference method; meanwhile the polygon outlined in red color represent previous wetland mapped in the SWAMP project.

Some areas are perfectly detected by the model due to this area contains standing water surrounded by vegetation. Meanwhile, other areas that are not completely detected by the model contain trees, gentle slopes and vegetation of various heights.
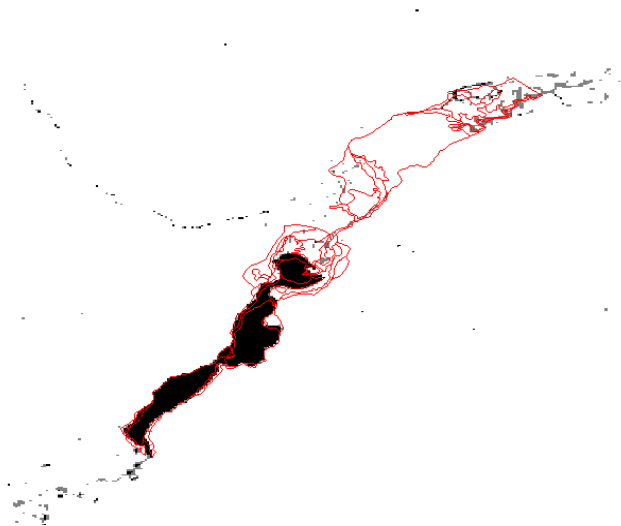

Figure 10: Accuracy of the Difference raster model using SWAMP data as reference

It is important to highlight that every method discussed in this project is only a first step for detecting possible wetlands in kml format, which can be overlaid as a "lakes and wetlands" basemap using Google Earth Pro (as it is shown in Figure 11).

Some of the flat areas obtained dry out at some times of the year and they are time consuming to detect using remote sensing techniques, so for that reason is important to have all the possible locations of wetlands using the DEM methodology.

Figure 11 Final kml displayed on Google Earth

8. Automated generation of flat areas using subtraction method

Figure 12 shows a graphical representation of the process for delimiting wetlands and flat areas using difference and slope method. Meanwhile the aspect method was not represented due to its similarity in results with the slope method. Blue ovals represent the input data enter by the user, yellow rectangles represent the process, green ovals represent the intermediate results and purple ovals represent the final result in kml format.
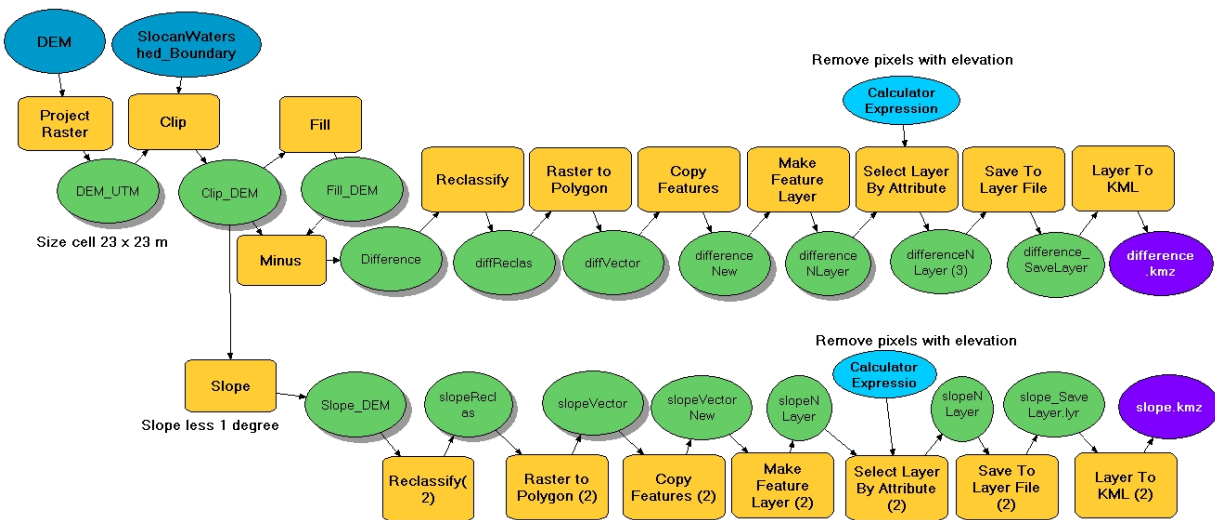

Figure 12 ModelBuilder diagram

Additionally, a Python script was created to automate the detection of wetlands and flat areas in just 5 minutes using the first methodology (raster difference). This program requires from the user the location of the DEM, geodatabase and final output path as it is shown in Figure 13, 14 and 15. After that several

process and functions are executed and finally the user received the location where the kml files are located.
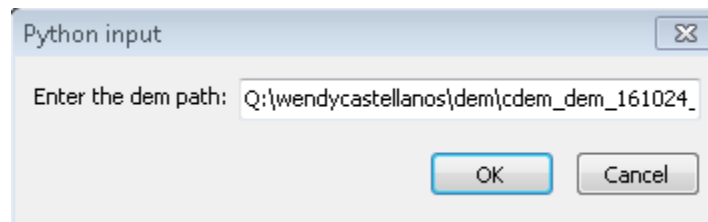

Figure 13 User input (DEM path)
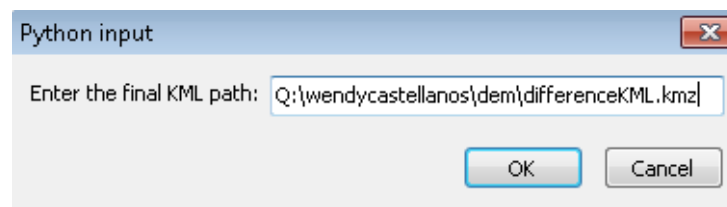

Figure 14 User input (Geodatabase path)

Figure 15 User input (Final kml path)

After the user correctly introduces each requirement, the program creates the following outputs:

- demUTM : DEM converted to UTM
- fillDEM : DEM after using hydrologic tool "Fill"
- diffReclas: Raster containing the result of difference method. Results are classified using 1 for flat areas and 0 for areas with elevation.
- diffVectorOriginal: Vector layer of the result of difference method. Raw results including noises.
- DiffVector : Vector layer containing exclusively flat areas and wetlands.
- difference.kmz : KML file containing the result of the difference method without noises and small pixels.

9. Web-Map application

For better visualization of the final results of this project, a web map application was created where the final user could compare the area in square meters for each method. This web-map is available at:

http://www.arcgis.com/apps/CompareAnalysis/index.html?appid=f56c4239295846a28015a1fb24c1
6f94

One of the advantages of this application is that it is flexible, easy to use and the final user does not have to open Google map several times for comparing the same area, as it is show in Figure 16
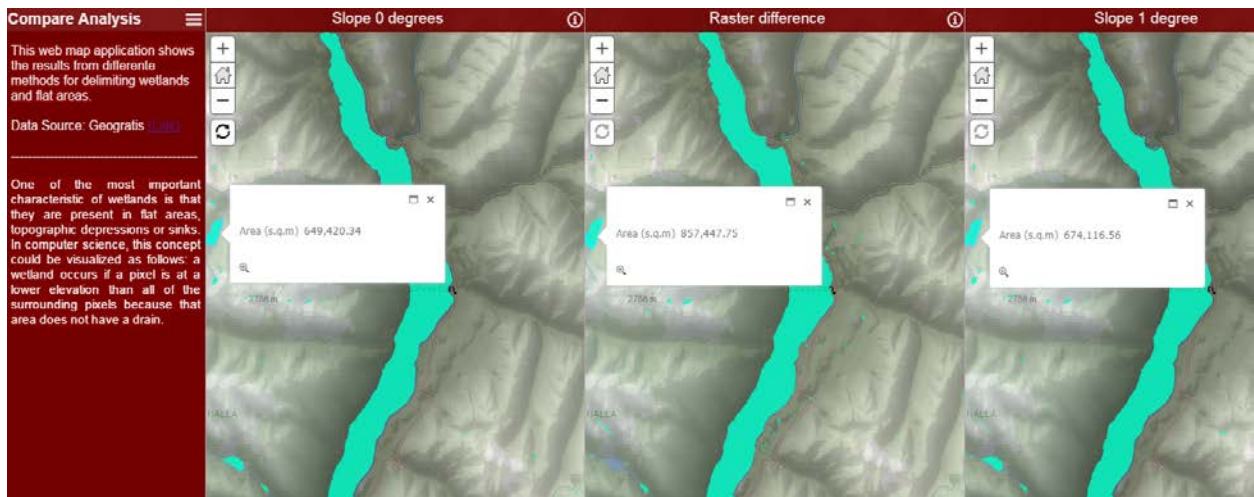
Figure 16 Web-map application that compares final result of Raster difference, Slope 0 and 1 degree.

10. Conclusion

Three methodologies were analyzed in this project: Difference raster, Slope, and Aspect method. The results obtained in each process were slightly different with the exception of aspect method and slope 0 degrees. After analyzing each result simultaneously using the web-map application created for this project, it was concluded that each method is complementary and there is not a unique and perfect method.

The advantage of this project is creating an automatic, portable and adaptable model as a first step for determining possible locations of wetlands that could be checked by site visits or satellite and air photo interpretation (remote sensing techniques). This not only could increase productivity detecting wetlands but also will be used by professional wetland workers when they cannot visit remote sites on the ground.

11.Acknowledgments

12. Key Personnel

Wendy Castellanos

Wendy is a student in the Advanced Diploma in GIS at Selkirk College. She graduated from Central University of Venezuela as a Petroleum Engineer. After receiving her education, Wendy worked as economic analyst in PDVSA (Venezuelan's national energy company). In this position, she designed and simulated petroleum fiscal models and participated in high level negotiations to identify new business opportunities. She also completed a MBA in Natural Gas Business in 2015 at Simon Bolivar University.

Richard Johnson

Richard is the founder of Slocan Lake Research Centre and Opus Petroleum Engineering. He supports research in environment and nature in the West Kootenay region of BC. He is currently mapping the aquifers in the Slocan watershed and integrating that data into a hydrological picture that encompasses the wetlands which are being mapped by the Slocan Wetlands Assessment and Mapping Project. (SWAMP).

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