British Columbia's Provincial Stream Biomonitoring Program

Technical Documentation

GIS Tools for

Upstream Watershed Analysis

Prepared for
Water Protection and Sustainability Branch
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1. Background

The Provincial Biomonitoring Program provides an effective tool for monitoring aquatic ecosystem health. The program uses standardized national protocols (Canadian Aquatic Biomonitoring Network [CABIN]) to monitor changes to stream health and improve understanding of the effects of ecosystem stressors, such as chemical contaminants and/or habitat disturbance on aquatic biota.

In brief, the CABIN protocols are a set of methods for field collection and analysis of biological monitoring data that promote the use of the Reference Condition Approach (RCA) (Environment Canada 2012[1]). In the RCA, benthic invertebrate community data and habitat descriptors from a large number of relatively undisturbed reference sites are used to build models that allow comparison of test sites with an appropriate reference condition.

An important component of CABIN models is determining the relationship between the benthic communities and habitat at the reference sites. Benthic data from all the CABIN sites in a model area are grouped based on similarities in community structure. The field-based and landscape-level habitat data (e.g., climate, geology, land use, topography) are then assessed to determine which variables best explain the type of benthic communities found at reference sites. These habitat variables are known as "predictor variables".

Predictor variables are used to match the test sites to the appropriate group of reference sites in each model. The benthic community at a test site is compared with the range found within the reference group. If the test site falls within the range of natural variability found at similar reference sites, it is "similar to reference" and not affected by upstream stressors. If the site falls outside of the range natural variability, it is considered divergent, or different from reference, which indicates that stressors may be affecting the benthic community.

The landscape-level habitat variables used in CABIN to characterize the upstream watershed are calculated using GIS. To efficiently generate these summaries in a consistent and repeatable manner, a set of GIS tools/scripts have been developed that utilize provincial, national, North American, and global datasets to delineate upstream catchment areas and generate statistical summaries of the characteristics of these areas. This report documents the GIS tools' processing logic, all input data sources, and the output data generated.

[1] https://publications.gc.ca/collections/collection_2012/ec/En84-87-2012-eng.pdf

2. Upstream Watershed Analysis

2.1.DATA PREPARATION

2.1.1. Edit Sites to Align with Nearest Stream

CABIN site locations are provided as GPS coordinates collected in the field. Supplied coordinates are converted to point features, which are moved to intersect with the nearest stream in the National Hydro Network (NHN) stream network. This adjustment is required to locate the position of the site accurately on the stream network, which is important for correct upstream watershed delineation.

2.1.2. Bedrock Geology

Bedrock geology data is available from Natural Resources Canada (NR Canada), but most provinces will likely have higher resolution data for their jurisdiction. Natural Resources Canada bedrock data can be used, or this data can be merged with higher resolution provincial bedrock geology data for more accuracy, as long as the bedrock type classification is compatible.

1. BC Bedrock Geology Documentation can be found at the link below.
(https://catalogue.data.gov.bc.ca/dataset/bedrock-geology)
2. Download the data under the "Data and Resources" section. Note: summarisation field is "Rock_Type".
3. Natural Resources Canada Bedrock Geology documentation can be found at the link below.
https://open.canada.ca/data/en/dataset/6e12a18b-0dda-583d-a523-b9c4b7f67669
4. Contact NR Canada to obtain the data in shapefile format.

2.1.3. Surficial Geology

Surficial geology data is available from Natural Resources Canada.

1. Documentation can be found at the link below.
https://open.canada.ca/data/en/dataset/cebc283f-bae1-4eae-a91f-a26480cd4e4a
2. Download the data at the link below.
https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/downloade.web&search1=R=295462
Note: summarization field is "Unit1_Group".

2.1.4. Climate

Climate data is available form Natural Resource Canada as rasters with a 1 km resolution.

1. Obtain climate raster datasets by contacting Natural Resources Canada, contact information can be found at the link below.
https://cfs.nrcan.gc.ca/projects/3/6
2. Climate parameter rasters to obtain are:
   bio30_01 (mean annual temp)

bio30_05 (max annual temp)
bio30_06 (min annual temp)
maxt30_01 (max monthly temp – month 01)
maxt30_... (max monthly temp – months 02 to 11)
maxt30_12 (max monthly temp – month 12
mint30_01 (min monthly temp – month 01)
mint30_... (min monthly temp – months 02 to 11)
mint30_12 (min monthly temp – month 12
pcp30_01 (precip monthly total – month 01)
pcp30_... (precip monthly total – months 02 to 11)
pcp30_12 (precip monthly total – month 12)
pcp_Precip_Annual_Total (Derive by summing monthly precipitation grids)
sg30_10 (Degree Days – growing season)

3. For all climate rasters define the projection as geographic NAD83
4. To generate the total annual precipitation for the climate normal, sum all 12 monthly total precipitation rasters.
5. For the mean annual temperature use bioclimatic raster bio150_01 as described by http://cfs.nrcan.gc.ca/projects/3/8. Most of the bioclimatic rasters need to be divided by 10 (after converting to floating point), including bio150_01. Data values are accurate to one decimal place, significant server storage space is saved by multiplying the values by 10, then storing as integer rasters, rather than floating point. For example, the floating point value 10.3 can be stored more efficiently as the integer value 103. The smaller dataset size also allows for faster data transfer, and import into an operational GIS file. The raster values need to be multiplied by 10 to restore the true values before operational use
6. For minimum and maximum annual temperature, this is not always January and July, therefore use bioclimatic raster bio150_05 (for maximum temperature) and raster bio150_06 (for minimum temperature), as described by #5 and #6 at http://cfs/mrcan/gc/ca/projects/3/8
7. Degree-days during the growing season is raster sg150_10, as described by #10 at https://cfs/nrcan/gc/ca/projects/3/9

2.1.5. ASTER DEM

ASTER DEM data is available from the NASA website “https://earthexplorer.usgs.gov/ ”.
The steps to obtain the data are as follows:

1. Digitize a shapefile outline of the area of interest for which DEM data is required.
2. Reproject the shapefile to WGS84, and Zip.
3. Go to the website https://earthexplorer.usgs.gov/
4. Sign in or create a new account if you don’t have one
5. Click on the tab “KML/Shapefile Upload”
6. Select KML or Shapefile from the drop down
7. Click “Select File”

8. Navigate to, and select the zipped shapefile
9. Alternatively, click the Polygon tab, then start clicking on the map to define a selection polygon.

10. Click on “Datasets”
11. Type “ASTER” into the search box.
12. Select “ASTER Level 1T”
13. Click on “Results.
14. A list of ASTER DEM tiles that overlaps with the area of interest will appear.
15. The footprint icon can be clicked to display the footprint of the tile on the map. 16. The basket icon can be clicked to add desired tiles to your order.
17 Once all desired tiles have been selected, click “View Basket”
18. Click “Proceed to Checkout”, then “Submit Order”
19. Click on link to download each tile.
20. Unzip each data package.
30. Merge the enclosed .tif files to create a seamless DEM. This can be accomplished with ArcGIS using the MosaicToNewRaster command, and selecting 16 bit signed as the output type.

2.1.6. NHN Streams

The NHN streams can be obtained from the Geogratis website at the link below.
https://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977

1. Download the tile index shapefile (sub watersheds) at the link below.
(http://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_nhn_rhn/index/NHN_INDEX_WORKUNIT_LIMIT_2.zip)
Note: look for the feature class NHN_Index_20_Index_Workunit_Limit_2.
2. Display the watershed index, with sample sites, and 1:6 million streams
3. Note index tile values (field: DATASETNAM) for watersheds containing sample sites, and those upstream from sample sites.
4. Download NHN stream data packages corresponding to each index tile
(http://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_nhn_rhn/gdb_en/)
5. Merge stream lines from each tile (NHN_HN_Flow_1) into a single feature class

2.1.7. WSA Streams

The BC Watershed Atlas (WSA) 1:50,000 streams are required to perform stream order calculations, stream order information is absent from the NHN Streams dataset. For other jurisdictions, a local stream dataset with stream order information may be substituted. The WSA streams can be obtained from the BC geographic warehouse.

1. Documentation is located at the link below.
https://catalogue.data.gov.bc.ca/dataset/wsa-stream-centreline-network-50-000

2. Download the shapefile data package under “BC Geographic Warehouse Custom Download” link from the documentation page, followed by “Access/Download”

2.1.8. Land Cover 2000

1. Documentation is located at the links below.
https://open.canada.ca/data/en/dataset/97126362-5a85-4fe0-9dc2-915464cfdbb7
https://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_lcc_csc/doc/
2. Download the data index shapefile at the link below.
https://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_lcc_csc/index/
3. Identify the required index tiles that intersects the area of interest (field: NAME)
4. Download the land cover data at the link below, from the appropriate sub-folder
https://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_lcc_csc/shp_en/
5. Merge the land cover data tiles into a single feature class
Note: This dataset is no longer being updupdated ands been superseded by the Canada Land Cover (2015) raster dataset that is updated on a five year cycle.

2.1.9. Land Cover 2015

1. Documentation and data download (TIFF 1.9 GB) can be obtained at the link below.
https://open.canada.ca/data/en/dataset/4e615eae-b90c-420b-adee-2ca35896caf6

Note: This data is being updated on a five-year cycle and is part of the North America Land Change Monitoring System, documentation and North American data downloads can be found at the link below.
http://www.cec.org/north-american-land-change-monitoring-system/

Data should be downloaded from either source, clipped to your area of interest, and projected to a commonly used working projection.

2.1.10. Delineate Upstream Watershed

To extract and measure landscape level variables that influence the sites, the upstream watershed for each sampling site is delineated. This is accomplished by burning the known stream network into the ASTER DEM, and then filling any sinks in the processed ASTER DEM, followed by upstream watershed delineation. This is accomplished in ArcGIS using the Fill, FlowDirection, FlowAccumulation and Watershed tools.

2.1.11. Watershed QA/QC

Following delineation, the watersheds must be quality assurance checked, to ensure that the sites are at the correct stream locations, and that the upstream watershed boundary is appropriate. The watersheds can be viewed in a spatial viewer, along with useful companion datasets, such as the NHN stream network, and shaded relief.

Typical issues include watershed boundaries that are smaller or larger than they should be, watersheds that are extremely small (can be from sample points that are not accurately aligned to

the stream network, or flat topography). To correct these issues, sample sites may need to be moved up, or downstream slightly before re-running the automated watershed delineation process, or manual editing may be required, potentially using pre-existing watershed boundaries as a guide.

Steps should be taken to ensure that QA issues are fully resolved, and an accurate and reliable watershed layer is obtained before proceeding to the data summarization stage.

2.2.DATA SUMMARISATION

Once the data preparation steps have been completed, data summarization for the required variables can begin. An overview is provided below.

2.2.1. Bedrock Geology

Bedrock geology is overlaid with the watershed vector layer and summarised to show the percentage area of each bedrock type for each watershed, in pivot table fashion. This is accomplished in ArcGIS using the Intersect, Frequency, and Pivot tools.

2.2.2. Surficial Geology

Surficial Geology is overlaid with the watershed vector layer and summarised to show the percentage of each surficial geology type for each watershed, in pivot table fashion. This is accomplished in ArcGIS using the Intersect, Frequency, and Pivot tools.

2.2.3. Climate

Natural Resources Canada raster climate data (1 km grid size) is overlaid with the watershed vector layer to produce and summarized to show the mean condition for each climate variable for each watershed. Output climate summaries include: total precipitation for each month, total annual precipitation, minimum temperature for each month, maximum temperature for each month, annual maximum temperature, annual minimum temperature, annual mean temperature, and degree-days during the growing season. This is accomplished in ArcGIS using the Zonal Statistics as Table tool. Detailed data preparation steps are discussed in Appendix 2.

2.2.4. Land Cover

Land cover data from the North America Land Change Monitoring System project is overlaid with the watershed vector layer and summarized to show the percentage of each land cover type for each watershed. This is accomplished in ArcGIS using the Intersect, Frequency, and Pivot tools for the vector based 2000 data, or the Zonal Statistics as Table tool for the raster based 2015 data.

2.2.5. Topography

2.2.5.1. Elevation

Elevation statistics (maximum, minimum, and mean) are calculated for each watershed. In ArcGIS this is accomplished using the Zonal Statistics as Table tool applied to the ASTER DEM

data to generate maximum, minimum, and mean elevation statistics for each watershed, where each watershed is a zone.

2.2.5.2. Slope

Slope statistics (maximum, minimum, and mean) for each watershed area are calculated by generating a slope raster from the ASTER DEM data. In ArcGIS this is accomplished using the Zonal Statistics as Table tool applied to the slope data to generate maximum, minimum, and mean elevation statistics for each watershed, where each watershed is a zone.

2.2.5.3. Slope Class

Slope class statistics for each watershed area are calculated by generating a slope class raster from the slope raster, converting the slope class to vector, and overlaying with the watershed layer to create a resultant. In ArcGIS the Frequency tool is used to summarize area by slope class, and watershed CABIN code. Watershed area is joined to the frequency output table so that area for each frequency unit can be expressed as a percentage of watershed area.

2.2.6. Stream Length and Stream Order

NHN Streams are intersected with the watershed vector layer to produce a resultant. The frequency tool is used to generate a table summarising the total length of streams for each watershed. The WDIC streams are intersected with the watershed layer to produce a resultant. The statistics tool is used to calculate the maximum stream order value for each watershed.

2.2.7. Data Integration

The various data summary output tables are integrated into a single final reporting table by joining the tables on the CABIN code. This final reporting table is then exported to Excel, or other similar tool, for final formatting.

Appendix 1

Data Source Summary Table

Dataset Name	Data Source	Field(s) of Interest	Comment
Bedrock Geology	BC Geographic Warehouse 2019 1:50,000-1:250,000 scale (link 1.1) Natural Resources Canada 1:10 million scale (link 1.2)	Rock_Type (string)	Merged provincial bedrock geology (2019) vector data with federal data (outside provincial boundaries)
	Link 1.1 https://catalogue.data.gov.bc.ca/dataset/bedrock-geology Link 1.2 https://open.canada.ca/data/en/dataset/6e12a18b-0dda-583d-a523-b9c4b7f67669		
Surficial Geology	Natural Resources Canada, 2014 1:5 Million scale (link 2.1)	Unit1_Group (string)	Vector data
	Link 2.1 https://geoscan.nrcan.gc.ca/starweb/geoscan/servlet.starweb?path=geoscan/fulle.web&search1=R=295462		
Climate Data	Natural Resources Canada (data documentation - link 3.1) (other documentation - link 3.2)	Cell value (integer)	Raster of ~1 km cell size GeographicNAD83 projection
	Link 3.1 https://cfs.nrcan.gc.ca/projects/3/6 Link 3.2 https://climate.weather.gc.ca/doc/Canadian_Climate_Normals_1971_2000_Calculation_Information.pdf		
Land Cover 2000	Canadian Land Cover, geobase series circa 2000 (link 4.1)	Covtype (integer)	Last update 2000, some polygons have no defined cover type due to being obscured by cloud cover. Note: This is a legacy product.
	Link 4.1 https://open.canada.ca/data/en/dataset/97126362-5a85-4fe0-9dc2-915464cfdbb7		

Land Cover 2015	North America Land Change Monitoring System (2015) (link 5.1)	Cell value (integer)	Raster of 30m cell size Last update 2015, 5 year update cycle, 19 land cover classes
	Link 5.1 http://www.cec.org/tools-and-resources/north-american-environmental-atlas/north-american-land-change-monitoring-system		
Elevation (Topography)	ASTER DEM https://earthexplorer.usgs.gov/	Cell value (integer)	Raster of ~30m cell size Source data is tiled
Slope (Topography)	Derived from ASTER DEM	Cell value (float)	Raster of ~30m cell size
Slope Class (Topography)	Derived from slope	Slope_Class (integer)	~30m cell size Converted to polygon features
Stream Length	National Hydro Network (NHN) Streams (link – 6.1) 1:50,000 scale Watershed Index Shapefile (link – 6.2) NHN FTP (link – 6.3)	Shape_Length (float)	Vector data Source Data is tiled
	Link 6.1 https://open.canada.ca/data/en/dataset/a4b190fe-e090-4e6d-881e-b87956c07977 Link 6.2 http://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_nhn_rhn/index/NHN_INDEX_WORKUNIT_LIMIT_2.zip Link 6.3 http://ftp.maps.canada.ca/pub/nrcan_rncan/vector/geobase_nhn_rhn/gdb_en/		
Stream Order	WDIC Streams 1:50,000 BCGW (link – 7.1)	Stream_Order (integer)	Vector data
	Link 7.1 https://catalogue.data.gov.bc.ca/dataset/wsa-stream-centreline-network-50-000		

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