Mobile Conservation Zone Generation Spatial Tool

Submitted to:

Bruno Croft
Manager, Research and Monitoring
Environment and Natural Resources
Government of the Northwest Territories
Yellowknife, NT, X1A 2P9

Submitted by:

Caslys Consulting Ltd.
Unit 10 – 6782 Veyaness Road
Saanichton, BC, V8M 2C2

Contact: **Jason Shaw**
Tel: (250) 652-9268; Fax: (250) 652-9269
Email: jshaw@caslys.ca

September 2016

TABLE OF CONTENTS

LIST OF FIGURES

1.0 INTRODUCTION

The Mobile Conservation Zone (MCZ) was implemented as a strategy to ensure the conservation of the Bathurst caribou herd. The MCZ is a dynamic wildlife management unit that represents a 'no harvest zone' around the herd's current location. The MCZ boundary is updated approximately every four days to account for both daily and seasonal shifts in landscape use by the caribou. Since the MCZ boundary is continually changing, automating the MCZ process facilitates the easy generation and communication of MCZ boundaries by the Department of Environment and Natural Resources, Government of The Northwest Territories.

The objective of this project was to develop an ArcMap Add-In that utilizes telemetry data to generate MCZ boundaries for the Bathurst herd for a user-specified time period (e.g., every four days). As the spatial pattern of caribou landscape use is variable between time periods, three analysis methods have been implemented to facilitate MCZ boundary definition: minimum convex polygons (MCP), concave hull, and kernel density estimation (KDE). Based on the spatial distribution of telemetry locations, the user can select the analysis approach that best defines the MCZ boundary for any given time period. The MCZ boundary spatial files are exported to a variety of formats to support herd monitoring and management and improve the communication of MCZ boundaries to community stakeholders.

2.0 TOOL OVERVIEW

2.1 Tool Specifications

The MCZ tool has the following system requirements:

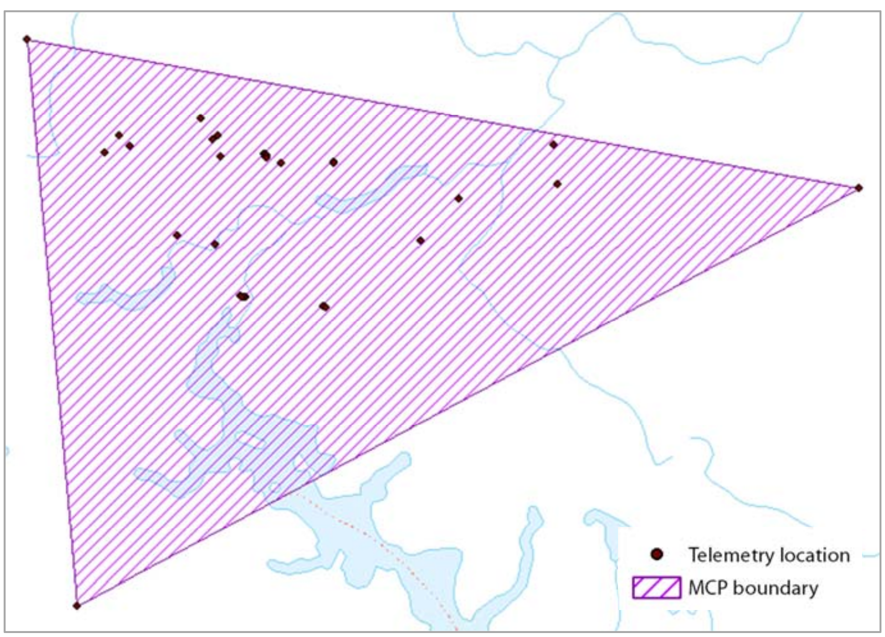
- Esri ArcGIS Version 10.3
- Spatial Analyst extension for ArcMap 10.3
- .NET Framework 4.5

2.2 MCZ Analysis Methods

2.2.1 Minimum Convex Polygon

The minimum convex polygon (MCP) method for generating MCZ boundaries creates a minimum bounding convex polygon around all points in a dataset (Figure 1). MCP is a straightforward approach to delineating MCZ boundaries: they are easy to implement and interpret, and no input parameter selection is required. However, MCP's simplicity is also limiting as it can overestimate MCZ size by incorporating unused areas between outlying points and assumes the landscape is used uniformly within its boundaries (Worton 1987). If the distribution of telemetry locations contains outliers, applying MCZ may generate a large zone that includes potentially unused parts of the landscape. MCP is most appropriate for use if telemetry locations are clustered.

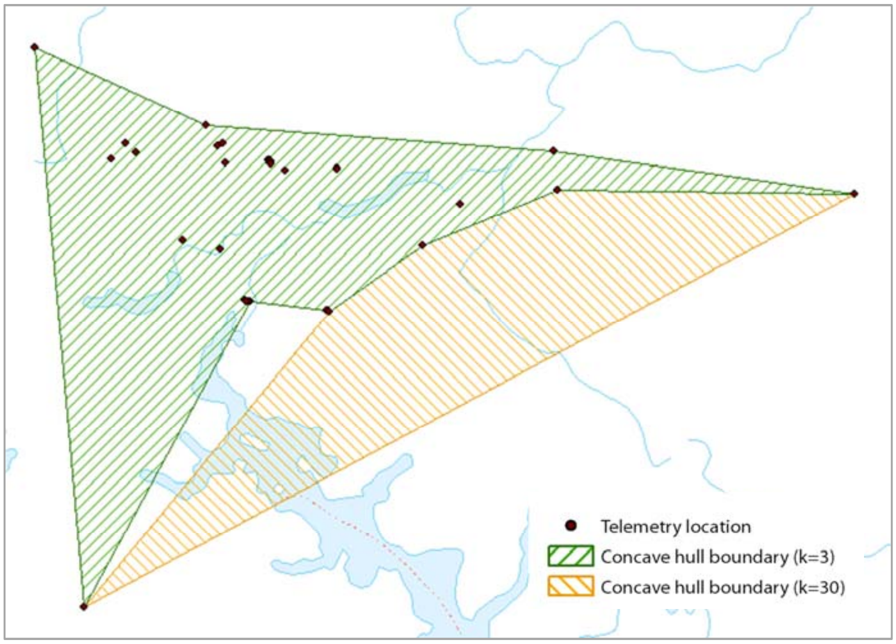
Figure 1. Example MCP Boundary Generated for a Subset of Telemetry Locations



2.2.2 Concave Hull

The concave hull method for generating MCZ boundaries applies a user-defined spatial neighbourhood (i.e., k-nearest neighbours) to delineate a concave polygon around the maximum number of points in a dataset. A large spatial neighbourhood (i.e., a large k value) will produce a smooth boundary that encompasses all locations in the dataset; while a small spatial neighbourhood (i.e., a small k value) will produce a more complex boundary, but may exclude any outlying locations (Moreira and Santos 2006) (Figure 2). The concave hull approach is most appropriate for use if telemetry locations are dispersed in space or are multiple discrete clusters.

Figure 2. Example Concave Hull Boundaries Generated for a Subset of Telemetry Locations



2.2.3 Kernel Density Estimation

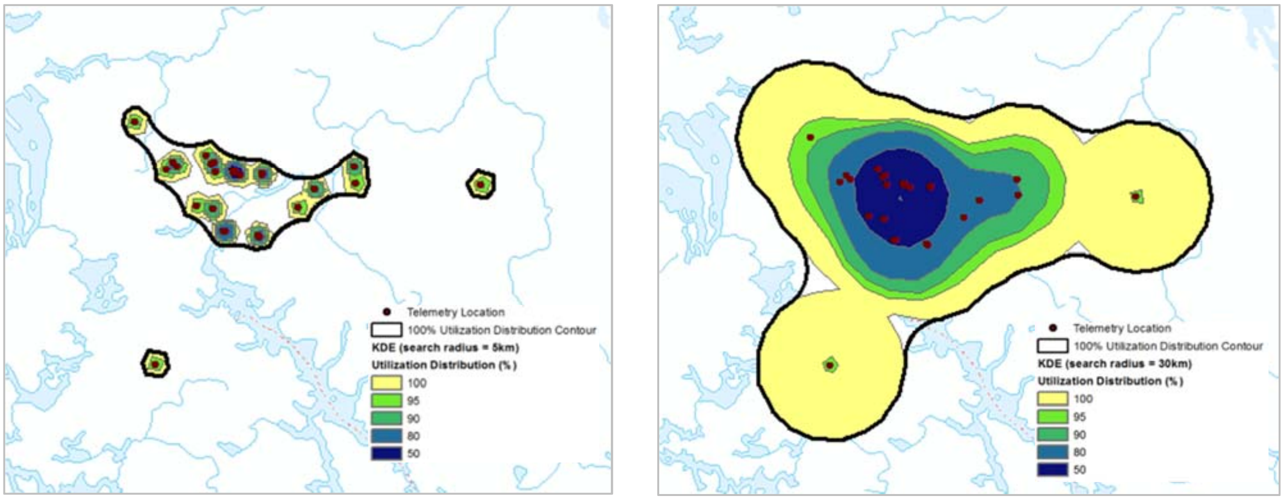
The kernel density estimation method (KDE) for generating MCZ boundaries differs from MCP and concave hull in that the boundary is derived from a utilization distribution. KDE generates a density surface from sample location points by placing a probability density function over each point telemetry location to estimate a density value for that area. Contours based on the probability of finding a caribou within the zone (i.e., 80%, 90%, 95%, and 100%) can be derived from the kernel density surface to provide a caribou utilization distribution (UD) for a given time period (Worton 1989).

The KDE approach requires the user to input a search radius to calculate the density surface. A large search radius (e.g., 30 kilometres) will create a smooth surface and a more generalized MCZ boundary; while a small search radius (e.g., 5 kilometres) will emphasize individual points and may produce a MCZ boundary made up of a series of polygons (Worton 1989) (Figure 3). To reduce the occurrence of MCZ boundaries being defined as a series of small polygons, some additional geoprocessing steps have been implemented within the tool:

- the individual UD polygons are buffered by a distance of 11 kilometres;
- the polygons, together with the 11 kilometre buffer zone, are dissolved; and
- a negative buffer of 11 kilometres is then applied to reduce the size of the polygon back to the selected UD contour (e.g., 80%, 90%, 95%, etc.).

Kernel density estimation is most appropriate for use if telemetry locations are are dispersed in space or in isolated clusters.

Figure 3. Example KDE Boundaries Generated for a Subset of Telemetry Locations



2.3 Tool Input Requirements and Analysis Outputs

2.3.1 Input Data Formats

The MCZ tool requires two data input types:

- a telemetry dataset representing caribou locations for the MCZ time period of interest; and
- a working file geodatabase where the analysis results will be stored.

2.3.2 Output Data Formats

When telemetry data is imported by the tool, a copy of the data is made in the working file geodatabase and tagged with a unique date/time label with the format: _dYYYYMMDD_thhmmss (e.g., _d20160915_t115221) (see section 4.1). During the import process, telemetry data are projected to NAD 1983 Northwest Territories Lambert to facilitate subsequent analyses. All spatial layers generated by the tool are stored in the working file geodatabase and tagged with the same date/time label as the telemetry data used to derive them. Analysis results can also be tagged with a unique label to differentiate boundaries generated from data subsets or different parameter settings (see sections 4.2 and section 4.3).

The final MCZ boundary can be exported to multiple formats that can be used to visualize the boundary across a variety of platforms (see section 4.4):

- ArcGIS File Geodatabase;
- ArcGIS Shapefile;
- Google Earth KML; and
- GPX for GPS.

The MCZ tool also generates a map product showing the final MCZ boundary and associated telemetry locations in relation to other relevant wildlife management unit boundaries in the NWT (see section 4.5).

3.0 GETTING STARTED

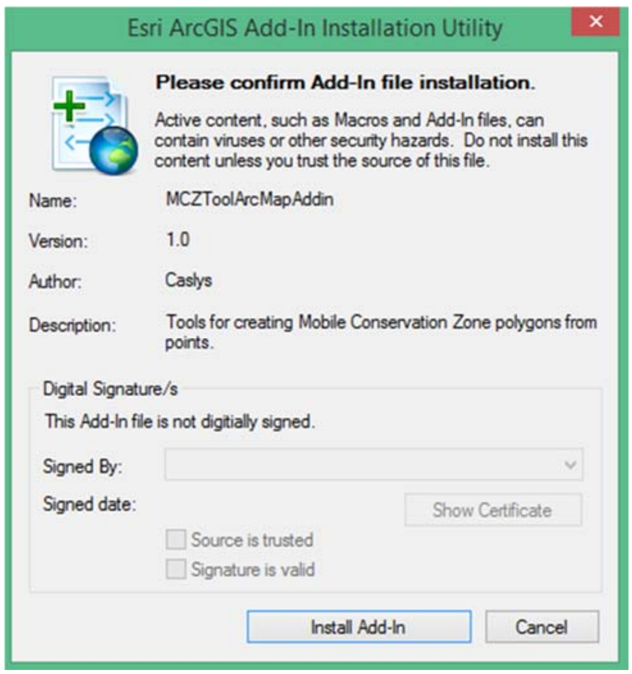
The following sections describe how to install the Add-In and access it through ArcMap.

3.1 Load MCZ Add-In to ArcMap

To add the MCZ Add-in to ArcMap:

I. Open ArcMap and select: 'Customize' > 'Add-In Manager'.
II. Click the 'Customize' button located in the bottom right corner of the Add-In Manager window.
III. Click 'Add From File' to navigate to the MCZ tool location.
IV. Select and Install MCZ tool (Figure 4).

Figure 4. ArcMap Add-In Manager Window for Loading MCZ Tool Add-In



* Double-clicking the Add-In file in Windows Explorer will also add it to ArcMap

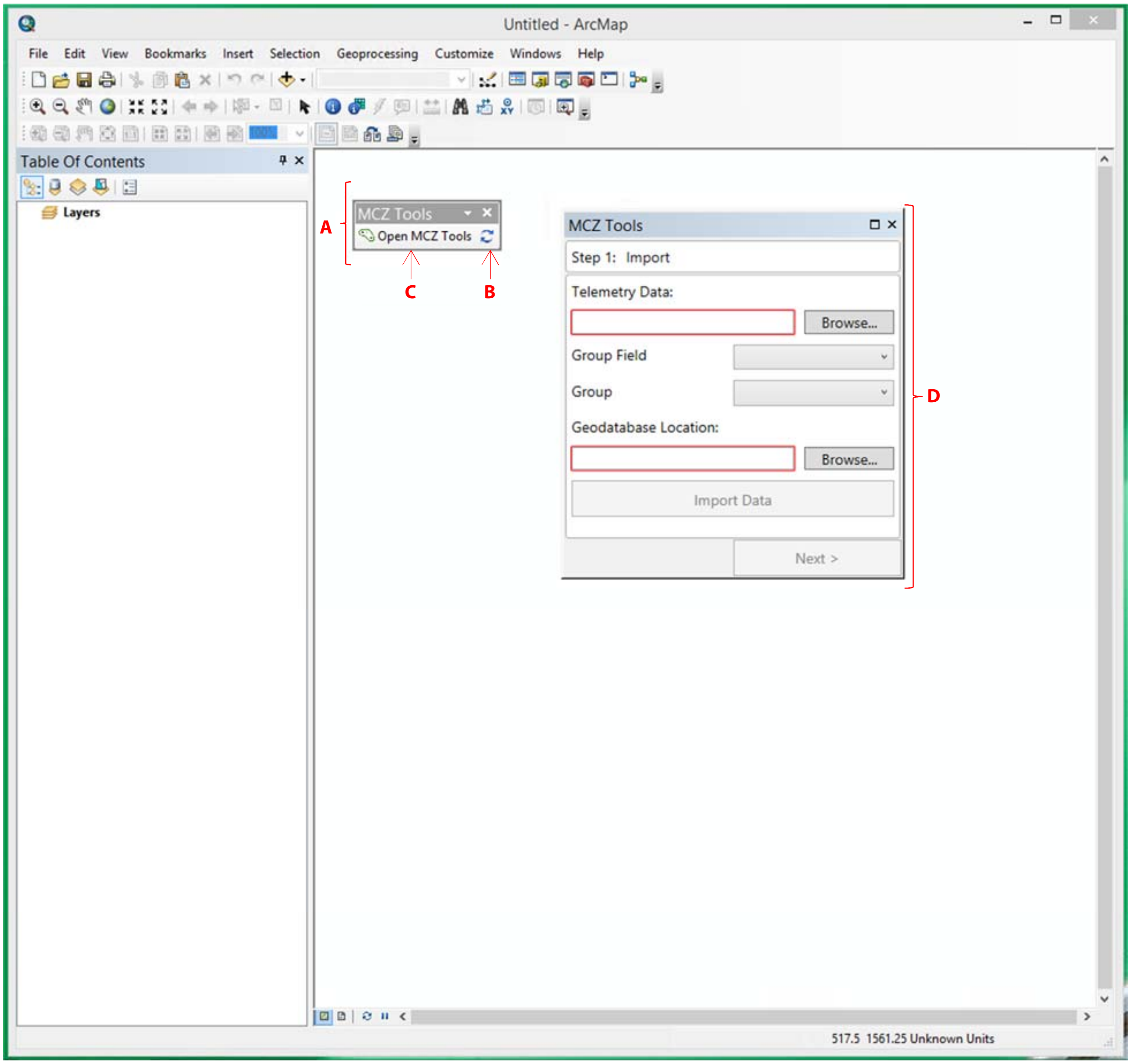
3.2 Opening the Tool

To open the MCZ tool:

I. Open ArcMap and select: 'Customize' > 'Toolbars'.
II. Select 'MCZ Tools' from the toolbar list.
III. The MCZ Tools window (Figure 5-A) will appear in the ArcMap data view window.
IV. At any time during the analysis, the tool can be reset by clicking on the 'reset' button (Figure 5-B). Using the reset button will clear all data from the tool, so the process can be started from the beginning.
V. Click on 'Open MCZ Tools' (Figure 5-C) in the tool window to launch the MCZ import window (Figure 5-D).

VI. Both the tool window and the import window can be moved and docked to any area within the ArcMap data view window.

Figure 5. Opening the MCZ Tool in ArcMap



4.0 MCZ SPATIAL LAYER GENERATION

The following sections describe the steps to generate a MCZ polygon using the tool.

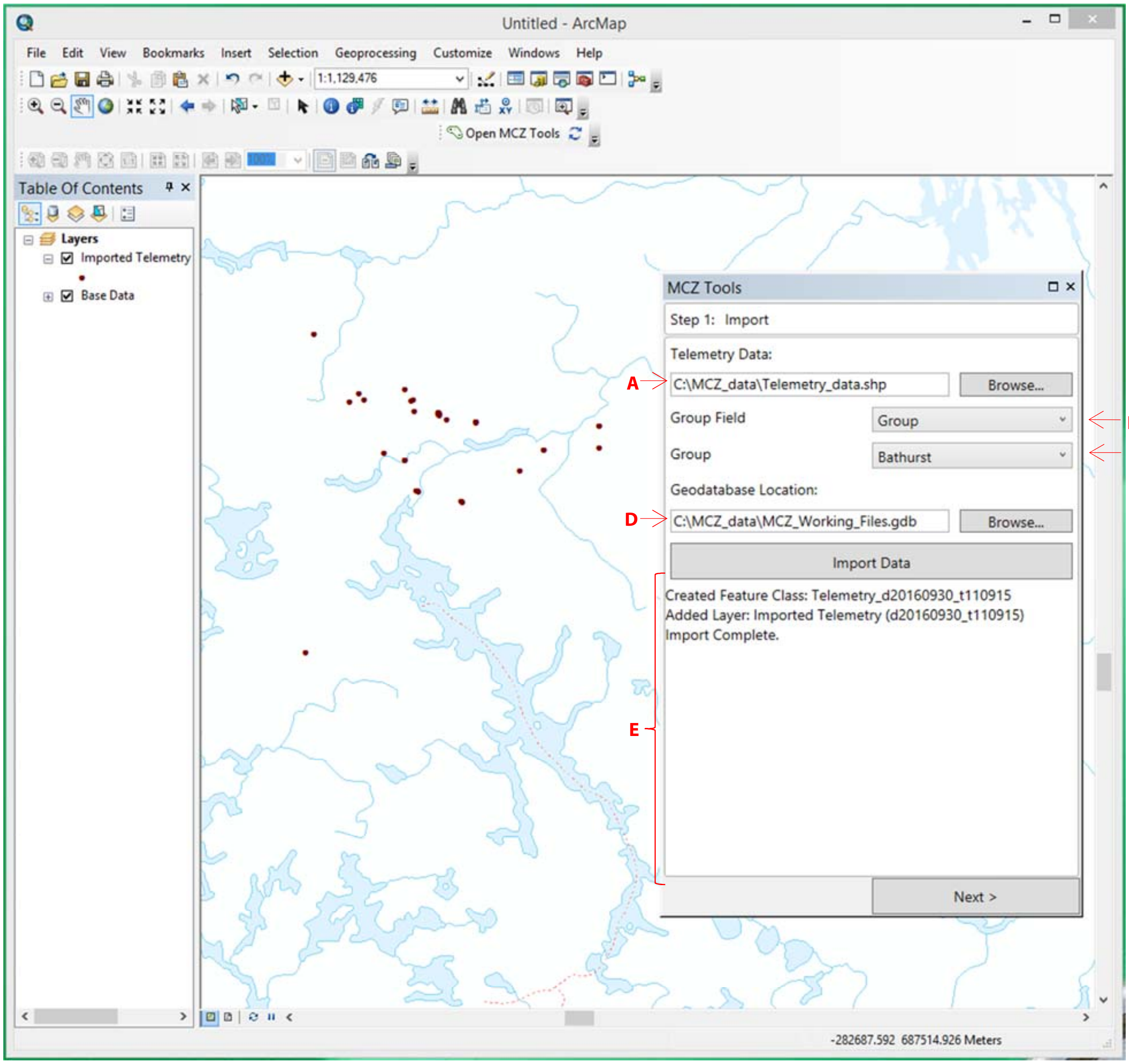
4.1 Step 1: Import

The first step in MCZ spatial layer generation is to import the telemetry data that will be used to generate the MCZ boundaries. The option exists to import a subset of the telemetry dataset based on a grouping field in the attribute table. The import step also requires the user to identify the location of the working file geodatabase. When telemetry data is imported by the tool, a copy of the data is made in the working file geodatabase and tagged with a unique date/time label with the format: _dYYYYMMDD_thhmmss (e.g., _d20160927_t102640).

To import data:

I. Use the 'Browse' button within the MCZ analysis window to select the location of the telemetry data to be used. The file pathway will appear in the 'Telemetry Data' field (Figure 6-A) once the telemetry file has been selected.
II. To create a data subset, select a 'Group Field' (Figure 6-B) and a 'Group' (Figure 6-C) from the drop down menus. The default settings will create a data subset for the Bathurst herd. To import the whole dataset, change the 'Group' selection from Bathurst to All using the drop down menu.
III. To select the location of the working file geodatabase click on the 'Browse' button at the bottom right. The file pathway will appear in the 'Geodatabase Location' field (Figure 6-D) once the file geodatabase has been selected.
IV. Click 'Import Data' to display telemetry locations.
V. Progress messages appear in the message window (Figure 6-E) during the data import process. A successful data import will be indicated by an 'Import Complete' message in the message window.
VI. Click 'Next' to begin generating MCZ boundaries.

Figure 6. Importing Telemetry Data



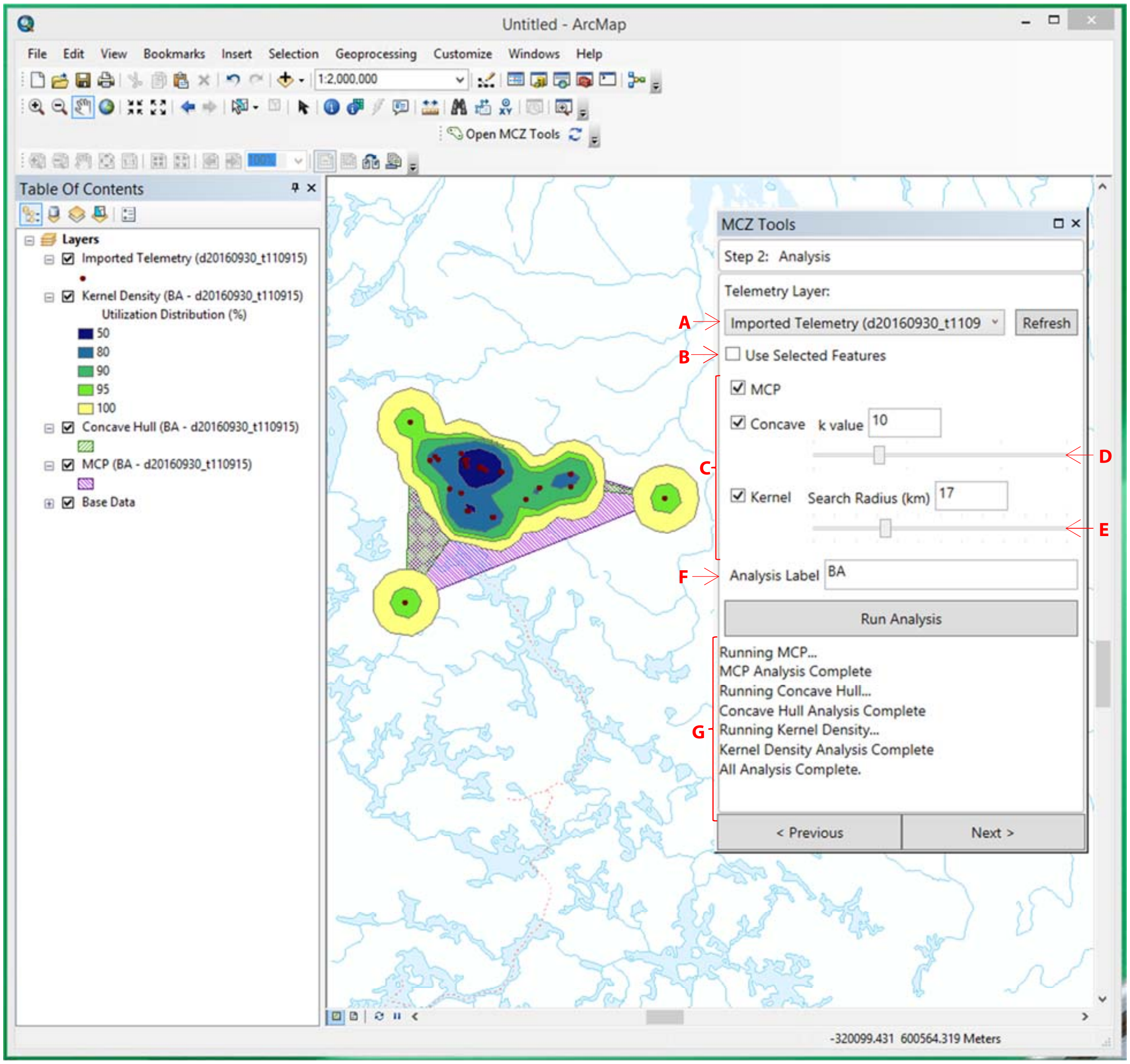
4.2 Step 2: Analysis

As mentioned previously, the MCZ tool provides three options for MCZ boundary generation: minimum convex polygon (MCP), concave hull, and kernel density estimation (see section 2.2). All analysis results will be automatically added to the ArcMap display and spatial layers stored in the working file geodatabase (Figure 7). Analysis results can be turned on or off by the user in the table of contents to facilitate visualization. All spatial layers will be named according to the user defined analysis label and unique date/time tag from the original telemetry data.

Boundaries can be generated for all features in the telemetry dataset or a subset of selected features. Features can be selected manually or using an attribute query. If a data subset is used, a new feature layer is created from the selected features in the working file geodatabase with the same date/time tag as the original telemetry data. The subset feature layer will be automatically added to the ArcMap display. In the example in Figure 7, the analysis was run for a subset of selected features representing the locations of individuals belonging to the Bathurst caribou herd.

An analysis label can be set to create a unique identifier for each analysis run. The analysis label makes it easier to compare boundary results when analysis methods and parameters are varied (e.g., different subsets of the telemetry data, different search radii for KDE). In the example, an analysis label of 'BA' is set to indicate the analyses were run on a subset data representing only individuals belonging to the Bathurst herd (Figure 7).

Figure 7. Generating MCZ Boundaries



To generate MCZ boundaries:

I. Select the appropriate telemetry layer from the 'Telemetry Layer' drop down menu (Figure 7-A) in the MCZ analysis window. If required, create a data subset manually or using an attribute query.

II. If the whole dataset is being used, make sure the 'Use Selected Features' box (Figure 7-B) is unchecked. If using a data subset, make sure the 'Use Selected Features' box is checked.

III. To select an analysis option, click the check box next to the analysis name (Figure 7-C). Analyses can be run individually or simultaneously.

IV. To change the number of neighbours (i.e., k value) used to generate the concave hull boundary, use the sliding bar (Figure 7-D), or type in a value. Moving the slider to the left will decrease the value of k, making the polygon more detailed, while moving the slider to the right will increase the value of k, making the polygon more general. The default value of k is 10 neighbours.

V. To change the search radius used to generate the kernel density surface, use the sliding bar (Figure 7-E) or type in a value. Moving the slider to the left will decrease the search radius, generating a UD emphasizing individual locations, while moving the slider to the right will increase the search radius, generating a more generalized UD. The default search radius is 17 kilometres.

VI. Set an analysis label in the 'Analysis Label' field (Figure 7-F) to identify any results generated by the analysis.

VII. Click 'Run Analysis'.

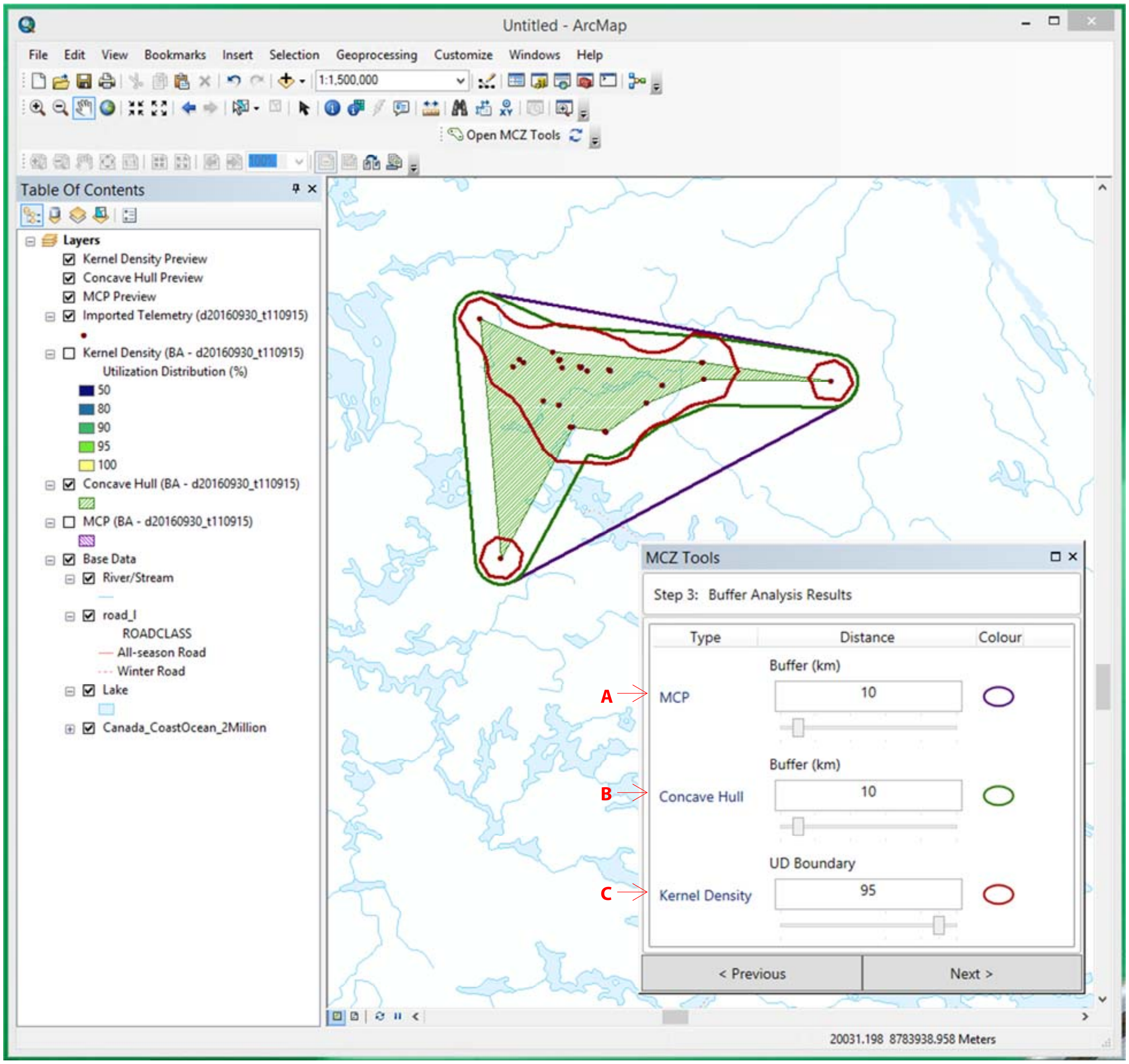
VIII. Successful boundary generation will be indicated by an 'All analysis complete' message in the message window (Figure 7-G).

IX. Click 'Next' to apply buffers for the MCZ boundaries.

4.3 Step 3: Buffer Analysis

After the MCZ boundaries have been generated, a buffer can be applied to the results to account for individuals in the selected group not represented in the telemetry dataset. The MCP and concave hull buffer distances are measured in kilometres, while the buffer distance for the kernel density boundary is determined using the UD contours (see section 2.2). The buffer for each boundary polygon will be generated automatically for the most recent set of analyses and added to the ArcMap Table of Contents (Figure 8). The buffers are labelled 'Kernel Density Preview', 'Concave Hull Preview' and 'MCP Preview,' respectively. The boundary polygon and associated buffer for each analysis method can be turned on and off in the ArcMap Table of Contents to facilitate visualization. Buffer distances can be visualized on-the-fly in the ArcMap data view window by using the tool slider bars associated with each boundary type. Figure 8 illustrates the concave hull boundary generated in the previous step in relation to a MCP buffer of 10 kilometres (Figure 8-A), a concave hull buffer of 10 kilometres (Figure 8-B), and a KDE buffer representing the 95% contour (Figure 8-C). All selected buffer distances will be carried forward in subsequent steps.

Figure 8. Buffer Analysis



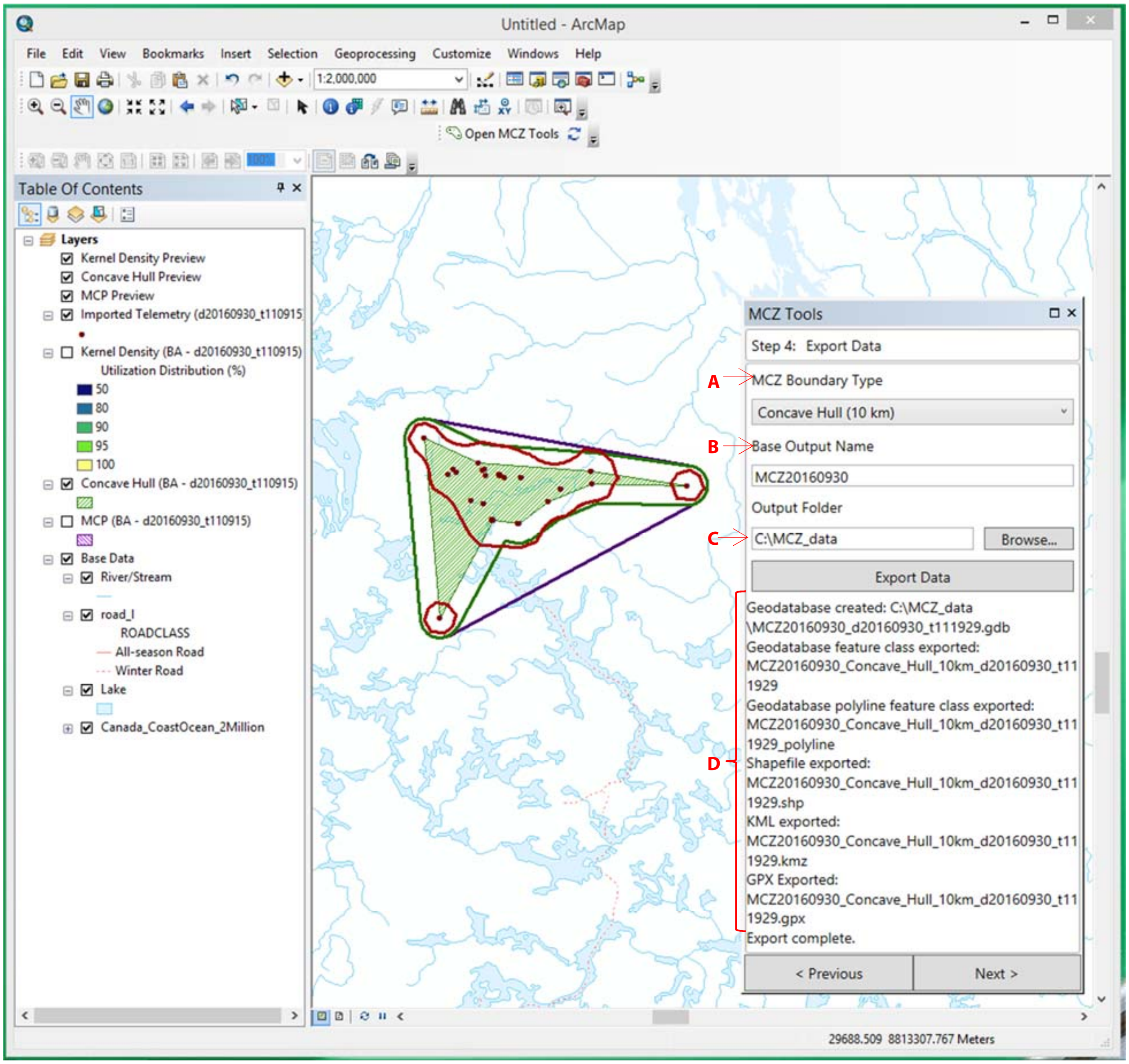
4.4 Step 4: Export Data

Once an appropriate MCZ boundary has been established using the functions in the previous step, the buffered boundary polygon will be exported to a variety of formats:

- A file geodatabase containing polyline and polygon feature layers of the selected MCZ boundary;
- A polygon shapefile of the selected MCZ boundary;
- A GPX file of the selected MCZ boundary for use with a handheld GPS unit; and
- A KML file of the selected MCZ boundary that can be loaded into Google Earth.

All of the output files will be tagged with a unique base output name to identify the final boundary generated by the analysis. In the example, a base output name of 'MCZ_20160916' is set to indicate that the boundary represents the MCZ for the four day period beginning September 16, 2016 (Figure 9).

Figure 9. Exporting MCZ



To export the MCZ boundary:

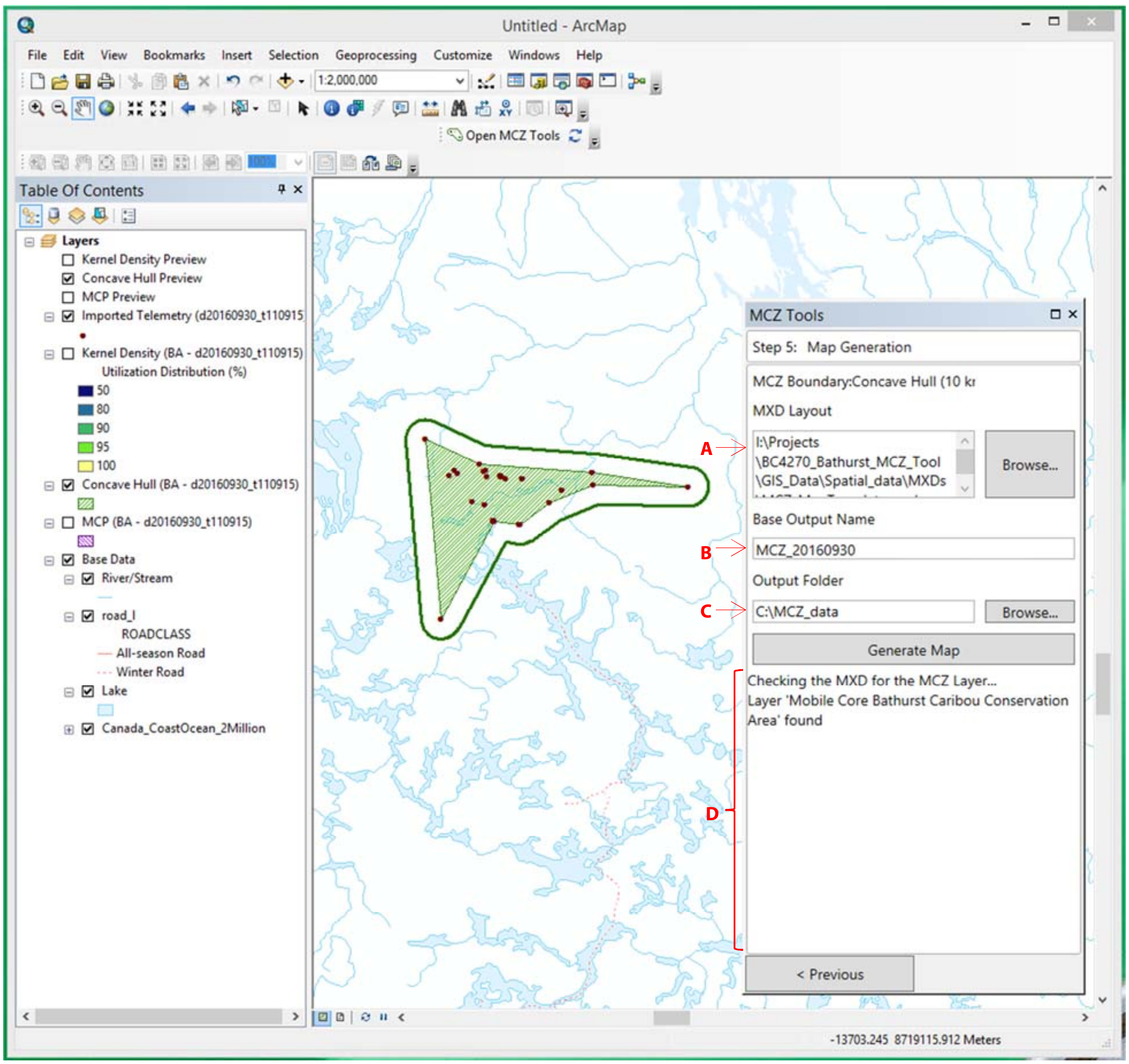
I. Select the desired MCZ boundary from the 'MCZ Boundary Type' drop down menu (Figure 9-A).
II. Designate a base output name in the 'Base Output Name' field (Figure 9-B) that will act as a unique identifier for all exported spatial layers.
III. Select an output location for the exported spatial layers using the 'Output Folder' browse button (Figure 9-C). This can be a different location than the working file geodatabase used previously.

IV. Click 'Export Data'.
V. Successful data export will be indicated by an 'Export complete' message in the message window (Figure 9-D).
VI. Once the data export is complete, Click 'Next' to generate a map of the MCZ boundary.

4.5 Step 5: Map Generation

The final function the MCZ tool performs is to generate a map of the selected MCZ boundary. The map is exported as PDF and JPEG files and the corresponding .MXD file is saved to a user-designated output location. Both the .MXD, PDF and JPEG map files will be tagged with a unique base output. In the example, a base output name of 'MCZ_20160916' is set to indicate that the boundary represents the MCZ for the four day period beginning September 16, 2016 (Figure 10). Generating the .MXD, PDF and JPEG files may take time.

Figure 10. Map Generation



To generate a map of the MCZ boundary:

I. Select an .MXD template using the 'MXD layout' browse button (Figure 10-A). This template must have a layer named 'Mobile Core Bathurst Caribou Conservation Area' representing the future MCZ polygon. The 'Mobile Core Bathurst Caribou Conservation Area' layer source pathway will be changed by the tool to display the new MCZ boundary when the map is generated.
II. Designate a base output name in the "Base Output Name' field (Figure 10-B) that will act as a unique identifier for the map files.
III. Select an output location for the generated map files using the 'Output Folder' browse button (Figure 10-C). This can be a different location than the working file geodatabase used previously.
IV. Click 'Generate Map'.
V. Successful map generation will be indicated by a 'Map output complete' message in the message window (Figure 10-D).

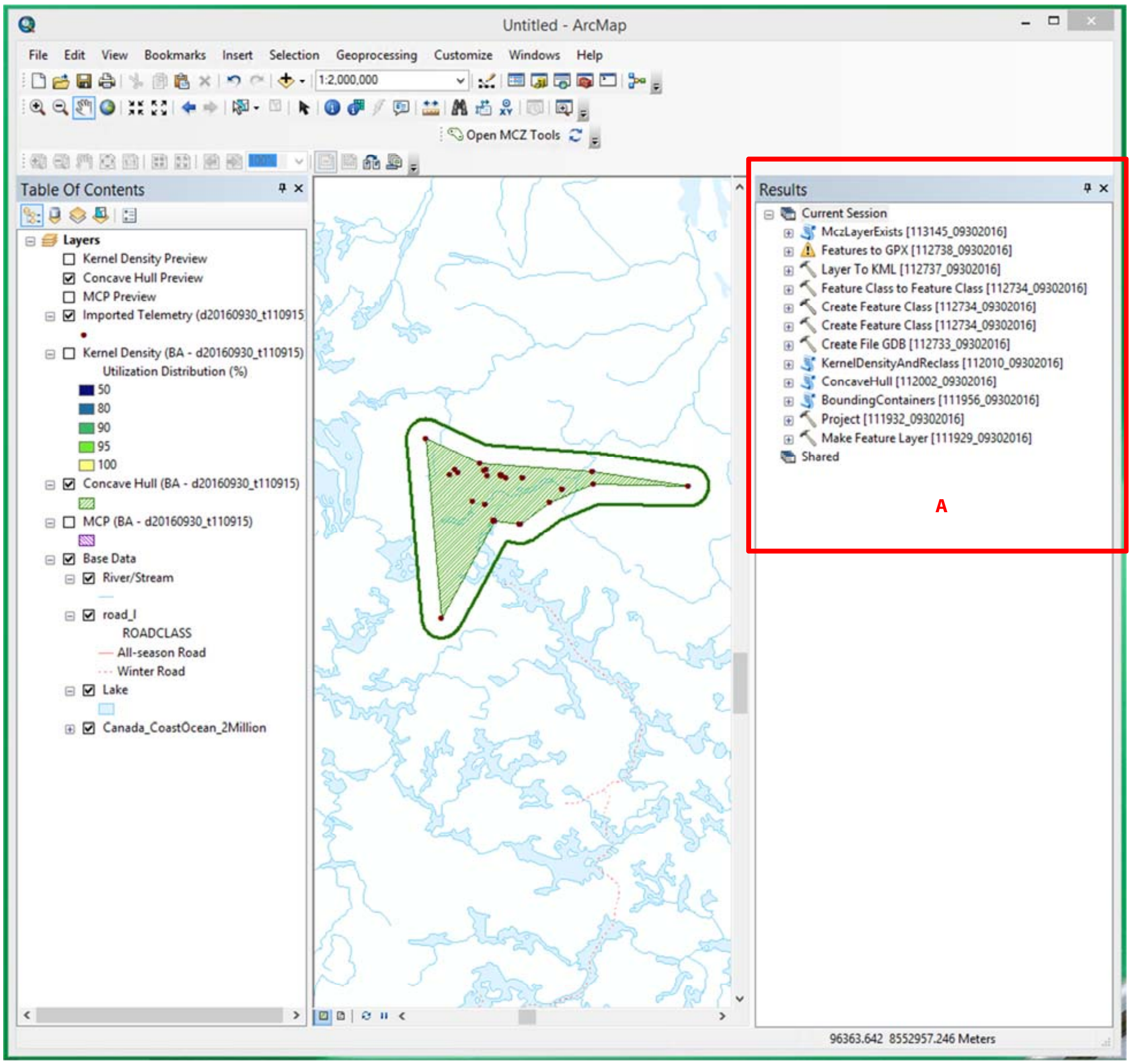
5.0 TROUBLESHOOTING

If any problems arise when operating the MCZ tool, use the ArcMap Geoprocessing Results window to view any error messages (Figure 11). The Geoprocessing Results window (Figure 11-A) can also be used to monitor the progress of MCZ tools at any time.

To access the geoprocessing results window:

I. In ArcMap, click Geoprocessing > Results
II. Expand the 'Current Session' group in the Results window (Figure 11-A).

Figure 11. Geoprocessing Results Window



6.0 TOOL LIMITATIONS

The following are limitations associated with the MCZ tool:

- The accuracy of the MCZ boundaries is determined by the telemetry data imported into the tool. Small telemetry datasets may generate boundaries that are not representative of caribou landscape use for a four day period, as overly generalized or specific polygons could be generated based on the distribution of a small number of points. Using telemetry datasets that capture caribou locations over multiple days prior to updating the MCZ boundary, may generate MCZ boundaries that are more representative of current selection set (e.g., Bathurst group) landscape use.
- Both the KDE and concave hull analysis methods require some user input during parameter selection (i.e, search radius and k-value, respectively). Multiple parameter values for each method should be tested to determine the most appropriate input parameters for MCZ boundary generation. As such, an understanding of how those parameters affect any analysis results is important for generating representative MCZ boundaries.

7.0 REFERENCES

Moreira, A., and M. Y. Santos. 2006. Concave Hull: A k-Nearest Neighbours Approach for The Computation of The Region Occupied By A Set of Points. Proceedings of the 2nd International Conference on Computer Graphics Theory and Applications (GRAPP 2007), Barcelona, Spain 61–68.

Worton, B. 1987. A review of models of home range for animal movement. Ecological modelling 38:277–298. <http://www.sciencedirect.com/science/article/pii/0304380087901013>. Accessed 13 May 2013.

Worton, B. 1989. Kernel methods for estimating the utilization distribution in home-range studies. Ecology 70:164–168. <http://www.esajournals.org/doi/abs/10.2307/1938423>. Accessed 18 Jun 2013.