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AN ONTARIO BASE MAP TERRAIN ANALYSIS TOOLBOX FOR RESOURCE MANAGERS

G. Mitchell and G.W. Crook

INTRODUCTION

Today, foresters are required to increase their use of expert systems to effectively manage Ontario's forested land base. As such, the Ontario Ministry of Natural Resources (OMNR) has created a digital data set of Ontario Base Maps (OBMs). OBMs are available at a scale of 1:20 000 for most of northern Ontario, and contain up to 19 layers of information. Each map covers an area of 100 km^2. OBM data can be used in a Geographic Information System (GIS) to create visual representations of natural resource information.

A "toolbox" of programs[1], which uses the elevation data of the OBMs, was also developed. These programs were designed as decision support tools for use by foresters and other resource managers in conjunction with traditional methods of information gathering, such as field evaluations and aerial photography. They should not be relied upon as the sole source of information for decision making. On this note, the toolbox has not been approved by the OMNR for producing slope-dependent buffers required by the Timber Management Guidelines for the Protection of Fish Habitat (Ontario Ministry of Natural Resources 1988), or for the sizing of culverts.

The programs are particularly useful to the forest industry for timber management planning, because they provide an improved, cost-effective, and environmentally sensitive allocation of human and capital resources for harvesting, access road construction, and silvicultural interventions.

The toolbox of programs is based on ARC/INFO (Version 7.0), the GIS standard in Ontario. Version 7.0 incorporates ANUDEM software[2], which significantly improves the processing of digital elevation data to produce accurate watersheds.

The purpose of this technical note is to describe the development of a Terrain Analysis Toolbox of six user-friendly programs (Variable Width Buffering Tool, Slope and Aspect Tools, Road Profiling Tool, Watershed Delineation Tools, and Culvert Calculation Tool) that provide decision support for resource managers using the new series of OBMs. The programs were developed using GIS technology.

SOFTWARE STANDARDS

The software was developed using the Arc Macro Language (AML) and is not encrypted, thereby allowing it to be both portable and capable of future modification. It was written for UNIX work stations for knowledgable ARC/INFO users. These users need not be GIS specialists or programmers, but must have a basic understanding of ARC/INFO data structures and software.

The software programs use ARC/INFO, TIN, and GRID Version 6.1, but the Watershed Delineation Program requires Version 7.0. The plot files created by the toolbox are designed for full color electrostatic or inkjet plotters.

[1] This software has been developed by MITIG Forestry Services Ltd. It is available free of charge, on 8-mm tape, together with a Users' Manual and Programmers' Manual, from Mr. Grant Mitchell, MITIG Forestry Services Ltd., 485 Queen Street East, Suite 102, Sault Ste. Marie, Ontario, P6A 1Z9. Telephone: (705) 254-2073.

[2] ANUDEM software was developed by M. Hutchison at the Australian National University, Canberra, Australia.

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The toolbox uses two programs to process elevation data. The Watershed Delineation Program uses the TOPOGRID command in GRID to produce the hydrologically correct elevation model for defining watersheds and for producing culvert sizes. TOPOGRID is the ARC/INFO Version 7.0 implementation of the ANUDEM software. The ARC/INFO TIN (Triangulated Irregular Network) package is used to produce the slope and aspect information required by the other applications.

DATA STANDARDS

The toolbox has been developed for use with the OBMs available for northern Ontario. Of the 19 layers of information that make up the OBM data sets, the Terrain Analysis Toolbox uses the NEAT layer (the map sheet boundary) and the DRAINAGE layer (all features related to water on a base map, such as lakes, streams, and swamps). Elevation data is available as the DTM layer or the CONTOUR and SPOTS layers.

The DTM data layer provides the most accurate elevation data. It is composed of 15 000 to 40 000 points, with an elevation attribute provided as mesh points that consist of a loose, 100-m grid that extends about 300 m beyond a map sheet boundary. All lakeshores, streams, roads, ridges, depressions, and other linear features have elevation points collected at triple intensity about every 30 m.

For areas where DTM data are not available, the CONTOUR and SPOT layers are used as a source of elevation information. The contours are interpolated from aerial photography at 10-m intervals. The SPOTS layer is used to assign elevations to lakes, and when creating the elevation model. If a lake has no elevation, 5 m is subtracted from the elevation of the closest contour line.

The Terrain Analysis Toolbox will allow the use of the DTM data layer, or a combination of the CONTOUR and SPOTS layers, as the data sources for each of the tools. Because the DTM provides better quality data, it should be used for terrain analysis. It is denser and more uniform than the CONTOUR information, and provides continuous information between contours in areas with relatively flat terrain. CONTOUR provides elevation values to the nearest 10 m, but the DTM layer provides submeter precision, thereby resulting in better vertical accuracy.

TERRAIN ANALYSIS TOOLBOX

Variable Width Buffering Tool

This program delineates buffers from lakes and streams (Fig. 1). Buffer widths depend on the shoreline slope, thereby allowing the user to choose the slope classes and buffer widths. The program's default settings correspond to the buffers required by the OMNR as follows, but the user can provide up to 10 classes:

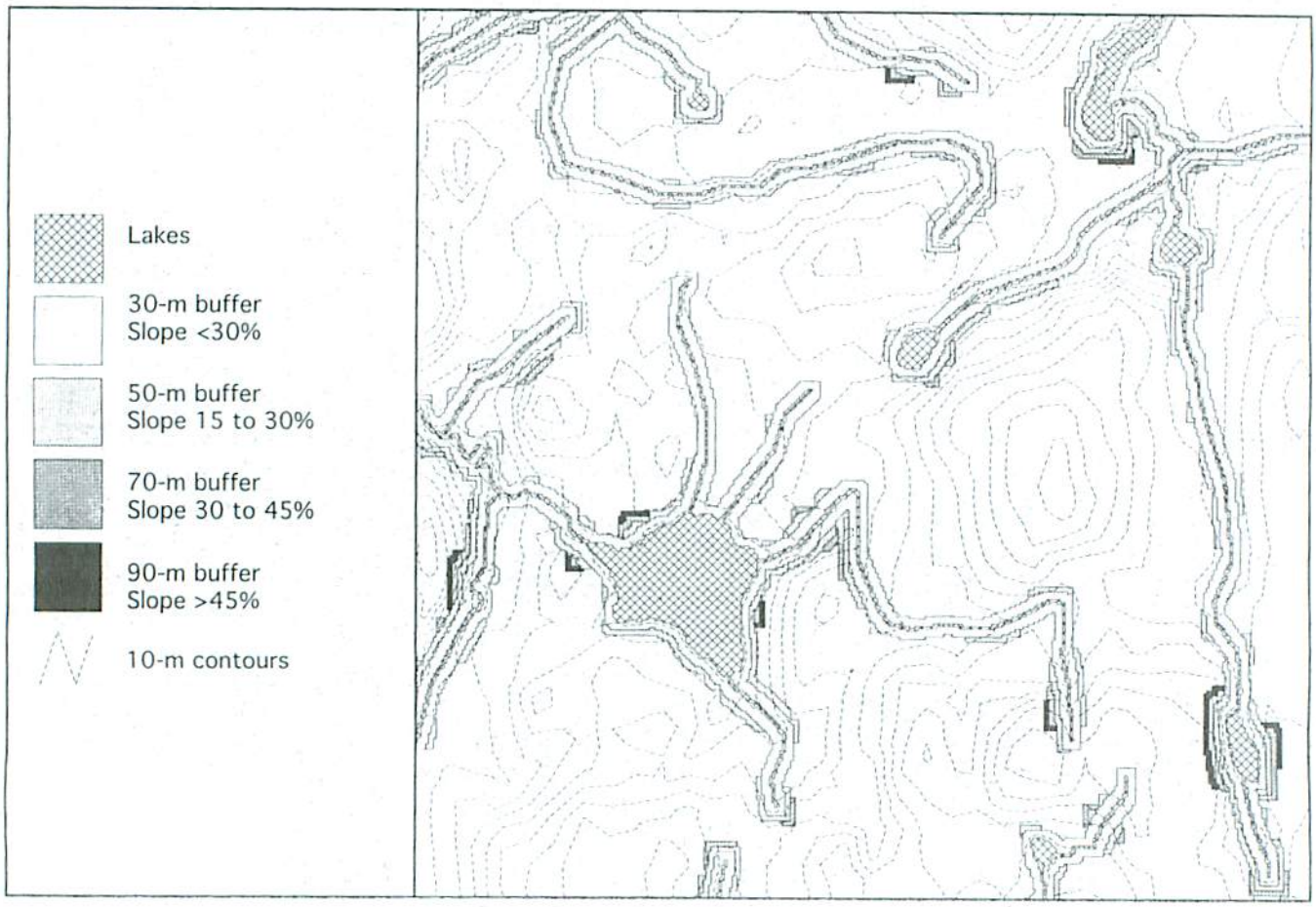

Figure 1. An example of the buffers produced by the Variable Width Buffering Tool.

Default slope classes (%)	Buffer width (m)
0 to 15	30
16 to 30	50
31 to 45	70
46+	90

Because of the large number of data input requirements, a MENU option was created to allow the user to interactively input the required data. This provides an easy method to change parameters and to view the output of each modification.

The input data source is the main factor to affect buffer quality. The DTM layer produces buffers that correspond well to those in approved timber management plans. However, if CONTOUR and SPOTS layers are used, buffers produced around lakes are usually of good quality, but buffer widths along streams are generally not reliable.

Slope and Aspect Tools

These programs allow the user to produce a plot of the slope and aspect variation on a single OBM map sheet. These tools are very easy to use—inputs include elevation data layers and a look-up table, which is provided. They also produce an excellent overview of a given area, one which is superior to contour maps.

Road Profiling Tool

This program quickly produces a profile of a planned or existing road (Fig. 2), shown as both profile and plan views. Each 50-m section of road is color coded for slope. The program assists the forester by quickly evaluating different access options and by providing supporting documentation.

Watershed Delineation Tool

This tool is composed of three programs that allow the user to produce watersheds over a maximum of 16 OBMs. WSMAKE constructs elevation and water flow grids for an OBM map sheet; WSJOIN assembles watershed data sets for up to 16 OBMs into a contiguous data set for the analysis of watersheds that extend beyond a given map sheet; and WSSHED is an interactive program that derives a watershed for any location selected by the user.

Culvert Calculation Tool

The Culvert Calculation Tool uses the watershed area, the average watershed slope, the swamp area, and the lake area to calculate required culvert sizes. The program calculates culvert sizes based on the program used by regional engineers.

In addition to the DRAINAGE and NEAT layers, the Culvert Calculation Tool requires a watershed polygon layer

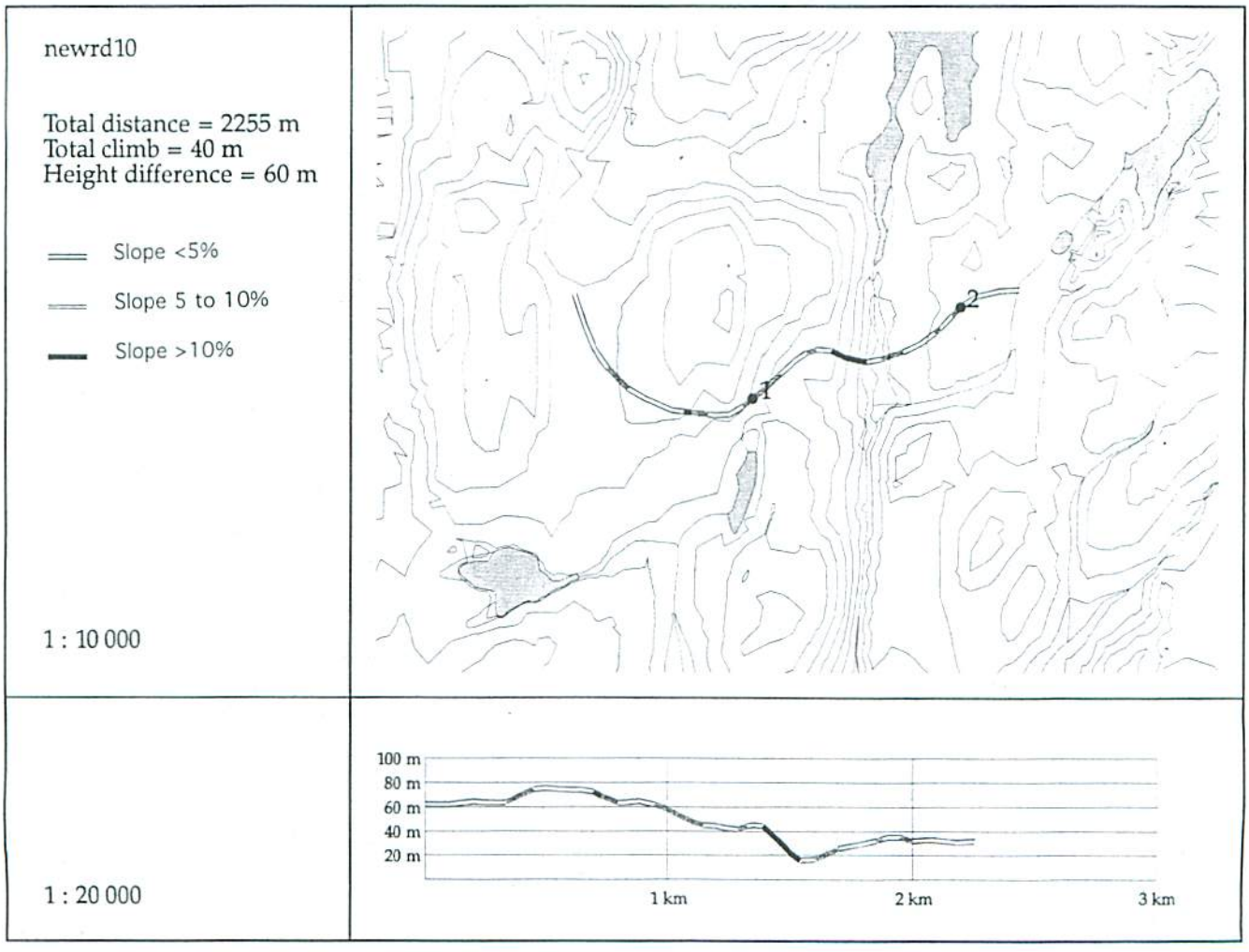

Figure 2. An example of the output produced by the Road Profiling Tool.

and a pour point layer produced by the Watershed Delineation Tool. The program produces a report with the suggested culvert sizes, and a plot file that shows the watershed, pour point, and suggested culvert sizes.

The user is prompted to supply information, such as the road name and the nearest upstream lake, after which the program calculates the average watershed slope in the area designated by the user. Also, the program can calculate the maximum elevation change for the entire watershed, so as to produce consistent average watershed slopes. This removes possible user subjectivity in calculating a watershed slope.

Two areas were used to compare approved culvert sizes to GIS-generated culvert sizes. The first area (Rinker Lake), with only CONTOUR and SPOTS layers available, had relatively flat terrain. The second area (Weikwabinonaw Lake) had DTM point data available, and included more rugged terrain. Table 1 shows the watershed statistics required to produce culvert sizes according to OMNR-approved and GIS-generated watersheds for the Weikwabinonaw Lake area. Table 2 provides a comparison of culvert sizes for the same watershed using OMNR-approved and GIS-generated culvert calculations.

Using DTM data, little difficulty was encountered when creating watersheds in the Weikwabinonaw Lake area. Nine OBMs were easily joined together with no edge effects. However, it was more difficult to produce an accurate watershed profile for the Rinker Lake area. Digitizing additional flow lines and adjusting tolerances were required to produce acceptable results. Anomalies, which could not be rectified, also occurred when joining the OBM map sheets together using WSJOIN.

Table 1. Comparison of watershed statistics between OMNR-approved and GIS-generated culvert calculations for the Weikwabinonaw Lake area.

OMNR-approved culvert calculations				
Water crossing	Watershed area*	Average slope	Lake area*	Swamp area*
483902 #2a	4.95	0.0024	0.075	1.35
483902 #2b	6.96	0.0113	0.156	0.936
484902 #5	0.45	0.024	0.0	0.0
484902 #10	23.38	0.00197	1.6	1.93
483902 #1	3.2		0.10	

GIS-generated culvert calculations				
Water crossing	Watershed area*	Average slope	Lake area*	Swamp area*
483902 #2a	6.46	0.0056	0.16	0.088
483902 #2b	6.46	0.0056	0.16	0.088
484902 #5	1.16	0.0087	0.00	0.02
484902 #10	19.91	0.0022	1.67	1.42
483902 #1	2.86	0.0041	0.09	0.23

*Areas are expressed in km^2.

Table 2. Comparison of culvert sizes between OMNR-approved and GIS-generated culvert calculations for the Weikwabinonaw Lake area.

OMNR-approved culvert calculations				
Water crossing	5-year flow*	10-year flow*	25-year flow*	100-year flow*
483902 #2a	1 200	1 200	1 400	1 400
483902 #2b	1 600	1 600	1 800	2 000
484902 #5	800	900	1 000	1 200
484902 #10		2 000		
483902 #1		1 400		

GIS-generated culvert calculations				
Water crossing	5-year flow*	10-year flow*	25-year flow*	100-year flow*
483902 #2a	1 400	1 600	1 600	1 800
483902 #2b	1 400	1 600	1 600	1 800
484902 #5	1 000	1 200	1 200	1 400
484902 #10	1 800	2 000	2 000	2 200
483902 #1	1 200	1 200	1 400	1 400

*Culvert sizes are expressed in mm.

MANAGEMENT CONSIDERATIONS

The OBM Terrain Analysis Toolbox is a valuable decision support tool for resource managers. The Variable Width Buffering Tool is an unbiased basis for negotiating Areas of Concern (AOCs) and for determining the total area within AOCs when carrying out analyses of wood supply or similar modeling exercises. However, because the buffers are produced using raster techniques, allowance must be made for the program's inherent inaccuracy.

The Slope and Aspect Tools allow managers to quickly produce an overview of a given base map. The Road Profiling Tool readily evaluates a variety of road location options. Although the program cannot select the appropriate option, it permits the forester to eliminate certain ones so that resources can be used to choose among the remaining viable road locations.

The Watershed Delineation and Culvert Calculation Tools produce excellent results, but are very sensitive to the input elevation data. DTM data provide consistently good results; CONTOUR data produce marginal results at times.

Before they are used operationally, the Variable Width Buffering Tool, the Watershed Delineation Tool, and the Culvert Sizing Tool should be thoroughly evaluated and verified. The accuracy of the OBM elevation data sets and the ability of each of the sets to support these applications should also be checked.

LITERATURE CITED

Ontario Ministry of Natural Resources. 1988. Timber management guidelines for the protection of fish habitat. Toronto, ON. 14 p.

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Natural Resources Canada
Canadian Forest Service–Sault Ste. Marie
Great Lakes Forestry Centre
P.O. Box 490
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P6A 5M7
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