Applying Space Shuttle Radar Technology to Road Locations and Gravel Searches

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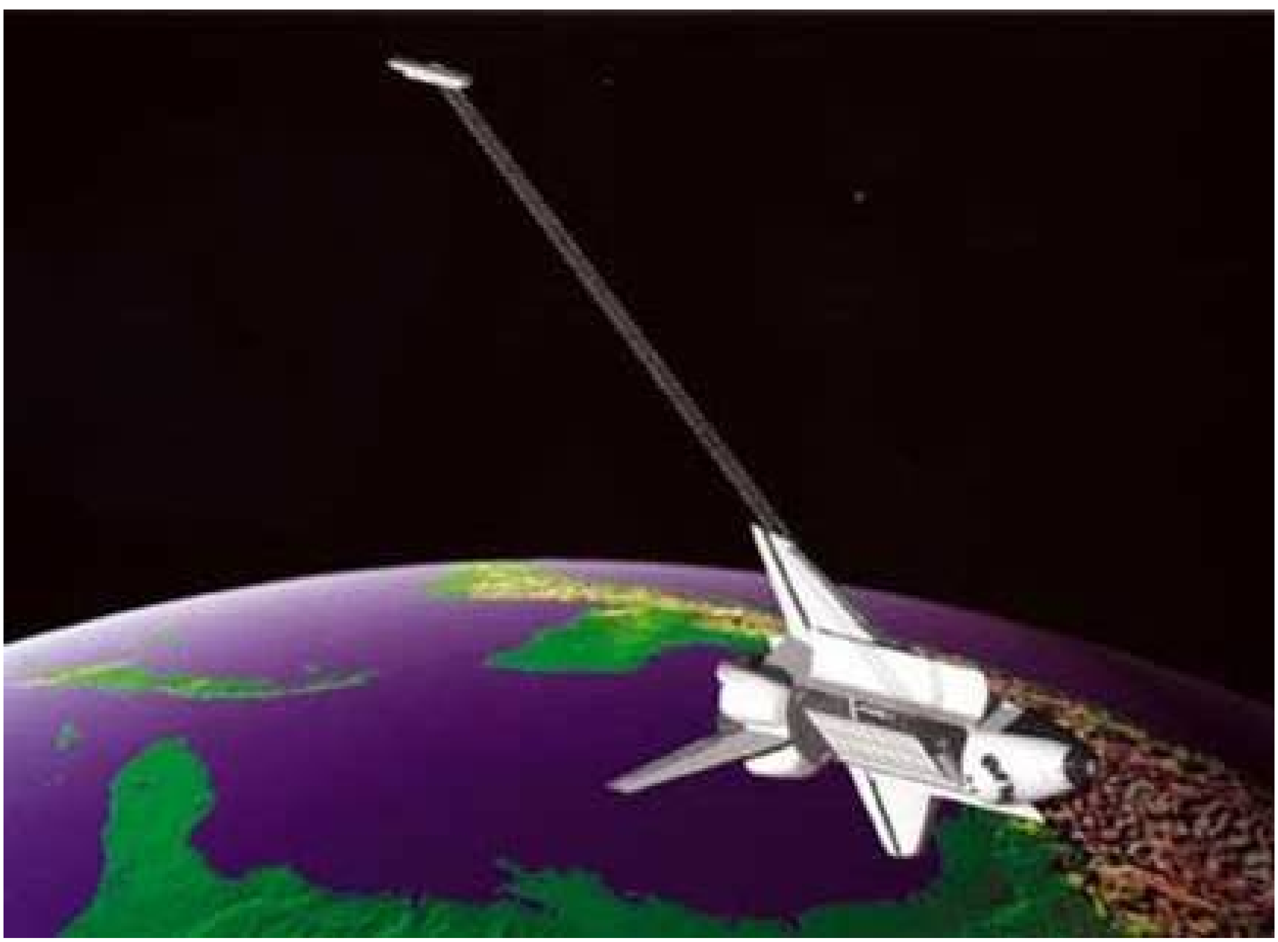

Abstract:

New technology has allowed the adoption of point elevation data collected by the space shuttle to be used for transportation applications. The paper will highlight two trials undertaken in Saskatchewan to apply the new shuttle radar elevation data to a route location in a remote area and in the search for aggregate.

Space shuttle radar elevation data is now available free for all of Canada south of 60 Degrees North Latitude. The digital elevation model of Saskatchewan that was created from this data now makes it possible to undertake analyses that were previously not possible or extremely expensive.

The first part of the paper will describe how the shuttle elevation data and model were used in GIS software to assess alternative routes for a proposed new road in northern Saskatchewan where no access or survey information was yet available.

The second part of the paper will describe how the shuttle elevation data and model were used in GIS software. GPS elevations from known delta deposits were used to re-establish water elevation of glacial lakes at the time gravel was being deposited into them, and then to identify potential areas to investigate for new gravel sources.

1. Introduction

The Shuttle Radar Topography Mission (SRTM), utilizing a specially, modified radar system flew onboard Space Shuttle Endeavour for 11 days in February of 2000. This radar system gathered data that resulted in the most accurate and complete topographic map of the Earth's surface that has ever been assembled. The more than 12 terabytes of data collected were processed at NASA's Jet Propulsion Laboratory over the next three years. By the spring of 2004 Canadian Government Agencies had access to download ground heights within 3 Arc Second grid cells.

Using the technique of radar interferometry, SRTM collected data over 80% of Earth's land mass, home to nearly 95% of the world's population at 30 – metre resolution. All of the radar data was collected during a single, 11-day Space Shuttle mission, and was processed to the same specifications. Collecting and processing the data this way ensured that the SRTM generated topographic maps would have the same characteristics.

In radar interferometry, two radar images are taken from slightly different locations. Differences between these images allow for the calculation of surface elevation, or change. To get two radar images taken from different locations the SRTM hardware consisted of one radar antenna in the shuttle payload bay and a second radar antenna attached to the end of a mast that extended 60 meters from the shuttle. The SRTM data were collected specifically with this technique and processed for the extraction of ground heights.

The processed SRTM radar data has been tailored to meet the needs of the military, civil, and scientific user communities. Other uses of this data include improved water drainage modeling, more realistic flight simulators, navigation safety, better locations for cell phone towers, and even improved maps for backpackers.   The current publicly available data outside of the continental U.S. is at 3 arc seconds (about 90-meters) resolution.

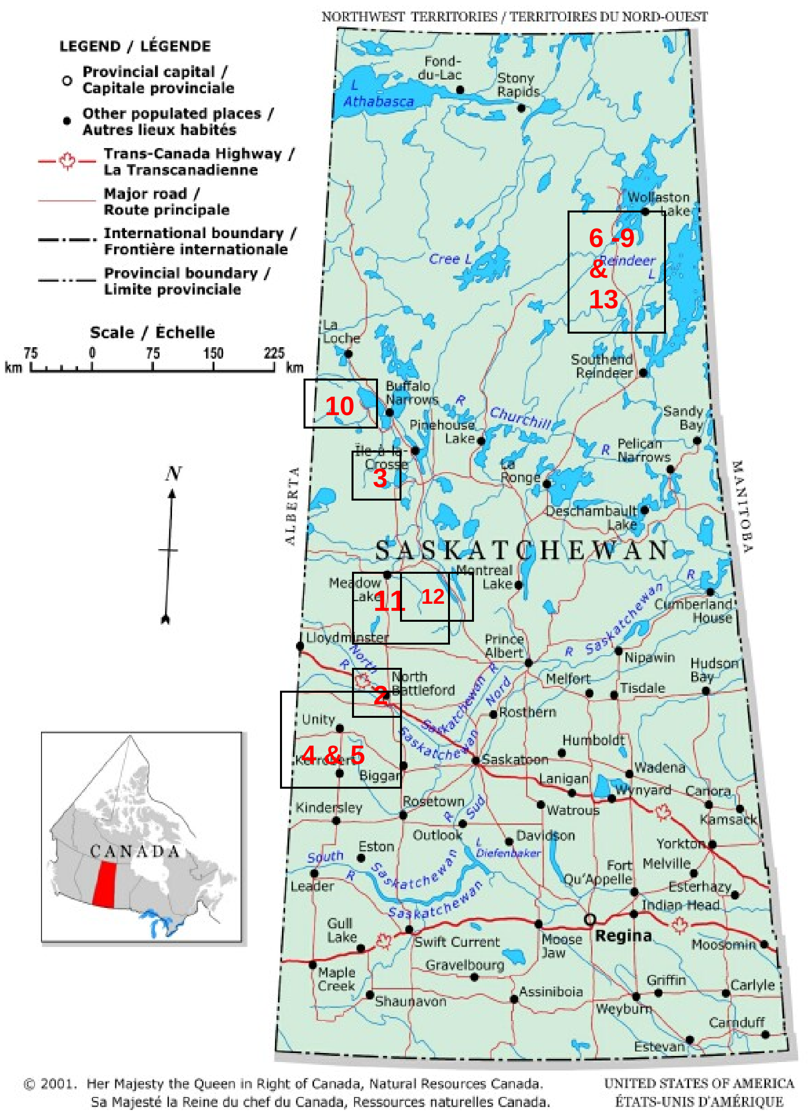

Figure 1 Map Showing Study Areas in Figures

Fig 2 North Battleford

Fig 3 Canoe Lake

Fig 4 & 5 North Battleford west to Alberta Border

Fig 6 to 9 & 13 Wollaston Lake

Fig 10 Garson Lake

Fig 11 Meadow Lake

Fig 12 Big River

2 Computer Requirements and Data Handling

Data was processed either within Intergraph's GeoMedia GIS software package or Esri's ArcVu GIS software package.   Computers having Pentium III processor or better, 256 MB of free disc space, 512 MB RAM, two 17 " High resolution Monitors and either Windows NT 4.0 SP6a, Windows 2000 SP3, or Windows XP SP1 or SP2 were used.

Elevation data was obtained from gisdata.usgs.net/website/Seamless/ and processed. The colors selected to depict specific ground elevations, vertical exaggeration, selection of azimuth, angle of inclination and transparency for the hill shade, flooding to a set elevation, tilting, and fly through were done within the software programs

3 Data Presentation

In forested areas, air photo and satellite imagery are predominately of the tree canopy which at times is up to 25 m. above the ground height. Comparisons of terrain models created from radar elevations vs. topographical map elevations of forested areas of Saskatchewan average up to 7m. vertical difference. Radar elevation data allows us to create terrain models that "see through" the tree canopy representing actual ground height.

In the southern great plains air photo and satellite imagery are cluttered with mankind's endeavours, cities, towns, farming practices, mines and so forth, taking away from the over view of the geomorphology.   Figures 2 and 3 show how radar elevation data allows us to create terrain models that are uncluttered by mankind's actions.

Figure 2 North Battleford Comparing Imagery on Left with Radar on Right

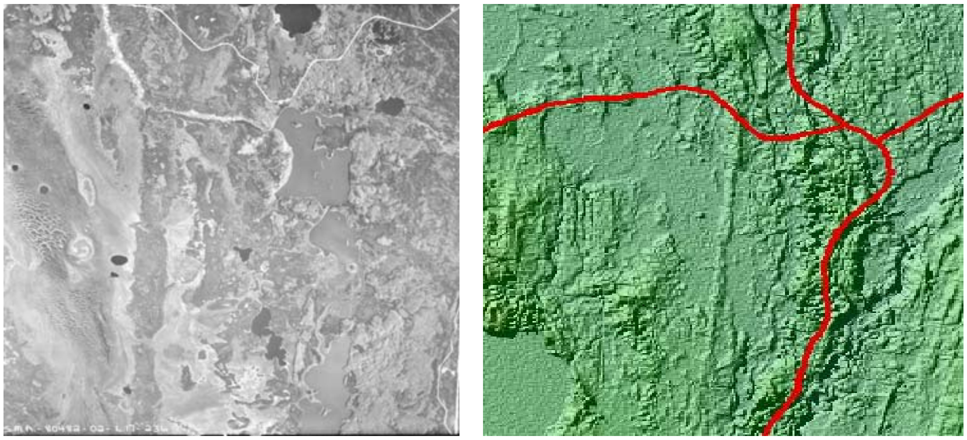

Figure 3 Canoe Lake Image Compared to Radar

3.1 Shaded Relief

A computer generated artificial light source illuminates the elevation data to produce a pattern of light and shadows. Slopes facing the light appear bright, while those facing away are shaded. On flatter surfaces, the pattern of light and shadows can reveal subtle features in the terrain. The direction of the light source can be rotated to determine the best image for the application. Shaded relief maps are commonly used in applications such as geologic mapping and land use planning.

Figure 4 shows a shaded relief map generated within GIS software using the elevation data as measured by the SRTM. Azimuth and angle of inclination of the artificial "sun" were selected to optimise the 3-D visual effect created.

3.2 Combined Shaded Relief and Color as Height Maps

In Figure 5 an image is generated by assigning colors to show the specific elevations as measured by the SRTM. Changes in color signify changes in height. Ranges of colors were compared, the rainbow spectrum selected, and "stretched" over the "range" of elevations required to depict all of Saskatchewan, 200 m. to 2200. This elevation data image is made transparent and overlain onto the shaded relief.

In Figure 6 the elevation data image with color as height overlain onto shaded relief has a contour line of control elevation. Contour mapping is the traditional method for graphically representing landforms of earth. Contour lines follow paths of constant elevation and are closely spaced on steep slopes and widely spaced on relatively flat terrain. By adding one contour to depict a control elevation known to be common to several deltaic depositions we perceive an approximation of the "shore-line" of the glacial lake at the time the deltaic depositions occurred.

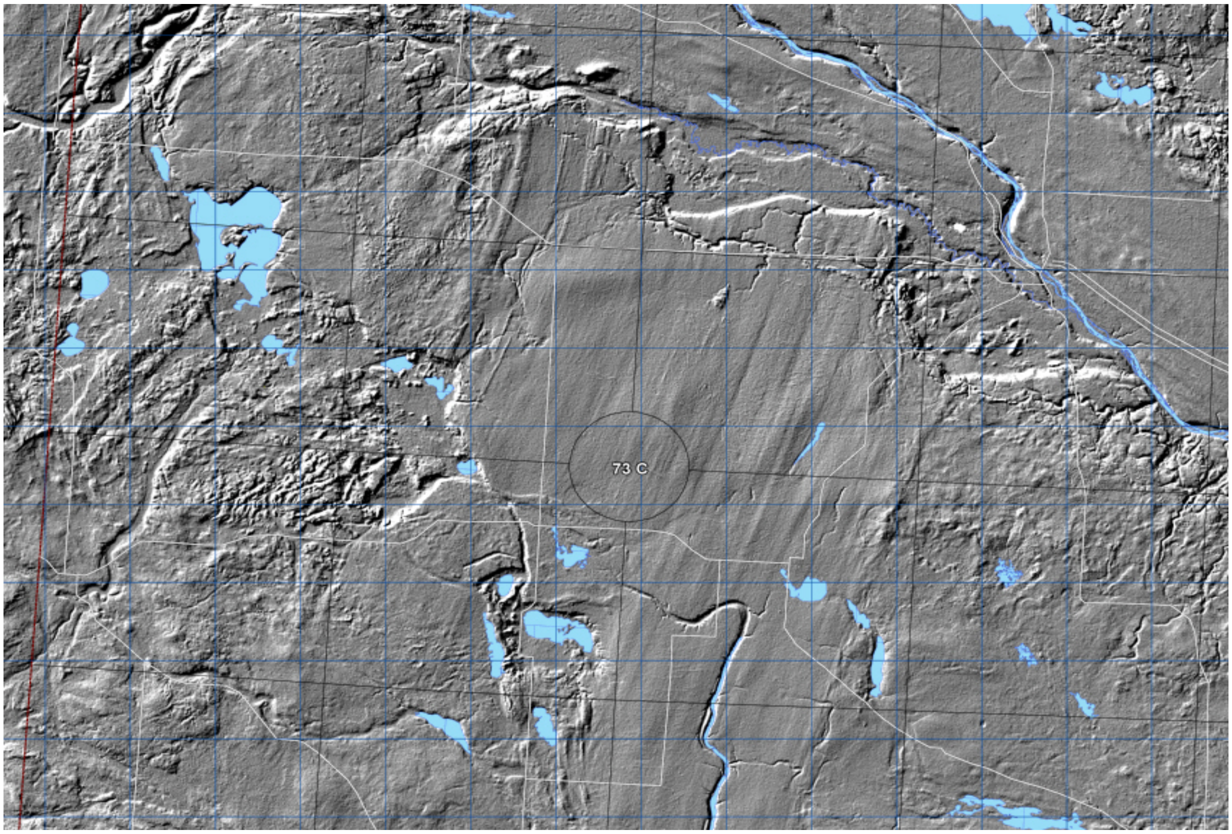

Figure 4 North Battleford to Alberta Border Shaded Relief Map

Additional examples can be seen in Figures 11 and 13 where the glacial lake is "flooded" within the contour. The area encompassed by the contour is coloured blue to depict the extent of the Glacial Lake at the time. This removes any terrain model representation from view within the bounds of the lake thus directing our focus only where it should be, on the land mass above water at the time.

In areas of very flat terrain minute changes in vertical relief are not discernable. If the vertical relief is exaggerated this enhances the elevation differences and allows us to perceive anomalies more readily. This is illustrated in Figure 7.

4. Shuttle Radar as a Route Location Tool

Two routes for a hundred kilometers of new road that has been proposed to join Wollaston Post to existing Highway 904, to alleviate the need for the barge in summer and ice road each winter. The routes had been previously selected from 1956 air photos of the region. The initial intent was to fly the proposed routes with lydar and then design on the subsequent terrain model. A digital elevation model was created using shuttle radar ground heights resulting in changes in the route location at some of the areas requiring significant rock cuts. Field surveys will be completed on several of these locations to confirm the accuracy of shuttle data and of the modeling capability in May, 2006.

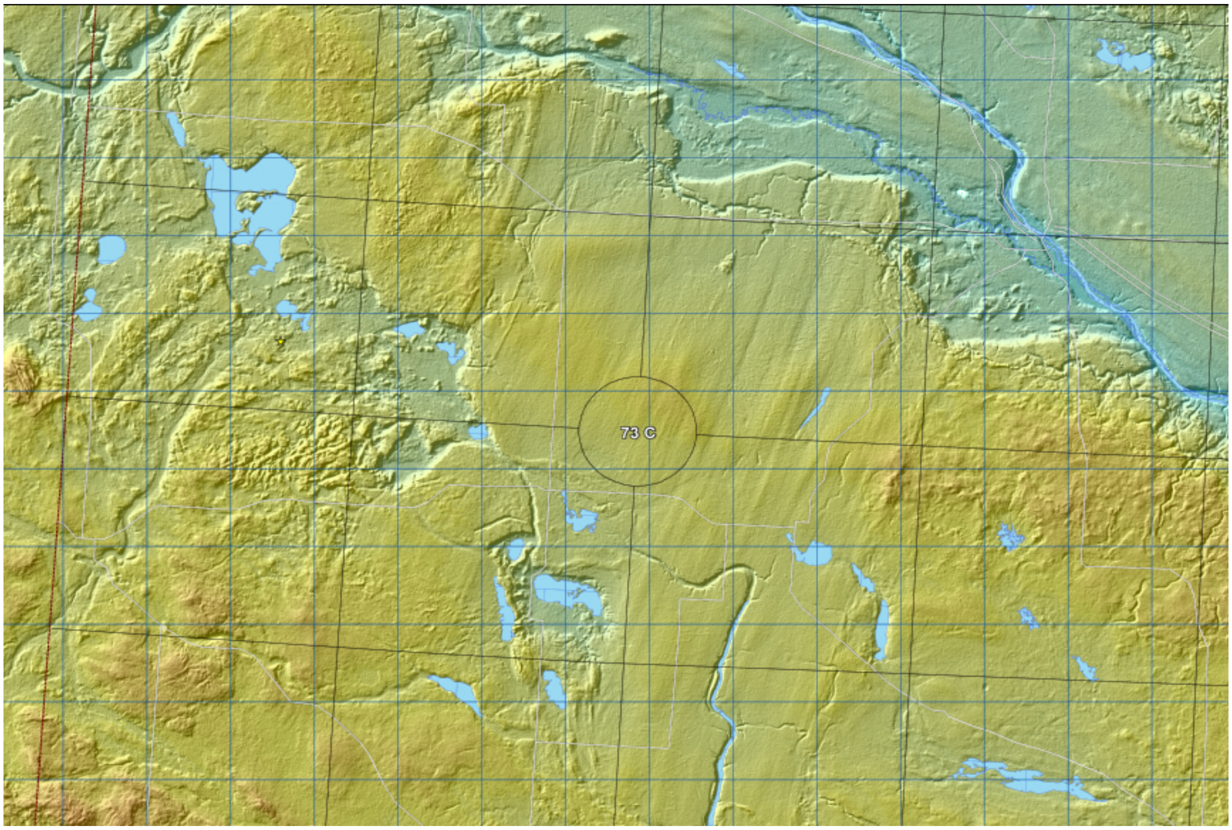

Figure 5 North Battleford to Alberta Border Shaded Relief and Colour

To give a perspective view of potential routes, an elevation data image with color as height is overlain onto shaded relief. The GIS software is utilised to generate a proposed road location on this “plan view”. The vertical relief is exaggerated and the view is “tilted” to one side to create this three-dimensional perspective view of the proposed route to Wollaston Post as shown in Figure 6.

The perspective view of the two Wollaston Post alternate road locations in Figure 6 has the “Yellow Posts” added as ten kilometer markers; the markers for Km 0 through Km 100 are visible in this image. Figure 7 with exaggerated relief shows the section from kilometer marker 50 to 60.

The Wollaston Post road location is over a rough terrain of exposed bedrock and lakes. The Perspective views in Figures 6 and 8 allow the proposed road location to be seen in 3-D while simultaneously viewing the profile. Thus “fine tuning” the route selection in order to minimize rock cuts in the planning stage is made quick, effective and easy.

Figure 8 shows an elevation data image generated with color as height overlain onto shaded relief and then a digital or photo image is “draped” over it.
This image is then “tilted” to one side. Overlays of Land sat, SPOT, Ikonos, or other false color image can be shown in three-dimensional perspective view this way.

GIS software is able to use the data to provide a “least-cost route” that can be set to minimize rock cuts, minimize grade, turning radius, and many other parameters. Supplemental ground survey data, land cover, soil type, wildlife habitat, slope and drainage information can all be incorporated into the model to provide input towards selecting an optimized route that is safe, cost effective and environmentally acceptable.

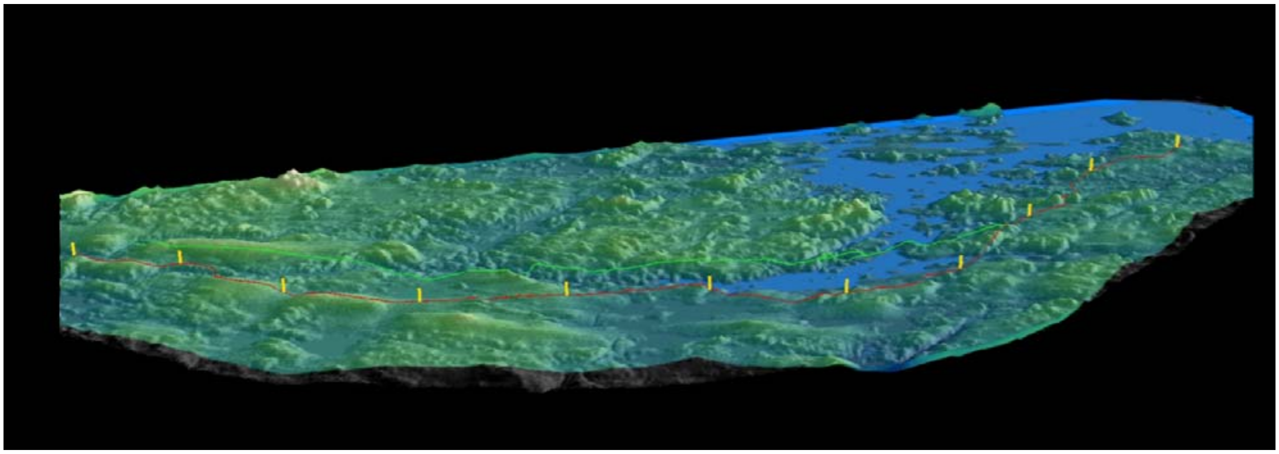

Figure 6 South of Wallaston Lake Showing Route Location Perspective View

Figure 7 Section of Wollaston Route showing Exaggerated Relief

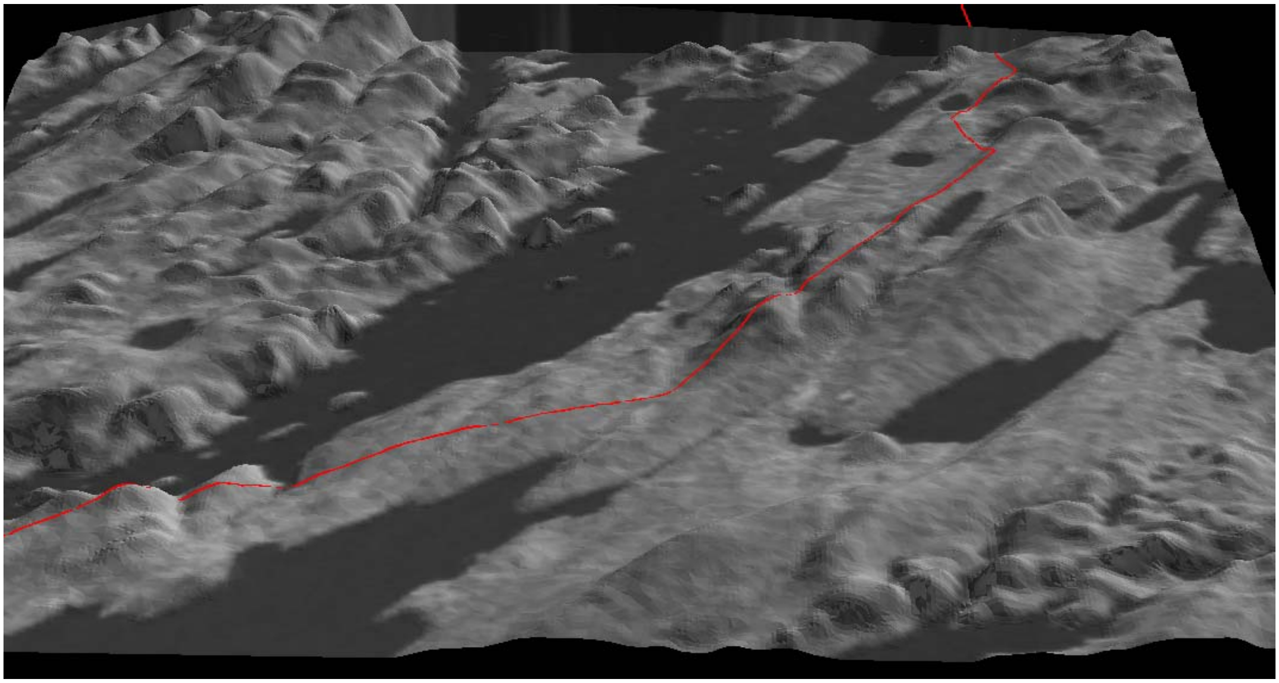

Figure 8 Wollaston Post Route Perspective Exaggerated Relief with Image Overlay

Figure 9 shows a digital elevation model at "Standard Plan-Profile" format and scale. It is overlain with both one and five meter contours and the corresponding profile of 1.5 kms of road location from Km. 70.9 to Km. 71.5 is shown.

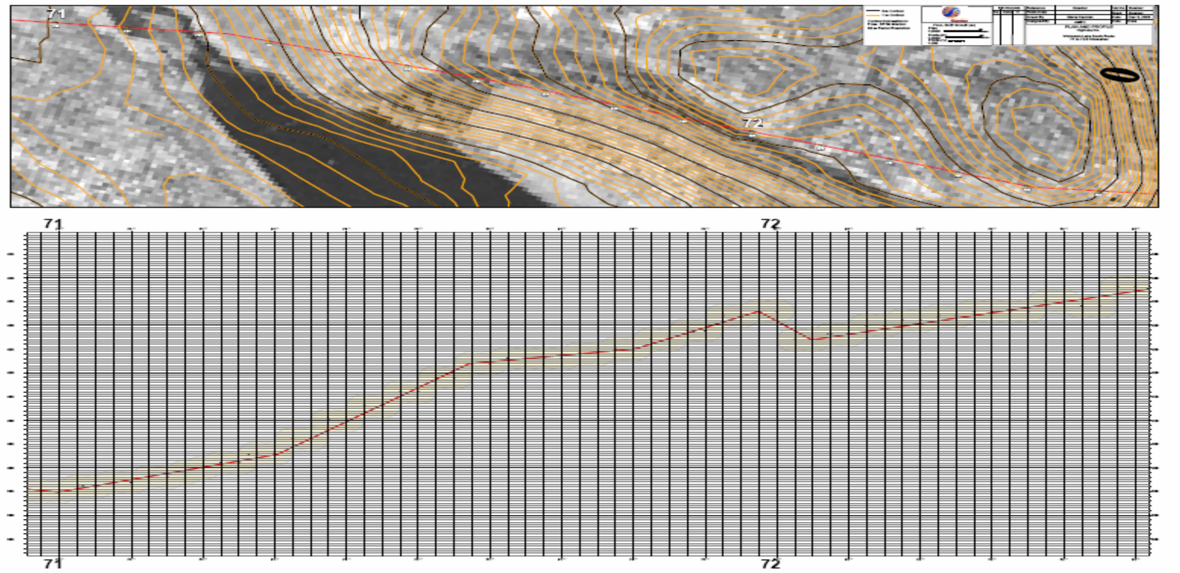

Figure 9 Standard Plan Profile Sheet

5. <u>Shuttle Radar as a Gravel Location Tool</u>

Saskatchewan Highways and Transportation is depleting its gravel reserves in several areas of the province forcing increasing haul distances and associated costs. Engineering Standards Branch has been given the mandate to assess all possible new technologies for their economic feasibility and utilize them to re-do the field searches within these gravel scarce areas.

Shuttle radar ground heights are proving to be a sufficiently accurate yet very economic data source for terrain modeling large areas. By adding to a shuttle terrain model from other data sources, we further increase our capability to detect new target search areas for gravel. These additional data sources include previous reports, carbon dates, GPS ground heights of known deltas, positions of the ice face at the time from known terminal moraines, and positions of the ice face at the time from perched valleys locations, both known and those determined from shuttle data analysis.

Interfacing hydrology software with shuttle elevation terrain modeling allows not only the simulation of glacial lakes but also probable spillways between them and thus more areas of potential gravel deposition.

Perched valleys are cut into a hillside when the ice face recedes down-hill just enough to allow a portion of a glacial lake to drain away with degradable velocity. Three of the four initial locations where shuttle was used were found to have “perched valleys” when a contour was generated at the elevation of known deltas.

Figure 10 shows a perched valley east of Garson Lake and immediately south of the Kimowin and Clearwater Lake Athabasca Spillways that were initially believed to have drained a portion of Glacial Lake Agassiz into Glacial Lake

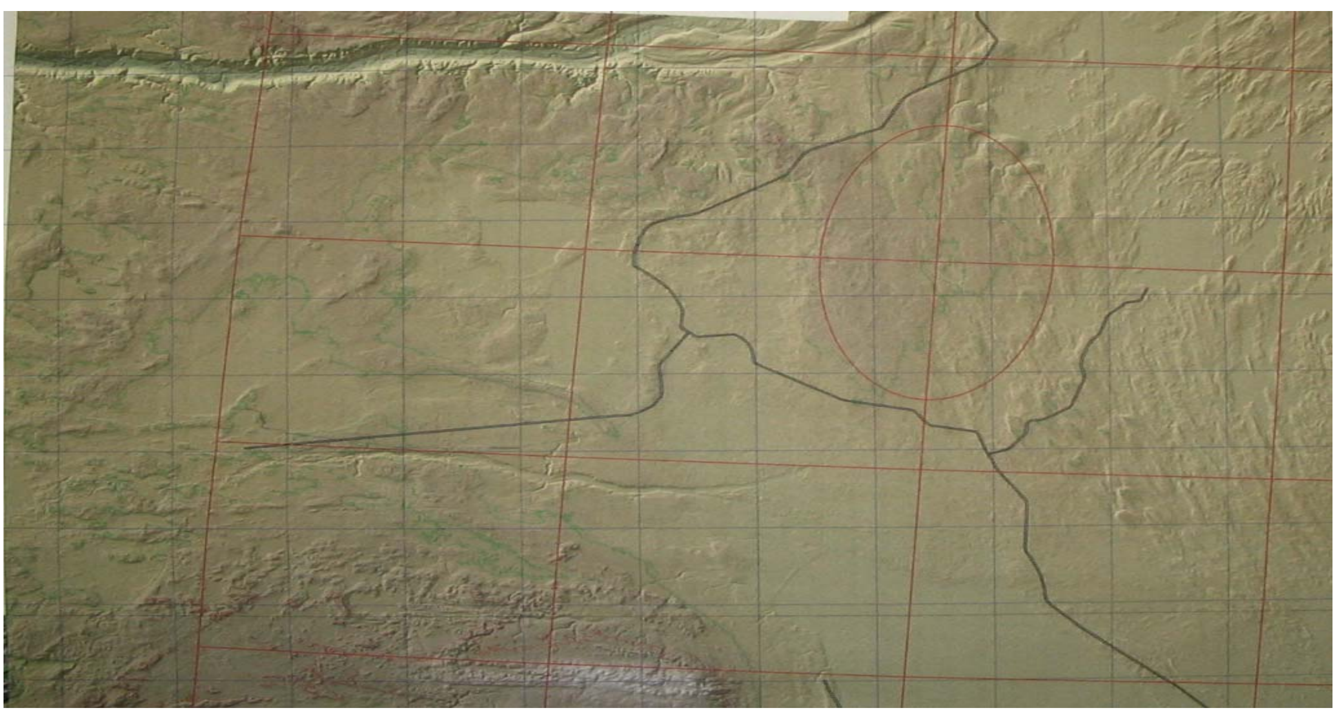

Figure 10 Perched Valley East of Alberta Border and Garson Lake

McConnell. Air photo interpretation and terrain analysis appear to indicate water actually drained eastward through it from McConnell to Agassiz depositing what appears to be a delta of sand or gravel downstream.

The Glacial Lake Meadow area shown in Figure 11 is 200 kms in length. It is predominately covered by Provincial Forest with a tree canopy of to 25 m. making air photo interpretation and terrain analysis very difficult. The ground elevations of known deltaic deposits in the area were measured with GPS. Elevations along this 200 km long glacial lake that drained north ranged from 540 m. in the south to 480 m. in the north. Both were assigned specific colors and generated on the terrain model. The 540 m. elevation determined for the south end is some 43 m. higher than the well established beach ridge around this end of the old glacial lake bed. Thus when contours were run our focus was directed some five to ten kilometers further up-hill on this gently sloping and heavily forested terrain.

Photo interpretation and terrain analysis were done at the locations that likely had concentrated melt-water flow running into the glacial lake (intersecting the contour line). The target areas were then selected for ground-proofing.

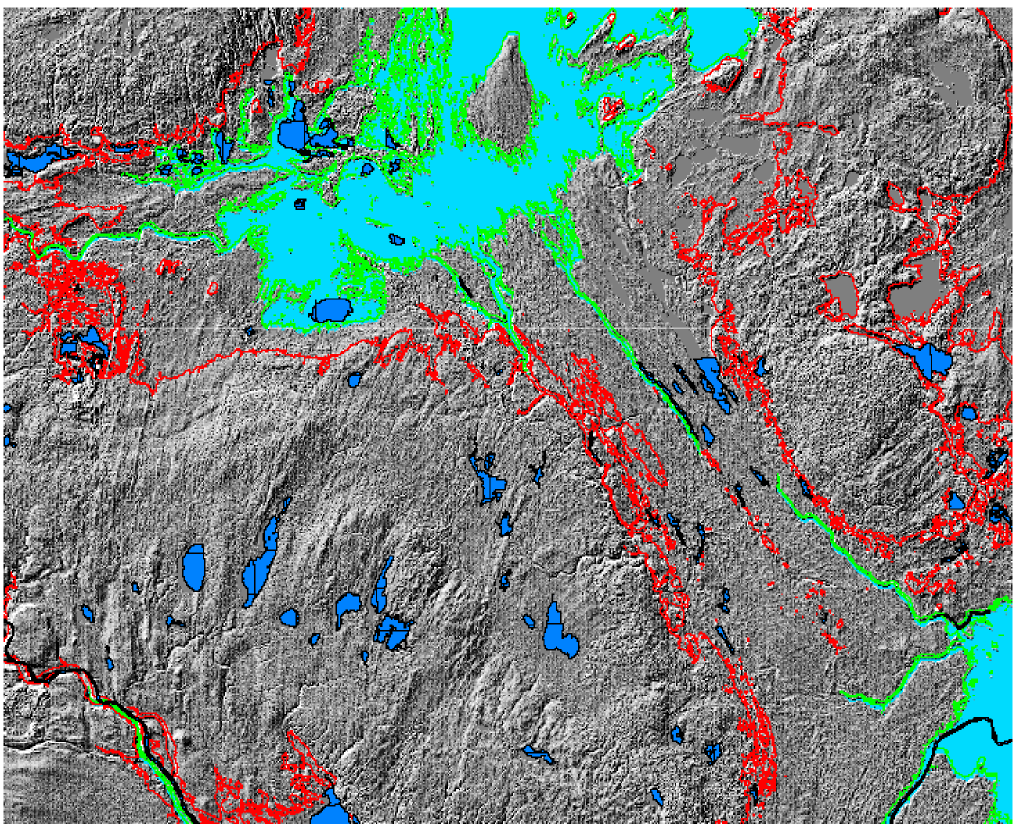

Figure 11 Glacial Lake Meadow Flooded to 480 Contour

Figure 12 shows and enlarged image of the glacial lake flooded to the elevation of the known pits.   The Perched Valleys west of Big River has been confirmed on the ground by the presence of several large deltas downstream.

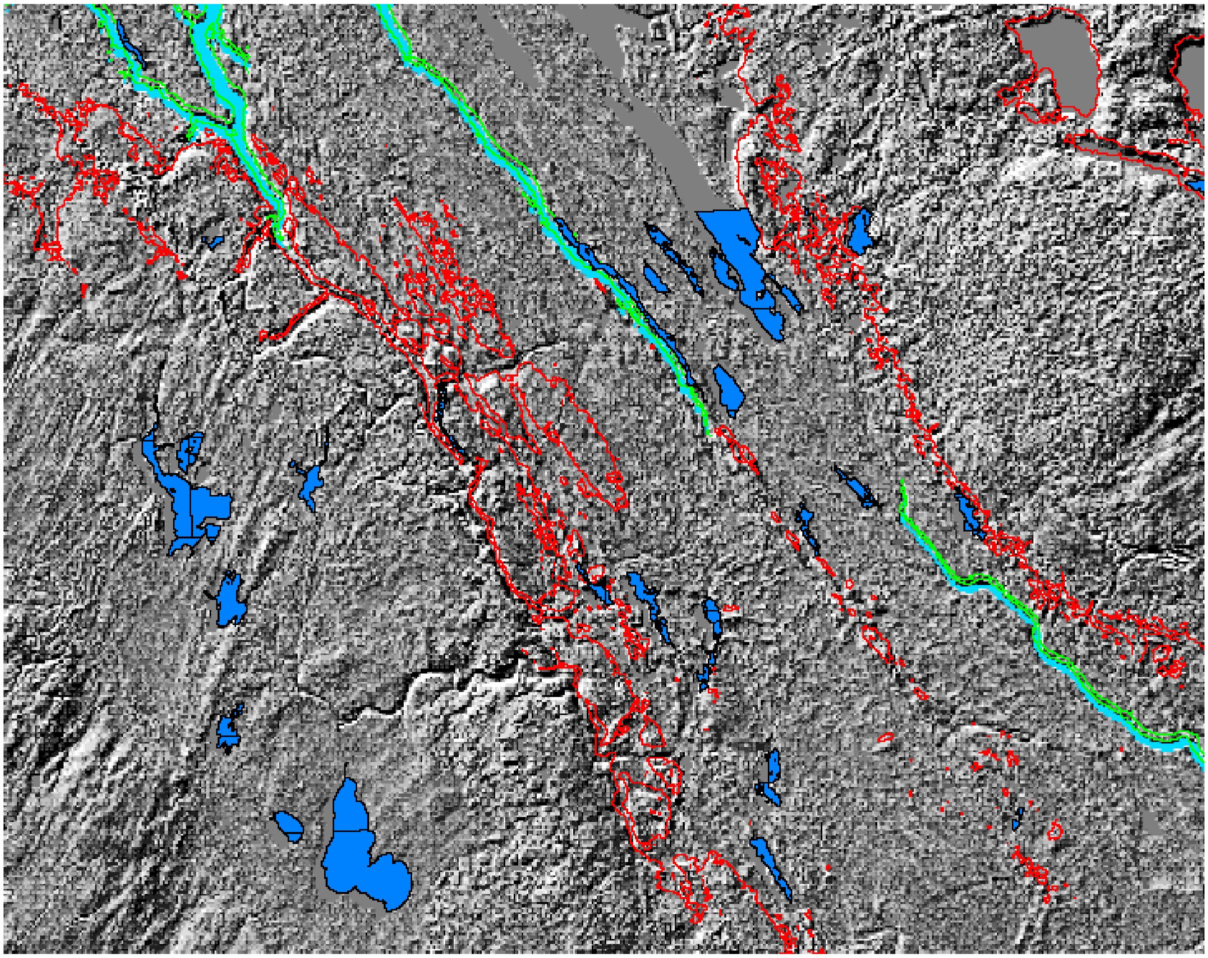

Figure 12 Enlarged Areas North of Big River

In conjunction with locating the proposed road to Wollaston Post described earlier, a review of available granular materials in the area was needed. Figure 13 has existing digital mapping of the large eskers in the area overlain onto a shuttle radar digital elevation model of the area. Normally these eskers are consistent and mostly continuous for hundreds of kilometers. An absence of eskers was noted where a temporary spillway may have occurred between glacial lakes. Contour lines of various elevations were tried until one "matched" reasonably well to the area without eskers.

Subsequent air photo interpretation and terrain analysis has determined the location of both probable deltaic depositions and beach ridges/strand lines. Preliminary ground proofing is to be attempted in May of 2006

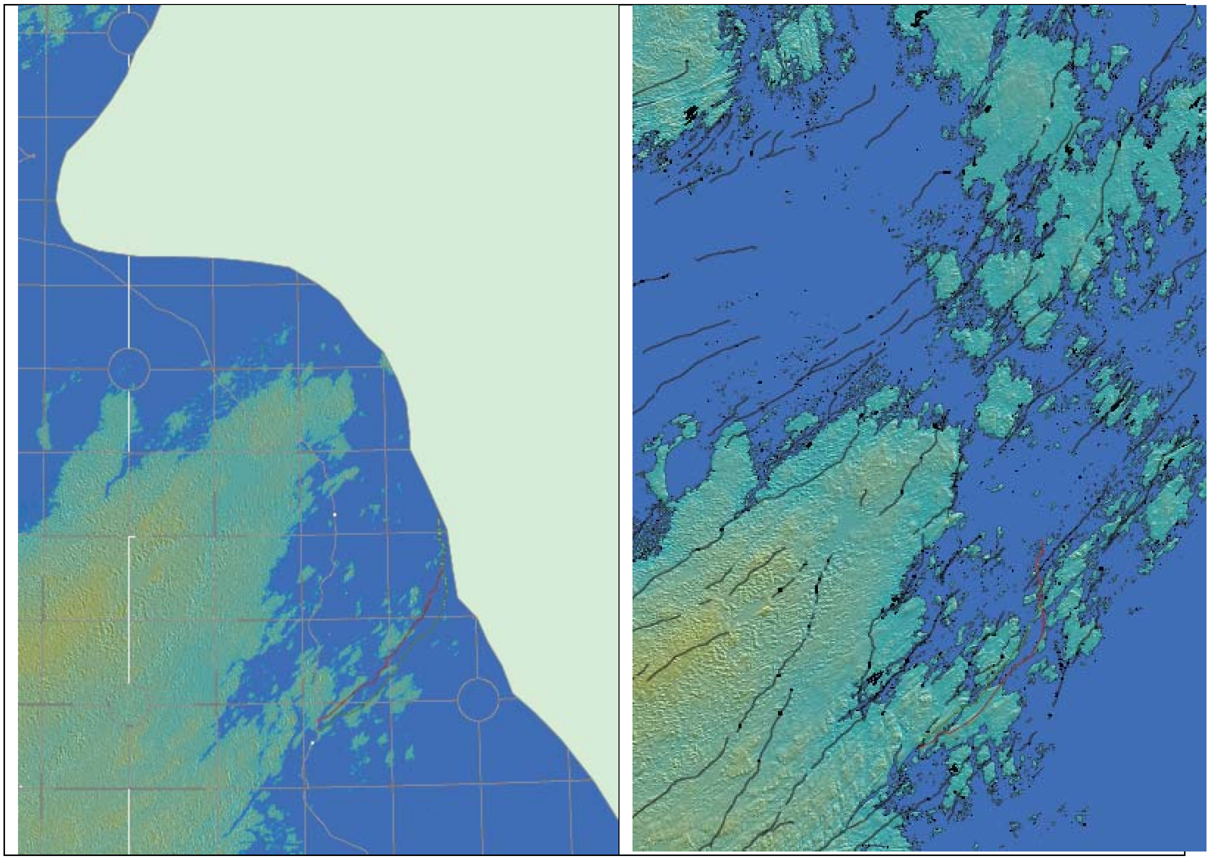

Figure 13 Wollaston Lake A Flooded at 420 Elevation B With Eskers Added

6. Future Plans for Shuttle

Modeling of glacial lakes and melt water channels in many areas of the Province has the potential for significant returns if new aggregate deposits are located.

The shuttle radar digital elevation model and the other sources of Saskatchewan Highways and Transportation data, comprise a large data set that is to be modeled with software in order to optimize potential for economically viable returns on gravel searches. These include locations of some 4,000 deltas in this

Province and logs of thousands of bore holes that Saskatchewan Highways has recorded along with respective custom software programs, previously reported terminal moraine and perched valley locations, and carbon dates.

Hydrology software is to be interfaced with GIS terrain modeling software to increase the capability and probability of predicting former locations of even temporary glacial lakes, spillways and melt water channels. Intergraph has written software to interface between their GIS package (GeoMedia Grid) and the recently released version of the Core of Engineers' hydrology modeling software (HEC-HMS).

Overlays using better quality satellite imagery needs to be investigated as they may further enhance terrain analysis. Hill shade may better be utilised to reveal anatomies if the artificial light source is moved fairly quickly across the horizon.

7. References and Information Sources

Public Inquiries Business Center
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