ERCB/AGS Open File Report 2009-08

Implementation of a Web-GIS Application with ArcGIS Server 9.2 for the Peace River Landslide Project, Alberta

Energy Resources Conservation Board

Alberta Geological Survey

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Implementation of a Web-GIS Application with ArcGIS Server 9.2 for the Peace River Landslide Project, Alberta

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Abstract

Alberta Geological Survey created a Web-GIS application for the Peace River Landslide Project to provide access to significant geological, geotechnical, remote-sensing and GIS data available for the town of Peace River. We developed this application as part of a project to provide a better understanding of the extent, rate and drivers for landslides in and around the municipality, and to provide information for planning to reduce risk to population and infrastructure from landslide hazards.

The design of this Web-GIS application aims to create a user-friendly Web interface for the public to display and manipulate available data of the area. These data, organized as map layers, include geotechnical and water-well boreholes, bedrock geology, surficial geology, physiography, satellite images and a digital elevation model (DEM) of the town of Peace River, urban infrastructure and hydrography. Users can turn on and off different map layers, navigate around the area, retrieve data, display borehole log information and create plots with geotechnical data.

Implementation of the design was a challenging exercise. It was our first attempt to create a customized Web-GIS application with ArcGIS Server and Web Application Developer Framework (ADF) in Microsoft® .NET Framework. In addition, this application incorporates many GIS functions created by the user community, a non-GIS charting tool, and a 3-D visualization utility. Section 3 provides an overview of our application architecture and implementation.

1 Introduction

The town of Peace River is in the Peace River Lowlands of Alberta, one of the most historically active areas of mass movement in Western Canada. The Peace River, which is adjacent to the town, has incised through approximately 200 m of Quaternary sediments and 30 m into the underlying bedrock. The ongoing incision and valley-widening processes have created various geological failures and hazards that affect the town's infrastructure, such as road, railway and utilities networks (Davies et al., 2005).

A geographic information system (GIS) is a computer-based system for managing, storing, querying, analyzing, modelling and displaying map database information. When GIS data and functionality are available on the Internet, the system is referred to as Web-GIS.

Alberta Geological Survey (AGS) and University of Alberta (UA) have used ArcGIS® Server and Web ADF (Application Developer Framework), developed by ESRI® in Microsoft® .NET Framework, to custom design a Web-GIS application for the Peace River Landslide Project. This application lets us provide the project stakeholders and the various levels of government easy access to a vast amount of geotechnical and geological information collected during the past 50 years of the municipality, and to view it in relation to available remote-sensing imagery and infrastructure data. These pieces of information are converted to a GIS dataset (ESRI shapefile format) and presented as map layers. Users can turn on or off each layer, navigate around the area using pan and zoom, query each layer spatially or by attributes stored in its database, obtain metadata, view area in three dimensions (3-D), and create geotechnical graphs and plots. The aim is to provide the public and stakeholders with a user interface that is intuitive and familiar.

By using the Web-GIS application to access the vast amount of available information, the public can gain a better understanding of the geology in the area and apply this to planning of future development or mitigatory measures for existing development. Government officials, land-use planners, utilities and railroad companies can use the spatial analysis and modelling capabilities of Web-GIS for planning and other purposes.

The purpose of this report is to provide the user of the Web-GIS application with a manual that provides information on the available functions. Much of the underlying code is available in Chao et al. (2009), to provide guidance to others embarking on the development of a similar tool.

Upon completion, the Peace River Landslide Project Web-GIS application will be on the AGS website at www.ags.gov.ab.ca.

2 Application Design Overview

The Web-GIS application for the Peace River Landslide Project has four panels: toolset panels on the left; and Map Contents, Overview Map and Navigation on the right. A map display window is in the middle. There are links to other AGS web pages in the banner above the Map Contents panel (Figure 1). The user can minimize most panels by clicking the triangle at the right end of their title bars.

2.1 Toolset Panel

The toolset panel contains tools for performing General and Advanced GIS functions with map layers in the map display window. Users select a tool based on its function.

Other users created several of the functions in the toolbox and posted them on the ESRI Developer Network (ESRI, 2008c). Alberta Geological Survey modified them for this application.

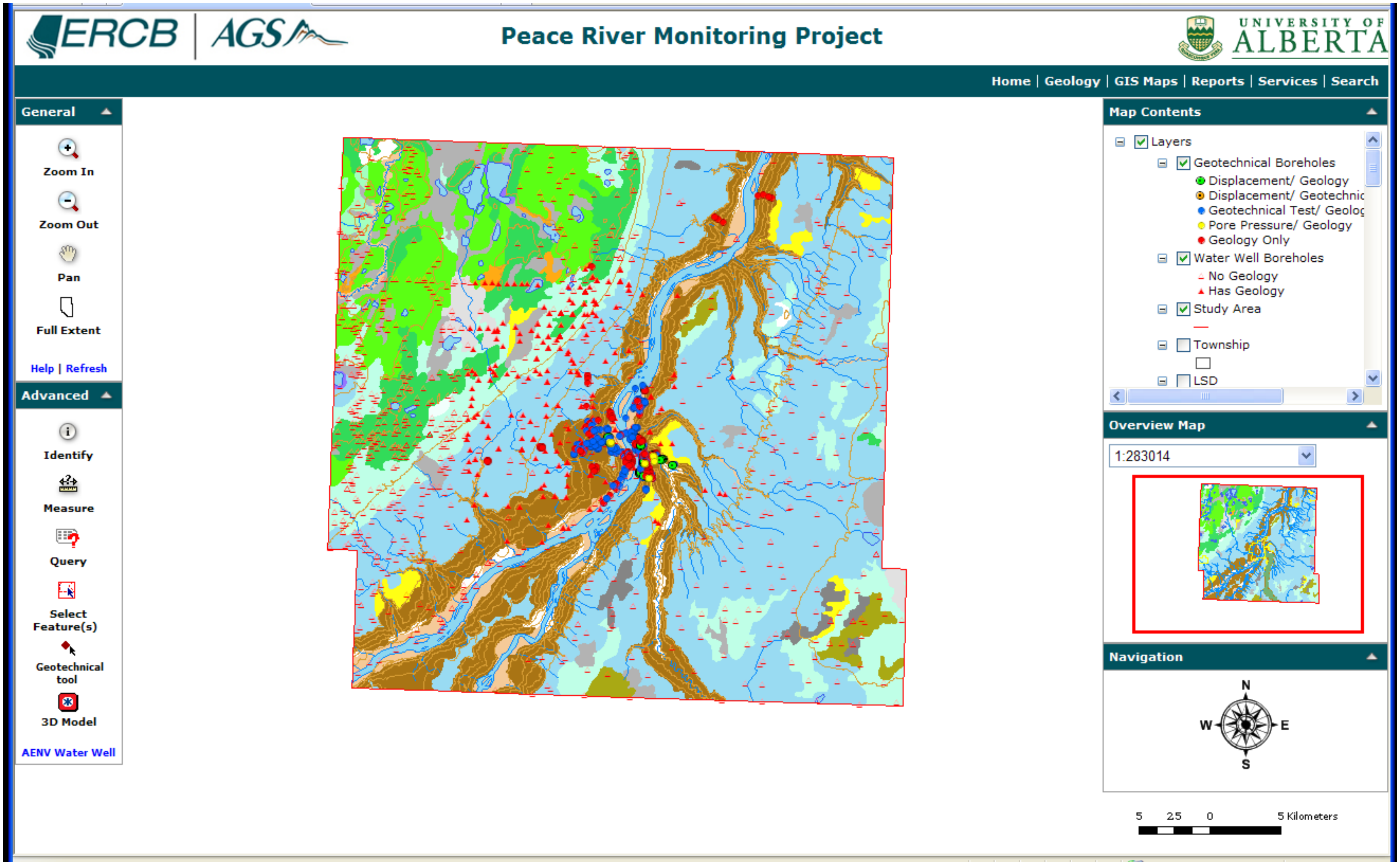

Figure 1. Peace River Landslide Project Web-GIS interface.

2.1.1 General GIS Functions

General GIS functions include navigation, a Help function on how to use this Web-GIS application and a Refresh function to redraw the map.

2.1.1.1 Navigation Tools

Navigation tools allow users to zoom in (Zoom In) and out (Zoom Out), move around (Pan) and reset back to original scale (Full Extent) in map display panel. These are built-in tools.

2.1.2 Advanced GIS Functions

Advanced functions include tools for Identify, Measure, Query, Select Feature(s), Geotechnical tool and 3-D Model. A hyperlink (AENV Water Well) to the Alberta Environment Groundwater Information System provides additional information on all water wells in the province.

2.1.2.1 Identify Tool

When users select the Identify tool and click on the map, it retrieves information (attributes) belonging to all active layers at that location and displays them in the Results window (Figure 2). Users can turn each layer on or off in the Results window to highlight its features. Right-clicking a feature allows them to zoom or pan to that location, or remove that feature from the Results window. For example, in Figure 2, ‘Colluvial deposits’ is a feature of the ‘Surficial Geology’ layer that is highlighted (a greenish colour) in the map display window. Unchecking both boxes removes the highlight.

This is an ArcGIS Server built-in function.

2.1.2.2 Measure Tool

The Measure tool displays the X and Y co-ordinates of a point location, calculates cumulative distance between locations and measures areas (Figure 3). To measure cumulative distance, click at a starting point on the map and then at sequential locations. Each line segment measures the distance between current and previous locations, and the Total Length is the distance between current location and the starting point. The Measure tool supports both metric and imperial units.

This is a built-in function.

2.1.2.3 Query Tool

The Query tool retrieves data for a map layer based on the user’s defined criteria (Figure 4). Filtered data are displayed in a table (grid view). The ‘Highlight feature’ checkbox highlights the corresponding feature on the map; the magnifying glass zooms to that location; and the ‘Export all records’ function saves the record as an Excel spreadsheet. The ‘Select all’ and ‘Unselect all’ functions check and uncheck the ‘Highlight feature’ checkbox. The ‘Zoom to all’ function zooms to an area that displays all selected records.

In Figure 4, the Water Well Boreholes layer was queried where Data Source is the Alberta Environment database (AENV Database). The query returned 500 records matching the criteria and displayed the information in the Results window.

This Query tool was downloaded from the ESRI Support Center website (Ciavarella, 2008).

The Grid view function in the Results window was downloaded from the ArcGIS Server Development Blog website (Brenneman, 2008). We customized it to include the ‘Export all records’ function described above.

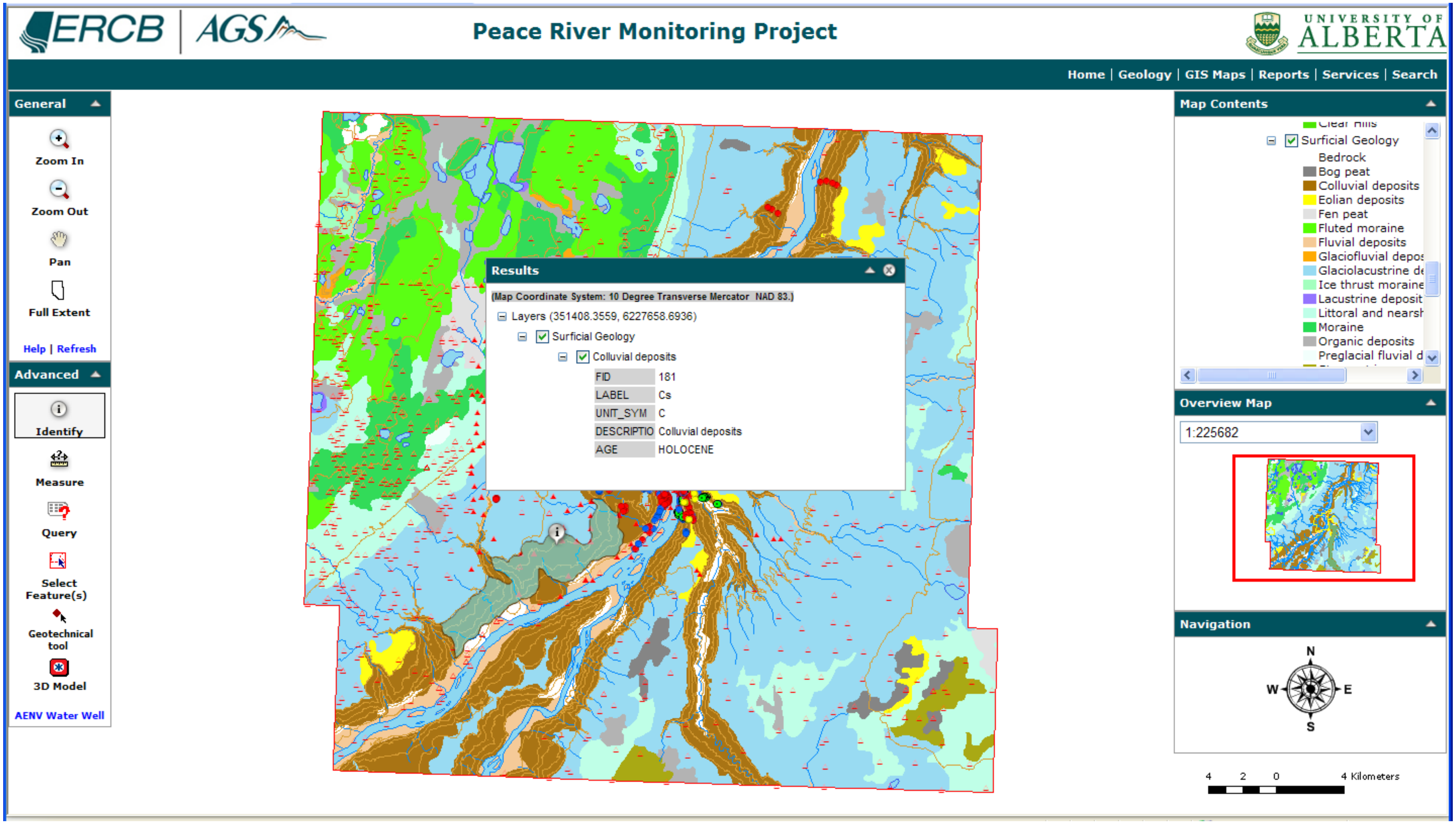

Figure 2. Results from Identify tool: checkboxes are used for highlighting features in the map display window.

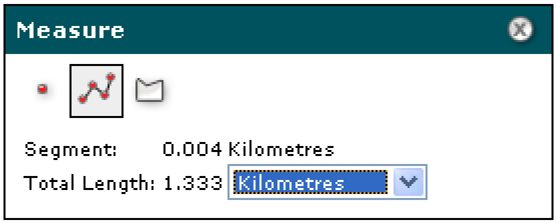

Figure 3. Measure tool interface.

2.1.2.4 Select Feature(s)

Similar to the Query tool, the Select Feature(s) tool lets users select/retrieve records based on spatial criteria. After clicking on the tool, they select a map layer of interest and either click a location or draw a line, square, polygon or circle on the map display window. The Results window displays the information on those features included in the area of interest (Figure 5).

This tool was downloaded from the ESRI Support Center website (Baker, 2007).

2.1.2.5 Geotechnical Tool

The customized Geotechnical Tool creates time-series displacement plots from slope inclinometer data, pore pressure plots from piezometric data, and geotechnical index test plots and stratigraphic plots from logging results for each borehole.

The data available for each borehole depend on the borehole type, as well as the tests performed during drilling and any instrumentation installed upon completion of the hole. The map application uses different symbols in the Map Content panel to indicate the borehole type and instrumentation type.

Inclinometers measure lateral deflection of soils and bedrock in the subsurface, locating the fracture surface in a slope or monitoring slope movements (Hunt, 2005). The time-series displacement plot uses inclinometer data from a borehole to draw cumulative displacement, incremental displacement or time displacement plots based on a selectable time period and depth interval. Users can use these plots to examine movements at any given time and depth for a specific borehole (Figure 6). A message window will appear if inclinometer data are missing for the displacement plots.

Piezometers measure groundwater levels or pore pressure. The piezometer plot shows water table depth from a water well borehole over the measured time period (Figure 7).

The geotechnical test function consists of two plots: standard penetration test (SPT) and pocket penetrometer measurements (Figure 8). The SPT plot provides detailed information on soil stratification for analyzing strength and compressibility (Hunt, 2005); the pocket penetrometer plot displays shear strength measured using a pocket penetrometer and is indicative of the material's unconfined compressive strength (Cornell University, 2008).

The stratigraphic plot function uses symbols and labels to show deposits such as clay, silt, sand and gravel at different depths in a borehole (Figure 9).

The Plot Compare function shows displacement, lithology and geotechnical test data for a selected borehole. The user can select which data to display, and the plots display in a single window for comparison. This is a useful tool for better understanding the soil conditions and slope stability of a specific location (Figure 10).

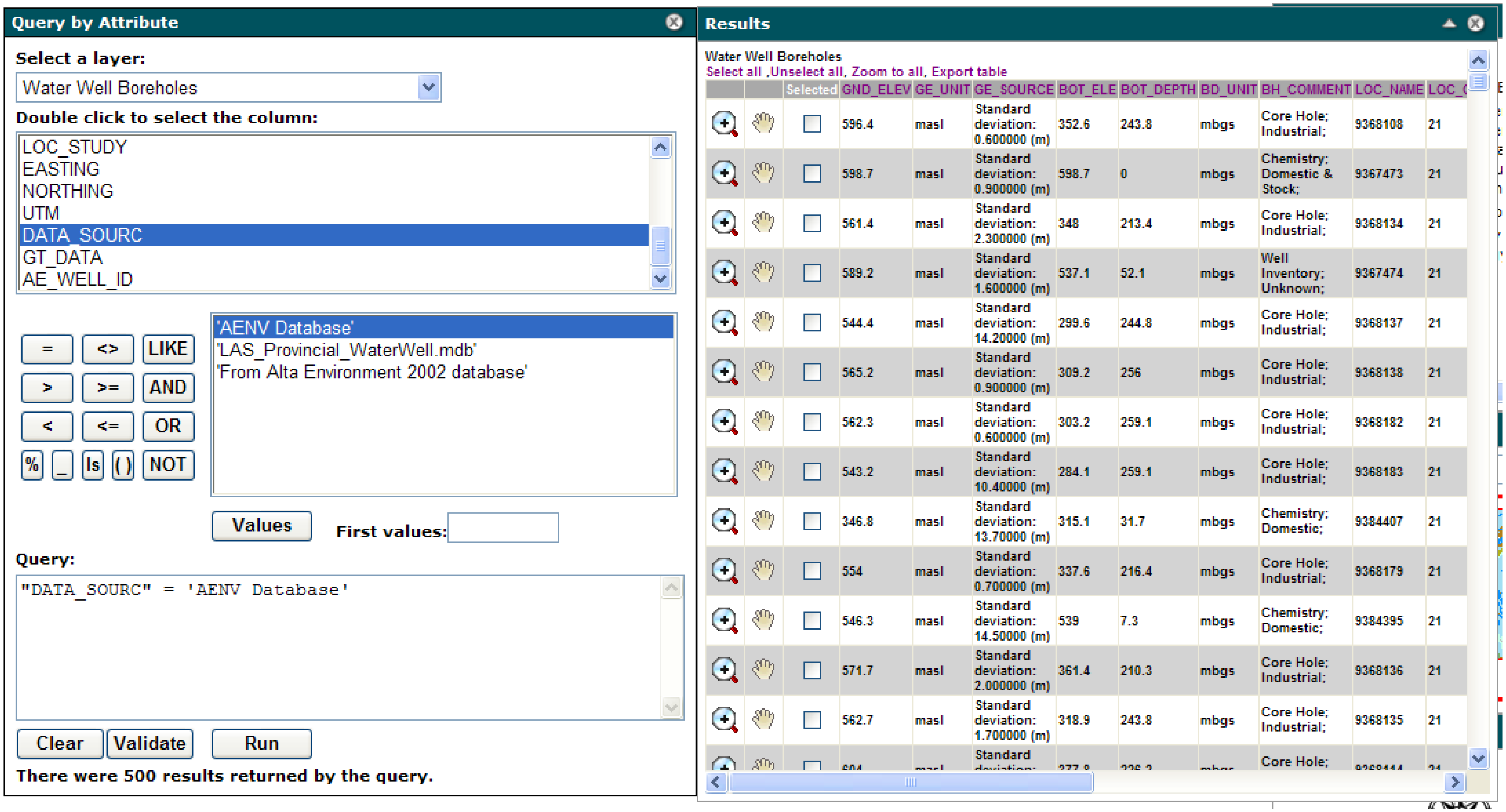

Figure 4. Query tool interface and Results table.

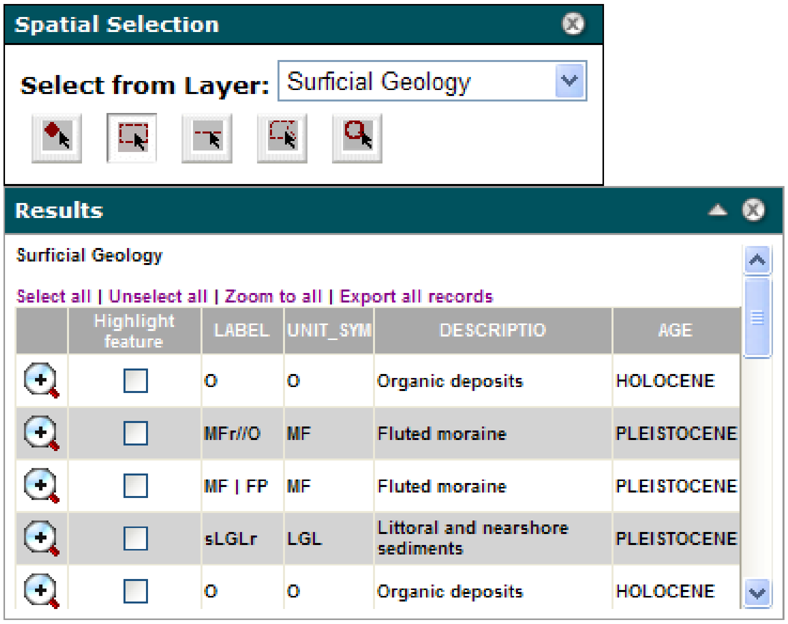

Figure 5. Select Feature(s) interface and Results table.

We modified the plotting utility from a free .Net charting class library called ‘ZedGraph’ (1999 Free Software Foundation, 1991).

2.1.2.6 3-D Model Tool

The 3-D Model tool uses a Virtual Reality Modelling Language (VRML) viewer to display a detailed view of the town of Peace River in three dimensions, created using high-resolution remote-sensing images such as RADARSAT-1, QuickBird, colour orthophoto, Shuttle Radar Topography Mission (SRTM) digital elevation model (DEM) and light detection and ranging (LiDAR) DEM (Figure 11). Users can zoom in or out and rotate the model in all directions (Figure 12). These 3-D images, illuminated at 30° altitude and 315° azimuth, were created in ArcGIS ArcScene and exported to VRML format to work with the VRML plug-in for the Internet. The viewer is a free Cortona VRML Client 5.1 plug-in by Parallel Graphics (2008).

RADARSAT-1 is a commercial Earth observation satellite launched by Canada in 1995. It uses a synthetic aperture radar (SAR) sensor to image the Earth day or night and in any weather conditions (e.g., cloud cover, rain and snow). The black and white imagery was processed using principal component analysis (PCA) at 30 m cell size to highlight its ‘surface roughness.’ It was then draped on the SRTM DEM at 60 m resolution and displayed at 5× vertical exaggeration.

QuickBird is a high-resolution commercial satellite launched in 2001. It collects panchromatic (black and white) images at 60–70 cm resolution and multispectral (colour) images at 2.4–2.8 m resolution. The image was draped on the LiDAR DEM at 10 m resolution and displayed at 2× vertical exaggeration. In addition, final image resolution was deceased to 10 m for optimal balance between display speed (broadband width) and image details. Geological Survey of Canada provided the QuickBird imagery for this project.

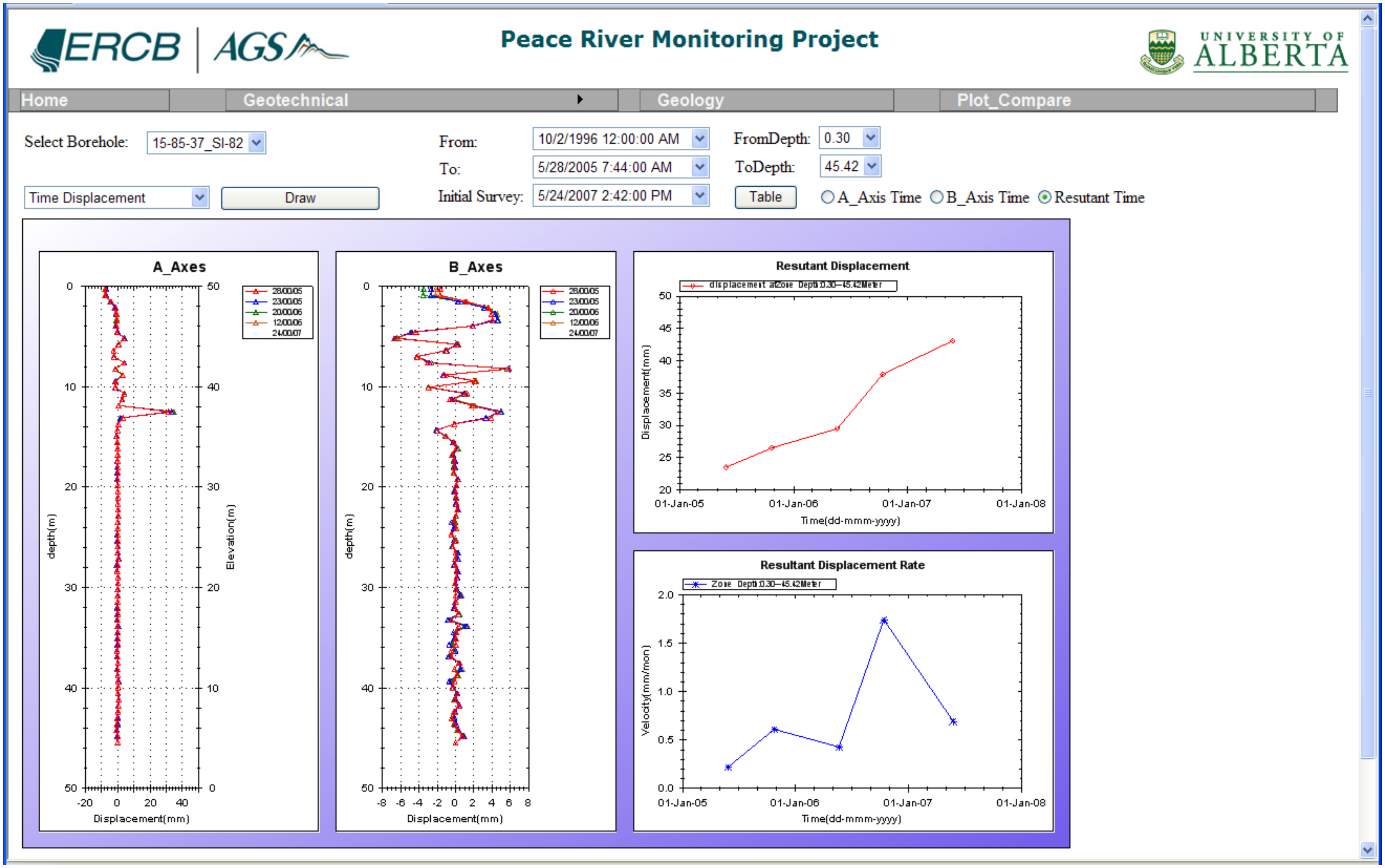

Figure 6. Time displacement plots showing resultant displacement and resultant displacement rate.

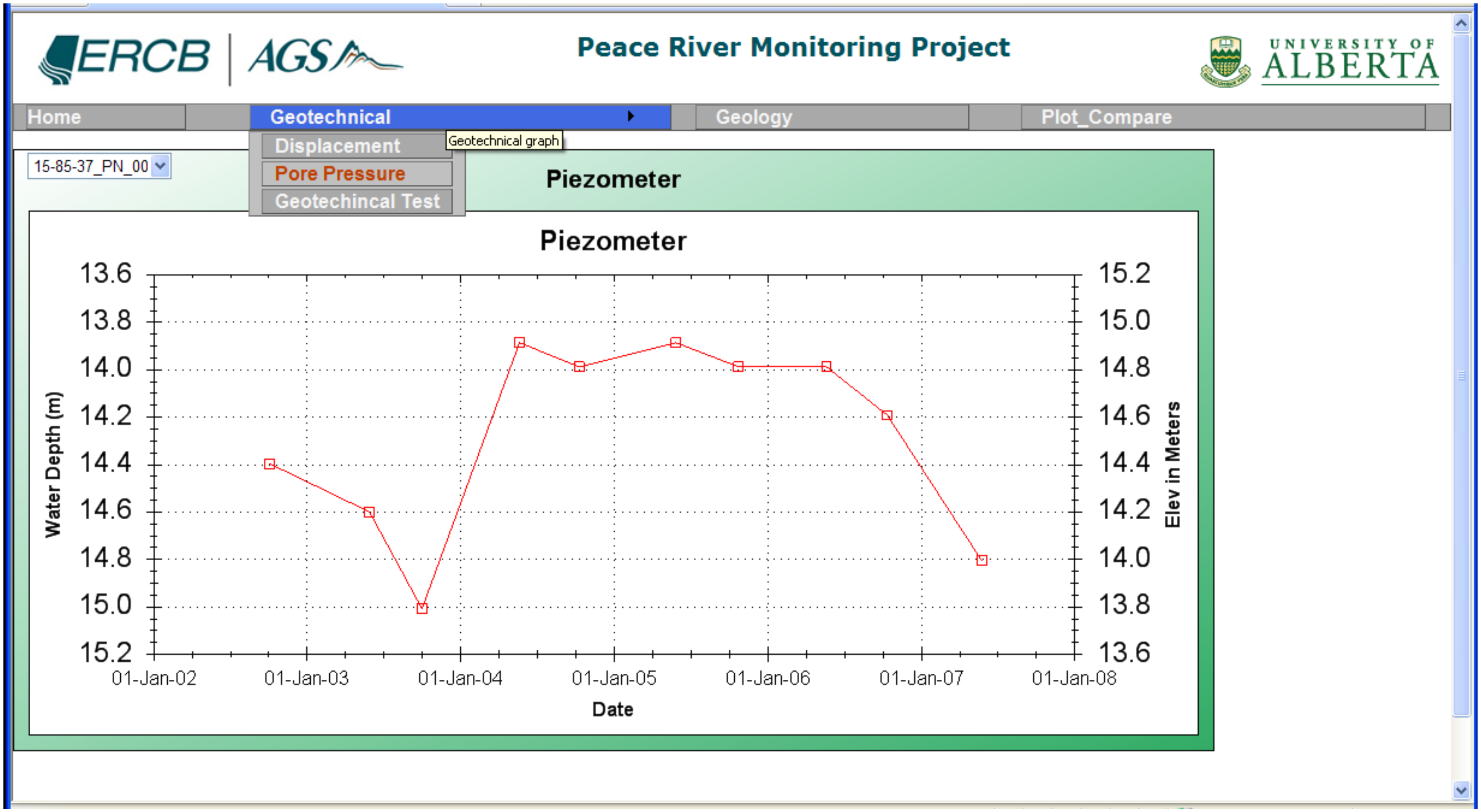

Figure 7. Piezometer reading of a water well borehole from January 2002 to January 2008.

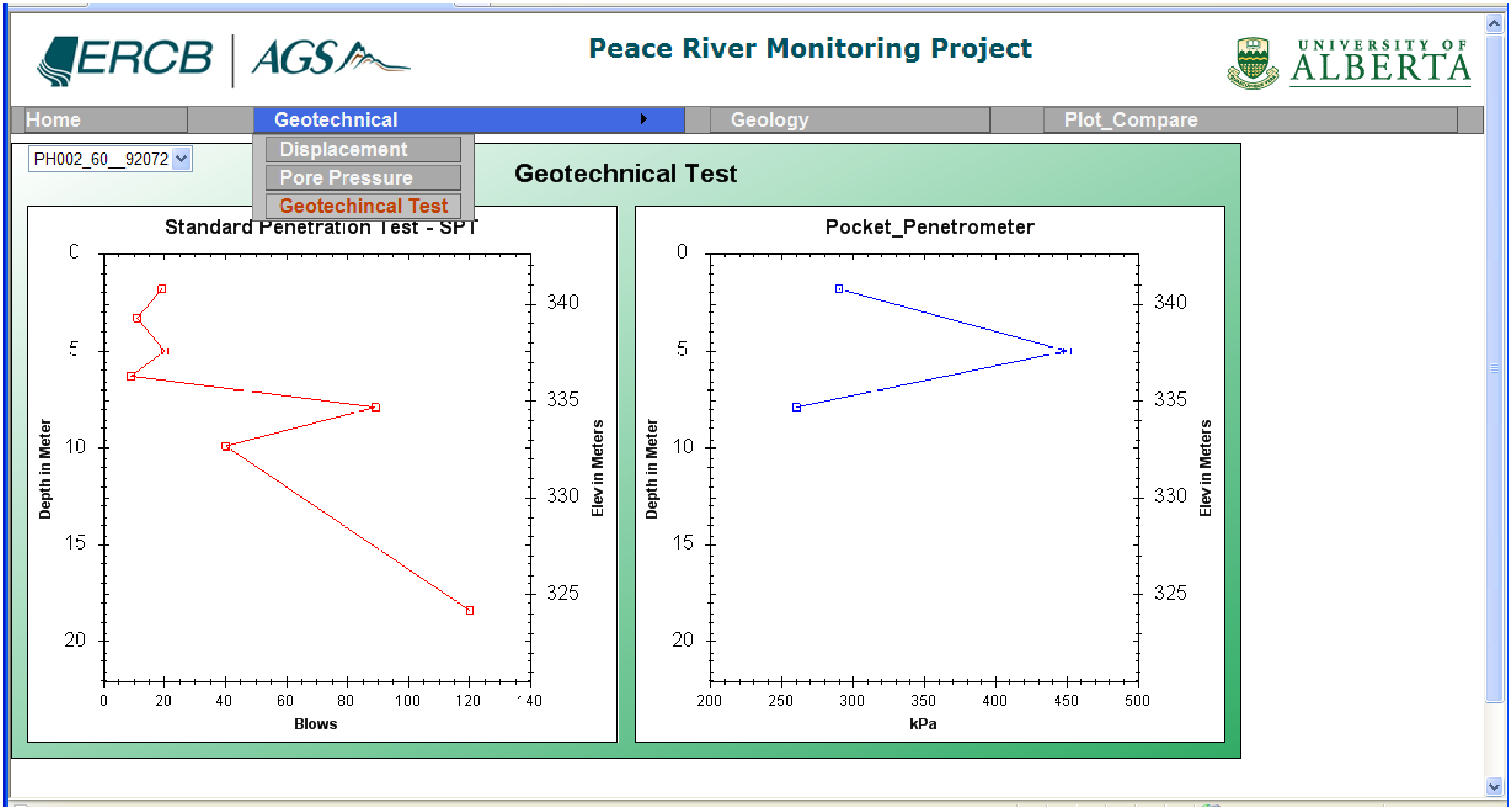

Figure 8. Plots showing standard penetration test and pocket penetrometer measurements.

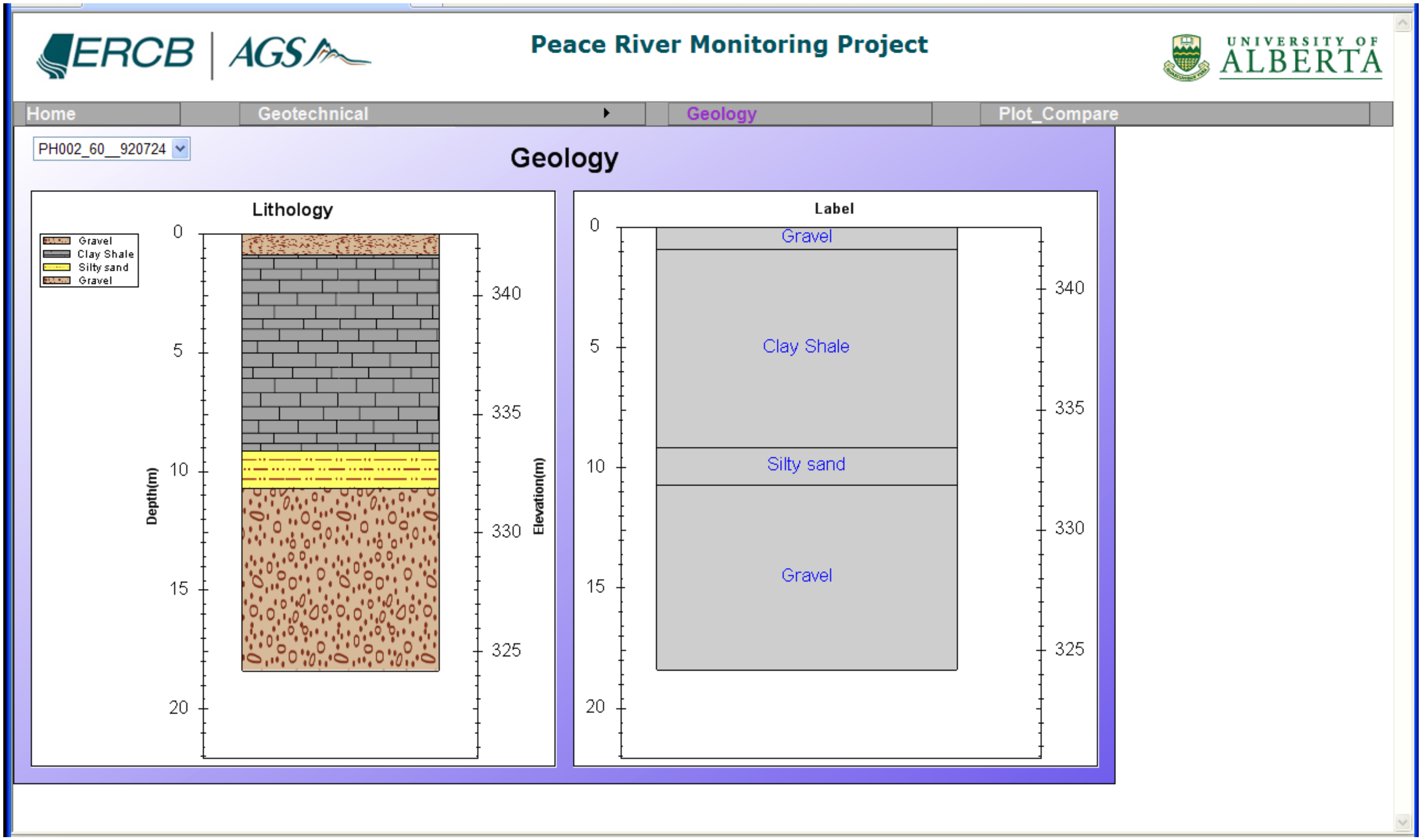

Figure 9. Stratigraphic plot showing lithology in various symbols.

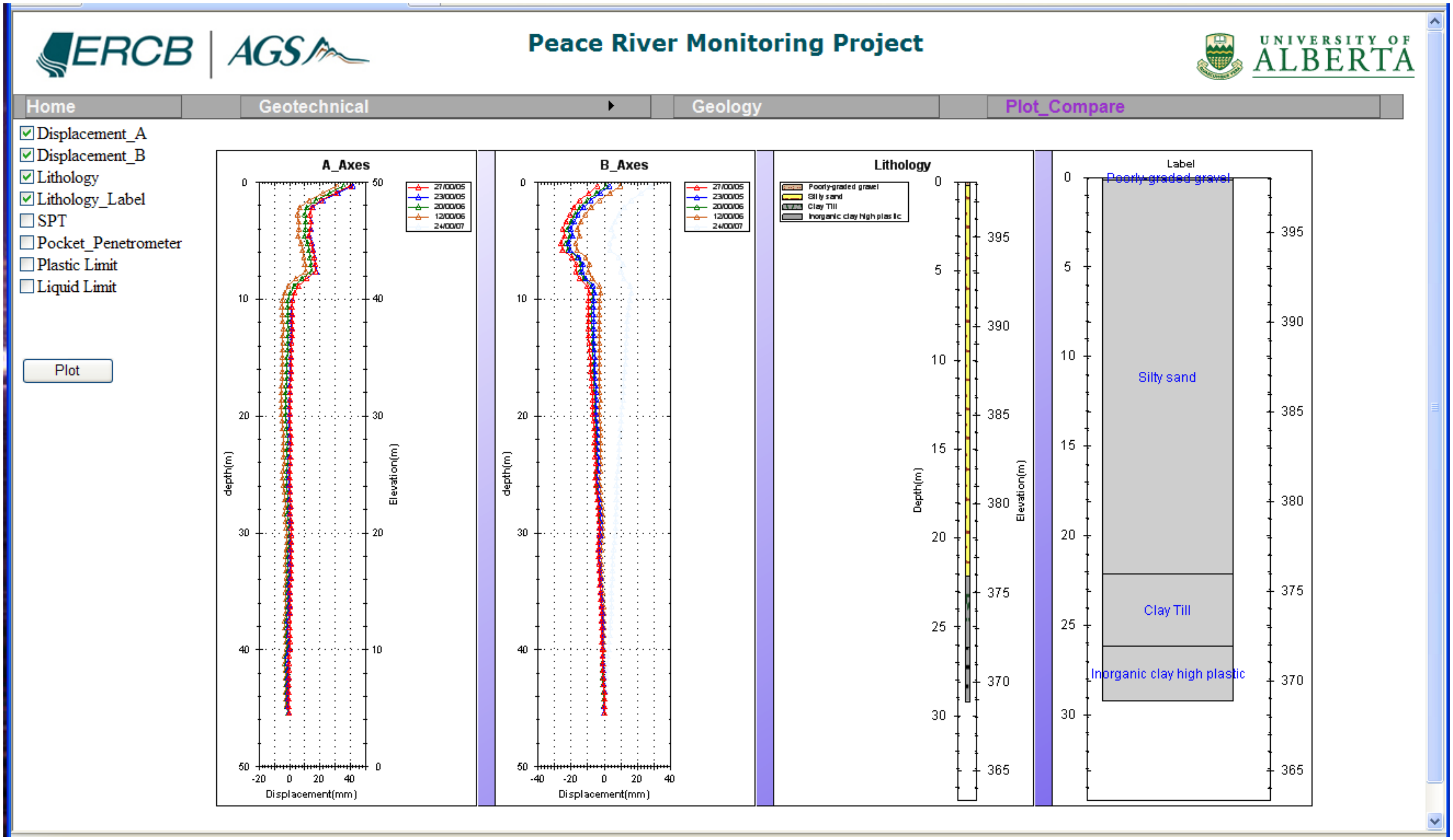

Figure 10. Plot comparison showing time-series displacements and lithology of a borehole.

The colour orthophoto is a mosaic of high-resolution airphotos that have been georeferenced and georectified to the study area. These techniques correctly orient all remotely sensed images from RADARSAT, QuickBird and airphotos to the ground with accurate geographic co-ordinates and map projection. We reduced the orthophoto image to 10 m resolution before draping it on the LiDAR DEM and displaying it at 2× vertical exaggeration.

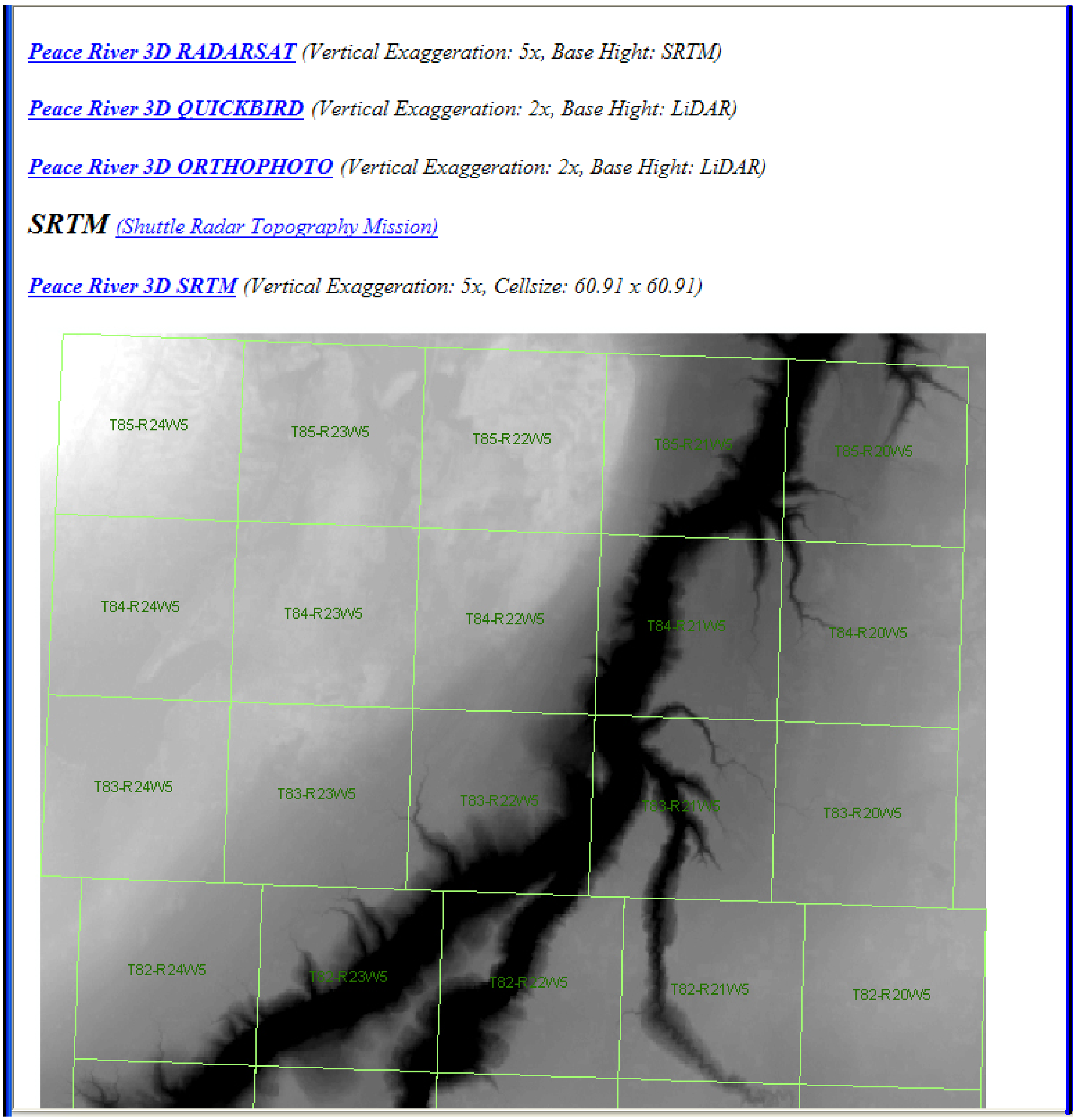

Figure 11. Three-dimensional remote-sensing images covering the town of Peace River. Abbreviation: SRTM, Shuttle Radar Topographic Mission.

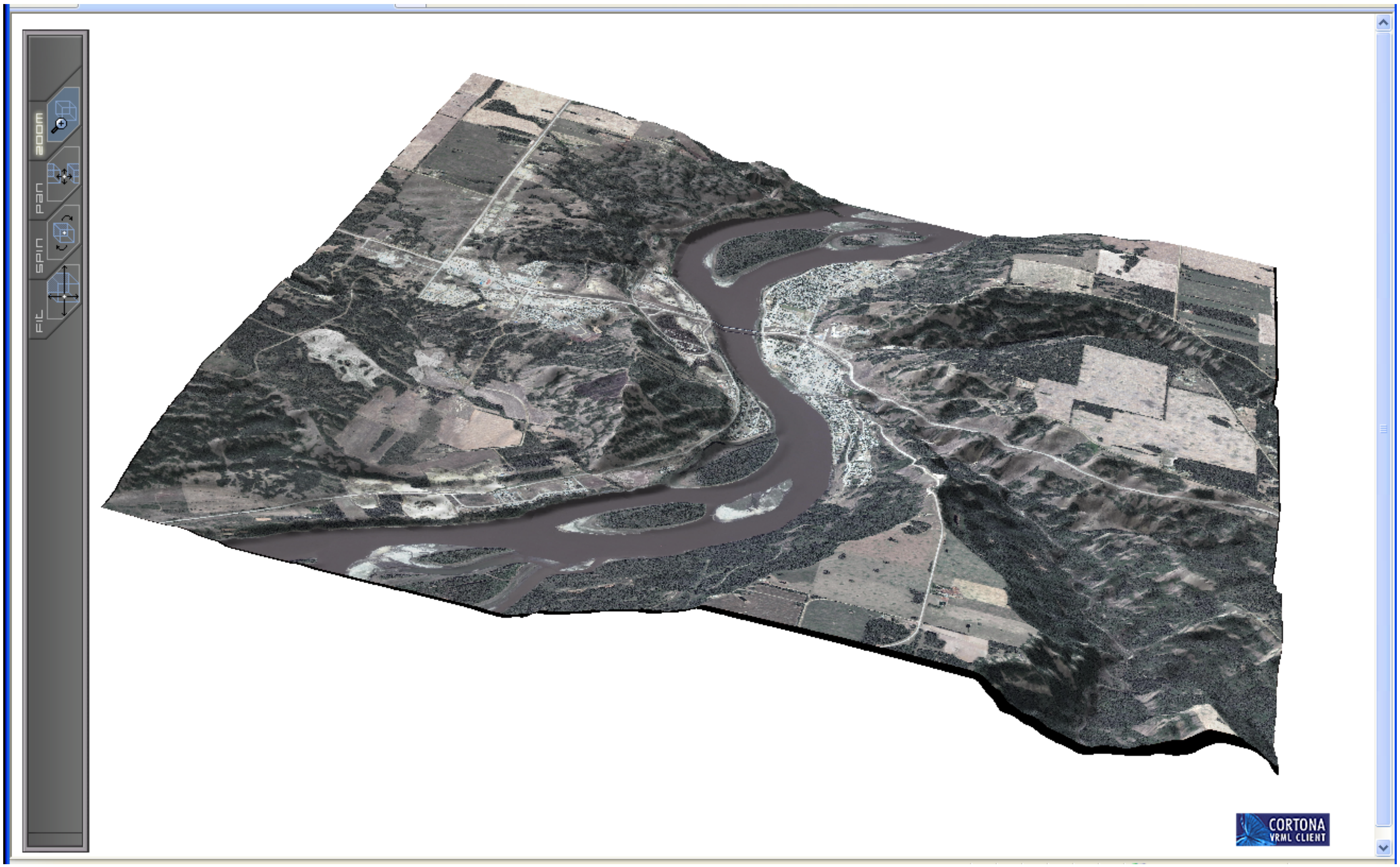

Figure 12. QuickBird 3-D image of the town of Peace River.

SRTM is a specially modified radar system used aboard the space shuttle 'Endeavour' in 2000 to capture a digital topographic database of the Earth at 60 m resolution to create a DEM. The SRTM DEM data can be downloaded for free from the NASA website. This application displays the DEM at 5× vertical exaggeration.

LiDAR is a new optical remote-sensing technology that uses laser pulses to capture DEM data at a resolution of 0.5–1m. The LiDAR data comprise four major components:

- Bare Earth DEM: produced by removing all vegetation and man-made structures
- Full Feature: includes all vegetation and man-made structures
- Intensity Image: image displaying measured energy that is reflected back to the sensor from any object
- Point Cloud Data: all digital data, such as location and height of the ground, vegetation or man-made structures above the ground, collected during the LiDAR survey

Bare Earth DEM is commonly used for geological applications. The application uses a reduced resolution of this DEM for 3-D display and the 1 m DEM for performing landslide studies.

2.2 Map Content

The Map Contents panel contains a list of GIS datasets presented as map layers. All GIS datasets are in ESRI shapefile format, Universal Transverse Mercator (UTM) Zone 11 projection and North American Datum (NAD) 83. Map layers have four major categories:

- **Geotechnical:** geotechnical boreholes with geological stratigraphy; geotechnical, displacement or pore-pressure data; and water-well boreholes with or without geological data. These layers can also be used with the Geotechnical tool for creating plots and graphs.
- **Base features:** study outline, township/range and LSD grids, infrastructure and urban developments, and hydrology and topography.
- **Geology and physiography:** bedrock and surficial geology, and physiography.
- **Satellite images:** 2-D, black and white, 60 m resolution SRTM DEM; 3-D landform generated from 1 m resolution LiDAR DEM; colour 0.5 m resolution QuickBird image; colour 1 m resolution orthophoto and resampled RADARSAT-1 image.

2.2.1 Geotechnical Category

The project collected data in hard-copy format from approximately 1400 stratigraphic holes. The location of each stratigraphic hole was derived either from co-ordinates associated with the hole or from maps included in reports. The types of testhole data collected and stored in the database include

- stratigraphic data, including major bedrock formation picks, from oil and gas wells in the ERCB data holdings;
- stratigraphic data for testholes derived from drillers' logs submitted to Alberta Environment for groundwater wells in the Alberta Environment database website (http://www.telusgeomatics.com/tgpub/ag_water/); and
- stratigraphic information derived from geotechnical logs of wells completed within the town of Peace River by consultants and Alberta Transportation, collected from the town of Peace River, Alberta Transportation and their consultants (EBA Engineering Consultants Ltd., Thurber Engineering Ltd. and AMEC).

The project collected the following data from the geotechnical wells:

- Slope inclinometer data: Some geotechnical boreholes had slope inclinometer instrumentation installed and therefore had the digital G-Tilt data available. These tabular data were converted and stored in the Microsoft® Access database.
- Piezometer data: A few geotechnical wells had historical piezometer data available in Microsoft® Excel format. We imported these into the Microsoft® Access database.
- Field testing / index testing data: For a number of the geotechnical testholes, both field tests and index laboratory testing data, including soil density and strength (standard penetration test and pocket penetrometer measurements) and index tests (Atterberg Limit test), were available and therefore manually entered from geotechnical reports.

2.3 Overview Map

The Overview Map works with navigation tools. The shaded red box in the Overview Map panel represents the zoom window in map display panel. Users can zoom in and out by specifying a map scale in the dropdown menu, and the red box will resize accordingly. They can also move the red box around for panning.

2.4 Navigation

The compass rose represents true geographic north and functions as a pan tool. Clicking on the side of the rose toward which a user wishes to pan causes the map display to move in that direction.

2.5 Map Display

The map display is the focal point of this application. Supported by the Toolsets, Map Contents, Overview Map and Navigation functions, it provides users with a bird's eye view of the Peace River study area. By adding and removing map layers, users can examine the spatial relationship among the four major categories in the Map Content panel.

3 Web ADF (Application Developer Framework) Architecture

3.1 ArcGIS® Server Architecture for Microsoft® .Net Framework

The Peace River Landslide Project Web-GIS application was developed using ArcGIS® Web ADF for Microsoft® .Net Framework, a set of developer tools that includes web controls, classes, frameworks and application programming interfaces (APIs) for building web applications in Visual Studio. The Web ADF is built on top of the Microsoft .Net Framework and leverages many capabilities provided with ASP.Net 2.0, such as the callback framework and embedded resources.

The Web ADF has four distinct components working in conjunction with one another:

- Web Controls or Web ADF controls
- Task Framework
- Common Data Source API
- Web ADF consolidation classes and graphics (Figure 13)

3.1.1 Web Controls

Web ADF Controls leverage the Common Data Source API to interact with multiple sources of data as resources. These resources are managed by a set of 'resource managers' controls. Other controls consume the managed resource directly or via another control. For example, the Map Resource Manager interacts with Main Map (Core Web Control), Query by Attribute Task (Task Web Control), Query (Core Web Control) and Grid Results (Task Framework Web Control) to create a listing of data for export (Figure 14).

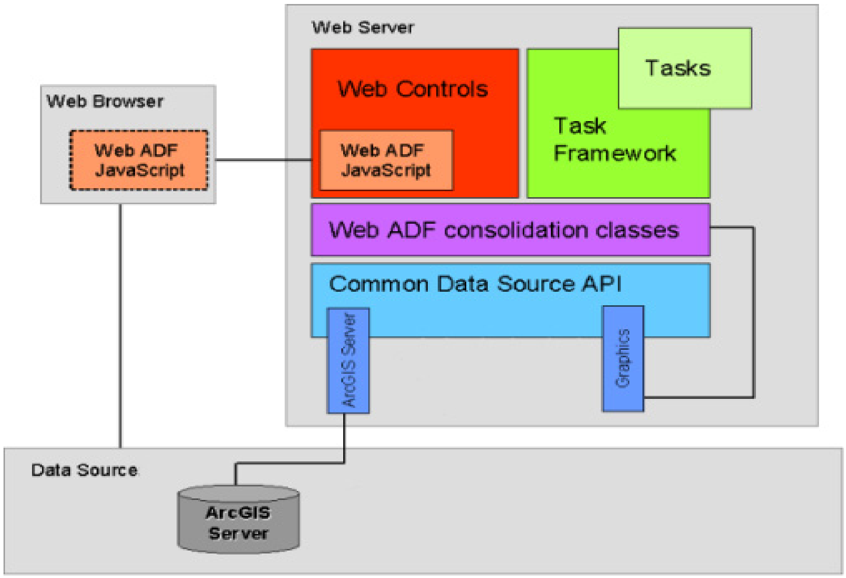

Figure 13. Most of the ADF components reside solely on the web server (*modified from* ESRI, 2008a).

3.1.2 Task Framework

Web ADF Task Framework enables the developer to integrate and deploy custom functionality as a 'Web Task' in a Web ADF application. 'Web Task' is a web control that encapsulates a set of related actions to generate results. In the Peace River application, Query and Select Feature(s) functions are custom 'Web Tasks.'

3.1.3 Common Data Source API

The Common Data Source API allows the developer to integrate and interact with data from different data sources at the same time, in the same application. Web ADF Controls use this capability to interact with other controls.

3.1.4 Web ADF Consolidation Classes and Graphics

Web ADF Consolidation Classes and Graphics determine how map layers and their symbols should display by enforcing their geometry types (point, line and polygon), renderings and symbols. It also interacts with other controls, such as Select Feature(s), to enable spatial selections.

Refer to the ESRI Developer Network web page (ESRI, 2008a, b) for full documentation on Web Application Developer Framework.

4 Application Implementation

4.1 Hardware and Software Configurations

We configured ArcGIS Server in a standard configuration with the Server Object Manager (SOM), Server Object Container (SOC) and the ArcGIS Web Application Developer Framework (ADF) Runtime for the Microsoft .NET Framework installed on a single server. Visual Studio 2005 and the .NET Web ADF Developer Kit were installed on an ArcGIS Desktop for developing the Web-GIS application.

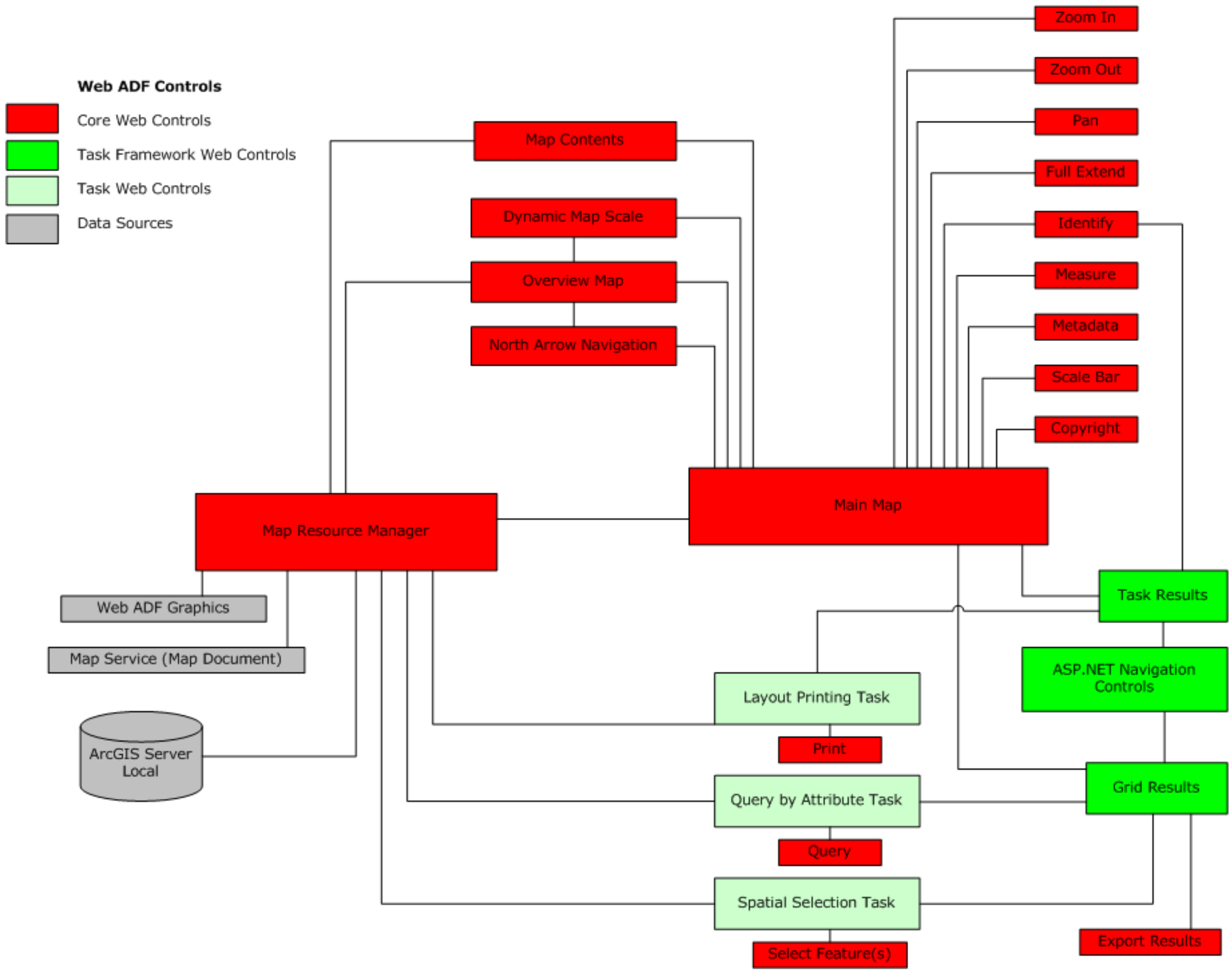

Figure 14. Schematic design of the Peace River Landslide Project Web-GIS application, showing the relationship between 'resource manager' controls and their related GIS tools and functions.

4.2 Installing Third-Party Assemblies as Web ADF Controls

Several GIS functions in the Peace River Landslide Project Web-GIS application toolset, specifically Select Feature(s), Query and Grid Results were downloaded from the ESRI Download Center and the ESRI Blog as Microsoft Windows assemblies (.dll), ArcScript and/or C# files. They were installed and integrated into the .NET Framework Components in Visual Studio 2005 according to instructions provided by each toolset. Table 1 lists each function and its assembly.

Table 1. Functions of third-party assemblies used in the Peace River Landslide Project Web-GIS.

Function	ADF Control	Assembly
Query	Task Web Control	Studioat.ARCGIS.ADF.Tasks.QueryBuilderTask.dll
Select Feature(s)	Task Web Control	SelectToolTask.dll
Grid Results	Task Framework Web Control	gridResults.dll

4.3 Customizing the Application Template

When redesigning the template for this Peace River Landslide Project application, we wanted it to be as user friendly as possible without sacrificing its GIS functionalities. We also wanted to include several GIS functions that were lacking in the default template.

It is beyond the scope of this report to describe in detail how we designed and implemented this template in Visual Studio, beyond the fact that it was a programming exercise in C#. For more information on template customization, refer to the appendices of Chao et al. (2009), which contain scripts for customizing the Default.aspx and WebMapApp.js files, and the GIS and 3-D tools.

4.4 Customizing Borehole Graphs

An Asp.net-compatible UserControl called ZedGraph plotted the borehole graphs. Once the user identifies the borehole ID and graphing type in ArcGIS Server, they are passed to the central database for retrieval of the corresponding datasets, which are then plotted using ZedGraph. Figure 15 shows the four primary types of graphs handled in this application.

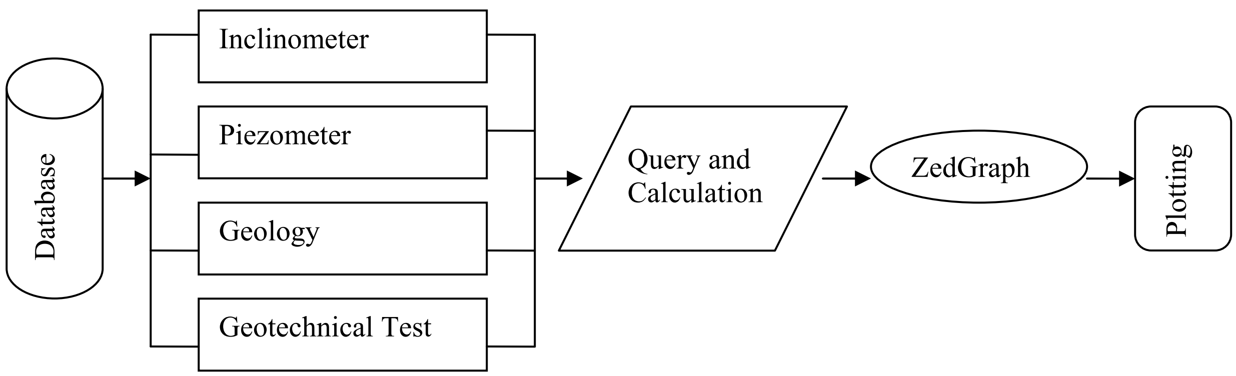

Figure 15. Workflow for charting.

4.4.1 ZedGraph

ZedGraph is a set of class libraries, a Windows Forms UserControl and an ASP web-accessible control for creating 2-D line and bar graphs of arbitrary datasets. It is written in C#. The classes provide a high degree of flexibility—almost every aspect of the graph can be user modified. At the same time, use of the classes is kept simple by providing default values for all of the graph attributes. The classes include code for choosing the appropriate scale range and step size based on the range of data values being plotted (http://zedgraph.org/wiki).

ZedGraph is compatible with .Net 2.0 and VS.net 2005. It includes a UserControl interface, allowing drag-and-drop editing in Visual forms editor, so it is easy to use when developing the application. A tutorial on the use of ZedGraph is available on a CodeProject website (http://www.codeproject.com/KB/graphics/zedgraph.aspx). We integrated the web UserControl of ZedGraph (ZedGraph.Web.dll) into the Peace River Landslide Application for plotting. This application uses ZedGraph version 5.09.

4.4.2 Line Chart

The line chart functions in ZedGraph plotted most of the charts in the system, including those for time-displacement, pore-pressure and geotechnical-test data (Figure 16). To get the values for each chart, the records were first extracted from the relevant database and then converted to a meaningful magnitude indicating different geotechnical measurements or test results. Usually, the Y axis for each chart is the borehole depth and elevation, and the X axis is the test or monitoring reading. For time-displacement and pore-pressure data, the X axis indicates the time and the Y axis the related readings.

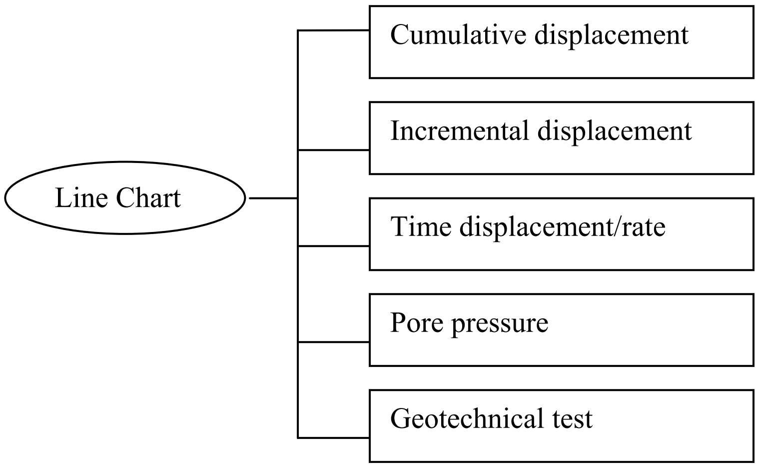

Figure 16. Data types that can be plotted in the Peace River Landslide Project Web-GIS application using the Line Chart function in ZedGraph.

4.4.3 Bar Chart

The Overlay Bar function is used for plotting geological stratigraphy. Each bar item represents a different geological layer. The Y-axis value for each bar is extracted from the file of depth and elevation in the geological database. The pattern fills for each bar item are managed by .png image files that illustrate different rock types (*see* Figure 9).

5 Summary

It has been a good learning experience to design and implement the Web-GIS application for the Peace River Landslide Project with ArcGIS® Server and Web ADF in Microsoft® .NET Framework. We have gained valuable insight on this technology and identified its strengths and weakness for our application.

The strengths of these tools are their flexibility for developing an application in the .NET environment and the extensive support available from the user community. The Web ADF allows us to integrate other .NET applications, such as ZedGraph for plotting borehole data, into the Web-GIS. We are able to select a particular borehole from the Geotechnical and Water Wells layers and pass its identifier to ZedGraph for creating various plots.

There is a wealth of information available, ranging from documentation and discussion forums to code exchange in the ESRI Developer Network. This was the primary site for our research during our application development. We have included and modified code such as Grid Result Control, shared by the user community, in our application.

The weakness of the software lies in its .NET programming. Unlike the ArcIMS that this technology is replacing, there is a very steep learning curve to develop a customized Web-GIS application for the Internet. There is a great deal to learn about .NET programming and ArcGIS Server's object library; and it could be extremely frustrating when debugging errors. In comparison, ArcIMS was much easier to customize for rapid deployment.

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