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LESSONS LEARNED FROM SUPPORTING A GEOHAZARD MANAGEMENT PROGRAM

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ABSTRACT

There are a number of geomatics tasks required to support a Geohazard Management Program (Program). For the program implemented by BGC Engineering Inc. for several midstream pipeline operators, these tasks range from identification of potential geohazards (landslide, river erosion), to setup and support for field navigation, through to geohazard database management. Doing these in an efficient and effective manner requires substantial amounts of spatial data and a toolset containing both software and hardware components. For this Program geohazards are classified as hydrotechnical (e.g. a pipeline crossing a river) or geotechnical (e.g. a pipeline traversing a slope). Lists of potential geohazards are generated and provided to field crews who then navigate to each site and perform a field inspection. Navigation and inspection observations are accomplished with the aid of a ruggedized laptop connected to wireless GPS. Upon return from the field, sites are uploaded to Cambio™, an internet database for managing geohazards. Each site is assigned a frequency of action commensurate with the estimated level of risk. Assigned actions include follow-up ground inspections, detailed investigations, monitoring, maintenance and mitigation. An audit trail of site inspections, surveys and mitigation reports, photos, and site survey drawings, are all available for review within Cambio™, allowing access to the information from any site with an internet connection. This paper will present an overview of the Geohazard Management Program from a geomatics perspective, highlighting the integration of geomatics tools into a system designed to be used by engineering personnel, field technicians, and project managers.

INTRODUCTION

The Geohazard Management Program (Program) is a field based systematic methodology established to assist operators with managing the risk posed to their pipelines from geotechnical (landslide), hydrotechnical (river and stream erosion) or seismic geohazards. The Program is designed to fit into a pipeline operator's proactive integrity management strategy by assisting in the identification and tracking of geohazards with a program of regular inspection monitoring, and mitigation. The importance of monitoring geohazards along pipeline networks has been discussed by others. Savigny *et al* (2005) mention the fact that geohazard related incidents tend to be expensive in terms of lost product and service disruptions, property damage, and can cause substantial environmental damage. They cite U.S. DOT (2004) research indicating that typical property damage from pipeline failures caused by ground movement is on the order of $430,000 U.S. per incident, which is more than twice the cost associated with other hazards. Other programs to monitor geohazards exist with similar goals and capabilities. Pritchard *et al* (2005) discuss a program established to rank and monitor rockfall hazards along railway networks. C-FER Technologies produce PIRAMID and describe it as a "risk-based integrity assessment and maintenance planning" tool (C-FER Technologies, 2010), where geohazards are considered in the risk analysis.

Implementing such a Program requires the coordinated efforts of several disciplines including geotechnical and hydrotechnical engineers, geoscientists, GIS and IT specialists. The GIS and IT group are tasked with building and maintaining the system, identifying potential hazards via GIS analysis, supporting the field inspection program and managing the day-to-day operations of Cambio™. The engineering and geoscience team members oversee system design and development, build frameworks for geohazard identification and review and conduct the field work (inspection, design, and construction supervision).

This paper will focus on the GIS and IT contributions and experiences related to the implementation of the program, specifically Cambio™'s website functionality, potential hazard identification, field inspection support, and system operation.

CAMBIO™

Cambio™ is Spanish for "change". It is the constant change intrinsic to geohazards that this database has been built to manage. The key functional components of Cambio™ include a custom developed website with an enterprise database backend. Information recorded in the database includes the nature of the geohazard (hydrotechnical, geotechnical or seismic); spatial location of the geohazard (latitude and longitude, UTM or Township and Range grid); Right-of-Way (RoW) location of the geohazard (chainage along the pipeline network); as well as numerous observations specific to the geohazard site including the pipeline depth of cover and local slope gradient or stream gradient, site photographs and drawings, and recommendations.

The Cambio™ geohazard management system stores information in a hierarchal tree: a pipeline system contains many pipelines; each pipeline has geohazards (hydrotechnical, geotechnical, and seismic), each geohazard site has one or more inspections; each inspection has one or more photographs.

The website is the interface to Cambio™ and mediates operator interaction with the data in a user friendly fashion. Users logging into Cambio™ are presented with the Geohazard Listing screen showing all geohazards found along the pipeline RoW. Users can sort geohazards by location, category, or risk ranking among other methods. Subsets of geohazards can be selected by filling out a selection criteria form as shown in Figure 1.

Selecting a particular hazard provides access to a geohazard summary report or to the inspection details and photos. Figure 2 shows an example of the hydrotechnical inspection form and pop-up photo viewer. Using the inspection form, the user may navigate through the inspections chronologically for a particular hazard, as well as see the photos for each inspection.

There is also the option to see the location of the hazard and corresponding information on a web map or via Google Earth (Figure 3). This is a powerful feature that provides practical and economical spatial context to a pipeline's potential geohazard magnitudes and frequencies.

POTENTIAL GEOHAZARD IDENTIFICATION

Previous work by Leir (2004) indicates that the average geohazard density along pipeline RoW in Western North America is one hydrotechnical site every three kilometers and one geotechnical site every thirteen kilometers. Thus a typical pipeline system will likely cross thousands of geohazard sites that could potentially pose a threat to the integrity of the pipe. The identification of potential hydrotechnical and geotechnical sites during a baseline (initial, first time) assessment of a pipeline is achieved through terrain analysis techniques including stereo aerial imagery interpretation and GIS. This preliminary inventory also incorporates geohazards already on record in the operator's files.

GEOTECHNICAL HAZARDS

In this Program, geotechnical hazards include landslides, surface water and ground water erosion, and settlement/subsidence. GIS analysis of Digital Elevation Models (DEM) along the RoW is used to identify locations where the pipeline is crossing a slope. Potentially problematic slopes are identified in the DEM and those that intersect the RoW are added to a potential geohazard list. The threshold value used to identify these slopes is determined through professional experience and varies from region to region within North America depending on the geomorphology and geology of the area. It is important to note that the slope threshold and the hydrotechnical threshold described below are intended to inventory most of the potentially problematic geohazard sites in order to compile a practical number of geohazards to review in the field. Sites falling outside the threshold are likely to be on file with the operator or have a low likelihood of occurrence.

HYDROTECHNICAL HAZARDS

Simple GIS analysis is used to build a preliminary watercourse inventory that is reviewed during baseline field work. The preliminary watercourse inventory usually consists of mapped watercourses crossing the pipeline centerline with greater than 1 km stream length upstream of the crossing point. As with the slope threshold described above, the selection of an upstream length is based on experience, varies with geography, and is intended to capture most of the potential problems in order to build a preliminary inventory of manageable size. It should be noted that the GIS does not provide insight into the specific nature of the hydrotechnical hazard at any location –

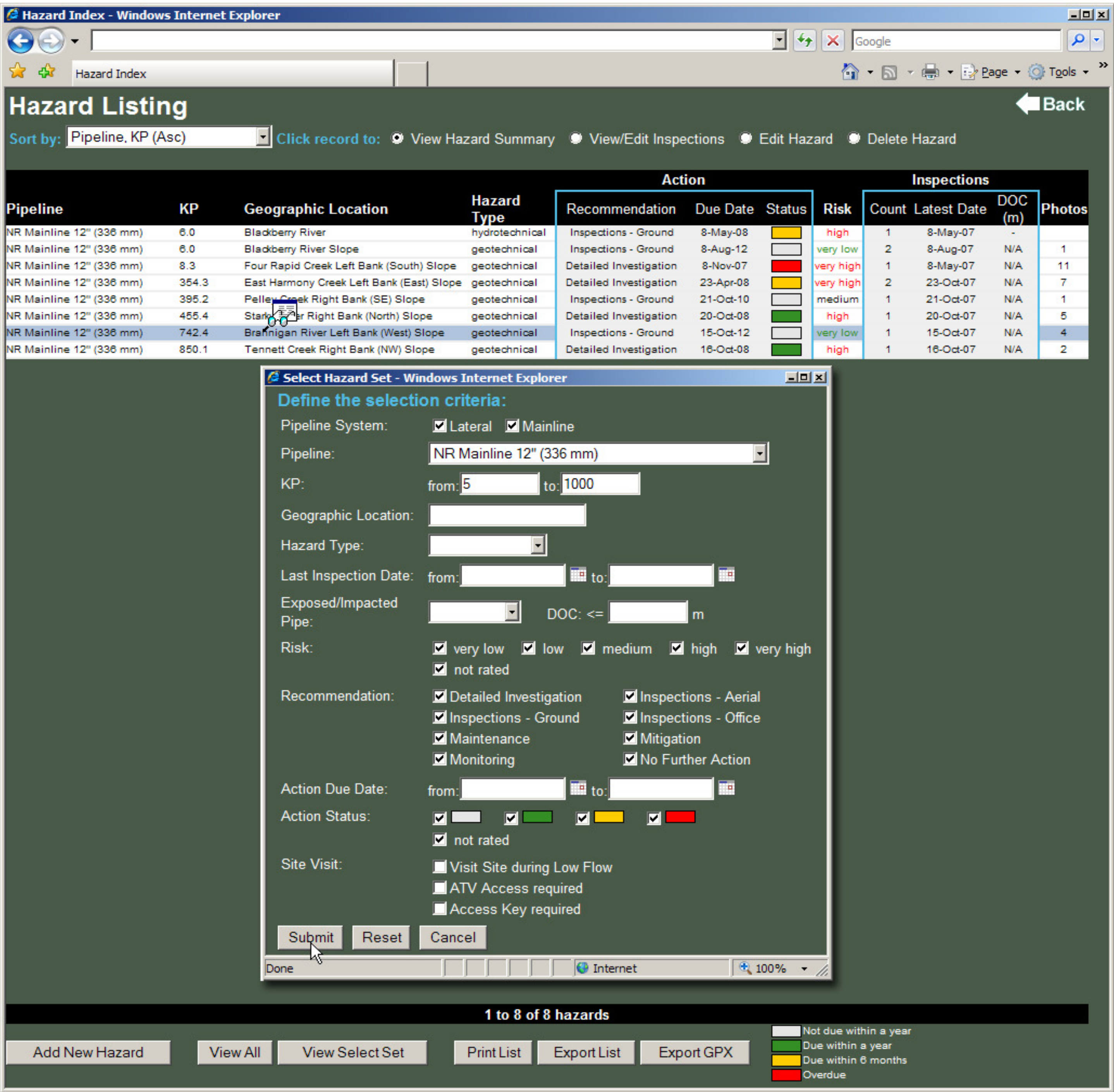

Figure 1: The geohazard listing screen is the "hub" of Cambio™ and summarizes information such as geohazard location (pipeline, chainage), geohazard type, most current recommendation and due date, current status, risk, and last inspection. It is from this page that a user can search for specific sites, view geohazards location on a map, view hazard or inspection information, or edit, add or delete geohazards.

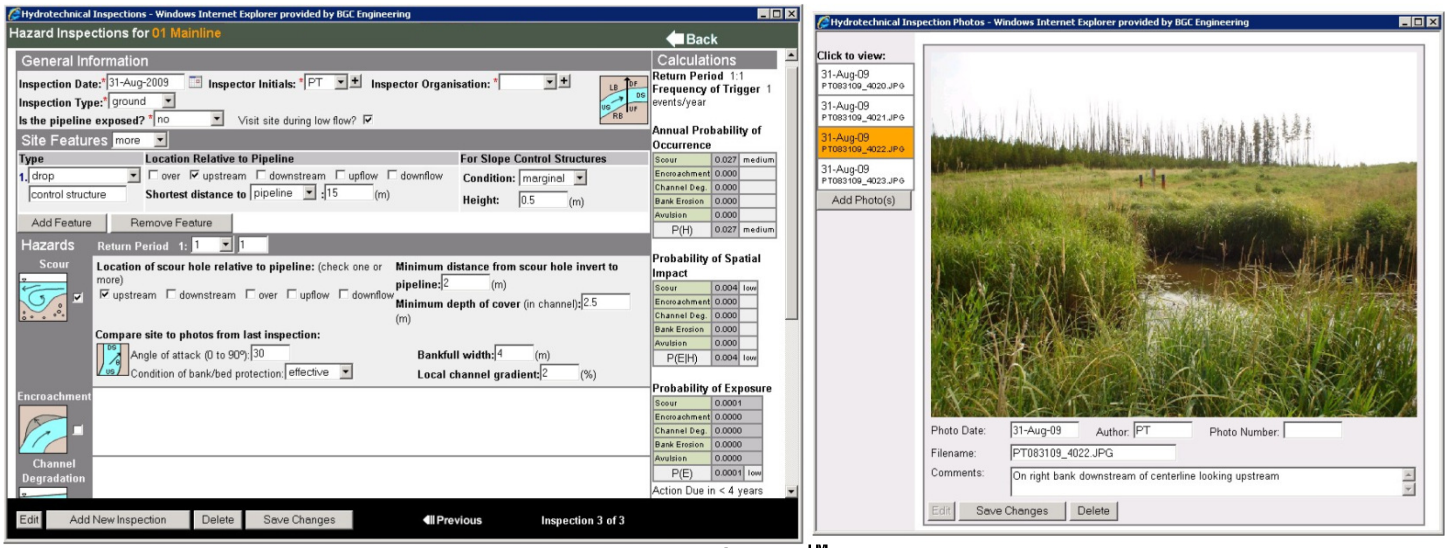

Figure 2: A sample hydrotechnical inspection as shown in the Cambio[TM] system. The scrolling inspection form is on the left, with the pop-up photo viewer on the right. The right side of the inspection form displays the calculations for hazard probabilities, as well as inspection frequency.

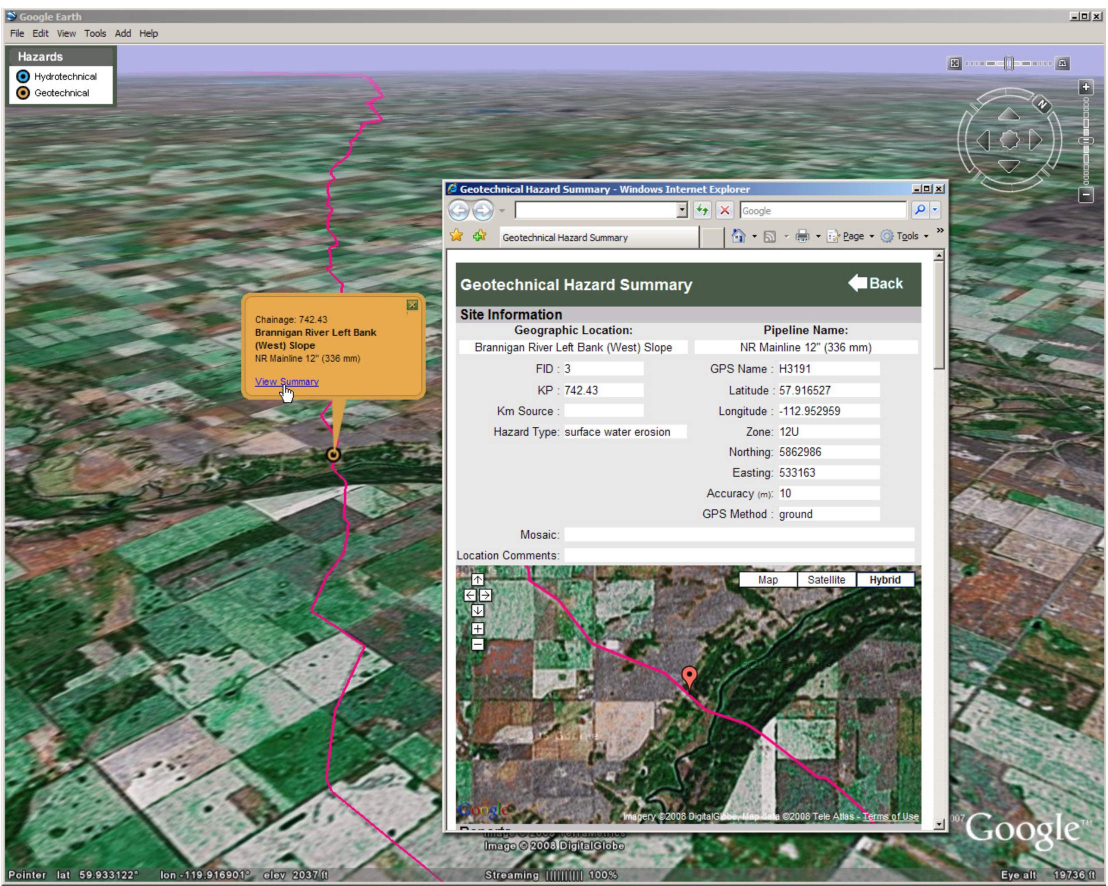

Figure 3: Live links to Internet mapping software. All or a subset of geohazard sites can be displayed in Google Earth or Google Maps. Clicking on the geohazard symbol on the map displays a page summarizing the hazard site including inspections, inspection photos, site sketches, and links to supporting PDF reports, as-builts, or CAD drawings.

field work is reserved for this. Field inspection is a key component to the Geohazard Management Program, and therefore is used to characterize the potential geohazard into one of the five subclasses of hydrotechnical hazards contained within Cambio™. The five subclasses include scour, channel degradation, bank erosion, channel encroachment and channel avulsion (Leir et al, 2004).

FIELD INSPECTION SUPPORT

As emphasized above, all potential hazard sites are inspected by field personal during the baseline inspections. A ground inspection trip ranges from 1 to 21 days in length and requires that the field crew be able to independently find their way quickly and safely to targeted geohazard sites. With the adoption of handheld GPS in 2003, geomatics support plays a key role in enabling the field crew to accomplish the mission successfully and economically. Prior to the trip, geomatics team members gather a variety of spatial data, prepare that data, as well as configure software and hardware for use by field personnel. In addition, lists of geohazards (both potential and previously identified) are generated. Navigational and reference material, (vector roads), satellite imagery, topographic basemaps, cathodic protection test lead locations, and elevation models are also gathered together and formatted for field use. During the ground or aerial inspection trips, navigational software is used in conjunction with GPS units to navigate through the field. Road networks, township and range grids, and high resolution aerial imagery (cached Google Earth images) are loaded into navigational software. Experience over the last 8 years has shown that high resolution imagery is extremely valuable for navigation once the crew travels off the public or forestry/lease road network and must navigate using unmapped features such as trails, seismic lines, fence lines, and pastures.

FIELD COMPUTERS

Field crews make use of ruggedized field computers (Figure 4) to record their observations, complete inspection forms, and support navigation. The field computer runs a local stand-alone version of the Cambio™ enterprise database and website application.

Prior to the introduction of the field computer into the field inspection program in 2008, geohazard inspections were conducted with paper forms and were manually transcribed into the enterprise database at the conclusion of the field trip by office staff. Adopting the field computer enabled field crews to record their observations directly into Cambio™ via electronic forms. Figure 5 shows an example of a geotechnical hazard inspection form. While there are benefits to using paper, such as a permanent hardcopy record of the field inspection work with field notes and sketches, there are also some disadvantages. Use of the field computer greatly reduces the time and effort required to post the field inspections into the master database. Thus for a given budget, more resources can be focused on conducting field inspections rather than post field data entry. The field computer also reduces errors and omissions through the use of error checking and data validation routines.

Figure 4: An example of a ruggedized Field Computer used by personal in the field inspection program

Additionally, having a local version of Cambio™ in the field provides the field crew with all previous inspections recorded for each site. Field inspectors can review prior inspection observations, site photos, and drawings in order to determine how the site has evolved over time. Also, because the field crew is recording data directly into the Cambio™ system, they can now see the calculated results of their current inspection while still on site. This added benefit of on-site results can be viewed as an additional layer of QC/QA. Experience has shown that the field PC modestly increases the time spent at each site as it is not as fast as paper and pen, but the benefits gained outweigh this modest increase.

The field PC has proven to be exceptionally robust, durable and reliable though not without incident. For this reason field crews still take along blank paper inspection forms to enable them to conduct the trip should the field computer fail.

FIELD PERSONNEL SAFETY

Field crews are required to follow a safety plan involving regular evening check-ins describing the section of the pipeline inspected that day, and the plans for the following day's inspections. Additionally, before leaving the vehicle at each site, the crew sends check-in messages via a Find-Me-Spot locator messenger device. Geomatics personnel work with the

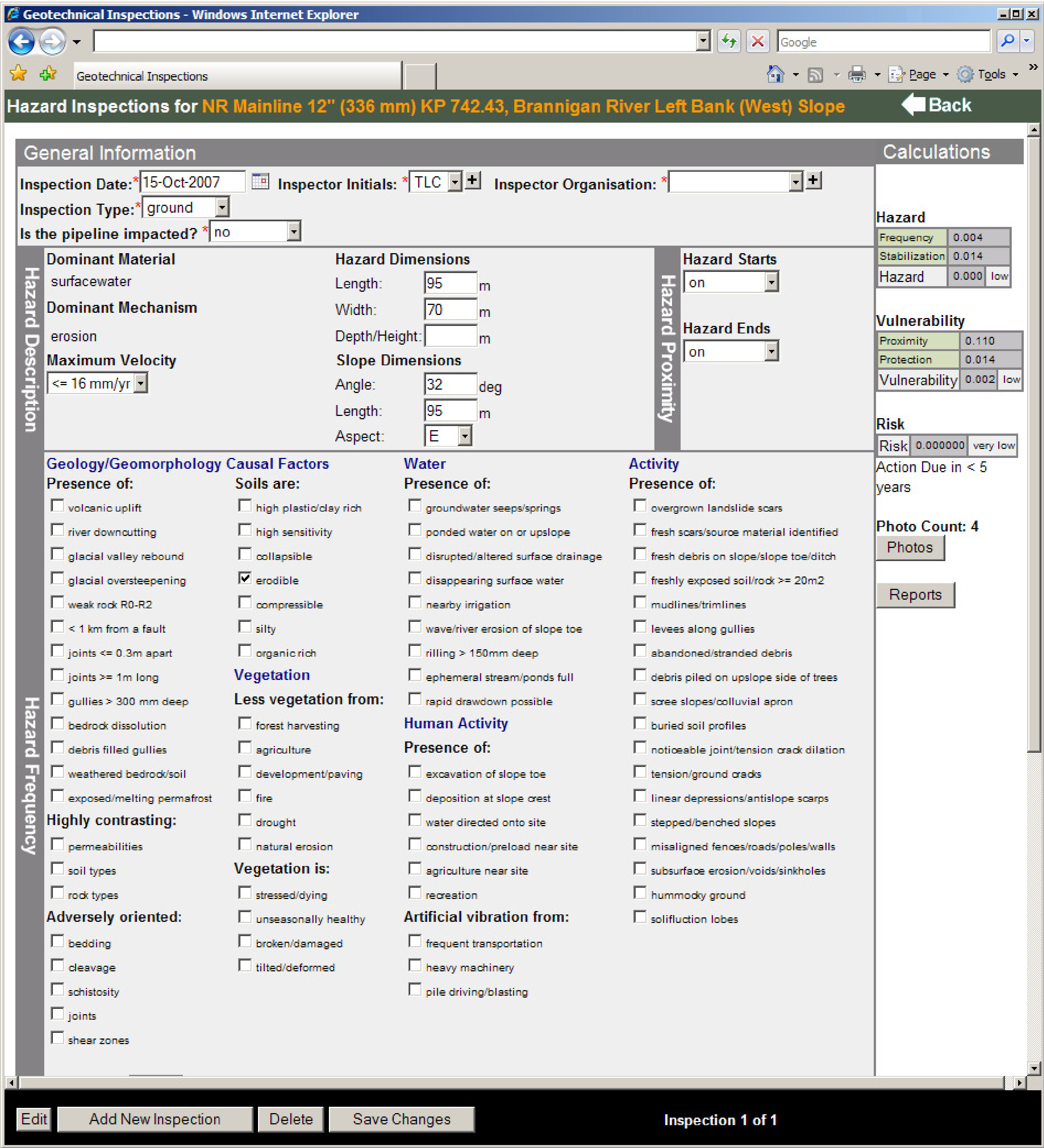

Figure 5: Geotechnical Inspection Form

office project manager to assist with coordinating a response if a field crew sends in a help request via the Find-Me-Spot locator. Geomatics personnel typically fill the role as office points of contact because of their familiarity with the pipeline and the work plan of the field crew.

FIELD TO OFFICE

Upon return to the office at the conclusion of a field inspection trip, the field observations are extracted from the field PC and integrated into the master enterprise database using a series of SQL queries to pinpoint new data. While elements of the integration task are automated there still remain some database administrator tasks to properly merge the field observations into the master database. Field inspection photos are also recovered from the field PC or camera for entry into the management system. Once the data integration is complete, senior inspectors then review each inspection as part of the QC/QA process, authorizing each verified inspection with their name and date. Only authorized inspections are incorporated into pipeline and geohazard statistics and reports.

The Cambio™ system is used to generate geohazard statistics about pipelines and pipeline systems, such as the frequency of pipeline exposure for each pipeline, system, and total system, annual percentages of sites requiring mitigation and other metrics to quantify the status of the Geohazard Management Program. It is an integral part of a pipeline Geohazard Management Program, as it not only stores geohazard site conditions and locations, but indentifies site inspection frequency and mitigation requirements, helping pipeline managers to plan and budget for yearly inspection and mitigation schedules.

CONCLUSIONS

This paper has discussed the practical aspects of geomatics support for a Geohazard Management Program for pipelines. Key tasks undertaking by geomatics personnel include potential natural hazard identification from source geospatial data, operation and maintenance of the Cambio™ database and website, and support of field inspection missions during and post field.

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