Proceedings of IPC'02
4th International Pipeline Conference
September 29-October 3, 2002, Calgary, Alberta, Canada

IPC2002-27103

NATURAL HAZARD DATABASE APPLICATION - A TOOL FOR PIPELINE DECISION MAKERS

Mark Leir, P.Eng
President

GroundControl GeoTechnologies Inc.
500-1045 Howe St, Vancouver, British Columbia
leir@groundcontrol.ca
www.groundcontrol.ca

Michael Reed P.Eng
Senior Pipeline Engineer

Trans Mountain Pipe Line Company Ltd.
2700-300 5th Ave SW, Calgary, Alberta
mikere@tmpl.ca
www.transmountain.com

ABSTRACT

Trans Mountain Pipe Line Company Ltd. (TMPL) owns and operates an 1146 km NPS 24 low vapor pressure petroleum products pipeline between Edmonton, Alberta and Burnaby, British Columbia. In 1998 TMPL retained BGC Engineering Inc. (BGC) to start a three-phase geotechnical and hydrotechnical hazard assessment of the right of way (ROW) from Hinton, Alberta to Kamloops, British Columbia. As part of this work GroundControl was asked to develop an electronic database with which to capture the information generated by BGC during the hazard assessment work. This paper describes the development and evolution of the database application that accompanied the study to quantitatively assess and prioritize the geotechnical and hydrotechnical hazard potential along the pipeline. This paper describes how the database provides TMPL employees across British Columbia and Alberta access to the current results of the hazard assessment plus supporting information such as multi-temporal images and internal and 3rd party reports about the pipeline. The purpose of the database and the unique architecture and functionality that accommodates ongoing monitoring and inspections of slopes and stream crossings is provided. Database security, access, and information sharing unique to TMPL are also described. Benefits and costs of the application plus technical and business challenges overcome by TMPL, BGC, and GroundControl are discussed. Recommendations from TMPL and GroundControl for similar information management initiatives are provided and future work is described. This paper is targeted to pipeline managers who are looking for economical, practical, and innovative information management solutions for managing their natural hazards. (Keywords: database, hazard, risk, pipeline, geotechnical, hydrotechnical, landslide, GIS, river, stream).

NOMENCLATURE

Database - A collection of data and objects related to a particular topic or purpose. A database can contain tables, queries, forms, and reports.

Database Application – Custom programmed functionality built around a collection of database objects designed for a specific purpose. The hazard management tool described in this paper is a database application.

Table – The fundamental structure of a relational database management system. A table is a database object that stores data in records (rows) and fields (columns). The data is usually about a particular category of things, such as geotechnical hazards or hydrotechnical inspections.

Field - An element of a table that contains a specific item of information, such as last name. A column or cell in a table represents a field. Many fields often comprise a single row. On a form, a control, such as a text box, is used to display data from a field.

Record – A collection of data about a hazard, an inspection, or some other item. A record is represented as a row in table, or query.

Control - A graphical object, such as a text box, a check box, a command button, or a rectangle, that are placed on a form or report to display data, perform an action, or make the form or report easier to read.

Form - A database object on which controls are placed for taking actions or for entering, displaying, and editing data in fields. Data in tables are often displayed with a form.

Query - A question about the data stored in the tables, or a request to perform an action on the data. A query can bring together data from multiple tables to use. Queries are often the source of data for a form or report.

Report - A database object that presents information formatted and organized according to user specifications. Examples of reports are summaries for a single hazard, a list of hazards, and reports that include photos and text. The results of query are often displayed in reports.

Hazard – A description of the landslide or hydrotechnical event, including magnitude plus a quantitative or qualitative description of probability of occurrence. In this paper hazard is expressed as a numeric hazard score.

Risk – The expected loss resulting from a hazard being triggered and impacting one or more elements. Risk is formally expressed in monetary terms.

BACKGROUND

In the last decade, Natural Hazard and Risk Management (NHRM) has become a widespread tool for multinational corporations. Proper risk management requires that the natural hazard be identified, assessed, and then managed in order to reduce its impact on public safety and the environment. However the management of natural hazards is not the sole responsibility of the engineering or environmental departments. The adoption of formalized risk management encourages an interdisciplinary approach to facility management that requires inputs from engineering, environmental, operational, legal, and financial departments. Database applications are often at the hub of this integrated approach as they provide shared access to data and tools necessary for the quantification of hazards and risk. Database applications are also there to help manage the diverse and detailed information that is collected over numerous cycles of hazard identification, monitoring, and mitigation. For the above reasons, TMPL required that a database application be constructed to conform to the four phase NHRM methodology developed by BGC. This paper describes that application.

PURPOSE

Proper risk management requires documented, repeatable and quantifiable methodologies. Documented for legal due diligence, repeatable from one assessor to another to minimize personal bias, and quantifiable in order to maximize objectivity. These requirements alone justify a database application. Furthermore, these requirements also indirectly encourage the assembly of corporate historical databases that are intended to serve many generations of employees. Key personnel may leave a company with a considerable amount of corporate history in their heads. Often very little of this experience has been well documented or can be efficiently passed on to the replacement personnel. Replacement personnel are often forced to rebuild their own corporate history. TMPL recognized that a database application would meet the requirements of risk management and could form the nucleus of information that would grow with TMPL's risk management programs. TMPL also recognized that a digital database could be efficiently shared amongst different interested departments in BC, Alberta, and Washington State.

When employing quantitative risk assessment methodologies project managers naturally gravitate to spreadsheets for their data management needs. However, as data collection evolves to include photos, reports, plans, maps and video, plus the number of users requiring access to this data increase, the spreadsheet often becomes too cumbersome to manage. Spreadsheets are strong tools for performing calculations but are poor tools for multi-user data management. More importantly, as a hazard management program moves forward into multi year site inspections, structured information management is required to ensure that hazard sites are prioritized correctly or not missed entirely. These are all strong arguments for a database application

DATABASE CONTENT

This database includes information about the geotechnical and hydrotechnical hazards and their inspections, surficial geology, geotechnical reports, and field photos. The information is grouped into their unique tables, which are listed below. The combination of pipeline name, KP, geographic name, and a date will often make a record unique. However, data maintenance is made easier if a unique numeric or alpha numeric ID (Hazard ID) is assigned to each geotechnical and hydrotechnical hazard. Although there are numerous other data sets that can be added to the application, the data contained in this database at present is a reflection of the minimum requirements for an effective hazard management tool. Figure 1 shows the basic database architecture and content. The database includes:

Geotechnical Hazards Table – Geotechnical hazards are described using the terminology from Cruden and Varnes (1996). It includes hazard ID, centerline kilometer post (KP), geographic location, start and end KP, photos, hazard type (rock fall, debris flow, soil slide), who first observed the hazard, how was it observed (helicopter, field visit, airphoto). The data in this table is relatively static in that it is not updated as often as inspection data. Nevertheless, it is required to help describe the nature and magnitude of the hazard.

Geotechnical Inspections Table – Again, the terms used here are from Cruden and Varnes (1996). This table includes Hazard ID, date observed, activity, cause, consequence, intensity, magnitude, observer comments, and the contributions of past, present, and future hazard scores to the overall hazard score. The past hazard scores quantitatively express the occurrence of historic hazards at a given location. Similarly, the present hazard score expresses the threat of existing and active hazards. The future hazard score quantifies the hazard potential of a given location by considering the nature of the contributing factors such as unfavorable geology and steep slopes. Inspection data is collected each time field personnel formally review a hazard site. There may be a number of records in the Geotechnical Inspections Table for every record in the Geotechnical Hazards Table.

Hydrotechnical Hazards Table – This table includes Hazard ID, stream order, stream gradient, drainage basin size, stream pattern and confinement, surrounding forest cover, nearby roads, bridges, railway, and other anthropogenic features. This data is relatively static and is not updated as often as inspection data. Nevertheless it is required to help describe the nature and magnitude of the hydrotechnical hazard.

Hydrotechnical Inspections Table – This table includes Hazard ID, date observed, observer's information, hazard type (scour, degradation, bank erosion, encroachment, avulsion), and hazard potential scores. Inspection data is collected each time TMPL or consulting staff reviews a hazard site. There may be a number of records on the Hydrotechnical Inspections Table for every record in the Hydrotechnical Hazards Table.

Photo Index Table – This table includes Hazard ID, photo date, filename, roll, negative and photo numbers, photographer, and comments. This catalog of photos is stored in jpeg format on a server or CD. They provide users a pictorial history of the geotechnical or hydrotechnical hazard. These images are automatically inserted into various forms and reports in the database.

Surficial Geology Index Table – This table includes location, terrain classification code, and description. This information is used in the calculation of the future geotechnical hazard score and as a reference for TMPL environmental personnel.

Geotechnical Reports Index Table – This table is an index to the hardcopy reports available for the pipeline. Report date, section of pipeline the report addresses, title, author and contact information, TMPL file number, storage location, TMPL contact, contents, (text, photos, plans, airphotos), subject, and keywords. This information can be queried to allow TMPL staff to quickly locate geotechnical references for specific sections of the pipeline.

DATABASE DESIGN

The database is designed to accommodate different levels of dynamic data. Data contained in the Geotechnical and Hydrotechnical Tables is relatively static and is only expected to change once every two to five years. However, it is possible to update the inspection information every time a site is observed by helicopter, field visit, or in a set of new airphotos. Dates of inactivity are equally as important as dates of noticeable hazard activity. Hence, a new inspection record can be created even if changes are not observed. A single hazard may be inspected a number of times resulting each time in a new record in the database, and possibly a new a new hazard score. Furthermore, many photographs may be taken during a single inspection. Hence, the database information is connected in a series of "One to Many" tables linked by a common hazard ID.

Figure 1 shows how the database is designed and how the tables are related to each other. This architecture reduces data duplication and makes data maintenance more efficient. The unique Hazard ID links records across various tables so that referential integrity can be maintained. Referential integrity maintains data quality by automatically maintaining links between records stored in different tables through out the database. It reduces duplicate and orphaned data records.

DATABASE FUNCTIONALITY

The database application stores hazard information and calculates hazard scores "on the fly". These scores are then ranked and used as a prioritization tool by TMPL to assist with selecting troublesome sites for annual inspection or capital remediation. The methodology used to generate the hazard score follows the first two phases of a four Phase approach of Natural Hazard and Risk Management (NHRM) (Savigny, Yaremko, Reed and Porter, 2002).

At present, the database allows TMPL staff to browse, search, and print hazard information in a number of ways. User can use the browser, go straight to detailed information, or print summary reports.

Summary Information – As shown in Figure 2, upon loading the application, the user is presented with a list of all hydrotechnical and geotechnical hazards along the pipeline. Pipeline, KP from and to, geographic description, hazard type and hazard score are initially displayed. Additionally, bullets and icons beside the record indicate whether the hazard has been inspected or if photos are available. The user may elect to sort this list by ascending pipeline KP, geographic location, or hazard score. The user may also view a sub set of this list by querying one or more of pipeline name, KP range, hazard type, hazard score range, or presence of photos.

Detailed Information – A tab along the top of the screen allow users to access more detailed information for select records. Figure 3 shows the layout of this detailed information. Users can scroll through records in this fashion and print selected records. Different details are presented depending on the type of hazard, if it was inspected or the type of hazard algorithm used. Figure 4 is an example of the powerful photo viewer that accompanies the detailed information.

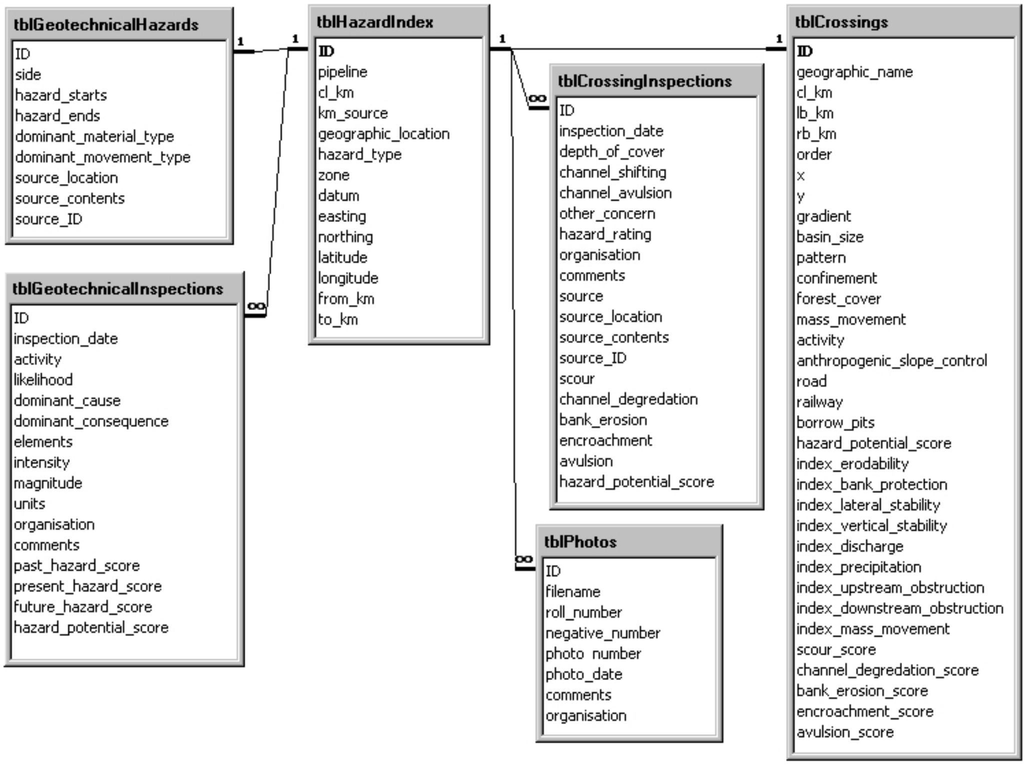
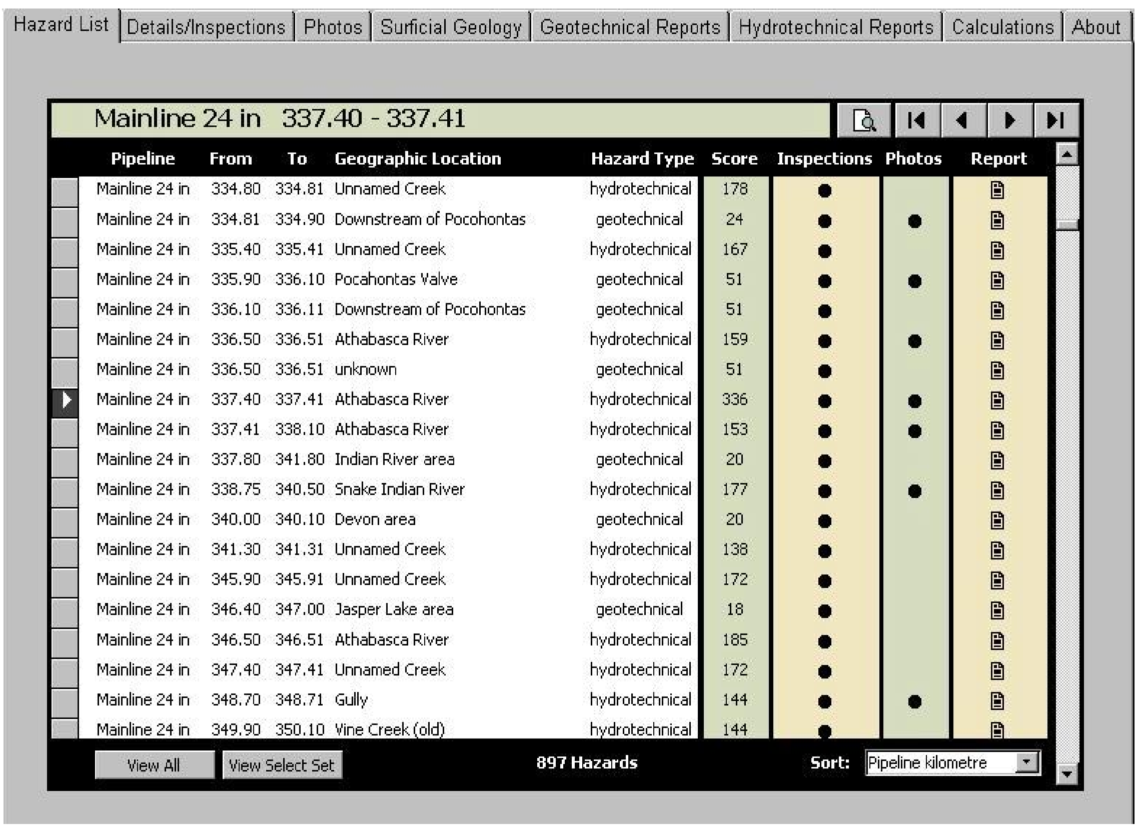


Figure 1 – Main table relationships and key fields of the database application.



Pipeline	From	To	Geographic Location	Hazard Type	Score	Inspections	Photos	Report
Mainline 24 in	334.80	334.81	Unnamed Creek	hydrotechnical	178	●		
Mainline 24 in	334.81	334.90	Downstream of Pocohontas	geotechnical	24	●	●	
Mainline 24 in	335.40	335.41	Unnamed Creek	hydrotechnical	167	●		
Mainline 24 in	335.90	336.10	Pocahontas Valve	geotechnical	51	●	●	
Mainline 24 in	336.10	336.11	Downstream of Pocohontas	geotechnical	51	●		
Mainline 24 in	336.50	336.51	Athabasca River	hydrotechnical	159	●	●	
Mainline 24 in	336.50	336.51	unknown	geotechnical	51	●		
Mainline 24 in	337.40	337.41	Athabasca River	hydrotechnical	336	●	●	
Mainline 24 in	337.41	338.10	Athabasca River	hydrotechnical	153	●	●	
Mainline 24 in	337.80	341.80	Indian River area	geotechnical	20	●		
Mainline 24 in	338.75	340.50	Snake Indian River	hydrotechnical	177	●	●	
Mainline 24 in	340.00	340.10	Devon area	geotechnical	20	●		
Mainline 24 in	341.30	341.31	Unnamed Creek	hydrotechnical	138	●		
Mainline 24 in	345.90	345.91	Unnamed Creek	hydrotechnical	172	●		
Mainline 24 in	346.40	347.00	Jasper Lake area	geotechnical	18	●		
Mainline 24 in	346.50	346.51	Athabasca River	hydrotechnical	185	●		
Mainline 24 in	347.40	347.41	Unnamed Creek	hydrotechnical	172	●		
Mainline 24 in	348.70	348.71	Gully	hydrotechnical	144	●	●	
Mainline 24 in	349.90	350.10	Vine Creek (old)	hydrotechnical	144	●		

Figure 2 – Summary Information window showing the list of hazards and the information available for each hazard.

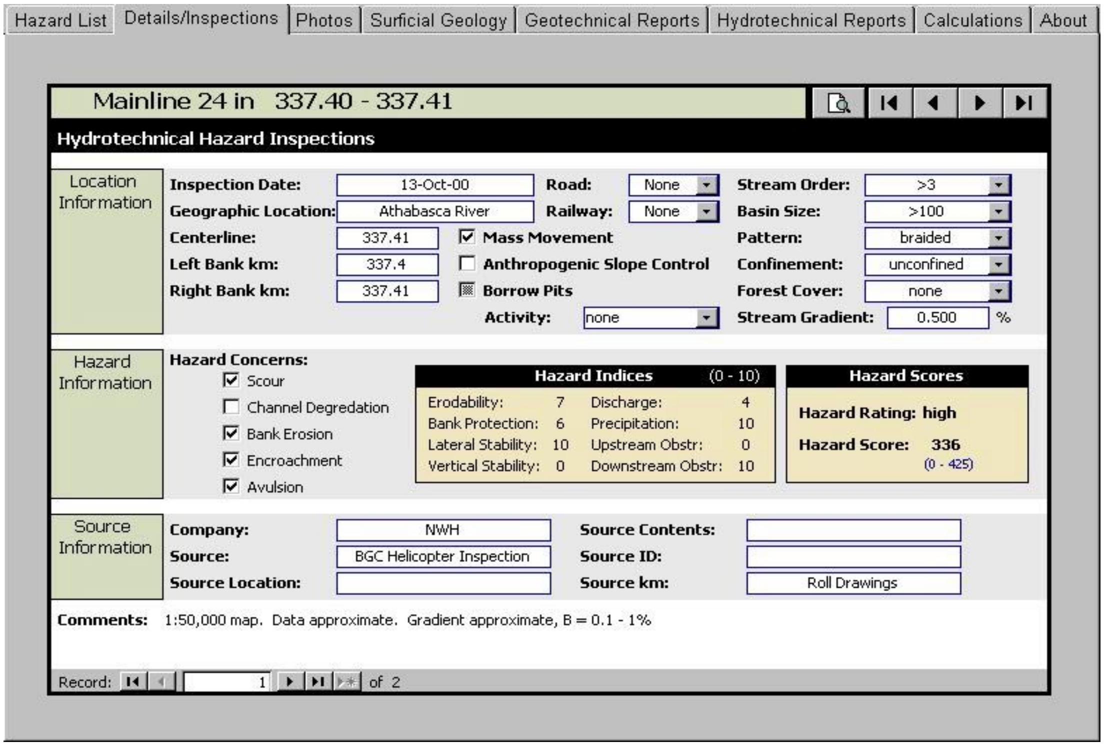


Figure 3 – Detailed information for one hazard divided into location, hazard and source information

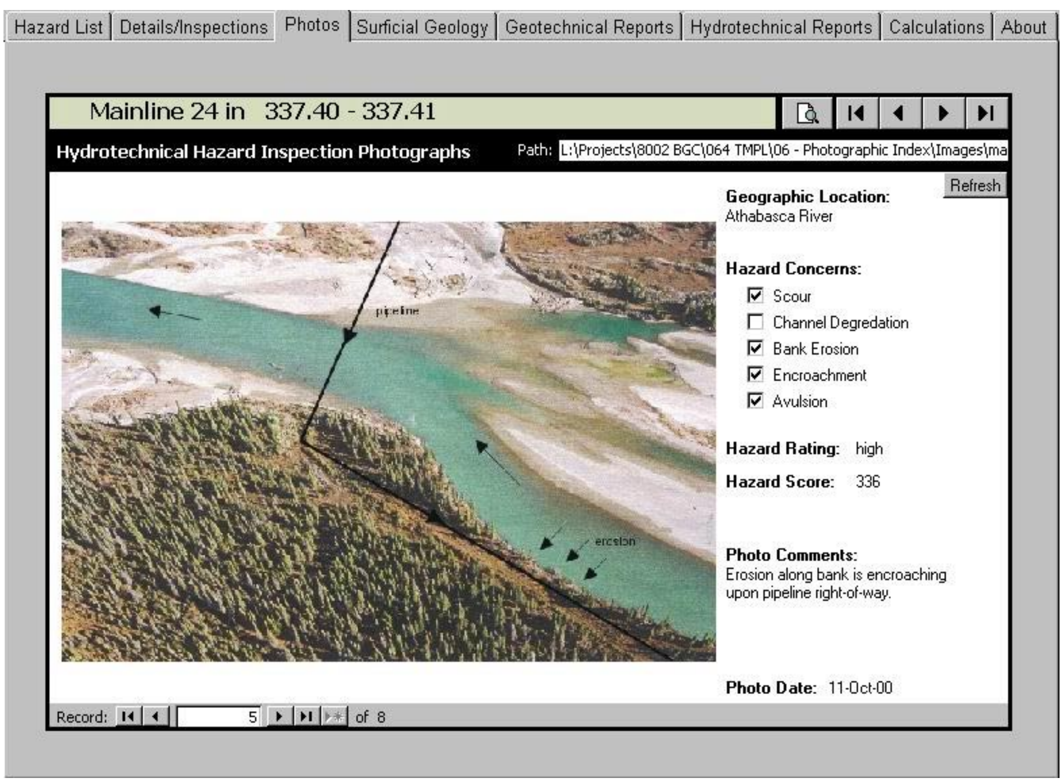


Figure 4 – A photo of a stream crossing with select inspection information.

Summary Reports – TMPL requested three different types of summary reports for hydrotechnical hazards. So far there are no summary reports for geotechnical hazards. The first is a summary report that can be sorted by ascending KP or various hazard scores. The other two reports rank the hazards using a "Top Ten" method and a "Statistical" method. All reports provide information such as the pipeline name, centerline KP, geographic description, and hazard scores.

DATABASE SECURITY

Security has been setup to allow for three levels of users, Common, Advanced, and Power. Common Users, which include various TMPL technical staff, are permitted to view, search, and print select information from they database. For security reasons, Common Users are not permitted to view or print the hydrotechnical hazard ranking reports nor adjust the input parameters to the hazard ranking algorithms.

Advanced Users, which include select TMPL managers, are permitted to view, search, and print select information or print the hydrotechnical hazard ranking reports. To prevent unilateral global changes to the hazard ranking algorithms, Advanced Users are not permitted to adjust the input parameters to the hazard ranking algorithms. Finally, Power Users, which include database administration personnel, have full administration rights to the database. These privileges are used to make modifications to the lookup tables, algorithms, data architecture and functionality of the database. Typically the hazard ranking algorithms are not adjusted without the consent of TMPL and the consulting engineers.

DATABASE ACCESS

TMPL has installed the database on a central Citrix server in Calgary and is shared over their secure Intranet. This architecture allows the database to be shared by users in the Calgary, Burnaby, Kamloops and Vancouver offices without the database being duplicated at each client computer. This architecture also allows database application upgrades to be distributed efficiently amongst the TMPL users. TMPL saves on the cost of application maintenance. An Internet application was not required because of TMPL's existing Citrix network.

DATABASE MAINTENANCE

TMPL's development of a program for systematically inspecting known natural hazards is a work in progress. A methodology for re-inspections and accompanying database functionality is to be determined. Hence, no data entry or editing functionality available for the Common or Advanced Users was incorporated into the current version of the database. At this time, updates to the database are expected to occur on the order of once a year. GroundControl, TMPL, and contributing geotechnical and hydrotechnical consultants will upgrade the content and functionality of the database and a new version of the database will overwrite older versions. In the future, the database application will be adapted to accommodate multi user data entry and editing when the workflow for inspections is designed by TMPL. Automatic maintenance logs will be considered as they will help document the changes to individual hazard sites.

BENEFITS AND COSTS

This database application allows multiple TMPL personnel to have instantaneous access to a common repository of historical and current hazard information. Access to current information encourages quantitative informed decision-making, and helps with communications within TMPL and with outside agencies. Easy access to historical photographs of each hazard site helps new and experienced personnel familiarize themselves with the dynamic nature of the hazards.

Systematic and quantitative hazard prioritization helps TMPL allocate finite resources to the mitigation. In future years as the cycle of inspection and mitigation continues, this centralized application will help TMPL rapidly quantify the benefits and costs of their hazard management program.

This database application encourages the collection of standardized hazard information. As TMPL retains various consultants for studies, this database can be used to specify the minimum standard of data collection, inspection, and reporting.

However, with benefits come costs. Initial financial investment and the effort required to build internal consensus on the scope of the application can be significant barriers to project start-up. Text book style projects traditionally require a significant proportion of resources be spent on defining and documenting the details of the application before development begins. However, in reality, flexibility and trust by each party are the best approaches if a project is to be affordable and proceed at all.

Database applications need to be maintained and resources are required for this maintenance. Efforts must be made to keep the database current, to promote its usefulness, and prevent deterioration of the information asset.

CHALLENGES AND LIMITATIONS

One of the challenges with the construction of the database was assembling the hazard inventory and determining the locations of the hazards. Although the concept of creating a hazard inventory is simple, the problems of accurately and cost effectively locating features in relation to pipeline facilities are common in facility management. Conventional ground surveys, Inline Inspection (ILI) surveys, GPS surveys, and airborne surveys are all useful methods of accurately locating features around the pipeline within sub meter accuracy. Although delineation of the pipeline centerline in real world coordinates is a prerequisite for future inventories, a system-wide high-accuracy survey could not be justified for this study alone.

Nevertheless, TMPL had a few sources for determining the Kilometer Point (KP) of the geotechnical hazard or a stream crossing. KPs could be determined from hardcopy sources such as roll drawings, historical hazard inventory reports, NTS maps, or airphotos. In the field, personnel could assign a KP by referring to these resources or, when required, subjectively interpolating the KP between two documented points. The major challenges to accurately locating natural hazards can include:

1. Incorrect interpolation of KPs
2. The accuracy of interpolations may be too coarse. For example, an unnamed steam crossing may be observed to the nearest 100m at KP 52.6. However, several other unnamed stream crossings between KP 52 and 53 may previously have been recorded at KP 52.55 and KP 52.64.
3. Hazards observed in the field may not be correlated with any of the historical hardcopy resources
4. Hazard identified in one or more historical hardcopy resources may not be located in the field.
5. Historical records may use geographic name references and not KP.

These discrepancies require considerable time to sort out.

Beside challenges with location, data integrity is also a concern especially with historical information. Although historic hazard records are valuable some of the information cannot be reliable because it was incorrectly located, the information is too subjective, or the information was not collected using a repeatable methodology.

This database was designed primarily as a data access tool and not a computational or modeling tool. It provides TMPL staff with access to information about the past, present, and future potential of geotechnical and hydrotechnical hazards affecting the pipeline and the ROW. At this time, there is no intention to incorporate any deterministic geotechnical or hydrotechnical modeling tools into this database application. This database application was also designed to support up to twenty simultaneous users and function as a standalone application for the engineering operations and environmental groups within TMPL. At present, it is not intended to be integrated with, or replace, other Facility or Risk Management applications at TMPL.

FUTURE WORK

TMPL recognizes that moving forward in their Risk Management program may require additional database functionality to manage the inspection information for the high priority hazards. This inspection functionality would allow consultants and TMPL field personnel to:

1. generate a schedule for inspections,
2. enter their observations before and after mitigation,
3. enter the costs of mitigation at various sites.
4. generate a revised hazard score showing the amount of hazard reduction versus to the costs of mitigation.

The database architecture for this application has been designed to work with linear referencing and dynamic segmentation within a Geographic Information System (GIS). (Brush, 2002). Linear referencing and dynamic segmentation are two GIS-based data management techniques that allow efficient storage and analysis of data along linear features such as pipelines, railways, roads, hydrology, and power lines. These techniques are essential to the practical application of any linear analysis such as GIS based pipeline integrity analysis.

CONCLUSIONS AND RECOMMENDATIONS

This project has demonstrated that successful NHRM starts with accurate and complete information about the location and magnitude of the hazards. Some of this information will come from historic records but, as formal NHRM is relatively new, many of the historic records will be incomplete. Initiating NHRM will require developing an inventory. The description of the hazard including an accurate location relative to the pipeline, date of first observation, hazard type, magnitude and activity are minimal requirements for a inventory. Most importantly, this information needs to be updated on a regular (i.e. annual) basis in accordance with the conventions set out an accompanying database application. Due to the multidisciplinary nature of NHRM, and the large volume of detailed information, NHRM often requires one or more standardized database applications to be integrated and serve as centralized source of information and processing tools. In order for the database to be scalable and be useful for a long period of time it should be designed to accept relatively static data as well as data collected from regularly scheduled inspections. The database architecture should also conform to linear referencing and dynamic segmentation conventions in order to be easily integrated with a GIS.

ACKNOWLEDGMENTS

GroundControl would like to acknowledge the technical, business, and financial contributions from Trans Mountain Pipe Line Company Ltd., BGC Engineering Inc. and Northwest Hydraulics Consultants Ltd. Their combined contributions in the fields of pipeline engineering and management, geotechnics, hydrotechnics, and hazard and risk management have made this project a success.

REFERENCES

1. Cruden, David M., and Varnes, David J., 1996, “Chapter 3-Landslide Types and Processes”, Landslides: investigation and mitigation, A. Keith Turner and Robert L. Schuster, editors. Special Report 247. Transportation Research Board, U.S. National Research Council; National Academy Press Washington, D.C., pp. 36-75.
2. Savigny, K.W., Yaremko, E., Reed, M., and Porter, M., 2002, “Natural Hazard and Risk Management for Pipelines”, Proceedings of IPC 2002, AMSE 2002 International Pipeline Conference.
3. Brush, R., 2002, “Open Geodata Standards for Pipelines Advances”, Energy IT, **7**, No.2, pp.42-43.

