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Distributing Access to Geohazard Information Using Web GIS for EDC Geothermal Field Sites

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ABSTRACT

Finding ways to better manage geologic hazards that continually threaten Energy Development Corporation's (EDC) geothermal assets are among the main concerns facing our geothermal field managers. Based on historical data, the effects of these hazards have cost EDC US$6.8 Million annually from 2006 to 2011 alone, in the form of disrupted operations, lost revenues and restoration costs. The key to effectively addressing the risks inherent to these hazards is timely access to information to aid our engineers and management to make decisions that will minimize, if not totally eliminate, these risks.

An interactive web map of EDC's geothermal field assets was developed to supplement EDC's efforts in curbing the vulnerability of its business assets to these risks. The map is an integrated interface for viewing data that has bearing in determining the risk exposure of EDC's facilities to geohazards. Importantly, site inspection reports are contextually retrieved directly from the map by mere click of a button. These pieces of information are valuable inputs when appropriate mitigating measures are being conceptualized for each of these sites. A web-browser is all that is needed to access the application and can be reached through an intranet based website. A fusion of GIS, server, and web technologies; the application has the potential to become a one-stop-shop for accessing data and information needed for effective geohazard risk management and monitoring.

1. INTRODUCTION

Due to the inherent hazards at EDC's geothermal production field sites, the conduct of a geohazard and geotechnical risk assessment is considered essential.

The analysis and identification of natural geological hazards associated with natural processes and adequate assessment of such risk is very important for operations management.

In 2011, to supplement EDC's expertise to undertake thorough geohazard assessment and monitoring, EDC initiated the implementation of a comprehensive geohazard assessment and monitoring program in its geothermal production fields through the engagement of a geotechnical consultant. The consultant conducted the necessary evaluations and mitigating measures were recommended to reduce, if not eliminate, the possible impact of the geohazards in EDC's five (5) production fields.

In 2012, the geotechnical consultant was re-engaged to carry on with the updating and further refinement of their 2011 work. There was also a sense of urgency to conduct re-assessments due to the damage brought about by severe weather that struck in December 2011 affecting some of EDC's facilities. Part of the re-engagement is for the consultant to conduct a 5-day training course on "geologic and geotechnical hazard assessment and mitigation" for the project sites' immediate stakeholders and geologists from head office. During the latter part of 2012, geohazard committees were established in each site to revitalize EDC's geohazard assessment capability and to continue the assessment work done by the consultant from 2011-2012 through the implementation of a regular in-house geohazard assessment and monitoring programs. The program aims to reduce the vulnerability of the geothermal facilities, inhabited structures, roadways and local communities to natural disasters. The annual geohazard assessment was first implemented in January 2013.

One of the consultant's key outputs during their 2011-2012 campaign was a development of a Geographic Information System (GIS) database that would integrate all the reported geohazards in EDC geothermal production fields, resulting in a system that can aid in hazard assessment and risk mapping. These data were presented in a GIS-based map that would later be the basis of a web-enabled version.

2. OBJECTIVE

The primary objective of this project is to present the geohazard assessment results in EDC's five (5) geothermal production fields giving special emphasis to risk areas identified from field inspections in an interactive, fast and up-to-date media such as web map.

The move to create an interactive web enabled map is to give easy access and fast sharing of the data to all stakeholders. The idea of the project is to have a one-stop-shop for accessing data and information needed for effective geohazard risk management and monitoring.

2.1 SCOPE

The scope of the project covers EDC's five (5) geothermal production fields, namely: Southern Negros Geothermal Production Field (SNGPF), Leyte Geothermal Production (LGPF), Bacman Geothermal Production Field (BGPF), Mt. Apo Geothermal Production Field (MAGPF) and Northern Negros Geothermal Production Field (NNGPF).

All of the consultant's geohazard assessment reports and in-house field inspection reports were used to build the current geohazard database.

3. GEOHAZARDS

The United Nations International Strategy Disaster Reduction (2009b) describes hazard as a "dangerous phenomenon, substance, human activity, or condition that may cause loss of life, injury or other health impacts, property damage, loss of livelihoods and services, social and economic disruption, or environmental damage" (PEJ, 2007, p. 12).

Hazards that were present in the five (5) sites were grouped into four major classifications. The summary of hazards can be seen in the table below.

Hazards	
Seismic Hazards	Faulting
	Ground Motion
	Induced Seismicity
Mass Wasting	Landslides
	Rockfall / Rockslides
Hydrologic Hazards	Flooding / Drainage
	Erosion
	Debris Flow
	Siltation
Volcanic Hazards	Ash falls
	Steam Explosions
	Mudflow

Table 1: Summary of Hazards

4. DISASTER RISK

Disaster risk is defined as the potential disaster losses, in lives, health status, livelihoods, assets and services, which could occur to a particular community or a society over some specified future time period. There are three parameters involved in evaluating disaster risk and these are hazard, exposure and vulnerability.

Hazards are threats that can possibly cause a disaster but it only becomes a risk if the two other parameters are present.

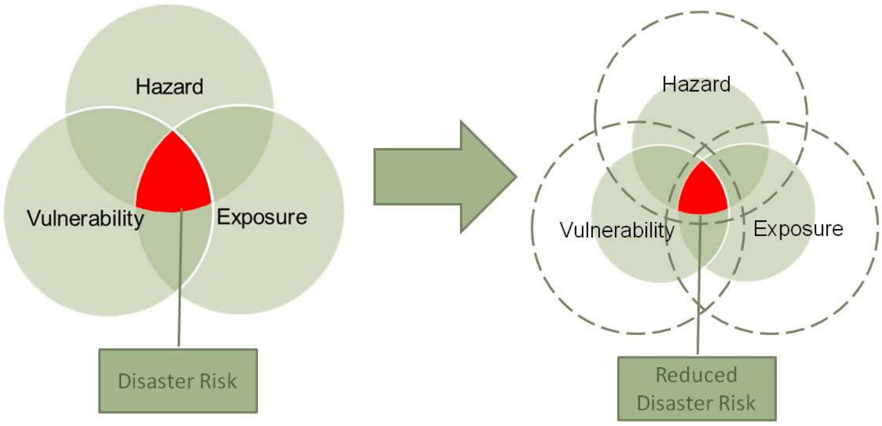

Figure 1: Disaster Risk Parameters

In EDC's geothermal fields, one of the most common types of hazard is landslide. The susceptibility of a slope to landslides refers to its likelihood of failing. The hazard may be reduced or eliminated by various man-made interventions such as trimming or excavating a slope or by providing it with a retaining structure.

Exposure refers to elements which have to confront a hazard. In EDC's case it may be expressed in terms of facilities - such as pads, pipelines, access roads, or building. People are also elements to exposure; examples are commuters or motorists travelling along access roads. Reduction to exposure may be achieved by relocation of residents but in case of geothermal facilities, it will be very expensive to do such move so other options must be considered.

The third parameter is vulnerability. It refers to the capacity of a facility, for example, to survive a hazard. Geothermal wells that are far from a slope are less vulnerable than wells found along the base of a slope.

4.1. RISK RATING

Considering the three parameters of risk, the following ratings defined below were found applicable for all EDC geothermal production fields. These ratings became the basis of inspection points representation carried out to map outputs.

Low Risk: Defined as an inconvenience that is easily corrected, not directly endangering lives or property such as a single block of small rock causing blockage of a small portion of roadway, which can easily be avoided and removed. In maps, low risk areas are represented by a green point or dot.

Moderate Risk: Defined as a more severe inconvenience, corrected with some effort, but not usually directly endangering lives or structures when it occurs, such as debris slide ending in one lane of a roadway and causing partial closure for a brief period until such is removed. In maps, low risk areas are represented by a yellow point or dot.

High Risk: Defined as complete destruction of roadways and facilities, important structures or complete closure of the way for some period of time. Lives are endangered during failure. In maps, low risk areas are represented by a red point or dot.

Figure 2: An example of a geohazard map legend with risk representation

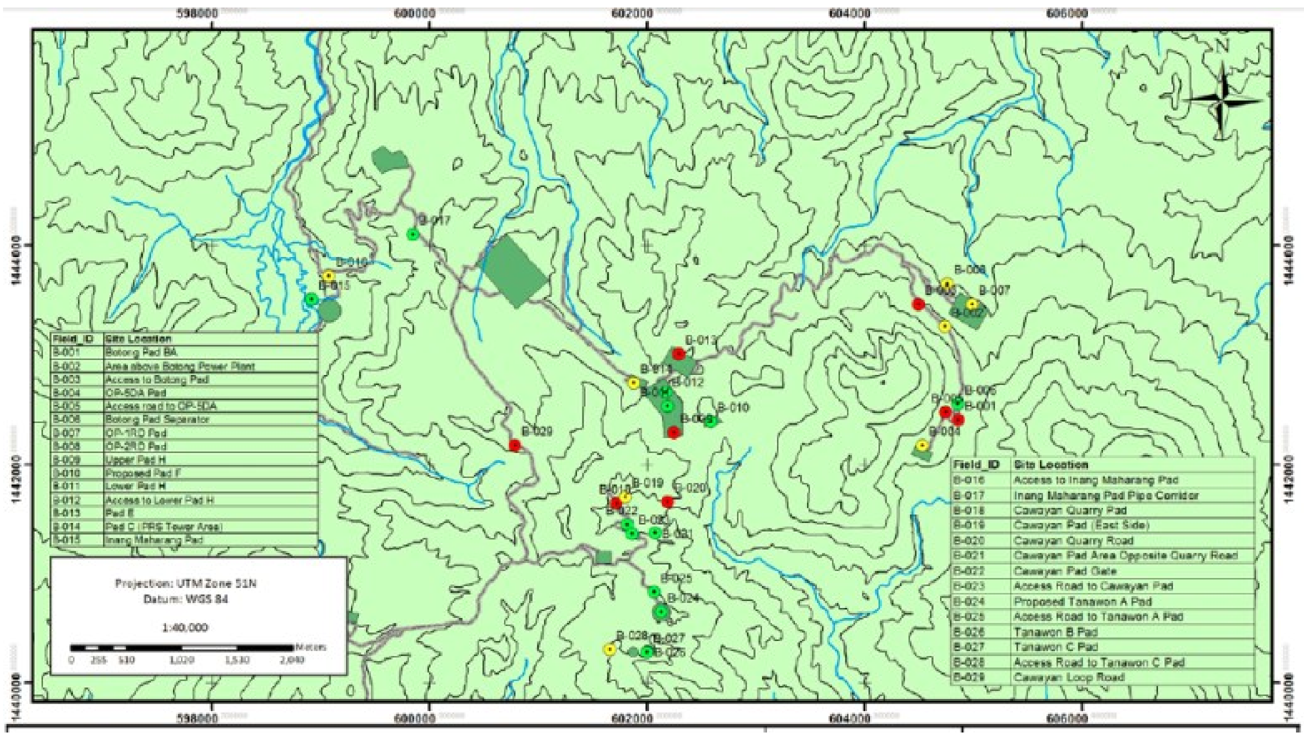

Figure 3: Site inspection points risk ratings map

5. DISASTER RISK MITIGATION

The figure below presents the Disaster Management Steps that are taken to ensure the safety of three objects of risk, which are way of life, life and property.

Figure 4: Disaster Management Steps

These steps are very crucial to effectively manage disaster risks and also the reason why monitoring programs are needed. With this, mitigation measures are enforced properly to reduce and/or prevent future damage. Figure 6 shows commonly used measures for either structural or non-structural mitigation.

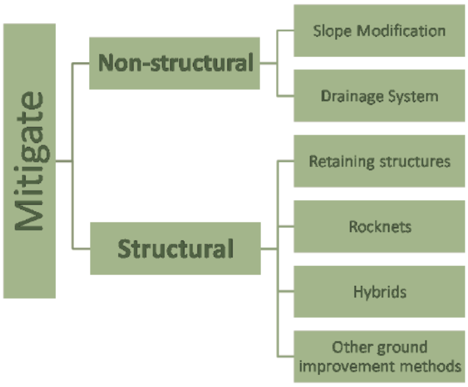

Figure 5: Types of Mitigating Measures

6. GEOGRAPHIC INFORMATION SYSTEM

A geographic information system (GIS) is a computer system design that integrates hardware, software and data for capturing, managing, analyzing and displaying all forms of geographically referenced information.

GIS enable users to easily visualize, understand and interpret data to understand the underlying relationship and patterns in the form of maps or other media.

In today's day and age, GIS technology has transformed into a multi-faceted system. It can now be integrated into any enterprise information system framework to quickly answer questions and solve problems by connecting to different sources of data.

In EDC, the GIS application being utilized is ArcGIS with its several applications such as ArcMap, ArcCatalog, ArcScene, and ArcGIS for Server.

6.1 GIS and Web Mapping

Web mapping is the process of using maps delivered by geographical information systems (GIS). Web maps provide easy access because it can be shared and used through a web connection without the user having to install any additional GIS software.

Some of the most popular web maps and web-mapping applications today are Google Maps (maps.google.com) / Google Earth (earth.google.com), OpenStreetMap (openstreetmap.org) and ArcGIS Online (esri.com).

7. EDC GEOHAZARD WEBMAP

To provide EDC stakeholders with faster and more up-to-date information regarding geohazard assessment and monitoring, the Geomatics team of EDC has made an integrated web-based mapping application.

An interactive web map of EDC's geothermal field assets was developed to supplement EDC's efforts in curbing the vulnerability of its business assets to hazard risks. The map is an integrated interface for viewing data that has bearing in determining the risk exposure of EDC's facilities to geohazards.

Importantly, site inspection reports are contextually retrieved directly from the map by mere click of a button. These pieces of information are valuable inputs when appropriate mitigating measures are being conceptualized for each of these sites.

8. METHODOLOGY

8.1 System Design

8.1.1 Existing System

The existing system for management and visualization of submitted geohazard assessment reports are accessed through an online Document Management System (DMS). Geohazard committee members shall submit all reports to the DMS administrator for upload and record keeping.

Visualization for end users is in the form of hard or soft copy GIS based maps. GIS utilizes ArcGIS for creation and preparation of maps for EDC. Existing geohazard maps are available in both ArcGIS map document (*.mxd file*) and in Adobe Portable Document (*.pdf*) format.

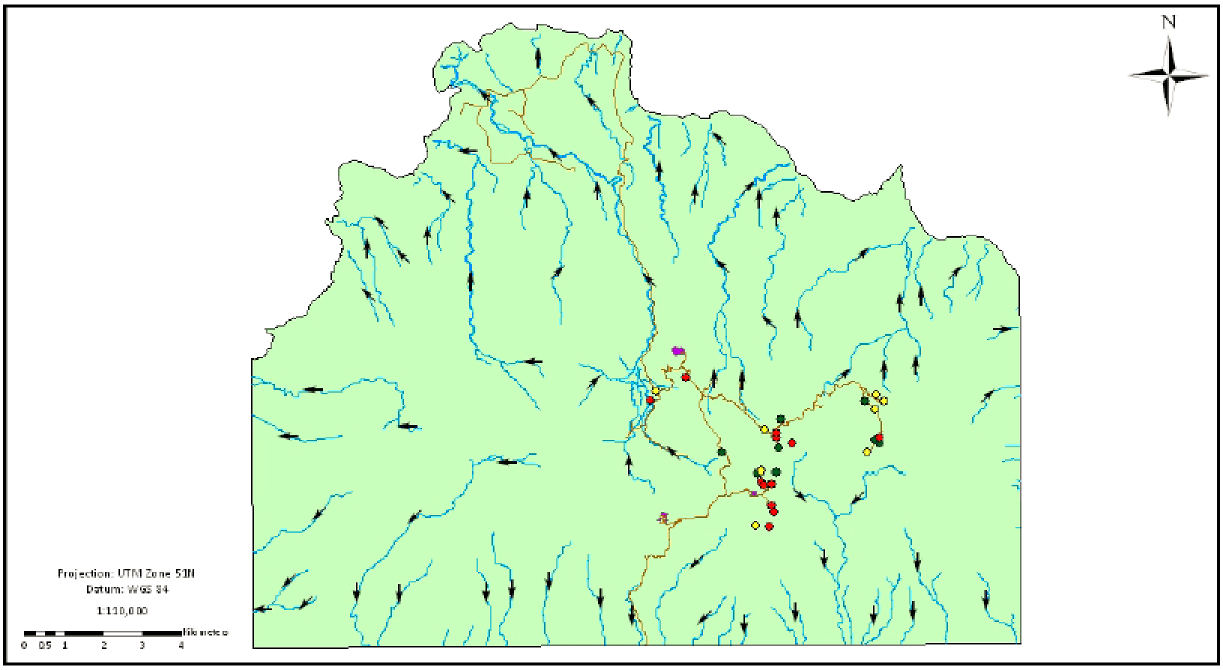

Figure 7: Sample Drainage Map

8.1.2 User Requirements

The general requirement is the information management system which could show the information of each geoahazard inspection points that can link to individual reports through a web map. The web map should be easy to use and the interface should be user-friendly.

8.1.3 Scope and Limitations

The system shall utilize EDCs current enterprise Geodatabase management system and also the usage of the GIS Server's web mapping capabilities. The system shall at least show the inspection points and its corresponding report located in the document management system.

8.2 Data

8.2.1 Data Storage

The primary spatial data storage for all GIS related projects for EDC is its enterprise geodatabase. Geodatabase is the common data storage and management framework for the GIS software being used in EDC. It has a capability to support all the different elements of GIS data such as vectors, rasters and tables.

8.2.2 Available Data

Data used in this project consist of the current database of geohazard reports prepared for previous site inspections, including data collected before hiring the consultants. Additionally, other supporting GIS data like geology layers and digital elevation models were used to add value to the web map.

Below are the data used for the creation of the web map and represented by a point, a line, or a polygon for vector layers and colorful image overlays for raster layers:

Vector Layers:

- geohazard (inspection points) – records of previous hazard events or potential hazard areas and also newly identified hazard areas.
- volcanic center – volcanic or mountain peaks
- pipeline – these are pipelines in the geothermal production field

- facility – these are man-made structures such as buildings, sumps, etc.
- development block – the boundary of geothermal development
- road network – existing access roads
- water body – these can be lakes or ponds
- structure – these are existing fault lines in the area of study

Raster Layers:

- DEM (digital elevation model) – these are high resolution DEMs used to create elevation contours, drainages and slope maps

8.3 Spatial Database

The spatial database used can be leveraged in desktop, server, or mobile environments and allows storage of GIS data in a central location for easy access and management.

8.3.1. Multiuser Geodatabase

EDC uses ESRI's ArcSDE spatial database engine technology for accessing and managing geospatial data. It is a multiuser geodatabase which utilizes a multitier architecture that implements advanced logic and behavior in the application tier (e.g., ArcGIS software) on top of a storage tier (e.g., relational database management system [RDBMS] software). The responsibility for managing geographic data in a multiuser geodatabase is shared between ArcGIS and the RDBMS software. EDC is using Microsoft SQL Server for its RDBMS implementation.

8.4 Front End Development

Creating a web map using ArcGIS technologies require step-by-step process that is summarized in the figure below:

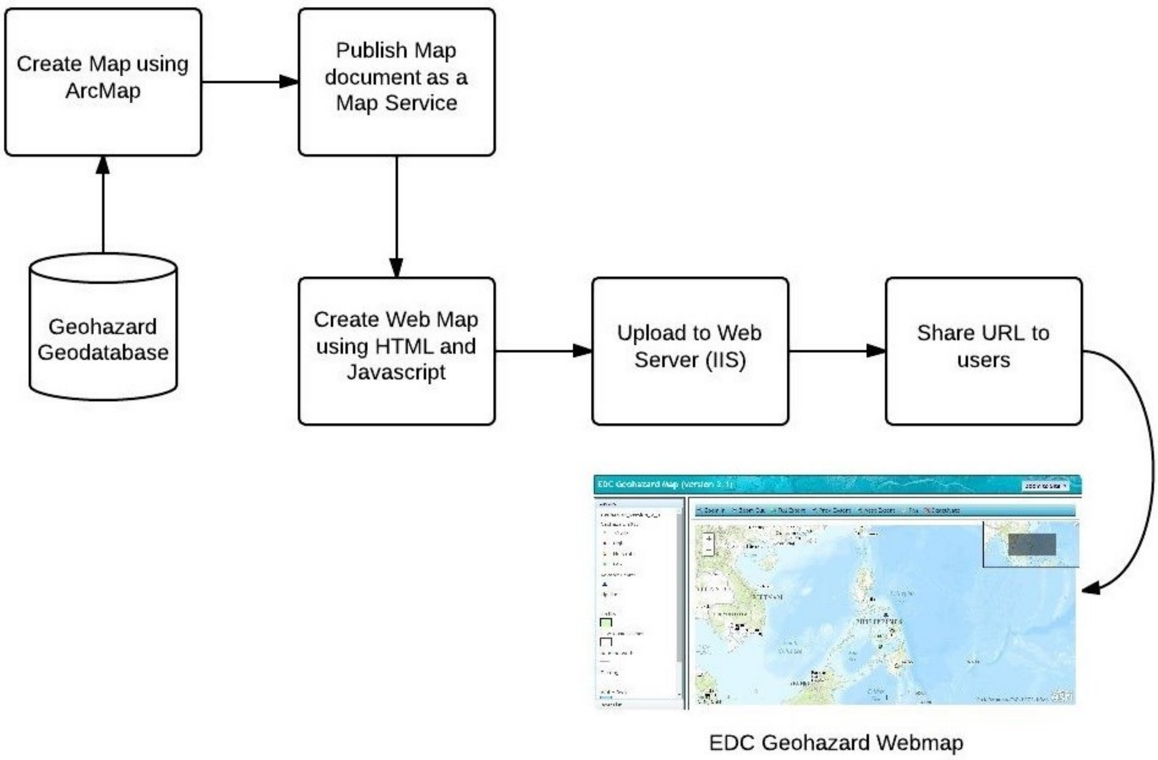

Figure 8: Basic web map creation process using ArcGIS technologies

8.4.1 The Map Document

The figure below shows a sample map created using Esri's ArcMap GIS software.

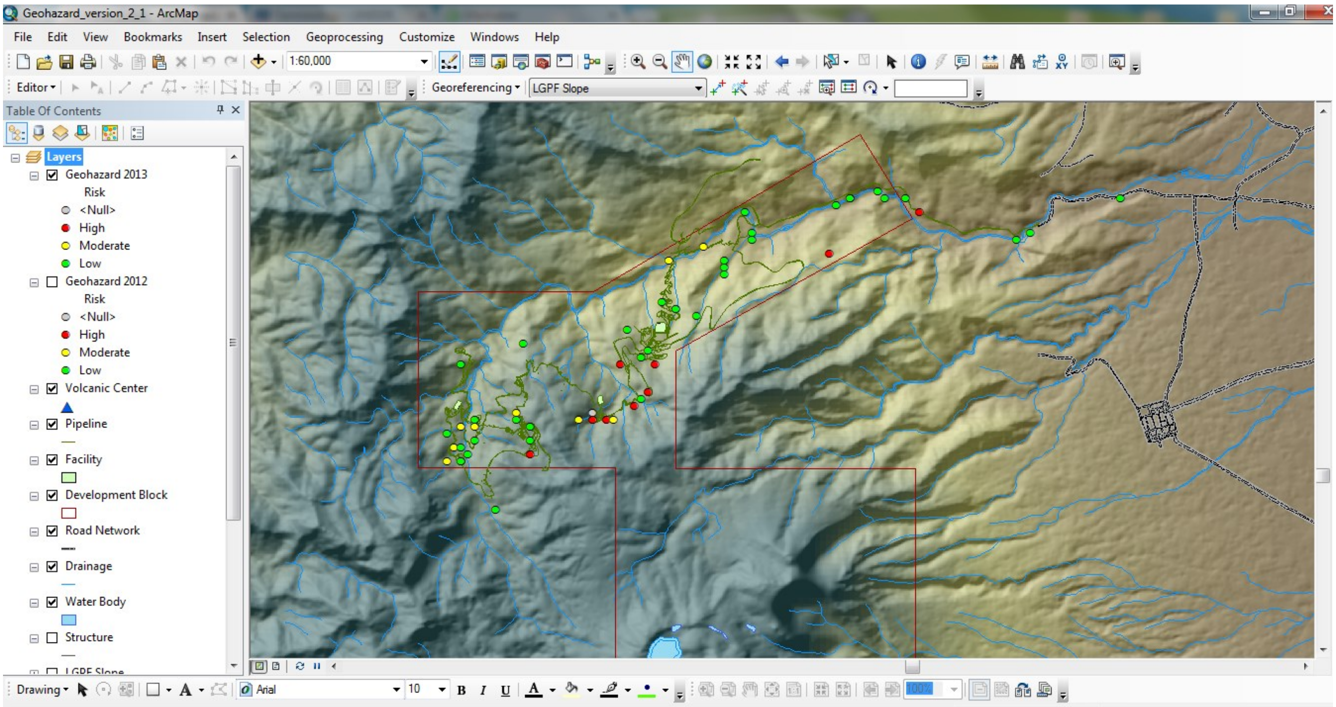

Figure 9: Geohazard Map created using ArcMap

8.4.2 ArcGIS Map Service

Maps created using ArcMap will have to be published as a service in the ArcGIS server so that it can be accessed or viewed via the ArcGIS REST Services Directory.

8.4.3 ArcGIS API for Javascript

The EDC Geohazard Web Map front end was made using Hypertext Markup Language (HTML) with the help of ArcGIS API for Javascript. The ArcGIS API for JavaScript is a lightweight way to embed maps and tasks in web applications.

The JavaScript API is hosted by ESRI on ArcGIS Online and is available for free use. In our implementation, we used the recommended approach for accessing the API through hosted version.

8.4.4 Web Server

A web server is a requirement when you have to deploy a web application over http. This means that web pages and apps using the ArcGIS API for JavaScript can be accessed over "http://" (or "https://") rather than "file://". Microsoft Internet Information Services (IIS) is recommended for the windows operating system but other windows compatible web servers will do.

9. RESULTS

The geohazard web application's interface is "What-You-See-Is-What-You-Get" (WYSIWYG). All the basic functionalities of a typical web map were incorporated in the interface for it to be user-friendly and to achieve a familiar look and feel.

Users can view the web application directly via an internal URL address and is currently limited to users connected to EDC local area network (LAN). It is not exposed to the internet because certain security measures have to be implemented first but future versions will eventually allow access through it.

9.1 Main User Interface

The interface design was created using HyperText Markup Language (HTML) and Cascading Style Sheets (CSS), while the map functionalities were done using ArcGIS API for Javascript.

The main interface displays an overview of the Philippines and locations of EDC's operating project sites. Left pane of the main display can be toggled to show either map legend or layers list. At the top are map navigation tools that can control map display extent, while at the top right corner is an overview map, showing general location of displayed map.

Figure 10: EDC Geohazard Map Main User Interface

Further at top right is the *Zoom to Site* dropdown list that allows quick zoom-in to a particular project site. Geohazard inspection sites are identified and classified in the map whether low, medium, or high-risk.

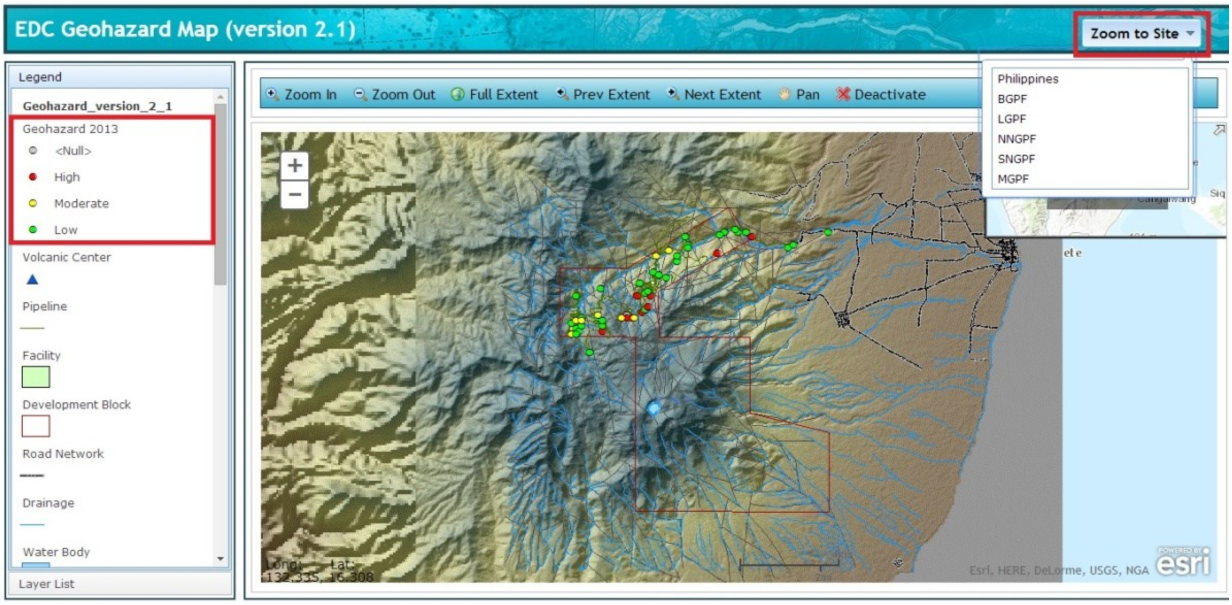

Figure 11: Site specific map showing inspection points and selectable layers from the left side bar

9.2 Identifying inspection points

A click on the map's geohazard inspection points pops-out an information box with context menu where the geohazard inspection report in EDC's document management system (DocuShare) can be retrieved.

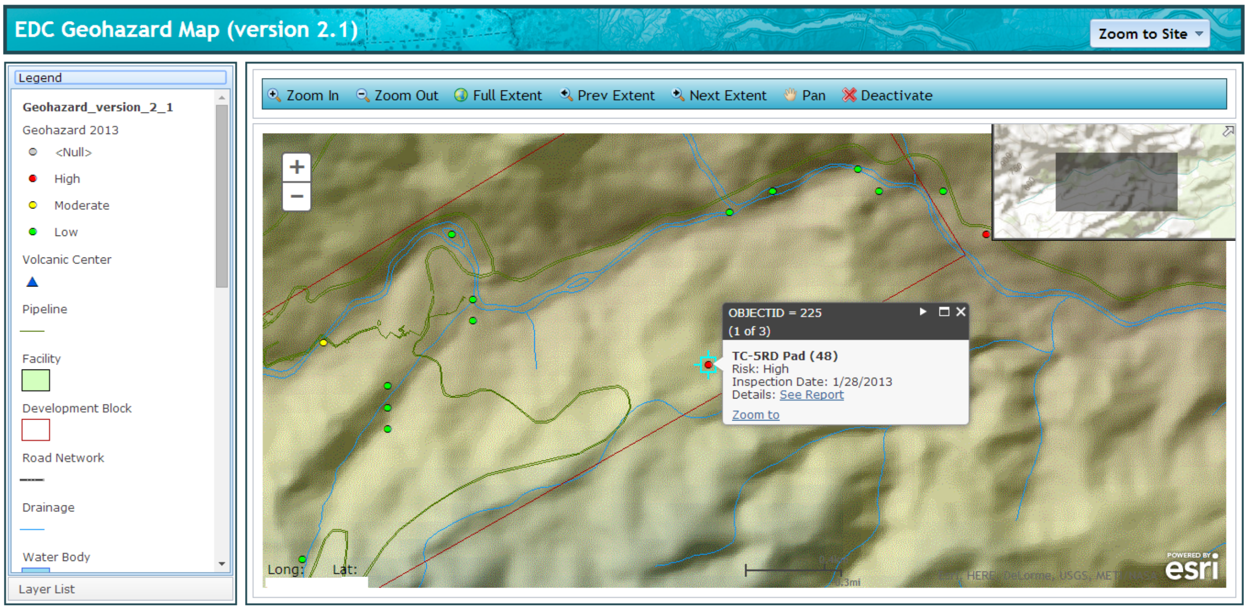

Figure 12: Clickable inspection point with pop-up details with a link to the report

9.3 Viewing reports

Log-on credentials to DocuShare are required to access the Geohazard Assessment Reports, as a security feature.

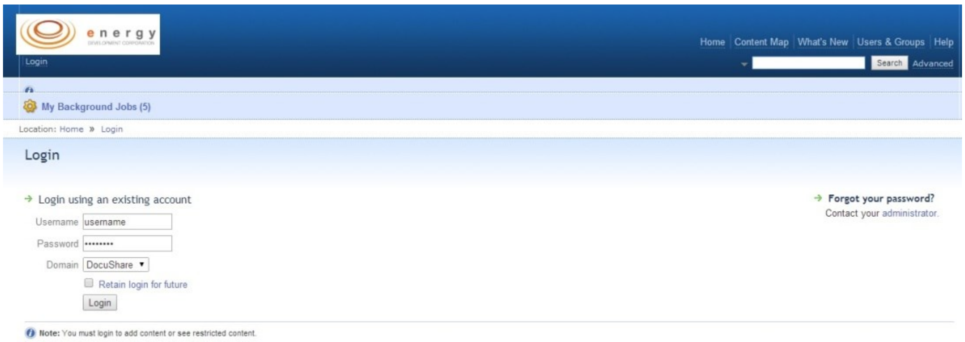

Figure 13: Document Management System Log-in page

9.4 Turning layers on or off

The application allows selection which layers are visible in the map display by checking or un-checking the toggle boxes.

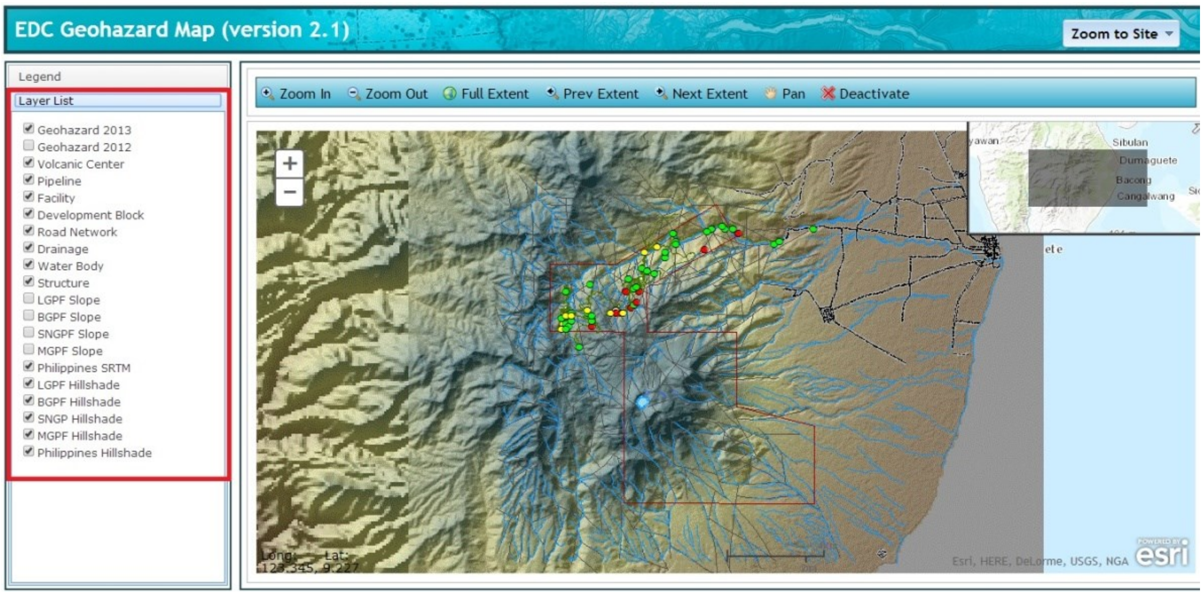

Figure 14: Showing the layer list on the left side pane

9.5 Turning layers on or off

Slope steepness is a major factor that influences a site's vulnerability to geohazard. This information is available in the Web App.

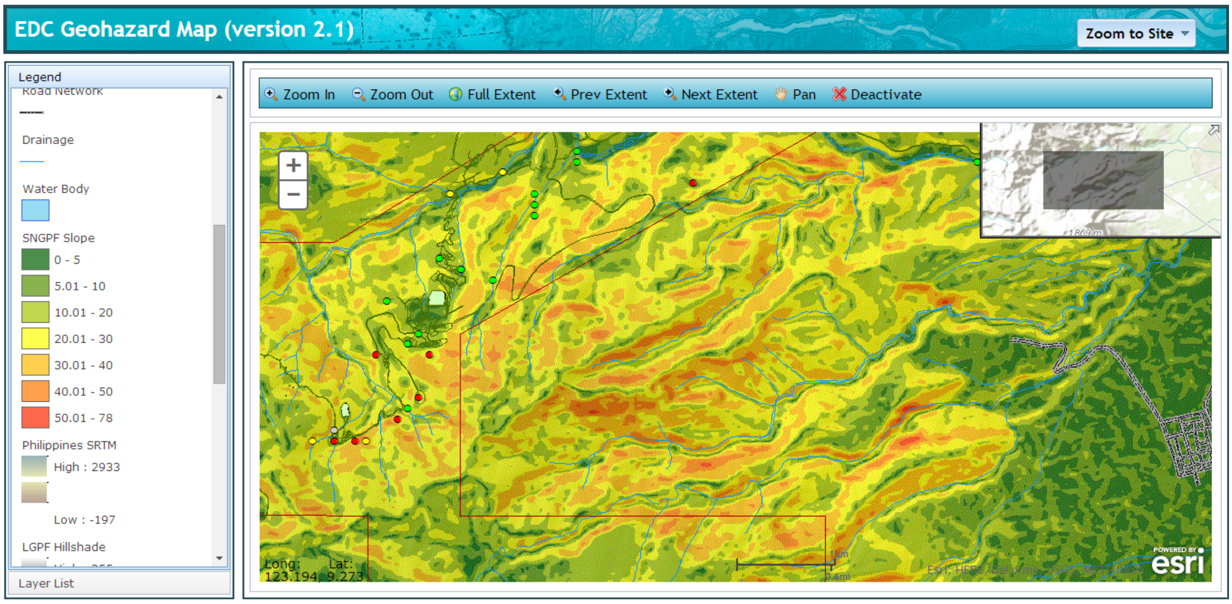

Figure 15: Slope map of SNGPF

10. RECOMMENDATIONS

To further improve the application's relevance to geothermal operations, certain aspects can be enhanced through implementation of our recommendations.

Geohazards occurrences were assessed individually and classified as high, moderate or low risks. Overtime as mitigating measures are applied and as new geohazards are developed, these risk rating will have to be updated, therefore, the need for constant update is deemed necessary.

All inspection points should have a corresponding GPS measurement. This is important for the plotting of data in GIS. Methodologies for data gathering must be further developed and improved.

The geotechnical consultant also recommended some improvements in both data gathering and map visualization:

1. Incorporate geology and hydrothermal alteration maps as additional GIS layers.

2. Expand and update the database by creating distinctions between the following:

    a) Rock slopes vs. soil slopes

    b) Types of hazard (landslides versus debris flows)

    c) Types of slope failure (circular failure, parallel failure, rock fall).

11. CONCLUSION / SUMMARY

GIS integrates all kinds of information and applications with a geographic component into one manageable system. The benefit of GIS applications is the ability to integrate and analyze all spatial data to support a decision-making process. GIS is a powerful system to effectively handle multiple data and visualize them in a quick and interactive manner such as web map.

A good GIS application is also dependent in the integrity and availability of data. Additionally, GIS applications must be implemented in such a way that it suits the organization's needs to achieve the goal of making better and informed decision based on all relevant information.

As for IT, implementing a web map application has it merits. First, there's no need for additional software installation for users. Second, it is platform independent since it is browser based. Third, web maps will improve accessibility and availability of data because it can be shared within the organization.

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