Ph.D. Thesis

Development of Web-based Geospatial Information System - A Case Study for sharing Geology and Mineral data of Thailand

ウェブ地質情報システムの構築

- タイの地質と鉱物資源データの流通・共有のためのケーススタディ

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Abstract

Mineral resources significantly contribute to economic growth of ASEAN countries. In order to rapidly develop the mineral resources sector, it is very important to show the mineral resource potential to foreign investors. ASEAN countries including Thailand started to develop the mineral resources database, but faced difficulty in making it highly accessible and usable to domestic and international users. The main purpose of this study is to develop a mineral information system for ASEAN and Thailand that is highly accessible, easy to use and cost effective. This study focuses on the creation of an information infrastructure that promotes sharing of information about geology and mineral resources across ASEAN region, especially Thailand.

There are several methods of integrating and disseminating distributed geo-information from diverse sources using Web-based Geographic Information System (WebGIS). However, the distributed geospatial information from diverse sources is difficult to integrate due to the differences in data formats, projections and database storage structure. This study introduces the technique on geospatial information system development and management for sharing geospatial information easily over the web in a cost effective way. This study uses WebGIS system for the mineral database of Thailand. WebGIS could handle large number of users, works on a wide array of operating systems and server architectures, cheap, easy to use and maintain and could be used for a wide range of applications. Users will just need an internet access and a browser to easily access distributed geospatial content.

This study uses free and open source software (FOSS) in the formulation of web services and rendition of geospatial content online. Users of FOSS are free to copy, study, and change the software. Free and open source software for geospatial data is called FOSS4G, which encompasses a broad range of applications in combination with the use of digital maps and georeferenced data. MapServer and GeoServer are FOSS4G applications used in this study. MapServer is used for publishing spatial data and interactive mapping applications to the Web, while GeoServer is a Java-based software server that allows users to display, share and edit geospatial data on the web.

Geospatial data interoperability is very important for data exchange on the internet. Therefore, one of the most important aspects of this study is the use of international standards on the web services for geospatial information processing and sharing. The Open Geospatial Consortium (OGC) provides the international standard for web services such as Web Map Service (WMS), Web Processing Service (WPS) and Web Feature Service (WFS). WMS provides interface for requesting map images from one or more geospatial databases. WPS defines rules for standardizing inputs and outputs of geospatial processing services, handles the spatial data queries and defines interface for publishing of geospatial processes. WFS defines interfaces for data access and manipulation operations on geographic feature from different sources. It includes a transaction operation to insert, update, or delete features.

The geospatial information sharing system proposed in this study is a web-based geospatial information system of Thailand using FOSS and OGC based web services and standards. It distributes geospatial content on the web through the formulation of web services such as WMS, WPS and WFS launched on a customized WebGIS portal. WMS and WPS are formulated using MapServer, while WFS is formulated using GeoServer. The WebGIS portal integrates WMS, WPS, WFS and customized applications on the web site to enable user to search, visualize and download geospatial data easily. It is a very powerful data sharing system to disseminate geospatial information to the public.

The proposed new system will play a critical role in the national dissemination of geology and mineral information. It also provides a template for other ASEAN countries to follow. If all ASEAN member state will have similar system, the ASEAN mineral information system will be automatically updated, providing up to date mineral resources information to the public. The primary advantages of using the system are its cost efficiency in the development and system maintenance, and the potential of the server software and web-based system to be used in other geosciences fields.

Chapter 1

Introduction

1.1 Motivation and objectives

Mineral Resources are important components for economic growth of many countries. Understanding the existence and availability of the resources is very important for effective management to optimize their economic value and protect the environment. Many organizations in mineral producing countries establish mineral resources database to support decision makers in the formulation of policies for mineral resources management. Economically advanced countries like USA, Australia and most members of the European Union allocate substantial amount of money in developing their advanced mineral information system. On the other hand, developing countries like Thailand have difficulty developing such system because of lack of technical know how and limited financial resources. Mineral resources in developing countries are also important inputs for the industries of developed economies. Because of this, many developed countries collect mineral data and developed mineral information system of developing countries for their own use. The United States, United Kingdom and France developed and maintain mineral resources database of South America. Russia and Germany maintain mineral resource database of Central Asia. However, the countries in these regions don't have their own mineral resources information system.

Recently, ASEAN countries started new project on mineral resource database. They decided to make the regional mineral resource database without any financial and technical support from developed countries, and open their database to the world. This move is in line with the strategy of promoting the development of the mineral industry of ASEAN region through the participation of local and foreign investors. For this purpose, they make their common mineral database and make the information easily accessible by opening it to the public. However, the project faced difficulties of getting enough data and competent manpower to developed and maintain the information system.

ASEAN is a region rich in mineral resources, and has huge potentials for new discovery [1]. The mineral resource is a key driver for economic growth for most of ASEAN countries including Thailand. However, ASEAN countries cannot get enough foreign investment for mineral resource development. The ASEAN Senior Official Meeting on Minerals (ASOMM) decided to establish the mineral resource database to show the mineral resource potential clearly to foreign investors.

The Department of Mineral Resources (DMR), which represents Thailand in ASOMM, developed and maintained the database on mineral resources of Thailand for the past 30 years. However, DMR faced difficulty in making the database useful for the mineral resource development in Thailand. The first database of DMR was developed by private company. It was inflexible, difficult to use for geospatial data sharing among organizations and expensive to maintain. Other ASOMM members face similar problems.

This study focuses on the creation of an information system for sharing geospatial information on geology and mineral resources among ASEAN countries with Thailand as a case study. This study also presents an alternative solution for the ASEAN mineral database. The main points of this study are the following:

1) To use free and open source software (FOSS).

2) To use Open Geospatial Consortium (OGC) based international standards and web services for data sharing.

3) To propose flexible system both for data entry and usage.

This study involves the use of internationally accepted standards and cost efficient software. Specifically, this study aimed at creating the new web based geology and mineral resources information system of Thailand using FOSS and OGC based web services such as Web Map Service (WMS), Web Processing Service (WPS) and Web Feature Service (WFS). This study is a model that other ASEAN countries could follow to have a regional distributed database system, where each country in the region will create and maintain its own database and formulate OGC based web services to serve their data to the public. The use of OGC standards and FOSS makes this information system cost efficient and interoperable. The develop system was also designed to be very accessible and user-friendly.

The ultimate objective of this project is to create an information technology platform for easy sharing and access of geospatial information among ASEAN countries and the world. A successful implementation of this study would make geology and mineral resources information easily available for use by policy makers, investors and the general public. The proposed system is very helpful for the development of mineral resources and economic growth of ASEAN countries, especially Thailand. Finally, this study will be a good information system not only for geology and mineral resources but also for other geoscience data.

1.2 Outline of the thesis

This thesis is organized as follows:

Chapter 1 presentation of the motivation, objectives and outline of this thesis.

Chapter 2 presentation of the background of mineral database of ASEAN and Thailand.

Chapter 3 presentation of literature review as research theory references. Review of the methods related to the proposed method, i.e., Geographic Information System (GIS) Technology, WebGIS, Spatial Data Infrastructure (SDI), Open Geospatial Consortium (OGC) standards and web services, and free and open source software for geospatial data (FOSS4G).

Chapter 4 presentation of the newly developed Thailand geospatial information sharing and development system. The design of the system architecture and development process are described in this chapter.

Chapter 5 presentation on how to use FOSS4G and web technology for creating geospatial database of Thailand. Creating geospatial database and inputting geospatial data into the database is described in this chapter.

Chapter 6 presentation on how to use FOSS4G and OGC standards and web services in creating and sharing geospatial information of Thailand on the web. The formulation of WMS, querying the database and downloading of geospatial information using WPS are described in this chapter.

Chapter 7 presentation on how to use FOSS4G and OGC standards and web services for sharing and editing geospatial data of Thailand. The procedure on sharing and editing geospatial data online using WFS is described in this chapter.

Chapter 8 presentation of the WebGIS portal of the new geospatial information system.

Chapter 9 discussion about the advantages of using the proposed web-based geospatial information system. Advantages of the newly developed system over the current system, including its contribution to the ASEAN mineral resources database and information system are discussed in this chapter.

Chapter 10 Summary and conclusion of this study.

Chapter 2

The current mineral database of ASEAN and Thailand

2.1 Background of the current mineral database of ASEAN and Thailand

2.1.1 ASEAN mineral resources database and information system

The mineral resources information are important inputs for policy makers to manage natural resources. Mineral resource reserves are important indicators of economic growth and social development. ASEAN countries currently consists of 10 member states which are Brunei, Kingdom of Cambodia, Lao People's Democratic Republic, Republic of Indonesia, Malaysia, Republic of the Union of Myanmar, Republic of the Philippines, Republic of Singapore, Kingdom of Thailand and Socialist Republic of Vietnam. The community is founded by 3 main pillars, namely, ASEAN Political and Security Community (APSC), ASEAN Economic Community (AEC) and ASEAN Socio-Cultural Community (ASCC). The pillar of AEC consists of all economic activities with many departments and ministries in ASEAN countries. AEC aims to make ASEAN single market and production base with the free movement of goods, services, investment, capital and skilled labor. Mining industry and logistics are part of this pillar. ASOMM is a group meeting of policy makers on mineral resources development of all ASEAN member countries under AEC. The permanent secretary on minerals or mines ministry from each member country will gather under ASOMM and tackle all issues on cooperation projects and regulations. These issues are prepared and proposed by ASOMM Working Groups consisting of:

1) WGMID (Working Group on Mineral Information and Database)
2) WGCBM (Working Group on Capacity Building in Minerals)
3) WGSMD (Working Group on Sustainable Mineral Development)
4) WGTIM (Working Group on Trade and Investment in Minerals)

These ASOMM working groups were organized in order to find better solution on mineral resources in ASEAN region. The mineral sectors of ASEAN countries have always been considered to be an engine for greater economic growth and social progress in the region. Minerals in the ASEAN region account for relatively large shares of world reserves [2]. Easily accessible information about mineral resources enhances trade and investment in the sector. It also encourages environmentally sound and socially responsible mineral development practices and optimum utilization of mineral resources. A well informed public about this important resource also discourages corruption. As the economic integration of the ASEAN region progresses, unimpaired movement of capital and knowhow across the region should further be guaranteed. This requires the creation of an information infrastructure that facilitates unhindered and efficient sharing of information.

In order to integrate information about mineral resources, the WGMID started to set up the ASEAN mineral resources database and information system (AMDIS), which was proposed by the governments of the Republic of Indonesia and Malaysia in 2004 during the 6th ASOMM. AMDIS project focuses on the creation of an information infrastructure that promotes sharing of information about mineral resources across the region. The project involves the use of internationally accepted standards and cost efficient software. Specifically, this project aims at creating an information infrastructure and efficient sharing of the web based ASEAN mineral resources information system. The first ASEAN WebGIS was developed by the Geological Agency of Indonesia (GAI) and other counterpart agencies of each ASEAN country. The information system uses a centralized database. Mineral sector of each ASSOM member needs to input data through the website of GAI. The system requires concerned agencies of ASOMM members to enter the data twice, first to their local database and the second to the centralized ASOMM database. Because of this, maintaining the database is very inefficient.

2.1.2 Geology and mineral resources database system of Thailand

The Department of Mineral Resources of Thailand (DMR) is the main governmental organization to serve technical knowledge and geological information to the Thai public. DMR conducts geological field surveys and explores mineral resources throughout the country. It also collects various geological and mineral information from the field. Such geological information are very important not only for infrastructure development, geohazard prevention and land use planning but also for mapping mineral resources. Minerals, rocks and sands are fundamental natural resources which are abundant in Thailand. The resources have been used as raw materials in various types of industries. The Thai government has concentrated on industrial mineral and rocks such as limestone, gypsum, kaolin, ball clay, quartz sand and dickite [3]. These rocks and minerals are sufficient to cater the needs of the industrial development of Thailand.

DMR stores the field observation data and manages the gathered information using Geographic Information System (GIS) for the past 30 years. GIS is a system developed to store, manage, process and manipulate geographically referenced information. It is the most efficient and cost effective tool in dealing georeferenced data [4, 5, 6]. GIS is an invaluable information system in managing natural resource information and in the processing, analysis and visualization of such information into more understandable configuration. The use of the World Wide Web for the processing of the geographically referenced information, commonly termed WebGIS, started to gain popularity in recent years. WebGIS is an information system that allows users to manage, process, analyze and views spatial data over the WEB. In this set up, GIS software and the database are found in centralized servers.

2.2 Architecture of the current mineral information system of Thailand

The Department of Mineral Resource of Thailand (DMR) had started GIS-based information system to manage the nationwide airborne geophysical data for the past 30 years. Since then, small group of DMR staffs were trained to use and maintain the system. DMR had been using WebGIS for the last ten years. Initially, DMR used commercial software which provide basic desktop tools to manage geospatial information. DMR relied on outsourcing to setup centralized database and WebGIS system on geology and minerals information. The WebGIS system was Client-Server architecture. Figure 2.2 shows the architecture and system components of the current WebGIS system of DMR-Thailand.

System Components	**Description**
Operating system	Window2003Server
Database Server	DBMS:Microsoft SQL 2000
GIS Server	web server, application server and ArcGIS server
Programming Language	ASP.net
Architecture: Client-Server	

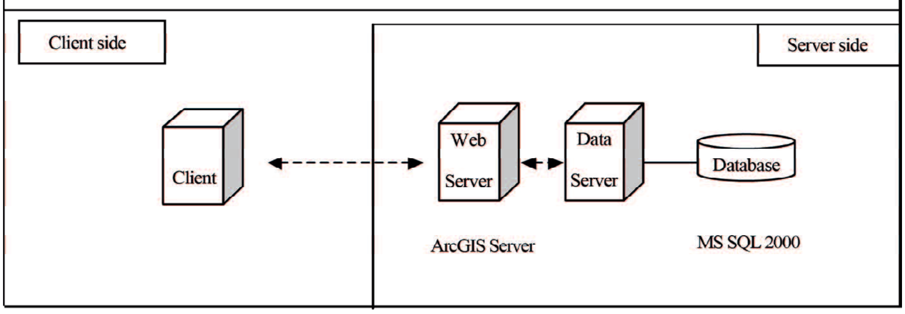


Figure 2.1 Architecture and system components of the current WebGIS system of DMR-Thailand

2.3 Problems of the current mineral information system of Thailand

DMR had deployed and setup a centralized database of geology and mineral resources since 2003. The system was developed by a private company. The government had allocated funds for development and maintenance of the centralized geo-database on geology and mineral resources in order to gather all departmental data. The main problem after the establishment of the information system was the difficulty in updating all feature classes information. Updating the software could not be done easily because of its rigid design. The database structure, did not improve consistently with rapid changes of information technology. DMR realizes that using commercial software is not sustainable due to cost constraints.

The current information system of Thailand faces various problems. The following is the summary of the problems.

1. Updating of all feature classes using web application is difficult.
2. Obtaining and using data from the database system is difficult.
3. Changing the structure of the database and tables is difficult.
4. Sharing geospatial data sharing among organizations is difficult.
5. Maintaining the information system is expensive.

These problems are caused by the following reasons.

1. Rigid design of web application and database system makes it not user friendly
   - Data updating involves inserting text by record or import a spreadsheet file (.xls) using a web application. This also involves the time consuming alteration of the spreadsheet columns to conform to the structure of the database.
   - The web application does not support data download capability.
   - Rigid database design is the main cause why the data in the database and the database structure are very difficult to update. This also prohibits the database to accommodate other geoscience data.
2. Lack of dissemination standard.
   - The difficultly in sharing geospatial data among organizations is due to the non compliance to interoperability standards.

- Limited budget

  Even though this web application requires improvement because of the aforementioned problems, it is not implemented because of lack of funds.

Thailand’s current database system uses MS SQL 2000. Updating information on the database is very difficult because of the rigid design of the web application and database model. The database system was also set up by a private company using commercial software making the maintenance of the system expensive.

The difficulty of sharing data among organizations using Thailand’s current WebGIS system is due to the fact that it does follow interoperability standard. It was developed by private company and uses commercial software hence upgrading to conform to some standards is expensive and difficult. To have a WebGIS system that is interoperable and cost effective, a new system should be developed using FOSS and OGC based web services.

Chapter 3

Current status of Spatial Information Technology

This chapter provides a brief review of the current status of spatial information technology, which is a key to the development of new geospatial information system proposed in this study. The chapter covers geographic information technology, geospatial data interoperability, Spatial Data Infrastructure (SDI), OGC web services and FOSS4G.

3.1 Geographic Information Technology

3.1.1 GIS and database

A Geographic Information System (GIS) is a computer-based mapping and analyzing tools for geographic phenomenon and events on Earth. GIS can store, manipulate and visualize geospatial data on computer. GIS technology integrates common database operations such as query and statistical analysis with the unique visualization and geographic analysis offered by maps [7]. GIS is very valuable to explain events, predicts outcomes, and plans strategies for a wide range of public and private enterprises.

Generally, a GIS includes four subsystems which are the data input, data storage and retrieval, data manipulation and data output. Data input is a function to capture, collect, and transform spatial and thematic data into digital format. Data storage and retrieval is a function to organize the spatial and attribute data. This function makes quick retrieval for analysis possible. Data manipulation and analysis function allows the user to define and execute spatial and attribute procedures to generate derived information. Data output is a function to generate graphic displays, normally maps, and tabular reports representing derived information products [7].

In GIS, geographic data is an abstraction of a real world phenomenon usually referenced in a coordinate system modeling a location on earth. The geographic data used in GIS is called as "geospatial data". The types of coordinate system are map projection and legal survey description. Map projection coordinates such as Universal Transverse Mercator (UTM) are measured in meters. Legal survey descriptions are composed of the Meridian, Township and Range such as the Alberta Township System. Geographic coordinates are usually referred by degrees, minutes, and seconds, but are sometimes identified as decimal degrees. There are three types of spatial data models which are the vector, raster and image in GIS. Vector and raster are two primary spatial data encoding techniques. Image data is useful to treat remotely sensed images. There are three major feature types which are the point, line and area. These are used to express all geographic features on the earth's surface. Point data expresses a feature with a single location in space. Line data shows a feature to be described by a string of spatial coordinates. Areal data indicates a feature to be described as polygon by a closed string of spatial coordinates [8].

Each geospatial feature yields attributes. Attribute data is stored internally, within the GIS software, or externally in a Database Management Software (DBMS), in which spatial data model is reflected. The most common data models for the storage and management of attribute data are "Relational" and "Object Oriented". Relational database model stores and manages data in tables. Table consists of columns and rows. Each row identifies to a separate spatial feature that consists of attributes or columns. Data is often stored in several tables. Tables can be joined or referenced to each other by common columns. Object Oriented database model stores and manages data through objects. An object is a collection of data elements in a table. The object-oriented database is a new model where querying is very natural, as features can be bundled together with attributes at the database administrator's discretion [8].

Geospatial data are commonly stored in geographical database using external DBMS with much more extensive querying and data integrity capabilities than the GIS internal relational data model [8]. External DBMS is a software package to set up, use and maintain a database. It supports to store and manipulate large data set, guard over data correctness, declare query language from computer program, ensure data availability using data backup and recovery, and provide concurrently the same dataset to many users [5].

Presently, GIS is basically information technology that relate with mapping and analysis tool. GIS has been widely used to store, manipulate and visualize geospatial data. There are many GIS software, either commercial or freeware, that users can selected. GIS is an effective tool used in various fields all over the world [9, 10, 11, 12].

3.1.2 WebGIS and its components

GIS has been used in stand-alone computers for a long time. However, recently users can choose a new type of GIS on the web. It is called WebGIS, a kind of distributed information system. WebGIS runs in web browsers using web technology, and serving desktop and mobile clients. The simplest architecture of WebGIS is composed of a server and a client (Two-tier). WebGIS application server, has a URL so that clients can find it on the web. The client is a web browser, desktop application, or a mobile application that relies on

HTTP specifications to send requests to the server. The server processes the requested GIS operations, and sends response in HTML format to the client again via HTTP. Many WebGIS applications consist of a client and a server, including a database at the server side (Three-tier) [13].

WebGIS has inherent advantages over its conventional desktop GIS counterpart. WebGIS could accommodate a large number of users, assures cross-platform capability, low cost, easy to use and provides unified update and diverse application. Users can access distant data and use the data using a computer with internet connection and a browser. Users can access WebGIS using web browsers running on diverse operating systems. WebGIS can provide various functions of GIS over the web. It can perform all GIS functions involving spatial information, including data capture, storage, editing, manipulation, management, analysis, sharing, and visualization. Thus, WebGIS is a very useful tool for government agencies and private sectors to disseminate and share geospatial information to the public.

3.2 Geospatial data interoperability

The development of web technology enables people to easily access geospatial data from different areas on Earth. There is an increase in demands to use geospatial data from the different servers for decision making. Interoperability of geospatial data is very important to use geospatial application on the web, where large amount of geographical data in different formats exist. Interoperability of geospatial data eliminates barriers for data sharing across organization, and allows users to directly access, map, visualize and analyze data in different spatial data formats. The approaches of data interoperability are database integration and standardization. Database integration approach is to provide user access to information sources. Standardization is to facilitate data exchange among different systems [14]. Presently, many standards have been developed to facilitate spatial data exchange on the web system such as Spatial Data Infrastructure (SDI), International Organization for Standardization (ISO) and OGC.

3.3 Spatial Data Infrastructure (SDI)

Spatial Data Infrastructure (SDI) is based on the collection of technologies, policies and institutional arrangements that facilitate the availability and access to spatial data [15]. It deals with sharing of spatial data between various geospatial information systems. Standards in SDI exist for all facets of GIS, ranging from data capture to data presentation and are developed by the ISO and OGC [5].

3.3.1 SDI architecture and components

An SDI architecture is usually conceptualized as a three-tier architecture [16]. The top layer resides the users and applications which provide access to geospatial content through either desktop or web client. The bottom layer serves as the geospatial content repositories where the spatial database server could also be found. The middle layer contains all services that assist the accessibility of the data repositories [15, 16] (Figure 3.1).

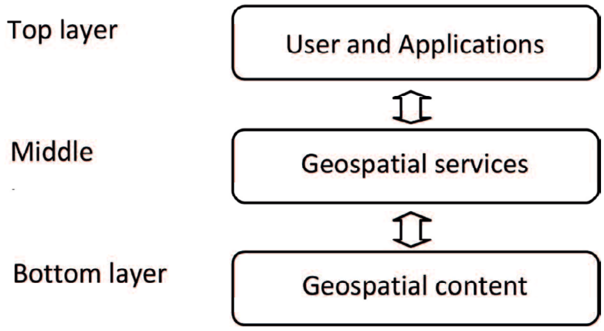


Figure 3.1 Three-tier architecture of SDI [15, 16]

An SDI provides its users with different facilities for finding, viewing, downloading and processing data over the internet as web based application. SDI functionality is provided by the so-called geo-web services, software that act as intermediate between geographic data (base), and the users of the web application. For spatial data handling online, these services commonly use standardized raster and vector representations following the ISO and OGC standards [5].

3.3.2 Standards used in SDI

Standard is a key requirement of the SDI, where component data resources and software systems are able to interoperate using well-defined and commonly supported open standards. SDI Standards are geospatial standards defined as a documented agreement between providers and consumers, established by consensus that provides rules, guidelines or characteristics in the creation of materials, products and services. The standards for geospatial information particularly define approaches, software interfaces or encodings for data. Software developers use these documents to build open interfaces and encodings into their products and services. The role of the international geospatial standards gradually become more important for quick identification and sharing of information across borders and organizations to provide economic stability to governments. Governments using the standards for interoperability between their departments need to develop a policy framework. International organizations such as ISO and OGC promote the development and management of the standards, and play important roles in the discussion involving the issues related to sustainability and interoperability [17].

International Organization for Standardization (ISO) is a non-governmental organization for the development and publication of international standards to facilitate the exchange of products and services by removing technical barriers to trade through the essential principles of global openness and transparency, consensus and technical coherence (ISO/TC). ISO/TC 211* develops a comprehensive set of standards for digital geographic information concerning objects or phenomena that are directly or indirectly associated with a location relative to the earth. These standards may specify, in the case of geographic information, methods, tools and services for data management (including definition and description), and the acquisition, processing, analysis, access, representation and transfer of such data in digital/electronic format between different users, systems and locations [17].

The Open Geospatial Consortium (OGC) is an international voluntary consensus standards organization organized in 1994 by the collaboration of more than 500 commercial, governmental, nonprofit and research organizations worldwide. Members collaborate in a consensus process encouraging development and implementation of open standards for geospatial content and services, GIS data processing and data sharing. OGC is harmonized with the works of other standard organization such as ISO/TC 211, OASIS** and the W3C*** to collaborate to integrate spatial data on the Web [18].

**: ISO/TC 211: Technical Committee on Geographic Information/Geomatics of ISO*

***: OASIS: Organization for the Advancement of Structured Information Standards, OASIS/TC e.g. Service Oriented Architecture*

****: W3C: World Wide Web Consortium, W3C Working Groups e.g. HTML, XML*

OGC provides technical documents that detail interfaces or encodings. Software developers use these documents to build open interfaces and encodings into their products and services. These standards are the main "products" of the OGC, and have been developed by the members to address specific interoperability challenges. When OGC standards are implemented in products or online services by different software engineers working independently, they work interoperable without further debugging [18].

3.4 Open Geospatial Consortium (OGC) based web services

Web services are self-contained, self-describing and modular breed of web application that can be published, located, included, discovered and invoked by other software across the web. A web service is an application that makes a function accessible using standard web technology following web services standards for data interoperability over the web. The web services concept is based on Services Oriented Architecture (SOA) paradigm where a complete application can be constructed from various service providing different functionalities. As SOA system, the fundamental concepts in web services are encapsulation, message passing, dynamic binding and service description and querying. Web service is publishing an Application Programming Interface (API) to communicate with other applications (and other web services) on the network and encapsulating implementation details using Hypertext Transfer Protocol (HTTP) and Extensible Markup Language (XML), which make web service to have interoperable capability for cross-platform, cross-language and integration of applications functionality [14, 19, 20].

Within the broader context of web services, OGC web services represent an evolutionary, standards-based framework that enables seamless integration of a variety of online geo-processing and location services. OGC web services allows distributed geo-processing systems to communicate with each other across the web using open non-proprietary internet standards like the WWW standards of HTTP (HyperText Transfer Protocol), Uniform Resource Locators (URLs), Multipurpose Internet Mail Extensions (MIME) types and the Extensible Markup Language (XML). The OGC web services provide a vendor-neutral, interoperable framework for web-based discovery, access, integration, analysis, exploitation and visualization of multiple online geo-data sources, sensor-derived information, and geo-processing capabilities. The OGC web services framework allows multiple services to be connected while at the same time allowing them to keep internal business logic independent. The OGC web services are a web of geo-processing services that can be connected in dynamic, open interoperable chains to create dynamic application. OGC provides web services specification standards as technical documents for developers to create application that makes clients to access and execute geospatial information from different sources across computing interfaces within an open information technology environment [19, 21]. The major web services specifications standards which are the Web Map Service (WMS), Web Processing Service (WPS) and Web Feature Service (WFS) are used in this study.

3.4.1 Web Map Service (WMS)

Web Map Service (WMS) implementation specification, published as ISO 19128, makes creating and displaying maps, that come simultaneously from various sources, in a standard image format possible. The WMS provides a simple HTTP interface for request on geo-registered map images from one or more distributed geospatial databases. The WMS request defines the geographic layer(s) and area of interest that will be processed by using a set of instructions in the form of Universal Resource Identifier (URI), consisting of the WMS Uniform Resource Locator (URL) and the request parameters. The response to the request is one or more geo-registered map images (returned as JPEG, PNG, etc.) or an XML documents that can be displayed by a web browser [22].

The WMS specification provides three operations which are GetCapabilities, GetMap, and GetFeatureInfo. Each operation is used in the distributed computing platform (DCP) comprising internet hosts that support HTTP URL (Table 3.1 and 3.2). The WMS specification defines different request URLs for each operation [22]. GetCapabilities operation enable clients to request a WMS server to show its mapping content, processing capabilities and response service metadata in a XML document. Table 3.3 shows the parameters needed for a WMS GetCapabilities request. GetMap operation enables client to send requests to multiple WMS servers to independently return a map. Table 3.4 shows the Parameters needed for a WMS GetMap request. GetFeatureInfo operation enables client to inquire metadata values of features represented in the picture of map. Table 3.5 shows the Parameters needed for a WMS GetFeatureInfo request [22].

Table 3.1 General reserved characters in OGC web services query string [22]

Character	Reserved usage
?	Separator indicating start of query string.
&	Separator between parameters in query string.
=	Separator between name and value of parameter.
,	Separator between individual values in list-oriented parameters (such as BBOX, LAYERS and STYLES in the GetMap request).
+	Shorthand representation for a space character.

Table 3.2 General structure of OGC web services request using HTTP GET (URL Prefix) [22]

URL component	Description
http://host[:port]/path[?{name[=value]&}]	URL prefix of service operation. [ ] denotes 0 or 1 occurrence of an optional part; {} denotes 0 or more occurrences.
name=value&	One or more standard request parameter name/value pairs as defined for each operation by this international standard.

Table 3.3 The parameters of needed for a WMS GetCapabilities request [22]

Request parameter	Mandatory/ Optional	Description
VERSION=version	O	Request version
SERVICE=WMS	M	Service type
REQUEST=GetCapabilities	M	Request name
FORMAT=MIME_type	O	Output format of service metadata e.g. MIME type “text/xml”
UPDATESEQUENCE=string	O	Sequence number or string for cache control

Table 3.4 The parameters needed for a WMS GetMap request [22]

Request parameter	Mandatory/ optional	Description
VERSION=1.3.0	M	Request version.
REQUEST=GetMap	M	Request name.
LAYERS=layer_list	M	The value of the LAYERS parameter is a comma-separated list of one or more valid map layer names.
STYLES=style_list	M	The value of the STYLES parameter is a comma-separated list of one or more valid style names.

Request parameter	Mandatory/ optional	Description
BBOX=minx,miny,maxx, maxy	M	Bounding box corners (lower left, upper right) in CRS units
CRS=namespace:identifier	M	CRS (Coordinate Reference System) or SRS (Spatial Reference System) is a horizontal coordinate reference system for the geographic information that serves as the source for a map. namespace prefix (CRS, SRS or EPSG), the colon, and a numeric or string code. For the example: EPSG:4326 refers to WGS 84 geographic latitude, then longitude
WIDTH=output_width	M	Width in pixels of map picture.
HEIGHT=output_height	M	Height in pixels of map picture.
FORMAT=output_format	M	Output format of map
TRANSPARENT=TRUE| FALSE	O	Background transparency of map (default=FALSE).
BGCOLOR=color_value	O	Hexadecimal Red-Green-Blue color value for the background color (default=0xFFFFFF).
EXCEPTIONS=exception_ format	O	The format in which exceptions are to be reported by the WMS (default=XML).
TIME=time	O	Time value of layer desired.
ELEVATION=elevation	O	Elevation of layer desired.
Other sample dimension(s)	O	Value of other dimensions as appropriate.

Table 3.5 The parameters needed for a WMS GetFeatureInfo Request [22]

Request parameter	Mandatory/ optional	Description
VERSION=1.3.0	M	Request version.
REQUEST=GetFeatureInfo	M	Request name.
map request part	M	Partial copy of the Map request parameters that generated the map for which information is desired.
QUERY_LAYERS=layer_list	M	Comma-separated list of one or more layers to be queried.
INFO_FORMAT=output_ format	M	Return format of feature information (MIME type).
I=pixel_column	M	i coordinate in pixels of feature in Map CS. The Map CS has a horizontal axis denoted i, and a vertical axis denoted j. The origin (i,j) = (0,0) is the pixel in the upper left corner of the map; i increases to the right and j increases downward.

Request parameter	Mandatory/ optional	Description
J=pixel_row	M	j coordinate in pixels of feature in Map CS.
FEATURE_COUNT=number	O	Number of features about which to return information (default=1).
EXCEPTIONS= exception_format	O	The format in which exceptions are to be reported by the WMS (default= XML).

When users submit URIs of WMS request over the web, WMS will be invoked. The requested server provides response format depending on request type. A map layer in WMS generally refers to a single file or a table in a database, and it may represent a number of features that have the same type of geometric and non-geometric properties. Different types of spatial data formats can be accepted behind the WMS, as user can access WMS server through a common interface over the web using a standard web browser**.** Different applications may publish their data with different format through WMS over the web. However, users of WMS can easily integrate and visualize these different data formats. Spontaneous access to different datasets at data servers of different locations is possible under WMS. WMS provides the foundation for users to easily access diverse remote geo-information through the web [14].

3.4.2 Web Processing Service (WPS)

Web Processing Service (WPS) defines rules for standardizing inputs and outputs (requests and responses) of geospatial processing services. Geospatial processes include any algorithm, calculation or model that operates on spatially referenced data. WPS interface standard defines how client can request the execution of a process and how the output from the process is handled. The WPS handles the spatial data (base) queries and defines interface for publishing of geospatial processes. The WPS is defined as online geo-processing services that enable clients to do one or more geo-processing of the provided layers underlying Application Programming Interface (API) at the portal. The WPS provides client access to pre-programmed calculations to discover and bind geospatial processing services. WPS provides a standard interface that simplifies the task of making simple or complex geospatial processing services using the Hypertext Transfer Protocol (HTTP). As WPS is based on a generic interface, clients can wrap it with other OGC web services to provide geospatial processing functions. For example, a data input for an intersection operation could be a polygon delivered in response to a WMS request, in which case the WPS data input would be the WMS query string. WPS assists much more the use of GIS functions (e.g. polygon intersection) on the web. WPS provides a robust, interoperable and versatile protocol for process execution of web services [23].

As WPS is a generic interface, WPS does not specify the specific processes that could be implemented by WPS. However, the specific processes and associated inputs and outputs of the supported processes could be published to the Service Registry. These processes can reduce the amount of programming required for the implementation of geospatial processing services that are used by other service developers. Each process must be specified in a separate document called an "Application Profile". An Application Profile consists of 1) an OGC URN (Uniform Resource Name) that uniquely identifies the process, e.g. OGC:WPS:somename (mandatory), 2) a reference response to a DescribeProcess request for that process e.g. input, input's data type, output, output's data type (mandatory), 3) a human-readable document that describes the process and its implementation (optional, but recommended), and 4) a WSDL (Web Services Description Language) description for that process (optional). WPS Application Profiles are used by Service Registries that maintain searchable metadata for multiple service instances [24, 25].

The WPS implementation specification provides three operations such as GetCapabilities, DescribeProcess and Execute operations. These operations can be requested by the client and performed by the server (Table 3.6). In **GetCapablilities operation**, clients can request and receive back service metadata documents describing the processes. **DescribeProcess operation** enable the clients to request and receive back detailed information about spatial processes. The processes include the input required parameters, allowable formats and the outputs that can be produced. **Execute operation** allows clients to run a specified spatial process implemented by the WPS. The Execute operation uses the input parameter values, and returns the produced outputs. Inputs can be included in the execute request, while the outputs can be returned as XML document that identifies the inputs and outputs. The XML document indicates whether or not the process is executed successfully, and contains a reference to the web-accessible resource, if it is successful [23].

Table 3.6 Example of WPS operation request [23]

WPS Operation	URL & Parameters of operation request for HTTP GET
GetCapabilities	http:// *URL prefix of service operation*? Service=WPS& Request=GetCapabilities& Versions=*1.x.x*&
DescribeProcess	http:// *URL prefix of service operation*? Service=WPS& Request=DescribeProcess& Version=*1.x.x*& Identifier= *Identifier name of process e.g. intersection, union*
Execute	http:// *URL prefix of service operation*? Service=WPS& Request=Execute& Version=*1.x.x*& Identifier= *Identifier name of process* & DataInputs= *List of inputs (optional)* ResponseDocument= *Response type e.g. BufferedPolygon (optional)*

3.4.3 Web Feature Service (WFS)

Web Feature Service (WFS) is an implementation specification, published as ISO 19142. WFS makes clients retrieve and update geospatial data encoded in GML (Geography Markup Language) from multiple WFSs. WFS defines interfaces for data access and manipulation operations on geographic feature from different sources. A transaction operation to insert, update or delete features is included in a Transaction WFS (WFS-T) [21, 26].

GML is an interchange format for geographic transactions on the internet developed by OGC and published as ISO 19136. GML is an XML encoding for geospatial information, provides different kinds of objects for describing geography including features and coordinate, and exchange spatial data among various computers using different software. Since XML is a universal format for structured documents and data on the web, it is easy to transform XML from one form to another [27]. GML provides the basis for Application Schemas, which support data interoperability within a community of interest [28]. Table 3.7 shows some public GML application schemas related to geology and mineral information.

Table 3.7 Example of the public GML application schemas [29, 30]

Public GML schemas	Description
GeoSciML or Geoscience Markup Language [29]	GeoSciML is a GML Application Schema that can be used to support interoperability of geologic information served from Geologic Surveys and other data custodians. The emphasis is on "interpreted geology" information that is conventionally portrayed on geologic maps. Its feature-type catalogue includes geologic units, mapped features, geologic structures, as well as earth materials (rocks and unconsolidated materials), and specializations of sampling features from the Observations and Measurements standard. Supporting resources such as vocabularies for geoscience terminology and timescales are developed in concert with the application schema.
EarthResourceML [30]	EarthResourceML is an XML-based data transfer standard for the exchange of digital information for mineral occurrences, mines and mining activity. The model describes the geological features of mineral occurrences, their commodities, mineral resources and reserves. It is also able to describe mines and mining activities, and the production of concentrates, refined products, and waste materials. EarthResourceML makes use of the existing GeoSciML data standard for describing geological materials associated with mineral deposits.

GML offers mechanism for linking multiple distributed resources into complex association using XLink (XML Linking Language) technology. XLink is a standard method to support hypertext referencing in XML. Through XLink technology in GML, WFS can link spatial feature from different sources. The data source from WFS can be updated automatically and immediately at the feature level over the web. The updated data is reflected in other related data sources or applications from WFS [14].

WFS provides transactions on and access to geographic features in a manner independent of the underlying “Data Store”. The Data Store represents a physical source of geospatial data as a database. It is used to store geographic features or layers which may be a table in a database or geospatial data file (Shapefile). The different geospatial feature formats are opaque to client application. The Data Store can transform those geospatial features into GML feature representation. Thus, the clients could access different geographic features through the WFS interface. Figure 3.2 shows the data retrieval process via a Data Store using WFS interface. When clients send their request in XML to WFS server using a URI, the WFS server process the request and send the response in GML back to the users [14, 31].

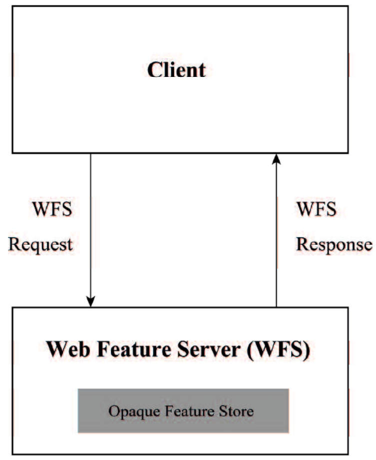


Figure 3.2 WFS interface [31]

WFS provides interface for five basic data manipulation operations on GML feature which are the Discover, Query, Locking, Transaction and Store Query operations. These operations make it possible for the users to access, query, create, update, and delete GML features over the web from WFS server. **Discovery operation** provides two kinds of services, such as the "GetCapability" and "DescibetFeatureTypes". The former determines the capabilities of WFS, and the latter describes the feature types to show how a WFS anticipates feature instances to be encoded on input and how feature instances to be encoded on output. **Query operation** can retrieve features or values of feature properties from the underlying Data Store through the "GetFeature" and "GetPropertyValue" requests. GetFeature returns to users a selection of features from a Data Store by using the query expressions, while GetPropertyValue brings a set of properties of the features in a Data Store. **Locking operation** allows exclusive access to features for the purpose of modifying or deleting feature. During one transaction access to a data item, this operation protects the other transaction to modify the same data. **Transaction operation** allows user to create, change, replace and delete from the underlying Data Store. **Stored query operation** allows users to create, drop, list, described and change parameterized query expressions through various query actions such as "CreateStoredQuery", "ListStoredQueries", "DescribeStoredQueries", and "DropStoredQuery". WFS manipulation in the feature-level data allows user to download only feature data of interest. Therefore, WFS is very useful for users to access specific data needed at the feature level from distributed sources. It can reduce the time needed on geospatial data acquisition and integration [26]. Table 3.8 shows the parameters used for WFS operation request.

Table 3.8 Parameter domains for WFS operation request [26]

Operation Name	Parameter Name	Description / Possible Values
All operations (except GetCapabilities)	version	The value type string e.g. "1.1.0", "1.0.0" or other vendor specific version number.
GetFeature, Transaction GetFeatureWithLock	srsName	List of CRS's that the WFS is capable of handling e.g. "EPSG:24047".
GetCapabilities	AcceptVersions	The value type string e.g. "1.1.0", "1.0.0" or other vendor specific version.
	AcceptFormats	The value MIME types e.g. "text/xml","text/html" or any other that the server support.
	Sections	The value type string e.g. "Zero", "ServiceIdentification", "ServiceProvider", "OperationsMetadata","FeatureTypeList", "Filter_Capabilities".
DescribeFeatureType	outputFormat	The value type string or MIME type that the server supports.
GetPropertyValue	outputFormat	The value type string or MIME type that the server supports.
	resolve	The value type string e.g. "none" and "local", "remote" and "all" indicating that the server can resolve remote resource references.
GetFeature	outputFormat	The value type string or MIME type that the server supports.
	resolve	The value type string e.g. "none" and "local", "remote" and "all" indicating that the server can resolve remote resource references.
GetFeatureWithLock	outputFormat	The value type string or MIME type that the server supports.
	resolve	The value type string e.g. "none" and "local", "remote" and "all" indicating that the server can resolve remote resource references.
CreateStoredQuery	language	The value indicating languages are supported.
Transaction	outputFormat	The value type string e.g. "none" and "local", "remote" and "all" indicating that the server can resolve remote resource references.
	vendorId	Any string that is used as a vendor identifier for the wfs:native element.

3.5 Free and Open Source Software (FOSS) for Geospatial

Free and open source software (FOSS) are computer software developed to be used free of charge. Free software means free to run, copy, distribute, study, change and improve the software [32]. The open source software are software with its source code made available and provide the right to study, use, change and distribute the software to anyone and for any purpose for free [33]. In contrast, proprietary software have restrictive copyright and hidden source code. The use of FOSS is cost efficient, improves security and stability, protects privacy and provides flexibility for users to control their own hardware. Recently, many software packages use free software and open-source licenses. For the example Linux and descendants of BSD are widely utilized FOSS operating systems.

FOSS is very important in the field of GIS. The Open Source Geospatial Foundation (OSGeo), a non-profit non-governmental organization, has been supporting and promoting collaborative development of open geospatial software. Free and open source software for geospatial data is called FOSS4G, which encompasses a broad range of applications involving the use of a combination of digital maps and georeferenced data. FOSS4G software is divided into four categories which are the geospatial library, desktop applications, web mapping (for server and client) and metadata catalog. Software in geospatial library includes GDAL/OGR (Geospatial Data Abstraction Library: geospatial data access library for read and write raster/vector format), GEOS (Geometry Engine - Open Source: for SQL spatial predicate functions and spatial operation), Geo Tools (Java code library which provides standards compliant methods for the manipulation of geospatial data), OSSIM (Open Source Security Information Management: for computer security), MetaCRS (a project encompassing several projections, and coordinate system related technologies e.g. PROJ.4, libproj, and libgeotiff), and PostGIS (spatial object for database). Well-known desktop applications include GRASS GIS, gvSIG, Marble, and QGIS (Quantum GIS). Applications of web mapping for server include MapServer, Geomajas, GeoServer and Degree. Applications of web mapping for client include GeoMoose Mapbender, MapGuide Open Source, MapFish and OpenLayers. GeoNetwork open source and pycsw comprise the Meta data catalog applications [34].

MapServer and GeoServer are the FOSS4G applications used in this study. MapServer is a FOSS for publishing spatial data and interactive mapping applications on the web. It was developed by the University of Minnesota (UMN) and initially released in 1994. It is written in C, and is spatially enabled internet application [35]. GeoServer is a Java-based software server that allows users to view and edit geospatial data. It allows users to display, share and edit geospatial data on the web. It is written in Java and built on GeoTools [36].

Chapter 4

New design of Thailand's geospatial information sharing system and system development method

4.1 Components and architecture

The new information sharing system focuses on the dissemination of geo-information using FOSS and OGC based standards and web services. SDI architecture is used by the Web-based GIS system. SDI architecture provides geo-web services linking the geo-database and user interface. This system could correct the weak points of the current DMR-Thailand WebGIS and ASEAN web-based mineral information system. It could be the template for the development of new web-based geospatial information sharing system of Thailand.

The new system uses an open source web-based database PostGIS. PostGIS is widely used software and a cost efficient alternative to proprietary software. PostGIS, which is an engine built upon the PostgreSQL object relational database management system (DBMS) software, handles geospatial data. PostgreSQL can handle large datasets effectively and allows the definition of access levels to databases and tables.

In order to solve the problem of current geo-information system, SDI architecture is applied to Web-based GIS system. Interoperability of geo-information is established by using OGC based web services WMS and WPS. User can display the request results either as maps or feature information. WMS enables users to create, share, gather and display geospatial data on the web portal. On the other hand, WPS enables users to search and access distributed geospatial information.

The newly proposed Thailand Web-based GIS system is setup using the data exchange protocol WFS, wherein clients can retrieve and update geospatial data from multiple data sources. Users can access the web services encoded in GML. Data encoded in GML could be easily transformed to another data formats.

Web application is user interface used to access data in the database. There are two user groups in the system which are the data developers (i.e. DMR's staff) and general users. Data developers are the ones who can upload, download, generate, edit and share the data using the web application. Meanwhile, general users are the ones who can access data in various formats on the internet. Thailand geo-information sharing system provides information to the public through the WebGIS Portal. The SDI architecture and system components of the proposed web-based geospatial information sharing system of Thailand using FOSS4G is shown in Figure 4.1.

This system is interoperable with other web-based information systems and applications that support standard web services via internet. It increases performance from three-tiers to multiple-tier (N-tier) by combining disparate locations of web services over the internet (mashup). The overview of Thailand's geospatial information dissemination system architecture is shown in Figure 4.2.

New Web-based geospatial information sharing system of Thailand

System Components	**Description**
Operating system	CentOS
Database Server	DBMS: PostGreSQL and PostGIS extension
GIS Server no.1	Apache web server, application server, and MapServer
GIS Server no.2	Apache web server, application server, and GeoServer
Programming Language	PHP, JavaScript

Architecture: SDI-Three-tier

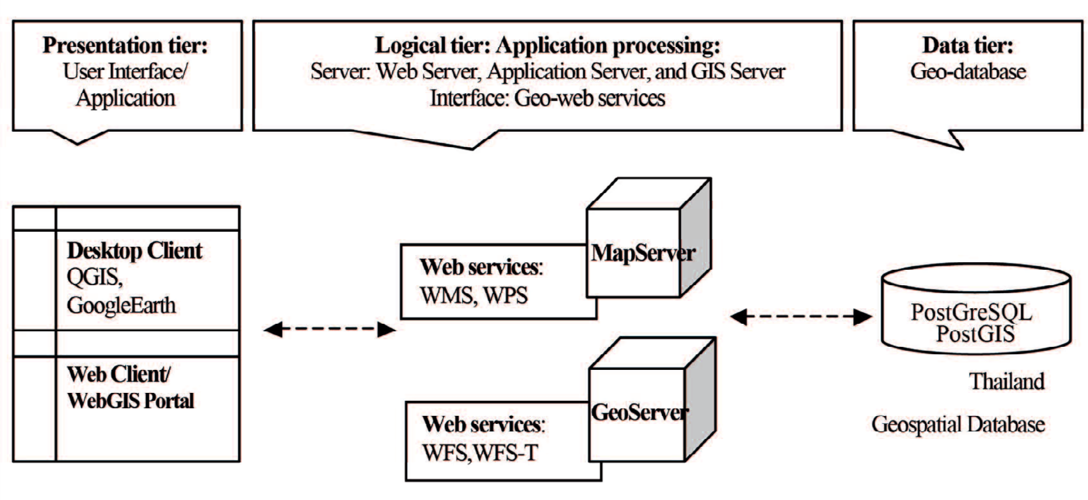


Figure 4.1 SDI architecture and system components of the proposed web-based geospatial information sharing system of Thailand using FOSS4G

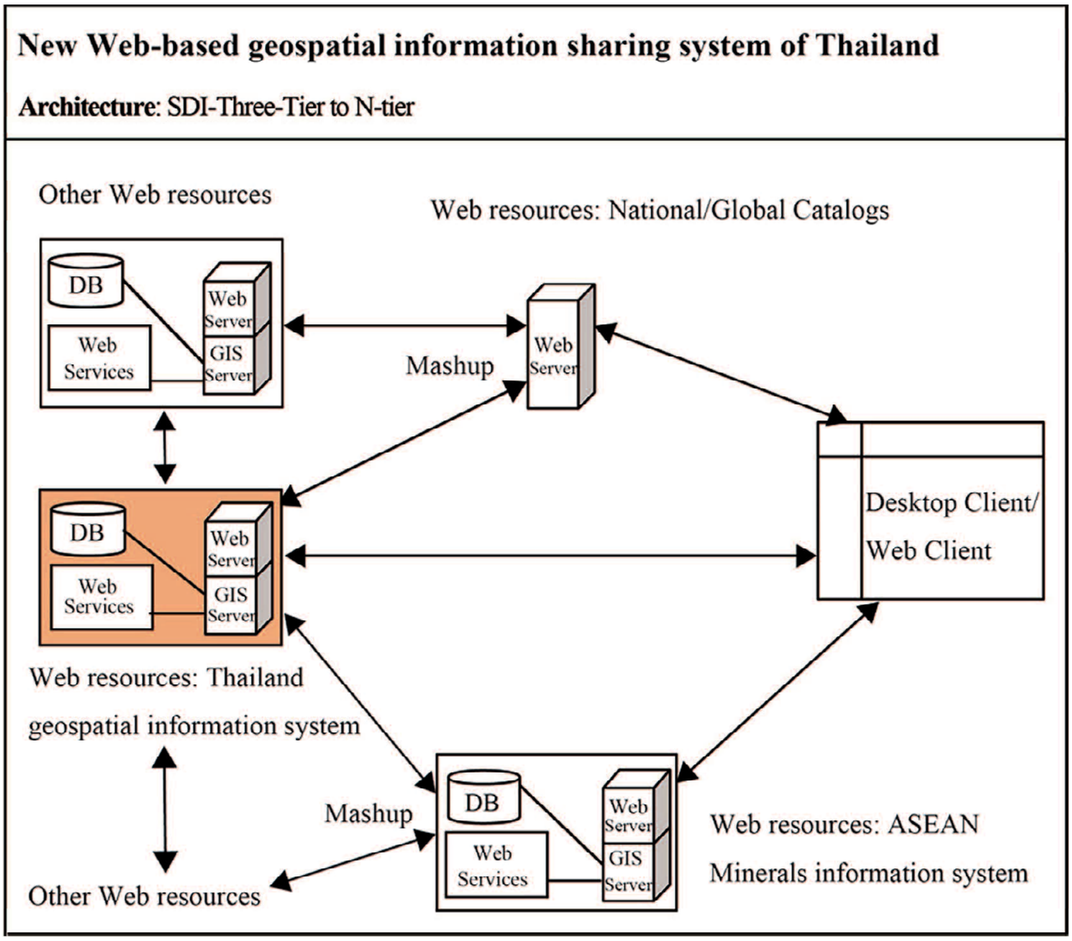


Figure 4.2 Overview of Thailand's geospatial information dissemination system architecture

4.2 System development method

The geospatial information sharing system of Thailand was developed following the method based on SDI architecture that consists of three components which are the geo-database, geo-web services and web application. The system development method in this study follows 3 processes which are the following:

1) Geo-database creation

- Installation of geo-database software on the server:
  PostGreSQL, PostGIS and PhpPgAdmin, PHP
- Formulation of web application form for inputting geospatial data into geo-database.

2) Geo-web services creation

2.1) Creating WMS and WPS

- Installation of web mapping server software on the server:
  Apache web server, MapServer and libraries.
- Creation of web form to formulate WMS
- Formulation of web application using OpenLayers API (Application Programming Interface) to display maps served as WMS online.
- Formulation of web application for WPS implementation to search and display maps served as WMS. This includes the use of WPS to download geospatial information in Shapefile and KML formats.

2.2) WFS and WFS-T formulation

- Installation of mapping server software on the server:
  GeoServer, Apache web server and libraries.
- Formulation of WFS and WFS-T using GeoServer Web Interface.
- Web application creation for searching geospatial data in GML format from WFS.
- Desktop client such as QGIS is used to view, create, edit and delete geospatial data in Shapefile format from WFS-T.

3) WebGIS portal Creation

- Creation of WebGIS portal using Joomla, a free and open-source content management system (CMS), to publish Thailand's geospatial web services (WMS, WPS and WFS). The portal is also used to combine web applications in a single site for the data developers (DMR's staff) and general users to easily access the services.

Chapter 5

Geospatial database

This chapter explains the distributed geospatial database system of Thailand. The discussion includes the procedure on how to create geospatial database and input the geospatial data into the database.

5.1 Creating geospatial database system

5.1.1 Geospatial database software and its installation

Geospatial database is a database that is optimized to store and query data that represents objects defined in a geometric space. Spatial database are available both in open source and proprietary software. PostGIS is the most popular open source database software. It is a good alternative to proprietary software like Oracle spatial and Microsoft SQL Server spatial. The Open Source Geospatial Foundation and several projects (e.g. [16, 37, 38]) set PostGIS as a core open source software component compliant with web mapping platform based on OGC standards. PostGIS is an extension of PostgreSQL database management system (DBMS) software that handles geospatial data. PhpPgAdmin is web-based user interface for managing PostgreSQL database. The newly proposed geospatial information system uses **PostgreSQL**, **PostGIS** and **PhpPgAdmin** for its database.

PostgreSQL is an open source object-relational database management system (ORDBMS), SQL compliant, has pluggable type extensions and highly scalable. It runs on all major operating systems including Linux, UNIX, and Windows OS. It offers high efficiency in handling large datasets and allows the definition of access levels to databases and tables. PostgreSQL also supports PostGIS extension plug-in as a spatial database for geographic object [39].

PostGIS is an open source software, released under the GNU-GPL (GNU General Public License). It is a spatially enabled PostGreSQL. PostGIS database is a PostGreSQL with Geometry and Spatial Reference System columns. PostGIS adds extra spatial object to the PostgreSQL database. Spatial object consists of spatial data types referring to geographic features (geometry, geography, raster and others). It includes functions, operators, and index that apply to these spatial data type. PostGIS supports simple feature defined by OGC and simple feature SQL. It could implement simple and complex spatial queries, and functionalities that are very important for handling geospatial data related information. PostGIS supports several third party open source and proprietary programs such as uDig, QGIS, ArcGIS, MapServer, GeoServer, ArcGIS Server etc [40].

PhpPgAdmin is a web-based administration tool written in PHP for managing PostgreSQL database. It is a web application that allows user to access PostgreSQL database using a browser. The web application provides functions for users to easily manage PostgreSQL database. PhpPgAdmin installation requires PHP, Apache and PostgreSQL on the server [41].

PostgreSQL, PostGIS and PhpPgAdmin are powerful database software packages that could be used for storing, querying and managing spatial data on distributed database system in this study. The following software are used to formulate Thailand's geospatial database system on the server. The software installation can be found in appendix A.

Server Side Software:

- Linux / CentOS (http://www.centos.org), operating system
- Apache web server (http://www.apache.org), web server
- PostgreSQL, (https://www.postgresql.org), database server
- PostGIS (http://www.postgis.org), spatial database extension
- PhpPgAdmin (http://phppgadmin.sourceforge.net), web-based administration tool for PostgreSQL.
- PHP (http://php.net), scripting language for web application.

5.1.2 Creation of geospatial database

Creating geospatial database is done using commands executed on the Linux console. A new database including spatial object features (PostGIS) and spatial reference system are created using commands shown in Figure 5.1.

```
Command1: Enter to the database system with user rights
#su – db_user_name
Command2: Create database
$/usr/local/pgsql/bin/createdb db_name
Command3: Install postgis.sql in folder of PostgreSQL install
$/usr/local/pgsql/bin/psql –f /usr/local/pgsql/share/contrib./postgis/postgis.sql –d  db_name
Command4: Install spatial_ref_sys.sql in folder of PostgreSQL install
$/usr/local/pgsql/bin/psql –f /usr/local/pgsql/share/contrib./postgis/spatial_ref_sys.sql –d  db_name
```

Figure 5.1 PostGIS commands for creating geospatial database

5.2 Inputting geospatial data into PostGIS database

5.2.1 Data set preparation

Geospatial data are information that describes either location or shape of all things on earth that are stored in a database. In this study, the original data were generated using GIS application software (e.g. QGIS, ArcGIS etc.). GIS software often handle data in Shapefile format (.shp). Shapefile is a popular geospatial vector data format because it can store the primitive geometric data types of points, lines, and polygons. Shapes (points/lines/polygons) together with data attributes can create infinitely many representations about geographic data. Data representation provides the ability for powerful and accurate computations. Shapefile consists of a collection of files with a common filename prefix stored in the same directory. The three mandatory files have filename extensions .shp, .shx, and .dbf. The actual Shapefile relates specifically to the .shp file, but is incomplete when used for distribution as the other supporting files are required [42]. Data in Shapefile format is used for creating a layer into the geospatial database in this study. Shapefile data used in this study are provided by the Mineral Resources Information Center of the Department of Mineral Resources of Thailand (DMR) (Table 5.1).

Table 5.1 Geospatial data used in this study

Set of Shapefile	Type	Description
minarea250k (.shp,.shx,.dbf)	Polygon	Thailand Mineral resources information, 1:250,000 scale
minoccur50k (.shp,.shx,.dbf)	Point	Thailand Mineral occurrence information, 1:50,000 scale
geology250k (.shp,.shx,.dbf)	Polygon	Thailand Geology information, 1:250,000 scale

5.2.2 Inputting Shapefile into PostGIS database

The original geospatial data was created by DMR’s geologists and DMR’s staff in Shapefile format. Tool for inputting the data to the database was developed in this study. The geospatial data are uploaded to the server and inputted into the PostGIS database system using a web application (Figure 5.2), which provides user friendly interface for inputting data. The web application was developed using PHP scripts and JavaScript. The web application is designed to input geospatial data into database by choosing a set of Shapefile (zip file) with their projections indicated by the European Petroleum Survey Group (EPSG) code. EPSG Geodetic Parameter Dataset is a collection of definitions of coordinate reference systems and coordinate transformations which may be global, regional, national or local in application [43]. The application will validate the Shapefile input whether it already exists as a layer (or table) in the database or not. After validation, the Shapefile will be inputted into the database using the PostGIS command "shp2pgsql". This command is an Extract Transform Load (ETL) tool used for loading Shapefile to PostGIS database as described in Figure 5.3.

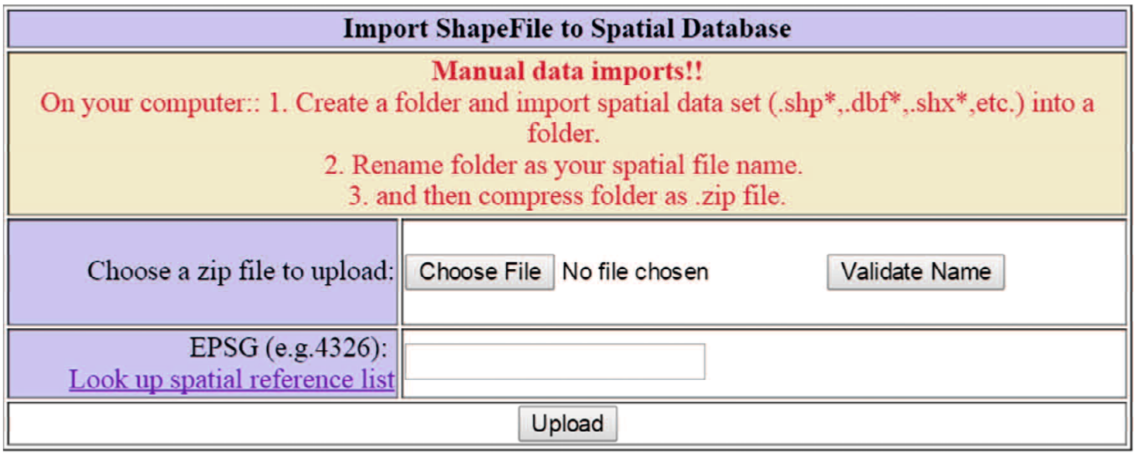


Figure 5.2 Web application for inputting Shapefile into PostGIS database

Command1: Transform Shapefile to sql file format

$/usr/local/pgsql/bin/shp2pgsql -W encoding -s epsg shape_file_name table_name database_name>sql_file_name

Command2: Import sql file into database

$/usr/local/pgsql/bin/psql -U database_user_name -d database_name -f sql_file_name

Figure 5.3 PostGIS commands for loading Shapefile to PostGIS database

5.3 Geospatial data on PostGIS database

Each map in the PostGIS database is stored as table. A table consists of attribute data and geometry column. PostGIS uses OGC's Well-Known Text (WKT) and Well-Known Binary (WKB) to represent geometry in SQL. WKT and WKB express spatial object in human and machine readable formats, respectively. WKB uses less time for CPU (Central Processing Unit) processing which makes database faster and lightweight. In PostGIS database, geometry is stored in WKB [44]. Figure 5.4 shows the transformed Shapefile (minoccur50k.shp) in PostGIS database table (minoccur50k) using the phpPgAdmin web application.

phpPgAdmin: PostgreSQL?: wmsdmr?: public?: minoccur50k?:

Browse

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 Next > Last >>

Actions		gid	m_occur_id	name_e	comm_name	comm_symbo	tam_nam_e	amphoe_e	prov_nam_e	geom
Edit	Delete	1	597.00000000	Pa Pae7	Tin	Sn	Pa Pae	Mae Taeng	Chiang Mai	0101000020EF5D0000701B0D2057541C41D456ECFF3C304041
Edit	Delete	2	598.00000000	Pa Pae8	Tin	Sn	Pa Pae	Mae Taeng	Chiang Mai	0101000020EF5D000020C05B6059221C41E4361A00A1304041
Edit	Delete	3	599.00000000	Pa Pae9	Tin	Sn	Pa Pae	Mae Taeng	Chiang Mai	0101000020EF5D0000D088D29ECF591C4194D40900492E4041
Edit	Delete	4	600.00000000	Pa Pae10	Tin	Sn	Pa Pae	Mae Taeng	Chiang Mai	0101000020EF5D0000E0240601A91D1C4100000000273C4041
Edit	Delete	5	601.00000000	San Maha Phon	Clay	Cly	San Maha Phon	Mae Taeng	Chiang Mai	0101000020EF5D000070128300AF311E41B88D0600B7244041
Edit	Delete	6	602.00000000	Sop Pong	Antimony	Sb	Sop Pong	Pang Ma Pha	Mae Hong Son	0101000020EF5D000020C9E53F6FDF19411CC9E5FFB15B4041
Edit	Delete	7	603.00000000	Pha Bong	Antimony	Sb	Pha Bong	Muang Mae Hong Son	Mae Hong Son	0101000020EF5D00007024973F60F617411CC9E51F06354041
Edit	Delete	8	604.00000000	Pong Sa1	Tin	Sn	Pong Sa	Pai	Mae Hong Son	0101000020EF5D0000E0361AC0FED41B4100000000C4264041
Edit	Delete	9	605.00000000	Pong Sa2	Tin	Sn	Pong Sa	Pai	Mae Hong Son	0101000020EF5D000090F6069F07AA1B41B49DEFFF8E1A4041
Edit	Delete	10	606.00000000	Muang Pang1	Tin	Sn	Muang Paeng	Pai	Mae Hong Son	0101000020EF5D0000001214BFD89E1A4124B9FCFF6D224041
Edit	Delete	11	607.00000000	Muang Pang2	Tin	Sn	Muang Paeng	Pai	Mae Hong Son	0101000020EF5D0000D0915C3EE8AC1A41701B0D002C234041
Edit	Delete	12	608.00000000	Muang Pang3	Fluorite	Fl	Muang Paeng	Pai	Mae Hong Son	0101000020EF5D0000D076BE9FA1031B4190E4F2FFB5394041
Edit	Delete	13	609.00000000	Pong Sa3	Fluorite	Fl	Pong Sa	Pai	Mae Hong Son	0101000020EF5D000060643B9FA01C1B4188F4DBFF5E3B4041
Edit	Delete	14	610.00000000	Pong Sa4	Fluorite	Fl	Pong Sa	Pai	Mae Hong Son	0101000020EF5D0000A09BC4209B201B412CA9130090374041
Edit	Delete	15	611.00000000	Muang Pang4	Fluorite	Fl	Muang Paeng	Pai	Mae Hong Son	0101000020EF5D000030772D61D79E1A41C07D1D00BC384041
Edit	Delete	16	612.00000000	Muang Pang5	Fluorite	Fl	Muang Paeng	Pai	Mae Hong Son	0101000020EF5D000090F6069FD8D01A4188F4DBFFA1344041
Edit	Delete	17	672.00000000	Pa Sak1	Gold	Au	Pa Sak	Wang Chin	Phrae	0101000020EF5D000038894140CFBA2041E0361AE05B0D3E41
Edit	Delete	18	67301.00000000	Sroi6	Barite	Brt	Saroy	Wang Chin	Phrae	0101000020EF5D000050499DC07FBF2041A8A44E206C023E41
Edit	Delete	19	67401.00000000	Pa Sak9	Barite	Brt	Pa Sak	Wang Chin	Phrae	0101000020EF5D0000C876BE9FF7C42041701B0DE0E3073E41
Edit	Delete	20	675.00000000	Sroi1	Gold	Au	Saroy	Wang Chin	Phrae	0101000020EF5D00003892CBDF478E2041C86D340054ED3D41
Edit	Delete	21	676.00000000	Prabat Wang Tuang1	Gold	Au	Phra Bat Wang Tuang	Mae Phrik	Lampang	0101000020EF5D0000504013A1D0601F41E0361A20305D3D41
Edit	Delete	22	681.00000000	Mae Prik1	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D0000D088D2DE45281F4198C420A033593D41
Edit	Delete	23	682.00000000	Mae Prik2	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000020C05BE0842A1F41B88D06209C563D41
Edit	Delete	24	683.00000000	Mae Prik3	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000020C9E5FF83131F4190E4F25FFD5C3D41
Edit	Delete	25	684.00000000	Mae Prik4	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000010B7D1C041181F41701B0D206D603D41
Edit	Delete	26	685.00000000	Mae Prik5	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000030894160F8241F41A8ADD87FAB5E3D41
Edit	Delete	27	686.00000000	Mae Prik6	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D0000505BB1BFC5221F415852274069623D41
Edit	Delete	28	687.00000000	Mae Prik7	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000090D2DEE0111D1F4130B29D1F96653D41
Edit	Delete	29	688.00000000	Mae Prik8	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D0000505227E0432C1F41E0361A00FF683D41
Edit	Delete	30	689.00000000	Mae Prik9	Gold	Au	Mae Phrik	Mae Phrik	Lampang	0101000020EF5D000020C05BA029411F4110E02D003B693D41

Figure 5.4 Example of Thailand mineral occurrence data in PostGIS database

The table of Thailand mineral occurrences (minoccur50k) consists of the attribute columns m_occur_id (ID number), name_e (location name), comm_name (commodity name), comm_symbo (commodity symbol), amphoe_e (district name), prov_nam_e (provincial name) and geom (geometry).

Chapter 6

Formulating Web Map Service

and Web Processing Service

The newly proposed geospatial information system creates geospatial content on the web, using FOSS and OGC based web services and standards such as Web Map Service (WMS) and Web Processing Service (WPS). This chapter will explain the WMS and WPS formulation techniques and WebGIS configuration for a quick and easy map rendition and data sharing. It is divided into four sections, which are 1) WMS and WPS in WebGIS, 2) Setting up of WMS and WPS Servers, 3) WMS formulation, and 4) WPS formulation.

6.1 WMS and WPS in WebGIS

The SDI architecture is followed in the creation of the new Web-based GIS system of Thailand. WMS and WPS, referred to Geo-Web Services, are the OGC based web services that are used in the system. Geo-web services are activated after receiving the requests from the web application component and implement them on the geo-database. Figure 6.1 shows the WMS and WPS components of the WebGIS.

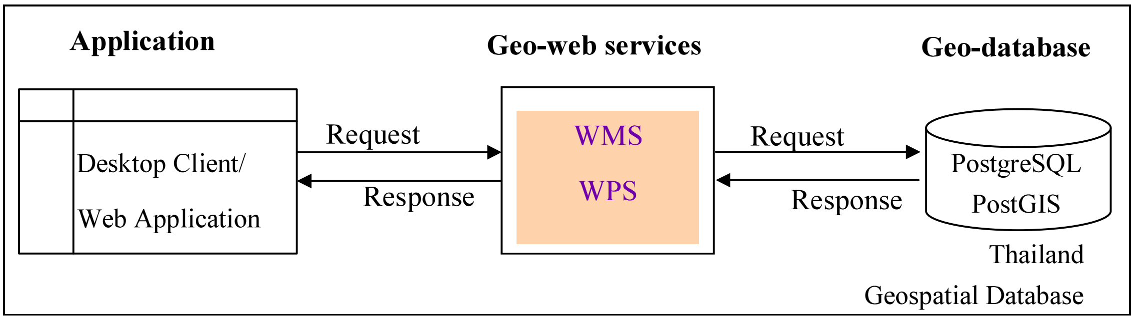


Figure 6.1 WMS and WPS components of the WebGIS following the SDI architecture

6.2 Setting up of WMS and WPS Servers

WMS and WPS are formulated using MapServer software in this study. MapServer is a popular open source web mapping software to display spatial data and query spatial databases over the internet. It supports OGC specifications such as WMS and WPS. In its most basic form, MapServer is a CGI program (mapserv.exe) that sits inactive on a web server. When a request is sent to MapServer, it uses information passed through a Universal Resource Identifier (URI) and Mapfile to create an image of the requested map. The request may also return images for legends, scale bars, reference maps based on the values of the parameters in Mapfile passed as CGI variables [35].

Uniform Resource Identifier (URI) consists of the WMS Universal Resource Locator (URL) and the request parameters. This URI is used to identify a resource on the WMS server. The syntax of generic URIs is “http://host:port/path?query_string#attribute”. When clients send the request through URI, Common Gateway Interface (CGI) program will be activated. CGI is a software for interfacing external application and web servers. CGI program, installed on a server, generates web pages dynamically. The request will be sent through Apache web server and MapServer which the CGI program used to generate dynamic output. MapServer uses a Mapfile, a structured text file (.map) for data access and styling. Mapfile provides MapServer information on how to query the database and where to output the map images. Mapfile is made up of different objects such as map object, layer object, class and style object etc. Each object has a variety of parameters. Parameters may define map coverage area, data type, data source, symbology etc. MapServer responses output through MapServer CGI variables that can refer to the parameters in Mapfile. Thus, Mapfile is used by MapServer to create the map over the internet. MapServer also can be customized using HTML template or Mapscripts. The template is an interface of data defined in the Mapfile. The template can define what data the user want to present to the client web browser and how to view the data through CGI variables. Template could be written in many languages (e.g. HTML, PHP, Javascript, Openlayers etc) [35]. The WMS and WPS server architecture is shown in Figure 6.2.

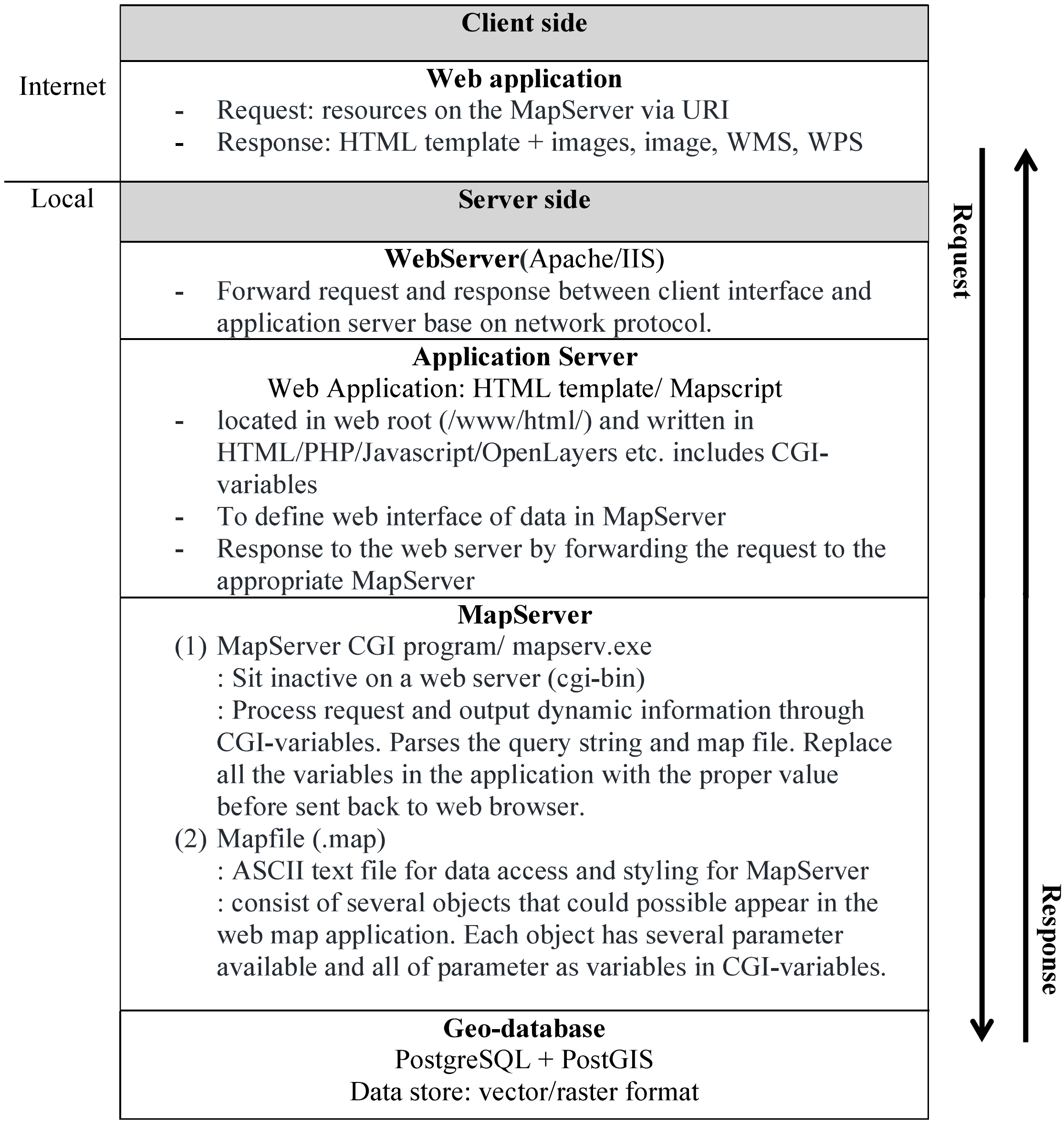


Figure 6.2 WMS and WPS server architecture

The new geospatial information system of Thailand uses FOSS for the geospatial applications. The WMS and WPS are formulated on a server running under Linux OS (CentOS), Apache web server, PostgreSQL, PostGIS and phpPgAdmin. The major software installed in the server includes MapServer and the needed libraries. The following is the complete list of libraries used for MapServer installation. The procedure for MapServer software installation can be found in Appendix A.4.

Server side:

- UMN MapServer (http://mapserver.org), map server software
- libproj, geospatial library that provides projection support
- libcurl, geospatial library foundation of OGC (WFS/WMS/WCS) that provides client and server support
- GDAL, geospatial data library that provides access to raster formats
- OGR, geospatial data library that provides access to data in vector formats
- OpenLayers JavaScript Library (http://openlayers.org), web client/user interface

Client side:

- Internet browsing software, web services visualization
    - Google Chrome, Moszilla FireFox, etc.
- GIS Application software, map visualization
    - QuantiumGIS (http://www.qgis.org), used for shape file and WMS Viewer
    - GoogleEarth (http://earth.google.com), used as KML file Viewer

6.3 WMS formulation

6.3.1 Methodology for WMS formulation

In order to formulate WMS, Mapfile is created based on the WMS request (e.g. GetMap, GetCapabilities, GetFeatureInfo). Some map parameters and metadata entries are mandatory in the Mapfile. Most of the metadata are required in order to produce a valid GetCapabilites output while others are required to have a valid GetMap output. Figure 6.3 shows the list of parameters in Mapfile as required for WMS configuration [35]. An example of Thailand mineral area Mapfile can be found in Appendix B.

At the MAP level (Object) :
Map Parameter:

- *NAME (Map name)*
- *EXTENT (output extent in the units of the output map)*
- *PROJECTION (object)*
    - *"init=epsg:_"*
- *OUTPUTFORMAT (object)*
    - *DRIVER ""*
    - *MIMETYPE ""*
    - *EXTENSION ""*
- *METADATA(object):*
    - *wms_title*
    - *wms_onlineresources*
    - *wms_srs (unless PROJECTION object is defined using "init=epsg:…")*
    - *wms_enable_request*

For each LAYER (Object) :
Layer parameter:

- *NAME (Layer name)*
- *METADATA (object)*
    - *wms_title*
    - *wms_srs (optional since the layers inherit the map's SRS value)*
- *DATA (data source)*
- *TYPE (POINT/LINE/POLYGON/RASTER etc.)*
- *STATUS*
    - *Layers set to STATUS DEFAULT will always be sent to the client.*
    - *Layers set to STATUS ON or STATUS OFF can be requested by the client.*
- *PROJECTION (object)*
    - *"init=epsg:_"*
- *TEMPLATE (required for GetFeatureInfo requests)*

For each CLASS (Object)

- *CLASSITEM (attribute within the layer)*
- *Expression (to specify to which features of the dataset the CLASS applies to)*

STYLE (Object) *(to style objects within the class)*

- *Color, outlinecolor, width, symbol, size*

END (Style object)
END (Class object)*…*
END (Layer object)*…*
END (Map object)

Figure 6.3 Parameters on Mapfile as required for a WMS configuration [35]

The parameters will be used by WMS request like GetMap. The GetMap is widely used to retrieve map image for a specified area and content using a web browser. Figure 6.4 indicates an example of GetMap request URI to display the mineral areas in Thailand and Figure 6.5 shows the result of the GetMap request.

http://wms4.dmr.go.th/cgi-bin/dmr_wms/minarea250k_wms?
REQUEST=GetMap&SERVICE=WMS&
VERSION=1.1.1&LAYERS= minarea250k&FORMAT=image/png&SRS=EPSG:24047
&BBOX=326161.25,620586,1265975.625,2265905.5&WIDTH=500&HEIGHT=700

Figure 6.4 Example of GetMap request URI to display the mineral areas in Thailand

Figure 6.5 WMS GetMap response

The GetCapabilities is a WMS request to retrieve an XML document with metadata of the map and the service. The metadata includes supported projections, map extent, available layers, data owner and additional information in the abstract and usage constraints. Figure 6.6 shows an example of GetCapabilities request URI to get information about WMS of the mineral areas in Thailand, and Figure 6.7 shows the result of GetCapabilities request.

http://wms4.dmr.go.th/cgi-bin/dmr_wms/minarea250k _wms?
SERVICE=WMS&VERSION=1.1.1&REQUEST=GetCapabilities

Figure 6.6 Example of GetCapabilities request URI to get information about the WMS of the mineral areas in Thailand

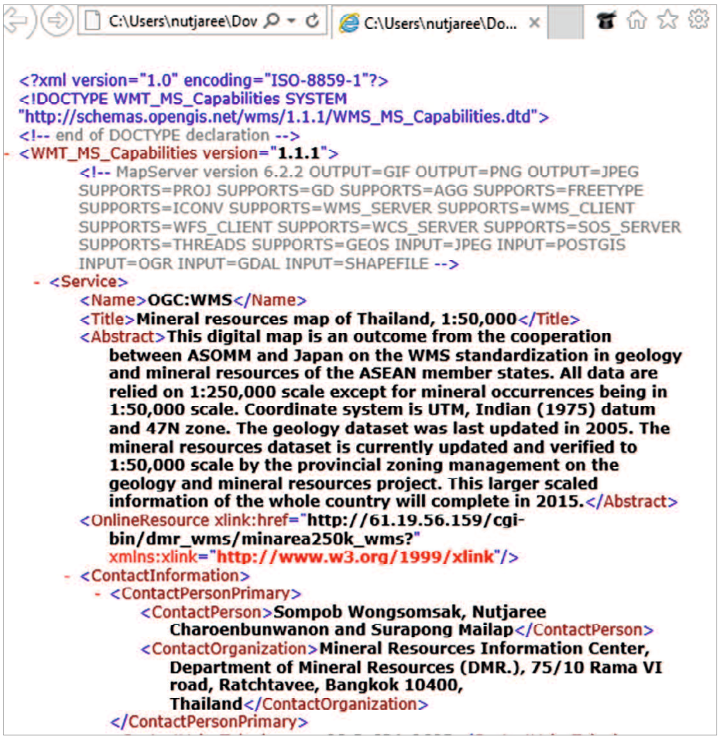


Figure 6.7 WMS GetCapabilities response

Other optional WMS requests are GetFeatureInfo, DescribeLayer, and GetLegendGraphic. GetFeatureInfo returns information about feature(s) at a query (mouse click) location. DescribeLayer returns an XML description of one or more map layers. GetLegendGraphic returns a legend image (icon) for the requested layer [35].

OpenLayers is an open source software used as WMS client. It has JavaScript mapping library constructors used to display results from WMS request. It provides Graphic User Interface (GUI) for implementing WMS requests and viewing results like map images and tables in XML format [45]. OpenLayers is used to render GetMap response covering the mineral resource area, mineral occurrences and geological maps of Thailand in map images. It is also used to retrieve the GetFeatureInfo response for the mineral resource and reserve information in tabular form. Figure 6.8 shows an example of a simple HTML document, which shows OpenLayers used to display the map and feature information. Figure 6.9 shows the result of WMS GetMap and GetFeatureInfo using OpenLayers.

```
<html><head>
<script src="http://openlayers.org/api/OpenLayers.js"></script></head><body>
//Display map
<div style="width:100%; height:100%" id="map"></div>
var map =new OpenLayers.Map('map');
var basemap = new OpenLayers.Layer.Google(
                "Google Physical",{type: google.maps.MapTypeId.TERRAIN}
var wms = new OpenLayers.Layer.WMS(
        "Map_Layer_title","wms_service_url",
        { layers: "layer_name", transparent: "true",format: "image/png"},
        {isBaseLayer: false});
map.addLayers([basemap, wms]);
//Display feature information
featureInfoPicker = new OpenLayers.Control.WMSGetFeatureInfo({
        url: ' wms_service_url ',title: 'identify features on click',queryVisible: true});
featureInfoPicker.events.register("getfeatureinfo", this, show_feature_info);
        map.addControl(featureInfoPicker);featureInfoPicker.activate();
 function show_feature_info(event)
        {if (event.text=="") return; if (popup != null) { popup.destroy(); popup = null;}
        popup=new
        OpenLayers.Popup.FramedCloud
        ("chicken",map.getLonLatFromPixel(event.xy),null,event.text,null,true);
        map.addPopup(popup);} map.addPopup(popup); }
</body></html>
```

Figure 6.8 Example of a simple HTML document using OpenLayers

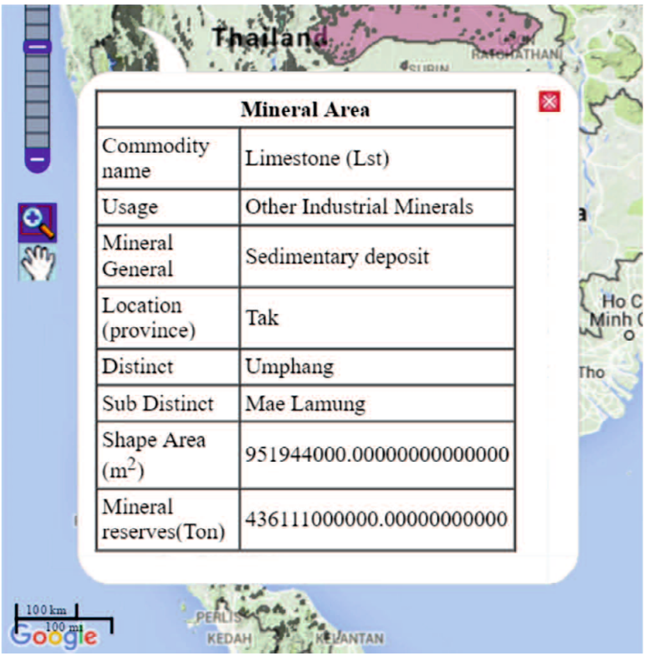


Figure 6.9 WMS GetMap and GetFeature responses using OpenLayers

6.3.2 Generating WMS and web map viewer using a web application

This study develops the web mapping application for easy formulation of WMS and a web map viewer to render the map online. This web mapping application could be used to develop a customized WMS based data sharing system. Web mapping application is developed using JavaScript and PHP to incorporate FOSS based software into one composite application. Google Maps and OpenLayers APIs are widely used to render the maps online. JavaScripts is used to incorporate Google Maps and OpenLayers, which provide functions for graphic display of spatial data. The web mapping application provides user-friendly interface and forms that data developers can use to easily formulate WMS and to display the request results either as maps or feature information.

To generate WMS and web map viewer from geospatial data, the functions of web mapping application are following three major processes.

1) Establishing distributed geospatial data that any application can access and retrieve. The web mapping application supports to import geospatial data into PostGIS (see chapter 5).

2) Establishing WMS services that make geospatial data interoperable. The web mapping application can make Mapfile and WMS script file.

3) Establishing web map viewer that user can easily use to display the request result either as maps or feature information. The web mapping application produces HTML template.

The concept of developing web mapping application for WMS formulation and viewing maps online is shown in Figure 6.10. The web mapping application for formulating WMS, and making map viewer uses OpenLayers to displays the map and feature information in response to the GetMap and GetFeatureInfo requests, respectively (Figure 6.11).

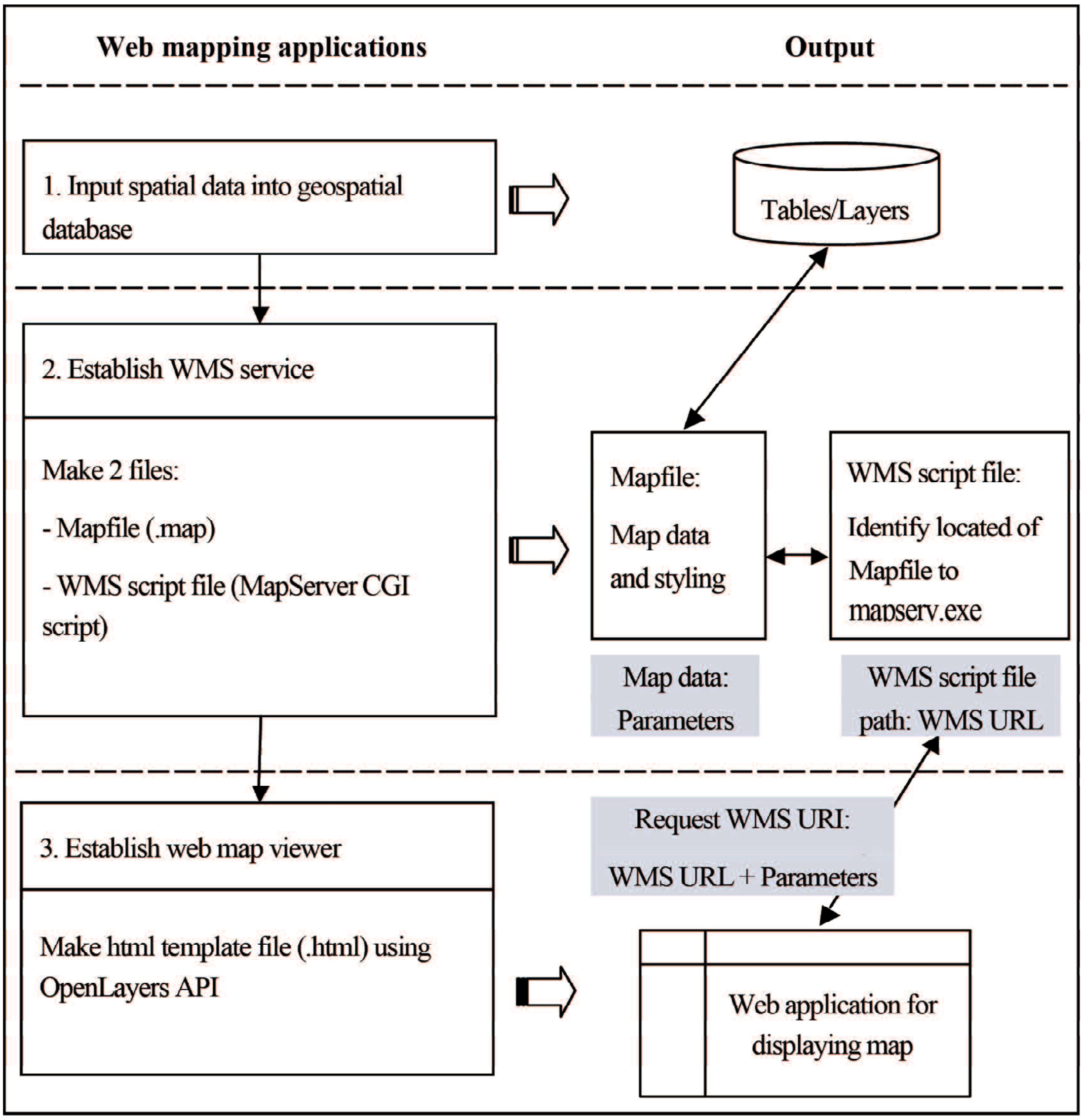


Figure 6.10 Concept of developing web mapping application for WMS formulation and viewing maps online.

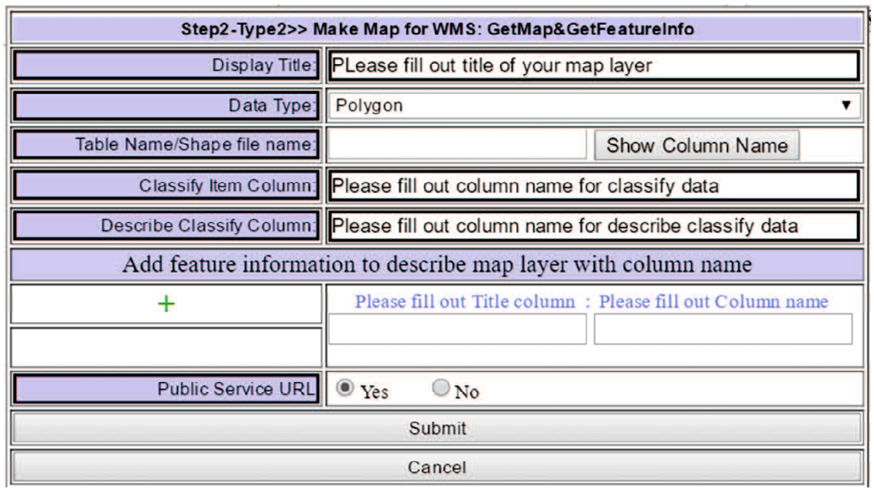


Figure 6.11 Web mapping application for formulating WMS and making web map viewer

Filling up and submitting the web mapping form would automatically generate the WMS of the map and the HTML document with the imbedded OpenLayers that automatically displays the map online (Figure 6.12). The resulting HTML page will serve as GUI providing tools to control how the map is viewed such as zooming in, zooming out and panning. OpenLayers is used to display the map and feature information of the selected polygon (Figure 6.13). The list of DMR WMSs is shown on the WMS data service page (Figure 6.14). The page consist of WMS URL, Layer name, URL of the HTML page using OpenLayers to display map and feature information, WMS GetCapablities and GetMap links. Users could use the WMS URL and layer name to display the map using other application.

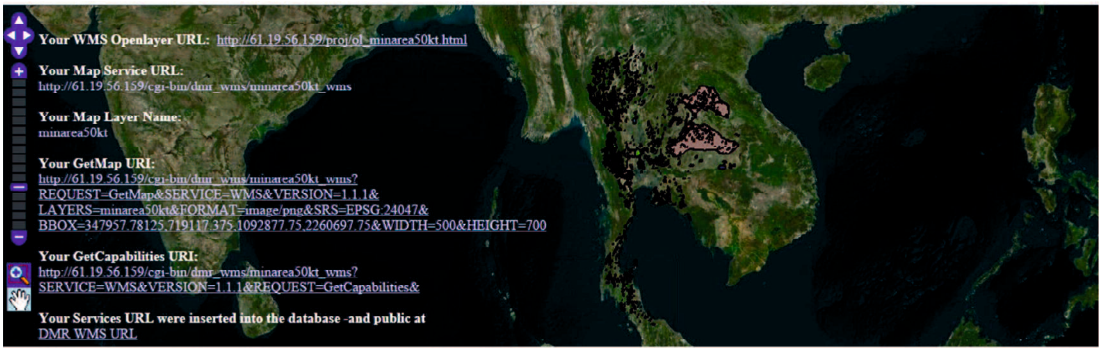


Figure 6.12 Page generated after submitting the WMS generation form

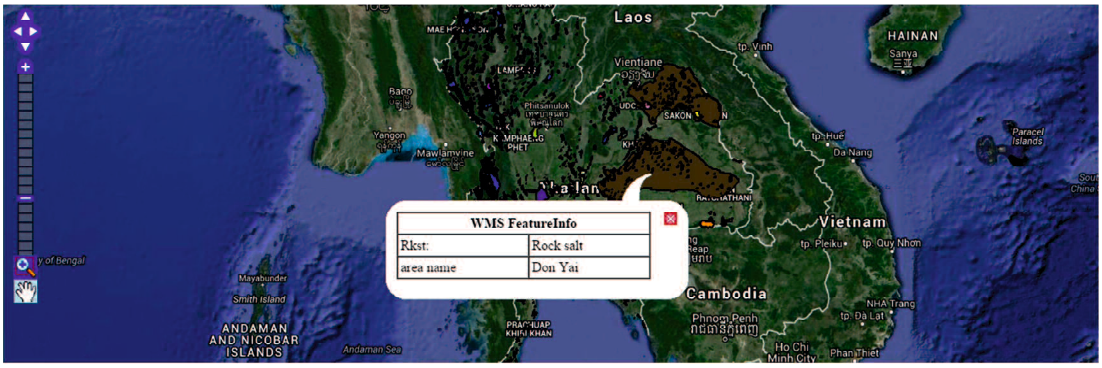


Figure 6.13 Page generated displaying the map and feature information using OpenLayers

wms4.dmr.go.th/proj/showwmsurl.php

List of all DMR WMS URL

Title	WMS URL	Layer Name	WMS Openlayer URL	GetCapabilities	GetMap
Thailand Mineral Occurence	http://wms4.dmr.go.th/cgi-bin/dmr_wms/minoccur250k_wms?	minoccur250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap
Thailand Mineral Area	http://wms4.dmr.go.th/cgi-bin/dmr_wms/minarea250k_wms?	minarea250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap
Thailand Geology	http://wms4.dmr.go.th/cgi-bin/dmr_wms/geology250k_wms?	geology250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap

Figure 6.14 WMS data services page

6.3.3 Generating web map viewer to view maps served as WMSs

The web mapping application could also be used by data developer to generate web map viewer to render available maps served as WMSs that are published online. The web map viewer can be customized for displaying a map or multiple maps using OpenLayers by inputting the WMS URL and layer name into the form (Figure 6.15). Filling up and submitting the form would automatically generate the HTML document with the imbedded OpenLayers that automatically display the map online. The template is capable of displaying one or multiple maps and also provides option to execute GetFeatureInfo request. Figure 6.16 shows the web map viewer displaying multiple map layers.

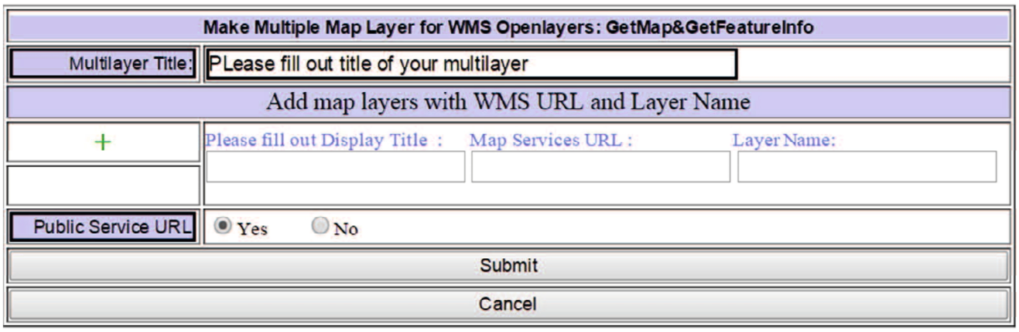


Figure 6.15 Web mapping application used generate web map viewer for viewing maps served as WMS

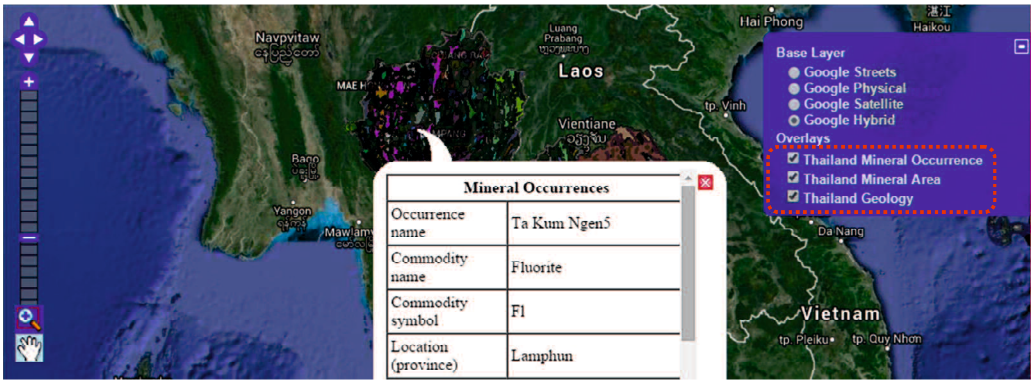


Figure 6.16 The web map viewer displaying multiple map layers

Users can also display multiple maps by entering their WMS URLs and layer names using the web application's form into the form as shown in Figure 6.17. The left side of the application's user interface provides the form to input the maps's WMS information. It also provides controls to delete, hide, show and adjust the opacity of the selected map. The right hand side provides the space to display the map and the feature information, including the control to choose the base map layer to display. GetFeatureInfo request can be implemented in this section to retrieve the layer attributes information by double clicking a point on the map.

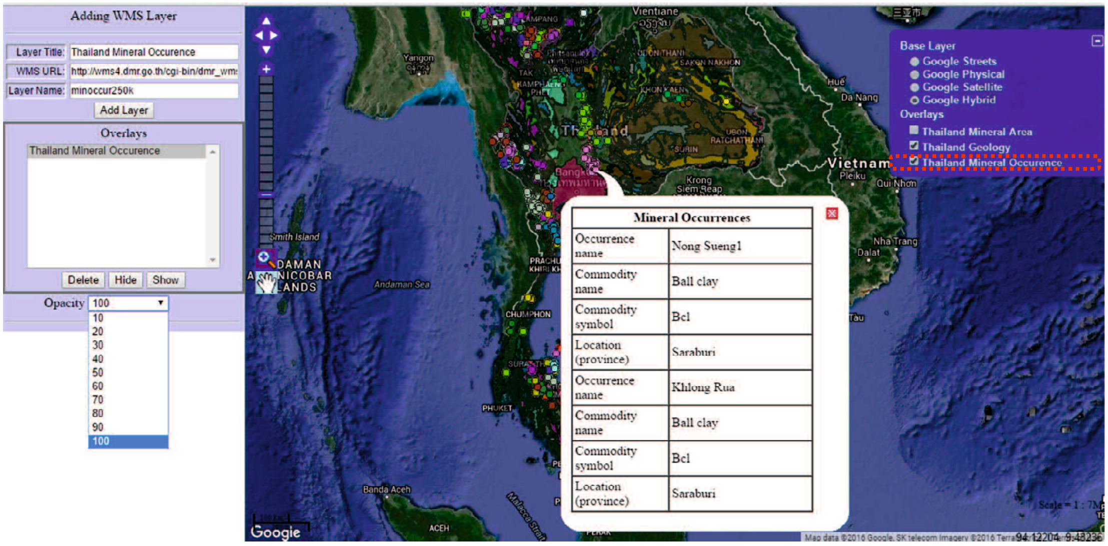


Figure 6.17 Displaying multiple maps served as WMSs using a web application

6.4. WPS formulation

This study formulates WPS for querying the database and downloading the query results.

6.4.1 WPS for searching geospatial data

Web application is developed as interface to implement the WPS for searching geospatial data. Information entered into the web application's form is used to formulate Structured Query Language (SQL) scripts to access and query the database. SQL is a standard language for accessing and manipulating databases. PHP scripting language and OpenLayers API are used to display data from WMS request response. Categories of query and SQL commands are shown in Table 6.1. In this study, the database table column names used to query the database are the mineral name column of the mineral area and mineral occurrence tables and the rock type column of Thailand geology table. The SQL is embedded and executed by the web application to query the database (Figure 6.18). The query result is saved as PostGIS table with its corresponding WMS automatically generated. Figure 6.19 shows an example of a request to query the mineral area layer including the query result served as WMS.

Table 6.1 Categories of query and SQL commands

Category of Query	SQL command	Result
Single	$sql="select $column1,ST_ASText(ST_Transform(geom,4326)) from $table1 where $column1='$which_value'";	Records of a table choosing a value in a column
Compound	$sql="select $column1, ST_ASText(ST_Transform(geom,4326)) from $table1 where $column1='$which_value1' or $column1='$which_value2'";	Records of a table choosing two values in a column
Within	$sql="select $column1, ST_ASText(ST_Transform($table1_geom,4326)) from $table1, $table2 where ST_Within (ST_Transform ($table1_geom,4326), ST_Transform($table2_geom,4326)) and $table2_column2='$which_value';";	Records of table1 within the chosen values of table2
Intersect	$sql="select $column1, ST_ASText(ST_Transform($table1_geom,4326)) from $table1 INNER JOIN $table2 ONST_Intersects($table1_geom,$table2_geom) and $table2_column2='$which_value';";	Chosen part of table1 covering the chosen part of table2

<u>SQL Command1</u>: Single query

$sql="select $column_name, ST_ASText(ST_Transform(geom,4326))

from $table_name_from_form where $column_name='$value_from_form'";

Figure 6.18 Example of a SQL command for querying geospatial database

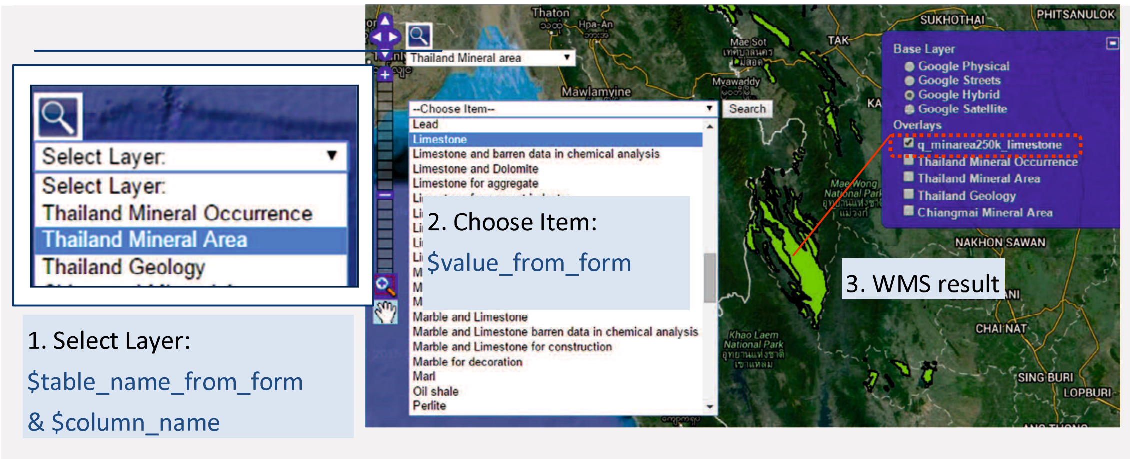


Figure 6.19 Web application for querying the database and displaying the result as WMS

6.4.2 WPS for downloading database query results

WPS used to download geospatial data is also provided by the web application using SQL and PHP scripts. The WPS was used to transform the generated query result in PostGIS table into Shapefile and KML (Keyhole Markup Language) file formats. Figure 6.20 shows the pgsql2shp command line to transform the PostGIS table to Shapefile.

PostGIS commandlines: Transforming table in PostGIS to Shapefile

$/usr/local/pgsql/bin/pgsql2shp -f shape_file_name -h localhost -p 5432 –u username database_name table_name_of_query_result

Figure 6.20 PostGIS command to transform PostGIS table to Shapefile

Keyhole Markup Language (KML) is a file format based on the XML standard used to display geographic data using Google Earth [46]. Figure 6.21 shows the script to transform the PostGIS table to KML file. Figure 6.22 shows an example of WPS on web application used to download geospatial data. The database can also be queried using a defined bounding box covering the area of interest (Figure 6.23). The downloaded Shapefile could also be handled by GIS software installed on desktop such as QGIS. Downloaded query results in KML file format can be easily handled by software installed on desktop such as Google Earth [47].

```
SQL Command: Select table to transform into KML format
$sql= "SELECT AsKML(ST_Transform(geom,4326)), column_name from
table_name_of_query_result ";
//Transform table in PostGIS into KML file using KML format as following:
<?xml version="1.0" encoding="UTF-8"?>
<KML xmlns="http://www.opengis.net/KML/2.2">
<Document><description>table_name of query result</description>
// For each Placemark
<Placemark>
        <description>column_name_value of query result table</description>
        <Style><IconStyle><color>determine_color_value </color></IconStyle>
        <LineStyle><width>determine_width_value </width>
        <color>determine_color_value </color></LineStyle>
        <PolyStyle><color>determine_color_value</color></PolyStyle></Style>
        <MultiGeometry><Polygon><outerBoundaryIs><LinearRing>
        <coordinates>geometryAsKML_value of query resulttable
        </coordinates></LinearRing> </outerBoundaryIs> </Polygon></MultiGeometry>
</Placemark>…//End loop Placemark
</Document></KML>
```

Figure 6.21 Transforming PostGIS table to KML file format using SQL scripts

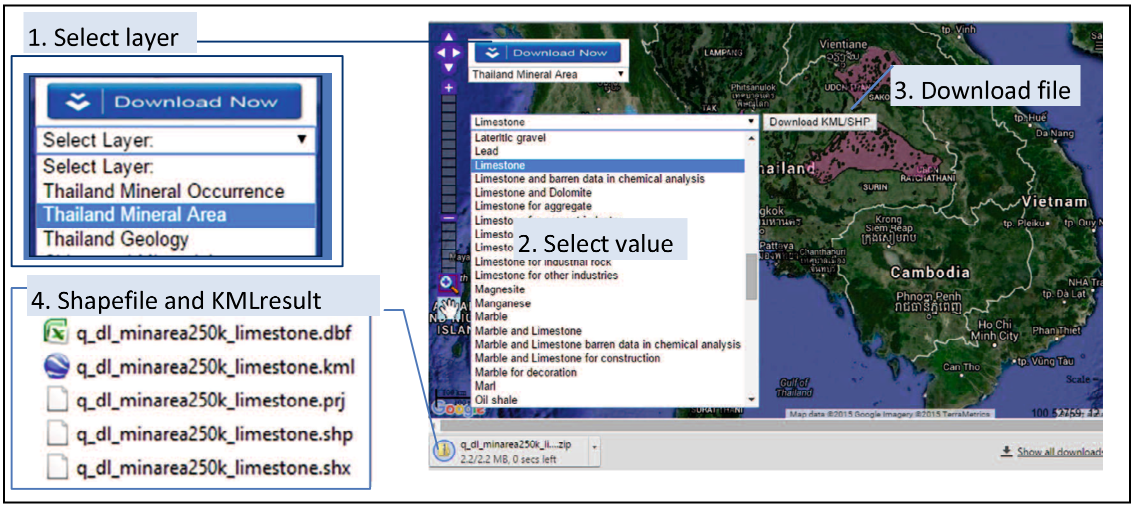


Figure 6.22 Web application used to download geospatial data

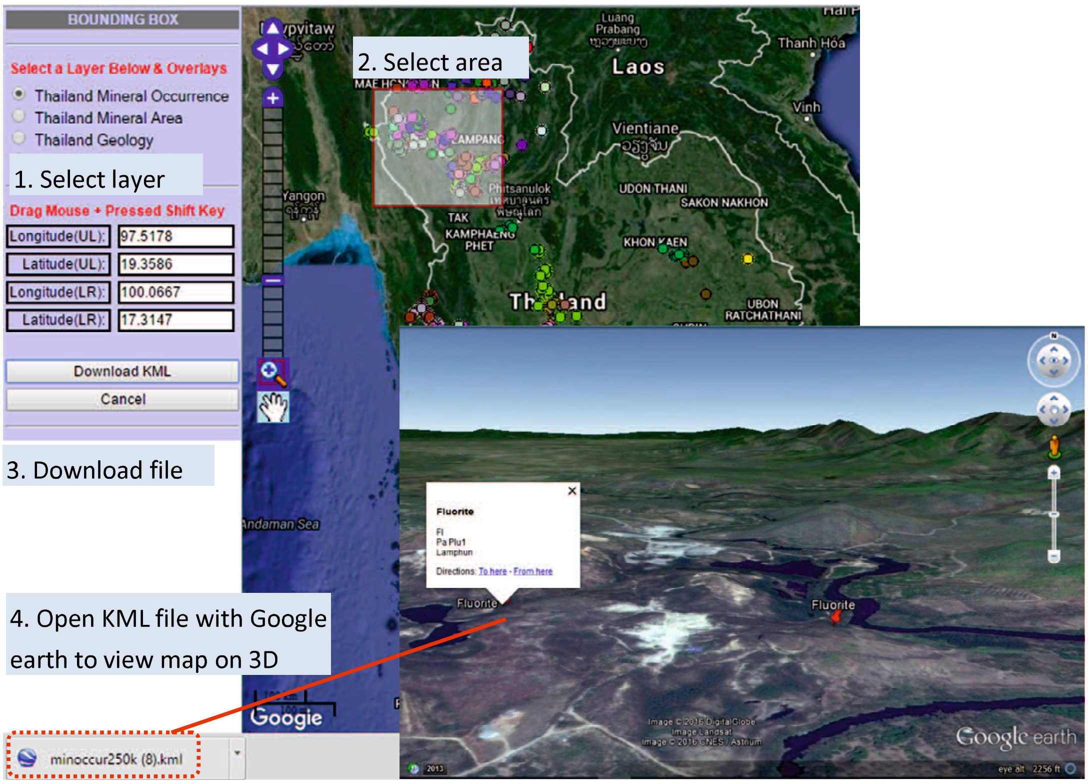


Figure 6.23 Web application showing bounding box to query and download the result in KML format and viewed in 3D using Google Earth.

Chapter 7

Formulating Web Feature Service

This chapter will explain the WFS formulation technique and configuration for sharing geospatial data using the free and open source software GeoServer. This chapter is divided into three sections, which are 1) WFS in WebGIS system 2), Setting up of a WFS Server, and 3) WFS formulation.

7.1 WFS in WebGIS system

To enable sharing and editing of geospatial data on the internet, OGC has establish a series of specifications such as the standard data exchange format Geographic Markup Language (GML) and data exchange protocol Web Feature Service (WFS). Figure 7.1 shows the WFS architecture in WebGIS system. The WFS provides transaction to access spatial data on Data Store. Data Store is WFS interface for accessing spatial data in various formats such as ESRI's Shapefiles or table in database. Data Store can read and write data pointed by a URL. Data Store can transform spatial data into GML format and send response in GML format to client application [14, 31].

Users can send WFS requests from client application using the service URLs to WFS server and retrieve the result from the Data Store. Data Store processes request and send the response in GML format back to the client application. GML format can link spatial data from difference sources. These make automatic and immediate spatial data source update over the internet using WFS possible [14, 31]. Table 7.1 shows the WFS data processing operations on GML feature. The WFS request in standard form is as follows:

"*URL*?service=WFS&version=*1.0.0*&request=*operation_name*".

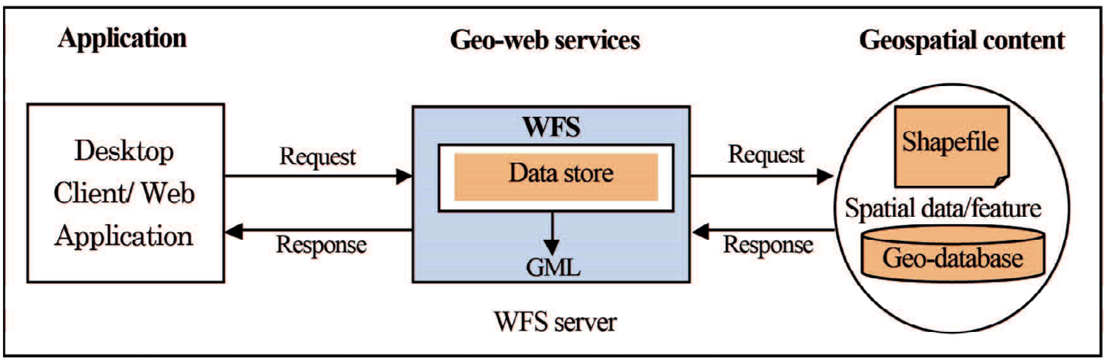


Figure 7.1 WFS architecture in WebGIS system

Table 7.1 WFS operations on GML features [31]

Operations	Description
Discovery:	Describes WFS on Server
- GetCapabilities	-capabilities
- DescriceFeatureType	-schema, and feature type
Query:	Retrieve feature from Data store
- GetPropertyValue	- properties of feature
- GetFeature	- feature
Locking:	Permit access to features for modify
- LockFeature	- no other transaction modify same data
- GetFeatureWithLock	- lock transaction and feature result
Transaction:	Allow user to
- Transaction	- create, modify, replace and delete feature
Stored query:	Allow user to
- CreateStoredQuery	- create store queries
- DropStoredQuery	- drop previous created store queries
- ListStoredQueries	- list store queries available
- DescribeStoredQueries	- describe detail of each store queries

7.2 Setting up a WFS Server

A WFS server is setup to host WFSs served for sharing and editing geospatial data on the developed web-based geospatial information sharing system of Thailand. There are numerous web mapping software that can create and publish WFSs. Three popular web mapping software are the open source software MapServer and GeoServer and the proprietary software ArcGIS [48, 49]. In the case of open source software that provides geo-web service for sharing and editing, GeoServer provides the best solution. GeoServer software provides the function for viewing and editing spatial data with flexible map creation and data sharing functions, because it uses the open standards of the OGC. GeoServer is very flexible in creating map and sharing data and could easily be integrated with OpenLayers. GeoServer could be used not only for WMS but also for the WFS, especially for data transaction termed Transaction WFS (WFS-T) for actual sharing and editing of the data. As it is a free open source application, the result can also be incorporated to other websites and applications. [36].

GeoServer is used on WFS Server in this study. WFS Server is required for connecting between client and server. GeoServer software uses Java Runtime Environment (JRE) needed to run Java application. The procedure on GeoServer software installation can be found in the appendix A.5. The server side software used for Geoserver software installation are the following:

- Apache Tomcat (http://tomcat.apache.org/), Web Server
- Java Standard Edition
  - Java Development Kit (JDK), http://www.oracle.com/technetwork/java/javase/downloads/index.html,
  - Java Runtime Environment (JRE), http://www.oracle.com/technetwork/java/javase/downloads/index.html,
- GeoServer (http://mapserver.org), GIS server software

The users can formulate web services after installing GeoServer using the Web Interface as shown in Figure 7.2. GeoServer Web Interface is available at http://wmsservice.dmr.go.th:8080/geoserver/web/.

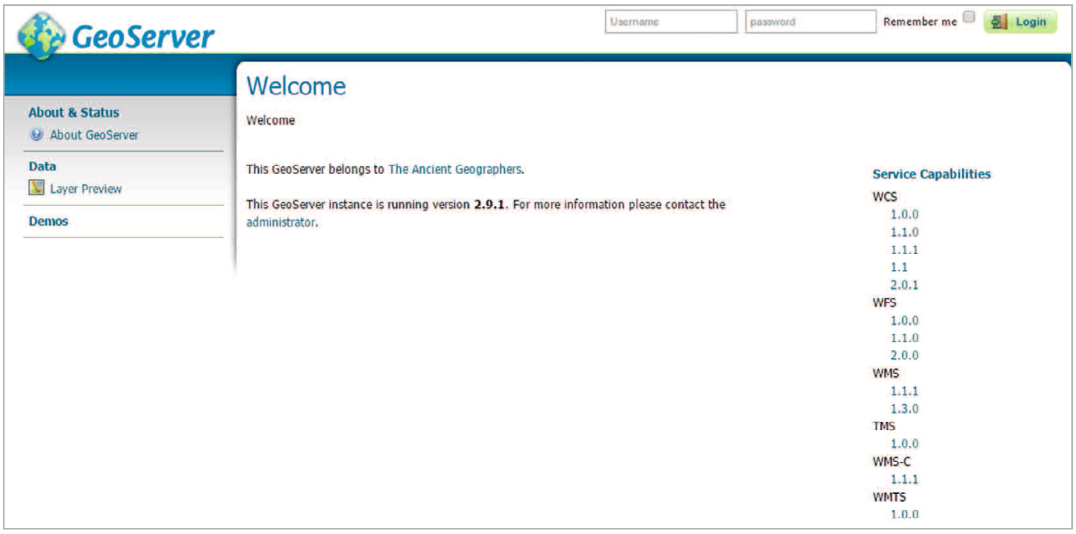


Figure 7.2 GeoServer Web Interface application [34]

7.3 WFS formulation

7.3.1 Methodology for WFS formulation

The procedure for the formulation of WFS for Thailand's WebGIS system consists of three components such as database, WFS server and web application (Figure 7.3). The database is setup on the server to store and disseminate spatial data. PostgreSQL and its spatial information processing extension, PostGIS, are used in this system.

The WFS server is setup to process and disseminate the geospatial data served as WFS. In this study, GeoServer is setup on the server and used to formulate WFS using the GeoServer Web Interface on the web application side. The WFS server receives requests from web application and processes the requests on the database.

The web application provides web-based Graphic User Interface (GUI) that allows users to access geospatial data. GeoServer Web Interface is used to create web services using a web browser such as Google Chrome, Mozilla Firefox and MS Internet Explorer (IE). The following are the 4 steps to follow to create a web service using the GeoServer Web Interface [50].

1) Workspace creation. The workspace is a container that is used to group similar layers together. Layer representing a feature, is a table in the database or a Shapefile. Name of the workspace will also be a prefix of the layer that is created from the store. The name of the workspace is used as namespace in the request URI. In this study, the workspace name is proj.
2) Setting up of the Data Store. Data Store is defined as data source that contains geospatial data. In this study, data source is the PostGIS database.
3) A layer is represented by a table in the database that contains the Data Store. Layers are used for generating web service such as WFS and WMS. A web service is generated by clicking the Publish button besides the layer name. In this study, the web services of the map with layer names minarea250k2, minoccur50k2 and geology250k2 are formulated.
4) Layer preview is the final step which involves the rendition of the published web services. Each layer provides geospatial data as WFS. WFS returns data in various formats such as GML, CSV, Shapefile, application/gml+xml, etc. Figure

7.4 shows a Layer Preview screen that displays web service of minarea250k2, minoccur50k2 and geology250k2.

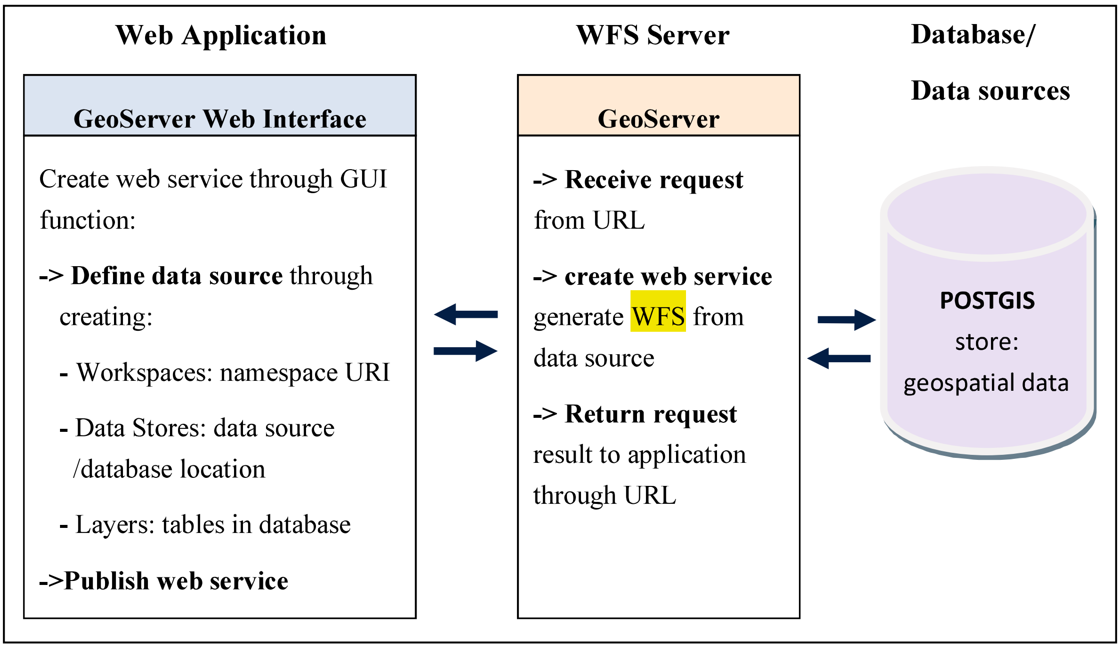


Figure 7.3 Methodology for WFS formulation

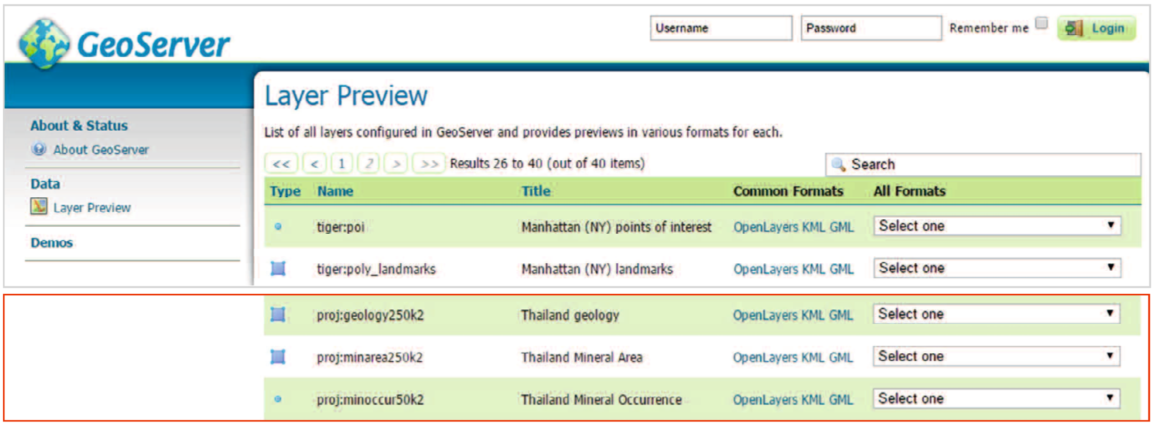


Figure 7.4 Layer Preview screen in GeoServer Web Interface

7.3.2 WFS for sharing geospatial data

WFS can provide excellent spatial data sharing function providing data in GML standard format which can be distributed among organizations and countries. GeoServer provides geospatial data serve as OGC standard compliant web service such as WFS. Users can search and display geospatial data using the GeoServer web interface application. WFS formulated using GeoServer can also be used to query and retrieve geospatial data served as web services from other applications using WFS request. WFS request is used to create, modify and exchange geographic information in vector format on the internet via HTTP, and encodes and transfers information in GML format. WFS performs the following basic operations:

(1) GetCapabilities is a request for a list of operations, services or capabilities that is supported by the server. Figure 7.5 shows an example of GetCapabilities operation request.

http://wmsservice.dmr.go.th:8080/GeoServer/proj/ows?
service=WFS&version=1.0.0&request=GetCapabilities

Figure 7.5 WFS GetCapabilities operation request

(2) DescribeFeatureType is a request to get information about an individual feature type, specifically a list of features and attributes. Figure 7.6 shows an example of DescribeFeatureType operation request.

http://wmsservice.dmr.go.th:8080/GeoServer/proj/ows?service=WFS&
version=1.0.0&request=DescribeFeatureType

Figure 7.6 WFS DescribeFeatureType operation request

(3) GetFeature is request to return a selection of features from the data source. Figure 7.7 shows an example of a GetFeature operation request of Thailand mineral area layer.

http://wmsservice.dmr.go.th:8080/GeoServer/proj/ows?service=WFS&
version=1.0.0&request=GetFeature&typeName=proj:minarea250k2

Figure 7.7 WFS GetFeature operation request

Figure 7.8 shows an example of WFS GetFeature response in GML format, showing the GML coding of Thailand mineral's WFS features. GML code consists of geospatial information including workspaces, layer name, data attributes, SRS (Spatial Reference System) and coordinate.


```
<wfs:FeatureCollection xmlns="http://www.opengis.net/wfs"xmlns:wfs="http://www.opengis.net/wfs
" xmlns:proj="proj_ws"xmlns:gml="http://www.opengis.net/gml" xmlns:xsi="http://www.w3.org/200
1/XMLSchema-instance" xsi:schemaLocation="proj_ws
http://wmsservice.dmr.go.th:8080/GeoServer/proj/wfs?service=WFS&
version=1.0.0&request=DescribeFeatureType&typeName=proj%3Aminarea250k2
http://www.opengis.net/wfs http://wmsservice.dmr.go.th:8080/GeoServer/schemas/wfs/1.0.0/WFS-
basic.xsd">
<gml:boundedBy>
<gml:null>unknown</gml:null>
</gml:boundedBy>
<gml:featureMember>
<proj:minarea250k2 fid="minarea250k2.1">
<proj:__gid>1</proj:__gid>
<proj:m_area_id>205</proj:m_area_id>
<proj:m_scale>1:250,000</proj:m_scale>
...
<proj:geom>
<gml:MultiPolygon srsName="http://www.opengis.net/gml/srs/epsg.xml#24047">
<gml:polygonMember>
<gml:Polygon>
<gml:outerBoundaryIs>
<gml:LinearRing>
<gml:coordinates xmlns:gml="http://www.opengis.net/gml" decimal="."cs="," ts=" ">
737113.2128,687594.2029 737387.0731,687403.7522 737508.8791,687252.303
...
</gml:coordinates>
</gml:LinearRing>
</gml:outerBoundaryIs>
</gml:Polygon>
</gml:polygonMember>
</gml:MultiPolygon>
</proj:geom>
</proj:minarea250k2>
</gml:featureMember>
…
</wfs:FeatureCollection>
```


Figure 7.8 Example of WFS GetFeature response in GML format

Geospatial data sharing is implemented using the OGC compliant web service such as WFS. User can access and use the web service to search for geospatial data from everywhere via the internet. A WFS Query web form is developed as is shown in Figure 7.9. The query results on Thailand's data on mineral resources (mineral area and mineral occurrences) and rock types (geologic units) are shown in GML format in the figure.

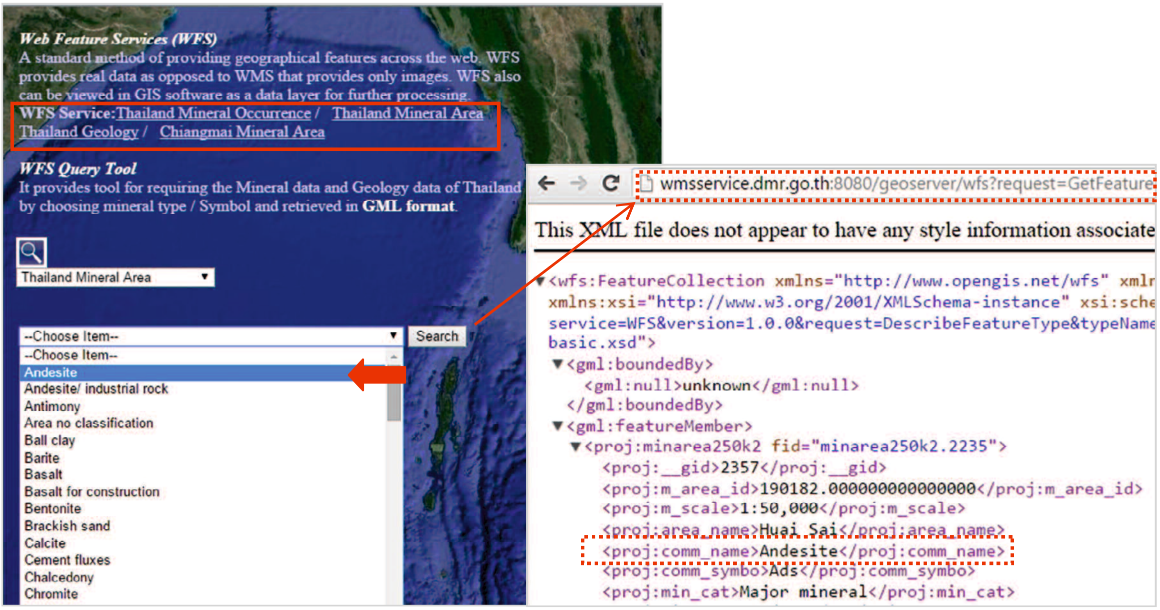


Figure 7.9 WFS Query Web form

7.3.3 WFS for editing geospatial data

WFS Transaction (WFS-T) is an operation in GeoServer used for geo-processing between GeoServer and other mapping applications. Presently, only GeoServer fully supports WFS-T. The use of GeoServer's WFS-T is promoted for database management using web services. WFS-T is very useful to create, delete, and update features on geo-database using FOSS instead of commercial software [51]. WFS-T can be utilized to manipulate geospatial database of Thailand in order to make data up-to-date and reliable in WebGIS. QGIS is one of free open GIS software that could be used to access or manipulate geographic feature with WFS and WFS-T [52]. GeoServer's WFS is also integrated with its security system that limits access to data and transactions [53]. GeoServer security system configuration can be found in appendix A.4.3.

In this study, Thailand's mineral area data served as WFS was accessed using QGIS. In QGIS, maps served as WFS can be added as a vector layer using the tool "Layer/add WFS layer..". In the example, Thailand's WFS feature (Thailand mineral area,Proj:minarea250k2) was added using the WFS URL "http://wmsservice.dmr.go.th:8080/geoserver/proj/ows" (Figure 7.10). Feature information can also be viewed by opening the attribute table and saved as Shapefile. Furthermore, QGIS application can be used to edit feature information (WFS-T) directly in the database server when user credentials are authentic. In this study, only authenticated users could edit features in the database server (Figure 7.11).

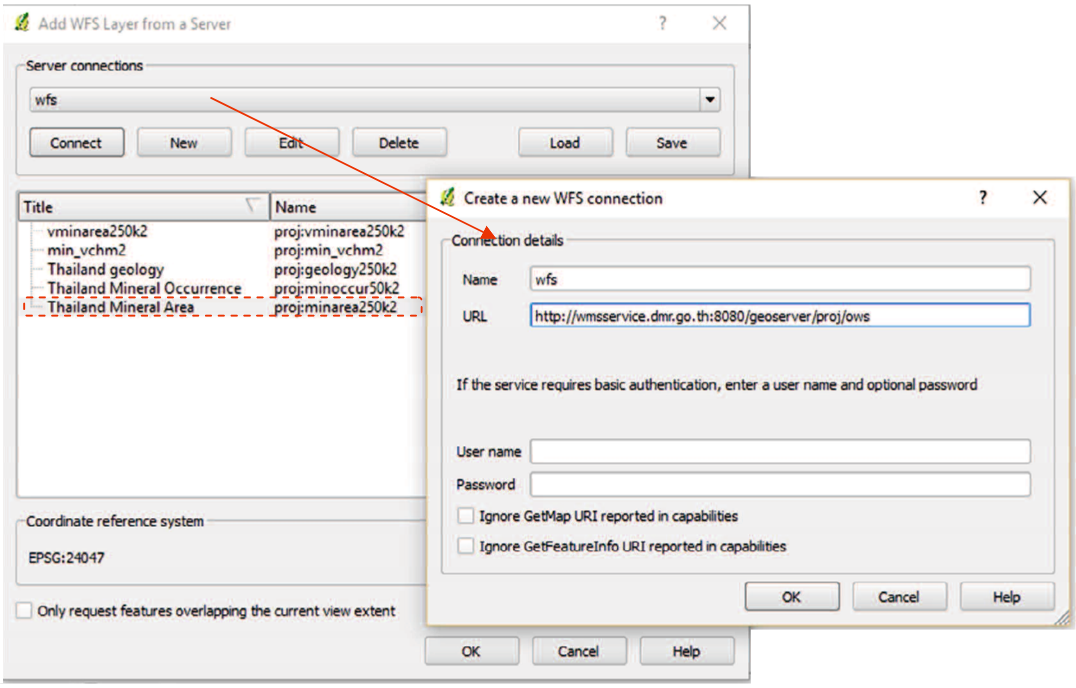


Figure 7.10 WFS server and WFS features connection

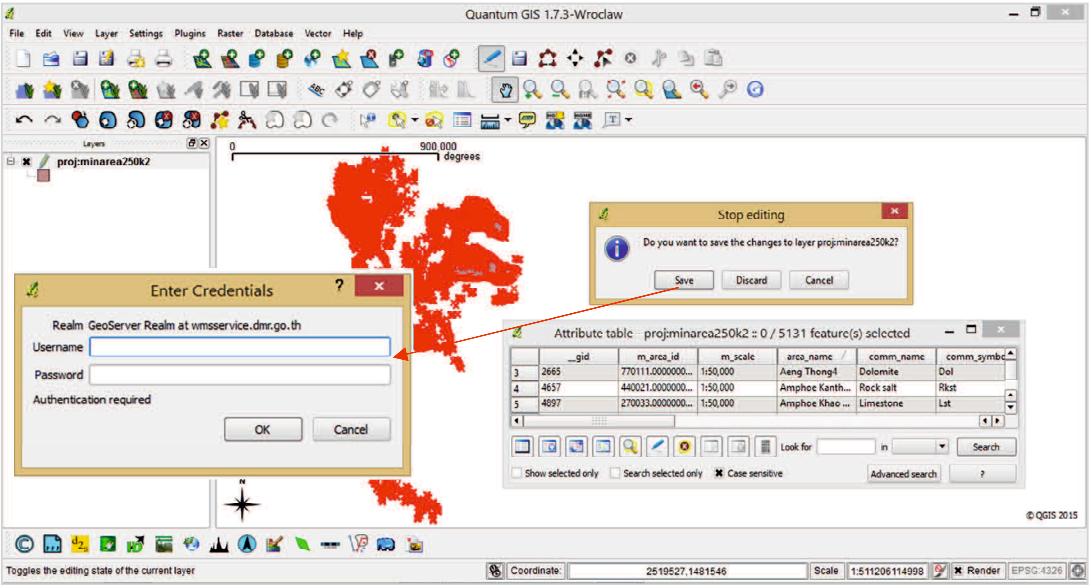


Figure 7.11 Accessing and editing feature information in the WFS database server using QGIS

Chapter 8

Creating WebGIS portal

The developed geospatial information system shares geospatial contents on the web using FOSS and OGC based web services and standards which are WMS, WPS and WFS. To make users access the web services easily, the WebGIS portal is developed as an interface between the web services and clients. This chapter will explain the WebGIS portal development and its components.

8.1 WebGIS portal development

The newly developed WebGIS portal is a web site that provides access to the contents and applications of Thailand's geospatial information sharing system. The WebGIS portal integrates WMS, WPS, WFS and applications sources on a web site to enable users search, visualize and download geospatial data easily. Thailand's WebGIS portal for geospatial information sharing system was developed using Joomla, a free and open source content management system (CMS). Joomla provides simple tools to build web site and powerful online application. The Joomla Administrator Web Interface makes the process of creating WebGIS portal easy (Figure 8.1). It is written in PHP, stores data using MySQL, MS SQL, or PostgreSQL database. Joomla uses object-oriented programming (OOP) techniques and software design patterns, and includes features such as site template, search, security (administrators and user login), and supports for language internationalization [54]. For Joomla software installation method, see Appendix A.6.

The following are the server side software needed to develop a WebGIS portal:

- Apache web server (http://www.apache.org), web server software, (see Appendix A.2).
- PostgreSQL (https://www.postgresql.org), database for Joomla, (see Appendix A.3).
- Joomla version 3.3.0 (https://www.joomla.org/), Joomla CMS software package, (see Appendix A.6)

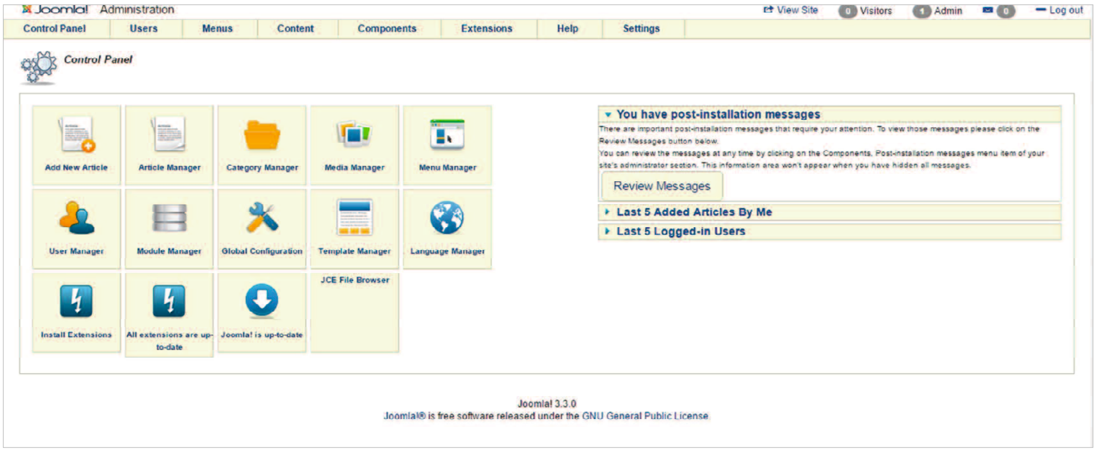


Figure 8.1 Joomla Administrator Web Interface [54]

8.2 WebGIS portal components

The WebGIS portal of Thailand's geospatial information sharing system uses CMS application. It is available at "http://wms4.dmr.go.th/wsdmr/". Figure 8.2 shows the main page of the WebGIS Portal.

Figure 8.2 Main page of Thailand's geospatial WebGIS portal

The WebGIS portal consists of various useful GIS tools for web-based visualization, analysis, query, upload, download and other spatial information related services. For the general user, WebGIS portal provides several useful functions (Figure 8.3).

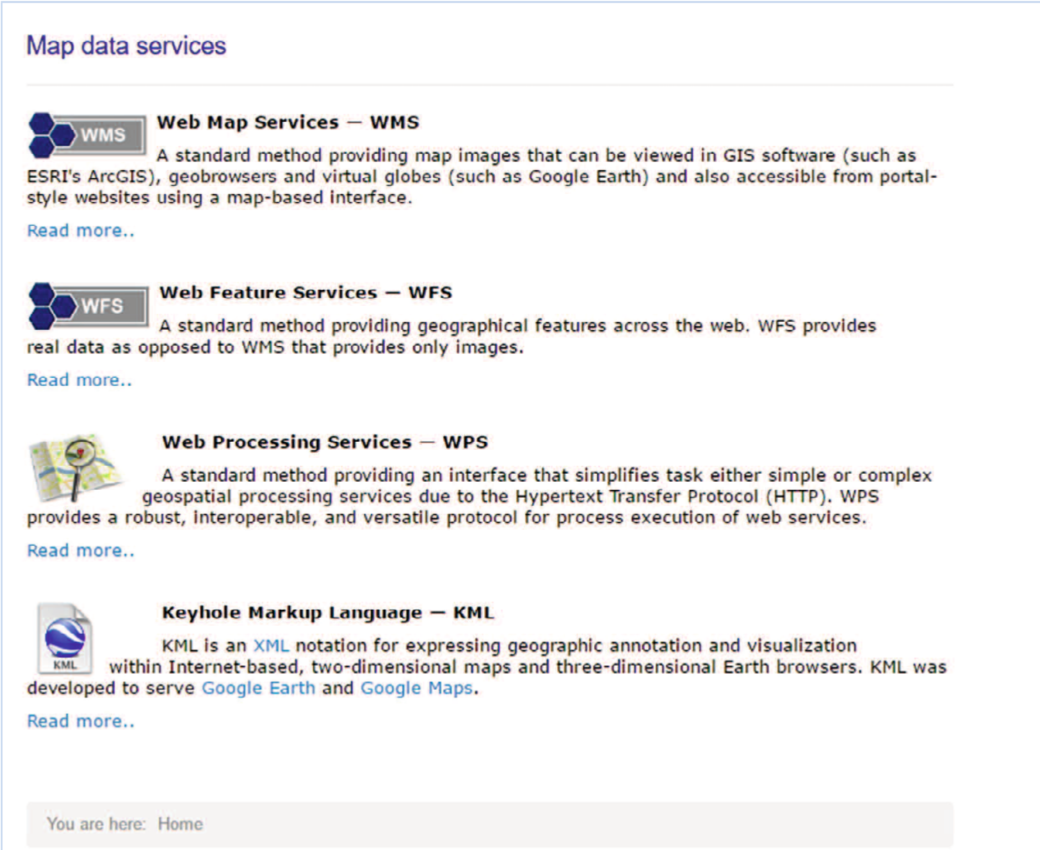


Figure 8.3 Data Services provided by the WebGIS Portal

The following are the main components of the WebGIS Portal

1. Web Map Service –WMS

This component provides a navigator of WMS information and functions to users at the main page (Figure 8.3). The following are some of the WMS functions.

- WMS Openlayer [Map Viewer]

  This function provides web application to display geology, mineral area and mineral occurrence information of Thailand on the web. The web application provides Graphic User Interface (GUI) for implementing WMS requests and viewer for displaying results as map images and feature information. Google base layers are included in the service (Figure 6.16).

- WMS Overlay map services

  WMS overlay function is used to overlay multiple WMS layers. The layers Thailand Geology and Thailand Mineral Area maps are base overlays in this application. Users can add available WMS layers by entering the WMS URL and layer name. Overlaying WMS layers is very useful for data analysis. Users can obtain information from each WMS layer. They can also use the delete, hide, show and adjust opacity functions provided in this application. GetFeatureInfo request can also be implemented to retrieve layer attributes (Figure 6.17).

2. Web Processing Service –WPS

   This component provides a navigator of WPS information and functions to users at the main page (Figure 8.3). The following are some of the WPS functions.

- Search Mineral Location

  Search Mineral Location function is a web application used to search location of commodities and rock types on the mineral area and geological maps of Thailand, respectively. The web application was developed using WPS. The application queries the database and displays the query results as WMS (Figure 6.19).

- Free Data Download

  This function provides web application to download geology and mineral information of Thailand. The web application provides options to query and download results in Shapefile or KML file formats (Figure 6.22). A bounding box could also be used to define the area of the map to be downloaded (Figure 6.23).

3. Web Feature Service –WFS

   This component provides a navigator of WFS information and functions to users at the main page (Figure 8.3). The following is an example of a WFS function.

- GeoServer-WFS

This function provides a form to query the mineral / and geology data using the WFS data services which return results in GML format (Figure 7.9).

The WebGIS portal provides users additional functions to formulate WMS and generate map viewer to render the map served by the service. The portal provides navigator of web application used to upload Shapefile to the server and input the data into the database (Figure 5.1). The main page also provides a navigator of web application for the WMS and map viewer formulation (Figure 6.11).

These tools allow users with limited GIS knowledge and computer programming skills to access information and formulate map services. The access right to formulate map services is controlled using the web security of CMS application via user login. The WebGIS portal can reduce operation and management costs, and assists people to share spatial information freely, easily and securely.

Chapter 9

Discussion

9.1 Advantages of using the proposed web-based geospatial information system

9.1.1 Advantages of using WebGIS

GIS and WebGIS can efficiently provide geospatial information. The benefits for using GIS lie in its capacity to visualize spatial information, to create maps with images for a vast range of tasks and to provide solutions for problems. However, obtaining and maintaining proprietary GIS software is very expensive. Furthermore, sharing data using the conventional GIS is difficult. Data sharing and reuse for new applications are daunting tasks because of the heterogeneity of existing systems in terms of data modeling concepts, data encoding techniques and storage structures [14].

WebGIS is system that provides GIS functionality in the forms of web services that are accessible online. The system has the potential to make distributed geographic information easily available worldwide. Internet users will be able to access GIS applications using their browsers without purchasing proprietary GIS software. However, its performance is affected by the bandwidth and network traffic between the server and client particularly when data traffic involves large files. Although GIS can be efficiently used to create and display maps, WebGIS offers a better solution if the purpose is to freely share spatial information.

Thailand's geospatial database faces problems of outdated data model and format and the difficulty of sharing data. Thailand's current information system was developed by a private company using commercial software. It is characterized by a rigid design and non user-friendly interface, which is difficult to change after the contract expired. The cost of signing a new contract to update the WebGIS system could be prohibitive. This study proposes to develop a new WebGIS based on SDI architecture using FOSS and OGC based web services for the dissemination and sharing of Thailand's geospatial information. The new WebGIS is a distributed WebGIS system for Thailand geospatial database.

A distributed WebGIS for sharing spatial information could encourage data providers to distribute data freely online. Establishing a distributed WebGIS system provides the following advantages for Thailand's geospatial database.

(1) DMR Thailand can manage geospatial data in its own server.

(2) Thailand's geospatial database could be easily revised because the data is stored in its own server.

(3) DMR Thailand can distribute geospatial data locally and to other system such as the ASEAN WebGIS portal.

DMR's staffs and other users in Thailand will benefit from the new WebGIS portal. Users can easily access geospatial data on geology and mineral resources using the new information system. Data developers of DMR can easily manipulate and update geology and mineral information in DMR's central database using the information system. Interested organizations around the world could also access the system and easily have an idea about the status of Thailand's geology and mineral resources.

9.1.2 Advantages of using Free and Open Source Software (FOSS)

Free and Open Source Software (FOSS) have extensively been used by many organizations in their information management system. The IT trend of moving the functionality of information system onto the web makes server based FOSS more attractive, not only because of their cost effectiveness, but also because of their robust capabilities. FOSS is very popular among GIS users processing geospatial data all over the world.

The use of FOSS will result to significant savings for the Thai government. The expenditure for buying and maintaining proprietary software will be minimized. The new geospatial information system of Thailand for geology and minerals contributes to the reduction in the cost for developing system and long term software license maintenance.

FOSS is also more secure, easy to customize and highly flexible and interoperable with other system compared to the commercial software. FOSS is developed and maintained by countless developers and users who are constantly working to improve the security and quality of the open source software. FOSS also supports internationally accepted standards making them more interoperable than proprietary software.

9.1.3 Advantages of using OGC standards

Open Geospatial Consortium (OGC) serves as a global forum for the collaboration of developers and users of spatial data products and services, and to advance the development of international standards for geospatial interoperability [18]. The use of open standards helps to reduce operating costs in the long term and advance the profit and benefits of investments. Governments face the challenges of next generation data sharing and collaboration. Thus, OGC can help define how OpenGIS standards are put to their best use for future requirements and mission [55]. OGC proposed various standards for spatial data and web services such as WMS, WPS and WFS.

In this study, MapServer and GeoServer, core open source software for web mapping service based on OGC standards, are used. MapServer supports the creation of WMS, WPS and WFS but does not support Transaction WFS (WFS-T) for editing data on the web. However, MapServer is very powerful for formulating WMS. MapServer uses only Mapfile to create and style map on the web. On the other hand, GeoServer provides the Web interface application for easy formulation of WMS, WFS and WFS-T. However, creating WMS using GeoServer Web Interface application will provide the map without styling by default. The styling will be done using the GeoServer Web Interface's styles after the WMS is generated. Thus, in the proposed system, MapServer is used for creating WMS and WPS and GeoServer is used for creating WFS and WFS-T. FOSS including Geometry Engine Open Source (GEOS), Geospatial Data Abstraction Library (GDAL) and PostgreSQL/PostGIS and their continued improvement made it possible to develop spatial information processing functions packaged in the forms of standardized web services and databases. Thus, OGC standards have valuable advantages for users of WebGIS system, and provide various advantages described in the following sections.

9.1.4 Advantages of using WMS and WPS

WMS and WPS are very important interoperable tools to manage and share geospatial data through the World Wide Web. WMS and WPS are mostly used to retrieve and share geospatial data from distributed geospatial databases, and display the map image that users easily understand.

In this study, WMSs of geospatial data to be shared could be easily formulated by DMR's staffs and other people without programming skills by using web application that is developed in this study. Users could easily access and search for geospatial data using Thailand's WebGIS portal at http://wms4.dmr.go.th/wsdmr/ (Figure 9.1). Users can access database and receive geospatial information in several formats using WPS. WPS provides geospatial data from database to the client not only in map image but also in Shapefile and KML formats. It also enables users to manipulate data with using other applications. The web application for creating and generating WMS in this study can be a good template in the development of web-based geospatial data sharing system in other field of geoscience. One of the good examples of such data sharing system is the ASEAN harmonize geological map project recently developed by the Coordinating Committee for Geoscience Programmes in East and Southeast Asia (CCOP). This project intends to share geology information to the public based on the harmonization concept used by countries in the ASEAN region as show in Figure 9.2.

Interoperability is very important for sharing data on the internet. OGC based standards and web services such as WMS and WPS enables the sharing of Thailand's geospatial data. The implementation of WMS and WPS in geospatial information system of Thailand can help DMR distribute geology and mineral information to the public easily. WMS and WPS enable users to easily view, search, analyze, study and manage Thailand geology and mineral information. WPS has a function to search for the desired information using SQL. Users can make query in the web portal using WPS and get result quickly. WMS is used to display the maps in the DMR database online. Users can choose which map to display using the correct URL of the service. This kind of data access is possible not only through the DMR web portal but also through any system that supports web services, if users know the WMS URL for the data in DMR server.

In order to control data dissemination, this new system can distribute data using the newly developed portal. Users can access and view any kind of geospatial information on geology and minerals of Thailand using the web-based geospatial information system.

Figure 9.1 Displaying map data using WMS and WPS on Thailand's WebGIS portal

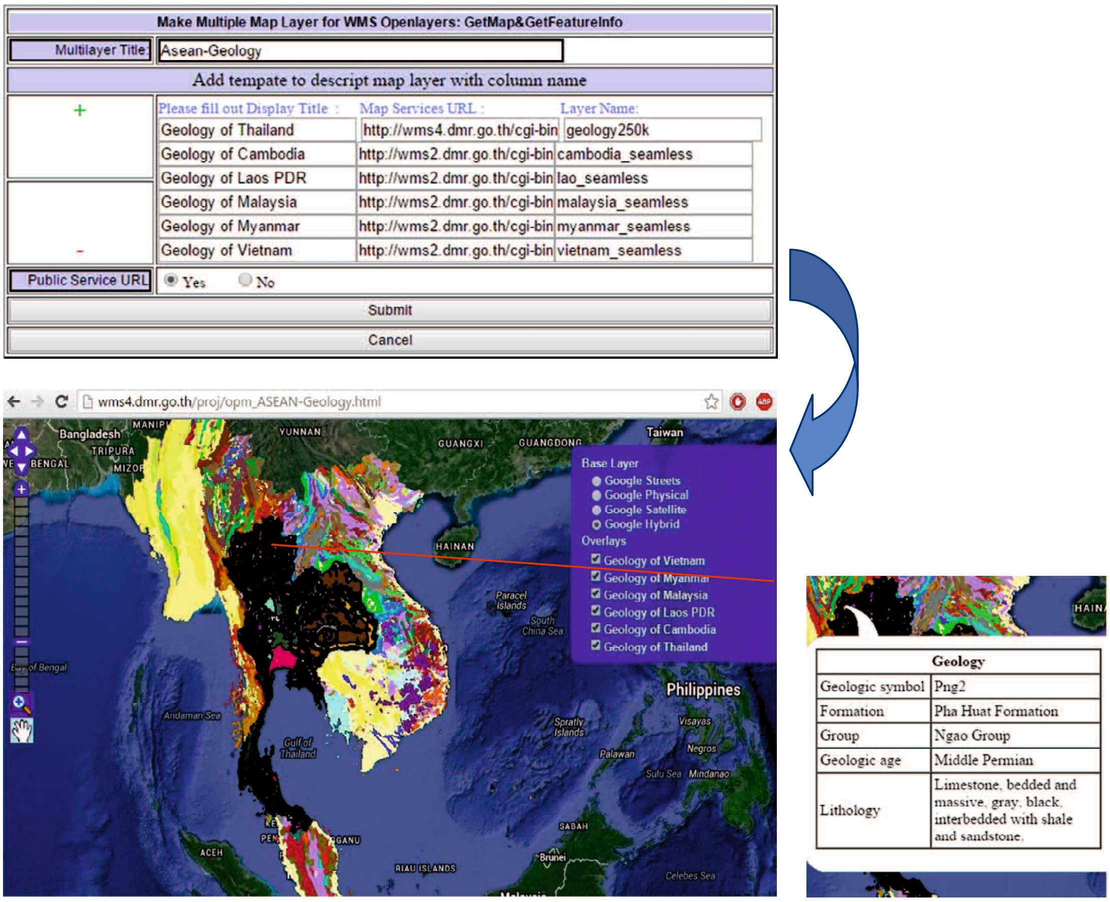


Figure 9.2 ASEAN harmonized geological map

9.1.5 Advantages of using WFS

WFS allows client to retrieve, create, modify and exchange geographic information in vector format on the internet via HTTP, and encodes and transfers information in GML format [31]. In this study, WFS provides excellent spatial data sharing in GML format that supports data exchange among organizations and countries. Moreover, WFS-T is used to access and update geospatial database of Thailand. The geospatial data could be edited using other software such as QGIS. QGIS is free GIS application that supports viewing and editing data from databases using WFS-T. In this study, QGIS was also used to edit and update geospatial data served as WFS. It is advisable to backup the data before editing. Editing session will be completed and changes in the geospatial data recorded after the user obtain permission to update the master database. The use of WFS in the geospatial information system of Thailand makes the information on geology and mineral information up to date and credible. Although WMS and WPS are very useful tools to search and get information on geology and minerals of Thailand, WFS and WFS-T are needed by data developers to revise and edit the data on the database. WFS enables data developers of DMR to access the database and edit or update the data using familiar GIS software such as QGIS. DMR geologists could access and get copies of the data in map images, Shapefile or KML formats because WFS returns map data in XML which can be converted to any map format easily. As this system provides geology and mineral information in the GML format, it makes geospatial information of Thailand interoperable with other data model such as GeoSciML and EarthResourceML.

The newly developed web-based geospatial information system provides function for easy data revision on the geo-information database of DMR by using WFS-T. Geologists of DMR can get the necessary and sufficient data for their fieldworks in advance from Thailand's mineral web portal. Field data could also be easily inputted to the database using QGIS through the new information system (Figure 9.3).

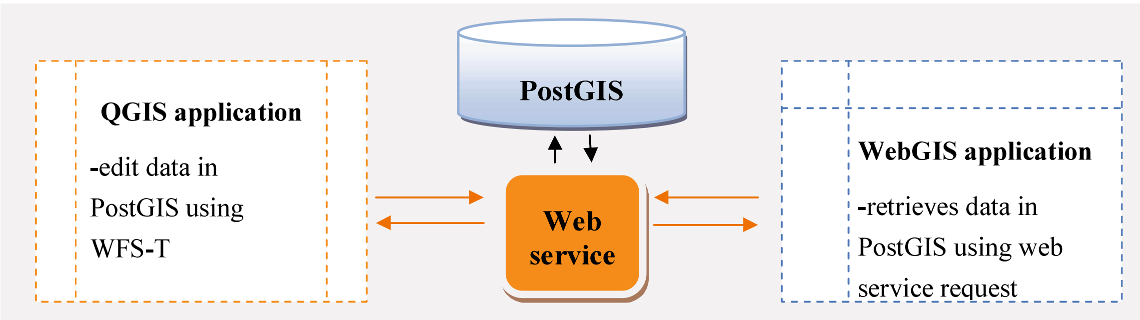


Figure 9.3 Updating and retrieving Thailand geospatial data in PostGIS database using WFS-T

9.1.6 Summary

The new web-based geospatial information sharing system of Thailand is very useful for sharing and editing data online. WMS and WPS are used for geospatial data query and sharing while WFS provides the function to share and update data in the distributed database.

In this study, WMS, WPS and WFS are formulated using MapServer and GeoServer. GeoServer web interface is used to quickly generate WMS to display maps in various format (i.e. jpg, png, kml etc) and WFS in GML format. On the other hand, WFS-T is formulated to access and update the database. However, even though GeoServer web application can formulate WMS quickly, the resulting web service has some default map setting problems like the random color assignment of the maps features. Because of this, MapServer is used to formulate the WMS in this study, the appearance of the map can be easily customized and modified using a Mapscript. The development of web mapping application to formulate WMS and WPS for sharing geospatial information using MapServer (chapter 6) and the utilization of WFS and WFS-T using GeoServer (chapter 7) are very important to share and manage geospatial information of Thailand. This information system is very useful for decision makers and general public to enact policies for the management and sustainable utilization of natural resources in Thailand and ASEAN countries.

9.2 Advantages of using the developed information system compared with the current one

9.2.1 Cost of system development and maintenance

The use of the new system significantly lowers the cost to develop and maintain the mineral resources and geology database system. DMR deployed and setup a centralized database system of geology, mineral resources in 2003 with the cost of 40 million baht (1,280 million yen). The system was developed using the services of a private company. The system development package includes hardware, software, applications and DMR staff training. DMR also allocates an annual budget of around 750,000 baht to maintain the information system. The government of Thailand has been using proprietary software for its operation for than ten years. The government needs to spend a lot of money to buy and maintain the software. For several years, Thai government started to reduce the cost of its operations every year. DMR is facing difficulty to have its proposed budget to improve and maintain its information system approved. The new information system is developed using free and open source software hence the development and maintenance cost is almost zero. The new system helps the Thai government to save money and to use its financial resources for other important projects.

9.2.2 Data entry process

Using the newly developed system makes it easier to input data into the database. The system can accept feature class in Shapefile format which can store a wide array of data such as locality name, commodity and symbols of minerals. The current system requires users to input data by typing records one by one which is difficult, prone to errors and time consuming.

The current system provides web applications for data entry to enter all departmental data such as mineral resources and geology of Thailand into the database. The database is a relational database model managed by Microsoft SQL. Database structure was specifically designed as relational structure for collecting data. The relational database structure of Thailand mineral occurrence is composed of a main table and 10 relational tables that separately store the details of feature information (Figure 9.4). To store data into database, users need to insert text record into theses tables using a web application.

A feature class consists of several features which are either points, lines or polygons. Thailand mineral area data consist of around 5,000 polygons, Thailand mineral occurrence and geology data consist of around 1,000 points and 7,000 polygons, respectively. Figure 9.5 shows an example of the web application used for entering data to the main table of Thailand mineral occurrence. In this case, the user needs to type the details of mineral occurrence feature such as occurrence ID, mineral name, occurred year, location zone, latitude, longitude and structure 1,000 times, a time consuming operation. Furthermore, the application only runs using Internet Explorer version 8 or later. Because of these data entry constraints, many DMR staffs refuse to use this system. These are the reasons why many important data are not entered into the system's database.

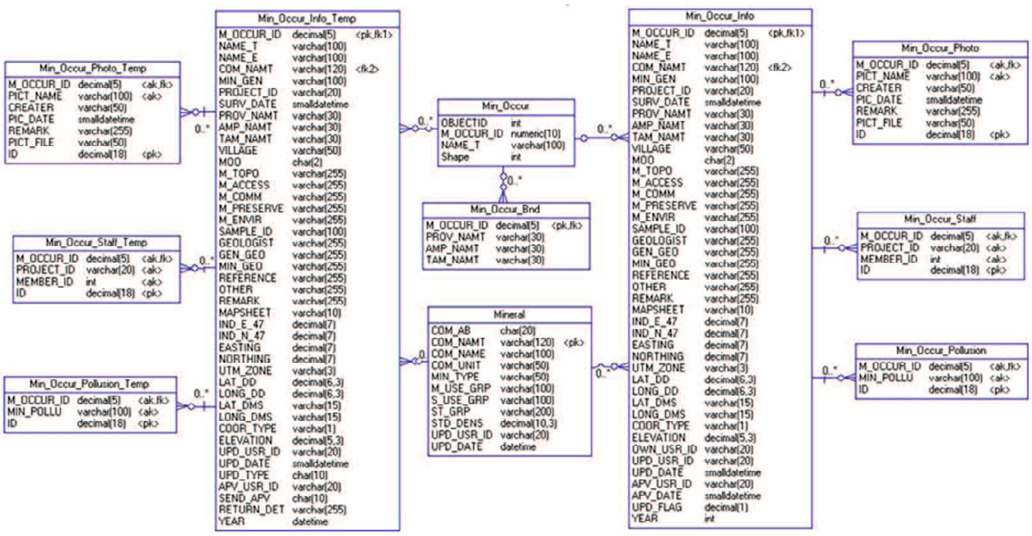


Figure 9.4 Database Structure for the current mineral occurrence information system of Thailand

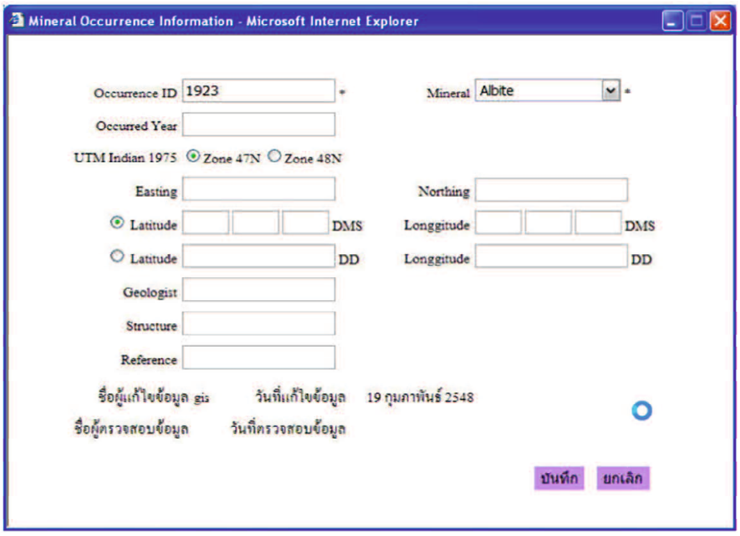


Figure 9.5 Web application for entering data to the current mineral occurrence database of Thailand

The new information system proposed in this study provides user friendly web application for data entry to the database, which also runs on all major web browsers. DMR's geologists use maps when they do their field work. Map is very useful to determine the location and other important information in the field. They collect data and create map for reporting and reusing data using GIS software in their own computers. The field data are then saved in Shapefile format. The new system provides web application for inputting Shapefile into the database (Figure 9.6). It uses PostGreSQL and PostGIS extension for geospatial data handling in the database system. The PostGIS database structure is an object relational database that supports collecting of data as objects. PostGIS database can obtain all features of a Shapefile as a table. Because of the flexibility of the database structure and simple application for data entry, user can input all features by choosing the Shapefile using the new system. Because of the ease of data entry, all geoscience data could be entered into the database efficiently. Furthermore, DMR data can be entered into the database at no cost to the government.

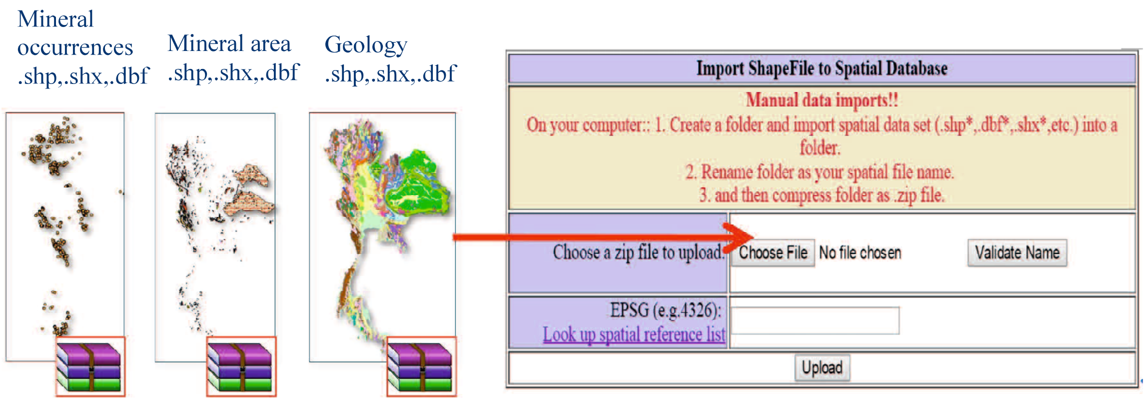


Figure 9.6 Web application for entering data to the database of the proposed information system

9.2.3 Data update process

Editing data using the new information system is also easier compared to the existing one. Users can directly access the data to be edited using a single process involving only one table. Editing data using the current system involves many tables related to the data to be edited. The current database system contains web applications to edit data in the main table and relational tables in the database by searching and editing text record. The web application includes filter form to search feature that user require to edit. Figure 9.7 shows an example of web application for editing the main table of mineral occurrence by filtering data using Occurrence Id or Mineral name. In this case, users need to know the Occurrence Id of the feature that they need to edit which is difficult to remember. Another filter is Mineral name which could result to many of search output as the search parameter results to many matches in the table. Users need to check each result to find the feature they need. The rigid design of web application makes it difficult to find a match for the feature to be edited. Editing a feature also requires editing records in many tables related to the feature. Because of the difficulty of editing features using the current information system, many data in the database are not updated.

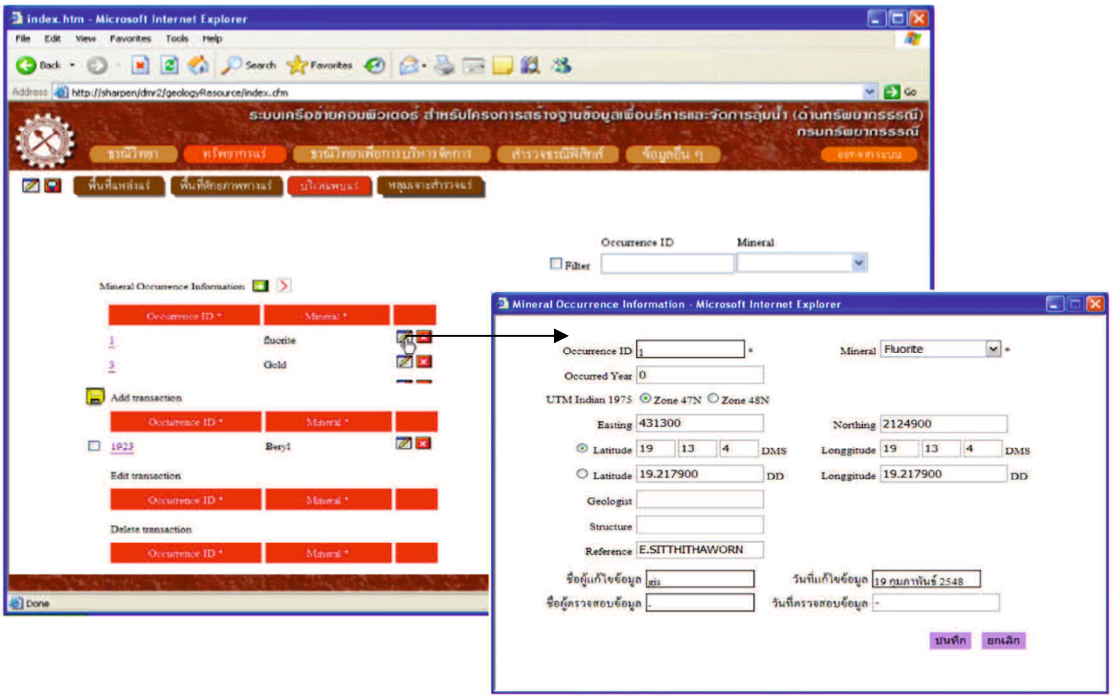


Figure 9.7 Web application for filtering and updating mineral occurrence data in the current database system

The new system provides function to edit data in database using QGIS via WFS. This system uses WFS to enable other applications to access the feature data in a database through the internet. QGIS provides several tools for geospatial data manipulation including access to the database and editing data using transaction on WFS. QGIS could display feature data from database as map image and show attribute table information (Figure 9.8). In this case, user can find feature that they need to edit from map image or using filter tool in attribute table. One of the functions on attribute table is a filter tool to search for feature by looking for the data in each column. An advanced search function is also available. Figure 9.9 shows features selected using the attribute table search tool. The search tool provides attribute column name for filtering by entering the search parameter. Figure 9.10 shows features selected using the advanced attribute table search tool. Advanced search tool provides column attribute name, values and condition function for filtering specific result. User can easily find feature data that they need to edit. The system also includes add and delete features using several tools provided by QGIS. Because of the flexibility of the PostGIS database structure, users can easily access and edit features within an attribute table. The new system provides functions to easily update information in the database which results to up to date information for the public.

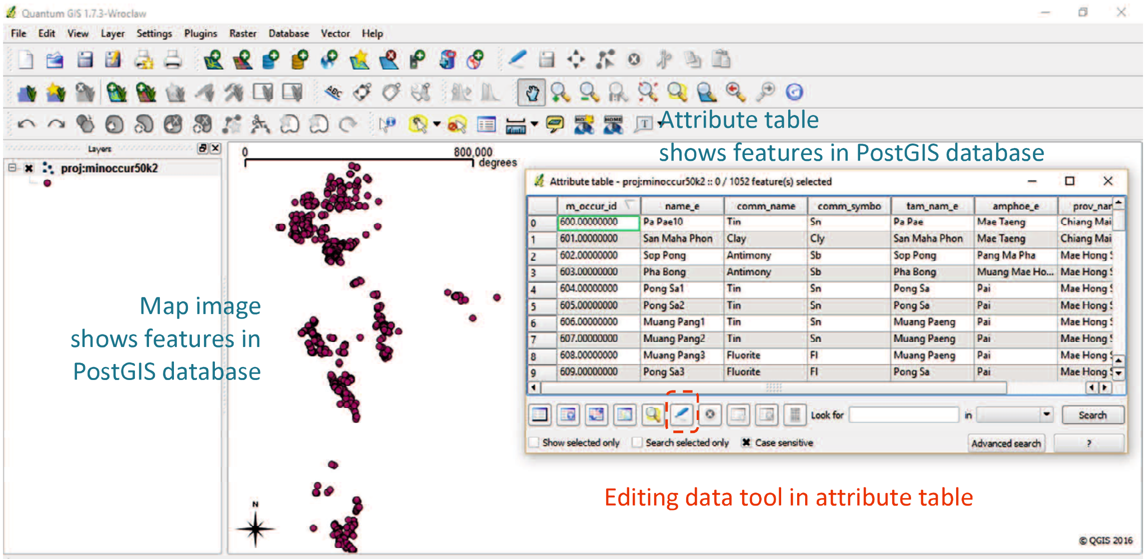


Figure 9.8 Editing features in PostGIS database via WFS in QGIS

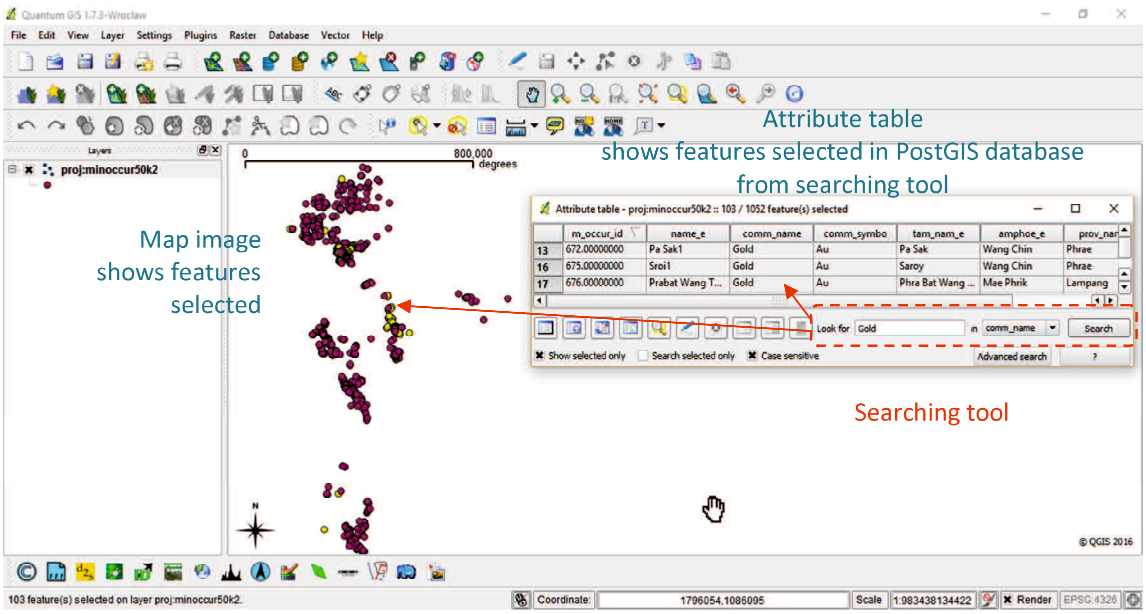


Figure 9.9 Editing features in PostGIS database via WFS using the searching and editing tools of QGIS

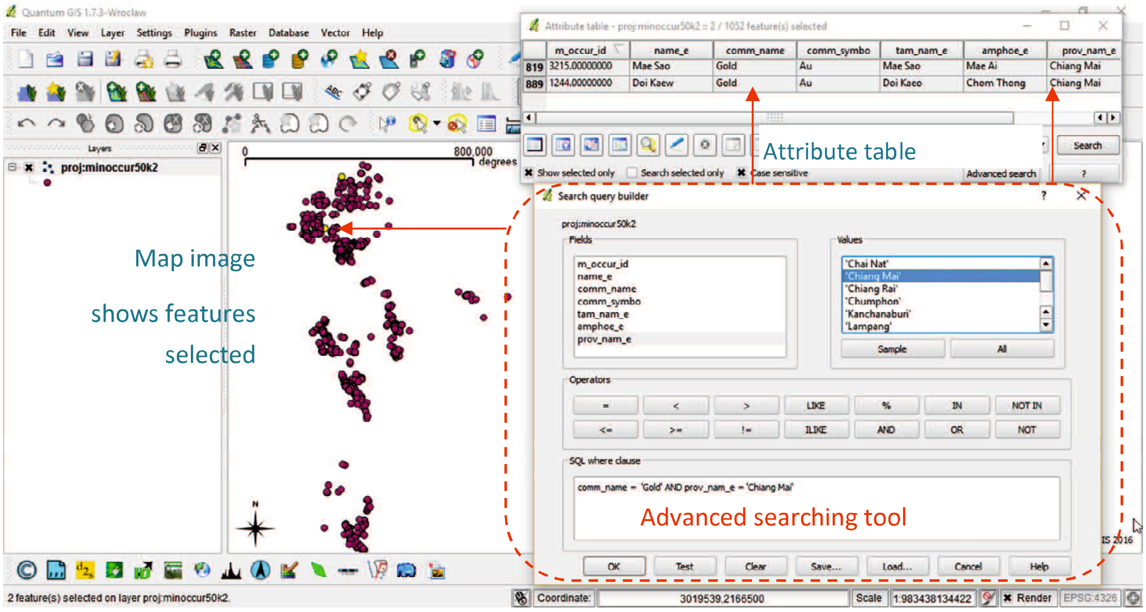


Figure 9.10 Editing features in PostGIS database via WFS using the advanced searching and editing tools of QGIS

9.2.4 Data sharing

Sharing data using the newly developed information system is much easier and faster compared to the current system. Data entered into the new system's database are immediately available to any users with proper credentials regardless of the users' location. Data can be easily downloaded in Shapefile format. The current system does not provide option for any user to directly query and download data from the database. To get the data, the user needs to ask an IT staff having user name and password to provide the needed data. Thus, the new system is superior compared to the current system on data sharing.

The current system displays data in the database as map using a web application which only runs on Internet Explorer version 8 or later. Information about the data will be displayed only using this application (Figure 9.11). The web application provides searching tool which provides fields where mineral type and location will be entered to search information from the database. The search results will be displayed in a map and the number of matching results. If users need to know the detail of each result, they need to click on the "number" to check the location on the map then click on the "mineral type" to see the detail of the data in that location (Figure 9.12). Users cannot click on the map directly to see the needed location information. The web application does not provide data download function.

If users need data in Shapefile format they need to export data from database using ArcSDE (Spatial Database Engine) API on ArcGIS Desktop software. In this case, users who get data access permission need to have ArcGIS software knowledge about the database connection (i.e. database server IP address, service port, database authentication, database name, feature dataset name and feature class name). The difficulty to search and download the data using this web application and proprietary software discourage the users to use the system. Currently, the systems are managed by the staffs of the information center. They need to import and export data from database of each department. DMR staffs cannot get current data immediately because of limited number of IT staffs of the information center.

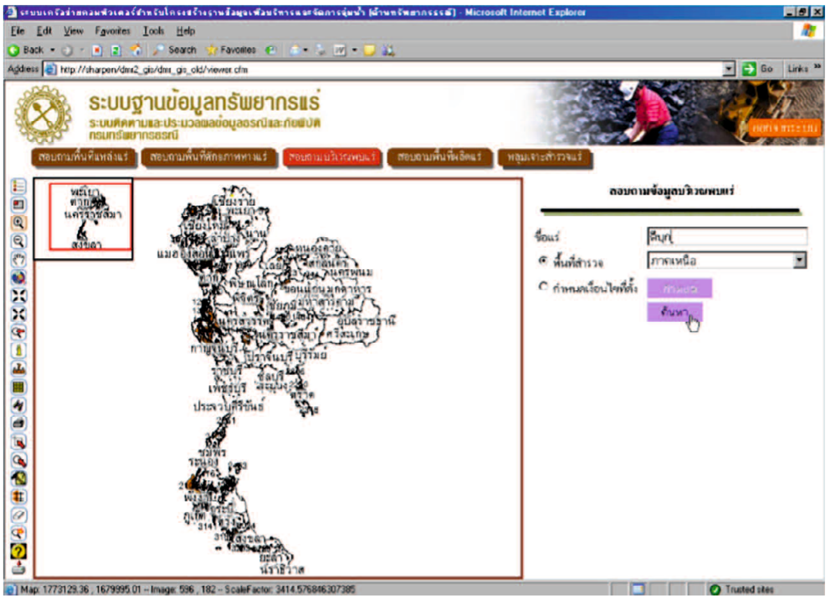


Figure 9.11 Web application for querying the current mineral occurrence database system of Thailand

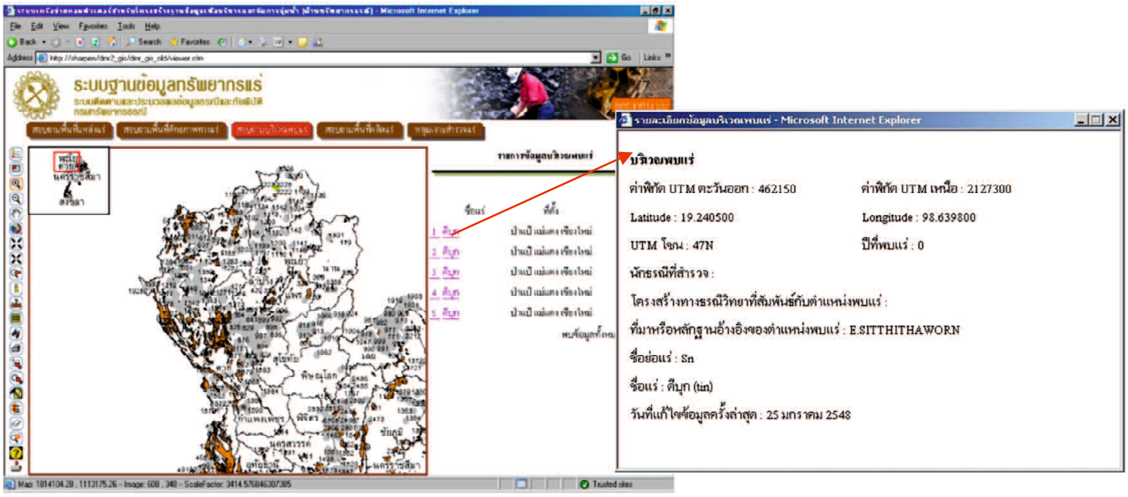


Figure 9.12 Web application for the current database system for showing query results in map image indicating the number of matching results

Furthermore, the current system does not provide data with formats that follow interoperability standard. Interoperability standard allows users or applications to directly access data repositories through standardized representations. The data in this system is in specific database structure design that makes it very difficult for other applications to reuse. To get the data from database, users need to know the database structure and get the permission to access it. The system is designed only for web application of DMR and ArcGIS software for DMR's users which can access the data in the database. Currently, when other organizations need the geospatial data of DMR, DMR staff needs to export data from the database through ArcGIS software. The system is prone to data duplication. The information in the database is also difficult to update consistently because data exist in different system. Thai government could not get up to date data from government organizations which the government badly needs for planning and solving the country's problems.

The new information system shares data in compliance with interoperability standard using SDI and OGC based web services such as WMS, WPS and WFS. The new system provides geospatial information from database to DMR's staffs and the public through these web services. These web services are generated using FOSSs and the developed web mapping application. The use of FOSSs and the developed web application enable DMR staffs to formulate web services without programming skill and reduce the cost of software acquisition, web applications design and system maintenance.

All users can access geospatial data served as web services in the database through Thailand's geospatial web portal by using any web browsers running in any device. Users can access geospatial data as map and view feature information by clicking directly on the location of interest on the map. Using this web application enable the users to easily access Thailand geospatial data anytime regardless of the users' location if internet connection is available. They can also search geospatial data in the database and download them in Shapefile or KML formats (Figure 9.13), which are the widely used spatial data format for a wide range of usage from field survey, land use planning and policy formulation.

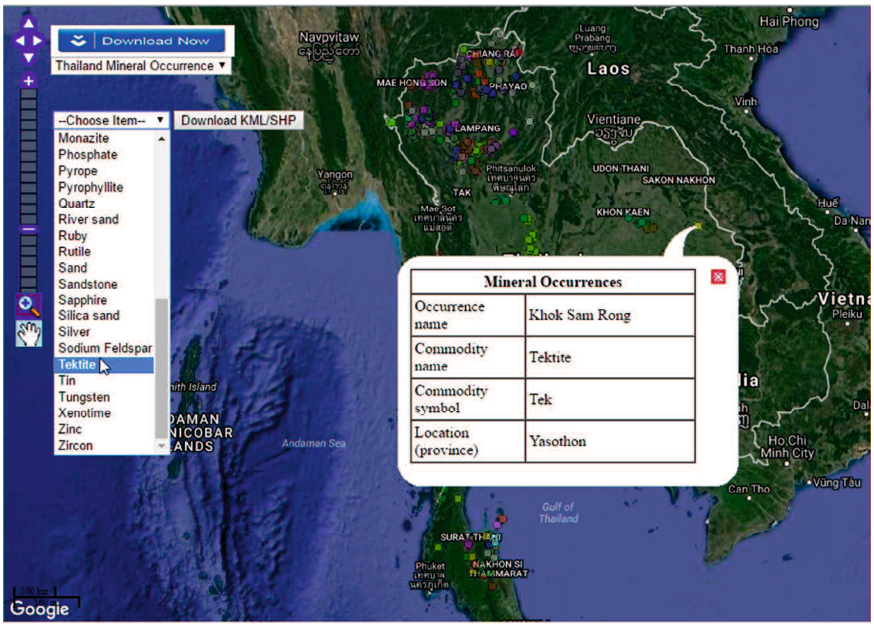
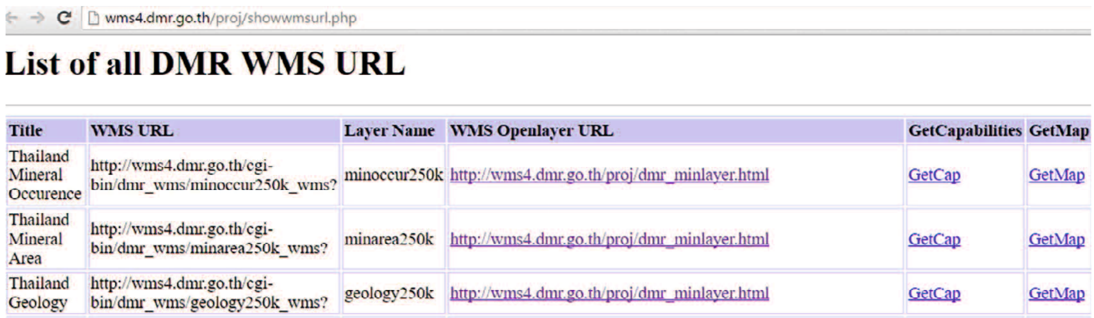


Figure 9.13 Web application for the proposed information system for querying and downloading geospatial information

The new system also shares data in the form of WMS to be used for other application. Applications support WMS can directly access the database and present geospatial data as map image and feature information on their applications. This system provides WMS data services to the public through Thailand's WebGIS portal (Figure 9.14). In this case, other organizations such as Ministry of Natural Resources and Environment of Thailand (MNRE) could use DMR's WMS data services on their applications to access mineral occurrences, mineral area and geology of Thailand stored in DMR's database. MNRE could get the real time data from DMR database on their applications. The updated data is very important for effective planning and managing of natural resources and environment of Thailand. Thus, data sharing using web services provided by the new system could provide reliable and up to date information for the management of natural resources in Thailand. This system could be used as a model for Thailand public agencies to follow to development an efficient and cost effective information system.


wms4.dmr.go.th/proj/showwmsurl.php

List of all DMR WMS URL

Title	WMS URL	Layer Name	WMS Openlayer URL	GetCapabilities	GetMap
Thailand Mineral Occurence	http://wms4.dmr.go.th/cgi-bin/dmr_wms/minoccur250k_wms?	minoccur250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap
Thailand Mineral Area	http://wms4.dmr.go.th/cgi-bin/dmr_wms/minarea250k_wms?	minarea250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap
Thailand Geology	http://wms4.dmr.go.th/cgi-bin/dmr_wms/geology250k_wms?	geology250k	http://wms4.dmr.go.th/proj/dmr_minlayer.html	GetCap	GetMap

Figure 9.14 DMR's WMS data services page

9.3 Contribution to the ASEAN mineral resources database and information system

The proposed system can be applied not only to Thailand geospatial database but also to the ASEAN mineral database. It should be a template for other ASEAN member countries to follow to establish the distributed ASEAN mineral information system. The new system is very effective for data sharing among ASEAN countries because it is a distributed database and information system compliant to internationally accepted interoperability standards. Although the current ASEAN mineral resources database requires the member countries to add and edit data in the ASEAN centralized database, additional works on the national mineral database is not needed using the new system. Once the ASEAN member countries develop a new information system proposed in this study, the new ASEAN mineral information system will be formed automatically.

The ASEAN mineral resources information system was developed using a centralized server to gather data from member countries through the ASEAN mineral web portal (Figure 9.15). Data from each member country are uploaded to the ASEAN mineral web portal by the member countries' representatives. The distributed data in servers of ASEAN member countries are stored in systems that are not compliant with interoperability standards. Because of this, updating the central ASEAN database from the data of these systems is difficult and time consuming. Furthermore, updating one member database also requires the same changes to be made at the ASEAN central database. Because of these, individual country's mineral information in the ASEAN central database are mostly not up to date, making the system to be an unreliable source of information for government decision makers and investors.

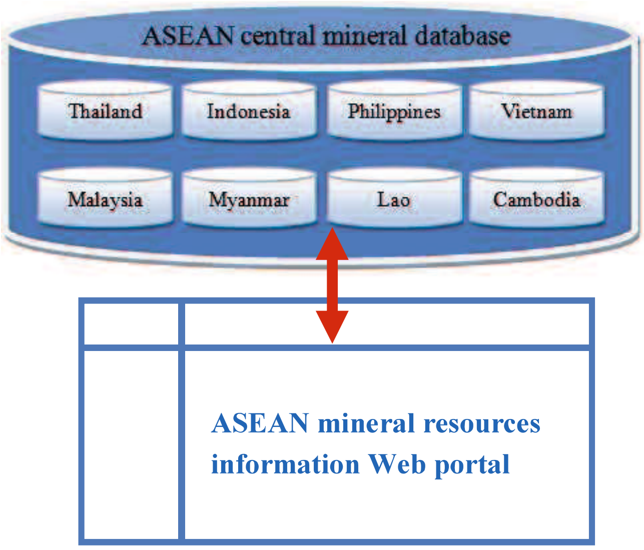


Figure 9.15 ASEAN mineral resources information system

The newly developed information system could be a very useful and important system to share mineral resource information among ASEAN countries. The new system could serve the mineral data of Thailand database as WMS to the ASEAN mineral resources WebGIS portal. In this case, ASEAN web portal could provide geospatial data of Thailand using WMS in real time. When DMR's data are updated, the ASEAN web portal will automatically get the updated mineral data from Thailand database. Thus, the new system is more efficient and requires less manpower to maintain making it cost effective. The ASEAN mineral web portal can provide up to date mineral resources information of Thailand to the public. Thus, the new system is a reliable source of mineral information for investors, and plays an important role for the economic development of Thailand and ASEAN region.

The new information system of Thailand can serve as a model of data sharing system for the other ASEAN member countries to follow. If the other ASEAN countries will develop the same information system, the ASEAN mineral resources information system will be updated and will provide reliable mineral resources information to the public (Figure 9.16). If each ASEAN member country will have its own database and information system that is compliant with internationally accepted interoperability standard, efficient and cost effective. The new ASEAN mineral resources information system will serve as a good template for other developing regions rich in mineral resources such as South America and Africa to follow in developing their own mineral information system.

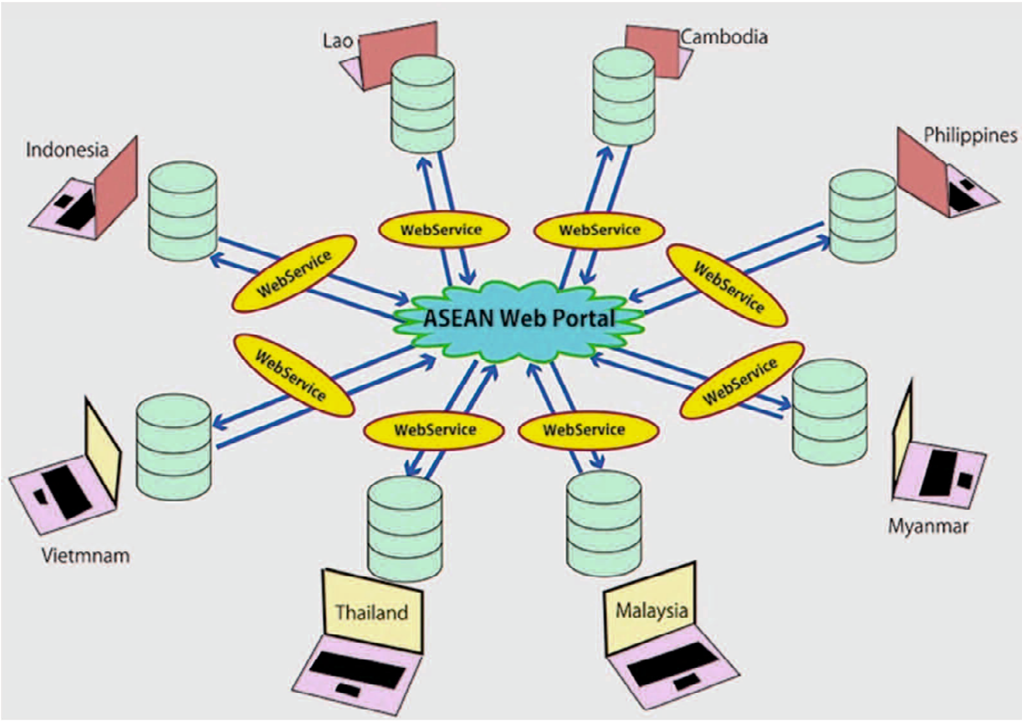


Figure 9.16 The new ASEAN mineral information system data model

Chapter 10

Summary and Conclusion

This study proposed the creation of an information infrastructure for sharing geology and mineral resources information of the countries in the ASEAN region with Thailand as the case study. FOSS and OGC based standards and web services are used successfully for managing and sharing geology and mineral resources information of Thailand.

One of the purposes of this study is to solve the problem in the dissemination of geo-information using Thailand's current WebGIS. The problems facing Thailand's WebGIS include the difficulty of updating the database structure and the information in the database because of its rigid design. It is also very difficult to share data using the system because interoperability standard is not used. Upgrading the system is expensive because it is using commercial software. Furthermore, even if the information system implemented interoperability standard, managing and updating the data on the database by authorized users is not possible. To solve the aforementioned problems, this study focuses on the development of a new WebGIS for geo-information management and sharing, following the SDI architecture, using FOSS and web services that are compliant with OGC standards. The new WebGIS system makes it easy for DMR's staffs to update and share geospatial information. The system makes geospatial information of Thailand highly available and accessible to policy makers, investors and the general public.

This study creates the distributed geospatial database system which is a very important component of the new web-based geospatial information sharing system. The distributed geospatial database is used to store geospatial information of Thailand such as mineral area, mineral occurrence and geology. Thailand's geospatial database system is setup using PostgreSQL software, PostGIS extension and phpPgAdmin to handle, store and manage geospatial information. Geospatial data in Shapefile format could be inputted into the PostGIS database system using the developed web application. The web application makes it easy for users to input and update data in the database. It is scalable and could store information from other fields of geoscience. PostGIS database is an open source software that supports multiple programs for storing and retrieving spatial data. The multiple programs include both open source and proprietary software on both the server and the client sides.

OGC based web services WMS and WPS and FOSS are useful to formulate and share the geospatial data of Thailand. The concept of formulating WMS and creating a web map viewer (WMS client) using a web mapping application is proposed in this study. Web mapping application is developed using JavaScript and PHP to incorporate FOSS based software into one composite application. The web mapping application generates WMS and displays the map using OpenLayers WMS client. The web mapping application provides user-friendly interface and forms that users can easily use to formulate WMS and display the request results either as maps or feature information. WPS is created for searching and downloading of geospatial data in various formats such as map image, Shapefile and KML using the web application. The development of web application to formulate WMS and use of WPS based on OGC standard and FOSS make geospatial information of Thailand easily accessible and sharable among organizations. DMR can share its new geospatial data served as WMS to the public. Geospatial data can also be downloaded easily using the system. Geospatial information of Thailand served as WMS could be interoperable with ASEAN mineral resources information system and other systems supporting WMS.

OGC based WFS is one of the key technologies of the new system proposed in this study. To enable sharing and editing of geospatial data on the internet, OGC has established the data exchange protocol WFS and WFS-T. In this study, GeoServer is used to generate WFS and WFS-T through its Web Administration Interface. GeoServer web interface is very efficient in generating WFS request result data in GML format and WFS-T. Users can access geospatial data of Thailand served as WFS in GML format using GeoServer's Web Interface application and Thailand's WebGIS Portal. Thailand's geospatial information served as WFS can support geology and mineral information interoperability with other data model such as GeoSciML and EarthResourceML that use GML schema for exchanging data among organization. WFS-T is used to access and update geo-database of Thailand through QGIS application. Users can use WFS-T and QGIS to manage and update Thailand's geo-database in a WebGIS. Thus, geospatial information of Thailand could be used for sharing and editing freely, easily and securely by using OGC based WFS and WFS-T and FOSS.

The WebGIS portal contains the contents and applications of Thailand's geospatial information sharing system, and provides OGC based web services WMS, WPS and WFS to the public. It is available at http://wms4.dmr.go.th/wsdmr/. It consists of various useful GIS tools for web-based visualization, analysis, query, upload, download, update and other spatial information related services. The development of WebGIS portal using Joomla, a free and open source CMS, provides simple tools to build web sites and powerful online application, taking advantage of its ease of use, secure and extensibility. These tools reduce operation and management costs, and assist people to access and share spatial information freely, easily and securely.

Thus, this study has succeeded in creating a new information infrastructure for sharing geology and mineral resources of Thailand. By using FOSS and OGC based standards and web services, the data sharing system is low cost, flexible and interoperable. The staffs of DMR-Thailand can access and edit geology and mineral resource data more easily. The newly proposed system can provide up to date geology and mineral resources information to the public. Finally, this system can be applied for the mineral databases of other ASEAN counties. It is expected that the new system contributes to the economic development of Thailand and ASEAN countries. The newly proposed system will serve as distributed node not only for the ASEAN mineral information system but also for the global information system on geology and minerals.

The future research plans of the author include the improvement of the proposed WebGIS information system, and increase of the diversity and volume of contents stored and served by the data sharing system. Other information such as geohazard, and land use will be inputted to the database of Thailand. Geohazard information can include data on sinkhole, landslide and active fault. Improvement of web application functions is also necessary like additional functions for color and pattern assignment which are very important in producing custom maps. DMR staffs will also be trained on how to use and maintain the system. Training on how to develop the information system will also be conducted for ASEAN member countries to hasten the sharing of up to date mineral resources information to the public using the ASEAN WebGIS portal.

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Appendix

Appendix A.

Software Installation to WebGIS Server

A.1 Linux Operating System software installation (CentOS)

1.1 Installation of CentOS Version 6.2 on the server. The source of CentOS can be downloaded from https://www.centos.org/download/. Burn the ISO file to DVD. Insert DVD to the server and reboot machine. Follow the default settings during the installation.

1.2 Configure network to the server, edit network-scripts file using vi editor as commands: *#vi /etc/sysconfig/network-scripts/ifcfg-eth0*

```
……………………………………………………………
DEVICE=eth0
TYPE=Ethernet
ONBOOT=yes
NM_CONTROLLED=yes
BOOTPROTO=static
HWADDR=4F:6D:8A:E6:31:60
DEFROUTE=yes
PEERDNS=yes
PEERROUTES=yes
NAME="System eth0"
IPADDR=172.16.X.XX
NETMASK=255.255.254.0
……………………………………………………......
```

Then activate the network following the command.

```
……………………………………………………………
#/etc/inid.d/network restart
#ifconfig                    // check IP address
……………………………………………………………
```

A.2 Web Server software installation (Apache)

Apache web server installation following the command as a root:

```
……………………………………………………………
#yum install httpd httpd-devel
#service httpd start
……………………………………………………………
```

A.3 Database software installation

A.3.1 PostgreSQL installation

Install first the C++ compiler and the libraries readline and zlib using the following commands:

………………………………………………………….
#yum install gcc-c++
#yum install readline readline-devel
#yum install zlib zlib-devel
………………………………………………………….

Download PostgreSQL installation file from the site http://www.postgresql.org/ftp/source/v9.1.3/. The following commands would unpack and install the downloaded PostgreSQL installation file postgresql-9.1.3.tar.bz2.

………………………………………………………….
#tar xjvf postgresql-9.1.3.tar.bz2
#cd postgresql-9.1.3
#./configure
#make
#make install
………………………………………………………….

After the installation, create a new user named "postgres" using the command:

………………………………………………………….
#adduser postgres
………………………………………………………….

Create and initialize the database directory at /usr/local/pgsql/data using the command sequence:

………………………………………………………….
#mkdir /usr/local/pgsql/data
#chown postgres /usr/local/pgsql/data
#su - postgres
$/usr/local/pgsql/bin/initdb -D /usr/local/pgsql/data
………………………………………………………….

Starting the PostgreSQL database server would be done by executing the command:

```
……………………………………………………………
$/usr/local/pgsql/bin/postmaster -D /usr/local/pgsql/data >logfile 2>&1 &
……………………………………………………………
```

The following procedure would enable PostgreSQL to be started as a Linux service. While inside the folder postgresql-9.1.3, do the following commands:

```
……………………………………………………………
#cp contrib/start-scripts/linux /etc/rc.d/init.d/postgresql
#chmod +x /etc/rc.d/init.d/postgresql
#service postgresql stop      //to stop PostgreSQL service.
#service postgresql start     //to start PostgreSQL service.
……………………………………………………………
```

A.3.2 PostGIS installation

PostGIS installation needs software Geos, Proj, libraries libxml2, curl, and PostGIS.

Geos installation file (geos-3.3.2.tar.bz2) could be downloaded from the site http://download.osgeo.org/geos/. Unpack and install the software following the commands:

```
……………………………………………………………
#yum install geos geos-devel
#tar xjvf geos-3.3.2.tar.bz2
#cd geos-3.3.2
#./configure
#make
#make install
……………………………………………………………
```

The proj installation file (proj-4.8.0.tar.gz) could be downloaded from the site http://download.osgeo.org/proj/. Unpack and install the software following the commands:

```
……………………………………………………………
#tar xzvf proj-4.8.0.tar.gz
#cd proj-4.8.0
#./configure
#make
#make install
……………………………………………………………
```

To install libxml2 and curl, execute the following commands:

…………………………………………………………
#yum install libxml2 libxml2-devel
#yum install curl curl-devel
…………………………………………………………

The PostGIS installation file (postgis-2.1.7.tar.gz) could be downloaded from the site http://postgis.refractions.net/download/. Unpack and install the software following the commands:

…………………………………………………………
 # tar xzvf postgis-2.1.7.tar.gz
#cd postgis-2.1.7
#./configure --with-pgconfig=/usr/local/pgsql/bin/pg_config
#make
#make install
…………………………………………………………

A.3.3 PHP and PhpPgAdmin installation

The PHP installation file (php-5.4.29.tar.bz2) could be downloaded from the site https://secure.php.net/releases/. Unpack and install the software following the commands:

…………………………………………………………
 # tar xjvf php-5.4.29.tar.bz2
#cd php-5.4.29
#./configure --with-apxs2 --with-pgsql --with-curl --enable-mbstring
#make
#make install
#cp php.ini-development /usr/local/lib/php.ini
…………………………………………………………

We need to edit file php.ini for uploading large shape files using PHP script. The corresponding lines in the php.ini file that should be edited are:

…………………………………………………………
post_max_size = 512M
upload_max_filesize = 512M
…………………………………………………………

Open httpd.conf at /etc/httpd/conf/ and add the following lines:

…………………………………………………………
LoadModule php5_module modules/libphp5.so
AddType application/x-httpd-php .php .php3 .phphtml
AddType application/x-httpd-source .phps
…………………………………………………………

The installation file of phpPgAdmin (phpPgAdmin-5.0.4.tar.bz2) could be downloaded from the site http://phppgadmin.sourceforge.net/doku.php?id=download. Copy the downloaded file *phpPgAdmin-5.0.4.tar.bz2* to the folder /var/www/html/ and do the following commands:

…………………………………………………………
#tar xjvf phpPgAdmin-5.0.4.tar.bz2
#cd phpPgAdmin-5.0.4
#./configure
#make
#make install
…………………………………………………………

To test phpPgAdmin, the apache server and postgresql should be started by executing the following commands:

…………………………………………………………
#setenforce 0
#service httpd start
#service postgresql start
…………………………………………………………

To allow user to access PostgreSQL through TCP/IP, the config.inc.php, pg_hba.conf and postgresql.conf should be edited as follows:

…………………………………………………………
 # vi /phppgadmin/conf/config.inc.php
…………………………………………………………

And edit:

…………………………………………………………
Conf['extra_login_security']=true to be
Conf['extra_login_security']=false
…………………………………………………………

…………………………………………………………
 # vi /usr/local/pgsql/data/pg_hba.conf
…………………………………………………………

Add 1 line:

…………………………………………………………
host all all 0.0.0.0/0 password
…………………………………………………………
…………………………………………………………
 # vi /usr/local/pgsql/data/postgresql.conf
…………………………………………………………

And edit:

…………………………………………………………
***#**listen_address ='**localhost**' # what IP interface(s) to listen on;* to be
listen_address ='' # what IP interface(s) to listen on;*
…………………………………………………………

Restart the service following the command:

…………………………………………………………
#service postgresql restart
…………………………………………………………

Change password to user postgres for db accessibility with commands:

…………………………………………………………
 # su – postgres
$ /usr/local/pgsql/bin/psql template1
Template1# ALTER USER postgres with password 'new password here';
Template1# exit
…………………………………………………………

Test the phpPgAdmin by pointing your browser to the URL:

http://172.16.X.XX/phpPgAdmin-5.0.4/index.php.

A.4 MapServer software installation

Before installing Mapserver, edit the library path in *ld.so.conf* (*/etc/ld.so.conf*).

Open *ld.so.conf* and add the following lines:

…………………………………………………………
/usr/local/pgsql/lib
/usr/local/lib
/usr/local
/usr/lib
…………………………………………………………

After editing, execute the following command to apply the changes:

…………………………………………………………
#ldconfig
…………………………………………………………

Mapserver installation needs the libraries ***gdal*** and ***gd***. Gdal installtion file (gdal-1.9.0.tar.gz) could be downloaded from the site http://trac.osgeo.org/gdal/wiki/DownloadSource. Unpack and install the software following the commands:

…………………………………………………………
 # tar xzvf gdal-1.9.0.tar.gz
 # cd gdal-1.9.0
#./configure
#make
#make install
…………………………………………………………

gd installtion file (gd-2.0.35.tar.gz) could be download from the site http://fossies.org/unix/www/gd-2.0.35.tar.gz/. Unpack and install the software following the commands:

…………………………………………………………
#tar xzvf gd-2.0.35.tar.gz
#cd gd-2.0.35
#./configure --without-xpm--with-freetype --with-libiconv-prefix=/usr
#make
#make install
…………………………………………………………

The Mapserver installation file (mapserver-6.2.2.tar.gz) could be downloaded from the site http://mapserver.org/download.html. Unpack the file and install the software with optional libraries as following the commands:

…………………………………………………………
```
#tar xzvf mapserver-6.2.2.tar.gz
#./configure --with-ogr=/usr/local/bin/gdal-config --with-gdal=/usr/local/bin/gdal-
  config --with-httpd=/usr/sbin/httpd --with-wfsclient --with-wmsclient --enable-debug
  --with-curl-config=/usr/bin/curl-config --with-proj=/usr/local --with-tiff
  --with-gd=/usr/bin/gdlib-config --with-jpeg --with-freetype=/usr/include
  --with-threads --with-wcs --with-xml2-config=/usr/bin/xml2-config
  --with-postgis=/usr/local/pgsql/bin/pg_config --with-geos=/usr/local/bin/geos-
  config
  --with-sos --with-agg --with-agg=/usr/local
#make
#make install
```
…………………………………………………………

After successfully installing the software, copy the file "mapserv" to the directory /usr/local/bin and make the file executable by following the command:

…………………………………………………………
```
#cp mapserv /usr/local/bin/
#chmod +x /usr/local/bin/mapserv
```
…………………………………………………………

A simple test to try and run the installed software.cab be done by following the command:

…………………………………………………………
```
$ ./mapserv
```
…………………………………………………………

The MapServer program is the "mapserv" binary executable. This is a CGI executable meant to be called and run by web server. To get the "mapserv" binary installed in a publicly accessible directory that is configured to run CGI programs and scripts, edit the httpd.conf (the main apache configuration file), following the command sequence:

Locate cgi-bin directory in /etc/httpd/config/httpd.conf and edit the installation path of compiled mapserv excutable.

```
……………………………………………………………………………….
# ScriptAlias: This controls which directories contain server scripts.
ScriptAlias /cgi-bin/ "/var/www/cgi-bin/"
#
<Directory "/var/www/cgi-bin">
   AllowOverride None
   Options None
   Order allow,deny
   Allow from all
</Directory>
#
…………………………………………………………………………………
```

Thus, script file that execute mapserv should be saved in cgi-bin directory. To run the output of this script file through a Web Server, the script should be reach using the URI: http://hostname/cgi-bin/*script_file&query_parameter.*

References:

1. Summary of Software Installations for a WEB-GIS Ready Server
   by Dr.Joel C. Bandibas
2. MapServer Documentation Release 7.0.1
   (http://www.mapserver.org/pdf/MapServer.pdf)

A.5 GeoServer software installation

GeoServer, is an open sources software that is supported by several operating systems such as Windows, OS X and Linux. In this study, the Windows Server was provided by the department for installing GeoServer software. GeoServer installation on Windows Server is presented below.

GeoServer requires Web Server and a Java Runtime Environment (JRE).

A.5.1. install Apache Tomcat web server

Download the software from https://tomcat.apache.org/download-80.cgi. In this study, download Apache Tomcat version 8.0 and install it following the default settings.

A.5.2. install Java Se Development kit 8

Download jdk-8u101-windows-x64.exe at http://www.oracle.com/technetwork/java/javase/downloads/jdk8-downloads-2133151.html and installed it following the default settings.

A.5.3. install Java Runtime Environment (JRE)

Download JRE jre-8u101-windows-x64.tar.gz from http://www.oracle.com/technetwork/java/javase/downloads/jre8-downloads-2133155.html and install it following the default settings.

A.5.4. install GeoServer software

Download GeoServer software from http://geoserver.org/download/. In this study GeoServer vesion 2.9.1 should be used. The following setting should be used:……………………………………………………………………………

- License Agreement: Agree
- Choose install location: destination folder of GeoServer program
- JRE: choose source path of JRE
- GeoServer Data Directory: choose "default" if setup first time or choose "Exist data directory" if was set up GeoServer.
- GeoServer Administrator: input username and password for managing GeoServer through Web Administration Interface.
- GeoServer Web Server Port: input port for entering Web Administration Interface such as "8080"
- Type of Installation: choose "Run manual" or "Install as a service" if you choose "Run manual" you need to start service before using GeoServer to track service information through the command line. On the other hand, if

you choose “Install as a service” tracking the service information is not possible when starting the service for GeoServer automatically. In this study choose “Run manual”.

……………………………………………………………………………………

Start the service GeoServer at the “Start Menu /GeoServer 2.2.4/ StartGeoServer”.

The Web Administration Interface through a brower will be used to manage Geoserver In this study, the Web Administration Interface is available at http://wmsservice.dmr.go.th:8080/geoserver/web/.

A.5.5. Security configuration of data and transactions on WFS.

GeoServer allows access on a service level (WFS). It cannot specify access to a specific OGC service on one specific layer. Thus, security configurations need to determine the services. Services are link to roles. Services and roles are linked in a file called “services.properties”, which is located in the security directory in GeoServer data directory. And role is link to user, not unless you want to deny access to everyone. Set this in the “users.properties” file, which is located in the security directory in GeoServer data directory. The process to limit the user to access data and transaction on WFS is describes as follow:

……………………………………………………………………………………

- Create User, In this case, create user through GeoServer Web Interface.
  an example username=”user”, Password=”password”
- Create Role, In this case create role through GeoServer Web Interface.
  an example Roles_name=” ROLE_WFS_WRITE”
- Setting security in services.properties with syntax as follow:
  wfs.GetFeature = ROLE_WFS_READ
  // link access to the WFS GetFeature method to the role ROLE_WFS_READ
  wfs.GetFeature = ROLE_WFS_WRITE
  // link access to the WFS Transactions to the role ROLE_WFS_WRITE.
- Setting security in users.properties with syntax as follow:
  user=password, ROLE_WFS_WRITE

……………………………………………………………………………………

References:

GeoServer Installation, http://docs.geoserver.org/latest/en/user/installation/index.html

A.6 Joomla CMS software installation

Joomla CMS is a software package run on Web Server. The software will be installed using the following procedure:

……………………………………………………………………………….
- Download package file Joomla 3.3.0 at "https://www.joomla.org/download.html"
- Move package file installation and unpack it to Website root on the server.
- Start installation by openning the web browser and browsing to the site's domain name and installation path. The installation screen will show at this stage.
- Enter the configuration information e.g. Site Name, Description, Admin Email Address, Admin Username, Admin Password and Site Offline (Yes/No).
- Configure database by choosing the database type. In this study choose PostGreSQL that already exists on the server. And then fill in information such as the Hostname (IP Address), Username, Password, DBname and Table Prefix.
- Install Sample data to the website (optional)
- And lastly check all website specific information and then click the install button.

……………………………………………………………………………….

Delete the installation folder after the installation. The web site can be managed by browsing to the domain name and administrator path. Login is using of username and password of administrator.

References:

Installing Joomla, https://docs.joomla.org/J3.x:Installing_Joomla

Appendix B.

Example of Thailand mineral area WMS script file and Mapfile

minarea250k_wms (wms script file, located at cgi-bin on web server)

```
#!/bin/sh

export MS_MAPFILE=/var/www/minarea.map
exec /usr/local/bin/mapserv
```

minarea.map (Mapfile, located at /var/www/ on web server)

```
MAP
 NAME OGC_WMS
 STATUS ON
 SIZE 256 256
 EXTENT 347957.78125 636396.6875 1067782.25 2260697.75
 IMAGECOLOR  255 255 255
 IMAGETYPE gif
 PROJECTION
  "init=epsg:4326"
 END

OUTPUTFORMAT
  NAME gif
  DRIVER "GD/GIF"
  MIMETYPE "image/gif"
  EXTENSION "gif"
  TRANSPARENT ON
 END

SYMBOL
   NAME "Circle"
    Type ELLIPSE
    FILLED true
    POINTS 1 1
   END
END

SYMBOL
   NAME "Solid"
    Type ELLIPSE
    FILLED true
    POINTS 1 1 END
END

WEB
```

```
 IMAGEPATH "/var/tmp/ms_tmp/"
 IMAGEURL "var/tmp/ms_tmp/"
 METADATA
     WMS_TITLE "map file from minarea250k"
     WMS_ABSTRACT "map file"
     WMS_ONLINERESOURCE "http://wms4.dmr.go.th/cgi-bin/minarea250k_wms?"
     WMS_CONTACTPERSON "Nutjaree Charoenbunwanon"
     WMS_CONTACTORGANIZATION "Department of Mineral Resources, Thailand"
     WMS_CONTACTVOICETELEPHONE "+66-2-621-9692"
     WMS_CONTACTELECTRONICMAILADDRESS " nutjaree@dmr.mail.go.th"
     WMS_FEATURE_INFO_MIME_TYPE  "text/html"
     WMS_SRS "EPSG:4326 ESRI:54004 EPSG:4326 EPSG:4612 EPSG:4301
EPSG:900913"
    END
 END

 LEGEND
   OUTLINECOLOR 200 200 200
   KEYSPACING 10 10
   LABEL
     TYPE bitmap
     SIZE small
   END
  END

 LAYER
   NAME minarea250k
   METADATA
     WMS_TITLE "Autogenerated minarea"
     WMS_ABSTRACT "Autogenerated map file"
     WMS_SRS "EPSG:4326 ESRI:54004 EPSG:4326 EPSG:4612 EPSG:4301
EPSG:900913"
   END

     connectiontype postgis
     connection "user= username password=password dbname=dbname host=localhost
     port=5432"
     data "geom from minarea250k using unique gid"
   TYPE POLYGON
   STATUS ON
   PROJECTION
     "init=epsg:4326"
   END

   CLASSITEM "comm_symbo"

   class
    name "Andesite"
    expression "Ads"
      style
```

```
        color  10 99 210
        outlinecolor 0 0 0
        width 2
      end
    end
    class
     name "Andesite/ industrial rock"
     expression "AdsAgg"
      style
        color  138 204 232
        outlinecolor 0 0 0
            width 2
      end
    end
    class
     name "Silver"
     expression "Ag"
      style
        color  147 94 243
        outlinecolor 0 0 0
            width 2
      end
    end
    class
     name "Gold"
     expression "Au"
      style
        color  211 29 42
        outlinecolor 0 0 0
            width 2
      end
    end
…..
End ## Layer End
End ## Map End
```

Appendix C.

Terms and definitions

Terms and definitions

Application Programming Interface:

A protocol intended to be used as an interface by software components to communicate with each other. Such interface helps developers extend reach of their apps and/or services.

Binding:

specific syntax and parameter values used by a client to invoke a specific server operation.

Bounding box:

portion of a coordinate space that lies between a lower bound and an upper bound in each dimension of a coordinate reference system

Client:

software component that can invoke an operation from a server

Content:

data or information stored in a server.

Coordinate Reference System:

coordinate system which is related to the real world by a datum [ISO 19111]

Coordinate System:

set of mathematical rules for specifying how coordinates are to be assigned to points

Datasets:

a collection of data, usually presented in tabular form.

Feature:

abstraction of real world phenomena [ISO 19101]

Function:

rule that associates each element from a domain (source, or domain of the function) to a unique element in another domain (target, co-domain, or range) [ISO 19107]

Geographic information:

information concerning phenomena implicitly or explicitly associated with a location relative to the Earth [ISO 19128]

Geographic Information Systems:

geospatial tools are information systems that integrate, store, edit, analyze, and display geographic information for decision making.

Layer:

basic unit of *geographic information* that may be requested as a *map* from a *server*

Map:

portrayal of geographic information as a digital image file suitable for display on a computer screen

Operation:

specification of a transformation or query that an object may be called to execute [ISO 19119]

XLink link:

an explicit relationship between resources or portions of resources

Interface:

named set of operations that characterize the behavior of an entity.

Interoperability:

capability to communicate, execute programs, or transfer data among various functional units in a manner that requires the user to have little or no knowledge of the unique characteristics of those units [ISO 2382-1]

Parameter:

variable whose name and value are included in an *operation request* or *response*

Platform:

the underlying infrastructure in a distributed system (Adapted from ISO 19119)

NOTE A platform describes the hardware and software components used in a distributed system. To achieve interoperability, an infrastructure that allows the components of a distributed system to interoperate is needed. This infrastructure, which may be provided by a Distributed Computing Platform (DCP), allows objects to interoperate across computer networks, hardware platforms, operating systems and programming languages. (Adapted from Subclause 10.1 of ISO 19119)

Request:

invocation of an *operation* by a client

Response:

result of an operation, returned from a server to a client

Resource:

any addressable unit of information or service [IETF RFC 2396]

NOTE The means used for addressing a resource is a URI (Uniform Resource Identifier) reference

Opaque:

not visible, accessible or meaningful to a client application

Server:

a particular instance of a service

Service:

distinct part of the functionality that is provided by an entity through *interfaces* [ISO 19119]

Service chain:

sequence of services where, for each adjacent pair of services, occurrence of the first action is necessary for the occurrence of the second action [ISO 19119]

Service metadata:

metadata describing the *operations* and *geographic information* available at a *server*

Spatial Reference System:

a projected or geographic *coordinate reference system*.

Version:

version of an Implementation Specification (document) and XML Schemas to which the requested operation conforms

Abbreviated terms

AEC	ASEAN Economic Community
AMCAP	ASEAN Minerals Cooperation Action Plan
AMDIS	ASEAN Mineral resources Database and Information System
API	Application Programming Interface
APSC	ASEAN Political and Security Community
ASCC	ASEAN Socio-Cultural Community
ASEAN	Association of Southeast Asian Nations
ASOMM	ASEAN Senior Official Meeting on Minerals
ASP	Active Server Page
CCOP	Coordinating Committee for Geoscience Programmes in East and Southeast Asia
CGI	Common Gateway Interface
CMS	Content Management System
CRS	Coordinate Reference System
CPU	Central Processing Unit
CS	Coordinate System
DB	Database
DBMS	Database Management System
DCP	Distributed Computing Platform
DMR	Department of Mineral Resources, Thailand
EPSG	European Petroleum Survey Group
ETL	Extract Transform Load

FOSS	Free Open Sources Software
FOSS4G	Free Open Sources Software for Geospatial Information Systems
GAI	Geological Agency of Indonesia
GDAL	Geospatial Data Abstraction Library
GEOS	Geometry Engine - Open Source
GIS	Geographic Information System
GML	Geography Markup Language
GNU-GPL	GNU General Public License
GSJ	Geological Survey of Japan
GUI	Graphic User Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
ISO	International Organization for Standardization
ISO/TC	Technical Committee of International Organization for Standardization
JDK	Java Se Development Kit
JPEG	Joint Photographic Experts Group
JRE	Java Runtime Environment
KML	Keyhole Markup Language
MIME	Multipurpose Internet Mail Extensions
MNRE	Ministry of Natural Resources and Environment of Thailand
MS SQL	Microsoft Structured Query Language
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium/ Open GIS Consortium
OOP	Object-Oriented Programming
OSGeo	Open Source Geospatial Foundation
OSSIM	Open Source Security Information Management

PHP	Hypertext Preprocessor
PNG	Portable Network Graphics
QGIS	Quantum GIS
SDI	Spatial Data Infrastructure
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SQL	Structured Query Language
SRS	Spatial Reference System
UMN	University of Minnesota
URI	Universal Resource Identifier
URL	Uniform Resource Locator
URN	Uniform Resource Name
UTM	Universe Transverse Mercator
WCS	Web Coverage Service
WebGIS	Web-based Geographic Information System
WFS	Web Feature Service
WFS-T	Web Feature Service Transaction
WGCBM	Working Group on Capacity Building in Minerals
WGMID	Working Group on Mineral Information and Database
WGS	World Geodetic System
WGSMD	Working Group on Sustainable Mineral Development
WGTIM	Working Group on Trade and Investment in Minerals
WKB	Well-Known Binary
WKT	Well-Known Text
WMS	Web Map Service
WPS	Web Processing Service

WSDL	Web Services Description Language
W3C	World Wide Web Consortium
XLink	XML Linking Language
XML	Extensible Markup Language

Appendix D.

Research papers published in journals and presented in conferences

1 Research papers published in journals

1.1 Nutjaree Charoenbunwanon, Koji Wakita, Joel C. Bandibas, "Web-based Mineral Information System of Thailand using Free and Open Source Software and Open Geospatial Consortium standards: A case study of ASEAN Region", Geoinformatics, vol.27, no.2, 2016, p.31-39.

1.2 Nutjaree Charoenbunwanon, Koji Wakita, Joel C. Bandibas, "WebGIS using FOSS and OGC Standards; A Case Study of Web Services for Sharing Geology and Mineral Resources Information of Thailand", ASEAN Journal of Geoinformatics, vol.16, no.2, 2016, p.18-32.

2 Research papers presented in conferences

2.1 Nutjaree Charoenbunwanon, Surapong Mailap and Sompob Wongsomsak "Development of new mineral database of Thailand based on Web GIS application", General session- Database (Oral) In: Geoinformatics, Geoinforum-2014 Annual Meeting Abstracts, Kyoto, 13 June 2014, vol.25 (2014), no.2.

2.2 Nutjaree Charoenbunwanon,"Newly Development Thailand Mineral Information System Based on International Standard", International Session (Poster) In: JpGU-Japan Geoscience Union Meeting 2015, Tokyo, 26 May 2015, MTT42-P09.

2.3 Nutjaree Charoenbunwanon and Koji Wakita,"New WebGIS system for geospatial data sharing of Thailand using open source software server and web service standard", International Session (Poster) In: JpGU-Japan Geoscience Union Meeting 2016, Tokyo, 22 May 2016, HTT09-P11.