GEOSPATIAL WEB SERVICES:
AN EVOLUTION OF GEOSPATIAL DATA INFRASTRUCTURE

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Abstract

Geographic information is a valuable resource for applications and analysis where location of objects and events can enhance policy, land use, and decision making activities. Interoperability of geospatial data has been an ongoing activity and goal of the geospatial information user community for decades, focusing on data formats and standards. The recent popularity and adoption of the Internet and Web Services has provided a new means of interoperability for geospatial information, differing from previous approaches to information exchange.

Traditional approaches to geospatial information exchange are inadequate. This thesis argues that utilizing interoperability and Web Services are better methods to achieve efficient data exchange than traditional approaches. The thesis demonstrates this by describing previous and traditional approaches and interoperable methods, followed by a comparative analysis of these in the context of common scenarios of geospatial data exchange. The thesis also discusses how Web Services affect organizational issues, data policy, copyright and security.

A reference software implementation is presented to illustrate the validity of the interoperable Web Service approach for which this thesis argues. It is argued that the issues discussed have implications for GIS as a whole.

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1 Introduction

Geographic information (any information with a locational component) is a valuable resource for applications and analysis where location of objects and events can enhance policy, land use and decision making activities. Interoperability of geospatial data has been an ongoing activity and goal of the geospatial information user community for decades. The 1970s saw the emergence of a growing requirement for national mapping and surveying agencies to create policies, agreements and processes for normalizing access to and application of geospatial information. The origins of a geospatial data infrastructure (GDI) in Canada emerged in the 1980s as an effective means of access to geospatial information (Groot and McLaughlin, 2000). While popular and appealing, the infrastructure approach also created complexities for the geospatial community. There has been an ongoing effort to produce commonly accepted, standards-based specifications and approaches for discovery, evaluation, access, visualization and exploitation of geospatial information (Global Spatial Data Infrastructure Association, 2001). The recent popularity and adoption of “Web Services” (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a) has provided a new means of interoperability for geospatial information, differing from previous approaches, such as static document based access, or non-digital acquisition methods.

1.1 Central Argument / Hypothesis

This paper argues that Web Services approaches to interoperability are better methods to achieve efficient data exchange. Traditional approaches to geospatial information exchange are inadequate. This paper tests this hypothesis by describing previous and traditional approaches as well as interoperable methods, then making a comparative analysis of these approaches in the context of common scenarios of geospatial data exchange. A reference software implementation demonstrates the validity of the thesis argument.

1.2 Statement of Research Question

The question this research attempts to address is: are Web Services adequate for solving issues of interoperability within geospatial data infrastructures?

The research goal of this paper is to investigate Web Services and assess their ability to overcome issues of interoperability in the context of geospatial data infrastructures. The following sub questions assist in addressing the research goal:

- How do previous geospatial data interoperability efforts lack in functionality?
- How do Web Services address issues of interoperability or the access, visualization, evaluation and discovery of geospatial information, in comparison to previous interoperable approaches?

- What changes and adaptations do Web Services create for organizations holding geospatial information?
- How do Web Services affect Geographic Information Systems (GIS) as a discipline?

Taking into account literature and technical publications on geospatial information, infrastructures, technology, standards and interoperability, this research will explore and investigate the potential of applying Web Services as a new approach to a geospatial data infrastructure. The research will use specifications endorsed by the Open Geospatial Consortium (OGC) and the Canadian Geospatial Data Infrastructure (CGDI) to enable the access, visualization, evaluation and discovery of geospatial data. Using application prototypes, this research will review and assess past trends in geographic information interoperability, and explore Web Services as a new approach to interoperability, in the context of GDI.

1.3 Significance of the Research

Infrastructures for geographic information have been present in organizations since the 1960s (Groot and McLaughlin, 2000), through data standards, policies, and practices. Early infrastructures focused on data interchange definitions, metadata structures and semantics, as well as data handling algorithms and encoding. The recent rise of the Internet has provided a platform for geographic information to be accessible online. Standards bodies provide the technological framework for open interfaces and specifications in enabling information sharing between and among organizations. The ubiquity of geospatial information combined with standards based methods via the Internet provides new opportunities for multiple diverse disciplines and application domains.

Geospatial information has been accessible through various means, from paper documents, to tape media, to computer compatible digital storage, to network accessible repositories. The process of the GIS framework has evolved in parallel, from manual collection methods, to initial computer storage, to GIS as desktop applications, to GIS as an enterprise network application, to GIS on the Internet (Hartman, 1997). Interoperability efforts have also developed in concert with geospatial information and GIS, from data exchange standards, to computer hardware standards, to network transmission standards, to the Internet as the gateway to the information highway.

There is a gap, particularly in academic circles, in applying infrastructure methodologies to geographic information in the context of geospatial Web Services. Many academic studies focus on the application and analysis of geographic information, and not the access or publishing of the same. Previous efforts outline the concept and benefits of infrastructure in the context of data standards and networking, but there is a lack of insight into applying geospatial

Web Services as prescribed by specifications and standards of the Open Geospatial Consortium (OGC).

The current climate of information technology and interoperability is focused on Web Services as the enabling information exchange approach. Geospatial information is also moving in this direction, with the advent of service based specifications from the OGC, and the adoption of these standards by mapping and surveying organizations.

Current academic literature and technical material do not fully address concepts of geospatial Web Services, and what is currently taking place in terms of visualization, access and discovery of data through common interfaces, in the geospatial community. Such concepts and early iterations of OGC Web Map Service (WMS), OGC Web Feature Service (WFS), or Geography Markup Language (GML), have little information with regard to implementation level issues or adequacy for interoperability, as applied to both the provider and consumer perspective. These technologies are standards-based interfaces, which are increasingly being used throughout organizations contributing to geographic information infrastructures. For example, WMS, WFS, and GML are all endorsed specifications of the CGDI, and are quickly being adopted by many other organizations (NASA, FGDC) for their geospatial information publishing and access activities.

There is a need to provide an analysis of Web Services to GDI, as an addition to analysis and study of previous work in the field of GIS technology and infrastructure. This research is significant in that it addresses the current wave of information exchange techniques and approaches as applied to geospatial information (Web Services). The thesis provides an outline of Web Services and how they have been applied to geospatial information. The research includes, as part of the research design, a software application prototype to demonstrate the applicability, benefits, and shortcomings of the proposed approach to geospatial Web Services. This includes satisfying real world, end user applications and requirements.

1.4 Research Design

To investigate Web Services and their potential for geospatial data infrastructures, a number of sub research goals have been established. First, an analysis and summary of previous geospatial interoperability efforts is presented. The shortcomings and recommendations of previous approaches of infrastructure interoperability are recognized as a platform for the transition to an exploration of Web Services.

A comprehensive investigation and analysis of Web Services and their benefits at multiple levels (business, managerial, organizational, technological) is made. A more specific analysis of Web Services is performed in the context of geospatial data infrastructures, by researching and analyzing abstract and technical documentation from the Open Geospatial Consortium, the Global Spatial Data Infrastructure (GSDI) committee, and other relevant literature.

Canada's GeoConnections program and the Canadian Geospatial Data Infrastructure (CGDI) are used as an information resource in the context of analyzing a national infrastructure program adopting Web Services. The research issues surrounding adoption of Web Services within a national infrastructure program, such as technology transfer and organizational acceptance and investment are considered. To illustrate this research sub topic, relevant documentation, publications, technical information and resources are available at the GeoConnections website (GeoConnections, 1999). The research also examines the acceptance and adoption of Web Services by assessing operational and available services through the CGDI.

An analysis is performed to assess the impact of Web Services on GIS as a discipline, and on the changing requirements created by the Web Services approach to geospatial infrastructure. The "GIS: Tool vs. Science" debate and literature by Goodchild, Proctor and Wright (1997) is helpful in assessing the impact of Web Services on GIS. Where geospatial Web Services fit in the debate is considered. An analysis is made to assess the impact of Web Services in the area of geospatial information policy and intellectual copyright.

Taking into account the previous sub research areas, a comparative analysis is performed between previous interoperability approaches to GDI and the Web Services approach, and observations, recommendations for further research are made.

In parallel with the various sub research areas, an application prototype is developed, to present a concrete example illustrating the advantages and disadvantages of the approach proposed. The application prototype has been developed as a software development and implementation exercise. This exercise has produced an Internet based, web accessible client application, exemplifying the Web Services approach to geospatial data infrastructures. Web services used are primarily from content via the Canadian Geospatial Data Infrastructure, as well as some services from international programs and organizations to assess non-Canadian adoption and adherence to geospatial Web Services. A similar exercise is performed on various existing GIS software tools and data to help conduct a comparative analysis of previous and Web Service type approaches.

2 Geospatial Information

2.1 Geo-Info

Geospatial information is an important resource in decision-making and policy support at various levels of organizations, programs, and activities. Geospatial information can be defined, at an abstract level, as any information, data or document possessing a locational component which can reference it to a location on the Earth (Groot and McLaughlin, 2000). Examples of geographic information include, but are not limited to: earth observation imagery, atmospheric science data, aerial photography, topographic information, sensor measurements, toponyms (placenames), journals, notes and annotations. Figure 2-1 illustrates a simple depiction of geospatial information.

Figure 2-1: Map of Geospatial Data (European Space Agency)

2.2 Geographic Information Systems (GIS)

Geographic Information Systems (GIS) are computer-based systems (software and hardware), which allow storage, editing, maintenance, dissemination, display and access of geospatial information. A GIS is typically used for acquisition, storage, and analysis of information where geographic location is significant to the analysis or model (Aronoff, 1995). A GIS facilitates the integrated analysis of geospatial information, by storing information spatially (e.g. Earth location, elevation), temporally (e.g. imagery acquisition date/time) and aspatially (e.g. information related to an object which is not necessarily geospatial in nature). Geospatial information is typically represented as vector (points, lines, polygons) or raster (imagery, aerial photos) repositories. Examples of GIS usage include, but are not limited to: forestry and wildlife management, land use mapping, disaster management, geology, policy / decision making support systems, etc. Table 2-1 provides an example vector record and how attributes might be represented in a GIS:

Type	Lat	Long	City	Province / State	Type	Population	Country
Point	43.7	-79.41	Toronto	Ontario	City	5 029 900	Canada
Point	49.25	-123.11	Vancouver	British Columbia	City	2 122 700	Canada

Table 2-1: Conceptual View of Geospatial Information

The combination of geospatial information and GIS has increased the potential of geospatial information for multiple and diverse applications, and can be vital to making decisions at various levels of organizations and activities / programs (Global Spatial Data Infrastructure Association, 2001). The growing ubiquity of geospatial information and applications of GIS has enabled new and widespread uses within organizations that, historically, may not have utilized geospatial information as part of their projects and activities in the past. GIS has made the production and analysis of geospatial data more efficient and user-friendly (Aronoff, 1995), as a result of combining and integrating information holdings in a digital encoding. Figure 2-2 displays the production output of vector and raster geospatial information in digital form. The power of GIS has also introduced discussion and debate as to whether GIS is a tool to supplement applications and analysis, or whether GIS should be regarded as a scientific discipline, fostering new thought and development (Goodchild and Proctor and Wright, D.J, 1997).

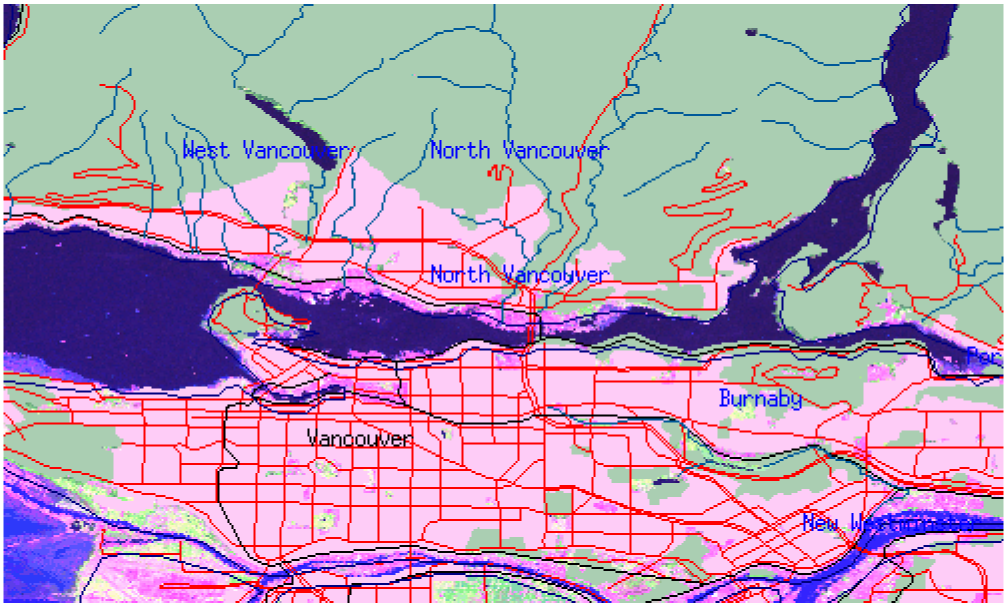


Figure 2-2: Raster and Vector Data (Natural Resources Canada)

Over the last three decades, governments and industry have invested billions of dollars in the development of GIS systems to serve various information communities, such as forestry, marine, health, etc. (Groot and McLaughlin, 2000). The mass of information collected by these organizations possesses the potential for multi-use and sharing between activities, systems and programs, thus creating a geospatial information network, highway, or infrastructure.

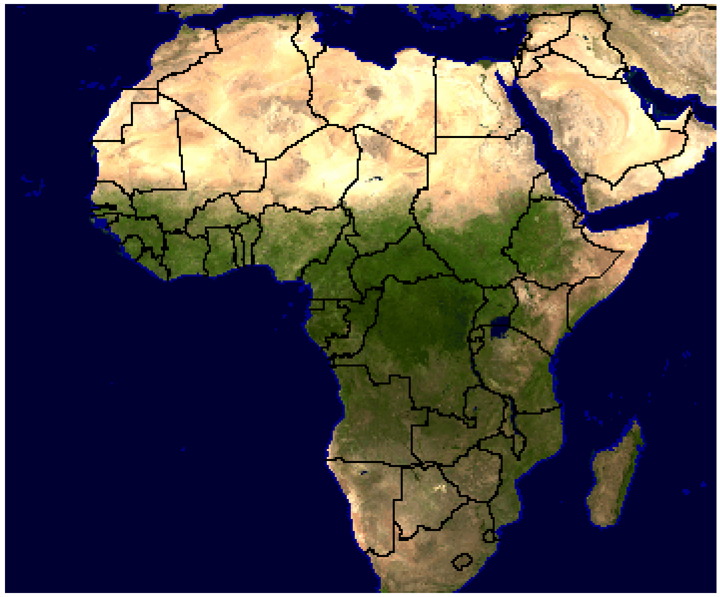


Figure 2-3: Vector and Raster Data (European Space Agency)

Despite the decrease in the cost of computer hardware and software systems, and the applicability of geographic information, it can be said that geospatial information is voluminous, multidimensional, and an expensive resource to develop, create and maintain.

3 Interoperability

3.1 Infrastructure, Internet and the Digital Age

A data infrastructure can be defined as the concept of a transparent, robust computer environment, which enables access to information using common, well-known and accepted specifications, standards and protocols (Global Spatial Data Infrastructure Association, 2001). A telephone network can be thought of as an infrastructure, providing users with connectivity service to communicate with one another, while the details behind telecommunication networks, wiring, etc., are transparent, and relatively unimportant to the end user. Infrastructure can be seen as an underlying foundation building block to enable applications, networks, etc. Although a critical topic, it is also mundane in its ubiquity; however its very existence makes enabling objects, technologies, and analysis possible (Harvey, 2000).

An infrastructure is the result of many nodes; data and services are decentralized, similar to many organizations going through restructuring. For example, in the 1980s and 1990s, head offices in Toronto slowly started to migrate to Toronto suburbs, or elsewhere to leverage lower overhead costs and networks as well as information sharing. Though location is an important aspect, the decentralization of industry and economies has shown that location is not as important in the context of doing business. This also applies to infrastructures of geographic information. Organizations can collect, publish and maintain their own data holdings, and publish them through clearinghouses, used by end-users or clients of geospatial data and / or services. Data is kept closest to the source of production or collection, which facilitates updating and completeness.

A GDI extends the infrastructure concept by focusing on the transport and transmission of geospatial information, in providing the relevant technologies, policies and agreements that assist in the availability of and access to geospatial information. A GDI provides the architectural underpinnings for discovery, evaluation, and application of geospatial information (Global Spatial Data Infrastructure Association, 2001). A concerted effort among government agencies is being made to enable the discovery, visualization and access of geospatial information at all levels, leveraging the Internet as a distributed infrastructure (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a; Global Spatial Data Infrastructure Association, 2001). Examples of organizations supporting such activities include the Federal Geographic Data Committee (Federal Geographic Data Committee, 2004), the National Aeronautics and Space Administration (National Aeronautics and Space Administration, 2004) and Canada's GeoConnections program (GeoConnections, 2004).

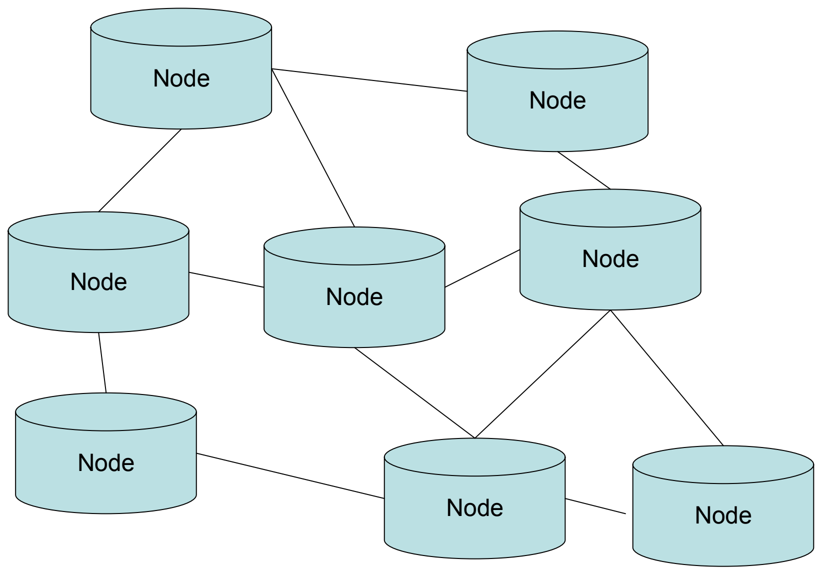


Figure 3-1: Conceptual View of a Nodal Infrastructure Model

Using the infrastructure approach to geographic information, organizations can discover, visualize and access geographic information over the Internet in a transparent fashion. GDI reduces the requirements for multiple standards for visualizing, accessing, and discovering geospatial information by establishing unified standards for data and content. GDI encompasses the networked geospatial databases and handling complex organizational, technical, human and economic issues which interact with one another. GDIs seek to support sharing of data via standards, such as national spatial reference systems, templates, etc. (Groot and McLaughlin, 2000). The cost and feasibility of multiple copies of geospatial information quickly becomes unmanageable, especially if users require up to date information; local copies result in large, ongoing data management budgets for organizations to sustain. The challenge in infrastructures in geographic information is not algorithms, but data access and handling. Data syntax, semantics, and schemas are vital to interoperability and data interchange (Groot and McLaughlin, 2000). With the Internet as the emerging platform, visualization, discovery and access of geographic information must be further investigated to create adequate semantics of applications online (such as correct tools for data manipulation, symbols, etc.).

Vital technology of GDI are the components for communicating geospatially (Groot and McLaughlin, 2000). Computer networks are vital to a GDI, and are based on communication technology (Groot and McLaughlin, 2000). Most distributed systems are made up of client-server architectures, where a central server provides services and information to client computers, providing an information exchange mechanism, which is vital to any infrastructure. There are multiple levels of technologies which power an information infrastructure, such as Internet, transport and application layers of the Transmission Control Protocol / Internet Protocol reference model (TCP/IP) (Groot and McLaughlin, 2000).

The Internet can be seen as an infrastructure of shared computing resources and information. The Internet originated from the United States Department of Defense Advanced Research Projects Agency Network (ARPANET) in the late 1960s (Begg and Connolly, 1998). The popularity of the Internet has reinforced and generated numerous diverse information highways in many information communities. Using the Internet, a network of computers can now be used as efficiently as a single computer (Hartman, 1997). Computers now leverage network technology to share disk drives, memory, and information (or data). The Internet, as part of the TCP/IP reference model, provides a means for transporting information 'packets' across a network, providing a framework (network addressing, fragmentation, timeouts, etc.) for peer to peer communication through TCP, and finally enabling an application layer for user-level protocols, such as File Transfer Protocol (FTP), and Hypertext Transfer Protocol (HTTP) (Groot and McLaughlin, 2000).

The Internet enables information holdings and services to be distributed in terms of location. Based on open communication standards and protocols, the Internet has enabled organizations to publish their information holdings over a distributed network infrastructure, as well as providing a medium for discovering and evaluating educational resources, commercial initiatives, government information, etc. Virtually any resource or service can be found or accessed using the Internet, such as online banking, vacation planning, dictionaries, thesauri, news, etc. The common standards and nature of the Internet allow a computer to connect to the Internet with little effort or complexity, and enable communication with other computers on the network, despite differences in computer hardware, software and other factors which have historically been impediments to communications between computers (Hartman, 1997). This results in a foundation layer of interoperability in network communications. The Internet has enabled the World Wide Web (WWW) to provide exchange of information through a user interface commonly known as a web browser (Groot and McLaughlin, 2000). Documents written for web browsers contain text and images, as well as linkages to other web content distributed throughout the Internet.

3.2 Interoperability

Interoperability can be defined as the ability of a system or components of a system to provide information sharing and inter-application co-operative process control, through a mutual understanding of request and response mechanisms (Groot and McLaughlin, 2000). Interoperability is the ability of a system (or component of a system) to access a variety of heterogeneous resources by means of a single, unchanging operational interface (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a). That is, two resources (such as a client and a server) are interoperable if there is a mutually agreed upon messaging vocabulary, which they can understand. While communications between them may relay different requests and responses, the two resources understand the frameworks in which they are delivered. Interoperability dovetails with the open systems model, an approach to software engineering and system design which enables and encourages sharing of resources (Gardels, 1999). These resources are regarded as objects, meaning that every resource can be seen as a component among other components which coexist under a common framework, thus promoting an operational model as opposed to data standards (Gardels, 1999).

One analogy of interoperability in action can be made from the concept of electrical adapters and cross country / continental travel (Guerrero, 2004). One can currently purchase a small adapter, usually at low-cost, and be able to operate their device at the power of the host country's power supply.

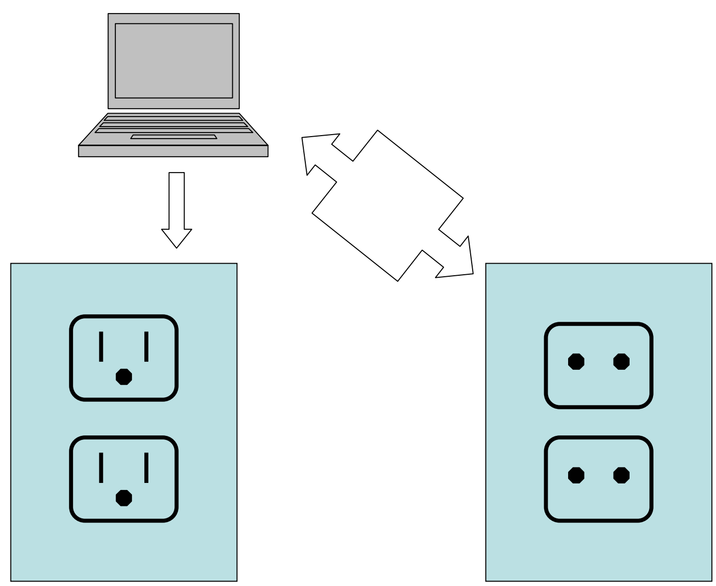


Figure 3-2: Interoperability Achieved with Adapter

This is much more efficient (and realistic!) than expecting a country to alter their entire infrastructure. One can perceive such 'adapters' as interfaces which can facilitate 'plug-and-play' infrastructure and interoperability.

Again, interoperability allows one to provide and consume resources as 'components', with little / no prior knowledge of the component. Revisiting

Guerrero's excellent adapter example, one is not very concerned with a) where the power comes from b) how the power is transmitted to the interface on the wall c) the nature of the power (220V vs. 110V) d) the interface connecting to the power which is being provided for one to operate their laptop, hairdryer, toaster, or other device.

3.3 Standards

The ubiquity of geospatial information results in massive information repositories by mapping and surveying organizations that publish content to geospatial data infrastructures. The Internet has had an enormous impact in enabling the discovery, access and visualization of geospatial information, for both information providers and consumers. The Internet has provided the utility to integrate database information holdings interfaced through the WWW and TCP/IP protocols, and provides a transparent layer to the end user interacting with a geospatial resource (Begg and Connolly, 1998). With the increase in computer technology and standards, GDI activities increasingly provide the opportunity for cost-effective collection, sharing and distribution of information with a geographic component within and between entities (Groot and McLaughlin, 2000). Information of all types is an expensive resource, taking into account efforts for creation, maintenance, and quality assurance. With the mass of geospatial information being produced and published to the Internet, issues emerge with regard to usability and suitability:

- Is the information in a format or structured in a way in which those wishing to utilize the information can comprehend and interpret it for their given application and analytical requirements?
- Does the information originate from an authoritative source or provider? Furthermore, is the information representative of the most current updates and maintenance by the authoritative provider?
- Is the consumer looking for the entire information product for their use, or for a specific parcel, region, or band combination of imagery? That is, the consumer may be seeking a subset of the information, but cannot afford to, or may not wish to, acquire the entire product collection
- Does the data have any security and / or policy issues with regard to usage?

The above bullets represent just a few issues with regard to geospatial data interoperability within a GDI. The causes of such problems can be due to differing organizational policies and practices, as well as contradictory approaches to information management and technology within the geospatial information community in the context of sharing resources. The geospatial information user community is exemplary of problems resulting from a lack of, or ineffective use of, specifications and standards (Groot and McLaughlin, 2000). Harmonizing approaches and standards for spatial data acquisition and exchange lessens the requirement for multiple data acquisition, publishing and exchange activities, which may become very expensive in resources and operating budgets. The 1970s saw the emergence of a growing requirement for national mapping and surveying agencies to create policies, agreements and processes for normalizing the access and application of geospatial information (Groot and McLaughlin, 2000). These requirements were initially narrow in scope and commonly focused on data standards. They then progressed to take account of organizational issues.

Standards initially provide three primary benefits for geospatial information: a) portability: use and reuse of information and applications, b) interoperability: multiple system information exchange and c) maintainability: long term updating and effective use of a resource (Groot and McLaughlin, 2000). Standards can save time and effort on reinventing approaches to discovery, evaluation, access and visualization of geospatial information. Standards organizations for GDI are evident at multiple levels, such as government organizations (CGDI, FGDC), independent bodies, such as the Canadian General Standards Board (CGSB), American National Standards Institute (ANSI), and the International Organization for Standardization (ISO), and industry associations, such as the Open Geospatial Consortium (OGC) (Groot and McLaughlin, 2000). A geospatial data infrastructure supports many standards for a wide range of applications. Low-level standards such as computer hardware, networks and operating system standards are utilized in GDI (Groot and McLaughlin, 2000). High-level standards (user interfaces, data formats, etc.) from such bodies as ISO, OGC and FGDC are also utilized (United States National Research Council, 1999).

Standards promote interoperability within an infrastructure, and provide benefits for information exchange. Standards are also designed for broad, long-term use; however they pose difficulties due to the design and definition process used to create them, which may take time initially (Groot and McLaughlin, 2000). It is up to the organization or program to utilize standards, which satisfy their geospatial information requirements.

The abovementioned enabling approaches and technologies provide endless possibilities for geospatial information. They also raise the issue of data copyright and intellectual property, and how the development of a useful legal framework for both private and public activity is vital. Geographic information is not cheap to produce and maintain (Aslesen, 1998). The capabilities of digital infrastructures and information communities create further concern over geospatial information and its potential misuse; control over copying data is difficult to implement (Aslesen, 1998). Geospatial systems can be dangerous in merging spatial data by identifying details and information otherwise not transparent independently (Aslesen, 1998).

Given the discussion above, it is not surprising that there is a geospatial community of interest on matters relating to GDI. How does this community communicate geospatially in terms of discovering, evaluating, accessing, and visualizing geospatial information? How is interoperability prescribed in a GDI and how does it satisfy the requirements of the community?

4 Traditional Approaches to Geospatial Data Interoperability

Since the inception of the Internet, attempts at interoperability have been mostly focused on the transport and transmission of information through simple Internet technologies, such as the downloading of data from an Internet website using Hypertext Transfer Protocol, or HTTP (World Wide Web Consortium, June 1999), and / or File Transfer Protocol, or FTP (Internet Engineering Taskforce, October 1985) over the Internet. Additional attempts at interoperability have been focused on data standards and formats, such as the ESRI Shapefile format specification (ESRI, 1998), a simple and useful format for storing geospatial and attribute information across relationally linked files.

Geospatial information, GIS and the Internet have provided significant advances in basic data acquisition and transfer. Delivery mechanisms such as physical mailing of analog and digital media have been significantly replaced by online capabilities, reducing the waiting process of data delivery from provider to consumer. Currently, users of geospatial data can acquire data from a provider's website in a myriad of forms, for a variety of purposes. Let's examine some current traditional methods of geospatial data acquisition and issues revolving around them.

4.1 GeoGratis

GeoGratis is a web and file transfer protocol (FTP) site that distributes Canadian geospatial data at no cost to users. GeoGratis provides a variety of geospatial data (vector – roads, land use, raster – satellite imagery, aerial photography), primarily via common Internet methods such as static file transfer methods (HTTP, FTP) and downloads (Natural Resources Canada, 2000). GeoGratis offers a file-based download structure, which users can visually navigate with the web browser to download products.

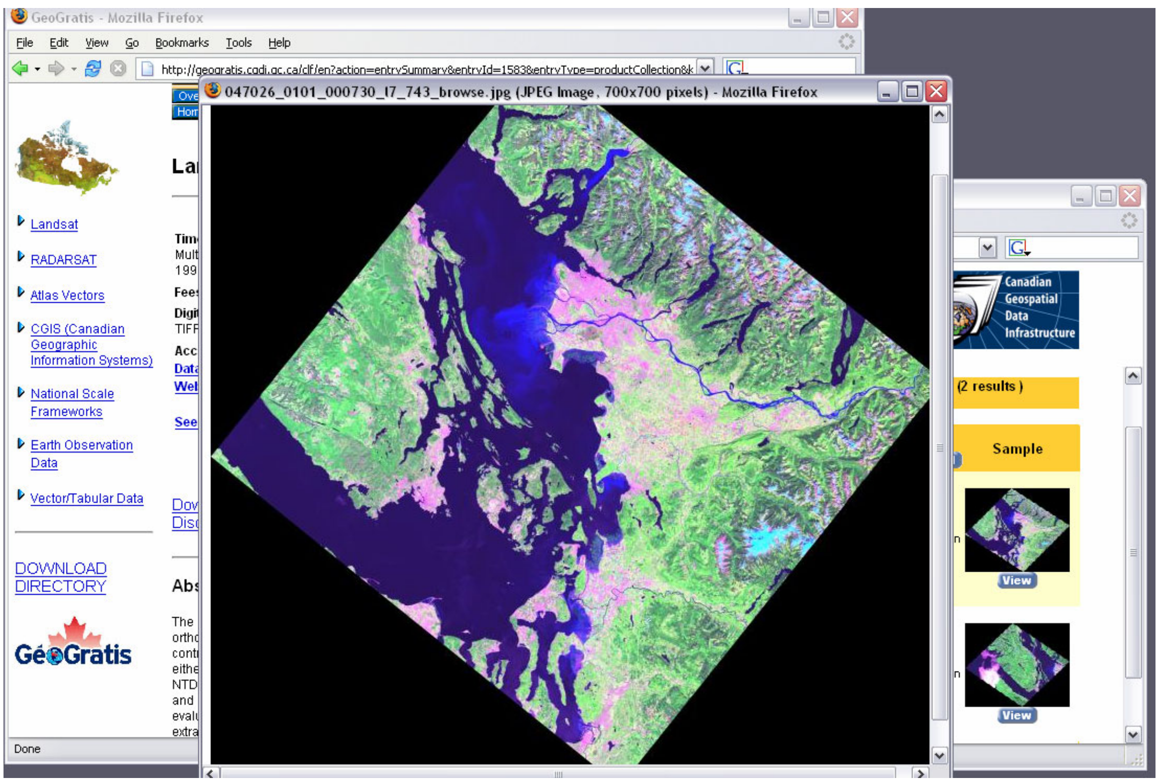


Figure 4-1: GeoGratis Website (Natural Resources Canada)

Figure 4-1 illustrates a Landsat 7 Orthorectified image for evaluation, from which the user can then download the entire scene of data (~150MB). Users are also enabled to access GeoGratis via an Application Programming Interface (API) to get information about a specific resource. For example, the following URL will provide metadata (data about data) information in HTML about Landsat 7 Orthorectified Imagery:

```
http://geogratis.cgdi.gc.ca/clf/en?action=fullMetadata&entr
yId=1583
```

The dynamic nature of this URL indicates that it will behave differently given different keyword value pairs. This is good. However, this API is developed by the GeoGratis website developers, and does not explicitly adhere to a commonly adopted mechanism for standards-based geospatial information retrieval. The output content provided by this URL provides HTML, which encompasses the look and feel of GeoGratis, and is cumbersome for other systems to interact with. GeoGratis also offers searching of its products through the geo profile of the z39.50 protocol, which allows users to spatially and aspatially search their repository. Chapter 7 will later illustrate the Web Services approach undertaken by the GeoGratis website as a means to improve upon the abovementioned approaches.

4.2 National Earthquake Information Service (NEIS)

The National Earthquake Information Service provides global information on past and current earthquake and seismic activity (United State Geological Survey, 2004). The mission of the National Earthquake Information Center (NEIC) is to rapidly determine the location and magnitude of all destructive earthquakes worldwide and to immediately disseminate this information to concerned national and international agencies, scientists, and the general public. As the World Data Center for Seismology, the NEIC compiles and maintains an extensive, global seismic database on earthquake parameters and their effects that serves as a solid foundation for basic and applied earth science research.

The NEIS provides a bulletin of near real-time current earthquake activity which is updated every 5 minutes for end users. Users can acquire this information in two methods. The first method involves a basic HTML page which is updated for user display. Although the inner operations of this service are not available to the author, it can be assumed that the information provided on this HTML page is generated from an internal, operational database / system and output to a web-friendly format for Internet clients. By navigating to this webpage, users can always see the latest activity.

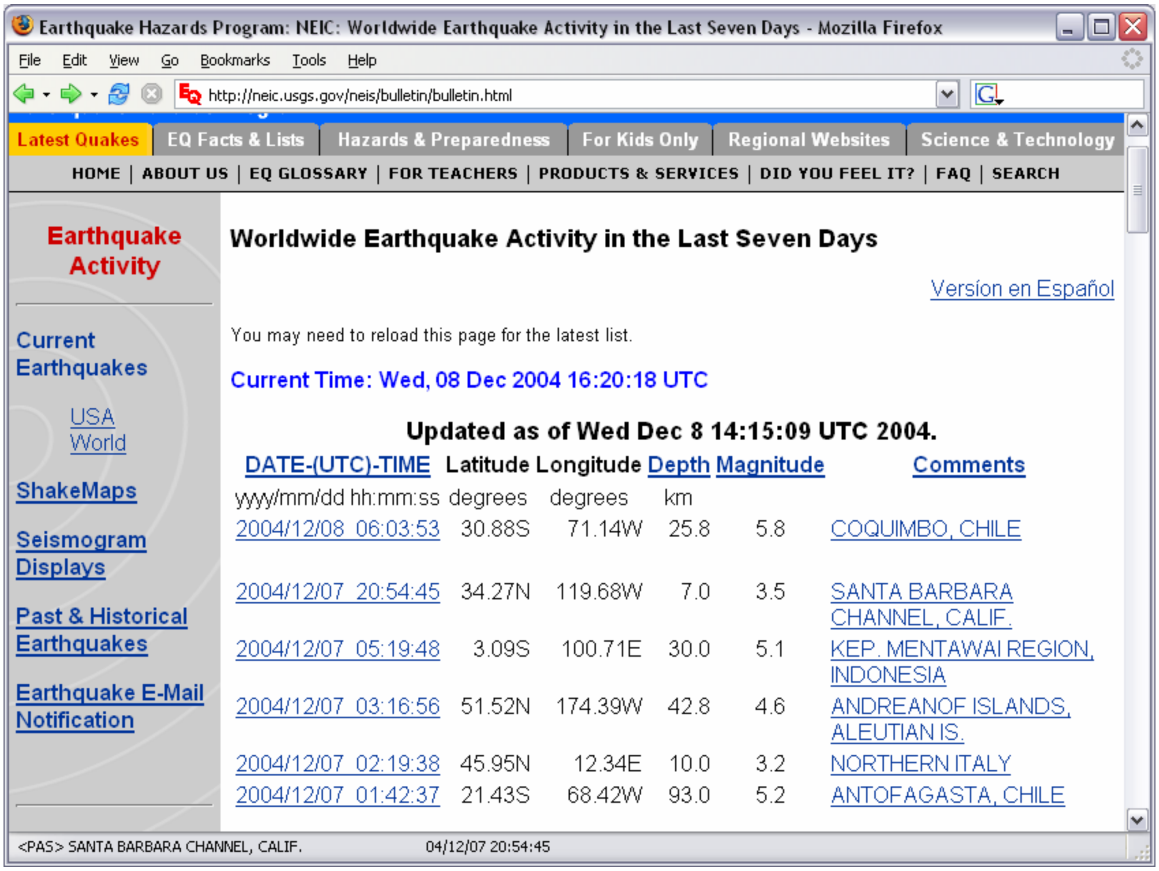
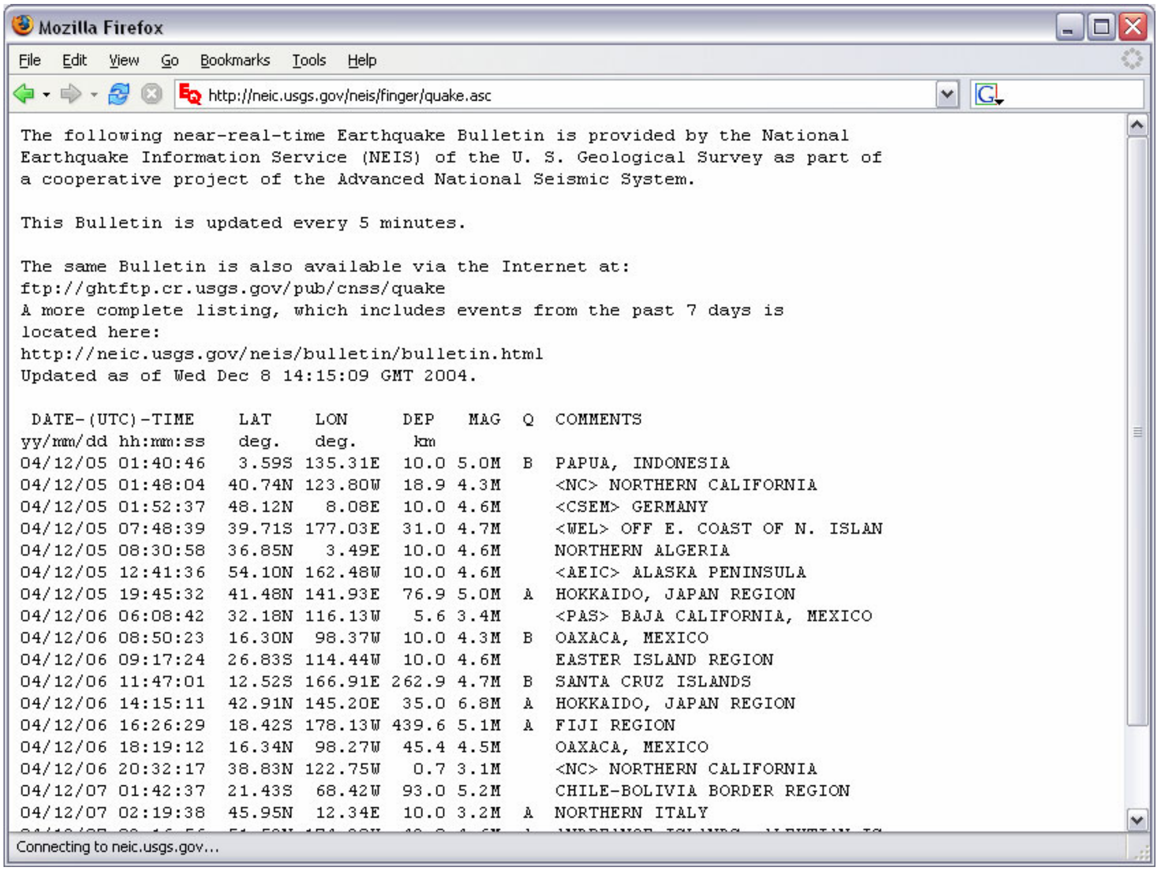


Figure 4-2: National Earthquake Information Center Bulletin (USGS)

The second method involves a more content driven approach, where the output information is not styled or coloured, yet plain, raw ASCII text. This information is also generated and updated every 5 minutes to a URL (http://neic.usgs.gov/neis/finger/quake.asc)

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The following near-real-time Earthquake Bulletin is provided by the National
Earthquake Information Service (NEIS) of the U. S. Geological Survey as part of
a cooperative project of the Advanced National Seismic System.

This Bulletin is updated every 5 minutes.

The same Bulletin is also available via the Internet at:
ftp://ghtftp.cr.usgs.gov/pub/cnss/quake
A more complete listing, which includes events from the past 7 days is
located here:
http://neic.usgs.gov/neis/bulletin/bulletin.html
Updated as of Wed Dec 8 14:15:09 GMT 2004.

 DATE-(UTC)-TIME    LAT    LON     DEP   MAG  Q  COMMENTS
yy/mm/dd hh:mm:ss   deg.   deg.     km
04/12/05 01:40:46   3.59S 135.31E  10.0 5.0M  B  PAPUA, INDONESIA
04/12/05 01:48:04  40.74N 123.80W  18.9 4.3M     <NC> NORTHERN CALIFORNIA
04/12/05 01:52:37  48.12N   8.08E  10.0 4.6M     <CSEM> GERMANY
04/12/05 07:48:39  39.71S 177.03E  31.0 4.7M     <WEL> OFF E. COAST OF N. ISLAN
04/12/05 08:30:58  36.85N   3.49E  10.0 4.6M     NORTHERN ALGERIA
04/12/05 12:41:36  54.10N 162.48W  10.0 4.6M     <AEIC> ALASKA PENINSULA
04/12/05 19:45:32  41.48N 141.93E  76.9 5.0M  A  HOKKAIDO, JAPAN REGION
04/12/06 06:08:42  32.18N 116.13W   5.6 3.4M     <PAS> BAJA CALIFORNIA, MEXICO
04/12/06 08:50:23  16.30N  98.37W  10.0 4.3M  B  OAXACA, MEXICO
04/12/06 09:17:24  26.83S 114.44W  10.0 4.6M     EASTER ISLAND REGION
04/12/06 11:47:01  12.52S 166.91E 262.9 4.7M  B  SANTA CRUZ ISLANDS
04/12/06 14:15:11  42.91N 145.20E  35.0 6.8M  A  HOKKAIDO, JAPAN REGION
04/12/06 16:26:29  18.42S 178.13W 439.6 5.1M  A  FIJI REGION
04/12/06 18:19:12  16.34N  98.27W  45.4 4.5M     OAXACA, MEXICO
04/12/06 20:32:17  38.83N 122.75W   0.7 3.1M     <NC> NORTHERN CALIFORNIA
04/12/07 01:42:37  21.43S  68.42W  93.0 5.2M     CHILE-BOLIVIA BORDER REGION
04/12/07 02:19:38  45.95N  12.34E  10.0 3.2M  A  NORTHERN ITALY
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Figure 4-3: National Earthquake Information Center Text Reporting (USGS)

As a result, users can always navigate to this plain text file and view the latest activity. This approach can be interpreted as an alternate expression of the HTML bulletin given in Figure 4-2.

4.3 Toporama

Toporama provides a simple visualization mechanism into Natural Resources Canada's (NRCan) National Topographic Database (NTDB). The NTDB is a digital database developed by Geomatics Canada. It covers the entire Canadian landmass and contains the features normally found on topographic maps at the scales of 1:50 000 and 1:250 000 (Toporama, 2004). The available themes are:

Hydrography, Hypsography (contours), Vegetation, Road Network, Roads, Rail Network, Power Network, Designated Areas, Relief and Landform, Water Saturated Soils, Toponyms and Manmade Features (Natural Resources Canada, 2003).

The NTDB is very useful to users of geographic information systems (GIS) and is a good data source for the creation of thematic maps (Natural Resources Canada, 2003). Figure 4-4 illustrates a sample, static image of NTDB data via Toporama. Chapter 7 will illustrate the Web Services approach Toporama has since undertaken.

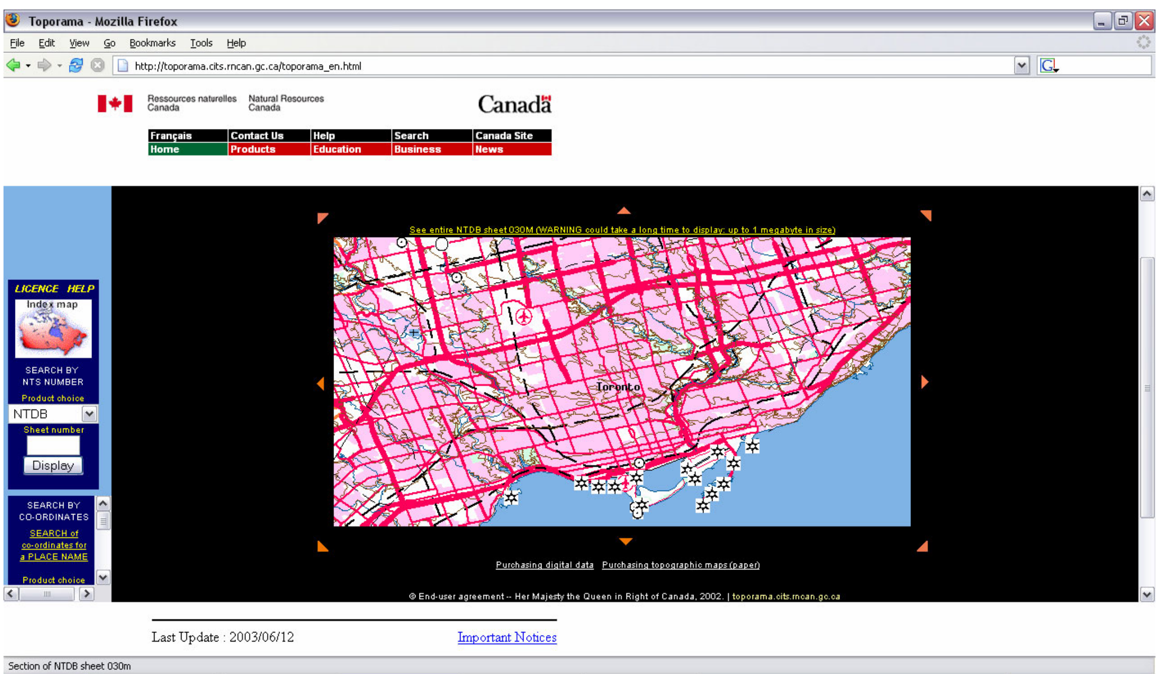

Figure 4-4: Toporama Website (Natural Resources Canada)

4.4 Issues with Traditional Approaches

The abovementioned approaches, as examples of many other similar applications are useful and popular online information services. Users are able to visualize and access geospatial data in the context, or container, or the given application / website.

In the context of interoperability and access, these websites / applications have the following characteristics in common:

- *File-based, static data*: all data is stored, delivered and acquired as a discrete document or file. Once an end user acquires this data by downloading to a desktop computer / network, the data is automatically dated, or stale. Any change in the source information (accuracy, precision, schema, format, structure) would render any previous versions of the data as dated and not current. The data user must be aware of alerts to any changes of the data they are using. This is a simple task given one or two datasets; however it becomes resource intensive to the data consumer when they are dealing with numerous external datasets for their activities.
- *Ad-hoc APIs*: The APIs prescribed as access mechanisms to acquire data or metadata are based on designs and developments of their respective websites. That is, one cannot apply the same logic of the GeoGratis metadata URL to that of Toporama or NEIS. As a result, while the API

approach (in general) serves as a more effective method at providing dynamic content, the syntactic interoperability of a user-defined API requires end users or developers to change their connection parameters each and every time a change is made to a particular (non-standards based) API

- *HTML, not XML*: HTML, with its origins in SGML, provides users with a simple yet effective markup language to display information to any client capable of rendering the HTML specification. HTML provides a hybrid approach to content and presentation, which subsequently introduces complications in maintenance for both webpages and applications. Another issue with HTML is vendor / application support. While HTML is indeed a standard which is implemented by numerous vendors and organizations in their web browser software (such as Mozilla Firefox, Microsoft Internet Explorer, Opera, etc.), the (potentially and usually) long standards process, coupled with end-user requirements and the competitive nature of the software industry has resulted in vendors implementing their versions (or "flavours") of HTML and associated technologies (such as JavaScript and DHTML). These "extensions" have resulted in much confusion for developers writing web applications and trying to keep applications accessible and behaving in the same way for a variety of web browsers and platforms. Additionally, HTML, while offering some structure, is often loosely structured, as a result of vendors allowing certain code definitions which may not adhere to the HTML standard, to "slip by". This results in difficulty for a user / software program or application to intelligently consume HTML content for reuse and analysis in their application. While HTML has become very simple to create with GUI-driven and "drag-and-drop" tools, and more web content is available than ever before, the reuse and maintenance of such information as HTML is often a high level of effort.

So what is the next step in geospatial information given these websites and their approaches? A user typically would:

- download static GIS data to their local computer or network
- perform data integration for data to "fit" within their system or application
- produce output (map, tabular, analysis, reports)

While these procedures may seem trivial for a limited amount of data, or one-time processing, for wider operational activities, this can become resource intensive when the nature of information changes (temporal updates, updates to data quality, accuracy, precision, etc.).

Scenarios are efficient methods of qualifying and quantifying level of effort. Consider the following two scenarios for map production and map sharing, given traditional approaches to geospatial data interoperability:

4.5 Scenario 1: Map Production of Real-time Earthquake Data

Name	Map production
Description	A natural hazards organization publishes real-time maps to the Internet to display latest earthquake activity on a global scale for advisory purposes
Precondition	Suitable data archive and catalog servers are available to the companies involved, and they support data schemas for all needed types of data and metadata. The needed data and metadata types are also already known by the participants. The available archive and catalog servers may already store some of the needed metadata and data. Base / reference data exists to produce the output map
Flow of events – basic path	
	The natural hazards organization operator / responsible party connects to http://neic.usgs.gov/neis/finger/quake.asc to acquire latest earthquake activity data
	The operator develops a process to convert the text document to a format which is recognized by their particular GIS software.
	The operator runs the process to convert the text document to a GIS format
	The operator launches their GIS application, and adds the

	earthquake data to the view, top base (or reference) map data
	The operator saves the view to a static output image file which can be visualized on the Internet
	The operator updates the website URL which displays the update map image.

Table 4-1: Scenario 1 Description

Figure 4-5 provides a visual representation of the scenario:

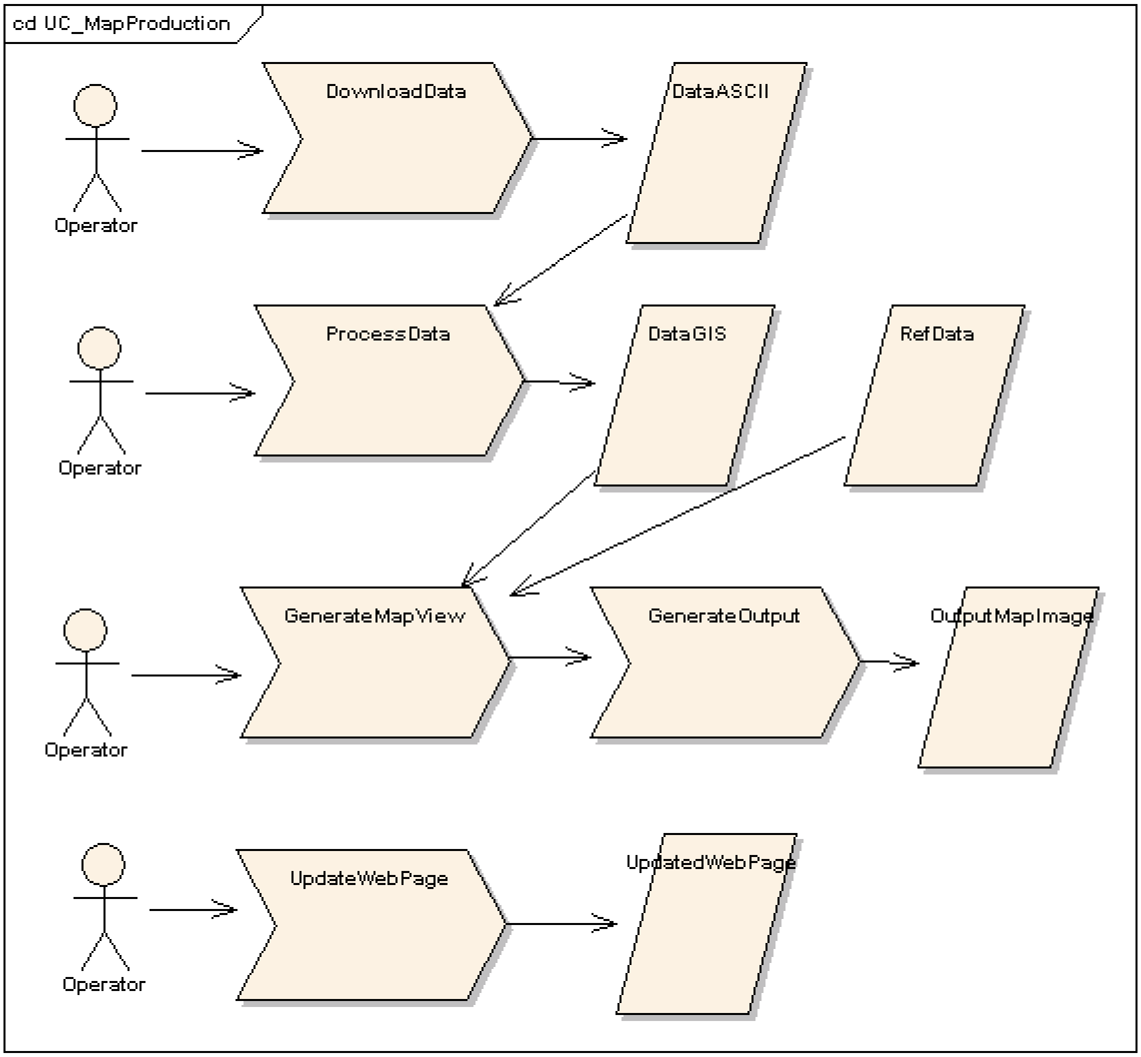

Figure 4-5: Scenario 1 View

4.6 Scenario 2: Map Projects Across Heterogeneous Environments

Name	Map sharing
Description	An environmental agency research scientist publishes spatial data based on water quality information. The research scientist

	is required to a prepare a view of water quality monitoring locations to a policy analyst for further processing and publishing for senior management level reporting on water quality monitoring activities
Precondition	Suitable data archive and catalog servers are available to the companies involved, and they support data schemas for all needed types of data and metadata. The needed data and metadata types are also already known by the participants. The available archive and catalog servers may already store some of the needed metadata and data. Base / reference data exists to produce the output map
Flow of events – basic path	
	The research scientist, using a GIS application, generates a map view of water quality monitoring station locations atop base / reference map data
	The research scientist saves the view in the GIS application so that the view can be regenerated and displayed at a later time in the same manner as it was saved
	The research scientist packages an archive (with textual instructions) of all file-based data used to generate the view and forwards the archive to the policy analyst
	The policy analyst operator receives the archive

	The policy analyst extracts the archive on their local computer / network
	The policy analyst launches their GIS application, and follows the research scientist's instructions on how to setup the map view (area of interest, layer visibility)

Table 4-2: Scenario 2 Description

Figure 4-6 provides a visual representation of the scenario:

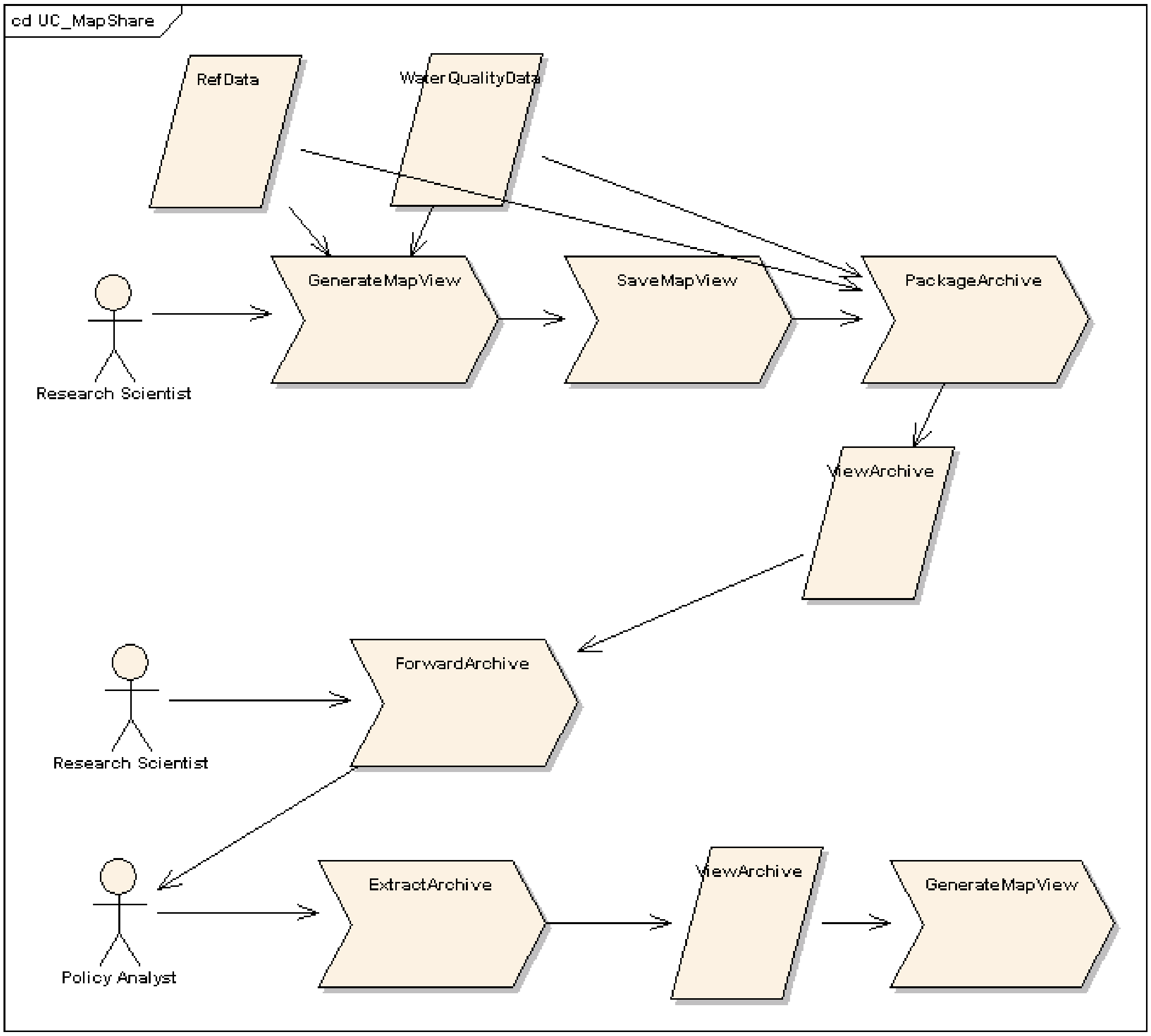

Figure 4-6: Scenario 2 View

4.7 The Gap

Given the scenarios above which represent traditional approaches to geospatial data interoperability and data exchange, it is evident that applications and tools are intimately tied to the data they are working with, or “tightly coupled’. Figure 4-7 illustrates this dependency.

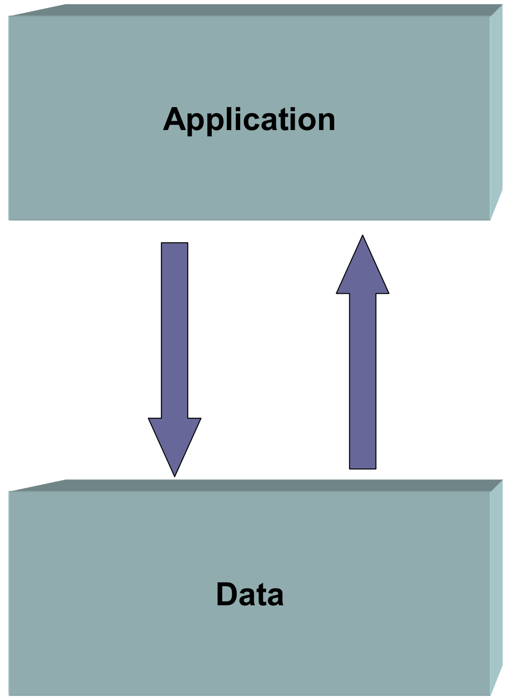

Figure 4-7: Two-Tiered Application Architecture

That is, any change or modification in the data syntax, schema or semantic triggers a functional change in the application which is using the data. Chapter 5 will discuss how the Web Services approach addresses this limitation.

Similarly, applications cannot use common data bindings to facilitate interchange from heterogeneous resources. Applications can be built with a look and feel and interface relative to the requirements and policies of a given organization; however the means by which they access geospatial data are currently not based on a common interoperable approach. This inhibits possibilities of integration of information across different applications, and breaks the information-sharing model, which many of the services they support are designed to support. Figure 4-8 illustrates this issue.

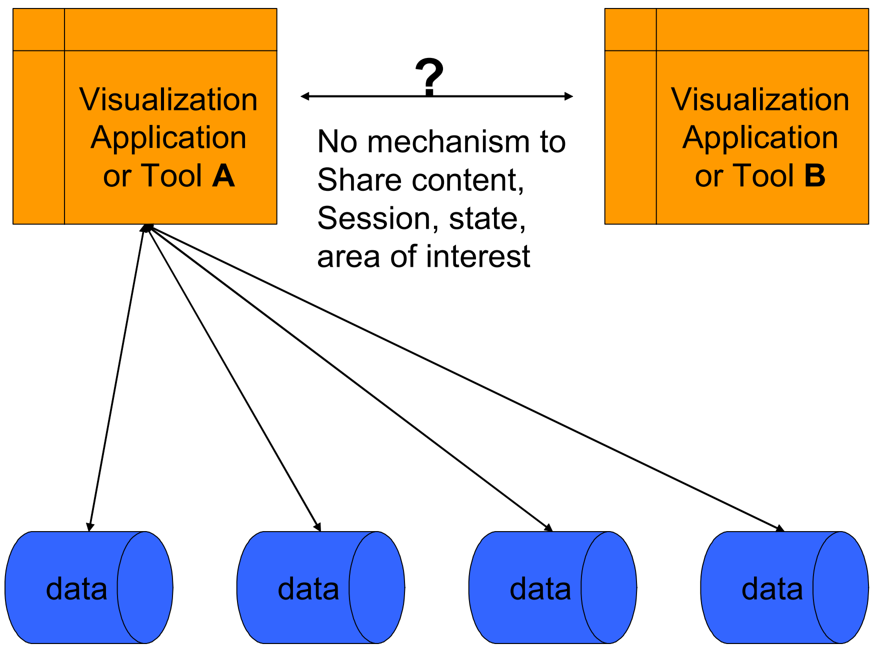

Figure 4-8: Lack of Interoperability between Applications

Take for example the concept of graphic images, either acquired from scanned photography, or generated from a geographic information system (such as earth observation / satellite imagery). A common information exchange mechanism exists in the image format, which allows a research scientist to visualize the information in GIS software such as ESRI ArcView. A policy maker can also view this image for inclusion of an image in their presentation using simple graphics software such as Adobe Photoshop. The applications above serve different purposes; however both support common images and documents for flexibility of the application in support of an end-user's goals.

A research scientist should be able to view geospatial information over a network within an analytical application tailored to their goals, just as a policy / decision maker should be able to visualize the same information in a basic map browsing application to support their activities. Given that applications can serve different purposes, a common exchange framework would prove beneficial in information exchange. Chapter 5 will introduce the interoperable approach to address this issue.

This example is analogous to the Toporama and GeoGratis website applications and their previous incarnations. While both applications provide value-added, monolithic services (Vasudevan, 2001), what happens if an end-user wishes to visualize both NTDB data and Landsat 7 imagery in one integrated visualization? Using traditional approaches, this represents the effort required in scenario 2. In the context of web approaches, it is impossible to virtually integrate datasets without first downloading the actual data to one's own computer / network. That is, the Toporama application could not integrate the GeoGratis Landsat 7 data and vice-versa. It should be noted that earlier versions of these websites and applications were developed in the absence of the Web Services approach. Chapter 7 will illustrate how these applications have since implemented the Web Services approach.

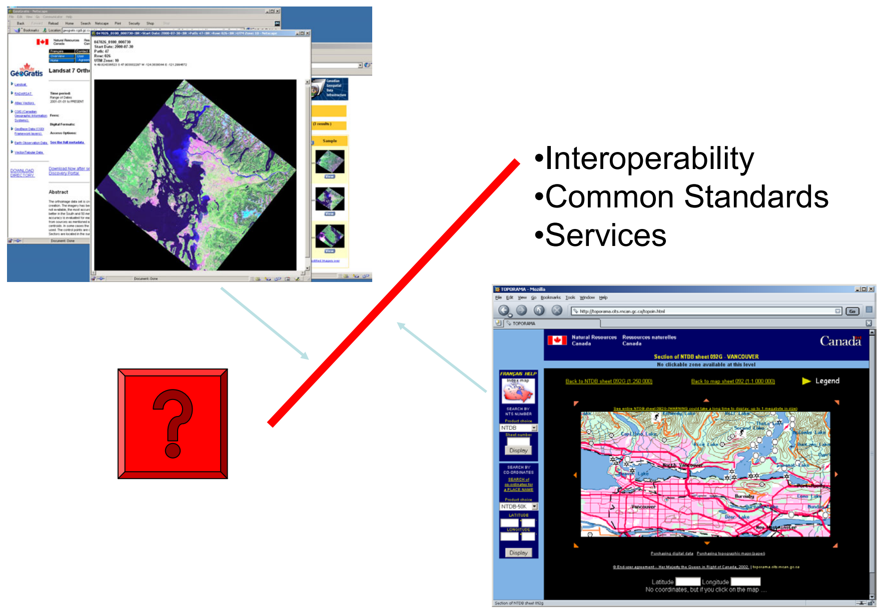

Figure 4-9: Lack of Interoperability between Real World Applications

It is evident that a different result is displayed between two applications with end users in pursuit of the same geospatial view. Below are the steps required by the end user of the second application in attempting to visualize the same data:

- Record connectivity information of each data layer
- Manually input this information into desired application
- Manually set area of interest and geographic projection

Even with the above steps, variances occur. As a result, it is currently difficult to recast geospatial information with the same context across various visualization tools.

Web mapping and visualization tools are complex interfaces, which require various levels of effort by the end user. End users should not have to become ‘experts’ in this software. The more user-friendly user applications become, the more they will be used in support of decision making, policy, analysis, and so on. A key concept in the success of web mapping and visualization applications is viewing the same content across the application of choice by the end user and organization.

In conclusion, much effort and development is evident in the standardization of geospatial data formats and structures, in addition to online information delivery models given the proliferation of the Internet. While these advances are significant, these approaches are still considered inadequate given the issues, scenarios and problems cited. There is an ongoing requirement for timely, accurate and authoritative information delivery.

5 Web Services

5.1 Overview

Until recently, since the inception of the Internet, attempts at interoperability have been mostly focused on the transport and transmission of information through simple Internet technologies, such as the download of data from an Internet website using Hypertext Transfer Protocol, or HTTP (World Wide Web Consortium, June 1999), and / or File Transfer Protocol, or FTP (Internet Engineering Taskforce, October 1985) over the Internet.

Traditional file-based approaches have focused on static information retrieval. In other words, once a user has downloaded a given dataset or resource, that dataset is automatically dated. Moreover, once a change (any change) or modification is made to the source or authoritative dataset, the downloaded dataset becomes even more out of date and inaccurate. This applies to virtually all facets of online, digital information delivery and access. The requirements are clear: consumers require the most accurate, up-to-date and authoritative information from their providers. Providers would like to deliver accurate, up-to-date, and authoritative information in the most cost efficient manner as part of their service delivery to clients.

Enter Web Services. A Web Service is a piece of business logic, located somewhere on the Internet, that is accessible through standard-based Internet protocols such as HTTP or SMTP (Vasudevan, 2001). Web Services are analogous to publishing software code methods or functions over the Internet for people to invoke. While an Internet website may be described by some as a “Web Service”, as it does deliver some sort of information service to the client, the Web Service definition employed here is in the context of standards-based Web Services which represent building blocks as part of a larger online information infrastructure.

Below are some of the properties of Web Services (Chappell, 2002):

- Primarily based on XML. Because XML is a platform independent data encoding, it provides a natural fit as the content model for Web Services to deliver information. XML hides the specifics of protocols. Web Services support the transparent exchange of documents
- Web Services allow the underlying software implementation to be reworked without impacting clients. This is commonly referred to as “loosely coupled”. Tightly coupled systems infer that if one interface changes, others communicating with it must be updated to accommodate the changes. Loosely coupled approaches allow for changes which allow more practical and manageable systems with simpler interaction and integration
- Web Services allow for sequential and forking procedures. For example, a user / software program can invoke a function which interacts with a

Web Service, while performing some other function while waiting for the Web Service to complete. This speeds up processing and software operations.

To further explain the concept of Web Services, let's make use of a simple, real world example: A pharmaceutical company provides goods to pharmacy retail outlets. A pharmacy retail store allows customers to fill their prescriptions, converse with the pharmacist, as well as to shop for day-to-day items. A typical interaction between a pharmacist and a customer with a prescription might be:

- customer arrives at pharmacy with prescription from general physician
- pharmacist fills the order
- verifies with general physician
- physically prepares the given order, i.e.:
- topical treatment
- counts capsules and deposits into vial
- informs customer that prescription is ready
- customer arrives at pharmacy (if not waiting)
- pharmacist discussed with customer about possible side effects, dosage, etc.
- customer purchases and leaves the pharmacy

This is a very simple everyday occurrence, however let's look at properties which may have affected this interaction:

- the contents of the prescription may have had to been ordered if the pharmacy was out of stock
- the pharmacist may have run out of vials or containers, resulting in the need to reorder
- the shipping of items may have been delayed because of an accident on the highway which prevented timely delivery of the content by the courier company, which has been contracted by pharmaceutical company to deliver to the pharmacy

Though these are all real world issues, none of these are (nor should be!) of concern to the customers who wants their prescription filled. Their main concern is their prescription and some advice from the pharmacist. The pharmacist indirectly assumes taking care of these issues on the customer's behalf, by coordinating with the pharmaceutical company and general physician, etc. Figure 5-1 illustrates the associated chain of events.

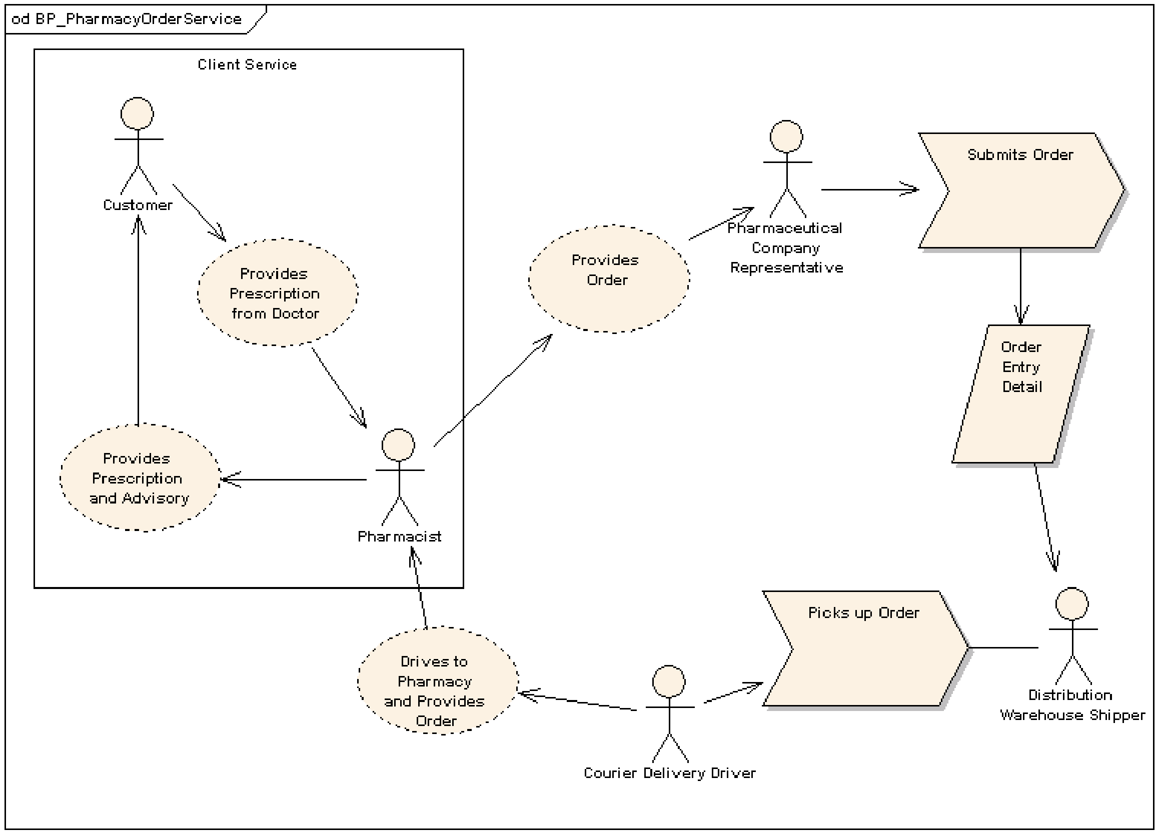

Figure 5-1: Business Process View of a Pharmacy Order

Imagine that the prescription called for 100 pills. The pharmacist may have 5000 pills on hand as part of their stock. However, the customer, at that given point in time, is only interested in acquiring 100 of those exact pills, not what they are derived from or how they are manufactured.

The pharmacist charges a dispensing fee to the customer as part of the sale of the prescription. This fee is representative of the underlying effort by the pharmacist to fill the prescription. The pharmacist performing these efforts is providing a service. The customer gets what they want, at that point in time, for a given purpose.

Web Services do just this in the domain of distributed computing and Internet. That is, Web Services allow for information to be exchanged over the Internet as a result of a customized request from a requestor. The requestor (or client) only receives what they ask for.

Consider the advantages of Web Services when applying to a database of a stock quotes archive. Past approaches would require a client to download the archive in its entirety in order to perform some sort of processing (e.g. provide the stock quote for stock XYZ on date 30 October 1972). The Web Services approach enables a client to make a ‘smart’ request to a Web Service, which has a known/adopted communication mechanism. An example of making such a request from a Web Service might appear as follows:

```
http://host/stockquote?stock=XYZ&date=30-10-1972&
```

As a result, the resulting response from the Web Service might appear as follows:

```
<?xml version=”1.0” encoding=”UTF-8” standalone=”yes”?>
<StockQuote>
     <Stock>XYZ</Stock>
     <Date>30 October 1972</Date>
     <Value currencyUnits=”CAD”>3.14</Value>
</StockQuote>
```

As a result, considering the potential size and frequency of updates made to the database to which the Web Service connects, the client is given data which they are explicitly interested in, which satisfies their requirements at that given point in time.

Conversely, if we apply the same scenario to one in which the client would like the most up-to-date quote for a given stock, the request might appear as follows:

```
http://host/stockquote?stock=XYZ&date=today&
```

…where the value ‘today’ in the request URL instructs the Web Service to provide the stock quote for the day on which this request is invoked. As a result, one could setup a website which utilizes this Web Service and displays the stock quote, which ensures that the latest daily information is provided to visitors of said website.

Although this example is a relatively minor part of a given task or requirement, Web Services enable content to be delivered as ‘components’ which contribute to part of a larger infrastructure. The Web Services model is also well suited for a distributed, service-oriented architecture (Chappell, 2002). That is, an information infrastructure can be built atop many Web Services, which, independently, achieve specific tasks, and also contribute to the overarching picture. Figure 5-2 illustrates the interaction we just described in a relative manner:

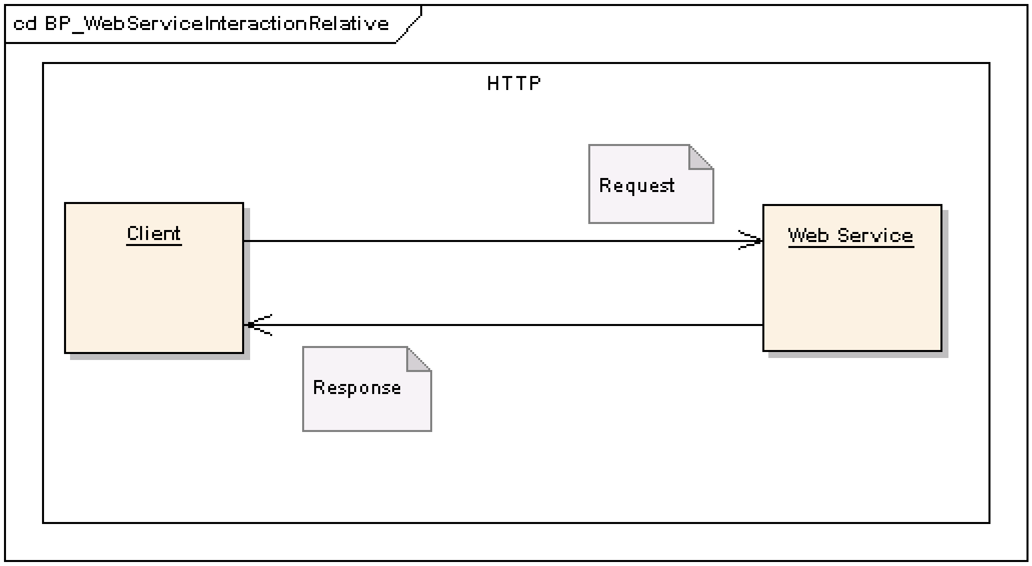

Figure 5-2: Simple Conceptual View of Server / Client HTTP Interaction

Figure 5-3 illustrates how an infrastructure can encompass many Web Services, which can be published or advertised to a registry, and used by clients to enable applications and tools specific to business requirements.

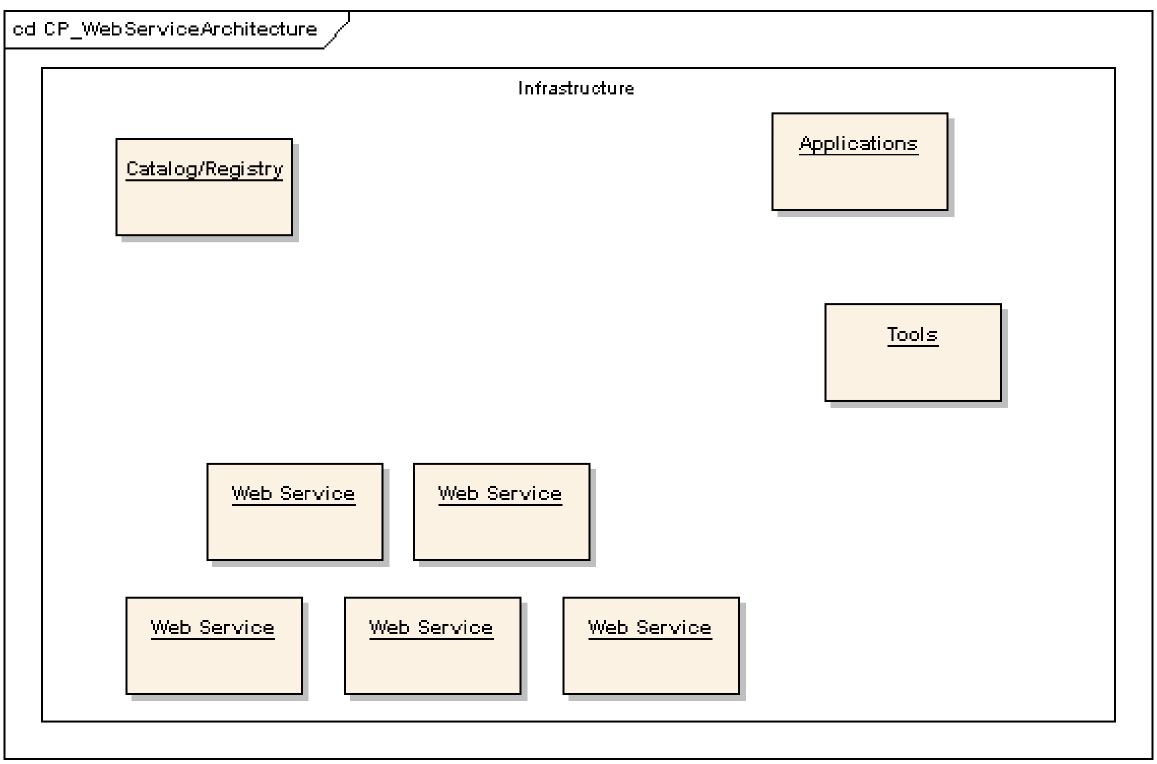

Figure 5-3: Scalable Web Service Oriented Infrastructure

The fictional infrastructure in Figure 5-3, based on the Internet, enables deployment of location independent components, as well as an efficient scaleable approach (i.e. room for growth). Note that file based architectures are also scaleable, however a Web Services approach enables more efficient options by reducing bandwidth requirements with custom, just-in-time access. The Web Service components enable the building of applications and tools to refine their use. This is directly due to the fact that such an infrastructure is based on Web Services, or what is commonly called a “Service-Oriented Architecture” (SOA). Each and every component in an SOA is based on Web Services. Figure 5-4 illustrates the communication and interfacing which takes place in such an approach.

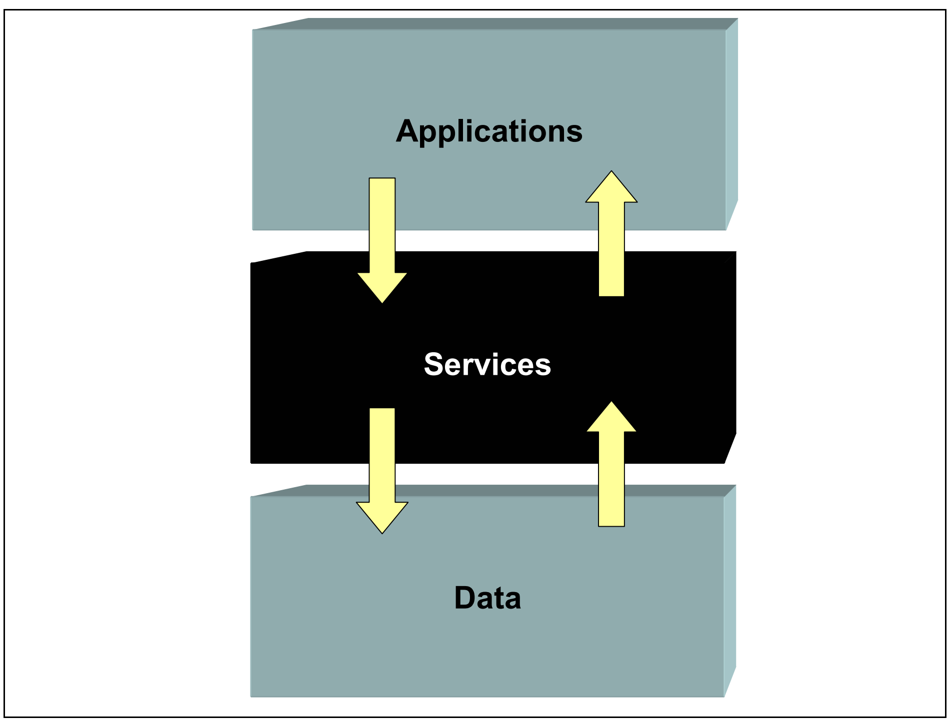

Figure 5-4: Three Tiered Application Architecture

As is evident, client applications or tools are never directly intimate with the raw data. Yet, the Web Service provides an expression, or representation, of a dataset, model, schema, business practice or report through a service.

The major Web Services platforms revolve around transport, service offering and service discovery (Chappell, 2002), which are:

- SOAP: defines a structure for exchanging XML documents
- WSDL: describes functionality and input / output parameters of a Web Service
- UDDI: represents a registry for advertising and discovery of Web Services

5.2 Organizational Advantages

Web Services possess numerous advantages in the realm of extending current business practices of many organizations:

Extended collaboration and Partnerships: using Web Services and Interoperability via standards-based approaches provides organizations the opportunity to provide open interfaces and communication mechanisms for distributed computing. Consider Figure 5-5:

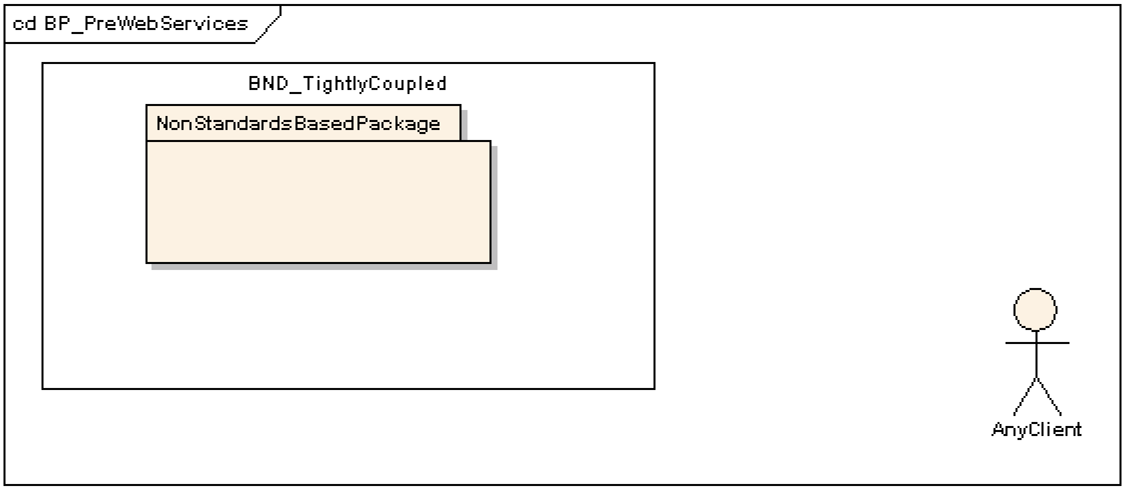

Figure 5-5: Difficulty of Integration given Tightly Coupled Approaches

Clients are ‘bound’ to the interfaces and operations as prescribed by the organization or service provider. The result of this is that whenever some business logic or process is modified at the service level, clients must align with those changes to ensure the same level of service and information. Using Web Services allows organizations to collaborate with an infinite number of clients as a result of using standards based procedures. This means that clients, whether intimately involved in the subject matter or not, can quickly connect to and consume Web Services when using standards.

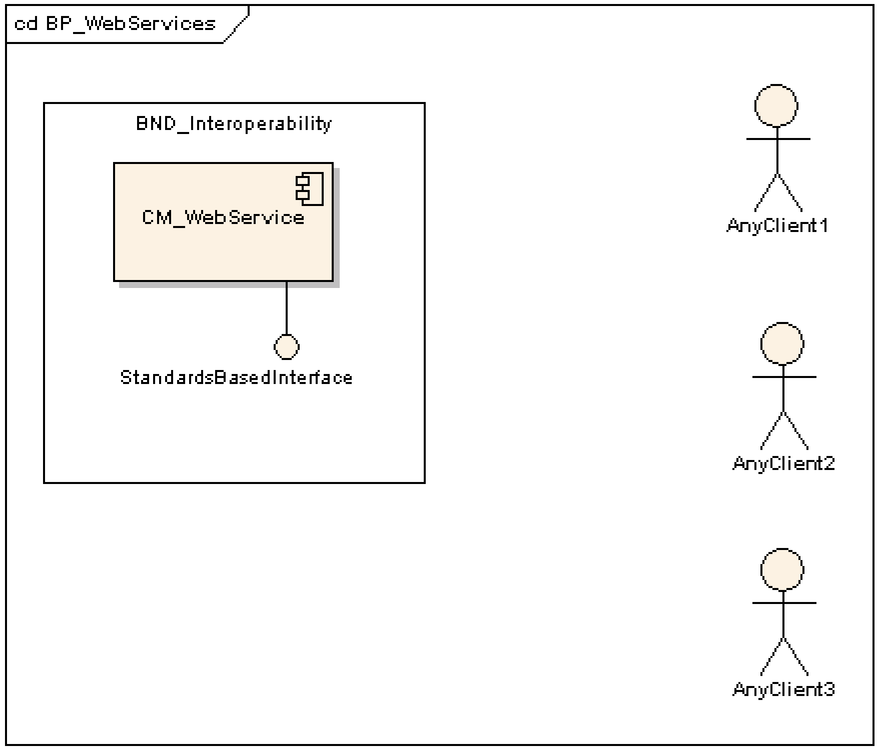

Figure 5-6: Ease of Integration given Loosely Coupled Approaches

Business-to-Business: using Web Services allows for organizations to both publish and consume information. The open-ended nature of this model allows for “vertical” or “mid-tier” Web Services, which entail a brokering paradigm for a middle-tier service provider to provide Web Services which themselves consume other Web Services and can a) aggregate information into b) perform value-added processing to information (statistical models, reports, etc.) and c) provide these in a unified fashion to end clients. Web Services thus result in lower costs of data transactions and shared services for both for data providers and consumers.

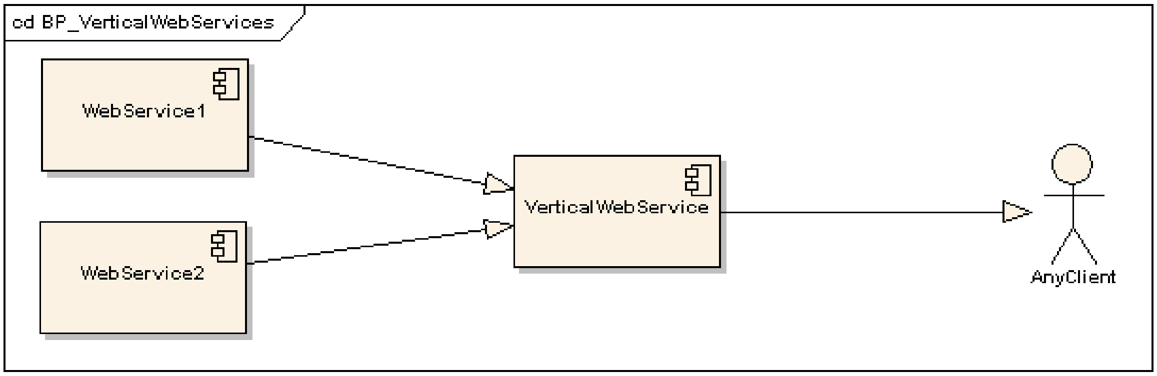

Figure 5-7: Vertical Web Services

5.3 Technical Advantages

There are numerous technical advantages in using Web Services:

- *Maintaining legacy systems*: many organizations posses information which may reside in an older format, or system architecture. On many occasions, for many various reasons (budgets, politics, operations, resources, etc.), an organization may not be willing to undergo a wholesale change to their legacy business data architecture or system. Web Services position themselves as a modular, componentized approach, which allows for a developer to add a service on top of a particular legacy database, system, or interface. As a result, internal processes are never affected, and information delivery can adhere to requirements using Web Services.
- *Independence from operating systems*: Because the nature of communication of Web Services is HTTP, the very nature of this protocol

abstracts the nature of an operation system's specific behaviour, methods and properties. That is, a Web Service which may run on a Red Hat Linux operating system can interact with a client making a request from a Mac operating system, or any operating system, for that matter. This flexibility once again allows for 'loosely-coupled' approaches between Web Services, regardless of their operating systems, which have been selected or deployed by their respective activities for whatever reason.

- *Independence from programming languages:* just as HTTP abstracts operating system specifics, it also abstracts programming language and development environment characteristics. For example, organization 'A' may write Web Services using the Java application development framework, with Java data types, functions, classes, and configurations. In parallel, organization 'B' may write applications using a scripting language such as Perl, with Perl data types, modules, packages, and configurations. Using Web Services allows for organization 'B' to communicate with organization 'A' even if their components are developed using heterogeneous development environments. Using Web Services also allows programming and development teams and activities the freedom to develop in their environment of choice, as well as alleviate restrictions of programming languages by abstraction.

5.4 Cross-Cutting Advantages

Web Services have hybrid benefits in both organizational and pure technical realms:

Reduction of Data Management Issues: the Web Services approach represents an ‘on-demand’ form of information delivery. In other words, a client accessing data via a Web Service has the ability to request and receive only what is required for their purpose at a specific point in time. This approach is beneficial for subsetting voluminous data repositories, as well as temporal slicing of historical data.

For example, provider ‘A’ possesses a large scale, densely populated watershed dataset in the Canadian province of Ontario. Consumer ‘E’ is working on a research project which requires watershed data in the greater Toronto area. Consumer ‘E’ can, via Web Services, extract a subset of data for their area of interest; nothing less, nothing more. The Web Service performs the subsetting instead of the client. Figure 5-8 illustrates this benefit.

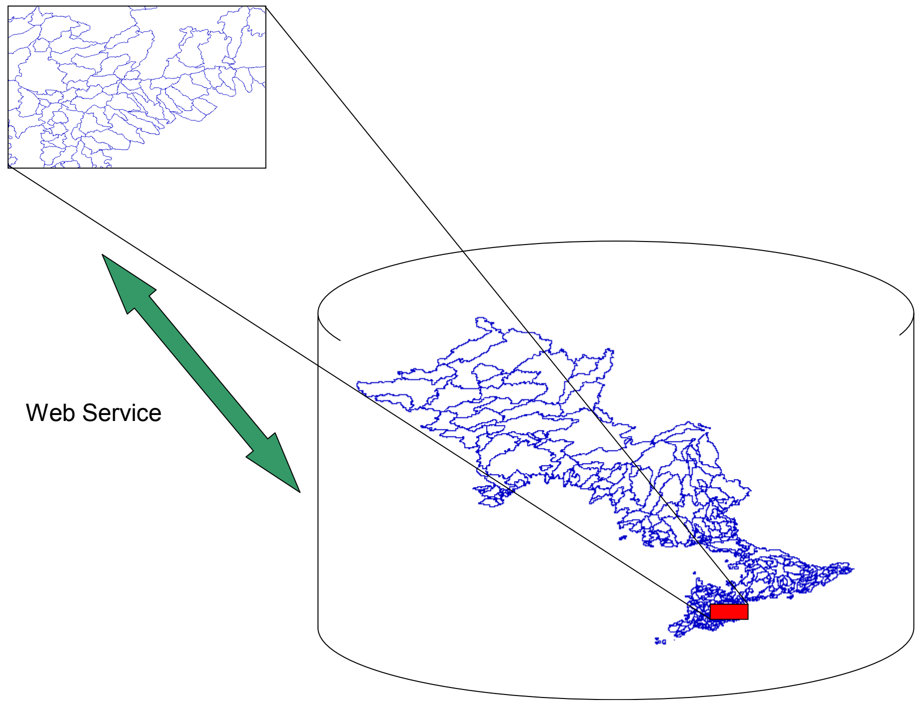

Figure 5-8: Data Extraction using Web Services

As a result, the researcher is not burdened with the bandwidth, data management and storage of the entire dataset. Benefits for data management also apply to temporal or dynamic information. Web Services enable clients to acquire the latest, up-to-date information from its authoritative provider. As multiple copies of data increase, so too does the level of effort for ensuring data is kept up to date with its source.

Hybrid application integration: Web Services enable opportunities for combining data from diverse information communities. For example, a developer can integrate data from a weather forecast Web Service and integrate with a map-based Web Service to visualize forecasts.

Rapid application development and integration: An application developer can design an application whose information viewpoint is based solely on the Web Services approach. This results in a) rapid application development, b) lighter applications with no explicit data embedding, c) multitude of data sources for integration and interuse. Consider Figure 5-9, displaying an application which, at any time, has access to various data as Web Services, without ever directly integrating the data. All data is kept at source, and requested on demand by the client application. Adding or deleting data in the application is subject to nothing more than enabling or disabling a 'connection' method.

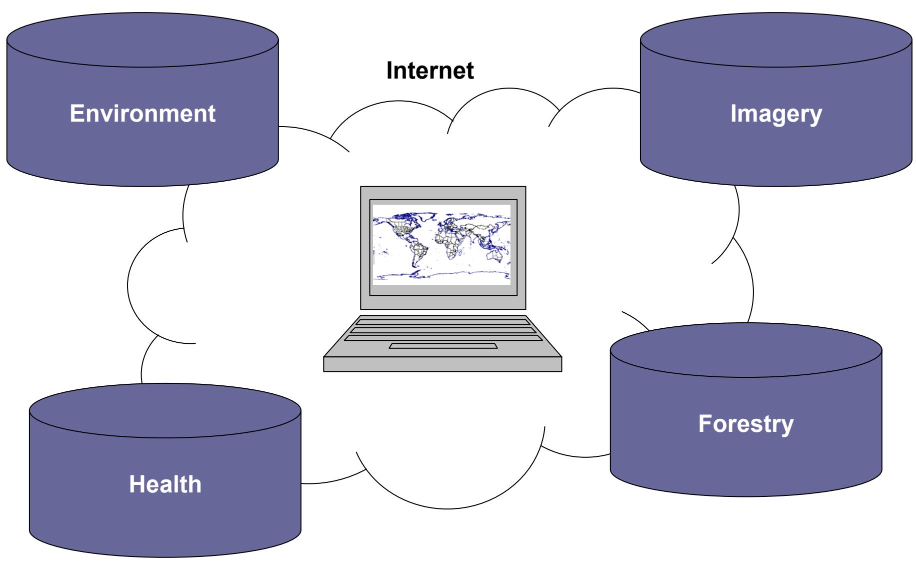

Figure 5-9: Enabling Infrastructure with Web Services

Reduced buy-in: Resource requirements are lessened in terms of barriers to integration. Because Web Services facilitate standards-based, easier integration, clients (or potential clients) have less of a ‘curve’ to integrate common approaches. As expertise grows over time, so does ease of use for clients and communities. With the advent of Web Services in heterogeneous information communities, this both enables rapid application development and fosters new ideas for information integration across communities who are using standards-based Web Services approaches. For example, geospatial Web Services are nothing more than another set of tools and services in the web development community, in the same manner as financial Web Services, and so on. In this context, numerous levels of buy in are possible. Providers buy into Web Services to streamline their information delivery activities. Consumers buy into Web Services to lessen their data handling requirements.

In summary, with the increasing focus and investment in interoperability within the information technology community, the advent of Web Services has gained much popularity (United States National Research Council, 1999). Web services allow communication of information through standards-based messaging vocabularies and grammars (eXtensible Markup Language [XML]), using the Internet as the Distributed Computing Platform (DCP). Web services provide a relatively new approach to information sharing over the Internet. Web services enable ‘just-in-time’ access to information, and further aid in the lessening of redundant information, and increasing the authoritative nature of information. Web Services also enable ‘plug and play’ type communications, which allow an end user to have no expert knowledge of the service provided, and encapsulate complexities in information models and schematics with a front-end interface for communication. Web Services provide application neutral content primarily using XML as the self-describing document structure markup language. Using XML allows providers to publish information independent of style and visual effects, and allows consumers to process and present content as per their analysis and application requirements. While there are many benefits of Web Services, the paradigm shift to just-in-time delivery of geospatial data also introduces issues of performance, data copyright and adaptation of a new approach by organizations. Chapter 9 discusses these and other issues in greater detail.

5.5 The Open Geospatial Consortium (OGC)

The Open Geospatial Consortium, Inc. (OGC), founded in 1994 as the OpenGIS Consortium, is a non-profit, international, voluntary consensus standards organization specializing in geospatial data and Web Services (Open Geospatial Consortium, 1998). The OGC consists of over 250 organizations from government, academia, industry and other groups. The OGC was founded on the concept of providing open specifications at no cost to the public to acquire and / or implement, thus providing standards-based interfaces for geospatial discovery, access, visualization and processing. The OGC leverages existing efforts from other standards organizations such as the World Wide Web Consortium (W3C), the International Organization for Standardization (ISO), and

Organization for the Advancement of Structured Information Standards (OASIS), and builds upon them in relevance to the geospatial domain.

5.6 The OGC Abstract Specification

The OGC Abstract Specification provides the reference model for implementation of OGC Specifications. Areas covered by the Abstract Specification include:

- Feature Geometry
- Spatial Reference Systems
- Locational Geometry
- Stored Functions and Interpolation
- The OpenGIS Feature
- The Coverage Type
- Earth Imagery
- Relations Between Features
- Accuracy
- Feature Collections
- Metadata
- The OpenGIS Service Architecture
- Catalog Services
- Semantics and Information Communities
- Image Exploitation Services
- Image Coordinate Transformation Services

The OGC Abstract Specification represents a carefully engineered process and framework in support of the discovery, access and visualization of geospatial information and services as resources. All OGC Implementation Specifications, Discussion Papers and Recommendation Papers are developed from the vision of the Abstract Specification. For example, all OGC Web Services provide models for metadata documentation. The Geography Markup Language (GML) specification models geospatial features and topological relationships between them. The Web Feature Service (WFS) describes a service-based supply of vector information as feature collections. All OGC Web Services (OWS) follow the Service Architecture Interoperability approach.

5.7 OGC Specifications

The OGC has a strong and progressive specification development process. OGC specifications are the result of consensus between specification working group members. OGC specifications are typically developed, tested and revised within the OGC testing environments (or “testbeds”), pilot projects and working group activities. The major benefit of this approach is the iterative process of software development in concert with specification development. Typical specification development takes place by defining, adopting and publishing the specification document for vendors, and others to implement. It is common practice for specifications not to take into account various aspects which may affect ease of software development, functionality and / or useability. The result of this is often a revision process which can become resource intensive and not time efficient. Vendors subsequently add “vendor specific” functionality, which is where variations begin to surface across vendor implementations of the same specification. In the OGC environment, because the specification is developed with software implementers, this risk is significantly reduced, allowing for specifications to be tested, analyzed and updated before they reach public adoption, resulting in a stronger, more robust version of a given specification, and multi-vendor interoperability of software products. This approach to specification development also introduces the unique concept of competing businesses in the geospatial industry working together in a co-operative fashion.

Currently (December 2004), there are fourteen adopted and publically available OGC specifications:

OGC Specification	Version
Catalog Interface (CAT)	2.0.0
Coordinate Transformation Services (WCTS)	1.0.0
Filter Encoding (Filter)	1.0.0
Geography Markup Language (GML)	3.0.0
Grid Coverages (GC)	1.0.0
OpenGIS Location Services (OpenLS)	1.0.0

Simple Features - CORBA (SFC)	1.0.0
Simple Features - SQL (SFS)	1.1.0
Simple Features – OLE/COM (SFO)	1.1.0
Styled Layer Descriptor (SLD)	1.0.0
Web Coverage Service (WCS)	1.0.0
Web Feature Service (WFS)	1.0.0
Web Map Context Documents (WMC)	1.0.0
Web Map Service (WMS)	1.3.0

Table 5-1: Adopted OGC Specifications

The specifications deal with a range of geospatial information approaches (data visualization, discovery, access, symbolization, query, encoding, and mobile applications). Many of these specifications behave as Web Services as defined in this paper, whereas other behave as data encodings, query definitions, and so on (Open Geospatial Consortium, 2004c).

All service specifications are collectively referred to as OGC Web Services (OWS). Having said this, all OWSs adhere to commonly agreed upon behaviour and communication via HTTP as the distributed computing platform. All OWSs also provide similar operational interfaces, a few of which listed below

Operation	Purpose
GetCapabilities	provide service level information
Describe*	provide description of dataset (attributes, data types)
Get*	access dataset in given context

Table 5-2: Unified Operations of OWS Specifications

5.8 OGC Momentum

Since the first major OGC specification, Web Map Service, was published in 1999, the OGC has gained much momentum in terms of organizational recognition, resulting in many early adopters of geospatial Web Services and interoperability. In fact, a recent survey indicated 166 public OGC WMS instances found via the Google search engine (Ramsey, 2004). The survey, though not authoritative or scientific, uses web development to collect and provides reports on OGC usage over the Internet. While the specific searching and interpretation algorithms of the survey remain subject to further interpretation, it is evident that the numbers of servers indicate a level of maturity and popularity with the OGC and Web Service approaches. OGC instances are found in Canada, the USA, Germany, Netherlands, Australia, Italy, Denmark, Czech Republic, Mexico (Ramsey, 2004).

The OGC specifications are also making their presence felt in major GIS vendor software packages, which can be attributed to industry recognition and in response to organizational requirements based on the underlying benefits of interoperability and the Web Services approach. Currently (December 2004), 241 vendor products either implement or directly conform to OGC specifications (Open Geospatial Consortium, 2004d).

6 Canadian Context: The Canadian Geospatial Data Infrastructure (CGDI)

6.1 Overview

GeoConnections is a national program, led by Natural Resources Canada, mandated to "putting Canada's geographic information on the Internet" (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a). GeoConnections focuses on such concepts as policy, standards, access, and frameworks with regard to geospatial data. The Canadian Geospatial Data Infrastructure (CGDI) is the product of the GeoConnections program, delivering distributed networks of geographic information at a national level (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a). The GeoConnections program leverages much of the OGC specifications in developing the CGDI, as well as selected ISO TC211 specifications. The GeoConnections program or CGDI does not define its own geospatial implementation specifications, but does contribute to the standards development process.

6.2 Architecture

The target vision of the CGDI defines the role of the GeoConnections project and CGDI, and includes the following three aspects: a mission statement, a vision statement, and guiding principles. The mission defines the role of

GeoConnections in developing the CGDI. The vision describes the core functionality and nature of the CGDI. The guiding principles describe the key defining elements and characteristics of the CGDI. The CGDI Architecture Description provides a technical view of the deployment of geospatial data and services, following guiding principles of the CGDI Vision, and endorsing selected services from the OGC specification program.

CGDI Architecture covers the following topics:

- The Vision Of CGDI
- The Mission of GeoConnections
- The Vision of CGDI
- Guiding Principals
- The Architecture of CGDI
- Conceptual Architecture
- Data
- Services and Interfaces
- Components, Systems, and Applications
- Architectural Characteristics
- Implementation plan for CGDI

The following specifications are formally endorsed by CGDI as enabling geospatial specifications:

- Web Map Service (OGC WMS): Provides visualization and simple map query functionality of raster and vector data
- Web Map Context Documents (OGC WMC) : Enables saving and setting map views which can be interchanged between supporting web mapping applications
- Styled Layer Descriptor (OGC SLD): Allows for custom symbolization of remote raster or vector data, without the requirement of modifying data at the source. Applications can custom style and symbolize data as per their requirements
- Filter Encoding (OGC Filter): Provides a common mechanism for spatial and aspatial queries when interacting with OGC Web Services
- Web Feature Service (OGC WFS): Provides raw data access to vector data in GML
- Geography Markup Language (OGC GML): Provides a data encoding standard based on the eXtensible Markup Language (XML) model for content
- ISO Metadata Standard (TC 211 DIS 19115): Defines a common framework for documenting data collections to support discovery and search operations
- GeoData Discovery, Catalog Service (OGC spec based on z39.50 profile): Provides an interface to query and discover data collections, schemas, web services and related resources

The CGDI endorsed specifications enable the development of tools and applications based on standards, as opposed to vendor specific implementations. This provides an increased factor of sustainability as well as technology choices as per organizational mandates, requirements and budgets.

6.3 Growth and Adoption

The CGDI has experienced a growing number of geospatial Web Services. In the past 24 months, the following OGC Web Services have been registered and published to the CGDI for access and consumption by the CGDI community:

OWS Specification	Number of Instances
OGC:WMS	**31**
OGC:WFS	**14**
Other (Gazetteer, etc.)	**18**

Table 6-1: Number of OWS Resources within CGDI

All of these OWSs are publicly accessible and available for anyone to connect to and consume, providing rich and diverse content accessible across networks. Subsequently, CGDI has seen many client tier applications (15) exploiting these services for various application domains and requirements.

The CGDI has also benefited numerous information communities by providing enabling infrastructure (Canadian Geospatial Data Infrastructure Architecture Working Group, 2001a). For example, the Canadian Information System for the Environment (CISE) is being built to assist in environmental decision making and integration of environmental data (Environment Canada, 2002). Similarly, the National Forest Information System (NFIS) provides current, authoritative and accurate information on Canada's forests and on sustainable forest management (Canadian Council of Forest Ministers, 2001). As part of CGDI, both of these communities are able to interoperate with one another, as well as globally given the CGDI’s recognition of international standards.

These enabling infrastructures thus provide an increased efficiency in the ability to fuse geospatial data from various application domains, and allow for easier integration of resources in support of decision making.

7 A Web Services Approach to Geospatial Data Interoperability

Web Services are positioned to provide on demand, dynamic information to the benefit of providers and consumers in heterogeneous environments, networks and activities, while providing flexible scalability. This part of the thesis will introduce a reference software implementation as a basis for comparative analysis of current/file-based vs. Web Services based approaches.

7.1 Reference Software Implementation: owsview

This thesis will use a reference software implementation to support the central argument. The concept of using a reference software implementation allows for a pragmatic approach to testing the scenarios discussed in this thesis, and develops practical illustrations to supplement the conceptual viewpoints which have been considered. The reference software implementation has been named “owsview”, to illustrate the notion of an OGC Web Services viewer application. Note that there are now (December 2004) many commercial software applications and toolkits which integrate Geospatial Web Services.

7.1.1 Overview

owsview is a web-based thin client prototype which supports discovery, access and visualization of supported specifications of the Open Geospatial Consortium

(OGC) and Canadian Geospatial Data Infrastructure (CGDI) endorsed specifications, such as Web Map Service (WMS), Web Feature Service (WFS), Web Coverage Service (WCS), Styled Layer Descriptor (SLD), Web Registry Service (WRS), Web Map Context Documents, Catalog Service, Gazetteer Service, Sensor Collection Service (SCS) and the GeoConnections Discovery Portal API (searching for products and services). owsview also exemplifies the benefits of standards based services for chaining between services for discovery, access and visualization of information holdings. This implementation was built using common, unified approaches as provided by standards, which allowed for rapid development.

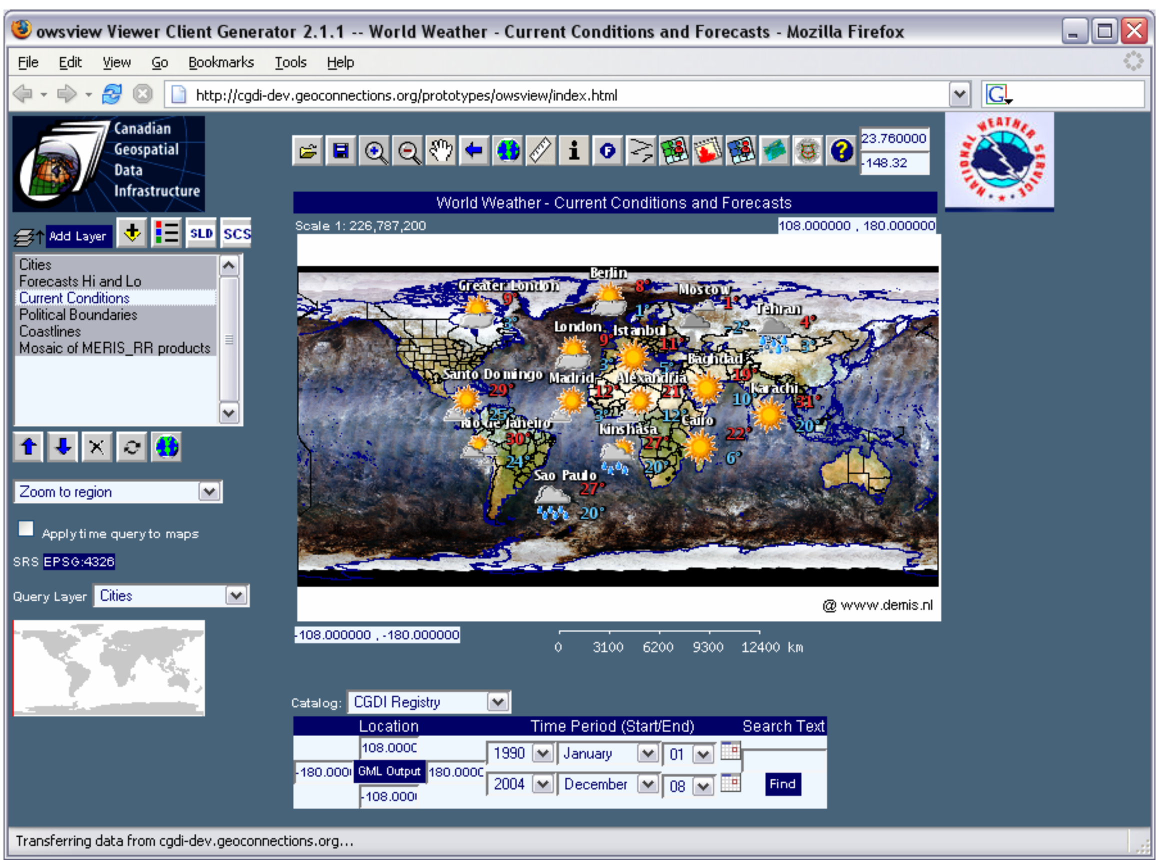

Figure 7-1: owsview

7.1.2 Purpose

The purpose of this application is to showcase the integration of geospatial content via Web Services, as prescribed by the Canadian Geospatial Infrastructure (CGDI) and the Open Geospatial Consortium (OGC). By demonstrating the interoperability of services built with application-neutral services, applications can use resources from multiple servers and integrate data and services into a seamless application, transparent to the end-user or client, using open interfaces.

7.1.3 Usage Requirements

owsview has the following requirements for use in this thesis

- Internet Explorer 5+ / Netscape Navigator 4+ / Mozilla / Firefox 1.0+ (any operating system)
- JavaScript enabled
- Cascading Style Sheets (CSS) enabled
- Internet connection (modem, cable, DSL, etc.)

The concept of using the Internet as the application platform base provides a ubiquitous means (the Internet web browser) for end users to use the application.

This means that users do not require anything more than a standard web browser, as is provided with most operating systems software.

7.1.4 Layer Control

Active map layers in the map view are highlighted in blue. Layers can be shifted up, down, as well as deleted from the layer stack. The view must be refreshed by clicking redraw or performing a zoom out/in/pan for the map view to reflect the layer changes made in the application. Because all data is accessed using standards, this functionality is simple to implement.

Clicking the Layer Properties button will launch a popup window with the attributes of each layer connected to the application. Active layers are highlighted in blue. Clicking the Add Layer button allows manual input of WMS layer information.

7.1.5 Adding WMS Layers

The user is able to interactively add layers from OGC:WMS instances by clicking the “Add Layers” tool, which allows for a user-defined input of a particular WMS layer. Users can alternatively use the “Add Layers from Services” tool, which allows users to enter the WMS server prefix URL and display a user-friendly view of layers and metadata for a particular OGC:WMS. Using the OGC Catalog

Service (as described in Section 6.2) allows for real-time discovery of Web Services.

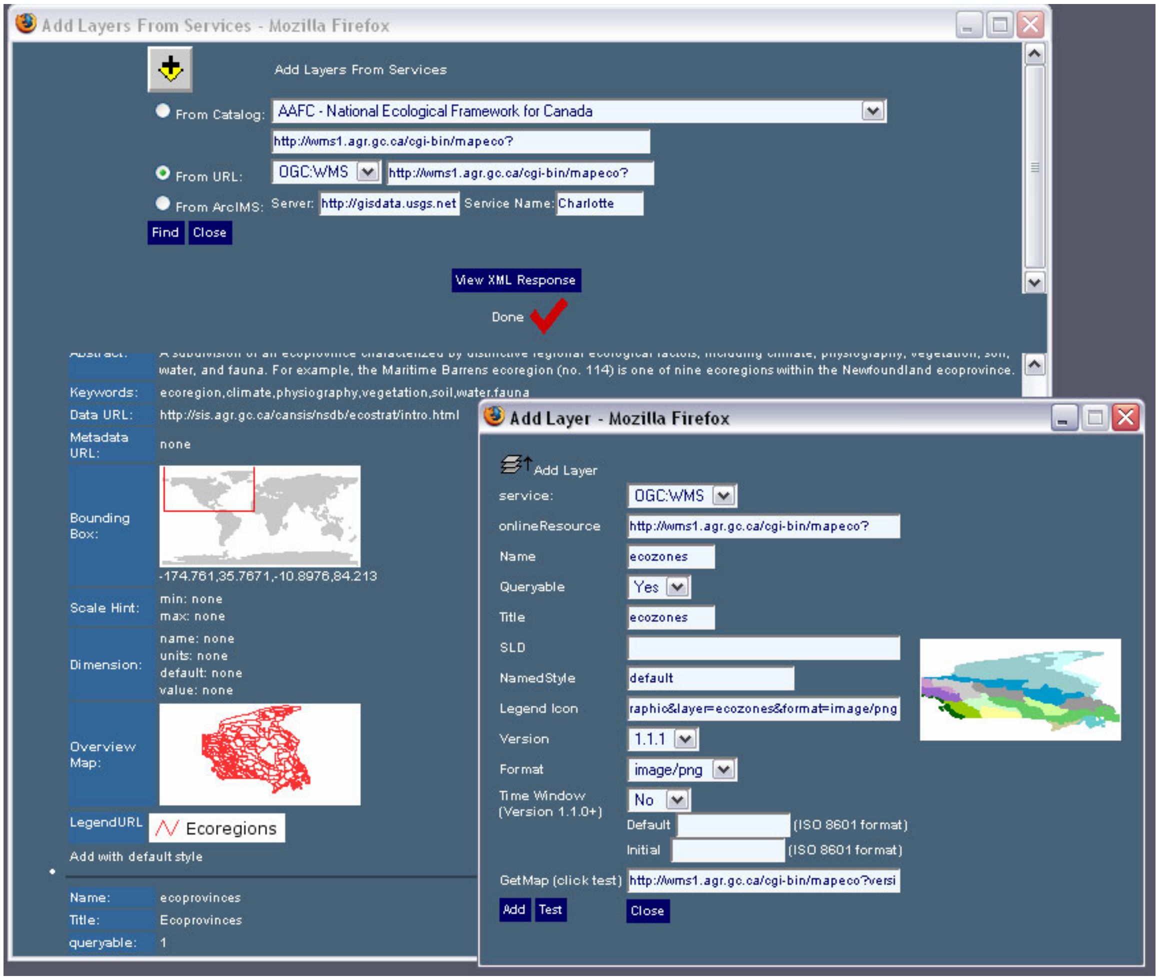

Figure 7-2: Adding Layers and Services

7.1.6 Saving and Loading Maps

The application supports web map context documents, and allows importing, exporting and bookmarking of context XML documents through the “open” and “save” toolbar buttons. Bookmarks can be enabled by appending 'context=contextURL' to the base URL of the application. Saved bookmarks can then be used in other applications supporting the Web Map Context Documents specification.

7.1.7 Navigation Control

Navigation takes place by zooming in, out, panning, and extent-based relocation. The user may define a bounding box in the map window (see Map View for more information), then clicking a navigation button. Zooming to an extent ignores any user-defined bounding box and refreshes the map view to the selected region. Map coordinates are displayed as the user moves their mouse over the map image. These are typical tools in geospatial applications which have been replicated for this application.

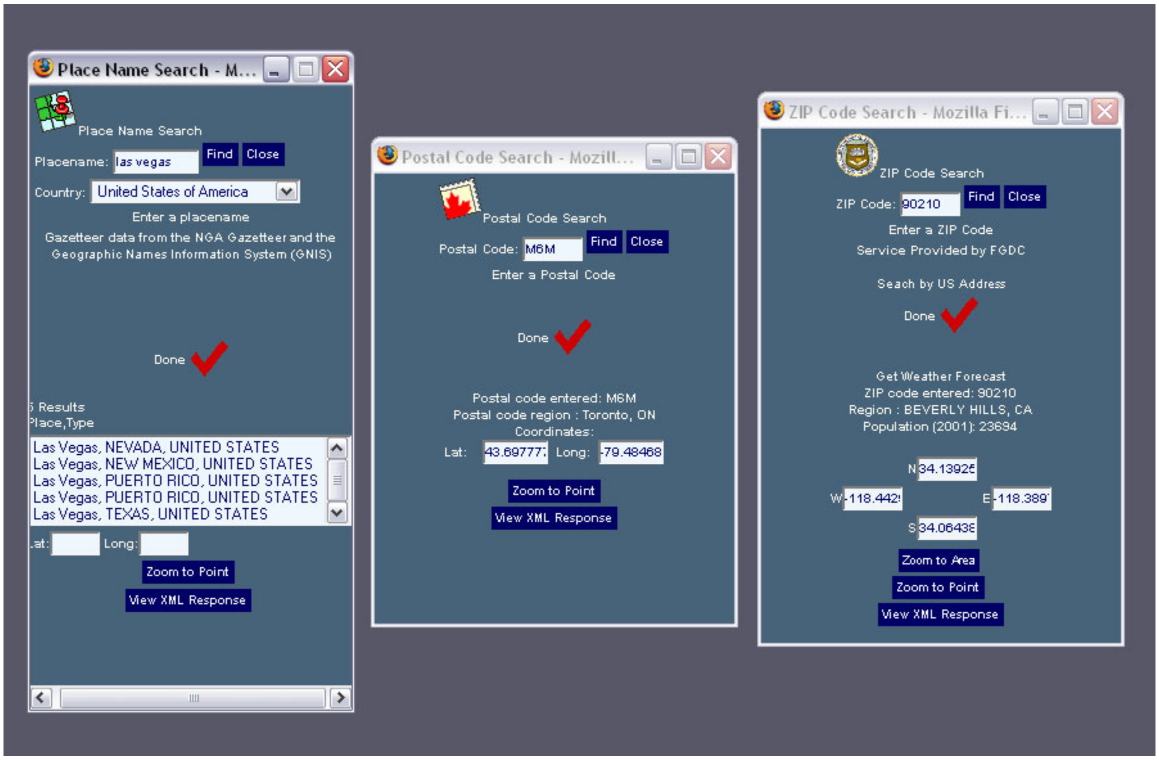

Figure 7-3: Navigating with Web Service Geocoding

Users may zoom into predefined areas by placename, postal code, NTS mapsheet, watershed, or zipcode. Querying these services returns results, at which point clicking the Zoom to Area button will navigate to the desired area of interest. Since all of these services are based on Web Services, there is no requirement for local data storage.

7.1.8 Main Map View

The map image is displayed, reflecting the user selected layers from the layer control. The user may draw a bounding box to define an area of interest within the map image, and then click a navigation control to zoom in or pan to the area.

The user may also choose a point for query features within the map image. Geographic extents (minx, miny, maxx, maxy) are displayed along the corners of the map image. The scalebar is updated as the map image changes with corresponding scale values.

7.1.9 GML Export

Users can select a point or bounding box polygon for export to Geography Markup Language (GML) format. The user will be prompted to assign a label for the shape selected, outputting a GML encoded XML document. GML 3.0.0 is used as the geometry content model. Using GML thus enables integration into applications supporting this OGC standard.

7.1.10 Reference Map

The reference map reflects the current area of interest of the map view as outlined by a red transparent box.

7.1.11 Searching for Data

Users can browse for online maps and data through the search interface. The search interface allows selection of querying catalogs as well as the

GeoConnections Discovery Portal. The returned layers from the Catalog Search are available to the user for import into the application for real-time viewing.

7.1.12 Technology

This application connects to and integrates the following specifications:

- OGC Web Map Service (WMS)
- OGC Styled Layer Descriptor (SLD)
- OGC Web Feature Service (WFS)
- OGC Filter Encoding Specification (FES)
- OGC Geography Markup Language (GML)
- OGC Stateless Catalog (CAT)
- OGC Web Map Context Documents (WMC)
- CGDI Gazetteer Service (CGDI:cgdigaz)
- CGDI NTS Lookup Service (CGDI:NTS)
- CGDI Postal Code Lookup Service (CGDI:postalcode)
- EC Watershed Lookup Service (EC:WatershedLookup)
- FGDC ZIP Code Lookup Service (FGDC:Zipcode)

This application uses a combination of DHTML and Perl. The open source UMN MapServer software is used as a client to control coordinates, and generate dynamic scalebars and reference maps.

This application, as the reference software implementation for this thesis, has been and will be a work in progress.

7.1.13 Security

This application connects primarily to Web Services over the HTTP protocol. Secure connections (x509 PKI certificates) are also possible, as this application does not broker any WMS GetMap requests. Because owsview was developed as an Internet thin based web client, the images requested from a WMS communicate directly with the remote WMS server, and not through an intermediary function. As a result, a secure WMS authenticates against the end-user's web browser certificate / security configuration, transparent to the application.

7.1.14 About

This software (originally named Web Mapping Prototype, or WMP) was originally developed in 2000 (building from the default UMN MapServer “Itasca” demonstration) as part of the Author’s graduate work at Carleton University. Development evolved from web visualization of locally integrated spatial data via Common Gateway Interface (CGI), to distributed data via Java Applet technology, to full blown OGC Web Services (OWS) connectivity and distributed geoprocessing via DHTML and Perl middleware. This software was also instrumental in the development of the OGC Web Map Context Documents Implementation Specification. The Author was a lead contributor to this specification. This software also supported the vision and development of Chameleon, an open source tool providing rapid application development for web mapping applications connecting to standards based Web Services.

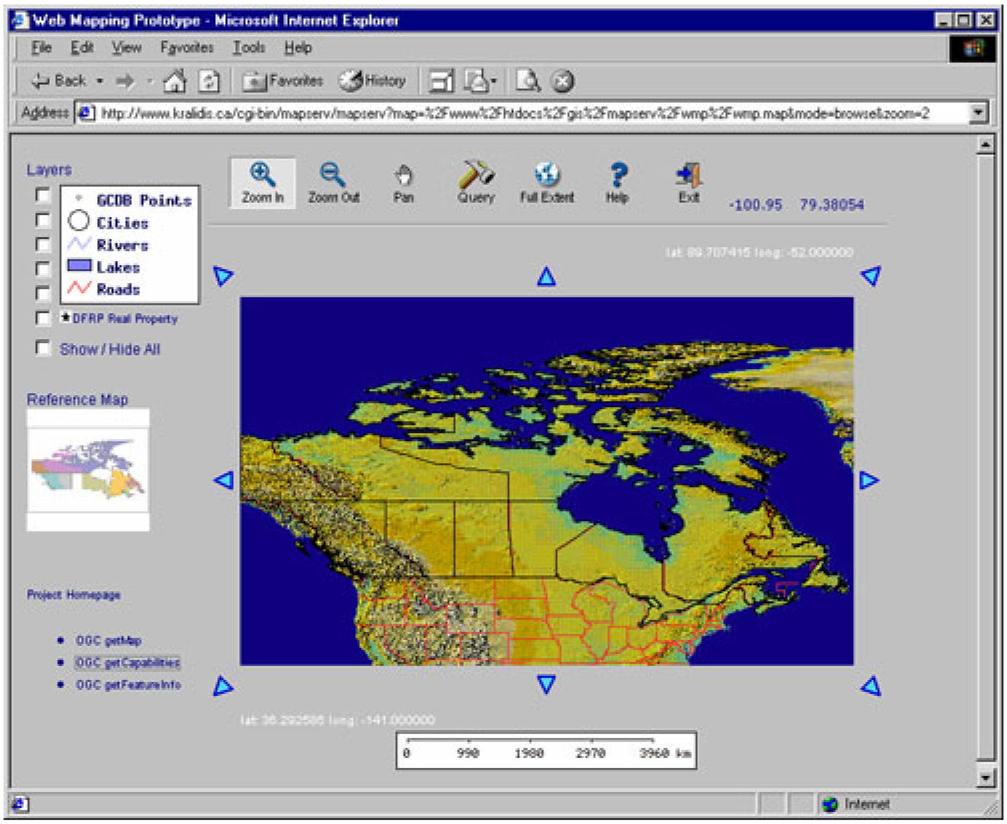

Figure 7-4: WMP Original Concept Prototype (2000)

This software is currently developed and maintained as a demonstration tool in support of the Canadian Geospatial Data Infrastructure. The Author recognizes and acknowledges the support of the GeoConnections program and Natural Resources Canada, Environment Canada, Government of Canada, for support and resources for development of this tool.

Bugs, comments and suggestions for improvement are welcome and appreciated. NOTE: if this application is to be used in a demonstration, please contact the Author to ensure availability and quality of service.

owsview is meant as a demonstration application prototype, and currently does not aspire to operate as a full blown software product implementation. Keeping owsview as a prototype allows for rapid prototyping, development, and flexibility for short-term demonstrations, pilots and testbeds. It is in this context that owsview does not have a formal bug reporting system or subsequent formal software development plan. The current location of owsview can be found from visiting the following location:

http://www.kralidis.ca/gis/masters/thesis/index.htm

7.2 Scenarios Revisited

We now recast both scenarios discussed earlier in the context of the Web Services approach using owsview as the tool to test the Web Service approach. Note that owsview is only one application example and this scenario is not limited to using this software. In this context, no static data is integrated, yet all data is provided through an interoperable OWS. Data is provided by the authoritative source, up-to-date, in real-time and on demand, through Web Services, as shown in Figure 7-5:

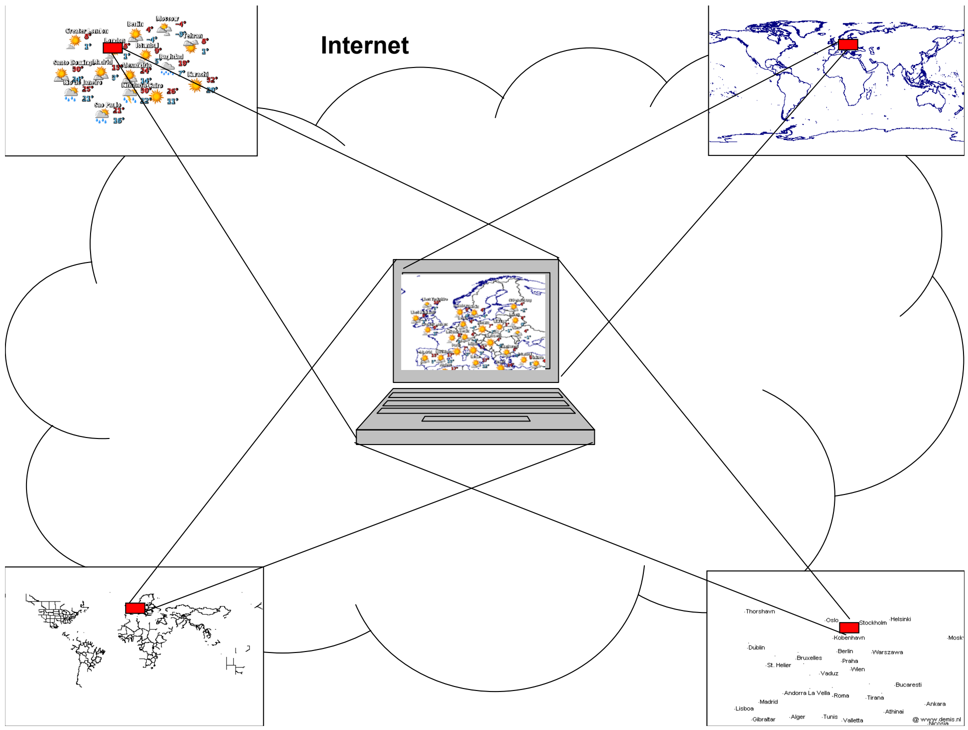

Figure 7-5: Web Services On Demand

7.2.1 Scenario 1

Let’s recast scenario 1 as described in Chapter 4 using the Web Services approach. Since the USGS NEIS currently does not offer their real time earthquake data through a Web Service, we emulate this behaviour by creating a Web Service from scratch as an established pre-condition behaviour; that is, the effort required to create the Web Service is not accounted for in the context of this scenario. We choose to generate an OGC WMS and OGC WFS using the University of Minnesota MapServer open source software package, which supports many OGC specifications. The reasons for implementing this pre condition are twofold: a) to provide NEIS as a Web Service for this thesis and b) to illustrate the ease of enabling data as Web Services from the service provider viewpoint. Figure 7-6 depicts the process involved in enabling the NEIS data as an OGC:WMS.

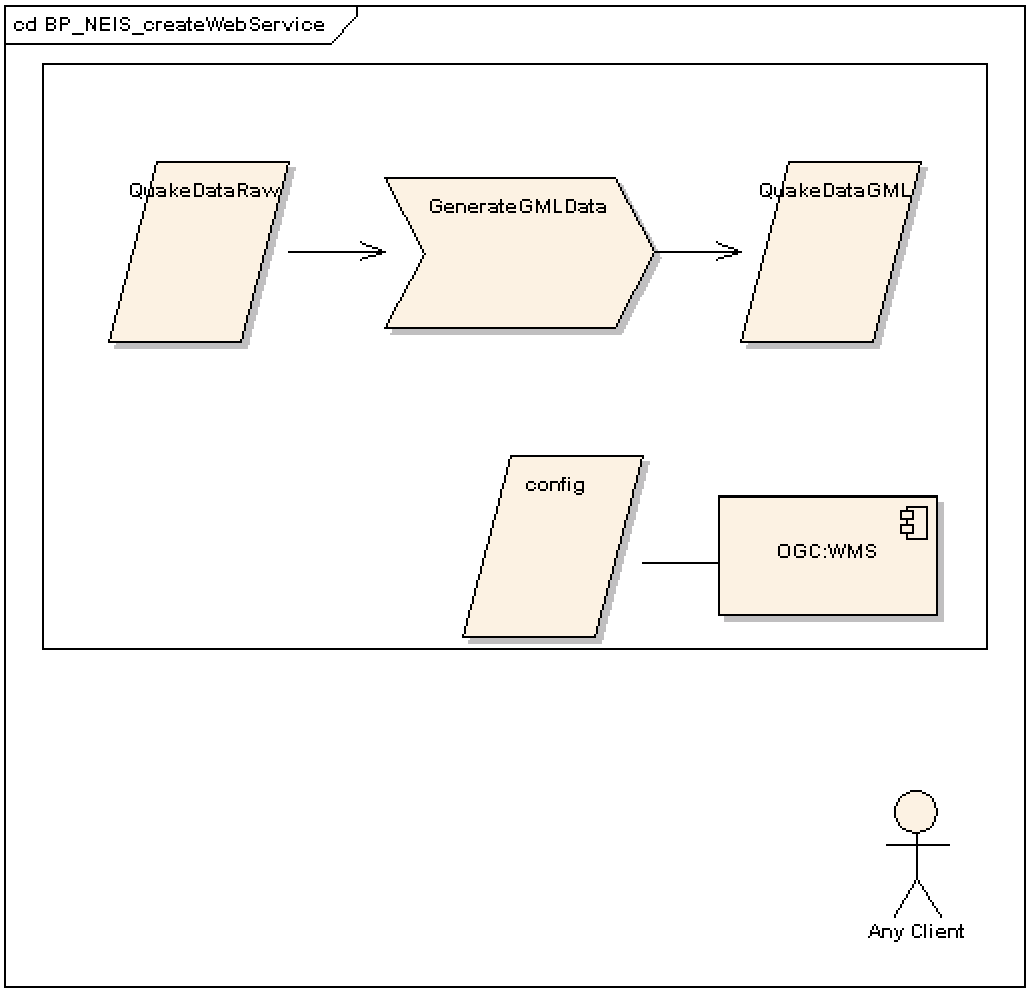

Figure 7-6: Scenario 1 Precondition

The first step in "OGC-enabling" this data is to fetch and reformat the text records into an interoperable, self-describing format. Keep in mind that if this Web Service existed, this step would not be required. Our initial process is to analyze the data format within the data located at http://neic.usgs.gov/neis/finger/quake.asc.

As this data has a geographic location as well as attribute information relative to a point on the earth, this turns out to be applicable for a GML model. The primary step in creating a GML document is to create a GML application schema. This application schema defines the data types, structures and objects in W3C XML Schema language. Because GML represents an enabling application building framework, which itself leverages XML Schema, a domain expert can easily construct their information model in a standards-based fashion. This reduces the level of effort in defining common nomenclatures and structures where others have already defined them, with consensus. Figure 7-7 illustrates the building block effect of a GML document.

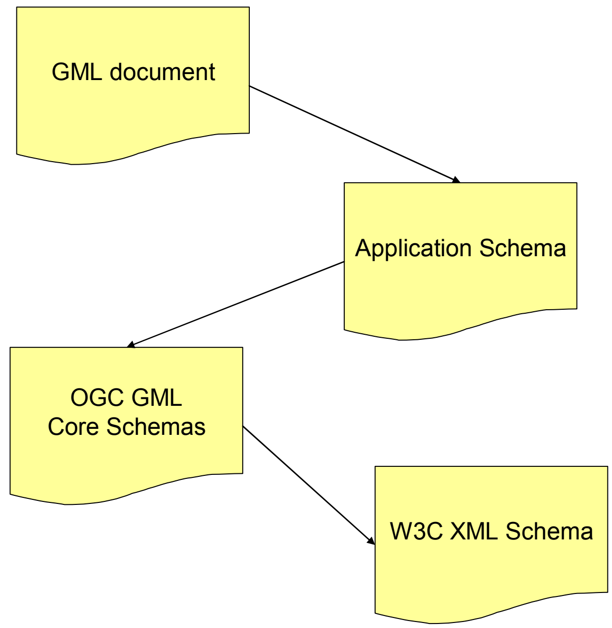

Figure 7-7: Leveraging Standards as Information Building Blocks

When creating our application schema, we find that the OGC GML core schemas possess many predefined blocks which we can reuse. This saves time and effort in eliminating the requirement for redefining common blocks and structures, as well as (and more importantly), providing an output information model in a manner in which common tools can process and interpret.

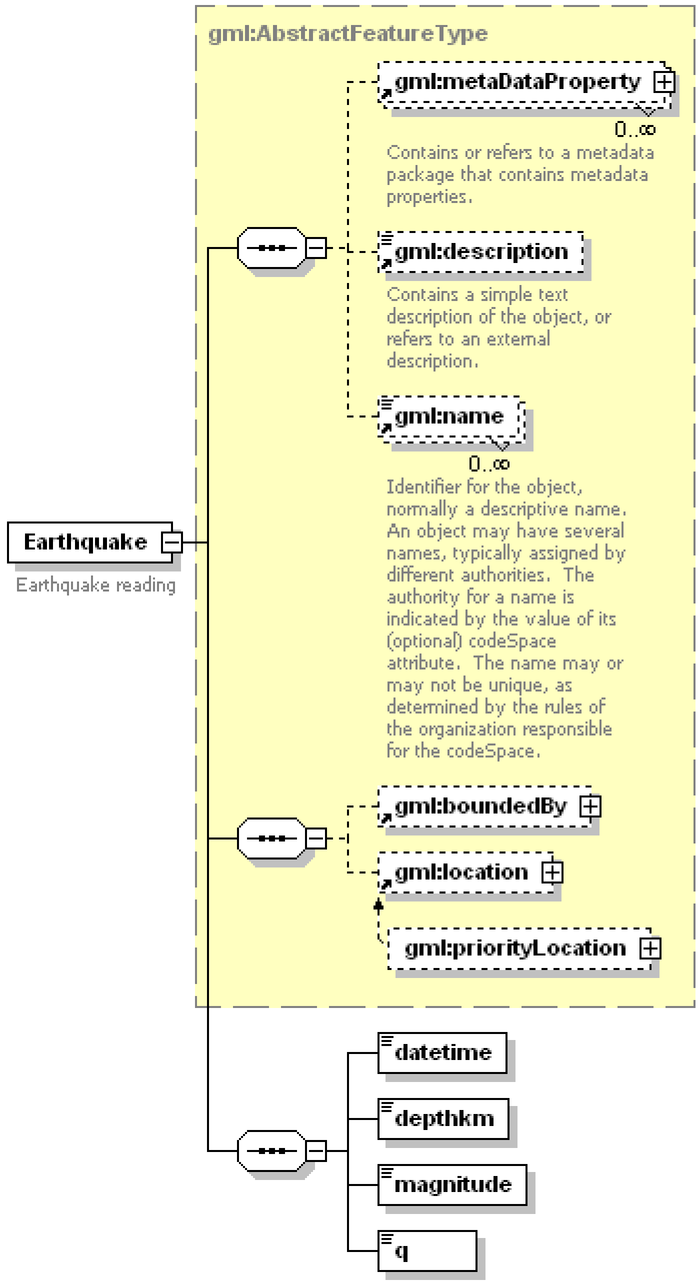

Figure 7-8: Schema Design View of Earthquake Data GML Model

As illustrated in Figure 7-8, objects defined in yellow indicate those inherited from the GML core model. The `gml:` namespace indicates reuse of an existing definition from the GML schemas. The objects are defined in the local application schema as specific to the NEIS data model.

A simple scripting process outputs a GML document as input for the OGC:WMS. We then configure a UMN MapServer installation to connect to the GML data. Again, this is a pre condition operation which would be transparent to the end user. Full details of the implementation are available in Appendix C.

Once this process is in place, the OGC:WMS and OGC:WFS can run standalone, unsupervised, as a Web Service with the self-updating process to gather latest updates from the NEIS data site. As a result, any OGC:WMS aware client application (web-based, desktop, etc.) can now interact with the NEIS readings for visualization, data extraction and / or analysis.

Name	Map production
Description	A natural hazards organization publishes real-time maps to the Internet to display latest earthquake activity on a global scale for advisory purposes
Precondition	Suitable data archive and catalog servers are available to the companies involved, and they support data schemas for all needed types of data and metadata. The needed data and metadata types are also already known by the participants. The available archive and catalog servers may already store some of the needed metadata and data. Base / reference data exists

	to produce the output map
Flow of events – basic path	
	The natural hazards organization operator / responsible party configures their webpage URL to point to an OGC:WMS to visualize latest earthquake activity data, as well as an OGC:WMS to display reference / basemap data

Table 7-1: Scenario 1 Description with Web Services

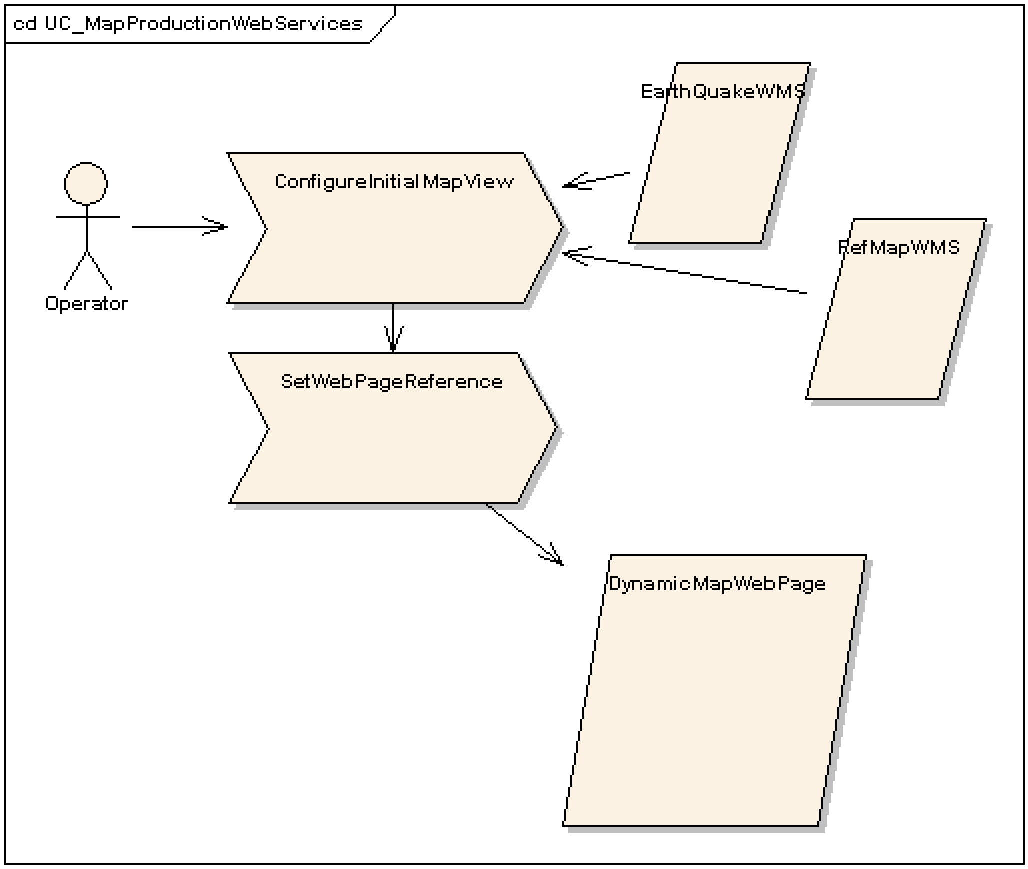

Figure 7-9: Scenario 1 Web Services View

At this point, the operator is no longer handling geospatial data, yet is part of a service-oriented component-base approach in which he / she connects to data dynamically. No further interaction is required with the data services or maintenance of the webpage showing the image.

Initially the operator uses owsview as an OGC-standards-based software tool to configure their Web Services connectivity information and add the earthquake Web Service to their map data view which is based on connected Web Services of basemap data.

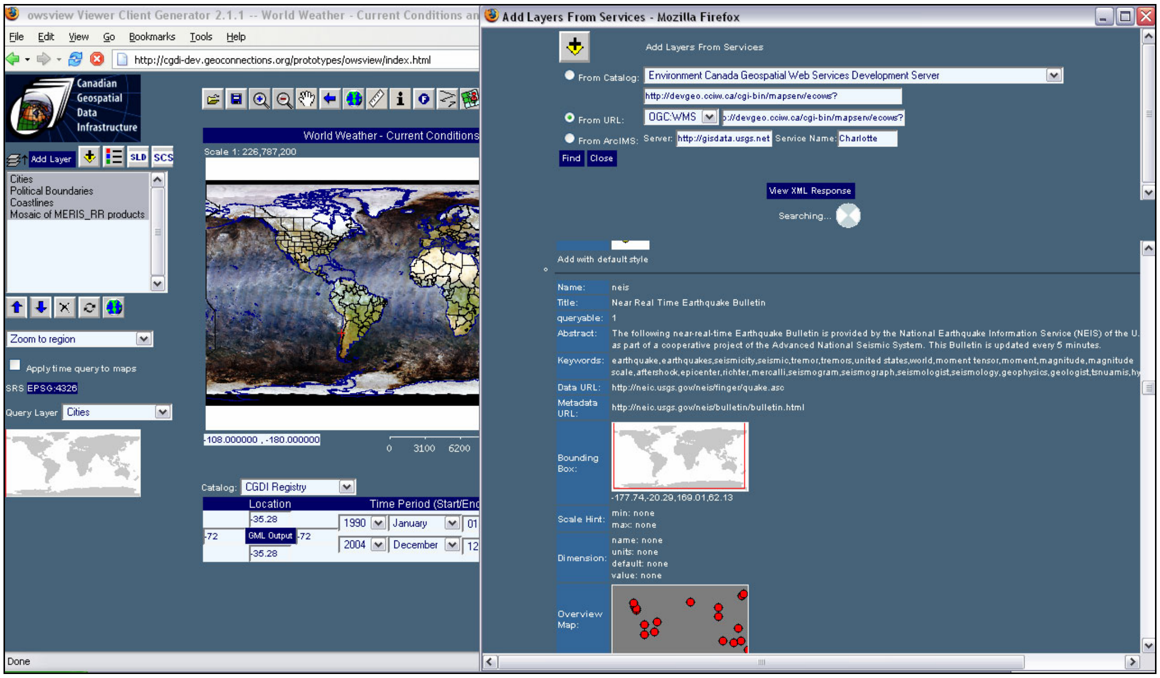

Figure 7-10: Adding earthquake WMS layer

The operator then saves this URL , which they embed as a reference to their webpage. The webpage, when requested by a client, cites an image object, which automatically connects to the WMS, which triggers connections to the various disparate OGC:WMS instances to produce the virtual webmap as shown in Figure 7-11:

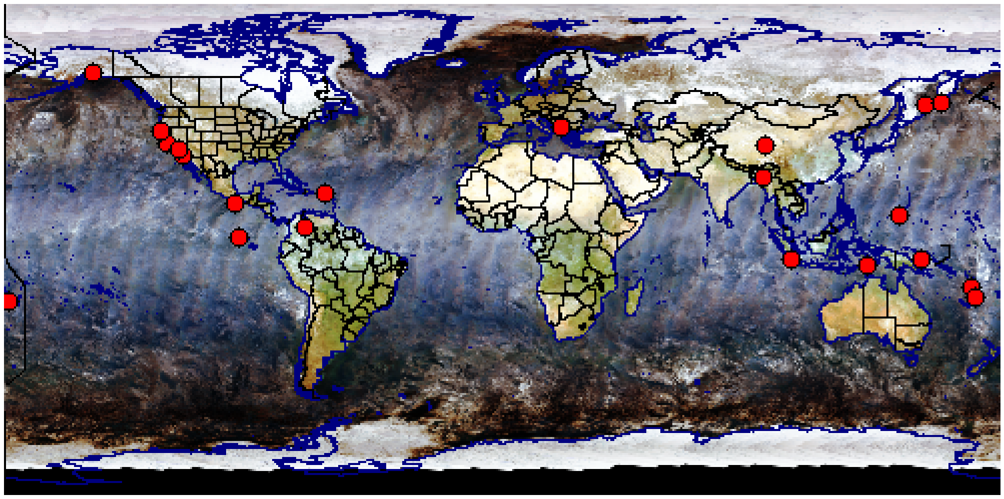

Figure 7-11: Web Services Dynamic Map Generation

Here is the OGC:WMS GetMap request embedded in the webpage:

```
http://host/wms?SERVICE=WMS&VERSION=1.1.1&REQUEST=GetMap&SR
S=EPSG%3A4326&BBOX=-180.0000000309986,-
112.5000000193741,180.0000000309986,112.5000000193741&WIDTH
=560&HEIGHT=350&LAYERS=neis&STYLES=&FORMAT=image%2Fpng&BGCO
LOR=0xFFFFFF&TRANSPARENT=FALSE&EXCEPTIONS=application%2Fvnd
.ogc.se_inimage
```

This request is a valid OGC WMS GetMap request connection, which means it can apply to any valid WMS server, given the correct URL location and content information. The advantage of using a standards based API is that it (or the logic used to generate it) may be reused and applied to an infinite number of applications.

7.2.2 Community Implementations

In recent months, there have been numerous web application clients leveraging the OWS approach to geospatial data interoperability. The GeoGratis website now offers most of its data offerings through the OGC:WMS specification. The Toporama website now offers NTDB, at both 1:50 000 and 1:250 000 scales, as an OGC:WMS instance. Figure 7-12 shows an example of data served from both Web Services integrated into a unified map view:

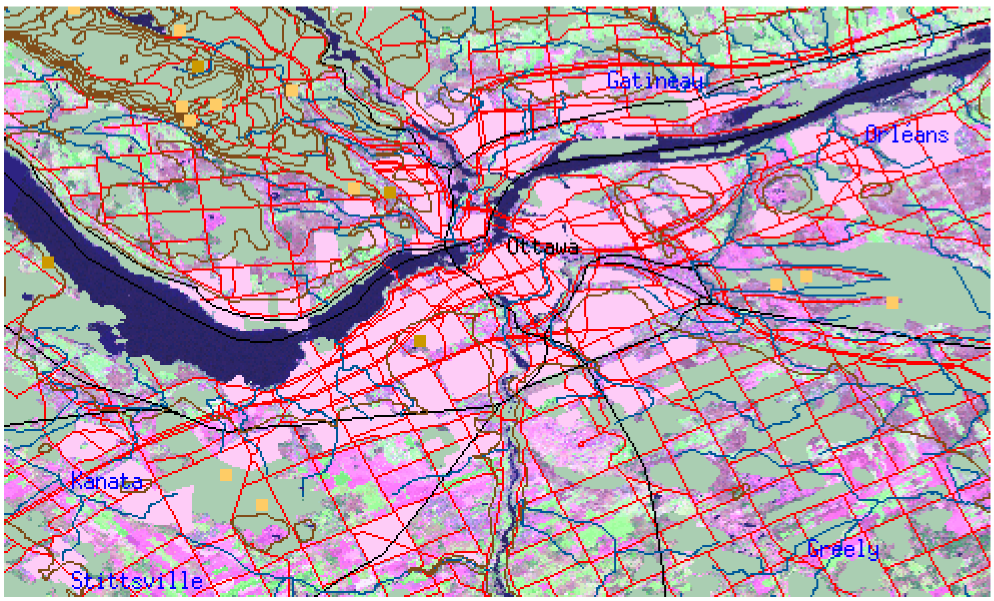

Figure 7-12: Online Mapping with Web Services

Though the data is coming from two Web Services, it is not apparent in the end visualization.

The WMS specification, as a Web Service, has also reduced barriers to integration for non-traditional geospatial data users. For example, the Finance Maps website offers free analysis and information on global investing with a focus on personal finance (Good Content Network, 2004). With the help of OGC standards and WMS, this website now easily provides map displays of global financial information as a means of integrating with current financial marketing conditions and forecasts. Specialized resources are not required to develop simple references to OGC based Web Services, thereby enabling ease of integration for applications.

As a result, with geospatial data available via Web Services, application developers can now integrate these data into their applications with less effort than previous approaches.

7.2.3 Scenario 2

Using the OGC Web Map Context Documents Specification for Scenario 2 can explicitly address the concept of creating and reusing a map of geospatial information using standards based methods. NASA and IONIC software originally proposed the concept of Context Documents during an OGC testbed activity to achieve interoperability of geospatial information. The initial gap in the CGDI architecture and implementation caused Natural Resources Canada's involvement, in support of the GeoConnections program, in further developing this concept into an adopted OGC specification, and an additional endorsed technology within the CGDI, and geospatial community in general.

WMC Documents provide an application neutral definition of data from one or many WMS resources, as well as the state of the data (area of interest, scale, projection, etc.). This concept is analogous to 'projects' or 'workspaces' in common GIS applications, which allow users to save and revisit their GIS application when desired and to continue their development and analysis at any point in time.

WMC Documents enable sharing of application scenarios, demonstration presentations, and can be saved, reused and discovered independent of the look, feel and functionality of a given application or tool.

WMC Documents use the eXtensible Markup Language (XML) as the document definition and encoding mechanism. XML ensures application neutral definition of information in a human readable and digestible manner.

WMC Documents do not contain data level information but rather references to context and connectivity of geospatial Web Services, thus providing a lightweight approach to information sharing and publishing.

WMC Documents separate visualization issues regarding content and interface / style definitions, which enable multiple levels of expertise to produce a visualization client for geospatial information.

Some possible uses of WMC Documents:

- enable various startup views for geospatial visualization tools of standards-based services such as WMS

- enables saving by end users at any state within their activity
- enables sharing by supporting applications serving different purposes
- enables publishing as a geospatial information resource and discovered in the same manner as a research project or activity

The importance of WMC Documents is the separation of content and style or functionality between geospatial visualization tools. A complex tool can perform statistical analysis on spatial information, while a simpler tool can act as a data browser in support of discovery of resources. Both tools can reference the identical information resources with this approach.

Figure 7-13 illustrates how WMC Documents can solve the interoperability problem between visualization applications and tools using WMS information:

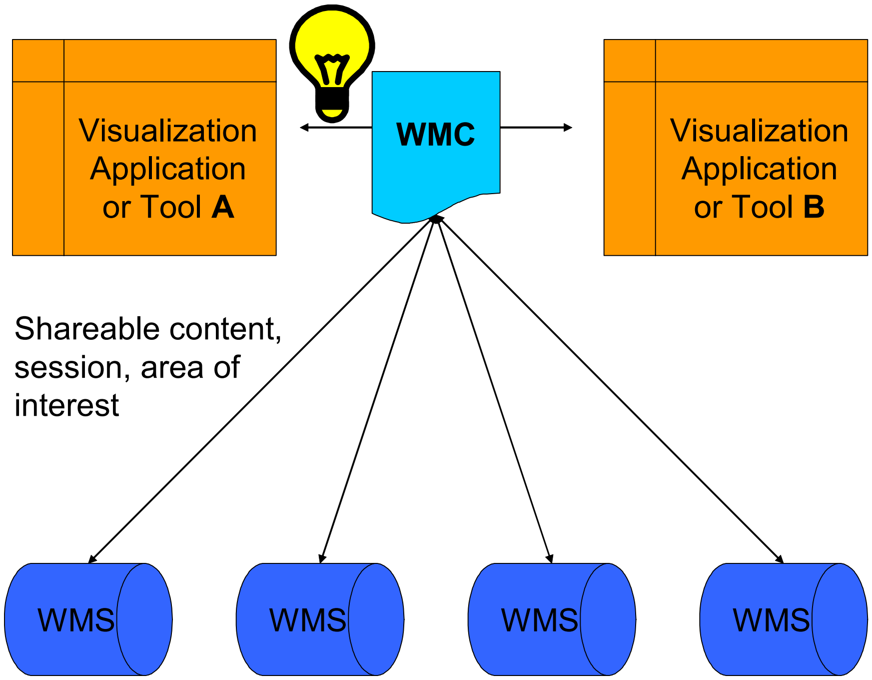

Figure 7-13: Leveraging WMC for Application Sharing

It is evident from the above figure that visualization tools can indeed be interoperable using the WMC approach. An additional document definition layer is added to the model, which, at first, may convey an additional level of complexity in GDI, however this extends and supports the model of data sharing in referencing visualization tools as service providers.

Let's revisit scenario 2 as outlined in Chapter 4, now possible using WMC Documents:

Name	Map sharing
Description	An environmental agency research scientist publishes spatial

	data based on water quality information. The research scientist is required to a prepare a view of water quality monitoring locations to a policy analyst for further processing and publishing for senior management level reporting on water quality monitoring activities
Precondition	Suitable data archive and catalog servers are available to the companies involved, and they support data schemas for all needed types of data and metadata. The needed data and metadata types are also already known by the participants. The available archive and catalog servers may already store some of the needed metadata and data. Base / reference data exists to produce the output map
Flow of events – basic path	
	The research scientist, using an OGC-standards-based application, generates a map view of water quality monitoring station locations atop base / reference map data
	The research scientist saves the view as a WMC document in the application so that the view can be regenerated and displayed at a later time in the same manner as it was saved
	The research scientist emails the WMC document to the policy analyst
	The policy analyst launches their OGC-standards-based

	application, and opens the WMC document

Table 7-2: Scenario Description 2 with Web Services

Using owsview, the research scientist prepares a view of the project, containing multiple data layers from disparate locations on the Internet through Web Services (Figure 7-14).

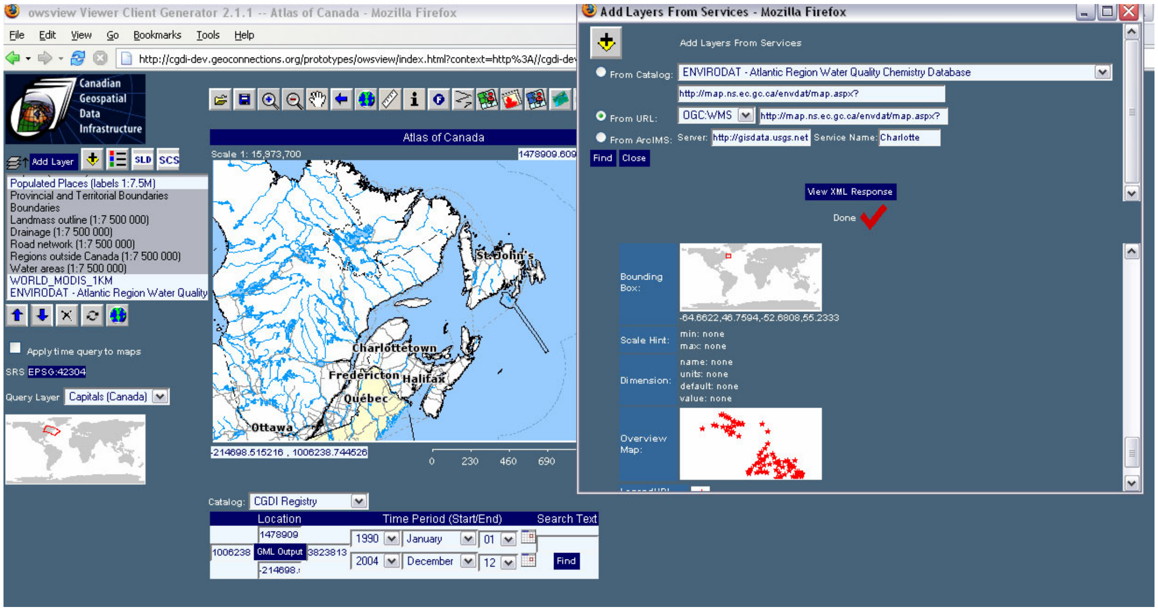

Figure 7-14: Adding Water Quality data via WMS

By using owsview, the research scientist saves the view to a WMC document (Figure 7-15).

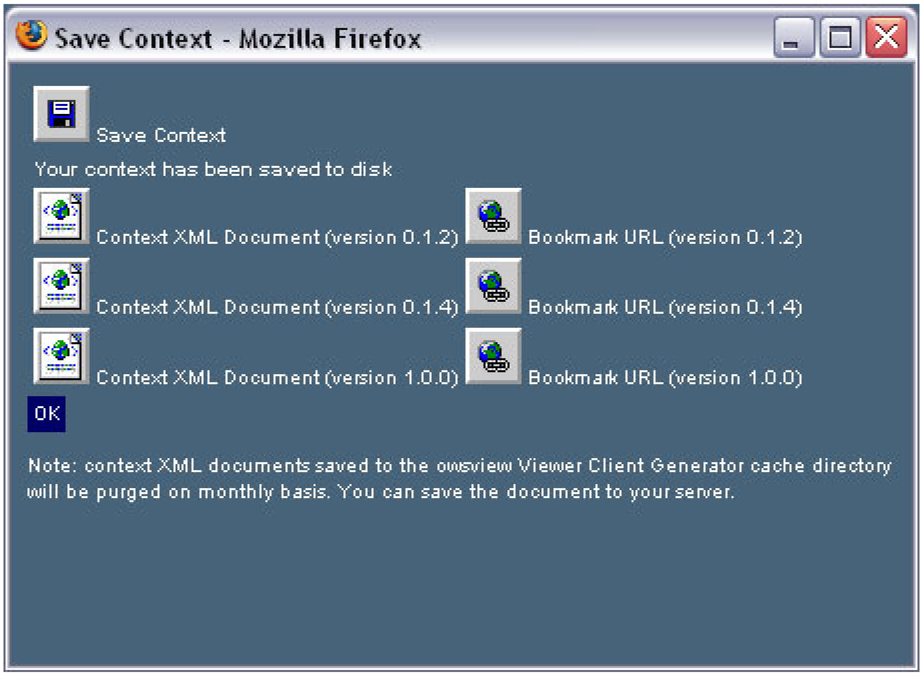

Figure 7-15: Saving the View with WMC

The policy analyst wishes to visualize the analysis in a separate, unrelated, yet OGC-standards-based visualization tool. Using WMC, any user is able to visualize this information in the application of their choice (say, a simple viewer), independent of the potential complex functionality in the application of the research scientist, however portraying the same information through a map. Figure 7-16 is a visualization of the same WMC document in the NASA web map viewer (National Aeronautics and Space Administration, 2001):

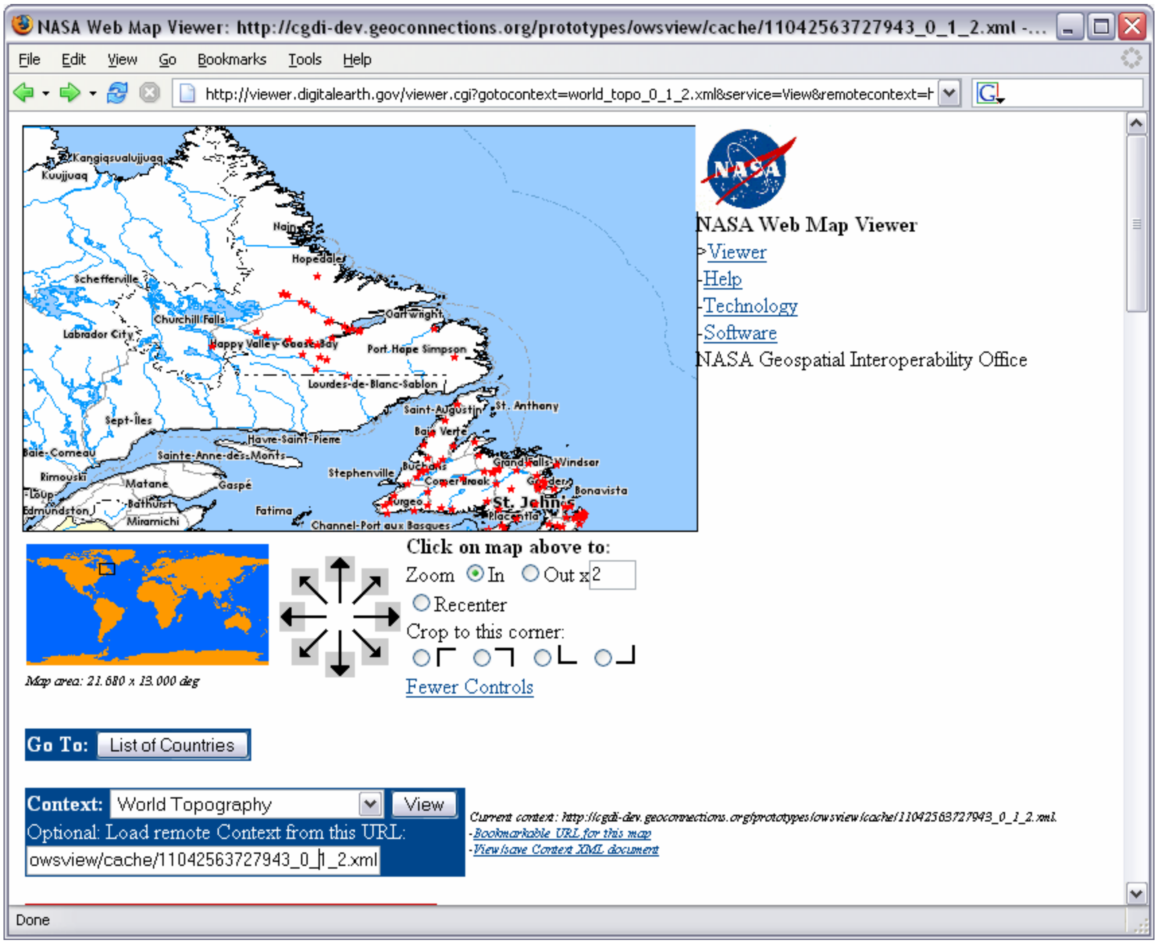

Figure 7-16: Same View, Different Application (NASA Web Map Viewer)

Furthermore, the look and feel of visualization tools can be developed independently of content sources and methods with the WMC approach. For example, a visualization tool developer can leave the geospatial information content information independent of the tool's functionality or capabilities. This can facilitate and focus the efforts of a tool developer on their specific skills, rather than on a high level of effort in data content definition. Figure 7-17 illustrates this concept by visualizing the same WMC document into the Gulf of Maine mapping application.

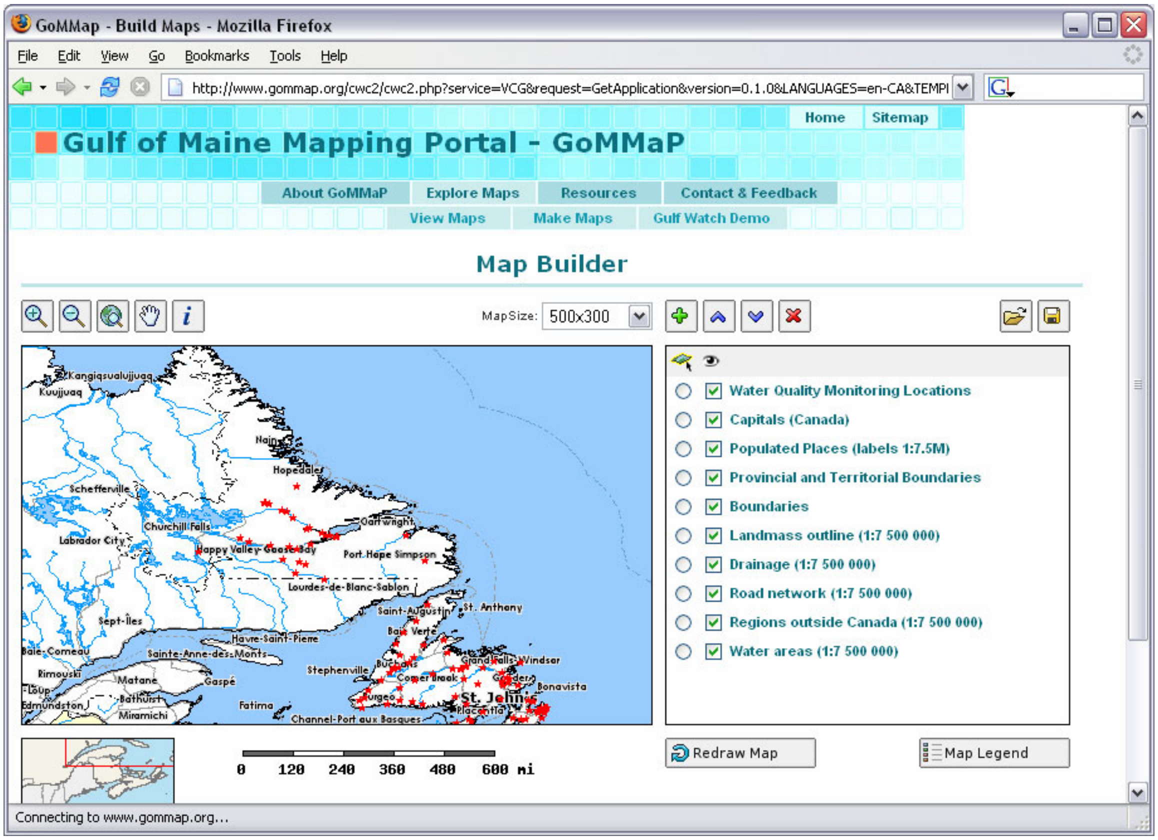

Figure 7-17: Same View, Different Viewer (Gulf of Maine Mapping Portal)

7.2.4 Community Implementations

As a result, at a conceptual level, WMC Documents can support and enhance the vision of geospatial information sharing through visualization and web mapping applications.

The NASA Digital Earth viewer client supports Web Map Context Documents, as does owsview. Both clients operate as demonstrative applications to illustrate the benefit of geospatial data interoperability. There are, however, some slight differences in functionality. The NASA tool enables validation of WMS services, as well as searching various NASA data repositories for scientific data collections. owsview enables navigation based on Canadian Postal Codes and locations, as well as using the tool to search the Discovery Portal information holdings. Both clients use WMS as the service which to perform visualization of maps and map data.

Figure 7-18 is a screenshot of the NASA tool with a map of locations of CEOS Earth Observation Data Information System (EOSDIS) gateways:

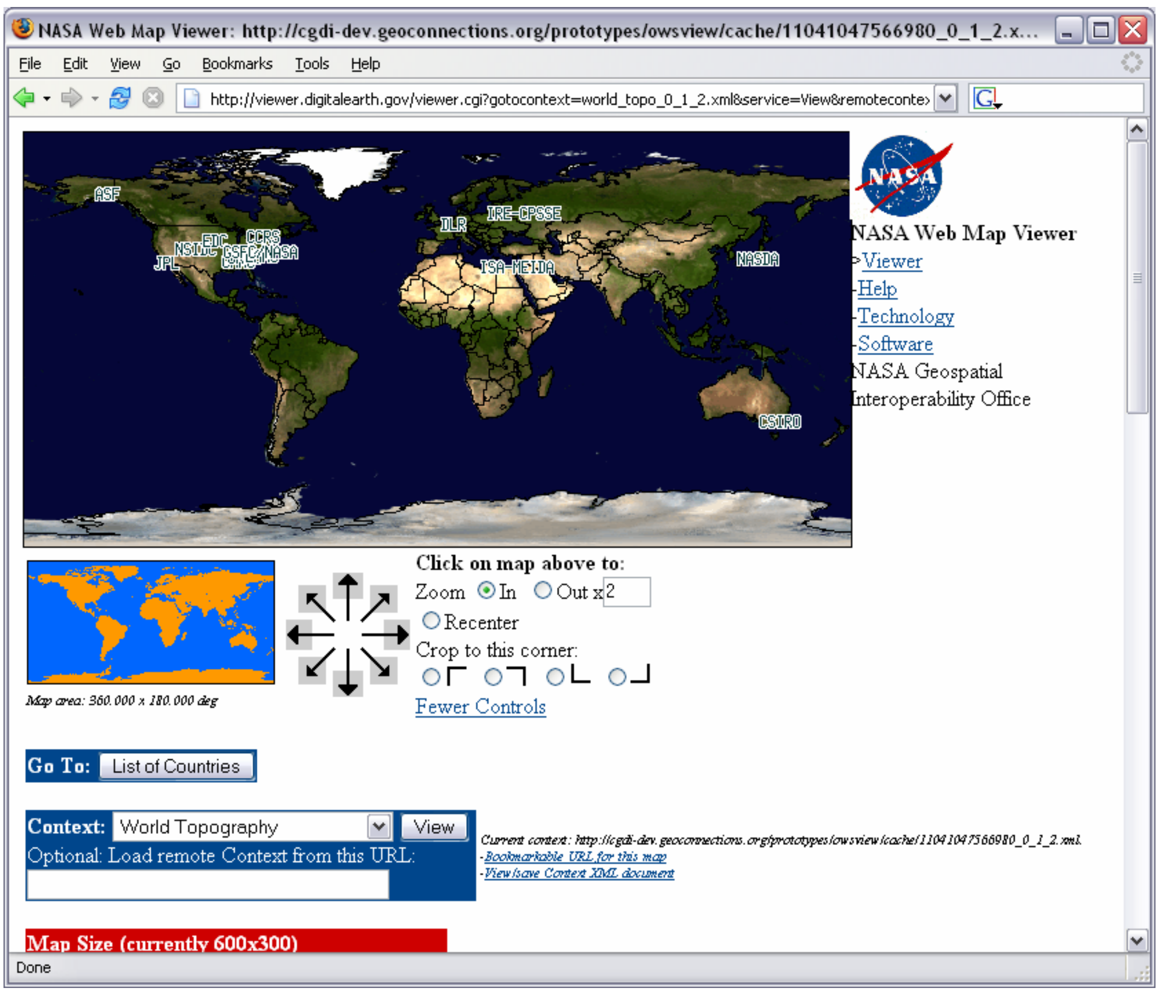

Figure 7-18: NASA Viewer WMC Export

End users can use this map composition to perform queries related to NASA scientific products.

Figure 7-19 is an accompanying screenshot of the owsview with identical content definition using a WMC Document exported from the NASA tool:

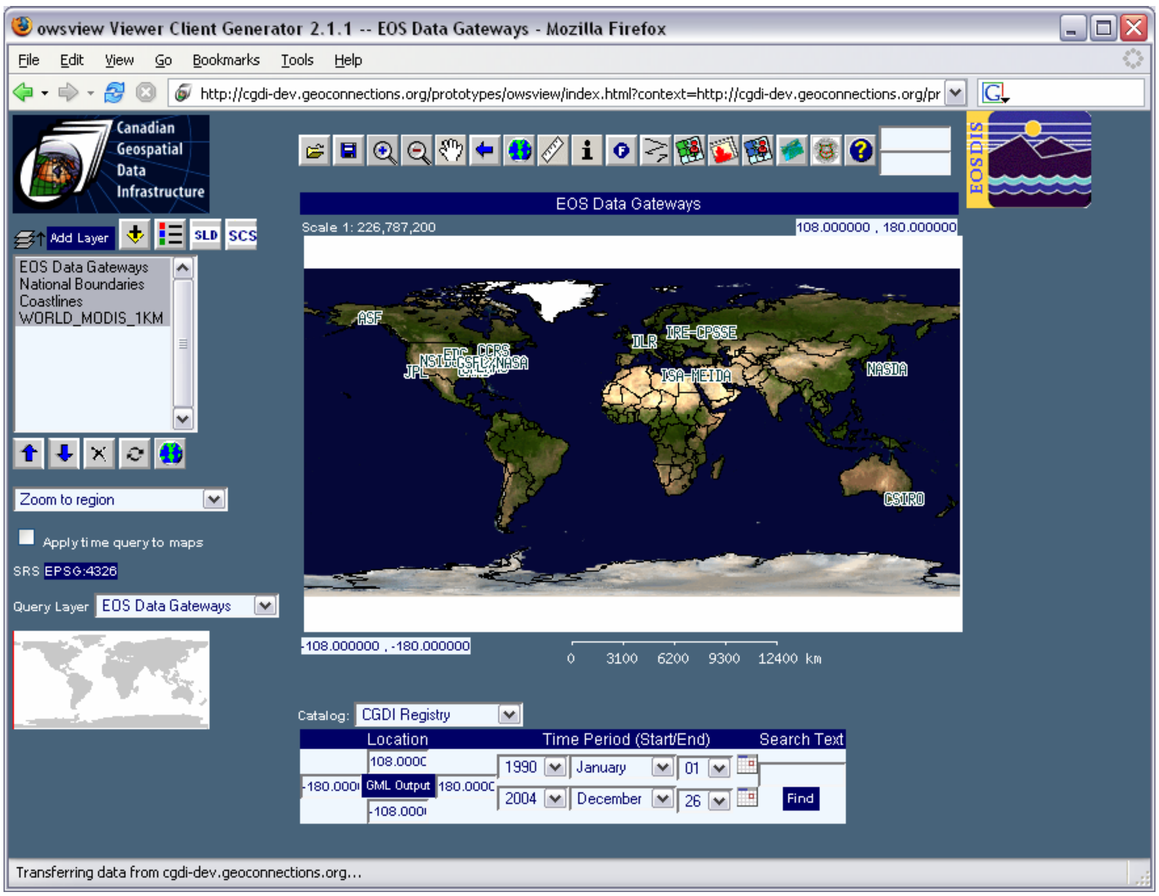

Figure 7-19: owsview Import of NASA WMC

Here, end users may wish to perform searches on the Discovery Portal to locate companies providing geospatial and scientific research and consulting services close to Canadian nodes of the EOSDIS network.

An additional example of interoperability is illustrated in the screenshot in Figure 7-20 from IONIC's GeoViewer software.

Figure 7-20: IONIC GeoViewer loading NASA WMC

Web Map Context Documents can facilitate and support the following issues:

- Map sharing: by various information communities with common mapping requirements
- Applications and websites independent of data access mechanisms, and deliver geospatial information as a visualization component as driven by Context Documents
- Discovery: Context Documents can supplement information 'portals' tailored to a specific area of interest. For example, the National Forest Information System (NFIS) program can build an application portal with emphasis on Forestry, and use Context Documents to provide visualization. Similarly, the National Land and Water Information Service (NLWIS), can build their own portal with emphasis on agricultural land use
- Communication: practitioners can more easily communicate across global communities without special instructions on how to view a map on the Internet
- Projects: many information communities can develop and publish Context Documents relative to their application domain, which can enable quicker access to discovery of information holdings with a specific theme and area of interest, which can be used by any application

WMC can provide a common fragment with regard to the following approaches, initiatives and programs as described earlier in this paper:

- OGC Abstract Specification: by adding and recognizing web clients in the client-server paradigm of the abstract, enhanced interoperability can be achieved, similar to sever to server communication
- CGDI and GSDI: by providing WMC as 'bookmarks' for stakeholders and partners within the GeoConnections program to facilitate geospatial data usage over the Internet
- GDI: by providing an interoperable approach to geospatial content sources, visualization tools can focus more on functionality rather than data access

WMC Documents can augment all of the frameworks and approaches above in facilitating data sharing and usage, in the context of visualization tools evolving into and adhering to common fragments. In this manner, practitioners from diverse application domains can visualize data from identical services, being provided as prescribed by their respective visualization tool or application.

It is evident from the recasting of scenario 2 that Web Map Context Documents enable information sharing with additional emphasis on the geospatial characteristics of a particular end user's analysis. Both visualization tools use the Web Map Context Document approach to import and export this type of document. The examples above are generated from a single Context Document and accessed through the Internet. This eliminates the requirement for duplicating and maintaining information resources, in the same manner that geospatial Web Services accomplish the same.

8 Comparative Analysis of Traditional and New Approaches

When comparing the file-based, static approach of Geospatial Data Interoperability to the Web Services approach, it is evident that the Web Services approach provides a lightweight, simple and efficient avenue, thanks to the advances of Internet technology and the development and implementation of standards-based approaches.

The hurdles of geospatial data management are a major issue. Perhaps the most significant advantages of the Web Services approach to geospatial data involve the consumption of data as determined by user requirements.

8.1 User-defined Data Access

Past approaches typically offered entire data sets, allowing users to download data by product or 'tile', to the user's desktop. Geospatial Web Services offer finer-grained access to data, which allows a user to access information with filters (allowing for data subsetting). Some examples of filters using Geospatial Web Services include:

- Spatial: users can download data as per user-defined area of interest, i.e. return data only within the bounding rectangle defined by minx miny maxx maxy
- Aspatial: users can download data which meet their specific attribution criteria according to their requirements, i.e. return census data only where census sub division population is greater than 10000
- Hybrid: the abovementioned filters can be combined for further fine-grained access, i.e. return data satisfying criteria x only within area of interest y

As a result, Geospatial Web Services offer better control for data access, giving the user what they want when they want. This introduces a change in paradigm from custodian / supply centric to a more user / demand centric, or client service oriented for geospatial data exchange.

8.2 Data Representation

Geospatial data is voluminous, especially for large scale product collections. A very common and ubiquitous use of geospatial data is to provide context for a particular report, analysis or visualization. In other words, a user may be interested in a satellite image as a reference image in their activity, as opposed to performing in depth analysis on the actual data. As depicted in scenario 2, the OGC Web Map Service provides a pictorial representation of geospatial data, and does not provide raw, actual data to the end user (OGC Web Feature Service satisfies this requirement for vector data; OGC Web Coverage Services satisfies this requirements for raster data). As a result, accessing a visualization of a subset of a satellite image via OGC:WMS is significantly less costly than acquiring the raw data.

8.3 Data Management

As a result, the nature of Geospatial Web Services provide a mechanism for users to discover, access, visualize and evaluate geospatial data in a dynamic and real-time fashion. This eliminates the requirement (and level of effort) of custodians, developers and administrators acting as data clients. Utilizing this approach, users are spared the need to harvest and manage data within their IT / IM domain. For example, NRCan's Landsat 7 Orthorectified Imagery data, offered as an OGC:WMS layer from GeoGratis, approximately equates to one (1) terabyte of disk storage and capacity. A partner community wishing to access this layer for visualization does need to undertake the onerous responsibility of data management resources of this data. All interaction is done through the Web Service connection paradigm. Data management issues are transparent and, subsequently, of much less concern to the client.

8.4 Data Timeliness

As a result of fine grained data access and expression of data via Web Services, another resulting advantage is timely response to information retrieval. Under the file-based approach, this can require longer response time, which is also influenced by the number of users requesting data. Web Services lessen the amount of data which is transported over the Internet, resulting in faster response times, benefiting the end user for data delivery for their respective project(s).

8.5 Data Quality

Data quality is of utmost importance to making sound decisions. Web Services do not directly affect data quality, as they provide only the transport mechanism. File-based approaches involve management of data by clients who may not be mandated, funded or supported to keep the data in its most pristine state. As a result, copies of data can become quickly outdated and provide another degree of separation from the original data. This is analogous to copying an audio analog tape from the original copy to a blank media device. The quality is instantly compromised. However, the result of the Web Service approach provides a higher probability for maintaining data quality.

8.6 Authoritative Data Sources

In a Web Services environment, information communities can benefit from maintaining only their domain specific information holdings, and leverage data from their partners without maintaining it. As a result, a user can acquire data directly from the source, instead of from a third-party reseller, or rogue website offering the data through other means. End users are subsequently comforted with the knowledge of always having the data “from source” for the application(s).

8.7 Accurate and Up-to-Date Data

The file-based approach automatically produces stale information for end clients given the static model it represents. The Web Services approach, dynamic in nature, ensures that users always receive the most up to date / latest information from their service provider. As data management budgets decrease as a result of the Web Services approach, data custodians will have more time and resources to put towards data completeness, quality, accuracy and precision.

8.8 So What?

Given the advantages discussed earlier, the Web Services approach, as applied in a Geospatial Data Infrastructure, is poised to make significant advances in data discovery, visualization, access, evaluation and use. Applications will become more streamlined and easier to develop and implement. The use of common standards will result in common tools which are developed with standards-based technologies. For example, an application developer may develop a processor which can interpret any GML data structure. While this itself is beneficial for a given requirement, the potential of reuse of the tool provides the "write-once, use many" analogy to development. Reusable tools and components will aid in the further use of data through Web Services, and enable application developers to build applications in a timelier manner. Redundant datasets are likely to decrease as a result. In addition, standalone applications based on two tier architecture will make way for three tiered applications, or "portals". Figure 8-1 illustrates this trend.

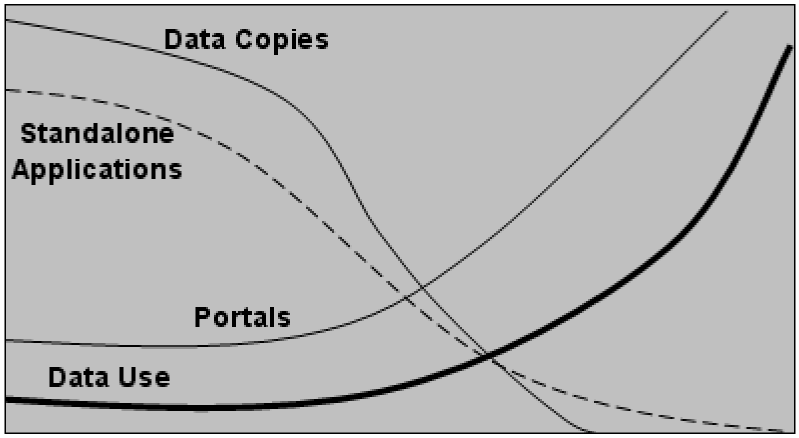

Figure 8-1: Web Services Interoperability Benefits Trend Graph

In addition, because Geospatial Web Services are based on standards based approaches and specifications from the OGC, whose approaches are, in turn, based on commonly adopted approaches in the broader IT / IM standards bodies (W3C, ISO, OASIS), these components represent, at a technical level, nothing more than another set of tools and applications which can be used by various IT developer / application communities. As a result, access to geospatial data is simplified and is more consistent with general IT / IM and Internet Web development practices. In fact, the geospatial community has already moved towards functioning in a broader context (Mann, 2004). In September 2004, the OGC changed its name from “Open GIS Consortium” to “Open Geospatial Consortium”. While some may regard this as a simple name change, the underpinnings of this change are significant in the context of the issues discussed earlier with broader communities. Geospatial data, now more than ever, can be applied to heterogeneous, multi disciplinary environments.

9 Web Services Issues

Anything new is poised to improve upon a previous development in time; the progression of an approach to satisfy goals of a research project or operational deployment. New approaches also face issues due to the fact that they have not been rigorously tested or accepted into the mainstream activities of a given community. The same holds true for Geospatial Web Services. While the aforementioned benefits have advantages, there are areas of concern as well given this paradigm shift of handling geospatial data.

9.1 Organizational

The recent survey of OGC deployment over the Internet (Ramsey, 2004), while encouraging, provides insight into how many publically available OGC Web Service instances are available for public consumption. While there has been a great many number of Geospatial Web Services enabled in recent months, these services are still in the minority as compared to traditional, monolithic, file-based services and proprietary systems and applications. Traditional approaches are still evident as the major method for geospatial data access and use in such websites as the GeoConnections Discovery Portal (GeoConnections, 2001), the Geospatial One-Stop (United States Department of the Interior, 2003) and the FGDC Clearinghouse (Federal Geographic Data Committee, 1999).

For many organizations, these approaches, especially in their state of infancy, represent an additional level of effort and resources to coordinate and provide training to staff, as well as a change in the information delivery model to a service-oriented architecture approach. While the long-term benefits to an organization undertaking this approach are many, the near term issues in adopting this approach may be cost prohibitive, especially for smaller organizations with resource constraints.

The survey additionally illustrates that many of those who have migrated to this approach are large, federal infrastructures with large programs to facilitate such a change, although many smaller organizations have also begun to adopting this approach. The issue of Geospatial Web Services adoption is analogous to the chasm of technology adaptation, as expressed in Figure 9-1 (Moore, 1991). This diagram illustrates the critical point between early adopters of technology and the upswing of community adoption. In the context of CGDI, organizations such as Natural Resources Canada, Environment Canada and Agriculture and Agri-Food Canada are all examples of early adopters of the Web Services approach. The Geospatial Web Services paradigm is currently in the gap of the adoption chasm.

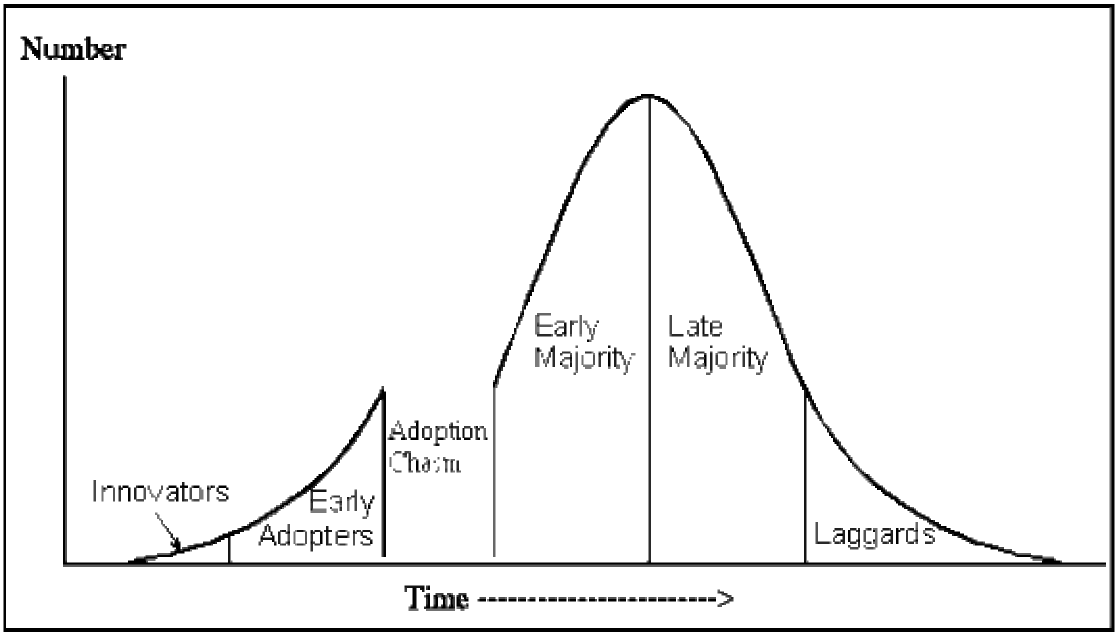

Figure 9-1: The Chasm of Adaptation (Moore, 1991)

9.2 Technical

While Geospatial Web Services exploit and leverage the infrastructure of the Internet, they also fall prey to broader Internet issues of connectivity. The Internet is only as fast as the slowest link in the routing mechanism. If any part of the Internet happens to be unavailable during connectivity from client to server, the entire connection is compromised. Figure 9-2 depicts a high level network of CA*net 4 connected institutions (CANARIE 2002), which can provide an idea of the consequences should one of the network nodes cease to operate.

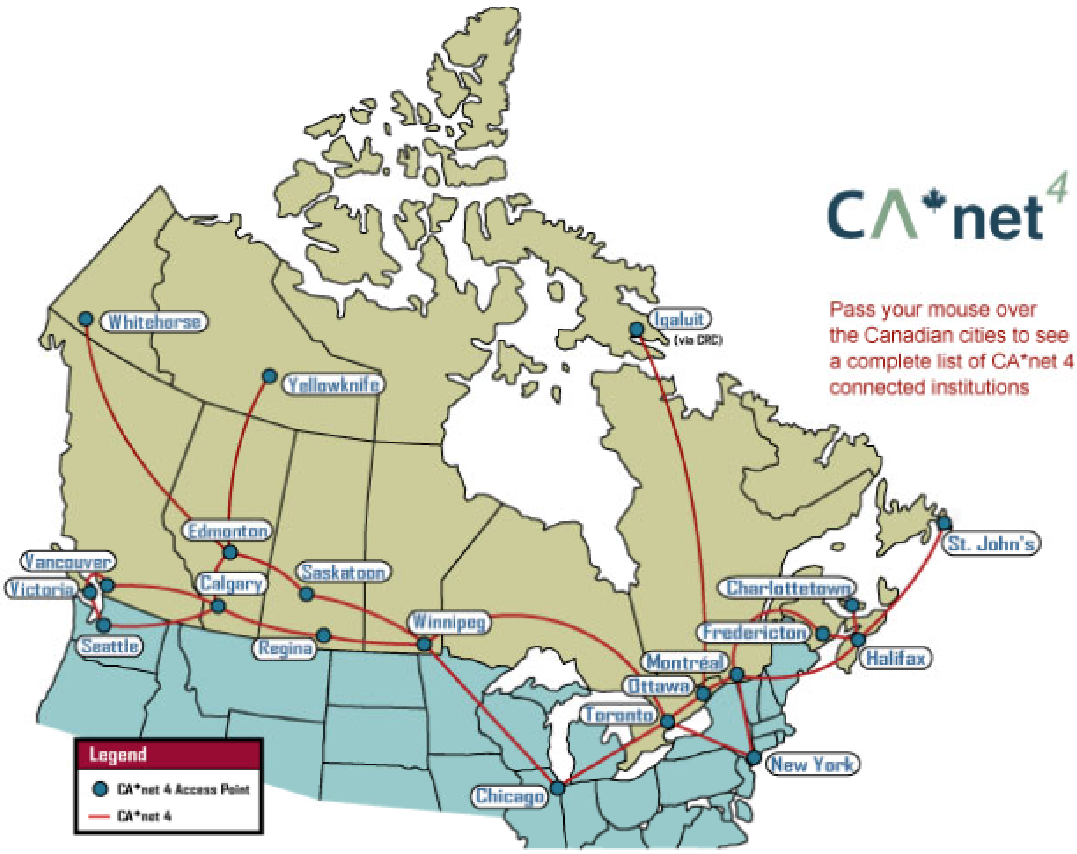

Figure 9-2: CA*net 4 Connected Institutions (CANARIE 2002)

In addition, network latency also presents an issue for areas with reduced capacity for network connectivity. Figure 9-3 (Wilson, 2002) nicely depicts correlations between distance and response time when performing network requests to various areas in Canada:

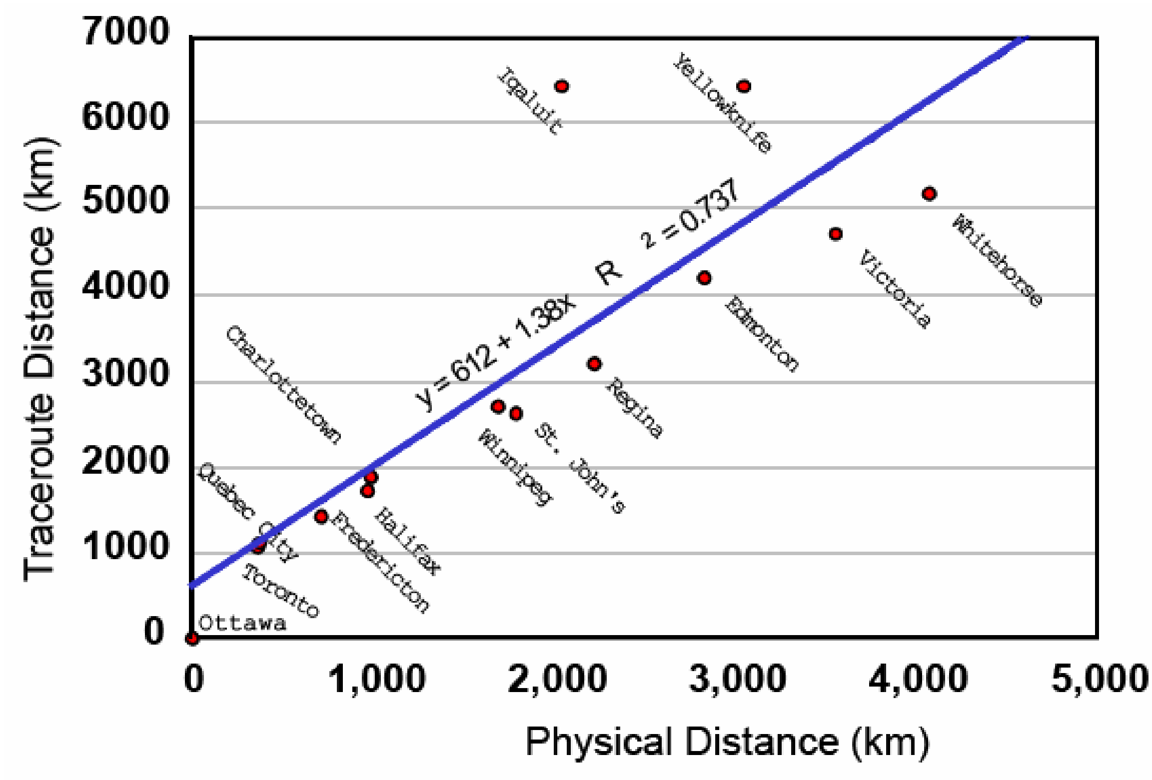

Figure 9-3: Network response time vs. Physical Distance (Wilson, 2002)

Network latency and failover, while broader IT issues, require acknowledgement in deploying Geospatial Web Services to provide quality and timely information. Much attention and thought is required to account for availability of service and failover of physical hardware and networks.

9.3 Applicability to More Advanced Problems

The scenarios discussed in this paper involve simple map production and sharing concepts. While these are quite common tasks in the geospatial community, so too are more advanced geoprocessing tasks such as image classification (ESRI, 1991), triangulation, intersection, point-in-polygon shortest route algorithms (de Berg, M., van Kreveld, M., Overmars, M., Schwarzkopf, O., 2000). These operations require advanced processing techniques in geospatial software tools, as well as more complex interaction from a client. Though the results of such operations as output data fall into the scenarios described, their actual operation and execution is worth attention in assessing the feasibility for a Geospatial Web Services approach to computer intensive geospatial algorithms. OGC:WMS implementations typically perform simple algorithms to convert real world coordinate data to a 2D image in XY space. The code chunks below illustrate simple C language macros to perform this simple function (Regents of the University of Minnesota, 2004):

```
#define MS_MAP2IMAGE_X(x,minx,cx) (MS_NINT((x - minx)/cx))
#define MS_MAP2IMAGE_Y(y,maxy,cy) (MS_NINT((maxy - y)/cy))
#define MS_IMAGE2MAP_X(x,minx,cx) (minx + cx*x)
#define MS_IMAGE2MAP_Y(y,maxy,cy) (maxy - cy*y)
```

Compare this to more intensive geometric algorithms, such as calculating the minimum bounding rectangle of a polygon. See Appendix E for this algorithm implemented in the Perl language.

9.4 Effects on GIS as a Discipline

The evolutionary stage of geospatial database development progressed from basic computer use to develop information systems, to emergence of GIS software, to distributed geospatial networks (Groot and McLaughlin, 2000). As a result, demand has already increased for GIS professionals with additional proficiency in computer databases, systems and Internet programming. Groot and McLaughlin (2000), provide a comprehensive and useful analysis of how the

Internet has changed the landscape of skills profiles in geospatial data infrastructures. They argue that there are now:

- Fewer mapping specialists
- More Internet-aware GIS experts
- GIS software experts replaced by application programmers for customized application development
- Increasing shifts from GIS experts to information systems specialists

The Web Services approach adds another layer of complexity for individuals to become familiar with to develop, implement and deploy Web Services. Though the proliferation of easy to use, standards based tools will ease integration for GIS specialists and developers, fundamental knowledge of Internet approaches is required for development and sustainability. This may include more collaboration with organizational information technology and infrastructure providers. The convergence of information management and information technology is evident in this scenario.

9.5 Data Policy, Copyright and Intellectual Property

The Internet has introduced much discussion over the issues of data ownership, cost of service and liability. For example, for USGS and NOAA, anyone may copy, distribute, and otherwise freely use Federal information, maps or reports (Guptill and Eldridge, 1998). Geospatial data is costly to create and maintain

(Aslesen, 1998). Geospatial Web Services extend this approach by allowing individuals to integrate and embed dynamic information from a given organization on their website, while presenting the look and feel of the individual connecting to the Web Service. It is important that products must be protected against misuse (Aslesen, 1998). This introduces significant issues in Geospatial Digital Rights, branding and potential liability of presenting a given organization's information holdings in a certain manner. This affects such issues as user acknowledgement of data copyright, cost recovery issues and multiple server security as systems interact with one another transparent to these issues. The Web Services approach presents a significant issue in the mode of business and policy of geospatial data providers in Canada.

The static / file-based approach of interoperability provides an "all or nothing" approach to information, whereas the Web Services approach provides various levels of information access and delivery, and introduces many shades of grey into this subject area. As data can be accessed at multiple levels of granularity, authorized use subsequently becomes complex in managing access to data.

The OGC has initiated a "Geospatial Digital Rights Management (DRM)" activity to investigate and provide approaches and specifications with regard to how geospatial information by a service provider is tracked, monitored, protected, as well as the management of rights-holder issues (Open Geospatial Consortium, 2004b). The results of this activity should prove to be interesting in this context.

In addition, further research is recommended with regard to the costing of Geospatial Information using Web Services as opposed to static data delivered on CDROM, or other physical media. As Web Services require more computer-intensive resource than previous approaches, this in turn can affect cost of data via services.

10 Recommendations and Further Research

10.1 Doing More

As discussed previously, the need for further research, testing and development would be beneficial in applying Geospatial Web Services to more advanced geospatial processing tasks, such as vector line intersection, raster image analysis, as well as dynamic linking of data over the Internet. The OGC has published public Discussion Papers on "geolinking" (Open Geospatial Consortium, 2004a), which investigate approaches, using Geospatial Web Services, to fit geospatial data attributes with aspatial data attributes, thereby extending the value of non-traditional information as geospatial data.

10.2 Geospatial Semantics

While the current approaches of Geospatial Web Services provide well defined operation syntax and behaviour for the transport of geospatial data, further research is required on the interpretation of the meaning of those results when coming from and processed by software implementations, and deciphering these results when consumed from disparate systems. For example, a Web Feature Service may return a chunk of information which may look like the GML chunk below:

```
<gml:featureMember>
  <event>
    <gml:name>14</gml:name>
    <depth>8</depth>
    <gml:location>
```

```
    <gml:Point srsName="EPSG:4326">
     <gml:coord>
      <gml:X>-115.86</gml:X>
      <gml:Y>32.16</gml:Y>
     </gml:coord>
    </gml:Point>
   </gml:location>
  </event>
 </gml:featureMember>
```

While a robust OGC:WFS client can easily consume this information, how can this client interpret what `depth` really means? Very specific implementations can interpret this information given prior knowledge of the semantics of the geospatial data. These however are subject to low levels of sustainability and scalability. Further research in investigating development of robust systems for semantic interpretation of Geospatial Web Services content models would be valuable.

10.3 Uptake in Organizations

Further research such as that by Ramsey (2004), is of utmost importance into the organizational uptake and acceptance of the Geospatial Web Service approach. This research consisted of a tool to query the Google search engine to find URLs which resembled OGC Web Services operations. The results were then tested for availability and validity, and subsequently formatted as a report and sorted by OGC Web Service and country of origin. The survey tool (updated monthly) provides a quick and interesting overview of the rate of deployment of the OGC Web Services, and provokes thought on the preparedness of organizations for the Web Services approach. Are organizations ready for Web Services? How do Web Services affect information management and technology practices?

How are Web Services and the supporting architecture best implemented in a given organization (bottom up developer driven, top down management policy driven)? Are organizations suitably resourced with staff to handle these changes? What are the cultural factors involved? Feedback from hesitant organizations will be valuable in assessing the way forward for broader implementation of a service oriented infrastructure.

10.4 Demand vs. Supply Driven Development

Too often software and systems are regarded as a “solution looking for a problem”. This thesis applied the Geospatial Web Services approach to data interoperability issues. Similar research would prove valuable in the context of end user requirements and assessing whether Geospatial Web Services can accommodate those requirements.

10.5 Versioning

Given the dynamic nature of Web Services, the benefit of the most recent geospatial data also raises issues of consistency and archiving issues. For example, consider an application which performs an analysis based on the content of a Web Service at a given time. The Web Service may update the data at source for any given reason. If the application chooses to repeat the analysis, the results and / or calculations may differ based on the nature of these updates.

Applications performing analysis or reports require a consistent method and source data. Web Services present the temptation of always providing the latest data, and not providing past versions of a given data set. This is not a problem of Web Services, yet the archiving and versioning practices of a service provider. Further research is recommended into how Web Services affect versioning and archiving of digital geospatial data and how this impacts the historical nature of the data.

10.6 Profiling Geospatial IM/IT Professionals

The concept of GDI has raised many issues relating to human resources and skill sets of those participating in GDI. The focus on technology with regard to GDI has changed the need for specific skill sets in geomatics. The need for a well-rounded geomatics professional is emerging (Groot and McLaughlin, 2000).

Shrink-wrapped GIS software presents an ease of use to end users that may be detrimental to creating adequate human resources within GDI. Individuals are increasingly geomatics professionals in terms of the software skills they develop. With the shift from desktop to distributed systems, the need for application programmers, who possess the knowledge and skills to develop and emulate desktop GIS software, has increased.

Academic institutions providing curriculums in geomatics may want to investigate these issues and implement courses / seminars to provide individuals with more awareness in geomatics and GDI.

The potential uses of Geospatial Web Services involve many different individuals at different levels. As a way forward, the first step is awareness at the academic level of the needs for the geospatial professionals of tomorrow.

Conclusion

The question this thesis attempted to address was: are Web Services adequate for solving issues of interoperability within geospatial data infrastructures? This thesis argued for Web Services as the preferred method to achieve geospatial data interoperability, as compared to existing static or file-based approaches. The review of traditional approaches identifies disadvantages and relevant issues of static methods of geospatial data exchange.

The discussion of Geospatial Web Services as a broad information technology approach illustrated benefits with regard to new, innovative development and integration. Using Web Services, agencies can now interact with one another very efficiently. Geospatial data can now interact with more types of domain specific data, including aspatial data, which presents possibilities for new research and development. Organizations, as providers or consumers, can benefit from this approach to more effectively manage their information assets and utilize other data.

Practical illustrations (scenarios and comparative analysis) present a pragmatic evaluation of the Geospatial Web Services versus traditional methods, in illustrating the ease of use and integration of this approach.

The owsview reference software implementation illustrated the ease of software development in the presence of consensus driven international specifications.

The development of this application in a standards-based manner demonstrated the integration of geospatial data from multiple agencies in a manner which is not possible using traditional approaches.

Geospatial Web Services also present technical (performance, advanced processing, semantics) and organizational (culture of adoption, human resources) issues which require further research.

The evidence presented together with important practical illustrations illustrate the benefits of Geospatial Web Services as a preferred method of geospatial data interoperability. Geospatial data, now more than ever, can be made more valuable for both data providers and consumers through utilizing Web Services. Geospatial Web Services significantly increase the use and ubiquity of geospatial data, which is a valuable resource for society.

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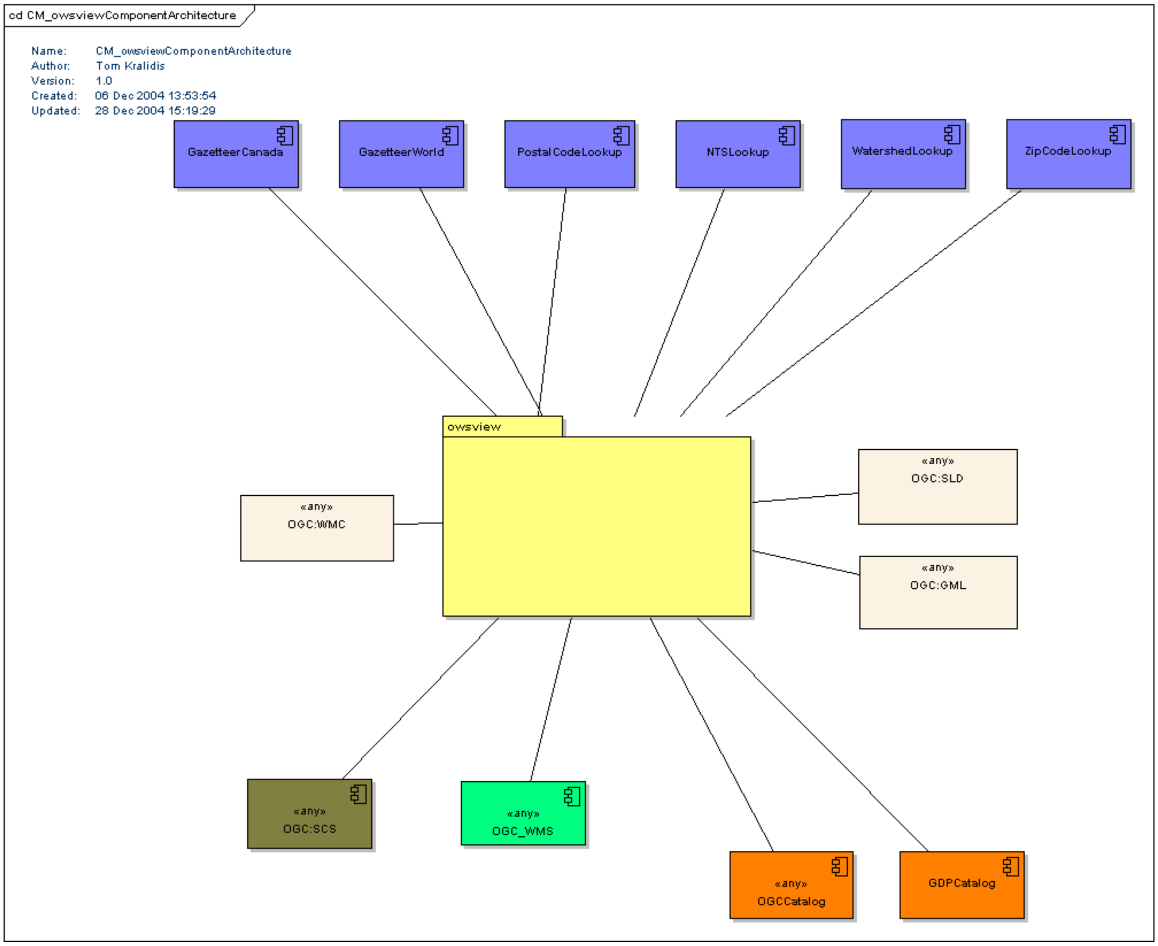
Appendix A: Acronyms

ANSI	American National Standards Institute
ARPANET	Advanced Research Projects Agency Network
CCRS	Canada Centre for Remote Sensing
CEONet	Canadian Earth Observation Network
CGDI	Canadian Geospatial Data Infrastructure
CGI	Common Gateway Interface
CGSB	Canadian General Standards Board
COTS	Commercial Off The Shelf
CSS	Cascading Style Sheets
DCP	Distributed Computing Platform
DHTML	Dynamic HTML
DTD	Document Type Definition
DNS	Domain Name Service
DRM	Digital Rights Management
EPSG	European Petroleum Survey Group
FGDC	Federal Geographic Data Committee
FTP	File Transfer Protocol
GCMD	Global Change Master Directory
GDI	Geospatial Data Infrastructure
GDP	GeoConnections Discovery Portal
GIF	Graphics Interchange Format
GIS	Geographic Information System
GML	Geography Markup Language
GSDI	Global Spatial Data Infrastructure
GUI	Graphical User Interface
HMI	Human Machine Interface
HTML	Hypertext Markup Language
HTTP	Hypertext Transfer Protocol
IEEE	Institute of Electrical and Electronic Engineers
IETF	Internet Engineering Task Force
IF	Interface
IP	Internet Protocol
IP	Intellectual Property
ISO	International Organization for Standardization
JPEG	Joint Photographic Experts Group
MIME	Multipurpose Internet Mail Extensions
NASA	National Aeronautics and Space Administration
NFS	Network File System

NNTP	Network News Transfer Protocol
NRCan	Natural Resources Canada
OASIS	Organization for the Advancement of Structured Information Standards
OGC	Open Geospatial Consortium
ORM	OGC Reference Model
OWS	OGC Web Service
owsview	OGC Web Services Viewer Client Generator
PDA	Personal Data Assistant
PNG	Portable Network Graphics
RFC	Request for Comment
SCOTS	Standards-based Commercial Off The Shelf
SCS	Sensor Collection Service
SGML	Standard General Markup Language
SLD	Styled Layer Descriptor
SMTP	Simple Mail Transfer Protocol
SOA	Service Oriented Architecture
SOAP	Simple Object Access Protocol
SVG	Scalable Vector Graphics
TCP	Transmission Control Protocol
UDDI	Universal Description, Discovery and Integration
UI	User Interface
URI	Uniform Resource Identifier
URL	Uniform Resource Locator
USGS	United States Geological Survey
VCG	Viewer Client Generator
WebCGM	Web Computer Graphics Metafile
W3C	World Wide Web Consortium
WCS	Web Coverage Service
WFS	Web Feature Service
WFS-G	Web Feature Service – Gazetteer Profile
WMC	Web Map Context Document
WML	Wireless Markup Language
WMS	Web Map Service
WMS_XML	Web Map Service eXtensible Markup Language
WMT	Web Mapping Testbed
WSDL	Web Services Description Language
WTS	Web Terrain Service
WWW	World Wide Web
XML	eXtensible Markup Language
XSD	XML Schema Document

Appendix B: owsview

B1: Component diagram



Appendix C: NEIS Web Service Enablement

C1: W3C XML Application Schema

```
<?xml version="1.0" encoding="UTF-8" standalone="no"?>
<xs:schema targetNamespace="http://neic.usgs.gov/neis"
xmlns:gml="http://www.opengis.net/gml" xmlns:neis="http://neic.usgs.gov/neis"
xmlns:xs="http://www.w3.org/2001/XMLSchema" elementFormDefault="qualified"
attributeFormDefault="unqualified" version="1.0.0">
 <xs:annotation>
  <xs:appinfo>neis.xsd 2004/12/10</xs:appinfo>
  <xs:documentation xml:lang="en">GML application schema for NEIS near real time
earthquake activity.  Field explanations from:
http://neic.usgs.gov/neis/finger/qk_info.html
</xs:documentation>
 </xs:annotation>
 <xs:import namespace=http://www.opengis.net/gml
        schemaLocation="http://schemas.opengeospatial.net/gml/3.0.0/base/feature.xsd"/>
<xs:element name="NearRealTimeEarthquakes" type="neis:NearRealTimeEarthquakesType"
substitutionGroup="gml:_FeatureCollection">
  <xs:annotation>
   <xs:documentation>Root element</xs:documentation>
  </xs:annotation>
 </xs:element>
<xs:complexType name="NearRealTimeEarthquakesType">
  <xs:complexContent>
   <xs:extension base="gml:AbstractFeatureCollectionType">
    <xs:sequence>
     <xs:element name="dateCreated" type="xs:dateTime" minOccurs="0">
      <xs:annotation>
       <xs:documentation>timestamp of document creation (ISO8601)</xs:documentation>
      </xs:annotation>
     </xs:element>
    </xs:sequence>
   </xs:extension>
  </xs:complexContent>
 </xs:complexType>
 <xs:element name="Earthquake" substitutionGroup="gml:_Feature">
  <xs:annotation>
   <xs:documentation>Earthquake reading</xs:documentation>
  </xs:annotation>
  <xs:complexType>
   <xs:complexContent>
    <xs:extension base="gml:AbstractFeatureType">
     <xs:sequence>
      <xs:element name="datetime" type="xs:dateTime">
       <xs:annotation>
        <xs:documentation>DATE-TIME is in Coordinated Universal Time (UTC).  This is
approximately the same as Greenwich Mean Time (GMT) which is 5 hours later than Eastern
Standard Time (EST) and 8 hour later than Pacific Standard Time (PST).</xs:documentation>
       </xs:annotation>
      </xs:element>
      <xs:element name="depthkm" type="xs:decimal">
       <xs:annotation>
        <xs:documentation>Distance below sea level in kilometers.
If the depth of an event is not satisfactorily determined by the data, it is held to a
default depth, and the Location Quality shows "depth fixed by location
program."</xs:documentation>
        </xs:annotation>
       </xs:element>
       <xs:element name="magnitude" type="xs:decimal">
        <xs:annotation>
         <xs:documentation>Six different magnitude types (MAG) may be quoted:  Ml (local,
the original Richter magnitude), Lg (mblg), Md (duration), Mb (body wave), Ms (surface
wave), and Mw (moment).  Since all magnitude types have been calibrated with respect to
one another, the differences are generally of interest only to seismologists.  Given the
```

```
size, location, and available information, the most meaningful magnitude will be quoted
for each event. </xs:documentation>
         </xs:annotation>
        </xs:element>
        <xs:element name="q" type="xs:string">
         <xs:annotation>
          <xs:documentation>Location qualities (Q) are A (good), B (fair), C (poor), and
D (bad).  The quality refers to the precision with which the earthquake location has been
computed.  A and B qualities mean that the location is quite reliable while a C quality
can be pretty uncertain.  Bad locations will generally not be reported.  No quality
implies a location held to the coordinates of another organization (e.g., a regional
network with better coverage of an event).  The comment is an automatically generated
region name and can be misleading for earthquakes near region
boundaries.</xs:documentation>
         </xs:annotation>
        </xs:element>
       </xs:sequence>
      </xs:extension>
     </xs:complexContent>
    </xs:complexType>
  </xs:element>
</xs:schema>
```

C2: Perl Script to Create GML Document

```
#!/usr/bin/perl -w

#####################################################################
#
# Program name: genData.pl
#
# Description : script to fetch earthquake bulletin
# and convert to shapefile
#
# $Id: genData.pl,v 1.6 2004/01/02 21:20:30 tkralidi Exp $
#
# Revisions: (see end of file for revision history)
#
#
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#
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# DEALINGS IN THE SOFTWARE.
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# http://www.opensource.org/licenses/mit-license.html
#
#####################################################################

# enable strict mode
use strict;
```

```
# load URL fetching module
use LWP::Simple;

# set variables
my @quakes;
my $datecreated;
my $month;
my $i        = 0;
my $basedir  = "/usr/local/wwwsites/apache/apps/mapserv/services/neis/";
my $filename = $basedir . "neis.gml";

# URL to raw data
my $url      = "http://neic.usgs.gov/neis/finger/quake.asc";

#
my $content = get($url);
my @arr     = split /\n/, $content;

# loop through file and pick up attributes
# we have to put a few conditions here
# to realize empty data
foreach my $line(@arr) {
  my ($date, $time, $x, $y);
  if ($line =~ /^0/) {
    # pick up attribute info

    # if "Q" is empty
    if ($line =~ /^(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s{5}(.*)$/) {
      $date                  = $1;
      $time                  = $2;
      $y                     = $3;
      $x                     = $4;
      $quakes[$i]{depthkm}   = $5;
      $quakes[$i]{magnitude} = $6;
      $quakes[$i]{q}         = "none";
      $quakes[$i]{comment}   = $7;
    }

    # if "MAG" and "Q"  are empty
    elsif ($line =~ /^(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s{10}(.*)$/) {
      $date                  = $1;
      $time                  = $2;
      $y                     = $3;
      $x                     = $4;
      $quakes[$i]{depthkm}   = $5;
      $quakes[$i]{magnitude} = 9999; # dummy numerical value
      $quakes[$i]{q}         = "none";
      $quakes[$i]{comment}   = $6;
    }

    # elsif "MAG" and "Q" are NOT empty
    elsif ($line =~ /^(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(\S+)\s+(.*)$/) {
      $date                  = $1;
      $time                  = $2;
      $y                     = $3;
      $x                     = $4;
      $quakes[$i]{depthkm}   = $5;
      $quakes[$i]{magnitude} = $6;
      $quakes[$i]{q}         = $7;
      $quakes[$i]{comment}   = $8;
    }

       lter coords to be expressed as +/- vals
    if ($y =~ /^(\d+\.\d+)N$/) {
      $y = $1;
    }
    if ($y =~ /^(\d+\.\d+)S$/) {
      $y = "-" . $1;
    }
    if ($x =~ /^(\d+\.\d+)E$/) {
      $x = $1;
```

```
    }
    if ($x =~ /^(\d+\.\d+)W$/) {
      $x = "-" . $1;
    }

    $quakes[$i]{y} = $y;
    $quakes[$i]{x} = $x;

    # format ISO8160 timestring like YYYY-MM-DDTHH:MM:SSZ to timestamp record
    $date =~ s/\//-/g;
    $quakes[$i]{datetime} = "20" . $date . "T" . $time . "Z";

    # get rid of magnitude unit symbol 'M' so we can classify
    # with numerical comparisons
    $quakes[$i]{magnitude} =~ s/M

    # strip angle brackets from comment for XML well-formedness
    $quakes[$i]{comment} =~ s#<#&lt;#;
    $quakes[$i]{comment} =~ s#>#&gt;#;
    $i++;
  }

  # format ISO8160 timestring like YYYY-MM-DDTHH:MM:SSZ to timestamp document
  if ($line =~ /^Updated as of (\S{3}) (\S{3}) (\d{2}) (\d{2}):(\d{2}):(\d{2}) GMT
(\S{4})/) {
    $month = "01" if $2 eq "Jan";
    $month = "02" if $2 eq "Feb";
    $month = "03" if $2 eq "Mar";
    $month = "04" if $2 eq "Apr";
    $month = "05" if $2 eq "May";
    $month = "06" if $2 eq "Jun";
    $month = "07" if $2 eq "Jul";
    $month = "08" if $2 eq "Aug";
    $month = "09" if $2 eq "Sep";
    $month = "10" if $2 eq "Oct";
    $month = "11" if $2 eq "Nov";
    $month = "12" if $2 eq "Dec";
    $datecreated = $7 . "-" . $month . "-" . $3 . "T" . $4 . ":" . $5 . ":" . $6 . "Z";
  }
}

$i = 0;

# OK, now that we have data, remove previous copies of data
unlink($filename);

#

open(FILE, ">$filename") or die "$!\n";

print FILE <<END;
<?xml version="1.0" encoding="ISO-8859-1"?>
<NearRealTimeEarthquakes xmlns="http://neic.usgs.gov/neis"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://neic.usgs.gov/neis ./neis.xsd">
 <gml:description>This is a GML document which provides locations of USGS NEIS near real
time earthquake data</gml:description>
 <gml:name>USGS NEIS Near Real Time Earthquake Bulletin</gml:name>
 <gml:boundedBy>
  <gml:Box srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
   <gml:coord>
    <gml:X>-180
    <gml:Y>-90</gml:Y>
   </gml:coord>
   <gml:coord>
    <gml:X>180</gml:X>
    <gml:Y>90</gml:Y>
   </gml:coord>
  </gml:Box>
 </gml:boundedBy>
```

```
END

# populate feature members
foreach my $k (@quakes) {
  print FILE <<END;
 <gml:featureMember>
  <Earthquake>
   <gml:description>$k->{comment}</gml:description>
   <gml:name>$i</gml:name>
   <gml:location>
    <gml:Point srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
     <gml:coord>
      <gml:X>$k->{x}</gml:X>
      <gml:Y>$k->{y}</gml:Y>
     </gml:coord>
    </gml:Point>
   </gml:location>
   <datetime>$k->{datetime}</datetime>
   <depthkm>$k->{depthkm}</depthkm>
   <magnitude>$k->{magnitude}</magnitude>
   <q>$k->{q}</q>
  </Earthquake>
 </gml:featureMember>
END

  print "$k->{datetime} -- $k->{y} -- $k->{x} -- $k->{depthkm} -- $k->{magnitude} -- $k-
>{q} -- $k->{comment}\n";
  $i++;
}

p  nt FILE <<END;
 <dateCreated>$datecreated</dateCreated>
</NearRealTimeEarthquakes>
END

close(FILE);

#####################################################################
#
# Revision History
#
# $Log: genData.pl,v $
#
#####################################################################
```

C3: Sample Output GML Document (one record shown for brevity)

```
<?xml version="1.0" encoding="ISO-8859-1" standalone="no"?>
<NearRealTimeEarthquakes xmlns="http://neic.usgs.gov/neis"
xmlns:xlink="http://www.w3.org/1999/xlink" xmlns:gml="http://www.opengis.net/gml"
xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xsi:schemaLocation="http://neic.usgs.gov/neis ./neis.xsd">
 <gml:description>This is a GML document which provides locations of USGS NEIS near real
time earthquake data</gml:description>
 <gml:name>USGS NEIS Near Real Time Earthquake Bulletin</gml:name>
 <gml:boundedBy>
  <gml:Box srsNam
   <gml:coord>
    <gml:X>-180</gml:X>
    <gml:Y>-90</gml:Y>
   </gml:coord>
   <gml:coord>
    <gml:X>180</gml:X>
    <gml:Y>90</gml:Y>
   </gml:coord>
```

```
  </gml:Box>
 </gml:boundedBy>
 <gml:featureMember>
  <Earthquake>
   <gml:description>BAJA CALIFORNIA, MEXICO</gml:description>
   <gml:name>14</gml:name>
   <gml:location>
    <gml:Point srsName="http://www.opengis.net/gml/srs/epsg.xml#4326">
     <gml:coord>
      <gml:X>-115.86</gml:X>
      <gml:Y>32.16</gml:Y>
     </gml:coord>
    </gml:Point>
   </gml:location
   <datetime>2004-12-10T10:49:29Z</datetime>
   <depthkm>6.0</depthkm>
   <magnitude>3.3</magnitude>
   <q>none</q>
  </Earthquake>
 </gml:featureMember>
 <dateCreated>2004-12-12T16:58:28Z</dateCreated>
</NearRealTimeEarthquakes>
```

C4: UMN MapServer OGC:WMS Service Configuration

```
##############################################################################
#
# Copyright (c) 2004 Athanasios Tom Kralidis
#
#                                             , to any person obtaining a
# copy of this software and associated documentation files (the "Software"),
# to deal in the Software without restriction, including without limitation
# the rights to use, copy, modify, merge, publish, distribute, sublicense,
# and/or sell copies of the Software, and to permit persons to whom the
# Software is furnished to do so, subject to the following conditions:
#
# The above copyright notice and this permission notice shall be included in
# all copies of this Software or works derived from this Software.
#
# THE SOFTWARE IS PROVIDED "AS IS", WITHOUT WARRANTY OF ANY KIND, EXPRESS
# OR IMPLIED, INCLUDING BUT NOT LIMITED TO THE WARRANTIES OF MERCHANTABILITY,
# FITNESS FOR A PARTICULAR PURPOSE AND NONINFRINGEMENT. IN NO EVENT SHALL
# THE AUTHORS OR COPYRIGHT HOLDERS BE LIABLE FOR ANY CLAIM, DAMAGES OR OTHER
# LIABILITY, WHETHER IN AN ACTION OF CONTRACT, TORT OR OTHERWISE, ARISING
# FROM, OUT OF OR IN CONNECTION WITH THE SOFTWARE OR THE USE OR OTHER
# DEALINGS IN THE SOFTWARE.
#
#                            ed from the MIT License at:
#
# http://www.opensource.org/licenses/mit-license.html
#
##############################################################################

MAP
 NAME neismap
 IMAGETYPE PNG
 STATUS ON
 EXTENT -180 -90 180 90
 SIZE 500 300
 SYMBOLSET "../../etc/symbols/symbols.sym"
 FONTSET   "../../etc/fonts/fonts.txt"
 IMAGECOLOR 125 125 125


  "init=epsg:4326"
 END
```

```
DEBUG ON

TRANSPARENT ON

WEB
 HEADER "query_header.html"
 FOOTER "query_footer.html"
 IMAGEPATH "../../tmp/"
 IMAGEURL  "/ms_tmp"
 METADATA
  "ows_schemas_location" "http://schemas.opengeospatial.net"

  # OWS common metadata

                         S"
  "ows_abstract" "NEIS WMS"
  "ows_keywordlist" "neis,earthquake,neic,usgs"
  "ows_service_onlineresource" "http://host/neis/index.html"
  "ows_onlineresource"    "http://host/cgi-bin/mapserv"
  "ows_fees" "none"
  "ows_accessconstraints" "none"

  # OGC:WMS

  "wms_feature_info_mime_type"  "text/html"

  "wms_addresstype" "postal"
  "wms_address"     "xx xxxxxxxx xxxxx"
  "wms_city" "Toronto"
  "wms_stateorprovince"
  "wms_postcode" "xxx xxx"
  "wms_country" "Canada"
  "wms_contactelectronicmailaddress" "tomkralidis at hotmail dot com"
  "wms_contactvoicetelephone" "+01-416-xxx-xxxx"
  "wms_contactfacsimiletelephone" "+01-416-xxx-xxxx"
  "wms_contactperson" "Tom Kralidis"
  "wms_contactorganization" "self"
  "wms_contactposition" "Systems Scientist"

  "wms_srs" "EPSG:4326"

  # OGC:WFS
  "wfs_namespace_uri" "http://neic.usgs.gov/neis"
  "wfs_namespace_prefix" "neis"
  "wfs_srs"    "EPSG:4326"


END

QUERYMAP
 STATUS OFF
 SIZE 400 300
 STYLE HILITE
 COLOR 255 255 0
END

LEGEND
 LABEL
  TYPE BITMAP
  SIZE MEDIUM
  COLOR 0 0 0
 END
END
LAYE
 NAME "neis"
 STATUS ON

 CONNECTIONTYPE OGR
 CONNECTION "neis/neis.gml"

 GROUP "Miscellaneous"
```

```
  TYPE POINT
  DUMP TRUE
  HEADER "neis/neis_query_header.html"
  TEMPLATE "neis/neis_query_body.html"
  TOLERANCE 30
  METADATA
   "ows_title"    "Near Real Time Earthquake Bulletin"
   "ows_abstract"   "The following near-real-time Earthquake Bulletin is provided by the
National Earthquake Information Service (NEIS) of the U. S. Geological Survey as part of
a cooperative project of the Advanced National Seismic System.  This Bulletin is updated
every 5 minutes."
   "ows_keywordlist"  "earthquake,earthquakes,seismicity,seismic,tremor,tremors,united
states,world,moment tensor,moment,magnitude,magnitude
scale,aftershock,epicenter,richter,mercalli,seismogram,seismograph,seismologist,seismolog
y,geophysics,geologist,tsnuamis,hypocenter,quake,quakes"
   "wms_opaque" "0"
   "ows_metadataurl_type" "FGDC"
   "wms_metadataurl_format" "text/html"
   "ows_metadataurl_href" "http://neic.usgs.gov/neis/bulletin/bulletin.html"
   "wms_dataurl_format" "text/plain"
   "wms_dataurl_href" "http://neic.usgs.gov/neis/finger/quake.asc"
   "wfs_metadataurl_format" "TXT"
  END
  PROJECTION
   "init=epsg:4326"
  END
  CLASS
   NAME " "
   COLOR 255 0 0
   OUTLINECOLOR 0 0 0
   SYMBOL 7
   SIZE 10
  END
 END
END
```

Appendix D: Example Web Map Context Document


```xml
<?xml version="1.0" encoding="utf-8" standalone="no" ?>
<ViewContext version="1.0.0"
             id="wqm_loc"
             xmlns="http://www.opengis.net/context"
             xmlns:xlink="http://www.w3.org/1999/xlink"
             xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
             xsi:schemaLocation="http://www.opengis.net/context
http://schemas.opengeospatial.net/context/1.0.0/context.xsd">
       <General>
              <Window width="500" height="300" />
              <BoundingBox SRS="EPSG:4326" minx="-67.7" miny="47" maxx="-52" maxy="60"/>
              <Title>Water Quality Monitoring Locations</Title>
              <KeywordList>
                     <Keyword>Water</Keyword>
                     <Keyword>Quality</Keyword>
                     <Keyword>Monitoring</Keyword>
              </KeywordList>
              <Abstract>This is a view of water quality monitoring locations in
Newfoundland and Labrador, Canada</Abstract>
              <LogoURL width="150" height="75" format="image/png">
                     <OnlineResource xlink:type="simple" xlink:href="http://cgdi-
dev.geoconnections.org/prototypes/owsview/graphics/cgdi.png"/>
              </LogoURL>
              <DescriptionURL format="text/html">
                     <OnlineResource xlink:type="simple"
xlink:href="http://www.cgdi.ca/"/>
              </DescriptionURL>
              <ContactInformation>
                     <ContactPersonPrimary>
                            <ContactPerson>Tom Kralidis</ContactPerson>
                            <ContactOrganization>self</ContactOrganization>
                     </ContactPersonPrimary>
                     <ContactPosition>Systems Scientist</ContactPosition>
                     <ContactAddress>
                            <AddressType>postal</AddressType>
                            <Address>xx xxxxxxxx xxxxx </Address>
                            <City>Toronto</City>
                            <StateOrProvince>Ontario</StateOrProvince>
                            <PostCode>xxx xxx</PostCode>
                            <Country>Canada</Country>
                     </ContactAddress>
                     <ContactVoiceTelephone>+01-416-xxx-xxxx</ContactVoiceTelephone>
                     <ContactFacsimileTelephone>+01-416-xxx-
xxxx</ContactFacsimileTelephone>
                     <ContactElectronicMailAddress>tomkralidis at hotmail dot
com</ContactElectronicMailAddress>
              </ContactInformation>
       </General>
       <LayerList>
              <Layer queryable="0" hidden="0">
                     <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                            <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                     </Server>
                     <Name>wa_7.5m</Name>
                     <Title>Water areas (1:7 500 000)</Title>
                     <Abstract>The surface area of oceans, lakes and large rivers
intended for display at the scale of 1:7 500 000.</Abstract>
                     <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                     <FormatList>
```

```
				<Format current="1">image/gif</Format>
				<Format>image/png</Format>
				<Format>image/jpeg</Format>
				<Format>image/wbmp</Format>
			</FormatList>
			<StyleList>
				<Style current="1">
					<Name>default</Name>
					<Title>default</Title>
				</Style>
			</StyleList>
		</Layer>
		<Layer queryable="0" hidden="0">
			<Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
				<OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
			</Server>
			<Name>roc_7.5m</Name>
			<Title>Regions outside Canada (1:7 500 000)</Title>
			<Abstract>Land areas outside Canada intended for display at the
scale of 1: 7 500 000.</Abstract>
			<SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
			<FormatList>
				<Format current="1">image/gif</Format>
				<Format>image/png</Format>
				<Format>image/jpeg</Format>
				<Format>image/wbmp</Format>
			</FormatList>
			<StyleList>
				<Style current="1">
					<Name>default</Name>
					<Title>default</Title>
				</Style>
			</StyleList>
		</Layer>
		<Layer queryable="0" hidden="0">
			<Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
				<OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
			</Server>
			<Name>roads_7.5m</Name>
			<Title>Road network (1:7 500 000)</Title>
			<Abstract>Road network and ferry routes intended for display at the
scale of 1:7 500 000.</Abstract>
			<SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
			<FormatList>
				<Format current="1">image/gif</Format>
				<Format>image/png</Format>
				<Format>image/jpeg</Format>
				<Format>image/wbmp</Format>
			</FormatList>
			<StyleList>
				<Style current="1">
					<Name>default</Name>
					<Title>default</Title>
				</Style>
			</StyleList>
		</Layer>
		<Layer queryable="0" hidden="0">
```

```
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>drain_7.5m</Name>
                        <Title>Drainage (1:7 500 000)</Title>
                        <Abstract>Coastlines, rivers and lakes shorelines intended for
display at the scale of 1:7 500 000.</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
                                <Format current="1">image/gif</Format>
                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
                </Layer>
                <Layer queryable="0" hidden="0">
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>can_7.5m</Name>
                        <Title>Landmass outline (1:7 500 000)</Title>
                        <Abstract>The outline of the landmasss of Canada</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
                                <Format current="1">image/gif</Format>
                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
                </Layer>
                <Layer queryable="0" hidden="0">
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>int_bounds</Name>
                        <Title>Boundaries</Title>
                        <Abstract>Canadian International boundaries and offshore
limits.</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
```

```
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
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                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
                </Layer>
                <Layer queryable="0" hidden="0">
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>nat_bounds</Name>
                        <Title>Provincial and Territorial Boundaries</Title>
                        <Abstract>Provincial and territorial boundaries</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
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EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
                                <Format current="1">image/gif</Format>
                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
                </Layer>
                <Layer queryable="0" hidden="0">
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>places_labels_7.5m</Name>
                        <Title>Populated Places (labels 1:7.5M)</Title>
                        <Abstract>Selection of Canadian populated places in four classes
based on 1991 Census data. It is intended for display at 1:7 500 000.</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
                                <Format current="1">image/gif</Format>
                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
```

```
                </Layer>
                <Layer queryable="1" hidden="0">
                        <Server service="OGC:WMS" version="1.1.0" title="Atlas of Canada
WMS">
                                <OnlineResource xlink:type="simple"
xlink:href="http://atlas.gc.ca/cgi-bin/atlaswms_en"/>
                        </Server>
                        <Name>cap_labels</Name>
                        <Title>Capitals (Canada)</Title>
                        <Abstract>National, provincial and territorial capital name
labels.</Abstract>
                        <SRS>EPSG:42101 EPSG:42304 EPSG:4269 EPSG:4326 EPSG:2294 EPSG:2295
EPSG:26922 EPSG:26921 EPSG:26920 EPSG:26919 EPSG:26918 EPSG:26917 EPSG:26916 EPSG:26915
EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
EPSG:26714 EPSG:26713 EPSG:26712 EPSG:26711 EPSG:26710 EPSG:26709 EPSG:26708 EPSG:26707
EPSG:2295 EPSG:2294</SRS>
                        <FormatList>
                                <Format current="1">image/gif</Format>
                                <Format>image/png</Format>
                                <Format>image/jpeg</Format>
                                <Format>image/wbmp</Format>
                        </FormatList>
                        <StyleList>
                                <Style current="1">
                                        <Name>default</Name>
                                        <Title>default</Title>
                                </Style>
                        </StyleList>
                </Layer>
                <Layer queryable="1" hidden="0">
                        <Server service="OGC:WMS" version="1.1.1" title="ENVIRODAT -
Atlantic Region Water Quality Chemistry Database">
                                <OnlineResource xlink:type="simple"
xlink:href="http://map.ns.ec.gc.ca/envdat/map.aspx"/>
                        </Server>
                        <Name>envirodat</Name>
                        <Title>Water Quality Monitoring Locations</Title>
                        <Abstract>ENVIRODAT is a repository of water quality information
including chemical, physical, biological, and selected hydrometric data which are stored
for surface, groundwater, wastewater, precipitation and various other water
types</Abstract>
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EPSG:26914 EPSG:26913 EPSG:26912 EPSG:26911 EPSG:26910 EPSG:26909 EPSG:26908 EPSG:26907
EPSG:26722 EPSG:26721 EPSG:26720 EPSG:26719 EPSG:26718 EPSG:26717 EPSG:26716 EPSG:26715
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                                        </LegendURL>
                                </Style>
                        </StyleList>
                </Layer>
        </LayerList>
</ViewContext>
```

Appendix E: Minimum Bounding Rectangle Algorithm

```
##############################################################################
#
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#
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#
##############################################################################

sub getMBR {
  my @polygonVertices = @_;
  my $minx = 0;
  my $miny = 0;
  my $maxx = 0;
  my $maxy = 0;

  if (isEvenXYPairs(@polygonVertices) == 1) {
    return "Corrupt inputs, must be even numbered xy vertices";
  }

  if (isPolygonClosed(@polygonVertices) == 1)  {
    return "Corrupt inputs, not a closed polygon";
  }

  for(my $i = 0; $i < (scalar(@polygonVertices) / 2 + 2); $i = $i + 2) {
    # initialize bounding box vals
    $minx = $polygonVertices[$i] if $i == 0;
    $miny = $polygonVertices[$i+1] if $i == 0;
    $maxx = $polygonVertices[$i] if $i == 0;
    $maxy = $polygonVertices[$i+1] if $i == 0;

    # test and set MBR
    $maxx = $polygonVertices[$i] if $polygonVertices[$i] > $maxx;
    $minx = $polygonVertices[$i] if $polygonVertices[$i] < $minx;
    $maxy = $polygonVertices[$i+1] if $polygonVertices[$i+1] > $maxy;
    $miny = $polygonVertices[$i+1] if $polygonVertices[$i+1] < $miny;
  }
  return "$minx,$miny,$maxx,$maxy";
}

sub isEvenXYPairs {
  my @coordArray = @_;
  if (! (scalar(@coordArray) % 2) == 0) {
    return 1;
  }
  else {
    return 0;
```

```
  }
}

sub isPolygonClosed {
  my @polygonVertices = @_;
  if ( ($polygonVertices[0] != $polygonVertices[-2]) ||
       ($polygonVertices[1] != $polygonVertices[-1])) {
    return 1;
  }
  else {
    return 0;
  }
}
```