Web Mapping for the Murray-Darling Basin Authority - The Challenges and Opportunities of Open Access

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The Murray-Darling Basin Authority (MDBA) is a Commonwealth agency responsible for the sustainable management of water resources in the Murray-Darling Basin. The Authority has identified the need for web mapping infrastructure to provide online access to the Authority's spatial information via discovery, access and publishing tools. In line with the requirement to harmonise the Authority's online information strategies with those of other Commonwealth agencies, it is imperative that any web based information services are provided on robust open standards. With this in mind, standardisation of systems that implement Open Geospatial Consortium (OGC) standards is a high priority task. We are undertaking a staged approach to these implementations, initially adopting ArcGIS Server at the back end to provide integrated and scalable web services that support WMS and KML. This paper describes the process of building an OGC compliant infrastructure for the Murray-Darling Basin's web mapping requirements.

Keywords: Internet/web, technology, mapping and GIS

1. INTRODUCTION

The Murray-Darling Basin Authority (MDBA) is a Commonwealth agency responsible for the sustainable management of the water resources of the Murray-Darling Basin. The *Water Act 2007* requires the MDBA to measure, monitor and record the quality and quantity of Basin water resources (s 172(1)(b)), the condition of their associated water dependant ecosystems (s 172(1)(c)) and to disseminate information about them (s 172(1)(i)). In October 2010, the MDBA released the Guide to the Proposed Basin Plan that comprises a series of 21 publications. These publications contained over 90 maps or cartographic products. While the cartographic products and maps provided sufficient overview of the spatial information, the full depth of the detailed information could not be presented in the guide. The Authority has therefore identified the need for web mapping infrastructures to provide online access to the proposed Basin Plan's spatial information, as well as to some of the Authority's other spatial information via discovery, access and publishing tools.

The Authority made significant investments in collection of various forms of geospatial data and maintenance of these assets over the past decade. While the MDBA is operating in an environment that is reasonably data rich, it is considered 'information poor', has limited data accessibly, little interoperability, minimal exploitation, localised collections with products being needlessly regenerated rather than using a "collect/create once and use many times" approach.

The Authority is committed to being open and transparent about the science behind the Guide to the Basin Plan. In line with the requirement to harmonise the Authority's online information strategies with those of other Commonwealth agencies, it is imperative that any web based information services are based on robust open standards that provide a clear development path for future combined online information portals. With this in mind, standardisation of systems that implement Open Geospatial Consortium (OGC) standards to provide discovery, use of web publishing services for the Authority's spatial data is a high priority task.

Amongst the many OGC standards, the Web Mapping Service (WMS) is one of the fundamental and most widely accepted standards that provides specifications for map visualization through internet or web mapping (Iosifescu-Enescu *et al*., 2010). It provides a means for web applications to utilize spatial information provided by different organizations via the internet (OGC, 2004). More cost effective web mapping applications can be rapidly deployed using existing web services published by different organizations (Haklay et al., 2008). This is primarily due to the smaller costs required for developing and maintaining spatial database infrastructures. WMS however, also has a major drawback, its limited spatial functionality (Farcy *et al*., 2005). Combining WMS with other OGC standards such as Web Feature Service (WFS), Web Coverage Service (WCS) and Keyhole Markup Language (KML), provides additional spatial functionality to web mapping services (OGC, 2008a, 2008b, 2010).

Maintenance of multiple databases at different scales or themes is generally no longer acceptable. Custodians of spatial information are moving towards building and maintaining an infrastructure database through closer co-operation between agencies, other map producers and GIS software vendors (Kazemi & Lim, 2007). Also, Kazemi *et al.,*(2004) noted that a holistic approach requires (1) building a seamless corporate 'object-oriented' database to support all map production needs, (2) deriving multiple map products in real time with minimal interactive work, (3) updating features only in the seamless database, (4) synchronising changes to all map products with no duplication of data costs, and (5) making cartographic edit capabilities available only on map products and not the seamless database. This allows the users to make adjustments to the output of simplified maps to add, remove, or otherwise change the appearance of objects as needed, and support web based delivery products such as Wireless Application Protocol (WAP) technology (Sarjakoski *et al*., 2002).

While cartographic visualization on both paper and web maps can be the same, the techniques related to its visualization are different. In paper maps, generally the media to be utilized (i.e. paper size) is known before the development of a map. Therefore, the size of cartographic components and a features' visualization can be easily determined. In web mapping applications, cartographic components can be visualized interactively at different levels of detail. However, interactivity is limited due to lack of web developer knowledge of the users' display resolution, operating system, web browser, internet connection etc., required for web mapping applications (Cartwright, 2003; Cecconi *et al*., 2002). Assumptions of the potential user environment are generally made based on the web statistics of similar applications developed by other agencies. Generally, web mapping applications developed with insignificant dependency on proprietary technology and using open standards in order to comply with the broader users' environment are most appropriate (Kulawiak *et al*., 2010).

This paper describes the process of building OGC compliant infrastructure for the Murray-Darling Basin's (MDB's) web mapping requirements. It highlights the development requirements, describes technical problems and solutions encountered during the process, and proposes future improvements, and the inclusion of WFS, WCS and Ontological search services.

2. METHODOLOGY

A. Study Area

As suggested by its name, the Murray-Darling Basin's boundaries are defined by the catchment areas of two major river systems in Australia, i.e. the Murray River and the Darling River. The basin covers 1,042,730 km^2 or about 14% of the Australian landmass. Its area extends across Queensland, New South Wales, Victoria, South Australia and the Australian Capital Territory (MDBA, 2010). With such a large catchment, presenting and communicating detailed spatial information in efficient and effective ways is a challenge.

B. System Configuration

The MDBA's spatial information program and ICT units maintain an Oracle spatial database that contains over 500 spatial datasets. This spatial database is accessible only from within the organization through an ArcGIS desktop connecting to the MDBA corporate spatial information system (ArcSDE). A number of web mapping applications are also available to provide non-GIS users with spatial information. However, each web mapping application offers different information, interface and functionalities, thereby, creating difficulties for entire web application systems.

Issues and requirements for the MDB's web-mapping infrastructure were examined. The first issue is the growing requirement of the organization to disseminate information, particularly in relation to the proposed Basin Plan. Therefore, web-mapping infrastructure needs to be easily scalable. Second, the system needs to be interoperable with other government organizations. This means that it needs to be compliant with common standards, which in this case are the OGC standards, the most widely accepted standard amongst the GIS community. The third issue is related to the performance of information delivery. Map delivery via the internet means significant amounts of data need to be transferred. Interactivity means that users could interact with the map which requires a significant amount of computing power and internet bandwidth (Cartwright, 2003). Therefore, a balance between server performance, response and delivery time needs to be considered in designing the application.

Initially, spatial datasets presented in the Guide to the Proposed Basin Plan were collected. Each dataset used to develop the maps or cartographic products in the Guide was noted and reviewed for inclusion in each web service. A layout was created for each dataset. Its extent, colour scheme and font size used was made as similar as possible to those in the Guide to the Proposed Basin Plan. This was intended to avoid confusion for the readers/users. Fields were selected and alias assigned to provide meaningful information, particularly if users query the information using the identify tool. Additionally, geoprocessing was performed to include only Murray-Darling Basin areas. This is expected to increase server performance since only a certain extent needs to be rendered.

Once the map layout is finalized, the map is optimised to improve the performance of the server. ESRI provides a straightforward method to optimise the map service using ESRI Map Services Publishing tool for versions 9.3 and above. According to ESRI (2009b) the use of optimized map service reduces response time from 2.21 seconds to 0.69 seconds compared to the standard map service. Once the map service is published into the ArcGIS Server, users with administrative privileges can build a cache for the map. A map cache is a collection of pre-rendered map tiles at different scales (ESRI, 2009a). It provides generalized maps at different levels of detail (Cecconi *et al*., 2002). The scales used in map creation are based on the best scale that displays overall information (i.e. 1:10,000,000) to the scale where the level of details is considered to have reached maximum (i.e. 1: 156,260).

As for the web-mapping application, the initial development carried out by ESRI using Silverlight/WPF API in a C+ environment. In this initial application, basic web-mapping functionalities and a legend generator was provided. This application was modified by the MDBA to add additional functionalities and information.

In early October 2010, an internal Beta Test was carried out to test the performance and functionality of the application. The test was followed by a survey to gain users' feedback on the interface, navigation and quality of information presented in the application. Additionally, users asked to provide comments on additional data and functionalities that needed to be included in the application. This is particularly important to improve the application, as well as for future development.

3. RESULTS

Based on the review, the MDBA's existing IT infrastructure is considered sufficient for providing basic web mapping functionalities. An improvement was made by adding an external server. This server will be used solely to host the web-mapping application and the spatial data required. Therefore, improvements in performance could be achieved compared to the application hosted by internal MDBA IT infrastructure. Additionally, the Demilitarized Zone (DMZ) used in the external server could increase security and protection of internal MDBA IT infrastructure. Since the external server is an exact copy of the internal server, this means that users outside the MDBA will have similar information to MDBA internal users. Timely updates will be performed on the external server in order to ensure that the information used for web mapping purposes is current.

The following is an example image of the Murray-Darling Basin web mapping user interface (**Figure 1**). The navigation toolbar on the top left side provides basic functionalities, including the ability to access and query attribute information of particular locations. The table of contents on the right hand side provides users with a list of available layers. Users are able to turn the layer on and off, as well as change the transparency level of the layer. Additionally, a button that will display Uniform Resource Locators (URLs) for OGC compliant web services (WMS, WFS, WCS and KML) is provided for each layer.

Internal testing shows that the performance of the application is satisfactory, considering the amount of data that needs to be transferred. In general, initial loading will take approximately 20 seconds and will take less for subsequent loadings. The survey shows that 75% of users were satisfied with the user interface and ease of use of the navigation tools. In term of the information provided, 87.5% of users considered the quality of information to be appropriate. However, 50% of users stated

that more information needs to be included in the application, particularly information related to specific projects.

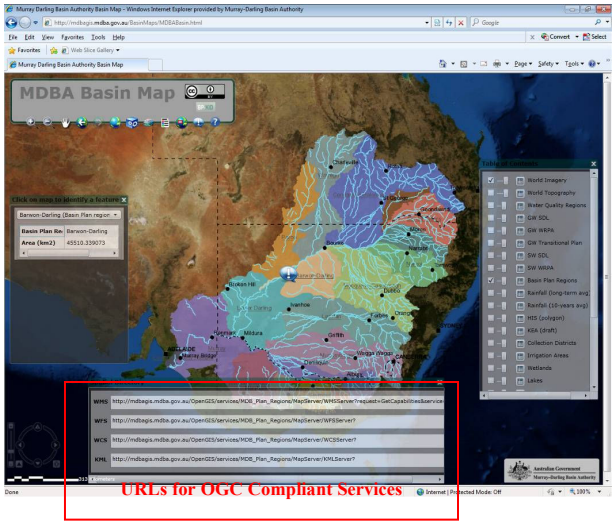

Figure 1. MDBA's web mapping user interface

4. DISCUSSION

The MDBA is undertaking a staged approach to the dissemination of its spatial information, initially by adopting the ArcGIS Server at the back end to provide integrated and scalable web services. This software is capable of providing web services that are compliant with OGC standards such as WMS, WFS, WCS and KML. Additionally, the ArcGIS Server works with a wide range of data storage systems. It does not require that spatial datasets are stored in a spatial database. With such flexibility, the MDBA was able to set up a replica of datasets and store it on an external server. This eliminates the need for connecting internal MDBA spatial databases to the external server, or the need to redeploy similar spatial database design in the external server.

Out of the OGC standards supported by the ArcGIS Server, only the WMS standard was fully utilized in the web mapping application. Spatial information can also be displayed in Google Earth through KML services. The WFS and WCS were also created. However, a user-friendly interface to enable users to utilize these services has not been developed. There are several reasons why MDBA delayed the development of these web services. The MDBA's current infrastructure, particularly its internet bandwidth, is considered insufficient to handle requests for large information that generally occur in WFS and WCS. Additionally, the organization is investigating the possibility of developing an application that specifically delivers satellite imagery of the MDB. This application will likely use the WCS standard to guarantee its interoperability.

During the development of the web mapping application, the MDBA realized that the authority does not have detailed information regarding the systems used by potential web users (Cartwright, 2003). Therefore, particular emphasis is given to developing the application in an environment that works with multiple browsers, devices and operating systems. Since the deployed services are compliant to the OGC standard, particularly WMS, a client application can be built in any environment (Alameh, 2003). Due to these reasons, Silverlight/WPF API is considered as the most suitable web application for selection. The selection of Silverlight is also based on its capability for maximizing the available space for maps and its capability in providing presentation rich interactive content. The interoperability offered by OGC also allows web developers to design web applications that perform similar spatial functions and visualization techniques using different spatial datasets (Altmaier & Kolbe, 2003). Therefore development can be focused on providing more complex functions rather than focusing on how to handle different spatial information formats.

Several problems were encountered during the development of the MDBA's web-mapping application. These problems can be divided into two main areas, i.e. problems related to the creation of web services in the ArcGIS server, and problems related to the creation of web mapping applications using Silverlight/WPF API. The first problem is related to the data used in the web-mapping application. According to the requirements, information presented in the application needs to be similar to the information presented in the Guide to the Proposed Basin Plan. It is understood that for the purposes of publication, several layers were used to represent one theme of information. For example, information regarding cities/towns was taken from both GEOTOPO 250K and Gazetteer 2005. While it is relatively easy to create a "mask" or "cosmetic layer" for print publication or to retrieve partial information from different datasets, it was not so easy to do this for interactive web services, in particular, because each layer needs to be presented as if it comes from one dataset. To solve this problem, individual query was performed on each dataset and then these datasets were combined. The combined datasets were then published as an individual service. This combines the datasets into one layer. However, publishing individual services puts a greater burden on the server as it needs to handle more services. Currently, the MDBA is working to develop a spatial data model to integrate spatial datasets from different sources and this will reduce the need to perform the extensive query to display information.

The second problem is related to some limitations in the optimized map service. While in general the optimized map service improves server performance, it also limits the information that can be presented, particularly relating to the representation of complex layers and symbology. For example, the optimized map service does not support symbology created from the combination of fields. Therefore, layers that require such symbology, such as surface water-groundwater connectivity, needs to be published as a standard map service. While a new field combining the required fields can be created and used for displaying symbology, such a solution will likely reduce the integrity of the datasets. Interactivity is one of the main features that the MDBA web mapping provides, this requires geoprocessing services, and while optimized map service might improve server performance, it does not support geoprocessing and limits the ability to develop interactive map services.

Several problems were also discovered during the development phase of the web mapping application. In general, these related to limitations with the Silverlight/WPF API. The foremost problem is that applications developed using Silverlight/WPF API require clients to install the Silverlight plug-in on their browser. While this is easily solved for users with administrative access to their computer, the use of a plug-in to display the information has reduced the perception of interoperability of the application to some extent.

The last problem is related to the generation of legends. The module currently available is used to dynamically generate legends for layers in the application. However, this legend

generator is only capable of producing a maximum of five layers, adding a sixth layer would lead to no legend being generated at all. While the MDBA's software engineers work on solving this problem, a conventional static legend is used in the application. Printing maps is another limitation for the Silverlight/WPF API. In version 1.2, no API is provided to enable printing from the application. At this stage the application uses web browser capabilities to print the information.

5. CONCLUSIONS

The main objective of this paper is to describe the process of building OGC compliant infrastructure for the Murray-Darling Basin's web mapping requirements. During the development phase, the MDBA encountered several problems related to web services and web application. Some problems relate to the limitations of the ArcGIS Server and the Silverlight/WPF API, such as the limitations in using optimized map services for complex layer, symbology and geoprocessing, an inability to develop map caches outside the ArcGIS Desktop and the absence of a printing functionality in API. Other problems that require serious attention originate from the structuring of the datasets used for web services.

While a workaround to these problems can generally be found, they still require improvement so that maximum performance of the web mapping infrastructure and its web service can be achieved. The following items will be considered for future improvement:

- The user interface design needs to be improved, in particular to accommodate additional functionalities without decreasing the space available for the map.
- Additional functionalities such as:
  - Capability to create a customized map layout and to print the map.
  - Capability to perform spatial analysis and geoprocessing.
  - WFS capability to enable an authenticated user to interact (select, update, insert and delete) with the spatial information. This would be useful to attract participative mapping from the public, especially to provide spatial input for MDBA in order to enhance the water management in the basin.
  - WCS capability to enable user to display raster datasets such as satellite imagery, DEM etc.
  - Capability to display 3D information.
  - Integrating semantic web technology to enhance the spatial web search.
- Maintaining a single corporate spatial database that supports many applications (rather than multiple simplistic map layers), in addition to a well-designed database. This would provide a platform to support data derivation, generalisation, symbolisation, and near real-time. A pilot project on enterprise spatial data modelling, including workshops with stakeholders and partners as well as testing the concept for some key MDBA spatial assets is a component of this activity.
- A project is being scoped regarding a new Enterprise Terrain and Imagery System that uses international best practice and cutting edge spatial information technologies for design of spatial data management and distribution portals. The proposed system can help to overcome the above major issues. The portal is an image data catalogue that allows the search, discovery, management and distribution of the MDBA terrain as well as remotely sensed data. This project truly aligns with the MDBA Enterprise Information Strategy that can be executed through the partnership of Australian Government agencies in 2011.

REFERENCES

Alameh, N. (2003). Chaining of Geographic Information Web Services. *IEEE Internet Computing, 7*(5), 22-29.

Altmaier, D. A., & Kolbe, B. T. H. (2003). *Applications and Solutions for Interoperable 3D Geo-Visualization.* Paper presented at the Photogrammetric Week 2003, Stuttgart, Germany.

Cartwright, W. (2003). Maps on the Web. In Peterson, M. P. (Ed.), *Maps and the Internet*. Amsterdam: Elsevier Science B.V.

Cecconi, A., Weibel, R., & Barrault, M. (2002). *Improving Automated Degeneralization for On-Demand Web Mapping by Multiscale Databases.* Paper presented at the Symposium on Geospatial Theory, Processing and Applications, Ottawa, Canada.

ESRI. (2009a). Best Practices for Creating an ArcGIS Server Web Mapping Application for Municipal/Local Government: ESRI.

ESRI. (2009b). High-Capacity Map Services: A Use Case with CORINE Land-Cover Data: ESRI.

Farcy, C., Terwangne, B. d., & Blerot, P. (2005). A Distributed Information System for Public Forest and Wildlife Management in the Walloon Region (Belgium) Using Open GIS Standards. *Computers and electronics in agriculture, 47*, 207-220.

Haklay, M., Singleton, A., & Parker, C. (2008). Web Mapping 2.0: The Neogeography of the GeoWeb. *Geography Compass, 2*(6), 2011-2039.

Iosifescu-Enescu, I., Hugentobler, M., & Hurni, L. (2010). Web Cartography with Open Standards - A Solution to Cartographic Challenges of Environmental Management. *Environmental Modelling & Software, 25*, 988-999.

Kazemi, S., & Lim, S. (2007). Deriving multi-scale GEODATA from TOPO-250K road network data. *Journal of Spatial Science, 52*(1), 165-176.

Kazemi, S., Lim, S., & Rizos, C. (2004). *A review of map and spatial database generalization for developing a generalization network.* Paper presented at the XXth Congress of the International Society for Photogrammetry & Remote Sensing, Istanbul, Turkey.

Kulawiak, M., Prospathopoulos, A., Perivoliotis, L., Luba, M., Kioroglou, S., & Stepnowski, A. (2010). Interactive Visualization of Marine Pollution Monitoring and Forecasting Data Via a Web-based GIS. *Computer & Geoscience, 36*, 1069-1080.

MDBA. (2010). Guide to the Proposed Basin Plan: Overview. Canberra: MDBA.

OGC. (2004). OGC Web Map Service Interface, Version 1.3.0: Open GIS Consortium Inc.

OGC. (2008a). OGC® KML. Version 2.2.0: Open Geospatial Consortium Inc.

OGC. (2008b). Web Coverage Service (WCS) Implementation Standard. Version 1.1.2: Open Geospatial Consortium Inc.

OGC. (2010). OpenGIS Web Feature Service 2.0 Interface Standard. Version 2.0.0: Open Geospatial Consortium Inc.

Sarjakoski, T., Sarjakoski, T., Lehto, L., Sester, M., Illert, A., Nissen, F., Rystedt, B., & Ruotsalainen, R. (2002). *Geospatial info-mobility services: A challenge for national mapping*

agencies. Paper presented at the International Symposium on Geospatial Theory, Processing and Applications, Ottawa, Canada.

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