Nature Environment and Pollution Technology
An International Quarterly Scientific Journal

ISSN: 0972-6268	Vol. 11	No. 1	pp. 51-58	2012

Original Research Paper

Advancing the Diffusion of Digital Spatial Data Handling for Upgrade of Decision Support for the Regional Environmental Managers

Nasrin Baby and Jim Peterson*
Bass Coast Shire Council, Victoria, Australia
*Centre for GIS, School of Geography and Environmental Science, Monash University, Clayton, Australia

Nat. Env. & Poll. Tech.
Website: www.neptjournal.com
Received: 6/11/2011
Accepted: 8/12/2011

Key Words:
Digital spatial data
GIS
Decision support
Data directory

ABSTRACT

History shows that from time to time, progress in advancing functionality in one or other of these requirements has contained the diffusion and adoption process. In Australia, at present, it is adoption by third-tier government agencies and local organisations that is such that the biggest gap between potential and actual deployment is exhibited. Especially, can it be argued from a survey of local-area (e.g. LGA, DSE regional offices) GIS Lab data processing practice, that there is a lack of data flow coherence. This paper presents results of an analysis of the relative significance of constraints upon adoption of the full power of digital spatial data handling with coherence in the service of the PINP and related organisations. The coherence problem is shown to be overcome by adopting a data directory model including well-trailed data dictionaries. The biggest constraint is shown to be access to adequate software for data sharing and maintenance; mainly a problem of finding the funds to pay proprietary software license fees. Although this is not unusual, it is shown that recent advances in efforts to promote data sharing and spatial data visualisation, worldwide (in the form of open-source software) promise a revolution in the construction of detailed geographies (time and space) such that transparency and utility are greatly improved, and the user-base of the digital spatial database can greatly increase in size by extending itself to include many naive users. Exemplification is made using several decision support tasks faced by Phillip Island natural park rangers, Shire environment officers and community LANDCARE groups. GIS, empowering the regional environmental managers in the interests of maximising the value of spatial information and the implementation of public policy promoting diffusion of digital spatial data handling and transparency in government. This main aim of this paper is the out-reach web GIS for regional environmental managers.

INTRODUCTION

From reading the School of G & ES, Centre of GIS research publications, http://careers.monash.edu.au/assets/docs/round-5-lead-or-follow.pdf including Wheeler et al. (2011), it can be argued that the steady diffusion and adoption of GIS, envisaged by public policy (first declared in Canberra two decades or so ago) has become inhibited. An explanation can be offered as outlined in the following derivative step-by-step argument.

a. There is failure of many non GIS Lab third-tier environmental management agency officers to take advantage of access to digital spatial data and related data handling tools. Most have not taken the first step to become naive GIS users.
b. Therefore, the scope for a critical mass of GIS users to form is constrained.
c. If such a critical mass is formed, the cost of meeting the demand for extra software licenses would be an inhibition that would not be easily overcome, and
d. In the face of such an impasse both technical and institutional issues must be addressed before the level of adoption and diffusion of GIS as envisaged by policy can be achieved.

This argument emerges from survey results reported in Wheeler (et al. 2011). They amount to an assessment of the status of digital spatial data handling among corporative third tier (government owned) agencies and government regional agencies in 2009. This was twenty years after the Commonwealth Government mandated the establishment of State Government geographic data coordination committees to instigate the adoption of digital information age methods in mapping (Goodchild 2007).

It was clear at the time that the new policy was established in recognition that the new data handling technology offered significant potential for improved decision support.

This must be part of the explanation for the gap between policy and practice in coastal and catchments management that has been identified lately e.g., see publications listed at www.monash.edu.au/ges/research/gis/public/wheeler.php. Certainly the gap can be said to have been recognised by the Phillip Island Penguin Foundation when it approved a Monash University School of Geography and Environmental

Science, Centre for GIS Research Grant Application for support of a project designed to test the scope for imposing coherence on the Phillip Island Nature Parks (PINP) decision support database with special reference to spatial data. The project, in effect, is called for;

1. An assessment of the nature of data and information flows in decision support in the PINP (with special reference to the 2006-2011 Management Plan).
2. An analysis of the data flows with special reference to coherence and communication.
3. An assessment of scope for improvement, with special reference to bridging the gap between the spatial data custodians who understand the IT (in case of the data supply for PINP, these officers are in Melbourne DSE Central Business District labs) and those for whom the data were built, but according to generalised producer-defined (albeit digital) specifications that refer to the Victorian SDI (Rajabifard 2007).
4. An assessment of the scope for improving the diffusion of digital spatial data handling within the PINP community and for establishing an interface through which relevant data can be shared with all stakeholders. Clearly, visualisation would be involved, and for that, a sound spatial database is a pre-requisite.

Thus, the scene was set for a research project formulation with a focus on increasing the GIS user population among decision support teams. The title of the project is "Advancing the diffusion of digital spatial data handling for upgrade of decision support for the regional environmental managers". The title refers to both in-house and out-reach data sharing and spatial data visualisation. In project formulation, it is recognised that unless obvious accountability can come to be ignored, the impasse mentioned above calls for exemplification of a technical solution, and that until recently, an obvious option (deployment of free-ware/open source software) was not likely to be very satisfactory because the functionality, especially in terms of visualisation, was not included (Douglas 2004).

RESEARCH OBJECTIVES

1. To identify the problems and constraints with GIS adoption by regional environmental management agencies.
2. To develop an open source GIS approach.
3. To diffuse digital spatial data handling to upgrade decision support for the PINP community.
4. To apply test results to the problem of extending the utility of spatial data to the regional environmental managers.
5. To assess the implications of the outcomes with regard to decision support in regional environmental management agencies.
6. To promote sharing of GIS resources within PINP and other stakeholder organizations.
7. To create data directory tables where location and attribute data can be effectively represented and visualized using GIS for decision-making.

RESEARCH QUESTIONS

1. Why is the current adoption of GIS tools in so many mainstream enterprises so undeveloped?
2. What is the main accessibility issue in open source GIS? Can a PINP research website assist and benefit Park managers?
3. How can PINP management benefit from a GIS data directory?
4. How can GIS support Management Action Plans?
5. Can Google Earth help in 3D visualization in aid of decision support?

There are the following main contextual questions:

A. Why, after twenty years of public policy promotion of the adoption and diffusion of digital spatial data handling in Australia, is the gap between potential utility and actual deployment so wide among third-tier public agencies (even in Victoria, the best mapped state of Australia) and among regional offices that report to higher levels of government, all of which have adopted the information-age methods?

As the research so far shows, adoption has taken place at the PINP but the gap between what policy envisaged and what is actually achieved is very evident, both in house and among clients. In the search for explanation, the following questions have been asked and answered.

1. Why is there a poor level of adoption of GIS tools in PINP? (There is only one ArcGIS seat and one part-time person responsible for data maintenance and processing.)
2. Now we have Web2, how can the PINP research website be configured to assist staff in managing the Park in ways that bring better return on the data-handling investment? In-house staff and some stakeholders welcome the idea of such a configuration that makes them ready to share data.
3. There is a need for PINP to have a GIS data directory: Once provided, will it be used to best effect? Probably, but the answer to this question will require future and on-going evaluation.
4. To what extent will GIS support for the current Management Action Plan be improved if the data directory is made familiar to PINP staff?
5. To what extent will 3D visualization improves support for management decision making?
6. If 3D visualizations are adopted, how much stakeholder

training will be necessary for it to become routine practice.

B. The PINP has failed to adopt the full power of GIS in decision support: What mitigation measures are available for demonstrating the advantage of adoption?

1. How many PINP staff actually use GIS? Only one, despite the fact that a range of Penguin Foundation-funded Research students assists PINP staff.
2. What constraints are inhibiting the PINP spatial data custodian from realising the potential of GIS in decision support? Does that person have of access to useful data, and GIS functionality?

Many in-house PINP staff and research students wish to have access to the data, but much of it is not fit to share at the moment .When a data directory becomes available, access will remain limited unless some way of sharing data that is fit to share can be devised.

OPPORTUNITY AND CONSTRAINTS

1. Understanding the organisational constraints for GIS adoption and diffusion.
2. Identify the approach and method that will promote diffusion of GIS and its adoption in PINP decision support.
3. Test the scope for PINP research website for promoting, educating and disseminating GIS technology.
4. Analysis of the potential of 3D visualization for enhancing management decision making.
5. Identify accessibility issues in Google Earth.
6. Assemble guidelines for web based GIS for the PINP stakeholders.

RESEARCH DESIGN

The purpose of this research is to provide to PINP, the basis of a new Geographic Information System (GIS) strategy, and to test its utility compared to that of the extant spatial decision support system. Accordingly, identification of PINP GIS requirements and how can they involve GIS technology to integrate data from and for a variety of projects is essential. Primarily, it is important that all those who need to use the information, acknowledge the need for a suitable Data Directory. Motivation for upgrading the decision support system refers not only to such matters but also to the need to manage the user base in the hope that the necessary support for upgrade will found as colleagues in the decision support team join the users.

In considering Fig. 1, it can be noted that the project starts with a phase referring to GIS development. The need for such development is dictated partly by the adequacies of the extant decision support system.

PINP DIGITAL SPATIAL DATA

Issues with PINP Digital Spatial Data

PINP GIS data sets include those of primary importance for PINP activities.

- Vic Map products, Oil Spill Response Atlas, Commissioned mapping and associated reports i.e., Vegetation Community mapping, Rare Plant mapping
- PINP has assembled the best bathymetrygeomorphology, soils, assets data sets available from various sources, but the scale of the maps is too small for detailed analysis.
- LiDAR and (scanned) aerial photo data are available, but the GIS operator is not trained to use the LiDAR and the air photos are used via interpretation rather than for pixel classification of true photo maps.
- Some key databases contain errors. Moreover, duplicated themes, from different sources do not overlay well and so, although they plot to hard-copy in a serviceable way, they lack topological consistency, for instance, snapping errors are noted and must be eliminated before the data set can be used in GIS.

Solution: GIS data integration: An account derived from interpreting answers to the questionnaire reported from the GIS Officer after inspection of the geo-data accessible to him and discussion of terms and tasks.

- For the PINP there is a clear need to create data sets mainly related to the management of crown land, i.e. pest plants and animal management, park access and infrastructure, proposed developments, education and interpretation, research into native plant and animal/bird populations and movements, vegetation management i.e., ecological burns, risk assessments, asset management to cite the assessment of the spatial data handlers at PINP.
- With limited resources, we find it a challenge to keep our in-house data sets up to date. Some data sets are not complete, i.e., weed and shearwater (bird species nesting grounds) mapping, assets, while others that where complete need to be redone to remain current, i.e., tracks, buildings and other infrastructural assets.
- A GIS data directory (all PINP spatial of attribute, GPS, Field data, video, Image, CAD drawing, Research Model, hard copy, etc.) is lacking.
- Technical map registration is lacking.

Comments and interpretations included: We want to build-up a geodatabase in the native data structure for ArcGIS because it is the primary data format used for editing and data management.

- There is a failure to realise that it is extremely important to rigidities using the correct origin for a project. Otherwise it may be impossible to provide quality output with the correct data and/or data information.

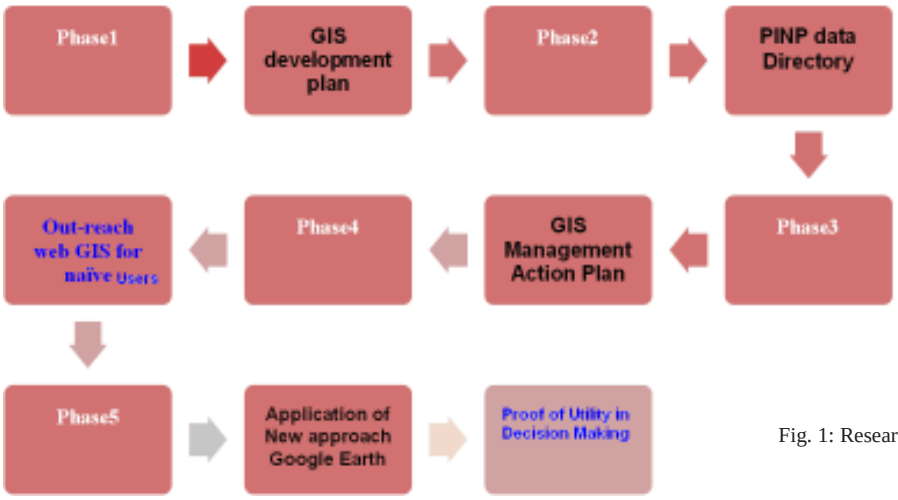

Fig. 1: Research design.

- It is clear that there is a need to check all types of data for quality control except for the SDI metadata online; the metadata is neither well kept, nor easily accessible.

Limitations of GIS Applications

- PINP GIS activity is based upon, a. Single ESRI ArcView, licence provided for data building, editing, layout viewing and data viewing, and b. One ArcPad unit for GPS field data collection.
- The additional functionality needed to increase ability to analyse/compare and share data sets is not provided.
- Only one GIS person is available to manage the significant amount of data/updating of data sets and to promote its use by PINP staff, even though the policy about adopting information age methods has been in place for decades.
- PINP currently has no GIS data integration or database/corporate system interfaces.
- PINP staff is not aware of the value of data sharing and data integration between management entities or stakeholders.

Solution: GIS Application Plan

- Access to ArcGIS extensions: XTools Pro, Spatial Analyst, 3D Analyst, Network analyst and LiDAR Analyst would greatly advance the data building tasks that face the GIS officer. Perhaps the tasks outside the functionality of the ArcView tool-kit could be sent to the central DSE GIS lab.
- Database/corporate system interfaces could be installed to advantage.
- Adopt data extraction tools for easy data capture, cleaning, editing and other proper data management tasks.
- Habitat planning, animal movement, alternate routes analysis and extension mapping could be implemented with available tools.
- GIS data visualization applications could be used to great effect.
- Clearly, PINP staff would benefit from time spent in training in digital spatial data handling.

GIS Knowledge and Training

GIS Knowledge and Training Limitation

- Available only once every few years or so. External training need (if identified) is on an 'as needed' basis, but ignorance is no basis from which to identify need.
- GIS software support is online via the software provider. General software and hardware support is managed by a local company. This is not a responsive enough system to rely on, day to day, the supporting budget being limited to system administration tasks.

Solution: Relevant GIS training plan and Web GIS solution.

GIS Data Delivery Problems

Data are not always delivered in compatible file formats or in the correct coordinate system. Several technical factors have to be taken into account for the development of the GIS data processing such as inadequacy of the 500 GB hard disk to store the volume of spatial attributes, LiDAR, aerial photo, image, PDF, video, customised tools not to mention the proposed, free software, development tools, extensions and KML etc. The problem is greater now that this project has delivered new data sets like coastal data (Metadata, fauna, flora, Kelp communities, marine substrates, rivers, estuaries, and seagrass. Management area, Nautical chart etc.), Subdivision Planning Electronic Drawing, Phillip Island Orth photography (2002 Phillip Island 35cm, 2004 Phillip Island 35cm, 2006 Phillip Island 15cm, 2009 Phillip Island 15cm, DTM (Cowes, Summerland, Rhyll, San Remo, Smith Beach,

Cape Woolamai, Churchill Island) 3D building and tree with height, water body and drainage data, Penguin Parade area animation map (tracking/movement). Vector to KML conversion tools and data Kirkwood 19 July 2011a page 127.

Solution: Upgrade the hard-drive sizes, or install a data server, and then, begin the process of configuring the data into a coherent geodatabase that it can support on-demand 3D and 2D environment modelling from:

a. real earth surface 3D model LiDAR data

b. elevation points collection by using LiDAR (includes earth surface features like trees, buildings, etc.).

Diffusion of digital data handling at PINP has progressed far enough to demonstrate that cost-effective solutions at hand can increase the efficiently of PINP spatial data management.

Scope for innovation becomes immediately apparent once the new tools and the newly-standardised PINP data can converge. These innovative aspects are both technical (identifying the relevance of an Information and Communication Technology (ICT) and cultural (identifying the causes of the limitations on bringing information-age policy to practise). The applications of the analyses and explanations for the gap between actual and potential adoption of name ITC are directly relevant to the debate about decision support reform among the third tier government agencies.

CONCEPTUAL THEORETICAL FRAMEWORK

This research conceptual framework refers to diffusion and adoption of GIS in environmental management. Potential benefits of adoption increase steadily but facilitating deployment in a cultural context presents many challenges (Tai 1998). Among the technical challenges are technical capacity sphere-GIS experts, GIS technology, data product, services and vendors. Until these are overcome, the motivation for overcoming the cultural/institutional challenges will be lacking. Securing support for addressing these challenges is probably best done in the context of decision support upgrade. Already, this project has assembled evidence that managers are keen to see testing of possible technical solutions as prerequisite to gathering support for its application in decision support upgrade.

Technical solutions: The range of possibilities is wide. Certainly, the following elements must be in preview.

- Spatial data infrastructure
- Citizens and voluntary sensors
- Detailed geography
- Neogeography (http://digitalurban.blogspot.com/920080 [cited in Lin and Battey (2009) pages 1-10].
- Google Earth
- Open source and interpretability
  The theory must inform and the application of the theory must be tested during the following activities.
- Survey of available data
- Survey of GIS hardware and software and acquisition of GIS hardware and software
- Detailed database planning and design
- Database construction
- Review/modify the original plan and GIS system integration
- GIS application development
- GIS use and maintenance

However, no matter how much the commoditization of spatial data handling technique has progressed, application is experimental unless relevant data are ready for input.

OPEN SOURCE INTERNET GIS FOR REGIONAL ENVIRONMENTAL MANAGEMENT

People in the environmental management community use GIS to organize existing information and communicate that information throughout their organizations. GIS can be used as a strategic tool to automate processes, transform environmental management operations by getting new knowledge, and support decisions that make a profound difference managing our environment. GIS is considered enterprise-central, if, by design, it is part of the overall information technology architecture of the organization. Open source internet GIS can be integrated with most standard corporate systems such as work management, customer service, and reporting systems. Both GIS functionality and data accessing ability can be embedded directly into other agency applications. GIS workflow applications simplify and automate procedures within environmental management operations, resulting in improved efficiency and significant time savings.

Open source internet GIS Google Earth brings to the environmental management community, benefit and value. This value comes from:

- Database-sharing architecture that supports decision-making and daily work tasks.
- Interpretable system solutions integrated workflow and data access.
- Internet mapping solutions support inter-agency collaboration projects.
- Quality control processes ensures accurate, high-quality data.
- Worker-friendly designs increase agency-wide access and application.
- Scalability supports and adapts to growing and evolving IT demand.

THE OUT-REACH WEB GIS FOR REGIONAL ENVIRONMENTAL MANAGERS

The out-reach web GIS for naive users is at http://www.pinpresearch.webs.com/ (Figs. 2 and 3). This website I was created for upgrade of spatial data communication in support of improved data integration in PINP management to encourage the adoption of spatial data and models by naive GIS users. This website is designed to solve the problem that besets regional environmental managers wishing to increase return on investment in GIS by extending/widening the agency GIS community by including the naive users but without further significant investment. In blog mode, it represents a repository for information and links to spatial data and information visualization, videos, free GIS software, environment modelling tools, web application and the link.

It supports exploration of the relationships between information visualization and complex systems in ways that are designed to engage the interest of the regional environmental managers, and thus to increase the tendency for the GIS to be referred to more often. This website provides critical tools for increasing success and efficiency. Accordingly, an executive is presented with a high volume of complex data in analysed form, as well as free environment modelling tools and tutorials. Environmental modelling (EM) is a platform designed to facilitate rigorous spatial analysis and modelling, create web based GIS, Video streaming for natural conservation and some free tools for data management, thus may emerge a total GIS solution for natural park managers. The result can be used at consensus building meetings among stakeholders. The Website helps PINP activity by being a new and central tool to:

- Organize your information and knowledge.
- Make informed decisions.
- Improve communication.
- Increase efficiency.
- Share your knowledge with others.
- Without cost and travel, learn GIS at leisure.
- Access to environment management tools and tutorial.

The website provides tools to question, interpret and visualize data. Simply put, the GIS technology deployed gives executives cutting-edge technology to make more-informed decisions. PINP benefits from this website which becomes a transforming technology by allowing businesses to view and analyse data from a geographic perspective. This website integrates business strategy and organizes necessary information for the business needs of decision makers. In addition, it can be adopted as a tool to streamline workflow processes.

This website deploys a number of example applications designed in this research to demonstrate the use of these platforms to visualize and communicate Google map, Arc Explorer, and other free GIS software and application tools for modelling and environment analysis of in-house data for the natural resource management system. Also served is GIS outreach and education and "crowd" knowledge-gathering. Arc Explorer is a freely available lightweight GIS data viewer that lets you perform a variety of basic GIS functions. With Arc Explorer, you can display, query, and retrieve data. It can be used as a stand-alone application with local data sets, or as a client for internet data and map servers and Arc Explorer free web service editing purposes. This webpage serves as a demonstration of new open source internet GIS to help managers in decision making and sharing data with other organizations (Köbben 2008). This also serves to demonstrate how to provide a map-based interface to other databases of information such as Wikipedia articles.

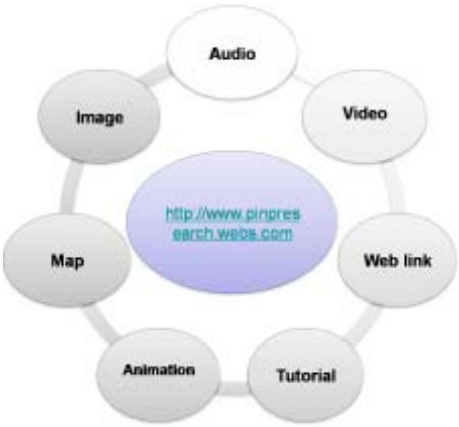

Fig. 2: The PINP GIS website: Conceptual representation.

This research is designed to develop several examples of how these platforms can be used to quickly build rich browse and index tools for display of imagery. By providing coverage and information for multiple instruments, the user is given the ability to directly browse another GIS database website and video for animal habitat mapping and conservation, and in its geospatial context, to find or offer quick links to both the raw and processed source data. These, examples show how website interfaces can dramatically simplify much of the environmental work involved in selecting and obtaining data for GIS analysis.

This research has been developing and adding a number of extensions for easing further data editing, cleaning, capture, and for organization of these as website entities to bring decision-making tools to the naive users. This website also involves components relevant to the works like reprocessing of the base map imagery; development of API extensions to provide access to that imagery and other GIS features from within users' websites; and development of KML (Keyhole Markup Language) content to provide access to

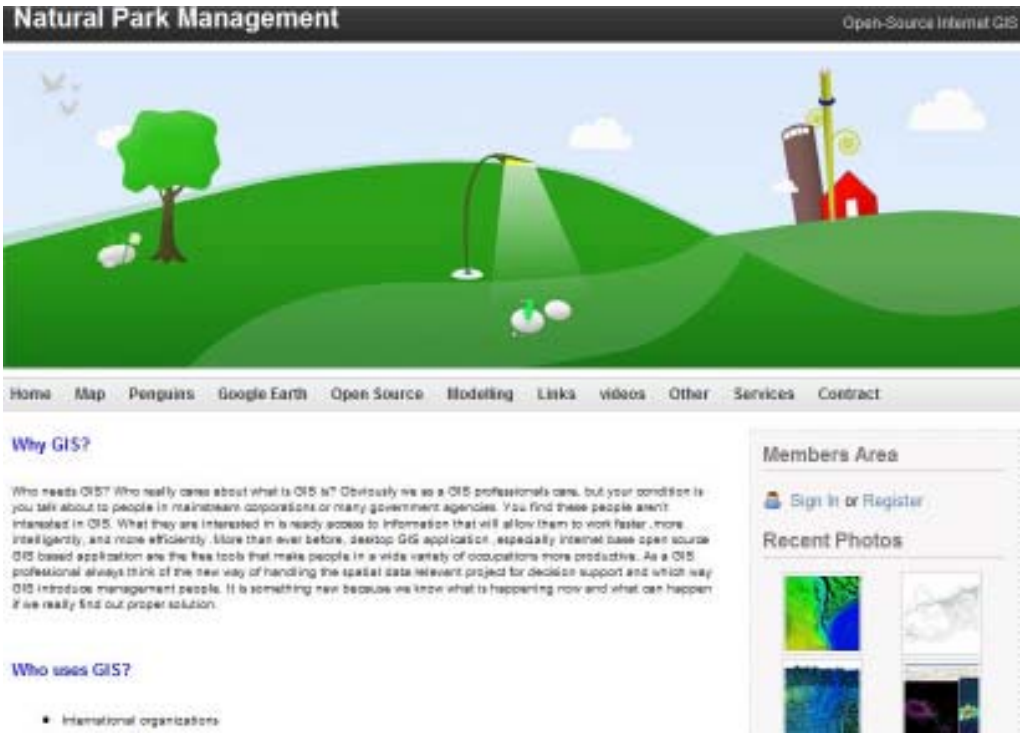

Fig. 3: Example of PINP research website: Display from query (http://www.pinpresearch.webs.com/)

that imagery and supporting data from within 3D geo browsers such as Google Earth. Also compatible is a spreadsheet (attribute data) to generate a set of place marks in Google Earth and Maps (Kennedy 2009).

As additional data become available and we are able to process it, application of the outcome of this research expands the list of base maps. Anyone can find Victorian free data locations after finding this website. In addition, its role in creating the video penguin movement tracking area is worth mentioning. This video is an excellent resource for penguin habitat mapping.

Making decisions based on geography is basic to human thinking. Where do we go, what will it be like, and what shall we do when we get there?

This website provides free and open source GIS software applications, the PINP map, geospatial data and shape files, tutorials and resources for not only managers but also students, GIS professionals, geographers and non geographers, cartographers and non cartographers alike.

This research also provides access to free satellite and aerial photography imagery and maps, Google Earth and Maps, mash-ups, resources and tools, topographic maps, and GPS applications, data and software. Some of the main categories and recent additions are listed below. Users will be invited to explore the spatial element of data that is becoming more freely available.

PINP RESEARCH WEBSITE

PINP Atlas is a MA research project that has the ambitious goal of being a useful resource for the various audiences that make up the management constituency of the Phillip Island Coastal Zone. From this website, everyone can enjoy GIS training. This research is a depot for traditional and digital information, which can be used to inform decision-making relating to the PINP. We provide background information for different GIS systems, access to interactive mapping, online geospatial analysis tools, videos, open source GIS, free environment analysis tools, Modelling, 3D visualization and direct download access to various planning and natural resource data sets relating to PINP management.

PINP RESEARCH WEBSITE FEEDBACK POTENTIAL

This research website is designed to present an analysis of feasible options and to make recommendations for future directions for the PINP GIS data management. In reflecting on the opportunities, GIS systems could provide the PINP. GIS team identified an opportunity for the management decision making to adopt a proactive approach and show leadership through the establishment of an appropriate GIS system.

WHY WE NEED TO OPEN SOURCE GIS GOOGLE EARTH

GIS is an excellent tool in providing spatially referenced information. Google Earth has made it possible for naive users to get the very basic information about a location, how to reach it, and how to find the shortest path to another location.

Introduction of GIS at a grass roots level is still a far goal. Delivering the knowledge and understanding of GIS to a critical mass of PINP users of relative value of licenced, open source and other stakeholder staff will use and implementation of GIS to get maximum benefit by the use of this technology.

In the management, the open source GIS provides efficient, interactive and user-friendly interfaces to the general public. As the ultimate stakeholder, they appreciate:

- Ease of use (visualization)
- User-friendly interface (interactivity)
- Platform independent (any operating system)
- Good response time (client's perspective)
- Maximum throughput (system's perspective)

RESEARCH RESULTS

Decision support systems evolve to suit the demands placed upon them, but the evolution can be constrained if multilateral decision making is called for by groups that have not maintained data that serve such wider purposes. However, in theory, modern ICT offers mitigation in these terms. To bring theory to practice it is necessary to exemplify utility. Our project is designed to exemplify the utility of maintaining stakeholder access to a website that provides scenario modelling functions using the new tools devised to service the naive GIS user. If the exemplifications are accepted, the multilateral decision making called for by integrated resource management policy can be routinely supported by all stakeholder agents who must access and maintain the data. This research has transferred the spatial data used in managing the PINP to a coherent and maintainable spatial database and brought it to web-based access, and demonstrated the routine data and information flow paths that would allow naive user to take part in the scenario modelling that must come before decision making. The PINP should now be able to minimise conflict between stakeholders and maximise effectiveness in resource inventory and maintenance.

ACKNOWLEDGEMENTS

The first author (NB) would like to express her heartfelt admiration to her supervisors from the Monash University School of Geography and Environment Science, Associate Professor Jim Peterson, Dr. Xuan Zhu and Dr. Shobhit Chandra. They gave the chance as well as freedom to pursue this study. NB is especially thankful to Associate Professor, Jim Peterson and fellow postgraduate candidates.

NB would like to thank Bass Coast Shire Council staff, in general, and the GIS and data system coordinator Paul Lennox in particular, for advice and constructive criticism. Thanks are also due to PINP Ranger Jon Fallaw and his supervisor Dr. Roz Jessop for the use of their PINP data. Thanks are also extended to the Penguin Foundation for favourable support and helpful association with the above mention people. Aerial photos were kindly provided by the Bass Coast Shire Council and the PINP, along with digital data access to the LiDAR data, and elevation data sets via the Department of Sustainable Development (DSE), Victorian Spatial Data Infrastructure (SDI) custodians.

REFERENCES

Douglas, D.N. 2004. Developing Spatial Data Infrastructure: The SDI Cookbook. Version 2.0, 25 January.

Goodchild, M.F. 2007. Citizens as Voluntary Sensors: Spatial Data Infrastructure in the World of Web 2.0, National Centre for Geographic Information and Analysis and Department of Geography, University of California, Santa Barbara, CA 93106-4060, USA.

Kennedy, H. 2009. Introduction to 3D Data, Modelling with ArcGIS 3Danalyst and Google Earth, Printed in the USA.

Köbben, 2008. A Short Introduction to Geo-Web Services, International Institute for Geo-Information Science and Erath Observation (ITC), The Netherlands.

Lin, H. and Batty, M. 2009. Virtual Geographic Environments. Science Press, Beijing.

OGC KML Standard (updated: 19/08/2008) http://www.opengeospatial.org/standards/kml/ (accessed: 04/08/2008).

Park Victoria. (http://www.geospatialworld.net).

Parks Victoria 1998. Mornington Peninsula National Park and Arthurs State Park, Management Plan, Parks Victoria, Melbourne.

PINP 2004. Phillip Island Nature Park Business Plan 2004/2005, Annual Report, Phillip Island, Phillip Island Nature Park.

PINP 2020. Strategic plan (http://www.penguins.org.au/images/stories/2020%20strategic%20plan.pdf)

PINP Strategic Plan 2006. 2011(http://www.penguins.org.au/images/stories/pdf/strategicplan%20final%20nov05.pdf)

Rajabifard, A. (Eds). 2007. Toward a Spatial Enabled Society, The Centre for Spatial Data Infrastructures and Land Administration, Department of Geometrics, The university of Melbourne, pp. 400

Rajabifard, A., Vaez, S. and Williamson, I. 2007. Facilitating land-sea interface through seamless SDI. Coordinates, 3(10): 14-18

Tai on Chan 1998. The Dynamics of Diffusion of Corporate GIS. M.Phil. Thesis, Department of Geometrics, University of Melbourne.

Wheeler, P.J., Peterson, J.A. and Gordon-Brown, L.N. 2010. Spatial decision-support for integrated coastal zone management (ICZM) in Victoria, Australia: Constraints and opportunities. Journal of Coastal Research, 27(2): 296-317.

Wheeler, P.J. 2011. http://careers.monash.edu.au/assets/docs/round-5-lead-or-follow.pdf including

Wheeler, P.J. and Peterson, J.A. 2005. http://www.arts.monash.edu.au/ges/research/gis/public/wheeler.php