Representation of Modelling Data in Virtual Worlds

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EXTENDED ABSTRACT

In complex environments, modelling illuminates the consequences of our actions or our failure to act. However, the message can be lost through poor communication. Knowledge sharing among scientists, decision-makers and the broader public can be enhanced through presentation in virtual worlds. In a virtual world, modelled environmental change may be merged with semi-realistic representations such that all users can understand and learn from exploration of the modelled environment.

This paper discusses representation options including: the choice of specific, typical, representative or generic vegetation; the combination of vector data with imagery or raster data as components of the surface drape; the options for portrayal of underground data such as depth to water table or its salinity; and the combination of these elements for communication of emerging or planned scenarios. The presentation choices are described in the context of automated creation of virtual worlds from spatial data infrastructure, and the use of these worlds as spaces for collaborative engagement on environmental issues.

The development of this automated process and software for creation of three-dimensional landscape models from two-dimensional spatial data has been described in Stock et al (in press). Briefly, there are two stages of software use: a Builder which is written in Visual Basic and works in the ArcGIS or ArcServer environments (www.esri.com) to create the 3D models; and, a Viewer which is developed from Torque Game Engine (TGE from www.garagegames.com) and allows users to view, explore and collaborate in the virtual world. Together these form SIEVE (Spatial Information Exploration and Visualisation Environment). SIEVE also supports representation of underground layers such as water-table (Figure 1).

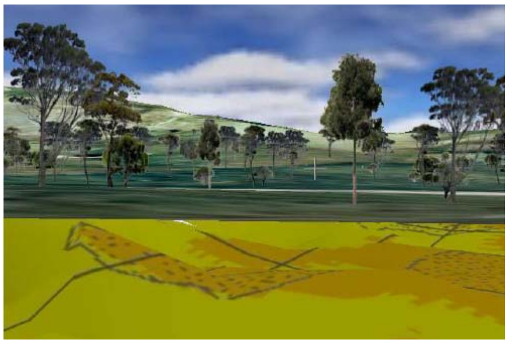

Figure 1. A view of the modelled water table.

A public evaluation of representational options is also reported. The small survey (N=12) supported the importance of foreground detail and the benefits of aerial imagery as a terrain drape. The advantages of combining a standard aerial photo drape with thematic data, the importance of moving beyond wholly generic vegetation, and the ability of people to view a combination of a realistic surface view with an abstract underground view while using surface objects to understand the subsurface scaling were also apparent. Broadly, the more detail and the more options that can be provided the better people will understand the issues and relationships which initiate the modelling process.

1. INTRODUCTION

Recent years have seen a change in emphasis from *planning for people* to *planning with people* (Batty, 2003). In complex situations modelling is an essential component of the planning process since it provides information on the consequences of actions (or not taking any action). When planning with people special care needs to be taken such that non-experts can understand and respond effectively to model outputs. This implies a form of representation which is as natural as possible, i.e. requiring the least specialized knowledge.

Scientific reports can be impenetrable to those unfamiliar with a specialist's language. Even maps have been found to be hard to interpret (Gilmartin & Patton, 1984). More natural is anything that portrays modelled consequences with elements of realism leading to direct interpretation based on world experience, i.e. as the general public understands the world. Of course, not all model outcomes can be represented realistically – we can normally only see underground by digging a hole – but many variables that we do not usually think of as visual do have visual consequences and can be naturally interpreted. Traffic volumes, airborne particle concentrations, the effects of soil salinity or soil saturation and tourism levels can all be interpreted visually. Certainly there remains scope for misinterpretation even through realistic representation. However, there is a *prima facie* case for realistic approaches, backed by the emergence of hardware and software capable of supporting detailed virtual worlds. The literature of visualization usability is summarized by Slocum et al (2001).

Existing software tools for environmental representation, however, tend to be unsuitable for widespread public engagement. Certainly there are both animation and real-time products which have sophisticated options for representation of terrain, natural vegetation, crops and built structures. However they require the three-dimensional landscape models to be precomputed, often requiring substantial labour time, and the combination of scientific data with natural elements is non-trivial. At the same time very few such programs also support multi-user exploration of a common virtual world which we argue is a powerful option for collaborative planning: Leica Titan (gi.leica-geosystems.com) and Skyline (www.skylinesoft.com) are also pursuing this objective. We thus began the research underpinning this paper with three objectives:

- Automated generation of virtual worlds from 2D spatial data as held in geographic information systems (GIS) and spatial data infrastructures (SDI)
- Integration of realistic and scientific visualization
- Availability as a collaborative virtual environment.

The development of an automated process and software for creation of three-dimensional landscape models from two-dimensional spatial data has been described in Stock et al (in press). Briefly, there are two stages of software use: a Builder which is written in Visual Basic and works in the ArcGIS or ArcServer environments (www.esri.com) to create the 3D models; and, a Viewer which is developed from Torque Game Engine (TGE from www.garagegames.com) and allows users to view, explore and collaborate in the virtual world. Together these form SIEVE (Spatial Information Exploration and Visualisation Environment).

In addition to being able to show the world as recorded in spatial data infrastructure, the objective of SIEVE is also to show the output of environmental models. The main model used in the development phase was a catchment analysis toolkit called CAT (Weeks et al, 2005), but the principles apply across any spatially explicit environmental modelling process. A range of decisions were necessary about how to represent the output of these models using both abstract and realistic paradigms. Both implemented and anticipated procedures are discussed below as they relate to: the choice of specific, typical, representative or generic vegetation; the combination of vector data with imagery or raster data as components of the surface drape; the options for portrayal of underground data such as depth to water table; and the combination of these elements for communication of emerging or planned scenarios.

The implemented options were informally evaluated using a survey of students. The collaborative aspect of the SIEVE development is incidental to this paper.

2. TECHNIQUES

2.1 Object Specification

SIEVE landscape models are made up from the terrain and its texture and objects which may sit on, above or below the terrain. 3D objects were created in *3D Studio Max* and exported to the DTS format using a free plugin. DTS objects can be static or animated models which are textured with images. Static objects include trees and buildings. Avatars, wind turbines or kangaroos are examples of animated objects. Trees may be simple billboard objects that are textured with photos of the correct species type. Our object library contains a range of 3D models and images, but procedures for library management are not well integrated as yet.

Figure 2. Specific objects such as the Lexton Hotel give unique locational character.

We consider objects, and their distribution, as being in four main classes:

- Specific: such as an actual identifiable building or tree. For example, the MCG Stadium in Melbourne or the Boab prison tree near Derby WA.
- Typical: individually located objects which are of the correct species (for trees) or building style (for houses) but don't represent each tree or house individually.
- Representative: Similar to typical but not individually placed. May be scattered within a town or forest boundary.
- Generic: randomly located trees or buildings not specific or even necessarily typical to the location.

Figure 3. An example of the use of typical vegetation and buildings.

This is an extension of the geo-typical, geo-specific distinction made by other authors (originally Graf et al, 1994). The more specific objects are, the greater the realism of the landscape model. Storing a 3D model of every object in the world would however be very expensive in terms of data collection, object creation and storage.

A balance between the types was used for prototyping in our chosen case study area. Some specific objects were used for 58 iconic buildings in the town of Lexton in central Victoria (Figure 2), typical objects, such as sheds and windmills were used in paddocks and representative trees were used for vegetation (Figure 3). Where location specific data is lacking, or when the objective is to display a spatial arrangement such as a farming system (Figure 4), generic models can be used.

Figure 4. Generic trees used to illustrate a farming system independent of location

As many environmental process models deal with land use changes, vegetation is particularly important for rural applications. Vegetation placement can be completed manually using high resolution air photos and ancillary information but this method is time consuming and not easily automated. For communicating the visual effects of land use change or environmental processes on a larger scale, representative vegetation can be considered sufficient. Ecological Vegetation Classes (EVC) describe distinct floristic communities across Victoria (*Department of Sustainability and Environment*, 2006). EVC have a wide range of documented attributes, such as the variety of trees that make up the class, the proportions they occur in and approximate heights.

Object placement is controlled by point layers. Object type and whether an object is specific or representative is controlled by the attributes of that point layer. If a GIS point layer for buildings specifies an existing 3D model for type, such as *new_house.dts*, that model will be added to the virtual landscape. If no model is specified, a generic 'tree' is assigned to each point. As availability of 3D models increases, *SIEVE Viewer* landscape models will be populated with more typical and less generic objects.

2.2 Merging Thematic and Image Drapes

As the terrain is to be textured, either with a satellite image or thematic texture, this information must also be resampled in the GIS and written into the terrain file. Aerial images provide an important context for landscape models. Draped over the terrain, they provide users with important local detail.

The user is provided with terrain texturing options of aerial image, thematic, or composite. A composite can be a combination of aerial image, thematic textures, and other GIS layers with grades of transparency (Figure 5). To do this the user selects the layers and levels of transparency they desire in the GIS before running the *Builder* and then chooses the *Export screen as ground texture option*. This choice is made available to allow users to create photo realistic landscape models or to incorporate traditional 2D mapping information.

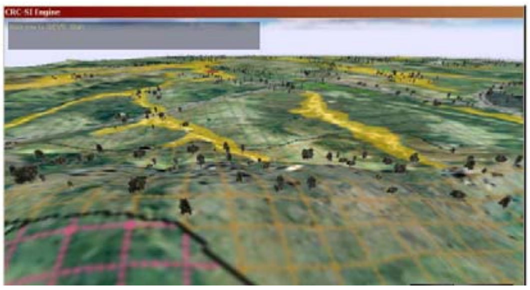

Figure 5. A combination of surface objects, airphoto drape and thematic data.

2.3 Underground Features

Figure 1 (in the abstract) illustrates how the ground can be removed using a foreground clipping plane to reveal sub-surface features. The clipping plane can be moved closer to or further from the viewer using key strokes. In this figure the surface of the water table was computed using the CAT model in combination with a specific revegetation scenario (the matching vegetation is shown above ground). The surface is truly three-dimensional and is coloured by depth and stippled by salinity level. As the user can fly around and can still recognize particular surface features the interpretation remains more natural than a map. It is also possible to move the camera to a point in between the terrain surface and a sub-surface layer. This provides a more complete view of the subsurface but makes orientation more difficult.

2.4 Scenario Presentation

Scenarios include actions and consequences. Visual representation of both can be a powerful and effective stimulus enhancing understanding of the relationship between action and outcome leading to a choice of preferred scenario. A simple example is a series of scenarios developed for the salinity prone catchment on Betbet in north central Victoria. The scenarios each involved different levels of revegetation of the catchment and the consequences related primarily to the effect of these vegetation options on the water table and hence on the salinity problem.

3. EVALUATION

Preliminary testing and feedback on a range of presentation options were undertaken. An environmental psychology class studying human/environment interactions and perceptions of environments was used. The sample (N=12) was not sufficient to provide statistically significant findings and the range of presentation options tested was not exhaustive.

The group was shown real-time SIEVE environments, controlled by an operator, and static visualisations. They were asked to individually state preferences, answer questions and give general comments on the visualisations with relation to display interpretation and communication of information.

The first question showed one ground level and one elevated visualisation (Figure 6) from both the Digital Songlines (Pumpa et al, 2006) virtual environments and SIEVE. The group was asked to identify which figure told them more about the landscape. Digital Songlines was selected for comparison as it also provides collaborative virtual environments of rural Australian landscapes using the Torque Game Engine (www.garagegames.com). Digital Songlines uses many more vegetation objects than *SIEVE* at ground level and does not use aerial imagery to texture the terrain.

At ground level, A (*Digital Songlines*) was slightly favoured, 7 to 5. Those who selected A stated: ‘vegetation looks more real in A, B looks more computer simulated’, ‘more elements, variety of trees and grasses’, ‘looks more like a real landscape’ and ‘too many dark patches (shadow?) in B’. Reasons given for selecting B (*SIEVE*) included: ‘prefer mini map and compass’, ‘appears more realistic’, ‘landmark (house) provides more spatial information’ and ‘lively landscape with greens, nature and man-made buildings’. For the

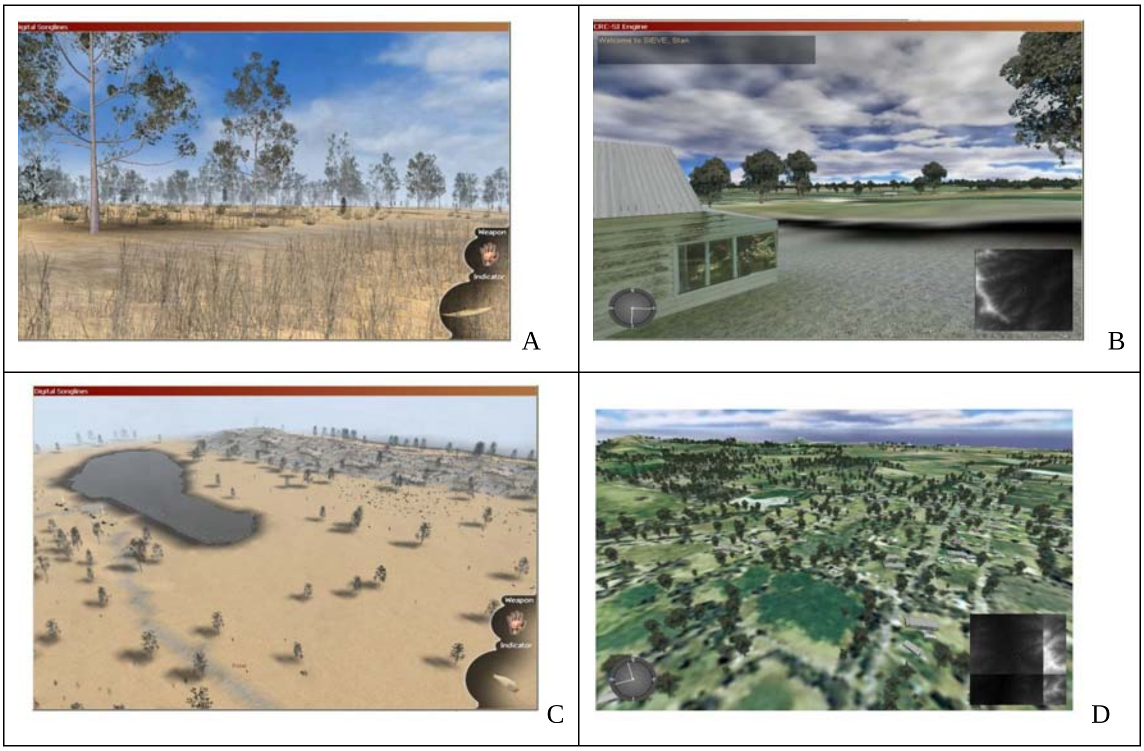

Figure 6. Stimuli for evaluation of (A) foreground detail through repeated vegetation elements and (B) geospecific texturing in both ground level and aerial views (C) and (D).

elevated visualisations, 11 of the 12 group members selected B. Comments included: ‘showed more detail and variations in the landscape’, ‘orients viewer more effectively with more natural features observable but with less detail’, ‘more real-looking’, ‘more depth’ and ‘clearer idea of what the landscape is’.

One group member commented of the elevated visualisations, that although *SIEVE* told them more about the landscape, in *Digital Songlines*, the ‘sparse foliage made it a little easier to understand’. The overwhelming preference for *SIEVE* at the elevated level shows that the group found the aerial imagery valuable to convey more information about the landscape. The comments in general indicated that the visualisation found to look more ‘realistic’, gave more information about the landscape. Based on this outcome the ideal appears to be to combine the ability to apply aerial imagery to the landscape with the ability to replicate simple vegetation (such as grasses) when viewing from near ground level.

The next question asked which, of three visualisations, tells more about land use distribution. The group was shown a legend of a thematic land use layer (Figure 7(a)), then an aerial image texture, the same image with semi-transparent land use overlay and lastly the thematic layer itself. The three images were shown in 2D (Figure 7(b)) and then as surface textures in oblique aerial views using *SIEVE* (Figure 7(c)).

In both 2D and 3D, most of the group selected the composite image (in the centre) as the most informative about land use distribution. Only one person selected the thematic only view for the 2D textures. This image is the closest representation to a traditional map shown to the group. Being selected by only one person suggests that shifts in media such as the incorporation of aerial imagery is favoured by users. In 3D four group members selected the thematic view indicating that the added dimension also increases the information conveyed.

The group were then shown three visualisations from *SIEVE* with a watertable layer visible below the surface (similar to Figure 1) and asked to identify the shallow areas and the depth of the deepest areas. The entire group correctly identified which areas were closest to the surface. With respect to the depth of the deepest areas, three group members were unsure, eight estimated 5m or less while one responded 100m (the areas in question were approx. 40-60m below the surface). Reasoning for estimates included using the colours and comparison with trees, buildings and land surface.

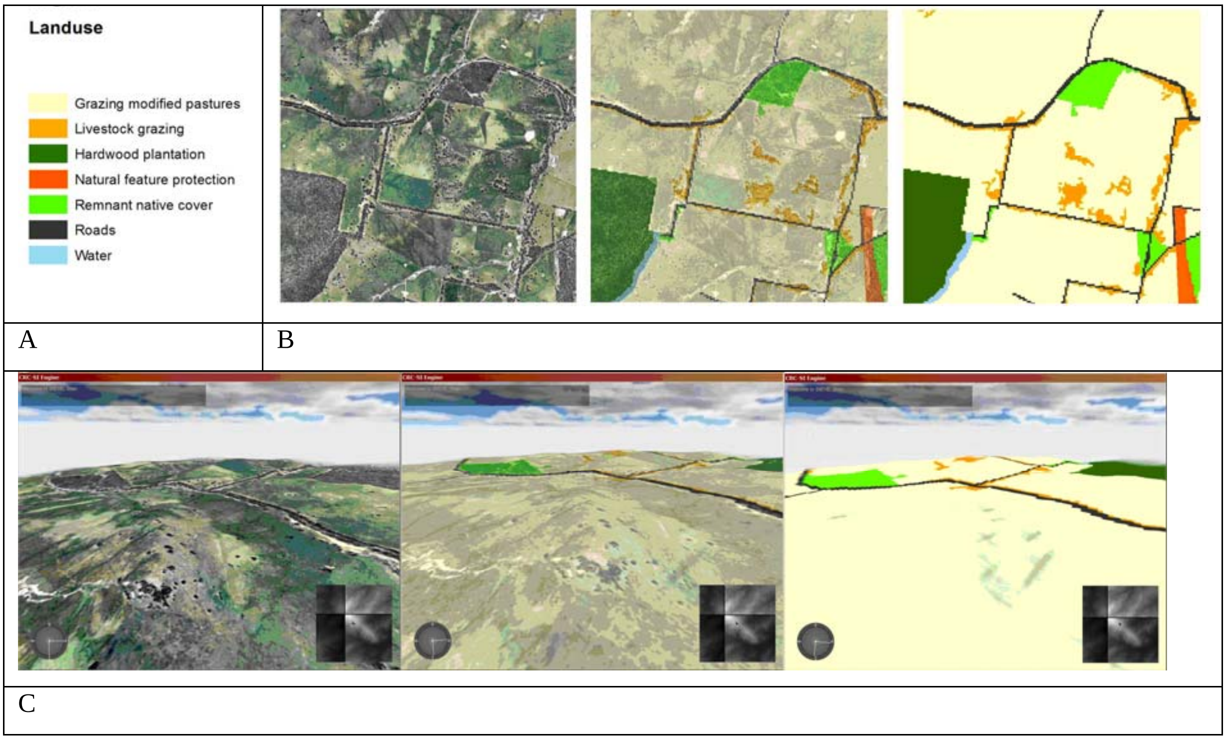

Figure 7. The land use legend (A), plan views (B) and oblique aerial views (C)

It was promising that all users could tell that the yellow areas were closest to the surface. This shows that the group could interpret subsurface information relative to the terrain in *SIEVE*. The mechanisms the group used to guess the depth of the water table showed a capability to compare the watertable relative to other objects and the terrain. The range of depth estimates and uncertainly of some group members suggest that quantitative measuring tools might be needed to make accurate assessments of distances in the subsurface. Once again, this may be clearer if the group were given a chance to interact directly with *SIEVE*. If they could 'fly' below the surface themselves and gain different perspectives, their estimates might improve.

The final question asked the group to select the visualisation that gave more information about vegetation distribution. Two sets of images were shown, one image in each set had the same tree object at every point (randomly scaled and rotated), and one had a variety of vegetation, including understorey (Figure 8). Ten and then eight of the twelve group members selected the images with greater vegetation variety, giving as reasons: 'more detail', 'visualisations involving same species of trees (homogenous vegetation), appears unrealistic and oversimplified', 'shows vegetation that may not be seen behind other larger vegetation'.

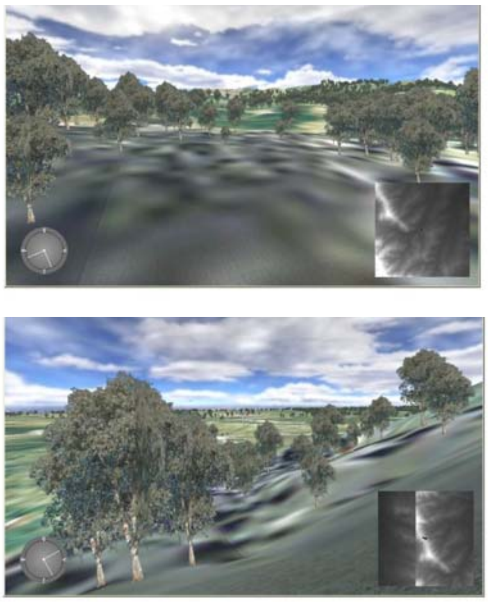

Figure 8: Comparison of generic (top) and typical (bottom) vegetation visualisations.

Overall the group preferred the more diverse vegetation and appreciated the variation, rather than being shown just one species of tree. This suggests that efforts in generating more than simple generic objects are worthwhile in terms of information communication. The additional cost in moving to representative or specific landscape objects may be justified in particular circumstances. Clearly the greater the degree to which higher level objects can be part of the automated generation of virtual worlds, the better.

4. DISCUSSION

A transition to more participatory planning requires development of landscape visualisation tools that are designed to suit broad non-specialist audiences. Along with the shift away from traditional representations of scientific data comes a need to understand which aspects of visual information about our landscape are of importance to audiences. Our preliminary survey of useability of the representational options showed that:

- a combination of a thematic layer and aerial image is found to give more information about land use than either on its own,
- at elevation, satellite imagery is perceived to give more information about the landscape than just thematic information,
- in general, the more 'realistic' a visualisation the more information it is perceived to give about the landscape,
- a visualisation with multiple vegetation species is found to give more information about vegetation distribution than one with a sole species,
- at ground level, detailed foreground objects such as grasses are considered to give more information about the landscape than draped satellite imagery alone,
- users can interpret subsurface information relative to the surface in a virtual environment and make estimates about its form using known objects above the surface.

Future research should pose similar questions to users who could explore virtual environments themselves to address issues of interactivity preferences as well as representational ones. Additionally, the same images and questions could be demonstrated to a much larger group, possibly over the Internet, to gain statistically significant feedback.

5. CONCLUSION

The representation techniques introduced here cover only a small part of the range of possibilities within the virtual world. We have barely touched urban infrastructure, not explored fire modelling or erosion in the landscape context. Our evaluation experiment was not definitive as numbers were low and the range of options incomplete. Nevertheless, insights were gained which can inform the next stage of development. The driving objective will remain natural representation of modelling outcomes supporting planning with people.

6. REFERENCES

Batty M, 2003, Planning support systems: technologies that are driving planning, in *Planning Support Systems in Practice* Eds S Geertman, J Stillwell, Springer, Berlin. v–viii

Department of Sustainability and Environment (2006) Ecological Vegetation Class (EVC) Benchmarks for each Bioregion. http://www.dse.vic.gov.au/dse. Accessed on: 01/6/2006.

Gilmartin, P. P. and J. C. Patton. 1984. Comparing the sexes on spatial abilities: Map-use skills. *Annals, Association of American Geographers* 74(4): 605-619.

Graf, K. C., Suter, M., Hagger, J., Meier, E., Meuret, P. and Nuesch, D. (1994) Perspective terrain visualization - a fusion of remote sensing, GIS and computer graphics. *Computers and Graphics.*18: 795-802.

Pumpa, M.R., Wyeld, T.G. and Adkins, B.A. (2006) Performing Traditional Knowledge using a Game Engine: Communicating and Sharing Australian Aboriginal Knowledge Practices. In *Proceedings Sixth International Conference on Advanced Learning Technologies (ICALT'06)*, Kerkrade, The Netherlands, pp 1-5.

Slocum, T. A., Blok, C., Jiang, B., Koussoulakou, A., Montello, D. R., Fuhrmann, S. and Hedley, N. R. (2001) Cognitive and Usability Issues in Geovisualization, *Cartography and Geographic Information Science*, 28, 61-75.

Stock, C., Bishop, I.D., O'Connor, A. Chen, T. C., Pettit, C.J. and Aurambout, J-P (in press) SIEVE: collaborative decision-making in an immersive online environment, *Cartography and Geographic Information Science***.**

Weeks, A., Beverly, C., Christy, B. and McLean, T. (2005) Biophysical Approach To Predict Salt And Water Loads To Upland REALM Nodes Of Victorian Catchments, MODSIM 2005 International Congress on Modelling and Simulation., Melbourne, December 2005, pp. 2776-2782.

7. AKNOWLEDGEMENT

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