Spatial Modelling in Decision Support for Land-Use Planning: a Demonstration from the Lal Lal Catchment, Victoria, Australia

IAN ALLAN and JIM PETERSON, *Monash University, Australia*

Abstract
The outcomes of selected, contested development permit appraisals in a Victorian water catchment show that implications regarding the development status of other land parcels were not examined during negotiation and/or appeal. Given access to an adequate spatial data base, Geographical Information System (GIS) technology can be used to model such implications rapidly enough to be useful in decision support, thereby significantly widening the common ground that can be sought while seeking resolution to land-use planning conflicts.

KEY WORDS *GIS modelling, conflict resolution, catchment management, land-use planning*

Introduction

Managers of Victorian reservoirs, especially in rural areas, must plan to meet the costs of preventing and coping with water quality decline. Fortunately for them, under sections 57 and 52 of Victoria's *Planning and Environment Act* (Victorian Government, 1987) they can exercise planning power (under their standing as planning referral authorities) during development permit appraisal. Further water quality protection requirements are officially imposed under the *Soil Conservation and Land Utilisation Act* (Victorian Government, 1958) and the *Land Conservation Act* (Victorian Government, 1970a) and, more recently, the *Water Act* (Victorian Government, 1989b) and various guidelines, notably those published by the Ministry for Planning and Environment (1987). The nature of water quality protection provided for in these acts is reflected in the water quality protection rules that, for instance, appear as part of administering shire/local government planning schemes. These rules include those designed to control proliferation of septic tanks.

Shire/local government councils, as administrators of local government planning schemes that must be created under State Government guidelines (for example Victorian Government 1958, 1970a, 1970b, 1973, 1978a, 1978b, 1987, 1989a, 1989b), are inclined to encourage a certain amount of closer settlement. Several motivations can be referred to. For instance, some farms consist of many titles as a legacy of the 'ghosting' of gold-rush townships (Bates 1978). If each title is perceived by bankers as having development potential, constituent titles of a farm can be mortgaged separately. Because mortgagable value of 'developable titles' is about double that of agricultural land (Zala, 1996, pers. comm.), each refusal to grant development

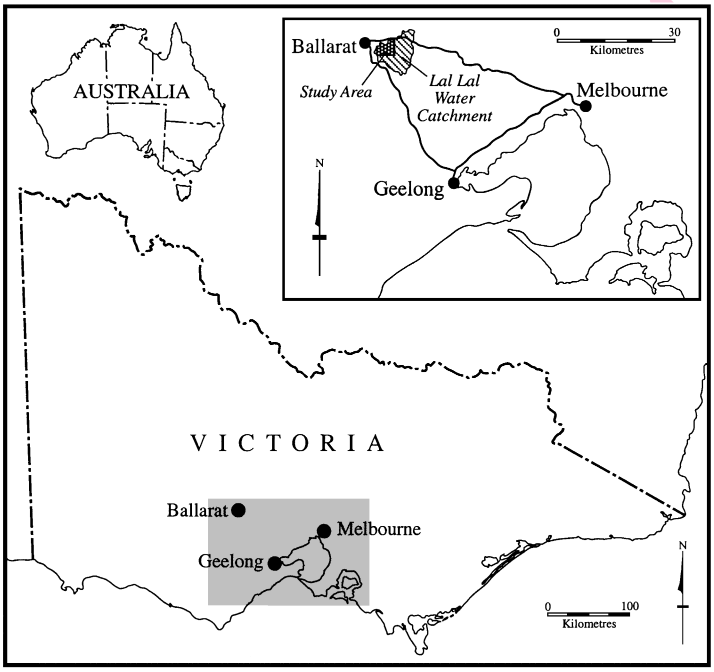

Figure 1 The Lal Lal water catchment is within commuting distance from the three major employment centres of Melbourne (the capital city of Victoria), Ballarat and Geelong. The latter two cities draw water from the Lal Lal reservoir. Commuting routes between the three cities are shown.

permission has significant potential to affect levels of business, land values, and rates.

In such situations, the scene is set for land-use conflict in those planning zones where land owners see a need to add dwellings (including (a) septic tank(s)) to their farms, or where there is potential for land value appreciation through sub-division into hobby farms. The conflict emerges when attempts to meet these needs are seen to compromise water quality protection.

We have previously (Allan and Peterson, 1993) argued that:

1. the Lal Lal water catchment (Figure 1) illustrates this potential for land-use conflict;
2. the Responsible Authority for the catchment (formerly the Shire of Buninyong but now the Shire of Moorabool) can have its planning rules incorporated in a Geographical Information System (GIS) and the spatial implications of these rules can be map modelled at the land parcel level of spatial resolution, and
3. even when the rules are applied, the water authority (formerly the West Moorabool Water Board but now Central Highlands Water) routinely opposes development permit applications that include an additional septic tank installation, thereby giving decision-making power to the Administrative Appeals Tribunal (AAT) or to negotiators.

At AAT appeal, instead of reference to the clearly-defined (Shire) rules about development potential of land parcels or portions of land parcels, decisions are made in 'equity and good conscience and [on] the substantial merits of the case without regard to technicalities and legal forms' (Victorian Government 1980, section 25).

Thus, at appeal, and case by case, the nature of previous decisions, and the planning rules, are somewhat set aside, in the interests of allowing administrative procedures to evolve to meet changing times. This recognises a traditional and long-accepted view that well-considered precedents are not always universally sensible, and that no set of rules can be good enough to remove the need for some discretion and common sense in deciding particular cases. Strictly speaking, therefore, AAT decisions are not to be regarded as precedents, because if they were, the status of Shire planning rules would be unclear.

Appeals are expensive for all parties involved, and are resorted to only when an interested party is aggrieved. Thus, at least one party to a dispute seeks a decision that for them will be fairer than the one proposed by the other party to the dispute. In rural catchments such as that of the Lal Lal reservoir, the water harvesting authority always seeks an outcome that will protect water quality well enough to save having to build water treatment works. There is therefore a tendency for opposition to septic tank proliferation to evolve as Water Authority policy.

Whichever party instigates the appeal process, land-holders will usually find that, in contrast to the rules that govern local government development permit appraisal before the intervention of the referral authority, outcomes are not easy to predict. Thus, an equity issue commonly arises: surely land-holders in the same district should be subject to the same rules? The problem they will see is that often a new variation in the planning rules is implied by the outcome of each appeal/negotiation, and although the procedures do not provide precedent, the implied variations can be an obvious information input for any future appeals.

It is demonstrated here that the cost, hitherto prohibitive, of testing the implications of the putative rule changes implied in each decision, can be reduced by using GIS. In aid of decision support, the status of land parcels in these terms can be logged, monitored and modelled, all, if necessary, in 'real time'.

Exemplification from the Lal Lal water catchment, Victoria

The above argument is tested by examination of the outcome of four objections made between March 1990 and January 1991 by West Moorabool Water Board to the granting of permits allowing septic tank installation upstream of the Lal Lal reservoir. The land parcels concerned lie in the uppermost part of the Lal Lal catchment in an area subject to planning rules under a single planning zone, the Agricultural A portion of Chapter 1 of the Shire of Buninyong Planning Scheme. This, our study area, extends over almost 31 km^2.

The Shire of Buninyong Planning Scheme specifies water quality protection rules, and the manner of applying them (Figure 2).

The rules recognise scientific findings indicating that:

1. micro-biological breakdown during soil absorption of septic tank effluent is the waste water decontamination process relied on in unsewered areas;
2. some soils absorb septic tank output more effectively than do others;
3. water quality protection buffers of arbitrary width will be imposed until experiments in developing reproducible quantified methods (for example, Xiang and Stretton, 1996) produce acceptable results.

As seen from Figure 2, these findings are used in planning permit application appraisal after they have been translated into (albeit somewhat arbitrary) enforceable rules and embedded in the planning scheme. Thus, for instance, in the Buningyong Shire, no land parcel was considered suitable as a site for septic tank installation unless it included a portion

1. further than 100 m from a stream, and
2. on a soil type deemed suitable according to the Soil Conservation Authority Land Capability map for septic tank effluent absorption (Jeffrey, 1980), and
3. with 0.4 ha (1 acre) available to act as an effluent decontamination zone, and down-slope of the proposed dwelling/septic tank site.

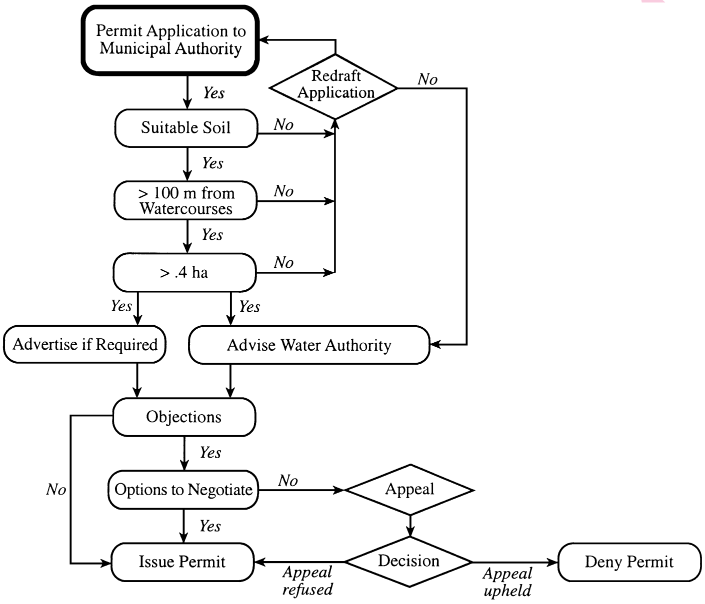

Figure 2 The Shire of Buningyong septic tank installation application permit appraisal path according to the water quality protection rules and scope for objection to applications of them.

These rules are readily map-modelled using a GIS. Rule 1 can be reproduced by creating a 100 m buffer around water features; rule 2 can be reproduced by creating a map of 'unsuitable soils', and rule 3 by relating the stream buffer and soil zones of constraint to the cadastre. Data sets for the necessary digital spatial data base are detailed in Table I, and the derived water quality protection zone according to the Shire rules is presented in Figure 3 together with the distribution of land parcels, dwellings and associated septic tanks. The latter pattern reminds us that many building permits pre-date the formulation and application of the water quality protection rules. Identification of these putatively 'illegal' sites allows prioritising of water quality mitigation works (Allan and Peterson, 1998).

The digital map base and its analysis

Operationally, the State Cadastre, water features from the Victorian topographic data base, and the reinterpreted land systems maps were the most important inputs to this study. Land system boundaries were assembled by interpretation of air photos guided by perusal of the 1:50 000 paper (Land System) map (lacking coordinates) in Jeffrey (1980), followed by ortho-rectification (using PHOTOGIS under ARC INFO). ORTHOPHOTOGIS (again under ARC INFO) was used to create an ortho-photo layer (derived using a DEM) so that the dwelling distribution map could be derived. Ground control points, at least five in each of the fourteen photos, that were used in the ortho-rectification were assembled using a Real-Time-Kinematic (RTK) Global Positioning System (GPS).

The spatial data analysis can be summarised as follows:

1. Using grid analysis techniques
   A. The map of soils unsuitable for development and the 100 m stream buffer map were combined to create a single map of environmental constraints.

Table I The digital spatial data base was assembled from various sources (some now identified as primary data custodians under the State Geospatial Data Policy and Coordination office/policies). All map layers were edited, validated and georeferenced to the quality required for this project.

Map Data Set	Scale	Form for Analysis	Layer Status	Comments
Spot heights	10 cm accuracy	Vector	Primary	Collected using real time kinematic Global Positioning System with 0.01 metre tolerance. Used for digital elevation model generation and orthophoto creation.
Contours	1:25 000	Vector	Primary	10 metre interval. Used for digital elevation model generation
Roads	1:25 000	Vector	Primary	Used as break-line features in digital elevation model creation
Digital Elevation Model (DEM)	Various	Vector	Derived	Created from the spot heights, contours, roads and watercourse layers. Air photos were digitally draped over this layer during the process of orthophoto creation.
Orthophotos	1:15 000	Grid	Primary	Fourteen colour air photographs, photogrammetrically corrected for photographic distortion and joined to be one image (orthophoto).
Existing Development	1:15 000	Vector	Primary	Interpreted from 1993 orthophotos
Land Systems	1:15 000	Grid	Primary	Reinterpreted & photogrammetrically corrected
Effluent Disposal by Soil Absorption	1:15 000	Grid	Derived	Derived from Land Systems map
Watercourse and in stream dams	1:25 000	Grid & Vector	Primary	Survey and Mapping Victoria
100 m stream buffer	1:25 000	Grid	Derived	Derived from Watercourse and in stream dams map
Constraints	1:25 000 and 1:15 000	Grid	Derived	Effluent Disposal by Soil Absorption and 100 m stream buffer overlaid
Titles	1:10 000	Grid & Vector	Primary	Survey and Mapping Victoria
Area of titles affected by constraint		Grid	Derived	Produced by multiplying grid cell constraint and grid cell titles

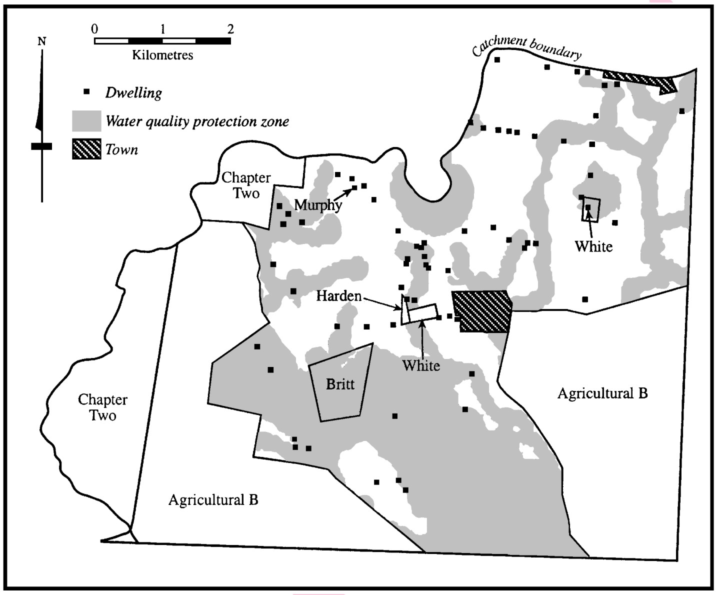

Figure 3 This extract from the (former) Shire of Buningyong Planning Scheme map shows a portion of the Lal Lal catchment boundary, part of (Planning Scheme Chapter One) planning zone 'Agricultural A' and adjacent parts of planning zone 'Agricultural B', together with portion of the catchment covered by another Chapter of the scheme. The water quality protection zone (shaded) as defined by the water quality protection rules (see Figure 2) is shown for the study area. Cadastral overlay gives the distribution of the disputed land parcels (labelled by owner's name).

B. The area of each land parcel, and the area of each parcel affected by the environmental constraint map was then determined. The difference between these two figures gives the developable area.

1 Using vector analysis and presentation functionality:

A. The results from the grid analysis were used as a basis for determining which undeveloped titles had a putative 'developable' status change resulting from the most recent planning decision, the query taking the following pseudo-code form:

select all titles within the Agricultural A zone that are presently undeveloped and have an area unaffected by constraints that is greater than or equal to that implied as acceptable by the previous planning decision and less than or equal to that implied as acceptable by the present planning decision.

This same technique could easily be used to determine which existing developments act to form a 'precedent' for a proposed development, and also which existing developments do not conform to the most recent planning decision.

Implied scope for land parcel status change in the study area, in terms of the septic tank siting rules, was derived in chronological order for each of the four conflicts under examination. Starting with the septic tank compatibility status pattern under the planning scheme rules (Figure 3), each parcel was reclassified according to each of the series of implied rule changes. Of the 345 land parcels in the study area, 213 had no change in status, 51 changed once, 69 twice, and 12 three times (Figure 4) if the implied rule changes had had to be adopted.

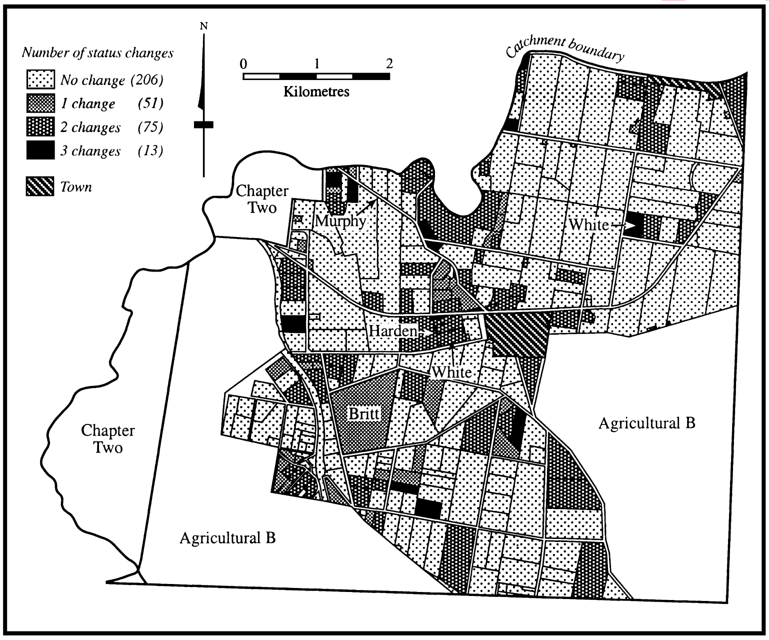

Figure 4 Distribution of septic tank compatibility status changes for the study area as implied by the series of land-use conflict outcomes examined. The parcels to which the disputes apply (1: Wilkinson 1989, 2: Shire of Buninyong 1990, 3: Shire of Buninyong 1991a, 4: Shire of Buninyong 1991b) are also shown.

Because the land parcel status changes discussed here are implied rather than imposed, this mapping amounts to scenario modelling. Thus it is demonstrated that the spatial implications of proposed changes to planning rules can be modelled. The scope is revealed for all parties in land-use conflict to seek spatial consistency in outcomes by referring to the same digital spatial data base using scenario modelling, and on a catchment-wide basis if the necessary digital spatial data base has been built.

Discussion

The diffusion of digital spatial data handling can be followed by adoption of GIS for:

1. planning permit application appraisal, and
2. land parcel status scenario modelling in preparation for and during appeal procedures.

Thus 'real time' permit appraisal becomes possible at LGA planning department counters, and while briefing learned counsel, thus helping to uphold respect for local government planning schemes among ratepayers.

The analyses made for this modelling were carried out in just a few minutes once the digital map data had been prepared. Deployment of this process with a more powerful (but nevertheless portable) computer would yield 'real time' modelling adequate for use at public meetings.

Implementation of the approach we have adopted would enable applications and appeals to be examined on an area-wide basis in what Harris (1991) would describe as a 'planning support' method. Thus the cumulative effect of certain decision types could be assessed in ways that might replace incremental decision making, the latter constituting what amounts to an uncontrolled experiment in land-use planning.

The use of GIS to focus decision-maker attention on the most environmentally sensitive land (Allan, 1996; Allan and Peterson 1998; Berry, 1993, 193–198), and to facilitate greater public participation in the planning process (Allan, 1996; Bosworth and Donovan, 1998, Walker *et al*., 1998) is not new, but neither is it routine. However, when LGA data bases are able to support consistently the kind of queries we have made in this study, some new practices in catchment and local government administration can evolve in ways that would open the way to greater public acceptance and participation in land use and related environmental quality maintenance planning activity.

Conclusions

In summary:

1. The land-use conflict in the Lal Lal water catchment is on-going so long as the Shire and the water industry hold different views about ways to protect water quality.
2. So far, solutions are only forthcoming on a land parcel by land parcel basis after expensive litigation and/or negotiation, as typified by the examples used in this paper.
3. The Lal Lal catchment Water Authority sought to achieve water quality protection by preventing developments that lacked trunk sewerage, even though application of the clear water quality protection rules in the Moorabool Shire Planning Scheme (and the clear directions in the Victorian planning guidelines) would have allowed approval.
4. Conflict has been resolved on a land parcel by land parcel basis, without regard to spatial consistency in outcome.
5. Contending parties can expect to have difficulty in predicting the outcome of future AAT hearings.
6. The outcome of a planning decision can rest easier with parties if it is seen by them to be consistent with previous planning decisions, and does not carry with it the potential to change the spirit of local government planning regulations at some time in the future, be that within an arbitrated forum, or within the LGA planning office.
7. In that the GIS software and hardware necessary for real time modelling are now readily available, public participation in debates about changing the planning rules in these and other terms could be conducted at public meetings. Spatial data bases built well enough to support variable width stream buffers modelling, would allow for establishment of stream buffer rules that are more sensitive (for example, Liu *et al*., 1998) to the landscape processes than are rules that feature buffers of fixed width.
8. One desirable result of such application of GIS would be that catchment-wide approaches to environmental management could be promoted while parties in conflict over proposed land-use changes can concentrate on map models rather than arguing from set positions based on a range of, often incompatible mental maps (Morris, 1974; Gould and White, 1974).

Correspondence: Dr Jim Peterson, School of Geography and Environmental Science, Monash University, Wellington Road, Clayton, Vic. 3168, Australia.
E-mail: Jim.Peterson@arts.monash.edu.au

ACKNOWLEDGMENTS
The authors gratefully acknowledge the financial support of the following organisations: Central Highlands Water, Australian Research Council, Victorian Department of Natural Resources and Environment, and State Data Centre Ballarat. We are also grateful to Ms Tannetje Bryant for her comments on an earlier version of this paper, and to the two anonymous referees.

REFERENCES

Allan, I.A. 1996: Towards land use conflict resolution through spatially consistent participatory scenario modelling. Unpublished MA thesis, Department of Geography and Environmental Science, Monash University, Australia.
Allan, I.A. and Peterson, J.A., 1993: The application of spatial data processing to land use conflict resolution in the Lal Lal Water Catchment of the Ballarat Growth Corridor; a case study from Chapter One of the Buninyong Planning Scheme, *Australian Geographer* 24, 76–88.
Allan, I.A. and Peterson, J.A., 1998: Site selection for post-facto water quality protection works: targeting the 'Dirtiest Dozen', *Asian Journal of Environmental Management* 6, 105–113.
Bates, W., 1978: *Lucky City: The First Generation at Ballarat 1851–1901*. Melbourne University Press, Melbourne.
Berry, J.K., 1993: B*eyond Mapping: Concepts, Algorithms and Issues in GIS*. GIS World Books, Fort Collins.
Bosworth, M. and Donovan, J., 1998: A Mapmaker's Dream: Public Involvement Applications Utilization of

GIS, *National Center for Geographic Information and Analysis (NGCIA) Specialist Meeting on 'Empowerment, Marginalization, and Public Participation GIS'*, http://www.ncgia.ucsb.edu/varenius/ppgis/papers/index.html

Gould, P. and White, R., 1974: *Mental Maps*, Penguin Books Limited.

Harris, B., 1991, Planning technologies and planning theories. Paper presented to the joint conference of the Association of European Schools of Planning and the Association of Collegiate Schools of Planning, Oxford, July. Quoted in Birkin, M., Clarke, G., Clarke, M. and Wilson, A., 1996: *Intelligent GIS, Location Decisions and Strategic Planning*, GeoInformation International, Cambridge, p.155.

Jeffrey, P., 1980: *A Study of Land Capability in the Shire of Buninyong*. Soil Conservation Authority, Kew Victoria.

Liu, G-J, Peterson, J.A. and Kader, M.B., 1998: An alternative approach to stream buffering for forest management plans. In Zhou, Q., Li, Z., Lin, H. and Shi, W. (eds) *Spatial Information Technology: towards 2000 and beyond*, CPGISI/CAGIS, Berkeley, 500–510.

Ministry for Planning and Environment, Melbourne, 1987: *Water Supply Catchments and Aquifer Intake Areas Interim Planning Guide*. Minister for Planning and Environment; Department of Conservation, Forests and Lands; Rural Water Commission; Department of Industry, Technology and Resources, Melbourne.

Morris, J.M., 1974: *Mental Maps of Victoria*. Monash Publications in Geography, 8, Department of Geography, Monash University, Australia.

Shire of Buninyong, 1990: Negotiated settlement for White (2022).

Shire of Buninyong, 1991a: Negotiated settlement for Britt (2469).

Shire of Buninyong, 1991b: Negotiated settlement for White (2470).

Victorian Government, 1958: *Soil Conservation and Land Utilisation Act*.

Victorian Government, 1970a: *Land Conservation Act*.

Victorian Government, 1970b: *Environmental Protection Act*.

Victorian Government, 1973: Lal Lal Reservoir Water Supply Catchment: Proclamation, *Victorian Government Gazette*, No. 49 (13/06/73).

Victorian Government, 1978a: *Crown Lands Reserve Act*.

Victorian Government, 1978b: *Environmental Effects Act*.

Victorian Government, 1980: *Planning Appeals Board Act* (Section 25).

Victorian Government, 1987: *Planning and Environment Act*.

Victorian Government, 1989a: *Local Government Act*.

Victorian Government, 1989b: *Water Act*.

Walker, D.H., Johnson, A.K.L., Cottrell, A., O'Brien, A., Cowell, S.G. and Pullar, D., 1998: GIS through community-based collaborative joint venture: an evaluation of impacts in rural Australia, *National Center for Geographic Information and Analysis (NGCIA) Specialist Meeting on 'Empowerment, Marginalization, and Public Participation GIS*,' http://www.ncgia.ucsb.edu/varenius/ppgis/papers/index.html

Wilkinson, W.N., 1989: *Administrative Appeals Tribunal; Hardin Appeal 1989/38030*.

Xiang, W-N. and Stratton, W.L., 1996: The *b*-function and variable stream buffer mapping: a note on 'a GIS method for riparian water quality buffer generation', *International Journal of Geographical Information Systems*, 10, 499–510.

Zala, P., 1996: *personal communication*. Mr P. Zala, Licensed Valuer to the Shire of Moorabool (9 July, 1996).