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IDENTIFICATION OF THE CRITICAL AREAS OF RIPARIAN ZONES IN RELATION TO THE PATTERN OF LAND USE AND INAPPROPRIATELY SITED SEPTIC TANKS IN THE WOORI YALLOCK CATCHMENT, VICTORIA

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ABSTRACT

Agricultural activities, settlements and septic tanks on rural properties are major sources of pollution of aquatic environments. These point (PS) and non-point source (NPS) pollutions have significant impacts on the water quality of rivers and streams. Riparian vegetation can play a significant role in protecting water quality by filtering runoff, trapping and removing nutrients, sediment, pesticides and other chemicals originating on land. The establishment and maintenance of riparian vegetation zones or buffers has been considered as an effective means of preventing pollutants from reaching rivers and streams and maintaining water quality. This paper presents a study on the use of GIS in the identification of the critical areas of riparian zones in the Woori Yallock Catchment, Victoria, which are susceptible to the threat of pollution from adjacent land uses and septic tanks. Updated maps of land use and surface hydrological features were derived from field survey. The riparian buffers were created in a GIS, which were then combined with the land use data to analyse quantitatively the riparian vegetation cover in the catchment and target critical riparian areas. The results indicated that about 6.7% of the riparian buffers lack protective vegetation cover and are susceptible to pollution. Maps showing the critical riparian areas were generated, which can be used to identify high-priority sites for riparian vegetation plantation or restoration.

BIOGRAPHY OF PRESENTER

Xuan Zhu is a Senior Lecturer in GIS in School of Geography and Environmental Science at Monash University. He received an MSc in Cartography and Remote Sensing from Nanjing University, P.R. China, and a Ph.D. in GIS from the University of Edinburgh. His main fields of research are GIS, knowledge-based systems, decision support systems, and their applications to resource and environmental management.

INTRODUCTION

Surface waters can be contaminated by either point source (PS) pollution or non-point source (NPS) pollution or both. PS pollution may come from any discernible, confined and discrete conveyances, such as pipes, ditches, channels, tunnels, conduits, wells, containers, rolling stocks, and concentrated animal feeding operations. NPS pollution is derived from dispersive sources, mainly caused by rainfall or snowmelt moving over and through the ground and carrying away natural and human-made pollutants, finally washing them into different water bodies, including lakes, rivers, coastal waters, and underground sources of drinking water. It has been shown widely that NPS pollutions, which are harmful for drinking water supplies, recreation, fisheries and wildlife, are the major contributors to water pollution and threaten the water quality (EPA Victoria 1983, ADRE 1983). NPS pollutions can be caused by a large range of complex pollutants, including nitrogen (N), phosphorous (P), heavy metals, and other chemicals from different sources (Muscutt *et al*. 1993). They, especially from agriculture activities, are difficult to detect and be treated (Narumalani *et al*. 1996). In this research, pollutions by septic tanks from dwellings are the only PS pollution we look at. The drainage from septic tanks by infiltration and discharge will contaminate the soil, ground water and surface water. This is a major pollution source from residents in the rural area. This kind of septic tank effluent, which contains plenty of nitrogen and phosphorus, may lead to nutrient enrichment and increase biological oxygen demand (Yeates 2001).

Riparian zones have high economic, social and biological values (Malanson 1993). They encompass rich plant communities, including aquatic plants in shallow water, moisture-loving plants along the bank, and upland plants in dry soils. They also play a vital role in a healthy and productive environment, offering an important habitat and corridors linking other parts of the landscape, and acting as a buffer to protect aquatic systems. Riparian vegetation buffers have been considered as the most efficient and cost-effective ecological method for stabilising stream banks and protecting water quality; providing fish habitats; enhancing wildlife habitats; supporting food chains; bringing thermal covers and controlling floods (Abernethy and Rutherfurd 1999, O'Grady *et al*. 2002). Particularly, they play a significant role in protecting water quality by filtering runoff, trapping and removing nutrients, sediments, pesticides and other chemicals originating on land (Correll 1996). It has been shown that effective riparian vegetation buffers can reduce 50% of nutrient chemicals and pesticides, 60% of some kinds of pathogen, and 70% of soil and sand entering waterways (Qin 2001).

This research aims to use GIS to identify the critical areas of riparian zones in the Woori Yallock Catchment, Victoria, Australia, which are susceptible to the threat of pollution from adjacent land uses and septic tanks. The information derived from this research can help build consensus among the regional stakeholder groups in developing water resource management strategies and improve the decision making process in identifying high-priority sites for riparian vegetation plantation or restoration.

STUDY AREA

The Woori Yallock Catchment (about 362km^2) is one of the catchments in Yarra Valley, located to the north east of Melbourne (Figure 1). It is administered by the Shire of Yarra Ranges (2/3) and the City of Cardinia (the upper catchment) (Yeates 2001). Woori Yallock Creek is the biggest river in the catchment. From its headwaters, it flows in a general north-easterly to northerly direction and joins the Yarra River northeast of Seville. The east portion of the catchment area is covered by a mix of forest, intensive horticulture and waters. The middle and northern part of the catchment have been used for grazing and horticulture. Most of the urban areas are located in the west and southwest portion of the catchment.

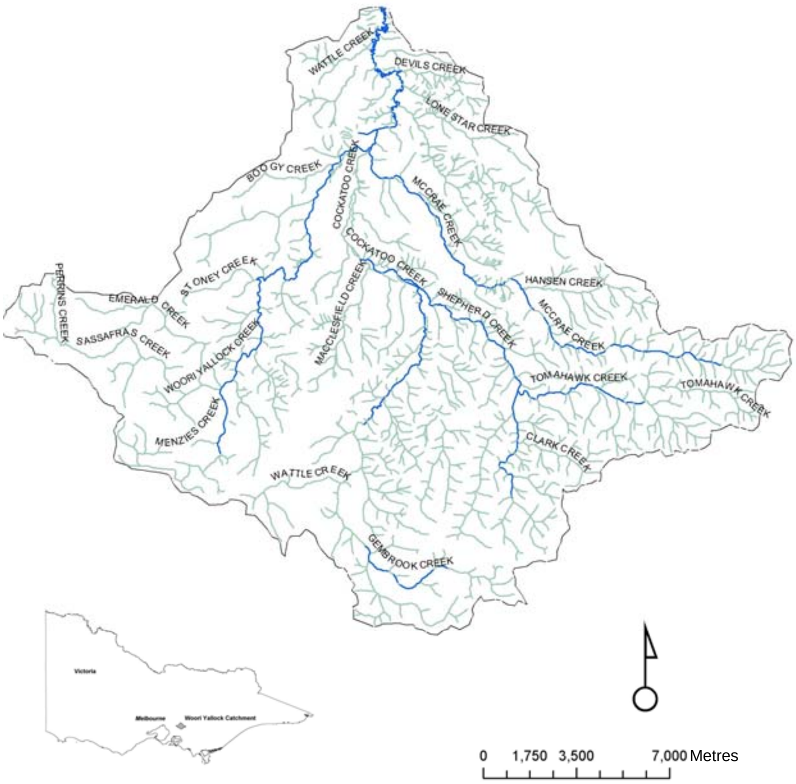

Fig. 1: Woori Yallock Catchment

In this area, water resource is mainly used for domestic use, irrigation, stock, on-stream dam filling and off-stream dam filling. The key management issues for this catchment include the loss of native vegetation, bed and bank erosion, water quality deterioration, weeds, fish barriers and maintaining stream flows. Many parts of the river system (especially near the residential areas) are not protected by natural vegetation buffers, and the water quality standards leave the river health ratings rather low on the river health scale (Peterson 2005). Identifying the critical areas of riparian zones that are susceptible to the threat of pollution is the first step in addressing those environmental issues and developing the water resource management and biodiversity conservation strategies for the catchment.

METHODOLOGY

This study uses GIS to identify the critical areas of riparian zones in the Woori Yallock Catchment, involving three major activities: data preparation, delineation of riparian buffers and identification of critical areas.

Data Preparation

The data used in this study include land use, digital terrain models (DEM), surface hydrological features (rivers and streams), and inappropriately sited septic tanks. They are all in ArcGIS data layers. The four data layers constitute a GIS database for this project, which is managed in ArcGIS.

The land use data layer was obtained from CRC for Fresh Water Ecology (now eWater CRC), which is at a scale of 1:25,000. It was verified, updated and reclassified through a field survey by the authors in the early November 2006. The land use layer contains eight types of land use: urban-residential, pasture, agriculture, water, riparian vegetation, parks, reserves & state forest, bushland and others (Figure 2). The DEM was from Vicmap of Land Victoria, Department of Sustainability and Environment. It was generated from 2002 1:25,000 topographic data with a 20m grid resolution. However, the DEM was not used in the process of analysis, only used for the visualisation purpose. The surface hydrological feature layer was also generated from 2002 Victorian 1:25,000 Topographic Map Series, obtained from Vicmap. The distribution of inappropriately sited septic tanks, which were identified using the house point data (building centroids from Yarra Ranges Council) based on the research outcomes derived by Yeates (2001) through hydrological modelling. There are 21 inappropriate septic tanks found in the catchment.

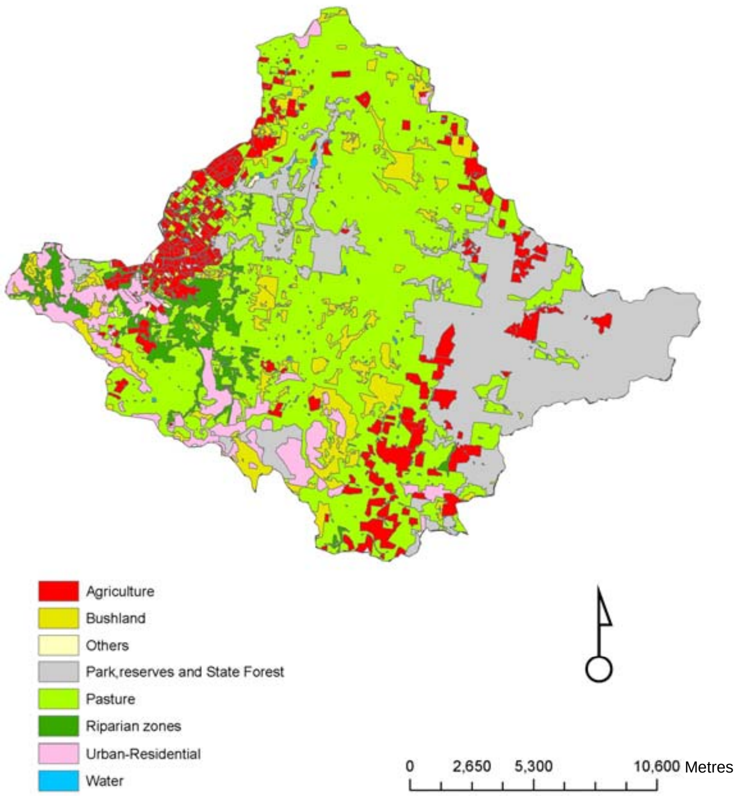

Fig. 2: Land use

Delineation of Riparian Buffer Zones

The critical areas of riparian zones in the Woori Yallock Catchment were identified in this research through the integrated analysis of the above four data layers using ArcGIS. The key issue in the analysis is the definition and delineation of riparian zones.

Different management objectives may require different widths of riparian vegetation buffer. The minimum widths of riparian vegetation are recommended by Land & Water Australia (Price *et al*. 2004) in order to achieve different management objectives (Table

1). The Code of Forest Practice Requirements (DSE 2004) recommends that the minimum retention of a buffer of riparian vegetation is 20 metres for permanent streams, springs and bodies of standing water, and 10 metres for temporary streams and drainage lines. In the report of "*An Assessment of Environmental Flow Requirements for the Woori Yallock Creek Catchment*" by the Department of Natural Resources and Environment (now the Department of Environment and Sustainability or DSE), the recommended width of buffer strips between cleared land and the creeks is approximately 30 metres (Zampatti *et al*. 1999).

Tab.1: Recommended Widths of Riparian Vegetation (*Source*: Price *et al*. 2004)

Management Objective	Recommended Minimum Width
Improve water quality	5–10 metres
Reduce streambank erosion	5–10 metres
Maintain natural light and temperature levels	5–10 metres
Provide food inputs and aquatic habitat	5–10 metres
Provide habitat for fish	5–30 metres
Provide terrestrial habitat	10–30 metres
Manage agricultural production	5–10 metres
Land clearing in riparian areas	See relevant State/Territory regulations

The minimum width of riparian vegetation buffers can also be determined based on soil capacity and slope (USDA 1991). As we do not have soil data for the catchment, this method for delineating riparian buffers cannot be used. The strategy we took is to apply 50-metre buffers along the rivers and 30-metre buffers along the streams. It is based on the recommendations from DSE as described above and the septic tank code of practice in the Woori Yallock Catchment which requires that each septic tank be located at least 50 metres from a waterway (Yeates 2001). The 50-metre and 30-metre riparian buffer zones of the catchment were delineated based on the surface hydrological feature layer using the buffer function of ArcGIS (Figure 3).

Identification of Critical Areas

Riparian buffer zones, land use and septic tank information were integrated to identify critical areas. Once the riparian buffer zones were created, the land use and septic tanks information within these zones was extracted through map overlay operations in ArcGIS. The extracted information was then used to identify those areas where there is a need for revegetation and restoration in order to reduce the threat of pollution. Two steps were involved in identifying critical areas. Firstly, agriculture and urban settlement areas within the riparian buffer zones were identified. And secondly, because the septic tanks may contaminate their surrounding areas, we built a 100 metre area centred in every inappropriate septic tank. The overlapped areas of the 100 metre buffers around the septic tanks with the riparian buffer zones were considered as critical areas which are subject to pollution from the septic tanks. After these two steps, the critical areas in relation to land use and septic tanks were identified.

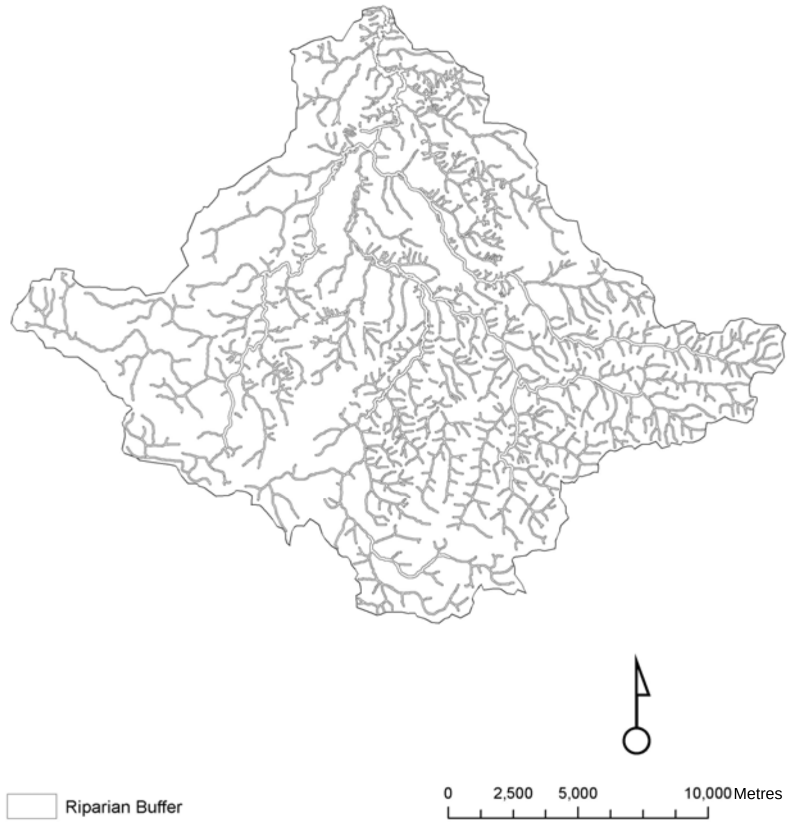

Fig. 3: 50-metre and 30-metre riparian buffer zones

ANALYSIS AND RESULTS

Land Use in the Riparian Buffers

The Woori Yallock catchment has a diverse range of land use as shown in Figure 2. The two major land uses in the catchment are pasture, and park, reserves and state forest. They occupy around 53% and 24% of the total catchment area respectively. Most pastures are located in the middle, northern and southern area of the catchment. Existing riparian vegetation zones mainly lie in the western portion of the catchment between agricultural and urban areas. It has been shown that the riparian vegetation along agricultural and urban areas can prevent instream habitant and water from pollution at some degrees (Qin, 2001). However, existing riparian vegetation zones only cover 4% of the total area. Most of the agricultural areas, especially in the south, and urban areas in the south-west do not have riparian vegetation to protect their surrounding rivers and streams. Figure 4 shows the percentage of each type of land use in the catchment.

There are various types of land use in the buffers. It is found that many riparian areas are not protected by vegetation. A detailed quantitative analysis of land use in the riparian buffer zones (as shown in Figure 3) resulted in Figure 5.

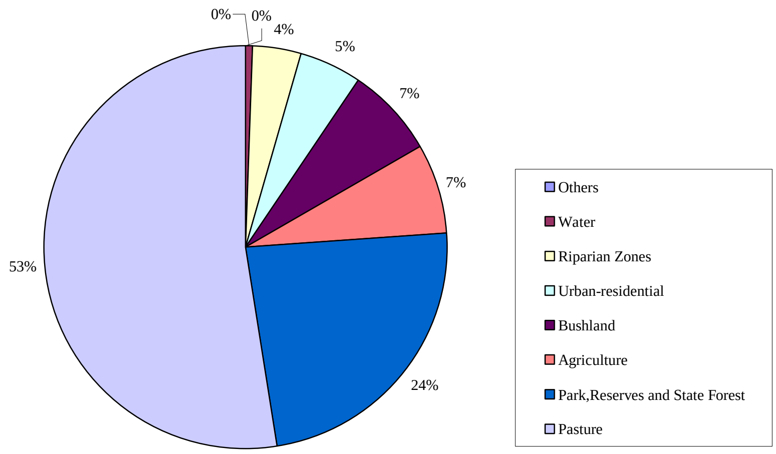

Fig. 4: Percentage of land use in the Catchment

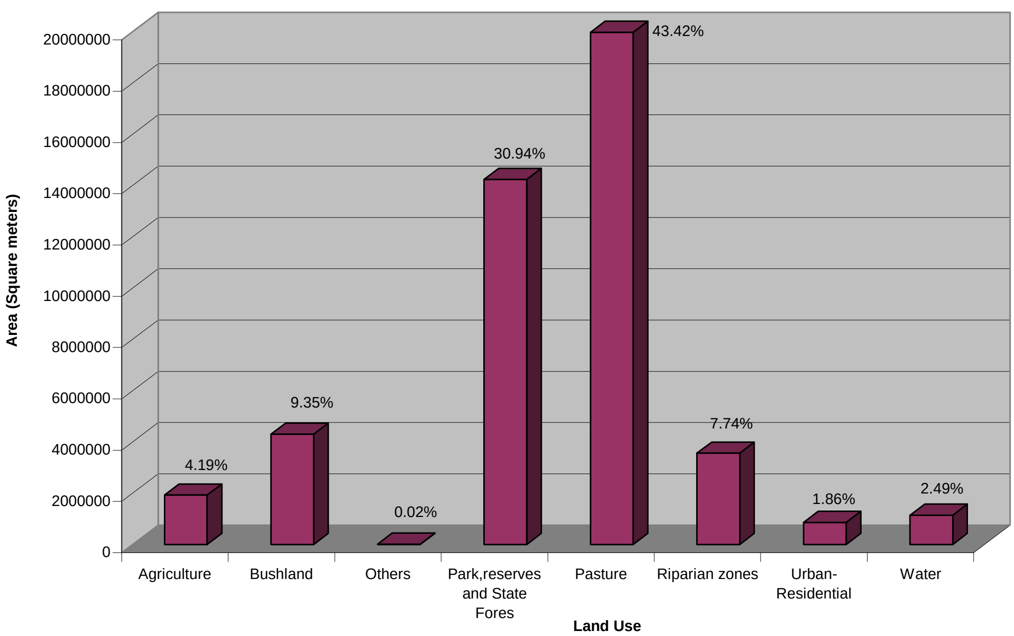

Fig. 5: Land use in the riparian buffer zones

According to Figure 5, the total area of the riparian buffer zones is over 46 km^2. Agricultural and urban-residential areas account for 4.19% and 1.86% respectively, which are the "critical areas" in the buffer zones. Thus, about 2.8 km^2 of the riparian zones are threatened by pollution in relation to land use.

Critical Areas in the Riparian Buffers

Figure 6 presents the distribution of the critical areas of 2.8 km^2 in relation to land use. It can be found that most of these "critical areas" are located in the western, southern and south-eastern reaches of the river system. The density of the "critical areas" along the west branch of Shepherd Creek is particularly high. There are also a few critical areas scattering in the north-east and south-west of the catchment. Distribution of the "critical areas" mostly aligns with agricultural land. Only a few "critical areas" are urban settlements, which are concentrated in the south-west of the catchment. Therefore, urban activities have less impact on the hydrological system than agriculture in the Woori Yallock Catchment. Agriculture is the biggest source of NPS pollution. The distribution of the "critical areas" caused by agriculture along the rivers and streams highlights the importance of agricultural activities to water pollution.

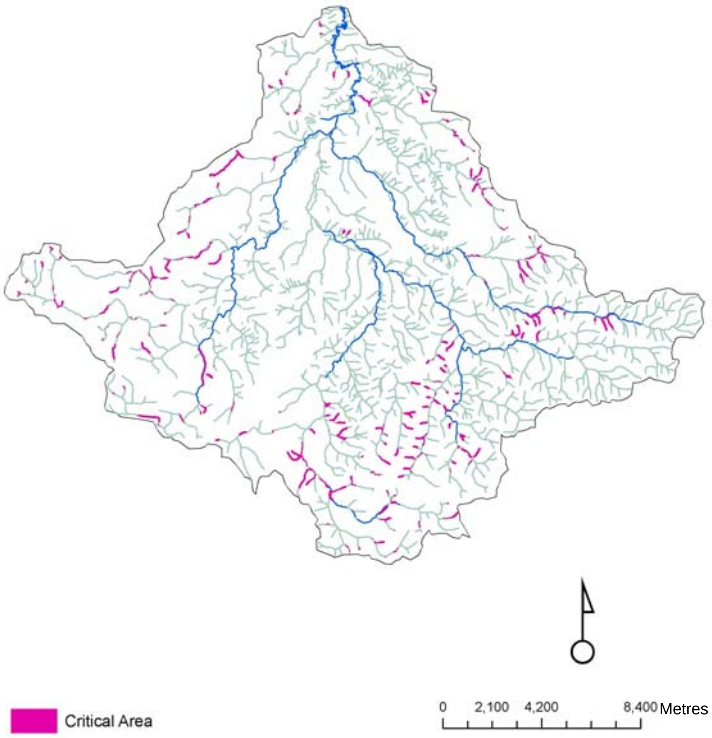

Fig. 6: Critical areas in relation to land use

A total of 0.36 km^2 of the "critical areas" in relation to inappropriately sited septic tanks is identified. Integration of the above two types of "critical areas" forms the total "critical areas" of the Woori Yallock Catchment, as shown in Figure 7. In total, approximately 6.7% of riparian buffer zones lack vegetation, and are therefore susceptible to NPS and PS pollutions. More importantly, the affected areas are spread along the first order streams, which have significant impacts on the water quality of the lower reaches of the river and stream system although their areas are not large compared with the total area of the riparian buffers.

In summary, although green footprints cover most of the Woori Yallock Catchment, the water quality has degraded. More measures need to be taken to protect the riparian zones of this catchment. In the future, the catchment authorities should concentrate on the development or restoration of riparian vegetation in those critical areas along the rivers and streams identified in this research, and look for a socially, economically and environmentally sustainable method to manage and preserve the vital natural resources in the catchment.

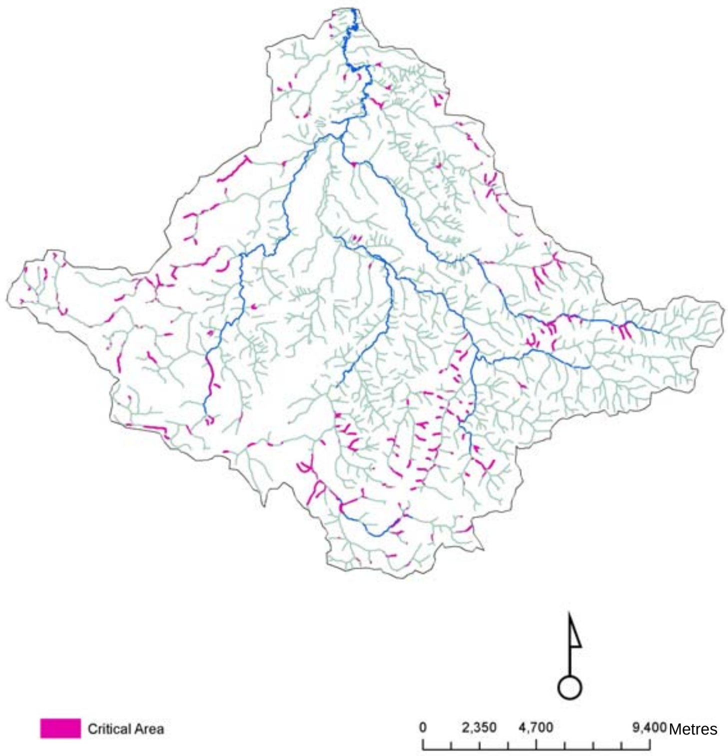

Fig. 7: Critical areas in relation to land use and septic tanks

CONCLUSIONS

This paper presented a study on the application of GIS in the identification of the critical areas that are susceptible to water pollution in the Woori Yallock Catchment. The use of GIS for the delineation and analysis of riparian buffers is not new (Narumalani *et al.* 1996). This study has further demonstrated that GIS provides a cost-effective and practical means for the identification of those riparian areas threatened by NPS and PS pollutions. However, there exist some limitations of the study. The width of riparian buffers is a major issue. Undersized buffers may not be effective to prevent aquatic and terrestrial sources of pollution. Development of riparian buffers should be based on management objectives, local physical conditions and effectiveness for improving regional environment. The selection of riparian buffer width in this study is only based on the requirement for protection of water quality. Efforts should have been made on collection of multiple biophysical datasets. In practice, riparian buffer widths should be determined by taking into account biophysical features (such as soils, slope and flow directions) in the study area. However, only two buffer widths, 50m for rivers and 30m for streams were adopted in the methodology because of lack of enough biophysical data for this catchment.

Nevertheless, the information derived by the use of the GIS approach can be used for policy making in environmental management in a catchment. Indeed, the findings from this study can be used by the local authorities to restore and replant in line with the identified “critical areas” to control water contamination and improve water quality in the catchment.

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