GIS-BASED MODEL TO ASSESS POTENTIAL RISK OF INDIVIDUAL ON-SITE EFFLUENT MANAGEMENT SYSTEMS – DEVELOPMENT ASSESSMENT MODULE (DAM)

R. I. McGuinness[1] and D. Martens[2]

1.Sydney Catchment Authority, 2.Martens & Associates Environmental Engineers

Abstract

In response to the McClellan inquiry into the water incident affecting Sydney's drinking water, the NSW Government (amongst other actions) introduced State Environmental Planning Policy No 58 – Protecting Sydney's Water Supply (SEPP 58). SEPP 58 targets development involving on-site effluent management to reduce the potential impact on water quality of development within the drinking water catchments of Sydney. SEPP 58 requires that development must demonstrate a "neutral or beneficial effect on water quality" and be "sustainable over the long term" before it can be approved.

The current practice of determining whether a development has a neutral or beneficial effect on water quality involves the preparation of a water cycle management study by a consultant. The final judgement of the potential impact still remains open to debate depending on the various input values.

To overcome some of this subjectivity, reduce costs, and produce consistent design and assessments of on-site effluent management systems, the SCA is developing a Geographic Information System (GIS) based model that draws upon natural resource spatial data to populate key fields, automate design calculations, and predict the potential extent of an effluent plume. This allows a visual interpretation and assessment of the potential impact of a development on water quality.

Keywords:

assessment, GIS, neutral or beneficial effect, on-site effluent management, risk,

1 INTRODUCTION

In 1999 the NSW Government introduced State Environmental Planning Policy No 58 (SEPP 58) – Protecting Sydney's Water Supply in an attempt to reduce the potential impact of development on the drinking water catchments of Sydney. SEPP 58 requires that development must demonstrate a "neutral or beneficial effect on water quality" before they can be approved.

Over 2200 applications have been referred to the Sydney Catchment Authority (SCA), of which 90% are for residential development with some form of on-site effluent management. The current practice of determining whether a development has a neutral or beneficial effect on water quality involves the preparation of a water cycle management study based on AS/NZS 1547:2000 (Standards Australia/Standards New Zealand, 2000) and the Environmental Health Protection Guidelines - On-site Sewage Management for Single Households (the silver book) (Department of Local Government, 1998).

Once received by the SCA, an assessment of the proposal's impact on water quality is made. This includes comparing the accuracy of the input values against existing figures and knowledge. The final judgement of whether the proposal will have a neutral or beneficial impact on water quality still remains open to debate depending on the various input values. This process can be time consuming and costly at around $700-$1,000 for the preparation of a normal consultant study and up to three weeks to assess.

To reduce this subjectivity, reduce costs, and produce consistent design and assessments of on-site effluent management systems, the SCA is developing a GIS based model, the Development Assessment Module (DAM) that draws upon natural resource spatial data to populate key fields, automate design calculations, and predict the potential extent of an effluent plume.

The SCA contracted Spatial Intelligence and Martens & Associates to develop the DAM. Martens & Associates developed the algorithms, while Spatial Intelligence incorporated the algorithms into the model, developed the GIS component and incorporated the DAM into the SCA's existing Development Assessment Register (DAR) providing the visual outputs.

The DAM resides as a module within the (DAR). The DAR contains a GIS, which utilises MapObjects as the visual front end. The DAR can be accessed via the SCA's Intranet from any SCA office within the catchments.

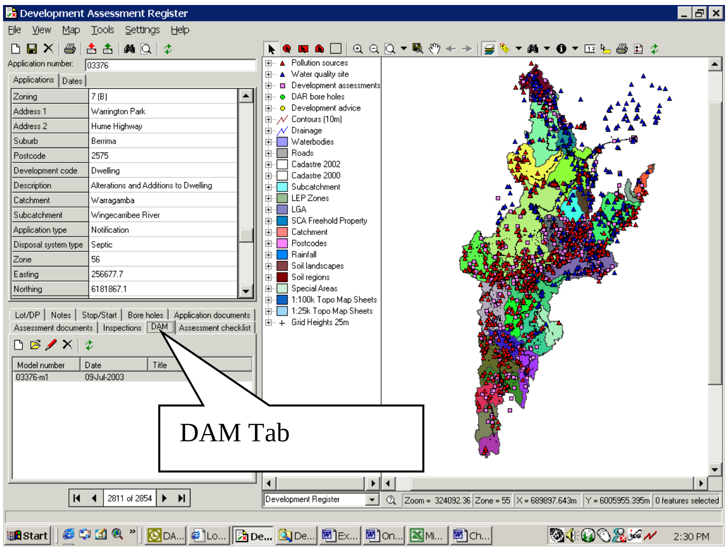


Figure 1. Front End of Development Assessment Register

2 TARGET DAM USERS

The DAM is aimed at helping designers or assessment officers, within the SCA area of operations, identify and locate an appropriate on-site system. It does, however, have wider potential application. The DAR is being amended for local government use and within this context the DAM could potentially be used in any local government situation. Alternatively it could operate over the Internet via either council or SCA websites. The limiting factor is the need to have sufficient GIS data layers to automate the DAM calculations, or to have sufficient data for manual input.

The methodology may also have application for broader sub-catchment impact or catchment scale impact assessment.

3 OPERATION OF THE DAM

The DAM is designed to operate with minimal inputs, with windows based "sheets" that the user must complete. The user moves through all the sheets, eight in total, and can fill in, or select default values. The default values are based on Martens & Associates model assumptions or drawn from the natural resource data layers within the GIS. If the user does not agree with the default values then the DAM has an option to nominate values. These would need to be justified as part of the assessment process.

The input sheets are as follows:

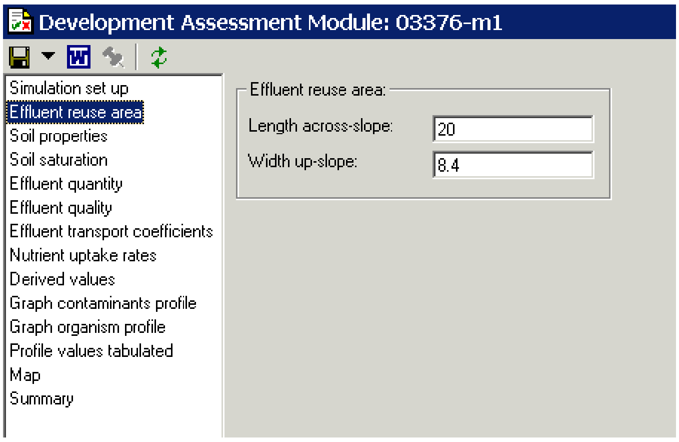


Figure 2. Simulation Setup

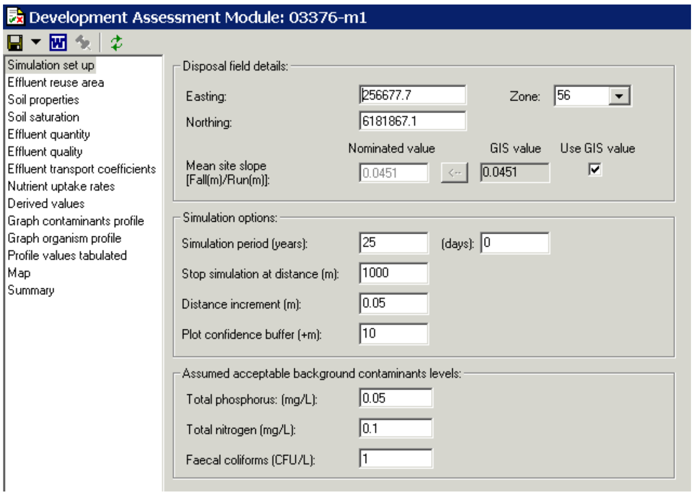


Figure 3. Effluent Reuse Area

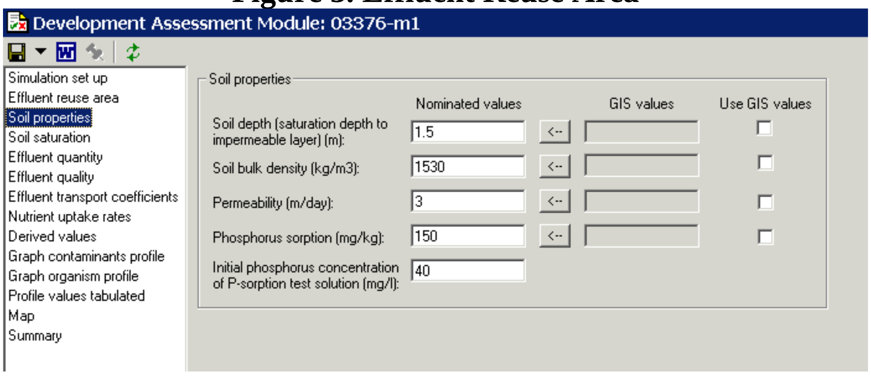


Figure 4. Soil Properties

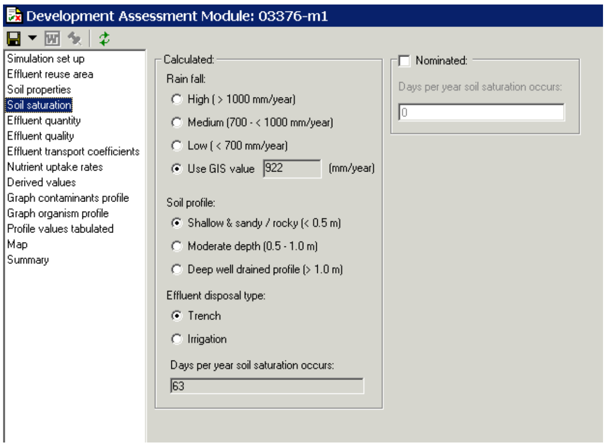


Figure 5. Soil Saturation

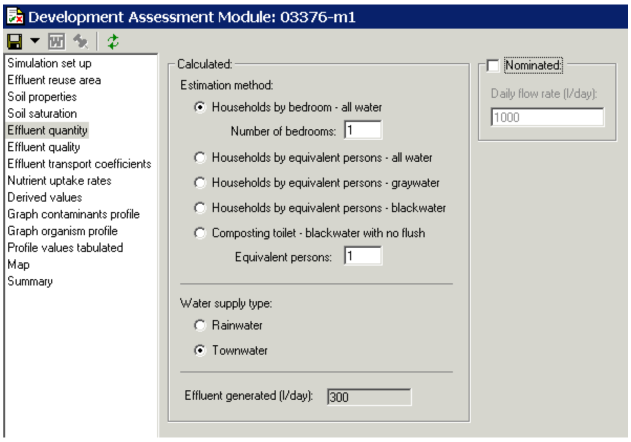


Figure 6. Effluent Quantity

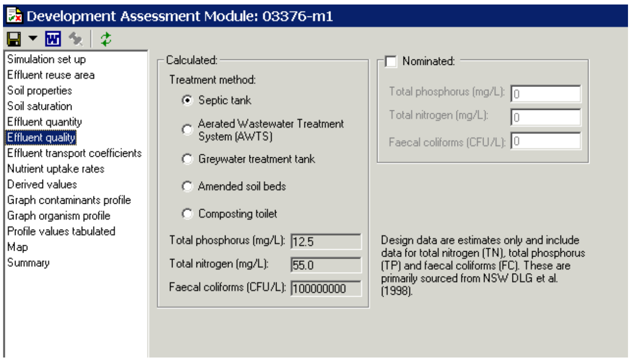


Figure 7. Effluent Quality

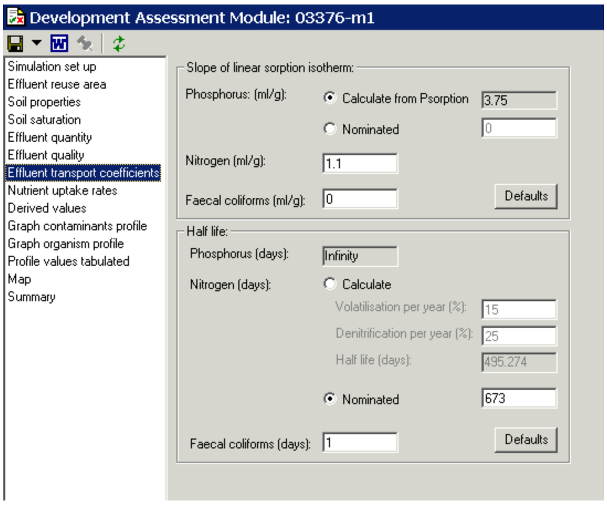


Figure 8. Effluent Transport Coefficients

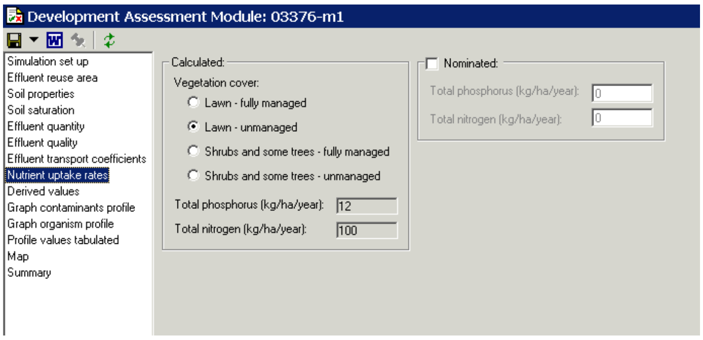
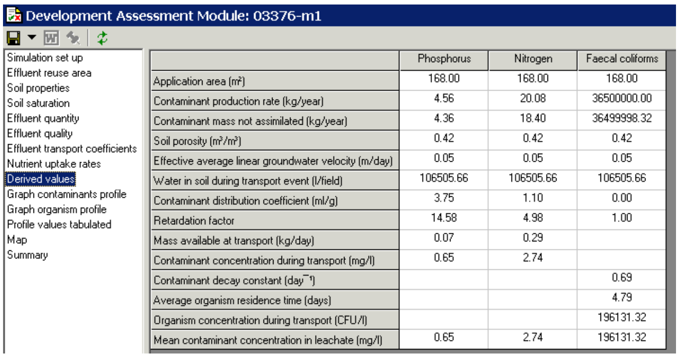


Figure 9. Nutrient Uptake Rates

Once all the input values are completed the DAM makes a series of calculations and predicts the potential impact in a number of forms: firstly as a summary of the factors affecting the predicted movement of effluent through the given soil profiles; next are graphs of the predicted contaminant and faecal coliform movement through the soil. The DAM also provides a spreadsheet of effluent movement through the soil at each of the increments nominated in the simulation set up.



	Phosphorus	Nitrogen	Faecal coliforms
Application area (m²)	168.00	168.00	168.00
Contaminant production rate (kg/year)	4.56	20.08	36500000.00
Contaminant mass not assimilated (kg/year)	4.36	18.40	36499998.32
Soil porosity (m³/m³)	0.42	0.42	0.42
Effective average linear groundwater velocity (m/day)	0.05	0.05	0.05
Water in soil during transport event (l/field)	106505.66	106505.66	106505.66
Contaminant distribution coefficient (ml/g)	3.75	1.10	0.00
Retardation factor	14.58	4.98	1.00
Mass available at transport (kg/day)	0.07	0.29	
Contaminant concentration during transport (mg/l)	0.65	2.74	
Contaminant decay constant (day^{-1})			0.69
Average organism residence time (days)			4.79
Organism concentration during transport (CFU/l)			196131.32
Mean contaminant concentration in leachate (mg/l)	0.65	2.74	196131.32

Figure 10. Derived Values

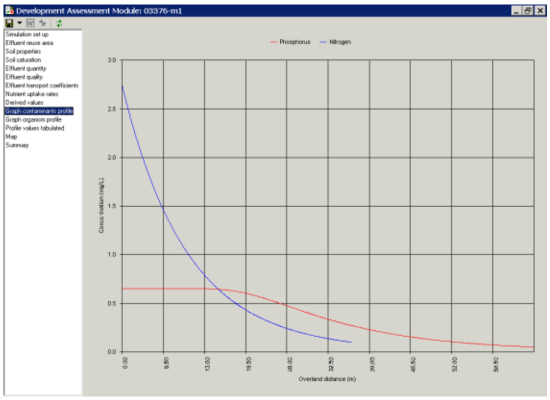


Figure 11. Graph Contaminant Profile

The DAM then plots the predicted effluent movement from the point of the disposal field (based on grid coordinates) through the soil taking into account the slope of the land and produces a plume on the GIS. The model assumes the effluent reaches the limiting soil layer then moves in the direction of the slope. Surface movement is not plotted due to the complexity of the variables. This plume is represented for each of the contaminants, nitrogen and phosphorus, and faecal coliforms. Whilst these are the only contaminants currently used, others can be readily added to the DAM.

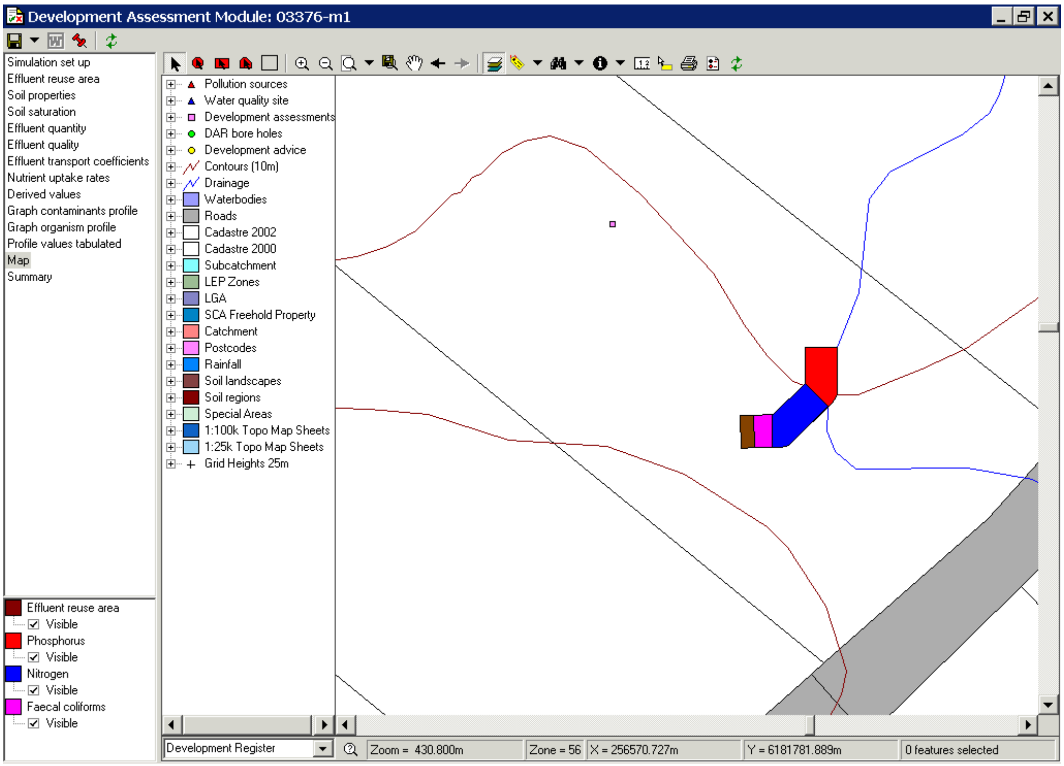


Figure 12. Map of Predicted Effluent Plume

If the effluent plume is predicted to leave the site, or reach a watercourse then the proposed on-site system will not have demonstrated that it will have a neutral or beneficial effect on water quality. The site of the proposed disposal field can be changed by mouse clicking on the "drawing pin" icon, and clicking a new point. The DAM then adjusts its calculations and produces a new plume based on the new coordinates.

The DAM will record the grid coordinates on the simulation set up sheet.

The DAM assessment can be saved as an attachment to the DAR record for the development application. Subsequent alterations to the assumptions can be made and saved as different versions if desired. The DAM will also convert all the information to a Word format for saving as a report on a hard copy file, or electronically.

4 DATA REQUIRED TO RUN THE DAM

The following spatial data layers are needed to fully automate the DAM:

- Cadastre
- Digital Elevation Model Grid
- Watercourses & water bodies
- Soil Landscapes (with derivative data including soil depth, bulk density, permeability, P sorption)
- Rainfall
- Roads

5 BENEFITS OF USING THE DAM

As the DAM resides with the DAR it becomes part of an integrated development assessment process. The DAM provides for a consistent approach to the design and assessment of the potential impact on water quality of on-site effluent management systems based on consistent data. The default values are set from within the GIS data sets and within recognised and accepted algorithms.

Should a person wish to use alternative values and can justify those values then the DAM has manual override functions and will operate normally on those alternative values. The DAM therefore provides the flexibility needed to suit various design scenarios.

The outputs provide a very simple visual synopsis of the predicted impacts that is easy to understand. The designer or assessor can make quick location or sizing adjustments to ensure the proposed system contains effluent on-site.

6 PEER REVIEW OF DAM

The DAM has undergone a peer review process to determine the accuracy and validity of the outcomes. This review includes:

- Review of Martens & Associates methodology, algorithms, and assumptions by Katrina Charles, Centre for Water & Waste Technology, University of New South Wales, Sydney
- Review of the methodology, algorithms, assumptions, GIS outputs, and a comparison of actual applications tested within the DAM against the consultant water cycle management studies by Whitehead & Associates Environmental Consultants Pty Ltd
- Comparison of actual outcomes from field research undertaken by Katrina Charles with DAM predicted outcomes.

7 CONCLUSION

The DAM can provide a level of consistency of design and assessment that will reduce the potential for effluent from an on-site system leaving a site or reaching a watercourse. The visual interface, graphs and map outputs make the DAM particularly user friendly. The tool is easy to use and has the potential for significant savings in cost and time.

A significant amount of spatial data is needed to fully automate the DAM (the most complex being the soils), however the majority of the data already exists, or can be readily derived.

REFERENCES

Department of Local Government et al 1998, Environmental Health Protection Guidelines - On-site Sewage Management for Single Households

Martens & Associates Pty Ltd, Domestic Effluent Pollutant Transport Model Development Assessment Module (DAM) Report 2001G608JC1

McClellan QC, Peter 1998 Sydney Water Inquiry, Final Report

Standards Australia/Standards New Zealand 2000, AS/NZS 1547:2000

Legislation

State Environmental Planning Policy No 58 – Protecting Sydney's Water Supply