On-site Sewage Risk Assessment System

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EXECUTIVE SUMMARY

The On-site Sewage Risk Assessment System (OSS RAS) provides a new management tool for councils and others to assist with strategic and regulatory responsibilities associated with management of decentralised sewage facilities. The OSS RAS provides a software-independent, GIS-facilitated framework for spatial hazard identification and subsequent risk analysis.

The need to sustainably manage decentralised sewage facilities in NSW was highlighted by a number of studies by councils which indicated that around 50-90% of on-site systems were failing or performing inefficiently, particularly in coastal catchments.

Identification of failure modes of on-site systems is of central importance to the OSS RAS. Failure modes include poor design or inappropriate system configuration, poor siting (the focus of OSS RAS) and/or poor management and maintenance. Indicators of failure modes are identified and classified with a risk orientation. Logic matrices enable spatial analysis (preferably using a Geographic Information System (GIS)) of sewage export hazard.

The OSS RAS requires classification of existing natural resource (particularly soils) and other data (e.g. lot size, water reticulation, sewerage reticulation, and environmental resource data such as oyster leases, groundwater bores, drinking water catchments) to enable mapping and interpretation of risk. Digital Elevation Models (DEM) provide enhanced resolution of resource information interpretation and spatial tracking of cumulative risk.

‘On-site sewage export hazard’ represents the relative potential for “failure” of an on-site system or the release of contaminants beyond the allotment boundaries. It is a relative risk of pollutant export.

‘Off-site risk’ is a measure of relative potential risk to public health or ecological impact. These risks include contamination of shellfish, potable or recreational waters as well as ecological effects such as elevated nutrient levels. Off-site risk involves hydrological tracking and cumulative risk analysis through the hydrologic functions of GIS. Two case study areas are evaluated in the OSS RAS handbook.

The OSS RAS is intended to guide and facilitate risk-based management actions relating to on-site facilities. OSS RAS can also be used for strategic planning and
analysis of other natural resource management issues, public environmental reporting and/or development of a Local Environmental Plan.

The OSS RAS provides examples and a flexible framework for developing rapid evaluation techniques for spatial assessment of sewage pollution risk. This can be applied to both existing and new unsewered developments. By using a logical, transparent and verifiable methodology provided in OSS-RAS to assess risks, councils can justify the resource allocation required to manage unsewered areas while addressing community expectations and needs.

The OSS RAS provides guidance for development of management options including improvements or retro-fits, the assessment of life cycle costs for new infrastructure, canvassing community expectations, and the assessment of environmental, social and economic impacts associated with each option. The OSS-RAS also provides an impact risk analysis tool and will assist long term management of decentralised sewage facilities, catchment management, monitoring and capability planning. The OSS-RAS does not preclude the need for site-specific investigations required for development, re-zoning or building applications.

KEY WORDS
On-site sewage systems, risk management, geospatial analysis, geographic information systems, strategic planning, decentralised sewage management.
INTRODUCTION
The purpose of the On-Site Sewage Risk Assessment System (OSS RAS) is to facilitate better planning and management of on-site facilities. The OSS RAS achieves this through guiding the assessment of risk associated with installation and operation of on-site sewage facilities and the subsequent risk of off-site impacts. Specifically this system has been designed to assist Councils to:

- develop risk-based assessment and management programs;
- develop rapid evaluation techniques for assessment of sewage pollution risk for existing and new unsewered developments;
- manage catchments in accordance with the principles of Ecologically Sustainable Development with specific reference to on-site facilities;
- identify whether the Development Control Plan and/or Local Environmental Plan supports best management practices for the location, extent and density of unsewered residential development;
- determine existing and future impacts of decentralised systems on the environment within any subcatchment;
- assess the density, location and layout of existing and future unsewered residential development to achieve sustainable pollutant loadings; and
- identify performance requirements of on-site facilities appropriate to varying environmental circumstances.

BACKGROUND

Why is the OSS RAS needed?
The OSS RAS is needed to support improved management of decentralised sewage facilities. Management of diffuse sources of pollution such as land-based disposal of sewage is being intensely scrutinised, particularly as many 'traditional' point sources such as sewage treatment plants are achieving reduced pollutant emissions.

What is the OSS RAS?
The OSS RAS handbook describes a conceptual framework for the classification and analysis of spatial data relevant to on-site sewage management. Logic matrices are used to classify and map the risk of on-site system failure and consequent pollutant export hazard. Spatial analysis tools are used to track potential pollutants in runoff as they accumulate in drainage lines. The OSS RAS provides case study examples undertaken in the Blue Mountains (Katoomba area) and Eurobodalla Shire (Tuross estuary) respectively (See Figure 1).
How is the OSS RAS used?
The OSS RAS is intended to be used as a software-independent process for spatial analysis of data relevant to on-site systems. Guidelines are provided within the OSS RAS for:

- identification of significant data sets;
- classification of data sets to assess and map on-site hazards, environmental sensitivity and off-site risk;
- usage of topographic information/digital elevation models to map and spatially track pollutant movement within catchments.

Council responsibilities

There are a number of statutory authorities involved in the approval and management of on-site sewage facilities in New South Wales (NSW) with local councils playing a major and the most direct role. Councils are responsible for determining approvals to construct, install, alter and operate sewage facilities. As a consequence, the responsibility for strategically managing the risks associated with potential impacts on the environment resides with Councils.

The OSS RAS is not a substitute for field inspection rather it is intended to assist strategic management and planning for on-site sewage facilities.

FAILURE MODES, HAZARDS AND RISK

The risk standards AS/NZS 4360: 1999 Risk Management and AS/NZS 3931: 1998 Risk Analysis of Technological Systems – Application Guide have been the two guiding standards. The OSS RAS defines ‘failure’ of an on-site sewage facility as unacceptable surcharge or seepage from the land application area beyond the allotment boundary. Failure constitutes a hazard for downstream sites. Figure 2 presents an overview ‘failure mode’ model for on-site sewage facilities and indicates the various failure modes. The current focus of the OSS-RAS is on appropriate siting of facilities however it provides guidance for both management measures and desirable performance/design requirements.
ON-SITE FAILURE MODEL

Failure Modes
- insufficient area
- inappropriate disposal method
- inappropriate system design
- climatic - storm, wet sequence, runoff
- over-loaded system

Failure Modes
- soil factors
- high slope
- shallow groundwater
- flooding/drainage
- inadequate buffer distance
- rockiness
- permeability loss

Failure Modes
- poor input care
- poor maintenance
- direct discharge of effluent
- overloaded system
- lack of system renewal
- dumping of pumpout material

POOR DESIGN OR INAPPROPRIATE FACILITIES CONFIGURATION → POOR SITING → RELEASE OF CONTAMINANTS FROM ON-SITE DISPOSAL SYSTEMS

COMPLEX PATHWAY TO RECEIVING ENVIRONMENT

Pathogens
Dilution...
Die-off...
Natural filtration.....

Nutrients
Dilution...
Adsorption...
Assimilation...

POTENTIAL OFF SITE EFFECTS

HEALTH FOCUS (Typically pathogen related)
- Pathogen contamination of food industries
- Drinking water supplies contaminated
- Loss of recreational uses of receiving waters

ENVIRONMENT FOCUS (Typically nutrient-related)
- Severe ecological changes (e.g. algal blooms)
- Weed invasion and proliferation

OFF SITE EFFECTS TYPICALLY DETERMINED BY "THRESHOLD" LEVEL OF CONTAMINANT
DISTANCE FROM SOURCE CAN BE USED AS FIRST APPROXIMATION

CUMULATIVE ENVIRONMENTAL, HEALTH AND ECONOMIC IMPACTS

FIGURE 2
ON-SITE FAILURE MODEL
PROCESS AND METHODOLOGY

Mapping natural hazard

Indicators of natural hazard are required to interpret and map spatial resource data related to potential failure of on-site facilities. Natural site characteristics determine the ability of a site to assimilate effluent without loss to surface or groundwater. Critical indicator groups include soil material, soil landscape, slope, flooding and climate/natural water balance. Key soil indicators require flexibility but include permeability, sodicity, fertility and salinity hazard.

Hazard maps are created by classifying and overlaying data using logic matrices applied through a Geographic Information System (GIS). Local ownership and justification of the inputs to the logic matrices is critical for system function and local ownership.

Rainfall variability is a critical element for analysing risk of systems failing due to hydraulic load. Climate variability and calculated trench surcharge for four areas of NSW is presented in Table 1. This table was developed using calculations derived from the earlier version of the Australian Standard for domestic on-site sewage management.

Table 1: Climate Variability and Surcharge Estimations using AS1547:1994 as design guide

<table>
<thead>
<tr>
<th>Climatic factor</th>
<th>Climate classification</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Katoomba</td>
</tr>
<tr>
<td>Mean Annual Rainfall (mm)</td>
<td>1,405</td>
</tr>
<tr>
<td>Decile 9 Rainfall (mm)</td>
<td>3,086</td>
</tr>
<tr>
<td>Rainfall Variability (mm)</td>
<td>2,067</td>
</tr>
<tr>
<td>Typical Trench Size (m²)</td>
<td>290</td>
</tr>
<tr>
<td>Calculated % Trench Surcharge*</td>
<td>35%</td>
</tr>
</tbody>
</table>

Soil, slope and climate are used to classify on-site natural hazard class which represents the potential difficulties adsorbing or assimilating sewage effluent without loss to either surface or groundwater.

Mapping on-site sewage export hazard

On-site sewage export hazard relies on natural hazard mapping (described above) together with built hazard overlays. Built hazards such as allotment size, and water reticulation influence export likelihood (Figure 3 provides a subset of the Katoomba case-study). Additionally, on-site hazard is related to the failure rate of the facility and its specific location. Spatial data and information on system design, management, failure rates and location are documented as potential additional elements of OSS RAS, however they have not been analysed due to the relative paucity of the required spatial data.

Assessment of allotment sizes is pivotal in the risk analysis and will assist with ongoing planning processes. ‘Lot Size Modelling’ is the subject of a separate paper and is described in an Appendix of the handbook.
Mapping environmental sensitivity and analysis of risk of pollution from on-site systems

Assessment of the sensitivity of the receiving environment is an important precursor to determining off-site risks. The OSS RAS draws on the NSW Local Government (Approvals) Regulation 1999 and Environmental Planning and Assessment Regulation 1994 for definition of ‘environmental sensitivity’. However, ‘sensitivity’ is also considered to be the threshold of a key contaminant (e.g. pathogens/nutrients) at levels above which the sector is ‘impacted’. Lower threshold levels suggest the sector is sensitive to pollutant sources from much greater distances assuming linear reduction in contaminants with distance from source.

As the determination of sensitive areas is linked to planning instruments such as Local Environmental Plans it is important that the Council is instrumental in the development of the sensitivity classes and ‘catchment boundaries’ required for the determination of off-site risk.

Risk analysis consists of two elements: probability and consequence. For the downstream receiving environments, the probability of pollutants reaching any particular site relies on both export probability and transport to the receptor. Consequence is assumed to be a measure of the site sensitivity. The transport factor presents considerable complexity in spatial analysis of the natural environment and may be determined by catchment characteristics including the arrangement of potentially exporting sites and receptors as well as other factors such as dilution, other contaminant sources, flow-path time, adsorption, assimilation and others. Similar to the approach for sensitivity described above, for the purpose of spatial analysis these factors need to be simplified to assume that distance from source is a measure of risk reduction.

Accurate spatial definition of catchment boundaries and drainage lines assists OSS RAS analyse off-site risk. Two preliminary examples are presented in Figures 4 and 5. Figure 4 indicates the ‘cumulative risk’ to drainage lines. Hydrological tracking of emitted pollutants has been used to classify the number of units of high and severe export risk upstream of any point in the drainage network. These are classified by colour into categories based on units of risk in the catchment. Figure 5 indicates the level of risk of impact in sensitive vegetation communities – hanging swamps. The approach assumes that those hanging swamps downstream and within 100m of on-site sewage areas with a high and severe hazard rating for pollutant export are those greatest at risk to nutrient-impacts.

Cost/benefit analysis of potential management solutions can be undertaken to assess risks and related potential economic, social and environmental impacts.

MANAGEMENT RESPONSES TO RISK AND HAZARD ANALYSIS

For each hazard, council should develop a risk management response, which could be articulated in the Council On-site Sewage Management Strategy. The aim of the risk classification process is to develop an Action Plan for individual catchments according to the probability of hazards or the need for consequence reduction. That is, reducing the duration or magnitude of the risk, or number of people affected, or removing the hazard altogether (eg implementing reticulated sewerage).
Further information will be required to develop management options including identifying options for improvements or retro-fits, the assessment of life cycle costs for new infrastructure, canvassing community expectations, and the assessment of environmental, social and economic impacts associated with each option. The ‘management feedback’ loop will be specific to each council, however a ‘model feedback loop’ is shown in the table following.

Table 3: Management Feedback Loop

<table>
<thead>
<tr>
<th>Failure Mode Description of hazard</th>
<th>Risk Class</th>
<th>Estimated % in catchment</th>
<th>Event Frequency</th>
<th>Population affected</th>
<th>Management Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inappropriate Soil type – heavy clay soil</td>
<td>Severe</td>
<td>90% of all land disposal systems</td>
<td>Every rainfall event</td>
<td>2000</td>
<td>Install Wisconsin mounds, sand filters, CED scheme, Reticulation scheme</td>
</tr>
</tbody>
</table>

USING THE SYSTEM FOR RISK VERIFICATION AND ANALYSIS – CONSTRAINTS AND OPPORTUNITIES

The introduction to this paper detailed the many opportunities, which the implementation of the OSS RAS opens up for Councils vested with the responsibility for managing unsewered settlements. To date, a number of constraints have been identified which could limit the ease with which the OSS RAS (or any type of environmental audit) can be currently implemented. These constraints include:

- Erratic availability of geospatial information and mixed access protocols between government departments;
- Format differences between proprietary systems;
- Data gaps where funding has been withdrawn or reduced for an information gathering program;
- Incompatible Web-based geodata servers and clients.

Metadata

Metadata is critical to OSS RAS and stringent quality assurance and high data management protocols will be required for effective usage of OSS RAS at its full capacity. Australia New Zealand Land Information Council (ANZLIC) Metadata Guidelines will be useful when understood and applied by all users. Spatial Data Transfer Standards and a Geographic Information/Geomatics Standard are also currently being developed to be implemented as appropriate in Australia.

For councils which need sound risk-based cost-effective planning and management strategies, the use of GIS to map and track assets and natural resources is a logical move and a field of enterprise which will no doubt progress rapidly in the next few years.

CONCLUSIONS

The OSS RAS is a flexible tool that provides a significant step towards improving management of on-site sewage facilities. It is particularly useful for analysing and tracking cumulative risk to downstream sites. The highly graphical nature of OSS
RAS provides excellent tool for analysis and communication of catchment-related issues.

Outputs of the OSS RAS can be used for other natural resource management activities, such as strategic planning/biodiversity management, state of the environment reporting or development of a Local Environmental Plan. Collation of the significant body of geospatial information required for the OSS RAS in itself is a useful exercise. The information can be used for many other management and planning responsibilities, such as investigations related to implementation of reticulated sewerage, or even the assessment of assets such as council parks with toilets and septic systems. The options for progressively complex hydrological analysis described in OSS-RAS will also assist councils quantify existing and cumulative impacts on water resources in unsewered areas.

The OSS-RAS will assist long term catchment management and capability planning as well as facilitate improved environmental monitoring programs. The OSS-RAS does not preclude the need for site-specific investigations required for development, re-zoning or building applications, however it greatly facilitates the delivery of ‘front desk’ advice to development proponents.

The OSS-RAS has significant potential to be applied to other diffuse sources of pollution in catchments. This could include erosion risk, road or urban runoff related pollutants (e.g. industrial sites) or semi-diffuse sources such as mines or agricultural industry.

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REFERENCES
Australian/ New Zealand Standard™ 1547:2000 On-site domestic wastewater management.


