

Status of Groundwater Quality in the Cockburn Sound Catchment



CSIRO

COCKBURN SOUND
MANAGEMENT COUNCIL

Community Summary
Paper

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**KWINANA
INDUSTRIES
COUNCIL**



Department of
Environment

Cockburn Sound is an iconic feature of the Western Australian lifestyle, supporting a rich variety of commercial, industrial, defence, tourism and recreational uses for the broader community. However, the environmental pressures on Cockburn Sound are increasing. Cockburn Sound Management Council has recognized that groundwater provides a pathway for pollutants to reach Cockburn Sound. This Community Paper presents a summary of the key findings of a study into the state of groundwater quality in the Cockburn Sound catchment and how it may affect the Sound.

The Groundwater Quality Study

This Study was commissioned by the Cockburn Sound Management Council (CSMC), with financial assistance from the WA Department of Environment and Kwinana Industries Council, to investigate the status of groundwater quality in the Cockburn Sound catchment, and to identify gaps in environmental management that could potentially lead to unwanted impacts on the Sound from the groundwater pathway. Apart from direct drainage (stormwater systems or industrial effluent channels), groundwater remains the dominant pathway by which contaminants from terrestrial sources can access the Sound directly, yet this pathway is still relatively poorly understood and cannot easily be regulated or intercepted. A range of new groundwater quality measures may need to be considered to inform the environmental management process in preparation for future challenges. All chemicals that might affect groundwater quality were included in the Study; however the terms of reference emphasized the need to consider direct impacts on Cockburn Sound, rather than general aspects of water quality throughout the catchment *per se*. Therefore the Study focused on classes of chemicals that are persistent in aquifers, and on other classes of chemicals that are used in close proximity to the coastline. The Study paid less attention to instances of groundwater contamination by chemicals that were thought to provide little risk of impact to Cockburn Sound.

The Study was conducted by CSIRO and focussed on providing:

1. A review of the current state of knowledge of the local groundwater systems;
2. A review of the legislative, policy and planning framework governing environmental management in the catchment; and
3. A survey of stakeholders (industry, government, community) and available data pertaining to groundwater quality and environmental management practices in the catchment.

The survey stage of the Study included direct contact with 79 industrial and construction premises, three local government authorities, seven State and Federal government agencies and corporations, plus the Kwinana Industries Council, WA Conservation Council, WA Vegetable Growers Association and Recfishwest. Other input was canvassed at two Community Forums held in the catchment in August 2005. The Study was project managed by CSMC with regular meetings between CSIRO staff and the CSMC Groundwater Quality Project Team, which included industry, community and government representatives.

The Study Report contains scientific and technical data as well as policy and other reference data. It is not possible to summarize all of the material within this Community Summary Paper. Therefore this Paper focuses on the general subject of groundwater quality and on highlighting the critical issues that were found to be most important for the sustainable management of Cockburn Sound.

Industry Participation

Although there was no compulsion on industry premises to supply groundwater quality data to the Study, a total of 50 premises kindly volunteered their data for the benefit of the Study. This participation allowed the Study to build a representative picture of groundwater monitoring, groundwater quality and management practices across the catchment. Any management gaps identified at participating industrial premises are likely to occur more widely across the catchment. The participating industrial premises are thanked for helping the Study identify areas for improvement of environmental management for Cockburn Sound.

Cockburn Sound and its Catchment

Because of its proximity to major population centres and its usually placid waters, Cockburn Sound now supports a range of recreational, urban and industrial activities, making it the most heavily used marine embayment in Western Australia. Examples of the activities supported by the Sound include recreational swimming and boating, aquaculture and fishing industries, and industrial and naval shipping. Cockburn Sound also experiences the pressures associated with on-shore industrial, semi-rural and urban developments, including burgeoning human populations, increasing heavy industrial activities, horticultural pursuits and the disposal of wastes. The on-shore districts adjoining Cockburn Sound form the Cockburn Sound catchment, as displayed in Figure 1. The catchment is home to the urban local authority areas of Rockingham, Kwinana and Cockburn, the industrial precincts of Kwinana and Rockingham, the Australian Marine Complex and HMAS Stirling, the semi-rural areas of Mandogalup and Baldivis, and the important wetlands of Thomson's Lake, Lake Richmond, Lake Coogee and The Spectacles.

It is tempting to view Cockburn Sound as a marine system that is distinct from the surrounding catchment. However, at an ecosystem level, linkages are more complex than this. What we do on land can have direct impact on marine environments, just as changes in marine environments can impact our land-based lifestyles. One of the major ways for



Figure 1. Groundwater Quality Study boundary (black line). For the purposes of this Study, the eastward draining catchments of Garden Island were included.

land-based activities to affect marine environments is through groundwater.

Understanding the Groundwater Pathway

What is Groundwater?

Groundwater is water that flows through or resides in the underground soil and rocks. It is found everywhere on land and, for the Perth Metropolitan Area, groundwater provides a significant amount of our water needs, including a percentage of our drinking water. Groundwater is replenished by rainfall and, sometimes, by the water we use (e.g. drainage, waste water, irrigation etc). Typically groundwater moves slowly underground towards rivers, wetlands and coasts. You can't easily see groundwater in its natural state, but you can see its effects. For example, many natural lakes on the Swan Coastal Plain fill and empty during the year as seasonal rainfall and summer evaporation causes groundwater levels to rise and fall. Sometimes, on



Figure 2. Groundwater seeping onto a beach at low tide.

beaches at low tide, groundwater is visible as it discharges through the sand over the beach down to the sea (see Figure 2).

Because groundwater moves through soil and rocks, a good understanding of groundwater requires a good understanding of geology. In the Cockburn Sound catchment, groundwater mainly encounters sand and limestone formations, called aquifers. The Tamala Limestone aquifer is a special case. It is characterized by occasional gaps in the limestone, known as caves, voids and solution channels, which allow the groundwater to flow rapidly in certain locations (Figure 3). The local aquifers intersect the sea floor and beach of Cockburn Sound, and groundwater and seawater are exchanged between the Sound and the aquifers constantly. Over time there is a net discharge of groundwater from the aquifers to the Sound. This is the basis of the Cockburn Sound groundwater flow regime – or hydrogeology.

What is Groundwater Contamination?

Every human activity uses chemicals and generates wastes, be they industrial, agricultural or domestic. Often these chemicals and wastes make their way to the groundwater, e.g. domestic fertilizers carried with rainfall down through the soil to the water table, industrial storage tanks leaking fluids onto the ground and then leaching to the groundwater, or urban runoff. Chemicals and wastes may be fluids, organic materials or solids, but they all produce or contain potential contaminants. Contaminants are substances that may reduce water quality to an unacceptable level. Many chemicals can be hazardous in water at very low concentrations (e.g. metals, pesticides, petroleum hydrocarbons), while others can sometimes be tolerated in the environment at much higher concentrations, e.g. nutrients and biological materials. Once in the groundwater, some kinds of chemicals can move long distances with the groundwater flow, whilst others are degraded or immobilised quickly in the aquifer.

Since groundwater discharges constantly to Cockburn Sound chemical loads carried by the groundwater may also find their way into the Sound, with consequent impacts to the marine environment. In order to manage this risk in Cockburn Sound we need to develop a firm understanding of the nature and prevalence of chemicals in the catchment and how they migrate with the groundwater (and their potential to act as contaminants) needs to be developed. Investigation of the Sound's contaminant hydrology is well under way, but much more needs to be done.

Contaminant Risks

Broadly speaking, there are two classes of groundwater contaminants of interest in the catchment – *persistent* and *non-persistent*. Persistent contaminants are those that do not readily degrade or stick to soil particles in the aquifer, such as nutrients and salts; these contaminants can travel with the groundwater over distances of many kilometres. Non-persistent contaminants may be degraded or consumed by soil microbes or can stick to soil particles via chemical reactions; these contaminants include pesticides, herbicides,

solvents, petroleum hydrocarbons, metals and biological materials. Of course, different contaminants may degrade at different rates in different aquifers and pose different contamination threats.

How the chemical loads are distributed in the catchment is also important in assessing environmental risk. Localized spills or releases of contaminants are called *point sources*. Once a point source contamination reaches the flowing groundwater a *plume* of contaminated groundwater results. In some cases plumes can be confined and even cleaned up. On the other hand, releases of contaminants over wide areas are called *diffuse sources*, e.g. fertilizers applied over whole urban and horticultural districts. Through their sheer scales, diffuse groundwater contaminations are extremely difficult to clean up and are best addressed through management interventions at the release stage.

How Clean is Clean?

Australia's Federal and State environmental agencies have agreed standards for water quality, especially with respect to drinking water and for marine and freshwater ecosystems (ANZECC/ARMCANZ Guidelines for Fresh and Marine Water Quality). Environmental management is facilitated by the development of threshold levels, called trigger values. For Cockburn Sound, phosphorus, ammonia and nitrogen oxides are identified as some of the most important water quality parameters. In general, the marine ecosystem water quality trigger values are more stringent than drinking water quality guidelines, but there is no direct quality standard applicable to groundwater. Instead, groundwater quality is managed in terms of its ultimate use, be it as a potable water supply (drinking water guidelines) or as a water supply for a marine ecosystem (marine water quality trigger values).

Urbanization and Development Impacts

Urban planning carried out by the State government has foreshadowed large increases in population for the Cockburn Sound catchment over the next few decades. To support this increase a raft of new land



Figure 3. Groundwater flowing rapidly from solution channels within the Tamala Limestone aquifer at an excavated site.

rezoning, development and infrastructure initiatives are planned or already underway, especially near Kwinana and Hope Valley. Land presently in semirural use will increasingly be redeveloped for urban housing, commercial precincts, schools, transportation and services hubs. Past experiences elsewhere on the Swan Coastal Plain tell us that urbanization of native environments can increase diffuse contamination of the underlying groundwater (via domestic fertilizers and organic wastes) which can yield increasing nutrient contaminants including phosphorus, ammonia and other nitrogen species.

Figure 4 shows the most recent government data available for ammonia species concentrations in groundwater across the catchment. All stations record concentrations above the marine trigger value, including the Jandakot Production Bores to the north-east of the Cockburn Sound catchment. A similar picture holds for nitrogen oxide species. There is potential for these concentrations to rise further due to the planned urbanization of the catchment. Fortunately, groundwater discharges only slowly into the Sound so it has the potential to be diluted appreciably by the ocean currents. For this reason the nutrient levels shown in Figure 4 may be manageable, but we need to monitor for future increases. An improved groundwater quality monitoring programme is needed throughout the catchment to assist with water quality management.

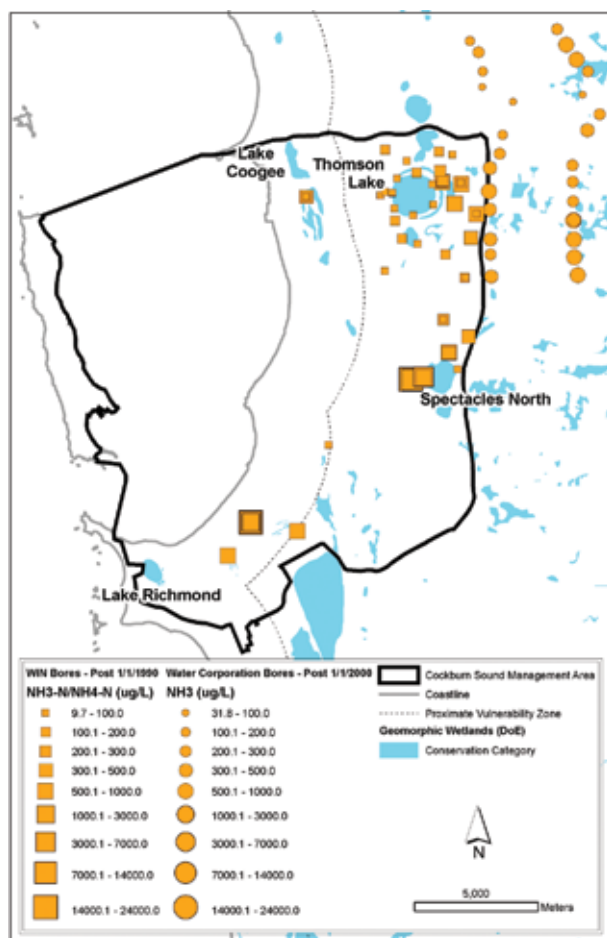


Figure 4. Measurements of ammonia concentrations in groundwater for the Cockburn Sound catchment. Data supplied by Department of Environment and Water Corporation. The marine trigger value for ammonia is 5 µg/L.

Table 1. Important Terrestrial Pathways for Future Contamination Risk to Cockburn Sound.

Classification	Pathway	Main Types of Contamination
Urbanization	Septic tanks, fertilizers, detergents, landfills	Nutrients, metals, pharmaceuticals
Industrialization	Spills, discharges	Nutrients, petroleum hydrocarbons, solvents, metals
Stormwater	Rainfall runoff, unregulated disposals	Nutrients, solvents, metals
Horticulture	Fertilizers, weed and pest control	Nutrients, herbicides, pesticides

In addition, it is recognised that historic input of agrichemicals (such as nutrients and pesticides) under horticultural lands in the catchment will continue to provide nutrient and other chemical plumes in groundwater, as will additional urban features such as landfill sites. These risks are summarized in Table 1.

Industrial and Other Impacts

There are numerous industrial and commercial premises in the catchment. Those premises that handle, produce or store large volumes of chemicals are classified as *prescribed premises* under the *Environmental Protection Act, 1986* and are subject to scrutiny by the Department of Environment. HMAS Stirling, a Commonwealth property, is managed under a Federal Act. The majority of prescribed premises are located along the coastal margin of the catchment, although there are large landfill, disposal pit and pond facilities operated further inland. Based on data volunteered by some industries (including prescribed and non-prescribed premises) and government agencies and corporations, the range of possible point source contaminants identified includes nutrients, metals, petroleum and chlorinated hydrocarbons, alkaline solutions, acids and salts.

Focusing on the potential impacts to Cockburn Sound, it was considered that alkaline and saline solutions were of minor risk. In view of the carbonate nature of the aquifers, acids in groundwater were also considered to present minor risk to the Sound. Proximity to the coast is an important factor in assessing potential impacts to the Sound of less mobile and non-persistent chemicals like metals and petroleum hydrocarbons. Figure 5 shows the location of some of the significant reported point source plumes in the catchment. Again, nutrients figure prominently in many of these plumes. It is emphasized that the Figure does not show all significant plumes in the catchment; rather it shows those plumes (represented in the data volunteered by some industries, corporations and agencies) that have potential for significant impact to Cockburn Sound water quality. Most of the plumes indicated in Figure 5 are under active management to reduce

impacts to Cockburn Sound (see Table 2). The study also highlighted some other instances where further groundwater quality information may be required to reassure that other significant plumes do not exist in the catchment.

The planned industrial redevelopments for Hope Valley may potentially be future sources of groundwater plumes, although the risks to Cockburn Sound may be reduced due to the distance from the shoreline.

Management Gaps

In any rapidly developing system like the Cockburn Sound catchment, the environmental management function must always be adapting to changes and new constraints. The Study identified a set of ways in which environmental management could be improved. These included:

- Promoting a tighter relationship between the planning and environmental protection functions of government.
- Defining a Proximate Vulnerability Zone for coastal industrial premises with an enhanced level of environmental scrutiny, consistent with powers under the Environmental Protection Act (1986).
- Renewing a groundwater quality monitoring program across the catchment to assist in the management of diffuse nutrient contamination.
- Promoting further collaboration between Department of Environment and local government authorities in tracking the distribution and use of potential contaminants across the catchment, and in running a contamination awareness programme amongst industrial and commercial premises and the broader community.
- Developing and instituting a public report card for groundwater quality in the catchment, in line with existing report cards produced by CSMC on chlorophyll and tributyl tin status in the Sound.

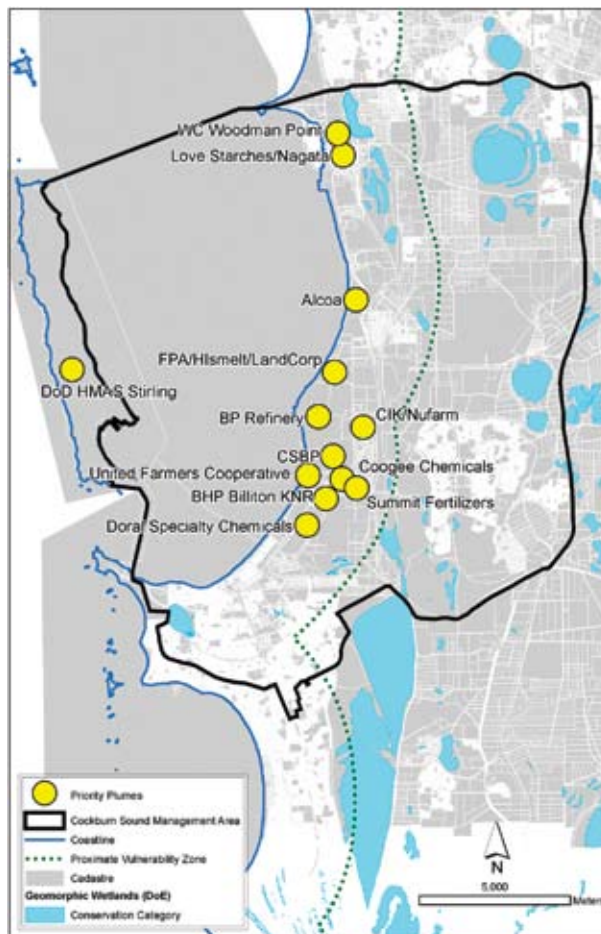


Figure 5. Some significant industry point source plumes in the catchment that have potential to impact Cockburn Sound (based on data voluntarily supplied by industry and government agencies).

Science Gaps

Whilst good research on Cockburn Sound has been done already, there are still important gaps in our understanding of the Sound and its catchment. We need to fill these gaps so we can have more confidence that our management of the Sound is sustainable and so we can continue to enjoy the Sound on a permanent basis. Some of the key science needs are:

- Improving our understanding of the aquifers and groundwater flows in the catchment.
- Understanding the ways that chemicals of concern move through the catchment and via the stormwater drainage system.
- Better definition of the relationship between groundwater chemical concentrations and marine ecosystem impacts in Cockburn Sound.

The Study recommended that CSMC consider establishing a research centre dedicated to investigating the unique mix of urban, industrial and environmental demands on Cockburn Sound and in its catchment.

Conclusions

Cockburn Sound is facing current stresses from groundwater contamination, particularly from excess nutrients, and there is potential for more stresses in the future. While many of the existing point source plumes have already been identified and are under environmental management, there is need to enhance efforts and the level of protection of groundwater quality in the catchment to safeguard against further contamination. As the Sound faces future challenges posed by the planned urbanization and industrialization of the catchment, a positive working relationship between planners, regulators, the community and industry will be essential.

The Report

The full Study Report was endorsed by the Cockburn Sound Management Council in February 2006. The report contains thirteen specific recommendations. Adoption of any recommendations of the Study depends upon broad support from community, government, industry and relevant associations.

Table 2. Instances of Significant Groundwater Contamination Risk to Cockburn Sound (based on data supplied voluntarily by industry and government agencies).

Location	Main Types of Contamination	Actively Managed
Alcoa Refinery	Nutrients, Metals, Fluoride	Yes
BHP Billiton KNR	Nutrients, Arsenic	Yes
BP Refinery	Petroleum Hydrocarbons	Yes
Coogee Chemicals	Nutrients	No
CSBP	Nutrients, Arsenic, Petroleum Hydrocarbons	Yes
Doral Specialty Chemicals	Nutrients	No
FPA – HISmelt – Landcorp	Nutrients	No
FPA – United Farmers	Nutrients	No
HMAS Stirling	Nutrients, Petroleum Hydrocarbons	No
Nagata/Love Starches	Nutrients	No Data
Nufarm/CIK	Herbicides/Pesticides	No
Summit Fertilizers	Nutrients	No
Water Corporation (Woodman Point)	Nutrients	Yes
Septic Tanks/Industrial and Urban Areas	Nutrients, Pharmaceuticals	No
Horticulture	Nutrients, Pesticides, Herbicides	No
Landfills	Nutrients, Hydrocarbons, Metals	No

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