

Groundwater in the Botany Sands Aquifer – Water for the past, water for the future?

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The Botany Sands Aquifer is a layer of sand containing a large volume of water surrounding Botany Bay south of Sydney, New South Wales (NSW), Australia. At a local scale, the aquifer runs from Centennial Park south east of Sydney city centre to the Botany Wetlands and into Botany Bay. The Botany Sands Aquifer is layer of sand filled with water beneath the ground. It covers an area of approximately 141 square kilometres. The average groundwater salinity is around 500 milligrams per litre (mg/L) of dissolved solids. Before European settlement, it formed an important source of water for wetlands supporting aboriginal communities. The Botany Sand aquifer was once Sydney's main water source. It remains an important source of water for parks, municipal and residential gardens, industry and wetlands. It may form an important part of Sydney's water future by capturing and storing stormwater for later use.

The aquifer is recharged by rainwater percolating through sand and sandstone which act as natural filters to remove solid litter, silt and harmful nutrients. The water holding capacity of the sand aquifer is enormous and has been estimated to contain up to 300 litres of water per cubic metre of sand. It is estimated the aquifer can sustainably supply 22,500 megalitres per year (ML/yr - a megalitre is one million litres) of groundwater. Currently only approximately 6,000ML/yr is allocated for use.

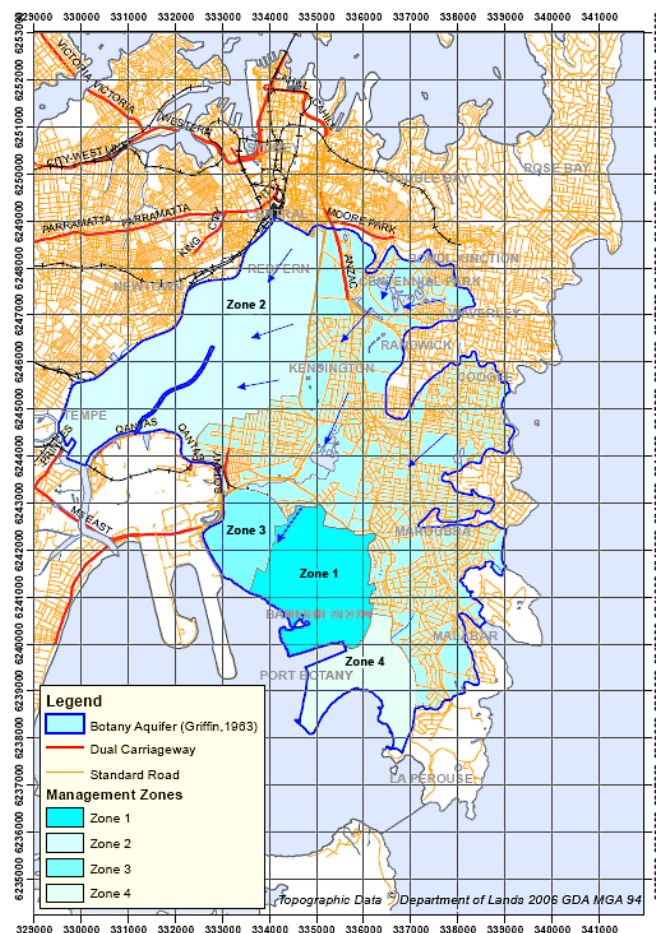


Figure 1: Extent of the Botany Sands Aquifer

The groundwater helps to support natural and man-made pond systems along its flow path. The natural ponds supported aboriginal communities in the Botany Bay area prior to European settlement. The ponds that exist today have been altered from the natural ponds. It was reported that the ponds may have dried out in the 1830s. Certainly in May 2006, during the last drought across eastern Australia, water levels in the wetlands were very low.

Most of the ponds get their water from both groundwater and stormwater. The level of the ponds depends on the amount of rainfall (stormwater), the volume of groundwater inflow to the ponds (which is affected by how much groundwater is pumped from bores) and evaporation. Ponds that exist today that are in part supported by groundwater include those in Centennial Park, The Royal Randwick Racecourse and ponds within golf courses including Eastlakes and Mill Pond.



Figure 2: An Example pond that is supported by groundwater – Eastlakes

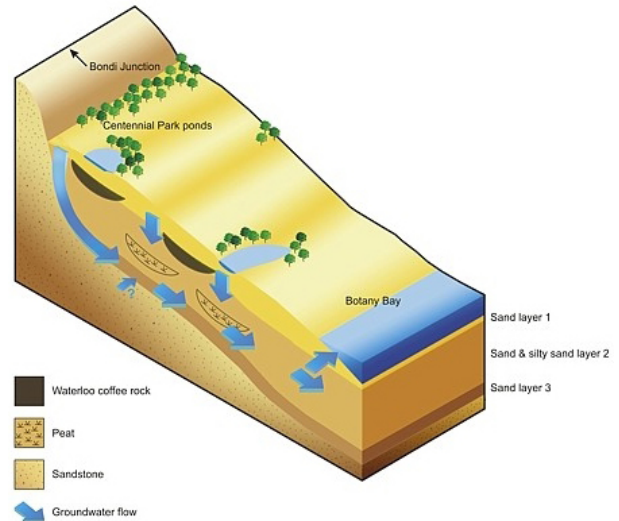


Figure 3: Example cross section of the Botany Sands Aquifer

A source of water for Sydney

When Lieutenant James Cook explored Botany Bay in April 1770, he and Sir Joseph Banks observed aboriginal “huts” on the northern shoreline of the bay and heathlands ascending to high sandy ridges beyond. With European settlement in 1788, it was not long before industry arrived in Botany with Simeon Lord establishing his wool factory adjacent to ponds north of Botany Bay in 1815. Other industries followed which allowed industrial contaminants to enter the surface water and the groundwater, affecting what the water could be used for. Sydney’s first water source, the Tank Stream, became unusable because of this contamination.

To meet Sydney's growing water needs, Governor Macquarie ordered the construction of a series of tunnels and shafts to collect groundwater and stormwater. In total approximately 28 bores and shafts connected into a 3.6km long tunnel that ran from Centennial Park to the growing city of Sydney. This complex, known as "Busbys Bore", supplied 1.5 million litres of groundwater and stormwater to Sydney every day. This was a significant contribution to Sydney's water needs until large dams and reservoirs were built in the 1890's. Even today, Busby's Bore still provides up to 490 million litres of water each year to the Royal Botanic Gardens in Sydney.



Figure 4: Busby's Bore

More information on Busby's Bore

https://www.sydneywater.com.au/web/groups/publicwebcontent/documents/document/zgrf/mdq0/~edisp/dd_044107.pdf

Wikipedia also now gives a good summary.

Contamination of the Botany Sands Aquifer

The Botany Sands aquifer remains an important source of groundwater in Sydney's south eastern suburbs. Groundwater from the aquifer is still being pumped and used by industry, golf courses, and residents for garden watering. However, for over 100 years increasing use of land above the aquifer for industry, the groundwater has been contaminated by industrial pollutants. Much of this contamination occurred before any environmental protection controls were in place and at that time basic measures to prevent pollution were not considered to be necessary. Groundwater managers are now dealing with this legacy in Australia and around the world.

A range of industries operated in the Botany area such as tanneries, metal platers, service stations and depots, landfills, dry cleaners and wool scourers. As a result, chemicals such as chlorinated hydrocarbons and other solvents, petroleum hydrocarbons such as petrol and diesel, and some heavy metals such as chromium, nickel, lead and arsenic, have contaminated the aquifer. A well publicised example of industrial contamination came from chemical production facilities in the Botany Industrial Park (BIP). However, these facilities are not the only source of contamination to the Botany Sands aquifer.

Botany Industrial Park (BIP) – an example of groundwater contamination

The BIP is a 73 hectare industrial complex in south-east Sydney. ICI Australia, who became known as Orica in 1998, commenced chemical manufacturing at the BIP in 1944. In the late 1970s and 1980s, volatile chlorinated hydrocarbons were identified in groundwater beneath the site.

Chlorinated hydrocarbon (CHC) is a generic term given to chemical compounds containing chlorine, carbon and hydrogen. The term can be used to describe pesticides such as lindane and DDT, industrial chemicals such as polychlorinated biphenyls (PCB), chlorine waste products such as dioxins and furans, and dry-cleaning products such as perchloroethylene (PCE) or tetrachloroethene (TCE).

It is suspected that the CHC contaminated groundwater came from a series of sources including the manufacturing plants, storage tanks, drum stores and leaks from the plant's wastewater treatment system. Some of the contaminants are heavier than water and dissolve very slowly in water. These contaminants are collectively called Dense Non-Aqueous Phase Liquids or DNAPLs.

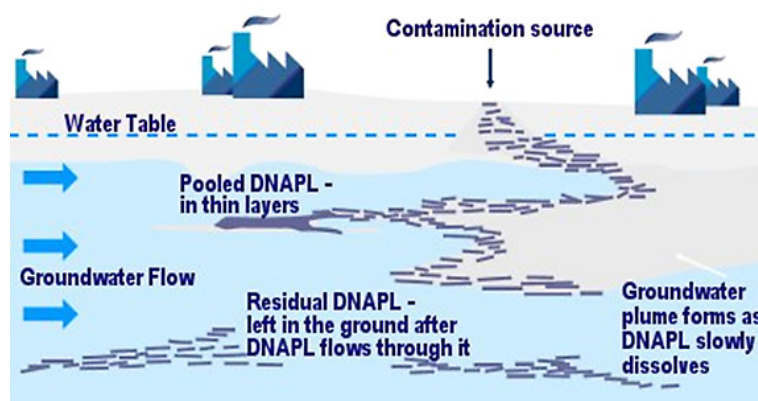


Figure 5: DNAPL forms a complex Source of contamination (Source: Orica Community Fact Sheet [2014] http://www.orica.com/ArticleDocuments/993/20140630_DNAPL.pdf.aspx)

Contaminated groundwater from the BIP cannot be safely used for most applications. The salinity of the uncontaminated groundwater in the Botany Sands Aquifer is generally around 500mg/L of dissolved solids. Under natural conditions, this would mean the water could be used for a wide range of applications including drinking water. With the addition of contaminants, the overall salinity may not change, but the contaminants may represent an unacceptable risk to human or environmental health. The groundwater also flows out to Botany Bay where contamination in the discharging groundwater may affect recreational users of the Bay and aquatic ecosystems.

The Environment Protection Authority regulates the clean-up of the contamination such as that from the BIP. To prevent contaminated groundwater at the BIP having adverse impacts on Botany Bay and adjacent wetlands, three containment lines were constructed. Each line extracts contaminated groundwater, intercepting it before it can reach Botany Bay. There are over 100 extraction wells pumping a total of about 6 ML/day. Once extracted, the groundwater is treated by a purpose built Groundwater Treatment Plant. The treated water suitable for non-drinking water uses such as garden watering and industrial use. To the end of 2016, in excess of 19,000 ML of groundwater has been extracted and an estimated 1,350 tonnes of CHCs has been removed and destroyed. Current estimates are that there are about 10,000 tonnes of CHCs in groundwater and that the clean-up works will continue for decades to come. The effectiveness of pump and treat as the preferred treatment option will diminish over time and alternative remedial options may be pursued in the future.

In addition to the actual clean-up program, there is extensive groundwater and surface water quality monitoring to understand where contaminants are and how they are responding to remediation. A comprehensive human health risk assessment has been undertaken to identify, and assist in mitigating any health risks. A community liaison committee meets regularly to discuss the progress of the remediation projects. Groundwater remediation experts from both Australia and overseas meet every couple of years to discuss whether or not the current remediation strategy remains effective and identify alternative options for the future.

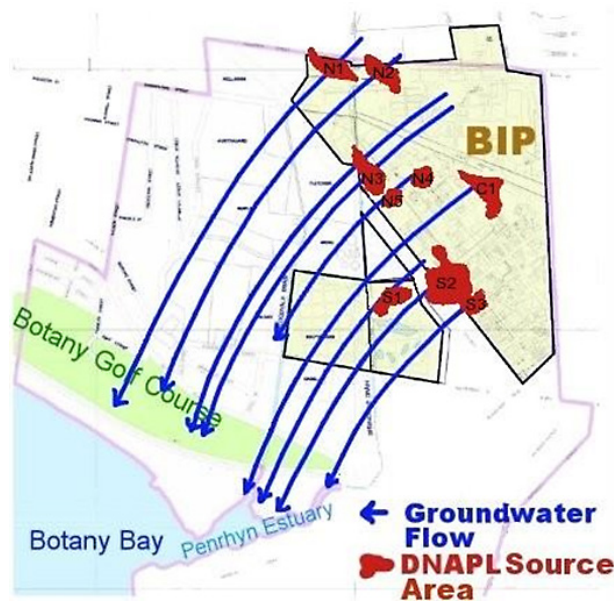


Figure 6: Dissolved contamination moves through the aquifer, affecting its quality and potentially affecting environmental values where it discharges (Source: Orica).

More information on the BIP / Orica site and its clean-up can be found at:

<http://www.orica.com/Locations/Asia-Pacific/Australia/Botany/Botany-Transformation-Projects/Groundwater-Cleanup#.WMfUbYVOLcs>

Approach to contaminant management across the whole Botany Sands aquifer

The NSW State Government has a robust contaminated land management approach. Whilst only a small proportion of the Botany Sands aquifer area is known to be contaminated, the legacy of past activities could have affected the groundwater in other locations. Because of this, the NSW Government has taken a precautionary approach to ensure public health is not put at risk from exposure to potentially contaminated groundwater.

The Government has divided the area into four management zones: the pre-existing BIP exclusion area (Zone 1) and three other management zones (Zones 2 to 4) – Figure 7.

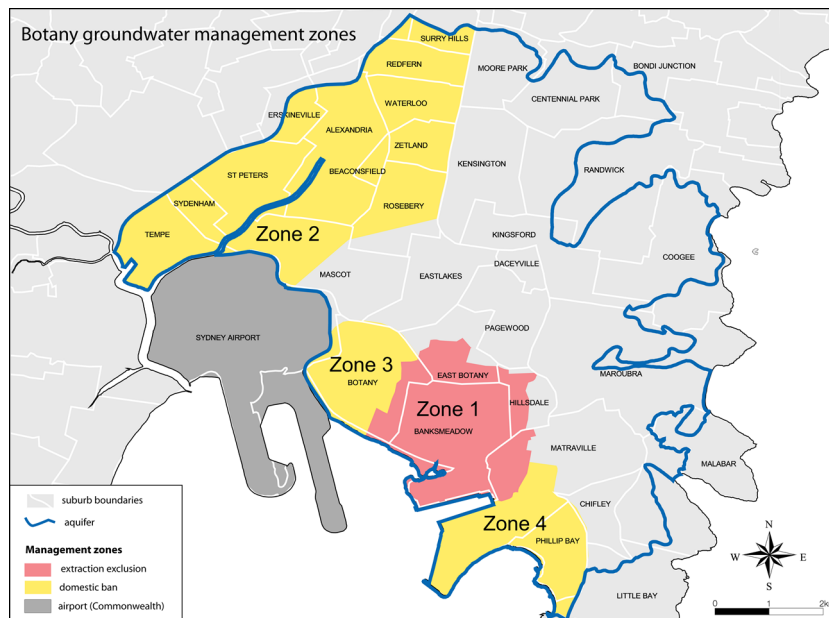


Figure 7: Management zones for the Botany Sands Aquifer

Zone 1 reflects the Groundwater Extraction Exclusion zone related to the contamination from the Orica site. All use of groundwater is banned in this area.

In Zones 2 to 4, the use of groundwater for drinking water, watering gardens, washing windows and cars, bathing, or to fill swimming pools is banned and industrial users of groundwater must test water quality annually and report it to the Government. These monitoring activities will help gain a better understanding of the extent and nature of any contamination in the area and the effectiveness of management and remediation approaches.

Since 2003, no new licences to extract groundwater have been issued in an initial area covering the most likely areas that could be affected by contamination. This embargo was extended to cover the entire Botany Sands Aquifer in 2007. However existing users outside the four zones illustrated in Figure 7 can continue using groundwater.

The management of groundwater in the Botany Sands Aquifer has recently been reviewed and a need for more community awareness has been identified. A temporary water restrictions order for the Botany Sands groundwater source is anticipated to replace the order made in September 2006. The temporary water restrictions order will simplify the water management zones and clearly outline the restrictions and exemptions that apply. A community awareness program will be initiated to explain the changes made.

More information on the management of the Botany Sands aquifer can be found at:

<http://www.water.nsw.gov.au/water-management/water-quality/groundwater/botany-sands-aquifer>

Opportunities for the future – Managed Aquifer Recharge (MAR)

The shallow, unconfined nature of the groundwater in the Botany Sands means that there is the opportunity to store extra surface water into the aquifer for later use. This approach is called Managed Aquifer Recharge.

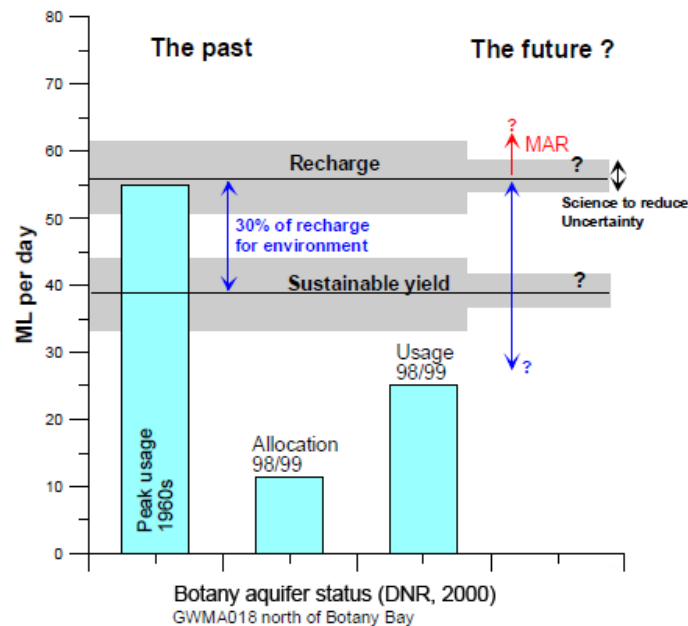


Figure 8: Potential to put more water into the aquifer, using it as a storage, so more water can be taken out.

The pond systems of Centennial Park currently recharge the groundwater systems. Over the years, stormwater has been directed into these ponds, which has effectively increased the amount of recharge. There is an opportunity to use this process to make more water available from the aquifer.

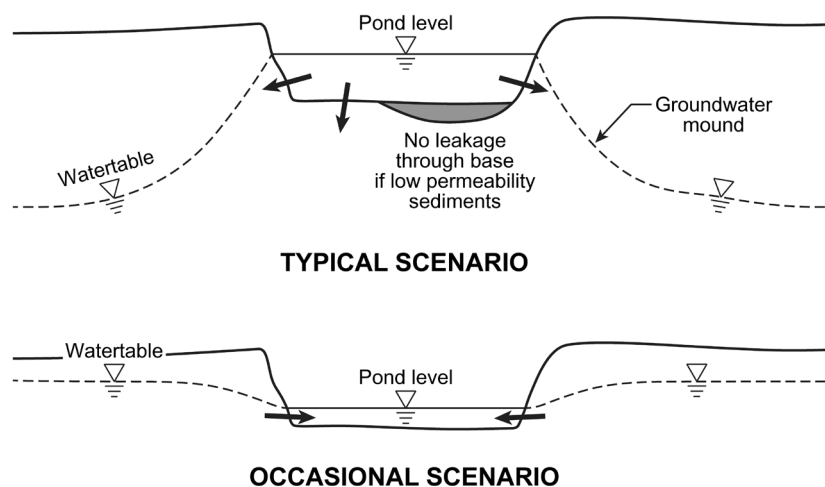


Figure 9: Centennial lakes – what currently happens. There is the potential to increase recharge (top Figure) by putting more water into the lakes at key times (Source: <http://www.connectedwaters.unsw.edu.au/research/projects/managed-aquifer-recharge-botany-aquifer>).

Making a decision – what is the best source of water to use for Managed Aquifer Recharge?

Different sources of water such as stormwater or recycled sewerage can be used to recharge the aquifer. Each of these water sources has different strengths and limitations. For instance, stormwater provides high volumes of water in short periods. It has lower overall reliability, and requires significant infrastructure to capture it for infiltration. Generally, however, stormwater requires very little treatment. In fact, the aquifer itself acts as a “filter” for the water.

Treated sewerage is a more reliable water source and systems can be built to provide an almost constant input to the aquifer. However, treated sewerage requires a very high level of treatment to reach an acceptable water quality standard. Also, there are issues with community acceptance of the use of treated sewerage!

More information on Managed Aquifer Recharge and the Botany Sands Aquifer can be found at:

<http://www.connectedwaters.unsw.edu.au/research/projects/managed-aquifer-recharge-botany-aquifer>

Summary

The Botany Sands Aquifer has a long history of providing water to support communities. Industrial development on the land over the aquifer has resulted in its contamination, reducing the water quality and the things it can be used for. Extensive remediation and management is underway to manage the effects of this contamination and ensure human and environmental health is protected. As there are increasing challenges for water supply for Sydney, the aquifer may again play an important role as a source of water through Managed Aquifer Recharge storing excess stormwater for later use. The importance of the Botany Sands Aquifer as a water supply underpins the need for effective management of this important natural resource.

References:

This case study was prepared using published information. The review of the content by members of the International Association of Hydrogeologists (NSW Branch) is acknowledged and appreciated.

Key Terms

Aquifer

A layer of soil or rock with sufficient porosity and permeability to enable usable quantities of water to be extracted from it.

Permeability

Permeability is a measure of how well connected the pores in soil and rock are to enable groundwater to move between pore spaces. How easily groundwater flows depends on how many gaps there are (porosity) and how well connected the gaps are (permeability).

Porosity

The volume of “space” between particles of soil or rock as a percentage of the total volume of the soil or rock.

DNAPL

A dense, non-aqueous phase liquid (or DNAPL), is a liquid that is heavier than water and does not readily dissolve in water. DNAPL contaminants can be difficult to manage in groundwater, as they move downward through the ground based on gravity and where the permeability is greatest. This makes it difficult to predict their movement and therefore to find them when looking to clean them up. Once in the ground, they form a long term source of contamination, as they slowly dissolve into the passing groundwater.

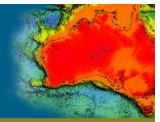
Managed Aquifer Recharge (MAR)

The basic concept of MAR is to capture additional surface water and use the aquifer as the storage for that water. The water can be put into the aquifer by pumping it in through bores, or by allowing it to infiltrate through ponds. It is then pumped back out for later use.

Recharge

The volume of rainfall or surface water that enters the pore space within an aquifer to become groundwater.

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CASE STUDY 1.008/ STUDENT ACTIVITY

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Example exercises

Example 1: Research the Botany Sands geological unit. How were the sands formed? What underlies the Botany Sands? What is the difference between sand and a sandstone? What is the process of forming sandstone from sand?

Example 2: Planning for the future, looking to the past. You are asked to develop a management plan for the Botany Sands Aquifer to integrate it as a source of water to meet Sydney's future water needs. Map out the history of the use of water from the aquifer. This will include the use before European settlement, early European settlement, industrialisation of Sydney, the late 20thC and today. Develop an approach for considering the relative value or importance of water from the aquifer over each of these periods. You may want to consider aspects such as cultural, drinking water, industrial water and water for the environment. Summarise the relationship between the value or importance, and what has occurred to the quality of water in the aquifer.

Summarise the current water quality in the aquifer and the quantity of water that is available. Consider the extent of the aquifer, and how water is accessed from the aquifer. Research what water is used for in Sydney. Identify all uses of water in both a residential and commercial / industrial setting. Also think through how the environment may also need to use groundwater. Using these considerations, identify the opportunities for how water from the aquifer can be used to meet Sydney's water needs. Develop a management plan to make the most of this water as part of an integrated water supply. Develop an action plan for what needs to happen to implement this plan.

In reflection, summarise how science has informed your plan. Think about how you used science to develop your understanding and the resultant plan. Given these considerations, what additional pieces of science would you need to improve your capacity to make decisions? Develop a knowledge plan to enhance the potential to make planning decisions.

Example 3: Research chlorinated hydrocarbons. Identify the chemical formulae for the contaminants in groundwater identified at the Orica plant. Summarise what it is that makes them "toxic". The remediation program used by Orica uses a range of techniques to remove the chlorinated hydrocarbons from water. Summarise the techniques and the chemical reactions that change the chlorinated hydrocarbons. Identify other chemical reactions that can reduce the concentration of chlorinated hydrocarbons. In developing this understanding, think about the products of the reactions and their toxicity.

www.tesep.org.au