

4.1 Introduction

This chapter outlines the key objectives for the BGC Project and the constraints that apply to the project, and presents a summary of the methodology followed by Orica to determine the most suitable treatment technology for the groundwater contamination at Botany. A description of several alternative treatment options is presented, followed by a brief description of Orica's preferred technology and the rationale behind its selection. In addition an independent assessment of alternative technologies was undertaken as part of this EIS process and is presented in **Appendix K**.

The NCUA mandates the use of 'pump and treat' technology (i.e. *ex situ* treatment) in the PCA. Orica has determined that *ex situ* treatment is also the most expeditious solution and has chosen to adopt it for all three containment areas. Consequently, no assessment of *in situ* processes has been discussed in this chapter.

Overall, this section provides a summary of the alternatives considered and conclusions reached, given the specific constraints for the required works, with reference to:

- international treaty frameworks;
- treatment plant location options;
- available and appropriate treatment technology options; and
- the implications of the 'do nothing' option.

4.1.1 Objectives

The primary objective of the BGC Project is to stop the contaminated groundwater plumes that are migrating towards Penrhyn Estuary and Botany Bay. The BGC Project objectives are described in **Section 3.4**. The following key objectives were considered mandatory in assessing alternative technologies for treatment:

- use of best practice technology;
- the technology chosen must use proven, safe and commercially viable, and able to be designed, purchased, installed and started up within the critical timeline; and
- the technologies must achieve a critical start-up timeline that stops the plumes in time to prevent high concentration contamination reaching Penrhyn Estuary and Botany Bay.

Further, it is recognised that the local community and the NSW Government, through its regulatory agencies, expects that Orica will utilise best practice for the cleanup strategy. For the BCG Project, 'best practice' is defined as:

- meets or exceeds all regulatory discharge, emission, and disposal limits required by the EPA and has been demonstrated for use in similar applications for liquid, air (or vapour), and solid waste streams;

- meets or exceeds any treatment technology efficiency standards required by the EPA and has been demonstrated for use in similar applications; and
- will protect public health and environmental values defined by the EPA, other regulatory agencies, and as a result of public and private interest inputs into the public participation process.

4.1.2 Key Constraints

Time

The NCUA issued by the EPA has mandated the hydraulic containment and treatment of contaminated groundwater from the Primary Containment Area (PCA), to maximise contaminant reduction by October 2005. Satisfying this demanding target requires the earliest practicable operation of a groundwater treatment plant (GTP). The preliminary project schedule in Orica's GCP targeted GTP completion in August 2005, assuming timely approvals were obtained. Meeting this timeframe is a key criteria for evaluating potential treatment alternatives.

Success Probability

The NCUA was prepared by the EPA with the assistance of international experts in the field of groundwater contamination and cleanup technologies, including representatives from the US EPA. This advice resulted in the mandated requirement that Orica should focus its efforts on the use of *ex situ* treatment technologies. *Ex situ* treatment is seen as offering a more reliable and predictable outcome than the *in situ* techniques that Orica has considered for part of the cleanup strategy.

In response, Orica carried out an assessment of available and practical treatment technologies for *ex situ* treatment as part the GCP. This formed the basis for the selection and development of the proposed treatment technologies that comprise the GTP.

International Conventions

Australia is a signatory to several international conventions covering the movement and treatment of hazardous chemicals and persistent pollutants. These conventions potentially influence the selection of a suitable cleanup strategy and need to be incorporated into Orica's technology selection criteria.

4.2 International Treaties Potentially Affecting Strategy Selection

4.2.1 Introduction

As part of the process of selecting a preferred technology to allow Orica to comply with the NCUA, there are a number of international agreements, of which Australia is a signatory, that are potentially relevant to this project and therefore require consideration.

4.2.2 Basel Convention

The Basel Convention on the Control of Transboundary Movements of Hazardous Waste and their Disposal came into force in Australia on 5 May 1992. Waste EDC is a chemical listed as a hazardous waste under the Basel Convention and, as such, the provisions of the Convention must be considered when determining groundwater treatment options.

The primary guiding principle of the Convention is that, in order to minimise the potential threat to human health and the environment, hazardous wastes should be dealt with where they arise unless very exceptional circumstances require their movement off-site or to other states, territories or countries. Under the Convention, transboundary movements of hazardous wastes can take place only upon prior approval of originating, receiving and transit jurisdictions.

Australia's obligations under the Basel Convention are regulated under the *Hazardous Waste (Regulation of Import and Exports) Act 1989*.

The potential option to export the contaminated groundwater, or the extracted contaminants, for treatment elsewhere is not considered consistent with the principles of the Basel Convention or the *Hazardous Waste Act*, and hence it is unlikely that the EPA would grant a permit for the movement of Botany groundwater or its constituents.

4.2.3 Stockholm Convention

The Stockholm Convention on Persistent Organic Pollutants came into force on 17 May 2004, and requires all signatory parties to phase out the use and manufacture of persistent organic pollutants (POPs). Australia ratified the Convention on 20 May 2004.

Persistent organic pollutants

Under Article 5 of the Convention ('Measures to reduce or eliminate releases from unintentional production'), signatory parties (i.e. governments) are required to "*develop an action plan within 2 years ... designed to identify, characterise, and address the release of [such] chemicals ...*". (UNEP, 2002)

The Convention applies to 12 named POPs, including dioxins and furans, that can be produced unintentionally as by-products of industrial combustion. This listing of dioxins and furans means that the requirements of the Convention have to be considered as part of the assessment of technology alternatives for the BGC Project. In summary, the relevant aspect of the Convention requires "*... governments to take steps to reduce the release of dioxins and furans as byproducts of combustion or industrial production, with the goal of their continuing minimisation, and, where feasible, ultimate elimination*" (UNEP, 2002).

National Dioxins Program

In the lead up to the Australian Government's commitment to the Stockholm Convention, in 2001/02 the National Dioxins Program was set up, to collect data, assess impacts and then determine appropriate measures to reduce and, where feasible, eliminate dioxins. Implementation of the program has three phases:

- Phase One: Gather information about the current levels of dioxins in Australia;
- Phase Two: Assess the potential risks of dioxins to the environment, and of the potential risks for human health from exposure; and
- Phase Three: Develop national management strategies to reduce and, where feasible, eliminate the release of dioxins in Australia.

Phase One and Phase Two have been completed, with 12 technical reports presenting the findings. One of these reports, the *Inventory of Dioxin Emissions in Australia 2004* (DEH, 2004), provides an overview of dioxin emissions in Australia, summarised in **Table 4.1** for emissions to air.

Table 4.1 Summary of dioxin emissions to air

Source Categories	Best Estimate g TEQ ⁽ⁱ⁾ /year	Contribution to Total Emissions
Uncontrolled Combustion Processes	330	66.8%
Metal Production	112	22.4%
Power Generation & Heating	35	7.1%
Transportation	9.1	1.8%
Waste Incineration	6.5	1.3%
Mineral Products	1.9	0.4%
Production of Chemicals & Consumer Goods	0.43	0.1%
Miscellaneous	0.31	0.1%
Total	500	100%

Note:

(i) TEQ is 'toxic equivalency' – as dioxins always occur in mixtures, each of the dioxins and furans has been assigned a toxic equivalency factor (TEF) based on its relative toxicity, and the TEFs can be used in combination with the concentration of each dioxin to calculate toxic equivalent concentrations of dioxins in air.

The data in **Table 4.1** show that by far the largest source of dioxin emissions to air is 'uncontrolled combustion processes', which includes bushfires, accidental fires and other uncontrolled waste burning.

Phase 3 of the program has yet to be developed, and there are no formal management strategies in place at present. In the absence of such formal strategies, the overall regulatory emphasis on avoiding emissions and/or justifying proposed emissions based on 'no adverse impacts' provides the basis for managing potential emissions of dioxins.

'Best Available Techniques'

Article 5 of the Stockholm Convention also requires the promotion and use of 'best available techniques' for new sources, within source categories defined within the Convention and as may be identified by a 'Party' in its action plan. The concept of 'best available techniques' is defined as "... taking into account the

technical characteristics of the installation concerned, its geographical location, and the local environmental conditions.”

Some thermal oxidation technologies have been linked with the formation of dioxins and furans as by-products of partial combustion. As such, the provisions of the Stockholm Convention needed to be considered in the technology selection process for the BGC Project.

4.3 GTP Location

Given the implications of the Basel Convention, Orica undertook an assessment and selection of the best location for the GTP. This assessment comprised overall consideration of a location on-site or off-site from the BIP.

4.3.1 Consideration of On-site/Off-site GTP Locations

It was found that off-site treatment was not feasible, primarily because there is no suitable existing plant anywhere in Australia that can treat the volume of groundwater that is required for the BGC Project. In addition, Orica considered that it was not feasible to identify an off-site location for a new plant, and gain the relevant approvals, in the required timeframe.

Even if an off-site location could be found and approvals secured, an off-site treatment option would involve the movement of about 15ML/d of contaminated groundwater. The transport options would comprise:

- road: a total of 750 tankers (of 20 m³) per day would be required, resulting in 1500 daily tanker movements;
- rail: similar rail tanker numbers would be required, for which available rail infrastructure does not exist, and the time required for developing such infrastructure means it would not be possible to complete in the timescale required by the NCUA;
- pipeline: planning, design and construction of a large scale transfer pipeline, and obtaining the necessary government and landowner approvals, would not be possible to complete in the timescale required by the NCUA; and
- ship: similar time constraints apply in the planning, design, approval, and construction of ship loading and unloading facilities, as well as logistical difficulties for transport to and from such facilities.

Given these difficulties, it is not feasible to locate the GTP at a remote location and transport the groundwater to it within the time constraints of the project as mandated by the NCUA. Consequently, Orica decided that the GTP should be on its own land at the BIP, as close as possible to the groundwater problem. This is in line with best practice for the treatment of groundwater.

4.3.2 Recovered Waste EDC Liquid Destruction On-Site/Off-Site

Certain waste extraction technologies (for example, steam stripping) that remove the EDC waste from the groundwater then require the recovered waste to be destroyed. This raises the issue of the location of the subsequent destruction process (on-site or off-site).

Off-site destruction may be advantageous, particularly if an existing destruction facility were available, or if the overall risk of transport and operation of a remote facility was demonstrated to be best practice.

The only identified destruction facility currently operating in Australia is the BCD Technologies Plascon unit in Brisbane. This unit has spare capacity for only a small fraction of the GTP requirement. There are no known plans for the installation of new commercial waste destruction facilities elsewhere in Australia, although such facilities may be constructed by other parties in response to the Orica demand.

Within the BGC Project's time constraints and the inherent safety principles of minimising the movement and long-term storage of hazardous material (such as the recovered waste EDC liquid), storage of this flammable and volatile material would require ongoing, stringent management to ensure that the potential risk was kept as low as reasonably practicable.

In preparation to receive recovered waste EDC liquid from the Steam Stripping Unit (SSU), Orica has identified up to 1660 m³ (about 2000 tonnes) of suitable storage at Terminals Pty Ltd's bulk liquid storage facility at Port Botany. The indefinite storage of the recovered material from the full scale GTP would require the commitment of significantly greater storage capacity at nearby facilities. Unlike a stable solid material, even the well managed long-term storage of this recovered liquid would pose a risk—one that is hard to justify in the light of internationally accepted destruction techniques. As discussed in **Section 4.7**, a reference paper prepared by the European Commission has identified destruction, using thermal oxidation, as the best available technology for chlorinated vent streams, rather than indefinite storage.

In addition, the movement of the material to the storage facilities and the eventual transfer to a destruction facility would pose an additional risk.

It should be noted that the storage of this liquid would not enable faster cleanup of the groundwater. The rate of groundwater cleanup is limited by technical and environmental constraints on the extraction of groundwater (e.g. subsidence on wetland systems).

The internationally accepted principle is that of minimising the inventory of hazardous material. As noted in *Loss Prevention in the Process Industries*, "the thrust should be to eliminate storage" (Lees, 1996). Orica does not support the indefinite storage of recovered waste EDC liquid from the operation of the BGC Project.

4.3.3 Consideration of Locations Within the BIP

Given the groundwater quantities and the potential timescale for the GTP, Orica has concluded that the preferred location for the GTP should be on Orica-owned land close to the groundwater extraction wells. A number of potential sites were considered:

- Southlands (south-east of the BIP): This was rejected because there are no adequate services or infrastructure;
- Beauchamp Road car park area (on the BIP): This was rejected because of its proximity to Beauchamp Road and the other industrial and residential areas beyond;

- Chlorine Plant Area (on the BIP): This was originally selected, because it is close to existing infrastructure, has relatively clear ground (minimising construction works), and has additional available space if required. However, upon detailed investigation, it was concluded that the site area was insufficient for the size of GTP required, and the site was rejected; and
- Silicates Plant Area (on the BIP): This was considered the most appropriate site. It has sufficient land for the treatment plant and buffer zones, generally clear ground (minimising construction works), proximity to existing infrastructure, and is located 325 m from the nearest residential areas on Denison Street.

4.4 Key Technology Selection Criteria

To achieve the requirements of the NCUA for *ex situ* treatment of the groundwater, the GTP must incorporate:

- 'best practice' technologies that would achieve relevant Australian and world-wide air emission and water quality standards;
- proven technologies that would be reliable and safe, throughout the estimated operating life of up to 30 years;
- technologies that would achieve the required cleanup within the specified time frame (this is determined by hydraulic containment design, not the treatment technology); and
- technologies that would achieve the required output from the input combination of very large quantities of groundwater to be treated (up to 15 ML/day) with low concentrations of contaminants (0.02% w/w), equivalent to three to four tonnes a day.

Based on these key criteria, the technology selection process incorporated a number of steps through which the final technology selection was made.

4.5 Initial Assessment of Treatment Processes

4.5.1 Initial Screening

As part of the preparation of the GCP, Orica carried out an assessment of potential treatment technologies, based on the US Government's Federal Remediation Technologies Roundtable (FRTR)'s *Remediation Technologies Screening Matrix and Reference Guide* (FRTR, 2002).

The matrix comprises a summary of the commonly used remediation technologies for soil, sediment, bedrock and sludge; groundwater, surface water and leachate; and air emissions/off-gases. The matrix and reference guide provides screening and evaluation of potentially suitable remediation technologies for treatment based on site-specific conditions and characteristics.

As presented in the GCP, Orica's review of the matrix identified nine component technologies for *ex situ* physical/chemical/biological treatment of groundwater, surface water and leachate, namely:

- adsorption/absorption;
- advanced oxidation processes;
- air stripping/steam stripping;
- granulated activated carbon (GAC)/liquid phase carbon adsorption;
- groundwater pumping;
- ion exchange;
- precipitation/coagulation/flocculation;
- separation; and
- sprinkler irrigation.

This list was then refined and expanded to identify a suite of technologies, including biological treatment, for further consideration. In order to systematically approach the technology selection, the treatment schemes were classified as either dealing with the contaminants in the water or after removal from the water.

4.5.2 Options to Deal with Contaminants in the Water

The options assessed by Orica were:

Biological Treatment: The whole groundwater flow could pass through a biological treatment process, similar to a sewage treatment plant, but with a mixed culture of microbes that would adapt to and consume the contaminants. This possibility was rejected due to the long lead time in developing an appropriate microbial culture, as well as some concern about the robustness of such a system to the challenging variations that might be encountered with the groundwater. This would have the potential to kill the active microbes, leading to no effective treatment until the culture was reinstated.

Advanced Oxidation: This process uses a combination of chemicals, whose action is enhanced through the use of ultraviolet light. Again, the whole groundwater stream would pass through suitably designed reactors, converting the contaminants to innocuous by-products. This system can suffer from fouling, leading to inadequate UV exposure. Further, it is reported that contaminant volatilisation can occur, leading to potential release of contaminants to air without treatment.

Activated Carbon: Passing the water through activated carbon is a proven technology for removing a wide range of organic compounds from a water stream. However, due to the large volume flows, relying only on activated carbon for contaminant removal would consume very large quantities of carbon, which would still require further treatment for contaminant destruction.

In summary, given the issues outlined above, none of these options were considered further.

4.5.3 Options to Remove Contaminants from the Water

From the FRTR matrix, two technologies were identified by Orica for the removal of the contaminants from the groundwater. These were air stripping and steam stripping. Once removed from the groundwater, the contaminants would still require destruction.

Air Stripping: The contaminants are removed by blowing an air stream through the contaminated water, driving the volatile compounds out of the water and into the air stream. The FRTR reports this as a “robust and well developed” technology. Once the contaminants are in the air stream, it is not practicable to remove them, so they must be destroyed as a dilute mixture of contaminants in a relatively large volume of air. Thermal oxidation was identified as the most appropriate destruction technology for use with air stripping.

Steam Stripping: This process is similar to air stripping, except that low pressure steam is used to drive the volatile contaminants out of the groundwater. The steam containing the volatile contaminants is then condensed to form two liquid phases: an aqueous stream for recycling back into the stripping column, and an organic liquid phase containing the contaminants, for subsequent destruction using a method selected from a wider range of destruction technologies. The FRTR does not offer details on experience with this technology, suggesting that if it is widely used, it is designed “in house” and public domain information is therefore not readily available. This technology has a substantial cost advantage where there is low cost excess steam available.

4.5.4 Options to Destroy Removed Contaminants

The technology identified for destruction of the contaminants in the gas stream from the air stripping process was **gas phase thermal oxidation**. This involves oxidising the removed wastes at high temperature. As outlined above, it is considered the only feasible destruction method for wastes removed in an air stripping process. This technology is well proven and widely supported by many reputable vendors around the world.

A range of technologies were identified for destruction of the recovered waste EDC liquid from the steam stripping process:

Gas Phase Reduction: This involves treating the waste at high temperatures and pressures in a hydrogen atmosphere. While proven, the process suffers from inherent safety concerns (the high-pressure and high-temperature hydrogen poses a significant potential hazard) and poor reliability, and there are currently no operational facilities worldwide. Before it ceased operation, the Ecologic unit at Kwinana was inspected by Orica and it was found to demonstrate extremely poor on-line availability. Additionally, this process is not commercially available since its proponent, the Canadian company Ecologic, has ceased trading. Access to the technology is therefore difficult, and would not be achievable within the time constraints of the BGC Project.

Base Catalysed Decomposition: In this process the contaminants are destroyed at elevated temperatures in the presence of caustic soda and oil. Again, the process offers limited inherent safety. It has been reported that the process generates significant quantities of waste for subsequent disposal. The process supplier has reported that it is not suited to the destruction of EDC.

Plasma Arc: This process destroys the contaminants by passing them through a high temperature plasma. This technology is commercially available but has limited throughput capacity, requiring the use of a number of units that would need to be operated in parallel in order to destroy the total contaminant load, thereby increasing operational complexity. In addition, the unit has limited reliability, requiring regular operator attention.

Liquid Phase Thermal Oxidation: Similar to the process described for air stripping, the contaminants are destroyed at a high temperature in the presence of oxygen. The unit required for treating the recovered EDC liquid would be much smaller than that required for the air stripping unit, and would probably require no supplementary fuel. This is well proven technology.

Other processes: A range of other technologies exist, such as super critical water, molten salt oxidation and molten metal oxidation. However, these are generally considered not to be fully proven, nor commercially available within the time constraints of the project.

4.5.5 Short-listed Treatment Processes

Orica concluded that the most practical means of treatment would be to strip the contaminants from the groundwater and then to destroy the resulting contaminant concentrate in the GTP.

Based on the discussion above, Orica determined that two processes warranted further investigation:

- air stripping with thermal oxidation of the off-gas; and
- steam stripping, with the subsequent destruction of the recovered waste EDC liquid yet to be determined.

4.6 Independent Assessment of Treatment Alternatives

Following the assessment by Orica, URS was appointed as part of the EIS process to carry out a detailed independent assessment of available groundwater treatment technologies and alternatives to meet the specific requirements and key technology selection criteria for groundwater treatment outlined above. The purpose of this assessment was to verify that the technology selection process undertaken by Orica was sound and that its findings were justified.

This independent assessment—largely prepared by Gary Smith of URS' Baton Rouge, Louisiana, office in the USA—is presented in **Appendix K**. It concludes that there are three possible treatment processes that would each achieve the requirements and key criteria for cleanup of the groundwater. These three options are:

- air stripping, with thermal oxidation treatment of the off-gas;
- steam stripping, with thermal pyrolysis treatment (e.g. plasma arc) of the recovered waste EDC liquid; and
- steam stripping, with thermal oxidation treatment of the recovered waste EDC liquid.

The evaluation, which included criteria relating to community expectations and concerns (identified at the workshops and stakeholder discussions outlined in **Chapter 8**) and the key sustainability issues, indicated that the two steam stripping alternatives were ranked slightly less favourably than air stripping, primarily because of the higher greenhouse gas emissions associated with the generation of steam and the high electricity consumption associated with the plasma arc thermal pyrolysis units (i.e. approximately 30–40% more tonnes of CO₂ per year). The above evaluation remained valid with or without operational and maintenance cost criteria being included.

It should be noted that, given the level of evaluation undertaken in this study, the differences outlined in the total numerical rankings are not considered significant enough to preclude any of the three alternatives being considered as candidate process trains to achieve the objectives of the BGC Project.

4.7 Development of the Preferred Option

4.7.1 Process Definition Study

Following the technology screening process, Orica commissioned the international engineering company Aker Kvaerner to undertake a Process Definition Study for the two waste extraction (air and steam stripping) processes, to determine the technical feasibility. Aker Kvaerner was not asked to identify or further study the destruction processes associated with steam stripping. The outputs of this study were the applicability of the processes for use in the GTP, and the identification of likely sizes, flows and utility consumptions to enable Orica to identify the most appropriate process to satisfy the specific objectives of the BGC Project.

In parallel, Orica investigated the commercial options for destruction associated with steam stripping. In particular, they contacted BCD Technologies in Brisbane, to explore the potential use of existing Plascon facilities. The Brisbane facility only had an available treatment capacity of 100 tonne/year, a capacity too small for the expected rate of contaminant generation (expected to be greater than 1000 tonnes per year). BCD Technologies also provided information about the potential for constructing new capacity in Brisbane or elsewhere (e.g. Botany) to provide sufficient capacity.

Orica's Preferred Technology

Aker Kvaerner identified that both air and steam stripping could provide the required performance. Orica chose the option of air stripping with thermal oxidation for the following key reasons:

- publicly available performance data for contaminant removal and destruction demonstrating applicability to the GTP;
- demonstrated performance in treating iron rich groundwater. (The groundwater is high in iron, which can cause fouling in some treatment processes. Air stripping units can be specifically designed for such conditions. Fouling was not observed in Orica's laboratory testing, but it had been with steam stripping);
- more widely available data describing the performance of air stripping for the particular contaminants in this project, allowing a more confident design, compared to steam stripping;

- no intermediate storage of hazardous, flammable liquid, which is contrary to the principles of inherent safety;
- simplified operation of a single destruction unit, compared to the multiple Plascon units associated with steam stripping; and
- best practice use of thermal oxidation for the destruction of dilute CHC contaminated air streams, as identified by the European Commission (IPPC Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry, Feb 2003) and the United Nations Environment Program (UNEP, 2004).

4.7.2 The Preferred Treatment Option

Subsequent to the screening assessment, and in parallel with conducting the independent alternatives assessment carried out by URS, Orica carried out further extensive investigation and assessment of the preferred process comprising air stripping with thermal oxidation treatment for the off-gas, to confirm the final process selection of the technologies to be used in the GTP.

This final alternative selection process included detailed review of potentially viable alternatives, justification of the final selection and an assessment of the final selection against best practice.

Thermal Oxidation Assessment

Given the proposed selection of air stripping and thermal oxidation, Orica recognised that further work was required to incorporate international best practice into the proposed technology selection and design, and undertook a series of visits to vendors and operating plant in the USA and Japan to obtain such information first-hand from recognised experts with practical experience.

The key elements of this further work were to identify best practice in design, operation, dioxin emission performance and regulations and the specification of the required destruction efficiency.

Dioxins and Furans

Dioxins can be emitted from a range of combustion processes, including thermal oxidation, through three primary routes:

- dioxins originally present in the feed material being inadequately destroyed;
- the presence of solids in the feed stream (which act as catalysts) leading to dioxin formation; and
- recombination of chemicals (known as de novo synthesis) through the cooling temperature range 450°C to 250°C (particularly in the presence of certain metals such as copper, which speed the reaction).

As shown in **Table 4.2**, the Australian regulations with regard to potential dioxin emissions from combustion processes (under which the GTP would operate) are equal to the strictest in the world, and therefore represent international best practice.

Table 4.2 International dioxin air emission regulations

Country/Region	Limit
Australia	< 0.1 ng/m ³
European Union	< 0.1 ng/m ³
Japan	feed stream of < 2 tonnes per hour: < 5 ng/m ³
	feed stream of > 2 tonnes per hour: < 1 ng/m ³
	feed stream of > 4 tonnes per hour: < 0.1 ng/m ³
USA	liquid/solids combustion: < 0.4 ng/m ³
	gaseous/vapour combustion: no dioxin regulation

Destruction Efficiency

Destruction efficiency in a thermal oxidiser is dependent on three factors: temperature, turbulence and residence time, and can be up to 99.9999% efficient in the destruction of highly toxic contaminants such as nerve gas. In the USA, the required destruction efficiency for chlorinated vent streams was 97%. Increased destruction efficiency is usually achieved by increasing temperature, with associated increases in energy demand (as support fuel) and in greenhouse gas emissions.

In the European Union, rather than specifying the destruction efficiency for a given application, best practice places a limit on the stack emission concentrations.

Best Available Techniques (BAT)

Within the European Union, BAT Reference Notes have been prepared by specialist committees to provide guidance to industry on the best available techniques and technologies available for minimising emissions, discharges and waste generation. For chlorinated vent streams, the Reference Notes identify thermal oxidation as BAT for destruction of the chlorinated contaminants (IPPC Reference Document on Best Available Techniques in the Large Volume Organic Chemical Industry Feb 2003).

In addition, the United Nations Environment Program also produced the *Draft Guidelines on Best Available Techniques and Provisional Guidance on Best Environmental Practices* (UNEP, 2004), which lists combustion as BAT for steams containing trace volatiles for the EDC/VC industry sector.

Thermal Oxidation Selection

During consultation with the regulators and the community, the issue of direct versus indirect thermal oxidisation has been raised. This typically relates to soil remediation. The context of this issue is described below.

In soil remediation, direct thermal oxidisation involves a flame in direct contact with the soil, while indirect thermal oxidisation heats the soil and destroys the contaminants, without the flame directly contacting the soil.

In groundwater treatment using air stripping units, the thermal oxidiser does not expose solid particles to a flame. The concepts of 'direct' and 'indirect' thermal oxidation are therefore not applicable in this case.

Recognising that thermal oxidation is sometimes a controversial technology, Orica is determined to ensure that only high quality processes from reputable vendors will be considered for incorporation into the GTP. Four types of thermal oxidisers were assessed in detail. These are described briefly below.

Recuperative Thermal Oxidisers: The hot gases leaving the reaction chamber are cooled by generating steam in a waste heat boiler and/or preheating the combustion air to the thermal oxidiser, thus reducing the overall energy requirement while still achieving very high destruction efficiencies. This type of thermal oxidiser is considered a suitable candidate for inclusion in the GTP.

Flameless Thermal Oxidisers: In these devices, the oxidising reactions take place in a ceramic matrix with a composition below the lower flammable limit, so that a flame as such does not exist. The uniform nature of the reaction zone ensures high destruction efficiency and low NO_x production. However, safety concerns about the operation of these units can arise if the 'flame' front moves beyond the designated reaction zone. Nevertheless, this type of thermal oxidiser, with its high destruction efficiency, is a suitable candidate for the GTP.

Regenerative Thermal Oxidisers: This type of thermal oxidiser has the highest energy efficiency of those reviewed, which is achieved by cycling the hot combustion gases through a ceramic bed, used to preheat the inlet gases. This is a lower cost unit that is extensively used in the USA on similar contaminant laden air streams arising from air stripping operations. However, the destruction efficiency is typically limited to 99.5%, which Orica (in consultation with the EPA) considered did not satisfy the best practice objectives of the selection criteria. While cost effective, this type of thermal oxidiser was rejected as a candidate for the GTP.

Catalytic Thermal Oxidisers: In these units, a catalyst is used to allow the oxidation reactions to occur at a lower temperature. The destruction efficiency is typically lower than other units, and the catalyst is subject to reduced performance over time. Orica considered that the best practice objective was not satisfied by this type of thermal oxidiser, and it was rejected as an option for the GTP.

Final Selection

On the basis of this detailed assessment work, Orica is proposing to use air stripping and thermal oxidation treatment technologies for the GTP, based on best practice design and regulated under international best practice dioxin regulations and the Stockholm Convention.

It is proposed to use a recuperative thermal oxidiser that operates at 1,000°C with a residence time of two seconds, giving a destruction efficiency of greater than 99.99%. This type of unit:

- will meet or exceed the best practice emission limits identified;
- has proven operation in the destruction of low concentration CHC air streams; and
- can be achieved in the timeframe.

A degree of energy efficiency will be achieved, including preheating the off-gas stream and the generation of steam for use within the GTP, thereby reducing the demand for energy from other sources.

4.8 Treated Groundwater Management

It is estimated that the GTP would process up to 15ML/d of groundwater. The final objective for the groundwater treatment process is to produce a treated groundwater that meets ANZECC marine guideline standards for the protection of slightly to moderately disturbed ecosystems (ANZECC, 2000), as well as process water standards and the quality standards of the Australian Drinking Water Guidelines (NHMRC/ARMCANZ, 2001).

Based on this objective, the following options were considered for the disposal of water once the contaminants had been removed:

- **Reinjecting back into the aquifer:** It was found that re-injecting the groundwater back into the aquifer was not feasible because:
 - the existing groundwater table is so close to the surface that there is insufficient space to create hydraulic mounding in the aquifer during injection without causing localised surface flooding;
 - the stripped water contains oxygen, which would lead to microbial fouling, blocking the re-injection wells; and
 - the stripped water could also cause similar blockages in the aquifer, which could also lead to localised flooding due to impairment of the hydraulic conductivity of the aquifer.
- **Discharge to the sewer system:** This option was rejected following initial discussions with Sydney Water, which identified that the sewer system could handle only a fraction of this volume during dry conditions, and would be even more restricted during periods of rain.
- **Discharge to Botany Bay:** This option provides an acceptable outlet for the treated groundwater following some further treatment, with the minimum potential impact (as discussed in **Chapters 13, 14 and 20**).
- **Reuse:** This option is preferred, because it would substitute the current use of townswater, thereby reducing demand for limited water resources.

4.8.1 The Preferred Groundwater Management Option

Reuse of the treated groundwater is the preferred option. The treated groundwater would be reused in various process operations (such as the boiler demineralisation water plant feed and cooling water make-up) around the BIP, as discussed in **Chapter 14**. There is a significant capital and operating cost associated with this reuse option, in terms of both the treatment itself and distribution of the treated water.

Orica has worked with the process plant operators in and around the BIP to achieve the proposed level of reuse (approximately 7.5 ML/day), and has allowed for additional expansion of the GTP to increase this level of reuse, if additional users are identified and agreement can be reached on the required investment in treatment and distribution. The remaining treated water would be disposed of to Botany Bay via Bunnerong Canal and Brotherson Dock.

Orica intends to maximise the reuse of treated water throughout the lifetime of the BGC Project. Orica has in-principle approval from the NSW Government to recycle the treated water and make it available for sale to other users. Orica would continue to work with relevant authorities and other potential users of the treated groundwater to maximise the level of reuse.

4.9 'Do Nothing' Option

A number of contaminant plumes are progressing toward Penrhyn Estuary and Botany Bay. The 'do nothing' option would mean that groundwater could not be extracted at the rates required (some 15 ML/day) to contain the plumes and to provide treatment of this volume of groundwater. Under the 'do nothing' scenario, the extraction of groundwater would be limited to the maximum treatment rate of the Steam Stripping Unit (2ML/day). However, the recommissioning and operation of the SSU is only intended as a short-term measure to achieve earliest capture of the most contaminated parts of the plume.

Without completion of the 15ML/day GTP, Orica would not be able to implement a proven process for the long-term containment and treatment of the contaminant plumes. As a result, the identified chlorinated contaminants in the groundwater plumes would be expected to discharge into Penrhyn Estuary and Botany Bay. Such discharges would result in a number of unacceptable outcomes:

- impacts on the terrestrial and marine flora and fauna in the Foreshore Beach and Penrhyn Estuary ecosystems, which could affect the migratory shorebirds listed under the EPBC Act 1999, with associated implications for compliance with Commonwealth obligations under international treaties (such as CAMBA and JAMBA);
- increased risks to human health for recreational users on the foreshore and within Botany Bay, and diminished quality of life for residents and workers in the area; and
- failure to achieve the aims of the NCUA and the associated GCP, through failure to provide hydraulic containment and hence prevent contaminant discharges below the level required by the ANZECC (2000) trigger values for protection of slightly to moderately disturbed ecosystems.

The 'do nothing' option would be socially and environmentally unacceptable.

4.10 Conclusion

An extensive review of the available treatment options, locations and output requirements has been completed, guided by a careful consideration of the BGC Project's key objectives and the constraints under which the project must proceed.

The most suitable site for establishing the GTP was found to be the former Silicates Plant Site within the BIP. The logistics of groundwater movement precluded off-site treatment options for the GTP, and the principles of the Basel Convention precluded extraction of the contaminants for off-site treatment or disposal.

The preferred process involves air stripping the groundwater to remove all volatile CHC components (including waste EDC) and then directly feeding this contaminant laden air stream to a recuperative thermal oxidiser. This thermal oxidiser would be designed to achieve greater than 99.99% destruction efficiency and to satisfy the best international air emission standards and Australia's obligations for the minimisation of dioxin and furan emissions under the Stockholm Convention.

The treated groundwater, with most of the CHC contaminants removed, would be further processed to maximise the quantity of extracted water that could be recycled for various industrial applications on the BIP and beyond.