Pinnacle Risk Management Pty Ltd

PRELIMINARY HAZARD ANALYSIS
NITRIC ACID TANK,
ORICA AUSTRALIA PTY LTD
KOORAGANG ISLAND, NSW

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Preliminary Hazard Analysis, Nitric Acid Tank, Orica, Kooragang Island

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EXECUTIVE SUMMARY

Orica Australia Pty Ltd (Orica) is proposing to build a nitric acid storage tank on the western boundary of the Kooragang Island facility. The tank is proposed to replace the nitric acid tank originally approved in the site's expansion project approval (08_0129), which has yet to be constructed. The proposed modifications to the site are summarised as follows:

- A 10,000 nitric acid storage tank;
- New pipelines and pipe bridge to connect the new tank to the existing nitric acid import / export pipeline;
- A tank vent scrubber with associated pumps and piping; and
- An additional nitric acid transfer pump.

To assess the risk associated with the nitric acid tank changes, a preliminary hazard analysis (PHA) has been performed.

The risks associated with the proposed nitric acid tank and associated systems at the Orica Kooragang Island have been assessed and compared against the Department of Planning and Infrastructure (DoPI) risk criteria.

The results of this PHA indicate that the risks associated with the proposed nitric acid tank and systems comply with the DoPI guidelines for tolerable fatality, injury, irritation and societal risk. Also, risks to the biophysical environment, the risk of propagation and the impact on cumulative risk in the Kooragang Island area from releases are acceptable (subject to the recommendations below).

Reviews of historical incidents associated with nitric acid facilities have shown that the off-site risks relating to losses of containment are acceptable due to the limited impact from releasing a corrosive liquid. This is supported by the findings of the site's existing PHA.

The recommendations from this study are:

1. Include the tank level instrumentation in a Layers of Protection Analysis (or similar) to determine the required level of reliability to reduce the risk of tank overflow to an acceptable level.
2. Perform a Layers of Protection Analysis (or similar) during the design phase of the project to ensure the risk of liquid releases to the environment is acceptable. Preferably, the bund sump pump system should be designed using the principles of inherent safety, i.e. design out the hazard. In this case, do not have a path for pumping any spilt nitric acid to the environment.
3. Perform a HAZOP study and a construction safety study on the proposed changes.
4. Update the existing safety management system, including the emergency response plan, for the proposed new tank and equipment.

GLOSSARY

AEGL	Acute Exposure Guideline Level
ALARP	As Low As Reasonably Practicable
AN	Ammonium Nitrate
ANP	Ammonium Nitrate Plant
ANS	Ammonium Nitrate Solution
AS/NZS	Australian Standard / New Zealand Standard
DoP	Department of Planning
DoPI	Department of Planning and Infrastructure
HAZAN	Hazard Analysis
HAZOP	Hazard and Operability Study
HIPAP	Hazardous Industry Planning Advisory Paper
LTI	Lost Time Injury
MTI	Medical Treatment Injury
NAP	Nitric Acid Plant
NDT	Non-Destructive Testing
NOx	Oxides of Nitrogen
OSHA	Occupational Safety and Health Administration
PEL	Permissible Exposure Limit
PHA	Preliminary Hazard Analysis
PPE	Personnel Protective Equipment
QRA	Quantitative Risk Analysis
SH&E	Safety, Health and Environment
SSAN	Security Sensitive Ammonium Nitrate
STEL	Short Term Exposure Limit
TLV - TWA	Threshold Limit Value – Time Weighted Average
TNO	The Netherlands Organisation of Applied Scientific Research

REPORT

1 INTRODUCTION

1.1 BACKGROUND

Orica Australia Pty Ltd (Orica) is proposing to build a 10,000 tonne (te) nitric acid storage tank at the Kooragang Island facility.

In 2012, Orica was granted approval to construct and operate a 2,000 tonne nitric acid storage tank as part of a site expansion project. This project has been delayed; however, additional storage of nitric acid is required to meet market demands for ammonium nitrate.

In lieu of the approved 2000 te tank, Orica is now proposing to construct a 10,000 te tank to store imported nitric acid or extra capacity nitric acid produced on site. The tank will allow Orica to meet the short term ammonium nitrate market demand during the transition period prior to constructing the additional approved Nitric Acid and Ammonium Nitrate plants.

The new tank is proposed to be connected to an existing, approved nitric acid transfer line from the K2 wharf at Kooragang Island.

Originally, this line was proposed to be used for nitric acid export to ships for delivery to overseas markets. This line was assessed in a Preliminary Hazard Analysis (PHA) and HAZOP study in 2004 (Refs 1 and 2) and found to comply with the Department of Planning (DoP) risk criteria in Hazard Industry Planning Advisory Paper (HIPAP) No. 4 (Ref 3).

In 2009, it was proposed to use the transfer line for importing nitric acid. The 2004 PHA was reviewed for any impacts on the conclusions (Ref 4). It was again found that the line operation would comply with the risk criteria in HIPAP No. 4. The import operation was also reviewed via the HAZOP technique (Ref 5).

As part of the project requirements for the new nitric acid 10,000 te storage tank, a Preliminary Hazard Analysis (PHA) is required to be produced in accordance with the guidelines published by the DoP HIPAP No 6 (Ref 6).

Orica has appointed Pinnacle Risk Management Pty Ltd (Pinnacle Risk Management) to produce the PHA.

1.2 OBJECTIVES

The main aims of this PHA study are to:

- Identify the credible, potential hazardous events associated with the new equipment including the proposed 10,000 te storage tank;
- Evaluate the level of risk associated with the identified potential hazardous events to surrounding land users and compare the calculated risk levels with the risk criteria published by the DoP in HIPAP No 4 (Ref 3);

- Review the adequacy of the proposed safeguards to prevent and mitigate the potential hazardous events; and
- Where necessary, submit recommendations to Orica to ensure that the proposed new equipment is to be operated and maintained at acceptable levels of safety and effective safety management systems are used.

1.3 SCOPE

This PHA assesses the credible, potential hazardous events and corresponding risks associated with the proposed new equipment at the Orica Kooragang Island facility with the potential for off-site impacts.

In summary, the assessment includes:

- The new 10,000 nitric acid storage tank;
- The new pipelines connected to the proposed new tank;
- The new tank scrubber and associated pumps; and
- The new nitric acid transfer pump.

As the wharf operations, shipping activities and pipeline transfers do not require changes as a result of the new tank then these areas are not included in this assessment as previous assessments have shown acceptable levels of risk.

1.4 METHODOLOGY

In accordance with the approach recommended by the DoP in HIPAP 6 (Ref 6) the underlying methodology of the PHA is risk-based, that is, the risk of a particular potentially hazardous event is assessed as the outcome of its consequences and likelihood.

The PHA has been conducted as follows:

- Initially, the new equipment and its location were reviewed to identify credible, potential hazardous events, their causes and consequences. Proposed safeguards were also included in this review;
- As the equipment is located at a significant distance from other land users, the consequences of each potential hazardous event were estimated to determine if there are any possible unacceptable off-site impacts;
- Where adverse off-site impacts can occur, the likelihood of each potential hazardous event was reviewed, using appropriate techniques / methods, to check if there is any significant increase to existing risk levels and if the risk levels are within the criteria in HIPAP 4 (Ref 3).

1.5 FINDINGS AND RECOMMENDATIONS

The risks associated with the proposed nitric acid tank and associated systems at the Orica Kooragang Island have been assessed and compared against the DoPI risk criteria.

The results of this PHA indicate that the risks associated with the proposed nitric acid tank and systems comply with the DoPI guidelines for tolerable fatality, injury, irritation and societal risk. Also, risks to the biophysical environment, the risk of propagation and the impact on cumulative risk in the Kooragang Island area from releases are acceptable (subject to the recommendations below).

Reviews of historical incidents associated with nitric acid storage facilities have shown that the off-site risks of losses of containment are acceptable due to the limited impact from releasing a corrosive liquid. This is supported by the findings of the site's existing PHA.

The recommendations from this study are:

1. Include the tank level instrumentation in a Layers of Protection Analysis (or similar) to determine the required level of reliability to reduce the risk of tank overflow to an acceptable level.
2. Perform a Layers of Protection Analysis (or similar) during the design phase of the project to ensure the risk of liquid releases to the environment is acceptable. Preferably, the bund sump pump system should be designed using the principles of inherent safety, i.e. design out the hazard. In this case, do not have a path for pumping any spilt nitric acid to the environment.
3. Perform a HAZOP study and a construction safety study on the proposed changes.
4. Update the existing safety management system, including the emergency response plan, for the proposed new tank and equipment.

2 SITE DESCRIPTION

A map of the area showing the location of the Orica Kooragang Island site is shown in Figure 1.

The Orica facility is surrounded by other industries to the north, south and west and the Hunter River to the east. Stockton is the nearest residential area across the north channel of the Hunter River (approximately 800 metres to the east). There are also residential properties to the west at Carrington and Mayfield, 1.5km and 2km away, respectively. Kooragang Island is an established industrial area with generous spacing between facilities.

Figure 1 – Site Location

The current Orica Kooragang Island manufacturing site consists of:

- An Ammonia Plant;
- Three Nitric Acid Plants: NAP1, NAP2 and NAP3 (nitric acid is used in the production of ammonium nitrate);
- Two Ammonium Nitrate (AN) Plants, namely ANP1 which manufactures Nitropril® (a porous prilled ammonium nitrate product) and ANP2 which manufactures Opal™ (a granulated ammonium nitrate product) and 88.5% ammonium nitrate solution;
- Storage, and bagging and bulk dispatch facilities for solid ammonium nitrate and granulated material;
- Storage facilities for anhydrous ammonia, AN solution and nitric acid;
- Ammonia ship loading / unloading facilities;
- Ammonia truck loading and bottling facility; and
- Ammonium Nitrate Solution (ANS) dispatch facility.

Additional information relating to the site's current infrastructure can be found in the Preliminary Hazard Analysis PHA Mod 1 report (Ref 7).

Existing security measures for the Orica site include:

- Site perimeter fence installed with locked or manned gates;
- The main gate is permanently manned by security staff;
- The plants are permanently manned;
- Patrols by security guards are performed;
- Relevant employees are Security Sensitive Ammonium Nitrate (SSAN) licenced;
- Buildings are locked closed when not in use; and
- There are two control rooms on the site which are occupied 24 hours per day. One of these control rooms has the ability to observe the site via closed circuit television.

There are approximately 200 people during normal business hours and 25 people outside of normal hours on the site. The shifts controlling the relevant plants have a minimum of 5 people per shift.

The site does not lie under a major flight path to any airport. The known natural hazards associated with this location are flooding and earthquake. To date, these events have not caused any significant hazardous events to plant and equipment.

3 PROCESS DESCRIPTION

3.1 OVERVIEW

Orica proposes to build a 10,000 tonne nitric acid storage tank and associated infrastructure. The proposed modification includes the following elements:

- A new 10,000 tonne nitric acid tank;

- A new overhead pipe gantry to connect the proposed tank to the existing import pipeline;
- A new tank scrubber including recirculating pumps;
- A new nitric acid transfer pump to the existing No. 1 Nitric Acid Tank; and
- Bunding for the scrubber system including a new sump pump.

The proposed tank will be constructed in place of the previously approved 2,000 tonne storage tank. The proposed tank will be used to store imported 68 w/w% nitric acid or provide additional storage capacity for nitric acid produced on site. The proposed location for the 10,000 tonne storage tank is on the western property boundary (as shown on Figure 2 and Figure 3).

Nitric acid (68%) will be unloaded from a ship at the K2 berth to the new tank utilising the ship's pump via the existing approved 150 mm diameter nitric acid import / export pipeline (see the drawing shown in Appendix 1). Ship loads of up to 8,000 tonnes will be typical. The acid will be pumped directly from the ship to the nitric acid import tank at a typical flowrate of 300 te/hr.

The nitric acid storage tank area is proposed to be a tank-in-tank design, i.e. the inner tank will be contained within an outer tank. The outer tank is therefore the secondary containment. The storage conditions will be approximately atmospheric pressure and temperature.

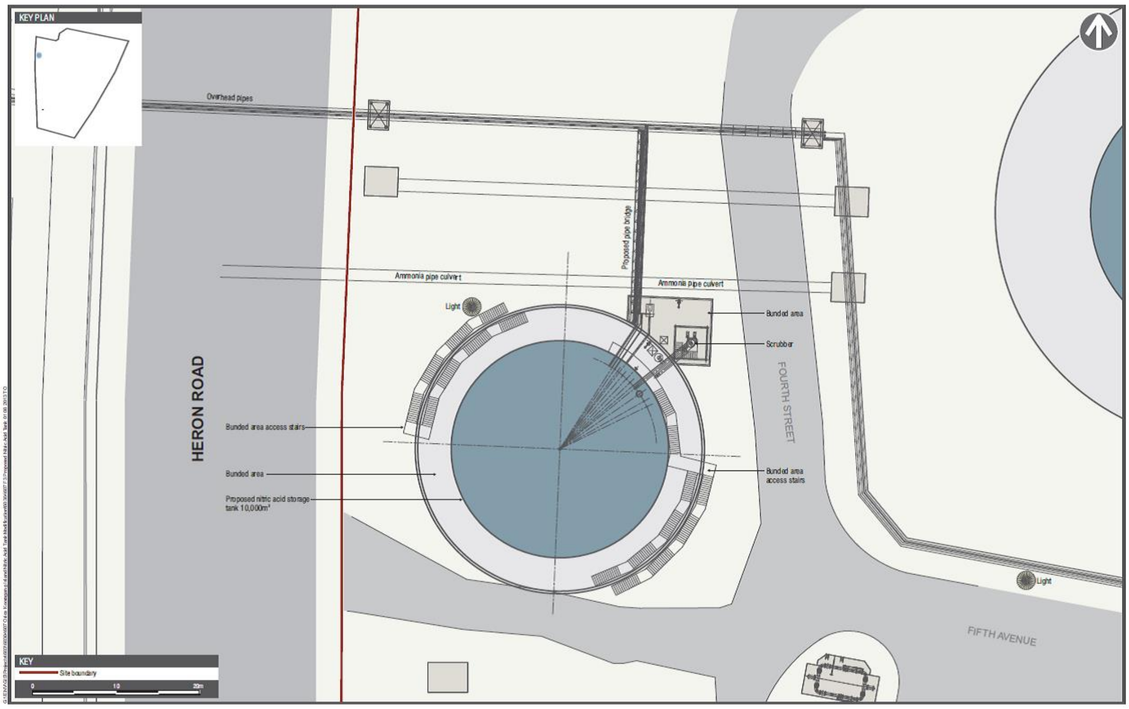
The inner and outer tanks are to include multiple level sensors for both low and high level alarm and trip functions, e.g. to prevent overfill of the inner tank during ship transfers. Should pressure within the inner tank deviate from the design basis, an overpressure / vacuum relief valve is to be installed for mechanical protection. Both the main liquid inlet and outlet lines are to have actuated valves that can be remotely operated in case of an emergency. These valves will be designed to fail closed on loss of instrument gas to the actuator.

Should the inner tank fail and hence release nitric acid into the secondary tank, the secondary tank can vent excess air / vapour to atmosphere to prevent overpressure.

The tank vent will be scrubbed to remove oxides of nitrogen (NOx). The NOx scrubber will be sized to scrub the fumes for ship to tank transfers and diurnal breathing.

Figure 2 – Nitric Acid Tank Location

Figure 3 – Tank Layout Details



The nitric acid will be transferred from the new tank to the existing No. 1 Nitric Acid Tank using the eastern section of the existing nitric acid import / export pipeline. A new pump is to be installed for this transfer process and it will be installed within a bunded area.

The 68% w/w nitric acid will be diluted with process condensate to produce 60% w/w nitric acid prior to entering the No.1 Nitric Acid Tank. The dilution system will utilise demineralised water as a backup to the process condensate.

Following dilution and storage of the 60% nitric acid, it will be reacted with ammonia within the existing ammonium nitrate plants to produce the required ammonium nitrate products.

The existing nitric acid import infrastructure will be modified to incorporate the new storage tank. This will include connections for nitric acid, demineralised water, effluent and other services.

3.2 SCRUBBER DESIGN INFORMATION

A new scrubber will be required to scrub the vent gases of NOx vapours from the head space of the tank.

The scrubber will be operated with demin water as the scrubbing liquid. The demin water will be continuously recirculated around the scrubber system. NOx fumes from the new nitric acid tank vent will be absorbed by the recirculating scrubbing liquor, creating dilute nitric acid. The scrubber liquor will be restricted to a maximum 10% w/w nitric acid by bleeding scrubber liquor back to the new nitric acid tank and refilling the sump of the scrubber with fresh demin water.

The scrubber will be a counter-current packed bed scrubber fabricated entirely from 304L stainless steel (compatible with nitric acid).

The column internals will consist of random packing, a liquid distributer, packing support, a bed limiter and an integral sump with vortex breaker.

The concentration of NOx in the scrubber outlet shall be designed to not exceed 350mg/m^3 NOx.

3.3 Import / Export Line Operations

The nitric acid import / export line is existing and has previous approval. The relevant aspects for this proposal associated with the existing import / export line are:

- The import section of the nitric acid import / export line (between the K2 wharf and the tank) will now be flushed with demineralised water and purged with air following each use. The purged liquid will flow into the nitric acid storage tank. The purged line will remain empty between ship transfers;
- The eastern section of the import / export line will be used for the transfer of 68% nitric acid to the existing No.1 Nitric Acid Tank. This section of the line will operate continuously except when the ship unloading operation is being performed; and
- The shipping frequency has not changed but the delivered quantity has increased, increasing the time that the ship is required to be berthed at the wharf as shown below.

Table 1 – Shipping Information

	Original (2008)	This Proposal
Number of ships per year	14 ships / year	14 ships / year
Quantity unloaded	1600 te	8000 te
Unloading duration	6 hours	26 hours

4 HAZARD IDENTIFICATION

4.1 HAZARDOUS MATERIALS

4.1.1 Nitric Acid

Nitric acid is a Class 8, Subsidiary Risk 5.1 Dangerous Good, i.e. it is corrosive. It is highly corrosive to many metals (hydrogen, a flammable gas, is evolved) and is a powerful oxidant. It may cause fire if in contact with organic materials such as wood, cotton or straw. If a fire does occur then highly toxic gases are evolved (nitrogen oxides).

As it is a corrosive liquid, it will cause severe burns to the skin, eyes and mucous membranes. It vapours are also corrosive and may cause pulmonary oedema which could prove fatal.

Nitric acid can be highly reactive, e.g. it can react explosively with metallic powders or when in contact with a powerful reducing agents.

The TLV/TWA is 2 ppm (5 mg/m^3) and the TLV-STEL is 4 ppm (10 mg/m^3). The freezing point for 60% strength is -17^{o}C whilst the same strength boiling point is 120^{o}C.

Nitric acid, being soluble in water, has high mobility in soil. It has a low potential of bio-accumulation. Even at low concentrations, it is harmful to aquatic life due to its acidic nature.

Oxides of Nitrogen

These gases can be liberated as a result of decomposition reactions involving nitric acid.

(a) Nitric Oxide (NO)

Nitric oxide is a Class 2.3, Subsidiary Risks 5.1 and 8, Dangerous Good, i.e. it is a toxic gas.

Nitric oxide is a colourless, permanent gas with a sharp, sweet odour (odour threshold down to 0.3 ppm). It is usually oxidised into nitrogen dioxide (see below) in air and turns brown. High concentrations act on the nervous system and are reported as also affecting the respiratory system. Pulmonary oedema can result. The recommended exposure standard is 25 ppm (permissible exposure limit, PEL). Since this gas will be associated with nitrogen dioxide the precautions listed below should be observed.

Nitric oxide is non-flammable but it is a strong oxidising agent. It will react violently with ammonia and many organic materials.

(b) Nitrogen Dioxide (NO_2)

Nitrogen dioxide is a Class 2.3, Subsidiary Risks 5.1 and 8, Dangerous Good, i.e. it is a toxic gas.

Nitrogen dioxide can be smelt at concentrations of around 5 ppm, however, the currently accepted exposure standard (TLV) is 3 ppm. The STEL is 5 ppm. It is a pungent gas.

At concentrations of 10-20 ppm, the gas is mildly irritating to the eyes and nose. There is little increase in these effects up to concentrations of 100 ppm for short exposures. However, exposure to 100 ppm for 60 minutes can cause death. At this concentration the gas should be visible in good light and have a reddish brown colour.

Exposure to nitrogen dioxide at higher concentrations can lead to pulmonary oedema which may not occur for up to 24 hours or more after exposure. Affected personnel should be kept under observation and treated symptomatically.

Nitrogen dioxide is non-flammable but it is a strong oxidising agent. It will react with ammonia and many organic materials and is corrosive in the presence of water. It has a boiling point of 21^oC.

Note that the other main oxide of nitrogen which may be present is nitrous oxide (N_2O) which is not harmful.

4.2 HAZARDOUS INCIDENTS REVIEW

In accordance with the requirements of *Guidelines for Hazard Analysis*, (Ref 6), it is necessary to identify hazardous events associated with the reviewed operations. As recommended in HIPAP 6, the PHA focuses on "atypical and abnormal events and conditions. It is not intended to apply to continuous or normal operating emissions to air or water".

A search of available literature and information was conducted to review the types of historical events that can occur with nitric acid. The search included the following references:

1. Frank Lees, Loss Prevention in the Process Industries (Ref 8);
2. US Occupational Health and Safety Administration statistics;
3. US Chemical Safety and Hazard Investigation Board statistics;
4. Orica's records and hazard study's results; and
5. Public sources available via the internet.

There has been a significant number of incidents recorded involving losses of containment of nitric acid. For example, the US Occupational Safety and Health Administration (OSHA) incident database includes 44 losses of containment of nitric acid since 1984. Only a few of these led to on-site fatalities. One fatality occurred some 15 days after exposure to the acid due to organ failure. The majority of injuries were, as expected, chemical burns. Clearly, these records show the need for robust control measures to avoid losses of containment.

It is noted, however, of the 44 recorded incidents, none occurred on a nitric acid production plant.

A summary of the reviewed incidents is included in Appendix 2 and is discussed further in Section 5 of this report.

4.3 HAZARDOUS EVENT IDENTIFICATION WORD DIAGRAM

In keeping with the principles of risk assessments, credible, hazardous events with the potential for off-site effects have been identified. That is, “slips, trips and falls” type events are not included nor are non-credible situations such as an aircraft crash occurring at the same time as an earthquake. The large majority of the specific release scenarios are generic equipment failures, e.g. failures of tanks, pipes etc, from previous industrial incidents. These are supplemented by process incidents due to other abnormal modes of operation, control system failure and human error.

The credible, significant incidents identified for the proposed new equipment are summarised in the Hazard Identification Word Diagram following (Table 2).

The Hazardous Event Word Diagram presents the causes and consequences of the events, together with major preventative and protective features that are proposed to be included as part of the design.

Table 2 – Hazard Identification Word Diagram

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
1.	Losses of containment from the new nitric acid pipes	Corrosion. Piping failure such as flange leak or weld defect. Human error, e.g. valve left open or maintenance error. Thermal expansion of acid due to heating by the sun when isolated in line	Failures lead to varying release rates / quantities. Potential exists for propagation to nearby equipment if the material(s) are not compatible. Potential for injury, environmental and business effects. Large releases have the potential for fatality to people nearby. Contact with combustible material (e.g. wood) is likely to result in a fire with the evolution of toxic vapours with impact on people and the environment	*Prevention Control Measures:* The new pipes are to be run via pipe racks and/or within bunded areas. Signage and pipeline markings. Materials of construction, including flange components, to be compatible with nitric acid. The new pipes are to be fully welded as much as possible to avoid corrosion within any flanges. Preventative maintenance procedures for pipes, e.g. inspection and testing. Pipes will subject to 100% non-destructive testing (NDT) prior to commissioning. Flange covers to be used as required. Training, procedures and audits. Use of checklists. Operations supervised. Thermal protection safety devices to be installed. Drain valves capped.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Pipe and structure to be designed to the Australian Standard for earthquake design requirements. Pipe to be earthed for lightning protection. *Mitigation Control Measures:* Emergency response actions for spills, rescue, First Aid, neutralisation etc. PPE stored on site. Fire water available for cloud suppression. Response from the Fire Brigade
2.	Overflow from the new nitric acid tank	Failure of the tank level measurement. High transfer rate from the ship. Loss of communication with the ship's crew. Reverse flow through the new nitric acid pump and into the tank via the recirculation line	Overflow to the outer tank / secondary containment which could result in an overflow to grade and hence impact to personnel, the environment and equipment	*Prevention Control Measures:* Multiple level sensors on the new nitric acid tank. Multiple sensors to detect the overflow from the inner tank to the secondary containment. Instrumentation maintenance. Tank level sensor to be Safety Integrity Level assessed for the expected level of reliability. Radios used for communication with the ship's personnel. Backup mobile phones can be used. Ship-to-shore transfer procedures to include monitor of tank level, transfer rate and pressure.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Non-return valve to be installed on the discharge of the new nitric acid tank pump to prevent reverse flow. The ship-to-shore transfer procedure is to include the need to isolate the flow path to the new nitric acid pump and the existing No. 1 Nitric Acid Tank *Mitigation Control Measures:* Emergency response actions for spills, rescue, First Aid, neutralisation etc. PPE stored on site. Fire water available for cloud suppression. Response from the Fire Brigade
3.	Failure of the new nitric acid tank	Construction defect, overpressure, e.g. overfilling or from blowing air from the ship, underpressure when pumping out	Loss of containment of the inner tank to the outer tank. This could lead to a release of acidic fumes from the outer tank vent and hence impact to personnel, the environment and equipment	*Prevention Control Measures:* The inner tank is to be designed to AS3780 and API650. 100% radiography on all new tank floor welds to check for construction defects. 100% NDT of tank structure to detect construction defects. The inner tank is to be constructed from 304/304L stainless steel which is compatible with nitric acid.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				The inner tank is free-vented via the scrubber for both over and under pressure protection. Sprays installed in the annulus space to absorb fumes. Level detectors in the annulus space. The inner tank is fitted with an over and under pressure relief device. *Mitigation Control Measures:* Emergency response actions for spills, rescue, First Aid, neutralisation etc. PPE stored on site. Fire water available for cloud suppression. Response from the Fire Brigade
4.	Failure of the scrubber	Loss of reflux flow, e.g. pump failure, loss of power	Release of acidic fumes via the scrubber and hence impact to personnel, the environment and equipment	*Prevention Control Measures:* Duty / standby scrubber recirculation pumps with automatic start on the standby. The scrubber recirculation pumps are to be on emergency power. *Mitigation Control Measures:* Scrubber stack is 26 m for improved dispersion. Low flow alarm on the scrubber recirculation liquid.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Ship transfer not to be initiated unless scrubber system is operating. Ship transfer to be stopped on loss of power or other abnormal event. Emergency response actions for spills, rescue, First Aid, neutralisation etc. PPE stored on site. Fire water available for cloud suppression. Response from the Fire Brigade
5.	Loss of containment from the new pump	Seal, shaft or casing failure. Pump deadhead	Failures lead to varying release rates / quantities. Potential exists for propagation to nearby equipment if the material(s) are not compatible. Potential for injury, environmental and business effects. Large releases have the potential for fatality to people nearby. Contact with combustible material (e.g. wood) is likely to result in a fire with the evolution of toxic vapours with impact on people and the environment	*Prevention Control Measures:* The pump is to be included in the prevention maintenance system. Pumps to be fitted with vibration and current monitoring to assist in preventative maintenance. The pump is to be dedicated nitric acid pumps with proven reliability for this liquid. The wetted parts of the pump are to be constructed from 304/304L SS which is compatible with nitric acid. Minimum flow dead head protection for the pump via FO 9111. Operating procedures and training to include the requirement to keep manual isolation valves open to prevent deadhead conditions.

Event ID No.	Hazardous Event	Causes	Possible Consequences	Proposed Prevention and Mitigation Control Measures
				Mitigation Control Measures: The new pump is to be in a bunded area. Low flow alarm on the scrubber recirculation liquid. Emergency response actions for spills, rescue, First Aid, neutralisation etc. PPE stored on site. Fire water available for cloud suppression. Response from the Fire Brigade
6.	Low pH liquid pumped to the River Pit	Failure of the bund sump pump discharge controls, e.g. pH meter failure	Environmental impact due to low pH liquid	*Prevention Control Measures:* Tank-in-tank design provides containment of concentrated acid. Bund system is only exposed to dilute acid. Level detection in the bund to alert operators of a spill. pH measurement with alarms and sampling prior to release to the River Pit. Hard piped lines to effluent neutralisation minimise risk of loss to environment. *Mitigation Control Measures:* In-line pH detection and alarms installed in the downstream effluent transfer lines. Emergency response

4.4 SAFETY MANAGEMENT SYSTEMS

Safety management systems are intended to minimise the risk from potentially hazardous installations by a combination of hardware (i.e. design) and managements systems such as procedures, policies, plans and training. To ensure safe operation of the nitric acid tank and associated equipment, both the hardware and the safety management systems must be of high standard.

Orica personnel, having operated nitric acid plants for up to 40 years at the Kooragang Island site, are well aware of the hazardous nature of nitric acid. However, it is acknowledged that the proposed nitric acid modifications will necessitate changes to the existing safety management system.

In general, the Orica procedures, guidelines etc are modified to suit the local site conditions where required.

The safety management system is built in layers, as shown below:

Vision and Values

Policy

SH&E Standards

SH&E Model Procedures

Local SH&E Procedures

Operating Procedures / Work Instructions

Senior management define the company's Vision and Values, SH&E Policy and Standards. For Orica and its group companies, there are 19 SH&E Standards to be followed. SH&E Model Procedures are developed to further detail key requirements for control of the company's operations and to provide a model for management of SH&E risks and for implementation of the company's SH&E Policy and Standards. There are 121 SH&E Model Procedures.

Local procedures and work instructions are developed to define additional requirements to, as far as practicable, control the risks arising from the operation of each facility and to assure compliance with the company's SH&E Policy and Standards, and the key requirements of the SH&E Model Procedures.

The range and detail of local procedures and work instructions are consistent with the complexity of the activity, the level of risk involved, and the skills and training of the people performing the activity.

Sufficient records of activities and events are retained in a secure, retrievable manner to demonstrate compliance with, and the effectiveness of local procedures and to capture adequate information regarding the company's SH&E impacts.

A Letter of Assurance is prepared annually, detailing the level of compliance with each of the SH&E Standards and action plans to close any gaps.

The suitability, adequacy and effectiveness of the company SH&E Policy, Standards and SH&E Model Procedures and local SH&E management systems is reviewed at least every two years.

Given the existing Orica safety management system, it is expected that modification to accommodate the nitric acid modifications should present little difficulty.

For information, the general procedures associated with the safety management systems at Orica are summarised in Table 3.

Table 3 - Summary of Safety Related Procedures

PROCEDURE	PURPOSE
Operations and Maintenance Manuals	To clearly define the method of operations of the plant. To ensure that accurate information about important aspects of the plant design and its operations are available and up to date. To define for the operators and maintenance team the methods by which sections of the plant may be safely and efficiently withdrawn from service, repaired and restored to safe efficient operating condition. To ensure that protective systems are in a good state of repair and function reliably when required to do so. This includes scheduled testing of trips and alarms and relief devices.
Operator Training, including safety and emergency training	To enable operators to run the plant to meet objectives safely. To enable trades personnel to carry out maintenance work so that they are themselves safe and do not jeopardise the plant safety systems or the safety of others. To provide personnel with an understanding of possible hazardous situations and the ability to respond appropriately. To provide an understanding of and practice in the use of basic emergency equipment that might be needed in tackling an emergency (e.g. self contained breathing apparatus, safety showers).
Permit to Work	To safeguard technicians (and others) and the plant by ensuring than that the plant is safe to work on, that the correct job is done using the right equipment, that any safety procedures are understood and adhered to, that operators know which parts of the plant are being worked on and that the plant is returned to safe condition before being returned to service.
Control of Plant Modifications	To ensure that proposed changes to both equipment and operating methods achieve the desired benefits without any unforeseen and undesirable side effects.
Unusual Incident Reporting and Investigation	To learn from "unusual incidents" that may or may not have had a hazardous outcome, but could have under different circumstances, to be proactive in preventing their occurrence.
Emergency Procedures	To facilitate effective response to emergency situations. To prevent or minimise the effect of potentially hazardous events by being prepared.
Scheduled Management Auditing of Procedures	To ensure that operating management are continually aware of how well the defined procedures and systems affecting safety and loss prevention are being followed in practice. To enable corrective action to be taken to improve adherence to procedures.

4.4.1 Safety Software in Risk Assessment

In risk assessments, incidents are assessed in terms of consequences and frequencies, leading to a measure of risk. Where possible, frequency data comes from actual experience. However, in many cases, the frequencies used are generic, based on historical information from a variety of plants and processes with different standards and designs.

The quality of the management systems in place in these historical plants will vary. Some will have little or no safety management systems, such as work permits and modification procedures, in place. Others will have exemplary systems covering all issues of safe operation. Clearly, the generic frequencies derived from a wide sample represent the failure rates of an "average plant". This hypothetical average plant would have average hardware and safety management systems in place.

If an installation with below average safety management systems is assessed using generic frequencies, it is likely that risk will be underestimated. Conversely, if a plant is above average, the risk will probably be overestimated. However, it is extremely difficult to quantify the effect of safety management systems on plant safety.

Therefore, Pinnacle Risk Management adopts a policy which does not attempt to quantitatively account for the presence of and quality of safety management systems. It is assumed that the generic failure frequencies used apply to installations which have safety management systems corresponding to accepted industry practice. It is believed that this assumption will be conservative in that it will overstate the risk from installations such as the Orica sites. Therefore, any quantitative approach is valid (i.e. conservative) only if safety management within the operation being assessed is of a high standard.

5 RISK ANALYSIS

The risk criteria applying to developments in NSW are summarised in Table 4 below (from Ref 3). Compliance with these criteria is required and is assessed for the identified potential hazardous events below.

Table 4 – Risk Criteria, New Plants

Description	Risk Criteria
Fatality risk to sensitive uses, including hospitals, schools, aged care	0.5×10^{-6} per year
Fatality risk to residential and hotels	1×10^{-6} per year
Fatality risk to commercial areas, including offices, retail centres, warehouses	5×10^{-6} per year
Fatality risk to sporting complexes and active open spaces	10×10^{-6} per year
Fatality risk to contained within the boundary of an industrial site	50×10^{-6} per year
Injury risk – incident heat flux radiation at residential areas should not exceed 4.7 kW/m^2 at frequencies of more than 50 chances in a million per year or incident explosion overpressure at residential areas should not exceed 7 kPa at frequencies of more than 50 chances in a million per year	50×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which would be seriously injurious to sensitive members of the community following a relatively short period of exposure	10×10^{-6} per year
Toxic exposure - Toxic concentrations in residential areas which should cause irritation to eyes or throat, coughing or other acute physiological responses in sensitive members of the community	50×10^{-6} per year
Propagation due to Fire and Explosion – exceed radiant heat levels of 23 kW/m^2 or explosion overpressures of 14 kPa in adjacent industrial facilities	50×10^{-6} per year

The assessment of risks to both the public as well as to operating personnel around this industrial development requires the application of the following basic steps:

- Assess the hazard potential of the materials involved;
- Identify the potential hazardous events (including incidents involving the materials and site specific occurrences);
- Evaluate the consequences of the potential hazardous events;
- If the off-site consequences are significant then evaluate the likelihood of the potential hazardous events;
- Assess the risk of the potential hazardous events; and

- Recommend further safeguarding if the existing, proposed safeguards are not deemed adequate.

As per HIPAP 6 (Ref 6), the chosen analysis technique should be commensurate with the nature of the risks involved.

The typical risk analysis methodology attempts to take account of all credible hazardous situations that may arise from the operation of processing plants etc. Possible events that are highly improbable are typically excluded from risk assessments, e.g. a meteor hits a facility.

For a typical quantitative risk analysis (QRA), this is done by first estimating the consequential impacts for the identified potential hazardous events and then, if off-site impact is possible, estimating the corresponding likelihoods. The risk of each event (i.e. consequence multiplied by the likelihood) is then summated to provide the overall levels of risk.

In this risk assessment, however, the approach adopted to assess the risk of the identified hazardous events is scenario based risk assessment. The reasons for this approach are that there are limited potential hazardous events that can lead to off-site impact, the material involved (nitric acid) is a Class 8 Dangerous good, i.e. a corrosive liquid, and off-site fatalities from such facilities do not historically occur as discussed below.

The scenario based risk assessment approach analyses each of the possible hazardous events that contribute to off-site impact individually, in this case via a risk matrix (Refs 9 and 10). A mixture of qualitative and quantitative techniques is used as appropriate to assess imposed risk.

A risk matrix used for risk assessment by Pinnacle Risk Management is shown in Figure 4. This matrix has been derived from a review of relevant Australian and British standards (e.g. AS/NZS 31000).

The risk matrix allows the combination of consequence and likelihood (i.e. risk – the likelihood of any defined adverse outcome) to be shown clearly and quickly on a graphical basis.

The position in the matrix of estimated risk allows an assessment of the magnitude of each risk contributor to the overall level of risk. That is, the higher the combination of likelihood and consequence, the higher the contribution to overall risk. This provides a basis for development of appropriate risk reduction strategies. Through inspection of the major risk contributors and an understanding of the cost associated with particular risk reduction strategies, cost-effective risk reduction strategies can be developed.

Figure 4 – Risk Matrix

Frequent >1/yr	II	II	I	I	I	I
Probable $>10^{-1}$ to 1/yr	III	II	II	I	I	I
Possible $>10^{-2}$ to 10^{-1}/yr	III	III	II	II	I	I
Unlikely $>10^{-4}$ to 10^{-2}/yr	III	III	III	III	II	I
Very Unlikely $>10^{-6}$ to 10^{-4}/yr	III	III	III	III	III	II
Extremely Unlikely $<=10^{-6}$/yr	III	III	III	III	III	III
Likelihood **Consequence**	Minor	Significant	Severe	Serious	Extremely Serious	Catastrophic

The generic form of the matrix allows its use for various risk categories, e.g.:

- Safety and health;
- Environment; and
- Business impact.

For the risk matrix shown in Figure 4, there are three broad categories of risk.

The Class I area indicates a high level of risk which is intolerable and where risk reduction is required. This requires the reduction of frequency and/or consequence.

The Class II area indicates a moderate level of risk. Whilst the risk is not unacceptable, there should be practical measures taken to lower the risk if economically viable. For risks where further mitigation is not economically viable, judgement needs to be exercised as to whether the level of risk is acceptable or not. This area is the beginning of the ALARP region (i.e. as low as reasonably practicable).

The Class III area indicates a low level of risk and is broadly considered to be acceptable. Further risk mitigation may not be required / appropriate. However, low and accepted risks should be monitored and routinely reviewed to ensure that they remain acceptable. Few risks remain static. This area includes ALARP as well as what are known as trivial or negligible risks.

Consequential impact can take many forms, e.g. impacts on safety and health, environment, public relations, financial, operations, competitive nature, social well-being, clients, cultural significance, security and legal issues. Consequence ratings can be determined for the selected area of interest and then applied to a risk matrix. Consequential impacts used in this report are given in Table 5.

Table 5 – Consequence Ratings

	Minor	Significant	Severe	Serious	Extremely Serious	Catastrophic
Safety and Health	One minor injury, First Aid	Recordable or single MTI	Multiple MTI or one LTI	Permanent disability casualty or multiple LTI	Multiple permanent disabilities or one fatality	Multiple fatalities
Environment	Very minor pollution. No offsite escape of material (contained within the operational areas). Onsite nuisance value only	Minor local pollution. Nuisance offsite effect, typically of short duration, e.g. noise, odours, dust and/or visible plumes for less than one hour	Evident pollution, local concern. Minimal duration offsite effects (e.g. waterway slightly discoloured, turbid etc around the point of release with no or very few fish killed)	Significant local pollution. For example, waterways discoloured 10s of metres, fire or smoke affecting people near to the site	Major local pollution. Observable offsite effect (e.g. waterways discoloured 10s to 100s of metres for a few weeks with a significant number of aquatic life adversely affected)	Extremely severe pollution. Ecosystems at high risk of destruction. Only resolved via long term solutions (potentially taking years)
Public Relations	Minor issue, one complaint	Local issue, 10 complaints	Local media, 100 complaints	Regional or state media	Wide media national coverage	Headlines, corporate damage
Financial Impact	< $25,000	$25,000 to $100,000	> $100,000 to $1 million	> $1 million to $20 million	> $20 million to $100 million	> $100 million

5.1 NITRIC ACID SPILLS – SAFETY AND HEALTH RISK

Identified potential hazardous events 1, 2 and 5 shown in Table 2 will result in a spill of nitric acid (the quantity will vary) whilst events 3 and 4 will result in emissions of acidic mist. Spills of nitric acid have occurred previously from industrial facilities and therefore the results of historical spills are used in this analysis to determine to most credible outcome.

As discussed in Section 4.2, there has been a significant number of incidents recorded involving losses of containment of nitric acid. A review of approximately 100 nitric acid spills of various quantities, e.g. ranging from a few kilograms to 75 tonnes, was performed in the preparation of this PHA. The results are shown in Appendix 2. In summary:

- There were no off-site fatalities for the incidents reviewed. Presumably due to limited consequential impact from releasing a corrosive liquid, early warning by the acidic mist / NOx odour and emergency response;
- There were on-site fatalities for some incidents;
- The off-site impacts are better described as 'irritation' rather than 'injury'; and
- There were no major accident events involving production facilities in the recorded incidents.

These findings are appropriate to the proposed nitric acid tank and associated systems at the Orica Kooragang Island facility.

These findings are also supported by the conclusions made in the quantitative risk assessment for the site (Ref 7), i.e.:

"*Nitric acid will cause severe burns with bodily contact however will not travel sufficient distances upon release to affect offsite populations*" (Section 1.3.7).

Given the above historical data and the existing site quantitative risk assessment, off-site fatalities due to nitric acid releases are not expected. Therefore, the fatality risk criteria presented in Table 4 to both residential areas (the nearest being approximately 800 m to the east) and nearby industry are expected to be satisfied.

Similarly, given the above historical data, injury and irritation impact at the nearest residential area (800 m from the site) is not expected. Therefore, the injury and irritation risk criteria presented in Table 4 to residential areas is expected to be satisfied.

As nitric acid is not itself a flammable or combustible material, the criteria applying to radiant heat and explosive overpressure impacts is not relevant. It is noted, however, that small local fires have occurred following some nitric acid releases given the oxidising potential of the acid. For this facility, there are to be no combustible materials kept within the bunded area as per the existing site practices.

5.2 PIPE FAILURES (EVENT NO. 1)

The new pipes conveying nitric acid will be located within the Orica site boundary. Where the pipes run outside of bunded areas, these are to be fully welded to minimise the likelihood of a loss of containment.

The low likelihoods for pipe failure events are supported by the following data.

For piping failures, frequencies have been estimated either from data compiled and published by ICI (Ref 11) or from frequency estimates published by the Institution of Chemical Engineers (Ref 12).

Table 6 - Piping Failure Frequencies

Type of Failure	Failure Rate per year
Pipelines	
13 mm hole	3×10^{-6} / m
50 mm hole	0.3×10^{-6} / m
3 mm gasket (13 mm hole equivalent)	5×10^{-6} / joint
Guillotine fracture (full bore):	
< 50 mm	0.6×10^{-6} / m
> 50 mm but < 100 mm	0.3×10^{-6} / m
> 100 mm	0.1×10^{-6} / m

The new nitric acid piping is expected to be 50 mm or greater in diameter.

Assuming, say, 100 m of new pipe for these diameters, the frequency of catastrophic pipe failure is 100 m x 3×10^{-7} times / yr.m, i.e. 3×10^{-5} times / yr. Given a conditional modifier of a person being present in the tank area when the pipes fail in the order of 5% then the likelihood of adverse impact to a person on-site is therefore approximately 1.5×10^{-6} times / yr. From the risk matrix shown in Figure 4, this is a low level of risk and not considered intolerable.

5.3 NITRIC ACID TANK OVERFLOW (EVENT NO. 2)

For these types of events, the adequacy of the safeguards, including the reliability of the instrumented protected systems, is best analysed via a Layers of Protection Analysis (or similar). These studies review the initiating event likelihood and then the probability of failure on demand of each of the protective safeguards, including the level sensors and the actuated valve on the tank liquid inlet line to prevent tank overflow. As Orica perform Layers of Protection Analyses then the reliability of the protective safeguards is best reviewed during the detailed design stage to confirm the risk of this event is acceptable. Therefore, it is recommended in this PHA to include this scenario in a Layers of Protection Analysis (or similar) during the design phase of the project to ensure the risk of tank overflow is acceptable.

5.4 NITRIC ACID TANK FAILURE (EVENT NO. 3)

Double-walled atmospheric storage tanks have a typical failure frequency of $1x10^{-6}$ / yr, e.g. Ref 13. Given the design of these tanks, the secondary (outer) tank is expected to contain the material from the inner tank.

An influx of nitric acid into the outer tank may result in the release of acidic mist into the environment. Given the results of the review of the 100 historical releases of nitric acid then the impact of this elevated mist release will be limited.

From the risk matrix shown in Figure 4 this is a low level of risk given a likelihood of approximately $1x10^{-6}$ / yr and there the risk is not considered intolerable.

5.5 SCRUBBER FAILURE (EVENT NO. 4)

Design information for the scrubber includes the following:

- The scrubber vent height is 26 m; and
- The design flowrate is 650 m^3/hr with a NOx concentration not exceeding 350 milligrams/m^3.

Based on tank NOx design levels 0f 0.9% and a flow of 650 m^3/hr through the scrubber, the maximum NOx release rate is 0.002 kg/s or 2 grams/s, i.e. a relatively low release rate for dispersion cases.

This potential emission rate was modelled using TNO's EFFECTS program to determine if there could be irritation and injury impact at ground level. As per the existing QRA for the site (Ref 7), the AEGLs for a 10 minute exposure were used in the modelling, i.e. AEGL-1 for irritation and AEGL-2 for injury. These values are 0.5 and 20 ppm, respectively.

Modelling of the low release rate from a 26 m stack height for both F2 and D3 atmospheric conditions showed that the expected ground level concentrations of NOX would be less than 0.5 ppm, i.e. adequate dispersion will take place and no irritation or injury impact is expected for this scenario.

5.6 PUMP FAILURES (EVENT NO. 5)

Typical frequencies for pump failures are as follows (Ref 11):

- Large seal failure = 0.005 times / year;
- Shaft failure = 1×10^{-4} times / year; and
- Casing failure = 1×10^{-5} times / year.

As discussed in Section 5.1, the most credible outcome is impact to people close to the point of release. Again, given a conditional modifier of a person being present in the tank area when the pumps fail in the order of 5% then the approximate likelihood of adverse impact to a person on-site is:

- 2.5×10^{-4} times / yr for a seal failure (this will be the smallest quantity of material lost for the three possible pump losses of containment scenarios and hence limiting the impact, i.e. fatality would not be expected);

- 5 x 10-6 times / yr for a shaft failure; and
- 5 x 10^{-7} times / yr for a casing failure.

From the risk matrix shown in Figure 4, this is a low level of risk and not considered intolerable.

5.7 RISK TO THE BIOPHYSICAL ENVIRONMENT

The main concern for risk to the biophysical environment is generally with effects on whole systems or populations.

Whereas any adverse effect on the environment is obviously undesirable, the results of this study show that the risks of the potential incident scenarios for losses of containment affecting the environment are limited by using a tank-in-tank design and bunding for the associated equipment, e.g. the scrubber and the pumps.

Scenario 6 in Table 2 shows the possibility of environmental impact due to incorrectly pumping a loss of containment of nitric acid from the new bunded area to the River Pit and hence the potential flow off-site.

As per the tank overflow scenario, the reliability of the protective safeguards is best reviewed during the detailed design stage to confirm the risk of this event is acceptable. Therefore, it is recommended in this PHA to include this scenario in a Layers of Protection Analysis (or similar) during the design phase of the project to ensure the risk of liquid releases to the environment is acceptable.

Preferably, the bund sump pump system should be designed using the principles of inherent safety, i.e. design out the hazard. In this case, do not have a path for pumping any spilt nitric acid to the environment.

5.8 CUMULATIVE RISK

Cumulative risk at Kooragang Island was considered by the Department of Urban Affairs and Planning (now the DoPI) in 1993. As shown in this PHA, the proposed nitric acid tank and associated equipment will have negligible impact on the cumulative risk results for Kooragang Island as the material involved is a corrosive liquid, i.e. the impacts of releases is largely local to the point of release. This is supported by anecdotal evidence from the spills reviewed in Appendix 2.

5.9 SOCIETAL RISK

The criteria in Table 4 for individual risk do not necessarily reflect the overall risk associated with any proposal. In some cases for instance, where the 1 pmpy contour approaches closely to residential areas or sensitive land uses, the potential may exist for multiple fatalities as the result of a single accident. One attempt to make comparative assessments of such cases involves the calculation of societal risk.

Societal risk results are usually presented as F-N curves, which show the frequency of events (F) resulting in N or more fatalities. To determine societal risk, it is necessary to quantify the population within each zone of risk surrounding a facility. By combining the results for different risk levels, a societal risk curve can be produced.

In this study of the proposed nitric acid tank and associated system, the credible risk of fatality does not extend off the site and is therefore well away from the residential areas. In fact, the nearest house is approximately 800 m away. The concept of societal risk applying to residential population is therefore not applicable for the proposed modifications.

6 CONCLUSION AND RECOMMENDATIONS

The risks associated with the proposed nitric acid tank and associated systems at the Orica Kooragang Island have been assessed and compared against the DoPI risk criteria.

The results of this PHA show that the risks associated with the proposed nitric acid tank and systems comply with the DoPI guidelines for tolerable fatality, injury, irritation and societal risk. Also, risks to the biophysical environment, the risk of propagation and the impact on cumulative risk in the Kooragang Island area from releases are acceptable (subject to the recommendations below).

Reviews of historical incidents associated with nitric acid facilities have shown that the off-site risks of losses of containment are acceptable due to the limited impact from releasing a corrosive liquid. This is supported by the findings of the site's existing PHA.

The recommendations from this study are:

1. Include the tank level instrumentation in a Layers of Protection Analysis (or similar) to determine the required level of reliability to reduce the risk of tank overflow to an acceptable level.
2. Perform a Layers of Protection Analysis (or similar) during the design phase of the project to ensure the risk of liquid releases to the environment is acceptable. Preferably, the bund sump pump system should be designed using the principles of inherent safety, i.e. design out the hazard. In this case, do not have a path for pumping any spilt nitric acid to the environment.
3. Perform a HAZOP study and a construction safety study on the proposed changes.
4. Update the existing safety management system, including the emergency response plan, for the proposed new tank and equipment.

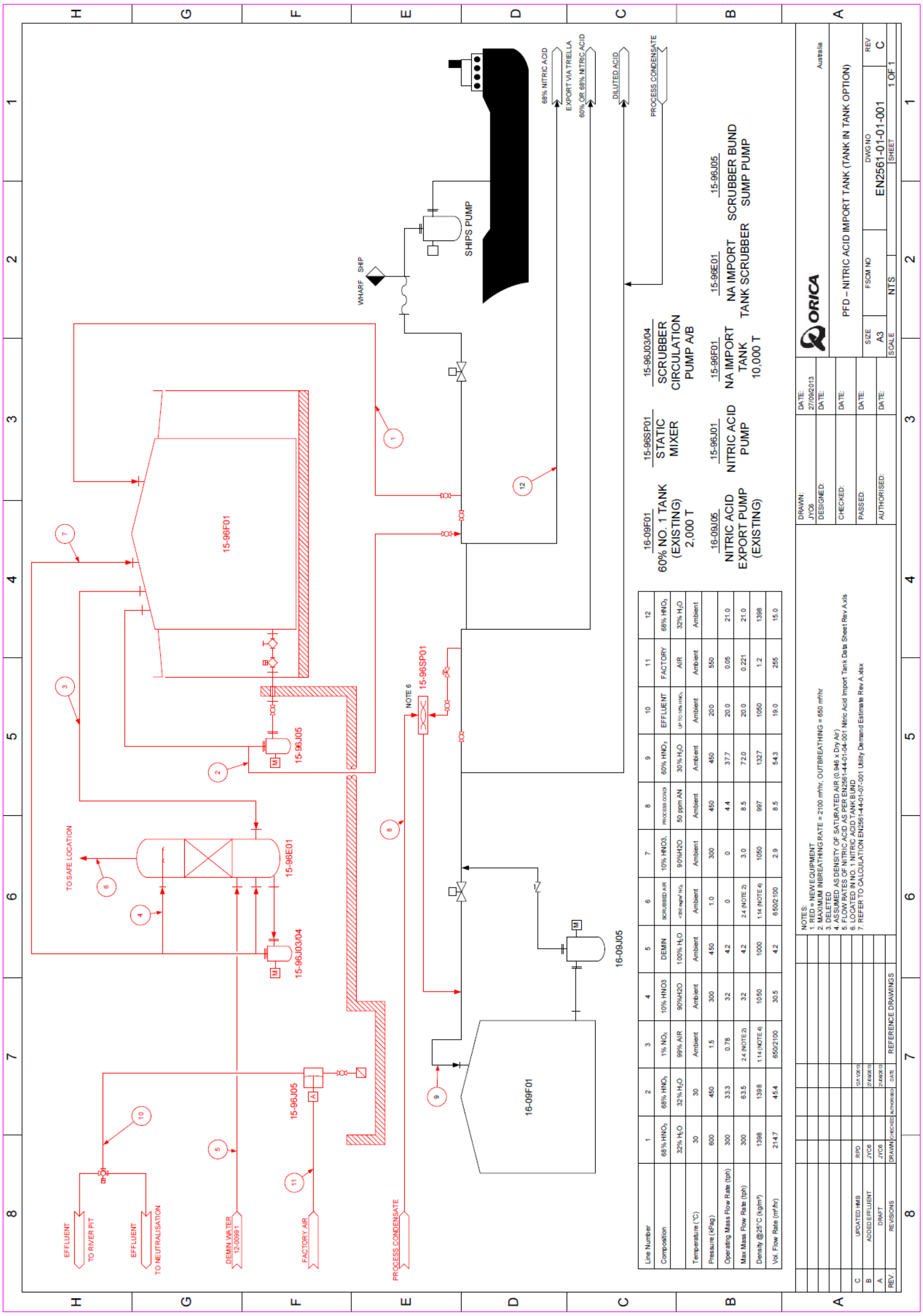
Appendix 1

Process Flow Diagram

Preliminary Hazard Analysis, Nitric Acid Tank,

Orica, Kooragang Island

Appendix 1 – Process Flow Diagram.



Appendix 2

Nitric Acid Releases Summary

Preliminary Hazard Analysis, Nitric Acid Tank,

Orica, Kooragang Island

Appendix 2 – Nitric Acid Releases Summary.

Year	Location	Amount	Number of Fatalities	Comments on Incident	Number of People Requiring Medical Treatment	Company
2012	Bad Fallingbostel, Germany	Unknown	0	Nitric acid poured into a caustic tank and hence reacted causing NOx. 1,800 people evacuated	Unknown	Kraft Foods
2012	Erwin	4,200 kg	0	Incompatible materials of construction in a flow meter caused the leak into a bund	0	NFS
2009	Singapore	Unknown	4	Nitric acid used to clean a fouled heat exchanger and, under pressure, the nitric acid was released with 4 workers killed	Unknown	Chemic Industries
2006	Source: OHSA	Unknown	0	Nitric acid released when transferring to a road tanker	2	Canton Rail Company
2005	Salt Lake City, USA	Unknown	0	Leaking rail car	0	Union Pacific
2002	Oshkosk, WI, USA	Unknown	0	Hydrochloric acid (4 m^3) mistakenly delivered into a nitric acid tank that fumed. Tank had a scrubber and bunding	0	Hydrite Chemical Company
1998	Carson, USA	6 kg	0	Leak from a 1,000 litre drum. NOx cloud approximately 13 m wide and 20 m high	0	Prime Wheel (plating company)
1997	Source: OHSA	840 kg	0	4 m^3 tank leaked from a failed nylon fitting	Several	Alcoa Memory Products
1997	Source: OHSA	Unknown	1	Employee mixed alcohol with nitric acid yielding NOx. Employee who was exposed died 15 days later from pulmonary oedema		Lg Epitaxy

Year	Location	Amount	Number of Fatalities	Comments on Incident	Number of People Requiring Medical Treatment	Company
1995	Source: OHSA	Unknown	0	Release of nitric acid from a hose during a transfer	1	General Dynamics Convair Division
1995	Source: OHSA	Unknown	1	Workers respirator dislodged when vat containing nitric acid ruptured and he was exposed to NOx (soaking drill bits in the vat)	o	Mine Tools
1995	San Diego, USA	Unknown	0	Nitric acid release from a hose and sprayed two workers	2	Moore Printed Circuits
1995	Source: OHSA	6 kg	0	Nitric acid leak onto cardboard causing fumes and a fire	8	United Parcel Service
1994	Anaheim, USA	170 kg	0	120 L of nitric acid added to a 205 L 'empty' drum which contained another material. Reaction generated NOx. Minor injuries only	16	Leach Corporation
1994	Ogden, UT, USA	Unknown	0	Worker suffered burns when he waded through 500 mm deep nitric acid in a bund wearing PPE that leaked	1	Dyce Chemical
1992	California, USA	550 kg	0	400 L spill caused 60 people (on and off site) to be affected (irritation only) and requiring treatment	60	(chrome plating company)
1991	Source: OHSA	280 kg	0	Drum leaked and reacted with the concrete causing NOx	9	Everco Industries
1991	Source: OHSA	Unknown	0	10 m^3 of nitric acid pumped into a 34 m^3 hydrochloric acid tank causing fumes	0	General Electric International

Year	Location	Amount	Number of Fatalities	Comments on Incident	Number of People Requiring Medical Treatment	Company
1991	Source: OHSA	220 kg	0	Drum lid opened when the drum was dropped splashing two workers	2	Dixie Trucking Company
1990	Source: OHSA	Unknown	0	Worker fell into a tank containing 10% nitric acid and 2% hydrofluoric acid	1	Avesta
1998	Glendale, California	1,100 kg	0	800 L of nitric acid mixed with other chemicals	5	American Metaseal
1998	Paramount, LA, USA	1,700 kg	0	Spill of nitric acid followed by a toxic cloud	0	STI
1987	Azle, Texas	"Thousands of kgs"	0	Truck leak on a road "slightly" injuring more than 50 people (Source: LA Times), i.e. irritation impact	50	-
1987	Lynwood, LA, USA	1,700 kg	0	1,200 L tank ruptured	Unknown	Chrome Nickel Plating
1985	Toronto, Canada	Unknown	0	Alcohol mixed with nitric acid – all 45 affected people were company employees	45	-
1983	USA	75,000 kg	0	Release of nitric acid from a rail wagon due to impact causing small fires and a large NOx cloud, 9,000 people evacuated from a 5 km^2 area	34	-

Notes:

1. Approximately 100 incidents were reviewed; a significant number of which involved laboratory incidents and cleaning activities. Hence small quantities were involved, i.e. a few litres.
2. There were no off-site fatalities for the incidents reviewed. Presumably due to limited consequential impact from releasing a corrosive liquid, early warning by the NOx odour and emergency response.

3. There were on-site fatalities for some incidents.
4. The off-site impacts are better described as ‘irritation’ rather than ‘injury’.
5. There were no major accident events involving production facilities in the reviewed incidents.

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