University of Southern Queensland

Faculty of Health, Engineering and Sciences

Feasibility on Vertical Column Gravity Separation of Class O Fluids

A dissertation submitted by

Ashley Brian

In fulfilment of the requirements of

ENG4111 and ENG4112 Research Project

towards the degree of

Bachelor of Engineering (Honours) (Civil)

Submitted October 2021

Abstract.

Ergon Energy owns, operates, and maintains hundreds of substations of various capacities located throughout Queensland. These substations consist of various equipment required to maintain the electricity network that provides power for everyday consumption. The backbone of these substations is the transformer, traditionally liquid filled using high volume of mineral based oil for cooling and insulation. Any leakage, or catastrophic failure of this equipment would create significant risk to the environment.

This project focuses on the gravity oil water separation systems used by Ergon Energy to investigate the apparatus capability of fulfilling its designed function to the current hierarchy of Acts, Regulations, Codes of Practice, and standards for wastewater discharge.

The project considered different types of hydrocarbons contaminates found in the insulating oil and utilised a simulated rain event with a containment system mimicking a bunded area, and a U-tube to perform water quality testing for any hydrocarbons passing through the system. Testing was conducted for Benzene, Toluene, Ethylbenzene and Xylene (BTEX), Polyaromatic hydrocarbons (PAHs), total recoverable hydrocarbons and total petroleum hydrocarbon (TPH).

The results have indicated the U-tube is capable of minimising the concentrations of hydrocarbons at a set inflow rate, and keeping hydrocarbons within the target amounts on the outflow.

Further testing would be required to assess the separation systems capability when designed for different flow rates.

Key words. Class O, Mineral oil separation, containment, oil water separator.

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Certificate of Dissertation

I certify that the ideas, designs and experimental work, results, analyses and conclusions set out in this dissertation are entirely my own effort, except where otherwise indicated and acknowledged.

I further certify that the work is original and has not been previously submitted for assessment in any other course or institution, except where specifically stated.

Ashley Brian

Student Number:[redacted]

Acknowledgements

I would like to express my gratitude to the following people:

Firstly, I would also like to thank my two daughters for sacrificing their time with me so I may achieve my goal of completing this degree in engineering and for their ongoing support and understanding throughout my studies.

I would like to thank my project supervisor Dr Malcolm Gillies for his patience, guidance, and feedback throughout the preparation of this dissertation.

ASHLEY BRIAN

Table of Contents

List of Figures

List of Tables

List of Appendices

Glossary of Terms

AEP	Annual Exceedance Probability
ARI	Average Recurrence Interval (years)
BOM	Bureau of Meteorology
Ergon	Ergon Energy
EQL	Energy Queensland Limited
EY	Average number of exceedances per year
HV	High Voltage (greater than 1000V)
IPWEA	The Institute of Public Works Engineering Australasia
kV	Kilo Volts
LV	Low Voltage (1000V and below)
MVA	Megavolt Amperes
NATA	National Association of Testing Authorities
PCBU	Person conducting a business or undertaking
PPM	Parts Per Million
SME	Subject Matter Expert
SWMS	Safe work method statements
TX	Transformer

Type S	Sub-Transmission Substations
Type T	Transportable Substations
Type Z	Zone Substations
uPVC	Unplasticized polyvinyl chloride
WHS Act	Workplace Health and Safety Act 2011
QA/QC	Quality assurance and quality control
QUDM	Queensland Urban Drainage Manual

Definitions

Bund/Bunded	A wall/barrier of sufficient height constructed around fluid filled equipment to contain spillage of liquids.
Flame trap	A pit with a down turned pipe used as a fire quenching mechanism.
Gravity separation	Oil-water separation without the use of chemicals or mechanical means i.e., using gravity only to separate particles.
NATA Accredited	An assurance of the testing laboratory's competence, with relevant international and Australian standards to provide reliable testing.
Trade Waste	Any matter or thing, whether solid, gaseous or liquid, that is refuse from any industrial, chemical, trade or business process or operation.
Waste	Captured oil and sediment within the oil containment system.

Chapter 1 - INTRODUCTION

1.1. Background

Power and distribution transformers have been in service for over a century in the distribution of energy throughout the world. They are a critical component in the energy distribution network varying in different megavolt amperes (MVA) capacity and voltage ranges. Transformers are used for indoor and outdoor applications (Mehta et al. 2016) in substations throughout the world. They are designed to either stepping up or stepping down the voltage of the electricity supplied (Cabral et al., 2010) to meet the needs of the network. Transformers in zone substations step down the voltage, then the network provides the electricity to our homes via the poles and wires seen in our streets to power our electrical goods.

Ergon Energy owns, operates and maintains hundreds of substations of various capacities located throughout Queensland, These substations can be categorised as, Type S (Table 1.1), Type Z (Table 1.2) and Type T (Table 1.3) (Ergon Energy, 2014). The forementioned types can be further classified by added numeric suffix that specifies the incoming and outgoing voltages ranging from 132/66 to 33/11 kV. The majority of these outdoor substations are Type Z (Zone) and are designed to N-1 standard. The Zone substation is configured into bays, comprising of equipment in a minimum of two feeder bays, with each bay being feed by its own transformers with a sections bus, tying the two bays together (Ergon Energy, 2014). Refer Figure 1.1: Typical Zone substation layout.

Table 1.1: Type S – Sub-transmission Substations

Network Connection		
S1	132/66	Ultimately an “N-1” design based on two primary feeders, two transformers, all switchgear and buswork is outdoor, except for 33kV where indoor is available.
S2	32/33	
S3	110/66	
S4	110/33	

Table 1.2: Type Z – Zone Substations

Network Connection		
Z1	132/22	Ultimately an “N-1” design based on a minimum of two primary feeders, two transformers, and a three section secondary busbar. At 66kV and above the bus is outdoors. Lower voltages use indoor switchgear
Z2	132/11	
Z3	110/11	
Z4	66/33	
Z5	66/22	
Z6	66/11	
Z7	33/11	

Table 1.3: Type T – Transportable Substations

Network Connection		
T1	66/33	“N” design based on one primary feeder, one transformer, switchgear is indoors except at 66kV. Two units can be used together to give “N-1”
T2	66/22	
T3	66/11	
T4	33/11	

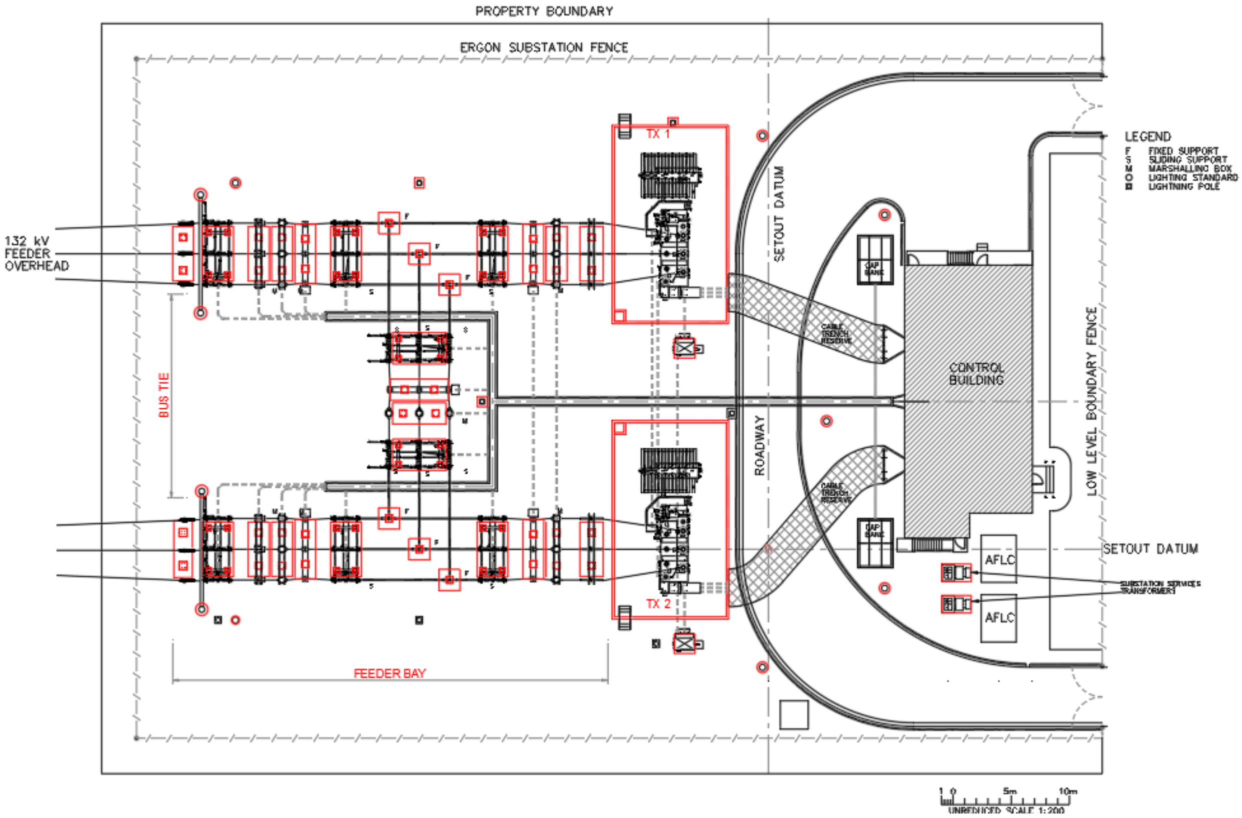


Figure 1.1: Typical Zone substation layout. (Refer Table 1.2: Type Z – Zone Substations)

Traditionally these transformers are liquid filled using a mineral based oil for its cooling and dielectric properties (Asano & Page, 2014). For a transformer to operate effectively, it will contain a high volume of insulating oil, which in the event of a leakage or catastrophic failure would create significant risk to the environment. Due to this risk, transformers are bunded which entails a floor surface with a wall constructed to its perimeter of a material that is impervious to the liquid it is to contain. This bund also provides an element of fire protection by containing the liquid with in its walls (EPA, 2017). In providing containment for the insulating oil, it also limits the ability for rainwater to escape the bunded area, and provisions need to be made to allow for the onflow of water without allowing environmental contaminates to escaping (Ergon Energy, 2003; Endeavor Energy, 2015; Ausgrid, 2017), oil contaminated rainfall runoff can be a problem. A typical bunded transformer can be seen in Figure 1.2: Transformer bund, Evelyn Substation.

Figure 1.2: Transformer bund, Evelyn Substation.

Prior to formation of Ergon Energy in 1999, legacy Boards had a number of approaches to substation transformer bunding and oil separation/retention methods. Under the newly formed Ergon Energy, a new standard was formed in the release of ‘Substations Standards Oil Containment’ in 2003 (Ergon Energy, 2003). With the introduction of this standard, the design of the gravity U-tube oil separator (Figure 1.3) was conceived for the separation of oil and water from the bunded transformers. The U-tube standard drawing was released for construction in May 2012 and its installation was implemented in the construction of new transformer bund projects, and rectification works of existing and previously un-bunded sites. The U-tube uses the principle of differential density and gravity to separate the oil from water in the vertical column, then discharges the separated heavier density water, leaving the oil contained in the transformer bund. This method is effective for static conditions but fails to take into consideration the dynamic effects of the surrounding environment.

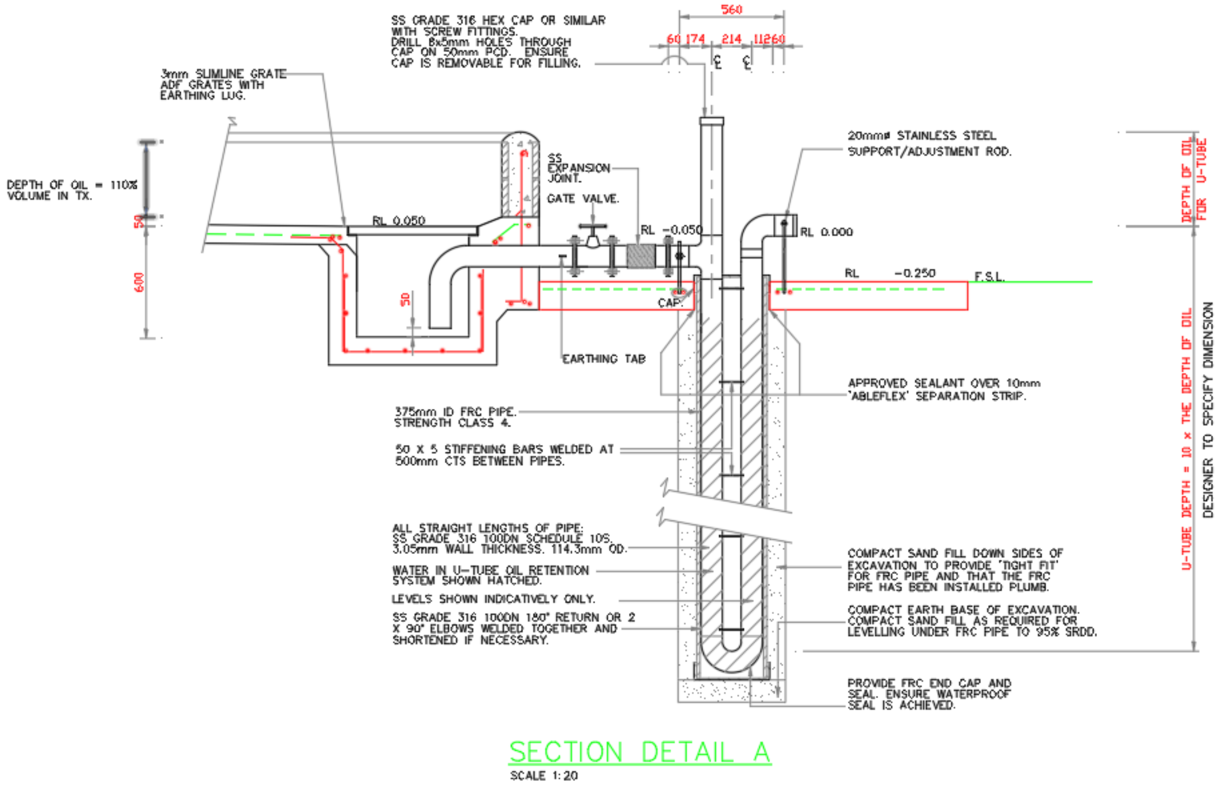


Figure 1.3: Ergon Energy revision OB, U-tube design

With the distribution of population across Queensland, comes the need for electricity supply, these locations come with issues inherent to their locations. Refer to Figure 1.4. Some of these contributing factors are:

- High rainfall intensity, creating high flow rates of water from the bund causing minimal dentition time allowing fluids to separate.
- low rainfall, allowing the evaporation of the water stored within the separator reducing the available depth to separate the fluids.
- Flooding, additional expense of raising the site.
- Proximity to estuaries and potential environmental damage.

Figure 1.4: Map of Energy Queensland Substations and Power Stations sites (Google maps)

Ergon Energy still predominantly uses transformers with mineral insulated oil for their distribution network throughout Queensland (Figure 1.4), with trials commenced at Comet zone substation 6.3 MVA 66/22kV transformer using class K fluid, MIDEL 7131, a synthetic ester (10,200 litre) as the insulating fluid. Comet substation is located in a rural area approximately 300km west of Rockhampton with no natural load growth to date, the synthetic ester trail is being conducted on then, a 10 month old transformer, retrofitted for MIDEL 7131. The purpose of the retrofit is primarily for economic reasons, the use of an earthen bund and containment tank for the easter outweighs the cost of extending the site for a traditional oil containment system (M&I Materials, 2020). To maintain these transformers, Ergon Energy periodicity test the insulating oil to ensure its properties are within acceptable levels. In addition to this maintenance program, a 5 yearly period contract for replacement oil is tendered, the schedule of requirements can be found in Appendix C. The contract is awarded to the supplier who is able to provide a fair and equitable tender to meet the outlined requirements. The current period contract is held by axieo for the supply of POWER TO 1020 60U UNHIBITED oil. The change in period contract may impact the oil water separator's ability to be work affectively unless the density of the new supplier's oil, is the less than or equal to the density used to design the separator.

Additionally with the use of esters such as MIDEL 7131, although the esters proprieties appear to have more environmental advantages than mineral oil (M&I Materials, 2020), it is still classed as a contaminate, and as such must be contained for appropriate disposable. This creates problems in separation with water as both fluids have very similar density.

1.2. Aim

The aim of the project is to ascertain the suitability of the existing oil-water separator design, for continued use in Ergon Energy's substations, for the containment and separation for O class oil in water. To test the system under static conditions for its ability to retain oil in the event of a catastrophic failure and site-specific dynamic conditions for the additional in flow from weather events to prove the effluent from the system meets the prescribed water quality.

1.3. Objectives

The project objective is to design a prototype gravity separation system based on the Ergon Energy Substation Standard (EESS) oil separator in conjunction with a replicated rainfall flow from a transformer bunded area. This will enable water quality tests to be performed on the effluent to ascertain if the effluent meets the current hierarchy of Acts, Regulations, Codes of Practice, and standards for wastewater discharge for hydrocarbons. This will be achieved by;

- Identify a representative transformer site and gather specifications including potential rainfall duration and intensity.
- Review relevant standards, Acts and guidelines for allowable levels of contaminants in effluent.
- Perform system model experiments in dynamic flow to test effluent for contaminants.
- Perform system model experiments in static condition to test containment.

1.3.1. Limitations

This research project will be focusing on mineral and easter based fluids, namely the use of POWEROIL TO 1020 60U UNINHIBITED and MIDEL 7131 transformer insulating fluid and meeting the environmental requirements for water discharge in Queensland.

1.3.2. Expected Outcomes and Benefits

Installation, inspection, and maintenance of oil retention systems cost millions of dollars each year. This project will provide outcomes to enable Ergon Energy to

- Adopt a permanent standard for oil-water separation.
- Investigation the need for addition oil-water separation devices to be added to the system.
- Planning for capital works and the associated cost for replacement of the system, in the event of system failure.
- Improve substation site stainability by the reduction of contaminates escaping to the environment.
- To limit the need for remediation works improving the environment and working conditions within the substation.

Chapter 2 - Literature review

2.1. Transformer (TX)

Society’s high dependency and demand for electricity to be supplied without interruption (Fernández et al., 2013), makes the transformer a vital component in the transition and distribution of power. A transformer function is based on the application of faraday’s Law of electromagnetic induction, that the primary windings are either more than the secondary winding for set-up transformer and reversed for step-down (Tyco Electronics Corporation, 2004), typical detail for this can be seen in Figure 2.1 below.

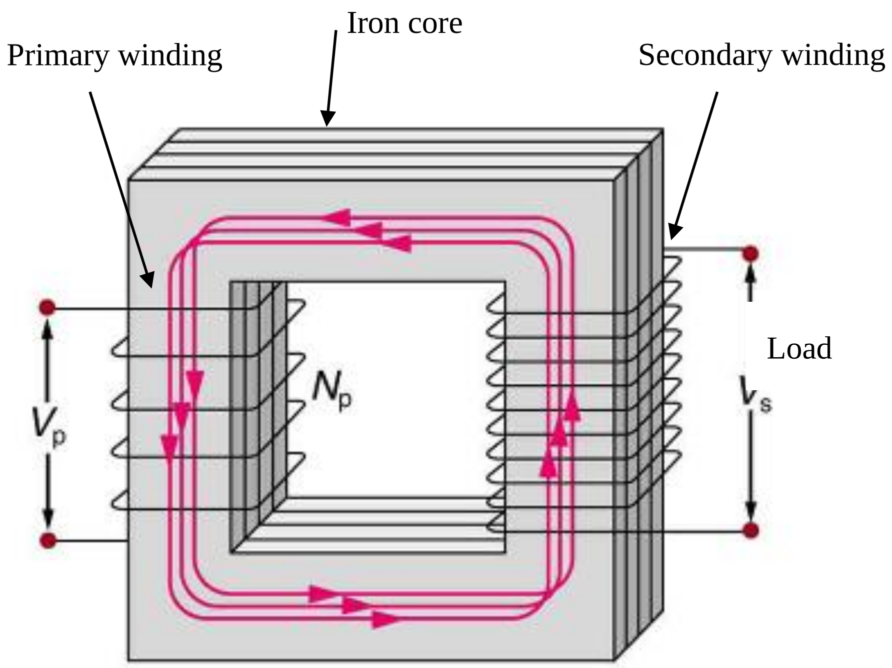
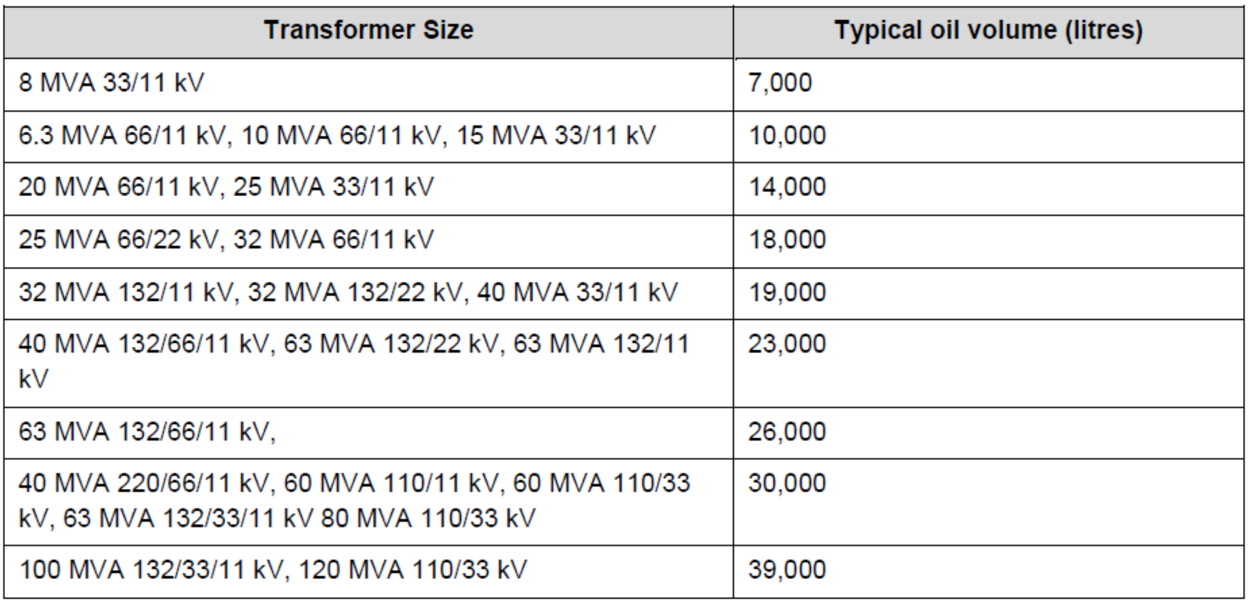


Figure 2.1: Typical transformer diagram (khan academy, 2021)

Transformers are rated by their ability to carry power and incoming and outgoing voltage. These details can be found on the nameplate with a MVA number that is an expression of power, it is the apparent power the transformers can supply, and two kV rating, firstly the incoming primary voltage followed by the secondary voltage, which is the actual power the transformer provide(Fundamentals of Electricity, 2021). Examples of this can be seen in Table 2.1 below.

Transformer rated size will depend on the purpose of the substation, a bulk supply substation can be configured from a 275/66 kV, 132/66 kV down to a 132/22 kV, for a zone substation feeding a residential and rural area, the transformer will step-down the incoming higher voltage, of 66kV or 33kV from the sub-transmission lines to 22 or 11kV then distribute the electricity through the network to residents. Table 2.1 shows typical transformer MVA sizes for voltage ranges with estimate on oil volumes.

Table 2.1: Approximate transformer oil volumes (Energy Queensland, 2021)



Transformer Size	Typical oil volume (litres)
8 MVA 33/11 kV	7,000
6.3 MVA 66/11 kV, 10 MVA 66/11 kV, 15 MVA 33/11 kV	10,000
20 MVA 66/11 kV, 25 MVA 33/11 kV	14,000
25 MVA 66/22 kV, 32 MVA 66/11 kV	18,000
32 MVA 132/11 kV, 32 MVA 132/22 kV, 40 MVA 33/11 kV	19,000
40 MVA 132/66/11 kV, 63 MVA 132/22 kV, 63 MVA 132/11 kV	23,000
63 MVA 132/66/11 kV,	26,000
40 MVA 220/66/11 kV, 60 MVA 110/11 kV, 60 MVA 110/33 kV, 63 MVA 132/33/11 kV 80 MVA 110/33 kV	30,000
100 MVA 132/33/11 kV, 120 MVA 110/33 kV	39,000

These transformers contain large amounts of oil, having the potential to cause significant environmental damage, fire hazard (Standards Australia, 2016; Energy Queensland, 2021) with cascading affects to the ecosystem (Duke, 2016) in the event of a spills through maintenance and or catastrophic failure (Al-Amin et al., 2013)

Transformers are expected to have a service life of 30 years (Fuji Electric, 2014), this life expectancy is dependent on the breakdown of the insulating oil and its impurities (Fernández et al., 2013). Operating temperature, moisture and oxygen content are all contributors to this aging process (Manito et al., 2016) and it is recommended the transformer oil be subjected to an oil gas analysis every two years (Fuji Electric, 2014) and replaced when moisture content reaches manufactures specifications.

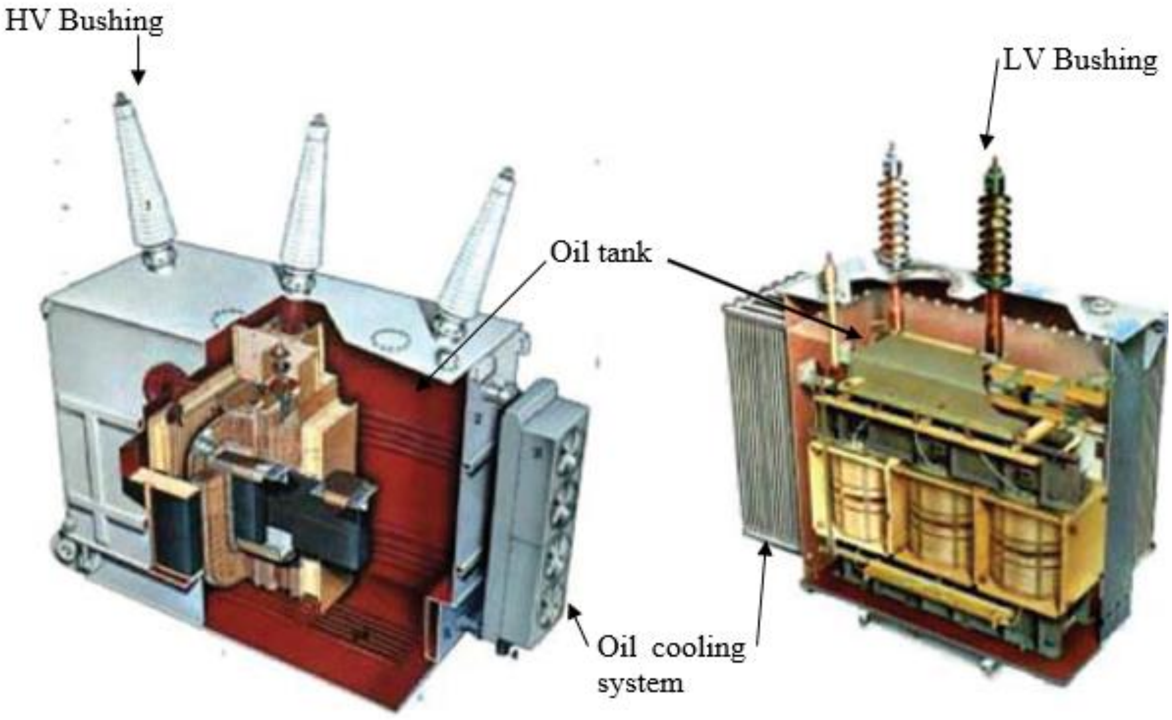


Figure 2.2: Cut out of large shell and core form transformers (Prevost & Oommen, 2006).

2.2. Purpose of transformer insulating fluids.

The insulating fluid contained in a transformer provides three main functions to its operation, it enables the transfer of heat from the windings, possesses dielectric capacity and provides mechanical support (Mehta et al., 2016). Additionally Some fluids offer a higher resistance to ignition providing a greater safety against fire in fault conditions (Perrier et al., 2010). For this research, the main interest is of the insulating fluid due to its effects on the environment.

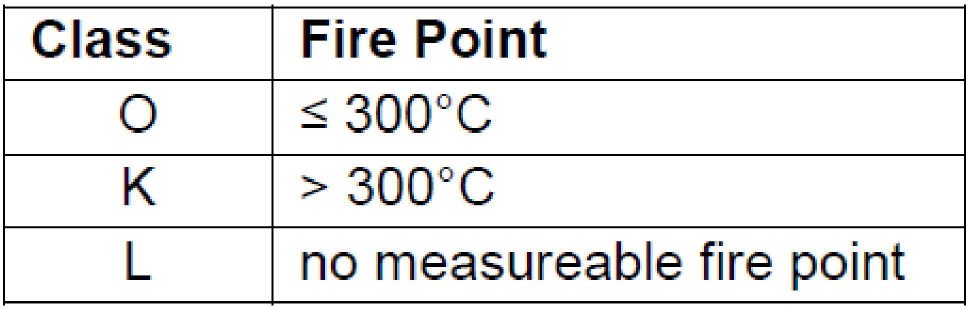
While in operation, the transformers coils generate heat during the conversion of the input voltage to the designed output voltage. This heat is produced from the electrical resistance between the core and coils which is exchanged through the oil and dissipated to the atmosphere via a heat sink (Hasan, 2017). Transformers are designed to allow for a temperature rise above ambient air temperatures with Horizon Power (2020) limiting this to 50°C. In general, transformers are limited to a maximum operating temperature of around 105°C, dependent on ambient temperature and may increase to 130°C during fault condition (Electrical Concepts, 2020).

The insulating oil becomes highly important when the equipment is under peak loads, these times are generally in the morning and evenings, when appliances are used to prepare meals, lights are switched on, and preparations are made for the day. Without the ability to maintain an operating temperature range, the transformer is limited to the amount of load the equipment can deliver (Hasan, 2017).

2.3. Types of insulating fluids

The classification of insulating fluids is managed by IEC 61039 - the classification of insulating liquids to fire point and net calorific value. Refer to Table 2.2: Classification of liquid below.

Table 2.2: Classification of liquid (Gyore, 2017)



Class	Fire Point
O	≤ 300°C
K	> 300°C
L	no measureable fire point

Mineral, high molecular weight hydrocarbons (HMWH), silicones and ester-based fluid both natural and synthetic are the main types of insulating fluids for transformers (Fernández et al., 2013).

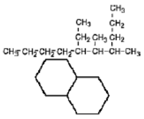
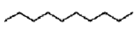
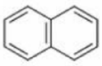
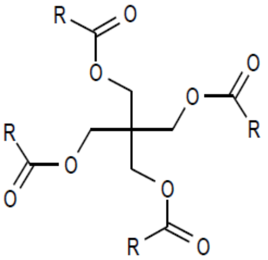
Mineral oil has been used to insulate power equipment since the 1890's, for a number of reasons (Mahanta & Laskar, 2017), the availability of the crude oil for refining, low cost and good aging capabilities (Fofana, 2013). The insulating fluid is refined from crude oil and consists of hydrocarbon compounds (Fernández et al., 2013). Mineral oil consists of two base types, paraffinic and naphthenic. Paraffinic-based oil performs poorly in low temperatures due to the insoluble sludge and high pour point from the wax component (Mahanta & Laskar, 2017). Naphthenic-based oil contains aromatic compounds (Mehta et al., 2016) and performs well in low temperatures maintaining the oils fluidity, but lacks fire safety due to its high flammability. Polychlorinated biphenyl (PCBs) is added to naphthenic-based oil to increase the fire safety of the oil. The chemical PCB was removed from service due to the extent of the health, and environmental concerns (Mehta et al., 2016), with the product banned for use in Australia in 1986 (Department of Environment and Science, 2016).

When reviewing Ergons current period contract for oil, “POWER TO 1020 60U UNHIBITED” is an even mixture of both paraffinic and naphthenic oil with a density of 0.895 kg/dm³. The oil falls in the classification of a Class O liquid with a flash point at or above 140°C. This becomes of greater interest to the containment and separation of the oil, as stated previously in the transformer section, the equipment has the potential to raise the oil temperature under fault conditions increasing the risk of ignition. Further details on the oil can be found in appendix C and D.

Both esters, synthetic and natural, have greater fire safety, readily biodegradable and create minimal environmental impact in comparison to mineral oil (Mahanta & Laskar, 2017). Synthetic esters are manufactured from plant acids (Fofana, 2013) and have excellent thermal stability and good low-temperature properties (Fernández et al., 2013).Natural esters are seed-based and are derived from glycerine, known as triglycerides (Fernández et al., 2013), they are capable of absorbing 20–30 times more moisture than mineral oil for the equivalent operating limits, which effects the dielectric capabilities of the oil (Rafiq et al., 2020) and lead to premature aging. Gravity separation is generally more difficult with esters as its density, 0.97 kg/dm³ (M&I Materials, 2019), is closer to that of water requiring much longer detention time for the two fluids to separate.

Table 2.3: A Comparison of the Key Properties of MIDEL 7131 and Mineral Oil

Liquid Type	Mineral Oil (Poweroil TO 1020 60U uninhibited)	Synthetic ester (MIDEL 7131)
Principle components	Complex mixture of hydrocarbons	Pentaerythritol tetra ester

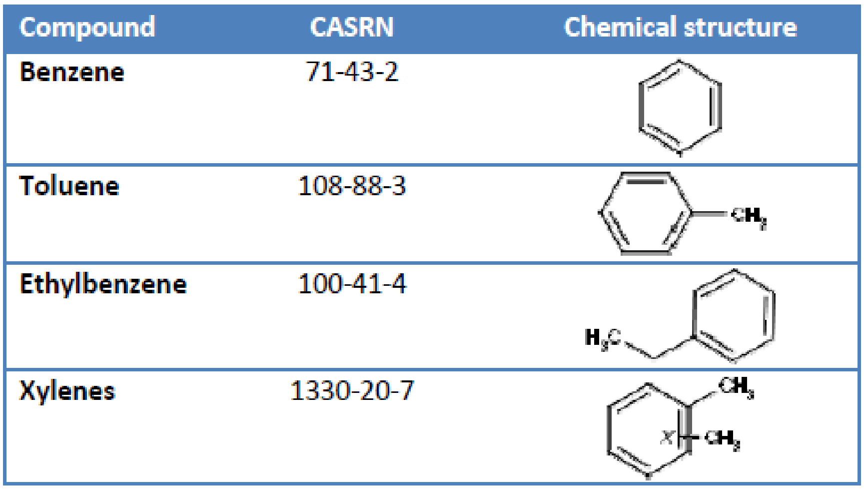
Liquid Type	Mineral Oil (Poweroil TO 1020 60U uninhibited)	Synthetic ester (MIDEL 7131)
Chemical structure	  	
Source	Purified from oil	Synthetic made from plant acids
Biodegradability	Very slow to biodegrade	Readily biodegradable
Moisture behaviour	Performance sensitive to moisture	Excellent moisture tolerance
Water saturation at ambient [ppm]	55	2600
Flash point, [°C]	140	260
Fire Point, [°C]	270	316
Fire Classification	O	K
Breakdown Voltage [kV]	Min 50	>75
Density at 20°C	0.895	0.90
Pour Point °C	-40	-60

2.4. Contaminants

Investigations into insulating fluids and additional discussions with Ergon’s senior environmental adviser, indicated mineral oils are the primary hazard, moreover, contain various hydrocarbons like paraffins, naphthene and fragrant hydrocarbons. The presence of total petroleum hydrocarbons (TRH) has a harmful effect to plant growth and human health (Adipah, 2018). Total petroleum hydrocarbon (TPH) is the term used to describe organic compounds mixtures that originate in, or are obtained from crude oil (Adipah, 2018). Soil contaminated with TPH has been gaining public attention over the past decades as a serious worldwide environmental problem (Adipah, 2018).

2.4.1. Benzene, Toluene, Ethylbenzene and Xylene (BTEX)

The simplest of the C6-C9 aromatic hydrocarbons (Cwlth, 2000), BTEX can be found naturally in crude oil and from other natural sources such as forest fires (DES, 2020). They are aromatic hydrocarbons and are common in industrial solvent and cleaners (Cwlth, 2000). Common contact to BTEX is via breathing air borne particles, namely through motor vehicle emissions and tobacco smoke (DES, 2020). BTEX is a concern for the environment for its highly active and volatile nature (Adipah, 2018), suspend in water, and at contaminated sites, found in surface and groundwater (Leusch & Bartkow, 2010).



Compound	CASRN	Chemical structure
Benzene	71-43-2	
Toluene	108-88-3	
Ethylbenzene	100-41-4	
Xylenes	1330-20-7	

Figure 2.3: Compound, chemical abstract service registry number (CASRN) and BTEX (Leusch & Bartkow, 2010).

2.4.1.1. Benzene

Benzene is a flammable, colourless-to-yellow transparent liquid (NHMRC, 2011) and out of the four chemicals, it is the only known carcinogen with a maximum of 1 part per billion (ppb) detection rate in drinking water specified by the Australian Drinking Water Guidelines (ADWG) (DES, 2020). It is prescribed that drinking water have no higher concentrate of 0.001mg/L of benzene for health considerations (NHMRC, 2011).

2.4.1.2. Toluene

A physical component of crude oil, toluene is an achromatic fluid, a solvent used in nail polish and paint adhesive (NHMRC, 2011). It is prescribed that drinking water have no higher concentrate of 0.0025mg/L of toluene for odour and taste while for health considerations, no more than 0.8mg/L (NHMRC, 2011).

2.4.1.3. Ethylbenzene

A product of oil refining, ethylbenzene is a transparent colourless fluid (NHMRC, 2011), with evidence that the compound is carcinogenic (ATSDR, 2004). Combined with xylene, ethylbenzene forms the major component of pesticides and paints (NHMRC, 2011), and is found as apart of asphalt (Cwlth, 2000). The Australian Drinking Water Guidelines 6 (2011) prescribes for taste and odour, that ethylbenzene ought not surpass 0.003mg/L and 0.3mg/L for health considerations.

2.4.1.4. Xylene

Xylene is a achromatic, combustible liquid with a sugary odour (NIOSH, 2019) and exists in coal tar (NHMRC, 2011) and in aircraft fuels (Cwlth, 2000). The Australian Drinking Water Guidelines 6 (2011) prescribes for taste and odour, that xylene shall not surpass 0.02mg/L and 0.6mg/L for health considerations.

2.4.2. Polyaromatic hydrocarbons (PAHs)

There are hundreds of PAHs known (Hussar et al., 2012; Driscoll, 2014), out of these, 16 are of great concern to the environment (Hussar et al., 2012). The international agency for research on cancer (IARC) have classified PAHs as suspected or a known carcinogen human (Driscoll, 2014). One of these potential toxins is naphthalene. Naphthalene is part of the aromatic hydrocarbon group (Rouse, 1998) and is the smallest in its family (Office of Parliamentary Counsel, 2013). It is a compound found in petroleum products derived from crude oil (Wexler, 2014).

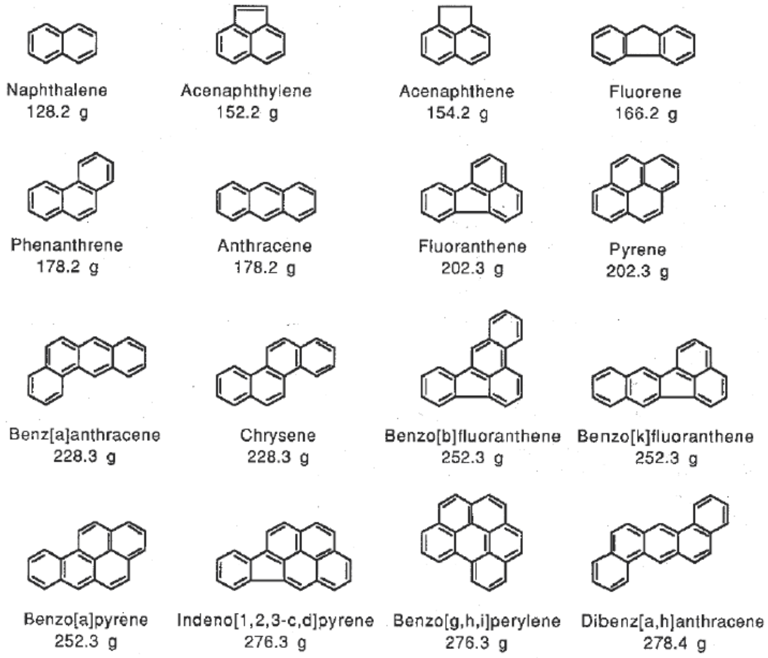


Figure 2.4: Structure of the 16 PAHs (Henner et al., 1997)

2.4.3. Polychlorinated Biphenyl (PCB)

PCBs are a chlorinated hydrocarbon (WHO, 1992) that can remain in the soil for many years and can be harmful to human health if released into the environment (Department of Environment and Science, 2016). The main cause of accumulation this chemical in humans is the consumption of fish from contaminated water, but exposure can also occur via other foods (WHO, 1993).

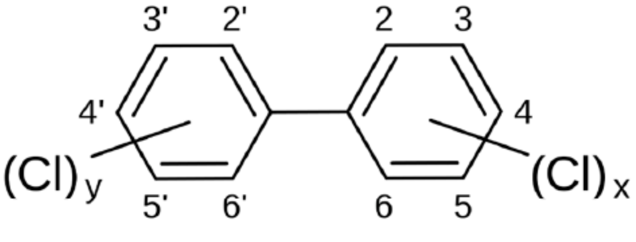


Figure 2.5: PCBs structure, 10 potential chlorine bind positions (Hens & Hens, 2018).

2.5. Contaminant guidelines

Water contaminants are prescribed in schedule 10 of Environmental Protection Regulation (Cwlth, 2019), it. This therefore requires all spills to be contained on-site. Discharge of the contaminant from the bunded area out to overland flow and or stormwater would be in breach of the regulation. Whereas the National Environment Protection Measures (NEPM) Schedule B1 tables the allowable limits for Environmental Screening Levels (ESLs) for ground contamination when land parcels are to be investigated as a result of hydrocarbon contamination. The table outlines the fractions of TPH from C6 to C40 as well as benzene, toluene, ethylbenzene and xylene (Larsen, 2013). Typically, the water output cannot have a sheen, with the presents of a sheen it is believed to be approximately 10ppm.

2.6. Containment infrastructure

A bund in essence, is a compound. It is a levee constructed of brick, concrete or earth, lined with an impervious material. The bund consists of a floor with a wall to its perimeter creating a barrier to contain the insulating fluid (EPA, 2017). Transformer bunds are designed with the guidance of AS 2067:2016 and AS 1940-2017 standards. Both standards prescribe transformers containing over 1000L of insulating oil shall provide containment for the equipment’s total fluid volume in the event of a leak, spill or fire. AS 1940-2017 proceeds further to instruct that the bunded area shall be able to contain the greater of, a minimum 110% of the TX oil capacity or, 25% of all the fluid filled equipment’s capacity within a single bunded area. Ausgrid (2017), Endeavor Energy (2015), Ergon Energy (2003), TasNetworks (2018) and TransGrid (2019) all require some sort of concrete bund constructed around their transformers, the overall surface area of the bund is also dependent to access to the transformer parts. AS 2067:2016 requires a minimum of 600mm separation from any structure or open door allowing access around the structure. Ergon Energy (2003) interpret AS 1940-2017 requirement of 2 vertical to 1 horizontal (26.6 degrees) spray angle to be from the tangent of any surface that contains oil and is depicted in Figure 2.6 below, this is to ensure that any leaks from the transformer will not spray outside the bunded area from available head pressure within the transformer. These energy network providers do however differ in their requirement of containment volume; most follow the requirement prescribed in AS 1940-2017 with some entities going over and above the standard.

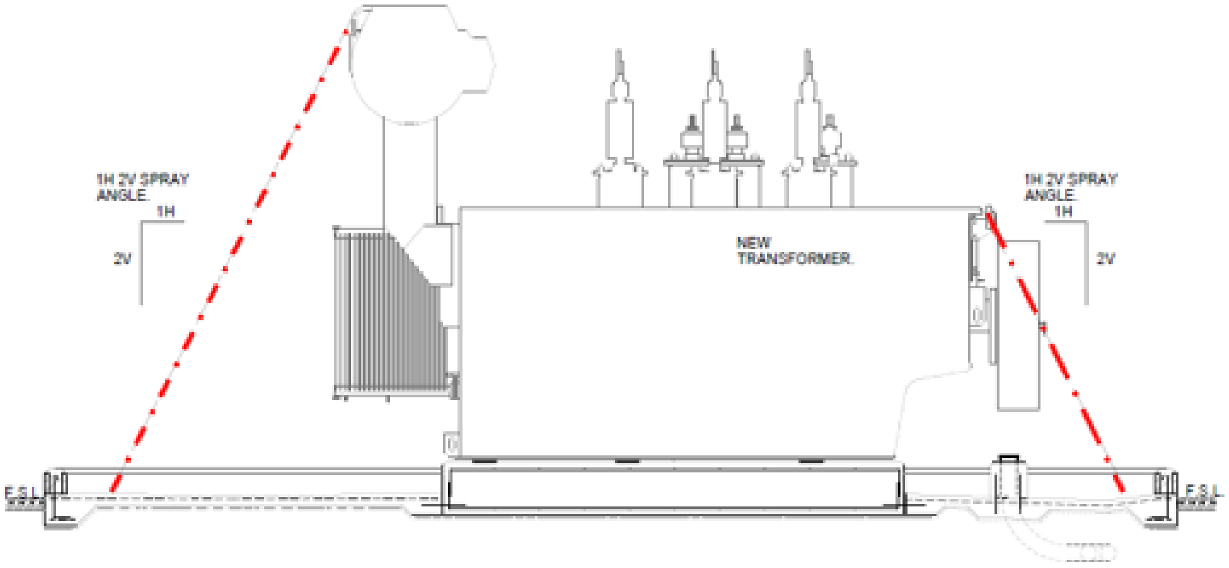


Figure 2.6: Typical spray angle (A Brian 2021, personal drafting, 2 October)

2.7. Containment Drainage

Provisions for rainfall to drain from the bunded area are considered through the bund design, allowing fluids to gravity drain to a sump located at the lowest point in the bund (Ergon Energy, 2003). In general, a 1:100 fall is adequate to direct any fluid that may fall within the bunded area to the sump that houses a flame trap. A flame trap, Figure 2.7 and Figure 2.8, consists of a down turned pipe or labyrinth used as a fire quenching mechanism, it is connected via the sump/pit to allow fluids, to leave the bund area without remaining in contact to the atmosphere thus preventing any combusted fluid leaving the bund and creating a further fire hazards (Standards Australia, 2016). There must be sufficient depth designed into the flame trap drainage to allow for location specific criteria such as evaporation. The level of water remaining in the sump/pit is reliant on the discharge level of the separator. The effluent is passed through an oil-water separator prior to being discharged to ground and into stormwater (Ergon Energy, 2003; Endeavor Energy, 2015; Ausgrid, 2017).

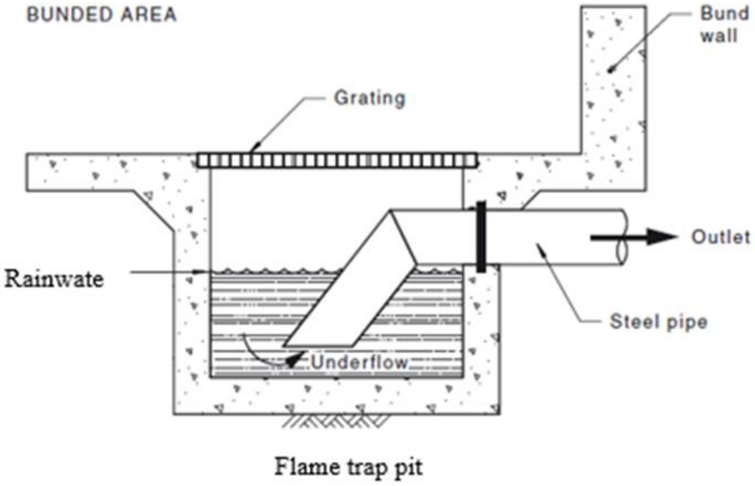


Figure 2.7: Flame trap example (a) (Standards Australia, 2016).

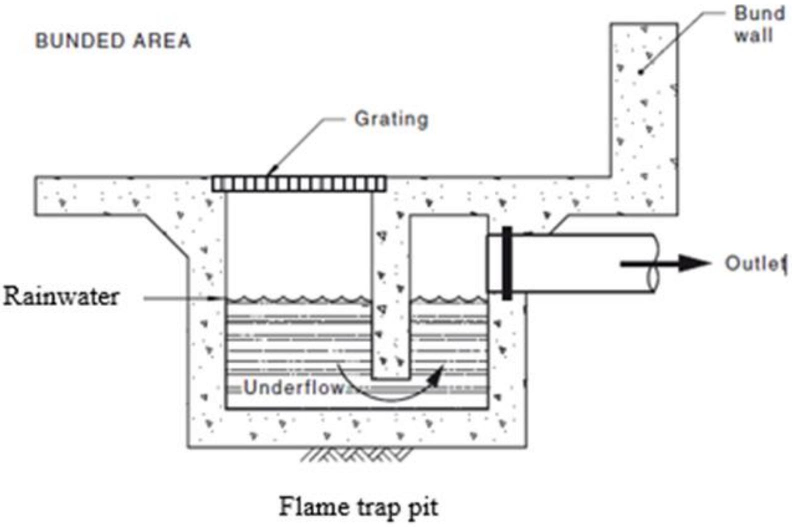


Figure 2.8: Flame trap example (b) (Standards Australia, 2016)

Ergon Energy (2003) allows for the provision of a control valve to be installed downstream from the flame trap and prior to the oil/water separator, this preventive measure is used to stop any fluid leaving the bunded when conduction maintenance work instead of relying on the oil separator in the event of a spills. Once the transformer maintenance work is completed, the valve is reopened.

2.8. Oil - Water Separation

Traditionally oil and water separators employ mechanical and physical methods to separate the two fluids. These methods consist of, but not limited to, gravity, coalescing, centrifuge, hydrocyclone and oil skimmer/separators (Bhushan, 2020). Operation of these separators generally require their containment area to be full of water and rely on flow paths for separation (Tolmie et al., 2008), that is for each time of inflow there must be an outflow, resulting in short residence time (Ondrey, 2006).

2.8.1. Horizontal oil-water separator tank (HOST)

Gravity separators rely on the difference in density of two fluids, hydraulic design, and retention time for droplet separation (Lopez-Vazquez & Fall, 2004; Abdullah et al., 2016). The time taken for fluids to separate is influenced by the terminal velocity of the fluid droplets though the water. This velocity is determined by Stokes Law as given in Equation (2.1).

$$V_p = \frac{g\, D^2\, (\rho_w - \rho_o)}{18\mu} \qquad \textit{Equation (2.1)}$$

Where $V_p = \ velocity$ (m/s)

$g = \ Acceleration\ due\ to\ gravity$ (m/s^2)

$\rho w\ and\ \rho o = \ density\ of\ water\ and\ oil\ respectively$ (kg/m^3)

$D = diameter\ of\ the\ oil\ globule$ (m)

$\mu = \ absolute\ viscosity\ (poise)\ of\ the\ water.$ (kg/ms)

This provides in a steady state, for a specified height, the droplet size that can climb to the surface is controlled by the available time the oily water is retained in the separator prior to exiting the outflow of the system. The amount of oil residual in the expelling water is governed by the remaining droplets smaller than the denoted droplet size (Tolmie et al., 2008).

This equation for velocity (V_p), for a fixed particle diameter, is proportional to the difference in the densities of the fluids, and is a function of the of the water viscosity. Considerations are required for temperature rise, emulsified oily water separation can reduce, with the increases of temperature, the density will decrease, creating additional issues if this is not linearly.

This separation process takes into consideration the treatment of sediment particles that are heavier than water and lighter pollutants that sit on top (Bering et al., 2016). Simply, these separators can be viewed as one or more retention basin joined together, or chambers in a tank, to contain the inflow of fluid mixture in order to slowing the discharge rate, allowing time for the fluid particles to separate from gradational force alone. This method allows the heaver sediment particles to fall and gather in the first chamber with initial separation of lighter particles moving to the surface prior to entering the second chamber for further separation of lighter particles prior to excess water being siphoned from the bottom of the tank leaving the oil layer on top of the water where it can be skimmed or pumped of the top for disposal (Gaaseidnes & Turbeville, 1999). Figure 2.9 is an example of a multistage tank.

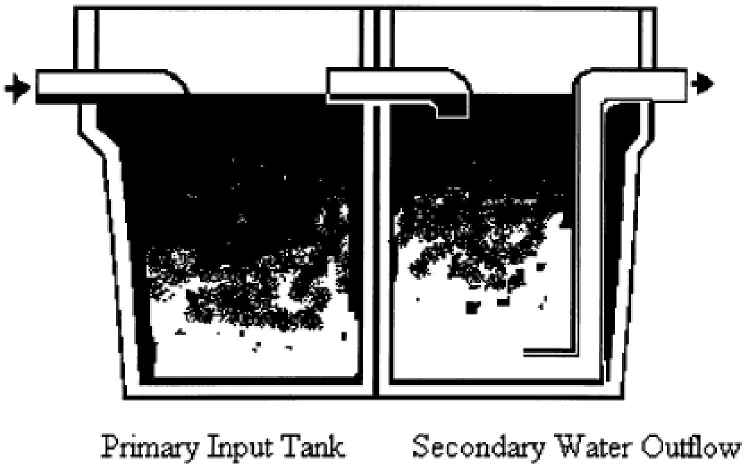


Figure 2.9: Basic type gravity separator (Gaaseidnes & Turbeville, 1999)

2.8.1.1. Extended gravity oil water separator (EGOWS)

Extended gravity oil water separator (EGOWS) is an extension of the American Petroleum Institute (API) separator, and is considered an improvement on APIs design. The units separation process is designed to function in a partially emptied state prior to the inflow of contaminated water (Ondrey, 2006) and uses the volume of the separation tank to capture the rainfall event allowing a longer residence time, this allows the higher velocity inflow to be controlled and released at a slow rate via the discharge siphon (Tolmie et al., 2008). This slow release rate, allows the incoming contaminated waters oil content to separate and reduced the oil content to below 10 ppm (Ondrey, 2006).

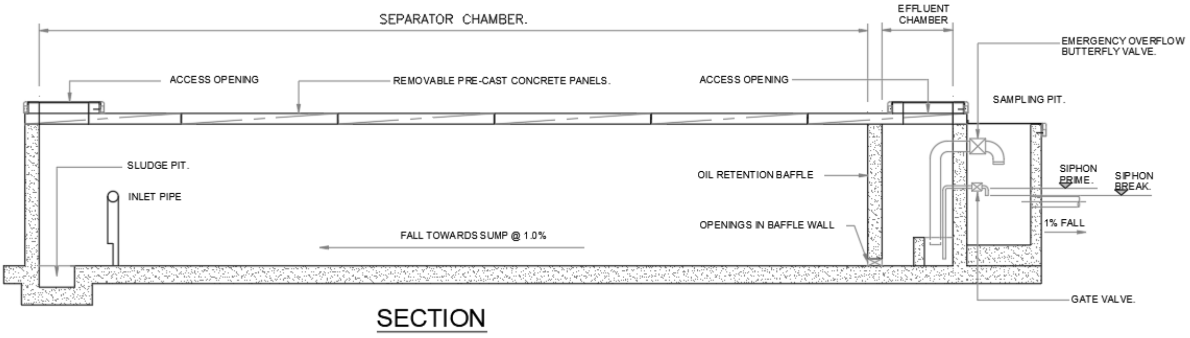


Figure 2.10: Berserker Substation Oil and Water Separator (A Brian 2021, personal drafting, 2 October)

Figure 2.10 is a cross section of an EGOWS unit at Berserker substation, the inflow is directed to a sludge pit to capture the majority of any solids from the effluent, with the base is sloping in the same direction to encourage other fallen sediments to migrate to the pit. A baffle is located at the end of the separation chamber extending from the roof to the base to retain the separated oil from migrating to the effluent chamber, water is allowed to pass under via three openings at the baffles base. The siphon located in the effluent chamber is surrounded by a nib wall to discourage silt reanimating in the water and migrating to the sampling pit, and out of the unit through the discharge point.

2.8.1.2. SPEL Puraceptor with coalescing

Gravity type coalescing separators are based off the horizontal gravity water separator with the use of a coalescing medium to encourage the emulsified fluid to coalesce. This medium/membrane, having a natural liking to oils, allows the oil droplet to collect. The collected oil droplets migrate towards each other, increase the droplets volume and its ability to float above the oil allowing a reduced detention time (Gaaseidnes & Turbeville, 1999; Luo et al., 2021) . This type of system is commonly engaged for use in petrol stations and associated industry for its efficient in dealing with oily waste with a low viscosity (Gaaseidnes & Turbeville, 1999; Drapper & Hornbuckle, 2016). Generally, these systems require an additional maintenance scheduling for optimal performance to the coalescing medium. Figure 2.11 below, shows the typical layout of a “SPEL Puraceptor” gravity and coalescing separator.

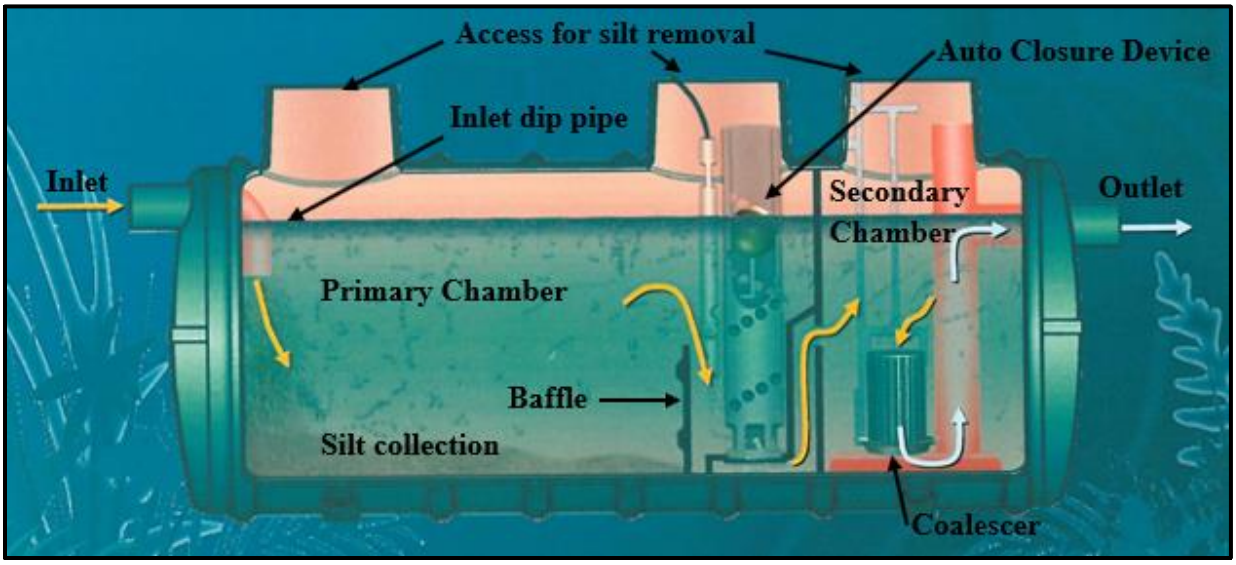


Figure 2.11: Spel puraceptor (Drapper & Hornbuckle, 2016)

The Puraceptor operates full of water and allows the influent fluid to pass into the first of two chambers through the inlet dip pipe to minimise turbulence in the water and to act as a flame trap. The first chamber utilised a baffle to contain Total Suspended Solids (TSS), silt, sediments, and pollutants, here is where majority of the lighter liquid are contained. The fluid then passes through the automatic closure device the automatic closure device (A.C.D.), using underflow principles to the second chamber. The A.C.D consisting of a density sensitive water-buoyant ball capable of closing the chamber with build-up of lighter liquids and will completely close the outlet in event of major spill. Separation is improved in the second chamber by the use of a coalescing process to filter and repel hydrocarbons, reducing the discharge water of pollutants (Drapper & Hornbuckle, 2016).

2.8.2. Vertical oil-water separator tanks (VOSTs)

Vertical oil-water separator tanks are similar to HOST separation systems, they to rely on the differential of two densities in fluid with the addition of inflow velocity force acting against the oils buoyance force.

2.8.2.1. U-tube

Ergon have based their design purely on differential gravity concept, removing the physical and mechanical component in its process of separating oil and water. This removes the need for servicing and replacement of moving parts through its operation life. The operation of the U-tube requires the tubular body and the flame trap pit to be constantly filled with water, and a key component in the successful operation in quenching ignited fluids. The system utilises the under flow of water, a secondary benefit of the flame trap, to retain some of the contaminates at the surface of the pit and to reduce turbulence created from the effluent travelling to, and into the flame trap pit. Unlike HOST systems the U-tube does not have the capacity to retain an oil spill or plant rupture within the system, this differential gravity concept relies on the containing oil in the bund. The depth of the U-tube must be adequate to support the level of oil in the bund. This is achieved by the use of Equation (2.2), diagrammatically shown in Figure 2.12.

$$\rho_o \times g \times (h_o + h_w) = \rho_w \times g \times h_w \qquad Equation\ (2.2)$$

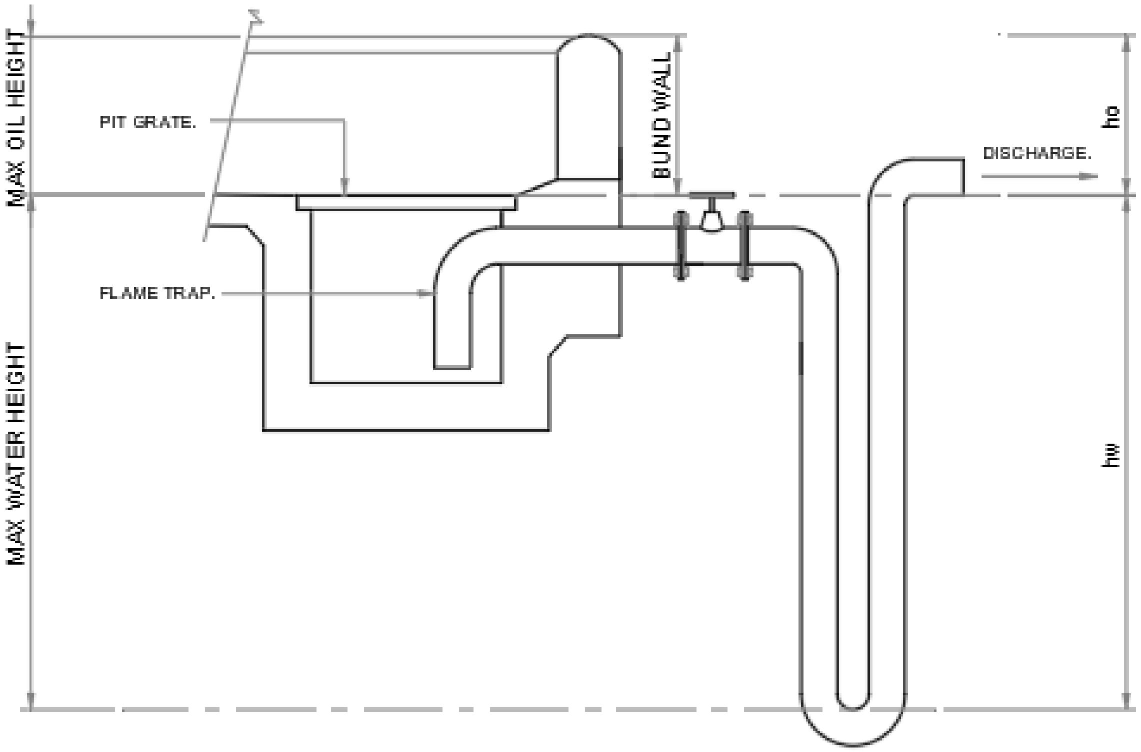


Figure 2.12: U-tube parameters

Where $\rho w \; and \; \rho o = density \; of \; water \; and \; oil \, respectively$ (kg/m^3)

$g = gravatational \, force$ (m/s^2)

$h_o \; and \; h_w = height \; or \; depth \; of \; oil \; or \; water \; respectively$ (m)

$$\therefore h_w = \frac{\rho_o}{\rho_w - \rho_o} \times h_o$$

Equation (2.2) used with some assumption attached; water density will remain at 1000 kg/m^3, the density of the oil regardless of temperature will not exceed 900 kg/m^{3}and the system is static. With the addition of a factor of safety for construction and fabrication errors, yielded Equation (2.3)

$$Column \; depth = 10 \times \; depth \; of \; oil \qquad \textit{Equation (2.3)}$$

There has been no study to date on the effectiveness of the U-tubes ability to separate oil from water during a rainfall event.

2.8.2.2. Vertical Gravity Separators (VGS)

This VGS (Figure 2.14) is a flooded system is designed to expedite the process of gravity to separation enabling oil particles to float to the water surface. The separators tank houses stacked truncated cones (Figure 2.13) spiralling downward filled with an oleophilic material. Influent oily water is introduced to the tank via the internal leg surrounded by the stacked cones, influent oil particles attach to the cones, once large enough, the oil droplets drift to the surface of the separator. Sludge is encouraged to settles at the bottom outlet value, while water is removed by under flow from the outlet positioned in the lower section on the side of the tank. Typically, this VGS system is capable of handling low to intermittent rates of flow, from approximately 1000L/hr to 3000L/hr and rely pumping effluent from a holding tank to control this rate (ISS, 2008), dependent on manufacture, this system is only capable of reduces light liquid pollutants in discharge water to 50 ppm.

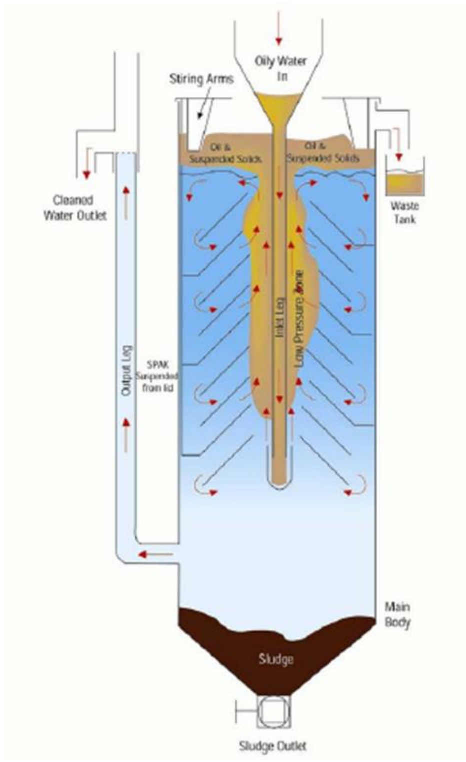


Figure 2.13: VGS Schematic Diagram(ISS, 2008)

Figure 2.14: VGS Diagram (ISS, 2008)

2.9. Intensity of Rainfall

Changes in the variability of weather conditions among the seasons has been identified in a number of regions in Queensland, it is recognised that between 2 and 7 years, the El Niño-Southern Oscillation (ENSO) impacts north-eastern Australian rainfall (Casey & Everingham, 2011).

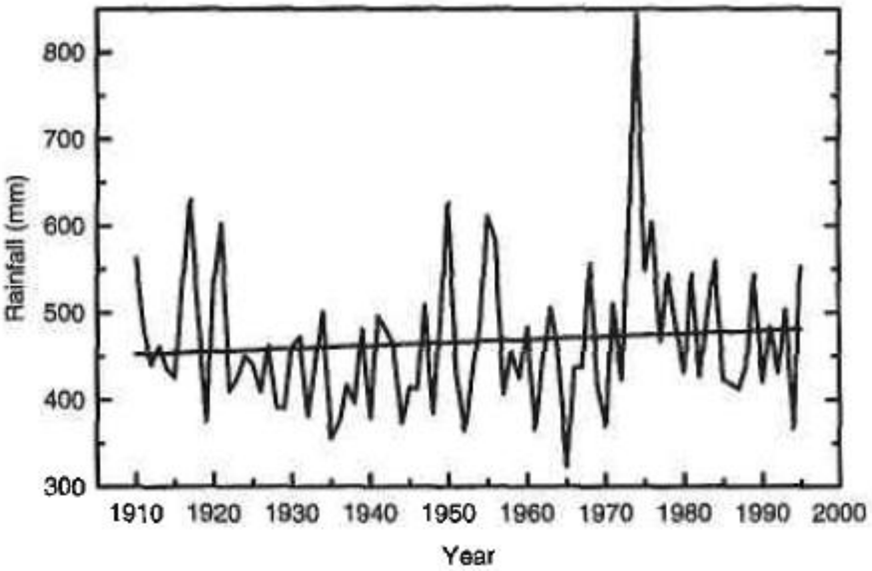


Figure 2.15: Australian annual total rainfall (mm) from 1910 to 1995.A least squares regression line has been fitted (Suppiah & Page, 1999).

Rainfall frequency and duration (Figure 2.15) will impact on the volume of water a catchment area receives, this intensity can impact the design of the gravity separator, there may be emulsification of the two liquids thereby changing the density and becoming more difficult to separate (Mahanta & Laskar, 2017). Cyclonic conditions should be taken into consideration as the high winds encounter in these events could alike to the water in oil-emulsions created by the turbulent agitation of the sea with oil spills (Casey & Everingham, 2011).

2.10. Chapter summary

Transformers play a vital role and are a key components in the power generation, transmission, and distribution electrical network (Mahanta & Laskar, 2017) and have an inherent environmental risk due to the liberal amounts of cooling oil required to maintain the equipment's operation. This hazard requires the oil to be contained within a concrete bund/oil separator tank for in the event of spills and or catastrophic failure.

If the concentrations in the surrounding soil exceed the acceptable levels for the land use, remediation must take place. If the parcel of land is unable to be remediated, the site is determined to be contaminated and must be placed on the governments contaminated land register. Once a parcel of land is on the register, sampling is required to remove spoil from site, if the samples are found to be contaminated, soil disposal permits are required to remove from site as trackable waste.

The gravity oil separators is simplistic in construction, low in maintenance and are accessible technology in its conventional form (Lopez-Vazquez & Fall, 2004), these designs still rely on using stokes law. Ergon have in use the separators outlined in the literature review, each have their advantages and disadvantages, these are listed below.

U-tube

Brown field (developed sites) construction contributes to the majority of the U-tubes being installed across the state, from Marreeba in the north, out to Cloncurry to the west, and Yarranlea to the south. The lack of available real estate at some of these sites is a major driver for installation. The last drawing to be released for construction in March 2019, it is unknown if installation took place.

- Advantages
  - Relatively inexpensive
  - No mechanical parts or power requirements
  - Small site area requirements
- Disadvantages
  - Quality of discharge water not certified
  - Retains oil within the bund at potential fire source
  - Requires significant depths, may not be achievable on some sites. Note – based on typical 400 mm bund height, 4m depth.
  - Performance requires the unit to be maintained full of water

EGOWS

The EGOWS system has been installed at a few sites in the Capricornia region of Queensland, these installations were primary due to new construction on green field sites (undeveloped site) with the last known unit constructed at the Berserker Substation in approximately 2010, and Parkhurst Substation in approximately 2011.

- Advantages
    - Captures and contains full transformer oil volume remote from the fire source
    - Little or no maintenance
    - No mechanical parts or power requirements
    - Capable of reducing oil concentrations in discharge water to less than 10 ppm.
- Disadvantages
    - Large unit, typically 16 m x 4m x 1.4 m deep
    - Custom designed hydraulically for each site by University of New South Wales
    - Custom designed structurally for each site
    - Large rigid tank, usually heavily reinforced and occasionally on piles to restrict differential movements
    - Requires fees and licence to operate from UNSW for each installation
    - Most expensive of installations covered by this presentation

SPEL

Typically, the smaller P004 and P005 units are used across the state in green and brown field sites throughout Queensland

- Advantages
    - Tried and tested product – global applications
    - Small unit will receive 1000 litres oil, then shut off.
    - Small units are approximately 2.6 m x 1.2 m diameter
    - Small unit has limited site area requirements
    - Large units will receive 36,200 litres oil prior to shut off
    - Larger units designed for full retention remote from fire source
    - More suitable for rock sites where deep drilling for U-Tubes not practical
    - Reduces light liquid pollutants in discharge water to 5 ppm or less
    - Ability to discharge above or below ground level
- Disadvantages

    - More expensive than U-Tubes
    - Large unit, typically 16 m x 2.48m diameter

VGS

Larger remote Power Stations use this system for remediation of storm water from their diesel fuel farms and oil overflow from the generation sets. The VGS are on a constant maintenance and replacement cycle.

- Advantages
    - Small unit size
    - Ability to discharge above ground level
    - Small site area requirements
- Disadvantages
    - Mechanical parts and power requirements for pump
    - Small capacity
    - Retains oil within the bund, potential fire source
    - Reduces light liquid pollutants in discharge water to 50 ppm

It has been identified in published works, on how reliant oil water separation systems are on Stokes Law for terminal velocity (Gaaseidnes & Turbeville, 1999). Due to the remoteness of some of these substation as can be seen in Figure 1.4, the oil separation system must be as simplistic as posable. This is to reduce the frequency of maintenance and the additional logistical cost for repairs.

Much of the literature accessible is directed towards HOST systems, with the placement of baffles, methods to increases droplet size and practical separation theory (Gaaseidnes & Turbeville, 1999), a very limited amount of research that has taken place on VOSTs with no attainable literature on systems such as the U-tube. From this review, it can be seen that further research is required to verify the U-tubes ability to retain/separate oil and water

Chapter 3 - Methodology

3.1. Site Selection

To test the Ergon Energy U-Tube separator, an appropriate site must be selected with a U-tube and high rainfall to adequately design a water flow. Although the oil separation would require to be designed for each specific site, it would be beneficial for this research to select a site with high average rainfall, to determine an adequate flow rate for testing the system. Relying on the historic knowledge from Ergon's field staff, Evelyn substation in Far North Queensland was recommended for review as this site is equipped with the U-tube as its oil separator. The Bureau of Meteorology (2021b) data confirms this this area is subjected to high yearly rain fall and can be seen in Figure 3.2 and Figure 3.2. For this reason, the Evelyn substation site has been selected to model a rainfall event to test the system.

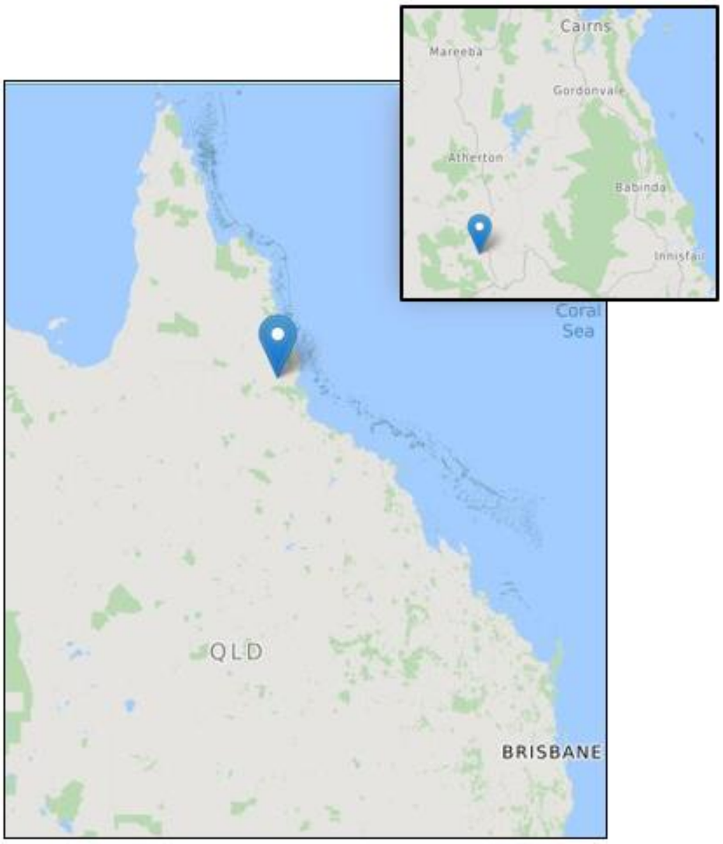


Figure 3.1: Substation location (Bureau of Meteorology, 2021a)

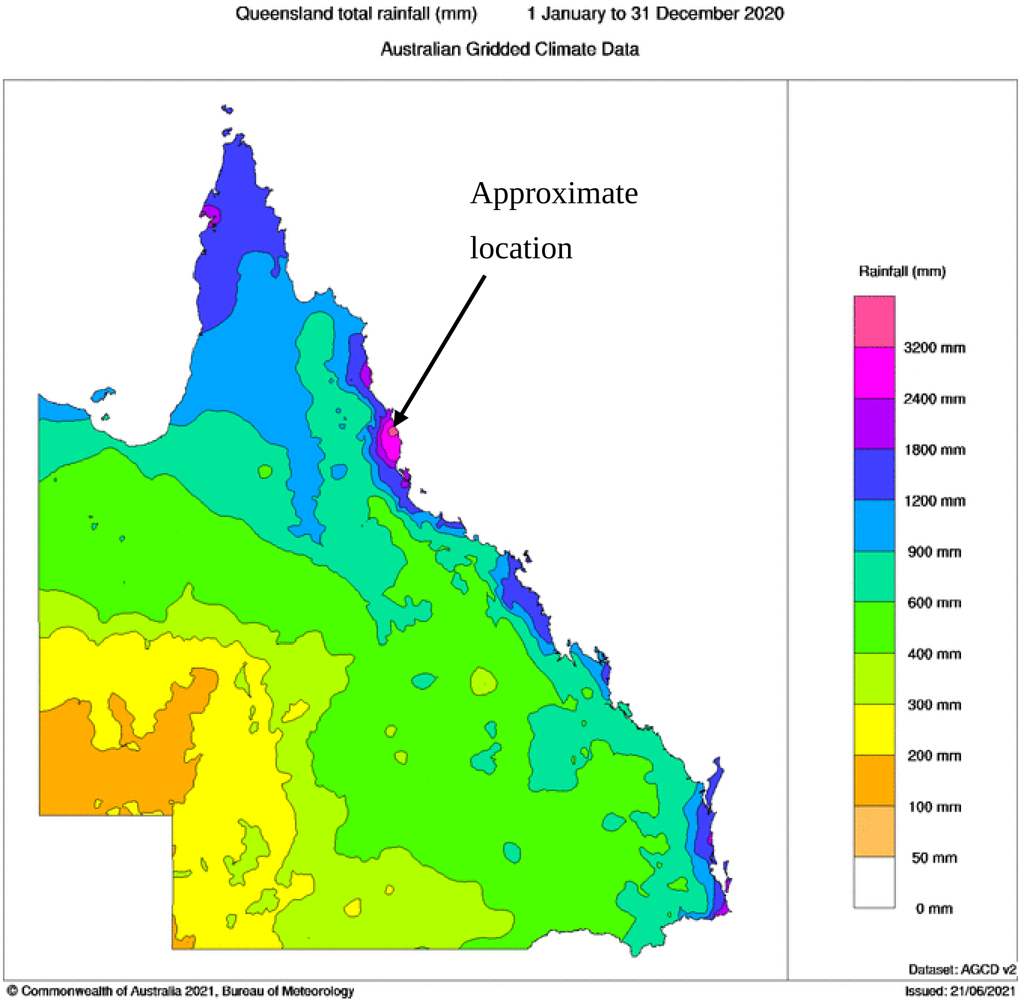


Figure 3.2: Observed total rainfall 2020 Queensland (Bureau of Meteorology, 2021b).

3.2. Site information

Evelyn substation is a 66/22kV distribution substation, with one 6.3MVA transformer with an oil capacity of 15,270 litres with an approximate total mass of 36.8 tonne. Complying with AS 1940, the 110% of the transformer oil volume would require the transformer's bund volume to retain a minimum of 16.8 kilolitres or 16.8 cubic metres of oil. TasNetworks (2018) require their wall heights to be a minimum of 0.3m, with TransGrid (2019), Ausgrid (2017), Endeavor Energy (2015) and Ergon Energy (2003) referring to the AS 1657 and 2067 for access and egress requirements. Consideration of the transformer's foundation displacement may be required if the equipment is raised on a plinth above the wall height to eliminate submersion if the bund drainage fails. Evelyn has been designed with a wall height of 0.2m with the transformer on top of a concrete plinth. The displacement of the plinth has been taken into consideration leaving the bund 10.4m x 7.4m internal dimension bund, as shown in Figure 3.3 below.

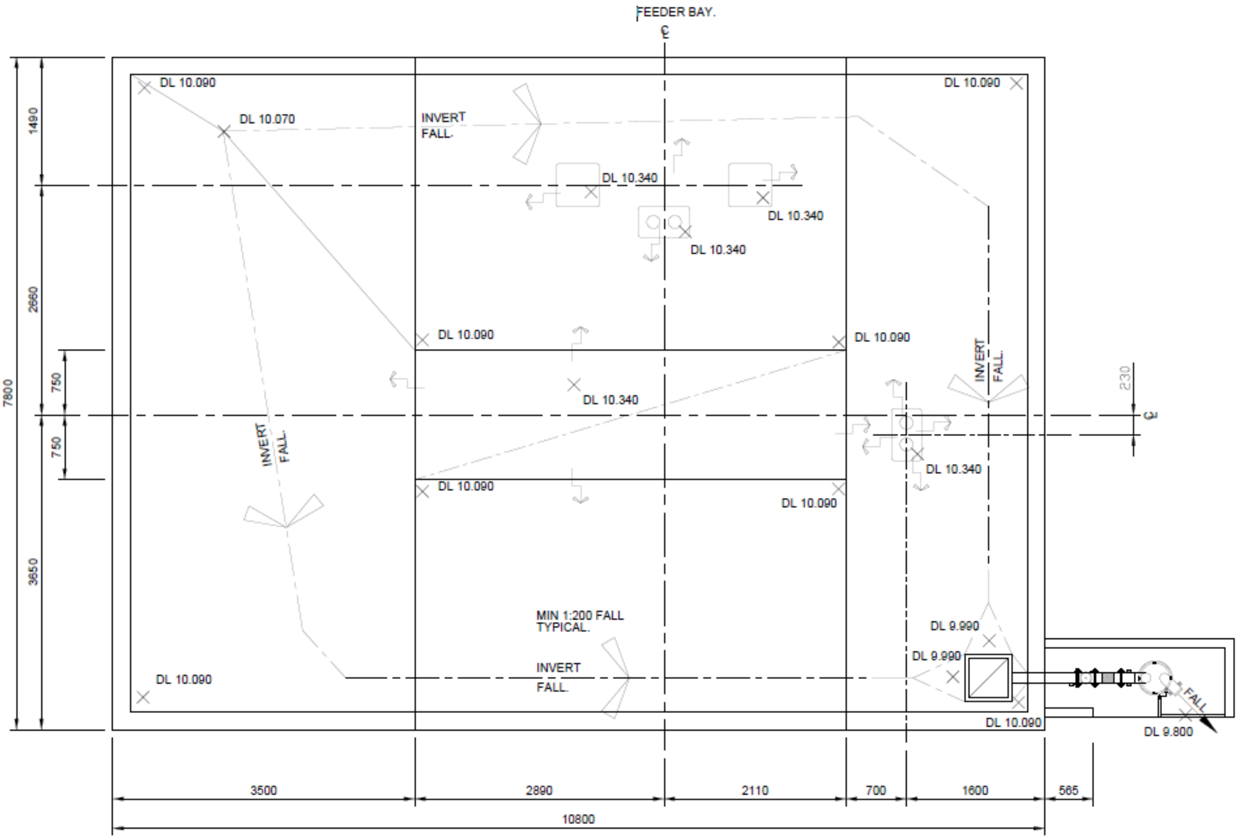


Figure 3.3: Evelyn Substation bund plan (A Brian 2021, personal drafting, 2 October)

3.3. System replication

The total replication of the Evelyn substation bund (Figure 3.3) is not required, the dimensions of the bund will be used to determine the catchment area required to calculated an appropriate rainfall event flow rate. The main focus is directed to the U-tube system, a full-scale model will be constructed in accordance with the Ergon EESS oil separator design drawing. Instead of a bund, a containment area will be constructed to deliver the water flow to the U-tube after the oil spill to test the system’s ability to retain the oil in the containment area.

3.3.1. Simulated rain event

The Rational Method as outlined in the Queensland Urban Drainage Manual will be utilised to calculate a flow rate in order to test the oil-water separator system (IPWEA, 2016). This method is simply described mathematical as $Q = C \times \mathrm{I} \times A$, where Q is a volumetric flow rate, C is a coefficient of discharge, I being a flow velocity and A is the area of catchment. This method allows the estimation of flows for small catchment areas.

For the design of the test flow rate the following equation will be used,

$$Q_y = \frac{C_y *^t I_y * A}{360} \qquad Equation\ (3.1)$$

where:

Q_y = peak flow rate (m³/s) for annual exceedance probability (AEP) of 1 in 'y' years

C_y = coefficient of discharge (dimensionless) for AEP of 1 in 'y' years

A = area of catchment (ha)

${}^t\mathrm{I}_\mathrm{y}$ = average rainfall intensity (mm/h) for a design duration of 't' hours and an AEP of 1 in 'y' years

t = the nominal design storm duration as defined by the time of concentration (t_c)

Since embarking on this project, Energy Queensland the overarching company to Ergon and Energex has released a joint document "Standard for oil containment". This Energy Queensland (2021) document calls for a 20-year ARI storm of 24 hour duration where Ausgrid (2017) have two rainfall criteria with 1 in 20-year ARI rain event with a 5-minute duration and 1 in 1 year ARI storms of 1 hour, 12 hour, 24 hour, 48 hour and 72 hour duration. Both entities refer to firefighting inflow, this will be ignored as the Ergon substation under review is not equipped with automatic firefighting system and only those that are trained and authorised under the electrical safety Act are able to enter a high voltage enclosure.

For purposes of this experiment, it was decided to use the Energy Queensland (2021) 1 in 20-year ARI rain event with a 24 hour duration which is equivalent to the 5% Annual exceedance probability (AEP). Using the rational method, the design peak flow was calculated for the Evelyn substation using the existing internal bund dimensions as the catchment area of 77m², provided a flow rate of 13.6 L/min. The predicted peak flow is used to provide a maximum rate of discharge for the 24-hour time period. The AEP data can be seen in Appendix E.

3.3.2. Containment bund

To simulate the transformer bund, a containment area, Figure 3.4 and Figure 3.7, was constructed out of form ply material with an arbitrary base measuring 0.5m wide, with length of 1.8m, slopping at a 1% grade for self-cleansing towards the 0.5m² flame trap pit to match Ergons construction practises, this allows the water and any oil pollutant left on the surface, to flow to the water filled pit that houses the flame trap which is connected to the separator.

Figure 3.4: Containment area (A Brian 2021, personal photograph, 22 September)

3.3.3. Oil – water separator

The flame trap pit has a depth of 0.5m matching Ergons general construction practices, with the opening to the flame trap (Figure 3.5), sitting 0.05m above the pit floor level as to the EESS standard design. The bend inverted level (IL) exiting the containment bund is 0.02m below the base IL, to keep retained fluids off the bund/shut floor.

Figure 3.5: Containment flame trap (A Brian 2021, personal photograph, 22 September)

The oil separator system is to full scale, based on the design used by Ergon at the Evelyn substation, substituting the 100mm Nominal Diameter (DN) stainless steel (S/S) tube for 100mm DN unplasticized polyvinyl chloride pipe (uPVC). Means the flow remains laminar due to Reynolds number being below 4000. The U-tube depth is determined by the maximum containment wall height and then multiplied by ten, giving this system 2.2m in depth from the IL of the flame trap to the obvert level (OL) of the ‘U’.

Figure 3.6: Constructed U-tube (A Brian 2021, personal photograph, 22 September)

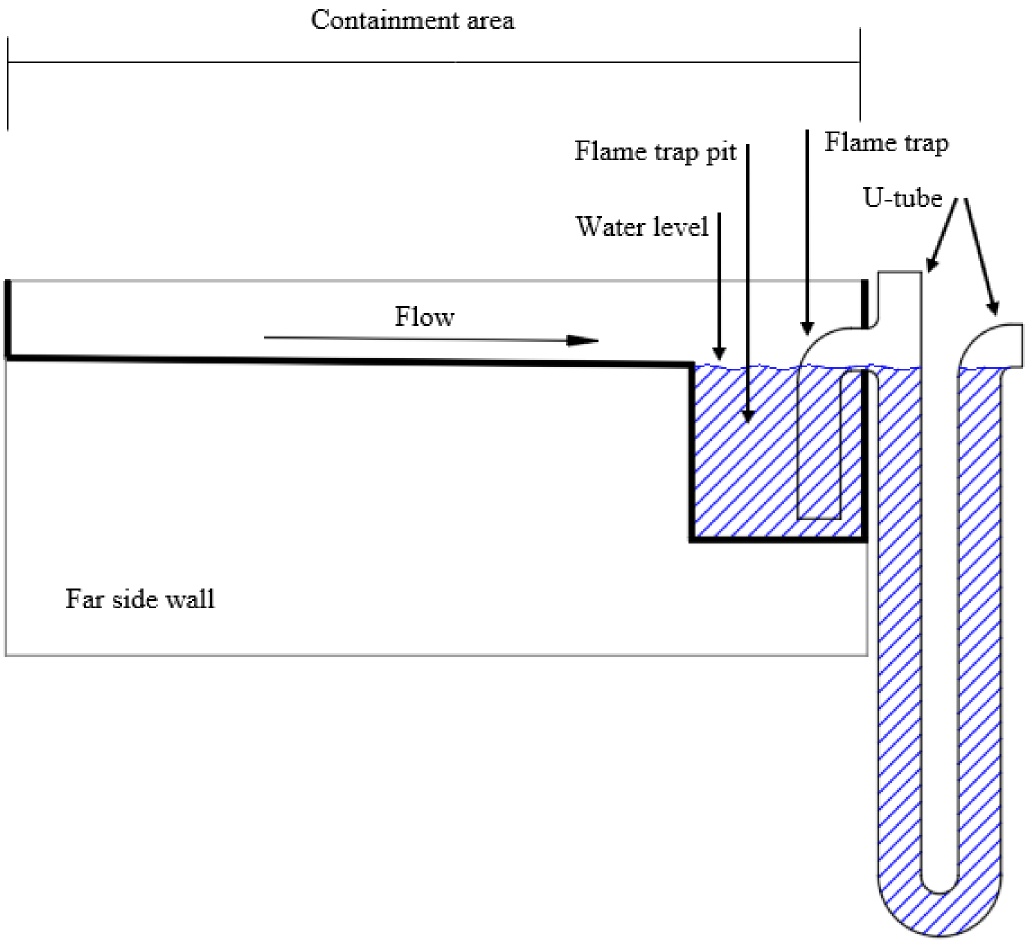


Figure 3.7: Sectional view of bunded area and U-tube

3.4. The experiment

The system was to be tested with two sets of parameters, the first to test the dynamic flow with a simulated rain event to test the system's ability to retain oil in the containment area. For the system to be deemed successful, testing on the effluent water quality will be required to return within allowable contaminate concentrations levels. The second parameter, in a static condition, assuming rupture of the transformer tank fill the containment area, followed by a weather event, this was to test the U-tubes ability to retain oil within the containment area via the density differential with an influx of water.

To be successful in the second parameter, the U-tube would be able to operate, allow the influx of rain water to leave the catchment, while keeping the effluent within allowable contaminate concentrations levels, testing of the effluent water quality would provide compliance.

Due to the cost of, and volume of the oil required to perform this experiment, the potential for high environmental risk, the second parameter of the project will no longer be investigated as the risk cannot be mitigated at the system testing site. To validate the U-tube system, the apparatus will be tested dynamically by simulating the 13.6 L/min water flow through the system for the adopted three minutes duration, this will ensure a full flush, Figure 3.9 and Figure 3.10. The flow will be measured via a digital flow meter, it is assumed the flow rate may occasionally fluctuated above the desired flow rate during the experiment due to the water supply being residential. The outflow will be captured in a vessel of known volume to calibration initial water flow, and to test the system for leaks. Samples will be taken after a simulated spill, of one litres of oil onto the base of the containment area and allowed to flow into the flame trap pit, Figure 3.8, the systems then repeat, where rain flow will be applied for three minutes, taking into consideration of the additional two minute on flow. Again, the outflow to be captured in a vessel and allowed to settle, allowing any oil contaminates to separate and settle on top of the contained water.

Figure 3.8: Oil spill (A Brian 2021, personal photograph, 22 September)

Figure 3.9 Flow setup (A Brian 2021, personal photograph, 22 September)

Figure 3.10: Inspection opening (A Brian 2021, personal photograph, 22 September)

Figure 3.11: Digital flow meter (A Brian 2021, personal photograph, 22 September)

3.5. Sampling framework

Based on the literature review and discussions with Ergon's environmental services staff, it was found that TPH, BTEXN, PAH and PCBs would be the most likely contaminants as minor residues may still be present in ageing TX and bunding infrastructure. As PCBs may be suspected at older TX sites, generally it be included, but considering the experiment is being conducted with new oil there will be no need to test for it. All testing must be undertaken by a specialist National Association of Testing Authorities (NATA) registered laboratory (Department of Environment and Science, 2016)

The water sampling to be undertaken, shall reference to the following guidelines:

- Australian Standard AS 4482.1–2005. Guide to the investigation and sampling of sites with potentially contaminated soil -Part 1: Non-volatile and semi-volatile compounds.

- Australian Standard AS 4482.2–1999. Guide to the sampling and Investigation of potentially contaminated soil -Part 2: Volatile substances.
- AS/NZS 5667.1-1998. Water quality - Sampling - Guidance on the design of sampling programs, sampling techniques and the preservation and handling of samples.
- AS/NZS 5667.10:1998. Water quality - Sampling Guidance on sampling of waste waters.
- National Environment Protection (Assessment of Site Contamination) Measure 1999
- National Environment Protection Council (NEPC) 2013, Canberra (NEPM 2013).
- Environmental Protection Regulation 2019.

3.6. Sampling

No sampling of the system took place prior to the testing of hydrocarbons, this was deemed unnecessary given the water is of residential supply, the supply's location, and the materials used to construct the apparatus. The system was operated as outlined in 3.4, a litre of oil was measured and applied central to the base, a period of two minutes passed prior to the instantaneous commencement of the water flow (Figure 3.11). The effluent outflow was captured in a vessel than covered, and permitted to settle for 24 hours, thus allowing particles with a diameter greater than 50µm to rise and collect on the surface prior to samples being collected (Figure 3.12). The samples were taken from the static effluent surface (Figure 3.13) with the laboratory supplied containers, these containers were used to skimming the surface of the effluent in order to capture any contaminates at this level (Figure 3.13). One set of samples were taken the samples were then stored directly in the packaging provided by the laboratory, then sent to the laboratory for testing.

The samples (Figure 3.12) consisting of

Figure 3.12: Samples (A Brian 2021, personal photograph, 22 September)

Figure 3.13: Outflow capture vessel (A Brian 2021, personal photograph, 22 September)

3.7. Chapter summary

Selecting a site set the basis to measure the U-tubes ability to perform under natural conditions, the meteorological data from the area help to set the upper boundary, with specific site information informing of catchment size set the lower boundary, this in turn determined an appropriate flow rate in which to test the U-tube design. A delivery mechanism was created to convey the water flow to the full-scale U-tube, assembled to the Ergons standard EESS drawing. System testing was conducted via the placement of one litre of transformer oil on the containment are followed be a flow rate of 13.6L/m for a three-minute duration. The discharge was collected where samples were taken for testing at a NATA registered laboratory.

Chapter 4 - System results

4.1. Observations

Minor fluctuation of 0.2L/min in flow rate was notated during both initial flow test and in the testing on the system, after the litre of oil was add (simulated spill) to the base of the containment area, the oil began to flow towards the flame trap pit. Once the three-minute, instantaneous water flow commenced from the far end, the oil could be seen moving with, and on top of the water (Figure 4.2) since the flow did not sheet the full width of the containment are, there were no visible signs of turbulence or emulsification in the flame trap pit (Figure 4.2). Turbulent activity was visually noted via the inspection opening (Figure 3.10), assumed this is due to the tee connection allowing the water to migrate up instead of smooth guidance from a bend. No notable oily smell or sheen visible in the captured downstream outflow in the containment vessel which suggest from the advice of senior environmental adviser, hydrocarbons, if any are below 10 ppm. Remediation of the retained fluid (Figure 4.1) in the flame trap pit visually confirmed a large quantity of oil remained in the flame trap pit.

Figure 4.1: Fluid remediation (A Brian 2021, personal photograph, 22 September)

Figure 4.2: Flame trap pit under flow (A Brian 2021, personal photograph, 22 September)

4.2. Laboratory analysis

Samples were taken to a National Association of Testing Authorities of Australia (NATA) accredited laboratory for testing, with testing comprise of the following.

- Total Recoverable Hydrocarbons (TRH).
- Total petroleum hydrocarbon (TPH).
- Benzene, Toluene, Ethylbenzene and Xylene compounds with Naphthalene (BTEXN).
- Polyaromatic hydrocarbons (PAHs) / Phenolic Compounds.

These were selected based on potential contaminants from the new, unused transformer oil supplied.

4.3. Laboratory results

In conjunction with the observations, the test results showed the sample taken from the effluent contained allowable levels of contaminate concentrations. In most cases, the level of chemical being investigated were less then what could be reliably recorded, this is the limit of reporting (LOR), noting the results are in parts per billion (PPB), with allowable levels of contamination reported in PPM.

The exception to this is the TRH reading of the aromatic hydrocarbons C6-C9 fraction, which gave a reading of 41 PPB, this is far below the acceptable water quality limit provided in table 1C presented in Schedule B1 “Guideline on Investigation Levels for Soil and Groundwater” (Larsen, 2013). The full analytical report is provided for review in Appendix F.

Table 4.1: LOR Table

Method Name	**Analyte Name**	**Units**	**Reporting Limit**	**Result**
Volatile organic compounds in Water	Benzene	µg/L	0.5	<0.5

Method Name	Analyte Name	Units	Reporting Limit	Result
Volatile organic compounds in Water	Toluene	µg/L	0.5	<0.5
Volatile organic compounds in Water	Ethylbenzene	µg/L	0.5	<0.5
Volatile organic compounds in Water	m/p-xylene	µg/L	1	<1
Volatile organic compounds in Water	o-xylene	µg/L	0.5	<0.5
Volatile organic compounds in Water	Total Xylenes	µg/L	1.5	<1.5
Volatile organic compounds in Water	Total BTEX	µg/L	3	<3
Volatile organic compounds in Water	Naphthalene	µg/L	0.5	<0.5
Volatile Petroleum Hydrocarbons in Water	TRH C6-C9	µg/L	40	**41**
Volatile Petroleum Hydrocarbons in Water	Benzene (F0)	µg/L	0.5	<0.5
Volatile Petroleum Hydrocarbons in Water	TRH C6-C10	µg/L	50	<50

Method Name	**Analyte Name**	**Units**	**Reporting Limit**	**Result**
Volatile Petroleum Hydrocarbons in Water	TRH C6-C10 minus BTEX (F1)	µg/L	50	<50
TRH (Total Recoverable Hydrocarbons) in Water	TRH C10-C14	µg/L	50	<50
TRH (Total Recoverable Hydrocarbons) in Water	TRH C15-C28	µg/L	200	<200
TRH (Total Recoverable Hydrocarbons) in Water	TRH C29-C36	µg/L	200	<200
TRH (Total Recoverable Hydrocarbons) in Water	TRH C37-C40	µg/L	200	<200
TRH (Total Recoverable Hydrocarbons) in Water	TRH >C10-C16	µg/L	60	<60
TRH (Total Recoverable Hydrocarbons) in Water	TRH >C10-C16 - Naphthalene (F2)	µg/L	60	<60
TRH (Total Recoverable Hydrocarbons) in Water	TRH >C16-C34 (F3)	µg/L	500	<500
TRH (Total Recoverable Hydrocarbons) in Water	TRH >C34-C40 (F4)	µg/L	500	<500
TRH (Total Recoverable Hydrocarbons) in Water	TRH C10-C40	µg/L	320	<320

Method Name	**Analyte Name**	**Units**	**Reporting Limit**	**Result**
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Naphthalene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	2 - methylnaphthalene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	1 - methylnaphthalene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Acenaphthylene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Acenaphthene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Fluorene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Phenanthrene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Anthracene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Fluoranthene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Pyrene	µg/L	0.1	<0.1

Method Name	**Analyte Name**	**Units**	**Reporting Limit**	**Result**
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Benzo(a) anthracene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Chrysene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Benzo(b&j) fluoranthene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Benzo(k) fluoranthene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Benzo(a)pyrene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Indeno (1,2,3-cd) pyrene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Dibenzo(ah) anthracene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Benzo (ghi) perylene	µg/L	0.1	<0.1
PAH (Polynuclear Aromatic Hydrocarbons) in Water	Total PAH (18)	µg/L	1	<1

Chapter 5 - Conclusion & Recommendations

The literature review was performed to recognise the challenges involving oil and water separation, this identified important issues which could be explored. Concern for the environment is a driver for the development of new technology, updating standards and improvements to transformer oils, as a result of these improvements, properties of transformer oil have the tendency to change, notably the density and variety of oil type. Majority of the propriety separators on the market rely on additional processing materials, and or mechanical aids, their designs are primary reliant on Stokes Law. In general, the separation of oily water is dependent on the density, vertical velocity of the oil droplet, and retention time of the oil droplet. Further gaps in in literature are noted concerning density change with temperature, considerations should be given to temperature rise within a transformer, and its effect on the oil's density, and of waters density from heat transfer should the two mix. Oil separators are an established part of the substation infrastructure, and one of the crucial components for the electrical network's stainability in the environment.

The study was performed to evaluate Ergons existing infrastructure, known as the U-tube, for its ability to retain oil contaminates within the bunded area through the use of gravity separate theory of oil and water. An experiment was conducted to evaluate the U-tubes performance in a controlled environment that would best represent in-service conditions.

Results and observations from the experiment indicate that the U-tube is capable of retaining oil from the discharge water, to levels of contaminate concentration of hydrocarbons below the target amounts, for a flow rate at or below 13.6L/min.

If Ergon Energy elects to continue to use the existing U-tube infrastructure, their outflow should be tested during storm events to ensure environmental compliance. Water testing is expensive coupled with the enormity of travel for this task, consideration for budget, and additional programmed works, this may not be acceptable, consequently several possible solutions are provided. For more remote areas, oil absorbent filters may be fitted to the downstream flow of the U-tube to fine polish the discharge to maintain hydrocarbons within the target amounts, install level indicators/float switch in the bunds with alarms connected to the supervisory control and data acquisition (scada) network, or more comprehensively a hydrocarbon sensor at the flame trap inlet. Long term may include design change to the bund in order to reduce the inlet horizontal velocity within the bund to allow the oil droplet coalescing with other droplets to achieve high rates of droplets rise toward flame trap pit.

5.1. Future work

There are various opportunities to broaden the work in oily water separation. Substations will continue to be in service while there is a need for an, electricity distribution network.

This study was limited to a one in 20-year peak rainfall event with a 24-hour duration. With funding, it would also be beneficial to investigate higher intensity rain events, different oil types and class, and temperatures rise in transformer oil and ambient water temperature, to take into consideration greater weather events and account for cyclonic conditions, these events are typically where most damage to infrastructure occurs, with consideration to catastrophic transformer failure.

Additionally, the study did not cater for the potential of PCB contaminates from older infrastructure, it would also be beneficial to consider such restrictions of the use of PCB free oil in the trail. PCBs are required to be under 2PPM.

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Appendix A – Project Specification

University of Southern Queensland

Faculty of Health, Engineering and Sciences

ENG4111/4112 Research Project
Project Specification

For: Ashley Brian

Title: Feasibility study on Vertical Column Gravity Separation of Class O Fluids

Major: Civil Engineering

Supervisors: Dr Malcolm Gillies

Enrolment: ENG4111 – EXT S1, 2021

ENG4112 – EXT S2, 2021

Project Aim: This project is to ascertain the feasibility of using the existing static design U-tube oil-water separation infrastructure for class O transformer fluids. A prototype model will be developed that replicate the in-service scenarios of the U-tube, to test the effluent and confirm the compliances of the separator with current environmental standards of waste discharge. This will allow recommendation to be made on the suitability for further use in containment and oil separation.

Programme: Version 2, 17th March 2021

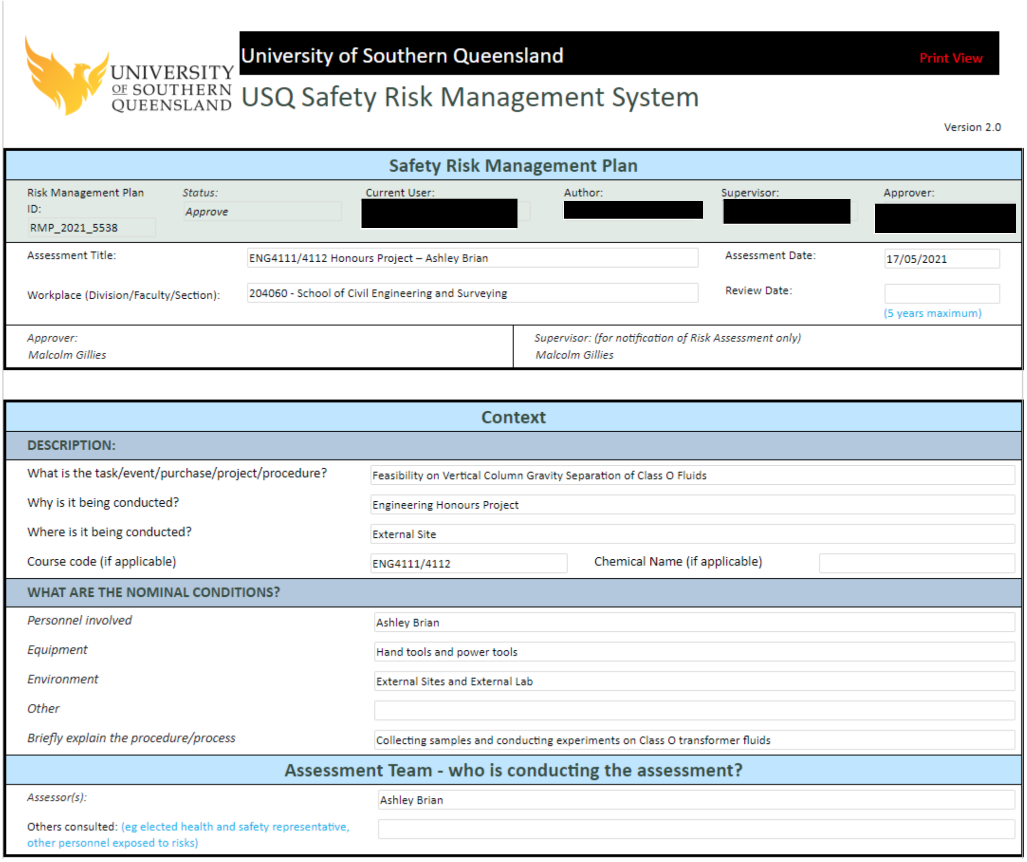
1. Conduct a literature review on the use of gravity (density) separation systems and transformer cooling oil properties.

2. Identify a representative transformer site and gather specifications including potential rainfall duration and intensity.
3. Review relevant standards, Acts and guidelines for allowable levels of contaminants in effluent.
4. Design and construct a protype system of the gravity separation system.
5. Perform system model experiments in dynamic flow to test effluent for contaminants.
6. Perform system model experiments in static condition to test containment.
7. Review and evaluate the performance of the gravity separation system in its ability to achieve the relevant standards.

If time and resources permit:

1. Desktop review of proprietary systems and recommend a system for further investigation for implementation.

Appendix B – Risk Assessment



University of Southern Queensland

Print View

USQ Safety Risk Management System

Version 2.0

Safety Risk Management Plan

Risk Management Plan ID: RMP_2021_5538	*Status:* *Approve*	Current User: [redacted]	Author: [redacted]	Supervisor: [redacted]	Approver: [redacted]

Assessment Title: ENG4111/4112 Honours Project – Ashley Brian

Assessment Date: 17/05/2021

Workplace (Division/Faculty/Section): 204060 - School of Civil Engineering and Surveying

Review Date:

(5 years maximum)

Approver:
Malcolm Gillies

Supervisor: (for notification of Risk Assessment only)
Malcolm Gillies

Context

DESCRIPTION:

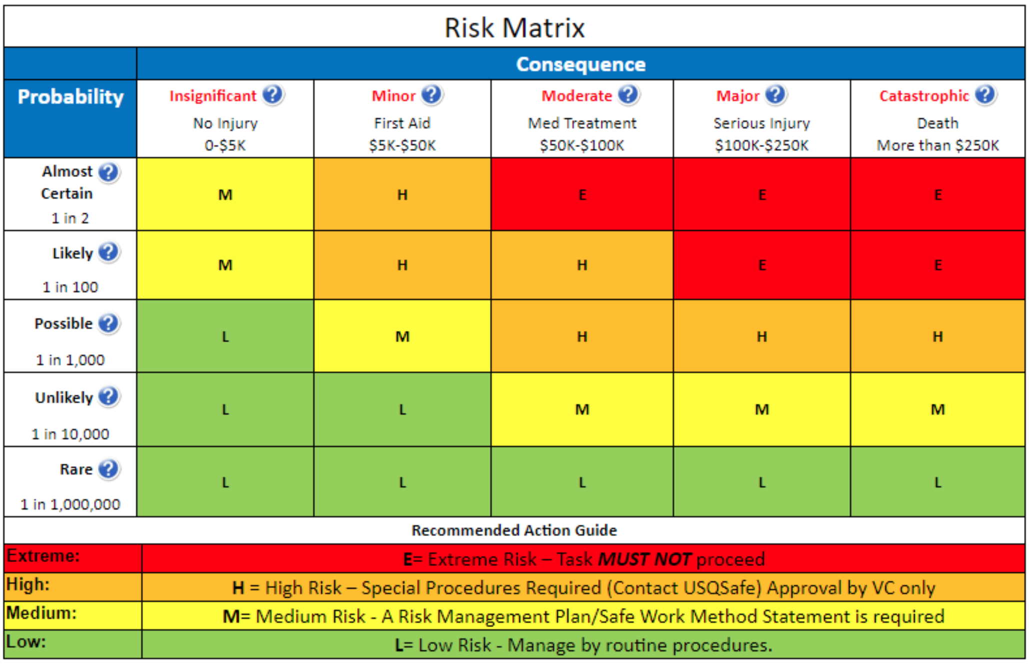
What is the task/event/purchase/project/procedure?	Feasibility on Vertical Column Gravity Separation of Class O Fluids
Why is it being conducted?	Engineering Honours Project
Where is it being conducted?	External Site
Course code (if applicable)	ENG4111/4112
Chemical Name (if applicable)	

WHAT ARE THE NOMINAL CONDITIONS?

Personnel involved	Ashley Brian
Equipment	Hand tools and power tools
Environment	External Sites and External Lab
Other	
Briefly explain the procedure/process	Collecting samples and conducting experiments on Class O transformer fluids

Assessment Team - who is conducting the assessment?

Assessor(s):	Ashley Brian
Others consulted: (eg elected health and safety representative, other personnel exposed to risks)	

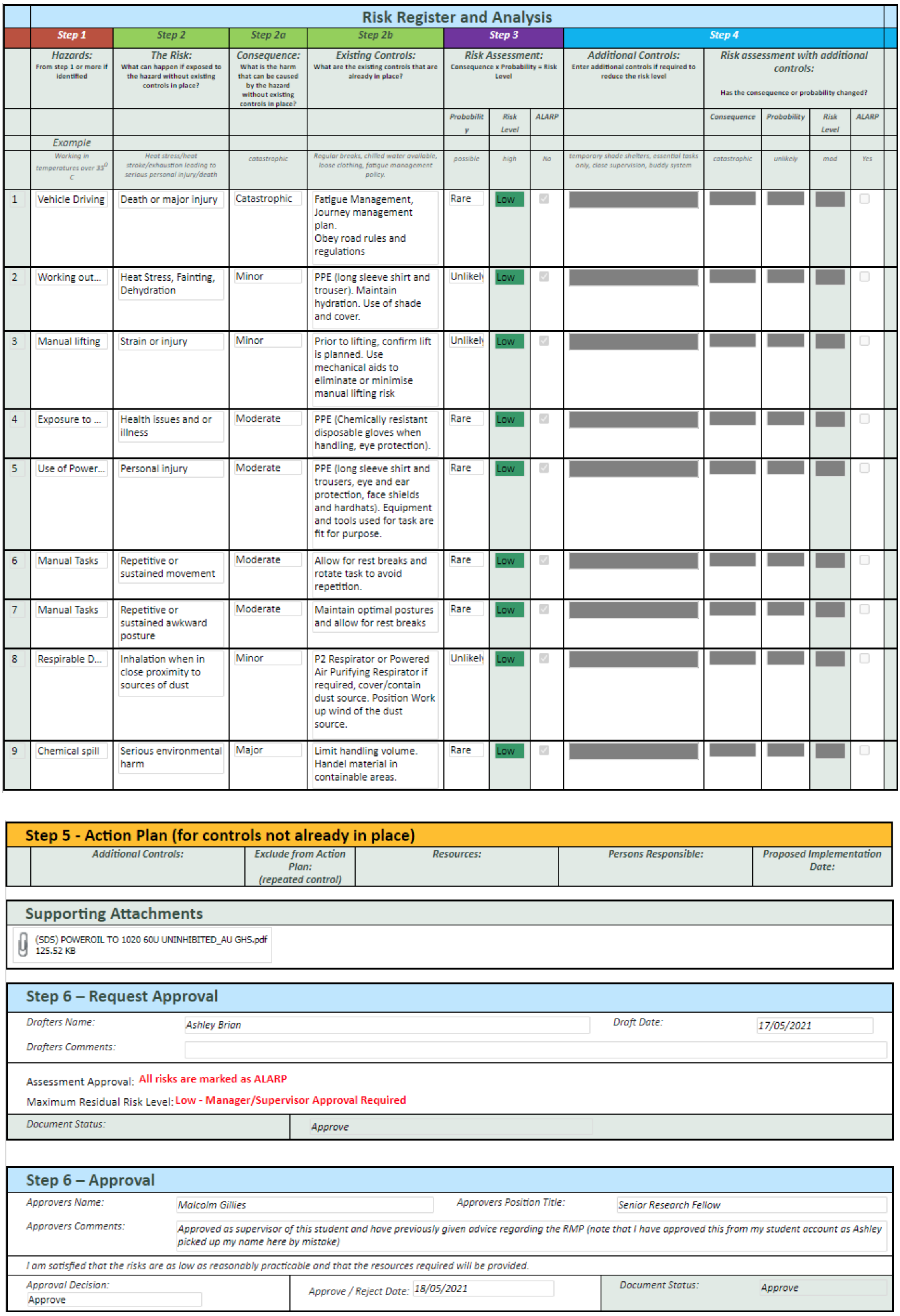


Risk Matrix

Probability	**Consequence**				
	Insignificant No Injury 0-$5K	**Minor** First Aid $5K-$50K	**Moderate** Med Treatment $50K-$100K	**Major** Serious Injury $100K-$250K	**Catastrophic** Death More than $250K
Almost Certain 1 in 2	M	H	E	E	E
Likely 1 in 100	M	H	H	E	E
Possible 1 in 1,000	L	M	H	H	H
Unlikely 1 in 10,000	L	L	M	M	M
Rare 1 in 1,000,000	L	L	L	L	L

Recommended Action Guide

Extreme:	**E**= Extreme Risk – Task ***MUST NOT*** proceed
High:	**H** = High Risk – Special Procedures Required (Contact USQSafe) Approval by VC only
Medium:	**M**= Medium Risk - A Risk Management Plan/Safe Work Method Statement is required
Low:	**L**= Low Risk - Manage by routine procedures.



Risk Register and Analysis

	Step 1	Step 2	Step 2a	Step 2b	Step 3			Step 4				
	Hazards: From step 1 or more if identified	*The Risk:* What can happen if exposed to the hazard without existing controls in place?	*Consequence:* What is the harm that can be caused by the hazard without existing controls in place?	*Existing Controls:* What are the existing controls that are already in place?	*Risk Assessment:* Consequence x Probability = Risk Level			*Additional Controls:* Enter additional controls if required to reduce the risk level	*Risk assessment with additional controls:* Has the consequence or probability changed?			
					Probability	*Risk Level*	*ALARP*		*Consequence*	*Probability*	*Risk Level*	*ALARP*
	Example											
	Working in temperatures over 35⁰ C	*Heat stress/heat stroke/exhaustion leading to serious personal injury/death*	*catastrophic*	*Regular breaks, chilled water available, loose clothing, fatigue management policy.*	*possible*	*high*	*No*	*temporary shade shelters, essential tasks only, close supervision, buddy system*	*catastrophic*	*unlikely*	*mod*	*Yes*
1	Vehicle Driving	Death or major injury	Catastrophic	Fatigue Management, Journey management plan. Obey road rules and regulations	Rare	Low	☑					☐
2	Working out...	Heat Stress, Fainting, Dehydration	Minor	PPE (long sleeve shirt and trouser). Maintain hydration. Use of shade and cover.	Unlikely	Low	☑					☐
3	Manual lifting	Strain or injury	Minor	Prior to lifting, confirm lift is planned. Use mechanical aids to eliminate or minimise manual lifting risk	Unlikely	Low	☑					☐
4	Exposure to ...	Health issues and or illness	Moderate	PPE (Chemically resistant disposable gloves when handling, eye protection).	Rare	Low	☑					☐
5	Use of Power...	Personal injury	Moderate	PPE (long sleeve shirt and trousers, eye and ear protection, face shields and hardhats). Equipment and tools used for task are fit for purpose.	Rare	Low	☑					☐
6	Manual Tasks	Repetitive or sustained movement	Moderate	Allow for rest breaks and rotate task to avoid repetition.	Rare	Low	☑					☐
7	Manual Tasks	Repetitive or sustained awkward posture	Moderate	Maintain optimal postures and allow for rest breaks	Rare	Low	☑					☐
8	Respirable D...	Inhalation when in close proximity to sources of dust	Minor	P2 Respirator or Powered Air Purifying Respirator if required, cover/contain dust source. Position Work up wind of the dust source.	Unlikely	Low	☑					☐
9	Chemical spill	Serious environmental harm	Major	Limit handling volume. Handel material in containable areas.	Rare	Low	☑					☐

Step 5 - Action Plan (for controls not already in place)

	Additional Controls:	*Exclude from Action Plan: (repeated control)*	*Resources:*	*Persons Responsible:*	*Proposed Implementation Date:*

Supporting Attachments

(SDS) POWEROIL TO 1020 60U UNINHIBITED_AU GHS.pdf
125.52 KB

Step 6 – Request Approval

Drafters Name: *Ashley Brian*
Draft Date: *17/05/2021*
Drafters Comments:

Assessment Approval: **All risks are marked as ALARP**

Maximum Residual Risk Level: **Low - Manager/Supervisor Approval Required**

Document Status: *Approve*

Step 6 – Approval

Approvers Name: *Malcolm Gillies*
Approvers Position Title: *Senior Research Fellow*
Approvers Comments: *Approved as supervisor of this student and have previously given advice regarding the RMP (note that I have approved this from my student account as Ashley picked up my name here by mistake)*

I am satisfied that the risks are as low as reasonably practicable and that the resources required will be provided.

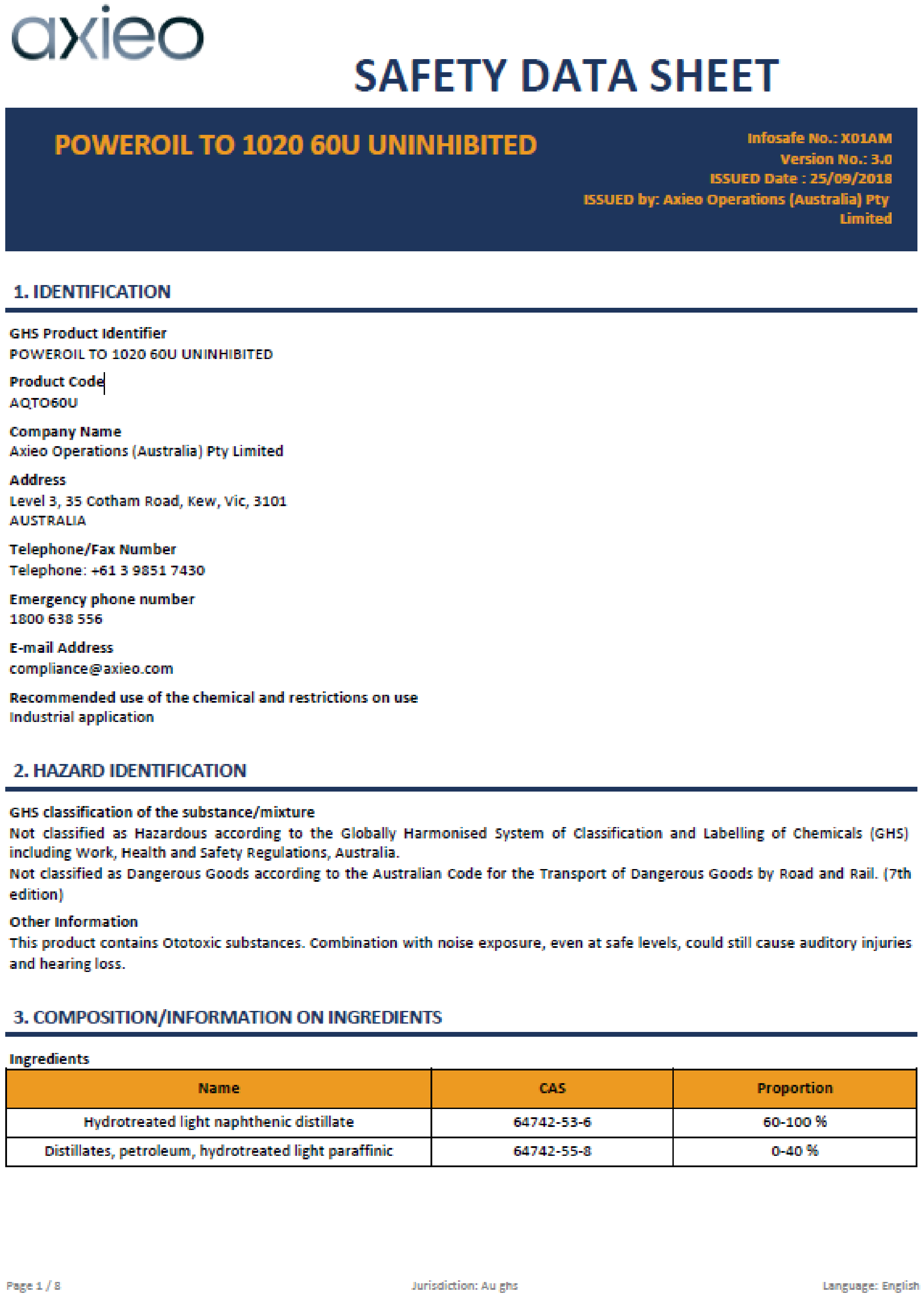
Approval Decision: Approve
Approve / Reject Date: 18/05/2021
Document Status: *Approve*

Appendix C – Schedule of oil requirements

Ref	**Particulars**	**Unit**	**Purchaser requirements**
A. TECHNICAL DATA			
A.1	Standards		AS 60296-2017
A.2	Class		Transformer Oils
A.3	Group		(U) Uninhibited
1. Function			
A.4	Viscosity		
	- At 70 °C	mm^2/s	Supplier information
	- At 40 °C	mm^2/s	Max. 12
	- At 20 °C	mm^2/s	Supplier information
	- At -15 °C	mm^2/s	Max. 800
A.5	Pour point	°C	Max. -40
A.6	Water content (drums - on delivery; bulk containers - when released from supplier's storage)	mg/kg	Max. 15
A.7	Breakdown voltage (drums - on delivery; bulk containers - when released from supplier's storage)	kV	Min 50
A.8	Density at 20 °C	kg/dm^3	Max 0.895
A.9	Dissipation factor at 90 °C and 40 Hz to 60 Hz		Max 0.005
A.10	Metal passivator additives		Not detectable
2. Refining / stability			
A.11	Appearance		Clear, free from sediment and suspended matter
A.12	Acidity	mg KOH/g	Max 0.01
A.13	Interfacial tension	mN/m	Min 40
A.14	Total sulphur content	% by mass	Max 0.15
A.15	Corrosive sulphur		Non corrosive
	Corrosive sulphur ASTM D1275		Non corrosive
	Potentially Corrosive sulphur IEC 62535		Non corrosive
	Corrosive sulphur DIN 51353		Non corrosive
	DBDS IEC 62697-1	mg/kg	Not detectable

A.16	Anti-oxidant additives		
	- Quantity (U) Uninhibited oil	% by mass	Not detectable
A.17	2-furfural and related compounds content IEC 61198	mg/kg	< 0.05 for individual compound
A.18	Composition		
A.19	Other neutral or synthetic additives		
3. Performance			
A.20	Oxidation stability @ 120 ^{o}C (U) Uninhibited oil 164 hrs IEC 61125		
	- Total acidity	mg KOH/g	Max. 1.2
	- Sludge	% by mass	Max. 0.8
	- DDF at 90^{0} C		Max. 0.5
A.21	Gassing tendency at 50 Hz after 120 minutes	µl/min	Max. 8
4. Health, safety and environment (HSE)			
A.22	Flash point	^{o}C	Min. 140
A.23	PCA content	% by mass	Max. 3
A.24	Total PCBs	mg/kg	Max 0

Appendix D – **Safety Data Sheets**



axieo

SAFETY DATA SHEET

POWEROIL TO 1020 60U UNINHIBITED

Infosafe No.: X01AM
Version No.: 3.0
ISSUED Date : 25/09/2018
ISSUED by: Axieo Operations (Australia) Pty Limited

1. IDENTIFICATION

GHS Product Identifier
POWEROIL TO 1020 60U UNINHIBITED

Product Code
AQTO60U

Company Name
Axieo Operations (Australia) Pty Limited

Address
Level 3, 35 Cotham Road, Kew, Vic, 3101
AUSTRALIA

Telephone/Fax Number
Telephone: +61 3 9851 7430

Emergency phone number
1800 638 556

E-mail Address
compliance@axieo.com

Recommended use of the chemical and restrictions on use
Industrial application

2. HAZARD IDENTIFICATION

GHS classification of the substance/mixture
Not classified as Hazardous according to the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) including Work, Health and Safety Regulations, Australia.
Not classified as Dangerous Goods according to the Australian Code for the Transport of Dangerous Goods by Road and Rail. (7th edition)

Other Information
This product contains Ototoxic substances. Combination with noise exposure, even at safe levels, could still cause auditory injuries and hearing loss.

3. COMPOSITION/INFORMATION ON INGREDIENTS

Ingredients

Name	CAS	Proportion
Hydrotreated light naphthenic distillate	64742-53-6	60-100 %
Distillates, petroleum, hydrotreated light paraffinic	64742-55-8	0-40 %

Page 1 / 8 Jurisdiction: Au ghs Language: English

4. FIRST-AID MEASURES

Inhalation

If inhaled, remove affected person from contaminated area. Keep at rest until recovered. If symptoms develop and/or persist seek medical attention.

Ingestion

Do not induce vomiting. Wash out mouth thoroughly with water. Seek medical attention.

Skin

Wash affected area thoroughly with soap and water. If symptoms develop seek medical attention.

Eye contact

If in eyes, hold eyelids apart and flush the eyes continuously with running water. Remove contact lenses. Continue flushing for several minutes until all contaminants are washed out completely. If symptoms develop and/or persist seek medical attention.

First Aid Facilities

Eyewash and normal washroom facilities.

Advice to Doctor

Treat symptomatically.

Other Information

For advice in an emergency, contact a Poisons Information Centre or a doctor at once. (131 126)

5. FIRE-FIGHTING MEASURES

Suitable Extinguishing Media

Carbon dioxide, dry chemical, foam, water mist or water spray.

Unsuitable Extinguishing Media

Do not use water jet.

Hazards from Combustion Products

Under fire conditions this product may emit toxic and/or irritating fumes, smoke and gases including carbon monoxide, carbon dioxide and oxides of nitrogen.

Specific Hazards Arising From The Chemical

This product will burn if exposed to fire.

Decomposition Temperature

Not available

Precautions in connection with Fire

Fire fighters should wear Self-Contained Breathing Apparatus (SCBA) operated in positive pressure mode and full protective clothing to prevent exposure to vapours or fumes. Water spray may be used to cool down heat-exposed containers. Fight fire from safe location. This product should be prevented from entering drains and watercourses.

6. ACCIDENTAL RELEASE MEASURES

Emergency Procedures

Wear appropriate personal protective equipment and clothing to prevent exposure. Extinguish or remove all sources of ignition and stop leak if safe to do so. Increase ventilation. Evacuate all unprotected personnel. If possible contain the spill. Place inert absorbent, non-combustible material onto spillage. Use clean non-sparking tools to collect the material and place into suitable labelled containers for subsequent recycling or disposal. Dispose of waste according to the applicable local and national regulations. If contamination of sewers or waterways occurs inform the local water and waste management authorities in accordance with local regulations.

7. HANDLING AND STORAGE

Precautions for Safe Handling
Avoid inhalation of vapours and mists, and skin or eye contact. Use only in a well ventilated area. Keep containers sealed when not in use. Prevent the build up of mists or vapours in the work atmosphere. Do not use near ignition sources. Do not pressurise, cut, heat or weld containers as they may contain hazardous residues. Maintain high standards of personal hygiene i.e.washing hands prior to eating, drinking, smoking or using toilet facilities.

Conditions for safe storage, including any incompatibilities
Store in a cool, dry, well-ventilated area away from sources of ignition, oxidising agents, strong acids, foodstuffs, and clothing. Keep containers closed when not in use, securely sealed and protected against physical damage. Inspect regularly for deficiencies such as damage or leaks. Have appropriate fire extinguishers available in and near the storage area. Take precautions against static electricity discharges. Use proper grounding procedures. Ensure that storage conditions comply with applicable local and national regulations.
For information on the design of the storeroom, reference should be made to Australian Standard AS1940 2017- The storage and handling of flammable and combustible liquids. Reference should also be made to all applicable local and national regulations.

Storage Regulations
Classified as a Class C2 (COMBUSTIBLE LIQUID) for the purpose of storage and handling, in accordance with the requirements of AS1940 2017.

8. EXPOSURE CONTROLS/PERSONAL PROTECTION

Occupational exposure limit values
No Exposure Limit Established

Biological Limit Values
No biological limits allocated.

Appropriate Engineering Controls
Provide sufficient ventilation to keep airborne levels below the exposure limits or as low as possible. Where vapours or mists are generated, particularly in enclosed areas, and natural ventilation is inadequate, a flameproof exhaust ventilation system is required. Refer to relevant regulations for further information concerning ventilation requirements.

Respiratory Protection
If engineering controls are not effective in controlling airborne exposure then an approved respirator with a replaceable vapor/mist filter should be used. Refer to relevant regulations for further information concerning respiratory protective requirements.
Reference should be made to Australian Standards AS/NZS 1715 2009, Selection, Use and Maintenance of Respiratory Protective Devices; and AS/NZS 1716 2012, Respiratory Protective Devices, in order to make any necessary changes for individual circumstances.

Eye Protection
Safety glasses with side shields, chemical goggles or full-face shield as appropriate should be used. Final choice of appropriate eye/ face protection will vary according to individual circumstances. Eye protection devices should conform to relevant regulations.
Eye protection should conform with Australian/New Zealand Standard AS/NZS 1337 2 & 6 2012 - Eye Protectors for Industrial Applications.

Hand Protection
Wear gloves of impervious material such as nitrile rubber, neoprene, PVC. Final choice of appropriate gloves will vary according to individual circumstances i.e. methods of handling or according to risk assessments undertaken. Occupational protective gloves should conform to relevant regulations.
Reference should be made to AS/NZS 2161.1 2016: Occupational protective gloves - Selection, use and maintenance.

Body Protection
Suitable protective workwear, e.g. cotton overalls buttoned at neck and wrist is recommended. Chemical resistant apron is recommended where large quantities are handled.

Other Information
No exposure standards have been established for this material, however, the TWA exposure standards for refined mineral oil mist is 5mg/m^3. As with all chemicals, exposure should be kept to the lowest possible levels.
TWA (Time Weighted Average): The average airborne concentration of a particular substance when calculated over a normal eight-hour working day, for a five-day week.
Source: Safe Work Australia

9. PHYSICAL AND CHEMICAL PROPERTIES

Form
Liquid

Appearance
Yellow liquid

Colour
Yellow

Odour
Mild petroleum odour

Decomposition Temperature
Not available

Melting Point
-45°C

Boiling Point
>250°C

Solubility in Water
Insoluble

Specific Gravity
0.89 (15°C) (maximum)

pH
Not available

Vapour Pressure
Not available

Vapour Density (Air=1)
Not available

Evaporation Rate
Not available

Odour Threshold
Not available

Viscosity
Refer to Section 9: Kinematic Viscosity and Dynamic Viscosity

Volatile Component
Not available

Partition Coefficient: n-octanol/water
Not available

Flash Point
>140°C (Pensky-Martens Closed Cup)

Flammability
Not flammable

Auto-Ignition Temperature
>270°C

Flammable Limits - Lower
Not available

Flammable Limits - Upper
Not available

Explosion Properties
Not available

Oxidising Properties
Not available

Kinematic Viscosity
10cSt (40°C) (typical)

Dynamic Viscosity
Not available

Other Information
DMSO extractable compound for base oil substance according to IP-346: <3%

10. STABILITY AND REACTIVITY

Reactivity
Refer to Section 10: Possibility of hazardous reactions

Chemical Stability
Stable under normal conditions of storage and handling.

Conditions to Avoid
Heat, open flames and other sources of ignition.

Incompatible materials
Strong oxidising agents.

Hazardous Decomposition Products
Thermal decomposition may result in the release of toxic and/or irritating fumes including: carbon dioxide and carbon monoxide.

Possibility of hazardous reactions
Reacts with incompatible materials.

Hazardous Polymerization
Not available

11. TOXICOLOGICAL INFORMATION

Toxicology Information
No toxicity data available for this material.

Ingestion
Ingestion of this product may irritate the gastric tract causing nausea and vomiting.

Inhalation
Harmful if inhaled. Inhalation of product vapours can cause irritation of the nose, throat and respiratory system.

Skin
May be irritating to skin. The symptoms may include redness, itching and swelling.

Eye
May be irritating to eyes. The symptoms may include redness, itching and tearing.

Respiratory sensitisation
Not expected to be a respiratory sensitiser.

Skin Sensitisation
Not expected to be a skin sensitiser.

Germ cell mutagenicity
Not considered to be a mutagenic hazard.

Carcinogenicity
Not considered to be a carcinogenic hazard.

Reproductive Toxicity
Not considered to be toxic to reproduction.

STOT-single exposure
Not expected to cause toxicity to a specific target organ.

STOT-repeated exposure
Not expected to cause toxicity to a specific target organ.

Aspiration Hazard
Not expected to be an aspiration hazard.

Other Information
This product contains Ototoxic substances. Combination with noise exposure, even at safe levels, could still cause auditory injuries and hearing loss.

12. ECOLOGICAL INFORMATION

Ecotoxicity
Aquatic toxicity data on base oils indicates LC50 values of >1000mg/l, which is considered as low toxicity.

Persistence and degradability
Inherently biodegradable.

Mobility
Low mobility due to low water solubilty and high viscosity.

Bioaccumulative Potential
Model suggests that petroleum oils may bioaccumulate but the bioavailability limitations may reduce this potential. Spills may form a film on water surfaces causing physical damage to organisms. Oxygen transfer could also be impaired.

Other Adverse Effects
Spills may form a film on water surfaces.

Environmental Protection
Prevent this material entering waterways, drains and sewers.

13. DISPOSAL CONSIDERATIONS

Disposal considerations
The disposal of the spilled or waste material must be done in accordance with applicable local and national regulations.

14. TRANSPORT INFORMATION

Transport Information
Not classified as Dangerous Goods according to the Australian Code for the Transport of Dangerous Goods by Road and Rail. (7th edition)
Not classified as Dangerous Goods by the criteria of the International Air Transport Association (IATA) Dangerous Goods Regulations for transport by air.
Not classified as Dangerous Goods by the criteria of the International Maritime Dangerous Goods Code (IMDG Code) for transport by sea.

U.N. Number
None Allocated

UN proper shipping name
None Allocated

Transport hazard class(es)
None Allocated

Packing Group
None Allocated

UN Number (Air Transport, ICAO)
None Allocated

IATA/ICAO Proper Shipping Name
Not dangerous for conveyance under IATA code

IATA/ICAO Hazard Class
None Allocated

IATA/ICAO Packing Group
None Allocated

IMDG UN No
None Allocated

IMDG Proper Shipping Name
Not dangerous for conveyance under IMO/IMDG code

IMDG Hazard Class
None Allocated

IMDG Pack. Group
None Allocated

IMDG Marine pollutant
No

Transport in Bulk
Not available

Special Precautions for User
Not available

15. REGULATORY INFORMATION

Regulatory information
Not classified as Hazardous according to the Globally Harmonised System of Classification and Labelling of Chemicals (GHS) including Work, Health and Safety Regulations, Australia.
Classified as a Scheduled Poison according to the Standard for the Uniform Scheduling of Medicines and Poisons (SUSMP).

Poisons Schedule
S5

16. OTHER INFORMATION

Date of preparation or last revision of SDS
SDS Reviewed: September 2018, Supersedes: August 2018

References
Preparation of Safety Data Sheets for Hazardous Chemicals Code of Practice.
Standard for the Uniform Scheduling of Medicines and Poisons.
Australian Code for the Transport of Dangerous Goods by Road & Rail.
Model Work Health and Safety Regulations, Schedule 10: Prohibited carcinogens, restricted carcinogens and restricted hazardous chemicals.
Workplace exposure standards for airborne contaminants.
Adopted biological exposure determinants, American Conference of Industrial Hygienists (ACGIH).
Globally Harmonised System of Classification and Labelling of Chemicals.
Code of Practice: Managing Noise and Preventing Hearing Loss at Work.

Contact Person/Point
IMPORTANT ADVICE: An SDS summarizes our best knowledge of the health and safety hazard information of the product and how to safely handle and use the product in the workplace. The information contained in this SDS is believed to be correct but is not guaranteed. Prior to using the product(s) referred to in this SDS, each user should read this SDS and consider the information in the context of how the product will be handled and used in the workplace, including its use in conjunction with other products. If clarification or further information is needed to ensure that an appropriate risk assessment can be made, the user should contact the supplier listed in section 1 of the SDS. Our responsibility for products sold is subject to our standard terms and conditions, a copy of which is sent to our customers and is also available on request. Axieo does not accept any other liability either directly or indirectly for any losses suffered in connection with the use and application of the product whether or not in accordance with any advice, specification, recommendation or information given by it.

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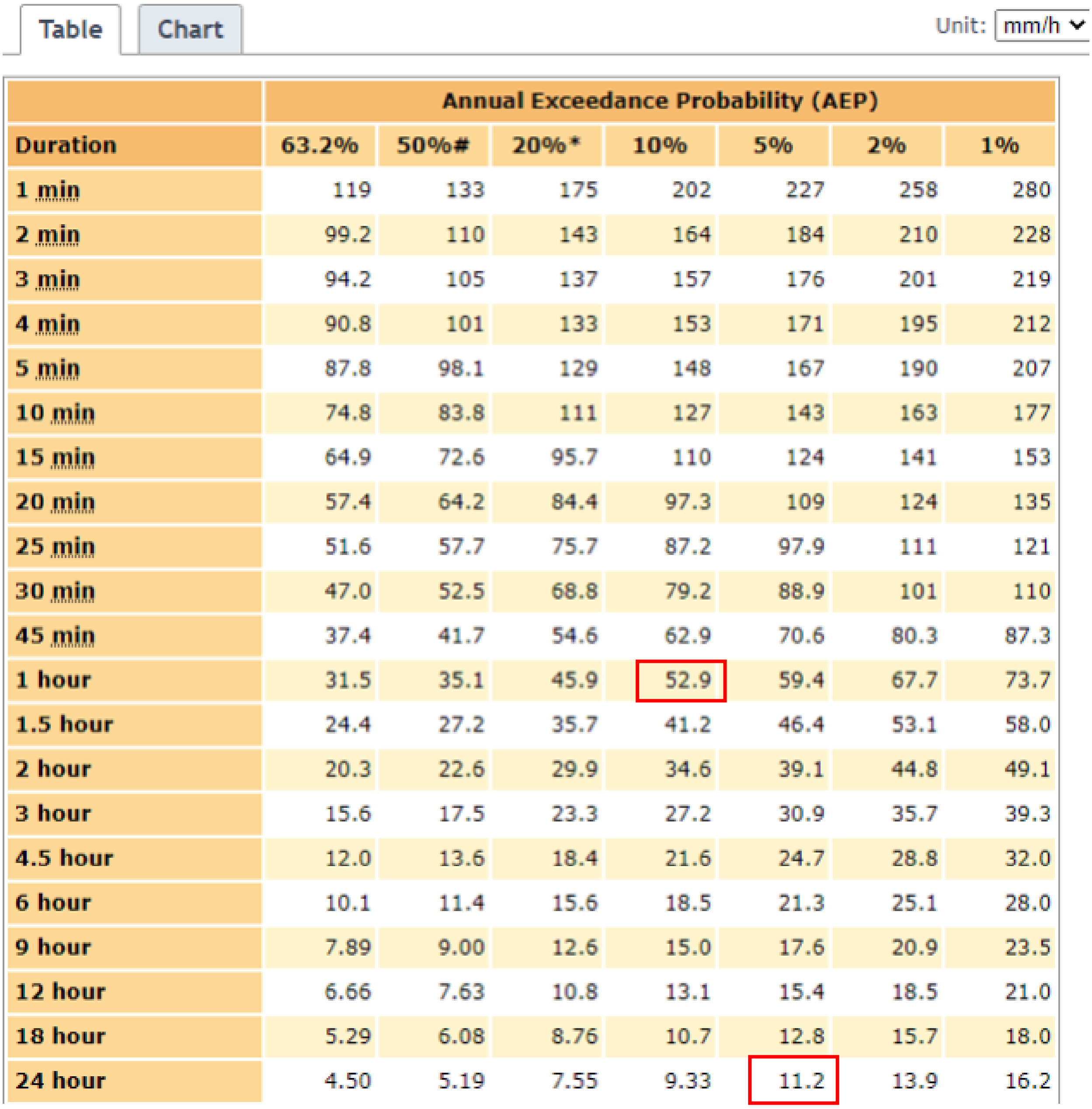
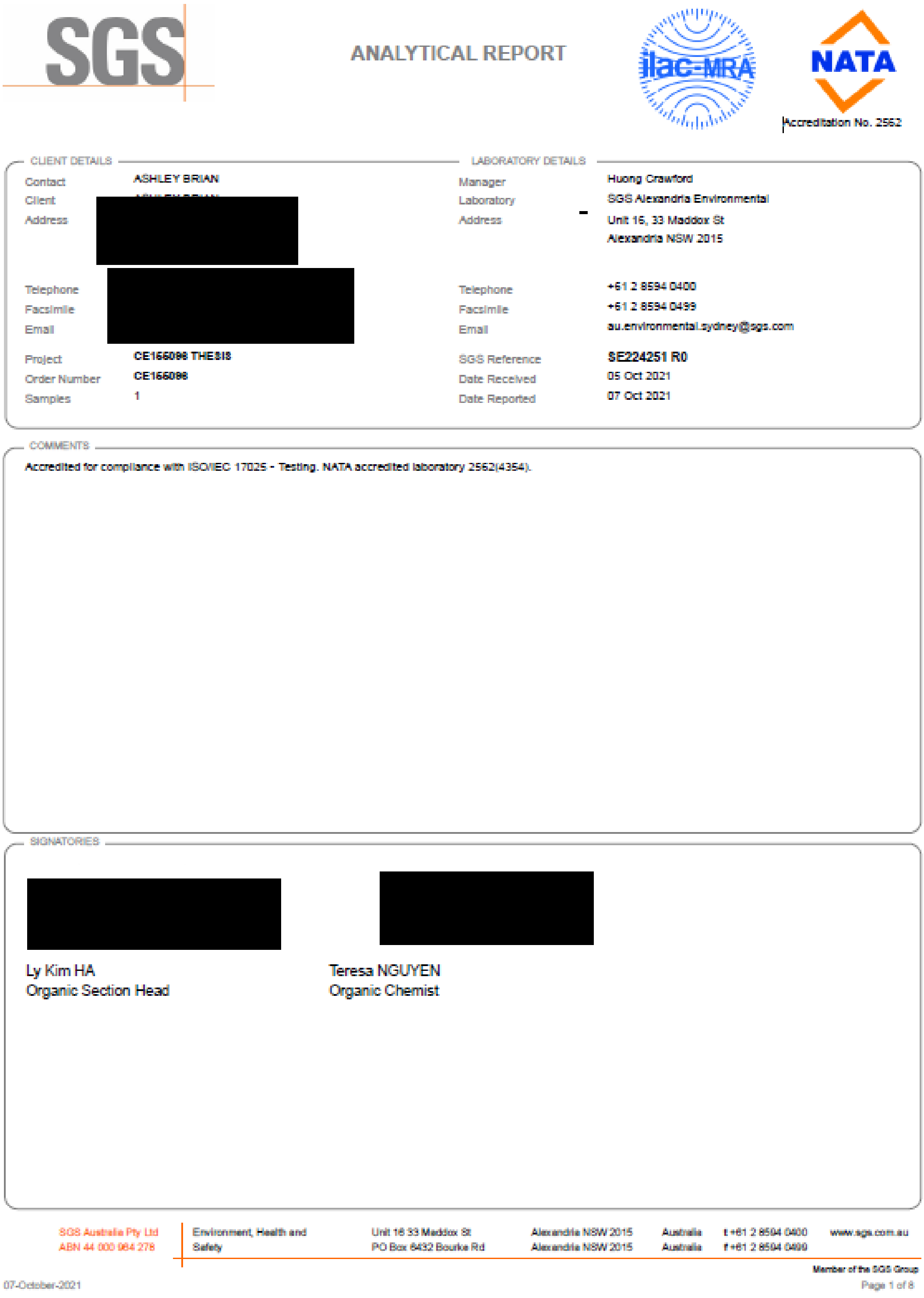
END OF SDS

Appendix E – **Design Rainfall Data**



	Annual Exceedance Probability (AEP)						
Duration	**63.2%**	**50%#**	**20%***	**10%**	**5%**	**2%**	**1%**
1 min	119	133	175	202	227	258	280
2 min	99.2	110	143	164	184	210	228
3 min	94.2	105	137	157	176	201	219
4 min	90.8	101	133	153	171	195	212
5 min	87.8	98.1	129	148	167	190	207
10 min	74.8	83.8	111	127	143	163	177
15 min	64.9	72.6	95.7	110	124	141	153
20 min	57.4	64.2	84.4	97.3	109	124	135
25 min	51.6	57.7	75.7	87.2	97.9	111	121
30 min	47.0	52.5	68.8	79.2	88.9	101	110
45 min	37.4	41.7	54.6	62.9	70.6	80.3	87.3
1 hour	31.5	35.1	45.9	52.9	59.4	67.7	73.7
1.5 hour	24.4	27.2	35.7	41.2	46.4	53.1	58.0
2 hour	20.3	22.6	29.9	34.6	39.1	44.8	49.1
3 hour	15.6	17.5	23.3	27.2	30.9	35.7	39.3
4.5 hour	12.0	13.6	18.4	21.6	24.7	28.8	32.0
6 hour	10.1	11.4	15.6	18.5	21.3	25.1	28.0
9 hour	7.89	9.00	12.6	15.0	17.6	20.9	23.5
12 hour	6.66	7.63	10.8	13.1	15.4	18.5	21.0
18 hour	5.29	6.08	8.76	10.7	12.8	15.7	18.0
24 hour	4.50	5.19	7.55	9.33	11.2	13.9	16.2

Appendix F – Analytical Report



SGS

ANALYTICAL REPORT

ilac-MRA

NATA

Accreditation No. 2562

CLIENT DETAILS

Contact	ASHLEY BRIAN
Client	[redacted]
Address	[redacted]
Telephone	[redacted]
Facsimile	[redacted]
Email	[redacted]
Project	CE166096 THESIS
Order Number	CE166096
Samples	1

LABORATORY DETAILS

Manager	Huong Crawford
Laboratory	SGS Alexandria Environmental
Address	Unit 16, 33 Maddox St Alexandria NSW 2015
Telephone	+61 2 8594 0400
Facsimile	+61 2 8594 0499
Email	au.environmental.sydney@sgs.com
SGS Reference	**SE224251 R0**
Date Received	05 Oct 2021
Date Reported	07 Oct 2021

COMMENTS

Accredited for compliance with ISO/IEC 17025 - Testing. NATA accredited laboratory 2562(4354).

SIGNATORIES

[redacted]

Ly Kim HA
Organic Section Head

[redacted]

Teresa NGUYEN
Organic Chemist

SGS Australia Pty Ltd
ABN 44 000 964 278

Environment, Health and Safety

Unit 16 33 Maddox St
PO Box 6432 Bourke Rd

Alexandria NSW 2015
Alexandria NSW 2015

Australia
Australia

t +61 2 8594 0400
f +61 2 8594 0499

www.sgs.com.au

Member of the SGS Group

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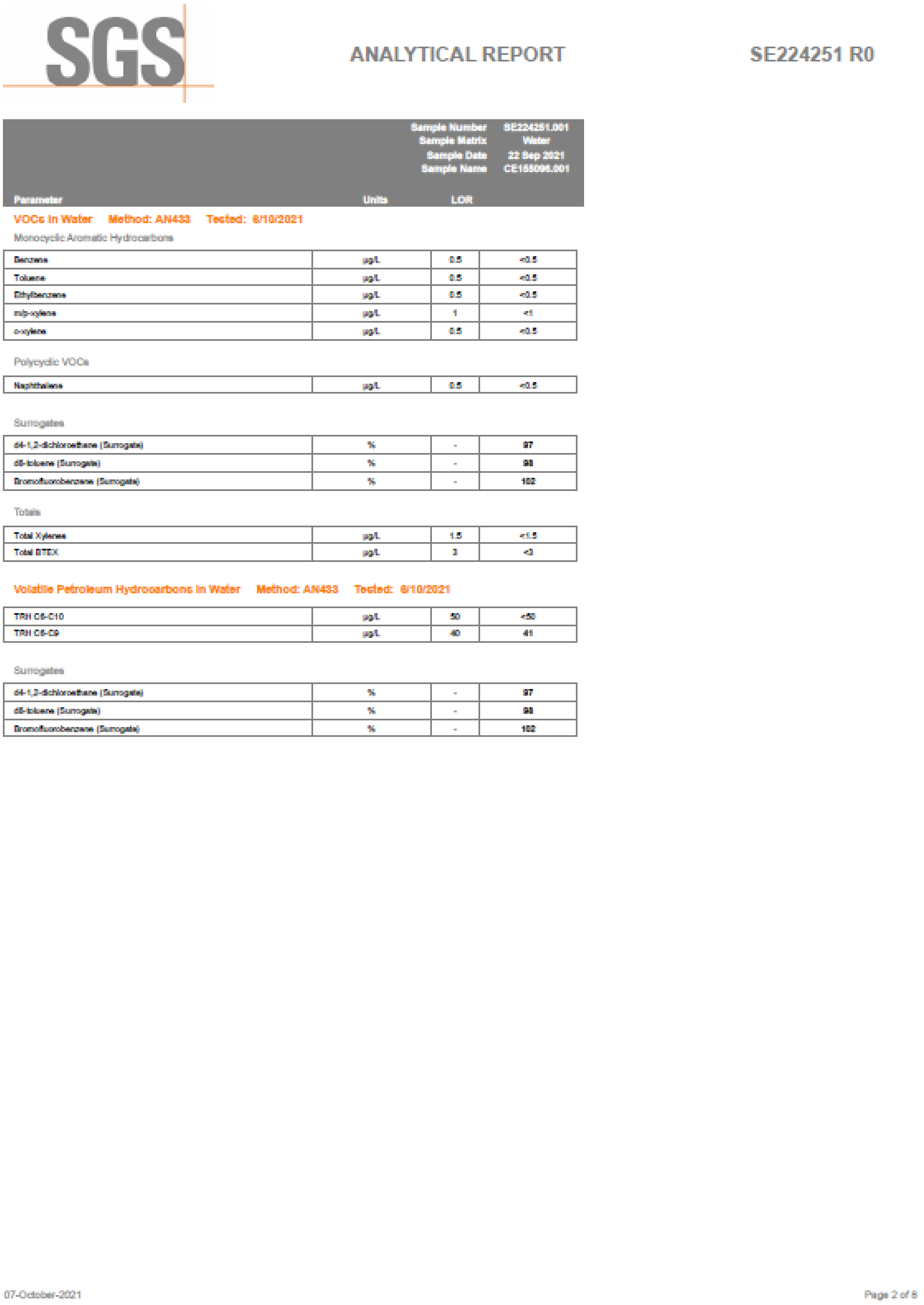
Page 1 of 8



ANALYTICAL REPORT SE224251 R0

		Sample Number	SE224251.001
		Sample Matrix	Water
		Sample Date	22 Sep 2021
		Sample Name	CE155096.001
Parameter	**Units**	**LOR**	

VOCs in Water Method: AN433 Tested: 8/10/2021

Monocyclic Aromatic Hydrocarbons

Benzene	µg/L	0.5	<0.5
Toluene	µg/L	0.5	<0.5
Ethylbenzene	µg/L	0.5	<0.5
m/p-xylene	µg/L	1	<1
o-xylene	µg/L	0.5	<0.5

Polycyclic VOCs

Naphthalene	µg/L	0.5	<0.5

Surrogates

d4-1,2-dichloroethane (Surrogate)	%	-	97
d8-toluene (Surrogate)	%	-	98
Bromofluorobenzene (Surrogate)	%	-	102

Totals

Total Xylenes	µg/L	1.5	<1.5
Total BTEX	µg/L	3	<3

Volatile Petroleum Hydrocarbons in Water Method: AN433 Tested: 8/10/2021

TRH C6-C10	µg/L	50	<50
TRH C6-C9	µg/L	40	41

Surrogates

d4-1,2-dichloroethane (Surrogate)	%	-	97
d8-toluene (Surrogate)	%	-	98
Bromofluorobenzene (Surrogate)	%	-	102

		Sample Number	SE224251.001
		Sample Matrix	Water
		Sample Date	22 Sep 2021
		Sample Name	CE155096.001
Parameter	**Units**	**LOR**	

Volatile Petroleum Hydrocarbons in Water Method: AN433 Tested: 6/10/2021 (continued)

VPH F Bands

Benzene (F0)	µg/L	0.5	<0.5
TRH C6-C10 minus BTEX (F1)	µg/L	50	<50

TRH (Total Recoverable Hydrocarbons) in Water Method: AN403 Tested: 6/10/2021

TRH C10-C14	µg/L	50	<50
TRH C15-C28	µg/L	200	<200
TRH C29-C36	µg/L	200	<200
TRH C37-C40	µg/L	200	<200
TRH C10-C40	µg/L	320	<320

TRH F Bands

TRH >C10-C16	µg/L	60	<60
TRH >C10-C16 - Naphthalene (F2)	µg/L	60	<60
TRH >C16-C34 (F3)	µg/L	500	<500
TRH >C34-C40 (F4)	µg/L	500	<500

PAH (Polynuclear Aromatic Hydrocarbons) in Water Method: AN420 Tested: 6/10/2021

Naphthalene	µg/L	0.1	<0.1
2-methylnaphthalene	µg/L	0.1	<0.1
1-methylnaphthalene	µg/L	0.1	<0.1
Acenaphthylene	µg/L	0.1	<0.1
Acenaphthene	µg/L	0.1	<0.1
Fluorene	µg/L	0.1	<0.1
Phenanthrene	µg/L	0.1	<0.1
Anthracene	µg/L	0.1	<0.1
Fluoranthene	µg/L	0.1	<0.1
Pyrene	µg/L	0.1	<0.1
Benzo(a)anthracene	µg/L	0.1	<0.1
Chrysene	µg/L	0.1	<0.1
Benzo(b&j)fluoranthene	µg/L	0.1	<0.1
Benzo(k)fluoranthene	µg/L	0.1	<0.1
Benzo(a)pyrene	µg/L	0.1	<0.1
Indeno(1,2,3-cd)pyrene	µg/L	0.1	<0.1
Dibenzo(ah)anthracene	µg/L	0.1	<0.1
Benzo(ghi)perylene	µg/L	0.1	<0.1
Total PAH (18)	µg/L	1	<1

		Sample Number	SE224251.001
		Sample Matrix	Water
		Sample Date	22 Sep 2021
		Sample Name	CE155096.001
Parameter	**Units**	**LOR**	
PAH (Polynuclear Aromatic Hydrocarbons) in Water Method: AN420 Tested: 6/10/2021 (continued)			
Surrogates			
d5-nitrobenzene (Surrogate)	%	-	42
2-fluorobiphenyl (Surrogate)	%	-	54
d14-p-terphenyl (Surrogate)	%	-	84

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

PAH (Polynuclear Aromatic Hydrocarbons) in Water   Method: ME-(AU)-[ENV]AN420

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
Naphthalene	LB234097	µg/L	0.1	<0.1	0%	72%
2-methylnaphthalene	LB234097	µg/L	0.1	<0.1	0%	NA
1-methylnaphthalene	LB234097	µg/L	0.1	<0.1	0%	NA
Acenaphthylene	LB234097	µg/L	0.1	<0.1	0%	79%
Acenaphthene	LB234097	µg/L	0.1	<0.1	0%	79%
Fluorene	LB234097	µg/L	0.1	<0.1	0%	NA
Phenanthrene	LB234097	µg/L	0.1	<0.1	0%	84%
Anthracene	LB234097	µg/L	0.1	<0.1	0%	83%
Fluoranthene	LB234097	µg/L	0.1	<0.1	0%	85%
Pyrene	LB234097	µg/L	0.1	<0.1	0%	88%
Benzo(a)anthracene	LB234097	µg/L	0.1	<0.1	0%	NA
Chrysene	LB234097	µg/L	0.1	<0.1	0%	NA
Benzo(b&j)fluoranthene	LB234097	µg/L	0.1	<0.1	0%	NA
Benzo(k)fluoranthene	LB234097	µg/L	0.1	<0.1	0%	NA
Benzo(a)pyrene	LB234097	µg/L	0.1	<0.1	0%	89%
Indeno(1,2,3-cd)pyrene	LB234097	µg/L	0.1	<0.1	0%	NA
Dibenzo(ah)anthracene	LB234097	µg/L	0.1	<0.1	0%	NA
Benzo(ghi)perylene	LB234097	µg/L	0.1	<0.1	0%	NA
Total PAH (18)	LB234097	µg/L	1	<1		

Surrogates

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
d5-nitrobenzene (Surrogate)	LB234097	%	-	50%	9%	50%
2-fluorobiphenyl (Surrogate)	LB234097	%	-	62%	4%	62%
d14-p-terphenyl (Surrogate)	LB234097	%	-	74%	18%	78%

TRH (Total Recoverable Hydrocarbons) in Water   Method: ME-(AU)-[ENV]AN403

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
TRH C10-C14	LB234097	µg/L	50	<50	0%	74%
TRH C15-C28	LB234097	µg/L	200	<200	0%	100%
TRH C29-C36	LB234097	µg/L	200	<200	0%	75%
TRH C37-C40	LB234097	µg/L	200	<200	0%	NA
TRH C10-C40	LB234097	µg/L	320	<320	0%	NA

TRH F Bands

Parameter	QC Reference	Units	LOR	MB	DUP %RPD	LCS %Recovery
TRH >C10-C16	LB234097	µg/L	60	<60	0%	93%
TRH >C10-C16 - Naphthalene (F2)	LB234097	µg/L	60	<60	0%	NA
TRH >C16-C34 (F3)	LB234097	µg/L	500	<500	0%	83%
TRH >C34-C40 (F4)	LB234097	µg/L	500	<500	0%	81%

MB blank results are compared to the Limit of Reporting
LCS and MS spike recoveries are measured as the percentage of analyte recovered from the sample compared the the amount of analyte spiked into the sample.
DUP and MSD relative percent differences are measured against their original counterpart samples according to the formula : *the absolute difference of the two results divided by the average of the two results as a percentage*. Where the DUP RPD is 'NA' , the results are less than the LOR and thus the RPD is not applicable.

VOCs in Water Method: ME-(AU)-[ENV]AN433

Monocyclic Aromatic Hydrocarbons

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Benzene	LB234157	µg/L	0.5	<0.5	117%	109%
Toluene	LB234157	µg/L	0.5	<0.5	118%	109%
Ethylbenzene	LB234157	µg/L	0.5	<0.5	119%	112%
m/p-xylene	LB234157	µg/L	1	<1	117%	111%
o-xylene	LB234157	µg/L	0.5	<0.5	120%	112%

Polycyclic VOCs

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Naphthalene	LB234157	µg/L	0.5	<0.5	NA	NA

Surrogates

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
d4-1,2-dichloroethane (Surrogate)	LB234157	%	-	98%	101%	100%
d8-toluene (Surrogate)	LB234157	%	-	95%	103%	98%
Bromofluorobenzene (Surrogate)	LB234157	%	-	97%	97%	90%

Totals

Parameter	QC Reference	Units	LOR	MB
Total Xylenes	LB234157	µg/L	1.5	<1.5
Total BTEX	LB234157	µg/L	3	<3

Volatile Petroleum Hydrocarbons in Water Method: ME-(AU)-[ENV]AN433

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
TRH C6-C10	LB234157	µg/L	50	<50	96%	100%
TRH C6-C9	LB234157	µg/L	40	<40	96%	100%

Surrogates

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
d4-1,2-dichloroethane (Surrogate)	LB234157	%	-	98%	101%	100%
d8-toluene (Surrogate)	LB234157	%	-	95%	103%	98%
Bromofluorobenzene (Surrogate)	LB234157	%	-	97%	97%	90%

VPH F Bands

Parameter	QC Reference	Units	LOR	MB	LCS %Recovery	MS %Recovery
Benzene (F0)	LB234157	µg/L	0.5		NA	NA
TRH C6-C10 minus BTEX (F1)	LB234157	µg/L	50	<50	92%	100%

METHOD	METHODOLOGY SUMMARY
AN403	Total Recoverable Hydrocarbons: Determination of Hydrocarbons by gas chromatography after a solvent extraction. Detection is by flame ionisation detector (FID) that produces an electronic signal in proportion to the combustible matter passing through it. Total Recoverable Hydrocarbons (TRH) are routinely reported as four alkane groupings based on the carbon chain length of the compounds: C6-C9, C10-C14, C15-C28 and C29-C36 and in recognition of the NEPM 1999 (2013), >C10-C16 (F2), >C16-C34 (F3) and >C34-C40 (F4). Where F2 is corrected for Naphthalene, the VOC data for Naphthalene is used.
AN403	Additionally, the volatile C6-C9/C6-C10 fractions may be determined by a purge and trap technique and GC/MS because of the potential for volatiles loss. Total Recoveerable Hydrocarbons - Silica (TRH-Silica) follows the same method of analysis after silica gel cleanup of the solvent extract. Aliphatic/Aromatic Speciation follows the same method of analysis after fractionation of the solvent extract over silica with differential polarity of the eluent solvents.
AN403	The GC/FID method is not well suited to the analysis of refined high boiling point materials (ie lubricating oils or greases) but is particularly suited for measuring diesel, kerosene and petrol if care to control volatility is taken. This method will detect naturally occurring hydrocarbons, lipids, animal fats, phenols and PAHs if they are present at sufficient levels, dependent on the use of specific cleanup/fractionation techniques. Reference USEPA 3510B, 8015B.
AN420	(SVOCs) including OC, OP, PCB, Herbicides, PAH, Phthalates and Speciated Phenols (etc) in soils, sediments and waters are determined by GCMS/ECD technique following appropriate solvent extraction process (Based on USEPA 3500C and 8270D).
AN433	VOCs and C6-C9 Hydrocarbons by GC-MS P&T: VOC's are volatile organic compounds. The sample is presented to a gas chromatograph via a purge and trap (P&T) concentrator and autosampler and is detected with a Mass Spectrometer (MSD). Solid samples are initially extracted with methanol whilst liquid samples are processed directly. References: USEPA 5030B, 8020A, 8260.