Assessment of Underground Storage Systems

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Assessment of Underground Storage Systems

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ABSTRACT

Underground Storage Systems (USS) pose one of the major sources of soil and groundwater contamination due to the potential for the leakage of product to the environment. The resulting contamination may represent, or potentially represent, risks to human health and the environment and impact on the acceptability of the site, or nearby sites, for their current or proposed use(s).

The prevention of contamination, in particular the migration of contamination, is of prime importance to ensure the protection of human health, property and the environment. Preventive measures are beyond the scope of this paper and reference should be directed to the relevant State regulators and authorities for legislative requirements, more specific information and guidance.

This paper is primarily aimed at identifying the major issues to be considered during the assessment of sites containing USS where the leakage of product has been identified or suspected. Emphasis is placed on the importance of preliminary site investigations prior to more detailed site investigation and understanding the importance of obtaining scientifically reliable and statistically defensible site information.

USS are most often associated with the storage of petroleum products (commonly referred to as Underground Petroleum Storage Systems UPSS), but other hazardous substances, including waste products, may also be stored in underground tanks.

1 INTRODUCTION

This paper discusses various approaches to the assessment of sites containing Underground Storage Systems (USS), both the more common USS at service station sites and USS on other sites, including industrial and commercial sites. This paper addresses those systems that store petroleum products and are commonly referred to as Underground Petroleum Storage Systems (UPSS) and Underground Storage Tanks (UST). USS includes the actual storage vessel and all associated ancillary equipment.

USS increasingly are subject to critical review of their environmental impacts, especially on groundwater quality. The potential environmental impacts of USS are usually understated. Rice (1995) states "After studying 345 UST leak cases, it was reported that only four percent of the leaks were detected by leak detection systems. Instead, most leaks are discovered during tank closure/ removal or other site activities." This is due to the nature of USS being wholly buried. Specific inspections of the condition of the USS and the inability to directly observe indicators of soil or groundwater contamination lead to the potential environmental impacts of USS being understated. As such, any environmental impacts are not usually identified until the system is removed from the ground, or groundwater assessment is completed, at which time potential contamination of soil and groundwater may be more readily identified. This is especially so in the case

of groundwater contamination that may not be identified for years after a USS has been abandoned or removed due to the geology of the site or inadequate environmental assessment.

The assessment process for sites containing USS should be completed in accordance with the National Environment Protection (Assessment of Site Contamination) Measure 1999. It is critical to the assessment of USS sites that a thorough preliminary investigation is completed prior to a detailed investigation.

The objective of the preliminary investigation is to gather as much information about:

- the history of development of the site
- the history of the storage systems on-site
- products stored within the USS
- other potential on-site and off-site sources of contamination
- chemicals stored at the site
- history of maintenance and operation of the USS
- other relevant background information.

2 BACKGROUND

USS pose one of the major sources of soil and groundwater contamination and have been the subject of environmental assessment and remediation projects for probably the past 15 years. The US EPA identified USS in 1988 as one of five activities posing major threats to groundwater quality (Bedient, 1994). USS are generally located on fuel retailing outlets that include service stations, motor vehicle dealerships, general stores, produce supplies and transport yards. USS may also be located on industrial and commercial facilities for chemical and fuel storage, including fuels for back up equipment such as generators.

Determining the number of USS in use in Australia is difficult, considering that in some states storage of combustible liquids does not require licensing and disused or abandoned USS are often overlooked. Information from the Australian Institute of Petroleum (AIP, 2002) indicates that as of end 2000 there were 8370 service stations operating within Australia. There are a number of USS on sites other than service stations and practical experience would indicate that this number could be at least twice the AIP number. Experience also suggests a further multiple of 2 to 5 could be used to make allowance for disused or abandoned USS.

Worldwide, there is growing awareness of the environmental impact of USS on the environment. The Leaking Underground Storage Tanks (LUST) program in the US has been operational since 1987 and involves identifying and rectifying the environmental impacts of USS. There has been a gradual realisation that groundwater quality should be protected due to its interactions with sensitive surface water and other ecosystems and the uses of groundwater, including drinking water supplies. Contamination, and the evaluation of, groundwater, as in management of USS, is generally difficult given the relative inaccessibility to the USS and groundwater. In addition, transport processes of contaminants in groundwater are very slow in comparison to surface water flow. There may be a long lead time from a USS leaking to resulting contamination of soil and ultimately contamination of groundwater.

In many cases investigation may have predominantly focussed on the assessment of soil conditions as part of an environmental or due diligence process to assess potential liability or to set baseline conditions at commencement of lease agreements or the sale or purchase of a property. Such an assessment may not have been completed for the total site and may not have adequately addressed potential groundwater contamination.

The understanding of the contaminants of concern, their behaviour in the environment and the potential complexity of the subsurface environment is critical to the adequate investigation of sites containing USS.

2.1 UNDERGROUND STORAGE TANK SYSTEMS

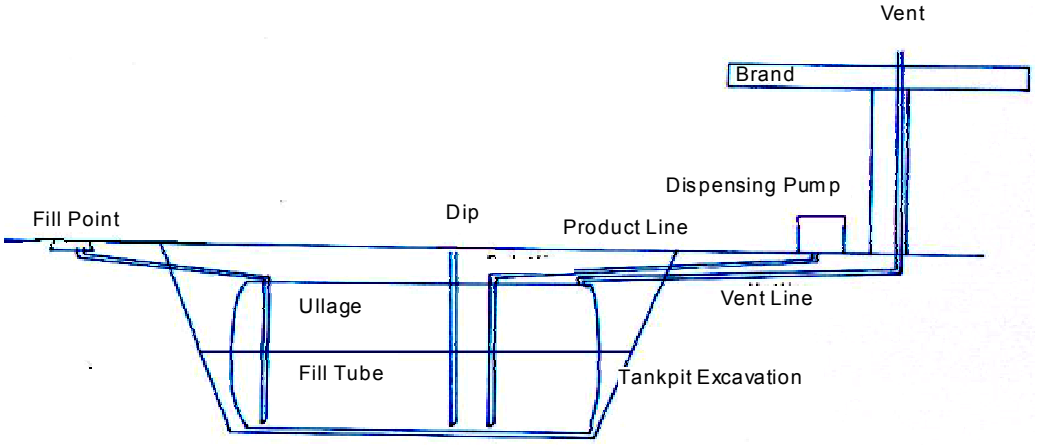
Underground Storage Tanks are defined in Australian Standard AS1940-1993 as being those systems where the storage vessel (tank) is either totally or partially installed below ground level.

Underground storage tank systems (USS) are likely to comprise some or all of the following:

- Storage tanks or vessels of varying sizes that may be compartmentalised
- Product delivery systems (dispensing pumps, suction lines, pressure lines, pipework joins, filters, valves, etc)
- Access tube to enable measurement of liquid volume within tank (Dip point)
- Direct or indirect tank filling point (indirect fills can be quite remote from the tank location)
- Vapour recovery systems
- Vent line and vent point
- Spill containment systems (dip, fill, under pump containment and drainage pipework)
- Tank backfill sands or gravels
- Tank anchoring system
- Electrical cabling
- Tank pit monitoring wells
- Corrosion prevention systems
- Groundwater monitoring wells
- Leak detection systems
- Automatic tank gauging systems
- Ullage space, tank headspace above the liquid level within the tank, including fill and vent lines
- Interstitial monitoring systems
- Overfill protection systems

The figure below provides a schematic overview of a USS that is typically located on fuel retailing sites. USS can contain multiple tanks connected to multiple dispensing points. USS may also contain one tank with multiple dispensing points such as may be present at a manufacturing plant.

Figure 1: Schematic plan of an Underground Storage System



The loss or leakage of USS contents may result from:

- Incompatible USS materials for the product being stored
- Incompatible geotechnical conditions, such as reactive or collapsing soils
- Corrosion of the USS material
- Human error (delivery losses, inadequate system management, poor installation, damage)
- Small incremental losses, even though stock monitoring does not identify product loss as an issue
- Catastrophic loss through line or tank failure
- Leaks from pumps, loose fittings, tank filling activities, maintenance activities (pressurised systems will exacerbate losses)
- Vapour loss to the subsurface or atmosphere
- Pilfering
- Under or over dispensing pumps
- Bent damaged or unsuitable tank dipping or gauging equipment

Losses from USS can be disguised through over or under dispensing pumps, fuel temperature, inappropriate further investigation thresholds, failure to complete physical system checks, etc. It should be recognised that there is no system that will control or prevent all leaks, as USS require equipment that will eventually age and may fail. There is always a factor of human error and accidents inevitably happen.

3 PREVENTION

Prevention is critical to the management of USS as there is not a system that will control or prevent all leaks due to failure of equipment as it ages, human error or accidents that inevitably occur. The EPA Victoria (2002) indicate that "improved practice and performance of UPSS is necessary to ensure protection of people, property and the environment."

Management of USS is critical in preventing leaks. Management involves correct operating procedures and preventative maintenance programs, which include:

- Selecting the correct materials for the USS
- Correct installation of the system

- Adequate operation and maintenance of the system, including statistical inventory reconciliation
- An understanding of the limitations of stock reconciliation, for example dip sticks only being marked in 100 litre or more increments
- A systematic approach to the investigation of any discrepancy in product volumes, such as the Statistical Inventory Reconciliation fail or inconclusive result (USEPA, 1995). Such an approach will include checks on pump calibration and equipment integrity testing
- Prompt action upon identification or suspicion of leakage.

4 INVESTIGATION

Investigation of sites containing USS can be initiated as a result of loss or suspected loss of USS contents, transfer in lease or ownership of the site, redevelopment of the site for a more sensitive land use or for due diligence purposes.

Schedule A of the National Environment Protection (Assessment of Site Contamination) Measure 1999 (NEPM) describes the process for the assessment of site contamination through use of a flow chart. The NEPM states "adequate data collection is the foundation for acceptable assessment of health and environmental risks associated with site contamination". Step 1 in the assessment process is a "Preliminary Investigation".
The investigation should consider the entire site, not just the USS.

5 PRELIMINARY INVESTIGATION

The preliminary investigation is defined in the NEPM as a data collection phase "to the point where analysis is undertaken when the site history indicates that contamination may be present".

For USS sites the data collection phase is particularly relevant to determine potential site contamination issues. This phase is often overlooked due to the presence of the USS itself being a trigger to proceed to a detailed site investigation. Potential site contamination issues are used to define the scope of sampling and any specific sampling techniques and analysis required to investigate the presence and distribution of chemicals or waste that may be present at the site.

Traditionally assessments of USS sites have assumed that the chemicals or waste present are petroleum hydrocarbons and lead associated with fuel additives.

This approach does not consider other potentially contaminating activities that may have occurred at the site, such as:

- any products that may have previously been stored in the USS or former USS
- drum cleaning and filling, eg pesticides, oil, grease, fuel, herbicides, solvents
- mechanical repairs including parts cleaning, brake machining and other repairs
- waste oil and cooling liquid disposal
- importation of fill, that may contain chemical substances or waste
- operation of oil-water separation systems
- surrounding land uses, including underground pipelines
- confirmation of fuel sources for previous boilers, etc that may include coal or fuel oil
- waste disposal practices

The information requirements for the preliminary investigation are listed in the NEPM and Australian Standard AS4482.1-1997 (AS4482.1). In addition to the information requirements listed in these documents, the following requirements should apply to USS:

- Obtain copies of reports or completion certificates for any maintenance, repairs or replacements, Equipment Integrity Testing (EIT) reports and stock inventory control records
- Confirm the construction methodology of the USS, including backfill materials
- Determine the condition of all pipework and tank removed from the site

5.1 SITE INSPECTION

A site inspection is an important step within the preliminary investigation.

The site inspection should be completed to confirm data obtained, as outlined in Section 3.1, and to investigate issues such as:

- Location of all USS, pipework and dispensing pumps, including former USS and pumps and any systems on adjacent land including kerbside tanks and pumps
- Former workshops that may now be expanded sales buildings, including bulk oil storage locations, interceptors and in-ground hydraulic hoist locations
- Confirmation of the number of tank vents and comparison to the number of identified tanks. Note that some installations may have a single vent for multiple tanks and that vents may be used for a combination of uses
- Confirmation of current USS layout including location of pipework through visual assessment of concrete patchwork, dip points, fill points, etc
- Areas of site filling
- Areas of pre 1960s bitumen
- Confirmation of the size and depth to base of all tanks
- Identify any concrete patchwork or new filled areas that may indicate previous tanks and/or equipment having been removed or replaced, or new tank locations
- Confirmation of data with site operators, including stock control records, age and size of tanks, maintenance, abandoned or disused tanks, previous site investigations and other relevant issues
- Confirmation of the location of all above and under ground structures and services to assist in planning of soil and groundwater sampling locations
- Identification and assessment of receptors that may be at risk should there be soil or groundwater contamination:
  - On-site: site workers, customers, maintenance workers
  - Off-site: underground utilities, preferential pathways, maintenance workers, land uses, surface water bodies
- Identification of the possible presence of concrete cores or monitoring well covers that would indicate previous soil and/or groundwater investigations
- Confirmation of waste disposal practices and stormwater management measures, ie does stormwater from the forecourt run through separators, stormwater disposal to groundwater aquifers, air compressor drainage waste, etc
- Inspection of underground services. Some services may form confined spaces to which entry is not recommended

5.2 CHEMICAL SUBSTANCES

Chemical substances that may be associated with USS include:

- Petroleum fuels, lubricating oils and additives such as organometallic compounds, surfactants, biocides, molybdenate compounds and corrosion inhibitors
- Chemicals associated with the chemical or fuel manufacturing process. Metals naturally occurring in the product being refined, including nickel, vanadium, copper, zinc and mercury. Catalysts and solvents that may have been used in the manufacturing process, such as vanadium, cobalt, molybdenum and platinum catalysts
- Degreasers and solvents
- Waste oils having highly variable compositions
- Other chemicals including ammonia solutions, copper chrome arsenate solutions, acids, caustics, coal tar distillates, paints, solvents, poisons and chrome solutions

6 DETAILED SITE INVESTIGATION

The completed preliminary investigation should provide sufficient information to design a detailed soil and groundwater sampling and analysis program specific to the layout of the site and chemicals and wastes which have been identified as potentially present on-site.

The timing of the detailed site investigation can be critical. Where improvements such as buildings and structures, including the USS, are on-site at the time of the detailed site investigation then a full assessment of the site cannot be completed due to restrictions in access to soil and groundwater sampling locations beneath the USS, buildings and structures.

Therefore, the detailed site investigation can be completed at the following stages, with increasing degrees of reliability:

- With the site in its current configuration, ie the USS and all site improvements remain in place
- Following the removal of all above ground site improvements, ie leaving underground improvements including USS and foundations in place
- Following the removal of all site improvements, including USS and all other above and below ground improvements

Completion of the detailed site investigation would ideally occur once all site improvements have been removed to allow access to the entire site, however, such an approach may not be feasible as, for example, the site may be proposed for sale with existing improvements.

Where the site assessor may need to compromise sampling locations due to buildings and structures, the uncertainty posed by lack of adequate assessment should be explained and accounted for in the investigation report.

6.1 ASSESSMENT OF SOILS

The objective of the soil sampling program for sites containing USS should be to identify and delineate the lateral and vertical extent of soil contamination and to arrive at a scientifically defensible and statistically valid data set characterising chemical concentrations in the soil.

Traditionally two samples per tankpit floor and one sample per wall of excavation have been used for validating the condition of soils within a USS excavation. Such an approach may provide a suitable confidence level for smaller excavations, however for the removal of larger storage systems, additional samples are required to obtain a suitable confidence level for potential hot spot detection of a predetermined size.

There are three statistical methods provided in AS4482.1 for determining the number of soil samples required to be taken to:

- Determine the degree of contamination
- Determine the average concentration of an analyte
- Detect a hot spot

To determine the average concentration of an analyte or the degree of contamination requires background information on chemical concentrations and a detailed understanding of imported fill and natural soil properties.

Hot spot size calculations do not require such site-specific contaminant information, rather they rely upon average size of breaches in the USS. Leakage from USS is unlikely to occur over the entire area of the product storage portion of the USS. Based on previous experience, leakage will occur at an opening to the tank, such as fill lines, product lines, etc or at a point of corrosion that may be in the pinhole to fingernail size range. The primary construction methods for older USS is steel which will corrode when left in the ground for long periods of time. Corrosion typically results in pitting of the steel and minute holes in the tank or lines where product may leak.

Such point sources of leakage would result in contaminated soil plumes of small cross section, significantly smaller than the dimensions of the tank. Therefore significant numbers of sampling locations would be required to provide a 95% confidence level that the investigation or validation program of an excavation, formerly containing a USS, can detect such small dimensioned contaminant hot spots.

Sampling the condition of soils surrounding USS is complicated by many factors, including soil porosity and permeability, presence of lenses of varying soil type, heterogeneity, extent of weathering, presence of fill and chemical state, ie vapour or liquid.

Specific locations to be sampled at USS sites include:

- Immediately above any current or former ground water level within the excavation
- The intersection of backfill materials with natural soils
- Concentrated at the base of the tankpit excavation where the more permeable tankpit backfill materials meet natural soils. Sampling will need to extend into natural soils.
- Extending beneath the USS to determine potential for accumulation of chemicals at depth, eg groundwater or non aqueous phase liquid (NAPL).

Hot spot detection should be the preferred method for the assessment and validation of the locations of USS to provide a statistically defensible methodology to determine with confidence that there are no residual areas of soil contamination.

6.2 ASSESSMENT OF GROUNDWATER

Groundwater assessment is critical in the assessment of the potential environmental effects of USS. The assessment of groundwater is a very complex issue. Leakage of USS contents to soil can often lead to low or non detectable concentrations within the soil matrix, although chemical concentrations of the USS contents within groundwater may often exceed drinking water standards. Assessment of groundwater often reveals the true impacts of the USS.

Migration of products that have leaked from USS have been reported to extend 450 metres from the source (Barber, 1996). Average groundwater plume migration lengths from a US study (Rice 1995) have been reported as 120 metres. Groundwater plumes have been reported by Bedient (1994) to extend 1600 metres from the source USS.

Significant seasonal variations and variations across the saturated zones also add to the complexity of groundwater assessment. The Environment Protection Authority Victoria (EPA Victoria, 2002) provides case studies indicating that the costs at a single site for decommissioning (and/or replacement), assessment and remediation resulting from USS losses may reach, and even exceed, one million dollars.

Groundwater assessment should include the following prior to undertaking any physical assessment of groundwater:

- a desktop review of the products stored at the site
- mobility
- site hydrogeology
- potential for preferential flow
- potential for groundwater mounding and resulting radial flow
- bedrock type such as fractured rock
- potential for impacts to deeper groundwater aquifers
- plunging groundwater plumes
- potential for the presence of either light or dense NAPL

The location of groundwater monitoring wells should be sufficient to define the vertical and lateral extent of contamination, taking into account those chemicals potentially present at or surrounding the site. The groundwater monitoring wells should be sited and constructed to allow for adequate information to be derived from any future groundwater monitoring event, ie allowances for seasonal groundwater level variations. For any groundwater assessment at least one groundwater monitoring well should be located directly beneath the former location of the USS. The presence of NAPLs should be investigated. However, the presence or absence of NAPL is difficult to confirm as residual NAPL trapped in soil pores is difficult to observe directly in soil samples and may not readily flow into monitoring wells.

6.3 QUALITY ASSURANCE AND QUALITY CONTROL

The nature of chemicals associated with USS, being generally liquid, highly mobile and containing volatile chemicals, is such that volatilisation, degradation and transformation may affect soil or groundwater sample integrity from the time the sample is recovered. Such processes will also affect soils exposed during remediation works that are proposed to be sampled during remediation works.

Therefore, specific attention to preserving the integrity of the sample should be observed. AS4482.1 provides guidance on sample methodology, health and safety, sample preservation, decontamination of sampling equipment and quality assurance. Specific issues that should also be addressed for USS sites include:

- Providing a chilled environment to store the recovered samples
- Taking immediate and separate duplicate samples for field testing as required
- Identifying appropriate sample locations to reduce the potential for obtaining disturbed samples that may not be representative of the soil to be sampled
- Sampling immediately upon the excavation of soils, ie do not sample excavations at any elapsed time after initial excavation
- Utilising a non reactive liner for sealing of the sample container
- Field work should be managed to reduce all potential for the loss of volatile chemicals
- Sampling from discrete locations or soil types and not obtaining samples over a depth interval greater than 100mm.

Sampling programs should be sufficient to provide a high quality data set that is scientifically defensible. Sample integrity should be maintained through correct sample gathering techniques and suitable preservation. Analysis of samples should be completed in accordance with standard laboratory analysis methodology by laboratories accredited to national standards such as National Association of Testing Authorities (NATA) and in accordance with Schedule B(3) of the NEPM. Sufficient sampling must be undertaken to adequately characterise the site and to provide sufficient data points to provide a statistically valid assessment of the site.

7 SUMMARY

Underground Storage Systems are considered to be one of the major worldwide sources of soil and groundwater contamination.

There are specific issues to be considered for assessment of sites containing underground storage systems in addition to the standard site assessment process as outlined in the National Environment Protection (Assessment of Site Contamination) Measure and Australian Standard AS4482.1.

Persons completing assessment of sites containing underground storage systems need to understand the history of site development and actual use of the site as well as an understanding of the complexities involved in assessing soil and groundwater conditions in order to provide a scientifically defensible and statistically significant data set. Such a data set should be able to be used to provide information for the assessment of human health and ecological risks. Hot spot detection should be the preferred method for the assessment and validation of the locations of Underground Storage Systems to provide a statistically defensible methodology to determine with confidence that there are no residual areas of soil contamination.

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