4.2 Water quality monitoring techniques

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Abstract

Environmental Earth Sciences NSW undertakes water quality monitoring of the remediated landfills across the Sydney Olympic Park parklands in accordance with the Remediated Lands Management Program (RLMP) developed by Sydney Olympic Park Authority (SOPA). Both physical and chemical water quality data is required to assess the condition and development of the remediated lands system, as well as pro-actively monitor the integrity of the remediated landfills.

Obtaining water quality information requires a variety of methodologies of surface water and groundwater sampling. The chosen method is determined on a case by case basis, and may be dependent on a variety of variable including hydraulic conductivity of the water bearing zone, level of contamination present and the well construction at each water sampling location. Examples of the water sampling techniques use include submersible pumps, bailers and tubing with foot valves. Throughout the sampling process, prevention of cross contamination, the collection of a representative sample and a strict adherence to work health and safety (WHS) requirements must be maintained.

Introduction

A crucial component of the management of Sydney Olympic Parks remediated lands is the monitoring of water quality across the parklands. Monitoring of the groundwater and surface water bodies of the site in their current state has been undertaken for approximately 15 years. The monitoring program has been designed and implemented to:

- inform routine and long-term management of the remediated landfill systems;
- enable assessment and reporting of landfill integrity and emerging management issues; and
- ensure any discharges from the system comply with licence conditions.

The need for monitoring is a result of the potentially harmful effects to human health and the environment of the materials contained within the remediated landfills. These can cause both acute and chronic health effects and as such, it is important to monitor the pathways between the sources of contamination (the remediated landfills) and the receptors (human health and the environment). From SOPA (2009), the most common pathways are:

- exposure to leachate – including failure to maintain appropriate hydraulic gradients between leachate drains and local groundwater systems & creeks, breaks in membranes and cut-off walls, broken pipes, pump failures, tanker spills, overtopping of evaporation or treatment ponds;
- exposure to landfill gases – including failure to maintain actively growing vegetation on landfill capping, failure or breakage of gas extraction and venting systems, and build-up of gases in confined places; and
- exposure to landfill solid waste – including erosion or excavation of landfill capping.

The mobility of the chemicals of concern within the remediated landfills into water is an ongoing concern at the site. As a result, a proactive water quality monitoring program is undertaken year round. A conceptual model of the remediated lands is shown in Figure 4.2.1.

This chapter discusses the different methods to undertake water quality monitoring of both surface water and groundwater on site. It will also cover other factors, such as work health and safety requirements, laboratory requirements, and quality assurance measure to ensure the data obtained is accurate and representative of the water systems being monitored. This discussion is focused on the chemical analysis of water, although some aspects of physical analysis will be discussed.

WHS

As part of planning for field work, work health and safety (WHS) requirements must be addressed. As a minimum, the following personal protective equipment (PPE) should be worn at all locations:

- disposable nitrile gloves;
- steel cap boots;
- long sleeve shirt;
- long pants;
- safety glasses; and
- hat.

Other safety equipment used around the site includes work gloves (e.g. rigger gloves or similar), half face respirators with organic, inorganic and fine particle filters, waders and wet weather gear. When sampling from watercraft (tinnies etc.) personal floatation devices should be used. The presence of

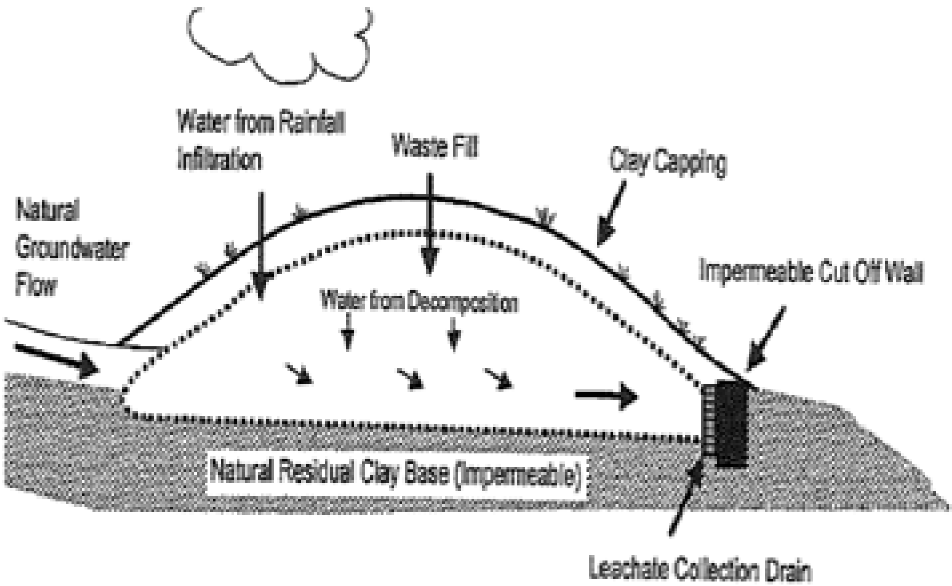

Figure 4.2.1. Typical remediated landfill containment (Source: SOPA 2009).

mosquitoes (Chapter 2.6) should also be considered. A fully stocked first aid kit should also be on hand. This is not an exhaustive list, and PPE requirements should be met on a case by case basis.

Field Equipment

The following table provides a list of equipment required for groundwater and surface water quality measurements at Sydney Olympic Park.

Groundwater Sampling

Groundwater sampling is carried out in the following sequence:

- Measurement of static water level;
- Purge water until representative sample present;
- Measure Field Chemistry Readings;
- Collect Samples; and
- Dispatch samples for analysis.

Each sequence is discussed in detail in the following sections.

Table 4.2.1. Equipment list for water sampling requirements

Job Component	Items
Setting up	• Groundsheet and/or plywood sheet 600 mm square • Work health and safety paperwork • Tool kit • Camera
Cleaning	• Appropriate cleaning implements (e.g. bailer brush, steel brush, bucket) and solutions (surfactant/detergent, clean bucket) • Cleaning solutions, low phosphate detergent • Deionised water
Sampling	• Appropriate sampling devices • Appropriate sampling containers • Appropriate pre-treatment solutions, filtration equipment • 2 x flow through cell • Spare tubing • Field chemical meters and relevant calibration solutions • Spare bottles
Packing up	• Ice filled esky • Rubbish bags

Static water level

Static water level is collected with an electronic dipper. The dipper is activated upon contact with water. This information is used to determine ground water flow direction and to inform decisions regarding purge volume.

As for all equipment used between locations, the dipper is cleaned between locations with detergent, fresh water and deionised water. This reduces the risk of cross contamination. Sampling may also be carried out from locations least impacted by chemicals of concern, to most impacted, thereby reducing the risk of false positives. This is termed sequential monitoring. Sequential monitoring is not, however, an alternative to cleaning equipment between locations.

Purging

Stagnant groundwater in a well is liable to differ from that in the formation due to prolonged contact with sampling materials and/or with the atmosphere as well as to changes in temperature and pressure (Miller 1982). In order to reduce the possibility of such alteration and to ensure that the groundwater sampled is representative of the water in the formation, all wells are purged before sampling.

Groundwater may be removed from a borehole using several different methodologies. Borehole development, whereby water and sediment are cleared from the screened area of a borehole, may require air-lift sampling, particularly after piezometer installation or after a period of disuse.

Purging and sampling methods for groundwater investigations at the parklands are often limited by the diameter of the observation borehole (piezometer) – the vast majority of these at Sydney Olympic Park are 50 mm diameter, with a range of 40 mm to 100 mm.

Where possible, removal of water from the well should be from the top of the water column in the well. This improves the chances for complete removal of the stagnant water in the well. The operator must also be aware that groundwater may be horizontally stratified and sampling should be confined to that section of the bore that has been purged properly. The volume of water in any sand or gravel pack adjacent to the well screen should also be considered, as that water may also be altered from the natural groundwater.

Most sampling guidelines recommend removal of three to ten standing volumes before sampling, where a standing volume is the volume of water in the well above the inlet under static conditions. The industry standard of purging three volumes of standing water, or until dry, has been employed in recent years at Sydney Olympic Park.

As such, a simple calculation for the volume of a cylinder can be carried out to determine appropriate purge water volume. The volume of a cylinder is calculated as:

$$V = \pi r^2 h$$

where V = volume

r = radius, and

h = height.

The height is taken as the difference between the standing water level and the total depth of the well.

For example a 50 mm monitoring well holds approximately 2 L of water for every 1m of standing water in the borehole column. Therefore, 10 m of standing water would equate to a volume of ~20 L, requiring at least 60 L of water to be purged. Purge water across the site is either stored and disposed of by a licensed waste removal contractor, or is returned to the nearest down gradient leachate pump pit.

In free flowing bores[1], field measurable parameters such as pH, electrical conductivity (EC), redox (pe or Eh) and temperature should be monitored as a minimum while purging (dissolved oxygen [DO], dissolved carbon dioxide [CO_2], alkalinity and chloride can also be determined). Stabilised readings of such parameters suggest, but do not confirm, that purging has been adequate. Once field chemical readings have stabilised and/or the standing water level has recovered, a sample may be taken.

Further detail of borehole purging and development methods can be found in the Land and Water Biodiversity Committee (2003) Minimum construction requirements for water bores in Australia.

There are several different techniques used to sample groundwater. These techniques are selected based on the type of well that is being sampled, or the level of contamination within the well. The three main techniques used at Sydney Olympic Park, namely submersible pumps, LDPE tubing with foot valve and bailer are discussed below. A comparison of the methodologies is presented in Table 4.2.2. Low flow and gas-driven sampling techniques are not currently utilised for groundwater monitoring at Sydney Olympic Park.

Sampling methodologies are generally consistent across all remediated landfills onsite. Free flowing wells are generally sampled immediately, while those wells purged dry are allowed to recover for a period of approximately 24 hours. Groundwater wells along Parramatta River are sampled on a falling mid to low tide to minimise the diluting influence of seawater.

Submersible Pump

Submersible pumps are cheap, durable and easy to clean. They are the most effective way to purge large volumes of water from a monitoring well. The pumps run water through plastic tubing and can be powered by a portable battery. They pump at approximately 10 L/min, although this rate varies depending on the depth of the borehole and the type of pump used.

Pumps used on site range in size from whale pumps connected in sequence, which are suitable for use in 40 mm diameter boreholes, to super twister pumps for boreholes >50 mm diameter. Submersible pumps are capable of pumping water from depths of between 6 and 40 metres, although the depths of boreholes at Sydney Olympic Park does not exceed 25 m.

Where used between locations, the pump must be decontaminated by triple rinsing through water with surfactant, tap water and deionised water. As such, the pumps are not suitable for wells with phase separated hydrocarbons.

LDPE Tubing & Foot Valve

Low density polyethylene tubing with a foot valve on the end is primarily used in monitoring wells that are too small for an electronic pump to fit into, or wells that require well specific sampling equipment (well specific sampling equipments will be discussed in Quality Assurance). A foot valve is a

[1] Free flowing bores are those that can sustain continual pumping at the rate applied to them. At Sydney Olympic Park, this is usually ~10 L/min for boreholes with a 50 mm diameter.

Table 4.2.2. Comparison of selected sampling equipment

Equipment	Advantages	Disadvantages
Bailers	• Simple • Portable • No power source	• Sample aeration • Not convenient for purging large volumes or deep boreholes • Slow purge rate
Submersible Pump	• Cheap, durable and easy to use • Can be useful for developing and purging due to pumping volumes • Provide minimally disturbed samples at a good rate	• Require battery power • Not suitable for low yielding wells • Requires careful cleaning if in use between locations
LDPE tubing and foot valve	• Simple • Low ongoing costs for well specific use • Low risk of cross contamination • Minimal aeration of samples	• Requires manual lifting • Inconvenient for wells with high (>20 L) purging requirements
Low flow methods	• Minimal atmospheric contact • Potential reduction in purge volume • Can be used to great depths	• Expensive • Can result in misleading field chemistry results • Requires careful cleaning between locations

small plastic one way ball valve that allows water to move up the pipe when it is moved up and down within the well.

This method was employed at the Sydney International Aquatic Centre Landfill to monitor the progress of a tracer through the landfill.

Bailer

Bailers consist of a rope attached to a length of tubing either sealed at the bottom, or with a check valves to allow entry but prevent exit of water. Bailers are suitable for developing and collecting samples from relatively shallow wells. They must be used with caution where sampling for chemicals of concern affected by volatilisation, degassing or contact with the atmosphere. Such parameters include pH, pe, dissolved gases and volatile organics.

Bailers are inconvenient for removal of large volumes of water or for sampling at depths greater than 5 m below ground level. Great care must also be taken to keep the rope clean and free from fraying.

Bailers are prevented from falling rapidly into the well as this leads to greater disturbance of the water and increases the chances of volatilisation or degassing. It also increases the likelihood that the rope will break or detach itself from the bailer.

If used more than once, bailers are cleaned between samples by rinsing copiously with distilled water (three to five thorough rinses) and with three rinses of water generated in the new well to be sampled (assuming sufficient water is present). If the bailer is initially lowered to just below the surface of the water in the well, the water collected can be used to thoroughly rinse the rope several times before it contacts any other water in the well. Otherwise the rope must be thoroughly rinsed with distilled water before sampling, a difficult task that requires large quantities of distilled water. The water sampled should be taken from next to the well screen or slotted casing in order to maximise the probability of collecting representative samples.

In shallow wells it is possible to use volatile vials or small bottles as bailers. This should reduce the potential for cross-contamination due to the use of the same bailer for all samples. Bailers (or any sampling equipment) may also be dedicated to a particular installation where cross-contamination problems might occur.

Low flow methods

Low flow methods are not used at Sydney Olympic Park. However, given the growing frequency of their use within the industry, they have been included in Table 4.2.2 for comparison. Low flow methods are considered inappropriate at Sydney Olympic Park as the yield of the monitored wells is either insufficient for low flow sampling, or sufficient to the extent that submersible pumps are more efficient.

Field Measurements

Field measurements are the first water quality measurements obtained and are a primary source of water quality data. Field measurements include measurement of the standing water level (as discussed in Chapter 4.1), field chemistry measurements, odours and colour.

Field chemistry measurements collected at all locations are:

- pH;
- electronic conductivity (EC);
- dissolved oxygen (DO);
- oxidation reduction potential (ORP); and
- temperature.

Other measurements may include dissolved carbon dioxide, total dissolved solids and turbidity. Groundwater pH measurements must be taken in the field as pH will generally rise when groundwater is equilibrated with atmospheric carbon dioxide post sampling, this may result in differences between field and laboratory pHs.

Field chemistry measurements provide important information about the related water body, and can be used as a check (against previous results) to determine whether the water is representative of the water bearing zone/surface water body, or if groundwater conditions have changed.

Field measurements should be taken with a water quality meter that has been calibrated to industry standards. The calibration standards applied are:

- pH – two point calibration at pH 4.01 in solution and 7.01 in solution (or 10.01 in solution if water is expected to exceed pH of 7.01);
- EC – one point calibration at 2,760 µS/cm in solution;
- ORP – one point calibration at 280 mV in solution;
- DO – two point calibration at 0% oxygen in solution and 100% air saturation; and
- Temperature – one point measurement of room temperature.

The electrodes of the meter being used are then placed into a flow cell, which allows the groundwater passing the electrodes to be as representative as possible of the aquifer from which the sample is being collected. If the groundwater is being pumped, the outlet of the pump is placed at the base of the flow cell so that the groundwater being tested is constantly replenished, and any change in the field measurement parameters can be observed. Minimal disturbance of the sample should be attempted as this can cause the water to become aerated, and the field and chemical parameters can be altered.

Odour and colour are taken from a clear sample bottle, free of preservatives. The presence of any non-aqueous liquids (e.g. phase separated hydrocarbons) is also noted.

Surface Water Sampling

Surface water sampling at Sydney Olympic Park has been undertaken across five different water body types:

- Fresh water creeks (such as Boundary Creek);
- Marine or intertidal creeks and waterways (such as Haslams Creek and Parramatta River);
- Treatment ponds (such as those in Wilson Park);
- Freshwater ponds (such as Narawang wetlands); and
- Evaporation ponds (such as Bicentennial Park evaporation pond).

Surface water samples are collected in different ways depending on the surface water medium.

If the surface water sample is to be collected from a stagnant source such as a pond, leachate dam or small lake, care is taken to sample away from sources which may unnaturally influence the readings (e.g. duck faeces, surface scum, etc). A sample is collected manually from towards the middle of the pond without disturbing the sediment on the bottom. The bottle is held at the base and is plunged neck downward below the

Table 4.2.3. Container types, preservation groups and recommended holding times.

Classified by Parameter			
Parameter	**Container Group[1]**	**Preservation Group[2]**	**Recommended Holding Time**
BOD	A	1	4 hours – 2 days
Colour	A	1	1 – 2 days
Cyanide	A	3	1 day
Dissolved Oxygen	C	1	4 – 8 hours
Metals*	A	1	1 – 28 days
Nitrogen: Ammonia	A	6	1 – 7 days
Kjeldahl	A	6	1 – 2 days
Nitrite	A	6	1 – 2 days
Nitrate			
Oil and Grease	A	2	1 – 28 days
Phenols	C	4	1 day – 28 days
Organics (aromatics)	C	5	7 – 14 days
Polynuclear aromatics	C	1	7 days
Monoaromatics	C	1	7 days

[1] Container Groups
A = Polypropylene, polyethylene, glass or Teflon
B = Polypropylene, polyethylene or Teflon only
C = Glass only (foil or Teflon cap, no head space)
[2] Preservation Groups
1 = 4°C or below only, unfiltered and stored in the dark
2 = 4°C or below, H_2SO_4 (pH<2)
3 = 4°C or below, NaOH (pH>12)
4 = 4°C or below, H_3PO_4 or H_2SO_4 (pH<4), l g/L $CuSO_4$
5= 4°C or below, 0.008% $Na_2S_2O_3$
6 = 4°C or below Phenyl mercuric acetate

surface. It is then turned upwards, without allowing air into the sample bottle, until the neck points slightly forward. The bottle is filled to the top. Samples are stored in a chilled esky and dispatched to the laboratory on the same day as sampling. If the samples cannot be taken to the laboratory on the same day of sampling, preservation of samples as discussed in Table 4.2.3 should be carried out in the field.

If the surface water sample is to be collected from a flowing water source such as a creek or river, the sample bottle should be rinsed thoroughly in stream water (where no preservative is required). For samples collected from marine or estuarine waters, sampling should be conducted on a falling mid to low tide, so as to minimise the diluting influence of seawater.

Laboratory Requirements

For correct analysis procedures to be adhered to, laboratories have specific requirements for sample size, sample container type and sample preservation. This ensures that the sample is received by the lab in an appropriate condition for analysis.

Depending on the laboratory used, there may be a requirement for certain sample bottles to contain preservatives. Table 4.2.3 presents a list of bottles used for all water sampling at Sydney Olympic Park, their corresponding preservatives, and the chemicals of concern that are currently analysed from each bottle.

Sampling containers vary for each analyte. Sample containers for metals and major cations or anions should be hard polyethylene or polypropylene. Most samples for inorganic parameters and indicators can be stored in plastic. Filtering removes particulate matter that if dissolves into solution, can bias the water analysis. Samples must always be filtered before acidification (preservation) because of the possibility of dissolution of metals on colloidal or suspended material.

However, it is preferred that no preservation is undertaken during sampling and the samples are stored in a chilled esky. This is because of the consistency enabled by laboratory sample preparation. We have found no significant differences in dissolved metal concentrations between samples that are field filtered and laboratory filtered within 24 hours of sampling. When analysing for metals, the sample should be filtered using (at least) 0.45 µm filter paper in order to remove suspended solids and colloids from the sample.

Samples should be transported to the laboratory within the holding times for each scheduled chemical of concern. This ranges between half a day to 28 days, as per Table 4.2.3.

Transportation of groundwater samples needs to be in sealed containers/coolers/boxes that are chilled and kept dark, and which have been packed to prevent the risk of breakage or spillage of samples. The containers should include all chain of custody (COC) documentation and should be tracked between the field and laboratory. Groundwater samples should aim to be delivered to the laboratory within 24 hours of collection, or 48 hours at a maximum.

All organic parameters are best stored in amber glass bottles/ vials with Teflon caps. Glass containers are used for organic indicators because of the increased adsorption of organics to plastics. Samples for BTEX compounds should be collected in small vials. Samples for volatile organics or gases should be free of void (head) space. The bottles should be filled to overflowing and capped so as to keep out air bubbles. If possible, sample bottles should be filled such that the sample water displaces the air in the bottle. This prevents any volatile compounds from being lost in the head space within the bottle.

Quality Assurance

Quality control samples provide information that ideally discounts any errors due to possible sources of cross-contamination, inconsistencies in sampling and checks on the analytical techniques used. Blank samples are required in order to monitor the introduction of contaminants or interference's into the sampling and analysis programs that may lead to the reporting of false positive data. The most common types are field, trip and laboratory blanks.

Field duplicates are a set of two discrete samples collected from the one sampling point. They are submitted to the laboratory as two independently labelled samples. Field duplicates are used to assess the combined precision of sampling, sample preparation and analysis. In water samples, significant variation in field duplicate results is often a result of colloidal material penetrating filters (e.g. for dissolved metals) or the present of phase separated hydrocarbons.

Field duplicates may be used to identify the variation in analyte concentration between samples collected from the same sampling point and/or also the repeatability of the laboratory analysis. For every 20 samples taken one set of blind samples should be collected. These samples should be submitted to the laboratory as two individual samples without any indication to the laboratory that they have been duplicated.

Trip blanks Trip blanks are used when project analytes include volatile organic compounds (VOC). Trip blanks are prepared by placing VOC free water (usually laboratory prepared deionised or distilled water) into VOC collection vials These are handled in the same manner as regular VOC sample collection vials (i.e. they are transported to and stored in the field, placed in ice chests and returned to the laboratory for analysis) with the exception that they remain unopened within the field. The collection of trip blanks enables the measurement of incidental or accidental contamination of VOCs during transportation. The rate of trip blanks varies, dependent on frequency of sampling and chemicals of concern.

Field rinsate blanks are samples of water from a known or controlled source (that ideally do not contain project analytes such as laboratory prepared deionised or distilled water) collected by sampling personnel in the same manner as regular samples. The associated sampling equipment is rinsed with this water at the completion of equipment decontamination. The rinsate is collected directly into the same types of containers used for regular samples. The collection of field blanks enables the measurement of incidental or accidental contamination during sampling, transport, sample preparation and analysis.

Rinsate blanks should be collected at the rate of one per sampling round, or one per 20 samples, whichever is the lesser.

A chain of custody (COC) should be completed on the departure of the samples from the site or office. The form should provide the following information:

- the sampler;
- nature of the sample;
- collection date;
- analysis to be performed;
- sample preservation method;
- departure time from site; and
- dispatch couriers.

Summary

We have attempted to outline a brief description of general field practices used for water quality monitoring at Sydney Olympic Park. The methods described are not exhaustive and should not necessarily be considered appropriate at other locations. Instead, the preferred method should be on a case by case basis, depending on client requirements, water type, water physical and chemical factors, timing considerations and with consideration of applicable legislative frameworks.

References

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