NATIONAL SOILS CONFERENCE

Canberra 18-23 November 2018

Conference Tour, Wednesday 21 November, 2018

Urban Soils

SOIL SCIENCE AUSTRALIA

Anzac Park East, unused since 1998 and contaminated with asbestos[1]

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Kelly Lee (SESL)
John O'Brien (Agon Environmental)

Introduction

Canberra prides itself on being progressive and innovative, and this means more than marriage equality and cultural holidays.

New soil science technologies and project management techniques are used at a number of sites across Canberra to maximise the benefit of the soils encountered, preserve Canberra's natural features, and minimise soil waste—potentially big problems in a city subject to intense urban development.

This field trip will explore how urban soil science has been used to landscape Canberra's newest infrastructure projects. We will explore how physical and chemical soil science has been used to transform thousands of tonnes of slurry into reusable soils and we will see how one of the most contaminated industrial sites in Canberra has been transformed into a peaceful up-market suburb (Figure 1). We'll travel via Canberra's new Light Rail and via bus, and discuss some of Canberra's unique soil features which have been protected from development including arsenic laden gossans, acid-sulfide rock deposits, the pedoderm, and its paleochannels while we go. This field trip is fully catered and comes with an ice-cream stop.

You'll need to be wearing **sturdy shoes, long sleeves, sturdy footwear, and sunglasses or glasses**. **You'll also need to wear long trousers or pants to meet safety requirements in place at different stops along the way.** You should bring a hat, sun-cream, and have a drink bottle and be capable of walking up to an hour at a time through the field sites.

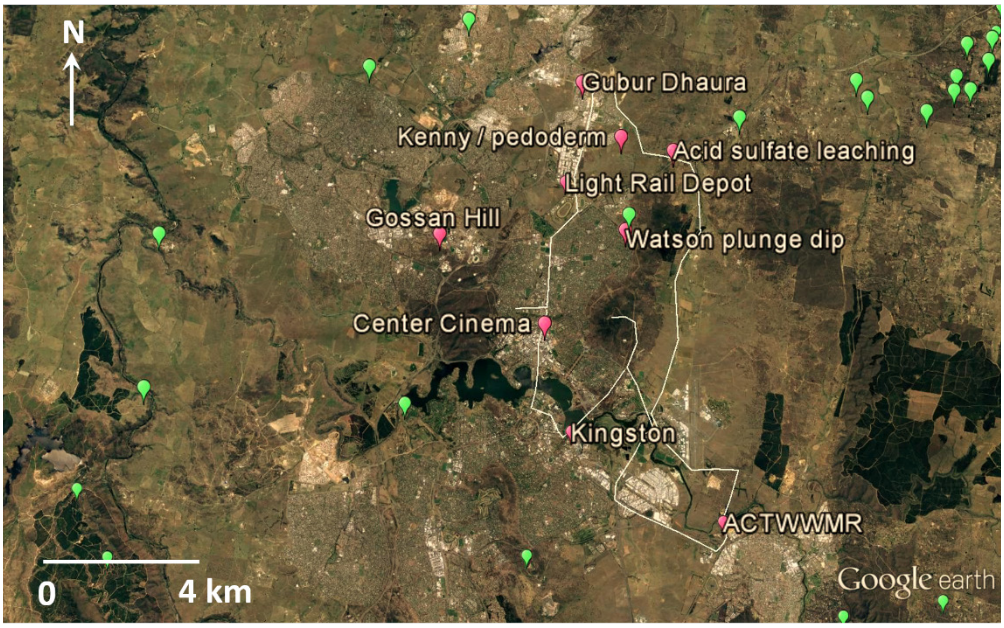


Figure 1. Features of the Urban Soils Field Trip. Green icons indicate metal deposits / mines, pink indicate other features discussed on the field trip

Timetable

From	To	Activity	Tour stop
		Toilets available – Hyatt Hotel	
0830	0900	Leave for Mitchell Light Rail Depot	
0900	0930	Trial plot for Canberra Metro—Mitchell Light Rail Depot	1
0930	1000	Terra Boxes for Canberra Metro—Gungahlin Town Centre	
		Toilets available—Gungahlin Town Centre	
1000	1030	Morning tea	
1030	1100	Leave Mitchell Light Rail Depot for Oaks Estate	
1100	1200	Oaks Estate – ACT Waste Water and Mud Recyclers	2
1200	1230	Leave Oaks Estate	
1230	1315	Lunch - Arrive top of Mt Ainslie for Picnic overlooking Canberra	
1315	1335	Leave top of Mt Ainslie	
1335	1430	Kingston Foreshore	3
1430	1500	Afternoon tea	
		Toilets available—Kingston Foreshore	
1500	1530	Leave Kingston Foreshore	
1530		Arrive back at Hyatt	

Stop one (9.00 to 10.00)
Urban soil science—Trial plot for Canberra Metro

Kelly Lee, SESL Australia

The current environmental trends of increases in temperature, reduced rainfall, growing infrastructure and urbanisation are placing greater pressure on governments to move towards a more eco-friendly, more sustainable future where an increased number of greener and cooling public spaces can be implemented and maintained, where the quality of water draining into our waterways is improved and where our natural resources are managed in a more sustainable manner.

The Canberra Light Rail project is the nexus between a sustainable greener future and an ambitious vision for the future growth of Canberra. Once completed, the project will provide greater connectivity and enable better capacity management of future growth corridors to the city centre.

It will also accommodate a multi-functional urban environment with distinctive visual swathes of green spaces for the community to enjoy and where thoughtfully placed eco-friendly infrastructure supports and improves the delicate local ecosystem.

The engagement of a soil science specialist during the early stages of the design process was critical to the ultimate success of the project. Canberra soil is renowned for being predominantly infertile, with degraded topsoil lacking a strong nutrient foundation and the ability to support any proposed high-quality landscape plantings. Incorrect soil treatment, inappropriate soil management and failed plantings would all incur significant additional costs and impact delivery deadlines if not managed correctly.

SESL's Overview

SESL Australia Pty Ltd (SESL) was delighted and proud to be selected to contribute our extensive knowledge and expertise to the success of this major lifestyle project for Canberra.

SESL Soil Scientists were able to prescribe precise site specific and plant specific treatment programs for topsoil and subsoil mixes which were uniquely designed for the ultimate intended use, utilising site-won resources.

To improve the harsh soil conditions, SESL designed new soil formulations based on the ability to make use of available site topsoil and considering the proposed planting species, with specific soil treatments/amendments tailored for the project.

SESL was therefore able to deliver a more environmentally sustainable project by assessing existing site topsoil for suitable reuse which minimised the need for imported topsoil, additional treatments, and reduced the risk of plant failures. These strategies ultimately lead to significant savings in project costs.

SESL's involvement in the project began with a detailed soil survey along the rail corridor to determine the quality of the available site soil as a reusable resource and its suitability for landscape development. We inspected more than 50 locations along the corridor from 2015 to 2017, and ran a series of chemical and physical analyses on multiple samples of the topsoil and subsoil (nutrients, cation exchange, particle size grading, hydraulic conductivity etc.) from a large number of sites along the rail corridor (Figure 2, Figure 3, Figure 4).

We identified different variations in the quality of the available soil resources from site inspection analysis, including acidic topsoil, magnesic topsoil and subsoil, and nutrient deficient topsoil. Most of the soil was prone to compaction as well. Some areas had imported topsoil that was of better quality.

As a result of the survey, site specific soil treatments were prescribed, with unique soil compositions designed for each type of landscape development, taking into consideration the quality of the available soil resource, the specific proposed landscape development, and the practicality of large-scale construction in the soil improvement program.

SESL also assisted in trials of the specifically designed soil using the proposed landscape plantings. These trials were conducted at specific trial plots located at the light rail depot and are now a permanent feature of the project (Figure 5).

Figure 2. One of the first test pits inspected with better quality topsoil

Figure 3. This trench had residual backfill sand material, common along the corridor where existing services are within vicinity

Figure 4. This was a road verge with fill material, hardly any suitable site soil resource for reuse

Figure 5. Start of the trial plot – September 2017

Our assistance proved invaluable in designing soils for vaulted tree planting areas for advanced tree planting in locations with limited soil for root growth. Think about street trees in urban environments where no soil is visible, it's all paved (Figure 6)! How do we ensure the trees will grow and become well established over the next 20 years? Where do roots go? How are we going to irrigate or add fertiliser? This is a critical aspect for the project as these areas typically have the highest amount of pedestrian traffic and the trees in these areas supply important green infrastructure to all users.

The most critical assistance provided by SESL was our expertise and advice, backed by extensive experience on previous projects regarding the most appropriate and economical use of the limited available topsoil, including validating imported site topsoil and assessing its suitability for use on site.

Soil must possess specific characteristics and properties in order to provide a strong foundation for its intended use. SESL's science based approach determined the most appropriate soil characteristics and properties that would support optimal and sustained plant growth for the project, regardless of the challenges. This included, in the event of insufficient site topsoil, that imported topsoil was assessed and validated by SESL Soil Scientists to ensure it could support the landscape as required, and to prescribe any treatment necessary (Figure 7).

As a result of the soil analysis and recommendations made by SESL Soil Scientists, the completed landscaping for the Canberra Light Rail project management will now include mature eucalypts trees, native dryland grasses, and an urban meadow of wildflowers and turf. These plantings allowed the vision of a greener and more sustainable space to be achieved and enjoyed now and into the future.

The importance of applying soil science in urban landscape infrastructure

The strategic use of soil science incorporated into the early stages of major projects is integral to the overall and long term success of these projects.

Historically, major landscape design projects, such as this one, usually have a specific landscape design (and plant species selection) completed before the site soil is assessed for its suitability for the design. However, it is more practical to first determine the quality of the soil and its planting suitability, and then create the landscape design, rather than try to ameliorate the soil to make it suitable for a pre-existing landscape design (and species selection).

An example of this strategy is the selection of trees in Northbourne Avenue. The trees in Northbourne Avenue prior to the project had been deteriorating for years, and the initial species selected to replace the trees was Scribbly Gum. SESL was engaged to determine if the soil and site conditions along the corridor would be able to support the selected tree species, and our assessment found that the soil was not suitable. This determination was based on the chemical properties of the soil in Northbourne Avenue, and that Scribbly Gum are typically found growing in impoverished soils on higher grounds (Mt. Ainslie) and not on low lying areas. If the project had proceeded without assessing the suitability of the soil for this tree species just imagine the significant risk it would have posed to the iconic linear infrastructure of our capital city!

Figure 6. This is a photo of a light rail system (tram) in Barcelona. Look at the tree plantings in limited space and surrounding services!

Figure 7. Some of the imported topsoil (better quality!)

Improved sustainability by using existing site soil resources to support urban landscape design is another area where SESL was able draw on its extensive project experience to offer additional support. This strategy assists in reducing costs by reducing the need for imported topsoil, thereby reducing the need for/ cost for amelioration.

High profile projects simply cannot afford to have failed plantings as this aspect of the project is the most visually significant and contributes greatly to the overall aesthetics of the project design. Generally, contractors, as a conservative measure, allow for a percentage of defective plantings or failed plantings. In addition to increased project costs caused by failed plantings, the resulting delay in project completion has further consequences. Factors that need to be considered are increased costs of soil treatment to ensure successful planting. This includes ameliorants, labour costs for treatment, pro-longed maintenance costs, costs incurred in acquiring additional plants, including time delays for advance tree plantings. Not to mention delays in project completion and associated additional construction cost can be project prohibitive.

Challenges

The Canberra location itself posed its own unique challenges for the project. Canberra is an inland city with challenging soil and climate conditions that need to be overcome in order to successfully support landscape development projects in the area. We are 'blessed' with harsh weather conditions with extreme heat in summer, severe lack of rain and long periods of winter with persisting daily frost. Canberra's weather patterns allow only limited periods of time for planting in autumn before the cold winter weather arrives, and in spring prior to summer heat waves.

Canberra soil is also typically infertile or has low fertility. Most development sites typically have very little topsoil and shallow rocky soil profiles (Figure 8 and Figure 9). Local topsoils are either acidic, or magnesic – this further contributes to low quality topsoil and requires treatment/amelioration to support plant growth. Magnesic subsoil also poses concerns from an erosion perspective as it has a weaker soil structure.

Also, a large portion of the project area had very limited topsoil due existing infrastructure (Figure 10).

Figure 8. Imported fill with no topsoil under a slab in a part of the project area thereby limiting the soil resource available for reuse. A large portion of the project area where there was bulk earthworks was similar to this, hence limited available soil resource

Figure 9. Where's the topsoil?

Additionally, project sites generally pose their own challenges such as soil compaction on planting sites from heavy construction vehicles. There can also be limited space in some areas to plant trees and to allow for sufficient root growth (root zone) due to the proximity of concrete slabs and/or the presence of large amount underground services in highly urbanised areas (i.e. light rail stops or city (Figure 10)).

Figure 10. Trench with services and limited topsoil

SESL Australia's soil science specialists have extensive and varied project experience and are therefore able to view major landscape development projects holistically from beginning to end and, more importantly, into the future. Engaging soil scientists in the early stages of a project can contribute enormously to the overall success of all aspects of the project.

Lunch stop (12.30 to 13.15)

Mount Ainslie—Canberra's contamination in context

Present day Canberra is a city purpose-built for bureaucracy and has largely avoided the negative impacts of large-scale polluting industries such as chemical factories and manufacturing plants, to which other industrial cities are subject. It has not avoided pollution altogether, however, with more than 1000 contaminated sites recorded in the ACT[2]. This includes probably the first recorded instance of hydrocarbon contamination of groundwater in Australia[3]. While some of Canberra's contamination would be better described as natural metals enrichment, in many other instances contamination is or was the result of human activity.

Geological context

Some sites and related soils in the Canberra region are naturally metal-rich and have been exploited by people for tens of thousands of years. Initially Canberra's indigenous peoples, the Ngunnawal, mined iron-rich gossans/ironstones for ochre, with evidence of such mining at Gubur Dhaura in Franklin (Figure 11). This site was also prospected for other metals by early European settlers, before being used as a source of kaolin (pipe clay)[4,5]. It is today preserved as an historic and educational site.

Figure 11. Historical artefacts at Gubur Dhaura, Franklin, surrounded by iron-rich soils and iron stone. Photo collected July 2018

Other metal-enriched deposits have been prospected or mined in the ACT and surrounding region in the 1800s and 1900s. These include deposits of tungsten, bismuth, molybdenum, barium, antimony, and iron, but more commonly gold, lead, copper, zinc, and silver[6]. These sites have left behind a large and obvious scarring on the landscape in some locations, such as at Captains Flat, where tailings, railways, and shafts are obvious to passers-by and are now part of our mining heritage. In most other locations such as at Mt Ainslie (manganese), Mugga Lane (lead), Spence (copper and gold), and Nicholls (gold), these mine sites either yielded low volumes of metals or were backfilled (Figure 12). With little visual indication of their former presence. It is only when analyses of soil samples undertaken as part of routine contaminated lands assessment indicate metals/metalloid concentrations above guideline levels that there are indications one might be on an area of mineralisation. Arsenic, nickel, lead, manganese, beryllium, silver, zinc, and copper are all elements considered contaminants of concern, which can naturally occur in high concentrations, and potentially over the National Environment Protection (Assessment of Site Contamination) Measure 1999 guidelines[7].

Remediation of these dips an integral part of the urban land development which has occurred continually here for more than a century. The livestock seen grazing the paddocks between suburbs indicate suburbs yet to be developed, and for which remediation and assessment has either not yet been undertaken or for which further development has been deemed unviable at this stage.

Figure 12.Metal-sulfide bearing Ainslie Volcanics near Mt Majura north of the Watson site which contains high concentrations of arsenic. Photo collected at the intersection of the Federal Highway and Majura Avenue, July 2018

Anthropogenic contamination

The sheep and cattle grazing which became widespread in the Canberra region prior to its establishment as Australia's capital, led to perhaps the first source of anthropogenic contamination—sheep and cattle dips. These were used to remove ticks, with arsenic compounds, later replaced by DDT, as the active ingredient in cattle dips due to tick resistance in the 1950s before this too was phased out in the 1980s[8]. Arsenic was flocced from the dips using lime, drained out of the dips, and buried beside the yards prior to the use of DDT. There are 153 cattle or sheep dips recorded on the ACT's contaminated sites database, in suburbs including Lyneham, North Lyneham, Watson, Downer, and Kenny[2,9]. The Watson sheep dip site was particularly complicated as the major source of arsenic present was found to be arsenic-rich rock and soils rather than the sheep dip, which was later remediated[10] (Figure 13). Arsenic in the rock was found to be much more bioavailable than in soils. Hydrocarbons also contaminate Canberra's soil and groundwater and this is primarily caused by underground fuel storage[11]. Plumes are known to have occurred at Civic, Braddon, and Mitchell with plumes of other contaminants occurring at Hume (phenol, tanin, and chromium), Pialligo, and West Belconnen (organic pollutants and heavy metals)[12,11].

Figure 13. Shorty's, where the Center Cinema was once located (left). Building construction at the corner of Mort and Elouera Streets where the former NRMA building was once located (right). Photo collected July 2018

The Civic plume was the first reported petroleum contamination of groundwater in Australia. It was discovered as the result of a fatal explosion in February 1977 after petroleum vapours intruding into the Center Cinema were ignited when pipes were being welded[13,3] (Figure 13). A plumber died and his assistant was injured in the explosion[3]. Fumes had been reported in the building since 1976 and petrol seeped into the building through the groundwater drainage system after periods of heavy rain. At the time, this building was located in the deepest excavation in Canberra and intercepted groundwater carrying the plume south from service stations in Braddon. There were twenty service stations and vehicle workshops with more than 60 underground petrol tanks in Braddon at the time[3]. The hydrogeological investigations initiated after the fatal Center Cinema explosion found that the plume was 4.5m deep in places, covered 5.3 ha, and contained 32 000L of petrol[3].

A separate and unconnected plume was discovered at the NRMA building in Braddon (corners of Northbourne Avenue and Elouera Street) in 1978, nine years after it was built. It covered an area of about 300m^2 and contained 2000 L of petrol (Figure 13). It was considered this plume was caused by overfilling of an underground storage tank—due to this tank being free of leaks when excavated.

Stop two (11.00 to 12 .00):
Soil science—ACT Waste Water and Mud Recyclers

Julia Jasonsmith, Murrang Earth Sciences

Non-destructive drilling has grown from infancy to the main means of service location in the ACT over the last five years. This is because it allows soils to be safely excavated from above underground services.

Prior to the construction of ACT Waste Water and Mud Recovery a slurry generated by the non-destructive drilling process was disposed of as waste at its waste facilities or dried using highly labour-intensive bunded areas. Two of the three facilities which currently accept drilling mud in the ACT—these being Concrete Recyclers and Mugga Lane Resource Management Centre—are sites where drilling mud is still dumped.

At ACT Waste Water and Mud Recovery, drilling mud is instead transformed into its component soil and water parts. Between 100 and 400 tonnes of mud is delivered to this facility every month, with water contents of between 50 and 95% and conversely 5 to 50% as solids. The facility only accepts Virgin Excavated Natural Material (VENM).

On 1 July 2017, the ACT Government brought into effect the Waste Management and Resource Recovery Act 2016 (Waste Act) with the object of increasing recovery and reuse, minimising landfilling, and to drive best practice, investment and innovation in the waste sector. As the aims of this Act become fully realised, it is anticipated that facilities such as ACT Waste Water and Mud Recovery become increasingly important to the ACT. The facility is not without its challenges however, with limited space and flocculation of solids from the liquid component of drilling mud a continual challenge. Drying of the mud can only occur to a certain extent also and the mud must be stockpiled and dried for some time before reuse also.

Figure 14. (Left) Non-destructive drilling (back-of-hole) and hydrovac (front-of-hole). (Right) Drillers mud being emptied from a hydrovac truck

Stop three (13.35 to 15.00):
Contaminated lands—Kingston Foreshore

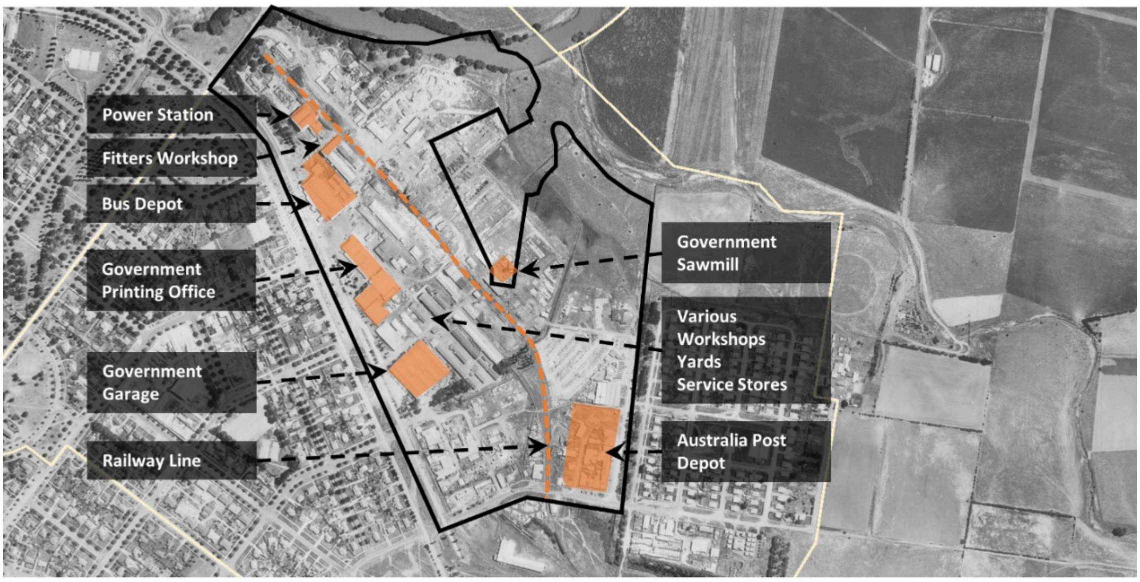
John O'Brien, Agon Environmental

The Kingston Foreshore is one of Canberra's first suburbs and its establishment dates back to the early 1900s. It hosted the city's first 'commercial/industrial zone' and played a critical role in the development of Canberra as we know it today. It should be noted that 'Kingston Foreshore' was initially planned by Walter Burley Griffin to be an interim industrial area for the city. All buildings were meant to be constructed of timber or other materials that could be dismantled and relocated.

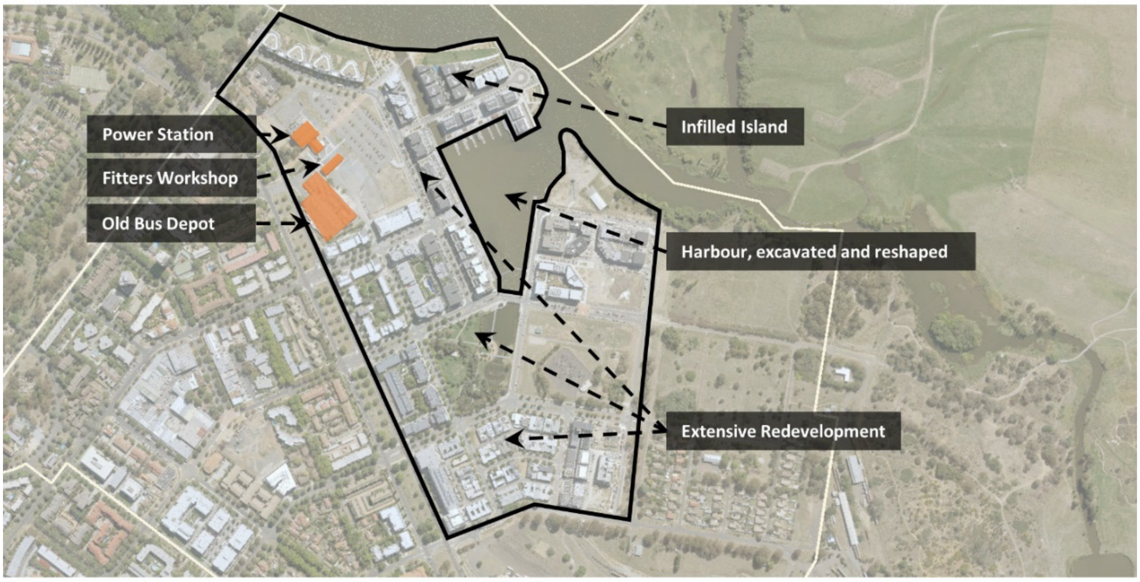
Key features of the Kingston Foreshore:

- The Kingston Powerhouse (i.e. the Glassworks): The first permanent building constructed in Canberra. At this time, it was considered the most modern power station in Australia and reflected the forward thinking of the engineers involved responsible for the establishment of the nation's capital.
- Excavation and dredging of Lake Burley Griffin for the construction of a boat harbour.

- Ancillary industrial/commercial services were subsequently built within the Foreshore, and included:
    - A wide range of workshops and stores including an explosives store, engineering services, coal bunker, timber mill, and bus depots
    - Australia Post Depot
    - Government Printing
    - A railway line that extended to the City and Fyshwick.



Kingston Foreshore – 1952



Kingston Foreshore – 2018

Figure 15. Redevelopment scale of the Kingston Foreshore (1952-2018). Base image retrieved 10/10/2018 from http://www.actmapi.act.gov.au/

As the city continued to grow industrial services shifted away from the Foreshore into more purposefully zoned suburbs such as Mitchell and Fyshwick. In addition much of the infrastructure had become redundant with the Power Station no longer used for the supply of electricity.

In 1995, the newly formed ACT Government initiated a land swap to acquire the Kingston Foreshore from the Federal Government and began to plan its redevelopment. This redevelopment initiative is most recently known as the Kingston Foreshore Development Precinct (KFDP) and aligns with Walter Burley Griffin's vision for this part of the City. Since 2004 the Kingston Foreshore has been progressively redeveloped to include high density residential apartments and public open space. The major activities involved in the redevelopment include:

- **Removal of redundant infrastructure:** Large scale demolition of industrial and commercial buildings and underground assets.
- **Contaminated land rehabilitation:** Extensive soil and groundwater testing and large-scale remediation of contaminated soils associated with former land uses. Primarily this involved the remediation of hydrocarbon and creosote impacted soils through 'land farming'. All environmental assessment works were subject to review and endorsement by an independent Environmental Auditor.
- **Physical reshaping of the Foreshore.** The Harbour was backfilled, dredged and reshaped to its current form. Other areas of the Foreshore were infilled to meet the final design levels of the Precinct.
- **Re-use of materials:** As a means to promote sustainability and minimise soil disposal costs, soils determined not to be contaminated (in other words, 'clean fill') were reused in filling/reshaping of the Foreshore.

What are some the Challenges when managing a long-term Contaminated Land Project? Examples relating to the Kingston Foreshore Project are:

- **Change in regulation / cleanup requirements:** The contaminated land industry transitioned into recognising Asbestos Containing Materials (ACM, i.e. bonded and friable asbestos) as a soil contaminant that poses an actual human health risk.
- **Change in standard re-use of site soils**: Much of the Foreshore infilling was undertaken using man made fill and soils excavated from the surrounding demolition and remediation works.

During early site redevelopment works in the early to mid-2000s, guidance documents for the quantitative assessment for the presence of asbestos and management in soils in a residential development were not available in Australia. This led to the possible presence of asbestos materials being acknowledged in initial reporting, however in the context of it being a nuisance waste material rather than a contaminant requiring specific assessment and management.

In practice, this meant the Kingston Foreshore contained a varying and unknown quantity of asbestos contaminated soils that require consideration during construction works, these considerations included:

- Classification of soils for offsite disposal
- Increased health and safety requirements during construction works (PPE, worker awareness, asbestos air monitoring etc.)
- Limitations for the potential re-use of soils containing asbestos
- Ongoing management post construction to account for possible future exposure during routine and non-routine works (i.e. tree planting and underground service repairs)
- Cost implications for increased environmental management and disposal costs of soils determined to be contaminated with asbestos

The Kingston Foreshore development highlights that industrial land can be redeveloped to a higher land use standard, and contaminated soils, when managed properly, can be reused on residential sites.

However, challenges can arise due to the evolving nature of the land contamination industry due to the growing scientific understanding of risks from known and emerging persistent contaminants of concern. Another recent example of an emerging contaminant of concern causing disruption to the contaminated land management field is PFAS.

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