Brownfields development in the Australian Capital Territory: a model for best practice environmental remediation in Australia

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Abstract

Within the central portion of the capital city of Australia, Canberra, lies Lake Burley Griffin along the edge of which an A$1 billion brownfields redevelopment project is currently in progress. For a comparatively young city with a limited development history, the legacy of past industrial land uses was somewhat unexpected for project developers and financiers. The discovery of a significant hydrocarbon contaminant plume had serious implications for project cost and time schedules. Initial site investigations revealed a hydrocarbon contaminant plume emanating from a former bulk storage fuel facility at the site; ash from a former coal fired power station was also identified as a contaminant. Subsequent investigations revealed a large portion of the site that required soil and groundwater remediation. A Remedial Action Plan (RAP) was developed that encompassed the principles of Ecologically Sustainable Development (ESD) adopted for the overall project within a cost effective and time efficient framework. The eventual remediation project set new benchmarks for environmental remediation in the Australian Capital Territory and demonstrated the importance of technical innovation as well as implementation of sound engineering and scientific practices during such remediation projects.
Keywords: brownfields, industrial, contaminant plume, soil and groundwater remediation, innovation.

1 Introduction

The Kingston Foreshore Development precinct, adjacent to Lake Burley Griffin in the Australian Capital Territory (ACT), is the most significant urban

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redevelopment project to be undertaken in the ACT. Initiated by the ACT Government, it has involved the urban renewal of historical industrial areas into a significant new consolidated residential/commercial precinct, which has its focus on the waters of artificially created Lake Burley Griffin. This urban renewal project is typical of many occurring throughout the world where under utilised brownfield sites are being remediated and redeveloped with the objective of transforming them into modern residential/commercial areas incorporating the principles of ecologically sustainable development (ESD).

One of the major elements to be undertaken at the Kingston Foreshore Development prior to the redevelopment was the remediation of the former Commonwealth Tank Farm which is located near the centre of the development precinct, and forms a significant proportion of the Development area. The remediation project involved the identification, excavation and validation of approximately 30,000 m^3 of contaminated soil, associated treatment of soil and groundwater, and site restoration. All works undertaken were required to satisfy the local environmental regulator, Environment ACT, and an independent Environmental Protection Authority appointed Site (Contaminated land) Auditor.

2 Site history and background

The Kingston Foreshore Development covers an area of 37 ha of former industrial land closely associated with the historical development and operation of Canberra from its earliest days to the mid 1990's. The site location is shown in Figure 1.

The Kingston Powerhouse, which provided coal-fired power to Canberra in its early days, was the first permanent building in Australia's National Capital [1].

South of the powerhouse, the central area of the site became a centre for vehicle operation and maintenance and contained parking, maintenance and administrative facilities for the Department of the Interior car and bus fleets. Facilities in this area also included a Government fuel station which was later operated as a commercial fuel outlet.

The central area of the site also housed the original Australian Government Printer (AGP), which was established to serve the Parliament of the Commonwealth when it relocated from Melbourne to Canberra in 1927. The central and southern areas of the site also housed over time a variety of works depot and storage facilities and functions, including a sawmill and the former Commonwealth Tank Farm which was an above ground fuel storage facility.

3 Site contamination issues

The subject area of the site, namely the former Commonwealth Tank Farm was contaminated, principally through historical release of hydrocarbons fuels from a number of large above ground storage tanks, and to a lesser extent by power station ash. It was characterised by:

- Total petroleum hydrocarbon (TPH) contamination in soil over an area of approximately 7,000m^2 extending to a depth of up to 6.5m below ground surface (and below the groundwater table) resulting in a total volume of approximately 30,000m^3 of contaminated soil.
- A shallow groundwater table (less than 2.5m depth to water) with dissolved phase hydrocarbons in groundwater over an area of approximately 10,000m^2.
- Some localised areas of Light Non Aqueous Phase Liquid (LNAPL), characterised as diesel fuel reached a maximum thickness of 25mm at the interface of the groundwater and unsaturated zone (as measured on the groundwater surface within monitoring bore installations).

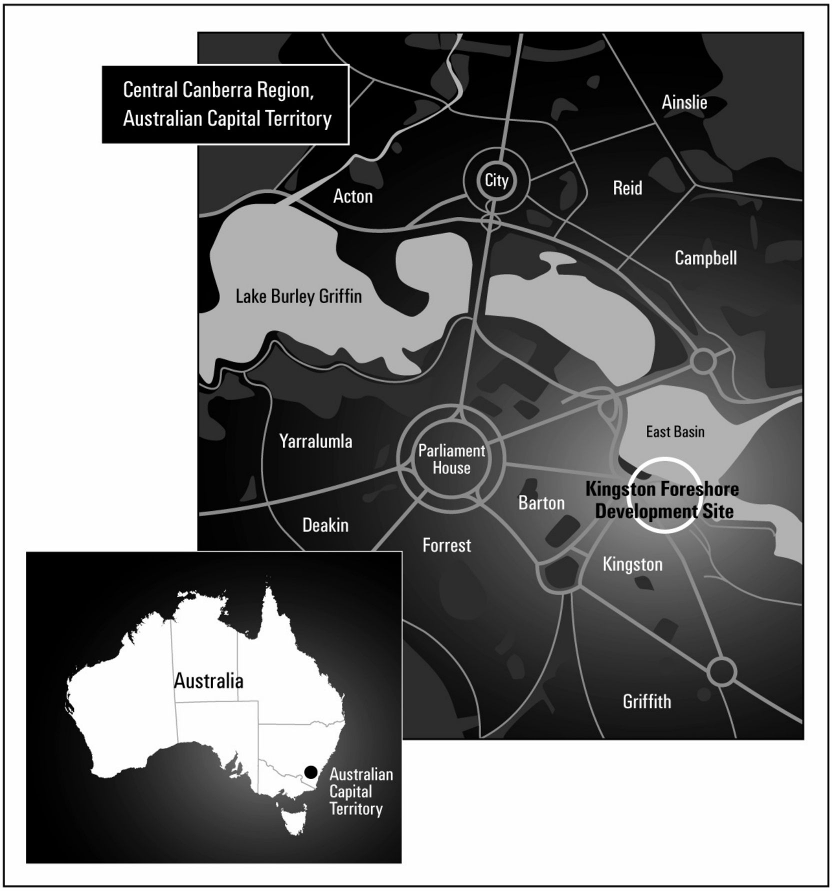

Figure 1: Kingston foreshore development site location plan.

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One of the unusual and complex aspects of the remediation program was the fact that soil contamination extended below the groundwater table. This was attributed to contamination having occurred prior to the filling of Lake Burley Griffin; as the lake filled the local groundwater table correspondingly increased in elevation. This resulted in the generation of a thicker than anticipated horizon zone of contamination, both above and below the current groundwater table, where a combination of dissolved and non-dissolved hydrocarbon contamination was present.

4 Regulatory framework and approval process

Prior to commencement of the overall site redevelopment, the ACT Land Development Agency (LDA), formerly known as Kingston Foreshore Development Authority (KFDA) entered into an Environmental Protection Agreement with the ACT Environment Management Authority (Environment ACT). The agreement concerned the assessment, remediation and audit of the Kingston Foreshore Development Area [1]. The aim of this agreement was to ensure that the assessment, remediation and audit are consistent with the objectives of the Australian Capital Territory's *Environment Protection Act 1997* (the Act) for the purpose of managing potentially contaminated land and to ensure the site was suitable for the permitted and proposed land uses.

Under that agreement, the LDA agreed to progressively manage or undertake the assessment, remediation and audit of the Kingston Foreshore Development Area in accordance with a number of conditions. The acceptance criteria for soils that were permitted to remain on site prior to, or post treatment were consistent with the current National objectives for the assessment and remediation of contaminated sites in Australia.

5 Remedial action program

5.1 Site assessment activities

Due to uncertainties in the extent of contamination at the site it was necessary to develop a detailed site contamination model based on site history, geology and hydrogeology, as well as an understanding of the mechanisms of release, migration and partitioning of the contaminants [2]. This model was used as the basis to prepare remedial cost estimates in order to secure funding to cover the full scope of remedial work. A shallow water table was identified at the site and it was apparent the project could not be successfully completed without de-watering. Numerical modelling was used to assess pre-excavation de-watering requirements. Contaminant degradation rates were also assessed to aid in the design of a system to treat recovered contaminated groundwater prior to and during remediation.

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5.2 Remedial planning and costing

It was apparent early in the life of the project that a difficult and costly remedial program could not be avoided. However, early emphasis was placed on the recognition and analysis of uncertainties and risks at the site. Established risk assessment modeling processes based on the Standards Australian model [3] were implemented. Pro-active management strategies were developed to deal with these uncertainties and risks and they were considered when developing and costing remedial strategies. Through the presentation of a range of options to the LDA and open communication of the uncertainties and risks associated with these, the LDA was able to make an informed decision in selecting the most viable alternative that met the requirements for the project. The presentation of a series of costs ranges for each alternative, along with the uncertainties, also provided the developer with a greater understanding of the basis of final project budgets.

5.2.1 Technical appraisal

The following technical issues were considered as part of the remedial planning process:

- Human Health Issues – volatile emissions (petroleum hydrocarbons) need to be minimised at all times (both during and after remediation).
- Reliability – this was assessed to measure the degree of certainty that a given remedial system would succeed in meeting the site remediation goals in both the short and long term.
- Regulatory Approvals – any remediation program needed to be endorsed by the relevant regulatory authorities.
- Disruptions to Site Structures and Activities – Remediation of the site would invariably involve some disturbance, both to the existing site structures, as well as to underground services which may pass through the remediation area.
- Ongoing Liabilities - Maintenance and Monitoring Requirements.
- Contractor Experience.
- Availability of Appropriate Disposal Sites - for excavation and off-site disposal of contaminated soil; and
- Implementation Time Frame – provided an indication as to the likely time frame involved in implementing each type of remediation strategy.

5.2.2 Prediction of remedial costs

Prediction of cost estimates in Australia has tended to follow a less prescriptive approach than that put forward by the United States Environmental Protection Authority [4]. Traditionally in Australia we have relied in many instances on "back of the envelope" cost estimates to provide order of magnitude estimates for what is sensed as the most feasible option [5, 6]. In many instances this "sensed" approach may be appropriate but it can cloud judgment, increase project risks and cause efforts to be channeled into inappropriate areas where alternatives are not considered.

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In contrast, the USEPA [4] approach for superfund sites comprises a much more prescriptive approach to predicting remediation costs which involves implementation of a detailed nine point process.

Remedial costs can be properly compared from a cost perspective following implementation of this process. It was through adaptation of the USEPA remedial cost estimation process that works cost scenarios were generated at the Kingston site.

5.2.3 Soil excavation and bioremediation

On-site soil remediation/treatment methodologies rather than conventional landfill disposal was utilised at the site to reduce project costs and provide a solution based on the principles of ecologically sustainable development (ESD). Bioremediation involves the use of microbial organisms to break down contaminants into less toxic constituents [7]. Aerobic bioremediation processes occur in the presence of oxygen, and generally result in the production of carbon dioxide, water and proteins [7, 8]. Artificial stimulation of micro-organisms by aeration and the addition of nutrients, in the form of nitrogen, phosphorous and potassium (NPK) fertilizer was used to enhance the process. Based on field trials, an N:P:K fertilizer with a ratio of composition ratio 4:3:2 was chosen and applied to the soil at a doseage rate of $8kg/10m^3$.

One of the advantages of bioremediation over other contaminated soil clean-up technologies was that it enabled soils to be rehabilitated to a near-natural ecological state.

Contaminated soil was selectively excavated using optimally selected equipment; the soil was then remediated on-site via a "land-farming" process that used natural microbes in the soil to assist in contaminant degradation. The process aimed to return soil to its pre-contamination condition, minimising waste and use of additional resources (e.g. imported fill).

A total volume of approximately $30{,}000m^3$ of hydrocarbon contaminated soil was treated in batches of approximately $5000m^3$ over a period of 18 months. The treatment of each batch of material generally took between 11 and 17 weeks to complete. An assessment of the cost of treatment per m^3 of contaminated soil was calculated to be approximately 30% of the comparable landfill disposal cost. The initial concentration of TPH fraction C_{10}-C_{40} recorded during the investigation and remediation of the Tank Farm ranged between 11,500mg/kg and 1,750mg/kg with an average concentration of approximately 4,000mg/kg. The adopted remediation criteria for the C_{10}-C_{40} TPH fraction was 1,000mg/kg. The adopted remedial methodology is summarised as follows:

- Soils requiring land farming were transferred from the contaminated excavation site to a prepared "land-farm" area.
- The soils were spread out within the treatment area at a height of approximately 0.8m.
- Baseline conditions, including soil moisture, temperature, nutrient levels and contaminant concentrations were monitored.

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- Soil nutrient was augmented with fertiliser (with an N:P:K ratio of approximately 4:3:2) at an average dosage rate of 8kg/10m^3 to enhance the biodegradation process.
- The soils were turned with a tracked 20T excavator, to promote aeration and microbial activity on a regular basis.
- The level of contamination of the soils was monitored at regular intervals during the treatment process. This was generally achieved by field observation (visual and olfactory) and field monitoring (photoionisation detector). In addition representative samples were collected for laboratory analysis during the landfarming process to provide data on biodegradation rates.
- At the completion of treatment validation samples were obtained at a frequency of 1 per 100m^3 of material. The 95% Upper Confidence Limit (UCL) was calculated for the TPH fraction C_{10}-C_{40} concentrations measured in the analysed validation samples.

5.2.4 Contaminant degradation rates

A graph summarising the TPH concentration versus treatment time is presented in Figure 2. The remediation of goal for TPH of 1000mg/kg was achieved within approximately ten weeks of commencement of landfarming. Treatment continued for up to seventeen weeks to provide further improvement to soil quality as other activities on the site allowed continuation of the landfarming activity without significant cost or delay to the overall project. A fitted exponential decay relationship shown in Figure 2 indicates TPH concentration reduced by approximately 50% every four to five weeks. The rate of decay in TPH concentration slowed as ambient temperatures fell during the late autumn and winter.

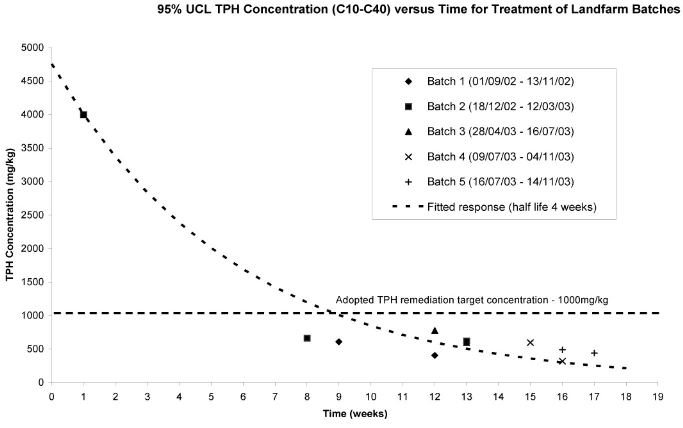

Figure 2: Decay in soil contaminant concentrations versus time.

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The results of a limited literature review relating to remedial rates of similar contaminants using landfarming/biopile processes in North America, South East Asia and Europe is presented within Table 1. Based on published literature it is apparent the contaminant degradation rates measured at the subject site compared favourably with degradation rates achieved during similar remedial programs across a range of geographic locations.

Table 1: Comparison of contaminant degradation rates and geographic locations.

Location	Contam-inant	Initial Conc. mg/kg	Final Conc. mg/kg	Estimated ½ Life
Kingston ACT	TPH	4,000	1,000	35 days
Northern Italy[9]	TPH	10,000	50	200 days
California USA[10]	TPH	11,600	2,000	21 days*
Philippines [11]	TPH	2,800	300	40 days
Montana USA[12]	TPH	4,200	2,100	98 days
California USA [13]	TPH	2,600	800	40 days
Hawaii USA [14]	TPH	1,549	590	60 days

* Denotes bench scale evaluative testing

5.2.5 Climatic influences on soil bioremediation

A comparison of the treatment times for the different batches at the subject site indicated that the environmental conditions for treatment of the soil were optimised during the summer months of 2002 and 2003. Although the effectiveness of bioremediation is controlled by the complex interaction of a multiplicity of factors, as listed above, it would appear that climate had a dominant role due to its influence on a number of key environmental factors i.e. temperature, soil moisture and humidity.

A graph of how Canberra's temperature fluctuates throughout the year is presented in Figure 3. The graph is compiled from data obtained from the Australian Bureau of Metrology [15].

Canberra has a relatively dry, continental climate with warm to hot summers and cool to cold winters (at least for Australian standards) [15]. Records are based on data from Canberra Airport, which opened in March 1939. The average annual rainfall is 629 mm with an average of 108 rain days per year. Rainfall is reasonably evenly distributed throughout the year with the wettest month being October (65.3 mm) and the driest being June (39.6 mm). Rainfall tends to be influenced by cold fronts during the winter 6 months and thunderstorms activity during the summer 6 months. Overall autumn tends to be the most stable weather period.

According to the USEPA [8] bacterial growth rate is a function of temperature. Soil microbial activity has been shown to decrease significantly below 10^{o}C and essentially cease below 5^{o}C. The microbial activity of most bacteria important to petroleum hydrocarbon degradation also diminishes at temperatures greater than 45^{o}C. Within the range of 10^{o}C to 45^{o}C, the rate of microbial activity typically doubles for every 10^{o}C rise in temperature [8]. The length of the landfarming season in Canberra therefore generally runs from

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September to June. This correlates well with the observed treatment times for the different landfarm batches, with batches four and five taking approximately four weeks longer to achieve the remediation targets.

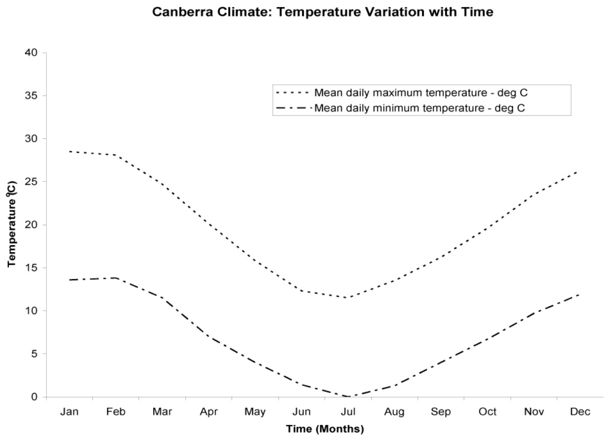

Figure 3: Seasonal temperature range in the Canberra region.

5.2.6 Groundwater recovery, treatment and disposal

A pre-excavation dewatering system was designed and implemented at the site to minimise the inflow to the excavation. The system was also used to reduce pore water pressures in the excavation to permit rapid excavation of the contaminated soils.

An on-site water management, treatment and disposal system was designed and commissioned at the site. The system was primarily used to treat up to 0.4ML/day of recovered contaminated groundwater and surface water encountered during the excavation. Treatment involved reduction in the concentration of hydrocarbon contamination to level with were acceptable for discharge to trade waste (typically reduction from 15-20 mg/L to less than 5 mg/L) and was accomplished by aeration, LNAPL skimming and detention. The treatment system was designed to retain recovered water for up to 24 hours while allowing for controlled discharge at a rate of up to 5L/sec.

The treated water was discharged to sewer under a Trade Waste agreement negotiated with the ACT Government. Treated water from a contaminated site had not been disposed to sewer in the ACT before this project, so this process set a benchmark for good waste water disposal practice for remediation projects in the ACT.

5.3 Site restoration

Upon completion of the remedial excavation works a backfilling plan was implemented that embraced issues such as filling below the water table on a saturated silty subgrade and stable installation of an array of 132kV underground electricity cables that would eventually feed electricity to Australia's Parliament

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House. Innovative thinking was required during the design of the filling program to incorporate the geotechnical constraints and ESD principles of the project while controlling costs. Geotextile fabrics and geo-grids were used in combination with recycled crushed concrete generated at the site from building demolitions to construct stable fill platforms below the water table. The costs of filling were reduced by approximately 15% through the use of recycled materials and by optimizing the placement method and controlling the thickness of fill layers.

6 Conclusions

The project set a benchmark for best practice in contaminated site remediation in the ACT. Hydrocarbon contaminated soil was remediated and reused on site in accordance with the principles of ESD. Contaminated water was treated on site and disposed to sewer under an agreement negotiated with the ACT Water Authority (Actew/AGL). Ultimately a contaminated site of limited use and worth was transformed to a socially, environmentally and economically valuable land parcel. The project was of direct and tangible benefit to the environment and the Canberra community as a whole. The project also provided a valuable opportunity to study a larger scale bio-remediation process (land-farming) and, in turn, document techniques for optimising treatment processes in the relatively dry continental climate of the Australian Capital Territory.

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