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Power Plants

Phytoremediation Gardens

STAGE ONE REPORT

THE UNIVERSITY OF NEWCASTLE AUSTRALIA

UNSW SYDNEY

UTS

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Contents

Partners and Contributors

2018 TEAM

Contributors	Role	Institution
Professor SueAnne Ware	Chief Investigator	University of Newcastle
Chris Johnstone	Principal Investigator	Bosque Studio (UON)
Kalyna Sparks	Research Assistant	University of Newcastle
Professor Penny Allan	Principal Investigator	University of Technology Sydney
Professor Martin Bryant	Principal Investigator	University of Technology Sydney
Daniel Rooke	Research Assistant	University of Technology Sydney
Hayley Mulder	Research Assistant	University of Technology Sydney
Alyssa-Jane Fomin	Research Assistant	University of Technology Sydney
Lecturer Ainslie Murray	Principal Investigator	University of New South Wales

Industry Partners

Michael Parsons	University Relations Officer	Landcom
Nicole Campbell	Collaborative Learning Manager	Landcom
Emma Kunkler-Warren	Communications and Engagement Assistant - The Bays Precinct	Urban Growth NSW
Karthik Kumaravel	Project Manager Bays West	Urban Growth NSW

University Partners

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Executive Summary

STAGE 01 REPORT

The Power Plant Stage 1 report provides research about various technical, design, and educative / interpretive means which will inform the Stage 2 installation of an annual plants demonstration garden at the White Bay Power Station in Sydney (WBPS).

The report is organised into four sections: Section 1 discusses phytoremediation techniques and types, Section 2 discusses relevant international and national precedents, Section 3 includes a historic site analysis and a short description of the White Bay Precinct today, Section 4 presents Garden One, an annual plants phytoremediation garden, which is to be the first garden experiment on site.

Our findings from Section 1 confirm that there are a number of ways in which phytoremediation takes place and various species of vegetation which are more suited towards this process. It also underpins the site-specific nature of such remediation activity, in that the specific toxins, growth conditions, and complex site contexts need to be taken into account.

In Section 2, after a thorough search through relevant international and national precedent projects, we discovered that while many design projects had incidental phytoremediation and water sensitive urban design (WSUD) strategies, that very few had deliberately utilised phytoremediation in a designerly fashion. Almost exclusively it has been relegated to environmental engineering solutions such as freeway verges, storm water treatment, and mining reclamation.

In Section 3 we discuss precolonial history of the site and the Bays precinct as well as its geological formation and hydrological function. The history of the WBPS is summarised and we introduce the current demonstration garden site and its analysis for Power Plants.

Section 4 includes the refined proposal for the concept design, planting plan, and staging process for Garden One. It also includes the anticipated performance plan and the final draft of the Power Plant Project website.

This research report is organised into key sections which can be utilised independently or can be recombined for other projects of this nature. Our research team is committed to 'open source' research which allows public access to our research investigations and our research outputs as a result. In short, we hope that as this report is circulated both in print and via our website, that it will be utilised for any number of other projects, educational opportunities, etc. We only ask to be acknowledged for our endeavours and to hopefully disseminate what we have learned and are continuing to learn more widely.

Introduction

STAGE 01 REPORT

White Bay Power Station (WBPS) is a unique site with a rich cultural and industrial heritage. The Power Station is envisioned to be a hub for knowledge-intensive and advanced technological industries, making WBPS an anchor of innovation and technology district for The Bays Precinct.

However, its previous operation as a coal fired power station generated site contaminants that remain in-situ. This collaborative project utilises phytoremediation techniques for expressing rehabilitation and restoring balance to publicly owned contaminated sites. It combines both innovative science with a unique activation opportunity for WBPS.

Phytoremediation is a low cost, plant (vegetative) and solar energy driven, soil remediation technique. Initial establishment of a series of phytoremediation gardens will remove a percentage of toxins from contaminated soils, through the selected plants absorbing and metabolising various pollutants into their tissues.

The project is two-fold: cleansing or repairing contaminated lands, and utilising ecological processes in an artful, performative, playful and educative manner. The initial phytoremediation gardens remove toxins from contaminated soils, while plant materials become a visual litmus. Plants metabolize various pollutants into their tissues. After planting and harvesting up to three successive phyto-gardens, to ensure the contaminates are reduced to the required levels, resilient goat communities might be introduced to the site. Feral goats consume the final garden breaking down PH imbalances through bio-agents found within their bodies. The project celebrates phytoremediation techniques and possibly goat herds as productive ecologies, which rejuvenate, degraded land in a beautiful and expressive manner.

While the actual physical site is the White Bay Power Station in Sydney, much of the project is accessed through the web and films. The milestones of this garden are planting and harvesting performances, However due to the toxins and other on-site safety hazards; access is limited. The project and its installation has a number of coordinated events which will result in films and a live website for open viewing.

Power Plants quite simply is an intertwined ecological system of repair for a disused and toxic site. However perhaps more importantly it embodies radical hope. In his 2007 book Radical Hope: Ethics in the Face of Cultural Devastation, philosopher Jonathan Lear investigates the concept of radical hope to explain how human beings confront the cataclysmic loss of traditional ways of life. “Radical Hope is the ability to maintain hope in a meaningful existence even when one’s existence has lost all meaning. It is hope that goes beyond one’s ability to formulate an idea of what one hopes for.” (p.15, 2007).

Photograph of specific site for Garden 01 with WBPS in the background (Moulah. B, 2017).

Phytoremediation

SECTION 01

What is Phytotechnology and Phytoremediation

“Phytotechnology is the use of vegetation to remediate, contain or prevent contaminants in soils, sediments and groundwater, and/or add nutrients, porosity and organic matter. It is also a set of planning, engineering and design tools and cultural practices that can assist landscape architects, site designers, engineers and environmental planners in working on current and future individual sites, the urban fabric and regional landscapes,” (Kennen & Kirkwood, pg. 3, 2015).

Phytoremediation is an aspect of Phytotechnology and refers to the direct utilisation of living green plants for in-situ, removal, degradation or containment of contaminants in soils, sludges, sediments, surface water and groundwater. Phytotechnology differs from Phytoremediation as it also refers to the stabilisation of the pollutant in the surrounding soil or root structure of the plant. It covers all plant based pollution remediation and prevention systems including constructed wetlands, bioswales, green roofs, green walls and planted landfill caps (Kennen & Kirkwood, 2015).

Phytoremediation has been successfully applied to a variety of sites including pipelines, industrial and municipal landfills, agricultural fields, wood treating sites, military bases, fuel storage tank farms, gas stations, army ammunition plants, mining sites and residential sites. Field studies have included the remediation of heavy metals, radionuclides, chlorinated solvents, petroleum hydrocarbons, polychlorinated biphenyls (PCBs), pesticides and explosives (EPA 2001; Sleegers, 2010).

It can be a low-cost, but time intensive alternative to traditional remediation, and is most effective when toxins are present at a shallow depth, in low concentrations over a large clean up area (EPA, 2001; YouAreTheCity, 2011). It is an effective approach to reducing the leaching of contaminants through soil or groundwater, reducing run-off of contaminated stormwater, beginning an initial level of clean up and improving the aesthetic of a site, and can be used in combination with other remediation techniques (EPA, 2001).

The time dimension can be turned into an advantage if each stage of the cleaning processes has a distinct character and sense of place while performing remediation and simultaneously creating green infrastructure (Sleegers, 2010).

Plants are unique organisms equipped with remarkable metabolic and absorption capabilities, as well as transport systems that can take up nutrients or contaminants selectively from the growth matrix, soil or water. Phytoremediation involves growing plants in a contaminated matrix, for a required growth period, to remove contaminants from the matrix, or facilitate immobilisation (binding/containment) or degradation (detoxification) of the pollutants. The plants must then be harvested, processed and disposed as they become contaminated waste (Kennen & Kirkwood, 2015).

Why we need phytoremediation

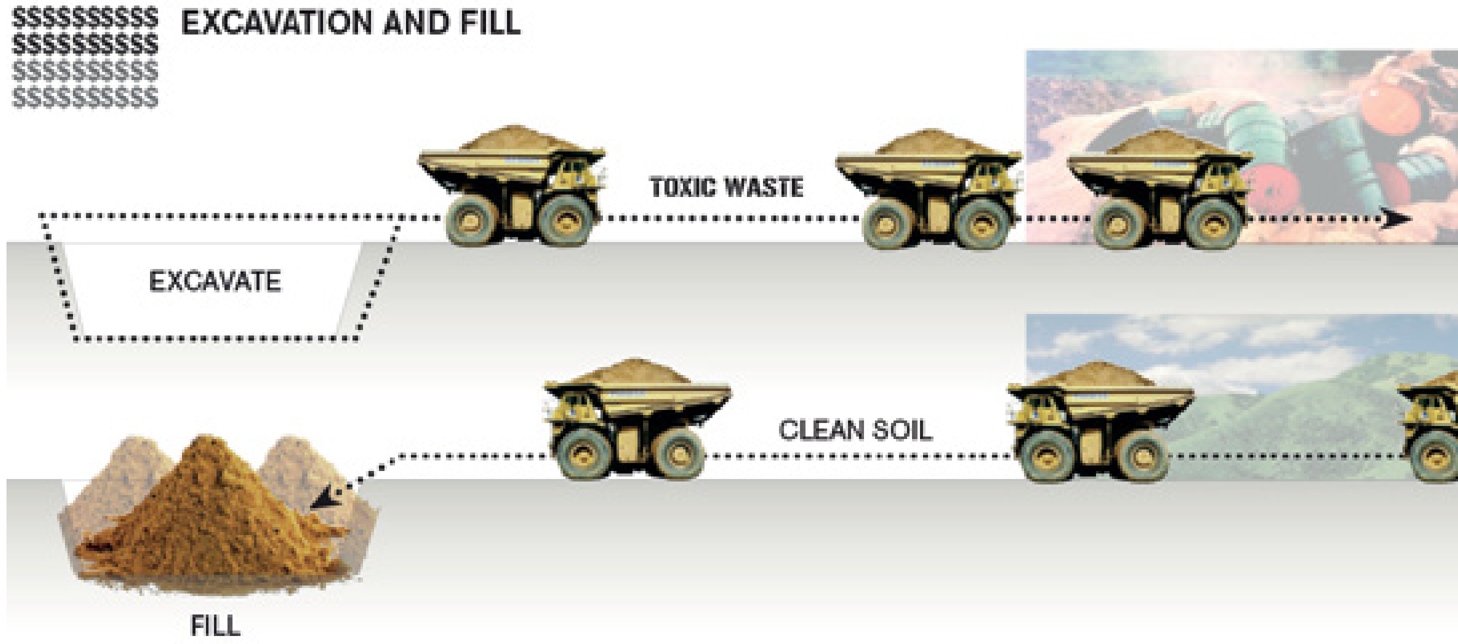
Urban brownfields are a common landscape in industrial and post-industrial cities. They occur in every country, on every continent in the world. Brownfields are defined by the US Environmental Protection Agency (EPA) as being, “...abandoned, idled or underused industrial or commercial facilities where expansion or redevelopment is complicated by real or perceived environmental contamination,” (US EPA, 2001). These sites are usually fenced, abandoned and access is strictly limited which inhibits economic growth and the use of that land. In recent times however, the sensual, aesthetic quality of these derelict sites has been successfully incorporated into landscape architecture projects (Sleegers, 2010). There is increasing interest in brownfield sites and their remediation due to their location, often being in urban areas where land values are on the rise.

In Australia, “There are somewhere between 40,000 and 80,000 contaminated sites. We spend about $300-million a year managing and remediating them. The overwhelming majority of that goes on the managing, using dig and dump to take the pollutants elsewhere, or cap and contain to seal them off. These approaches don’t solve the problem, not in the long-term anyway, but they are cheap- we have some of the cheapest landfill sites in the world.

Of that $300-million, only about $10-million is spent on bioremediation, a figure that could grow to $40-million in the next decade. It’s not going to be a big industry, unless there is serious regulatory pressure with heavy penalties for not remediating,” (Oakwood, M. 2001).Traditional remediation techniques used for brownfield rehabilitation usually involve the excavation of contaminated soils and their disposal into an off site landfill, or the capping of polluted soil with clay or concrete and then importing clean fill for planting over the top of the cap. Remediation processes can involve soil washing off site which results in contamination moving from the soil into water. Contaminated groundwater left on site must then be mechanically pumped, treated and recharged.

> “There are sunflowers that capture uranium, ferns that thrive on arsenic, alpine herbs that hoard zinc, mustards that lap up lead, clovers that eat oil and poplar trees that destroy dry-cleaning solvents”
>
> REVKIN, 2001

Example of soil contaminated with PAH's being extracted from a former manufactured gas plant in High Point NC. Image courtesy of NC DENR taken from (https://sph.unc.edu/files/2014/10/High-point-dig-004.jpg)



Traditional remediation technique of excavation of contaminated soil and its disposal, followed by importing clean fill into the site. Taken from (YouAreTheCity, pg. 17, 2011)

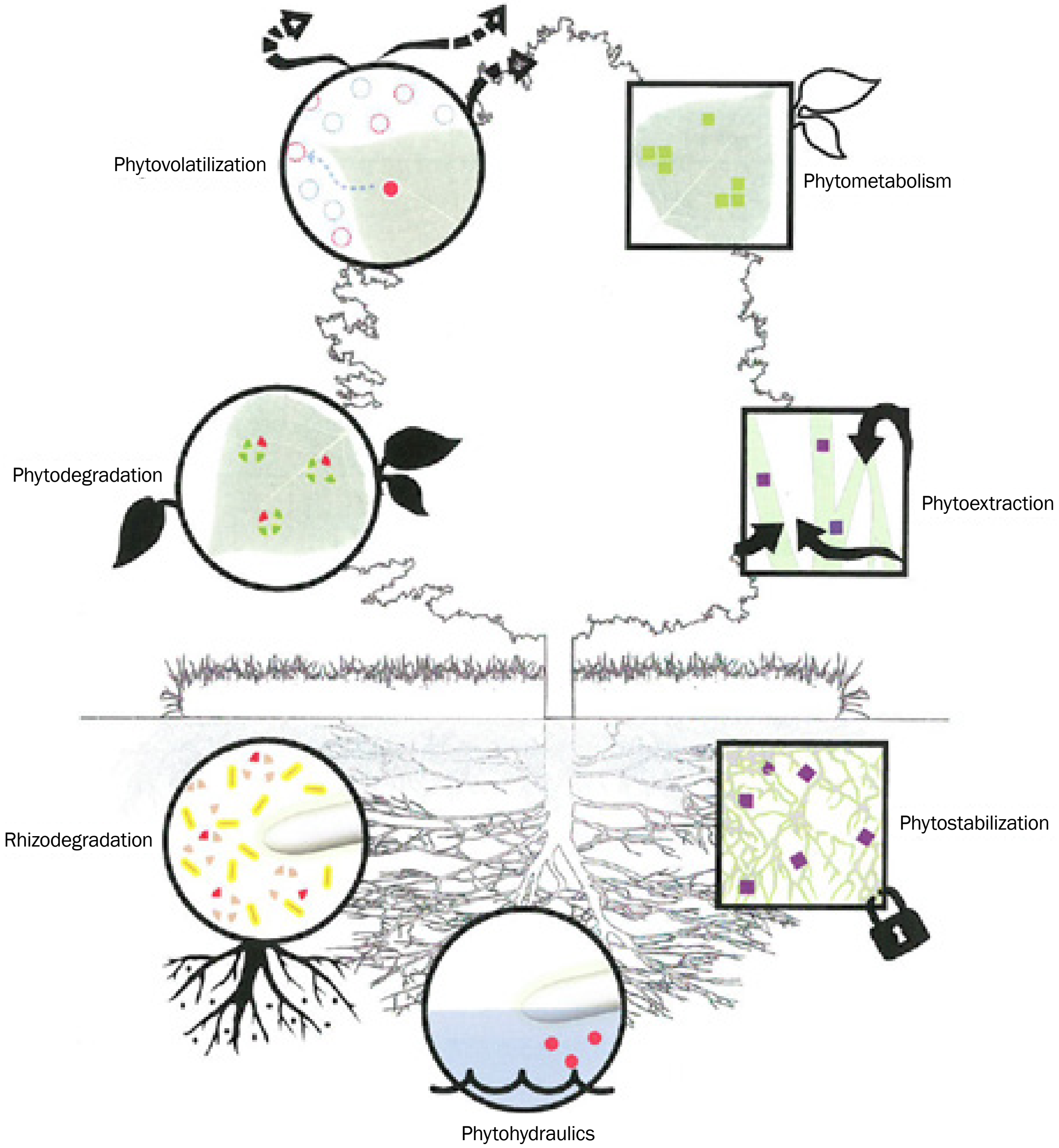
While these approaches fix the problem in the short term, it is expensive, energy intensive and simply band aids or moves the problem elsewhere. It is often invasive and destroys the microenvironment, sometimes leaving the soil infertile and unsuitable for agricultural and horticultural use (Kennen & Kirkwood, 2015).

There is increasing research into bioremediation processes which can involve desporption, in which contaminated soil is excavated and mixed with water and nutrients in a bioreactor tank to create ideal conditions for bacteria in the soil to degrade organic contaminants. It is however expensive, invasive and still requires the excavation and treatment of soil off site (Gillings School of Global Public Health, 2018).

The main benefit of utilising phytoremediation is in its treatment of inorganic and organic contaminants in-situ. It therefore offers a cheaper, less energy intensive solution that does not usually require mechanical pumping systems, utility power or much supporting infrastructure (Kennen & Kirkwood, 2015). Utilising plants in environmental clean up can be more than 10 times cheaper than other technologies. It is also less intrusive and more aesthetically pleasing (Doty from Steenhuysen, 2007). Phytoremediation presents a way of actively remediating and improving the soil while contributing to aesthetic quality which is often preferred by local residents.

It furthermore improves air quality, mitigates the further spread of contamination through stormwater absorption and contributes to increased ecology and biodiversity in the local area (YouAreTheCity, 2011).

In some cases overseas, the contaminated biomass is then incinerated at high temperatures to create energy, and can even be used to extract the heavy metals back out of the plant (phytomining) thereby creating an economic product (Kennen & Kirkwood, 2015).



The seven phytotechnology techniques. Taken from (Kennen. K & Kirkwood, pg 46, 2015)

Phytoremediation does have some set backs which means it is not suitable for all contaminated sites. Some soils may be too toxic or infertile to host any vegetation. If there is deep soil contamination, root systems may not be able to reach them. Furthermore, many research experiments testing phytoremediation apply soil additives and chelates such as EDTA which increases the mobility of heavy metals. This results in plant absorption being higher than under natural conditions. The problem of adding EDTA on site is that it could create more environmental pollution than previously recorded due to potential leaching of contaminants into groundwater and soil. More research is required to test plants in the field when they are exposed to site specific climatic and nutrient cycles. Phytoremediation processes allow contaminants to become more bioavailable (i.e. moving from soil into plant material) which can result in them moving up the food chain into animals and even humans. Finally because phytoremediation is a system which utilises photosynthesis, it has an elongated timescale. Many phytotechnologies take 5-50 years (Kennen & Kirkwood, 2015). The Power Plants Phytogardens will test whether fast growing annual plants over a period of 1 year can effectively remove contaminants from the soil. Traditional remediation techniques used for brownfield rehabilitation usually involve the excavation of contaminated soils and their disposal into an off site landfill, or the capping of polluted soil with clay or concrete and then importing clean fill for planting over the top of the cap. They can also involve soil washing off site which results in contamination moving from the soil into water. Contaminated groundwater left on site has to be mechanically pumped, treated and recharged. While this approach fixes the problem in the short term, it is expensive and energy intensive and simply band aids or moves the problem elsewhere. It is often invasive and destroys the microenvironment, sometimes leaving the soil infertile and unsuitable for agricultural and horticultural use (Kennen & Kirkwood, 2015).

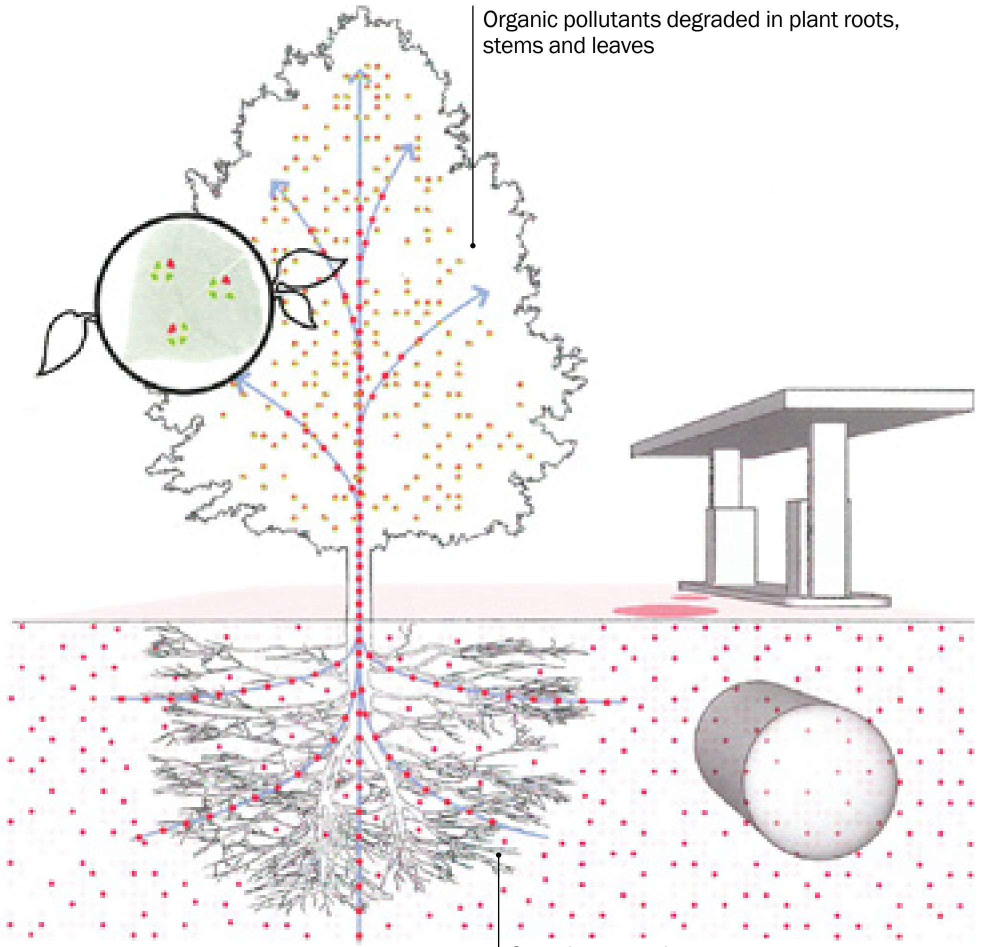
Phytoremediation processes

There are several processes in which plants can clean up and remediate contaminated sites. Organic and inorganic contaminants are treated through different processes. Plants can either break down and degrade organic pollutants or contain and stabilise inorganic pollutants. They do this by acting as filters or traps and metabolise or accumulate toxins in the plant material above and below the ground. A specific plant often performs multiple processes and can treat multiple organic or inorganic toxins at the same time.

The plant species typically utilised in phytoremediation include poplars, willows, grasses, reeds, cattails, penny-cress and mustard (Sleegers, 2010).

The plants' roots and microbiological organisms in the rhizosphere (area around the roots) allow the transportation of chemicals from the soil into the plant when the toxin is dissolved in water. Therefore the solubility of the toxin in water is important for phytoremediation processes to take place. The plants and their associated rhizosphere also increase the microbiological activity in the soil which results in improved soil structure along with reintroducing organic matter into the soil through the deposition of leaves, branches and root cells (Sleegers, 2010).

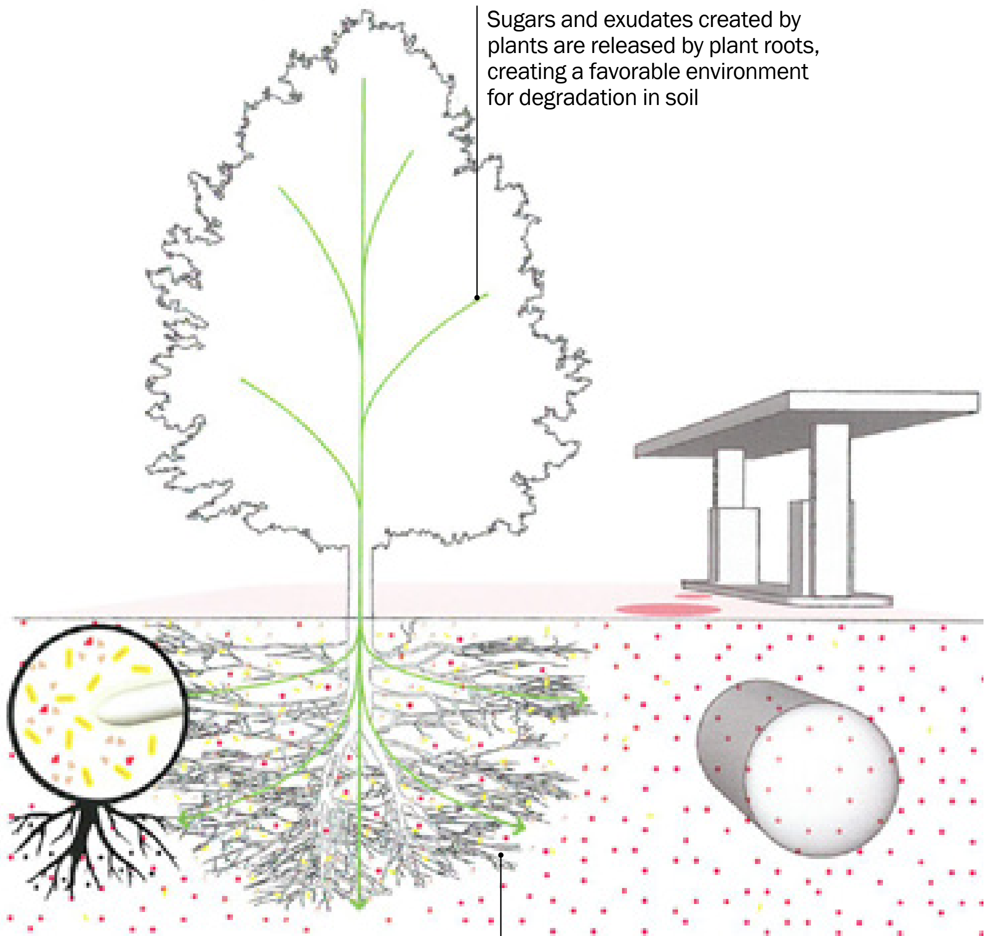
The processes of phytoremediation which are described in the following pages ultimately results in the contaminant being transported into the plant, leaving only residual levels of pollutants in the soil (Ensley, 2000).



Phytodegradation process. Taken from (Kennen. K & Kirkwood, pg 35, 2015)

Phytodegradation | organic

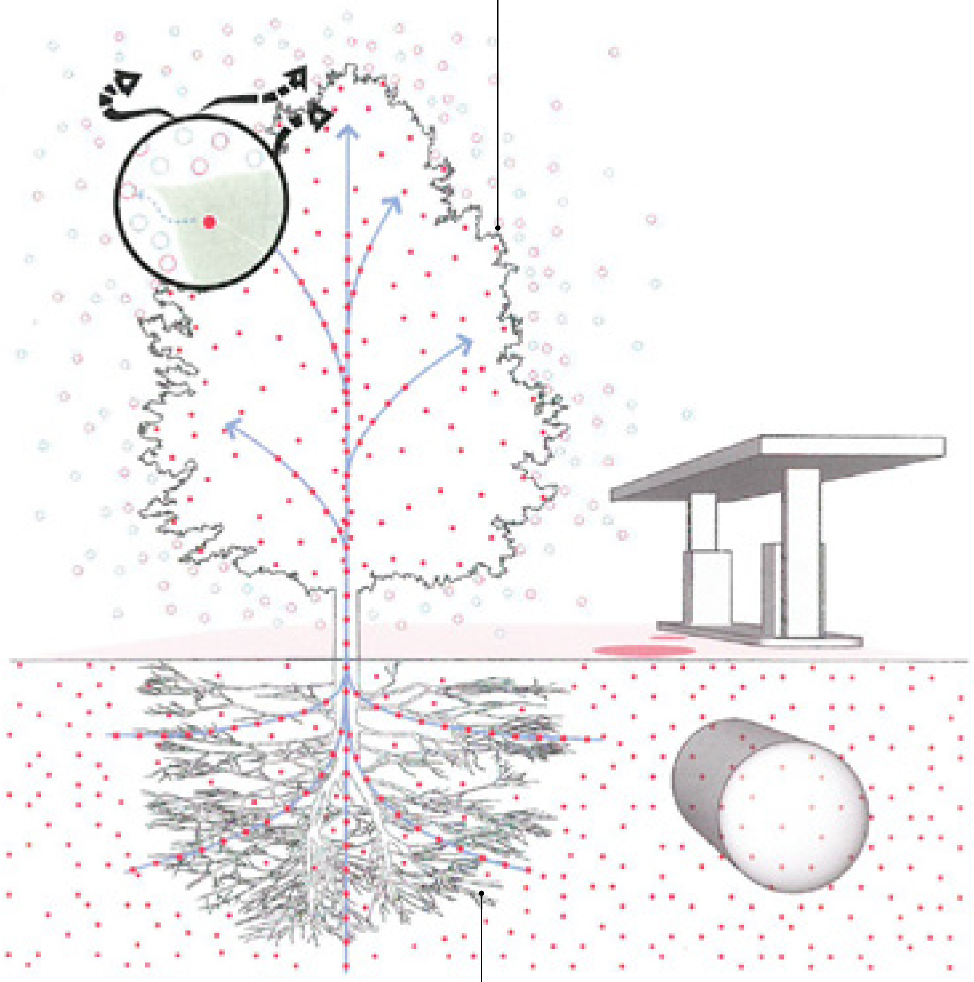
Plant destroys the contaminant which is broken into smaller, usually non toxic parts via photosynthesis, internal enzymes and/or internal microorganisms. The plant uses the byproducts from the break down for its growth processes, leaving little contamination (Kennen & Kirkwood, 2015).



Rhizodegradation process. Taken from (Kennen. K & Kirkwood, pg 36, 2015)

Rhizodegradation | organic

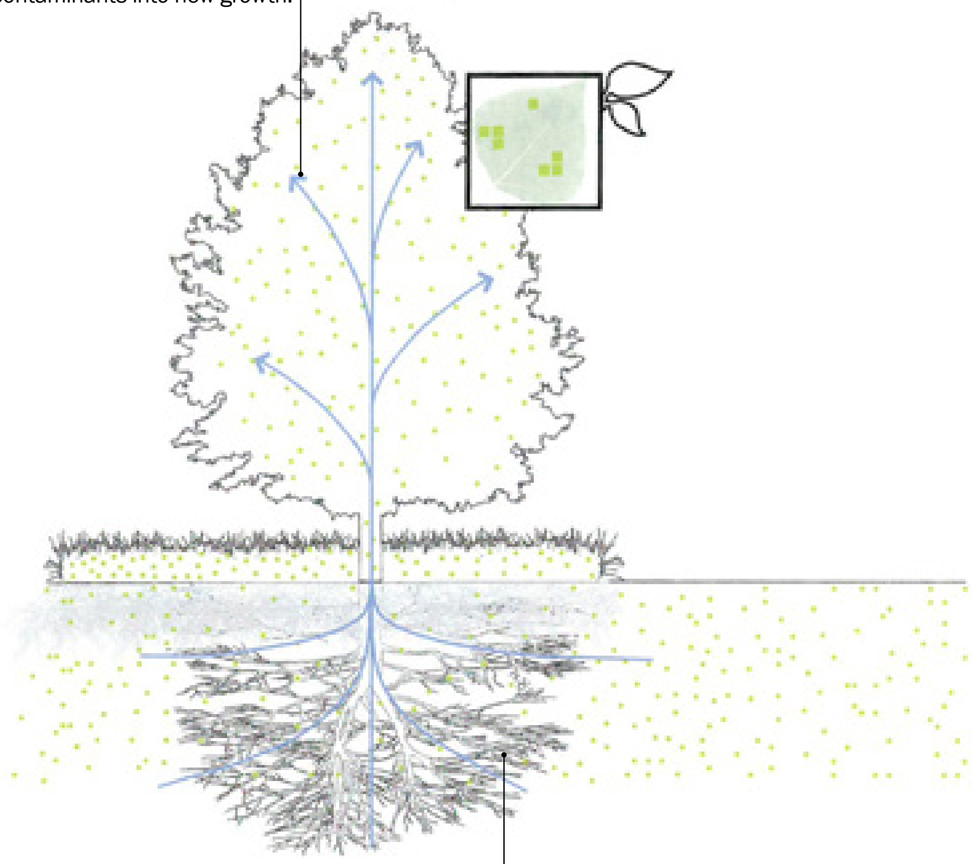
The roots of the plant release sugars and phytochemicals which stimulate microbiological activity in the root zone (rhizosphere). The microbes as well as the chemicals released by the root break down the contaminant by utilising its carbon source as food. (Kennen & Kirkwood, 2015).



Phytovolatilization process. Taken from (Kennen. K & Kirkwood, pg 37, 2015)

Phytovolitization | organic | Inorganic

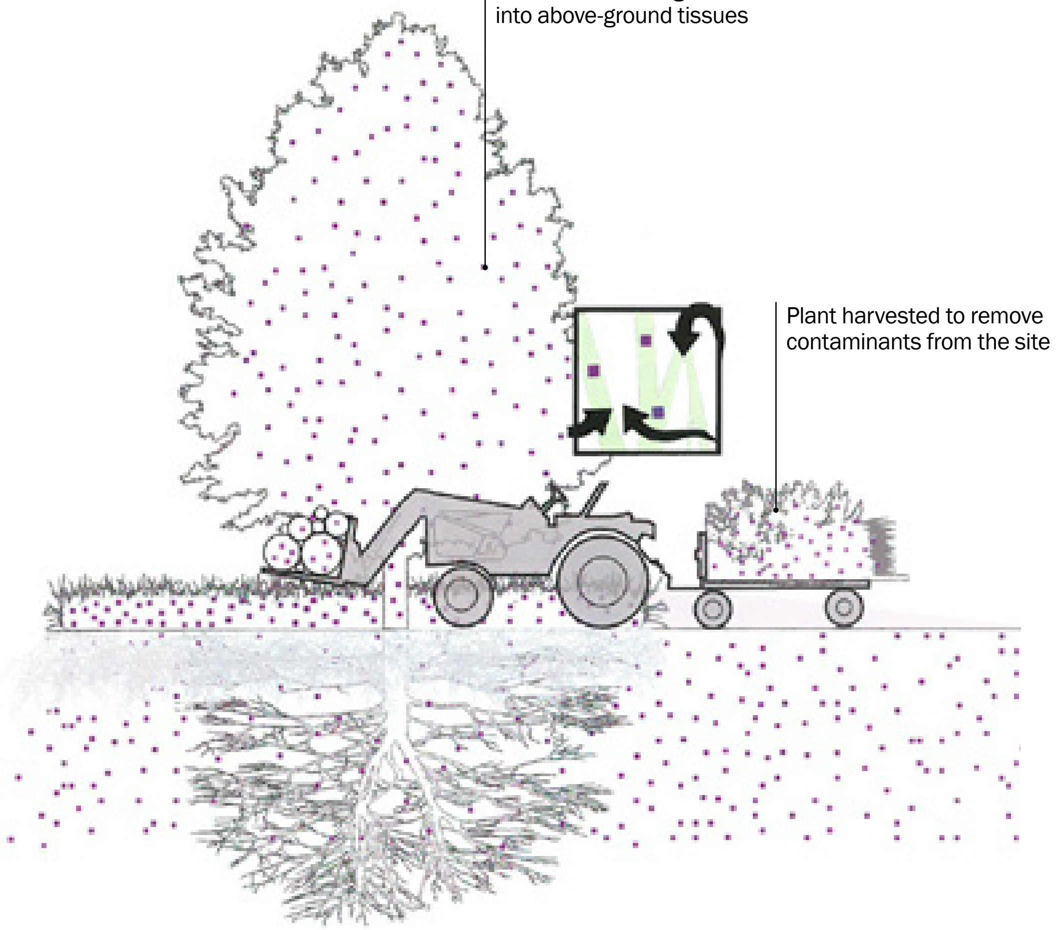
The plant takes up the pollutant and transpires it to the atmosphere as a gas, thus removing it from the site. The gas is usually released slowly enough that the surrounding atmosphere is not significantly effected (Kennen & Kirkwood, 2015).



Phytometabolism process. Taken from (Kennen. K & Kirkwood, pg 38, 2015)

Phytometabolism | organic | inorganic

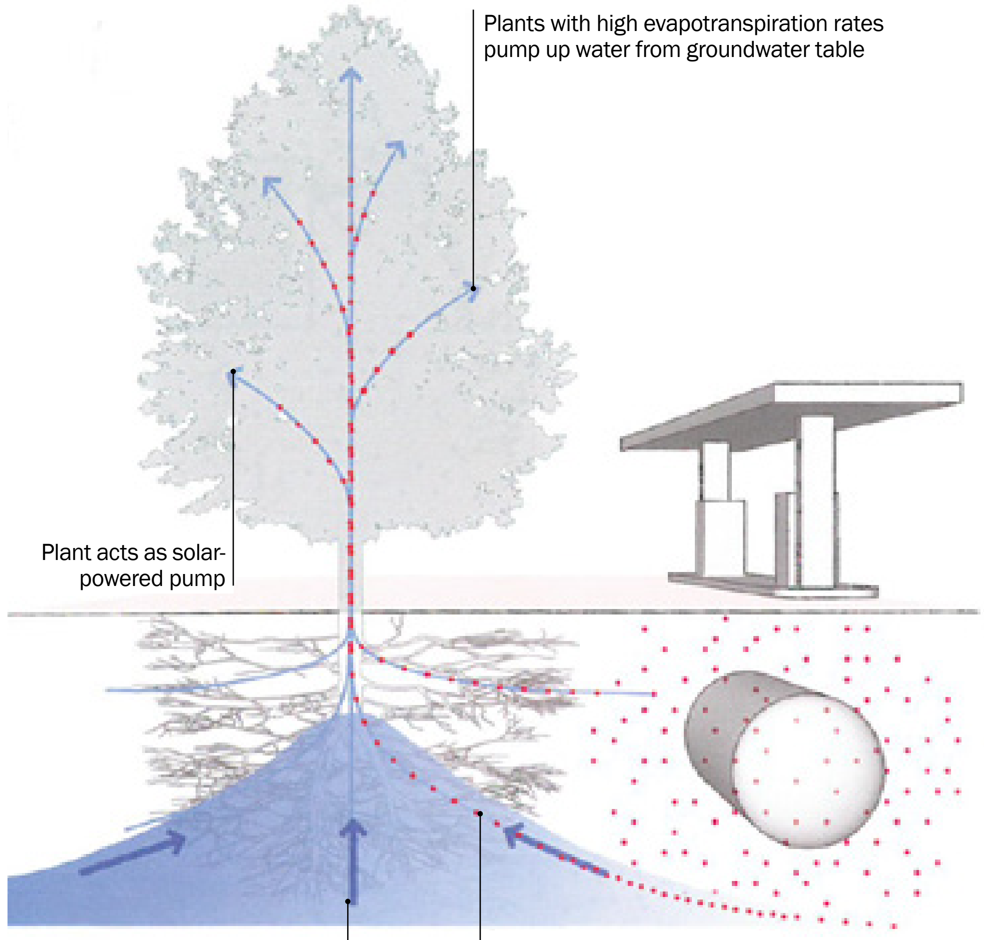
The process whereby the nutrients (Nitrogen, Phosphorus, Potassium) needed by plants to phytosynthesis and produce biomass are metabolised (Kennen & Kirkwood, 2015).



Phytoxtraction process. Taken from (Kennen. K & Kirkwood, pg 39, 2015)

Phytoextraction | organic | Inorganic

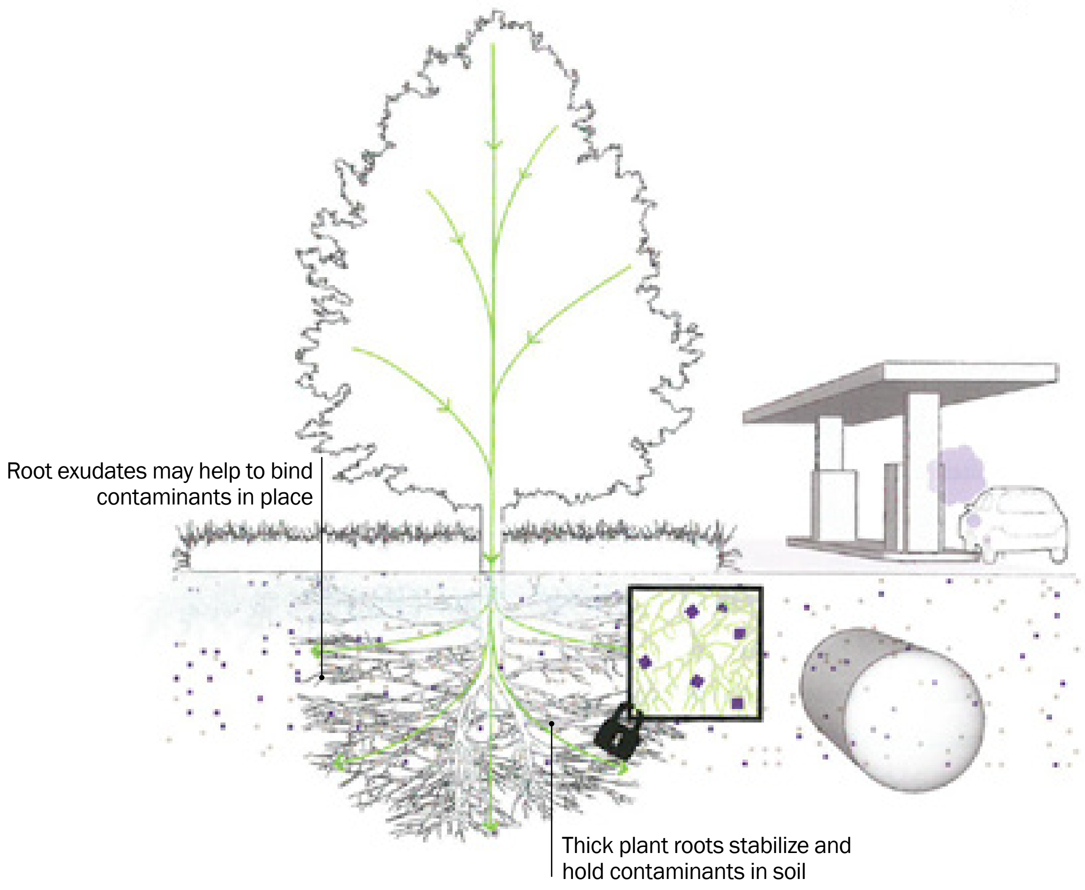
The plant extracts the contaminant from the soil, water and moves it into the plant parts. For organics, phytoextraction comes after phytodegredation and removes the toxin from the site. However with inorganics, they cannot be broken down into smaller pieces. The plant stores them in the biomass and plants must be harvested before seed production and die back to ensure the toxin is removed from the site (Kennen & Kirkwood, 2015).



Phytohydraulics process. Taken from (Kennen. K & Kirkwood, pg 40, 2015)

Phytohydraulics | organic | Inorganic

As the plant pulls up water, dissolved contaminants may come with it. The pull of the ground water by the plant is called phytohydraulics. Masses of planting can change the direction and stop the flow of the groundwater and may be able to stop migrating plumes of contaminated groundwater. The plant may then utilise other processes, including phytodegredation or phytovolitiation to treat the pollutant (Kennen & Kirkwood, 2015).



Phytometabolism process. Taken from (Kennen. K & Kirkwood, pg 38, 2015)

Phytostabilization | organic | inorganic

The plant holds the contaminant in place so it does not move off site. The vegetation covers the contamination and the plant may release phytochemicals that bind contaminants to soil particles, making them less bioavailable (Kennen & Kirkwood, 2015).

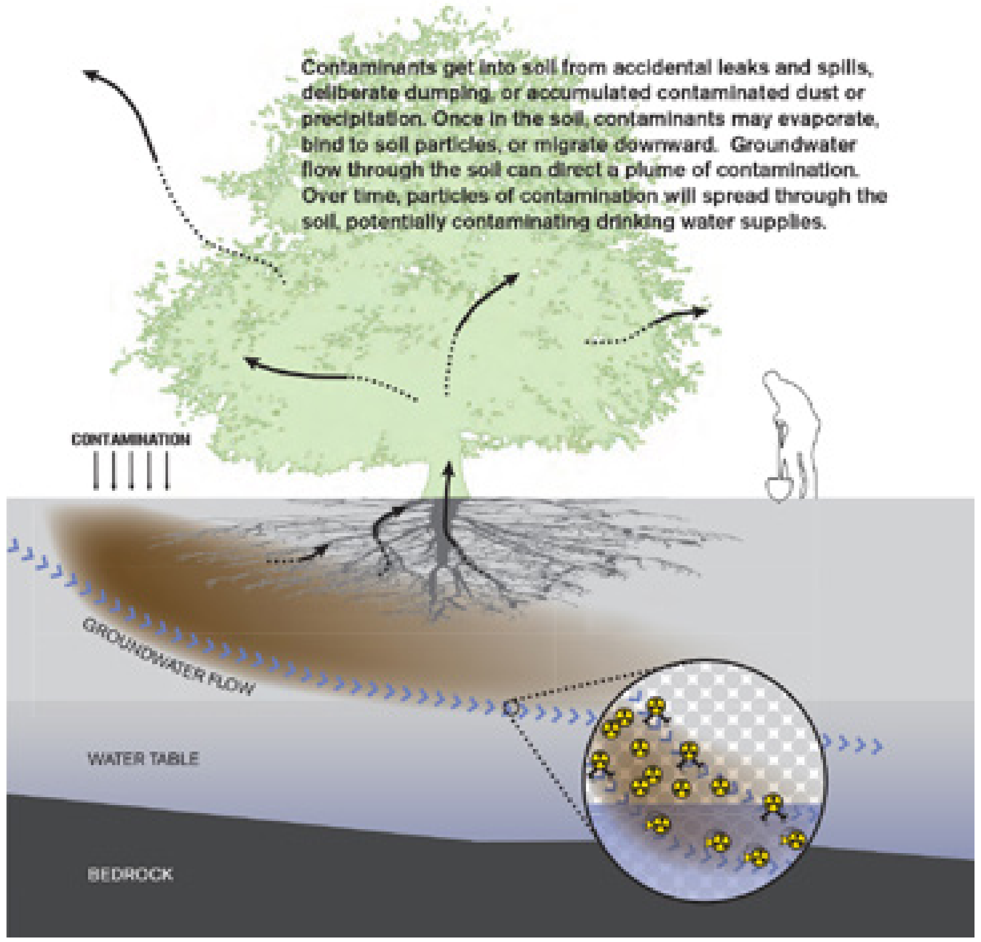
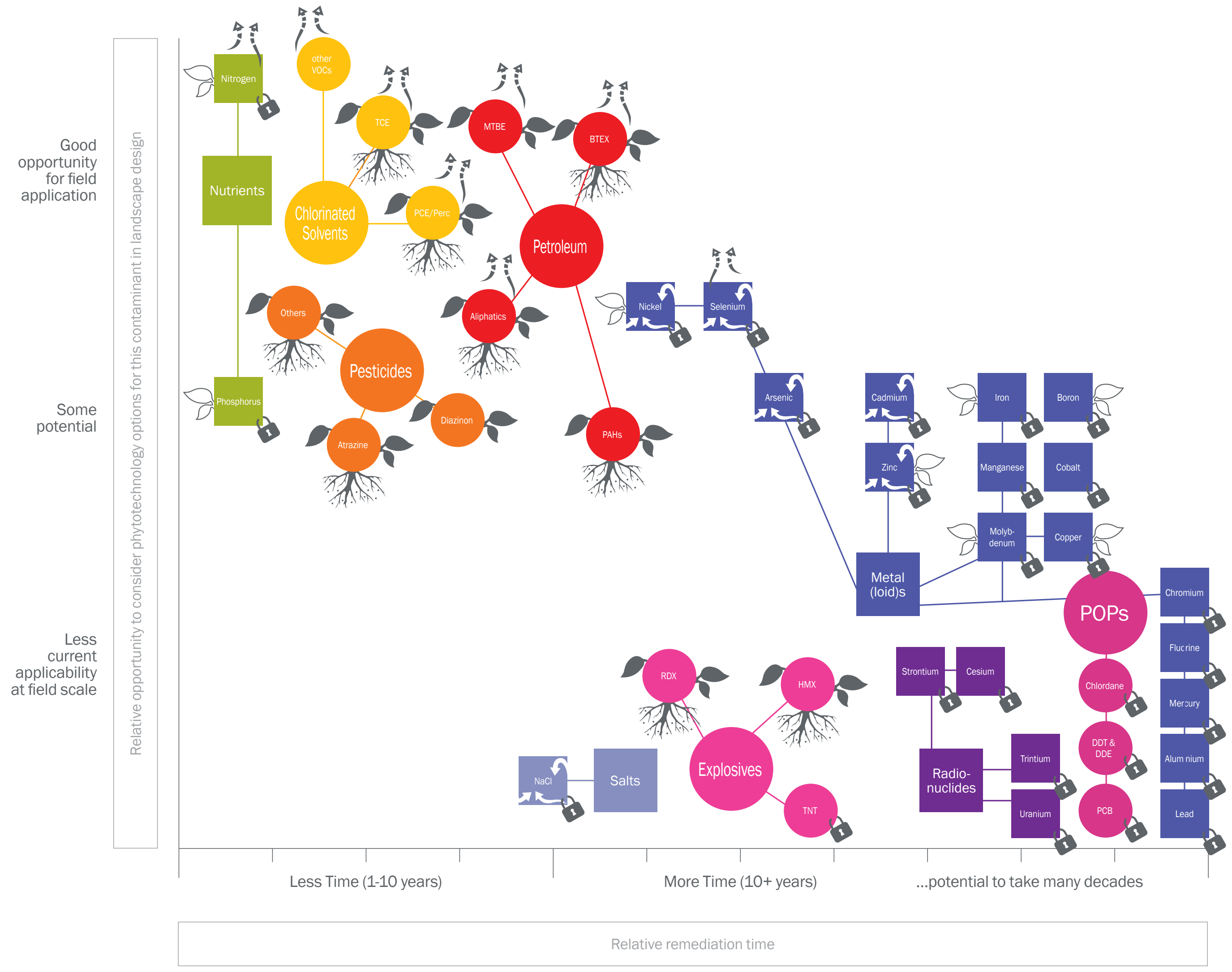
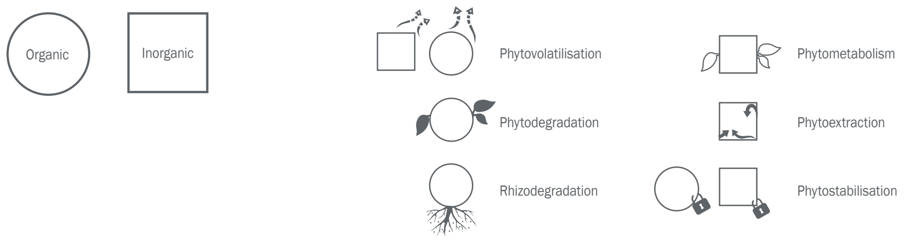


Diagram showing how common contaminants get into the soil and water table. Taken from (YouAreTheCity, pg 13, 2011)



Contaminant Diagram Key

Potential Phytotechnology Mechanisms



Site Contaminants Table. Taken from (Kennen & Kirkwood, pg 63, 2015)

What can be treated with phytoremediation

Phytotechnology treatment techniques are contaminant specific. The contaminants are either organic or inorganic.

ORGANIC pollutants are compounds that typically contain carbon, nitrogen and oxygen and are man-made. Due to the pollutants being compounds, many can be degraded by plants which break down the toxin into smaller, less toxic compounds. They can also be degraded outside the plant in the root zone (rhizosphere) and then be metabolised into the plant where they are either bound to plant tissues or released to the atmosphere through evapotranspiration. The ideal scenario is when the organic contaminant is completely degraded by the plant so it disappears and there is no need to harvest the plant (Kennen & Kirkwood, 2015).

INORGANIC pollutants are naturally occurring elements found in their most basic form in the periodic table, meaning they cannot be degraded or destroyed. Human industrial activities such as the burning of fossil fuels and production cause the release of large amounts of inorganic elements causing toxicity. Some plants can accumulate or hyperaccumulate these toxins into their biomass, however they then become contaminated and must be harvested to remove the pollutant from a site. They might be disposed of into a landfill however their is increasing research around phytomining, where the plants are incinerated and the metals are extracted for reuse.

If extraction is unable to occur, some plants can stabilise the inorganic contaminants around their root mass, making them less bioavailable and reducing the risk of leaching (Kennen & Kirkwood, 2015).

Common contaminants are identified in the previous page.

Evidence for it working

Phtyoremediation is a relatively new science that was first tested in 1990 and has become increasingly popular over the last decade. However, current research is still in its infancy and there is an opportunity to commence research in this largely unexplored field. It is now the cheapest and most economical way to remove pollutants from soil in environmentally damaged landscapes. Previous methods mostly involved removal of massive amounts of soil to landfill or lenghty chemical treatments. Both are enormously expensive and have a carbon burden due to the thousands of truck loads generally needed to move ground material. Perhaps the only drawback of phytoremediation is that it can take years for the process to be completed and it can be difficult to determine which plants will do best in which climate.

Application in garden 01

In proposing phytoremediation gardens for the Power Plants project we will be testing the affecasy of various specific plant species and various types of phytoremediation techniques. Our project aims to be a living laboratory and educational demonstration project disseminated widely so others may take this initial research and utilise it in other brown field sites. The next section of this report examines both international and national precedent projects to assist us to understand what others have learned before us and to help us situate the findings of this project in terms of international best practices.

Elements

Elements are made up of one type of atom. Some occur naturally in soil, but can be toxic at high concentrations. Elements of concern include:

- **As** Arsenic
- **Al** Aluminium
- **Sb** Antimony
- **Ba** Barium
- **Be** Beryllium
- **Cd** Cadmium
- **Cr** Chromium
- **Co** Cobalt
- **Cu** Copper
- **Fe** Iron
- **Pb** Lead
- **Li** Lithium
- **Mn** Manganese
- **Hg** Mercury
- **Mo** Molybdenum
- **Ni** Nickel
- **Se** Selenium
- **Ag** Silver
- **Tl** Thallium
- **Sn** Tin
- **U** Uranium
- **V** Vanadium
- **Zn** Zinc

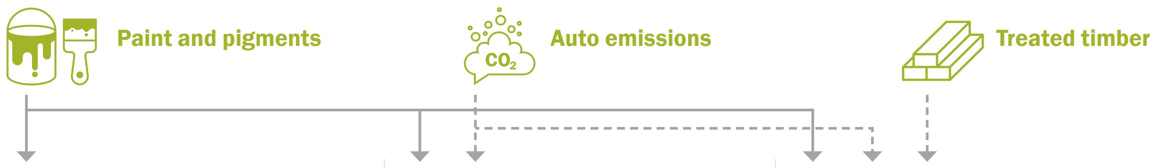
Compounds

Compounds are sets of elements bound together. Toxic compounds are oftrn human made, for direct use or as a byproduct. Compounds of concern include:

- **Benzidines/Aromatic amines**
- **Dioxins, Furans, PCBs**
- **Hydrocarbons**
- **Nitrosamines/ethers/alcohols**
- **Organophosphates and carbamates**
- **Pesticides**
- **Phenols/phenoxy acids**
- **Phthalates**
- **Radionuclides**
- **Volatile organic compounds**

List of common elements (inorganic) and compounds (organic) that make up industrial contamination. Taken from (YouAreTheCity, pg 68, 2011)

Common Contaminants - and how they got into our soil



Cd Cadmium

Cadmium is a soft bluish-white metal and occurs as a by-product of zinc production.

Why is cadmium in our soil?
Cadmium can be found in many industry and consumer products, mainly batteries, pigments, metal coatings, and plastics. It enters our soil and water through the disposal of these products. It enters our air through the burning of coal and household waste.

Risk to Humans:
- can cause kidney damage and fragile bones

Pb Lead

Lead is found in zinc, silver or copper ore and is extracted with these other metals.

Why is lead in our soil?
Prior to 1978 most fuels contained lead. Cars exhaust lead oxide, which would then filter into the soil (near heavy trafficked roads). Lead-based paint, also phased out now was used until the late 1970's for the exterior of buildings. As the paint got old, chips containing lead would fall off and mix into the soil. Lead is also used in construction and various industries.

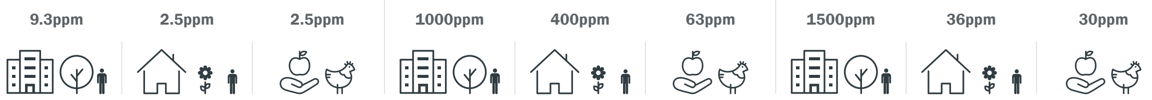
Risk to Humans:
- toxic to the heart, bones, intestines, kidney, reproductive and nervous system
- can cause learning and behaviour disorders

Cr Chromium

Chromium is a steel-grey hard metal that can be found in the enviroment in chromium-containing rocks.

Why is chromium in our soil?
Chromium compounds are used for chrome plating, the manufacturing of dyes and pigments, leather tanning and timber preservation amongs other things. Cement contains chromium. Emissions from automobile brake lining and catalytic converters containing chromium lead to higher levels of chromium in the air and soil near busy roads.

Risk to Humans:
- irritation to the nose and skin
- itching, nosebleeds, sneezing
- can cause cancer and liver damage



List of common contaminants and how they got into the soil. Taken from (YouAreTheCity, pg 10, 2011)

Treated timber **Mining** **Pesticides**

As Arsenic

Arsenic is a chemical element that occurs in many minerals usually in conjuction with sulfur and metals.

Why is arsenic in our soil?
Mining, smelting of non-ferrous metals and burning of fossil fuels are the major industrial processes that contribute to arsenic contamination of air, water and soil. The use of arsenic in pesticides and in the preservation of timber has also led to contamination of the environment. Especially fruit tree orchards are often affected by arsenic contamination through th euse of pesticides.

Risk to Humans:
- can cause cancer in the skin, lung, bladder and kidney

16ppm 16ppm 13ppm

Hg Mercury

Mercury is an extremely rare metal that occurs in deposits throughout the earth's crust.

Why is mercury in our soil?
Mercury enters our air, water and soil through the waste stream of products that contain mercury such as old thermometers, barometers, batteries, flourescent lightbulbs, paint, electrical switches and tooth fillings. Coal fired power plants used to emit mercury. Some mercury compounds are also found in fungicides.

Risk to Humans:
- damage to the brain, kidney and developing fetus
- skin rashes and effects on the lungs and eyes

2.8ppm 0.81ppm 0.18ppm

DDT Pesticides

DDT is one of the most well-known pesticides. Pesticides are chemical substances intending for preventing, destroying, repelling or mitigating any pest. DDT was banned in 1972, but pesticides containing other toxic substances are still in use today.

Why is DDT in our soil?
Over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target species. Pesticides leak from production facilities or storage tanks, run off fields when overused, or are sprayed and discarded.

Risk to Humans:
- premature birth and low birth weight
- breast cancer
- impared child neural development

47ppm 1.7ppm 0.0033ppm

List of common contaminants and how they got into the soil. Taken from (YouAreTheCity, pg 11, 2011)

Petroleum **Industry** **Paint and pigments** **Electrical Transformers** **Industrial Solvents**

PAH Polyaromatic Hydrocarbons

Polyaromatic Hydrocarbons are over 100 chemicals, formed during the incomplete burning of many organic substances.

Why is PAH in our soil?
PAHs are found in exhaust from motor vehicles and other gasoline and diesel engines, emission from coal-, oil-, and wood-burning furnaces, cigarette smoke; general soot and smoke, and cooked foods, especially charcoal-broiled; in incinerators, coke ovens, and asphalt processing and use.

Risk to Humans:
- red blood cell damage leading to anemia
- supresses the imune system
- known to cause cancer

1ppm 1ppm 1ppm

PCB Polychlorinated Biphenyls

Polychlorinated Biphenyls are man-made organic chemicals, manufactured in the United States between 1928 and its ban in 1979.

Why is PCB in our soil?
PCBs were used in industrial and commercial products including electrical, heat transfer, and hydraulic equiptment; as plasticizers in paints, plastics, rubber products, and other industrial applications. Today, PCDs can be released into the soil due to improper disposal of PCB-containing products or leaks from electrical transformers.

Risk to Humans:
- affects reproduction system, immune system, nervous system
- known to cause cancer

1ppm 1ppm 0.1ppm

TCE Trichloroethylene

Trichloroethylene is a non-flamible, colourless liquid that belongs to a group of chemicals known as "Volatile Organic Compounds" (VOCs).

Why is TCE in our soil?
It is used in adhesives, paint and spot removers, and as a solvent for degreasing engine parts. It has also been used in food production, dry cleaning, medicine (as an anesthetic) and film cleaning. Its widespread use since the 1920s continues today, yet use has declined in th elast decade.

Risk to Humans:
- dizziness and sleepiness
- short term: symptoms similar to alcohol intoxication, can lead to death
- Long term: liver and kidney cancer, leukemia, non -Hodgkin lymphoma

200ppm 10ppm 0.47ppm

List of common contaminants and how they got into the soil. Taken from (YouAreTheCity, pg 9, 2011)

Precedent Study

SECTION 02

This section of the report includes a number of design precedents as well as technical remediation project examples. It is important to note that while many are brown field site redevelopments, we were unable to find many examples of phytoremediation gardens in post industrial, urban sites. So while certain aspects of WSUD and the water cleansing properties of phytoremediation were quite common, it appears that our proposal for WBPS may be the first of its kind in Australia and one of the few in the world. This selection also offers a wide variety of designerly ways to approach post industrial environments from an educative and interpretive manner.

International

Park De Ceuvel
Buiksloterham Port | Amsterdam | Netherlands

Landschaftspark
Duisburg Nord | Germany

Westergasfabriek
Amsterdam | Netherlands

Freshkills park
Staten Island, New York | United States

Belmont Goats
Portland | United States

National

Sydney park water re-use project
Sydney | Australia

Phytoremediation potential on ex mining sites
Queensland | Australia

Kopu timber waste-pile
Kopu | New Zealand

Millenium parklands sydney
Sydney | Australia

BP Parkland | Waverton Peninsula
Sydne | Australia

Park de Ceuvel

AMSTERDAM

DETAILS

LANDSCAPE ARCHITECTS:
DEVLA Landscape Architects

COLLABORATION WITH:
Metabolic, Transsolar, Bas van Schelven, Witteveen en Bos, Huib Koel, Woodies at Berlin

LOCATION:
Buiksloterham Port, Amsterdam, Netherlands

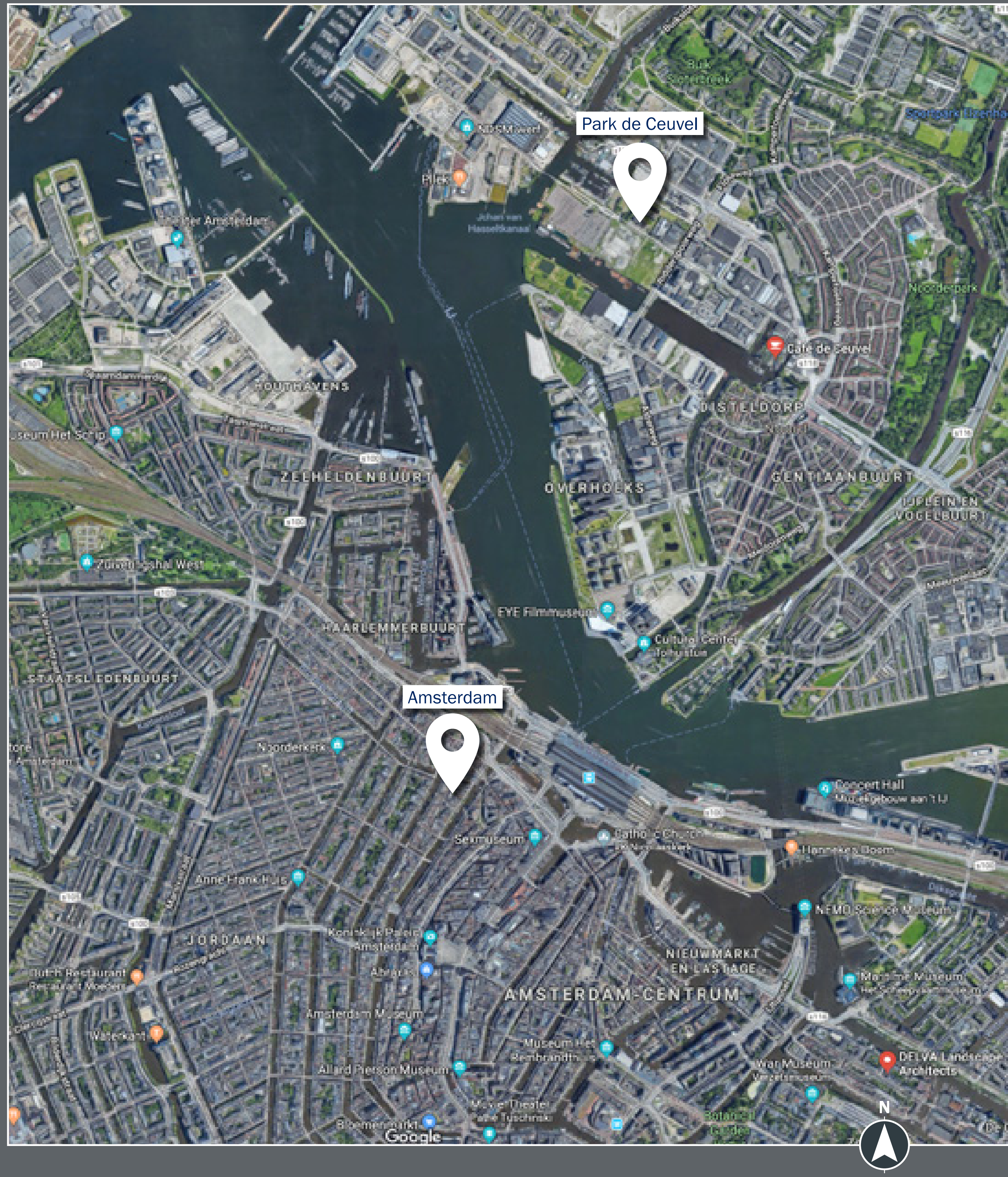
YEAR OF CONSTRUCTION:
2012-2014

FORMER USE:
Shipyard

AREA:
4,470m^2

(Image: DEVLA Landscape Architects, 2014)

Google maps image showing Park de Ceuvel in reference to Amsterdam CBD



PRECEDENT ANALYSIS

Context of Buiksloterham

Buiksloterham is a unique neighbourhood within Amsterdam and has been envisioned as a living lab for Circular, Smart and Biobased development (Metabolic et. al, 2014). The site is located five minutes travel away from the old centre of Amsterdam across the IJ River. Buiksloterham because of its industrial past left up to 80% of its plots highly polluted. This pollution is the result of its former uses as a waste incineration plant and ship yard.

The Buiksloterham Action Plan of 2014, investigates Information Technology (IT) interventions and urban biodiversity as the core strategies to bring long term resilience to the area while keeping local residents engaged and informed. It pilots the transformational potential of neighbourhoods with an industrial past via sustainable design and designates the area as an official Experimental Zone or Living Lab (Metabolic et. al, 2014).

Buiksloterham's polluted soils were originally deemed the greatest challenge, however they have ended up becoming one of the largest local opportunities. Different phytoremediation and bioremediation techniques have been applied to the polluted plots where crops are grown for material and energy production whilst also cleaning the soil. In some cases, the level and type of pollution has permitted temporary activities to take place on the plots while bioremediation continued, opening up flexible development options (Metabolic et. al, pg 34, 2014).

Ship building in 1894 in the greater area of Buiksloterham, http://www.ndsm.nl/story/scheepswerf-naar-plek-creatieven-en-experiment/

Masterplan of Park de Ceuvel from; http://www.spaceandmatter.nl/de-ceuvel/

Site images taken during the construction of Park De Ceuvel (DEVLA Landscape Architects, 2014)

From the beginning of development, the monitoring and tracking of data has been seen as an important objective to keep residents updated. Smart water, energy and air quality monitoring was the first local investment. The system incorporates sensors with an aim to live stream of data via the neighbourhood online portal. The live stream of data has not yet been realised (Metabolic et. al, 2014).

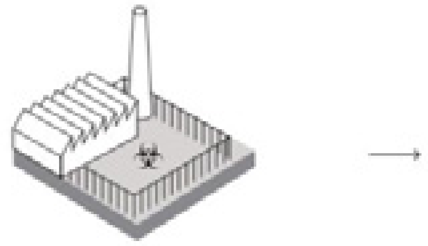
Design agenda for Park de Ceuvel

Park de Ceuvel covers an area of 4,470m2. In 2012 the site was secured for a 10 year lease from the Municipality of Amsterdam after a group of architects won a tender to turn the site into a regenerative urban oasis (De Ceuvel, 2014).The design envisioned De Ceuvel as a temporary creative zone with offices in retrofitted houseboats on a polluted plot. The site was initially planned to be remediated mechanically but a lack of funding meant an alternative, less capital-intensive way of developing was required. The contaminants present in the soil included heavy metals, asbestos, mobile agents, volatile chlorinated organic compounds (VOC's) and mineral oil. Therefore phytoremediation processes were utilised to remediate the contamination below while creative industries worked above. The site would be activated further by the café- Café De Ceuvel.

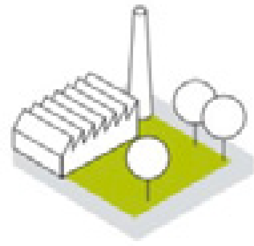
It has received national and international interest since its completion and has successfully incorporated a bottom up approach in its design with tenants, volunteers and students working on the boats, jetty, Café and park.

The site has high sustainability targets of 100% renewable energy, heating and hot water, 100% water self sufficiency, 100% waste water management, 50-70% nutrient recovery and 10-30% food production on site (Metabolic et. al, 2014).

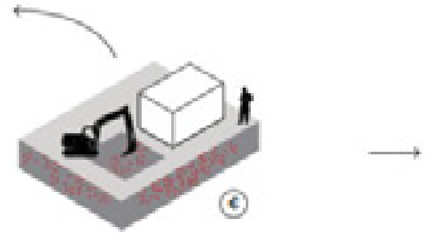
Houseboats were often upcycled by the company that has come to occupy them (DEVLA Landscape Architects, 2014)



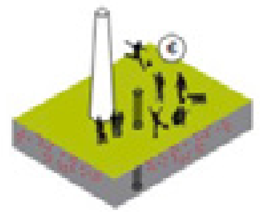
Polluted grounds are inaccessible and take a lot of space



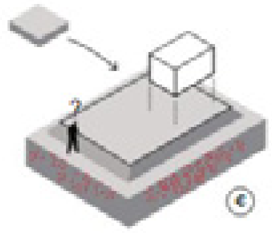
Phytoremediation or biological treatment in combination with biomass production



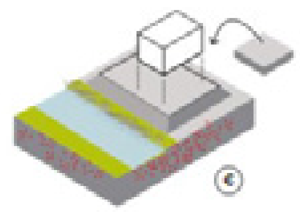
Traditional remediation: the soil is dug away or covered



Creating societal value through tendering for innovative concepts



Traditional development brings clean soil from elsewhere to heighten ground and cover pollution



Selective raising with clean soil from within Buiksloterham

Action Plan aims to overturn traditional treatment methods for polluted sites (Metabolic et. al, pg 63, 2014)

Contamination and remediation

The phytoremediation plan designed by DELVA Landscape Architects with consultation from the University of Ghent utilises a specially selected combination of plants and includes grasses, perennials, short rotation coppice and mature trees for the uptake and degradation of toxins. The planting contributes to an increased biodiversity in the area. The project also features elevated platforms of water-cleaning gardens and micro-greenhouses for food production (DEVLA Landscape Architects, (2014)).

A raised timber jetty ensures that there is no direct contact with the polluted soil. The trail winds through the planting connecting the different houseboats. The prunings of any plants remain on the property and are utilised to create products from biomass. An on-site biomass digester converts biomass into energy that is used in the area.

Monitoring and maintenance

Research on the purification and low-impact biomass production at 'De Ceuvel' is conducted by the University of Ghent (Belgium). It serves as a test site and pilot project for graduate and doctoral study programs. A knowledge route through the area shows the results of these studies and informs visitors about the sustainable principles of the organic purification and low-impact biomass production at the park.

The soil contamination is no longer the problem of this place but is the catalyst of innovative concepts and initiatives in the field of sustainability.

In 2017, the original planting has matured with the only surviving plants being the willows, poplars and some grasses. Since 2016 there has been continued research into the plants that have spontaneously established themselves on site. They are being examined for their potential use in phytoremediation, while plants already known for their accumulator qualities are simultaneously sown (De Ceuvel, 2017).

Kitchen garden for Cafe de Ceuvel (DEVLA Landscape Architects, (2014))

Effectiveness of project

The upcycled houseboats were retrofitted through DIY practices with only €5000 for materials which returned the investment in three years (Space&Matter, 2012).

The houseboats offer space for different artists and creative entrepreneurs. Some boats are shared by different companies or individuals, other boats are rented by just one company. Many of the current tenants have helped to build de Ceuvel or their own office boat (DeCeuvel, 2014).

The inclusion of Cafe De Ceuvel in the masterplan is an effective way to activate the site out of office hours and on weekends. Events can be held there and in the courtyard in front. The cafe incorporates sustainable systems including the recovery of phosphates from urine, a greenhouse on the roof where herbs are grown for use in the cafe, as well as the world's first Biogas Boat in which organic waste is transformed into biogas to cook on (DeCeuvel, 2014).

Epilobium angustifolium
Wilgenroosje

Typha latifolia
Grote Lisdodde

Digitalis purpurea
Vingerhoedskruid

Achillea millefolium
Duizendblad

Salix nigra
Zwarte wilg

Lolium perenne
Raaigras

Agrostis capillaris
Struisgras

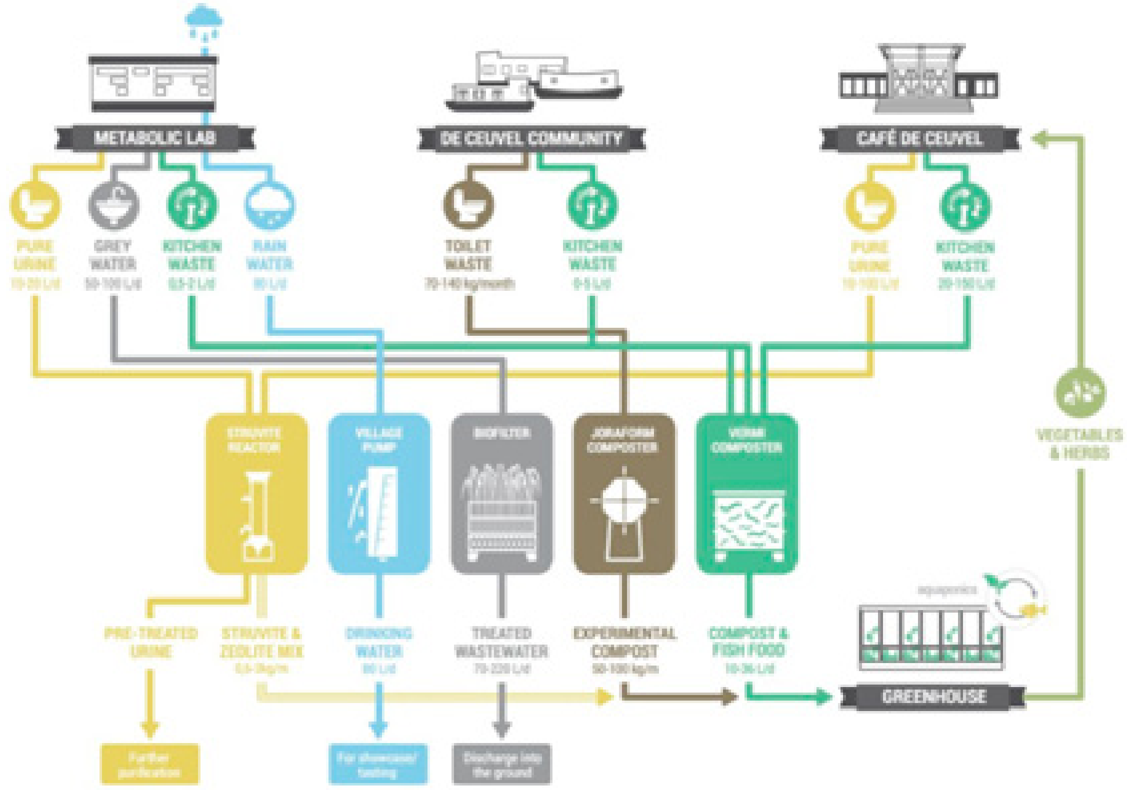
Festuca arundinacea
Rietzwenkgras

Original plant palette for phytoremediation developed by DEVLA Landscape Architects and Ghent University (DEVLA Landscape Architects, 2014)

Timber winding pathway separates pedestrians from the contaminated soil and allows users to connect with the water and plants. (DEVLA Landscape Architects, 2014)

Cafe de Ceuvel with an event occupying the cafe and the courtyard infront. (DEVLA Landscape Architects, 2014)

Energy and nutrients flows on De Ceuvel:



We call De Ceuvel a Cleantech Playground. The concept was developed to stimulate new ways of thinking about how we manage our resources in our communities. The Cleantech Playground is a concept that responds to the ambitious sustainability targets set early on by the De Ceuvel community while offering a fun and engaging educational environment. Through De Ceuvel are showcases of technologies that operate on a small scale to close local cycles and bring us back in touch with our basic needs. The creative reuse of waste materials through the site is a key component of extracting value and nutrients from what many people view as waste.

You can explore the techniques at De Ceuvel though the overview below. We aim to continue to evolve over time, and so will the technologies used on-site. Working with new technology partners, research institutes, and government agencies enables us to create a rich educational environment for exploring the future of circular urban environments.

Image showing Energy and Nutrient Flows within De Ceuvel, (http://deceuvel.nl/en/about/sustainable-technology/)

The project is experimental and it is therefore important to keep the public informed about events that are happening at the site as well as how the project is functioning on a systematic and scientific level. The De Ceuvel website's aim is to engage, inform and also provide open source information which can be utilised by people around the world who are engaging in this type of work. The Power Plants project's website aims to also engage, inform and provide open source information.

The project is the only project in the international precedents that utilises phytoremediation in its truest sense. Its effectiveness is in its transformation from abandoned lot, to thriving hub of the local community.

Landschaftspark

DUISBURG-NORD

DETAILS

LANDSCAPE ARCHITECTS:
Latz + Partners

LANDSCAPE COLLABORATION WITH:
Latz-Riehl, G. Lipkowsky

LOCATION:
Duisburg, Germany

BUDGET:
€15,500,000

YEAR OF CONSTRUCTION:
1992-2002 (ongoing)

FORMER USE:
Coal and Steel Plant

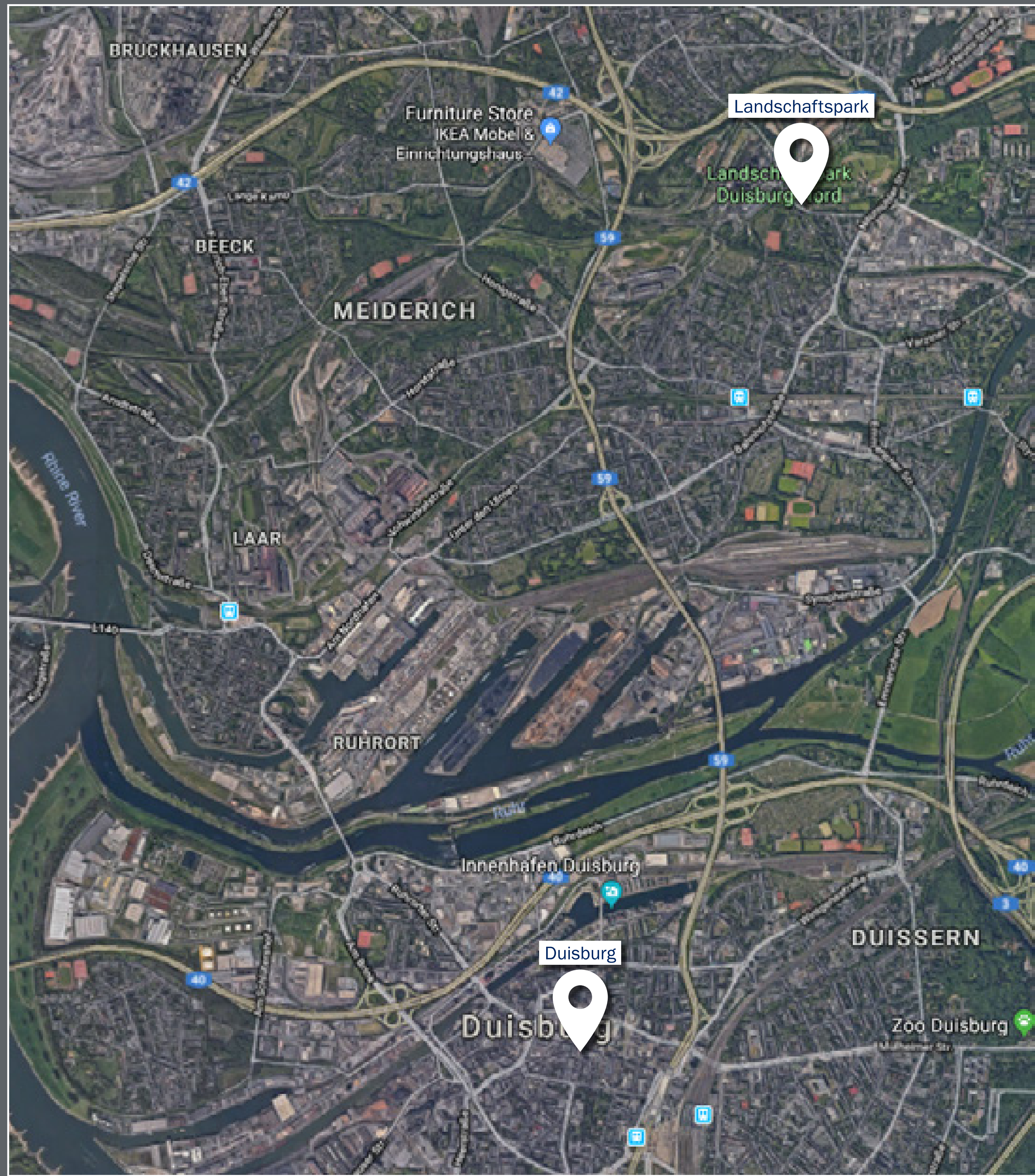
AREA:
230 ha

REALISATION BY:
North Rhine Westphalia, citizens' action, associations and employment schemes

CLIENT:
Landesentwicklungs-gesellschaft Nordrhein-Westfalen, Stadt Duisburg, Emschergenossenschaft Essen, Kommunalverband Ruhrgebiet

Image: ©DZT/Landschaftspark Duisburg-Nord GmbH (Mark Wohlrab)

Google maps image showing Duisburg-Nord in reference to DuisburgCBD



PRECEDENT ANALYSIS

Context of Emscher Park, Ruhr District

Landschaftspark was developed from 1990-2002 as one of 100 projects in the larger redevelopment project by the International Building Exhibition (IBA) of Emscher Park.

The IBA is a regional consortium that acts as an agent for change and innovation in regions challenged by economic transformation in Germany. They typically focus on a specific site for 10 years to develop goals of structural transformation and are funded publicly. They prioritise parks and public greenway projects to establish a landscape armature to enable a new sense of belonging, connectivity and attract new investments from the private sector (Sieweke, 2013). Many projects implemented by IBA, including Duisborg Nord, are considered international best practice for post-industrial sites.

Emscher Park spans 450km of ex-industrial landscapes in the Ruhr Valley. Its overall strategy is to create public open spaces and greenways alongside preserved and re-imagined infrastructure from its industrial past.

The process of IBA in Emscher Park has helped to attribute value to the industrial identity of the area by incorporating many cultural and arts amenities to the redevelopment sites (Sieweke, 2013). As most of the sites are contaminated, remediation of the land in situ has been adopted as a strategic and cost effective treatment method. Soil remediation in Landscaftspark is achieved by burying the most polluted soils in the sinter bunkers under a sealed concrete cap and capping the rest with clay and a clean fill overlay (confirmed via email to the Biological Station at Landscaftspark, see email in Appendix 2).

Design agenda for Landschaftspark duisborg nord

The site for Landschaftspark is 570 acres (230 ha) and was formally Meiderich Ironworks, a coal and steel production plant. It began operating in 1903 and by 1985 the last of the blast furnaces was shut down, leaving the site abandoned and significantly polluted. The owner at that time, Thyssen wanted to hand over the site, including its contamination to public authorities but demolish all the industrial structures in order to collect revenue by selling the scrap. Interest Group (IG) Nordpark, a citizens group argued for its conservation as an industrial monument. The City of Duisburg made the site part of the Emscher Landscape Park within the International Building Exhibition (IBA). The site then passed into the ownership of North Rhine Westphalia (the property fund of the federal state), which held many industrial sites in trusteeship for their future development (Ganser,K. 2016). The IBA followed five key tenets to be included into the design:

- Ecological transformation of the Emscher river system,
- Work in the park
- New residential and neighbourhood development
- Industrial monument conservation and industrial culture
- New proposals for social, cultural and sports activities (Latz, 2016).

In 1991 Latz + Partners' was commissioned to design a public park after winning a design competition for the site. The brief was to create a masterplan that did not incur follow up maintenance costs (Ganser,K. 2016). The approach by Latz + Partners was to take the site's disturbed and complex conditions as nuisances that must not be erased or camouflaged. Rather they should be mined for their creative potential to be reused and reclaimed.

The transformed site creatively repurposes existing structures and incorporates a number of amenities that promote recreation and community, which reinvigorates the site through the attraction of a diversity of users (Latz + Partners, 1999).

The site was broken down into partial 'projects,' which follow rules to reflect the existing conditions. Existing access points via roads and railways were investigated. Specific plant species that grew in each area were recorded.

The new design weaves a series of walkways and waterways that follow the footprint of old railway and sewer systems. Each piece retains its specific character and creates a dialogue with the site surrounding it. Within the main complex, Latz emphasized specific programmatic elements: the concrete bunkers create a space for a series of intimate, enclosed gardens, former natural gas tanks have become pools for scuba divers, concrete walls are used by rock climbers, and the middle of the former steel mill, has become a piazza. Each of these spaces uses elements to allow for a specific reading of time.

According to Latz, the site was designed with the notion that a grandfather, who might have worked at the plant, could walk with his grandchildren, explaining what he used to do and what the machinery had been used for. Therefore memory was central to the vision for the design. This idea of memory informing a visitor of the site has become a prevalent concept during and after Postmodernism (Latz + Partners, 1999).

Masterplan of Landshaftspark Duisburg Nord (Latz + Partners, 1991 - 1994)

Site contamination and remediation

When the former steel works closed in 1985 the site incorporated different vegetation patches based on the soil type. These were in early stages of vegetation succession and were dominated with pioneer species. Six vegetation communities were identifies by Latz + Partners as being important:

- Black slag rock from viterous slag with mosses and succulents
- Areas or banks with crushed blast furnace slag, in parts covered with acid materials (previously coal and coke store)
- Randomly mixed substrates, mixed soils, generally with a high pH value
- Birch regeneration on black colliery waste with low pH value
- Growth on natural stone ballast on the goods railway line and its system
- Agricultural soils with field and meadow species

These were however abandoned as the habitats developed rapidly in only a few growing seasons after the closure of the steel and coal plant.

A number of different procedures and methods for the treatment and securing of contamination have been incorporated into the design. They however do not utilise purposeful phytoremediation.

- Contaminated ground water is collected in a catch water drain parallel to the Old Emscher and pumped to a wastewater treatment plant on the Rhine
- The Bunker Forecourt lies above former settling basins which was covered with a one - two metre thick layer of gravel and soil to immobilise the existing contamination
- The Clarification Basins contained arsenic sludge. The sludge was dewatered and the dried contamination was put into barrels and stored in a mine. The clarifiers were cleaned and now serve as reservoirs for the Clear Water Canal
- The Cyan Decontamination plant was dismantled down to its foundations and turns into temporary water gardens after rain
- The Chimney of the former sinter plant was blown up and the contaminated inner lining stored in the first three compartments of the sinter bunkers, sealed with concrete lids and then planted as green roofs
- The tar lake, which was a 12 metre deep basin filled with polycyclic compounds formed a hardened uppermost layer, hard enough to walk across. The tar lake was cleaned up after the IBA
- Blast furnace slag found in almost all areas of the site contains heavy metals which form stable bonds as long as the pH-value is alkaline. Usable areas were covered in dolomite chippings to increase the pH of the soil. In some areas the slag has solidified into black rock through vitrification, binding all the toxic compounds together
- Part of the Ferromanganese Foundry and casting beds remains highly polluted and therefore has been fenced in. Access is prohibited
- The gas purification plant remains highly polluted, particularly the tanks and pipes in the eastern gas purifying plant, dating back to the first production plant. They are secured by a high fence. Spontaneous vegetation occurs there and is removed every 10 years- one of the examples of unintentional phytoremediation
- Isolated spots of contamination were found in agricultural soils at Emstermannshof. In these instances the plot is cleared, laid with 1m of clean soil and the plots are newly laid out (Latz.P, 2016)

Monitoring and maintenance

The Western Ruhn Biological Station monitors the vegetation within Duisburg Nord and extensive material is published online (in German)! The park has become a refuge for rare and endangered plants and ecology is returning to the site. The Biological station continues to monitor spontaneous growth of vegetation on the site .

BLAST FURNACE PARK & PIAZZA METALLICA

The Piazza Metallica is the symbol and heart of the park and is located within the remaining Blast Furnace infrastructure. It symbolises the transformation of the existing hard and rugged industrial structure into a public park utilised by the surrounding community. Iron plates that were once used to cover casting moulds in the pig-iron casting works are utilised as platform elements in the Piazza. These cast iron plates have been eroded by natural physical processes over time and continue to rust and erode in their new location, eventually becoming overrun by grasses.

At the time of its construction it was a controversy to create a public space in amongst the former blast furnace plant. In the late 90s, the fear of pollution and contamination moved to a calm acknowledgement of the old structures.

During festivities up to 50,000 people can gather in these spaces in between blooming poplar trees, forming a bizarre framework of the blast furnaces, windheaters and nature. (Latz + Partners, 1999).

Former industrial use of site with the iron plates lining the casting moulds (Latz + Partner (1999)

All images of Blast Furnace Park taken from (Latz + Partner (1999))

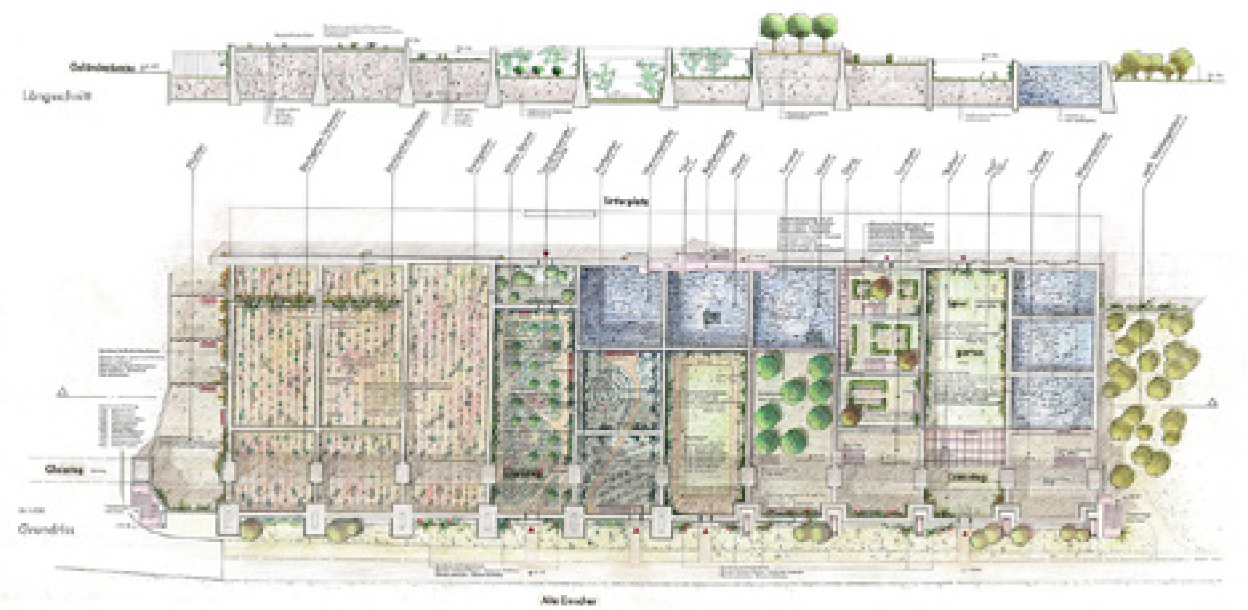
SINTER PARK

The sinter plant formerly processed fine grain raw materials into course grain iron-ore sinter. The enclosed concrete bunkers were utilised to store ore, coal, lime and ashes. This left the site heavily contaminated, especially with heavy metals and the chimney of the sinter plant had to be completely demolished. The bunkers with the level change hold pollutants and the contaminated lining of the chimney under a planted concrete cap.

Latz + Partners' approach was to reimagine the bunkers as enclosed gardens filled with different plants in order to form intimate places of retreat and contemplation for small groups or individuals. According to Latz, this breakdown of space is an important aspect of a large, open, public park.

Also included in this "partial project," is a meadow, a shady grove and a large gathering place, framed to the side of the blast furnace plant by the remainders of the former overhead railway and a high level walk of 300 metres. The high level walk leads across the bunkers and offers views down into the gardens.

The new adjacent windmill is not only part of the new ecological water cycle but a symbol of renewal in a once desolate area. (Latz + Partner 1999)



Cross section of Sinter Park, Sinter Park Vegetation Layout (Latz + Partner (1999))

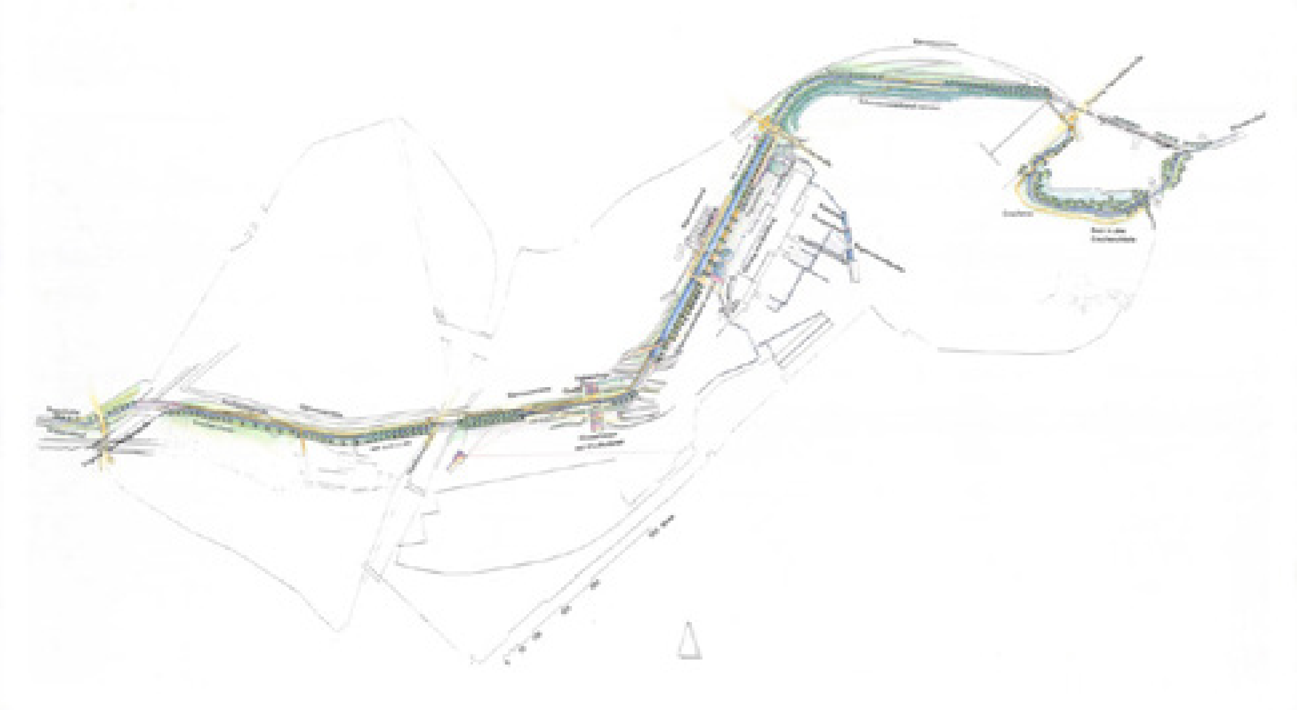
All images of Sinter Park taken from (Latz + Partner (1999))

WATERPARK

The existing open waste water canal of the “Old Emscher” which crosses the park from east to west was utilised in the new scheme to create an ecological clean water system.

Bridges and footpaths cross the canal which is exclusively fed by rainwater. The waste water is now carried within an underground 3.5m diameter main. It is sealed by a layer of clay and collects run off from the buildings, bunkers and former cooling ponds that may contain contaminants. A windpower installation was set up in the mill tower of the former sintering plant to passively transport the water to the treatment plant on the Rhine.

The clear water channel and the water system are an artefact, which aim to restore natural processes in a degraded environment post-industry. These processes are governed by the rules of ecology, but are initiated and maintained by people and technological means. Man uses this artefact as a symbol for nature, but remains in charge of the process.
(Latz + Partner ,1999)



Water Park layer of the park, taken from (Latz + Partner (1999))
All images of Water Park taken from (Latz + Partner (1999))

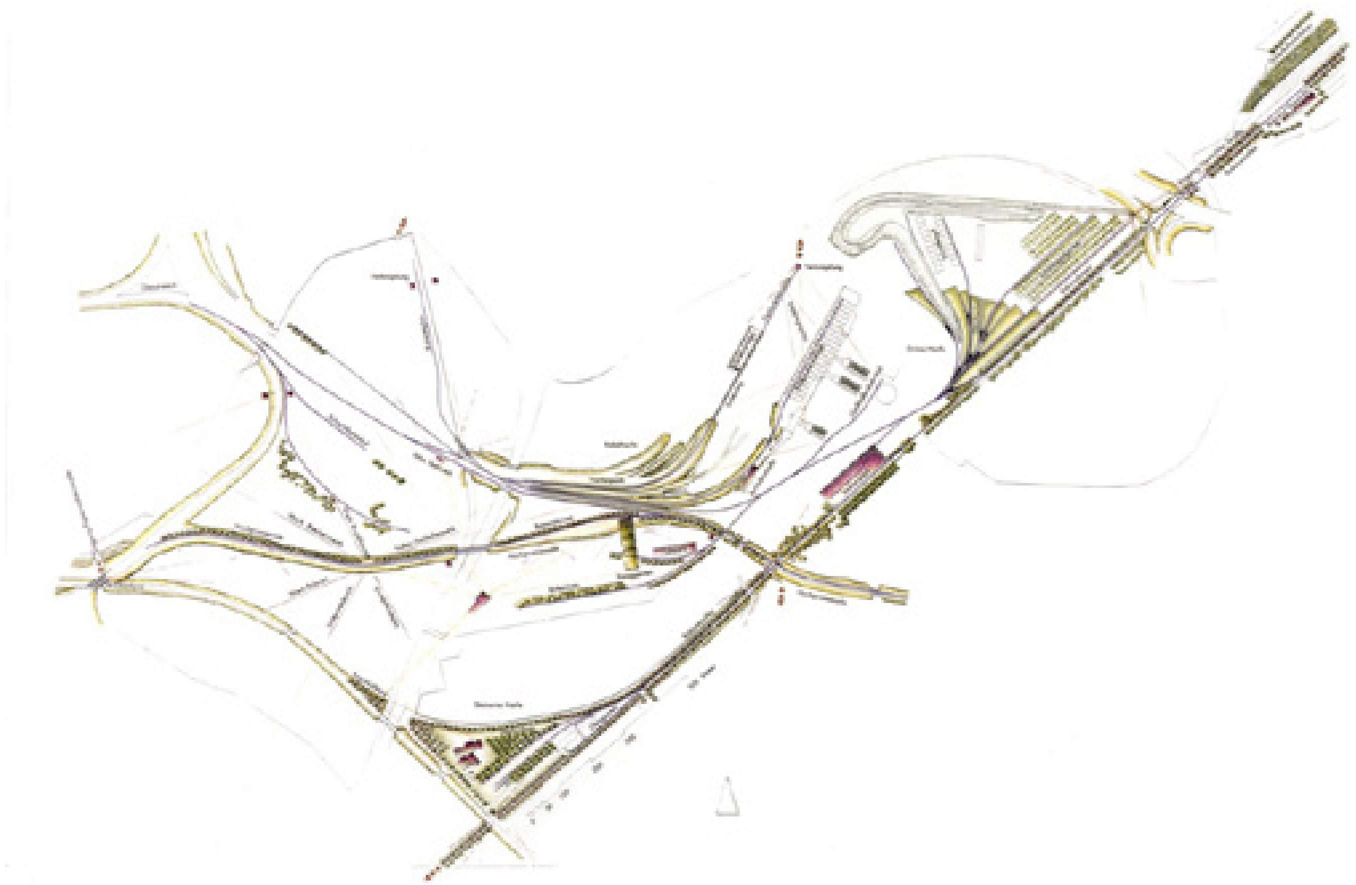
RAILWAY PARK

The former railway lines have either been repurposed into walking spines or are still utilised as heavy rail, and are the most continuous connections into and within the park. They form a filigree pattern, connecting deep into the living and working areas of the surrounding city quarters.

The railway park develops according to the transportation plan of the past. Numerous bridges and paths open up specific perspectives on different levels and secure the coherence in this fragment.

The colourful vegetation represents the flora which immigrated with the ore from all around the world. The management of the park takes this unique situation into consideration and is cleared every 10 years to achieve a meadow effect, made up of primary succession

The railroad tracks end at the sinterplant where a high level walk was built with recycled material on the pillars of the former overhead railway. This invites users to experience the space in a new and different way. (Latz + Partner, 1999)



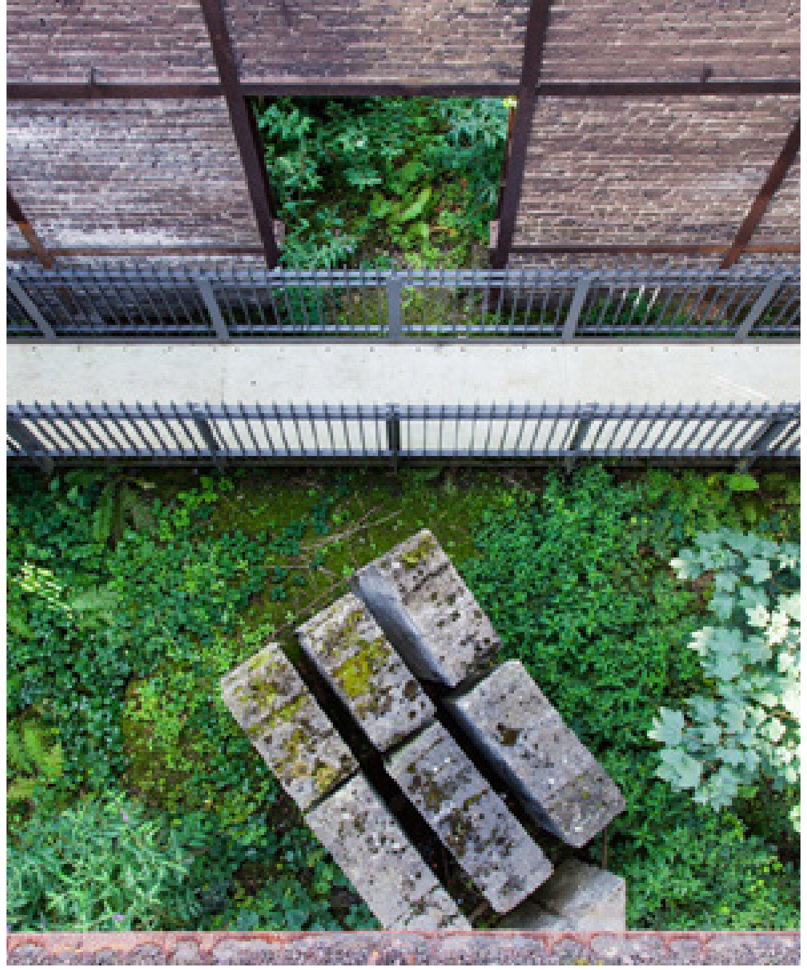
Plan of Railway Parks Network , Duisburg Nord (Latz + Partners,1999)
All images of the Railway Park taken from (Latz + Partner, 1999)

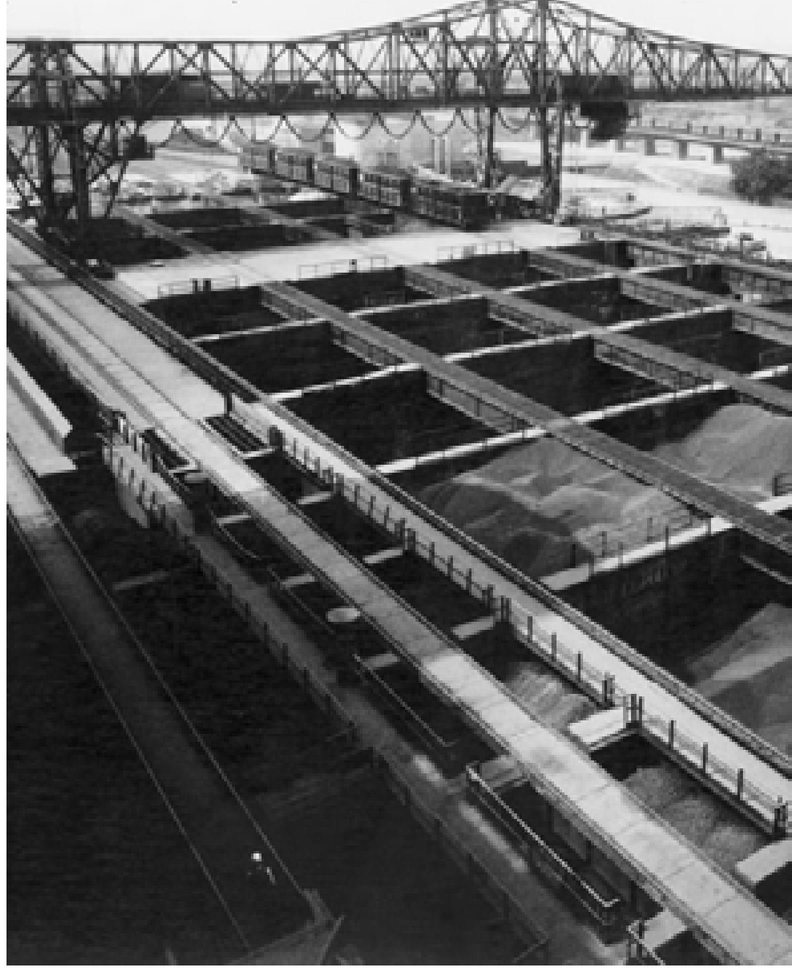
ORE BUNKER GALLERY

The Ore Bunker Gallery was designed in collaboration with artists and the Lehmbruck Museum in Duisburg.

Concrete saws cut into the massive 2-3 metre thick walls to form doorways. They act as subtle insertions, connecting paths and footbridges throughout the labyrinth complex. They open up completely new prospects for the future gallery, the dark rooms of which had previously only been visible from above.

The paths and gallery spaces are interspersed with artificial gardens with different microclimates, featuring sound effects and various artistic interventions. (Latz + Partner, 1999).





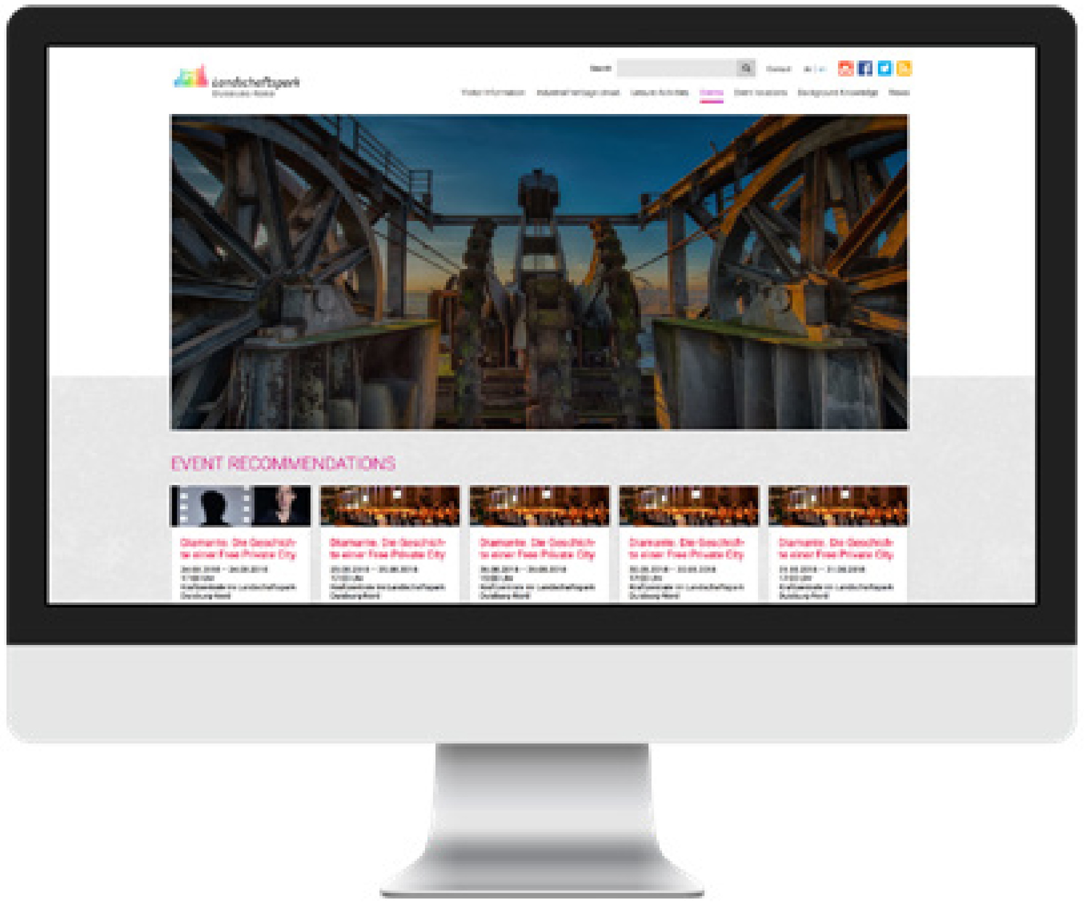
All images of the Ore Bunker Gallery taken from (Latz + Partner, 1999)

SITE AT NIGHT

Effectiveness of project

Although the project did not focus on phytoremediation as a decontamination strategy, it is a rigorous and detailed example of how ex-industrial sites can be meaningfully restored to contribute effectively to public amenity and local environmental and cultural ecologies.

Because of the parks' educative and public engagement mission we also felt it very important to examine its website and calendar of public and educational events. The following pages are taken directly from the website and allowed us to consider our own website's navigation and offerings. The public events programme was particularly interesting given various concerns over toxic environments being made into public parks. This type of programming maybe useful for the masterplanning team.



Above: Images of the Landschaftspark website which provides detail on the landscaping and history of the site as well as providing details into various events held at the park. Images sources from (http://en.landschaftspark.de/startseite

Right: Community programs of monitoring wild life and planting new areas contributes to community ownership and engagement in the park's development into the long term. Images from (http://en.landschaftspark.de/startseite)

All images taken from (Latz + Partner, 1999)

Westergasfabriek

AMSTERDAM

DETAILS

LANDSCAPE ARCHITECTS:
Gustafson Porter + Bowman

COLLABORATION WITH:
Mecanoo Architects, Arup Engineering, Tauw Engineering, Pieters Bouwtechniek Engineering, Marcus BV Contractor, Northcroft Belgium Project Management

LOCATION:
Amsterdam, the Netherlands

BUDGET:
€31 million

YEAR OF CONSTRUCTION:
1997 competition won, 2004 completed

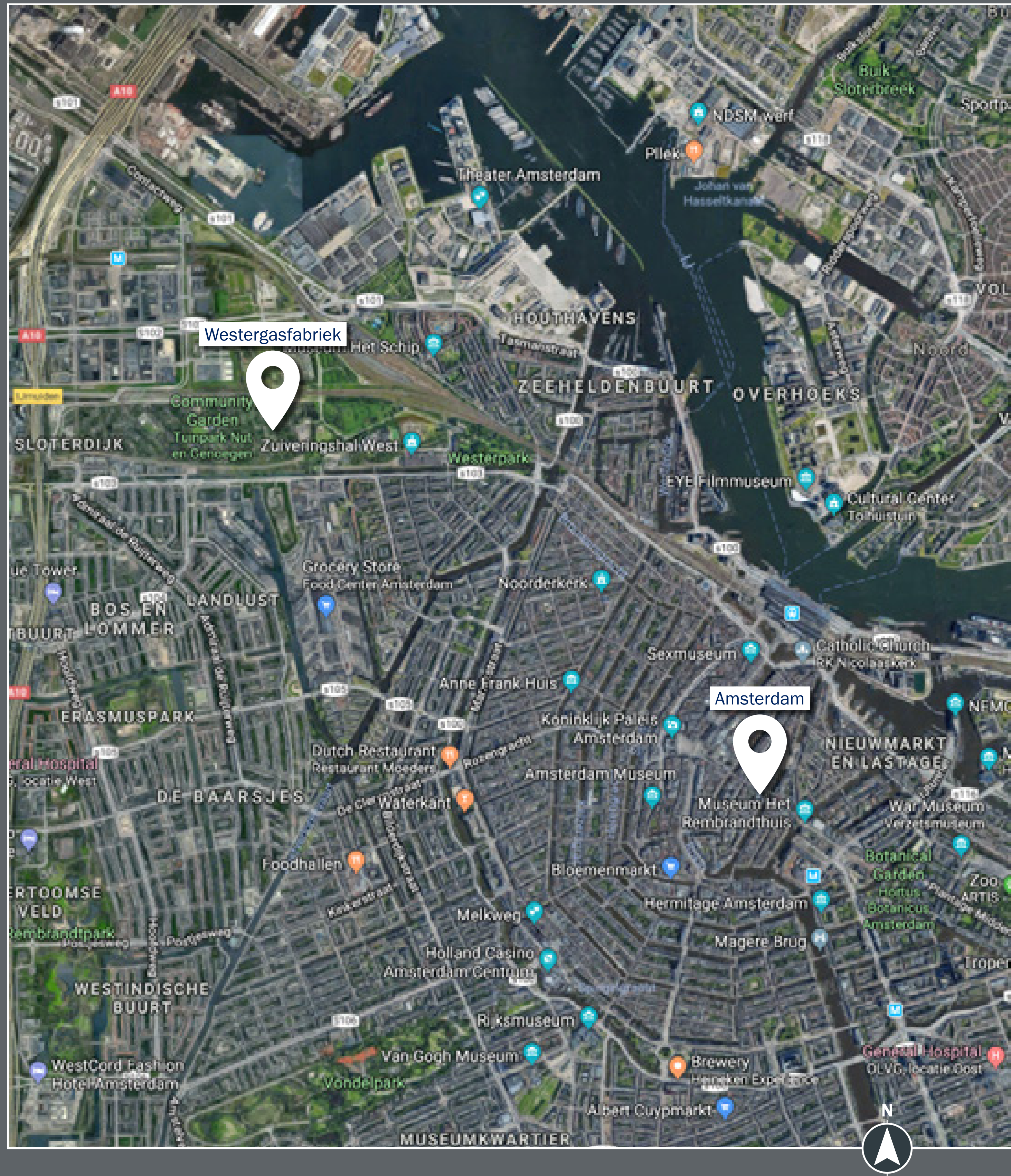
FORMER USE:
Gas facility

AREA:
11.5 ha

CLIENT:
Cultuurpark Westergasfabriek, Westerpark District Council and City of Amsterdam

Image from; (Westergasfabriek, (2018))

Google maps image showing Westergasfabriek in reference to Amsterdam CBD



PRECEDENT ANALYSIS

Context of Westergasfabriek

Westergasfabriek was formerly one of Amsterdam two coal gas factory complexes and was built in 1885 by the Imperial Continental Gas Association (ICGA). It was strategically located near waterways, the rail network and access roads to ensure ease of access to gas supply.. The buildings were designed in Dutch Renaissance style.

The gas produced at the plant was originally utilised for the city's street lighting. In 1898 ICGA's concession was withdrawn and the city council took over running the factory, expanding the site as production increased.

Gas production at the facility was gradually reduced as the city council sourced more of its gas from Hoogovens in IJmuiden, and following the discovery of natural gas in 1963 in Slochteren the city sourced natural gas from there. Gas production in Westergasfabriek ceased in 1967 (Westergasfabriek, 2018).

The site was left heavily polluted, particularly with heavy metals, tar, cyanide and asbestos (Land8, 2015), making it difficult to re-purpose the site. The the Municipal Energy Company (GEB), continued to use the site for storage and a repair workshop until the early 1990's.

In 1981 the site was rezoned as recreational space and in 1989 it was zoned as a site of historical interest (Land8, 2015).

From 1992 the buildings were used temporarily for creative and cultural activities and it became apparent that the site was an ideal location for festivals and events due to its proximity to the historic centre of Amsterdam (Westergasfabriek, 2018).

Westergasfabriek in backgorund showing gasholders c1960 taken from (Westergasfabriek, History 2018)

Masterplan of Westergasfabriek
Gustaffson Porter + Bowman

Timber walkways and terraced decks on canal adjacent to Klonneplein. Reeds filter stormwater and help maintain water quality in canal. Willow trees planted in background. Taken from (ArchDaily, 2017) Image (Thomas Schljper)

BEFORE: Gas holder during clean up in 2000 with a tent constructed over it to trap hazardous gases (Project Westergasfabriek, 2018)

Design agenda for Westergasfabriek

In 1997 landscape architect Kathryn Gustafson together with Francine Houben of Mecanoo Architects, won the competition to design the masterplan for Westergasfabriek.

Gustafson Porter + Bowman's design, ""Changement," demonstrates a delicate balance between contamination and accessibility, invention and interpretation, restoration (of contaminated land) and revelation (of the potential of a post-productive site)," (Gustafson Porter + Bowman, 2006).

Central to the design approach was the necessity to treat the contaminated soil on site. The alternatives; transporting soil off site and moving the problem not deemed a viable solution.

The alternative adopted involved calculation of a cut-and-fill balance, bringing in new soil to displace polluted soil, retaining existing ground levels around the buildings and creating a new undulating terrain that was the consequence of surplus soil (Gustafson Porter + Bowman, 2006) (Landzine, 2015).

The masterplan incorporates a green park environment with a cultural centre for indoor and outdoor activities. A central promenade 'The Axis' links the town hall with the Cite des Artist and a variety of spaces in between providing a varied ambiance. At the east end, the park is more formalised with the Events Field reflecting post-war attitudes of landscape as a support for sports, leisure and recreation. The field slopes into a stone-lined lake which can be drained for large events and festivals. Reinforced grass allows for the traffic of equipment for concerts and fairs (Landzine, 2015).

The Lake and Amphitheatre Mound to its north, framing the space. It shields the park from the noise of the railway and provides a south-facing surface with good access to sunlight, whilst the proximity of water and stepping-stones in the lake make it a perfect area for play on hot summer days (Landzine, 2015).

The existing large trees are enhanced by a band of new trees and woodlands running in a diagonal direction from south to west, northeast of the newly created mound. Salix babylonica (weeping willow) and Salix alba (white willow) are planted around the remnants of the gasholders which have been sealed and filled with the worst contamination to create ponds and aquatic gardens with floating timber walkways and terraces (Landzine, 2015).

The design furthermore considers the pedestrian experience, bicycle trails, and the vehicular requirements of the many arts organizations located in the historic buildings. This means the park has become an integrated landscape of experiences that continues to be frequented by visitors and locals.

Westergasfabriek is today considered to be a model of brownfield reclamation within a physically dense urban context and a complex set of stakeholders. It demonstrates social sustainability as it has transformed into a vibrant cultural centre for the arts and a meeting place for its surrounding communities (Gustafson Porter + Bowman, 2006).

Contamination and remediation

Westergasfabriek required separate contamination management plans for the buildings and the external environment and was designed by Arup Engineers (Land8, 2015). It utilises a capping method of remediation rather than exclusive phytoremediation. It does however include some phytoremediating plantings around water courses and vegetation.

Soil studies were undertaken in 1990 to investigate the extent of pollution based on years of industrial use. The results showed considerable contamination however soil toxicity wasn't high enough to render the site unusable. The toxins included tar, mineral oils, cyanide and benzene that were released during the production of coal gas. The toxins were present in the soil profile as well as the water table. The City of Amsterdam and The Central Environment Ministry eventually agreed on a clean up plan after years of negotiation (Project Westergasfabriek, 2010).

AFTER: Former Gas holder transformed into Aquatic and Water Lily Pools with floating timber walkways. Heavily polluted soil buried in foundations of Gasholder beneath concrete cap and aquatic gardens (Gustafson Porter + Bowman, 2006)

Buildings remediation

When clean up work began in 2000, heavily polluted waste was discovered in the foundations and cellars of a number of buildings. This meant that they had to be fitted with vapour-proof concrete floors that seal off the polluted ground and do not allow any toxic vapours to penetrate. (Project Westergasfabriek, 2008).

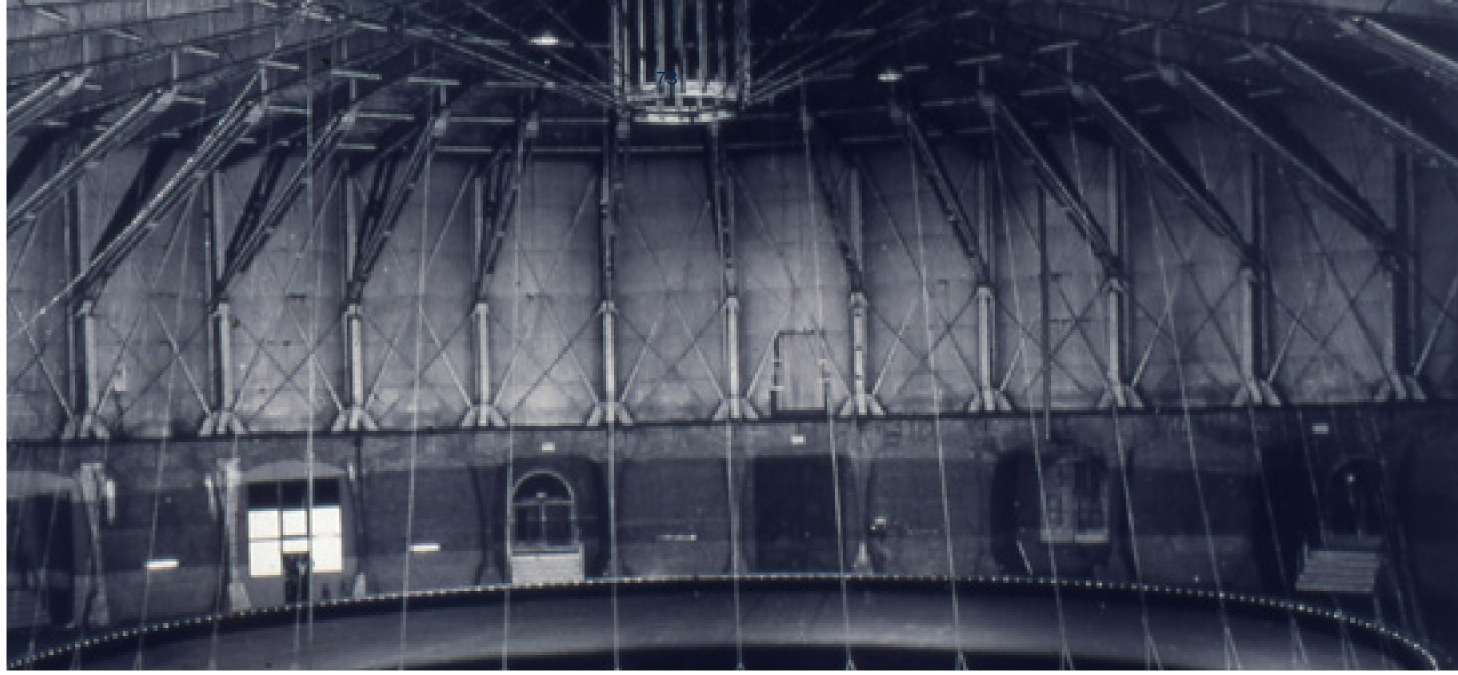
The former gasholders as part of the new landscape masterplan were to be turned into water gardens, however when clean up began, a terrible stench was released. For years they had served as an on site landfill and were full of toxic sludge. After three months work had to pause so a new environmental and safety analysis could be made. Tons of heavily polluted sludge had to be removed and disposed of. For safety reasons and to prevent the spread of dangerous substances and smells, a tent construction was built over the gas holder while it was cleaned. The air in the tent was extracted and purified and the workers were required to wear haz-mat suits and have an independent breathing air supply. The hydraulic caterpillar-track excavator was altered to be equipped with a specially developed compressed air installation. (Project Westergasfabriek, 2008).

The public enjoying a sunny day in and around the stone lined shallow lake adjacent to the Events Field (Gustafson Porter + Bowman, 2006)

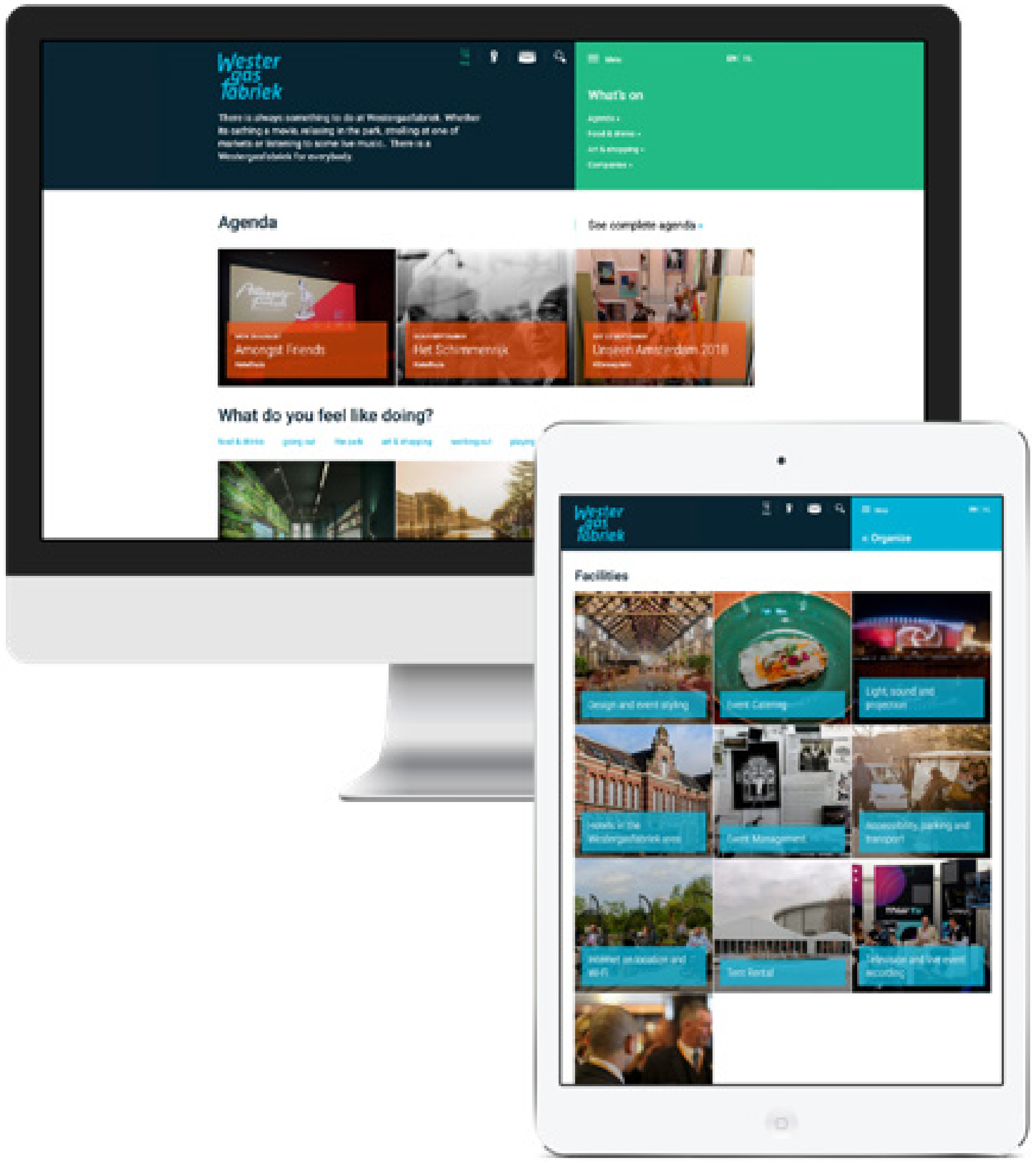
Sections of the waterway running to the north of the site, east of the events field are treated differently according to their surroundings. Here the water course includes reeds to help purify the water as well as a waterfall edge to add interest (Gustafson Porter + Bowman, 2006)

Ecological response to the watercourse with water loving remediating plants and willows (Gustafson Porter + Bowman, 2006)

Waterfall condition along watercourse (Gustafson Porter + Bowman, 2006)



Top: Former Gasholder c1960. Image taken from (Westergasfabriek, 2018)
Middle: Former Gasholder c1966 utilised as oven storage by GEB . Image taken from (Project Westergasfabriek, 2008)
Bottom: Former Gasholder transformed into a performance space. Image taken from (Unique Venues of Amsterdam, 2018)



Westergasfabriek's website showing their events page and on site facilities. This enables the public and visitors to be informed and engaged in the life of the park (Westergasfabriek, 2018)

External environment remediation

The first plan for remediating the external environment was based on digging up and removing all contaminated soil. This would have been extremely expensive and was therefore rejected. The second plan involved isolating the pollution between sheet piling, under a layer of asphalt. This however meant the site could only be utilised for storage and parking and was therefore also rejected (Project Westergasfabriek, 2018).

The remediation plan that was ultimately employed was the 'isolation-plus variant,' approach designed by Arup. The polluted ground would be isolated beneath a layer of cloth with a 'living layer' of 1m deep, clean soil above. In total $35,000m^3$ of clean soil was brought into the site and $65,000m^2$ of geotextile was used to cover approximately 51,000 m^3 of polluted, redistrubutd soil. Where there was no planting, the ground was paved (Project Westergasfabriek, 2008).

Willows and water loving plants including reeds are used in phytoremediation installations around and in water bodies and in plantings throughout the park to act as a vegetation cap, restricting the flow of groundwater (Land8, 2015).

Monitoring and maintenance

The 1m layer of soil is deep enough to act as a buffer from the polluted soil beneath as well as minimising contamination by ground water. A second phase of groundwater management is implemented in Westergasfabriek to prevent the horizontal spreading of groundwater and potential contamination. Measuring tubes have been installed on the north side in the polder and on the south side near to the Haarlemmerweg to determine the distribution. If pollution increases, the flow of groundwater to the surroundings must be stopped by installing sheet piling and pumping out the ground water. There is also a separate clean groundwater system installed under the geotextile cap which carries water to a reservoir under the new Korfball field. A pump installation makes the water circulate and can be utilised during drought for irrigation (Project Westergasfabriek, 2008).

Effectiveness of project

The success of the project can be attributed to an effective design process which incorporated public input and site-specificity from its inception. The process of design included a full year of well-organized public consultation and also incorporated the transformation of former industrial areas to the south of the site into a mixed-use housing development (Gustafson Porter + Bowman, 2006).

The use of the park is varied and intensive. Information markets and neighbourhood parties are held frequently on the Market Square which enable the constant involvement by locals. Westergasfabriek has transformed into one of Amsterdam's main cultural venues. This is largely due to its availability for temporary cultural uses following the closure of the gas works. Today the combination of permanent tenants in the form of cultural enterprises, temporary rentals for festivals and events, and commercial and cultural letting provides a good basis for successful operation of enterprise within the park. (Project Westergasfabriek, 2008).

Westergasfabriek has its own dedicated website where information is shared about events and event organisers can get in touch with the operational team. There is also information relating to the design and basic process of clean up of the park. There are links to social media and a mailing list sign up. These online portals allow the public to be actively engaged and informed into the life of the park which contributes to its ongoing success and utilisation.

Freshkills Park

NEW YORK

DETAILS

LANDSCAPE ARCHITECTS:
James Corner Field Operations

LOCATION:
Staten Island, New York, United States

BUDGET:
Approx US$1.2 billion over 30 years

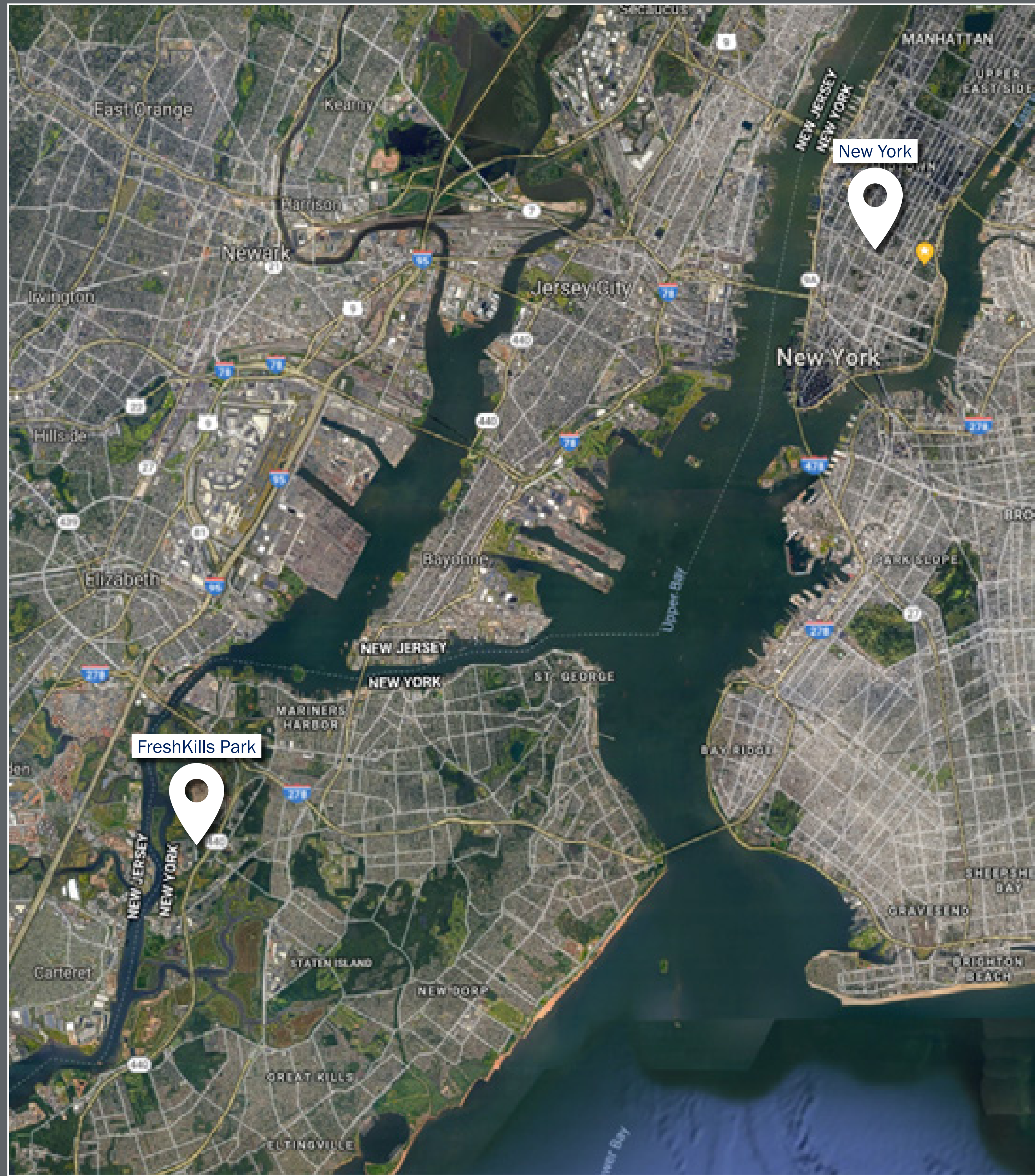
YEAR OF CONSTRUCTION:
2001-2036

FORMER USE:
Landfill

AREA:
890 ha or 2200 acres

COLLABORATION WITH:
Hamilton, Rabinovitz & Akschuler, AKRF, Inc, Applied Ecological Services, Arup, GeoSyntec, Skidmore, Owings & Merrill, Stan Allen Architect, L'Observatoire International, Tomato, Richard Lynch, Curry & Kerlinger, Mierle laderman Ukeles

Image: Arch Daily, 2013, Courtesy of Department of Parks and Recreation



Google maps image showing Freshkills Park in reference to NewYork City

PRECEDENT ANALYSIS

Context of Freshkills

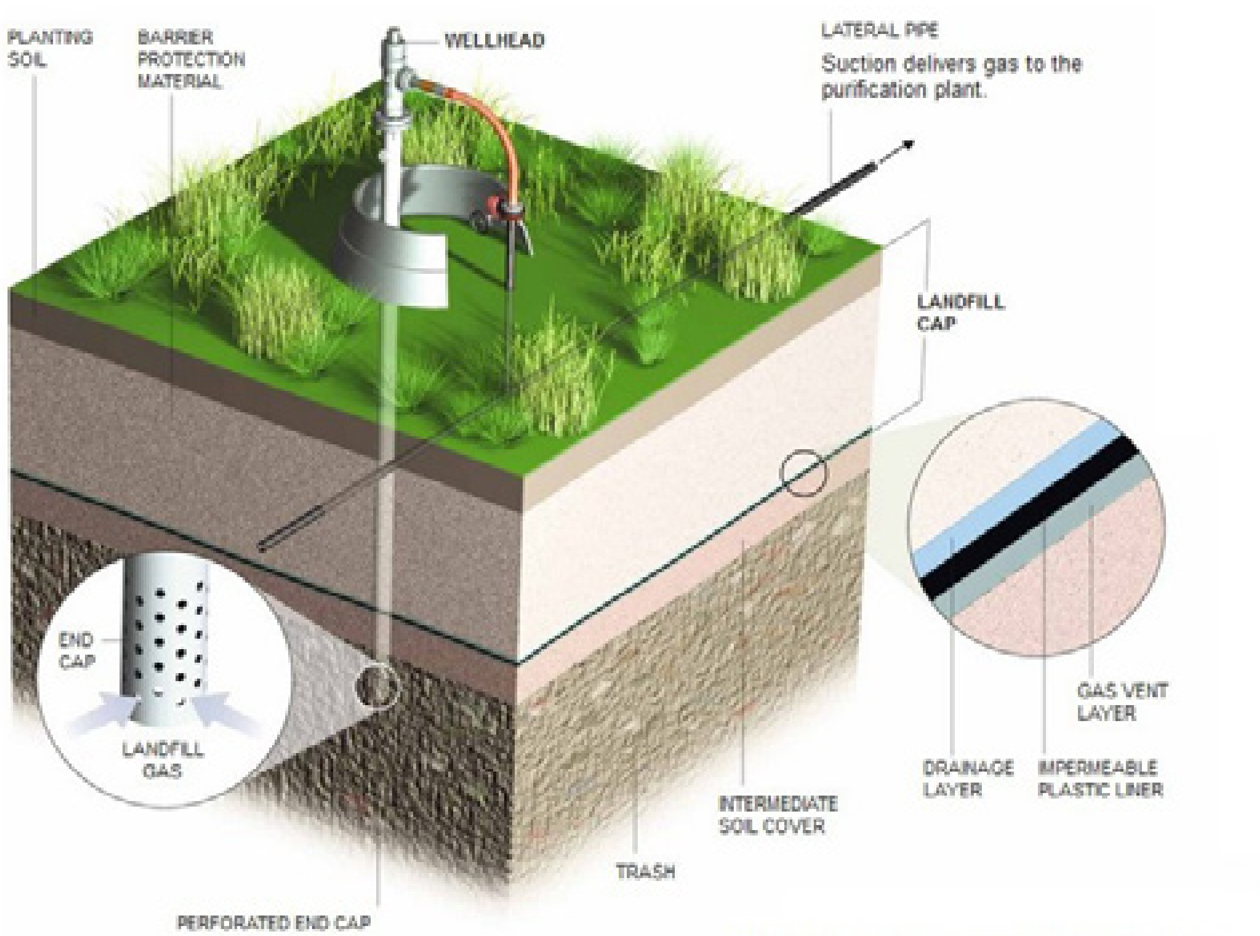
Freshkills was formally a sea level wetland running along the western coast of Staten Island, west of New York City. In 1948 it became a landfill as a temporary solution for NYC's waste. It had a convenient waterside location where transporting rubbish could be done easily and cost effectively on barges (Freshkills Park timeline, 2018).

The rise in consumption post World War II solidified its continued operation and it became the US's largest landfill, accepting all of NYC's solid waste by 1991. Its garbage hills could be high as 200-feet (60m), burying nearly 30,000 tons of trash daily (ArchDaily, 2013). During the 1960s, the landfill became overrun with a rat population that threatened to take over the island. Birds were introduced to manage the rats, and the landfill was deemed a wild bird sanctuary (Atlas Obscura, 2018). Residents of Staten Island regularly complained about the odour and plans were drafted to someday close the landfill. It became known as the world's largest man-made structure and will continue to undergo radical transformation to become a pubic park, three times the size of Central Park (Freshkills Park, 2018).

Freshkills was officially closed on March 22nd, 2001 however, 9/11 meant Freshkills was partially reopened to allow the debris from the Twin Towers to be investigated by forensics looking for clues and remains. There is an estimated 1,250,000 tons (approx) of rubble and human microremains at the site now known as West Mound where a memorial is planned (The Guardian, 2016).

Freshkills during its former use as New York City's landfill. 1961 when the landfill grew to occupy 1284 acres. Taken from http://timeline.freshkillspark.org/

Masterplan of Freshkills Park, Field Opperations



Freshkills Landfill cap section courtesy of New York City Sanitation Department. Illustration by Frank O'Connel. Taken from (Freshkills Park, 2018)

Design agenda for FreshKills

Since the decommissioning of Freshkills as a Landfill in 2001, the Department of City Planning along with the New York Department of State's Division of Coastal Resources developed a 30 year master plan to regenerate the site into New York's largest park by 2036. Planning called for five main areas to provide natural habitats for wildlife, reinstate the natural topography, program a variety of activities and design the circulation through the 2200 acre expanse (ArchDaily, 2013).

In the same year a design competition was held to address the planning and stage the redesign into three, ten-year phases. James Corner Field Operations won the competition with their incorporation of sustainable energy infrastructure. Natural gas collection from the decomposing waste will be harnessed to heat approximately 22,000 homes and also includes the consideration for photo-voltaics, wind turbines, and geothermic heating and cooling (ArchDaily, 2013). The site also utilises an innovative strategy to improve the fertility of the new soil. It consists of planting, cutting and replanting grasses in quick succession to add organic matter back into the soil in order to make way for future tree plantations (Field Operations, 2006).

The specific zones in the Park are made up of:

The Confluence: A cultural and recreational waterfront park, including Creek Landing with access to the city's waterways and areas for gathering and recreation and The Point, with sports fields and event spaces (Freshkills Park, 2018).

North Park: An extensive natural setting featuring footpaths, trails with scenic overlooks, meadows, wetlands and creeks (Freshkills Park, 2018).

South Park: Natural settings and active recreational areas (Freshkills Park, 2018).

East Park: With interconnectivity into existing road infrastructure and routes with programming for nature education. The road will be designed as a scenic route integrated into the landscape. Includes a nature education area with specifically designed wetlands, boardwalks, exhibits and public art installations (Freshkills Park, 2018).

West Park (including West Mount): n earthwork monument remembering 9/11 on a vast hilltop (Freshkills Park, 2018).

In 2001, the Fresh Kills landfill on Staten Island became a sorting ground for debris and personal effects from Ground Zero. Photograph: Mike Segar Reuters. Taken from (The Guardian, 2016)

Contamination and remediation

The New York State Department of Environmental Conservation (NYSDEC) requires a landfill cap to be installed over all closed landfills (Freshkills Park, 2018). As Freshkills collected the municipal solid waste of NYC for 53 years, a deep cap was specified of approximately 3-12 feet (approximately 914mm-3657mm), (Freshkills Park, 2018).

The cap features an impermeable plastic liner and eight additional layers of barrier material to separate the ground above from the landfill beneath. There are several systems in place to manage the landfill gas and leachate byproducts. Some are visible, such as the white stacks of the Flare Stations, but most are invisible, such as the extensive network of piping which transport the gases to the on site purification plant and then onto the electricity generators. Drainage channels collect the leachate which is then pumped to the Freshkills Landfill Treatment Plant where pollutants are removed. It is then discharged into Arthur Hill (City of New York, 2001; NYC Parks, 2018). Furthermore there is a collection of swales, down chutes and retention ponds to manage the water table above the impermeable layer which also helps to reduce the risk of erosion to the cap by rainwater (FreshKills Park, 2018).

The landfill cap consits of the following layers:

Waste Layer: Original clay-like soil at the bottom of the waste layer helps prevent vertical migration of leachate and waste into the ground water. The waste itself was covered with layers of soil over time to create stability within the mounds and minimize odour (Freshkills Park, 2018).

Soil Barrier Layer: Directly on top of landfilled waste is at least two feet of soil known as the soil barrier layer. This layer covers the garbage and ensures the hills are stable. It has varying degrees of thickness so the mounded waste could be shaped into the rolling hills that exist today. Each hill has been graded to be between 4% and 33% fall to facilitate storm water drainage (Freshkills Park, 2018).

Gas Venting Layer: The gas venting layer is a thick geotextile made to promote collection and absorption of gas in soil. This specific type of geotextile consists of two synthetic fabrics heat-bonded to either side of a hard plastic netting . By laying this geotextile over the soil barrier layer, any stray gases moving up through the lower layers will be absorbed by the geotextile. The empty space created by the hard plastic netting allows the particles to move laterally, eventually ending up in the landfill gas collection system (Freshkills Park, 2018).

Impermeable Plastic Liner: The impermeable plastic liner is a different type of geotextile made from a thin, durable plastic material. Neither water nor gas can move through this layer. It provides separation between the waste layer below and clean soil above as well as preventing the escape of gases upwards into the atmosphere. It also prevents the absorption of rain water by the waste layer. Tiny micro-spikes along the surface of the impermeable liner help keep the liner from slipping (Freshkills Park, 2018).

Drainage Layer: A geotextile similar to the gas venting layer is used as a drainage layer. It functions the same as the gas venting layer, but in reverse. The drainage layer prevents water from traveling downward through the top layers of the landfill cap. Water then moves laterally through the geotextile to the stormwater down chutes and away from mounded waste (Freshkills Park, 2018).

Barrier Protection Material: The barrier protection material is made of at least two feet of sandy soil placed on top of the drainage layer. This soil protects the geotextiles underneath (Freshkills Park, 2018).

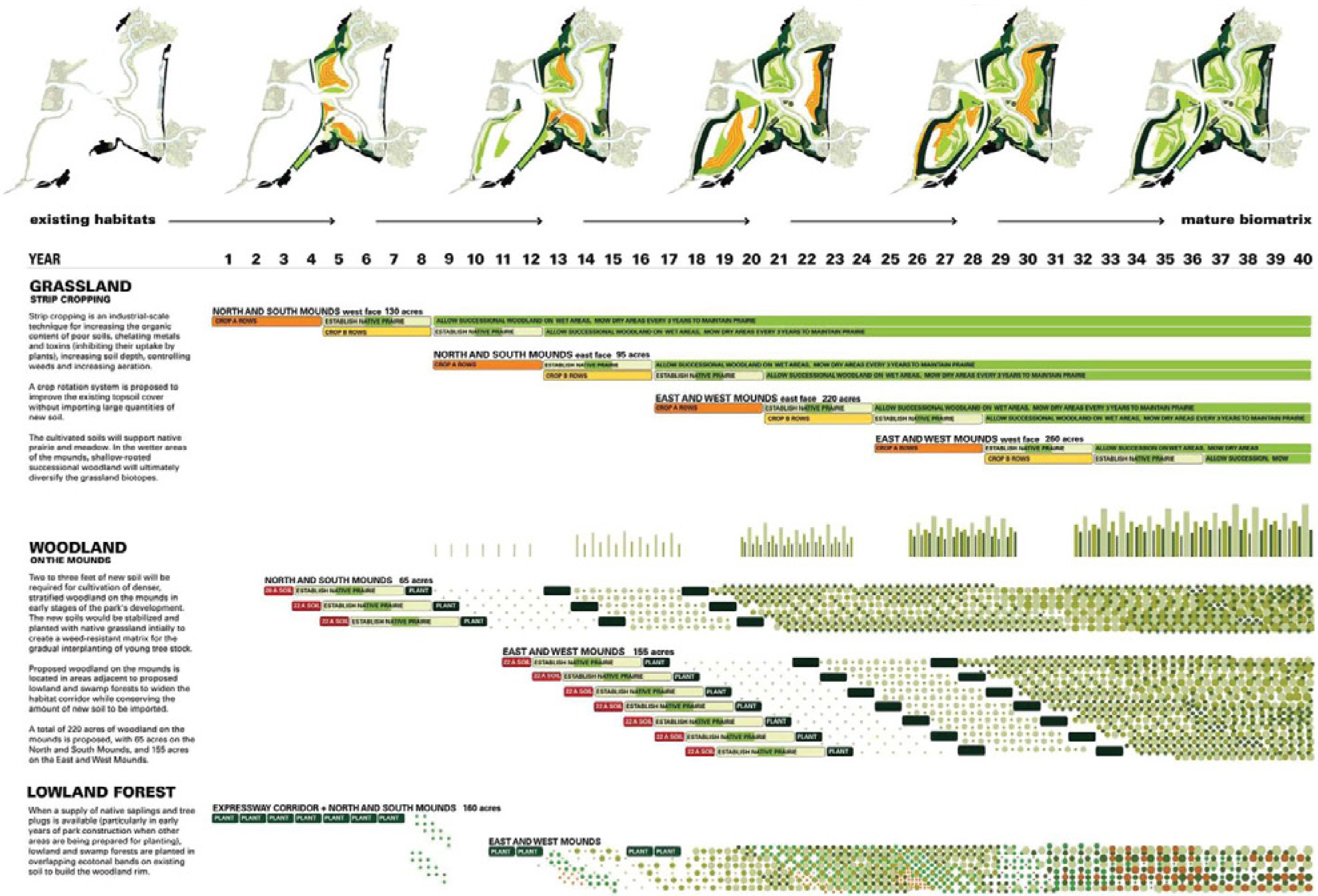
Planting Soil: Lastly, at least six inches of clean planting soil is spread over the barrier protection material. The soil is seeded with a native plant mix, whose roots help stabilize the mounds and absorb water (Freshkills Park, 2018).

Over time, the landfill will subside as materials break down and gas and leachate are removed from the mounds. Because of this landfill settlement, the height of the mounds decreases by 10% - 15% over time. Approximately half of this settlement will occur in the first five to ten years after the final waste is placed, with further settlement continuing at a decreasing rate for at least another 20 years (Freshkills Park, 2018).

The process of capping 'Muldoon Avenue Mound' (completed in 2015) which relocated approx 305,822m³ of waste. The cross section of the cap is made up of General fill, Select fill, two layers of geocomposite sandwiching a layer of geomembrane, barrier protection material, embankment fill, planting soil and seed mix with the erosion blanket. Image from Tully Construction, http://www.tullygroup.us/Capabilities/Environmental/Fresh-Kills-Landfill

Access stormwater that drains through the cap is collected in a network of swales, channels and downchutes and then stored in detention basins at the bases of the hills. Gabion retaining walls support the soil matrix. Image taken from Freshkills Park Instagram account, 2017

View over Freshkills to NYC beyond. Image courtesy of Jo Cavollo, 2017, taken from (Urban Omnibus, 2018).



The Landfill mound restoration plan which firstly plants pioneering native grasses which rapidly create topsoil and improve the soil matrix, and gradually moves to a more wooded landscape. Image from (Field Operations, p.g. 33, 2006).

Researcher checking a bird box at Freshkills, 2011. Image taken from Freshkills Park Instagram account

Image of the flare stacks in the background of a shared bike and pedestrian path. The stacks are not used, rather the captured methane gas is purified and used as an energy source. Image courtesy of MIchael Anton. Taken from (Urban Omnibus, 2018).

Monitoring and maintenance

The site is regulated and overseen by government agencies at the federal, state, and local levels to ensure that the quality of its air, water, and soil are at safe levels for the public to enjoy the park now and into the future, (NYC Parks, 2018). There are many Environmental control systems and monitoring programs to protect the environment, public health and indigenous and migratory wildlife from impacts associated with the landfill. Potential pathways for pollutant exposure including areas used by hikers or kayakers are monitored and regularly tested to ensure public health and environmental health are protected (Field Operations, 2006).

In 2012, NYC parks hired twenty Anglo-Nubian goats for six weeks to restore a wetland within Freshkills by eating their way through 2 acres of the invasive weed phragmites. The managers of Freshkills were also testing the ability for goats to help manage the park into the long term, "*We want to introduce the idea of using goats to help in vegetation management... The sanitation department mows once a year. But this is 2,200 acres. We need help.*" Eloise L. Hirsh, Freskills administrator, (NY Times, 2012). If successful, Freshkills may house a permanent herd.

Effectiveness of project

The landfill site has been transformed into a public park nearly three times the size of Central Park. It has effectively restored parts of the tidal marshes and creeks, contains 40 miles (approx. 64km) of pathways and trails, contains recreational, cultural and educational amenities, including a proposed monument to honour the 9/11 recovery effort undertaken at Freshkills. But it has still taken over US$1 billion to achieve (Freshkills Park, 2018). Even though Freshkills has closed, the consumption and waste of New York City has not been curbed. The waste has simply been redirected to several landfills in New Jersey (ArchDaily, 2013).

During Hurricane Sandy, the FreshKills site absorbed a critical part of the storm surge which protected nearby neighbourhoods from severe flooding. It demonstrates the role of wetland buffers in protecting the coast during adverse weather events and rising sea levels as a result of climate change, (NY Times, 2012).

Belmont Goats

PORTLAND

DETAILS

LANDSCAPE ARCHITECTS:
Brett Milligan

COLLABORATION WITH:
University of California,
Davis and Creative
Woodworking NW

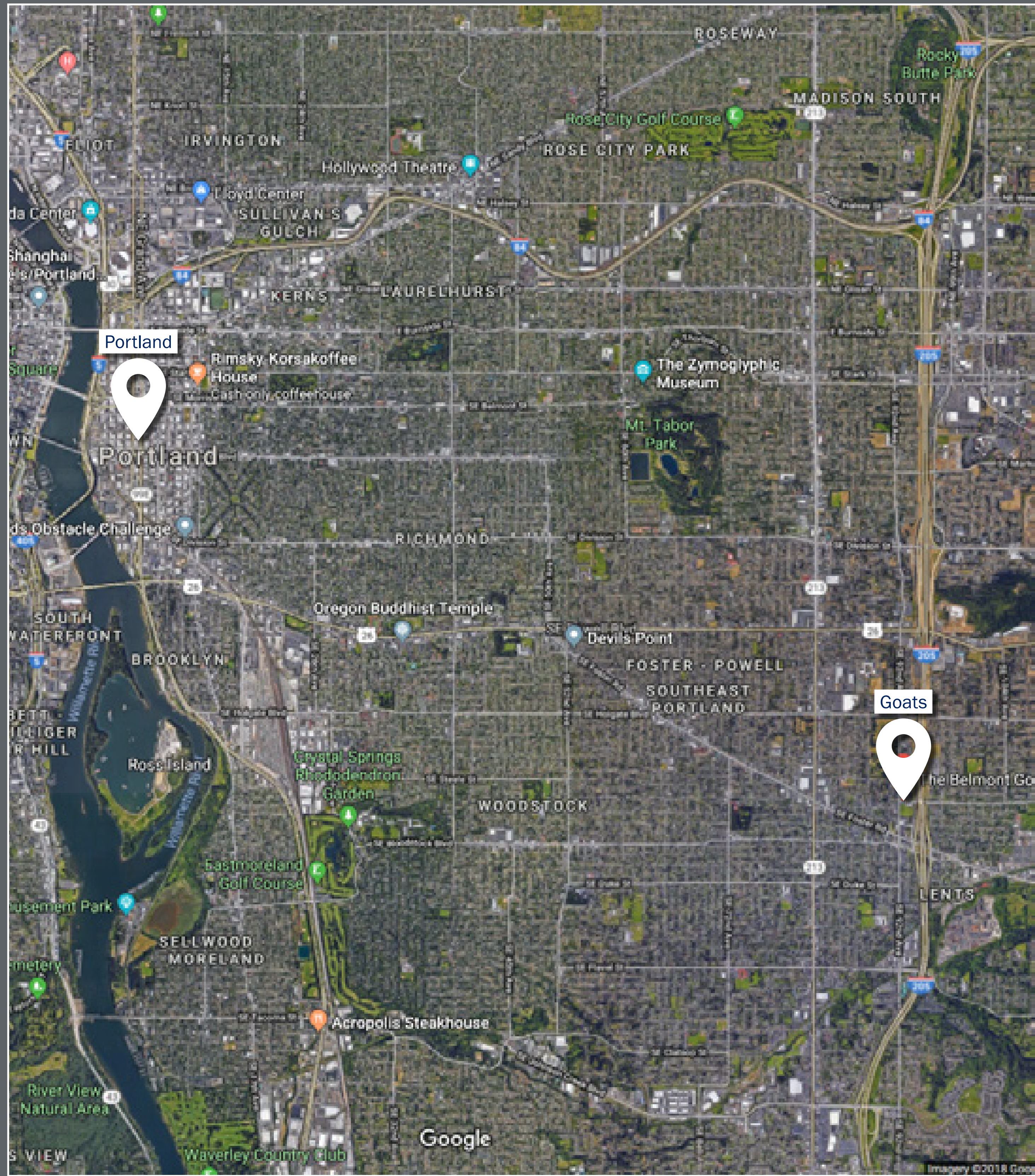
LOCATION:
SE Belmont Street,
Buckman (Portland),
Oregon, USA

PROJECT DURATION:
2007-2014, then ongoing.

CLIENT:
Killan Pacific & Portland
Development Commission

Images from https://thebelmontgoats.org/

Google maps image showing Belmont Goats in reference to Portland



PRECEDENT ANALYSIS

Context of the Belmont goats

Originally residing at what was known colloquially as Goat Field (or, to the local development community, “the goat blocks”), two city blocks bounded by SE Belmont and Taylor Streets and SE 11th and 10th Avenues, The Belmont Goats were preceded by three summers of unrelated herds rented from Goat Rental NW and Sauvie Island Goat Rental to clear brush.

Those rented herds came to the field as a suggestion to developer Killian Pacific by landscape architect Brett Milligan, whose other, secret agenda was the social experiment of what residents would think of goats living in the middle of the urban, partly-industrial Buckman neighbourhood.

2012 - 2013

After those first three years, Creative Woodworking NW—whose shop stands directly across the street from the property, and who’d helped care for the rented herds—arranged to have their own goats.

This new herd began in October of 2012 and grew as its owner found and bought additional animals in pairs from area farms. Unlike their predecessors, these goats would take up residence rather than be hired out to weed other property, something that remains true to this day.

This is the herd which both the Buckman neighbourhood and the greater Portland community came to know and love over the course of the Spring and Summer of 2013, becoming, in the words of one early supporter, the “nexus of an unexpected and spontaneous community”.

Late in October of 2013, after a year of uninterrupted residency, an approaching deadline to make way for a long-anticipated development project raised the possibility of the herd being split up. Instead, a handful of its volunteer caretakers stepped up to purchase the herd in order to ensure that it remained intact, for the good of both the herd and the community—with the goal of finding a new, publicly-accessible home.

2013 - Now

While the herd no longer resides on SE Belmont Street, its new owners officially named them The Belmont Goats in recognition of the pioneering history of urban goats at Goat Field; in March of 2014 they formed a non-profit of that name.

Early in October of 2014, at the invitation of the neighbourhood and in an early partnership with Green Lents, The Belmont Goats conducted a successful crowd funding campaign and relocated to Lents Town Centre, onto land provided by the Portland Development Commission (now known as Proper Portland). In the middle of May of 2016, with a long-awaited redevelopment coming to its new neighbourhood, the herd relocated to another lot just two blocks away.

The Belmont Goats will reside at their current location at SE 92nd & Harold until June of 2018.

Information from https://thebelmontgoats.org/

Effectiveness of the project

The engagement of the community in remediation projects is vital to their ongoing success. It allows a way for interested individuals to express their care and consideration for the place in which they live and gives an outlet for the concept of ‘Radical Hope’ mentioned in the introduction. The use of goats in this case acts as a catalyst for the project to connect with the community in a tangible way through being immediately and naturally drawn to the site to engage with the animals and then learn more about the job they are doing and the significance to their community.

The Power Plants team is hoping similar engagement is possible through the evolution of the floral display of garden 01 throughout the year.

Images from https://thebelmontgoats.org/

Sydney Park Water Re-Use Project

SYDNEY

DETAILS

LANDSCAPE ARCHITECTS:
Turf Design Studio

COLLABORATION WITH:
Environmental Partnership

LOCATION:
Sydney Park Road, St Peters, NSW, 2044

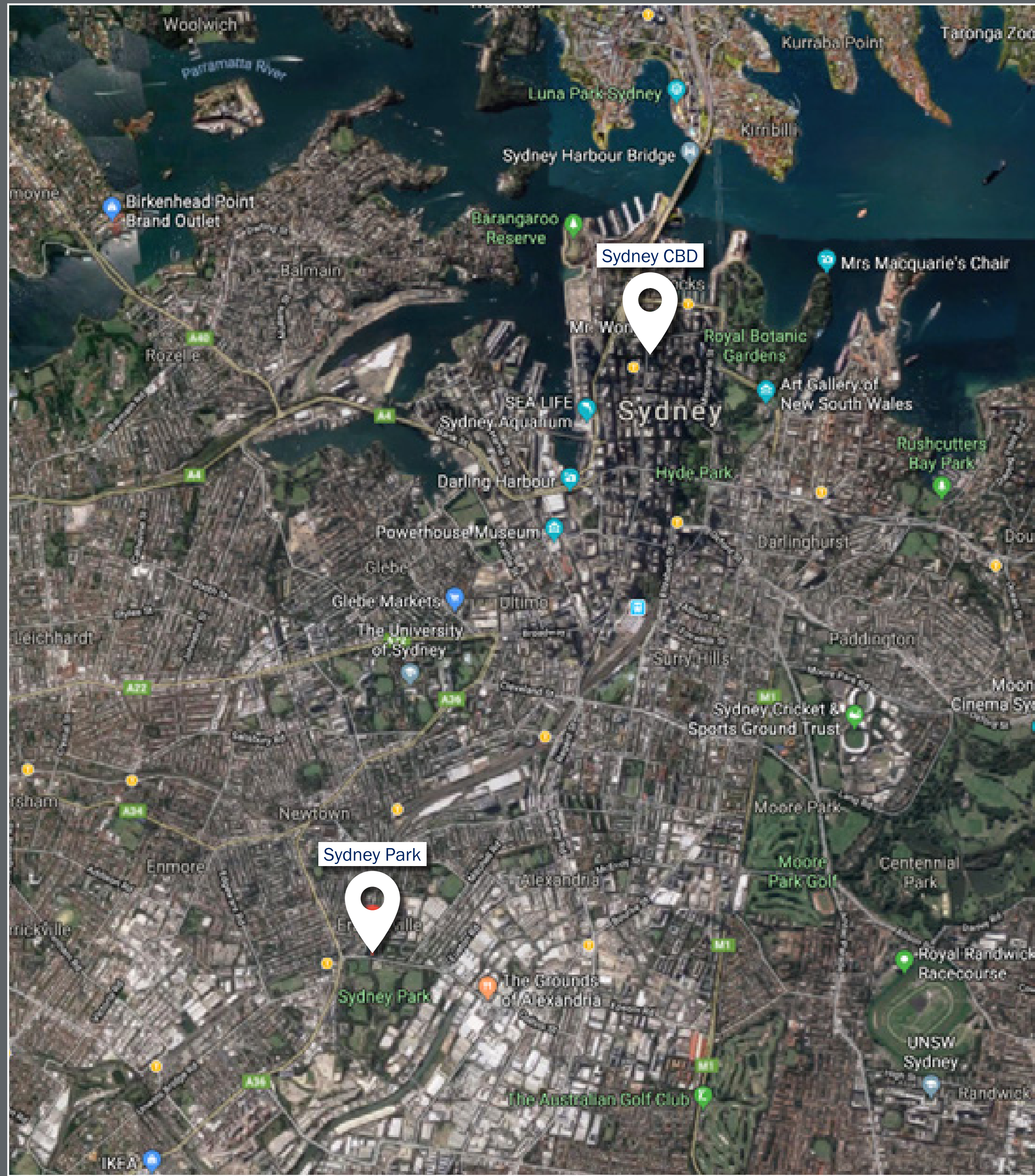
BUDGET:
$11.3 million

YEAR OF CONSTRUCTION:
July 2015

FORMER USE:
Brickworks (Industrial Site) and Waste Disposal

AREA:
44 hectares

Aerial Photograph of Sydney Park (Image from Ethan Rohloff (2016)



Google maps image showing Sydney Park in reference to Sydney CBD

PRECEDENT ANALYSIS

The Sydney Park Water Re-use Project by Turf Design has transformed a dilapidated post-industrial site into a living, breathing stormwater capture and filtration system with high biodiversity value and recreational opportunities. It is currently the city's largest stormwater harvesting and re-use facility, and is capable of retaining 850 million litres of water annually. This project connects ideas of remediation and rehabilitation to the public, bridging the gap for phytoremediation to become commonplace in Australia.

Context

The site, located in Sydney's St Peters, has attracted a range of different functions over the course of its history. This is primarily due to the rich alluvial soil that can be found in the area. Prior to the industrialisation, the landscape was composed of a combination of marshland, heathland, swamps and Wianamatta Shale forest, and showed great importance as a hunting ground for the Gadigal and Wangal people. Over the 19th century, the site became a perfect opportunity for industrialisation particularly because of the availability of clay, which was ideal for pottery and brick making. The Austral Brick Company operated here from 1936-1983, which later used these brick pits as a waste disposal site used for the disposal of household wastes.

In 1991 when the St Peters tip was closed, a layer of soil and building rubble was placed over the site to fill the land and create a new regional park (City of Sydney 2007). Since the site's former post-industrial use and waste disposal history, much has been achieved over the past two decades to transform the Sydney Park site into 44 hectares of parkland and a valuable asset for the growing communities of Sydney's southern suburbs.

The project was led by landscape architects Turf Design Studio and Environmental Partnership who orchestrated a multi-disciplinary collaboration intersecting design, art, science and ecology. This was done through a team of experts including water specialists from Alluvium, artists from Turpin + Crawford Studio, ecologists from Dragonfly Environmental, engineers from Partridge and Sydney's own Landscape Architects (Turf Design 2018).

The Sydney Park Water Reuse Project is one of Sydney's largest environmental projects to date, and is an integral component of Sustainable Sydney 2030; targeting 10% of water demand to be met through local water capture and re-use in the park (Turf Design 2018).

Masterplan of Sydney Park from: https://www.archdaily.com/793523/sydney-park-water-re-use-project-turf-design-studio-plus-environmental-partnership-alluvium-turpin-plus-crawford-dragonfly-and-partridge

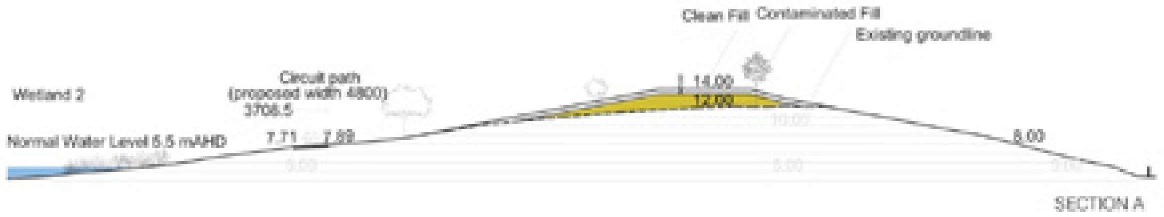
Design agenda

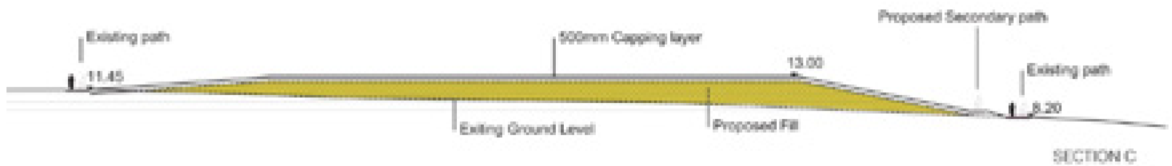
The park functions through a series of bioretention wetlands that capture and clean the equivalent measure of 340 Olympic-sized swimming pools worth per annum, and successfully improve local water quality, habitat, and reduces potable water consumption in the area. This has significantly improved the sites ecological habitats and increased biodiversity in the area (Arch Daily 2016).

Public art is interwoven into the project through Turpin + Crawford Studio's 'Water Falls' which celebrates clean water release and works with the flow of the cascades to aerate water in the final phase of the bioremediation treatment infrastructure (Arch Daily 2016).

The function and processes of water harvesting and cleansing is enhanced through the form of the landscape, with pathways intersecting through the wetlands and directing the users to explore a variety of experiences within the landscape. These experiences of calm and quiet to dramatic and playful connect people with the narrative of water in the parklands.

St Peters Brickworks, (City of Sydney Archives, SRC17506, 1984)





Diagrams from Arch Daily (2016)

Contamination and remediation

The design addresses the sites' previous issue with contaminated soils by layering more 'clean fill' soil to further cap the contaminated fill. They also utilise the excess soil from the site's construction phase to create a base layer which can be further modified and shaped into mounds and formations in the parklands (refer to diagrams on next page).

Remediation of the site is further shown through it's transformation from an industrial wasteland to a key component in the Sustainable Sydney 2030 targets for local water capture and reuse. The project harvests 850 million litres of water a year from the Newtown catchment and returns filtered water through this dynamic waterscape (Architecture AU 2016).

The project's first stage of infrastructure in May 2011 used a diversion pipeline from a stormwater catchment at Barwon Park Road. The catchment water flows through a gross pollutant trap and is then filtered through a bio retention treatment system before going through the parklands wetland system (Architecture AU 2016).

The second stage of infrastructure now pumps up to 1000 litres of stormwater from Munni Channel into Sydney Park. This stormwater goes through a gross pollutant trap and is filtered by bioretention beds (approximately 500m²) which flank the three major wetland bodies in the parklands (Architecture AU 2016).

PLANTING LIST

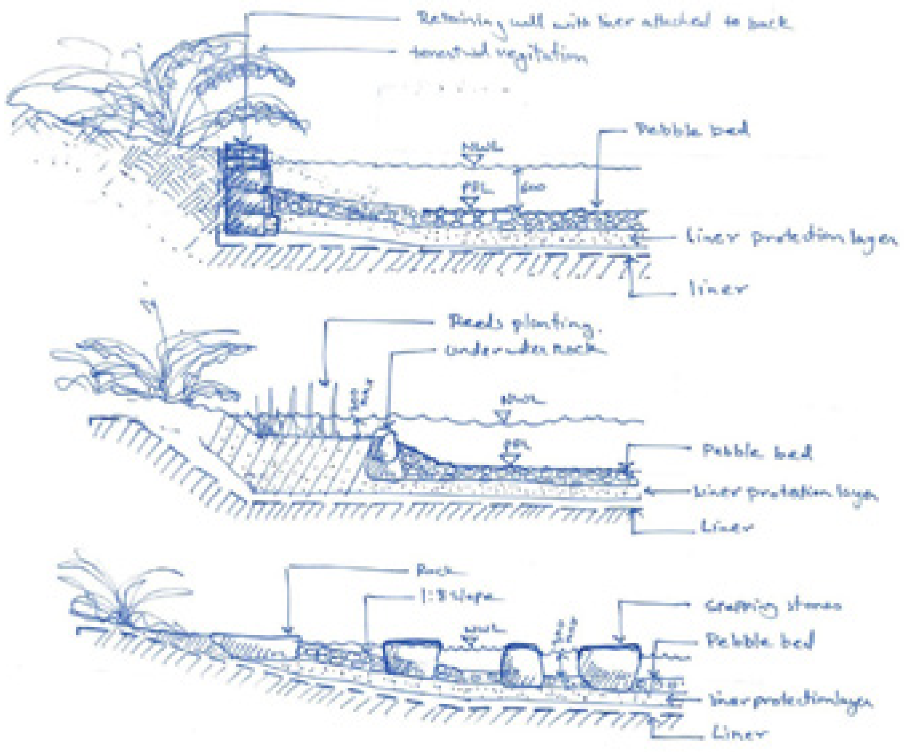
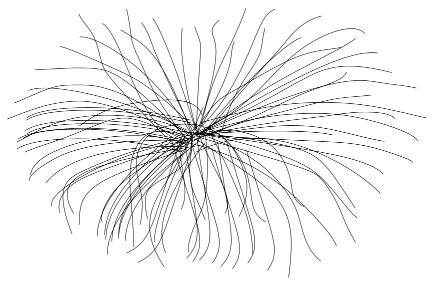
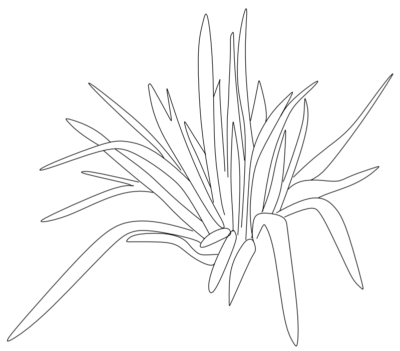


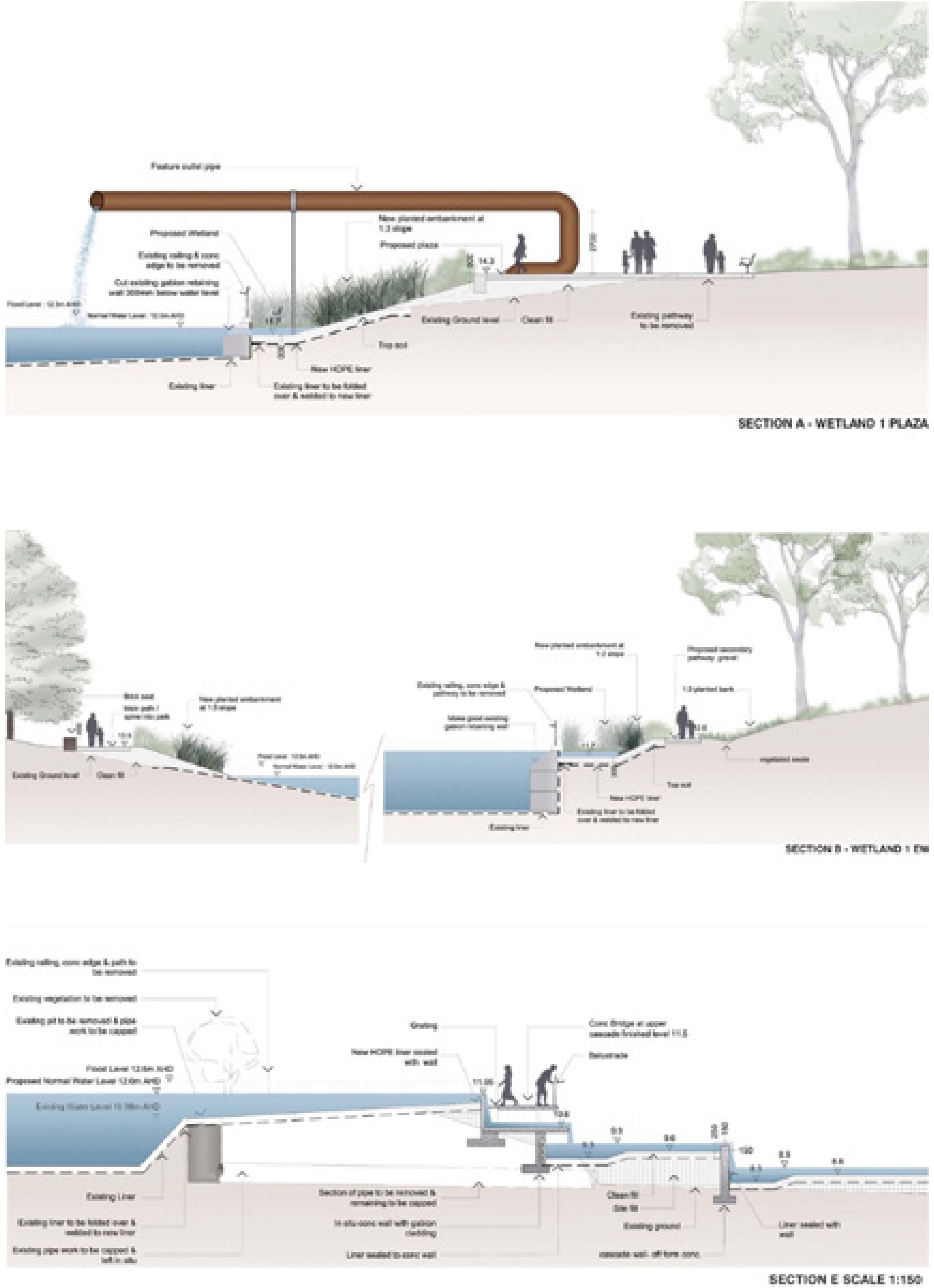
Diagram from (Arch Daily, 2016)





Carex radiata 'Halifax'

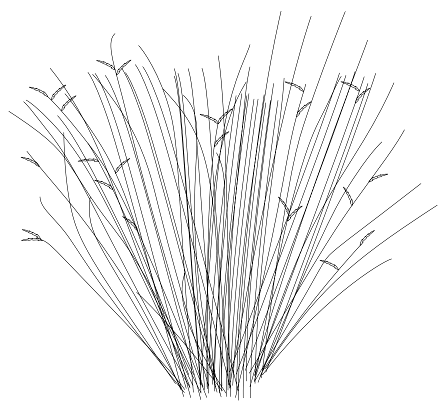
Dianella tasmanica 'Silver Streak'



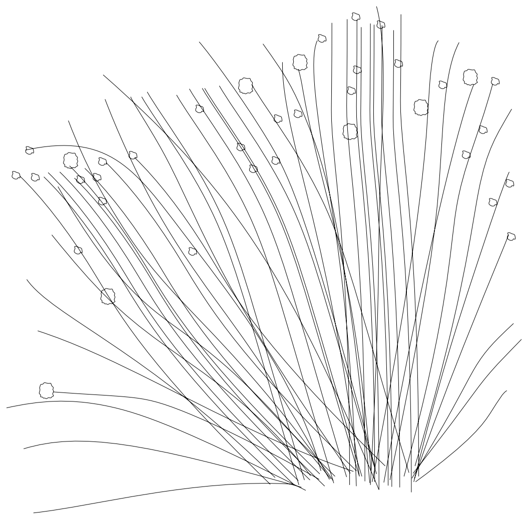
Diagrams from (Arch Daily, 2016)

Effectiveness of project

The Park is overall very successful in terms of site remediation, and has transformed difficult site conditions of contaminated soil with an industrial history into a safe, recreational space. The Sydney Park Project is especially effective considering water reuse and filtration. Stormwater has been channeled from catchments in Newtown, Barwon Park and the Munni channel, and redirected to the site to be filtered through a series of bioretention wetlands. This targets local capture and reuse, and plays a key component to achieve the goal for a Sustainable Sydney by 2030. Not only does this physically remediate the contents of the site, but also develops a focus towards recycled water in the users of the space. The project is an excellent example of WSUD and phytoremediation for water cleansing, however it deploys traditional means (capping and clean fill soil) for the contaminated ground.



Juncus effusus "Soft Rush"



Isolepsis Nodosa (Ficinia) "Knobby Club Rush"

Grasses used for the bioretention swales - Turf Design + Environmental Partnership

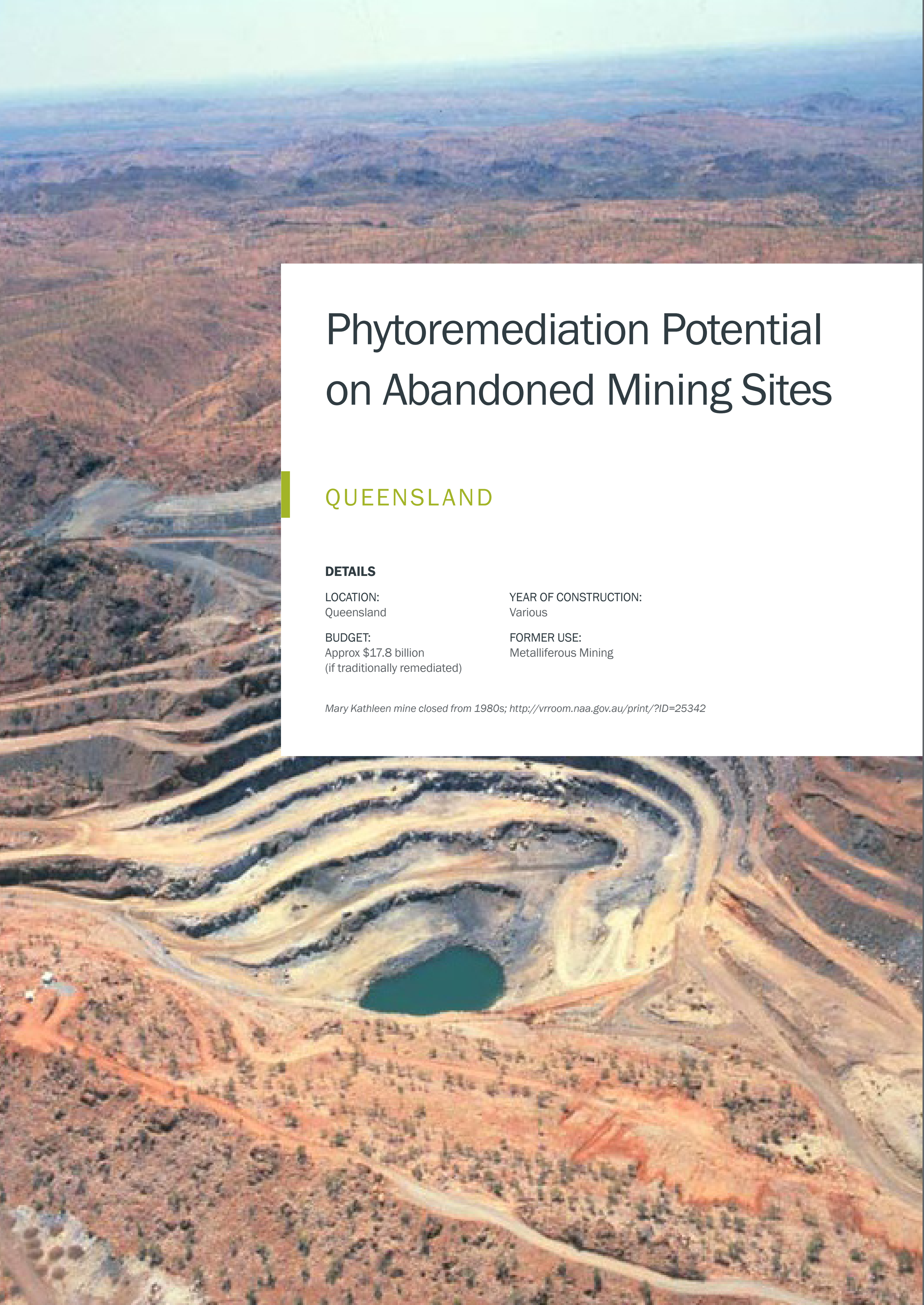
Bioretention is the process in which contaminants and sedimentation are removed from stormwater runoff. Stormwater is collected into the treatment area which consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, planting soil, and plants. (United States Environmental Protection Agency 1999, p1)

Image from (Arch Daily, 2016)

Image from (Arch Daily, 2016)

Image from (Arch Daily, 2016)

Image from (Arch Daily, 2016)



Phytoremediation Potential on Abandoned Mining Sites

QUEENSLAND

DETAILS

LOCATION:
Queensland

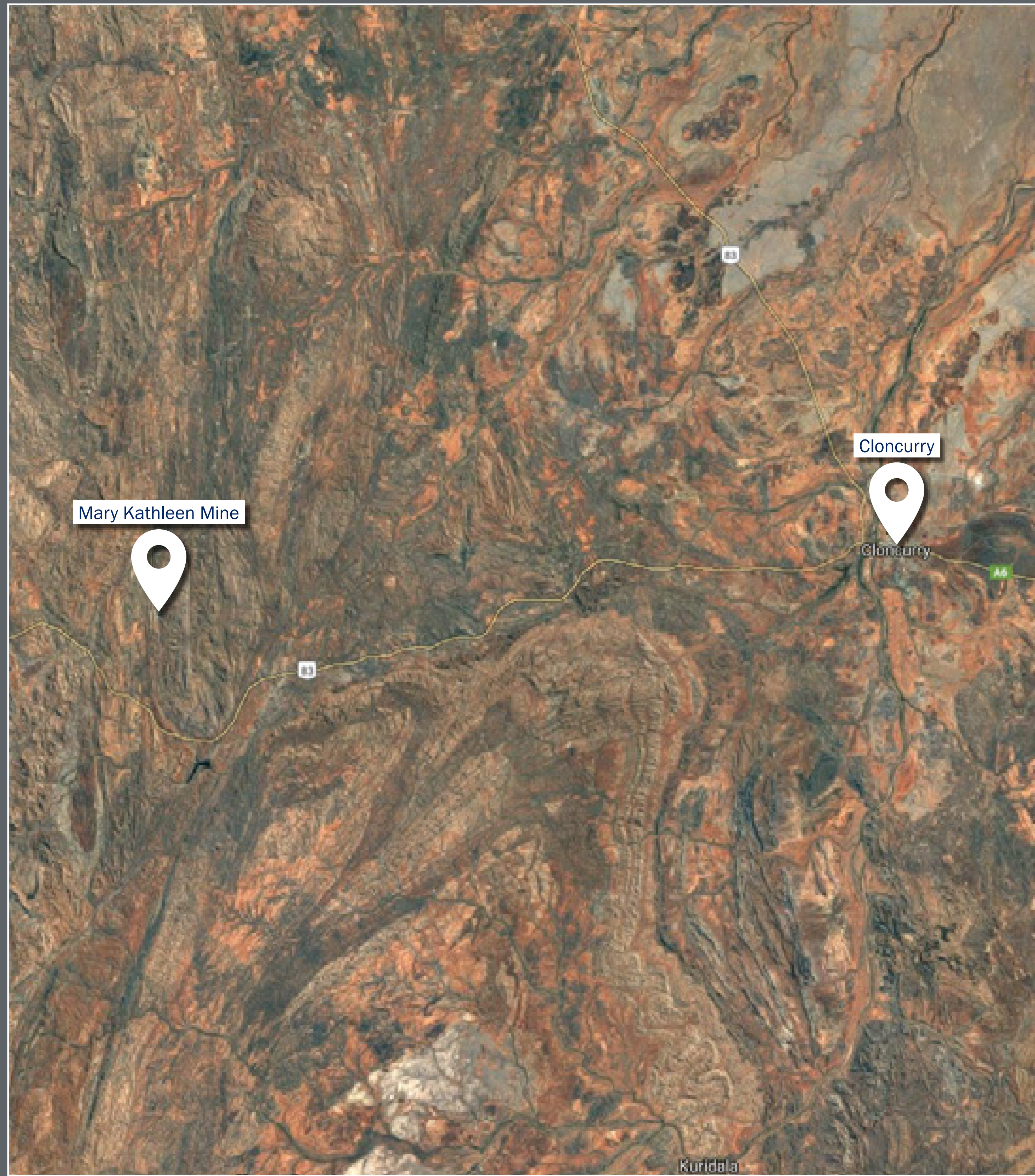
BUDGET:
Approx $17.8 billion
(if traditionally remediated)

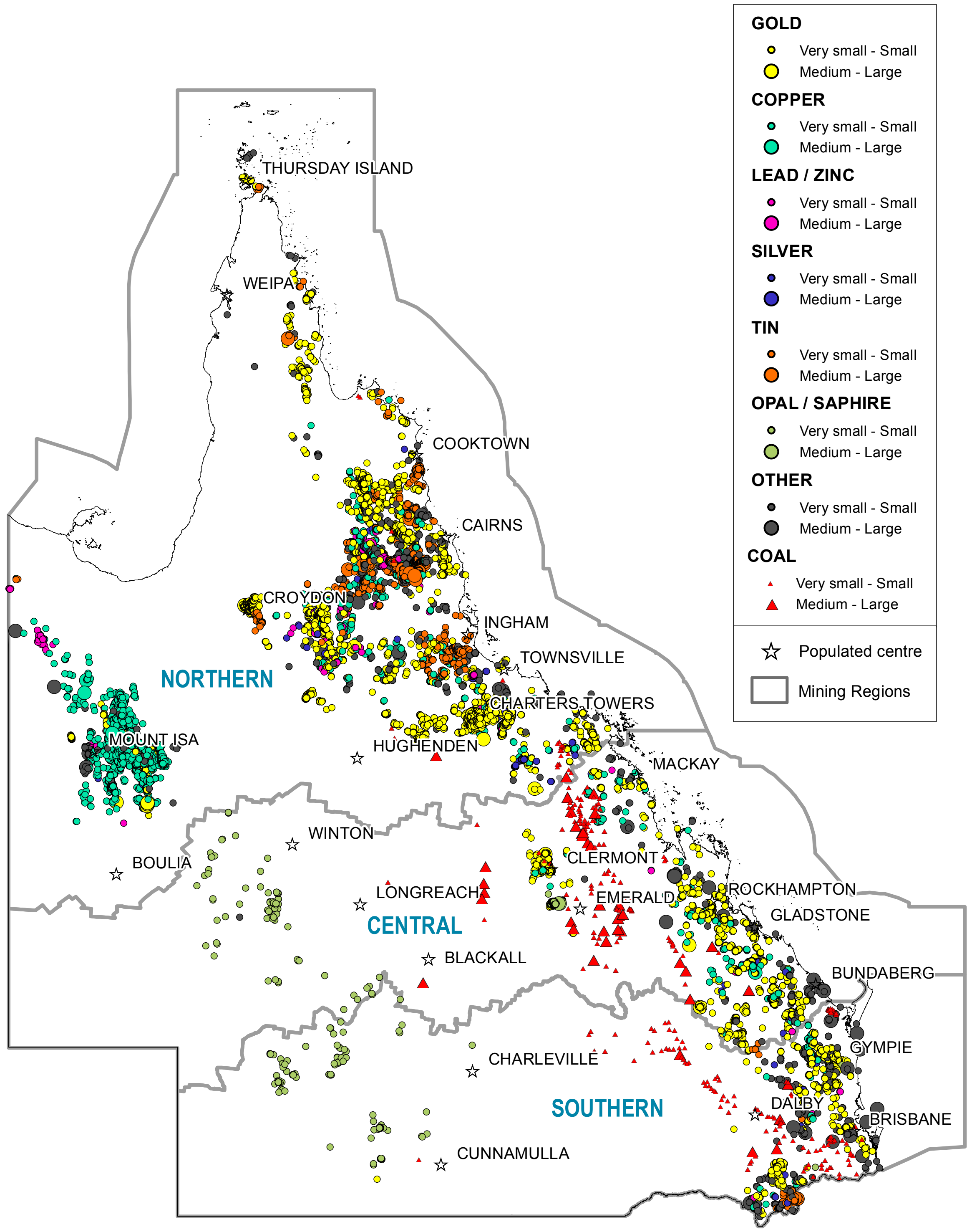
YEAR OF CONSTRUCTION:
Various

FORMER USE:
Metalliferous Mining

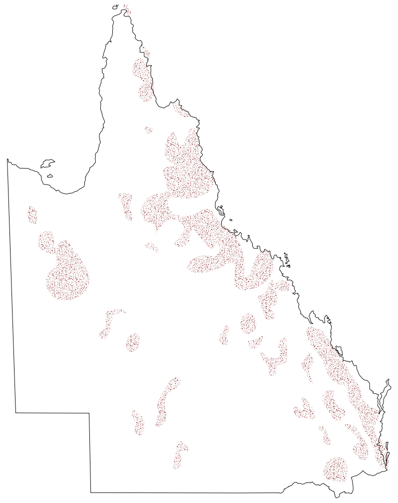
Mary Kathleen mine closed from 1980s; http://vrroom.naa.gov.au/print/?ID=25342

Google maps image showing Mary Kathleen Mine Site in reference to Cloncurry



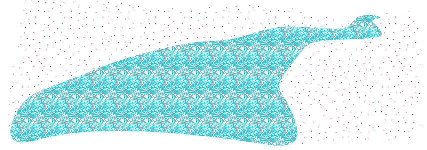


Map of Abandoned Mines in QLD from;
https://www.dnrm.qld.gov.au/__data/assets/pdf_file/0003/262659/abandoned-mines-map.pdf



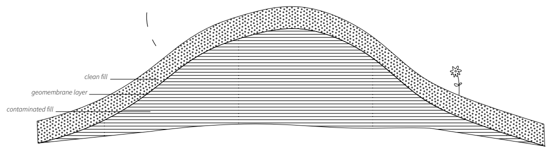
Current issue:

There is over 15,000 abandoned mines in QLD alone. Majority of which are not rehabilitated and pose a contamination risk to the surrounding landscape.



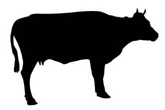
Current issue:

An example of this is Mt Oxide which was an open cut copper mine that closed in 1971. Only in the past decade has regulation of abandoned mines been placed by the government. In 2009 the mine went through severe acid mine drainage. Acid mine drianage is when the geology is disturbed by processes such as mining and leaks an abundance of sulfate minerals. This leached into the surrounding water bodies and caused detrimental damage to the surrounding ecosystems with many plants and animals dying from the toxicity.



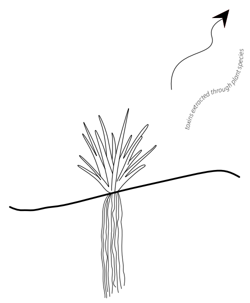
Current framework:

Current framework on dealing with abandoned mines is through expensive earthworks, capping and soil removal. If 65% of the 15,000 mines that require rehabilitation went through this process it would cost a third of the profits that mining produces.



Current framework:

Many mining tenements are surrounded by pastoral leases, and following mining closure are required by regulation to support a form of agricultural land-use.



Future potential:

According to various scientific studies and overseas precedents, phytoremediation has great potential to remediate these abondoned mines. It would be a significantly cheaper alternative to the current method used which is impractically expensive, and therefore unlikely for remediation to occur if change does not happen.

PRECEDENT ANALYSIS

The greatest potential for phytoremediation in Australia lies within mining-affected lands (Anderson Robinson 2007). There are over 15, 000 abandoned mines in Queensland alone (Willacy 2016) that are potentially contaminated and pose a public health risk. Current methods of dealing with contaminated soils (including capping, earthworks, etc.) however, are extremely expensive and become a major issue when concerning the adequate remediation of the sites. Phytoremediation would be a significantly cheaper alternative to the current methods being used, and considering these sites lie on relatively low value land this becomes a viable long-term solution.

So while this example is included in our study for technical purposes and techniques mainly, it is not a comparable design project per say.

Context

Metalliferous mining has a worth of over $8.3 billion in Queensland, showing extremely high value as an industry (Department of Environment and Heritage Protection 2007). The north and north-west Queensland mineral provinces contain the majority of Queensland's metalliferous mines, however over 15, 000 of these are abandoned (Willacy 2016). This has created thousands of potential environmental hazards with unknown levels of contamination.

Current statistics show that out of all the land mined in Queensland, only 35% has been successfully rehabilitated, which is predominantly due to the cost of rehabilitation. The cost of total rehabilitation has been predicted to amount to over $17.8 billion dollars when considering necessary earthworks, capping and sealing against Acid Mine Drainage (AMD), water issues, runoff, tailings dams, topsoil replacement, fertilizing the soil with gypsum, decommissioning fuel stations on site and a host of other things that have to be done to rehabilitate the land.

Subsequently, the total cost of rehabilitation would amount to over 30% of the total income generated by Australia's coal industry in the past seven years, being $55.4 billion (estimate by Cameron Amos at The Australia Institute). These figures put into perspective the sheer scale of the destruction taking place, making finding an alternative method of remediation of utmost priority.

Mt Oxide, an abandoned mine and its contamination on the land; http://www.mininglegacies.org/mines/queensland-2/mount-oxide/

Design agenda

The current framework for dealing with contaminated site rehabilitation includes earthworks, soil extraction and capping; being all extremely expensive methods of remediation. Mining tenements are also usually surrounded by pastoral leases, meaning they must support a framework of agricultural land-use requirements following their closure. Non-hazardous mine waste is usually directly revegetated after excavation, with a thin veneer "cap" of plant-growth laid down if necessary. If the mine wastes are deemed hazardous, they are generally isolated in large tailings, which are later capped at considerable expense using various geologic and synthetic materials. This must all take place before the site can be revegetated. Although the site has been capped, this does not ensure guaranteed safety of the site.

Root systems of these vegetated areas will invariably become exposed to the metals and metalloids contained in the medium, and may accumulate in the tissues of above ground vegetation and ultimately pass contaminated material down the food chain (Nicholas & Egan, 1975).

Issue with this:

'New Hope' is the energy company associated with the controversial mine situated on the lush Darling Downs. The release of glossy PR material showcasing the 'rehabilitation of 300 hectares of land' has caused speculation regarding the safety of the land which has evidently been returned for cattle to graze upon. Consumers are unknowingly buying and eating products coming from cattle that have been grazing on 'rehabilitated' land.

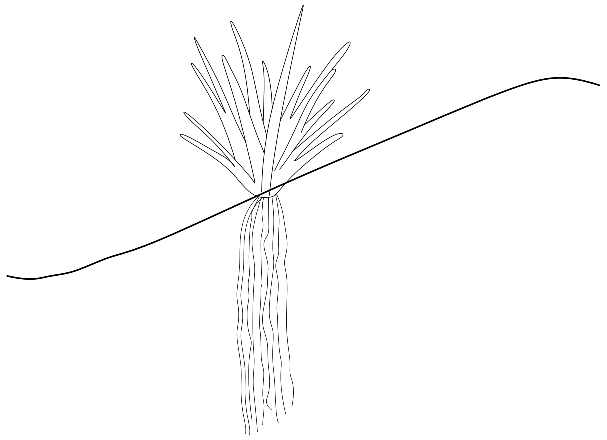
New Hope's Acland rehabilitation program has won various awards; https://www.beefcentral.com/production/grazing-trial-examines-cattle-performance-on-rehabilitated-mining-land/

Gavin Mudd, an Environmental Engineer at Monash University in Melbourne discussed the topic of mine rehabilitation, stating that due to the geological nature of the timeframes involved, many years must pass before you can categorically say that a piece of land has been effectively rehabilitated, making it clear that there is no substantial evidence when a mining company says "that piece of land 'X' is rehabilitated".

"You see, sometimes the Acid Mine Drainage – AMD – may not show up for years, so you need to monitor it for a long time — five, ten years, maybe even longer than that. Sometimes it takes that long. Everything may be operating fine on the ground and suddenly the water flow changes, or there is a bit of subsidence in the Earth, and the AMD may reappear." (Gavin Mudd, 2013)

Another issue associated with the rehabilitation of contaminated land is when the site falls on private land. Without governmental monitoring, sites are often left untreated or not adequately remediated. For example, the Queensland Flood Commission Inquiry revealed that approximately 12,000 out of 15,000 abandoned mines in Queensland are located on private land and consequently are not considered the responsibility of government, and have little chance of achieving the requirements set for properly remediated sites.

Vetiver grass (Vetiveria zizanioides)



Rhodes grass (Chloris gayana)

http://www.molokaiseedcompany.com/product/sunshine-vetiver-grass/

https://www.feedipedia.org/node/480

PLANT ANALYSIS

"Phytoremediation using vetiver grass (Vetiveria zizanioides) has been regarded as an effective technique for removing contaminants in polluted water and soils. Results showed that VG was effective in removing all the heavy metals, but removals greatly depend on root length, plant density and metal concentration. Longer root length and higher density showed greater removals of heavy metals due to increased surface area for metal absorption by plant roots. Results also demonstrated significant difference of heavy metals uptake in plant parts at different concentrations indicating that root has high tolerance towards elevated concentration of heavy metals. However, the effects were less significant in plant shoot suggesting that metals uptake were generally higher in root than in shoot. The findings have shown potential of VG in phytoremediation for heavy metals removal in water thus providing significant implication for treatment of metal-contaminated water."

(Truong 2002; Chomchalow 2003; Danh et al. 2009; Shu 2003; Truong et al. 2010; Vargas et al. 2016)

"This study concludes that Rhodes grass is well suited to the revegetation of mine tailings–polluted soils,and at low levels of contamination,mine tailings may improve the species growth potential. Low levels of metal and metalloid accumulation in aboveground tissues indicate a low fodder toxicity risk and suggest the species may be better suited to revegetation of metalliferous soils than Vetiver grass and Buffel grass. However, it is likely that Zn toxicity (1,000 µg/g) will significantly affect plant growth. It is recommended as a species for mine-tailings rehabilitation where there are no major issues for biodiversity conservation and where pastoral land use is a desired outcome."

(Keeling, Warren 2005, pg 59)

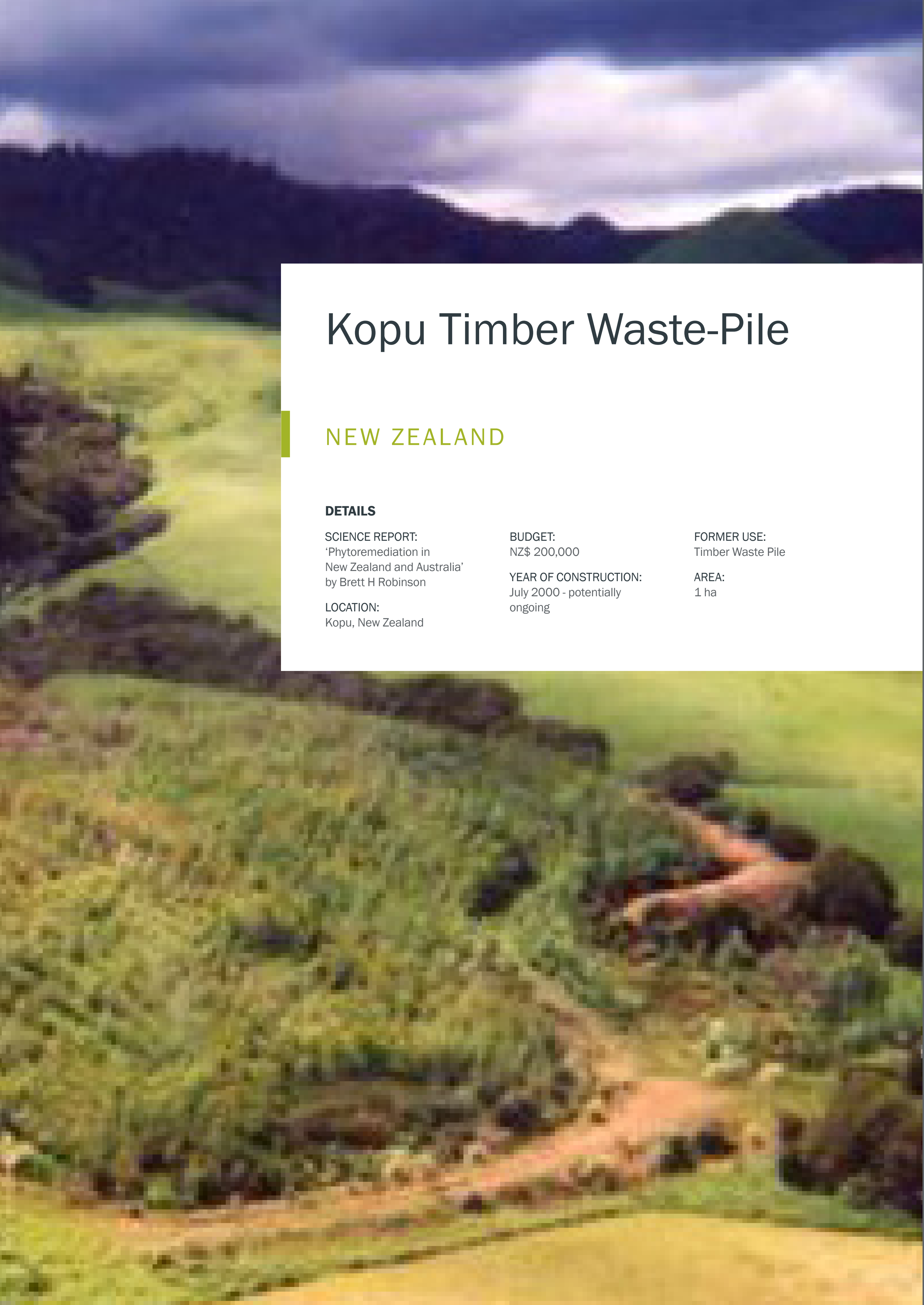
Effectiveness of project

As a biotechnology, phytoremediation harnesses only natural plant processes that over time, remediate the site to a safe state. This is significantly less invasive than capping or earthworks, as it poses minimal disturbance to surrounding native plant communities and species. Not only is it less invasive, but it is also incredibly cost efficient. In comparison to hiring an excavator, digging out a contaminated site and moving the waste to landfill, phytoremediation (despite being a slower process) can be up to ten times cheaper to implement.

Despite the countless reasons for the implementation of this type of land remediation, the lack of research surrounding the field has meant that phytoremediation is used far less in Australia than overseas. This is something with heightening potential as the number of untreated mining sites increases, and we become more aware of the dangers associated with improperly treated sites.

While our site is a post-industrial urban site, we envision that our research might be extended towards the design of former mining sites. As cities begin to extend further and grow into surrounding landscapes, such encounters with former mining sites may become potential new sites for living. This research while focusing on a post industrial site well within Sydney, could also be extended to regional cities who are now facing extensions into post mining environments.

https://www.governmentnews.com.au/2014/07/deep-dig-answers-disused-mines/



Kopu Timber Waste-Pile

NEW ZEALAND

DETAILS

SCIENCE REPORT:
'Phytoremediation in New Zealand and Australia' by Brett H Robinson

LOCATION:
Kopu, New Zealand

BUDGET:
NZ$ 200,000

YEAR OF CONSTRUCTION:
July 2000 - potentially ongoing

FORMER USE:
Timber Waste Pile

AREA:
1 ha

Google maps image showing Kopu phytoremediation Site in reference to Kopu Town

PRECEDENT ANALYSIS

A scientific trial of phytoremediation in Kopu, New Zealand was carried out to reduce leaching and contamination in the area. Populus deltoides (poplar trees) proved to be successful in growing in the semi-permeable soil as well as reducing the toxins. Anderson and Robinson (2007) also highlight that a lot of plant-based environmental projects are considered as a type of 'phytoremediation' in Australasia. This project is included for its technical performance and its scientific approach, with less emphasis on its spatial or experiential result.

Context

New Zealand has 1.6 million hectares of Pinus radiata plantations for timber production which has been treated with biocides to prevent decay. Historically these were treated with the chemicals pentachlorophenol and boron. Today, copper-chromium-arsenic is used. These treatment sites are now contaminated with the biocides and pose a risk to ground/ surfaces waters through contaminant leaching.

The area studied in this project is a timber-waste pile located in Kopu, New Zealand. For thirty years (1966-1996) the chemically treated sawdust and yard scrapings were dumped on this site leaving the soil contaminated. The site is designed to not have any water enter it. However, due to NZ's heavy rainfall/ climate the small holding pond which was placed to prevent leaching, overflowed and brought high levels of toxic boron to the local streams (Robinson Anderson 2007).

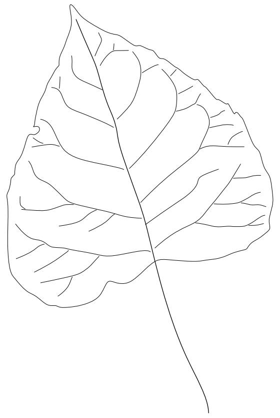
Engineering agenda

This project was a site trial of phytoremediation on contaminated land at a former timber industry waste site.

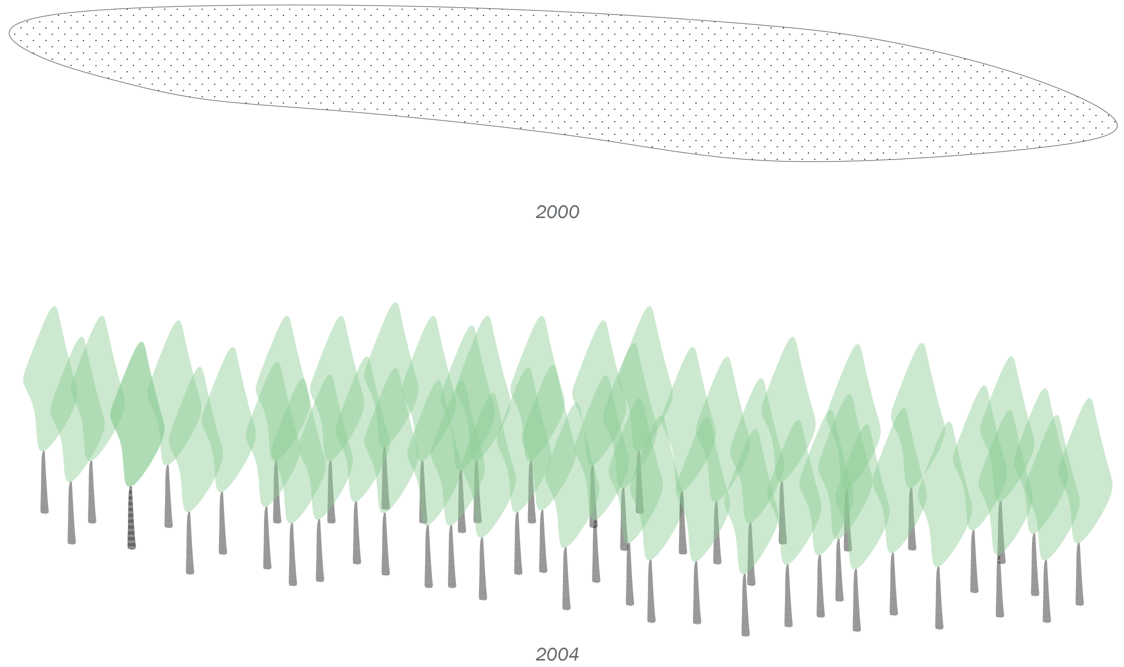
It started in July 2000, on a 1 hectare piece of land. Ten cloned poplar and willow trees, as well as two species of Eucalyptus were trialled. The species Populus deltoides (Necklace Polar) was chosen as the best candidate for phytoremediation. The poplar tree was planted to 7000 trees per hectare.

Google maps image showing Kopu phytoremediation Site

PLANT ANALYSIS



Poplar tree (Populus deltoides)



Poplar trees on phytoremediation trial site 2000 vs 2004

https://commons.wikimedia.org/wiki/File:Populus_deltoides_(5026724621).jpg

https://www.ibiblio.org/pic/Tree_pages/Populus_deltoides_var_deltoides.htm

Fig. 1 Arial photograph of the revegetated Kopu timber waste pile, October 2003. Image sourced from; Robinson (2007)

Effectiveness of project

These trees helped with the leaching which occurred monthly on the site. Summer months are of greatest concern for contamination of the local waterways because streams flows are lower and there is less dilution of the contaminants. The trees impact helped reduced the amount of drainage needed of water in summer, when trees are fully leafed and transpiring. The leaching that occurs during the winter months can be irrigated onto the trees or in times of drought during the summer, or diverted into the stream when it is at high flow.

Poplar leaves sampled contained Cu (copper) and Cr (chromium) concentrations that were on average 6.6. and 4.9 mg/kg dry mass. Arsenic concentrations were below detection limits.

At the end of the season the average leaf Boron (B) concentration was 700 mg/kg dry mass, 28 times higher than the B concentration in the sawdust.

These results show how that poplars could not only control leaching at the site but also reduce the B loading by phytoextraction.

These trees would be harvested (otherwise most of the B is returned to the sawdust via leaf fall) and used as an organic supplement to trees in orchards that are B deficient.

The concentrations of other metals in the leaves are not likely to cause further environmental problems.

The cost of phytoremediation at Kopu is estimated to be $200,000 NZ. This includes a site maintenance plan for five years, site assessment, scientific trails, and chemical analysis. The alternative cost of capping the site was estimated to be over $1.2 million NZ dollars. Capping also requires ongoing costly maintenance (Anderson Robinson 2007). This shows that phytoremediation is an effective and viable alternative for remediation.

In future landscapes on WBPS the use of tree species for both their spatial effects (shade and cover) as well as phytoremediation should be a consideration. Given our demonstration site has very shallow soils, we maybe unable to test significantly many tree species during this trial.

Phytoremediation in New Zealand and Australia

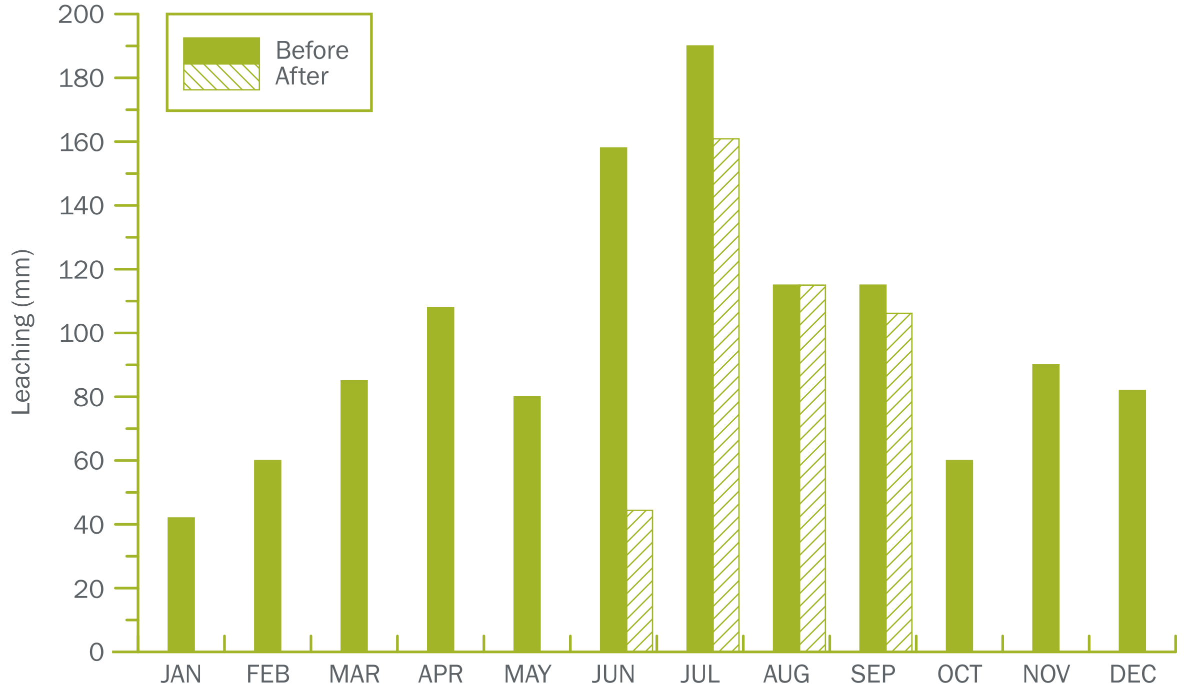
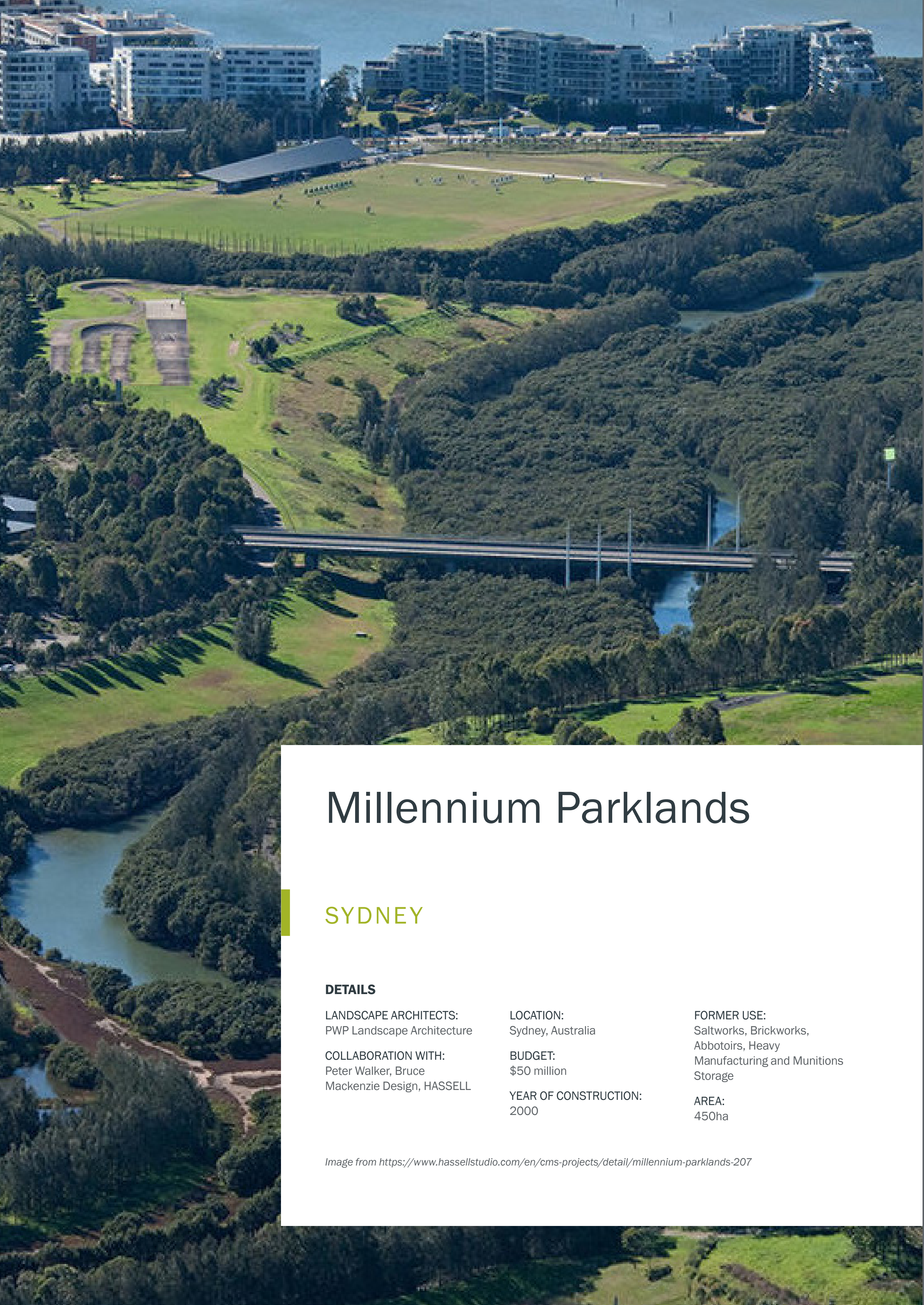


Fig. 2. Model calculations of average monthly leaching from the Kopu sawdust pile before and after phytoremediation. Image sourced from (Robinson, 2007)



Millennium Parklands

SYDNEY

DETAILS

LANDSCAPE ARCHITECTS:
PWP Landscape Architecture

COLLABORATION WITH:
Peter Walker, Bruce Mackenzie Design, HASSELL

LOCATION:
Sydney, Australia

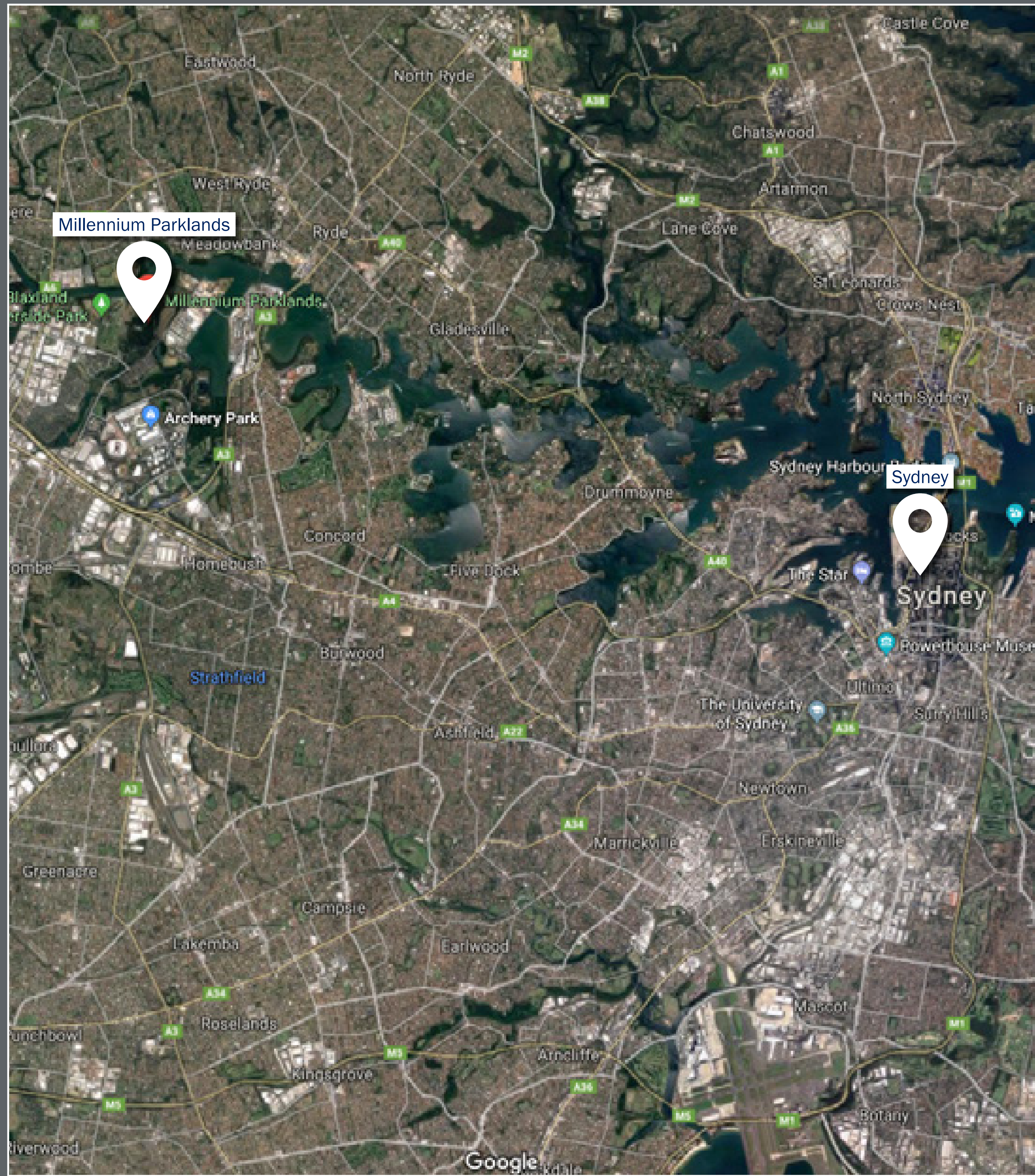
BUDGET:
$50 million

YEAR OF CONSTRUCTION:
2000

FORMER USE:
Saltworks, Brickworks, Abbotoirs, Heavy Manufacturing and Munitions Storage

AREA:
450ha

Image from https://www.hassellstudio.com/en/cms-projects/detail/millennium-parklands-207



Google maps image showing Millennium Parklands in reference to Sydney CBD

PRECEDENT ANALYSIS

The Millennium Parklands of Homebush Bay is a site that had once been home to various industrial uses and was highly contaminated with commercial and industrial waste. The design strategies devised to deal with the huge quantities of contaminated material, clean fill generated from the construction of the sites Olympic venues and their integration with various technical water recycling systems, created an environment in which native plants could thrive and set a new world standard for this type of approach. Beyond the technical resolution of this self sustaining landscape the resulting parklands were designed to reconnect residents from the western suburbs back to Sydney's major waterways and provide recreation and education opportunities for 2.5 million visitors annually.

Context

Prior to European settlement of Sydney Homebush Bay and the neighbouring lands and waterways were believed to have been comprised of a diverse environment including forests, grasslands, waterways, salt marshes and mangrove wetlands, all with associated communities of fauna. The site was also the traditional home to the Wann-gal Aboriginal people. Since European settlement it has been home to various industrial uses and has essentially been contaminated with commercial and industrial waste.

The Millennium Parklands at Homebush Bay surround the site of the 2000 Sydney Olympics and cover an area of around 450Ha, slightly larger than New York City's Central Park.

Design agenda

To function properly within the environmental context of an urbanised landscape careful thought was given to the soil profile as central in creating an equilibrium within the geology and natural processes at work on the site's surface. This is where the rehabilitation of the landscape was able to begin.

The reburial of waste from old landfills, combined with the exposure of large areas of poor quality clay fill left large areas of the landscape without an adequate topsoil layer to planting into. A severe unexpected shortfall in available clean topsoil from the stripping of the Newington Village only exacerbated this issue and left the Olympic Coordination Authority with no choice but to look at waste soil fill materials for the reconstruction of a workable soil profile, as the cost economically and environmentally of importing quality commercial topsoil in such quantities as deemed untenable.

The landscape masterplan was based on three unifying design themes; lowlands, elevated landforms and a park-wide system of woodlands and forests, acting as walls. The walls defined spaces and provided connections between the various facilities within the park and play a key role in providing habitat diversity and green corridors to connect the various ecosystems of Homebush Bay.

"The future park of Homebush must move beyond the concept of the picturesque landscape, beyond images of embalmed nature, and beyond the realm of landscape as a spectacle for the masses. The landscape at Homebush Bay is not intended to be experienced as a fixed element, nor an object of desire, but an on-going process of evolution."

Millennium Parklands Concept Plan, 1997.

Masterplan of Millenium Parklands from; http://www.pwpla.com/projects/millennium-parklands/&details

The aerial photograph shows the SOPA site in the 1980's prior to development, during construction of the first phases of the parklands along Haslam Creek in about 1998 and in about 2007. The change has been significant.

Images sourced from http://182.160.150.115/projects/NSW/olympic/docs/HASSELL/Millennium%20Parklands%20 10%20Years%20On2.pdf

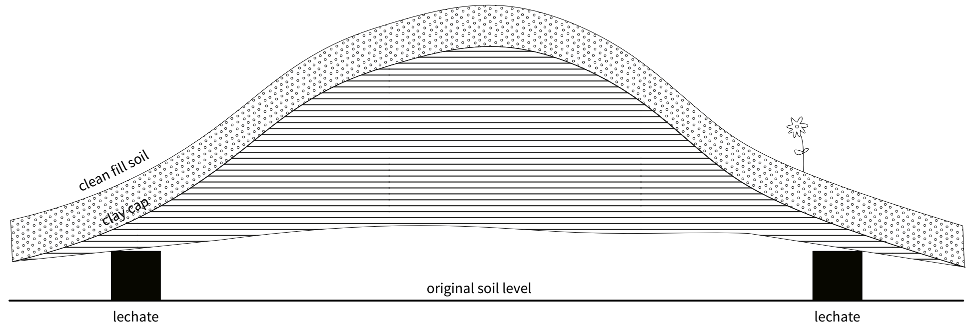
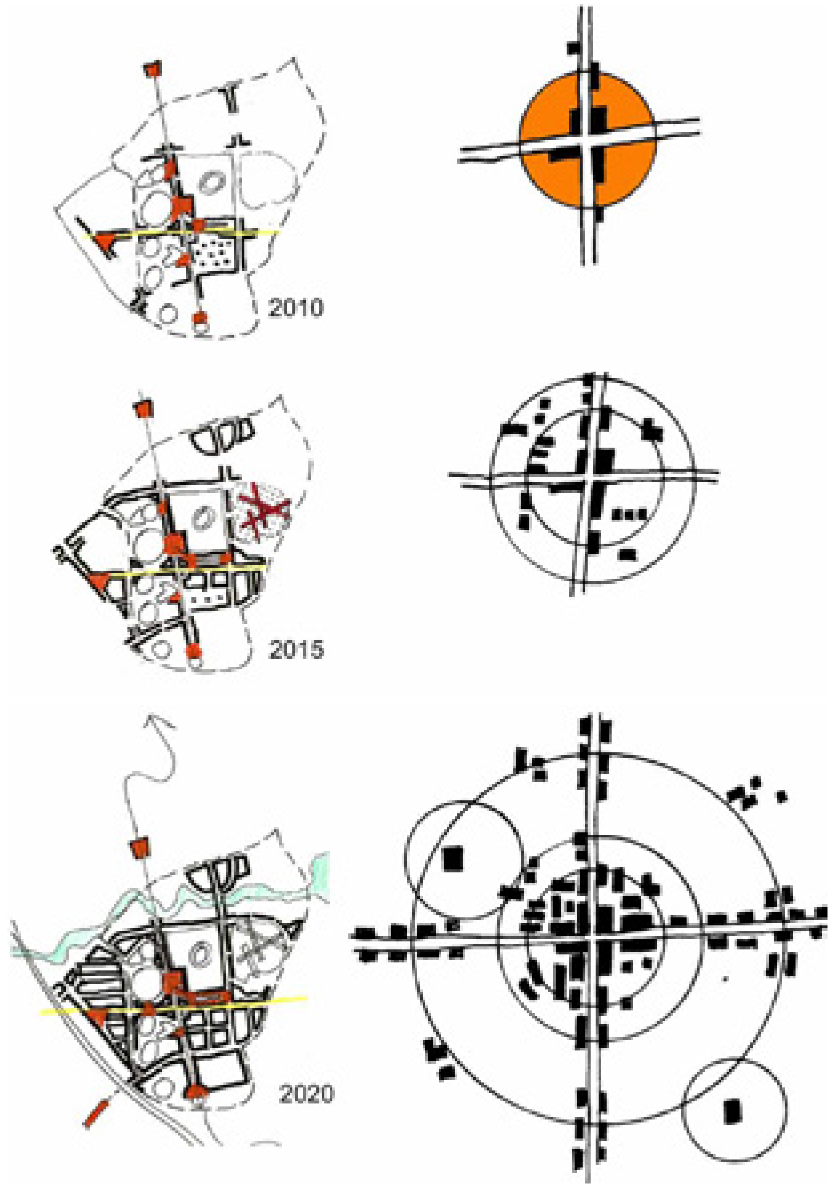


Diagram of the process of capping at Millennium Park



https://www.hassellstudio.com/en/cms-projects/detail/millennium-parklands-207

https://www.hassellstudio.com/en/cms-projects/detail/millennium-parklands-207

Effectiveness of the project

According to the Soil Scientist, Waste Services NSW had to strip, relocate, and 'encapsulate' hundreds of thousands of tonnes of waste over large areas along the Haslam's creek corridor, with some of this waste being of high toxicity. This was due to the material originally being placed in 'the old fashioned manner' where a swamp/ salt marsh area was used as a landfill site, with waste placed on top of a 1-1.5m deep sheet of swamp land and roughly covered with clean fill.

The 'encapsulation technique' is where an impermeable clay base is constructed with waste material then placed in a naturalistic landform on top before being covered by a specially designed impermeable clay cap. The 'Kronos Hill' and 'North Newington hills' are examples of waste reburials developed in this manner.

So while phytoremediation on this example is mainly in the form of WSUD, it is an interesting example of using an international event (the Olympics) to regenerate a toxic landscape and provide future public amenities as well as much needed extension for Sydney. It was also highly publicised at the time as the "Green Olympics." Thus working to educate the general public on the transformational effects of more sustainable landscape regeneration and celebrating large scale, brownfield site redevelopment.

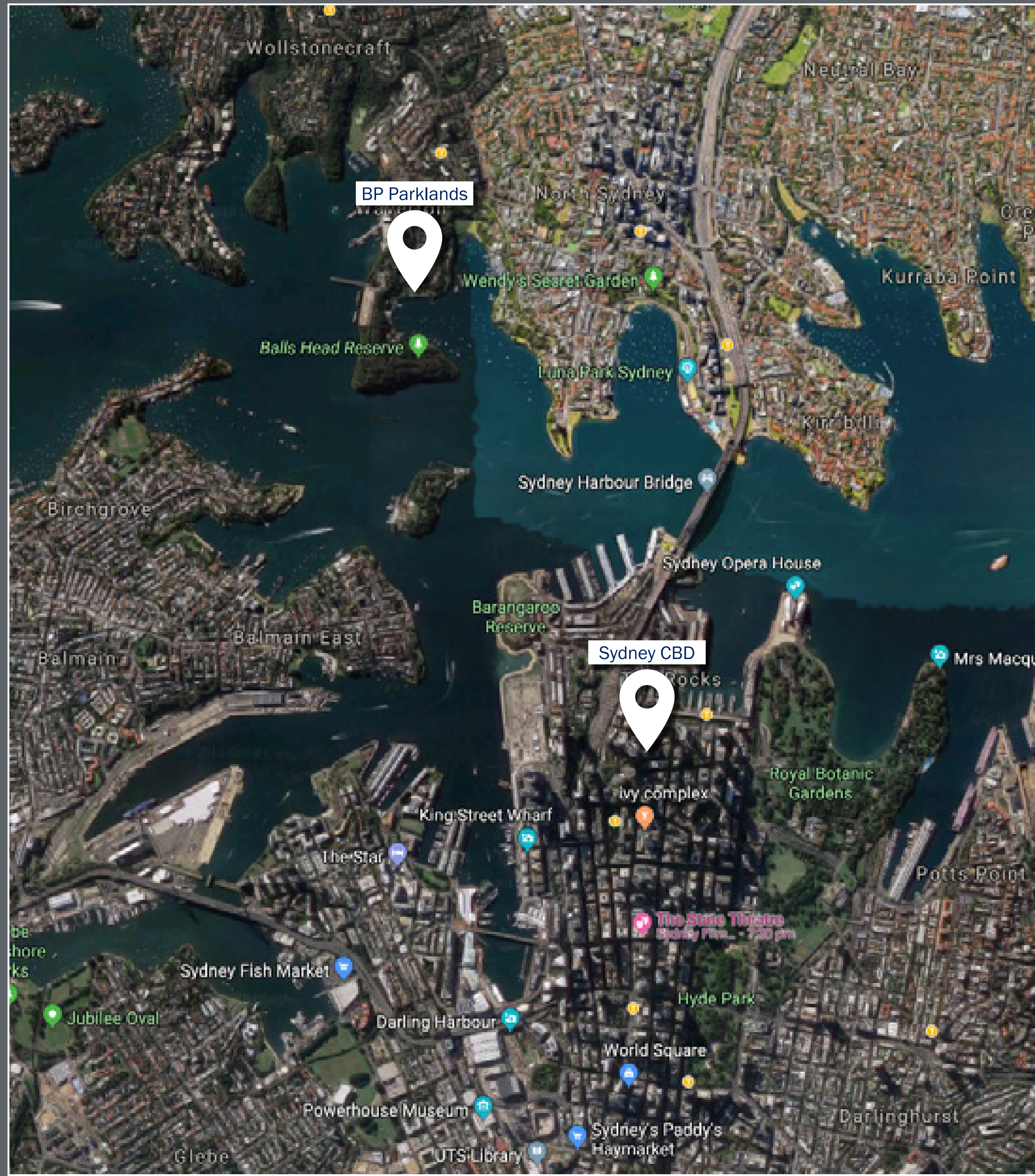
BP Parkland

SYDNEY

DETAILS

LANDSCAPE ARCHITECTS: McGregor Coxall	BUDGET: $3.4 million	FORMER USE: Fuel Storage
LOCATION: Sydney, Australia	YEAR OF CONSTRUCTION: 2005	AREA: 2.5ha

Google maps image showing BP Parkland in reference to Sydney CBD



PRECEDENT ANALYSIS

The 2.5 hectare Former BP site has emerged from it's polluted past to become a contemporary post industrial harbour front park. The design by McGregor Coxall uses the site's industrial heritage as a juxtaposition against its environmental framework of regenerating wetland and bushland.

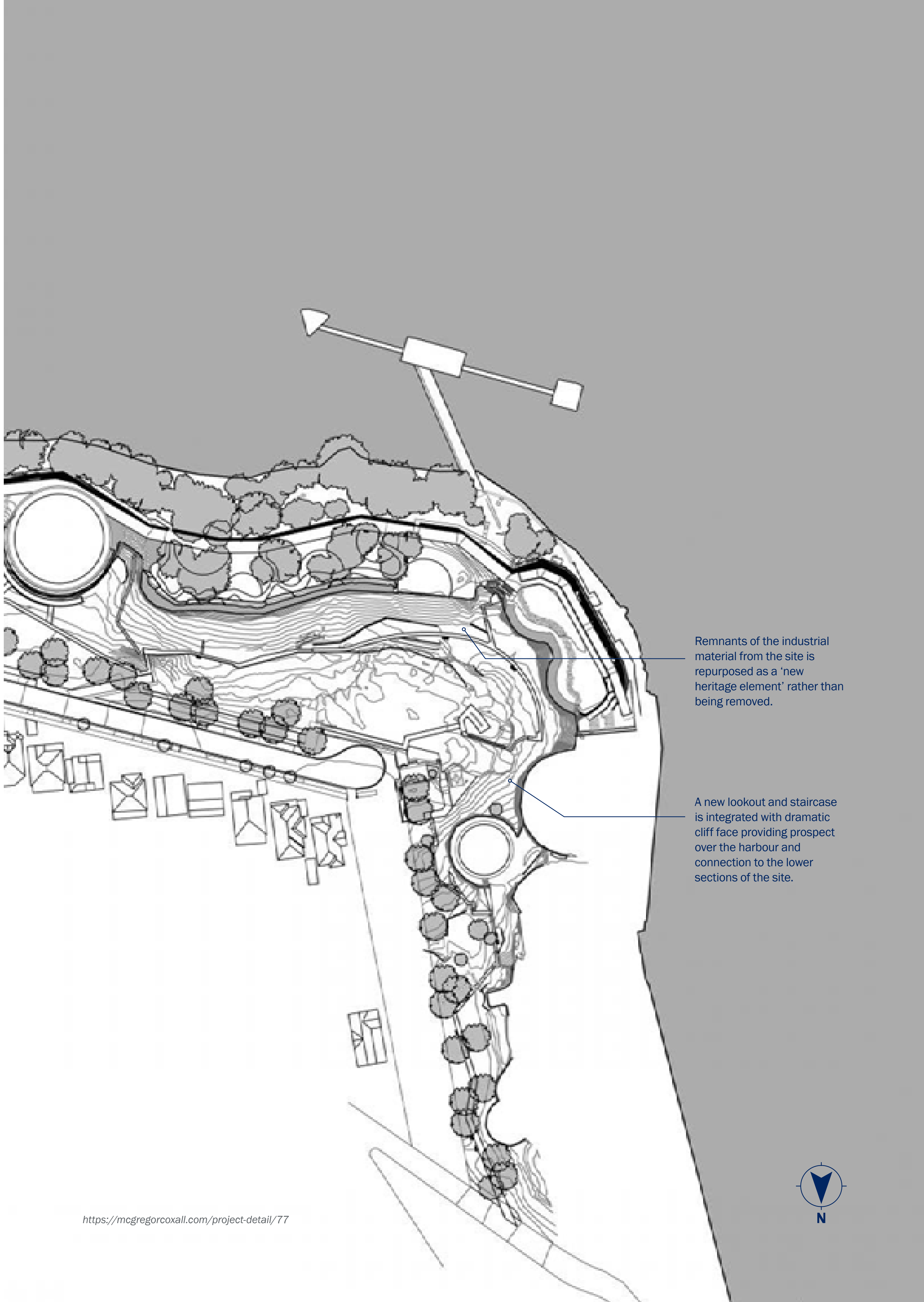
Context

The history of the BP Parkland site dates back to the 1920s, when the British Petroleum Company (BP) acquired the coastal site on the eastern side of Waverton Peninsula. It soon became the location for the industrial scale storage tanks required to transfer fuel from inbound ships to motor tankers servicing ships in the harbour.

Fuel tanks

In 1923, Anglo-Persian Oil Company built the first oil tank to be placed on the site. It was then leased to Commonwealth Oil Refineries, however still controlled by the parent company of British Petroleum from 1967 until its closure. The site was further modified when railway infrastructure was constructed to carry kerosene drums from the western wharf to the store. In 1933, the Commonwealth Oil Refineries demolished warehouse structures on the site along with the excavation of the natural sandstone escarpments to provide room for more fuel storage tanks. The original sandstone was reused to build the existing bund wall on the western part of the site, and encircled five tanks by 1937. By 1939 there were a total of 11 tanks on the combined BP and Carradah Park sites, increasing to 31 tanks by 1967.

The western timber wharf is a wide timber pile wharf, designed to provide space for loading and unloading product, and is the oldest wharf, dating from as early as the 1930s. Pipes that were originally used to transfer fuel to and from the storage tanks on the shore, are now cut off and sealed with concrete. The timber T-wharf was built in the1960s to replace an earlier timber wharf to increase the mooring capacity of the site.



https://mcgregorcoxall.com/project-detail/77 *http://saveberrysbay.org.au/background-history/*

http://www.deucedesign.com.au/former-bp-site-park/

https://www.weekendnotes.com/carradah-park/

Removal of fuel tanks

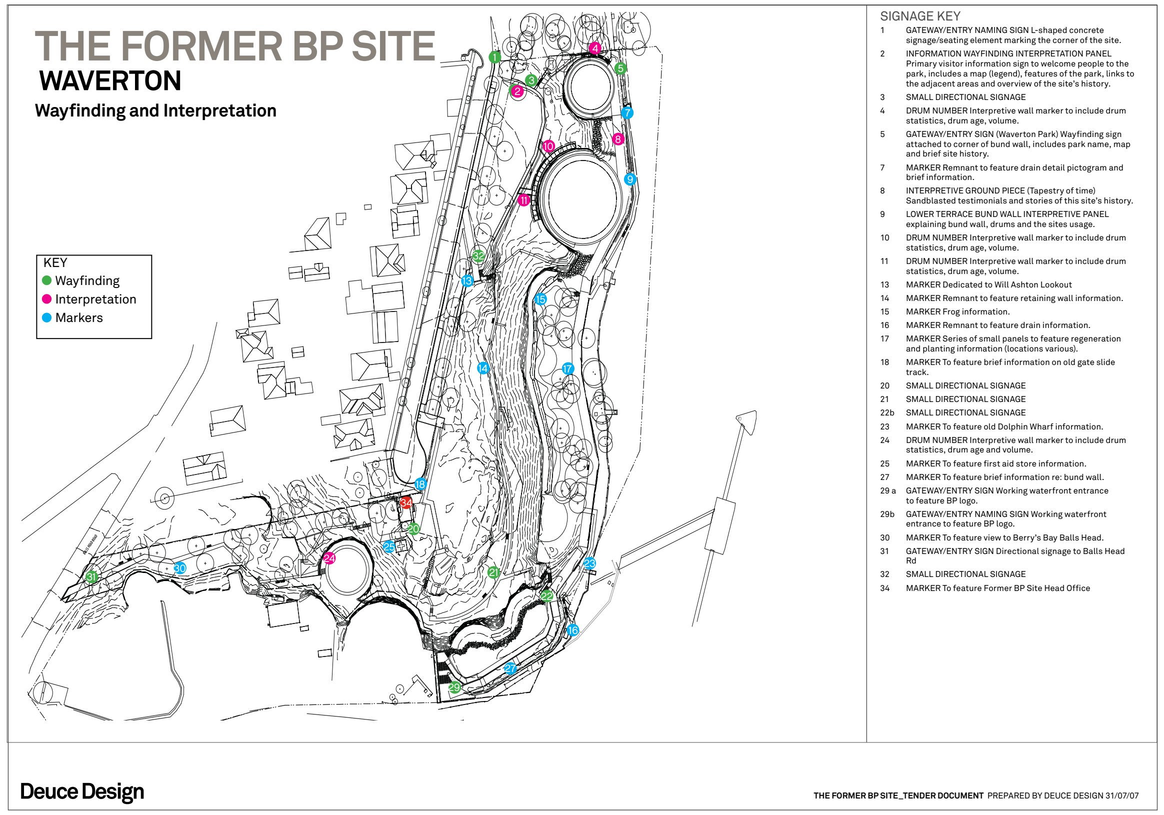
After it's official closure, the tanks were removed and site sold off in 1996. The remnants of the BP oil storage site and the neighbouring Coal Loading Facility on the western side of the Waverton peninsula can be seen as relics of the history of the working harbour and its relationship to maritime trades.

When BP abandoned the facility in the 1980s, the site had further deteriorated and become contaminated. The North Sydney Council was faced with the challenging task of finding it a new post-industrial future. This resulted in the site lying dormant for a quarter of a century and a further investment of $3.4 billion to regenerate the site.

Waverton Peninsula task force and mid-1990s - lobbying

After the leases of BP and Coal Loader/ Caltex depot came to an end, North Sydney Council established the Waverton Peninsula Planning Taskforce, along with representatives of the Department of Planning and the Sydney Harbour Foreshores Committee. This urged for public open space on these harbourside sites, whilst the NSW Government continued to press for major residential development.

Community groups campaigned for the Commonwealth Government to dedicate redundant Commonwealth-owned defence sites as public open space, and in 1995, North Sydney Council endorsed the public open space proposals.



https://www.northsydney.nsw.gov.au/.../waverton.../bp_interpretive_signage.pdf

https://www.weekendnotes.com/carradah-park/

In August 1997, Bob Carr (the current NSW Premier), turned down plans for residential subdivision of the former BP site and dedicated it to public open space, along with the nearby Coal Loader and Caltex depot sites. Premier Carr stated; "The NSW Government recognises that there is a need to maintain the commercial viability of the Port of Sydney and that part of the site is appropriate for 'waterfront industrial' uses."

Strategic masterplan (March 1999) and rezoning (January 2003)

The Waverton Peninsula Strategic Masterplan was developed by North Sydney Council after consultation with stakeholders and the community, and in January 2003, the NSW Government rezoned the northern part of the BP site for open space and placed it under the care, control and management of North Sydney Council. The parklands adjacent to the subject BP site were opened in March 2005, retaining 0.98 hectares of the overall site for the 'waterfront industrial' use.

DESIGN AGENDA

Today, the site has been redesigned into a recreational and environmental space, designed by landscape design firm Mcgregor Coxall.

The 2.5 hectare Former BP site has become a contemporary post industrial harbourfront park. Galvanized steel walkways and stairs cut diagonally across the landscape towards a steel viewing deck, strategically framing the sandstone cliff, whilst concrete and steel stairs wrap over and around the topography. The site's industrial heritage is cross programmed into an environmental framework of regenerating wetland and bushland; the juxtaposition of industrial materials and raw stone is a powerful contrast. The viewing decks and walkways float over the descending landscape providing uninterrupted views of the CBD and the Harbour Bridge in the distance.

The design reconnects the relic fragments of industrial structures, then contrasts them against sophisticated modern structures to retain both their aesthetic and cultural prominence. The site's industrial heritage is celebrated within the framework of the natural environment of regenerating bushland and constructed wetlands.

https://mcgregorcoxall.com/project-detail/77

https://mcgregorcoxall.com/project-detail/77

https://mcgregorcoxall.com/project-detail/77

https://mcgregorcoxall.com/project-detail/77

Effectiveness of project

The design successfully reconnects the history of the site through fragments of industrial relics, whilst simultaneously contrasting them against a modern framework to retain both their aesthetic and cultural prominence. The project has won five awards including the Australian Institute of Landscape architects NSW design excellence award of 2005.

Summary of findings

Section 2 examines and analyses design and engineering precedents for various types of brownfield and degraded landscapes. We selected these examples after a thorough review of design projects internationally and nationally to establish benchmarks but also to learn from how others approached these very complex sites. Many of the projects are reasonably successful in terms of their current use as large scale parks and cultural precincts, the more successful ones in terms of gaining public support and understanding, negotiate the difficult terrain of public engagement. They do this through a variety of means; they employ active public engagement across all stages of planning and development, inviting the public in through physical events on site, virtual means, and public discussions. In some instances, after the projects are completed, active websites continue to monitor the progress of the landscape reclamation and activation events on the sites. For the purposes of the Power Plants project, we have gleaned a great deal from these projects and their authors' learnings. Firstly, phytoremediation while commonly deployed in large scale landscape remediation efforts for environmental engineering, is seldom utilised in a designerly fashion. Secondly, the ongoing extraction and tracking of the effects on the soil condition is not reported or recorded live, in data which is accessible and understandable to the public. Thirdly, the opportunity to utilise the implementation process as an artistic event as a way of engaging the public via a film and as an educational opportunity has not been done before. And lastly, demonstration gardens are generally untested as a pre-development opportunity for ongoing public engagement and learning activities.

Site analysis

SECTION 03

The White Bay Power Station is located in the suburb of Roselle, 3km west of the Sydney CBD and is part of Urban Growth's Bays Precinct Transformation Program. The Bays Precinct has a rich indigenous, multicultural and industrial history of transformative functions for Sydney and Australia. It was a place of trade between Aboriginal clans and became an essential part of maritime commerce in the new Colony.

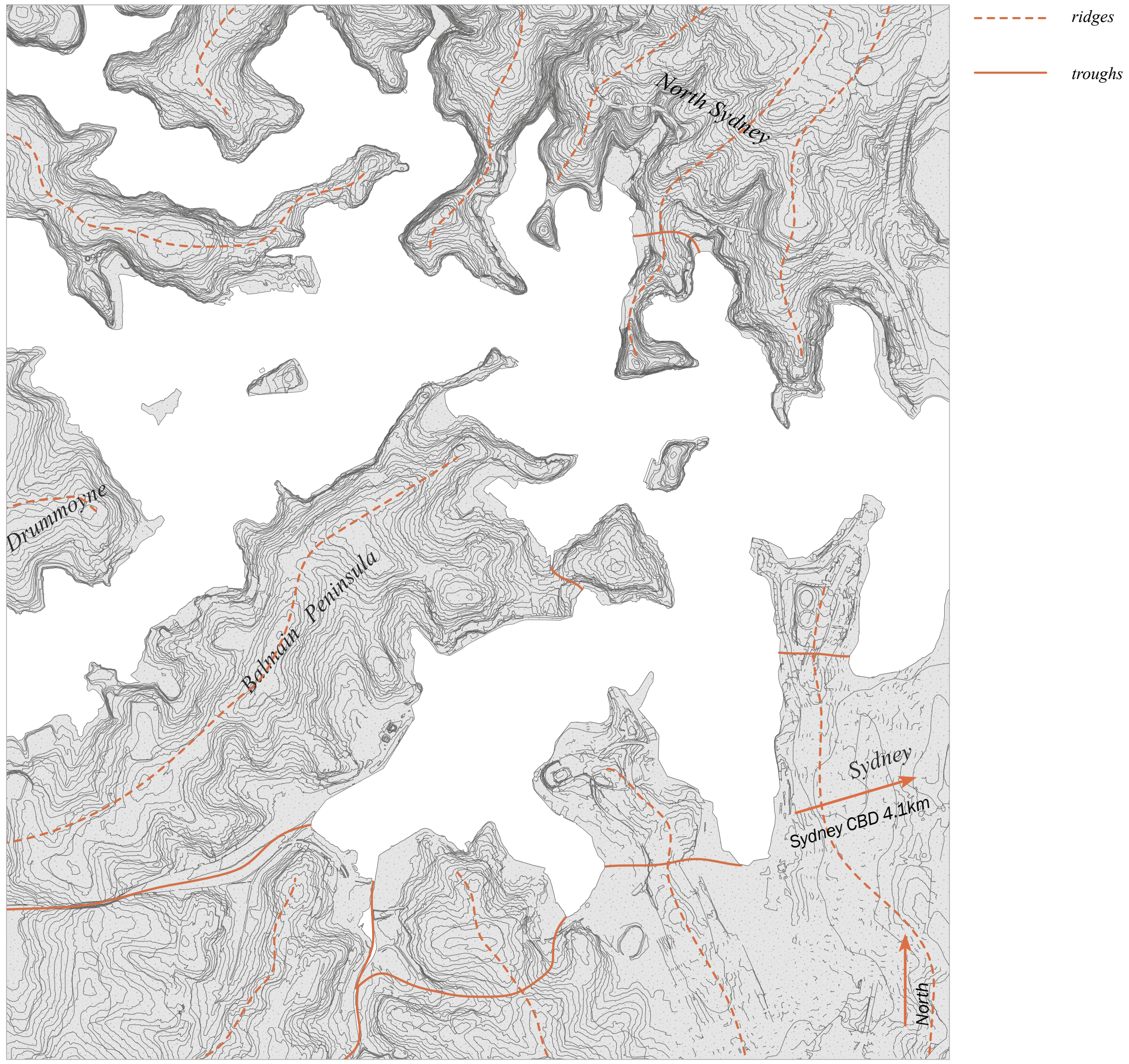
The following site analysis explores the history of the White Bay Power Station site from its geological formation until its use into the present day.

The Power Plants phytoremediation project is ideally suited as an urban laboratory and demonstration project. It is a temporal project implemented during the pre-development phase, which aims to remediate soils in the WBPS post-industrial site. The Power Plants Project also has a number of educational and engagement activities which are detailed in the next section of this report.

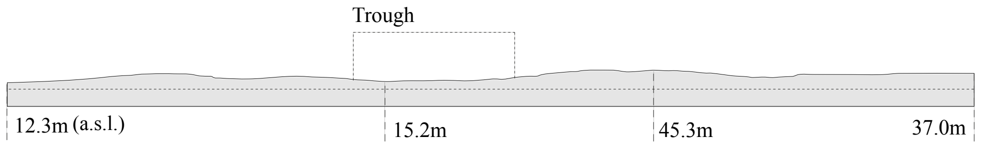
Land form and settlement Pre- 1788

The Sydney Basin was formed when the earth's crust expanded, subsided and filled with sediment between the late Carboniferous and Triassic periods. Around the future Sydney Harbour, the Basin was covered in quartz sandstone by extremely large braided rivers that flowed in from the south and the north west to deposit the Hawkesbury Sandstone.

The topography of the Drummoyne and Balmain peninsulas has naturally occurring dips or 'troughs' along their ridges. These ridges and troughs informed the way the landscape was used and travelled pre European settlement and how the area was occupied by the Indigenous tribes of the Wannagal.

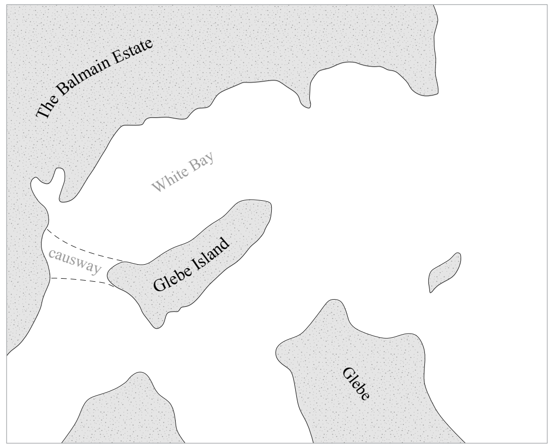


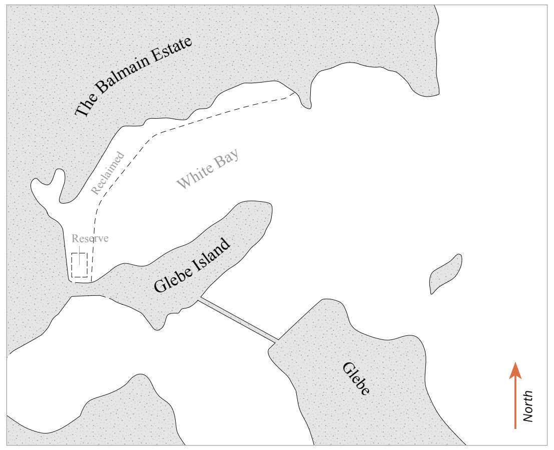
Topographic Map of Sydney



Section of Balmain Peninsula

Illustrations, (UTS, 2018).





Illustrations (UTS, 2018).

Reclamation 1840

The rocky outcrop known as Glebe Island was originally only accessible from the Balmain shoreline at low tide, until a causeway was laid in the 1840s.

1855

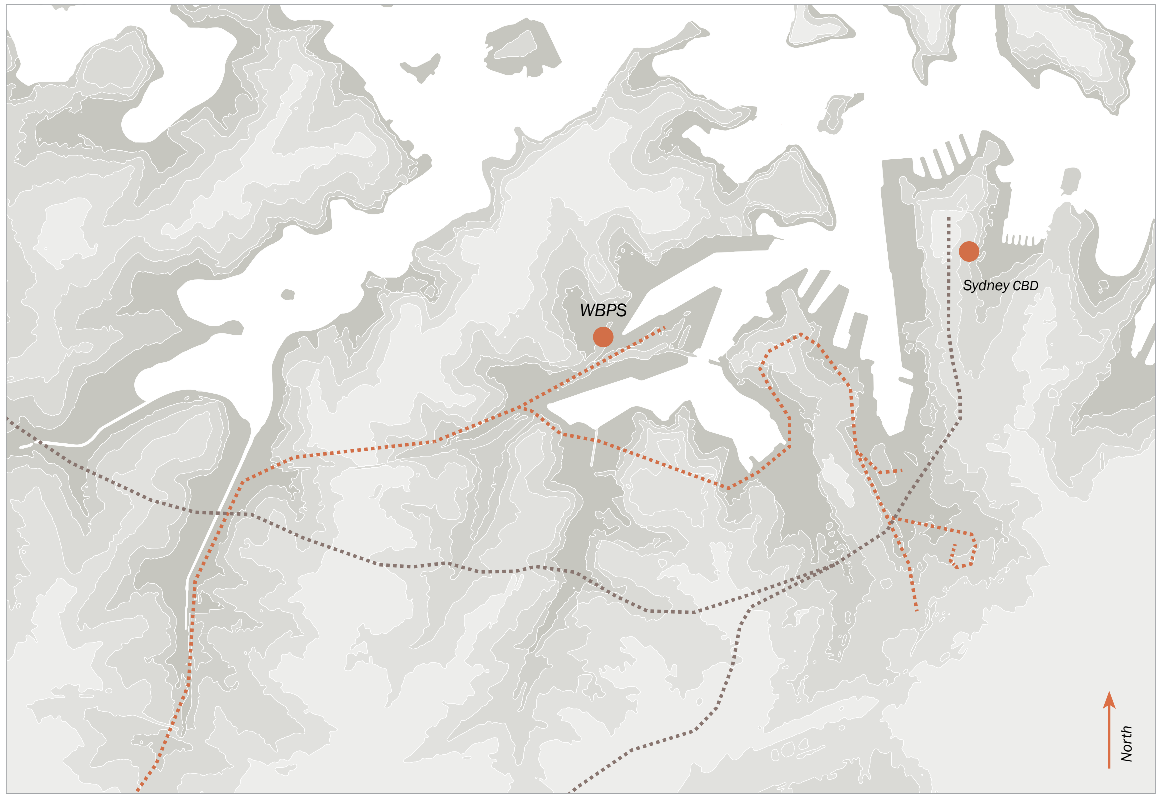
In 1855 White Bay was still a mud flat. In 1862, a low-level timber framed bridge was built that connected the island to Pyrmont, and thus to the city. Around 1890 a dyke was built from Balmain across the mud flat to Glebe island which reclaimed the land at the head of the bay for a public reserve.

In the middle years of the 19th Century, there was considerable pressure to subdivide Balmain for housing to accommodate the workers in such industries as the abattoirs on Glebe Island, W.Bell Allen's boiling down works, timber milling in Rozelle Bay and Cowan and Isreal's Soap and Candle factory on the Annandale foreshores.

Transport and Industry 1855 - The Opening of the Sydney Goods Line

After the construction of the main rail line from Central Station to the far West, the Sydney Goods Railway Line opened in 1855.

Following naturally occurring troughs and ridges, the rail line linked the region's resources to the Harbour of Sydney.

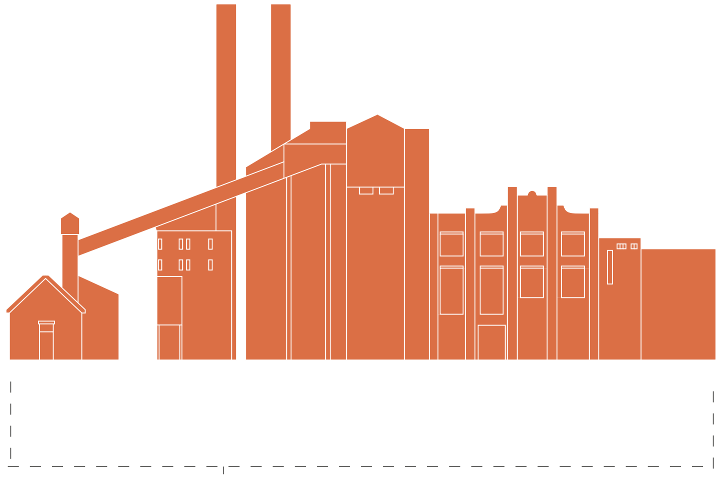


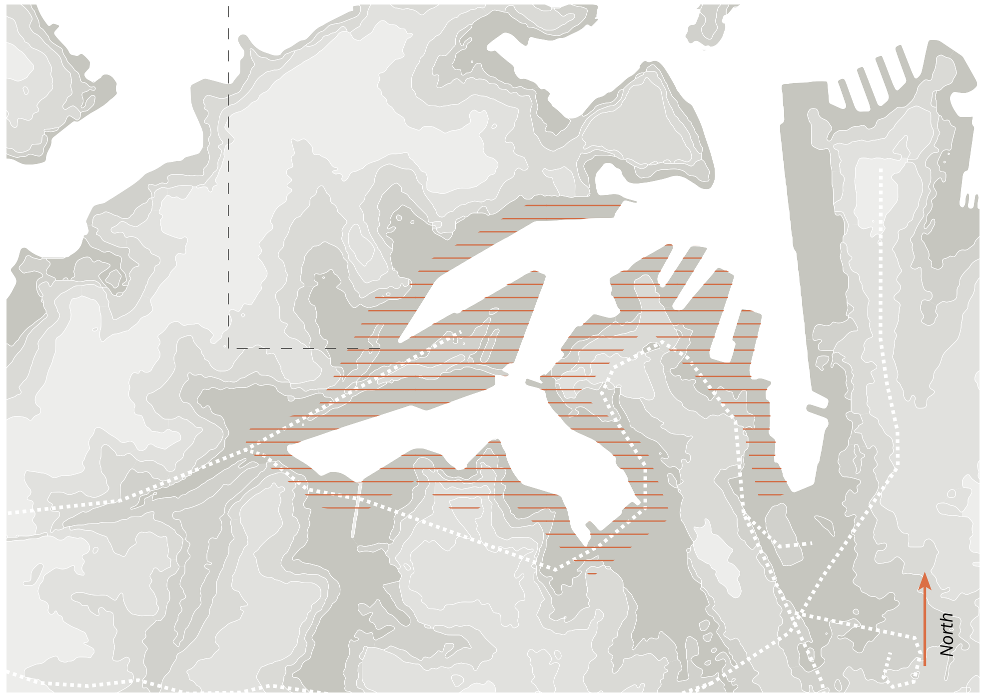
Illustrations (UTS, 2018).

Sydney goods railway line (1855) Main Railway Line

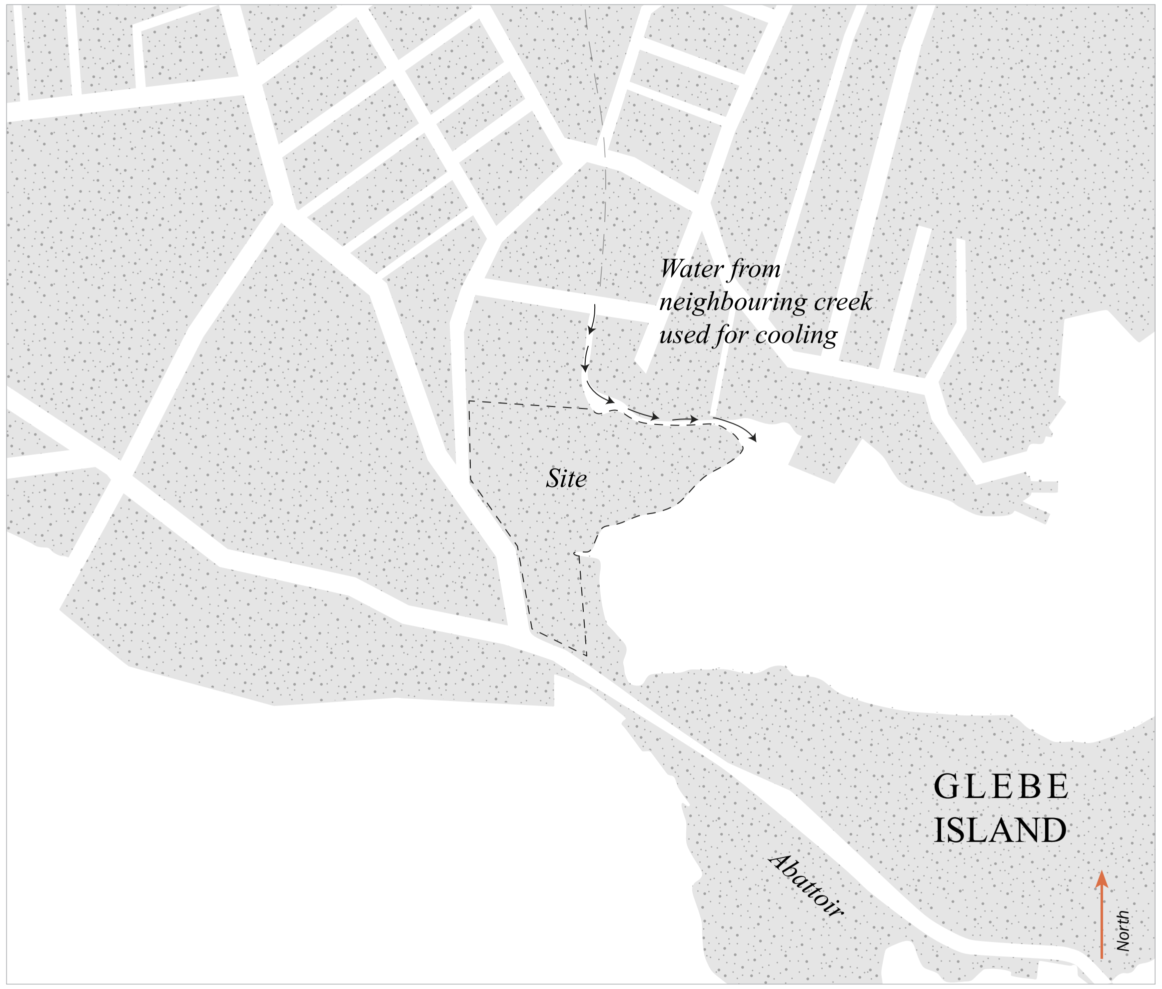
The Industrial Belt 1900's-

Following the construction of the Goods Line Railway, heavy industry claimed the perimeter of the harbour in White Bay, Johnstons Bay, Blackwattle Bay and Darling Harbour. This was also known as the 'industrial belt'. A strong pride in industrial advancement with heroic buildings and infrastructure was achieved at the expense of the health and ecology of the natural landscape, for example industry heavily contaminated the soil of the site.





Illustrations (UTS, 2018).



Illustrations (UTS, 2018).

1911- Locating the Site

The White Bay Power Station was sited at the head of White Bay to make use of the location's close proximity to water. The rail line at this site brought coal in, both for use in the power station and for export from the harbour.

Greater site of WBPS.

Power plant operations

The 3.8 ha site contains the former coal fired power station which was first commissioned in 1917 by the Department of Railways. The power station provided additional electrical power for the Sydney tram network and it remained online until its decommissioning in 1983.

Along with being an important contributor to Sydney's industrial capacity the White Bay Power Station was also an important generator of social and economic gain for communities of Roselle and Balmain by providing stable employment to generations of its residents.

(ww.environment.nsw.gov.au/heritageapp/ViewHeritageItemDetails.aspx?ID=4500460, Accessed 07 June 2018).

Cooling canal leading to the WBPS.

Cooling canal leading to the WBPS.

Coal shovelling, WBPS.

Material storage, WBPS.

Parsons turbine and pumps, WBPS.

The site as it is today

White Bay Power Station was decommissioned in 1983 and has stood abandoned and fenced off ever since.

White Bay power Station has recently been used as a film set for productions such as The Matrix reloaded, Mad Max Fury Road and The Great Gatsby. It is often used as a backdrop for fashion shoots as well as romanticised through online photography blogs such as Lost Collective- shown below.

Urban Growth NSW and the Bays Precinct Team is looking beyond these temporary uses for a new or adaptive way to revitalise this iconic part of Sydney's built industrial past, a way that can maintain the heritage listed Anglo-Dutch style of its buildings. It is anticipated that over a fifteen-year time frame a master planning solution will be found and implemented. This began in February 2011 when the Sydney Foreshore Authority opened the site up to the public to expose them to the diverse character of this piece of industrial infrastructure and to encourage people to submit ideas for its future use. The planning and design work has continued through many proposals but with no long-term propositions being adopted to date. Recently, a team of consultants were appointed to design a master plan, (https://thebayssydney.nsw.gov.au/, Accessed 07 June 2018).

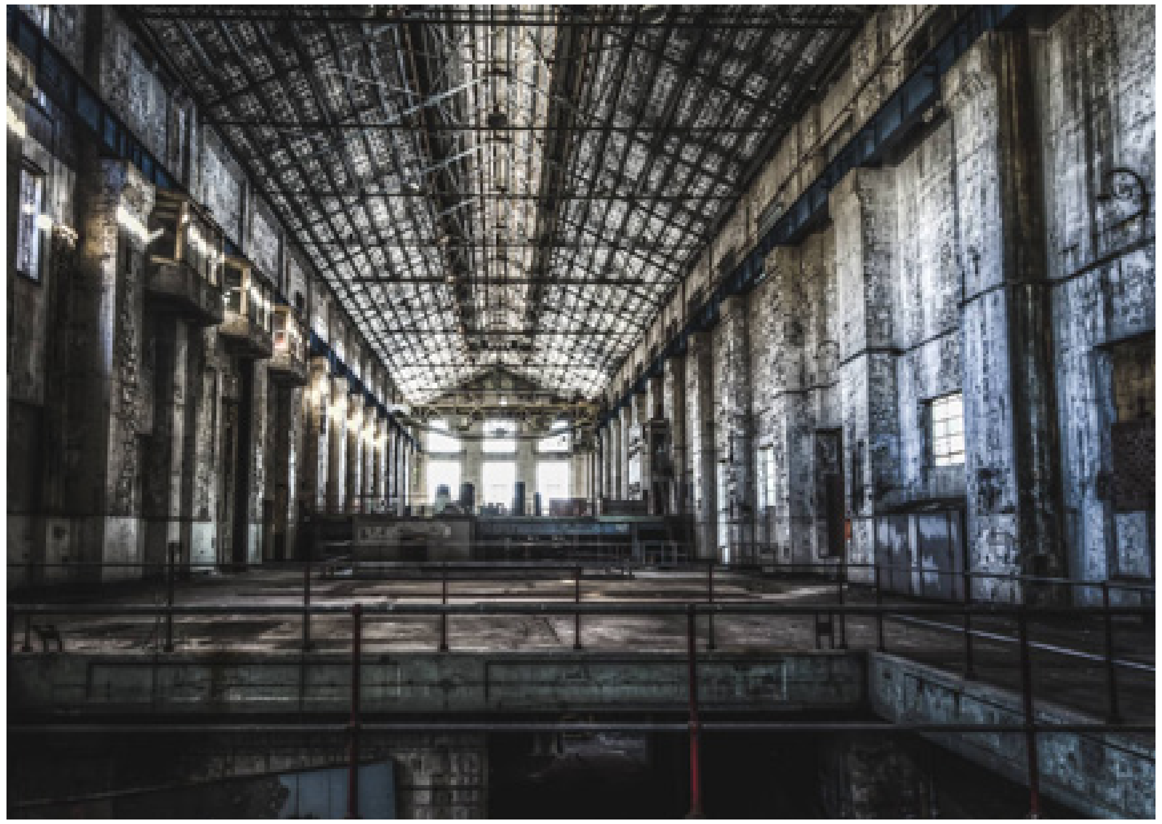
External windows.

A metal staircase constructed during the making of The Matrix Reloaded remains in the boiler house.

The catwalk between the boiler house and the workers club.

A unique 1950s mural clad entertainment room complete with a small stage and original billiard tables are also part of the White Bay Power Station building. Image taken during a WBPS Open Day.

Lost Collective image a Control Room at WBPS (Patman, B. 2015).



Lost Collective image of the Turbine Hall at WBPS (Patman, B. 2015).

Lost Collective image of the pedestrian bridge leading to the administration entrance at WBPS (Patman, B. 2015).

The Bays transformation plan

The eight destinations, including White Bay Power Station, within the Bays Precinct total 95 hectares of land and 94 hectares of Sydney Harbour. The Bays Precinct today wraps part of the iconic inner Sydney Harbour and is surrounded by well-established urban villages.

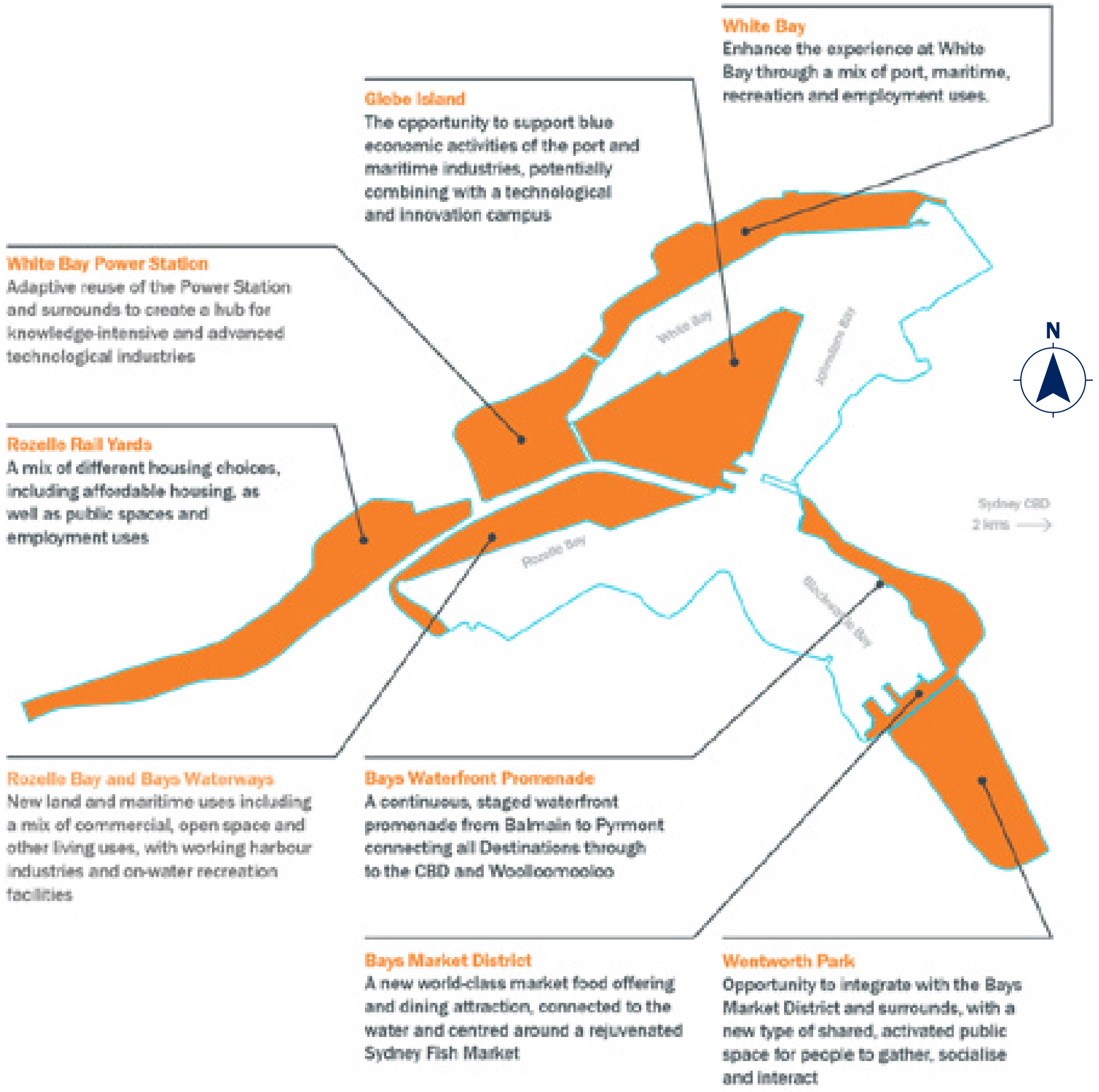
Its waterways and most of its land is Government owned and predominately used for port, maritime and commercial uses with a significant part of its 5.5 kilometres of foreshore not being publicly accessible. The Bays Precinct contains several significant heritage items like Glebe Island Bridge and the White Bay Power Station, which was built on the shores of White Bay to power Sydney's tram network.

The White Bay Power Station (WBPS) is one of the key destinations for action by Urban Growth NSW and Landcom and will anchor a broader innovation district that when completed will also incorporate Glebe Island.

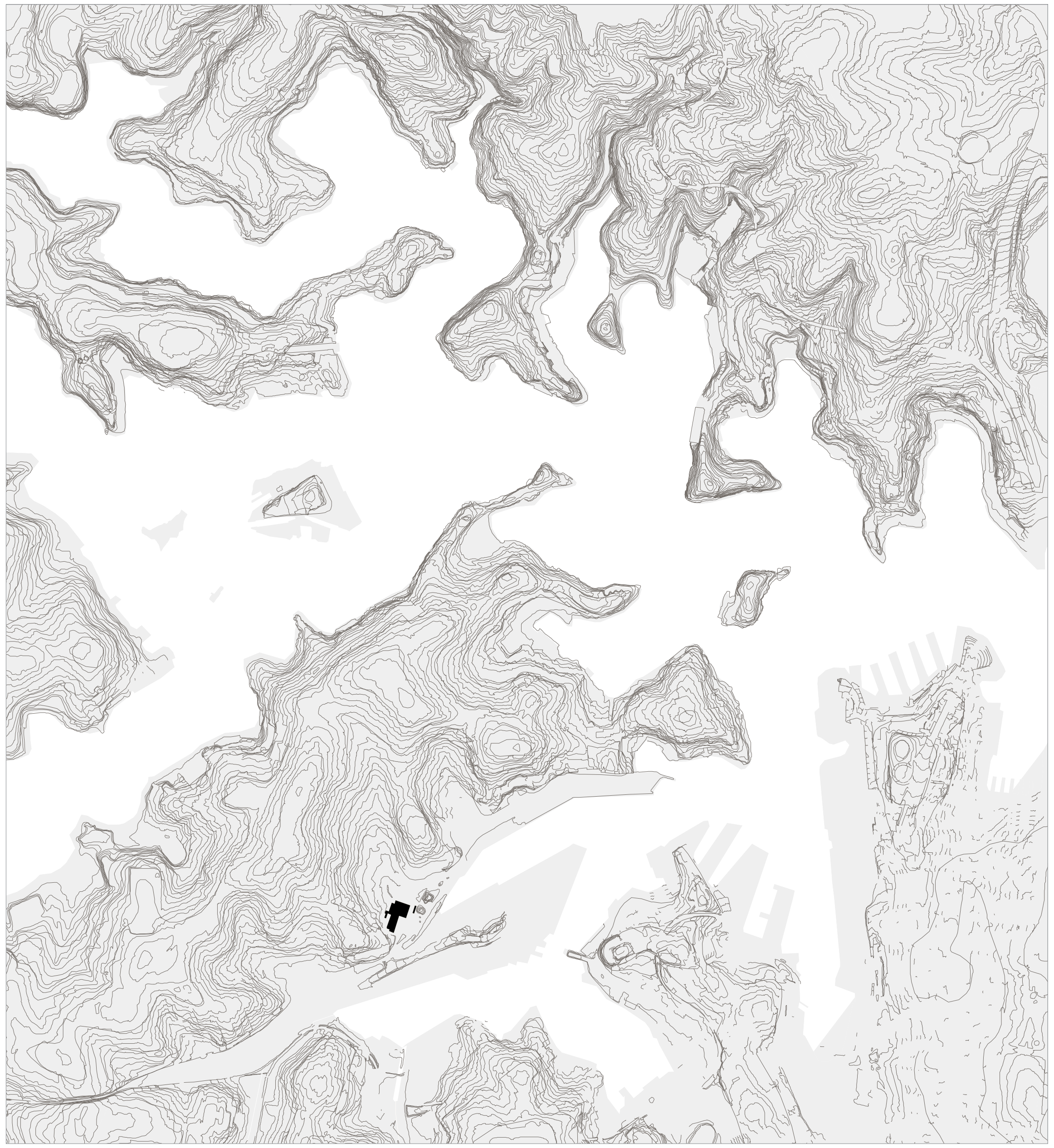
"We want White Bay Power Station to be the best example in Sydney of how living, working and learning can be woven together to create a prosperous and thriving economy. This requires us to think about the most appropriate mix of uses, including residential, for the Power Station and surrounding land and how this can benefit nearby areas, We want to activate the Destination outside working hours, position the Power Station at the heart of The Bays Precinct, and draw on international examples that have returned industrial spaces to their cities. A global and regional destination within the Asia-Pacific that co-locates research, business, education, science, academia, technology and start-up incubators to drive global competitiveness and innovation is part of our vision for The Bays Precinct," (Urban Growth NSW, 2015).

The Transformation Plan is the strategy document for delivery of the Bays Precinct and outlines a number of key principles and objectives, including:

- Building on the unique history of the Bays Precinct (Principle 1)
- Unlock public access to the Harbour's edge and waterways along the entire coastline (Principle 5)
- Prioritise planning for public spaces, White Bay Power Station and Sydney Fish Market (Principle 8)
- Build the capacity for The Bays Precinct to be a place that contributes to healthy, prosperous and resilient lifestyles (Principle 11)
- Introduce environmental and ecological systems to improve water quality, address ongoing sources of water pollution and encourage public recreation (Principle 15)



The Bays Precinct Transformation Plan identifying the opportunities for redevelopment at each of the eight 'destinations,' (Urban Growth NSW, 2015).



N

contour

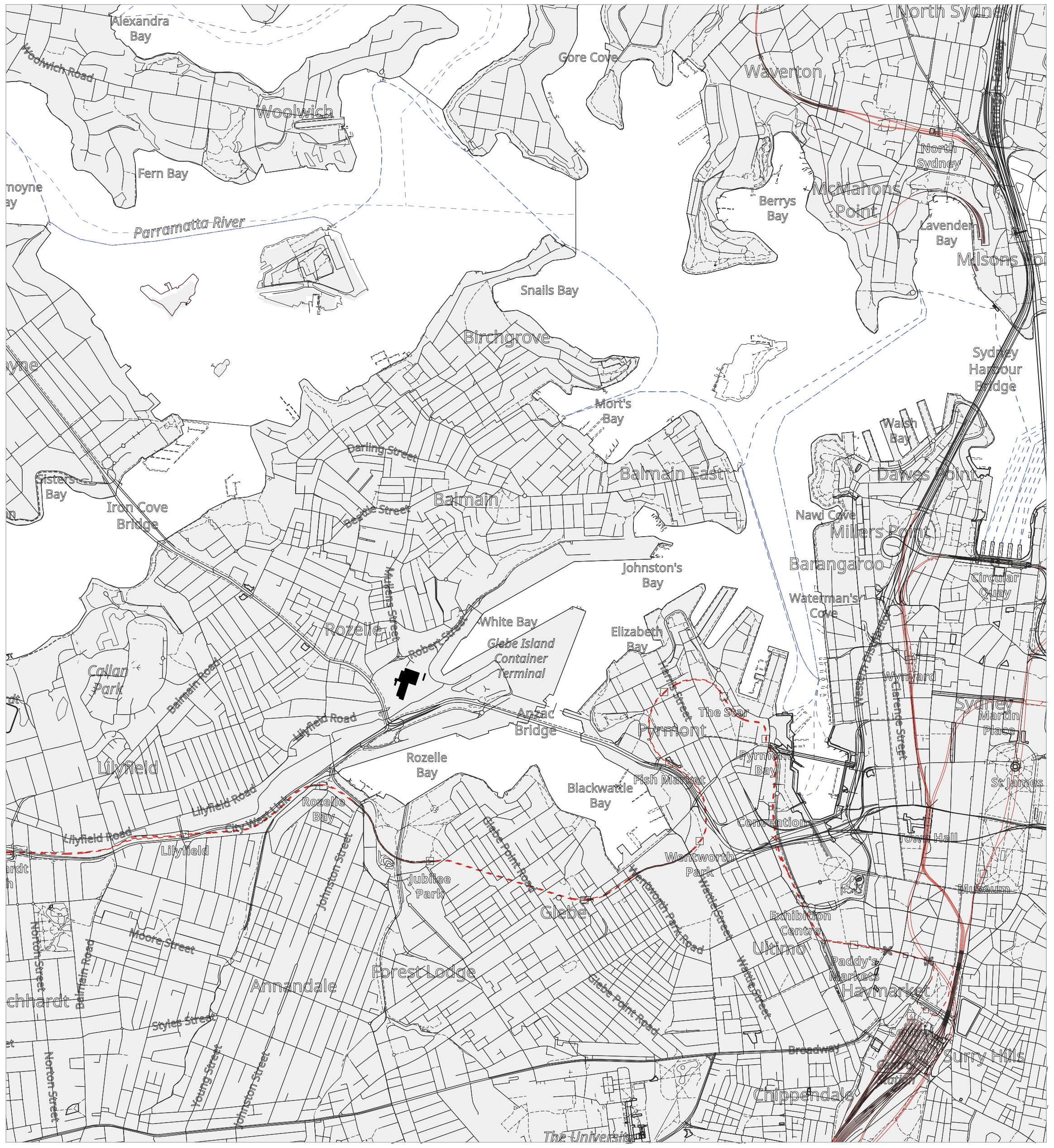
site

reclaimed land

Illustrations (UTS, 2018).

Topography today

Steep topography near the harbour limited the usability of shorelines. On the South side of the harbour between Balmain and Darling Harbour, much land was reclaimed from the sea to provide platforms that take advantage of the deep water harbour. The White Bay Power Station and its flat surrounding land is a part of the story of the challenge of Sydney's topography.



N

motorway

secondary roads

roads

train line

light rail

ferry route

Pathways and cycleways

site

Illustrations (UTS, 2018).

Transport today

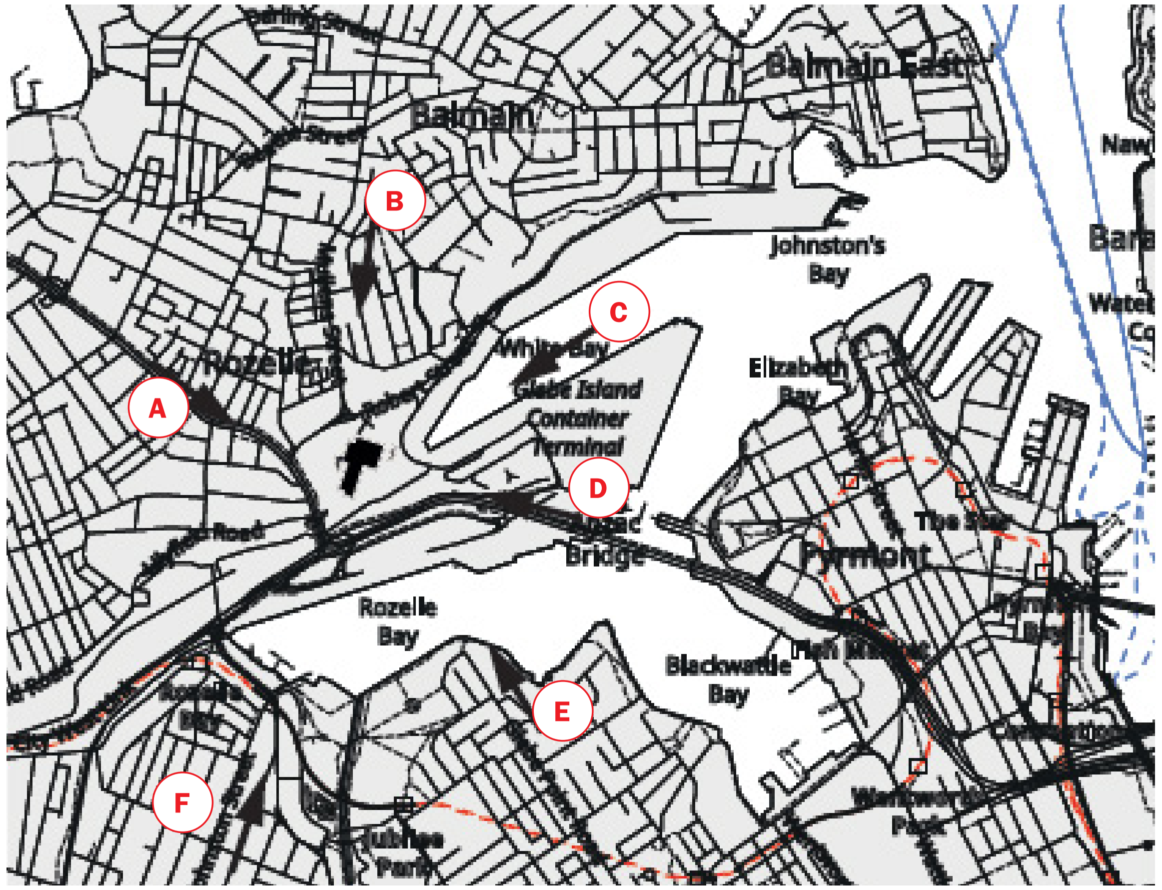
Major transport routes today are a product of the topography, the Harbour and the settlement pattern. The White Bay Power Station is at nexus of these routes. These have resulted in strategic benefits but also natural environmental impacts.

Views Into WBPS

The images adjacent show the visibility of the White Bay Power Station Building from the roads and Harbour. The Building itself is one of the most recognisable landmarks in the Bays Precinct and due to the tall smoke stacks it is identifiable from long distances.

The Garden 01 site itself however will not be able to be seen as it is on the eastern side of the WBPS building where there is no public or visible access due to tall chain mesh fences with screening blinds and dense vegetation along the boundary of the site.

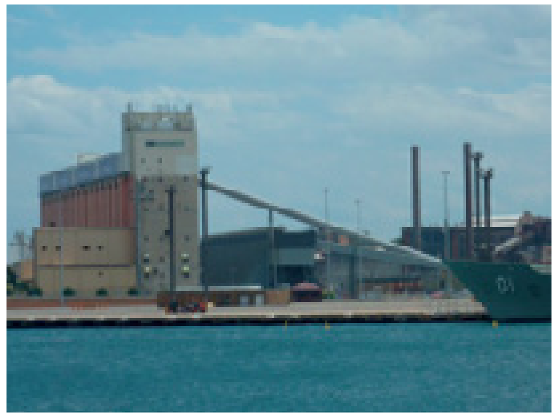
Due to the lack of visibility into the Phytoremediation Garden 01 site and no unrestricted public pedestrian access into and around the WBPS site, it is necessary to include an extensive digital platform as an activation and communication strategy for the site. Happily, curated visits by school children offered through the long standing partnership between The Bays Precinct and the Observatory Hill Environmental Education Centre will continue. This, along with establishing a walking route adjacent to the Garden 01 site for WBPS Open Days, is considered vital to inform, educate and inspire the general public about the phytoremediation processes taking place in Phytoremediation Garden 01.



A

B

C



D

E

F

Illustrations (UTS, 2018).

Power Plants Phytoremediation Garden Site

SECTION 04

Power Plants Garden 01

The Power Plants project is a series of phytoremediation demonstration gardens which will decontaminate soils while the White Bay Power Station is awaiting redevelopment. The building forms the backdrop to the Phytoremediation Garden 01 which was located on this site to assist in enabling the Bays Precinct activation operation's educational and urban living laboratory programme which is hoped it will set a precedent and process for the treatment for future contaminated brownfield development sites.

The following pages investigate the specific site conditions of Phytoremediation Garden 01 that have informed the design of the Garden.

BEFORE: The location of Phytoremediation Garden 01 (Moulah. B, 2017).

The Garden 01 site is located next to White bay & the Anzac bridge. (Six Maps, 2018.)

The Garden 01 site n the eastern side of the power station (Six Maps, 2018)

Site Location of Garden 01 within WBPS

The site of Garden 01 is located on the eastern side of the WBPS site and measures 100m long and 10m wide equalling 1000m2 in area. The site was primarily selected due to the presence of existing vegetation, which further alluded to the presence of adequate soil being present to build a garden on the site. Other conditions such as a north easterly aspect, good accessibility and its close proximity to the building which forms an evocative backdrop for Phytoremediation Garden.

Along with the power station the site is bordered to the north west by the former power stations settling & cooling ponds and former rail yards which now also have vegetation growing over them. The southern and eastern part of the site is defined by a concrete retaining wall which forms the sites surface stormwater drainage channel before it then leads out to the concrete hard stand and the harbour beyond. The prime location for viewing the Phytoremediation Garden and the most captivating angle for photography and video is currently from this side of the site.

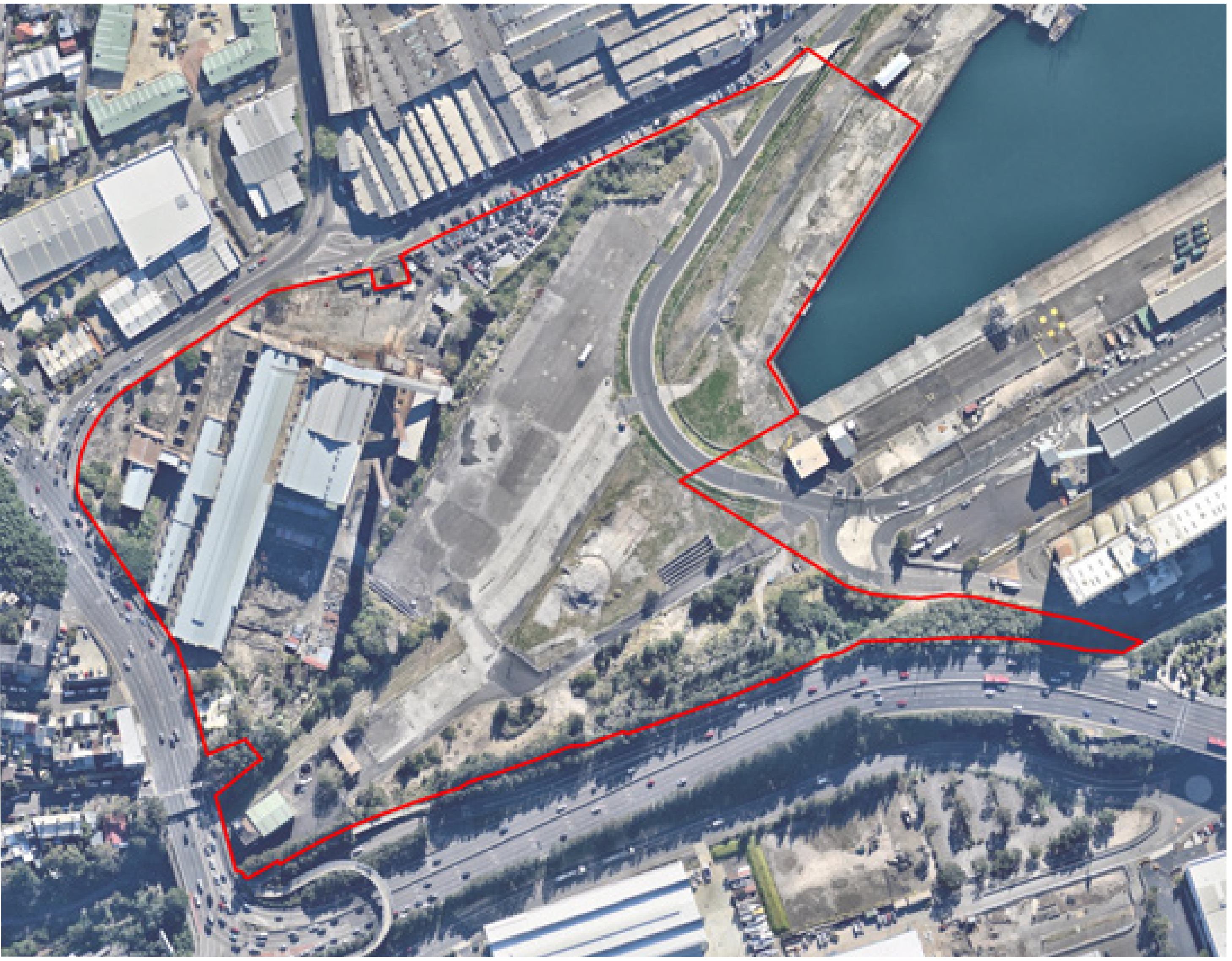
The 1000m2 site of Garden 01 highlighted in orange (Moulah. B, 2017).

WBPS Site Ownership

The WBPS is approximately 3.8ha in area and its boundaries are shown by the red line in the aerial below.

The land ownership within the site boundary is shared between two NSW State Government bodies; Urban Growth NSW and the Port Authority of NSW. The boundary of the two bodies crosses the hard stand area to the east of the Garden 01 site.

The WBPS site boundary (Urban Growth NSW, 2015).



Landownership within the WBPS site (Urban Growth NSW, 2015).

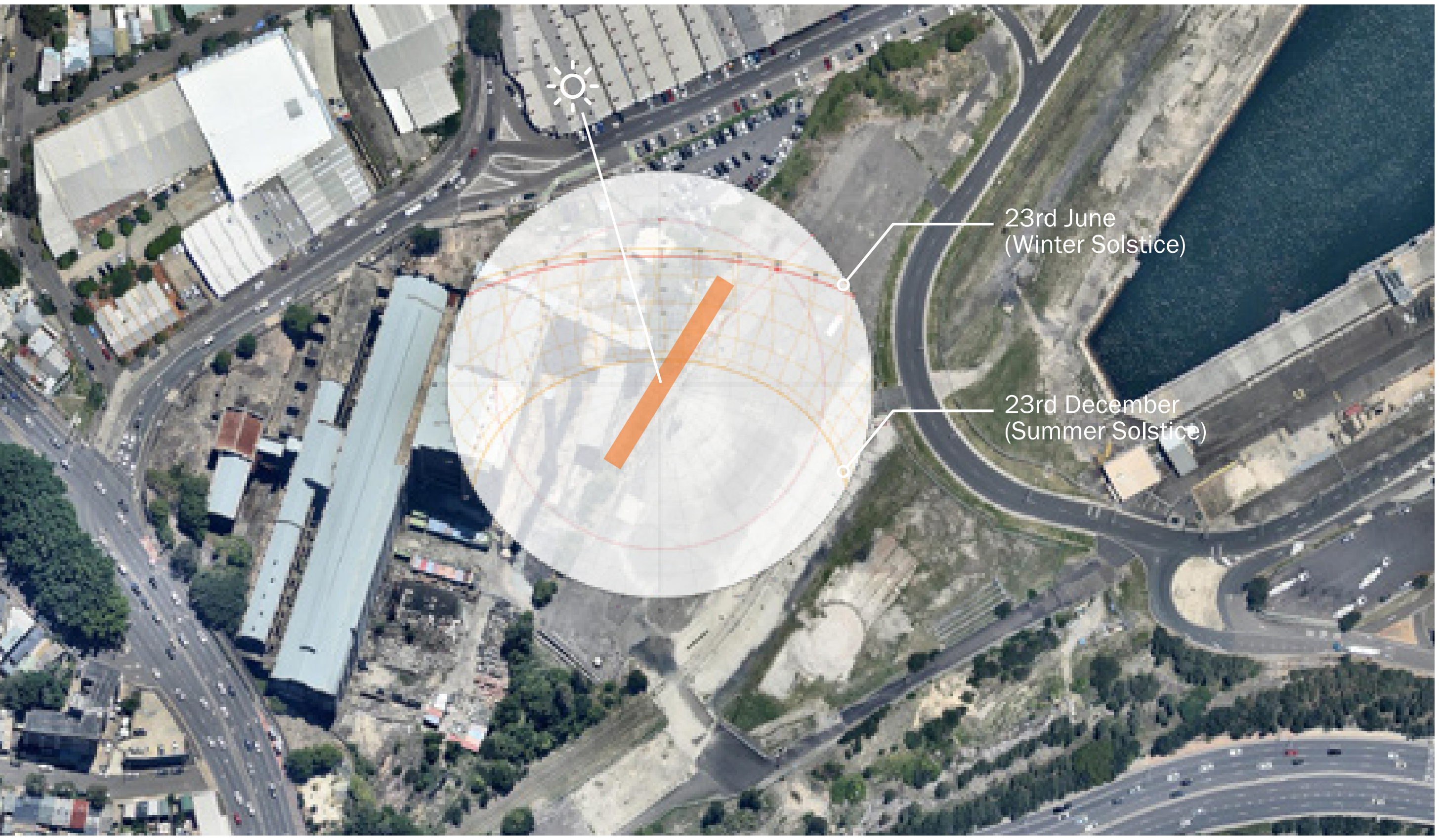
Sun paths

The aerial below shows the site of Garden 01 with a sun path diagram overlaid to show how the sun performs across the site at different times of day and throughout the year. Through analysis of the sun path diagram we are able to determine here and when the site will be cast into shadow as the sun moves behind the White Bay Power Station Building.

During the Winter Solstice, when the sun is the lowest in the sky, the southern half the site will be cast into shadow from approximately 1.00pm with the northern half of the site falling into shadow at around 3pm.

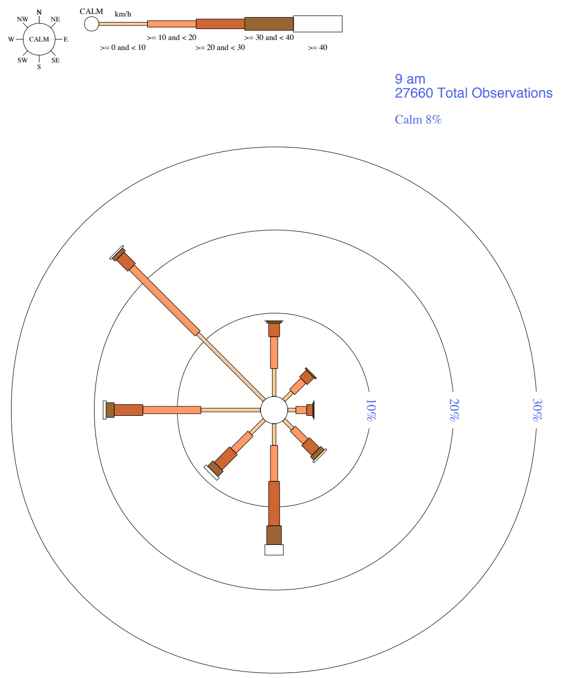
During the Summer Solstice, when the sun is the highest in the sky, the southern half the site will be cast into shadow from approximately 12.30pm with the northern half of the site falling into shadow at around 5pm. However during the summer, the day length is longer and the site will therefore receive an extra 3 hours of sunlight.

The Garden 01 site with Sun Path Diagram overlaid (Near Maps, 2018).



Prevailing winds

The diagram on the right shows the prevailing winds in Sydney and is measured from Sydney Airport. The strongest winds generally occur in the direction from the North West , West as well as from the South. The WBPS building and the abutment to the Anzac bridge protects the site from the strongest winds from these quarters. Leaving only Unusually strong winds from east and White Bay the most likely to affect the site in this manner.



Wind Rose for Sydney Airport (BOM, 2018).

The Garden 01 site with the adjacent building acting as a barrier from the strongest Sydney winds (Near Maps, 2018).

Climate Data

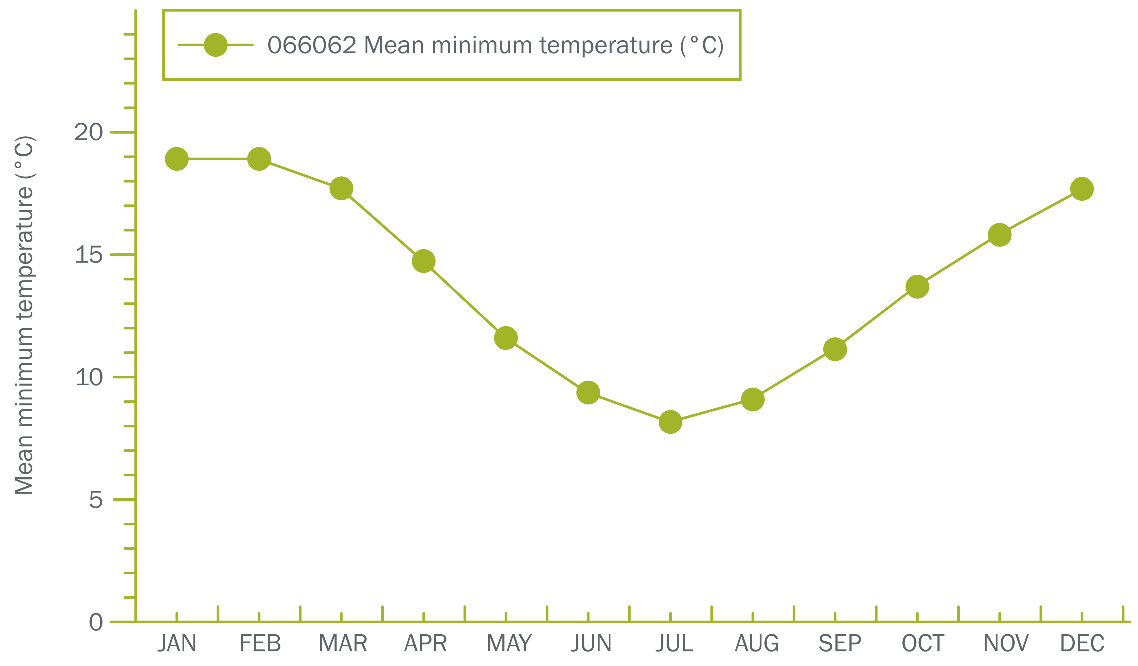
The following data as been taken from the Bureau of Meteorology and shows the average monthly rainfall along with the minimum and maximum temperatures.

Rainfall

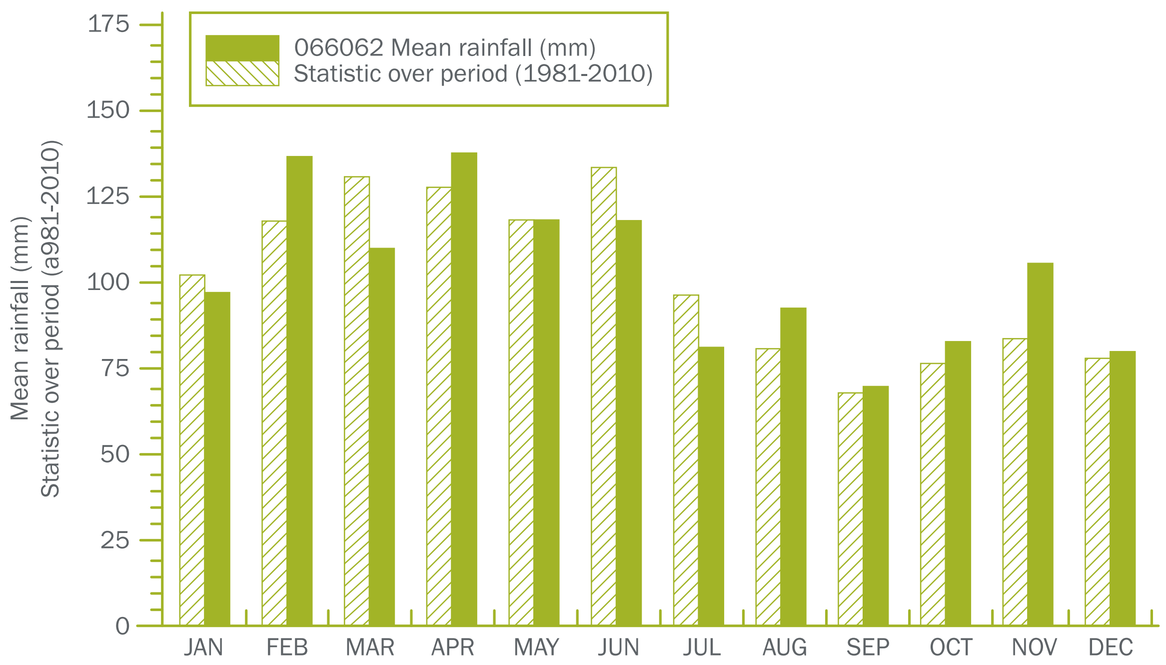
Garden 01 is to be implemented in August 2018 and we can see from the data below that August, September and October are on average the driest months of the year. Therefore the design must incorporate means to irrigate the gardens to ensure their growth if rainfall is not adequate.

Temperature

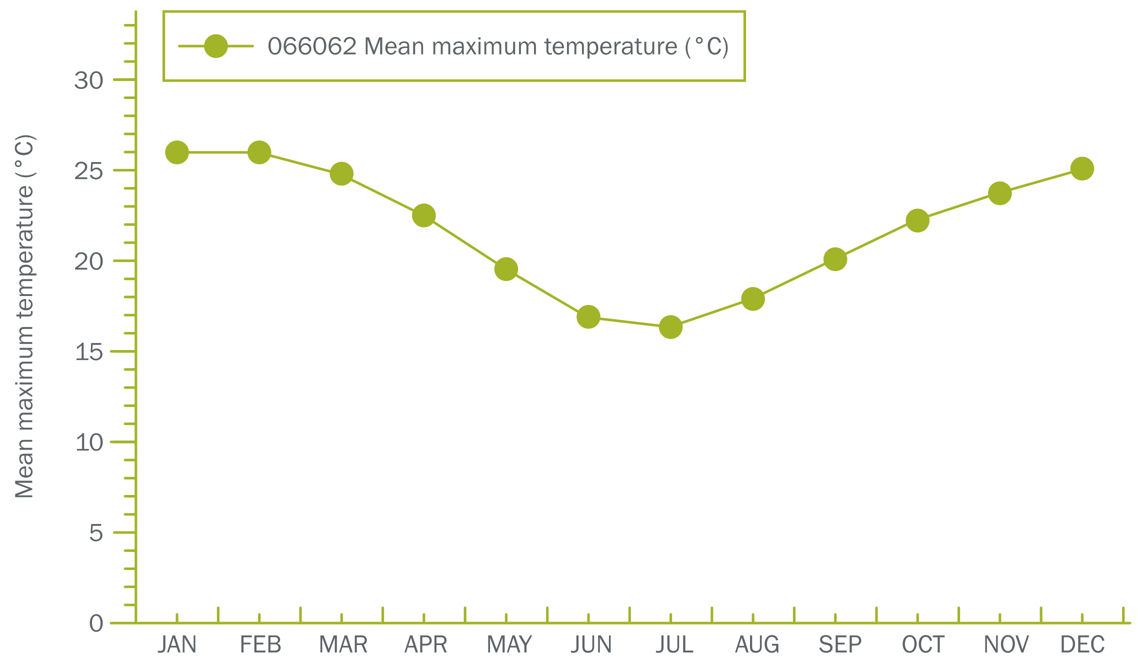
The gardens implementation coming into spring means the average temperatures will be increasing as the season develops. From the sun path analysis above we know that the WBPS building will help shade part of the site by 12.30pm in the summer. The garden is however surrounded by the thermal mass of concrete on the ground. This will create a heat island affect that when combined with hot winds will likely increase the temperatures to a point where additional irrigation is required to negate the effects. Monitoring of temperature and moisture is vital to ensure the growth of the garden.



Location: 066062 SYDNEY (OBSERVATORY HILL)



Location: 066062 SYDNEY (OBSERVATORY HILL)



Location: 066062 SYDNEY (OBSERVATORY HILL)

Views Around the Garden 01 site

These site images show various aspects from the eastern side of the Garden 01 location along with some of the elements forming its boundaries or acting as key historical and natural features within it.

Looking north west at the building across the Garden 01 site (Johnstone, 2017).

Looking north at the building toward the cooling ponds (Johnstone, 2017).

Looking south west at the building across the drainage channel and the Garden 1 site (Johnstone, 2017).

Looking south west cross the Garden 1 site with the iconic WBPS backdrop (Johnstone, 2017).

Looking north at the existing retaining wall and drainage channel which acts as he eastern barrier to the Garden 01 site (Johnstone, 2017).

Looking south long the Garden 01 site (Sooprayen, 2017).

Looking west at some of the existing vegetation with the WBPS behind (Johnstone, 2017).

Soil depth

A site visit was undertaken on the 23rd of March, 2018 and included the digging of test holes across the site to view the soil matrix and profile as well as identify the location of key features within the proposed site. The site images of 6 of the 7 test holes are shown on the next page. It was intended to dig more holes but due to the extremely hard material it was only possible to manually dig past the surface in a few areas.

At each successful test hole we were unable to dig further than between 200mm and 300mm as a concrete slab was found at the bottom of every test hole. When considering this in conjunction with the spread out nature of the test holes the team concluded that it is very likely there is a concrete slab beneath the whole site.

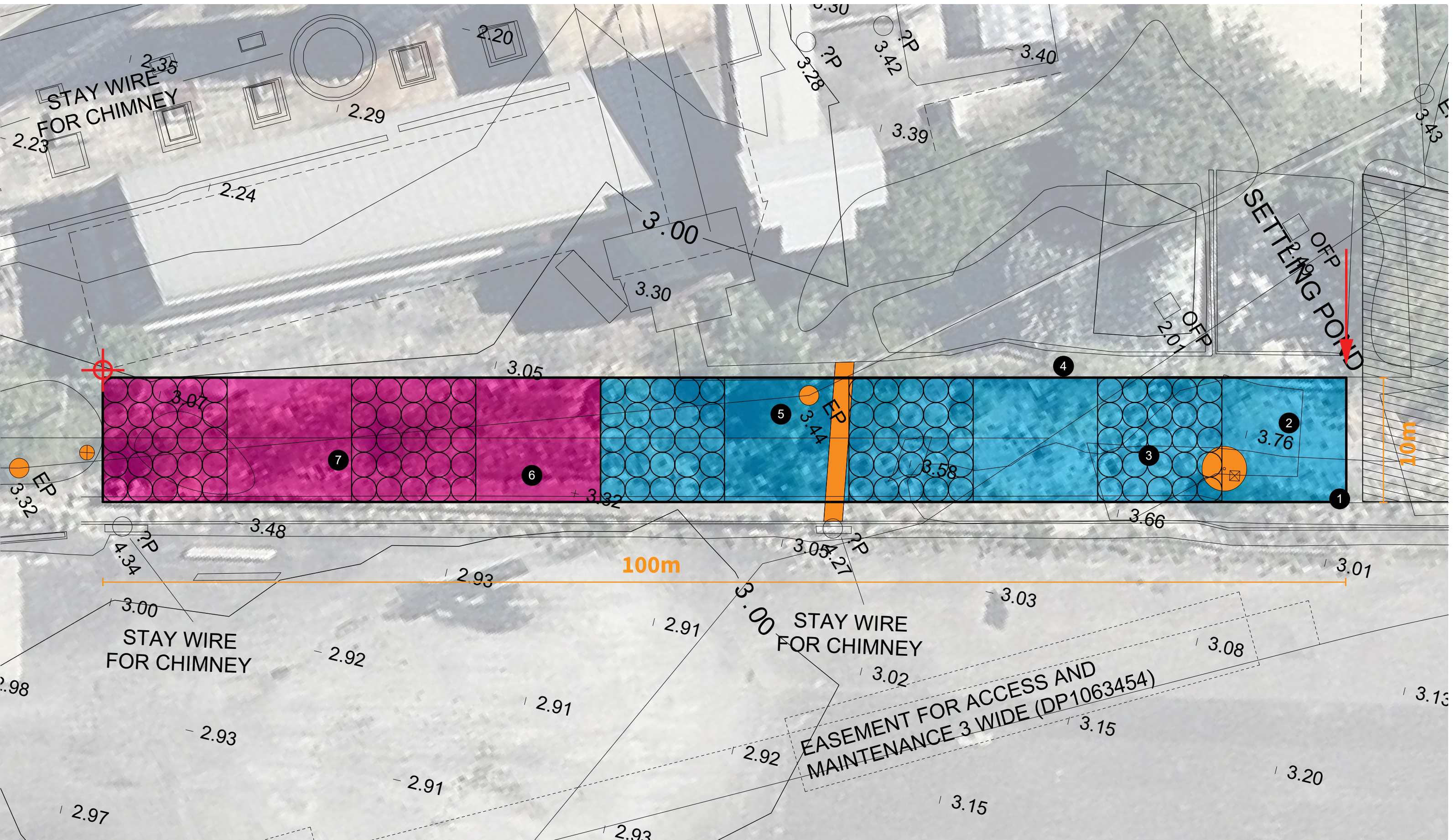
As a result our plans for preparation of the site have adjusted to allow for the following; 4 of the 10 plots will be planted into with the existing soil depth (400m2), the remaining 6 plots (600m2) will have supplementary material added sourced form the area north of the garden 01 site. This area will be cleared of vegetation and the soil deposited onto the 6 plots to achieve a 500mm soil depth. It is expected that the 500mm soil depth will be adequate for successful plant growth however this will be monitored with Garden 01 and additional material retrieved if required for Garden 02

A plan showing where this added material will be retrieved from is shown on page 174.

Retain existing soil depth

500mm supplemented soil zone

Garden 01 Soil Depth Plan (Sparks, K. 2018)



Test hole 1. Soil matrix of hummus, sandstone chips and coal dust.

Test hole 2. Impenetrable due to dense layer of gravel.

Test hole 4. Larger roots in hummus layer 280mm soil depth .

Test hole 5. Increased hummus layer.

Test hole 6. Deepest pit of approx 300mm of depth. Layered soil matrix of hummus, sandstone and coal dust.

Test hole 7. Dense root system due to grasses. Large poly pipe beneath found to be disconnected.

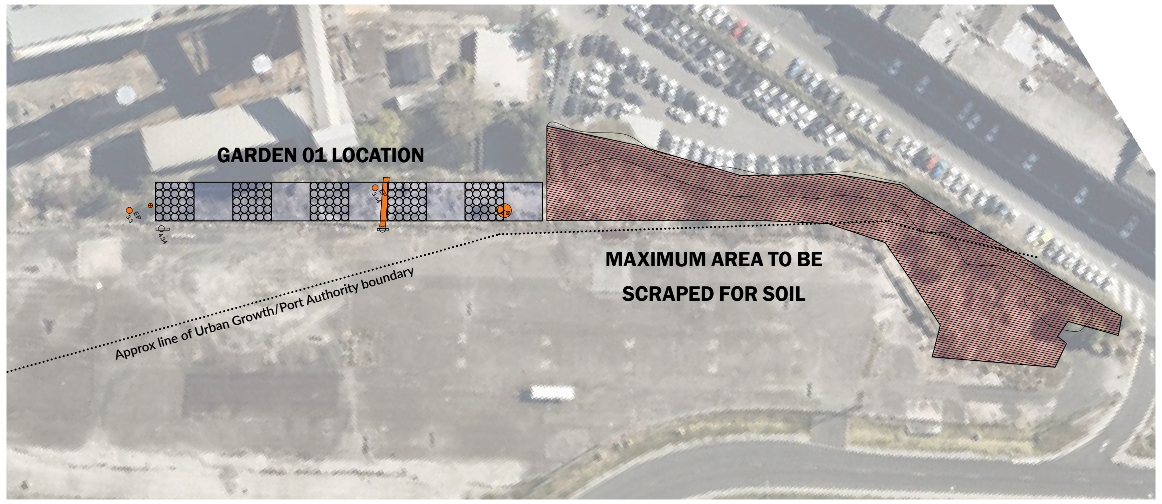
Additional soil retrieval area

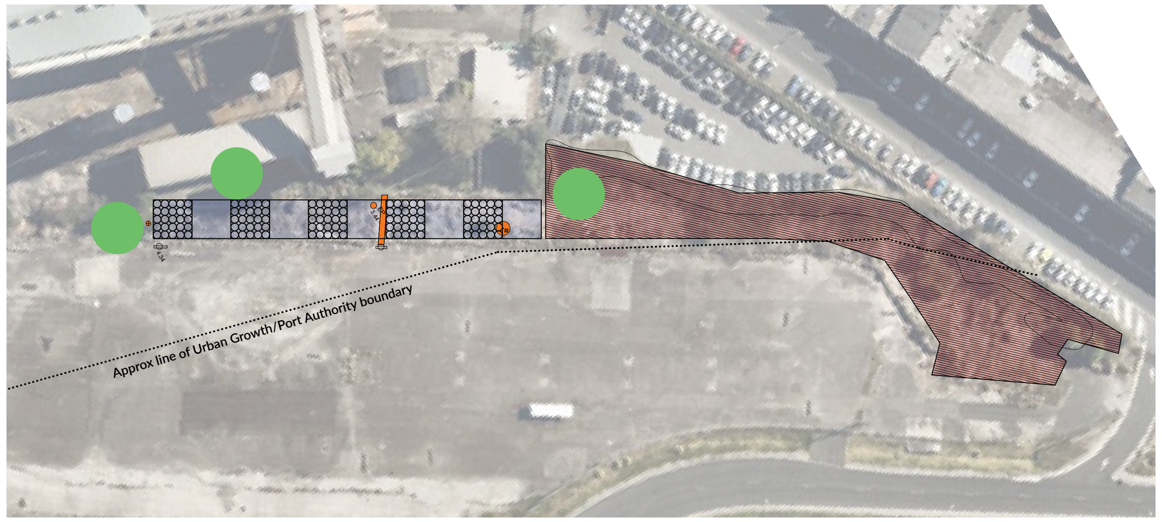
The area shaded black in the diagram below is the maximum extent that soil will be retreived from to achieve a soil depth of 500mm on 6 of the 10 plots of Garden 01.

Vegetation to be removed and composted on site

The area of Garden 01 as well as some of the area in the black shaded zone is required to be cleared of vegetation for the site preparation of Garden 01. The vegetative material can either be disposed of at a landfill (and must be treated as contaminated waste) or it can be composted on site. If the material is retained on site some of the composted material may then be incorporated back into the soil matrix to increase the organic matter in the next stage This could be advantageous as organic matter is in limited supply and it is a fundamental component of soil health as it encourages microbial activity which in turn improves plant vitality and thus assists in the phytoremediation processes.

The current locations under consideration for storage and composting of cleared vegetation, as well as harvested material from Garden 01 re shown in the diagram below and photos opposite.



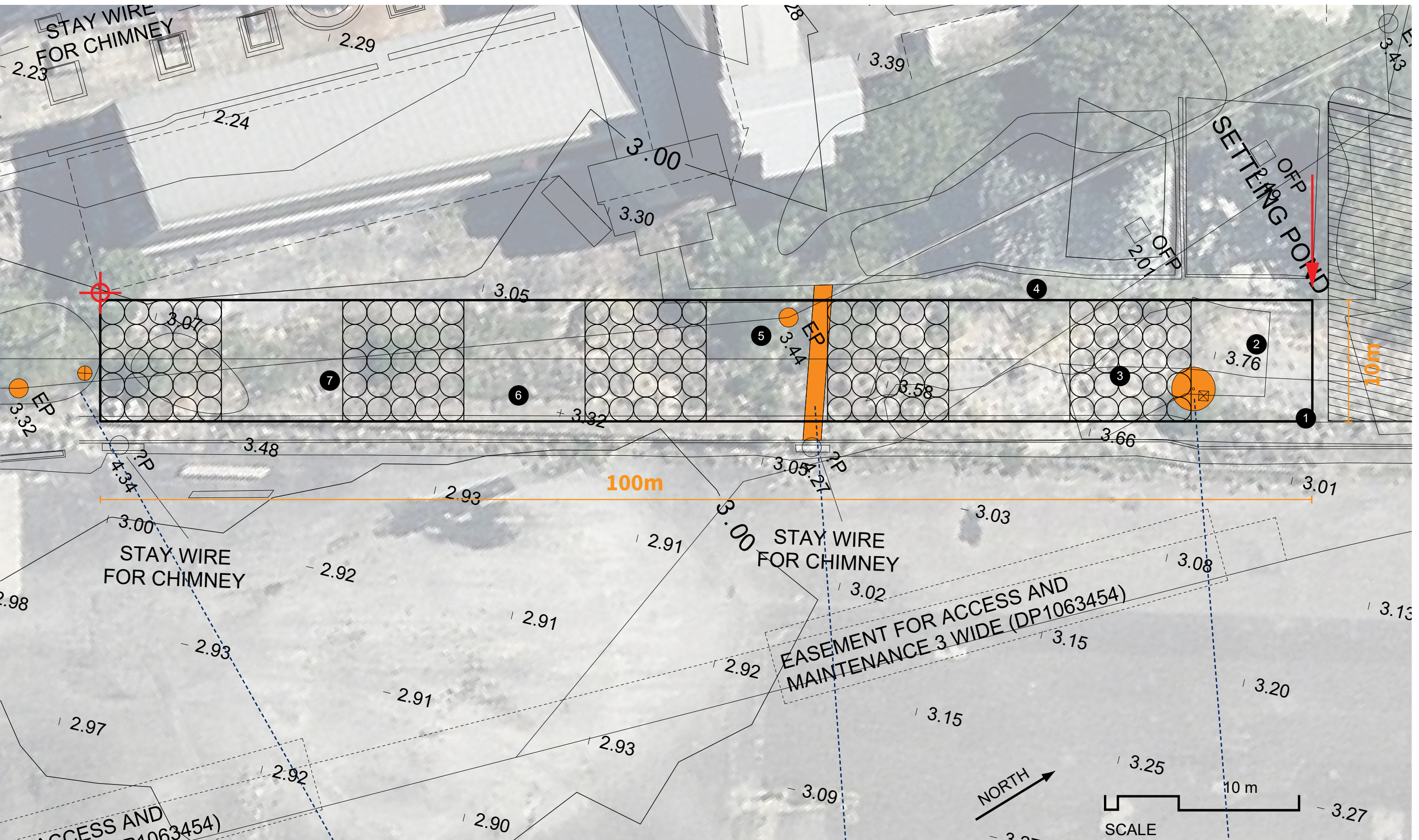


Potential locations for on site composting

Potential location for composting adjacent to concrete formed wall (Sparks.K, 2018).

Potential location for composting to the west of Garden 01 around existing trees (Sparks.K, 2018).

OBJECTS TO AVOID

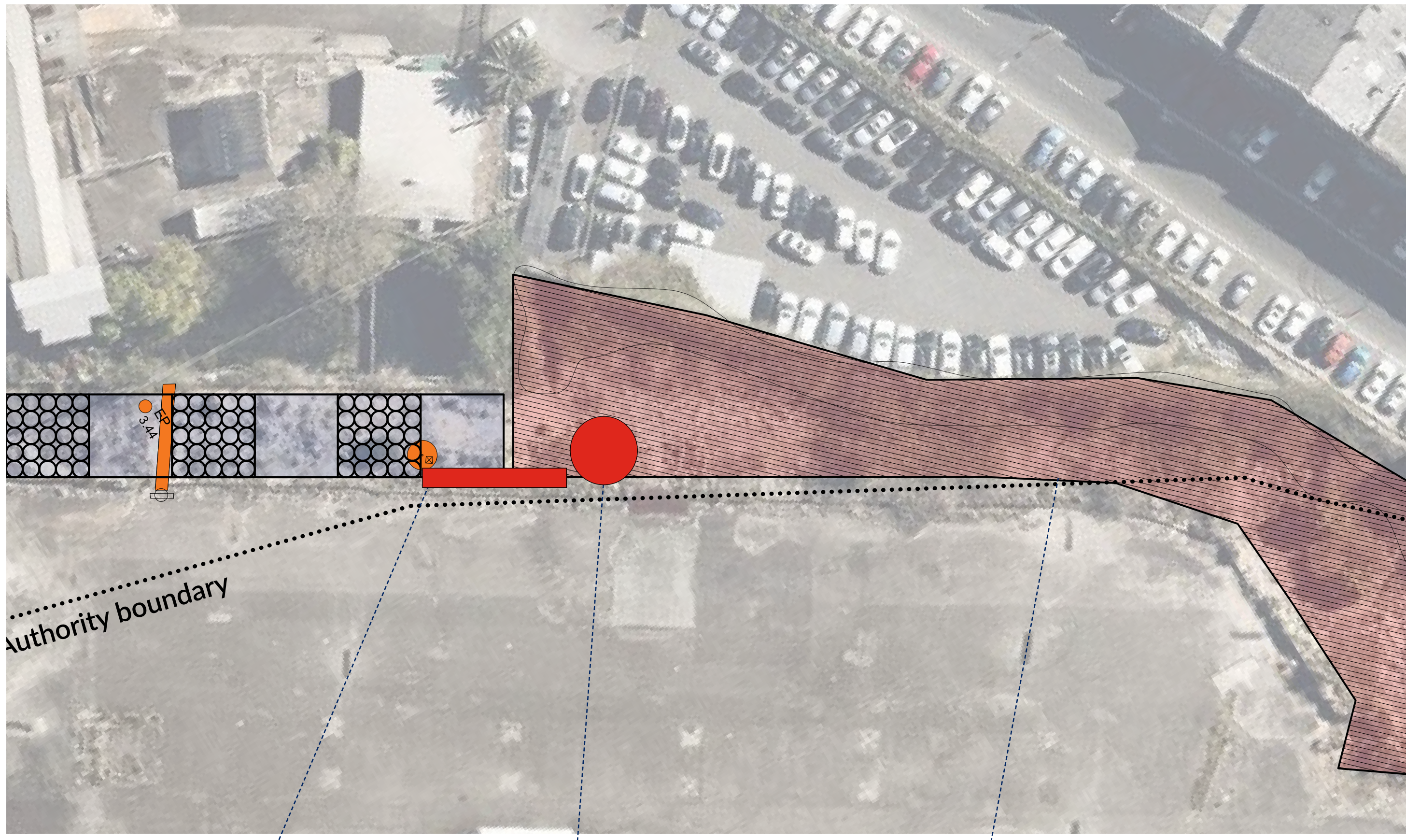


Man hole to avoid

Drain to avoid
Poly pipe to avoid

Existing olive tree to keep
Footing to avoid

OBJECTS TO REMOVE



Large poly pipe to remove

Steel ducting to remove

Dense vegetation to remove

Inventory of objects to retain/avoid/ protect & maintain within garden 01

The site visit on the 23rd of March, 2018 also uncovered a series of items that must be protected during site preparation. They are highlighted in the diagram below in orange.

It is expected that further important objects and features will be found during the site preparation and soil retrieval processes and they will receive the same care and consideration as the objects nominated.

Inventory of objects to remove

The site visit on the 23rd of March, 2018 also uncovered a series of obstacles that must be removed in order for the oil retrieval and preparation to occur. They are highlighted in the diagram opposite in red and photos are shown to illustrate the immediate context.

Again, It is expected that further objects and will be found during the site preparation and soil retrieval processes and they will receive the same consideration as the objects nominated.

Summary of findings

Throughout the history of Bays Precinct there has been an ebb and flow of water and people. This section describes both the natural abiotic and biotic forces on the site as well as the human made systems. By examining these factors and the site's complex natural and cultural systems at a range of scales, we have grown to appreciate the dynamic conditions we are working within. The next Section 5 puts forward the concept plan for Garden One, an annual plant garden for phytoremediation. We describe our intent behind the design, put forward our implementation and data collection processes a as well as the performative and educational event(s) associated with its installation.

Garden 01 Design

SECTION 05

Design agenda for garden 01

The Power Plants Phytoremediation Garden 01 is to be implemented during August 2018. It incorporates a palette of annual, fast growing plants and a large portion originate from agricultural industries. The plant species have been selected from literature on phytoremediation and are proven to remove toxins in field and laboratory experiments. We have matched the plant selection with the known toxins found on our site, as well as included plants which have notable bloom and foliage qualities.

The proposed planting remains experimental and the results will be greatly influenced by the specific site conditions (known and unknown) at White Bay Power Station.

It is anticipated that the plants will remove a percentage of toxins from the site as well as improve soil microbiology and nutrition. The planting will contribute to local green infrastructures and aims to enhance the existing site before it is eventually redeveloped.

Garden 01 is specifically annual plants to test what can occur in a relatively short period of time, provide floral and foliage interest, and to ready the soil for Garden 02 in one year's time.

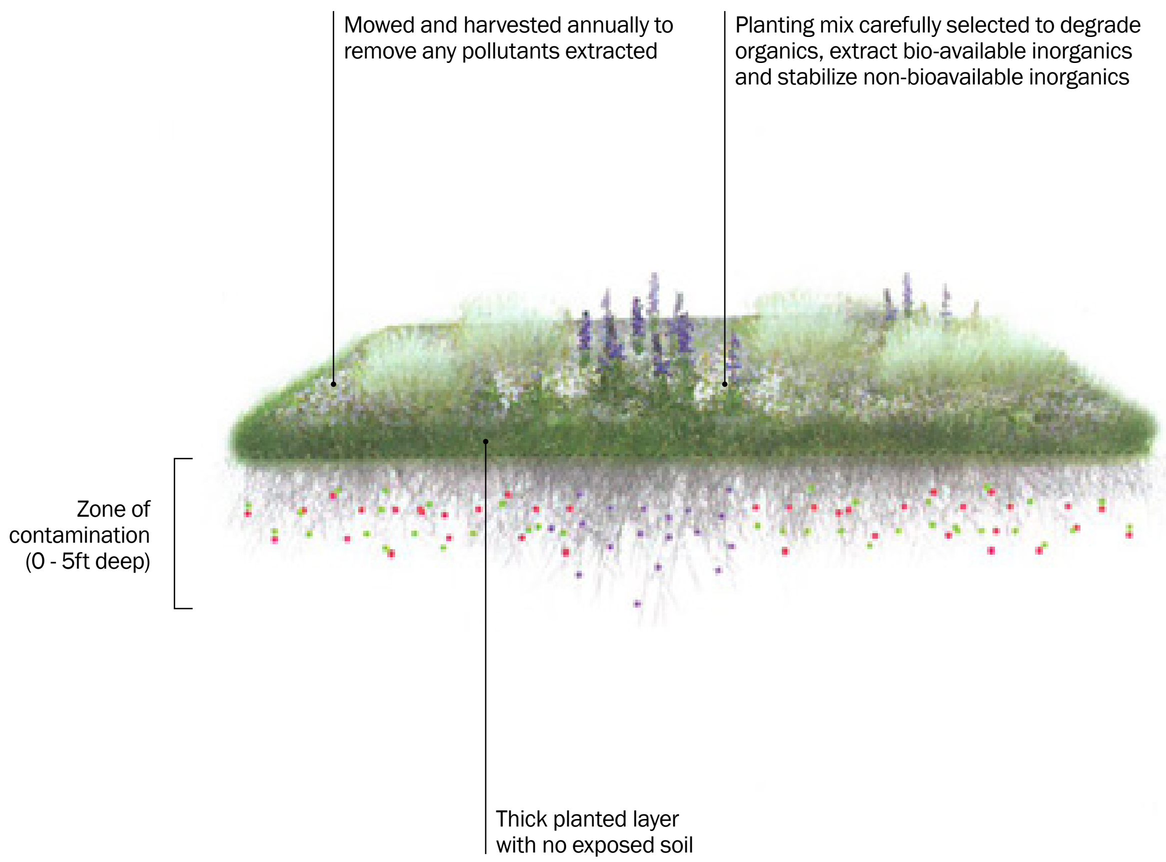
In mid 2017, students from the University of Newcastle and the University of Technology Sydney undertook an intensive two week design elective to investigate the possibilities of Garden 01 in terms of its planting and engagement. The student speculative propositions are shown in Appendix 01.

The concept landscape and planting plan for Garden 01 takes inspiration from the student propositions and has evolved to reflect budget and site constraints.

Garden 01 also takes inspiration from Kirkwood and Kennens book, PHYTO (2015), which explores various planting layouts in order to target specific toxins. The specific garden typology utilised for Garden 01 is the 'Multi-mechanism mat,' which utilises multiple phytotechnology processes to extract multiple toxins.

The initial planting will be celebrated as a digital event/ performance and will include film and photography to be live streamed via the website www.phytogardens.com. It may also include a public event with a small audience but this depends on site accessibility and further negotiations with Urban Growth NSW and Landcom team members.

Garden 01 will be in the ground for up to 12 months and will include ongoing monitoring, testing, and data collection / reporting of plant material. The monitoring of soil health as well as the documentation of plant growth via time lapse photography and film will be regularly posted on the project website. The harvesting and composting of materials in Garden 01 may also be a recorded event.



Multi-mechanism mat garden typology to achieve multiple treatment methods in one garden (Kennen & Kirkwood, pg 228, 2015)

Concept design for garden 01

Garden 01 is 1000m² and is broken up into ten 100m² plots. The planting concept reflects the methods of planting and the toxins present on the site.

The design has evolved as a result of a concrete slab being found below the entire site.

The 100m² lots are either planted with monoculture or meadow mixed seeds to explore the viability of competing plant species to extract toxins (see larger planting plan on facing pages 186-187).

Monoculture

The monoculture plots are directly sewn with seeds using 2m diameter stencils made of sections of PVC pipes as an edging. For example one pipe circle is planted with sunflowers, another with sorgum. This type of planting regime explores the potential for a specific plant to remove toxins, without competing with other plants.

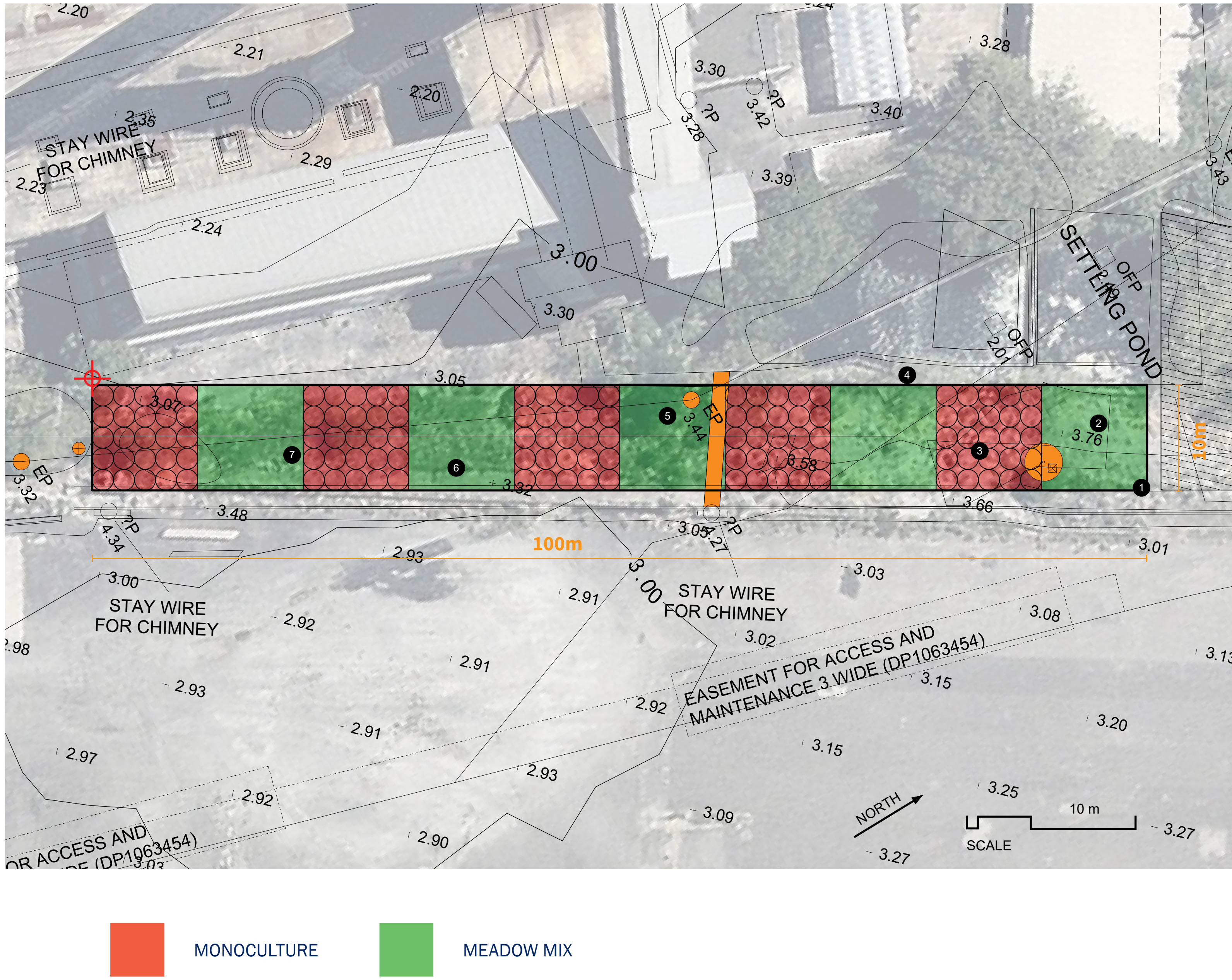
The space between the pipe circles allows for spontaneous growth to occur.

The monoculture plot sections are planted to show colour variety, height variability, foliage and textural variability as well as structural interest throughout the year as foliage, flowering and seed heads form and die back (see section image on page 192-193).

Meadow mix

The meadow mix plot section contains a variety of seeds mixed together and sewn directly into the 100m² 'meadow' sections (see diagram opposite and on facing pages 186-187). This planting regime explores the potential of species that may out compete other species and/or work in companionship with each other to create ideal rhizosphere conditions for toxin removal.

The types of plot sections (monoculture and meadow) will be investigated and tested throughout the full site, for their viability to extract toxins from the soil and water table.



Summary of toxins on site

The following pages include a site plan indicating the various amounts of toxins found throughout the WBPS site that exceed the allowable standards. (Refer to the soil study- “Detailed Site Investigation White Bay Power Station Proposed Lot 1” by JBS&G, 21 April 2017). The toxins and soil test pits indicated in orange are those that exceed Australian safety standards and are included on our site. These are the toxins that we have utilised to test the specific phyto-remediatic plants as shown on the Garden 01 Planting plan on 186-187 and in the Plant List on page 196-197. The site also has many trace contaminants and these can be found in Appendix C.

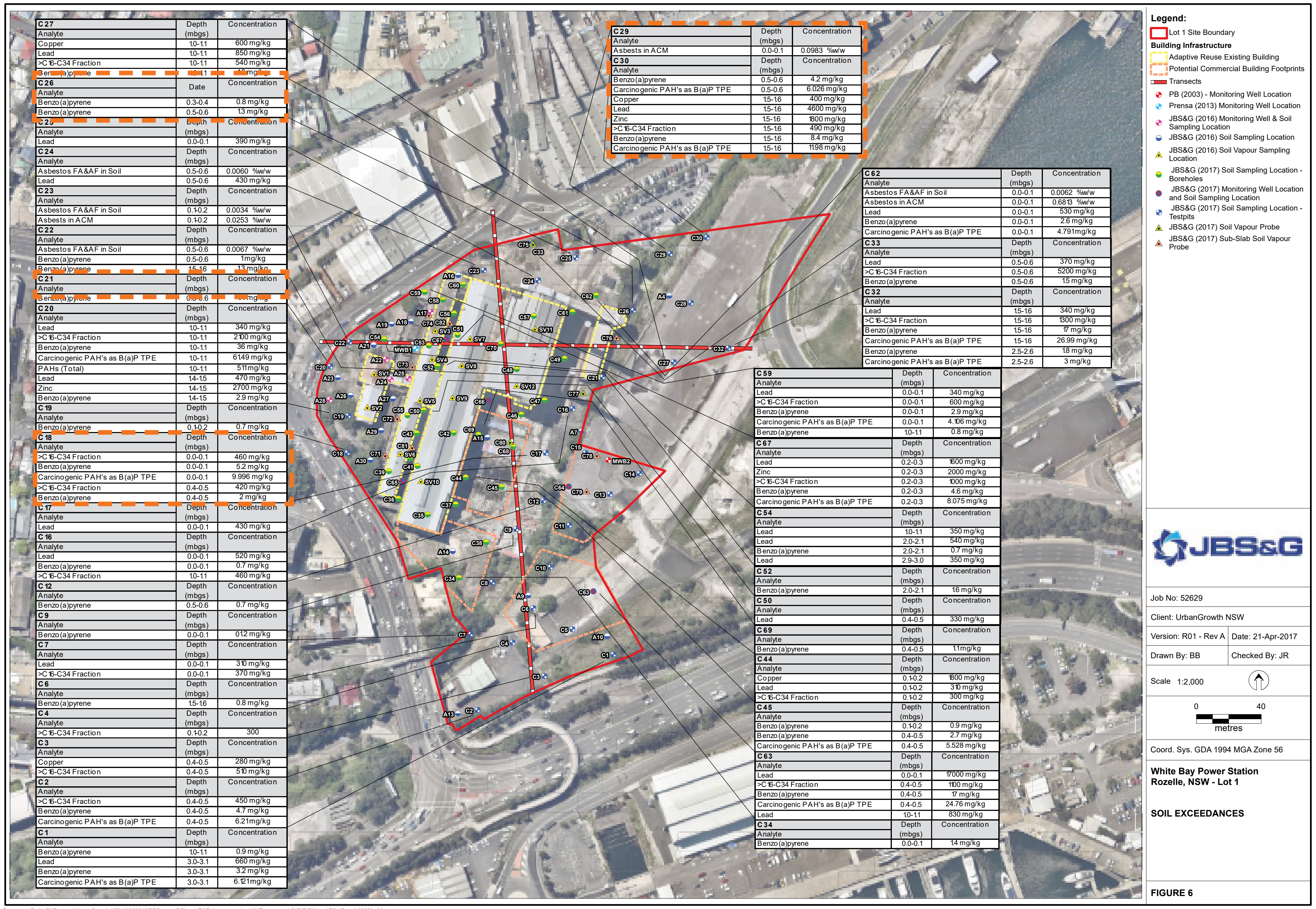
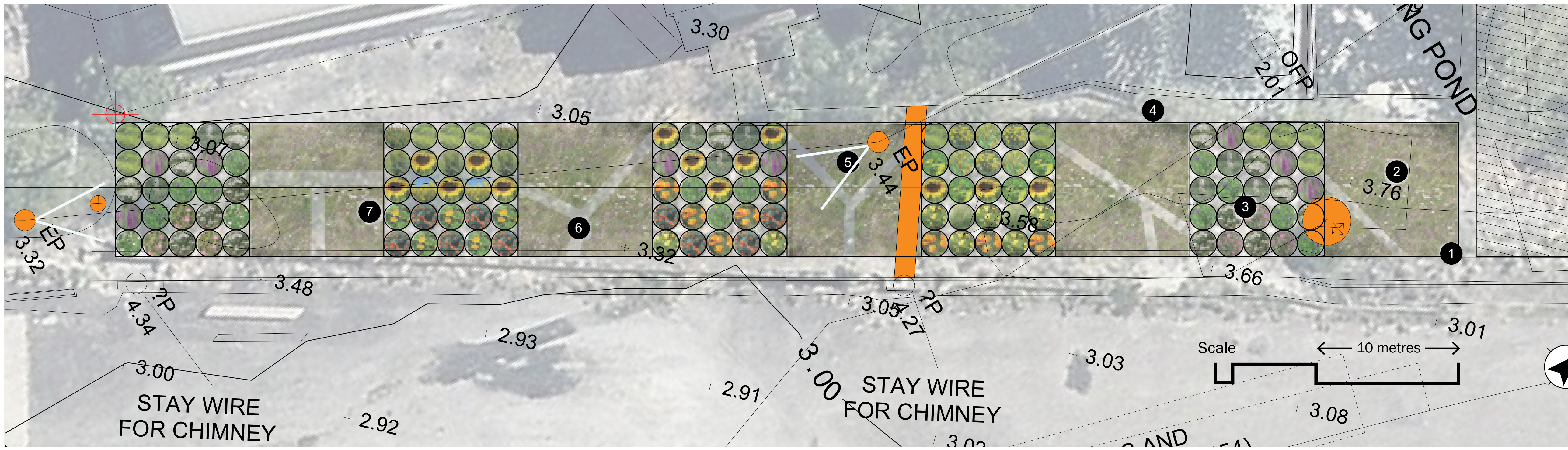


FIGURE 6

Document Path: G:\Projects\UrbanGrowth NSW\52629 WBPS Lot 1 DSI and RAP documentation\03 Figures and GIS\GIS\Maps\R01 Rev A\52629_06.mxd
Reference:

Site plan planting plan



Monoculture 1

Vetiver Grass
White Lupine
Queen Anne's Lace
Common Foxglove
Dryland Lucerne
Pig face
White Clover
Alpine Pennycress

Meadow mix

Common Rush
Indian Mustard
Sunflower
Marigold
Alpine Pennycress
Viola
Saltbush
Rapeseed
Wild Fennel
Braeckea dwarf
Field Mustard
Queen Annes Lace
White clover
Lucerne
White Lupine
Scrub Nettle
Sorgum
Paper daisies
Sea Lavendar

Monoculture 2

Vetiver Grass
Corn
Sunflower
Curly dock
Rapeseed
Pumpkin
Marigold

Monoculture 3

Sunflower
White Lupine
Common Foxglove
Dryland Lucerne
Queen Anne's Lace
Californian Poppy
Marigold
Viola

Monoculture 4

Vetiver Grass
Wild Fennel
Sorghum
Sunflower
Indian Mustard
Viola
Californian Poppy
Common Rush

Monoculture 5

Vetiver Grass
Common Foxglove
Queen Anne's Lace
White Lupine
Dryland Lucerne
Red Clover
Alpine Pennycress

Planting Plan and Garden 01 visualisation

The planting plan and the following images are how we envision Garden 01 evolving over time. They are a rough guess based on what we currently know about the site, the plants, and conditions present. We expect a few surprises along the way but these visualisations helped us to consider our planting designs more thoroughly. Additionally, given that we are maintaining the current soil depth (roughly 200-250mm) in the first four plot sections, but providing additional soil from the adjacent site to the test site for the remaining plot sections (roughly 500mm), we anticipate a differentiation in outcomes where there is greater soil depth. (See Existing Conditions Soil Depth pages 172-173).

Plant growth visualisation

The following three images describe the projected growth rates and evolution of the floral display within Garden 01.

Site Planting 3-6 months

Site Planting 0-3 months

Site Planting 6-9 months

Cross Section through Garden 01

Showing raking of soil on edges to achieve 500mm depth over 6 of the 10 plots of the 1000m² site. The section shows the terraced monoculture planting with meadow mix beyond. Colour swatches imply foliage, flower, seed head and fruit interest during different seasons.

Final Plant list

The following plant list explores the specific species of plants that will be utilised in Garden 01. Each plant has been researched through literature for proven phytoremediating qualities both in the field as well as in the laboratory. The plants have been selected for their foliage, structural, flowering, colour, textural and seed head qualities.

They are grouped around the toxins they extract, being heavy metals (inorganic), Pesticides (organic) and BTEX (organic).

Approximate blooming cycles are mapped to demonstrate that Garden 01 will evolve over time with seasonal change however during every season there will be interest in the garden.

Hyperaccumulating plants are marked in red in the end column. These plants have an ability to extract a significant concentration of toxins which would usually impede on other plants function and growth. Most of the other plants are known as accumulating.

Toxin	Pit	Plant Name	Vegetation	Annual/Perenial	Native to
Heavy Metals					
Aluminium Arsenic Lead Manganese	All	**Common Rush**	Herbaceous	Perenial	Australia
Arsenic Lead	All	**Indian Mustard**	Herbaceous	Annual	Central Asia
Arsenic PAH Cadnium Zinc Nickel	All	**Sunflower**	Herbaceous	Annual	North and South America
Arsenic Nickel Cadnium	All	**Marigold**	Herbaceous	9,11	Central America
Cadnium Chronium Cobalt Copper Nitrogen Zinc		**Corn**	Herbaceous	Annual	Central America
Cadnium Chronium Cobalt Copper Nitrogen Zinc	All	**Penny Cress**	Herbaceous	Annual	Europe
Cadnium Copper Lead Zinc	All	**Alpine Pennycress**	Herbaceous	Perenial	Scandinavia
Copper Lead Zinc	All	**Pig Face**	Herbaceous	Perenial	Australia
Cadnium Copper Zinc	All	**Tussock grass**	Herbaceous	Perenial	Australia
Cadnium Lead Zinc		**Viola**	Herbaceous	Annual	Central Europe
Cadnium Zinc Copper	All	**Vetiver Grass**	Herbaceous	Perenial	India
Lead	All	**Rapeseed/Canola**	Herbaceous	Perenial	Eurasia
Cadnium	All	**Common Foxlove**	Herbaceous	Annual, Biennial or Perenial	Europe
Petroleum hydrocarbons		**Californian Poppy**		Perenial	North America
Arsenic Cadnium Copper Lead Zinc		**Wild Fennel**	Herbaceous	Perenial	Europe
Zinc	All	**Baeckea dwarf**	Herbaceous	Perenial	Australia
Pesticides					
DDE (weathered DDT)	All	**Field Mustard**	Herbaceous	Annual	Europe
Endosulfan	All	**Queen Anne's lace**	Herbaceous	Annual	North America
PCB (Polychlorinated Biphenyls)	All	**White Clover**	Herbaceous	Perenial	Europe
PCB (Polychlorinated Biphenyls)	All	**Pumpkin**	Herbaceous	Annual	North America Central America
PCB (Polychlorinated Biphenyls) Zinc Cadnium Nickel	All	**Alfalfa/Lucerne**	Herbaceous	Perenial	Middle East
Arsenic	All	**White lupine**		Annual	Europe
Weathered DDT PCB Cadnium Zinc	All	**Curly dock**	Herbaceous	Perenial	Eurasia
BTEX					
TPH Zinc	All	**Red Clover**	Herbaceous	Perenial	Europe and temperate Asia
Benzene Toluene Zylene		**Scrub nettle**	Herbaceous	Annual	
Benzene Toluene Zylene Ar PAH Nitrates		**Sorgum**	Herbaceous	Annual or Perenial	Africa

Implementation of Garden 01

It is anticipated that the implementation of Garden 01 will begin in August 2018. The research team in collaboration with Urban Growth NSW will prepare a separate WHS Management Plan – This will be supplementary to this Stage One Report. This is to ensure the risks associated with the Power Plants project are managed, so far as reasonably practicable, in order to ensure the health and safety of workers.

The following implementation program is an outline of activities and their chronological order (staging) on the site:

1. Document and identify existing plant species
2. Collect samples of existing vegetation for sampling
3. Mark out Phytoremediation Garden site
4. Install time lapse and/or CCTV systems
5. Define and mark boundaries of soil retrieval area (see images on pages 174-175)
6. Mark & protect existing structures and elements as required (e.g. Retaining Walls, footings, drains, etc.)
7. Strip all existing vegetation & stockpile in composting area
8. Place retrieved soil on Garden site (500mm depth) leaving 4 plot sections with their original depth (200mm depth). Batter edges of the garden site to meet existing levels (See Section Image on pages 192-193)
9. Collect initial soil samples from Garden 01 site for testing before planting occurs
10. Rip, shape and prepare surface of garden site for seed sowing
11. Install, connect and test irrigation system
12. Mark out planting design
13. Fabricate Polypipe circular single species planting templates (pipe circles) & install on site
14. Hand sow seed; meadow mixes and single species as per design (See Image on pages 186-187)
15. Irrigate
16. Hydro-mulch garden site
17. Monitor and record growth as well as toxin levels throughout the year

There are a number of yet to be determined factors around the accessibility of the site during the Garden 01 installation stage. Currently, we have advice that there will be limited access via the Port of Sydney hard stand, directly south of the site because of pending infrastructure works. It is preferable for us to utilise the Port of Sydney access road and gates as it is more direct access. However, if this is unavailable we will utilise the existing site access through the Power Station site's main entrance. In order to access the bayside of the site, all visitors will be required to wear PPE unless control measures are implemented to eliminate this requirement. The Urban Growth White Bays team has indicated that they will be erecting fencing around the Garden 01 site.

The Power Plants project team will work with Urban Growth WBPS team to assist them in meeting their WH&S obligations, so far as is reasonably practicable, to ensure the health and safety of workers and other people like visitors and volunteers.

These obligations include:

- safe systems of work
- safe use of plant, structures and substances
- notification and recording of workplace incidents
- adequate information, training, instruction and supervision
- compliance with requirements under the Work Health and Safety Regulation

This will be outlined in further detail in a separate WHS Management Plan.

The project implementation plan is shown in the following pages.

Program for implementation of Garden 01

Draft - June, 2018

ID	Task Mode	Task Name	Duration	Start	Finish	Pred	Labour required	Designer	Contractor	Site access for large equiptment
1		**Preliminary site inventory**	**1 day**	**Mon 04/06/18**	**Mon 04/06/18**					
2		Document and identify existing plant species	0.2 days	Mon 04/06/18	Mon 04/06/18		2			
3		Collect samples of existing vegitation for testing	0.2 days	Mon 04/06/18	Mon 04/06/18	2SS	2			
4		Documentation: Photography, hand held film	0.2 days	Mon 04/06/18	Mon 04/06/18	2SS	2			
5		**Site mark out**	**1 day**	**Mon 23/07/18**	**Mon 23/07/18**					Access required for Scissor lift all days
6		Mark out Phytoremediation Garden site	0.2 days	Mon 23/07/18	Mon 23/07/18		2-3			
7		Install time lapse and/or CCTV system on electrical posts	0.5 days	Mon 23/07/18	Mon 23/07/18	6SS	2-4			
8		Define and mark boundaries of soil retrieval area	0.5 days	Mon 23/07/18	Mon 23/07/18	6SS	4			
9		Mark and protect existing structures and elements as required e.g. retaining walls, footing, drains, vegetation to keep	0.5 days	Mon 23/07/18	Mon 23/07/18	6SS	4			
10		Documentation: All channels	1 day	Mon 23/07/18	Mon 23/07/18	6SS	2			Scissor lift
11		Download Timelapse Content	0.5 days	Mon 23/07/18	Mon 23/07/18	9	1			
12		**Site preparation**	**6 days**	**Mon 30/07/18**	**Mon 06/08/18**	9	2			Access required for Bob Cat and Scissor lift all days
13		Strip all vegetation and stock pile on site	2 days	Mon 30/07/18	Tue 31/07/18		2			Bob Cat
14		Complie retrieved soil on garden site to 500mm depth	2 days	Wed 01/08/18	Thu 02/08/18	13	2			Bob Cat
15		Rip, shape and prepare surface of garden site for seed sowing	1 day?	Fri 03/08/18	Fri 03/08/18	14	2			Bob Cat
16		Retrieve soil samples for testing	0.5 days	Mon 06/08/18	Mon 06/08/18	15	2			
17		Documentation: All channels		Mon 30/07/18	Mon 06/08/18	13SS	2			Scissor lift
18		**Irrigation installation**	**1 day**	**Tue 07/08/18**	**Tue 07/08/18**	16				Access required for Plumbing Van all days
19		Install, connect and test irrigation system	1 day	Tue 07/08/18	Tue 07/08/18		2			Plumbing Van
20		**Installation of Garden 01**	**1 day**	**Wed 08/08/18**	**Wed 08/08/18**	19				Access required for Scissor lift and Hydromulch truck all days
21		Mark out planting design	0.1 days	Wed 08/08/18	Wed 08/08/18		2-6			
22		Fabricate polypipe circular single species planting templates and install	1 day	Wed 08/08/18	Wed 08/08/18	21SS				
23		Hand sow seed; meadow mix and single species as per design	0.2 days	Wed 08/08/18	Wed 08/08/18	22	2-8			
24		Irrigate	0.1 days	Wed 08/08/18	Wed 08/08/18	23	4			
25		Hyrdo-mulch garden site	0.5 days	Wed 08/08/18	Wed 08/08/18	24	1			Hydromulch truck
26		Completion of Garden 01 Install		Wed 08/08/18	Wed 08/08/18	25	2			
27		Documentation: All channels	1 day	Wed 08/08/18	Wed 08/08/18	21SS	2			Scissor lift
28		**Download Timelapse Content**	**95.2 days**	**Fri 17/08/18**	**Fri 28/12/18**					
29		Download Timelapse Content 1	0.2 days	Fri 17/08/18	Fri 17/08/18		2			
30		Download Timelapse Content 2	0.2 days	Fri 27/08/18	Fri 27/08/18		2			
31		Download Timelapse Content 3	0.2 days	Fri 31/08/18	Fri 31/08/18		2			
32		Download Timelapse Content 4	0.2 days	Fri 07/09/18	Fri 07/09/18		2			
33		Download Timelapse Content 5	0.2 days	Fri 14/09/18	Fri 14/09/18		2			
34		Download Timelapse Content 6	0.2 days	Fri 21/09/18	Fri 21/09/18		2			
35		Download Timelapse Content 7	0.2 days	Fri 28/09/18	Fri 28/09/18		2			
36		Download Timelapse Content 8	0.2 days	Fri 05/10/18	Fri 05/10/18		2			
37		Download Timelapse Content 9	0.2 days	Fri 12/10/18	Fri 12/10/18		2			
38		Download Timelapse Content 10	0.2 days	Fri 19/10/18	Fri 19/10/18		2			
39		Download Timelapse Content 11	0.2 days	Fri 26/10/18	Fri 26/10/18		2			
40		Download Timelapse Content 12	0.2 days	Fri 02/11/18	Fri 02/11/18		2			
41		Download Timelapse Content 13	0.2 days	Fri 09/11/18	Fri 09/11/18		2			
42		Download Timelapse Content 14	0.2 days	Fri 16/11/18	Fri 16/11/18		2			

Monitoring and testing to continue until august 2019

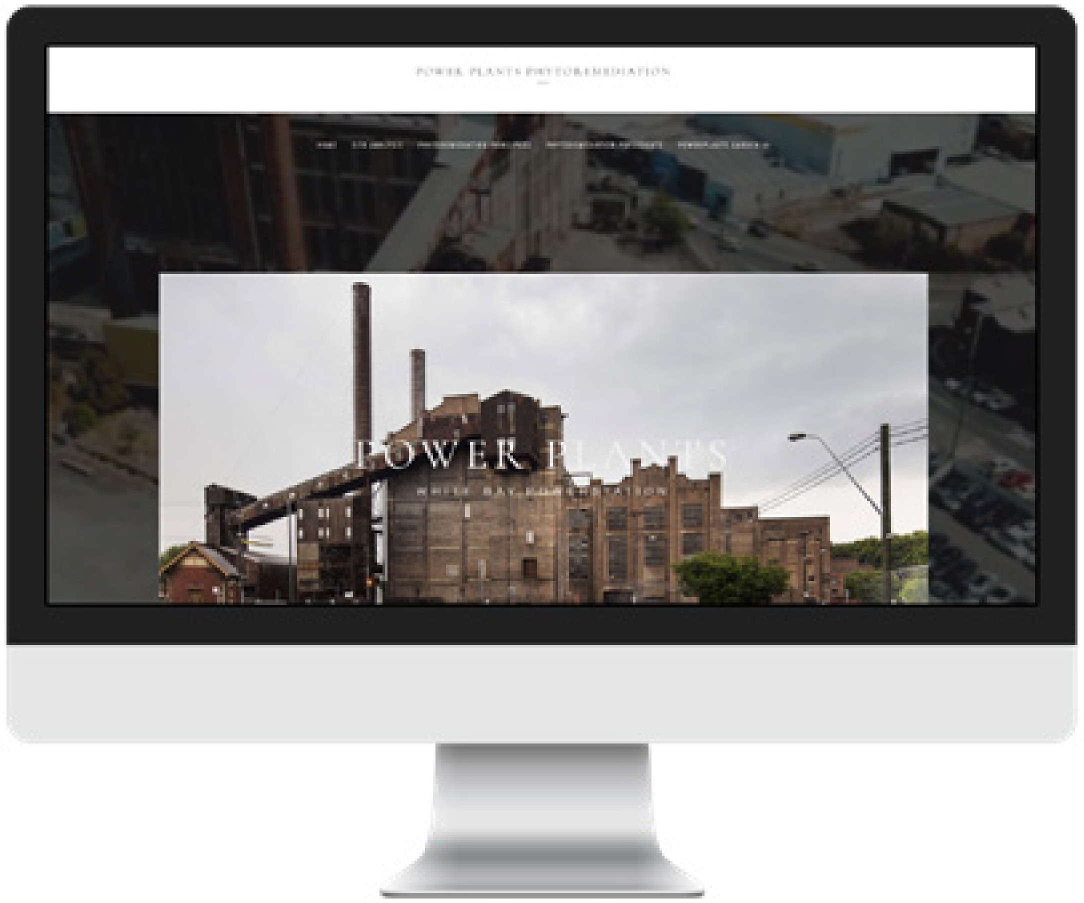
WEBSITE DIGITAL PLATFORM

Website design as digital platform for garden 01 site activation

The Power Plants Project website is an important component of the overall project. Because the site has limited accessibility to the public, the website will act as a portal and dissemination point about the project and its transformations. While there may be special events which are coordinated with the WBPS team, it is envisioned that many will experience the project mainly via the website. We have included a few stills of the website to demonstrate some of the content areas including: the data collection and updates of how the phytoremediation is progressing, student projects which produced in association with the Power Plants Project, the performance videos, a calendar of events (if appropriate), and research included in this report regarding phytoremediation techniques, design precedent studies, and various aspects of site analysis.

The Power Plants Website is currently not active and will not go live until we have the endorsement of Landcom and Urban Growth team members.

Power plants phytoremediation



Speculative Propositions

Performance

Scientific data in transition

Calender of Events

PERFORMANCE PLAN

Power Plants Performance Plan
Ainslie Murray & Katrina Simon

For Garden 01, a multi-channeled video will capture various performative aspects of the installation and growth of the garden. The following text describes the performance works, their intents, and formats as well as speculates how film might be utilised in Garden 02 and Garden 03.

Statement of Intent

We will produce a compelling creative work designed to reach a broad and diverse audience. An on-site performative event with a small audience in August 2018 forms one component of a multi-channel video that is progressively produced over the life of the project.

Key goals

- Inform, educate and engage a broad audience about phytoremediation.
- Communicate the processes involved in phytoremediation at the White Bay Power Station test site.
- Produce a creative research output that is developed from a site-specific event at the White Bay test site, which is subsequently distributed to a broader audience.

Key products

- A small event at the White Bay test site in August 2018 with a hand-picked, participatory audience.
- A multi-channel video reflecting different stages of the project.

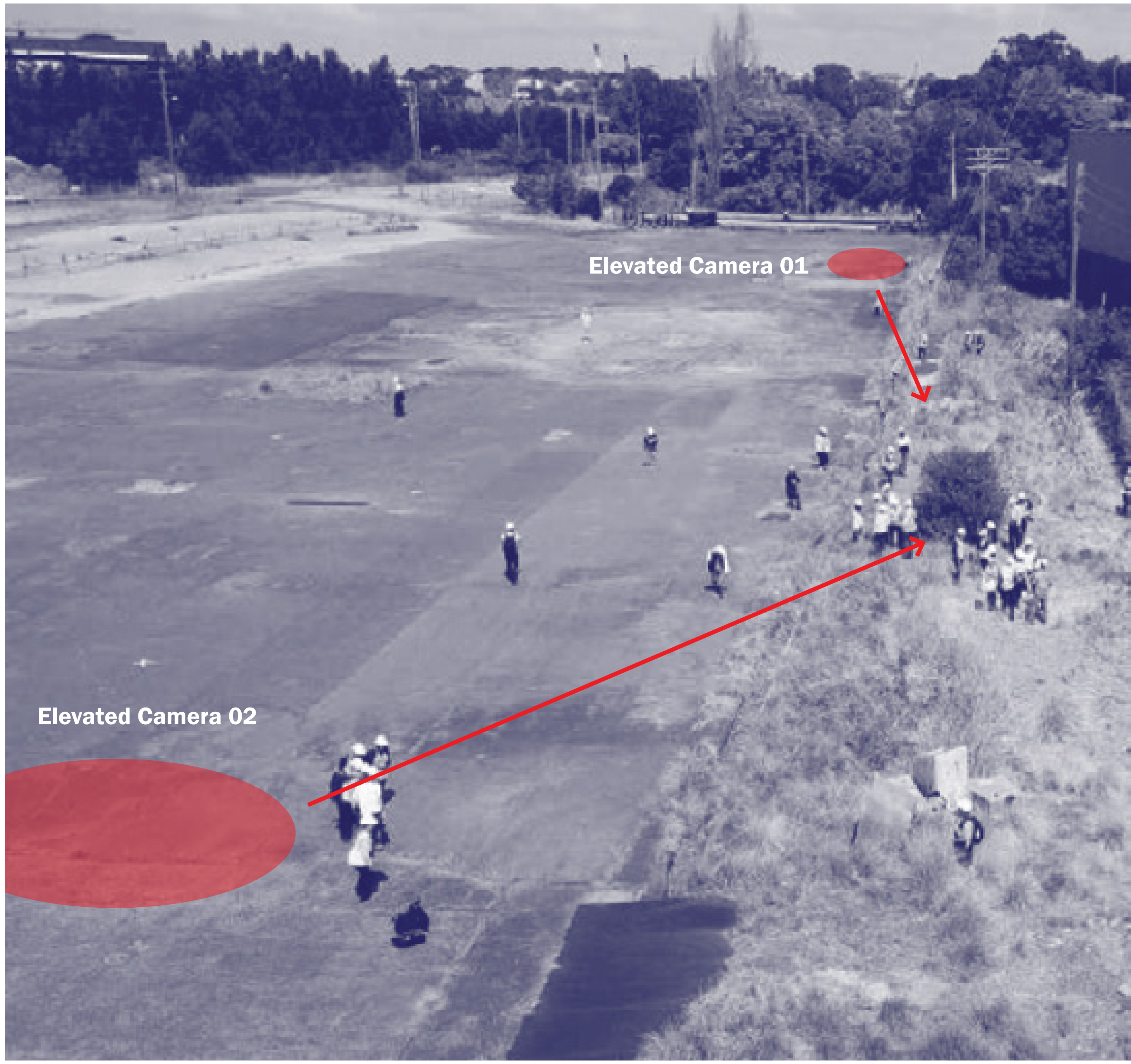
We recognise a need to produce an enduring creative record of the project that documents and celebrates each stage of the installation of Garden 01. The video will strategically capture each stage of the implementation of the garden, and provide a crucial insight into the research. Each stage of the project is conceived as an independent channel that can be flexibly assembled for different scenarios (e.g.. website, symposium, film festival, gallery). An on-site performative event at the hydromulching stage of the project will engage a small audience, and form a key component of the video. Practical considerations such as site access and safety are manageable, and the project is communicated to a broad audience via the project website, social media and Landcom's own channels. Disparate information and stages of the project can be utilised together or independently for a variety of purposes.

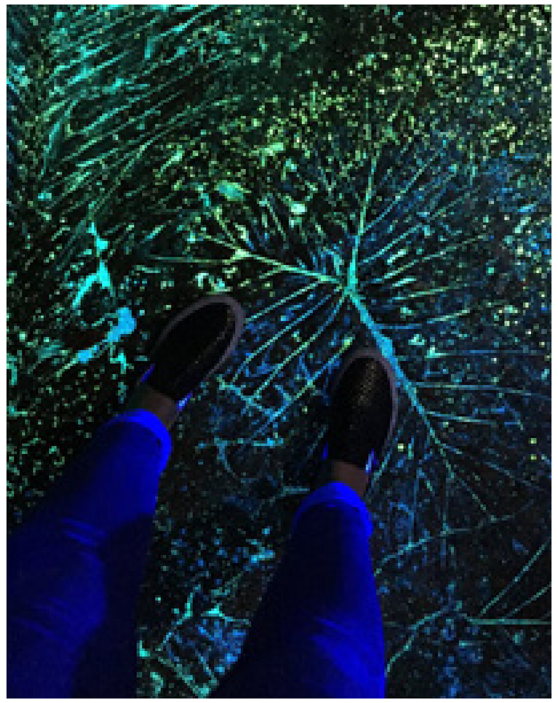
Video Multi-channel

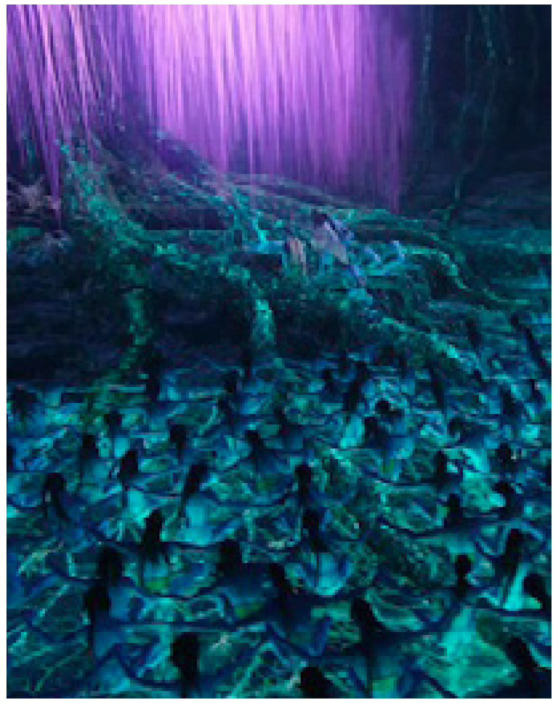
A multi-channel video is a series of independent videos to be viewed as a single artwork. In this format, the work can expand and contract for different situations (e.g.. The website might show all 3 channels in a linear formation; an exhibition might show 3 channels in a spatial installation; a single channel could be used as a promotional video).

Duration

Each channel is of relatively short duration [3 minutes maximum]. Played one after another, total duration is 9 minutes. Played simultaneously, total duration is 3 minutes. Played with slight offsets, total duration is around 5 minutes.







Production

Two scissor lifts are located on site overlooking the garden from two different perspectives (see image above). From the commencement of site works, the garden is consistently filmed from an elevated position on each lift and also from a third position at ground level [possibly roaming].

Proposed channels

Channel 1
Digging/Tilling/Layout of the garden

- The preparation and layout of Garden 01 is conceptualised as a large-scale drawing.
- The placement/formation of the circular forms that edge each plant group is performed theatrically to capture a sense of why the layout is as it is [i.e. varied species in particular proximities and patterns].
- Preparatory site works including removal of unwanted material, ripping of soil, tilling of soil, application of lime/gypsum are filmed.

Channel 2
Planting of the garden

- The planting of Garden 01 is conceptualised as a performance.
- The methodical and repetitious gestures of hand-sowing are emphasised to capture a sense of care and attention in a phytoremediation process.
- Repetitious movements associated with seed preparation, soil displacement, seed placement and watering are filmed.

Channel 3
Hydro-mulch 'painting' of the garden

- The hydro-mulching of Garden 01 is conceptualised as a large-scale painting in which a small, hand-picked audience is invited to participate in the hydro-mulching process.
- Mulch is dyed with a series of biodegradable luminescent dyes to visually evoke processes of phytoremediation.
- Participants are inducted into the site, dressed in haz-mat suits, and trained to apply hydro-mulch in response to a choreographic intent.
- The daytime application of hydro-mulch is filmed to capture the physical conclusion of the planting process.
- The night time glow of the hydro-mulch is filmed to capture a sense of the processes of phytoremediation [i.e.. inspires imaginative visualisation of invisible processes].

Channel 4
Garden 02 & Garden 03 (Goats) [beyond 2018]

- The garden is periodically filmed as it grows from a simulated goats-eye view.
- Goats are filmed doing ordinary goaty-things in the garden from a simulated goats-eye view.
- Long-term time-lapse (i.e. every month for the duration of the project).

Channel 5
Atmospheric elements & visualisation of data [beyond 2018]

- Various weather conditions are filmed in consideration of the processes of phytoremediation.
- Data emerging from the project is visualised [e.g. toxin levels in plants and goats.

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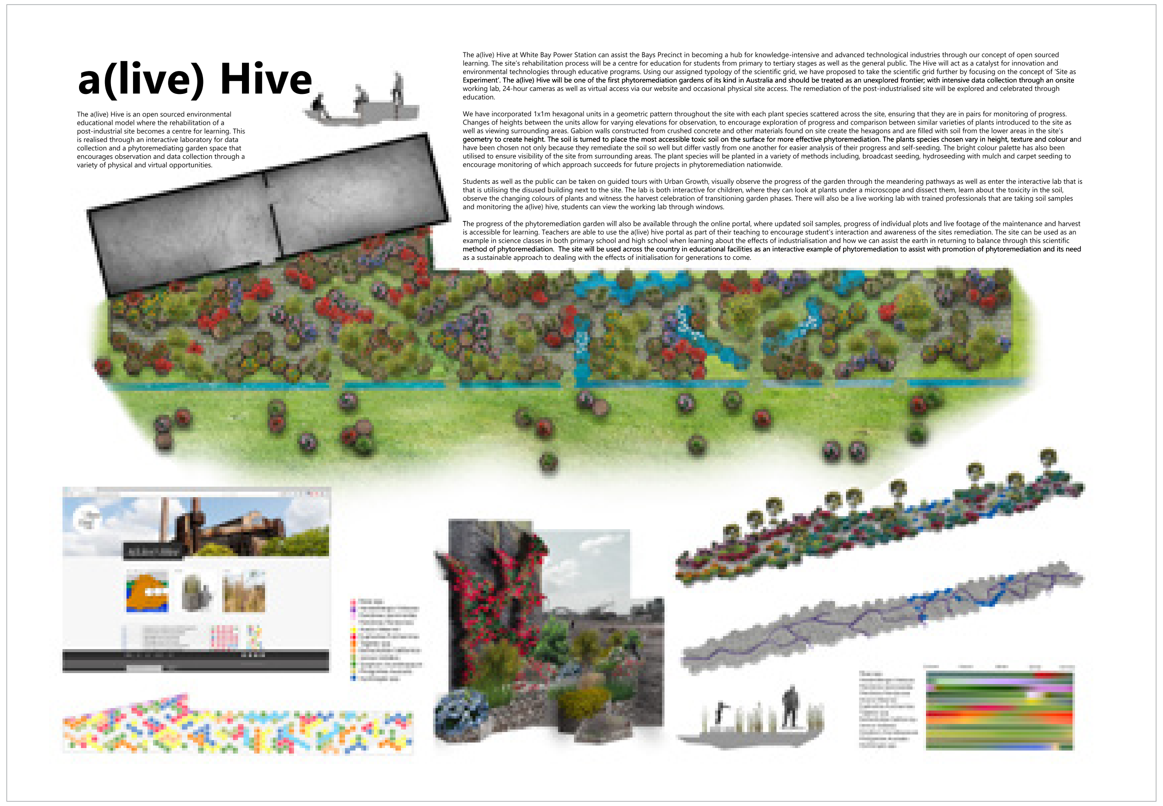
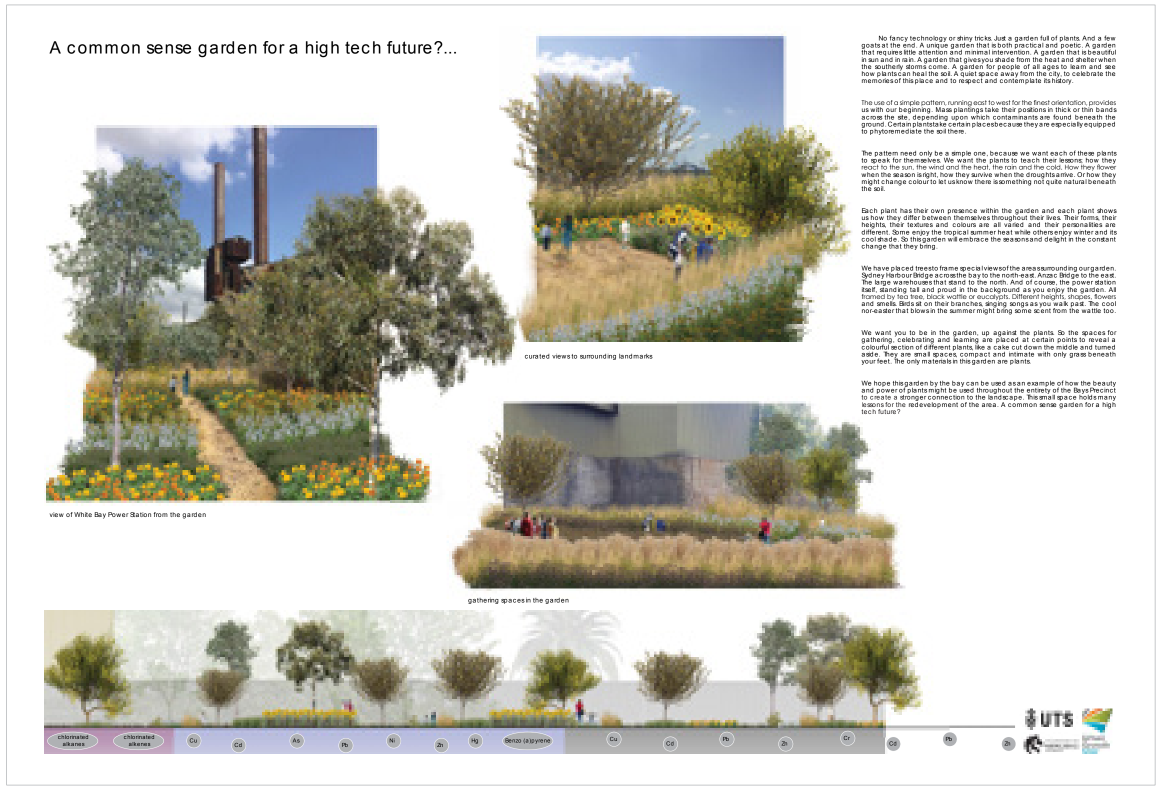
Appendix A

STUDENT SPECULATIVE PROPOSITIONS

Design Elective 2017




A common sense garden for a high tech future?...
UTS


MEADOW-MORPHOSIS
THE CONTEXT
ABSTRACT
UTS


PHYTO
EDUCATE
UTS
UoN: Derrick Chu, Luca Hudson, Yiran Zhou
UTS: Jiao Gu, Yousef Ghazal, Jeremy Chivas
TO USE THE PROCESS OF PHYTOREMEDIATION IN A GARDEN AT THE WHITE BAY POWER STATION THAT EDUCATES THE PUBLIC ABOUT THE TOXINS IN THE GROUND, REMOVES THEM, AND PREPARES THE LAND FOR IT'S NEXT DEVELOPMENT.
Our garden aims to use the process of Phytoremediation to remove harmful toxins from the ground, whilst also celebrating and respecting the various stages of history at the site, and educating the public about the the toxins. As our site has such rich historical and cultural layers, we thought it was important to celebrate these. Throughout the garden we celebrate the Native heritage of the site, the Industrialisation of the site in the 1900's, and the current state of the site moving into the future. Each of these periods are represented by various plant types and artefacts that are specific to each.
Throughout the garden various shrubs and trees specific to each era of history will be planted that remove the specific toxins in each area of the garden. To highlight the Native heritage native plants such as Pittosporum and Sugar Gum will be planted, to highlight the Industrialisation of the site Mulberry Trees, Tussock Grass & Lantana will be planted and finally to highlight the current state of the site moving into the future, plants that remove multiple toxins each have been chosen to represent a move toward a cleaner and more technologically focused future.
As well as this, we though it was important to educate the public about the toxins underneath the ground that are unseen by the everyday eye. This will be achieved through various 'pods' that will be implemented throughout the site. Each pod will contain a sample of the toxin underneath it's location in the garden, a QR code, a PH indicator that will change colour based on the level of toxicity, and a 360 degree camera. The pods will be limited in numbers at the beginning of the garden and will increase toward the 'present/future' section. The purpose of the QR code is to provide a fun and interactive way of educating people that pass through the garden about the toxins, and what the plants surrounding the pods are doing to phytoremediate the garden. They also allow people viewing the site through virtual means to interact with the garden and learn about the toxins and phytoremediation process. The 360 degree cameras will allow virtual visitors to move through the site as they would physically, providing them with a complete view of the garden. Both raised paths and lower paths within the garden will be used, using the natural decline of the land for natural progression from one end to the other.
Native Vegetation
Industrial
Present/Future
SYDNEY
WHITE BAY
CIRCULAR QUAY
DARLING HARBOUR
White Bay Power Station
Circular Quay & Darling Harbour

POWER PLANT // POWER PLANTS

By Scapegoat Studio

Anita Eckstein, Luke Grey, Daniel Rooke, Thomas Woodhead & Ye Yang

The **Power Plant // Power Plants** project presents a multifaceted and nuanced remediation of the White Bay Power Station site. It achieves this by linking the site's narrative and proposed garden to the larger surrounding context of the Bays District's public green spaces. In this way, this garden presents opportunities for investigation, discovery and education through a number of design interactions both active and passive.

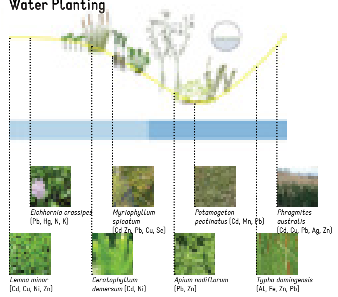
This project seeks to unite the micro scale of site remediation with the macro scale of the site's place within its past, present and, most importantly, future context. As illustrated above, the garden strives to communicate a speculative place amongst the continued greening of new public space from the post-industrial sites of the Bays District. It aims to achieve this through three main strategies: access, ambition and engagement.

Access to the garden site is proposed from the Robert Street entrance, adjacent to the car park. This is in a bid to make the garden more accessible to a larger volume and variety of people, and ties in with future installation opportunities undertaken in the carpark. Allowing visitors to by-pass the main site of the power station could potentially mean a reduced amount of safety concerns, as well as provide for less mobile patrons. This new access, also provides the potential to push the ambition of the scale of the site chosen for remediation. By increasing the area of the garden, more soil can be remediated at once, as well as the toxic pools of water on the site. This also has implications for the circulation around the garden, allowing a loop circuit that can change the linear nature of the garden, increasing opportunities for engagement through out.

The project aims to offer an engaging and performative aspect to all visitors of the site, not just at times of special events. The proposal for an installation of camera obscuras [pictured right] judiciously dotted throughout the site, provides opportunity for both novel and informed engagement with the garden, directing and sharpening visitor attention between the macro and micro of on and off-site—anchoring the garden's contextual bearing and relevance. Made from relic metal material found on site, they establish a dialogue between a historic past and speculative future. The installation offers a reprive from a world of high technology, and offers visitors opportunity for reflection on the low-tech, organic processes present on the site juxtaposed with the technological heritage of the site. For further engagement, a range of artists or community groups can be engaged to design a series of sculptural or artistic chasises for the camera obscuras.

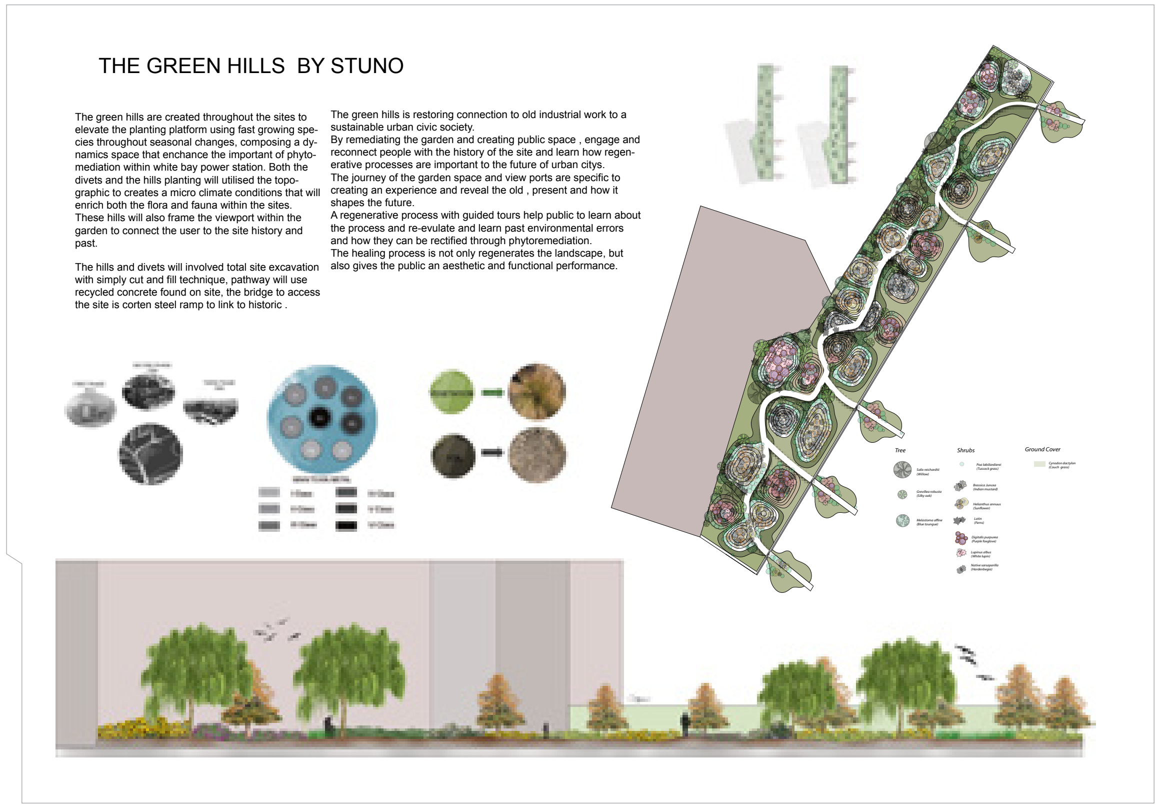
Below are the planting plans for the site. They're colour coded with the large site map above: the darker colour signaling taller and denser planting, towards the lighter colour which scales down to ground cover. They also indicate the plants that would be found within each of those density zones. This style planting being a meadow-come-shrub boarder ensures a diversity of plants across the site, as they have been chosen not just on the environmental conditions of the site, to collect the widest array of toxins.

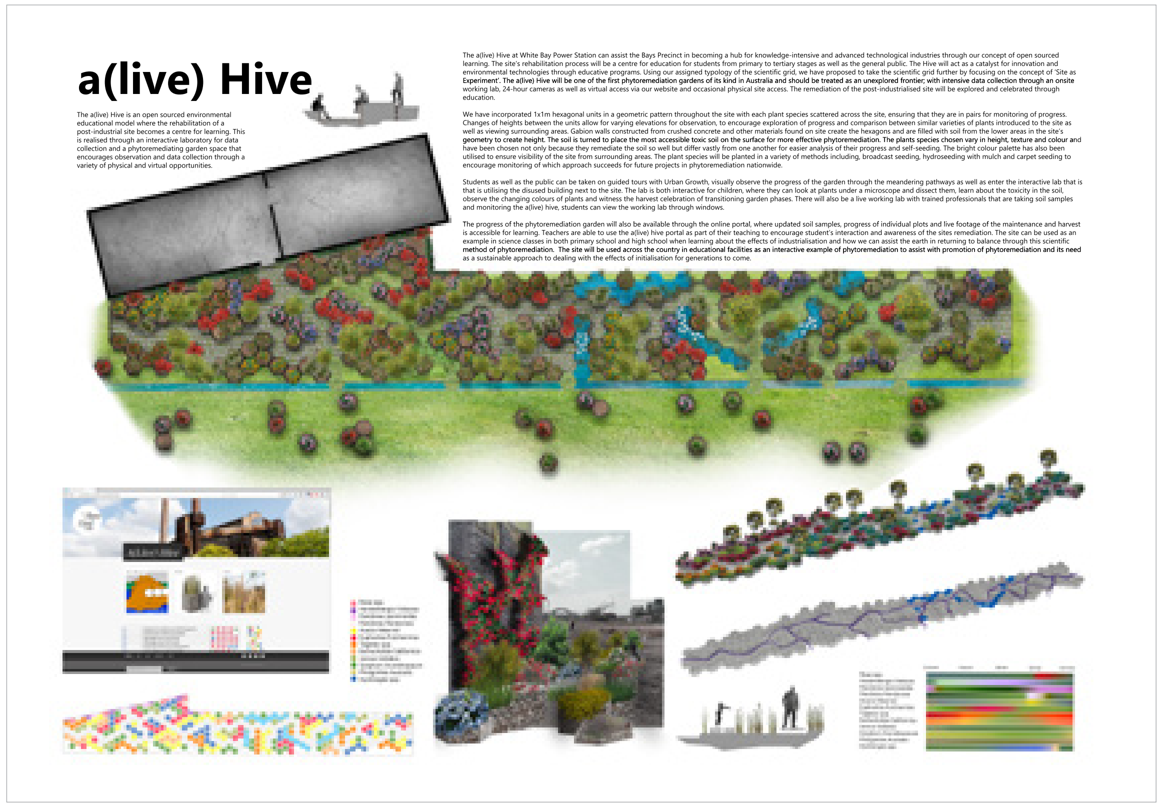
Water Planting




From the new entry a central axis is created, and two gathering space are created for events and education opportunities. Tracks through the garden are imagined as 'goat-tracks', are dirt paths stablised with a metal grid which is used also as a boardwalk around and over the ponds, and as seating/podiums throughout the garden. This materiality ensures a pragmatic approach to garden infrastructure, allowing materials to me easily re-purposed in future garden design iterations as well as being able to integrate with the industrial aesthetic of the site and blend into the garden, as a background element.
The planting of two hybrid poplars also mimic the chimneys of the power plant, and provide an landmark for the garden to not only signal its presence from off site, but as a metaphor for the new direction of the site and district: away from heavy industry and towards the new industries and technologies of the future.
The above figurative section shows the new plan for remediating the ponds, the second larger pond is split into two. Pond one and three are developed into anoxic pools with emergent and free-floating planting while pond two becomes aerobic with submerged planting. Water from the higher first pond is allowed to cascade into the second pond, helping to oxygenate the water. This water is then let to flow through to the third pond. In preparation for this new cycle, it would be prudent to dredge the ponds of the toxic sediment no doubt located at the bottom in order to try and get a head start in letting the plants take-hold. The remediation of these ponds is just as crucial as that of the soil, but it also increases the level of interest and variety for visitors to the site, and what they learn about. It also promotes a more meaningful and holistic approach towards the remediation of the site.
Overall, the planting style and selection offers a visitor to the a varied experience as they walk through the garden, planting schemes are chosen to provide a range of plant types, aesthetics, shapes and colours with a mono-chromed colour scheme of white and yellow flowering plants to echo subconsciously the toxicity of the site. The looped circulation provides for different experiences of discovery depending on which way the site is traversed, with the calculated planting of tall and dense areas to block views, reveal vistas and provide an overall feeling of depth and variety to the garden.
Dry/Sunny Planting
Wet/Shaded Planting
UTS


THE MEADOW
THE PROCESS


THE GREEN HILLS BY STUNO
The green hills are created throughout the sites to elevate the planting platform using fast growing species throughout seasonal changes, composing a dynamics space that enchance the important of phytomediation within white bay power station. Both the divets and the hills planting will utilised the topographic to creates a micro climate conditions that will enrich both the flora and fauna within the sites. These hills will also frame the viewport within the garden to connect the user to the site history and past.
The hills and divets will involved total site excavation with simply cut and fill technique, pathway will use recycled concrete found on site, the bridge to access the site is corten steel ramp to link to historic .
The green hills is restoring connection to old industrial work to a sustainable urban civic society.
By remediating the garden and creating public space , engage and reconnect people with the history of the site and learn how regenerative processes are important to the future of urban citys.
The journey of the garden space and view ports are specific to creating an experience and reveal the old , present and how it shapes the future.
A regenerative process with guided tours help public to learn about the process and re-evulate and learn past environmental errors and how they can be rectified through phytoremediation.
The healing process is not only regenerates the landscape, but also gives the public an aesthetic and functional performance.


a(live) Hive
The a(live) Hive is an open sourced environmental educational model where the rehabilitation of a post-industrial site becomes a centre for learning. This is realised through an interactive laboratory for data collection and a phytoremediating garden space that encourages observation and data collection through a variety of physical and virtual opportunities.
The a(live) Hive at White Bay Power Station can assist the Bays Precinct in becoming a hub for knowledge-intensive and advanced technological industries through our concept of open sourced learning. The site's rehabilitation process will be a centre for education for students from primary to tertiary stages as well as the general public. The Hive will act as a catalyst for innovation and environmental technologies through educative programs. Using our assigned typology of the scientific grid, we have proposed to take the scientific grid further by focusing on the concept of 'Site as Experiment'. The a(live) Hive will be one of the first phytoremediation gardens of its kind in Australia and should be treated as an unexplored frontier; with intensive data collection through an onsite working lab, 24-hour cameras as well as virtual access via our website and occasional physical site access. The remediation of the post-industrialised site will be explored and celebrated through education.
We have incorporated 1x1m hexagonal units in a geometric pattern throughout the site with each plant species scattered across the site, ensuring that they are in pairs for monitoring of progress. Changes of heights between the units allow for varying elevations for observation, to encourage exploration of progress and comparison between similar varieties of plants introduced to the site as well as viewing surrounding areas. Gabion walls constructed from crushed concrete and other materials found on site create the hexagons and are filled with soil from the lower areas in the site's geometry to create height. The soil is turned to place the most accessible toxic soil on the surface for more effective phytoremediation. The plants species chosen vary in height, texture and colour and have been chosen not only because they remediate the soil so well but differ vastly from one another for easier analysis of their progress and self-seeding. The bright colour palette has also been utilised to ensure visibility of the site from surrounding areas. The plant species will be planted in a variety of methods including, broadcast seeding, hydroseeding with mulch and carpet seeding to encourage monitoring of which approach succeeds for future projects in phytoremediation nationwide.
Students as well as the public can be taken on guided tours with Urban Growth, visually observe the progress of the garden through the meandering pathways as well as enter the interactive lab that is that is utilising the disused building next to the site. The lab is both interactive for children, where they can look at plants under a microscope and dissect them, learn about the toxicity in the soil, observe the changing colours of plants and witness the harvest celebration of transitioning garden phases. There will also be a live working lab with trained professionals that are taking soil samples and monitoring the a(live) hive, students can view the working lab through windows.
The progress of the phytoremediation garden will also be available through the online portal, where updated soil samples, progress of individual plots and live footage of the maintenance and harvest is accessible for learning. Teachers are able to use the a(live) hive portal as part of their teaching to encourage student's interaction and awareness of the sites remediation. The site can be used as an example in science classes in both primary school and high school when learning about the effects of industrialisation and how we can assist the earth in returning to balance through this scientific method of phytoremediation. The site will be used across the country in educational facilities as an interactive example of phytoremediation to assist with promotion of phytoremediation and its need as a sustainable approach to dealing with the effects of initialisation for generations to come.


SENSORY SEGUES

Appendix B

EMAIL TO LANDSCHAFTSPARK REGARDING PHYTOREMEDIATION

Kalyna Sparks

From: Tobias Rautenberg <tobias.rautenberg@bswr.de>
Sent: Tuesday, 6 March 2018 3:30 AM
To: Kalyna Sparks
Cc: 'Dr. Peter Keil'
Subject: RE: Your request for data on phytoremediation in Landschaftspark

Dear Mrs Sparks!

There is a lot of data about the vegetation, plant communieties and there is also some data about soils in the Landschaftspark but there is nothing about toxinextraction by plants.

Landschaftspark is not a really good example for phytoremediation because this has never been an aim of management here.
Highly poluted (dangerous for the health of people) soils have been removed or covered with other soils in the past but were not cleaned by phytoremediation.

Best wishes

Tobias Rautenberg

****

Zentrale:
Biologische Station Westliches Ruhrgebiet e.V.
Ripshorster Str. 306
46117 Oberhausen
Tel.: 0208 4686090
www.bswr.de

Dependance im Landschaftspark DU-Nord:
Dipl.-Biogeograph Tobias Rautenberg
Biologische Station Westliches Ruhrgebiet e.V.
Lösorter Str. 119
47137 Duisburg
Tel.: 0203 4179282

Fax: 0203 4179289

Von: Egbert.Bodmann@landschaftspark.de [mailto:Egbert.Bodmann@landschaftspark.de]
Gesendet: Mittwoch, 28. Februar 2018 13:31
An: tobias.rautenberg@bswr.de
Cc: peter.keil@bswr.de
Betreff: Neue Kontaktanfrage

Absender: Mrs. Kalyna Sparks
Address: 143 Parkway Avenue, 2303 Hamilton South, NSW, Australia
Mail: kalyna.sparks@newcastle.edu.au
Telephone: (+61)401292776

Nachricht:

1

Appendix C

LIST OF TOXINS INCLUDING TRACE TOXINS ON THE SITE OF GARDEN 01

C21			
Benzo (a)pyrene	1.4	0.5-0.6	Pg 57/1122 - Plan
Heavy Metals			
Arsenic	5 0	5-0.6	Pg 372/1122 - Table
Cadmium	<0.4	0.5-0.6	Pg 372/1122 - Table
Chromium (Total)	5 0	5-0.6	Pg 372/1122 - Table
Copper	31	0.5-0.6	Pg 372/1122 - Table
Lead	140	0.5-0.6	Pg 372/1122 - Table
Mercury	<0.1	0.5-0.6	Pg 372/1122 - Table
Nickel	8.9	0.5-0.6	Pg 372/1122 - Table
Zinc	310	0.5-0.6	Pg 372/1122 - Table
Total Recoverable Hydrocarbons - 1999 NEPM Fractions			
TRH C6-C9	<20.0	0.5-0.6	Pg 370/1122 - Table
TRH C10-C14	<20.0	0.5-0.6	Pg 370/1122 - Table
TRH C15-C28	95	0.5-0.6	Pg 370/1122 - Table
TRH C29-C36	<50.0	0.5-0.6	Pg 370/1122 - Table
TRH C10-36 (Total)	95	0.5-0.6	Pg 370/1122 - Table
BTEX			
Benzene	<0.1	0.0-0.1	Pg 370/1122 - Table
Toluene	<0.1	0.0-0.1	Pg 370/1122 - Table
Ethylbenzene	<0.1	0.0-0.1	Pg 370/1122 - Table
m&p-Xylenes	<0.2	0.0-0.1	Pg 370/1122 - Table
o-Xylene	<0.1	0.0-0.1	Pg 370/1122 - Table
Xylenes - Total	<0.3	0.0-0.1	Pg 370/1122 - Table

4-Bromofluorobenzene (surr.)	75%		Pg 370/1122 - Table
Total Recoverable Hydrocarbons - 2013 NEPM Fractions			
NaphthaleneN02	<0.5	0.5-0.6	Pg 370/1122 - Table
TRH >C10-C16 less Naphthalene (F2)N01	<50	0.5-0.6	Pg 370/1122 - Table
TRH C6-C10	< 20	0.5-0.6	Pg 370/1122 - Table
TRH C6-C10 less BTEX (F1)N04	< 20	0.5-0.6	Pg 370/1122 - Table
Polycyclic Aromatic Hydrocarbons			
Benzo(a)pyrene TEQ (lower bound) *	1.9	0.5-0.6	Pg 370/1122 - Table
Benzo(a)pyrene TEQ (medium bound) *	2.1	0.5-0.6	Pg 370/1122 - Table
Benzo(a)pyrene TEQ (upper bound) *	2.4	0.5-0.6	Pg 370/1122 - Table
Acenaphthene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Acenaphthylene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Anthracene	1.4	0.5-0.6	Pg 370/1122 - Table
Benz(a)anthracene	1.0	0.5-0.6	Pg 370/1122 - Table
Benzo(a)pyrene	1.4	0.5-0.6	Pg 370/1122 - Table
Benzo(b&j)fluorantheneN07	1.4	0.5-0.6	Pg 370/1122 - Table
Benzo(g.h.i)perylene	0.7	0.5-0.6	Pg 370/1122 - Table
Benzo(k)fluoranthene	1.4	0.5-0.6	Pg 370/1122 - Table
Chrysene	1.3	0.5-0.6	Pg 370/1122 - Table
Chrysene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Fluoranthene	1.6	0.5-0.6	Pg 370/1122 - Table
Fluorene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Indeno(1.2.3-cd)pyrene	0.7	0.5-0.6	Pg 370/1122 - Table
Naphthalene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Phenanthrene	1.1	0.5-0.6	Pg 370/1122 - Table
Pyrene	2	0.5-0.6	Pg 370/1122 - Table
Total PAH*	14	0.5-0.6	Pg 370/1122 - Table
2-Fluorobiphenyl (surr.)	112%	0.5-0.6	Pg 370/1122 - Table
p-Terphenyl-d14 (surr.)	68%	0.5-0.6	Pg 370/1122 - Table
Organochlorine Pesticides			
Chlordanes - Total	< 0.1	0.0-0.1	Pg 371/1122 - Table
4.4'-DDD	< 0.05	0.0-0.1	Pg 371/1122 - Table
4.4'-DDE	< 0.05	0.0-0.1	Pg 371/1122 - Table
4.4'-DDT	< 0.05	0.0-0.1	Pg 371/1122 - Table

a-BHC	< 0.05	0.0-0.1	Pg 371/1122 - Table
Aldrin	< 0.05	0.0-0.1	Pg 371/1122 - Table
b-BHC	< 0.05	0.0-0.1	Pg 371/1122 - Table
d-BHC	< 0.05	0.0-0.1	Pg 371/1122 - Table
Dieldrin	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endosulfan I	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endosulfan II	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endosulfan sulphate	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endrin	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endrin aldehyde	< 0.05	0.0-0.1	Pg 371/1122 - Table
Endrin ketone	< 0.05	0.0-0.1	Pg 371/1122 - Table
g-BHC (Lindane)	< 0.05	0.0-0.1	Pg 371/1122 - Table
Heptachlor	< 0.05	0.0-0.1	Pg 371/1122 - Table
Heptachlor epoxide	< 0.05	0.0-0.1	Pg 371/1122 - Table
Hexachlorobenzene	< 0.05	0.0-0.1	Pg 371/1122 - Table
Methoxychlor	< 0.2	0.0-0.1	Pg 371/1122 - Table
Toxaphene	< 1	0.0-0.1	Pg 371/1122 - Table
Dibutylchlorendate (surr.)	78	0.0-0.1	Pg 371/1122 - Table
Tetrachloro-m-xylene (surr.)	113	0.0-0.1	Pg 371/1122 - Table
Polychlorinated Biphenyls (PCB)			
Aroclor-1016	<0.5	0.0-0.1	Pg 371/1122 - Table
Aroclor-1232	<0.5	0.0-0.1	Pg 371/1122 - Table
Aroclor-1242	<0.5	0.0-0.1	Pg 371/1122 - Table
Aroclor-1248	<0.5	0.0-0.1	Pg 371/1122 - Table
Aroclor-1254	<0.5	0.0-0.1	Pg 371/1122 - Table
Aroclor-1260	<0.5	0.0-0.1	Pg 371/1122 - Table
Total PCB*	<0.5	0.0-0.1	Pg 371/1122 - Table
Dibutylchlorendate (surr.)	78%	0.0-0.1	Pg 371/1122 - Table
Total Recoverable Hydrocarbons -2013 NEPM Fractions			
TRH >C10-C16	<50	0.5-0.6	Pg 371/1122 - Table
TRH >C16-C34	130	0.5-0.6	Pg 371/1122 - Table
TRH >C34-C40	< 100	0.5-0.6	Pg 371/1122 - Table
Cyanide (total)	<1.0	0.5-0.6	Pg 371/1122 - Table
Phenolics (total)	0.0	0.5-0.6	Pg 371/1122 - Table

C26			
Benzo (a)pyrene	0.8	0.3-0.4	Pg 57/1122 - Plan
Benzo (a)pyrene	1.3	0.5-0.6	Pg 57/1122 - Plan
Heavy Metals			
Arsenic	10.0	0.5-0.6	Pg 372/1122 - Table
Cadmium	<0.4	0.5-0.6	Pg 372/1122 - Table
Chromium (Total)	<5.0	0.5-0.6	Pg 372/1122 - Table
Copper	41.0	0.5-0.6	Pg 372/1122 - Table
Lead	140.0	0.5-0.6	Pg 372/1122 - Table
Mercury	0.2	0.5-0.6	Pg 372/1122 - Table
Nicke	8.9	0.5-0.6	Pg 372/1122 - Table
Zinc	140.0	0.5-0.6	Pg 372/1122 - Table
Total Recoverable Hydrocarbons - 1999 NEPM Fractions			
TRH C6-C9	<20.0	0.5-0.6	Pg 370/1122 - Table
TRH C10-C14	<20.0	0.5-0.6	Pg 370/1122 - Table
TRH C15-C28	170	0.5-0.6	Pg 370/1122 - Table
TRH C29-C36	<50.0	0.5-0.6	Pg 370/1122 - Table
TRH C10-36 (Total)	170	0.5-0.6	Pg 370/1122 - Table
BTEX			
Benzene	<0.1	0.5-0.6	Pg 370/1122 - Table
Toluene	<0.1	0.5-0.6	Pg 370/1122 - Table
Ethylbenzene	<0.1	0.5-0.6	Pg 370/1122 - Table
m&p-Xylenes	<0.2	0.5-0.6	Pg 370/1122 - Table
o-Xylene	<0.1	0.5-0.6	Pg 370/1122 - Table
Xylenes - Total	<0.3	0.5-0.6	Pg 370/1122 - Table
4-Bromofluorobenzene (surr.)	77%	0.5-0.6	Pg 370/1122 - Table
Total Recoverable Hydrocarbons - 2013 NEPM Fractions			
NaphthaleneN02	<0.5	0.5-0.6	Pg 370/1122 - Table
TRH >C10-C16 less Naphthalene (F2)N01	<50	0.5-0.6	Pg 370/1122 - Table
TRH C6-C10	< 20	0.5-0.6	Pg 370/1122 - Table
TRH C6-C10 less BTEX (F1)N04	< 20	0.5-0.6	Pg 370/1122 - Table
Polycyclic Aromatic Hydrocarbons			
Benzo(a)pyrene TEQ (lower bound) *	1.7	0.5-0.6	Pg 370/1122 - Table

Benzo(a)pyrene TEQ (medium bound) *	2	0.5-0.6	Pg 370/1122 - Table
Benzo(a)pyrene TEQ (upper bound) *	2.2	0.5-0.6	Pg 370/1122 - Table
Acenaphthene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Acenaphthylene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Anthracene	1.8	0.5-0.6	Pg 370/1122 - Table
Benz(a)anthracene	1.0	0.5-0.6	Pg 370/1122 - Table
Benzo(a)pyrene	1.3	0.5-0.6	Pg 370/1122 - Table
Benzo(b&j)fluorantheneN07	1.3	0.5-0.6	Pg 370/1122 - Table
Benzo(g.h.i)perylene	0.6	0.5-0.6	Pg 370/1122 - Table
Benzo(k)fluoranthene	1.3	0.5-0.6	Pg 370/1122 - Table
Chrysene	1.4	0.5-0.6	Pg 370/1122 - Table
Chrysene	< 0.5	0.5-0.6	Pg 370/1122 - Table
Fluoranthene	1.5	0.5-0.6	Pg 370/1122 - Table
Fluorene	< 0.5	0.5-0.6	Pg 371/1122 - Table
Indeno(1.2.3-cd)pyrene	< 0.5	0.5-0.6	Pg 371/1122 - Table
Naphthalene	< 0.5	0.5-0.6	Pg 371/1122 - Table
Phenanthrene	1.4	0.5-0.6	Pg 371/1122 - Table
Pyrene	1.9	0.5-0.6	Pg 371/1122 - Table
Total PAH*	13.5	0.5-0.6	Pg 371/1122 - Table
2-Fluorobiphenyl (surr.)	130%	0.5-0.6	Pg 371/1122 - Table
p-Terphenyl-d14 (surr.)	66%	0.5-0.6	Pg 371/1122 - Table
Organochlorine Pesticides			
Chlordanes - Total	< 0.1	0.5-0.6	Pg 371/1122 - Table

LANDCOM

UrbanGrowth NSW Development Corporation

Contact details

Landcom

Phone (02) 9841 8600

Mail Level 14
60 Station Street
Parramatta NSW 2150

UrbanGrowth NSW Development Corporation

Phone (02) 9216 5700

Mail Level 12, MLC Centre
19 Martin Place
Sydney NSW 2000