

Geotechnical Aspects of the Sydney 2000 Olympic Site

Roberta Lindbeck, Douglas Partners Pty Ltd, Sydney, Australia

Summary This paper reviews the geotechnical aspects of the Sydney 2000 Olympic Site at Homebush Bay: a geological environment of shale, residual clays, alluvial sediments, and filling. Of these materials, the soft alluvial sediments provided some of the most challenging geotechnical conditions. The paper focuses on one particular geotechnical case study, which was the investigation for proposed irrigation ponds in the former landfill areas. The work involved the investigation of the soft alluvial materials for the assessment of slope stability of the ponds.

1 INTRODUCTION

The site for the 2000 Olympic Games is located at Homebush Bay in Sydney's inner west. Homebush Bay is a low-lying area, which was previously covered by natural wetlands and has been utilised for industrial and land filling purposes since the early 1940's.

The redevelopment of the Homebush Bay area for the Olympic Games involved the development of the previously industrial area into major sporting, recreational, and residential facilities. The construction activities have resulted in much geotechnical investigation being undertaken in the area over the past decade.

The geological environment in the Homebush Bay area consists of Ashfield Shale of Triassic age, residual clays, Quaternary alluvium, and man-made filling. The development therefore required construction to be undertaken in a challenging geotechnical environment, comprising filling and soft alluvial deposits.

2 HISTORY OF THE HOMEBUSH BAY AREA

Originally, the Homebush area was greatly influenced by Homebush Bay and its tributaries: Haslam's Creek, Powell's Creek, and Duck Creek. A map of the area is included in Figure 1.

The area comprised extensive tidal wetlands and thick woodlands. From the mid 1800's, large areas

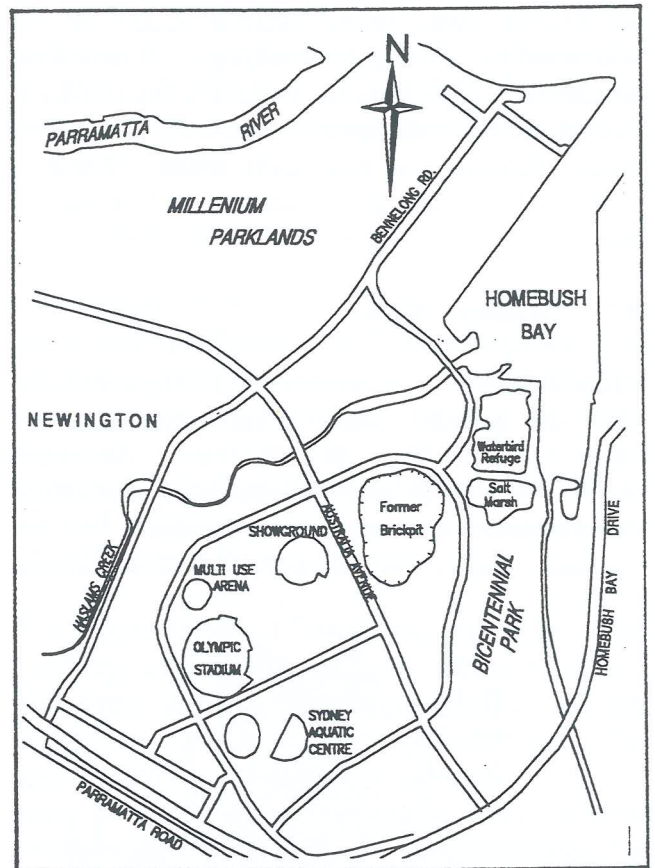


Figure 1. - The Homebush Bay Area

of the wetlands were gradually reclaimed, and the forests cleared. The low-lying areas of Newington and along the fringes of Homebush Bay have been extensively modified by filling operations¹. The area comprised a number of industrial and commercial enterprises, such as a brickworks, a racecourse, an armaments depot, and an abattoir. From the 1960's, parts of Homebush Bay were used for the uncontrolled dumping of industrial wastes². Extensive development began in the 1980's when recreational facilities, such as Bicentennial Park, were opened. Sydney's

successful bid for hosting the 2000 Olympic Games resulted in the next surge of development for Homebush Bay.

3 GEOLOGY OF THE HOMEBUSH BAY AREA

The following section details the geology of the area, with examples of geotechnical work undertaken as part of the Olympic development.

The prevailing geology of the area comprises rocks of Triassic age, with Ashfield Shale of the Wianamatta Group overlying Hawkesbury Sandstone³. Overlying the rocks are Quaternary to Recent alluvial sediments deposited within the creek channels, and man-made filling. Figure 2 shows the different geological areas of Homebush Bay.

3.1 Ashfield Shale

The Ashfield Shale is predominantly black and grey shale and laminite, which is heavily jointed. The shale is present in the upland areas of the nearby suburb, Newington, and underlies filling and alluvial deposits across the remainder of the site².

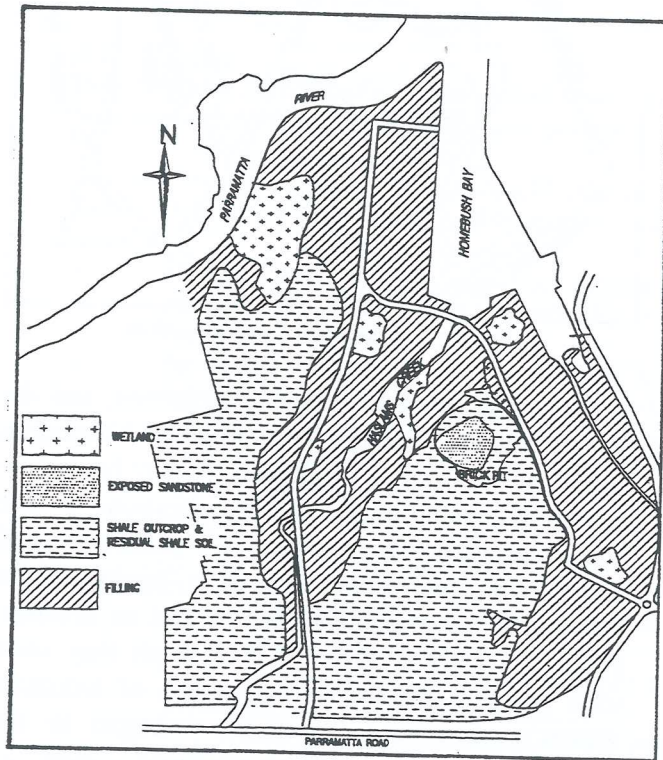


Figure 2. - The Geology of Homebush Bay

Some excellent exposures of the shale are evident in a previous quarry, known as the 'Brickpit', which was, at one stage, proposed for use as a water treatment facility for the Olympic site and surrounds, but now may be used for recreational purposes. Geotechnical projects undertaken at the 'Brickpit' site have included the assessment of stability of the existing excavation walls, to determine the suitability of the area for public access.

3.2 Residual Soils

The residual soils are red brown clays and silty clays which grade into stiff grey and red brown clays. The layer of residual clays is typically 3m to 4 m thick, although the soils range from a variable thin cover on the uplands to a thick laterised profile which has been locally preserved. Excavation has been so extensive that the residual soils are now limited to the upland areas of Newington, although some have been preserved below the alluvial sediments in Haslam's Creek and the wetlands⁴. As the extent of the residual soils is quite limited, most of the geotechnical work in these materials comprised design of shallow footings and bulk earthworks for facilities such as the Olympic Village.

3.3 Alluvial Sediments

The alluvial sediments mainly comprise black to grey, silty and sandy clays, and occasional peat layers. The sediments are up to 11 m thick in places, but are typically 2 m to 4 m thick⁴. The estuarine or alluvial deposits are variable in thickness, but are consistent in lithology. Shell fragments are common and are concentrated in discrete layers, which confirm the sediments' marine origin. The Irrigation Ponds case study as detailed later in this paper, investigates the geotechnical properties of these alluvial sediments.

3.4 Filling

The filling of the Homebush Bay area shows a great variability, and comprises putrescible waste, vegetation, paper, rubber, timber, plastics, building rubble, metallic debris, bituminous waste, batteries, asbestos, and excavated spoil. Much of the filling was placed in low-lying areas and the relocation of

the filling was required as part of the redevelopment. The filling has now been stored in a number of mounds, designed to be landscaped as recreational features. Geotechnical investigation related to this development comprised assessment of the slope stability of the mounds.

4 CASE STUDY - IRRIGATION PONDS

As mentioned earlier, whilst the geology of the site for the 2000 Olympic Games comprises a variety of different sequences, some of the most interesting geotechnical work comprised investigation of the soft alluvial sediments, in particular. The remainder of the paper provides discussion of one particular case study - the Irrigation Ponds on Hill Road.

The redevelopment of the Homebush Bay site for the 2000 Olympic Games resulted in the removal of uncontrolled filling from low-lying areas of Newington, and replacement with imported clay filling material. The resultant refilled area was proposed for recreational use, comprising a number of water features that could be used as irrigation ponds and for flood control. A plan showing the area of the proposed ponds is included as Figure 3.

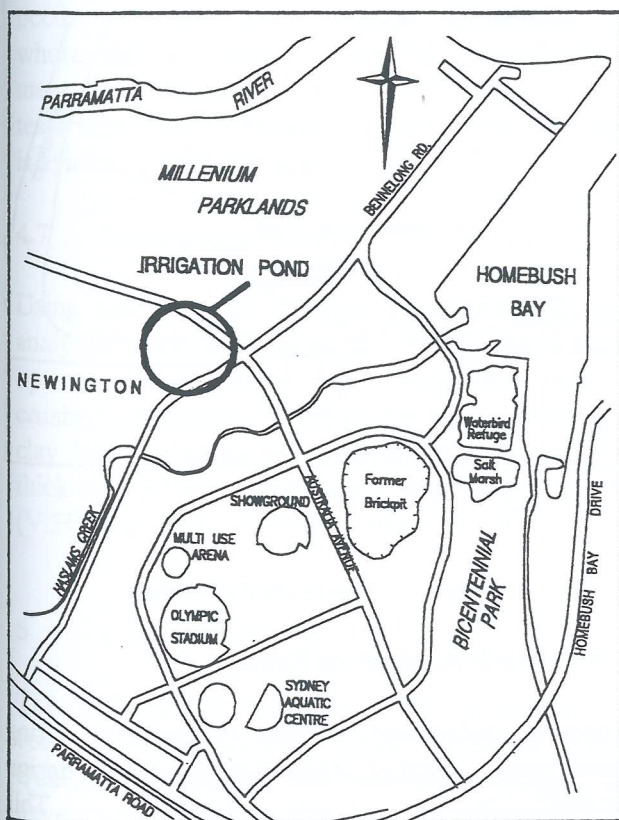


Figure 3. - The Irrigation Ponds

During the removal of the waste filling, it became evident that the proposed pond area was underlain by soft clay, and as a result, investigation was carried out by Douglas Partners Pty Ltd (DP) to assess the stability of the proposed ponds⁴.

4.1 Site Description and Geology

The area of the proposed irrigation ponds is located between Hill Road and the Olympic Village, in a flat area which is part of the flood plain of Haslam's Creek. Reference to geological maps and previous investigations undertaken in the area indicated that the site's geology comprised man-made filling, overlying alluvial clay ranging in strength from soft to hard. In the area of the failed ponds, the uncontrolled filling had been replaced by 4 m to 5 m of clay filling.

4.2 Field Investigation

The initial investigation was undertaken in September and October 1997, and comprised cone penetration tests to determine the soil profile and characteristics. A series of test pits were also excavated, and these were used to assist in the estimation of strength parameters. The test pits allowed sampling of the subsurface soils and identification of the soft silty clay.

The results of the CPT indicated man-made filling overlying soft silty clay and very stiff to hard clay. The depth of filling and the thickness of the soft silty clay varied across the investigation area. The layer of filling was found to be generally 4 m to 5 m thick, however, was as thin as 1 m to 2 m in some locations. The layer of soft clay underlying the filling was found to be about 0.8 m to 2 m thick⁴. The soil profile can be seen in Figure 4.

The CPT results had indicated total cone resistance, q_c , of between 200 kPa and 500 kPa. and sleeve frictions of less than 10 kPa. Pore pressures were not measured during the testing.

4.3 Stability Analyses

Stability analyses were undertaken in December 1997 to determine safe design slopes for the irrigation ponds. Analysis for circular slip failures, using a computer slope stability program, were

undertaken. The analyses assumed typical strength parameters for the soft clay layer, based on previous experience and the results of the CPT undertaken in the area of the Irrigation Ponds.

The previous CPT had indicated a cone resistance, q_u , of 200-500 kPa in the layer of soft clay. Lunne et al.⁵ (1997) provide a method of calculating the undrained shear strength of fine grained soils using the total cone resistance, the total in situ vertical stress, σ_{vo} , and an empirical cone factor, N_k , using equation (1).

$$s_u = \frac{(q_c - \sigma_{vo})}{N_k} \quad (1)$$

The total cone resistance is provided by the CPT, and the total in situ vertical stress is determined from the pressure applied by the overburden clay filling. Lunne and Kleven (1981)⁶ showed that for normally consolidated marine clays, the cone factor varied between 11 and 19, with an average of 15.

Using this method, the undrained shear strength of the soft clays can be calculated as ranging between 12 kPa and 29 kPa.

Thus, in the stability analyses of December 1997, a strength of $S_u=10$ kPa was assumed, based on the results of site specific field data. The results of the analyses indicated that the factor of safety of the ponds would be satisfactory if the slopes were maintained at no steeper than 1:2 (V:H)⁷. The graphical output of the stability analyses are shown in Figure 4.

4.4 Failure of the Irrigation Ponds

Whilst the initial design slopes for the ponds were specified to be 1:2 (V:H), excavation conditions during construction allowed slopes of 1:1.3 (V:H). In January 1998, during construction, an entire section of the edge of one of the ponds slumped, resulting in post failure slopes of 1:6 (V:H). It was found that the layer of soft clay had failed, causing the overlying clay filling to move along the soft clay layer. Large transverse cracks were visible at the head of the slide.

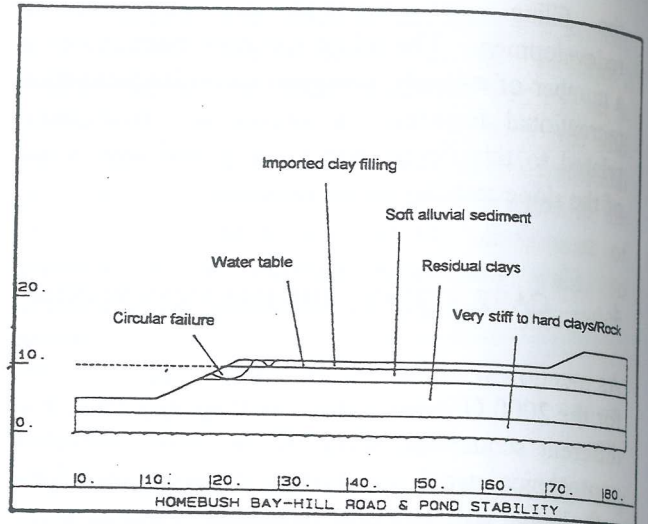


Figure 4. - Stability Analysis of the Pond Slopes

A plan of the pond, showing the cracks is included in Figure 5.

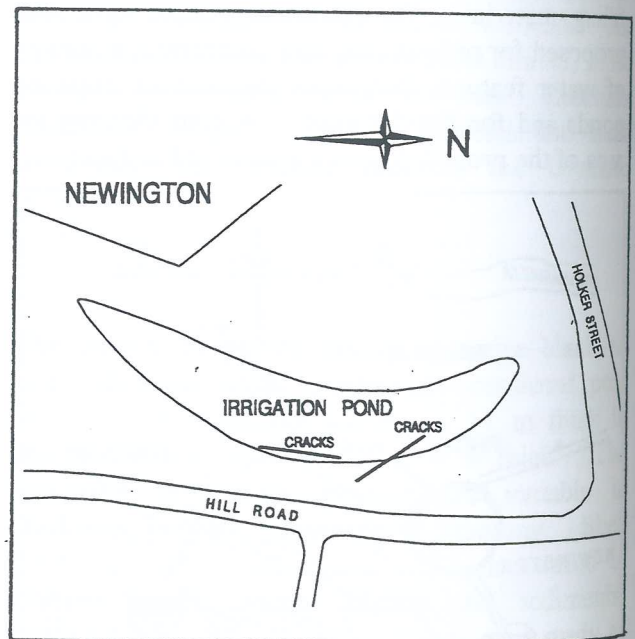


Figure 5. - Plan of the Failed Pond

4.5 Back Analysis of Failure

Following subsequent failures of the ponds during construction, further investigation of the design strength parameters was undertaken. This comprised back analysis of the observed failures to

assist in determination of shear strength. Revised stability analyses were then performed and these allowed stabilisation measures to be designed and ultimately implemented.

Using the pre-failure geometry of the slope, and trialling various combinations of strength parameters, stability analyses were undertaken to achieve a factor of safety less than 1.0. This back analysis indicated that the strength of the soft clay was as low as $c_u=5 \text{ kPa}$ ⁸, as opposed to the value of 10 kPa, which had been used in the stability analyses and was based on field CPT results.

4.6 Discussion of Differences in Undrained Shear Strength

There are obvious differences between the strength assumed for the purpose of stability analyses and the strength calculated from the back analysis of the failed pond. It is considered that the differences could be attributed to variations in conditions between the CPT locations and where the pond failure actually occurred.

The CPT were located near the Irrigation Ponds, but not directly at the locations where failures occurred. Thus, the resistance of the soft clay where failure occurred had not actually been measured. The importance of accurately locating tests when relying heavily on site-specific field data is evident in this case study.

4.7 Subsequent Design of Stabilisation

Using the amended strength parameters, stability analyses were undertaken on various stabilisation options. It was found that a supporting layer of crushed sandstone, covering the face of the soft clay layer, resulted in improved stability. A 3 m thick layer of sandstone with a slope angle of 1:3.5 (V:H) resulted in a factor of safety of 1.4⁹.

5 CONCLUSIONS

The geological environment in the Homebush area consists of Ashfield Shale, residual clays, Quaternary alluvium, and man-made filling. The development of the area for the Sydney 2000 Olympic Games therefore required construction to

be undertaken in a challenging geotechnical environment. The Irrigation Ponds case study investigated the geotechnical properties of the alluvial sediments. Geotechnical investigations in the area of the proposed ponds comprised cone penetration testing, excavation of test pits, and stability analyses. Following the failure of part of the Irrigation Ponds, back analysis revealed that the undrained strength of the soft clays was as low as 5 kPa, which was much lower than anticipated. Furthermore, it was about half of that back calculated from previous failures in the vicinity. The variations in ground conditions between test locations and the position of the ponds. It pointed to a clear need to carry out site specific investigations rather than rely on global strength parameters determined elsewhere in the region.

¹ CH2MHill (1995), "Site Assessment Report, Homebush Bay/Newington, Stage 2 Contamination Study", (unpublished)

² INTERNET SEARCH (1999), "Building for the Games - Planning for the Future", www.magna.com.au/~knight/fsgen.htm.

³ DEPARTMENT OF MINERAL RESOURCES (1983), "1:100 000 Geological Series Sheet 9130 - Sydney"

⁴ DOUGLAS PARTNERS PTY LTD (1997) "Stability Assessment, Hill Road, Homebush Bay, Project 24341B", (unpublished).

⁵ LUNNE, T., ROBERTSON, P.K., AND POWELL, J.J.M. (1997) "Cone Penetration Testing in Geotechnical Practice", Blackie Academic & Professional

⁶ LUNNE, T. AND KLEVEN, A. (1981) "Role of CPT in North Sea foundation engineering". Session at the ASCE National Convention: Cone Penetration Testing and Materials, St. Louis, 76-107, American Society of Engineers, (ASCE)

⁷ DOUGLAS PARTNERS PTY LTD (1997), "Pond Stability, Hill Road, Homebush Bay, 24341B", (facsimile - unpublished).

⁸ DOUGLAS PARTNERS PTY LTD (1998), "Stability of Haslam's Creek Widening, 24341B", (facsimile - unpublished)

⁹ DOUGLAS PARTNERS PTY LTD (1998), "Stability, 24341B", (facsimile - unpublished)