SYDNEY FOOTBALL STADIUM REDEVELOPMENT

STATE SIGNIFICANT DEVELOPMENT APPLICATION

Concept Proposal and Stage 1 Demolition

SSDA 9249

APPENDIX T:

Groundwater Assessment Report

NSW GOVERNMENT

Infrastructure New South Wales

Sydney Football Stadium Redevelopment

Groundwater Assessment Report

260159-GEHG-RPT-0001

Final | 21 May 2018

Job number 260159-20

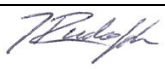
Arup
Arup Pty Ltd ABN 18 000 966 165

Arup
Level 10 201 Kent Street
PO Box 76 Millers Point
Sydney 2000
Australia
www.arup.com

ARUP

Document Verification

ARUP

Job title		Sydney Football Stadium Redevelopment			**Job number** 260159-20
Document title		Groundwater Assessment Report			**File reference**
Document ref		260159-GEHG-RPT-0001			
Revision	**Date**	**Filename**	260159-GEHG-RPT-0001_Draft.docx		
Draft 1	06 April 2018	**Description**	First draft		
			Prepared by	Checked by	Approved by
		Name	Taya Rudolph	Jason Carr	Jason Carr
		Signature			
Final rev 0	21 May 2018	**Filename**	260159-GEHG-RPT-0001_rev 0		
		Description	Final		
			Prepared by	Checked by	Approved by
		Name	Taya Rudolph	Jason Carr	Jason Carr
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
		Filename			
		Description			
			Prepared by	Checked by	Approved by
		Name			
		Signature			
				Issue Document Verification with Document	✓

Contents

Appendices

Appendix A

Figures

Appendix B

Groundwater works

1 Introduction

This report supports a State Significant Development (SSD) Development Application (DA) for the redevelopment of the Sydney Football Stadium which is submitted to the Minister for Planning pursuant to Part 4 of the Environmental Planning and Assessment Act 1979 (EP&A Act). A staged approach to the planning applications is proposed which includes:

- **Stage 1** – Concept Proposal for the stadium envelope and supporting retail and functional uses as well as development consent for the carrying out of early works, including demolition of the existing facility and associated structures.
- **Stage 2** – detailed design, construction and operation of the stadium and supporting business, retail and functional uses.

This report relates to the Stage 1 Concept DA and detailed Early Works package.

Infrastructure NSW is the Proponent for the Stage 1 planning application.

1.1 Background

The Sydney Football Stadium (SFS) is a significant component of the sports facilities that comprise the Sydney Cricket and Sports Ground (SC&SG). Completed in 1988, the SFS has hosted numerous sporting events in its 30 years of operation for a number of sporting codes including football (soccer), rugby league and rugby union as well as occasional music concerts.

In 2012, the NSW Government announced the *NSW Stadia Strategy 2012* which provided a vision for the future of stadia within NSW, prioritising investment to achieve the optimal mix of venues to meet community needs and to ensure a vibrant sports and event environment in NSW. A key component of the strategy included development of master plans for Tier 1 stadia and their precincts covering transport, integrated ticketing, spectator experience, facilities for players, media, corporate and restaurant and provision for entertainment. SFS is one of three Tier 1 stadia within NSW, the others being Stadium Australia (Olympic Park) and the Sydney Cricket Ground.

In order to qualify for Tier 1 status, a stadium is required to include:

- Seating capacity greater than 40,000
- Regularly host international sporting events
- Offer extensive corporate facilities, including suites, open-air corporate boxes and other function/dining facilities
- Be the home ground for sporting teams playing in national competitions

Following release of the NSW Stadia Strategy, the Sydney Cricket and Sports Ground Trust (SCSGT) undertook master planning culminating in the 2015 Preliminary SCG Master Plan. This master plan defines the context for future redevelopment of the SCG, SFS and related sports infrastructure to ensure that the

precinct continues to meet the needs and expectations of visitors and tenants into the future.

In a competitive national landscape, the existing Allianz Stadium (SFS) is now facing serious commercial and operational challenges to remain relevant and competitive. The SFS was constructed many years ago and therefore it fails to meet certain criteria for modern Tier 1 stadiums. The stadium has aged poorly and fails to meet expectations with regards to patron experience, crowd management, safety/security, accessibility, facilities for core tenants, operational efficiency, premium hospitality and food/beverage offerings and media requirements.

On 24 November 2017, the NSW Premier announced the redevelopment of the SFS into a world-class stadium with up to 45,000 seats. The redevelopment will include demolition of the existing facility and replacement with a modern, globally competitive stadium that achieves the requirements for a Tier 1 stadium to meet future requirements. Redevelopment of the SFS will assist in supporting the realisation of the Master Plan principles to:

- Create a flexible venue suitable for sports, e-sports and major events alike
- Include technology for the future
- Create a venue for the growth of men's and women's elite sport, as well as the ability to adapt to new sports and the rise of e-sports
- Create a publicly accessible entertainment and recreational facility
- Create a stadium integrated with its surrounds including Centennial and Moore Parks and the surrounding residential and business areas
- Create a sustainable future

1.2 Site Description

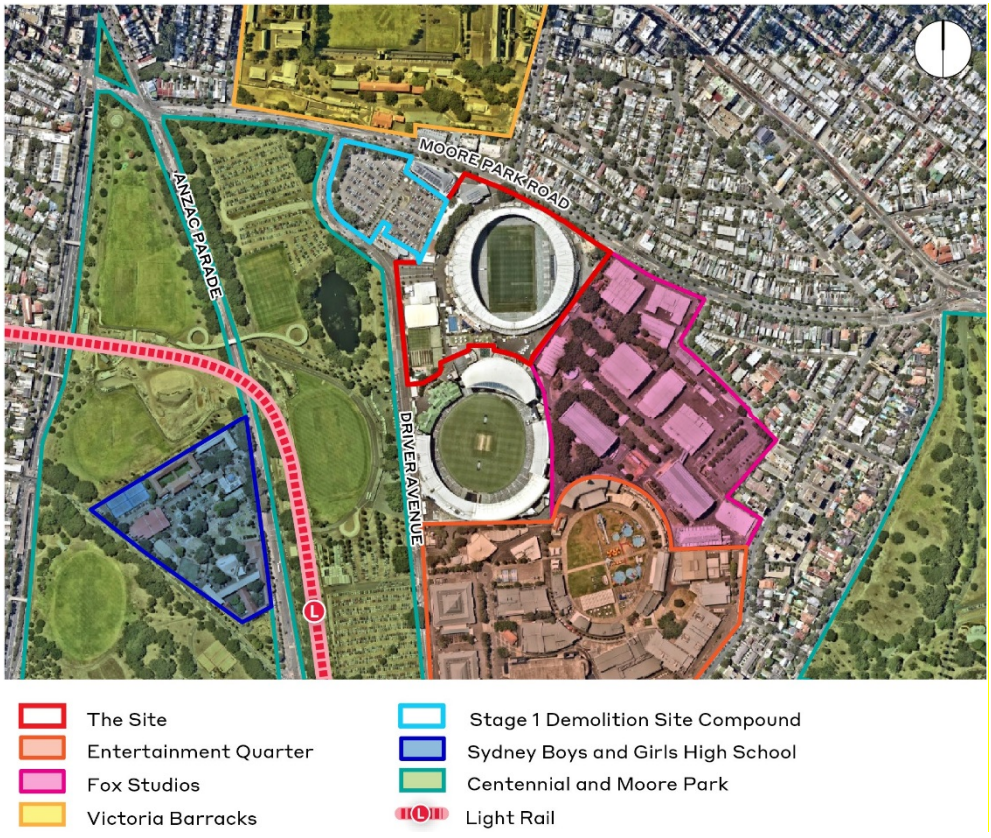
The site is located at 40-44 Driver Avenue, Moore Park within the Sydney Cricket Ground Precinct. It is bound by Moore Park Road to the north, Paddington Lane to the east, the existing SCG stadium to the south and Driver Avenue to the west. The site is located within the City of Sydney local government area.

The site is legally described as Lots 1528 and 1530 in Deposited Plan 752011 and Lot 1 in Deposited Plan 205794. The site is Crown Land, with the SCSGT designated as the sole trustee under the *Sydney Cricket and Sports Ground Act 1978*. The site is wholly contained within designated land controlled by the Sydney SCSGT under Schedule 2A of the *Sydney Cricket and Sports Ground Act 1978*.

In a broader context, the site is largely surrounded by Centennial and Moore Parks, the Fox Studios and Entertainment Quarter precincts and the residential suburb of Paddington. Located approximately 3km from the Sydney CBD and approximately 2km from Central Station, the site is connected to Sydney's transport network through existing bus routes and will benefit from a dedicated stop on the soon to be completed Sydney CBD and South East Light Rail. The locational context of the Site is shown in Figure 1, whilst the site boundaries and existing site features are shown in Figure 2.

Figure 1 Regional site context

Figure 2 Site area and local context



1.3 Overview of Proposed Development

The SFS Redevelopment Stage 1 application includes a Concept Proposal and Early Works package.

The Concept Proposal comprises:

- A new stadium with up to 45,000 seats on the site of the existing stadium including:
  - New facilities for general admission
  - New playing pitch
  - Hospitality facilities
  - Ancillary food and beverage and entertainment facilities
- New basement with service vehicular access for servicing and bump-in/bump-out
- New public domain works surrounding the stadium, building on the venue's unique parkland setting
- Urban Design and Public Domain Guidelines
- Signage strategy

Indicative concept building envelope plans are included within the Environmental Impact Statement for the project. These plans outline the extent of the proposed stadium building envelope and surrounding public domain to be included in the Stage 1 planning application.

From a capacity, operational and mix-of-use perspective, the new stadium will be consistent with the existing Allianz Stadium.

The Stage 1 Early Works comprises:

- Site establishment, including erection of site protection fencing and temporary relocation of facilities
- Decommissioning and demolition of the existing stadium and associated structures including the existing Sheridan, Roosters and Waratahs buildings and the administration building of Cricket NSW to ground level and 'make safe' of the site
- Use of the existing Moore Park 1 (MP1) car park for construction staging
- Make good of the site suitable for construction of the new stadium (subject to separate Stage 2 application)

The SFS Redevelopment will create a new stadium with up to 45,000 seats through a range of seating styles and corporate facilities. The stadium will include state of the art technology with digital screens throughout to improve the fan experience. Sightlines will be improved and facilities including catering, amenities and accessibility will be designed to service future needs, creating a world-class customer experience befitting a global city such as Sydney.

1.4 Scope and purpose of this report

This Groundwater Assessment Report (GAR) presents the results of the groundwater desktop study and assessment to inform an Environmental Impact Statement (EIS). The scope of this report includes:

- A summary of relevant state legislation related to groundwater
- Review of existing geological and geomorphological environments in the project area
- A conceptual groundwater model

2 Relevant Legislation

Federal and state guidelines pertaining to this groundwater assessment are as follows:

- *Water Management Act 2000*
- *Water Management (General) Regulation 2011*
- *NSW Aquifer Interference Policy 2012*
- *Risk Assessment Guidelines for Groundwater Dependent Ecosystems 2012*
- *NSW State Groundwater Policy Framework Document 1997*
- *NSW State Groundwater Quality Protection Policy 1998*
- *NSW State Groundwater Dependent Ecosystems Policy 2002*
- *NSW Water Extraction Monitoring Policy 2007*
- *NSW Water Sharing Plans*

2.1 Water Management Act 2000

The NSW Department of Primary Industries (DPIs) Water Management Act of 2000 (WM Act) governs the issues of water pumping licenses to carry out further pumping works where a sharing licence or framework is already in place. The WM Act is primarily a means to manage and safeguard the existence of rivers and aquifers used for commercial purposes.

2.2 Water Management (General) Regulation 2011

The Water Management (General) Regulation 2011 provides information and guidelines for the licensing and approvals process for various water bodies, commercial businesses seeking licences, water supply authorities, private drainage boards, civil works authorities, elections and irrigation corporations. This legislation provides steps on how to navigate the approval and licensing process for dealings and applications.

2.3 NSW Aquifer Interference Policy 2012

The purpose of the Aquifer Interference Policy is to clarify the role and requirements of the Minister in charge of administering the WM Act in the water licensing and assessment processes for aquifer interferences. Furthermore, the policy aims to clarify the requirements for licensing regarding aquifer interference activities as well as establishing a consideration and advice structure for potential impacts of an aquifer interference activity.

2.4 Risk Assessment Guidelines for Groundwater Dependent Ecosystems 2012

The risk assessment guidelines are used to manage land and water use activities that pose a potential threat for groundwater dependent ecosystems (GDEs). The guidelines consist of four volumes that include the conceptual framework, worked examples, identification of high potential GDEs and their ecological value for coastal aquifers, and the risk of groundwater extraction on the coastal plains of NSW.

2.5 NSW State Groundwater Policy Framework Document 1997

The groundwater policy framework document is used to provide ecologically sustainable management guidance regarding groundwater quality protection, quantity management, dependent ecosystems, and resources for the people of NSW.

2.6 NSW State Groundwater Quality Protection Policy 1998

The groundwater protection policy falls under one of the three sub-categories of the groundwater policy framework document. The focus of this policy is to protect groundwater from polluted subsurface waters and the ecosystems from which these waters are recharged or into which they discharge.

2.7 NSW State Groundwater Dependent Ecosystems Policy 2002

The Groundwater Dependent Ecosystems Policy falls under one of the three sub-categories of the groundwater policy framework document. The GDE policy document is designed to protect valuable ecosystems that rely on groundwater to survive, maintain the biophysical functions and preserve these ecosystems for the resources of future generations. Furthermore, the policy provides practical guidelines that can be used as tools to suit a specific need based on a given groundwater dependent ecosystem or environment.

2.8 NSW Water Extraction Monitoring Policy 2007

The objective of the Water Extraction Monitoring Policy is to increase the extent of active monitoring of water extraction with a future aim of having 90% of the total volume of water in each water sharing plan being subject to active monitoring. This policy sets out the rules and guidelines for holders of groundwater extraction licenses.

2.9 NSW Water Sharing Plans

The NSW Office of Water defines Water Sharing Plans so that the equitable sharing of water and resources can occur sustainably and under a strict licensing and approvals process. Water sharing plans fall under the WM Act.

3 Methodology

Environmental impact assessment guidelines provided by the NSW Government have been consulted to develop this groundwater assessment. The guidelines provide guidance on factors that should be considered in the assessment of environmental impacts, which may require mitigation measures during the construction and operation phases of the project to minimise impacts.

The following methodology was adopted to assess the potential impacts upon groundwater caused by the proposed development:

- Review of existing public resources comprising: literature relating to the project area such as geological and environmental maps, published journal articles and government reports, proclaimed areas and available groundwater level, quality and flow data (within a 1 km radius of the site)
- Review of investigation reports provided for this project and Arup in-house resources
- Development of a conceptual groundwater model

3.1 Publicly available sources

The conceptual groundwater model was developed in consultation with the following public resources:

- The Sydney 1:100,000 scale Geological Series Sheet (Herbert, 1983)
- The DPI Office of Water groundwater bore network (Office of Water, 2018)
- Bureau of Meteorology (BoM) past climate data
- Sydney Light Rail (2016) Hydrogeology and Groundwater Protection Design Report, Reference No. SLR-DJV-D40-DRA-REP-000040

3.2 Previous investigations

In addition to the publicly available resources listed above, the following investigation reports were reviewed to inform the conceptual groundwater model:

- Arup (1985) Sydney Sports Centre Moore Park, Geotechnical Investigation Report, Reference No. 3970
- Arup (2008) Sydney Cricket & Sports Ground Trust, Bradman and Noble Stand Redevelopment, Geotechnical Desk Study, Reference No. 205405
- Arup (2014) Moore Park Shared Path Bridge, Geotechnical Design of CFA Bridge Piles, Technical Note, Reference No. 235446
- Douglas Partners (1996) Report on Vibration Assessment, Shafts 16 and 21, Busby's Bore Moore Park Film Studios, Reference No. 23662B
- Douglas Partners (2006) Report on Geotechnical Investigation, Proposed New Hill Stand, Sydney Cricket Ground, Moore Park, Reference No. 444417-1
- Douglas Partners (2007) Investigation Report Summary, Proposed Replica Scoreboard, Sydney Cricket Ground, Moore Park, Reference No. 45050
- Douglas Partners (2008) Report on Geotechnical Investigation, New Day Stalls & Civil Infrastructure, Randwick Racecourse, Reference No. 45236.01
- Douglas Partners (2009) Report Geotechnical Investigation and Preliminary Waste Classification Assessment, Proposed Bradman and Noble Stands Redevelopment, Sydney Cricket Ground, Moore Park, Reference No. 45867
- Douglas Partners (2010) Report on Preliminary Contamination, Salinity and Acid Sulphate Soil Assessment, Proposed Stables Precinct, Royal Randwick Racecourse, Randwick, Reference No. 71976.01
- Douglas Partners (2010) Report on Preliminary Geotechnical Assessment, Proposed Development of Spectator Precinct, Royal Randwick Racecourse, Racecourse, Reference No. 71976
- Douglas Partners (2010) Final Report on Contamination and Validation Assessment, New Day Stalls Site – Randwick Racecourse, Randwick, Reference No. 45236.08
- Douglas Partners (2015) Report on Geotechnical Investigation, Australian Rugby Development Centre, Moore Park Road, Moore Park, Reference No. 84881.0
- Jeffery and Katauskas (2006) Report to Leighton Contractors Pty Ltd on Geotechnical Investigation for Proposed New Grandstand at Sydney Cricket Ground, Reference No. 20488SL
- Godden Mackay Logan (2006) Entertainment Quarter, Australian Film, Television and Radio School, Environmental Assessment- Heritage Impact Statement – Addendum Report
- NSW Department of Commerce (2007) Aussie Stadium Water Efficiency Audit, Reference No. DD2953a

- URS (2011) Royal Randwick Racecourse, Watertable Assessment, Reference No. 43167905

4 Existing environment

4.1 Topography

The proposed redevelopment site is located on relatively flat ground at approximately 40 m AHD between Moore Park Road and Driver Avenue, Moore Park. Surrounding the northern and eastern sides of the project area is a ridgeline, which the alignment of Oxford Street and Cook Road generally follows. The ridgeline is up to 70 m AHD where the site is located beyond the toe of the associated hillside slopes (Appendix A, Figure 5).

4.2 Regional geology

The Sydney 1:100,000 scale geological series sheet indicates the proposed site is underlain by Holocene aged marine sands (Qhd) with Triassic aged Hawkesbury Sandstone (Rh) on the northern and eastern sides of the project area (Herbert, 1983). The mapped location of Hawkesbury Sandstone coincides with the ridgeline feature of the surrounding topography. The geological boundary of the Holocene aged sands and Hawkesbury Sandstone runs approximately southeast-northwest along the northern side of Moore Park Road and around the eastern side of the Moore Park precinct where it aligns approximately southwest-northeast.

Holocene sands are typically underlain by Pleistocene sand deposits commonly known as ‘Botany Sands’ from 10 to 30 m below the ground surface over the Pleistocene aged clay beds unit (Qps) (McNally and Branagan, 1998). Descriptions of the mapped regional geological units in the project area are tabulated in Table 1 and are presented in Appendix A, Figure 6.

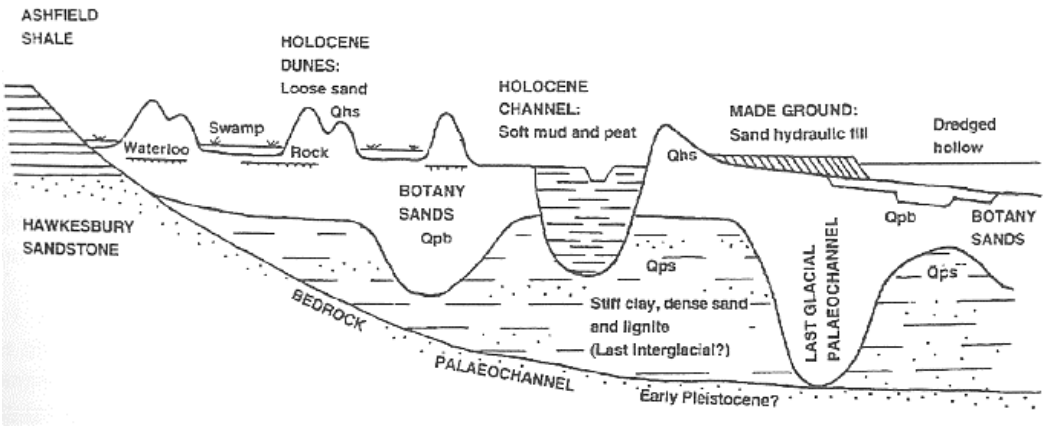
Table 1 Mapped geological unit descriptions (Herbert, 1983; McNally and Branagan, 1998)

Geological unit (code)	Description	Origin
Holocene marine sands (Qhd)	Loose, medium to fine grained “marine” sand with podsols	Transgressive dunes
Botany Sands (Qpb)	Uniformly graded, fine to medium sized quartz grains with lenses and bands of organic clay	Aeolian and littoral sands
Pleistocene clay beds (Qps)	Dense, beach and dune sands with lignite lenses and stiff marine clays and sandy clays.	Estuarine and fluvial clays, aeolian sands
Hawkesbury Sandstone (Rh)	Medium to coarse grained quartz sandstone, very minor shale and laminite lenses	Braided alluvial channel fill

The Great Sydney Dyke which runs from Waverly to Rozelle is mapped within the Hawkesbury Sandstone unit east of the project area and in Ashfield Shale west of the project area in Surry Hills (Herbert, 1983; McNally and Branagan, 1998). The dyke has not been recorded at the proposed site, however the site is located along the strike of the mapped occurrences.

The idealised stratigraphy of the Botany Basin is presented in Figure 3. The proposed site is anticipated be located in an area similar to the left-hand half of the diagram, underlain by Holocene aged dune deposits (Qhs) over Pleistocene aged Botany Sands and clays (Qpb and Qps) within a Hawkesbury Sandstone paleovalley that drain in a southerly direction.

Figure 3 Relationship between stratigraphic units in the Botany Basin, roughly northwest to southeast (not to scale) (McNally and Branagan, 1998)



4.3 Acid sulfate soils

The NSW Office of Environment and Heritage Acid Sulfate Soil (ASS) Risk Map dataset does not identify any risk of ASS in the vicinity of the project area (Naylor et al., 1998).

4.4 Salinity

The proposed site is not within a mapped soil salinity risk area. Limited water quality data is available within the DPI Office of Water groundwater bores dataset, however the data available indicates salinity levels are < 300 mg/L i.e. 'fresh' water quality (Australian Water Resource Council, 1976). A review of bores in the northern zone of the Botany Sands aquifer, where the project area is located recorded salinity levels between 130 – 600 uS/cm, also indicating 'fresh' water quality (Bish et al., 2000).

4.5 Rainfall

Rainfall data available from the BoM was reviewed for two stations in the vicinity of the project area: the Centennial Park station and the Randwick Racecourse station. Details of the rainfall stations are provided in Table 2 and a summary of key rainfall statistics are summarised in Table 3.

Table 2 Available rainfall stations near the project area

Weather station	Station number	Data availability	Approximate distance from site
Centennial Park	066160	June 1900 to July 2015	800 m
Randwick Racecourse	066052	January 1937 to present	2 km

Table 3 Summary of rainfall statistics

Weather station	Mean annual rainfall	Highest monthly average	Lowest monthly average
Centennial Park	1256.8 mm	April, 131.7 mm	September, 71.3 mm
Randwick Racecourse	1323.5 mm	March, 147.2 mm	September, 66.5 mm

The available monthly rainfall data from 1900 to present is graphed in Appendix A, Figure 7, where the available data from Centennial Park station has been supplemented with rainfall data from the Randwick Racecourse station from August 2015 to February 2018. A cumulative rainfall distribution plot based on the monthly average rainfall data is presented in Appendix A, Figure 8.

4.6 Surface water features, catchments and flow

The proposed site is located within the Georges River Catchment, which has a catchment area of 1,890 km^2 and drains into Botany Bay located approximately 7.8 km south of the proposed site. Surface water receptors near the proposed site include Kippax Lake (approximately 150 m west) and the Centennial Park ponds (approximately 940 m south), which act as drainage basins for stormwater runoff.

4.7 Surrounding land use

4.7.1 Current land use

The current Sydney Football Stadium is surrounded by a variety of land uses including residential, commercial and recreation areas. The northern side of the stadium is bounded by Moore Park Road, which separates the site from Victoria Barracks and residential properties. Within the Moore Park precinct commercial land use includes film studios and the Sydney Cricket Ground. The Moore Park Parklands including Kippax Lake are located on the western side of the current stadium.

4.7.2 Heritage land use

Busby's Bore is a heritage listed tunnel constructed in between 1827 and 1837 to supply water from Centennial Park to Hyde Park, via the Moore Park precinct (Godden Mackay Logan, 2006). The tunnel was constructed between vertical shafts and the nominal cross section of the tunnel is 1.8 m high and 0.9 m wide, which varies along the alignment (McNally and Branagan, 1998). Indicative plans and references indicate Busby's Bore runs along the eastern and northern sides of the current Sydney Football Stadium where it has been suggested that the tunnel was constructed within sandstone in this area (Godden Mackay Logan, 2006; McNally and Branagan, 1998).

4.8 Groundwater

4.8.1 Groundwater occurrences, levels and flow

Two aquifers are present within the project area including the Botany Sands aquifer, which is underlain by the porous rock Hawkesbury Sandstone aquifer of the Sydney Central Basin Groundwater Source (Office of Water, 2011a). It is anticipated that the project will primarily interact with the Botany Sands aquifer, which this groundwater assessment has focused on.

The Botany Sands aquifer comprises Pleistocene and Holocene sediments that have been deposited within the Hawkesbury Sandstone basin. The Pleistocene and Holocene sediments largely comprise sand with some peat and clay lenses, underlain by a basal layers of estuarine clays, sands and gravel lenses (Hatley, 2004). The proposed site is located at the northern edge of the basin, where the aquifer is generally unconfined (Hatley, 2004). Semi-confined aquifers occur within the Botany Sands aquifer due to discontinuous silt, peat, clay and Waterloo Rock (coffee rock) layers separating lower aquifers from the overlying unconfined sands.

The Botany Sands aquifer is primarily recharged by rainfall, where open spaces such as the Centennial Park and Moore Park parklands offer large areas for rainfall to infiltrate. A second source of recharge is from rainfall on the surrounding jointed sandstone rim (Jankowski and Beck, 1998). Groundwater flow in the project area is towards the south-west and broadly follows the topography and surface drainages features and ponds across the basin (Hatley, 2004). Similarly, groundwater levels recorded in the DPI Office of Water groundwater bore locations and geotechnical investigations support this south-west flow model. At the northern end of the current Sydney Football Stadium, groundwater levels recorded are recorded at approximately 36 mAHD and decrease to approximately 32 mAHD at the southern end of the Sydney Cricket Ground and towards Anzac Parade (Appendix A, Figure 9). Groundwater yield from the northern area of the Botany Sands aquifer typically ranges from 1 to 41 L/s, with an average yield of 5 L/s (Bish et al., 2000).

The interaction between Botany Sands aquifer and the Hawkesbury Sandstone aquifer are not widely understood (Hatley, 2004). It is anticipated that the Hawkesbury Sandstone aquifer does receive some recharge from the overlying

Botany Sands aquifer and groundwater flow paths are largely due to defects within the rock mass related to local scale stress relief effects and broader scale deformation features (Russell et al., 2009). Groundwater yield from Hawkesbury Sandstone in the project area is typically between 0.3 and 1 L/sec, and salinity ranges from 80 to 500 mg/L (Russell et al., 2009).

4.8.2 Groundwater quality

Groundwater quality in the Botany Sands aquifer has been affected by contamination associated with industrial developments, urbanisation and over-abstraction from the aquifer (Acworth and Jankowski, 1993). The chemical composition of groundwater in the northern zone of the Botany Sands aquifer, is the results of rainwater recharge mixed with stormwater run-off from the surrounding urban areas, producing a Cl-HCO_3-SO_4-Ca-Na water type (Acworth and Jankowski, 1993). Relative to the rest of the Botany Sands aquifer, the Moore Park area has lower conductivity values (fresh water) and Na^+ concentrations, higher pH, significantly higher values of Ca^{2+} and HCO_3^- and depleted SO_4^-, where the difference is accounted for by the flux of contaminated water and redox reaction in the aquifer (Jankowski and Yu, 1998).

An extract of groundwater quality results sampled from wells installed in Moore Park for the Sydney Light Rail project (SLR DJV, 2016) and the relative 2004 Australian Drinking Water Guideline (ADWG) aesthetic value is presented in Table 4.

Table 4 Extract of groundwater quality results and ADWG values in Moore Park

Parameter	Units	ADWG aesthetic value	SLR DJV 2016	
			Range	Average
pH	pH units	6.5 – 8.5	5.78 - 6.25	6.1
Conductivity	µS/cm	N/A	360 - 593	455.5
Temperature	C	N/A	19.3 - 21.3	19.9
Dissolved oxygen	mg/L	>85%	0.85 - 3.67	2.5
Redox	mV	N/A	33 - 49	44.8
Calcium (dissolved)	mg/L	N/A	11 - 35	21.0
Potassium (dissolved)	mg/L	N/A	2.4 - 4.7	3.4
Sodium (dissolved)	mg/L	180	29 - 39	33.0

Parameter	Units	ADWG aesthetic value	SLR DJV 2016	
			Range	Average
Magnesium (dissolved)	mg/L	N/A	6.3 - 8.7	7.5
Bicarb alkalinity as CaCO3	mg/L	N/A	15 - 79	48.7
Carbonate alkalinity CaCO3	mg/L	N/A	<5	<5
Total alkalinity as CaCO3	mg/L	N/A	15 - 79	48.7
Sulphate (SO4)	mg/L	250	11 - 26	16.3
Chloride (Cl)	mg/L	250	10 - 15	13.0

4.9 Hydraulic conductivity

Previous studies of the Botany Sands aquifer have shown that minor changes in lithology can have significant impacts upon the hydraulic properties of the aquifer (Jankowski and Beck, 1998). Changes to the depositional environment within the Botany Basin have created a sequence of discontinuous estuarine, swamp and aeolian deposits with varying material compositions. As a result, the hydraulic conductivity (K) of the Botany Sands aquifer can vary both vertically and laterally and significant, localised changes in the hydraulic conductivity are common (Jankowski and Beck, 1998). A summary of published hydraulic conductivity values for the Botany sands aquifer is presented in Table 5.

Table 5 Summary of hydraulic conductivity values for the Botany Sands aquifer

Source	Description	Lower bound K (m/s)	Upper bound K (m/s)	Adopted K (m/s)
Merrick 1994	Laboratory testing	1.4×10^{-4}	3.4×10^{-4}	-
	Aquifer testing	2.3×10^{-4}	9.8×10^{-4}	-
	Default model value	-	-	3.2×10^{-4}
	East Botany industrial area model	-	-	2.3×10^{-4}
	Adjacent to Alexandria Canal model	-	-	1.6×10^{-4}

Source	Description	Lower bound K (m/s)	Upper bound K (m/s)	Adopted K (m/s)
SLR DJV 2016	BH-10-S, Sand	-	-	1.8×10^{-5}
	BH-11-S, Sand	-	-	4.2×10^{-6}
	BH-12-S, Sand	-	-	5.4×10^{-6}
Jankowski and Beck 1998	Quartz sand	2.1×10^{-4}	2.5×10^{-4}	-
	Silty/peaty sand	5.8×10^{-5}	1.4×10^{-4}	-
	Sandy peaty/clay	0	1.2×10^{-7}	-

The hydraulic conductivity of Hawkesbury Sandstone is largely dependent upon the defect characteristics of the rock mass which are influenced by overburden pressure and in-situ stress conditions (Tammetta and Hewitt, 2004). In the project area it is anticipated that the hydraulic conductivity of the Hawkesbury Sandstone unit is significantly less than the Botany Sands aquifer.

4.9.1 Groundwater users

A search of the DPI Office of Water groundwater bore database indicates there are 20 groundwater bores within a one-kilometre radius of the proposed site, where 13 are either active or the licence has been converted from *Water Act 1912* to *Water Management Act 2000.* The bores are privately owned or the owner is unknown and are used for purposes including recreation/irrigation, monitoring, domestic and one test bore.

The Sydney Cricket Ground owns three groundwater wells under water extraction licence 24543, which allow 20 ML/year of groundwater to be extracted from the Botany Sands aquifer.

4.9.2 Groundwater sharing plan

The project area is located within the NSW *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* with specific rules that apply to the Botany Sands aquifer. The Botany Sands aquifer has been divided into two management zones covered under section 324 of the *Water Management Act 2000* prohibiting the extraction of groundwater for purposes other than recreational or commercial irrigation, and water taken for monitoring purposes (Figure 4). The project site is located at the northern end of Botany Management Zone 2, where an embargo was placed in 2007 to prevent additional commercial extraction of groundwater under the *Water Act 1912* (Office of Water, 2011a). A summary of the Botany Sands aquifer groundwater allocations is presented in Table 6.

Figure 4 Botany Sands aquifer management zones, excerpt from (Office of Water, 2011b)

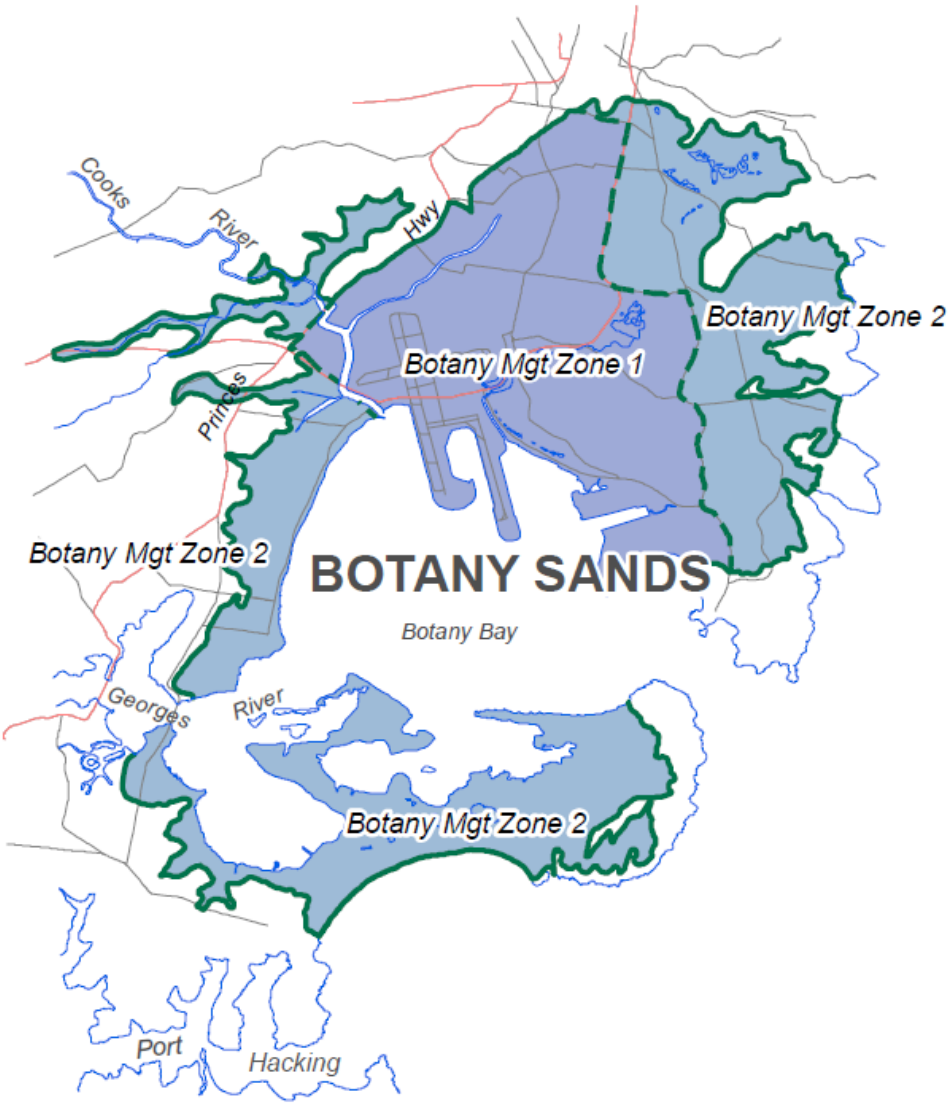


Table 6 Botany sands aquifer groundwater recharge and allocations (Office of Water, 2011a)

Aquifer area	91.12 km^2
Average annual rainfall	101,413 ML
Infiltration	3%
Total estimated average annual rainfall recharge	30,424 ML/year
Planned environmental water	15,740 ML/year
Long term average annual extraction limit	14,684 ML/year

4.9.3 Groundwater Dependent Ecosystems

A review of the BoM Groundwater Atlas and *Water Sharing Plan for the Greater Metropolitan Region Groundwater Sources 2011* indicates there are no Groundwater Dependent Ecosystems (GDEs) within the project area. Terrestrial GDEs were identified within Centennial Park approximately 900 m and 1400 m south east of the proposed site (Appendix A, Figure 10). Terrestrial ecosystems rely on the subsurface presence of groundwater, which includes the following vegetation ecosystems in Centennial Park:

- Eastern Suburbs Banksia Scrub
- Coastal Freshwater Lagoon
- Coastal Sand Swamp Forest

5 Conceptual hydrogeological model

A conceptual hydrogeological model is presented for North-South and East-West alignments of the proposed project area in Appendix A, Figure 11. Three systems have been considered in the hydrogeological model: surface water and two regional aquifers.

- The conceptual hydrogeological model comprises two aquifers: The Botany Sands aquifer is an unconfined aquifer typically encountered within 9 m depth below ground surface in the project area. The aquifer comprises surficial fill material underlain by sands up to approximately 12 m thick over estuarine silts, clays and sands increasing in thickness up to approximately 10 m towards the south-west. Upon review of local groundwater levels and the project plan it is not anticipated that the excavation for a basement will intercept this aquifer.The aquifer is largely recharged by rainfall events and flows in a south-westerly direction. The aquifer is used for irrigation/recreation, monitoring and domestic purposes due to its low salinity water quality and relatively high yields. Due to favourable water quality and high yields, the aquifer is susceptible to contamination.
- The Hawkesbury Sandstone aquifer underlies the Botany Sands aquifer and comprises medium to coarse grain quartz sandstone. The estimated depth to Hawkesbury Sandstone is approximately 12 m and 2.5 m at the northern and eastern sides of the proposed site, respectively, where the top of rock level dips to the south west. Upon review of local groundwater levels and the project plan it is not anticipated that the excavation for a basement will intercept this aquifer.

6 Impact assessment

6.1 Construction phase impacts

The construction phase of the proposed redevelopment may impact upon the following aspects of groundwater including:

- Levels, flow and connectivity due to dewatering or temporary cut-off walls required for construction to reduce and redistribute flow paths, particularly when groundwater is perched following rainfall recharge
- Groundwater chemistry, including groundwater pollution due to spills and leakages from construction plant
- Groundwater users, due to interference with the current groundwater regime that may affect anthropogenic or surface water receptors such as Kippax Lake that rely upon particular groundwater levels and quality

6.2 Operation phase impacts

The operation phase of the proposed redevelopment may impact upon the following aspects of groundwater including:

- Levels, flow, connectivity and groundwater storage due to the redistribution of groundwater flow paths, particularly if additional piles and/or basements are included in the redevelopment
- Groundwater chemistry, from pollution caused by vehicles accessing the site and chemicals used for stadium maintenance, which are anticipated to be minor
- Groundwater users, which are not anticipated to cause a major impact once the redevelopment is complete, but there could still be groundwater level and quality impacts upon anthropogenic user and surface water receptors

6.3 Safeguards, management and mitigation measures

Mitigation measures are required to minimise the impact of the project's construction and operation on groundwater. The major impacts to the groundwater regime in the project area are changes in groundwater levels and quality.

Prior to construction a Groundwater Management Plan (GWMP) should be developed and implemented. A mixture of deep and shallow groundwater monitoring wells should be installed prior to construction where deep wells monitor the Hawkesbury Sandstone aquifer and shallow wells monitor the Botany Sands aquifer. The wells should be installed upstream and downstream of the site in the following arrangement:

- Two shallow wells and one deep well on the northern side of the site with a groundwater level data logger in one of the shallow wells

- Two shallow wells and one deep well spread between the western and southern edges of the site with groundwater level data loggers installed in the southern-most shallow well and in the deep well.

The existing groundwater regime and quality should be established prior to construction and wells should be monitored regularly during construction for adverse regime changes or changes to water quality induced by construction. Further monitoring details should be included in a groundwater monitoring plan (GWMP), which reflects the water quality criteria in the National Water Quality Management Strategy Guideline No. 4 (ANZECC and ARMCANZ, 2000) or Australian Drinking Water Quality Guidelines (NHMRC and NRMMC, 2011).

Other safeguards and mitigation measures to be adopted before and during construction are presented in Table 7.

Table 7 Groundwater safeguards and mitigation measures

Impact	Groundwater safeguard / mitigation measure	Responsibility	Timing
Changes to groundwater flow and levels, disturbance of surface water receptors	• Construct groundwater monitoring wells including level loggers • Implement a Groundwater Management Plan	Contractor	Pre-construction and construction
Water pollution during construction	• All fuels and chemicals are to be stored in a secure, impervious bunded area at least 50 m from drainage receptors in the construction compound and in accordance with relevant Material Safety Data Sheets • A Spill Response Procedure should be established for the project • On site drainage measures and erosion and sediment controls should be in accordance with Landcom's Managing Urban Stormwater: Soils and Construction guidelines (Blue Book)	Contractor	Pre-construction and construction
Water pollution during operation	• All fuels and chemicals are to be stored in a secure, impervious bunded area at least 50 m from drainage receptors on site and in accordance with relevant Material Safety Data Sheets	Operator	Post construction

Impact	Groundwater safeguard / mitigation measure	Responsibility	Timing
	• A Spill Response Procedure should be established for the site		
Disturbance to groundwater users, particularly surface water receptors	• Minimise changes in groundwater levels that may impact upon nearby surface water receptors • A Groundwater Management Plan should be developed and implemented where groundwater is encountered during the works	Contractor	Construction

References

Acworth, I., Jankowski, J., 1993. Hydrogeochemical zonation of groundwater in the Botany Sands aquifer, Sydney. AGSO J. Aust. Geol. Geophys. 14, 193–199.

ANZECC and ARMCANZ, 2000. Australian and New Zealand guidelines for fresh and marine water quality, Volume 1. Australian and New Zealand Environment and Conservation Council, Agriculture and Resource Management Council of Australia and New Zealand.

Australian Water Resource Council, 1976. Review of Australia's Water Resources, 1975. Department of National Resources, Canberra.

Bish, S., Realica, S., Wischusen, J., 2000. Botany Sand Beds (GWMA 018), Botany Basin, NSW. Northern, Southern and Western Zones. Status Report No. 2. Department of Land and Water Conservation – Sydney-South Coast Region.

Godden Mackay Logan, 2006. Entertainment Quarter, Australian Film, Television and Radio School, Environmental Assessment - Heritage Impact Statement - Addendum Report.

Hatley, R.K., 2004. Hydrogeology of the Botany Basin. Australian Geomechanics 39.

Herbert, C., 1983. Sydney 1:100,000 scale Geological Series Sheet.

Jankowski, J., Beck, P., 1998. Micro-scale hydrogeological and hydrochemical heterogeneity of the saturate portion of a sandy aquifer, Botany Sands Aquifer, Sydney, in: Environmental Geology of the Botany Basin. Conference Publications for the Environmental, Engineering and Hydrogeology Specialist Group, Geological Society of Australia, Springwood, NSW, pp. 70–92.

Jankowski, J., Yu, X.W., 1998. Hydrogeochemistry of the Botany Sands aquifer, in: Environmental Geology of the Botany Basin. Conference Publications for the Environmental, Engineering and Hydrogeology Specialist Group, Geological Society of Australia, Springwood, NSW, pp. 37–57.

McNally, G.H., Branagan, D.F., 1998. An overview of the engineering geology of the Botany Basin, in: Environmental Geology of the Botany Basin. Conference Publications for the Environmental, Engineering and Hydrogeology Specialist Group, Geological Society of Australia, Springwood, NSW, pp. 1–23.

Naylor, S.., Chapman, G.A., Atkinson, G., Murphy, C.L., Tulau, M.J., Flewin, T.C., Milford, H.B., Morand, D.T., 1998. Acid sulfate soil risk mapping.

NHMRC and NRMMC, 2011. Australian drinking water guidelines 6. Commonwealth of Australia, Canberra.

Office of Water, 2018. Groundwater Monitoring Sites.

Office of Water, 2011a. Water Sharing Plan, Greater Metropolitan Region Groundwater Sources, Background document. NSW Government, Sydney, NSW.

Office of Water, 2011b. Water sharing plan for the greater metropolitan region groundwater sources 2011. Groundwater sources, management zones & groundwater dependint ecosystems.

Russell, G., McKibbin, D., Williams, J., Gates, G., 2009. A groundwater resource assessment of the triassic rocks of the Sydney Basin. Presented at the Groundwater in the Sydney Basin Symposium, IAH NSW, Sydney, NSW.

SLR DJV, 2016. Design report, hydrogeology and groundwater protection (No. SLR-DJV-D40-DRA-REP-000040).
Tammetta, P., Hewitt, P., 2004. Hydrogeological properties of Hawkesbury Sandstone in the Sydney region. Aust. Geomech. 39, 91–107.

Appendix A

Figures

Legend

- Proposed stadium footprint
- Busby's bore (approximate)

Client	
Infrastructure New South Wales	
Job Title	
Sydney Football Stadium Redevelopment	
Figure Title	
Locality plan	

Metres: 0 50 100 150 200

Issue	Date	By	Chkd	Appd
P	16/03/2018	TR	JC	JC

ARUP

Level 10, 201 Kent Street
PO Box 76 Millers Point
Sydney, NSW 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A3	Figure Status
1:4,000	Preliminary

Coordinate System: GDA 1994 MGA Zone 56

Job No	Figure No
260159-00	005

Legend

- Qhd - Botany sands
- Rh - Hawkesbury Sandstone
- Proposed stadium footprint

Client
Infrastructure New South Wales

Job Title
Sydney Football Stadium Redevelopment

Figure Title
Regional Geology

Metres
0 50 100 150 200

Issue	Date	By	Chkd	Appd
P	16/03/2018	TR	JC	JC

ARUP
Level 10, 201 Kent Street
PO Box 76 Millers Point
Sydney, NSW 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A3: **1:4,000**
Figure Status: **Preliminary**
Coordinate System: **GDA 1994 MGA Zone 56**
Job No: **260159-00**
Figure No: **006**

\\global.arup.com\australasia\SYD\Projects\260000\260159-00 Sydney Football Stadium\Work\Internal\Design\Hydrogeology\01 GIS\03_Map\01_Desktop\20180315_Allianz_Hydrogeo_Fig4.mxd

ARUP

Job No.	Sheet No.	Rev.
260159		0

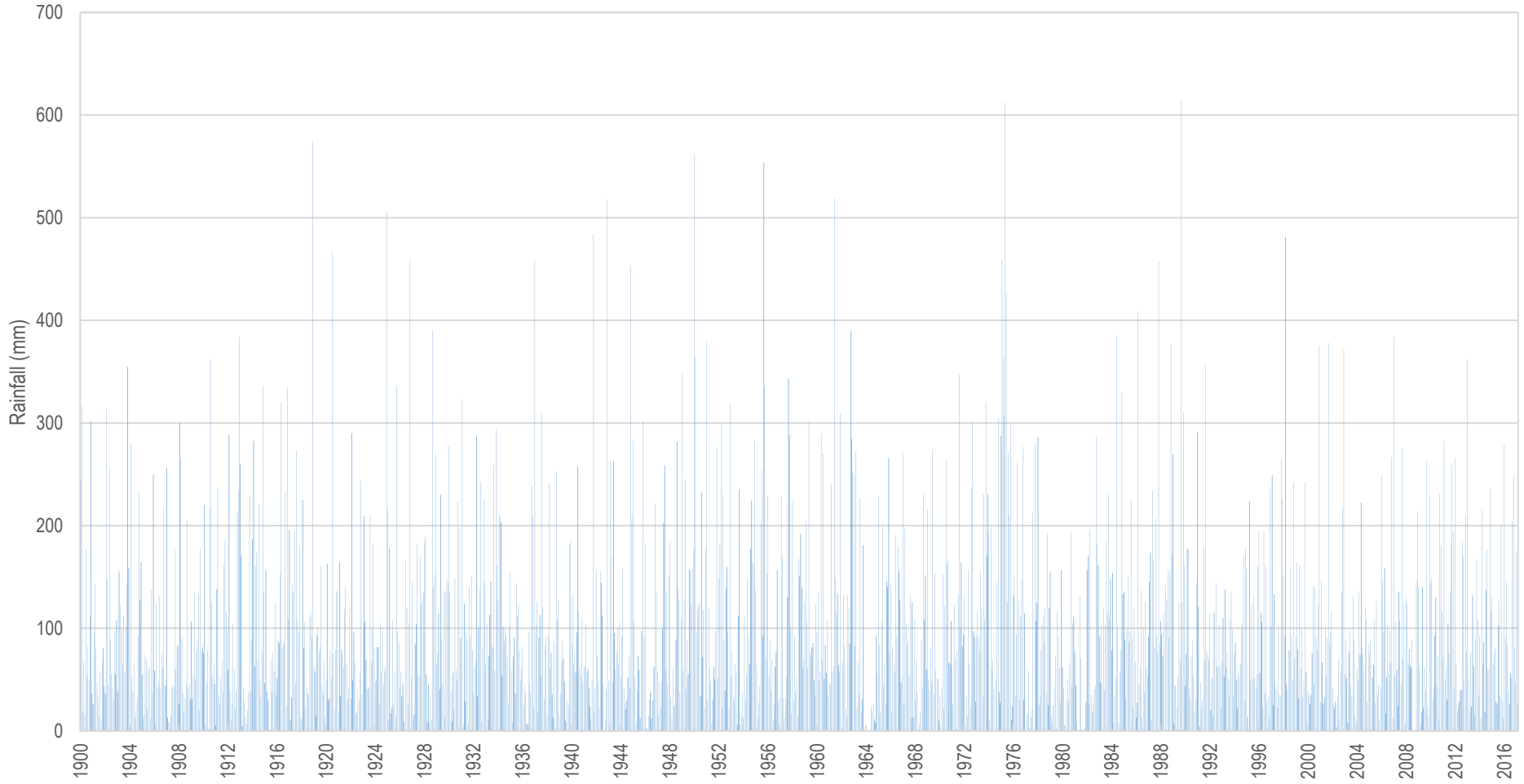
Member/Location: Sydney

Job Title: Sydney Football Stadium Redevelopment

Figure: 007

Design Element: Groundwater Assessment - Monthly rainfall

Made by: TSR | Date: 15/02/2018 | Chd.: JC



ARUP

Job No.	Sheet No.	Rev.
260159		0

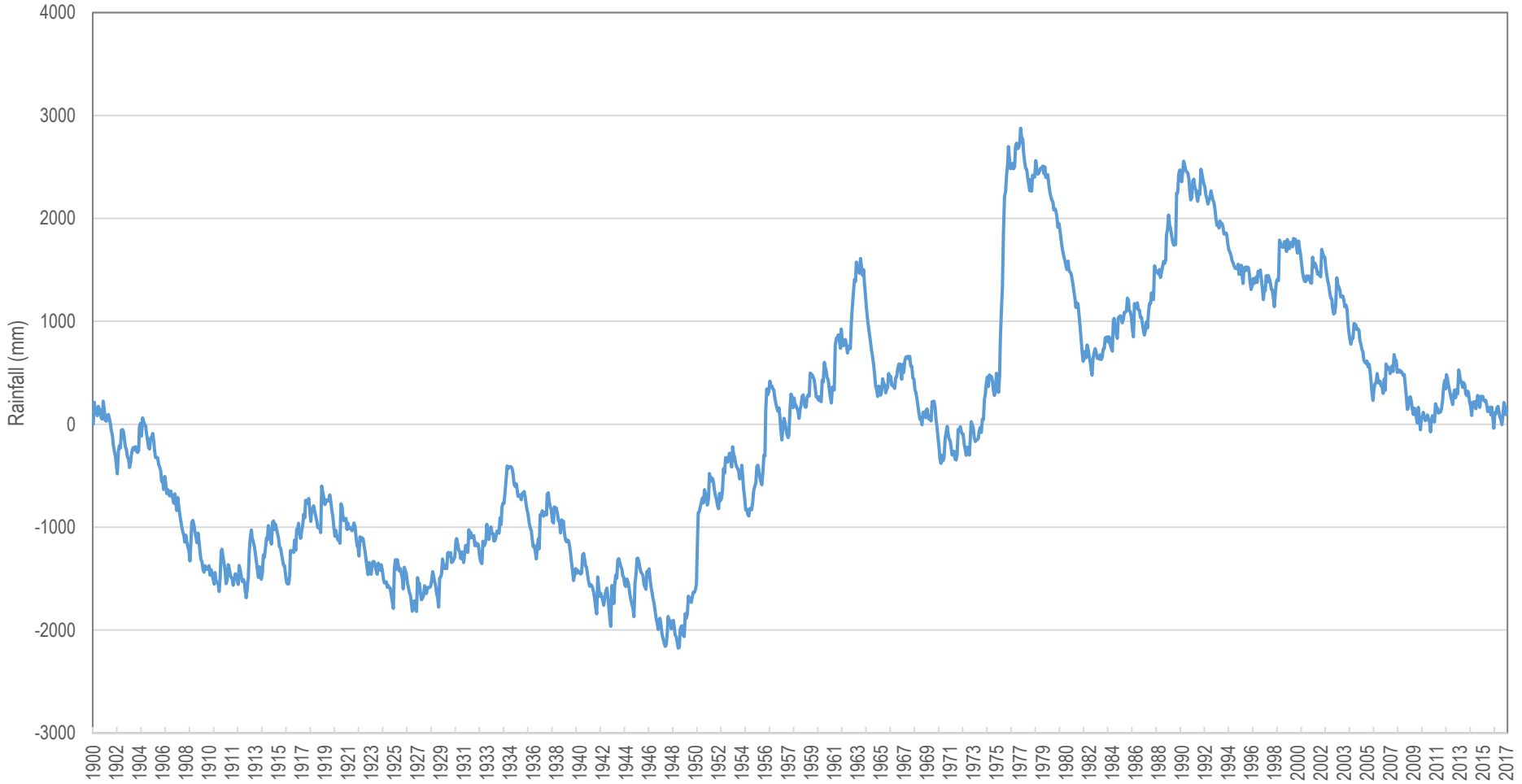
Member/Location: Sydney

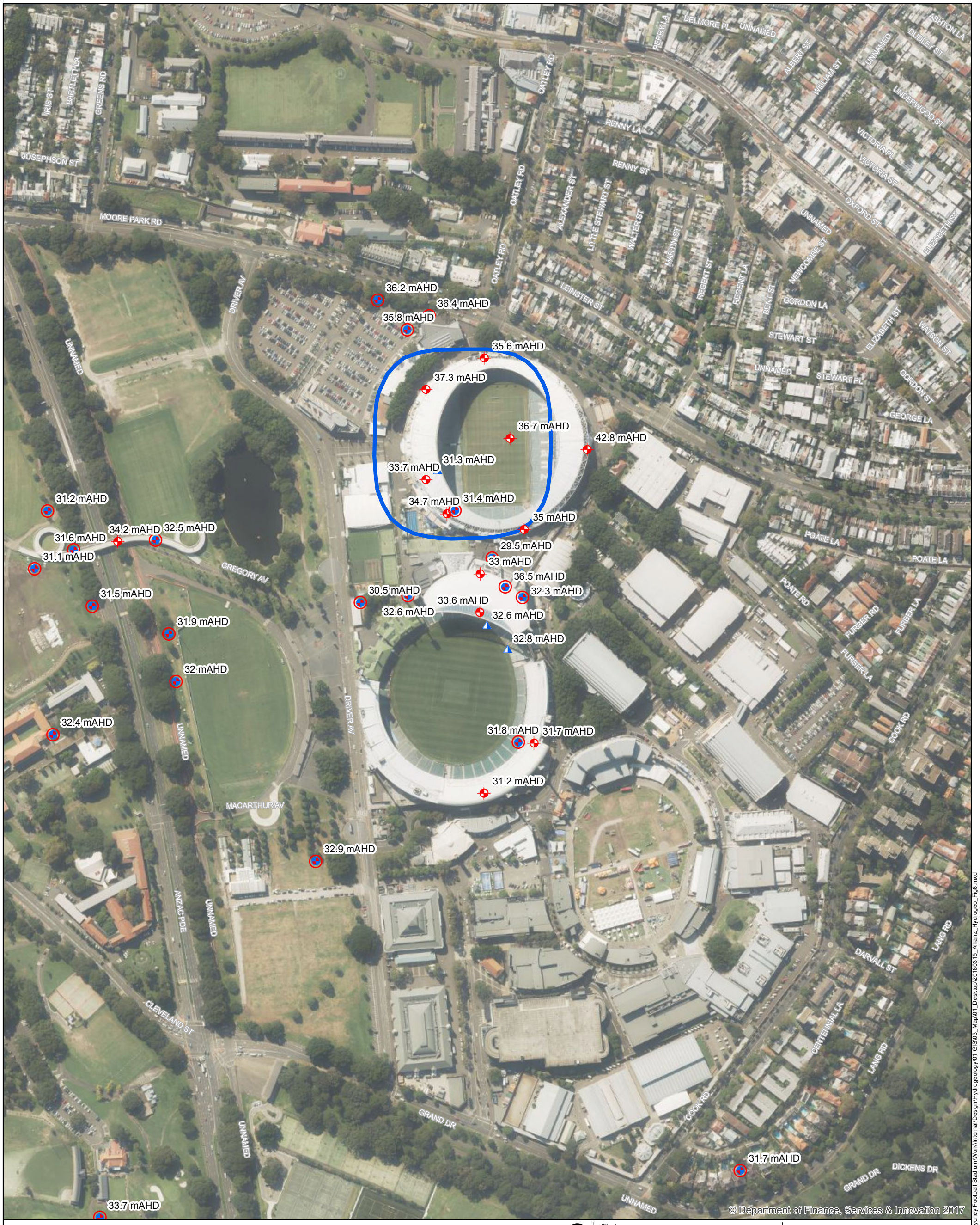
Job Title: Sydney Football Stadium Redevelopment

Figure: 008

Design Element: Groundwater Assessment - Cumulative rainfall distribution

Made by	Date	Chd.
TSR	15/02/2018	JC





Legend

- Borehole
- Cone penetration test
- Standpipe
- Proposed stadium footprint

Client
Infrastructure New South Wales

Job Title
Sydney Football Stadium Redevelopment

Figure Title
Groundwater levels

Metres
0 50 100 150 200

Issue	Date	By	Chkd	Appd
P	16/03/2018	TR	JC	JC

ARUP
Level 10, 201 Kent Street
PO Box 76 Millers Point
Sydney, NSW 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A3	Figure Status
1:4,000	Preliminary

Coordinate System
GDA 1994 MGA Zone 56

Job No	Figure No
260159-00	009

\\global.arup.com\australasia\SYD\Projects\260000\260159-00 Sydney Football Stadium\Work\Internal\Design\Hydrogeology\01 GIS\03_Map\01_Desktop\20180315_Allianz_Hydrogeo_Fig8.mxd

Legend

- Terrestrial GDE
- Waterbodies
- Proposed stadium footprint

Client
Infrastructure New South Wales

Job Title
Sydney Football Stadium Redevelopment

Figure Title
Groundwater Dependent Ecosystems

Metres
0 100 200 300

Issue	Date	By	Chkd	Appd
P	19/03/2018	TR	JC	JC

ARUP
Level 10, 201 Kent Street
PO Box 76 Millers Point
Sydney, NSW 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A3: **1:8,000**
Figure Status: **Preliminary**
Coordinate System: **GDA 1994 MGA Zone 56**
Job No: **260159-00**
Figure No: **010**

\\global.arup.com\australasia\SYD\Projects\260000\260159-00 Sydney Football Stadium\Work\Internal\Design\Hydrogeology\01 GIS\03_Map\01_Desktop\20180315_Allianz_Hydrogeo_Fig7.mxd

West

Distance (m)

East

−100 0 100 200 300 400 500 600

Elevation (mAHD)

80 70 60 50 40 30 20 10

Proposed stadium location

Rainfall infiltration

Rainfall infiltration

Rainfall infiltration

Kippax Lake

3970_P6 (−25.0)

3970_P7 (−25.0)

3970_A4 (−25.0)

3970_A6 (−25.0)

3970_P4 (−15.0)

3970_A7 (−12.0)

Botany Sands aquifer
Holocene sands

Botany Sands aquifer
Pleistocene silts, clays and sands

Hawkesbury Sandstone aquifer
Porous rock

COMMERCIAL IN CONFIDENCE

Legend

- Variable groundwater table
- Botany Sands aquifer - Holocene aged
- Botany Sands aquifer - Pleistocene aged
- Hawkesbury Sandstone aquifer

Client
Infrastructure New South Wales

Job Title
Sydney Football Stadium Redevelopment

Figure Title
Conceptual Groundwater Model

Issue	Date	By	Chkd	Appd
D1	19/03/2018	AO	TR	JC

ARUP

Level 10, 201 Kent Street
PO Box 76 Millers Point
Sydney, NSW 2000
Tel +61 (2)9320 9320 Fax +61 (2)9320 9321
www.arup.com

Scale at A3	Figure Status
N/A	Preliminary

Coordinate System
N/A

Job No	Figure No
260159-00	011

\\global.arup.com\australasia\SYD\Projects\260000\260159-00 Sydney Football Stadium\Work\Internal\Design\Hydrogeology\01 GIS\05_Sections\EW_section_new.mxd

Appendix B

Groundwater works

Location	Easting	Northing	Owner	Monitoring Status	Purpose	End of hole depth (m)	Top of screen (m)	Bottom of screen (m)	Screened strata	Groundwater level (m)	Yield (L/s)
GW017356	335442	6247835	Local Government	Cancelled	Monitoring	30.5	21.3	30.4	Sand	9.1	19
GW024057	335740	6248539	Private	Converted	Recreation (GW)	13.1	-0.2	6.2	Fill, sand, loam, clay	8	1.3
GW024058	335843	6248428	Private	Cancelled	Recreation (GW)	-	-	-	Sand, sandstone	-	-
GW100268	335539	6248483	Private	Inactive	Test Bore	-	-	-	Fill, sand, sandstone	-	-
GW100293	335640	6247770	Private	Converted	Recreation (GW)	20	12	18	Sand, silty sand, sand	6.9	7.5
GW101640	335689	6248243	Private	Converted	Recreation (GW)	17.9	13.2	15.4	Fill, sand, sandstone	7	-
GW104131	335213	6248371	Unknown	Cancelled	Test Bore	20	12.2	18.2	-	7	-
GW104133	335155	6248200	Unknown	Cancelled	Test Bore	20.5	9	14	-	5.5	-
GW105076	335388	6248388	Unknown	Converted	Test Bore	10	0	10	Sand	6	-
GW105473	335922	6249333	Unknown	Active	Monitoring	2.4	-	-	Sand, sandstone	-	-
GW105480	335906	6248557	Unknown	Converted	Recreation (GW)	13.5	0	8	Fill, sand, sandstone	5.1	1
GW105485	335891	6248590	Unknown	Converted	Recreation (GW)	11.5	0	8	Fill, sand, sandstone	7.2	0.5
GW105525	335025	6248227	Unknown	Converted	Domestic	5.5	4.5	5.5	Soil land fill, sandy clay	2.8	1
GW105920	335321	6248323	Unknown	Cancelled	Test Bore	14	-	-	-	6	-
GW106328	335504	6248103	Unknown	Cancelled	Test Bore	9.5	-	-	Sand	-	-
GW106913	336048	6247765	Private	Converted	Domestic	9.5	-	-	Sand	-	-
GW106985	336175	6247889	Private	Converted	Domestic	159	-2	14	Topsoil, sand, sandstone	14	0.1
GW112180	335167	6249351	Private	Active	Monitoring	-	-	-	-	-	-
GW112181	335201	6249161	Private	Active	Monitoring	-	-	-	-	-	-
GW112182	335240	6249077	Private	Active	Monitoring	-	-	-	-	-	-