Barangaroo South

Mod 8 Concept Plan (MP06_0162 MOD 8)

Sydney Observatory Sky View Impact Assessment

Lend Lease and UNSW Global, September 2014

Lend Lease

Table of Contents

1.0 Introduction

This report supports a modification to Concept Plan (MP06_0162) submitted to the Minister for Planning and Infrastructure pursuant to Section 75W of Part 3A of the *Environmental Planning and Assessment Act 1979* (EP&A Act).

The proposed application is the outcome of negotiations between Lend Lease and the NSW Government, including the Barangaroo Delivery Authority, to relocate the approved landmark hotel building site from a pier over Sydney Harbour to a location on land elsewhere on the Barangaroo South site. It also incorporates a number of consequent and related changes to the urban design guidelines that are required to maintain an appropriate built form and public domain outcome for the Barangaroo South site.

1.1 Overview of Proposed Modification

The proposed modification to the Concept Plan seeks to:

- Relocate the landmark building (Block Y) from the harbour onto the land in the Barangaroo South site in front of the existing Blocks 4A, B and C;
- Revise the layout of Blocks 4A-C;
- Amend the size and location of the Southern Cove and public domain;
- Redistribute the GFA, public domain and land uses across development blocks 1-3, 4A-C, X and Y;
- Increase the maximum GFA on the site to provide for additional GFA within the hotel building and redistribution of land uses;
- Increase the height of the buildings within modified 'Block 4' and the relocated Block Y, and;
- Amend the conditions of the Concept Approval to reflect the modifications to development.

It is also proposed to amend Part 12 of Schedule 3 of the Major Development SEPP to reconcile the SEPP with the modifications to the Concept Plan, including amending the location of the RE1 and B4 Mixed Use zone boundaries.

1.2 Site Location

Barangaroo is located on the north western edge of the Sydney Central Business District. It is bounded by Sydney Harbour to the west and north, the historic precinct of Millers Point (for the northern half), The Rocks and the Sydney Harbour Bridge approach to the east and a range of development dominated by large CBD commercial tenants to the south.

The Barangaroo site has been divided into three distinct redevelopment areas (from north to south) - the Headland Park, Barangaroo Central and Barangaroo South. Concept Plan (Mod 8) relates to Barangaroo South only as shown in in Figure 1.

1.3 Background on Sky View Impact Assessment

Sydney Observatory is located at 1003 Upper Fort Street, Millers Point NSW on top of Observatory Hill North East of the Barangaroo South site. Refer to Figure 1 for the location in relation to Barangaroo South. The Observatory was essential to navigation, meteorology, timekeeping and star studies in the 19th and 20th Centuries. Today the Observatory no longer serves these functions and is a museum and public observatory, and provides astronomy education and public sky viewing.

Sydney Observatory initially contacted the Barangaroo Delivery Authority with concerns about the impact of the proposed hotel on its ability to view the path of the planet Venus and have subsequently confirmed that such views are not impacted.

Lend Lease contacted and met with the Sydney Observatory in December 2013 to understand the important view corridors of the Western Sky to view the Sun, Moon, Planets, the Southern Cross and other celestial objects.

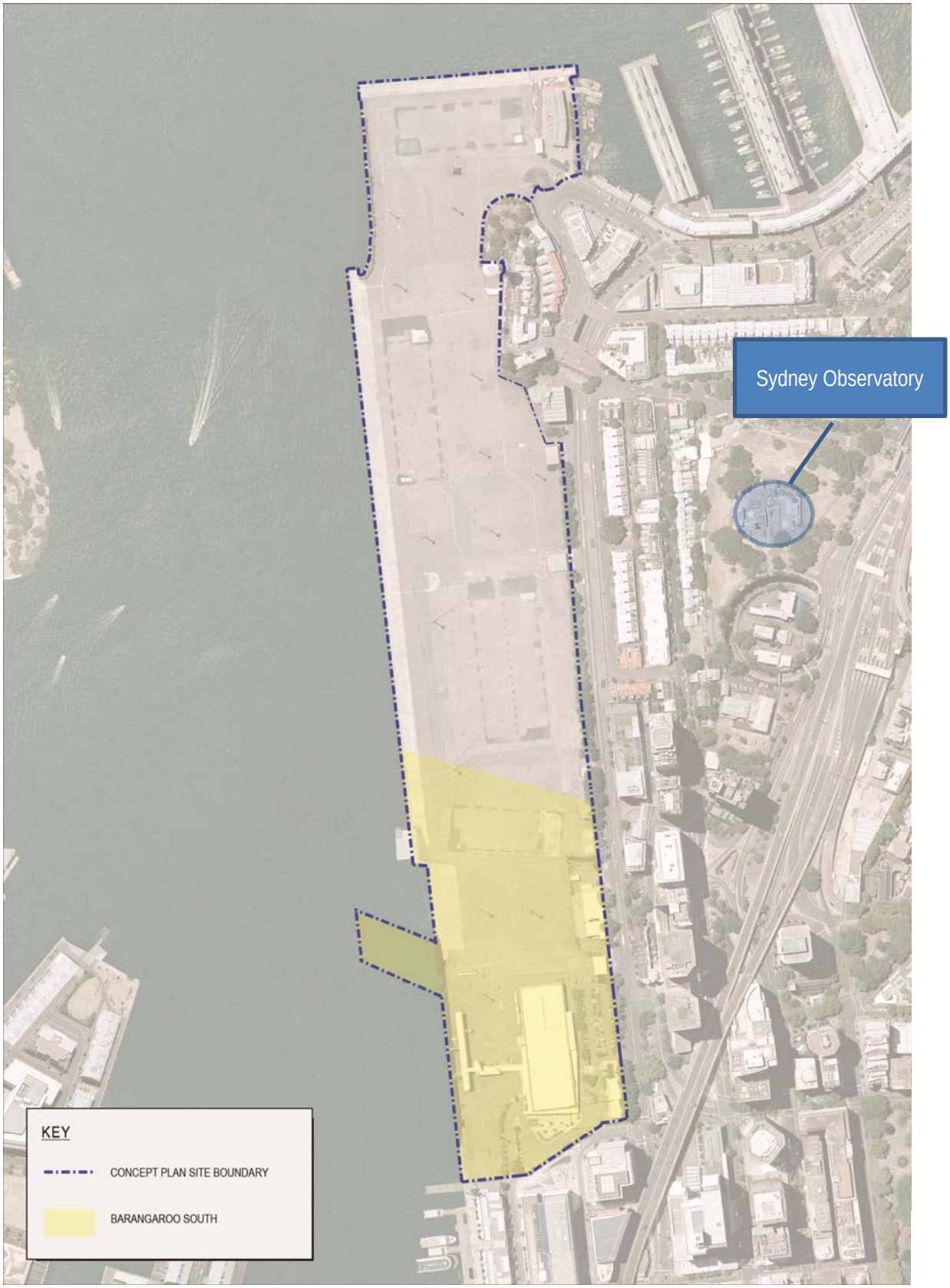


Figure 1: Indicative Site Boundary for Barangaroo South (existing), and Sydney Observatory Location

Modified Director General's Requirements (DGR's) were provided as per Section 75W of the Environmental Planning and Assessment Act 1979 on 15 April 2014. Contained within Item 19 of the Key Issues was the requirement to address the potential impact on the Sydney Observatory, as copied below:

19. Prescribed ~~Airspace for Sydney Airport and~~ Sydney Observatory impacts

- ~~*Identify any impacts of the proposal on the prescribed airspace for Sydney Airport.*~~
- *Undertake an analysis of potential sky view loss and resultant impacts on the functioning of the Sydney Observatory and astronomical sightlines.*

Sydney Observatory has also made comment on previous Concept Plan Modifications (namely Mod 4) within a letter dated 20 June 2011. This letter is contained within Appendix 2. Extracts of the Sydney Observatory concerns relevant to Sky View Impact are copied below:

> *"It is vital that the views from Observatory Hill to the western horizon remain unobscured by built structures, nor diminished by poor-quality lighting at night"*
>
> *"Lighting of the public headland park area is the most significant factor affecting Sydney Observatory"*

These two specific issues with regards to western views and lighting over and within Headland Park and Barangaroo Central are not impacted by this Modification 8, which is associated with Barangaroo South.

This report is prepared to answer the Director General's Requirements and to provide commentary on the specific concerns more recently identified by the Sydney Observatory.

2.0 Sydney Observatory Concerns

The concerns identified by the Sydney Observatory can be summarised as the sky view loss of key target objects in the western sky and the increase of light spill. The Sydney Observatory has concern that these two elements would affect the operation and the functioning of the astronomical observatory.

2.1 Clear View Requirements to the Western Sky

The important view corridors are determined in consultation with the Sydney Observatory (refer to the Sydney Observatory document contained in Appendix 3) are as follows (Note: 'Azimuth' is the angle measured from North to East):

Sun, Moon and Planets:

- The Sun:
  - Winter solstice - 298^{o} Azimuth, and;
  - Summer solstice - 241^{o} Azimuth.
- The Moon: +/- 5^{o} further North or South of the Sun (i.e. between 236^{o} and 303^{o} Azimuth).
- The Solar System Planets: Less than 5^{o} from the Sun at Sunset (i.e. between 236^{o} and 303^{o} Azimuth).

The Southern Cross and nearby objects (Jewel Box, Alf-Cen, Omega-Cen[NGC5139]):

- The Southern Cross (Crux), Jewel Box Cluster (Kappa Crucis Cluster [NGC4755]), and Pointers (Alpha-Centauri and Beta-Centauri, also known as Rigil Kentaurus and Hadar respectively): From 225^{o} up to 210^{o} Azimuth.
- Omega-Centauri (NGC5139) globular cluster: Up to 298^{o} Azimuth at 18^{o} altitude.

Ring Nebula and Star Albireo:

- To the North the Ring Nebula (M57, a dead star) and Albireo (Beta Cygni, a multi-coloured twin star): From 303^{o} Azimuth at 15^{o} altitude.

In summary, the view corridors can be determined as:

- Between 210º and 225º Azimuth at 18º altitude, and;
- Between 236 º and 303 º Azimuth.

2.2 Light Spill

The Sydney Observatory has identified concern about poor quality lighting at night in their 20 June 2011 letter (refer Appendix 2). The Observatory has requested a number of considerations as part of the overall lighting strategy, which can be summarised below:

- Light direction: No light directed up to the sky or horizontally. Light should be directed downward and spill minimised.
- Minimising glow and potential uses of the site: Reduce light-reflecting surfaces and large areas of light emissions producing a glow. Creation of distinct 'night' from 'day approach to not 'flood' the site at nighttime.
- Light timers: To reduce lighting at night.
- Specific lighting recommendations: Use lowest level of lighting as allowed by Australian Standards, light fittings with full cut off with zero UWLR, correlated colour temperature of the light sources should be 2700k (warm white) or less, and minimise unnecessary outdoor lighting.

3.0 View Analysis

The Indicative Master Plan for Concept Plan Mod 8 for Barangaroo South is shown in Figure 2 below.

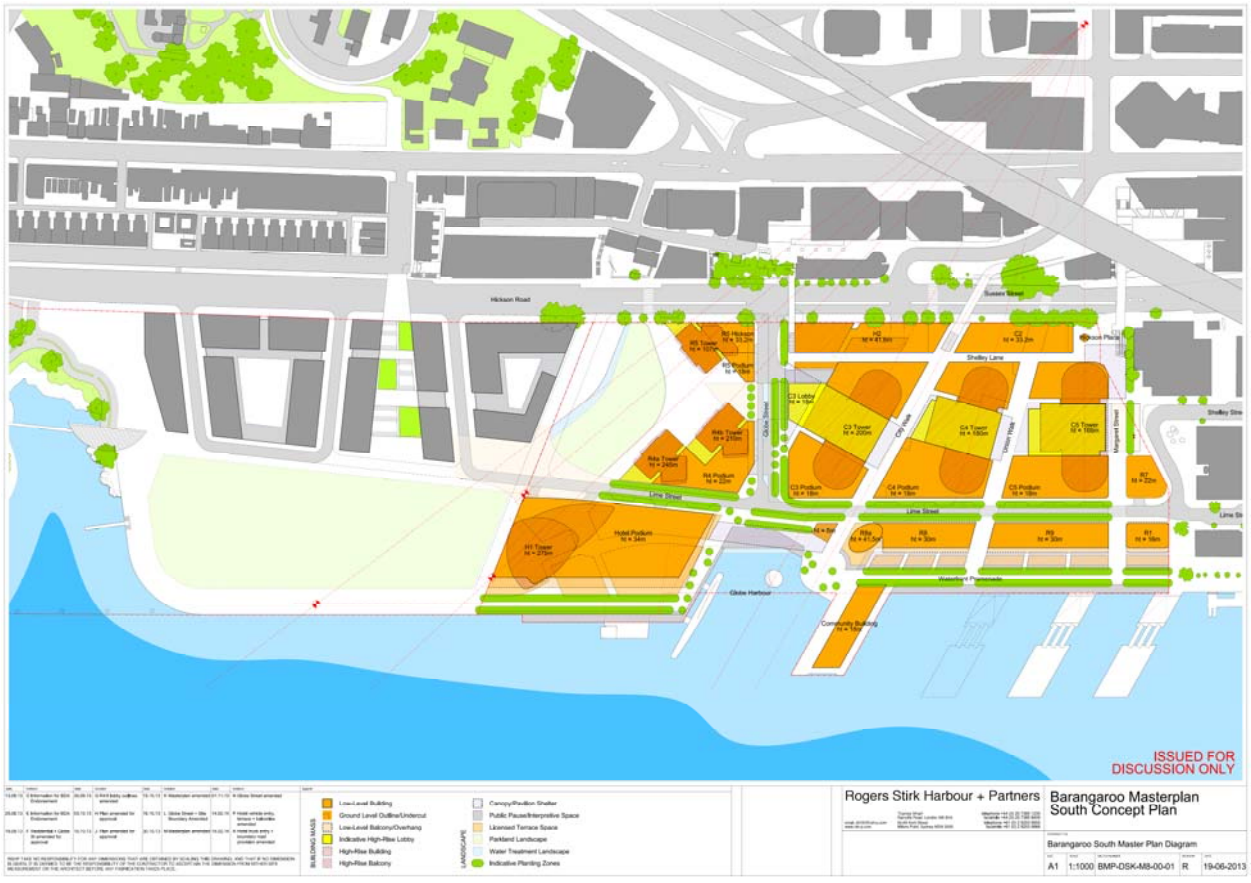


Figure 2: Barangaroo South Indicative Master Plan (Rogers Stirk Harbour + Partners, BMP-DSKM8-00-01/N)

Lend Lease design was commissioned to undertake an assessment of the Sydney Observatory view corridors and has plotted the corridors into a three-dimensional (3D) model. Associated scale diagrams are provided in Appendix 4. For the purposes of this analysis, the Sydney Observatory South Dome is located at N 6,251,973.00, E 333,901.94 and is at a RL of 55.0 metres, and the North Dome is located N 6,251,959.50, E 333,901.81 and is at an RL of 54.5 metres (refer to drawing ASK_SO_001 in Appendix 4).

3.1 Sun, Moon, Planets, Ring Nebula and Star Albireo; Western View Assessment

The view assessment from the Sydney Observatory north and south telescopes towards the West between 236° and 303° Azimuth is shown on Figure 3 below, showing that the Concept Plan does not impact the view corridor for the Sun, Moon and Planets, or the Ring Nebula and Star Albireo.

The Hotel building (H1) is south of 236° Azimuth, and Barangaroo Central is below the view corridor altitude if the current building height envelopes are maintained in accordance with the State Environmental Planning Policy (Major Development) 2005 Height of Buildings Map[1]. Building heights proposed for Barangaroo Central are under an RL of 35 metres, and the Observatory Domes are above this height; at an RL above 54 metres. Note that this modification does not apply to the Barangaroo Central portion of Barangaroo.

Figure 3: View Corridor Diagram from Sydney Observatory, between 236° and 303° (Sun, Moon and Planets - West)

1. SEPP 2005, Height of Buildings Map, SEPP_MD_BAR_HOB-001_20101129, 16 December 2010 to date

3.2 The Southern Cross and Nearby Objects (Jewel Box, Omega-Centauri, Alf-Cen); South Western View Assessment

The view assessment from the Sydney Observatory north telescope towards the South West between 210º and 225º Azimuth at 18º altitude is shown on Figure 4 below.

Results indicate that:

- The Hotel (H1) is north of 225º Azimuth and does not sit within the view corridor;
- The Residential Tower R5 is south of 210º Azimuth and does not sit within the view corridor;
- The Residential Tower R4A sits within the view corridor at between 213.4º and 218º Azimuth, between an altitude of 18º up to 26º altitude. Views are unrestricted above 26º altitude, and;
- The Residential Tower R4B sits within the view corridor at between 208º and 212.5º Azimuth, between an altitude of 18º up to 21º altitude. Views are unrestricted above 21º altitude.

The view corridor impact of Residential Towers R4A and R4B are further indicated on Figure 5 below.

Figure 4: View Corridor Diagram from Sydney Observatory, between 210º and 225º (Southern Cross - SW Sky)

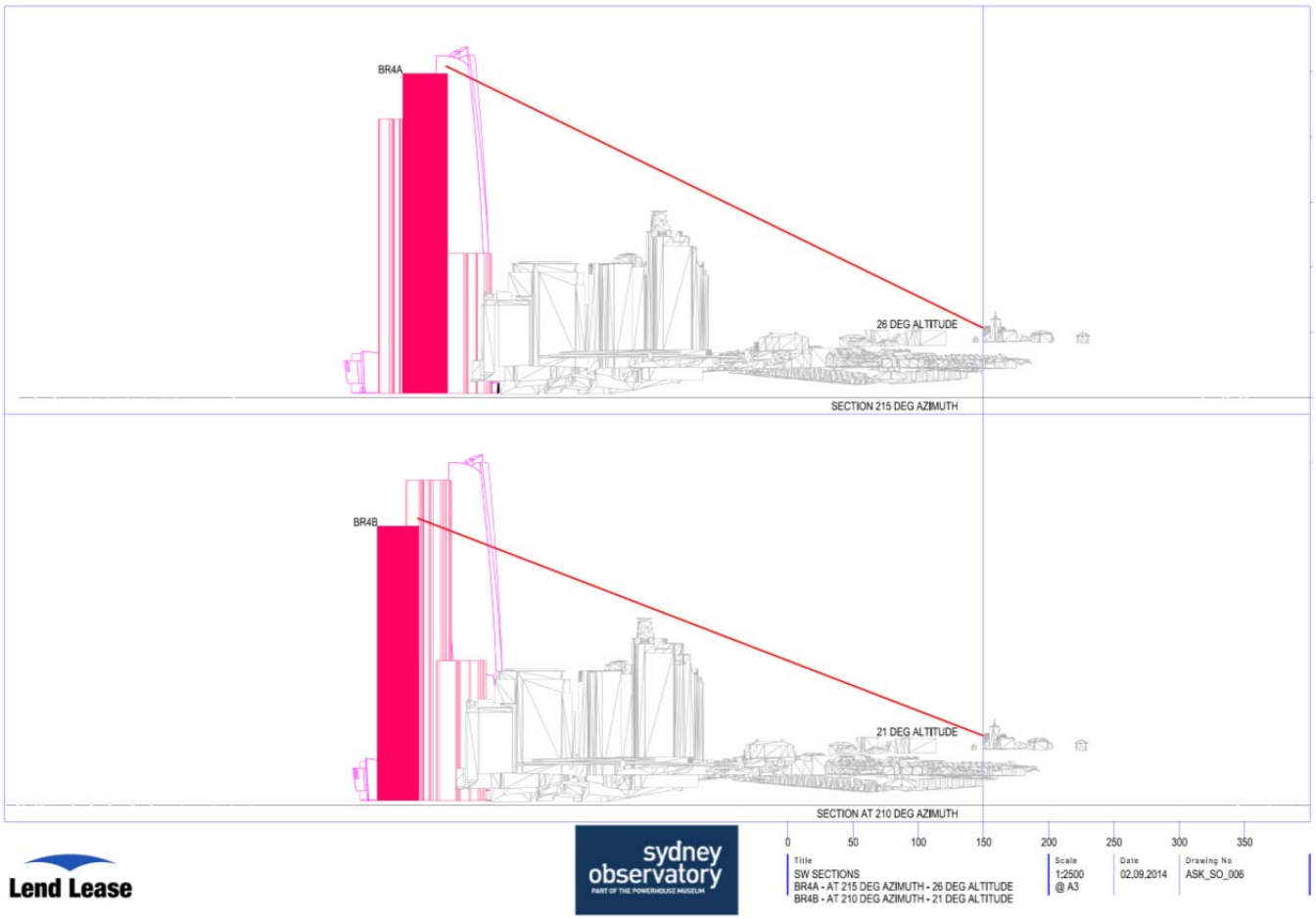


Figure 5: View Impact Sections of Residential Towers R4A and R4B from Sydney Observatory - SW Sky

3.3 View Analysis Summary

From the assessed 3D models, the following observations have been made:

- The Stage 1A Barangaroo South development does not obstruct any of the Sydney Observatory view corridors of the Sun, Moon, Planets, Ring Nebula and Star Albireo (between 205^{o} and 225^{o} Azimuth at 18^{o} altitude, and; between 236^{o} and 303^{o} Azimuth);
- The Stage 1B Hotel (H1) does not obstruct any of the Sydney Observatory view corridors (between 205^{o} and 225^{o} Azimuth at 18^{o} altitude, and; between 236^{o} and 303^{o} Azimuth);
- The Stage 1B Residential Towers R4A and R4B does not obstruct any of the Sydney Observatory view corridors of the Sun, Moon, Planets, Ring Nebula and Star Albireo (between 236^{o} and 303^{o} Azimuth). However views of the Southern Cross and nearby objects (Jewel Box, Omega-Centauri (NGC5139) globular cluster and alf-Cen) are impacted at between 213.4^{o} and 218^{o} Azimuth between an altitude of 18^{o} up to 26^{o} altitude, and between 210^{o} and 212.5^{o} Azimuth between an altitude of 18^{o} up to 21^{o} altitude, and;
- The proposed Barangaroo Central development is unlikely to obstruct any Sydney Observatory view corridors, provided that the current building height envelopes of under RL 35.00 are maintained.

4.0 Timing Analysis

Based on the findings within Section 4.0 of this Report, it is determined that the following target objects are affected by the Mod 8 Concept Plan at between 213.4^{o} and 218^{o} Azimuth between an altitude of 18^{o} up to 26^{o} altitude and between 210^{o} and 212.5^{o} Azimuth between an altitude of 18^{o} up to 21^{o} altitude:

- Southern Cross (Crux);
- Jewel Box cluster (Kappa Crucis Cluster [NGC4755]);
- Omega-Centauri (NGC5139) globular cluster, and;
- The Pointers (Alpha-Centauri and Beta-Centauri. Note: Rigil Kentaurus and Hadar are the old names for Alpha and Beta Centauri respectively).

At no stage is there any view loss on the view corridors of the Sun, Moon, Planets, Ring Nebula and Star Albireo and therefore it is deemed that no further assessment would be required for these target objects.

Unisearch Expect Opinion Services through UNSW Global were commissioned to undertake a study of view times affected by the impact of the Mod 8 Concept Plan. Assistance and data was provided by George Georgevits (B E Hons). The associated report is contained within Appendix 1.

To take into consideration the field of view of the telescope (of 5.7^{o}), to allow a suitable margin for error and allow for some light spillage from bright sources on the top of the building/s just outside the telescope field of view, the assessment herein has been made to a larger and worse-case area than that determined with Section 4.0. All data following has been sampled off the following views corridors from the Sydney Observatory:

- Azimuth Range, between 210^{o} and 219^{o}, and;
- Altitude Range, between 18^{o} and 26^{o}.

It was determined that there are no other well-known target objects of interest to the public that will be obstructed additional to the 4 listed in Section 4.0 above.

4.1 Sydney Observatory Operation and Night Time Viewing Hours

The Sydney Observatory is listed on both the State and UNESCO heritage registers. It was essential to navigation, meteorology, timekeeping and star studies in the 19th and 20th Centuries. Astronomers worked and lived in the building until 1982. Today the Observatory is a museum and public observatory and provides astronomy education and public sky viewing.

Although the Observatory is historically significant as an astronomical observatory the building no longer serves this function. With regards to astronomical observations, the state of NSW is now served by the Australian Astronomical Observatory at Coonabarabran, between the Central West and North West Slopes of regional NSW.

Based on information from the Sydney Observatory website, Night Time Visit Times and Opening Hours are as follows:

> *"Open nightly Monday to Saturday except Christmas Day, Boxing Day and Good Friday holidays; open Sunday nights during school holidays.*
>
> *Evening sessions of about one and a half hours are held regardless of weather. If viewing through the telescopes is not possible due to sky conditions, a fun planetarium session is provided instead.*
>
> *Night session times. Times vary due to time of nightfall and daylight saving; sessions are approximately 90 minutes.*
> - *1 February to 5 April, 8.15pm;*
> - *6 April to 4 October, 6.15pm and 8.15pm;*
> - *5 October to 31 November, 8.15pm, and;*
> - *1 December to 31 January, 8.30pm."*

In summary, it is assumed within this assessment that night time viewing times are as follows:

- Monday to Saturday (6 days) during school term, 7 days outside of school term, excluding Christmas, Boxing Day and Easter Friday;
- 1 February to 5 April, 8.15pm to 9:45pm;
- 6 April to 4 October, 6.15pm to 7.45pm (1st Session), and 8.15pm to 9:45pm (2nd Session);
- 5 October to 31 November, 8.15pm to 9.45pm, and;
- 1 December to 31 January, 8.30pm to 10pm.

Based on the above viewing times, the number of viewing days, sessions and hours on an annual basis would total approximately 326 nights, 491 viewing sessions and 737 viewing hours. This is based on 165 days of double night viewings (two 90 minute Sessions) between 6 April and 4 October and 161 days of single night viewings (one for 90 minutes) on all other dates.

The following times have been assessed, taking into account all night viewing hours from the Sydney Observatory:

Night Viewing Dates	Start	Finish
6 April to 4 October	6.15pm	10.00pm
5 October to 30 November	8.15pm	10.00pm
1 December to 31 January	8:30pm	10.00pm
1 February to 4 April	8.15pm	10.00pm

4.2 Sky View Assessment against Night Time Visit Hours

After detailed analysis by George Georgevits, it was determined that views of the four (4) target objects are obstructed annually by the proposed Modification 8 Concept Plan buildings for a period of time during the night viewing hours between the end of August and through September.

Figure 6 below shows a general view of the night sky sampled at 8.00pm on 16 September with the target objects overlaid within the obstructed views between Azimuth 210° and 219°, and altitude 18° and 26° as identified by the Red box shown.

As an example, at 16 September at 8.00pm, the Mod 8 Concept Plan buildings obstruct 4 out of 5 stars of The Southern Cross (Crux) and the Jewel Box Cluster, but does not obstruct Omega-Centauri or The Pointers (Alpha-Centauri (Rigil Kentaurus) and Beta-Centauri (Hadar)).

An analysis of all night sky views has been undertaken for all target objects defined by the Sydney Observatory which is affected by the Mod 8 Concept Plan against the Sydney Observatory Night Viewing Times. Detailed analysis of the effect on each of the four (4) target objects is summarised as follows:

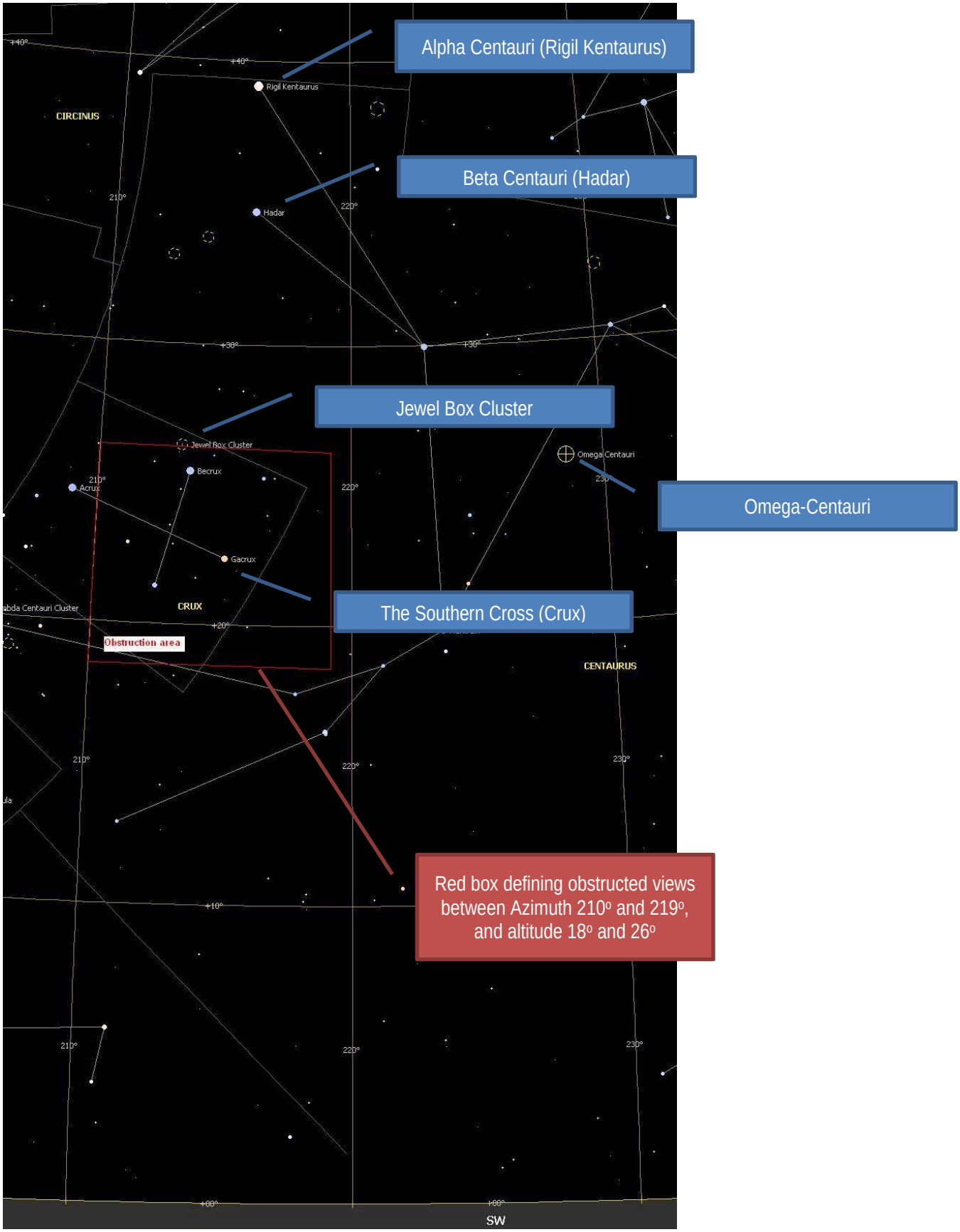


Figure 6: Sample Sky Image at 8.00pm on 16 September, showing obstructed area (in Red) and specified Target Objects (in Blue)

Southern Cross (Crux):

Target Object: Southern Cross (Crux)											
Date (week):	Prior to 4-Aug	4-Aug	11-Aug	18-Aug	25-Aug	1-Sep	8-Sep	15-Sep	22-Sep	29-Sep	After 29-Sep
Obstruction Times:	Does not enter obstructed area	9.41pm to after 10.00pm	9.13pm to after 10.00pm	8.46pm to after 10.00pm	8.18pm to after 10.00pm	7.50pm to 10.00pm	7.23pm to after 10.00pm	6.56pm to after 10.00pm	6.28pm to after 10.00pm	Before 6.15pm to after 10.00pm	Target sets below 18° behind trees and buildings, until early February the next year
Duration of obstruction during Sessions:		4 minutes	32 minutes	59 minutes	90 minutes	90 minutes	112 minutes	139 minutes	169 minutes	180 minutes, both Sessions	
Suggested alternative viewing times:		Full 1st Session, 2nd Session between 8.15pm and 9:41pm	Full 1st Session, 2nd Session between 8.15pm and 9:13pm	Full 1st Session, 2nd Session between 8.15pm and 8.46pm	Full 1st Session only	Full 1st Session only	1st Session between 6.15pm and 7.23pm	1st Session between 6.15pm and 6.56pm	1st Session between 6.15pm and 6.28pm	No views available either Session	

Summary:

- Obstruction of any of the five (5) stars of The Southern Cross (Crux) due to the Mod 8 Concept Plan buildings occurs only between 4 August to 29 September annually.
- Approximate loss of viewing hours due to the Mod 8 Concept Plan buildings is 97 minutes per night for a total of 63 viewing nights out of 326 annual viewing nights.
- Due to current tree and building obstructions up to 18° altitude, the Sydney Observatory currently loses views of The Southern Cross between October and February annually (or around a total of 111 viewing nights, or around 167 viewing hours).
- It is anticipated that a worse-case total of 46 viewing sessions (the 2nd Session between 25 August and 6 October, and the 1st Session of the week commencing 29 September) out of a total of 494 annual viewing sessions will occur where it will not be possible to view the full five (5) stars of The Southern Cross due to the Mod 8 Concept Plan buildings locations.

Jewel Box Cluster (Kappa Crucis Cluster [NGC4755]):

Target Object: Jewel Box Cluster (Kappa Crucis Cluster [NGC4755]):										
Date (week):	Prior to 11-Aug	11-Aug	18-Aug	25-Aug	1-Sep	8-Sep	15-Sep	22-Sep	29-Sep	After 6-Oct
Obstruction Times:	Does not enter obstructed area	9.57pm to after 10.00pm	9.30pm to after 10.00pm	9.02pm to 9.51pm	8.35pm to 9.23pm	8.12pm to 8.56pm	7.40pm to 8.28pm	7.11pm to 8.01pm	6.45pm to 7.33pm	Target sets below 18° behind trees and buildings, until early February the next year
Duration of obstruction during Sessions:		None	15 minutes	43 minutes	48 minutes	41 minutes	18 minutes	34 minutes	48 minutes	
Suggested alternative viewing times:		Available both Sessions	Full 1st Session, 2nd Session between 8.15pm and 9:30pm	Full 1st Session, 2nd Session between 8.15pm and 9:02pm	Full 1st Session, 2nd Session between 8.15pm and 8.35pm	Full 1st Session, 2nd Session between 8.56pm and 9.45pm	Full 1st Session, 2nd Session after 8.28pm	1st Session between 6.15pm and 8.01pm, Full 2nd Session	1st Session between 6.15pm and 6.45pm or after 7.33pm, Full 2nd Session	

Summary:

- Obstruction of the Jewel Box Cluster due to the Mod 8 Concept Plan buildings occurs only between 11 August to 6 October annually.
- Approximate loss of viewing hours due to the Mod 8 Concept Plan buildings is 31 minutes per night for a total of 57 viewing nights out of 326 annual viewing nights.
- Due to current tree and building obstructions up to 18^{o} altitude, the Sydney Observatory currently loses views of The Jewel Box Cluster between October and February annually (or around a total of 111 viewing nights, or around 167 viewing hours).
- It is anticipated that there will be no viewing sessions where it will not be possible to view the Jewel Box Cluster due to the Mod 8 Concept Plan buildings locations if the target viewing schedule is arranged appropriately.

Omega-Centauri (NGC5139) globular cluster:

Target Object: Omega-Centauri (NGC5139) globular cluster									
Date (week):	Prior to 25-Aug	25-Aug	1-Sep	8-Sep	15-Sep	22-Sep	29-Sep	6-Oct	After 6-Oct
Obstruction Times:	Does not enter obstructed area	9.38pm to after 10.00pm	9.10pm to after 10.00pm	8.42pm to after 10.00pm	8.15pm to after 10.00pm	7.47pm to after 10.00pm	7.20pm to after 10.00pm	6.52 to after 10.00pm	Target sets below 18^{o} behind trees and buildings, until early March the next year
Duration of obstruction during Sessions:		7 minutes	35 minutes	63 minutes	90 minutes	90 minutes	115 minutes	143 minutes	
Suggested alternative viewing times:		Full 1st Session, 2nd Session between 8.15pm and 9:38pm	Full 1st Session, 2nd Session between 8.15pm and 9:10pm	Full 1st Session, 2nd Session between 8.15pm and 8.42pm	1st Session only	1st Session only	1st Session between 6.15pm and 7.20pm only	1st Session between 6.15pm and 6.52pm only	

Summary:

- Obstruction of Omega-Centauri due to the Mod 8 Concept Plan buildings occurs only between 25 August to 6 October annually.
- Approximate loss of viewing hours due to the Mod 8 Concept Plan buildings is 78 minutes per night for a total of 51 viewing nights out of 326 annual viewing nights.
- Due to current tree and building obstructions up to 18^{o} altitude, the Sydney Observatory currently loses views of Omega-Centauri between October and March annually (or around a total of 135 viewing nights, or around 203 viewing hours).
- It is anticipated that a worse-case total of 27 viewing sessions (the 2nd Session between 15 September and 6 October) out of a total of 494 annual viewing sessions will occur where it will not be possible to view Omega-Centauri due to the Mod 8 Concept Plan buildings locations.

The Pointers (Alpha-Centauri and Beta-Centauri):

Target Object: The Pointers (Alpha-Centauri and Beta-Centauri)								
Date (week):	Prior to 1-Sep	1-Sep	8-Sep	15-Sep	22-Sep	29-Sep	6-Oct	After 6-Oct
Obstruction Times:	Does not enter obstructed area	9.44pm to after 10.00pm	9.17pm to after 10.00pm	8.31pm to after 10.00pm	8.22pm to 9.40pm	7.55pm to 9.13pm	7.28pm to 8.45pm	Target sets below 18° behind trees and buildings, until early March the next year
Duration of obstruction during Sessions:		1 minute	28 minutes	74 minutes	78 minutes	58 minutes	77 minutes	
Suggested alternative viewing times:		Full 1st Session, 2nd Session between 8.15pm and 9:44pm	Full 1st Session, 2nd Session between 8.15pm and 9:17pm	Full 1st Session, 2nd Session between 8.15pm and 8.31pm	Full 1st Session, 2nd Session between 8.15pm and 8.22p or after 9.40pm	Full 1st Session, 2nd Session after 9.13pm	1st Session between 6.15pm and 7.28pm, 2nd Session after 8.45pm	

Summary:

- Obstruction of either of The Pointers due to the Mod 8 Concept Plan buildings occurs only between 1 September to 6 October annually.
- Approximate loss of viewing hours is 53 minutes per night for a total of 39 viewing nights out of 326 annual viewing nights.
- Due to current tree and building obstructions up to 18° altitude, the Sydney Observatory currently lose views of The Pointers between October and March annually (or around a total of 135 viewing nights, or around 203 viewing hours).
- It is anticipated that there will be no viewing sessions where it will not be possible to view the The Pointers due to the Mod 8 Concept Plan buildings locations if the target viewing schedule is arranged appropriately.

4.3 Timing Analysis Summary

Based on the assessment undertaken by George Georgevits, the following summarises finding on the impact to the view during Sydney Observatory night viewing times:

- At no stage is there any impact of view loss on the view corridors of the Sun, Moon, Planets, Ring Nebula and Star Albireo;
- Obstruction of any of the five (5) stars of the Southern Cross (Crux) occurs between 4 August to 29 September annually, accounting for at most 46 out of 491 night sky viewings per annum (or 9%) where The Southern Cross cannot be viewed in its entirety from the Observatory. The actual times where it affects the Observatory operation will, in reality, be much less, due to a 50% chance of cloud;
- Obstruction of the Jewel Box Cluster occurs between 11 August to 6 October annually, however there are no night sky viewing sessions where the Jewel Box Cluster will not be able to be viewed from the Observatory if the target viewing schedule is arranged appropriately;
- Obstruction of Omega-Centauri occurs between 25 August to 6 October annually, accounting for at most 27 out of 491 night sky viewings per annum (or 5%) where Omega-Centauri cannot be viewed from the Observatory. The actual times where it affects the Observatory operation will, in reality, be much less, due to a 50% chance of cloud;
- Obstruction of either of The Pointers occurs between 1 September to 6 October annually, however there are no night sky viewing sessions where The Pointers will not be able to be viewed from the Observatory if the target viewing schedule is arranged appropriately, and;
- The Sydney Observatory currently loses views of four target objects between October and February to March annually due to existing obstructions below 18° altitude.

The specified target objects which are affected by the Mod 8 Concept Plan can be summarised in the following table:

Target Objects ,Viewing Sessions Affected Summary												
Date (week):	Prior to 4-Aug	4-Aug	11-Aug	18-Aug	25-Aug	1-Sep	8-Sep	15-Sep	22-Sep	29-Sep	6-Oct	After 6-Oct
Southern Cross (Crux):	No obstruction	Can be viewed both Sessions			Can be viewed during the 1st Session only						Below trees until Feb	
Jewel Box Cluster:	No obstruction				Can be viewed both Sessions							Below trees until Feb
Omega-Centauri:	No obstruction					Can be viewed both Sessions		Can be viewed during the 1st Session only				Below trees until Mar
The Pointers:	No obstruction						Can be viewed both Sessions					Below trees until Mar

4.4 Current Observation Issues at Sydney Observatory

Please note that the above hours, times and dates are based on a best-case situation in each account where there is no other factors affecting astronomical observations from the Sydney Observatory; a 'total clear sky' approach.

There are many factors that affect the ability to conduct these night viewing sessions from the Sydney Observatory, as summarised below and further entertained within George Georgevits's report contained within Appendix 1:

- Light glare. Glare from city lights, the low altitude of the Observatory and the proximity to water makes seeing conditions at the Observatory poor even on the best nights;
- Cloud cover. Based on 55 years of BOM weather data for Sydney Observatory assume a 50% chance of there being too much cloud cover to make astronomical observations;
- Smog and Particulate Pollution. Assume that astronomical observations will be more greatly affected by smog, bushfire smoke, light spill and contract when observing at low altitudes such as those lower than 26^{o} altitude;
- Scintillation. Increase of air mass further degrades observations at low altitudes below 30^{o} due to scintillation compared to those viewed at zenith/90^{o}, and;
- Existing trees and buildings. The observatory cannot view below 18^{o} altitude at present due to current tree and building constraints around Observatory Hill.

5.0 Lighting Impact

As detailed within Sections 4.1 and 4.4 prior, the Sydney Observatory is no longer an astronomical observatory. It is a museum which provides astronomy education and public sky viewing. The location of the Sydney Observatory is not ideal for making astronomical observations due to light glare, smog, pollution and sky view constraints. It is also unfortunately located adjacent to one of the worst light polluting structures in Sydney; the Sydney Harbour Bridge.

The Barangaroo South Mod 8 Concept Plan is not expected to result in an increased light spill effect on the Observatory given the existing surrounding environment. The intent for lighting at Barangaroo South is to prevent an increase to light spill through consistency with the requirements of AS4282 and the requirements of EMI-7 Green Star Light Pollution Credit.

Specific details on how the lighting design for the Mod 8 Concept Plan proposes to address this are as follows:

- Brightly lit surfaces are kept to a minimum;
- Luminaires will have glare shields;
- 3000 degrees K is used for the majority of light sources;
- Up lighting has been kept to a minimum (by not exceeding a 5% Upward Light Output Ratio or by not exceeding 0.5 Lux for any initial point of illuminance to the site boundary and no greater than 0.1 Lux to 4.5 metres beyond the site into the night sky);
- Light sources are down facing, the proposed blue lights along the shore line play through trees and illuminate grey paving with no light trespass and/or light pollution;
- Light levels decrease on approach to the water's edge, and;
- Light levels are provided for pedestrian safe movement.

The lighting intent for Barangaroo South is efficient, sustainable, code complying and fit for purpose. The lighting scheme has been devised to provide visual interest, ambiance and safety.

6.0 Conclusion

Impacts to the Sydney Observatory Sky Views:

- At no stage is there any impact on the views of the Sun, Moon, Planets, Ring Nebula and Star Albireo;
- There are no night time viewing sessions where The Jewel Box Cluster or The Pointers will not be able to be viewed if the target viewing schedule is arranged appropriately;
- Obstruction of any of the five (5) stars of the Southern Cross (Crux) occurs between 4 August to 29 September annually, accounting for at most 46 out of 491 night sky viewings (or 9%) where it cannot be viewed in its entirety (which excludes the 50% chance of cloud affecting the sky view);
- Obstruction of Omega-Centauri occurs between 25 August to 6 October annually, accounting for at most 27 out of 491 night sky viewings (or 5%) where it cannot be viewed (which excludes the 50% chance of cloud affecting the sky view);
- Views of four target objects are lost currently between October and between February and March annually due to existing obstructions below 18^{o} altitude, and;
- Lighting design will be managed appropriately to meet Australian Standards and to also meet the Green Star Light Pollution Credit. This is not expected to result in an increased light spill effect on the Observatory given the existing environment.

Overall Conclusions:

- The greatest sky view impacts occur to views to The Southern Cross and Omega-Centauri for a 9 week period. When considered overall this is a very small impact to the functioning of the Observatory;
- Limited viewing sessions are affected by the view impacts. When one or more of the target objects listed by Sydney Observatory are not available for viewing due to obstruction, there are a great many other interesting night sky targets that are much more favourably positioned in the sky that could be viewed instead. Given the poor conditions under which the target objects are observed when near the horizon (and the obstruction) it would make sense to view other targets that are better located at much greater altitudes, and;
- The likelihood of meteorology conditions (cloud cover, smog, pollution and scintillation) and the location of Sydney Observatory (surrounding constraints and light spill) further decrease the impacts by these partial view obstructions. It is assumed that over 50% of night viewing sessions would currently be affected by current standard meteorological conditions, with cloud cover being the most likely cause.

Overall, impacts on the functioning of the Sydney Observatory due to the Mod 8 Concept Plan are considered negligible.

7.0 Appendices

7.1 Appendix 1 - Sky View Loss Assessment by George Georgevits (UNSW Global)

UNSW Global AUSTRALIA

Unisearch Expert Opinion Services

COMMERCIAL-IN-CONFIDENCE
Report prepared on behalf of Expert Opinion Services
A business of UNSW Global Pty Limited

BARANGAROO SOUTH PROJECT

SYDNEY OBSERVATORY SKY VIEW LOSS ASSESSMENT

for

Lend Lease Group

by

George Georgevits (B.E. Hons)
Consulting Engineer

Date of Issue: 23 September 2014
Our Reference: J085821

Unisearch Expert Opinion Services PO Box 6666 UNSW Sydney NSW 1466 Australia
T: +61 2 9385 5555 | F: +61 2 9385 6555 | E: experts@unisearch.com.au | W: www.unisearch.com.au

CONTENTS

Page

1. TERMS OF REFERENCE

1.1 QUALIFICATIONS

1 This report was prepared by George Georgevits, managing director of and principal consulting engineer for Power and Digital Instruments Pty Ltd (**PDI**).

2 I have an honours degree in electrical engineering and 40 years experience as an engineer, specialising in the fields of communications, electronics and power.

3 In addition, I am also presently completing a PhD in Astrophysics at the University of NSW.

4 My astronomical PhD work has entailed the use of the 1.2 metre UK Schmidt Telescope and the 0.5 metre Automated Patrol Telescope, both located at Siding Spring Observatory, Coonabarabran NSW.

5 I have conducted presentations of my work at a number of overseas and Australian conferences on Astrophysics.

6 An article referencing my work has appeared in Science magazine (see Appendix 2), and it has been cited in a paper appearing in Nature.

7 I have also co-authored a Chapter in a text book on the outer solar system.

8 I have owned and operated a number of small astronomical telescopes over the years.

9 I am thus very familiar with observational astronomy and also the astronomical objects that are the subject of this matter.

10 A brief CV for George Georgevits is provided in Appendix 3 and a brief capability statement for PDI is provided in Appendix 4.

1.2 TERMS OF ENGAGEMENT

1 I have been engaged by Lend Lease to provide astronomical advice in relation to this matter.

2 The matter entails an assessment of the loss of sky view from Sydney Observatory (north dome) as a result of the construction of buildings associated with the Barangaroo South project.

3 I have been provided with a brief, including a letter of instruction and a copy of correspondence from Sydney Observatory that outlines their areas of concern.

4 As part of my brief, Lend Lease have provided me with a set of drawings that depict viewing angles from Sydney Observatory towards the Barangaroo South development, with possible areas of view obstruction.

5 My brief also contains information relating to the make, model and location of the telescope used by Sydney Observatory for night time astronomical observing, plus the opening hours for the observatory (refer Appendix 1).

6 I have also made my own enquiries in relation to certain aspects of this matter.

7 Where I have used material from other sources for this report, I have provided the relevant references.

2. OBSERVATIONAL ASTRONOMY – A VERY BRIEF PRIMER

1 In the southern hemisphere, the night sky appears to rotate clockwise around a point in the sky known as the South Celestial Pole (see Fig.1).

2 This point represents the intersection of the extension of the southern end of the Earth's axis of rotation with the sky plane.

3 Thus the sky plane completes one rotation every 24 hours, which means it rotates at a constant angular velocity of 15^o per hour.

4 Thus, in order to observe a sky plane object, a telescope must first find the object and then track it as the sky rotates.

5 In addition to this, the Earth moves in its orbit around the sun, completing one revolution approximately every 365.25 days.

6 Thus, at any particular time (e.g. 8:00pm), and at any particular altitude and azimuth (**alt/az**) co-ordinate in the sky plane (e.g. 26^o, 210^o), a different part of the sky will appear at that co-ordinate location at 8:00pm on each day of the year.

7 Another way of looking at this is that the same part of the sky will be at another location every night of the year.

8 For example, on the 1st September, at 8:00pm, α Centauri is at alt/az 43^o, 216^o.

9 On 1 October, at 8:00pm, it is at alt/az 23^o, 213^o, the change being due to the fact that the Earth has moved further along in its orbit around the sun.

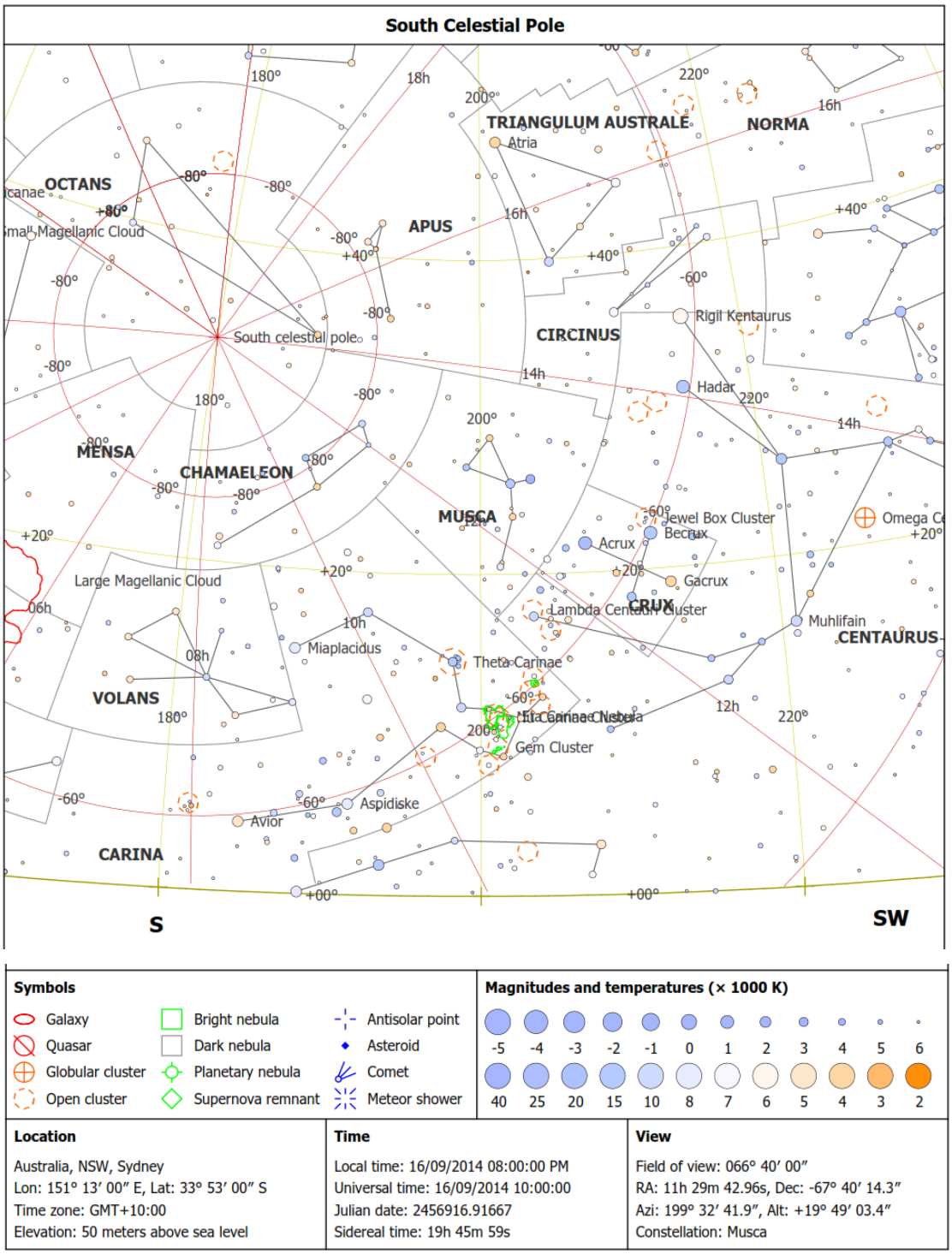


Fig.1 - Map of the night sky showing the location of the South Celestial Pole and the target objects of interest, as they appeared on 16 September, 2014 at 8pm.

3. OBSERVING ISSUES AT SYDNEY OBSERVATORY

1 A number of factors affect the ability to conduct astronomical observations from any particular location.

2 These factors determine whether observing is even possible, and if so, the quality of the image presented by the telescope.

3.1 CLOUD COVER

1 Depending on the nature of the clouds, this can degrade the transparency of the atmosphere to the point where it becomes opaque, making observing impossible.

2 With translucent clouds, observing is possible, but scattered light from the various bright city light sources (e.g. Harbour Bridge) will degrade the observed images by degrading the contrast and altering the colours.

3 The Bureau of Meteorology statistics state the following for the weather station at Observatory Hill:

Statistics	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual	Years	
Mean number of clear days	6.8	5.3	7.1	9.1	9.5	9.1	12.0	13.4	10.9	8.1	6.0	6.6	103.9	56	1955 2010
Mean number of cloudy days	13.4	13.0	12.8	10.7	10.8	10.9	8.7	7.7	8.5	11.4	12.5	12.8	133.2	56	1955 2010

Fig.2 - 56 year average BOM weather data for Observatory Hill

4 From this, we can assume that there will be a roughly ~50% chance of cloud at any particular time/date.

3.2 SMOG AND PARTICULATE POLLUTION

1 Smog and particulate pollution affects the transparency of the atmosphere.

2 It causes selective absorption of the short wavelengths of light (blue end of the spectrum), making images look redder (hence the bright orange sunsets during bushfire season).

3 Smog is worse looking at low altitude across the western suburbs of Sydney, and it tends to be worse in summer under certain weather pattern conditions.

4 It can also be bad during bushfires, and during ground cover burn off activities in winter and spring.

5 Smog will also scatter light from nearby bright ground based sources (e.g. Harbour Bridge), thereby increasing the overall sky brightness.

6 These effects will degrade the observed image because the image contrast is reduced and the colours are changed.

3.3 SCINTILLATION

1 Scintillation is caused by air density variations due primarily to air movement (turbulence).

2 It results in image distortions that fluctuate with time.

3 Scintillation is also a function of the air mass.

4 The minimum column of air through which the light has to pass occurs for targets directly overhead (i.e. at zenith).

5 As we move away from zenith towards the horizon, the column of air we have to look through (and the turbulence it contains) increases.

6 The air mass at 30^{o} altitude is twice that at zenith (90^{o}altitude), and therefore the scintillation effects are much worse.

7 These effects then worsen rapidly as the horizon is approached.

8 Scintillation effects also worsen with increasing air temperature (heat haze) and with increasing humidity.

3.4 OBSERVATORY OPENING TIMES

1 Sydney Observatory is only open at specific times on specific days (refer Appendix 1).

2 Thus in order to assess the impact on viewing caused by any particular obstruction, the required target object locations must be tracked throughout the year so as to determine when or even if they intersect with the obstructed area of sky, and if so, for what proportion of the observatory's opening hours on the days it is open.

4. SYDNEY OBSERVATORY SKY VIEW LOSS ASSESSMENT

4.1 BACKGROUND

1 The Sydney Observatory site is located on Observatory Hill at The Rocks, Sydney NSW, about 600m south west of the Sydney Harbour Bridge.

2 The observatory building was built between 1857 and 1859. It is now part of the Powerhouse Museum.

3 Due to the glare of the city lights (the nearby Harbour Bridge in particular), the low altitude of the site and the proximity to water, seeing conditions are poor at the observatory even on the best nights.

4 Research astronomy has not been conducted at the site for many years now.

5 The observatory does, however, conduct public astronomical observing sessions from the north dome building using a 16" Meade Schmidt Cassegrain telescope.

6 The observing times vary, depending on the time of year. A complete list of observatory opening hours is provided in Appendix 1.

4.2 IMPACT OF THE BARANGAROO SOUTH DEVELOPMENT

1 The Barangaroo South development consists of two tall residential buildings known as R4B and R4A (the **buildings**), located approximately 440 metres south west of the Sydney Observatory north dome building.

2 Due to the presence of heritage listed trees in the park surrounding the observatory, the portion of the view from the observatory in the direction of the buildings below altitude 18^o is obscured.

3 Due to their height, the buildings will obscure a further ~8^ox9^o block of sky.

4 This represents less than 0.3% of the area of the night sky that is visible from Sydney Observatory (assuming everything below 18^o altitude is obscured by trees, in all directions).

5 Sydney Observatory has indicated that their area of concern covers the azimuth angle between 210^o and 218^o, between altitudes 18^o to 26^o.

6 In addition, they have indicated that the view of the following night sky objects is likely to be obstructed by the buildings at certain times of the year.

- The Southern Cross
- The Pointers
- The Jewel Box Cluster (open star cluster)
- ω Centauri (globular star cluster)

7 See Fig.3 below for a sky map showing the location of all of these objects, plus the area of sky obscured by the buildings.

8 The area below the red square (i.e. below 18^{o} in altitude) is obstructed by trees.

9 The aim of this report is to independently quantify the observatory's concerns in relation to the above.

10 In addition, Lend Lease have suggested a few other sky objects to investigate, as follows:

- Ring Nebula (in Cygnus)
- Sun, moon and planets

11 These are also included in the findings.

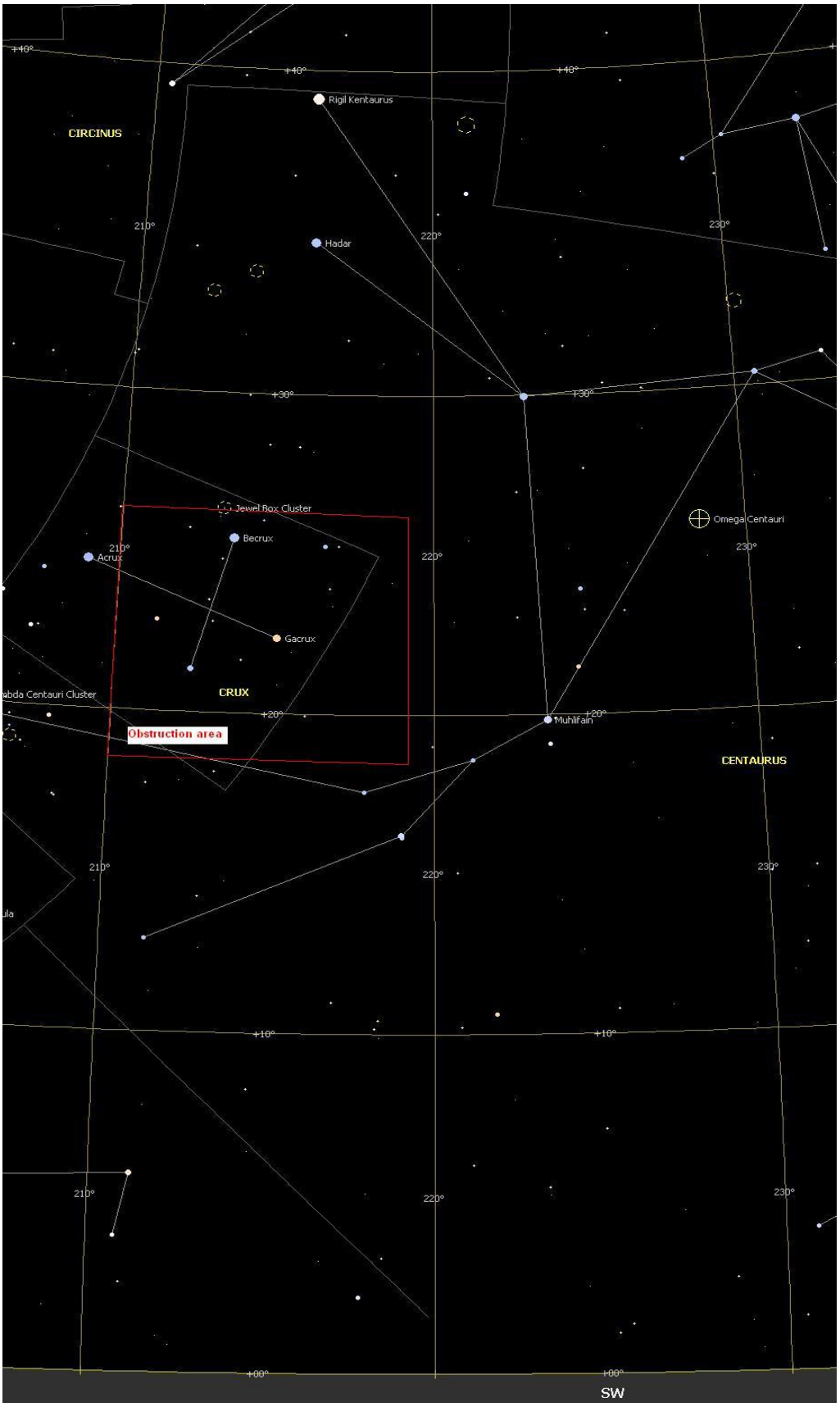


Fig.3 - Area of sky as it appeared on 16th September, 2014 at 8:00pm, showing the area obstructed by the buildings (red square) and position of all four targets.

5. FINDINGS AND CONCLUSIONS

5.1 FINDINGS

1 Some targets pass through the area of sky that is obstructed by the buildings in the months of August and September.

2 Fig.4 summarises, on a weekly basis, the periods of time during which the buildings obscure the view of the listed sky targets.

3 It shows, for each target, on the Monday of each week, the period of time over which it is obscured.

4 The week to week changes are immediately apparent, and the daily changes may be derived by interpolating the weekly data.

5 Some targets are obscured by the buildings for only parts of some nights during these months.

6 These nights should not be considered problematic because if the target viewing schedule is arranged appropriately by the observatory, the affected targets could be viewed first, while they are still unobstructed, with no real inconvenience to the observatory.

7 Hence only those nights where the target is not accessible for at least 10 minutes during any observing session should it be considered as problematic.

8 These are highlighted in yellow in Fig.4 below.

Observatory Telescope Specifications:	
Make:	Meade
Model:	LX200
Type:	Schmidt Cassegrain
F ratio	f/10
Focal length	4064mm
Clear aperture	406mm
Field of view	5.7 deg.

Observatory Opening Times Monday to Saturday	Open	Close	Open	Close
6th Apr - 4th Oct	6.15pm	10pm	18:15	22:00
5th Oct - 30th Nov	8.15pm	10pm	20:15	22:00
1st Dec - 31st Jan	8.30pm	10pm	20:30	22:00
1st Feb - 4th Apr	8.15pm	10pm	20:15	22:00

Obstructed Area:			
Altitude range	18	26	degrees
Azimuth range	210	219	degrees

TARGET OBJECT	Obstructed Area:	enters	leaves	enters	leaves	enters	leaves	enters	leaves	enters	leaves	enters	leaves	enters	leaves	enters	leaves	enters	leaves
Sydney Observatory Target Objects of Concern:																			
Jewel Box cluster	**Date:**	11/08/2014		18/08/2014		25/08/2014		01/09/2014		08/09/2014		15/09/2014		22/09/2014		29/09/2014		06/10/2014	
NGC 4755	**Times:**	21:57	>22:00	21:30	>22:00	21:02	21:51	20:35	21:23	20:12	20:56	19:40	20:28	19:11	20:01	**18:45**	19:33	<20:15	<20:15
Southern Cross	**Date:**	04/08/2014		11/08/2014		18/08/2014		25/08/2014		01/09/2014		08/09/2014		15/09/2014		22/09/2014		29/09/2014	
Crux	**Times:**	21:41	>22:00	21:13	>22:00	20:46	>22:00	20:18	>22:00	19:50	>22:00	19:23	>22:00	18:56	>22:00	**18:28**	>22:00	**<18:15**	>22:00
Pointers	**Date:**	11/08/2014		18/08/2014		25/08/2014		01/09/2014		08/09/2014		15/09/2014		22/09/2014		29/09/2014		06/10/2014	
alpha & beta Centauri	**Times:**					>22:00	>22:00	21:44	>22:00	21:17	>22:00	20:31	>22:00	20:22	21:40	19:55	21:13	19:28	20:45
Other Targets Suggested by Lend Lease:																			
Ring Nebula	**Date:**																		
M57	**Times:**	never enters the obstructed area																	
Omega Centauri	**Date:**	11/08/2014		18/08/2014		25/08/2014		01/09/2014		08/09/2014		15/09/2014		22/09/2014		29/09/2014		06/10/2014	
NGC 5139	**Times:**			>22:00	<22:00	21:38	>22:00	21:10	>22:00	20:42	>22:00	20:15	>22:00	19:47	>22:00	19:20	>22:00	**18:52**	>22:00
Albireo	**Date:**																		
Beta Cygni	**Times:**	never enters the obstructed area																	
Sun, moon, planets	**Date:**																		
	Times:	never enter the obstructed area																	

Notes:
1. Still twilight for time entries shown in bold
2. Where leave time is shown as >22:00, either the observatory is closed or the target has set behind trees

Fig.4 - Sky targets of interest showing, on a weekly basis, the periods of time during which each enters and leaves the area of obstruction.
This data applies to 2014. However, it would be valid for every year with a very small margin of error.

9 For example, on 25th August, the Jewel Box Cluster is obscured between 9:02 and 9:51pm. This should not present a problem, because the observing session starts at 8:15pm, and it could be scheduled to be observed first.

10 After 9:51pm, however, the trees obscure the target, so the fact that it is also obscured by the buildings is irrelevant.

11 The table in Fig.4 finishes at the beginning of October.

12 After this, all targets have set behind the trees during observatory opening times.

13 In situations where the observatory runs two observing sessions on the same night, each session needs to be considered separately, as some targets may sometimes not be visible for one entire session.

5.2 CONCLUSIONS

1 In brief, the four sky targets flagged by Sydney Observatory as having possible problems are generally not observable for a period of about one month, centred on September, due to the obstruction caused by the buildings.

2 Based on Bureau of Meteorology weather data for Observatory Hill for September:

- on average, there will be some cloud cover for about half of the time
- there will be 10.9 clear days
- there will be 8.5 days when it is totally clouded over.

3 In addition to the four objects noted by Sydney Observatory, I have conducted a search for other well known sky objects that may be of interest to the general public that may pass through the area of obstructed sky during certain times of the year.

4 I have found no other such objects.

5 The seeing conditions for the part of the sky immediately above the buildings will generally be poor due to its low altitude, the large air mass through which it is viewed, the light pollution from nearby bright sources such as the Harbour Bridge, the effects of smog, scintillation, humidity and so forth.

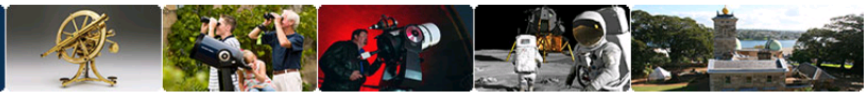
6 Consequently, observing targets around the area obstructed by the buildings would be done under observing conditions that are far from ideal, and the image quality would be relatively poor on most nights.

George Georgevits
B.E. (Hons)

APPENDIX 1

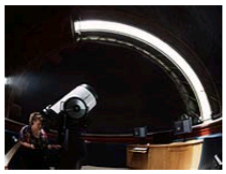
Sydney Observatory Public Viewing Schedule

sydney observatory
PART OF THE POWERHOUSE MUSEUM



Hours and charges

Certificate of Excellence
2014 WINNER
tripadvisor
Sydney Observatory



NIGHT VISIT

Open nightly Monday to Saturday except Good Friday, Christmas Day and Boxing Day holidays. Open Sunday nights during school holidays.

Bookings are necessary for night sessions (of approximately 90 minutes duration). Phone (02) 9921 3485 or **book online**.

Night telescope/3D theatre session times
April to September – 6.15pm and 8.15pm
October and November – 8.15pm
December and January – 8.30pm
February and March – 8.15pm

Night charges for telescope/3D theatre sessions
Adult – $18
Child (4 to 15 years) – $12
Concession – $14
Family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $50
Member (adult) – $16
Member (child) – $11
Member (family) – $43

Sessions are held regardless of weather. If viewing through the telescopes is not possible due to sky conditions, a fun digital planetarium session is provided instead.

All night visits must be booked and prepaid prior to arrival at the Observatory. Payment for night tickets is not refundable. However if you notify us by phone on 9921 3485 by noon on the day you are scheduled to attend your night visit, we can either transfer your booking to another available night; or offer you a 'rain check' ticket, valid for three months from first booking, to the same value as your original booking.

Debit and credit card fees: As part of a NSW Government requirement, Sydney Observatory applies a surcharge on all transactions made by debit or credit cards. Surcharge rates are determined on a cost-recovery basis only. No surcharge is incurred when paying with EFTPOS, cheque or cash. Payments made on VISA and Mastercard attract 0.40%

Review your visit on facebook
Would you like to tell others about your visit to Sydney Observatory? Then you might like to **review your visit on facebook**.

DAY VISIT

Open 10am – 5pm daily
except Good Friday, Christmas Day and Boxing Day holidays
Open 10am – noon New Years Eve

Day telescope/3D theatre session times
Monday to Friday (school term) – 2.30pm, 3.30pm and 4.00pm
Weekends and school holidays – 11am, noon, 2.30pm and 3.30pm
Bookings are not required for day sessions.

Day charges for telescope/3D theatre sessions
Adult – $10
Child (4 to 15 years) or concession – $8
Family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $26
Member adult – $6
Member child (4 to 15 years) or concession – $4
Member family (1 adult and up to 3 children;
or 2 adults and up to 2 children) – $16

Daytime admission for a self-guided visit to the gardens and the Observatory exhibitions is free – but does not include visits to the telescope towers, telescope viewings and 3D theatre sessions.

Debit and credit card fees: As part of a NSW Government requirement, Sydney Observatory applies a surcharge on all transactions made by debit or credit cards. Surcharge rates are determined on a cost-recovery basis only. No surcharge will be incurred when paying with EFTPOS, cheque or cash. Payments made on VISA and Mastercard will attract 0.40%

The Powerhouse Museum is an Affiliate of the NSW Government's Department of Ageing, Disability and Home Care's Companion Card program. This means that carers who accompany a person with a disability will be eligible for free entry on presentation of their Companion Card. For more information visit **www.companioncard.org.au**

1003 Upper Fort St, Millers Point, NSW, 2000.
Bookings / enquiries: PH: (02) 9921 3485
NSW Government

APPENDIX 2

Science Article

ASTRONOMY

Twinkling Stars May Reveal Stuff of Early Solar System

Australian researchers say dips in the brightness of stars may tell of a vast array of objects beyond the planets, but others aren't so sure

CATANIA, ITALY—The Kuiper Belt, resting place of much of the detritus left over from the creation of the solar system, may contain many more small objects than previously thought. Australian astronomers scanned the outer reaches of the solar system by looking for a brief dimming of the light of distant stars as subkilometer-sized bodies passed in front of them. Preliminary results presented at a workshop here earlier this month* suggest that huge numbers of such objects lurk beyond the orbit of Neptune. Although most Kuiper Belt researchers are cautious, studies by some other teams suggest the Australians may be onto something. "If this is true, it would be fantastic," says Alessandro Morbidelli of the Observatoire de la Côte d'Azur in Nice, France, because information about the smaller denizens of the Kuiper Belt cannot be found any other way.

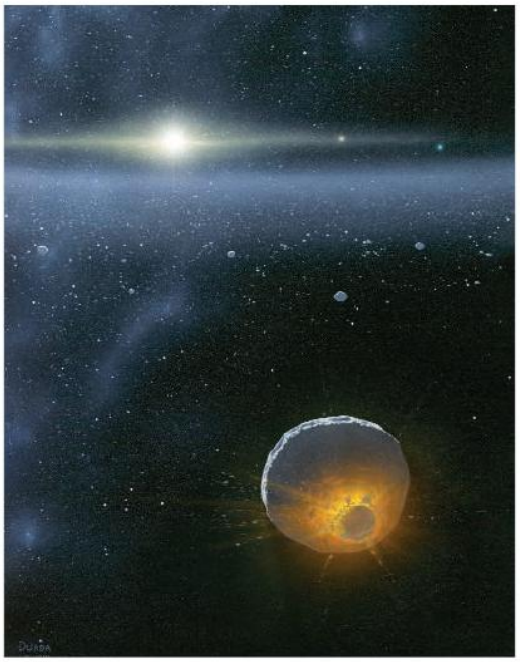
Astronomers have found more than 1000 bodies in the Kuiper Belt, including an object known as 2003 UB_{313} (nicknamed Xena) that is slightly larger than Pluto. But because they are several billion kilometers away, even the most powerful telescopes can't see Kuiper Belt objects smaller than about a hundred kilometers across. Researchers are keen to know more about their size distribution, as it would shed light on the early youth of the solar system.

An effort to fill that gap has been going on since last year. The Taiwanese-American Occultation Survey (TAOS) operates three automated 50-centimeter telescopes at Lu-Lin Observatory, Taiwan, which scan starlight for telltale dimming that signals a Kuiper Belt object passing in front of, or "occulting," the star. So far, the survey has drawn a blank. Team member Federica Bianco of the Harvard-Smithsonian Center for Astrophysics (CfA) in Cambridge, Massachusetts, says TAOS can't observe very brief dips in brightness, so it is capable of spotting only the relatively rare objects larger than a few kilometers in diameter.

* Trans Neptunian Objects: Dynamical and Physical Properties, Catania, Italy, 3–7 July.

But George Georgevits and Michael Ashley of the University of New South Wales in Sydney and Will Saunders of the Anglo-Australian Observatory in Siding Spring say the Kuiper Belt may teem with objects too small for TAOS to see. Using a fast detector at the 1.2-meter U.K. Schmidt Telescope in Siding Spring, they saw well over a thousand brief brightness dips, each lasting for a tenth of a second or less, while monitoring dozens of stars for about 2 weeks.

"It's very important work, and they should certainly continue," Morbidelli says. "But the results so far are very strange," because current theories of the evolution of the solar system do not predict huge numbers of small Kuiper Belt objects. Michael Brown of the California Institute of Technology in Pasadena, who discovered 2003 UB_{313}, adds that "the believability factor [of these results] isn't very high. Unfortunately, you can never go back and check." But Georgevits counters that he has checked and ruled out every other possible cause of the stellar winks.



When worlds collide. Two icy bodies crash in the Kuiper Belt in this artist's depiction. Could such collisions have populated the belt with tiny objects?

CREDIT: DAN DURDA/FIAAA

So are the results real? "Well, it seems they are observing *something*," says David O'Brien of the Planetary Science Institute in Tucson, Arizona, although he adds that no one has yet carried out a detailed statistical analysis of the Australian results. According to O'Brien, collisions in the Kuiper Belt may have produced hordes of small objects. "If confirmed, these results could tell us something about the strength properties of Kuiper Belt objects," he says.

Some other studies support the Australian results. Taiwanese astronomers have uncovered similar brief occultations of the well-known x-ray source Scorpius X-1 in data from NASA's Rossi X-ray Timing Explorer satellite. A team led by astronomer Ping-Shien Wu of the National Tsing Hua University in Hsinchu presented the finding in April at the Chinese Astronomical Society Taiwan's meeting in Taichung and is due to publish it in *Nature* next month. And at the Catania workshop, Françoise Roques of the Paris Observatory described three brief occultations detected with the 2-meter Bernard Lyot Telescope in the French Pyrenees, which Roques says may also represent small Kuiper Belt objects.

Not everyone is convinced. "They have to do more checks on possible false alarms," says Matthew Lehner of CfA. For instance, the dips might be caused by unknown effects in Earth's atmosphere. To avoid these, you need to observe from space, says Lehner, who is part of a team that has pitched to NASA a $425 million occultation mission called Whipple, which would detect Kuiper Belt objects as well as comets in the much more distant Oort Cloud.

Meanwhile, Georgevits hopes to raise half a million dollars for a purpose-built ground-based telescope equipped with a very fast video camera. Such a device could survey the whole Kuiper Belt for a fraction of the cost of a space mission, he says. And although his team's preliminary results raised some eyebrows, everyone agrees on the need for a more comprehensive search. Says O'Brien: "Small Kuiper Belt objects will never be observed directly. Occultation surveys have a lot of potential to fill in this gap."

–GOVERT SCHILLING

Govert Schilling is an astronomy writer in Amersfoort, the Netherlands.

APPENDIX 3

Brief Curriculum Vitae for George Georgevits

1 In 1972 I was awarded a cadetship with the then Postmaster General's Department to complete my Bachelor of Electrical Engineering degree at University of NSW.

2 I graduated in 1974 with honours.

3 I have 40 years experience as an electrical engineer, specialising in the fields of telecommunications, electronics and power.

4 During the first eight years of my career, I worked as an engineer for the PMG's Department, later known as Telecom Australia and then as Telstra.

5 In 1981 I founded Power and Digital Instruments Pty Ltd. (PDI) with a view to establishing a consulting engineering practice specialising in communications and electronics. A brief capability statement for PDI appears in Appendix A2.

6 Through PDI, I have successfully completed thousands of engineering projects for some 300 corporate and government clients.

7 PDI also owns and operates a test and measurement laboratory. The primary function of this laboratory is to conduct a wide variety of electrical tests on various types of active and passive components and equipment using sophisticated laboratory test equipment.

8 In addition, I regularly write technical articles on topical communications and power technology issues for *Cabling Connections, Cabling Home Solutions and Electrical Connections* magazines, these being Australian trade journals.

9 Although my formal qualifications relate primarily to electrical engineering, I also have extensive experience with the concepts of physics, electromagnetic waves, advanced mathematics and errors in measurements.

10 I am presently undertaking a part-time PhD in Astrophysics at the University of NSW.

11 My work Astrophysics has been cited in an article in the internationally recognised journal *Science* and also referenced in an article appearing in *Nature.*

APPENDIX 4

Capability Statement for PDI

POWER AND DIGITAL INSTRUMENTS PTY LTD.

PDI

Electronics and Communications Consulting Engineers

POSTAL:
P.O. BOX 422
ROSEVILLE NSW 2069

BUSINESS OFFICE:
66A FINDLAY AVE
ROSEVILLE NSW AUSTRALIA

TEL: +61 2 9411 4442

ABN 21 002 065 769

Jan'14

CAPABILITY STATEMENT

FIELDS OF EXPERTISE:

- Data Cabling Systems and Components - Design, Testing and Certification
- Voice and Data Communications and Telephony Technology
- Radio Communications, HF, VHF, UHF and Microwave
- Power Systems, Equipment, Distribution Networks & Providers
- Assessment of Damages Claims for Communications, Power and Gas Infrastructure
- Communications Equipment and Service Suppliers and Carriers
- Lightning Protection, Surge Suppression and Earthing Systems
- Electronics Design, Manufacturing, Test & Measurement and Troubleshooting
- Equipment and Component Testing and Certification
- Computer Networks and Computer Technology
- Project Management and Specification
- Regulatory and Legal Aspects of Power and Communications Systems, Networks and Equipment and Standards Compliance
- Patent Specification Technical Preparation and Advice

SPECIFIC AREAS OF WORK:

- Testing and Certification of Cat 7A, 7, 6A, 6, 5e, 5 and Fibre Optic Components, Cables and Installations to EIA, ISO & Australian standards
- Cat 6A, Cat 6 and Cat 5e Connector Design and Testing
- Optical Fibre Cabling Technologies, including Testing
- Power Systems and Equipment, Cabling, Testing, Magnetic Field Radiation Surveys
- Troubleshooting and Testing Installed Cabling Networks
- Lightning and Surge Protection, System Design and Testing
- Earthing System Design and Testing and Power Co-ordination
- RF Test and Measurement (PDI has a well equipped test lab)
- Radio Interference, Noise, EMC investigations and RF Sweeps for Debugging
- Assessment of Damages Claims for Insurance Purposes
- Troubleshooting Electronics and Computer Circuits and Systems
- Electronics Design, Analogue, Digital and RF
- Electronics Manufacturing and Reliability Engineering
- Specialised Software Development and Interface
- Process Control, Automation, Instrumentation and Data Acquisition
- PABX Systems, Voice Over IP, Key Systems, Mobile and Cordless Telephony

METHODOLOGY

Mr Georgevits has an Honours degree in Electrical Engineering and 38 years experience in the industry as a consulting engineer.

Mr Georgevits is managing director of PDI (established in 1980). PDI has a well-proven track record in engineering consultancy, test & measurement, electronics troubleshooting and computer technology. PDI operates a well-equipped test and measurements laboratory.

PDI has successfully completed thousands of engineering projects for over 300 corporate and government clients.

Consultancy work is carried out primarily by the Principal, Mr George Georgevits. In addition, suitably qualified associates may be called upon from time to time, as required, to meet the specialised demands of particular projects.

ENGAGEMENT

Engagement to perform consultancy work is carried out on a contract basis. Fees may be structured on a fixed lump sum basis for clearly defined tasks, or on an hourly rate for other work, as required and mutually agreed with the Client.

PDI offers a completely independent advisory service. PDI has no affiliations with suppliers of equipment or services.

BRIEF LIST OF REFERENCES

Some Current Assignments:

- Amphenol Canada Corporation (Connector Manufacturer)
- Connection Magazines Pty Ltd (Cabling Magazine)
- Clayton Utz Lawyers
- Knapp AG (warehouse distribution logistics)
- NSW Crown Solicitor's Office
- PRYSMIAN Telecom Cables & Systems Australia Pty Ltd
- QBE Insurance (Aust) Ltd (all states)
- Technical Assessing Pty Ltd (Loss adjusters)
- Thiess Ltd.
- Tyco Electronics, was ADC Communications (Krone)
- University of NSW Communications Services

Some Completed Assignments:

- Acheron Project – James Cameron's Submarine (Avatar & Terminator fame)
- Australian Astronomical Observatory
- Australian National University (ANU)
- Bluescope Steel – Port Kembla Steelworks
- Clipsal Datacomms (Schneider Electric)
- Lantek Electronics – Taiwan (Connector Manufacturer)
- Leighton Contractors M2 Tunnel Widening (Major Projects Contractors)
- Molex Industrial Division (connector manufacturer - US)
- Tenix Group (Major Projects Construction & Defence Contractors)
- Underwriting Agencies of Australia Pty Ltd (Insurance)

7.2 Appendix 2 - Sydney Observatory Letter dated 20 June 2011

+ www.sydneyobservatory.com

sydney observatory
PART OF THE POWERHOUSE MUSEUM

20 June 2011

Barangaroo Submissions
GPO Box 5341
Sydney NSW 2001

Dear Ms Sussex AM and Ms Penn,

Thank you for the opportunity to submit comments in regards to the terms of reference for the independent review of Barangaroo. Relevant to Sydney Observatory are the following three areas:

1. *The Concept Plan approval MP06_0162 (Modification 4) including in relation to land use mix, scale/density and relationship to the Sydney Central Business District.*
2. *The adequacy of planned transport arrangements to meet the demand generated by the site at full development;*
3. *The proposed Headland Park*

Item 1: Concept Plan approval

The Barangaroo site, west of Observatory Hill, is important to the ongoing work of the Observatory as many astronomical events occur in the western sky. It is vital that the views from Observatory Hill to the western horizon remain unobscured by built structures, nor diminished by poor-quality lighting at night.

Both day and night Sydney Observatory operates a highly active astronomy program attracting over 180,000 visitors annually. Our ethos is that everyone has the right to be able to see the stars at night and that astronomy is central to the history of Australia. This began with the rich 'dreamtime' heritage of the Indigenous people that relates to specific star formations and the ability to see these is important to retain for all Australians.

The Observatory's night-time program uses telescopes from both the South and North Domes and portable telescopes on the Northern courtyard facing the west horizon. New-moon nights are the best nights for astronomy and viewing the constellations and planets with the naked eye. During the day solar viewing and other astronomical items are often viewed to the west.

Item 2: Planned transport arrangements

Ideally planned transport increases public access to the area and minimises the need for vehicles. Sydney Observatory programs run until 10pm nightly hence it is important that the transport is operational until that time throughout the week. Again it is also important that lighting of the transport route does not affect night viewing.

Watson Road, Observatory Hill, The Rocks, Sydney + PO Box K346 Haymarket NSW 1238 Australia
Museum of Applied Arts and Sciences incorporating Powerhouse Museum, Sydney Observatory and Powerhouse Discovery Centre

Item 3a: The Proposed Headland Park

Lighting of the public headland park area is the most significant factor affecting Sydney Observatory. Consequently, we make the following comments with specific recommendations below:

- Direction
It is vital that there is no light directed up into the sky or horizontally. Pathway and safety lighting should be directed down and spill minimised.

- Minimising glow and potential uses of the site.
Light-reflecting surfaces and large areas of light emission produce a glow. It is very important that there is an objective to create a distinct 'night' from 'day' approach and not flood the Barangaroo site with light at night. With good lighting, it is highly possible that Sydney Observatory could hold large public viewings from Barangaroo for major astronomical events or astronomy festivals.

- Timing
Timing devices may be considered useful for energy efficiency, however, we would encourage that people who use Barangaroo at night have the opportunity to let their eyes adjust to the night and that minimal lighting is maintained.

- Specific recommendations:

* Lighting levels should of necessity meet the relevant Australian standard AS/NZS 1158.3.1:2005 but should not exceed the minimum requirements of illumination.

* The light fittings should be full cut-off with zero UWLR.

* The correlated colour temperature of the light sources should be 2700K (warm white) or less.

* The use of unnecessary outdoor lighting (that is lighting not needed for public safety and security) such as decorative lighting of buildings, monuments and bridges, illuminated billboards and outdoor video screens, should be minimised, shielded so that all light spill is downwards and subject to curfew.

It should also be noted that Barangaroo is in close proximity to the Miller's Point residential area. Similarly, it is within the line of sight of the residents of Balmain. That is of importance as it is now generally accepted that night-time lighting is a risk factor for both breast and prostate cancer as it disrupts the melatonin cycle within the body. This gives a further reason for the necessity of minimising illumination levels. Further the biological effects of night-time lighting peak at 460nm (in the blue part of the spectrum) and this should also be taken into account.

Furthermore the proposed Headland Park has high visibility for significant and busy sections of Darling and Sydney harbours. Excessive night time lighting creates a major navigation hazard for ferries and other boats on the waterways by reducing contrast, eliminating dark adaptation and diminishing the visibility of navigation and hazard lights.

Item 3b: Proposed Headland Park – Cultural opportunity

There is potential in Sydney to develop a planetarium as a business with an emphasis on indigenous astronomy. This could be under the hill which is located at the headland of Barangaroo. Sydney Observatory currently operates a small planetarium and 3D Space Theatre and has the skills to manage, operate and, as a member of the International Planetarium Society, have access to and co-develops content appropriate for the site. Based on the visitor numbers to Melbourne planetarium, a 120 seat planetarium operating 7 sessions/day 350 days a year with 75% capacity could attract 220,500 per annum. While Sydney Observatory is interested in managing such a facility we are unable to commit any funding towards development and construction.

Watson Road, Observatory Hill, The Rocks, Sydney + PO Box K346 Haymarket NSW 1238 Australia
Museum of Applied Arts and Sciences incorporating Powerhouse Museum, Sydney Observatory and Powerhouse Discovery Centre

Thank you for the opportunity to comment. Sydney Observatory looks forward to working with and making use of an environmentally friendly Barangaroo precinct.

Please do not hesitate to contact me for further information or discussion.

Yours sincerely

T Stevenson
Sydney Observatory

Watson Road, Observatory Hill, The Rocks, Sydney + PO Box K346 Haymarket NSW 1238 Australia
Museum of Applied Arts and Sciences incorporating Powerhouse Museum, Sydney Observatory and Powerhouse Discovery Centre

7.3 Appendix 3 - Sydney Observatory notes on Clear View Corridors, provided mid 2013

Information prior to August 2014

From Sydney Observatory

Clear View Required to Western Sky from Sydney Observatory

Sydney Observatory requires an unobstructed view of the western sky to view the Sun, Moon, planets, the Southern Cross and other celestial objects. This document defines the sky access required in terms of the limiting azimuth and altitude angles measured from the Observatory's domes.

Sun, Moon and Planet limits
At the summer solstice the Sun sets furthest south on the horizon.
At the winter solstice the Sun sets furthest north on the horizon.

Sunset at winter solstice is at Azimuth=298deg (angle measured from North thru East)
Sunset at summer solstice is at Azimuth=241deg

The Moon can be up to +/-5deg further north or south of the Sun. All the planets are less than 5deg (in azimuth) from the Sun at sunset.

Therefore, for regular solar system objects (Sun, Moon & planets), we need a clear horizon between azimuths of 236 & 303degrees.

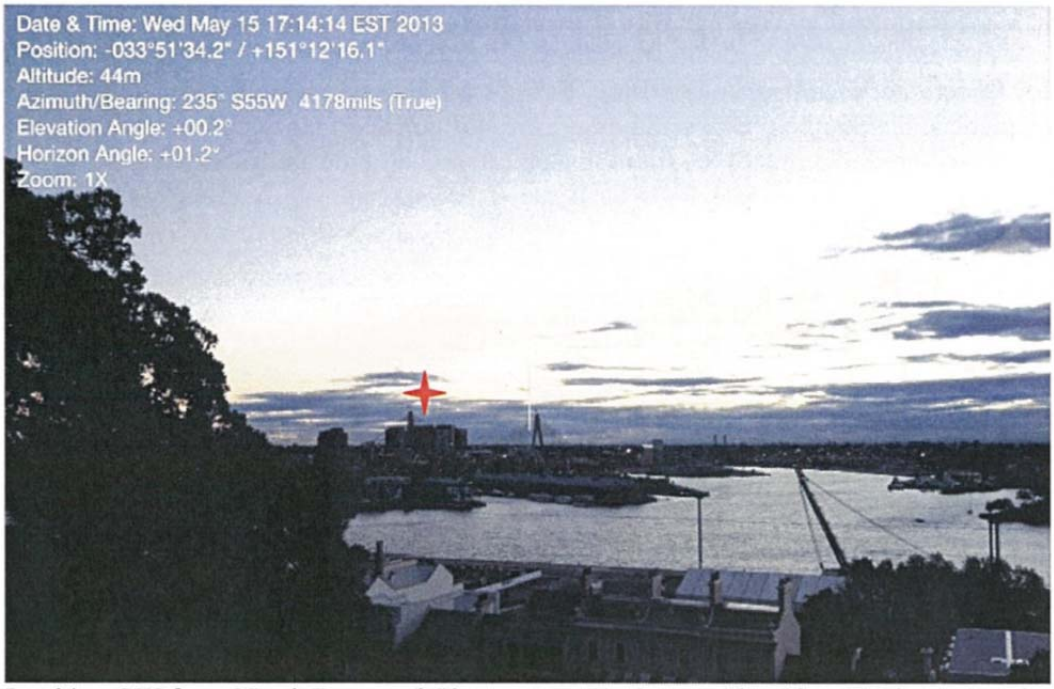
Southern Cross and nearby objects (e.g. Jewel Box, alf-Cen, omega-Cen[NGC5139])
To view celestial objects in the SW sky (including Southern Cross, Jewel Box, alf-Centauri, etc) Observatory needs a clear view up to and including azimuths of 210deg (at 18deg altitude).
Including Omega-Centauri [NGC5139], a globular cluster, to this list requires a clear view up to an azimuth of 225deg (at 18deg altitude).
[18 degrees is the altitude of the top of the residential tower and tree that presently obstructs our view to the SW]

Ring nebula and star Albireo
To the north the Ring nebula (a dead star) and Albireo (a multi-coloured twin star) require a clear view from azimuth 303deg (at altitude of 15deg).

Southern Cross and nearby objects (e.g. Jewel Box, alf-Cen, omega-Cen[NGC5139])
To view celestial objects in the SW sky (including Southern Cross, Jewel Box, alf-Centauri, etc) Observatory needs a clear view up to and including azimuths of 210deg (at 18deg elevation).
Adding omega-Centauri [NGC5139], a globular cluster, to this list requires a clear view up to an azimuth of 225deg (at 18deg elevation).
[18 degrees is the altitude of the top of the tree that presently obstructs our view to the SW]

Therefore, any obstruction to the SW must be limited to azimuths between 225 & 236deg at most, up to an altitude of 18deg. Any obstruction to the NW must be limited to azimuths greater than 303deg (318deg) and up to an altitude of 15deg.

Information prior to August 2014



Looking SW from North Dome of Observatory. Red cross identifies 236deg azimuth. [photo & white cross from iPhone app 'Theodolite' but poorly calibrated – correct angle derived from telescope alignment]

Looking NW from North Dome of Observatory. Red cross identifies 303deg azimuth. [photo & white cross from iPhone app 'Theodolite' but poorly calibrated – correct angle derived from telescope alignment]

7.4 Appendix 4 - View Impact Diagrams, Scale Versions

B10_ASK_SO_001.dgn
1:42:03 PM
5/09/2014
ndaddo

0 10 20 30 40 50 60 70

Lend Lease

sydney observatory
PART OF THE POWERHOUSE MUSEUM

Title	Scale	Date	Drawing No
LOCATION PLAN WITH MGA COORDINATES	1:500 @ A3	05.09.2014	ASK_SO_001

AZIMUTH 303 DEGREES

AZIMUTH 236 DEGREES

OBSERVATORY

Hickson Road

H1

Map Grid Australia
N 6,252,000.00
E 334,000.00

GN
TN
1°0'0.13"
Grid Convergence

238°0'0"
303°0'0"

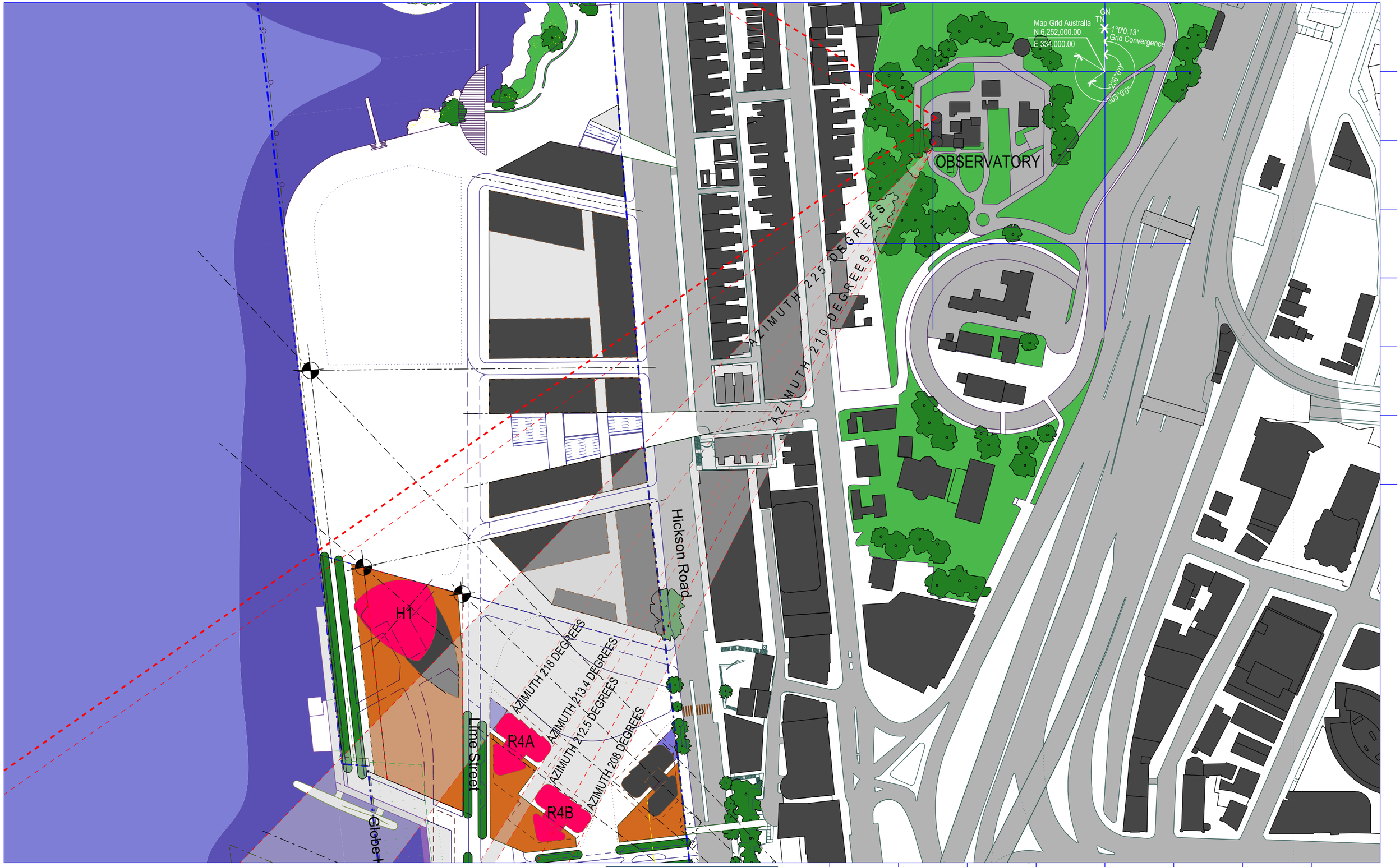
0 40 80 120 160 200 240 280

B10_ASK_SO_003.dgn
1:52:30 PM
2/09/2014
rdaddo

Lend Lease

sydney observatory
PART OF THE POWERHOUSE MUSEUM

Title	Scale	Date	Drawing No
WESTERN SKY CLEAR VIEW BETWEEN AZIMUTH 236 & 303 DEGREES	1:2000 @ A3	01.09.2014	ASK_SO_003



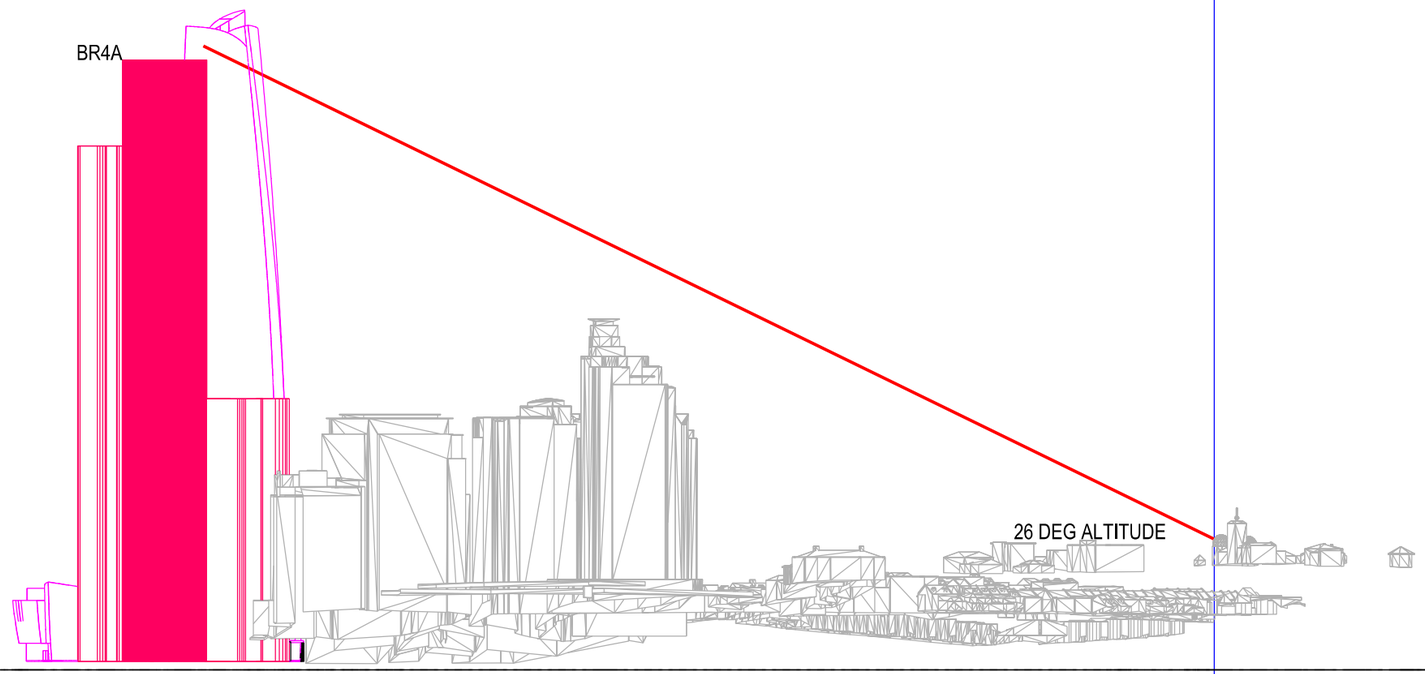
B10_ASK_SO_004.dgn
1:50:35 PM
2/09/2014
rdaddo

NOTE: SW SKY OBSTRUCTIONS BY
RESIDENTIAL TOWER 4A
UP TO 26 DEGREES ALTITUDE
RESIDENTIAL TOWER 4B
UP TO 21 DEGREES ALTITUDE
SEE ASK_SO_006

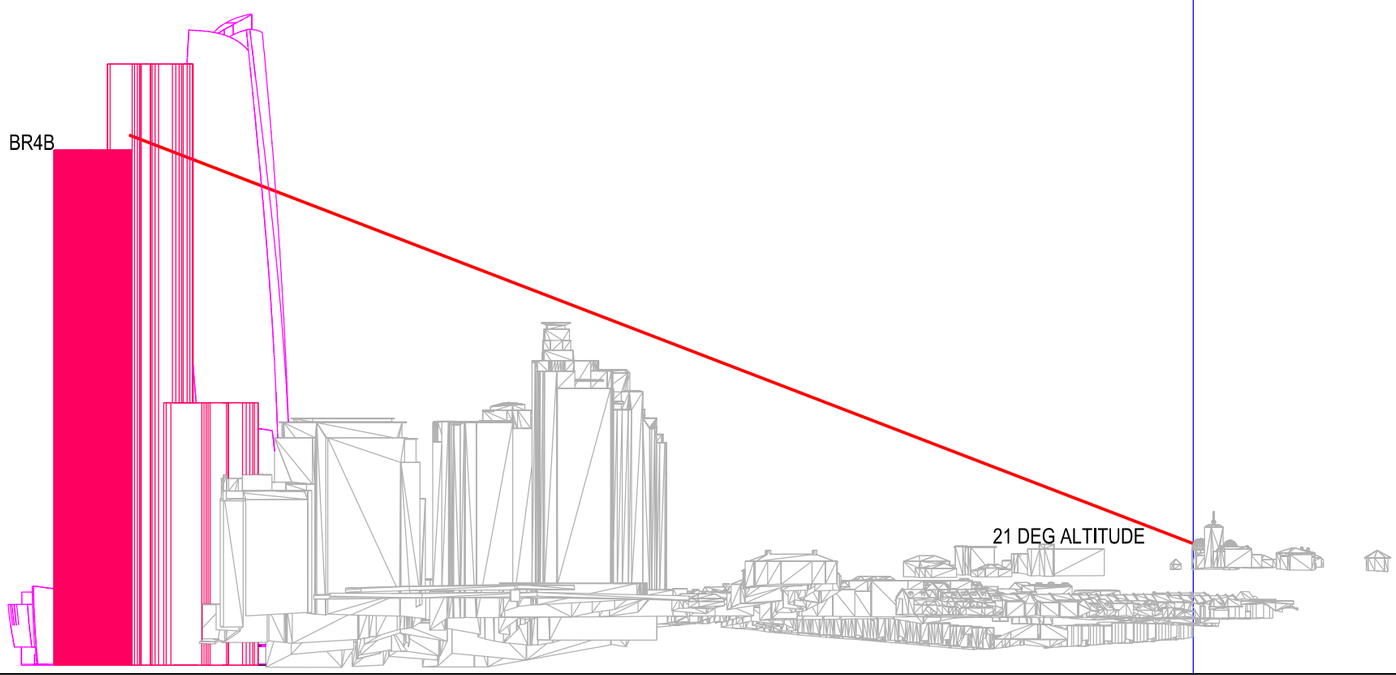
Lend Lease

sydney observatory
PART OF THE POWERHOUSE MUSEUM

Title	Scale	Date	Drawing No
SW SKY OBSTRUCTIONS BETWEEN AZIMUTH 208 & 225 DEGREES ABOVE 18 DEGREES ALTITUDE	1:2000 @ A3	01.09.2014	ASK_SO_004



SECTION 215 DEG AZIMUTH



SECTION AT 210 DEG AZIMUTH

0 50 100 150 200 250 300 350

B10_ASK_SO_006.dgn
1:21:04 PM
2/09/2014
rdaddo

Lend Lease

sydney observatory
PART OF THE POWERHOUSE MUSEUM

Title	Scale	Date	Drawing No
SW SECTIONS BR4A - AT 215 DEG AZIMUTH - 26 DEG ALTITUDE BR4B - AT 210 DEG AZIMUTH - 21 DEG ALTITUDE	1:2500 @ A3	02.09.2014	ASK_SO_006