



Chapter 7 Key assessment requirements

7.1 Heritage and archaeology

An Archaeological Management Plan and Heritage Impact Statement for the project was prepared by Godden Mackay Logan Pty Ltd (2009). A summary of the findings of the assessment is provided in this section. The full report is provided in Appendix B.

7.1.1 Methodology

The assessment was undertaken following a thorough conservation planning process. It considered potential Aboriginal and historical archaeological resources. The methodology was based on the guidelines contained in the *NSW Heritage Manual* and the *Archaeological Assessments* (Department of Urban Affairs and Planning and the Heritage Council of NSW, 1996) and applies the principles contained in *The Burra Charter: The Australia ICOMOS Charter for Places of Cultural Significance 1999*.

7.1.2 Existing environment

History of Bennelong Point

There has been development on Bennelong Point since the earliest period of European settlement in Sydney Cove between 1788 and 1795, when Bennelong Point was the location of Bennelong's brick hut and a salt works and windmill. The early settlers also recognised the defensive value of Bennelong Point and a redoubt was constructed in 1789, which was later replaced by a 'half moon battery' in 1798.

Work commenced on the construction of a fort (Fort Macquarie) at the northern tip of Bennelong Point in 1817, with large parts of the rest of the peninsula and surrounding area being reserved for parks and public space. Fort Macquarie dominated the area between 1817 and 1901. In the late nineteenth century the western shore of Bennelong Point was converted for use by trading companies for major longshore wool, mail and passenger wharves, whilst the western rampart of the fort was demolished to make way for facilities associated with the P&O operation that dominated the western shore.

The early twentieth century saw Bennelong Point accommodate a number of jetties for use by the public, serviced by a tram line to a new 'tram-car house' known as 'the shed'. The shed was built on the site of Fort Macquarie and was large enough to house 72 trams on twelve parallel tracks. The shed became redundant in the 1950s.

The years after 1955 saw the conception of Sydney Opera House, which was completed over the next two decades and opened in 1973.



Existing heritage items and status

The project is located on land that forms part of a number of different heritage listings and also has the potential to contain archaeological deposits due to the past use of the land. A summary of the heritage listings are located in the following sections, along with an assessment of the archaeological potential of the site.

Sydney Opera House

Sydney Opera House was constructed during the 1960s and 1970s and was opened in 1973. Since then, Sydney Opera House has become an architectural and national icon which is reflected in its listing on a number of heritage lists, outlined below:

- ▶ UNESCO World Heritage List –Sydney Opera House was included on the World Heritage List in June 2007 , under Criterion (i), for its Outstanding Universal Value and as a Masterpiece of Human Creative Genius;
- ▶ National Heritage List –Sydney Opera House was included in the National Heritage List (protected under the EPBC Act) in July 2005 under a range of criteria, including its significance as:
 - a masterpiece of modern architectural design;
 - engineering and construction technology in Australia; and
 - a national icon that has become an internationally recognised symbol of modern Australia.
- ▶ Register of the National Estate under a range of criteria, including its significance as:
 - an internationally recognised symbol of Sydney and Australia;
 - an exceptional design enhanced by setting;
 - a considerable technical accomplishment; and
 - the scene of many notable achievements in the performing arts;
- ▶ The NSW State Heritage Register (protected under the Heritage Act) for its significance as:
 - a twentieth century architectural masterpiece with exceptional aesthetic, scientific and technical significance;
 - an internationally recognised symbol of Sydney and Australia;
 - a performing arts venue with extensive associations with many famous people and important themes in Australian history; and
 - an outstanding visual, cultural and tourist focal point for Sydney and Australia.
- ▶ Sydney Local Environmental Plan 2005 for its significance as:
 - A national icon of exceptional significance both aesthetically and scientifically; and
 - A performing arts centre of world renown.

Bennelong Drain

The Bennelong Drain was constructed in 1856. The section within the Sydney Opera House site was realigned during the construction of Sydney Opera House in the 1960s and 1970s and the Sydney Opera House carpark in the 1980s.



The Bennelong Drain (and curtilage) is listed on Sydney Water's Section 170 register (as 'Bennelong Stormwater Channel No 29A'). The listing notes that it:

- ▶ Is of high historical and technical significance as it was one of the five original combined sewers built in Sydney around 1857;
- ▶ Was originally known as the 'main sewer' because it serviced the CBD area; and
- ▶ Was also the first oviform ('egg shaped') sewer to be built in Australia.

The Sydney Water Section 170 Heritage Register Item Report notes that the Bennelong Drain has dimensions of 1.5 m x 1.2 m. It was made of brick and some sections were tunnelled in sandstone along The Tarpeian Way (Circular Quay East). The Bennelong Drain drains the Sydney Cove slopes to as far south as Bathurst Street, extending generally from Macquarie Street in the east to York Street in the west. The most upper stream point is at the Obelisk ventshaft at Hyde Park. From here it works its way down along Pitt, Castlereagh, Elizabeth, Phillip and Macquarie Streets to the outlet at Bennelong Point. The channel contains the following branches: Macquarie Street, Phillip Street, Elizabeth Street, Castlereagh Street and Pitt Street. The Macquarie Street Branch was originally constructed by the old city council in 1856. In 1916, 54 m was reconstructed during the construction of the City Railway. Modifications were also made to the channel in the early 1970s for the construction of Sydney Opera House and during the late 1980s for the building of the Sydney Harbour Tunnel.

It is understood that a section of the original drain extends immediately north of the Tarpeian Way wall for approximately 20 m. The original channel was diverted at this point in the 1960s-1970s as part of the Sydney Opera House construction works, with the diversion constructed as a concrete box culvert. Part of the drain was also relocated in the 1980s in association with the construction of the underground carpark.

Seawall

The existing seawalls around Bennelong Point were largely rebuilt in association with the construction of Sydney Opera House. It is unclear how much, if any, of the fabric of the original seawall survives behind the outer face of the suspended sea wall.

The section of the seawall immediately north of the Man O' War Jetty was constructed when the boat slip in this area was demolished and the area was reclaimed in association with construction of Sydney Opera House. This section of wall therefore would date to the 1960s-1970s. The section of wall immediately to the south of the Man O' War Jetty may also have been rebuilt during this period; however, without further evidence it has been assumed that this section of the seawall was built in the 1860s and represents one of the earlier surviving sections of the seawall surrounding Bennelong Point. The extent of surviving original fabric has not been confirmed as part of the heritage assessment.

Assessment of significance (potential archaeological deposits)

Aboriginal archaeological potential

The study area does not contain any known Aboriginal sites.



There is some potential for parts of the study area to contain relatively intact natural soil deposits that may contain evidence of Aboriginal use or occupation of Bennelong Point, either prior to the arrival of Europeans in 1788 or during the early years of the colony. Much of the study area appears not to have been subject to major disturbance that would have definitely removed any potential deposits associated with this phase of the site's history. However, while this area has remained largely undeveloped throughout its history relative to the rest of Bennelong Point, it has been subject to land modification and extensive use for pedestrian and vehicle traffic, including trams, which would have had some impact on the survival of any evidence of Aboriginal use or occupation of the area. On that basis, the study area is considered to have low potential to contain any Aboriginal archaeological evidence.

The study area also includes some areas of reclaimed land. These areas would have no potential for in-situ Aboriginal archaeological objects features to be present. There is some potential for introduced fill deposits across the site to contain unstratified objects, but the likelihood of such evidence is impossible to determine.

Historical archaeological potential

The historical archaeological potential of the forecourt area is outlined in Table 7.1.

Table 7.1 Archaeological potential of the forecourt area

Site features	Date	Potential remains	Likelihood of survival
There is no specific development or land use activity recorded within the study area during this period	1788-1802	Deposits associated with the original shorelines and original land form Evidence associated with incidental activities in this area, such as artefact scatters/rubbish dumps	Low to moderate
Rubbish dumps into water – later reclaimed land	1788-1960s	Concentrations of artefacts within area of reclaimed land beneath introduced fill deposits	Moderate to high
Rectangular structure shown on plans adjacent to eastern shoreline (form/function unknown)	By 1829	Structural remains	Low
Fort Macquarie (the southeastern section of the battery extends within the study area)	1817-1901	Stone foundations associated with the southern section of the battery	Moderate to high
Fort Macquarie	1817-1901	Structural remains associated with internal and/or external features or additions of this section of Fort Macquarie	Low to moderate
Fort Macquarie	1817-1901	Deposits associated with occupation/use of Fort Macquarie (internal and external)	Low



Site features	Date	Potential remains	Likelihood of survival
Fort Macquarie	1817-1901	Roadways and pathways around Fort Macquarie	Low
Boat harbour/slip in southeastern section of Bennelong Point	By 1845 to 1960s	Remains of stone seawalls defining boat harbour, stone steps on external face of sea wall, stone boat ramp	Moderate to high
Infrastructure associated with boat harbour/slip	By 1845 to 1960s	Structural remains (stone, brick, timber) associated with sheds, offices, stores and waiting rooms adjacent to boat harbour/slip.	Low to moderate
Wharf infrastructure – western shoreline	By 1860s to 1960s (rebuilt upgraded 1889)	Stone seawall piers, structural remains and remains of other wharf infrastructure	Low to moderate
Tram-car house – associated infrastructure	1901-1950s	Tram tracks, roads, footpaths extending from and adjacent to the tram-car house The tram-car house itself was located wholly outside the study area	Moderate to high
Bennelong drain	From 1857	Ovioid channel and concrete diversions	Known feature
Seawall along eastern shore of Bennelong Point	1860s - 1960s/1970s	Stone seawall	Known feature
Evidence associated with the construction of Sydney Opera House	Post 1963	Any such evidence would generally not be considered as 'relics' under the Heritage Act	N/A

Summary statement of significance

Sydney Opera House is a heritage item of local, state, national and international significance. However, the potential archaeological remains within the forecourt area of the Sydney Opera House site have no direct association with Sydney Opera House itself or this significant phase of the site's history. The site's potential archaeological resource is associated with various significant phases in the site's historical development that have influenced its current form. In particular, the study area has potential to contain archaeological evidence associated with the modification of Bennelong Point's shoreline, Fort Macquarie, nineteenth- and twentieth-century wharf and harbour facilities and the twentieth-century tram operations.

Archaeological evidence of the changing shoreline therefore has the potential to contribute to our understanding of the landforms that existed around Sydney Cove prior to non-Aboriginal settlement and after land reclamation works in the nineteenth century. Such evidence would have high archaeological significance. Any evidence associated



with Aboriginal occupation or use of the site, including isolated objects in disturbed contexts, would have high archaeological significance.

Archaeological remains associated with Fort Macquarie, including structural remains or associated deposits or features, would have high archaeological significance and research potential for their ability to contribute to our understanding of this major period in the historical development of Bennelong Point.

The development of the eastern side of Sydney Cove along the western shore of Bennelong Point for wharves, ferries and other facilities related to seaborne trade is a matter of considerable historical interest, having a bearing on our understanding of the local area's development and the growth of Australian trade and industry during the nineteenth century. Relics relating to the nineteenth-century wharf facilities in particular have the potential to shed light on early and changing attitudes to the aesthetics of the harbour (from the picturesque to the utilitarian) and the changing functions of Bennelong Point (from defensive position to transport hub). Their potential in this regard is likely to be limited by a degree of disturbance caused by subsequent activities on the site. Such evidence would have moderate archaeological significance.

Archaeological investigation of relics associated with the operation of the trams on Bennelong Point would have limited potential to yield information relating to the development of Sydney's public transport system. Such evidence would have low archaeological significance.

Aboriginal heritage

A search of the Aboriginal Heritage Information Management System (AHIMS), the database of recorded Aboriginal sites maintained by the DECCW, identified one registered site within the study area (Site No. 45-6-1615). This site is described in the NPWS site card as a midden, from which 'shells ... were used by the early settlers in lime-burning, to provide building mortar'. The registered coordinates for the site indicate that it was located near the base of the Tarpeian Wall, though the actual location of the site is uncertain. The site card records the site's condition as 'destroyed' and it is clear that it had been destroyed some time before its inclusion in the database in 1983.

7.1.3 Impact assessment

This assessment focuses on three heritage components of the site that would be potentially impacted by the project, these components are:

- ▶ Potential archaeological remains within the study area (both historical relics or Aboriginal 'objects');
- ▶ The Bennelong Drain; and
- ▶ The existing seawall along the eastern boundary of the study area.

The project does not involve any works to Sydney Opera House, and the heritage significance of Sydney Opera House would not be impacted by the project.



Potential archaeological impacts

Potential archaeological remains that may be affected by the proposed excavation works are listed in Table 7.2.

Table 7.2 Potential archaeological impacts

Potential Archaeological Remains	Date	Significance	Potential impacts
Deposits associated with the original shorelines and original land form	1788-1802	High	Potential partial disturbance due to excavation for drain diversion
Evidence associated with incidental activities in this area, such as artefact scatters/rubbish dumps	1788-1802	High	Unknown

The potential archaeological remains within the forecourt area, while generally assessed as being limited in extent or intactness, have also been assessed as having moderate or high significance for their historical associations as well as their potential to address research questions regarding the nature and extent of the early settlement and development of this part of Sydney and its changing landforms.

Excavation for the project would have the potential for relatively minor archaeological impacts, limited to potential evidence of the early shoreline and landform and any incidental (unrecorded) remains in this area of the site. These would be managed by implementation of the recommended archaeological management plan (refer Appendix B).

Impacts on the seawall

The project would involve removal of some fabric of the eastern seawall to allow construction of a new outlet. Construction of the new outlet through the existing outer sandstone seawall has the potential to result in minor impacts to potentially significant historical fabric. Impacts relate mainly to potential visual impacts, which are considered in section 7.4.

Potential impacts to Bennelong Drain

Construction of the project is likely to involve:

- ▶ Removal of up to approximately 8m of the original ovoid drain - decommissioned section of the original drain located to the north of the 1960s-1970s diversion junction point; and
- ▶ Construction of a new junction point connected to the existing ovoid drain.

The Bennelong Drain has been identified as an item of high historical and technical significance at a local level. The significance of the drain is partly related to its degree of intactness, relative to similar infrastructure that was constructed during the same period. However, the section of drain that extends along Bennelong Point was substantially



modified in association with the construction of Sydney Opera House. The project therefore represents another phase in the drain's evolution.

The area of proposed disturbance and removal of fabric is adjacent to a section of drain that has been subject to substantial modification and diversion. The proposed diversion would have a major impact on the historic fabric of the drain, but would allow the original stormwater system, albeit partly modified, to continue to function effectively.

The significance of the Bennelong Drain is also partly related to its relationship with cultural and historical structures on the Sydney Opera House site. The Bennelong Drain would maintain its relationship to the Sydney Opera House once the drain is diverted.

Compliance with the Sydney Opera House Management Plan

The heritage impact assessment/archaeological management plan (Appendix B) was prepared to address the heritage impacts of the project in relation to the requirements of the Management Plan for the Sydney Opera House and the 2003 Conservation Plan. The heritage assessment is consistent with the objectives of the Management Plan.

It concluded that the project does not include any activities that would have significant adverse impact on the National and World Heritage values of Sydney Opera House.

The mitigation measures recommended by the heritage assessment (and summarised in the following section) are consistent with the objectives of the Management Plan. The assessment concludes that the project complies with relevant policies of the Conservation Plan.

Royal Botanic Gardens

The project requires excavation of a small area of land that is owned by the Royal Botanic Gardens Trust. There would be no physical impact on the QEII gate at the entrance to the gardens, nor on the gardens themselves. The heritage impacts would be limited to a temporary disruption to the visual setting of this part of the gardens and the limited visibility of the stormwater drain outlet. These impacts are not considered likely to affect the heritage significance of the Royal Botanic Gardens or the QEII gate.

Aboriginal archaeology

There is some potential for parts of the study area to contain relatively intact natural soil deposits that may contain evidence of Aboriginal use or occupation of Bennelong Point, either prior to the arrival of Europeans in 1788 or during the early years of the colony. Much of the study area appears not to have been subject to major disturbance that would have definitely removed any potential deposits associated with this phase of the site's history. While this area has remained largely undeveloped throughout its history relative to the rest of Bennelong Point, it has been subject to land modification and extensive use for pedestrian and vehicle traffic, including trams, which would have had some impact on the survival of any evidence of Aboriginal use or occupation of the area. On that basis, the study area is considered to have low potential to contain any Aboriginal archaeological evidence.

The study area also includes some areas of reclaimed land. These areas would have no potential for in-situ Aboriginal archaeological objects features to be present. There is



some potential for introduced fill deposits across the site to contain unstratified objects, but the likelihood of such evidence is impossible to determine.

During the course of this study, consultation was undertaken with Allen Madden of the Metropolitan Local Aboriginal Land Council (MLALC), in order to inform MLALC of the proposed works to the site and to invite comment. This consultation was undertaken on Wednesday 15 April 2009 with Laura Farquharson, Consultant from Godden Mackay Logan. There were no issues raised by MLALC about the proposed works during this meeting. There was also no suggestion made that the study area has any special associations with MLALC. On this basis, further assessment of the site's Aboriginal cultural values, beyond its archaeological potential, has not been undertaken.

7.1.4 Mitigation measures

Potential archaeological impacts

- ▶ Archaeological investigation and recording would be undertaken consistent with the recommendations of the archaeological management plan detailed in Section 5 of Appendix B.
- ▶ Relevant site personnel would attend a site induction prior to commencement of the works to ensure that all on-site personnel are aware of the heritage issues associated with the site and the role of the archaeologist(s) on site.
- ▶ Any ground disturbance in areas of archaeological sensitivity should be undertaken under the supervision of a monitoring archaeologist and in accordance with the methodologies described in the archaeological management plan.
- ▶ In the event that any archaeological remains are exposed during site works, they should be appropriately documented according to the procedures outlined in the archaeological management plan.
- ▶ Subsurface disturbance should be limited to those areas defined by the project plans so as to avoid disturbance of other potential archaeological remains at this site.
- ▶ In the event that unexpected archaeological evidence is encountered during site works, works in the immediate vicinity should cease and the Heritage Branch, Department of Planning, should be notified immediately. Further assessment and/or approval may be required before works could recommence.
- ▶ In the event that unexpected Aboriginal archaeological evidence is encountered during site works, works in the immediate vicinity should cease and DECCW should be notified immediately in accordance with the *National Parks and Wildlife Act 1974*. Works must not recommence until Sydney Opera House Trust receives written authorisation from DECCW.

Bennelong Drain

- ▶ The removal or disturbance of any sections of the original ovoid channel (currently functioning or previously decommissioned) should be minimised wherever possible.



- ▶ Any sections of the original drain that are to be removed should be photographed in situ prior to removal (including sections of the original ovoid drain and later diversions).
- ▶ Any exposed sections of the original ovoid drain that will not be removed should be protected during excavation works, as well as in association with construction of the new diversion junction.
- ▶ Removal of any sections of the original ovoid drain would be undertaken in consultation with Sydney Water.
- ▶ Sydney Water would be consulted in relation to any preservation requirements, including the retention and storage of any fabric or artefacts recovered from the Sydney Water asset.

Seawall

- ▶ To match the existing fabric of the seawall, the drain would be lined with sandstone to about 1-1.5 m from the outlet.
- ▶ All works to the seawall should retain and respect the existing material configuration where possible.
- ▶ The amount of sandstone removed from the seawall for construction of the outlet should be minimised.
- ▶ Removal of stone from the seawall should be undertaken in a manner that does not disturb, damage or destabilise the surrounding fabric.

Interpretation

- ▶ Interpretation of any exposed archaeological features and the contribution of this evidence to archaeological research may also mitigate any adverse archaeological impacts. Any such interpretation should be part of a holistic approach to the interpretation of the site. Potential archaeological evidence that may be of particular interest would include:
 - Remains of Fort Macquarie, associated with a major period in the historical development of Bennelong Point; and
 - Any evidence of Aboriginal use or occupation of the site, including any isolated artefacts that may be discovered during site works.

7.2 Hydrology and drainage

A hydrology and drainage assessment of the project was prepared by GHD. A summary of the findings of the assessment is provided in this section. The full report is provided in Appendix E.

7.2.1 Methodology

The methodology for the hydrology and drainage assessment included:

- ▶ Site visit and field reconnaissance;



- ▶ Collate and review relevant data;
- ▶ Develop hydrology and stormwater drainage model of proposed diversion drain;
- ▶ Generate rainfall intensity frequency duration data for catchment;
- ▶ Estimate stormwater design inflows at strategic locations for four annual exceedance probability design storm events;
- ▶ Assess hydraulic behaviour of project;
- ▶ Interpret modelling results; and
- ▶ Estimate potential sediment yield and assess sediment entrainment and sediment deposition characteristics.

7.2.2 Existing environment

The Bennelong Drain catchment has an area of approximately 72 ha. It is bounded by Clarence Street to the west, Bathurst Street to the south, Macquarie Street to the east, and Sydney Harbour to the north (refer Figure 7-1).

The existing drainage system consists of a series of drains aligned in a north-south direction within the Sydney CBD. Stormwater runoff generally flows in a northerly direction through these stormwater drains, until it reaches Alfred Street at Circular Quay.

At Alfred Street, the drainage system branches into three outlets. The primary outlet is the Bennelong Drain, which veers in a north-east direction towards Bennelong Point. This drain is rectangular in shape (3.05m wide by 1.22m high) and discharges into Sydney Harbour.

Two smaller drains for the catchment discharge at Alfred Street, one near the Loftus Street intersection and the other near the Phillip Street intersection. Both these drains have smaller capacities and overflow at Circular Quay directly into Sydney Cove.

Based on information provided by Sydney Water, it is estimated that the Bennelong Drain has a capacity of between the 12 to 15 year ARI storm event. By contrast, the Phillip Street drain only has a capacity of between the 1 to 2 year ARI event, while the Loftus Street has a capacity of between the 0.5 to 1 year ARI event.

Discussions with Sydney Water indicated that a sediment trap is installed within the Sydney Opera House car park. Very little sediment removal is required at this trap. This is mainly accounted to the fact the City of Sydney Council has a well developed street cleaning program that reduces the volume of debris entering the stormwater system.

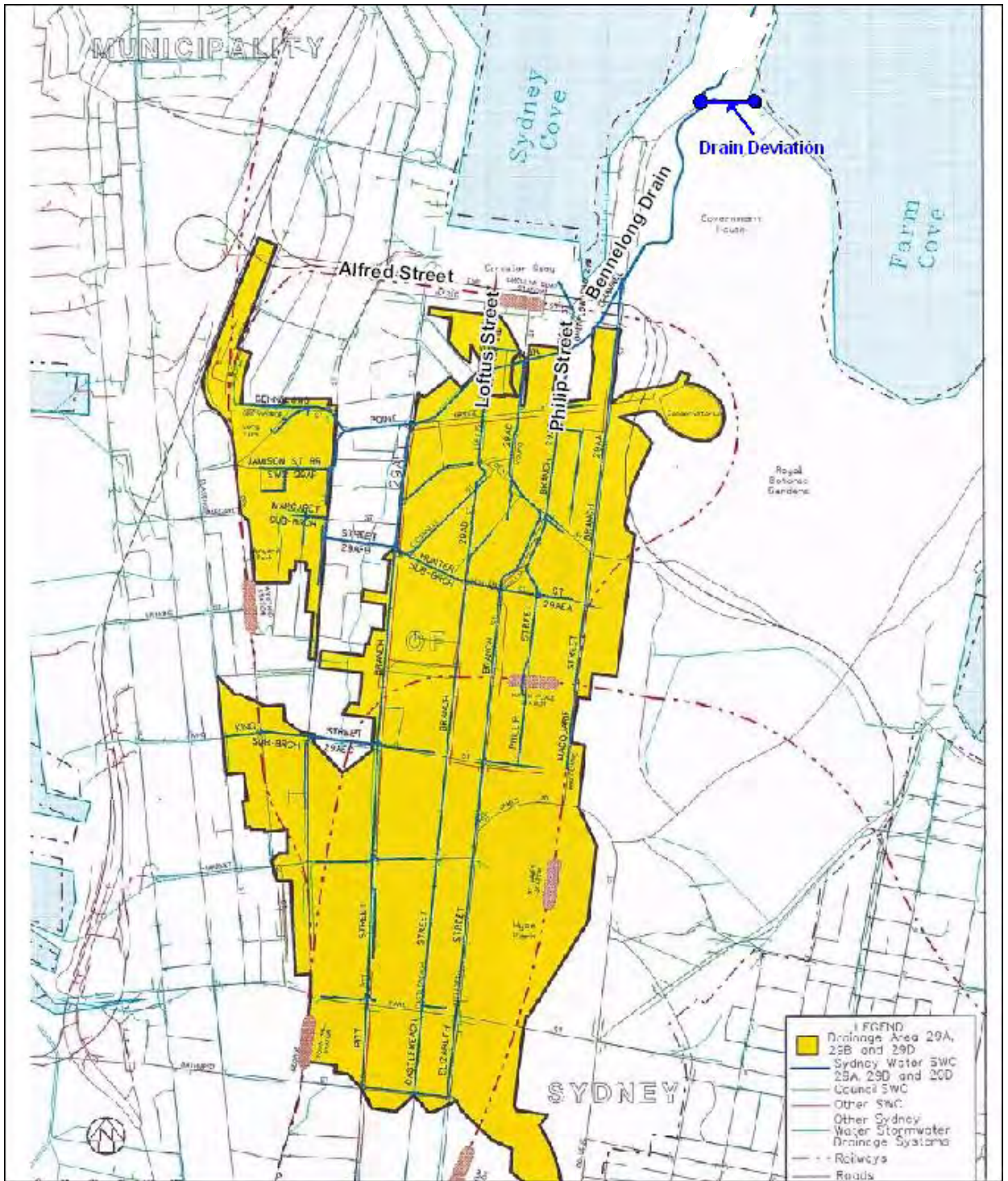


Figure 7-1 Bennelong drain catchment



7.2.3 Impact assessment

Potential impacts of the project include:

- ▶ Construction impacts;
- ▶ Impacts on upstream flooding;
- ▶ Sediment deposition and scour; and
- ▶ Climate change impacts.

Construction impacts

The main potential for impacts during construction relates to potential water quality impacts. These are considered in Section 8.2.

Impacts on upstream flooding

Hydrology

Design flows at the diversion outlet were estimated and the results are summarised in Table 7.3, which shows the 1 in 5 year average recurrence interval (ARI) flow at the Bennelong Drain is estimated to be 7.8 m³/s.

The design flows presented in Table 7.3 are essentially the same under both the existing and proposed drainage conditions. This is because the catchment areas and flow travel times are unchanged, with the net result that the design flows are not changed. In this regard, while the forecourt areas in the vicinity of the drain are slightly different under existing and proposed drainage conditions, the forecourt areas have their own drainage outlets. The forecourt areas do not discharge into either the existing or proposed section of drain, and therefore do not impact on the drain catchment areas and design flows.

Table 7.3 Design flows

Design ARI (yrs)	Intensity (mm/hr)	Runoff coefficient	Catchment discharge (m ³ /s)	Bennelong drain discharge (m ³ /s)
1	52.1	0.68	7.1	0.9
2	67.3	0.73	9.7	3.5
5	87.0	0.81	14.0	7.8
10	98.7	0.85	16.7	10.6
20	114.3	0.89	20.3	14.2

Catchment Area = 71.1 ha, Impervious fraction = 85%, Time of concentration = 24.3min

Overall, the design flows as a result of the project are expected to remain the same under existing and proposed development conditions, for the full range of storm events. No adverse impacts are expected on upstream flooding behaviour.



Flow hydraulics

The hydraulic capacities of the existing and proposed sections of drain were estimated. The hydraulic capacity of the existing drain is estimated to be about 10.6 m³/s. This corresponds to a storm magnitude of about the 10-year ARI. By comparison, the hydraulic capacity of the Bennelong Drain as a result of the project is estimated to be about 12.5 m³/s. This is estimated to equate to an ARI event of about 15 years.

As the capacity of the proposed drain (12.5 m³/s) is estimated to be greater than the existing drainage capacity (10.6 m³/s), the project is not expected to have any adverse impacts on the upstream flooding behaviour.

It is noted that the proposed drain has a capacity equivalent to about the 15-year ARI flood. While this is relatively low for a trunk drainage system, Sydney Water has agreed that it would be adequate in this case because the project would be undertaken at the downstream end of an existing system and there are no plans to upgrade the upstream sections of the system.

Overall, the project is not expected to have any adverse impacts on the existing upstream flooding behaviour.

Impacts on sediment deposition and scour

Sediment yield

Sediment yield data within the catchment is not available. However, based on typical export rates for urban catchments, it is estimated that the sediment yield for the Bennelong Drain catchment would be between 17,000 kg to 35,000 kg per year.

It should be noted that Sydney Water advised that there is a sediment trap within the Sydney Opera House Car Park which is immediately upstream of the subject section of drain. This trap contains relatively small volumes of sediment and only requires to be emptied infrequently. This suggests that sediment yield at the stormwater outlet is likely to be low.

Sediment deposition and flushing

Estimated discharge velocities at the proposed outlet, for various storm ARI events, are estimated in Table 7.4. These velocities correspond to high tide conditions, and the exit velocities are therefore expected to be higher under low tide conditions.

Table 7.4 Discharge velocities at proposed drain outlet

ARI (yrs)	Discharge (m³/s)	Drain Flow Depth (m)	Outlet Velocities¹ (m/s)
1	0.9	0.40 - 0.94	0.4
2	3.5	0.42 - 0.94	1.6
5	7.8	0.73 – 0.94	3.5
10	10.6	0.90 – 0.94	4.7



ARI (yrs)	Discharge (m ³ /s)	Drain Flow Depth (m)	Outlet Velocities ¹ (m/s)
Approx 15	12.5	1.02	5.1
20	14.2	1.02	5.1

1: Under high tide conditions

Table 7.4 indicates that for design storms between the 1-year to 20-year ARI events, the outlet discharge velocities would range from 0.4 m/s to 5.1 m/s. Velocities of 0.6 m/s are usually required to facilitate self-flushing of drainage pipes. Flows at and above the 2-year ARI event are therefore expected to be sufficient for sediment entrainment and flushing to occur along the drainage line.

However, for lower flows up to the 1-year ARI event, some sediment deposition is expected to occur along the drainage system. Nevertheless, the deposited sediment is expected to wash into the harbour during the larger storm events.

Scour and sediment deposition at diversion outlet

Potential scour and sediment deposition at the outlet is a complex function of a large number of interacting variables, including the outlet velocities and shear stresses, flow alignment, sediment and bed characteristics, hydraulic structure design, time factors, regional factors, coastal currents, and tidal effects.

At the existing drainage outlet, sediment washed into the harbour is carried and redistributed by the tidal flows and coastal tides and currents. It is apparent that sediment washed into the harbour at the existing outlet has not posed any sedimentation issues. As indicated previously, effective operation of the sediment trap within the Sydney Opera House Car Park is likely to reduce the volume of sediment discharged by the Bennelong Drain. This is likely to be due to sufficient depths of water available between the drain invert and the seabed, which is estimated to be several metres. In addition, the location of the existing drain, is where the river and tidal currents are likely to be relatively high, thus minimising the potential for sediment deposition to occur in that area.

By comparison, the proposed outlet is located at the southern end of the Bennelong Point and on the leeward side of the tidal flows. At the outlet, the available flow depth is estimated to be about 0.5 to 1m under normal flow conditions.

Field observations at the vicinity of the proposed outlet indicate that an area of limited circulation is likely to exist at the southern corner of the groyne structure (wharf) with the eastern seawall. This region is estimated to extend 10-30m along the seawall and 10-30m along the groyne structure. It is noted that this is an estimate based on visual inspections.

In this area of limited circulation the local flow velocities are likely to be low and not significantly affected by lateral currents along the shoreline, with the flow being due mostly to tidal fluctuations and turbulence. The significance of this region is that any sediment load derived from the upstream catchment and washed into the bay at this outlet is likely to accumulate within this region.



To further assist in understanding the sediment deposition behaviour at the vicinity of the diversion outlet, typical urban sediment particle distribution sizes, as well as the critical shear stresses and critical velocities for sediment entrainment, have been estimated. The results are presented in Table 7.5.

It is noted that, based on the typical urban particle distribution data adopted, the sediment may be classified as non-uniform (standard deviation greater than 1.35). Under this condition, armouring of the bed surface is expected to occur under low flow conditions. Armouring means that a top layer of coarser size sediment would develop through sediment sorting, which would protect and cover the finer sediment sizes underneath. It is expected that the armour layer may not be stable due to the tidal fluctuations and bursts of turbulence that would occur in the field. However, re-stabilisation of the armour layer is also expected to occur over time.

Table 7.5 Critical shear stresses and velocities for sediment entrainment

Typical urban particle size (mm)*	Tc (N/m ²)	Vc (m/s)
D ₈₄ = 2 mm	1.3	1
D ₅₀ = 0.4 mm	0.26	0.45
D ₁₆ = 0.1mm	0.065	0.22

* Particle size distribution derived from urban data presented in Australian Runoff Quality Guidelines (2003)

Tc = Critical Shear Stress based on Shields Entrainment Function

Vc – Critical Velocity based on critical shear stress for sediment entrainment

Comparison of the culvert discharge velocities in Table 7.4, with the critical velocities for sediment entrainment in Table 7.5, indicates that flow discharges smaller than the 1-year ARI event (high tide conditions) are unlikely to break up the armour layer or entrain more than 50% of the sediment sizes. Under these conditions, sediment deposition is expected to occur at the diversion outlet.

At higher discharges greater than the 1-year ARI event, however, the critical velocities for sediment entrainment are exceeded, and flushing of the sediment further out into the bay area is expected. The risk remains, however, that the tidal currents are likely to carry and deposit the sediment in the area of limited circulation.

A potential issue is that the proposed diversion outlet is located within the area of limited circulation. At this location the transport of sediment further out into the bay area is generally more difficult, with any sediment deposited likely to remain trapped in this general area. As indicated previously, effective operation of the existing sediment trap upstream of the subject section would reduce the volume of sediment discharged at this point.



In terms of potential scour at the diversion outlet, the design flow velocities, while relatively high, are not considered to be an issue. This assumes that the vicinity of the proposed outlet is characterised by sandstone bedrock (as indicated in the design drawings), which would be fairly resistant to those flows. It is noted that loose rocks up to 1m in diameter would be unstable and subject to movement at velocities exceeding 5 m/s.

Climate change impacts

The NSW Government Draft Sea Level Rise Policy (February 2009) states that sea level along the NSW coast is expected to rise by up to 0.4m by year 2050 and 0.9m by year 2100.

The NSW Floodplain Risk Management Guidelines (2008) suggests that, in order to take into account climate change effects, the following impacts would need to be assessed:

- ▶ Rainfall intensities – increases of 10%, 20% and 30%; and
- ▶ Sea level rise – 0.18m (low level scenario), 0.55m (mid level) and 0.91m (high level).

Design flow estimates, assuming a 30% increase in rainfall intensities, indicate that the 5-year ARI design flow would increase from 7.8 m³/s to 12.8 m³/s. Effectively, for this scenario, the climate change 5 year ARI flow would increase significantly and correspond to the existing 15-year ARI flow.

The performance of the project is further assessed taking into account a 30% increase in rainfall intensity, and coupled with sea level rise. Results of modelling indicates that the overall effects of climate change are such that the hydraulic efficiency of the proposed diversion drain would be significantly reduced, from a proposed design capacity of about the 15-year ARI to climate affected capacity of between the 2 and 5 year ARI event.

It is noted that the above findings are for a 30% increase in rainfall intensity. For less severe increases in rainfall intensities, the impacts are expected to be lower.

Under storm tide conditions, some backwater is expected upstream along the drainage system, which would result in a reduction in the drainage capacity. However, both the existing and proposed diversion drains would behave in a similar manner, hydraulically, under climate change conditions. On this basis, no adverse impacts are expected to occur, relative to existing conditions.

Sydney Water was consulted regarding the need to design the project to accommodate climate change scenarios. Sydney Water advised that it would not be appropriate for the project to accommodate these scenarios because it is located at the extreme downstream end of an existing system and there are no plans to upgrade the upstream sections of the system.

7.2.4 Recommended mitigation measures

The following mitigation measures would be implemented to minimise potential impacts:



Construction

- ▶ As described in section 7.3.4, a detailed erosion and sedimentation control sub-plan would be prepared as part of the construction environmental management plan, describing safeguards to minimise the adverse impacts on water quality from erosion, sediment transfer and sedimentation during the construction phase.
- ▶ Construction methods and management measures would be developed to ensure that the drain can remain operational during the construction of the diversion.

Operation

- ▶ It is recommended that a monitoring program be established to monitor the amount of sediment that may be deposited at the outlet once it has been commissioned. The quantity of sediment discharged from the outlet to the receiving environment would be further quantified post construction. This would be undertaken as part of Sydney Water's existing operational plan for the overall stormwater network and would involve six monthly inspections of the sediment trap immediately upstream of the project to ensure it is operating effectively.
- ▶ If the sediment yield is found to be significant and significant sediment deposition problems are observed to be occurring, a potential mitigation strategy would be to upgrade the sediment sump that is currently located within the Sydney Opera House Car Park, immediately upstream of the project.
- ▶ It is also recommended that a boom be temporarily installed at the proposed diversion outlet to monitor and capture any floating debris and gross pollutants that may be discharged into Farm Cove. This would provide an indication of the amount of floating debris discharged from the drain. If the amount of floating debris is found to be significant, a permanent boom could be designed, otherwise the temporary boom would be removed.

7.3 Aquatic ecology and water quality

An aquatic impact assessment of the project was prepared by GHD. A summary of the findings of the assessment is provided in this section. The full report is provided in Appendix F.

7.3.1 Methodology

The assessment methodology consisted of:

- ▶ A review of literature and databases on aquatic flora and fauna in the area;
- ▶ Field surveys; and
- ▶ Impact assessment in accordance with the requirements of relevant Acts.

The field survey was undertaken on 12 May 2009. The survey methodology included:

- ▶ Deployment and survey of five line intercept transects (shown in Figure 7-2) within the immediate vicinity of the proposed outlet and three line intercept transects positioned within the surrounding area (including one at the existing outlet location). Each



transect ran from a position on the rock wall perpendicular out into the harbour, with total length limited by depth and visibility.

- ▶ The length of each transect was surveyed recording the type of habitat and the coverage distance of each habitat type.
- ▶ Incidental sightings of fish and other fauna were recorded.

An assessment of the potential impacts of the project on species, populations and ecological communities listed by the EPBC Act, *Fisheries Management Act 1994* (FM Act) and *Threatened Species Conservation Act 1996* (TSC Act) was undertaken in accordance with the guidelines for assessment for these acts.

7.3.2 Existing environment

Habitat description

Intertidal

The intertidal zone is comprised of a vertical sandstone seawall that continues around Bennelong Point and Farm Cove. The habitats observed during these surveys were typical of many intertidal habitats within Sydney Harbour.

Dominant species observed on the seawall included the Sydney Rock Oyster (*Saccostrea glomerata*), limpets (*Cellana tramoserica* and *Patella* sp), Murex shell (*Morula marginalba*) and an unidentified species of Chiton. Aforementioned species were observed as common throughout all seawall areas surveyed and are typical of the many rocky, intertidal habitats within NSW coastal waters.

No threatened species were observed within this area.

Subtidal

The majority of the subtidal environment within the immediate vicinity of the proposed outlet was characterised by macroalgal growth, areas of bare substrate and some rocky reef. Overall, this area was reasonably modified, however, despite large quantities of foreign man-made items littering the ocean floor, the study area retained a diversity of habitat suitable for a variety of aquatic biota.

The benthos within the area surveyed was generally medium grained sands with areas of shell grit and rocky rubble. Rubbish such as tyres, bottles, bricks, scrap metal and other construction material was prevalent throughout.

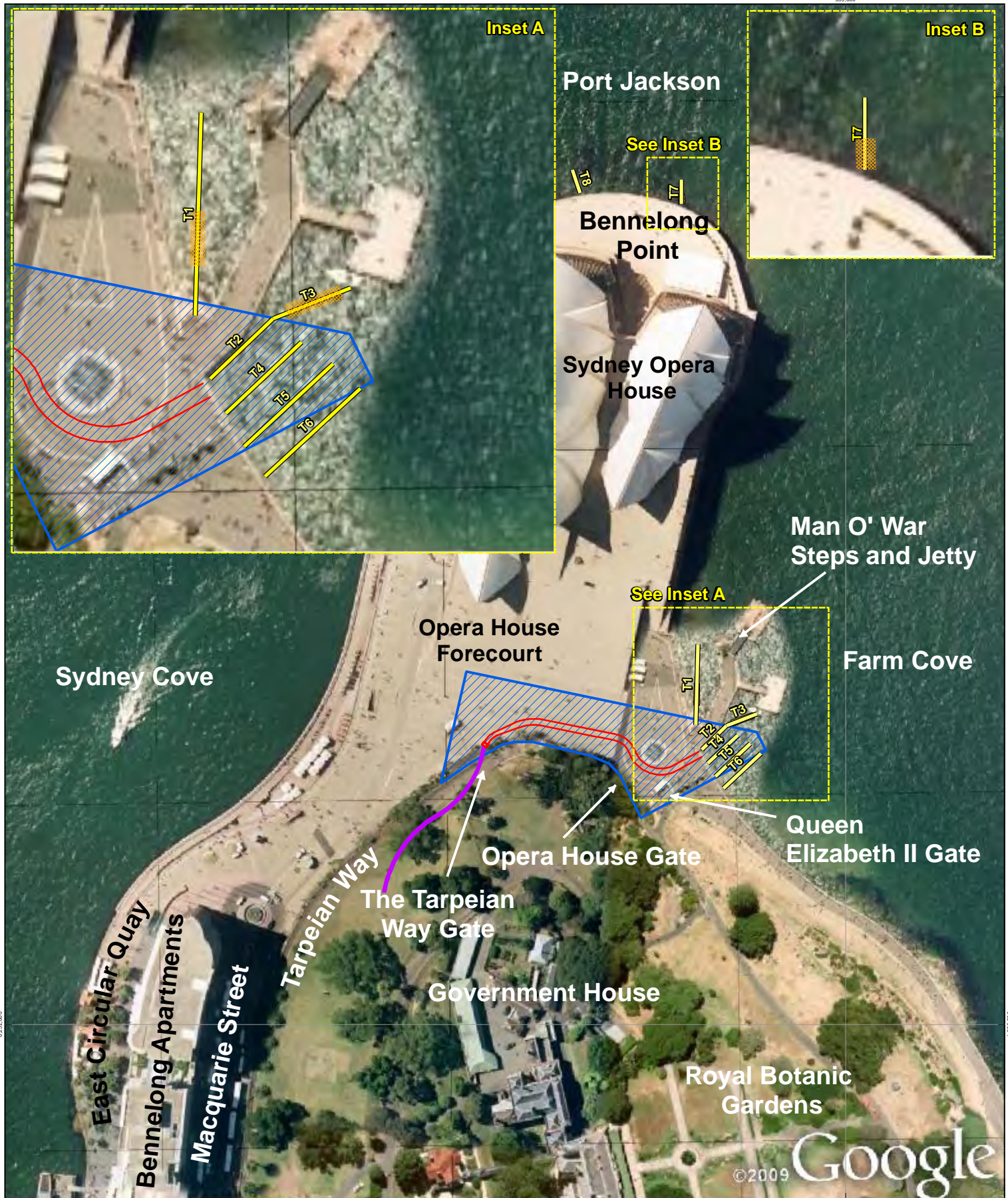
The habitat within the location of the proposed outlet was generally dependent on the presence of structure to provide an anchor point for green and brown algae. The green algae *Caulerpa filiformis* and the common kelp *Ecklonia radiata* were the dominant species occupying the hard substrate within the immediate vicinity of the seawall where they provide up to 100 % cover in localised areas. They were particularly prevalent along the Man O' War Jetty structure. However, the majority of the area surveyed within the vicinity of the proposed outlet is sandy rubble, with a very sparse and patchy coverage of *Ecklonia*, *Sargassum*, *Padina* and *Caulerpa* within around 10 m of the seawall. Further



out no benthic organisms were observed and the substrate was predominantly sand and shell grit that continued to at least 15 m from the seawall.

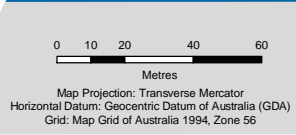
The only fish species observed during the survey were two Smooth Toadfish (*Tetractenos glaber*) and one Fan-bellied Leatherjacket.

Of most significance was a small localised area of *Zostera* seagrass that was identified along Transect 3. The seagrass was observed from 3.9 m to 7.8 m, providing approximately 20 % cover with moderate epiphytic growth. The area occupied by the seagrass lay within close proximity to an area that experiences a high level of disturbance. The extent of this seagrass bed was minimal and estimated to be approximately 20 m². This was the only threatened species identified within the survey area considered to have the potential to be impacted by the project.



Legend

- Study Area
- Upstream Drain Alignment
- Aquatic Ecological Transects
- Proposed Drain Realignment
- Extent of Seagrass



CLIENTS | PEOPLE | PERFORMANCE

Sydney Opera House Trust
Bennelong Drain Diversion Project
Aquatic Ecology Assessment

Job Number | 21-18445
Revision | B
Date | Jan 2010

Transect Locations

Figure 7.2



Threatened and endangered species

The results of the literature review and database searches indicate that a number of threatened species have been recorded within the study area (the 'study area' for the purpose of the flora and fauna assessment is five kilometre radius surrounding the site) or have the potential to occur.

Threatened species considered to have the potential to occur based on the presence of habitat are listed in Table 7.6.

Table 7.6 Likelihood of occurrence of threatened and protected species within the study area

Order	FM Act Status	EPBC Act Status	Likelihood of occurring within the study area
Fish			
Weedy Sea Dragon <i>Phyllopteryx taeniolatus</i>	P		Likely: Suitable habitat present.
Elegans Wrasse, Elegant Wrasse <i>Anampses elegans</i>	P		Possible: Suitable habitat is present (i.e. seaweed beds preferred by juveniles), however this species naturally occurs in low abundance and the study area is already highly modified.
Black Cod <i>Epinephelus daemeli</i>	P		Likely: Suitable habitat present.
Macquarie Perch <i>Macquaria australasica</i>	E	E	Highly Unlikely: Suitable habitat not present.
Bleekers Blue Devil Fish <i>Paraplesiops bleekeri</i>	P		Unlikely: Suitable habitat not present.
Green Saw-fish, Green Sawfish, Longcomb Sawfish, <i>Pristis zijsron</i>	PE	V	Highly Unlikely: Presumed extinct within waters of NSW (<i>NSW FM Act 1994</i>).
Estuary cod <i>Epinephelus coioides</i>	P		Likely: Suitable habitat present.
Mammals			
Southern Right Whale <i>Eubalaena australis</i>		E	Likely: Suitable habitat present.
Dwarf Minke Whale <i>Balaenoptera acutorostrata</i>		P	Unlikely: Suitable habitat not present.
Unidentified Rorqual		E/V/P	Likely: Suitable habitat present.



Order	FM Act Status	EPBC Act Status	Likelihood of occurring with in the study area
<i>Balaenoptera sp.</i>			
Humpback Whale		V	Likely: Suitable habitat present.
<i>Megaptera novaeangliae</i>			
Common Dolphin		P	Likely: Suitable habitat present.
<i>Delphinus delphis</i>			
Risso's Dolphin		P	Unlikely: Suitable habitat not present.
<i>Grampus griseus</i>			
Killer Whale		P	Likely: Suitable habitat present.
<i>Orcinus orca</i>			
False Killer Whale		P	Unlikely: Suitable habitat not present.
<i>Pseudorca crassidens</i>			
Spotted Dolphin		P	Unlikely: Suitable habitat not present.
<i>Stenella attenuata</i>			
Striped Dolphin		P	Unlikely: Suitable habitat not present.
<i>Stenella coeruleoalba</i>			
Bottlenose Dolphin		P	Likely: Suitable habitat present.
<i>Tursiops truncatus</i>			
Pygmy Sperm Whale		P	Unlikely: Suitable habitat not present.
<i>Kogia breviceps</i>			
Sperm Whale		P	Unlikely: Suitable habitat not present.
<i>Physeter macrocephalus</i>			
Strap-toothed Beaked Whale		P	Unlikely: Suitable habitat not present.
<i>Mesoplodon layardii</i>			
Seagrass			
Eel-grass	P		Likely: Suitable habitat present.
<i>Zostera capricorni</i>			
Strap-weed (<i>Posidonia australis</i>)	P		Unlikely: Suitable habitat present however this species is highly susceptible to disturbance and thus is not expected within the study area.
Paddle-grass (<i>Halophila sp.</i>)	P		Likely: Suitable habitat present.

Legend to table:

PE = Presumed Extinct, CE = Critically Endangered, E = Endangered, V = Vulnerable, P = Protected.



Water quality

Water quality in Sydney Harbour is typical of an urbanised catchment. It is likely that a number of port and non-port related activities including accidental spills and polluted stormwater run off from land combine to affect water quality. This includes sediment in runoff from construction and maintenance activities and litter and other contaminants such as oil from the catchment.

Water quality within Sydney Harbour is heavily influenced by runoff following large rain events. Runoff from urban areas is generally contaminated with sediment, nutrients, hydrocarbons, heavy metals, pathogens, and other toxic, and occasionally persistent chemicals (DEC, 2006). This contamination originates from roads, sewer overflows, spills, industrial activities, building sites and other sources. Water quality is comparatively better during drier periods with reduced volumes of runoff.

The impacts of such contamination include a reduction in species diversity, loss of pollution-sensitive species and high levels of persistent toxicants in sediments and marine species (DEC, 2006). The main threats to water quality, and therefore aquatic biota, as a result of stormwater input are:

- ▶ Sedimentation, as suspended sediment reduces light penetration and affects photosynthesis and can smother habitat;
- ▶ Deoxygenation as a result of organic loading; and
- ▶ Pollutants.

7.3.3 Impact assessment

Noise and vibration

Construction of the project has the potential to impact upon the marine biota via the generation of noise and vibration associated with machinery working in and around the water during construction. This impact is unlikely to be significant as the noise and vibration generated during construction would be intermittent, short term and limited to the area immediately adjacent the proposed outlet. In an urbanised location such as this, and with the large volume of boat traffic regularly using the area, it is unlikely that construction noise would pose a significant impact to the marine environment.

Impacts of sedimentation on aquatic habitat

Sediment mobilisation has the potential to decrease water quality and smother seagrass and algae in the immediate vicinity of the study area during both construction and operation. If inadequately managed, there is the potential for sediment mobilisation as a result of construction of the outlet and indirectly from runoff associated with construction of other parts of the project.

The potential for sedimentation as a result of the operation of the project is considered in Section 7.2. The potential for an increase in the deposition of sediment within the immediate vicinity of the outlet depends on the quantity of sediment flushed from the drainage catchment. The presence of a sediment trap immediately upstream of the project would minimise the volume of sediment discharged. As this sediment trap is



existing, there would be no change to the quantity of sediment discharged to Sydney Harbour by the Bennelong Drain.

The small community of *Z. capricorni* which lies adjacent Man O' War Jetty is limited in size and modelling suggests that sedimentation may not extend to this region. It is possible that impacts of sedimentation may extend beyond the junction between the wharf and seawall to the small bed of *Z. capricorni* (located during Transect 3) if deposition has been underestimated. *Z. capricorni* is a hardy, tolerant species which can recolonise by vegetative growth and can therefore survive small-scale disturbances. As this patch is relatively limited in size and the impacts of sedimentation are not expected to extend to this area, the impacts on this patch of seagrass should be largely negligible.

Sedimentation has the potential to smother, and therefore, adversely impact the dense communities of *C. filiformis* and *E. radiata* which were identified. The impacts of the project upon macroalgal communities within the wharf/seawall junction are unlikely to be significant at a species level as both *C. filiformis* and *E. radiata* are common throughout Sydney Harbour.

Habitat removal

The main potential for habitat loss would be as a result of the removal of the small section of seawall to construct the outlet. This section is occupied by intertidal habitat which is prevalent within the outer harbour. As such this impact is considered negligible.

Threatened species

Many of the threatened species identified are either unlikely to occur within the study area or are threatened by processes exclusive of activities relevant to the project. The potential for impacts on threatened species are considered in Table 7.7.



Table 7.7 Possible impacts to threatened species

Name	Threat	Risk	Reason
Weedy Sea Dragon <i>Phyllopteryx taeniolatus</i>	Habitat loss Water quality	Low	The proposed site contains various species of seagrass and macroalgae, which provide habitat for this species. Some marginal habitat has the potential to be removed, and some habitat may be impacted by sedimentation, however, the impact of the project is relatively restricted in area. Provided that discharge waters are intermittent, threats to this species should be minimal. There is however, a risk of adverse affects to individuals if discharge water is highly polluted.
Elegant Wrasse <i>Anampses elegans</i>	Habitat loss	Low	Risk to this species should be low as it is relatively uncommon; however, inshore seaweed beds have been identified as important habitat for juveniles.
Black Cod <i>Epinephelus daemeli</i>	Habitat loss	Low	Juveniles are known to inhabit rocky shorelines; however, they prefer sheltered areas such as rock pools and estuaries. As the area to be impacted is relatively small any impacts of habitat loss should be minimal at a species level.
Southern Right Whale <i>Eubalaena australis</i>	Acoustic pollution Habitat loss Water quality	Low	As noise produced as a result of construction will be intermittent and the project site is already heavily industrialised, acoustic impacts upon this species are presumed to be negligible. As this site receives a high quantity of boat traffic it is unlikely to be a significant site for feeding, calving or resting. Therefore habitat loss and water quality within the study area are unlikely to impact this species.
Unidentified Rorqual <i>Balaenoptera sp.</i>	Acoustic pollution Habitat loss Water quality	Low	Rorqual whales are more likely to occur in offshore habitats and therefore the project is not likely to impact this species.
Humpback Whale <i>Megaptera novaeangliae</i>	Acoustic pollution Habitat loss Water quality	Low	As noise produced as a result of construction will be intermittent and the project site is already heavily industrialised, acoustic impacts upon this species are presumed to be negligible. As this site receives a high quantity of boat traffic it is unlikely to be a significant site for feeding, calving or resting. Therefore habitat loss and water quality within the study area are unlikely to impact this species.
Bottlenose Dolphin <i>Tursiops truncatus</i>	Habitat loss Water quality	Low	This species is known to generally inhabit offshore marine waters, however, they are also known to frequent inshore mud, sand and seagrass habitats. As this site receives a high quantity of boat traffic it is unlikely to be a significant site for feeding, calving or resting. Therefore habitat loss and water quality within the study area are unlikely to impact this species.



Name	Threat	Risk	Reason
Common Dolphin <i>Delphinus delphis</i>	Habitat loss Water quality	Low	<p>This species is known to generally inhabit offshore marine waters, however, they are also known to frequent inshore mud, sand and seagrass habitats.</p> <p>As this site receives a high quantity of boat traffic it is unlikely to be a significant site for feeding, calving or resting. Therefore habitat loss and water quality within the study area are unlikely to impact this species.</p>
Eel-grass <i>Z. capricorni</i>	Sedimentation Water quality	Moderate Low	<p>There is the potential for indirect impacts to the immediate bed of <i>Zostera</i> during construction and operation if construction activities are inadequately managed and sedimentation results during operation. The area to be disturbed is limited in size and is highly disturbed. Furthermore, <i>Zostera</i> is relatively hardy and has the ability to recolonise from surrounding rhizomes. As a result, impacts to the community within Farm Cove as a whole are thought to be negligible.</p> <p>As the community identified lies just beyond the area of potential impact, the risk of sedimentation upon the immediate area is moderate.</p> <p><i>Zostera</i> is a tolerant species which already exists within close proximity to the existing outlet. Further more, the community identified during Transect 3 is further removed from the outlet. Impacts upon this species as a result of variable water quality are therefore considered negligible.</p>



Other species

Other species are expected to be present within Farm Cove. However, the potential for wider habitat impacts as a result of the project is expected to be minimal as the project site is relatively contained, is located within a highly modified environment and involves replacing a nearby structure of similar design and function.

Impacts of water quality on aquatic ecology

During construction, there is potential for a decrease in water quality due to erosion and sedimentation. This is considered to be a minor impact and able to be managed by implementing the recommended mitigation measures.

During operation, the new outlet has potential to result in a short term localised impact on water quality during periods when stormwater is discharged from the drain. As the project involves relocating an existing outlet and due to the high chance of mixing, there would be no change to the overall quality of water discharged to Sydney Harbour from the Bennelong Drain and far field impacts are not considered to be significant. The potential for impacts to water quality relate mainly to potential sediment deposition due to the flush of sediment out of the drain during periods of high rainfall and this is discussed above.

7.3.4 Mitigation measures

Construction

- ▶ Mitigation measures during construction would be based on the management of the site outlined in the CEMP and the erosion and sediment control plan. Whilst impacts have not been identified as significant, particular emphasis would be required for the management of sedimentation. Construction has the potential to increase sedimentation impacts that would decrease water quality values in the direct vicinity of the works. The CEMP includes measures to minimise impacts on water quality.

Operation

- ▶ Recommended measures to address the potential for sedimentation impacts during operation are provided in Section 7.2.4.

7.4 Visual impacts

7.4.1 Existing environment

Existing visual environment, receivers and viewpoints

The land uses of the site and immediate surrounds are described in section 2.2, and include:

- ▶ The Sydney Opera House forecourt, which provides:
 - an entrance to Sydney Opera House;
 - venue for events; and



- Pedestrian thoroughfare.
- ▶ Sydney Opera House;
- ▶ Farm Cove;
- ▶ Man O'War Jetty and steps; and
- ▶ Royal Botanic Gardens.

The site is located within a visible location on the forecourt of Sydney Opera House. The site is viewed by visitors to Sydney Opera House and surrounds, and pedestrians walking through the forecourt area. It is also visible from selected locations within the Royal Botanic Gardens, such as the foreshore area around Farm Cove, and elevated areas to the south.

Other views to the site are available from the commercial and residential development located at the northern end of the development at East Circular Quay. Views from Farm Cove and Sydney Cove to the site are virtually uninterrupted from the east and west, although views would generally only be available from larger vessels on Sydney Harbour, due to the slightly elevated nature of the forecourt when compared with the waterways.

The forecourt can potentially be viewed from the western side of Circular Quay from the Sydney Harbour Bridge and buildings located at West Circular Quay. Views of the outlet would be potentially available from the Man O' War steps and jetty.

Significant features of the existing environment

Of those elements of the existing environment with potential heritage and/or visual significance, the project would directly affect the seawall. The seawall is described in section 7.1.2. As noted by the heritage assessment (Appendix B), it has been assumed that this section of the seawall was constructed in the 1860s, and represents one of the earlier surviving sections of the seawall surrounding Bennelong Point (although the extent of surviving original fabric was not confirmed as part of the heritage assessment). It is considered that this section of seawall may include significant historic fabric and have some historical significance associated with early phases of land reclamation of Bennelong Point. It also contributes to the setting of Sydney Opera House.

7.4.2 Key features of the project

The key features of the project are described in section 5.1. In summary:

- ▶ The drain would be located underground;
- ▶ The only visible elements of the drain would be the access hatch and the outlet;
- ▶ The access hatch would be located at the western end of the site above the proposed junction pit at the base of the Tarpeian Wall; and
- ▶ The outlet would be approximately 2.4 m wide by 1.8 m high (internal dimensions), located to the south of the Man O'War Jetty, and visible above mean sea level.



7.4.3 Impact assessment

Construction

Construction of the project has the potential to generate visual impacts during the construction period. However, the visibility of the construction works would be limited by the erection of hoardings according to the standard procedures for construction projects at the Sydney Opera House site. The hoardings would reduce views to the construction works from the forecourt area and other areas at the same level as the works, as well as maintain public safety around the construction area. There is potential for views of the works from elevated positions such as the Royal Botanic Gardens at the Tarpeian Way, and from the top of the Sydney Opera House steps. These impacts would be temporary and limited to the construction period.

Operation

Drain

As the drain component of the project would be located below ground under the forecourt, there would be minimal visual impacts. The access hatch would be located within the landscaped garden located at the base of the Tarpeian Wall and would not be visible from the forecourt.

Outlet and seawall

The greatest potential for visual impacts would be associated with the location of the new outlet in the seawall south of the Man O' War Jetty.

The majority of the outlet opening would be visible above the mean sea level, which would be most visible when viewed straight on (eg from a vessel on Farm Cove) but in most cases such views would be incidental. The outlet would also be visible when looking south from the Man O' War Jetty (Figure 7-3 and Figure 7-4), but this view does not include Sydney Opera House itself and does not represent a significant view corridor. Given the curve of the seawall in the vicinity of the outlet, the outlet would only be visible from a couple of distant locations (Figure 7-5, Figure 7-6 and Figure 7-7) along the Farm Cove seawall and it would generally not be visible from the Royal Botanic Gardens. Visual impacts from distant locations and locations along the seawall would be negligible.

To match the existing fabric of the seawall, the drain would be lined with sandstone to about 1-1.5m from the outlet. This would reduce the potential for visual impacts of the outlet.

Sydney Opera House

The heritage assessment (Appendix B) considers how the project would comply with the Management Plan for the Sydney Opera House and the 2003 Conservation Plan. Policy 2.1 of the Conservation Plan relates to views and vistas.

'Policy 2.1 All agencies of government and local government involved in planning the continued development of Bennelong Point and nearby peninsulas and bays should give consideration to the creation, retention and recovery of views and vistas to and from the Opera House when considering proposals. These objectives should be progressively incorporated into any relevant development strategies.'

The heritage assessment (Appendix B) concludes that the project would not result in any significant visual impacts that would affect the setting of, or views to and from, Sydney Opera

House, and would not include the introduction of any elements that would obstruct or obscure existing views to and from Sydney Opera House.



Figure 7-3 View of proposed outlet from Man O' War Jetty at low tide



Figure 7-4 View of proposed outlet from Man O' War Jetty at high tide



Figure 7-5 View of proposed outlet from eastern side of Farm Cove



Figure 7-6 View of proposed outlet from walkway adjacent to Farm Cove



Figure 7-7 View of proposed outlet from walkway adjacent to Farm Cove

7.4.4 Mitigation measures

Construction

- ▶ Erection of construction hoardings in accordance with standard Sydney Opera House procedures. All construction activities and equipment would be contained within these hoardings.

Operation

- ▶ The drain would be lined with sandstone to about 1-1.5m from the outlet to match the existing fabric of the seawall.

7.5 Construction noise and vibration

A construction noise and vibration assessment of the project was prepared by GHD. A summary of the findings of the assessment is provided in this section. The full report is provided in Appendix H.

7.5.1 Methodology

The assessment methodology involved:

- ▶ Characterising the existing noise environment by conducting attended noise monitoring at representative locations (see below);
- ▶ Calculating noise goals in accordance with relevant guidelines;



- ▶ Calculating noise goals in accordance with relevant guidelines;
- ▶ Establishing potential noise levels associated with the project at sensitive receivers; and
- ▶ Assessing the potential impacts of the project.

Noise monitoring

An attended background noise survey was undertaken on Thursday 23 April 2009 in order to quantify the ambient noise environment in the vicinity of the construction site and potentially affected receivers. Attended noise measurements were undertaken at the following locations (as shown in **Figure 7-8**):

- ▶ L1 – Macquarie Street roundabout near Bennelong Apartments.
- ▶ L2 – Sydney Opera House steps;
- ▶ L3 – Northern end of Sydney Opera House;
- ▶ L4 – Tarpeian Way near Government House; and
- ▶ L5 – Northern end of the Royal Botanic Gardens.

Sensitive receivers

Sensitive receivers in the area are considered to consist of:

- ▶ Bennelong Apartments;
- ▶ Government House;
- ▶ Sydney Opera House;
- ▶ Royal Botanic Gardens; and
- ▶ The Sydney Opera House forecourt.

7.5.2 Existing environment

Noise monitoring results are summarised in Table 7.8.

Site observations indicate that the monitoring locations are representative of the ambient noise environment of the area including the potentially affected receivers. However, it should be noted that the background noise environment would vary depending on localised ambient noise sources.

Table 7.8 Measured background noise levels, dB(A) 15 minute

Monitoring location	L _{A90}	L _{Aeq}	L _{Amax}
L1	60	63	73
L2	53	55	68
L3	58	60	69
L4	52	55	69
L5	47	50	73



7.5.3 Noise and vibration criteria

Construction noise considerations

The DECC's Construction Noise Guideline: Draft for consultation (August 2008) provides guidelines for assessing the noise impact from construction sites. The DECC's general approach to the control of noise from construction sites is outlined below.

Limiting hours of operation

General construction hours specified in the Noise Control Guideline: Site Construction Noise are:

- ▶ Monday to Friday – 7 am to 6 pm;
- ▶ Saturday – 8 am to 1 pm; and
- ▶ Sundays and public holidays – no work permitted.

Noise emission objectives

The draft Construction Noise Guideline provides noise management levels for both residential and other sensitive land uses. For non-residential sensitive land uses, the management levels apply only at times when the sensitive land use is occupied. For this assessment the non-residential sensitive land use in the vicinity of the works is mostly passive recreational areas, therefore the management level is 60 dB(A)_{L_{Aeq,15min}}.

The management levels at residences are to be calculated based on the adopted rating background level and are shown in Table 7.9. The minimum measured background noise level was used to establish noise criteria.

Table 7.9 Construction noise criteria at residences, dB(A)

Time period	Background level	Construction Noise Guideline management level
	L _{A90} (period)	L _{Aeq} (15 min)
Recommended standard hours	Between	Noise affected level – 57 dB(A)
	47 dB(A) and 60 dB(A)	Highly noise affected level - 75 dB(A)

The 'noise affected level' of 57 dB(A) represents a point at which there may be some reaction to noise by the community. The 'highly noise affected level' of 75 dB(A) represents a point where there may be a strong reaction to noise from the community.

The City of Sydney 'Code of Practice: Construction Hours / Noise within the Central Business District' provides noise criteria for residential receivers. Sydney Opera House falls within the area to which the Code applies. The City of Sydney criteria for residential receivers are:

- ▶ 7 am – 8 am – Background + 5 dB(A);
- ▶ 8 am – 7 pm – Background + 10 dB(A);
- ▶ 7 pm – 11 pm – Background + 3 dB(A); and
- ▶ 11 pm - 7 am – Background.



During general construction hours the noise criteria are identical to those in the DECC Construction Noise Guideline except for the period between 7 am and 8 am where it is 5 dB(A) less at residential receivers.

Vibration criteria

Vibration criteria have been set with consideration to the DECC 'Assessing Vibration: A Technical Guideline, 2006. BS 6472 – 1992, Guide to Evaluation of Human Exposure to Vibration in Buildings (1 Hz to 80 Hz)' This is recognised by the DECC as the preferred standard for assessing the 'human comfort criteria'.

The BS 6472 human comfort peak vibration limits are shown in Table 7.10 for the frequency range of 1 Hz to 80 Hz, which is applicable to construction works. These values are limits that may cause loss of amenity to the occupant, however for short duration construction projects they are considered conservative.

BS 6472 also recognises that higher vibration levels are tolerable for short-term construction projects as undue restriction on vibration levels can significantly prolong construction works and result in greater annoyance.



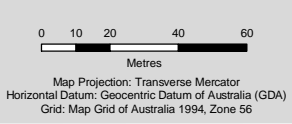
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Legend

- X Monitoring Location
- Upstream Drain Alignment
- Proposed Drain Realignment



CLIENTS | PEOPLE | PERFORMANCE

Sydney Opera House Trust
 Bennelong Drain Diversion Project
 Environmental Assessment
Noise Monitoring Locations

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Figure 7.8



Table 7.10 BS 6472 human comfort vibration limits from 1 Hz to 80 Hz (mm/s Peak¹)

Receiver type	Period ²	Continuous vibration (mm/s Peak ³)	Impulsive vibration (mm/s Peak)	Intermittent vibration dose value (m/s ^{1.75})
Residential	Day	0.28	8.6	0.2
	Night	0.20	2.8	0.13

Notes:

1 Based on sinusoidal vibration sources

2 Day is between 7 am and 10 pm and night is between 10 pm and 7 am.

3 Based on sinusoidal vibration sources

7.5.4 Impact assessment

Construction noise assessment

The noise emissions from construction have been assessed at sensitive receivers during the general construction hours. A quantitative assessment has been undertaken with consideration to the DECC's Construction Noise Guideline.

The typical noise generating equipment to that would be used on site has been assumed to be as follows:

- ▶ 18 tonne 90 kW wheeled excavator;
- ▶ 5 tonne dump truck;
- ▶ Hand-held circular saw cutting paving slabs;
- ▶ Rock saw; and
- ▶ 67 kW hydraulic rock breaker.

Construction noise predictions were undertaken using the model Computer Aided Noise Abatement (CadnaA) to predict the effects of construction noise at surrounding potentially affected receivers.

Predicted noise levels for potentially effected receivers are shown in Table 7.11 and the predicted noise contours are shown in Figure 7-9.



Table 7.11 Predicted construction noise levels, dB(A)

Potentially effected receiver	Noise criteria	Predicted noise level
Bennelong Apartments	57 (52) ¹	48
Government House	57 (52) ¹	51
Sydney Opera House	Internal Criteria	63
Royal Botanic Gardens	60	See contour map
Sydney Opera House forecourt	60	(Figure 7-9)

Notes:

1 City of Sydney Criteria 7 am to 8 am

The noise levels at the Bennelong Apartments and Government House are predicted to comply with the noise criteria; therefore the project should not adversely impact any residences.

There are no specific external noise criteria for Sydney Opera House but rather an internal noise level requirement that should be achieved. The predicted noise level at Sydney Opera House's nearest façade is 63 dB(A), which is below the maximum noise levels measured in the area. Therefore there is unlikely to be any significant increase in noise levels inside of Sydney Opera House.

The noise levels at the Sydney Opera House forecourt area and the northern end of the Royal Botanic Gardens are predicted to exceed the Construction Noise Guideline noise criteria of 60 dB(A) $L_{Aeq(15min)}$ for the area shown in Figure 7-9. The exceedance is not considered significant since the background noise levels in the area are already high and only a small area of the Sydney Opera House forecourt and Royal Botanic Gardens exceed the criteria. In addition, the impacts would be temporary and limited to the construction period. However, since construction noise is expected to exceed noise criteria for parts of the forecourt area and northern end of the Royal Botanic Gardens, it is recommended that the mitigation measures detailed in section 7.5.5 be considered and implemented where feasible and reasonable to reduce potential noise impacts.

Construction vibration impact assessment

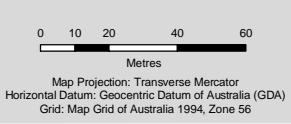
The excavator and breaker are the only items of equipment on site that are anticipated to generate appreciable vibration impacts. There is the potential for other equipment to cause ground vibrations, though these are expected to be minimal.

The predicted ground vibrations at various distances are shown in Table 7.12 for typical excavators.



Legend

- Upstream Drain Alignment
- Proposed Drain Realignment
- 60dBA
- 55dBA
- 50dBA



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Sydney Opera House Trust
 Bennelong Drain Diversion Project
 Environmental Assessment
**Construction Noise
 Contours**

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Figure 7.9



Table 7.12 Estimated excavator vibration levels (mm/s Peak)

Plant Item	Vibration level at distances (mms Peak)				
	10 m	20 m	50 m	100 m	200 m
Excavator	3	1	0.3	0.1	0
Breaker	5	2	0.5	0.2	0.1

The Government House and Bennelong Apartments residences are located over 100 m from the site; therefore excavation activities are unlikely to produce vibration levels that are perceptible at these receivers.

7.5.5 Recommended mitigation measures

It is recommended that the following construction noise and vibration mitigation measures be included in the construction environmental management plan for the project, to reduce the impact on surrounding receivers:

- ▶ Where possible, the amount of materials that are dropped from heights should be minimised;
- ▶ Where practical, machines should be operated at low speed or power and should be switched off when not being used rather than left idling for prolonged periods;
- ▶ Where possible, equipment should be selected to minimise noise emissions, should be fitted with appropriate silencers and should be in good working order;
- ▶ An excavator likely to produce low noise emissions should be selected;
- ▶ Machines found to produce excessive noise compared to normal industry expectations should be removed from the site or stood down until repairs or modifications can be made;
- ▶ Noise emissions from reversing alarms should be minimised, although use of such alarms should still be satisfactory to achieve occupational health and safety requirements;
- ▶ Construction activities should be limited to recommended standard construction hours;
- ▶ All site workers should be made aware of the potential for noise impacts and encouraged to take practical and reasonable measures to minimise noise during the course of their activities;
- ▶ Rock breaking activities should be minimised, where possible; and
- ▶ Construction hoarding should be used, in accordance with standard practice for construction activities at Sydney Opera House.



7.6 Geotechnical conditions

7.6.1 Existing environment

Topography and the physical form of Bennelong Point

The physical development of Bennelong Point over the nineteenth and twentieth centuries has affected the ground levels of the site. Historical photos (refer Appendix B) indicate that the top of the original Bennelong drain was exposed during the late 1850s. The existing Bennelong drain is now located approximately two metres below the existing forecourt area, which suggests that this area may have been built up by approximately two metres since the 1850s.

Modifications to ground levels throughout the history of Bennelong Point, particularly within the forecourt area, have largely involved the introduction of fill deposits and reclamation of shorelines.

The most significant modification to ground levels across Bennelong Point were most likely in association with construction of the tram house and associated track infrastructure in the early twentieth century, as well as the construction of Sydney Opera House in the 1960s–1970s.

Construction of Sydney Opera House had a dramatic impact on the physical form of Bennelong Point, including:

- ▶ Modification of the shape of Bennelong Point with the construction (and some replacement) of seawalls around the shoreline;
- ▶ The introduction of fill deposits to create a level forecourt;
- ▶ Excavation for the construction of basement levels and other structural elements of Sydney Opera House itself; and
- ▶ Construction of other infrastructure associated with Sydney Opera House and its operation.

Soils

The Sydney (9130) 1:100,000 Soils Landscape Series Sheet describes the soils at the site as disturbed terrain. The site is defined by terrain that has been disturbed by human activity. In this case the site is located on reclaimed land.

Boreholes and construction of the Sydney Opera House Car Park have indicated that approximately 1-3 metres of fill is located along the alignment of the drain. This fill is underlain by Hawkesbury Sandstone. The fill is generally less than two metres deep along most of the new alignment, with it only becoming deeper closer to the sea wall (refer to Appendix G). Figure 7-10 shows the approximate depth of the underlying sandstone and indicates the approximate depth of fill.

A copy of the geotechnical report is located in Appendix G.

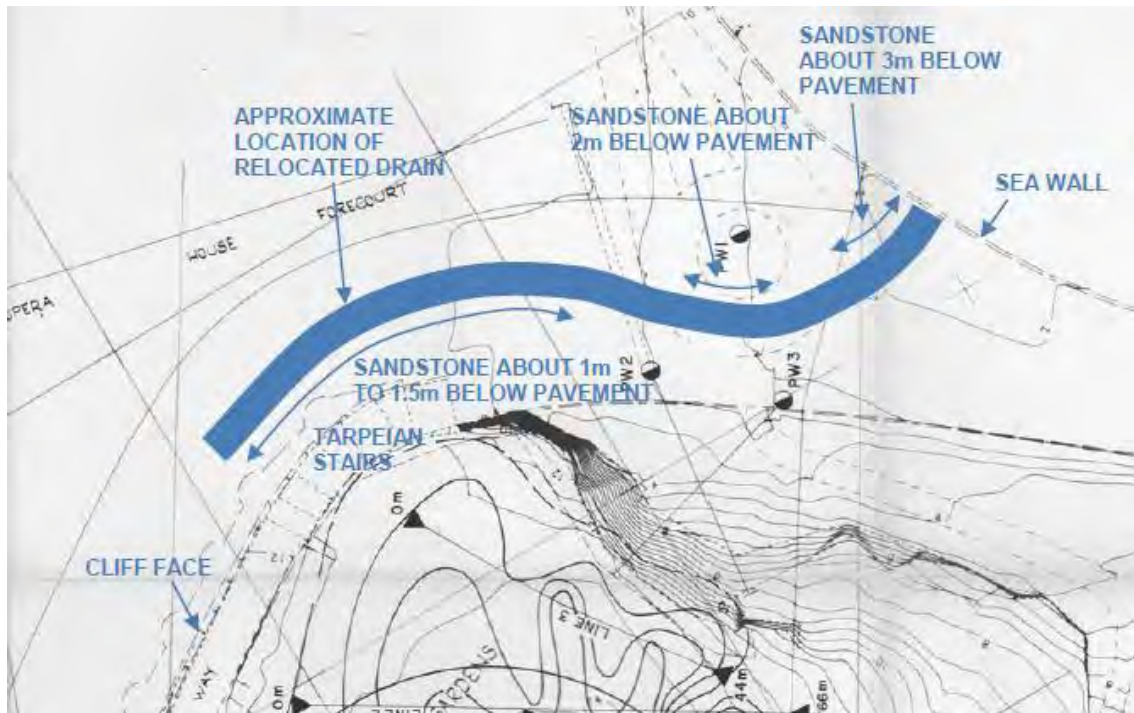
Contamination

Based on excavations undertaken for the construction of the ventilation shaft for the car park, it is concluded that the fill comprises mostly of crushed sandstone and sandstone fragments

(Appendix G). The underlying sandstone which is to be excavated is classified as Virgin Excavated Natural Material (VENM).

Acid sulphate soils

A search of the CSIRO (Land Water division) Australian Soil Landscape Information System indicates that there is a low probability of acid sulphate soils on the site. The land beneath the water bodies surrounding the site have a high probability of containing acid sulphate soils.



Source: Pells, 2009

Figure 7-10 Indicative depth of fill along alignment

7.6.2 Impact assessment

Construction

Potential issues relate to soil and contamination are likely to be associated with the construction phase of the project. The project involves excavations to prepare the trench in which the drain would be laid. During construction, it is likely that spoil would be loaded into skips and removed from site to avoid the need to stockpile material onsite. This would need to be confirmed by the contractor during construction planning. Section 7.6 outlines the details of spoil and waste management for the project.

Construction would involve excavation of fill materials typically between 1m - 2m deep underlain by slightly weathered to fresh Hawkesbury Sandstone. The fill materials would be excavated by backhoe and the underlying sandstone would be cut by rotary saw and then excavated within the lines of saw cuts by hydraulic impact breakers.



Overall, it is estimated that between 1,000 – 3,000 m³ of spoil would be generated. This is an estimate only, with the volume of excess spoil potentially changing with additional geotechnical information or due to the type of materials encountered during the excavation.

The underlying sandstone is classified as Virgin Excavated Natural Material (VENM). Geochemical testing has not been undertaken to confirm whether contaminated material is present at the site. Based on previous excavations for the ventilation egress shaft, it is considered likely that fill at the site comprises mostly crushed sandstone and sandstone fragments from the original quarrying operations, overlain by road pavement materials. Therefore, it is considered unlikely that the excavated material would be contaminated, and that it would be classified as General Solid Waste under the Department of Environment and Climate Change (DECC) Waste Classification Guidelines. During construction, all spoil removed from site would be assessed, classified and managed in accordance with this guideline. If contamination is present at the site, management measures would be developed and included in the Construction Environmental Management Plan that would be prepared by the contractor.

Operation

During operation, the project would not have any impacts on soil and contamination as the drain would function as it currently does, just with a different outlet location.

7.6.3 Mitigation measures

- ▶ In the event that indications of contamination are encountered (ie. odorous or visually contaminated materials) as a result of exposure of sub soils during construction, work in the area would cease until an environmental consultant can advise on the need for remediation or other action, as deemed appropriate.
- ▶ All waste including spoil will be managed in accordance with DECCs 'Waste Classification Guidelines' (2008).
- ▶ A detailed erosion and sedimentation control plan detailing safeguards to minimise the adverse impacts on water quality from erosion, sediment transfer and sedimentation during the construction phase would be prepared as part of the construction environmental management plan developed by the contractor. It would incorporate measures to manage erosion and runoff in accordance with the specifications outlined in 'Managing Urban Stormwater: Soils and Construction' (Volume 1, 4th Edition, the 'Blue Book', Landcom, 2004);
- ▶ The erosion and sediment control plan prepared as part of the construction environmental management plan would ensure:
 - Sediment and erosion control measures, such as sediment fences and bunding, are installed and maintained, with particular attention where the drainage is towards Farm Cove;
 - Use of silt curtains as a minimum during construction adjacent the outlet construction area;
 - Stockpiles are stabilised and remain covered and appropriate sediment and erosion control measures are installed down slope of all stockpiles;
 - Spill kits are made available to construction vehicles;

- Implementation of sediment controls in the vicinity of the outlet construction; and
- Any dangerous goods used on site would be handled, used and stored in accordance with relevant material safety data sheets, Australian Standards, and the Dangerous Goods Code. Procedures are included for the management of accidental spills to minimise potential contamination during construction.

7.7 Waste management

7.7.1 Wastes generated

It is expected that the following wastes would be generated during construction:

- ▶ Spoil;
- ▶ Brick / concrete / sandstone materials;
- ▶ Sediment at the bottom of the existing drain; and
- ▶ General waste from site personnel – such as packaging, scraps and paper etc.

Issues associated with spoil management are discussed in Section 7.6.

7.7.2 Mitigation measures

The management of wastes including spoil would be in accordance with relevant NSW legislation and the principles of the waste management hierarchy as set out in the NSW 'Waste Avoidance and Resource Recovery Strategy'. Figure 7-11 illustrates the hierarchy for management of wastes. Proposed waste management measures are described in Table 7.13.



Figure 7-11 The waste hierarchy



Table 7.13 Proposed waste management measures

Waste	Management measure
Excess spoil	Reuse as backfill where practicable. Excess spoil to be disposed to appropriately licensed landfill.
Brick / concrete materials	Disposed to appropriately licensed landfill.
Sediment	Disposed to appropriately licensed landfill.
General waste from site personnel	Recycling bins to be provided for site personnel. Recyclable materials (such as paper, cardboard, plastics, paper, aluminium cans etc) to be collected separately and recycled.

Wherever practicable, spoil would be reused onsite as backfill. Any surplus spoil that cannot be reused would be transported off-site to recycling facilities or to approved landfill sites. The material would be tested in accordance with the 'Waste Classification Guidelines' (DECC, 2008). Any transfers of waste would take place in accordance with legislated docket tracking systems that ensure waste reaches the appropriate destination. Only licensed contractors and drivers would be used.

As part of the construction environmental management plan, a waste management sub-plan would be prepared. The sub-plan would be framed using the waste management hierarchy principles outlined above. The sub-plan would be prepared prior to construction commencing and be consistent with the *Waste Avoidance and Resource Recovery Act 2001* and the 'Waste Classification Guidelines'.

The sub-plan would:

- ▶ Identify requirements for waste avoidance, reduction, reuse and recycling;
- ▶ Provide procedures for handling, stockpiling, and reuse of wastes;
- ▶ Identify disposal sites and relevant testing; and
- ▶ Set out procedures for obtaining the required approvals for offsite management of spoil.



Chapter 8 Management of other environmental issues

8.1 Overview

Chapter 7 assesses the potential impacts on key issues associated with the project. In addition to the key potential impacts, there are a range of other issues that have been considered to order to develop an appropriate environmental management framework for the construction and operation of the project.

These issues include:

- ▶ Traffic and access;
- ▶ Air quality;
- ▶ Land uses; and
- ▶ Infrastructure.

This chapter considers the nature of the potential environmental issues and the management initiatives proposed to ensure that environmental impacts during construction and operation are minimised.

8.2 Traffic and access

8.2.1 Potential issues

Construction

As the project would be constructed within the forecourt of the Sydney Opera House, there are minimal impacts on vehicular traffic on the surrounding road network. Impacts to the surrounding road network would be associated with delivery of materials and equipment and the removal of spoil. Due to the relatively small number of vehicles required for material delivery and spoil removal these impacts are considered to be minimal. Construction vehicles are also unlikely to need to travel far on city streets, as the site is located approximately 500 m and 1000 m from the Cahill Expressway onramp (northbound) and the Eastern Distributor onramp (southbound) respectively.

The project would require small vehicles and heavy vehicles to access the forecourt that is used by pedestrians. There is potential for impacts as a result of this interaction between vehicles and pedestrians. These impacts would be minimised through the implementation of appropriate construction vehicle management.

The project has the potential to impact on pedestrian access within the Sydney Opera House forecourt. Due to the high pedestrian numbers within the forecourt and its connection to East Circular Quay and the Royal Botanic Gardens, maintaining access to and within the forecourt is



important. As the project traverses the forecourt in an east-west direction there is potential for impacts to access across the forecourt. Much of the proposed realignment (towards the western end) is located in close proximity to the Tarpeian Wall and therefore would have very minor impacts on access. As the alignment heads east, the construction works would be located in close proximity to the Tarpeian Way, Queen Elizabeth II and Opera House Gates which all provide access to the Royal Botanic Gardens. As the project requires the development of site compounds around the works, pedestrian access would be limited in the vicinity of the works. Figure 8-1 identifies indicative pedestrian flow paths that would be available during the three general stages of the works.

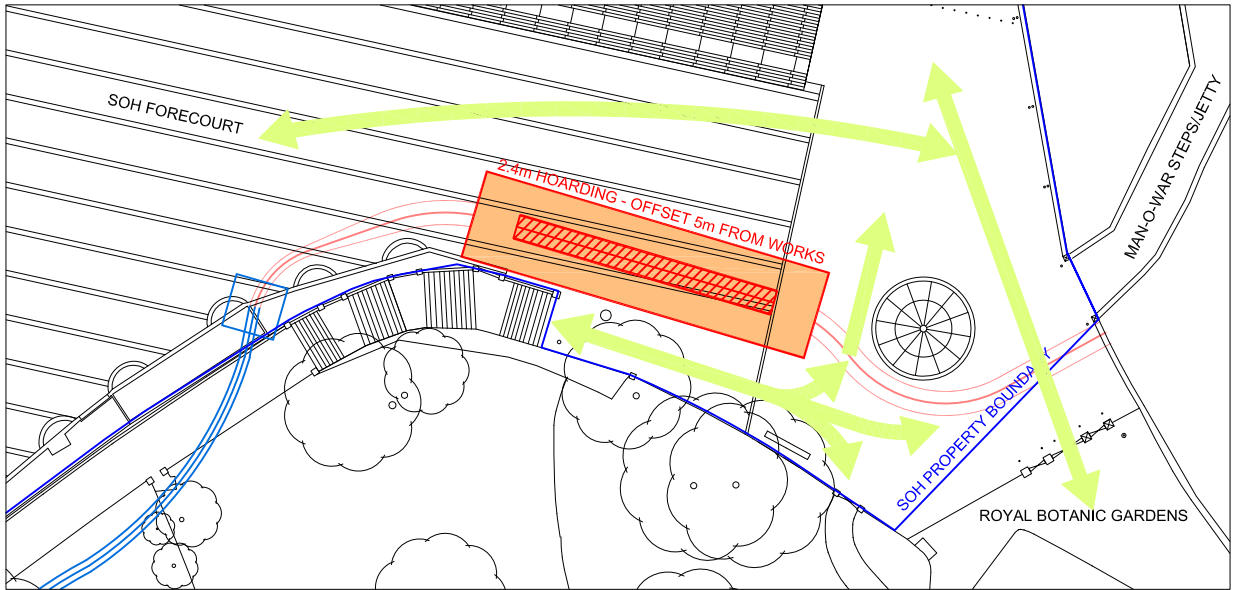
The potential for impacts on pedestrian access to the Royal Botanic Gardens would be managed by undertaking the project in stages to ensure that pedestrian access would be maintained at all times.

Access to the Man O' War Steps and jetty would be maintained at all times.

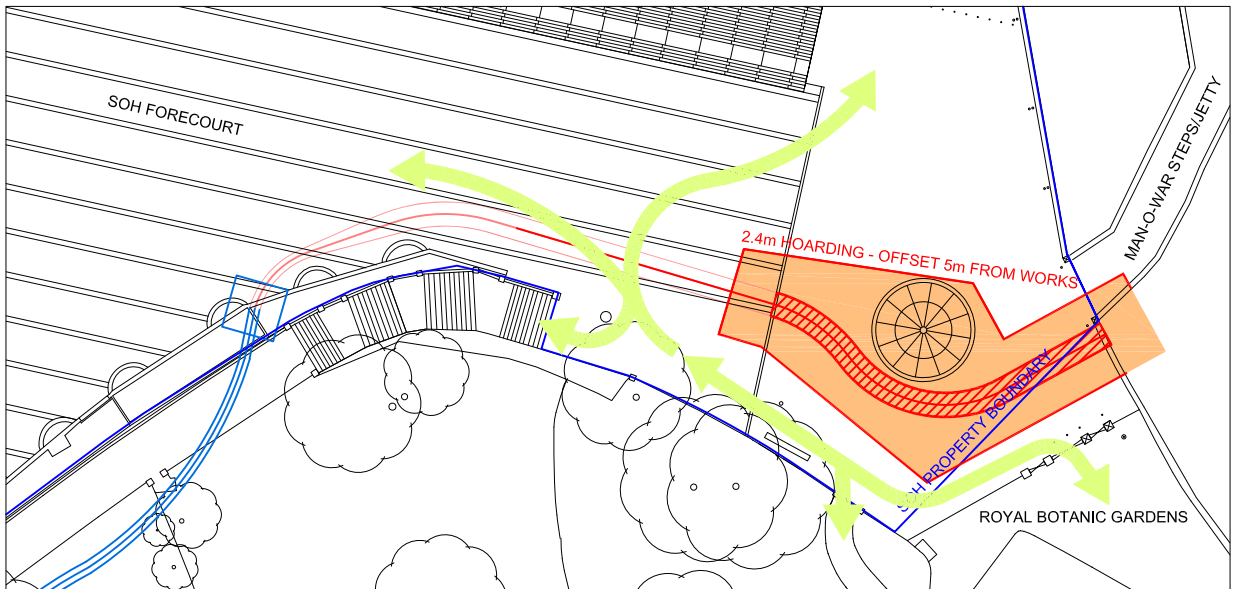
Operation

Operational impacts on the traffic network would be limited to infrequent maintenance activities that would be short term and result in negligible impact on the overall traffic and transport network.

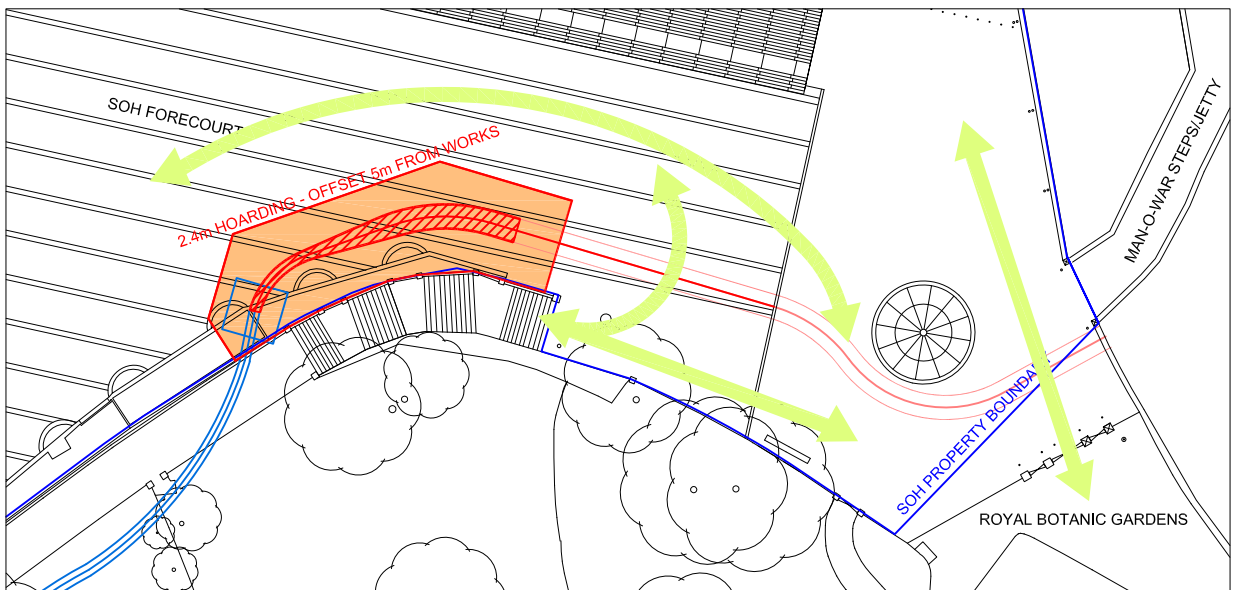
As the drain would be located below the surface of the forecourt, there would be no operational impacts on access.



Stage 1 : Middle section construction zone & pedestrian movement paths



Stage 2 : Eastern section construction zone & pedestrian movement paths



Stage 3 : Western section construction zone



8.2.2 Traffic and access management

A traffic and access management plan would be prepared as part of the construction environmental management plan and would include measures such as:

- ▶ Vehicles are to remain on internal road network where possible;
- ▶ Vehicles to minimise distance travelled across forecourt where possible;
- ▶ Alternate parking to be found for personnel vehicles that are not required to be on site;
- ▶ Where possible, heavy vehicle movements for delivery of materials/equipment and removal of spoil should be restricted to off peak times or when forecourt use is low;
- ▶ Access to Man O' War Steps to be maintained at all times; and
- ▶ Access to the Royal Botanic Gardens to be maintained at all times during construction.

8.3 Air quality

8.3.1 Potential issues

Construction

The project has the potential to generate dust from excavator and truck movements and from infilling works during the construction process. Construction plant and equipment have the potential to impact upon local air quality by generating vehicle emissions. However, these potential impacts would be localised, short-term in nature, and implementation of construction environmental management measures would minimise the potential impacts.

Operation

The project would not result in any air quality impacts during operation as the drain would operate as it currently does with an alternate discharge location.

8.3.2 Air quality management

A dust management plan would be prepared as part of the construction environmental management plan, including measures such as the following:

- ▶ Areas with the capacity to cause dust would be dampened to suppress dust emissions;
- ▶ Materials transported in trucks would be appropriately covered to reduce dust generation;
- ▶ Vehicle movement controls would be installed, particularly entrance to and exit from construction work sites;
- ▶ Construction activities that generate high dust levels would be avoided during high wind periods;
- ▶ Rehabilitation of disturbed surfaces would be undertaken as soon as possible;
- ▶ All construction plant and machinery would be fitted with emission control devices complying with Australian Design Standards and would be regularly maintained; and



- ▶ Plant and machinery would be turned off when not in use.

8.4 Land uses

8.4.1 Potential issues

Construction

Impacts on land uses during the construction of the project would be minimal and limited to the following uses that occur in the vicinity of the project:

- ▶ As a public forecourt to Sydney Opera House;
- ▶ For occasional major functions and events; and
- ▶ Pedestrian access between the forecourt and Sydney Opera House, East Circular Quay and the Royal Botanic Gardens.

Potential access issues are considered in section 8.2.

The forecourt is also occasionally used to host major functions and events. To ensure that impacts on programmed events are minimised, where possible construction works or the event would be timetabled to avoid coinciding with forecourt events. Construction would be staged to minimise the extent of the construction footprint used at any one point in time.

Operation

The project would not have an ongoing impact on land use as it would be located beneath the forecourt. Maintenance of the drain would not impact upon the use of the forecourt as the maintenance hatch is located off the forecourt within the landscaped garden.

8.4.2 Management

No specific management measures are required as potential conflicts will be minimised by scheduling construction works or events.

8.5 Infrastructure

8.5.1 Potential issues

The forecourt contains a number of underground services, such as electricity, communications, water infrastructure, sewerage and car park ventilation. A number of these services are located along the alignment of the proposed diversions.

The project does not include the removal or relocation of any electricity or communications infrastructure, as the existing infrastructure would be supported or pulled back during construction. These services would then be reinstated upon completion of construction.

The only water infrastructure to be impacted during the construction phase is the existing Bennelong Drain. An approximately 8m long section of this drain would be removed to accommodate the new junction pit and drain diversion. Impacts to this drain would be minimised



by staging construction. The drain would continue to operation during construction, until it is required to be decommissioned.

8.5.2 Management

- ▶ Services searches undertaken by the construction contractor would confirm the location of any services.
- ▶ Consultation with service providers would be undertaken prior and during the works to ensure that all services located in the area are located and protected during the works.

8.6 Cumulative impacts

Other projects (existing or proposed) that may be undertaken in the next one to two years in the Sydney Opera House forecourt include construction of a vehicular tunnel to provide direct access to the basement loading dock from the end of Macquarie Street. This would be subject to a separate approval process. Events at Sydney Opera House and construction activities would be scheduled to minimise the potential for cumulative impacts.

8.7 Ecological sustainable development

The project has been assessed against the following four principles of ecologically sustainable development:

- ▶ The precautionary principle;
- ▶ The principle of inter-generational equity;
- ▶ The principle of biological diversity and ecological integrity; and
- ▶ The principle of improved valuation of environmental resources.

An assessment of compliance of the project with these principles is provided below:

Precautionary principle

The assessment of the potential impacts of the project is considered to be consistent with the precautionary principle. It is considered that the assessments presented throughout this environmental assessment are consistent with rigorous scientific and professional methods and in accordance with relevant guidelines.

These investigations have identified a number of potential impacts of the project on the local or regional environment. Where impacts have been identified, a number of management measures have been nominated to reduce, or remove, the impacts.

It is considered that these management measures, outlined in Chapter 9, would satisfactorily protect the environment during both construction and operational phases. Further, any contractor awarded the site works would be required to prepare a detailed environmental management plan detailing measures to be put in place to manage environmental and other issues identified.



Intergenerational equity

It is recognised that the construction and operation of the project would involve activities that have the potential to lead to some environmental and social disturbance.

The project has identified no long term impacts associated with the operation or construction of the project that would lead to the degradation of the Sydney Opera House site. This, in conjunction with the proposed management and mitigation measures, would ensure that the potential for any long term impacts are significantly decreased.

The project would improve the function of Sydney Opera House by enabling implementation of the Sydney Opera House strategic building plan. This would deliver social benefits for this and future generations.

The project has been assessed in accordance with the requirements of the Management Plan for Sydney Opera House, and no significant impacts to archaeology or heritage were identified.

Conservation of biological diversity and ecological integrity

An aquatic ecology study was undertaken to identify potential adverse impacts on aquatic flora and fauna. The study concluded that the project would not adversely impact on any populations of threatened flora and fauna. The project is therefore considered to be consistent with the principle of conservation of biological diversity and ecological integrity.

Improved valuation and pricing of environmental resources

The cost of environmental resources includes the costs incurred to protect the environment. The safeguards imposed to minimise adverse impacts would result in economic costs to the construction and operation of the project. This indicates the valuation of environmental resources has been assigned.

The project has been designed to minimise adverse impacts on the environment by confining works to defined areas and implementing appropriate mitigation measures when impacts are expected.



Chapter 9 Draft statement of commitments

Section 75F(6) of the EP&A Act states that the 'Director-General may require the proponent to include in an environmental assessment a statement of the commitments the proponent is prepared to make for environmental management and mitigation measures on the site'. In accordance with this requirement, this section provides the Sydney Opera House Trust's commitments for environmental mitigation, management and monitoring for the project.

9.1 Environmental management

9.1.1 Construction environmental management plan

A construction environmental management plan would be prepared and implemented. The plan would outline environmental management practices and procedures to be followed during site preparation and construction. The plan would cover the environmental protection practices, resources and sequence of activities required to comply with relevant environmental legislation, conditions of any applicable licence, approval and permit. The plan would be prepared in accordance with Guideline for the Preparation of Environmental Management Plans (DIPNR, 2004) and include:

- ▶ A description of all activities to be undertaken on the site during the site preparation and construction of the stage of the project;
- ▶ Statutory approval and other obligations that would be fulfilled during site preparation and construction, including all approvals, consultations and agreements required from authorities and other stakeholders, and key legislation and policies;
- ▶ Details of how the environmental performance of the site preparation and construction works would be monitored, and what actions would be taken to address identified adverse environmental impacts. In particular, the following environmental performance issues would be addressed:
 - Measures to minimise impacts to heritage
 - Measures to monitor and minimise soil erosion and the discharge of sediment and other pollutants to lands and/or waters during construction;
 - Measures to monitor and control noise emissions during construction and commissioning; and
 - Measures to manage traffic and pedestrian access during construction.
- ▶ The construction environmental management plan would incorporate the measures recommended in chapters 7 and 8;
- ▶ A description of the roles and responsibilities for all relevant employees involved in the construction of the project; and



- ▶ Complaints handling procedures during construction.

9.1.2 Operation environmental monitoring

The project would be owned and operated by Sydney Water as part of the overall stormwater drainage network. As such, Sydney Water would be responsible for ongoing management of the asset. This would involve periodic water quality and sedimentation inspections and/or monitoring undertaken as part of routine operations. This would include inspection of the sediment trap upstream of the project to ensure it is operating effectively.

9.2 Statement of commitments

The proponent commits to implement the measures outlined in Table 9.1 to minimise the potential for environmental impacts.

Table 9.1 Statement of Commitments

Environmental Issue	Commitment
Construction Environmental management plan	<p>A construction environmental management plan would be prepared and implemented to guide environmental management and monitoring activities during construction. The construction environmental management plan would include the following sub-plans:</p> <ul style="list-style-type: none"> ▶ Noise management plan – The plan would address how noise will be mitigated and managed during construction activities, in accordance with DECC's Draft Construction Noise Guideline and the measures described in section 7.5.5; ▶ Erosion and sedimentation control plan – The plan would address how potential construction impacts on water quality would be mitigated and managed during construction, including the measures listed in section 7.2.4; ▶ Traffic and access control plan – The plan would address how potential construction impacts on local traffic and access within and across the forecourt would be managed during construction, including the measures listed in section 8.2.2. ▶ Dust management plan – The plan would outline mitigation measures to control dust from exposed areas, stockpiles, and construction activities, including the measures listed in section 8.3.2; ▶ Soils and waste management plan – The plan would include disposal requirements, measures to prevent the generation and measures to reduce, re-use or recycle wastes where possible. It would also detail measures to manage any potentially contaminated fill, as described in section 7.7.2.
Consultation	<p>Relevant utility authorities will be consulted prior to construction commencing to confirm the location of services and utilities in the vicinity of the proposal and ensure that relocation and/or restoration of services or utilities meets the requirements of the relevant stakeholder.</p>



Environmental Issue Commitment

	<p>Sydney Opera House will undertake all engineering investigations and engineering structural work required prior to and during the project to obtain an Engineering Certificate to confirm that the project will not have any material adverse affect on the easment for support and the structural integrity of the Sydney Opera House Car Park and its associated ventilation shafts. This certificate will be provided to the Trust Company of Australia (lessee of the car park).</p>
<p>Potential archaeological impacts</p>	<p>Archaeological investigation and recording would be undertaken consistent with the recommendations of the archaeological management plan as detailed in Section 5 of Appendix B.</p> <p>Relevant site personnel would attend a site induction prior to commencement of the works to ensure that all on-site personnel are aware of the heritage issues associated with the site and the role of the archaeologist(s) on site.</p> <p>Any ground disturbance in areas of archaeological sensitivity should be undertaken under the supervision of a monitoring archaeologist and in accordance with the methodologies described in the archaeological management plan.</p> <p>In the event that any archaeological remains are exposed during site works, they should be appropriately documented according to the procedures outlined in the archaeological management plan.</p> <p>Subsurface disturbance should be limited to those areas defined by the project plans so as to avoid disturbance of other potential archaeological remains at this site.</p> <p>In the event that unexpected archaeological evidence is encountered during site works, works in the immediate vicinity should cease and the Heritage Branch, Department of Planning, should be notified immediately. Further assessment and/or approval may be required before works could recommence.</p> <p>In the event that unexpected Aboriginal archaeological evidence is encountered during site works, works in the immediate vicinity should cease and DECCW should be notified immediately in accordance with the <i>National Parks and Wildlife Act 1974</i>. Works must no recommence until Sydney Opera House Trust receives written authorisation from DECCW.</p>
<p>Other heritage issues</p>	<p>Bennelong Drain</p> <p>The removal or disturbance of any sections of the original ovoid channel (currently functioning or previously decommissioned) should be minimised wherever possible.</p> <p>Any sections of the original drain that are to be removed should be photographed in situ prior to removal (including sections of the original ovoid drain and later diversions).</p> <p>Any exposed sections of the original ovoid drain that will not be removed should be protected during excavation works, as well as in association with construction of the new diversion junction.</p> <p>Removal of any sections of the original ovoid drain would be undertaken in consultation with Sydney Water.</p> <p>Sydney Water would be consulted in relation to any preservation requirements, including the retention and storage of any fabric or artefacts recovered from the Sydney Water asset.</p> <p>Seawall</p> <p>To match the existing fabric of the seawall, the drain would be lined with</p>



Environmental Issue	Commitment
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sandstone to about 1-1.5 m from the outlet.

All works to the seawall should retain and respect the existing material configuration where possible.

Methodologies employed for the construction of the eastern section of the drain will be selected to minimise construction vibration and to avoid any impact on surrounding structures including the sea wall and QEII gates.

The amount of sandstone removed from the seawall for construction of the outlet should be minimised.

Removal of stone from the seawall should be undertaken in a manner that does not disturb, damage or destabilise the surrounding fabric.

Interpretation

Interpretation of any exposed archaeological features and the contribution of this evidence to archaeological research may also mitigate any adverse archaeological impacts. Any such interpretation should be part of a holistic approach to the interpretation of the site. Potential archaeological evidence that may be of particular interest would include:

Remains of Fort Macquarie, associated with a major period in the historical development of Bennelong Point; and

Any evidence of Aboriginal use or occupation of the site, including any isolated artefacts that may be discovered during site works.

Hydrology and drainage	Construction
	Operation

As described in section 7.6.3, a detailed erosion and sedimentation control sub-plan would be prepared as part of the construction environmental management plan, describing safeguards to minimise the adverse impacts on water quality from erosion, sediment transfer and sedimentation during the construction phase.

Construction methods and management measures would be developed to ensure that the drain can remain operational during the construction of the diversion.

It is recommended that a monitoring program be established to monitor the amount of sediment that may be deposited at the outlet once it has been commissioned. The quantity of sediment discharged from the outlet to the receiving environment would be further quantified post construction. This would be undertaken as part of Sydney Water's existing operational plan for the overall stormwater network and would involve six monthly inspections of the sediment trap immediately upstream of the project to ensure it is operating effectively.

If the sediment yield is found to be significant and significant sediment deposition problems are observed to be occurring, a potential mitigation strategy would be to upgrade the sediment sump that is currently located within the Sydney Opera House Car Park, immediately upstream of the project.

It is also recommended that a boom be temporarily installed at the proposed diversion outlet to monitor and capture any floating debris and gross pollutants that may be discharged into Farm Cove. This would provide an indication of the amount of floating debris discharged from the drain. If the amount of floating debris is found to be significant, a permanent boom could be designed, otherwise the temporary boom would be removed.

Aquatic ecology	Construction
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A detailed erosion and sedimentation control plan detailing safeguards to minimise the adverse impacts on water quality from erosion, sediment transfer



Environmental Issue	Commitment
	<p>and sedimentation during the construction phase would be prepared as part of the construction environmental management plan developed by the contractor. It would incorporate measures to manage erosion and runoff in accordance with the specifications outlined in 'Managing Urban Stormwater: Soils and Construction' (Volume 1, 4th Edition, the 'Blue Book', Landcom, 2004);</p>
Visual impacts	<p>Construction</p> <p>Erection of construction hoardings in accordance with standard Sydney Opera House procedures. All construction activities and equipment would be contained within these hoardings.</p> <p>Operation</p> <p>The drain would be lined with sandstone to about 1-1.5m from the outlet to match the existing fabric of the seawall.</p>
Construction noise and vibration	<p>Where possible, the amount of materials that are dropped from heights should be minimised;</p> <p>Where practical, machines should be operated at low speed or power and should be switched off when not being used rather than left idling for prolonged periods;</p> <p>Where possible, equipment should be selected to minimise noise emissions, should be fitted with appropriate silencers and should be in good working order;</p> <p>An excavator likely to produce low noise emissions should be selected;</p> <p>Machines found to produce excessive noise compared to normal industry expectations should be removed from the site or stood down until repairs or modifications can be made;</p> <p>Noise emissions from reversing alarms should be minimised, although use of such alarms should still be satisfactory to achieve occupational health and safety requirements;</p> <p>Construction activities should be limited to recommended standard construction hours;</p> <p>All site workers should be made aware of the potential for noise impacts and encouraged to take practical and reasonable measures to minimise noise during the course of their activities;</p> <p>Noise intensive and vibration generating activities, such as rockbreaking, should be minimised; and</p> <p>Construction hoarding should be used, in accordance with standard practice for construction activities at Sydney Opera House.</p>
Geological conditions	<p>In the event that indications of contamination are encountered (ie. odorous or visually contaminated materials) as a result of exposure of sub soils during construction, work in the area would cease until an environmental consultant can advise on the need for remediation or other action, as deemed appropriate.</p> <p>All waste including spoil will be managed in accordance with DECCs 'Waste Classification Guidelines' (2008).</p> <p>A detailed erosion and sedimentation control plan detailing safeguards to minimise the adverse impacts on water quality from erosion, sediment transfer and sedimentation during the construction phase would be prepared as part of the construction environmental management plan developed by the contractor. It would incorporate measures to manage erosion and runoff in accordance with the specifications outlined in 'Managing Urban Stormwater: Soils and Construction' (Volume 1, 4th Edition, the 'Blue Book', Landcom, 2004);</p>



Environmental Issue	Commitment
	<p>The erosion and sediment control plan prepared as part of the construction environmental management plan would ensure:</p> <ul style="list-style-type: none"> ▶ Sediment and erosion control measures, such as sediment fences and bunding, are installed and maintained, with particular attention where the drainage is towards Farm Cove; ▶ Use of silt curtains as a minimum during construction adjacent the outlet construction area; ▶ Stockpiles are stabilised and remain covered and appropriate sediment and erosion control measures are installed down slope of all stockpiles; ▶ Spill kits are made available to construction vehicles; ▶ Implementation of sediment controls in the vicinity of the outlet construction; and ▶ Any dangerous goods used on site would be handled, used and stored in accordance with relevant material safety data sheets, Australian Standards, and the Dangerous Goods Code. Procedures are included for the management of accidental spills to minimise potential contamination during construction.
Waste management	<p>As part of the construction environmental management plan, a waste management sub-plan would be prepared. The sub-plan would be framed using the waste management hierarchy principles outlined above. The sub-plan would be prepared prior to construction commencing and be consistent with the <i>Waste Avoidance and Resource Recovery Act 2001</i> and the 'Waste Classification Guidelines'.</p>
Traffic and access	<p>A traffic and access management plan would be prepared as part of the construction environmental management plan and would include measures such as:</p> <ul style="list-style-type: none"> ▶ Vehicles are to remain on internal road network where possible; ▶ Vehicles to minimise distance travelled across forecourt where possible; ▶ Alternate parking to be found for personnel vehicles that are not required to be on site; ▶ Where possible, heavy vehicle movements for delivery of materials/equipment and removal of spoil should be restricted to off peak times or when forecourt use is low; ▶ Access to Man O' War Steps to be maintained at all times; and ▶ Access to the Royal Botanic Gardens to be maintained at all times during construction.
Air quality	<p>A dust management plan would be prepared as part of the construction environmental management plan, including measures such as the following:</p> <ul style="list-style-type: none"> ▶ Areas with the capacity to cause dust would be dampened to suppress dust emissions;



Environmental Issue	Commitment
	<ul style="list-style-type: none"> ▶ Materials transported in trucks would be appropriately covered to reduce dust generation; ▶ Vehicle movement controls would be installed, particularly entrance to and exit from construction work sites; ▶ Construction activities that generate high dust levels would be avoided during high wind periods; ▶ Rehabilitation of disturbed surfaces would be undertaken as soon as possible; ▶ All construction plant and machinery would be fitted with emission control devices complying with Australian Design Standards and would be regularly maintained; and ▶ Plant and machinery would be turned off when not in use.
Land use	Construction of the works and events would be timetabled to avoid construction coinciding with forecourt events.
Infrastructure	<p>Services searches undertaken by the construction contractor would confirm the location of any services.</p> <p>Consultation with service providers would be undertaken prior and during the works to ensure that all services located in the area are located and protected during the works.</p>
Safe work method statement	Following confirmation of the final construction method, the Contractor will develop a detailed safe work method statement to ensure delivery and installation of the project maintains the integrity of the surrounding heritage fabric of the Sydney Opera House site.
Operation and maintenance	As the asset would be owned and operated by Sydney Water, Sydney Water would be responsible for operation and maintenance, including any ongoing monitoring or inspections. This would include six monthly water quality or sedimentation investigations undertaken as part of routine operation of the wider stormwater drainage system.



Chapter 10 Justification and conclusion

10.1 Justification

The project would realign the Bennelong Drain from its current alignment and provide flexibility to accommodate future projects which are proposed under the Sydney Opera House Strategic Building Plan. By realigning the existing Bennelong Drain, projects such as the provision of a new loading dock and associated access and the provision of new corridors and lifts would be able to be constructed on the site in the future. The project is considered to be justified as it is an essential precursor to other projects would benefit the Sydney Opera House by improving the functionality of the building and site.

The project would result in some adverse impacts, though it is considered that these impacts would be short-term and relatively minor in nature and would be mainly restricted to the construction phase of the project. Operation of the drain is not considered to generate any significant adverse effects as the operational impacts would not vary significantly to those of the existing drain. As the adverse impacts of the project are primarily limited to the construction period and are relatively minor and short-term and minor in nature, the environmental impacts of the project are considered to be justified. The benefits of the project are considered to outweigh the adverse environmental impacts.

The engineering design has been developed based on known geological conditions at the site. Consultation was also undertaken with Sydney Water regarding the design principles, in particular the design capacity, to ensure it will satisfy ongoing operational and maintenance requirements. The project is therefore considered to be viable and justified from a design perspective and has been designed in accordance with Sydney Water's standards.

10.2 Conclusion

This environmental assessment has considered the potential impacts of the proposal to divert a section of the Bennelong Drain within the Sydney Opera House site. The project would involve replacing the existing section of the Bennelong Drain with a new section that would travel in an easterly direction underneath the forecourt to Sydney Opera House and discharge via a new outlet within the eastern seawall at Farm Cove.

The environmental assessment has been prepared in accordance with the provisions of Part 3A of the *Environmental Planning and Assessment Act 1979* and the requirements of the Director-General of the NSW Department of Planning. The environmental assessment has documented the potential environmental impacts associated with the project, considering both potential positive and negative impacts, and recommends management and mitigation measures to protect the environment where required. These management measures are documented in the Statement of Commitments.

Investigations undertaken during preparation of the environmental assessment to assess the potential environmental impact included specialist assessment of issues including heritage and archaeology; hydrology and drainage; aquatic ecology; geotechnical, and construction noise. A number of potentially negative impacts have been identified that primarily relate to the construction phase, negative impacts include the potential for impacts on the heritage significance of the site,



generation of sediment, construction noise, visual impacts and management of traffic and access arrangements. Monitoring will be undertaken to determine whether operation of the project is leading to sedimentation impacts. Should this occur, additional sediment collection devices could be installed if required. The environmental assessment concludes that the project is unlikely to result in any significant environmental impacts provided that:

- ▶ The archaeological management plan developed as part of the heritage assessment is implemented during construction; and
- ▶ A construction environmental management plan is developed that incorporates actions to address the Statement of Commitments.



References

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