NSW GOVERNMENT

Transport for NSW

Beaches Link and Gore Hill Freeway Connection

4 – Assessment of potential effects of the immersed tube tunnel sill

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4 Assessment of potential effects of the immersed tube tunnel sill

4.1 Overview

The immersed tube tunnels for the Middle Harbour crossing would form a maximum 9.2 metres high sill above the existing bed of the harbour in a water depth of 32 metres around 1.5 kilometres upstream of the Spit Bridge. Whilst there are natural sills within Middle Harbour (the most notable one being the natural sill at the Spit Bridge which has a depth of 10 metres below the mean sea level surface) construction of the immersed tube tunnels would divide the existing deep water channel into two partially separated sections. This would include a 1.5 kilometre section between the Spit Bridge and the immersed tube tunnel sill and a 3.5 kilometre section of deep water upstream of the immersed tube tunnel sill extending to near Yeoland Point.

Potential impacts to marine water quality and benthic ecology that could arise from changes to tidal flushing due to the sill formed by the immersed tube tunnels were reported in the environmental impact statement in Appendix Q (Technical working paper: Marine water quality) and Appendix T (Technical working paper: Marine ecology). These studies were carried out to comply with the updated Secretary's environmental assessment requirements (SEARs) issued by the Department of Planning, Infrastructure and Environment on 22 April 2020, specifically biodiversity SEAR 6, Part 10 which requires that the project:

> *Identify and assess the impact of tidal flushing on the crossing of Middle Harbour. The assessment should also include details of any potential sediment accumulation and the impact this may have on marine populations that dwell on the harbour floor.*

Tidal flushing times upstream of the immersed tube tunnel sill would increase from 1.6 days to 2.4 days after the construction of the project as discussed in Section 17.5.2 of the environmental impact statement and Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling). In general, flushing times greater than four days may lead to deteriorating water quality. As the predicted flushing times due to the project would be less than four days, an increase in flushing times is not likely to have significant impacts on biodiversity. The environmental impact statement findings were that:

- Based on water quality sampling, the water quality upstream of The Spit under existing conditions could be subject to periods of naturally low dissolved oxygen concentrations after rainfall
- Periods of depletion of dissolved oxygen near the bed of the harbour are likely to last for only a few days and the subsequent vertical mixing by the tidal currents is likely to rapidly dilute any potential effects of this deep water on the mid-depth and surface waters
- The potential for a greater duration of individual mortality events to deep water soft sediment benthic infauna or epibiota, as a result of the proposed immersed tube tunnel sill, is not considered to be a major impact given these assemblages are already exposed to similar disturbances naturally and would be expected to be resilient to slight increases in the longevities of these disturbances, through rapid recolonisation.

Following exhibition of the environmental impact statement, concerns were raised by the Department of Planning, Industry and Environment and Northern Beaches Council regarding the assessment of potential impacts of the immersed tube tunnel sill on levels of dissolved oxygen and other physio chemical parameters in Middle Harbour, including salinity and temperature. In response to issues raised, an additional assessment has been carried out by Cardno and is provided in Appendix A of this preferred infrastructure report. A summary of the additional assessment is included in this Section.

The aim of the additional assessment was to model potential changes to dissolved oxygen and other water quality parameters that could occur both upstream and downstream of the immersed tube tunnel sill due to reduced tidal flushing and mixing, and to update the findings of the environmental impact statement reported in Appendix T (Technical working paper: marine ecology) where required.

To assess potential impacts to marine ecology, a dissolved oxygen concentration threshold of 4.6 milligrams per litre (mg/L) has been used for the assessment as adopted from Vaquer-Sunyer and Duarte (2008) (refer to Section 1.3 of Appendix A of this preferred infrastructure report). This is considered to be a precautionary limit for conserving biodiversity and is based on a comprehensive review of over 800 published experiments that considered dissolved oxygen concentration and/or time thresholds on about 200 benthic fauna species. The dissolved oxygen concentration of 4.6 milligrams mg/L is the lowest concentration that would not affect populations of most groups of species, apart from the 10 per cent most sensitive to lower dissolved oxygen concentrations.

It should be noted however that monitoring has shown that dissolved oxygen in Middle Harbour may naturally decrease down to levels of about 4 mg/L to 5.5 mg/L.

4.2 Methodology

The modelling carried out by Cardno for this preferred infrastructure report utilised a modified and locally re-calibrated Sydney Harbour Ecological Response Model (SHERM). The SHERM was designed to simulate a range of water quality and biological processes, including physical processes, nutrients, algal processes and biological contaminants (refer to sections 2 and 3 of Appendix A of this preferred infrastructure report).

Existing water quality data collected as part of the environmental impact statement as reported in Section 3.3 and Annexure B of Appendix Q (Technical working paper: Marine water quality) was used to verify outputs from the SHERM. The sampling periods monitored a range of parameters to understand the physio-chemical conditions at the location of the Middle Harbour crossing, as well as upstream and downstream of the crossing, at various depths throughout the water column from the surface to the bed of the harbour. The key variables measured in relation to potential impacts from the project were turbidity (to understand the additional effects of dredging on natural levels during construction of the project) and dissolved oxygen (to understand if the sill formed by the immersed tube tunnel crossing would decrease ambient levels near the bed of the harbour during operation of the project). The potential impacts of dredging during construction of the project have been considered and assessed in Appendix Q (Technical working paper: Marine water quality) and Appendix T (Technical working paper: Marine ecology).

The modelling carried out as part of this preferred infrastructure report has focused on the operational impacts of the immersed tube tunnel sill. The predictive modelling results have then been used to assess and confirm potential impacts on benthic fauna that dwell on the bed of the harbour.

In assessing and confirming the potential impacts on benthic fauna, the dissolved oxygen threshold of 4.6 mg/L (as discussed in Section 4.1 above) has been applied. The model has also been used to predict whether there would be any changes to salinity and temperature near the bed of the harbour and through the water column.

The selected three month duration water quality simulation scenarios used to model potential changes have included:

- Simulation period 1 – December 2017 to February 2018 (Sampling period 1 from Appendix Q (Technical working paper: Marine water quality))
- Simulation period 2 – April to June 2020 (Sampling period 2 from Appendix Q (Technical working paper: Marine water quality))
- Simulation period 3 – January to March 2012 (indicative of a wet period over summer).

The modelling also included a range of sensitivity tests to assess summer-winter meteorological influences, effects of vertical mixing and the sensitivity to sediment oxygen demand (a measure of the rate of dissolved oxygen that is consumed by the bed of the harbour).

4.3 Modelling results

The modelling results for the predicted change in dissolved oxygen as a result of the immersed tube tunnel sill are presented in terms of near bed time-series plots of dissolved oxygen and longitudinal depth versus distance plots along the Middle Harbour and Sailors Bay thalweg (ie a long section along the deepest part of the harbour). These are shown in Section 7 of Appendix A of this preferred infrastructure report.

Simulation periods 1 and 2 generally show that the near bed dissolved oxygen concentrations reduce up to 0.3 mg/L for short periods after heavy rainfall once the immersed tube tunnels have been constructed. However, recovery of dissolved oxygen generally occurs within the same time (up to 10 hours of the existing case) and is generally very rapid. Simulation period 3 considers high rainfall events (ie greater than 100 millimetres in a day) and experiences a slower recovery of dissolved oxygen generally within 18 hours of the existing case. Near bed dissolved oxygen concentrations reduce up to 0.4 mg/L after heavy rainfall once the immersed tube tunnels have been constructed. Modelling results of all simulations show that dissolved oxygen levels would still remain within an acceptable range that is above the precautionary threshold limit for dissolved oxygen of 4.6 mg/L for conserving biodiversity and that the predicted lower dissolved oxygen would be limited to the deeper parts (depth of greater than 10 metres below the surface) of the waterway. This would be below the depth and outside of the area of any identified nearshore sensitive habitats, with the largest decreases predicted to occur immediately upstream of the proposed immersed tube tunnel sill in the middle of the channel, which is a naturally occurring deep basin (greater than 27 metres deep).

An increase in dissolved oxygen in deeper areas downstream of the immersed tube tunnel sill is predicted including increases of up to 1.0 mg/L in the deep areas between the Spit Bridge and the immersed tube tunnel sill. This could be considered an environmental benefit as increased dissolved oxygen levels could help offset against any natural decreases, particularly from background events that result in levels going below 4.6 mg/L.

As discussed in Section 4.2, sensitivity testing was also carried out to assess the sensitivity of the model and included consideration of season, vertical turbulence and mixing and sediment oxygen demand (refer to Section 8 of Appendix A of this preferred infrastructure report). Sensitivity testing indicated that:

- Near bed dissolved oxygen depletion is a seasonal phenomenon, during winter the near bed dissolved oxygen concentration is relatively stable, and does not decrease to the same extent as in summer

- Vertical mixing does play a role in the predicted near bed dissolved oxygen concentration. The modelling for the simulation periods conservatively assumed very low vertical mixing within Middle Harbour. By increasing vertical mixing, the model results in less dissolved oxygen depletion near the bed of the harbour upstream of the tunnel sill
- The model, and hence dissolved oxygen in upper Middle Harbour itself, is sensitive to sediment oxygen demand:
  - With a higher sediment oxygen demand rate, the near bed dissolved oxygen levels tend to reduce further. The model predicted that the near bed dissolved oxygen upstream of the immersed tube tunnel sill would be up to 0.9 mg/L lower once the immersed tube tunnels are constructed with a higher sediment oxygen demand. However, recovery of dissolved oxygen is still predicted to occur rapidly and within 12 hours of the existing case without the immersed tube tunnel sill
  - Near bed dissolved oxygen upstream of the immersed tube tunnel sill would be up to 1.2 mg/L lower once the immersed tube tunnels are constructed when a sediment oxygen demand increased to 1.5 g/m^2/day is considered. However, given the composition of the bed of the harbour, a scenario of sediment oxygen demand such as 1.5 g/m^2/day is considered to be unlikely. This is further supported by the bed of the harbour sediment sampling carried out by Douglas Partners and Golder Associates (2018) for the environmental impact statement, which found the average total organic carbon content in the surface sediment near to the Middle Harbour crossing to be around 3.6 per cent. This value is low and is indicative that high sediment oxygen demand would not be expected.

The modelling indicates that at the peak of the low dissolved oxygen events, the area upstream of the immersed tube tunnel (where dissolved oxygen is predicted to change) is less than one per cent of the tidal area, or 1.8 per cent of the area where the bed level is below 10 metres (Australian Height Datum (AHD)). As a worst case scenario based on the sensitivity testing, the affected area is only slightly larger, being 1.8 per cent of the tidal area and 3.6 per cent of the deep water area.

The model also predicted very minor changes to near bed salinity and temperature due to reduced mixing and flushing. The immersed tube tunnel sill has the potential to slightly change near bed of the harbour salinity and temperature due to reduced mixing and flushing. However, based on the modelling results, changes to these parameters are expected to be minimal upstream and downstream of the immersed tube tunnel sill (refer to Section 7 and Annexure B of Appendix A of this preferred infrastructure report). As the changes to the near bed salinity and temperature are minimal, they are unlikely to affect existing marine flora and fauna and have not been considered further in Section 4.4.

4.4 Ecological impact assessment

4.4.1 Environmental impact statement findings

Dissolved oxygen in Middle Harbour can reduce after heavy rainfall as indicated in Appendix Q (Technical working paper: Marine water quality. After heavy rain (ie greater than 100 millimetres in a day), it is likely that nutrient enrichment from freshwater inflows results in a mass influx of particulate organic matter to the sediments (eutrophication). The decomposition of this organic matter leads to a rapid acceleration of oxygen consumption, and potential depletion of oxygen in bottom waters. In a stratified water column, which may occur in summer in a tidal estuary such as Middle Harbour, bottom waters may become isolated from oxygen enriching processes and can give rise to anoxic (near zero dissolved oxygen) and hypoxic (dissolved oxygen levels are less than 2.0 mg/L) events. Hypoxia can cause major mortality to marine flora and fauna and can affect the survival of organisms. The findings of the environmental impact statement were that the immersed tube tunnel sill would have negligible effects in the surface waters and would be unlikely to effect the identified nearshore habitats such as seagrass and subtidal rocky reef which are located in shallow waters.

4.4.2 Intensity of low dissolved oxygen events and dissolved oxygen thresholds

Monitoring and modelling of dissolved oxygen in the deep basin upstream of the immersed tube tunnel sill observed near bed concentrations of dissolved oxygen to be generally far above 4.6 mg/L (the precautionary limit for conserving biodiversity in marine ecology, as outlined in Section 4.1) in dry periods over summer, ranging roughly between 6.0 and 7.5 mg/L. After heavy rainfall, it has been determined that dissolved oxygen levels in Middle Harbour may naturally decrease to levels down to roughly 3.0 to 5.5 mg/L. Modelling indicated that the amount of rainfall over 50 millimetres had little effect on the minimum concentration of dissolved oxygen reached.

Hydrodynamic modelling carried out for the environmental impact statement has shown that the immersed tube tunnel sill would reduce tidal flushing of the deep pool basin behind the sill (refer to Appendix P (Technical working paper: Hydrodynamic and dredge plume modelling). Modelling carried out for this preferred infrastructure report has indicated that the immersed tube tunnels is likely to reduce concentrations of dissolved oxygen near the bed of the harbour (after heavy rainfall) to levels below those that would occur without the immersed tube tunnels. However, changes in concentrations of dissolved oxygen between modelled scenarios with or without the immersed tube tunnels were not substantial after heavy rainfall, with a maximum difference of about 0.5 mg/L at the peak of dissolved oxygen decline. As such, at the peak of dissolved oxygen concentration decline after heavy rainfall, the effect of the immersed tube tunnel sill would reduce the concentration of dissolved oxygen to levels of about 4.7 mg/L. These levels are close to, but still above the dissolved oxygen threshold level of 4.6 mg/L which is considered to be a precautionary limit. Importantly, given the immersed tube tunnel sill did not appear to extend the longevity of low dissolved oxygen events generally by more than half a day, regardless of the level of peak decline, low dissolved oxygen events would not be an issue to benthic fauna.

Sensitivity testing carried out as part of the modelling indicated that a high sediment oxygen demand could possibly explain the naturally low dissolved oxygen concentration observed in sampling during the preparation of the environmental impact statement. In this situation, modelling indicated that the additional effect from the proposed immersed tube tunnel sill could potentially reduce the concentration of dissolved oxygen a further 1.0 mg/L. However, a scenario of high sediment oxygen demand is considered to be unlikely and sediment sampling from Douglas Partners and Golder Associates (2018) found the average total organic carbon content in the surface sediment to be around 3.6 per cent, which is low and indicates that high sediment oxygen demand would not be expected. To confirm this, it is proposed to carry out pre-construction monitoring of sediment oxygen demand, as detailed in Section 4.6.

4.4.3 Duration of low dissolved oxygen events

The longevity of low dissolved oxygen events is important to the survival of marine flora and fauna. Although mobile fauna such as fish can move away from hypoxic waters, most benthic fauna are unable to. Notwithstanding this, other studies have indicated that some benthic species within Middle Harbour (eg some of the worms, bivalves and echinoderms) would potentially have metabolic adaptations that will allow them to survive times of low dissolved oxygen for hours or even days (Vaquer-Sunyer and Duarte, 2008). Monitoring and modelling carried out has indicated that the concentration of dissolved oxygen reduced gradually after rain (with or without the immersed tube tunnel sill) and it only generally reduced to levels close to 4.6 mg/L (ie where benthic fauna would be affected) for a very short time (eg one or two days) prior to rapid recovery. Given the immersed tube tunnel sill did not appear to extend the longevity of low dissolved oxygen events generally by more than half a day, regardless of the level of peak dissolved oxygen concentration decline, low dissolved oxygen events would not be considered to be an issue to benthic ecology.

4.4.4 Extent of low dissolved oxygen events

Under most simulation scenarios, dissolved oxygen is reduced after heavy rainfall (with or without the immersed tube tunnels) but only in the deeper part of the water column where water depth is greater than 10 metres, and this is generally confined to small areas immediately upstream of the immersed tube tunnel sill in the middle of the channel (ie the deep basin). Effects generally become negligible within a few hundred metres upstream of the immersed tube tunnel sill and do not extend to the sides of the channel. Given that sensitive Type 1 or Type 2 Key Fish Habitat in the vicinity of the immersed tube tunnels, such as seagrass or subtidal rocky reef, are located in shallow water close to the shoreline of Middle Harbour, these habitats would be unaffected by any changes in dissolved oxygen levels in deeper waters downstream of the immersed tube tunnel sill.

4.5 Conclusion

Benthic fauna in deeper areas of Middle Harbour within the vicinity of the immersed tube tunnel sill are already subject to occasionally low concentrations of dissolved oxygen in summer, after heavy rainfall that reach, or become slightly less than, the dissolved oxygen threshold of 4.6 mg/L that may cause mortality to part of the population.

Modelling has shown under most simulation scenarios, the immersed tube tunnels would only slightly decrease concentrations of dissolved oxygen near the bed of the harbour in deeper waters after heavy rain from what would be expected to occur under natural conditions and would not substantially increase the duration of occasionally naturally low dissolved oxygen concentrations. The small changes predicted would be confined to an area of deeper water in the deep basin immediately upstream of the immersed tube tunnels. The magnitude, duration, and spatial scale of the effect of the immersed tube tunnel sill to benthic fauna in these areas would not be measurable beyond natural impacts from the occasionally low dissolved oxygen events.

Given that sensitive Type 1 or Type 2 Key Fish Habitat in the vicinity of the immersed tube tunnels, such as seagrass or subtidal rocky reef, are located in shallow water close to the shoreline of Middle Harbour, these habitats would be unaffected by any changes in dissolved oxygen levels in deeper waters downstream of the immersed tube tunnel sill.

These findings support the conclusions made in the environmental impact statement and Appendix T (Technical working paper: Marine ecology) in regard to addressing Biodiversity SEAR 6, Part 10 (refer to Section 4.1). As such, there would be no requirement for additional offset requirements under the *Policy and Guidelines for Fish Habitat Conservation and Management* (NSW Department of Primary Industries, 2013) for managing impacts to marine ecology.

4.6 Additional environmental management measure

As noted above, the modelling indicates that the near bed of the harbour dissolved oxygen levels is sensitive to the assumed high sediment oxygen demand. As such, new environmental management measure WQ20 (refer to Appendix C of this preferred infrastructure report) has been proposed to carry out pre-construction monitoring as follows:

> Monitoring of dissolved oxygen, temperature, salinity, turbidity and sediment oxygen demand will be carried out for a period of 12 months prior to construction in Middle Harbour. The monitoring will include:

a) Vertical profile monitoring of dissolved oxygen, temperature, salinity and turbidity at one location within the deep basin upstream of the immersed tube tunnel location where the changes to dissolved oxygen are predicted to occur

b) Monthly vertical profiling of dissolved oxygen, temperature, turbidity and salinity upstream and downstream of the immersed tube tunnel location at up to six locations within Middle Harbour

c) Monthly sampling of sediment oxygen demand at the location in a) above and every three months at each upstream vertical profile site in b) above.

The need for further modelling or post-construction monitoring of potential dissolved oxygen changes will be determined following the completion of the pre-construction monitoring.

4.7 Consultation

Prior to the commencement of the modelling, Transport for NSW met with the Department of Planning, Industry and Environment to discuss the assessment approach, modelling methodology and seek input on the modelling sensitivity scenarios.

Prior to lodgement of this preferred infrastructure report, further meetings have been held to present the assessment outcomes to the Department of Planning, Industry and Environment as well as Northern Beaches Council. These meetings were held on 23 July 2021 and 9 August 2021 respectively.

Transport for NSW would continue to work closely with the Department of Planning, Industry and Environment and Northern Beaches Council during the pre-construction monitoring period. This would include periodically providing the results of the pre-construction monitoring. Once the pre-construction monitoring has been completed, Transport for NSW would discuss the need for further modelling and monitoring post-construction with the Department of Planning, Industry and Environment and Northern Beaches Council, as required.