Summary of key outcomes:

Numerical modelling techniques have been used to assess potential changes to the wave climate, currents and stability of coastal sediment on a Bay-wide basis as a result of the proposed Port Botany Expansion.

Wave climate studies examined swell waves, wind generated local sea waves and long waves. Swell waves and local sea waves are the primary wave types which affect sediment transport and shoreline stability in Botany Bay.

The results of the wave modelling showed that beyond the northeastern embayment of Botany Bay (i.e. between the Parallel Runway and Molineux Point) wave climate in Botany Bay would be effectively unchanged as a result of the construction of the new terminal. There would be a minor reduction in sediment transport on Towra Beach, however, any changes would be imperceptible. There would also be a small change in wave direction, in the order of 1° at Silver Beach. However, this would be accommodated within the existing groynes hence there would be no identifiable impact.

The results of the modelling also showed that currents in Botany Bay would be essentially unchanged as a result of the construction of the new terminal. Subsequent detailed modelling and analysis therefore focused on changes in wave climate in the northeastern embayment between the Parallel Runway and Molineux Point.

Within the northeastern embayment, potential changes to swell wave energy, notably along the Parallel Runway, have been minimised by careful design of the dredge area and the new terminal. With the proposed dredging profile and rock embankment design for the new terminal, there would be no increase in swell wave energy on the eastern side of the Parallel Runway and local sea wave heights along the Parallel Runway would be reduced.

A large reduction in wave energy would be expected at the existing mouth of Penrhyn Estuary due to the "blocking effect" of the new terminal. Construction of the new terminal would therefore significantly reduce erosion and transportation of sediment along the southeast portion of Foreshore Beach. There would continue to be westward sand transport along the remaining exposed section of Foreshore Beach. However, a groyne would be built as an extension to the Mill Stream training wall to trap this sediment and prevent it from blocking the Mill Stream waterway.

15.1 Introduction

The study of water movement, predominantly caused by tides and wind is termed “hydrodynamics”. Consideration of hydrodynamic issues is important when major development is proposed in estuarine or coastal settings, particularly as coastal developments may result in changes to wave climate which can impact areas remote from the development site.

Botany Bay is a wide, shallow estuary exposed to winds from all directions and waves from the adjacent high energy coastal zone. Waves and currents determine the erosion, deposition, transportation and therefore, the ultimate fate of sediment in the Bay. Changes to the Bay hydrodynamic conditions can affect transportation of sediment around the Bay and hence impact on the stability of beaches and infrastructure. Previous developments, most notably in northern Botany Bay, have modified the foreshores and substantially changed the hydrodynamics of the Bay.

This chapter describes the existing hydrodynamics and coastal processes in Botany Bay and assesses any impacts of the proposed Port Botany Expansion. It is based on investigations undertaken by Lawson and Treloar (2003) in a report titled *Proposed Expansion of Container Port Facilities in Botany Bay, NSW – Coastal Processes and Water Resources Issues: Volume 3 Waves, Currents and Coastal Process Investigations*. The results of the investigations are provided in **Appendix H**.

15.2 Existing Conditions and Processes

The entrance to Botany Bay is about 1.1 km wide and is open to ocean swell from the east. Despite the exposure to waves and a small tidal range, tidal processes are the predominant influence of circulation and flushing in Botany Bay. Botany Bay is relatively shallow (mean water depth is about 5 m) and shoals westward from the dredged navigation channel at the entrance. The foreshores of Botany Bay include rocky headlands, sandy beaches and sheltered embayments. Numerous developments on the foreshore of Botany Bay have modified the hydrodynamics and shoreline of Botany Bay.

The major riverine input to the Bay is from the Georges River in the southwest corner of the Bay. The smaller Cooks River discharges to the northwestern corner of the Bay, west of Sydney Airport. The fresh water flow from both rivers is normally small compared to the tidal flow.

Developments such as the Caltex Oil Refinery, Parallel Runway and Port Botany have extensively modified Botany Bay. The Caltex Oil Refinery was established at Kurnell in 1953 and the approach channel and jetty berths were dredged and extended in several stages.

Construction of Sydney Airport was completed in several stages and involved the relocation of the Cooks River and Alexandra Canal west of their original courses. The north-south runway of Sydney Airport was extended into Botany Bay in two stages (1964-66 and 1970-71) using sand dredged from Botany Bay southwest of the runway and from the entrance of the Bay. The Parallel Runway was constructed in 1994 from sand extracted from the Bay to the east of the runway.

Port Botany was constructed between 1978 and 1982. As part of the construction, an armoured revetment wall extending south from Bumborah Point was built and dredging of a ship navigation channel from the entrance of the Bay to the port was undertaken.

The construction of Sydney Airport and Botany Bay has created hard edged structures within the Bay.

Changes to Bay hydrodynamics have impacted on sediment transport and beach stability around the Bay. Consequently seawalls have been constructed on Lady Robinsons Beach, and Silver Beach and southern Lady Robinsons Beach have been stabilised by groynes.

15.2.1 Tides

The tidal regime in Botany Bay is essentially the same as in Port Jackson with a mean tidal period of 12.4 hours. Generally two high tides and two low tides occur each day (semi-diurnal) and are almost simultaneous throughout the Bay. The tidal amplitude varies fortnightly on a high and low range tidal cycle (spring and neap tides, respectively) and the maximum and minimum heights of each successive tide vary significantly. The range of astronomical tides is approximately 2.1 m, mean high to mean low water spring tides is some 1.3 m and mean high to mean low water neaps is around 0.8 m.

15.2.2 Currents and Circulation

Currents in Botany Bay are predominantly generated by tides, winds and river flow. Irregular, long period waves originating offshore (e.g. storm surges) are capable of generating currents. However, the current velocities are low (less than 2 cm/s in Port Botany) due to the low amplitude and long period. During low rainfall periods, currents in the Bay are dominated by tidal flow to and from the Georges River.

Tidal currents that produce a periodic flow in and out of Botany Bay are generally low in velocity. The highest velocity tidal currents occur at the entrance to the Bay, at the mouth of the Georges River, near Molineux Point and around the southern edge of the Parallel Runway. Only minor alterations to the tidal current flow and direction have resulted from existing infrastructure as the major (east west) flow is south of the Parallel Runway (i.e. in the middle of the Bay). Maximum tidal velocities are likely to cause only local resuspension of the sandy sediment that predominates throughout the Bay. Tidal currents in the northeastern embayment of Botany Bay are generally low (less than 0.1 m/s) due to the confined nature of the northeastern embayment, but higher velocity flows occur near the Mill Stream.

Wind blowing across a water body generates water currents by transference of momentum. Current velocities are dependent on strength, fetch and duration of wind. Botany Bay is exposed to winds over large stretches of open water (fetch) and wind driven currents assist in exchange and mixing of estuarine waters.

Botany Bay is stratified immediately after heavy rainfall (greater than 50 mm per day) as turbid, buoyant freshwater plumes exit the estuary mouth (Kingsford 1994). The freshwater plumes are some 1-2 m thick and have little interaction with underlying saline waters. After the freshwater flow ceases, the surficial layer deepens due to wind mixing and the estuary reverts to low-flow conditions after a week of dry conditions.

15.2.3 Wave Climate

Two principal wave types occur within Botany Bay, wind generated local sea waves and ocean waves (swell waves) generated offshore that pass through the entrance to Botany Bay. Three wave classifications, i.e. local sea, swell and long waves, have been considered throughout Botany Bay as part of this assessment.

Waves generated by wind blowing over restricted areas of open water are referred to as local sea waves. Due to the open expanse of water in Botany Bay, waves can be generated by winds from all points of the compass. Local sea waves can be important in controlling circulation and near-shore resuspension and transportation of sediment. Water depth has little effect on the generation of local sea waves, but increases in water depth (e.g. from dredging) can change the shoaling of waves and sediment transportation patterns.

Diurnal northeast winds (~8 m/s) during summer produce waves with periods typically about 2.5 seconds that affect Towra and Silver Beaches on the southern foreshores of Botany Bay. The Sydney Airport runways have limited the fetch of easterly winds to Lady Robinsons Beach on the western foreshores of Botany Bay. Strong southerly winds (~10 m/s), particularly late on summer afternoons, are usually of short duration, but can produce wind waves that temporarily influence water circulation in northern Botany Bay. Westerly winds, which can persist for up to a week at a time in winter, have long fetches in Botany Bay, but the waves generated in deeper water near the mouth of Botany Bay are probably insignificant in terms of resuspension of sediment.

Swell refers to waves generated by distance disturbances, e.g. storms and cyclones, that have longer wavelengths and periods than local sea waves. Botany Bay is subject to ocean swell from the east, however, the swell wave climate near the new terminal area is described as “mild” since energy from incoming waves is redirected by entrance dredging, or obstructed by the armoured revetment wall north of Molineux Point. The swell wave climate has substantially changed with developments in the Bay, which has contributed to erosion and accretion problems in some areas.

Long waves (wave periods generally between 25 and 300 seconds) have a variety of sources including distant storms, changes in atmospheric pressure and wave grouping. Long waves have the potential to cause excessive movement of moored vessels, but disruptions from long waves have not been reported in Botany Bay. The long wave climate in Botany Bay interpreted from nearly 5 months of wave data from Waverider buoys has been described as “very mild” and horizontal currents generated from long waves are less than 0.02 m/s.

15.2.4 Coastal Processes

Coastal processes in Botany Bay include the erosion, transportation and accumulation of sediment and therefore the shape and nature of beaches. The stability of sandy beaches on the western and southern shoreline of Botany Bay is influenced by ocean swell waves that penetrate the entrance to the Bay. Dredging for navigational purposes at the entrance to Botany Bay has substantially changed the wave climate and therefore erosional and depositional areas in the Bay. To a lesser extent, locally generated wind waves and currents also influence sediment transport and beach stability in Botany Bay.

Silver and Towra Beaches on the southern shoreline of the Bay are subject to ocean swell waves through the entrance of Botany Bay. These sandy beaches represent dynamic sedimentary environments as the beaches are not aligned parallel to the impinging waves. Storm erosion on Silver Beach has been reduced by groynes placed on the beach in 1969-70, 1980 and 1992. In contrast, existing westward sand transportation along the unprotected Towra beach is estimated at about 6,000 m^3 per annum.

Ocean swell has been almost completely excluded from the northern foreshores of Botany Bay due to the existing terminals at Port Botany and the Sydney Airport runways. Tidal currents are also low and sediment is accumulating in previously dredged areas. Sand is accumulating along the northern section of the beach from northerly transport of sediment.

Muddy embayments (e.g. Woolooware and Quibray Bays) are low energy, depositional environments on the southern shoreline of Botany Bay and are largely sheltered from wave effects.

Foreshore Beach is presently subject to moderate wave energies, particularly during strong southerly winds. Migration of sand (i.e. longshore drift toward the Mill Stream outlet) is causing erosion along Foreshore Beach and recession of beach dunes. A comparison of recent photographs with those taken in 1996 also indicates that sand has accumulated in outer Penrhyn Estuary, in the form of a spit northwest of Brotherson Dock. Sand accumulation in the outer sections of Penrhyn Estuary has reduced access to the Estuary to a narrow "neck" and necessitated relocation of the boat ramp in Penrhyn Estuary.

The existing dredged area between Port Botany and the Parallel Runway is a low energy environment.

15.3 Methodology

Investigations were undertaken by numerical computer modelling and included assessment of wave climate, currents and coastal processes. Potential changes as a result of the proposed Port Botany Expansion were assessed on a Bay-wide basis. Detailed assessments were also undertaken within the northeastern embayment of Botany Bay between the Parallel Runway and Molineux Point.

Modelling included the following:

- waves - two modelling systems were used to determine the extent of wave climate change (at mean sea level) in Botany Bay. The SWAN wave model was used to investigate the propagation of swell into Botany Bay from the Tasman Sea and the generation of wind generated local sea waves within the Bay. The MIKE-21 Boussinesq Wave (BW) model was used to model swell wave and long wave propagation in the Port Botany area between the Parallel Runway and Molineux Point; and
- currents - two models were developed both using the Delft 3D modelling system - a whole of Bay model extending up the Georges River to Lugarno, and a northern Bay regional model extending north from a line between the Parallel Runway and Molineux Point (**Figure 15.1**); and
- the stability of coastal sediment in Botany Bay was assessed using historical information and the results from the wave and current modelling. In addition, the LITPACK coastal processes model was applied to Towra Beach and Foreshore Beach to determine potential impacts on sediment transport rates in these areas.

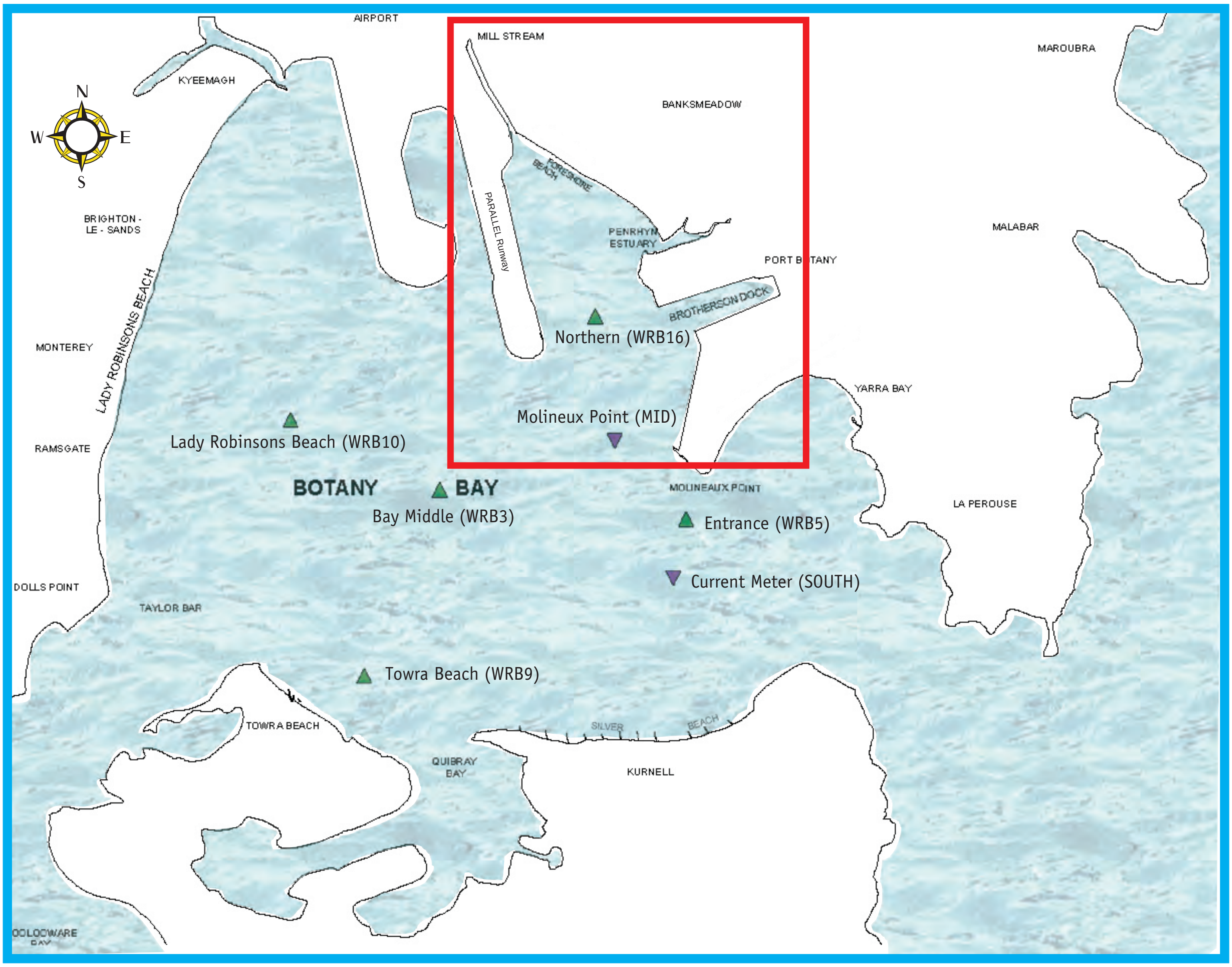
The modelling systems are described in more detail in the following sections.

15.3.1 Modelling of Waves

As outlined above, two numerical modelling systems were used to investigate present and post development wave conditions in Botany Bay.

The SWAN wave model was used to investigate the propagation of swell into Botany Bay from the Tasman Sea and the generation of local sea within the Bay. The model was set up using a constant grid size of 50 m throughout the Bay, from the 100 m depth contour offshore to Sandringham Bay on the northern side of the Georges River entrance.

For swell wave investigations, waves from nine offshore directions from north through east to south, combined with nine wave periods from 3 to 11 seconds were modelled, totalling 81 basic cases. In each case, the offshore wave height adopted was 1.5 m. To investigate changes in swell wave conditions along the Bay shorelines, 67 locations around the Bay were selected for model output for the SWAN wave model.



Source: Lawson & Treloar Pty Ltd 2003, Vol 3

Location of Data Collection Instruments and Extent of Northern Bay Regional Flow Model

Figure 15.1

0 500 2000m

Waverider Buoy

Current Meter

Extent of Northern Bay Regional Flow Model

The SWAN wave model was also used to investigate potential changes in the local sea or wind generated wave conditions within Botany Bay. Wave simulations were undertaken for varying wind speeds from 0 m/s to 25 m/s (in increments of 2.5 m/s) for all directions at increments of 22.5°. For local sea waves, 60 years of Mascot wind data was applied to the SWAN model results.

The MIKE-21 BW model was used to model swell waves propagating into the port area between the Parallel Runway and Molineux Point. The model was set up with a grid size of 4 m for swell waves and operated with a time step of 0.25 seconds. The investigation included modelling of both a rock embankment wall (the preferred design for the new terminal) and a fully reflective vertical wall.

The long wave model set up was also based on the MIKE-21 BW system, but with a 12 m grid size and simulations over 30 minutes to ensure equilibrium was established.

The wave models were calibrated to ensure that the modelling system would accurately reproduce swell and local sea wave conditions in Botany Bay. This was achieved using measured data collected by the Waverider buoys at the locations shown in **Figure 15.1**.

The models were firstly calibrated using data from the Waverider buoys at the Entrance Channel (WRB5), Towra Beach (WRB9), Lady Robinsons Beach (WRB10) and in the middle of the Bay (WRB3) with wave length and period data from Sydney Ports Corporation's offshore Botany Bay Waverider buoy, and wave direction from Manly Hydraulics Laboratory's Long Reef Waverider buoy. The second calibration was undertaken investigating propagation of waves at locations near the Parallel Runway (WRB16) and Molineux Point (MID) and similar offshore data to the first calibration exercise. The outcomes of the calibration analyses for the combined SWAN/MIKE-21 BW modelling system provided a high level of confidence in the modelling results.

Several months of wave data recorded by Sydney Ports Corporation from the Waverider buoy near the Parallel Runway (WRB16) and wind data from the Mascot Airport anemometer were available for calibration of the SWAN wave model for local sea conditions. The modelled and measured wave heights were compared and the agreement was found to be very good.

It is important to note the modelling has been undertaken on a comparative basis. In other words, the model focused on the differences between wave conditions for existing and post-development cases. Therefore, any discrepancy in model performance would be similar for both cases and would not influence the assessment of possible changes due to the proposed Port Botany Expansion.

15.3.2 Modelling of Currents

The potential changes to currents within Botany Bay were examined using numerical modelling methods. Two models were developed: a whole of Bay model and a northern Bay regional model extending north from the line between the Parallel Runway and Molineux Point. Both models were based on the Delft3d modelling system that has been used extensively for major national and international projects.

The whole of Bay model was developed using a grid structure generally consistent with the major tidal flows in the Bay. The model was driven using tides, winds and stormwater inflows into the Bay. However, this model could not resolve the small changes proposed in the Port Botany area therefore the northern Bay regional flow model was applied to the detailed investigation of local issues in the Port Botany area.

Tidal predictions in Botany Bay are generally similar to those in Sydney Harbour and tidal constants at Fort Denison (Sydney Harbour) were used in modelling to predict currents. Wind data was taken from recorded Mascot airport anemometer data, as required. Catchment discharge data, where needed, was prepared using data from hydrological investigations (**Appendix I**).

Calibration of the models was undertaken to provide confidence that the modelling systems can realistically reproduce observed current structure. While it is difficult to reproduce current structure near the entrance to Botany Bay, the outcome of these calibration processes demonstrates that the models provide a generally reliable description of currents within Botany Bay. Similar to the wave modelling, the current modelling was undertaken on a comparative basis and therefore any discrepancy in model performance would be the same for both the existing and post-development cases.

15.4 Assessment of Impacts

Changes to wave climate, currents and sediment transport attributed to the new terminal are likely to be subtle, complex and interrelated. The following post constructional changes to hydrodynamic conditions in Botany Bay have been considered:

- local sea wave conditions throughout Botany Bay, along the Parallel Runway wall, within the northeastern embayment and within Brotherson Dock;
- swell wave conditions throughout Botany Bay, along the Parallel Runway wall, within the northeastern embayment and within Brotherson Dock;
- long waves in Botany Bay, along the Parallel Runway wall, within the northeastern embayment and within Brotherson Dock;
- stability of foreshores in Botany Bay and the northeastern embayment; and
- currents in Botany Bay, along Foreshore Beach and at the Mill Stream outlet.

15.4.1 Wave Conditions

Local Sea Waves

Assessment of local sea waves showed that negligible changes to existing conditions would occur in parts of Botany Bay outside the immediate Port Botany area. The fetch of northerly winds (Port Botany to Kurnell) would be reduced by the new terminal. No change to wave heights would be expected, however, about a one degree westward change in local sea wave direction is predicted at Silver Beach and Towra Beach. This may cause a minor change in erosion and deposition of sand, however, no overall impact on beach stability is predicted as sediment transport resulting from local sea waves is small compared to that caused by swell waves. Additionally, the groynes on Silver Beach would accommodate any change. The net result on Towra Beach would be a marginal reduction in the rate of westward sediment transportation, however, such a reduction would be imperceptible.

A large reduction in wave energy would be expected at the existing mouth of Penrhyn Estuary due to the "blocking effect" of the new terminal. Construction of the new terminal would therefore significantly reduce erosion and transportation of sediment along the southeast portion of Foreshore Beach and the current accumulation of sand in outer Penrhyn Estuary. There would continue to be westward sand transport along the remaining exposed section of Foreshore Beach. However, a groyne to be built as an extension to the Mill Stream training wall would act as a barrier to this transport and prevent sand from accumulating in the Mill Stream. There may be a need to remove sand collected by the groyne every four to five years and replace it near the boat ramp.

The wave height at the proposed new boat ramp area is suitable for a boat ramp.

A reduction in the significant height of local sea waves would be expected along the Parallel Runway due to the shorter fetch created by construction of the new terminal. Local sea conditions would not cause sediment transport along the eastern side of the Parallel Runway due to the depths being too great, therefore changes in wave direction are not an issue. No increase in local sea wave conditions is predicted in Brotherson Dock. Local sea wave conditions at the proposed new berths are predicted to be very mild.

Swell Waves

Possible changes to wave climate due to the new terminal were assessed at 67 locations around the perimeter of Botany Bay. Output from the SWAN model indicated that no changes to swell wave height would occur throughout the Bay. A change in wave direction of less than 0.1° was identified at Towra Beach. However, this change is at the limit of capability of any model to simulate and essentially describes a no-change scenario. This change would not be measurable against the natural regression rate in this area.

Numerical modelling investigated the impact on the Parallel Runway of berth designs using rock revetment or vertical walls. Smaller changes in wave energy were predicted for designs incorporating rock revetments, which is the preferred design for the new terminal. The proposed port development with rock revetment and dredging would marginally reduce wave heights along the eastern side of the Parallel Runway.

Existing wave heights within the Brotherson Dock are low (less than 0.11 m), however the MIKE 21 BW model indicated an increase in wave height due to increased swell wave penetration after construction of the new terminal. The resultant wave heights are still very low therefore the post development swell wave climate would not affect berthed ships or existing port facilities.

Long Waves

Berthed ships are susceptible to movement from long waves and the resultant motion can affect the loading and unloading of vessels. Results of modelling indicate that the long wave climate throughout Botany Bay would not be changed by the proposed development, with the exception of minor amplification and increase in long wave activity within Brotherson Dock. Results of the modelling indicate that although current speeds generated by long waves are predicted to increase by about 10% in Brotherson Dock, they would remain below 2 cm/s. The low predicted velocities would be unlikely to cause significant disturbance to loading/unloading activities of berthed ships.

There would be no change in long wave activity along the Parallel Runway.

Vessel Operations

Waves generated by ships (wake) would not be expected to substantially change the wave climate in Port Botany and would not affect the stability of shorelines and existing structures.

Wake from tug operations would be unlikely to increase the overall wave climate on nearby Foreshore Beach. Similarly, propeller wash from tugs manoeuvring ships would not affect the stability of sediment adjacent to the Parallel Runway. A rock groyne is proposed to protect recreational vessels using the boat ramp from tug propeller wash.

15.4.2 Currents

Reclamation for the new terminal would result in a minimal decrease (~0.7%) in the total tidal prism of Botany Bay. In addition, the new terminal is proposed in the northern embayment of Botany Bay and would not obstruct the predominant tidal flow between the entrance of the Bay and Georges River. Therefore, the direction and speed of tidal currents in Botany Bay would not change significantly as a result of the new terminal. This conclusion is supported by modelling of changes to peak velocities at the southern end of the Parallel Runway that indicate the new terminal would not significantly change current velocities at that location.

Existing tidal current velocities in Port Botany are low (less than 10 cm/s) and a possible slowing of these currents due to changes to the tidal prism would not have an obvious effect on sediment transportation in the port area. There would be virtually no change in current speed or direction and therefore sediment transportation in northeastern Botany Bay, including the Mill Stream outlet, as result of the Port Botany Expansion.

No significant changes to wind generated surface currents from the new terminal would be expected due to the small changes predicted for significant wave heights and directions.

15.4.3 Coastal Processes

Botany Bay

Changes to coastal processes in Botany Bay due to the new terminal would be negligible for the following reasons:

- the change to the tidal prism in Botany Bay is minor (decreased by some 0.7%);
- circulation in Botany Bay would not be obstructed or reduced;
- the reclamation would not impede tidal currents to and from the Georges River;
- modification to water depths in high energy environments (i.e. the entrance to Botany Bay) would not be required; and
- the new terminal would be constructed in a low energy environment sheltered from swell waves by Molineux Point.

Changes to the fetch of local sea waves by construction of the new terminal would result in small changes in wave directions on the southern foreshore of Botany Bay. However, the magnitude of these changes on coastal processes would be small compared to the effects of swell propagating through the entrance to Botany Bay. Changes to coastal processes resulting from the development would be predominantly confined to the northeastern embayment of Botany Bay.

Northeastern Botany Bay

Under existing hydrodynamic conditions, the eastern section of Foreshore Beach is undergoing long term recession and sand is accumulating at the western end of the beach near the Mill Stream outlet. The proposed development would reduce wave energies and hence regression rates at the present mouth of Penrhyn Estuary, but coastal processes at the Mill Stream end of Foreshore Beach would be essentially unchanged.

The Mill Stream presently discharges to northeast Botany Bay through a 40 m wide lined channel between the Parallel Runway and Foreshore Road. Part of the proposed port expansion includes an enhanced beach area to be established within a compartment formed by a southeastward extension of the northeastern Mill Stream training wall and the proposed boat ramp at the western end of the flushing channel from Penrhyn Estuary. The extended Mill Stream training wall provides an expansion of the Mill Stream Entrance, thereby leading to reduced currents in the lower Mill Stream. Assessment of changes to the current structure shows that there is a continuous flow from the combined flows from the Mill Stream and drains on Foreshore Beach. At low tide, water depth in this area is only about 1.4 m and peak current speeds presently reach 0.7 m/s. However, the velocities decrease rapidly with distance from the mouth of the Mill Stream and approximately 300 m from the Mill Stream, adjacent to the Parallel Runway, current velocities are much lower and well below speeds that can cause sediment movement.

The western section of Foreshore Beach (approximately 500 m in length) is to be rehabilitated and maintained between the proposed boat ramp and the proposed extension to the northern wall of the Mill Stream outlet. The local sea wave climate for this region would be very mild, but there would be continuing westward sand transport. A groyne about 25 m in effective length is proposed as part of an extended northern training wall to the Mill Stream. This structure would trap the longshore transport of sediment and prevent its accumulation in the Mill Stream. Hence, there is likely to be a continuing need to undertake beach maintenance by removing sand as it is transported to the groyne and deposit this near the boat ramp every four to five years.

Present accumulation of fine grained sediment in Penrhyn Estuary is low, probably due to a small influx of material from the catchment. In addition, fine grained sediment is presently resuspended by wave action at the mouth of Penrhyn Estuary. Due to the lower energy regime of Penrhyn Estuary following construction of the new terminal, sedimentation in the larger confined area of the Estuary would occur during low-flow conditions.

Catchment modelling indicates that during high rainfall events, peak flow into Penrhyn Estuary from Springvale and Floodvale Drains would exceed 30 m^3/s. The resultant peak flow velocities near the constriction in Penrhyn Estuary are predicted to reach 0.26 m/s (5 years ARI) (refer to Location C in **Figure 16.2**) which is similar to the present modelled velocity of 0.30 m/s. The peak flow velocities during some high rainfall events may be sufficient to scour and redistribute fine grained sediment from the upper reaches of Penrhyn Estuary during storm events. An increased velocity at the eastern end of the new channel (refer to Location D in **Figure 16.2**) is predicted, but the velocities remain low (less than 0.12 m/s).

Intertidal sand flats in Penrhyn Estuary would be created as part of the habitat enhancement for migratory birds. During a fresh water flood, notably at tides above mean sea level, there is likely to be some flow outside the formed flow path through the Estuary that may result in creation of additional channel(s). The result would be some redistribution of sediment and “wandering” of the channel(s) within Penrhyn Estuary.

15.5 Mitigation Measures

The results of the modelling show that the effects of the proposed Port Botany Expansion on the hydrodynamics and coastal processes within Botany Bay are essentially unchanged. Therefore, no specific mitigation measures are proposed. However, the following provides a summary of the design features which were incorporated into the Port Botany Expansion to minimise potential impacts on the hydrodynamics and coastal processes of the Bay. These include:

- sloping rock revetment design for the new terminal to minimise reflection and propagation of waves;
- alignment of the dredging profile to minimise potential increases in swell waves along the Parallel Runway and throughout the Bay;
- construction of a wide (130 m) channel to ensure adequate flushing of Penrhyn Estuary; and
- provision of a rock groyne at the northwestern end of Foreshore Beach to reduce sediment accumulating in the mouth of the Mill Stream.

The hydrodynamic modelling undertaken has been calibrated and verified against recorded measurements in Botany Bay. As such, there is a high level of confidence in the results and predicted impacts from the modelling. Nevertheless, it is recognised that even the most advanced models remain approximations of reality. Consequently, a monitoring programme would be undertaken by Sydney Ports Corporation to measure and compare tidal current flows and beach processes against predicted impacts of the proposal. The monitoring programme would include:

- continuous recording of wind and wave climate in Botany Bay and offshore;
- beach profiling or aerial photographic record/photogrammetric analysis of Silver Beach, Towra Beach, Spit Island, Lady Robinsons Beach and Foreshore Beach to assess and quantify any significant changes in sandy beaches and nearshore shoals; and
- ongoing assessment of the need for removal of accumulated sand at the groyne and any replenishment required at the new boat ramp.

15.6 Conclusion

Results of numerical modelling indicate that currents in Botany Bay would be essentially unchanged as a result of the dredging, reclamation and construction of the new terminal.

Swell waves penetrating the Botany Bay entrance and local sea waves are the predominant waves affecting sediment transport and shoreline stability in Botany Bay. The swell wave climate in Botany Bay would be effectively unchanged as a result of the construction of the new terminal. Potential changes to swell wave energy, notably along the Parallel Runway, have been minimised by careful design of the dredge area and hard surfaces of the new terminal.

Assessment of local sea waves showed that negligible changes to existing conditions would occur in parts of Botany Bay outside the immediate Port Botany area. Any change in longshore transportation rates on the southern shoreline of Botany Bay would be imperceptible. Minor changes to the long wave climate would not be expected to affect sediment transport along the Parallel Runway. The minor changes predicted to the wave climate in northeastern Botany Bay would not have an adverse effect on ships berthed at the proposed or existing terminals.

Construction of the new terminal would likely increase accumulation of fine grained sediment in Penrhyn Estuary. However, the influx of fine grained sediment from the catchment would be low. Sediment would continue to accumulate near the Mill Stream outlet, but a groyne would be constructed to capture the sand and prevent it from entering the Mill Stream.

Summary of key outcomes:

Hydrologic modelling (to determine surface water flow rates under design rainfall conditions) and hydraulic modelling (to determine the flood water levels) before and after the proposed development showed that the proposed Port Botany Expansion would not have an adverse impact on local flood behaviour in the catchments surrounding Port Botany or cause an increase in flood levels within Penrhyn Estuary. A minor impact of 0.02 m would occur in the Floodvale Drain catchment during extremely rare events (i.e. the Probable Maximum Flood (PMF)) however, this change is at the limit of the model's predictive capability. There would also be a minor increase in water level near the outlets of the two eastern most beach drains during the PMF, of the order of 0.06 - 0.12 m.

The proposed Port Botany Expansion would not affect the quality of water draining from the catchments surrounding Port Botany. Current catchment runoff has high levels of nutrients and low dissolved oxygen.

The partial enclosure of Penrhyn Estuary resulting from the reclamation for the new terminal would affect the transport and dispersion of water contaminants and suspended solids in Penrhyn Estuary and would likely result in increased siltation rates and nutrient and faecal coliform concentrations as well as slight changes in temperatures and dissolved oxygen concentrations.

Modelling under ambient conditions (i.e. typical dry weather conditions) showed that the increased concentrations of nutrients and faecal coliforms in the Estuary would not exceed the Australian and New Zealand Environment and Conservation Council (ANZECC) (2000) water quality guideline values. Under transient conditions (i.e. short duration wet weather events), increases in peak nutrient and faecal coliform concentrations would occur but these exceedences would be of short duration. Faecal coliform concentrations at the location of the proposed boat ramp and enhanced beach at the northwest end of Foreshore Beach, however, would be reduced under transient and ambient conditions.

The sediment and suspended solid load (and hence nutrient load) of the stormwater entering Penrhyn Estuary from the catchments could be minimised through the installation of stormwater quality improvement devices at the outlets of Springvale and Floodvale Drains. However, the installation of these devices would be subject to detailed studies of their impact on upstream flooding.

The proposed Port Botany Expansion would not incorporate any elements that would impede the natural flow regimes of existing stormwater channels which discharge to Botany Bay. The new terminal's stormwater management system would minimise contaminated runoff discharging into Botany Bay through a first flush capture and treatment system and would provide for reuse of treated stormwater runoff from the terminal for washdown and irrigation purposes.

16.1 Introduction

This chapter presents the findings of the following assessments conducted as part of this EIS:

- *Hydrologic and Hydraulic Studies*, by Lawson and Treloar (**Appendix I**);
- *Water Quality Investigations*, by Lawson and Treloar (**Appendix J**); and
- *Terminal Stormwater Management System, Port Botany Expansion* by Arup (**Appendix K**).

The Lawson and Treloar studies describe the local catchment hydrology and water quality and assess the potential impacts of the proposed Port Botany Expansion on surface water flow and quality. The Arup study describes the proposed terminal stormwater management system.

16.2 Methodology

16.2.1 Catchment Hydrology and Hydraulics

The assessment of catchment hydrology and hydraulics focused on the four catchments draining to the northeastern portion of Botany Bay, between Sydney Airport and the existing port (see **Figure 16.1**). An understanding of the existing flows and flood levels of the catchments, and any changes to flood levels associated with the proposed development, was obtained by numerical modelling for various design storm events.

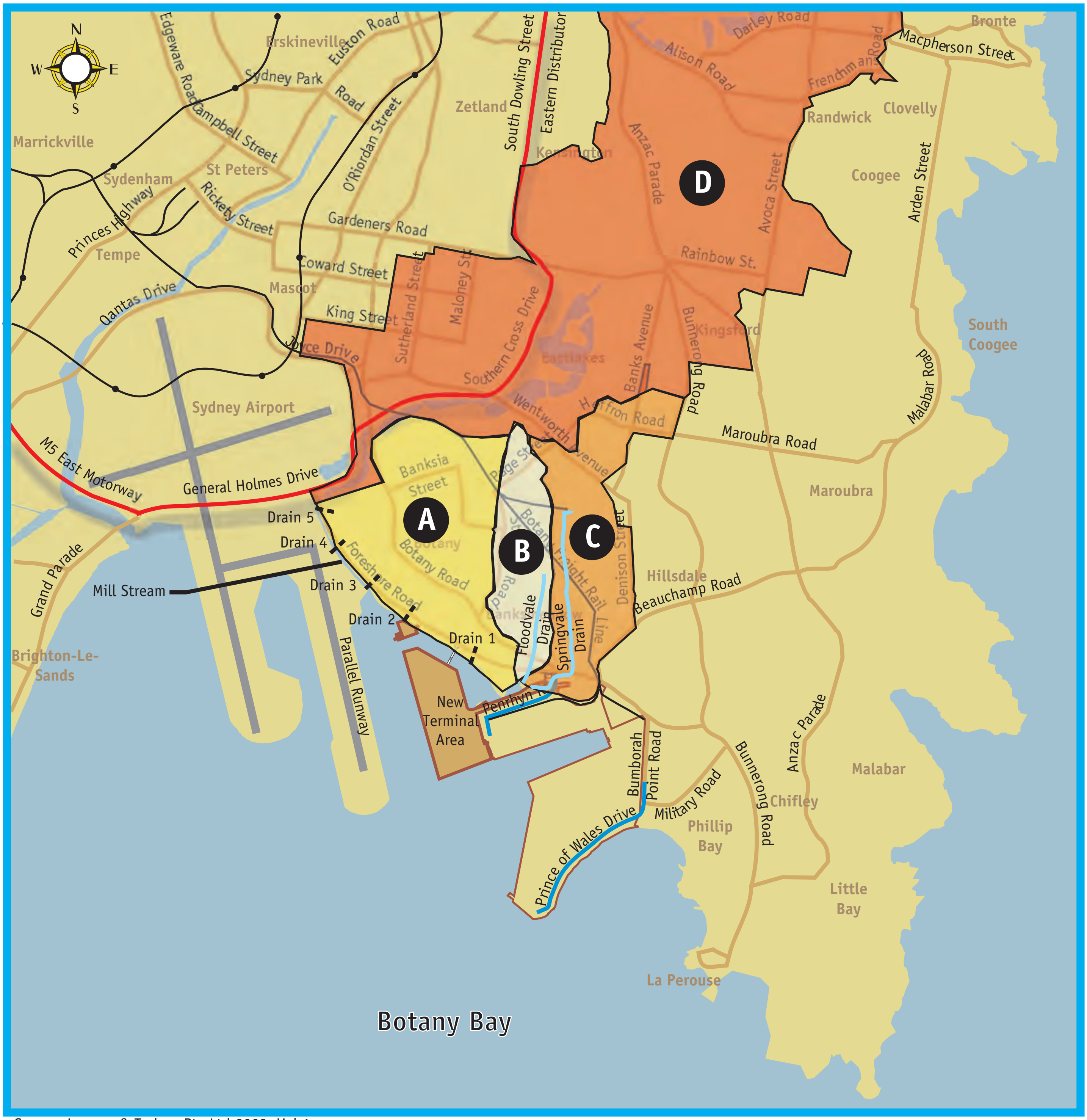
A hydrologic model was used to produce surface runoff hydrographs for the 200 year, 100 year, 20 year and 5 year Average Recurrence Interval (ARI) rainfall events, using design rainfall inputs, catchment topography and land use characteristics. A Probable Maximum Flood (PMF) hydrograph was also generated. A historical storm event and previous studies were used to validate the model.

The surface runoff hydrographs were used as inputs to a hydraulic model for the estimation of the levels of various design floods. Both low and high tailwater conditions in the Bay were considered. The model was used to identify any changes in flood levels following the proposed expansion. The model was validated by comparison with a historical storm event.

16.2.2 Water Quality

The assessment of surface water quality also focused on the four catchments draining to the northeastern portion of Botany Bay. Surface water quality was assessed by using the findings of previous water quality investigations in the catchment and Botany Bay, supplemented by additional field data, to develop a catchment water quality model.

The catchment water quality modelling tool MUSIC (Model for Urban Stormwater Improvement Conceptualisation) was used to develop a catchment water quality model. Output from this model was used as input to the numerical hydrodynamic modelling of the transport and dispersion of contaminants in Penrhyn Estuary and Botany Bay to establish the baseline and assess post-development water quality in the Bay.



Source: Lawson & Treloar Pty Ltd 2003, Vol 1

0 0.5km 2.5km

Catchments Draining to Northeastern Botany Bay

Figure 16.1

- A — Foreshore Beach Catchment
- B — Floodvale Catchment
- C — Springvale Catchment
- D — Mill Pond Catchment
- Pipe Drainage Discharge Locations
- Channel Drains

Note; Mill Pond Catchment Extends Beyond Boundary of this Map

For the purpose of assessing water quality data and modelling results, the ANZECC (2000) water quality guidelines were adopted. It should be noted that the ANZECC guideline (trigger) values are for “ambient” water quality (i.e. associated with day to day low flows in dry weather) and do not apply to “transient” water quality (i.e. associated with short duration, wet weather events). They have been derived to apply to the ambient waters that receive stormwater discharges and not the stormwater discharge itself. For northeastern Botany Bay, the marine guidelines were adopted because there are no guidelines for estuarine systems.

The ANZECC guideline values used in the assessment are guidelines for “slightly to moderately” disturbed systems. The northeastern shores of Botany Bay could be characterised as a “highly disturbed system” and therefore the values adopted, which were for “slightly to moderately” disturbed systems, are conservative.

Where no specific Australian guideline was available, other documents were consulted for guideline values.

16.2.3 Site Stormwater Management

An integrated approach to stormwater management was taken in the design of the terminal stormwater system. The objective of the system is to minimise the impacts of the proposed development on the existing environment, particularly the receiving waters of Penrhyn Estuary and Botany Bay, by collecting and treating stormwater runoff.

16.3 Existing Environment

16.3.1 Catchment Overview

Approximately 86% of the Botany Bay catchment area is drained by the Georges and Woronora Rivers, about 9% by the Cooks River, and the remaining area by other watercourses, including the Mill Stream and Springvale and Floodvale Drains.

The environmental assessment focuses on the four catchments that drain to the vicinity of the proposed development between the existing port and airport. These catchments and their areas are as follows:

- Mill Pond – 1,773 ha;
- Springvale – 241 ha;
- Floodvale – 118 ha; and
- Foreshore Beach – 339 ha.

The four catchments cover an area of 24.7 km^2 and extend over parts or all of the suburbs of Botany, Mascot, Banksmeadow, Daceyville, Eastlakes, Pagewood, Maroubra Junction, Kingsford, Randwick, Kensington, Bondi Junction, Waverley, Paddington and Centennial Park. These catchments are the major sources of stormwater and pollutants that impact on the water quality of Botany Bay in the vicinity of the proposed Port Botany Expansion.

The catchment boundaries are shown in **Figure 16.1**.

Mill Pond Catchment

The Mill Pond catchment includes Centennial Park in its upper portions to the north and the Botany Wetlands to the south. The ponds at Centennial Park are connected to the Botany Wetlands by a stormwater system. These discharge to the Mill Stream, which discharges to Botany Bay adjacent to the Parallel Runway.

The natural landform of the Mill Pond catchment comprises rounded sand dunes and expanses of gentle slopes with local depressions and exposed water tables. The Botany Sands, which is the predominant soil type in this catchment, provides an extensive generally shallow aquifer that is closely linked to surface water features and has a high infiltration capacity.

The Mill Stream is a highly modified system which was diverted as part of the construction of the Parallel Runway. The channel is approximately 2 m deep with vertical walls and a flat bed. The system is tidally influenced up to a weir at Foreshore Road. It has a number of stormwater outlets conveying runoff from Sydney Airport hard stand areas. Sand has accumulated in the Mill Stream outlet to Botany Bay.

Springvale and Floodvale Drain Catchments

The Springvale and Floodvale Drain catchments discharge stormwater to Botany Bay via Penrhyn Estuary. The northern part of the Springvale and Floodvale Drain catchments is mainly residential with some large open space areas. The southern part is mainly industrial, including petroleum industries, food processing plants, chemical industries, shipping container yards and light industry.

There are significant open areas in the vicinity of Floodvale and Springvale Drains between the Botany Freight Rail Line and Macpherson Street. These are low-lying wetlands that act as storage for overflows from trunk stormwater drains. Except for the wetland areas, the soils in the Springvale and Floodvale Drain catchments are Botany Sands.

Floodvale Drain is some 2.9 km in length, with about 2.1 km consisting of closed conduit and 0.8 km open channel. Springvale Drain is about 3.9 km in length, with about 2.5 km closed conduit and 1.4 km open channel.

Foreshore Beach Catchment

The Foreshore Beach catchment is mainly residential and industrial, with an open space area between Foreshore Road and Botany Road. There are eight pipe culverts discharging into the Bay at five locations between Penrhyn Estuary and the Mill Stream outlet. Currently these pipes are partially obstructed by sand.

Foreshore Road, the main access to Port Botany, is a 3 km arterial road comprising dual carriageways separated by a wide median strip. It was constructed in the late 1970's on land reclaimed from the Bay utilising dredged sand. On the road's foreshore side, stormwater runs off the road into the adjacent sand dunes where it either percolates into the ground or, during heavy rainfall events, flows overland into the Bay which is only about 50 m away from the road. There is no kerb and guttering on either side of the road.

16.3.2 Sources of Stormwater Contamination

The major sources of potentially contaminated stormwater discharge in this part of Botany Bay include:

- EPA Licensed Premises – There are about 50 premises within the four catchments licensed by the EPA under the load-based licensing regulations. These premises may generate contaminated runoff which could enter the stormwater system that discharges to Botany Bay.
- Sydney Airport – Runoff from the airport discharges via a number of systems to Botany Bay, the Mill Stream and Cooks River.
- Port Botany – Runoff from the port areas discharges via a number of systems, generally to Brotherson Dock, with some portions discharging to Springvale Drain.
- SWSOOS – The South and Western Suburbs Ocean Outfall Sewer (SWSOOS) is an asset managed by Sydney Water Corporation. It crosses the Mill Stream upstream of Foreshore Road and is prone to overflowing into the Mill Stream in both dry and wet weather.
- Shallow groundwater contamination – Historical contamination of shallow groundwater from some industrial facilities may be discharging to the stormwater drainage system of the area.
- General contamination due to urban runoff.

16.3.3 Surface Water Quality

Existing water quality was reviewed as part of the water quality study contained in **Appendix J**. These datasets indicate that input waters (i.e. water draining from the catchments) had high levels of nutrients and low dissolved oxygen (DO). These input waters were significantly diluted by the receiving waters of Penrhyn Estuary and Botany Bay. Total Petroleum Hydrocarbon (TPH) levels were well above ANZECC guidelines and the limited data on metals suggests that Cadmium, Copper, Iron, Lead, Mercury, and Zinc can also greatly exceed ANZECC guidelines.

Water quality data shows that Penrhyn Estuary has high levels of nutrients, Biological Oxygen Demand (BOD) and TPH but acceptable levels of DO. Limited data on metals indicate that Aluminium, Cadmium, Copper, Lead, Manganese and Zinc can greatly exceed ANZECC guidelines.

Faecal coliform (Fc) levels in the catchments, Mill Stream, Penrhyn Estuary and Botany Bay receiving waters are highly elevated.

Fc concentration data for Foreshore Beach from the NSW EPA Harbourwatch sampling program (covering the period January 1995 to June 2002) shows that the probability of exceedance of the ANZECC (2000) guideline value for primary contact recreation (i.e. swimming) of 150 cfu/100 mL is 20%, i.e. approximately 20% of the time the waters are unsuitable for primary contact recreational use. Considerable non-compliance was observed during wet weather periods. Reasons for this non-compliance are related at least in part to the SWSOOS which crosses the Mill Stream upstream of Foreshore Road and is prone to overflowing into the Mill Stream in both dry and wet weather.

Data on nutrient concentrations for Botany Bay in the vicinity of Foreshore Beach shows that Total Nitrogen (TN) levels do not exceed ANZECC (2000) guideline values, while Total Phosphorous (TP) may be slightly exceeded.

16.4 Assessment of Impacts During Construction

16.4.1 Surface Water Flow and Levels

The major potential impacts during construction of the proposed Port Botany Expansion on surface water flow and discharge regimes relate to the following:

- dredging and reclamation works potentially impeding tidal flushing of Penrhyn Estuary; and
- construction activity along the foreshore potentially causing siltation, constriction or blockages to the existing drains in this area.

Tidal flushing of Penrhyn Estuary would be maintained throughout construction of the Port Botany Expansion via a channel at least 130m wide between Foreshore Beach and the area to be reclaimed for the new terminal.

With the use of appropriate construction methodologies and environmental safeguards, it is anticipated that construction activity would not cause blockages to water flow through Springvale and Floodvale Drains and the Mill Stream. Therefore, there would be no impact on water flows or levels in the Drains or the Mill Stream due to the construction. The Foreshore Beach drains would be preserved to allow continuation of stormwater discharge from the Foreshore Beach catchment. Should any redirection or lengthening of these pipes be required, a detailed drainage analysis would be required to identify any impacts on stormwater conveyance.

Other construction areas, such as equipment depots and laydown areas, would not be expected to pose any direct impact on surface flow and discharge.

16.4.2 Surface Water Quality

Dredging and Reclamation

The major potential impacts during construction on surface water quality relate to turbidity during the dredging operations.

Dredging operations would relocate some 7.5 million m^3 of sediment from the bed of Botany Bay, southeast of the Mill Stream outlet and east of the Parallel Runway. Hydraulic dredging (e.g. a large cutter suction dredge) would be used as this type of equipment generally produces less turbidity than mechanical dredging. Sediment would be pumped directly to the reclamation site and allowed to settle behind rock berms to form the new container terminal. Some fine-grained dredged material may be stockpiled separately for use in the Penrhyn Estuary habitat enhancement works.

Negligible turbidity would be generated at the cutter head of the dredge. However, discharge of the pumped material would create turbidity at the discharge point during dredging operations. Currents, density differences, turbulence and bathymetry would influence the dispersion of sediment plumes generated by dredging.

Turbidity during dredging operations for the Parallel Runway was low, probably due to the relatively high mean sediment grain size of the dredged material. Previous analyses of seabed sediments in the proposed dredging areas for the Port Botany Expansion have shown that the material to be dredged would be similar to the material dredged for the Parallel Runway. Therefore, it is anticipated that turbidity associated with dredging operations for this proposal would also be low.

Lawson and Treloar used a five layer model to assess the sediment plume created by dredging. The model assumes that dredged spoil would be discharged just below the water surface to form the mound that would become the new terminal. This scenario is a potential worst case condition and the results showed that without a silt curtain, a plume defined by 20 mg/L suspended sediment concentration would occupy the area between the Parallel Runway and Molineux Point. Turbidity concentrations would increase inwards to the dredging deposition point. Concentrations exceeding 20 mg/L may generate a visible plume in surface waters. Therefore, a silt curtain of appropriate pore size would be deployed around the dredge discharge area to reduce turbidity, as discussed in Section 16.8. This silt curtain would be limited in size as it would be placed around the location of the discharge pipe.

The control of turbidity would protect the seagrass communities outside the footprint of the proposed development, particularly east of the Mill Stream channel and on the shallow terrace adjacent to the Parallel Runway. The latter could be used to transplant some seagrasses during construction. The management of impacts to seagrasses by the proposed development are discussed in **Chapter 19** *Aquatic Ecology*.

During the advanced stage of reclamation, the discharge of dredged sediments would take place above water and be contained within bunding and terraced rock berms, allowing significant settlement of fines before the water is returned to the Bay. Simulation by numerical modelling showed that apart from the immediate vicinity of the discharge, surface concentrations would not exceed 5 mg/L. This level of turbidity would not be readily perceived.

Initial consolidation of material in the reclaimed area is expected to take up to two years. During this time the surface of the reclamation, if not protected, may be subject to erosion. To control erosion, the surface of the newly reclaimed area would be stabilised and profiled to form sediment detention basins to contain sediment runoff until the reclaimed area is covered with an impervious surface. These control measures would be documented as part of the Construction EMP for the project.

Erosion and Sedimentation

Dredged or construction material stockpiles and active construction areas may be subject to erosion and sedimentation from surface runoff. Erosion and sedimentation control measures would be implemented for these stockpiles and work areas to minimise sediment load on surface runoff, as discussed in Section 16.8.1.

Spills and Leaks

There is a potential for spills and leaks from plant and equipment and onsite fuel storage during construction. Some onsite storage of fuel in aboveground fuel storage tanks may be required for onsite refueling during construction. Control measures to minimise the potential for and to mitigate the impacts of spills and leaks are discussed in Section 16.8.1.

16.5 Assessment of Impacts During Operation

16.5.1 Surface Water Flow and Levels

The main impact to catchment surface water flow anticipated from the new terminal relates to the potential of the development to pose an impediment to catchment discharges entering Botany Bay. This impact was assessed using hydrologic and hydraulic modelling of the existing environment and post-development scenario to determine discharge rates and water levels during various storm events.

A comparison of the modelling results for the existing and post-development cases shows that:

- for flood events up to the 200 year ARI event, the proposed Port Botany Expansion would not have any adverse impact on local catchment flood behaviour. A minor impact (0.02 m) would occur in the Floodvale Drain catchment during extremely rare events, i.e. the PMF. This is at the limit of the model's ability to predict change;
- the proposed development would not cause an increase in flood levels within Penrhyn Estuary for the full range of flood events;
- for events up to the 200 year ARI event, there would be no impact on the Foreshore Beach catchments drained by the pipe culverts under Foreshore Road. During the PMF, there would be a minor increase in Bay water level near the outlets of the two eastern most beach drains of the order of 0.06 – 0.12 m;
- the proposed railway bridge and road bridge would not impact upon water levels if the total channel flow area under these bridges is maintained as per design;
- the proposed habitat enhancement works in Penrhyn Estuary would not reduce flow conveyance in the area; and
- there would be no impact on water levels within the Mill Stream for the full range of flood events.

It should be noted that the new terminal would not impact on the existing ratio of the catchment pervious/impervious surfaces, and therefore on the runoff infiltration rates, except for the construction of the boat ramp and relatively minor road and rail works near Foreshore Road. Therefore, the proposed development would not change the stormwater flows from the catchment.

16.5.2 Surface Water Quality

Catchment Water Quality Modelling

The catchment water quality model (MUSIC) was established using meteorological, topographic and water quality data and was used to calculate the load of three pollutants: Total Suspended Solids (TSS), Total Phosphorous (TP) and Total Nitrogen (TN). Rainfall data and details about other model parameters, calibration and verification are presented in **Appendix J**.

The model was run under existing conditions to establish a baseline for the purpose of comparison with conditions resulting from the proposed port layout. The modelling results for the existing conditions, which represent stormwater quality at catchment discharge points modelled using hour steps, are shown as water quality time series for TSS, TP and TN concentrations in **Appendix J**. The results are summarised in **Table 16.1**.

Table 16.1 Modelling Results under Existing Conditions

CATCHMENT	TOTAL RUNOFF		TOTAL SILT LOAD		TP		TN	
	mm	C*	mg/L**	Tonnes	mg/L**	Tonnes	mg/L**	Tonnes
Mill Stream	660	0.51	8.15	98.3	0.07	0.8	0.57	17.1
Springvale	849	0.65	18.3	82.1	0.14	0.5	1.84	4.1
Floodvale	1,030	0.79	18.7	48.7	0.14	0.3	1.84	2.5
Drain 1	836	0.64	16.7	27.5	0.13	0.2	1.82	1.4
Drain 2	974	0.75	17.2	36.8	0.13	0.2	1.82	1.7
Drains 3 & 4	1,015	0.78	17.3	42.1	0.13	0.2	1.82	1.9
Drain 5	1,004	0.77	17.4	43.0	0.13	0.2	1.82	1.9

Note: ANZECC (2000) guideline values for the catchments: TP = 0.05 mg/L; TN = 0.5 mg/L

- *Refers to volumetric runoff coefficient*
- *** Refers to the average concentration over the entire year. Simulation period was from 01/07/1998 to 31/01/2000. The MUSIC model results shown are for the 1999 calendar year.*

The modelled concentrations under existing conditions for TP ranges from a minimum of 0.06 to a maximum of 0.53 mg/L, and TN concentrations range from a minimum of 0.51 to a maximum of 3.89 mg/L. These results indicate that nutrients at the catchment outlets can be elevated compared to the ANZECC freshwater lowland river systems guideline values of 0.05 mg/L and 0.5 mg/L for TP and TN respectively.

The results of the catchment modelling as shown in **Table 16.1** indicate that on average the annual silt load delivered to the northeastern part of Botany Bay would be in the order of 378 tonnes. This is likely to be a conservative estimate as the modelling assumes an unlimited supply of material available to be washed from the catchment. However, the estimate provides a rational basis for comparing the existing and post-development cases.

The proposed development would not change pollutant concentrations from the catchment therefore the above concentrations of inflowing nutrients and sediment would be unchanged.

Estuary and Beach Water Quality Modelling

The construction of the proposed Port Botany Expansion would partly enclose the existing Penrhyn Estuary, thereby reducing the present levels of flushing. It is anticipated that this would impact on the transport and dispersion of contaminants and suspended solids in Penrhyn Estuary. These processes were investigated through a numerical hydrodynamic model using the results derived from the catchment modelling as input for water quality at each catchment discharge point.

Both 'Transient' and 'Ambient' impacts were considered for the existing and developed cases. Transient impacts are defined as those observed during wet weather events which are short in duration, however, stormwater runoff can have significant impacts. Ambient impacts are defined as those observed during the day to day delivery of low flows from the catchment in dry weather.

Estuarine modelling was based on the assumption that the catchment freshwater flows and contaminant loads would be the same for both the existing and developed cases as the Port Expansion will not impact on catchment stormwater quality.

Transient Impact Nutrient Modelling

A wet weather event was simulated, using the discharge and concentration time series from the catchment water quality model and applying the natural phasing of tides. The modelling approach adopted allows an assessment of the relative impact of the port expansion. The results for TN and TP in terms of peak event concentrations for the locations illustrated in **Figure 16.2** are presented in **Table 16.2**.

Table 16.2 Concentrations of TN and TP – Transient Case, Surface Layer

LOCATION	TN CONCENTRATION (mg/L)		TP CONCENTRATION (mg/L)	
	Existing	Developed	Existing	Developed
A	0.08	0.02	0.01	<0.01
B	0.62	2.32	0.09	0.34
C	2.25	2.40	0.33	0.36
D	0.35	2.05	0.04	0.30
E	1.00	0.50	0.12	0.06
G	0.81	1.24	0.10	0.16

In the developed case, TN and TP concentrations would increase in the region of Locations B, D and G. There would also be a marginal increase at Location C that would not be identifiable. Concentrations would decrease at Locations A and E due to increased water depth which would lead to greater dilution. There would be no changes beyond Location A.

The modelling results also indicate that the nutrient concentrations would remain at higher concentrations for a longer period of time, however, these elevated levels would still be short term and occur immediately after rain events.

It is not appropriate to compare transient concentrations with ANZECC (2000) guidelines as the guidelines are only applicable to ambient conditions.

Ambient Impact Nutrient Modelling

Ambient levels of TN and TP at selected locations were assessed by modelling using a constant discharge of TN and TP into the Estuary from the catchment. Two approaches were considered:

- use of total annual load, including wet weather events, therefore producing a more conservative result; and
- use of an annual dry weather load only, which is more characteristic of all ambient periods.

Source: Lawson & Treloar Pty Ltd 2003, Vol 2

Water Quality Model Output Locations **Figure 16.2**

0 500m

3D Model Output Locations

G41, 195 Model Grid Coordinates

The typical annual discharges and average concentrations of TN and TP for input into the modelling were developed from the results of catchment water quality modelling (refer to **Table 16.1**). For annual dry weather loads, the contribution of wet weather events was excluded. This is a more appropriate assessment of ambient conditions and the results of this assessment are given in **Table 16.3**.

Table 16.3 Median Concentrations of TN and TP – Ambient Case, Surface Layer Dry Weather Load

LOCATION	TN CONCENTRATION *(mg/L)*		TP CONCENTRATION *(mg/L)*	
	Existing	Developed	Existing	Developed
A	0.06	0.06	0.008	0.008
B	0.057	0.15	0.006	0.015
C	0.10	0.17	0.013	0.021
D	0.04	0.12	0.005	0.014
E	0.07	0.06	0.008	0.007
G	0.10	0.09	0.011	0.010

ANZECC (2000) guideline values applied for Botany Bay and Penrhyn Estuary: TN = 0.3 mg/L; TP = 0.03 mg/L

The results indicate that there would be:

- no increase in nutrient concentrations beyond the proposed port development area (Location A) (**Table** 16.3);
- increases in concentrations at Locations B, C and D within Penrhyn Estuary due to reduced estuarine flushing; and
- a marginal reduction at Locations E and G due to changes in the flow structure.

The results for pre and post port development for the dry weather loads at all locations do not exceed the ANZECC (2000) water quality guidelines.

Siltation and Turbidity

Modelling of the suspended sediment surface-plumes for a storm event under existing conditions (no development) shows that peak suspended solids concentrations would be in the order of 50 mg/L within Penrhyn Estuary, rapidly reducing to zero at the model boundary. Following construction, the plume would have higher concentrations but would be confined to the northwest Penrhyn Estuary waterway. However, these higher concentrations would not persist for longer than about four hours.

Siltation rate modelling under ambient conditions (which conservatively included both wet and dry period annual loads) showed that the maximum siltation depths, including initial deposition and resuspension, would be in the order of 2.6 cm/annum within a very localised portion of the inner Penrhyn Estuary for both existing and developed cases. The fine silt discharged from the Foreshore Beach drains would be dispersed and no siltation would be expected to occur at the shorelines.

In the existing case, the local sea environment works to disperse the fine sediments deposited in Penrhyn Estuary. Following the development of the new terminal, Penrhyn Estuary would be protected from the local sea, resulting in less resuspension of fine sediments. Therefore, the proposed port development would likely increase sediment accumulation in Penrhyn Estuary. However, the rate of accumulation would be low and would depend on sources within the catchment.

Temperature Dynamics

Seawater temperatures in the Sydney region may reach 22–24°C during the summer months. Modelling showed that there would be a very minor temperature increase of about 0.3° C within Penrhyn Estuary mainly because the average water depths would reduce due to the proposed creation of intertidal flats as part of the enhancement of the Estuary as an ecological habitat. Temperatures would reduce at three other locations (Locations A, E and G), mainly because water depths there would be slightly deeper. These temperature changes are considered to be negligible.

Faecal Coliform – Transient Case

Modelling of the existing and developed cases for a wet weather event shows that peak Fc concentrations for the post-development case would generally increase within Penrhyn Estuary (Locations B, C, D and E) (**Table 16.4**). The highest concentrations would occur at Location C, closest to the Springvale and Floodvale Drains, as the development of new intertidal flats would reduce the volume available for initial dilution of flows from the Springvale and Floodvale Drains. Peak Fc concentrations would, however, be reduced at Location G, which is significant, as this would be the site for the future boat ramp. Peak concentrations would also reduce at Location A which is representative of change to the Bay beyond the expansion.

Table 16.4 Peak Faecal Coliform Concentrations - Transient Case (cfu/100mL)

	LOCATION					
	A	B	C	D	E	G
Existing	160	1,250	5,700	360	520	1,100
Developed	20	8,000	10,700	4,600	1,000	900

Any potential risk to human health due to the increased Fc concentrations in the Estuary and channel would be minimised as primary and secondary contact recreation in these areas would be prohibited.

Faecal Coliform – Ambient Case

Simulations to investigate the effect of reduced flushing within Penrhyn Estuary on Fc concentrations during low runoff conditions showed that median Fc concentrations at Locations B, C and D would generally increase but would remain much less than the 150 cfu/100 ml ANZECC (2000) guideline value for primary contact recreation (**Table 16.5**). Peak concentrations would decrease at Locations E and G, and at Location A which is representative of changes to the Bay beyond the expansion.

Table 16.5 Median Faecal Coliform Concentrations – Ambient Case (cfu/100 mL)

	LOCATION					
	A	B	C	D	E	G
Existing	1	5	20	4	12	20
Developed	0	65	90	37	8	15

Note: Modelling assumed that initial Fc concentration in Botany Bay was zero.

Oxygen Processes

Simulations of DO concentrations in Penrhyn Estuary for the pre- and post-development cases showed that:

- there would be small reductions in the average DO concentration following the proposed port expansion;
- DO concentrations would not approach 4 mg/L, the level below which marine organisms are likely to become seriously affected, though not killed;
- there would be a smaller range of DO concentrations within Penrhyn Estuary following the proposed port expansion, mainly due to a change in the tidal regime.

The proposed development would not have an adverse impact on the DO concentration within Penrhyn Estuary or Botany Bay.

16.6 Stormwater Management at the New Terminal

The site stormwater management system would address the collection and disposal of stormwater runoff and water quality impacts of the proposed development on the existing environment, particularly the receiving waters of Botany Bay and Penrhyn Estuary.

The concept design of the stormwater management system proposed for the new terminal is described in detail in *Terminal Stormwater Management System, Port Botany Expansion* by Arup (2003) (**Appendix K**) and summarised in this section.

16.6.1 Stormwater Volumes

The runoff coefficient for the proposed development would be close to 1.0 as most of the new surface would be paved. It is estimated that peak discharges from high intensity short duration (5 minute) storms would be in the order of 35 m^3/s for a 20-year ARI storm to 45 m^3/s for a 50-year ARI storm, with intensities of about 210 mm/hr and 269 mm/hr respectively.

16.6.2 Stormwater Quality

During most storms the initial runoff dislodges and transports deposited pollutants from paved surfaces. This initial runoff, called first flush, can be expected to pick up heavy metals (zinc, cadmium, and iron), rubber, combustion products, greases, dust and grit that settle on surfaces as a result of normal operations of plant and equipment and wind-borne deposits from external sources. The site itself would be almost completely paved so that generation of dust and grit can be expected to be very low. The levels of pollutants would depend on how well plant and equipment is maintained and on the level of operation. In addition, higher levels of pollutants could accumulate due to long periods between rain events. It is expected that concentrations of hydrocarbons would be 0.1 to 3.0 mg/L and concentrations of suspended solids would be between 5 and 100 mg/L in the first flush.

A discharge of contaminated water offsite could also result from incidents during operations at the new terminal, including:

- chemical spills (from damage to containers or loss of containment);
- fuel or oil leaks or spills from port equipment;
- spill or leak from onsite diesel aboveground storage tank; and
- firewater runoff.

16.6.3 Stormwater Management Process

The stormwater management process would consist of four steps:

- collection of first flush water and spills;
- testing and treatment of potentially contaminated water;
- reuse of clean water for irrigation/washdown purposes; and
- appropriate disposal of excess clean water and contaminated water.

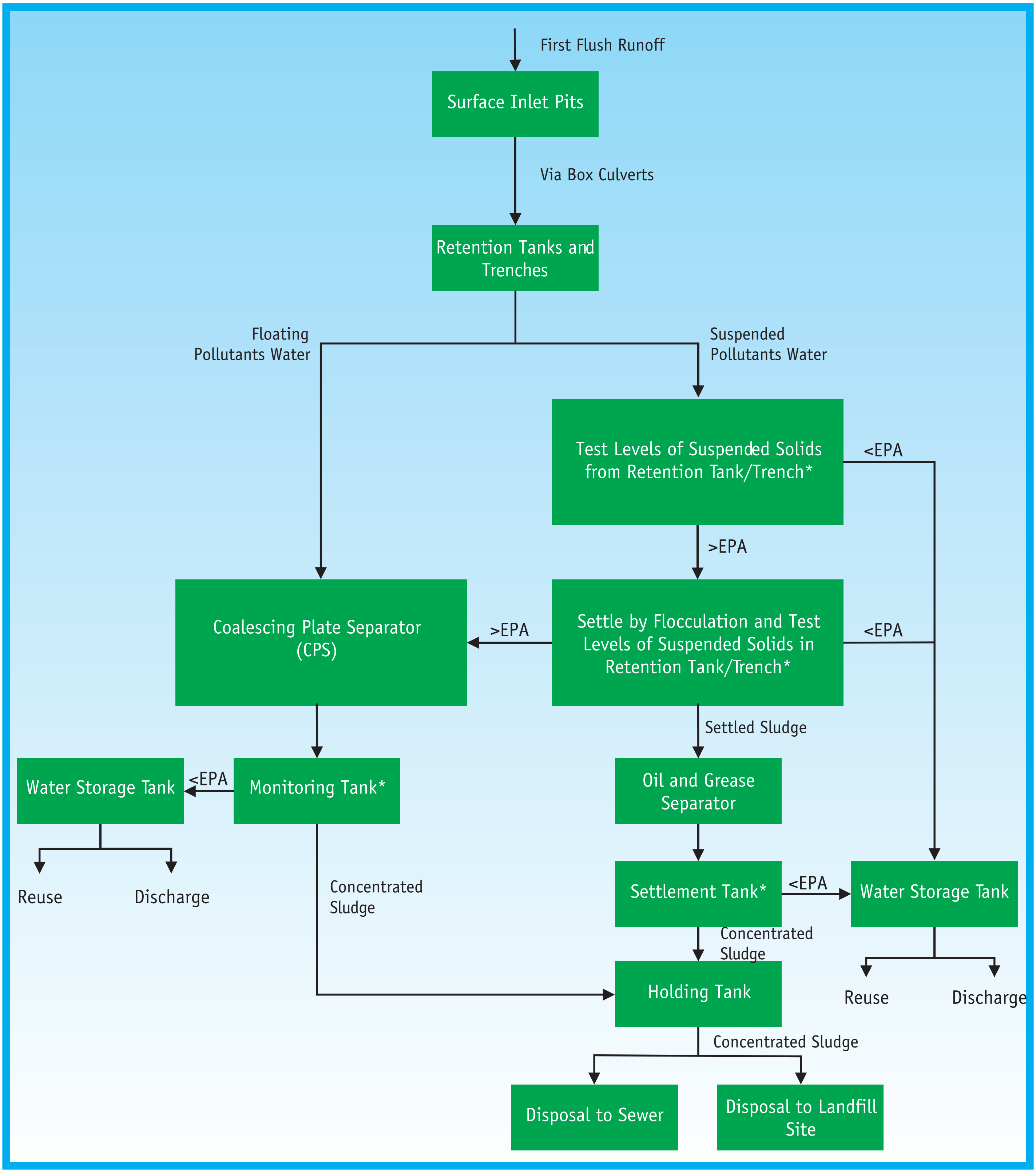
The first flush collection and treatment flow diagram is shown in **Figure 16.3** and the proposed layout of the stormwater management system is shown in **Figure 16.4**.

Capacity

The first 10 mm of rainfall would be collected from the terminal for treatment in accordance with EPA design criteria for mostly impervious sites. As the paved portion of the site would be approximately 60 ha, the first flush collection system would have a capacity of 6,000 m^3.

Collection

In order to reduce the effects of time lag from long flow paths, the site would be divided into subcatchments. Each of these would have surface inlet pits whereby collected stormwater would drain via box culverts with capacity to convey the 20-year ARI storm without surcharge. The first flush from each box culvert line would discharge into a first flush retention tank or trench along the edge of the site. The retention tank would be a covered version of the retention trench, and would be capable of supporting medium duty or heavy duty loads to support terminal equipment. Subsequent flows, which would be cleaner runoff, would bypass the trenches and tanks and continue to flow to the discharge points in Penrhyn Estuary and Botany Bay without disturbing the first flush water. Gridmesh covers would be installed over the retention trenches as a safety measure and to prevent access by birds and other animals and the ingress of wind-blown debris.



Source: Arup 2003

First Flush Collection and Treatment Flow Diagram

Figure 16.3

*Sampling and Analysis Points for Suspended Solids and Hydrocarbons

<EPA Suspended Solids Less Than EPA Limits in Treated Water

>EPA Suspended Solids Greater Than EPA Limits in Treated Water

Source: Arup 2003

0 300m

Site Stormwater Management **Figure 16.4**

First Flush Detention Trench

First Flush Detention Tank - Medium Duty

First Flush Detention Tank - Heavy Duty

Box Culvert

Surface Inlet Pit

Sediment Pollutant Carrier

Floating and Suspended Pollutants Carriers

Direction of Flow

Bio Remediation Swale with Sump Pit and Outlet with Flood Gate

Discharge Lines

Treatment, Reuse and Disposal

Each first flush retention tank or trench would contain a series of baffles to separate runoff containing floating pollutants (such as hydrocarbons and litter) and runoff containing suspended pollutants (such as sediment).

The surface water collected in the retention tank or trench would be pumped to a coalescing plate separator (CPS) to separate pollutions such as oils, greases, other hydrocarbons and any liquid pollutant which is less dense than water, from an “oily water” mix. The cleaner water would then flow into a small monitoring tank for sampling. If “clean”, the treated water would be pumped to storage tanks for reuse in irrigation or washdown purposes or discharged directly to Botany Bay or the tidal channel. Clean water would be stored in two 10,000 L tanks located near the northern end of the new terminal.

Stormwater collected in the retention tanks and trenches which exceed EPA requirements for suspended solids (normally 50 mg/L) would require treatment by flocculants to settle out the solids. Alternatively, the water could be passed through the CPS system to remove smaller particles that could not be removed via flocculation and gravity settlement.

After the removal of suspended solids and floating matter, the sludge and sediment from the bottom of the retention tanks/trenches and from the sump pits (at the end of each retention trench/tank) would be either collected separately or pumped to a settlement tank via an oil/grit separator. The removed pollutants would be transferred to a holding tank for disposal to the sewage system under licence or for transportation by a licensed waste management contractor to an approved landfill.

A separate stormwater collection and treatment system would drain the proposed inter-terminal access road and rail sidings to the north of the Patrick Stevedores terminal adjacent to Penrhyn Road, as shown in **Figure 16.4**. The system would be in the form of a bioremediation swale that would run parallel to the rail sidings and Penrhyn Road. A bioremediation swale is a constructed catch drain using shaped or graded earth materials and stabilized with site suitable vegetation. The system would be equipped with a number of sump pits that could trap gross pollutants. Clean water would discharge from the sump pits to Penrhyn Estuary.

16.6.4 Stormwater Treatment Devices

The new terminal would install CPS units. These units would generally remove solids 10 to 40 μm and greater and would be more effective than settling tanks. CPS units take advantage of the buoyancy of oil droplets in water to perform a separation. The system consists of stacked corrugated plates, forming a set of narrow channels through which oily water is made to flow. As the water flows between the plates, the oil droplets rise and meet the underside of the plates where they are captured to form large drops. The large oil droplets rise to the surface of the separator through holes provided for that purpose and are removed by skimming devices.

The oil/grit separator could be a commercially available precast unit (e.g. Ecosol model RSF 5000), or similar, consisting of two parallel channels and a collection/filtration silo. Through a series of apertures and baffles the unit separates pollutants. The separator would act as an end-of-line collecting unit for oil and grease, and gross, coarse and fine sediments.

Sump pits in retention tanks/trenches would have depressed bases to accumulate sediment. The feature supplements the oil/grit separator as a primary treatment.

The bioremediation swales would also have sump pits to act as pollutant traps.

As an environmental safeguard, outflows would be monitored during the first year of operations and additional treatment installed as required. The proposed sampling locations within the treatment process are indicated in **Figure 16.3**. The monitoring program would be described in more detail in the Operational EMP for the new terminal.

16.6.5 Spill Management

Accidents resulting in oil spills or loss of containment on the terminal during port operations would be contained through the first flush system. It is anticipated that a major accidental spill could be in the order of 20,000 L (approximately 20 m^3). Spills at this scale could be easily contained in the retention tank/trench which has a volume of 6,000 m^3. Following containment, the spill would be disposed of in an appropriate manner. As spills may be volatile, all electrical equipment would require spark arrestors and suitable isolation to prevent explosions.

16.6.6 Operations Area Management

The areas of the site designated for equipment maintenance and refueling would be provided with the appropriate spill containment measures such as bunding to keep washdown and stormwater runoff separate from the rest of the terminal's drainage system. All discharges from this area would be directed to sewer after appropriate treatment in accordance with a Trade Waste Agreement with Sydney Water Corporation. The Trade Waste Agreement would determine the level of treatment required before discharge. As an alternative measure, washdown and stormwater runoff from the equipment maintenance and refueling area could be treated in a smaller scale first flush system (e.g. CPS unit).

16.6.7 Firewater

Firewater runoff from the equipment maintenance and refueling area would be discharged through the same collection and treatment system handling washdown and stormwater runoff. Likewise, fire suppressant foams and other chemicals would be contained and discharged to sewer after the appropriate treatment. As there are various types of foams and chemicals, their handling and disposal would depend on the manufacturers' instructions and recommendations.

Firewater and chemicals outside the maintenance areas would be contained and treated in a similar manner to a spill in the first flush system. Firewater in excess of the capacity of the first flush retention tanks/trenches would be stored in gated box culverts which add significant capacity to the storage capacity of the system if required.

16.6.8 Rail Corridor

The rail line extension would occupy a 14 m wide corridor about 12 m from and parallel to Foreshore Road. The proposed works would reduce the extent of natural ground for infiltration and restrict the overland flow path to the Bay. Stormwater drainage in the form of bioremediation swales or constructed open catch drains discharging to the Estuary through grit/oil arresting sump pits would be provided between the rail corridor and the road.

16.6.9 Public Recreation Areas

The boat ramp and the tug berth would comprise a 2.5 ha largely paved reclamation abutting the foreshore over a length of approximately 200 m. This would reduce the extent of natural ground for infiltration and restrict the overland flow path of stormwater to the Bay. Surfaces would be contoured as necessary at gradients not exceeding 3% to direct stormwater into bioremediation swales located adjacent to parking blocks. The collected stormwater would pass through a proprietary oil/grit interceptor(s) prior to discharge into the Bay. Water from fish cleaning would be disposed to sewer.

The intersection of the main access road for the new terminal with Foreshore Road would occupy a fairly localised area. It would be designed to blend with the existing stormwater drainage arrangements and would not be expected to require any additional stormwater augmentation.

Stormwater drainage from the road and rail bridges would be piped into the new terminal stormwater management system and would undergo treatment prior to discharge into the Bay.

16.7 Port Operations

Other surface water quality issues with the potential to arise during operations include the following:

- vessel spills;
- ballast water exchange; and
- ship hull antifouling agents.

16.7.1 Vessel Spills

The proposed new terminal would not be handling oil and chemical tankers which would normally use the bulk liquid berths in other areas of Port Botany. The risk of vessel spills from container ships using the new terminal would come mainly from fuel or oil leaks or from loss of containment in containers in the event of ship/container impact or similar accident. The hazards from such spills are discussed in **Chapter 28** *Preliminary Hazard Analysis*.

It is Sydney Ports Corporation's responsibility to manage spills in Sydney Harbour and Port Botany. Its Oil Spill Response Procedures and *Port Botany Emergency Plan* outline the actions and responsibilities in the event of an emergency, including spills in Botany Bay.

The impact of vessel spill on water quality is expected to be localised. However, immediate reaction from an oil spill response team would be required to contain the spill. Sydney Ports Corporation has a 24-hour emergency response crew. Oil spill cleanups use specialised equipment and absorbent materials. Sydney Ports Corporation personnel are trained to use different equipment and special absorbents to pick up the oil. Oil spill from vessels would also be prevented from reaching Penrhyn Estuary by a permanent oil boom that would be placed across the tidal channel under the road bridge to the new terminal. Further details of spill response are provided in **Chapter 32** *Emergency and Incident Management*.

16.7.2 Ballast Water

Ballast water is water taken on board or discharged as required to maintain a ship's balance and stability. Depending on where ballast water was taken in, foreign marine pests taken in with this water could have potential environmental and economic impacts when released with discharged ballast water in Botany Bay.

It is estimated by Sydney Ports Corporation that up to 420,000 tonnes of ballast water is discharged into Botany Bay annually (HRC, 2000), the majority of which is discharged by tankers loading at the Kurnell Oil Refinery. Container ships do not typically discharge ballast water, therefore it would be unlikely that the operation of Port Botany Expansion would result in additional ballast water discharges or increased risk of marine pests in Botany Bay.

16.7.3 Ship Hull Antifouling Agents

Ship hull antifouling agents provide a deterrent to organisms attaching themselves to ship hulls, thereby assisting in reducing the risk of foreign marine species being brought into Australian waters. The potential impacts of ship antifouling agents on the aquatic environment are discussed further in **Chapter 19** *Aquatic Ecology*.

16.8 Mitigation Measures

16.8.1 Construction

The main mitigation measure required during construction would be to contain turbidity. Based on the results of simulation of discharge of dredged sediments to the reclamation area below the water surface, a silt curtain would be required around the dredge discharge area to prevent plume development, particularly over seagrass areas. The diameter of the silt curtain would be sufficiently large to prevent a build up of water and allow a practical working area without the need for frequent shifting of the curtain. The proposed silt curtain pore size in the order of 2 μm would result in suspended sediment concentrations outside the silt curtain not exceeding 50 mg/L. This concentration would reduce to 20 mg/L within a distance of 500 m from the silt curtain.

Turbidity would be monitored during dredging and reclamation based on the following criteria:

- a limit of 20 mg/L in normal dry weather conditions for the outermost zone (i.e. approximately 500 m to 1 km from the discharge point) measured by 0.75 m secchi depth (depth at which a plate-sized black and white disk called a secchi disk, when lowered into the water, disappears from view); and
- a limit of 50 mg/L outside the silt curtain for the middle zone (i.e. approximately up to 500m from discharge point).

The innermost zone would be the turbidity containment area with no limit.

During the latter stage where discharge of dredged sediments takes place within a bunded area above the water surface, simulation of plume development shows that, apart from the immediate vicinity of the discharge, surface concentrations would not exceed 5 mg/L. Silt curtains would not be needed at this stage of the works. However, monitoring would be undertaken to ensure that there is a low return of silts to the Bay.

Aside from turbidity control, the following mitigation measures would be implemented to minimise the impact of the construction on surface water flow and water quality:

- dredged material intended to be redeposited along Foreshore Beach and Penrhyn Estuary and other bulk construction material would be stored in protected locations and contained or covered as required to minimise sediment in runoff;
- erosion and sediment control measures would be employed during construction activities over Springvale and Floodvale Drains, including the rail line and bridge, access road and cycleway, to minimise any disturbance or constriction of these channels;
- construction activities would be conducted in a manner that minimises the potential for spills or leaks, including the regular inspection and maintenance of plant and equipment, and providing bunding or similar spill containment structures for onsite fuel and oil storage;
- appropriate equipment and material handling practices would be specified for the enhancement works in Penrhyn Estuary;
- any spills or leaks would be contained or cleaned up as quickly as possible;
- resealing and revegetation of all exposed surfaces as soon as practical to prevent extended exposure to erosion;
- erosion and sediment control planning and implementation would apply to all areas which may be disturbed. Regular inspection of all structures would occur after heavy rain and during periods of prolonged rainfall;
- any redirection or lengthening of the stormwater pipes that discharge to the Bay from the Foreshore Beach catchment would not be undertaken until drainage analysis of the impacts of such works was undertaken; and
- a Soil and Water Management Plan (SWMP) would be prepared in accordance with the guidelines contained in *Managing Urban Stormwater - Soils and Construction Manual* (Department of Housing 1998) and incorporated into the Construction EMP for the project. Details of erosion and sediment control measures would include:
  - temporary structures such as sedimentation ponds and silt fences surrounding stockpiles to prevent offsite movement of sediment;
  - control of drainage from areas adjacent to construction areas using earth bunds and diverting structures such as earth drains;
  - minimisation of traffic in construction zones and provision of dedicated parking areas; and
  - removal of soil from vehicle wheels and undercarriages before departing the site to reduce soil carried offsite.

16.8.2 Operation

The following mitigation measures would be implemented to minimise the impact of the operation of the Port Botany Expansion on surface water flow and water quality:

- a first flush system would be installed, maintained and monitored during operation of the Port Botany Expansion to minimise stormwater pollution;
- stormwater would be reused on site where possible;
- on site diesel storage facilities would be enclosed with spill containment structures (i.e. bunding) and warning systems in accordance with *Australian Standard AS 1940 Storage and Handling of Flammable and Combustible Liquids*;
- spills on site would be controlled and managed mainly through the first flush system and by spill response procedures;
- spills from ships would be controlled and managed by spill response procedures (refer to **Chapter 32** *Emergency and Incident Management* for details);
- the public recreation areas would be equipped with appropriate amenities, drainage, and waste management to reduce the likelihood of contaminated water, waste and litter being discharged to the Bay;
- an Operational EMP would be implemented which would include sampling and monitoring activities associated with the first flush system; and
- water quality would be measured on a regular basis within Penrhyn Estuary. Indicators would include turbidity, DO, temperature, salinity, pH, nutrients, heavy metals and organic contaminants. In particular, organic contaminants would be measured in relation to an influx of contaminated groundwater into Penrhyn Estuary from existing groundwater plumes (refer **Chapter 17** *Groundwater*).

There is an opportunity to install stormwater quality improvement devices to capture litter and sediment from the Floodvale and Springvale Drain catchments so as to reduce the litter and sediment load entering Penrhyn Estuary. However, this measure would only be implemented if detailed flooding studies demonstrate that these devices would not result in upstream flooding issues. Capture and removal of sediment would also remove nutrient and other contaminants, and therefore the load of these pollutants entering Penrhyn Estuary would also be reduced. This is not a critical component of the project but could provide added community and ecological benefit.

16.9 Conclusion

Hydrologic and hydraulic modelling showed that:

- for flood events up to the 200 year ARI event, the proposed Port Botany Expansion would not have any adverse impact on local catchment flood behaviour. A minor impact (0.02 m) would occur in the Floodvale Drain catchment during extremely rare events, i.e. the PMF. This is at the limit of the model's ability to predict change;
- for the full range of flood events, the proposed development would not cause an increase in flood levels within Penrhyn Estuary;

- there would be no impact on the Foreshore Beach catchments drained by the pipe culverts under Foreshore Road for flood events up to the 200 year ARI event. There would be a minor increase in Bay water level near the outlets of the two eastern most beach drains in the PMF of the order of 0.06 - 0.12 m;
- the proposed railway bridge and road bridge would not impact upon water levels if the total channel flow area under these bridges is maintained;
- the proposed habitat enhancement works in Penrhyn Estuary would not reduce flow conveyance in the area; and
- there would be no impact on water levels within the Mill Stream for the full range of flood events.

Waters draining from the catchments surrounding Port Botany have high levels of nutrients and low DO content but are significantly diluted by the receiving waters of Penrhyn Estuary and Botany Bay. The proposed development would not increase the mass of contaminants entering Penrhyn Estuary or the Bay.

Estuary modelling showed that reduced flushing in Penrhyn Estuary as a result of the proposed development would affect the transport and dispersion of contaminants and suspended solids and would likely result in the following changes during ambient conditions:

- a general increase in nutrient pollutant concentrations within Penrhyn Estuary, but not above the ANZECC (2000) guidelines;
- increased sediment accumulation within Penrhyn Estuary, but this would be low and would be influenced by sources in the catchment;
- negligible increases in depth averaged ambient sea temperatures within inner Penrhyn Estuary;
- general increase in median Fc concentrations within Penrhyn Estuary and along the tidal channel but not exceeding the ANZECC (2000) guideline value for primary contact recreation;
- reduced median Fc concentrations at the location proposed for the new boat ramp and the public recreation area west of the boat ramp; and
- small reductions in the average DO concentration and a smaller range of DO concentrations within Penrhyn Estuary.

During transient conditions, the following would occur:

- a temporary increase in the level of peak nutrient pollutant concentrations and an extension of the duration for which the elevated level would occur after rain events;
- higher suspended solids concentrations within the northwest Penrhyn Estuary waterway, but these would typically not persist for longer than four hours after rain events;
- an increase in peak Fc concentrations within Penrhyn Estuary with the highest concentrations occurring close to Springvale and Floodvale Drains; and
- a reduction in peak Fc concentrations at the location proposed for boat ramp and the public recreation west of the boat ramp.

The Port Botany Expansion would not incorporate any elements that would impede the natural flow regimes of existing stormwater channels which discharge to Botany Bay. The sediment and suspended solid load (and hence nutrient load) of the stormwater entering Penrhyn Estuary from the catchments could be reduced through the installation of stormwater quality improvement devices at the outlets of the Springvale and Floodvale Drains, however, the installation of these devices would be subject to detailed studies of their impact on upstream flooding. These devices are not a critical component of the project but could provide additional community and ecological benefit.

The new terminal's stormwater management system would minimise contaminated runoff discharging into Botany Bay by means of a first flush and wastewater capture and treatment system. The system would provide for reuse of treated stormwater runoff from the terminal for washdown and irrigation purposes.