Department for Planning and Infrastructure

Review of Sand Bypassing at Dawesville and Mandurah

Coastal Engineering Investigation

Technical Report 446
July 2006

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Executive Summary

The Dawesville Channel and Mandurah Ocean Entrance connect the Peel Inlet and Harvey Estuary to the Indian Ocean. To manage the movement of sand across the entrances, and minimise the natural siltation within the channels, mechanical sand bypassing is undertaken. The purpose of this report is to review the previous 10 years of sand bypassing, assess the efficiency of the current system and provide recommendations for improvement with a view towards the future bypassing contracts and the potential for capital site improvement works.

The previous 10 years of bypassing operations have been completed by CGC Dredging Pty Ltd, under contract to the Department for Planning and Infrastructure (DPI). The technique adopted involves excavation of sand from a sand trap using conventional land-based earthmoving plant, creation of sand slurry using the specialised equipment ‘Slurrytrak’ and pumping of the slurry by pipeline to a disposal site on the other side of the channel.

The current bypassing targets are 85,000m^3 and 100,000m^3/year for Dawesville and Mandurah respectively. Bypassing is typically undertaken at Dawesville over summer and Mandurah over winter. In addition, some supplementary bypassing in the order of 10,000m^3/year is undertaken by the City of Mandurah, excavating sand from the Dawesville sand trap and transporting it by truck to Falcon Beach to alleviate local erosion.

The sand trap areas are formed by the channels’ rock training walls, and at Dawesville, by an additional spur groyne. Both sites contain a rock shelf underlying a relatively thin layer of sand. Sand is excavated from the traps by removing strips perpendicular to the beach moving away from the training walls. Typically excavation will extend to the underlying rock.

Since the commencement of the current bypassing regime 10 years ago there has been substantial development, both commercial and residential, of the coastline in the vicinity of the operations. This has raised the potential for public conflict and poses challenges for the future bypassing works.

The annual wave climate and water level have a significant impact on the level of sand movement along this stretch of coastline. These factors vary from year to year and together are used to give a rating of the annual ‘storminess’. Typically, the majority of sand movement occurs from south to north over winter under the influence of south-westerly swell waves. During this period, it has been found that most sand movement occurs in ‘slugs’, estimated at between 10,000-30,000m^3, following storm events.

There are a number of relationships between wave climate, mean sea level and the volume of sand bypassed. When the wave climate and water level are higher, a higher / steeper beach is formed. Sand is efficiently captured in the sand traps and mechanically bypassed. When the wave climate and water level are lower, a lower/ flatter beach is formed. More sand naturally bypasses the sand traps and the operations are less efficient.

The current bypassing operations have been successful in maintaining a largely stable coastline and navigational channels. There are no significant variations in the coastal alignment up or down drift of either entrance. Between Dawesville and Mandurah, there are areas that are experiencing localised erosion, for example Falcon; however, this is likely to be a result of the local rock reefs and bathymetry and not a consequence of the bypassing operations.

Based on this review, it is recommended that for future operation the current target bypassing volumes and schedules be maintained. Aesthetic improvements could be made to the disposal site at Mandurah by providing fixed outlets on both sides of the training wall.

Options for split disposal by pipeline to Falcon Beach, to replace trucking, have been investigated. It is also recommended that the sand excavation undertaken by the City be coordinated to benefit the overall bypassing.

Alternative bypassing systems, including the use of fixed jet pump intakes, have been previously considered and are potentially feasible at both locations. Site upgrade works, including the installation of electrical motors to reduce noise disturbance, are under investigation for the longer term.

Table of Contents

Figures

Tables

Appendix

1 Introduction

The Dawesville Channel and Mandurah Ocean Entrance connect the Peel Inlet and Harvey Estuary to the Indian Ocean. The Dawesville Channel is a manmade waterway opened in 1994 to increase the water quality in the Peel – Harvey Estuary System. The Channels provide access for both recreational and small commercial vessels to the estuary and popular canal estates. An annotated aerial photograph of the area is provided in **Figure 1**.

The sandy coastline experiences a relatively high rate of littoral drift, predominantly northwards. To manage the movement of sand across the channel entrances and minimise the natural siltation within the channels mechanical sand bypassing is undertaken.

The current bypassing system uses land-operated plant and has been in operation since 1995. Since commission, a significant amount of coastal monitoring data has been collected. In addition, the current bypassing operation is facing increasing pressure from ongoing residential and commercial development of the area.

The purpose of this report is to review the previous 10 years of sand bypassing, assess the efficiency of the current system and provide recommendations for improvement. The view is towards future bypassing contracts and the potential for capital site improvement works.

1.1 Scope of Works

The designated scope of works for this report is to review:

- current target bypassing volumes;
- current sand trap areas in relation to the current operations and the possibility of a fixed pick-up;
- current disposal practices and consider alternatives, in particular at Mandurah;
- the impacts of the current bypassing regime on adjacent beaches and the ways to potentially minimise any adverse impacts; and
- the inefficiencies in the current bypassing regime, in particular with respect to offshore sandbar accumulations and the necessity of nourishment at Falcon Bay.

Figure 1 – Location Plan

2 Current Operations

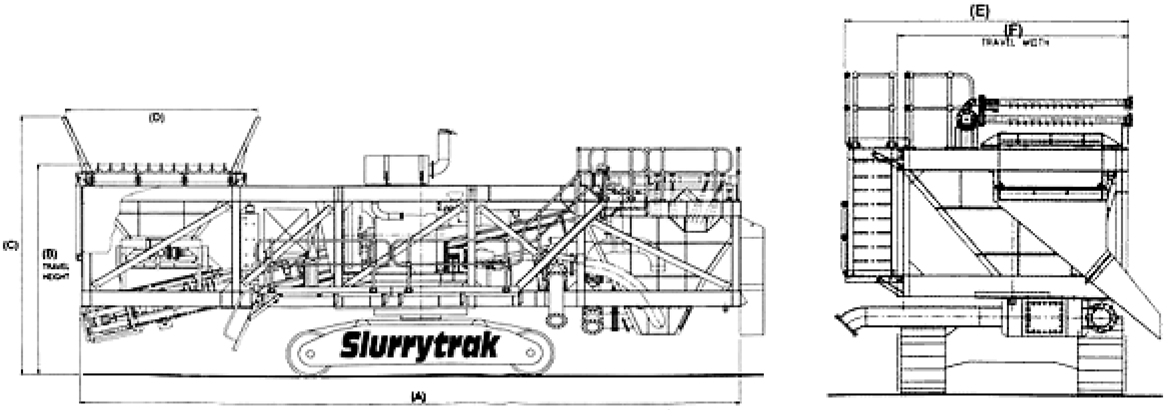
2.1 Introduction

The Department for Planning and Infrastructure (DPI), previously the Department of Transport, contract the sand bypassing operations at Dawesville and Mandurah. The two contracts awarded to date, both five years in length (1995-2000; 2000-2005), have been undertaken by CGC Dredging Pty Ltd using the same plant and technique. A one-year contract extension was granted in 2005 to allow bypassing to be undertaken in 2006. This has provided the opportunity for a comprehensive review and investigations prior to award of the next contract this year.

Sand is bypassed from south to north to coincide with the predominant northward littoral drift. The same bypassing system is currently in use at both locations and comprises of:

1. Sand excavation from a designated sand trap up drift of the entrance using conventional land-based earthmoving equipment.
2. Sand feed directly into ‘Slurrytrak’, a mobile screening and pumping unit (refer to **Figure 2**). Sand is screened for debris and then mixed with water to form slurry.
3. Slurry pumping through a pipeline under the channel to a single disposal area up drift of the entrance.
4. Sand deposition directly onto the beach at the disposal area, generally above high water level.

Figure 2 – Mobile screening and bypassing plant ‘Slurrytrak’



(Image taken from http://www.cgcgroup.com.au/eq_slurry.html)

The current bypassing target is 85,000m^3/year at Dawesville and 100,000m^3/year at Mandurah. Bypassing at each site takes several months and has generally been undertaken at Dawesville over summer/autumn and Mandurah over winter/spring, with the aim of coinciding with the highest inflow of sediment at each site. The split timing allows the use of the same equipment at both locations.

In addition, supplementary bypassing is undertaken by the City of Mandurah. Sand is excavated primarily from the sand trap at Dawesville and deposited at Falcon Beach to relieve erosion. Sand is excavated using conventional earth moving plant and transported by truck.

The following sections provide further details on the two bypassing sites.

2.2 Dawesville Channel

Dawesville channel is located approximately 75km south of Perth and 10 km south of Mandurah. The channel is approximately 200m wide and –6m to –6.5m Chart Datum (CD) deep at its ocean entrance. The entrance is defined by rock training walls, designed to provide a narrow entrance angled to the north, aimed at reducing siltation within the channel.

The channel entrance and bypassing areas, described in more detail below, are shown in **Figure 4** (DPI 789-4-1) presented at the end of this section. This figure is an extract from the 2001-2005 contract documents.

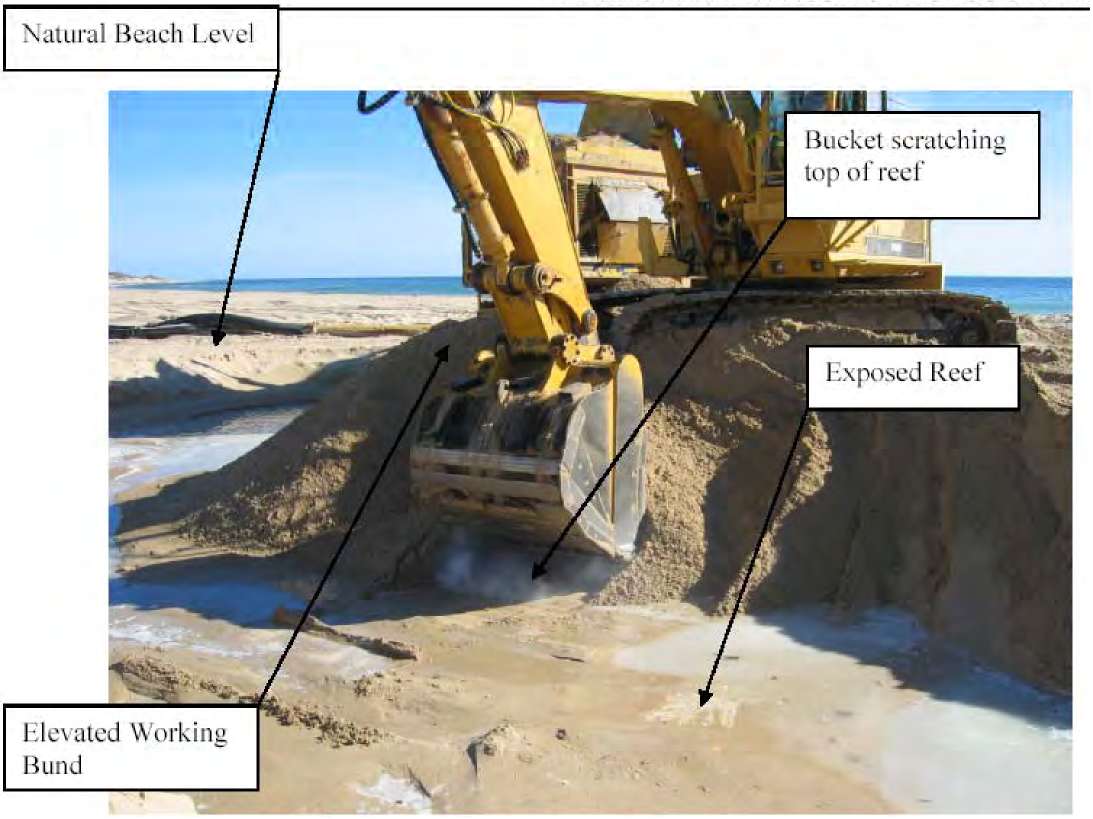
2.2.1 Excavation Area

A 200m spur groyne extending from the southern training wall defines the northern extent of the existing sand trap. The designated excavation area within this sand trap under the original contract (1995-2000) extended 200m south of the training wall. However, it was reported by the Department of Transport (1998) that sand accretion to the south of the sand trap was causing a realignment of the coastline and reducing the effectiveness of the bypassing operation. Accordingly, the sand trap was extended 700m further south and under the present contract (2000-2005 & 2006) is defined as Area A and Area B, extending 250m and a further 450m south from the training wall respectively.

The coastline at Dawesville comprises of a rock shelf overlain by a relatively thin layer of sand. Jet probes undertaken within Area A identify underlying rock at a depth of up to –4m CD adjacent to the spur groyne, shallowing to +1m CD 200m south (refer to DPI 789-4-2, **Appendix A**). This information is supported by CGC's experience, boreholes collected during the channel investigation which identified underlying Calcarenite rock, and pre-construction dive inspections which indicated prevalent exposed reef within the entrance area. More extensive rock probing is scheduled for prior to the next contract.

Under the current operations, sand excavation begins at the spur groyne and moves south, with strips being excavated perpendicular to the beach. The current aim is to excavate the maximum possible volume of sand from Area A before moving on to Area B. In most areas, the beach is excavated down to the level of the underlying rock. A typical excavation is shown in the following **Figure 3**.

Figure 3 – Typical excavation at Dawesville; note exposed rock reef (JFA, 2005)



It is reported by CGC that the average grain size of the sand within the excavation area increases significantly south from the groyne. Formal grain size testing is necessary prior to the next contract. The combination of increased grain size and distance means that a booster pump is required to excavate the southern area of the sand trap.

Intermittent layers of partially degraded seagrass are typically encountered when excavating the northern extent of the sand trap. If excessive, these can lead to blockage of the machinery, but generally these do not cause mechanical difficulties to the current operations. Similarly, rocks occur throughout the beach and have hindered operations in certain years.

A small compound area is designated on the dune area at the back of the beach. Behind the beach area, the land is currently being redeveloped as part of the Port Bouvard – South Port estate. This residential development work also includes redevelopment of the public car parking area and the proposed construction of a lifesaving club to the south of the site. Currently, there are no services to the compound area; however, there may be an opportunity to provide power with the redevelopment of the car park area.

The increased residential development and improvements to the current facilities are likely to further increase the popularity of this beach area. Currently, segregation between beach users and bypassing plant is maintained by the installation of temporary signage around the works. Previous complaints have been received regarding noise at Dawesville and this is likely to become more of an issue when the adjacent residential housing is constructed. In 2005, noise measurements were collected, but no significant changes made to the current system.

2.2.2 Disposal Area

The disposal area is located on the northern side of the channel and under the current contract is split into Area A, extending approximately 300m north, and Area B, extending a further 300m north. Area A is backed by a rock revetment with minimal / no beach when disposal is not occurring. Exposed rock reef is evident throughout the disposal areas.

Disposal has primarily been to Area A, with the disposal pipe running directly off the rock revetment. Sand movement away from the disposal area is not usually instantaneous. When sand has built up around the end of the pipe it is extended seaward.

To alleviate previous erosion at Avalon Beach, a trial was undertaken in 1998 discharging 48,000m^3 of spoil northward of the usual disposal area. The disposal point was approximately 200m north of the northern end of the rock revetment. In the follow-up report by the Department of Transport (2001) it was noted that increased accretion was observed at Avalon Beach. However, subsequent disposal to a similar location was considered unnecessary. It was also noted by CGC that, during the trial, the pipeline was subject to ongoing wave damage beyond the end of the rock revetment where it ran along the back of the beach.

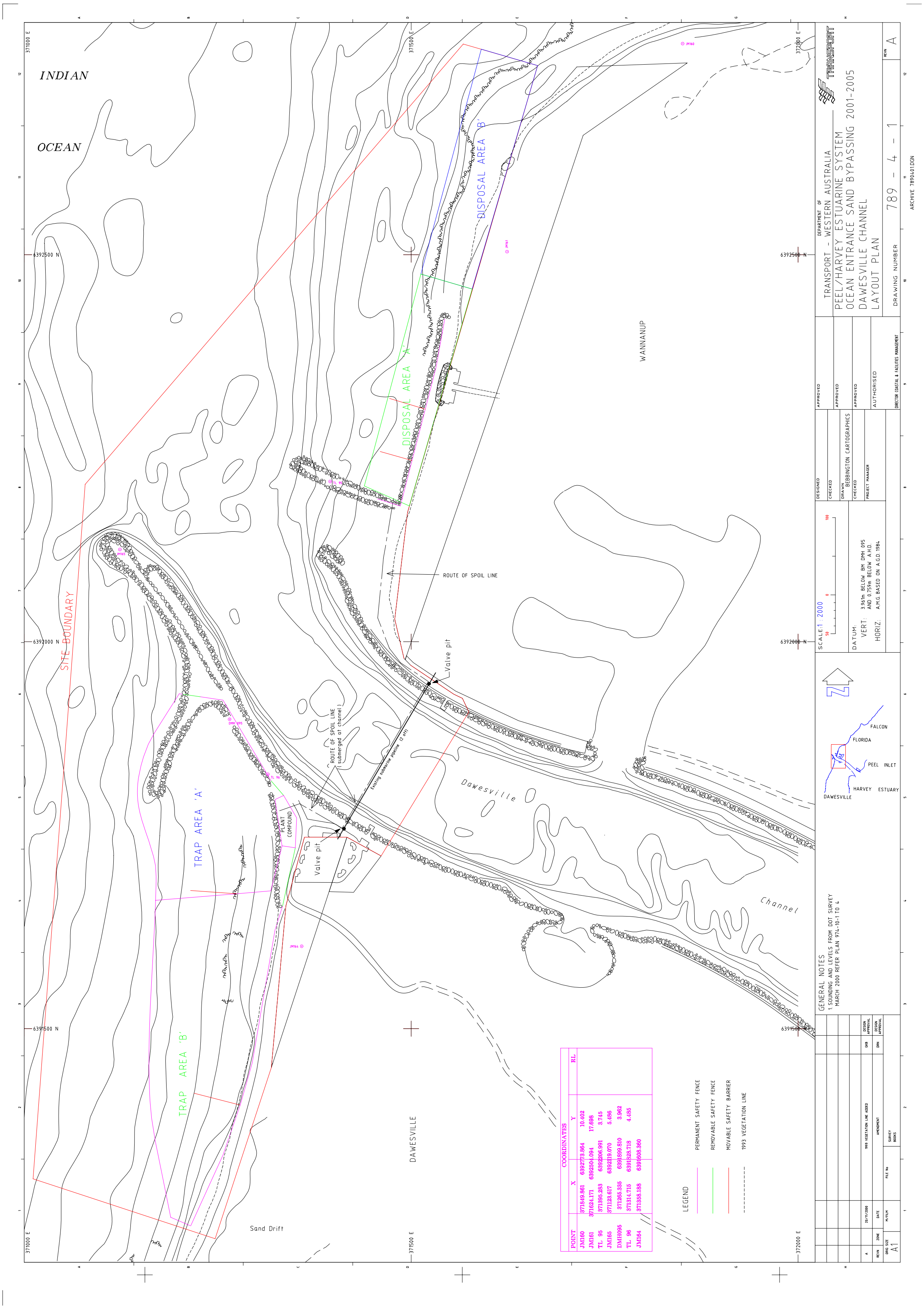
Minimal conflict between been beach users exists at the current location; however, previous complaints have been placed by adjacent residents regarding the smell from the discharge spoil. CGC have noted that complaints occur only when excavating the intermittent seaweed layers (previously discussed) at the northern extent of the sand trap.

2.2.3 Pipelines

Two 315 OD MDPE pipelines were installed under the channel during construction, and are under DPI ownership. The intent was to use one pipeline solely until failure before swapping to the other, though since commencing operations only the first pipeline has been used. During the 2004/05 bypassing session, damage to this pipeline was discovered, due to wear on the north side of the channel where the pipe turns a right angle to return to the surface. CGC replaced the joint and the pipeline became operational again; however, the wear indicates that this pipeline is nearing the end of its serviceable life.

It is noted that there is no defined easement for the pipelines. This may result in land ownership difficulties in the future when maintenance or replacement is required. Land tenure for these works is thus currently being resolved by DPI.

Figure 4 – Dawesville Channel Layout Plan (DPI 789-4-1)



2.3 Mandurah Ocean Entrance

The natural entrance to the Peel – Harvey Estuary is located in Mandurah, approximately 65km south of Perth. The channel is approximately 100m wide with a -3m CD deep rock sill across its ocean entrance. The entrance is defined by rock training walls, constructed in 1987 and 1988, to stabilise the ocean entrance and improve the hydraulic efficiency of the channel. Similar to Dawesville, they provide a narrow entrance directing the flow to the east, in an attempt to reduce siltation within the channel. In addition, a 550m long rock reflection wall was constructed to the east of the entrance to help minimise the formation of a sand bar.

Prior to the commencement of the formal sand bypassing scheme in 1995, bypassing was undertaken on an as-needed basis, typically at the end of winter to provided adequate navigation for the start of the fishing season. An average of 56,000m^3/year was bypassed between 1985 and1994. Excavation was undertaken by dragline, and later by dredge, primarily to the inner shoal on the western side of the channel.

The channel entrance and bypassing areas, described in more detail below, are shown in **Figure 6** – Mandurah Ocean Entrance Layout Plan (DPI 789-3-1) (DPI 789-3-1) presented at the end of this section. This figure is an extract from the 2001-2005 contract documents.

2.3.1 Excavation Area

Under the current contract (2000-2005; 2006) the existing sand trap extends from the western training wall to the rock groyne approximately 300m west and seaward to the –2m CD contour. This is a slight increase on the previous contract area.

Similar to Dawesville, the area is underlain by a rock shelf. The previous contract drawings (refer to 789-02-01A, **Appendix A**) indicate the level of rock in the excavation area as –2.5m CD. This information is supported by CGC's experience. Some rock probes are recorded adjacent to the western training wall, which indicate that the level of rock may be slightly deeper (refer to **Appendix A**), however the level datum is not recorded. More extensive rock probing is scheduled for prior to the next contract.

Under the current operations, sand excavation begins at the training wall and moves west, excavating strips perpendicular to the beach. Excavation is typically down to the level of the underlying rock. CGC noted that this location is less prone to seaweed than Dawesville and no related problems have occurred.

A small plant compound is located at the back of the beach adjacent to the training wall. This area is backed by a small reserve and, in turn, a residential development.

2.3.2 Disposal Area

The disposal area is located at the end of the wave-reflecting wall approximately 600m east of the channel entrance. Under the current contract (2000-2005; 2006) the designated disposal area extends approximately 200m along the beach. Sand is currently disposed at the corner of the beach in a 'rainbow' (refer to **Figure 5**). CGC have found that sand moves away from the disposal area relatively quickly and that altering the discharge point, due to sand build up, is not often required.

This section of the coastline has undergone significant development since the start of the bypassing in 1995. The recent construction of neighbouring resort style apartment blocks and hotels is likely to promote use of the beaches and surrounding area, which will potentially conflict with the current bypassing scheme. DPI has been offering the City of

Mandurah ongoing assistance with the management of their northern beaches. A balance is required between maintaining local / regional beach amenity and minimising disruption to beach users and local residents.

Currently, further harbour developments are also being considered at Mandurah, which could result in additional construction extending offshore. These developments are currently envisaged under a 10+ year time frame (Mandurah 2020).

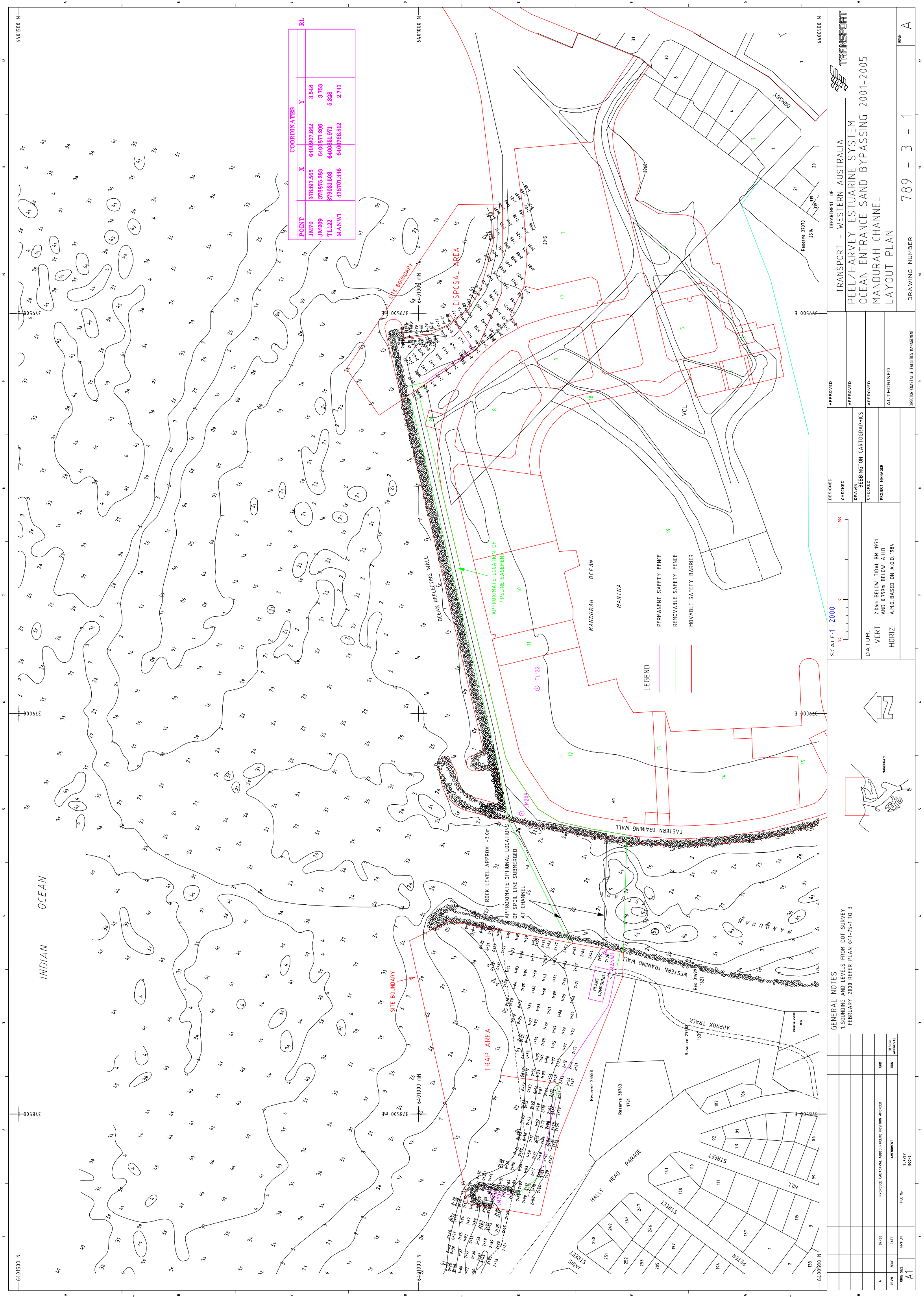
Figure 5 – Disposal of spoil at Mandurah by 'rainbow' discharge

2.3.3 Pipelines

A single pipeline, under the ownership of CGC, extends across the entrance. This pipeline rests on the channel bed in an arched shape to provide improved resistance against the ebb tides. There are a number of manholes along the reflecting wall in case of blockage, however these have never been used.

Similar to Dawesville, it is noted that there is no defined easement currently provided for the pipelines. This may result in land ownership difficulties in the future when maintenance or replacement is required. Land tenure for these works is thus currently being resolved by DPI.

Figure 6 – Mandurah Ocean Entrance Layout Plan (DPI 789-3-1)



3 Transport Mechanisms

Several studies have been undertaken to investigate the driving mechanisms underlying sand movement within this region. These can be summarised as:

- Wave height – The wave climate consists of two fractions: dominant south-westerly swell waves and shorter period north-westerly wind waves. The majority of wave energy is found to occur over the winter months and is concentrated to individual storm events.
- Water level – The average water level can vary by up to 200mm due to the global effects of El Niño and La Niña. In addition, the increase in wave energy over winter tends to promote increased water levels.
- Channel Flow – The estuary flow is increased as a result of rainfall and is generally highest in late autumn and winter and lowest over summer.
- Local Bathymetry – There are a number of rock reefs within the area, which control and restrict the movement of sand.

These conditions lead to seasonal trends of sand movement. It is found that the majority of sand is driven northward over winter under south-westerly storms, resulting in a predominant south-north littoral drift. Previous studies have identified that the majority of sand movement occurs in 'slugs', estimated between 10,000-30,000m^3, following winter storm events. These slugs have been identified on historic aerial photographs between Roberts Point and Mandurah Ocean Entrance and to the west of Mandurah Ocean Entrance; an example is seen in **Figure 7**, below.

Figure 7 – Aerial Photograph: Mandurah, September 1996

Some reversal, moving sand south, occurs under north-westerly wind waves. However, this is generally only noticeable during 'calmer' years when south-western storms are less prolific. Typically, the volume of sediment moved southward is relatively insignificant in comparison to the net northward littoral drift. It has previously been estimated that the total net northward littoral drift within the region is in the order of 200,000m^3.

Sand movement along this coast is not constrained to the beaches alone and can extend several kilometres offshore into relatively deep water. This band of sand movement can be observed in the satellite image of the coastline provided in **Figure 8**. The actual sand movement close to the shore was previously estimated as 85,000m^3 and 100,000m^3 at Dawesville and Mandurah respectively.

In addition, the two entrances have a natural ability to bypass sand. Dependent on the relative flow through the channel and rate of littoral drift, sand will tend to form in a shoal or bar across the entrance. Simplistically, if the channel's flow is relatively low in comparison to the rate of littoral drift, a bar will tend to form across the entrance and may result in the temporary closure of the channel. This deposition was seen at Mandurah before formal bypassing occurred in 1995, where the channel would be partially or fully closed by the end of winter.

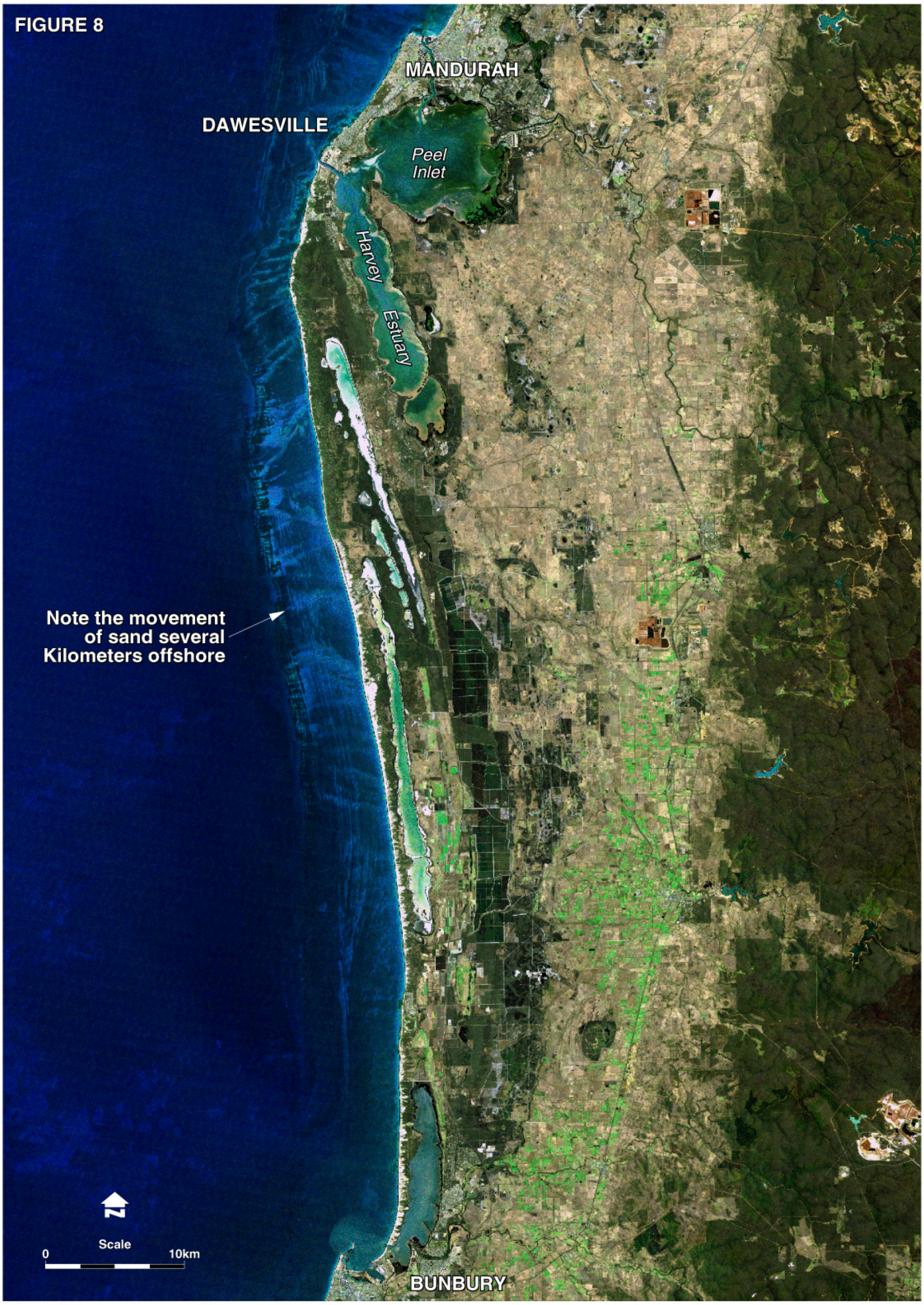
Alternatively, if the flow is relatively high, the bar will tend to form further offshore from the entrance. This is currently observed at Dawesville and Mandurah where the natural littoral drift across the entrance has been substantially reduced by mechanical bypassing. For this reason, both Dawesville and Mandurah entrance channels were designed to be relatively narrow to promote the flow though the channel and push any siltation further offshore.

Riedel & Byrne's 1987 review of sediment transport between Bunbury and Rockingham found no apparent offshore sources or sinks and that the littoral transport system is confined to the nearshore region. However, it is apparent that local sections of the coastline are experiencing mild erosion or accretion.

In other areas, typically where there is shallow reef, it appears that the movement of sand is temporally 'held up'. This is evident at Roberts Point to the east of the Mandurah Ocean Entrance, where shallow reef extends north from the shoreline. A review of aerial photography by the Public Works Department (1983) identified that the reef was covered by the end of summer, but visible over winter. The explanation provided is that sand built up against the reef over summer is bypassed by the higher water levels and larger wave heights that occur over winter. It has been found that sand tends to move off Roberts Point during storm events resulting in 'slugs' arriving at Mandurah.

An additional factor that has been considered is the height to which sand builds up within the sand trap. Sand build up above the mean sea level can only be achieved by wind driven forces. Therefore, sand movement at higher water levels tends to form a higher beach. In addition, the larger wave heights, which are often associated with higher water levels, tend to form steeper beaches. Alternatively, lower water levels with calmer wave climates tend to form lower and flatter beaches. Photographs of beach profiles at Dawesville following 'stormy' and calmer winters are provided in **Figure 9**. These factors will influence the efficiency of a sand trap to capture all sand movement along the coast.

Figure 8 – Satellite image of the coastline Bunbury to Mandurah



Plan No.: 789-07-01 Date 07 March 2006
Date of Imagery: 16 December 2001

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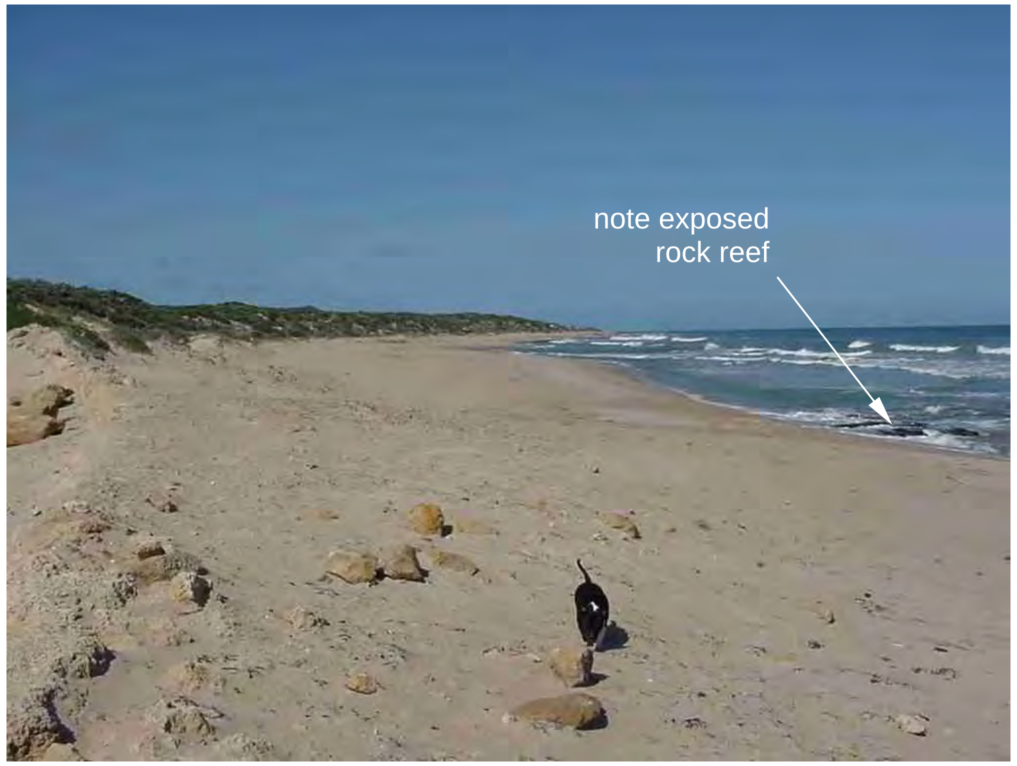
Figure 9 – Dawesville Sand Trap

September 1999 – Following a 'stormy' year note the relatively steep beach profile and high elevation at the back of the beach



December 2005 – Following a relatively calm year note the relatively flat low beach profile

4 Review of Bypass Volumes

The volumes bypassed at Dawesville and Mandurah since commencement of the sand bypassing operations are presented in **Table 1** on the following page. For comparison, this information has been reviewed against the recorded wave height at Rottnest Island and water levels at Fremantle. Volumes of supplementary bypassing, as undertaken by the City of Mandurah predominantly via trucking from Dawesville to Falcon Bay, are provided in the following **Table 2**, where known. Detailed session dates and volumes are provided in **Appendix B**.

For this analysis, the severity of the wave climate was assessed by reviewing the number of occurrences of storms containing wave heights in excess of 5m, with no consideration made to storm duration. Based upon the sum of occurrences, each year was rated as either above, below, or average for the 10-year period. The water levels were similarly rated by comparing the mean water level in each year against the average mean water level for the 10-year period.

The annual wave climate and water level are often combined to provide an indication of the ‘storminess’ of the year. Varied analysis can provide slightly different storm rating for each year; however, it is generally agreed that:

- 1996 was the stormiest of recent years, with higher than average wave heights and water levels.
- 2003 was relatively stormy, but with lower than average water levels.
- 1997 was the calmest of recent years with lower than average wave heights and water level.
- 1998 to 2001 were relatively calm, but with high water levels between 1999 and 2000.

From this information, it is possible to identify some relationships between wave climate, water level and the volume of sand bypassed. In particular, at Dawesville when the wave climate has been below average, the volume bypassed has been below the target and a longer bypassing session has been required. Most noticeably, in 1997, when the total volume bypassed was lowest, the average water level was at its lowest point since bypassing had started.

In previous years (in particular 2004), CGC have complained that there has been insufficient sand in the sand trap to bypass the target volumes of 85,000m^3 and 100,000m^3 at Dawesville and Mandurah respectively. During these years, sand has been collected from the full extents of the sand traps. Collection over a wider area resulted in a less efficient operation and longer operational period.

In comparison, it is reported that in 1996, the stormiest of recent years, a large flux of sand at Mandurah caused breaching of the sand trap and overflow into the channel.

A monitoring survey of the area is undertaken annually. A pre- and post- works beach survey, to confirm the elevation and slope of sand within the sand traps, is proposed for the next contract.

Table 1 – Recorded sand bypassing volumes

Year	Volume Bypassed (m^3)												Total Volume (m^3)	Wave Climate	Water Level
	Summer		Autumn			Winter			Spring						
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec			
1995						44,000							44,000	H	-
1996	26,000		22,000						142,000				190,000	H	H
1997	39,000					39,000			16,000		58,000		152,000	L	L
1998				75,000					105,000				180,000	L	-
1999				96,000					112,000				208,000	H	H
2000			93,000					108,000					201,000	-	H
2001		71,000						100,000					171,000	L	-
2002		92,000						100,000					192,000	-	L
2003				100,000					100,000				200,000	H	L
2004				72,000					99,000				171,000	L	L
2005				87,000					100,000				187,000		

Dawesville Mandurah

'H' – Higher than average, 'L' – Lower than average, '-' – Average

In 1994, to reduce the cut-off of sand to the north during the construction of the Dawesville Channel, 107,000m^3 was excavated from the Channel and deposited on the beaches to the north of the channel.

Table 2 – Supplementary sand bypassing volumes

Year	Supplementary Volume Bypassed by Truck (m^3)												Total Volume (m^3)
	Summer		Autumn			Winter			Spring				
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
1994													10,000
1995													14,000
1996													8,000
1997													3,000
1998													unknown
1999													unknown
2000													unknown
2001		15,000									6,500		21,500
2002													unknown
2003													unknown
2004						4,500						7,500	12,000
2005						2,200						6,100	8,300

Dawesville Mandurah

4.1 Review of Monitoring Surveys

Survey information is available at Mandurah dating back to 1978 and at Dawesville back to 1995. Sediment movement trends observed in these surveys are summarised below:

4.1.1 Mandurah Ocean Entrance 1978-1988 (pre-formal bypassing)

Pre-1995 sand bypassing was undertaken by dragline or floating dredge on an as-needed basis. The recorded dredged volumes and locations are provided in **Appendix B**. The historic surveys clearly show the formation of a shoal across the entrance from the west and extending offshore during winter/spring. Over summer, this shoal is removed and the entrance remains relatively clear.

It was noted by the Public Works Department (1983) that some natural clearing of the channel occurred at the end of autumn, when sand is still retained at Roberts Point and flows are relatively high. However, dredging tended to be undertaken over summer if the channel did not naturally clear to provide navigation access for the commercial fishing season.

4.1.2 Mandurah Ocean Entrance post-1995

An offshore bar in the shape of a ‘halo’ extending from the western training wall 400-500m offshore and back to the eastern end of the reflecting wall is present on all surveys. The position of the bar has been relatively constant. Its size has decreased to its smallest between 2000-2002 and has remained relatively stable since. The depth across the bar to the north-west has generally remained from –2.0 to –2.5m CD.

Given that the bar is not continually increasing in size, it can be assumed that it is not acting as a sink and that sand is either being moved from the bar to the northern beaches or further offshore. From observations of aerial photographs, it is generally considered that the majority of sand moving along the bar is returned to the beach 200-300m beyond the western extent of the reflecting wall.

However, the survey comparison plot January/May 1998 to May 1990 (DOT 041-57-01) shows the slight deposition of sediment 100m to the north-east (offshore) of the bar. Sand deposited to this area, although not lost from the transport system, is unlikely to return as quickly to the northern beaches. It may continue to travel northward, but at a distance offshore.

The survey comparison plot February 1999 to June 1995 (DOT 041-62-01) shows slight accretion within the channel approximately 500m from the head of breakwaters, but otherwise a relatively constant depth of –2.5m to –3m across the entrance. The deposition may be the result of the underlying rock sill known to be present across the entrance.

4.1.3 Fairbridge Bank

Siltation occurs on the western side of the channel towards the ocean entrance forming a bank, which extends from the vicinity of Port Mandurah’s northern entrance to Mary St Lagoon. This bank, or sand bar, is referred to as Fairbridge (Road) Bank and can be seen in **Figure 10**. The ongoing siltation of Fairbridge Bank necessitates maintenance dredging at the northern entrance to Port Mandurah and, on occasion, the entrance to Mary St Lagoon. However, this does not affect navigation of the ocean entrance. This work is undertaken by the City of Mandurah and is not within the scope of the current sand bypassing contract at the ocean entrance.

Determining the source of sediments accumulating on Fairbridge Bank is difficult as siltation is the result of a number of complex processes. Suspended sediments can enter the channel from both the ocean and the estuary. Factors that affect the volume of sediments in suspension and the rate of siltation within the channel include:

- rainfall and overland flow rates, with particular consideration to flood events;
- mean sea level; and
- number, severity and duration of storms.

The channel bed levels have been compared to the recorded flow rate for the Murray River; however, no relationships between flow rates and sediment accession or erosion were identified. To an extent, this may be because no significant floods, i.e. greater than 1 in 10 year return period, have occurred in recent years. In addition, mean sea level and storm activity can vary substantially from year to year.

Prior to commencement of the formal bypassing, the rate of deposition within the channel was high, typically starting with a lobe at the entrance. The current rate of deposition, although persistent, is relatively small. It is unlikely that the bypassing in itself is the cause of sedimentation within the channel. Excavation of sand from the beach can cause localised turbidity; however, this is insignificant compared to the movement of sediments that can occur under storm or flood conditions.

It has previously been suggested that the offshore sand bar at Mandurah is the source of sediments deposited on the Fairbridge Bank and that increasing the volume bypassed would reduce deposition to the bar and subsequently reduce Fairbridge Bank. Increasing the volume bypassed, if possible, is likely to reduce the size of the offshore bar. However, there is no clear relationship between the size of the offshore bar and deposition within the channel. Under storm conditions, sand can be mobilised from the entire seabed area offshore from Mandurah Ocean Entrance.

The review of ongoing hydrographic surveys and aerial photos can provide measurement of the long-term trends of deposition within the channel. However, as the actual bed level changes are relatively small, determining short-term changes (i.e. over one month, or <200mm) is extremely difficult, as changes in bed level are beyond the accuracy of current hydrographic measuring techniques.

Figure 10 – Mandurah Ocean Entrance (extract from M Rogers, 2004)

4.1.4 Dawesville Channel post-1995

Review of monitoring surveys from February 1999, March 2000, March 2002, February 2003 and February 2004 indicates that the –2m CD contour is approximately 30m closer to shore on the 1999 and 2000 surveys. However, these surveys were collected during the sand bypassing operations and therefore may not provide a true representation. Nonetheless, the steeper beach profiles in 1999 and 2000 correspond to higher than average water levels and wave climate.

Sand accretion is evident to the south of the southern groyne, in a bar offshore from the entrance. It would appear that construction of the southern groyne has caused the build up of sand close to the beach for approximately 1km south, however this now appears to have stabilised with no further increase between February 2004 and March 2005.

JFA's 2005 review of sand volumes identified the general trend for the ocean entrance to be one of stabilisation in 2004 and 2005 following relatively heavy accretion in 2001, 2002 and 2003. It is interesting to note that in 2001, the sand bypassing volume was well below the target, corresponding to a below average wave climate and an only slightly above average water level.

It is possible that when the wave climate and/or water level is lower than average, a lower and flatter beach is formed. Under these conditions, the current sand trap and bypassing method are likely to be insufficient to capture the littoral drift, as the toe of the beach will extend beyond the trap. In these years, it is possible that although a smaller overall volume of sand is moving naturally along the coast, a larger than average volume is 'leaking' around the sand trap to the offshore bar.

4.1.5 Coastal Movement Trends

Historic coastline alignments taken from aerial photographs do not show any significant areas of accretion or erosion in the areas up and down drift of both entrances. This is a good indication that the bypassing is not having any significant adverse effect on the coastal processes by over or under bypassing and that there are no significant sediment sinks within the system.

Between Dawesville and Mandurah, there are areas experiencing localised erosion or accretion. However, this is likely to be resultant from the local rock reefs and bathymetry and cannot be reasonably associated with the bypassing operations.

4.2 Summary

The total rate of littoral drift along the coastline is greater than the volume mechanically bypassed. This is evident by the presence of sand bars at both Dawesville and Mandurah. Possible sinks are evident at Dawesville down drift of the groyne (now probably saturated) and offshore from the sand bar at both entrances. However, in review of the coastline movement plots, there are no significant variations in the coastal alignment up or down drift of either location. Between Dawesville and Mandurah, there are areas that are experiencing localised erosion, for example Falcon; however, this is likely to be a result of the local rock reefs and bathymetry rather than the bypassing operations.

5 Options for Improvements to Current Operations

The current operating system has been successful in maintaining a navigable channel at both Dawesville and Mandurah. Since the bypassing commenced in 1995, minimal additional dredging or excavation has been required.

However, additional factors such as potential conflict with beach users and residents have prompted a review of the current operations. This section provides recommendations for the future operations at Dawesville and Mandurah.

5.1 Sand Trap Areas

Further increasing the depth or length of the sand traps is not considered feasible due to the shallow underlying rock, the increased pumping distance and the narrow beach width. Increasing the sand traps by extension of the rock groynes, although likely to be effective, is not currently considered as financially justified.

5.2 Target Volumes

The current target bypassing rates and volumes for Dawesville and Mandurah are:

- Dawesville: 4,500-7,000m^3/week and 85,000m^3/year
- Mandurah: 4,500-7,000m^3/week and 100,000m^3/year

These targets were previously estimated to capture only the nearshore littoral drift. With the current sand trap arrangements and plant, there is little scope for increasing these bypassing volumes, except under years of high wave heights and/or water levels. Currently during lower wave height/ water levels years (when the beach is lower and flatter), it has been difficult to achieve the existing targets.

In review, the offshore sand bar at each entrance appears relatively stable and only results in a slight loss of sand from the nearshore sediment balance. Similarly, the beaches up/down drift and channels do not appear to be experiencing significant levels of accretion or erosion. It is therefore recommended that the existing annual bypassing targets be maintained.

Consideration has been given to increasing the bypassing volumes to improve navigation, in particular at Mandurah, with the intention of reducing siltation within the channel and on the offshore bar. Dawesville is naturally deep and the current depth across the sand bar, of around –6m CD, is more than adequate to maintain the current boating demands. The depth across the bar at Mandurah has generally remained from –2.0m to –2.5m CD north-west from the entrance.

Neither Dawesville nor Mandurah are declared channels with a designated maintained depth. The previous *Channel Depth and Mooring Study*, undertaken by the Department of Transport (1999), analysed the boating demand for Mandurah Ocean Entrance and Marina. Given the high cost associated with deepening and maintaining a deeper channel, a target depth of –2.5m CD was recommended. At the time, this analysis found that a depth of –2.0m CD allowed unrestricted access to 98.5% of the private vessels registered in the Peel region.

Increasing the target bypassing volume at Dawesville is not currently considered necessary. Increasing the target volume at Mandurah may improve navigation across the offshore bar and may, without any guarantee, reduce siltation within the channel and at Fairbridge Bank.

However, this increase is not currently considered financially viable, due to the high costs associated with increasing the bypassing volumes within the current operations.

5.3 Bypassing Schedule

The current bypassing is generally undertaken at Dawesville over summer/autumn and in Mandurah over winter/spring. Both sites now form popular beaches, in particular during the summer months and holiday periods. However, the current land-based plant (or any similar bypassing plant) is limited to operation at one site at a time and currently operations at each site can take up to six months to complete.

Therefore, using the current plant, it is recommended that the existing bypassing schedule be maintained because:

- Sand moving along the coast to Mandurah tends to be ‘held up’ on the reef at Robert Point and only reaches Mandurah over winter;
- Dawesville is more exposed to the increased storm activity, which occurs over winter. Operation during winter at Dawesville is likely to result in increased downtime due to adverse wave conditions; and
- Multiple remobilisation between sites would significantly increase the cost of the operations.

It is however recommended that no bypassing using heavy machinery be undertaken during the peak summer beach use periods, principally school holidays, during December and January. If an alternative bypassing system is adopted, consideration should be given to rescheduling of bypassing times.

5.4 Alternative Bypassing Options

Alternatives to the current system include the use of a fixed pump arrangement. Various fixed pump systems are currently in use around the world. Some of the advantages and disadvantages of adopting a fixed pump arrangement are summarised in the following table.

Table 3 – Advantages/Disadvantages of a Fixed Pump Bypassing System

Advantages	Disadvantages
Relatively low running ongoing costs.	Relatively high capital costs.
Minimal disruption to beach users; no requirement to close large sections of the beach.	Excavation of the underlying rock is likely to be required to extend the sand trap.
Bypassing can be undertaken at night to minimise visual impact at the disposal site.	Existing system is proven; the success of an alternative system can only be assumed.
Bypassing can be undertaken on a regular basis, throughout the year to prevent a large build up of sand at any one location.	Sand movement is typically seasonal and in ‘slugs’ following storm events. This may cause ‘flooding’ of a fixed system.
Operational under the majority of wave / weather conditions.	The current rock groyne arrangement may not be appropriate.

Improved safety and aesthetics by removal of heavy plant from the beach.	Potential problems with both seaweed and rock unknown.

The feasibility of using a fixed pump arrangement has previously been investigated for both Dawesville and Mandurah. It is considered that such a scheme would be easier to implement at Mandurah, due to the slightly increased sand depth, but could be designed to operate efficiently at both locations.

Combined options such as using fixed pumps with additional mobile inlets on cable or similar should be considered. Such schemes would allow the collection of sand bypassing fixed inlets. Previous fixed bypassing concepts and designs are provided in **Appendix D**.

5.5 Supplementary Bypassing by the City of Mandurah

The City of Mandurah currently bypasses sand by excavator and truck from the Dawesville sand trap, and occasionally the Mandurah sand trap, for disposal to Falcon Beach to alleviate erosion, typically prior to Christmas. The volumes bypassed are not well defined, but have been up to 20,000m^3/year. There is no designated excavation area and sand is typically excavated from above the mean water level. In previous years, this has impacted on the overall bypassing operations. However, DPI is currently coordinating with the City of Mandurah to ensure that any additional bypassing is beneficial to the overall bypassing.

It is recommended that future excavation by the City of Mandurah be undertaken at the northern end of the sand trap but, more importantly, that a significant proportion of the excavation area extend beyond lower low water level. This will provide the maximum opportunity for the excavation to infill and reduce the likelihood of the excavation forming a trap for seaweed or debris. Excavation undertaken in this manner would be most beneficial if undertaken during or at the end of winter when the sand trap is full, as it would reduce sand ‘leaking’ around the spur groyne.

5.6 Disposal Areas

The current disposal areas appear to provide relatively efficient dispersion of spoil to the down drift areas. However, extension of the disposal pipeline from Dawesville to Falcon Bay, by approximately 2.8km, to allow some disposal directly to Falcon is under consideration. This would preclude the current requirement for trucking undertaken by the City of Mandurah. In addition, intermediate pipe outlets at additional locations could be considered to further improve spoil dispersion.

The installation of the additional pipeline is considered feasible, but at a capital cost, and would require additional booster pumps to operate. Post-installation, the cost of bypassing by pipe as compared to trucking is considered fairly similar.

At Mandurah, it is recommended that spoil disposal to the end of the reflecting wall be maintained. However, it is suggested that a trial be undertaken to dispose of spoil to the seaward face of the reflecting wall, at its eastern end, to assess the dispersion to the beach. Under south-westerly swell conditions, it is likely that the disposed spoil would rapidly be driven to the beach. If successful, an outlet layout similar to the one provided in is recommended. A balanced dispersion either side of the reflecting wall would ensure that the corner of the beach is maintained, but also that the visual impact of disposal is minimised. In combination with this scheme, it is recommended that the practise of ‘rainbowing’, although more efficient at dispersion to the beach, be avoided to further improve aesthetics. With the use of a number of outlets, rainbowing is considered unnecessary to disperse sediments.

Further aesthetic improvements could be made to the operations by using electric motors instead of diesel. This would greatly reduce the noise generated by the operations.

5.7 Fairbridge Bank

The primary aim of the bypassing operations is to continue the natural movement of sand along the coast and, in doing so, maintain a stable coastline and minimise the requirement for dredging the entrance channels. As previously discussed, the formation of Fairbridge Bank may not be directly related to the bypassing operations; however, options to assist the City of Mandurah have been considered.

One option is to bypass additional sand. Increasing the volume bypassed at Mandurah by 50%, to 150,000 m^3/year, is estimated to capture the majority of sand passing the entrance. This may reduce the size of the offshore sand bar and, in turn, may reduce the siltation of Fairbridge Bank according to some beliefs. However, this option is not considered cost-effective for the following reasons:

- The current capacity of the sand trap at Mandurah does not allow the collection of a volume of sand much greater than the existing bypassing target. Expansion of the sand trap, by extension of the training wall, would be required for the current bypassing system.

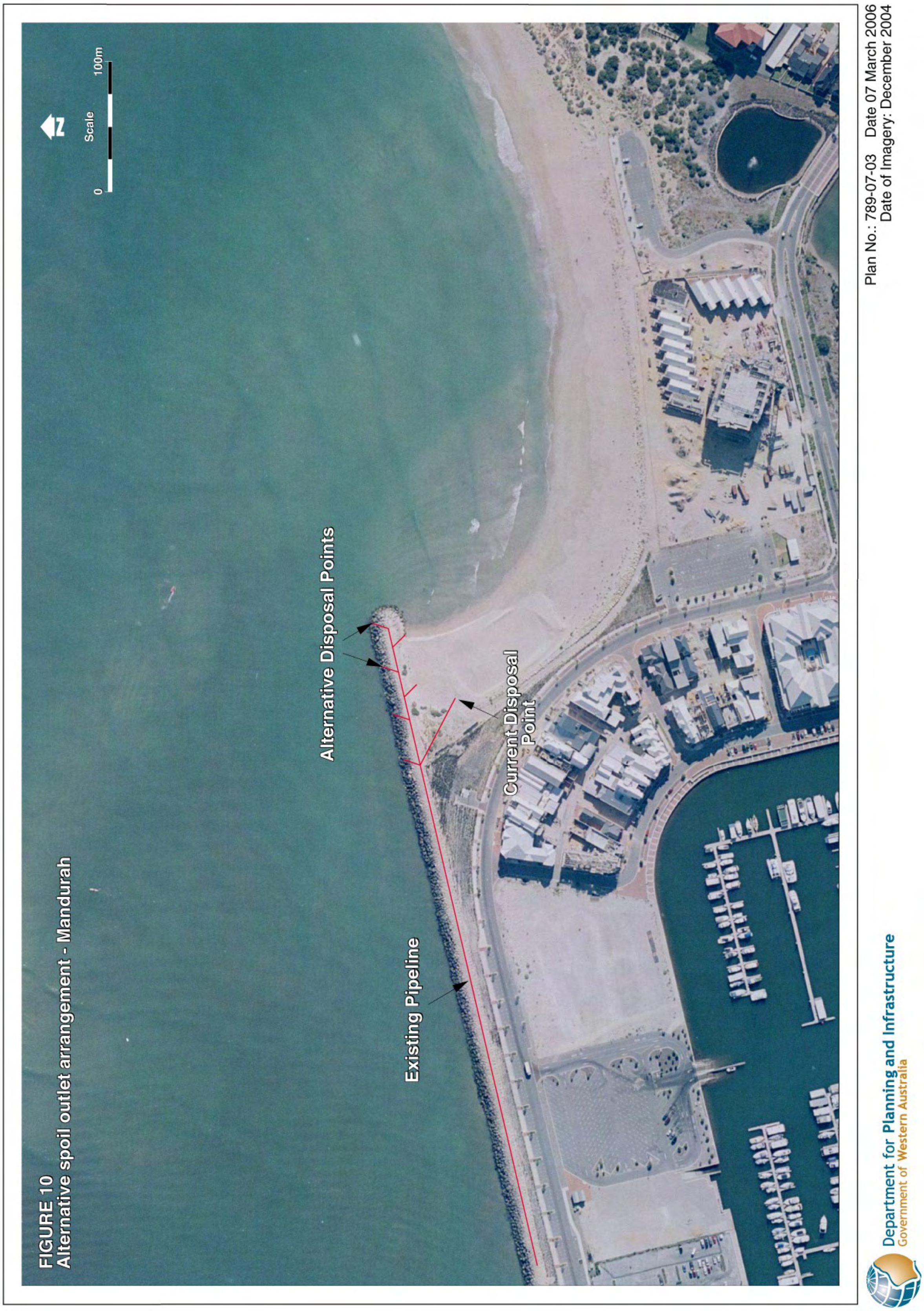
- Increased bypassing and removal of the offshore sand bar may not reduce the formation of Fairbridge Bank. The area offshore from the ocean entrance is shallow and under storm conditions sand may be mobilised from any portion of the seabed.

- The cost of the increased bypassing would far outweigh the cost of separate mobilisation of a small dredge to undertake the maintenance of the channel, especially if this dredging could be combined with other maintenance dredging of the canals or marina.

Turbidity during the excavation works is unlikely to be a significant factor causing siltation within the channel. The volume of sediments mobilised is insignificant in comparison to the mobilisation during a storm, or flood event.

Options are available for the disposal of dredged spoil from the channel to the sand bypassing disposal area using the existing pipes. This has previously been done; however, is dependant upon the properties of the material dredged from the channel, with particular regards to the aesthetics of the beach. Sediment tests could be undertaken to determine the type of material (silts or sands) and the likelihood that it will be anaerobic (black in appearance and odorous) when discharged to the beach.

Figure 11 – Alternative Disposal Locations at Mandurah



6 Recommendations

6.1 Recommendations for Current Operations

A balance is required between maintaining the local and regional beach amenity, while minimising the disruption to beach users and local residents. The following recommendations are provided for the current operations:

- Maintain the existing bypassing target volumes.
- Maintain the current bypassing schedule, targeting Dawesville over summer/autumn and Mandurah during winter/spring. However, exclude operations during the peak summer beach use periods, principally school holidays, during December and January.
- Maintain the current sand trap areas.
- Maintain the current disposal location at Dawesville. However, consider the option of split disposal to Falcon Bay. This should consider the relative cost compared to trucking and the availability of land for siting the pipeline and booster pumps.
- Trial alternative disposal locations at Mandurah with the aim of providing multiple disposal outlets on both sides of the reflecting wall and refraining from disposal by ‘rainbowing’. This recommendation is aimed at improving aesthetics.
- Collection of pre and post dredge surveys for each sand trap to determine the relative elevation and slope of the beach. This will allow a quantitative comparison of the sand available for bypassing each year.
- Ongoing diligent management of potential safety conflicts with beach users. This should include a review of current signage.
- Review the methods for calibrating the bypassing rate / volume as a method for determining payment. Accurate calibration will also be a requirement for future tenderers.
- Supplementary bypassing by the City of Mandurah should be undertaken such that excavation within the Dawesville sand trap:
    - takes place at the northern end of the sand trap;
    - has a significant proportion extending beyond lower low water level; and
    - is undertaken during or at the end of winter.

6.2 Recommended Further Research

It is recommended that the following items be addressed prior to tender for the next contract, to ensure that adequate information can be provided to future tenderers proposing the use of alternative systems:

- Finalisation of land tenure arrangements for all pipelines and associated infrastructure. This is to ensure that there are no restrictions on future maintenance or replacement of the existing infrastructure.
- Assessment of pumping requirements sufficient to determine: if electrical pumps could be installed as an alternative to diesel booster pumps; the benefits of DPI installing such pumps for use by potential tenderers; and the associated electrical supply requirements.

- Assessment of an optimum location for the pipeline crossing at Mandurah to minimise restrictions on the channel's depth as well as methods for pipeline removal and replacement.
- Assessment of the volumes and types of seaweed moved along the nearshore with the potential for disrupting bypassing.
- Detailed geotechnical investigation, using probing, to determine the level of the underlying rock throughout the two sand traps. It is also recommended that bore hole samples are collected in the area of the sand traps where rock excavation is likely to facilitate a fixed pump system.
- Collection of sand samples to determine the typical variation in grain size throughout the sand traps, as this will particularly influence pumping requirements.
- Assessment of the required bypassing volumes and rates for a fixed system. A fixed system, operating throughout the year, may capture a larger percentage of the sediment drift.
- Review of current and forecast boating demand for Mandurah Ocean Entrance. Requirements to maintain or increase the current channel depth by increasing the volumes bypassed will need to be specified for future tenderers.
- Review of the environmental requirements for turbidity thresholds, in particular at the disposal locations. Restrictions on turbidity levels may influence the tenderers' selection of pumps and other equipment.

6.3 Subsequent Investigations

DPI is working closely with the City of Mandurah to ensure that the desired project outcomes are met. Following the first draft of this report, a number of the recommendations listed have been implemented. The subsequent work undertaken includes:

- Cost analysis of beach nourishment options at Falcon Bay.
- Review of pumping requirements, including options for the installation of electric motors and assessment of the bypassing rates.
- Detailed rock probing of both sand traps to map underlying rock.
- Collection of sand samples to determine grain size distribution within the sand traps (report included as **Appendix E**).

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Appendix A
Geotechnical Information

Appendix B
Bypassing Volumes & Dates

Appendix C
Survey Information

Appendix D
Previous Fixed Bypassing Design

Appendix E
Analysis of Sediment Samples