Comparison of Turbidity Concentrations Resulting from Dredging at the Outer Bar Cutting

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	Synopsis:	Measurement of the dredging plume turbidities from the PBC dredger *Brisbane* and a comparison with previous results for the *Brisbane* and *Sir Thomas Hiley*.

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1 EXECUTIVE SUMMARY

The Port of Brisbane Corporation (PBC) operates dredging plant to maintain navigable water depths within declared channels. From the 1970's until November 2000, the Corporation operated the *Sir Thomas Hiley*, a trailing arm suction dredger as the principal dredger for maintenance of navigable channels within the Port of Brisbane. In November 2000, the *Sir Thomas Hiley* was replaced with the new dredger *Brisbane*, which was purpose-designed and built for PBC.

Originally, WBM Oceanics Australia undertook turbidity measurements within sediment plumes generated by the *Sir Thomas Hiley* whilst dredging the Outer Bar Cutting of the Brisbane River in September 1995. Similar turbidity measurements were made during dredging of the Outer Bar Cutting by the *Brisbane* in January 2002 to document potential improvements in the dredging plumes resulting from operation of the then new dredger *Brisbane*. These measurements were recently repeated in February 2004, following a change to the operational method of dredging fine sediments. This report examines the nature and longevity of turbid plumes created by the *Brisbane* during maintenance dredging of the Outer Bar Cutting in February 2004.

The dredging method currently used by the *Brisbane* in soft marine mud and silt differs from that used in 2002. The difference is that each hopper load of dredged material now involves only a minimal hopper discharge. Compared with the previous mode of dredging operations, dredging is undertaken for only 10-15 minutes after the hopper begins to overflow and discharge. The change to the mode of dredging was an important reason for repeating turbidity plume measurements whilst the *Brisbane* was dredging muddy-silty sediments.

Prior to hopper overflow, the turbidity measurements showed a small increase in near-bed turbidities resulting from dredging. Surface and midwater turbidities were also slightly elevated compared with the pre-dredging turbidity. The slight increase in turbidity in the water column appears to have resulted from a small leak of sediment from the hopper of the *Brisbane*. The aerial photographs show a faint turbidity plume evident from the stern of the *Brisbane*, prior to hopper overflow.

Following hopper overflow, there was an increase in surface and mid-depth turbidity with a corresponding decrease in the surface water clarity. By comparison, the near-bed turbidity levels remained at low levels in the minutes immediately following the passage of the dredger. Comparative initial surface and mid-depth turbidities within the hopper overflow plume were approximately half the turbidity levels measured in February 2002. Similarly, the water clarity initially measured in the dredge plume was double that measured in 2002.

Approximately 45 minutes after dredging, turbidity levels in the upper section of the water column were approaching pre-dredging levels. Between 1 ¼ to 1 ½ hours after dredging, the turbidity levels at all locations in the water column had fallen to pre-dredging levels.

The dredging plume turbidity measurements compiled for the *Brisbane* in 2004 compared favourably with those recorded for the *Brisbane* in 2002 and *Sir Thomas Hiley* in 1995. The initial plume turbidities at all depths were much lower than previous measurements and the time for settlement of suspended material within the dredge plume to pre-dredging concentrations was shorter than or consistent with prior measurements.

The suspended solids concentrations in hopper overflow water samples collected from the *Brisbane* in 2004 were much lower and had a smaller range from the start of the hopper overflow to the end of dredging than previous dredging episodes. The maximum suspended solids concentration in the hopper overflow was approximately 3 times lower than the peak concentration from the *Sir Thomas Hiley* in 1995 and 1.5 times lower than that from the *Brisbane* in 2002. The lower concentrations of suspended solids in hopper overflow were consistent with the lower measured dredge plume turbidities and the lower visual intensity of the plume as evidenced from secchi disc measurements and aerial photographs. The change to the mode of dredging on the *Brisbane* has resulted in higher retention of fine sediments in the hopper and a hopper overflow plume that has a lower concentration of suspended solids when compared to previous operating procedures.

Comparison of aerial photographs of dredging plumes from the *Brisbane* in 2004 and 2002 and *Sir Thomas Hiley* in 1995 indicates that the plume dimensions and their apparent spread and form were comparable. The main difference was that the dredging plumes generated by the *Brisbane* in 2004 did not appear as initially turbid as those generated in 2002 or in 1995.

2 INTRODUCTION

The Port of Brisbane Corporation (PBC) operates dredging plant to maintain navigable water depths within declared channels. From the 1970's until November 2000, the Corporation operated the *Sir Thomas Hiley*, a trailing arm suction dredger as the principal dredger for maintenance of navigable channels within the Port of Brisbane. In November 2000, the *Sir Thomas Hiley* was replaced with the new dredger *Brisbane*, which was purpose-designed and built for PBC.

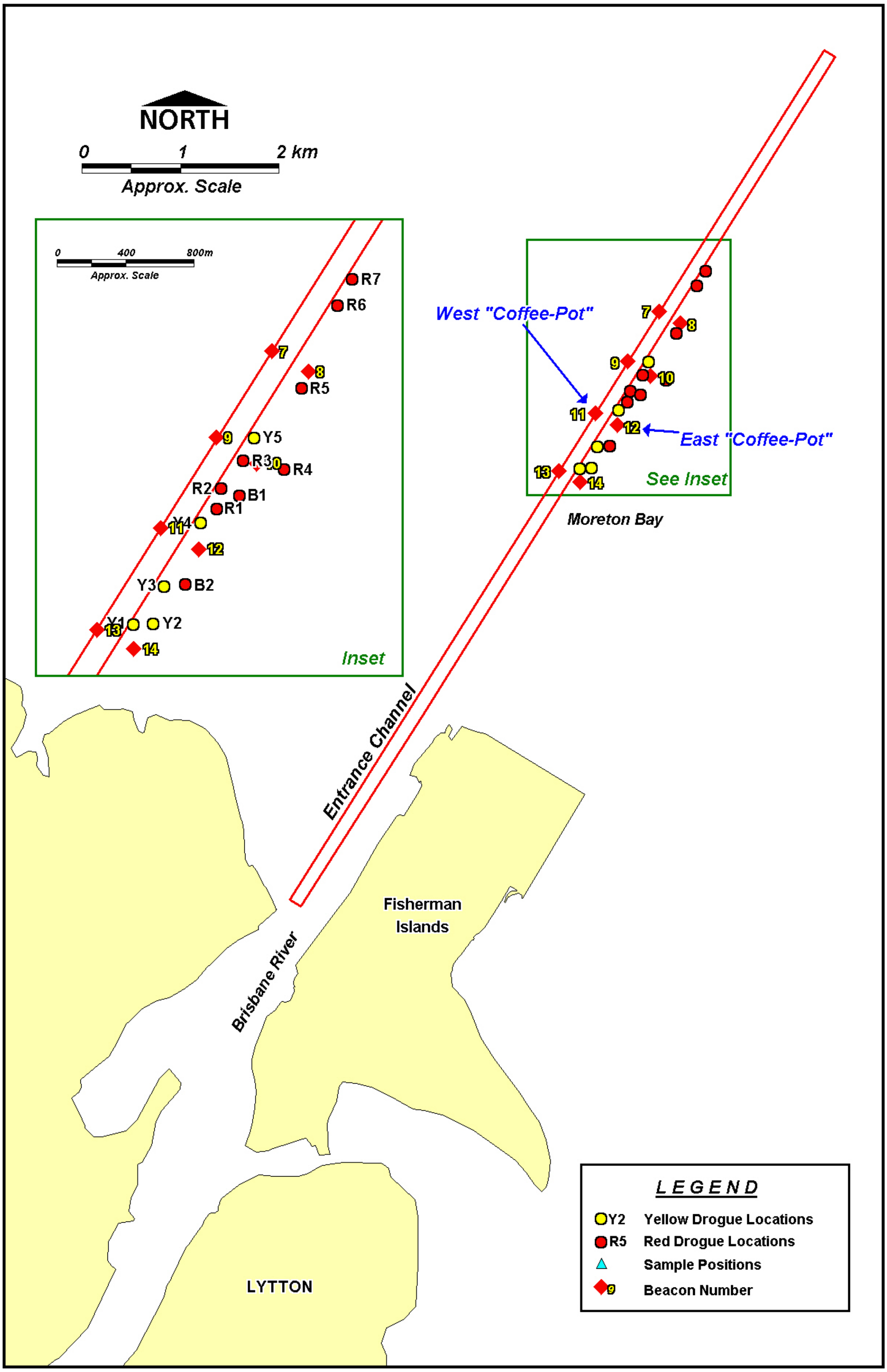
The two vessels are similar, being trailing arm suction hopper dredges. The *Brisbane* has a larger hopper capacity (2,900m^3) than the *Sir Thomas Hiley* (approx 2,000m^3). The other principal difference is the method of hopper discharge during loading. The Corporation specified a single hopper discharge at keel level in the *Brisbane*, whereas the *Sir Thomas Hiley* discharged via two overflow ports (one on each side) at deck level.

The revised hopper design on the *Brisbane* results in discharge of hopper overflows at depth (some 5m below surface), as opposed to discharging the hopper overflow above the water surface and therefore provides a greater opportunity for material settlement and reducing plume dispersion. The central hopper overflow on the *Brisbane* consists of a telescoping central weir, which allows more control over the overflow, potentially allowing greater sediment retention within the hopper and reduced suspended sediment concentrations in the overflow water from the hopper.

Originally, WBM Oceanics Australia undertook turbidity[1] measurements within sediment plumes generated by the *Sir Thomas Hiley* whilst dredging the Outer Bar Cutting of the Brisbane River in September 1995 (WBM Oceanics Australia, 1997). Similar turbidity measurements were made during dredging of the Outer Bar Cutting by the *Brisbane* in January 2002 to document potential improvements in the dredging plumes resulting from operation of the then new dredger *Brisbane* (WBM Oceanics Australia, 2002). These measurements were recently repeated in February 2004, following a change to the operational method of dredging fine sediments. This report examines the nature and longevity of turbid plumes created by the *Brisbane* during maintenance dredging of the Outer Bar Cutting in February 2004.

As the percentage of material released into suspension by hopper overflow depends upon the characteristics of the sediment to be dredged, the same working area was specified for the *Brisbane* as was previously used for the *Sir Thomas Hiley*. The dredging area specified consisted of fine-grained (silt/sand) sediments from the Outer Bar Cutting in the vicinity of the 'Coffee Pots' (beacons 11 and 12) between beacon pairs 9 and 10 and 13 and 14 (refer to Figure 2.1). Dredging was scheduled for the morning of Thursday 19th February 2004 with a favourable light wind forecast and ebb tidal conditions similar to those in 1995 and 2002 (2.1m ebb tidal range, compared to1.8m in 2002 and 1.9m in 1995). Weather conditions on the day were fine and sunny. Light northerly winds less than 5 knots were experienced until approximately 0930 hours, followed by a building northerly wind to 10-12 knots by noon.

[1] Turbidity is a measure of the clarity of water. The turbidity or cloudiness of water, which increases relative to the amount of material in suspension, is measured in 'NTU' (nephelometric turbidity units, from the Greek *nephele* meaning cloud). By contrast, the concentration of suspended solids in water is measured in mg (of suspended matter)/L (of water) from a water sample.



Locality Plan
- Outer Bar Cutting, Brisbane River

Figure 1.1

3 METHODS

The master of the dredge *Brisbane* was briefed by PBC personnel on the proposed turbidity measurement exercise and was asked to execute maintenance dredging of the Outer Bar Cutting on the morning of Thursday 19th February 2004. His brief was to replicate all aspects of a normal maintenance dredging exercise, concentrating on the removal of sediment from the eastern toeline of the shipping channel, between navigation beacon pairs 9, 10 and 13, 14.

Dredging of the channel began in the vicinity of beacon 14 shortly after high water (at approximately 0935hrs) and dredging progressed in a seaward direction to the vicinity of beacon 10, whereupon the *Brisbane* turned and dredged the same area of the channel whilst moving into Port. Both port and starboard suction dragheads were operational whilst dredging. Dredging was completed at approximately 10:10 and the *Brisbane* continued into Port to discharge the dredged sediments at the Fisherman Islands pump-out (Berth No.8).

Turbidity measurements were undertaken from the survey vessel Resolution II which was able to communicate and co-ordinate measurement and sampling activities with the *Brisbane* via VHF marine radio channel 12. Aerial overflights and photography of the dredging operation and the turbid plumes residual from dredging were co-ordinated by mobile phone with WBM personnel at Hempel Aviation at Archerfield airport. A single engine fixed wing aircaft was used to collect oblique aerial photographs of the dredging area and the turbid plumes created by dredging operations. Aerial photography was planned to coincide with the start of dredging, and approximately 1 hour after dredging. The first aerial photographs were captured prior to overflow of the dredge hopper at approximately 0935 hrs (approximately 1/2 an hour after local high water). The plane remained on station to collect further photographs of the turbid plumes from the *Brisbane* during overflow dredging before returning to Archerfield. The second and final flight for aerial photography occurred approximately 1 ¼ hours after the conclusion of dredging with the first photographs at approximately 11:30.

Prior to the start of dredging, Resolution II was positioned between the Coffey Pots (beacons 11 and 12) and beacons 9 and 10 to collect background turbidity measurements and water samples. During dredging, representative turbidity measurements were collected within the stern wake of the *Brisbane* before and after the overflow of sediment-laden water from the sediment hopper. Turbidity measurements and suspended solids samples were collected for a further 2 hours following the conclusion of dredging. Drogues of the type shown in Figure 3.1 were used to mark and re-locate the dredging plumes. The vanes of each drogue were positioned at a depth of 3-4m below the water surface, which allowed them to move freely from the shipping channel to shoal banks either side of the channel.

Turbidity profile measurements from the water surface to depths close to the bed of the channel were recorded using a using a YSI model 6600 water quality instrument connected to a YSI Model 650 multiparameter display unit. The instrument's turbidity sensor was two point calibrated before use in distilled water (0.0 NTU) and in a 100 NTU polymer bead solution. On each profile, water depth and turbidity were measured at 5-second intervals as the sonde was lowered in 2m depth increments to the seabed. A Secchi disc deployed from the survey vessel was used to record the surface water clarity.

To provide a relationship between turbidity and suspended solids in the vicinity of the Bar Cutting, background and dredging overflow plume water samples were collected for suspended solids analysis coincident with turbidity measurements. Samples of the hopper overflow water were also collected at regular intervals during dredging, by PBC personnel aboard the *Brisbane*. These samples were collected to provide a comparative measure of the mass of suspended solids lost via the hopper overflow. (Similar samples were collected in 1995, from the deck overflow on the *Sir Thomas Hiley*, and in 2002 from the *Brisbane*).

Spot measurements of dredging related turbidity and collection of coincident water samples for suspended solids analysis and secchi disc measurements were begun east of beacon 14 after the seaward passage of the dredger at approximately 09:45. These measurements were initially focussed on the resultant water turbidity before hopper overflow and a yellow drogue was launched to mark the measurement location. Plume measurement activities were next transferred to the vicinity of beacon 10, where the *Brisbane* had recently turned and begun dredging into Port. At this time, the *Brisbane* had been in hopper overflow mode for approximately 10 minutes and a second red drogue was launched into the stern wake of the *Brisbane* where the visible intensity of the turbid hopper overflow plume was greatest. On the return dredging track into Port, the *Brisbane* passed very close to the yellow drogue. The location of the yellow drogue was later visually confirmed as being representative of the overflow plume location close to the end of dredging (i.e. approximately 18 minutes after the start of hopper overflow).

Each of the drogues was tracked for approximately 2 hours until the dredging related plume was no longer visible or evident from the turbidity measurements. Approximately 35 minutes after deployment of the red drogue, it was re-located approximately 200m south of its original position to the then visible centre of the turbid plume.

Six hopper overflow samples collected aboard the *Brisbane* and 20 background or plume water samples from the Outer Bar Cutting were analysed for suspended solids by Australian Laboratory Services Pty Ltd at Stafford.

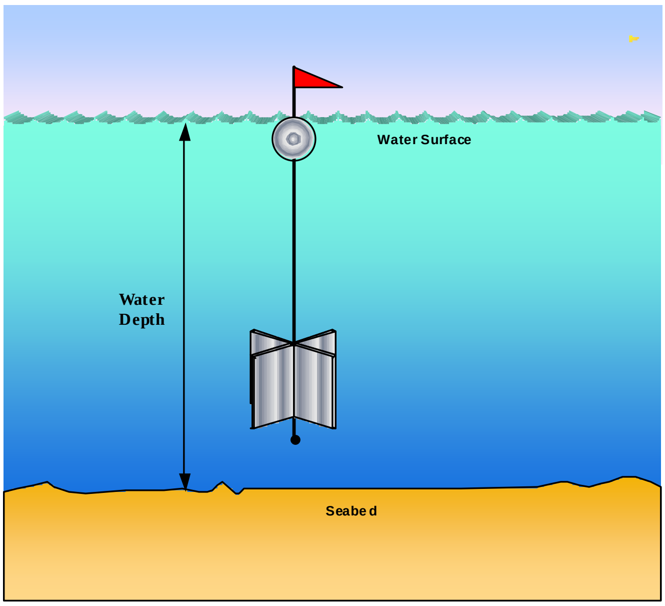


Figure 3-1 Typical Drogue Configuration

Table 3.1 summarises the field conditions and timetable of dredging and aerial surveillance activities undertaken as part of the dredge plume monitoring on 19th February 2004.

Table 3.1 Schedule of Events on 19th February 2004

Time	Event	Comments	Field Conditions
09:02	High water – 2.54m	Predicted time and level of local high water.	Fine conditions, clear sky, light north wind at 2-5 knots. Predicted ebb tidal range of 2.1m
09:15 – 09:32	Background turbidity profile measurements and water sample collection.	Turbidity measurements at Coffey Pots (beacons 11, 12) and beacons 9, 10.	
09:34	*Brisbane* starts dredging	Dredging commences just seaward of beacon 14	
09:37	Charter plane arrives on site	First aerial photos captured soon after the start to dredging.	
09:44	Undertake turbidity measurements before hopper overflow and collect water samples	Turbidity measurements adjacent to yellow drogue. Continue to track drogue and collect turbidity measurements.	
09:50	Hopper overflow begins on *Brisbane.*	Hopper overflow begins when *Brisbane* is seaward of beacon 12 (East Coffey Pot).	
10:00	Undertake turbidity measurements after hopper overflow	Turbidity measurements after *Brisbane* has turned into Port, adjacent to red drogue. Continue to track drogue and collect turbidity measurements.	
10:10	Dredging concludes and plane returns to Archerfield		
11:25	Charter plane returns to site.	Aerial photos captured between 11:30 and 11:50. Plane returns to Archerfield.	
12:15	Conclude turbidity profiling measurements and water sample collection.		Fine conditions, clear sky, north wind at 12 knots. Tide ebbing strongly. Predicted time of low water is 15:46.

4 RESULTS

A summary of the turbidity results for the ebb tide dredging of the Outer Bar Cutting by the *Brisbane* on the 19th February 2004 is presented in Table 4.1.

Table 4.1 Outer Bar Cutting Turbidity Profiles, 19th February 2004

Time (h) *(Background - Before Dredging)*	Total Depth (m)	Depth	Turbidity (NTU)	Secchi Disc Visibility (m)
9:15	14.0	surface mid-depth bed	1.7 - 2 2.2 - 2.9 3.2 - 4.3	2.5
9:30	15.0	surface mid-depth bed	1.8 - 2.4 2.3 - 2.4 2.2 - 6.8	2.2
Time (h) ***(Start Dredging at 0934, Hopper Overflow starts at 0950, Finish Dredging at 1010)***	**Total Depth (m)**	**Depth**	**Turbidity (NTU)**	**Secchi Disc Visibility (m)**
09:45 *(before hopper overflow)*	9.0	surface mid-depth bed	4.2 - 6.7 4.2 - 5 3.4 - 18.1	1.7
10:00 *(after hopper overflow)*	11.5	surface mid-depth bed	32.1 - 46.4 8.3 - 31.9 5.2 - 14.3	0.4
10:12	9.0	surface mid-depth bed	16.3 - 18.3 15.9 - 29.2 4.2 - 39.7	0.5
10:25	8.0	surface mid-depth bed	9.3 - 11.7 4.7 - 10.1 4.3 - 33.1	0.7
10:38	9.0	surface mid-depth bed	4 - 7.4 2.3 - 3.3 2.4 - 32.1	1.4
10:56	8.0	surface mid-depth bed	1.9 - 2 3.1 - 4.1 3.6 - 22.8	2.3
11:02	7.0	surface mid-depth bed	6.8 - 7.8 3 - 5.9 3 - 4.9	1.9
11:20	9.5	surface mid-depth bed	3.1 - 4.3 3 - 3.8 3.1 - 10.2	2.1
11:35	13.5	surface mid-depth bed	2 - 2.2 2.2 - 3 2.4 - 4.6	2.6
11:55	13.0	surface mid-depth bed	2.3 - 2.7 2.4 - 2.6 2.4 - 3.2	2.4

Figure 4-1 illustrates the pre-dredging turbidities in 2004 and comparative turbidities for the *Sir Thomas Hiley* in 1995 and *Brisbane* in 2002 and 2004 as measured in the surface, mid-depth and near-bed sections of the water column. Note that the turbidity values shown for measurements in 2002 and 2004 were the maximum measured values.

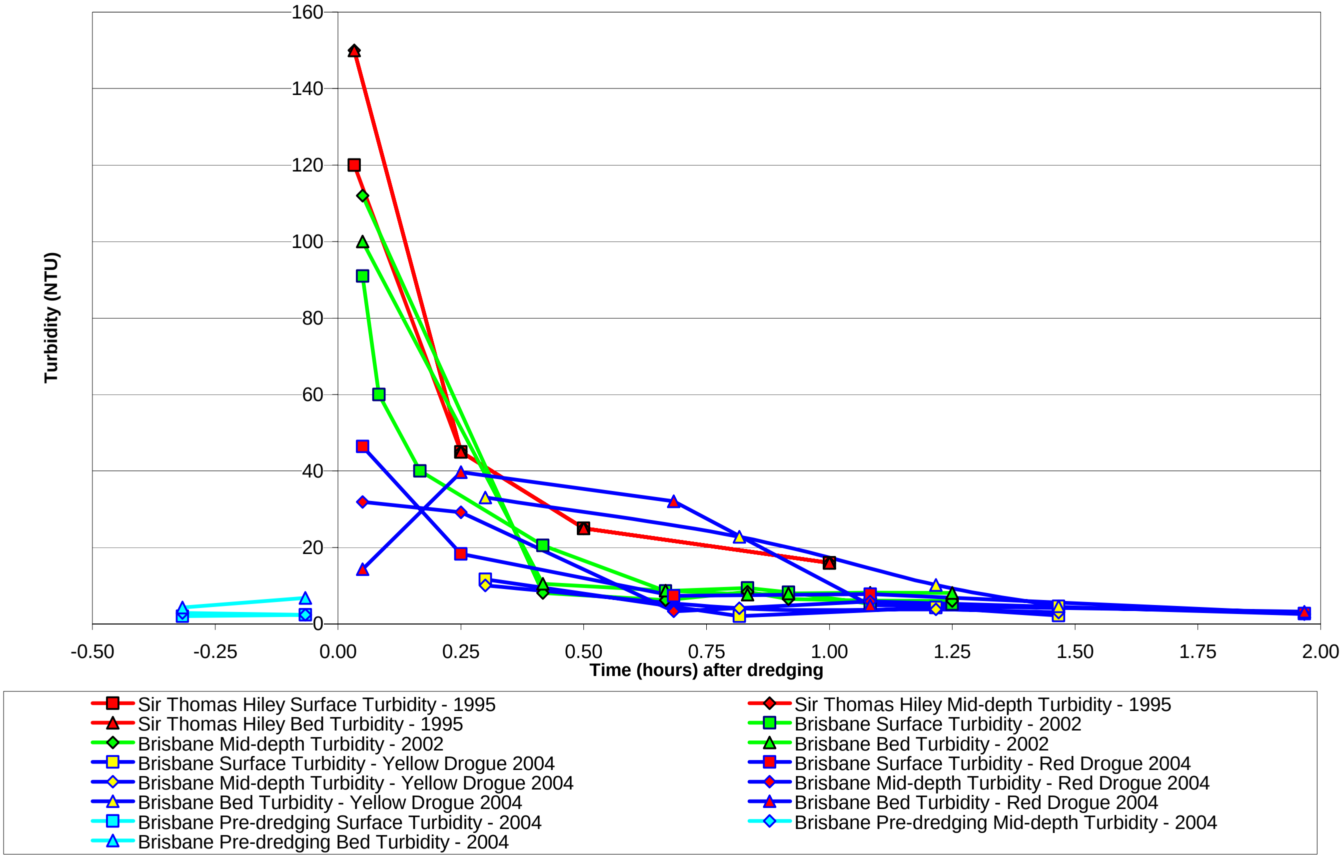


Figure 4-1 Comparative Plume Turbidities for Dredgers *Brisbane* and *Sir Thomas Hiley*

Figure 4.2 illustrates the surface water clarity before, during and after dredging by the *Brisbane* on the 19th February 2004 as indicated from secchi disc depth measurements.

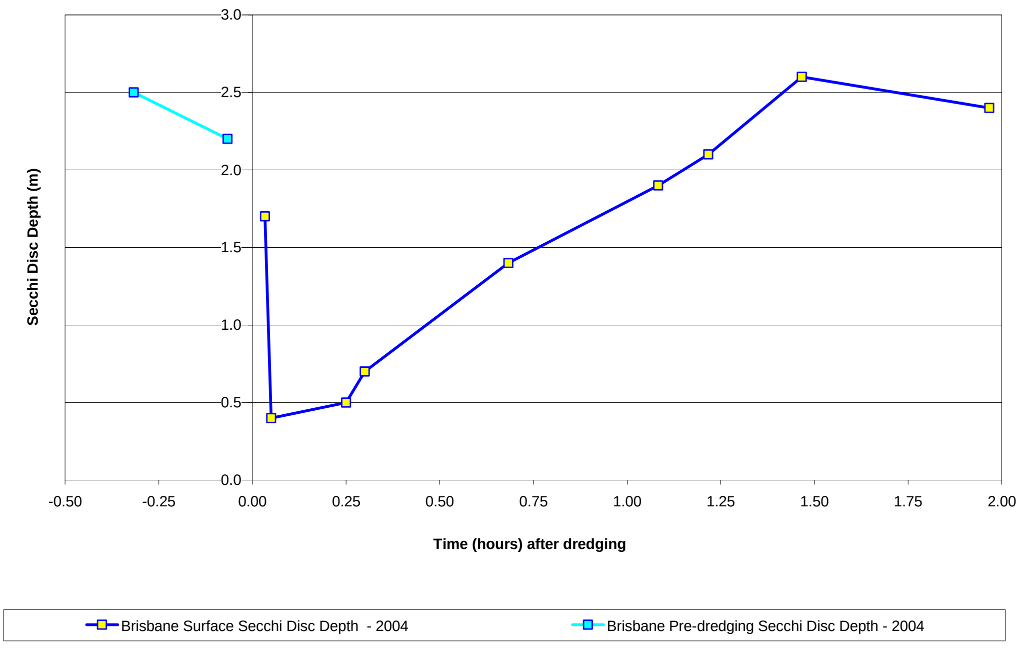


Figure 4-2 Secchi Disc Depth Measurements- Outer Bar Cutting – 19th February 2004

Figure 4.3 depicts the turbidity versus suspended solids relationship for the Outer Bar Cutting sediments, based upon the analysis of forty (40) collected water samples, including twenty samples from 2002 and a further twenty samples from 2004. In each instance, the water samples consisted of both pre-dredging and dredging plume samples. Figure 4.4 shows the comparative suspended solids concentrations of water samples collected from the hopper overflow of the *Brisbane* and *Sir Thomas Hiley* during dredging operations in the Outer Bar Cutting.

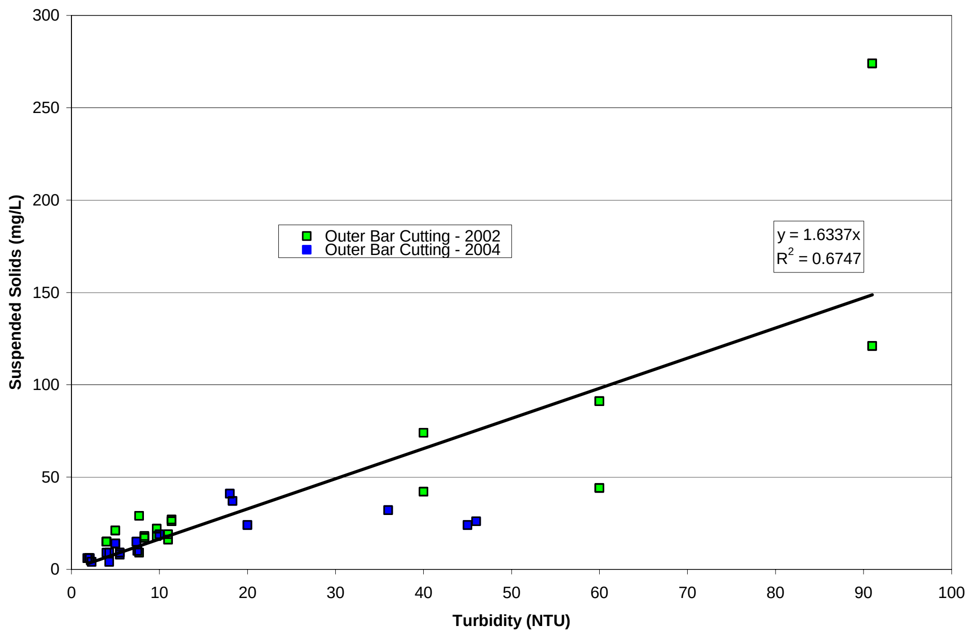


Figure 4-3 Turbidity versus Suspended Solids Concentrations at the Bar Cutting

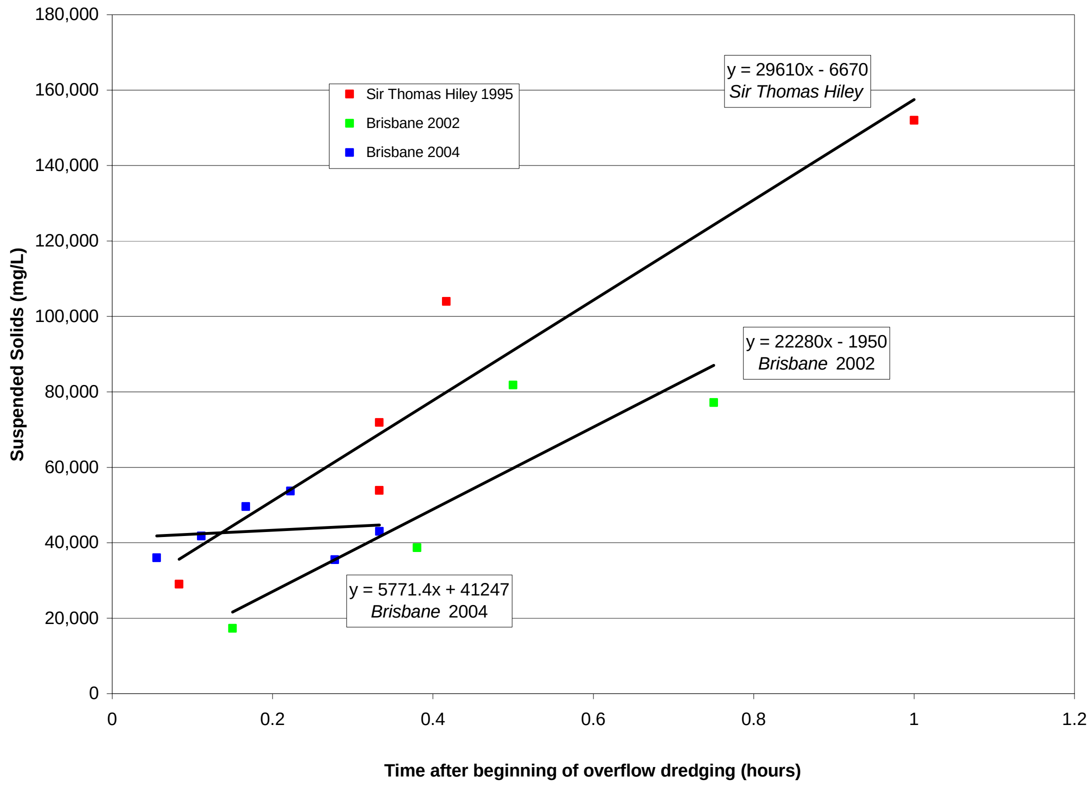


Figure 4-4 Suspended Solids Concentrations in Hopper Overflow

Aerial photographs of the dredging plumes are illustrated in Appendix A.

5 DISCUSSION

The dredging method currently used by the *Brisbane* in soft marine mud and silt (and employed on the 19th February 2004 at the Outer Bar Cutting) differs from that used in 2002. The difference is that each hopper load of dredged material now involves only a minimal hopper discharge.

The *Brisbane* has a single hopper overflow discharge (located approximately amidships), which is equipped with concentric elevating weirs that control the depth of water and sediment within the hopper. Previously, the weirs were initially set at a low level until the density of the dredged material within the hopper was optimal and then the next weir would be elevated and overflow again permitted until the density of dredged material was optimal. This process was repeated in sequence until the top weir level was reached and density of the dredged material within the hopper was optimised. In muddy environments such as the Brisbane River channels this technique was found to result in high suspended bed loads of material in the channels following dredging. These low-density sediment suspensions then proved difficult to remove by follow-up dredging without lengthy delays to allow them to settle. Therefore a change was made to the way in which dredging was conducted in silty and muddy sediments.

Compared with the previous mode of dredging operations, the discharge weir within the dredge hopper is now initially set to the top level of the hopper and dredging is undertaken for only a minimal period, typically 10-15 minutes after the hopper begins to overflow and discharge. By comparison, each load of dredged material is collected in a shorter time interval and although it may require additional dredging cycles to cover a specified dredging area, the method appears to be effective in minimising the need for follow-up maintenance dredging resulting from the re-distribution of sediments lost from the hopper. The change to the mode of dredging was an important reason for repeating turbidity plume measurements whilst the *Brisbane* was dredging muddy-silty sediments. Plume measurements were last conducted whilst the *Brisbane* was operating at the Outer Bar Cutting in January 2002. Previous turbidity plume measurements were also available for the *Sir Thomas Hiley* dredging the same area in September 1995 and were included for comparative purposes.

With the outlined change to the *Brisbane's* operational dredging method, it was anticipated that PBC would require information on the characteristics of the turbidity plumes generated before and after hopper overflow. For this reason, two drogues were employed on the 19th February 2004 to mark the following measurement locations for turbidity monitoring (refer to Figure 2.1):

- The first (yellow drogue) within the dredging track of the *Brisbane*, prior to hopper overflow; and
- The second (red drogue) within the hopper overflow plume.

As it transpired, the yellow drogue was close to the track of the *Brisbane* on its return dredging leg into Port. Therefore after the initial set of pre-hopper overflow turbidity measurements, the yellow drogue was subsequently used to relocate a second part of the dredge plume resulting from hopper overflow.

The results of the background and plume turbidity measurements for the *Brisbane* on the 19th February 2004 are summarised as follows:

- Background turbidity measurements between beacons 9 and 10, approximately 10 minutes after high water at 09:12 showed little variation with approximately 2 NTU near the water surface (0-4m depth), 2-3 NTU at mid-depth (4-9m) and 3-4 NTU close to the seabed (10.0-14.0m depth). Background measurements close to the east toeline of the channel at beacon 12 (East Coffey Pot) were very similar with a small increase in turbidity to 6 NTU, close to the seabed. The surface water clarity as indicated by the secchi disc depth varied between 2.2 and 2.5m.

- Prior to hopper overflow, the results of turbidity measurements within the stern wake of the *Brisbane* (adjacent to the yellow drogue position Y1- refer to Figure 2.1 and Table 4.1) show an increase in near-bed turbidities resulting from dredging (18 NTU, compared with a pre-dredging turbidity of 4-6 NTU). Surface and midwater turbidities were sometimes also slightly elevated (typically 4-6 NTU) compared with the pre-dredging turbidity in the vicinity of Beacon 12 (typically 2-3 NTU). The slight increase in turbidity in the water column appears to have resulted from a small leak of sediment from the hopper of the *Brisbane*. The aerial photographs confirm that there was a faint turbidity plume evident from the stern of the *Brisbane*, prior to hopper overflow. A commensurate reduction in the surface water clarity was noted, with a secchi disc depth of 1.7m.

- Following hopper overflow, there was a large increase in surface and mid-depth turbidity (measurements of 32-46 NTU near the water surface and 8-32 NTU at mid-depth) with a corresponding decrease in the surface water clarity (secchi disc depth measurement of 0.4m). By comparison, the near-bed turbidity levels remained at low levels in the minutes immediately following the passage of the dredger. The near-bed turbidities typically remained close to background e.g. 5.2-6.8 NTU, whilst adjacent to the bed itself the turbidity increased to 14.3 NTU. Whilst elevated, the surface and mid-depth water turbidities were considerably lower than comparative measurements from the *Brisbane* in 2002. Similarly, the secchi disc depth initially measured in the plume was greater than that measured in 2002 (0.4m in 2004 compared with 0.2m in 2002). As shown in Figure 4.1, comparative initial surface and mid-depth turbidities within the hopper overflow plume were 91-112 NTU in January 2002, which were approximately double the turbidity levels measured in February 2004.

- During the initial hour of plume tracking measurements, the direction of plume movement appeared to be unusual. In 2002, the previous direction of movement of the turbid plumes on an ebbing tide was to the north, with the plume quickly leaving the channel and moving over shoal banks north of the channel. In this instance however, the visible near surface component of the plumes and the drogues moved at first in an east to southeasterly direction beyond the east margins of the channel during the first hour of the ebbing tide (water depth approximately 8-9m). During this time the visible surface component of the plume outstripped the movement of the red drogue and at 10:34 (half an hour after its deployment), it was relocated approximately 200m southeast of its former position. It is possible that the prevailing northerly wind may have contributed to the southerly component of movement of the plume. After the initial hour of movement, the plume appeared to return to the channel and move in a seaward (northeasterly) direction along the channel alignment (refer to Figure 2.1).

- The direction of the ebb tide current and its affect upon the dredging plume is believed to have resulted in the profound change in the near bed turbidity concentrations noted between the 2002 and 2004 plume monitoring surveys. In 2004, the plume remained within the channel for a longer period so that the near bed turbidity increased as suspended material in the hopper overflow plume began to settle towards the bed. In contrast to the 2004 plume measurements, turbidity measurements in 2002 in the comparatively shoal water north of the channel, did not show any near bed increase in the suspended material. In 2002 the dredging plume moved quickly north of the channel, which limited the opportunity for similar mid-depth and near bed turbidity measurements in deeper waters of the channel. The initial plume measurements at that time indicated that the mid-depth and near bed turbidity levels were higher than the surface concentrations. The rapid movement of the plume to the north away from the channel would have resulted in interception of suspended material in lower horizons of the plume by the side slopes of the channel. This process may have limited further movement of suspended material in lower levels of the water column out of the channel.

- In 2004, 15 minutes after dredging, surface turbidity levels at the red drogue had fallen from 46 NTU to 18 NTU, a little less than half the maximum initial surface turbidity level. The mid-depth concentration had reduced slightly from 32 to 29 NTU. By comparison, the maximum near bed turbidity level had risen to approximately 40 NTU, which was consistent with the initial near surface turbidity levels. The same trend of elevated near bed turbidity was also evident at the yellow drogue.
- Approximately 40 minutes after dredging, turbidity levels in the upper section of the water column in the vicinity of the red drogue were getting close to pre-dredging levels, being 7 NTU near the water surface and 3 NTU at mid-depth whilst remaining elevated at 32 NTU close to the seabed.
- Between 1 and 1 1/2 hours after dredging, the turbidity levels at each drogue had dropped close to the background levels at all locations in the water column (a range of 2-8 NTU).

The plume measurement results compiled for the *Brisbane* in 2004 shown in Table 4.1 and Figure 4.1 compared favourably with those compiled for the *Brisbane* in 2002 and *Sir Thomas Hiley* in 1995. The initial plume turbidities at all depths were much lower (approximately half the comparable initial turbidity) than previous measurements and the time to reduce the turbidity within the plume to pre-dredging concentrations was shorter than or consistent with prior measurements. Figure 4.2 illustrates a return to pre-dredging surface water clarity (as indicated by secchi disc depth) within 1 1/4 to 1 ½ hours after dredging.

Generally it is not possible to convert measurements of turbidity to suspended solids concentrations, since the former depends upon the particle size and refractive index of particles in suspension. However estimates of the suspended solids concentration can be interpreted for a particular location provided there is sufficient comparative (turbidity and suspended solids) data. Figure 4.3 is based upon the concurrent measurement of water turbidity and collection of water samples for suspended solids analyses in 2002 and 2004. The figure shows the best estimate of a suspended solids concentration (mg/L) in the vicinity of the Outer Bar Cutting is approximately 1.6 times the measured turbidity in NTU.

Suspended solids concentrations were analysed from hopper overflow water samples collected at regular intervals through the approximate 20-minute period of hopper overflow in February 2004. The suspended solids concentrations in hopper overflow water samples collected from the *Brisbane* in 2004 (shown in Figure 4.4) were much lower and had a smaller range from the start of the hopper overflow to the end of dredging than previous dredging episodes. The hopper overflow concentrations of suspended solids varied from 35,500-53,700 mg/L in 2004. The maximum concentration (53,700 mg/L) was approximately 3 times lower than the peak concentration from the *Sir Thomas Hiley* in 1995 and 1.5 times lower than that from the *Brisbane* in 2002. Unlike previous analysis results from the *Sir Thomas Hiley* in 1995 or the *Brisbane* in 2002, there was no consistent trend of increasing suspended solids concentrations with time in the dredge hopper overflow. This may be due to the increased height of the overflow weir allowing some settling in the hopper before overflow. The suspended solids concentrations increased over the first four samples but then reduced to be consistent with the initial samples from the overflow. The lower concentrations of suspended solids in hopper overflow were consistent with the lower measured dredge plume turbidities and the lower visual intensity of the plume as evidenced from secchi disc measurements and aerial photographs. The change to the mode of dredging on the *Brisbane* has resulted in higher retention of fine sediments in the hopper and a hopper overflow plume that has a lower concentration of suspended solids when compared to previous operating procedures.

A comparison of the aerial photographs of the dredging plumes from the *Brisbane* in 2004 (Plates 1-10) and 2002 (Plates 11,12) and *Sir Thomas Hiley* (Plates 13,14) illustrates that the plume dimensions and their apparent spread and form were approximately comparable with each other on similar tidal conditions. The main difference was that the plumes generated by the *Brisbane* in 2004 did not appear as turbid as those initially generated in 2002 or in 1995.

6 REFERENCES

WBM Oceanics Australia (1997) Port of Brisbane Management Plan, Dredging and Dredged Material Placement. Prepared for Port of Brisbane Corporation.

WBM Oceanics Australia (2002) Comparison of Turbidity Concentrations Resulting from Dredging at the Bar Cutting. Prepared for the Port of Brisbane Corporation.

APPENDIX A: AERIAL PHOTOGRAPHS

Plate 1: *Brisbane* dredging the east toeline of the Outer Bar Cutting in a seaward direction. Overall view shows dredging plume before and just after start of hopper overflow. Plates 1 to 10 refer to dredging activities on the 19 February 2004.

Plate 2: Illustrates the survey vessel *Resolution II* within the dredging plume before hopper overflow.

Plate 3: Close up view of dredge plume before hopper overflow.

Plate 4: Dredging plume from the *Brisbane* before and just after the start of hopper overflow. Beacon 12 (East Coffey Pot) in foreground with *Brisbane* dredging in seaward direction.

Plate 5: Dredge plume from hopper overflow just after *Brisbane* turns and begins to dredge back into Port. Survey vessel in foreground, with crew collecting water samples.

Plate 6: Dredge plume resultant from hopper overflow during dredging into Port. Previous (seaward) plume is just visible to the left of the track of the *Brisbane*.

Plate 7: Overall view of turbidity plume from *Brisbane* during dredging on return leg into Port. Beacon 12 foreground, with survey vessel and beacon 10 in background.

Plate 8: Survey vessel involved in water sample collection at red drogue near beacon 8. There was little evidence of any surface plume at this time.

Plate 9: As Above.

Plate 10 Turbidity monitoring about yellow drogue near beacon 10. Vestiges of the plume remained at depth at this time

Plates 11 and 12 showing the size and shape of dredging plumes associated with operation of the *Brisbane* on the ebb tide of 11th January 2002.

Plates 13 and 14 showing the comparative size and shape of dredging plumes associated with operation of the *Sir Thomas Hiley* on the ebb tide of 27th September 1995.