Monitoring Of Tweed River Entrance Dredging and Nourishment Activities

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ABSTRACT

The entrance navigation channel of the Tweed River in northern NSW, Australia has been maintained by dredging since April 1996. To May 2001, 3,640,000 cubic metres of sand from the entrance had been used to nourish the southern Gold Coast Beaches in Queensland. The dredge activities have been monitored to ensure dredge navigation safety, maintenance of the design channel, achievement of the desired beach nearshore profiles, monitoring compliance with relevant approvals and for payment purposes. The first three objectives have been achieved by hydrographic survey, monitoring of the dredge depth sounders and tracking dredge position. Sand volumes for payment could not be accurately ascertained from survey due to the high rate of natural sand drift. Therefore, sand volumes were obtained using dredge hopper dippings and ullage tables, and by mass flow rate metering on the dredge pipe where available. The tracking program involved logging dredge coordinate details.

1 INTRODUCTION

The entrance navigation channel of the Tweed River in northern New South Wales, Australia has been maintained during the last six years by trailer suction hopper dredging (TSHD) as part of a joint NSW & Queensland State Government project in conjunction with Gold Coast City Council. Table 1 summarises the dredging and nourishment work carried out from 26 April 1995 to 3 May 2001.

While a permanent fixed sand slurry pumping system was commissioned in 2001, dredging is programmed to continue until August and supplemental dredging on a needs basis will continue thereafter.

Shoaling of the entrance channel occurs due to littoral sand drift of the order of 500,000 m^3/a net northerly (Hyder *et al*, 1997). The dredges have removed sand from the entrance and deposited it between 1 to 2 km to the Northwest of the dredge location. Placement has been by both pumping ashore and bottom dumping in shallow water (4-10 meters depth) adjacent to the southern Gold Coast beaches (Snapper Rocks to Kirra). Refer to Figure 1 for a site plan.

Table 1 - Tweed River entrance dredging and southern Gold Coast beach nourishment

Date	Dredge	Sand Volume [m^3]
26/04/95 - 02/06/95	Pearl River	1,518,356
03/05/95 - 19/11/95	Ngamotu	213,593
07/01/96 - 28/02/96	Krankeloon	270,688
22/07/96 - 20/08/96	Krankeloon	301,715
20/09/97 - 28/05/98	Port Frederick	778,900
22/12/97 - 04/05/98	Faucon	21,507
01/04/00 - 05/09/00	Port Frederick	324,153
10/11/00 - 03/05/01	Port Frederick	208,331
Total		**3,637,243**

Note: Sand Volume at insitu bulk density

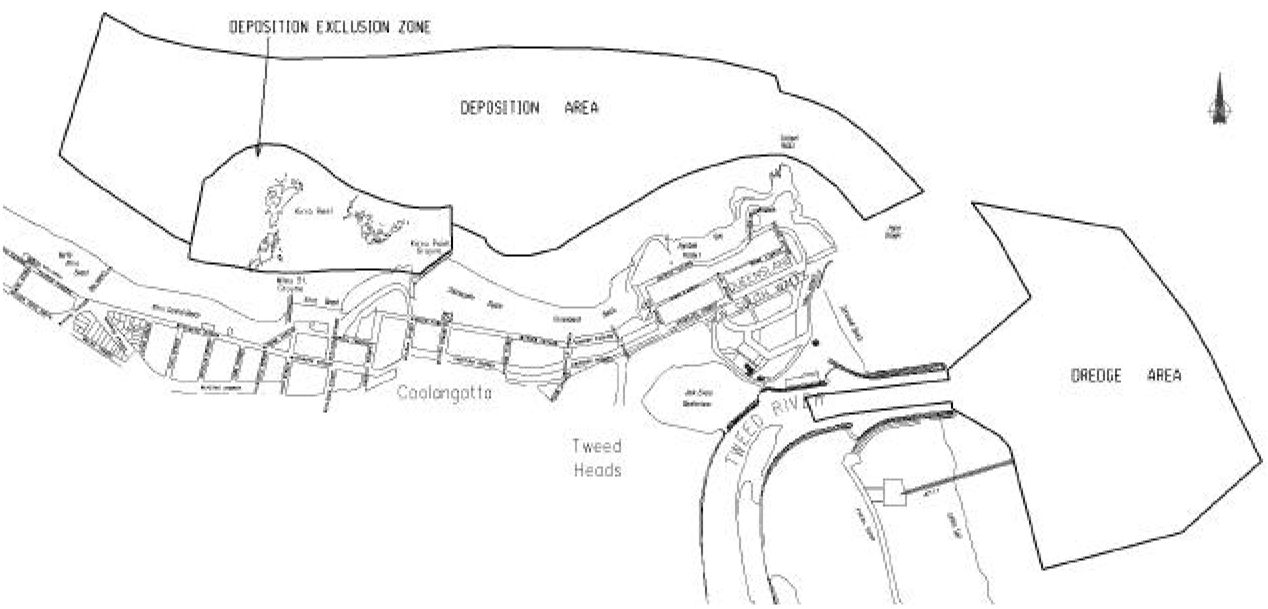

Figure 1 : Site Plan

About 600,000 m^3 was pumped by the "Pearl River" directly onto the beaches from Rainbow Bay to Kirra using a floating pipeline. The remainder was bottom dumped into the nearshore zones.

Details of the dredges are listed in Table 2. These dredges are designed so that the hopper can be filled in one hour.

Table 2 - Dredge details

Dredge	Hopper Volume [m3]	Draft Light [m]	Draft Laden [m]	L.O.A [m]
Pearl River	17,000	7.0	10.4	144
Ngamotu	490	2.5	3.5	61
Krankeloon	2,700	4.5	6.5	94
Port Frederick	400	1.7	3.1	50
Faucon	400	0.9	3.2	43

The dredged material was generally clean well sorted quartzose marine sand with median grain size (D_{50}) in the range of 0.18 to 0.26 mm. Despite being a river entrance the fines content is very low (<2%) and the fines are generally lost in the dredging process. The lack of fines is probably due to the vigorous currents that almost are always present: wave oscillatory, East Australian Current, longshore drift, freshwater outflow and the presence of marine sand estuarine deposits. Only one upriver load contained a small river gravel lens. Minor amounts of shell and debris (eg wood, litter) were encountered during dredging together with some indurated sand.

2 DREDGING AND NOURISHMENT MONITORING METHODS - BACKGROUND

Monitoring of the dredging and nourishment work is necessary for the following reasons:

- Achievement of the desired navigation channel and adjacent sand traps
- Achievement of the desired beach and nearshore profiles
- Payment
- Statutory requirements (including environmental conditions)
- Dredge navigation safety.

Most dredging contracts use hydrographic surveys to monitor all of the above. Surveys had limitations due to the natural high rate of sand movement in the entrance area and along the coast, and the difficulty of performing accurate regular surveys due to the sea and weather conditions. Therefore a combination of survey, measurement of hopper volume, dredge pipe mass flow rate, dredge draft and dredge location as recorded from the navigation system Differential Global Positioning System (DGPS) were used.

3 MONITORING METHODS

3.1 Pearl River, Ngamotu & Krankeloon

The international dredging firm Dredeco operated these three dredges during the first phase of the initial dredging and nourishment works. For navigation and safety needs hydrographic surveys were performed in the entrance area daily and in the nourishment area at least fortnightly. The surveys were loaded on the dredge's navigation screen as a contour plan. The dredge was navigated along contour lines during deposition. The nearshore nourishment area was divided into dump boxes. These boxes were used as a planning and bookkeeping device for bottom dumping. Sand volumes were allocated to each box to achieve the desired profile and to ensure navigation safety. The nourishment area surveys were used to update the allocations.

Monitoring of achievement of design profiles relied on hydrographic survey, however the surveys were not accurate enough to determine quantities. Hopper soundings using Government dredge inspectors were used for payment purposes. These inspectors were on the vessel whenever it was dredging. This is referred to as the "manual system". Timed dredge track plots were used to confirm the location of dredging and deposition.

3.2 Port Frederick & Faucon

Two smaller dredges have also been used on the project by a local firm McQuade Marine. Most of the dredging undertaken by McQuade Marine was performed by the Port Frederick because of its high manoeuvrability (due to a favourable power to weight relationship, the presence of bow trusters and two rotatable stern thrusters called aquamasters) and an efficient dredge head design. This vessel dredged at a slower speed (<1.0kt) than the other dredges (≈ 2.0kts), due to its manoeuvrability. Due to these reasons, bow sounder observations were used for navigation safety requirements instead of frequent hydrographic surveys.

The other dredge, the Faucon was restricted to calm sea conditions and as a consequence the volume dredged by this vessel was small. During 1997 and 1998 the Faucon did not have a trailing suction arm, but instead had an over the bow arm which was used to dig craters while the dredge was stationary. The work was mainly associated with the relocation of a wrecked trawler from the entrance channel to further off shore.

In 1997 and 1998 a manual system was used for payment purposes. Government inspectors were on the dredge whenever it was dredging. Given the high inspection costs the Governments and McQuade Marine began discussions in early 1998 on introducing an automated logging system such as the Silent Inspector System developed by the US Army Corps Engineers (Cox *et al*, 1996). However time limitations to undertake the 1997/98 campaign prevented development of a integrated system.

In 2000, McQuade Marine, offered a semi-automated system for payment purposes which involved hopper dipping by the Contractor that could be cross checked against dredge pipe mass flow rate, dredge draft and dredge location recordings. This offer was reviewed by the Governments and accepted with some additional audit requirements.

3.3 Ullage Measurements

A survey of the dredge hopper was used to develop an ullage table (ie hopper volume as a function of sand surface depth below a pre-determined datum).

As the dredge cruised from the entrance to the nourishment areas a number of measurements were taken from the datum line to the sand surface in the hopper using graduated staffs. These hopper dip measurements were averaged and then converted to a volume using the ullage table.

The location of the dredging and deposition was noted from the dredge navigation screen in terms of dredge and dump box labels. The depth of the dredge head was monitored visually to ensure that overdredging was not taking place. Additional information that was recorded included:

- Weather, sea state and tide
- Time. The dredge, cruise and dump times plus delay times become a continuous time series record in the form of a ship's log.
- Delay causes.
- Other events (eg rescuing other boats)

The bulk sand volume measured in a hopper is not necessarily the same as the in-situ volume prior to dredging, or the "fill" volume post deposition. The in-situ and "fill" volumes are not necessarily the same either. Where fine sediment is dredged the hopper density would be lower than the in-situ density. However sediment sampling in 1995 combined with continual surveying checks revealed that at the Tweed River Entrance the differences between hopper, in-situ and fill densities are small and could be considered to be equivalent.

3.4 The "Semi-automated System"

The components of the "semi-automated" system used in 2000 and 2001 were:

- Manual ullage measurements taken by the dredge crew as described in section 3.3.
- Recording of mass flow rate vs time manually, digitally and on paper.
- Recording of draft vs time digitally
- Recording of DGPS location of the dredge vs time digitally (ie a "track plot") as well as manually for dump locations.

These methods were audited by Government inspectors. This included on board witnessing and recording.

Computer programs have been developed to dynamically show the activities of the dredge and monitor the outcomes (See Figures 2 & 4).

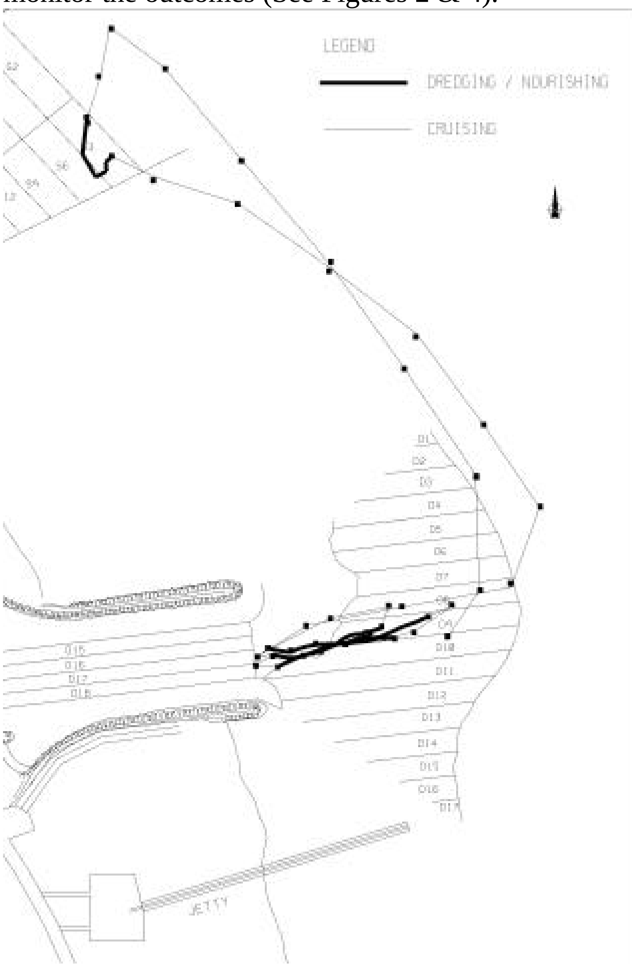

Figure 2 : Tracking Program Plot

4. MONITORING METHOD ANALYSIS

4.1 The "Manual System"

The manual system advantages were:

- The Governments inspector is on board observing work first hand. Events , problems and actions are witnessed and recorded as they happened.
- Inspectors with extensive experience dredging the Tweed Entrance and elsewhere were able to assist the Contactor's decision making.
- A simple robust system based on traditional existing navigation systems and manual hopper dipping.

Disadvantages were:

- Significant cost to the Governments for the inspection process. This cost was about $0.50/ m^3 in 1998. There was also a cost to the contractor to provide accommodation on board and down time from inspector shore transfers.
- Human recording errors.

The hopper ullage process works best if the hopper is full. Unfortunately, partially full hoppers can have a sand surface that if far from level due to the way the sand distributes from the inlet channels and from vessel heave and roll.

Sometimes it was noted that the hopper was leaking during the cruise from the dredge area to the dump zone. Leakage is mainly due to damaged hopper door seals. The most common source of damage is a door chain caught in the seal. This leakage manifests itself with cracks and cones in the surface of the sand in the hopper.

By 1998 the "manual system" was refined to the extent that data would arrive almost daily by mobile phone, and this data required very little post processing.

4.2 The "Semi-automated system"

In 2000 it was agreed to implement the semi-automated system for economic reasons. There was also the potential to have digital data transfer directly from the dredge to maps of dredge depth and placement height. These maps might give an approximate indication of channel dredging and nearshore beach nourishment progress while waiting for suitable conditions for a hydrographic survey (Refer Section 5).

The mass flow rate in the dredge pipe is measured by combining the signals from an electromagnetic flow meter and a nuclear densometer. Not all of the sand measured in this fashion ends up in the hopper; some of it passes over the overflow weirs. Due to this problem a calibration between the flow meter and the hopper dipping had to be developed in the presence of Government's inspectors at the start of the project, and checked from time to time. The electromagnetic flow meter appeared to be a stable device but the nuclear densometer had electronic circuitry failures and its calibration changed over time. This occurred even though these meters self-correct for decay of the source. A plot of the ratio of volume by this method to the volume by the hopper calculation (Figure 3) was useful in detecting any drift in the meters.

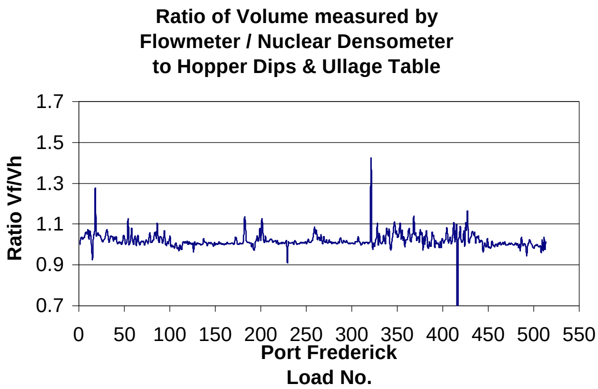

Figure 3 : Ullage Flowmeter Comparison

The dredge draft was measured using a bubbler system (ie the pressure required to inject gas into the water column). This system gives a record of both dredging times (ie increasing draft) and in particular dumping time (ie rapidly decreasing draft).

The above data was related to the position of the dredge via the DGPS vs time file. In theory this is straightforward, but it was found that the various logging systems used different clocks and have different sampling intervals. Unfortunately, these clocks were not always synchronised.

Data flow from the dredge to shore is not easy, and not as fast as desirable for management purposes. Mobile phone email systems were found to be too slow, prone to dropping out in the lee of the Point Danger cliffs and unable to operate while downloading or travelling. So computer diskettes and paper forms were adopted and these had to be transferred by launch. This process depended on the weather and dredge activity.

While there were some development and auditing costs needed to bed down this more complex recording system, it is now working quite successfully and cost savings are being realised.

5 DREDGING & NOURISHMENT PROGRESS ESTIMATION USING DREDGE MONITORING DATA

The deposition design consists of a grid of “dump boxes” designed to achieve
(1) a smooth bathymetry and
(2) placement in areas of high littoral drift where natural dispersion may create the desired effect.

Similarly for the 2000/01 activities, the dredging design involved parallel dump boxes running the length of the removal area in approximately an East-west alignment to suite preferred dredging paths.

In May 2001, there were 89 dumping boxes used by the dredging contractor for deposition and 17 boxes available for dredging (at the entrance of the river). Manual records can be used to produce schematic isopach map. This is not particularly accurate as the boxes are large compared to the dump volumes, but there is an indication of which boxes are full, and how much volume is left in any dredging box to level the sea bed to the “model ideal bathymetry” based on conditions that existed prior to the extension of the Tweed entrance training walls and to monitor levels for potential non-compliance with relevant approvals. It also gives an indication of dredging progress and which dredge boxes should be deepened. With this information it is possible to modify the dredging and dumping allocation plan as used by the dredge (See Figure 2).

Ideally, frequent hydrographic surveys would be used to control the deposition but this is expensive and often surveys by boat cannot be undertaken due to sea and weather conditions. Therefore an approximate control method uses numerical analysis of the manual dumping co-ordinates. To get a better sea bottom description the electronic set of data given by the semi-automatic method is used.

A simple algorithm was used to link the DGPS position of the dredge, draft and flowmeter recordings to get a more detailed picture of the deposition and dredging progress. The deposition data was transferred to a 10m square grid. Depth changes are assumed to be equal over this grid cell. Lateral dispersion of each dump is assumed to be proportional to its quantity, using a simplified Gaussian plume assumption.

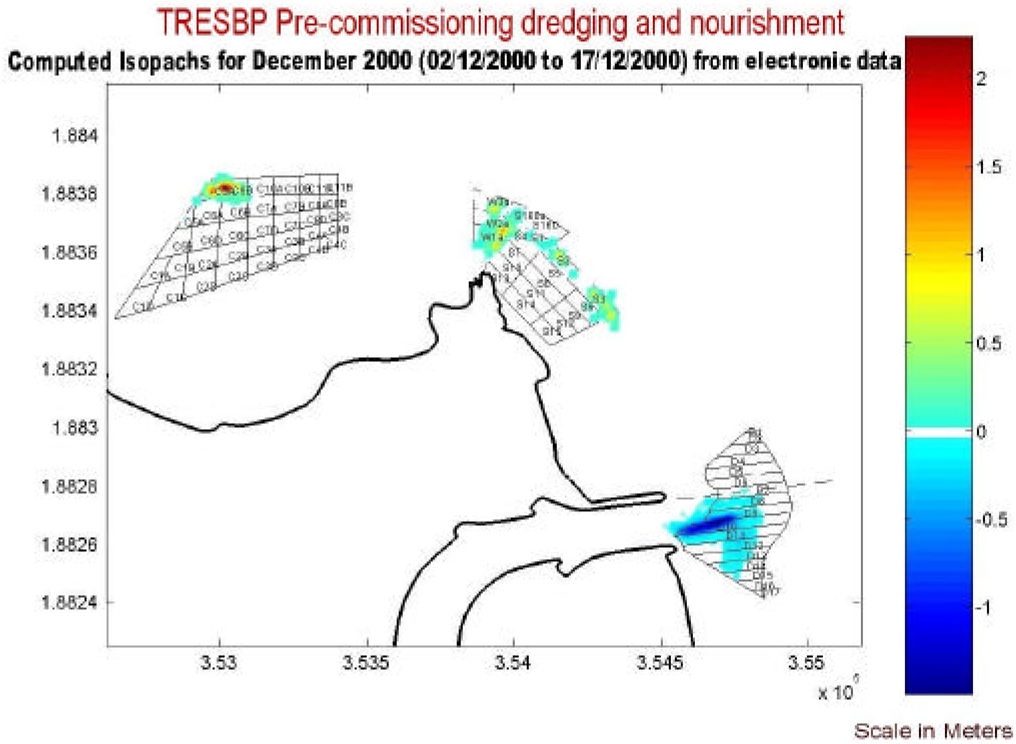

Figure 4 : Isopach Drawing

The dumps are accumulated and plotted as "No-natural movement isopachs". (See Figure 4). These isopachs would then be superimposed on the most recent surveys to get an idea of the bathymetry "smoothness". Monitoring using this method can help avoid the formation of "hills" and "troughs" created by repetitive dumping at the same location. This is important as irregular bottom features will adversely impact on the type of wave available for surfing.

Natural processes will change the bottom contours and hydrographic surveys are used to compare bathymetry with design profile and feedback.

6 CONCLUSION

The system evolved for monitoring dredging and nourishment activities has provided a useful tool for managing these works, particularly where limitations are imposed on removal and placement area bed levels or working with rate contracts in dynamic environments.

The semi-automated system was found to be a successful cost-effective method of supervising dredging. However, there is still a need for manual inspection work to audit such systems, and quick provision and checking of recorded data when supervisors are not on board.

7 ACKNOWLEDGMENTS

The authors wish to acknowledge the permission and assistance of Brown & Root Asia Pacific Pty Ltd, NSW Department of Land and Water Conservation, Queensland Environmental Protection Agency, McConnell Dowell Constructors (Aust.) Pty Limited, International Coastal Management Pty Limited, and McQuade Marine No 2 Pty Limited.

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