Tweed River Entrance Sand Bypassing Long Term Average sand transport rate

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Introduction

Background

Artificial sand bypassing of the Tweed River entrance (Figure 1) has operated since 2001. That followed initial Stage 1 dredging of the entrance area, which commenced in 1995, to transfer sand previously accumulated at the Tweed River entrance to southern Gold Coast beaches. The long term sand delivery target of the sand bypassing operations is specified in the legislation to correspond to the Long Term Average (LTA) rate of sand transport, which takes account of the natural net supply of sand along Letitia Spit and the amount of sand that reaches Queensland by natural means. The initially specified LTA was 500,000m^3/yr, based on a range of investigations undertaken previously (Delft Hydraulics Laboratory, 1970; Pattearson and Patterson, 1983; Roelvink and Murray, 1993).

Figure 1: Tweed River entrance location

BMT WBM undertook re-assessment of the LTA on the basis of the operations to July 2009, using the sand delivery records together with survey and wave monitoring data, in accordance with the requirements of the legislation. The study also aimed to advance understanding of the effects of the sand bypassing operations on the coastal processes in the vicinity of the entrance to assist future management of the bypassing scheme by examining all available monitoring data since 1993. This paper outlines the methodology for the reassessment and the key findings with respect to the LTA and the associated sand transport processes.

Sand bypassing project objectives and legislative provisions

The objectives of the Tweed River Entrance Sand Bypassing project (TRESBP) have been from its inception:

- to maintain a safe, navigable entrance to the Tweed River; and
- to provide a continuing supply of sand to the Southern Gold Coast beaches consistent with natural drift rates, together with the initial additional sand needed to restore the recreational amenity of the beaches.

The sand bypassing operations are carried out in accordance with the Deed of Agreement between New South Wales and Queensland under the *NSW Tweed River Entrance Bypassing Act 1995* and the *Queensland Tweed River Entrance Sand Bypassing Project Agreement Act, 1998*. The 'Long Term Average' (LTA) is defined in the Deed of Agreement as "*the long term average annual net littoral transport of sand that would, in the absence of any artificial actions to influence it, cross a line perpendicular to the coastline, situated one kilometre south of the southern training wall at the Tweed River entrance and extending to the 20 metre depth contour, less the annual net quantity of sand which, after the commissioning of the System, crosses that line and reaches Queensland*".

The sand bypassing operations thus aim to capture and deliver sand to the southern Gold Coast beaches at an average annual rate, equal to the LTA, required to maintain navigation improvements at the river entrance and ensure total supply of sand to Queensland equivalent to the natural long term net supply to Letitia Spit, taking account of the natural transport past the entrance that reaches Queensland (the 'natural bypassing'). Additionally, while the LTA is the basis of the long term average annual target sand quantity to be delivered by the system, a balance quantity (the Supplementary Increment) remained to be transferred at the commencement of bypassing operations and was incorporated into the quantities delivered over the first six annual periods.

The Deed of Agreement requires that the LTA be re-assessed at 10 year intervals, or as agreed by the states.

LTA reassessment objectives

The aim of the study was to reassess the LTA on the basis of the data available from the monitoring program (Boswood *et al*, 2001) up to July 2009. More broadly, the study also aimed to advance the level of knowledge of the wave and sand transport processes relating to the TRESBP operations and future reassessments of the LTA, for application to ongoing management of the bypassing system. The study outcomes thus include detailed analysis of the component sand transport processes (sand supply to Letitia Spit and natural bypassing past the entrance), the sand bypassing operations (pumping and dredging) and net changes in coastal compartment quantities both annually and over the longer term. Further, the study aimed to provide, as part of the deliverables, additional information about the data collection and factors to assist in future estimates of the LTA.

LTA Reassessment

Methodology

An assessment strategy was adopted that made maximum use of the considerable survey data obtained from the monitoring program implemented over the period from 1995 to 2009, including the period of Stage 1 initial entrance dredging and sand bypassing operations. Additional useful survey data was also available from previous investigations, dating from 1993.

The LTA assessment method was determined on the basis of its definition in the Deed of Agreement as (essentially) the long term average of the net sand transport into Letitia Spit minus the natural bypassing to Queensland. That is, the LTA is the long term average of:

Net sand transport to Letitia Spit – Natural bypassing to Qld (1a)

Each of these transport components varies from year to year. Neither can be measured directly. They may be expressed in terms of the net sand volume change along the Letitia Spit/Tweed River entrance coastal unit, accounting for the gain or loss to or from the river, and the volumetric rate of the bypass system pumping and entrance dredging (Figure 2), based on:

Net Quantity Change = Transport in – Natural Bypassing – Sand Pumping/Dredging + River supply

Thus, the LTA is the long term average of:

Pumping/Dredging (total) + Net Quantity Change – River supply (1b)

(Note: The net quantity change along Letitia Spit has been negative over the bypassing period)

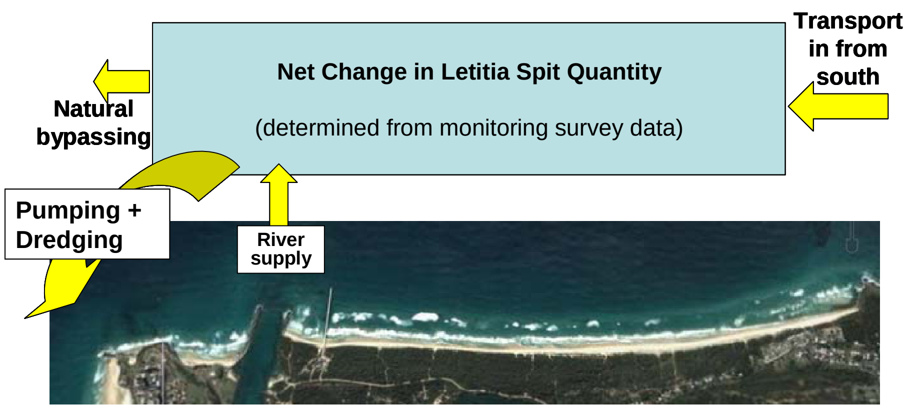

Figure 2: Conceptual sand budget for Letitia Spit

Analysis of component sand transport rates at various locations and the natural bypassing to Queensland necessarily required calculation of a reference sand transport rate. Currumbin, at the northern end of the monitoring survey compartments, was adopted as the most suitable reference location for that purpose, being less subject to complexities in wave propagation and sand transport processes than other locations. This facilitated analysis of the natural bypassing to Queensland as illustrated in Figure 3 as:

Natural Bypassing = $Tran_{Currumbin}$ + ΔQ (Qld) – Sand Pumping/Dredging (total) (2)

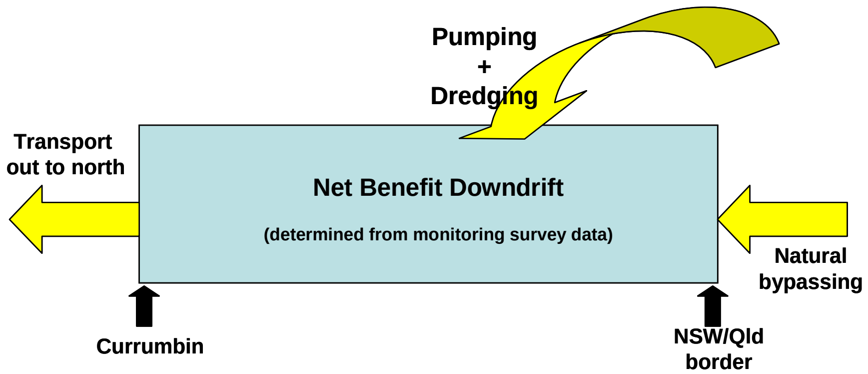

Figure 3: Conceptual quantification of natural bypassing

While the total sand transport past the NSW/Qld border is the ‘natural bypassing’ plus the sand placed at Duranbah, it has been adopted that all quantities delivered as part of the sand bypassing operations, including that to Duranbah, have been effectively delivered to Queensland and are thus included in the ‘pumping + dredging’ quantity, leaving the balance as the natural bypassing for this purpose.

Additionally, sand transport rates at various locations along Letitia Spit may be calculated from the rates of transport at the NSW/Qld border (providing for the Duranbah quantities) on the basis of the sand budgets within the surveyed coastal compartments there, as illustrated in Figure 4.

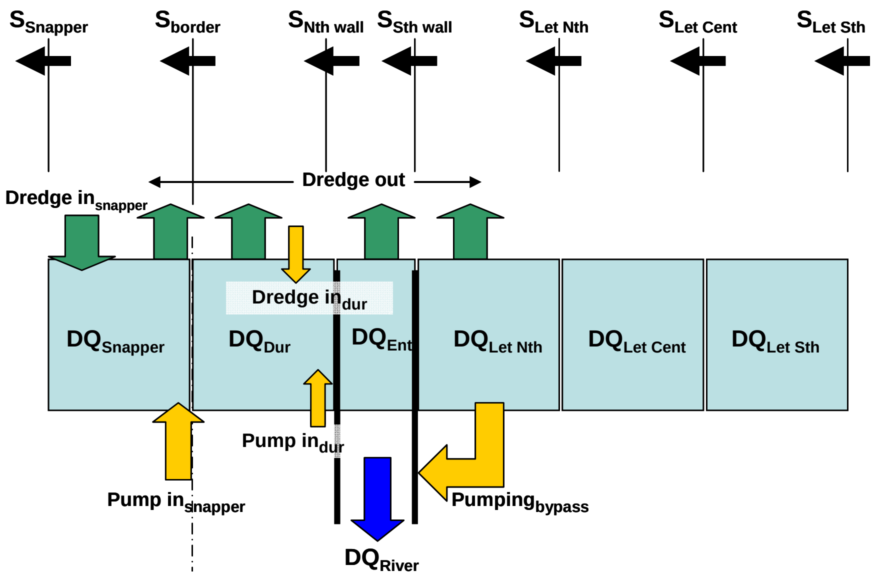

Figure 4: Conceptual sand budget for Letitia transport calculations

Uncertainties and limitations

There are uncertainties and error margins in the calculation of the LTA and the sand transport rates introduced through:

Surveyed quantities:

- Systematic errors such as incorrect datum correction or equipment calibration;

- Random errors in taking each depth sounding;
- Spatial sampling error if the survey coverage is insufficiently refined.

Sand bypass system quantities:
- Systematic errors in sediment concentration and/or flow measurements in the bypass jetty delivery system;
- Errors in estimating the equivalent sand volumes in the dredge hopper.

Longshore transport calculated from wave data:
- Random errors in wave data sampling;
- Wave data deficiency in representation of coexistent wave trains as a single height, period and direction combination based on the spectral peak values;
- Systematic error inherent in the wave transformation analysis;
- Errors in the theory for predicting breaking wave conditions;
- Systematic error inherent in choice of representative shoreline alignment;
- Error in the theory for calculating sand transport;
- Calibration error.

The LTA estimated directly from the monitoring data is subject only to the errors in the quantities derived from the surveys and bypassing operations. Considerable design control has been incorporated in measuring the pumping and dredging quantities. Survey quantity errors could be significant but are random rather than cumulative. Thus, these errors will become relatively less significant when averaged over a progressively longer time-frame. Review of the survey data has been undertaken with respect to the time-series of quantities within each compartment and some discrepancies identified and corrected. A relatively minor loss of sand to deep water beyond the limit of the calculation compartments in the vicinity of the river entrance was identified and has been accounted for in the assessments undertaken.

Determination of the component sand transport and natural bypassing rates is dependent on theoretical calculation of sand transport from Currumbin. That location is not subject to significant natural changes in shoreline alignment or sand transport process anomalies that may be affected by the sand bypass system operations. Nevertheless, there will be error in the calculated sand transport there, however, systematic error should be acceptably minimal since wave propagation to the site and sand transport relationship coefficients have been suitably calibrated and verified.

Sand transport rates

To determine the transport rates at Currumbin over the period of monitoring, calculations were made using suitably calibrated conventional sand transport relationships from the time series wave data as propagated to that location. The measured directional wave data collected offshore of Point Lookout (‘Brisbane’) in 80m depth and off Letitia Spit (‘Tweed’) in 26m depth were utilized. A comprehensive SWAN wave propagation and sand transport calculation procedure was adopted, based on conventional coastal engineering practice. The wave propagation analysis was calibrated to measured nearshore wave data at Bilinga (Figure 5), the Spit (‘Gold Coast’) and Tweed. The CERC (Shore Protection Manual, 1984) and Queens (Kamphuis, 1991) sand transport relationships utilised yielded directly equivalent sand transport rates (Figure 6). Their coefficients were calibrated to the known annual average net longshore transport rate through the region of 500,000 to 550,000m^3/yr for the available wave data, noting that the rate derived is dependent on the period of data used (Table 1). The adopted CERC coefficient (K_1) is 9.6×10^{-3} for m^3/s in the form $Q=K_1 H_b^2 C_g \sin(2\alpha_b)$ where H_b is the significant wave height and C_g and α_b the group velocity and angle to the shoreline respectively at the breakpoint. The recommended Queens coefficient of 0.133×10^{-2} is adopted in combination with a beach slope of 0.03 and bulk sediment porosity of 0.35. The sand transport results from the Queens relationship were adopted for the reassessment.

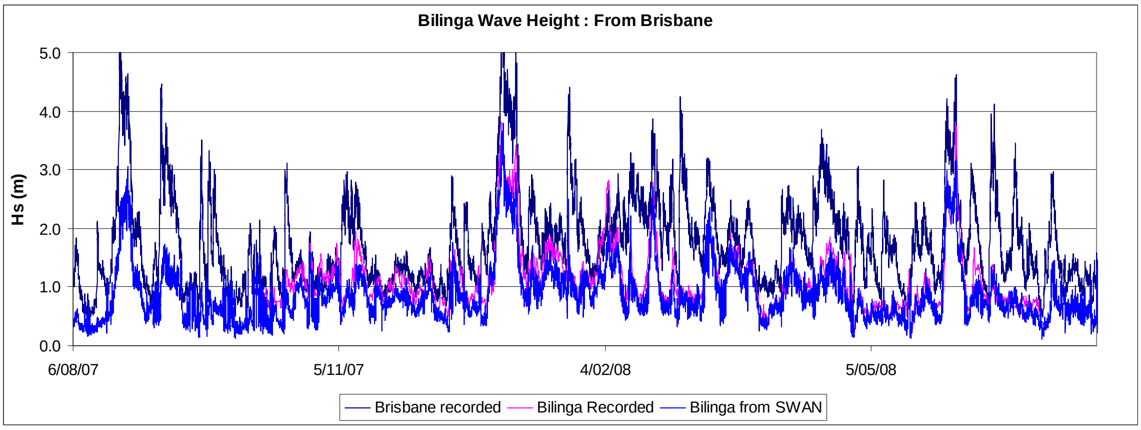

Figure 5: Validation of SWAN model; Bilinga nearshore from Brisbane offshore

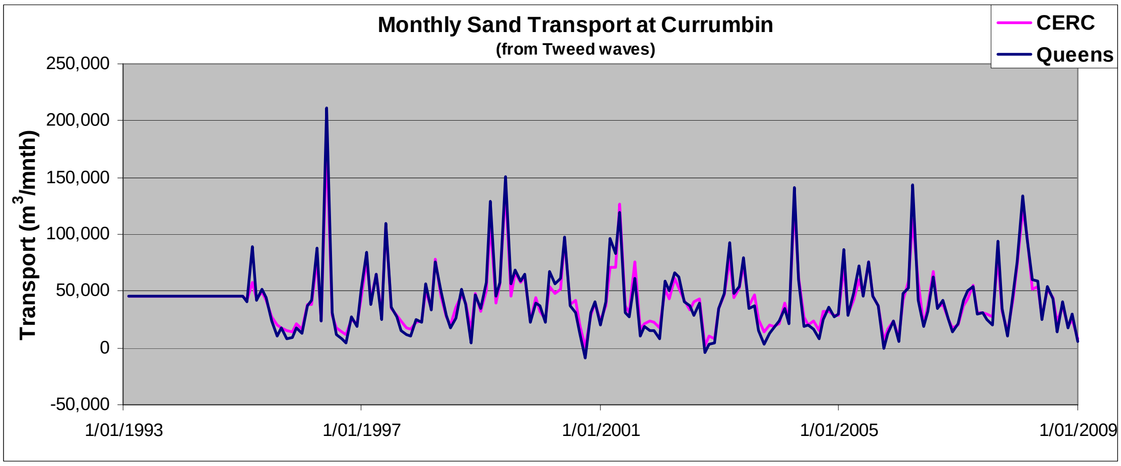

Figure 6: Calibrated CERC versus Queens transport at Currumbin

Table 1: Calculated transport at Currumbin

Annual Average Net Transport at Currumbin (m^3/yr)		
Period of Calculation	**From Brisbane waves**	**From Tweed waves**
1995 to 2008		506,000
1995 to 2009		527,000
1995 to 2000		511,000
1997 to 2009	553,000	540,000
2001 to 2009	548,000	537,000

The analysis of sand transport rates undertaken for Letitia Spit and southern Gold Coast locations has been based on a time series of average monthly values of the respective surveyed sand quantities within each of the survey analysis compartments (Figure 7) and the sand transport rate values at Currumbin. The survey quantities for NSW and Queensland are summarized in Figures 8 and 9. The time series approach adopted identifies the variability and prevailing trends of behaviour, particularly in the context of patterns relating to the period prior to and since the sand bypassing operations commenced in 2001 and the influence of the Supplementary Increment incorporated in the sand bypassing delivery over the first 6 years of its operation.

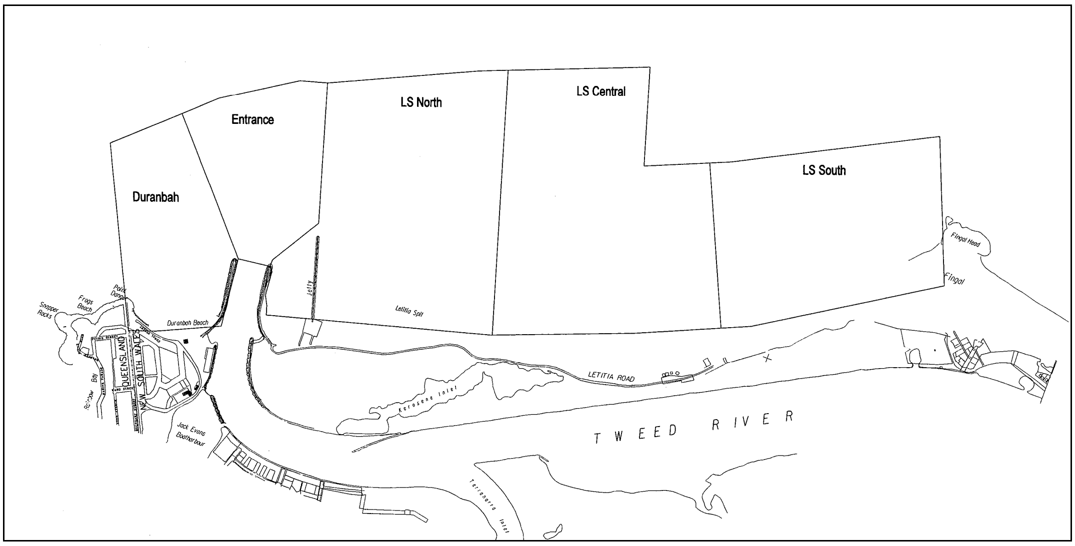

Figure 7: Letitia Spit survey analysis compartments

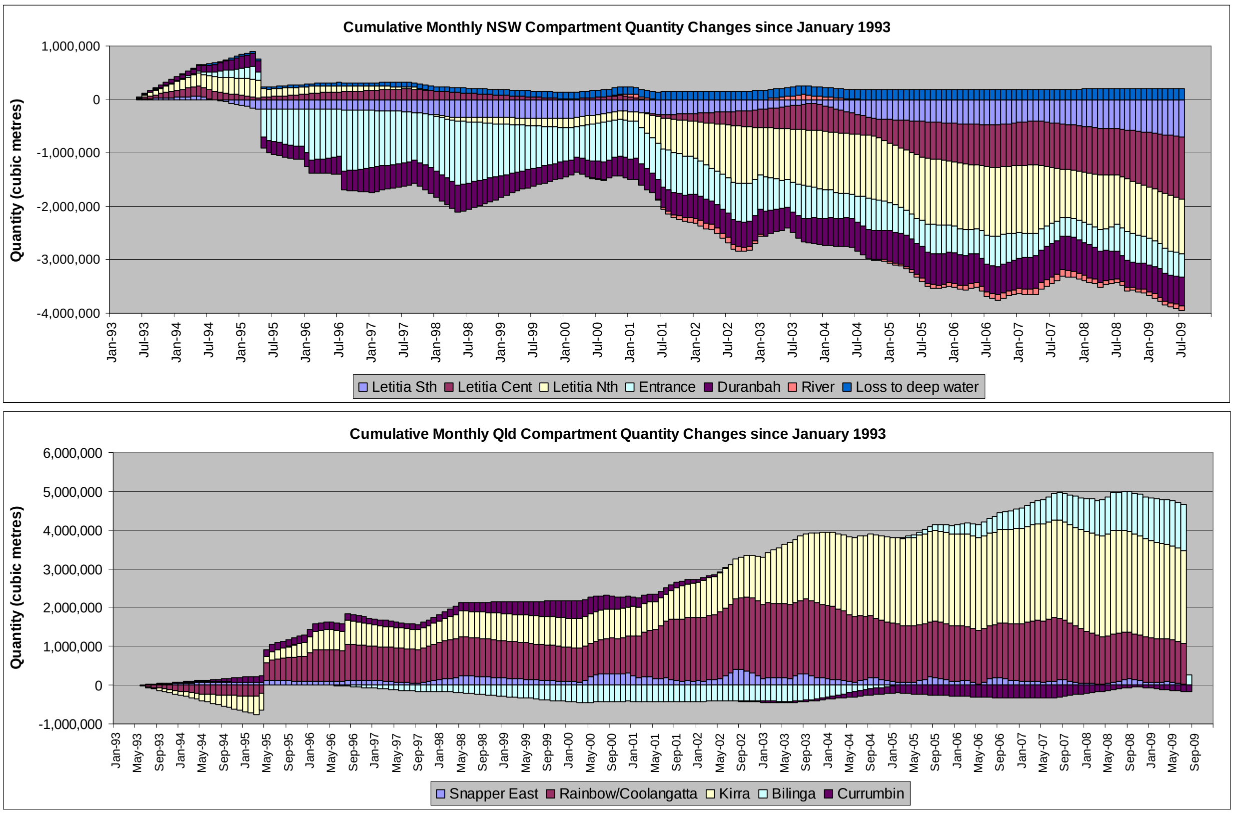

Figure 8: Monthly changes in survey compartment sand quantities along NSW (top) and Qld (bottom)

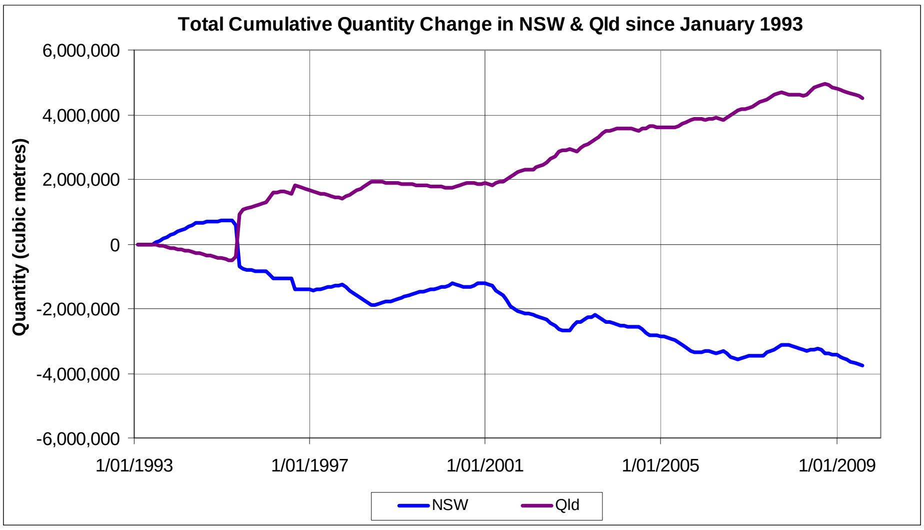

Figure 9: Changes in total sand quantities in NSW and Qld

The monthly net sand transport rates at the various locations along Letitia Spit and at Snapper Rocks have been calculated using the compartment budget analysis in Figure 4, as illustrated in Figure 10 and listed in Table 2. Notably, this indicates:

- annual average net transport rates at letitia South in excess of 550,000m^3/yr for the periods analysed, being 562,000m^3/yr for 1995-2009 and 553,000m^3/yr for the period of bypassing operations; and
- substantially higher transport rates at Letitia North, about 750,000m^3/yr since 2001.

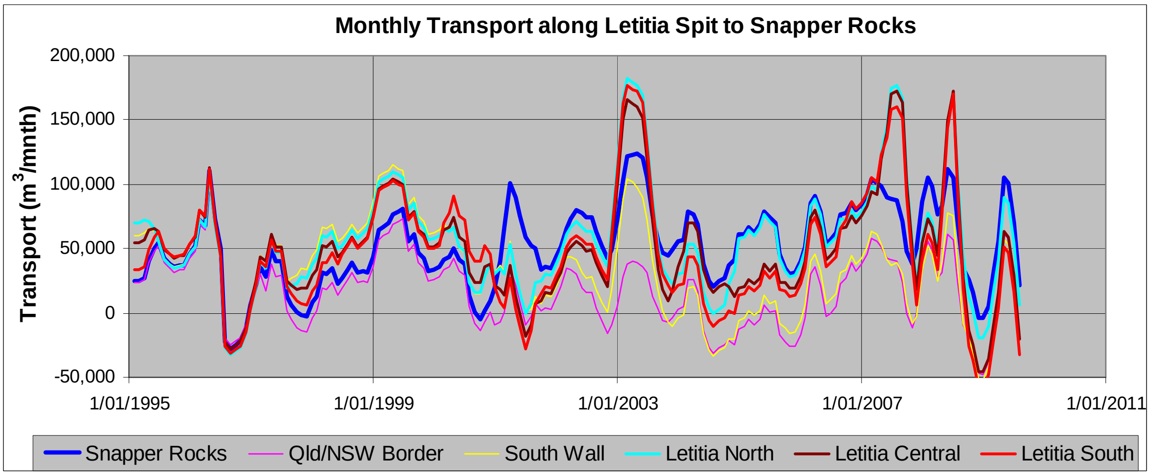

Figure 10: Monthly net transport along Letitia Spit

Table 2: Calculated transport at Letitia Spit

Period of Calculation	Average Annual Net Transport at Various Letitia Locations (m^3/yr)					
	Snapper	North Wall	South Wall	Letitia Nth	Letitia Cent	Letitia Sth
1995 to 2009	620,000	139,000	399,000	690,000	603,000	562,000
1995 to 2000	397,000	310,000	635,000	600,000	595,000	574,000
2001 to 2008	784,000	22,000	243,000	771,000	639,000	591,000
2001 to 2009	777,000	20,000	234,000	752,000	609,000	553,000

Comparison was made between the transport rates determined by this approach at Letitia North, 1,000m south of the river, and those calculated there directly from the Tweed recorder wave data using the calibrated longshore transport relationship coefficients. It was found that the shoreline alignment at that location has altered significantly since bypassing operations commenced, as illustrated in Figure 11, which had to be incorporated into the wave-based calculations. The comparative results are illustrated in Figure 12 and listed in Table 3.

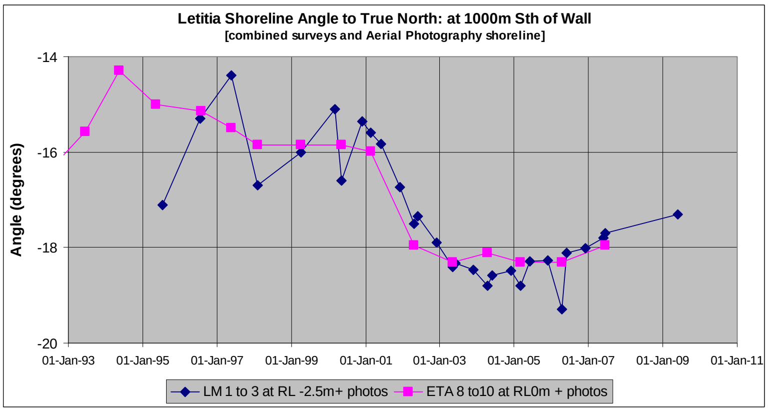

Figure 11: Variation in shoreline alignment at Letitia Spit

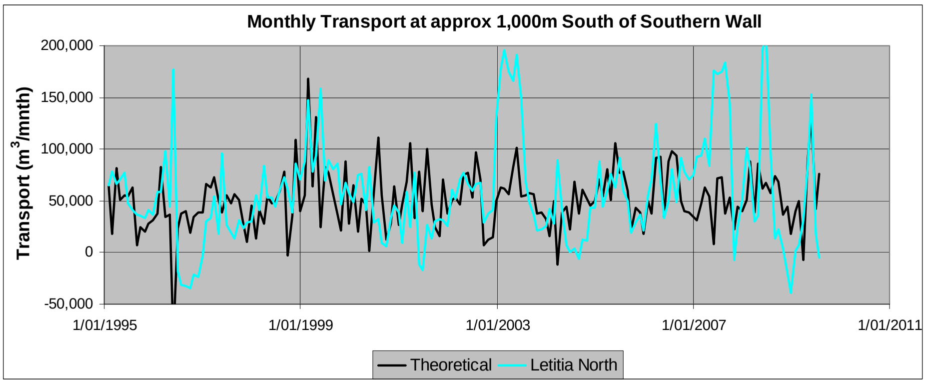

Figure 12: Monthly net transport 1,000m south of southern training wall

Table 3: Transport rates 1,000m South of Walls

Annual Average Net Transport at 1,000m south of walls (m^3/yr)		
Period of Calculation	**Derived from Surveys & Currumbin Transport**	**Theoretical from Waves**
1995 to 2009	690,000	610,000
1995 to 2002	582,000	578,000
2001 to 2009	752,000	646,000

It can be seen (Figure 12) that there are significant differences between the derived and theoretical rates at certain times, notably in early 2003 and in 2007-08, while quite close agreement is evident at other times, for example 1995 to end 2002. The periods of difference involve short term periods (months) of 'slug' transport behaviour that are difficult to explain other than by processes acting there that the theoretical approach does not cater for. These are possibly related to mechanisms involved in the movement of sand through the gap between Cook Island and the mainland at Fingal. For the period 1995 to

2002 for which no transport slugs are evident, the annual average net transport rates for the two methods agree quite closely (Table 3), indicating reasonable confirmation of the adopted sand transport relationship coefficients.

Natural bypassing at NSW-Qld border

The calculated monthly increments of the 'natural bypassing' (equation 2) and the total wave-current driven sand transport at the NSW/Qld border ('natural bypassing' plus the sand placed at Duranbah) are shown in Figure 13. These rates show a clear trend of marked reduction in natural bypassing after commencement of the sand bypass operations in 2001. There are extended periods of negative (southward) transport across the border alignment indicating that sand discharged there from the bypass system outlet may drift south into the Duranbah embayment from time to time. There is not a substantial difference between these transport rates, the placement at Duranbah being relatively minor.

These results indicate the progressive natural bypassing rates at the border as listed in Table 4. The average natural bypassing for 1995-2000 during which the initial Stage 1 dredging was carried out was 322,000m^3/yr, compared to the estimate by Roelvink and Murray (1993) leading up to that time of 350,000 to 400,000m^3/yr, the reduction being the result of the dredging. This decreased substantially to an average of 40,500m^3/yr over 2001-2009 as a result of the bypassing operations.

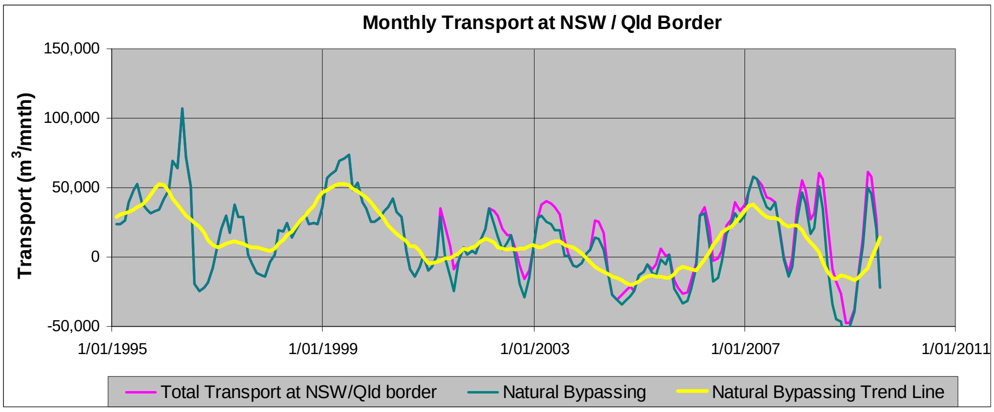

Figure 13: Natural Bypassing and total transport at NSW/Qld border

Table 4: Calculated natural bypassing at NSW/Qld Border

Period of Calculation	Natural Bypassing (m^3/yr)
1995 to 2000	322,000
2001 to 2009	40,500

Bypassing operations

The reduction in the natural bypassing over the period 2001 to 2009 has been achieved by pumping and dredging substantially more than the net rate of longshore sand supply, including bypassing of the Supplementary Increment of about 1.66 million m^3 over the period 2001 to 2006. The total bypass pumping and dredging rates have been about 894,000 m^3/yr for March 2001 to December 2006 inclusive, the period including the Supplementary Increment, reducing to 630,000m^3/yr for January 2007 to August 2009 inclusive. All of these rates are significantly higher than the assessed sand supply to Letitia Spit and yet there is still significant natural bypassing when slugs of transport pass through the system.

An estimate of the proportion of the longshore transport intercepted by the jetty system has been made on the basis of the longer term cumulative ratio of the leakage, taken to be the transport past the south wall, to the transport into the Letitia North compartment. The leakage rate expressed as a percentage of the transport into Letitia North is has trended to about 30% of the transport into Letitia North. As well, an estimate of the amount of dredging required to maintain the entrance channel as a percentage of the transport of sand into the channel past the south wall has been made, suggesting about 60-100 %, trending down but continuing to fluctuate since 2007 to an average of about 80% by 2009. The natural bypassing would be thus approximately 20% of the leakage through the jetty system, or about 6% of the total transport to the bypass jetty.

Regional wave climate variability and long term context

It is likely that decadal weather and wave climate cycles of behaviour, possibly associated with El Nino/La Nina cycles or other influences, may result in significant sand transport variability and affect assessment of the natural bypassing and the LTA as assessed over the period of bypassing operations (2001 to 2009). Even if good accuracy of the calculated transport rates is achieved, it is of benefit to know the context of that period in the longer term pattern of wave climate variability for better understanding of the LTA.

Proxy indicators including the Southern Oscillation Index (SOI) were reviewed with no clear pattern that could be utilized to determine the long term context of the calculated results. An approach was adopted based on relationships for various locations of derived monthly sand transport rates with the deep water monthly average wave energy flux and monthly energy-weighted mean wave direction, derived from global wave model hindcast directional wave data from BMT Argoss at a location about 32km offshore of the Gold Coast (being more representative of deep water than the Brisbane or Tweed buoys). While the relationships for locations with different exposure and shoreline alignment will be different, there will be a common deep water energy-weighted mean direction and wave energy flux that yields a common long term rate of annual average net transport through the coastal system.

Wave energy flux and mean direction parameters were determined on the basis of the CERC equation in order to provide weighting to their significance in terms of sand transport. It can be shown that the CERC equation may be approximated in terms of exclusively deep water parameter variables as:

$$Q \alpha\, g^{0.6} H_o^{2.4}\, T_p^{0.2}\, f^n(\mathrm{Dir_o}) \qquad (3)$$

This leads to the energy-weighted parameters, shown in time series in Figures 14 and 15:

Wave energy flux parameter = $g^{0.6}H_o^{2.4}\, T_p^{0.2}$ (m^3/s) (4)

Weighted mean direction = $\Sigma\, (g^{0.6}H_o^{2.4}\, T_p^{0.2}\, \mathrm{Dir_o}) \,/\, \Sigma\, (g^{0.6}H_o^{2.4}\, T_p^{0.2})$ (degrees) (5)

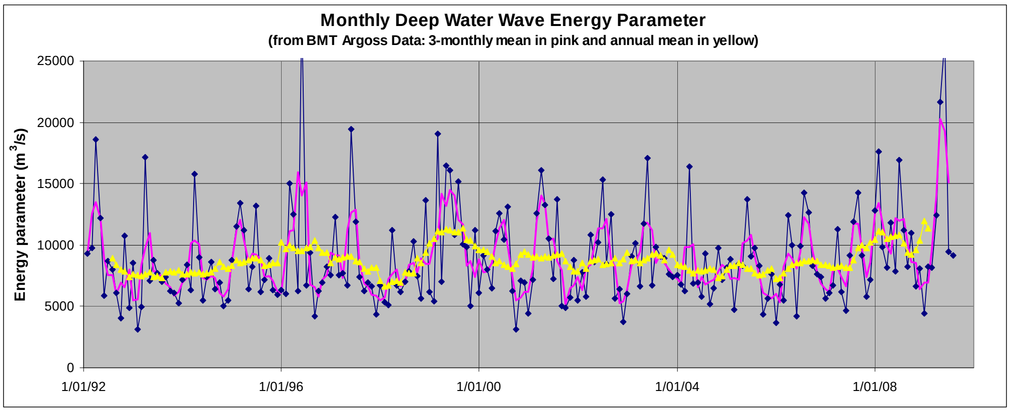

Figure 14: Monthly mean wave energy flux

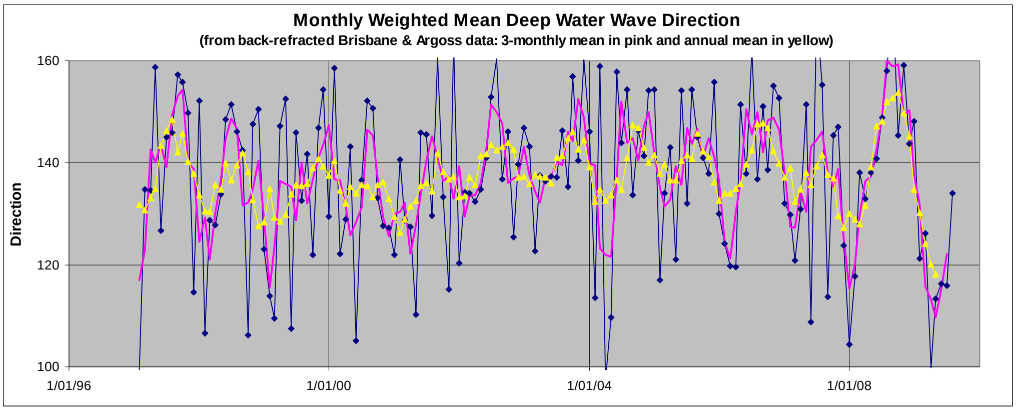

Figure 15: Monthly energy- weighted mean direction

The trend lines show substantial variability and indicate that the period since 2001 is not fully representative of the longer term. The average value of the weighted mean direction over the whole period of data is 137.0°. The average value of the wave energy parameter is 9,044 (m^3/s). There are some distinct temporal trends in the wave energy and weighted mean wave direction plots, namely:

- Higher annual mean wave energy in 1999 and since 2008, peaking in the first few months of 2009;
- Variable annual weighted mean direction, with a lower (more easterly) mean value through 1998 to 2001 of about 135° and a marked shift to the southeast after 2001 to typically about 140°; and
- During 2009, a combination of unusually high monthly wave energy (average 17,580m^3/s) and relatively more northerly (111°) 3-month mean wave direction for March to June.

Figure 16 shows trend lines of monthly sand transport rates, normalised in terms of the monthly versus long term mean wave energy flux, as a function of the weighted mean deep water direction for Currumbin and Cudgen, south of Kingscliff. This indicates a direction of about 135° for equal long term net transport at both sites, with a corresponding annual average net transport of 45,830m^3/month (550,000m^3/yr). For the Currumbin function trend line, a direction of 137.0 degrees corresponds to 43,940m^3/month (527,300m^3/yr), consistent with the calculated rate there of 527,000m^3/yr for 1995 to 2009.

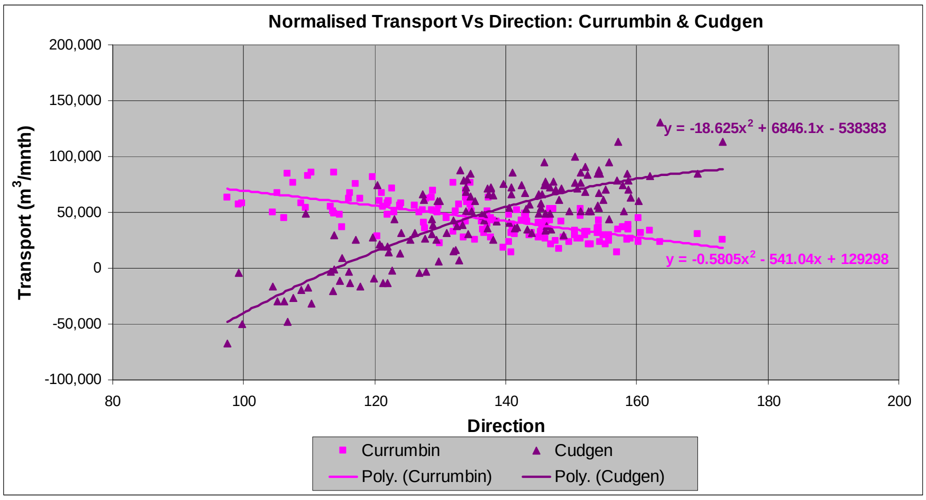

Figure 16: Normalised sand transport vs energy- weighted mean direction

It is evident that the El Nino period 2001-08 following commencement of bypassing operations had an energy-weighted mean direction significantly more towards the southeast than the long term mean, while the La Nina period from the start of 2009 has substantially reversed that trend. Accordingly, the first 6 months of 2009 had a substantial impact on the annual average net longshore transport rates calculated, particularly in increasing the Currumbin rate and reducing the rate at Cudgen and Letitia South. The weighted mean direction for those 6 months was 115.5^o compared with the long term mean of 135^o, with a mean wave energy parameter of 14,440m^3/s compared with the overall mean of 9,040m^3/s. This had a profound effect on the sand transport, emphasizing the up-coast rates along the northeast facing beach at Currumbin while retarding those at Cudgen which faces towards the east-southeast.

Regional sand budget

The surveyed loss of sand from the Tweed River entrance and NSW beach system north from the Letitia South compartment on Letitia Spit and corresponding gain of sand at the Gold Coast beaches are:

- Loss from NSW north of Letitia South: 4.47 million m^3
- Gain to Queensland beach system to Currumbin: 4.98 million m^3
- Net gain to the system covered by the surveys: 0.51 million m^3

The difference in these quantities is consistent, within survey accuracy, with the difference in rates of sand supply in at Letitia South and the transport out at Currumbin. In the broader regional sense, it can be explained only if there is an additional area of net loss of sand within the NSW coastal system south of the Letitia South survey compartment. This is supported by evidence there of significant erosion and analysis of the cumulative sand transport rates at Cudgen, Dreamtime Beach and Letitia South.

Discussion and key findings

Sand transport rates

The assessed sand transport rates depend on calculation of the rates at Currumbin from modeled wave propagation and conventional transport relationships. These have been calibrated and verified with respect to previous assessments of the annual average net transport through the coastal system of 500,000 to 550,000m^3/yr. While 'slug' transport behaviour affects the Letitia Spit transport, reasonable correlation of the rates at Letitia North calculated by independent methods for an extended non-slug period 1995-2002 provides confidence in the calibrated coefficients used.

The rate of sand supply to Letitia Spit past Fingal is highly variable, with rates determined to be 562,000m^3/yr for the period 1995-2009 and 553,000m^3/yr for 2001-2009. The transport along Letitia Spit has been substantially affected by the sand bypass system activities through changes in the shoreline alignment (Figure 11), with rates of transport into Letitia North, approximately 1,000m south of the southern training wall, of 752,000m^3/yr for 2001 to 2009. The shoreline re-alignment that has occurred in the vicinity of the bypass system jetty suggests that the sand bypassing operations have been the dominant contributor to this increase.

The 'slug' transport in 2003 and 2007-08 appears to be the result of periodic strong inputs of sand past Fingal into and along Letitia Spit past Fingal. There is clear evidence of the form of these slugs in the surveyed profiles which, for example in 2003, show a marked but temporary bulge at 4-8m depth. This has affected the transport of sand to the sand bypass system. It contrasts with the temporal pattern at Currumbin, which is generally more uniform. However, it is subject to occasional high transport associated with larger waves from more easterly directions, as occurred during early 2009, reaching 130,000 and 200,000 m^3 in the single months of April and May 2009 respectively. This relatively short period of high transport increased the average annual net rate from about 506,000 m^3/yr for 1995 to 2008 to 527,000 m^3/yr for 1995 to 2009 (Table 1), with 735,000 m^3 being transported there in the single year August 2008 to August 2009.

Long Term Average (LTA)

The LTA rate depends on both the prevailing average annual net sand transport through the coastal system and the jetty pumping/entrance dredging rates required to satisfy the channel depth criterion. The long term average annual net sand transport through the coastal system has been assessed at about 550,000m^3/yr. The natural bypassing of sand past the entrance area to Gold Coast depends on the nature and effectiveness of the sand bypassing system operations, as well as the net sand transport along Letitia Spit. It has averaged 40,500m^3/yr for the period 2001-2009 (Table 4).

The component monthly values given derived by equation 1 directly from the survey data are shown in Figure 17, with the cumulative trend since 2001 shown in Figure 18.

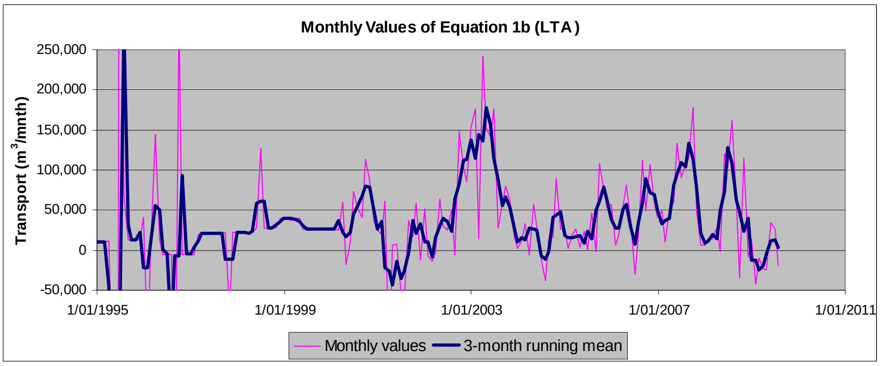

Figure 17: Monthly values of sand supply minus natural bypassing

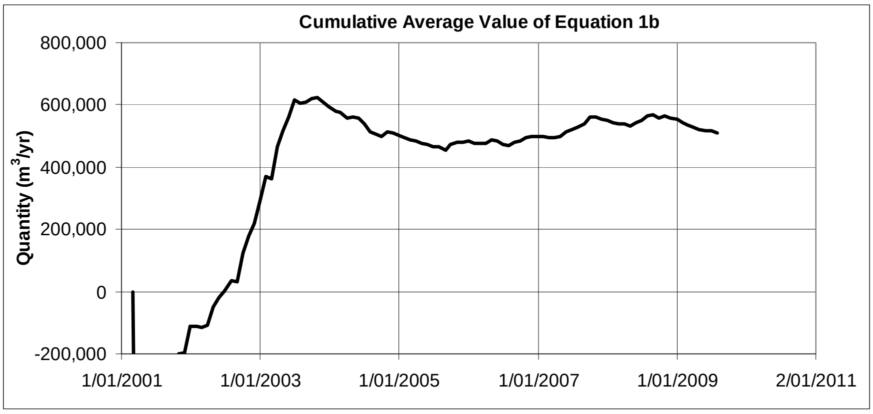

Figure 18: Trend of cumulative average sand supply minus natural bypassing

The average annual LTA rate thus derived from the monitoring data for the period from January 2001 to July 2009, covering the period of sand bypass operations, is 509,000m^3/yr, consistent with the determined sand supply and natural bypassing rate. Based on the bypass system operational trends derived, for a sustainable long term average situation, the leakage (30%) through the jetty system is likely to be about 165,000m^3/yr, corresponding to an effective jetty pumping rate of 385,000m^3/yr. Adopting a dredging need of 80% of the transport past the south wall, the dredging required would be 132,000m^3/yr and the natural bypassing 33,000m^3/yr.

However, this analysis of natural bypassing is highly sensitive to the proportion of the transport past the south wall that needs to be dredged. For example, should that proportion be 75%, the natural bypassing would be 41,250m^3/yr, close to the average since 2001. That is, based on this approach, the LTA rate would be in the range 509,000 to 517,000m^3/yr compared with 509,000m^3/yr derived directly from the data for the period 2001-2009. This is within a surprisingly a small range, given the potential and actual high variability of the processes and the uncertainties inherent in the assessment.

It is considered appropriate to give greater weighting to the result derived directly from the survey data of 509,000m^3/yr. Accordingly, a reassessed LTA rate of 510,000m^3/yr has been adopted, within 2% of the original estimate.

The proportion of the LTA that would be pumped compared with that dredged could vary substantially, depending on the ability of the jetty pumping system to intercept the longshore transport, particularly during high energy episodic wave events. For optimum utilisation of the jetty system infrastructure, the operational average target jetty pumping rate should be as high as possible for cost efficiency and to be consistent with the natural net littoral drift rates, up to the long term average sand supply rate. Nevertheless, some dredging to achieve suitable conditions in the entrance channel will most probably be needed and natural bypassing will occur because the jetty system will not achieve a 100% interception rate.

Future monitoring

The monitoring to date has been comprehensive and invaluable as a data source for this reassessment of the LTA. Careful ongoing monitoring and review of the operations are needed to assess progressively how the system operations are trending and, in particular, the development of a longer term pattern of dredging and its influence on the natural bypassing rates and the trend towards the situation in which the LTA is being delivered in the longer term. The identification of a minor leakage of sand to deeper water beyond the 20m limit of the calculation compartments in the vicinity of the entrance suggests that there would be considerable value gained over the future longer term in extending at least some of the surveys somewhat further offshore in that area.

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