WAGONGA INLET ENTRANCE CHANNEL - OPTIONS FOR NAVIGATION MANAGEMENT

REVIEW OF ENVIRONMENTAL FACTORS

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1 REVIEW OF ENVIRONMENTAL FACTORS OVERVIEW

This Review of Environmental Factors (REF) reviews and documents the nature of the potential environmental impacts of the proposed improvements to navigation within the entrance channel of Wagonga Inlet, at Narooma on the south coast of NSW. This REF has been prepared for Eurobodalla Shire Council (ESC) and is the environmental assessment required under Part 5 of the Environmental Planning and Assessment Act.

2 BACKGROUND

The background to this project is fully described in a Feasibility Study (*PSA September 2005 - see references*) which investigates improvements to boating navigation in the entrance channel of Wagonga Inlet. This feasibility study concludes that sustainable improvements to navigation appear viable, based on aerial photograph interpretation of shoaling behaviour since the 1940's. As a result it proposes low-scale sand dredging at three locations within the inlet channel.

Improvements as proposed fall into two categories:

- To improve boating safety principally, lowering of a rock pile located mid-channel just downstream of the Princes Highway bridge; and
- To improve navigation by dredging shoaling channels. The strategy includes placement of dredged sand within shallow channels to redirect tidal flow to reestablish a more durable pattern.

The entrance channel links the inlet's marinas and slipway work areas in Forsters Bay to the downstream reaches of the channel. Larger vessels moored in Forsters Bay, and commercial vessels moored at the town wharf and jetties at Mill Bay are unable to navigate the channel except at the highest of tides. This is the case particularly for the reach immediately upstream of the Princes Highway bridge where the Lewis Island channel is decreasing in width and shallowing.

Details of commercial vessels on the inlet made available by NSW Maritime are provided in **Table 1**. The list includes the RVCP vessel which is the largest vessel routinely using the channel - it is required at times to respond to breakdown emergencies in the inlet lake basin.

Table 1: Commercial and rescue vessels operating on Wagonga Inlet (June 2005)

Vessel Name	Length (m)	Breadth (m)	Draft (m)
Jenelle	14.60	4.43	1.20
Kayla	7.49	2.66	0.85
Innovator	10.70	3.60	1.40
Shearwater II (NPWS)	11.86	3.40	1.18
Fisco 1	22.46	5.36	2.38
Dreamtime	11.95	4.84	1.32
Sea Eagle	12.49	3.55	1.74
Silver Dollar	8.38	2.82	1.10
Dallas	10.26	3.54	2.10
Fibre Lady	16.35	4.57	1.40
Narooma Lifeboat (*RVCP Cat 3 vessel*)	13.40	3.65	1.22

3 DESCRIPTION OF PROPOSED WORKS

3.1 Rock Pile Lowering

This part of the project proposes to lower a pile of rocks which prove to be a regular danger to small boat users. The rock pile is also a navigation hazard to the larger vessels which enter and exit from the wharves at Mill Bay. The approximate location of the proposal is shown on **Figure 1**. These rocks reportedly were accidentally dumped from a works barge which was backfilling the sewer main crossing in the 1970's. The previous proposal to 'remove' the rock pile (*PSA September 2005*) has been amended to 'lowering' in order to maintain habitat.

Located in the mid- entrance channel just downstream of the highway bridge, the rock pile currently extends to within 200mm of the surface at low tides. It is proposed to lower the top of the rock pile by approximately 2.5 meters.

The lowering of the rock pile should be carried out on a slack tide and into the commencement of a run-out tide. It is anticipated that the rock would be spread along the bed, which has a depth at this location of almost 4 meters below a mean tide. Disturbance of the rocks in this area will fragment macroalgae. This may be unsightly for a short period. It is best dealt with by distributing downstream into the channel rather than allowing suspended organic material to pass upstream towards oyster leases. A Harm Marine Vegetation permit from DPI Fisheries will be required prior to the works being undertaken.

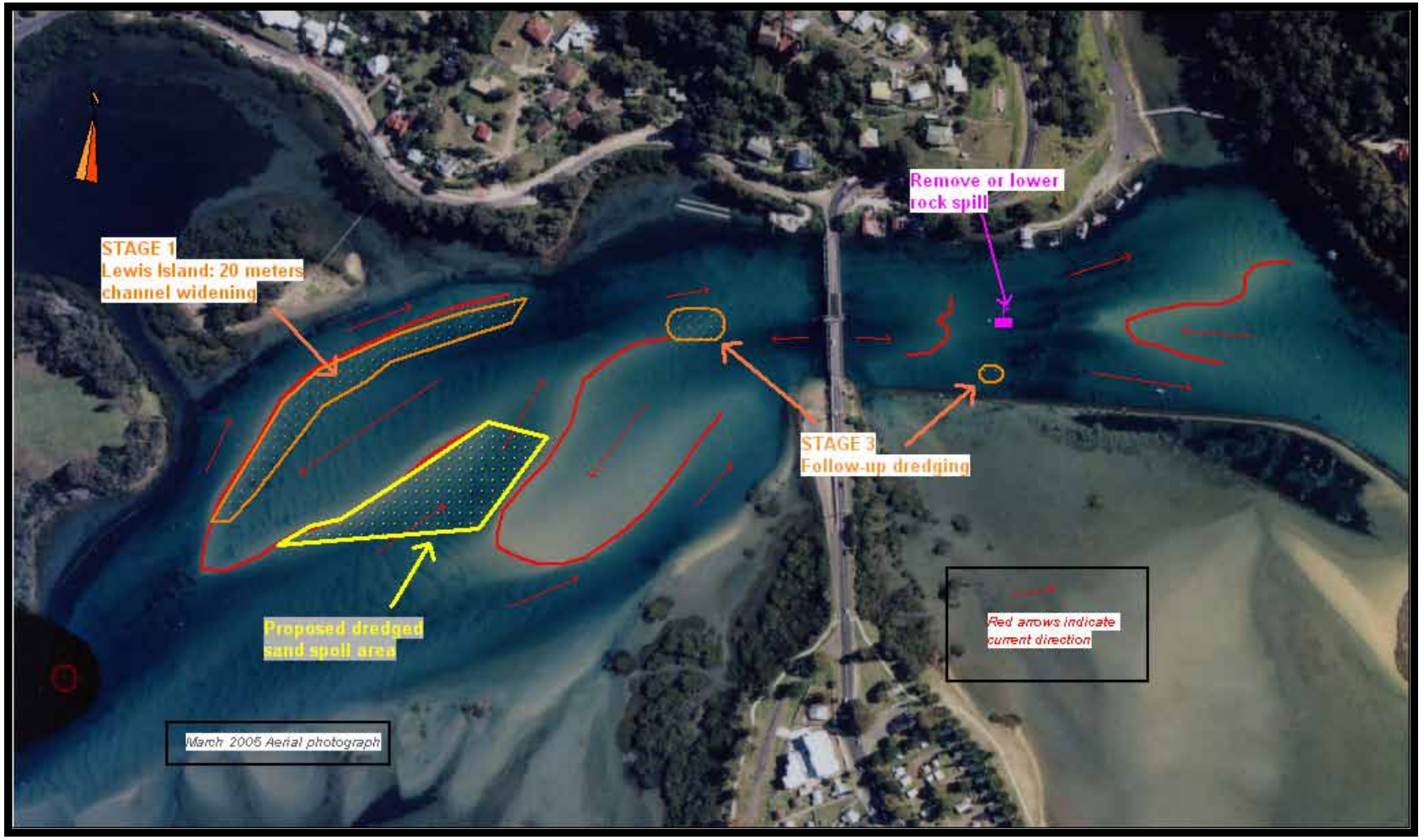


Figure 1a Localities of proposed mid-channel works around highway bridge (2005 aerial photo base).

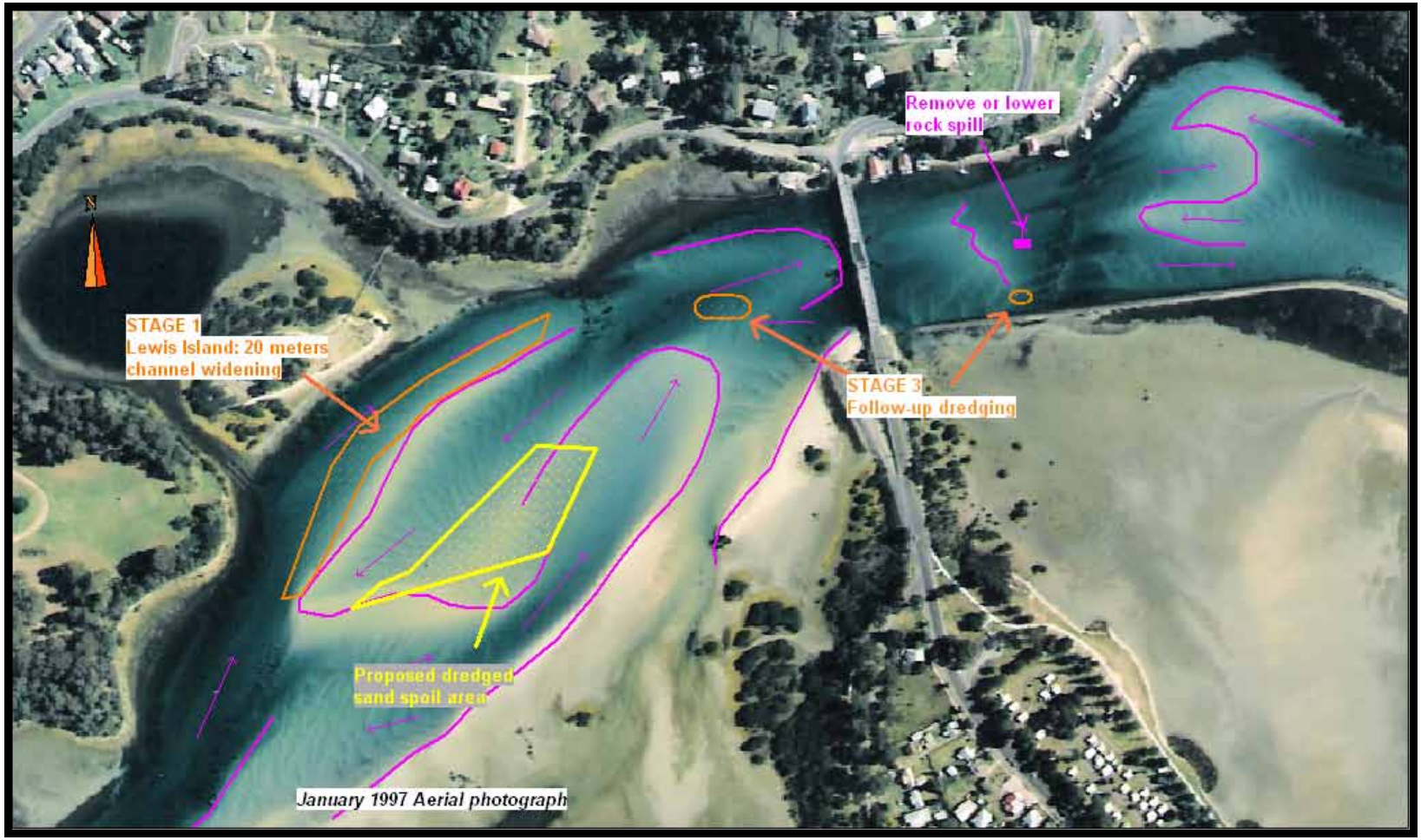


Figure 1b Localities of proposed mid-channel works around highway bridge (Jan 1997 aerial photo base).

Figure 2 Location of proposed dredging at the drop-off

3.2 Sand Dredging in Entrance Channel

This part of the project involves sand dredging in three localities to improve navigation. The sites have been selected after an aerial photographic review of historical inlet behaviour since March 1944. The depths of sand removal is limited largely to reproducing natural channel depths recorded by the then DLWC's estuary hydrosurvey in May 1997 (*Plan Cat. No. 53175*). It is noted that this would not necessarily provide navigation to all vessels at all tides. However the works are expected to provide sustainable benefits over the medium term. The scale of the works aims to avoid influencing the channel's sediment patterns beyond their observed natural configuration.

Finished cut batters would emulate shoal edges, and would be no steeper than 1:7 to comply with DPI Fisheries' standard requirements. Note that sand depths and volumes are estimates in the absence of an up to date detailed hydrosurvey. Channel configurations should be checked by survey and compared to the 1997 survey to determine volumes, prior to works commencing.

3.2.1 LOCALITY OF PROPOSED WORKS

The sites proposed for dredging are:

1. Lewis Island channel widening (**Figure 1a**) to expand the existing narrow channel by about 20 meters to its pre-existing location as defined by the 1997 hydrosurvey. **Figure 1b** depicts the 1997 pattern that is to be re-created, and clearly shows the area to be dredged as part of the main channel. A sand volume to be removed is estimated at 9,000 cu.m. based on an area of 6.800 sq.m. at an average depth of just over 1.3 meters.
2. Shallow skim dredging at the dropoff (**Figure 2**) will lower a gently graded flood tide ramp at the upstream end of the marked navigation channel to a similar level as the remainder of the navigation channel at the dropoff. This involves the dredging of about 1,500 cu.m. of sand over a width of 20 meters, requiring the removal of 0.8 to 1.5 meters of sand (depth ranging to nil sand at the dropoff) over a distance of about 70 meters downstream from the dropoff.
3. The shoal cross-over just upstream of the highway bridge, and the small shallow bar just downstream of the highway bridge at the south end of the sewer main (**Figure 1a**). Total sand volume is minimal, estimated at 1,000 cu.m. but requiring survey to determine depths.

3.2.2 LOCALITIES & TIMING OF SAND PLACEMENT

Dredged sand is to be placed in the following locations.

1. Sand from the Lewis Island channel widening (approximately 9,000 cu.m.) is to be placed within the central ebb channel. This volume would fill the dredge disposal area to an average depth of about 1.1 meters. Filling should commence from the upstream ebb shields on either side of the central channel and progressing downstream towards the bridge. The timing shall coincide with slack tidal flow and will be permitted into the flood tide so long as sand transport out of the deposition zone does not occur. A sediment

curtain would be provided as an additional protection to contain sand movement. Deposited sand would mimic natural sub-tidal or intertidal shoals, and would not form an island.

2. Shallow sand dredging at the dropoff (**Figure 2**) (1,500 cu.m.) will emulate natural sand movement over the edge of the dropoff to spread into the deeper area of the lake basin. Water depths here are 10 to 12 meters. This discharge pipe will be at sufficient depth to ensure that sand in suspension cannot reach nearby oyster leases.
3. Sand from the final dredging immediately upstream and downstream of the bridge (1,000 cu.m.) shall be discharged to the upstream end of the central ebb channel under slack or flood tidal flow.

3.2.3 ORDER OF DREDGING WORKS

The order of works is as enumerated in 3.2.2 above. This will allow the sand placed within the central ebb channel to settle before dredging other immediately downstream areas. These areas may inadvertently receive some of this sand due to tidal movement in the short term.

4 ALTERNATIVES

There are no viable alternatives to this project, should improvement of boating navigation be considered necessary. The issues associated with the desirability of the scheme are dealt with in the Estuary Management Study and Plan (*see References*). The adoption of this Estuary Management Plan followed thorough consultation which concluded that there would be positive benefits to be gained by dredging.

The benefits are improved navigation for the users of the entrance channel linking the Apex Park boatramp and downstream moorings (at Mill Bay and the Town Wharf) to the lake basin and to commercial marinas and slipways in Forsters Bay. Enhanced opportunities for access to the lake for the large Royal Volunteer Coastal Patrol (RVCP) vessel will also result.

Alternative larger scales of dredging were initially investigated in the Estuary Processes Study. The Feasibility Study (*PSA Sept 2005*) concludes that for the available budget and the potentially limited life, large-scale dredging is neither feasible nor economic. It could also create unpredictable perturbations to shoaling patterns and lead to instability of the foreshore.

Previous Estuary Management Committee discussion has focused on dredging the old channel into Forsters Bay by widening a few narrow 'nick point' areas as a minor maintenance dredging exercise. However, *Posidonia australis* has spread so well into this area over recent years that it could not be stated with certainty that dredging in these locations would not affect seagrass beds. This is due to the high likelihood of temporarily destabilizing nearby channel edges containing seagrasses. This option is also not considered a viable alternative to shallow dredging at the dropoff.

5 RELEVANT LEGISLATION, REGULATIONS AND PERMIT REQUIREMENTS

5.1 Legislation and Approvals

5.1.1 ENVIRONMENTAL PLANNING AND ASSESSMENT ACT 1979

Environmental assessment of this project is required under the provisions of Part 5 of the EP&A Act. Council must satisfy the provisions of Section 111 of the Act in determining whether the proposed activity is likely to have a significant effect on the environment. This is generally referred to as a Review of Environmental Factors (REF) and its conclusions may take the following form:

- The proposal is not likely to have a significant effect on the environment and the determining authority can then give approval (if other requirements under other legislation and policy is satisfied). OR
- The proposal is likely to have a significant effect on the environment and therefore-
  - the preparation of an Environmental Impact Statement (EIS) should be undertaken to enable a more detailed assessment before a decision is made, or
  - modifications to reduce any likely significant effect are in order; or
  - a decision not to proceed is made.

5.1.2 CROWN LANDS ACT 1989

The bed of the Wagonga Inlet is Crown Land. As such, the Department of Lands will be requested to issue a licence to ESC to carry out maintenance dredging in accordance with the conditions outlined in the Feasibility Study and this REF. Licence conditions would be included in the tender documents.

Fisheries Management Act 1994 and Fisheries Management Amendment Act 1997

Sections 198 and 200 of the Fisheries Management Act require a local Council proposing to undertake dredging works to obtain a permit. However these sections do not apply if the dredging is authorised under the Crown Lands Act or by another relevant authority (other than a Local Government). Therefore, assuming the Department of Lands (DoL) issues a licence for dredging, a dredging permit from DPI (Fisheries) would not be required. Note that DoL would refer the licence application to DPI for its conditions.

Sections 204 and 205 (damage to marine vegetation i.e. macroalgae) would apply to lowering the rock pile. This will require a permit from DPI.

5.1.3 NATIONAL PARKS AND WILDLIFE ACT 1974

This Act provides the primary basis for the legal protection and management of Aboriginal sites in NSW. Under this act it is an offence to knowingly destroy an Aboriginal site, relic or artefact. Consents regarding the use or destruction of Aboriginal objects operate under a NPWS system of

permits and consents under the provisions of sections 87 and 90 of the Act. Assessment of these applications requires adequate archaeological review together with local Aboriginal community liaison and involvement.

5.1.4 THREATENED SPECIES CONSERVATION ACT 1995

This Act requires an assessment of whether threatened species, populations or ecological communities are likely to be affected by the activity. This assessment is in the form of an eight part test of significance. If a significant impact on threatened species is likely, a Species Impact Statement (SIS) must be completed and a licence obtained.

Determinations under the Act list a number of Key Threatening Processes that require consideration. Of the Key Threatening Processes that have been listed under Schedule 3, none are relevant to this project.

Endangered Ecological Communities declared under Part 3 of Schedule 1 of the TSC Act exist along the lake foreshore. Threatening processes to the Wagonga Inlet saltmarsh community *(Coastal Saltmarsh in the NSW North Coast, Sydney Basin and South East Corner Bioregions)* would include modified tidal flow, weed invasion and climate change.

Landward of the saltmarsh community is a second endangered ecological community dominated by Casuarina glauca - *Swamp Oak Floodplain Forest of the NSW North Coast, Sydney Basin and South East Corner bioregions*. This community occupies low-lying fringes of parts of Wagonga Inlet in a narrow band where flooding is periodic. Threats to the local community would include weed invasion.

5.1.5 FISHERIES MANAGEMENT ACT 1994

This act gives DPI Fisheries management responsibilities in regard to fish and fish habitat including marine vegetation. This is relevant to the project due to potential impacts on seagrasses, and threatened marine species. Further, DPI confirms that a Harm Marine Vegetation permit under the act will be required in order to damage marine macroalgae on the submerged rock pile.

5.1.6 ENVIRONMENT PROTECTION AND BIODIVERSITY CONSERVATION ACT 1999

The EPBC Act is Commonwealth legislation that protects matters of national environmental significance. It acts in parallel with the TSCA and requires separate tests of significance, should listed species or processes be potentially impacted by the works.

If it were determined that an action is not likely to have a significant impact, then the action is not a controlled action. Approval under the EPBC Act is not required and the action may proceed, subject to obtaining any other necessary permits or approvals.

5.2 State Environmental Planning Policies

5.2.1 SEPP35 MAINTENANCE DREDGING OF TIDAL WATERWAYS

The excavation of or widening of a navigation channel falls under the provisions of SEPP 35. It establishes a referral and response procedure for maintenance dredging and removes the requirement to obtain development consent for maintenance dredging operations. Environmental assessment is required under the provisions of Part 5 of the EP&A Act.

A Council proposing a SEPP 35 activity will be a determining authority by virtue of Section 110 of the EP&A Act.

5.2.2 STATE ENVIRONMENTAL PLANNING POLICY NO 14 COASTAL WETLANDS

There are a number of State Environmental Planning Policy 14 (SEPP14) wetlands that fringe the upper reaches of the Wagonga Inlet. All SEPP 14 wetlands are remote from both proposed dredging areas and sand disposal sites.

5.2.3 SEPP26 LITTORAL RAINFOREST

This SEPP is not relevant in this instance since no areas are mapped in the Wagonga Inlet area.

5.2.4 SEPP 71 COASTAL PROTECTION

This policy aims for improved state, regional and local planning and encourages management decisions to better protect the coast. It gives the Minister for Planning the consent authority role for specified developments or State significant developments. The considerations of SEPP 71 are not applicable to this project.

5.3 Local Environmental Plans

The waters of the Wagonga Inlet upstream of the Princes Highway bridge are uncoloured under Council's *Eurobodalla Rural Local Environment Plan 1987*. Downstream of the bridge the waters of the inlet are unzoned under both the Rural LEP 1987 and the Eurobodalla Urban LEP 1999.
Regardless of zoning, assessment of maintenance dredging activity is required under the provisions of Part 5 of the EP&A Act.

5.4 Draft Environmental Planning Instruments on Exhibition

There are no Draft Environmental Planning Instruments on exhibition relevant to the proposal.

5.5 Draft State Environmental Planning Policies submitted to the Minister

No draft SEPPs are of relevance.

5.6 Development Control Plans

No DCPs are relevant.

6 DESCRIPTION OF THE EXISTING ENVIRONMENT

6.1 Estuary Characteristics

The Wagonga Inlet is permanently open to the ocean with an entrance channel that has been stabilised by the construction of training walls at the entrance as well as along the inlet channel up to the highway bridge. The inlet has a small ebb tidal delta extending seawards of the entrance training walls. More focal to this study is the entrance channel which links the entrance to the main lake basin. This channel comprises flood tidal delta deposits which extend past the highway bridge to the drop-over into the lake body.

In the Wagonga Inlet's downstream reaches up to the highway bridge, flows within the channel are confined by rock walls, and the flood tidal delta deposits cannot disperse laterally. In this reach, deposits are restricted to longitudinal bars, either attached to the sides or mid-channel with ebb and flood tide channels on either side. These features are defined in **Figure 3**.

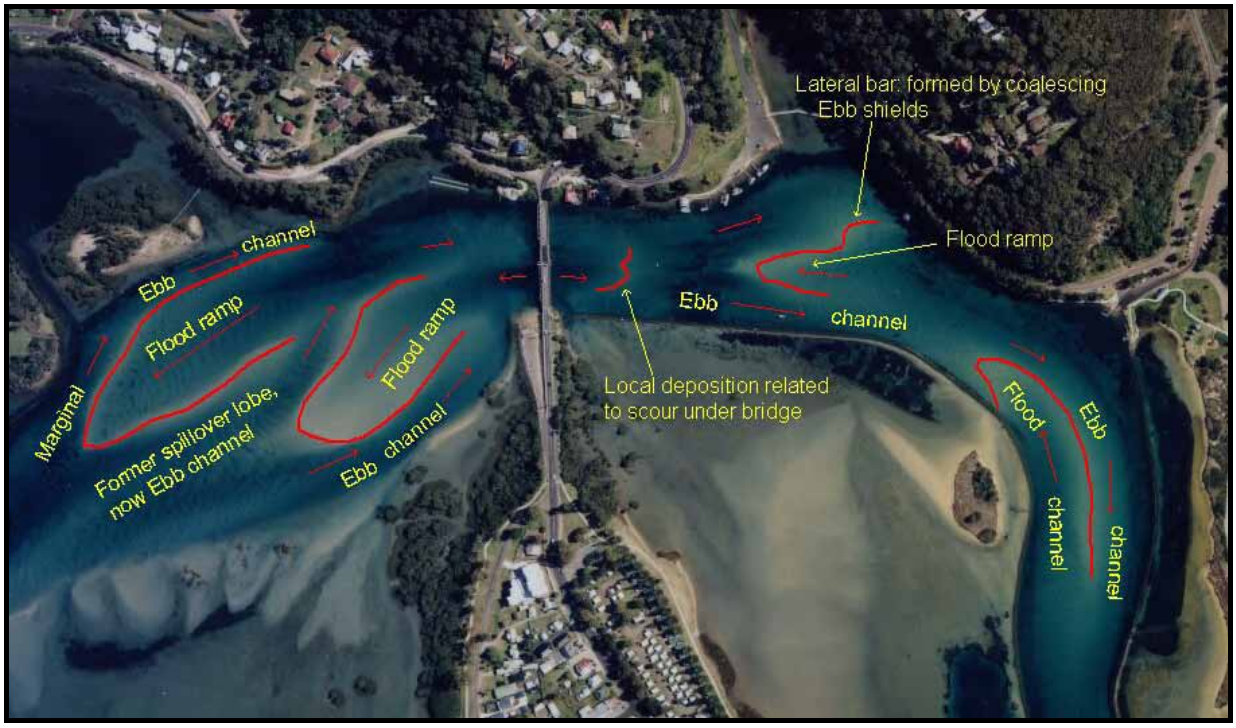


Figure 3 Mid-channel sediment features - 2005 aerial photograph

Where inlet channels are unconfined west of the highway bridge, flood tidal delta deposits have spread in a complex pattern of flood ramps, with peripheral ebb channels. Longitudinal bars separate these channels, allowing flows in both directions to occur near the time of tide reversal. Because of this complex pattern, different locations are dominated by either flood or ebb oriented sediment transport. The interlinking of these channels provides the opportunity for the sediment to be recycled through a rotational pattern of erosion, transport and deposition without any net gains in sediment mass to the inlet. However, where the flood tidal channels meet the main lake body,

sediment transport is one directional as the material moves upstream over a drop-off into the deeper lake body.

6.2 Sediment Characteristics

The sediments in the ebb and flood tidal deltas of Wagonga Inlet are composed of marine sands, originally deposited close to the time when the sea level became relatively stabilised some 6,000 years ago. Small amounts of marine sand may still enter the estuary from the coast but these would be limited both in amount and extent.

Tidal currents in the channel have velocity above the threshold for fine material such as silts and clays It is expected that tidal flow would flush fines through the system rather than settle in the shoals.

To test this supposition, core samples were taken from the proposed dredge shoal opposite Lewis Island (LI 1 and LI 2). The location of samples is shown on **Figure 4**. Two cores to a depth of 500mm were sampled by hand-driven polycarbonate tube and analysed by University of Wollongong School of Geosciences Sedimentology Laboratory for grainsize and fines content. Samples of the proposed disposal area in the ebb channel were also taken for grainsize comparison, and to check for in-fauna content (**Section 6.6.4**). Results are summarised in **Table 2** overleaf, with a detailed report contained in **Appendix 2**.

Figure 4 Location of sediment cores October 2005

Table 2: Sediment Analysis (University of Wollongong).

Sample	% Sand	% Silt and Clay	Median Grainsize (mm)	Comment
LI 1 composite	100	0	0.390	Lewis Island shoal
LI 1 lower layer	100	0	0.365	Grey anoxic sand in shoal
LI 2	100	0	0.437	Bar on Lewis Island shoal
EBB 1	100	0	0.310	Ebb channel to be filled
EBB 2	100	0	0.343	Ebb channel to be filled

Analysis confirms that the Lewis Island shoal and the ebb channel both comprise totally clean marine sand with no silt, clay or organic content. Other areas proposed to be dredged lie in similar tidal flows and would also comprise clean marine sand.

The more mobile areas of the Lewis Island shoal contained clean yellow sand over the top 200mm to 500mm (sample 'LI 2' was taken on a recent bar formed on the shoal). An layer of greyish sand ('LI 1 lower') underlying the surface layer is noted to contain very slightly finer sand (0.37 mm as against 0.44 mm median grainsize) with no organic matter or silt content. The grey colouration is due to lack of oxygen in a reducing environment. From observation the yellow colour reappears when re-exposed (*E. McLean pers. comm*.). Sample 'LI 1 composite' is a mix of both sand types, typical of sediment that would result from the dredging operation.

The ebb channel samples (EBB 1 and EBB 2) comprise clean sand with slightly finer grainsize than the Lewis Island shoal. This is indicative of slightly lower current velocity in this channel compared to the main Lewis Island channel. It also suggests that the Lewis Island shoal sand would be likely to remain reasonably stable under average tidal conditions when placed in the ebb channel.

6.3 Water Quality

The water quality of Wagonga Inlet is routinely better than many of the numerous south coast estuaries. This is due to its permanently open (trained) entrance and large (up to 600mm) tidal range. As a result the estuary is well flushed with its entrance channel and the lower areas of the main estuary basin having salinity similar to the marine environment.

6.4 Acid Sulphate Soils

Acid sulphate soils are those that have been formed in low energy, depositional environments over the last 6000 years. In NSW, potential acid sulphate soils have been mapped in every estuary and embayment along the coastline.

Potential acid sulphate soils are mapped as located within the entrance channel in all areas to be dredged. The mapped data indicates a high probability of acid sulphate soils in estuarine bottom sediments. However both the shallow depth of dredging proposed, and the very recent depositional history of sand shoals to be dredged (i.e. over the last 3 or 4 years), would strongly suggest that acid sulphate issues will not be encountered.

Further supportive evidence of the negligible likelihood of acid sulphate issues is provided by the presence of Lewis Island, which was formed by dredging the inlet many decades ago. There is no sign of ASS influence on seagrass or mangroves adjacent Lewis Island.

6.5 Flora

6.5.1 AQUATIC FLORA AND ALGAE

The waters of the Wagonga Inlet entrance channel comprise complex patterns of sand shoals with a rocky shoreline, mostly constructed rock training walls. Aquatic flora in these sandy areas comprises seagrasses in stable areas with relatively sheltered tidal currents or to mostly marine macroalgae species that are adapted to rocky substrate and remain unaffected by strong currents.

The dominant seagrass species recorded within the estuary are eelgrass (*Zostera capricorni),* and strapweed *(Posidonia australis)* as depicted in **Figure 5** overleaf with a base date of 1984. In particular beds of *Posidonia* are extremely healthy, displaying strong growth in recent years across some of the more stable sand shoals near the Forsters Bay entrance (*Ron West pers. comm*.). Patchy strapweed extends from the bridge to the eastern edge of Mill Bay. Paddle weed (*Halophila sp.*) is found in sheltered embayments such as the area in the lee of Lewis Island. Impacts of the works on seagrasses are discussed in **Section 7.4**.

Forms of attached algae are both found in the inlet. Neptune's necklace (*Hormosira banksii*) is commonly found, which emphasises the marine character of the estuary. The inlet channel also contains bubble weed (*Phyllospora camosa*) and kelp (*Ecklonia radiata*) along the base of the retaining walls and on the rock pile. Patches of *Sargassum* are found from the entrance upstream as far as Clarks Bay. Long strands of *Sargassum* are attached to subtidal rocks forming the retaining walls along the entrance channel.

6.5.2 MANGROVES AND SALTMARSH

Patchy stands of grey mangroves (*Avicennia marina)* are associated with the estuary, located on **Figure 5** overleaf. Saltmarsh covers narrow bands on the high shore just above regular tidal inundation and is also patchy in its distribution.

6.6 Fauna

The Wagonga Inlet is reported to support an abundant and diverse range of fauna (*MHL 2001*). Large numbers of vulnerable and some endangered fauna are present, notably birds. The estuary supports more diverse assemblages of zooplankton, benthic invertebrates and fish than other estuaries in the Eurobodalla Shire. This diversity is attributed to the higher salinities and extensive strapweed beds present in the inlet.

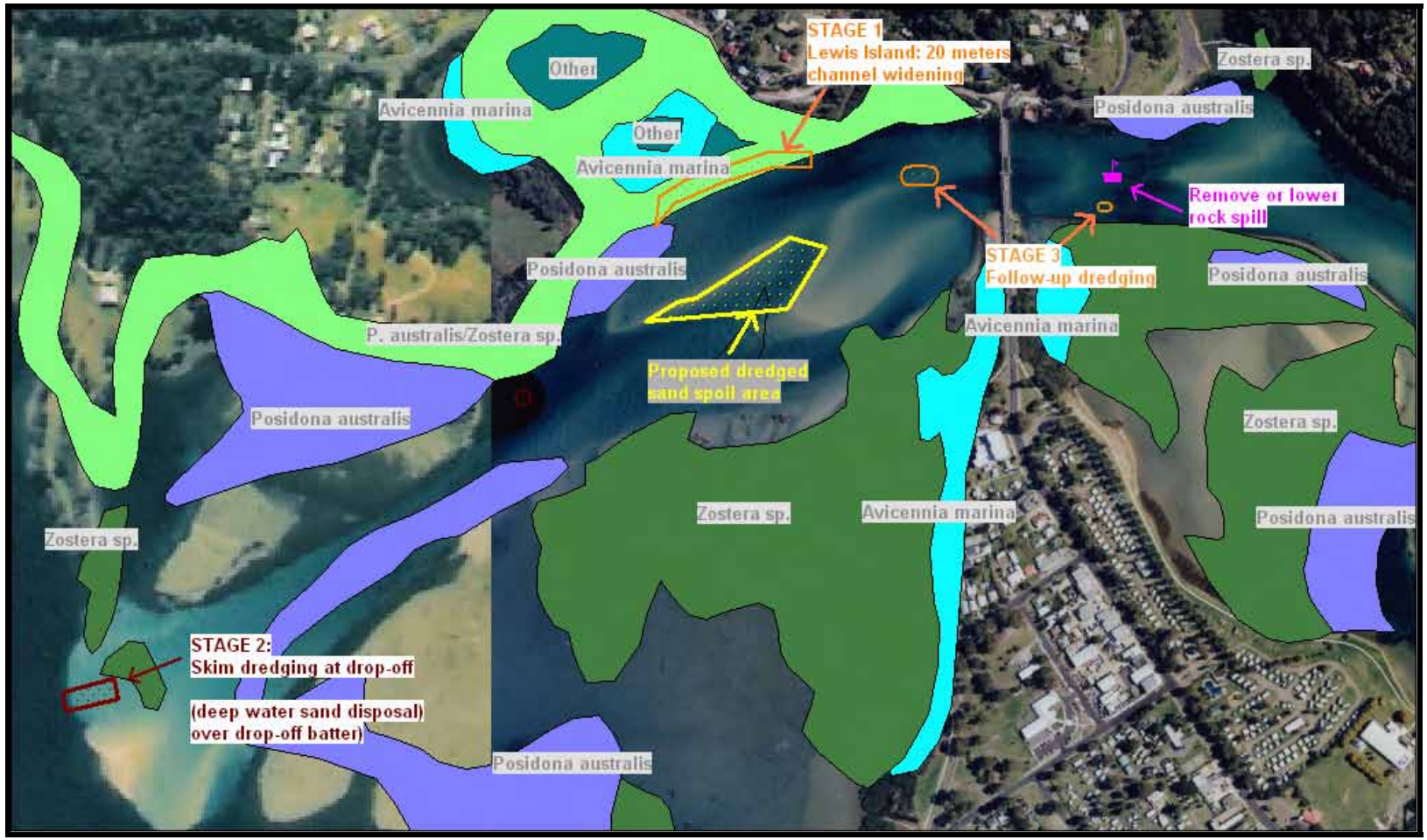


Figure 5 Location of seagrass beds and mangroves in mid-entrance channel

(from 1984 mapping by *West et al*)

6.6.1 FISH

The Estuary Processes Study (MHL 2001) reports the findings of two studies that indicate the estuary to be very diverse in the range of fish. It is noted that the estuary has not been commercially fished since the 1930's. Records of fish species within the inlet are limited to a few research projects.

The most recent sampling of Wagonga Inlet by West et al occurred during February and July 1999, and the eight seine hauls caught 956 fish. Twenty-six species were found. Eleven of these species were considered to be of importance to commercial and recreational fisheries. The most abundant species caught were sea mullet (*Mugil cephalus*) small mouth hardyhead (*Atherina microstoma*) and glassy perchlet (*Ambassis jacksoniensis*). The main economically important species caught were from the mullet family and tailor (*Pomatomus saltator*). In an earlier 1992 study, tarwhine, bream, luderick and eastern blue groper were found to be the most abundant fish of economic importance associated with strapweed beds.

Macroalgae beds on the retaining walls along the entrance channel form suitable habitat for *Syngnathids*. These are a unique family of fish which includes seahorses, pipefish, pipehorses and seadragons. *Syngnathids* are listed as a protected species under Section 19 of the NSW Fisheries Management Act 1994.

Fishes of the family *Syngnathidae* are found in tropical and temperate coastal waters around the world, and seahorses occur throughout this range. Many members of this family occur in temperate marine waters along the south-eastern and south-western coasts of Australia. Some species are endemic to Australia. Pipefish habitat varies from coral reefs to sheltered sandy coastal bays, with a few species inhabiting marine algae beds. Seahorses, seadragons and pipehorses can be found in shallow protected waters in seagrass, algae beds and under wharves.

Wagonga Inlet provides suitable habitat for these species in macroalgae beds located amongst rocks on the rock pile and along the training walls. The lowering of the rock pile would impact on suitable habitat for *Syngnathids*. However given the minimal scale of habitat loss and the extensive areas of suitable habitat along rock walls along the inlet's entrance channel, potential impact on the species is judged to be insignificant. Major threats to *Syngnathids* include pollution, urban drainage, dredging of rocky habitat and discharge of sewage. The proposed activity is considered a threatening process, however its impact is mitigated by its minimal extent

6.6.2 BIRDS

The Estuary Processes Study (MHL 2001) lists 197 bird species recorded for the Wagonga Inlet estuary and surrounding area. The Estuary Management Plan (Nelson Consulting 2001) also

provides a summary of significant bird species found on or around the Inlet, from which this review draws much of the following information.

Birds commonly using the entrance channel area and lower end of the estuary include seabirds and migratory waders. The tidal flats between Shell Point and the entrance, and the sand flats along Riverside Drive are considered important habitat for wading and sea birds. The sand spit behind the training wall on the eastern side of the bridge is a significant habitat for pelicans, gulls, terns and migratory waders / shorebirds. NPWS consider this area as potential breeding site for Pied Oystercatcher.

Wagonga Inlet is one of nine important sites for waders on the Eurobodalla Coast. Large numbers of several species are regularly recorded,. Including Pied Oystercatcher (up to 30 birds) Red Knot (70) and Bar-tailed Godwit (300).

Migratory wader species such as godwits, knots and curlews feed around the shallow sandflats although in general, species from this group tend to prefer strongly tidal habitats dominated by muddy rather than sandy substrates.

Bird species protected under the National Parks and Wildlife Act, the *Threatened Species Conservation Act (TSCA) 1995* and international treaties are known to use the estuary. Species classified as 'endangered' or 'vulnerable' under the TSCA recorded from the local area are listed in **Table 3** with an assessment of their habitat preferences.

Table 3: Endangered and Vulnerable estuarine bird species whose range coincides with Wagonga Inlet.

Hooded Plover (Endangered)	Known to feed on estuarine flats on Little Lake (Narooma) and nearby Corunna Lake.
Sooty Oystercatcher (Vulnerable)	Feeds on intertidal flats on the inlet, also forage at nearby Nangudga, Corunna and Mummuga Lakes.
Pied Oystercatcher (Vulnerable)	Breeds on a sand island in the inlet, also breed at nearby Mummuga and Corunna Lakes.
Little Tern (Endangered)	May on occasion forage for fish in the estuary, known in nearby Corunna Lake.
Great Knot (Vulnerable)	Forage on tidal mud flats.
Osprey (Vulnerable)	Patrols over water.
Black-tailed Godwit (Vulnerable)	Known to feed on intertidal flats near Narooma Golf Course.

A number of bird species known to occur at or near Wagonga Inlet are subject to international migratory bird agreements with Japan and China. These include the White-breasted Sea Eagle,

Little Tern, Great Knot, Black-tailed Godwit, Great Egret, Caspian Tern, Red Knot, Curlew Sandpiper, Red-necked Stint and Bar-tailed Godwit.

Additionally, the following listed bird species (non-shorebirds) have been recorded in the region (**Table 4**), and may inhabit or feed in the open woodlands and forests within or near the estuary catchment.

Table 4: Listed bird species recorded in the catchment of Wagonga Inlet.

Powerful Owl	Ninox strenua
Sooty Owl	Tyto tenebricosa
Masked Owl	Tyto novaehollandiae
Square-tailed Kite	Lophoictinia isura
Regent Honeyeater	Xanthomyza phrygia
Bush-stone Curlew	Burhinus grallarius

The incidence of the species listed in **Table 4** has no impact on considerations for this project due to their habitats being remote from and suffering no impact from the works.

With consideration of the requirements of the TSC Act, an Eight part test is prepared in **Appendix 1** of this REF for the **Pied Oystercatcher**. This is the only species in **Table 3** that is known to breed on the inlet. Other bird species may forage opportunistically on the inlet, but the dredging operations are considered to have such an insignificant and temporary short-term bearing on this behaviour that impacts are remote.

6.6.3 OTHER TERRESTRIAL FAUNA

Nine species listed as Vulnerable under the TSC Act have been recorded in the estuary's catchment or nearby estuarine areas.

One vulnerable amphibian species has been recorded from the region: the Giant Burrowing Frog. Common frogs noted in the Processes Study for the catchment of the inlet are Verreauzii's Tree Frog, Spotted Grass Frog and Brown Striped Frog. None of the frog species mentioned are likely to occur in the habitats directly connected to the estuary due to excessive salinities and preference for different habitat types. It will be assumed that no frogs would be present in the estuarine areas subject to dredging works.

Apart from frogs, terrestrial mammals found in the catchment of the inlet number some 36 species including 8 species listed as vulnerable under the TSCA. These are Southern Right Whale, Humpback Whale, Tiger Quoll, Yellow-bellied Glider, Long-nosed Potoroo, and the bats Great Pipistrelle, Golden-tipped Bat and Common Bent-wing Bat. None of these species of mammals has a reliance on estuarine habitat and would not be present in or adjacent to estuarine areas

subject to dredging works. Accordingly no eight-part test for any mammals is provided in **Appendix 1**.

6.6.4 OTHER MARINE FAUNA

Sand shoals within the estuary provide potential habitat for marine and estuarine species such as crustaceans, molluscs and polychaete worms. The areas to be dredged are mobile areas of bare clean sand and have not been heavily populated by these in-fauna.

Similarly, areas of ebb channel proposed to be filled with dredged material (see **Figure 1**) contain very few species of in-fauna, with those present at low densities. Site inspection in October 2005 revealed no molluscs and few signs of worm habitation at a density averaging one per ten square meters.

Sediment coring in the ebb channel (four random shallow cores to 200mm depth in two localities) was analysed for biological content. Both samples contained a small amount of broken shell material but contained no living shelly fauna. Both samples contained a few empty sandy tubes probably created by polychaete tube-worms in the Phylum Annelida. No live annelids of tube worm genera were present in the collected material. Two small Nephtyidae (2-3 cm long segmented carnivorous worms, probably *Nephtys australiensis*) recorded in sample EBB2 represent the only visible living material greater than 1 mm in size. This confirmed that these areas provide low value habitat for these species which would prefer lower velocity areas with more fines and organic content.

Estuarine muds at the base of the dropoff are in water depths of 10 to 12 meters and would be low in oxygen and light. Fisheries officers confirm that macrofaunal populations in these areas would be sparse or non-existent.

6.7 Landscape Qualities

The most noteworthy qualities of the broader local landscape are

- The estuary's waters and sand shoals provide the most notable visual features from distant and nearby vantages.
- Relatively steep hillslopes grade up to mature eucalypt forests on ridges, providing a significant visual backdrop to the inlet. Mount Dromedary (*Gulaga*) to the south is a dominant visual and cultural feature of the landscape.
- Stands of mangroves, with or without fringing Swamp-oak forest provide filtered views of the estuary.

6.8 Recreational Uses

Wagonga Inlet supports a range of recreational uses including swimming, boating, sailing and fishing, mostly from a boat but also shore-based. The southern foreshore areas of the inlet within the Narooma township are used for walking, sightseeing and exercise.

Proposed works will not adversely affect these activities. Improvements to navigation will in turn improve the quality of boating on the lower estuary, and will improve the navigability of the channel linking the entrance to the Forsters Bay boating and mooring facilities.

6.9 Archaeology

Many sites of Aboriginal cultural significance, such as middens, campsites and a burial site are known to be present around the foreshores of the Wagonga Inlet. (*Navin Officer 1997*). None of these sites would be impacted by the proposed works.

7 POTENTIAL ENVIRONMENTAL IMPACTS & MANAGEMENT

7.1 Water Quality Impacts

Impacts on the inlet's excellent water quality from dredging could potentially occur. Disturbance of any fine sediments present within the estuarine sands could occur adjacent to the cutter suction head. However sand sampling confirms that the sands to be dredged contain no fine sediment, and the risk of release of fine sediment from the dredging operation would be negligible.

Sediments close to a vehicle traffic crossing such as the Princes Highway bridge could potentially contain heavy metals. Concentrations in fine sediments would be an issue, however the clean marine sand does not have the ability to hold heavy metal concentrations that would provide a threat to estuary health.

Short term visual impacts from lowering of the rock pile may occur. It is assumed that the rock pile would contain algae and other organic material, sand filling crevices in the rocks, and possibly some fine sediment. This would be released upon initial disturbance for a very short time.

This review recommends that the initial disturbance of rock pile lowering be undertaken on an ebb tide so the disturbed material would travel downstream to the entrance rather than up into the estuary. The material would disperse and dilute with distance from the source, and should be undiscernible within 100 meters from the pile. It would not represent a potential threat to estuary health.

7.2 Impacts on Oyster Leases

If left uncontrolled, fine sand could feasibly travel a short distance in suspension in the channel (peak velocities are up to 1 meter per second at the highway bridge). Most sand disturbance would be near the bed, which would re-suspend over a limited height above the bed. There would be a slight possibility of adverse impact on oyster leases, should tidal currents transport fine sand to oyster beds. Oysters are filter feeders and would trap and hold sand grains in their filter system. This would be deleterious to their growth or even fatal if sand was in sufficient concentration (*J. Croucher pers. comm.*).

Oyster leases are located around the areas proposed to be dredged (see **Figure 6**). One lease - 50.304 on the shore of Lewis Island - is no longer active. The three leases located between Lavender Point and the highway bridge that would be potentially most impacted (Leases 78.076, 69.626, and 87.159 - see **Figure 6**) are all catching leases. These leases aim to trap oyster spat entering the estuary, and consequently operate between April and December each year. Oysters are later relocated for growing further up into the estuary.

The seasonal timing of dredging operations cannot be planned to avoid the operational window of these leases. The daily timing of dredging and sand placement operations is planned to minimise the possibility of impacting oyster leases. However as an additional safeguard to the dispersal of a sand plume, a sediment curtain will be required to protect the sand placement area upstream of the bridge.

Those leases located around the dropoff are at no risk from sediment release when the dropoff is dredged, as disposal from this dredging will be into 10m to 12m deep water at the edge of the drop-off delta.

Figure 6 Location of oyster leases in mid-entrance channel

7.3 Impacts on Threatened Species

The impact of the dredging operations on threatened species is detailed in the Eight-part tests in **Appendix 1 and 2**.

Impacts on threatened birds are considered minimal and limited to noise effects that may affect potential foraging habits of shorebirds and waders in the immediate locality. Impacts would be short lived over the 4 to 6 week works period.

Impacts on *Syngnathids*, a protected family of fish including seahorses and pipefish are possible but extremely limited in terms of scale. An insignificant area of suitable habitat would be modified

or lost due to rock pile lowering. The remaining length of training walls forming suitable habitat along the entrance channel is of far greater magnitude and importance for these species.

7.4 Impacts on Seagrasses

Figure 5 depicted the mapped location of seagrasses and mangroves in the study area. Seagrass mapping data is derived from *West et al,* based on mapping in the early 1980's. Proposed dredging sites and sand disposal areas are superimposed.

Potential impacts on seagrasses are evident from **Figure 5** in the Lewis Island channel area and at the dropoff. All dredge and disposal sites have been inspected to determine if seagrass mapping as shown in **Figure 5** is valid. The conclusions are that

- any seagrasses previously mapped in the Lewis Island channel have been lost as the shoal moves across the channel. The area to be dredged is an actively moving shoal. The proposed disposal area is also clear of seagrass, having been scoured over recent years.
- there are no seagrasses near the proposed skim dredging at the dropoff.

It is concluded that the proposed works have no potential to impact on seagrasses within the inlet.

7.5 Long Term Impacts

No long-term impacts of the proposed works are identified. The scale of dredging proposed is intentionally not significant enough to cause major changes in tidal channel patterns.

7.6 Aboriginal Cultural Heritage

It is concluded that this project has no potential to impact on Aboriginal cultural heritage sites on the foreshore of the estuary.

7.7 Operational Issues

Access to the waterway for a dredge would most likely be from the south-western end of the highway bridge. This area is suited to plant exit and entry, and is appropriate for short-term equipment storage (floats, pipelines, boat) in a site shed or container. Forming part of the highway road reserve, this land is owned by the Roads and Traffic Authority (RTA), and permission to occupy this land for the project life should be sought. There would be no impacts associated with this occupation provided refuelling activities were performed using best practice.

Interruptions to boat traffic on the estuary while dredging is underway would be expected. Temporary speed restrictions may be necessary to supplement the boating regulation requiring a 4-knot speed when within 100 meters of a dredge. NSW Maritime and Council should publicise the dredging activity including any local restrictions. Dredging plant should carry compliant navigational lights.

8 CHECKLIST - MATTERS FOR CONSIDERATION

Clause 82 of the Environmental Planning and Assessment Act Regulation lists the factors to be taken into account when considering the likely impact of an activity on the environment under Part 5 of the EP&A Act. The following section deals with each of the matters considered to be relevant to the project.

a) Any environmental impact upon a community

The community most likely to be affected if there were to be an impact would be the residents of the township of Narooma and North Narooma. There will be no significant adverse impact upon these communities.

b) Any transformation of a locality

The locality will not be transformed in any significant manner. Channels in the sand shoals will be restored to a configuration representative of expected long-term behaviour.

c) Any environmental impact on the ecosystems of the locality

The possible impacts are discussed above under **Section 7**. These are considered minor in nature when managed with regard to the recommendations of this REF and the Feasibility Study (*PSA Sep 2005*).

d) Any reduction of the aesthetic, recreational, scientific or other environmental quality or value of a locality

There is not likely to be any reduction in the aesthetic or other quality or value of the locality as a result of the proposed works. Improvements to recreational boating will result from the proposed navigation improvements.

e) Any effect on a locality, place or building having aesthetic, anthropological, architectural, cultural, historical, scientific or social significance or other special value for present or future generations

There are no potential effects upon Aboriginal archaeological sites or sites of cultural, scientific or social significance.

f) Any impact on the habitat of protected or endangered fauna

As noted above, species of bird recorded from Wagonga Inlet which potentially use the estuary's habitats and entrance area are classified as Vulnerable or Endangered. The eight-part test in Appendix 1 concludes that any bearing on these species is unlikely.

Potential impacts upon suitable habitat for *Syngnathids* (seahorses and pipefish) are acknowledged due to lowering of the rock pile and subsequent loss of macroalgae. The eight-part

test in Appendix 2 concludes that loss or modification of habitat would be insignificant in area compared to the available habitat along training walls in the entrance channel.

g) Any endangering of any species of animal, plant or other form of life, whether living on land, in water or in the air

There will be no endangering of any species of animal, plant or other life form.

h) Any long term effects on the environment

The probability of long-term impacts on the environment are negligible.

i) Any degradation of the quality of the environment

There will be no permanent degradation of the quality of the environment from the project.

j) Any risk to the safety of the environment

It is unlikely that the environment will be any less safe as a result of carrying out these works.

k) Any reduction in the range of beneficial uses of the environment

There will be no reduction in the range of beneficial uses of the environment. The project will improve the navigation of the inlet for small to medium boats so that navigation can safely be gained for more of the tidal cycle.

l) Any pollution of the environment

Pollution of the environment (noise, minor diesel fumes) may be experienced while construction equipment excavates a channel across the sand shoals.

m) Any environmental problems associated with the disposal of waste

There are no waste disposal issues associated with the project. The sand deposits to be dredged all have been in their present form after recent deposition of the order of a few years and are extremely unlikely to contain deleterious substances.

n) Any increased demands on resources (natural or otherwise) that are, or are likely to become, in short supply

There are no recognised increased demands on resources.

o) Any cumulative environmental effect with other existing or future activities

It is unlikely that this activity would have a cumulative effect with other activities.

9 CONCLUSIONS

The proposed activity is not likely to have a significant environmental impact upon threatened species or endangered ecological communities of the Wagonga Inlet in either the short term or in longer time frames.

The proposed activity - works for the improvements to navigation at the entrance channel of Wagonga Inlet - could possibly impact nearby oyster leases. This risk can be managed.

Implementation should be conditional upon the following mitigation strategies:

- the timing of sand dredging activities will be controlled in accordance with the details within this document to minimise risk to oyster leases. Subsequent sand movement will be monitored visually and operations will be managed with limitations to restrict dredging to suitable times within the tidal cycle to manage this possibility.

10 DECLARATION

Having considered this document and the factors listed in Clause 82 of the Environmental Planning & Assessment Regulations, Eurobodalla Shire Council is of the view that the works covered by this REF - works for the improvements to navigation at the entrance channel of Wagonga Inlet - will not have a significant adverse environmental impact.

This Review of Environmental Factors provides a true and fair review of the proposal in relation to its potential effects on the environment.

…….. ……

Signed **Date**

Eurobodalla Shire Council

11 REFERENCES

Australian Museum Web Site www.austmus.gov.au/fishes

Gary Blumberg & Associates Pty Ltd (1999) *Wagonga Inlet Flooding Investigation*

Manly Hydraulics Laboratory (April 2001) *Wagonga Inlet Estuary Processes Study*

Navin Officer (1997) *Archaeological Survey for Aboriginal Sites, Wagonga Inlet Foreshores, Narooma, NSW* Prepared for Eurobodalla Shire Council

Nelson Consulting (November 2001) *Wagonga Inlet Estuary Management Study and Plan*

NSW Fisheries (1998) *Policy and Guidelines Aquatic Habitat Management and Fish Conservation*.

NSW Fisheries (August 2003) *The Protection of Syngnathids in NSW Waters* Discussion Paper

Paling E I and van Keulen M (April 2003) *Pilot seagrass transplantation trials in Forsters Bay, Narooma, NSW* (Marine and Freshwater Research Laboratory, Murdoch, Western Australia)

Peter Spurway & Associates Pty Ltd (September 2005) *Wagonga Inlet Entrance Channel - Options for Navigation Management* - Feasibility Report prepared for Eurobodalla Shire Council

Webb McKeown & Associates Pty Ltd (October 1997) *Narooma Bar Dredging Investigation*

West R., Thorogood C., Walford T. and Williams R. (1985) *An Estuarine Inventory for New South Wales, Australia*. Division of Fisheries, NSW Department of Agriculture, Sydney.

West R. and Jones M. (2000) *Fish in Shallow Waters of NSW South Coast Estuaries*. FRDC Project Report 97/204

12 APPENDIX 1

EIGHT PART TEST ON PIED OYSTERCATCHER

Section 5A of the Environmental Planning and Assessment (EP and A) Act (1979), as amended by the TSC Act (1995) sets out the factors to be considered in deciding whether there is likely to be a significant effect on threatened species, populations or communities and / or their habitat.

ASSESSMENT OF IMPACTS

This eight-part test consider the Pied Oystercatcher. The other threatened bird species that have been recorded within the general area will not be considered, as in the case of these other shorebirds and waders, the potential for impact on foraging activity is minimal and insignificant.

1. in the case of a threatened species, whether the life cycle of the species is likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction,

The Pied Oystercatcher occurs on the coast especially in intertidal mudflats, sandbanks and open beaches (Marchant and Higgins, 1993). They forage on exposed sand, mud, rock or coral for molluscs, worms, crabs and small fish (Marchant and Higgins, 1993).

They nest on areas of sand immediately above the high-water mark of beaches, sand bars and margins of estuaries and lagoons (Marchant and Higgins, 1993). Usually two eggs are laid in an unlined scrape between September and December in southern Australia (Marchant and Higgins 1993). The 2003-04 breeding season at Narooma saw one pair of birds produce two eggs and one fledgling. Nesting takes place east of the main sand spit about 1 kilometre from the mid-channel dredging sites.

The dredging of the entrance channel of Wagonga Inlet would have a minor impact on the foraging habit of the Pied Oystercatcher. However given the distance from the nesting site to the works site and the suitable habitat areas not impacted by dredging works, potential impact on the species is judged to be minimal.

The above facts indicate that the life cycle of the Pied Oystercatcher is not likely to be disrupted such that a viable local population of the species is likely to be placed at risk of extinction.

2. in the case of an endangered population, whether the life cycle of the population that constituted the endangered population is likely to be disrupted such that the viability of the population is likely to be significantly compromised,

No populations currently listed under Part 2 Endangered populations of Schedule 1 occur in the area. No assessment is required.

3. in relation to the regional distribution of the habitat of a threatened species, population or ecological community, whether a significant area of known habitat is to be modified or removed,

The region is defined by NPWS as the area south from Kioloa State Forest to the NSW / Victorian border. Habitat of the Pied Oystercatcher has been included in the reserve system as a consequence of the Regional Forest Agreement. The size of the proposed works area at any time is very small in relation to the available foraging habitat in the region. No significant area of known habitat shall be removed or modified as part of the development.

4. whether an area of known habitat is likely to become isolated from currently interconnecting or proximate areas of habitat for a threatened species, population or ecological community,

The proposed works will not isolate interconnected habitat of this species.

5. whether critical habitat will be affected,

Critical habitats are areas of land that are crucial to the survival of particular threatened species, populations and ecological communities. No critical habitat has been listed for this species.

6. whether a threatened species, population or ecological community, or their habitats, are adequately represented in conservation reserves (or other similar protected areas) in the region,

The region is defined by NPWS as the area south from Kioloa State Forest to the NSW / Victorian border. Habitat of the Pied Oystercatcher is conserved in several conservation reserves in the region.

For Pied Oystercatcher, the adequacy of the number within the reservation system is complicated by the large home range of the species. Hence, conservation of these species requires the retention of habitat within and outside of the reservation system.

7. whether the development or activity proposed is of a class of development or activity that is recognised as a threatening process,

The proposed activity is not considered a threatening process.

8. whether any threatened species, population or ecological community is at the limit of its known distribution.

The Pied Oystercatcher is found in Australia, Irian Jaya and Papua New Guinea (Marchant and Higgins 1993). In Australia it occurs around the entire coast (Simpson and Day 1998). The Pied Oystercatcher is not at the limit of its known distribution.

Additional References for this Eight-part Test

Daly, G.; Dawson, J.; Schwarz, E.; Pietsch, R.; Saxson, M.; Claridge, A. and Oliver, L. (2000). Threatened Fauna of the Shoalhaven. Shoalhaven Catchment Management Committee and NSW National Parks and Wildlife Service, Queanbeyan.

Marchant, S. and Higgins, P. J. (1993). *Handbook of Australian, New Zealand and Antarctic Birds. Volume 2 Raptors to Lapwings.* Oxford University Press, Melbourne.

National Parks and Wildlife Service (April 2005) *South Coast Shorebird Recovery Newsletter*

Simpson and Day (1998) *The Claremont Field Guide to the Birds of Australia*

13 APPENDIX 2

SEDIMENT SAMPLING ANALYSES

Samples of sediment within the Lewis Island shoal and in the central ebb channel were collected by Peter Spurway & Associates on 26th October 2005. Samples were analysed at the University of Wollongong's School of Geosciences Sedimentology Laboratory. The laboratory's report is presented in full overleaf including grainsize distribution plots.

Discussion of results is contained in **Section 6.2** and cores are located as shown on **Figure 4** of the REF.

Grain size and faunal analysis for Wagonga Inlet

Brian G Jones
University of Wollongong

Laser Diffraction Grain Size Analysis

A small portion from the centre of each sample was extracted for grain size analysis using a Malvern laser diffraction particle size analyser. Prior to analysis, each sample was subjected to 30 seconds of ultrasonic treatment to separate any clay minerals or organic matter. The results for the grain size analysis are presented in *Table 1*.
None of the samples contained measurable quantities of silt, clay or organic matter, i.e. they all consist of 100% sand. They were all well sorted, unimodal medium-grained sands with essentially symmetrical grain size profiles representing normally distributed sandy sediments. The sediments from the dredge site areas (LI 1 and LI 2) are slightly coarser grained than those from the proposed spoil dump sites (EBB 1 and 2), suggesting that the former come from slightly higher current velocity areas.

Table 1 Grain Size Analysis for Wagonga Inlet samples using laser diffraction particle size analysis

Sample	%sand	%silt	%clay	Volume weighted D[4,3] mean	Graphical Mean (um)	Mode1	Mean (phi)	Sorting	Skew-ness	Kurtosis
LI 1 composite	100	0	0	405	390	390	1.36	0.41	0	0.96
LI 1 lower	100	0	0	379	365	365	1.45	0.4	0	0.96
LI 2	100	0	0	457	439	437	1.19	0.41	-0.01	0.96
EBB 1	100	0	0	324	309	310	1.69	0.45	0	0.95
EBB 2	100	0	0	358	342	343	1.55	0.44	0.01	0.95

Biota

The two samples from the proposed dredge spoil site were sieved through a 1 mm mesh sieve to separate out any living biota larger than microfauna. The material retained on the sieve was analysed for biological content.

Both samples contained a small amount of broken shell material but contained no living shelly fauna. Both samples contained a few empty sandy tubes probably created by polychaete tube-worms in the Phylum Annelida. No live annelids of tube worm genera were present in the collected material. Two small Nephtyidae (2-3 cm long segmented carnivorous worms, probably *Nephtys australiensis*) recorded in sample EBB2 represent the only visible living material greater than 1 mm in size.

Summary

The well-sorted sand at both the dredge and spoil sites represents material that has been reworked frequently by tidal currents. The lack of fine material indicates that current velocities are predominantly above the settling velocity for silt and clay. This accounts for the very sparse macrofauna present in the proposed dredge-spoil dump area.

Grain Size Terminology

Size: the mean grain size of the sediment

	σ	**μm**
Coarse-grained sand	0-1	1000-500
Medium-grained sand	1-2	500-250
Fine-grained sand	2-3	250-125
Very fine-grained sand	3-4	125-62.5
Silt	4-8	62.5-4
Clay	>8	<4

Sorting: a measure of the uniformity of the grain size distribution.

	σ_I
Very well sorted	<0.35
Well sorted	0.35 –0.50
Moderately well sorted	0.50 – 0.71
Moderately sorted	0.71 – 1.00
Very poorly sorted	1.0 – 2.0
Very poorly sorted	2.0 – 4.0
Extremely poorly sorted	>4.0

Skewness: a measure of the degree of asymmetry of the grain size distribution. A positive skewness indicates an excess of fine material whereas a negative skewness indicates an excess of coarse material compared to a normal distribution.

	Sk_I
Strongly fine skewed	+1.00 – +0.30
Fine skewed	+0.30 – +0.10
Near symmetrical	+0.10 – -0.10
Coarse skewed	-0.10 – -0.30
Very coarse skewed	-0.30 – -1.00

Kurtosis: a measure of the peakedness of the grain size frequency distribution. If the central portion of the curve is better sorted than the tails it is peaked or leptokurtic. If the tails are better sorted than the centre the curve is flattened or platykurtic – this often indicates a bimodal grain size distribution.

	K_G
Very platykurtic:	<0.67
Platykurtic:	0.67 – 0.90
Mesokurtic:	0.90 – 1.11
Leptokurtic:	1.11 – 1.50
Very leptokurtic:	1.50 – 3.00
Extremely leptokurtic:	>3.00

Result Analysis Report

School of Geosciences
University of Wollongong

Sedimentology Laboratory

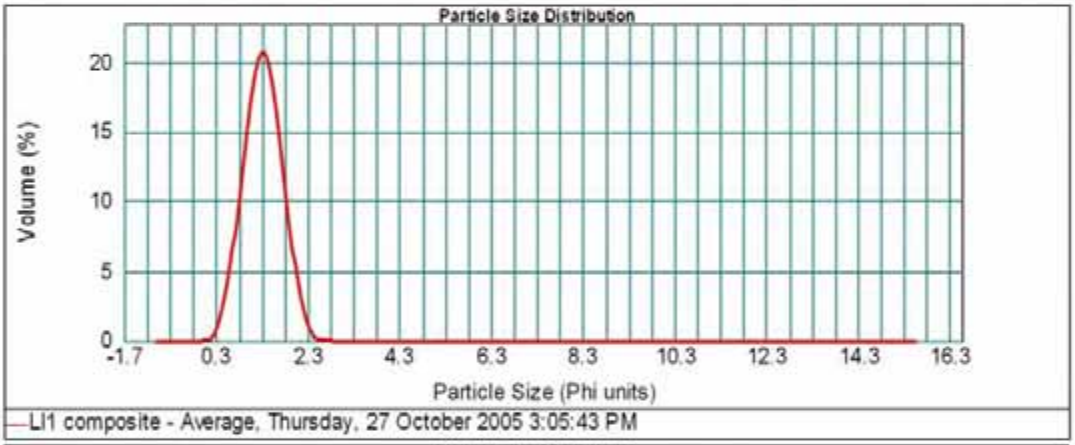
Sample Name: LI1 composite - Average
Measured by: brianj
Sample bulk lot

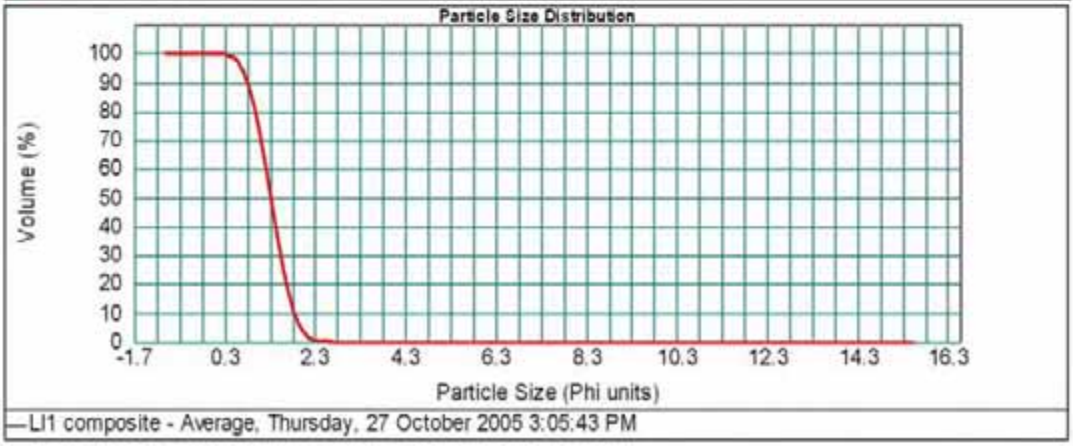
Measured: Thursday, 27 October 2005 3:05:43 PM
Analysed: Thursday, 27 October 2005 3:05:44 PM
SOP

D[4,3] = 405.03um = 1.3phi	D[v,0.5] = 389.56um = 1.36phi	Kurtosis = .24
D[v,0.05] = 246.2um = 2.02phi	D[v,0.84] = 518.57um = .95phi	Skewness = .67
D[v,0.16] = 292.76um = 1.77phi	D[v,0.95] = 616.63um = .7phi	Standard Deviation = 114.54 um = 3.13phi

Inclusive Standard Deviation = .41 phi (Well Sorted)
Inclusive Skewness = 0 (Near Symmetrical)
Inclusive Kurtosis = .96 phi (Mesokurtic)
Inclusive Mean = 1.36 phi (Medium Sand)

% Sand	Percentage between 63.00 µm and 2000.00 µm : 100.00%
% Silt	Percentage between 4.00 µm and 63.00 µm : 0.00%
% Clay	Percentage between 0.00 µm and 4.00 µm : 0.00%





Malvern Instruments Ltd.
Malvern, UK

Mastersizer 2000 Ver. 5.22
Serial Number : 34403-134

File name: Brianjj.mea
Record Number: 137

Result Analysis Report

School of Geosciences
University of Wollongong

Sedimentology Laboratory

Sample Name: LI1 lower - Average

Measured by: brianj

Sample bulk lot

Measured: Thursday, 27 October 2005 3:11:43 PM

Analysed: Thursday, 27 October 2005 3:11:44 PM

SOP

D[4,3] = 379.36um = 1.4phi	D[v,0.5] = 365.21um = 1.45phi	Kurtosis = .32
D[v,0.05] = 232.11um = 2.11phi	D[v,0.84] = 483.97um = 1.05phi	Skewness = .68
D[v,0.16] = 275.53um = 1.86phi	D[v,0.95] = 574.19um = .8phi	Standard Deviation = 106.1 um = 3.24phi

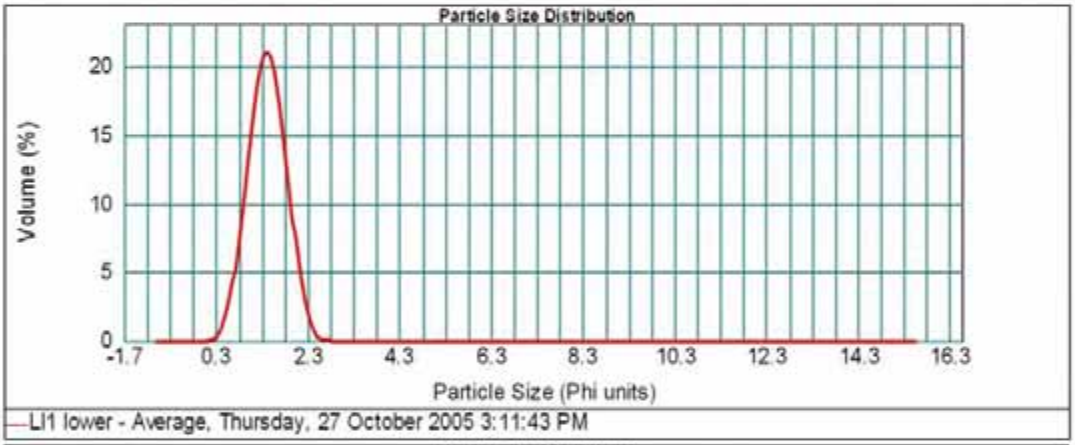
Inclusive Standard Deviation = .4 phi (Well Sorted)

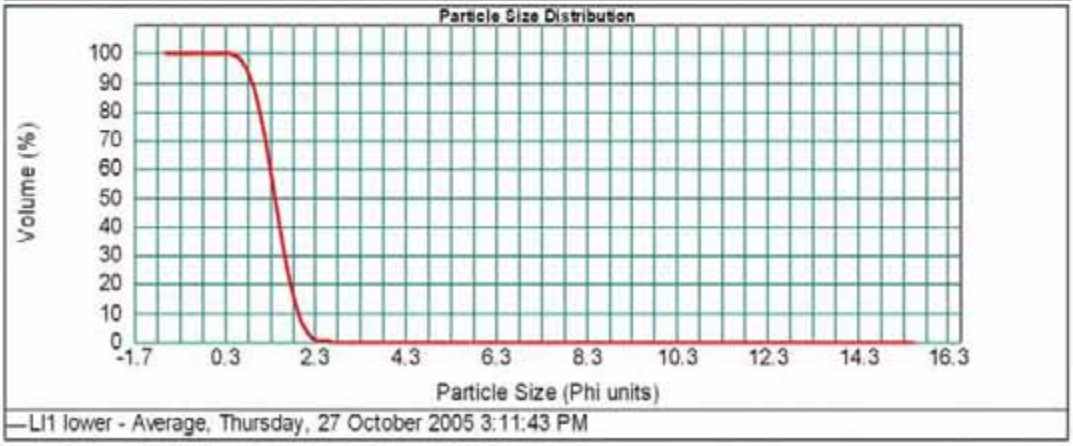
Inclusive Skewness = 0 (Near Symmetrical)

Inclusive Kurtosis = .96 phi (Mesokurtic)

Inclusive Mean = 1.45 phi (Medium Sand)

% Sand	Percentage between 63.00 µm and 2000.00 µm : 100.00%
% Silt	Percentage between 4.00 µm and 63.00 µm : 0.00%
% Clay	Percentage between 0.00 µm and 4.00 µm : 0.00%





Malvern Instruments Ltd.
Malvern, UK

Mastersizer 2000 Ver. 5.22
Serial Number : 34403-134

File name: Brianjj.mea
Record Number: 141

Result Analysis Report

School of Geosciences
University of Wollongong

Sedimentology Laboratory

Sample Name: LI2 - Average

Measured by: brianj

Sample bulk lot

Measured: Thursday, 27 October 2005 3:59:09 PM

Analysed: Thursday, 27 October 2005 3:59:10 PM

SOP

D[4,3] = 457.33um = 1.13phi	D[v,0.5] = 438.74um = 1.19phi	Kurtosis = .48
D[v,0.05] = 277.8um = 1.85phi	D[v,0.84] = 585.67um = .77phi	Skewness = .74
D[v,0.16] = 329.85um = 1.6phi	D[v,0.95] = 699.5um = .52phi	Standard Deviation = 131.08 um = 2.93phi

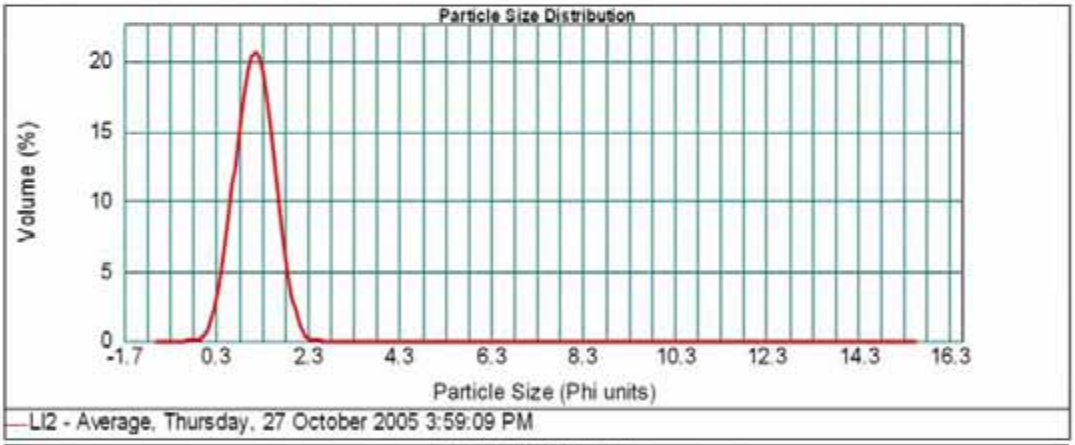
Inclusive Standard Deviation = .41 phi (Well Sorted)

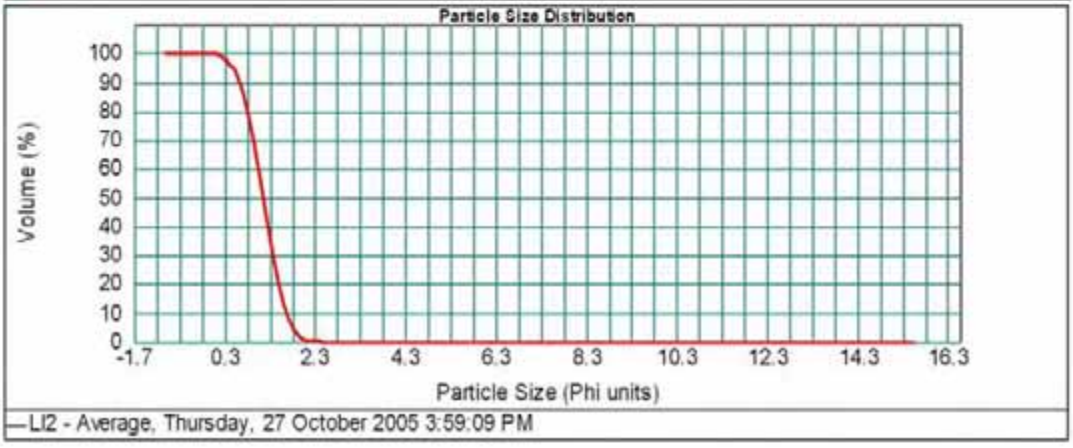
Inclusive Skewness = .01 (Near Symmetrical)

Inclusive Kurtosis = .96 phi (Mesokurtic)

Inclusive Mean = 1.19 phi (Medium Sand)

% Sand	Percentage between 63.00 µm and 2000.00 µm : 100.00%
% Silt	Percentage between 4.00 µm and 63.00 µm : 0.00%
% Clay	Percentage between 0.00 µm and 4.00 µm : 0.00%





Malvern Instruments Ltd.
Malvern, UK

Mastersizer 2000 Ver. 5.22
Serial Number : 34403-134

File name: Brianjj.mea
Record Number: 145

Result Analysis Report

School of Geosciences
University of Wollongong

Sedimentology Laboratory

Sample Name: EBB1 - Average

Measured by: brianj

Sample bulk lot

Measured: Thursday, 27 October 2005 4:05:22 PM

Analysed: Thursday, 27 October 2005 4:05:23 PM

SOP

D[4,3] = 324.11um = 1.63phi	D[v,0.5] = 309.65um = 1.69phi	Kurtosis = .21
D[v,0.05] = 186.54um = 2.42phi	D[v,0.84] = 424.16um = 1.24phi	Skewness = .69
D[v,0.16] = 225.61um = 2.15phi	D[v,0.95] = 510.95um = .97phi	Standard Deviation = 100.23 um = 3.32phi

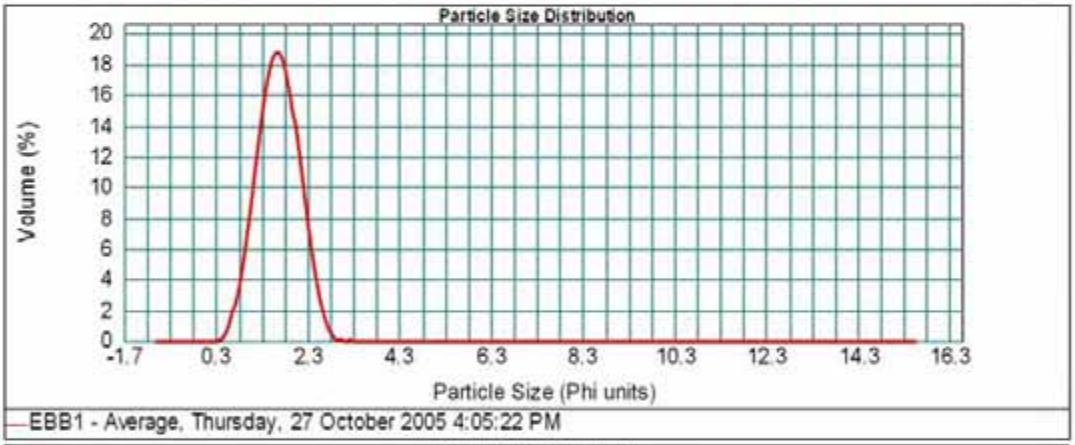
Inclusive Standard Deviation = .45 phi (Well Sorted)

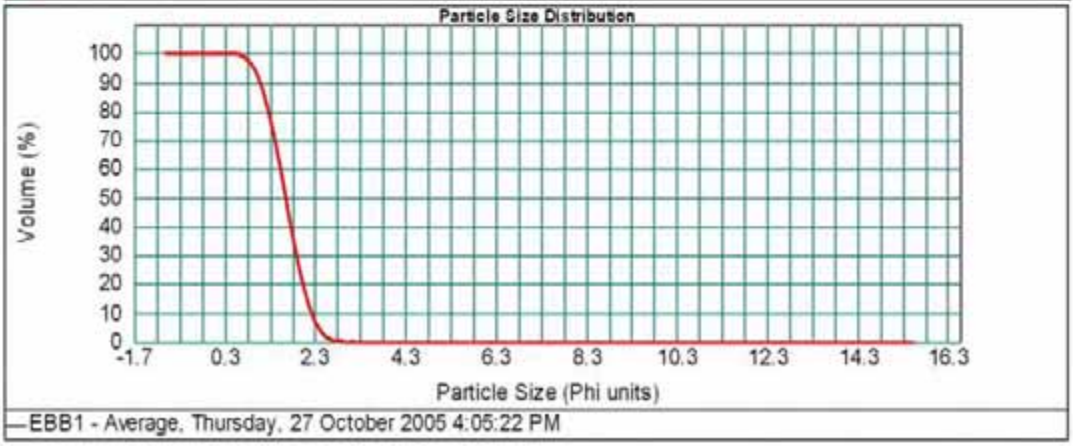
Inclusive Skewness = 0 (Near Symmetrical)

Inclusive Kurtosis = .95 phi (Mesokurtic)

Inclusive Mean = 1.69 phi (Medium Sand)

% Sand	Percentage between 63.00 µm and 2000.00 µm : 100.00%
% Silt	Percentage between 4.00 µm and 63.00 µm : 0.00%
% Clay	Percentage between 0.00 µm and 4.00 µm : 0.00%





Malvern Instruments Ltd.
Malvern, UK

Mastersizer 2000 Ver. 5.22
Serial Number : 34403-134

File name: Brianjj.mea
Record Number: 140

Result Analysis Report

School of Geosciences
University of Wollongong

Sedimentology Laboratory

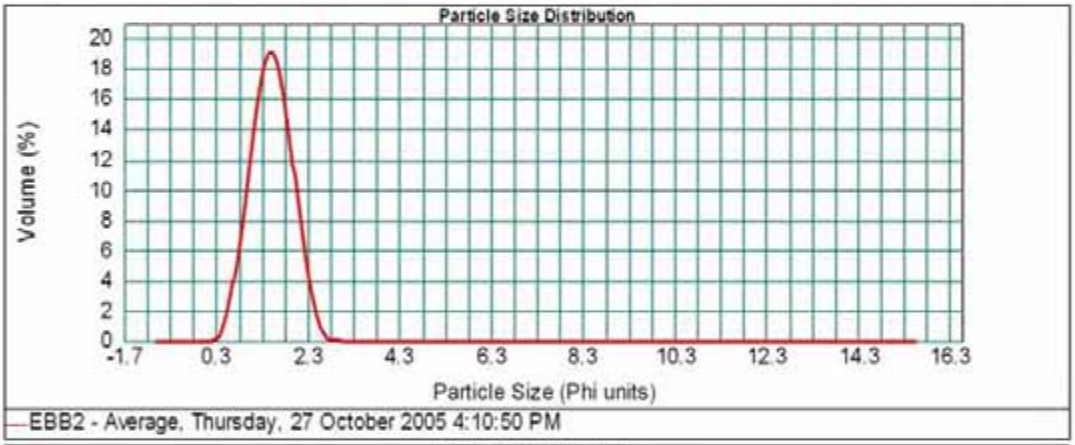
Sample Name: EBB2 - Average
Measured by: brianj
Sample bulk lot

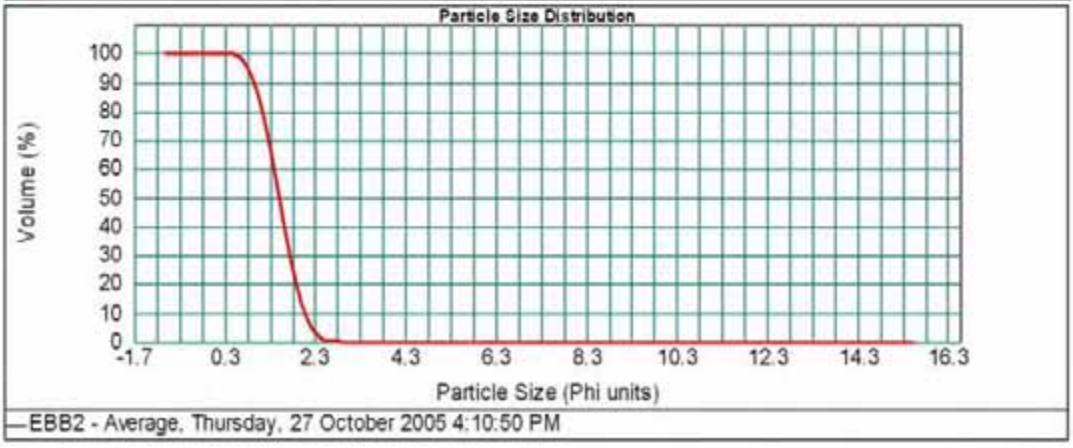
Measured: Thursday, 27 October 2005 4:10:50 PM
Analysed: Thursday, 27 October 2005 4:10:51 PM
SOP

D[4,3] = 357.52um = 1.48phi	D[v,0.5] = 342.21um = 1.55phi	Kurtosis = .19
D[v,0.05] = 207.82um = 2.27phi	D[v,0.84] = 466.22um = 1.1phi	Skewness = .68
D[v,0.16] = 250.62um = 2phi	D[v,0.95] = 559.78um = .84phi	Standard Deviation = 108.55 um = 3.2phi

Inclusive Standard Deviation = .44 phi (Well Sorted)
Inclusive Skewness = -0.01 (Near Symmetrical)
Inclusive Kurtosis = .95 phi (Mesokurtic)
Inclusive Mean = 1.55 phi (Medium Sand)

% Sand	Percentage between 63.00 µm and 2000.00 µm : 100.00%
% Silt	Percentage between 4.00 µm and 63.00 µm : 0.00%
% Clay	Percentage between 0.00 µm and 4.00 µm : 0.00%





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Malvern, UK

Mastersizer 2000 Ver. 5.22
Serial Number : 34403-134

File name: Brianjj.mea
Record Number: 153