Shoalhaven River Entrance Management Plan for Flood Mitigation

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Preface

Shoalhaven City Council has prepared this draft Shoalhaven River Entrance Management Plan for Flood Mitigation in consultation with the Shoalhaven community and NSW Government agencies.

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1 Introduction

1.1 Why an Entrance Management Plan?

If the entrance of the Shoalhaven River at Shoalhaven Heads (see Figure 1) were to remain closed during a flood, water levels would be significantly higher for longer in some parts of the river's floodplain. This would result in greater impacts on the Shoalhaven community, especially at the village of Shoalhaven Heads, in terms of inundation of houses and other property, cutting of access roads and possibly through increased injury or loss of life.

The Shoalhaven River entrance area is also of high environmental significance. The scenic and recreational values of the area are very important to residents and visitors of the region. The entrance area is one of the most important sites on the New South Wales coast for populations of migratory wading birds protected under international agreements and, at times, threatened species of other shorebirds may nest at the site.

The purpose of this Shoalhaven River Entrance Management Plan is to put in place a clear plan to facilitate:

- expedient and swift mechanical intervention in the path of floodwaters to reduce the impact of flooding on the Shoalhaven community AND
- responsible environmental management of the entrance berm and shorebird habitat, and the protection of the structural integrity of the coastal dune system.

This Shoalhaven River Entrance Management Plan describes:

- the procedures to be followed by Shoalhaven City Council for artificial openings of the entrance, should this course of action be necessary
- the conditions that should be satisfied prior to an artificial opening
- the responses that may be requested of state agencies in response to artificial or natural opening events and
- a course of actions to reduce the sand burden needed to be removed in an emergency opening of the entrance in times of flood (maintenance of a "dry notch").

1.2 Objectives

The general objectives of the Shoalhaven River Entrance Management Plan are:

1. To attempt to control flood breakout in an effort to reduce flood levels and reduce chances of major morphological changes in the river channel and foreshores.
2. To ensure that the Shoalhaven River entrance is managed in an ecologically sustainable manner.
3. To ensure that speedy intervention is possible if local flooding is predicted.
4. To determine key responsibilities and to streamline the decision making process by quantifying the variables to be addressed by these decision makers.
5. To set out the entrance management strategy so that all participating managers can undertake responsibilities in sympathy with overall objectives.
6. To set out the entrance management strategy so that the broader community can understand, support and/or assist the process.

The specific objectives of the Shoalhaven River Entrance Management Plan are:

1. To clarify responsibilities and accountabilities in relation to sand trapping and dune care in the entrance environs to ensure that all efforts are consistent with overall entrance management strategies.
2. To clarify responsibilities and accountabilities in relation to the maintenance of the coastal berm whilst the entrance is closed.
3. To clarify responsibilities and accountabilities in relation to breaching the entrance.
4. To clarify when, where and how the coastal berm is to be breached.
5. To detail the procedures and responsibilities for monitoring the entrance.

1.3 Limitations

Opening of the entrance of the river will not prevent all flooding of houses. Even if the entrance is fully open at the start of a large flood (i.e., it has recently been scoured by a preceding flood) there are existing houses that will be flooded. The plan aims to reduce, not eliminate, the impacts of flooding. Further, there may be circumstances (eg, closed roads, dangerous sea conditions) where, despite its best endeavours, Council cannot act to open the entrance of the river at the level indicated in this plan.

The opening of the entrance during times of flood is only one of a range of floodplain management measures. It should not be considered in isolation as the overall solution to the flood problem. Other management measures are also being considered as part of the overall Lower Shoalhaven River Floodplain Risk Management Study.

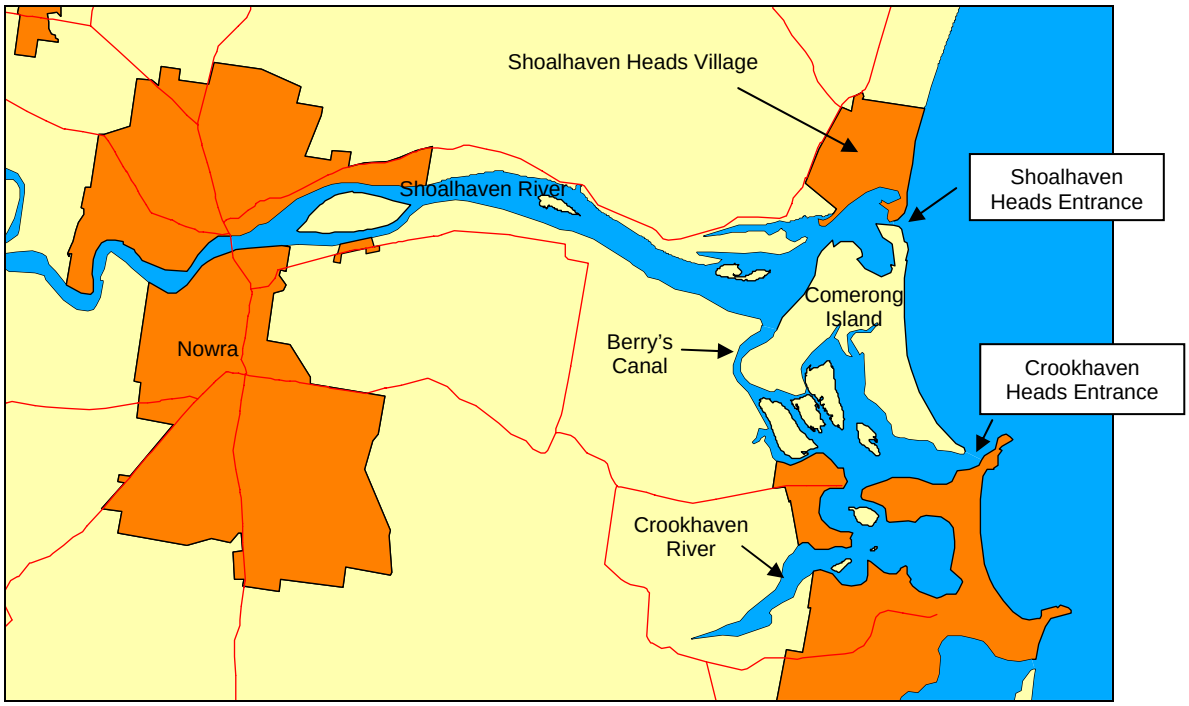


Figure 1. The Lower Shoalhaven River system.

However, that does not mean that it will be practical to reach a stage where no intervention at the entrance is required. Indeed there are real concerns that if the entrance of the river at Shoalhaven Heads were to remain closed during a large flood event, not only would there be significant flooding of buildings at Shoalhaven Heads and elsewhere, there could be major geomorphological changes such as the creation of a new opening through Comerong Island, or massive erosion of Berry's Canal.

The investigation and/or justification to open the entrance for water quality, recreational, aesthetic or purposes other than flooding have not been considered as part of this plan. If considered important, these issues could be addressed separately in the context of an Estuary Management Study. If that were done, then this plan would need to be reviewed.

1.4 Plan Development

This plan has been developed from several decades of research and debate. It builds on experience from past entrance behaviour and management regimes, and is based the most recent information and current community values.

For a number of years, technical experts, Shoalhaven residents and visitors, NSW Government agencies and Shoalhaven City Council have debated the relative merits of the following general courses of action:

- maintaining a permanent open entrance at Shoalhaven Heads,

- employing artificial means (pumps, dredges, bulldozers) to manipulate the opening for various purposes (recreation, visual and water quality, fishing, environmental and flooding),
- closing Berry's Canal or constructing floodgates,
- allowing nature to take its course.

There has been a wide range of strong and divergent views regarding the relative benefits and drawbacks of opening the entrance either during a flood or in non-flood times.

This plan has been developed as part of the floodplain management process and is motivated by the desire to minimise the effects of flooding on upstream properties. The approach adopted in this document is to consider and balance all of the relevant issues and propose appropriate management solutions which address the main problems.

Some of the main studies and reports that have informed this plan are described below.

Up until 1993 Council opened the mouth of the Shoalhaven River as required. Authority was vested in Council by 1919 Local Government Act. This authority was not carried forward into Local Government Act 1993. Generally speaking, if floods greater than 3.0m AHD at Nowra Bridge were anticipated, the entrance area was excavated to assist, and control, the opening of the entrance. The actual level of the excavation was somewhat dependent on time available, plant being used, and quantity of sand to be removed, etc.

In 1984 the Shoalhaven River Entrance Management Report by the Public Works Department recommended that a “dry notch” be constructed at the entrance area. The purpose of the notch was to dispense with the need to mechanically open the river when a flood arrived. A level of 2m AHD was recommended for the notch. This level appears to have been recommended on the basis that it was the minimum practical level not affected by normal hydraulic beach processes (tide/wave run-up), i.e., lower levels would be built up too quickly by wave action. The notch would breach without intervention when river water reaches the appropriate level.

In 1986 a **Shoalhaven River Entrance Study** was undertaken by the Water Research Laboratory for the Public Works Department. The study supported the ongoing maintenance of the notch and made recommendations in regard to making the community more aware that Council was doing the work.

Shoalhaven City Council, in accordance with the NSW Floodplain Development Manual (NSW Government, 2005), has commissioned the following reports that cover the whole of the floodplain from Nowra to the sea:

Stage 1. The **Lower Shoalhaven River Flood Study** (completed in April 1990) which defines design flood levels within the floodplain.

Stage 2. The **Lower Shoalhaven River Floodplain Risk Management Study** – draft prepared 2002. This builds on the Flood Study by examining flooding issues and addressing the management of the flood problems relating to the floodplain area associated with the Lower Shoalhaven River. The primary objectives of the Risk Management Study were to define the nature and extent of the hazard; to identify, assess and optimise measures aimed at reducing the impact of flooding on both existing and future development; and to make recommendations for the future management of the study area. The draft included a discussion paper on Shoalhaven Heads Entrance Flood Management, the purpose of which was "to facilitate the development of a simple and clear policy which will responsibly manage the entrance, waterbird habitat and structural integrity of the Shoalhaven Heads entrance."

Stage 3. **Lower Shoalhaven River Floodplain Risk Management Plan** – in preparation. Once the Risk Management Study is completed and a preferred scheme adopted, an overall Floodplain Risk Management Plan will be prepared.

The **Healthy Rivers Commission Inquiry into the Shoalhaven River System**, July 1999, undertook extensive investigation and consultation about the processes impacting on Shoalhaven Heads. The Commission recommended that, in accordance with the underlying principle of maintaining natural variations in entrance conditions, the following management measures should prevail:

- The establishment of a permanently open entrance and the closure of Berrys Canal should not be pursued or further investigated. Major attempted intervention would cost a great deal, is unlikely to resolve perceived problems and is very likely to create new problems and uncertainties.
- The "dry notch" should be maintained at approximately the 2m AHD[1] level to afford some flood protection to low-lying areas in the vicinity of the Heads (either by natural breaching or by allowing easier mechanical opening in emergency situations).
- Documentation of entrance conditions, natural processes and management activities pertaining to Shoalhaven Heads should be significantly expanded. As a first step, urgent action should be taken to preserve local recollections by local observers of past events and circumstances through the formal recording of oral histories by an appropriate specialist.

[1] Note Expressing heights in metres above (or below) AHD is a surveying practice, which allows a standard comparison of levels across Australia. AHD stands for Australian Height Datum, with 0.0 m AHD being very close to mean sea level. The highest high tides on our part of the coast are just over a metre above AHD and the lowest low tides are almost a metre below AHD. Therefore 2 metres AHD is about 2 metres higher than the average level of the ocean, about a metre above our highest high tides and just over a metre and a half above our average high tide level.

A **Draft Policy for Opening Shoalhaven River Entrance at Shoalhaven Heads** was developed by Council in February 1999. The policy aimed to compile the existing information in relation to opening the entrance and provide a strategy for future occasions. It was commented on by a number of Government agencies, including the Department of Urban Affairs and Planning, NSW Fisheries, the National Parks and Wildlife Service and the Department of Land and Water Conservation.

The draft policy was further developed in 2000 and 2003, including referral to the Shoalhaven River Floodplain Management Committee for comment. In 2006 a technical review was undertaken by Webb McKeown & Associates. This included the results of photogrammetric analysis of historical air photographs of the entrance area and some additional computer modelling of flood behaviour to test the effects of various entrance management options on flood levels.

This current entrance management plan has incorporated recommendations from all of the above documents.

1.5 Plan Review

This Shoalhaven River Entrance Management Plan is intended to be a dynamic document.

- It should be updated to incorporate new information (for example in relation to sea level change), new legislation and the community's changing needs as required. In particular it should be reviewed as soon as the Lower Shoalhaven River Floodplain Risk Management Plan is completed.
- It should be regularly reviewed at no less than 5 year intervals, to ensure staff and community understanding of the principles to be applied.
- A licence under the Crown Lands Act will need to be applied for every five years. The Entrance Management Plan and the Review of Environmental Factors will need to be reviewed prior to each new application.
- It should be reviewed after each event, if Council staff, the community and/or any Government Agency suggest that any part of the procedure is inappropriate.
- Given that a primary consideration is mitigating the effects of flooding on surrounding properties, it should be reviewed in light of changing flood patterns and/or other flood protection strategies.

2 Background

2.1 The Shoalhaven River Entrance

On the New South Wales coast, as sea level approached present day mean sea level, extensive outer sediment barriers were formed across the mouths of broad, shallow embayments. Landward of these barriers, estuaries were created in the form of broad tidal lakes connected to the ocean by narrow tidal inlets through the barrier. The different stages of maturity within each estuary type on the coast reflect the gradual infilling that began about 7,000 years ago, at the end of the last post-glacial marine transgression. Infilling has occurred from the seaward side (marine sand), from the landward side (fluvial sediments), and by the accumulation of suspended fine sediments and calcareous and carbonaceous material produced by biological processes within the estuary itself (eg plankton and molluscs) (NSW Government, 1992).

The Shoalhaven River catchment covers an area of 7300 square kilometres with approximately 120 square kilometres of floodplain downstream of Nowra. The Shoalhaven River estuary is classified as a mature barrier estuary, having been created by an extensive river system with relatively high sediment loads. The high sediment loads have infilled the initial back barrier lake with alluvium, causing the development of sinuous river channels discharging directly into the ocean. Contiguous floodplains with backwater swamps and cut off bays are vague reminders of the former back barrier lakes (NSW Government, 1992).

Much of the coastal barrier is contained within Comerong Island, to the south of Shoalhaven Heads. At the southern end of Comerong Island is the Crookhaven River, which was formerly a deltaic arm of the Shoalhaven River. Over the last ten thousands years, the continuous eastward migration of the lower river's meander has resulted in the Crookhaven River being cut off from direct river flow on at least three occasions. The two rivers then flowed unconnected into the Pacific Ocean either side of Comerong Island (Chafer, 1998).

Two hundred years ago the main entrance and the natural mouth of the river was at Shoalhaven Heads. Survey plans in 1805 and 1822 indicate that the Shoalhaven River had a relatively narrow entrance, which was largely unnavigable. Lives were lost in attempts to cross the bar and for this reason, in 1822, Alexander Berry's men dug the "canal" to provide a link between the Shoalhaven River and the Crookhaven River to the south, and hence to provide ocean access to upstream settlements. Since the initial excavation, the Shoalhaven River has gradually eroded the "canal" to a width of several hundred metres and the Crookhaven River has become the permanent ocean-river entrance.

Due to estuarine, coastal and flood processes, the Shoalhaven Heads entrance now intermittently opens and closes to the sea. When the entrance

at Shoalhaven Heads is closed, the river is still connected to the sea via Berrys Canal and the entrance at Crookhaven Heads (see Figure 1). When closed, the Shoalhaven Heads entrance is cut off from the ocean by a sand berm and dune about 100 metres wide east-west. It opens, either naturally or by mechanical intervention, in flood events (say 20% AEP[2] or greater events) and may remain open, or partially open, for several months or years depending on the prevailing conditions. When it is open, the Shoalhaven Heads entrance is exposed to wave action and onshore winds which deposit sand in the entrance. In addition, the incoming tide brings sand into the bay which is then not completely scoured out by the weaker ebb tide, resulting in the build up of sand/silt deposits in the area.

When it is closed, the Shoalhaven River entrance area is subject to major sediment movements involving a range of transport mechanisms, including flood erosion and supply, littoral zone wave movements, storm bite erosion, sea level rise recession and aeolian transport. Most of these mechanisms are beyond or difficult for Council to control. However, Council can maintain the entrance area to reduce aeolian and wave accretion (see Section 3).

Chafer (1998) analysed the recent behaviour of the entrance using aerial photographs from 1936 to 1996. He found that, over that period there appears to be a cycle in the entrance condition, with open and closed regimes lasting for about 6 – 9 years. There was a loose relationship with the Southern Oscillation Index (SOI). A strongly positive SOI is often associated with storm events and hence floods that would open the river, while a strongly negative SOI is often associated with prolonged dry periods, lower than average river flow and build up of sediments at the entrance (along with *El Nino* events in the eastern Pacific). The georeferenced photographs of the entrance supplied by Mr Chafer are in Figure 2. They clearly demonstrate the dynamic nature of the entrance area. In addition to the opening and closing regime, Chafer documented the development and vegetative invasion of a major dune on the southern side of the entrance channel, the development and expansion of salt marsh communities, the alteration and subsequent realignment of the beach front after breaching and substantial changes in the intertidal flats.

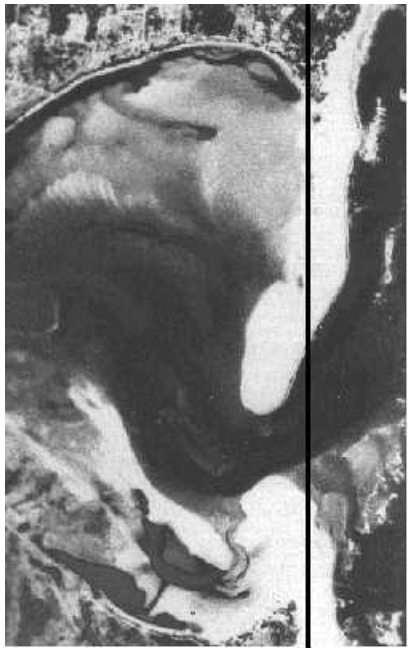
Further information together with comments on the main issues regarding human intervention at the Shoalhaven River entrance is presented in Table 1.

[2] AEP stands for Annual Exceedance Probability. It is the chance of a flood of a given or larger size occurring in any one year. A flood event with a 20% AEP means there is a 20% chance (i.e., a one in five chance) of a flood of that size or larger occurring in any one year. This is preferable to describing the event as a one in five year event because, whilst a 20% AEP flood will recur *on average* every five years, such events can occur much closer together or much further apart than that time period.

Table 1: Summary of Entrance Conditions and Human Intervention in Opening of the Entrance at Shoalhaven Heads (modified from Lower Shoalhaven Floodplain Risk Management Study)

Event or Action	Comment
Council Intervention	Interviews with Council staff indicate that Council has been involved in opening the entrance or maintaining a lower sand dune at the entrance since at least the mid 1970s. However no formal records are available.
Non-Council Intervention	In March 1986, 1500 people congregated on the beach asking the authorities to open the entrance for aesthetic, water quality and recreational reasons. There are no records suggesting that the local residents have initiated an opening on their own. At other intermittent ocean entrances along the NSW coast, residents have intervened contrary to Council's advice.
August 1974 Flood	Entrance closed with dune at approximately 1 m AHD
June 1975, October 1976 and March 1978 Floods	Each of these three floods occurred within approximately 12 to 18 months of the previous flood. Consequently the entrance was partially open at the time the floods occurred.
March 1978, March 1983 and August 1986 Floods	The partially open entrance was fully opened (naturally) by this flood and only closed in 1981. It then remained closed until the April 1988 flood, as the March 1983 and August 1986 events (less than 3.0 m AHD at Nowra) were not large enough to overtop the dunes.
April 1988 Flood	Entrance closed at the time but dune had been lowered previously by Council in 1986/87. Some time prior to the April 1988 flood occurring, Council placed a number of poles along the southern part of the beach to assist in maintaining a "dry" notch. Floodwaters washed the poles into the ocean through the heads.
June 1997	A minor flood occurred in June 1997. Prior to that flood, a “wet” notch had been constructed (clearly visible in 1996 air photo, Figure 2). It is not clear whether the wet notch had filled in with sand prior the 1997 flood.
August 1998 and October 1999	On 8 August 1998, the entrance was opened by Council around 4:00pm following a river peak of 3.35 m AHD at Nowra (around 12 midday). A subsequent flood occurred on 19 August with a peak level of 3.12 m AHD at Nowra. The second intervention occurred on 24 October 1999. The river level peaked at 3.53 m AHD at Nowra Bridge around 10:00pm on the 24th. Darkness prevented manual opening of the entrance occurring until the following morning and the highest level recorded on the Wharf Road gauge was 1.85 m AHD (it is possible that the gauge jammed).

1949 closed

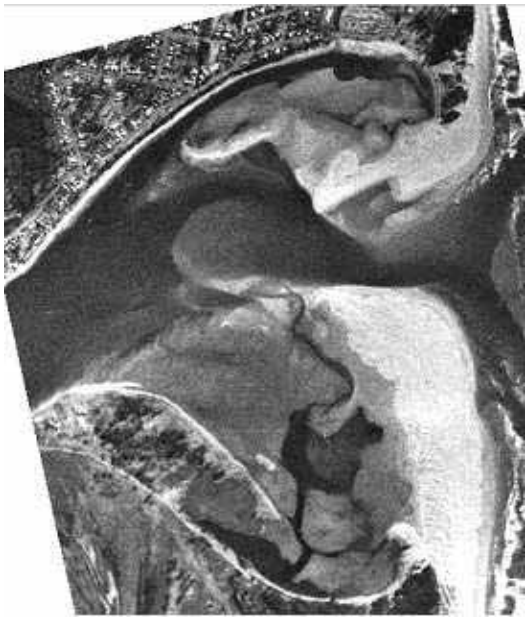


1961 open

1970 closed

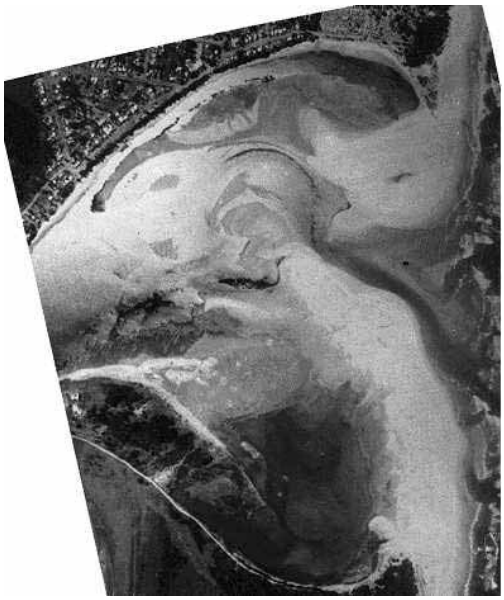
1974 open

Figure 2. Georeferenced aerial photographs of the Shoalhaven River entrance (from Chafer, 1998).



1977 open

1979 open



1980 closing

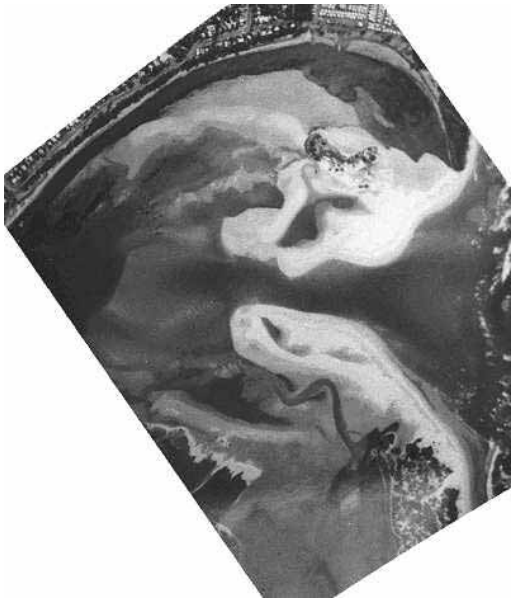
1981 closed

Figure 2 continued

1984 closed

1986 closed

1989 open



1991 open

Figure 2 continued

1993 closing

1996 closed

Figure 2 continued

2.2 The Flooding Problem

Flooding in the Lower Shoalhaven floodplain can result from any or all of the following:

- flow from the Shoalhaven River catchment
- backwater flooding from the floodplain (e.g. Worrigee Swamp) which initially occurs as a result of local runoff but in larger events is augmented by flow over the river bank elsewhere,
- overbank flooding from Broughton Creek,
- local flooding at the Shoalhaven Heads township,
- ocean waves penetrating through the two entrances (Shoalhaven Heads and Crookhaven Heads).

The relative effects of these mechanisms depends on the prevailing meteorological conditions (influence of regional storm cells), volume of flow in the river, the local rainfall and the nature of the entrance at Shoalhaven Heads.

The devastating floods of 1860 and 1870 caused most of the population of Terara to move to the higher ground at Nowra with the subsequent decline of Terara. Nowra is now the main centre of population but there are a number of smaller developed centres, such as Shoalhaven Heads and Greenwell Point, which exist on the floodplain downstream of Nowra. The majority of the lower Shoalhaven River floodplain is used for agricultural purposes and contains numerous rural homesteads.

2.2.1 Flood Records

Historical flood records for the Shoalhaven River are available since 1860. Since then, there appears to have been 48 floods recorded at Nowra which have equalled or exceeded the currently accepted ‘minor’ flood level of 2.3 metres AHD. Of these, 16 were minor (2.3 – 3.3 metres at Nowra), 11 were moderate (3.3 – 4.3 metres at Nowra) and 21 were major (4.3 metres or higher at Nowra). It is likely that more floods have occurred which have not been recorded, particularly in the minor or moderate flood ranges. In addition, there would have been many events (“freshes”) that have not reached the level of 2.3 metres AHD.

Table 2 lists some of the floods thought to have exceeded the 3.3 metre AHD level at Nowra. For events prior to 1960 the levels have been assessed by extrapolation of data from other locations and there is still debate about the exact magnitude of these events. After 1960, the levels are as read at Nowra itself.

The flood of April 1870 was probably greater than a 1% AEP event. It inundated the Terara township, the original settlement on the south bank of the Shoalhaven River, by over a metre and swept away approximately one third of the village. Five lives were lost in rural areas along the Shoalhaven River. According to some accounts, the earlier 1860 flood was even more devastating and carried away over 50 buildings. Several lives were lost as well as some 79 acres (32 hectares) of land. More recent significant floods occurred in August 1974, June 1975, March 1978 and April 1988. The 1978 flood had an average rate of rise of 0.135 metres per hour.

Table 2. Some Major and Moderate Flood Events in the Shoalhaven River (from Draft Shoalhaven City Local Flood Plan). Note that flood heights prior to 1960 are estimates and there is debate about their preciseness.

Month and Year of Flood	Estimated Flood Height at Nowra (metres AHD)	Month and Year of Flood	Estimated Flood Height at Nowra (metres AHD)
February 1860	5.7	27 May 1925	4.4
June 1864	5.2	June 1949	4.0
April 1867	5.0	February 1956	4.6
June 1867	5.1	October 1959	4.7
March 1870	5.5	March 1961	4.2
April 1870	6.5	November 1961	3.4
May 1871	4.5	June 1964	3.5
February 1873	6.2	August 1974	4.9
June 1891	5.3	June 1975	4.9
February 1898	5.0	October 1976	4.1
July 1900	4.4	March 1978	5.3
July 1904	3.7	April 1988	4.8
January 1911	3.6	August 1990	4.3
October 1916	5.3	June 1991	4.0
December 1920	4.2	October 1999	3.5
July 1922	4.2		
11 May 1925	5.4		

2.2.2 Flood Modelling

Selected peak design flood levels are shown in Table 3. Peak flood levels will be different depending on whether the entrance at Shoalhaven Heads is open or closed at the start of the flood. The effect of initial entrance condition diminishes with increasing distance upstream.

On very rare occasions, flooding of extreme proportions will occur. Extreme floods can reach far greater heights than any previously recorded flooding. Moreover, such floods are generally both faster to rise and more dangerous in terms of depth and velocity than previous floods. It has been estimated that the Probable Maximum Flood at the Nowra Gauge could reach 8.8m, which is 2.5m above the 1% AEP (1 in 100 year) flood.

Table 3. Design flood levels (m AHD) (from Lower Shoalhaven River Floodplain Risk Management Study).

Flood Location	Extreme	0.2% AEP	0.5% AEP	1% AEP	2% AEP	5% AEP	10% AEP
Nowra Bridge	8.9	7.3	6.8	6.3	5.8	5.3	4.8
Shoalhaven River at Terara	7.4	6.1	5.8	5.5	5.1	4.8	4.4
Numbaa Island	6	4.8	4.4	4.1	3.6	3.3	3
Shoalhaven Heads at Wharf Road	4.2	3.9	3.6	3.3	2.9	2.7	2.5
Greenwell Point	5.2	4.1	3.7	3.4	2.9	2.4	2
Orient Point	4.7	3.7	3.3	3	2.6	2.2	2

Note: Assumes that the entrance at Shoalhaven Heads is closed at the start of the flood event and then scour out with the passage of floodwaters.

2.2.3 Effect of Entrance

The possible opening of the Shoalhaven Heads entrance during a flood is a major issue for both the residents of the floodplain, particularly at Shoalhaven Heads, and Shoalhaven City Council.

The nature of flooding experienced at Shoalhaven Heads is directly influenced by the conditions prevailing at the entrance (open or closed at the start of the flood). In the 10% AEP design scenario where the entrance is assumed to be closed at the start of the flood (and allowed to scour out with the passage of floodwaters) some 116 properties are potentially flooded with 39 building inundated above floor level.

The difference between flood levels at Shoalhaven Heads for entrance open/entrance closed scenarios has been modelled and is shown in Table 4. The entrance open scenario assumed that a large flood occurred just prior to the subject flood and that the river entrance connected to the sea with its bed at -2.0 m AHD for a north south distance of 400 m. For the entrance closed scenario it was assumed that, prior to the flood, the dune and berm were initially at 2 m AHD for a distance of 50 m east-west and 400 m north south and was then allowed to erode with the passage of the event. It was assumed that west of the dune the sand bed was at 0 m AHD for an east-west distance of 500 metres extending into the bay area of the river..

More recent modelling and analysis of ground surveys and air photos (Webb McKeown and Associates Pty Ltd, 2006), has indicated that the total volume

of sand in the entrance area is important and can have a significant impact on flood levels. This includes the amount of sand that is in the bay to the west of the entrance dune, as shown in Table 5. As long as the current flood planning levels are in place, the entrance, when opened during a flood, must have the opportunity to scour to a north-south width of 400 metres.

Table 4. Flood Levels at Shoalhaven Heads (from draft Lower Shoalhaven River Floodplain Risk Management Study).

Flood Event	**Entrance Conditions (Flood Levels in m AHD)**	
	Open	**Closed (2m AHD)**
1% AEP	2.7	3.3
2% AEP	2.4	2.9
5% AEP	2.2	2.6

Table 5. Effects of Varying Amounts of Sand in the Entrance Area ((Webb McKeown and Associates Pty Ltd, 2006).

Height of Sand Flats (m AHD)	0.0	-1.0	+1.0	-1.0	0.0	+1.0
Width East-West (m)	500	500	500	250	250	250
Flood Impact (m)	base	-0.32	+0.32	-0.41	-0.17	+0.13

2.2.4 Effects of Flooding

In part, problems caused by flooding stem from large areas that originated as older subdivisions which predated any flood requirements. Many areas of Shoalhaven Heads are relatively low lying and therefore vulnerable to inundation from floodwaters in even the smaller, more frequent events. Access roads may be cut early in storm events and dwelling sites flooded later, some by high velocity flows, creating major evacuation problems.

The Lower Shoalhaven Floodplain Risk Management Study includes a floor level database obtained by Council in Jan/Feb 2001 with details of all habitable dwellings believed to lie within the floodplain. Caravans, garden sheds, garages, oyster sheds and other non-habitable buildings were not surveyed. Table 6 indicates the estimated number of buildings likely to be flooded for a range of event magnitudes. The average annual tangible damages (AAD) for the Lower Shoalhaven River floodplain are estimated to be of the order of $1.8 million. This does not include damages to public utilities.

A brief summary of floor levels and inferred potential flood affectation for existing properties at Shoalhaven Heads is presented in Figure 3 and Table 7. At Shoalhaven Heads, there are a number of properties which would suffer floor covering, furniture losses etc, at flood levels below 2 m AHD. The lowest

residential building floor level is at 1.4 m AHD (a two storey building) with the lowest single storey residence at 1.8 m AHD. There are a total of 10 residential building floors below 2.0 m AHD, 13 below 2.3 m AHD, 21 below 2.4 m AHD and 33 at or below the 10% AEP flood level of 2.5 m AHD. It should also be noted that there are a number of septic tanks with inlets below 2.5 m AHD. Of the 33 residential buildings inundated in the 10% AEP event, 22 (67%) are single storey dwellings.

Table 6. Buildings Inundated (from Lower Shoalhaven River Floodplain Risk Management Study).

Area	Extreme	1% AEP	2% AEP	5% AEP	10% AEP
Nowra	104	34	12	5	3
Riverview Road Area	117	7	2	nil	nil
Terara Village	55	44	13	1	nil
Bomaderry	77	33	27	24	11
Shoalhaven Heads	199	134	92	60	39
Greenwell Point	382	350	275	211	137
Orient Point/Crookhaven	207	132	90	64	27
TOTAL	**1141**	**734**	**511**	**365**	**217**

Note: The above assessment is based on the assumed modelling scenario (Flood Study design conditions) where the entrance at Shoalhaven Heads is closed at the start of the flood event and allowed to scour out progressively with the passage of floodwaters (includes at least one level at each caravan park).

The 5% AEP flood at Shoalhaven Heads could cause over-floor inundation of about 60 buildings, requiring evacuations. Large numbers of people living in Shoalhaven Heads are elderly (census 2001, 796) and may need assistance with raising furniture and/or evacuating.

In addition to the private residential properties, there are also several caravan parks in the Shoalhaven Heads area affected by flooding. Below 2.5 m AHD there are 6 such parks while at 2.0 m AHD there are 4 parks with caravans, cabins or amenities facilities which would be inundated. Three of these would already experience problems at 1.7 m AHD.

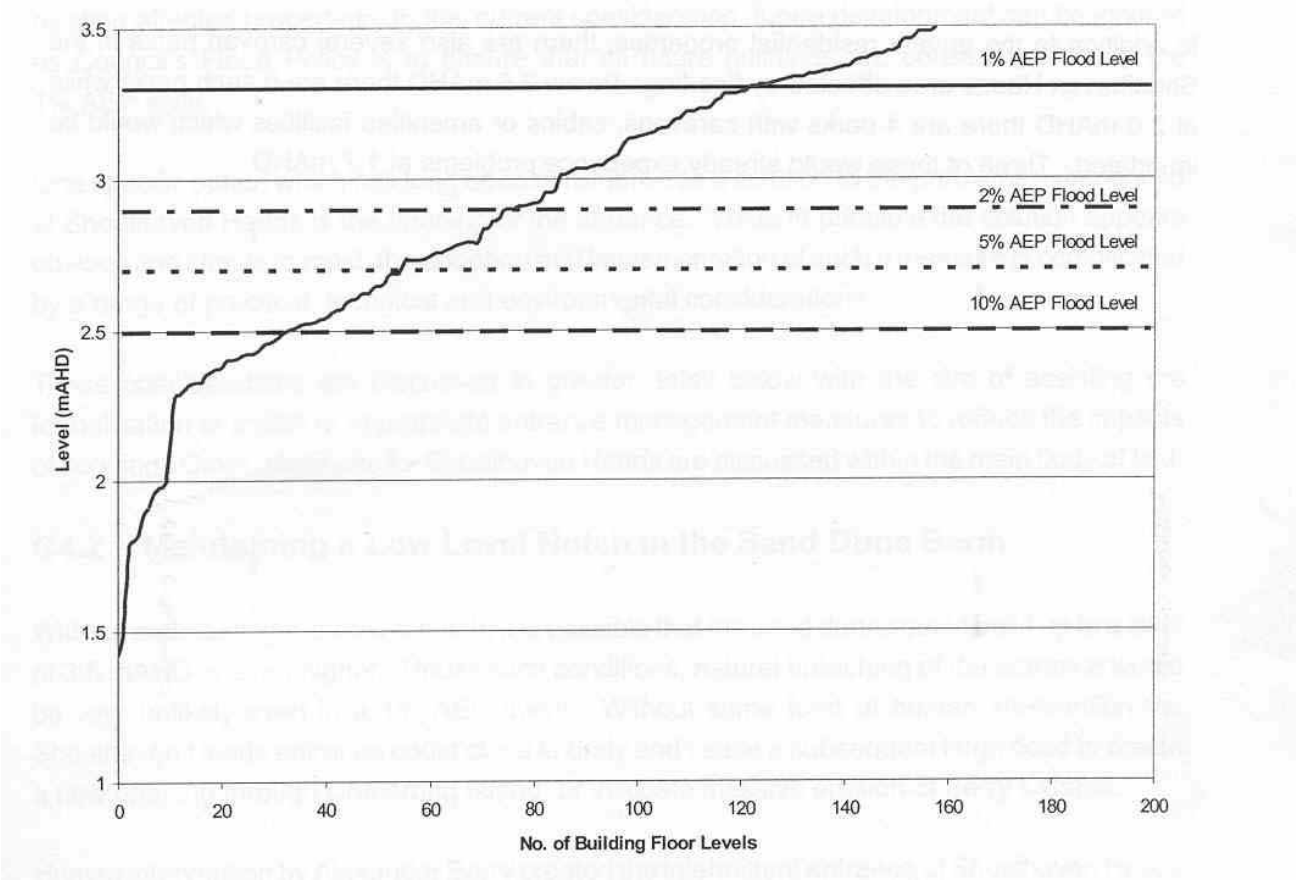


Figure 3. Flood affectation for Shoalhaven Heads properties (from draft Lower Shoalhaven River Floodplain Risk Management Study 2002)

Table 7. Estimated flood damages for Shoalhaven Heads properties (from draft Lower Shoalhaven River Floodplain Risk Management Study 2002)

Event[1]	**Level[2] (m AHD)**	**Yards Inundated**	**Properties with Buildings Inundated[3]**	**Flood Damages**
Extreme	4.2	215	199	$5.85 M
1% AEP	3.3	189	134	$3.02 M
2% AEP	2.9	154	92	$1.70 M
5% AEP	2.7	128	60	$0.95 M
10% AEP	2.5	116	39	$0.64 M
				AAD[4] $274,000

Notes: (1) Closed entrance – berm at 2.0 m AHD
(2) As an approximation a single peak flood level has been shown, although there is approximately a 0.3 m gradient from Hay Avenue to the ocean.
(3) The above figures include allowance for amenities buildings, cabins, etc. at caravan parks.
(4) Average Annual Damages. These are calculated by multiplying the damages that can occur in a given flood by the probability of that flood occurring in a given year and then summing across the range of floods.

2.3 Flood Mitigation Measures

As part of the Floodplain Risk Management process, a list of all possible measures which could conceivably be applied were developed and provided to the Shoalhaven Floodplain Management Committee for information and consideration. A number of measures were identified as not worthy of further consideration. A summary of the various measures being considered in the Lower Shoalhaven River Floodplain Risk Management Study is presented in Table 8, together with a brief assessment of their viability for implementation. The preferred options will be incorporated into a Floodplain Risk Management Plan which will describe how the flood liable lands will be managed into the future.

By placing development restrictions on all new development in flood prone areas it is hoped that less properties will eventually be flooded. Education and evacuation planning will further help reduce the risk to life.

The accuracy of the design flood levels can be improved with further flood and rainfall data to confirm the calibration of the existing computer models. Procedures have been developed to ensure that the information available from future floods is accurately obtained and analysed.

The nature of flooding experienced at Shoalhaven Heads is directly influenced by whether the entrance is open or closed at the start of the flood. As the entrance is normally closed, this has been the basis of flood planning agreed to by Council and the NSW Government. However, even in the “closed entrance” scenario, the flood levels predicted from modelling are based on the entrance being breached when flood levels at the entrance reach 2 m AHD.

Response *during* a flood can be extremely important in mitigating the impact of the flood on Shoalhaven communities. The draft Shoalhaven City Local Flood Plan covers preparedness measures, the conduct of response operations and the coordination of immediate recovery measures from flooding within the Shoalhaven City Council area. It covers operations for all levels of flooding within the Council area. Measures undertaken just prior to, during and after a flood include coordination of communication and information flow, road closures, traffic control, flood rescue, essential services, logistics, evacuations, resupply of isolated towns and villages, resupply of isolated rural properties, assistance for animals, stranded travellers, assistance with emergency travel and recovery.

Table 8. Summary of Floodplain Risk Management Measures considered in draft Lower Shoalhaven River Floodplain Risk Management Study. At the time this Entrance Management Plan was being written, the Risk Management Study and Risk Management Plan were still being developed. The measures below will be refined and the most appropriate will be adopted.

MEASURE	PURPOSE	COMMENT	BENEFIT-COST ASSESSMENT	IMPLEMENTATION VIABILITY
FLOOD MODIFICATION:				
SHOALHAVEN HEADS ENTRANCE MANAGEMENT	Formalise management of the entrance conditions to establish if or when the entrance can be opened to allow floodwaters out to the ocean through Shoalhaven Heads and so reduce flood levels for areas immediately upstream.	May lower levels for catchment runoff dominated events but may raise them for ocean dominated events. Previous studies have shown that it is not viable to maintain a permanent entrance. Local community very aware of problem. It is essential that some form of Entrance management scheme is included in the Plan.	Some 39 properties would benefit in small events (10% AEP). Ongoing maintenance costs and potential environmental issues.	Recommended as an interim measure.
FLOOD MITIGATION DAMS, RETARDING BASINS, OSD	Reduce flows from upper catchment areas	Tallowa Dam has insufficient storage capacity for flood benefit. Welcome Reef site is unlikely to proceed and few other opportunities available for such measures.	Generally not viable from a purely flooding perspective.	Not appropriate.
FLOODWAYS	Provide a defined overbank area where a significant volume of water flows during floods.	Few opportunities available for such measures.	High capital maintenance and environmental costs typically make this measure impractical.	Not appropriate.
CATCHMENT TREATMENT	Reduce runoff from catchment	Negligible impact on a large catchment but the general principles should still be applied.		Not appropriate.
RIVER IMPROVEMENT WORKS 1. Desnagging 2. Dredging 3. Realignment 4. Reconstruction 5. Remove hydraulic restrictions	Increase hydraulic capacity of the Shoalhaven River to reduce flood levels.	More applicable on smaller rivers. For the Shoalhaven River these measures provide only marginal hydraulic benefit, are not economically viable and would raise significant environmental concerns. 1. Not applicable. 2. Limited benefit and high cost. 3. Not applicable 4. Environmental concerns. 5. Not applicable. • high cost, • environmental impacts, • limited benefit. A detailed analysis of all these measures was not undertaken due to the high cost, limited benefit and significant environmental damage resulting from these works. These measures are not compatible with best management practice for floodplain management on the Lower Shoalhaven River and have been rejected for inclusion in the Plan.	Relatively minor benefit for significant ongoing costs.	Not generally appropriate.

IMPROVED LOCAL DRAINAGE	To reduce the incidence of local runoff ponding in yards and/or streets.	Flooding in this manner does not inundate buildings. Further investigation is a matter for Council and the local residents. Issue should be dealt with as part of Council's Stormwater Management Planning.		Not appropriate as mainstream flood management measure.
LEVEES	Prevent or reduce the frequency of flooding of protected areas.	Viability of levees typically dependent on nature of flooding and physical situation. Can create problems in addition to solving. A number of levee options were considered but typically involve a high economic cost and significant social and environmental consequences. There is some potential opportunity to provide cost effective protection to parts of Greenwell Point but further detailed investigation is required.	Some 137 properties at Greenwell Point could be protected in a 10% event with an estimated B/C of slightly >1.0. In a 1% event up to 350 could be protected for a B/C of around 2.6.	Greenwell Point situation has some potential worthy of further investigation.
FLOOD REFUGE MOUNDS	Reduce loss of stock in rural areas by raising area of land.	Property owner decision and at their expense. Hydraulic implications need to be considered.	Varies	Depends on individual property situation.
PROPERTY MODIFICATION:				
VOLUNTARY PURCHASE	Purchase of the most hazardous flood liable properties.	High cost per property. Applicable for isolated high hazard residential buildings but cannot be economically justified to purchase all buildings. It could be considered as a long term means of reducing the number of flood liable buildings.	Costs likely to far outweigh benefits. B/C typically <0.5.	Some potential for up to 203 properties inundated above habitable floor level in 10% AEP (1 in 10 ARI) flood.
HOUSE RAISING	Prevent flooding of existing buildings by raising habitable floor levels above the flood level.	All flood damages will not be prevented. House raising may not be practical for social and heritage reasons. Can be expensive	Costs up to $640K. With approx. $1.25M reduction in AAD. B/C around 2.0.	Some potential for up to 16 properties.
FLOOD PROOFING	Sealing entrances to buildings to minimise ingress of water and reduce the damage	Flood proofing should be considered. Maybe more beneficial for commercial properties.	Local benefits can be high for nominal cost.	Has some merit for appropriate situations particularly commercial/industrial areas at Bomaderry.
REVIEW AND FORMALISE CURRENT FLOOD POLICY	Formalise Council's Policy with regards to flood prone land.	Council's existing policy needs to be updated in accordance with the guidelines provided in the 2001 Floodplain Management Manual.		Recommended.
FLOOD PLANNING LEVELS	Establish Flood Planning Levels to define an area of land subject to flood related development controls.	Provides the means by which Council controls development in flood prone areas.	Future Benefits.	Recommended.
REVIEW AND UPDATE SECTION 149 CERTIFICATES	Used to advise owners whether their property is affected by flood related development controls. Update to address latest terminology/approaches and include findings from this study	A review should be undertaken. It is essential that the words are unambiguous and clearly inform the purchasers of the relevant constraints.		Recommended.

REVIEW AND UPDATE LEP AND DCP	Update to include findings from this study.	Council undertaking concurrent initiatives.		Recommended.
PLANNING REGULATIONS CARAVAN PARKS	Ensure safe evacuation procedures are in place.	Council's policy needs to e enforced. A risk assessment for all parks should be undertaken.		Recommended.
MONITOR FILLING OF THE FLOODPLAIN	Ensure minor development is monitored to minimise significant loss of floodplain storage or adverse impact on flood behaviour.	Minor filling is unlikely to have any significant impact on flood levels. Ensure cumulative fill in floodplain does not alter local flood behaviour.		Monitor.
MONITOR GREENHOUSE EFFECT	To ensure that flood levels do not rise and consequently impact upon minimum floor levels or Flood Planning Levels.	The increase is predicted to be relatively minor but must be closely monitored.		Monitor.
RESPONSE MODIFICATION:				
FLOOD WARNING	Enable people to evacuate and reduce actual flood damages.	System currently in place but could be enhanced.		Monitor.
EVACUATION PLANNING	To ensure that evacuation can be undertaken in a safe and efficient manner.	The SES has a Local Flood Plan. This could be enhanced to provide more detail on the particular problems at Greenwell Point and Shoalhaven Heads.	Benefits likely to be significant for relatively low costs.	Recommended.
AWARENESS AND READINESS PROGRAM	Educate people to minimise flood damages and reduce the flood problem.	A cheap effective method but requires continued effort. Examples of methods are provided.	Benefits likely to be significant for relatively low costs.	Recommended.

2.4 Environmental, Recreational and Scenic Values

The entrance are of the Shoalhaven River at Shoalhaven Heads has significant environmental, recreational and scenic values. The relatively natural coastal landscape with broad expanses of beach, sand dunes, ocean and river provide opportunities for appreciation by walkers, fishers, swimmers and other users of the area.

In terms of the NSW coast, the Shoalhaven estuary is a high priority site for shorebird conservation. Important sites include the entrance area, Comerong Lagoon, Old Man Island, Numbaa Island and their adjacent mud flats, and Crookhaven Heads. The following is summarised from Smith (1991).

More than 40 species of shorebirds have been observed in the Shoalhaven estuary, some of which are threatened species protected by NSW and Commonwealth legislation and many of which are protected under international agreements. The Shoalhaven estuary is one of the two most important NSW sites for the Double-banded Plover, the second most important site for the Pacific Golden Plover, and the third most important site for the Eastern Curlew. Large flocks of Mongolian Plovers and Ruddy Turnstones have been reported sporadically in the past.

Some of the species present in the Shoalhaven are amongst the world's greatest migrants. They travel huge distances to a strict annual schedule which imposes rigorous demands on them. Millions of wading birds of many species migrate each year between northern breeding grounds in eastern Siberia and Alaska and southern summer feeding grounds in southern Asia, the Pacific Islands, Australia and New Zealand. Other species spend the southern winter in the east coast of Australia and migrate to breed in New Zealand in spring.

The entrance area at Shoalhaven Heads can be important for shorebirds as a beach nesting site, an intertidal feeding area and as a high tide roost area. Species that nest only on beaches, such as the Little Tern and the Pied Oystercatcher, can easily be subject to levels of disturbance which severely reduce their breeding success. The intertidal feeding grounds are important for long distance migrants because the travelling involves continual heavy demands on the birds and availability of an adequate food supply is likely to be a critical factor in their ecology. Most wader species in estuaries congregate at high tide in specific roosting sites, such as sand bars, spits, and beaches. There is usually only a limited number of roosting sites for each estuary. Disturbance of birds when they are attempting to rest at roost sites is energy-consuming and is likely to have a deleterious effect on survival rates.

Accompanying this plan is a Review of Environmental Factors (REF), prepared in accordance with the requirements of the Environmental Planning and Assessment Act, 1979. The objective of the REF is to detail the environmental impacts of artificially opening the river and of maintaining the

dry notch. Recommendations from the REF have been incorporated into the plan and procedures section of this document.

2.5 Statutory and Policy Context

2.5.1 Crown Lands Act 1989

The Shoalhaven River entrance area is vacant Crown Land. A licence from the Department of Lands under Part 4, Division 4 of the Crown Lands Act is required to remove material from the dry notch. A land assessment prepared in accordance with the Crown Lands Act, which identifies the proposal as a preferred use, will generally be required before approval is granted. A land assessment may be waived where it is in the public interest to do so and due regard has been given to the principles of Crown land management.

In this instance the licence requested will be for a period of five years. As no material is to be removed off site no royalty will be payable.

2.5.2 Environmental Planning and Assessment (EP&A) Act 1979

The **Shoalhaven Local Environmental Plan 1985** adopts clause 35 of the EP&A Act Model Provisions. Therefore, development consent is not required for flood mitigation works (schedule 1, point 11 of the Model Provisions).

Nevertheless, Part 5 section 111 of the EP&A Act requires that a public authority by or on whose behalf an activity is to be carried out (in this case Shoalhaven City Council) has a duty to examine and take into account to the fullest extent possible all matters affecting or likely to affect the environment. Furthermore, this duty to consider environmental impacts extends to any public authority whose approval is required for the activity (in this case Department of Lands). A Review of Environmental Factors has been prepared and is attached to this plan.

Section 112 of the EP&A Act requires that if any of the above authorities considers that there is likely to be a significant effect on the environment then an Environmental Impact Statement must be prepared. To assist in this assessment, the NSW Government's publication "Is An EIS Required?" has been utilised during preparation of the REF.

Section 111 of this Act also requires that the environmental assessment includes consideration of, amongst other things, whether there is likely to be a significant effect on threatened species, populations or ecological communities or their habitats. The matters for consideration are in section 5A of the Act and are known as the "assessment of significance." If any of the above authorities considers that there is likely to be a significant effect, a

Species Impact Statement must be completed and concurrence of or consultation with the Director-General of the National Parks and Wildlife Service is required.

2.5.3 State Environmental Planning Policy (SEPP) No. 35 - Maintenance Dredging of Tidal Waterways

The maintenance dredging of a tidal waterway to enable it to function as a tidal waterway, or to resume its function as a tidal waterway, may be carried out in accordance with this SEPP. This legal mechanism has been used for opening of some coastal waterways that are intermittently open to the ocean. The effect of invoking SEPP No. 35 is to remove any requirement for development consent. Since development consent is not required anyway for the activities at Shoalhaven Heads SEPP No. 35 does not apply.

2.5.4 State Environmental Planning Policy No. 14 – Coastal Wetlands

If SEPP No. 14 wetlands were to be affected by direct excavation for river opening, then the consent of Council and concurrence of the Director-General of Planning would be required. Under the SEPP, a number of matters must be taken into consideration when a development proposal is considered. A SEPP No 14 wetland is present to the southwest of the Shoalhaven River entrance. However, as no excavation within SEPP No. 14 wetlands is proposed, the requirements of this SEPP are not triggered. Nevertheless, the possible indirect effects of the activity on SEPP No 14 wetlands have been considered in the REF.

2.5.5 State Environmental Planning Policy No 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. Proposals for development in sensitive coastal locations fall under SEPP No. 71. SEPP No. 71 has no impact on the proposed activity.

2.5.6 Threatened Species Conservation (TSC) Act 1995

The TSC Act lists species that are considered to be at risk of becoming extinct and provides a framework of measures that aim to prevent that extinction happening. A licence under the TSC Act would be required if the activity would “harm” any animal or “pick” any plant that was part of a threatened species, population or ecological community, or cause damage to their

habitat. This is possible (though may be avoidable) if, for example, nesting Little Terns were present when there is a need for an emergency opening of the river entrance. The matter is discussed in more detail in the REF, including measures for avoiding harm to threatened species. Offences relating to the harming of threatened species, populations and ecological communities (being animals) and the picking of threatened species, populations and ecological communities (being plants) are contained in the National Parks and Wildlife Act 1974.

2.5.7 National Parks and Wildlife Act 1974

It is an offence under this Act to knowingly destroy an Aboriginal site, relic or artefact. No Aboriginal site, relic or artefact has been recorded from the area where entrance opening works will be carried out, and as entrance barriers are extremely dynamic environments it is unlikely that any would be present in this locality.

It is generally an offence to harm threatened or protected wildlife. Potential impacts upon wildlife are addressed in the accompanying REF. It is considered extremely unlikely that threatened or protected species would be harmed by the activity. If it was to occur, the legislation protects Council in the following relevant cases:

- an activity by a determining authority within the meaning of Part 5 of that Act if the determining authority has complied with that Part, or
- an activity in accordance with an approval of a determining authority within the meaning of Part 5 of that Act if the determining authority has complied with that Part, or
- was authorised to be done by or under the State Emergency and Rescue Management Act 1989 or the State Emergency Service Act 1989 and was reasonably necessary in order to avoid a threat to life or property.

2.5.8 Fisheries Management Act 1994

A licence under this Act would be required if the activity would “harm” any fish or marine vegetation that was part of a threatened species, population or ecological community, or cause damage to their habitat.

Sections 198 and 200 of the Act require a local council proposing to undertake dredging works to obtain a permit. These sections do not apply if the dredging is authorised under the Crown Lands Act 1989 or by another relevant authority (other than a local government). Sections 204 and 205 (damage to marine vegetation) could apply if seagrasses were to be damaged.

The works proposed under this plan are likely to be authorised under the Crown Lands Act and will be confined to the unvegetated entrance area.

There are no threatened fish species issues identified for the Shoalhaven River entrance. Therefore, approvals under the Fisheries Management Act will not be required.

2.5.9 Environment Protection & Biodiversity Conservation (EPBC) Act 1999

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

Under Part 9 of the EPBC Act (1999) an action that has, may have or is likely to have a significant impact on a matter of national environmental significance may only be taken with approval of the Commonwealth Minister for the Environment.

The EPBC Act lists threatened species and migratory species protected under international agreements (JAMBA and CAMBA). An assessment of whether the actions at Shoalhaven Heads would require the approval of the Minister is included in the REF.

2.5.10 Aboriginal Land Rights Act 1983

This legislation would be relevant where an Aboriginal land claim has been made which affects submerged Crown Land or areas of Crown Land that may be proposed for processing, storage or use of dredged material. The Commonwealth Native Title Act (1993) and Native Title (New South Wales) Act (1994) may also be relevant in this regard.

2.5.11 Water Management Act 2000

The NSW Government will ultimately replace the use of SEPP 35 for artificial openings of estuaries with an approvals system under the Water Management Act 2000. Controlled activities approvals will replace Part 3A of the Rivers and Foreshores Improvement Act 1948, which will be repealed when the new approvals system commences. The new requirements may apply to entrance openings of the Shoalhaven River.

Controlled activity approvals may be issued for up to 10 years under the Water Management Act 2000. However, these approvals cannot be issued until a management plan that contains provisions for the management of controlled activities has been made under the Water Management Act 2000. Certain activities could be excluded from requiring an approval, for example where Council has adequately addressed necessary considerations. These considerations would need to be specified in the relevant management plan.

3 Entrance Management Policy and Procedures

If the level of the dune at Shoalhaven Heads builds to a height of 3.5m AHD and no action is taken prior to flood, then, except in an extreme event, the entrance would not be expected to be breached by floodwaters. This would greatly increase the impacts of the floods on Shoalhaven communities downstream of Nowra and could lead to major geomorphological changes in the lower river channel, such as the creation of a new opening through Comerong Island, or massive erosion of Berry's Canal. This plan is designed to help avoid those impacts.

3.1 Management Principles

The concept of a dry notch acting as a weir that would be breached without mechanical intervention when it is overtopped by flood waters is no longer considered practical (1984 Public Works Department, see section 3.4). Therefore Council will make every effort possible to manage the river entrance according to the following principles:

1. To assist in the protection of some existing development at low levels and to otherwise reduce the impact of flooding on the Shoalhaven community, Shoalhaven City Council will act to have the Shoalhaven River entrance at Shoalhaven Heads open when floodwaters reach a level of 2m above AHD at Shoalhaven Heads. If it is confidently expected that floodwaters will reach 2m, the entrance may be opened before it reaches that level if other conditions (such as tide, time of day, ocean conditions, etc) make that more suitable.

2. To reduce the sand burden needed to be removed in an emergency opening of the entrance in times of flood, whenever the Shoalhaven River entrance is closed, a “dry notch weir” will be maintained at the entrance area as long as the current flood planning levels are in force.

3. All future development will only be approved at the higher Flood Planning Levels derived from the “Shoalhaven Heads entrance closed scenario,” thereby assisting Council in satisfying its obligations under the NSW Floodplain Development Manual 2005.

The current Flood Planning Level for buildings at Shoalhaven Heads is based on modelling of flood levels expected if the beach berm or dune is at a height of 2 m AHD and the entrance scours when river water levels at the entrance reach that height. This implies that maintenance of the dry notch is a long term strategy.

This plan more clearly describes the local (Shoalhaven Heads) conditions under which the entrance will be artificially opened than have previous documents. The predicted flood levels at Nowra are still used as triggers for preparations at Shoalhaven Heads, but it is consideration of local conditions

(river water level, ocean water level, including tide and other factors, and operator safety) that determine the most appropriate time to make the breach.

Precise procedures for Council's Flood Engineer and Site Supervisor are included as attachments to this plan. They summarise the decisions that will need to be made and the actions that will need to be taken for emergency opening of the entrance. The following subsections of this plan provide detail and discussion on each aspect of the procedures.

3.2 Responsible Officers

The responsible officer in respect to sanctioning mechanical intervention is Shoalhaven City Council Director City Services or his/her appointed delegate.

The responsible officer in managing the mechanical excavation and monitoring process shall be Shoalhaven City Council City Services Works and Services Manager. Works and Services Manager would normally delegate responsibility for regular maintenance of dry notch and emergency openings, in accordance with this plan, to officers in Council's Natural Resources and Floodplain Management Unit ("Flood Engineers"). The site works would normally be delegated to Council's Northern Maintenance Engineer who will assign the task to the "Site Supervisor."

The Works and Services Manager will also nominate an officer to liaise with other groups as required. These would include Council's Rangers, Council's Liaison Officer at the Emergency Operations Centre, the State Emergency Service and NSW Government agencies such as the Departments of Environment and Conservation, Lands, Natural Resources and Primary Industries.

Contact will be made with officers of Department of Natural Resources and the Community Representative nominated by appropriate Shoalhaven City Council processes, in respect to sand disposal options.

The National Parks and Wildlife Service Area Manager, Nowra Area, is the officer that will arrange for Shoalhaven City Council City Services to be informed any time that shorebirds are known to be nesting at Shoalhaven Heads.

Details of essential emergency communications are set out in the "Procedures" attachments to this plan.

3.3 Dry Notch Weir and Dune Management

The purposes of the notch and associated dune management are to:

- reduce the burden of sand required to be removed at the time of a flood emergency
- control the location of the entrance channel for the protection of the beach and associated assets to the north and for the safety of the operator at the time of breach.

3.3.1 Monitoring of Closed Entrance Area

Council will monitor sand levels in the entrance area as follows:

- detailed survey at approximately six-monthly intervals and at other times considered necessary;
- spot height checks at other times if weather/sea conditions lead to suspicion that sand build up may have occurred;
- spot height checks when Flood Watch notice is received.

Cost effective and rapid survey techniques will be further investigated, particularly for the surveys that are to be done in response to a Flood Watch notice.

In the past, rows of coloured poles have been placed at the entrance. The aim was to raise community awareness of the existence of the notch, and to allow the community to assist in monitoring by watching sand levels against marks on the poles. There are two reasons why the poles are not recommended as part of this plan:

- The environmental impact is considered to be inappropriate. There is a direct impact on the high scenic value of the area and an indirect impact on bird population through the increased activity in the area (it is considered the poles would attract more people to the area who are curious to have a look).
- The cost of fabricating, installing and maintaining the poles, which would be damaged, displaced or removed by heavy seas, and would be washed away each time the entrance opens

At the time of writing, a bench mark is located on a single pole in the north western part of the entrance area. The bench mark is a large galvanised iron nail set into the southern face of the pole and painted yellow. It is set at a height of 1.84 m AHD. A single pole with a bench mark of known height will be installed at the southern side of the entrance area, near the existing nature reserve sign, for greater ease of reference during surveys.

As part of Council's commitment to the expanded documentation of entrance conditions and natural processes, detailed surveys of ground levels at the entrance area have been completed at approximately 6 month intervals since

June 2001. These surveys indicated that on most occasions the berm crest was just above 2m AHD and so no excavation was required for maintenance of the dry notch. However, these surveys are in addition to more frequent but less detailed inspections of the area by Council staff. In February 2003, it was noticed that deposition of sand had occurred to the extent that removal was required.

If the future inspections indicate that excavation is necessary then the following design will be used.

3.3.2 Location, Configuration and Maintenance of the Dry Notch

On occasions in the past, there has been a tendency for an open entrance to scour northward threatening public facilities and scouring the main surf beach. This pattern of scour is dependent on a number of factors such as the position of the dry notch, the existing sand burden on the coastal berm at the entrance and to the north, prevailing winds, prevailing ocean currents, etc. Therefore, the dry notch is to be as far south as is reasonable, preferably within the area shown in Figure 4. However, the following considerations will determine the exact position of the notch on each occasion:

- the natural variations in the height and shape of the entrance berm and dune that occur from time to time;.
- the location of deeper water inland, which may mean that less sand needs to be scoured when an emergency opening takes place;
- the location of nesting shorebirds.

Given the importance of minimising the volume of sand in the entrance area (see Section 3.3.5), greater consideration needs to be given to the location of the notch immediately after closure of the entrance. The procedure should be based on aerial photography and/or land survey and hydrosurvey. This procedure should allow Council to determine the area that provides the least volume of sand for a future breakout, as well as meeting the other requirements.

The configuration of the notch is shown diagrammatically in Figure 5.

The notch will be excavated to a level of 2 m AHD for a north-south width of 50 metres. The east-west length of the notch will be determined by the shape of the entrance berm and dune at the time. The western limit of excavation will be determined by the point where the natural sand level drops below 2 m AHD. The eastern limit of excavation is discussed below.

The crest of the berm (over a fairly narrow east-west distance) will naturally rise and fall significantly over fairly short time periods in response to the sea. Experience at Shoalhaven Heads has shown that it is not practical or desirable to attempt to maintain this berm or dune crest at 2 m AHD. Not only would the work be futile, but it may compromise the maintenance life of the notch further to the west, by allowing more frequent wave wash-over and dumping of sand in the notch. This wash-over could also affect the nesting

success of shorebirds that may be present (such as Little Terns and Pied Oystercatchers).

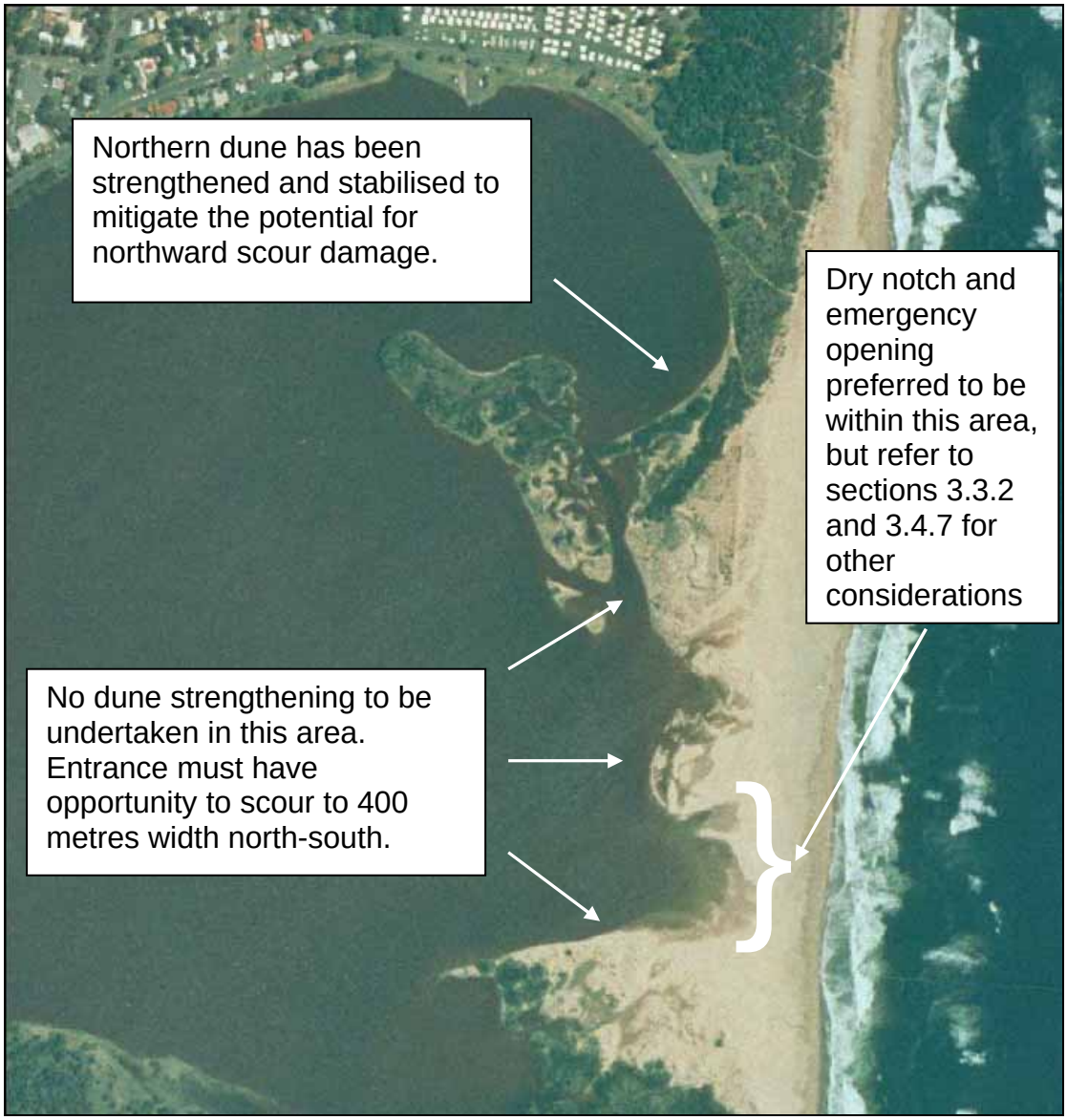


Figure 4. Shoalhaven River entrance area

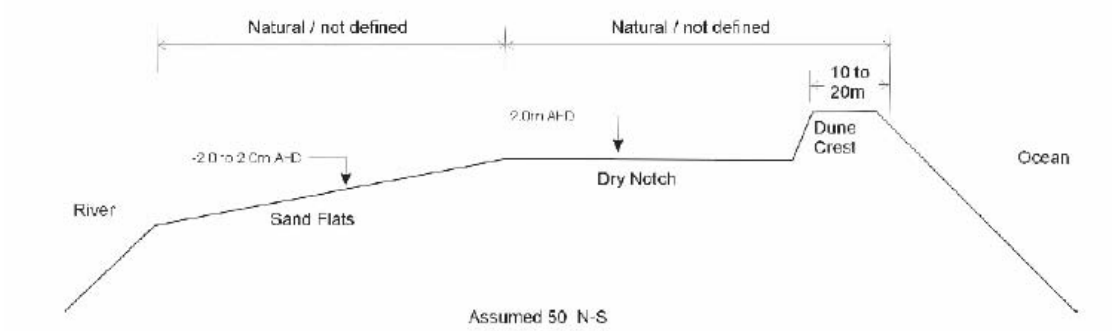


Figure 5. Diagrammatic East-West Section Showing Configuration of the Dry Notch.

For these reasons the notch will not extend to the fullest extent possible eastward, through the crest of the berm or dune, but will be maintained as follows.

During the months of March to October the dry notch will be mechanically excavated to 2.0 m AHD to within approximately 10 metres west of the high point of the berm or dune. If considered prudent at the time, the 10 metres west of the high point be reduced to 3 m AHD as part of this operation.

During the potential shorebirds breeding season (i.e. October to March) the dry notch will be mechanically excavated to 2 m AHD to within approx. 20 metres west of the high point of the berm or dune, if this can be done without direct disturbance to nesting birds.

Computer modelling (Webb Mckeown and Associates, 2006) indicates that the volume of sand contained within the higher dune crest is not large and would not significantly impact on flood levels, provided the crest is breached when or before local flood levels reach 2 metres AHD.

If it is necessary to undertake notch maintenance when shorebirds are actually nesting or roosting, vehicles and people should be restricted to the immediate surrounds of the dry notch work area, and the disposal area to avoid disturbing the birds. It may be necessary, and will be considered reasonable, to compromise the disposal strategy to avoid these birds. National Parks & Wildlife Service will mark the nests and roost areas to ensure that Council, its Contractors and the public know where they are located.

If nesting birds could not be avoided, no excavation will take place until the “all clear” is received from National Parks & Wildlife Service that the coastal berm or dune is no longer being utilised by nesting shorebirds, unless the work is being done in response to a Flood Watch.

3.3.3 Dune Strengthening Strategy

For some years there was an ad-hoc strategy of opportunistically strengthening dunes on the northern sector of the entrance to mitigate the potential for northward scour damage. A well vegetated dune is now established there (Figure 4). The vegetation on this northern dune will also assist in preventing inland sand migration by heavy seas and/or onshore winds.

Earlier drafts of this document indicated that this strengthening of the northern dune should continue further southward into the entrance area. However, the 1990 flood study assumed that the entrance would be able to scour to a north-south width of 400 metres. Table 9 shows the results of additional modelling (Webb McKeown and Associates, 2006) of the impact of restricting the final north-south dimension of the channel.

Table 9. Results of Modelling Effect of North South Scour Width

N-S dimension (m)	400	300	200	100	50
Flood impact (m)	base	+0.14	+0.31	+0.53	+0.68

It is therefore important that the channel be allowed to scour to a north-south width of at least 400 metres in order to maintain current flood planning levels. Dune strengthening works that would prevent this from happening should not be undertaken. There should be no strengthening of the dune in the area indicated in Figure 4.

When the entrance is closed, some areas in the northern part of the bare entrance area fluctuate in height and it is possible that, in a flood, the river could break through in that area with possible stranding of machinery to the south and erosion damage to the north. If affordable, sand to be removed during maintenance of the dry notch could be utilised to assist in reducing the chance of that happening.

The decision on where and how to utilise this material to strengthen the northern sector of the entrance area should be taken on consultation between Council and relevant government agencies. It is acknowledged that officers may choose to involve others in the discussion but responsibility rests with these organisations to arrive at an agreed strategy in each instance.

3.3.4 Earthmoving Machinery Required For Regular Maintenance Of Dry Notch

If possible, sand removal for notch maintenance should be utilised to contribute to strengthening of the northern sector of the entrance area (section 3.3.3). This will generally mean transportation of material. The recommended combinations are -

- Bulldozer of approx CATD7 size, and 2/3x4WD Scrapers, or
- Excavator and 2/3 x6WD Dump Trucks

Otherwise, maintenance of the notch can be carried out by hydraulic excavator.

3.3.5 Sand Flats West of the Entrance Area

The amount of sand in the bay to the west of the entrance dune can vary considerably from the conditions assumed in the 1990 Flood Study. Table 10 shows the results of additional modelling (Webb McKeown and Associates, 2006) of the impact on 1% AEP flood levels from the volume of sand in the sand flats west of the entrance area.

Table 10. Results of Modelling Varying Sand Flats E-W Dimensions on 1% AEP flood level.

Height (mAHD)	0.0	-1.0	+1.0	-1.0	0	+1.0
Width (E-W) (m)	500	500	500	250	250	250
Flood Impact (m)	base	-0.32	+0.32	-0.41	-0.17	+0.13

The results cover a wide range of conditions some of which have not been experienced in recent decades. However, they do indicate that the impact of a much larger total volume of sand is considerable and much more critical than the crest size.

In early 2006, the dune configuration was at or above 2.0 m AHD for around 40 to 50 m E-W, with the sand flats from 2.0 to 0.0 mAHD for a further 250 m. Within the precision of the CELL Model, this is similar to the assumed base case in the 1990 Flood Study. Surveys indicate that these dimensions were consistent for at least the previous 5 years.

However, photogrammetry indicates that in the past (1980's) the dune was above 2.0 mAHD for up to 250 m E-W. This appears to have resulted from the movement of sand into the bay from the sea when the entrance was open, i.e., the development of an extensive flood tide delta.

Should such conditions develop again, consideration will need to be given to an appropriate course of action. It may be considered that any potential increase in flood level is accounted for in the “freeboard” provisions of the flood planning levels. Alternatively, consideration could be given to major dredging of the sand flats, though this would result in significant environmental impacts and may not receive the necessary approvals. Another option would be to monitor the development of the tidal inflow delta when the entrance is open and consider options for restricting its extent, though this would be extremely difficult to achieve.

3.4 Emergency Opening

The PWD concept of the notch as a weir that would be breached when it is overtopped by flood waters, i.e., without mechanical intervention, is no longer considered practical. It is considered that, despite maintenance of a dry notch, mechanical breaching of the entrance is advantageous for the following reasons:

- The location of the entrance breach can be controlled, in case low points have developed elsewhere on the entrance berm and dune (despite the dune management strategy outlined above).
- The crest of the berm (over a fairly narrow east-west distance) will naturally rise and fall significantly over fairly short time periods in response to the sea. It could be above 2m AHD at the time of a flood and so would need to be mechanically breached. It is not considered practical or desirable to attempt to maintain this berm crest at 2 m AHD
- The notch through the sand behind (to the west of) the berm may be infilled by unfavourable weather/sea conditions just prior to a flood, despite the monitoring and notch maintenance strategy outlined above.
- There could well be situations where high seas in conjunction with river flooding mean that the appropriate course of action is to leave the crest in place at least until the tide falls and the situation becomes safe, even if the flood level at Shoalhaven Heads rise above 2.0 mAHD.
- There may, in certain circumstances, be advantages in terms of reducing flood impacts and operator safety if the entrance is opened at a lower river level than 2 m AHD.
- It may be possible to take advantage of a falling and low tide so as to maximise the cumulative hydraulic gradient and hence entrance size.

Neither the dry notch nor the emergency opening strategy outlined here can protect all houses at Shoalhaven Heads from being flooded. Appropriate strategies for dealing with this problem will be addressed in the Lower Shoalhaven River Floodplain Risk Management Plan which is in preparation.

Emergency opening procedures for the “Flood Engineer” and “Site Supervisor” are included as attachments to this plan. They have been developed based on the following considerations.

3.4.1 Water level indicators

There are two automatic water level recorders in the river at Shoalhaven Heads - one at the western end of Hay Avenue near the creek entrance and one opposite the River Road boat ramp at the caravan park. A gauge that used to be at the end of Wharf Road was decommissioned when the Hay Avenue gauge was installed. The gauges are maintained by the Manly Hydraulics Laboratory. They are real-time gauges and Shoalhaven City Council has access to the water level information via computers. The Hay Avenue gauge will generally be used by the Flood Engineer in the case of a flood, but the River Road gauge should be monitored as a backup.

There is also a gauge plate in the water next to River Road (Figure 6). The numbers on the plate are in metres above AHD. This will be monitored by the Site Supervisor.

3.4.2 River Water Level Triggers

When a Flood Watch notice is received from the Bureau of Meteorology (via the SES), Council's Site Supervisor and Flood Engineer will get things ready for an emergency opening if it becomes necessary (including putting machinery on standby and inspecting the site for sand build up). If there is considerable sand build up in the notch then an excavator should be moved to the site and excavation will commence at this stage. Once the notch is re-established, consideration should be given to keeping the machine at Shoalhaven Heads (e.g., if alternative work can be found) for the duration of the "Flood Watch."

A minimum of 6 to 9 hours warning will be available of significant river rises at Nowra.

Immediately after a Flood Warning is received predicting a FLOOD LEVEL EXCEEDING 2.5 m AHD or greater at Nowra Bridge, machinery will be deployed to Shoalhaven Heads and excavation will commence, working from inland towards the Pacific Ocean.

Figure 6. Water level indicators at River Road – gauge plate in foreground and automatic recorder in background.

In the 1986 UNSW Shoalhaven River Entrance Study it was stated that “the most important factor in a flood break-out was the water level in the bay. Once the water level had reached 2 metres above MSL in the bay and 3 metres on the Nowra gauge, a break-out could be successfully initiated.

Ordinarily the final breach should not take place unless 3.0 m AHD is reached, or forecast is for continued rise beyond 3.0 m AHD AT NOWRA BRIDGE, or if the water level at Shoalhaven Heads is rapidly approaching 2 m AHD, indicating that Broughton Creek catchment may be contributing significant flows.

The process should be aborted if subsequent forecasts are revised to be confident that a level of 3.0 m AHD is not anticipated to be reached and/or sustained at Nowra Bridge.

The final breach should not be made if it is considered that sea conditions are inappropriate.

The detailed procedures undertaken at each of these stages by the Flood Engineer and Site Supervisor are included in attachments 1 and 2.

Once the criteria above have been met, the exact timing of the opening will be determined based on local Shoalhaven Heads conditions as set out in the flow chart on the last page of the “Site Supervisor” procedures.

3.4.3 Relativity In Flood Heights

Although it is acknowledged that there are many variables (such as ocean levels, ocean activity, location of rainfall in the catchment, state of entrance etc) which affect the flood gradient downstream, hydrographs suggest that flood levels in the vicinity of 3.5 m AHD at Nowra Bridge will most probably cause flooding to 2 m AHD at Shoalhaven Heads. During prolonged flooding, flood levels of 3 m AHD at Nowra Bridge can have the same effect.

Indicative Peak Flow Times For the Shoalhaven River (from Draft Shoalhaven City Local Flood Plan) - estimated river flow time from Nowra are:

a. Broughton Creek: 30 minutes.
b. Crookhaven Heads: 2 hours.

3.4.4 Broughton Creek Catchment

Under extreme circumstances, if there is a large amount of coastal rain and the Broughton Creek catchment is contributing greatly to flows in the Shoalhaven River it may be possible that the water level at Shoalhaven Heads could rise to 2 m AHD without Nowra reaching 3m. A flood study of the Broughton Creek system will help to answer this question, but this is unlikely to be completed for a number of years. Measures to take this

potential hazard into account, in the form of water level monitoring, are included in the procedures for Flood Engineer and Site Supervisor.

3.4.5 Hydraulic Benefit

The timing of the manual opening is crucial to its overall success and resultant hydraulic benefit (reduction in flood level). Opening too early may be unsuccessful in fully scouring out a channel if there is insufficient water level difference between the bay and the ocean. Thus in small floods the chance of success is reduced. For the design events it is assumed that the peak rainfall burst occurs in conjunction with an elevated ocean level. This means that the benefit of opening will be less than if the peak were to occur in conjunction with a lower ocean level (or low tide).

A reduction in flood level is only achievable if the heads are opened prior to the flood peak occurring. This means that the initial opening should be several hours earlier. Opening after the peak will only achieve a reduction in the duration of inundation. However, it does mean that roads can be opened earlier, "clean up" exercises can be started, and the community will gain a psychological boost. It would also provide a means of ensuring that the bay is "flushed" by floodwaters and some of the sand build up removed (this may or may not be viewed as advantageous).

The reduction in peak level that would be achieved in a given flood, as a result of opening, is impossible to accurately quantify. The main influences are:

- the amount of time available before the peak at Shoalhaven Heads (dependant upon flood forecasting),
- the capability of the earth moving equipment,
- the ocean level,
- the peak volume of floodwaters arriving and the resulting peak level at Shoalhaven Heads,
- the amount of sand in the bay and across the beach berm.

Where possible, the excavation is to be planned so that final breakout occurs on a receding tide to optimise available scouring time. However, if the river level has already reached 2 m AHD and sea conditions are considered appropriate, then the opening should proceed irrespective of whether the tide is rising or falling.

When consideration is given to manually opening the heads each of these factors need to be assessed at the time of the flood event. The flow chart at the end of the Procedures for Site Supervisor (attachment 2) takes these factors into account. Some of the factors, such as the level of the ocean in relation to the level of the river, will require careful judgement, but they are important.

Computer modelling (Webb McKeown and Associates, 2006) indicates that lowering the opening level from 2.0 m AHD to 1.8 m AHD would only reduce the flood level by 0.01 m. This is because the early breach does not

significantly advance scour of the breakout channel due to the fact that the initial head difference between the river and the ocean is small. In other words, most entrance outflows and erosion occur as the size of the channel grows and the (hydraulic) gradient between the river and the ocean increases.

3.4.6 Ocean Water Level

More often than not, when the Shoalhaven River is in flood, stormy conditions will also have raised the level of the ocean on the adjacent coast. Low atmospheric pressure, strong onshore winds and large waves cause the elevated water levels. This is known as “setup” and can typically raise the coastal water level from 1 to 2 metres. Modelling has predicted that the ocean water level at Shoalhaven Heads could reach 2.5 m AHD. In addition, the uprush of water from a breaking wave, known as wave “runup,” can increase the water level by several more metres when each wave reaches the shore.

This elevated ocean level and large waves can aggravate flooding effects within the Shoalhaven floodplain. The record flood of 1870 produced a very high peak at Greenwell Point because it occurred simultaneously with strong wave set-up and surge conditions in the ocean. In June 1975, wind and wave action caused the pushing up of water levels in Crookhaven Bight to the extent that water levels at Nowra were higher than those caused by greater up-river flows during previous floods. Consequently, significant backwater effects occurred in the lower reaches of the river (Draft Shoalhaven City Local Flood Plan).

If the ocean water level is higher than the river water level then breaching the river entrance could exacerbate flooding at Shoalhaven Heads by allowing the sea to flow into the bay. The hazard may be increased if ocean waves were to penetrate into the bay and break across the foreshore of the caravan park.

Finally. elevated ocean levels and large waves may make conditions on the entrance berm and dune so treacherous that it would be impossible to take machinery there to open the river. This may require waiting until conditions subside and/or the tide falls sufficiently to allow mechanical opening to proceed.

Further investigation will be undertaken to identify an effective way of monitoring ocean levels during a flood event. This may involve use of water level recorders in the ocean off Batemans Bay and Port Kembla or just inside the Crookhaven River entrance.

3.4.7 Preferred Physical Opening Location

The exact breach position is to be determined on site. It is to be as far south as is reasonable preferably within the area shown in Figure 4. It is then to be determined on economies: shortest, lowest line of sand will obviously be

quickest and cheapest. This will generally be in the line where the dry notch has been maintained. Naturally judgement is required as quantity of sand to be removed, access to deeper water inland and other related factors will play a part.

There is a local opinion that supports the premise that an entrance opening is more likely to be sustainable if the east west reach from Berrys Bay to the entrance is maintained.

On occasions, in the past, there has been a tendency for the entrance to scour northward threatening public facilities and scouring the main Surf Beach. This pattern of scour is dependent on a number of factors such as position of dry notch, existing sand burden on coastal berm and on beach, prevailing winds, prevailing ocean currents, etc. These are difficult to forecast over the duration of a successful opening, and caution must be exercised. Cognisance does need to be given to the potential damage that can occur if the scour is northward and/or the entrance opening begins too far northward. Diligence to attempt to mitigate this factor is strongly emphasised.

3.4.8 Earthmoving Machinery Required

Although it would be desirable to utilise sand removed to create the breach to contribute to strengthening of the northern sector of the entrance area, or to at least remove the sand burden from the immediate environs of the breach - it is recognised that time available will generally not allow this to occur. However, operators should be aware of this benefit and advantage taken opportunistically, if possible. For example if suitable machinery was on site, or nearby, this may be possible to some degree.

Generally speaking, the recommended machinery required to breach the berm is one or two hydraulic excavators. The number of hydraulic excavators required will depend on the quantity of sand burden to be removed, availability of bigger machines and urgency of operation. Equally one big excavator, and one CATD7 dozer (or bigger) would be suitable – the excavator to get depth in the trench and the dozer to remove the sand burden as far as is possible from the scouring area.

3.4.9 Access Roads

Machinery would, more often than not, be required to travel on Bolong Road from Bomaderry to Shoalhaven Heads. Under most circumstances, it will be possible to get machinery to Shoalhaven Heads before the road is closed by floodwaters at the following levels.

This road can be closed at Bomaderry when the Nowra Bridge gauge reaches 2.05 m AHD and further towards Broughton Creek when the Nowra Bridge gauge reaches 2.25 m AHD. It may be possible to move heavy trucks

through water over the road at these and higher levels. This should be further investigated.

Comerong Island Road is unlikely to provide alternative access as the ferry ceases to operate at 1.8 m AHD the Nowra Bridge gauge.

3.4.10 Entrance Opening Procedure

A channel about 1 metre deep and 4 metres wide should be excavated from the river to the ocean. Excavation should commence on the river side of the entrance sand dune and progress towards the ocean, so that advantage can be taken of drier conditions on the lower ground in the early stages of the job. The exact dimensions of the channel will be determined by given restraints in time, natural repose of the sand, etc. The machinery should not waste time and money by trying to dig deeper than natural forces will allow to remain.

The final breach is to be prepared but the berm should not be breached until all conditions outlined in the “Procedures” (see attachments) have been met.

The breach is to be as clear as possible of surplus sand in its immediate environs. Thus the sand burden removed to create the breach is to be moved as far as is possible from the channel. This is where, if it is practically possible and affordable, an additional excavator (or a D7 type dozer, or bigger) would be beneficial as one can be digging and the extra machine can be removing sand away from the channel to mitigate against scouring in width escalating the infilling of the breach.

3.4.11 Cost

An approximate cost for an excavator with associated personnel for 6 hours would be of the order of $2000. The overall cost to Council could be between $5,000 and $10,000 when all staff time is included (eg, rangers, flood engineer, media manager and other staff).

3.4.12 Risk to Life & Equipment (OH&S)

The machinery is likely to be operating in a harsh environment (high seas, wind and wave action, possible darkness) with a significant risk to life and potential for loss of equipment (bogged or cut off from retreat).

A Risk Assessment has been carried out for the activity and is included as attachment 3. It includes measures for mitigating the risks to operators and equipment.

There is considerable danger to members of the public that might choose to be at the site during excavation. The potential hazards include being hit by large machinery or being swept to sea by the river as the banks of the scouring entrance channel collapse. To help reduce such risks, Council’s Rangers will provide crowd control when an opening is taking place.

The operation would be more hazardous if carried out in darkness. The procedures for the Site Supervisor provide for opening of the entrance before nightfall if other conditions allow. Despite this, there may be times when the job will need to be done in darkness.

Personnel will be trained to undertake the task.

3.4.13 Monitoring Of Open Entrance

A record of the excavated east-west length, north-south width, and depth of the breach should be recorded. This should be supported by photos from one or two consistent vantage points.

Once the breach is completed and water starts flowing outwards, an hourly record of approximate depth and north-south width of channel in respect to initial breach should be recorded. If possible this information should be supported by photos from the same vantage points as above. This hourly record should revert to daily once the tide turns, unless extraordinary infilling, or scour, conditions prevail. Basically, the intent is to record the event in such a way that the scouring process can be studied/assessed after each event so that opportunities to progressively improve the process are optimised. Tides and prevailing winds should also be recorded.

Reference is made to Page 29 of Healthy Rivers Commission of NSW, Independent Inquiry into the Shoalhaven River System, Final Report, July 1999 which states A water quality monitoring program should be implemented to clarify any linkages between entrance closure and water quality in the vicinity of the Heads, to assist in the formulation of priorities for longer term management of water quality.

This water quality monitoring program is a matter for Shoalhaven City Council's Environmental Services Manager, and any proposed emergency opening should be brought to his attention to ensure the success of this program.

4 References

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