2 SUMMARY OF ESTUARY PROCESSES

An Estuary Processes Study of Killick Creek was carried out by the NSW Department of Public Works and Services, Manly Hydraulics Laboratory (MHL, 2002). The following sections provide an interpretation of this report, plus additional information that was made available for the study.

2.1 Location and Geographic Context of the Creek

Killick Creek is a small estuary located adjacent to the township of Crescent Head, within the mid-north coast of NSW. The immediate catchment area of Killick Creek is approximately 5 km^2, and a waterway area 0.6 km^2. There are two main tributaries to the Creek – Muddy Arm to the west, and the flood-cutting to the north-west (refer Figure 1-2).

Killick Creek is artificially connected to the Belmore River and Maria River floodplains through a series of agricultural drains and floodgates. Killick Creek is an important element of the Macleay Flood Mitigation Scheme, and has been used for over 100 years to help drain low-lying lands around the Belmore River following flood and local rainfall events.

2.2 Past Usage of the Creek

2.2.1 Pre-European Conditions

GECO (2005) report that " observations of government surveyor Clement Hodkinson who travelled through the Macleay valley in the 1830s and 1840s stated in his description of the Macleay River..

> These borders of alluvial brush land on the banks of the river are generally half a mile or a mile wide and are then backed by extensive swamps of many thousands of acres in extent whose verdant sea of high waving reeds and sedge, stretches away to the base of the distant forest ranges. There are several lagoons in these swamps and the stagnant water is very diffuse over their surface".

Figure 2-1 shows an image of Belmore Swamp being cleared of reeds.

2.2.2 Contemporary development

In the late 19th Century, an informal connection was established between Killick Creek and the Macleay River floodplain, which facilitated the drainage of floodwaters from the area around Upper Belmore Swamp (thus minimising the time the land was inundated and thus not suitable for agriculture). Nonetheless, the Belmore Swamp and Kinchela Swamp areas still represented significant flood storage, and formed semi-permanent wetlands.

Figure 2-1 Clearing of Belmore Swamp (Source: KSC archives)

In 1952, connection between Killick Creek and the Belmore Swamp area was formalised through the construction of the Killick drain (see Figure 1-1). Works were also carried out in Killick Creek itself to improve the efficiency of flood drainage. These works included construction of the flood-cutting, which significantly widened and deepened the upper reaches of Killick Creek and connected it with the agricultural drains, and straightening and training of the creek entrance. The works at the entrance involved significant dredging and reclamation using marine sands from the estuary. The site of the current caravan park at Crescent Head is located on the land reclaimed as part of these works.

Scotts Drain was completed in 1974, which forms a formal link between the Belmore River, Killick Drain and Killick Creek. Scotts Drain is separated from the Belmore River by a series of floodgates.

Killick Drain, and thus Killick Creek, is also connected to the Upper Maria River system, through Connection Creek (see Figure 1-1 and Figure 1-6).

The estuarine waters of Killick Creek and the Agricultural waters of Killick Drain are separated by a one-way floodgate. The floodgate is designed to prevent ingress of saline waters into the drains, but allow discharge from the drains into the estuary when water levels in the drains are high. Drop boards can also be put in place to prevent the outflow of waters from the drains into the creek, which are used on an occasional, as-required basis (refer Figure 2-2).

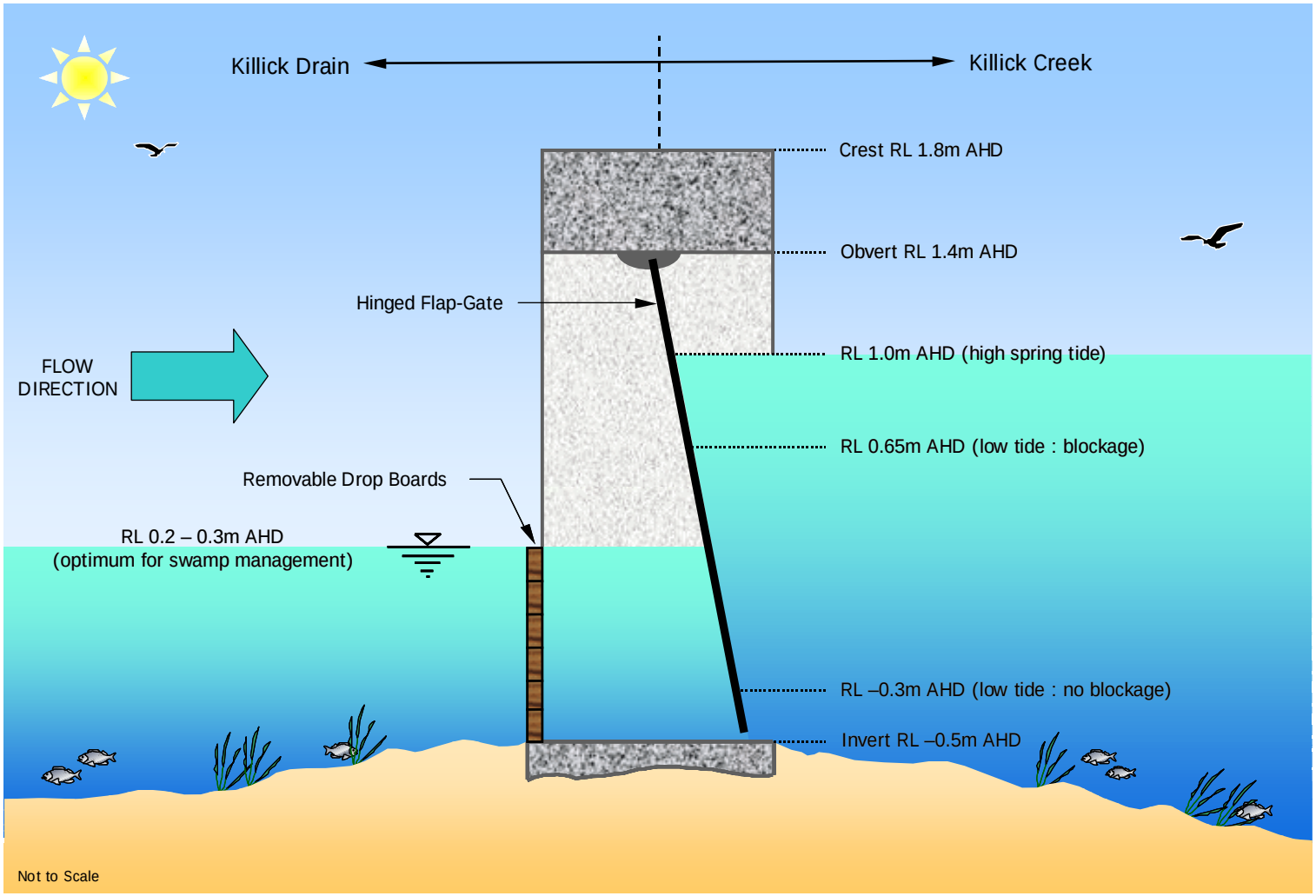


Figure 2-2 Schematic representation of Killick Creek floodgates

2.3 Current Environmental Condition of the Creek

2.3.1 Tidal Movement and Flushing

Killick Creek is well flushed in the lower reaches due to a large tidal range and small total volume of the estuary (ie there is a high exchange ratio). The volume of the estuary is approximately 95 ML, which is comparable to the spring and neap tide prisms.

In the upper reaches, tidal flushing is poor due to greater depths and lower tidal velocities. As a consequence, the upper reaches are susceptible to persistent vertical stratification (ie water separates from top to bottom, with poor water quality on the bottom).

2.3.2 Impacts of Flooding

Major rainfall and/or flooding events in the Upper Belmore / Connection Creek area can result in significant discharges to Killick Creek, which can potentially replace all resident waters within the estuary in a matter of hours. Sustained freshwater runoff during post-flood times can remain at the surface of the creek (due to the density differential between salt and freshwater) forming distinct stratification, which would inhibit the effective tidal flushing of the estuary.

Discharges from the agricultural drains would also introduce sediment and organic loads, which are discussed further below.

2.3.3 Water Quality

The major pollutant inputs to Killick Creek are from the agricultural drains (upstream of the floodgates) and from urban runoff (stormwater) drains. MHL (2002) states that during major regional flood events between 100,000 and 5,000,000 m^3/day of water can discharge into Killick Creek from the Belmore Swamp area, while the local catchment runoff would contribute up to 5,000 m^3/day. These compare to the tidal exchange of the estuary, which was estimated to be approximately 40,000m^3/day (MHL, 2002). The agricultural drains introduce freshwater to the estuary that has low oxygen and low pH levels, as well as high levels of organics and silts. The urban runoff drains contain high levels of nutrients (nitrogen and phosphorus), bacteria / pathogens, and litter. Water quality data suggests that Killick Creek can suffer from low dissolved oxygen, high chlorophyll-a, high phosphorus and high faecal coliforms.

There are a large number of stormwater drains discharging into Killick Creek, particularly along the Caravan Park foreshore, which drain the Crescent Head urban area. Existing bacterial monitoring carried out in the entrance channel of Killick Creek suggests that the creek is mostly in compliance with standard guideline levels. Given the very high recreational use of the entrance channel, especially during the summer holiday period, water quality within the creek, including base flow discharges from the drains, needs to be very good to avoid health problems for bathers.

Sewage from the township of Crescent Head is treated at a wastewater facility located adjacent to Muddy Arm, before being discharged to the ocean at Little Nobby's Headland. Design overflows (eg at pump stations) within the reticulated sewerage system are directed to the estuary. Runoff from

isolated rural on-site sewerage systems located around Killick Creek may also represent a potential source of nutrients and bacteria to the estuary.

It has also been reported that water quality within Killick Creek can be affected by marine macroalgae (including 'red weed' and 'cornflake weed'). If large amounts of marine macroalgae become trapped within the estuary, it will impart a significant oxygen demand on the waterway when it settles and breaks down. UNE (1992) conclude, however, that flood events would be more responsible for poor water quality and fish kills in Killick Creek due to the mixing of decomposing bottom sediments and the associated demand that this places on dissolved oxygen.

2.3.4 Sediments and Acid Sulfate Soils

The sediments of Killick Creek are mostly fine sands, and reflect its coastal nature and Late Quaternary geomorphic evolution. Marine sediments have migrated into the estuary as far as Muddy Arm. It is expected that the marine tide delta has expanded inside the estuary following the entrance works in the 1950s, which essentially provided the estuary with a permanently open entrance. The flood tide delta has expanded to the point whereby it can now completely close the creek entrance. Entrance closure has been relatively frequent over the past 2 years – a condition that has been unprecedented for more than 50 years. The flood tide expansion over the past 30 – 50 years has been witnessed first hand by many community members, and has prompted concerns regarding flushing and flood evacuation. A hydrosurvey of Killick Creek was carried out in July 2001 by the then DLWC (refer Appendix D). It is considered that this hydrosurvey may reflect post-flood conditions, as major floods occurred in March 2001, and that the present-day shoaled condition would be different to that presented in Appendix D.

In the early years after entrance training and dredging works, the accumulation of marine sands within the entrance were easily removed by periodic flood events, including major events in the early and mid 1970s. Since that time, there has been a dearth of major floods, which has allowed substantial deposition of marine sediment within the entrance channel to the point that flood events can no longer remove substantial amounts of sediment from the entrance. Existing sedimentation in the entrance channel (up to Muddy Arm) is expected to form a significant constriction to the evacuation of flood waters from the estuary during major Lower Macleay River flood events.

Artificial deepening of the upper reaches of Killick Creek has allowed the creek to infill with fine sediments washed off the catchment. Sediment washing off the catchment (particularly from the swampy areas) is often high in organic content, and as a result, many sections of the creek now contain a black oozy bed (particularly in the upper backwater reaches where tidal velocities and flushing is low). The black ooze acts as a large store of nutrients (which are recycled back into the water column under certain environmental conditions), and can produce unpleasant odours when exposed to the air.

The Belmore Swamp and Upper Maria River – Connection Creek areas have been identified as Priority Acid Sulfate Soils 'hot spots'. Drainage of runoff from these areas into Killick Creek can potentially introduce an acid load to the estuary, resulting in lower pH, and associated consequences to estuarine vegetation and wildlife.

2.3.5 Ecological Processes

There has been a number of fish kills in Killick Creek, both upstream and downstream of the Killick floodgates. The fish kills are likely to have been due to a combination of anoxia (lack of oxygen in the water), acid sulfate soils (ASS) runoff (resulting in too low pH levels), and metals toxicity. Anoxia in the creek can result from the decay of organic matter deposited in the estuary from agricultural runoff, and/or the breakdown of marine algae and other organics washed into the estuary through the entrance. It is expected that the fish kills in Killick Creek are accompanied by sub-lethal impacts on the benthic biota.

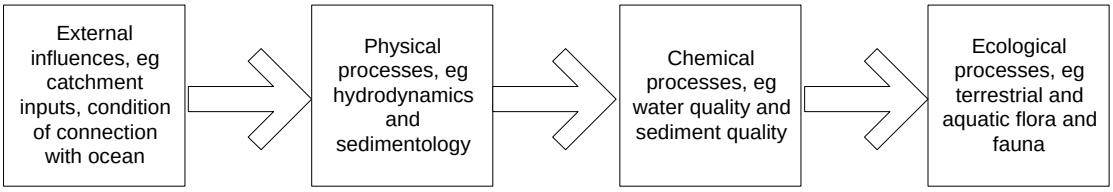
Over the past 50 years, the ecology of Killick Creek has become more marinised due to permanently open entrance and higher salt content of the water. This has included a significant increase in the number of mangroves in the estuary, and a greater diversity and abundance of fish. The increased biodiversity does not mean it has improved the system, it has just altered its ecological balance. The ecology of Killick Creek is influenced by many factors, including the condition of the entrance, flooding, operation of the floodgates, recruitment and spawning patterns and seasonal processes.

The ecological health of Killick Creek is likely to be quite variable through time, influenced by a range of persistent, on-going factors, such as the constant flushing and internal cycling of organics and nutrients, as well as intermittent, episodic factors, such as agricultural runoff, flooding and urban runoff. Periodic fish kills within the creek suggest that the system suffers occasional anoxia (deficit of oxygen) as organic inputs to the creek exceed the capacity of the environment to break down and assimilate the organic load (particularly following episodic inputs of organic-rich floodwaters).

2.4 Interactions between the processes

The physical, chemical and biological processes of estuarine environments, such as Killick Creek, are highly inter-related. For example physical processes influence chemical behaviour, chemical processes influencing biological behaviour and so on. External impacts on the system include Catchment Inputs and Entrance Conditions, which primarily influence higher order physical processes within the estuary. These two factors, more than any other, tend to control the overall environmental condition of the estuary and the habitats that it supports.

In simple terms, the external processes influence the physical hydraulic processes, which in turn influence the chemical responses, which in turn, define the ecological structure of the system (see below).



Based on this structure, the net result of changes to higher order processes (i.e. inputs to the system) is a change to the ecological structure and communities supported by the estuary. Changes also manifest in other processes, such as hydrodynamics, sediments and water quality, in response to the

change in inputs, however, these can be considered as intermediate links between the inputs and the resultant natural ecology.

2.4.1 Major Externalities Influencing Estuary Condition

2.4.1.1 Catchment Inputs

The local catchment of Killick Creek is relatively small (~ 5km^2). With the exception of the urban area of Crescent Head, the runoff from the local catchment would play a relatively insignificant role in the environmental processes occurring within the estuary. The major inputs to the system that would influence and largely control the whole environmental condition of the system would be the runoff from the Crescent Head urban area (mostly in respect to the downstream reaches and after runoff events), and the drainage of agricultural lands within the Upper Belmore Swamp area.

Whilst most inputs to the system would occur episodically, the influence of these events on the condition of the estuary can persist long after the episodic event, as the system slowly adjusts to the new material deposited within the estuary (sediments and organics) and the material slowly breaks down (thus consuming oxygen and releasing nutrients).

2.4.1.2 Entrance Conditions

The entrances of estuaries control the effectiveness of tidal exchange between the estuary and the ocean. Prior to training of the Killick Creek entrance, it is likely that the estuary was periodically closed to the ocean. By having a permanently open entrance, the response of the system to the catchment inputs has changed.

The mostly open entrance of Killick Creek allows relatively effective flushing and exchange by oceanic waters (particularly in the lower reaches closest to the entrance). However, the open entrance also permits inputs from the ocean in the form of nutrient-rich waters (which can lead to algae blooms) and/or inputs of marine seaweed and algae (which can get trapped in the estuary before breaking down and imparting a significant oxygen demand on the system).

Entrance conditions are also important in defining the recruitment of marine life into the estuary, as well as influencing the vegetation of the estuary and its surrounds.

In recent years, the entrance has reverted back to a predominantly heavily shoaled / closed conditions, which if permitted to persist, will once again change hydrodynamics, water quality and ecological processes.

2.4.2 Human Impacts on the Estuary

It is considered that the existing environmental structure and ecological function of Killick Creek has been significantly impacted by human activities within and surrounding the estuary since European settlement of the area. Human impacts are prevalent throughout the estuary, including changes to the physical shape and structure of the estuary, to changes in the water and sediment chemistry, to changes in the vegetation and fauna communities (including episodic mortality of fauna through inputs exacerbated by human activities).

With respect to the interaction between processes, human impacts have occurred at the highest processes level, which has triggered follow-on effects to all other environmental processes occurring within the estuary, including hydrodynamics, water quality, sedimentation and ecology.

2.5 Management Recommendations based on Processes Understanding

A series of further studies were recommended by MHL (2002) in order to fill knowledge gaps regarding several environmental processes of Killick Creek. These further studies include:

- Hydraulic / Flood modelling study to assess the options for removing Killick Creek from the Macleay Flood Mitigation Scheme.
- Land management assessment for the marginal agricultural lands in the Upper Belmore River area, particularly in light of sea level rise and climate change. The land management assessment should also consider the urban inputs to Killick Creek (from Crescent Head) to assess their contributions to the system in terms of flow and water quality.
- Periodic detailed entrance surveys, and immediately following flood and storm events.
- Detailed surveys of flora and fauna along the foreshores, as well as an investigation of the impacts of red algae on water quality and odour.
- Continuous water quality monitoring at a number of representative sites around the estuary, as well as short-term specific studies looking at denitrification efficiency of the sediments and nutrient inflows to the creek and internal cycling of nutrients during normal, wet and dry conditions.

It is clear that the focus for future management should be on addressing catchment management inputs. It could be argued that entrance conditions could be modified further to also improve the condition of the estuary, however, experience has shown that any modifications to the physical structure of estuaries has both positive and negative effects (some which may not manifest for some time, particularly given the longer timescales for many processes, such as sediment accumulation).

Future catchment-based management works should target a significant reduction in pollutant loads in the first instance. Alternatively, a reduction in catchment runoff volumes could also be targeted, particularly in respect to the agricultural drainage from the Upper Belmore Swamp / Connection Creek area as this is runoff from beyond the natural catchment area of the estuary.

While it is acknowledged that the system cannot be returned to its natural state, there are significant opportunities where the activities and uses of the estuary could be better managed in order to minimise the degrading effects of human activities on this once-pristine waterway.