Managing morphological changes through urban planning

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ABSTRACT

Tallebudgera Creek is a wave-dominated estuary on the Eastern Coast of Australia. Offshore wave condition is a key parameter, which controls morphological changes at the entrance of this creek. Numerical modeling shows that under dominant southeasterly wave condition significant mouth infilling can happen. This can result in full blockage of the creek mouth (over a few years period), partial blockage (over a year period) or sudden blockage during cyclonic events. Full or partial blockage of the creek mouth can have substantial impact on flood risk on heavily populated Tallebudgera Creek floodplain. Another consequent of such blockage is degradation of water quality of the Tallebudgera estuary. Currently an annual costly dredging program is undertaken to mitigate the flood risk by keeping the creek mouth open. This study investigates the feasibility of an alternative approach to dredging for keeping the creek mouth open. This approach focuses on increasing the tidal forces of the estuary. An increase in tidal prism is expected to increase flow velocity at the mouth of the creek and therefore flushing the deposited sand into the ocean. The increase in tidal prism can be achieved through town planning (effective connection of the existing lake system within the study area to the main river, developing new recreational lakes or building new canal estates in the basin of the creek).

1. INTRODUCTION

It has long been understood that Tallebudgera tidal inlet act as a significant depositional sinks for littoral sediments moving along the coast resulting in partial or (in the absence of a dredging program) occasional full blockage of the entrance. Hydrodynamic of this estuary in the context of flooding has already been studied (Mirfeneresk 2001). A more recent study (Frachisse, Castelie 2006) investigated the flooding impact as a result of creek mouth blockage. This paper examines the possibility of having the depositions at the Creek mouth flashed into the ocean by artificially increasing tidal forces. To this end the study looks into enhancing tidal forces by controlled increase of tidal prism of the estuary.

Tallebudgera Creek Estuary is located in the southeast corner of Queensland, Australia ($153.43^0 E, 28.13^0 S$), figure 1. It drains runoffs from the Tallebudgera Creek catchment into the Pacific Ocean at Burleigh Heads. Tallebudgera Creek rises near Springbrook and flows in a generally northeasterly direction. Its catchment is elongated and narrow with an approximate length of 22 km. The catchments area is approximately 98 square km. The mouth of Tallebudgera Creek is stabilized to some extent by a rock groyne on the southern side of the mouth. This groyne is expected to some degree to trap northbound littoral drifts. It may also reduce the likelihood of the blockage of the creek mouth in the course of cyclonic storms, which usually coincide with floods. Hydrodynamic parameters at a number of stations along the Tallebudgera Creek are measured; the location of stations and their distances from the river mouth are shown in Table 1 and Figure 1.

Station No.	Name	Distance From Creek Mouth km
1	Saffron Street	7.5
2	Tallebudgera Connection Road	10

Table 1 Measurement stations

Figure 1- Layout of the study area.

2. Methodology

This study contains the following steps:

1) Collection of water level, salinity and temperature data for the study area. This data set provides an insight into the hydrodynamic behavior of the Tallebudgera Creek. A quantitative description of this behavior is presented by identifying the major tidal constituents of the tidal signal in the estuary.
2) Development of a hydrodynamic model for more detailed investigation of hydrodynamic behavior of the study area.
3) Calibration of the hydrodynamic model using the collected data.
4) Testing a number of scenarios to assess the impact of increasing tidal prism on the creek.

3. DATA ACQUISITION

Two CTD350 Greenspan gauges were used to measure absolute pressure, conductivity and temperature at two stations along the creek (as shown in table 1). Recording time interval for the gauges was set to 15 minutes with an averaging interval of 10 seconds (to minimize the impact of ripples, wind generated waves, localized boat wash, etc.). The sensor sampled the water level at a rate of 1 sample per 2 seconds. The tidal gauge at station 1 was installed on the pier of a pontoon and the one at station 2 was installed on one of the piers of the Tallebudgera Connection Road Bridge. The data record span for both stations were 35 days; providing an adequate time period for resolving the primary tidal constituents at each site. Since these gauges measure absolute pressure, the water pressure readings were corrected for variations in atmospheric pressure, once the data was downloaded from each gauge. Data obtained from the Bureau of Meteorology (BOM) station at the vicinity of the study area was used to make atmospheric pressure corrections. Conductivity and temperature data was collected simultaneously with water level measurements.

These data were used to correct the impacts of salinity and temperature on measured pressure. To this end, first conductivity data were converted to salinity using the UNESCO practical Salinity Scale and then density of water was calculated based on the calculated salinity and the measured temperature. Measurements show that density variations within the water column were minor at all station sites during normal conditions. This situation can be attributed to the strong mixing processes at the measurement sites. On this basis density variation inside the water column was not applied to the readings. To adjust measured water level to a known vertical datum, the tidal gauges were surveyed relative to benchmarks. The result from each gauge is a time series representing the variations in water surface elevation relative to the Australian Height Datum. Australian Height Datum is a standard vertical reference representing mean sea level in the region.

Figures 2 and 3 depicts time series of water level variations at stations 1 and 2 during an arbitrary 10-day period. Solid lines in these figures indicate field data and dots represent model results. To quantify the tidal characteristics of the study area a frequency domain analysis is carried out for measured tidal time series. The purpose of tidal analysis is to determine the amplitude and phase (tidal harmonic constants) of the individual cosine waves each of which represents a tidal constituent. Tidal harmonic analysis of water level is carried out using ISO method. Figures 4 and 5 depict amplitude for the 6 tidal constituents at the stations 1 and 2. These constituents are derived from a 35-day time series of water level variations at the measurement stations. The dominant diurnal tides are K1 and O1 constituents, with K1 having 30% more amplitude than O1. M2 is the dominant semi-diurnal constituent, with amplitude 4 times greater than either the N2 or S2 constituents.

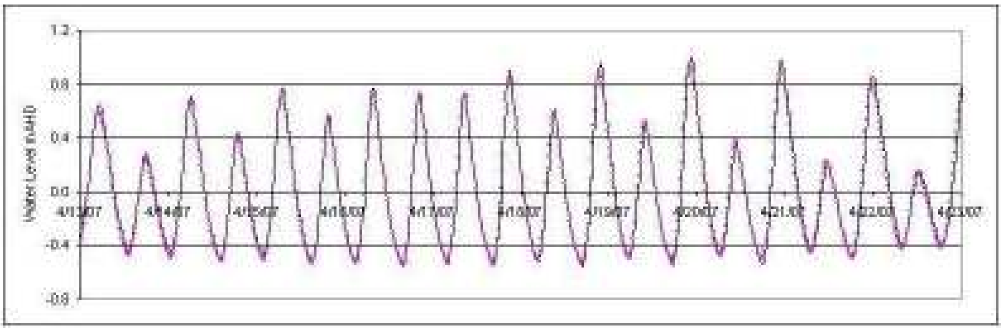

Figure 2 – Water level variation (station 1)

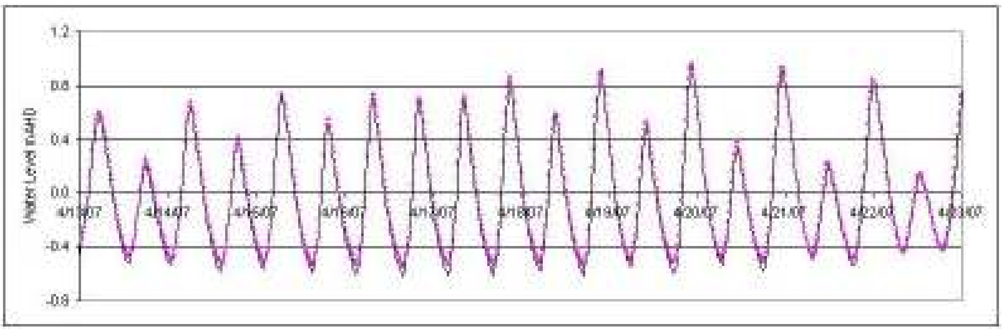

Figure 3– Water level residuals (station 2)

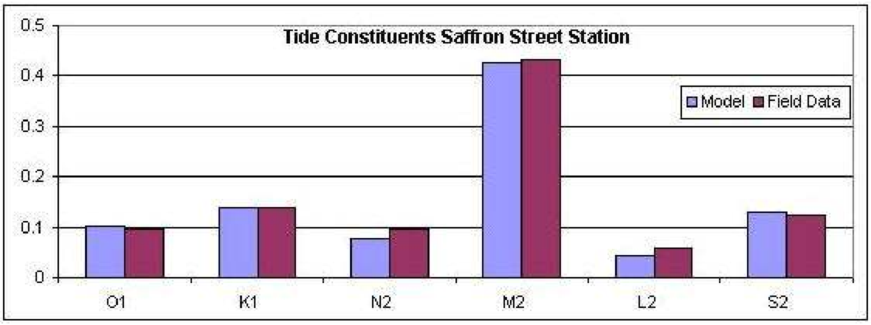

Figure 4 – Tidal level constituents (station 1)

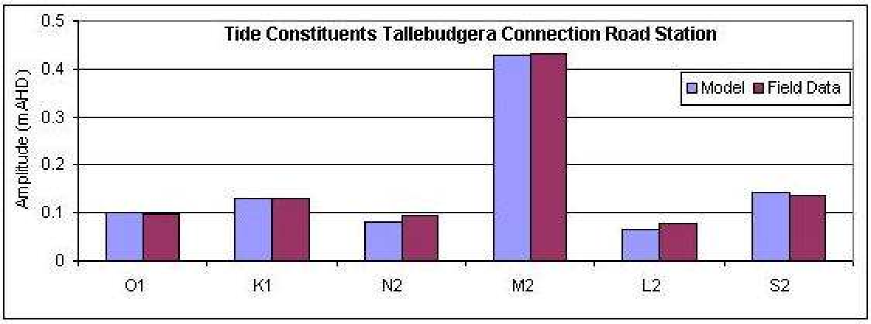

Figure 5 – Tidal level constituents (station 2)

4 NUMERICAL MODELLING

A one-dimensional numerical model (using Mike11 package, DHI, www.dhigroup.com) was developed for the simulation of tidal flow within the Tallebudger Creek Estuary. Fresh water inflow into the estuary is insignificant for the most part of the year and due to strong mixing processes, the estuary remains well mixed for the most part of the year. Random salinity measurement within the study area confirms this. On this basis the numerical modelling for this study is based on a barotropic condition assumption. Bottom friction is modelled using Manning's coefficient. The model is fully dynamic and is driven by tide. The model is initially run for a few days to establish the tidal momentum within the estuary prior to the calibration. Model was run using the recorded water level variations at the mouth of the Estuary. Calibration was achieved by adjusting the Manning 'n' for different sections of the model. To this end the model was run for a number of different values of Mannings 'n'. The best correlation of the model and the recorded data was obtained using a combination of manning coefficient between 0.025 and 0.035 for tidal reaches of the estuary. A constant value of Mannings 'n' was adopted for each cross-section. This was considered acceptable due to the homogenous nature of cross sections. Tidal water level, measured simultaneously for a period of 35 days, at two stations within the study area is used for calibration of the model. A comparison between the results from the calibrated model and the measured water level is shown in figures 2 and 3. This result shows that the model simulates water level variations satisfactorily.

5. Scenario Testing

Three various scenarios were tested to examine the effectiveness of suggested methodology. In these scenarios it was assumed that 20, 30 and 40 hectares of additional lakes or canals will be developed within the floodplain (or alternatively some of the exiting lakes would be fully connected to the main river). Figure 6 shows the additional (indicative) bed shear stress associated with these scenarios at 4 different locations along the estuary (at the mouth, 2, 4 and 6 km upstream of the mouth). It can be seen that in all locations bed shear stress increases and the highest rate of rise is associated with 20 hectare extra lakes and Canal.

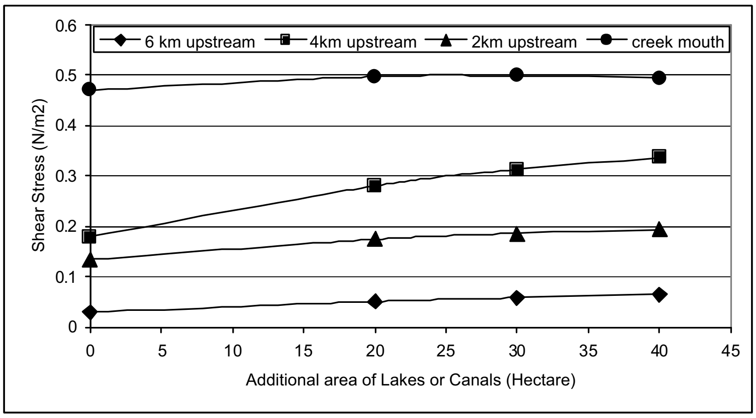

Figure 6 – Bed shear stress variations at various locations along the creek as a result of tidal prism increase.

6. Tidal Regime

Tidal characteristics at Tallebudgera Estuary is identified as mixed predominantly semi diurnal using the form number as defined by Pugh (1987):

$$N = \frac{O1 + K1}{M2 + S2} \tag{1}$$

Form number for Tallebudgera Estuary is approximately 0.4. A form number between 0.25 and 1.5 is regarded as mixed semidiurnal regime.

7. Tidal Asymmetry

Tidal asymmetry and the resulting flood or ebb dominance play an important role in the sediment transport. Since sediment transport is proportional to the flow velocity above threshold to some power, the higher flood or ebb velocities can result in a net (coarse) sediment transport into or out of the estuary. Aubrey and Speer (1985) showed that whether an estuary is flood dominant or ebb dominant depends on the phase difference;

$$2\theta_{M_2} - \theta_{M_4} \tag{2}$$

where θ is the phase of tidal height. Expression 2 refer to the phase difference of M2 and M4 components of tidal height. A 90^0 phase difference of tidal height means shorter flood duration (compared with ebb duration). This results in a higher flood current velocity and consequently a flood dominant situation. A 270^0 phase difference of tidal hight means longer flood duration, which can result in higher ebb current velocity than flood current velocity. Aubrey and Speer (1985) and Friedrichs and Aubrey (1988) conducted theoretical and fieldwork on tidal asymmetry for estuaries with semi-diurnal tidal regime.

Based on their study, under a semi-diurnal regime, an estuary has Flood-dominant current when $0^0 \langle 2\theta_{M_2} - \theta_{M_4} \langle\ 180^0$ and ebb-dominant current when $180^0 \langle 2\theta_{M_2} - \theta_{M_4} \langle\ 360^0$. Tidal regime at the Tallebudgera Estuary is predominantly semidiurnal with the values of the expressions 2 to be between 51^0 and 54^0, indicating a flood dominant tidal asymmetry throughout the Tallebudgera Creek.

8. SUMMARY AND CONCLUSIONS

This study presents analysis of the data collected for the Tallebudgera Creek. A calibrated hydrodynamic model for the estuary is developed and is used to further analyze tidal behavior at the estuary. Tidal analysis shows that in Tallebudgera Creek, tidal regime is semi-diurnal and flood dominant. The idea of flushing depositions at the mouth of the creek by increasing tidal forces is partly examined. In this stage, tidal force is enhanced by assuming that more recreational lakes or canal estates will be developed within the Tallebudgera floodplain. This can alternatively be achieved by more effective connection of exiting lakes within the study area to the main river. Preliminary results show that this method results in an increase in bed shear stress and potentially moving more sands out of the estuary. There is a need for a more comprehensive model that links coastal process to estuarine processes to fully examine the effectiveness of this method. It should be noted that enhancing tidal dominance in the estuary could result in adverse impacts on bank stability along the creek. This issue needs more investigation at the next stage of the study.

9. ACKNOWLEDGEMENT

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