The Importance of Accurate Prediction of Tidal-Induced Water Level Variations in Small Tidal Inlets

Saeed Shaeri[1], Rodger B. Tomlinson[1], Amir Etemad-Shahidi[2], Darrell Strauss[1]
[1] Griffith Centre for Coastal Management, Griffith University, Gold Coast Campus, QLD 4222
[2] School of Engineering, Griffith University, Gold Coast Campus, QLD 4222

Introduction

Tidal inlets are a very important feature of coastal areas. The periodic exchange of water between the ocean and the back barrier water body has a number of advantages. This includes the provision of fresh nutrients from the ocean for all the inhabitants of the back barrier. Moreover, the inlet acts to connect the inland-side port, harbour or privately-owned small jetties to the open ocean. Therefore knowing about the navigational condition of these waterways is an essential requirement for making a safe and pleasant voyage.

For medium to large and populated tidal inlets, the establishment of safety conditions are normally not a complicated task; although mostly, they need a well-financed budget. However, for small inlets, where the benefits are not immediately clear, local authorities are unwilling to expend effort to maintain full safety of the area. Instead, to reduce the lump sum cost, some aspects are disregarded, even though they are still important for particular stakeholders of the inlet.

Tidal inlets are openings at the coast and their existence is mainly governed by tidal forces. By this definition, knowing about tidal variations, cycles and currents are important for stakeholders of the inlet. However, due to lack of finance, presenting accurate information about tidal exchange is often ignored. Although there are tidal predictions based on regional or global information that local geographical effects still play a major role in accurate tidal predictions (Thurman, 1994).

In this research, a comparison between predictions of a tidal table and actual tidal recordings is presented. The study also aims to investigate the likelihood of incorrect predictions of tides for a secondary port based on parameters of a major port. These predictions are tested for Currumbin Creek tidal inlet by measuring tidal changes and comparing them with tidal data for the nearby main/standard station. It is concluded that a comparatively low correlation exists between the actual and predicted data of a standard port in comparison to data collected for a secondary port. Moreover, derivation of tidal parameter for the secondary port, using a time lag and water level difference to a main port is strictly influenced by individual geographical characteristics of a particular region.

Study Area

The City of Gold Coast is situated in south-east Queensland, Australia (Figure 1- top left). This city is a very popular regional tourist destination. There are a number of tidal inlets and waterways which are great assets for the city. However, as with many other regions, there are limited tidal recording stations, which implies reliance on further predictions for the secondary ports based on prediction of a nearby main port. In fact, there is only one tidal recording station for Gold Coast which is at the Southport Marine Operation Base (MOB) (Figure 1- right) and managed by the Bureau of Meteorology (BOM). Therefore, this site is regarded as the main port for prediction of all secondary ports or locations of all Gold Coast waterways and creeks (published in tide tables). However, this station is situated in a protected location inside the Broadwater area, which is actually an inland water body into which the Nerang River discharges and then flows out to the Pacific Ocean through two inlets, the Gold Coast Seaway and Jumpinpin.

Data Collection

The required data for this research are obtained from two locations: the Southport Marine Operation Base (MOB) (Figure 1- right) and Currumbin Creek (Figure 1- bottom-left). The

Southport MOB station offers two separate datasets: 1) the daily extremes of predicted tides (BOM, 2013) and 2) the 10 minute actual recording of water levels (MSQ, 2013). The data for Currumbin Creek was also obtained from an extensive project dealing with the investigation of the Currumbin Creek tidal inlet geomorphological evolution (Shaeri et.al, 2013a, 2013b). To facilitate a more accurate evaluation of the tidal propagation along the creek, there were three different stations named Upstream, VMR and Lagoon. The upstream station was situated almost 3.4 km from the inlet entrance. The VMR station (in front of the Currumbin Volunteer Marine Rescue (VMR) office) was located 1.4 km from the entrance and the Lagoon station was placed 0.3 km on the inland side of the inlet entrance.

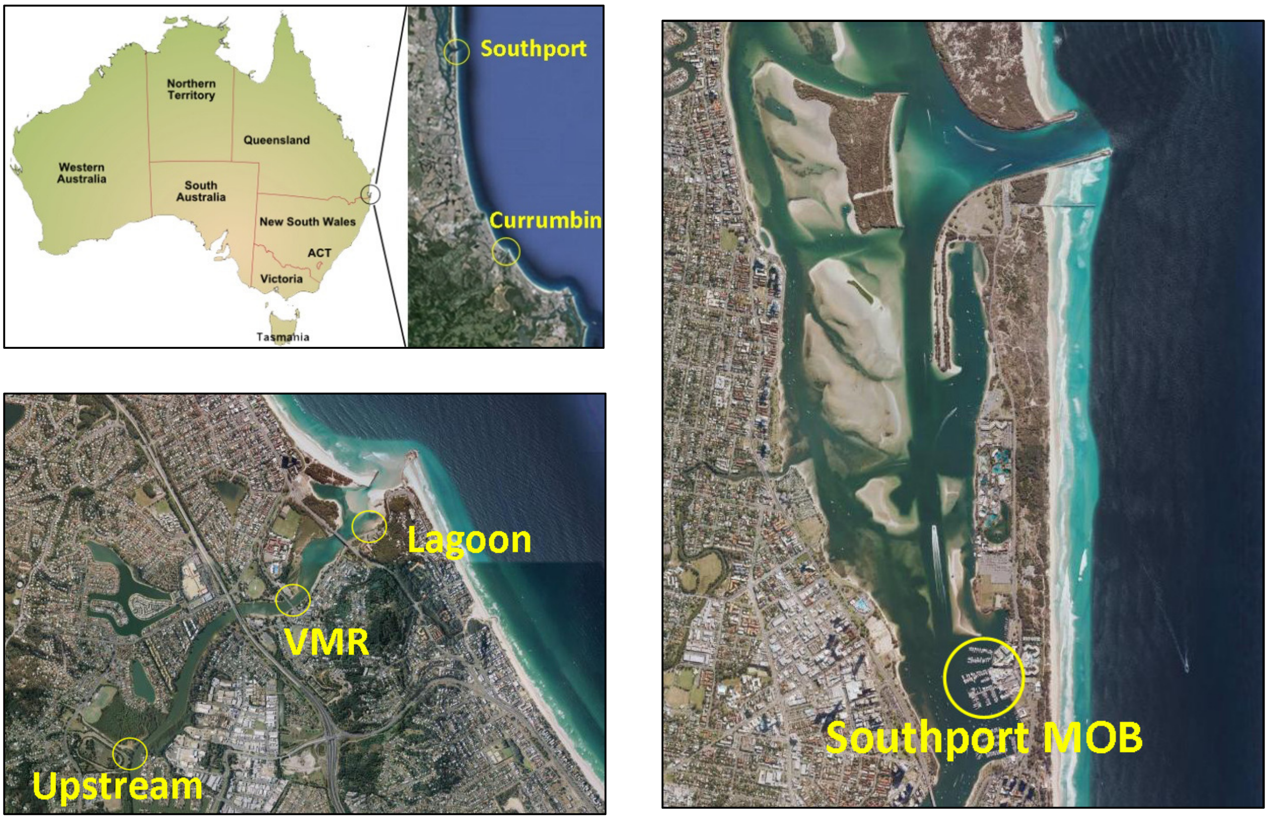


Figure 1 – Regional aerial photos (top-left), Southport MOB station (right) and Currumbin Creek (bottom-left)

For the purpose of a better comparison and a detailed analysis, a part of the Southport MOB datasets was chosen for 18 months from January 2012 to July 2013. While a period of 18.6 years is considered necessary for an accurate representation of all possible tidal variations of a particular place (Pugh, 1987, Marchuk et.al, 1989), in view of the constraints on this research, only 18 months duration was selected. The recordings of Currumbin Creek have also been collected by RBR's submersible data loggers during a 6 week period. The Upstream station contains 3 weeks of data in April, the Lagoon station contains 3 weeks of data in May and the VMR data contains the entire 6 weeks from April to May.

Data Analysis

Southport MOB Tide Table predictions and actual recordings

Comparison of the predicted and recorded data for the Southport MOB station reveals the following. In terms of average, maximum and minimum values, in general, during the 1.5 years period the tide table predicted levels, are always about 5-10% less than the actual recordings (Table 1 and Figure 2). Such differences are not a fixed shift of levels for this dataset, as is also evident when comparing the yearly and monthly statistics (Table 2). There is range of about -4.1% to 16.1% differences in levels for the yearly/monthly predicted levels in comparison to the recordings. Moreover, considering the regional wet season (which is mainly from Dec. to Mar.), there is no distinct relationship or meaningful difference between the predicted and recorded figures (despite the extra water from the rainfall discharge).

Apart from the water level, the tidal cycle of predictions and recordings are also comparable (Figure 3). For simplicity, only the cycle of HHW (daily highest high-water) levels are shown here. In general there is no evident similarity between the predictions and actual tidal cycles. Moreover, as the recording is bound to 10 minute intervals, the derived tidal cycles (from the recordings) look more categorised than randomly distributed. The other important finding (Figure 3-right) is that the range of tidal cycle variation of the predicted data (25.50-24.75=0.75 hrs) is about 62% narrower than the recorded data (26.0-24.0=2.0 hrs) and it also lies within the range of recorded cycles.

It can also be inferred from the histogram in Figure 3-right that tidal table prediction cycles for the HHW level begin from 24.75 hrs and the majority of them (47%) are between 24.75 and 25 hrs. However, the cycles for the HHW recordings have a bell shaped distribution between 24 and 26 hrs with 25 hrs as the most probable (26%) cycle.

Table 1 – Comparison of general statistical parameters of the tidal table prediction and tidal recordings of the Southport MOB station from Jan. 2012 to Jul. 2013 (in meters)

		Average	Max	Min	Range	Range Difference (%)
1.5 Years 2012-mid 2013	Tide Table	0.82	1.95	-0.09	2.04	5.6
	Recordings	0.90	2.16	0.00	2.15	
2012 (full)	Tide Table	0.81	1.93	-0.09	2.02	3.5
	Recordings	0.88	2.09	0.00	2.09	
2013 (half)	Tide Table	0.84	1.95	-0.02	1.97	9.3
	Recordings	0.96	2.16	0.00	2.15	

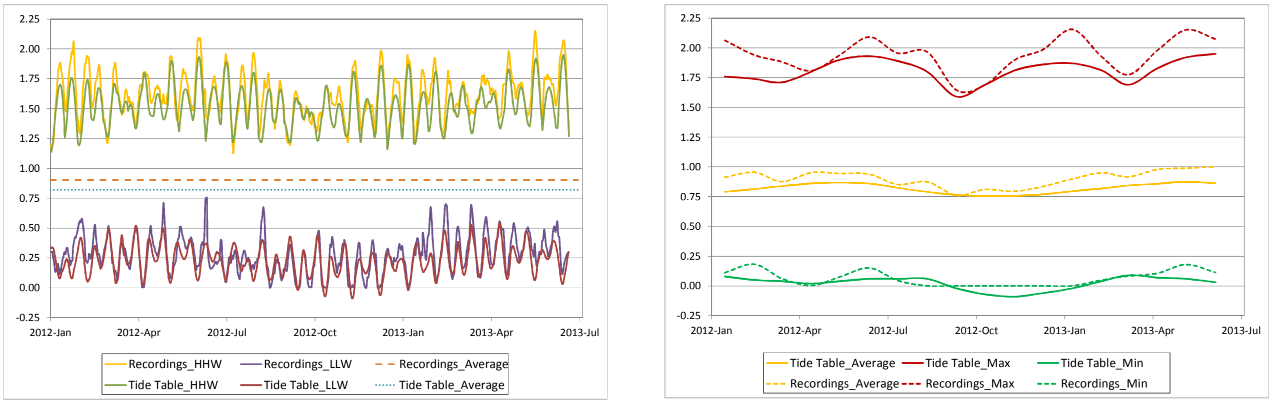


Figure 2 - Comparison between Southport (Marine Operation Base) recordings and Tide Table predictions for tidal level variation of a) daily extremes (left panel) and b) monthly extremes (right panel)

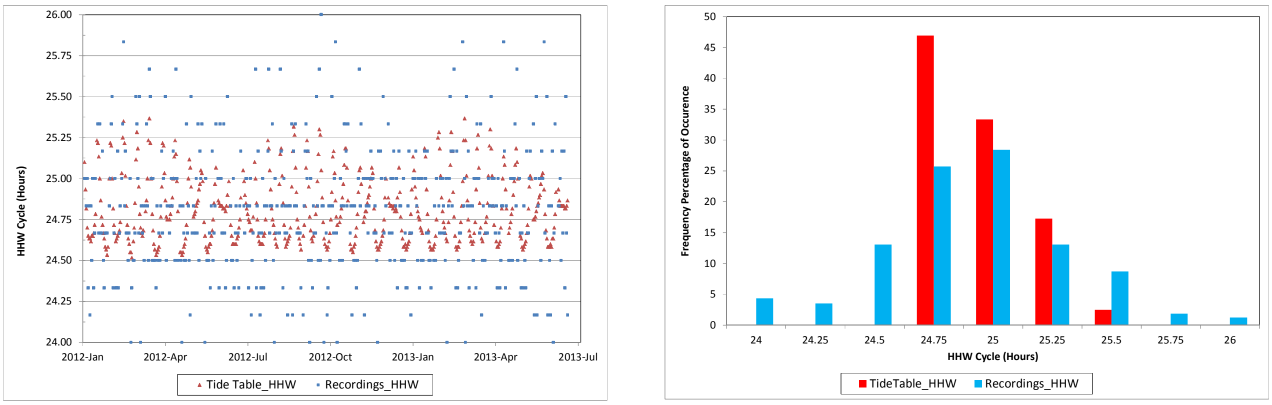


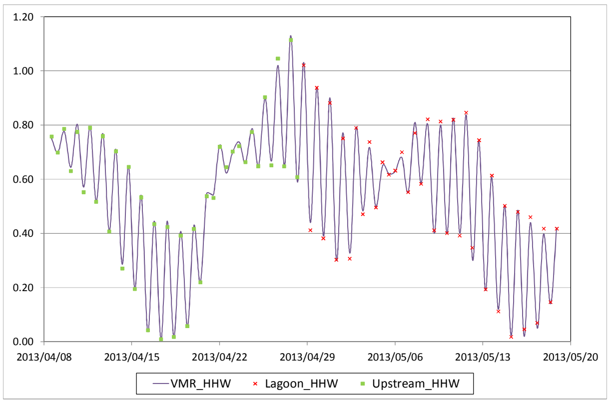
Figure 3 - Comparison between Southport (Marine Operation Base) recordings and Tide Table predictions for HHW cycle a) all data (left panel) b) categorised data by the histogram graph (right panel)

Currumbin Creek measurements

As described earlier, there were three stations along the Creek. Figure 4-left shows that HHW level records at the stations have no distinct relationship. In other words, neither the entrance geometry nor the distance of the Upstream station from the entrance has particular effects on the tidal variation of the HHW levels. Likewise, the LLW levels (Figure 4-right) are without a distinguishable correlation/relationship. There is also almost no similarity between the HHW tidal cycles (as a sample for comparison, Figure 5). All the values are greater than 24 hrs and less than 26 hrs, and the most probable duration is about 24.75 hrs for all three stations. For the Upstream and VMR stations, the histogram shows bell-shaped distributions while the Lagoon tidal cycles are more unordered. This is mainly the influence of entrance geometry on the tidal cycle.

Table 2 – Comparison of monthly statistical parameters of the tide table prediction and tidal recordings of the Southport MOB station for 2012 and 1st half of 2013 (in meters)

		Tide Table				Recordings				Range
		Average	Max	Min	Range	Average	Max	Min	Range	Difference (%)
2012	1	0.79	1.76	0.08	1.68	0.91	2.06	0.11	1.95	16.1
	2	0.81	1.74	0.05	1.69	0.95	1.94	0.18	1.76	4.0
	3	0.84	1.71	0.04	1.67	0.88	1.88	0.06	1.82	9.0
	4	0.86	1.80	0.02	1.78	0.95	1.81	0.00	1.80	1.3
	5	0.87	1.90	0.04	1.86	0.94	1.94	0.08	1.86	0.2
	6	0.86	1.93	0.06	1.87	0.94	2.09	0.15	1.94	3.7
	7	0.83	1.89	0.06	1.83	0.85	1.96	0.05	1.91	4.4
	8	0.79	1.80	0.06	1.74	0.87	1.97	0.00	1.97	13.0
	9	0.77	1.59	-0.02	1.61	0.76	1.65	0.00	1.64	2.1
	10	0.76	1.69	-0.07	1.76	0.81	1.69	0.00	1.69	(-4.1)
	11	0.76	1.81	-0.09	1.90	0.79	1.90	0.00	1.90	(-0.2)
	12	0.77	1.86	-0.06	1.92	0.84	1.99	0.00	1.98	3.3
2013	1	0.80	1.87	-0.02	1.89	0.90	2.16	0.00	2.15	14.0
	2	0.82	1.81	0.04	1.77	0.95	1.93	0.05	1.88	5.9
	3	0.84	1.69	0.09	1.60	0.92	1.77	0.08	1.69	5.7
	4	0.86	1.83	0.07	1.76	0.98	1.98	0.11	1.87	6.5
	5	0.88	1.92	0.06	1.86	0.99	2.15	0.18	1.97	6.0
	6	0.86	1.95	0.03	1.92	1.00	2.07	0.11	1.96	2.1



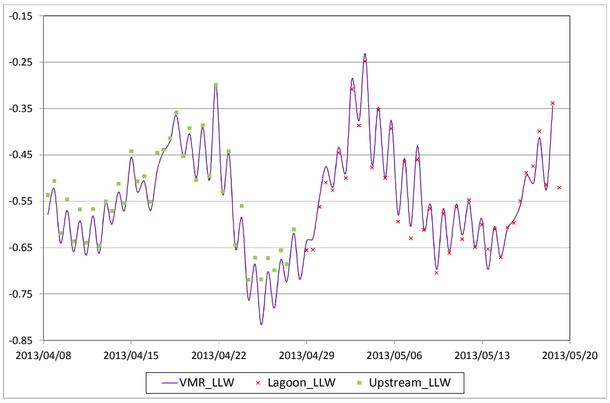


Figure 4 - Comparison between the creek's stations in regard to a) HHW levels (left panel) b) LLW levels (right panel) Ref. to LAT

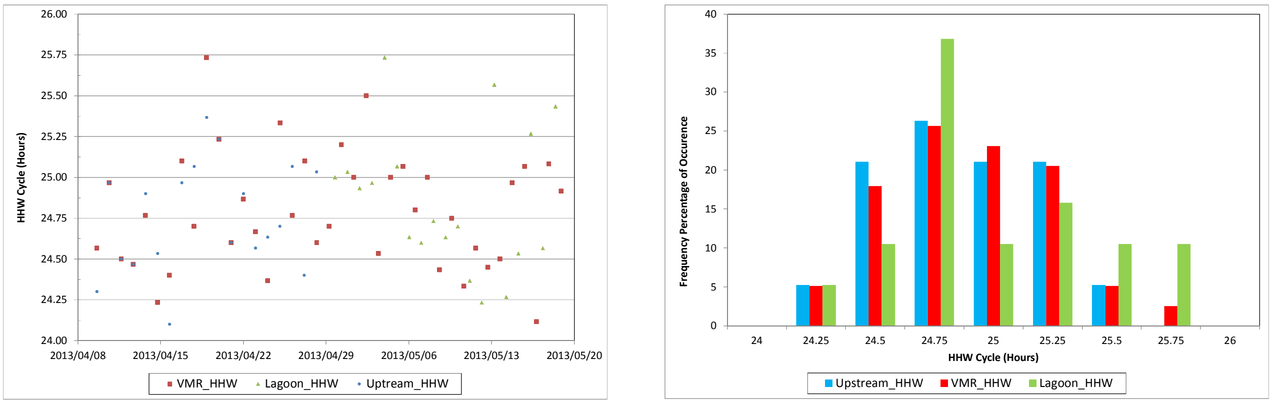


Figure 5 - Comparison of the creek stations HHW cycles for all (left panel) and categorised data (right panel)

Discussion

The extent of the difference between the predicted levels and the measured values in Southport MOB (Figure 2-left panel) suggests cautious usage of tide table values in the absence of actual recordings. Specifically when considering a 0.5m difference is critically important for designing purposes (like dredging or so forth), although it looks insignificant, it should be carefully noted. Obviously, such distinctions are apart from the abnormal water level exerted to waterways from the rainfall discharge. As the design water level is mainly based on a long-term average, the temporary effects (like rainfall) are not considered here in the final result.

While using predictions, the other important consideration, is the change in tidal cycle (Table 3). There are at least half an hour differences between the tide table's daily cycles of HHW in comparison to actual recordings. Therefore, the time of extreme daily water levels or the slack water is sometimes critical. For instance, implementation of a bathymetric survey for shallow water depth of flood shoal areas can be carried out simply at the time of slack water. However, incorrect prediction may influence the results of the survey. As seen in Figure 3-right panel, the distribution of actual tidal cycles around the average value is more symmetric than the predicted figures. It seems more reasonable to have a bell-shaped pattern rather than a skewed one. Hence, this can be another important indication that the time of extreme daily water levels or slack water should be investigated precisely.

In addition to all necessary considerations to be made before selecting the accurate parameters for a major port, transferring these parameters to secondary ports is also of high importance. It is inferred from the Figure 5-right panel that the tidal cycle of inner water bodies (like the back barrier area of the creek) is not solely related to the external forces (e.g. oceanic tidal variation) and geometrical or geographical limits can widely influence them. However, the detailed analysis of wave/wind induced currents and rainfall discharges (which may have major roles for some locations,) will need to be considered separately in further studies.

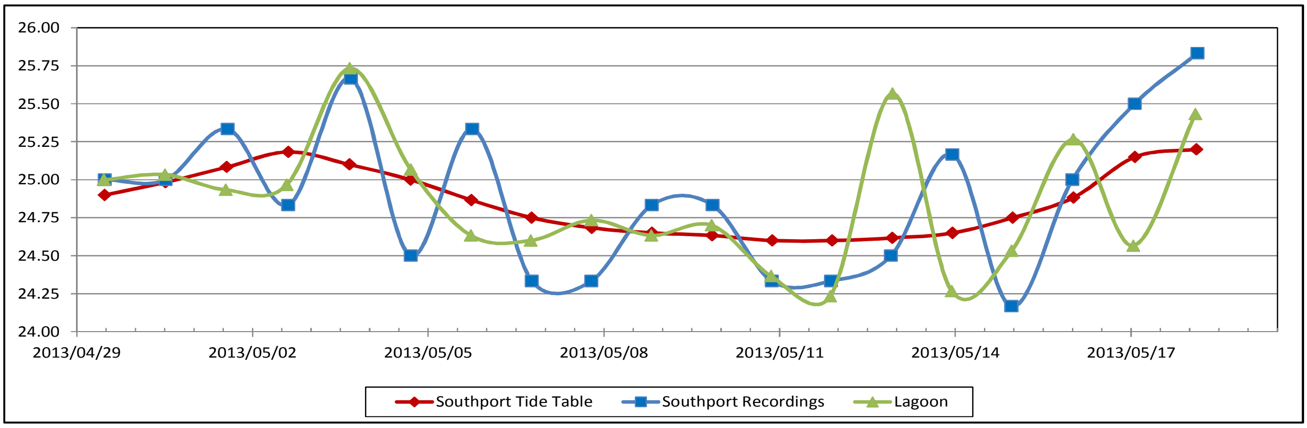


Figure 6 - Comparison of the Lagoon station, Southport recordings and Tide Table for HHW cycle (hours)

Table 3 – Time lag (minutes) between the Lagoon station daily HHW, Southport recordings and Tide Table

Date	Recordings & Tide table	Lagoon & Ttide table
2013/04/28	-2	-26
2013/04/29	4	-20
2013/05/01	5	-17
2013/05/02	20	-26
2013/05/03	-1	-39
2013/05/04	33	-1
2013/05/05	3	3
2013/05/06	31	-11
2013/05/07	6	-20
2013/05/08	-15	-17

Date	Recordings & Tide table	Lagoon & Tide table
2013/05/09	-4	-18
2013/05/10	8	-14
2013/05/11	-8	-28
2013/05/12	-24	-50
2013/05/13	-31	7
2013/05/14	0	-16
2013/05/15	-35	-29
2013/05/16	-28	-6
2013/05/17	-7	-41
2013/05/18	31	-27

Hence, the last part of these analyses relates to the selection for the time lag from the tide table charts. Based on available procedure (Semidiurnal Tidal Planes, BOM, 2013), the time lag between the extreme water levels of Currumbin Creek is recommended as 20 minutes before the Southport MOB for each cycle. This relationship is actually based on predicted parameters. However, as can be seen from Figure 6, the duration of the HHW cycle of the Southport MOB measured and predicted data does not show any consistency. These differences were explained in the previous paragraphs. However, regarding the Lagoon HHW cycle, it is inferred from the graph that its HHW cycle does not follow any of the other trends. Besides, this observation is not in accordance with the procedure used for prediction of the secondary port from the tide table. In addition, Table 3 shows that there is a range of almost an hour for the possible time lag between the Currumbin Lagoon and the Southport MOB stations.

Take Home Message

The aim of this research is to find concordance between the actual and predicted data of a main/standard port in comparison to data collected for a secondary port. The outcome of this investigation shows a comparatively low correlation. In fact, the extent of tidal water level variations are more complicated than can be easily predicted by simplified/generalized formulae. It is confirmed that the geographical features also have a significant influence on the observations. Therefore the concordance between the predicted and observed tidal cycles and levels, at the standard port is far from perfect. Particularly, for extreme levels like HHW, the predicted levels are lower than the observations and range of daily tidal cycle variations are also narrowed to certain durations. In addition, derivation of tidal parameters from a main port for a secondary port, does not always result in accurate parameters. As for the effect of local and geographical constraints, the current method which is based on using time lags and water level differences is strictly influenced by individual characteristics of a particular region. These findings are vital for the local SLSCs (Safe Life Saving Clubs) and VMRs to know about the exact time of the ebb and flood and also the actual extreme daily water levels. By using incorrect levels, any type of advice delivered to swimmers, surfers, boat users and so on, is mixed with the uncertainties, errors and possible dangers.

Acknowledgement
This research is part of complex study concerning the hydro-morphological changes of the Currumbin Creek. The data used here was collected with the support of Griffith Centre for Coastal Management (GCCM) and the Gold Coast City Council (GCCC).

References
- The Bureau of Meteorology (BOM), 2013, Commonwealth of Australia, < www.bom.gov.au/oceanography/tides/>
- Marchuk, G.I. and Kagan, B.A., 1989. Dynamics of Ocean Tides. Kluwer, Dordrecht.
- Marine Safety Queensland (MSQ), 2013, Department of Transport and Main Roads, Queensland Government. < www.msq.qld.gov.au/Tides.aspx>
- Pugh, D.T., 1987. Tides, Surges and Mean Sea-Level. Wiley, Chichester.
- Shaeri, S., Tomlinson, R.B., Etemad-Shahidi, A., Strauss, D. and Hunt, S., 2013. 'Field Measurement for Investigating the Dynamics of Currumbin Creek Entrances', Journal of Coastal Research, Special Issue No. 65, pp. 1212-1217.
- Shaeri, S., Tomlinson, R.B., Etemad-Shahidi, A., Strauss, D. and Hughes, L. P., 2013. 'Hydrodynamics of a Small Jettied Tidal Inlet, Case Study: Currumbin Creek', Proceedings of the RCEM2013 conference, Santander, Spain, 2013.
- Thurman, H.V., 1994. Introductory Oceanography, seventh edition. New York, NY: Macmillan.