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29 May 2019

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Dear Matthew,

MHL2677 – Tweed Sand Bypass Tidal Analysis 2018/19

MHL is pleased to provide this report for a tidal analysis of the Tweed River entrance for the period March 2018 – February 2019. The study consists of a tidal harmonics analysis for three locations on the Eastern Australia coastline: two in northern NSW and one on the Sunshine Coast in QLD (Figure 1). By observing long term trends in tidal response characteristics against two control sites, it can be determined if the entrance dynamics of an estuary are changing over time.

Figure 1 – Location of study area

1 Tweed Entrance Behaviour

A tidal harmonic analysis was performed on three tidal measurement datasets: Letitia 2A at the Tweed River entrance, Coffs Harbour Jetty, and Mooloolaba on the Sunshine Coast. This harmonic analysis can be used to, among other things, remove meteorological and flood events from a measured tidal signal, extracting from the noisy measurements only those components which can be described by periodic astronomical forcings. From these components, descriptive characteristics of the tidal signal at the given location can be generated and it is these characteristics which are analysed and compared over time to gain insight into whether the morphology of the entrance is changing.

Figure 2 shows the Mean Water Level behaviour over the preceding 12 months. Mean levels behave consistently between all three sites with Mooloolaba and Letitia behaving nearly identically over the period. Three anomaly events can be observed at all three sites (Figure 6) during March, April and May 2019, which result in elevated ocean levels during these months. After this period, mean levels return to normal at all three locations for the remaining 9 months.

The Spring Tidal Range is steady across the 12-month period and consistent with the previous year's analysis. The ratio of Spring Tides between sites similarly remains consistent with last year's records.

For this period of analysis, the residuals range from high of 0.17m at Letitia 2A, down to values around 0.048m with the median residuals of 0.09m for Coffs Harbour, 0.05m for Mooloolaba, and 0.12m for Letitia 2A.

Monthly rainfall at Murwillumbah is presented in Table 1. Contrasting to last year, this 12-month period was characterised by very little rain, with only two years exceeding average totals and only 2 significant events during the year in March and September. Only around 60% of the long-term yearly total fell over the recorded period and January 2019 was the driest ever recorded at that site. Therefore, the majority of anomalies recorded at Letitia were meteorological in nature (rather than floods) and were observable at the other tide locations along the coast as well.

2 Tidal Comparison

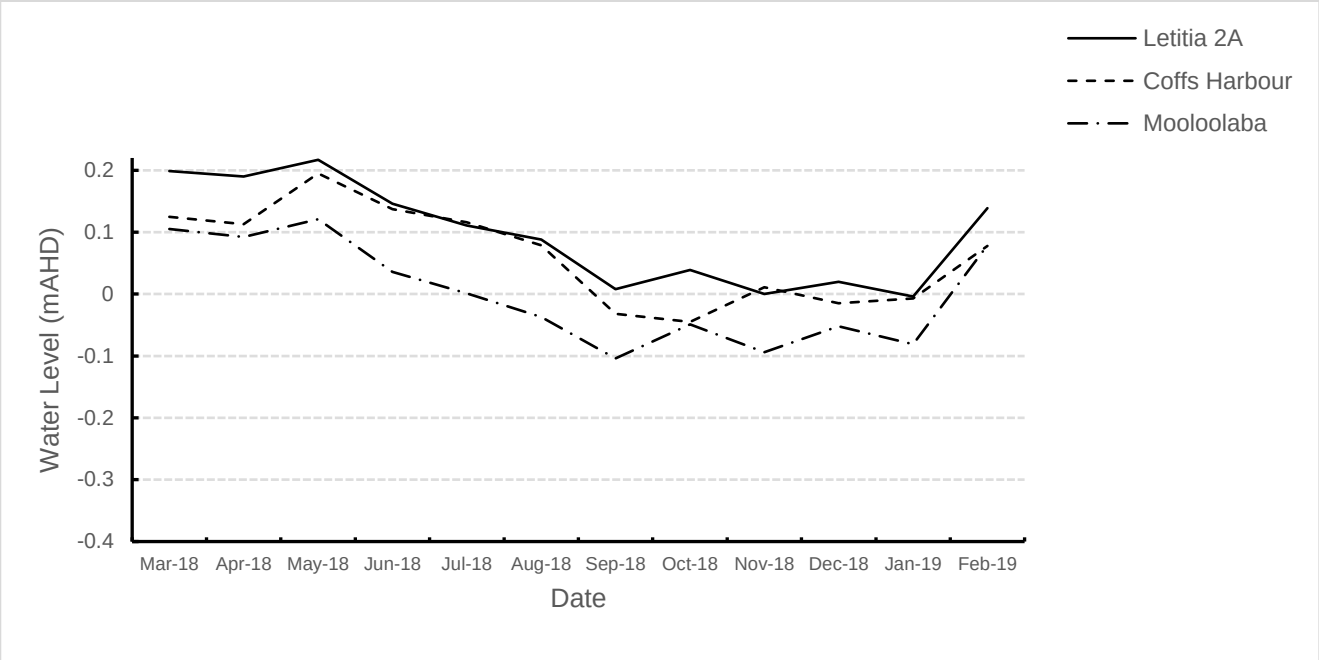


Figure 2 – Mean Water Level Comparison

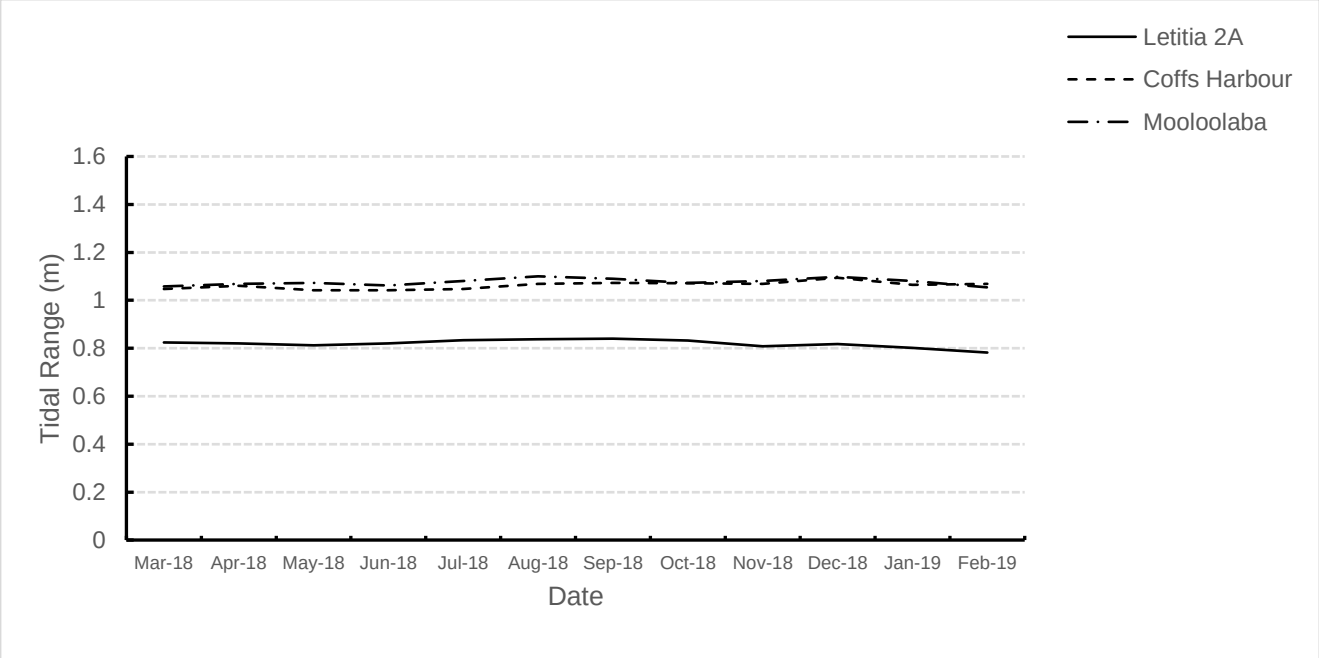


Figure 3 – Spring Tidal Range Comparison

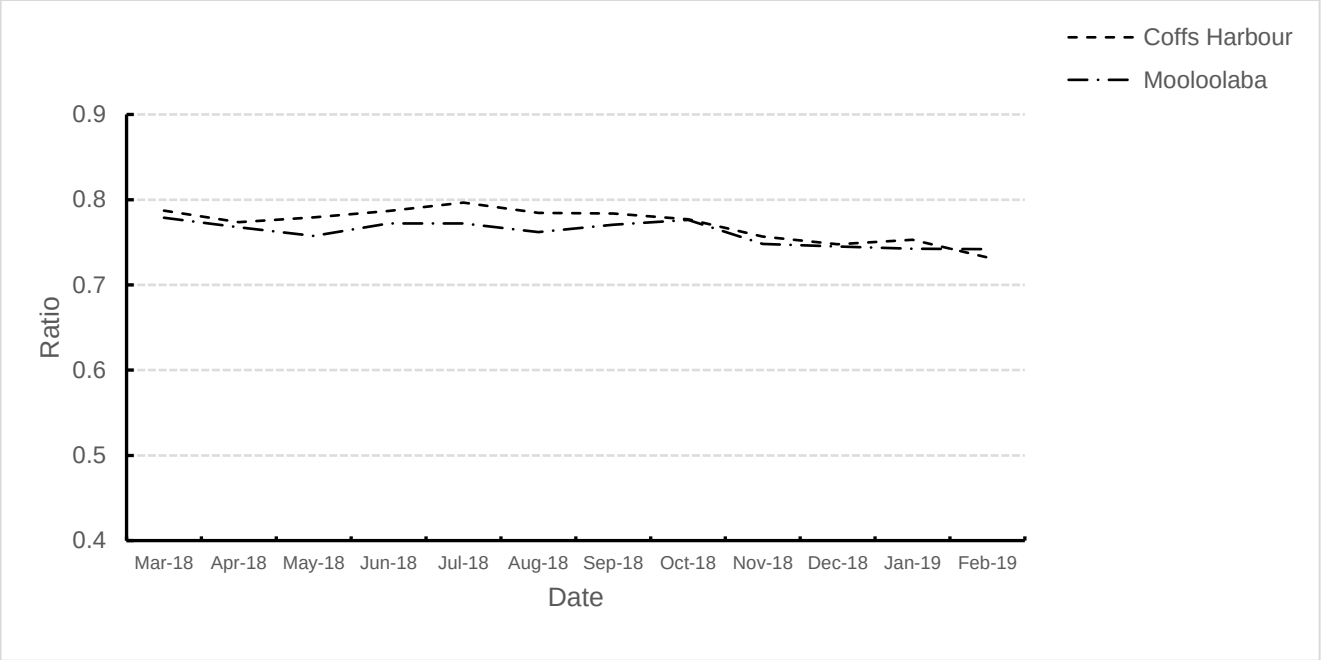


Figure 4 – Spring Tidal Range Ratio Comparison (Letitia 2A to Other Sites)

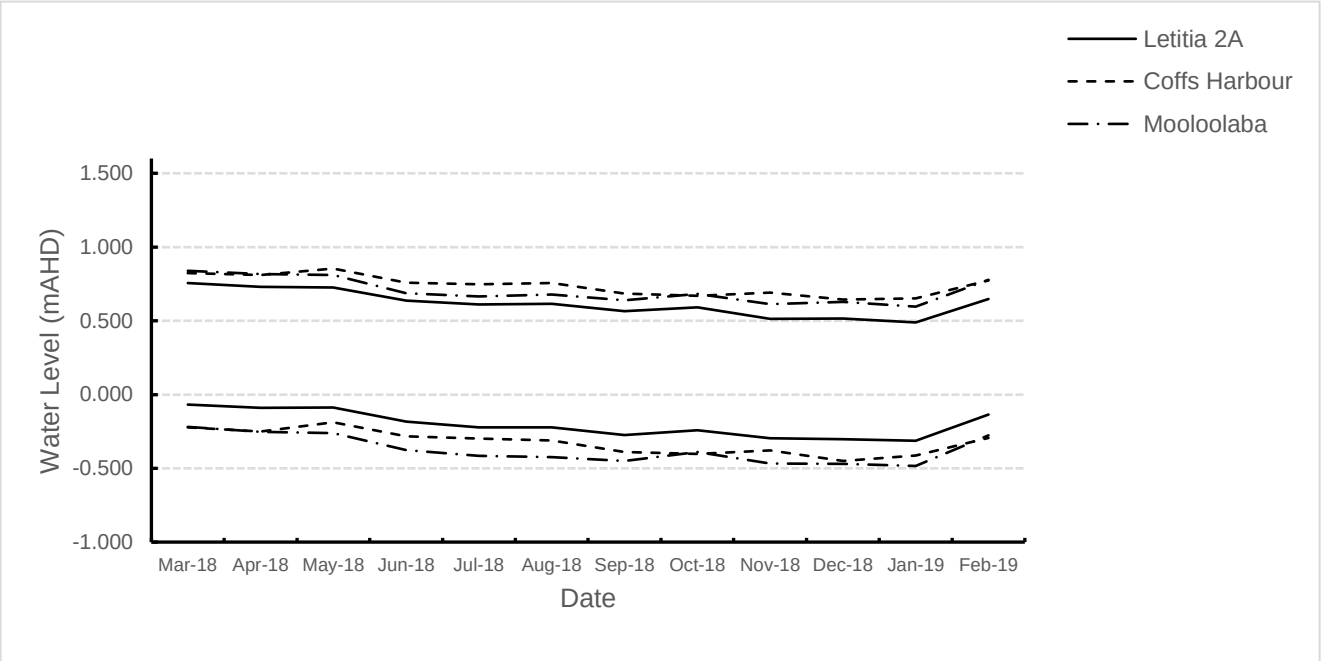


Figure 5 – Spring Tidal Planes Comparison

Table 1 – Murwillumbah recorded rainfall for the period March-2018 to February 2019 (all values in mm)

	Long Term Average	Monthly Totals	Highest Daily Recording	% Monthly Avg
Mar-18	259.7	255.0	56.8	98.19%
Apr-18	154.5	78.0	35.8	50.49%
May-18	139.2	16.4	7.0	11.78%
Jun-18	117.6	41.2	24.0	35.03%
Jul-18	75.1	35.2	18.2	46.87%
Aug-18	67.4	39.4	24.0	58.46%
Sep-18	46.5	50.8	14.0	109.25%
Oct-18	122.9	278.2	58.6	226.36%
Nov-18	123.9	43.4	21.8	35.03%
Dec-18	188.5	154.6	45.6	82.02%
Jan-19	226.7	5.2	2.4	2.29%
Feb-19	273.7	61.8	18.2	22.58%
Mean:			27.2	64.86%
Sum:	1783.9	1059.2		

3 Tidal Planes

Presented below are a series of monthly tidal plane tables for the five selected sites.

Key:

- **HHWS** - Highest High Water Springs
- **MHWS** - Mean High Water Springs
- **MHWN** - Mean High Water Neaps
- **MWL** - Mean Water Level
- **MLWN** - Mean Low Water Neap
- **MLWS** - Mean Low Water Springs
- **LLWS** - Lowest Low Water Springs
- **MSTR -** Mean Spring Tidal Range
- **MNTR** - Mean Neap Tidal Range
- **Residual** - Root Mean Square Residual

Table 2 – Tidal planes and ranges for March 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.050	0.970	1.086	0.989	0.874
MHWS	0.824	0.756	0.839	0.777	0.667
MHWN	0.473	0.466	0.429	0.462	0.441
MWL	0.125	0.199	0.105	0.189	0.202
MLWN	-0.574	-0.358	-0.629	-0.399	-0.263
MLWS	-0.223	-0.068	-0.219	-0.084	-0.037
LLWS	-0.800	-0.572	-0.876	-0.611	-0.470
MSTR	1.398	1.114	1.468	1.176	0.930
MNTR	0.696	0.534	0.648	0.546	0.479
Residual	0.091	0.091	0.051	*NA*	*NA*

Table 3 – Tidal planes and ranges for April 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.037	0.948	1.071	0.980	0.868
MHWS	0.810	0.730	0.816	0.760	0.656
MHWN	0.476	0.470	0.436	0.478	0.451
MWL	0.113	0.190	0.092	0.186	0.199
MLWN	-0.584	-0.350	-0.632	-0.389	-0.257
MLWS	-0.250	-0.090	-0.252	-0.106	-0.052
LLWS	-0.811	-0.568	-0.887	-0.608	-0.469
MSTR	1.394	1.080	1.448	1.149	0.912
MNTR	0.726	0.560	0.688	0.584	0.503
Residual	0.084	0.098	0.061	*NA*	*NA*

Table 4 – Tidal planes and ranges for May 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.132	0.983	1.117	1.024	0.927
MHWS	0.854	0.725	0.811	0.765	0.676
MHWN	0.578	0.521	0.503	0.543	0.512
MWL	0.195	0.217	0.121	0.222	0.243
MLWN	-0.464	-0.291	-0.569	-0.320	-0.190
MLWS	-0.188	-0.087	-0.261	-0.098	-0.025
LLWS	-0.742	-0.549	-0.875	-0.579	-0.440
MSTR	1.318	1.016	1.380	1.086	0.866
MNTR	0.766	0.608	0.764	0.641	0.536
Residual	0.066	0.069	0.055	*NA*	*NA*

Table 5 – Tidal planes and ranges for June 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.076	0.927	1.028	0.968	0.869
MHWS	0.759	0.637	0.686	0.677	0.592
MHWN	0.559	0.475	0.448	0.500	0.463
MWL	0.138	0.146	0.036	0.154	0.179
MLWN	-0.484	-0.345	-0.614	-0.369	-0.234
MLWS	-0.284	-0.183	-0.376	-0.192	-0.106
LLWS	-0.801	-0.635	-0.956	-0.660	-0.512
MSTR	1.242	0.982	1.300	1.046	0.826
MNTR	0.842	0.658	0.824	0.692	0.569
Residual	0.123	0.131	0.089	*NA*	*NA*

Table 6 – Tidal planes and ranges for July 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.069	0.907	1.006	0.944	0.843
MHWS	0.748	0.611	0.665	0.648	0.559
MHWN	0.531	0.445	0.417	0.465	0.427
MWL	0.116	0.111	0.001	0.114	0.139
MLWN	-0.516	-0.389	-0.663	-0.421	-0.280
MLWS	-0.299	-0.223	-0.415	-0.237	-0.148
LLWS	-0.837	-0.685	-1.004	-0.716	-0.564
MSTR	1.264	1.000	1.328	1.069	0.839
MNTR	0.830	0.668	0.832	0.702	0.575
Residual	0.082	0.109	0.053	*NA*	*NA*

Table 7 – Tidal planes and ranges for August 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.048	0.882	0.982	0.919	0.805
MHWS	0.756	0.615	0.677	0.653	0.550
MHWN	0.470	0.399	0.349	0.415	0.382
MWL	0.079	0.088	-0.037	0.088	0.111
MLWN	-0.598	-0.439	-0.751	-0.478	-0.329
MLWS	-0.312	-0.223	-0.423	-0.239	-0.161
LLWS	-0.890	-0.706	-1.056	-0.744	-0.584
MSTR	1.354	1.054	1.428	1.131	0.879
MNTR	0.782	0.622	0.772	0.654	0.543
Residual	0.097	0.116	0.050	*NA*	*NA*

Table 8 – Tidal planes and ranges for September 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.926	0.788	0.894	0.820	0.693
MHWS	0.684	0.565	0.639	0.598	0.480
MHWN	0.325	0.291	0.243	0.299	0.271
MWL	-0.032	0.008	-0.104	0.003	0.024
MLWN	-0.760	-0.513	-0.781	-0.547	-0.382
MLWS	-0.389	-0.275	-0.451	-0.293	-0.222
LLWS	-0.990	-0.772	-1.102	-0.814	-0.645
MSTR	1.431	1.114	1.486	1.190	0.913
MNTR	0.713	0.566	0.694	0.592	0.493
Residual	0.112	0.176	0.067	*NA*	*NA*

Table 9 – Tidal planes and ranges for October 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.906	0.807	0.926	0.841	0.733
MHWS	0.670	0.591	0.683	0.629	0.530
MHWN	0.312	0.319	0.291	0.331	0.315
MWL	-0.045	0.039	-0.049	0.041	0.074
MLWN	-0.748	-0.549	-0.847	-0.592	-0.432
MLWS	-0.402	-0.241	-0.389	-0.249	-0.167
LLWS	-0.996	-0.729	-1.024	-0.759	-0.585
MSTR	1.429	1.104	1.464	1.176	0.911
MNTR	0.713	0.560	0.680	0.580	0.481
Residual	0.109	0.125	0.048	*NA*	*NA*

Table 10 – Tidal planes and ranges for November 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.987	0.777	0.918	0.819	0.711
MHWS	0.690	0.513	0.612	0.554	0.455
MHWN	0.400	0.295	0.280	0.314	0.281
MWL	0.011	0.000	-0.094	0.000	0.023
MLWN	-0.668	-0.513	-0.800	-0.553	-0.410
MLWS	-0.378	-0.295	-0.468	-0.313	-0.236
LLWS	-0.965	-0.777	-1.106	-0.819	-0.666
MSTR	1.358	1.026	1.412	1.107	0.865
MNTR	0.778	0.590	0.748	0.627	0.517
Residual	0.083	0.141	0.050	*NA*	*NA*

Table 11 – Tidal planes and ranges for December 2018

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.981	0.804	0.979	0.849	0.743
MHWS	0.644	0.515	0.629	0.557	0.466
MHWN	0.420	0.343	0.365	0.368	0.329
MWL	-0.015	0.020	-0.052	0.022	0.048
MLWN	-0.674	-0.475	-0.733	-0.514	-0.371
MLWS	-0.450	-0.303	-0.469	-0.324	-0.234
LLWS	-1.011	-0.764	-1.083	-0.805	-0.647
MSTR	1.318	0.990	1.362	1.071	0.837
MNTR	0.870	0.646	0.834	0.692	0.563
Residual	0.118	0.117	0.045	*NA*	*NA*

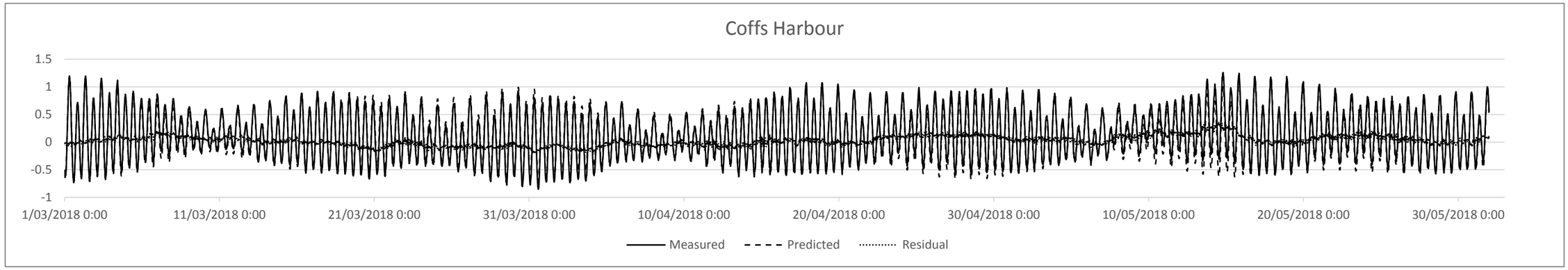
Table 12 – Tidal planes and ranges for January 2019

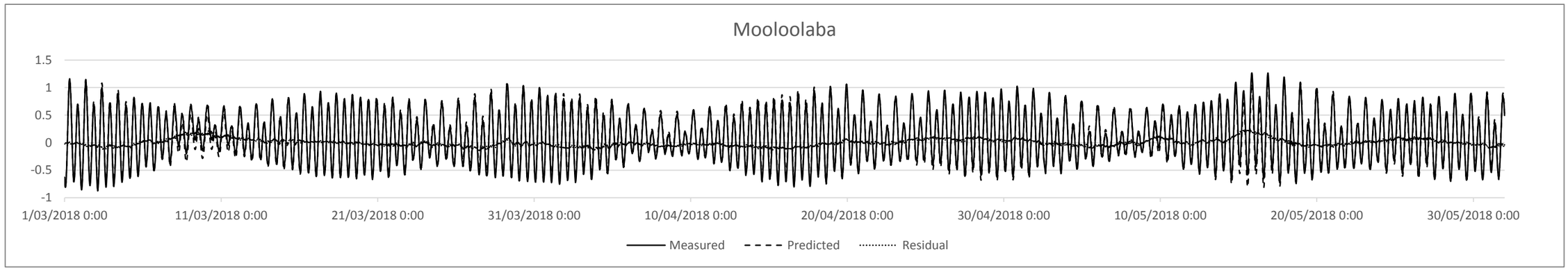
	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	0.986	0.782	0.941	0.828	0.718
MHWS	0.651	0.489	0.596	0.532	0.438
MHWN	0.400	0.305	0.322	0.327	0.290
MWL	-0.007	-0.004	-0.081	-0.002	0.021
MLWN	-0.665	-0.497	-0.758	-0.536	-0.396
MLWS	-0.414	-0.313	-0.484	-0.331	-0.249
LLWS	-1.000	-0.790	-1.103	-0.832	-0.676
MSTR	1.316	0.986	1.354	1.068	0.834
MNTR	0.814	0.618	0.806	0.658	0.539
Residual	0.087	0.120	0.065	*NA*	*NA*

Table 13 – Tidal planes and ranges for February 2019

	Coffs Harbour	Letitia 2A	Mooloolaba	Kerosene Inlet	Tony's Island
HHWS	1.060	0.905	1.074	0.949	0.834
MHWS	0.774	0.647	0.777	0.688	0.587
MHWN	0.450	0.413	0.435	0.430	0.394
MWL	0.078	0.139	0.079	0.141	0.153
MLWN	-0.618	-0.369	-0.619	-0.407	-0.281
MLWS	-0.294	-0.135	-0.277	-0.148	-0.088
LLWS	-0.904	-0.627	-0.916	-0.667	-0.528
MSTR	1.392	1.016	1.396	1.095	0.869
MNTR	0.744	0.548	0.712	0.578	0.482
Residual	0.071	0.086	0.075	*NA*	*NA*

4 Residual Plots





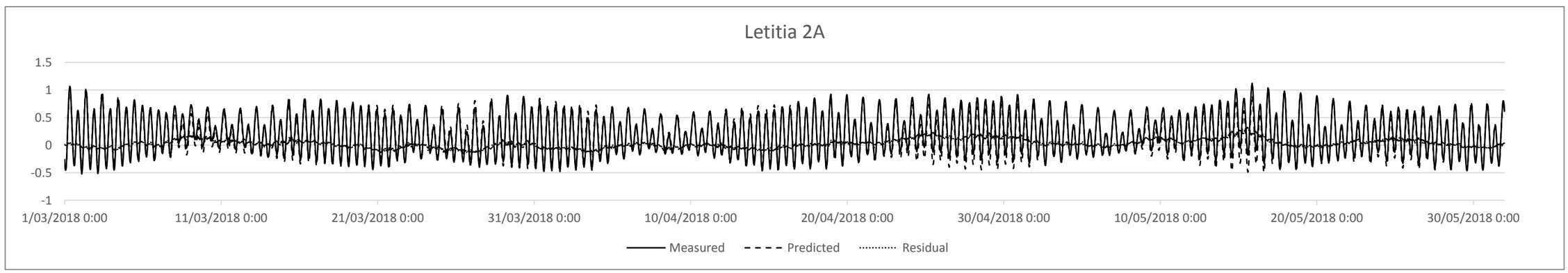
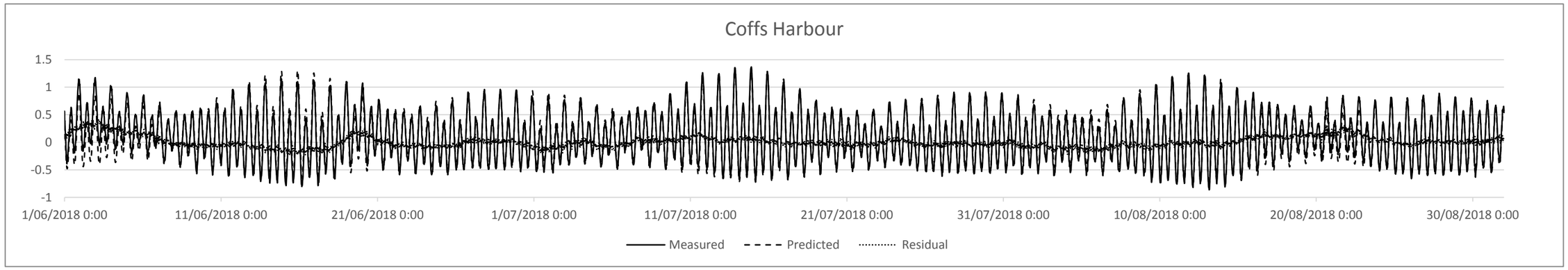
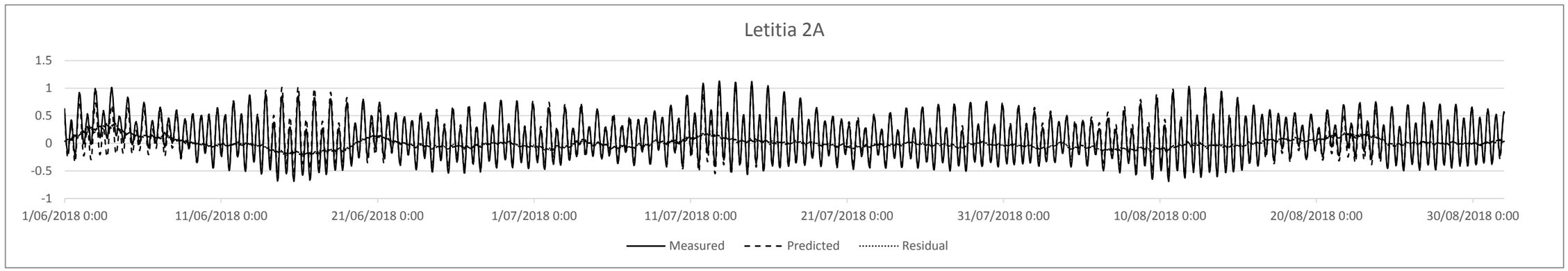


Figure 6 – March 2018 to May 2018 Water Levels





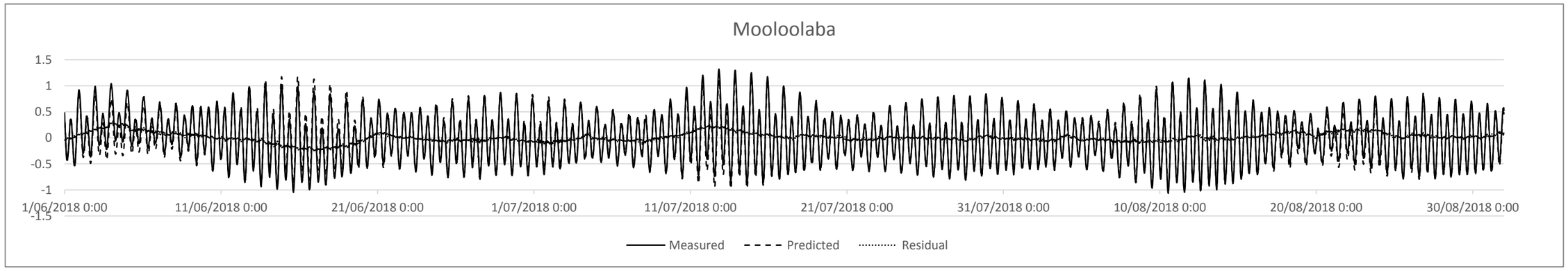


Figure 7 – June 2018 to August 2018 Water Levels

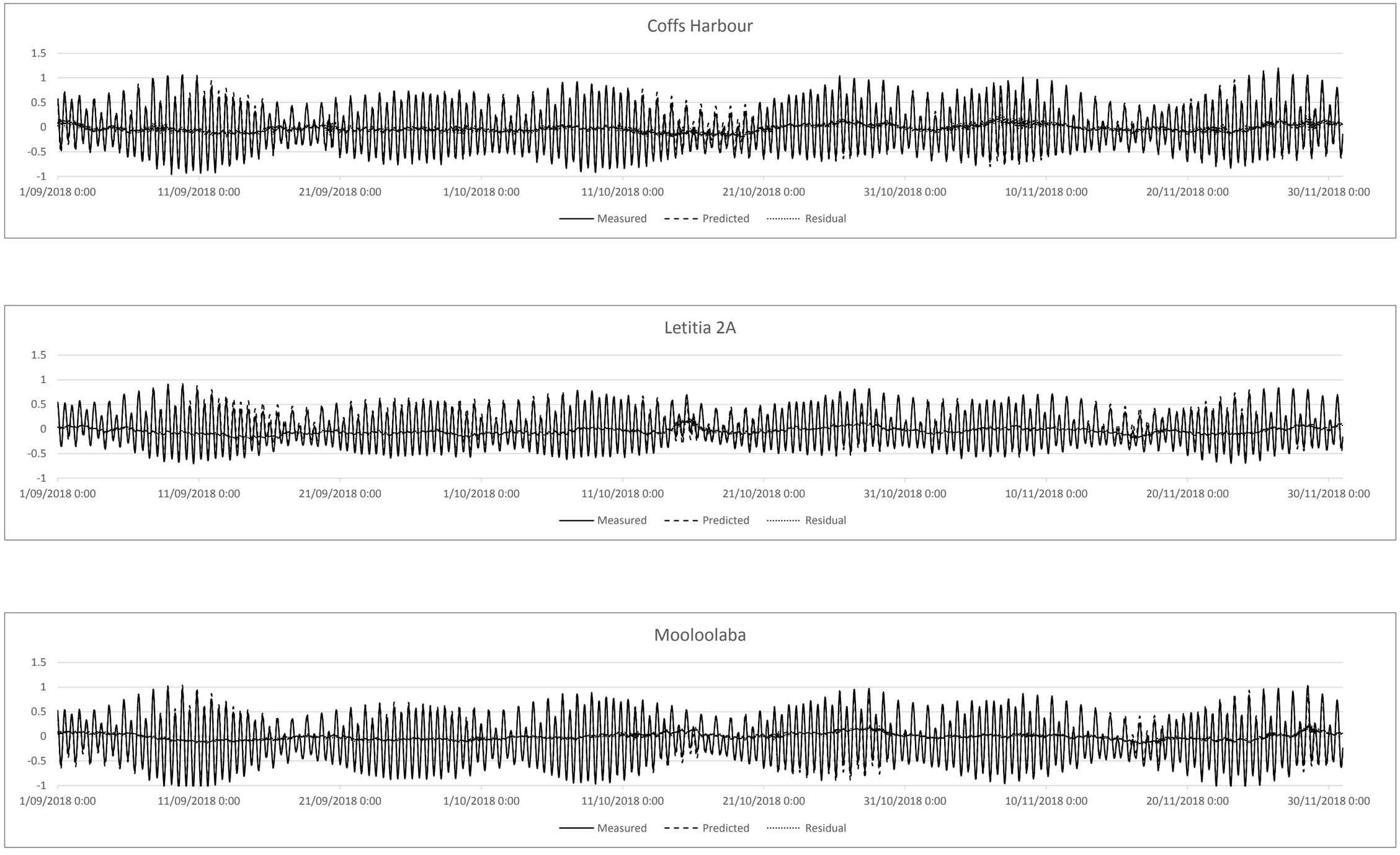
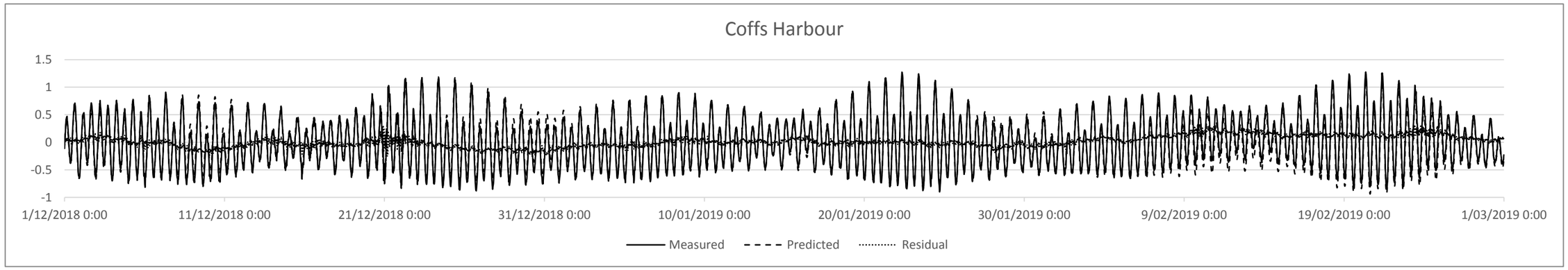
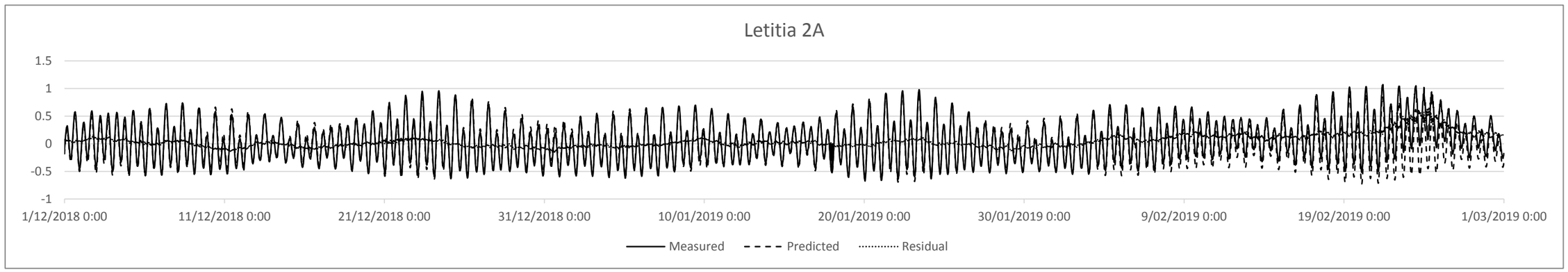


Figure 8 – September 2018 to November 2018 Water Levels





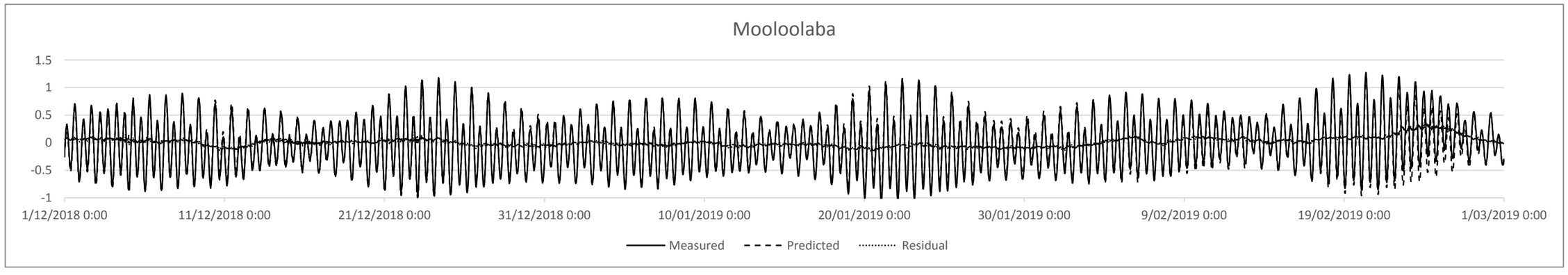


Figure 9 – December 2018 to February 2019 Water Levels

5 Conclusions

Based on the analysis presented above it is unlikely that the Tweed entrance has experienced any significant morphological changes in the preceeding 12-months which would manifest in changes to the astronomical tidal response.

Should you require further information please contact **Bronson McPherson** on (02) 9949 0244 or by email at Bronson.Mcpherson@mhl.nsw.gov.au

Yours sincerely

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Document Control

Issue/ Revision	Author	Reviewer	Approved for Issue	
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