Tide Gauge Survey Instructions and Forms

1. Work to be Carried Out at each Tide Gauge

In accordance with the procedures and recommendations contained in these instructions, carry out the following work:

1.1. Subject to the owners agreement calibrate each automatic recorder.

1.2. Complete "Tide Gauge Details" sheets for each tide gauge.

1.3. Inspect existing benchmarks and, where necessary, install additional or supplementary marks to bring the number of stable marks in the vicinity of each gauge to at least three.

1.4. Determine the difference in height between each of the tide gauge benchmarks and the zero of the tide staff and/or recorder at each installation.

1.5. If not already, and where reasonably possible, connect the tide gauge benchmarks to a level traverse of the national Levelling Survey.

1.6. Make a photographic record of each automatic recorder, the tide staff and nearby features.

1.7. Prepare a plan of each tide gauge installation.

1.8. If necessary, identify each gauge and the benchmarks on aerial photography.

1.9. Discuss with the owners and/or operators of the gauges any faults found with and possible improvements to each gauge and its records.

1.10. Send a copy of all documentation to the TSLWG as soon as possible after installation.

2. Calibration of Automatic Recorders

Automatic recorders may be calibrated in accordance with the following procedure:

2.1. Each gauge should be calibrated both before and after cleaning of the sensor or stilling well inlets unless inspection shows them to be clear.

2.2. Use the "Tide Gauge Calibration" forms provided to record the level of the sea inside the stilling well as indicated by the automatic recorder, the level of the sea outside the well as indicated by the tide staff, and the date and time of observation, and other relevant details, every 1/4 hour on the 1/4 hour, continuously for a period of the complete tide range including both the rising and falling tide, ideally at springs.

2.3. Clean the sensor or stilling well inlets and repeat the test.

2.4. Where the tide staff is not conveniently placed to enable observation of the recorder height and the tide staff height to be simultaneous, a temporary tide staff is to be established in a suitable position and its height is to be related to the existing tide staff.

2.5. A careful inspection of the tide staff should be made to see that it is firmly fixed and in a vertical position. If necessary, but only with the agreement and co - operation of the operator of the gauge, the tide staff should be firmly secured in a vertical position without disturbing the height of the tide staff zero. Any work carried out on the tide staff should be noted on both the tide gauge chart and the calibration record.

2.6. In exposed locations or in rough water the tide staff may be difficult to read without adequate stilling precautions. If necessary, a length of 1/2 inch diameter clear plastic tube, open at the top and fitted with a suitable notched plug at the lower end, may be fixed to the tide staff so that the water level in the tube can be read. It is essential to ensure that the tube does not become clogged and that there is sufficient opening at the lower end. It there is any wave movement on the outside, the water in the tube should show perceptible oscillation.

2.7. Record wind speed and direction and atmospheric pressure during the calibration period at 6 hourly intervals, unless readings are available from an nearby meteorological station

2.8. Make arrangements, if possible, with the owner or operator of the gauge for the supply to the Tides and Sea Level Working Group of a copy of at least that portion of the recorder chart and or digitally recorded readings covering the period of the calibrations.

3. Tide Gauge Details Sheets

3.1. In consultation with the owner and or the operator of the gauge and by personal inspection and observation complete the 4 pages of "Tide Gauge Details" in as much detail as possible.

3.2. These sheets serve as a permanent record of the tide gauge installation and it is important that as much information as possible be obtained and that the information is accurate.

3.3. If any information differs from previous records attempt to find out when the changes occurred and note. Do not destroy the old information.

3.4. With reference to environmental effects (Question 28) describe in detail any feature which may limit exposure of the gauge to open water (e.g. shallows narrows etc.).

4. Benchmarking

4.1. Inspect existing permanent benchmarks in the vicinity of each tide gauge and if these are inadequate in number and/or quality establish new permanent marks so that at least three marks of good quality and stability are available at each gauge.

4.2. New marks should be about I00 metres apart and away from any anticipated construction activity or other possible cause of disturbance.

4.3. Marks established as tide gauge benchmarks should preferably be constructed of brass rod set at least 150 mm into solid rock concrete foundations or other suitable structures the top of the rod protruding not more than 5 mm and indicated by a brass numbering plate. If no suitable rock or structure is available benchmarks are to be established in accordance with Part C "Recommended Marking Practices" of the ICSM

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4.4. The identification number allocated to each new benchmark is to be legibly stamped on the brass numbering plate.

4.5. Each new benchmark is to be fully described in the field level book and a Permanent benchmark Record is to be prepared for each new mark on the forms provided.

4.6. Benchmarks established during the level observations from the tide gauge benchmarks to National Levelling, Survey traverses shall be constructed in accordance with the above Schedule.

4.7. Supply a copy of all Permanent Benchmark Records to the State Survey Authority.

5. Levelling to the Zero of Tide Staffs

5.1. The differences in height between all tide gauge benchmarks and the zero of the tide staff is to be determined in accordance with section 6.1 and 6.2 below.

5.2. A diagram showing the differences in height between the tide gauge zero and the tide gauge benchmarks is to be prepared for each gauge.

5.3. Information relating to any change in the position of the tide staff or damage to it in recent years should be sought from the gauge owner or operator and included in the report on the tide gauge.

5.4. Check the graduations on the tide staff itself for accuracy and note any anomalies.

6. Connection to the National Levelling Survey

6.1. If the tide gauge benchmarks have not already been connected to a traverse of the National Levelling Survey such a connection shall be carried out to class LC in accordance with Part B Best Practice Guidelines for Surveys and Reductions sub section 2.4 Differential Levelling of the ICSM Special Publication 1 "Standards and Practices for Control Surveys Version 1.7 September 2007

6.2. All levelling is to be checked and a summary completed before leaving the site of the survey.

6.3. The levelling summary should be submitted to the State Survey Authority for incorporation into the National Levelling Survey adjustment.

6.4. An Ellipsoidal height should be available on at least one of the TGBM's. If not, attempts should be made to observe an "Absolute" ellipsoidal height with GPS see 2.6.14 of ICSM Special Publication 1 "Standards and Practices for Control Surveys Version 1.7 September 2007. Heights to be entered into the tide gauge meta-data sheet.

7. Photographic Record of the Tide Gauge

7.1. Two photographs of each tide gauge benchmark shall be taken. One photograph shall be a close - up of the actual mark and the other shall show the detail of the area surrounding the mark.

7.2. Two photographs of the tide gauge recorder hut shall be taken, from different directions.

7.3. Two photographs of the tide staff shall be taken, one a close - up of the tide staff and the other, if possible, showing both the tide staff and the recorder hut.

7.4. Two photographs showing the recorder inside the hut shall be taken from different positions.

7.5. Two or more photographs shall be taken from a considerable distance and shall show the tide gauge installation in relation to other prominent local features.

7.6. A record of the exposures in their correct sequence is to be kept on the photography record sheet provided.

7.7. On completion of a film it is to be labelled with the names of the photographed tide gauges on both the wrapping paper and the cassette or container.

8. Plan of the Gauge Installation

8.1. The position of the recorder, the tide staff and all benchmarks shall be shown on a large scale plan of the area.

8.2. A suitable map of the area can usually be obtained from local authorities. Where such plans or maps are unobtainable a sketch shall be prepared showing the recorder hut, the tide staff, the benchmarks and other local features in their proper relative positions and identify their location on aerial photography as described below.

8.3. The automatic recorder and all benchmarks shall be identified on aerial photography by pricking their positions on the photos with a fine needle and by suitable annotation.

Where an identification is in doubt, an easily identifiable point nearby shall be identified. The photo annotation shall refer to this nearby point as the "Photo Reference Point" and shall indicate its bearing and distance from the recorder and the benchmarks.

8.4 The plan of tide gauge installation should be included with the Tide Gauge Details sheets.

9. Discussion with Owners and Operators

9.1. The owners of the gauges should be advised well in advance by letter that the survey party from a designated organisation will be visiting each gauge. A few days before the party is expected to arrive at each gauge the party leader shall try and contact the operator by telephone to let him know when to expect the party.

9.2. Any faults in the gauge or the records shall be discussed with the owner and or operator but no adjustments are to be made without the agreement of the owner or operator.

10. Tides and Sea Level Working Group

10.1. Supply a copy of the Tide Gauge Details sheets, plan of installation, annotated aerial photograph (if applicable) and height connection diagram (see paragraph 5.3) to the TSLWG as soon as possible after installation.

10.2. If any changes occur to the details provided or the gauge is removed, the TSLWG should be informed immediately.

Tide Gauge Details

In addition to details of the site, type of gauge, owner and operator, the "Tide Gauge Details" form requests technical details of the gauge, the frequency and method of connection to benchmarks, and environmental effects, the last referring in particular to any impediment to the exposure of the gauge to open water which may reduce the accuracy of the records obtained. This information is required to facilitate comparison and interpretation of the tide gauge records.

Operators are invited to refer to the committee any difficulties encountered in completing the form any suggestions as to how it might be improved.

Station Number		***Name***			
Latitude		***Longitude***		***Horizontal Datum***	
1 : 100, 000 Map Name		***Number***			
M.G.A. Northing		***M.G.A. Easting***			

Site description	
Operator's Name	
Address	
Telephone	
Type of Recorder	
Makers Name	
Date of manufacture	
Serial Number	
Range of Gauge	
Commencement of Operation	
Period for which continuous records are available	
Period of intended operation of gauge	
Frequency of recorder chart change	
Frequency of height check	
Frequency of time check	
Method of height check	
Method of time check	
Tide staff graduations	
Chart height scale	
Chart time scale	
Type of record	
Records stored at	

Float operated gauge:	
Diameter of float	
Diameter of well	
Height of inlet above the sea bed	
Specifications and configuration of inlet/s	
Pressure operated gauge: (Strain gauge, gas purge, etc)	
Type of sensor/s	

Depth of sensor/s below gauge zero	
Distance of sensor/s from recorder	
Method of pressure transmission	

Pulse flight time operated sensor (downward looking radar or acoustic pulse sensor)	
Type of Sensor/s	
Height of sensor above gauge zero	
Distance of sensor from recorder	

Are water density, temperature and salinity measured? If yes, how often:	

Recorder Calibrated:	
Period	
Method	

Environmental effects on gauge	

Description of benchmarks	
Height of benchmarks in metres:	
Above tide staff zero	
Above recorder zero	
Above Australian Height Datum	
Above Hydrographic chart datum	
Above the Ellipsoid	
Above Low Water Datum	
Above Other Datum (Specify)	

A.H.D. height in metres of:	
Tide Staff Zero	
Recorder Zero	

Levelling Section (A.H.D. connection)		
Number		
Levelling by		
Level Books		
Levelling Date		
Ellipsoidal height in metres of:		
Tide Staff Zero		
Recorder Zero		
Ellipsoidal Heights Information (SP1)		
ITRF Epoch (MMM/YYYY)		
ITRF Height above BM	*is*	
ITRF Height above TGZ is		
Length of GPS Observations		
Method of determination		

Reference to Ellipsoid (preferably the Australian Datum at the date of Survey)	
Name of Ellipsoid	
Date of Survey	
Field Record ID	
Elevation calculation record id	
List of elevation control marks with elevation	
Nature of elevation calculation (constrained or unconstrained to elevation control marks)	

Other relevant details	

Issue		*Prepared By*		*Date*	

Name:			**Number:**		
Date	**Standard Time**	**Recorder Time**	**Recorder (m)**	**Staff (m)**	**Weather Conditions**
Observer				**Time Zone**	

Record of Exposures: Film/cassette/digital media have been labelled thus: -

Name of Station	
Date of Photography	
Log of Exposure	

Signature of Surveyor..

1.1 Interpretation of the Tidal Constituent Sa

A comparison of the Doodson numbers in the IOS (UK) and IOS (Canada) prediction programs revealed a difference in the interpretation of the constituent Sa that has the potential to degrade the accuracy of tidal predictions in Australia. The former program is used by the former National Tidal Facility Australia, the National Tidal Centre, Bureau of Meteorology and the Transport Department of West Australia while the latter program is used by the Hydrographic Office RAN and a significant number of other Australian organisations.

Constituent Sa, which represents the seasonal variation (with period of about one year) in mean sea level is quite significant in Australian waters. It may have an amplitude of up to 0.4 metres but generally is in the order of 0.1 metres.

The Doodson numbers for Sa used in the IOS (UK) program (Reference A Table 4) are 0 0 1 0 0 0. Those used in the IOS (Canada) (Reference C, Appendix 4) are 0 0 1 0 0 -1. The former set involves only the mean longitude of the sun and its rate of change. The latter set also involves the mean longitude of the solar perigee and its rate of change. The effects of the difference in the last number are calculated in Annex A. While the effect on the speed of the constituent is almost negligible, the effect on our programs calculation of the initial phase of Sa is large giving rise to inaccurate tidal predictions.

Source of Constituent Constant	IOS (UK)	Difference	IOS (Canada)
Constituent name	Sa		Sa
Interpretation Doodson numbers	0 0 1 0 0 0		0 0 1 0 0-1
Speed (degrees/hour)	0.0410686	0.0000019	0.0410667
Period (mean solar days	365.24254		365.24995
Phase in degrees at time origin	(0000 GMT 1/1/76)		
	278.78841	-77.472360	357.26077
Phase in degrees at	(0000 GMT 4/4/84)		
	9.54387	-77.33048	86.874358

It is not particularly important which Doodson numbers are used for the constituent as long as those used in the prediction program are the same as those used in the tidal analysis.

The effect of the differing Doodson number on the accuracy of past predictions was demonstrated by test predictions for a year using Sa with Doodson Numbers 0 0 1 0 0 0 and 0 0 1 0 0 1. Using a typical amplitude of 0.1 m, the difference in tidal height varied from zero to 0.13 m.

There are two ways to deal with the difference in interpretation

1. Include details of the Doodson number for Sa in the metadata accompanying tidal constituent constants
2. Modify analysis and prediction programs to use the IOS (UK) interpretation i.e. the Doodson number for Sa is 0 0 1 0 0 0

It would be prudent to implement both.

References

A: "The Fine Resolution of Tidal Harmonics" by M. Amin 1975.

B: "The Harmonic Development of the tide generating Potential" by A.T. Doodson 1921.

C: "Manual for Tidal Heights Analysis and Prediction" MGG Foreman. IOS (Canada) 1977.

1.2 Ellipsoidal Height Measurements at Offshore Locations

Overview

The measurement of sea level at an offshore location is typically undertaken using moored oceanographic sensors including pressure gauges, and temperature and salinity sensors. Sea level data derived from these sensors is relative to the gauge zero, often located at significant depth. In order to transform this sea level to become relative to an international or national datum (e.g. the International Terrestrial Reference Frame, ITRF), and expressed on an ellipsoid, simultaneous GNSS measurements of sea level at the offshore site must be undertaken. This process is undertaken regularly by the Australian Integrated Marine Observing System (IMOS) in order to derive data at key locations comparable with satellite altimetry (see Watson et al. 2011). In this case, GNSS equipped buoys (Figure 17) are deployed over an array of moored oceanographic sensors, typically for multiple periods of ~48 hours duration. Post processed sea level data is obtained with respect to the ITRF and directly comparable with other ellipsoidal based data that use the same datum.

Hardware

The hardware required consists of a floating platform, typically a buoy of some description, equipped with a geodetic grade GNSS receiver (e.g. Figure17). Data acquisition is typically undertaken at 1 Hz at both the buoy, and at a nearby reference GNSS station if differential carrier phase based processing is being undertaken. The height of the GNSS antenna above the water surface must be accurately determined. Significant changes in the orientation of the platform with respect to the vertical may introduce systematic error, and in the case of large structures (e.g. large offshore buoys or boats used as the floating platform), may require additional measurement and correction (see Watson, 2005 for review).

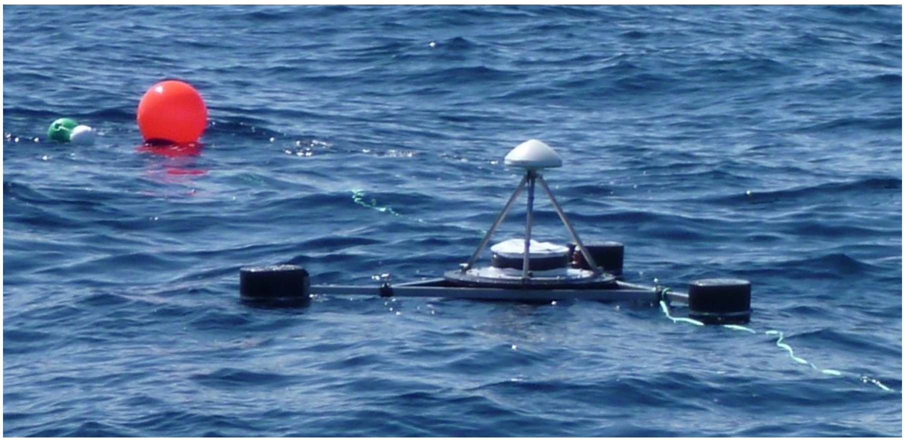

Figure 1 The IMOS GPS buoy used by Watson et al. (2011)

A number of commercial providers produce off the shelf GNSS equipped buoys (e.g. ‘HydroLevel Buoy’ by Axys Technologies http://www.axystechnologies.com/). A larger number of providers produce GPS equipped ‘wave-rider’ buoys for computing directional wave spectra (e.g. ‘DWR-G by Datawell http://www.datawell.nl). Note these are not designed for estimating accurate ellipsoidal sea surface height.

Processing

Two processing strategies are available for GNSS buoy data. Differential carrier phase based techniques require additional data from a static land based GNSS reference site operating at the same data rate as the GNSS buoy. Processing may be undertaken in a number of commercial and research orientated packages that support kinematic processing. The alternate mode of processing is known as kinematic Precise Point Positioning (kPPP). This technique doesn't require a land based reference station, but requires a minimum data span of several hours and slightly more sophisticated software that is not supported by as many commercial providers.

Processing of GNSS buoy data is typically undertaken post-collection, however provided a communication link is available, real time processing is readily possible on the buoy or at a shore based location in the case of the differential carrier phase based technique (known as Real Time Kinematic, RTK, processing).

Processing of the GNSS buoy data yields epoch-by-epoch estimates of sea surface height relative to the chosen datum and expressed on a chosen ellipsoid. GNSS time series of sea level may then be filtered to remove wave effects and compared against offshore tide gauges to derive the required offsets to transform the mooring sea level onto the datum imposed by the GNSS buoy time series (see Watson et al. 2011 for further detail).

Accuracy

Accuracy of the GNSS derived estimates of sea level is affected by a range of variables, only some of which are unique to the ocean GNSS buoy environment. In the case of the IMOS buoys used for scientific purposes, the RMS of the difference between mooring sea level and the filtered GNSS sea level is at the 2 cm level. With a sufficiently long acquisition of data over multiple days, the error about the mean difference (mooring – GNSS sea level), is at the cm level. Typical swell experienced at the IMOS deployment locations is 1-2 m, with deployment locations typically ~20 km from the coast. The main factors that influence the accuracy of the technique are briefly mentioned below:

GNSS Related factors:

1) In the case of differential carrier phase based processing, proximity to land based GNSS reference station(s) is important (preferred < 25 km).
2) Duration of the GNSS buoy deployment (preferred > 24-48 hours)
3) Sea state at the time of the GNSS buoy deployment (large waves can cause loss of lock to the GNSS signals), and high dynamics associated with rougher conditions make kinematic processing problematic.
4) Water level to GNSS antenna separation (easy to determine for a custom buoy but more challenging if a larger platform or boat is used).

Tide gauge factors:

1) Quality of the pressure sensor (i.e. low drift, high resolution etc).
2) Ability to determine a dynamic height correction based on temperature and salinity through the water column (requires appropriate sensors).
3) Ability to remove atmospheric pressure from pressure gauge time series (requires access to observed data or meteorological models interpolated to the measurement location).

References

Brown, N., J. McCubbine, W. Featherstone, N. Gowans, A. Woods, and I. Baran (2018), AUSGeoid2020 combined gravimetric–geometric model: location-specific uncertainties and baseline-length-dependent error decorrelation, Journal of Geodesy, 92(12), 1457-1465.

Watson, C.S., White, N., Church, J., Burgette, R., Tregoning, P., and Coleman, R. (2011) Absolute Calibration in Bass Strait, Australia: TOPEX, Jason-1 and OSTM/Jason-2. Marine Geodesy, 34:3-4, pp242-260.

Watson, C.S. (2005). Satellite Altimeter Calibration and Validation Using GPS Buoy Technology. Thesis for Doctor of Philosophy, Centre for Spatial Information Science, University of Tasmania, Australia. 264pp. http://eprints.utas.edu.au/254/