Sea Level Measuring Systems

D. Sundar

Observed Sea Level = Mean Sea Level

+

Tide

+

Non tidal residuals

Why do we measure Sea level?

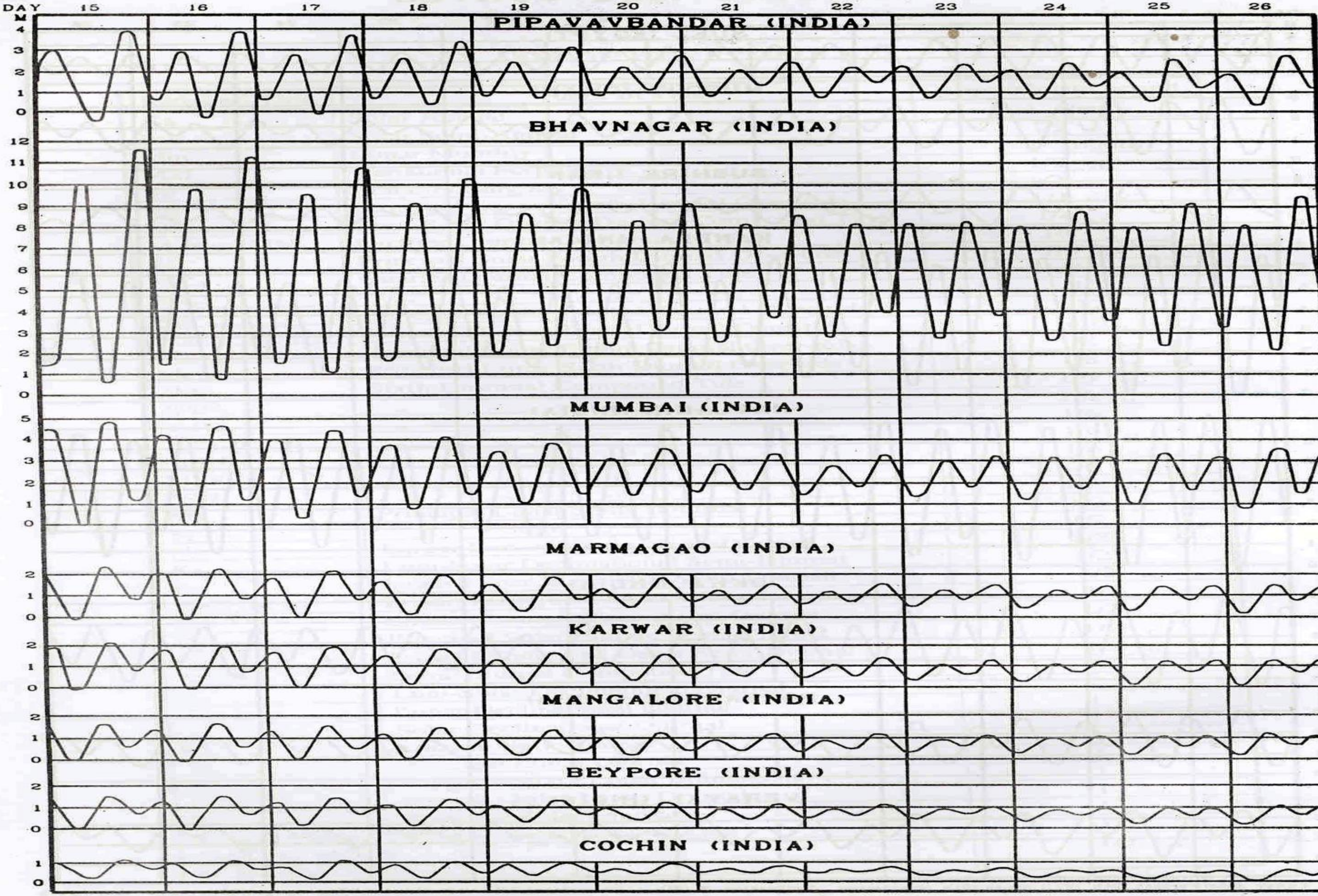
- For navigation and dredging purposes.
- For pollution studies.
- Tide analysis and tide prediction.
- Extreme events (Surge and Tsunami) studies.
- Secular changes.

Tides - three pronged

- Earth tides – affects the earth's crust
- Atmospheric tides – affects the height of the atmosphere
- Ocean tides – affects the sea level

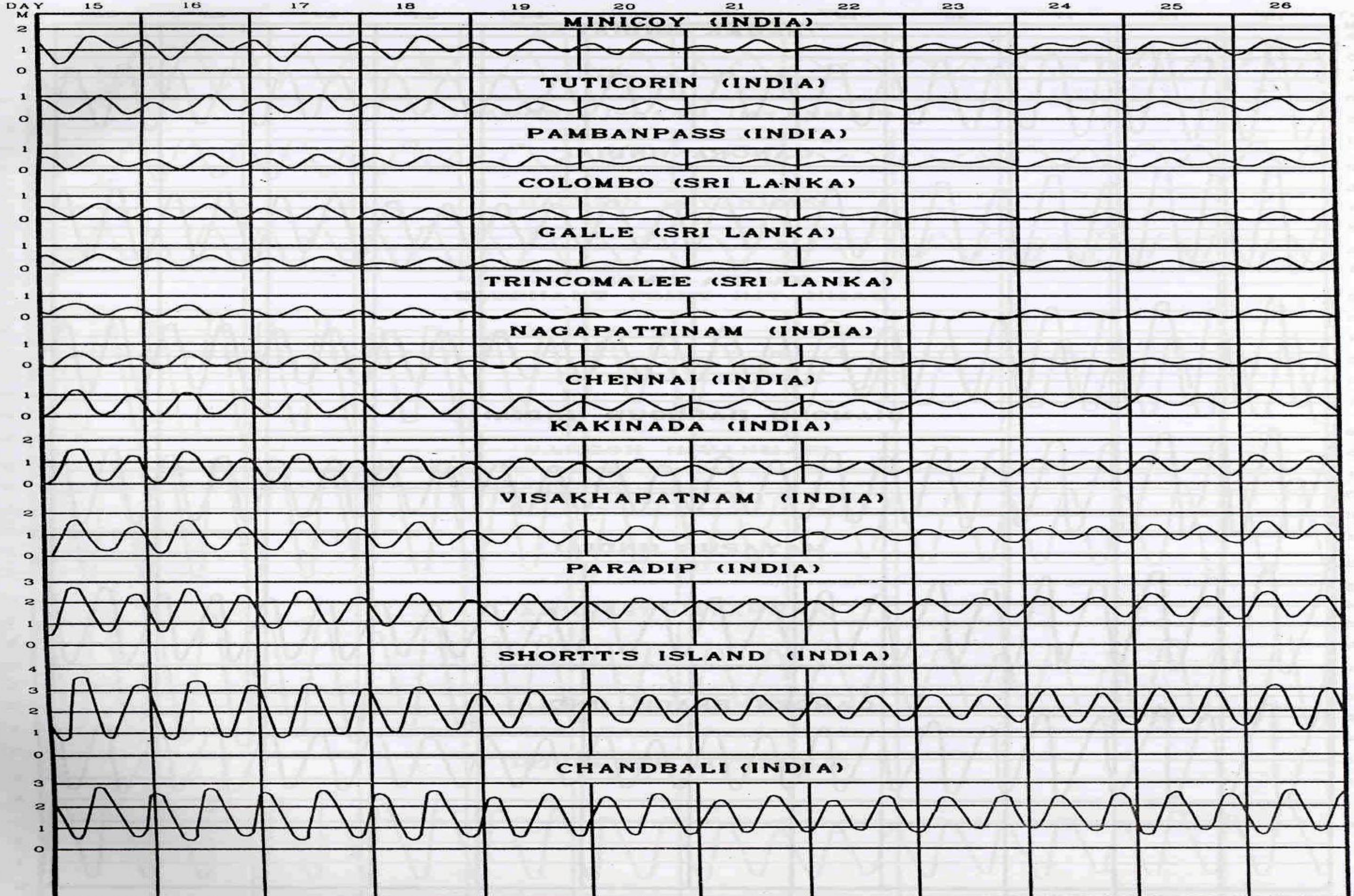
- Gravitational Tides
- Meteorological/Radiational Tides

TYPICAL TIDE CURVES



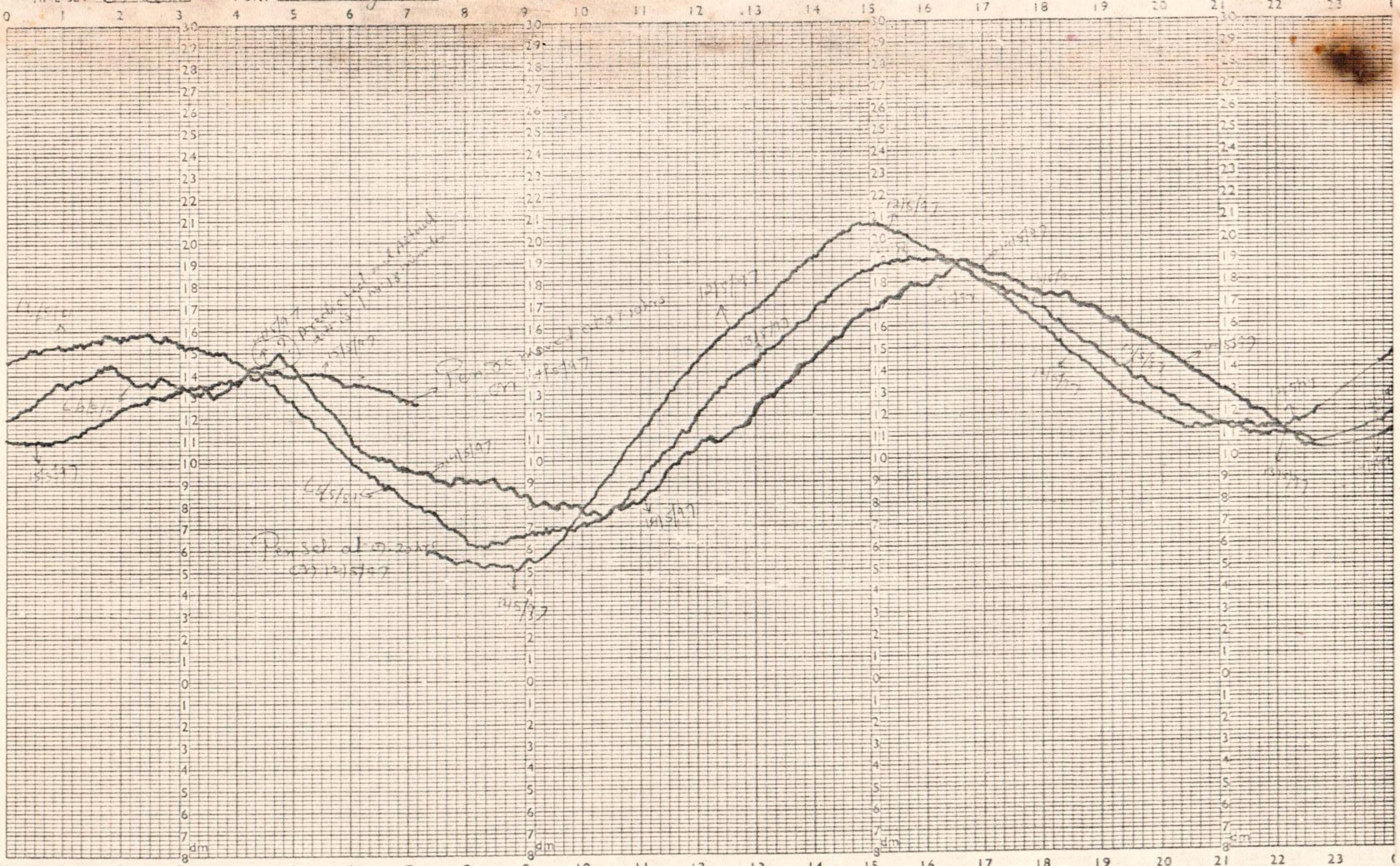
Lunar data: Perigee 12th ; full moon 13th ; maximum declination S 15th ; last quarter 20th ;

TYPICAL TIDE CURVES



Lunar data: Perigee,12th : full moon,13th : maximum declination S.,15th : last quarter,20th : on equator,22nd : apogee,25th : new moon,29th

TIME SET 07.20hrs PORT Marmugao SURVEY OF INDIA TIDE RECORDER RANGE 3·8 m DATE 12/5/97



Reg. No.3388 P.Z.D. '69 (G.&R.B.69) 3000-3000'73-3000'76-3000'80-5000'84-3000'91-5000'94.

PRINTED AT THE (P.Z.O.) PRINTING GROUP OF SURVEY OF INDIA

- Major design requirement of a sea level gauge is to resolve the large amplitude short period waves and the small amplitude long period tide.
- GLOSS requires data accuracy better than:
  - 0.01 m in height measurements
  - 0.03 m/s in current observations
  - 1 minute over one week in time

GLOSS requirements (some more)

- Recording interval needs to be 6 or 15 minutes. If Tsunami detection is the objective, 1 min or less is preferred
- Overall instrumentation should be compatible to target the required accuracies
- Measurements should be with respect to TGBM
- Atmospheric pressure and if possible wind and other environmental parameters must also be observed
- Gauge sites should be equipped for automatic data transmission along with local recording
- Regular monitoring of daily data

Site Selection Criteria

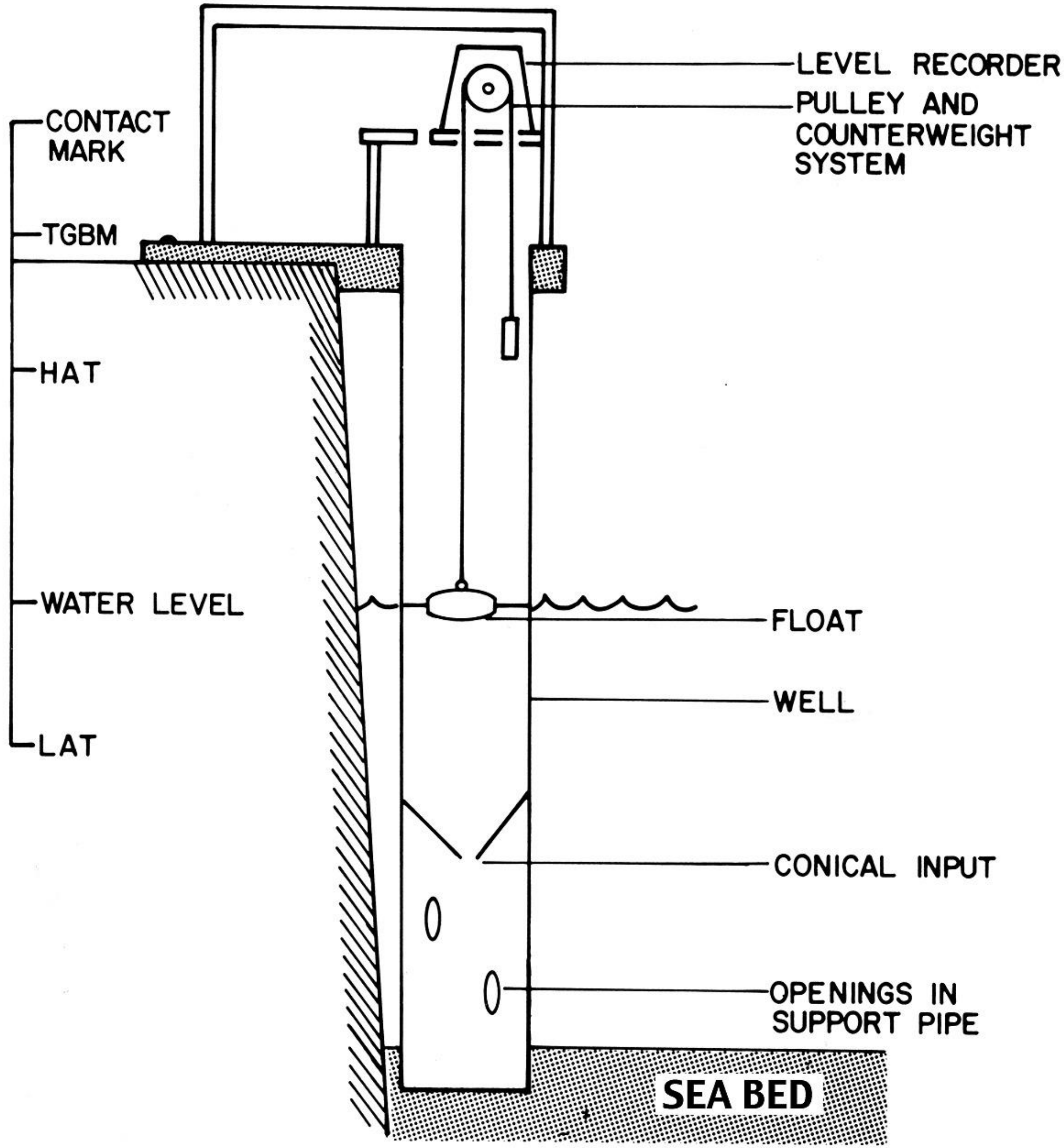
- Must be capable of withstanding worst environmental conditions
- Must be stable; no subsidence or erosion
- Avoid river estuaries, if possible
- Avoid areas where impounding may occur at low waters
- Avoid proximities to outfall
- Ensure mains power, telephone and satellite transmission access
- Adequate access for maintenance and ensure safety from vandalism and theft.

Types of Tide Gauges

- VTS (Visual Tide Staff) is a graduated pole made to stand upright in the sea.
- Accuracy of about 0.02 to 0.10 m
- Advantage is the low cost and ease of operation
- Disadvantage is low accuracy due to the manual errors and difficulty in reading in rough weather (Alleviated to some extent by use of a transparent hollow tube).


5 4 3 2 1 3M 9 8 7 6 5 4 3 2 1 2M 9 8 7 6 5 4 3 2 1 1M 9 8 7 6 5 4 3 2 1 0


4
3
2
1
1M
9
8


LEVEL RECORDER
PULLEY AND COUNTERWEIGHT SYSTEM
CONTACT MARK
TGBM
HAT
WATER LEVEL
LAT
FLOAT
WELL
CONICAL INPUT
OPENINGS IN SUPPORT PIPE
SEA BED

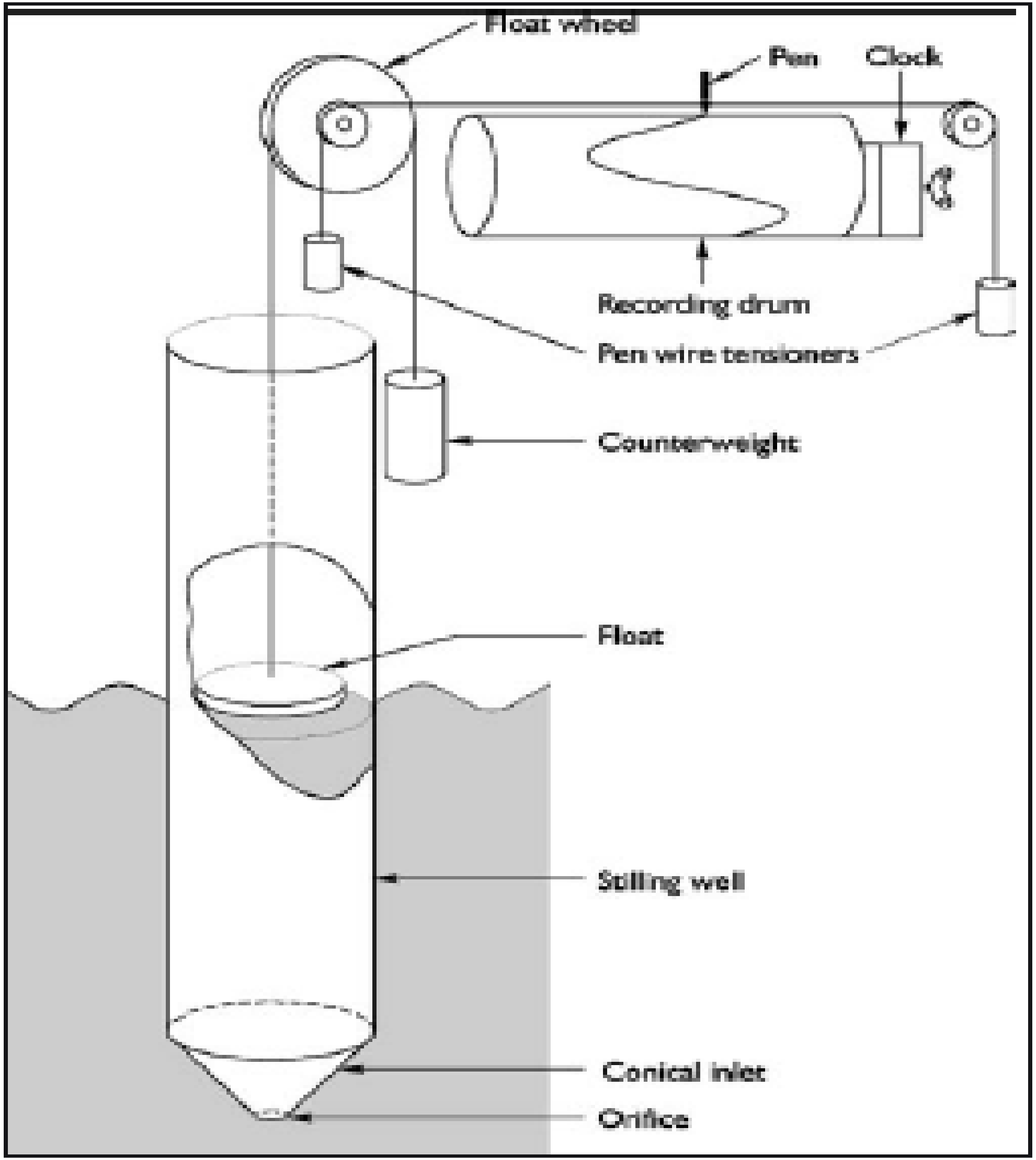
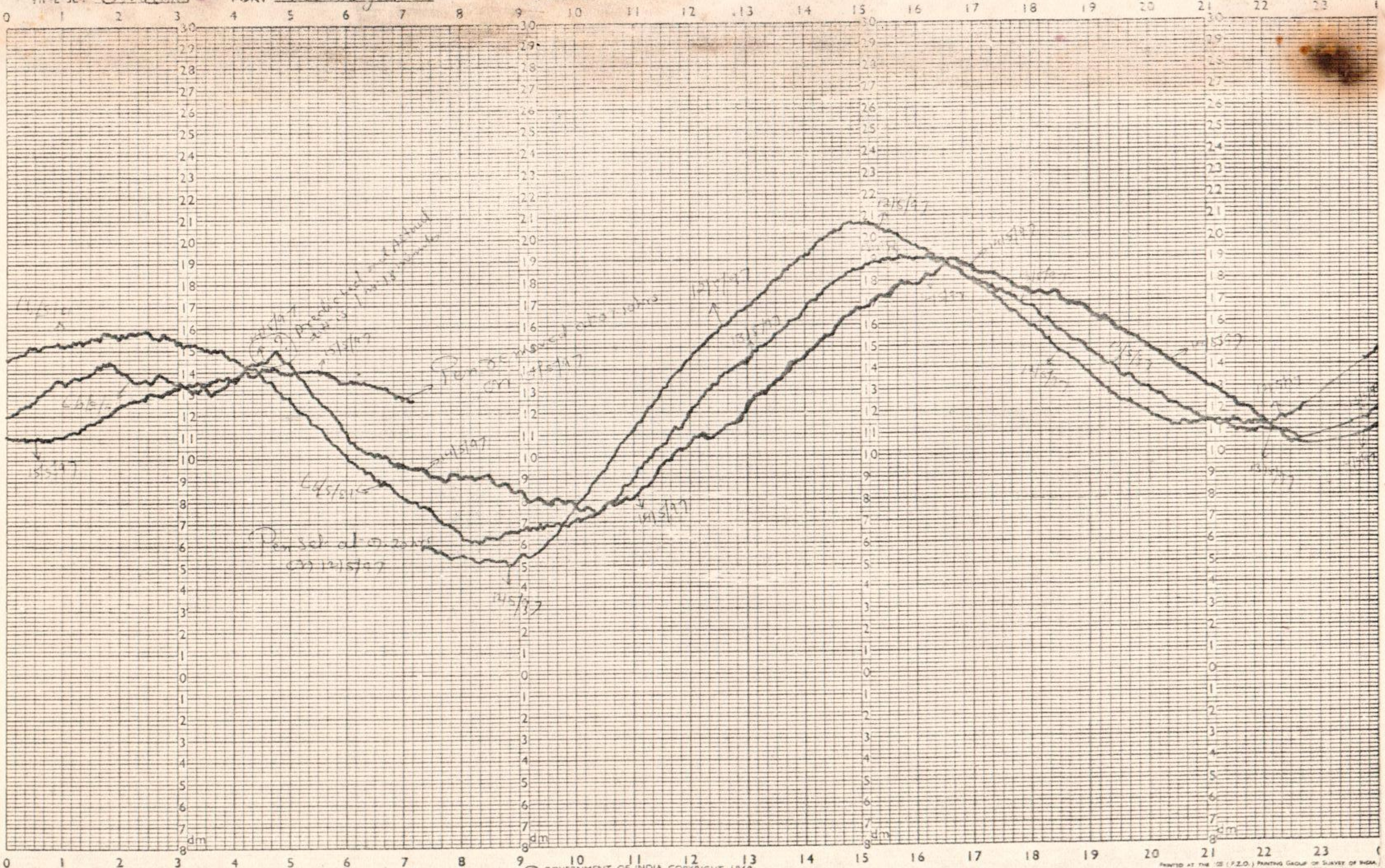


Figure 3.1 Stilling well tide gauge.

TIME SET 07.20 hrs PORT Marmugao SURVEY OF INDIA TIDE RECORDER RANGE 3·8 m DATE 12/5/97



Reg. No. 3388 P.Z.D. '69 (G.&R.B.69) 3000-3000'73-3000'76-3000'80-5000'84-3000'91-5000'94. © GOVERNMENT OF INDIA COPYRIGHT, 1969. Printed at the ... (P.Z.O.) Printing Group of Survey of India

DC from 1.6.87 to 28.6.87 = −0.0232 Appli
from 29.6.87 to 30.6.87 = −0.0011 Appli

भारतीय सर्वेक्षण विभाग
SURVEY OF INDIA

पृष्ठ Page (61)

(1) ज्वार विश्लेषण
(1) Tid. Anal.

संख्या No. 68 (T.) पार्टी Party (G & R.B.) सीजन Season 19 .

29 दिन/वार्षिक प्रसंवादी विश्लेषण आंकड़े 29 days/Annual Harmonic Analysis Data

ज्वारमापी आरेखों से ली गई घंटेवार ऊंचाइयां—मीटरों में Hourly Heights in metres from T.G. Diagrams

पत्तन Port MARMAGAO

अक्षांश Lat.:

देशान्तर Long.:

वर्ष Year 1987
मास Month June
समय Time I.S.T.

मध्यवर्ती दिन C. D.

मासिक Monthly जोड़ Sum: 926.99

माध्य Mean: 1.2875
DC = −0.0031
CMSL = 1.2844

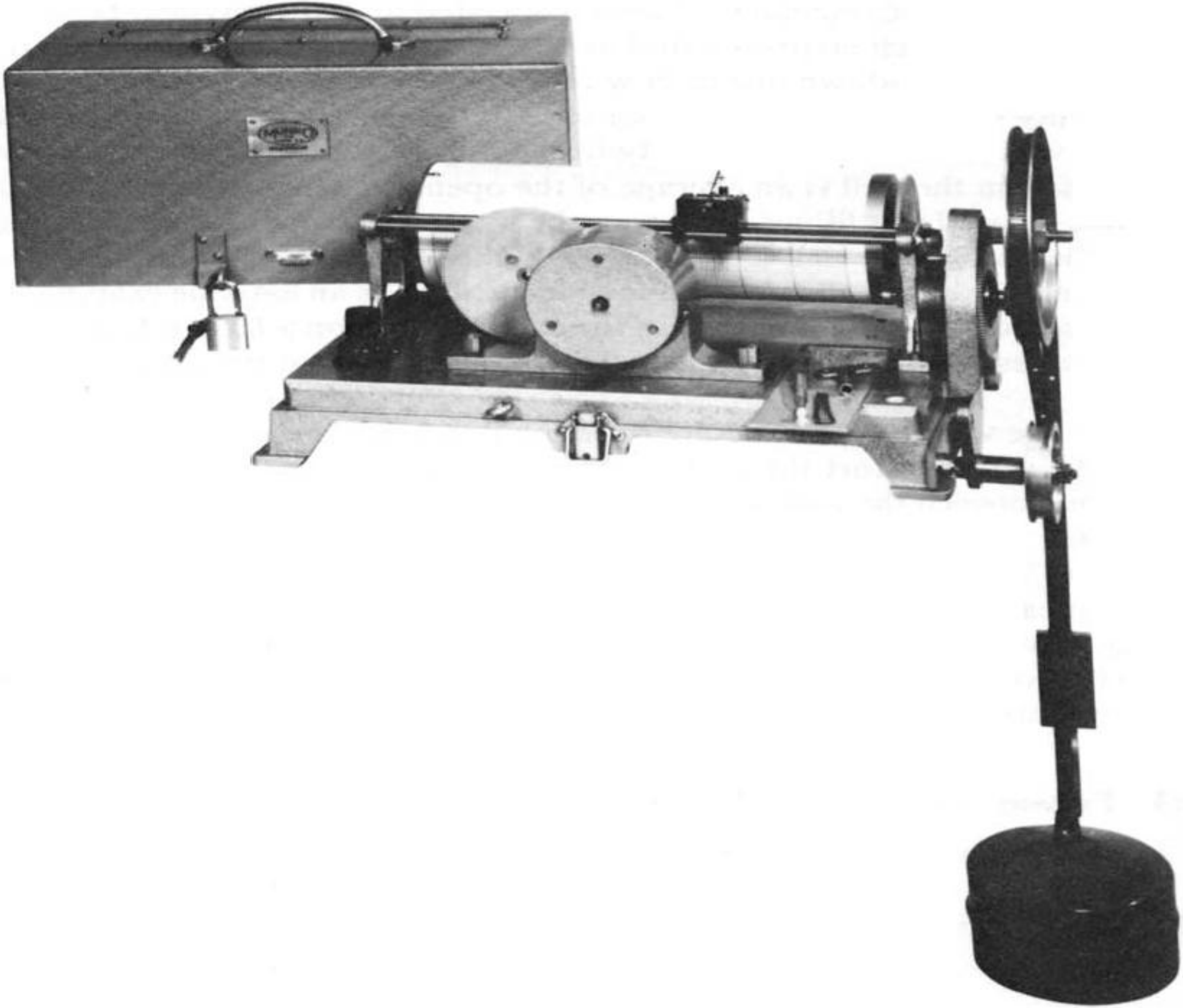
तारीख Date/समय Hour	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	जोड़ Sum
1-6-1987	1.74	1.69	1.54	1.34	1.10	0.89	0.70	0.62	0.66	0.85	1.11	1.38	1.64	1.83	1.94	1.92	1.82	1.64	1.47	1.36	1.30	1.33	1.44	1.54	32.85
2	1.63	1.62	1.60	1.44	1.26	1.08	0.90	0.72	0.67	0.76	0.99	1.21	1.48	1.66	1.82	1.92	1.88	1.75	1.62	1.42	1.30	1.29	1.34	1.40	32.82
3.	1.48	1.56	1.58	1.53	1.36	1.21	1.07	0.90	0.80	0.82	0.95	1.11	1.33	1.54	1.74	1.84	1.87	1.82	1.66	1.48	1.35	1.26	1.22	1.24	32.72
4.	1.32	1.42	1.47	1.49	1.42	1.32	1.20	1.04	0.90	0.87	0.98	1.00	1.16	1.36	1.56	1.73	1.84	1.84	1.74	1.60	1.42	1.28	1.18	1.15	32.21
5.	1.17	1.26	1.35	1.43	1.46	1.44	1.35	1.22	1.10	1.00	0.96	0.96	1.06	1.24	1.44	1.63	1.78	1.84	1.80	1.71	1.57	1.38	1.22	1.10	32.49
6.	1.03	1.08	1.16	1.28	1.39	1.49	1.53	1.50	1.42	1.32	1.18	1.05	1.06	1.19	1.34	1.49	1.64	1.76	1.78	1.68	1.54	1.36	1.12	0.94	32.33
7.	0.62	0.75	0.84	0.98	1.15	1.29	1.43	1.52	1.52	1.44	1.34	1.22	1.14	1.14	1.29	1.45	1.62	1.76	1.86	1.85	1.78	1.62	1.35	1.00	32.16
8.	0.75	0.62	0.64	0.74	0.94	1.17	1.38	1.53	1.62	1.64	1.58	1.44	1.27	1.15	1.19	1.25	1.39	1.54	1.66	1.73	1.74	1.64	1.37	1.05	31.07
9.	0.73	0.54	0.41	0.45	0.64	0.84	1.16	1.44	1.65	1.78	1.79	1.64	1.47	1.30	1.19	1.20	1.30	1.41	1.58	1.72	1.77	1.70	1.52	1.23	30.46
10.	0.87	0.53	0.31	0.24	0.38	0.60	0.92	1.27	1.52	1.76	1.91	1.87	1.68	1.43	1.27	1.20	1.18	1.26	1.42	1.58	1.70	1.75	1.63	1.38	29.66
11.	1.01	0.61	0.28	0.10	0.06	0.22	0.55	0.97	1.31	1.61	1.88	1.97	1.84	1.69	1.46	1.26	1.11	1.13	1.28	1.45	1.62	1.73	1.76	1.58	28.48
12.	1.35	0.96	0.58	0.26	0.12	0.12	0.30	0.61	1.02	1.35	1.66	1.87	1.92	1.80	1.58	1.36	1.16	1.04	1.08	1.24	1.41	1.58	1.70	1.72	27.79
13.	1.53	1.28	0.90	0.56	0.29	0.14	0.16	0.37	0.66	1.06	1.40	1.68	1.88	1.91	1.74	1.54	1.29	1.09	0.98	1.04	1.20	1.38	1.55	1.65	27.28
14.	1.68	1.56	1.24	0.86	0.54	0.36	0.18	0.22	0.43	0.74	1.10	1.44	1.73	1.86	1.86	1.70	1.45	1.18	0.99	0.92	1.00	1.18	1.35	1.52	27.03
15.	1.62	1.62	1.43	1.12	0.80	0.50	0.30	0.19	0.28	0.46	0.78	1.14	1.49	1.76	1.86	1.82	1.66	1.36	1.08	0.92	0.86	0.95	1.13	1.29	26.42
16.	1.48	1.58	1.58	1.38	1.13	0.74	0.48	0.30	0.21	0.33	0.64	1.01	1.29	1.61	1.85	2.02	1.93	1.68	1.40	1.10	0.91	0.88	0.96	1.12	27.61
17.	1.30	1.47	1.58	1.60	1.49	1.24	0.96	0.73	0.58	0.55	0.68	0.94	1.24	1.52	1.78	1.95	1.98	1.88	1.66	1.40	1.14	0.96	0.90	0.97	30.50
18.	1.12	1.30	1.46	1.60	1.62	1.50	1.34	1.15	0.98	0.88	0.90	1.04	1.28	1.51	1.74	1.93	2.06	2.04	1.92	1.70	1.43	1.18	1.00	0.91	33.59
19.	0.97	1.10	1.28	1.44	1.55	1.65	1.65	1.56	1.40	1.24	1.17	1.16	1.23	1.40	1.64	1.82	1.94	2.03	1.98	1.83	1.63	1.38	1.08 ~~0.89~~	0.88	35.01
20.	0.80	0.90	1.04	1.18	1.34	1.50	1.64	1.67	1.58	1.45	1.35	1.24	1.21	1.31	1.44	1.62	1.78	1.86	1.86	1.80	1.66	1.43	1.16	0.88	33.70
21.	0.70	0.66	0.70	0.88	1.08	1.28	1.49	1.66	1.71	1.66	1.56	1.45	1.32	1.27	1.33	1.46	1.60	1.70	1.77	1.79	1.71	1.57	1.29	1.01	32.65
22.	0.76	0.62	0.55	0.65	0.83	1.07	1.37	1.59	1.72	1.75	1.74	1.60	1.47	1.38	1.32	1.32	1.43	1.54	1.64	1.72	1.71	1.61	1.44	1.16	31.99
23.	0.86	0.66	0.48	0.43	0.61	0.82	1.07	1.35	1.61	1.76	1.83	1.76	1.61	1.47	1.36	1.31	1.31	1.39	1.49	1.60	1.68	1.64	1.51	1.32	30.93
24.	1.05	0.76	0.54	0.44	0.46	0.64	0.92	1.20	1.48	1.71	1.87	1.89	1.79	1.64	1.46	1.31	1.28	1.31	1.41	1.51	1.61	1.66	1.61	1.41	30.96
25.	1.17	0.91	0.65	0.48	0.42	0.50	0.72	1.03	1.36	1.65	1.85	1.92	1.89	1.77	1.57	1.37	1.27	1.24	1.30	1.42	1.56	1.64	1.66	1.58	30.93
26.	1.37	1.10	0.78	0.54	0.45	0.44	0.58	0.88	1.21	1.51	1.73	1.91	1.96	1.66	1.69	1.52	1.36	1.27	1.26	1.34	1.50	1.62	1.68	1.66	31.24
27.	1.50	1.27	1.00	0.74	0.54	0.48	0.54	0.74	1.04	1.38	1.68	1.88	1.99	1.99	1.89	1.68	1.47	1.32	1.26	1.33	1.43	1.57	1.68	1.69	32.04
28.	1.58	1.45	1.18	0.89	0.68	0.54	0.50	0.63	0.91	1.21	1.56	1.76	1.87	1.89	1.80	1.62	1.42	1.22	1.09	1.12	1.20	1.35	1.50	1.56	30.53
~~29~~	~~1.55~~	~~1.47~~	~~1.26~~	~~1.00~~	~~0.66~~	~~0.49~~	~~0.42~~	~~0.48~~	~~0.66~~	~~0.93~~	~~1.25~~	~~1.51~~	~~1.71~~	~~1.85~~	~~1.88~~	~~1.78~~	~~1.56~~	~~1.35~~	~~1.12~~	~~1.07~~	~~1.14~~	~~1.26~~	~~1.39~~	~~1.53~~	
~~30-6-1987~~	~~1.57~~	~~1.54~~	~~1.40~~	~~1.20~~	~~0.93~~	~~0.68~~	~~0.52~~	~~0.48~~	~~0.58~~	~~0.79~~	~~1.09~~	~~1.38~~	~~1.62~~	~~1.79~~	~~1.84~~	~~1.80~~	~~1.62~~	~~1.42~~	~~1.20~~	~~1.06~~	~~1.07~~	~~1.16~~	~~1.29~~	~~1.40~~	
29-6-1987	1.57	1.49	1.28	1.02	0.70	0.51	0.44	0.50	0.70	0.95	1.27	1.53	1.73	1.67	1.86	1.71	1.52	1.35	1.14	1.09	1.16	1.28	1.41	1.55	29.63
30-6-1987	1.59	1.56	1.42	1.22	0.95	0.70	0.54	0.50	0.60	0.81	1.11	1.40	1.64	1.81	1.86	1.82	1.64	1.44	1.22	1.08	1.09	1.18	1.31	1.42	29.91
																									926.99

ज्वारमापी आरेखों को पढ़ने व दर्ज करने वाला: T.G. Diagms. read and entered by: 12-7-90

ऊंचाइयां आधार/ज्वार दण्ड के शून्य/ज्वारमापी के शून्य के सन्दर्भ में है
Heights are referred to Datum/~~Zero of T.P./Zero of T.G.~~
ज्वार दण्ड/ज्वारमापी के शून्य के ऊपर/नीचे आधार की ऊंचाई

मिलान/जांच कर्ता: Compared/Checked by:

तारीख Date 18/9/90



Bench Mark and Leveling

To ensure that the tide gauge is on a rigid bed and has not sunk or gone up, a bench mark is etched on a firm surface.

Periodically the level of the tide gauge is checked against this bench mark by leveling exercise.

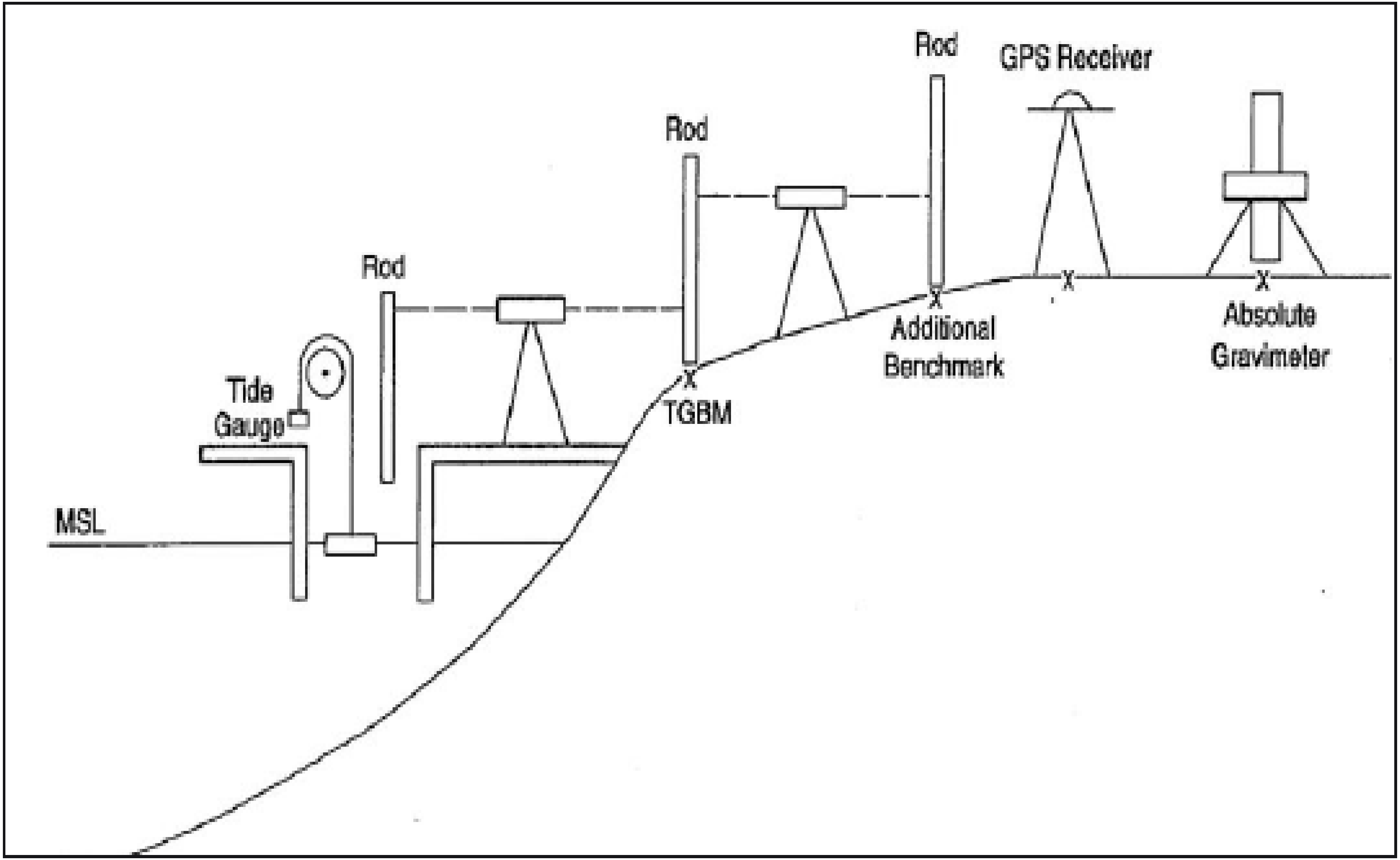


Figure 4.2 Schematic of levelling required between various benchmarks at a tide gauge station.

Bubbler Gauge

Compressed air is allowed to bubble steadily in a slow rate out of an inverted bowl. The compressed air pressure required to do so is the hydrostatic pressure of the water column above the inverted bowl and is the measure of the tide.

$$\text{Height} = (P - P_a)\ / \rho\ g$$

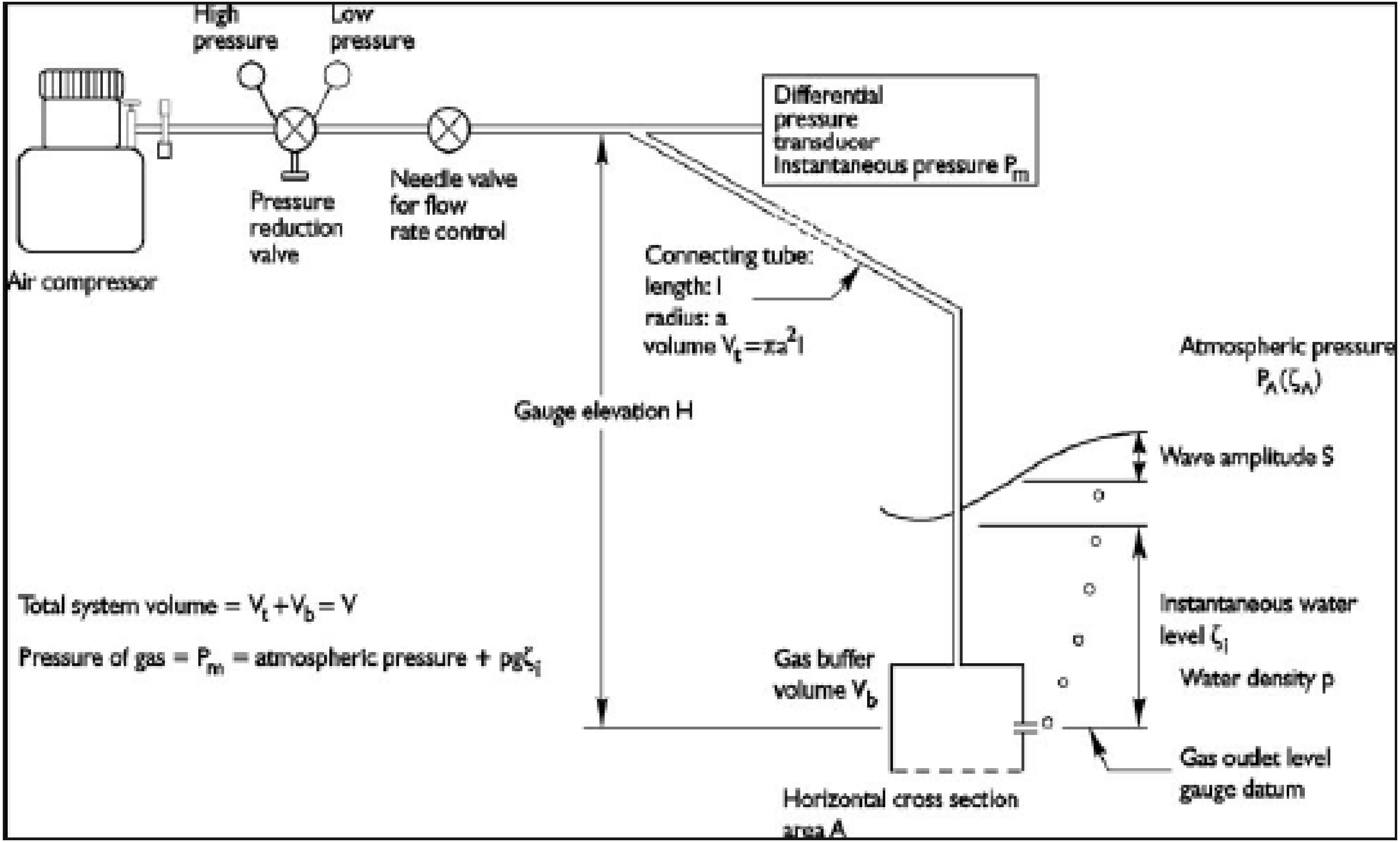


Figure 3.2 Bubbler pressure gauge.

Bubbler Gauge

Connecting tube and outlet bowl are the only components out at sea. Replacement is relatively simple.

Can be installed at any location as connecting tubes can be several hundreds of meter in length.

Suffers from density layers like any other pressure observing system.

With wave action water might enter the connecting tubes leading to serious errors in data.

Accuracy of about 0.01 m

Pressure Gauges

Digiquartz pressure sensor based gauges measure the hydrostatic pressure of the water column above the gauges and which is the measure of the tide.

$$\text{Height} = (P - P_a) \ / \ \rho g$$

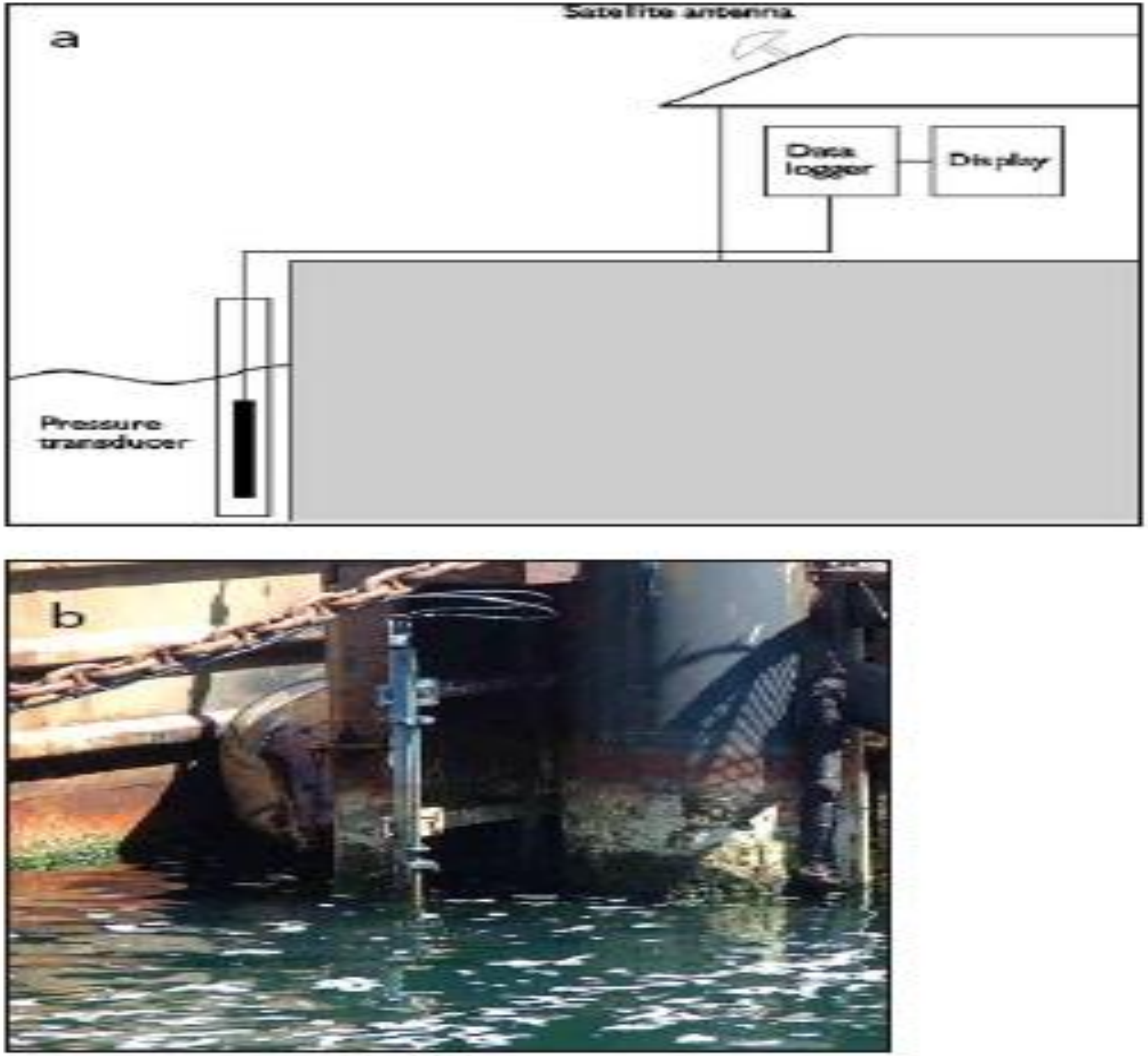


Figure 3.3 Pressure gauge.
(a) The pressure sensor is mounted directly in the sea. (b) In this case, it is fastened to a pier in Port Stanley harbour.

Pressure Gauges

Absolute pressure sensor measures pressure due to sea level and atmospheric pressure both.

Vented differential pressure sensor measures the sea level pressure alone.

Pressure Gauges

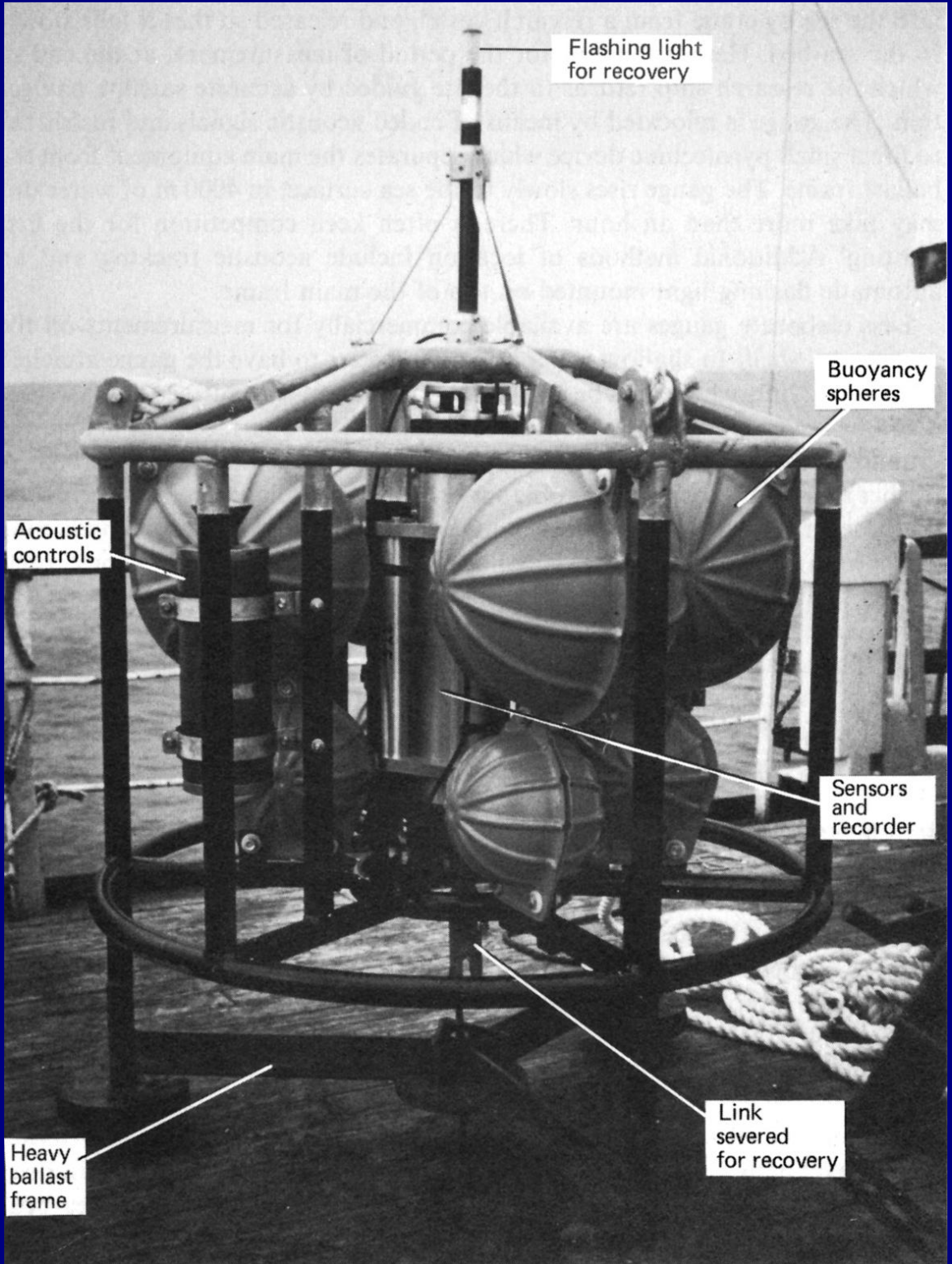
This is used at all locations, even at very hostile environments like polar regions

No vertical structure is needed

Density layers affect the observation

Wave action needs to be corrected

High maintenance cost


Flashing light for recovery
Buoyancy spheres
Acoustic controls
Sensors and recorder
Link severed for recovery
Heavy ballast frame

Offshore Pressure Gauges

Used at shallow and deep waters both

Deep water gauge data from long time installation is retrieved through acoustic link through passing ships

Complements the satellite altimeter data at high latitudes where satellites do not reach.

Used at places where long time data at fixed location with better temporal resolution is needed

Acoustic Tide Gauge

The principle of working is similar to the echo sounders.

Sound pulses are emitted from the transducer at a known height from the chart datum and their flight time from the transducer to the water level and back is calculated.

Accuracy of about 0.005 to 0.01 m

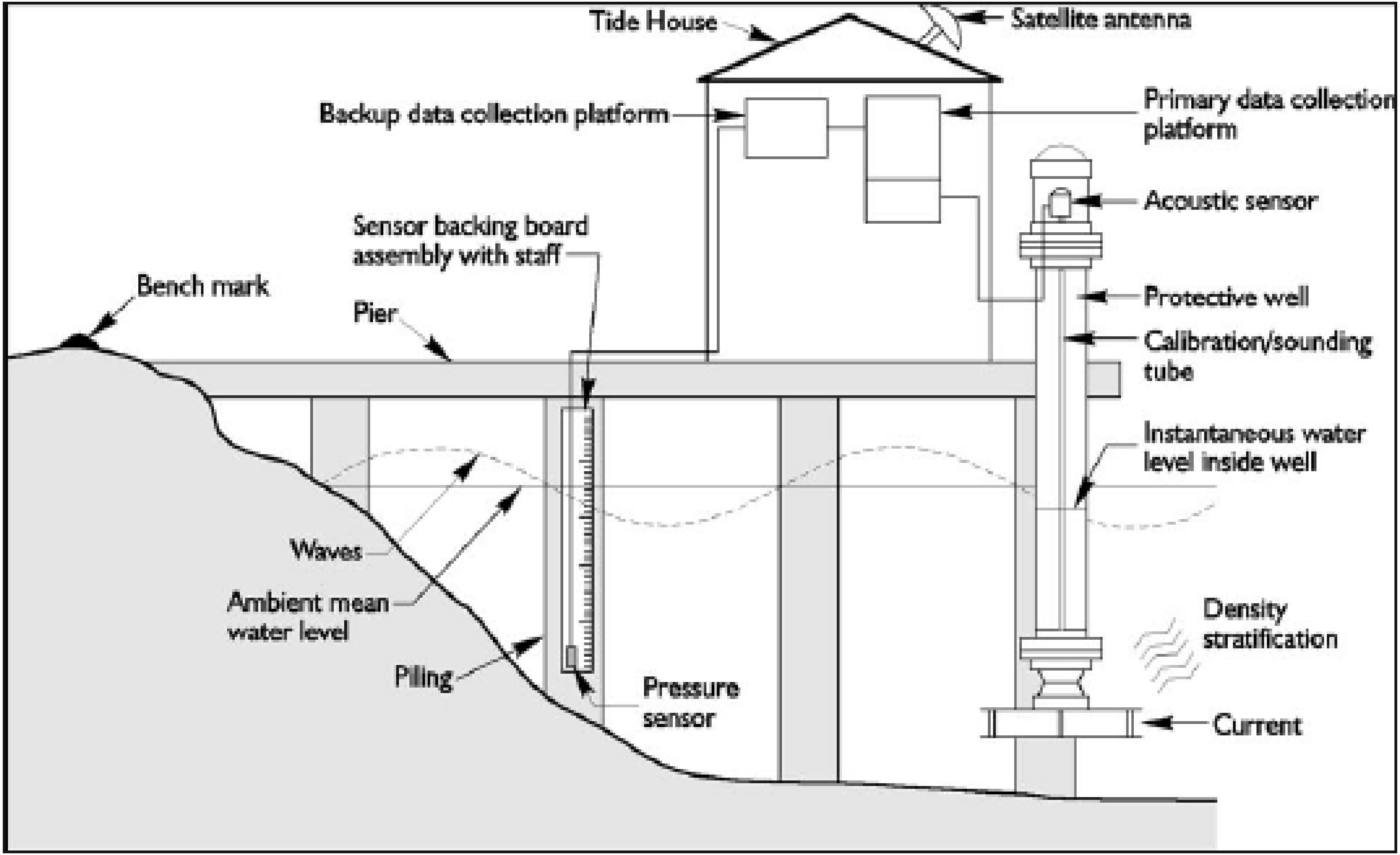


Figure 3.5 NGWLMS tide gauge.

Acoustic Tide Gauge

- Velocity of Acoustic pulses in air changes with the change in temperature gradient. Hence thermistors are present to correct the temperature variation
- Acoustic gauge in protective tube and in open air, both options are available
- Open air type suffers from secondary reflection from different surfaces of crest and trough of waves

Radar Gauge

- Radio waves, instead of acoustic pulses, from the transducer to get the height of the water level
- Averages are taken over a period of minutes which limits the use in certain field
- There are two types: 1) Frequency Modulated Continuous Wave (FMCW) where phase shift is observed. 2) Radar pulses are emitted and their flight time is observed.
- Accuracy of about 0.005 to 0.01 m

Figure 3.6 Radar tide gauges.
(a) diagram comparing a radar and a bubbler gauge (Woodworth and Smith, 2003);
(b) an OTT Kalesto test installation at Liverpool.

GPS on Surface buoys

Seems to be a straight forward observation that water level heights are with related to the reference ellipsoid.

Suffers from some defects:

Response of mean level of antenna in response to waves.

Bio-fouling affecting the settling of buoy over long period

Datum Reduction

Process of checking and preparation of data before submission to data banks

Correct data for timing errors

Height errors should be handled with utmost discretion

Gaps in data

Final stage is to deposit the data to oceanographic data bank along with:

meta data

datum correction, if any

interpolation of data, if any

GPS location coordinates

Data Sources

PSMSL – Permanent Service for Mean Sea Level

UHSLC – University of Hawaii Sea Level Center

GLOSS – Global Sea Level Observing System

Data Sources

Real time information:

for navigation, flood, tsunami warning-raw data-only automatic quality control done

Fast Data:

for gauge performance, ocean circulation variability forecast, to check satellite altimetry data stability

Delayed mode data:

Full quality control is done.

Thank you.