Iranian Tide Gauge Network

IOC/GLOSS
Technical Expert Visit to
National Cartographic Center (NCC)
Tehran, Iran

7-14 March 2004

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Norwegian Hydrographic Service
Stavanger, Norway, 4 May 2004

1 INTRODUCTION

The intention of the GLOSS technical expert visit to National Cartographic Center (NCC) in Iran was to provide advice in setting up sea level measuring stations, upgrading of equipment to provide observations in real-time, processing of historic sea level data, tidal analysis and predictions etc.

This report gives a description of the existing Iranian tide gauge network, a short report from a reconnaissance travel to three standard ports and suggestions of what should be considered when modernizing the Iranian tide gauge network.

The agenda for the technical vist is shown in Table 1.

Date	**Agenda for the day**
7 March 2004	Arriving Tehran
8 March 2004	Introductory meeting with Hydrography and Coastal Zones Surveying Department, NCC (Mr. Khoddam, Mr. Moshiri, Mr. Mehdipour) Meeting with Technical Deputy, NCC (Mr. Sarpoulaki)
9 March 2004	Inspection of tide gauges in Nakhl-e Taghi (Assalouyeh), Kangan and Bushehr (Persian Gulf)
10 March 2004	Presentation of the Norwegian Tide Gauge Network, GLOSS, Norwegian Mapping Authority and Norwegian Hydrographic Service at NCC.
11 March 2004	Mr. Moshiri and I looked on the software NCC are using for harmonic analysis and predictions and also on the system from paper charts, digitizing and storing of data.
12 March 2004	Holiday
13 March 2004	Meeting with the Director (Dr. Madad) and Technical Deputy (Mr. Sarpoulaki) at NCC. I informed them about GLOSS and about different types of tide gauges.
14 March 2004	Departure Tehran

Table 1. Agenda for the technical visit to Iran.

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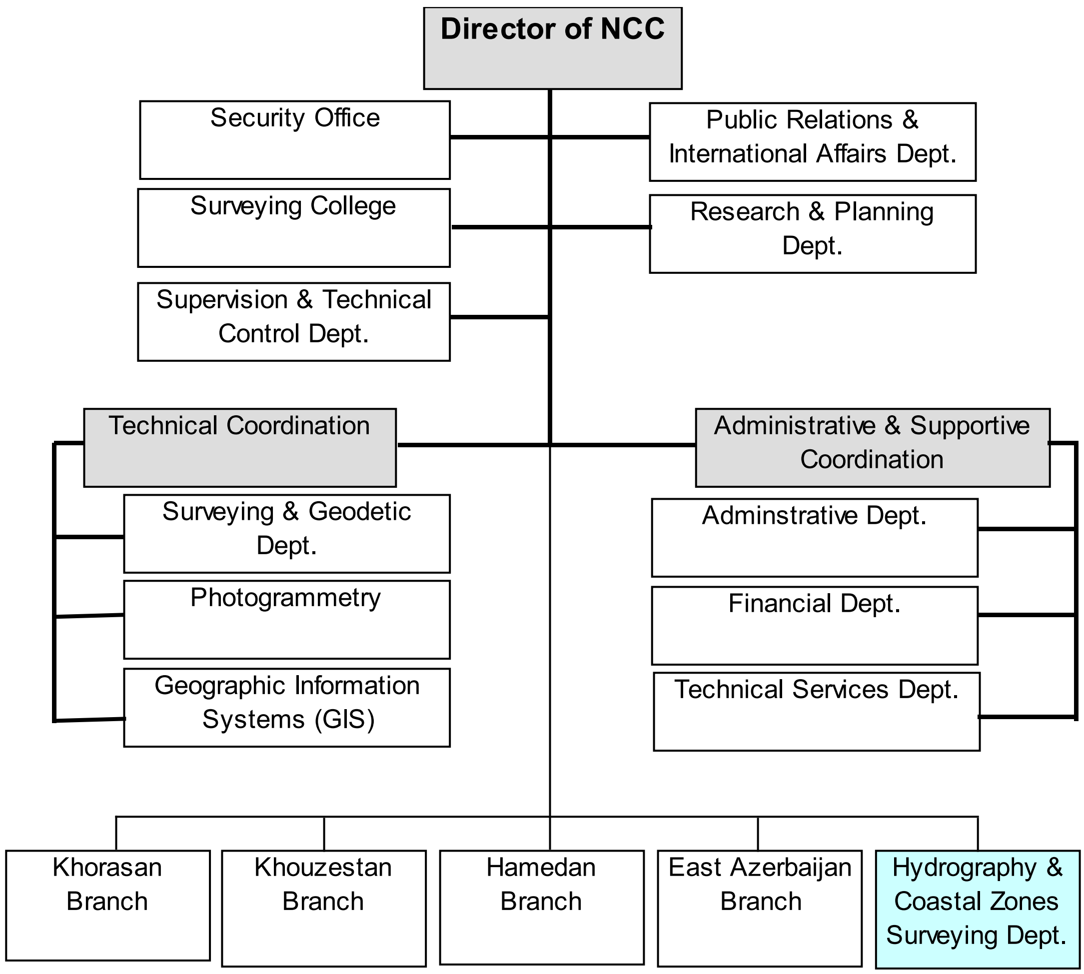
2 NATIONAL CARTOGRAPHIC CENTER (NCC)

National Cartographic Center of Iran (NCC) was established in 1953. NCC is responsible for planning, directing, standardization and supervision of map and spatial information production in Iran. The organization is located in the western part of Tehran and has about 1000 employees who are working in different departments and sections to achieve the objectives and goals of NCC.

Dr. Mohammad Madad is the Director of NCC and the Deputy of Management & Planning Organization in Iran.

Organization Chart



2.1 Hydrography and Coastal Zones Surveying Department

The most important tasks of the Hydrography and Coastal Zones Surveying Department are:

- Preparing paper and digital navigational charts of Persian Gulf, Oman Sea and Caspian Sea.
- Establishment of permanent stations for tidal observations along the southern coasts and sea level observations along the Caspian Sea coasts in order to determine the mean sea level and chart datum.
- Preparing annual tide tables.
- Short-term tide observations along the southern coasts in order to determine the sea surface topography.

The department has about 55 employees and 4-5 of these are working with tides (sea level measurements, digitizing of paper charts, tidal analyses, tidal predictions, tide tables etc.).

Mr. Mohammad Hassan Khoddam Mohammadi is the Head of the Department.

3 EXISTING TIDE GAUGE NETWORK

3.1 Background

The permanent tidal stations in Iran were established by NCC in order to :

- correct measured depths (sea surveying)
- determine chart datum (CD), mean sea level (MSL) and other tidal datums for sea surveying
- make tide tables and tidal predictions

For the sounding operation, tidal information is necessary for the reduction of soundings to a datum. The requirement is twofold. On the one hand, a suitable datum must be determined, and on the other hand, observations of tidal height above the datum are required throughout the sounding operation for the reduction of soundings.

3.2 Tide Gauge Network

The Iranian Tide Gauge Network, operated by the National Cartographic Center (NCC), records tidal elevations at 9 locations along the Persian Gulf and the Oman Sea. At 8 of the locations the water level is measured using a mechanical float gauge manufactured by the Ott company in Germany. In Nakhl-e Taghi there is a Valeport Model 710 tide gauge system. This is a vented strain gauge transducer system. The first NCC tidal stations were established in 1989 in Bushehr, Kangan and Shahid Rajaee

3.2.1 Mechanical float gauge (Ott)

The float gauge consists of a traditional float, chain and counterweight system and a recording chart mounted on a rotating drum which is driven at a constant speed by a mechanical clock mechanism. A typical stilling well in Iran is a steel tube which is flat bottomed and has a side inlet about 30 cm above the bottom of the tube. The diameter of the tube is about 30 cm and the diameter of the inlet is about 10 cm according to the staff at the Hydrographic Department. The tube is fixed to the quay level and to the quay front or quay pillar. The paper chart is sent every month by the local operator to NCC in Tehran.

Comments : For a normal stilling well the international recommendation is that the ratio between the inlet and well diameter should be 1:10, while NCC is using 1:3. It is therefore a very mild damping in Iran.

3.2.2 Valeport Model 710

Using a vented strain-gauge transducer, the Model 710 measures water level referenced to local chart datum, and can be calibrated on site for local water conditions. All data can be displayed on site and logged to a memory capable of storing 5 years of data. The data are downloaded by a local operator every month using a PC connected to a RS232 output channel on the gauging station display unit. The data are sent to NCC in Tehran for storing and analysing.

3.2.3 Standard Ports

Table 2 and Figure 1 lists the current NCC operated tide gauge network. All observed tidal date are on digital form are stored and available at NCC.

Port	Position	Year of establishment	Z_0 (m)
Khorramshahr	30°25'N, 48°12'E	2003	0.66
Imam Hassan	29°50'N, 50°15'E	1990	1.52
Khark Island	29°16'N, 50°20'E	2002	1.29
Bushehr	28°59'N, 50°50'E	1989	1.21
Kangan	27°50'N, 52°03'E	1989	1.21
Nakhl-e Taghi	27°30'N, 52°35'E		1.21
Shahid Rajaee:	27°06'N, 56°04'E	1989	2.30
Jask harbour	25°39'N, 57°46'E	1997	1.68
Chabahar	25°17'N, 60°37'E	1990	1.71

Table 2. NCC operated tide gauges. Z0 is the distance between mean sea level (MSL) and Chart Datum (CD).

Figure 1. Location of Iranian tide gauges.

3.2.4 Bench Marks (BM) and Levelling

A tide gauge must be coupled to Bench Marks (BM) in the vicinity of the gauge. The tide gauges in the Iranian Tide Gauge network are connected to Bench Marks established by NCC. NCC does the precise levelling, i.e . they are responsible for determining the vertical distance between the Bench Marks and the Contact Point at the tide gauge. The levelling is performed several times every year. The NCC Bench Marks are connected to the Iranian National Levelling Network.

Comments: The 'GLOSS standard' is levelling once a year so this is very acceptable.

3.2.5 Calibration
The tide gauge is calibrated by making its readings equal to the observations on a tide pole installed beside the tidal station.

3.3 Data Management at NCC
The paper charts are digitized by staff at the Hydrographic Department at NCC and 30 minute water level observations on digital format are available from all the tide gauges. The observations are stored in files, each file contains one year with data from one tide gauge.

Using Microsoft Excel the observations are compared with tidal predictions. If the inspection of the data reveals errors in the observed heights, the data are manually corrected.

The 30 minute values may be converted to hourly values using software developed by NCC. The resulting file is a ”tide2.dat” file which is the input file to the IOS (Institute of Ocean Sciences) Tidal Package (M.G.G.Foreman).

3.3.1 Harmonic analysis and tidal predictions
NCC is using the IOS Tidal Package (Foreman) for tidal analysis and prediction. This software is a set of programs, manuals, and test data for analysing and predicting tidal elevation time series.

3.3.2 Tide Tables
Times and heights of high and low water are calculated using the IOS Tidal Package. The resulting FILE10.DAT file from this package is converted to a format specified by NCC using software developed by NCC.

"Iranian Tide Tables (Persian Gulf and Oman Sea)" are published by the NCC annually. The tables give times and heights of high and low waters for all the standard ports and about 50 temporary ports along the Persian Guld and the Oman Sea. A list of the main harmonic constants (M_2, S_2, K_1, and O_1) for the ports are included in the publication.

The times of high and low water are given in Iranian standard time (=UT + 3.5 hours). When Summer Time is being kept, one hour must be added to the predicted times.

The heights are given in metres above Iranian Chart Datum.

3.3.3 Chart Datum – Iran
NCC is using a ”modified” Indian Spring Low Water (ISLW) as Chart Datum.

The original formula for ISLW as Chart Datum is : $Z_0 - (H_{M2} + H_{S2} + H_{K1} + H_{01})$
Iran is using this formula : $Z_0 - 1.1\,(H_{M2} + H_{S2} + H_{K1} + H_{01})$

Indian spring low water (ISLW) *- A tidal datum approximating the lowest water level observed at a place, originated by G.H. Darwin for the tides of India at a level below MSL being equal to the sum of amplitudes of the harmonic constituents M2, S2, K1 and O1; usually below that of the lower low water at spring tides. Also called Indian tide plane. (Hydrographic Service, Royal Australian Navy).*

3.4 Existing competence at NCC

The people responsible for the tidal activities at NCC have hydrographic education from Iran and from courses abroad (e.g. India). During their education they have got knowledge of tidal fundamentals (e.g. tidal forces), vertical datums, water level observations, analysis and predictions, use of tide tables, shallow water dynamics, tidal streams etc.

The staff has experience in operating the Iranian tide gauge network, maintenance and calibration of tide gauges (Ott and Valeport), levelling, running the IOS Tidal Package for tidal analysis and predictions, making annual tide tables for Iran, digitizing paper charts etc.

3.5 Temporary Tide Gauges

The immediate function of a temporary water level gauge is to provide the information necessary for the transfer or establishment of chart datum and for the reduction of soundings to this datum. If properly recorded and documented, however, the information from such gauges may serve other functions as well, such as provision of harmonic constants for tidal prediction and of information on short-term water level fluctuations.

NCC is using vertical mounted tide poles (staff gauges) as temporary tide gauges. Local operators read the water level every 30 minute on the tide pole and write down the readings on a form, which is sent to NCC in Tehran for digitizing. Normally NCC try to obtain at least one month with water level record at each location, to permit proper tidal analysis of the data.

3.6 Tides in the Persian Gulf

The Persian Gulf is a shallow sea which has mixed diurnal and semidiurnal tide. It is a largely enclosed basin with only a limited connection to the Oman Sea through the Strait of Hormuz. The semidiurnal tides develop two anticlockwise amphidromic systems, with a node or anti-amphidrome in the middle of the basin, see Figure 2. Near the centre of the basin the changes in tidal level are predominantly semidiurnal, whereas near the semidiurnal amphidromes they are mainly diurnal. At the northwest and southeast ends of the basin the tidal levels have mixed diurnal and semidiurnal characteristics.

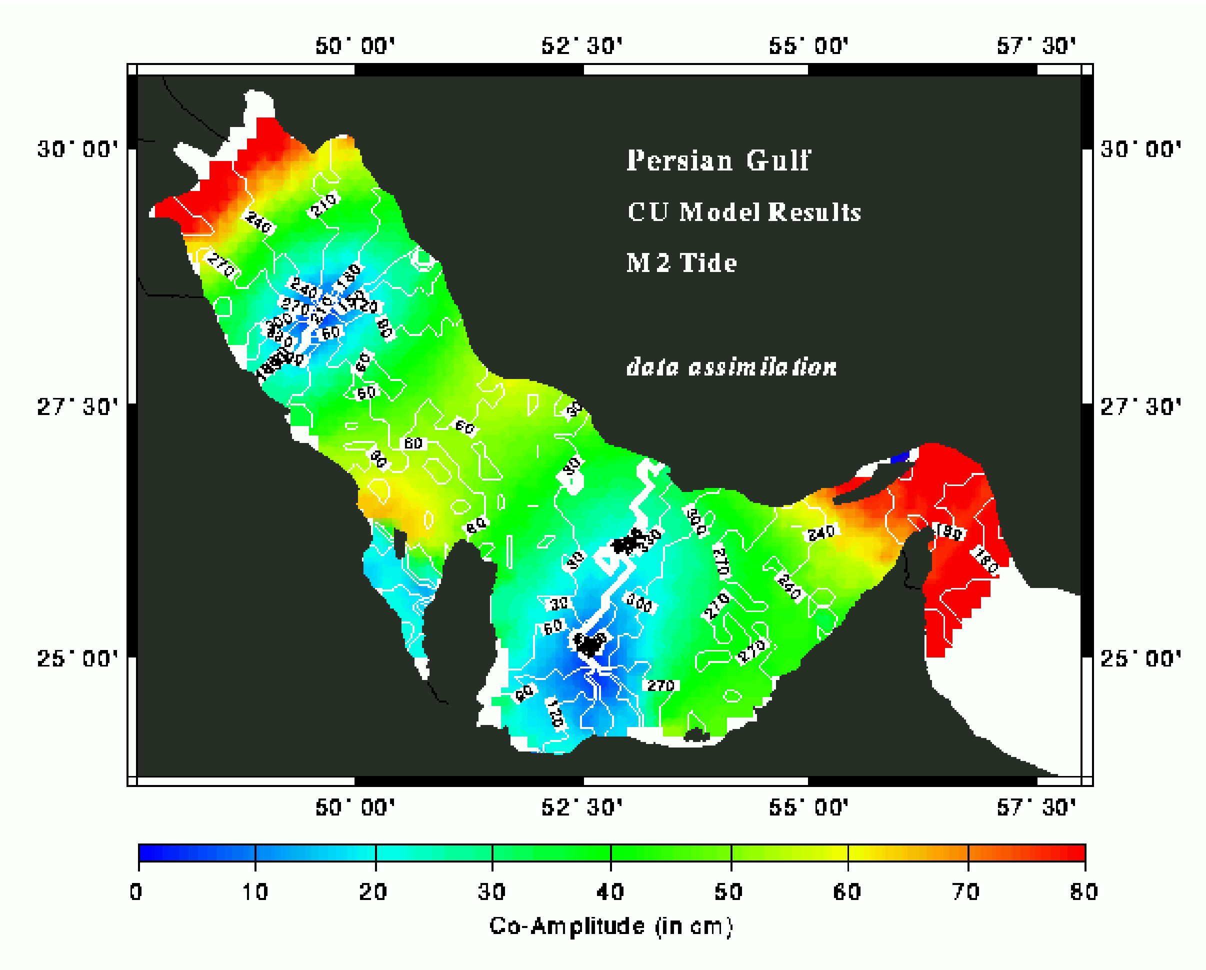


Figure 2. The Persian Gulf M2 tide derived from the CU/NAVOCEAN model using data assimilation of tide gauges. 18 km resolution on an inclined grid. Source: Naval Oceanographic Office.

4 INSPECTION OF SITES

On Tuesday 9 March 2004 I visited three standard ports (Nakhl-e Taghi, Kangan and Bushehr) at the Persian Gulf together with staff from NCC (Mr. Khoddam and Mr. Moshiri).

4.1 Nakhl-e Taghi (Assalouyeh)

The tide gauge is located in a busy fishing port in the village Nakhl-e Taghi. The sensor is installed in a solid tube which is fixed to the quay wall (see Figures 3-6). There is mounted a steel construction around the tube to protect it and the Valeport sensor against collision from the fishing boats. As we can see from the pictures it is not a good location for a permanent tide gauge. The staff from NCC is aware of this and we therefore had a meeting with the Port Authorities in the area and they would assist NCC to find a better location for the tide gauge at the new port, which is under construction.

When choosing a new site, my recommendation is that it must be possible to install any kind of tide gauges at the location. If one is choosing for example to install a float gauge now, it must be possible to install a radar, pressure sensor or a acoustic tide gauge at the same location in the future. There should be no problem to get access to 220VAC, but it is recommended to have battery bakcup for the tide gauge. For data transmission it is possible to use ordinary telephone line (preferably) or mobile telephone line. Other communication methods could be satellite links or radio links. But this has to be further investigated.

Figure 3 and 4. Valeport Model 710 installed at the fishing village Nakhl-e Taghi.

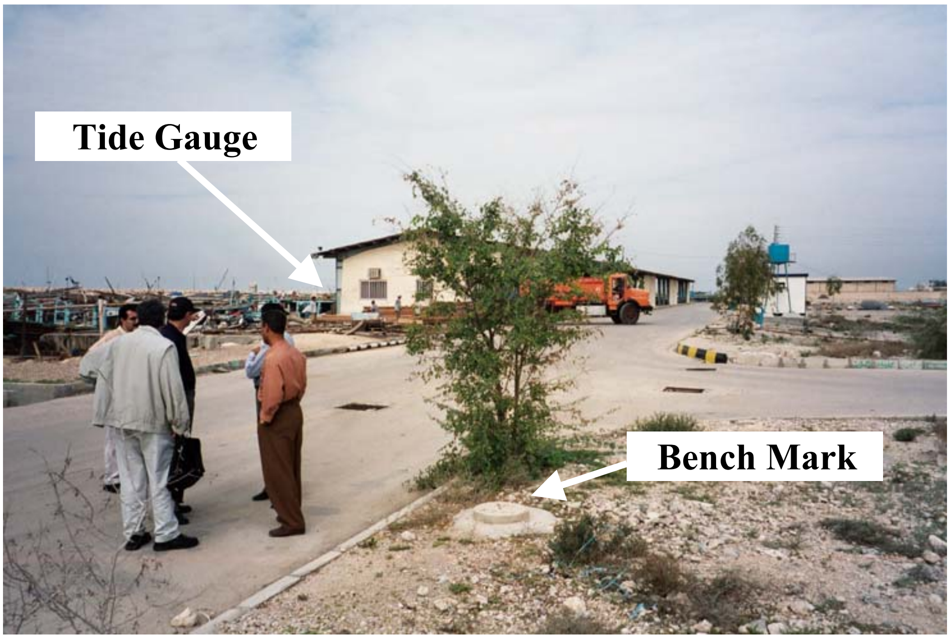


Figure 5. Location of Tide Gauge and Bench Mark at Nakhl-e Taghi. The bench marks are located near the tide gauge and are tied into the Iranian levelling network.

Figure 6. Bench Mark at Nakhl-e Taghi

4.2 Kangan

The tide gauge (float gauge, Ott) is located on a quay in the Kangan port. Kangan is a small fishing village located about 250km south-east of Bushehr. The infrastructure at this location makes it possible to choose among several types of tide gauge sensor (i.e. float, pressure sensor, radar or acoustic tide gauges). There should be no problem to get access to 220VAC, but it is recommended to have battery bakcup for the tide gauge. For data transmission it is possible to use ordinary telephone line (preferably) or mobile telephone line. Other communication methods could be satellite links or radio links. But this has to be further investigated. There exist bench marks not far from the tide gauge and they are tied into the Iranian levelling network.

Figure 7. Location of tide gauge in Kangan port.

Figure 8. Float gauge manufactured by the Ott company.

4.3 Bushehr

The tide gauge (float gauge, Ott) is located on a quay in the Bushehr port. The population in Bushehr is about 200,000 and the port area is quite busy with boat connections to major cities in the Persian Gulf (e.g. Bahrain, Kuwait and Qatar).

The infrastructure at this location makes it possible to choose among several types of tide gauge sensor (i.e. float, pressure sensor, radar or acoustic tide gauges). There should be no problem to get access to 220VAC, but it is recommended to have battery bakcup for the tide gauge. For data transmission it is possible to use ordinary telephone line (preferably) or mobile telephone line. Other communication methods could be satellite links or radio links. But this has to be further investigated. There exist bench marks not far from the tide gauge and they are tied into the Iranian levelling network.

Figure 9 and 10. Float gauge (manufactured by the Ott comapny) in Bushehr.

Figure 11. Float gauge (manufactured by the Ott comapny) in Bushehr.

Figure 12 and 13. Bench Marks in Bushehr. The bench mark are located near the tide gauge and are tied into the Iranian levelling network

5 NEW TIDE GAUGE NETWORK

Modernizing a tide gauge network (or establishing a new modern tide gauge network) is a combined technical and organisational challenge.

5.1 Competence

NCC has since 1989 been running a tide gauge network using mechanical float gauges (in Nakhl-e Taghi they have been running a digital Valeport Model 710 gauge the last 2-3 years). They have during these 15 years gained a lot of knowledge running an analog tidal network. But it is very important that the competence in modern tide gauge technology, digital signal processing, data analysis, database technology, programming etc. is built up during the modernization. The organization has to be aware that operating a modern tidal network is a continuous development process where the routine operation is done parallel to running improvements and development work.

Recommendation 1:

NCC establish co-operation with international institutions to build up competence in modern tide gauge technology.

5.2 Training materials, training courses, transfer of technology

The PSMSL (Permanent Service for Mean Sea Level) and GLOSS (Global Sea Level Observing System) provide information and training materials in electronic form:
http://www.pol.ac.uk/psmsl/training/training.html

With funding from IOC and with various national inputs a sea level training course has been held almost every year since 1983. Announcements of future courses are posted on the PSMSL web page (see above). The role of training is crucial, in order to instill and maintain common, high standard throughout the GLOSS network.

If NCC gets assistance from e.g. other Hydrographic Offices, international companies or manufacturers, to install and implement a modern tide gauge network then a part of the contract should be training and transfer of technology to local staff.

Recommendation 2:

NCC staff attend IOC/GLOSS sea level training courses.

5.3 Tide gauge network, overview.

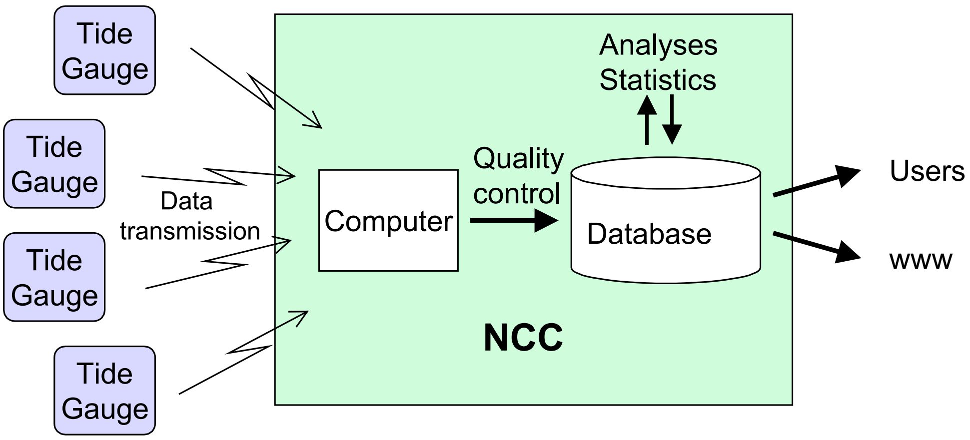


Figure 14. Tide gauge overview.

A modern tide gauge network consists of several tide gauges that are connected to a central computer by some kind of communication system (telephone, satellite, radio etc.). After quality control the data are stored in a database where they can be analysed and distributed to internal or external users.

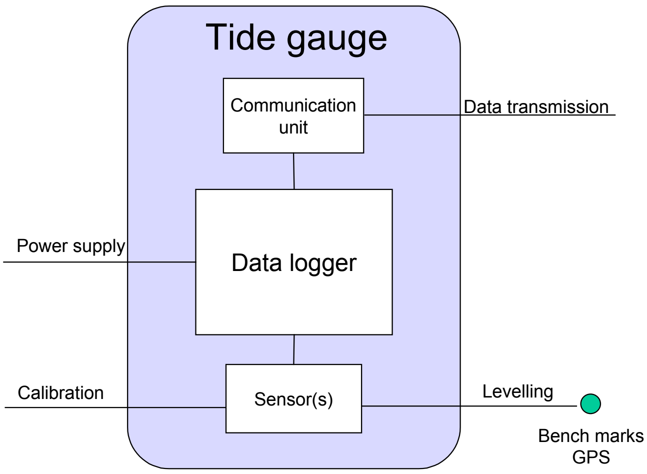


Figure 15. Tide gauge.

The tide gauge itself is composed of a data logger that reads and stores data from different sensors and a modem that communicates with a computer at National Cartographic Center (NCC). Some kind of power supply is needed (with battery backup), and the water level sensor needs to be levelled from a stable bench mark and calibrated at regular intervals. Furthermore a solid and stable construction for the sensors is required, and the site has to satisfy certain conditions concerning water depth, environmental conditions, ships traffic, currents, access etc.

5.4 Tide gauge

5.4.1 Site selection

The number of tide gauges in the network and the areas where they should be located depends on different requirements and other relevant information. An important objective of a tide gauge network is to give good coverage of the entire coast as seen from a tidal point of view. And also taking into consideration existing Iranian tide gauges, the needs of NCC and other Iranian institutions, international needs (e.g. GLOSS) etc. This should, of course, be achieved by the lowest possible number of stations in order to minimise logistic burden and overall costs. Reconnaissance visits must be made to each site, and the reconnaissance report must describe things like:

- Existing tide gauges
- Water depth
- Environmental conditions
- Proximity to rivers
- Strong currents
- Permission from land owners and/or local authorities
- Easy access
- Electrical power
- Telephone
- Existing bench marks or possibilities to build stable ones (three bench marks are preferred).
- Possibilities for continuous GPS measurements
- Future plans for the site (construction works)
- Etc.

It is advised that personnel from National Cartographic Center (NCC) participates in this work.

In the IOC Manuals on Sea-Level Measurement and Interpretations, Volume I – III, there are guidelines for choosing a tide gauge site.

Comments : GLOSS most likely is interested in original higher frequency data from 2-3 of the Iranian standard ports.

Recommendation 3:

By taking into consideration existing Iranian tide gauges, the needs of NCC and other Iranian institutions, international needs (e.g. GLOSS) etc. NCC (in co-operation with other international institutions) should do an analysis to estimate the needed number of stations in the Iranian tide gauge network.

5.4.2 Technology

Traditionally the water level has been measured with a float gauge in a stilling well. Today several other sensors can be used like pressure sensor tide gauges, acoustic tide gauges and radar gauges. They all have their advantages and disadvantages concerning both function and price. The preferable solution is to use the same sensor at all the sites. In the IOC Manual on Sea-Level Measurement and Interpretation, Volume III, there is a table presenting a summary of the main conclusions on the relative merits of each gauge technology, estimates of the likely cost of a basic system with gauge, data transmission (e.g., modem) and meteorological package etc. There is a range of prices, and also a range of hidden costs associated with installation, maintenance, data acquisition and data processing which have to be taken into account before one can make a proper choice.

Some options could be:

- **Radar gauge**
  Several companies now supply water level recorders, which use the time of flight of a pulse of radar, to measure sea level. In principle, radar should be insensitive to the temperature effects. Radar gauges have during the last years been undergoing tests in UK (Proudman Oceanographic Laboratory), USA (National Oceanic and Atmospheric Administration), Spain for ESEAS (European Sea Level Service), France, The Netherlands etc. The radar gauges offer advantages over some other types of gauge with regard to ease of installation and maintenance. However, these features could present drawbacks in certain locations, if sites are exposed to harsh environmental conditions or if there are site security problems. Therefore, they may not be suitable for all locations, even if they may prove to have acceptable ($\leq$ 1 cm) accuracy over long periods.

- **Float gauge – Upgrading**
  The float gauge could be upgraded to modern standards using shaft encoders, data loggers and electronic data transmission. Norway now operate float gauges with shaft encoders and electronic data transmissions. One reason for an operator to choose a float system is the advantage of its being 'low-tech' and, therefore, relatively low cost. But it is clear that there can be stilling well density and siltation problems using a float gauge. There is also a need for bulky stilling well installations.

  Recommendation 4:

  To get some experience with new technology NCC should purchase 2-3 new tide gauges and install them in e.g. Kangan and Bushehr and operate them parallel with the Ott float gauges.

5.4.3 GLOSS Requirements and needs

The tide gauge must be capable of measuring to centimetre accuracy in all weather (especially wave) conditions for the temporal averaging indicated (typically hourly).

An important principle is that if one technology is replaced by another, then there should be a period of overlap during which both are operated in parallel and inter-compared in order to validate the centimetric requirement. An ideal period would be a decade. However, such a long period will be impractical in most cases, and several years will be more suitable.

GLOSS:

- Establishment of high quality global and regional sea level networks for application to climate, oceanographic and coastal sea level research
- Sea level stations around the world for long term climate change and oceanographic sea level monitoring
- Coordinated by the Intergovernmental Oceanographic Commission (IOC)
- Major contributor to IOC's Global Ocean Observing System (GOOS)

For GLOSS it is very important do receive mean sea level (MSL) and high frequency (HF) data from sea level stations all around the world. Sea level data from Iran would therefore be very appreciated.

5.4.4 Data transmission

The method of data transmission used depends on the time delay considered adequate and the distance involved. Time delays can vary from zero (i.e. 'real time' data) to perhaps a year or longer (e.g. if a data logger is to be recovered from a remote site). The following exists:

- Telephone line (public or fixed line)
- Mobile (GSM)
- Internet
- Satellite links
- Radio links

Communication software can be available from the manufacturers of the data loggers, but it might be necessary with modifications to satisfy the specified requirements.

5.4.5 Datums and datum connections at the tide gauges

A tide gauge must be coupled to bench marks in the vicinity of the gauge. At least three bench marks are advised, even more if the ground is unstable.

It is now possible to measure the vertical position of the tide gauge by continuos GPS (Global Positioning System) measurements. This gives the height of the sea level relative to the "centre of the earth", independent of any local vertical movements of the ground. Some of the gauges should have this equipment (there must be free sight to the satellites).

Recommendation 5:

It is recommended that NCC get in connection with international institutions/services like UHSLC, ESEAS, POL etc. to get information about how and where CGPS – stations should be installed.

5.4.6 Calibration, levelling and maintenance

If local people or authorities can do this, the operation of the network will be easier and cheaper. The levelling must be done with high precision equipment.

5.5 Data management

The tide gauges and data transmission are only part of the network. Quite as important is a good system for quality control, documentation, data processing (analyses) and archiving.

5.5.1 Quality control

Must be done regularly and before the data are made available for the users.

5.5.2 Data base

The best way to archive the data is in a database. Important documentation (equipment change notes, calibration records, levelling reports, maps, photographs etc.) should also be stored in the database.

5.5.3 Data analyses and statistics

Software for tidal analyses, tidal predictions, statistics and secondary port analyses must be installed if National Cartographic Center (NCC) wants to be able to provide a basic service. The necessary competence must also be present in the organisation. NCC already has competence in using the IOS Tidal Package for tidal analysis and predictions.

5.5.4 Data export, data exchange

A database is a very good foundation for displaying and exporting data. For internal use there should be a possibility of displaying data on the local network. For external use the Internet is a solution preferred by many agencies.

Recommendation 6:

Data is sent to PSMSL and GLOSS on a regular basis:

• PSMSL, Monthly and annual means.	Simon Holgate,	simonh@pol.ac.uk
• BODC, Higher frequency data (delayed mode).	Lesley Rickards,	ljr@bodc.ac.uk
• UHSLC, Higher frequency data (fast mode).	Mark Merrifield,	markm@soest.hawaii.edu

It is important to be aware of that sea level data is important not only for NCC but also on a:

- **Locally and nationally perspective**
  - ✓ calculate tidal datums and stastics to help harbour authorities, local governments, contractors etc.
  - ✓ traffic guidance and safety ('near' real time data)
  - ✓ determine vertical chart datum
  - ✓ vertical land movements

- **Regionally perspective**
  - ✓ numerical models (e.g. storm surge forecast)
  - ✓ research

- **Globally perspective**
  - ✓ global change research
  - ✓ calibration of satellite altimetry
  - ✓ earth system research

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