# INTEGRATION OF HYDROGRAPHIC AND TOPOGRAPHIC DATA FOR COASTAL GIS SOLUTIONS

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## 1. INTRODUCTION

Maritime commerce is a basic element for a nation's economy. Some statistical information tells us, that more than 80% of international trade in the world is carried by sea. What shipping industry needs is efficiency and safety. Poorly charted areas and lack of information can cause voyages to be longer than necessary, may prevent the optimum loading and unloading of ships and thus increasing costs.

Slovenia is a member of the International Hydrographic Organization (IHO) since 15. April 2002. This brings certain rights and also some responsibilities for Slovenia as a young maritime country. Although we have only some 45 km of a coastline, we have to assure safe navigation through our waters. That means hydrographic activities, production and updating of nautical charts and publications, and also survey of a coastline.

Slovenia started its hydrographic activity soon after independence. First hydrographic survey was finished in 1998 with a co-operation with Navoceano, USA, in 1999, 2000 and 2003 three surveys were done by Slovenia, in 2002 a joint survey in co-operation of Slovenia, Croatia and Italy was done in area of the Bay of Piran. With this we acquired required data for production of our own nautical charts. In 2001 and 2002 we surveyed also complete coastline from the border with Italy to the border with Croatia.

Having all this data available, they soon started to be interesting source of information for a number of different users, from research purposes, coastal zone development, to construction of piers and marinas. All this data and information were pointing in a direction of establishing a maritime GIS. For purpose of such a GIS, the "link" between hydrographic and topographic data is needed. And precise coastline suits this purpose very well. The hydrographic and land data meet on a coast.

## 2. TOPOGRAPHIC DATA

### *2.1 Precise coastline – why?*

History of hydrographic and land survey is long and interesting. Surveys were carried out in a lot different way then today. The equipment was different and less accurate, the methods were suitable for instruments of that day. Using lead line for acquisition of soundings nowadays when we use modern ultra sound sonars seems distant memory. The same is with the determination of ship's position. From visual methods (measuring angels by optical instruments – sextant or theodolite) in the old days, we switched to electronic methods and lately to satellite positioning methods, GPS.

The accuracy of "old" surveys, comparing to the equipment of today, seems poor. But, for the time being that was sufficient. Problems, or rather difficulties, arise today, with greater maritime traffic, bigger ships and more precise depths. Hydrographic offices, understandably, due to the lack of funds, time and increasing need for fast and precise navigational information, integrate old coastline with newly acquired soundings. This of course reflected in a difference of position of old survey of a coastline and new depths. There is also the effect of transformations of co-ordinates between old coordinate systems, in which nautical charts used to be and new system (nowadays based on ellipsoid of WGS84). There were occasions where new depths "landed" on a coast.

In order to avoid such a situation, the best way is to survey (or re-survey) a coastline. This is also practical since in years a coastline changed. The erosion, accumulation by rivers, construction of new ports and marinas created a new coastline.

### *2.2 Definition of a coastline*

There are many definitions of a coastline. Lets say, that for the purpose of hydrography we use definition from the Hydrographic dictionary (IHO 1994): "Coastline is the line, where shore and water meet." Terminology of coast and shore is rather confused and terms shoreline and coastline are generally used as synonymous.

Although the definition is rather obvious, looking into details, one may soon be faced with difficulties. Determination of a coastline for navigation must mean that it is safe for navigation. And what is safe for navigator? The coastline in high or low tide? In both cases the definition stands correct – line where shore and water meet. We felt somewhat relieved in this matter since the difference between low and high tide in Slovenia is not very high. The maximum difference would be around 1 metre. And shoreline itself is not flat, so horizontal difference between high and low waterline is not great. Still, we need clear answer which level of water has to be used as coastline used for navigation.

The reference document for that is The Law of the Sea (IHO 1993), which recognizes three different, and for navigation important coastlines (figure 1):

- Hydrographic coastline (which is determined as High Water Level),
- Geodetic coastline (which is determined as Mean Sea Level, and is usually used as datum level for land (topographic) maps),
- Limit of drying heights known also as Chart Datum (which is determined as Low Water Line).

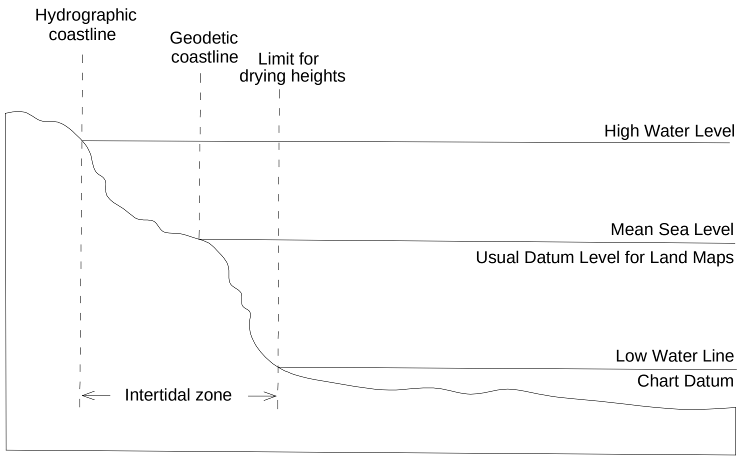


*Figure 1: Different coastlines*

On the other hand Slovenian Maritime Law (from Official gazette of Republic of Slovenia, No. 26-1582/01) doesn't give the definition of a coastline, but we can find it in Slovenian Water Act as: "Coastline extends to the line of highest tide."

Further investigation of definitions leads us to IHO chart specifications (IHO 2001b), among hydrographers known also as M-004. There we find the following definition, how the coastline should be charted on nautical charts: "The coastline (shoreline) shall be represented by high water mark, or by the line of mean sea level where there is no appreciable tide. In tidal waters where there is a beach the coastline is landward limit of the beach and therefore corresponds roughly to the high water line of the highest tides."

Analysing all the available information and definitions (including the coastline definitions of neighbouring countries), we decided which level shall be used as coastline on Slovenian nautical charts. In order to facilitate the survey and give some general guidance for the surveyor we put together some guidelines:

- For definition of coastline we use Mean High Water;
- The level of high water mark can be determined on the field by observing the dark line of some typical sea organisms and algae;
- Where such a line cannot be seen, survey must be done in high tide in order to determine high water line;
- In order to eliminate other effects, tides must be observed at all times at closest possible tide gauge;
- In build-up areas (piers, marinas, buildings) the edge of constructed coast objects shall be used for determination of coastline;
- The accuracy of coastline determination must be better than 2 m.

### *2.3 GPS survey of a coastline*

For the purpose of survey, Slovenian coastline was divided in two parts. South part was surveyed first in 2001 and covered area between town Izola and border with Republic of Croatia. North part was done one year later, in 2002 and covered area from town Izola to border with Italy.

Survey team was composed of two people, GPS operator and hydrographer who was responsible for determining the right level of water, writing the notes and remarks. A great volume of photographs was also taken. With this we gathered great amount of documentation about our coastline. Survey was done in high tide, in build-up areas also in other periods, since the water level has no effect on coastline.

*Figure 2: Survey team at work*

For the survey Ashtech GPS receiver and antenna were used. Surveyed data were stored in Compaq Palmtop with appropriate software. For precise GPS correction Ashtech GPS reference station was set in the vicinity of the Port of Koper. DGPS correction was transmitted using GSM network. Data processing was done using home made software for PC. GPS equipment was calibrated daily on very precise reference point, and that gave the precision of 1 cm. The accuracy of RTK survey was very good, around 1 cm. Due to difficult determination of a coastline (especially when the coast was flat), the accuracy of established coastline is estimated to be better than 2 m. Since the IHO standard for hydrographic survey describes minimum accuracy for natural coastline to be 10 m, our survey corresponds to these specifications.

*Figure 3: GPS antenna and palm computer*

## 3. HYDROGRAPHIC DATA

So far we conducted several hydrographic surveys in Slovenia. Chronological they are the following:

- 1998: Survey by Navoceano, USA at the scales 1 : 1000, 1 : 2500, 1 : 5000 and 1 : 10 000;
- 1999: Survey by Slovenia (up to 200 m from shore) at the scale 1 : 1000;
- 2000: Survey by Slovenia (up to 200 m from shore) at the scale 1 : 1000;
- 2002; Survey by IMA, Trieste 100% multibeam coverage;
- 2003: Survey by Slovenia at the scale 1 : 1000.

All surveys adhere to Order 1 of IHO hydrographic survey standard (IHO 1998), which requires the accuracy of soundings to be better than 0.5 m, accuracy of horizontal positioning to be better than 5 m and line spacing to be 25 m. All our surveys satisfy these demands. All together we acquired about 130 millions of soundings, most of them for the Bay of Piran, where 100 % coverage was accomplished by surveying with multibeam sonar.

Positions of aids to navigation (lights, beacons and buoys) were also determined by means of GPS. Same IHO standard for hydrographic surveys also gives some directions for accuracy of positioning of such objects: for fixed aids to navigation and features significant to navigation up to 2 m, for floating aids to navigation up to 10 m. The mean position of our objects adhere to this standard. For all we checked also the light characteristics and other important information such as shape and colour. We put all information into database and for all we follow the changes and if necessary we up-date database, nautical charts and publications.

Also all other information and data important for navigation (wrecks and other dangers to navigation, tide information, bottom sampling, sub-bottom profiling, Secci disc survey data) are stored in special database.

## 4. INTEGRATION OF DATA

A set of fair sheets in different scales is the result of a hydrographic survey. For our surveys we compiled quite a number of fair sheets:

- 5 fair sheets form 1998 survey (at the scale 1 : 25000, 1 : 7500 and 1 : 5000);
- 21 fair sheets from 1999 survey (at the scale 1 : 1000);
- 26 fair sheets from 2000 survey (at the scale 1 : 1000);
- 43 fair sheets from 2002 survey (at the scale 1 : 2000, 1 : 12 000, 1 : 75, 1 : 60, 1 : 150 – last three are special fair sheets for discovered wrecks)
- 10 fair sheets from 2003 survey (at the scale 1 : 1000).

Until now we have 86 different aids to navigation in our database:

- 22 lights;
- 1 beacon;
- 61 buoys;
- 2 leading lights.

For the compilation of nautical charts we basically use land (topographic) maps at the scale 1 : 5000 for compilation of land part of a chart, together with the help of aerial-photographs in different scales and orthophoto at scale 1 : 5000.

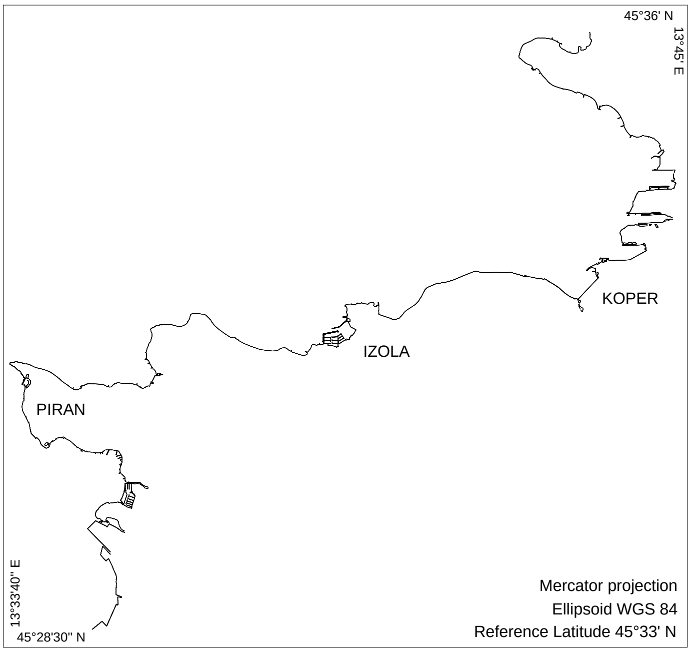


*Figure 4: Slovenian coastline in Mercator projection*

We expanded the database also with newly surveyed coastline. Original coastline survey data are in geographical co-ordinates on WGS 84 ellipsoid. All the post processing (cleaning and smoothing of data) was also done on the original data. After completing this phase, the quality control was done in order to assure that all the important information were stored and surveyed properly. During the survey also some additional objects on or close to the coast were surveyed (bridges, lights). Those were added to the checked coastline. The final coastline data were then transformed in to three different systems:

- Original in geographical WGS 84 co-ordinates;
- Transformation in Gauß-Krüger projection on Bessel ellipsoid (all fair sheets are in this system);
- Transformation in Mercator projection (figure 4) on WGS 84 (in which the final result, the nautical chart is).

New coastline was used in production of fair sheets of three latest hydrographic surveys. The updating of the Bay of Koper chart with new coastline has not been done yet. Due to the complexity of up-dating the whole chart with new coastline, it is better to produce new edition of a chart rather than up-date it. Until now, the new coastline was inserted in Electronic Navigation Chart (ENC) of the Bay of Koper. This ENC is also completed and willsoon be released for use on board ships.

## 5. DATA REQUESTS

From the start of our own hydrographic activities and first nautical chart (first edition is dated June 1999), our Hydrographic office received several different requests for data stored in our database. Mostly they were for research purposes, some for coastal zone development and construction of piers, marinas and pipelines. Great economic, tourist and ecological importance of the region, and the existence of such data, encouraged various experts to use this data and information as part of their GIS solutions.

If we would summarise some requests for data:

- For research of fresh water springs on the sea bottom (the request was for the depths of the sea around the water springs and for side scan sonar (SSS) images;
- Research of undersea names and the deepest Slovenian water depth (figure 5);
- Data for coastal zone development in town Izola.

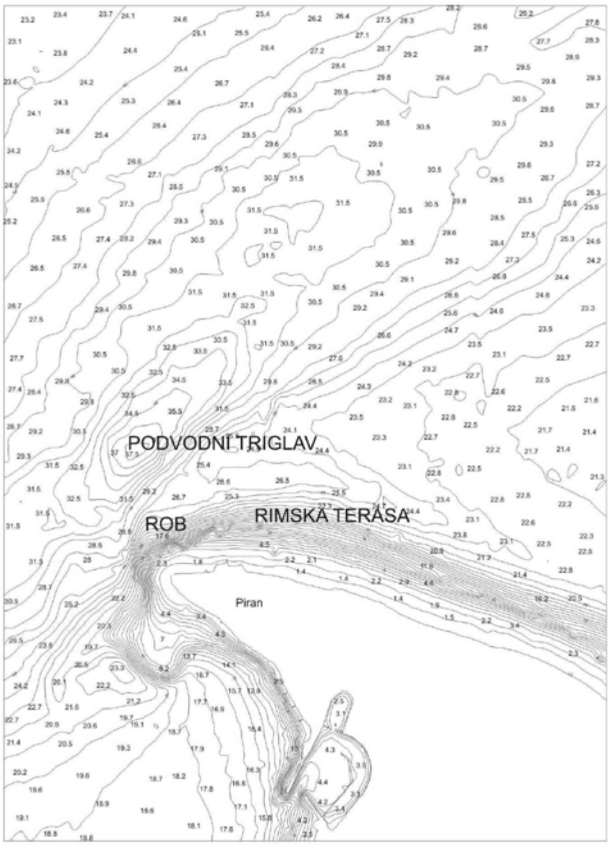


*Figure 5: Chart of the deepest Slovenian water*

Processing these requests Hydrographic office faces some difficulties, or rather different situations handling them. Original hydrographic data are usually not for public use. The amount of soundings and other information is such, that they have to be processed, selected and arranged for each case separately. That means that data and information must be processed accordingly to individual need. Understandably that means a lot of extra work for Hydrographic office. This is especially noticeable, when the users do not know exactly what they need or what data and information we have in our database. Establishing own maritime GIS, for easier handling the data and information seem reasonable idea. In this selected data and information would be stored and easily processed to satisfy users need.

## 6. CONCLUSION

Maritime countries have their hydrographic offices in order to assure, that information needed for safe navigation, are acquired, processed, organised and delivered to mariner. With the development of coastal regions, growing demand from tourist and ecological aspects, are forcing also other users to use hydrographic data and information. Research and local coastal zone development play great roll in this process and need such information.

Hydrographic surveys are essential in this process. The coast changes, new ports are build and new piers added. Users need up-to-date data and information in real-time. They are forced to establish their own GIS for management of their area of responsibilities.

Hydrography helps to provide up-dated nautical charts and publications; conducting hydrographic and geodetic surveys of sea, coast and land in the vicinity of the sea; integrating all these data and information and process them until they are suitable for daily use. That means to clean and subtract overload of information and use only the relevant ones. This can than be used to answer to users' requests for data.

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