

A Case Study in Land and Sea Data Interoperability

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SUMMARY

In Mozambique most of the population lives in lowland coastal areas, where infrastructure is weak or even non-existent. These conditions mean a high vulnerability of both people and landscape to tropical cyclones, tsunamis and sea level rise.

Tools for coastal zone management and disaster protection are therefore necessary. In cooperation between Dutch and Mozambican organizations a pilot project was set up to build a seamless topographic and bathymetric elevation model of the areas of Beira and Quelimane in Mozambique. This paper presents this case study outlining the development of the project, stakeholders and the technical developments built with Off-the-Shelf software products. CARIS assisted with expertise and tools to manage and visualize the data, which resulted in a model that can be used as a basis for further research and decision making to mitigate effects of natural disasters.

The paper represents a case study illustrating how technologies can be used to develop solutions for local communities, in particular, to assist coastal communities to live with a greater understanding of their environment. This knowledge leads to better disaster planning for the local coastal communities, especially in remote and developing regions.

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1. INTRODUCTION

This paper describes a project derived from an IOC-IHO initiative to improve the capability for emergency planning and response in the Indian Ocean. The Pilot Project Coast-Map-IO TopoBathy Database is an extension of the IOC-IHO project ‘Coast-Map-IO on Improving Emergency Response to Ocean-based Extreme Events through Coastal Mapping Capacity Building in the Indian Ocean’¹. It represents a case study illustrating how the current technologies can be used to develop solutions to add value, information and knowledge for local communities and in particular to assist coastal communities to live with a greater understanding of their environment.

2. BACKGROUND

As part of the larger IOC project ‘Indian Ocean Tsunami Warning System’ (TSU-REG-05/CSS10-REGION), the objective of Coast-Map-IO has been to allow states to compute where and in what direction destructive waves will impact their coastlines. Or, more specifically:

- To enhance available expertise to locally produce accurate bathymetric and topographic maps on either side [-200 to +50 meters] of the high tide-line.
- To provide modeling capacity for inputs to tsunami arrival, run-up and inundation in coastal areas.
- To transfer necessary skills to national Disaster Management and Preparedness agencies to use bathymetric and terrestrial datasets in developing targeted maps and services, including flooding maps, determination of set back lines, coastal ecosystem mapping, and zonation for coastal users.

In this framework IOC-IHO identified the need for coastal states ‘to generate, maintain and update topographic / bathymetric databases of digital information and produce maps of the most vulnerable coastal areas’. After assessment visits to all participating countries, Mozambique was identified as one of the countries where a pilot Coast-Map-IO Database could be developed:

‘The Instituto Nacional de Hidrografia e Navegação (INAHINA), with its competent personnel, its experience of hydrographic surveying and nautical charting and its equipment, has the potential to efficiently contribute to the establishment and management of the COAST-MAP-IO bathymetric and topographic seamless database, on condition that additional training and equipment are provided’².

The pilot project could not be realized however the Netherlands Government Programme ‘Partners for Water’ offered an opportunity for the Netherlands companies CARIS BV and BMT-ARGOSS BV, in cooperation with INAHINA in Mozambique, to jointly develop and

implement the required Pilot Coast-Map-IO Bathymetric and Topographic Database.

¹ www.ioc-cd.org/index.php/activities/coast-map-io/26-coast-map-io

² COAST-MAP-IO Project - Assessment Missions Report:
www.ihodata.org/mtg_docs/CB/CBA/Technical%20visits/TV08/Assessment_COASTMAPIO.pdf

‘Partners for Water’ supports the Dutch water sector to capitalise on its technologies and expertise internationally and contribute to solving world water challenges (www.partnersvoorwater.nl).

CARIS BV is specialized in the provision and support of geomatics software solutions for land and marine applications. (www.caris.nl).

BMT-ARGOSS is specialized in the provision of satellite-derived bathymetric data of shallow water areas (www.bmtargoss.com).

INAHINA is the hydrographic office of Mozambique and as such responsible for hydrographic survey, nautical cartography and navigation of the Mozambican waters (www.inahina.gov.mz).

3. PROJECT OBJECTIVES

The objectives for which the support was obtained through the ‘Partners for Water’ programme were:

- Development of a pilot database for the creation and management of integrated datasets of coastal bathymetric, topographic and ancillary information that is required for prediction of tsunami arrival, run-up and inundation in coastal areas.
- Implementation of the database at the Instituto Nacional de Hidrografia e Navegação of Mozambique and training of their staff.
- Compilation of a demonstration version and accessory documentation.

4. ORGANISATION AND PLANNING

In this project CARIS BV was responsible for installation of the database and training of INAHINA personnel, INAHINA was responsible for collection of existing bathymetric and topographic data of the pilot areas, while BMT-ARGOSS was responsible for the provision of additional satellite-derived bathymetric data of these areas. As leading partner in the project, CARIS BV had the overall coordination.

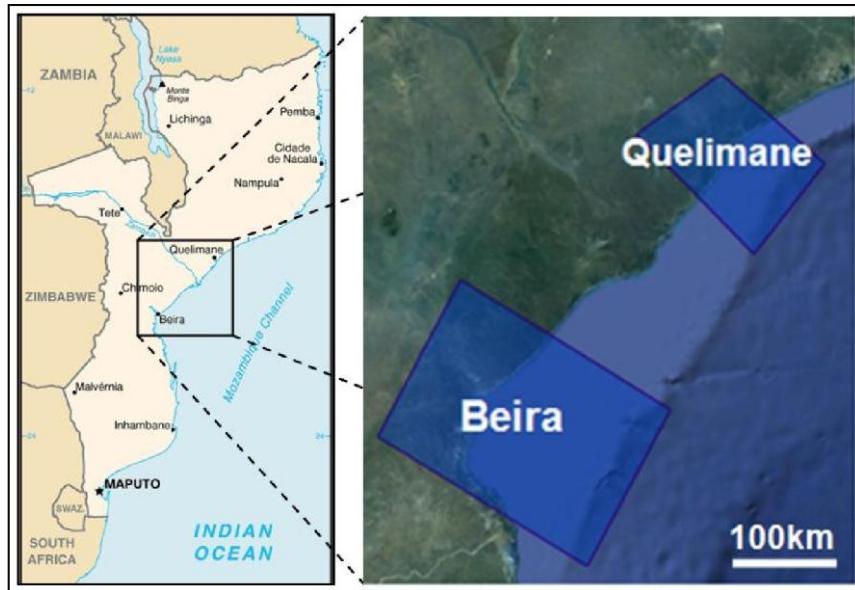


Figure 1: Location of the Pilot Areas in Mozambique

Already during the IOC-IHO Coast-Map-IO assessment mission to Mozambique, INAHINA, in consultation with IOC and IHO, had selected two pilot areas that were considered to be vulnerable to ‘extreme ocean events’. One near the Port of Beira and the other near the Port of Quelimane. These areas are shown in figure 1.

The planning scheme as shown hereunder was executed and will be discussed in more detail in the next chapter.

Dates	Subject
October 2011	INAHINA: Assessment of available data in the pilot areas and specification of need for additional data.
November December 2011	BMT ARGOSS: Selection of appropriate satellite images. Acquiring depth calibration data.
November 2011 January 2012	CARIS: Import digital datasets for Beira, convert to same horizontal and vertical reference systems and combine as seamless elevation model in the TopoBathy Database
January 2012	CARIS: Create Training Manual for the Beira pilot area.
February 2012	CARIS & INAHINA: Training of involved INAHINA staff in Mozambique & Installation of TopoBathy Database
March – June 2012	INAHINA: Create seamless elevation model for Quelimane
July 2012	CARIS & INAHINA: Consultancy in Mozambique to discuss the Quelimane results and the road ahead

5. PROJECT EXECUTION

The aim of the pilot project was to load different topographic and bathymetric datasets for the Beira and Quelimane areas in the TopoBathy Database and combine them into one seamless elevation model. This is shown in figure 2 below.

Using the CARIS Bathy DataBASE software package, CARIS BV developed a practical workflow for this project and implemented this for the Beira pilot area. Then, based on this exercise, prepared a training manual to be used by INAHINA.

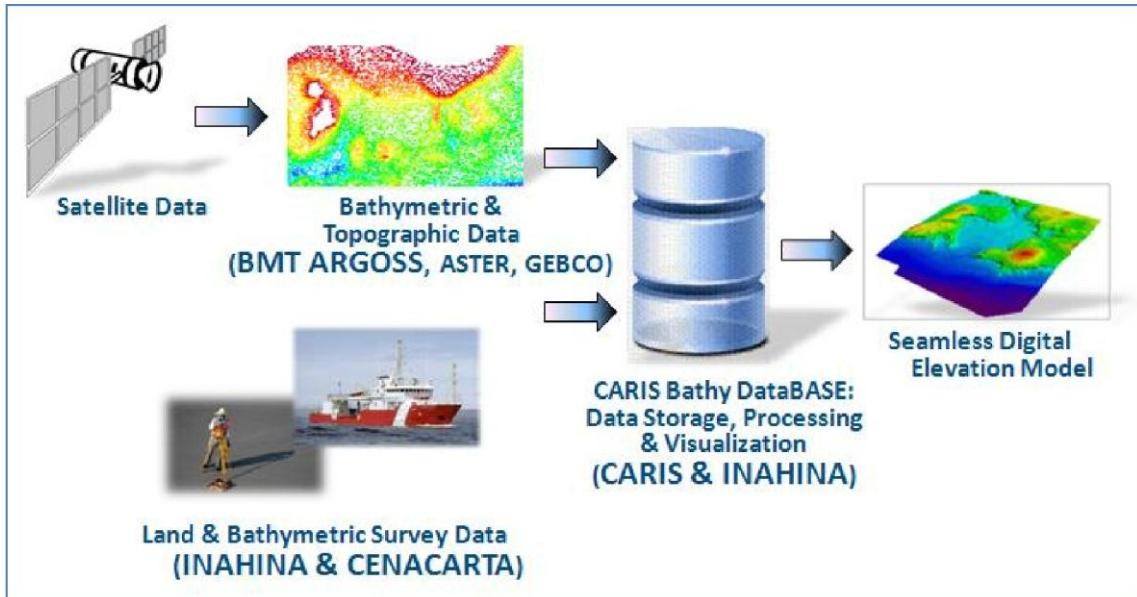


Figure 2: Topobathy database workflow

In October 2011 the project started with a first assessment of available geospatial data of the coastal area of Beira and Quelimane to put in the database. This resulted in a few recent INAHINA singlebeam bathymetric surveys as well as some topographic vector data for both cities acquired from CENACARTA (the topographic service of Mozambique)³.

However, to be able to use the data in the Topobathy database to create a good model for (tsunami) wave prediction, more bathymetric data was needed.

With respect to bathymetry BMT ARGOSS offers an efficient alternative to conventional surveys for shallow water areas where no adequate bathymetry information is available⁴. Using Landsat satellite images of the areas of Beira and Quelimane, the assessment of bathymetric information is based on the optical properties of the water and the seabed. By calibrating the intensity of light reflection with the existing INAHINA bathymetric survey data and existing nautical charts a good approximation of bathymetric depths could be accomplished.

³ www.cenacarta.com

⁴ www.argooss.nl - Services & Capabilities - Shallow Water Bathymetry

For this pilot project this resulted in two datasets with depth information of 50 metre horizontal resolution for an area of about 150x75 km around Beira and about 100x50 kilometres around Quelimane, which could be imported into the Topobathy database.

This depth approximation is not as accurate as a ship survey, so the data should not be used for navigation. However, the accuracy is much higher than any data currently available for the area and is therefore a good input for further modelling.

Apart from the INAHINA, CENACARTA and BMT ARGOSS data, two publicly available datasets have been used to fill the database in those parts of the pilot areas where no other data was available.

For the bathymetric data the GEBCO dataset has been used. GEBCO (General Bathymetric Chart of the Oceans) provides the most authoritative, publicly-available bathymetry for the world's oceans. It operates under the joint auspices of the IOC and the IHO⁵. For the pilot areas the GEBCO data is mostly derived from ship track data, that has been interpolated with the use of gravity anomalies, to give an indication of the seafloor depth. Therefore the depth accuracy of this data is not too high.

For areas on land where there was no CENACARTA elevation data available, the public dataset used was the ASTER topographic elevation model. ASTER (Advanced Spaceborne Thermal Emission and Reflection Radiometer) is an imaging instrument flying on Terra, a satellite launched in December 1999 as part of NASA's Earth Observing System (EOS)⁶. The ASTER nadir- and backward-looking telescopes allow acquisition of stereo image pairs from which an elevation can be computed.

As described above and as can be seen in figure 3 there were in total 5 different data sources used for the initial filling of the Topobathy database for Beira. These datasets were imported into the TopoBathy Database application. If the source data was dense the datasets were directly stored as continuous grids called BASE Surfaces. If the data was sparse it was first imported in a so called point cloud. This data was interpolated to create BASE Surfaces as well.

All 5 surfaces were combined into one digital elevation model for the pilot area with 100 metre resolution, but only after all surfaces had been shifted to the same mean sea level (MSL) vertical datum. This meant that the surfaces of the INAHINA bathymetric survey data and the derived BMT ARGOSS satellite data, which had a vertical datum of lowest astronomical tide (LAT), were shifted with the difference between MSL and LAT for Beira and Quelimane respectively.

Horizontal reference for all surfaces was WGS-84, so no horizontal shift had to be executed.

⁵ www.gebco.net

⁶ asterweb.jpl.nasa.gov

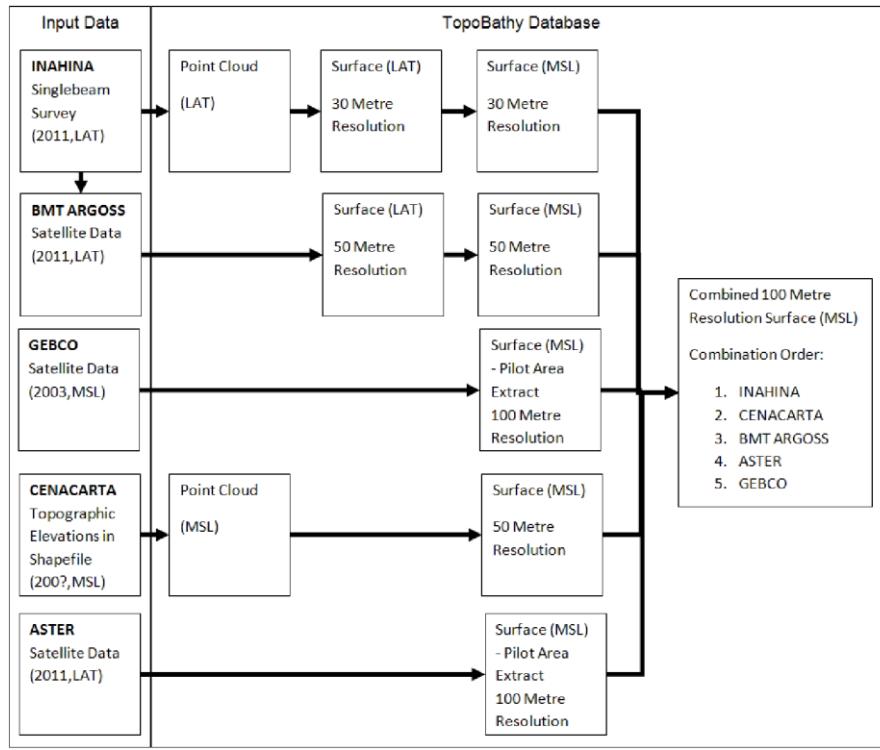


Figure 3: Datasets used for the Topobathy Database

The combination of the surfaces in the TopoBathy Database is based on specific rules, which ensure that in those areas where there is an overlap between datasets, the better data has priority in the final surface. So if there is INAHINA survey data available it gets priority over the BMT ARGOSS data, while that data has priority over the low accuracy GEBCO data. The CENACARTA height information was given a priority over the ASTER satellite derived heights. The data sources that are used in the different areas for Beira can be seen in figure 4 below.

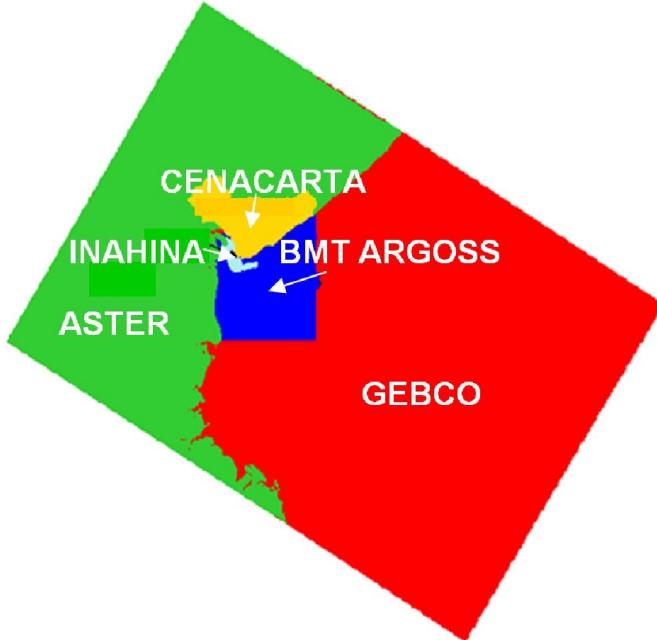


Figure 4: Data Sources for the combined Beira Elevation Model

Based upon the workflow to create a combined elevation model for Beira as described above, a training manual was created and in February 2012 a two-week training event was held at the INAHINA office in Maputo, Mozambique. Apart from hydrographers, cartographers and an oceanographer from INAHINA, some additional personnel from associated local agencies participated in the training including INAM⁷ the national meteorological institute of Mozambique which will use the resulting Topobathy elevation models, to better model (tsunami) waves and currents.

In the first week the students were trained in the management and visualization of the different geospatial datasets and the workflow to create a combined Topobathy elevation model for the Beira area, as described in the manual.

In the second week the CARIS Bathy Database suite was installed and implemented at INAHINA, so that it can be used to store and manage all bathymetric and topographic datasets in a central location.

In the period of March to June 2012 INAHINA executed the same workflow that was set up for Beira, to create a combined Topobathy elevation model for Quelimane. A document has been written about this procedure by INAHINA.

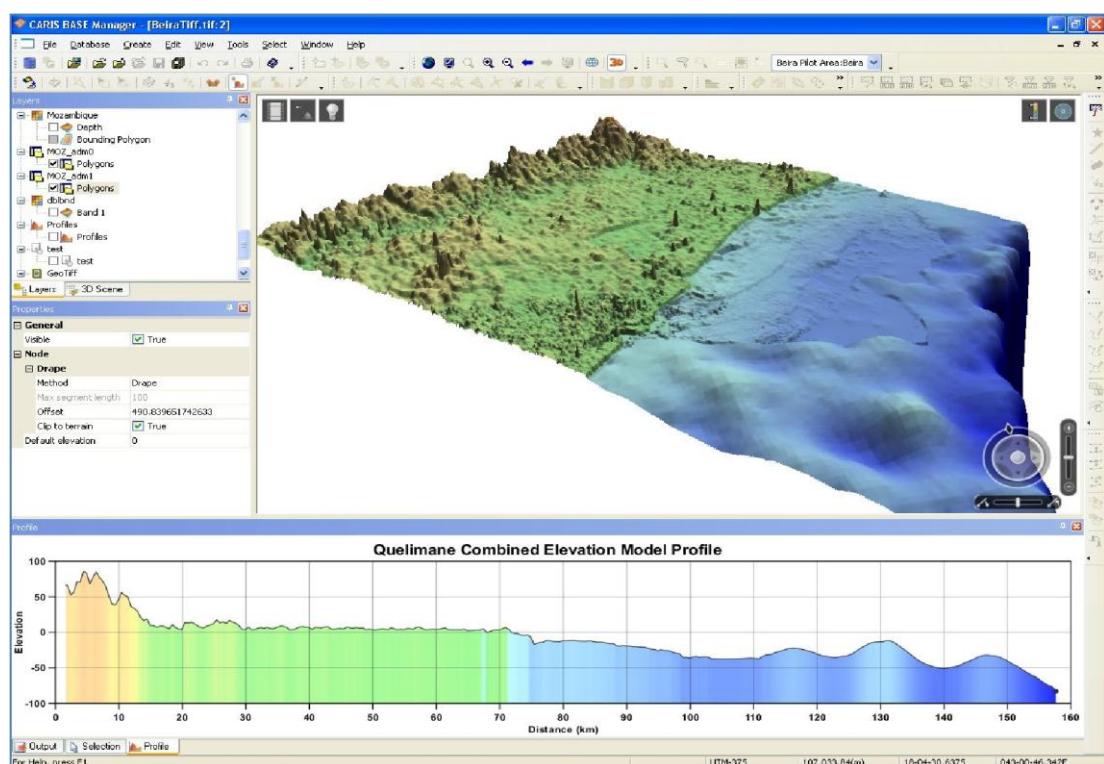


Figure 5: The elevation model for Quelimane shown in CARIS BASE Manager

⁷ Instituto Nacional de Metereologia (www.inam.gov.mz)

In July 2012 a CARIS consultant came to INAHINA for another week to discuss the results for Quelimane and help with further issues. The project was finalised as planned with an elevation model of both Beira and Quelimane stored in the TopoBathy Database.

In figure 5 an example screenshot is shown from the TopoBathy Database which both visualises the Quelimane elevation model in 3 dimensions as well as a cross section elevation profile of the same area.

As an example in figure 6 below some inundation maps of the Beira area are shown. These are screenshots from the TopoBathy Database application as well. The elevation model of Beira is shown in 3D with a Landsat image draped on top of it. The city of Beira is in the middle of the picture.

On the leftmost picture the current situation is shown, with no sea level rise. In picture in the middle a sea level rise of 5 metres is represented and in the picture on the right the area that would flood with a 10 metre sea level rise or tsunami wave or storm surge is shown (unfortunately no digital cadastral information of Beira was available).

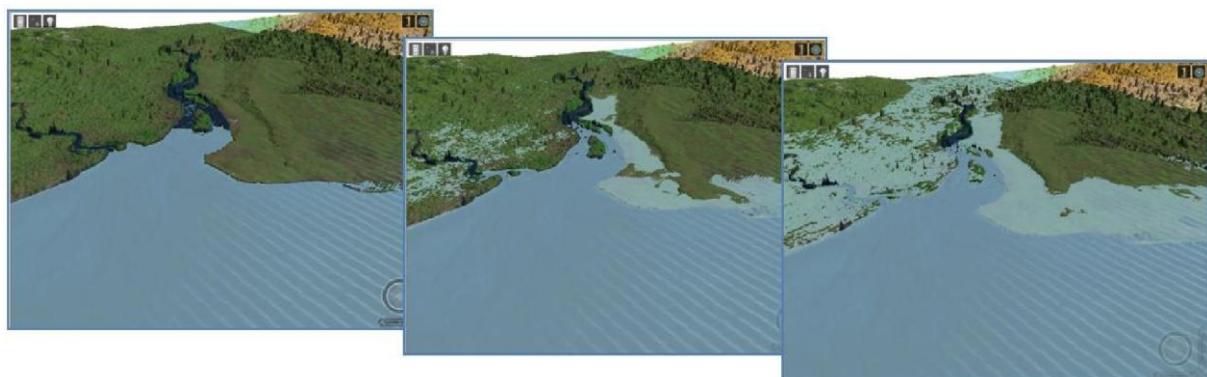


Figure 6: Beira Inundation Maps – 0, 5 & 10 metre sea level rise

6. PROJECT DELIVERABLES

- The Project deliverables of this pilot project are:
- Different topographic and bathymetric datasets were gathered of both Beira and Quelimane from INAHINA, CENACARTA, BMT ARGOSS, ASTER & GEBCO.
- BMT ARGOSS has written a report on the methodology used to create satellite derived bathymetry.
- An elevation model of Beira has been created by CARIS.
- A training manual has been created containing the workflow how to create a combined topographic & bathymetric elevation model for the Beira area in Mozambique based on 5 different datasets.
- Training based on this manual has been delivered involving participants of INAHINA, INAM & CENACARTA.

- A TopoBathy DataBASE client-server system has been set up at INAHINA, including backups and helpdesk support.
- An elevation model of Quelimane has been created by INAHINA.
- Both the Beira and the Quelimane models have been loaded in the TopoBathy Database at INAHINA with other survey datasets loaded into the database as well.
- Plots of the Beira and Quelimane models were created for further distribution to the other involved institutions.
- The resulting elevation models will be used as input for Tsunami modelling software, to better predict tsunami and storm surge arrival, run-up and inundation in coastal areas.

7. CONCLUSIONS

With these results the project has successfully been concluded as both the Coast-Map-IO objectives as well as the Partners for Water objectives have been met :

- CARIS, BMT-ARGOSS and INAHINA jointly developed and implemented the required Pilot Coast-Map-IO Bathymetric and Topographic Database ‘to generate, maintain and update topographic / bathymetric databases of digital information and produce maps of the most vulnerable coastal areas’.
- As confirmed by the INAHINA Report (Annex 3) on preparation of the Quelimane TopoBathy Elevation Model, necessary skills were successfully transferred to the relevant Mozambican agencies.

In the conclusion of the INAHINA internal report the following is stated:

‘Thus, both the Beira and Quelimane TopoBathy Elevation model built, play an important role for tsunami hazard assessment, land use planning, tropical cyclone and storm mitigation and further studies. In the meantime, it is necessary that a tsunami hazard assessment for the coastal communities is done. On both the Beira and Quelimane TopoBathy Elevation Model can clearly be seen how much land would be flooded if the sea level rises 5 metres above MSL. However, it is necessary to make an assessment in terms of population and economic infrastructures expected to be affected in case of a tsunami event, sea level rise or flood’.

8. THE FUTURE

INAHINA will continue to load other survey data into the TopoBathy Database as soon as it becomes available. There are also plans to continue to create topobathymetric models for other vulnerable coastal areas in Mozambique, like Maputo, Chinde, Pemba and Angoche. In this way the TopoBathy Database serves as the central storage location for all survey data that INAHINA needs to manage, visualise and export.

The results of this Pilot Project will be presented to IOC and IHO, after which they will be communicated with the other, in Coast-Map-IO participating, countries. A plan will be

developed to make the software available to these countries and provide them with proper training in its usage.

For organizations that are in the process of capacity building in the field of hydrographic survey data processing and production of paper and electronic charts, the Coast-Map-IO TopoBathy Database is of particular interest. As it is based on the CARIS Bathy DataBASE toolset it can be easily extended with other CARIS modules like the CARIS Paper Chart Composer and CARIS S-57 Composer for paper and electronic chart production.

The paper aims to represent a case study illustrating how the current technologies can be used to develop solutions to add value, information and knowledge for local communities and in particular to assist coastal communities to live with a greater understanding of their environment. With more focus on the world's natural environment and the concern for communities being affected by changes in climate and natural disasters collaborations such as the one described in this paper can deliver real value and knowledge to sustain the future coastal communities.



Figure 7: Working on the TopoBathy Database at INAHINA.

BIOGRAPHICAL NOTES

Andrew Hoggarth is the head of Sales for CARIS, based in Canada. Educated in England. After spending a number of years, on a variety of offshore survey projects, he moved to Canada where he is the global sales manager for CARIS.

Gordon Johnston BSc(Hons), MRICS, FRIN is a consultant to private companies, NGOs and government agencies relating to Geodetics, Hydrography and Data Management. He is a chartered surveyor and is a vice chair of FIG Commission 4.

Charles de Jongh is a senior member of the CARIS BV Technical Sales staff with extensive experience and knowledge of the implementation of training and systems in developing regions and organisations.

Peter Schwarzberg is Sales Manager at CARIS BV with responsibility for the Africa region and is heavily involved in the promotion and introduction of Bathymetry data systems.

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