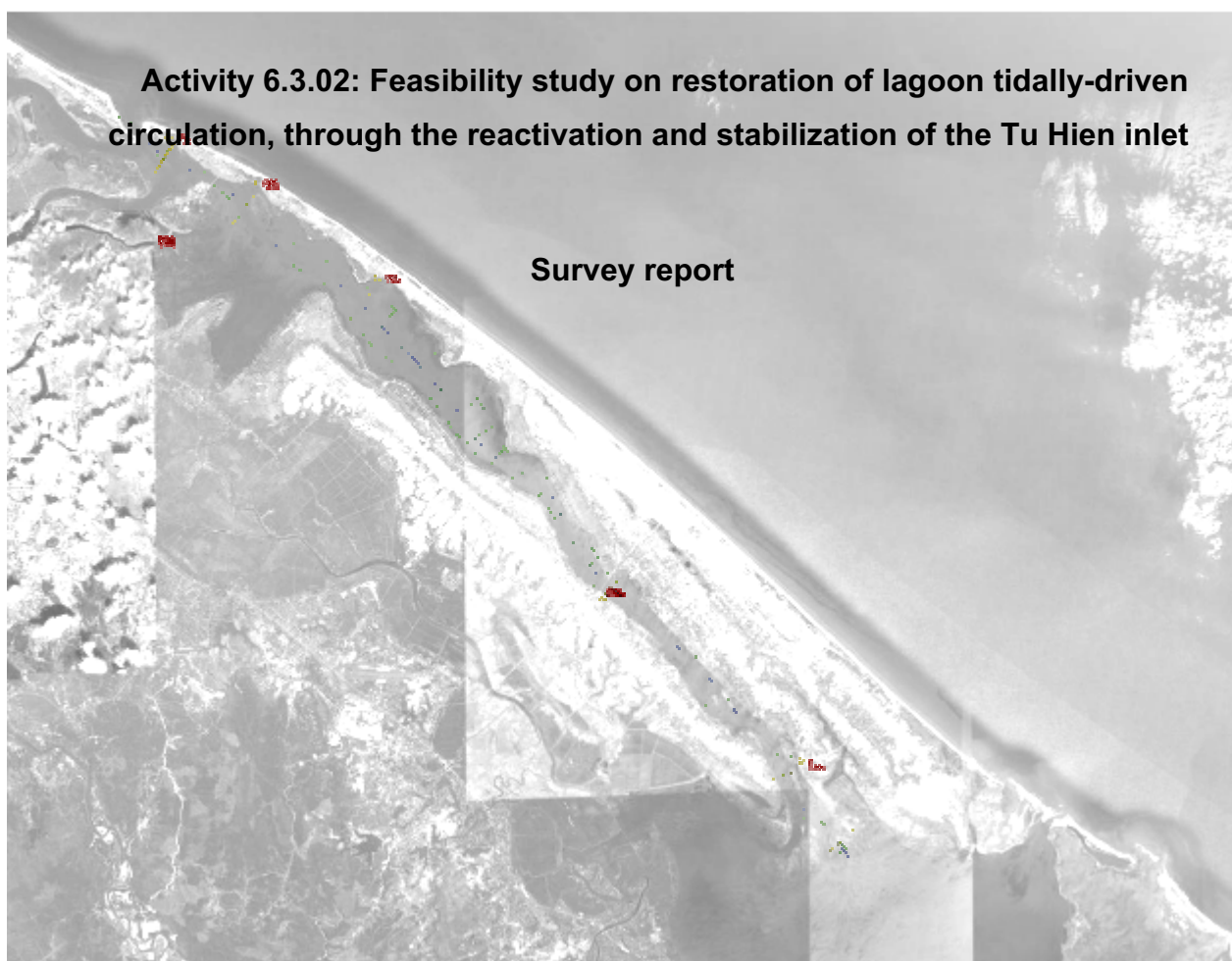


FAO - The Food and Agriculture Organization of the United Nations
*FAO project for the Integrated Management of Lagoon Activities in Thua
Thien Hue Province*

Contract # 04/2009 – GCP/VIE/029/ITA IMOLA II Phase


Hydrological, bathymetric and tide-metering surveys in the lagoons of Thuy Tu and Cau Hai



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1. BACKGROUND AND INTRODUCTION

1.1. FAO project of Integrated Management of Lagoon Activities (II phase)

Every year, during October and November in the middle of the tropical typhoon season, Central Viet Nam and in particular the Thua Thien Hue province, has to cope with some severe flooding: fisheries, aquaculture and many other activities are paralyzed for some weeks. Most of the hundreds of thousands of people living in the area, largely dependant on the activities they carry out in the lagoon as aquaculture (shrimp, seaweed, carp), fisheries, transport and tourism are severely affected, putting a high pressure on the socio-economic system, on the lagoon-dweller community and on the natural resource that provide livelihood and subsistence.

The FAO project for the Integrated Management of the Lagoon Activities in Thua Thien Hue Province (GCP/VIE/029/ITA IMOLA II Phase) has an overall development objective of assisting in sustainable management of the natural resources of the Tam Giang Cau Hai lagoon and finalizing the Integrated Lagoon Management Plan. Under the main scope, for the environmental management of the lagoon it is essential to understand the main hydro-morphological and biological processes and conduct feasibility study on restoration of lagoon tidally-driven circulation, through the reactivation and stabilization of the Tu Hien inlet.

In this view, the intervention of Te.Ma. snc has been requested in order to gather the necessary information on lagoon hydrology, bathymetry, tidal regime and topography of critical lagoon segments.

1.2. Overall plan and expected results

The purpose of the requested services was to implement an integrated hydrological and morphological survey of the southern lagoon of Tam Giang-Cau Hai, for the purpose of fishery planning, circulation improvement and designing of inlet stabilization interventions.

The survey, in the original Terms of Reference developed by the contracting agency FAO, had to include the following:

- a detailed bathymetric survey,
- a tide-metering campaign,
- a current meter survey,

in order to understand the overall circulation pattern of the southern lagoon during a specific time of the year (winter, post-typhoon) in which circulation is enhanced and river runoff is at its climax. The results of the survey would subsequently contribute to the following:

- assist in designing the fishery plan,

- assist in designing vivification interventions,
- enhance tidally driven circulation, oxygen distribution and promote productivity
- assist in designing inlet stabilization infrastructures
- study methods to enhance circulation by using the dual-inlet system

Because few data about lagoon circulation are available, a wide range of investigations and surveys has to be realized in different seasonal conditions, in order to achieve the goal above mentioned. Results of the survey campaign realized in December 2009 is an indispensable preliminary step to portray present-day situation during the typhoon season and set the baseline for further detailed monitoring.

2. SURVEYS

2.1. Geodetic reference survey

In order to achieve an exact geo-referencing of the acquired data, a geodetic reference survey was implemented, using double-frequency GPS receivers and high precision GPS antennas, applying the GPS static differential methodology (Figure 1). The Te.Ma. network thus established was linked to the IMOLA CGT network developed in 2007.

2.1.1. Instrument specifications

The GPS static survey was implemented using the following set of instrumentation:

- 3 GPS Receivers ASHTECH Z-Surveyor, operating in double frequency P and C/A, with 12 digital channels and Z-tracking option for P code recording.
- 3 High precision geodetic antennas for Ashtech GPS receivers
- 3 tripods with calibrated masts and bubble level
- Pen-pad computers and laptop computers to operate the receivers and process data.

2.1.2. The Geodetic survey methodology

Thirteen benchmarks were installed and verified in the survey area, at a distance to one another not exceeding than 10 km. A detailed monograph of each benchmark installation is produced as an appendix to the survey report.

The geodetic network survey was designed and conducted applying the GPS static differential methodology, following the specifications herewith listed:

- 2 sessions, 90 minutes duration each, for each surveyed benchmark surveyed.
- Baseline, less than 15 km
- PDOP, less than 4 km



Figura 1 - Trimble GPS antenna on site on the IMOLA CGT benchmark established on the roof of the project office, to link IMOLA CGT and TeMa networks.

- Horizon elevation angle, higher than 15°
- A minimum of 5 satellite signals received on each session
- Use of calibrated masts and tripod, with bubble level
- Accurate measuring of GPS antenna height above the benchmark, before and after the session.

The acquired data were processed using professional surveying software for baseline computation, data reduction and rigorous compensation, accordingly with EU standards. In particular, the following processing software was used to compute the geodetic network:

- Trimble TTC
- Terrasat Geogenius 2000
- Ashtech Solutions

The results of this process have been combined with available National Reference System coordinates, to determine the most probable 7 parameters of Molodenskji-Helmert, necessary for real-time navigation in DGPS RTK mode to be adopted during the bathymetric and ADCP surveys.

2.2. Bathymetric survey

In order to obtain the most reliable configuration of the lagoon bottom in proximity of the inlet, for purpose of modeling, Te.Ma and IMOLA personnel implemented a high-precision bathymetric survey, during a ten-days campaign at the end of November 2009. Considering the difficulties of navigation among shallow shoals, partially submerged rocks and obstacles in the inlet area, assistance of local fishermen was ensured in order guarantee reliable results and safety of personnel.

2.2.1. Bathymetric survey methodology

The bathymetric survey was implemented applying the following methodology:

1. Setup of temporary hydrographic boat. A suitable local launch was provided by the local Provincial Police Department (Figure 2), assembled as a survey vessel according to IHO disciplinary for hydrographic surveys. The single-beam echosounder transducer was installed on the keel by using a steel-arm specifically designed for the purpose (Figure 3). Moreover, the mutual offsets between single-beam transducer, ADCP transducer and DGPS RTK antennas were precisely measured by means of kelerimetric techniques, in order to ensure an accuracy of less than 1 cm.
2. The geo-referencing of the bathymetric and ADCP data were performed in DGPS RTK mode. During every survey session, a GPS Master Station was installed on the benchmark nearest to the site of interest, consisting of a GPS receiver and a



Figure 2 - The hydrographic vessel used during the survey, provided by the Provincial police and adapted to host the surveying instruments



Figure 3 - Design of the ADCP installation on the hydrographic vessel used for survey

radio-modem: its purpose was to propagate to every Rover Station in a 10 km radius, the DGPS differential correction. The adoption of this system guarantees accuracy in the positioning of each sounding of less than 3 cm.

3. In order to ensure the best possible accuracy, a sound-velocity profile investigation was performed before each survey session and every four hours during the session itself, using a Valeport MiniSVS probe. The resulting SVP profile was then used to correct the echo-sounders raw data, in order to obtain an accuracy of the sounding of less than 2 cm.

4. The bathymetric survey was executed by using the professional Hydrographic software RESON PDS2000 on a ruggedized laptop computer. PDS2000 is a complete hydrographic suite with the following specifications:

- Combining and synchronizing all raw data coming from each sensor,
- Managing the acquisition of single-beam, multi-beam, sub-bottom, ADCP data and the geo-referencing in any local system
- Real-time navigation, run-lines management, waypoint and obstacles definition
- Import/export of cartography, DXF maps etc.
- QC of every instrument connected
- Tidal correction
- Post-processing and editing of raw data
- 3D modeling and volume computation
- Exporting of maps in the most common formats

5. In the lagoon area, the acquisition was carried out by navigating along run-lines and following a grid scheme. Supervision to navigation by a crew of local sailors and fishermen was ensured, to avoid any possible hazardous situation.

In the Tu Hien channel area, the navigation was designed along parallel cross-lines, more or less perpendicular to the channel shores and the supposed water-flow.

6. During the post-processing, all bathymetric data were reprocessed and eventual spikes removed. The tide was computed by the DGPS positioning system, compared with tide-gauge data, in order to ensure maximum accuracy and quality of the final dataset.

7. At last, the final dataset was used to create a Digital Terrain Model of the mapped area.



Figura 4 – Computerized control console of the RESON PDS2000 hydrographic suite for bathymetric survey

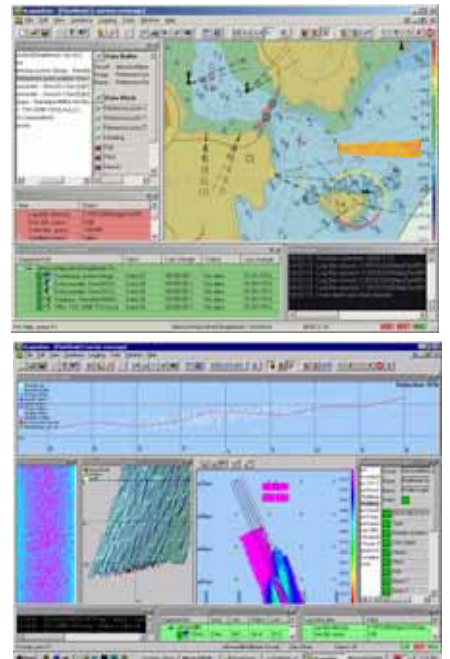


Figura 5 – Screen captures of the RESON PDS2000 bathymetric data acquisition

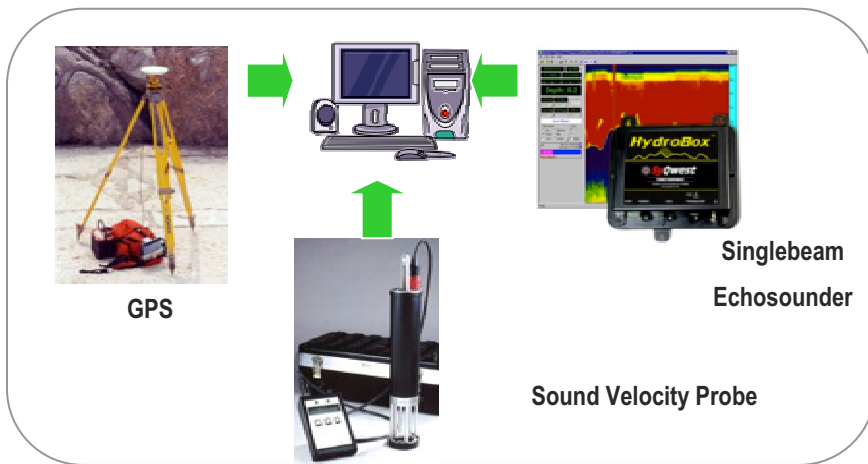


Figure 6 – The RESON PDS2000 hydrographic suite deployed during the bathymetric survey of Tam Giang: GPS receivers for positioning were integrated with a singlebeam echosounder and sound-velocity probe under the control of a computerized console for data storage and pre-processing.

2.3. Tide- meter survey

In order to improve the understanding of the lagoon dynamics and water circulation, seven tide-gauge stations were installed in proximity of the geodetic benchmarks. Tide data were collected from the seven stations during the entire campaign, one measurement every 15 minutes, by local operators trained by qualified personnel of Te.Ma.. Manual recording were transcript into Excel files and later processed.

2.3.1. Tide-meter survey methodology

The activity of tidal monitoring was implemented according to the following specifications:

- Each tide-gauge station was located in a suitable position, allowing the operator to easily access the water level and obtain a reliable measure of water height.
- The stations were altimetrically connected to the geodetic benchmarks by means of kelerimetric techniques, so to ensure a reliable elevation with reference to the National Geodetic System.
- Tide measuring teams were trained by Te.Ma qualified personnel for data collection and reporting.
- The data were collected through the entire campaign, 1 water-level value every 15 minutes, at each station.

2.4. Current meter survey

The current meter survey has been conducted in 2 phases and applying two different integrated methodologies.

The first proposed methodology consists in the installation of two InterOcean S4 electromagnetic current meters at fixed stations, at approximately 1,5-2,0 m below the water level, to continuously record intensity and direction of the currents for the whole duration of the campaign.

In particular, considering that only two instruments were available, locations were investigated with care, in order to maximize the results of the campaign. The chosen options were to deploy one S4 current-meter in proximity of the Tu Hien lagoon inlet and another instrument in the Thuy Tu channel, midway between the Tam Giang and Cau Hai basins. The main reasons of this choice were:

- to understand the average water-flow crossing the Tu Hien inlet and the balance in a selected time period.
- to understand the tidal pressure is in relation with the flow, both in the lagoon area and in the channel.
- to understand how much discharge occurred through the channel connecting Tam Giang and Cau Hai basins.

Whilst continuous current monitoring is ensured by stationary devices, a second current-metering survey was implemented by deploying an Acoustic Doppler Current Profiler (ADCP) in the Cau Hai basin and Thuy Tu channel according to an array of cross-lines approximately normal to lagoon coastline and supposed flow.

On the same hydrographic vessel used for single-beam bathymetry, an ADCP RDI Rio 600Khz was installed, allowing simultaneous acquisition of current directions and intensities along the entire water column and water-depths, along the same track lines. The ADCP cross-line array is traced approximately perpendicular to the Thuy Tu coastlines and normal to the supposed water flow, from the Thuan An narrow and the Cau Hai basin, so to have instant portray of the current intensity, direction and overall discharge in the area of interest, at a certain time and during a certain day.

2.4.1. Current meter survey methodology

Stationary current-meter survey

The survey was conducted according to the following guidelines:

1. Installation of the S4 instruments in suitable position within the flow, at an average depth of 1,5-2 m below the water level. In particular, stations were identified in a safe position, one in a port structure in the vicinities of the village of Vinh Hien and another on a tripod north of Truong Hà bridge, serving as support for navigation signals, near the center of the flow where current intensity is highest, so to have the most representative dataset of the maximum discharge.
2. Once deployed, the S4 devices were set in such a way to record current intensity and direction at the two stations for the whole duration of the campaign, with the frequency of one measurement every 3-5 minutes.
3. In order to ensure that no external factors could affect the measurements, a surveillance service was established for the whole duration of the campaign.

ADCP current-meter survey

The ADCP survey has been carried out along cross-lines approximately perpendicular to lagoon shores and to the flow of the current. A number of approximately equally spaced cross-lines have been selected from the Thuan An narrows to Cau Hai, so to obtain a complete representation of the current intensity, direction and overall discharge in the area of interest.

One limitation of the study is represented by the short duration of the survey, such that detected parameters are instantaneous measurements, at a certain time within the tidal cycle and on a specific day of the year. Continuous measurements over a longer period of time, in different seasons and under different hydrological regimes are recommended.

The ADCP survey was conducted applying the following methodology:

1. The geo-referencing of the bathymetric and ADCP data were carried in DGPS RTK mode. During every survey session, a GPS Master Station was installed at the benchmark nearest to the surveying station. The GPS Master Station consisted of a GPS receiver and a radio-modem; its purpose was to propagate to every Rover Station, the DGPS Differential Correction in a 10-km radius. The adoption of this system guarantees an accuracy in the positioning of each sounding higher than 3 cm.
2. In order to ensure the best accuracy possible, a Sound Velocity Profile measurement was performed before each survey session and every 4 hours during it, by using a Valeport MiniSVS probe. The resulting SVP profile was then used to correct the echo-sounders' raw data, in order to obtain an accuracy for each sounding higher than 2 cm.
3. The ADCP survey was executed using the professional Hydrographic software RDI Winriver II on a ruggedized laptop computer. Winriver is an ADCP acquisition and processing software with the following specifications:
 - Combining and synchronizing all raw data acquired by each sensor.
 - QC of every instrument connected.
 - Post-processing and editing of raw data.
 - Exporting of ASCII data or JPG files.

2.4.2. Instrument specifications

Stationary current-meter instruments

The following instrument were deployed on site, anchored to permanent structures existing in proximity of the selected stations for safety and stability, at or close to the maximum intensity of the flow. Positioning was acquired through deployment of the listed GPS receivers.

- 1 GPS Receiver ASHTECH Z-Surveyor, double frequency P and C/A, with 12 digital channels and Z-tracking option for P code recording.
- 2 electromagnetic current meters INTEROCEAN S4, operating at 2Hz, fluxgate compass embedded, accuracy of 1 cm/ sec and 0,5°.

ADCP Currentmeter survey

- 2 GPS Receivers ASHTECH Z-Surveyor, double frequency P and C/A, with 12 digital channels and Z-tracking option for P code recording operating in DGPS RTK mode with radio-modem connection.
- 1 ADCP device RDI Rio Grande 600 Khz, shallow water option enabled.
- 1 CTP probe VALEPORT MiniSVS, allowing the acquisition along the water column of salinity, pressure and speed of sound in the water with a precision of 0.1 m/s.

3. OUTPUTS

The following outputs are delivered as a result of the survey:

- 13 benchmark monographs (see Figure 8, below)
- Bathymetric map with contour lines every 0.5 m and 3D views (see Figures 10 and 11)
- Digital Terrain Model of the inlet (3D bathymetric chart) (see Figure 9, below)
- Tide meter stations positioning map and observed tide values (see Figures 12 and 13)
- Current pattern for current-meter fixed stations
- Current profile positioning, bathymetric profile and current pattern for ADCP survey (see Figure 14).



Figure 7 – Navigation signpost used to anchor the InterOcean S4 current-meter instrument during the survey. The structure is located in the mid-section of the Thuy Tu channel, north of the Trường Hà bridge.

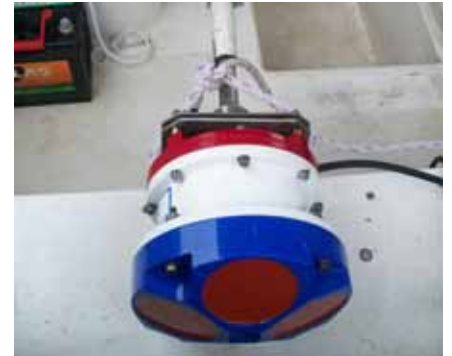


Figure 8 – ADCP sensor for current-metering.



Figure 9 - Examples of layout of benchmark monographs produced in support of the geodetic reference network

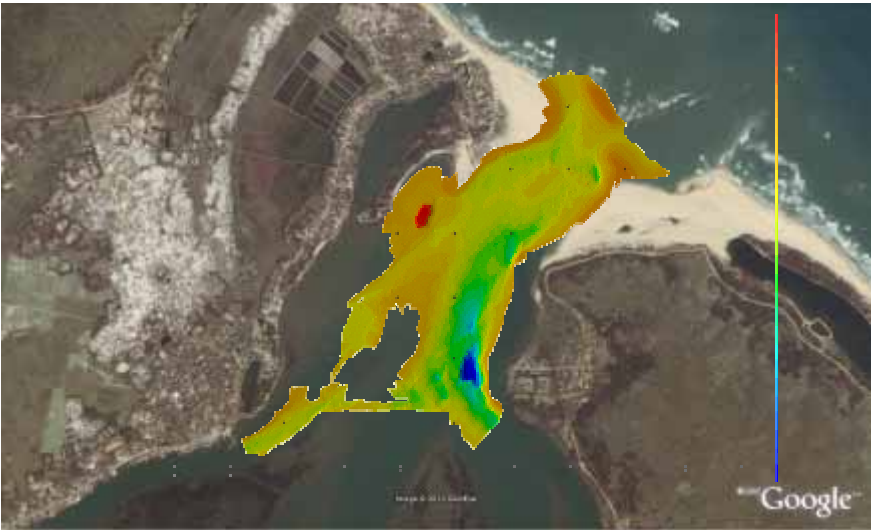


Figure 10 – Example of DTM of the Tu Hien inlet overlain on a geo-referenced satellite image



Figure 11- Example of bathymetric map of the inlet area including three-dimensional rendering

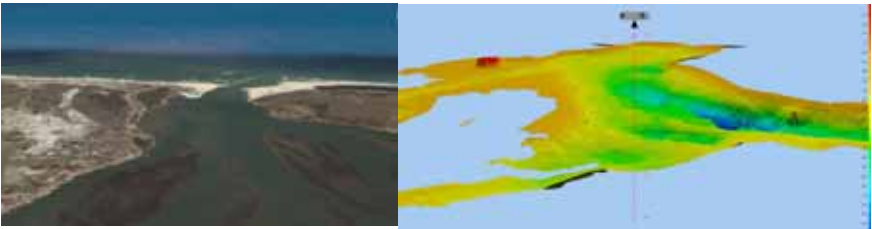


Figure 12 - Examples of bathymetric data processing and three-dimensional rendering

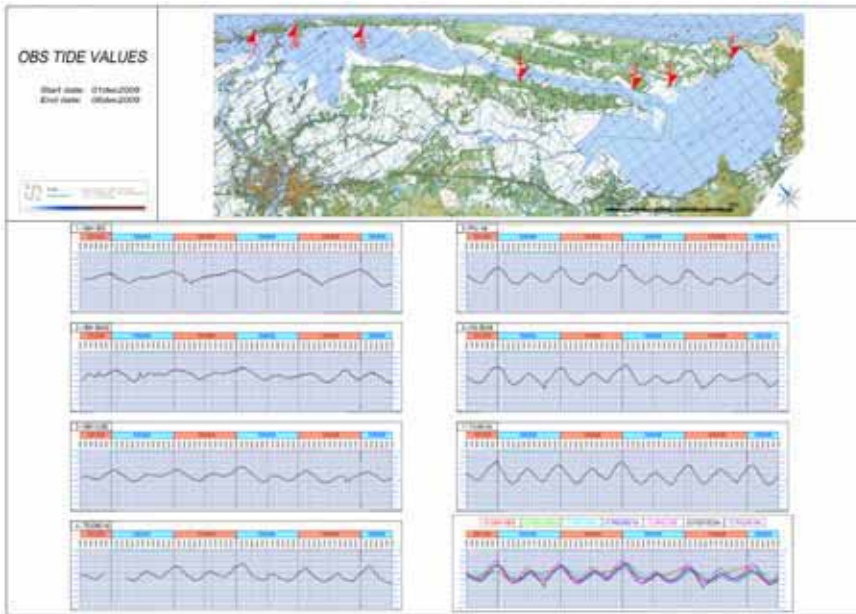


Figure 13 - Tide-metering station position and preliminary observed tide values

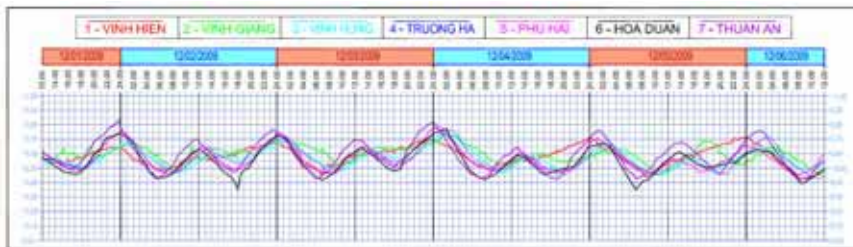
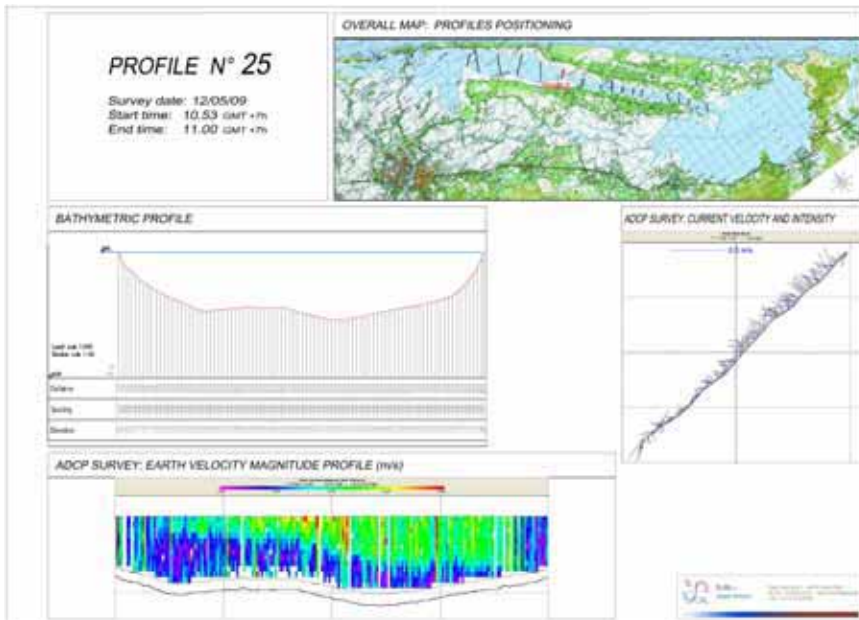


Figure 14 - Details of tide values of each tide meter station during survey period



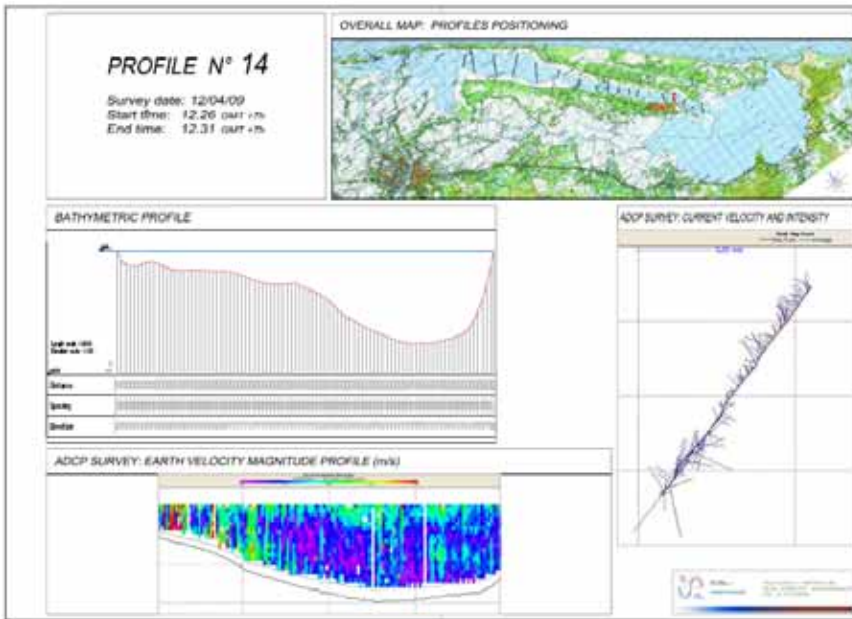


Figure 15 – Examples of profile positioning, bathymetric profile and current pattern for ADCP survey

4. DISCUSSION AND RECOMMENDATION FOR INTERVENTIONS

4.1. Analysis and discussions of collected data

According to the final results and data processing of the hydrographic campaign, the following considerations can be summarized:

- The bathymetric survey suggests that the Tu Hien inlet is almost obstructed. Along the longitudinal axis of the inlet there is a natural shoal that splits the passage of the water and can be dangerous to the navigation; the discharge of sea-water towards the lagoon is considerably reduced because of the very shallow waters configuration of the inlet.
- The tide-gauge survey revealed considerable dissipation of the water-exchange pressure provided by the astronomical tide in the area of interest. More in detail, the effect of tidal variations within the area of interest (between Tu Hien and Thuan An inlets) are not sufficient to produce the expected motive force in the channel area and in the Cau Hai lagoon.
- The current meter survey and the analysis of the datasets produced during the five days of continuous recording (during different tidal configuration and weather conditions), shows a very low water speed in the mid tract of the Thuy Tu channel (from 0.1 m/s to 0.25 m/s) and similarly low water speed in the Tu Hien inlet (from 0.1 m/s to 0.35 m/s).
- Active areas subject to tidally-driven circulation during the five days observations are remarkably limited: this means that water exchange with the open sea during an tidal cycle is restricted to the vicinity of the inlet and water-movement in the channel does not exceed the mid-portion, within a range of 5 kilometer (Figures 15). This concludes that the southern part of the lagoon is not significantly affected by tidal circulation, neither receiving clean sea water within a tidal cycle.



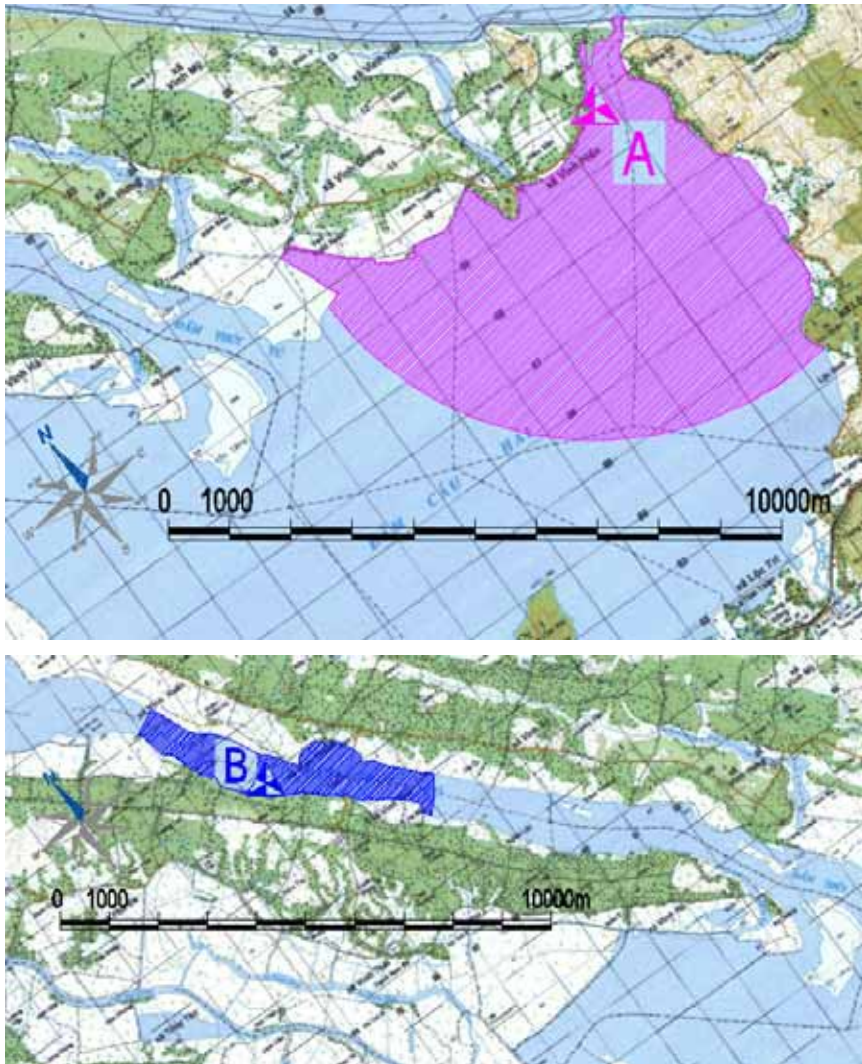


Figura 16a-c - Active areas of tidal currents within the zone of influence of the two current-meter stations: *A* (Tu Hien lagoon inlet), *B* (channel between Tam Giang and Cau Hai lagoon). Starred triangles indicate instrument location.

- The ADCP survey performed along the channel connecting the inlets of Thuan An and Tu Hien, while confirming the above conclusions, better signals that stagnation is amplified in the middle and southern parts of the Thuy Tu channel while to the north, enhanced water-circulation is related to the vicinity of the Thuan an inlet.
- Data acquired during limited time exclude the possibility to develop a complete water circulation model of the area, because of heterogeneous physiographic and climatic conditions prevailing in the lagoon and high disturbance due to human factors (obstacles, buildings, clam-farming precincts, dangerous and navigation restricted areas). Notwithstanding, this preliminary survey has been indispensable to provide a baseline for further studies, to ascertain the most relevant conditions and needs for further

investigations, in order to proceed to any modeling exercise in the future.

- The ADCP and bathymetric survey show a number of relevant “nodes” of the water model circulation, allowing a consistent optimization of any eventual further study performed in the same area.

4.2. Recommendations for interventions in support of vivification

According to the preliminary observations and data analysis commented in chapter 4.1, there is a remarkable effect of water stagnation located in the central and southern tract of the Thuy Tu channel and in the landward half of Cau Hai. In order to fully understand the circulation pattern under different climatic conditions, a complete hydrological investigation is recommended, with the scope of:

- Determining the most probable balance of water-exchange from both inlets
- Finding out all the fresh-water sources “feeding” the area of interest
- Improve the water circulation model by installing a reasonable number of current-meters in every relevant “node” of the water circulation model.
- Extend the observation to a longer period and in a different season of the year, in order to verify a possible correlation between the 2 campaigns.

4.3. Recommendations for support of improved circulation of the basin of Cau Hai

The area subject of the hydrological investigation is characterized by very shallow water, hindered circulation and low water speed. This effect is maximized in the central and southern area, where the human influence is stronger, waters are shallower and natural and artificial obstacles have higher density. In order to enhance water circulation of the southern compartment (from Thuan An to Tu Hien), a robust intervention of reorganization is imperative. In particular the following points are to be considered with priority:

- Dredging interventions and maintenance in the Tu Hien inlet, in order to increase its capacity to exchange water between the lagoon and the sea.
- Dredging intervention and maintenance of the southern part of the Thuy Tu channel: the entrance of Thuy Tu into Cau Hai is consistently obstructed; all structures and features that create impediment to the flow should be removed or modified.

- Dredging intervention and maintenance of the channel connecting Tu Hien and Thuan An inlets, in order to favor discharge through Thuy Tu.

The above mentioned interventions are considered indispensable to enhance water circulation in the southern compartment and reduce stagnation in the mid section. However, at this preliminary stage it is impossible to evaluate the extent of dredging needed because water circulation model should be implemented with more systematic measuring and monitoring.

An alternative more drastic intervention to overcome stagnation of the mid-section of the Thuy Tu channel is to open an artificial inlet in central area (Figure 17), in the case no improvement are introduced by dredging interventions recommended above. Any modification of the current morphology has to be supported by adequate modeling to appraise possible implications.

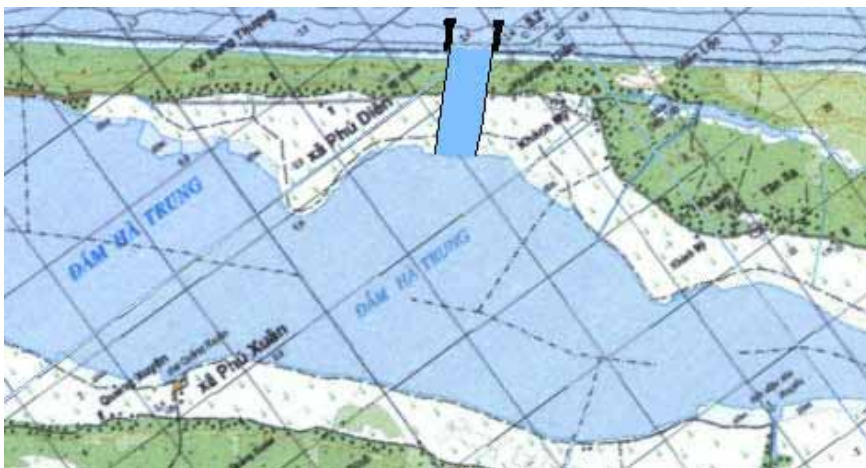


Figure 17 - Artificial inlet hypothetically open in the sand stripe of Phu Dien, in the mid-section of Thuy Tu channel where the beach barrier is narrower, to overcome the lack of circulation in this critical passageway of the Tam Giang-Cau Hai lagoon.

4.4. Technical difficulties, problems encountered and lessons learned

The following drawbacks manifested during the survey, that might require higher attention in the event of subsequent investigation.

There is a general lack of concern on environmental protection measures by local inhabitants, which is instead of utmost priority among a number of countries in the world. This should be increased by constant attention to impacts caused by any human activities even scientific surveys.

There is a general lack of concern and experience in handling and using high-technology instruments by local resource persons; hence, care should be taken in the future, with additional training sessions.

There is furthermore too much confidence in local capacity in handling different situations, in such a way that decisions taken by responsible officers in charge are not fully followed, with the consequence of

potential risk for people and instruments (this was the cause of damage to instruments).

On the contrary, the IMOLA support personnel and management demonstrated solid technical knowledge and professionalism in every phase of the activities.

5. REFERENCES

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6. ANNEX LIST

- Annex 1 - Digital Terrain Model (DTM) of the Tu Hien inlet (Cau Hai)
- Annex 2 - Contour map of the Tu Hien inlet (Cau Hai)
- Annex 3 – Chart of observed tide values, period 1st- 6th December 2009
- Annex 4 – Overall map with profile locations, tide stations, current meter positions and areas of influence of tidally driven currents in Tu Hien inlet (Cau Hai) and Thuy Tu channel (lower panel)
- Annex 5 – Benchmark monographies (13 files)
- Annex 6 – ADCP velocity profiles and bathymetries