LIDAR TECHNOLOGY APPPLIED TO THE DEFINITION OF PUBLIC USE GOODS IN COLOMBIAN COASTLINES

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ABSTRACT

To know with certainty the characteristics of the colombian coast lines, as well as the limit between state property terrains (public use goods) and the private property is of great importance for the national maritime community, as well as colombians who want to develop maritime activities and the General Maritime Direction. Nevertheless, to ensure this information, technical, administrative and juridical elements are required to be integrally approached. This article issues the current problems and proposes from a technical point of view, an operatively viable solution, based on state of the art technology for the acquisition of spatial information and GIS, in order to elaborate the cartographic base for these spaces to be defined, as well as contributing to the production of fundamental data for the Colombian Infrastructure of Spatial Information (ICDE).

Keywords: Public use goods (State property terrains), coast line, Cartographic Base, LIDAR, GIS, ICDE.

INTRODUCTION

Coastlines are complex and weak geographic areas, where there is a wide variety of eco-systems, living together in a dynamic balance, which can be easily altered by the intervention of man, who feels attracted by the landscapes and his need to exploit economically its potentials, through the development of aquatic, touristy and port activities, among others.

The dynamic balance found in coastal lines generates forms in the coastline, as a result of the interaction between the waves, tides and currents with the structures that form the coast per se. Because of this, the shape of the coast itself can change a great deal; moreover, if we find there the outfall of a river, with its sediment contents. The before-mentioned scenario isn't always compatible with some of the ways man wants to use the coast, where he requires that the dynamic balance becomes static. This situation generates a level of risk to said human activities.

The previous characteristics (dynamic balance, high use pressure and the associated risk) make it necessary to establish special policies in order to use those spaces in a proper way. Thus, Colombian laws give a status of Public Use Goods to beaches, low tide terrain and ocean waters, getting them out of private property and trade status. This way, their uses are restricted, to such an extent that if any activity is meant to take place in those areas, it is mandatory to request and clear special permissions that will only be granted once a verifying process concludes that there won't be any negative consequences afterwards.

To accomplish efficiently this government law, it's completely necessary to achieve an accurate definition about the limit between public and private areas. Therefore, concepts as the Highest Tide Line and the Inner Beach Limit become relevant as key elements to define the jurisdiction of Maritime Direction.

How can we reach a technical definition of the jurisdiction of Maritime Direction over Colombian coastlines? This is the core idea of this article, where we can evidence the starring role of geomatics, supporting the management of a government task.

METHODOLOGY

To take on this issue, we identify three key factors, as follows: Technical, Administrative and Legal.

From a technical point of view, it is necessary to determine –among others-, a basic reference cartography, to specialize the different variables used to manage the coastlines; determine the extension of the area we're going to study (both spatially and temporarily); define the precision level needed required for the information we're going to use; obtain data and determine the methodology to establish the Highest Tide Line; Inner Beach Limit and the coastal risks associated to ocean dynamics.

From an administrative point of view, it is necessary to know the current uses of coastlines and also the location of every natural or legal person dwelling there. Besides, we have to determine the anthropic behaviors that have modified the coastal area, setting a difference between their natural and current conditions. Just as well, it becomes necessary to create a database able to be associated to the developing cartographic basis, where we can also post all the permissions granted by the National Marine Authority and any penalty imposed by it before illegal settlements.

Finally, the third dimension of the issue consists of the legal aspects. It is necessary to evaluate areas such as the valid legal frame and the definitions included there, as well as how reality adjusts to this frame. Additionally, it is necessary to evaluate the legal issues about the settlements in coastal areas and the subsequent actions to carry about them.

Taking into account all of the aforementioned, a conceptual and methodological frame with a wide multi-disciplinary participation has been developed, emphasizing a strong geomatic component, to answer to everything we have stated so far, relying on the use of tools such as GIS and applying the concepts of Spatial Data Infrastructure (IDE in Colombia), which would allow to handle efficiently an important volume of national-covering data, coming from different sources. Because of its dimension, it isn´t possible to present it in this article that focus on some of the technical and administrative concepts, specially related with geomatic topics, without including neither legal aspects, nor physical oceanography nor risk analysis and evaluation.

DISCUSSION

There are two possible scenarios to discuss. The first one, related to some technical aspects of the issue and the second is related with the formulation of a conceptual model meant to determine the limits, spatial location and other characteristics of Colombian coastlines, emphasizing the beaches and low-tide areas.

I. TECHNICAL ELEMENTS OF THE ISSUE

Colombian coastlines, have been defined by the Law Decree 2324 (1.984) and they involve a complex technical frame from its articles. Said technical frame was studied,

discussed and analyzed in detail by a technical, multi-disciplinary team, formed by public officials from the Maritime Direction, from different research centers (Oceanographic and Hydrographic Research Center "CIOH" in Cartagena, and Pacific Pollution Control Center "CCCP" in San Andres de Tumaco), Harbor Authorities and Central Level Staff, aiming to identify and document the technical elements that are necessary –according to the legal frame- to define said spaces and the operative issues that have occurred while trying to find a solution to the issue.

To address the issue, some key variables have been identified. As an example, four of the technical elements of geo-spatial that are necessary to evaluate are presented, as follows:

1. Scale and Detail level of the reference spatial information (Basic Cartography)
2. Associated Data Bases
3. Information Accuracy
4. Extension of the Study Areas

a.) Reference Spatial information (Basic Cartography)

To locate the Colombian coastline geographically, we need Reference Cartography, which can be used as a foundation to understand every related variable and technical element spatially. A high level of cartographic detail (that permits accurate identification of existing landed property on the coastline) is required, because this is an area that involves Public Use Goods as well as Private Property. Said level is only reached through a cartographic scale of 1:2000 or higher.

There isn´t a Caribbean and Pacific Ocean Colombian coastline Basic Cartography in the aforementioned scale. It simply doesn´t exist and it´s not foreseeable to be generated in the short or mid term, because of other national priorities about the making of cartography in this scale, from the main towns with mainly fiscal purposes.

Thus, the need to initiate the coastline cartographic base production on a 1:2000 scale was pretty evident, as a means to achieve a basic reference level to conduct cartography studies at the coastlines.

b.) Associated Data Bases

As a complement of basic cartography, it was necessary to record the resulting information on themed census that the government entity (DIMAR) has already performed about said spaces, to complete the remaining technical elements that are involved in the characterization of the coastlines and their public and private places.

At the same time, it was also necessary to associate the cartographic base with the information that resulted from DIMAR´s administrative management, acquainted with the concessions, building permissions and site authorization orders issued, through which the use and enjoyment of public use goods is cleared, according to legal dispositions.

And this is where the Geographic Information Systems (GIS) tools become the element that brings the different variables together, supporting the coastline characterization process and their later management process.

c.) Information Accuracy

As it had been previously established, there are two key elements from which we can clearly define the public or private character of a specific property. They are the Highest Tide Line and the Beach Inner Limit.

To establish the former, it´s necessary to have a series of time variations of the sea average level in every required point on the coast. This information is not available in the country; not even the main points, where the marigraphs have been recently installed. (First by IGAC and now by IDEAM). In both cases, there are considerable "gaps" in the registers, which further complicates the task to determine the Highest Tide Line.

As for the beaches, the law provides us with several elements to determine their Inner Limit. (Non-consolidated material zone that extends from the point where a marked change in the material or physiographic shape occurs, to the point where the Storm waves reach or where the permanent vegetation line begins) Usually, that´s the limit of the storm waves. The key element here is the Storm surge, that places us before a flooding risk limit frame caused by said storm surge.

Because of all the aforementioned reasons and even though the ***x,y*** variables in the cartographic base are very important (specially because of the already mentioned work scale), the need to carefully observe the variable ***z*** arises, because of the Tide´s Top Heights and the Storm Surge.

d.) Extension of the study areas.

The official colombian coastline length figures are 1.600 km. facing the Caribbean ocean and 1.300 km. facing the Pacific Ocean. However, the research performed by DIMAR (through its research Center CCCP) about this particular issue shows a different measurement in the Pacific Ocean case, which exceeds the official figures, ranging at 1.591 km.

This record allows us to infer the existence of a Colombian Coastlines total length of more than 3.000 linear km. this represents an extensive geographic space, whose interest area´s average width is equal to 1.5 km. of coast line. In the area context, this equals a base cartography (on a 1:2000 scale) of about 4.500 square km. of coast line.

As a summary, the extension of the study areas according to cartography, plus the detailed cartography level required for ***x, y, z*** led our technical team to explore the technological alternatives currently available in the market, to allow us to cover large expanses in a short time, while evaluating the accomplishment of the demanding technical specifications required by DIMAR.

In Figure Number 1, we can see the results of the alternative exploration, pointing out the 16 possible sources of spatial data needed to generate the cartographic base; only 3 of them were found to be technically suitable to generate the 1:2000 scale cartography required by DIMAR, in accordance to the planimetric precision (***x,y***) signaled by the Instituto Geográfico Agustin Codazzi (IGAC) in its resolution N. 64 (1994), that is equivalent to a 0.30 mm factor to the map scale (1:2000).

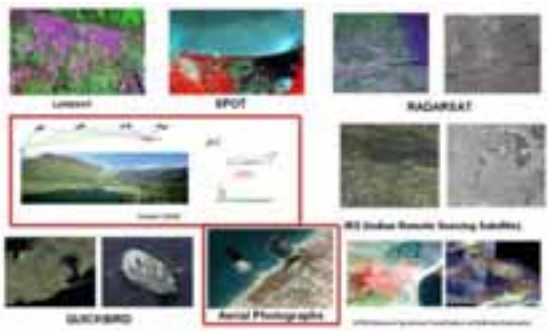

Figure No. 1. Alternatives Exploration

For the (***z***) axis, a 30 cm precision was established, to a 90% reliance interval, according to the technical requirements to determine the space of the aforementioned Highest Tide Line.

Subsequently, the technically-suitable alternatives were evaluated, keeping into consideration the operative elements to set in motion this type of technology, as its performance in the particular conditions of the Caribbean and Pacific coastlines, specifically in what is related to vegetation penetration and proper identification of water mirrors in mangrove areas, costs, and information-gathering time. LIDAR technology, combined with digital metric aerial photographs was finally selected as the source of spatial data.

The most representative technical reasons that supported the election of LIDAR technology as the main source of spatial data to generate the project´s cartographic base were:

1. The "Laser"´s outstanding ability to penetrate the vegetation
2. The High positional accuracy displayed in its three coordinates (***x, y, z***), highlighting the importance of coordinate ***z*** (height).
3. Short information-gathering time and the ability to minimize the production costs under the extreme conditions in the Coast Lines.

WHAT IS "**LIDAR**"? (**LI**ght **D**etection **A**nd **R**anging)

Laser scanning is an active system that allows us to perform distanced measurements on the earth´s surface, from an aerial-transported sensor. The system obtains three-dimensional points, from which Elevation Digital Models (MDE) can be generated.

This technology consists of the following components: Aerial platform, GPS Unit, Inertial Movement Unit, Laser Unit and Digital Camera. By combining all these elements, elevation points are obtained through the emission of light signals that travel from the source (sensor) to the objects located on the earth´s surface, and then go back to it. The return time is recorded in the system and its position is calculated through the GPS system, and the Inertial Movement Unit (IMU). The digital camera captures the planimetric information of the studied area, through taking aerial photographs, that complement the altimetric information.

II. POSING THE CONCEPTUAL MODEL

In order to provide an integral solution to the issue, it was decided to develop a conceptual model, including technical procedures and specifications for the development of each one of the technical components that are involved in the determination of Colombian coastlines; especially those key elements that will allow us to establish a spatial difference

between Public Use Goods and those susceptible to become private properties. This is a very relevant task, for all those who are interested in the use of such important national spaces.

The conceptual model was prepared from the content of the Law Decree 2324 (1984) and from the operative experience of the technical staff at DIMAR Research Centers (CIOH & CCCP) and also the Harbor Authorities, complying with their coast line management function.

The structure of the proposed model consists of seven information clusters, as seen on Figure Number 2.

The first cluster represents the generation of basic cartography that allows the spatial location and flawless identification of the technical elements required to determine the jurisdiction which, as we mentioned before, will be collected with the support of LIDAR technology and the digital metric aerial photographs.

The second one, corresponds to the gathering and generating of the associated databases, as a complement to the Cartographic base, that includes general information about the coast line settlements, as well as the database of the administrative performances of the National Maritime Authority and other entities like the Concessions National Institute (INCO), from the Transportation Ministry.

The Highest Tide line is the third cluster; it is perhaps one of the most important to define spatially the jurisdiction, according to what the Law Decree 2324 (1984) establishes. This variable involves complex numeric models developed by DIMAR, and showcases information provided by oceanographic data from several sources, including the information supplied by DIMAR.

The fourth one corresponds to the anthropic performance analysis upon Public Use Goods, that alter the natural balance of the coastlines, such as land fillings and coastal engineering works, among others, analyzing their influence in the stabilizing or altering of the natural Coastline.

Figure Number 2.

The beaches are the fifth information cluster, intended to apply the cartography to the beaches inner limit, along the coastlines, from the different technical criteria of decision, such as the storm waves limit, the marked change in the physiographic shape, the change in the constituent material and the permanent vegetation limit that had been mentioned before.

The punctual jurisdiction determinations performed before posing the current conceptual frame supply a first reference level in their definition. This is what the sixth cluster is about.

The seventh cluster corresponds to risk analysis, under the light of physical vulnerability. The objective of this analysis is to identify those coast line zones that are prone to suffer some risk from natural-type threats, because of their spatial location, natural physiology and social-economic dynamics.

The integration of these seven big information clusters (through the use of the spatial analysis functions of the GIS tools), will allow us to form a theme cartography that includes the jurisdiction limits, as a foundation for the entity management around the Public Use Goods located in the Colombian coastlines.

RESULTS

The conceptual model proposed was tested in pilot areas of both the caribbean and the pacific coastlines. The principal results obtained were:

a) A unique conceptual model to determine DIMAR´s jurisdiction, documented through procedures and technical specifications for the development of each one of the elements involved in the technical definition of the jurisdiction, based on cutting-edge technology to gather spatial data and GIS tools to manage and handle said information.
b) The model allows us to obtain a precision cartography of Colombian coastlines. This result contributes to the elaboration of fundamental data in the “Colombian Spatial Data Infrastructure (ICDE) in the following topics:

Geodesic Control: The control points for the elaboration of the cartographic base are referred to the National reference geo-centric frame (MAGNA), as the geo-positioning standard for Colombia.

Orthoimages: The resulting cartographic base includes orthophotographs created from the digital metric aerial photographs and the elevation digital model obtained from the data captured by the LIDAR sensor.

Elevation Data: The three-dimensional information captured by the LIDAR sensor corresponds to elevation data with a 30 cm.-accuracy factor, referred to the Elipsoide WGS84.

Transportation: The cartographic base includes the sea transportation infrastructure related with harbors, docks, marinas, etc. because it is a coastal area. The current terrestrial transportation infrastructure in the coast lines is included, as well.

Hidrography: Basic cartography includes water bodies and hidrographic nets present in the study area.

Political-Administrative Limits: Considering DIMAR's jurisdiction, as one of them.

Real Property Census: As an inventory of real estate, under a purely physical and themed approach, as far as the occupational status of the DIMAR's jurisdictional spaces goes. (See Figure Number 3, Orthophotomap created from metrical and digital information and aerial photography).

Just the same, a lot of effort went into work within DIMAR, about how to implement the geo-positioning standards and geographic information documentation, represented in procedures and technical specifications that stand internally for the conceptual model's operability.

Figure Number 3 . Orthophotomap created from metrical and digital information and aerial photography

c) The model allows us to obtain an inventory of the National Public Use Goods at Colombian coastlines, giving them character, according to the needed requirements asked for by the control entities, about their quantification, occupational status, geographic position and other aspects, complying that way, the tasks assigned by the national Government.

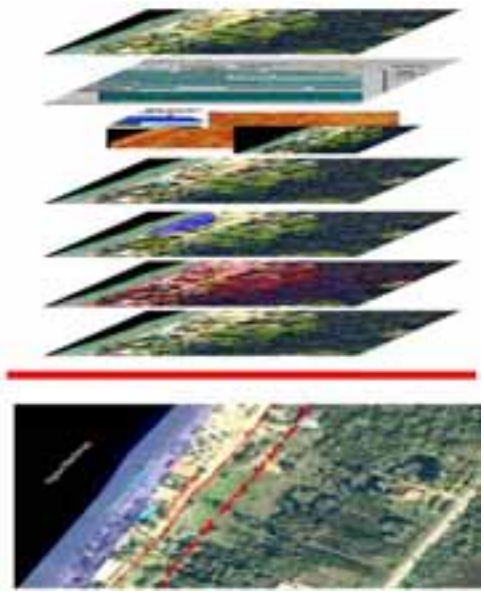

Figure Number 4. Public Use Goods In Colombian Coastlines

d) Others Applications:

Figure Number 5. GIS Application (SIGDIMAR)

Figure Number 6. Coastline Update in Nautical Charts

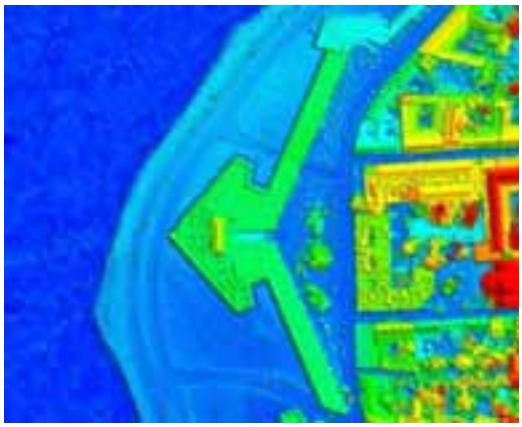

Figure Number 7. Elevation Digital Models

Figure Number 8. Flooding Maps

The resulting products allow DIMAR to exert a higher control of the Administrative performances of the National Maritime Authority and it speeds up the needed paperwork at the coastline area, by setting the outline of their jurisdiction in an area upon which said paperwork is being carried on.

CONCLUSIONS

- DIMAR's jurisdiction definition can't be approached from a purely technical approach; it's necessary to analyze the legal environment and administrative implications of any jurisdiction proposals submitted.

- The cutting-edge technology related with the spatial data acquisition, offers a technically suitable technology to generate a cartographic base from such a particular environment as the coastal areas in Colombia, contributing like this to provide fundamental data, as of Spatial Data Colombian Infrastructure (ICDE)

- The project to elaborate the cartography of Colombian coastlines, focused on the determination of the public use goods limits that exist there, as well as their current tenants, the degree of man intervention and the associated risks, are a very valuable tool for the coastal administrations to elaborate the plans or schemes of territorial ordering, for national administrations, in charge of fundamental topics (like tsunamis or dock expansion plans), for the inhabitants of the Coastlines, since it will allow them to know the extent of their private properties and where the public use goods begin. The national Maritime authority will be able to ease the administration of these spaces through this information, because of the availability of this technical information that will prove priceless when it comes down to taking decisions about granting or not a concession, a building license or a site clearance.

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