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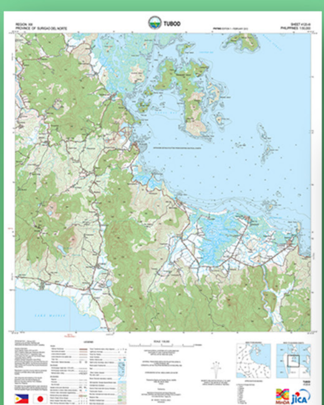
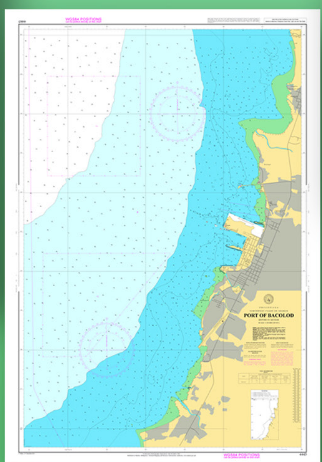
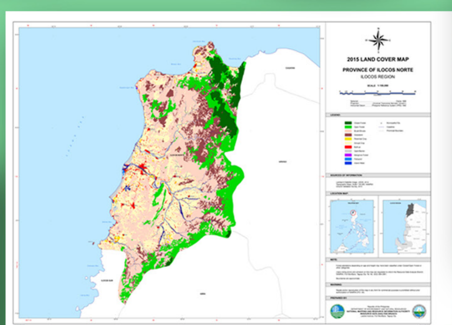
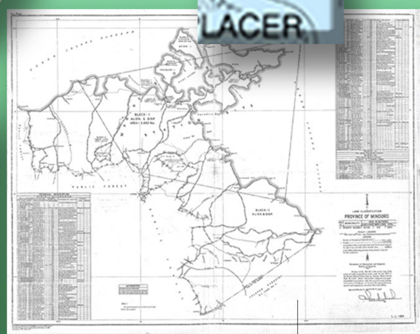
MAP 101

"...a basic understanding of maps and charts towards a geospatially-enabled Philippines."

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FOREWORD

The creation of the National Mapping and Resource Information Authority (NAMRIA) dates back to 10 June 1987 through Executive Order number 192, otherwise known as the Reorganization Act of the Department of Environment and Natural Resources (DENR). NAMRIA, pursuant to Section 22 (a) of the EO, is mandated to provide the DENR and the government with map making services and to act as the central mapping agency, repository, and distribution facility for natural resources data in the form of maps, charts, texts, and statistics. Its core functions are geodetic reference system development; topographic mapping; hydrography, physical oceanography, and nautical charting; environment and natural resource mapping; maritime zones and boundaries mapping; and geospatial information management and services.

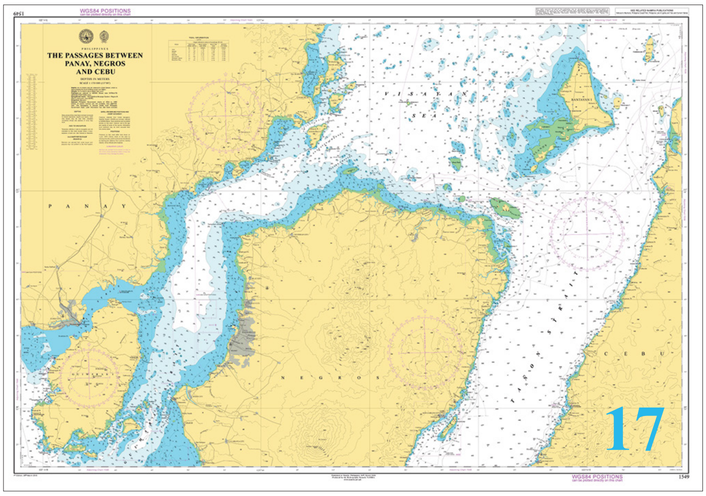
After three decades of existence, NAMRIA goes back to the basics for this issue of *Infomapper*. This edition features the most plain and simple approach to map reading, map making, thematic mapping, and geographic information system or GIS in the light of NAMRIA's responsibility to the general public on awareness raising and re-education. Nowadays, people realize the added value of maps as tools in planning, decision making, development, management, and governance. Many individuals in various organizations at local and international levels have sought out and collaborated with NAMRIA to produce maps for applications in the areas of resource management, climate change, and disaster-risk management, among others. These collaborations have enriched the experience of NAMRIA in map making while further ensuring its contributions to national development.

By going back to the basics and simplifying how the general public might understand the maps, NAMRIA brings the benefits of these maps within their reach. A basic approach to appreciating the maps is a way towards having a geospatially-enabled Philippines.

While basic may sound easy for the reader, it is not so for NAMRIA. Considering the agency's decades-old history and the wealth of experience it has gained from working with clients and partners, simplifying the complicated and technical mass of knowledge on hand, choosing what is most relevant, and organizing it in a way that most readers can understand are somewhat challenging.

To our dear readers and clients, now is just about the right time to do it. •

Usec. PETER N. TIANGCO, PhD
Administrator



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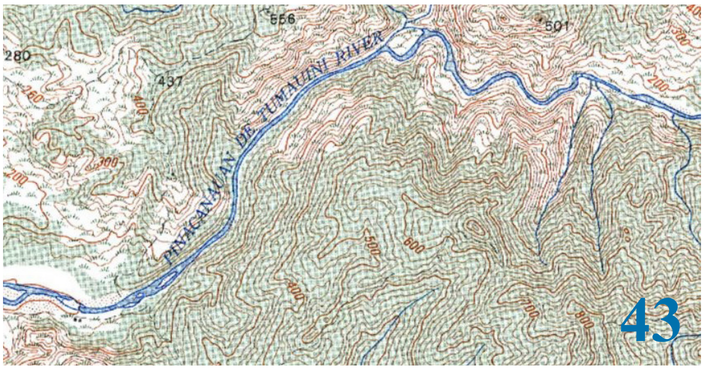

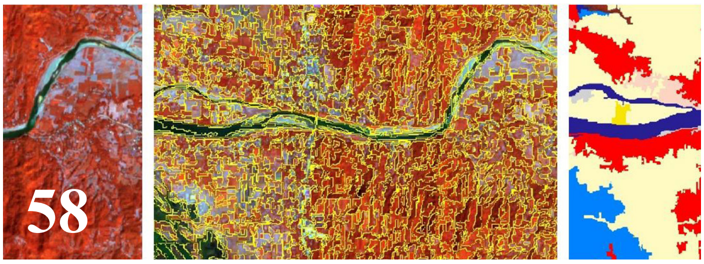

Map Reading 101

by Lcdr Aaron Andro V. Ching[1], Joseph C. Estrella[2], Alvin F. Laurio[3], and Rosalyn D. Sontillanosa[4]

Appreciating maps begins with knowing what they are, their parts, and the information that can be derived from them. Further appreciation will entail learning how to read maps, knowing the other types, recognizing their purposes, and even understanding how they are made.

Maps are used because of various reasons but in most cases, they help us plan a particular activity. They are essential tools in helping people locate features and navigate their way on the surface of the Earth. They provide information that are important for planning, decision making, operations, and governance.

Exploring maps further can get us more interested in discovering the tremendous usefulness of these tools in analyzing situations and our environment. Studies show that 80% of the information needed in everyday life are related to the location of people, places, events, and things.

What is a map?

A map is a graphic representation of the Earth's natural features; artificial or human-made structures; or observable facts, occurrences, or circumstances; usually drawn on a flat surface or in a two-dimensional (2D) medium. On a map, the real world or any defined geographical area is depicted by using symbols in their correct positions and on a reduced scale. A map contains geographic or geospatial information or information describing the locations and names of features beneath, on, or above the Earth's surface. It also tries to show relationships among the elements in an area such as objects, regions, or themes.

This article will try to guide us through basic map reading by using, as references, the two basemaps produced by NAMRIA. These are the topographic maps and nautical charts. Oftentimes, basemaps form the background setting for plotting or presenting specialized types of maps. Since they contain the essential figures and outlines, basemaps serve as framework or foundation maps to which other kinds of datasets are referred or overlaid to produce customized or thematic maps.

How to Read a Topographic Map?

The ability to understand and interpret accurately a topographic map is a basic skill for navigation and mapping. It can give us a birds-eye view of the ground. It can also help us visualize the terrain, especially in a mountainous landscape.

(continued on the next page)

How to Read a Nautical Chart?

The nautical chart is the mariners' best friend. It serves as their guide in the sea by giving direction and helping them avoid dangers that can sink their ship. It also gives them an overview of the rules that they must follow while navigating near the coasts.

(continued on page 17)

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Topographic maps are used by many individuals and organizations. Among them are travel enthusiasts, civil works engineers, environmental planners, surveying companies, census bureaus, the members of academia, and local governments. Whether we use topographic maps for personal or professional purposes, it is a great advantage if we are familiar with the details they contain. NAMRIA studies show that the agency's basemaps are commonly used by private companies and individuals, the members of the academia, and the national government agencies; and for the purposes of research, transportation and shipping, geographic information system, and mapping and surveying.

What is a Topographic Map?

A topographic map *(Figure 1)* is a graphic representation of an area that shows detailed information about the landscape and relief of the Earth's surface. It enables us to visualize a three-dimensional (3D) terrain from a flat piece of paper. It contains illustrations about some ground features like contours, elevations, mountains, valleys, vegetation, bodies of water, roads, buildings, and boundaries. It also includes toponymy or the names of geographic features.

The contour and elevation information distinguish the topographic maps from other maps.

The most practical way to read a topographic map is to gain an understanding of its contents and parts *(see centerfold)*. Visual illustrations will supplement some explanations on mapping concepts, technical terminology, and examples of symbols used to represent features on a topographic map.

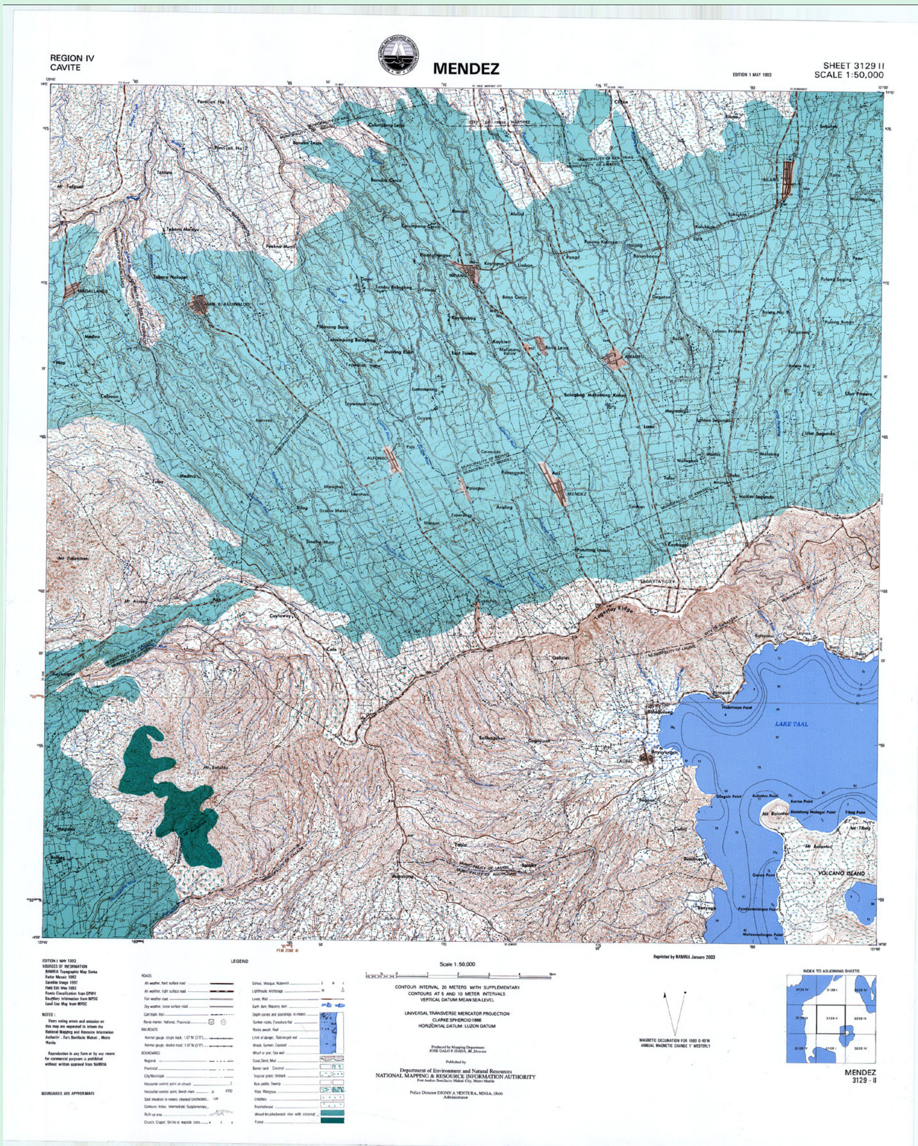


Figure 1. An example of Philippine topographic map on scale 1:50,000 with 20 meters contour interval

Knowing the directions

The first step in reading a topographic map, or any map for that matter, is to know the directions. Most of the time, there is a North Arrow symbol on the map which indicates directions. It is a basic requirement to understand the four "cardinal" directions. These are North, East, South, and West. On a standard topographic map, the North direction is directly up, East is directly right, South is directly down, and West is directly left.

To further understand directions, let us take for example Figure 2. Wack-Wack Golf Course, on the upper right corner of the topographic map, is located between the North and East directions. It is in the "northeast" of Hagdang Bato.

However, nowadays, if we want to navigate to our chosen destination or simply determine our estimated location on the ground, the aid of a traveling device, such as a compass or a Global Navigation Satellite System (GNSS) receiver, will certainly complement our setting of directions. GNSS is the standard generic term for global satellite navigation systems that provide geospatial positioning and timing data. The Global Positioning System (GPS) of the United States is one of those systems; others are Russia's GLONASS, European Union's Galileo, and China's BeiDou. Other systems of regional coverage are Japan's QZSS and India's IRNSS.

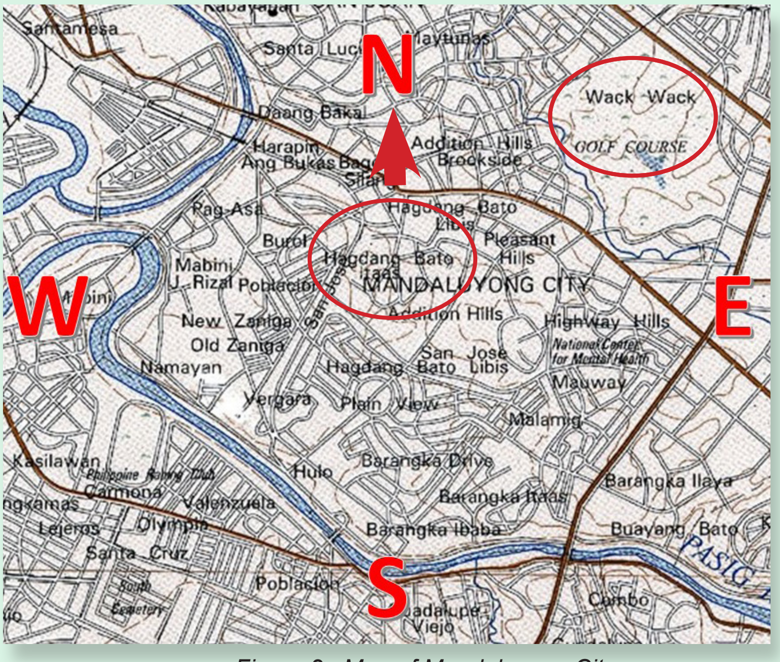


Figure 2: Map of Mandaluyong City

Identifying the ground features

Besides directions, the topographic map contains general information about the features on the ground. The features are commonly divided into three categories *(Figure 3)*. These are **Relief**, represented by contour lines which are the marked interconnected points of equal elevation above mean sea level; **Hydrography**, represented by water bodies which include lakes, rivers, streams, creeks, and swamps; and **Culture**, represented by the artificial features which include roads, airports, urban development, and buildings.

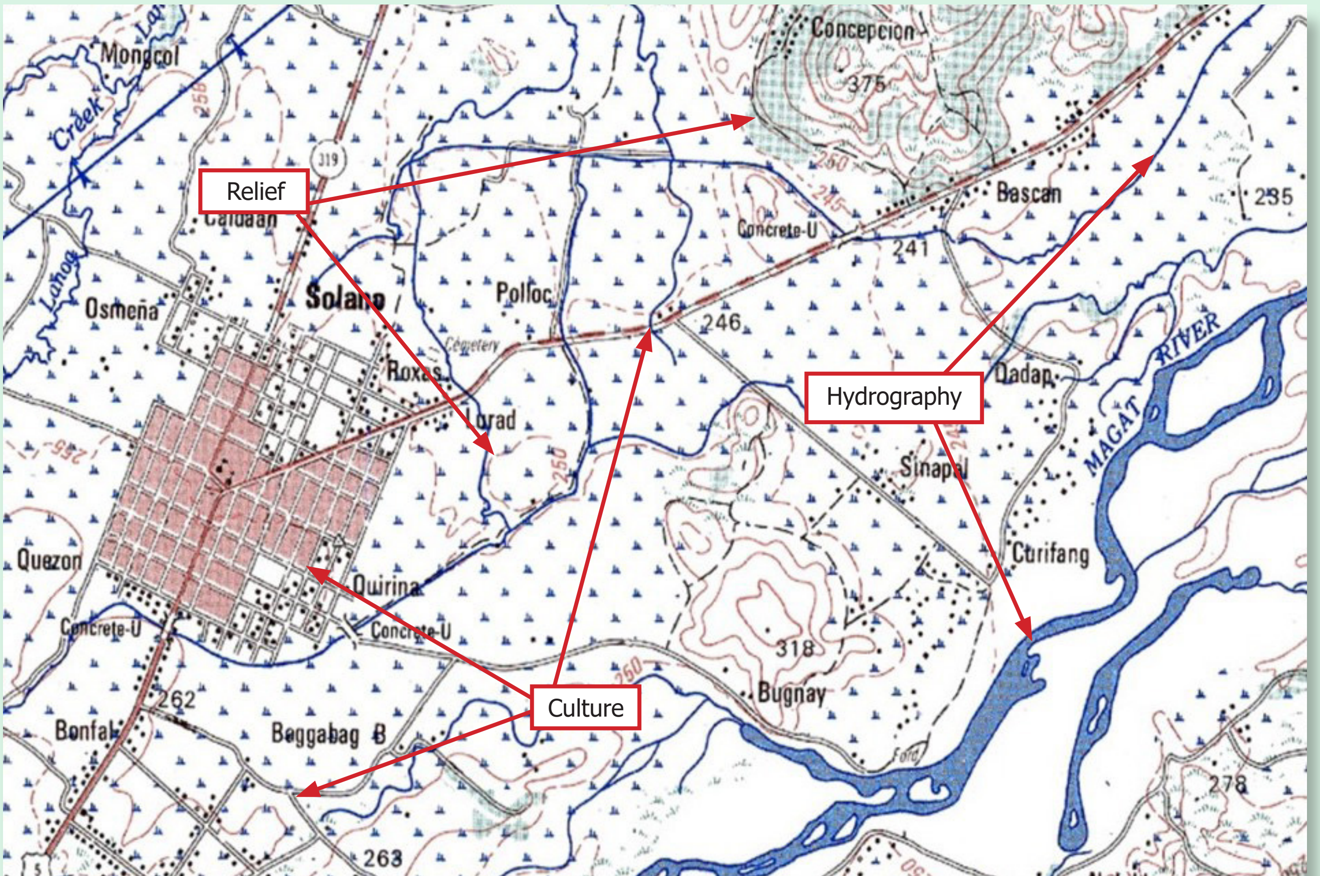


Figure 3. Different ground features on a topographic map

On a NAMRIA topographic map, the ground features can be identified through their symbols and associated colors. Vegetation and wooded areas are usually presented in **green**, water bodies in **blue**, cultural features like houses and built-up areas in **black**, and roads in **light brown**. Contour lines are usually presented in **dark brown**. Sometimes, the same color may be used to symbolize different features, but in varying shades. Hence, it is very important to refer to the map legend *(Figure 4)* for colors and other symbolization marks used.

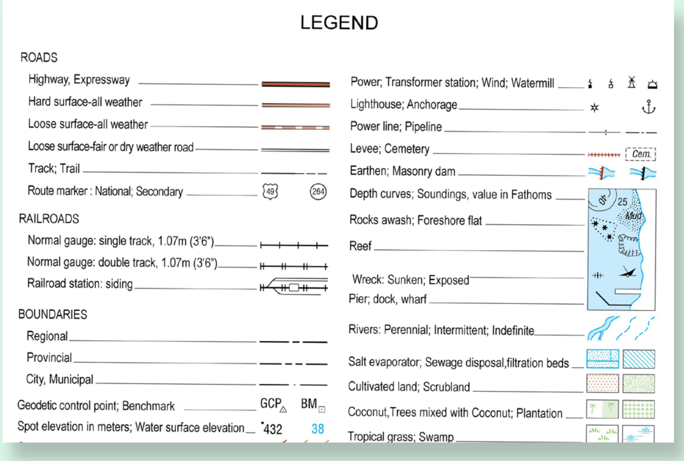


Figure 4. Map legend

The legend of the topographic map indicates other information about the ground features. It is important to familiarize ourselves with the legend information to understand what particular symbols represent which features on the ground. As a common practice, real ground features are represented on the topographic map as points, lines, or areas (or polygons). For example, houses and buildings may be represented as points or areas depending on the scale of the map *(A separate section discusses this topic).*

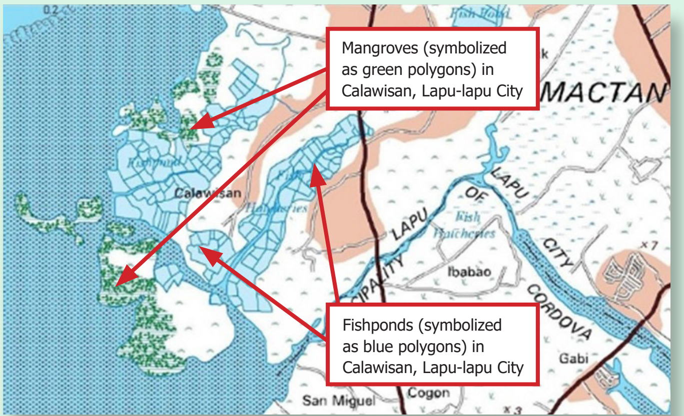


Figure 5. Mangroves and fishponds

Sometimes, the location and position of the feature on the topographic map will give us a hint of what it is in reality. For example, in Figure 5, **green** polygons relatively located near coastal areas or on riverbanks can be identified with high possibility as mangroves. Similarly, **blue** polygons within a waterbody are fishponds.

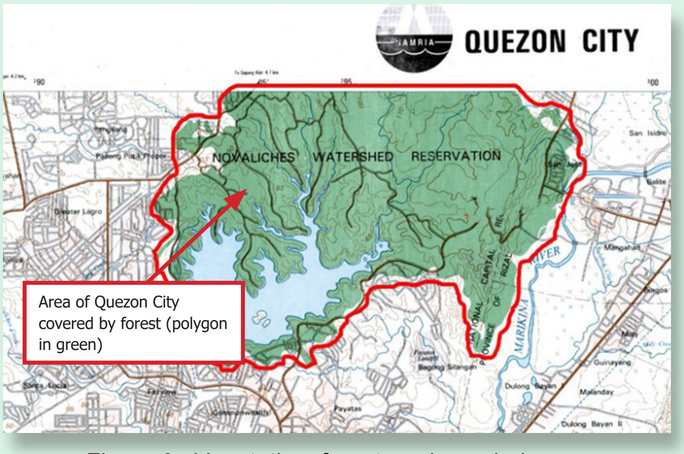


Figure 6. Vegetation, forest, and wooded areas

In Figure 6, the **green** polygon symbolizes the vegetation in the area. Forested and vegetated areas are shown in **green** with varying types of symbols depending on the vegetation type being described on the map.

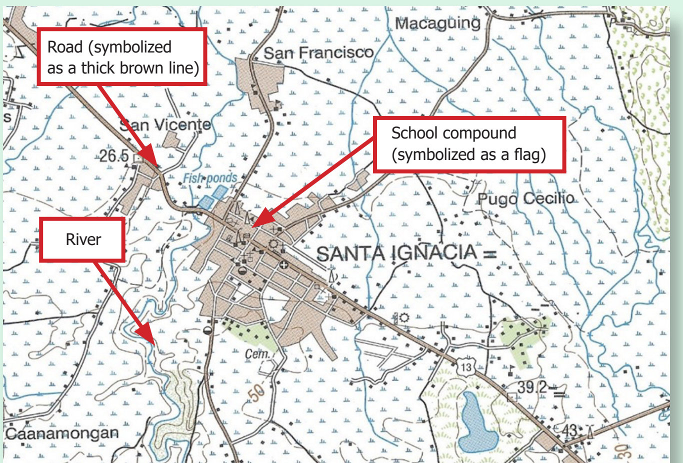


Figure 7. Artificial roads, natural roads, built-up area, and rivers

In Figure 7, the **light brown** lines symbolize the roads, the **blue** lines pertain to the rivers or water streams, and the **black** dots represent the buildings.

On a topographic map, points, lines, areas, and other assigned symbols are plainly indicative in nature and may not necessarily reflect the absolute positional accuracy of the actual ground features represented. To minimize, if not avoid confusion, a general explanation is usually included in the map. Boundaries provide a typical example of this situation.

In Figure 8, the boundaries between or among administrative or political units are symbolized by **red** broken lines. Because of their sensitive nature, boundary lines are usually supported by marginal notes to indicate their approximate accuracy.

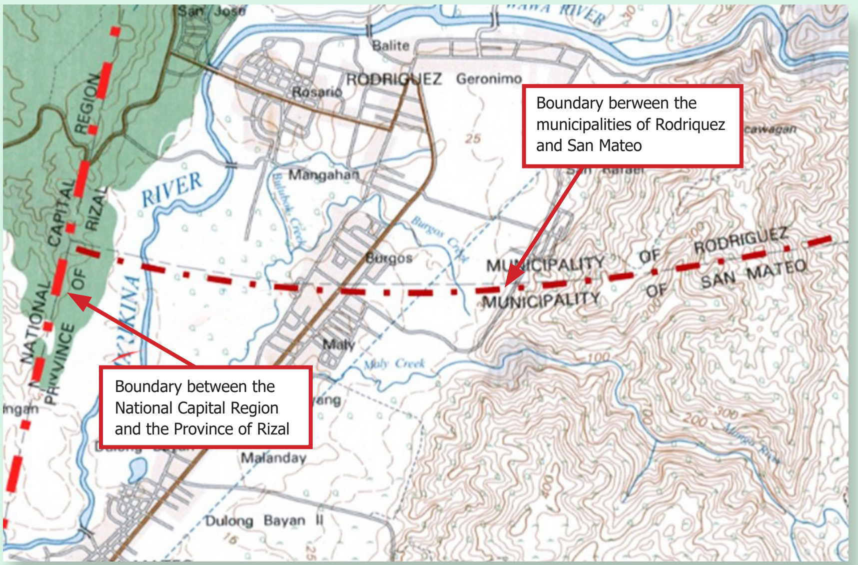


Figure 8. Boundaries are symbolized as red broken lines. Note that boundary lines in NAMRIA maps are approximate as stated in the marginal notes found in them.

Understanding the contour lines

The topographic map also contains information about terrains. The terrains, which indicate the steepness and shape of the ground, are represented on the map by the contour lines. As mentioned, the contour and elevation information distinguish the topographic map from other maps.

Contour lines are imaginary lines that show the elevation (the vertical distance above or below sea level) and relief (shape of the terrain) of the different features on the surface of the Earth. Note that they are usually drawn on the topographic map in **dark brown** lines.

Contour lines enable us to determine elevations or heights when we look at 3D features or objects on top, like mountains and hills, and project them in a 2D form *(Figure 9)*. They are basically the "circles" that follow the same elevation around a feature. No matter what shape the mountain or hill is, the contour line will always close back into itself. In principle, a contour line is formed by connecting, in succession, a number of points having the same elevation.

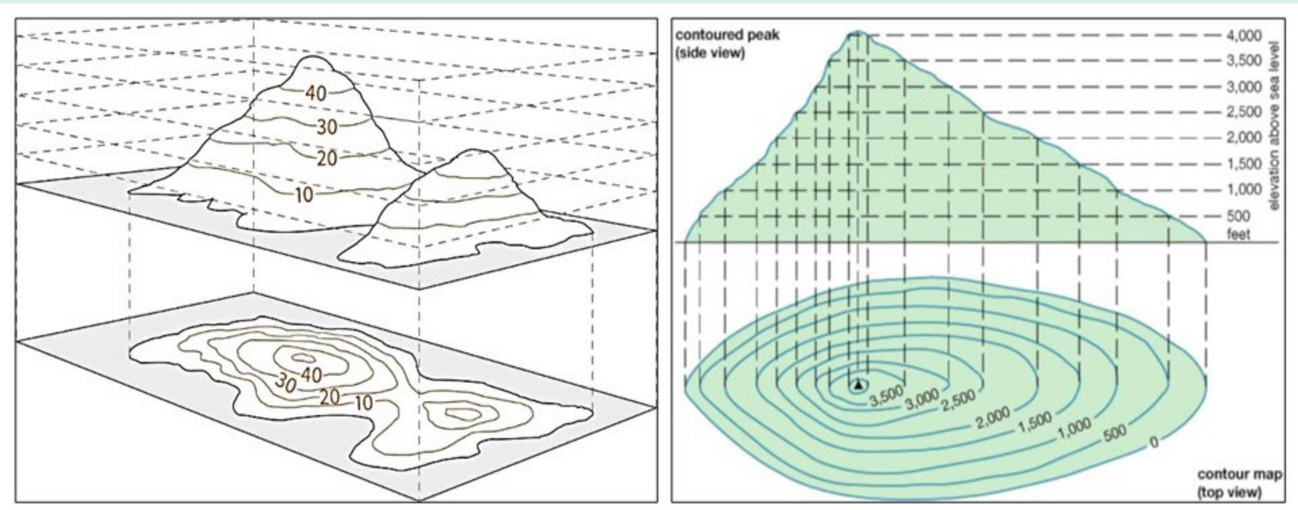


Figure 9. The shape and elevation of the hills are represented on the map as contour lines. Each number marks the elevation above sea level.

On a topographic map, contour lines are drawn corresponding to the even or equal spacing of the actual elevations. The spacing is called a **contour interval (or interval)**. While the actual elevations are spaced out evenly, say every 10 meters, the corresponding contour lines may appear as irregular and misaligned "circles" on the map. For clarity, interval numbers are marked between contour lines.

Contour intervals vary depending on the scale of the topographic map. In the Philippines, contour interval is 10 meters (m) for 1:10,000 scale maps; 20 meters for 1:50,000; and 100 meters for 1:250,000. In Figure 9, we can visualize the shape of the terrain and contour lines shown at an interval of 10 linear units.

All elevations on a contour map are measured based on the vertical datum called **mean sea level or MSL** *(Figure 10)*.

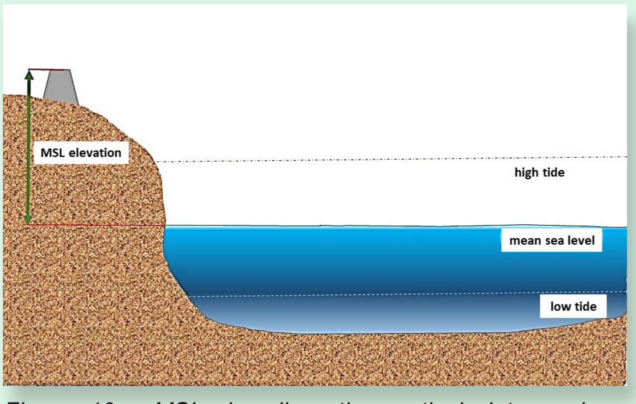


Figure 10. MSL describes the vertical datum where elevation/height values are referenced.

Figure 11 shows the three kinds of contour lines on a topographic map. These are the index, intermediate, and supplementary contour lines. **Index** contour lines are considered primary lines. They are represented with heavier or thicker marks so that these lines will be the first thing to catch our eye when we look at a topographic map. They are usually labeled by a number showing the elevation. **Intermediate** contour lines, which are the most common, are the lines between index contour lines. They are thinner compared to **index contour lines**. They are evenly spaced but do not have any number label. The purpose of intermediate contour lines is to show the shape or relief of the terrain or landscape that is generalized by the index. **Supplementary** contour lines are used to portray significant relief on sharp summits or isolated tops and slope in flat areas that would not be shown by the normal contour interval. They are shown in dashed or dotted lines.

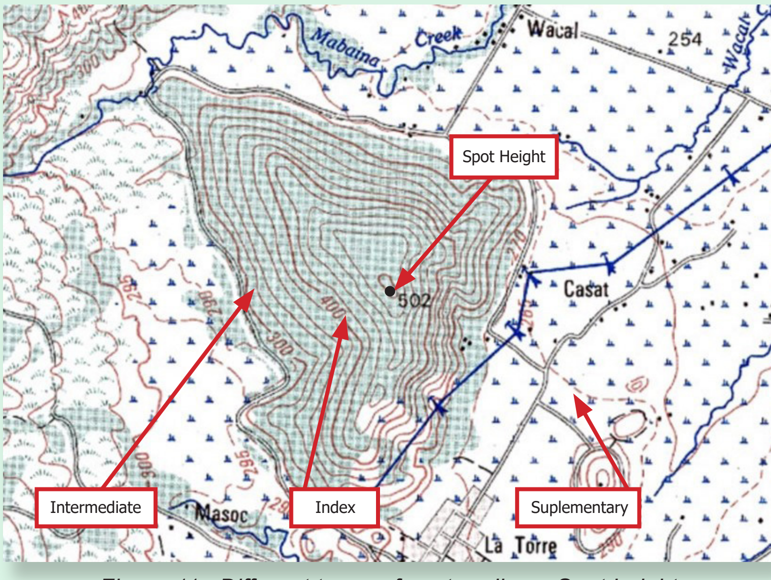


Figure 11. Different types of contour lines. Spot height is shown to indicate top elevation.

Note that the numbering of contour lines is from the bottom going uphill. In addition to contours, there are points on the map called **spot heights** or **elevations** in support of the relief presentation. They are shown in prominent natural features such as hilltops, isolated summits, mountain tops, saddles, and other high points that dominate an area and on the other hand, on the bottoms of significant depressions. They are also displayed on road junctions, high points on highways and extensive flat areas in order to add to the relief presentation. The value of the spot heights or elevations is usually displayed beside the point represented by a black dot.

The spacing between contour lines indicates the steepness of the terrain *(Figure 12)*. The closer the contour lines are, the steeper the slope because the elevation is changing rapidly in a short distance. On the other hand, contours that are far apart indicate

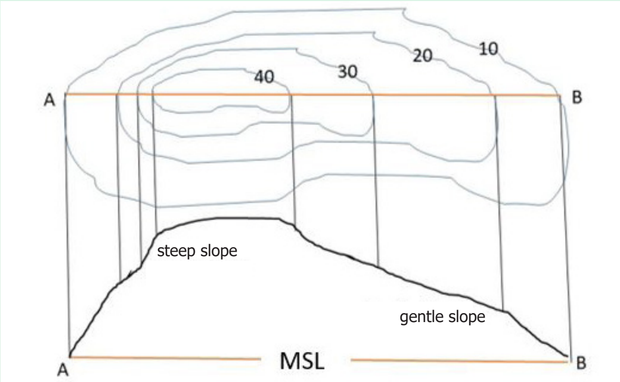


Figure 12. Contour lines indicating slopes

a gradual slope. Slopes are crucial in trekking and hiking.

Different contour line formations can help us recognize quickly various terrain features on the map. These features are hill, valley, ridge, saddle, cliff, spur, gully, cut, fill, and depression. Shown in Figures 13 to 20 are patterns of contour lines and their corresponding forms and shapes on the ground.

*Figure 13. Like a volcano, a **hill** is composed of contour lines forming concentric circles. The smallest circle indicates the peak of the hill.*

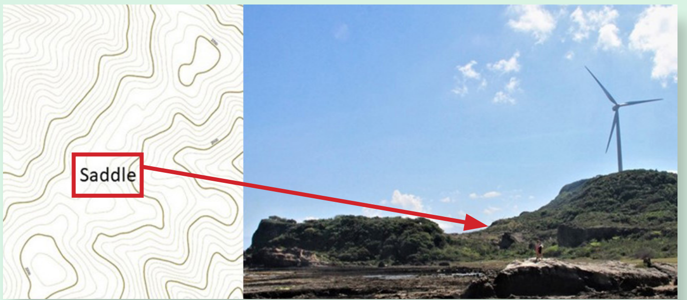


*Figure 16. A **saddle** is a low point between two hilltops or peaks.*

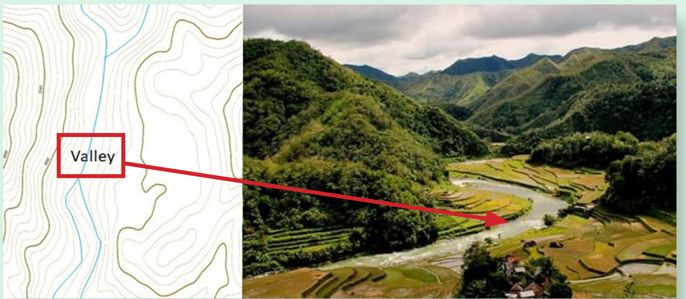


*Figure 14. Lowland areas between ranges of mountains or hills are often with a river or streams running through it. On a topographic map, we will notice a cluster of contour lines separated by a blue line. The area between these contour lines where the blue line is running is the **valley**. It is either U-shaped or V-shaped.*

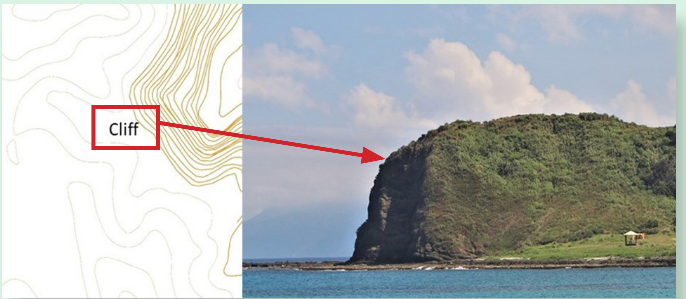


*Figure 17. A **cliff** is a vertical or near vertical ground feature. On a topographic map, cliffs are represented by very close contour lines and sometimes they appear as one line. However, some cliffs may not appear on a topographic map depending on the scale of the map.*

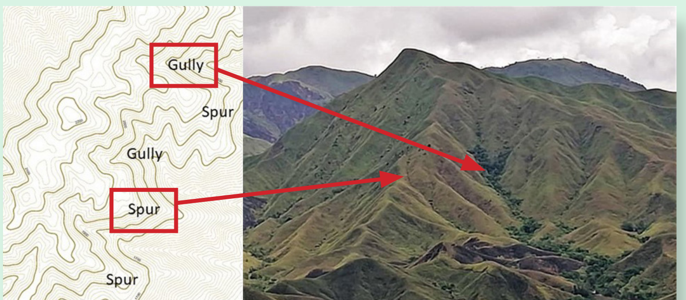


*Figure 15. A **spur** is a piece of land protruding out from the side of a ridge. It is depicted as U or V contour lines and pointing away from higher elevation. A **gully** is formed from the action of water. It is depicted as U or V contour lines and pointing toward higher elevation.*

*Figure 18. A **ridge** is located on a high ground which usually connects peaks or hilltops.*

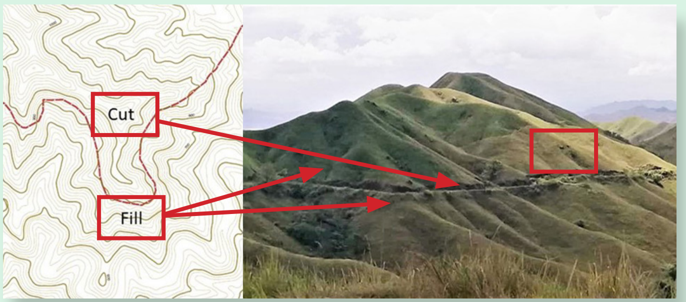


*Figure 19. A **cut** is where soil or rocks were removed, usually from a mountain side, to form a level bed for a road or railroad track. It is usually a break in the contour line. A **fill** is an artificial feature resulting from the filling up of both sides of the cut with soil or rocks.*

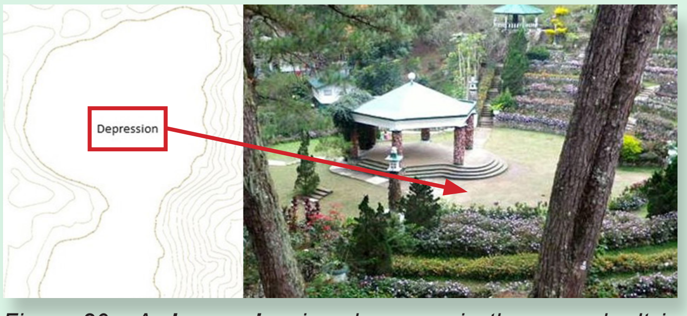


*Figure 20. A **depression** is a low area in the ground. It is depicted on the map with ticked contour lines that delimit areas of lower elevation than the surrounding terrain.*

Interpreting the scale

Another important thing to learn in reading a topographic map is the ability to interpret the scale of the map. A scale indicates the relationship between the distance measured on the map and the actual distance on the ground. Scales are commonly written as a ratio. For example, a scale of 1:10,000 (also 1/10,000 in fraction format) means that one unit of measure on the map is equivalent to 10,000 units of the same measure on the ground. A scale of 1:50,000 or 1/50,000 means that one unit on the map is equivalent to 50,000 units on the ground.

Given the last example, let us try to analyze and interpret a measurement of two centimeters (cm) on the map.

Map Distance	2 cm	2 cm	2 cm	2 cm
Ground Distance	2 cm x 50,000	100,000 cm	1,000 m	1 km

On a scale of 1:50,000, two cm on the map means one kilometer (km) on the ground, which is derived from multiplying two cm by 50,000 units. Further, one km is simply the result of a series conversions as shown in the table. Likewise, a map user will then be able to visualize a 10 cm road on the map to be actually five km long on the ground or vice versa.

To understand more about scales, let us take this exercise about planning a short trip. To carry out this plan, let us use the simplified topographic map as displayed in Figure 21.

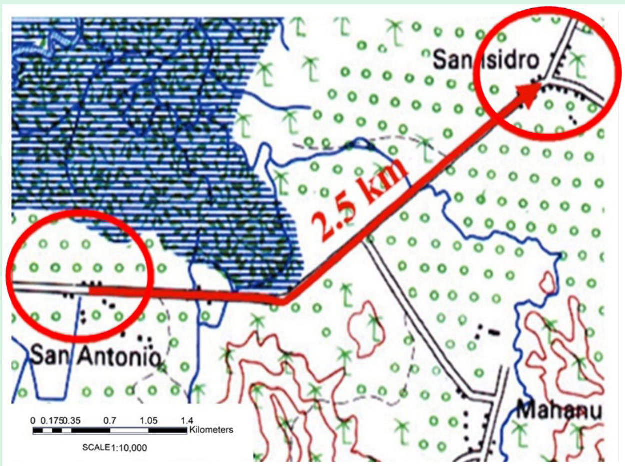


*Figure 21. The **distance** from San Antonio to San Isidro is approximately 2.5 km.*

The scale of the map is shown to be 1:10,000. The plan concerns about my wish to visit a friend who just moved into a new place somewhere in San Isidro, a small town nearby. With the same map in hand, I know that my house is located around San Antonio, also a small town. Before I make my visit, I want to find out the estimated *distance between our houses. Using a standard ruler to measure the bar scale, I measured the line between our two places to be 25 cm. Here's how I went through with the rest of my computation:*

Map Distance	2 cm	2 cm	2 cm	2 cm
Ground Distance	25 cm x 10,000	250,000 cm	2,500 meters (m)	2.5 kilometer (km)

At 2.5 km and setting aside other conditions, I can decide whether I will set my trip on foot or by riding a bicycle.

Scales are presented on maps in three different types: Verbal Scale, Bar Scale, (also Graphic or Linear Scale), and Representative Fraction (also Ratio Scale).

The **Verbal Scale** uses simple words for describing the scale. An example is "1 cm = 1 km" or "1 inch = 5 miles". The **Bar Scale** contains a line bar which is divided into uniform parts or grids. Each grid is labeled with its corresponding ground length. The **Representative Fraction** shows the relationship or equivalent of 1 unit on the ground. For example, "1:10,000" means 1 cm on the map is equivalent to 10,000 cm on the ground. Or, one inch on the map means 10,000 inches on the ground. Regardless of the unit used, the ratio would still be the same, hence it is also called the **ratio scale**. Unlike the Verbal Scale, the Representative Fraction uses numbers or values expressed in fraction or ratio.

The two most commonly used scales in NAMRIA's topographic maps are the Bar and Ratio Scales *(Figure 22)*.

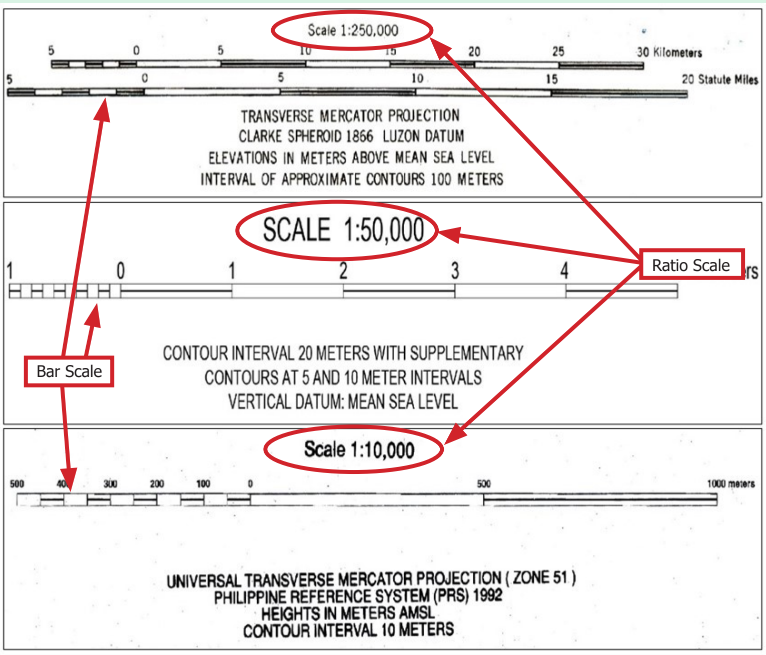


Figure 22. The scale bars and representative fractions in red circles are used in topographic maps.

Sometimes, map users are confused about the difference between and among large-, medium-, and small-scale maps. We tend to associate large numbers with large-scale maps and small numbers with small-scale maps. In scale, it is actually the other way around. Remember that scale is a fraction (or ratio) where the numerator (or number left of ratio sign ":") is always a constant value "1" and the denominator (or number right of ratio sign ":") is a variable number. Mathematically, fractions are a division operation. The larger the denominator is, the smaller the resulting value (quotient) becomes. Conversely, the smaller the denominator is, the larger the resulting value (quotient) becomes. In theory, a small quotient can be associated with cramped or little amount of information and vice versa. Relating this to a map, a small scale means that any defined area anywhere on the map can relatively hold a limited amount of information details. However, cartographers always have a way of designing maps in order to keep the entire map still relevant and meaningful to the user.

Scales are therefore inversely proportional to the details of information contained in a map. On large-scale maps, represented ground features are easy to visualize and recognize. It also follows that any defined area anywhere on this map can hold a judicious amount of information. But as the scale becomes smaller, represented ground features may no longer be recognizable and purposely visible on a map. Again, as a reminder, this is where a map legend plays its important part in map reading. Now we can think of how ground features are represented on medium-scale maps or any scale in between.

Using NAMRIA's topographic maps, large-scale maps are those on scale 1:10,000 and higher. Here, the word "higher" means any number with a value smaller than 10,000 such as 4,000 or 1,000; medium-scale maps are those on 1:50,000; and small-scale maps are those on 1:250,000 or lower. Figure 23 shows the maps on different scales.

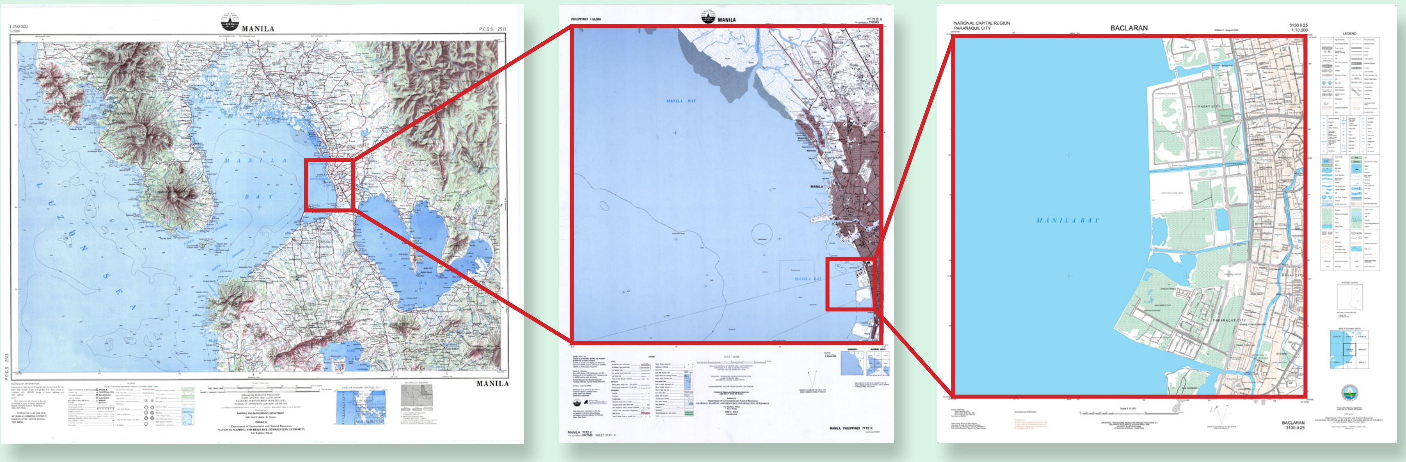


Figure 23. Three topographic maps of Manila - The first map is a small-scale map on 1:250,000 scale, with few details but large-area coverage of approximately 1.8 million hectares. The second map is a medium-scale map on 1:50,000 scale covering an area of approximately 76,000 hectares. The third map is of Baclaran on 1:10,000 scale, with more details shown on the map but small-area coverage of approximately 3,000 hectares.

As earlier mentioned, real-ground features are represented on the topographic map as points, lines or areas (or polygons). For example, houses and buildings may be represented as points on a small-scale map while they may be represented as polygons on medium- to large-scale maps. In Figure 24, the orthophoto on the left shows Colegio de San Agustin in Makati City taken by a large-format mapping camera mounted on an airplane. On a 1:10,000 map on the right, the ground features, and the surrounding buildings and houses are represented as polygons. On the small-scale map in Figure 25, those buildings are no longer visible. Only the main roads or highways are recognizable on the map.

Various applications use different map scales. It is important to know what map scale is appropriate for the work we are going to do. For planning purposes,

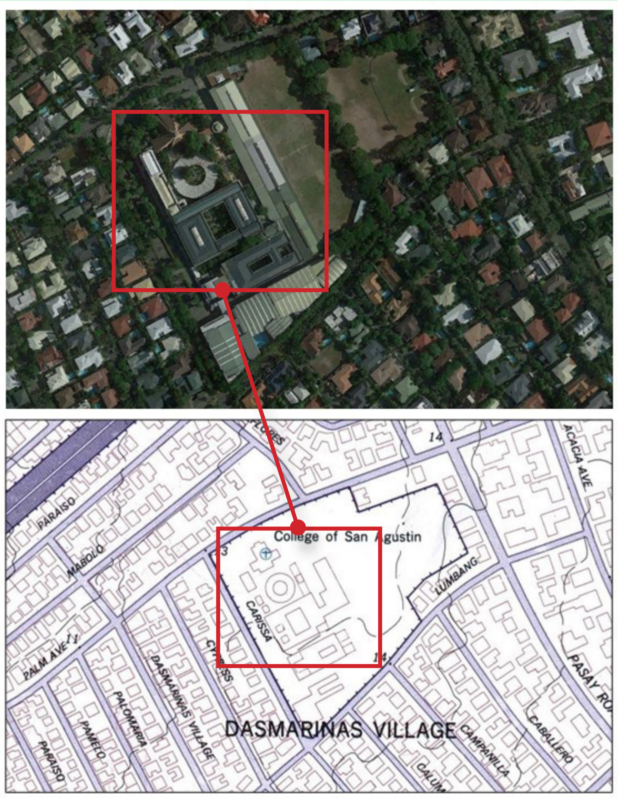


Figure 24. On medium- to large-scale maps, buildings are represented as areas.

the following scales are suggested:

- national planning - 1:1,500,000;
- regional planning - 1:250,000;
- provincial planning - 1:50,000;
- metropolitan planning - 1:25,000;
- and city/town planning:

  general use - 1:5,000/1:10,000/1:25,000

  and urban use - 1:2,000/1:4,000.

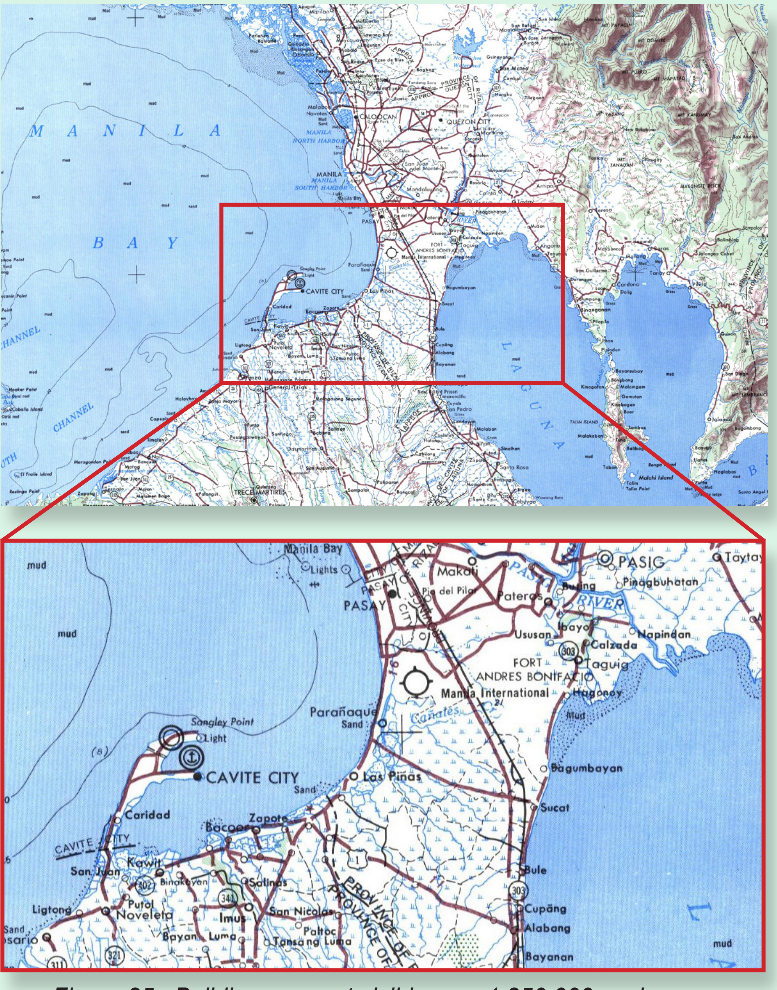


Figure 25. Buildings are not visible on a 1:250,000-scale map.

Knowing the coordinates

A map is a convenient tool in pinpointing the location of features that, otherwise, would have been challenging to determine in the real world. It contains position information, called a **geographic coordinate system** or **coordinate system**, that helps us visualize correctly the places on the surface of the Earth. Simply put, it becomes easier to find the precise location of a place if its coordinates are known.

A geographic coordinate system is a grid of imaginary lines wrapped around and over the Earth. These lines are called **longitudes** and **latitudes** *(Figure 26)*.

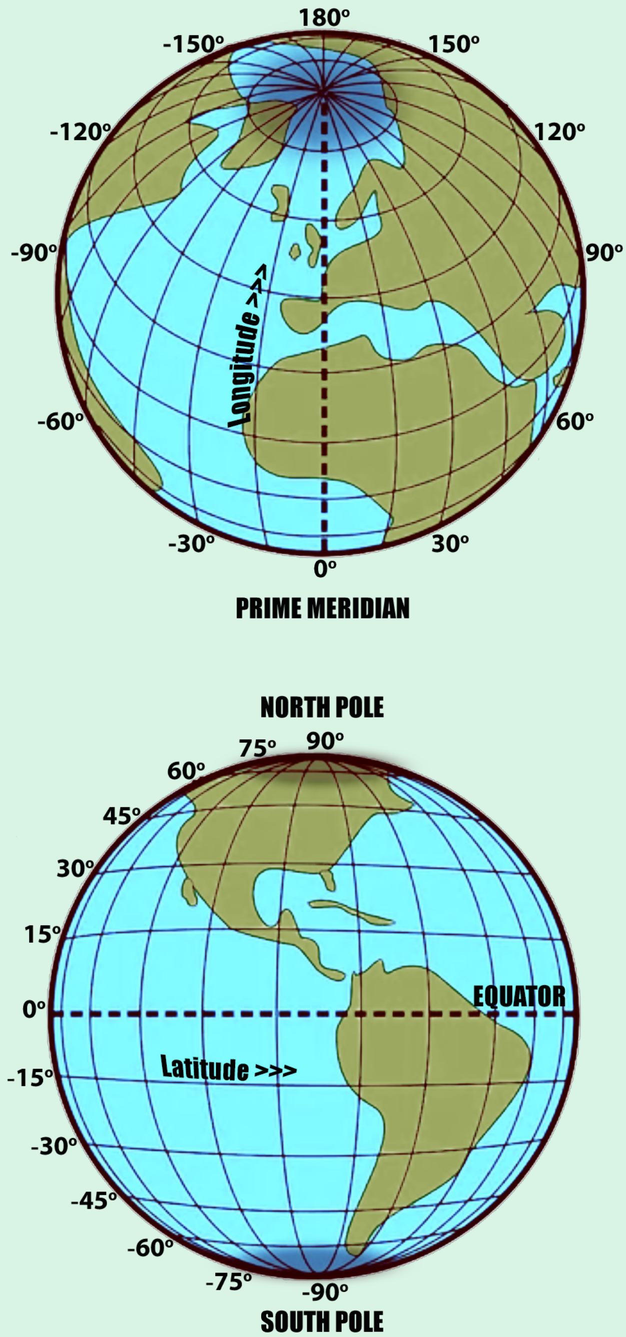


Figure 26. Longitudes and latitudes

Longitude

Longitude is the angular distance of a place east or west of the Prime Meridian. Set at Greenwich, England, the Prime Meridian is a fixed line of reference running from the North Pole to the South Pole. It is represented as zero degrees (0°) longitude. Lines of longitude are vertical lines that stretch from the North Pole to the

South Pole. The complete rotation around the Earth from and to the Prime Meridian is equivalent to 360°. Figure 26 displays the lines of longitude from the Prime Meridian eastward and westward from 0° to 180°. All lines of longitude east of the Prime Meridian are indicated with the letter 'E' to denote east of the Prime Meridian. Therefore, we have 30°E, 60°E, 90°E, 120°E, and so on. All lines of longitude west of the Prime Meridian are indicated with the letter 'W' to denote west of the Prime Meridian. Therefore, we have 30°W, 60°W, 90°W, 120°W, and so on.

Latitude

Latitude is the angular distance of a place north or south of the Equator which is measured in degrees (°). Lines of latitude are horizontal lines that stretch from east to west across the globe. The longest and main line of latitude, which divides the Earth equally between the northern and southern hemispheres, is called the **Equator**. The Equator is represented as 0° latitude. From the Equator, the North and South Poles are measured separately at 90° latitude. Figure 26 displays the 15°, 30°, 45°, 60°, 75°, and 90° lines of latitude above and below the Equator. All lines of latitude above the Equator are indicated with the letter 'N' to denote north of the Equator. Therefore, we have 15°N, 30°N, 45°N, and so on. All lines of latitude below the Equator are indicated with the letter 'S' to denote south of the Equator. Therefore, we have 15°S, 30°S, 45°S, and so on.

Longitude and latitude values are traditionally measured either in decimal degrees or in degrees (°), minutes (′), and seconds (″) or DMS. Also, it may be helpful to equate longitude values with X and latitude values with Y. Hence, we call a pair of coordinate values as **X, Y**.

Take note that a geographic coordinate system is based on a sphere or spheroid, which is the commonly known shape of the Earth. This system is then converted into a flat 2D surface and projected onto a map. However, a spheroid cannot be flattened easily to a plane. Like a piece of orange peel, it will tear. In order to "perfectly" flatten the 3D surface, a mathematical transformation is used. This is commonly referred to as a map projection. In the process, the proper map projection is being used to be able to preserve the Earth's surface in two dimensions and minimize, if not avoid, distortions in the shape, area, distance, or direction of the original information.

On a topographic map, this grid of intersecting longitudinal and latitudinal lines arranged in rows and columns are now called **graticules** *(Figure 27)*. These lines are evenly spaced horizontally and vertically, usually in minutes (′).

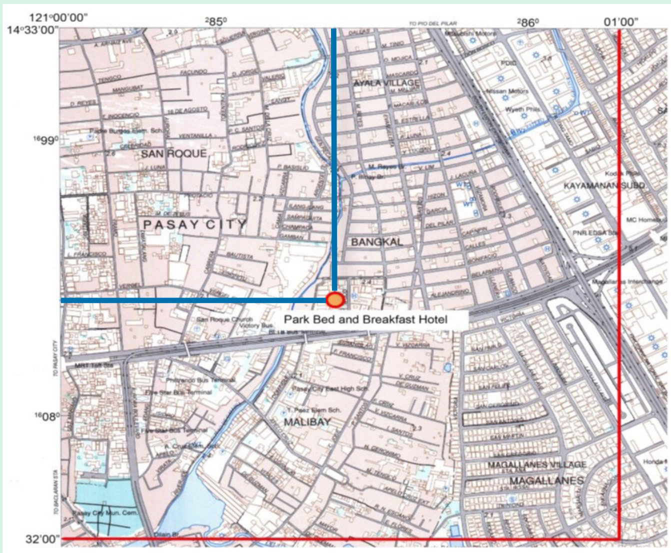


Figure 27. Grid and geographic coordinates on a map

Let us use Figure 27 to illustrate how the graticule can help us find the location or coordinates of Park Bed and Breakfast Hotel, which is encircled in red. The upper leftmost corner of the map tells us that the coordinates are X = 121°0′00″ and Y = 14°33′00″. We will use these points as our reference. From this corner, we can read horizontally to the right that the X coordinate, in terms of DMS, increased by 1 minute (01°00′). The next X value now should read 121°1′00″. Similarly, from the same corner and reading vertically downward, the Y coordinate decreased by 1 minute (32′00″). Therefore, the next Y value should read 14°32′00″.

From simple visual inspection, the estimated location of the hotel is midway between 121°0′00″ and 121°1′00″ along the X line and also midway between 14°33′00″ and 14°32′00″ along the Y line. Hence, the coordinates of the hotel building are X = 121°0.5′00″ and Y = 14°32.5′00″. Since 0.5 or half of a minute is 30 seconds (30″), we can also express the coordinates as X = 121°0′30″ and Y = 14°32′30″. With the help of a GPS receiver, we can validate the accuracy of these coordinates by taking the reading of the actual or estimated position of the hotel building.

Take note that the coordinates are in DMS format. We can also convert DMS into decimal degrees by dividing 0.5′ by 60 (there are 60 minutes in 1 degree). The result is 0.008 degree hence X = 121.008°. Similarly, 32.5′ now becomes 0.542° (32.5 divided by 60). The coordinates in decimal degrees is X = 121.008° and Y = 14.542°. We can also validate these values using a GPS receiver. ●

(continued from page 5)

Just like any other friendship, the mariners are duty-bound to know their best friend well. Maritime schools have specialized courses that train future mariners on reading nautical charts.

What is a Nautical Chart?

The nautical chart *(Figure 28)* is a graphic representation of a maritime area and the adjacent coastal features. The main purpose of the nautical chart is to aid mariners in navigation and ensure their safe passage along their intended route.

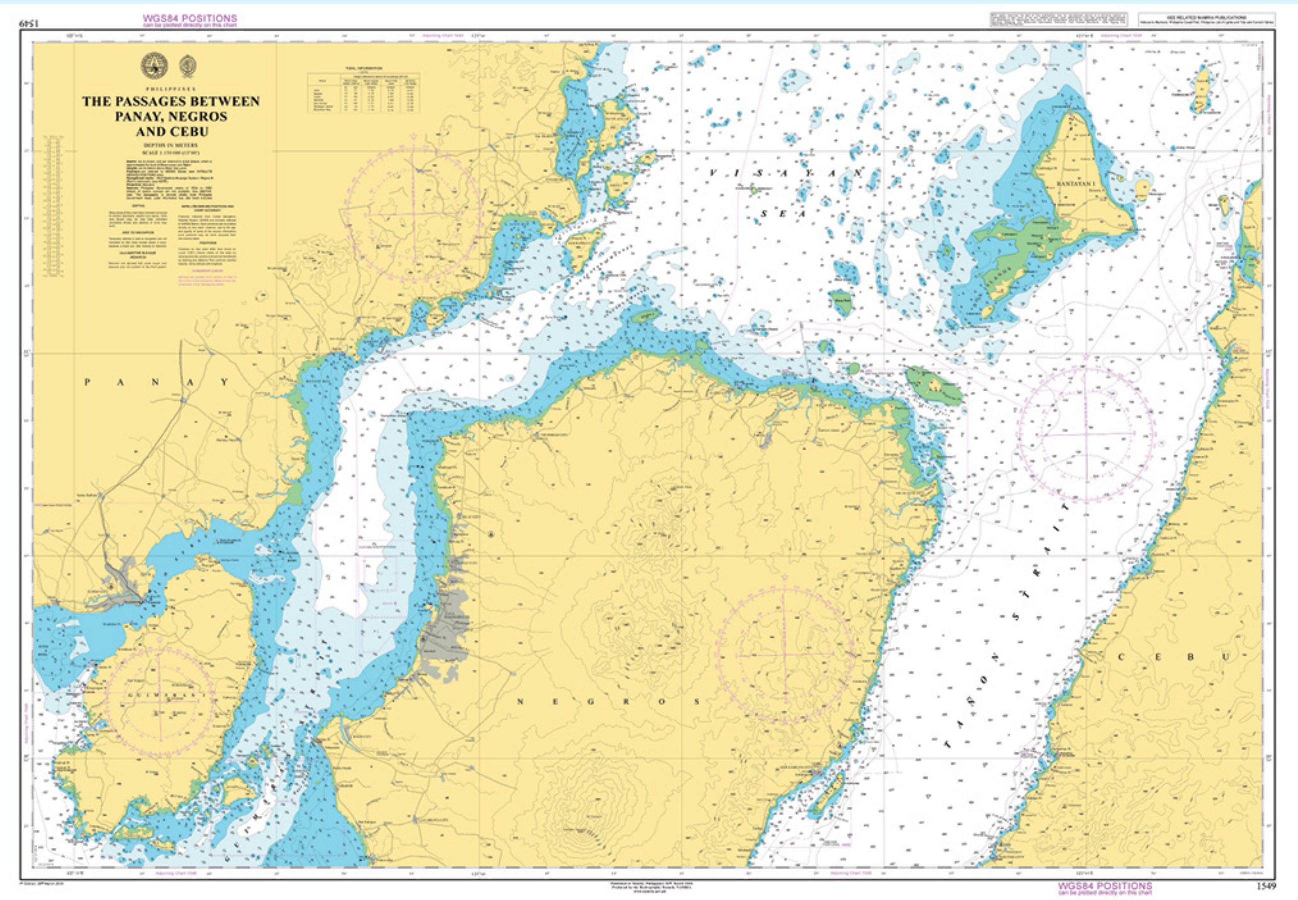


Figure 28. An example of a nautical chart on a scale of 1:150,000

The nautical chart is considered as very essential to the safety of navigation that it can only be published by a national hydrographic office. The Hydrography Branch of NAMRIA is the Philippines' national hydrographic office. It publishes the official Philippine nautical charts.

The nautical chart is also subject to the standards set by the International Hydrographic Organization (IHO), which is an organization composed of hydrographic offices throughout the world. The IHO promulgates the standards for hydrographic surveying and nautical charting, and it promotes safety of navigation.

Notes on Reading a Nautical Chart

As a graphic representation of the Earth, the nautical chart is filled with symbols that represent natural and artificial features, and rules and regulations that affect the navigation in an area. Details of these symbols may be read in the publication Symbols, Abbreviations, and Terms Used on Charts (INT 1), which may be downloaded from the IHO website.

Reading a nautical chart does not only mean understanding the chart symbols but it also refers to the ability to draw a planned route on it. In reading a nautical chart, these three elements should always be consulted: compass rose, depth, and latitude/longitude scale.

The **compass rose** aids the mariner in plotting the direction of the planned route. It shows the true direction or bearing that is referred from the geographic north, which is symbolized by the star, and the magnetic bearing that is referred to the magnetic north of the area. The magnetic north is symbolized by a half arrowhead and coincides with the north in the magnetic compass. The true direction is printed on the outside circle of the compass rose, while the magnetic direction is printed in the inner circle. The value indicated in the compass rose indicates the difference between the geographic north and the magnetic north in the year indicated. This is called the **magnetic declination** or **magnetic variation**. The variance changes per year as indicated by the value in parentheses.

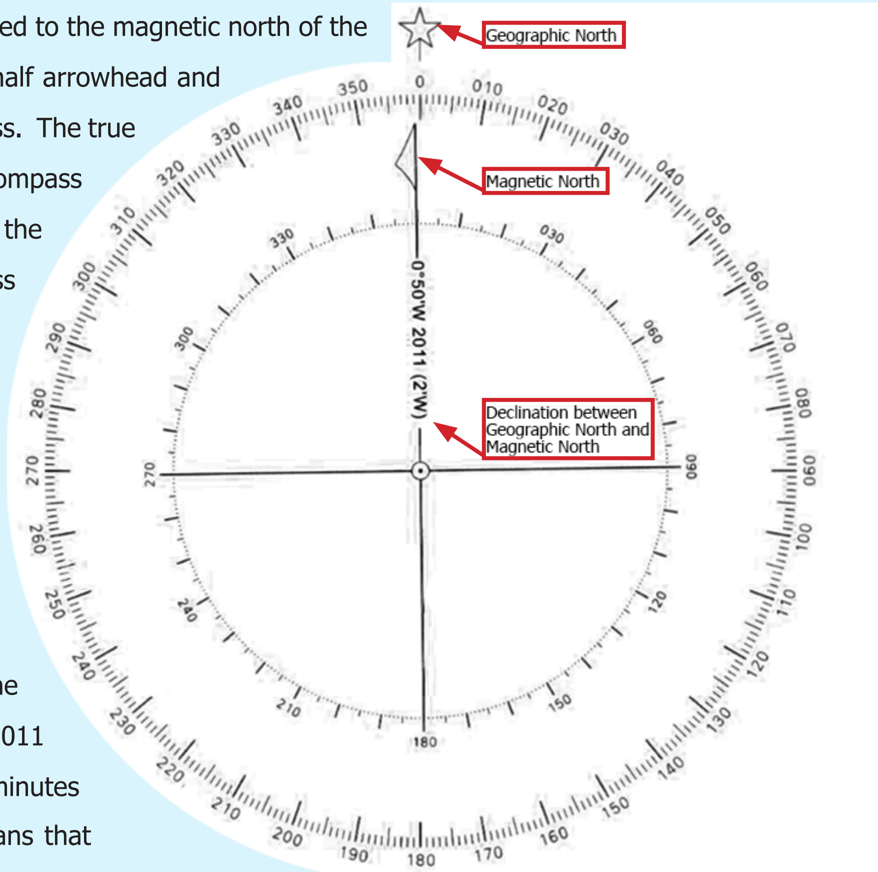


Figure 29. Compass rose

In Figure 29, the compass rose indicates that the difference of the magnetic north from the geographic north is 50 minutes west (50'W) in 2011 with the increase in difference of values of two minutes west (2'W) in the succeeding years. This means that between 2011 and 2018 (seven years), the difference between the magnetic north and the geographic north is 50 minutes west plus 14 minutes west (2' x 7 years) or 64 minutes (50 + 14). Since one degree is equivalent to 60 minutes, the difference can also be read as one degree, four minutes west (1° 04' W).

For example, if our magnetic compass shows that we are moving in the direction of 20 degrees (20°), then that means we are actually moving in the direction of 20 degrees plus one degree, four minutes or 21 degrees, four minutes (20° + 1° 04' or 21° 04') in seven years. Knowing our true direction or bearing is important because the nautical chart is referred to the geographic north.

The bearing or direction is drawn on the chart using a parallel rule *(Figure 30)*. To draw the bearing, we must put our parallel rule alongside our desired bearing on the compass rose then slide it to the area in the chart where we plan to draw that bearing.

The depth values on the nautical chart indicate the depth of the water in a particular area *(Figure 31)*. The depth on the Philippine nautical chart is in meters and is referred to the mean lower low water, which is the mean height (or depth) of the lower of the two low tides occurring in a day. Knowing the depth values is important because it tells us where it is safe to navigate.


Figure 30. Parallel rule

Mariners usually measure distances using the nautical distance. A nautical mile is equivalent to a minute on the nautical charts. Thus, the **latitude/ longitude scale** *(Figure 32)* at the margins of the nautical chart is not only used for plotting the geographic position but also for measuring distance. Now that we are acquainted with the compass rose, depth, and the latitude/longitude scale, let us try to read a nautical chart. For this reading exercise, we will use NAMRIA Nautical Chart No. 4236 entitled Fairways & Anchorage Chart of Manila Harbor.

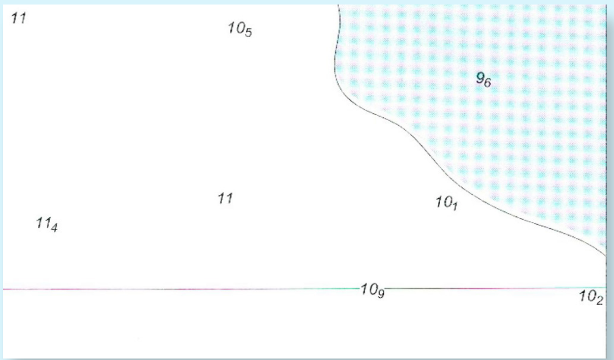


Figure 31. Example of depth values on a nautical chart (It should be noted that the shallowest depth is 9.6 meters.)

Reading and Navigating with a Nautical Chart

It is a good practice to know the draft and the highest point of the boat before navigating. The draft is the distance between the waterline and the bottom of the boat. It determines the minimum depth that the boat can navigate on. The highest point, on the other hand, determines the minimum height of bridges, power cables, and other overhead obstructions that the boat can pass through. Figure 33 illustrates the draft and the highest point of a boat.

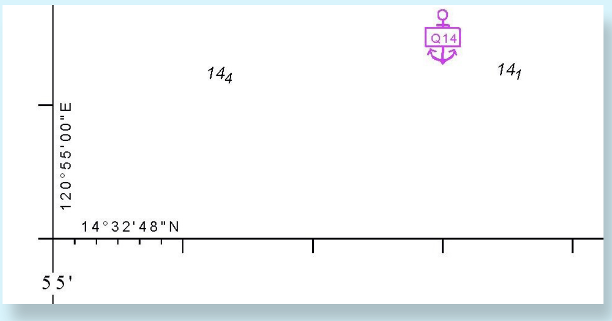


Figure 32. Latitude/longitude scale

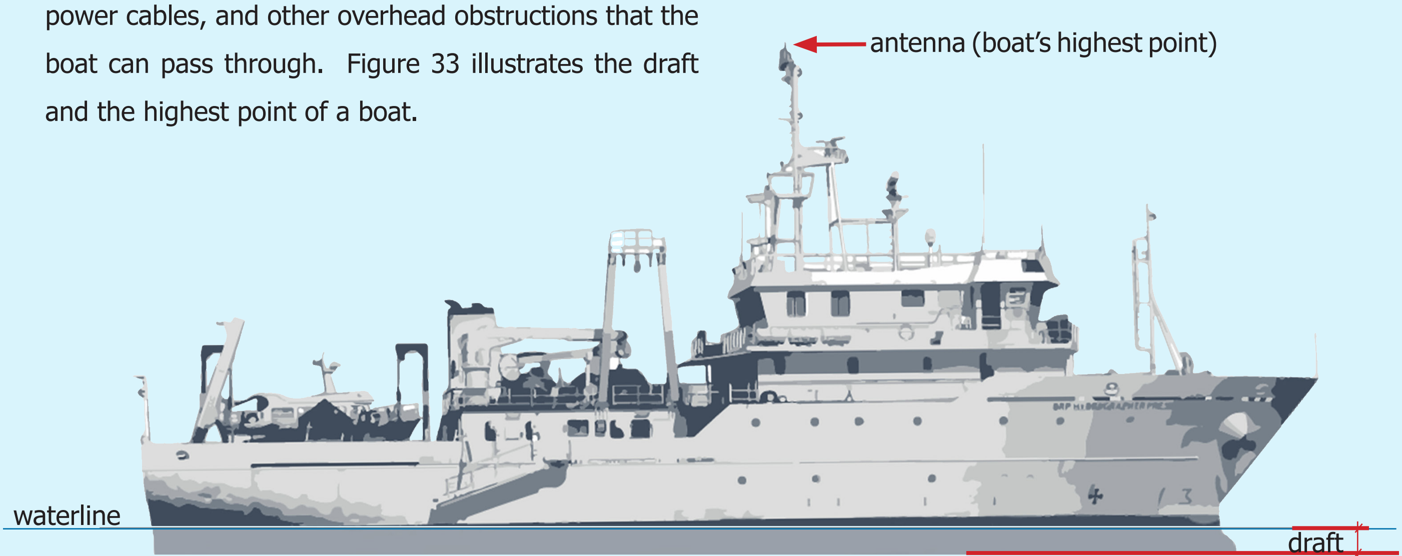


Figure 33. The draft and the highest point of a boat

For this demonstration, let us assume our boat has a draft of about two meters. The highest point on our boat is the radio antenna with a height of two meters from the waterline. Using our boat, we will be navigating from Manila Yacht Club to Manila Post Office. We will be starting our navigation from the anchorage area of Manila Yacht Club. We will go north to the mouth of the Pasig River, then go upriver until we reach our destination, which is Manila Post Office.

The following tips will come in handy before starting the trip:

1. Study the latest edition of the nautical charts thoroughly[5].
2. Look for wrecks, obstructions, bridges, power lines, shallow waters, and other dangers that lie along the planned route.
3. Look for buoys, lighthouses, prominent features, and other landmarks that can be used in confirming our boat's position.

Let us begin our journey in Manila Yacht Club Basin *(Figure 34, and see Chart 4236 of centerfold)*. As we go out of the breakwater of the yacht club, we will see at the starboard, or the right side of our boat, a symbol with the text **Fl.G.5s**, while on the port side, or the left side of our boat, symbols with texts **Fl.4s** and **Fl.R.5s11m7M**. These symbols are lights displayed on metal posts. **Fl.G.5s** means flashing green light every five seconds. **Fl.4s** means flashing white light every four seconds. **Fl.R.5s11m7M** means flashing red light every five seconds. This is displayed at an elevation of 11 meters and is visible up to seven nautical miles. Details of lighted aids to navigation may be obtained from the *Philippine List of Lights*, which is also available in NAMRIA[5].

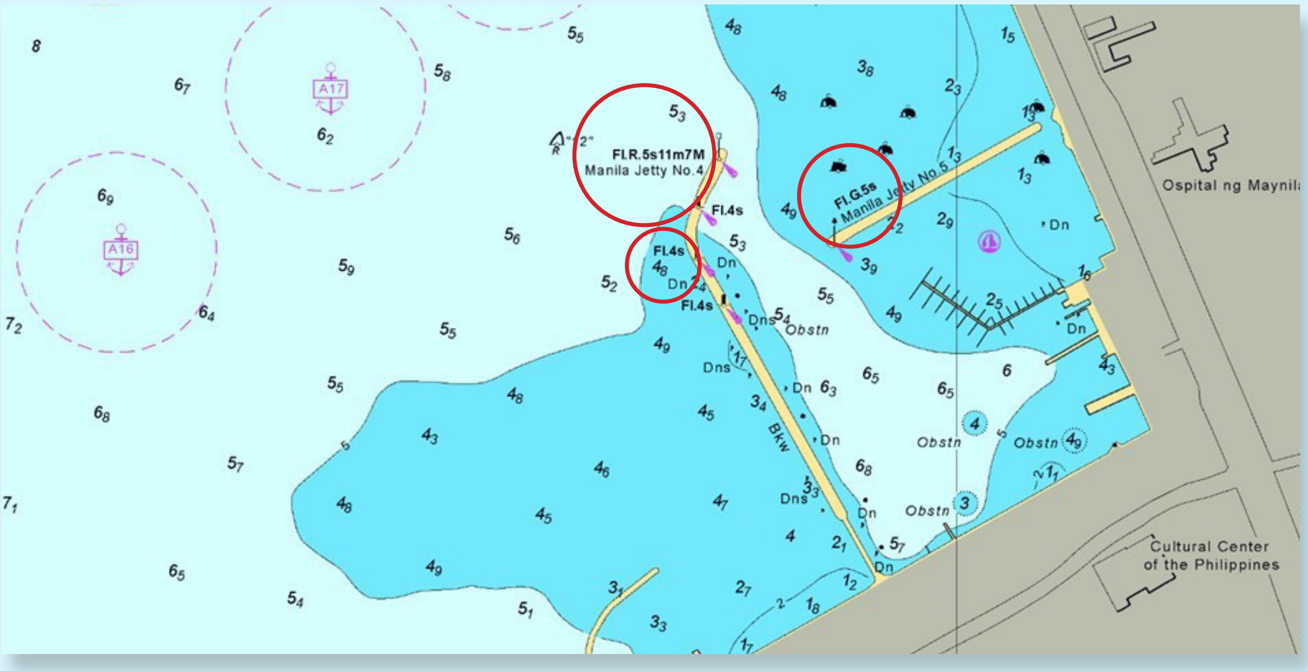


Figure 34. Manila Yacht Club Basin as shown on Chart 4236

We take note that the general depth on the area, as indicated by the numbers on the chart, is deeper than the draft of the boat *(Figure 35)*. Thus, we do not have to worry about hitting the seabed. As we go out of the breakwater, we will see symbols of buoys at the starboard side. We will also encounter a red buoy marked "12" as seen in Figure 36.

[5] *Call or visit the NAMRIA Map Sales Office (MSO) for information about the latest editions of nautical charts. Address - 421 Barraca Street, San Nicolas, Manila; Telephone numbers - (632) 8245 94 98; (632) 8241 34 94, local 117*

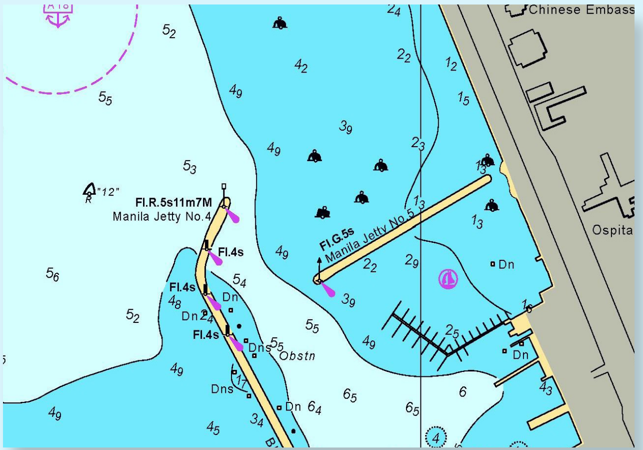


Figure 35. The breakwaters and entrance of Manila Yacht Club Basin

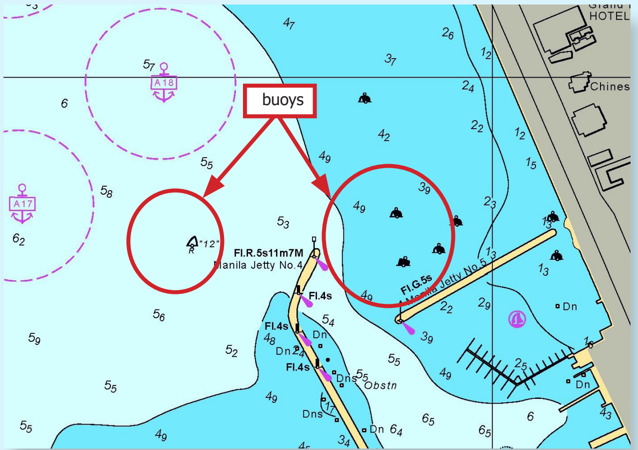


Figure 36. Buoys at the entrance of Manila Yacht Club Basin

From the breakwater entrance of Manila Yacht Club Basin, we will proceed eastward towards the area just east of Manila Jetty No. 3 Light *(Figure 37)*. We take note of the anchor symbol, which indicates anchorage area for large commercial ships. We should be on the lookout for anchored ships in the area and adjust the course to avoid collision with them. The blue line in Figure 37 shows the planned route for the boat.

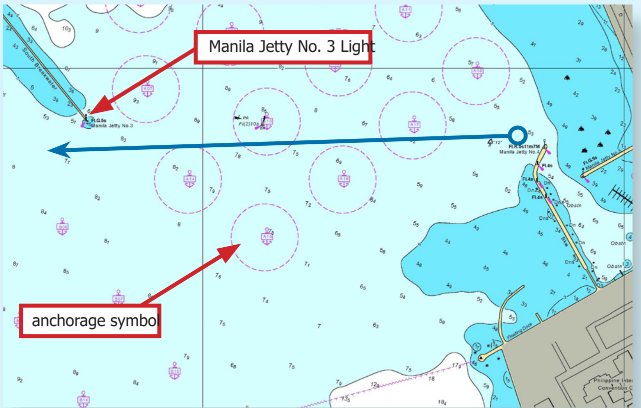


Figure 37. Planned route from Manila Yacht Club Basin to Manila Jetty No. 3 Light

Manila Jetty No. 3 Light exhibits flashing green light every five seconds with an elevation of seven meters and is visible within seven nautical miles. We should take note of the light characteristics of lighted aids in the area where we are navigating because they are very useful at night.

The breakwater where Manila Jetty No. 3 Light stands marks the boundary of Manila South Harbor as shown in Figure 38. It is a busy port so we should be on the lookout for large commercial vessels going in and out of the harbor.

From Manila Jetty No. 3 Light, we take the northwest course until we reach the mouth of Pasig River. Depending on the wind and current directions, we may opt to navigate in Manila South Harbor Basin which is protected by the breakwaters.

At the entrance of Pasig River, the ruins of a breakwater that extends southwest from BASECO Compound are the dangers that should be avoided.

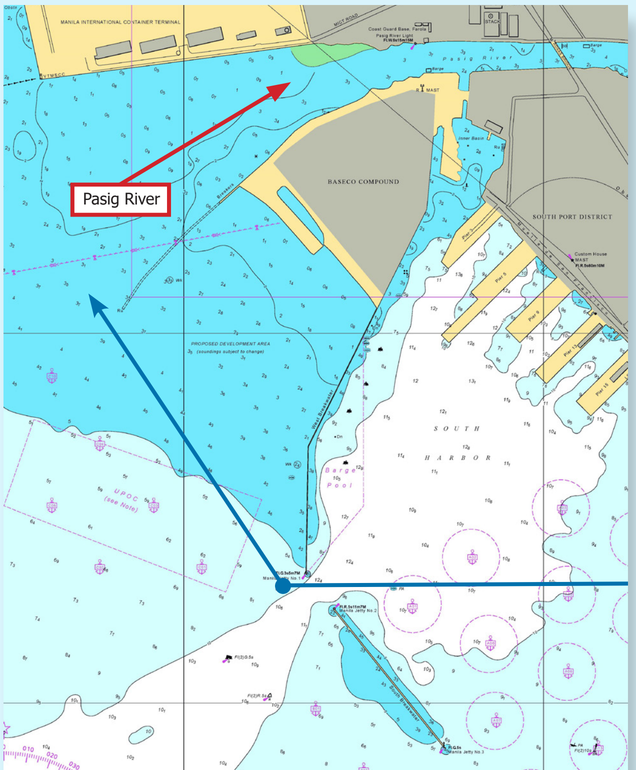


Figure 38. Planned route from Manila Yacht Club to the mouth of Pasig River

As shown in Figure 39, the water at the entrance is shallower than the two-meter draft of our boat. Thus, we have to pass through the very narrow channel with a depth greater than two meters.

The deep water area widens once we pass through the narrow channel. We will encounter two bridges, namely, M. Roxas Bridge and Jones Bridge before we reach Manila Post Office.

We have to take note of the horizontal clearance and the vertical clearance of the bridges before we can pass through. The horizontal clearance is the lateral offset clearance between the columns of the bridge. The vertical clearance, on the other hand, is the distance from the mean high water to the lowest part of the bridge. High water is the highest water level or highest tide in the area.

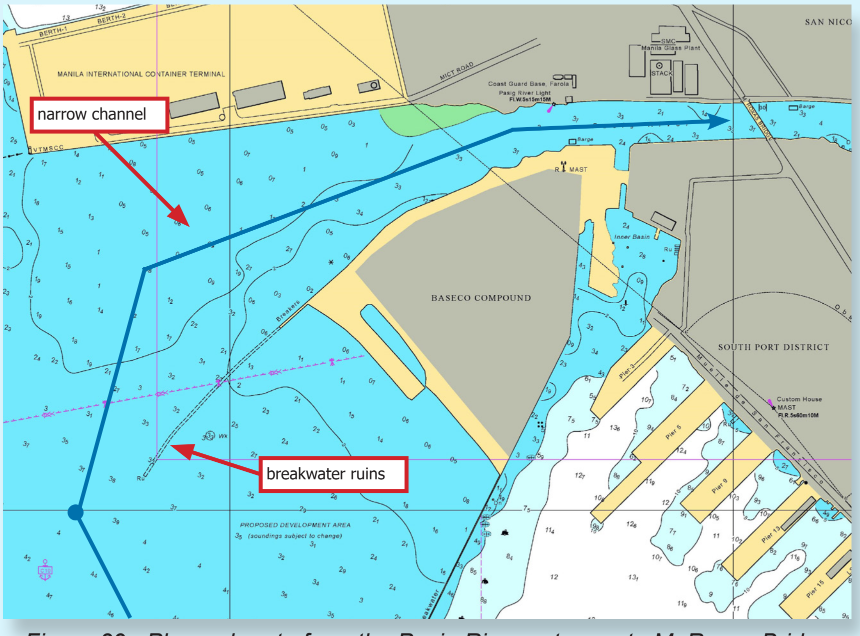


Figure 39. Planned route from the Pasig River entrance to M. Roxas Bridge

The nautical chart only provides the horizontal clearance for M. Roxas Bridge. The 30-meter horizontal clearance is wide enough for our boat. Because the vertical clearance is not known to us, we should carefully observe that our boat's two-meter high-radio antenna will not hit the bridge while passing under it. According to local knowledge of the area, M. Roxas Bridge is high enough because barges larger than our boat can pass under it. In navigation, we use local knowledge, experience, and visual inspection alongside the use of nautical charts.

We take note that there are numerous wrecks (Wk) and shallow areas along Pasig River *(Figure 40)*. We should navigate carefully to avoid these dangers.

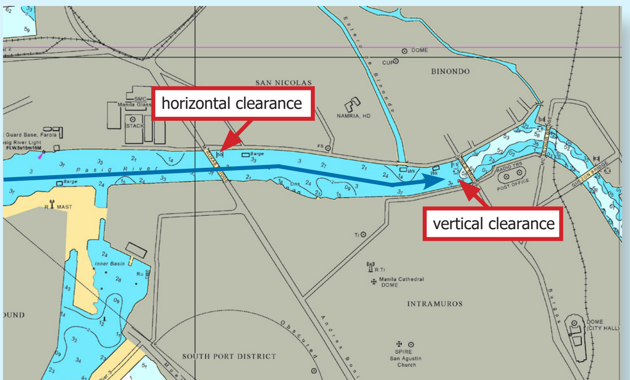


Figure 40. Planned route from M. Roxas Bridge to Jones Bridge

Jones Bridge is the last bridge that we have to pass through before we can reach Manila Post Office. The nautical chart *(Figure 41)* indicates that Jones Bridge has a horizontal clearance of 11 meters and a vertical clearance of four point three meters. The clearances are wide enough for our boat and high enough for the boat's radio antenna. Therefore, we can pass beneath Jones Bridge until we successfully reach our destination. ●

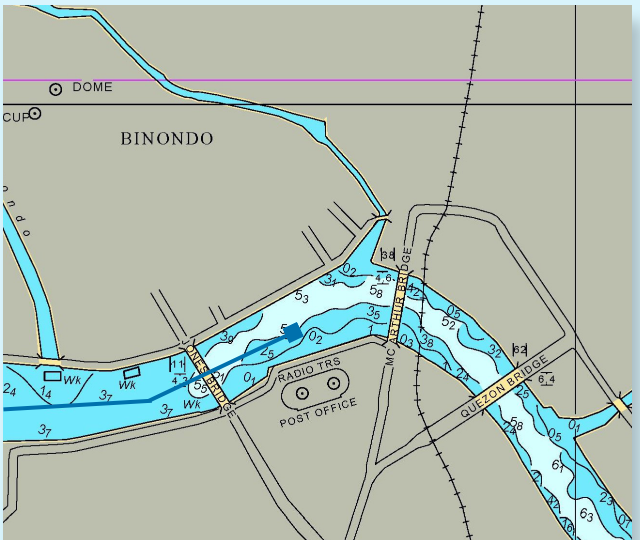


Figure 41. Planned route from Jones Bridge to Manila Post Office

Reference

International Hydrographic Organization. (2018). Symbols, Abbreviations and WTerms used on Charts (Edition 9). Retrieved from https://docs.iho.int/iho_pubs/restricted/INT1_EN_Ed9_2018.pdf

GIS 101

*by Eriberto N. Brillantes**

What is GIS?

GIS or geographic information system is a framework designed to capture, organize, analyze, understand, and present geographic data. It stores data in a database and represents them visually on a map. Modern-day GIS involves the use of hardware, software, and modeling procedures, not to mention the people who operate the technology and process the data.

Geographic information, popularly known now as geospatial or spatial information, are associated with locations. These information, which may come from various sources, serve as essential inputs to GIS to create maps of location-based themes.

GIS stores geospatial features and their characteristics. These features are classified as points, lines, and areas or polygons *(Figure 1)*. GIS data can be categorized into two: geospatial and attribute (tabular). Geospatial/spatial data are location-specific, i.e., they can be found somewhere, usually, on the surface of the Earth. They contain geographic coordinates called latitude and longitude. Examples are schools (points), roads and streams (lines), and municipal boundaries (areas). Attribute data are text-based data that describe the geospatial data *(Figure 2)*. Examples are fisherfolk in a barangay, types of health facilities, land use zones, land cover classifications, descriptions of schools, and profiles of provinces.

Figure 1. Classifications of geospatial features

CAVITE 856HF Table

ID	FACILITY CODE	HEALTH FACILITY NAME (DOH list)	HEALTH FACILITY NAME (from Survey)	TYPE OF HEALTH FACILITY	STATUS
30001	DOH000000000033325	NAIC RURAL HEALTH UNIT LYING IN CLINIC	NAIC BIRTHING	BIRTHING HOME	FUNCTIONAL
30002	DOH000000000006126	NAIC RURAL HEALTH UNIT	NAIC RHU	RURAL HEALTH UNIT	FUNCTIONAL
30003	DOH000000000026827	TIMALAN CONCEPTION BARANGAY HEALTH STATION	TIMALAN CONCEPTION BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30004	DOH000000000026826	TIMALAN BALSAHAN BARANGAY HEALTH STATION	TIMALAN BALSAHAN BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30005	DOH000000000026787	MUNTING MAPINO BARANGAY HEALTH STATION	MUNTING MAPINO BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30006	DOH000000000026046	IBAYO SILANGAN BARANGAY HEALTH STATION	IBAYO SILANGAN HC	BARANGAY HEALTH STATION	FUNCTIONAL
30007	DOH000000000026043	IBAYO ESTACION BARANGAY HEALTH STATION	IBAYO ESTACION BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30008	DOH000000000026124	LATORIA BARANGAY HEALTH STATION	LATORIA BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30009	DOH000000000026032	BUCANA SASAHAN BARANGAY HEALTH STATION	BUCANA SASAHAN BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30010	DOH000000000026825	SAPA BARANGAY HEALTH STATION	SAPA BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30011	DOH000000000032003	BUCANA MALAKI BARANGAY HEALTH STATION	BUCANA MALAKI BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30012	DOH000000000026026	BAGONG KARSADA BARANGAY HEALTH STATION	BAGONG KALSADA BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30013	DOH000000000026030	BANCAAN BARANGAY HEALTH STATION	BANCAAN BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30014	DOH000000000026783	MABOLO BARANGAY HEALTH STATION	MABOLO BHS	BARANGAY HEALTH STATION	FUNCTIONAL
30015	DOH000000000026117	LABAC HC	LABAC BHC	BARANGAY HEALTH STATION	FUNCTIONAL
30016	DOH0000000000		BUCANA SCHOOL BASED FACILITY	SCHOOL-BASED HEALTH FACILITY	NOT YET FUNCTIONAL, NEW HF
30017	DOH000000000026116	KANLURAN HC	KANLURAN CLINIC	BARANGAY HEALTH STATION	FUNCTIONAL
30018	DOH000000000033424	NAIC HOLY SPIRIT MEDICAL AND LYING IN CLINIC	HOLY SPIRIT MEDICAL AND LYING IN CLINIC	BIRTHING HOME	FUNCTIONAL

Figure 2. Attribute or tabular data

* *Information Technology Officer II, GDMD-NAMRIA GISMB*

The strength of GIS lies in its ability to organize spatial relationships *(Figure 3)*. To illustrate, GIS can represent a particular geospatial feature, e.g., a school, by its known location and associate it with other geospatial features or data layers like its barangay jurisdiction, its vulnerability to a flood hazard, its proximity to a hospital, and to a road network. GIS can also manage the attribute information the school holds such as the type of materials it is made of, the number of students (female and male), and the names of school officials, among others.

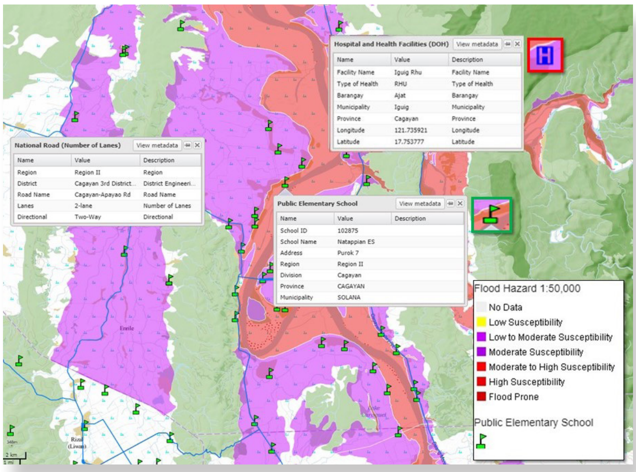


Figure 3. This shows the spatial relationship of the geospatial feature, school, with other features.

Types of GIS Data

It is important to understand the two major types of geospatial data: raster and vector *(Figure 4)*. **Raster** data *(Figure 5)* are in the form of images. Examples are satellite imageries, aerial photographs, scanned maps, digital elevation model (DEM), and interpolated data such as temperature and precipitation. Raster data are basically made up of pixels or picture elements. These pixels contain location (coordinates) and color values. They are stored in grids or rows and columns. A pixel contains only one information such as elevation or height, or volume or amount. Colors can be assigned to pixels to represent the degree or intensity of a particular data or to differentiate Earth features such as water bodies and land characteristics. Raster data when zoomed in usually become pixelated *(Figure 6)*.

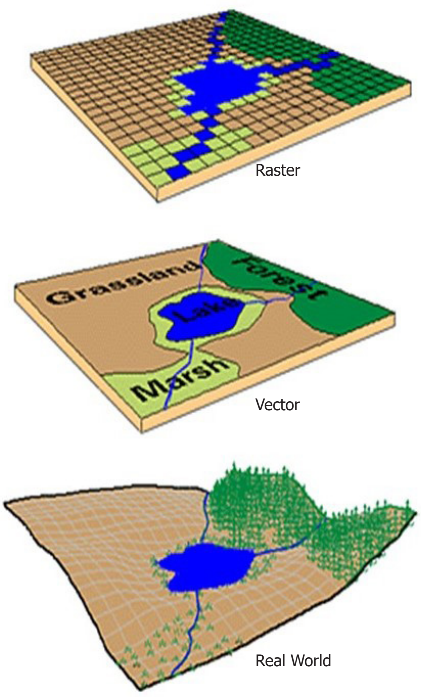


Figure 4. Types of GIS data

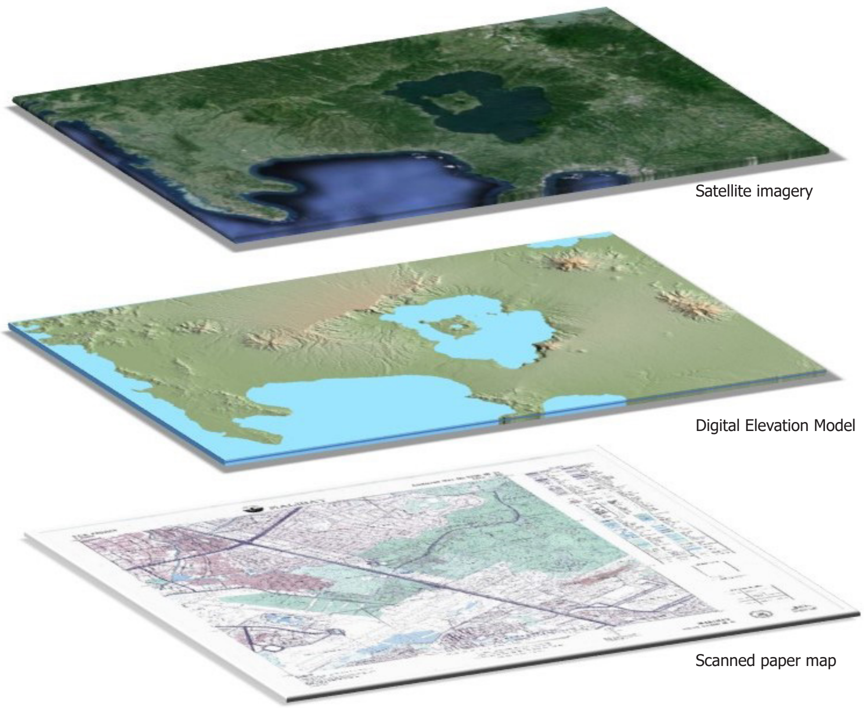


Figure 5. Raster data

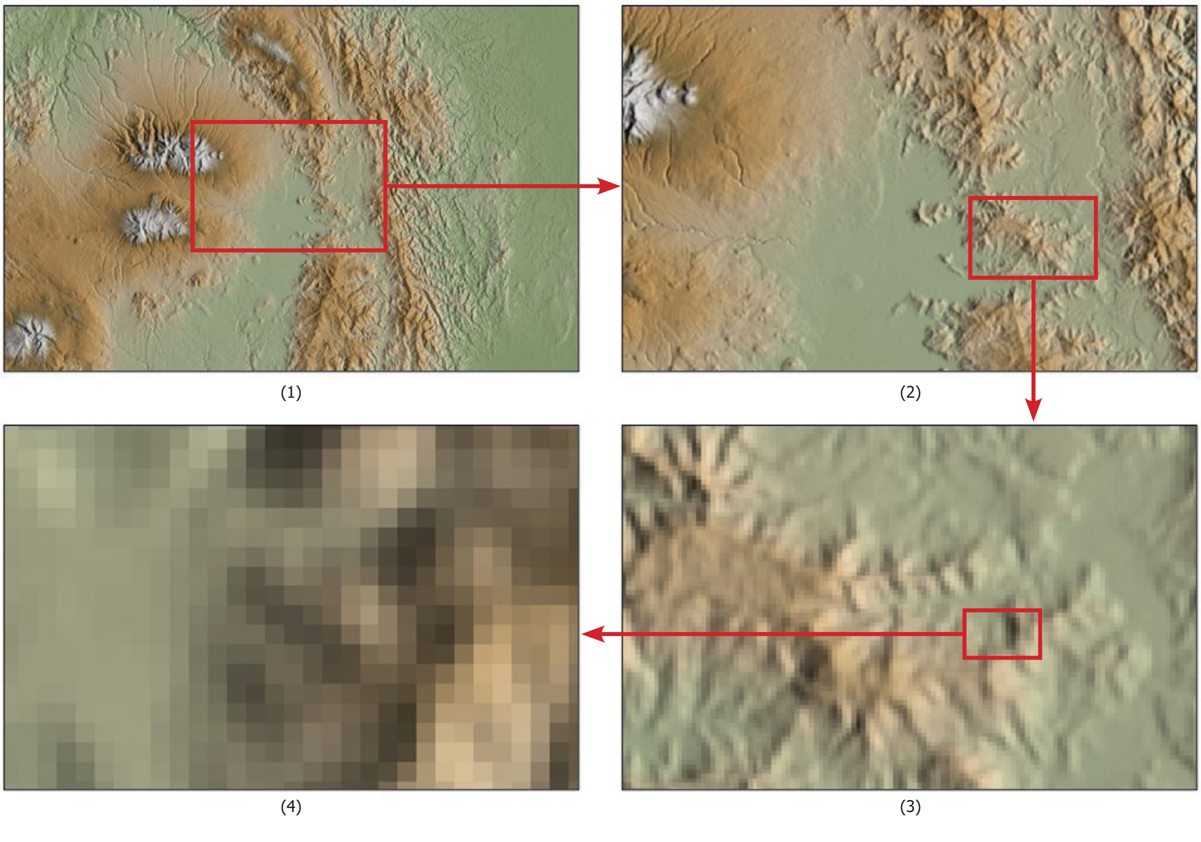


Figure 6. Pixels are illustrated by square cells (4).

Vector data *(Figure 7)*, on the other hand, are data that have exact locations or boundaries. They are represented as exact points, lines, and areas. For example, locations of schools, evacuation centers, and locations of fire hydrants can be represented as points; road network, rivers, and streams can be represented as lines; and municipal boundaries and land use categories can be represented as areas. We can zoom in on any vector data as close as we wish without losing its integrity. There are various vector data formats that can be used in GIS. They include *shp, dwg, dxf, e00,* and *kmz,* just to name a few. Raster data formats include *img, geotiff, tiff, jpeg, bmp, ecw,* and *png,* among others.

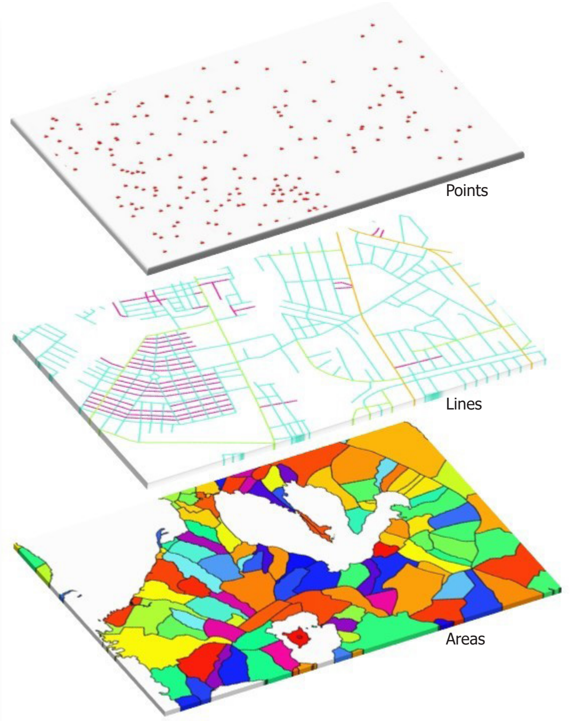


Figure 7. Vector data

GIS Data Layers

A GIS data layer is a dataset that specifies a particular theme of data, including its symbols and labels. It can either be a vector or raster dataset. Examples of layers are boundaries, rivers, and elevations *(Figure 8)*. Using a GIS software, layers can be added, and overlaid to each other in different combinations and in various orders, depending on the particular information to be conveyed *(Figure 9)*.

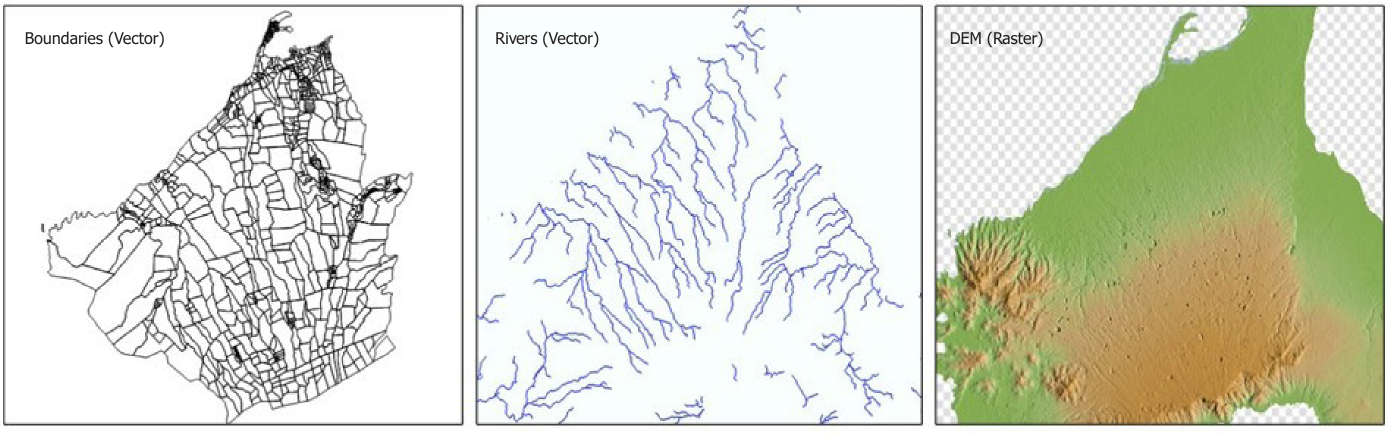


Figure 8. Examples of three GIS data layers

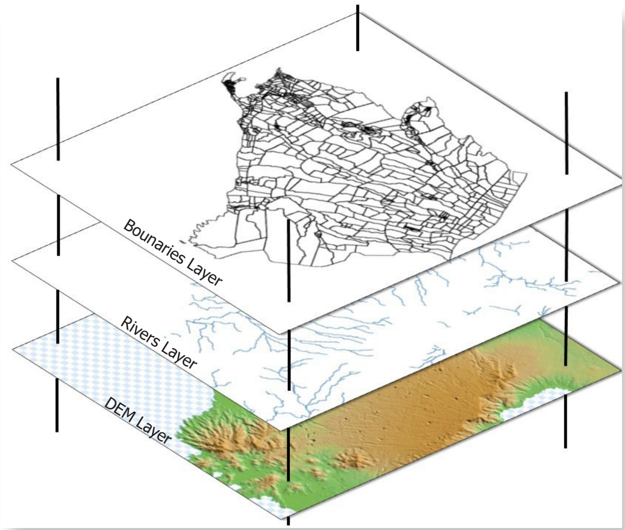


Figure 9. Overlay of GIS data layers

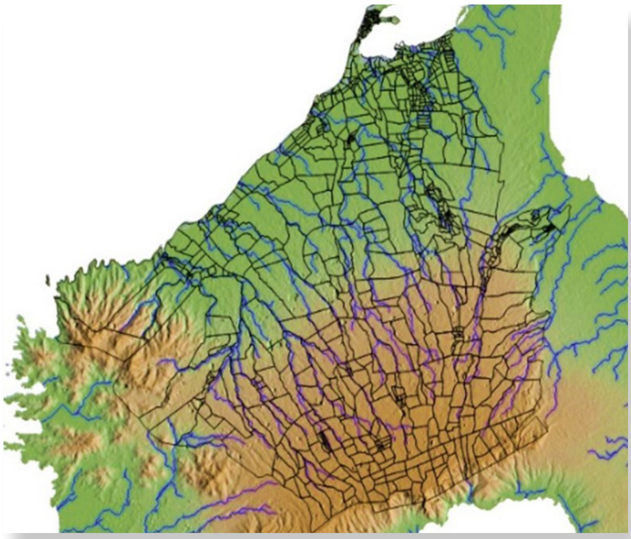


Figure 10. Result of GIS data layer

Data management is critical in GIS. To achieve thorough analysis and maximum efficiency, it is best to present the GIS data in separate layers. GIS layers when stacked or overlaid create a thematic map *(Figure 10)*. Different sets of GIS layers can mean different thematic maps. And for easy identification, the layers can be represented by colors, patterns, symbols, and labels.

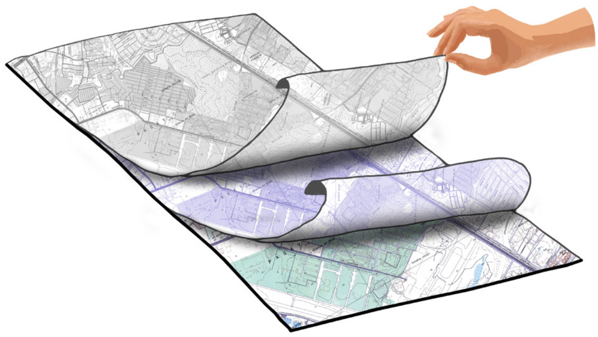


Figure 11. Freehand sketching or drawing by overlaying acetate or tracing paper on the map

Components of GIS

Maps can be created without the aid of computers. Before automation, maps were generated by freehand sketching or drawing and the analysis was done by overlaying acetate or tracing papers *(Figure 11)*. Although GIS may not be fully automated, it is best appreciated in a digital environment.

Before embarking on the use of GIS technology, important decisions have to be considered. In a fully automated system, GIS requires the following essential components:

(a) Hardware

Hardware is important in modern GIS. It is composed of equipment needed for the acquisition, storage, analysis, and display of geospatial data. Hardware includes desktop and laptop computers, scanners, printers, plotters, and storage devices. GIS practically runs on any computer platform. Recently, it can also be performed on mobile devices such as phones and tablets.

(b) Software

Software is the processing engine of GIS. It provides the functions and tools necessary to perform processing, analysis, visualization, and printing of desired map layouts. There are several GIS software which are available off-the-shelf and the prices vary depending on their functionalities. Open-source GIS software are also available in the market for free. A database management system or DBMS may also be considered to enhance the organization of data in GIS.

(c) Data

GIS requires planning and choosing of correct information for a particular application. Data is the most important component of GIS. Without data, nothing can be processed and analyzed. A wide variety of data sources exists for both geospatial and attribute types. The most common sources of primary geospatial data are from Global Navigation Satellite System (GNSS), unmanned aerial vehicle (UAV) or drone, satellite imagery from Earth observation satellites, and aerial photographs. Other data sources are those derived from scanned paper maps.

(d) People

People make it possible to encode, manipulate, interpret, analyze, and present the geospatial data in a GIS application. Well-trained GIS professionals are essential to the GIS process. Ideally, a GIS unit should have people like GIS Manager, GIS Specialist, GIS Analyst, GIS Technician, and GIS Computer Programmer.

(e) Method

Method is a well-designed implementation plan and application-specific business rules that describe how GIS technology will be utilized by the organization. Methods vary depending on the requirements and strategies of organizations. They include setting up of and adhering to guidelines, standards, and procedures. Data development and sharing are important considerations in implementing a GIS plan.

Benefits Provided by GIS

GIS eliminates all manual forms of geography-based analysis. There is no longer a need to draw maps on transparency or tracing paper to overlay different layers in order to perform analysis. GIS data are overlaid to a single map window without limit to come up with a thematic map. GIS can mathematically transform map features from one scale to another or from one projection to another. GIS can convert and project all data on the same coordinate system and scale with ease. Cartographers and mapmakers are gradually shifting away from using paper maps and making their job simple by utilizing GIS technology.

How to Get Started in GIS

Here is a basic workflow to produce a simple thematic map in GIS: (1) determine the desired thematic map output; (2) identify and acquire the data needed to come up with the map; (3) encode data into GIS; (4) prepare the data by using various GIS processing tools; and (5) prepare final map layout for printing.

For example, we are tasked to create a road map based on a topographic map and generate a printed map layout. Following the workflow stated above, the tasks involved are: (1) Prepare the scanned topographic map. If there is no available digital topographic map, convert the topographic map into its digital format (e.g., *jpeg, tiff,* etc.) by scanning it; (2) Load the scanned topographic map into the GIS software; (3) Georeference the topographic map and apply the correct coordinate system.

Georeferencing *(Figure 12)* is the process of adjusting the scanned map into its correct geographic location. The next step is to perform (4) Digitization. Digitization is the process of creating vector data from raster or image. Digitization is like laying a tracing paper over the image and then tracing the lines in the image *(Figure 13)*.

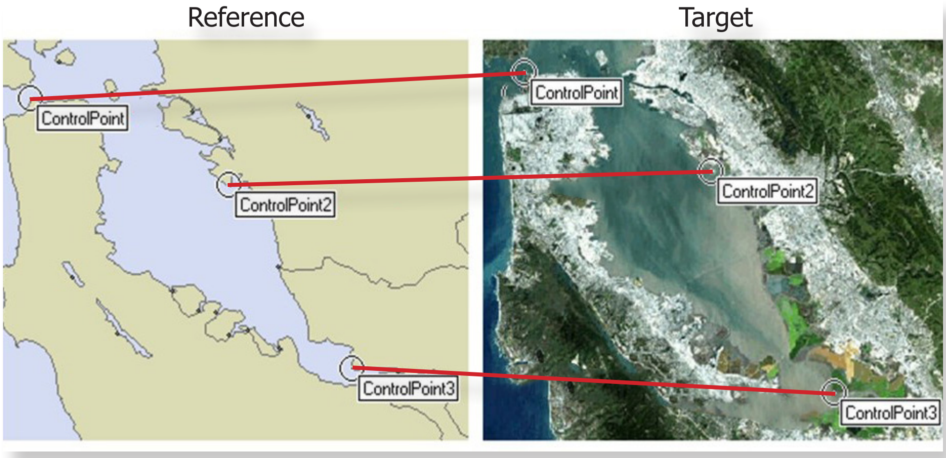


Figure 12. Georeferencing illustration

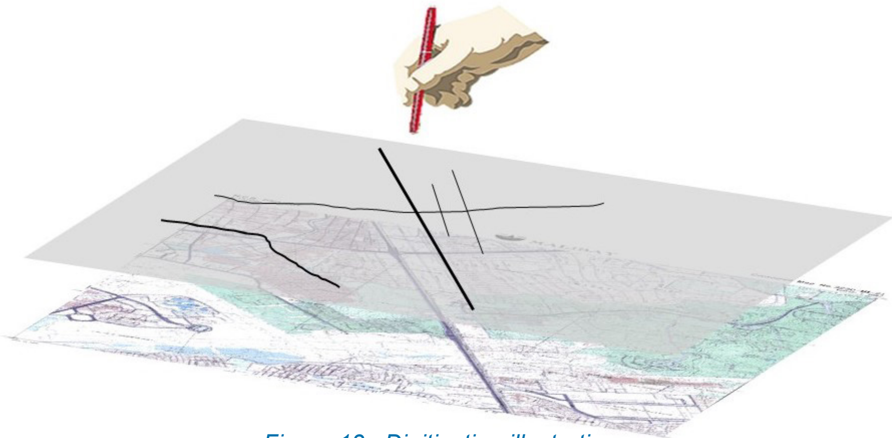


Figure 13. Digitization illustration

Digitize the roads from the topographic maps to create a layer of roads in the form of lines. The resulting lines after digitization need to go through the editing process. The process also includes inputting the attributes and assigning symbols, colors, and labels.

After editing, (5) Create the final map layout for printing. The map layout should contain the basic map elements such as thematic content, title, legend, north arrow, scale bar, coordinate system, and other relevant information *(Figure 14)*.

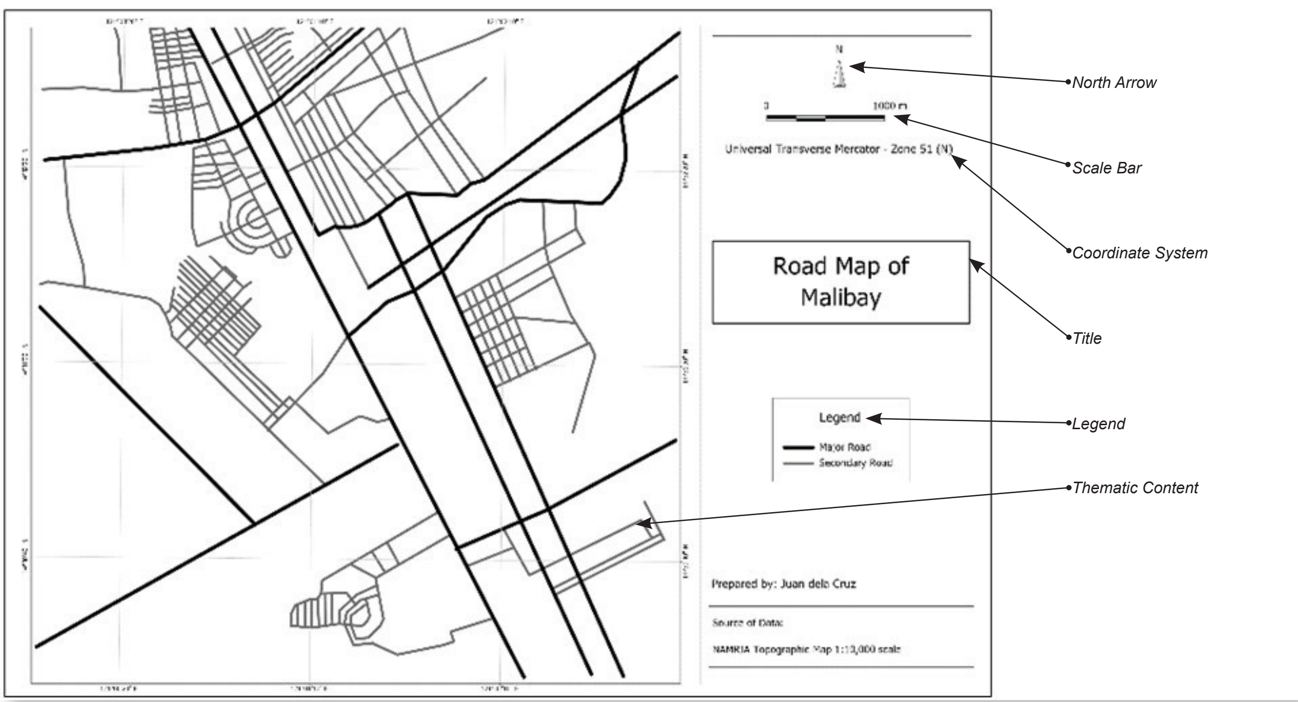
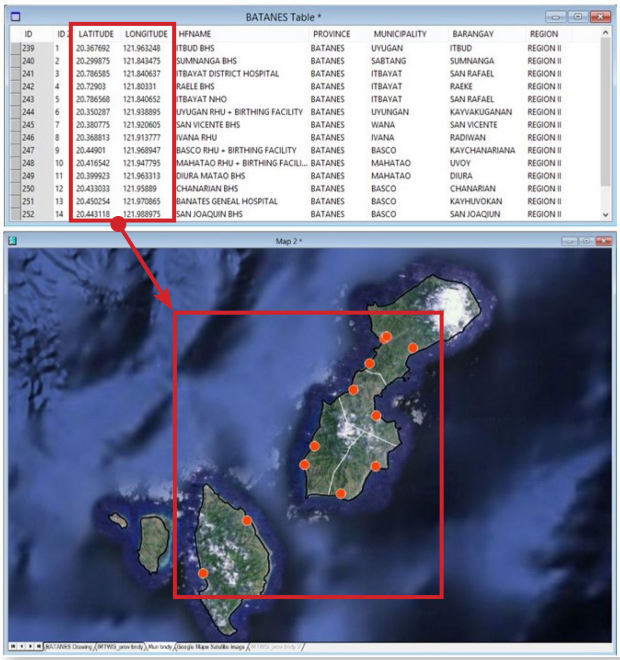


Figure 14. A simple map layout

How GIS Works

In GIS, geographic analysis can easily be done by understanding how an object on the Earth relates to other things in a geographic context. For instance, can we visualize a spreadsheet table that indicates the locations of health facilities with longitude and latitude columns? The answer is no. So what exactly can we do to make the table more understandable? The answer is to convert the table into a vector format, in this case, points. A table with latitude and longitude columns, called a **geocoded table**, can be easily converted into points to show their exact locations on Earth *(Figure 15)*.



ID	ID 2	LATITUDE	LONGITUDE	HFNAME	PROVINCE	MUNICIPALITY	BARANGAY	REGION
239	1	20.367692	121.963248	ITBUD BHS	BATANES	UYUGAN	ITBUD	REGION II
240	2	20.299875	121.843475	SUMNANGA BHS	BATANES	SABTANG	SUMNANGA	REGION II
241	3	20.786585	121.840637	ITBAYAT DISTRICT HOSPITAL	BATANES	ITBAYAT	SAN RAFAEL	REGION II
242	4	20.72903	121.80331	RAELE BHS	BATANES	ITBAYAT	RAEKE	REGION II
243	5	20.786568	121.840652	ITBAYAT NHO	BATANES	ITBAYAT	SAN RAFAEL	REGION II
244	6	20.350287	121.938895	UYUGAN RHU + BIRTHING FACILITY	BATANES	UYUNGAN	KAYVAKUGANAN	REGION II
245	7	20.380775	121.920605	SAN VICENTE BHS	BATANES	WANA	SAN VICENTE	REGION II
246	8	20.368813	121.913777	IVANA RHU	BATANES	IVANA	RADIWAN	REGION II
247	9	20.44901	121.968947	BASCO RHU + BIRTHING FACILITY	BATANES	BASCO	KAYCHANARIANA	REGION II
248	10	20.416542	121.947795	MAHATAO RHU + BIRTHING FACILI...	BATANES	MAHATAO	UVOY	REGION II
249	11	20.399923	121.963313	DIURA MATAO BHS	BATANES	MAHATAO	DIURA	REGION II
250	12	20.433033	121.95889	CHANARIAN BHS	BATANES	BASCO	CHANARIAN	REGION II
251	13	20.450254	121.970865	BANATES GENEAL HOSPITAL	BATANES	BASCO	KAYHUVOKAN	REGION II
252	14	20.443118	121.988975	SAN JOAQUIN BHS	BATANES	BASCO	SAN JOAQIUN	REGION II

Figure 15. A spreadsheet table of locations of health facilities converted into points showing the exact locations on the Earth

When asked to prepare a map of the Philippines showing the provincial boundaries with each province represented by colors, how is it done? The answer is simply displaying the Philippine map with provincial boundaries and changing the appearance by selecting the color palette *(Figure 16)* to display the provinces in different colors *(Figure 17)*.

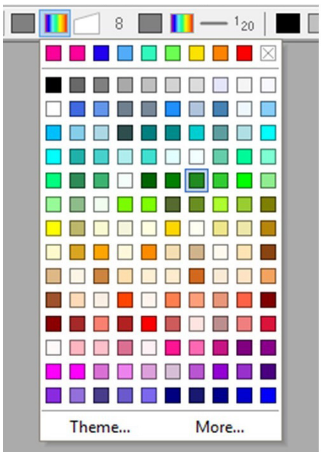


Figure 16. Color palette

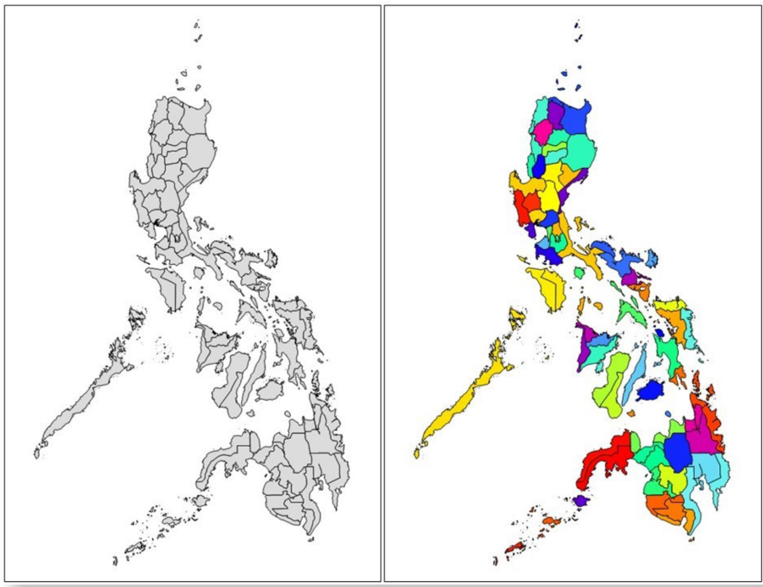


Figure 17. Assigning of colors to show the different provinces

Spatial analysis tools can help one understand the relationships between spatial and attribute data. Some spatial analysis examples are shown below in a Question (Q) and Answer (A) format:

Q: How many buildings or structures in a particular municipality are highly susceptible to flood?

A: Use Geoprocessing tool. Calculate the number of buildings inside the High Susceptibility hazard zone *(Figure 18)*.

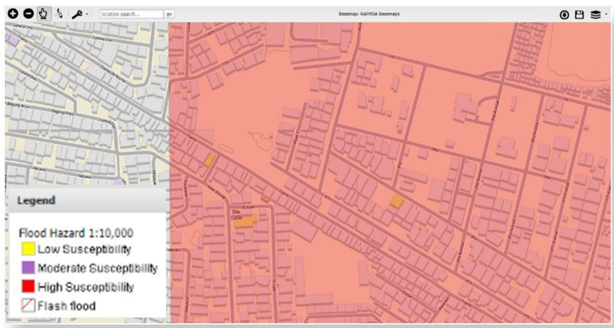
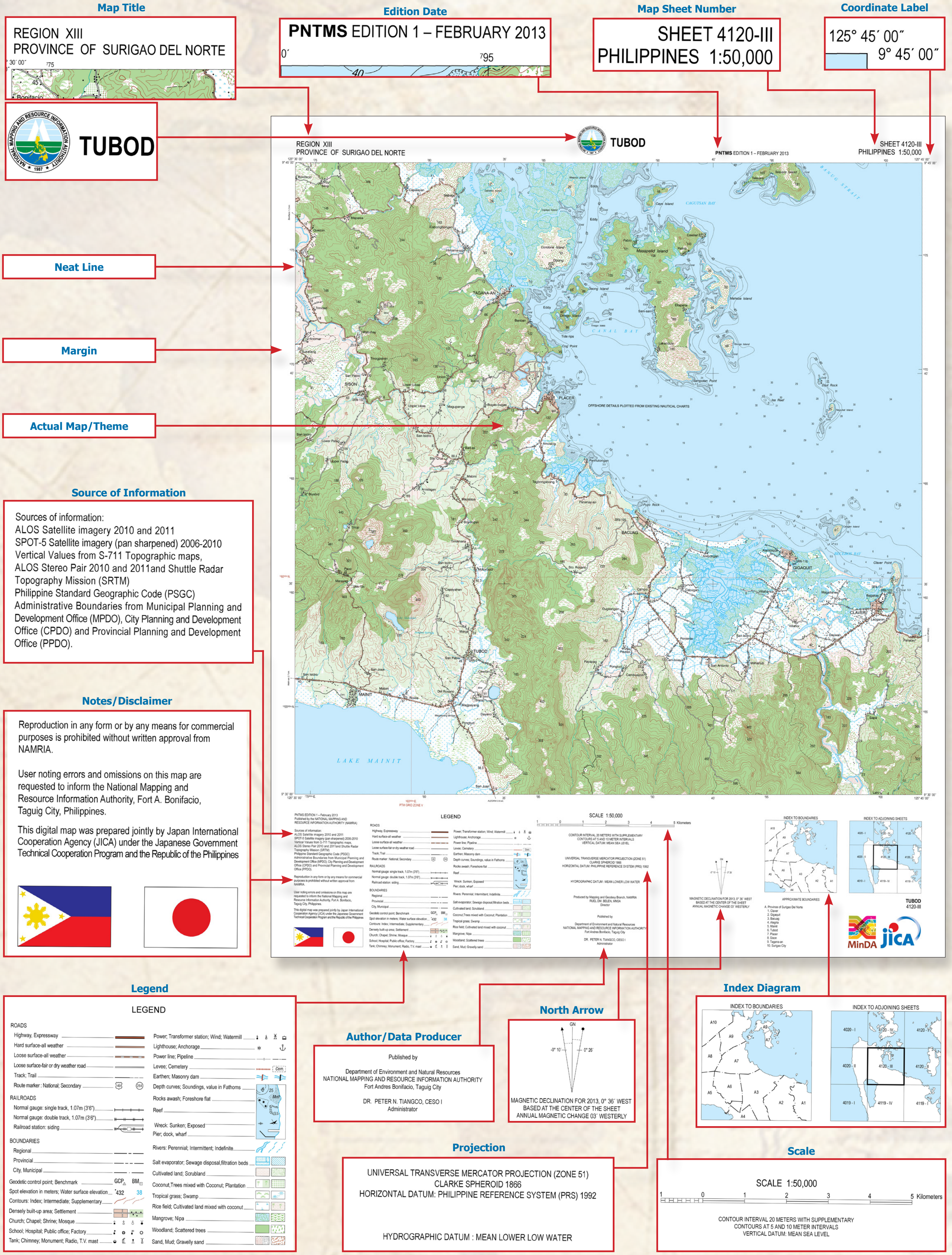


Figure 18. The red highlight indicates the areas highly susceptible to flooding.

Q: How many schools are within one-kilometer proximity to a particular hospital?

A: Run the buffer command. Calculate the number of schools inside the buffer zone *(Figure 19)*.

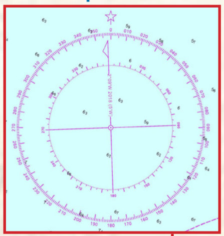
TOPOGRAPHIC MAP



semaps

NAUTICAL CHART

Compass Rose



Cautionary and Explanatory Notes

Depths are in meters and are reduced to Chart Datum, approximately the level of Mean Lower Low Water.
Heights are in meters above Mean Sea Level.
Positions are referred to WGS84 Datum (see SATELLI DERIVED POSITIONS note).
Navigational marks: IALA Maritime Buoyage System- (Red to starboard). (see NOTE)
Projection: Mercator
Sources: The origin, scale, date and limits of the hyd information used to compile this chart are shown in th Diagram. The topography is derived from Philippine Go maps. Later information has also been included.

AIDS TO NAVIGATION — IALA MARI (RE

ary defects in aids to navigation are not ed on this chart except where a buoy — Mariners are advis

Related NAMRIA Publications

SEE RELATED NAMRIA PUBLICATIONS
Notices to Mariners, Philippine Coast Pilot, Philippine List of Lights and Tide and Current Tables

Chart Title

INTERNATIONAL
CHART SERIES
PHILIPPINES
WEST COAST OF LUZON
FAIRWAYS & ANCHORAGE CHART OF MANILA HARBOR

Scale

DEPTHS IN METERS
SCALE 1:10 000 (14°35')

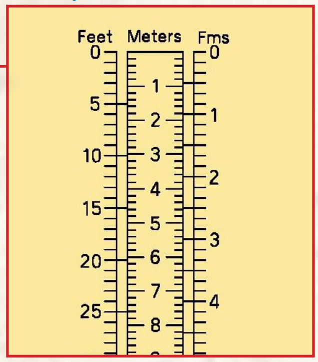
Tidal Information

TIDAL INFORMATION
(2018)

Height referred to datum of soundings

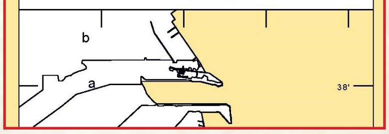
Mean High Water Interval		Mean Higher High Water	Mean Tide Level
hr.	min.	meters	meters
10	20	1.00	0.49
10	20	1.09	0.52

Depth Unit Conversion Table



Source Data

SOURCES
NAMRIA Surveys
a. Single-beam Survey 2010
b. Multi-beam Survey 2008
c. Single-beam Survey 1997
d. Single-beam Survey 1996
Other Sources
MICT - EGS ASIA INC
e. Multi-beam Survey May 2017
f. Multi-beam Survey May 2013

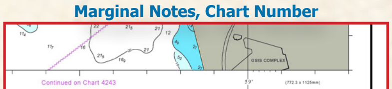


Author / Data Producer

57'

Published at Manila, Philippines February 1983
Produced by the Hydrography Branch, NAMRIA
www.namria.gov.ph

Marginal Notes, Chart Number



WGS84 POSITIONS can be plotted directly on this chart — INT 5601 — 4236

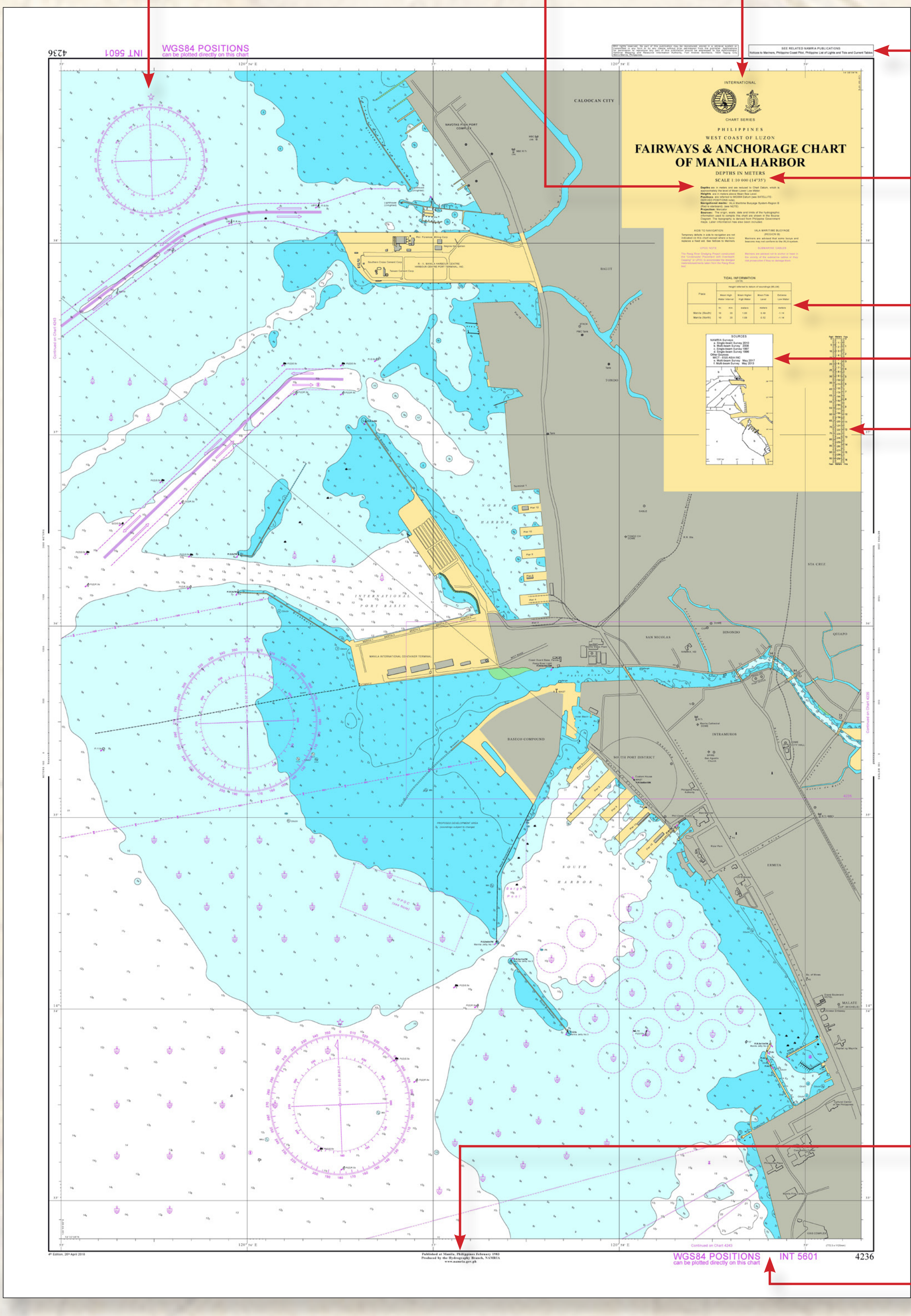


Figure 19. The circle indicates the one-kilometer buffer zone to a particular hospital highlighting the schools within.

Q: Can you identify all the health facilities in a particular barangay?

A: Run the clip command. It will display all the health facilities in a particular barangay, eliminating all other health facilities outside *(Figure 20)*.

Figure 20. The health facilities in a particular barangay after using the Clip command

Q: Can GIS tell me the distance between my house in Taguig City in Metro Manila and Sky Ranch in Tagaytay City in Cavite?

A: Use the Measuring Tool. The simplest way to measure the distance from Point A, your house to Point B, Sky Ranch in Tagaytay is using the straight line measurement *(Figure 21)*.

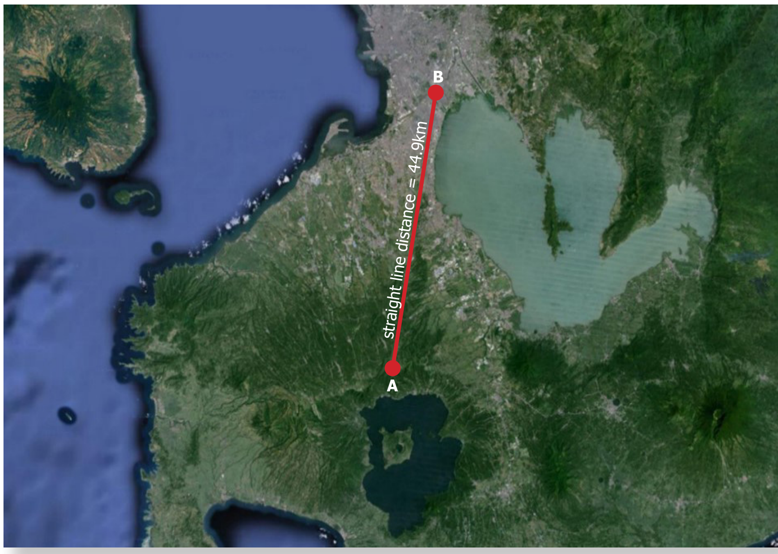


Figure 21. Straight-line distance measurement from Point A to Point B

Aside from spatial analysis tools, geoprocessing tools can also help in answering questions. Consider the following examples:

Q: Can GIS generate slope data?

A: Yes. Generating slope data is not complicated. A digital elevation model (DEM) is needed to achieve the result. It should be noted that different GIS software have different approaches to generating slope information *(Figure 22)*.

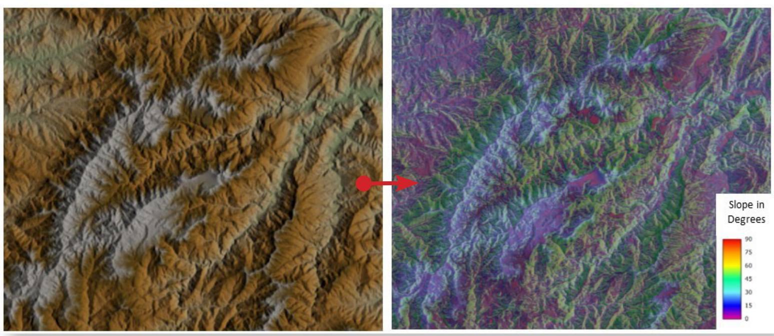


Figure 22. Spectral colors represent the slope in degrees generated using the geoprocessing tool with the DEM as input.

Q: Is it possible to identify the areas below five meters in elevation?

A: Yes. Certain parameters or conditions, however, should be taken into consideration. DEM is an input to attain the desired output *(Figure 23)*.

Figure 23. Based on the DEM, which contains the height information, areas with elevation of five meters and below can be easily identified.

The GIS Output

The final output for GIS is the map layout *(Figure 24)*. The map layout is a compilation of various layers of data intended to provide the reader with a detailed and more comprehensive set of information.

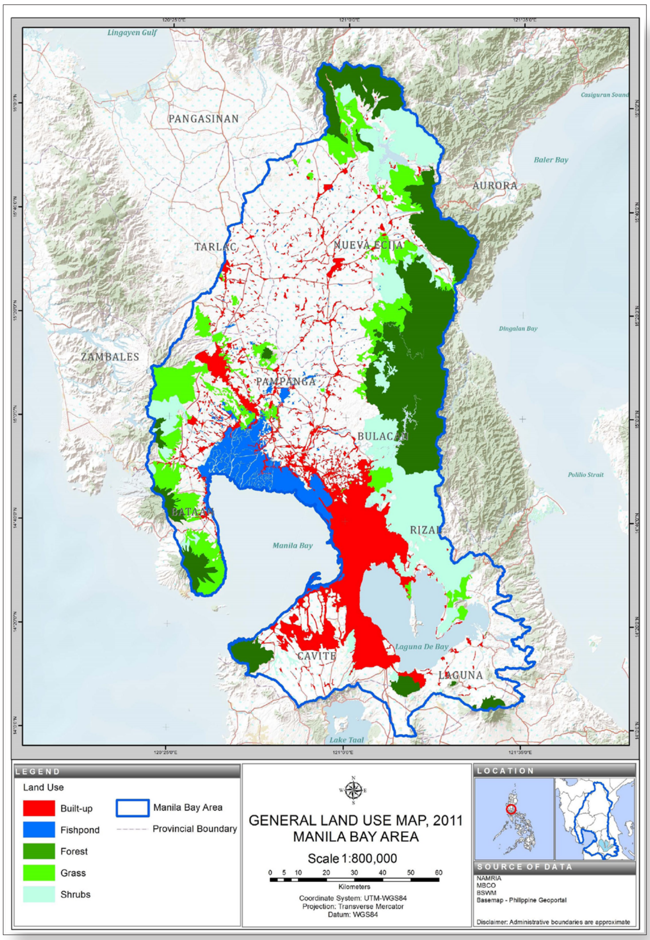


Figure 24. An example of a map layout containing various GIS data layers

GIS Application

GIS application is practically limitless depending on the data availability and accessibility. The following are some examples of areas where GIS technology can be applied: environment and natural resources such as land cover mapping and forest inventory; agriculture such as crop production mapping and locations of aquaculture areas; government, urban, and regional planning such as land use and zoning maps; public works such as water and wastewater mapping, site selection for building bridges, dams and airports, and building management; public health such as epidemiology mapping and locations of health facilities; surveying such as topographic mapping and cadastral mapping; emergency and disaster management such as hazard mapping, locations of evacuation centres, and disaster planning and response; law enforcement such as crime incident mapping, and crime trends and patterns mapping; transportation such as transportation planning and vehicle routing; and utilities such as electricity distribution mapping.

Valuable Technology

Viewing and analyzing data geographically impact the way humans understand the world they live in. The discussion in the article was hopefully enough to provide readers with a good working knowledge of GIS and an appreciation for this great innovative technology. •

References

Map 22. General Land Use Map, Manila Bay Area. Reprinted from Manila Bay Area Environmental Atlas (2nd Edition), by the DENR-Manila Bay Coordinating Office and NAMRIA. Copyright 2015 by the DENR-Manila Bay Coordinating Office. Reprinted with permission.

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Manifold. (2018). [Manifold System Release 8 User Manual]. Retrieved from http://www.georeference.org/doc/manifold.html

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Map Making 101

by LCdr. Aaron Andro V. Ching[1], Neil Eneri R. Tingin[2], Ens. Angelica B. Prado[3] and Leo B. Grafil[4]

Map making has been part of the human course of history and development. Maps have been produced for different purposes using whatever technologies are available during specific periods of civilization.

The earliest maps, which date back to prehistoric times, come in the form of cave drawings or petroglyphs. These parietal arts or cave arts show trails, symbols communicating time and distances traveled, as well as terrains in the form of rivers, landforms, and other geographic features.

Nowadays, maps are being made using advanced hardware and software technologies in the fields of data acquisition, data analysis, presentation, and printing.

This article presents the highly technical art and science of map making being employed by NAMRIA. We will focus on the processes involved in the making of NAMRIA's basemaps: the topographic maps and the nautical charts.

Topographic Map vs. Nautical Chart

As defined elsewhere in this publication, a **topographic map** is a map of the landscape and relief of the Earth's surface while a **nautical chart** is a map that depicts the configuration of the shoreline and seafloor *(see centerfold)*. Generally, the major components of both maps are **elevations** (topography) and **depths** (bathymetry), respectively.

Topographic elevations and the bathymetric depths are often shown with contour lines. A **contour line** is a line on a map representing a corresponding imaginary line on the surface of the land or bottom of the sea that has the same elevation or depth along its entire length. A **bathymetric char**t, which is considered as a subset of a nautical chart, is the submerged equivalent of an above-water topographic map. An accurate presentation of the submerged terrain and other underwater features is the goal of the bathymetric chart, while safe navigation is the requirement of the **nautical chart**. Simply put, the nautical chart is intended to show the land if overlying waters were removed in exactly the same manner as the topographic map.

In an ideal case, the joining of a nautical chart and a topographic map of the same scale and projection of the same geographic area, should be continuous and seamless at the designated sea level datum.

The topographic maps of NAMRIA are produced on three different scales. These are 1:250,000; 1:50,000; and 1:10,000; *(Figure 23, page 14)* categorized as small-, medium-, and large-scale maps respectively. The following are the number of map sheets covering the entire country: 55 map sheets on a 1:250,000 scale *(Figure 1)*, 680 map sheets on a 1:50,000 scale *(Figure 2)*, and more than 12,800 maps sheets on a 1:10,000 scale. However, for practical reasons, only selected highly urbanized areas are prioritized setting aside the sparsely populated mountainous areas *(Figure 3)*.

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[2] *Chief, Nautical Publication Section, Maritime Affairs Division-NAMRIA HB*
[3] *Nautical Publications Section, Maritime Affairs Division-NAMRIA HB*
[4] *Engineer IV, Photogrammetry Division-NAMRIA-Mapping and Geodesy Branch (MGB). Holds a Master in Photogrammetry and Geoinformatics degree from Stuttgart University of Applied Sciences in Stuttgart, Germany, and Diploma in Applied Geodesy and Photogrammetry degree from the University of the Philippines (UP) in Diliman, QC*

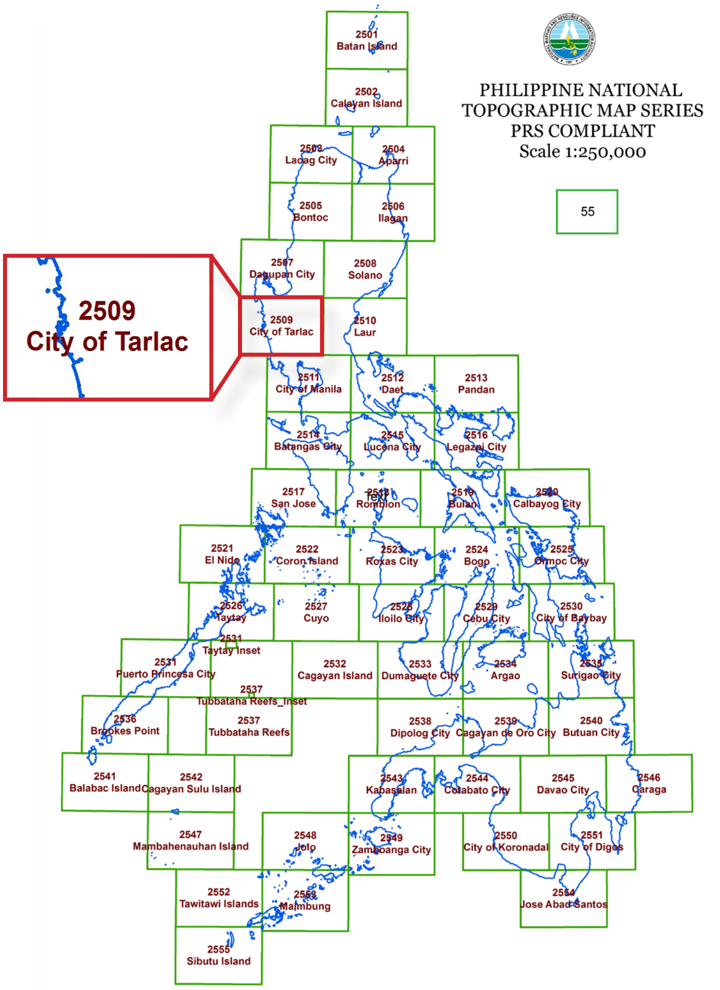


Figure 1. The rectangles show the extent of all the 55 map sheets on a 1:250,000 scale.

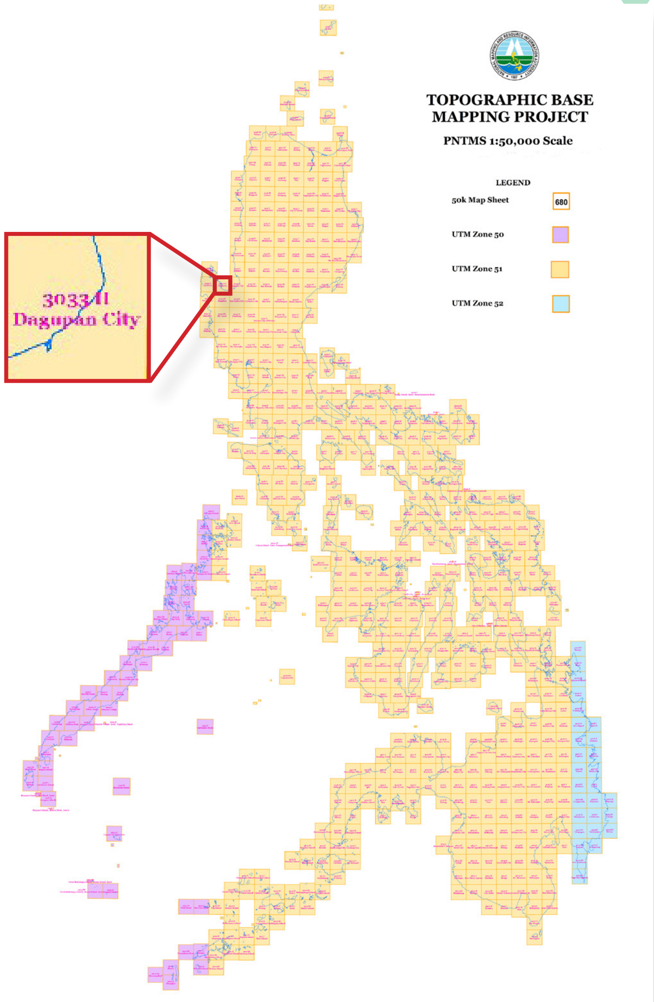


Figure 2. The small squares show the extent of the 680 map sheets on a 1:50,000 scale. Zoning under the Philippines' Universal Transverse Mercator (UTM) is shown by the pink, orange, and blue colors representing Zone 50, Zone 51, and Zone 52, respectively.

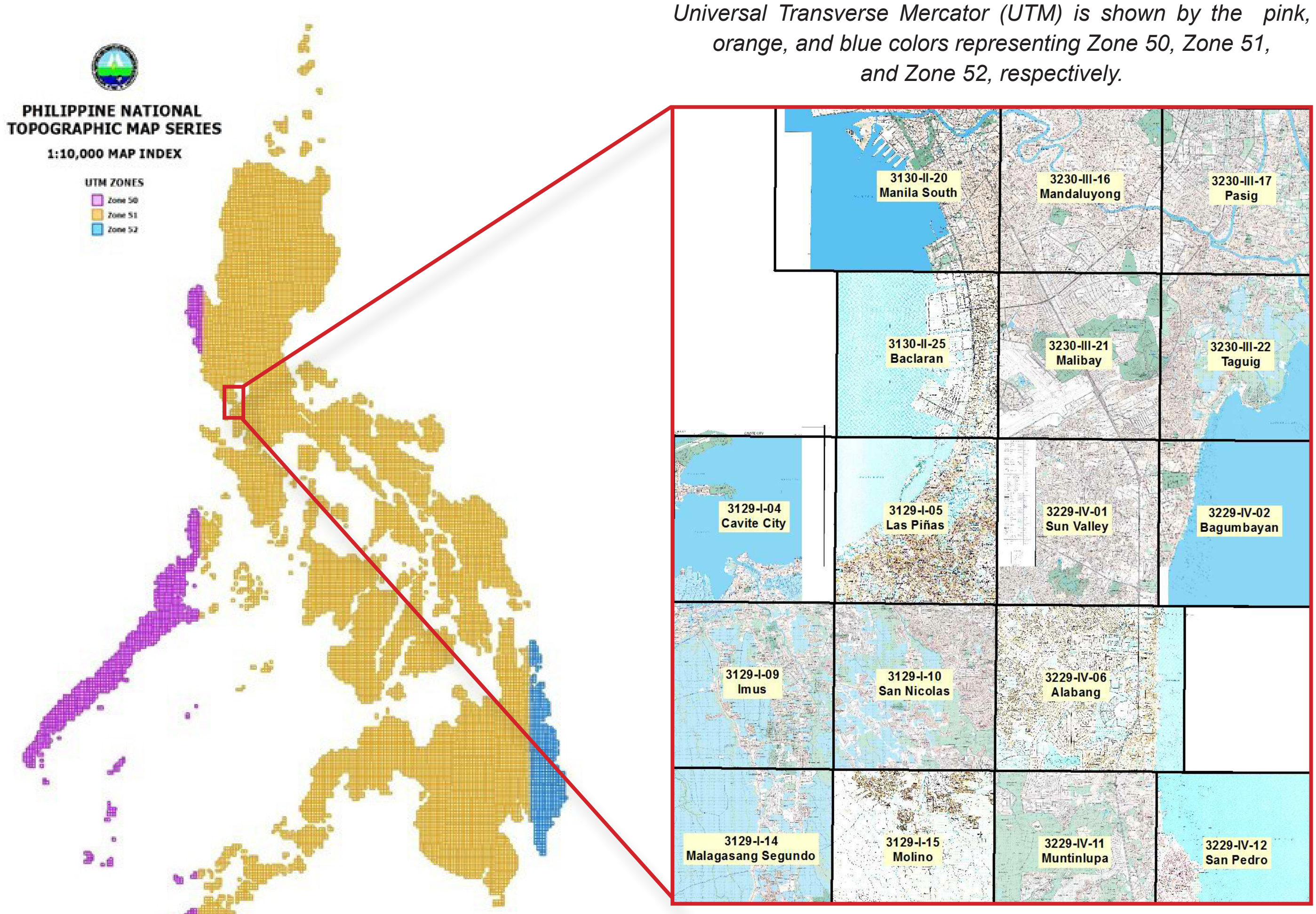


Figure 3. The small squares show the extent of maps on a 1:10,000 scale (left) and an enlarged portion covering National Capital Region or Metro Manila (right).

Nautical charts are produced on various scales *(Figure 4)*. These charts cover the entire country—in specific coastal areas, and approaches to ports and harbors. More than 400 nautical charts have been produced by NAMRIA including those currently available in the map sales offices and those that are kept in archives.

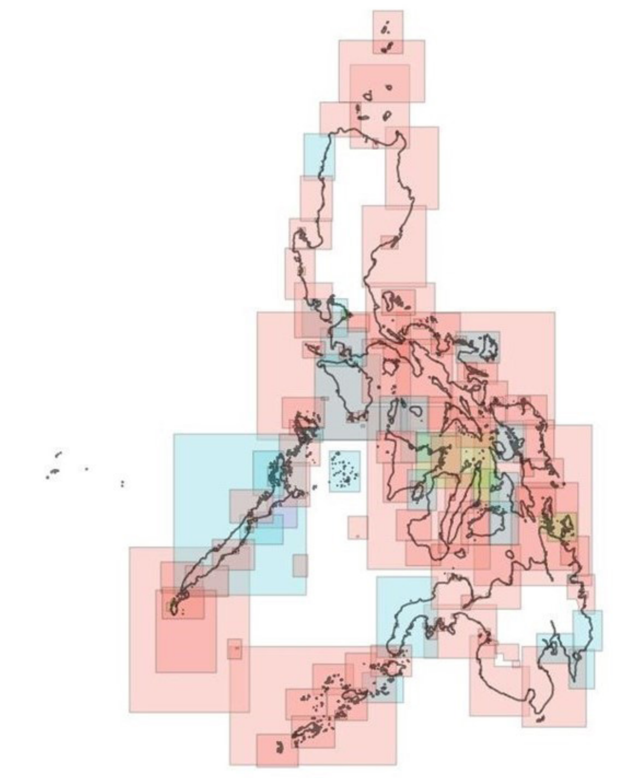


Figure 4. This shows the extent of some of the nautical charts on various scales.

The Map Making Process

Nowadays, maps can be produced easily using a wide range of tools by anyone with access to Internet. But to be useful, these maps need to be precise and accurate. The production of precise and accurate maps need to follow strict standards that could only be provided by professionals. While NAMRIA maintains a manual of standards in producing maps, the procedures are largely based on the discipline of **Cartography** which deals with the conception, production, dissemination, and study of maps. Cartography as a process, links map makers, map users, the physical reality, and the map itself.

This article focuses only on the first half of the cartographic process that starts with the environment or the physical reality to the map maker then to the physical map. The other half that deals with map use, map reading, and map analysis is discussed in other articles presented elsewhere in this publication.

The succeeding sections discuss separately how NAMRIA makes the topographic map and the nautical chart.

How is a Topographic Map Made?

NAMRIA produces, maintains, and updates topographic maps on various scales based on international mapping standards. The agency strictly observes controls in its topographic mapping process and applies the correct and acceptable criteria for the final map products.

NAMRIA's topographic maps are widely used in various sectors such as the government, academia, business, and private organizations as basic references and for thematic mapping. Thus the agency ensures the quality and uniformity of maps across all uses and platforms.

(continued on the next page)

How is a Nautical Chart Made?

NAMRIA is mandated to produce the nautical charts of the country following the conventions and standards of the International Hydrographic Organization (IHO). The standards ensure the uniformity of symbols and representations used in the nautical charts all over the world. In this case, any mariner, local or foreign, will be able to understand and use NAMRIA's nautical charts when navigating on Philippine Waters.

Unlike the production of topographic maps that heavily relies on image-processing, the huge bulk of work in chart production falls under the acquisition of bathymetric data and other maritime information such

(continued on page 45)

Data Acquisition

The map making process *(Figure 5)* begins with the acquisition of primary data such as aerial photographs or aerial photos and satellite images, digital elevation model, and Ground Control Points (GCPs). These data are needed to locate accurate geographic features on a topographic map.

Figure 5. The map making process

NAMRIA acquires the most current commercially available high-resolution aerial photographs and satellite images. Usually acquired as raw data, aerial photographs and satellite images undergo a thorough evaluation following NAMRIA's specifications. Nonconforming images are rejected and need to be replaced. These are images with excessive cloud covers and shadows that obscure features, void areas (no data), striping, unbalanced tone, ghosting (double image), degradation, insufficient overlaps for overlapping pairs of images or stereo pairs, and poor ground sample distance (GSD).

The **digital elevation model** (DEM), a topographical model or a representation of the ground or landscape of surface features, is essential in image processing. It can be generated by extracting elevation data from stereo pairs. Nowadays, NAMRIA can readily acquire a DEM from external providers through imaging systems, namely, Light Detection and Ranging (LiDAR) and Interferometric Synthetic Aperture Radar (IfSAR). Both systems can produce high-resolution images of ground elevations or DEMs. Contour lines are then derived from DEMs.

Ground control points (GCPs) are other important inputs to topographic mapping. They make up a collection of positional information of known point features on the ground that are easily identifiable in the images. GCPs are usually positioned at road intersections, utility infrastructures, and intersections of rice field paddies or other agricultural plots of land. They are established through the use of a precise survey-grade Global Navigational Satellite System (GNSS) receiver.

An image containing known GCPs can now be georeferenced to a established local map projection and coordinate system such as the Universal Transverse Mercator (UTM) Philippine Reference System of 1992 (PRS92), thus positioning its accurate location on a map.

Image Processing

As mentioned, NAMRIA acquires raw images for topographic mapping. Since these images are taken remotely from airborne or space-borne platforms, they contain distortions caused mainly by the curvature of the Earth. Objects captured on the images may be warped, leaning away from or into the center of the image, or exaggerated in size. In order to correct the distortions, the raw images undergo **orthorectification**, **mosaicking**, and **image enhancement**.

a. Orthorectification

Conventional photographs and satellite imagery are central perspective images. This means that on vertical photos, which are more commonly used in photomapping, the scale will most likely be distorted away from the center of the image. This is called **radial displacement**. The greater the height or depth of features is from the center of the photo or image, the greater is its radial displacement *(Figure 6)*. Thus, the scale is not homogeneous and is not suited for measurement.

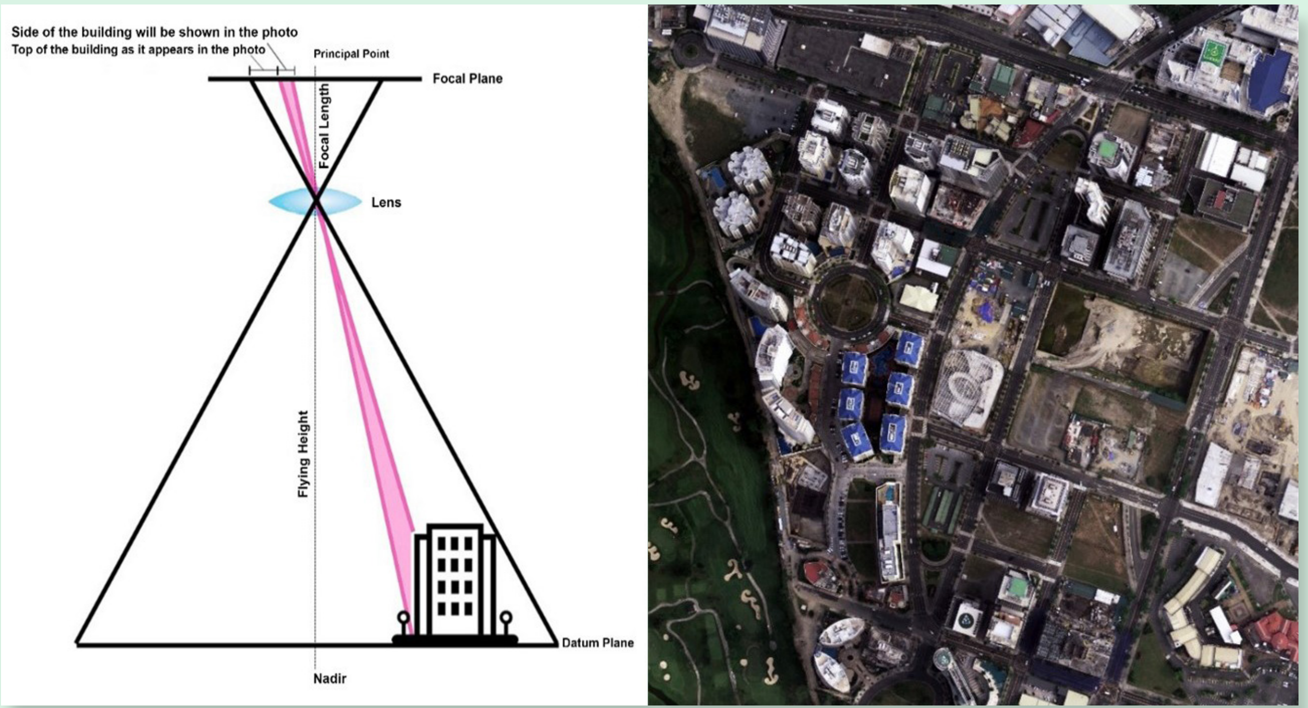


Figure 6. Basic geometry of vertical aerial image shows how displacement occurs (left). Greater displacement is observed as one moves farther away from the principal point of an aerial image. Displacement is also more prominent for objects with considerably greater height above the datum plane, as observed in the high-rise buildings in Bonifacio Global City (right).

In order to remove radial displacement, it is necessary to turn the central perspective image into a parallel or orthogonal perspective image by physically altering the geometry of the image using a DEM. This process is called **orthorectification**. The inaccurate scales of standard images caused by radial displacement are removed, providing a constant scale. GCPs which establish the relationships between the images and the ground are additional components in orthorectification. Orthorectification allows all features to appear in their true positions. This process can be readily accomplished using computer systems. The resulting modified image is called an **orthorectified image** or **orthoimage**. The prefix ortho means "corrected."

The observer assumes a vantage point directly above each mapped point simultaneously. The result is a plan view, as a floor plan of a house or a planimetric map. Accurate spatial dimensions, including size relations, are preserved in all spots on the map. Thus, the spatial form (or geometry) of the map is true-to-Earth. We say that features are shown in true-planimetry. This makes it possible to determine the spatial character of all features simply and quickly, permitting all kinds of meaningful analyses involving position, direction, and distance relations.

The drawback of planimetric mapping is that all cues relating to the vertical aspect of the environment are eliminated. It is as if we are looking straight down on our environment, and we get no impression of elevation or topography. The succeeding paragraphs will illustrate how the concern on topography is addressed. Steps like further image processing, feature extraction, and contour generation are applied.

b. Mosaicking and Image Enhancement

Mosaicking is the splicing or stitching of orthoimages in order to produce a photo of one broad contiguous or larger homogeneous image area *(Figure 7)*. Smoothing, color balancing, and other image enhancement techniques are applied first for each image in order to have a better, homogeneous image of the larger area.

In mapping, the mapmaker is usually concerned with what is visible (identifiable) from an aerial perspective. Therefore, in satellite images, we use bands (channels of spectral colors such as red, green, and blue) that are

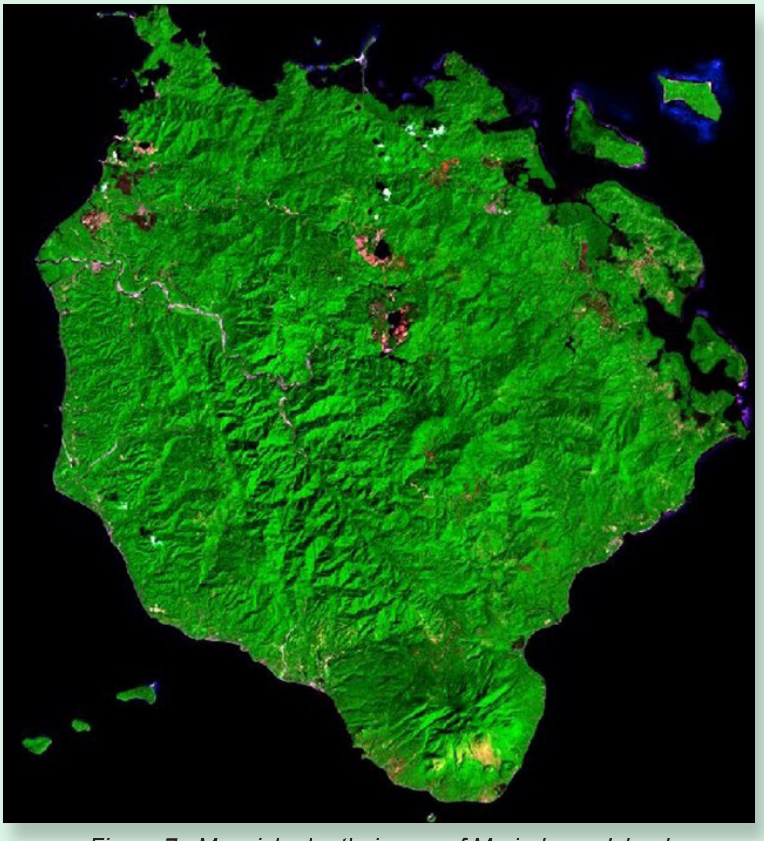


Figure 7. Mosaicked orthoimage of Marinduque Island

in the visible and near-infrared range to process image inputs to mapping. These bands are used for image interpretation based on knowing the spectral signatures or unique properties of features. The interpreted images are then subjected to image enhancement to allow for better feature interpretation in the later processes.

Some satellite images come in both **multispectral** (i.e., with multiple bands measuring reflectance at different wave lengths) and **panchromatic** (black-and-white band with wide bandwidth). **Pansharpening** is a technique wherein we use panchromatic images of the same area to upscale the resolution of multispectral images. It is important to note that the wide bandwidth of panchromatic bands allows for a higher signal-to-noise ratio (i.e., higher ratio of usable information against noise/clutter), and can, therefore, produce higher-resolution images compared to their multispectral counterparts *(Figure 8)*.

Figure 8. A multispectral image has a lower image resolution (left) compared to a panchromatic image of the same area (middle). In this example, the multispectral image has a spatial resolution of two meters while the panchromatic image has a spatial resolution of 30 centimeters. The images are processed against each other to create a pansharpened image: that is, a multispectral image with a spatial resolution equal to that of the panchromatic image (right). Notice how the details were enhanced in the resulting image.

Another form of image enhancement is **natural color composite production**. An image composite is produced by rendering three bands using three primary colors. Since we want to produce a true color composite, we use the red, green, and blue bands for each of the additive primaries of the same color. However, aerial images and satellite products are obtained during different times of the day under different lighting conditions. This results in slight color variations among similar features across different images. For example, in one true color composite, vegetation may either appear bluish or yellowish. Some images may look hazy or smoky (grayish), while others may appear closer to true color. To address this issue, images undergo minor color matching to ensure that the color profile of different scenes closely matches each other *(Figure 9)*. Scenes are then cut along linear features to make seams less noticeable before mosaicking *(Figure 10)*. The final result of image enhancement is a seamless mosaic of images over an area. Mosaics are then used for feature extraction.

Figure 9. The figures show natural color processing applied over a scene. The unprocessed image (left) returns darker greens over vegetated areas, whereas the processed image (right) shows vegetation closer to their appearance in ideal lighting conditions.

Figure 10. Colors are matched between multiple scenes (left) to create a seamless mosaic (right) of the area. Images are usually cut along identifiable features (e.g., roads, paddies) to make seams less prominent.

Feature Extraction

An orthoimage is equivalent to a map or referred to as an image map wherein the scale is constant throughout, regardless of elevation, thus providing accurate measurements of distance, size, and direction. It can be optimized for viewing within a GIS environment. However, in the interest of base mapping, images still contain a lot of extraneous information that can be removed from a map in order to create a less cluttered map. Features of interest or relevance are extracted. These features are categorized as **planimetric** or **altimetric** features.

a. Planimetric Features

Planimetric features are those identifiable and interpretable features from images such as roads, rivers, buildings, vegetation cover, cultural, and other physical objects. These features are extracted from images. In essence, orthoimages are digitized or vectorized where visible features in images (in raster format) are converted into feature-based representations *(Figure 11)*. In a GIS environment, features are represented as vectors or in the form of points, lines, and polygons.

Point features are used for spot locations in maps, usually small places or landmarks. Lines are used for linear features such as roads, rivers, railways, and boundaries. Polygons are used to represent areas with measurable extents, such as land cover, lakes, islands, and building footprints.

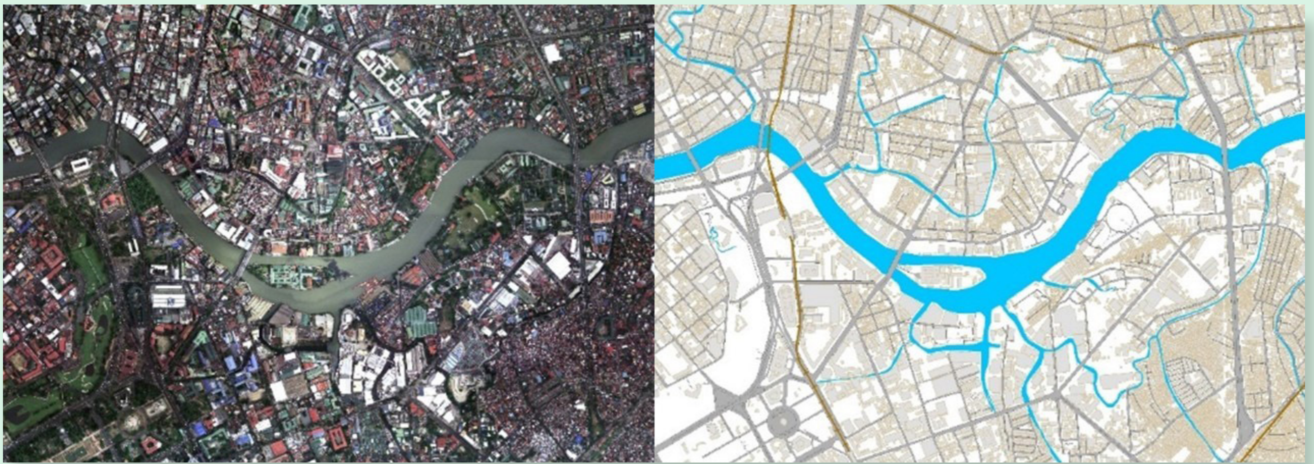


Figure 11. From an orthoimage (left), features of interest such as rivers, roads, railways, and building footprints are vectorized, allowing us to produce vector layers highlighting these features (right).

It should be noted that the ways in which features are represented in maps vary depending on the scale and the relative sizes of surface features within them. On large-scale maps, linear features such as rivers and roads can also be represented as polygons, while smaller waterways can be represented as lines. Conversely, large areas such as cities or townships can also be represented as points on small-scale maps.

b. Altimetric Features - Contour Generation

It is possible to know where you are in terms of two horizontal dimensions and yet be completely out of tune with the important third dimension of the environment—the vertical (elevation). It is easy to forget the significance of the vertical dimension because most of the time we live in a flat world. We tend to think of position in purely horizontal terms. This is often a perfectly good way to simplify our world. However, such a simplified viewpoint sometimes causes conflict. Ships run aground, airplanes crash into mountainsides, and hikers die of exposure at high altitudes—all because the third dimension was not taken into account.

When vertical information about the land is important, planimetric maps give only horizontal information and are not of much use. In such cases, we should turn to topographic maps that contain altimetric features showing the configuration of the land surface through contours and spot elevations.

Maps treat the vertical dimension of our environment in several ways. To give the vertical positions of different points on Earth's surface a precise numerical interpretation, map makers have agreed to use one of several tidal surfaces of reference. The most useful of the tidal reference datums is the **mean sea level** (MSL), which is the average of all recorded sea levels over a 19-year period. This average ocean surface is theoretically extended under or through the continental landmasses around the globe. Thus, the elevation of any spot on Earth can be given with reference to this datum.

Mean sea level provides the base for most topographic maps. One should not assume, however, that elevation values on a given map were determined with reference to MSL. You may encounter other datums, which give the "negative" elevations of depth reading such as in nautical charts. These datums include the arithmetic average of all the low water levels recorded over a 19-year period, known as the **mean lower low water** (MLLW). NAMRIA uses the MLLW in producing its nautical charts.

Vertical dimensions are ideally represented on maps using contour lines *(Figures 12 and 13)*. Contour layers that are added to NAMRIA topographic maps are rendered from IfSAR-derived high-resolution **digital terrain models** (DTMs). The DTM is a "bare earth" that contains elevations of natural terrain features. All vegetation and cultural or built features such as buildings are removed.

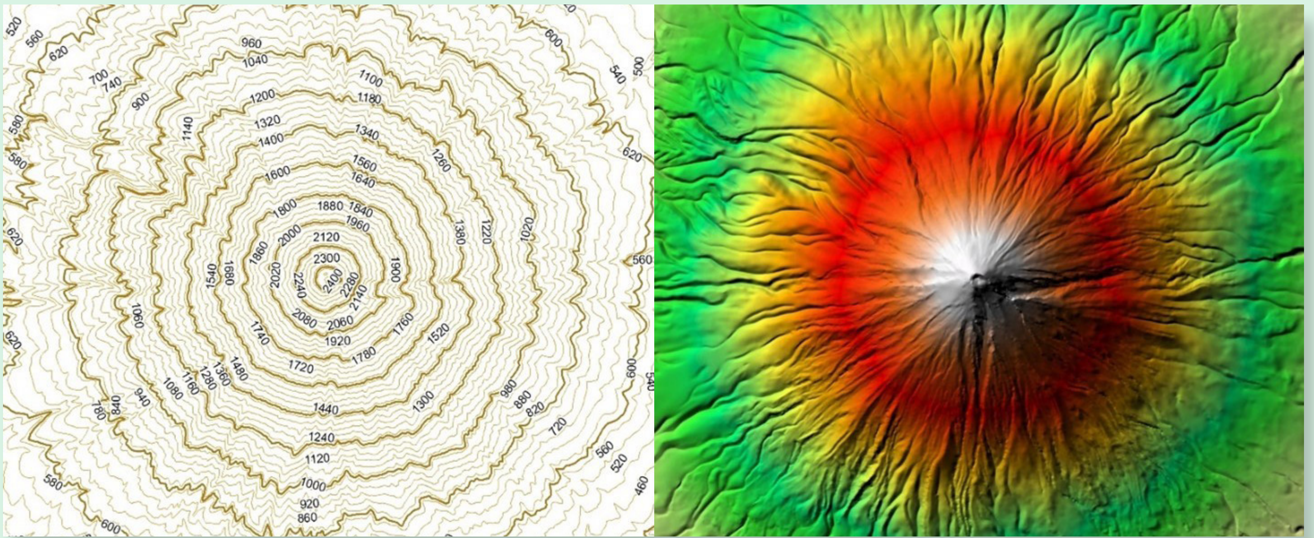


Figure 12. Contour lines of Mayon Volcano are lines that connect points of equal elevation on topographic maps (left). These lines form concentric polygons around elevated areas, providing us with a picture of the topographic relief of an area, as shown by the IfSAR DTM and hillshade of the same area, where the contours are generated from (right).

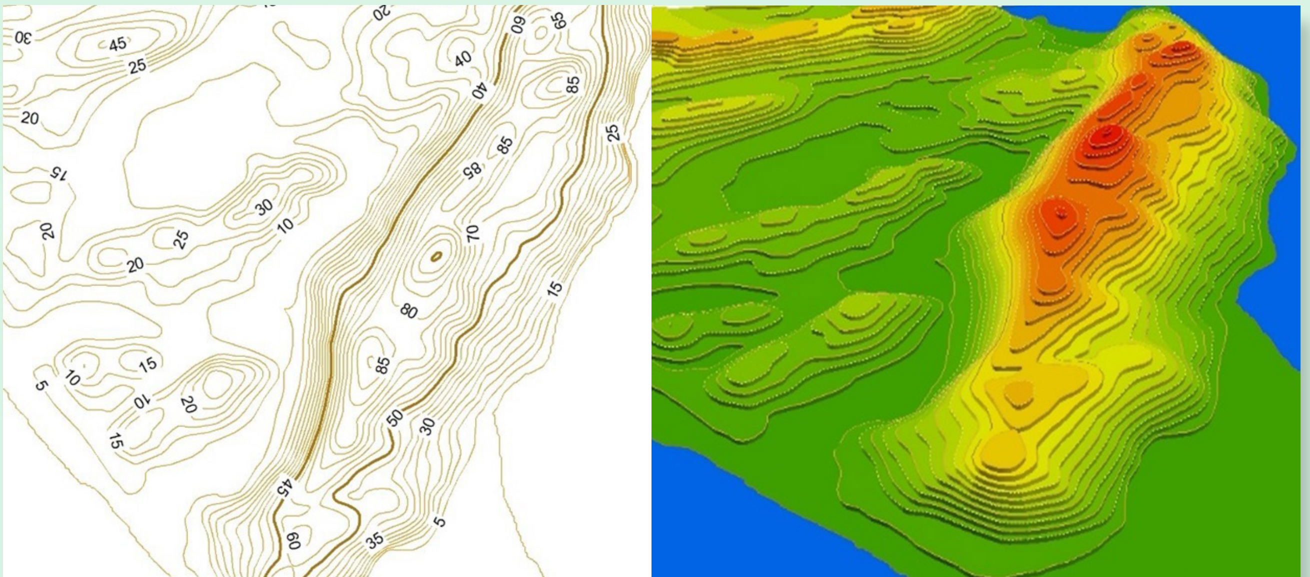


Figure 13. The image on the left shows a visualization of how contours are read. Contours form concentric circles around elevated areas and depressions. Areas where contours are bending inwards to elevated areas are troughs or dips, while areas where contours are bending outwards are ridges. The image on the right shows contour lines rendered in 3D.

Contours are rendered on specific intervals. The contour interval gives the vertical difference between adjacent contours on a surface. A contour interval of 20 draws a new contour line for every 20-meter rise on the elevation of the ground. It follows that a smaller contour interval makes for higher contour density on a map. To prevent clutter on the final map, contour intervals are decided depending on the scale. On some maps with varied terrain, contour intervals are also adjusted. For example, the 1:50,000 map sheet covering Tumauini in Isabela has a supplementary contour interval of five meters in the plains, while the contour interval is set at 20 meters in the highlands *(Figure 14)*.

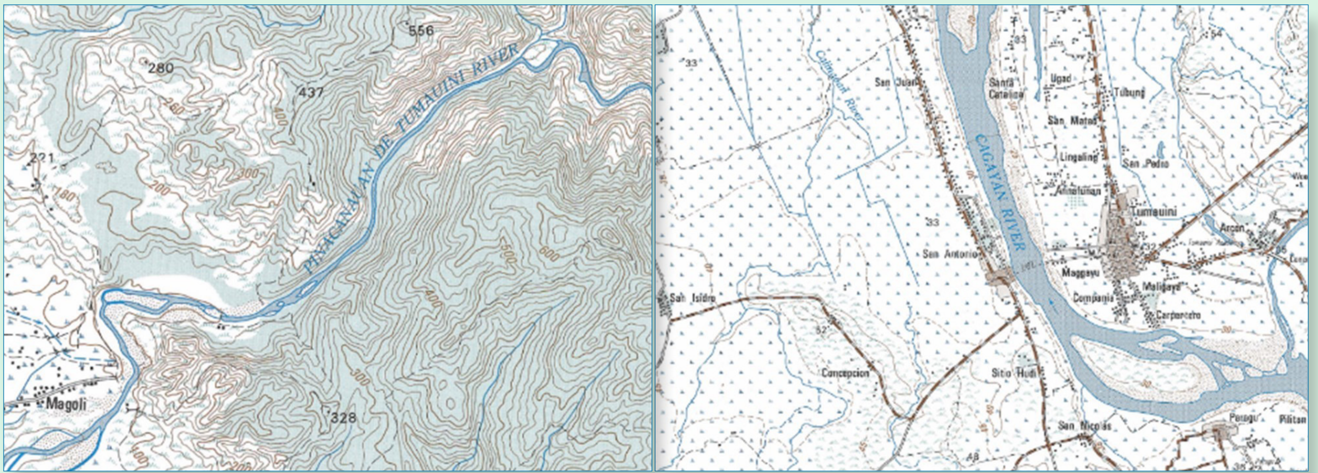


Figure 14. Contour interval may be adjusted within the same sheet to optimize contour density. For example, for the areas found within the same map sheet covering Tumauini, Isabela, notice how the mountainous area (left) has a contour interval of 20, while the plains around the Cagayan river have contour intervals of five (right).

On large-scale maps, a limit for contour interval is set depending on the precision and accuracy of the acquisition method. For contours rendered from IfSAR-obtained datasets, the lowest contour interval that can be rendered is three meters.

Contours are usually complemented with spot heights. Spot heights are points drawn over different areas of a map, usually on hills and mountain peaks, to indicate the exact elevations of those spots. Spots marked with heights do not coincide with contours; they are usually placed within the circular polygon formed by the highest contour line.

All extracted or compiled planimetric and altimetric features are stored in a geospatial database. However, they only contain shapes and locations that correspond to actual ground features as seen in the images. These shapes are then associated with other information, including names, planar measurements (length and area), and other descriptors that will be gathered from the field verification stage.

In a GIS environment, feature-based vector layers are attached to an attribute table or a database file. The attribute table contains columns storing information in the form of text, integers, floating-point values, and dates, among others *(Figure 15)*. These are presented as fields in the table. Each field contains records, presented as table rows. As shown in Figure 15, each feature is listed on the attribute table, and selecting the corresponding record also selects the linked feature within the map view. Conversely, selecting a feature on the map view also selects its record in the attribute table. In a database, field values for each row entry are entered to add attribute information regarding each feature. For example, a building feature has attributes such as name, type, existence, and measurement (area and perimeter), among others. Data entered can be used to classify, symbolize or label features in a map layout. This would allow cartographers to label features on the resulting topographic map, as well as to store geographic information should vector layers be needed as inputs to GIS analysis.

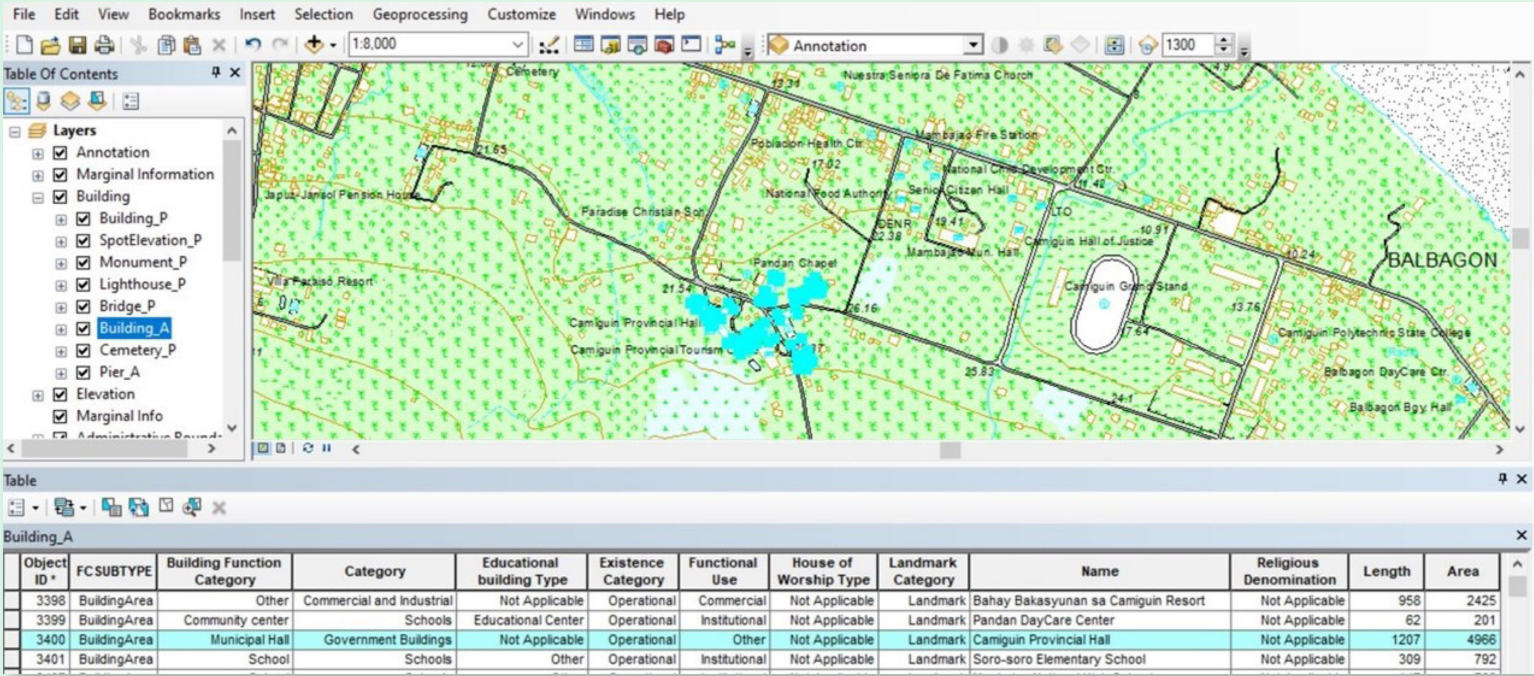


Figure 15. Features in a vector dataset are actively linked to an attribute table.

Field Data Gathering, Identification, and Verification

After extracting the coastal or inland objects from the image, a draft map is prepared by placing all extracted planimetric and altimetric data together. It must be noted that some objects may be difficult to identify or differentiate. Attributes added to features in the topographic database undergo actual on-the-ground verification or field validation since only features seen and analyzed on the image can be extracted. Individual place names are usually obtained using secondary sources.

In the field, GNSS handheld receivers are used to identify location of objects on the ground or points of interest (POIs) such as municipal or barangay halls, public schools, government offices, health facilities, place of worship, landmarks, bridges, ports, piers, and other objects of sociocultural and maritime significance. The receivers are also used to record location of verified information such as vegetation cover, access roads from one place to another, and road surface types.

A courtesy call to respective Local Government Units (LGUs) and other government offices are also part of the field survey. The field survey team conducts a briefing regarding the project and presents the preliminary maps for comments. These units and offices can also be the official sources of administrative boundaries and other relevant secondary information.

The topographic database is then updated based on these information. Corrections are also applied for incorrect image interpretation.

Cartographic Enhancement

Cartographic enhancement combines science, aesthetics, and technique in modeling the reality to communicate spatial information to the map users effectively. It reduces the complexity of the characteristics of the features through generalization and organizes the elements of the map to best convey its message (map design).

Cartographers extract the relevant information from the database and symbolize them according to standard conventions for consistency, representation, and readability. NAMRIA uses its own standards patterned after the American Society for Photogrammetry and Remote Sensing standards for topographic mapping. These standards include several considerations: proper masking (i.e., layers are overlain in a specific order), correct symbology (for polygon features colors and pattern; for line feature styles, weights, and colors; and for pre-determined point features marker symbols), alignments and labeling. The key to a well-enhanced map usually lies in striking a balance between the richness of information and the potential clutter. White spaces or the areas on a map containing relatively little information are also avoided.

Additional map elements such as title, legend or key to features, index to adjoining sheet or location diagram, scale bar, north arrow, and reference grid or tick marks are also added in accordance with the map design. The details about the map, corresponding map sheet number, including the projection used, data sources, contact information for feedback, and other marginal information are added as annotations. Annotations serve as the fine print where all other relevant information can be found.

After undergoing internal quality control (e.g., correct colors and symbols, label placements, letter spacing and alignments, edge matching, etc.), the cartographically-enhanced maps are printed to its true scale. Copies are presented to concerned LGUs for validation. Comments and corrections are re-validated by conducting final ground validation surveys. If necessary and appropriate, validated comments and corrections are incorporated into the enhanced map and geospatial database. The digital maps are then exported into raster format (*pdf* and *geotiff*) for mass printing and distribution.●

(continued from page 36)

as coastal topographic data, navigational data, tidal data, and magnetic data. The bathymetric data collected will then be processed and will undergo quality control (QC). After QC, the processed data, together with other maritime information, will be compiled to produce a nautical chart on a scale appropriate to the covered area. Chart compilation is a recurring process until the final chart is approved for printing or publication.

Survey Planning

The whole process *(Figure 16)* starts with determining what type of nautical chart is going to be published. NAMRIA produces different types and scales of nautical charts based on functions or uses *(Figure 17)*. The general sailing charts (1:150,000) and coastal charts (1:50,000) are used in route planning and navigation in deep waters. The approach (1:50,000 and higher scale), harbor (1:10,000) and berthing (1:5,000) charts are used by mariners to see more details of an area. These charts are especially consulted when a vessel plans to approach and dock at a port.

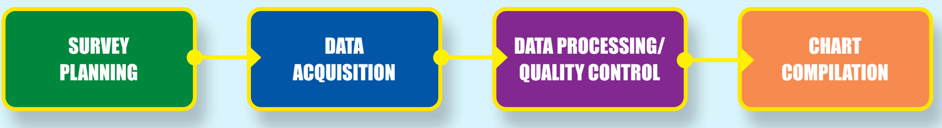
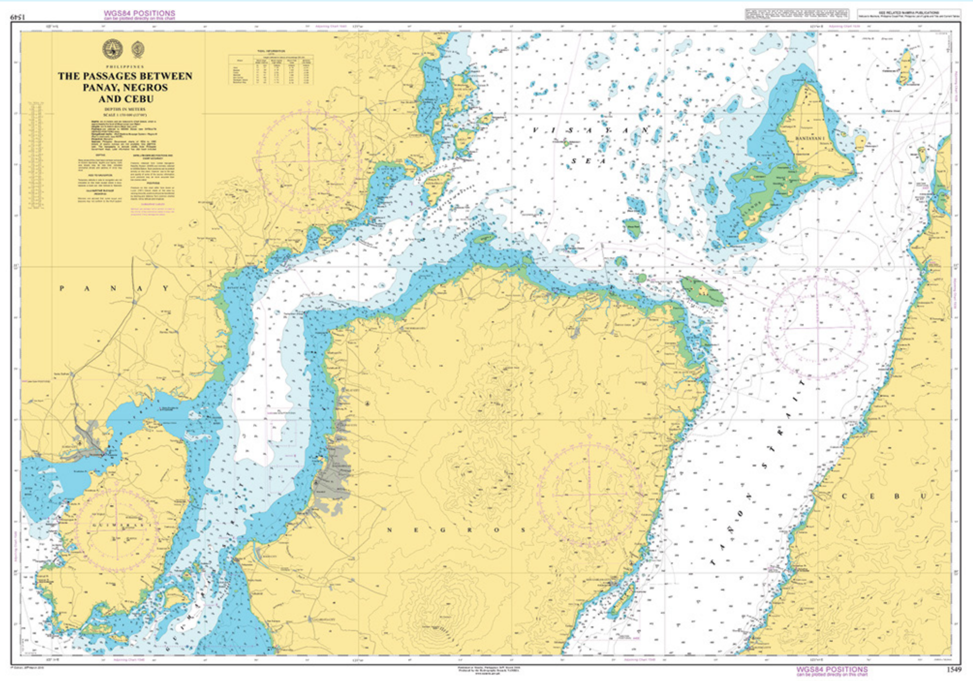


Figure 16. The chart production process



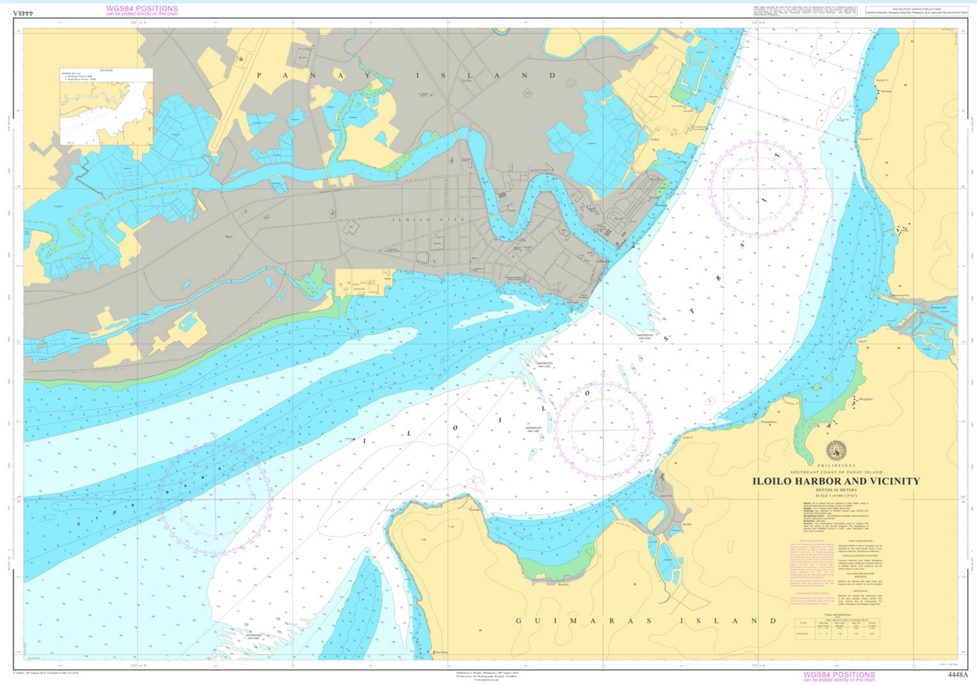


Figure 17. Types of nautical charts: Coastal Chart of Panay, Negros, and Cebu Chart No. 1549 on a 1:150,000 scale (top), and Harbor Chart of Iloilo Harbor Chart No. 4448A on a 1:10,000 scale (bottom)

Survey planning proceeds after identifying the survey coverage. During survey planning, the survey team is selected, survey equipment is set, and coordination with concerned government agencies and private entities is conducted.

When all preparations are completed, the survey team is deployed to the survey area to collect the data needed for the nautical chart.

Data Acquisition

The features found on a nautical chart such as positions (latitude/longitude), water depths, compass rose, and other features important to navigation are acquired through different survey procedures, namely, **positioning**, **hydrographic survey**, **coast lining**, **coast pilot survey**, **tidal observation**, and **magnetic survey**.

(a) Positioning

When a chart is read, the user should be able to determine the position of a feature on it. This is what sets a chart apart from an ordinary image. Hence, getting the coordinates of a feature on a nautical chart is one of the most important aspects of data gathering.

In the past, conventional survey techniques using instruments that measure angles and distances between points on the Earth's surface were employed to get the positions. The advancement of technology, however, has enabled the use of satellite-based positioning or the Global Navigational Satellite System (GNSS).

GNSS, as discussed in other articles, is the generic term for the satellite navigation systems that provide geospatial positioning with global coverage. Satellites consistently circling around the Earth transmit signals to GNSS receivers *(Figures 18 and 19)*. The receivers use the data to determine locations. The Global Positioning System (GPS), a United States (US)-based GNSS, is a more familiar term since it is integrated with most modern devices and is frequently used in different applications involving positions.

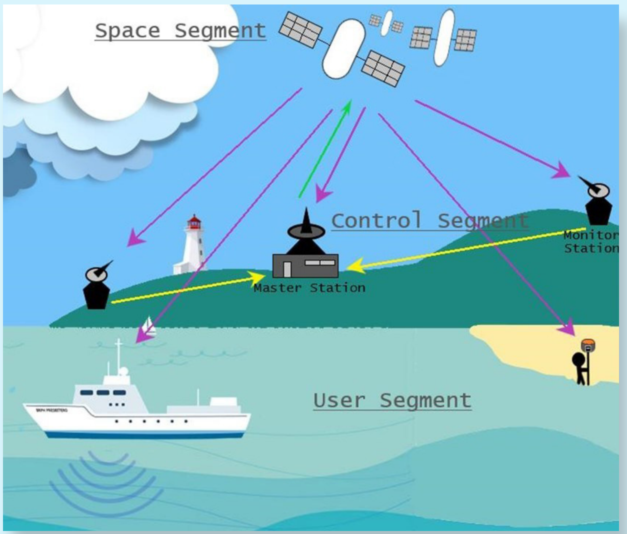


Figure 18. US-based GNSS GPS and its segments


Figure 19. GNSS receivers used during survey

(b) Hydrographic Survey

Data needed for nautical charts are obtained through a **hydrographic survey**. A hydrographic survey is conducted primarily to determine the depths or bathymetry of the water areas. Other information gathered during the survey are the nature of the seabed, tide heights and current velocity, and features that may affect the safety of navigation.

During a hydrographic survey, the survey team comes aboard a platform (a boat or vessel) equipped with an **echosounder**, a type of sonar equipment, to measure the depth of the water area. The echosounder measures depths by transmitting a sound pulse to the seabed and receiving the reflected signal (*Figure 20*). The time interval between the transmitted and received signal is recorded. How fast sound travels in water, called **Sound Velocity** (SV), is also measured using sensors such as the sound velocity profilers (SVP). The depth is calculated using the time interval and SV. The water depths have corresponding positions via the GNSS receiver hooked to the echosounder system.

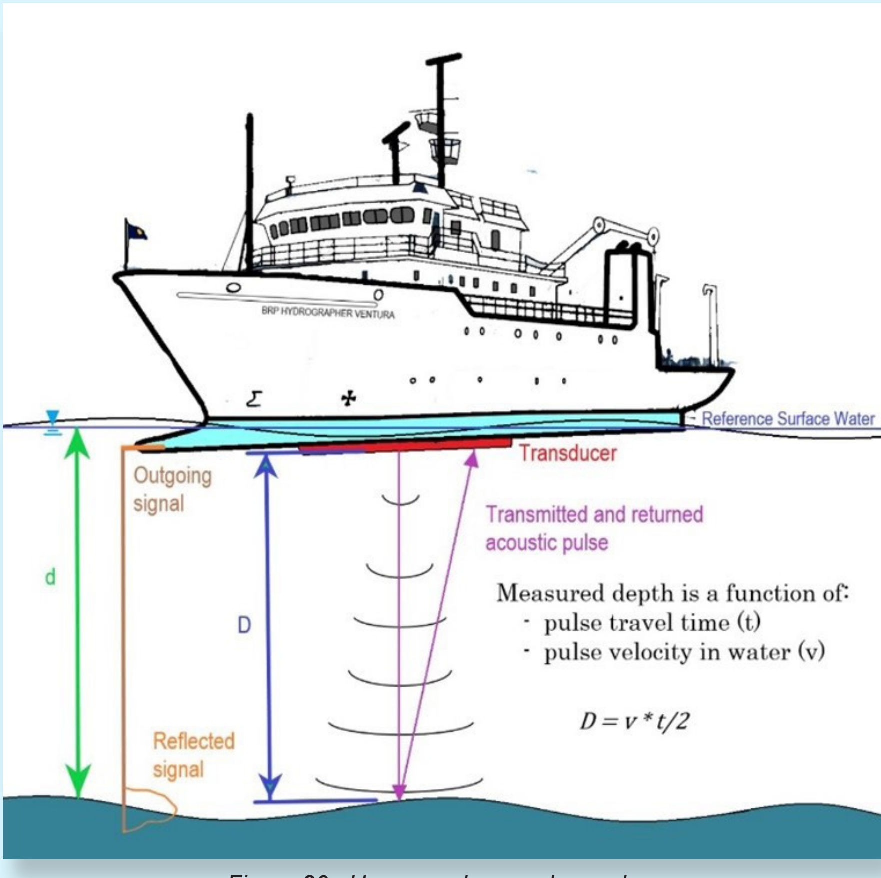


Figure 20. How an echosounder works

There are two types of echosounders being used when conducting a hydrographic survey, namely, **Single Beam Echosounder** (SBES) and **Multibeam Echosounder** (MBES). The SBES produces a continuous single pulse to measure shallow depths on unnavigable portions of the water. It is usually installed in an aluminum skiff or any small survey platform. The MBES, on the other hand, produces a sweep of multiple beams to measure a wider area of coverage than the SBES *(Figure 21)*. MBESs are normally installed in larger survey platforms such as motor launches or ships *(Figure 22)*.

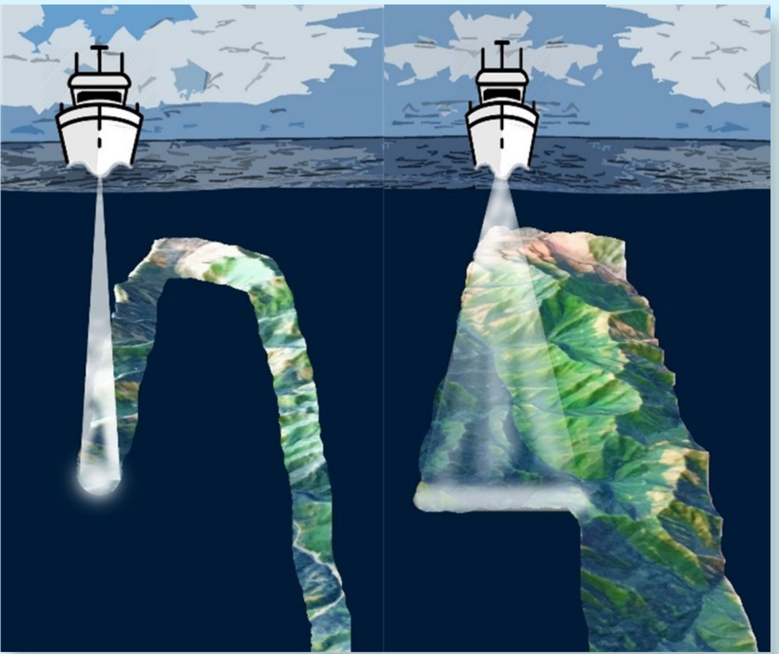


Figure 21. SBES vs MBES survey coverage

Figure 22. NAMRIA survey platforms

(c) Coast Lining

Coast lining or coastal topographic survey is conducted to delineate and describe the coastline of an area. This is a vital survey for harbor and berthing charts since the mariners need to visualize the features of the coastline while approaching a port. During coast lining, the surveyors carry a survey-grade GNSS receiver called a **rover** to get point-to-point coordinates of the coastline. Connecting the gathered points reveals the actual coastline shape. Furthermore, the surveyors take notes of the coastline features; and describe artificial structures such as the port's piers and wharves, and nearby settlements and the coastline's natural features like sand, mangroves, and cliffs *(Figures 23 and 24)*.

Figure 23. Coast lining of natural features such as mangroves and cliffs

Figure 24. Actual port and its chart

d) Coast Pilot Survey

Coast pilot survey focuses on getting data on **aids to navigation** (ATONs), **dangers to navigation** (DTONs), and other port information. As their names imply, ATONs, like lighthouses and buoys, guide mariners while DTONs, like wrecks and shoals, are hazards that should be avoided during navigation. These features are also plotted on the nautical charts *(Figure 25)*.

Figure 25. Buoy and lighthouse and their chart representations

Important details of the ports that cannot be indicated on the nautical charts are noted down in NAMRIA's nautical publications such as the *Philippine Coast Pilot* and the *Philippine List of Lights (Figure 26)*. The *Philippine Coast Pilot* contains descriptions of islands, ports, and features indicated on the nautical charts, as well as information on rules and laws that may affect marine navigation. The *Philippine List of Lights*, on the other hand, contains a list of lighted ATONs such as lighthouses and lighted buoys.

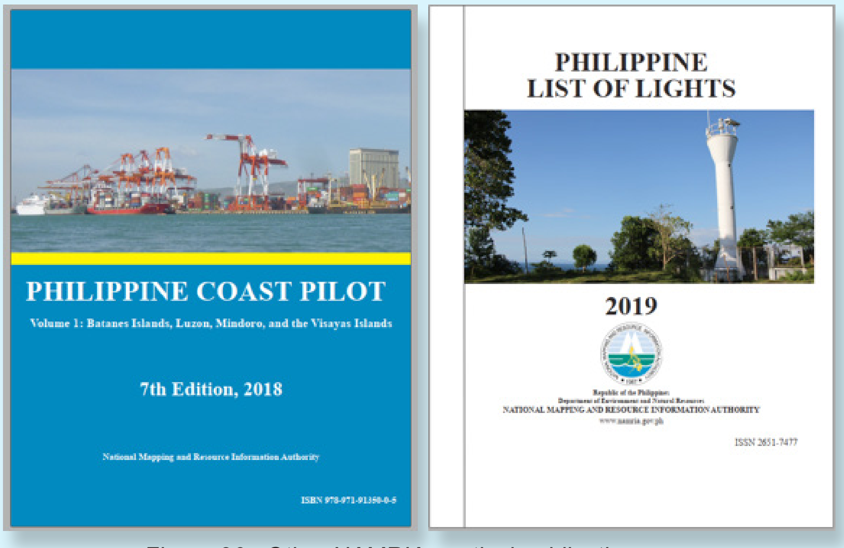


Figure 26. Other NAMRIA nautical publications

e) Tidal Observation

A standard feature of NAMRIA'S nautical charts is the **chart datum**. The chart datum indicates the level of water that serves as the basis for the mariners' safest route for navigation. A chart datum is obtained from the tidal datum which has been generated from an established NAMRIA tide station. For NAMRIA, a tidal datum is estimated close to **Mean Lower Low Water** (MLLW) which is the average height of the lowest low tides recorded in an **epoch** or over several years *(Figure 27)*. In most cases, this epoch is referred to as the **National Tidal Datum Epoch** or a 19-year period tide observation.

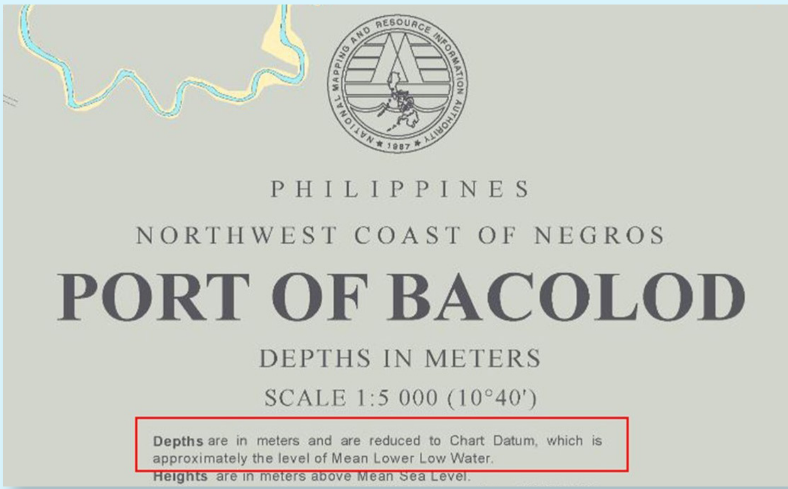


Figure 27. Chart datum at MLLW

NAMRIA maintains a number of tide stations that are strategically placed in the major ports of the country *(Figure 28)*. They are equipped with instruments that continually collect tidal data that can be used to enhance the epochal tide observation.

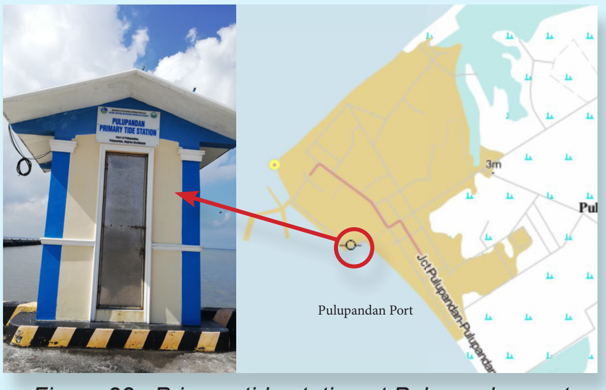


Figure 28. Primary tide station at Pulupandan port

Figure 29. Establishment of temporary tide gauge

If there is no tide station in the area or vicinity where a hydrographic survey is conducted, the NAMRIA survey team establishes temporary tide gauges to obtain the tidal datum *(Figure 29)*. Generally, a 30-day observation is conducted to gather tidal data. These data that mainly factor in actual tide heights and sounding data, are further processed by eliminating variances to generate a number of tidal datums until a final tidal datum is obtained.

NAMRIA also uses the tidal data obtained in each port for generating the predicted values of tidal heights in the area. These values, which are published in the *NAMRIA Tide and Current Tables*, are essential to shipping companies that regularly monitor the tidal conditions in the various ports of the country *(Figure 30)*.

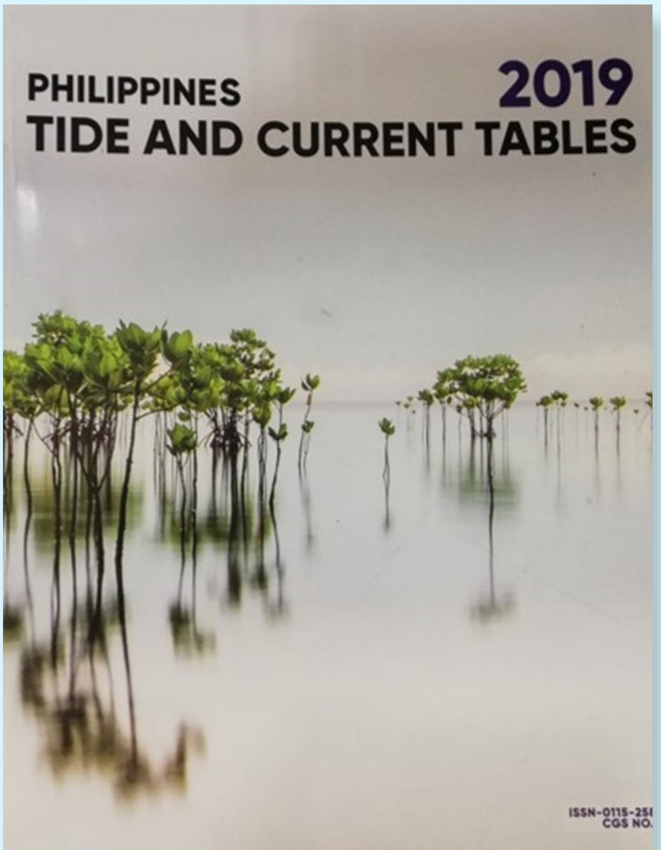


Figure 30. NAMRIA Tide and Current Tables

(f) Magnetic Survey

Magnetic declinations for the compass roses on nautical charts are derived from the **Philippine Magnetic Model** *(Figure 31)*.

The **compass rose** aids the mariner in plotting the direction of the planned route. It shows the true direction or bearing referred from the geographic north, which is symbolized by a star, and the magnetic bearing referred to the magnetic north of the area. The magnetic north is symbolized by a half arrowhead and coincides with the north in the magnetic compass. Compass rose data are used by the cartographer to determine the variation between the geographic north and the magnetic north.

The **Philippine Magnetic Model** is the spatial representation of the magnetic field at any point in the country. Through this model, the degrees of variation from the Magnetic North and the True North can be determined relative to one's position within the Philippines.

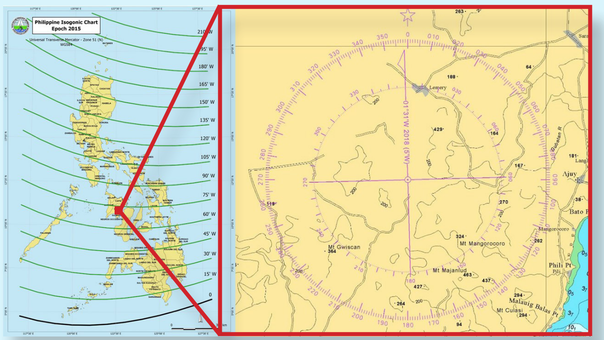


Figure 31. Philippine Magnetic Model for 2015-2019 and the compass rose for magnetic declination

The magnetic model is formulated through a five-year magnetic observation *(Figure 32)*. This is done in the Muntinlupa Magnetic Observatory and Magnetic Repeat Stations (MRS) of the NAMRIA. Continuous observations at the magnetic observatory allow the recording of the total magnetic force (F), horizontal magnetic component force (Hx, Hy) and vertical magnetic component force (Z) to produce reference values to be used in the magnetic surveys of the MRS.

Figure 32. Magnetic survey and solar observation at MRS

Baseline observation is done so that observed values of the magnetic field can be tied geographically to their locations. Lastly, MRS observation is conducted to know the representative magnetic field in the selected region or area.

The processed data from these observations are used to compute the declination coefficient needed to compute the magnetic declination of a point in the Philippines.

Data Processing and Quality Control

All the data gathered from the surveys undergo data processing. During this stage, all corrections are applied to get the water depths (soundings) and contours to comply with the standards set by IHO. Some of the corrections applied are the tide reducers, sound velocity profile, and position corrections. The coastline's shape from the points collected during coast lining is also related to its equivalent description during processing. Port information, ATONs, and DTONs are archived and databased. Bathymetric data are analyzed to extract DTONs like wrecks and shoals. The survey team's outputs include the hydrographic smooth sheet which displays sorted soundings according to an appropriate scale, topographic smooth sheet, and survey documentation and reports *(Figure 33)*.

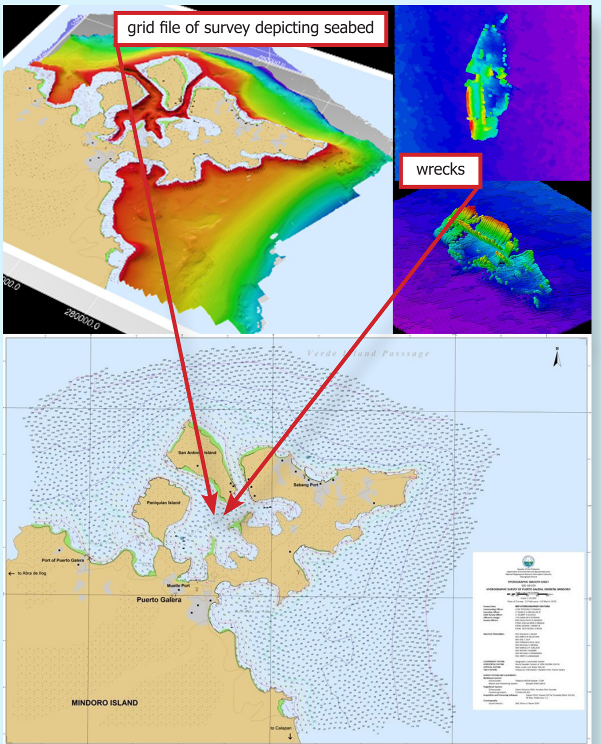


Figure 33. Data processing to produce hydrographic smooth sheet

Quality control involves double-checking if the data submitted by the survey team are within the IHO standards. After quality control, the processed data are forwarded to the cartographers for the compilation of the chart.

Chart Compilation

Chart compilation is the translation of the processed data to the final nautical chart *(Figure 34)*. All the processed and corrected data including the soundings or depths, ATONS, DTONS, configurations of the coastline, magnetic information, tidal information among others are compiled and edited to produce a nautical chart according to its scale and navigational purpose. Using geographic information system or GIS, the cartographers are able to capture, store, manipulate, and analyze spatial information in order to generate a chart with reliable geographic data that will be useful to mariners for safe navigation. The necessary GIS software is utilized to realize this process.

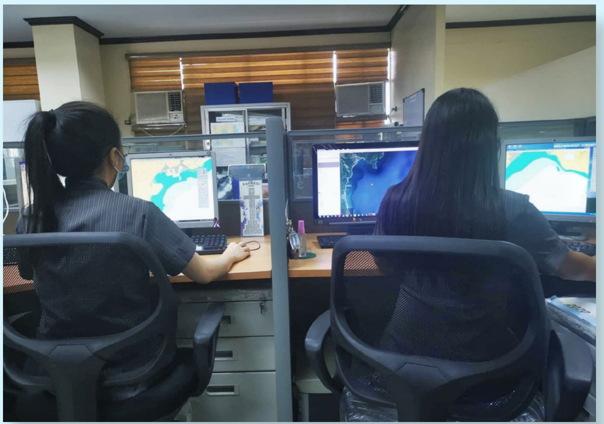


Figure 34. Chart compilation

It is the cartographer's duty to use the correct format and symbols specified in the *IHO S-4 Regulations for International Charts.* Aside from the processed data from the survey and field survey report submitted by the survey team, the cartographers consult other references such as the *Philippine Notice to Mariners* (NMs), satellite images, *Philippine List of Lights*, and other references for updated information not covered during the survey. A corresponding electronic navigational chart or ENC for the nautical chart is produced *(Figure 35)*. It is a vector chart created for use with the Electronic Chart Display and Information System or ECDIS installed in a ship or vessel. Symbolization, formatting, and cartographic editing should conform with the *IHO Publication S-57- IHO Transfer Standard for Digital Hydrographic Data.*

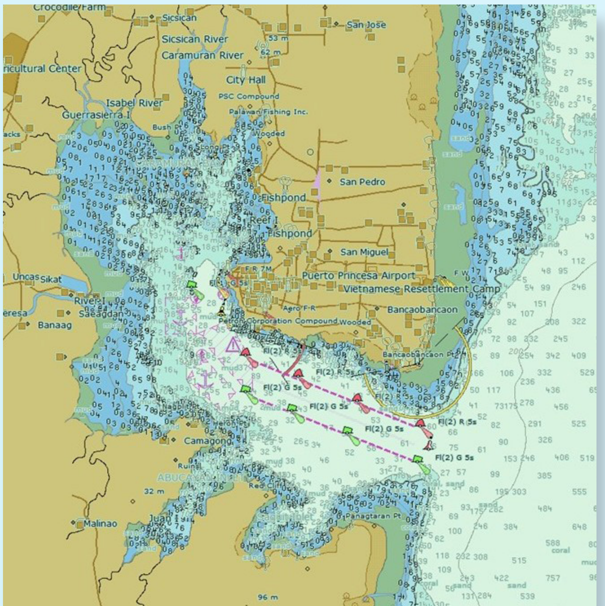


Figure 35. ENC of Puerto Princesa Harbor

It is important to ensure that nautical charts are correct and thoroughly checked before publication as these will serve as legal documents to the mariners. Draft charts are printed and verified for inconsistencies and erroneous data until deemed appropriate for publication *(Figure 36)*. Upon finalization, some charts are printed for mass production while some are printed on demand.●

Figure 36. Chart verification

Thematic Mapping 101

by Benjamin P. Balais[1], Federico D. Macaraeg[2], Raul T. Magabo[3], Sylvia L. Esperanza[4], Margie T. Parinas[5], and Angelito P. Cinco[6]

Thematic mapping is the process of making a map that focuses on a particular theme, topic or area of interest. The result of this process is a **thematic map**. Most often, a thematic map illustrates the spatial distribution and relationship of one or more features which can be used as a basis for planning, decision making, and analysis, among others.

In making a thematic map, a **basemap** is used to enhance the understanding of the users on the former's theme and purpose. Features like coastlines, roads, rivers, political boundaries, and city locations are some of the essential information from the basemap that are usually used in a thematic map. Information from the basemap are combined with the thematic information to provide geographical and visual contexts to the users *(Figure 1)*. Different mapping tools like the geographic information system (GIS) are helpful in performing this process.

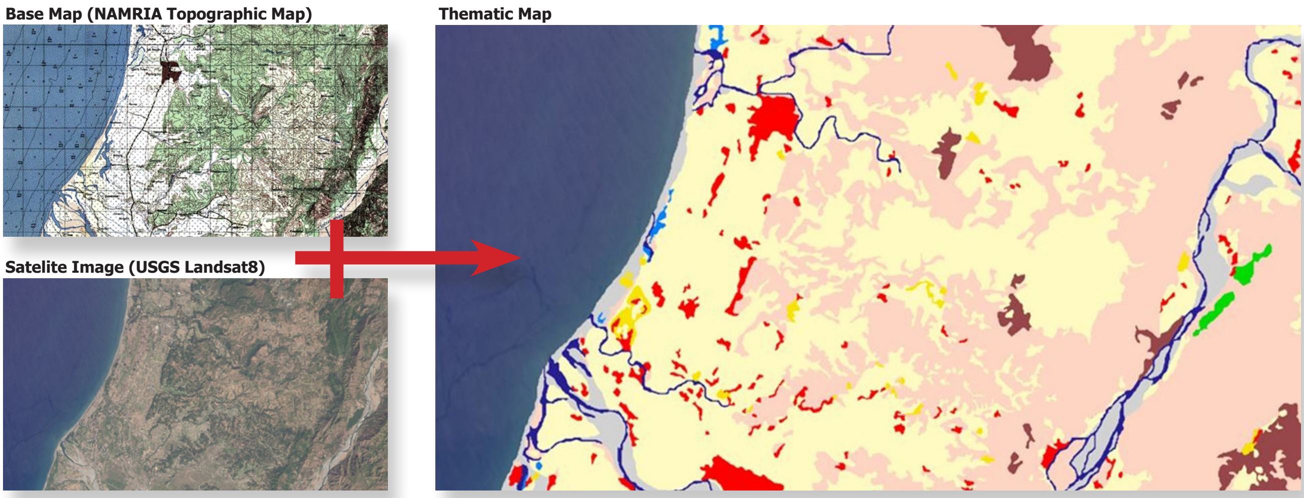


Figure 1. Overlaying information on a basemap

NAMRIA's topographic maps and nautical charts are examples of basemaps that can be used in generating various thematic maps.

There are various ways to illustrate the theme of the map like altering colors to represent different classes, changing the shapes and sizes of features or using different patterns to distinguish one class from the other. However, the best way to represent the information to emphasize the map's theme would depend on the type

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of data to be used. These data can either be quantitative or qualitative. Although both types of data can be represented through polygons, lines, points or raster, their mapping approaches are not the same.

Thematic maps showing quantitative or numerical data can be portrayed using symbols of varying color shades, shapes or sizes based on their associated values. One typical example of this is the population density map which can be displayed using one color, e.g., red, but presented in light to dark sequential shades to depict low to high population density range values *(Figure 2)*.

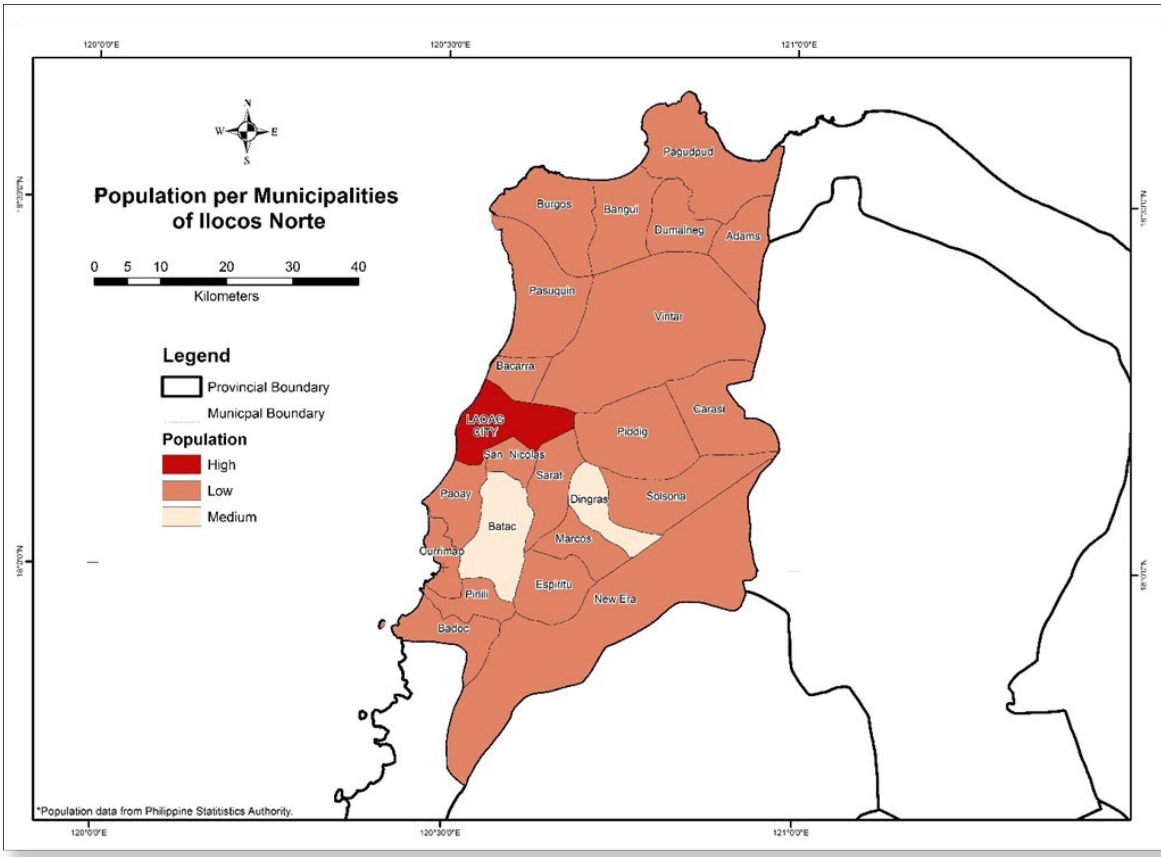

Figure 2. Sample of thematic map showing quantitative data

On the other hand, thematic maps that show qualitative data are based on descriptions of particular features. Qualitative data are usually represented on a thematic map by filling the area with varying color shades or textures. In the case of point data, categorical differences among classes can be symbolized by changing the shape of points. Examples include maps showing varying land uses, vegetation types, geological data, soil types, and point locations of different ethnic groups in a region.

In NAMRIA, the most common thematic maps produced are **land classification map, land cover map**, and **coastal resource map**. These maps are produced based on agency standards.

The **land classification (LC) map** is widely used as a reference for land titling application, proposed legislation, policy formulation, and planning. The map depicts two land classification categories, namely, forestland; and alienable and disposable (A&D)/agricultural land. These categories are based on the four land classifications of the public domain as specified in the Philippine Constitution of 1987, under Article 12, Section 3. These are agricultural, forest or timber, mineral lands, and national parks.

LC maps are produced using original data collected through field surveys. The process of land classification determines which portions of the public domain are needed for forest purposes and which portions are to be released as agricultural land for disposition under the Public Land Act. The process to produce an LC map entails preliminary data preparation, field survey, data presentation, and final mapping.

In preliminary data preparation, the locations of unclassified public forests are first identified through compilation of existing LC maps. Topographic maps, high-resolution satellite images, and aerial photos are used to determine the topography, slope, land cover, existing road networks, and rivers. Data on soil, faults, and geohazards also serve as additional inputs to determine the best suitable use/classification of the land.

Based on the recommended land use/classification categories, a basemap is prepared to show the pre-determined boundary lines between forestland and agricultural land on the standard scale of 1:20,000. Pre-determined coordinates are also generated to serve as guides in the actual conduct of evaluation/assessment and delineation survey of the boundary between the proposed forestland and agricultural land.

Prior to the actual field survey, coordination with the Department of Environment and Natural Resources (DENR) field offices, local government units (LGUs), and other government offices concerned is conducted by the NAMRIA Land Classification Teams. It is done so as to notify and consult these stakeholders about the socio-economic acceptability of the proposed land classification within their jurisdiction.

The coordinates of the pre-determined corners are verified and marked with concrete monuments (15cm x 15cm x 60cm) on the ground using Global Navigation Satellite System (GNSS) survey grade instrument. GNSS is also commonly known as **Global Positioning System** (GPS). During the field survey, the pre-determined coordinates are adjusted based on the actual situation on the ground with due consideration to slope, accessibility, land cover, soil, drainage network, and others. Simultaneously, the lists of actual occupants within the proposed agricultural land and forestland are gathered to serve as bases for the assessment of the proposed land classification.

After the field survey, the project report and preliminary LC map are prepared. The outputs are then presented to the DENR Land Classification Technical Working Group (TWG). The TWG is composed of technical representatives from the different DENR bureaus as specified under DENR Administrative Order (DAO) No. 1995-0015: *Revised General Guidelines in the Implementation of the Sub-classification of Forestlands and Other Inalienable Lands of the Public Domain*.

The TWG is tasked to review and evaluate the project reports and accompanying maps in accordance with the implementing guidelines stipulated in the said DAO. During the deliberation, the proposed project report and preliminary LC map are scrutinized. The inputs from the member bureaus are considered and integrated to ensure that no problems will arise upon the approval of the final map. The TWG will then endorse the LC map, including the project reports and results of deliberation, to the National Technical Evaluation Committee (NTEC).

The NTEC is chaired and co-chaired, respectively, by the DENR Undersecretary for Policy, Planning and International Affairs, and the NAMRIA Administrator. Its other members are the DENR Undersecretary for Field Operations and Bureau Directors. The committee convenes to evaluate all deliberated LC maps and project reports and endorses the same to the Office of the DENR Secretary for approval. All NTEC members affix their signatures on the original copy of the final LC maps. The DENR Secretary then issues the corresponding DAO for the approved LC maps. These maps will now serve as the official reference in the management of forests and disposition of public lands for agricultural purposes.

NAMRIA serves as the official repository of all approved LC maps. Based on record, the first and oldest LC map or the LC-1 covering Labo, Camarines Norte was certified on 22 June 1920 *(Figure 3)*. Since GIS technology was not yet introduced at that time, most of the maps were manually produced by cartographers using technical pens and tracing cloths. In some LC maps, forestlands were symbolized as hatched polygons while A&D lands as hollow polygons *(Figure 4)*. Various line symbols were also used to indicate features like roads, creeks, and rivers.

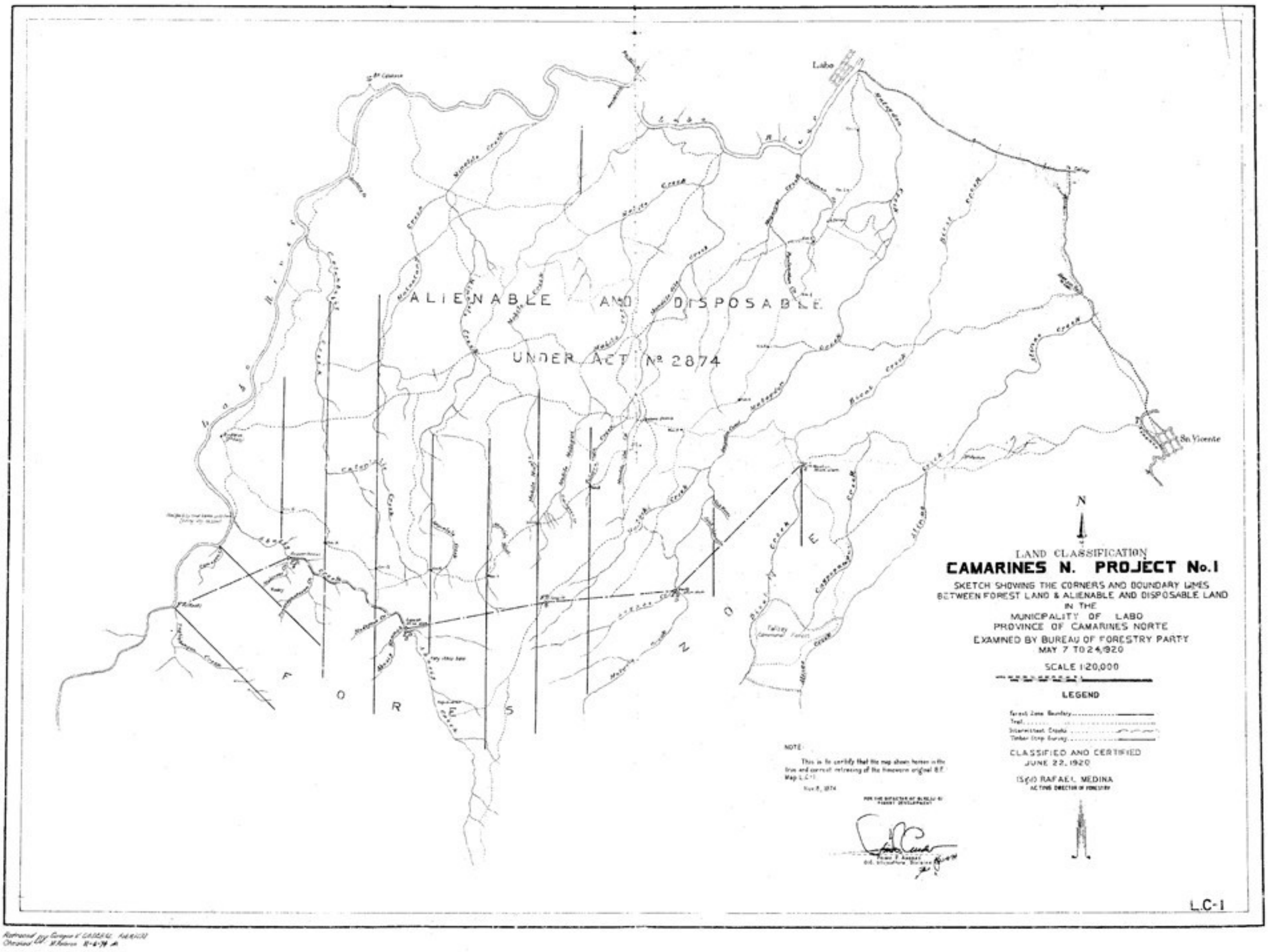

Figure 3. LC-1 map

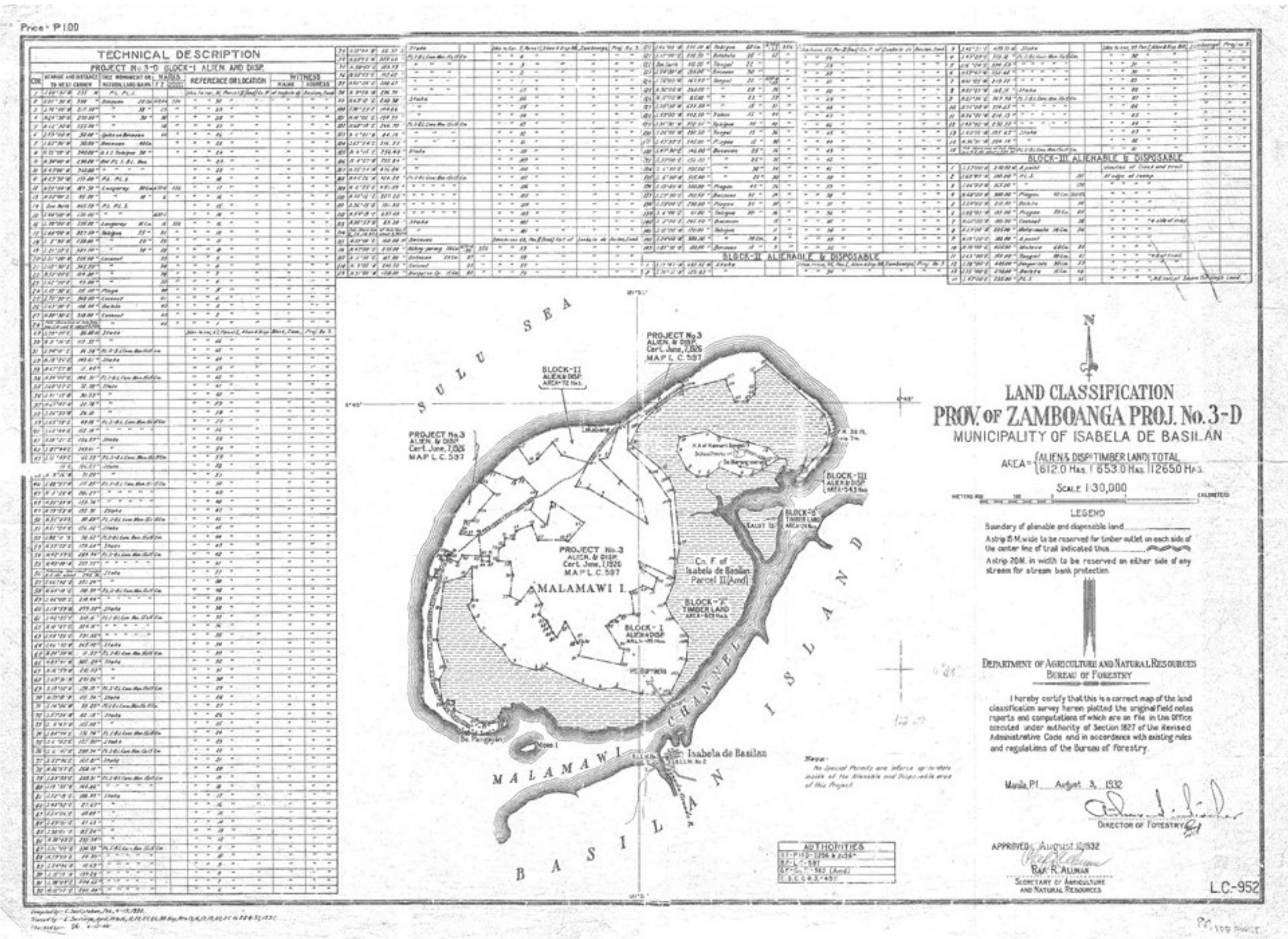

Figure 4. Land classification map showing forestland (timberland) in hachure polygon, and A&D land in hollow polygons

The **land cover map** shows the extent of the country's finite land resources *(Figure 5)*. It displays the surface cover over land including vegetation, rock, and human-modified surfaces such as buildings. Classification categories of the land cover map such as open/closed forests, shrubs, grassland, and built-up areas, among others, are based on *DENR Memorandum Circular 2005-005: Adopting Forestry Definition Concerning Forest Cover/Land Use, and the Food and Agriculture Organization standards of the United Nations*.

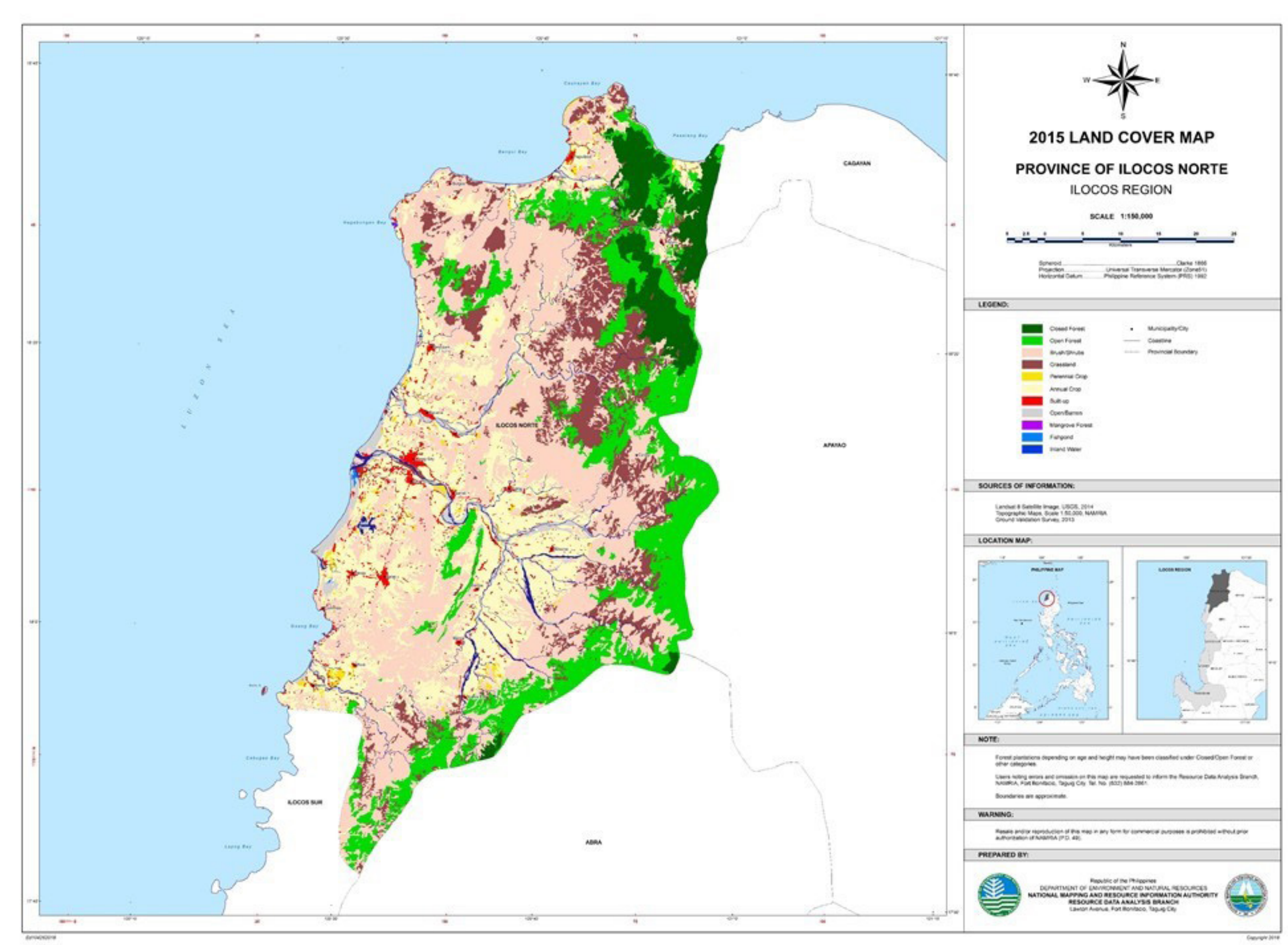

Figure 5. Land cover map

The information on various land cover types are derived from the interpretation of satellite images either through visual, digital or a combination of both methods with the use of remote sensing techniques and GIS. Satellite images are composed of different spectral bands which are capable of discriminating various land cover types like soil, vegetation, and water, among others. The basic principle behind this is based on the measurements of radiation from the different regions of the electromagnetic (EM) spectrum through remote sensing techniques. Each spectral band of the satellite image represents a specific range of wavelengths in the EM spectrum. When EM radiation interacts with various Earth surfaces, the different surface materials such as barren land, water or vegetation would give reflections corresponding to specific ranges of wavelengths. The radiation reflected from each surface material is called the **spectral signature** of the material and these are recorded in the satellite image as digital numbers. Knowledge of these spectral signatures at different spectral bands is therefore essential in image classification in order to discriminate each land cover type.

To be able to produce a land cover map, the different image spectral bands are combined together into a single multilayer image file through layer stacking. The layer-stacked image file undergoes segmentation and classification processes *(Figure 6)*. In image segmentation, each pixel of an image is determined to have the same set of attributes. Neighboring pixels with the same attributes are grouped together. Each group is called a **segment**.

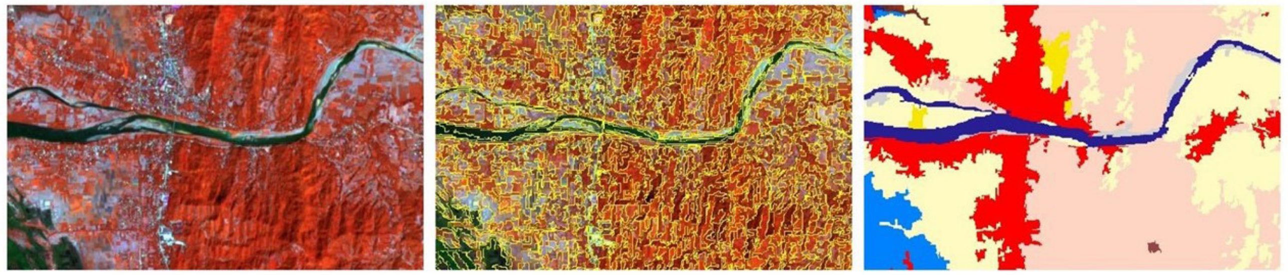

Figure 6. (left) False color image, (middle) segmented image, and (right) classified image

After segmentation, the image segments are classified based on pre-determined spectral signature threshold values. The spectral signature threshold values are computed using the mean, standard deviation, and other statistics. Using these values, the criteria describing the texture are generated. It is assumed that each segment has a homogenous feature or corresponds to a particular land cover type. Using the pre-determined spectral signature threshold values, the land cover type of each of the segments can now be classified. Thereafter, classified image objects are visually checked for quality control using other available imagery like Google Earth images. All observed inconsistencies in classification are modified to ensure accuracy of output.

To verify the accuracy of the classified image, field survey activities are conducted. Stratified random sampling points based on Congalton & Green (2009) are generated per land cover type. These points are checked on the ground with the use of handheld GPS units to verify the actual location. Digital cameras are also used for documentation. Validation points that were not ground validated are visually interpreted in the office using available very high-resolution (VHR) imagery. Actual classifications of validation points are then compared with the classified image. From this, a confusion matrix is generated to measure the accuracy of the classified image. The matrix simply shows a comparison between the actual classification on the ground and VHR validated sampling points and the classified image.

To incorporate local knowledge, the processed classified image is presented to the Regional DENR, Provincial Environment and Natural Resources Offices (PENROs), Community Environment and Natural Resources Offices (CENROs), LGUs, non-government offices (NGOs), state universities and colleges (SUCs), and other local stakeholders for their review. All comments during the presentation are considered to improve the classified land cover data. Image classification modification is applied after the comments from stakeholders have been verified by NAMRIA's technical personnel.

Final mapping is undertaken once all the necessary modifications have been incorporated. The different classification categories are displayed on the map using varying color shades to visually distinguish each land cover type. Depending on the required scale of the map, features from the basemap like boundaries of provinces, point locations of municipalities/cities, rivers, and road networks can be overlaid to the final land cover map.

A land cover map is usually printed to cover one entire province. The print copies of the map including digital files are distributed to all local DENR offices, LGUs, and other stakeholders. The data is also published in **Geoportal Philippines** (www.geoportal.gov.ph) which can be accessed by the public users.

Like the land cover map, the **coastal resource map** (CRM) is also generated from classified satellite imagery, except that the features of interest are coastal resources like mangrove forests, seagrasses, and the coral reefs *(Figure 7)*. The same procedures for land cover mapping are employed for producing the CRM. Image layer-stacking, segmentation, and

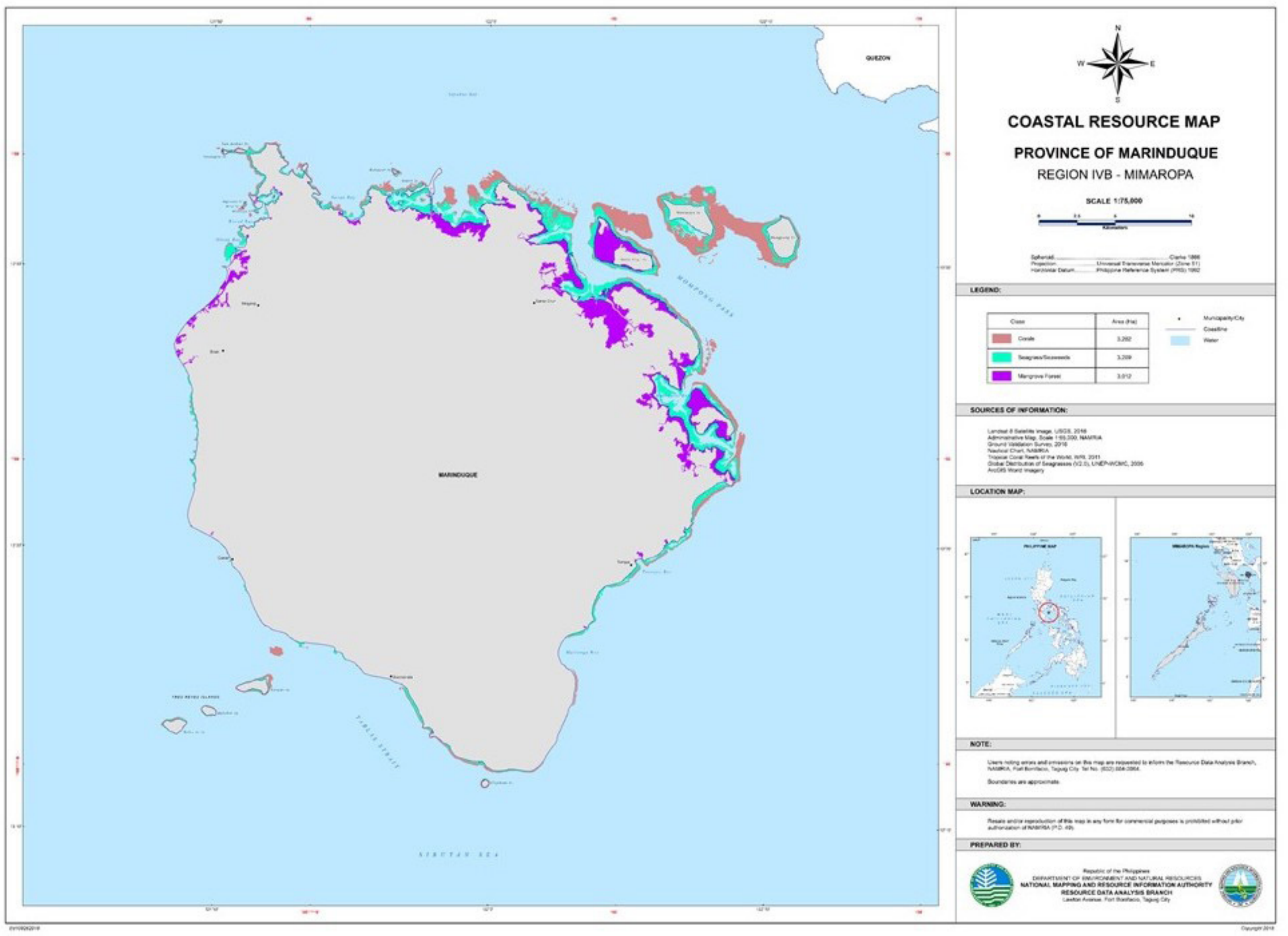

Figure 7. Coastal resource map

classification processes are done to generate the preliminary CRM. Sampling points are randomly selected per class to validate the accuracy of the preliminary map. Field survey is conducted to validate the actual coastal resource class of the sampling points using handheld GPS and underwater camera with location tracker. Mangrove forests and seagrass beds are validated expediently due to their accessibility along the shore, especially during low tide. This is in contrast to the validation of coral reefs which requires diving in shallow and deep waters with the use of snorkels and Self-Contained Underwater Breathing Apparatus (SCUBA) diving gears. Sampling points that are not ground validated are also subjected to image validation in the office. Thereafter, a confusion matrix is produced based on the results of the comparison between the actual classification of sampling points and the classified image.

The preliminary CRM is presented to relevant stakeholders for their evaluation and comments. All inputs are incorporated in the final map, as applicable.

The final CRM is also produced as provincial maps and distributed to various stakeholders for their reference. The public can also access the maps through **Geoportal Philippines** (www.geoportal.gov.ph). ●

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