# Chapter 2

# Data and Method

## 2.1 Jakarta Bay Characteristics

Jakarta Bay extends from Tanjung Kait in the west to Tanjung Karawang in the East. It covers about 514 $km^2$ that bordered by 3 provinces; they are Banten in the west, Special Capital Region of Jakarta (DKI Jakarta) in the south, and West Java in the east with the approximate length 89 km. The northern area of Jakarta Bay is directly faced the Java Sea with Seribu Islands in the north-west side. Jakarta Bay is a rather shallow bay with the average depth is about 15 m. the furthest distance from the eastern part to the western part of this bay is 40 km (Department of Communication DKI Jakarta).

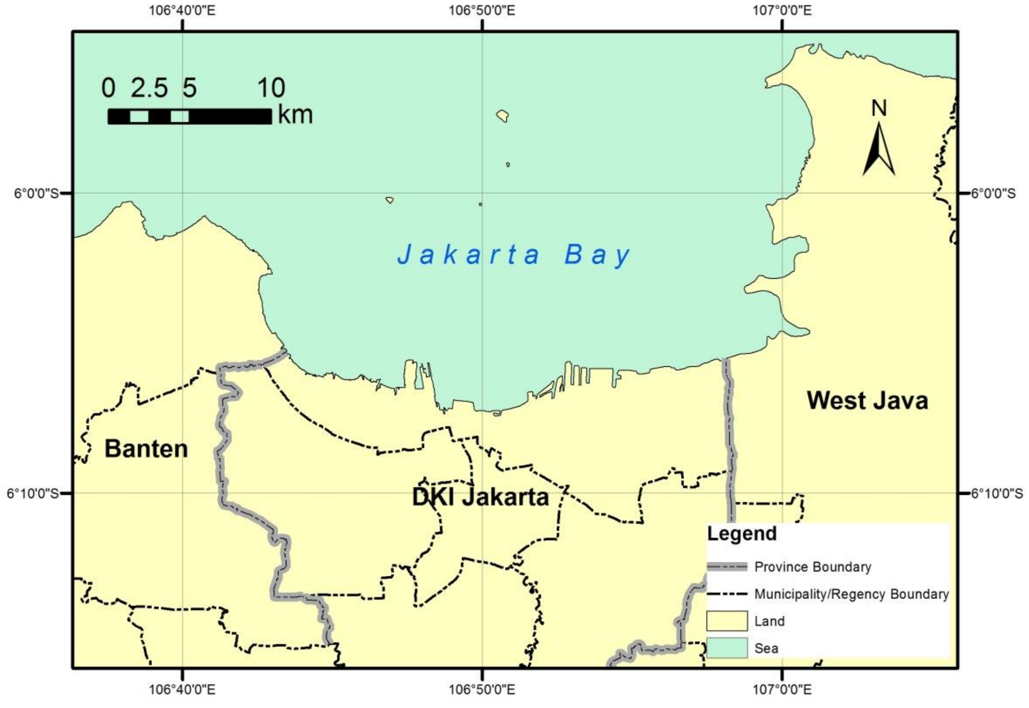


**Figure 2.1** Jakarta Bay and surrounding area

Jakarta Bay becomes a very complex area because its surrounding land is a metropolitan area called Jabodetabek (Jakarta-Bogor-Depok-Tangerang-Bekasi). This metropolitan area is a busy area since it becomes the centre of many activities both governmental and non-governmental in Republic of Indonesia. Besides that, Jakarta Bay also has an important role in international shipping and trade with Tanjung Priok port as the centre.

### 2.1.1 Geographical and morphological characteristics

There are 13 rivers that flow towards Jakarta Bay bringing waste and sediments. Among those 13 rivers, there are 3 big rivers; Cisadane River in the western part, Ciliwung River in the middle part, and Citarum River in the eastern part. They all bring waste and sediments from 3 provinces where they flow through and then settled in Jakarta Bay. This sedimentation affects the morphology of Jakarta Bay.

Coastal morphology of Jakarta Bay varies from slight to steep. Ongkosongo (1986) divided the coastal morphology of Jakarta Bay into 3 types of coast based on the slope angle, slight coast (0°-5°), slope coast (5°-15°), and steep coast (15°-90°). The conditions of the coasts can be determined based on the slope. The slight coast is usually the coastal area where the mangrove swamps grow and thus, it experiences less erosion. It can be found in Kamal and Angke. The slope coast can be found in sandy coast with high energy of wave, such as along Marunda to Segara Makmur coast. The steep coast usually happens in eroded coast that composed by clay. It can be found along Cilincing to Marunda coast (BPLHD DKI Jakarta, 2014).

### 2.1.2 Oceanographical and meteorological characteristics

#### *2.1.2.1 Wind*

As the part of Java Sea, Jakarta Bay has similar characteristics of meteorology and oceanography to Java Sea. Monsoon is seasonal wind corresponded to the change of precipitation. It causes the dry and wet season in tropical area. Monsoons always blow from colder to warmer area. They are most often associated with Indian Ocean.
Monsoon that moves over Jakarta Bay is following the wind pattern over Java Sea. The monsoon moves from west and north-west to the east during West Monsoon

(December-January-February). In this period, Indonesia will experience rainy season. Otherwise, during East Monsoon (June-July-August), wind move from east and south-east to the west. While, during transitional monsoon in March-May and September-November, wind have random pattern with less power than West and East Monsoon (Putri, 2005).

#### *2.1.2.2 Flow*

Ocean flow is movement of water mass in water column. It is generated by some forces, such as wind, temperature and salinity gradient. Flow modelling of Jakarta Bay done by Putri (2015) shows that during West Monsoon (December-February), the highest flow speed can reach 0.143 m/s. While, the highest flow speed during the East Monsoon can reach 0.142 m/s.

#### *2.1.2.3 Tides*

Tide is vertical movement of sea water due to the gravity forces of earth-moon system and earth-sun system. Type of tide in Jakarta Bay is mixed tide prevailing diurnal. Mixed tide prevailing diurnal is a tidal type that in one day, this location experiences one high and one low tide, but sometimes also experiences two high tides and two low tides in one day with very different height and period (BPLHD DKI Jakarta, 2014). Tidal height modelling of Jakarta Bay done by Putri (2015) shows that highest tide in Jakarta bay can reach 0.516 m above MSL and the lowest tide can reach 0.435 m below MSL.

#### *2.1.2.4 Wave*

Ocean wave is the movement of ocean water that is created by energy or disturbance that passing over water surface. Wave has some parameters, such as wavelength, period, amplitude, speed, and wave height. There are several energy sources that can generate ocean wave, but wind is the most dominant energy or disturbance generating ocean wave. The wave parameters in wind wave depend on wind speed, duration, fetch, and initial condition of the ocean. Wind wave modelling of Jakarta Bay done by Sya'bana (2015) shows that during West Monsoon, the maximum significant wave height is 0.578 m, while during East Monsoon, the maximum significant wave height is 0.278 m. Significant wave height is the average height of one third of highest waves.

### 2.1.3 Biodiversity characteristics

Biodiversity in Jakarta Bay consists of coral reefs, seagrass, beds mangrove forests, and some animals. Some of them were threaten or even damaged that caused by human activities in both land and sea. The damage of coral reefs is caused by physical and biological factor. Erosion and reef exploitation are the biggest problem for the life of coral reefs. In Bidadari Island and Onrus Island, where coral reefs had been damaged, seagrass beds grow densely. Each of them has density of 67% and 49% with only 3 and 2 species respectively (Estradivari *et. al.*, 2007).

Mangrove forests in Jakarta Bay mostly lived along the coast in Muara Gembong, the eastern part of Jakarta Bay and along Jakarta coast in the southern part. The remaining mangrove forests in Jakarta coastal area lived under conservation in Muara Angke and Kapuk. According to Kusmana (2002), during 42 years, mangrove area in Jakarta coast decreased about 80%. This high level of deforestation is mainly caused by land use conversion into settlement area, aquaculture, and tourism facility.

## 2.2 Mangrove

The term of mangrove refers to a single plant, whereas mangrove swamp, mangrove forest, or mangal refer to a community of this plant. Mangrove is an intertidal organism that lived in coastal area or in the river mouth of earth tropical and subtropical regions. It covered about 60 to 75% of coastline in these regions (Nybakken & Bertness, 2005). They play a role as barriers of coastal area from little wave action.

### 2.2.1 Structure and adaptations

Mangroves are flowering land plants that adapted to live in intertidal area. According to Laili & Parsons (1993), mangrove forests are composed by trees and shrubs that belong to 12 genera and approximately 60 species. The dominant genera are *Rhizopora*, *Avicennia*, *Bruguiera,* and *Sonneratia*. Mangroves have special characteristics compared to other plants. They have shallow roots that allow them to live in shallow marine water. The roots spread widely over the mud. They also have aerial roots that sent up by the shallow roots to the surface of water. The aerial roots allow them to receive oxygen when the mud where they grow is anoxic. Some of the species have peculiar prop roots that extending down from the trunks or branches of plant to give extra support. Since mangroves live in marine water, they are salt-tolerant plants. They have some unique mechanisms to solve osmotic problem of living in saline soils. Some of them have salt glands on the leaves to excrete the salt. Some also have special process, called reverse osmosis, by separating salt water and fresh water at the roots.

According to Rabinowitz (1978), mangroves have two reproductive strategies; vivipary and dispersal by water. During the vivipary stage, the seed, while still on the parent plant, germinates and grows into seedling. After the seedling becomes heavier, it drops from the parent plant into water. Then, it floats in the water and carried by water current until entering shallow water area. When the seedling contacts the bottom, it will produce roots that attached to the bottom and soon will grow into a tree. **Figure 2.2** shows illustration of mangrove's reproduction stages.

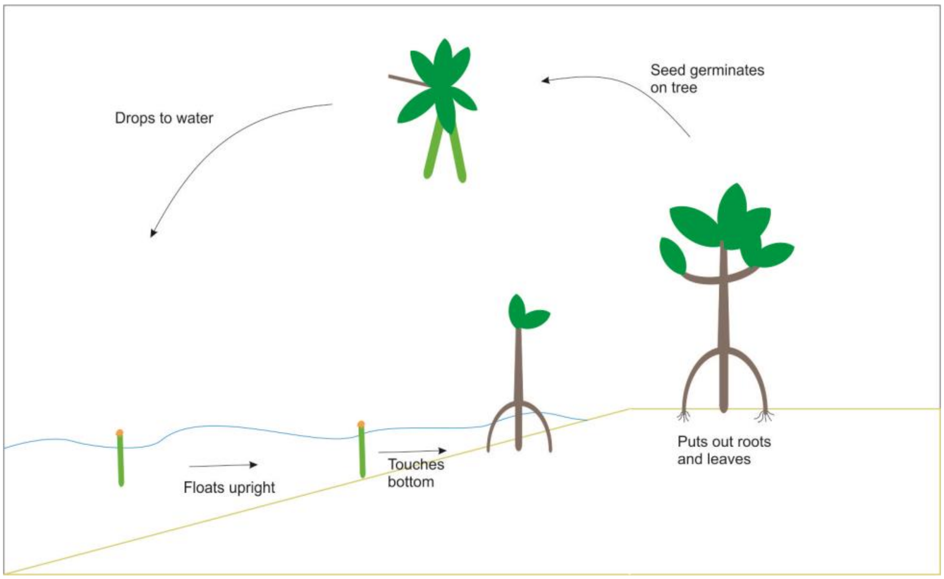


**Figure 2.2** Life cycle of typical mangrove tree
(Modified from Nybakken & Bertness (2005))

### 2.2.2 Physical conditions

Mangroves are intertidal organisms. Intertidal zone is coastal area that lies within high tide and low tide. Intertidal zone is strongly influenced by tidal action. It also has little wave action. Mangroves can only live on shores that are protected from wave action because they need to reproduce by the water carrying seeds into shallow area before attached to the bottom. Significant wave actions will cause the seeds fail to ground and attach their roots to the ground. Thus, the first characteristic of mangrove habitat is coastal area that has minimal water motion.

Mangroves also have a role to lower wave action. As stated before, mangroves have peculiar prop roots that grow downward from the trunks or branches. A community of mangrove trees usually creates a very dense roots system. This dense roots system can be a break-water for the wave action coming from the offshore area. It can decrease the water movement.

The second characteristic of mangrove habitat is salinity. Mangroves can grow in freshwater area, but they do not develop well. Kuenzler (1974) speculates that they are not competitive in freshwater area. High salinity is a weapon for them to reduce competitors from freshwater and terrestrial plants.

The next characteristic of mangrove habitat is tide. Mangroves grow in shallow water and intertidal areas and are thus they are influenced by tides. High fluctuation of tides will create a larger intertidal area. The larger the area will make mangrove community develops better and bigger. This may be responsible to determine what kind of mangrove can live in the area and the types of mangrove zonation.

### 2.2.3 Importances

Mangrove trees have varies advantages from their roots to the leaves for humans, other animals, and the surrounding environment. As they live in a community of their species, they form a barrier along the coastline. They play role as a wave, hurricane, or even tsunami breaker that reduce the coast from properties damage and erosion. Beside their important role as coast barrier, mangrove forests also have other ecological and economical values. FAO (2007) classified the uses of wood and non-wood of mangroves into 10 categories as shown in **Table 2.1**.

**Table 2.1** Mangrove uses – wood and non-wood forest products (FAO, 2007)

| **Category** | **Uses** |
|---|---|
| Fuel | Fuelwood, charcoal. |
| Construction | Timber, scaffolding, heavy construction, railway sleepers, mining props, boat-building, dock pilings, beams and poles, flooring, panelling, thatch or matting, fence posts, chipboard. |
| Fishing | Fishing stakes, fishing boats, wood for smoking fish, tannin for nets/lines, fish-attracting shelters. |
| Textile, leather | Synthetic fibres (rayon), dye for cloth, tannin for leather preservation. |
| Other natural products | Fish, crustaceans, honey, wax, birds, mammals, reptiles, other fauna. |
| Food, drugs, and beverages | Sugar, alcohol, cooking oil, vinegar, tea substitute, fermented drinks, dessert topping, condiments (bark), sweetmeats (propagules), vegetables (fruit/leaves). |
| Agriculture | Fodder. |
| Household items | Glue, hairdressing oil, tool handles, rice mortar, toys, match sticks, incense. |
| Other forest products | Packing boxes, wood for smoking sheet rubber, medicines. |
| Paper products | Paper – various. |

The trees have been traditionally used as firewood and charcoal since a long time ago. Their water resistant timber also can be used as the primary material to construct boats and houses. Their leaves are used for roof thatching and used as fodder for cattle, cows, camels, and goats. The leaves even can be used as cigarette wrapper for young, unfolded and leaf sheaths for certain species. As well as their economical values, mangroves can also be a protective nursery for some species of animals.

Their roots systems are good places for fishes, shrimps, lobsters, and even crabs to live. Their leaves canopy is also utilized as nesting site for some tropical bird.

#### 2.2.4 Threats

Coastal area in many places becomes very dynamic as the human activities take place there. Dredging, land reclamation, and settlement construction near-shore, for example, give significant impacts for mangroves habitat. These activities change the characteristics of mangrove habitat, such as the sedimentation, flows, and tides. Thus, they indirectly change the intertidal zone where mangroves live. Overcutting of mangroves happened for centuries make the population decrease by time, although some countries developed replantation programs. This happened because the overcutting and eliminating activities of mangroves occurred faster than the afforestation. In many countries, the destruction of mangrove forests has done to open a new area for aquaculture and agriculture.

Besides the impact of human activities, in fact, typhoons and hurricanes may be the greatest agents of mangrove forests destruction. When they occurred frequently in large area, not only damage the uproot mangrove trees, but they also affect the salinity of water and soil. The typhoons and hurricanes also cause massive sedimentation. Thus, policies are needed to prevent mangroves from extinction and to protect the coastal area.

## 2.3 Landsat

Landsat is a remote sensing satellite that provides the moderate resolution of earth surface imagery. It is developed by the collaboration of National Aeronautics and Space Administration (NASA) and U.S Geological Survey (USGS). Landsat Program had provided this service for about 42 years. Landsat 1 was first launched in 23$^{rd}$ July 1972 with original name ERTS-A (Earth Resources Technology Satellite) before renamed to Landsat 1. Since the first launching, Landsat has already launched 8 satellites with certain interval of time. The most recent launched satellite is Landsat 8, which launched in February 2013 with the latest technology embedded inside (USGS, 2015).

### 2.3.1 Landsat 7 ETM+

Landsat 7 satellite was launched on April 15, 1999 from the Western Test Range of Vandenberg Air Force Base in California. It was lifted to the orbit by Delta-II expendable launch vehicle. Landsat 7 orbits on altitude of 705 kilometres. It has 233 orbit cycles that cover the entire globe every 16 days, except for the high polar latitude area.

Landsat 7 used Enhanced Thematic Mapper Plus (ETM+) sensor that has 8 spectral bands, including the panchromatic band and thermal band. The spatial resolution of Landsat 7 is 30 meter, with 15 meter resolution of panchromatic image and 60 meter resolution of thermal image. Landsat 7 is accurately calibrated earth observing satellite that has the most stable sensor instrument. Landsat 7 worked perfectly until May 2003 when there was a failure in the instrument that made some missing data in Landsat 7 images.

**Table 2.2** Band description of Landsat 7 ETM+
(http://landsat.usgs.gov/band_designations_landsat_satellites.php)

| Band | Wavelength (micrometers) | Resolution (meters) |
|---|---:|---:|
| Band 1 | 0.45-0.52 | 30 |
| Band 2 | 0.52-0.60 | 30 |
| Band 3 | 0.63-0.69 | 30 |
| Band 4 | 0.77-0.90 | 30 |
| Band 5 | 1.55-1.75 | 30 |
| Band 6 | 10.40-12.50 | 60 (30 after February 25, 2010) |
| Band 7 | 2.09-2.35 | 30 |
| Band 8 | 0.52-0.90 | 15 |

### 2.3.2 Landsat 8 OLI/TIRS

Landsat 8 has some improvements from the previous generation, Landsat 7. It has 2 sensors, Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS). OLI sensor has 9 spectral bands, including a panchromatic band and 2 new bands for detecting cirrus cloud and observing coastal zone. TIRS sensor has 2 spectral bands with 100 m spatial resolution, while Landsat 7 has 60 m spatial resolution for thermal bands. Spatial resolution of Landsat 8 is still the same as Landsat 7, 30 m with 15 m panchromatic resolution (USGS, 2014).

**Table 2.3** Band description of Landsat 8 OLI/TIRS (http://landsat.usgs.gov/band_designations_landsat_satellites.php)

| Band | Wavelength (micrometers) | Resolution (meters) |
|---|---:|---:|
| Band 1 – Coastal Aerosol | 0.43-0.45 | 30 |
| Band 2 – Blue | 0.45-0.51 | 30 |
| Band 3 – Green | 0.53-0.59 | 30 |
| Band 4 – Red | 0.64-0.67 | 30 |
| Band 5 – NIR | 0.85-0.88 | 30 |
| Band 6 – SWIR 1 | 1.57-1.65 | 30 |
| Band 7 – SWIR 2 | 2.11-2.29 | 30 |
| Band 8 – Panchromatic | 0.50-0.68 | 15 |
| Band 9 – Cirrus | 1.36-1.38 | 30 |
| Band 10 – TIRS 1 | 10.60-11.19 | 100 |
| Band 11 – TIRS 2 | 11.50-12.51 | 100 |

### 2.3.3 Landsat levels of processing

Landsat images that are available for free in USGS website have several levels of processing. They are classified into 6 levels depend on the correction applied:

1. Level 0R data product (L0R) provided raw uncorrected data (no radiometric and no geometric correction). They were once available for ETM+ and TM, but since September and December 2008, L0R were no longer available for ETM+ and TM respectively.

2. Level 1R data product (LIR) provided radiometrically corrected L0R data, but geometric correction was not applied. L1R were also no longer available.

3. Level 1G data product (L1G) provides both radiometric and geometric correction to the data. The geometric accuracy parameters are derived from data collected by sensors and spacecraft. The scene will be rotated, aligned, and georeferenced to a user-specified map projection.

4. Level 1P data product (L1P) provides precise radiometric and geometric accuracy by using Ground Control Points (GCPs). Accuracy and precision of corrected product will depend on availability of local GCPs.

5. Level 1Gt data product (L1Gt) provides systematic radiometric and geometric accuracy and also uses Digital Elevation Model (DEM) for topographic accuracy. Topographic accuracy of the product depends on the resolution of DEM used.

6. Level 1T data product (L1T) provides systematic radiometric accuracy, geometric accuracy, by including GCPs and also employing DEM for topographic accuracy. Geodetic accuracy depends on GCPs and resolution of DEM used.

## 2.4 Data

This research need some data acquired to be processed. Data that used here can be seen in **Table 2.4**.

**Table 2.4** Research data (1)

| No | Data | Source | Information |
|---|---|---|---|
| 1. | Landsat 7 ETM+ images | U.S. Geological Survey website (http://earthexplorer.usgs.gov/) | An image per year downloaded of Jakarta Bay area in path 122 and row 64 from 2006 to 2012 with the acquisition date and level of processing:<br>- June 11, 2006 (L1T) |

**Table 2.4** Research data (2)

| No | Data | Source | Information |
|---|---|---|---|
| 1. | Landsat 7 ETM+ images | U.S. Geological Survey website (http://earthexplorer.usgs.gov/) | An image per year downloaded of Jakarta Bay area in path 122 and row 64 from 2006 to 2012 with the acquisition date and level of processing:<br>- August 17, 2007 (L1T)<br>- July 2, 2008 (L1T)<br>- July 21, 2009 (L1T)<br>- May 21, 2010 (L1T)<br>- August 28, 2011 (L1T)<br>- August 30, 2012 (L1T) |
| 2. | Landsat 8 OLI/TIRS images | U.S. Geological Survey website (http://earthexplorer.usgs.gov/) | An image per year downloaded of Jakarta Bay area in path 122 and row 64 from 2013 to 2015 with the acquisition date and level of processing:<br>- August 25, 2013 (L1T)<br>- August 28, 2014 (L1T)<br>- August 31, 2015 (L1T) |
| 3. | Coastal Slope Index Map of Tangerang | Centre of Marine and Coastal Resources Research and Development, Ministry of Marine Affairs and Fisheries | Printed in December 2009, with scale 1:50,000. |

**Table 2.4** Research data (3)

| No | Data | Source | Information |
|---|---|---|---|
| 4. | Coastal Slope Index Map of Jakarta | Centre of Marine and Coastal Resources Research and Development, Ministry of Marine Affairs and Fisheries | Printed in December 2009, with scale 1:40,000. |
| 5. | Coastal Slope Index Map of Bekasi | Centre of Marine and Coastal Resources Research and Development, Ministry of Marine Affairs and Fisheries | Printed in December 2009, with scale 1:35,000. |
| 6. | Tidal data | TPXO 7.2 Global Tides Model | Water levels from MSL during the acquisition time of images generated by the model. |

## 2.5 Mapping Method

In order to map mangrove distribution from satellite images, there are several steps to process the image. The process is divided into 3 main processes; they are image pre-processing, image processing, and accuracy assessment. Image pre-processing consists of some correction processes of image. Image processing step consists of some methods to classify and identify objects in image. Accuracy assessment consists of calculation of mapping accuracy based on reference data.

### 2.5.1 Image pre-processing

Image corrections that applied to these Landsat images are atmospheric correction (for all images) and SLC-off correction (for Landsat 7 ETM+ images). Radiometric and geometric corrections were not applied to the images because they have L1T level of processing that means they are already radiometrically and geometrically corrected. An image of Landsat 8 aqcuired in 2015 is being overlaid by RBI map and 14 Independent Check Points are placed on the image to check the geometric accuracy.

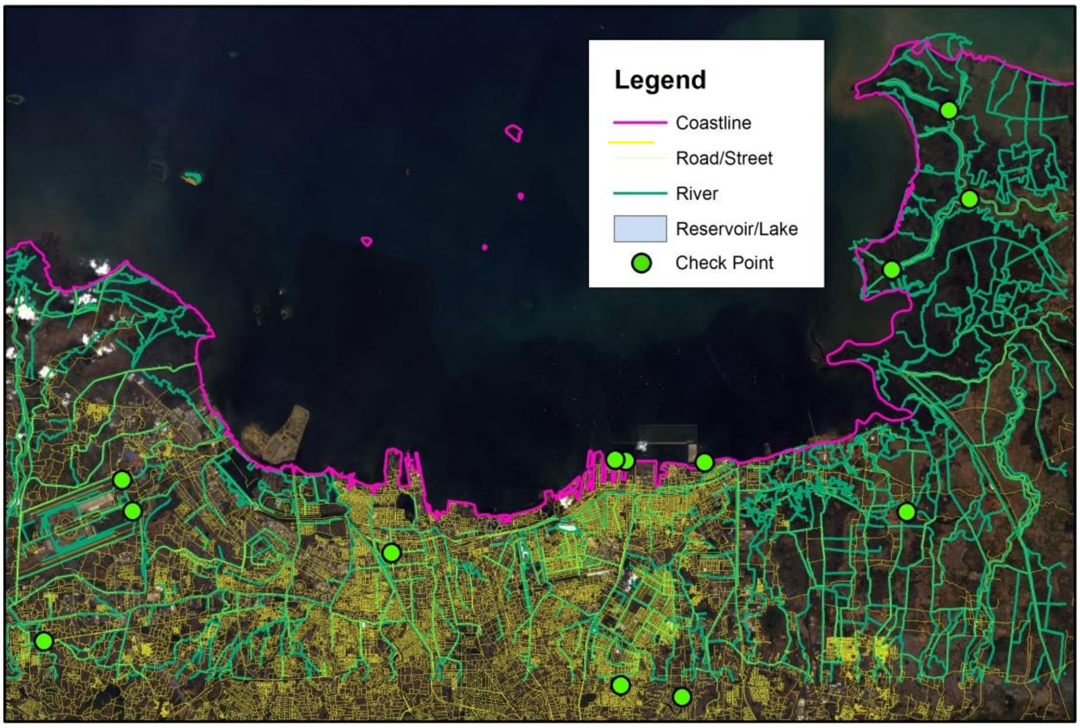


**Figure 2.3** Landsat 8 image (2015) overlaid by RBI map and ICP

Coordinate accuracy is calculated using Root Mean Square Error (RMSE) with formula:

$$RMSE = \sqrt{\frac{1}{N}\sum_{n}^{i=1}((x_i - \hat{x}_i)^2 + (y_i - \hat{y}_i)^2)} \quad (1)$$

where $x$ and $y$ is image coordinate and $\hat{x}$ and $\hat{y}$ is map coordinate. The value of RMSE resulted from the calculation of 14 ICPs shown in figure above is 25.46 meter. With 30 meter resolution of image, the RMSE value is less than the resolution. It means the geometric correction of image is well done. Then, the next steps of pre-processing are shown in **Figure 2.4**.

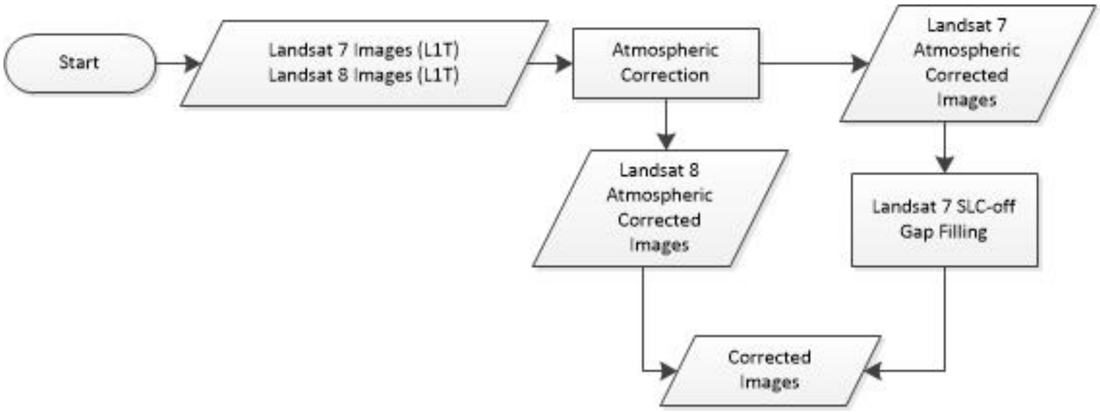


**Figure 2.4** Image pre-processing workflow

### *2.5.1.1 Atmospheric correction*

Atmospheric correction needs to be performed on satellite image because some atmospheric conditions give significant effects to the image. Atmospheric conditions are different depend on longitude and latitude and the acquisition time of image. They make the digital numbers or image values do not characterized the object because value recorded at a given pixel includes not only the reflected radiation from the surface, but also the radiation scattered and emitted by the atmosphere as well. Atmospheric correction changes the image values from radiance into reflectance or emissivity and temperature values.


**Figure 2.5** Visual Comparison of Original and Atmospheric Corrected Image

### *2.5.1.2 Landsat 7 ETM+ gap-filling*

Scan Line Corrector (SLC) is a component of Landsat 7 ETM+ sensor. On May 31, 2003, failure happened to SLC. It caused some data loss in the images. Since that time, the lost data looks like stripes laid over the left and right side of image. In order to get sufficient information from Landsat 7 ETM+ SLC-off, we have to do gap-filling to the areas which has no data. Fortunately, the stripes of SLC-error located in different places in each time the scene acquired.

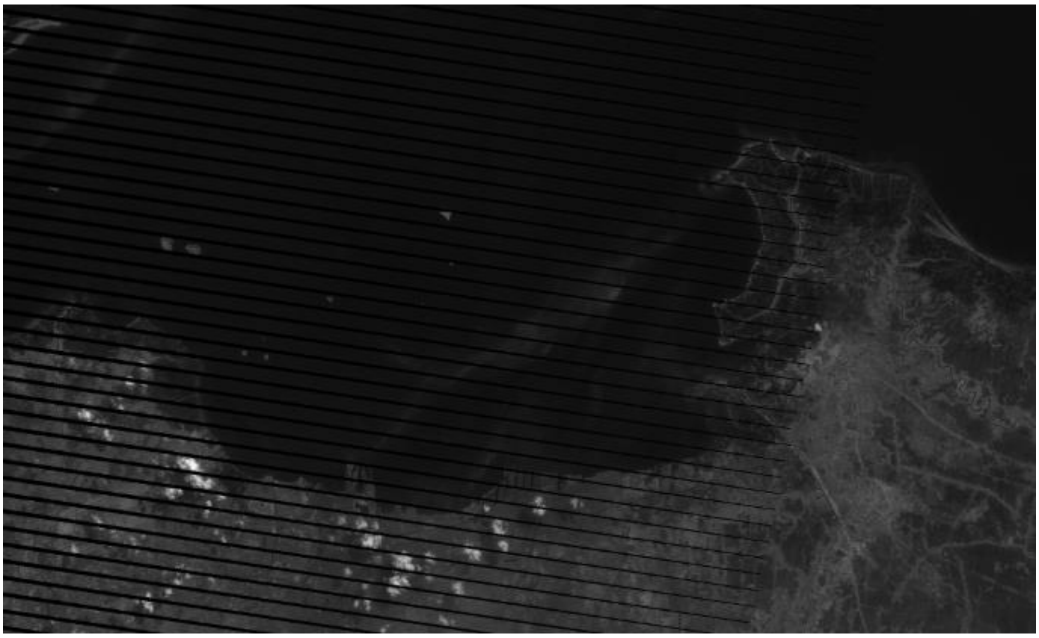

**Figure 2.6** Landsat 7 ETM+ SLC-off in Jakarta Bay

The principle of gap-filling is filling the lost data in an image with another image that has available data in stripes area of the first image or with other methods of filling. There are some tools available to do the gap-filling. Gap-filling tool used in this research is landsat_gapfill of ENVI software.

Landsat_gapfill tool offers 2 types of gap-filling; single file gap fill and two band gap fill. Single file gap fill uses only an image file with stripes. The gap filling process is done by resampling the value or digital number from the neighborhood pixels. In the other hand, two band gap fill needs another image which has complete data to cover the lost data in the first image.

Landsat 7 ETM+ images used in this research were acquired in 2006 to 2012 which there are no other images with the same or approximate acquisition time that are free from SLC-off. In this research, we need to make maps of the real situation in Jakarta

Bay in each year. This make the two band gap fill type cannot be used. Single file gap fill is the possible gap filling method to complete the information of images.

### 2.5.2 Image processing

After the images are corrected, they must be processed to give some primary information for this research. Because mangrove forests live in intertidal zone, the first information must be extracted is coastline. After the coastline has been defined, the living area of mangrove forest can be determined.

#### *2.5.2.1 Coastline delineation*

Actual coastline of the image is a boundary between land and sea when the image was acquired. One of many methods that can be used to delineate coastline on an image is false colour combination (composite band). Quinn (2001) stated that the combination involves no visual band, they are SWIR 1, SWIR 2 and NIR band, defined the coastlines well. This combination also provides best atmospheric penetration since infrared wave can penetrate haze.

In this combination, water appears as black colour as seen in the **Figure 2.7**. Vegetation appears as blue and built-up area appears as beige colour. This makes delineation of coastline is easier than using natural colour combination. Then, coastline was delineated using ArcGIS software.

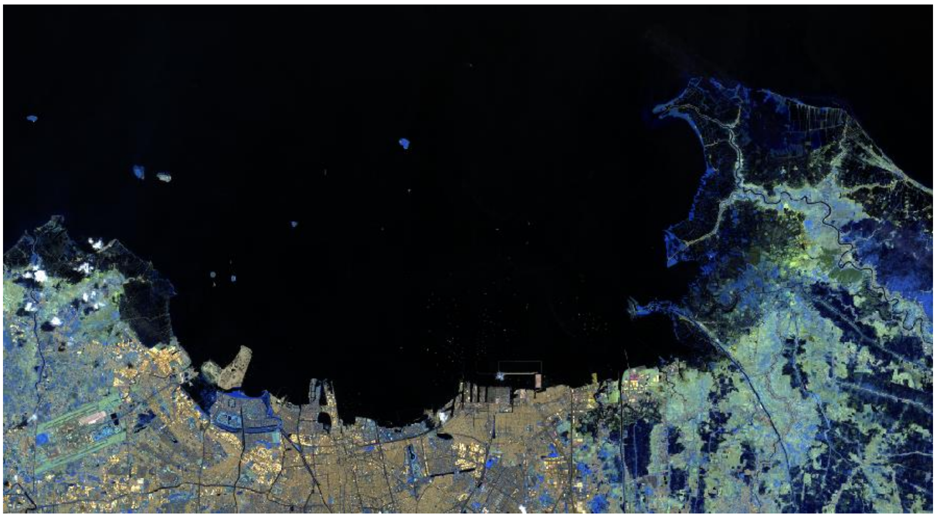

**Figure 2.7** Image of Jakarta Bay with SWIR 1-SWIR 2-NIR combination

### 2.5.2.2 *Intertidal zone determination*

Intertidal zone is area that lies between high tide and low tide. Determination of intertidal zone on the image can be done by knowing the actual water level, tidal range of the area, and the coastal slope. Actual water level can be predicted using TPXO 7.2 Global Tide Model by entering tidal constituents. Geofana (2012) found that there are 10 main tidal constituents for Jakarta Bay. Those tidal constituents are S2, K2, M2, N2, K1, P1, O1, Q1, MF, and M4.

Actual water level acquired from TPXO 7.2 Global Tide Model is referenced to Mean Sea Level (MSL). According to Geofana (2012), tidal range in Jakarta bay is 0.81 meter. Tidal range is height difference between highest water level and lowest water level. Calculation of intertidal zone illustrated in **Figure 2.8**.

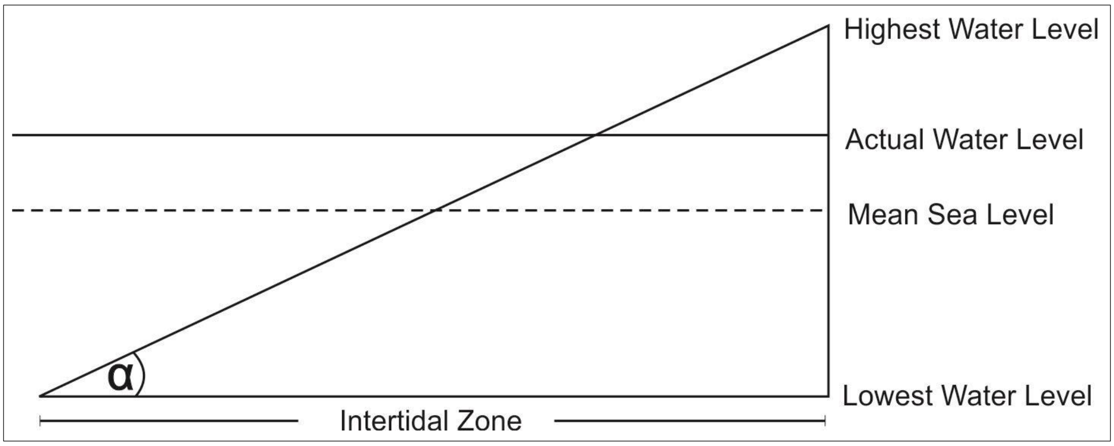


**Figure 2.8** Intertidal Zone Illustration

If $d$ is intertidal zone width, $\alpha$ is coastal slope, and $h$ is tidal range, the width of intertidal zone can be calculated using formula:

$$\tan \alpha = \frac{h}{d} \tag{2}$$

From that formula, width of intertidal zone from actual coastline varies from 37 meter to 303 meter towards the land. The steeper slope will have narrower the intertidal zone. Due to the unavailable data of coastal slope in Seribu Islands and new reclamation island, all the land part of these islands will be mapped.

#### 2.5.2.3 *Normalized Difference Vegetation Index (NDVI)*

NDVI is one of vegetation indexes that can detect vegetation in image well. NDVI is a ratio of Near Infrared (NIR) reflectance and red reflectance. The value of NDVI is from -1 to 1. Formula of NDVI is

$$NDVI = \frac{(\rho_{NIR} - \rho_{RED})}{(\rho_{NIR} + \rho_{RED})} \quad (3)$$

where $\rho_{NIR}$ is reflectance value in NIR band and $\rho_{RED}$ is reflectance value in red band. NDVI gives negative values for water, near zero values for bare soil, and high values for green vegetation.

By using NDVI, mangrove forests are easier to detect. They live in intertidal zone that has been determined before. Mangrove forests have high NDVI values as vegetation area. Satyanarayana *et. al.* (2011) found that NDVI value for young, healthy, and growing mangrove site is greater (0.40-0.68) than the unhealthy mangrove site (0.38-0.47). The total area of mangrove forests is calculated by summing up the pixels with corresponding values.

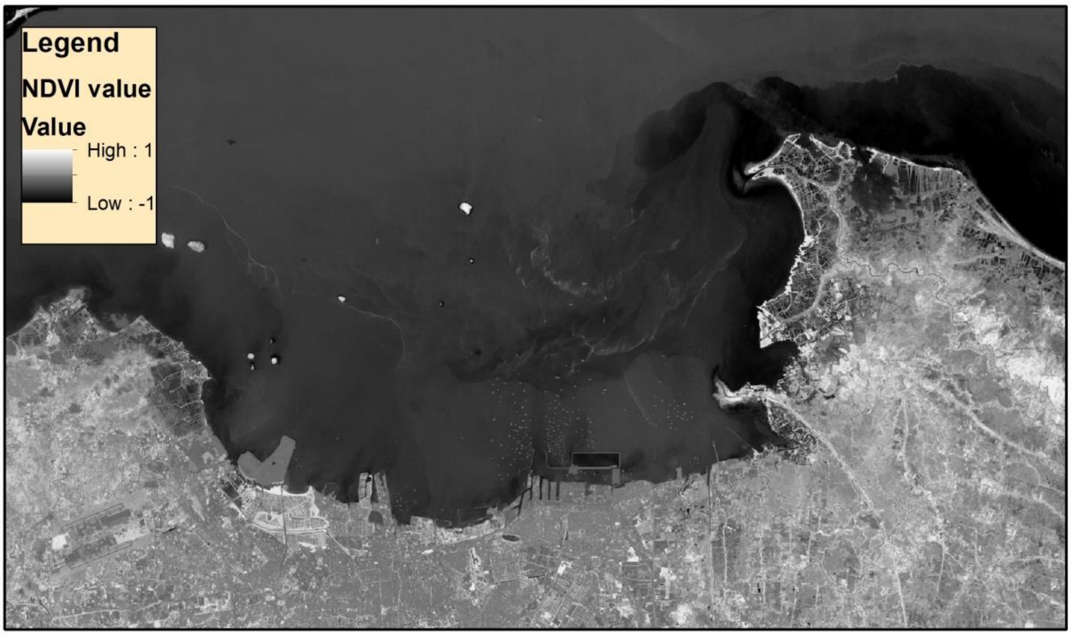


**Figure 2.9** NDVI image of Landsat 8

### 2.5.3 Accuracy assessment

Accuracy assessment is used to determine the accuracy of mangrove mapping process using NDVI on Landsat 7 and Landsat 8 images. There are several values that indicate the accuracy. They are calculated based on the comparison of classified pixels number in Landsat images and reference data. The accuracy values are:

1. Overall Accuracy is a percentage of pixels that are classified correctly based on reference data.
2. Kappa Coefficient measures the agreement between classification and reference pixels; its range is from 0 to 1. Value of 0 shows no agreement and 1 shows the perfect agreement.
3. Commission Error represents the pixels that belong to another class are labelled as belonging to the class of interest.
4. Omission Error represents the pixels that belong to the reference class but the classification process failed to classify them into proper class.
5. Producer Accuracy is a value indicating the probability of a pixel that has classified into Class A is also identified as Class A in reference data.
6. User Accuracy is the fraction of correctly classified pixels with regard to all pixels classified as this class in the classified image.