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แผนที่ความลึกจากดาวเทียมของอ่าวปากพนัง จังหวัดนครศรีธรรมราช

โดยใช้การเรียนรู้ของเครื่องจักร

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SATELLITE DERIVED BATHYMETRY OF PAK PHANANG BAY,  
NAKHON SI THAMMARAT PROVINCE USING MACHINE LEARNING

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พื้นที่อ่าวปากพนังเป็นพื้นที่ที่มีความสำคัญทั้งทางด้านเศรษฐกิจและระบบนิเวศ เนื่องจากเป็นเส้นทางในการสัญจรของเรือสินค้าจากอ่าวไทยเข้าสู่แม่น้ำปากพนัง โดยในอดีตได้มีการขุดร่องกลางอ่าวเพื่อให้เดินเรือได้อย่างสะดวก แต่จากการศึกษาในปี พ.ศ. 2562 พบว่าความลึกในร่องมีการเปลี่ยนแปลงจากความลึกมาตรฐานที่กรมเจ้าท่ากำหนดไว้ที่ 4 เมตร โดยมีทั้งบริเวณที่ลึกขึ้นเนื่องจากการกัดเซาะและบริเวณที่ตื้นขึ้นเนื่องจากการสะสมตะกอน ทำให้เกิดปัญหาต่อการเดินเรือ จึงมีโครงการประเมินสภาพแวดล้อมของอ่าวปากพนังเพื่อการขุดลอกร่องครั้งใหม่ในอนาคต งานวิจัยนี้จึงมีจุดมุ่งหมายที่จะสร้างแผนที่ความลึกและศึกษาลักษณะการเปลี่ยนแปลงของร่องเนื่องจากกระบวนการทางตะกอนในพื้นที่อ่าวปากพนัง โดยใช้วิธีการสร้างแผนที่ความลึกจากดาวเทียม ร่วมกับวิธีการเรียนรู้ของเครื่องจักร ในงานวิจัยนี้เลือกใช้ดาวเทียม SENTINEL-2A band 5 และใช้วิธีการเรียนรู้ของเครื่องจักรที่ชื่อว่า Gaussian Process Regression (GPR) เพื่อสร้างเส้นความลึกจากข้อมูลค่าจุดภาพ และ K-means clustering เพื่อช่วยในการแยกความแตกต่างของความลึก ในผลการศึกษาพบว่าวิธีการสร้างแผนที่ความลึกในงานวิจัยนี้สามารถสร้างแผนที่ความลึกบริเวณพื้นที่ร่องได้และความลึกที่ได้สัมพันธ์กับความลึกจริง อย่างไรก็ตาม ผลจากการเรียนรู้ของเครื่องจักรด้วยวิธี GPR พบจุดรบกวน และยังไม่สามารถแยกความแตกต่างของระดับความลึกบริเวณที่มีการเปลี่ยนแปลงความลึกน้อยได้ สำหรับกระบวนการทางธรณีสันฐานสามารถแบ่งได้เป็น 2 บริเวณ คือบริเวณร่องที่ตื้นและบริเวณร่องที่ลึก บริเวณร่องที่ตื้นเกิดจากการสะสมตัวของตะกอนที่มีที่มาจากแม่น้ำปากพนัง รวมถึงแม่น้ำสายย่อยอื่นๆที่ไหลสู่อ่าวปากพนัง และตะกอนที่แขวนลอยในทะเล และบริเวณร่องที่ลึกกอนุมาณสาเหตุการเกิดเนื่องจากกระแสน้ำของแม่น้ำที่ไหลลงอ่าวปากพนังทางด้านตะวันตกและฝั่งตกวันออกบรรจบกัน ทำให้กระแสน้ำกัดเซาะพื้นที่บริเวณนั้น

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WIPAPORN NUTTASIN: SATELLITE DERIVED BATHYMETRY OF PAK PHANANG BAY,  
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Pak Phanang bay is an important area in both terms of economics and ecosystems. Because, it hosts a shipping route from Gulf of Thailand into Pak Phanang river. In the past, a canal which located in the center of the bay was canalized. But, from the study in 2019 found that the depth in the canal had changed from the criteria of the Marine Department which defines the standard depth equal to 4 meters. There were changes in both the deeper parts from erosion and the shallower parts from the sediment deposition. According to the changing of the depth in the canal that causes problems for navigation, there is a project to assess the environment of Pak Phanang Bay for new trench dredging in the future. So, this study will make the bathymetry and study the geomorphology of Pak Phanang bay to be a supporting information for the future construction project by using satellite derived bathymetry together with machine learning. Sentinel-2A band 5 was choosed to be a satellite data. Gaussian Process Regression (GPR) is one of the machine learning which was used for creating bathymetry from pixel values. Another machine learning is K-means clustering which was used To help differentiate the depths. The result of from this study proves that this method was able to map the depth of the canal in shallow area and the depth relative to the real data. But the GPR also generated noise and still unable to distinguish the area with little change in depth. Geomorphological processes can be divided for two areas including shallow area and deep area. In shallow area are formed by the deposition of the sediments from the Pak Phanang rivers and the suspended sediments in the seawater. And the deep area was inferred the cause by the flowing of the flows in both sides of coasts causing the current to erode in this area.


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## CHAPTER 1 INTRODUCTION

### 1.1. Introduction

Bathymetry is important for studying and construction in marine area. There are numerous methods for measuring water depth. Most measurement typically comes from Sound Navigation And Ranging (SONAR) technique. The result can be used to generate high accuracy of seafloor map. However, SONAR data is slow and expensive to collect. Moreover, some studies have shown that SONAR survey also affects marine animals (Southall et al., 2019). Light Detection And Ranging (LIDAR) is another technique to measure water depth that involves the transmission of laser light. It is faster to cover a wide area and safer for mapping near-shore bathymetry (Japan Coast Guard, 2018). Although mapping bathymetry with LIDAR sensor aboard aircraft is still expensive.

Remote sensing method uses multi-spectral or hyper-spectral sensors to estimate depth since the 1970s. This analyzing from satellites can access in shallow areas that boat or plane are difficult, and also more cost efficient than SONAR. (Poppenga et al., 2018). The studies which obtain depth data from analyzing satellite is called Satellite Derived Bathymetry (SDB). Machine learning becomes a key to improve SDB. Sagawa (2019) used Random Forest by create decision trees from pixel value and water depth. Gaussian process (GP) is another supervised learning that can create regression model from pixel value.

Pak Phanang Bay is a shallow marine area between Pak Phanang river and Gulf of Thailand located in Nakorn Sri Thammarat province (Figure 1.1). This area is important in terms of Ecosystem and Economic. In the past, a 4-meter-trench was canalized in accordance with the criteria by the Marine Department, so the cargo ships can pass into the river. But when the time passed, sediment had deposited into the and resulted in the ships can't access into the river. Therefore, in 2020, marine department has begun project to canalize in this area again (Paphawasit, 2008).

This research aims to propose a novel approach to create a recent bathymetric model of the Pak Phanang Bay. The SDB technique is applied with Gaussian Process Regression (GPR) by creating regression model from reflection of Sentinel-2. This study will help creating bathymetry data in the areas that are unreachable by boat or airplane.

## **1.2. Study area**

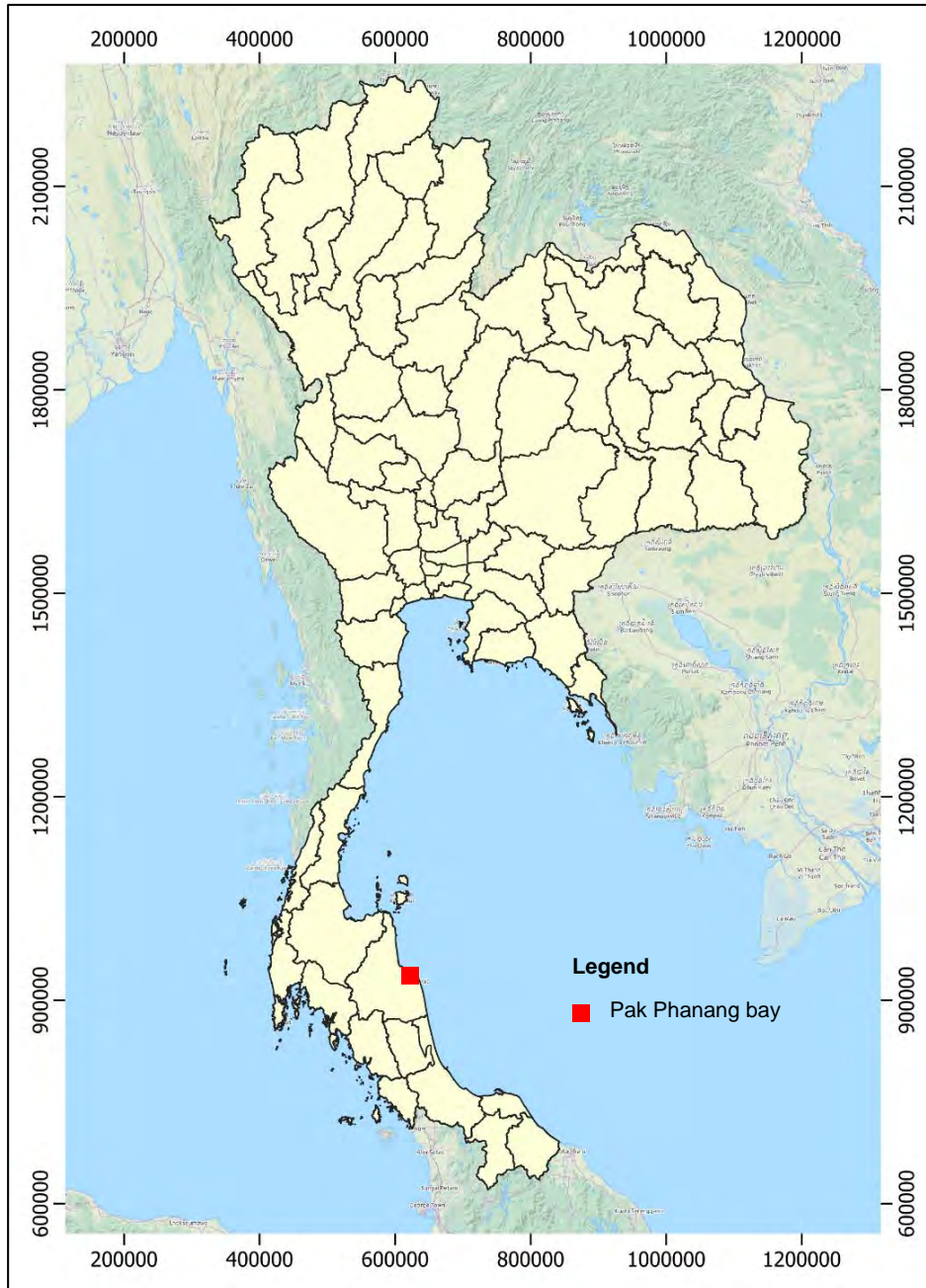
The study area is located on Pak Phanang Bay (Figure 1.2), Pak Phanang District Nakhon Si Thammarat Province which is rich in natural resources. It is one of important ports of Southeast Asia peninsula and hosts a ship route connecting between Gulf of Thailand and Andaman sea. At the center of bay has the canal which was digged to has 4 meters depth from lowest sea water level. This area has a high sediment deposition rate (STS Engineering Consultasnts, 2020). Resulting in the problem of shallow channel making main drainage canals in coastal area inability to drain water effectively causes flooding in many areas. It is also a major obstacle of passing through and out of the merchant ships throughout the season causing time and money to transport goods increase. Therefore it is imperative to continually excavate and maintain the channel. The location of channel is shown in Figure 1.3.

## **1.3. Objectives**

- 1) To create a new bathymetric model of Pak Phanang Bay, Nakhon Si Thammarat
- 2) To identify marine geomorphological features in Pak Phanang Bay, Nakhon Si Thammarat

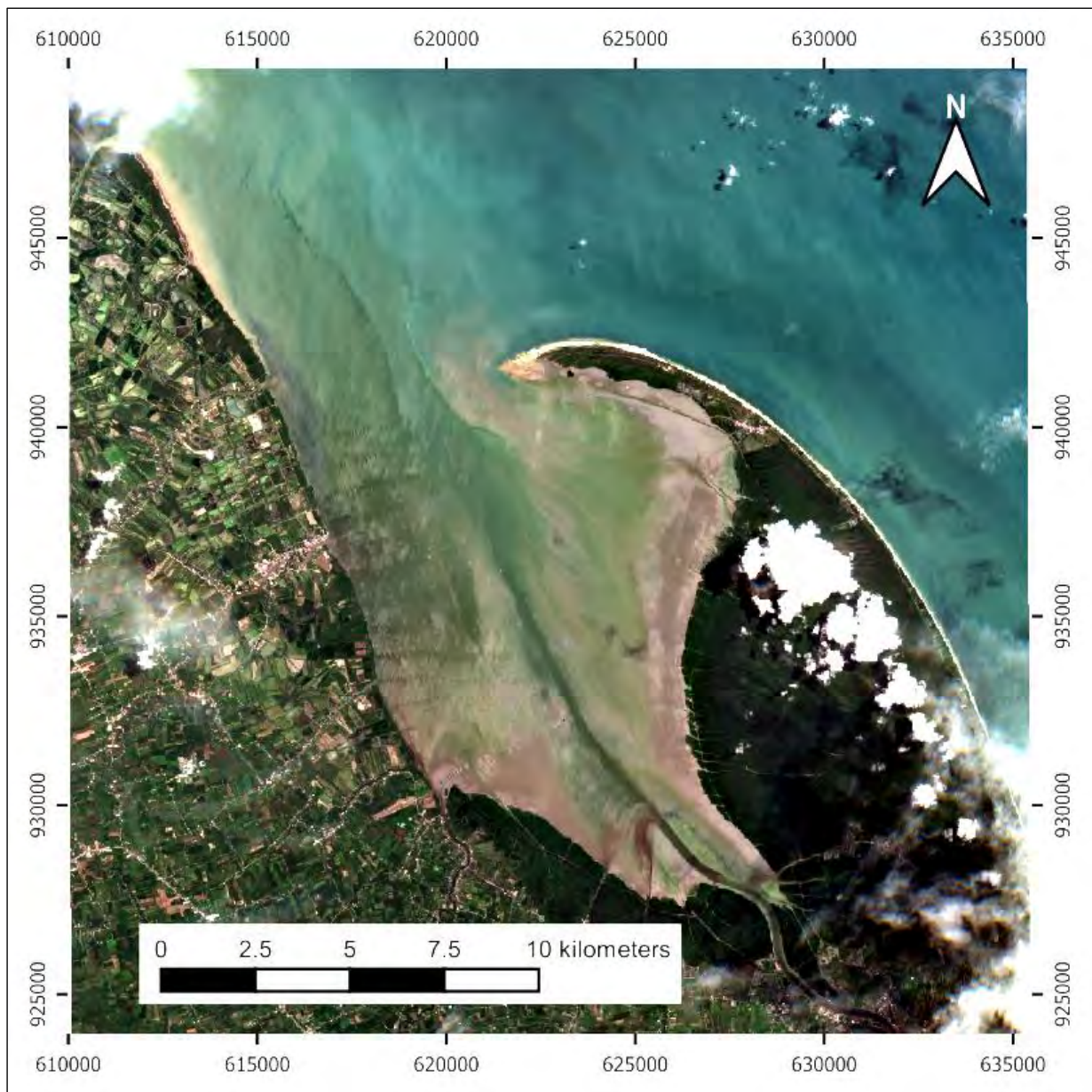
## **1.4. Expected Results**

- 1) A new high-resolution bathymetric map of Pak Phanang Bay, Nakhon Si Thammarat
- 2) Detailed information of marine geomorphology of Pak Phanang Bay, Nakhon Si Thammarat



**Figure 1.1** The map of Pak Phanang bay (red rectangular) in Thailand.





**Figure 1.2** The satellite image of the study area in the Pak Phanang Bay, Nakhon Si Thammarat province.



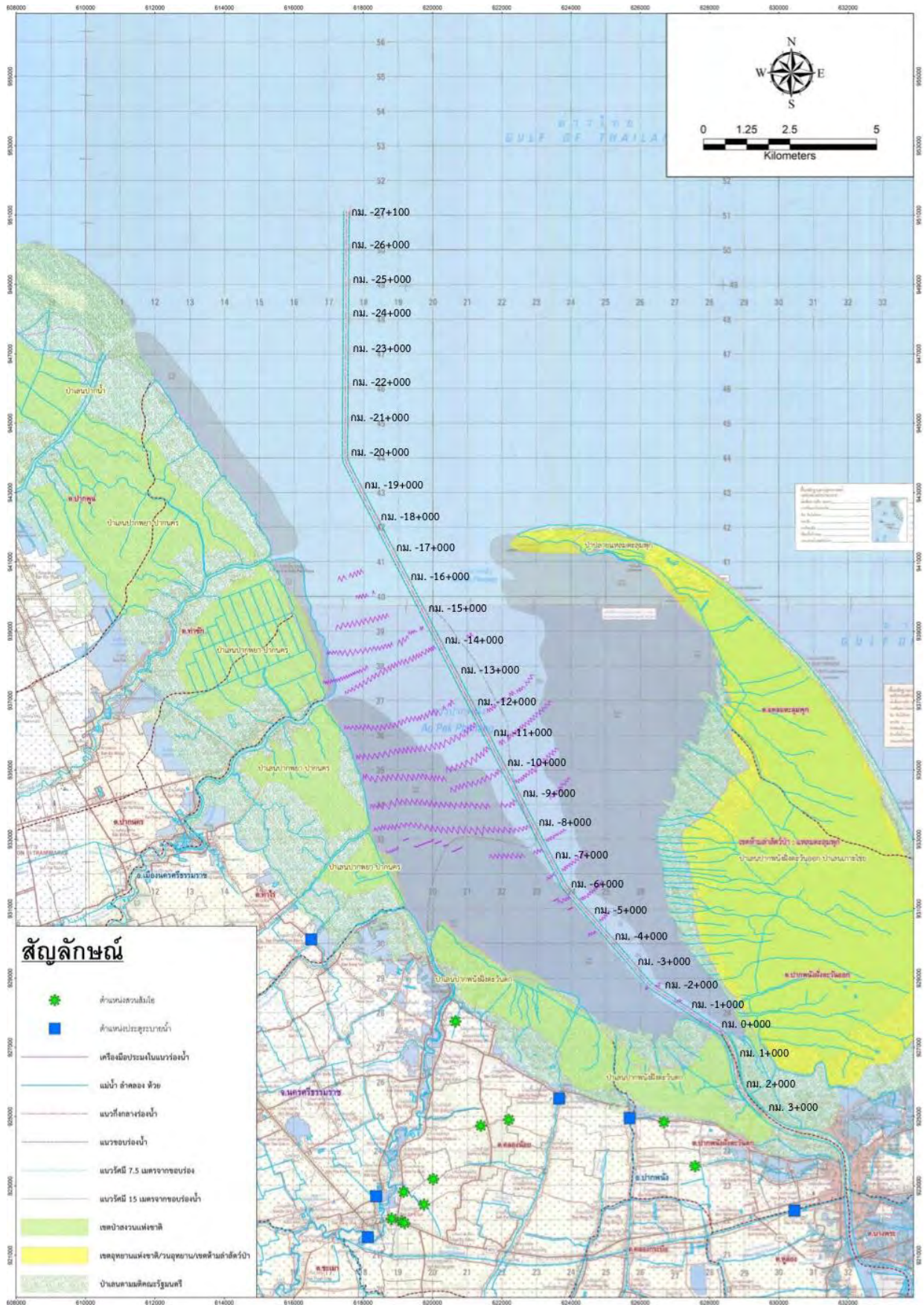


Figure 1.3 Location of the canal in center of Pak Phanang bay in topographic map.

## CHAPTER 2 LITERATURE REVIEW

### 2.1. General informations of Pak Phanang bay

Pak Phanang bay locates in Pak Phanang District, Nakhon Sri Thammarat province, on the western side is near Nakhon Sri Thammarat range or Banthat range and on the eastern side is adjacent with Gulf of Thailand. It is a large, shallow bay, resting northwest-southeast direction, sheltered from the Gulf of Thailand by a long northwest-pointing sandbar of Laem Talumphuk. It is approximately 16 kilometers long, maximum width is around 11 kilometers and narrowed near the mouth of bay with 1 meter minimum width. Total surface water area is approximately 120 square kilometers. This area is in tidal flat condition which often emerges from the water when the water is very low, the water depth is very shallow approximately only 1 meter (Boromthanasart et al., 1991). There is a canal in the middle of the bay, which has been dredged to a planned depth of 5 meters below the lowest water level. But the slippage of the sediments beside the canal cause the water depth to be below the threshold. The sediments are flown together along runoff from the Pak Phanang basin comprising Pak Phanang river as a main river, Pak Nakhon canal, Pak Phaya canal and other branch rivers. (Paphawasit, 2008)

#### 2.1.1. Pak Phanang river

Phanang river is the main river of Pak Phanang basin which approximately 150 kilometers long, forms by many branch riveres that flow along with the main river like vein, the headwaters originated from Nakhon Sri Thammarat range or Banthat range flows through Cha-uat district, Chian Yai District and has a branch in Hua Sai District, then flows together at Ban Pak Phraek to become Pak Phanang River flowing into the bay. The branch rivers which flows to Pak Phanang bay are Bang Ta Khian canal, Bang Sai canal, Na Nork canal and Bang Toei canal that join with the Pak Phanang river, Pru canal and Ai Daeng canal that flow together with the Ban Klang canal and then join with Pak Phanang river or called the Hua sai canal which influenced by tidal. Some other branch canals flow directly into the sea.

#### 2.1.2. Coastal evolution

Coastal geomorphology of the Pak Phanang Basin composes of Paleozoic, Mesozoic and Cenozoic rocks (Paphawasit, 2008). Coastal characteristics in Thailand had a long evolution of geological changes since the last time of ice age during the melting period about 6,000 years ago made the highest sea water and flooded into the lowland area causing the and the accumulation of sediments to accumulate in the sea. Later, when the sea water level down steadily until reaching the current level, making Thailand has more coastal areas. In the same

way, the Pak Phanang River Basin is an area that it is also caused by the evolution of the morphological changes after the maximum penetration of sea water.

### **2.1.3. Topography of Pak Phanang Basin**

The topography of Pak Phanang basin can be divided into three characteristics. On the Western area has the high Nakhon Sri Thammarat mountain range resting north-south direction which is very steep around 1:200 to 1:400. Next to the foot of hill, it is undulating intersperses between high hill and plain. Next is plain area slopes into the mouth of the Pak Phanang River.

### **2.1.4. Ecosystem**

The ecosystems of Pak Phanang can be classified into 4 types according to their different water salinity : fresh water and sour water from swamp, brackish water from fresh water mixed with salt water and salt water or sea water. This creates diversity of ecosystems, animals and plants such as swamp forests, mangrove forests, sago forests, terrestrial forests and seagrass, which are all breeding grounds for living organism making this area very fertile.

## **2.2. Climate**

Pak Phanang basin is in tropical zone. The important seasons are dry and rainy season. Rainy season is during October to December which received high precipitation from the northeast monsoon which blows through the South China sea and brings humidity to to the Gulf of Thailand. Dry season starts in January and ends in September. This season spans summer season and the southwest monsoon season, which also receives one amount of rain from the southwest monsoon that blows through the Indian Ocean, bringing humidity to the lower south of Thailand. But there is the Nakhon Sri Thammarat range running in North-South direction that blocking wind causing heavy rain in the west area and lefting some rain to fall in east part. The temperature throughout the year ranged from 19.5 to 36.7 degrees Celsius, average relative humidity 49.1 to 96.3 percent, the number of rainfall throughout the year 152 days, rainfall about 2,646.3 millimeters.

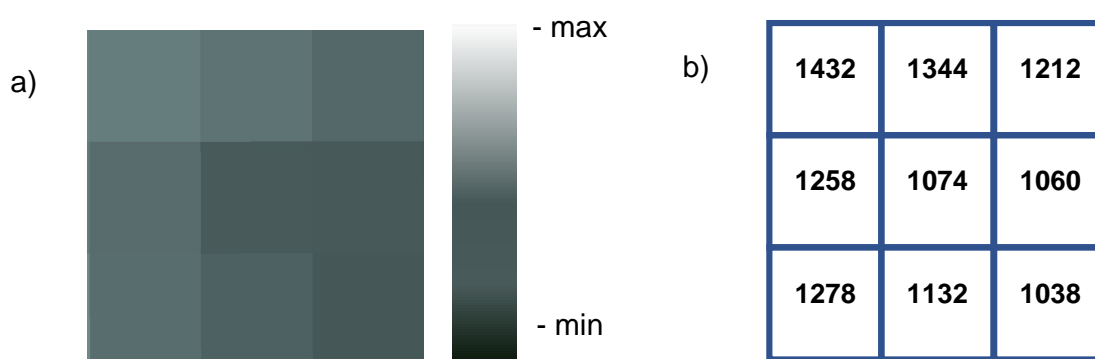
### **2.2.1. Tidal characteristics**

From data of Department of Marine, in each day tide level has range only 0.57 m., the highest tide is around 1.5 m. from mean sea level and the lowest tide is around 1 m. from mean sea level, the water surface in Pak Phanang bay dries up, leaving only water in the canal when the water is at lowest tide.

### 2.3. Informations of satellite image

Satellite is an artificial object orbits around the earth for collecting information or for communication by using reflectance of electromagnetic waves. Band or Spectral band is referred to specific range of reflected waves of satellite to objects on the earth. Satellites which have a small number of bands (normally 3 to 15) were called Multispectral satellite. Some examples of multispectral satellite are Landsat-8 and Sentinel-2.

The satellite images are the product from satellites. The type of satellite images are raster data when zoom the images will see the tiny, different colors boxes or can called pixels (Figure 2.1a) arranged in rows and columns, in each pixel contain pixel value (Figure 2.1b) that presents reflectance. (ArcGIS for Desktop, n.d.)



**Figure 2.1** a) The example of pixels in raster data and its scale b) The example of pixel values in each pixel.

### 2.4. Satellite Derived Bathymetry (SDB)

Satellite Derived Bathymetry (SDB) is a technique to create bathymetry in shallow marine area that boats are difficult to access by analyzing pixel value of satellite data (Landsat, Sentinel) with reference depth data (e.g. SONAR LIDAR).

### 2.5. Sentinel-2 satellite images

In this part will write about general information about Sentinel-2 satellite images including their products and resolution from ESA website (The European Space Agency, n.d.)

#### 2.5.1. Product

Sentinel-2 has two products available for users including Level-1C and Level-2A. The information of the products are listed in Table 2-1. Each product shows different of its as shown in Figure 2.1. In this study will use only Sentinel-2 Level 2A because it can see objects under atmosphere.



Name	High-level Description	Production & Distribution	Data Volume
Level-1C	Top-of-atmosphere reflectances in cartographic geometry	Systematic generation and on-line distribution	600 MB (each 100x100 km <sup>2</sup> )
Level-2A	Bottom-of-atmosphere reflectance in cartographic geometry	Systematic generation and on-line distribution and generation on user side (using Sentinel-2 Toolbox)	800 MB (each 100x100 km <sup>2</sup> )

**Table 2-1** Sentinel-2 product types



**Figure 2.2** shows TOA Level-1C image data (left) and associated Level-2A BOA image data (right) generated using Sen2Cor processor

### 2.5.2. Resolution of Sentine-2 satellite

Sentinel-2 has 13 spectral bands and 3 spatial resolution including

- **10 meter** : three visible bands (Red Blue Green) and a Near Infra-Red band (NIR)
- **20 meter** : four narrow bands in the vegetation red edge spectral domain (VNIR)
- **60 meter**: two bands focused on cloud screening and atmospheric correction named Aerosols and Water Vapour and two bands focused on cirrus detection named Short wave Infra-Red (SWIR)

The description of the band of satellite is shown in table 2-2.

<b>Band Number</b>	<b>Name</b>	<b>Wavelength</b>	<b>Pixel size (m)</b>
1	Aerosols	443.9nm (S2A) / 442.3nm (S2B)	60
2	Blue	496.6nm (S2A) / 492.1nm (S2B)	10
3	Green	560nm (S2A) / 559nm (S2B)	10
4	Red	664.5nm (S2A) / 665nm (S2B)	10
5	Red Edge 1	703.9nm (S2A) / 703.8nm (S2B)	20
6	Red Edge 2	740.2nm (S2A) / 739.1nm (S2B)	20
7	Red Edge 3	782.5nm (S2A) / 779.7nm (S2B)	20
8	NIR	835.1nm (S2A) / 833nm (S2B)	10
8A	Red Edge 4	864.8nm (S2A) / 864nm (S2B)	20
9	Water vapor	945nm (S2A) / 943.2nm (S2B)	60
11	SWIR 1	1613.7nm (S2A) / 1610.4nm (S2B)	20
12	SWIR 2	2202.4nm (S2A) / 2185.7nm (S2B)	20

**Table 2-2** The description of the band of Sentinel-2 satellite.

## 2.6. Machine Learning

The convergence of Computer Science and Statistics has led to the creation of Machine Learning. Unlike Computer Science, which has traditionally concentrated on how to manually program computers, Machine Learning is concerned with how to teach computers to program themselves (from experience plus some initial structure). Machine Learning includes additional questions about what computational architectures and algorithms can be used to most efficiently collect, store, index, retrieve, and merge these data, how multiple learning subtasks can be orchestrated in a larger framework, and questions of computational tractability, while Statistics has focused primarily on what conclusions can be inferred from data (Mitchell, 2006).

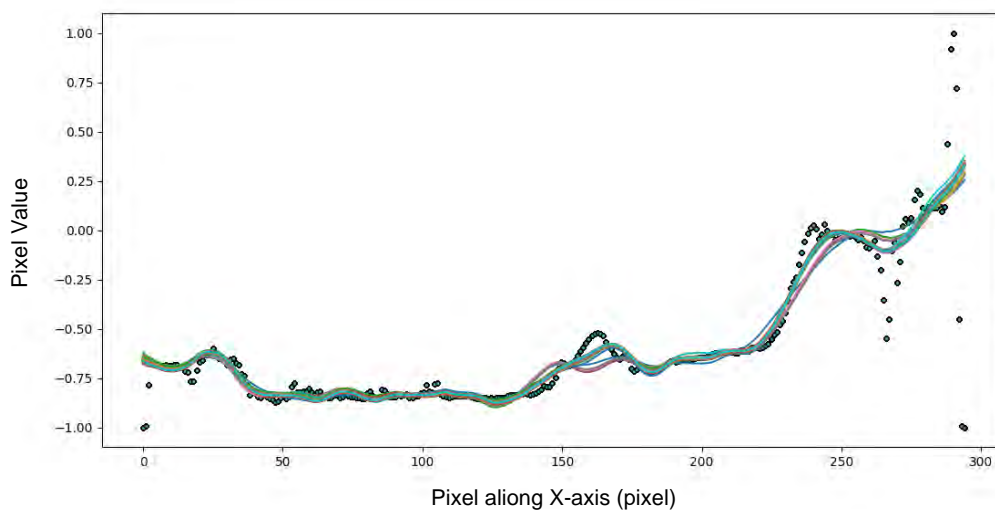
## 2.7. Gaussian Process Regression

Gaussian process regression (GPR) is one of the machine learning method, it is a nonparametric, bayesian stochastic process to creating regression for nonlinear and random data by complex functions ("Quick Start to Gaussian Process Regression", 2021). In contrast to many common supervised machine learning algorithms, which learn exact values for each parameter in a function, the Bayesian approach infers a probability distribution over all possible values (Zhao, 2020).

The example of result of GPR is shown in Figure 2.3. The colorful lines are the regressions that forms by training the point data (blue circles) with GPR by defining number of regression or iteration equals to 50. GPR will change the error value in each iteration to try to fit the data. So, if number of iteration is enough, the regression will be close to the data. Therefore, the number of each parameter that given to GPR is very important.

To conclude, The reason that in this study uses GPR because GPR has the ability to build regression from messy point data like the pixel values. We will assume that the regression represents the bathymetry. it also can decrease noise of data and. In this study uses PYMC3 which is python packages to help in calculating GPR (Salvatier et al., 2016).

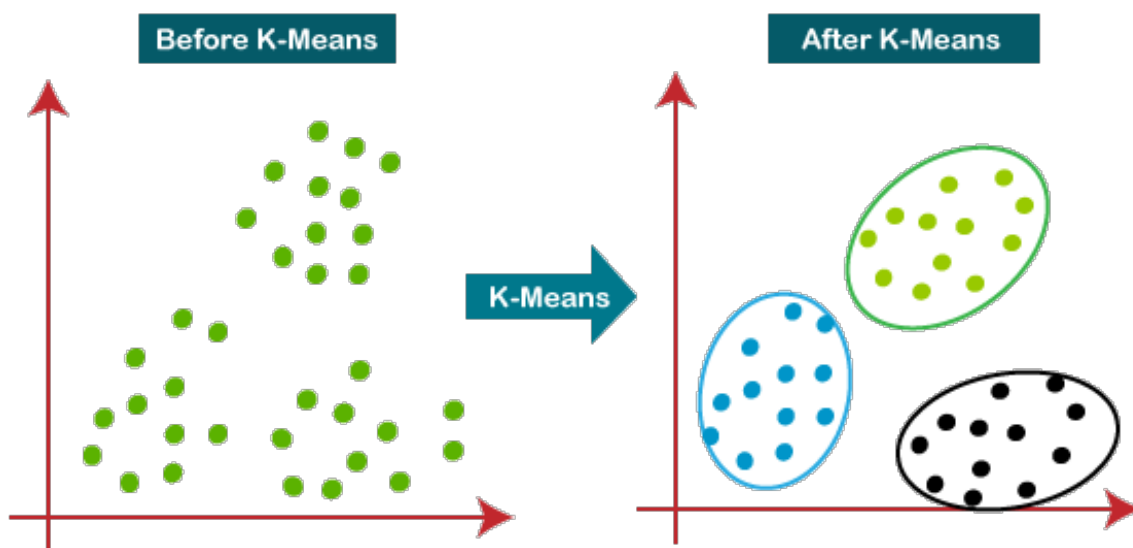




**Figure 2.3** The example working of Gaussian Process Regression

## 2.8. K-means Clustering

Unsupervised Learning algorithm K-Means Clustering divides the unlabeled dataset into separate clusters. It's a centroid-based algorithm, which means that each cluster has its own centroid. The main goal of this algorithm is to reduce the number of distances between data points and the clusters that they belong to. The algorithm takes an unlabeled dataset as input, divides it into a k-number of clusters, and repeats the procedure until no better clusters are found. In this algorithm, the value of k should be predetermined. (JavaTpoint, n.d.)



**Figure 2.4** The example of working of K-means Clustering (K=3)

The following steps will illustrate how the K-Means algorithm works:

**Step 1:** To determine the number of clusters, choose the number  $K$ . (For examples:  $K=2$ )

**Step 2:** Choose  $K$  points or centroids at random. (It may be anything different from the input dataset.)

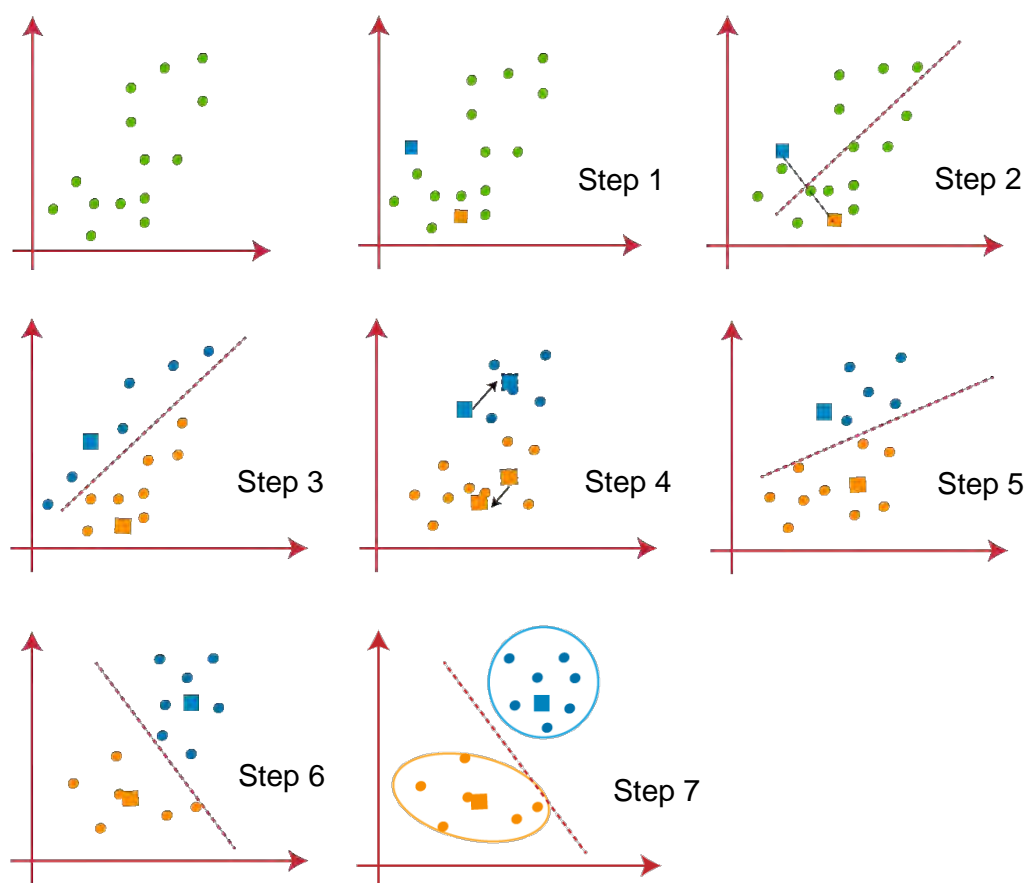
**Step 3:** Assign each data point to the centroid that is nearest to it, forming the predefined  $K$  clusters.

**Step 4:** Determine the variance and reposition each cluster's centroid.

**Step 5:** Repeat the third step, which is to reassign each datapoint to the cluster's new closest centroid.

**Step-6:** If any reassignment occurs, proceed to step-4; otherwise, proceed to FINISH.

**Step 7:** The model is complete.



**Figure 2.5** The 7 steps of working of K-means clustering.

## 2.9. Literature Review

The most of SDB method from passive satellite imagery is the band-ratio technique or called the natural logarithm method with concept is the bottom radiance of one band will decay faster than the other bands, the ratio between two bands will vary with depth (Pe'eri and other, 2014) by using calculating as in equation 1.

$$z = m_1 \left( \frac{\ln(L_{obs}(\lambda_i))}{\ln(L_{obs}(\lambda_j))} \right) - m_0$$

Where

$z$  is the relative vertical profile depth estimates,

$m_1$  and  $m_0$  are the gain (tangent of the slope angle) and offset (intercept), respectively, that are empirically determined,  $\ln$  is the natural logarithm ratio of the attenuation between observed radiance estimated (reflectance for WV-3 ACOMP)

$L_{obs}(\lambda_i)$  observed radiance of the Landsat blue band or observed reflectance of the WV-3 coastal band, and

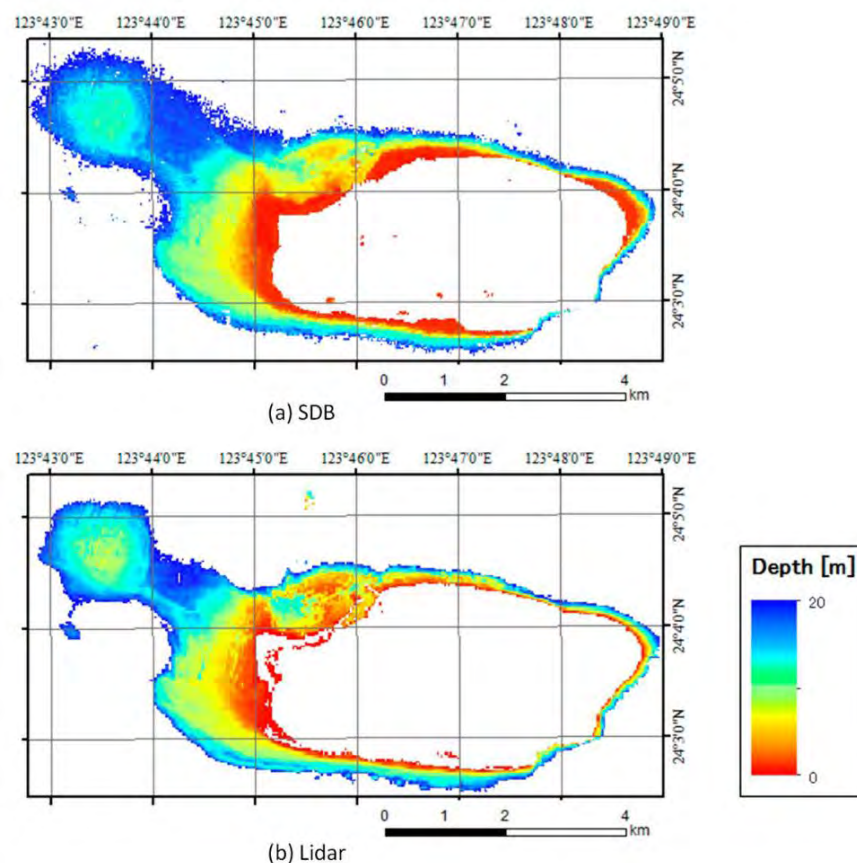
$L_{obs}(\lambda_j)$  observed radiance of the Landsat green band or observed reflectance of the WV-3 red band. The resulting values represe



**Figure 2.6** shows the SDB on the Majuro Atoll from Poppenga (2018)

Poppenga (2018) applied band-ratio technique to blue/green band and coastal/red band of Landsat-8 and blue/green band of Worldview-3 in the coastal waters surrounding the Majuro Atoll and validated depth estimate model with Lidar data. The result, as shown in figure 3 has  $R^2=0.9324$  from blue/green band-ratio of Landsat-8,  $R^2=0.9597$  from coastal/red band-ratio of Landsat-8 and  $R^2=0.9574$  from blue/green band-ratio of Worldview-3. The RMSE of lidar bathymetry (1.112 m) is a bit higher than than the L8 blue/green band ratio (1.065 m), but the overall mean error for Worldview-3 SDB was a bit lower (0.867 m) than the L8 blue/green ratio (0.947 m).

Sagawa (2019) improve SDB method by using Random forest, one of the machine learning methods. Random forest can automatically creates regression models from the decision trees that using the water depth as training data and pixel value as predictor values. This method, compared to the previous simple empirical models, Random forest is more flexible and accurate models. Many Landsat-8 satellite images was downloaded on Google Earth Engine which enables masking cloud functon in five study areas: 2 study areas in Japan and 1 study area in USA, Puerto Rico and Vanuatu from April 2013 to August 2018. The reference bathymetry of five areas are from airborne lidar bathymetry (ALB) and single beam sonar. Every study area is considered as area of highly transparent. The depth is vary from 0-20 meters. From accuracy assessment, the RMSE of five study areas was 1.41 m.

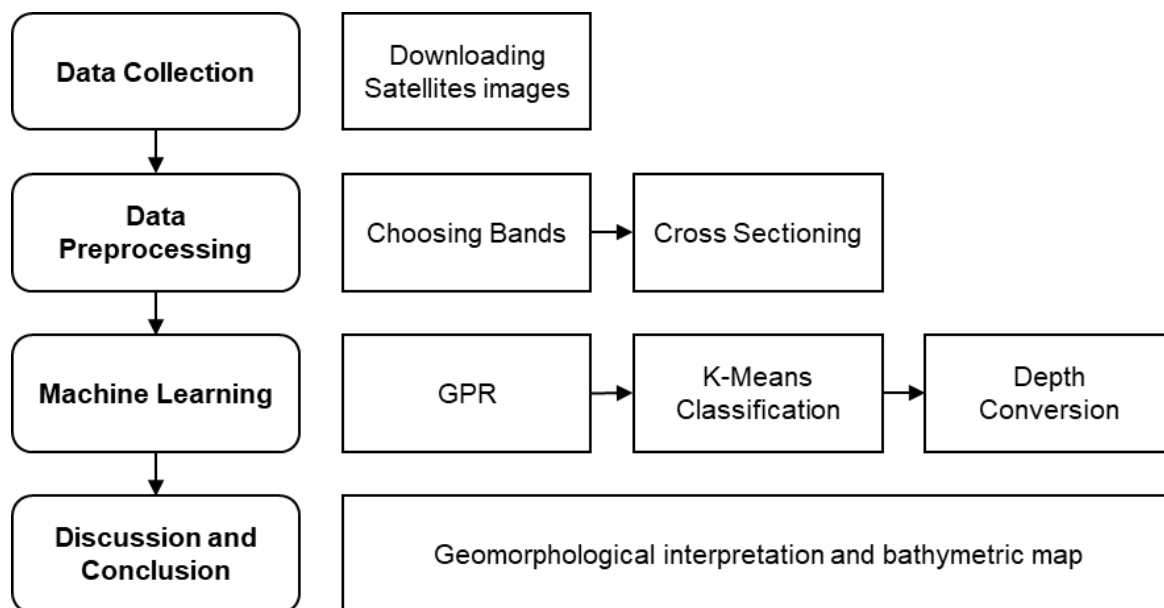


**Figure 2.7** shows the bathymetry that was created from Sagawa (2019)

## CHAPTER 3 METHODOLOGY

### 3.1. Overview of the workflow

The methodology is divided into four main steps: Data Collection, Data Processing, Machine Learning and Discussion and Conclusion. Workflow and methodology in this study is shown in figure 3.3. Datasets used for this project mainly composed of the satellite image from Google Earth Engine.



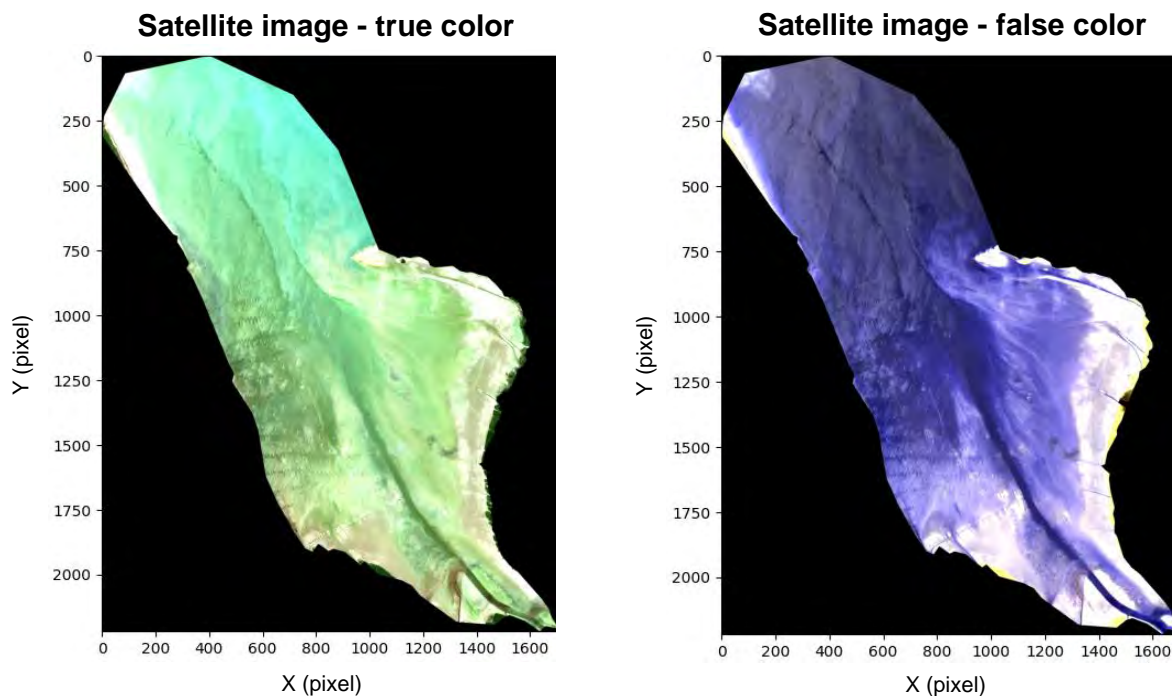
**Figure 3.1** Workflow and methodology used in this study.

### 3.2. Data Collection

Sentinel-2 Level-2A which provided by European Union/ESA/Copernicus in Pak Phanang bay, Pak Phanang District, Nakorn Sri Thammarat province on 2020 was download from Google Earth Engine (GEE) in georeferenced GeoTIFF format in Universal Transverse Mercator (UTM) Zone 47 North projection. which was clipped only water area and collected only cloudless day (Figure 3.2). The image size is 1705 x 2219 square pixels. It has 23 bands ( 13 bands from original data in table 2.1 and new 10 bands from GEE). The radiometric resolution of the MSI instrument is 12 bit, capacitate the potential light intensity values or pixel values over range 0 to 4095.

### 3.3. Data Preprocessing

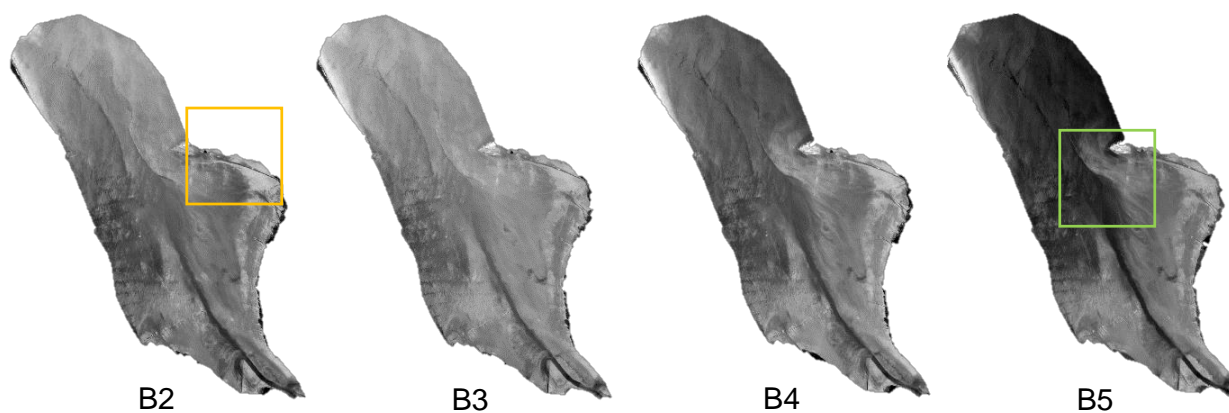
This step can be divided into two steps which are Selecting band and Cross Sectioning.



**Figure 3.2** shows products of downloading Sentinel-2, Level-2A satellite image in Pak Phanang bay, Pak Phanang bay, Pak Phanang District, Nakorn Sri Thammarat province from GEE. (a) and (b) presents in True color (B4 B3 B2) and false color (B7 B6 B5) respectively.

### 3.4. Selecting band

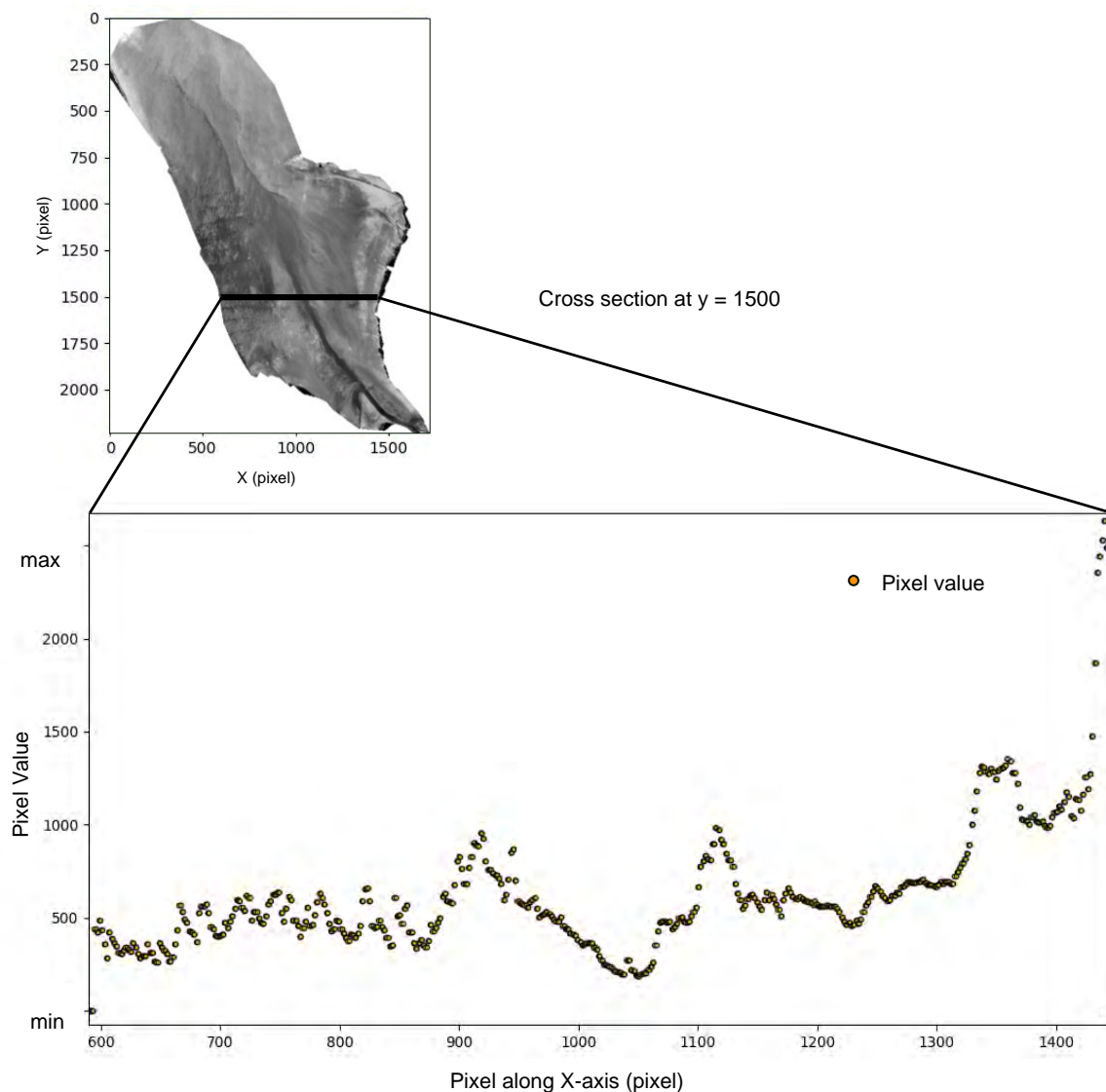
The images of band 2 – 5 is shown in Figure 3.3. It shows that each band can reflect well in different objects. From the images, Band 2 can reflects well in shallow area in yellow rectangle in Figure 3.3. However, in this study aims to focus on the canal, so in this work will use band 5 which best reflects in the canal area in green rectangle in Figure 3.3.



**Figure 3.3** shows the image of single band from band 2 to band 5. The yellow and green rectangles indicate best reflection area in their bands.

### 3.5. Cross sectioning

After choosing band 5, next step is cross sectioning. Cross sectioning is a process to section the image at each y-axis. The following steps will work by writing code in Python. The result of cross sectioning is the graph of pixel value along x-axis in that y-axis. The example of cross section at y-axis = 1500 is shown in figure 3.5



**Figure 3.4** Graph shows pixel value along X-axis in Y = 1500 in band 5



### 3.6. Machine Learning

Machine Learning will work by writing code in Python. In this step can divided into three steps including GPR, K-means clustering and Depth Conversion.

### 3.7. GPR

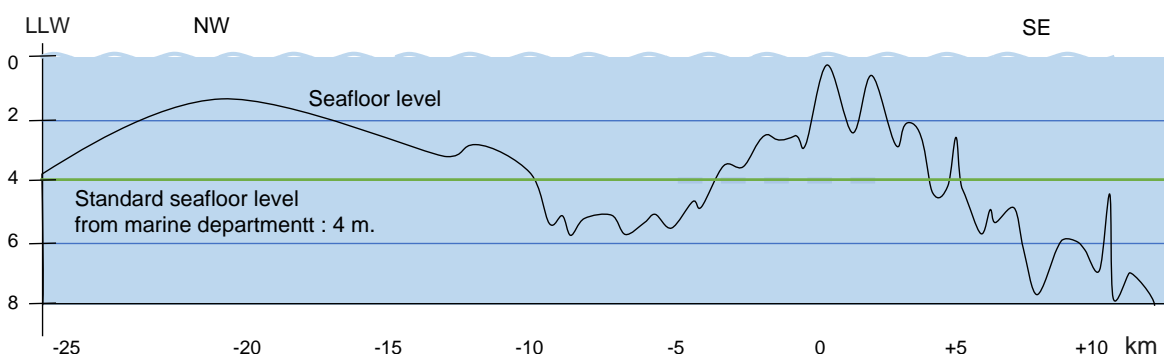
Each section from previous is used for GPR training to predict bathymetry. But, in this work doesn't aim to get the regression that best fits the data. So, in this study defines the iteration equals to 2000 and the error value of GPR equals to mean error in every section. The result of GPR training is shown in figure 4.1b

### 3.8. K-means Clustering

K-means clustering was used to help display the result and applied to the result of GPR training in previous step (Figure 4.3b), the satellite image in band 5 without GPR (Figure 4.3a) and the image which extract only canal area (Figure 4.4).

### 3.9. Depth Conversion

Depth conversion is the process to change scale from pixel value to depth by referencing depth value from Figure 3.6



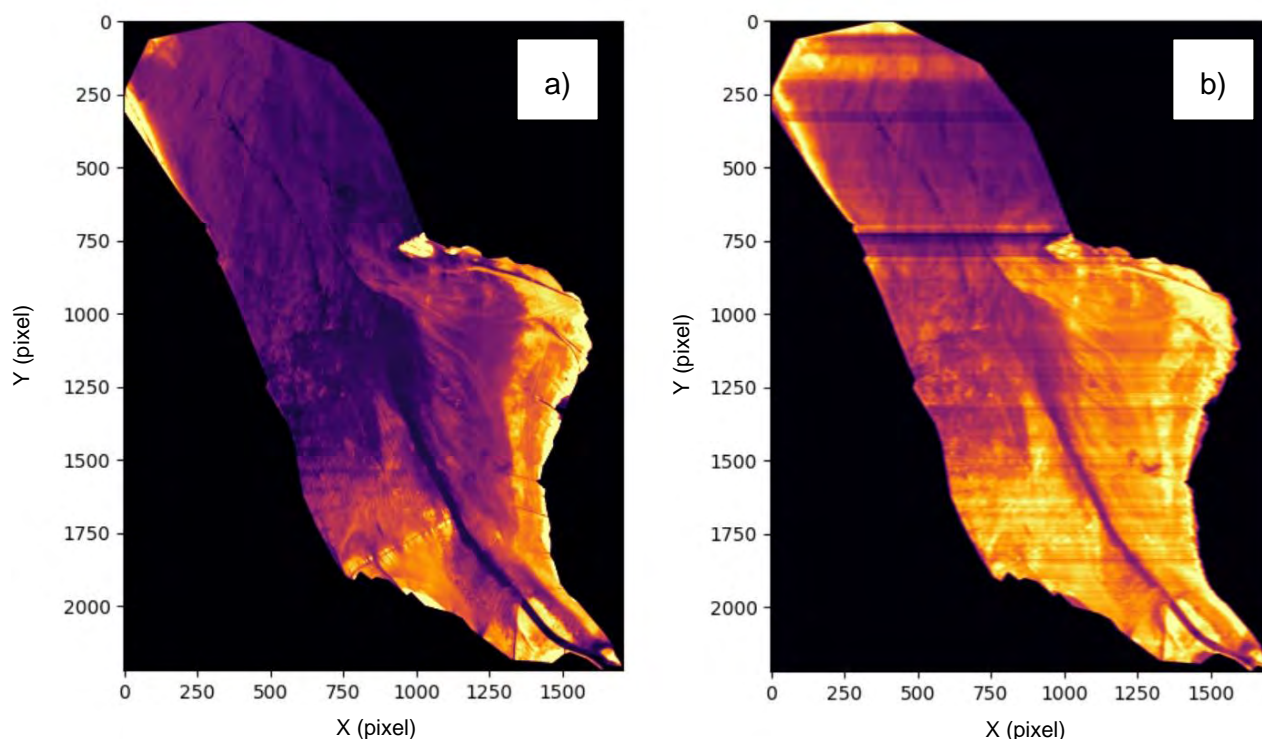
**Figure 3.5** The graph shows the depth and seafloor level along the canal and standard seafloor level according to the Marine Department which modified from the survey result of STS Engineering Consultants in 2019.



## CHAPTER 4 RESULT AND DISCUSSION

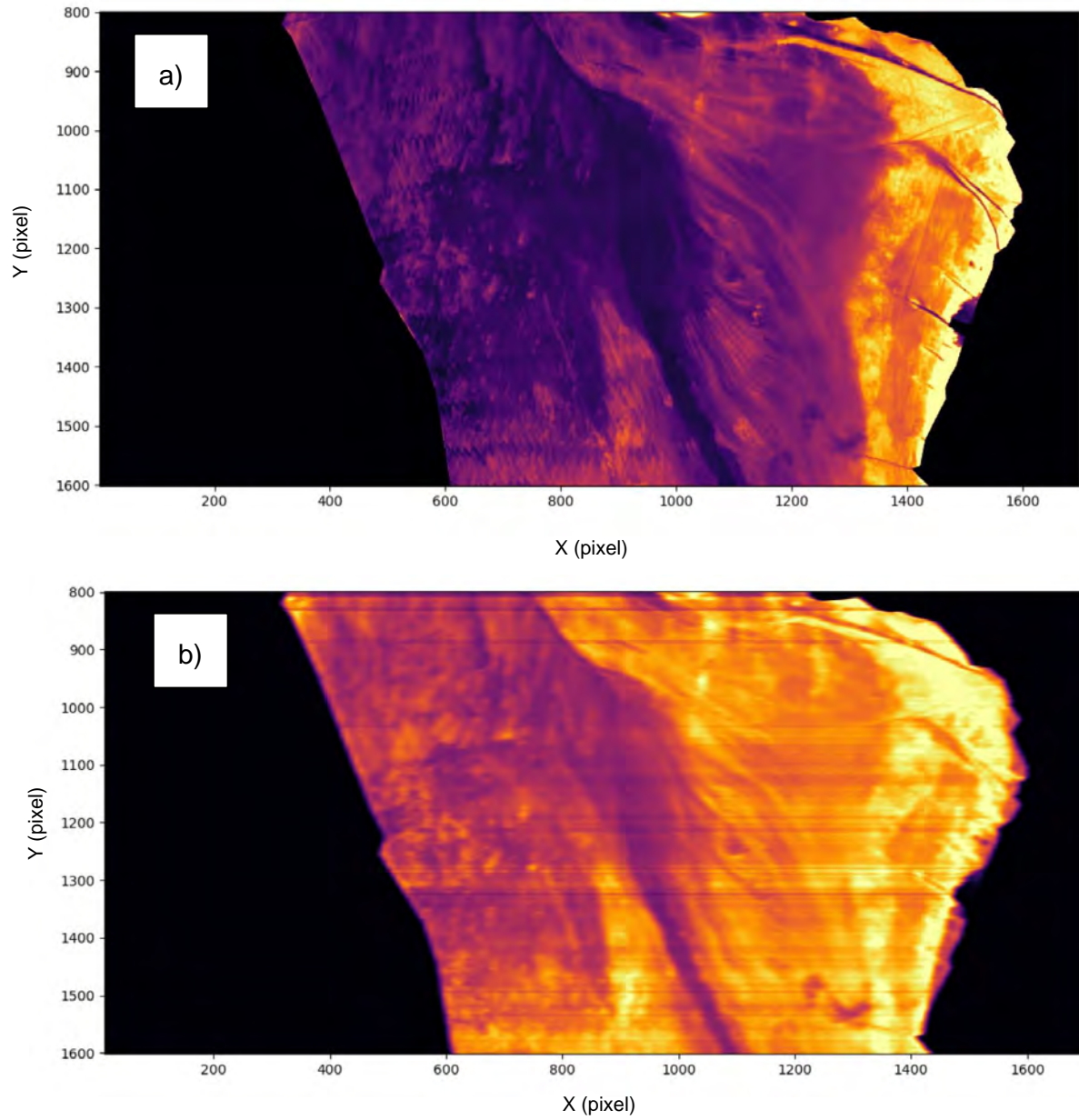
### 4.1. Comparing result with GPR and without GPR

Comparing satellite image in this area displaying in inferno colormap (Figure 4.1a) and the result of satellite image with GPR displaying in same colormap (Figure 4.1b), the result with GPR is less resolution and has more noise especially in the upper part of the image. This problem is due to the computation time of GPR is more than expected. One section spends around 1 day. The image has around 2,000 sections. Therefore, in this study adjust GPR's parameter to decrease run time by increasing smooth of graph and defining every section to use same error value equal to mean error. With this action resulted in resolution decreasing and noise enhancing in some sections.



**Figure 4.1** The images compare between a) the satellite image without GPR and b) the satellite image with GPR

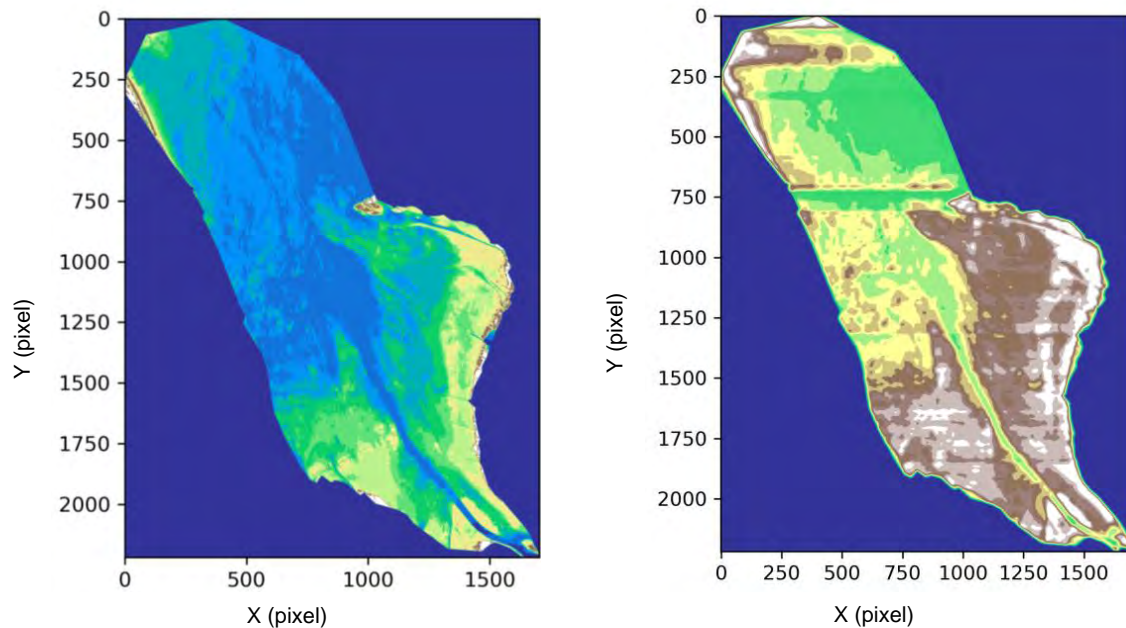
The images with zooming to see the details of the result are shown in figure 4.2a and figure 4.2b. The result of GPR with mean error can smooth image and enhance big feature like canal, but small features like drainage systems will be filtered.



**Figure 4.2** The images zoom in canal area compare between a) the satellite image without GPR and b) the satellite image with GPR

#### 4.2. Comparing result of K-means clustering with GPR and without GPR

In canal area, the result of GPR and K-means (Figure 4.3b) can classify feature in canal area better than the result of only K-means (Figure 4.3a).

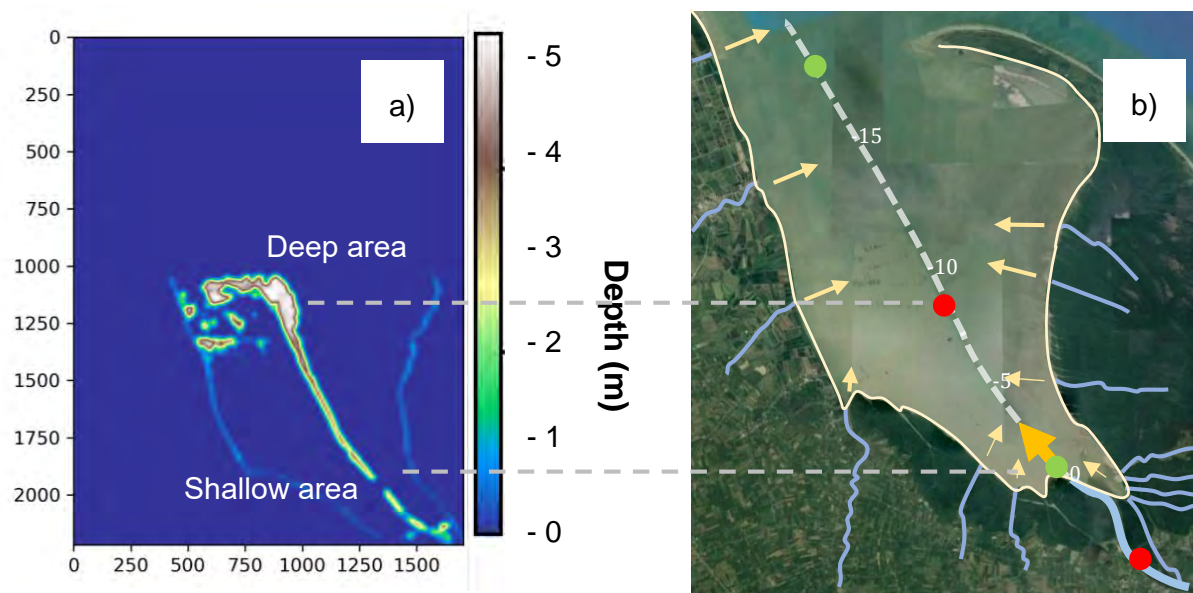


**Figure 4.3** The images compare between a) the result of only K-means and b) the result of GPR and K-means

#### 4.3. Bathymetry map and Geomorphological process

The final bathymetry map extracting only in canal area is shown in Figure 4.4. The result shows that in the canal has different depth including both shallow area and deep area. Comparing to the real information, the real data also has both shallow and deep area in same position. Therefore, this bathymetry map is consistent with reality.

For geomorphological processes in this area can be divided into two processes following by the shallow area and depth area. The shallow area is the area of deposition of sediments. The source of sediments are the sediments that gradually flow from the rivers including Pak Phanang rivers and other rivers along both western and eastern coasts and the sediments that suspend from seawater in Gulf of Thailand. The deep area is the area of erosion, but the reason of erosion is not clear. Normally erosion under water occurs by water current. The conclusion by inference is this deep area has rivers flowing down on both sides with the same flowing line, when the current meets may cause the water currents to erode this area.



**Figure 4.4** The bathymetry in canal area (a) compare with the satellite image which show the flowing direction of sediments (b). The circles in red represents area of erosion and the circles in green represents the area of deposition.

## CHAPTER 5 CONCLUSION

This study aim to create bathymetry in Pak Phanang bay, Nakhon Sri Thammarat province by using SDB technique to Sentinel-2 Level 2A satellite image together with machine learning which are GPR and K-means clustering and describe geomorphological processes which related to construction project in the canal in this area. The conclusion from this study are:

- From all of 13 bands of the satellite image of Sentinel-2 level-2A, in this study used Band 5 because can best reflect in canal area.
- Using GPR with K-means can rough estimates the water depth in shallow marine.
- GPR can helps K-means to smooth and enhance data, so K-means can classify better
- The result can show the geomorphological process in the canal, both its deposition and erosion which related with real data.
- From the results found that there are both 2 geomorphological processes including weathering and deposition. The weathering process occur in deeper area by and the deposition process occur in shallower area by sediment flowing from rivers and branch rivers in this area.
- By improving parameters of GPR, the result can has same resolution as spatial resolution of satellite and less noise, but needs more time for computation.

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