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THESIS

DECISION SUPPORT SYSTEM FOR COASTAL PROTECTION DESIGN

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A Thesis Submitted in Partial Fulfillment of
the Requirements for the Degree of
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The new system called DSS4CPD (the decision support system for coastal protection design) has been developed in this research. It is used for solving the complicated process of coastal structure design. For coastal structure design, three major models are needed for simulation and evaluation. There are wave hind-casting model, wave transformation model, and shoreline change model. In fact, those models require massive input data such as data of waves, bathymetry, beach profiles, tides, sediment sizes, and Aerial photo.

The DSS4CPD consists of three major parts of decision support system which are 1) Data base, 2) Model base, and 3) Dialog base. All of three parts are systematically linked and worked together in order to simulate, evaluate,and analyze, all decisive information to help the coastal engineers or designers for finding to coastal structure layout solution. For modelbase, three main models have been integrated by MapWindow Plug-in on GIS. The wave model, WAM has been used for deep water wave prediction. Wave transformation model, RCPWave has been used for simulating the wave condition which is directions and heights from deep water transforming to the beach, and to demonstrate the wave breaking zone map for making the coastal structure layout alignment. The shoreline change model, GENESIS, by using Genetic Algorithm (GA) to get the optimal coefficients, K1 and K2 in model calibration, has been used for calculating all shoreline change scenario results impacted from any coastal structure layouts. Then, the spatial evaluation (sDSS) and multicriteria analysis (MCA) have been used for evaluating and ranking to find the most appropriate layout solution.

Student's signature | Thesis Advisor's signature | / /

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Cdr. Phinai Jinchai
October 2012

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LIST OF ABBREVIATIONS

y = perpendicular distance from y and x axes

$C(x,y)$ = Wave Celerity

σ = Angular Wave Frequency

k = Wave Number

σ^2 = $kg\tanh(kh)$

T = Wave Period

C_g = Group Velocity

$\varphi(x,y)$ = “Complex Velocity Potential” function

g = Gravitational acceleration

$h(x,y)$ = Still water depth at (x,y) coordinate

$H(x,y)$ = Wave height at (x,y) coordinate

$s(x,y)$ = Wave phase function

∇ = Gradient Operation

C_0 = Deep water wave celerity

θ_0 = angle between deep water wave and reference axis

θ = angle at any position

L_0 = Deep water wave length

m = Sea slope

h_b = Water depth at breaking zone

H_b = Wave height at breaking zone

L_b = Wavelength at breaking zone

Hb = wave amplitude where it breaks

Cgb = wave-group amplitude where it breaks

α_b = diffraction angle where the wave breaks

LIST OF ABBREVIATIONS (Continued)

Q = coastal-parallel sediment movement rate

y = distance measured along the shoreline

Hb = wave amplitude where it breaks

Cgb = wave-group amplitude where it breaks

w = Weight of individual stone (N)

γ_a = Specific weight of stone (N/m3)

Kd = Stone shape coefficient

Sa = Specific gravity of stone (N/m3)

α = Slope angle of breakwater

DECISION SUPPORT SYSTEM FOR COASTAL PROTECTION DESIGN

INTRODUCTION

1. Background

Thailand has its length of coasts for approximately 2,614.0 kilometers. It is divided into two parts: the Gulf of Thailand coast which has its length of 1,660.0 kilometers and covers 17 coastal provinces (including Bangkok). Its length extends to the Malaysian boundary in the south and the Cambodian's in the east. And the latter is the coast of the Andaman Sea which has its length of 954.0 kilometers and covers 6 coastal provinces. Its lengths is also extends to Malaysian boundary in the south and Burmese's in the north. There are more than 12.0 million people now living in the coastal area.

The coasts of Thailand are high in tourism potentiality. They have been recognized as the world-class tourism places from both Thais and tourists around the world. They are the location of the sites which are the target of tourism development strategy of Thailand, such as Chonburi (Pataya), Rayong, Prachuabkirikhan (Huahin) Phetchburi (Cha-um), Nakornsrithammarat, Suratthani, Phuket, and Krabi. This will provide employment and income to the local community. In addition, this will be the development in order to support the tourism industry and the other tourism-related industries which consequently come. The loss of the tourist-attractive beaches from the coastal erosion process deteriorates these worthy resources.

Houses and residences, schools, temples, communities, including the historic sites in those coastal areas are encountering this erosion problem. These places need to be immigrated into the new safer areas where the erosion problem is unlikely. The immigration will, in turn, affect or change the people their way of life and may, additionally, impact their quality of life.

2. Problem Statement

For finding coastal erosion problem solution, there are many possibilities of combinations in decision making procedure in any steps of the process such as the dominant energy alternatives, coastal structure position and alignment, sizes and spacing of coastal structures (breakwaters). All steps are related to each other and can give lots possible combinations for decision makers along the way. Hence, the decision support with knowledge and statistics are needed for the best solution based on all resources the support system has. In this research, all procedures have been integrated including scenarios and alternatives in the possible combination that we have.

To illustrate, wind and wave that influences the coast is the main factor of near-shore sediment movement. If wave energy that influences the coast is homogeneous along the coast, the coastline would be straight because the movement of sediment will be homogeneous as well. However, for any coastal area with some factors to alter the original wave energy, or the barrier which blocks the movement of sediment is developed, such coastal area will lose its equilibrium. The erosion and sedimentation will be developed to reach new equilibrium.

Coastal alteration is the natural mechanism as the consequence of wind-wave influence to the shore and pocket beach system. However, the coast will finally reach its equilibrium. The coast will change again when the factors for the coast to lose its equilibrium occur. Every time of equilibrium always means erosion and accretion. If the erosion occurs in the areas which are not significant to social, economical, or environmental concerns of the nation we will be able to wait for the new equilibrium of such pocket beach system. However, if the erosion occurs in the unallowable areas, the coastal protection system shall be developed to protect that area. The coastal protection system development requires data and complicated analysis and appropriateness in various aspects including positive and negative impacts of the protection system. This causes the difficulty to the coastal engineer who primarily designs the system which involves considerable time and budget.

This research paper is, therefore, aiming to develop the decision support system for or to be used by the coastal engineer for the coastal protection design. Such supporting system shall be capable of analyze, evaluate, and check for the criteria used in the coastal protection design together with recommendations for further action of the engineer.

OBJECTIVES

The primary objective of this doctoral research is to develop and apply mathematical models and create decision support system for coastal protection design. The specific objectives are:

1. To develop the decision support system for coastal protection design (so called DSS4CPD) including to create coastal database and to integrate coastal models

2. To test the system with the studied area.

LITERATURE REVIEW

1. Overview

Coastal erosion is one of the most important socio-economical problems that challenge the capabilities of states and local authorities. Whether it is due to natural or anthropogenic reasons, coastal erosion causes significant economical losses, social problems, and ecological damages. The problem of erosion may extend its influence hundreds of kilometres alongshore in the case of large deltaic areas, and may have transboundary implications. In the case of pocket beaches on the other hand, it could be a very local phenomenon affecting only the residents of a nearby town and/or the tourism industry. (Özhan, 2002)

Coastal erosion is defined as the long term loss of the shore material (volume) relative to fixed reference line (baseline) and initial reference volume seaward of this line above some, arbitrary vertical datum (Basco, 1999). Coastal erosion is always accompanied with the shoreward recession of the shoreline and the loss of land area. (Basco, 1999),

The natural causes of long term coastal erosion are the followings:

a. Sea level rise (Pranzini & Rossi, 1995; Khalil, 1997)

b. Coastal subsidence due to tectonic events (Khalil, 1997)

c. Climatic changes (changing of the storm intensities, shift of the dominant storm directions affecting the approach angle of waves; variation of precipitation and the river regimes and discharges) (Medina & Lopez, 1997)

d. Increased vegetation cover over the river watersheds due to climatic changes (causing decreased soil erosion and sediment supplied to the coast)

e. Sediment sinks (presence of offshore canyons, movement to great depths at steep slopes, wind transport of sand to inland areas) (Golik & Rosen,1999)

f. Changing of river courses and mouths in deltas (PAP/RAC, 2000; Berriolo, Fierro & Gamboni, 2001)

The locations of the historical coastal erosion and the erosion rates can be estimated by using the followings:

a. The historical aerial photographs and coastal topographic maps (Preti, Carboni & Albertazzi, 1997, Golik and Rosen, 1999; Suzen & Özhan, 2000; Berriolo, Fierro & Gamboni, 2001; Bowman & Pranzini, 2001, Fatallah & Gueddari, M., 2001). These sources provide information on the past shoreline positions and the rate of shoreline recession.

b. The old bathymetric maps. Comparison of the successive bathymetric maps provides information on the regions of erosion and accretion, and their average rates) (Golik and Rosen, 1999).

c. A numerical model to calculate the sand transport rates from the historical time series of wave data, and the resulting morphological changes (Golik and Rosen, 1999; Rakha, & Abul-Azm 2001)

There are three types of managerial options in response to coastal erosion (Van der Weide, de Veroeg & Sanyang (2001). These are:

- Retreat;
- Accommodate for the present;
- Defend

A. Coastal defense

The defense strategy for an eroding coast may incorporate the so-called “hard” or “soft” measures, or a combination of them. The “hard” measure is the generic name given to those using classical coastal structures. There are several types of structures that have been used to stabilise an eroding beach. Most commonly used types are groins (Bartoletti et al., 1995), breakwaters (Özhan & Vefai, 1991; Hassan & Baset, 1997), revetments and sea walls. The rubble-mound breakwaters were widely used along the Italian coast in the past, but they are no longer popular (Bowman & Pranzini, 2001). The basic function of these structures is to provide shelter to the segment of the shoreline, which they protect. Consequently, the protection is limited to this segment. The presence of coastal defence structures is almost always accompanied with accelerated downcoast erosion. Therefore, coastal defence structures do not stop beach erosion, but transfer this problem to another location downcoast. In some applications, the accelerated downcoast erosion is compensated by beach nourishment (Rakha & Abul-Azm, 2001).

In addition to transferring erosion downcoast of the protected segment, the coastal defence with hard structures are generally found unattractive by the beach users and are known to contribute negatively to coastal water quality. The so-called “soft” coastal defence measures are listed below:

- Beach nourishment

- Generation of gravel beaches

- Low-crested (submerged) structures (breakwaters, groins)

- Others (dewatering of beach face to decrease erosion-dry beaches, planting sea grass on the sea bottom)

Beach nourishment, which has been the most important soft defense measure during the last decades, indicates the process of feeding a beach periodically with material brought from elsewhere, either to artificially increase the beach area for accommodating a larger number of beach users, or to compensate for the amount of sand that has been removed from the area by erosion.

In the USA, a major shift occurred in the late 1960's from coastal defense utilizing hard structures to beach nourishment. In the mid 1970's, about 80 % of the budget spent for shore protection projects carried out by the Federal Agency (USA Army, Corps of Engineers) was for beach nourishment, and only 20 % was for coastal structures (Basco, 1999). The reason for this change was said to be both ecological and economical.

B. Predicting future erosion

Numerical modeling has developed to be a powerful tool for predicting past, present and future changes in the sea bed topography and shoreline position. The prediction of the historical changes by numerical models helps to understand the scale and composition of the factors that contribute to coastal erosion. Knowledge on the present and future erosion patterns and rates that would occur under different scenarios and strategies is a very important information that contribute significantly to rational coastal development plans and management practices.

A coastal model has three components:

- Wave prediction and transformation
- Wave breaking and breaker zone hydrodynamics
- Shoreline changes

Modeling of highly irregular, turbulent water motion in the breaker zone due to wave breaking and broken waves, and associated sediment transport has been challenging subjects for many researchers for years (Özhan, 1982, 1983, 1987). Several sediment transport models of various complexity levels have been developed. The greatest difficulty in using these models arises from the inadequacy of available information on the parameters that are required by the models (especially by the comprehensive models).

2. Wave model (WAM)

A. Model description

The WAM-model is a third generation wave model which solves the wave transport equation explicitly without any presumptions on the shape of the wave spectrum. It represents the physics of the wave evolution for the full set of degrees of freedom of a 2D wave spectrum.

The model runs for any given regional of global grid with a prescribed topographic dataset. The grid resolution can be arbitrary in space and time. The propagation can be done on a latitudinal-longitudinal or on a Cartesian grid. The model outputs the significant wave height, mean wave direction and frequency, the swell wave height and mean direction, wind stress fields corrected by including the wave induced stress and the drag coefficient at each grid point at chosen output times, and also the 2D wave spectrum at chosen grid points and output times.

The model runs for deep and shallow water and includes depth and current refraction. The integration can be interrupted and restarted at arbitrary times. The source terms and the propagation are computed with different methods and time steps. The source term integration is done with an implicit integration scheme while the propagation scheme is a first order upwind flux scheme. The wind time step can be chosen arbitrarily.

Sub-grid squares or so called coarse grid can be run in a nested mode or so called fine grid. In a coarse grid run the spectra can be outputted at the boundaries of a sub-grid. They can then be interpolated in space and time to the boundary points of the fine sub-grid and the model can be rerun on the fine mesh grid.

The model was developed at the Max-Planck-Institute fur Meteorology in Hamburg (Germany) by S. and K. Hasselmann with the aid of P. Janssen and G. Komen (KNMI, Netherlands), and L. Zambreski and H. Gunther (GKSS, Germany, ECMWF, Reading, UK) (1995). It has been installed at about 35 institutions worldwide and is used for research and also operational application. In Thailand, there are many organizations doing researches or working on wave prediction such as Meteorological Department, Hydrographic Department, Chulalongkorn University, GISTDA, etc. It is also being applied for interpreting and assimilating satellite wave data.

The model is continually updated to incorporate the latest results of research. The further development of the model is decided by the WAM model development group (Chairman K. Hasselmann, 1995). The WAM model is available to the entire research and forecasting community. It is expected that results achieved with in the model are made available in return to the wave modeling group.

So far four cycles of the model have been issued. The last cycle, cycle 4, is a technically enhanced version of cycle 3 carried out by H. Gunther, 1995 (ECMWF, Reading) and in addition includes new wind input physics developed by P. Janssen,

1991. When a new cycle of the model is available members of the WAM-group are automatically informed.

3. Wave transformation model

After the collection process of wind-wave, seabed, and near-shore sediments, the processing of wave, i.e. computational process to find the breaking zone and wave crest’s angle to the shoreline at the breaking zone, is conducted to be used for erosion and sedimentation volume computation and to be used as the data for coastal structure layout design and material sizes. This study used the “Linear wave theory” since this method is widely used especially for the “short wave” computation and its precision is acceptable while the computational process is not so complicated.

When waves move from the deep sea into shore, wave parameters such as height, direction, and wave-induced current will also be changed. Wave transformations, including diffraction, refraction, and reflection, and the motion of waves to the shallow water can be theoretically predicted implementing wave mechanics principles and maritime research papers. Moving-wave parameters and wave at any reference position can be described with following relations:

A. Wave motion

Wave motion equation in the mild slop sea was introduced by Berkhoff (1976) as followed:

$$\frac{\partial}{\partial x}\left(CC_g\frac{\partial\varphi}{\partial x}\right)+\frac{\partial}{\partial y}\left(CC_g\frac{\partial\varphi}{\partial y}\right)+\sigma^2\frac{C_g}{C}\varphi=0 \qquad (1)$$

Where y = perpendicular distance from y and x axes

$C(x,y)$ = Wave Celerity

= $\frac{\sigma}{k}\ x$

σ = Angular Wave Frequency

= $\frac{2\pi}{T}$

k = Wave Number

σ^2 = $kg\tanh(kh)$

T = Wave Period

C_g = Group Velocity

= $\frac{\partial\sigma}{\partial k}$

$\varphi(x,y)$ = “Complex Velocity Potential” function

g = Gravitational acceleration

$h(x,y)$ = Still water depth at (x,y) coordinate

For $\varphi(x,y)$ of “Linear wave”, it can be written in the function of complex number as followed:

$$\varphi = ae^{is} \tag{2}$$

where $a(x,y)$ = Wave amplitude function

$= \dfrac{gH(x,y)}{2\sigma}$

$H(x,y)$ = Wave height at (x,y) coordinate

$s(x,y)$ = Wave phase function

If substitutes $\varphi(x,y)$ from equation 2 in equation 1, it can be written:

$$\frac{1}{a}\left\{\frac{\partial^2 a}{\partial x^2}+\frac{\partial^2 a}{\partial y^2}+\frac{1}{\left(CC_g\right)}\left[\nabla a.\nabla\left(CC_g\right)\right]\right\}+k^2-\left|\nabla s\right|^2=0 \tag{3}$$

or,

$$\nabla.\left(a^2 CC_g \nabla s\right)=0 \tag{4}$$

where ∇ = Gradient Operation

and Wave Phase Function $s(x,y)$ can be written as:

$$\nabla s = \left|\nabla s\right|\cos\theta\vec{i} + \left|\nabla s\right|\sin\theta\vec{j} \tag{5}$$

where $\vec{i}$ and $\vec{j}$ are unit vectors in x and y directions, respectively. Wave refraction can be predicted from Snell's Law of Refraction, as followed:

$$\frac{\sin\theta}{C} = \frac{\sin\theta_0}{C_0} \tag{6}$$

where,

C_0 = Deep water wave celerity, which is:

$$= \frac{gT}{2\pi}$$

θ_0 = angle between deep water wave and reference axis

θ = angle at any position

Wave height H at any (x, y) coordinate will be dependent on the deep water wave height (H_0) and coefficients k_S and k_R, and the wave height can be determined from:

$$H = k_S k_R H_0 \tag{7}$$

where,

k_S = Shoaling Coefficient

$$= \left[\frac{1}{\left(1 + \frac{2kh}{\sinh(2kh)}\right)\tanh(kh)}\right]^{1/2}$$

k_R = Refraction Coefficient

$$= \left[\frac{\cos \theta_0}{\cos \theta} \right]^{1/2}$$

When waves are approaching the shore the energy density will increase until they reach the surf zone where the wave front is steep, and finally the waves break because of the rapidly decreased water depth. From field study and theoretical analysis it was found that breaking waves occur, if:

$$H_b = 0.78 h_b \tag{8}$$

and,

$$H_b = 0.142 L_b \tanh\left(\frac{2\pi h_b}{L_b} \right) \tag{9}$$

From above conditions, Komar and Gaughan (1972) proposed that,

$$H_b = k^* g^{1/5} \left(T H_0^2 \right) \tag{10}$$

where,

k^* = Dimensionless Coefficient equal to 0.39

There are many other equations describing the wave breaking other than equations 8, 9, and 10, for example: Le Mehaute and Koh (1967) equation,

$$H_b = 0.76 H_0 \left(\frac{H_0}{L_0} \right)^{-1/4} m^{1/7} \tag{11}$$

Goda (1970) equation,

$$H_b = 0.17 L_0 \left(1 - \exp\left[-1.5\pi \frac{h_b}{L_0} \left(1 + 15m\right)^{4/3} \right] \right) \tag{12}$$

Weggel (1972) equation,

$$H_b = \frac{\bar{b} h_b}{1 + \frac{\bar{a}\bar{b}}{gT^2}} \tag{13}$$

where,

$\bar{a}$ = $43.75\left[1 - e^{(-19m)}\right]$

$\bar{b}$ = $\dfrac{1.56}{\left\{1 + e^{(-19.5m)}\right\}}$

L_0 = Deep water wave length

m = Sea slope

h_b = Water depth at breaking zone

H_b = Wave height at breaking zone

L_b = Wavelength at breaking zone

The above equations can be solved by Finite Difference suing the RCPWAVE (Regional Coastal Process Wave Model) computer program developed by Coastal Engineering Research Center (CERC), US Army Corps of Engineers in 1986.

4. Shoreline change Model

A. The One-Line Concept

The 1-line concept rests (As shown in Figure 1) on a common observation that the beach profile maintains an average shape that is characteristic of the particular coast, apart from times of extreme change as produced by storms. For example, steep beaches remain steep and gently sloping beaches remain gentle in a comparative sense and in the long term. Although seasonal changes in wave climate cause the position of the shoreline to move shoreward and seaward in a cyclical manner, with corresponding change in shape and average slope of the profile, the deviation from an average beach slope over the total active profile is relatively small. Pelnard-Considere (1956) originated a mathematical theory of shoreline response to wave action under the assumption that the beach profile moves parallel to itself, i.e., that it translates shoreward and seaward without changing shape in the course of eroding and accreting. If the profile shape does not change, any point on it is sufficient to specify the location of the entire profile with respect to a baseline (Figure 2). Thus, one contour line can be used to describe change in the beach plan shape and volume as the beach erodes and accretes. This contour line is conveniently taken as the readily observed shoreline, and the model is therefore called the "shoreline change" or "shoreline response" model. Sometimes the terminology "one-line" model, a shortening of the phrase "one-contour line" model is used with reference to the single contour line.

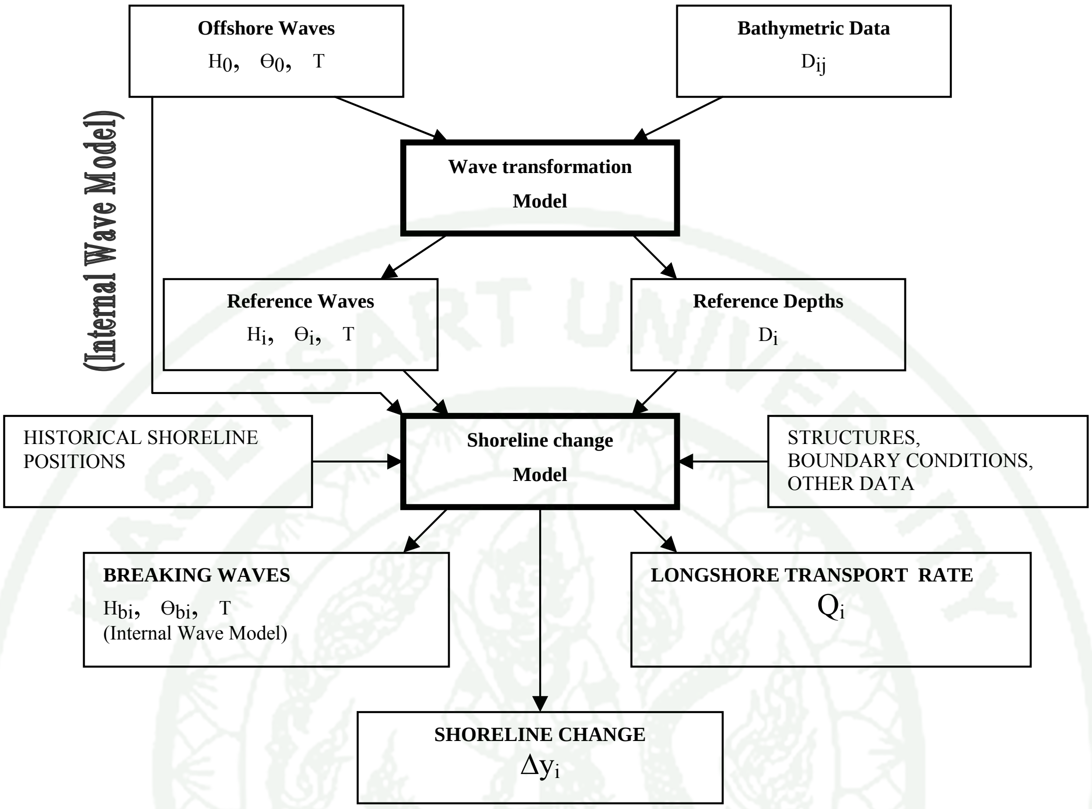


Figure 1 Basis of shoreline change model

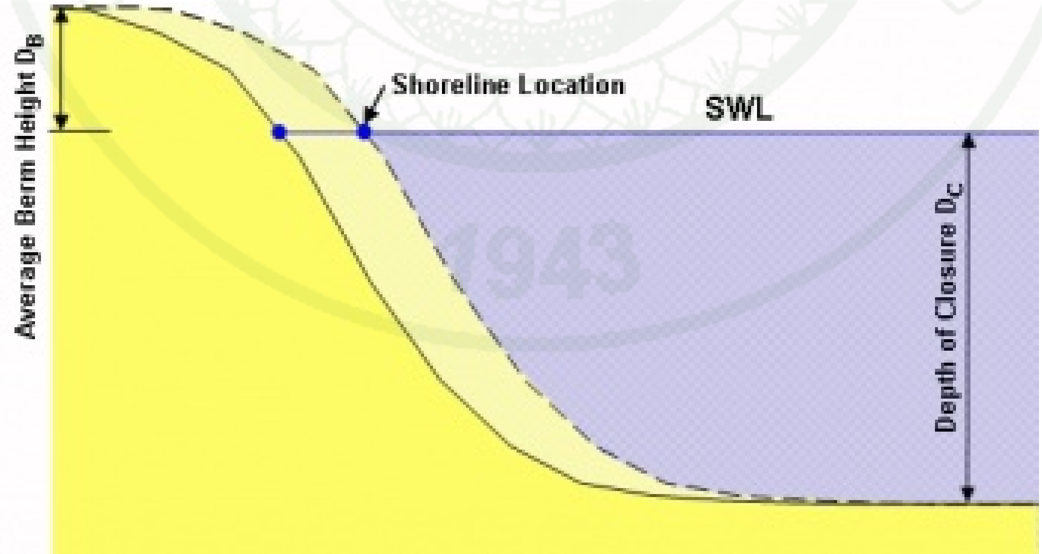


Figure 2 Shoreline change and associated bottom profiles

A second geometrical-type assumption is that sand is transported alongshore between two well-defined limiting elevations on the profile. The shoreward limit is located at the top of the active berm (DB in Figure 2), and the seaward limit is located where no significant depth changes occur, the so-called depth of closure (DC in Figure 2). Restriction of profile movement between these two limits provides the simplest way to specify the perimeter of a beach cross-sectional area by which changes in volume, leading to shoreline change, can be computed. Thus, it is assumed that the beach profile translates seaward or shoreward along a section of shore without changing shape when a net amount of sand enters or leaves the section during a time interval Δt. The change in shoreline position is Δy (Figure 3), the length of the shoreline segment is Δx, and the profile moves within a vertical extent defined by the height of the berm DB and the depth of closure DC. The change in volume of the section is $\Delta V = \Delta x \Delta y\ (DB + DC)$, and it is determined by the net rate of sand entering and leaving the section from its two sides. The volume change results if there is a difference in the longshore sand transport rates Q at the lateral sides of the cells. This net volume change is $\Delta V = \Delta Q \Delta t$. Rearrangement of terms yields the governing equation for the rate of change of shoreline position:

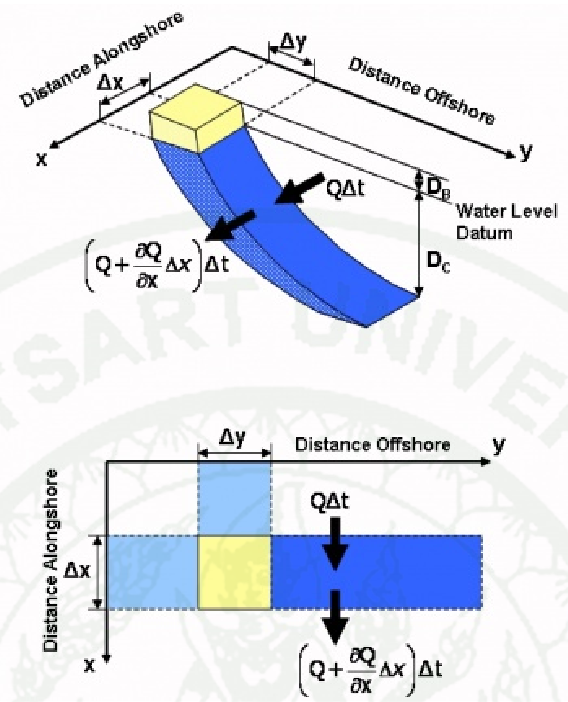


Figure 3 Definition sketch for shoreline change calculation

$$\frac{\Delta y}{\Delta t} + \frac{1}{(D_B + D_C)} \frac{\Delta Q}{\Delta x} = 0 \tag{14}$$

The model also requires predictive expressions for the total longshore sand transport rate. For open-coast beaches, the transport rate is a function of the breaking wave height and direction alongshore. The predictive formula for the longshore sand transport rate used in GENESIS is

$$Q = (H^2 C_g)_b (a_1 \sin 2\alpha_{bs} + a_2 \cos \alpha_{bs} + \frac{\partial H}{\partial x}) \tag{15}$$

in which H = wave height, Cg = wave group speed given by linear wave theory, b = subscript denoting wave breaking condition, and αbs = angle of breaking waves to the local shoreline. The non-dimensional parameters a1 and a1 are given by

$$a_1 = \frac{K_1}{16(s-1)(1-p)W} \tag{16a}$$

and

$$a_1 = \frac{K_2}{8(s-1)(1-p)W\tan\beta} \tag{16b}$$

in which K1 and K2 = empirical coefficients, treated as a calibration parameters, s = ρs/ρ, ρs = density of sand (taken to be 2.65 103 kg/m3 for quartz sand), ρ = density of water (1.03 103 kg/m3 for sea water), p = porosity of sand on the bed (taken to be 0.4), tanß = average bottom slope, and W = a numerical factor (W = 1.4165/2) used to convert from significant wave height, the statistical wave height required by GENESIS, to root-mean-square (rms) wave height. Figure 5 shows the representation of several cells along a coastal stretch down-drift of a short groin.

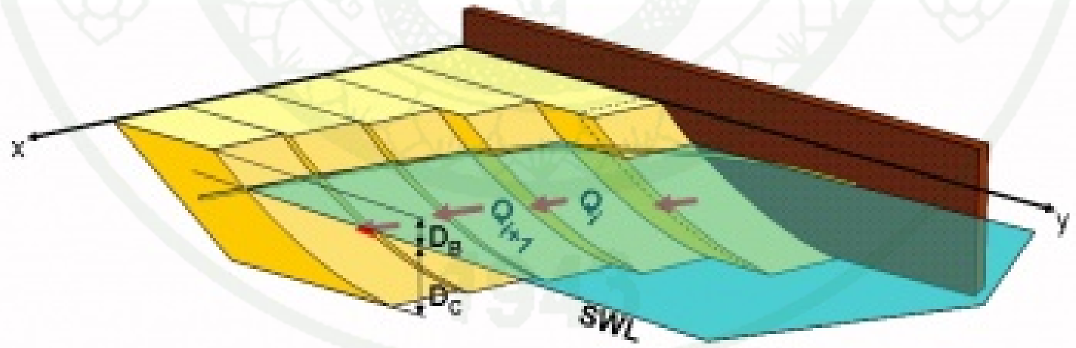


Figure 4 Coupled calculation cells alongshore.

B. GENESIS MODEL

The mathematical model called GENESIS (Generalized Model for Simulating Shoreline Change) developed by the Coastal Engineering Research Center, US Army Corps of Engineers, Department of the Army will be used. The coastal wave data to be input to the model is the transition of wave in the deep water moving into shore to which the analysis of refraction-analysis mathematical model is required.

GENESIS is designed for coastal change analysis in the long term occurring due to the coastal sediment movement. The model is also able to analyze the change due to the construction of coastal structures and beach nourishment. The input data of the model are offshore wave characteristic, beach characteristic, detail of structures, sand nourishment, etc.

The following equation is used to calculate the coastal-parallel sediment movement rate in GENESIS:

$$Q = \left(H_b^2 C_{gb}\right)\left(K_1 \sin 2\alpha_b - K_2 \cos\alpha_b \frac{\partial H_b}{\partial y}\right) \tag{17}$$

where

H_b = wave amplitude where it breaks

C_{gb} = wave-group amplitude where it breaks

α_b = diffraction angle where the wave breaks

Q = coastal-parallel sediment movement rate

y = distance measured along the shoreline

K_1, K_2 = coefficients of sediment flow.

The fundamental assumptions of GENESIS are:

- Static beach pattern
- Land and sea boundaries of the cross section remain unchanged.
- Sand is carried along the coast by the breaker's force.
- Long term coastal change

GENESIS is one-dimensional model and grid pattern calculation. The values along the x axis represent the distances along the coastline while the values in the y axis represent the distances perpendicular to the coastline. The model will calculate for the coastline and grid using input parameters i.e. coordinate system and grid size, suitable area boundary, offshore and near shore wave conditions, coastal structure, sand size, beach, critical depth of sand movement, coefficients of coastal movement K_1 and K_2, and the original coastline.

Decision Support System

For the coastal protection design, in each specific area, there are the differences in wave, wind, tide, current and shoreline conditions. Such data are important for choosing the coastal protection design. In general, the coastal protection designing process starts with the deep water wave condition calculation in the studied area by using the Wave Hind-casing Model. Then, the Wave

Transformation Model working together with topographic data will present the wave energy condition coming from the deep water to the beach in any studied area. As a result, the above output data is used for choosing the coastal protection design in the coastal structure layout and their dimension and materials. In this research, the analysis will be done by using various possible coastal structure scenarios and Multi-criteria Analysis (MCA) to evaluate all impacts both negative and positive ways caused from those scenarios. After that, the whole system will be integrated by GIS development for decision support system of coastal protection design system. The detailed topics will be mentioned as followed:

- Decision support system
- Coastal protection design
    - Wave hind-casting model
    - Wave transformation model
    - Shoreline change model
    - Geographical Information Systems (GIS)
    - Coastal structure design

1. Decision Support System (DSS)

Decision Support Systems (DSS) are a specific class of computerized information system that supports business and organizational decision-making activities. A properly designed DSS is an interactive software-based system intended to help decision makers compile useful information from raw data, documents, personal knowledge, and/or business models to identify and solve problems and make decisions(cf., Natis, 2003; Whetten, 2001).

Typical information that a decision support application might gather and present would be:

- Accessing all of your current information assets, including legacy and relational data sources, cubes, data warehouses, and data marts

- Comparative sales figures between one week and the next

- Projected revenue figures based on new product sales assumptions

- The consequences of different decision alternatives, given past experience in a context that is described

A DSS is an interactive computer-based system or subsystem intended to help decision makers use communications technologies, data, documents, knowledge and/or models to identify and solve problems, complete decision process tasks, and make decisions. Decision Support System is a general term for any computer application that enhances a person or group's ability to make decisions. Also, Decision Support Systems refers to an academic field of research that involves designing and studying Decision Support Systems in their context of use. In general, Decision Support Systems are a class of computerized information system that support decision-making activities (cf., Booch, Rumbaugh and Jacobson, 1999; Eeles, 2006; Gamma, Helm, Johnson and Vlissides, 1995). Four specific Decision Support System bases include (Figure 5):

- Data base

- Model base

- Dialogue base

- Knowledge base

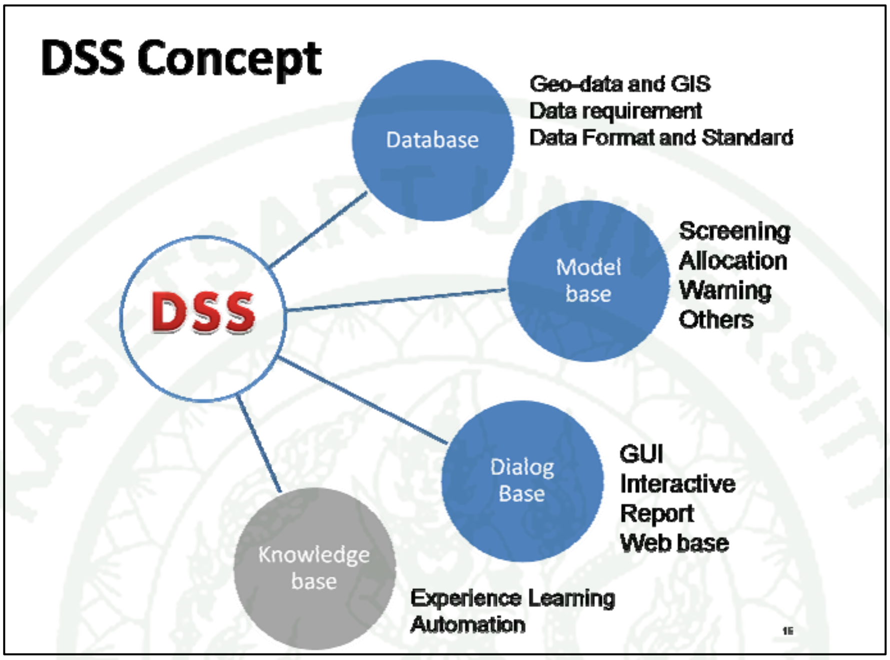


Figure 5 Four specific decision support system bases

2. Types of Decision Support System

It is important to note that the DSS field does not have a universally accepted model. That is to say, there are many theories vying for supremacy in this broad field. Because there are many working DSS theories, there are many ways to classify DSS.

For instance, one of the DSS models available bears the relationship of the user in mind. This model takes into consideration passive, active, and cooperative DSS models. Decision Support Systems that just collect data and organize it effectively are usually called passive models. They do not suggest a specific decision, and they only reveal the data. An active DSS actually processes data and explicitly shows solutions based upon that data. While there are many systems that can be active, many organizations would be hard pressed to put all their faith into a computer model without any human intervention.

A cooperative Decision Support System is when data is collected, analyzed, and then given to a human who helps the system revise or refine it. Here, both a human and computer component work together to come up with the best solution. While the above DSS model considers the user's relationship, another popular DSS model sees the mode of assistance as the underlying basis of the DSS model. This includes the Model Driven DSS, Communications Driven DSS, Data Driven DSS, Document Driven DSS, and Knowledge Driven DSS (Sprague, R.H. and Watson, H.J. 1993).

A. Model Driven DSS

A Model Driven DSS is one in which decision makers use statistical simulations or financial models to come up with a solution or strategy. Though these decisions are based on models, they do not have to be overwhelmingly data intensive.

B. Communications Driven DSS

A Communications Driven DSS model is one in which many collaborate to come up with a series of decisions to set a solution or strategy in motion. This model can be in an office environment or on the web.

C. Data Driven DSS

A Data Driven DSS model puts its emphasis on collected data that is then manipulated to fit the decision maker's needs. This data can be internal or external and in a variety of formats. It is important that data is collected and categorized sequentially, for example daily sales, operating budgets from one quarter to the next, inventory over the previous year, etc.

D. Document Driven DSS

A Document Driven DSS model uses a variety of documents such as text documents, spreadsheets, and database records to come up with decisions as well as further manipulate the information to refine strategies.

A Knowledge Driven DSS model uses special rules stored in a computer or that a human uses to determine whether a decision should be made. For instance, many day traders see a stop loss limit as a knowledge driven DSS model. These rules or facts are used in order to make a decision.

The scope in which decisions are made can also be seen as a DSS model. For instance, an organizational, departmental, or single user decision can be seen in the scope-wide model.

3. Spatial decision support systems (sDSS = GIS+DSS)

Spatial decision support systems (sDSS = GIS+DSS) developed in parallel with the concept of decision support systems (DSS). An sDSS is an interactive, computer-based system designed to support a user or group of users in achieving a higher effectiveness of decision making while solving a semi-structured spatial problem. It is designed to assist the spatial planner with guidance in making land use decisions. For example, when deciding where to build a new airport many contrasting criteria, such as noise pollution vs. employment prospects or the knock on effect on transportation links which make the decision difficult. A system which models decisions could be used to help identify the most effective decision path.

A spatial decision support system typically consists of the following components:

- A database management system – This system holds and handles the geographical data. A standalone system for this is called a geographical information system, (GIS).

- A library of potential models that can be used to forecast the possible outcomes of decisions.

- An interface to aid the users interaction with the computer system and to assist in analysis of outcomes.

- Geographical Information Systems (GIS)

The term GIS was first used in the development of the Canadian Geographic Information system in the early 1960's (Carter J.R., 1988). Since those years, the technology has been widely used and its performance has been improved largely, especially in the last decade, when the use of GIS grew dramatically for many diverse applications. Consequently, many definitions of a GIS have been developed (Burrough P.A., 1986; Star J. and Estes J., 1990). The simplest one considers a GIS as a computer system capable of holding and using data describing places on the earth's surface, while the more complex defines it as an organized collection of computer hardware, software, geographic data and personal designed to efficient capture, store, update, manipulate, analyze and display all forms of geographically referenced information.

A GIS can map any information stored in spreadsheets or databases that has a geographic component to allow you to see patterns, relationships, and trends that could not otherwise have been seen in a table or list format. It gives an entirely new, dynamic perspective on information and helps make better decisions.

A GIS is characterized by a unique ability of a user to overlay spatial layers information and perform spatial queries to create new information, the results of which are automatically tabulated and mapped. Graphical elements describing the location and shape of layer features are dynamically connected to databases, which describe the properties of the features.

Two major types of GIS exist: vector and raster systems (Pearson II F., 1990). In vector systems, location data is populated by structures around coordinates (x, y) and topological relationships. The x, y coordinates identify geographic features locations, and topological data are described using arc, node, and polygon relationships. In raster systems, data are stored as a matrix of grid cells. Each grid cell covers a known, rectangular (generally square) area with one category assigned to each cell and multiple map layers with the same grid representing different parameters.

C. Decision Support System for Coastal Protection Design (DSS4CPD)

The DSS4CPD model described herein is a MapWindow (Ames 2010) plug-in for the design of sprinkler irrigation pipe layouts. The plug-in was developed in VB .NET and compiled as a dynamic link library (DLL file). MapWindow can connect to the DLL, or plug-in, with interfacing functions, and data and event commands

Although it is a single plug-in to MapWindow, it involves the components give above which perform various sophisticated functions and include several thousand lines of code.

1) MapWindow GIS Desktop Application Installation

The MapWindow GIS desktop application is a free, open source, standards-based standalone software package that can be used to view and edit GIS data in many file formats. The user can download the installation software from http://www.MapWindow.org/download.php.

The Plug-in was developed using VB .NET and compiled as a DLL file for MapWindow desktop. For this research the plug-in has three main components:

- Site DATA plug-in
- Wave hind-casting plug-in
- Wave transformation plug-in
- Structure layout design plug-in
- And DSS for coastal protection report

5. Spatial evaluation

In the evaluation process, the impacts from any coastal structure layouts are evaluated by spatial evaluation method. The calculated results are from the intersection between the polygon of Landuse with the Polygon of land and sea areas. In fact, Polygon of land and sea areas is from the shoreline change prediction by using Geo function named intersection. Intersect creates a new coverage by overlaying the features from the input coverage and intersect polygon coverage. The output coverage contains the input features or portions of the input features that overlap features in the intersect coverage. The output features have the attribute from the original feature from the input coverage and the feature in the intersect coverage, which they intersect.

Intersect is one of several Overlay tools available. The tool most similar to Intersect is Clip, which does not transfer any attribute from the overlay feature class to the output. Input Coverage features can be polygons, lines, or points. The intersect coverage must have polygon topology. Output coverage features resulting from the overlay are of the same type as the input coverage features. They are split when they intersect with the polygons of the intersect coverage. Topology is built for the output coverage.

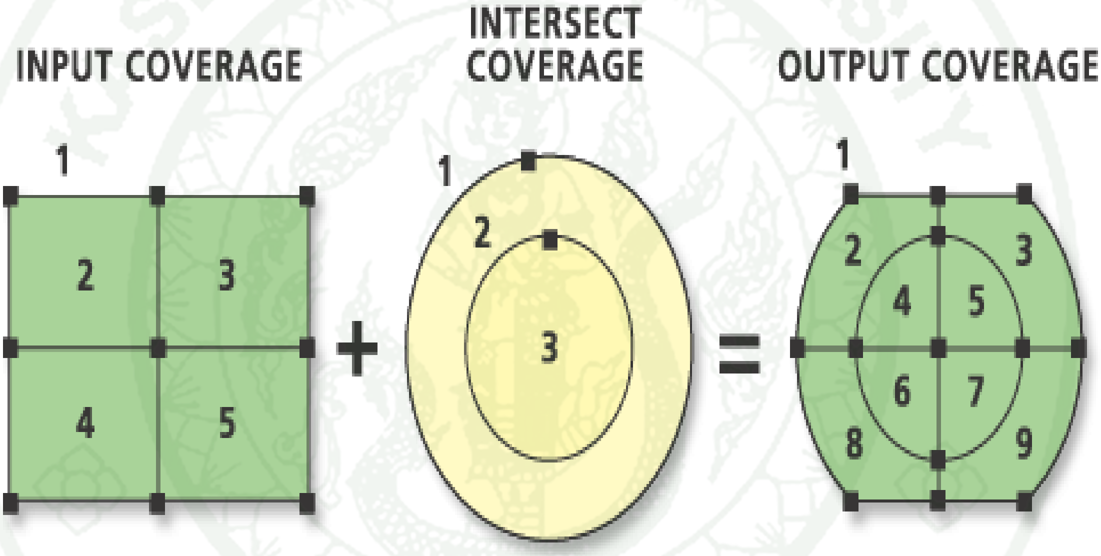
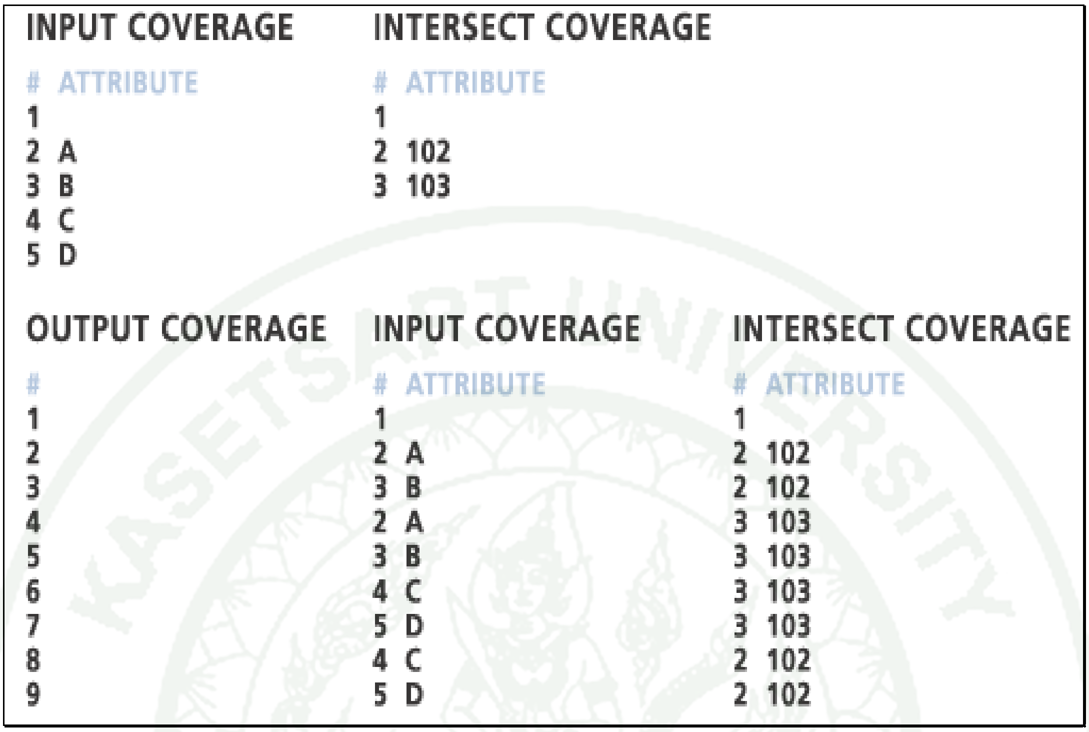


Figure 6 Polygon intersection

Attribute tables are updated. The attribute table for the output coverage contains items from both the input and intersect coverage attribute tables. Items are merged using the old internal number of each feature. The two tables below list the items that are written to the attribute table of the output coverage.



INPUT COVERAGE		INTERSECT COVERAGE	
#	ATTRIBUTE	#	ATTRIBUTE
1		1	
2	A	2	102
3	B	3	103
4	C		
5	D		

OUTPUT COVERAGE	INPUT COVERAGE		INTERSECT COVERAGE	
#	#	ATTRIBUTE	#	ATTRIBUTE
1	1		1	
2	2	A	2	102
3	3	B	2	102
4	2	A	3	103
5	3	B	3	103
6	4	C	3	103
7	5	D	3	103
8	4	C	2	102
9	5	D	2	102

Figure 7 Polygon intersection result table

6. Multi Ccriteria Analysis (MCA)

Multiple-criteria decision-making or multiple-criteria decision analysis is a sub-discipline of operations research that explicitly considers multiple criteria in decision-making environments. Whether in our daily lives or in professional settings, there are typically multiple conflicting criteria that need to be evaluated in making decisions. Cost or price is usually one of the main criteria. Some measure of quality is typically another criterion that is in conflict with the cost. In purchasing a car, cost, comfort, safety, and fuel economy may be some of the main criteria we consider. It is unusual to have the cheapest car to be the most comfortable and the safest. In portfolio management, we are interested in getting high returns but at the same time reducing our risks. Again, the stocks that have the potential of bringing high returns typically also carry high risks of losing money. In service industry, customer satisfaction and the cost of providing service are two conflicting criteria that would be useful to consider.

In our daily lives, we usually weigh multiple criteria implicitly and we may be comfortable with the consequences of such decisions that are made based on only intuition. On the other hand, when stakes are high, it is important to properly structure the problem and explicitly evaluate multiple criteria. In making the decision of whether to build a nuclear power plant or not, and where to build it, there are not only very complex issues involving multiple criteria, but there are also multiple parties who are deeply affected from the consequences.

Structuring complex problems well and considering multiple criteria explicitly leads to more informed and better decisions. There have been important advances in this field since the start of the modern multiple criteria decision making discipline in the early 1960s.

7. Genetic algorithm

A Genetic algorithm (GA) is a random search algorithm that provides a robust method for searching for the optimum solution to complex problems (Goldberg 1989). In a GA, the problem is represented by a population of string (or chromosome, in biological terminology). Each string comprises a number of blocks, which represent the individual decision variables of the problem (genes, in biological terminology). The variables represented in the string can be processed in an evaluation function or fitness function, which is in effect the objective function. In early GAs, decision variables were represented in binary coding in which each block, or gene, is further broken down into a series of binary digits (Goldberg 1989). It has been demonstrated [for example, Wardlaw and Sharif (1999)] that real-value representation, in which genes represent a single variable as a real number, offer a significant advantage over binary coding for some problems.

Strings are processed and combined according to their fitness (objective function value) in order to generate new strings that contain the best features of two parent strings. Strings with the highest fitness have the greatest chance of contributing to future generations, as in the process of natural selection. Excellent introductions to GAs are giving by Goldberg (1989) and Michalewicz (1992).

A. Fundamental Operators of Genetic Algorithms

Three fundamental operators are involved in manipulating strings and moving to a new generation: selection, crossover, and mutation. The approach taken to the operators of selection, crossover, and mutation can influence the results obtained, and different problems may require different approaches.

B. Selection

The selection operator is that through which strings are selected for inclusion in the reproduction process and for participation in the next generation. The fittest strings have the highest probability of being used in reproduction. There are a number of approaches to selection, all of which determine the probability of selection as a function of fitness. A brief review of alternative selection schemes has been given by Wardlaw and Sharif (1999), from which it is clear that tournament selection (Goldberg and Deb 1991; Yang and Soh 1997) offers a means of maintaining diversity in the population. Selection: The selection scheme of DE also differs from other evolutionary algorithms. On the basis of the target vector of current population, $X_{j,i,G}$ and the trail vector of the next population $V_{j,i,G+1}$, the child population, $X_{j,i,G+1}$ is created as follows:

$$X_{i,G+1} = \begin{cases} U_{i,G+1} = u_{j,i,G+1} \text{ if } f\left(U_{i,G+1}\right) \text{ better than } f\left(X_{i,G}\right) \\ X_{i,G} \text{ otherwise} \end{cases} \tag{18}$$

In equation 5, the trial vector $U_{i,G+1}$ is compared to the target vector $X_{i,G}$ using the greedy criterion. If the vector $U_{i,G+1}$yields a better cost function value than $X_{i,G}$, then $X_{i,G+1}$ is replaced by the trial vector $U_{i,G+1}$; otherwise, the old value of the target vector $X_{i,G}$ is retained. The process of mutation, crossover, and selection is repeated until a termination criterion such as maximum number of generation is satisfied. The algorithm then terminates proving the best point that has been explored over all the generations.

C. Crossover

Crossover is an extremely important part of a GA. The crossover operator permits the exchange of blocks of information between pairs of strings in population. This operator offers the possibility of good genetic material from different individual strings being combined to create an even fitter individual. The operator is intended to preserve the best material from two parent strings. The number of strings in which material is exchanged is controlled by the crossover probability, which is an input to a GA and is normally in the range of 0.5 and 1.0. Three approaches to crossover are described by Goldberg (1989) and Michalewicz (1992): one-point crossover, two-point crossover, and uniform crossover. An excellent summary of these crossover operators has been given by Wardlaw and Sharif (1999).

Crossover: This process is performed to increase the diversity of the perturbed parameter vectors. In this step, the trial vector, $U_{i,G+1}$ is produced by duplicating some elements of the mutant vector, $V_{i,G+1}$ or some elements of the target vector, $X_{i,,G}$with proability equal to CR. For the first generation, target vector is the best vector of all individuals in initial population and it is the best vector obtained of all individuals obtained from selection process (as will be described in the next topic) for subsequent generation. As shown in figure.8, a random number (ran) is generated for each element of the target vector. If $randb(j) \leq CR$ or $j = rnbr(i)$, the element of mutant vector is copied, otherwise the target vector element is copied. The trial can be expressed as:

$$U_{i,G+1} = \left(U_{1i,G+1}, U_{2i,G+1}, \ldots, U_{Di,G+1}\right) \tag{19}$$

and the crossover process can be presented in a mathematical form as:

$$U_{i,G+1} = \begin{cases} V_{i,G+1} & if \ \left(randb(j) \leq CR\right) \ or \ j \ = \ rnbr(i) \\ X_{i,G} & if \ \left(randb(j) > CR\right) \ or \ j \ \neq \ rnbr(i) \end{cases} \tag{20}$$

where *randb(j)* is the jth evaluation of a uniform random number generator with outcome $\in$ [0,1]; *CR* is the crossover constant $\in$ [0,1] which has to be determined by the users; *rnbr(i)* is a randomly chosen index $\in$ 1,2,3,..,D which ensures that $U_{j,i,G+1}$ gets at least one parameter from $V_{j,I,G+1}$. Usually, the suitable values for F, CR and NP can be found by experimentation after a few tests using different values. Practical advice on how to select control parameters NP, F and CR can be found in Storn and Price (1997). A reasonable first guess is: F = 0.9, CR = 0.9 and NP = 10D.

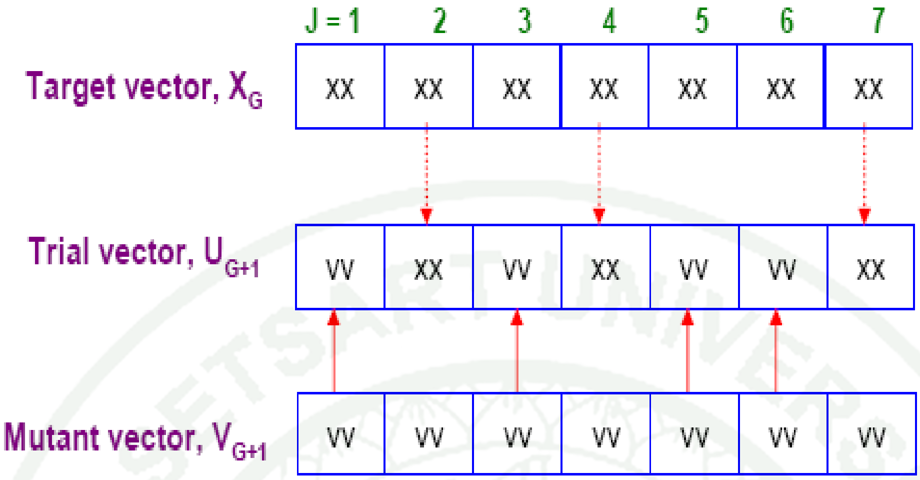


Figure 8 Illustration of the crossover process for $D = 7$ parameters.

Source: Modified from Stron and Price (1997); Srivinas and Rangaiah (2006).

D. Mutation

The mutation operator permits new genetic material to be introduced into a population. A mutation probability can be specified that permits random mutation. In binary representation, individual alleles or bits of a gene simply have their values changed from 0 to 1 or vice versa. For real-value representation, Michalewicz (1992) has outline two basic approaches to mutation uniform and non-uniform. In uniform mutation, the value of a gene can be mutated randomly within its feasible range of values, while modified uniform mutation permits modifications of a gene by a specified amount. In non-uniform mutation, the amount by which genes can be mutated is reduced as the run progresses, thereby reducing the risk of disturbing good solutions.

Mutation: there is the usage a self-referential population recombination scheme, which is different from the other evolutionary algorithms, for creating new generation. From the first generation onward, vectors in the current population, P_G, are randomly sampled and combined to create candidate vectors for the subsequent generation, P_{G+1}. The population of candidate, or mutant vectors, $P'_{G+1} = V_{i,G+1}$, is generated as follows:

$$V_{i,G+1} = X_{r1,G} + F\left(X_{r2,G} - X_{r3,G}\right),\ i=1,2,3,...,NP \tag{21}$$

where r_1,r_2 and r_3 belongs to the set {1,2,3,…, NP} and $X_{r1,G}$, $X_{r2,G}$ and $X_{r3,G}$ represent the three random individuals chosen in the current generation, *G*, to reproduce the mutant vector for the next generation $V_{i,G+1}$. The random numbers r_1,r_2 and r_3 should be different from each other and also different from the running index, *i,* and hence *NP* should be at least 4 to allow mutation. *F* is weighting factor, real number between 0 and 2; this value is used to control the amplification of the differential variation between the two random vectors.

Coastal Protection Design

The coastal protection system in this research is to use coastal structure. For the coastal structure design, the designers are required to understand wind and wave conditions, geographic information, and etc. that influenced on decision making. All data and information are from model calculation results which have the inputs from database. DSS for coastal protection design (DSS4CPD) that has been developed from this research is the integration of many elements related to the coastal structure design. The details will be mentioned later.

1. Types and Functions of Coastal Structures

Coastal structures are used in coastal defense schemes with the objective of preventing shoreline erosion and flooding of the hinterland. Other objectives include sheltering of harbor basins and harbor entrances against waves, stabilization of navigation channels at inlets, and protection of water intakes and outfalls (Shore Protection Manual, 1984)

A. Seawalls

Seawalls are usually massive, vertical structures used to protect backshore areas from heavy wave action, and in lower wave energy environments, to separate land from water (Figure 9). They can be constructed using a range of materials, the most common being poured concrete, steel sheet pile, concrete blocks, gabions, and timber cribs. There are various types of seawalls.

Figure 9 Seawall

Usually massive structures, constructed with poured concrete, curved seawalls have a slight concave curve built into their face that is designed to deflect incoming wave energy up and away from the bottom, thereby reducing scour at the base of the wall.

B. Groins

Groins are the oldest and most common shore-connected, beach stabilization structure (Figure 10). They are structures that extend, fingerlike, perpendicularly or nearly right angles from the shore (see photo at right), and are relatively short when compared to navigation jetties at tidal inlets. Usually constructed in groups called groin fields, their primary purpose is to trap and retain sand, nourishing the beach compartments between them.

Figure 10 Groin

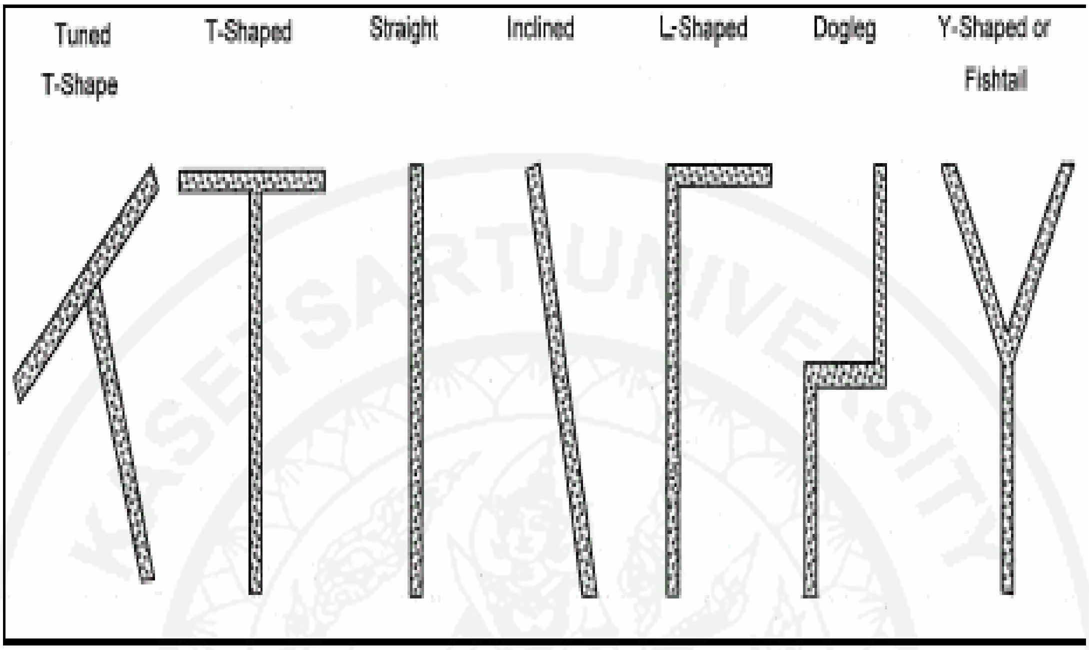


Figure 11 Groin types

C. Breakwaters

Breakwaters are generally shore-parallel structures that reduce the amount of wave energy reaching the protected area. They are similar to natural bars, reefs or nearshore islands and are designed to dissipate wave energy. The reduction in wave energy slows the littoral drift, produces sediment deposition and a shoreline bulge or "salient" feature in the sheltered area behind the breakwater. Some longshore sediment transport may continue along the coast behind the nearshore breakwater (Figures 11 and 12).

Figure 12 Breakwaters

A series of breakwaters constructed in an "attached" fashion to the shoreline and angled in the direction of predominant wave approach such that the shoreline behind the features evolves into a natural "crenulate" or log spiral embayment Breakwaters are typically constructed in high wave energy environments using large armor stone, or pre-cast concrete units or blocks. In lower wave-energy environments, grout-filled fabric bags, gabions and other proprietary units have been utilized. Typical breakwater design is similar to that of a revetment, with a core or filter layer of smaller stone, overlain by the armoring layer of armor stone or pre-cast concrete units.

2. Rock size calculation

Rubble mound structures consisting of interior graded layers of stone and another armor layer of stone or specially shaped concrete units are employed in the coastal zone as breakwaters, jetties, groins, and shoreline revetments. An advantage of rubble mound structures is that failure of the armor cover layer is not typically sudden, complete, and due to a few large waves but gradual and usually partial in extent, and spread over the duration of the higher waves that occur in a storm. If damage does occur, the structure usually continues to function and the damage can be repaired after the passage of the storm. In some cases it may be economical to use smaller size armor units, anticipate a certain amount of damage during a design storm, and provide for subsequent repair of the structure.

Armor units must be of sufficient size to resist wave attack. However, if an entire structure were to consist of units of this size, the structure would allow high levels of wave energy transmission and finer material in the foundation or embankment below the structure could easily be removed. Thus, the structure unit sizes are graded in layers, from the large exterior armor units to small quarry-run sizes and finer stone at the core and at the interface with the native soil bed.

Hudson formula is to be used for calculating the coastal structure rock size which relies on the wave height. In fact, the wave transformation data result is to be used by DSS4CPD in the calculation of the structure as shown in Figure 13.

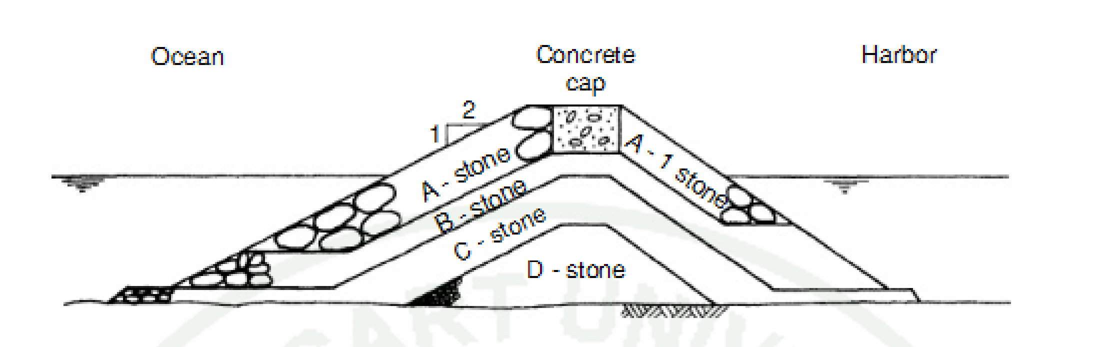


Figure 13 Typical rubble mound breakwater cross-section.

To illustrate, the rock size in layer A which is the biggest rock size layer, is to be able to absorb the wave energy directly. For the next layer, the rock size is varied under the standard ratio. The governing equation is as followed: Hudson's formula

$$w = \frac{\gamma_a H^3}{k_d (s_a - 1)^3 \cot(\alpha)} \tag{22}$$

where:

w = Weight of individual stone (N)

γ_a = Specific weight of stone (N/m^3)

k_d = Stone shape coefficient

S_a = Specific gravity of stone (N/m^3)

α = Slope angle of breakwater

MATERIALS AND METHODS

Materials

The development of Decision Support System for Coastal Protection Design (DSS4CPD) software required the following materials. The software was developed by using Visual basic .NET programming language. The developed modeling was tested using personal computers CPU 3.0 GHz with 1 GB of RAM. Finally, several official apparatus such as a printer, paper, etc. were also required to complete this work.

Methods

1. Overview of DSS for coastal protection design

This research has its objective to use wave model and wave transformation model to understand wave characteristics coming from deep water to shallow water, to develop a wave breaking zone model in order to make an appropriate coastal structure layout alignment, and to use a shoreline change model to evaluate the shoreline changes impacted from the coastal structure layouts, and then, to integrate all models together to be used as the decision support system, DSS. DSS for coastal protection design is later so called DSS4CPD consisting of three major elements: 1) Data base, 2) Model base, and 3) Dialog base, which all three parts will be working together in order to evaluate, analyze, and demonstrate all decisive information to help the coastal engineers or designers to make such decisions. In this research, the 3 models have been integrated to work together with GIS to demonstrate the wave condition which is directions and heights from deep water transforming to the beach, and to demonstrate the wave breaking zone nearshore for making the coastal structure layout, and to show all shoreline change scenario results impacted from any coastal structure layouts, and then the appropriate layout solution.

To illustrate, the deep water wave in this study is from the results of WAM model to be used as the boundary condition, and it is represented in the picture of wave rose, wave table, and wave direction and magnitude maps. For the wave transformation model, RCPWave model is used for demonstrating the waves transformed from deep water to shallow water, and also having the wave breaking zone. All data are very helpful for coastal engineers and others in order to use as the supporting data for coastal structure layout design. In order to make the appropriate coastal structure layout, the designers will use all mentioned data and make all possible layout scenarios. After that, all layout scenarios will be analyzed by using developed equilibrium shoreline change model to be used for the evaluation. The evaluated results are presented as the shoreline changes from time to time, and they are presented in the amount eroded area or accumulated area in order to understand the seriousness of the erosion of any layout relevant to land use in the project area. When the positive and negative impacts both sizes and positions are known from doing the mentioned evaluation, the most appropriate layout solution will be chosen from all possible scenarios; so, the decision makers can make the right decision in doing that. The DSS4CPD framework is as shown in Figure 14.

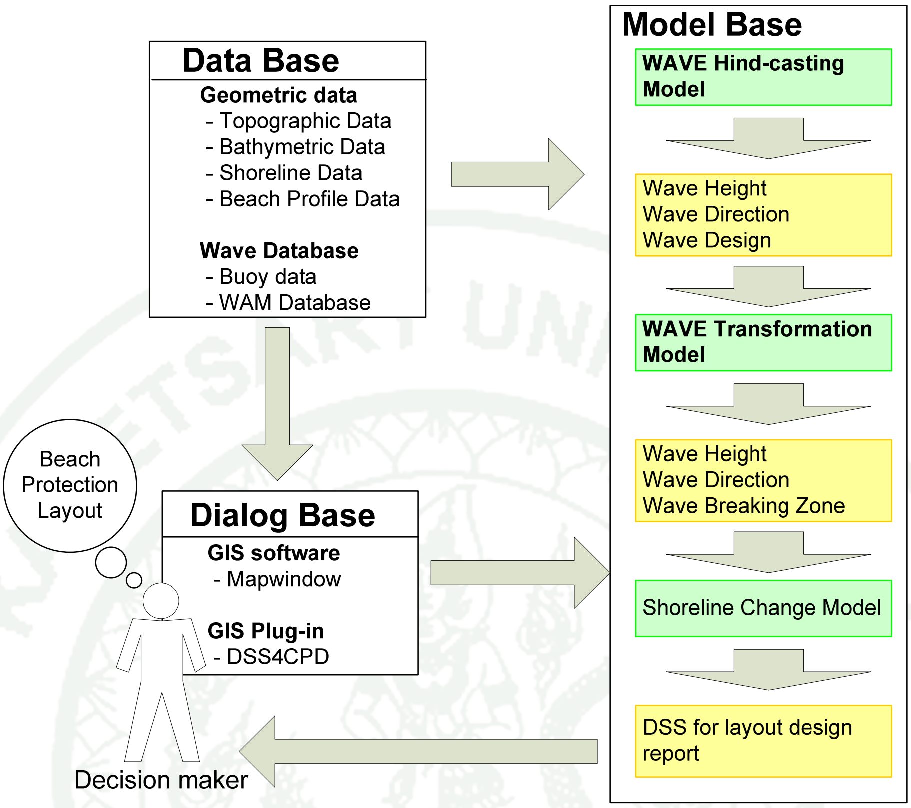


Figure 14 DSS4CPD Framework

2. System Development

A. Data base development

The database used for the DSS can be divided into 3 components, which are physical information on study area, wave information in the required area, and the information on coastal protection structure. In the development process of database, 3 formats of database were used including GIS map (shapefile, Grid file and image map file). For wave information, the format of data would be tabled. Information used in DSS4CPD of:

- Wave Data
- Bathymetry data
- Arial photo

- Shoreline data
- Designing Baseline data
- Beach profile
- D_{50}

With the following details:

1. Wave Data

Wave data used for DSS database development are from WAM simulation of the Hydrographic Department, Royal Thai Navy with 12 wave parameters:

1. Wind Speed
2. Wind Direction
3. Mean Wave Direction
4. Wave Peak Frequency
5. Wave Peak Period
6. Mean Wave Period
7. Normalized Wave Stress
8. Drag Coefficient
9. Mean Frequency
10. Friction Velocity
11. Significant Wave Height
12. Maximum Wave Height

2. Bathymetric data

Bathymetric data is the important data for coastal structure design. In fact, the bathymetric data shows cross section profiles, and water depth contour. The water depth affects wave ray diffraction and reflection coming from deep water to shallow water. When the data is considered together with cross section profiles and sediment size, the active depth and its distance from shore can be demonstrate in the map picture as shown in Figure 15 in order to calculate the shoreline change later on.

Surveying data, from sounding or depth measurement using echo Sounder and positioning using DGPS receiver, are stored in a database directory created by Hydrographic Survey Software “HypackMax” which was run on a notebook. This operation called “Automation Sounding System” provides high accuracy of data on each point. Its easy principal is that HypackMax software synchronously stored the point’s depth from echo sounder and its position from GPS receiver every second via connected cables from both instruments to a notebook. Therefore, at each of every second, there are always depth and position data stored for its exact point.

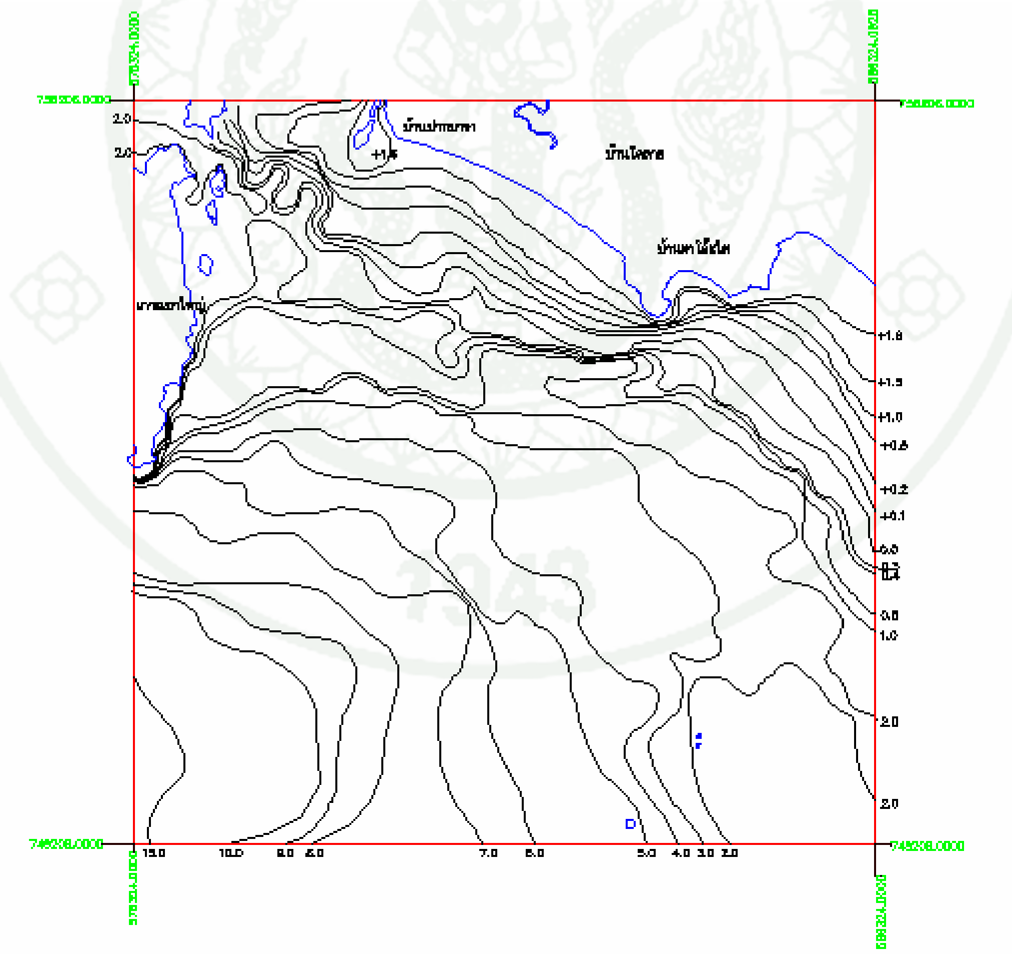


Figure 15 Example of Bathymetric Survey Data

3. Aerial photo

The shoreline change historical data have been recorded by remote sensing or Aerial photo for many years. The Aerial photo data is very important data that shows the accumulation and erosion of beach for all recorded times. In Thailand, the data can be got from Military Map Department, and GISTDA. Mostly, Aerial photos are different in format, size, and position; so, before using them, they are needed to be in the same coordinate system. After photo map digitization, the Aerial photo comparison can be calculated to find the amount of erosion or accumulation area from year to year. In addition, such data is the main important data for model calibration and verification.

4. Shoreline data

Shoreline data is the line of coast changing from time to time depending on the dominant energy in that area. The shoreline change is the historical data recorded and digitized from the Aerial photos for many years. In fact, the Aerial photos are significant data for study areas. They show the coastal change, erosion or deposition, and where. These data will be used for correction and adjustment of the model. The study areas show the changes below: General methodology for define shoreline change as shown in Figure 16.

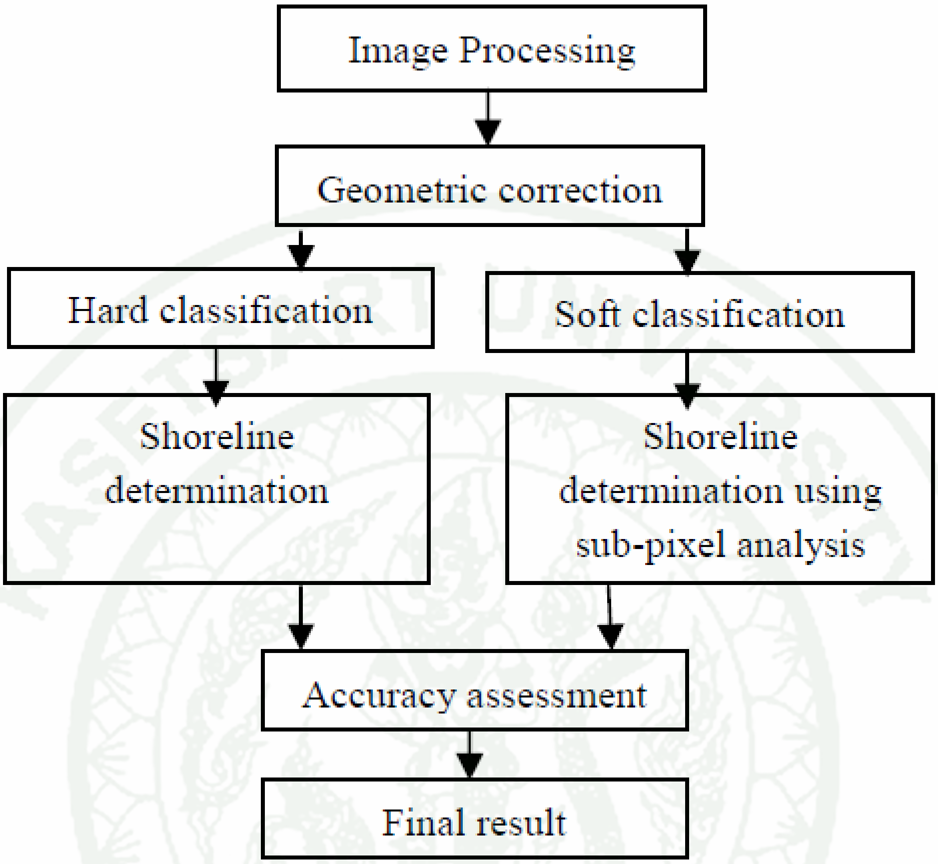
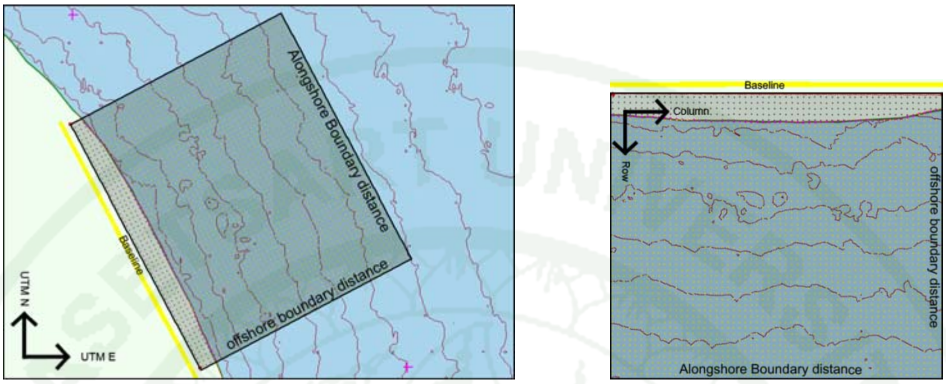


Figure 16 General methodology

5. Designing Baseline data

The baseline is a straight line created by the coastal protection designers by considering coastal engineering aspect. The baseline covers the project area and refers to the map coordinate system and the model coordinate system being used in DSS4CPD. In order to make the baseline, it should be as parallel as it can to the project area shoreline. The baseline is created by starting from having two points along the shoreline on UTM grid system, and those points needed to cover the whole length project area. Then, the straight line is made from those two points, and the baseline is relative to the azimuth (referring to North). However, there is the difference in angle reference from maps and models. As a result, there is the developed function to transform both coordinate systems in order to have the model getting the right input data, and to have the output data getting the right coordinate results in the map as shown in Figure 17.



(a)UTM system (B) Grid system

Figure 17 Model coordinate system

6. Beach profile

The beach profile data is from leveling survey. There benchmark is needed in the survey area for a reference points, Bm-01 and BM-02 referring to the reference leveling monument, were created for a baseline survey of the project. The coordinates of these bench marks were measured by GPS. The coordinates(X and Y) of the base line points is transferred to the control points by traverse method. The elevations is transferred by leveling method. Poling survey is used to measure the positions and elevations of the beach to get the beach profile in the project area. Beach profile data is very important data for knowing depth of closure in the project area. To illustrate, the depth of closure is the distance from shore that wave energy has the impact on the sediment transport in the area. In addition, the sieve analysis is also related to sand sampling in the beach profile position which is also the input data in the model.

7. Median Grain Size (D_{50})

Median grain size, $D_{50}$is the median diameter of sediment transport is the representative of the sediment size in the project area. Sediment properties commonly used include: grain size, grain density, fall velocity, angle of repose, and volume concentration. Sediment size distribution and grain shape are also important because the sediment size is one of the elements in shoreline change process in the study area. For the sand sampling, the sand samples are collected positioning along the beach profile. For the sediment seabed sampling, grab is used as the instrument for sediment sample collection in the sea as shown in Figures 18 and 19. All sand samples both on shore and in the sea are analyzed by sieve analysis method (Shepard ,1954).

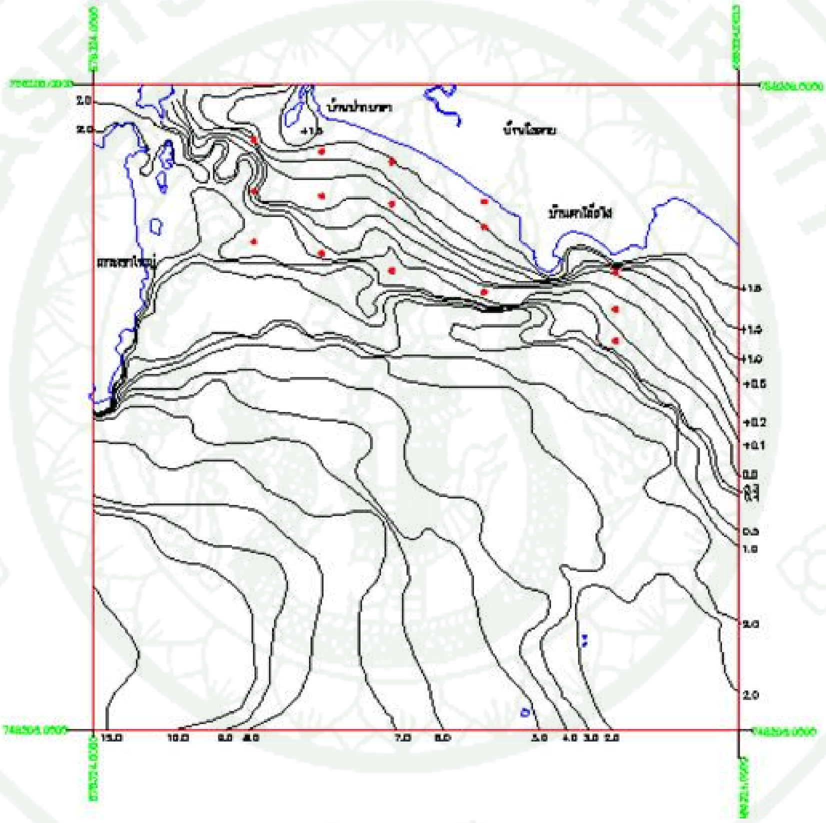


Figure 18 Sand sample collecting points

Figure 19 Sand Survey Sampling Methods

B. Model base development

1. Overview

There are two major parts of the models using in DSS4CPD which are:

1) wave design model to give the results of

a) map of waverose showing wave statistics in magnitude or wave height, frequency, and direction of deep water wave at the project area boundary in the sea

b) wave breaking zone map showing the position of breaking

c) map of wave transformation showing wave magnitude, frequency, and direction of wave coming from deep water to shallow water

In wave design model, there are wave model used for being the deep water wave at the boundary, and wave transformation model giving the data of wave height, wave direction, wave period and breaking zone. For the model integration, GIS Application is used for integrating all models together, and Geo-metric data (Bathymetry, Shoreline, beach profile) and time series data (wind, wave) are also needed as the input data.

2) shoreline change model evaluates the impact of the coastal structures from different coastal structure layout scenarios by using all mentioned data from the data base. Also, details related to the model integration framework as shown in Figure 20.

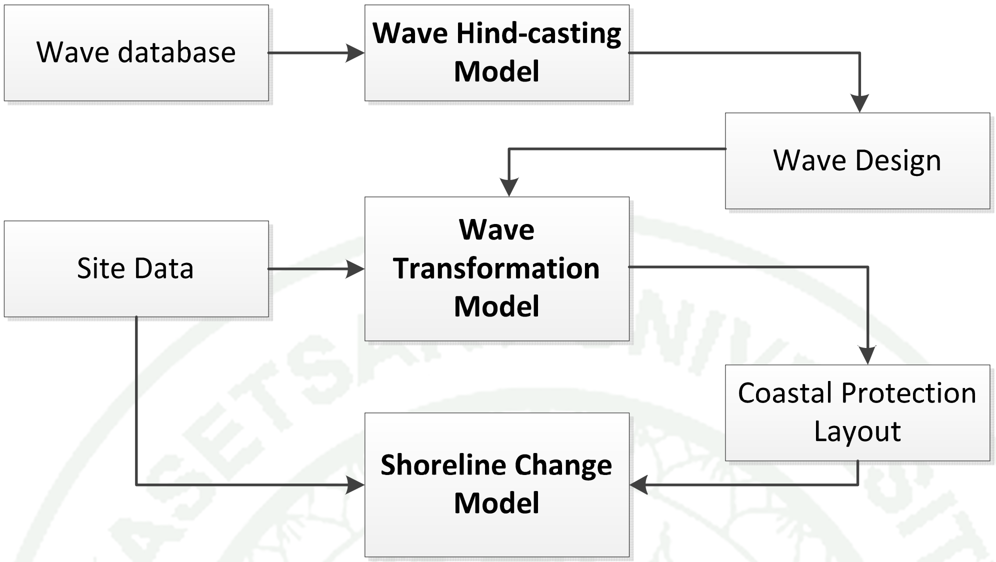


Figure 20 The model integration framework

2. Wave design Model

There are two main wave models using in Wave design model which are: Wave hind-casting model, and Wave Transformation Model In this research, the Wave Hide-Casting Model to be used in the project is WAM. The WAM-model solves the wave transport equation explicitly without any presumptions on the shape of the wave spectrum. The model runs for any given regional or global grid with a prescribed topographic dataset. The model outputs the significant wave height, mean wave direction and frequency, the swell wave height and mean direction, wind stress fields corrected by including the wave induced stress and the drag coefficient at each grid point at chosen output times, and also the 2D wave spectrum at chosen grid points and output times. The model result will be stored as the database.

In this research, WAM is used for wave calculation in both Gulf of Thailand and Andaman Sea from Latitudes 6 to14, and Longitude 97 to 105 by having the calculating grid of 0.25 degree or 15 minute of 1,920 * 1,920 grid points as shown in Figure 21. There is daily wave prediction or wave forecast of WAM by Meteorological Division, Hydrographic Department, Royal Thai Navy as shown in

Figure 22. For the calculated hind-casting data is stored as time series database for further work.

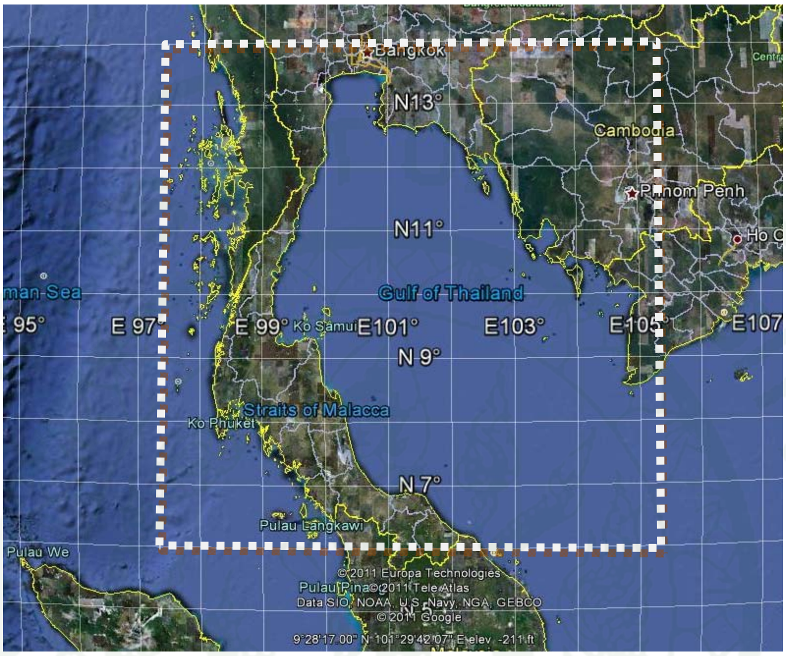


Figure 21 Simulation area of WAM model

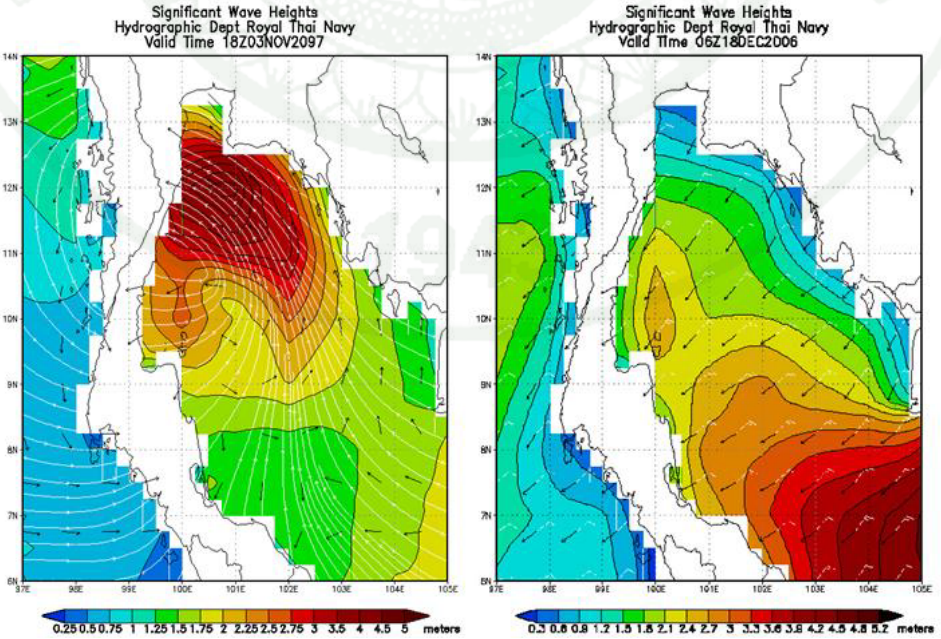


Figure 22 Sample of WAM Simulation result

For the wave design process in any study areas, one selected point on the UTM grid system to be the deep water wave representative at the boundary is required to act as the time series data in the database resulted from WAM model. After that, the deep water wave calculation result demonstrates the picture of waverose showing wave statistics in magnitude, frequency, and direction of deep water wave at the project area boundary as shown in Figure 23.

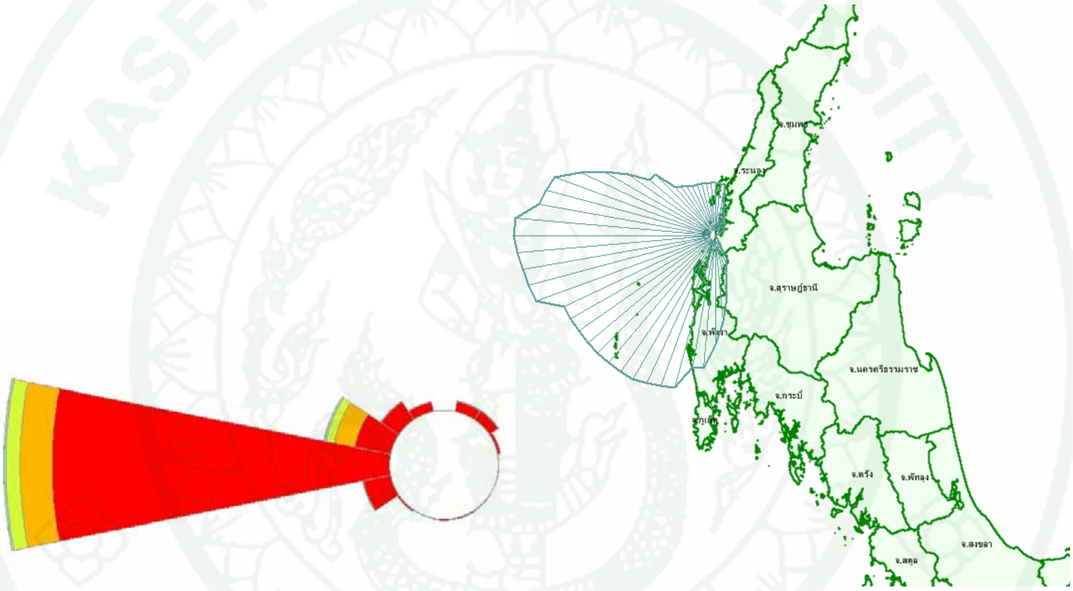


Figure 23 Wave Rose and effect length

Wave height data in the dominant directions from table 1 is statistically analyzed, and gives the results in term of wave height in the return periods of 2, 5, 10, 20, 50, and 100 years. Mostly, for the coastal engineering design, the 50 year return period wave height is used for the design. From waverose, the dominant waves are presented in magnitude (height), periods, and directions. In Thailand, the wave period for using in the study model should be 4 to 10 sec based on the statistics of waves in the Gulf of Thailand. Therefore, the possible scenarios in this research is number of dominant directions multiply number of wave heights multiply number of wave periods as shown in Figure 24.

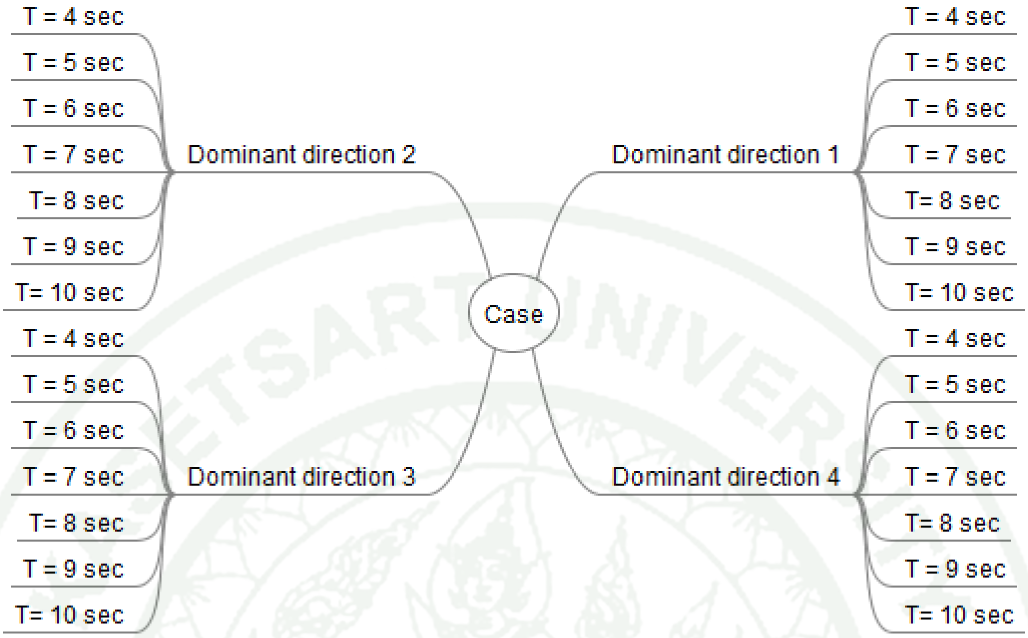


Figure 24 Tree diagram of wave scenarios

The information needed for coastal engineering designers in order to make the coastal protection layout design consists of:

1) Map of wave transformation from deep water to shore in the picture of wave height, frequency, and directions.

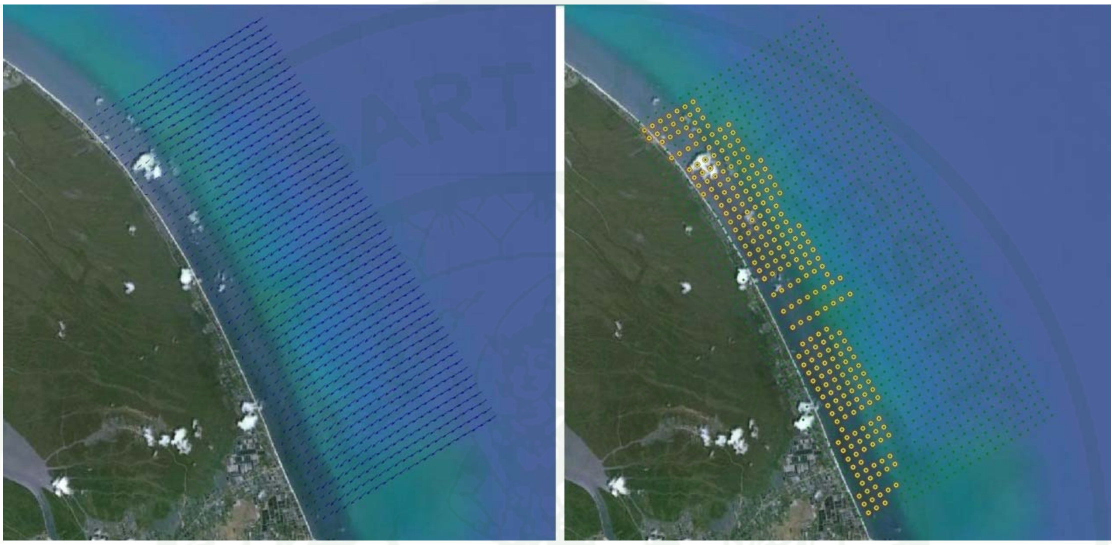
2) Map of wave breaking zone to see the position line of wave breaking

3) Map of significant wave height to see the wave energy at any position

2. Wave transformation model

All data and information are from the calculation results from all scenarios of wave simulation. For wave transformation model simulation preparation (RCPWave), it starts from making baseline (alongshore boundary distance)and the distance perpendicular to the baseline (offshore boundary distance). The DSS4CPD creates the bathymetric grid data and other required data for RCPWave. All scenario data are stored in the folder of wave model data base.

The results of wave simulation for all wave scenarios showing the wave breaking position, wave direction, and wave height at any grid. DSS4CPD demonstrate the final results of all cases. The example is as shown in Figure 25.



(a)Wave height and Direction (B) Wave breaking position

Figure 25 RCPWave simulation result

3. Shoreline change model

In this study, GENESIS (Generalized Model for Simulating Shoreline Change) is the major model for shoreline change prediction. The new predicted shorelines in the model are impacted by the coastal structure layouts for each alternative

a) GENESIS model

The model data for Genesis in all alternatives are generated by DSS4CPD. In DSS4CPD, there are folders for each alternative, and the system will copy files GENESIS.EXE to each folder for the model calculation. After the calculation, the system will get the results which are the new shorelines referred to the baseline. Then DSS4CPD will create the shapefiles to later be presented on GIS. As a result, the designers or decision makers can see and understand all impacts for all alternatives; so, the solution can be made.

b) Calibration for Shoreline change model using GA

The transport equation is used to estimate sand transport under the influence of incident breaking waves which induce longshore transport, where Q is the longshore sediment transport rate (Figure 26), H is waveheight (m), C_g is wave group speed given by linear wave theory (m/sec), b subscript denoting wavebreaking condition, $2\theta_{bs}$ is the angle of breaking waves to the local shoreline, a_1 and a_2 are calibrationparameters strongly correlated with transport coefficients K_1 and K_2 (Equations 23 and 24).

$$a_1 = k_1/(16*(S-1)*(1-\rho)) \tag{23}$$

$$a_2 = k_2/(8*(S-1)*(1-\rho \tan 2H_{br})) \tag{24}$$

Where, ρ is the density of sand, S is the ratio of the density of sand to the density of water, $H_{br}$is theheight of breaking wave, which depends on the transmission coefficient K_t of engineering structures. It was noted from equations 3 and 4 that the transport coefficient K_1 varies with environmental conditions and beach sediment grain size, and the calculated shoreline change is particularly sensitive to K_2 values along the coast having strong wave height gradients in the lee of detached breakwaters.

Genetic algorithm (GA) is used for finding the optimal transport coefficients K_1 and K_2 for each individual shoreline in any place. GA is used by comparing the differences between initial shoreline and final shoreline until it get the optimal shoreline with the minimum error as shown in Figure 27

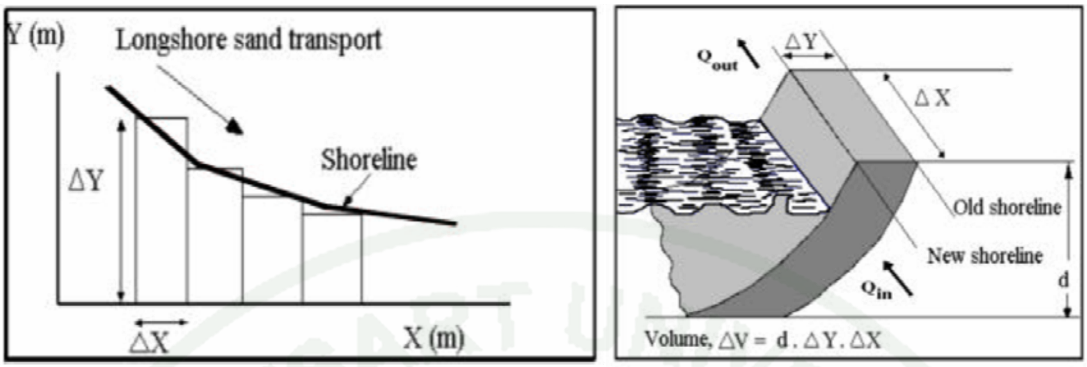


Figure 26 GENESIS Shoreline change model concept

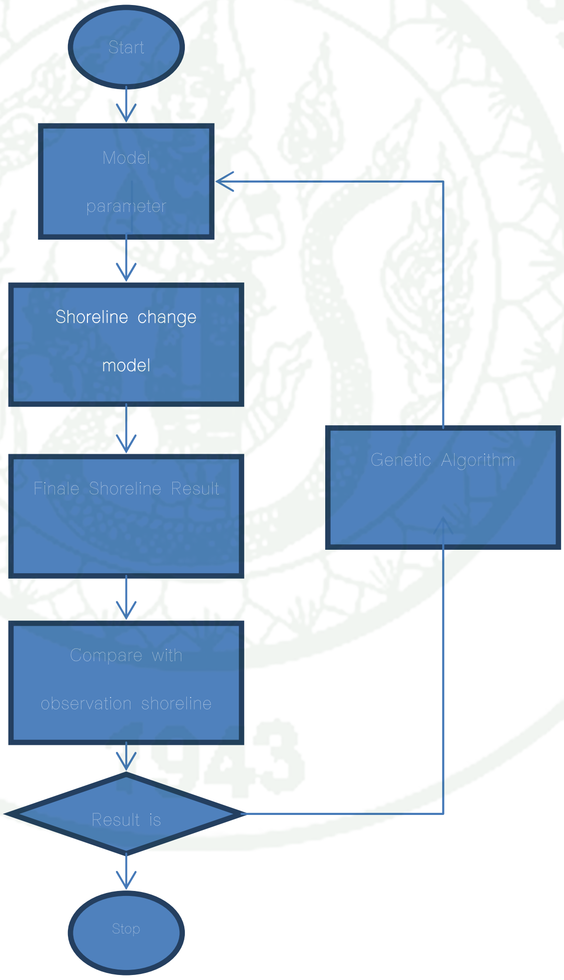


Figure 27 Framework of GA for shoreline change model and related coefficients: K_1, and K_2.

C) Multi Criteria Analysis (MCA)

The decision making for coastal protection design has to deal with many conditions and many dimensions; thus, the tool for analyzing and managing such aspects is needed to get the understandable result. In fact, it should be convenient for users or decision makers in order to find the solution. The multicriteria analysis (MCA) is one of the standard methods to solve such complicate problem. The multicriteria analysis (MCA) which works with Geographic Information System (GIS) called Spatial Multi Criteria Analysis is widely used (Boroushaki and Malczewski, 2008; Liu et al., 2007; Malczewski, 2006a). Some systems includes MCA for their analysis method such as IDRISI (Eastman, 1997). In addition, MCA can analyze the area data in polygon format with GIS as ArcInfo program (Hill et al., 2005) in Arc Macro Language (AML).

In this research, the Spatial Multi Criteria Analysis had been applied by having three MCA layers in GIS to work in the evaluation process. The three layers are (1) Landuse Layer, (2) Building Layer, and Sensitive area Layer. The weighting ratio are 0.5, 0.2, and 0.3 consequently. The details are as followed:

(a) Land used criteria

Land used criteria consists of five landuse types which have their own scores as in Table 1

Table 1 Land use score

Type	Description	Score
1	habitat	100.0
2	industry	75.0
3	fishery	50.0
4	agriculture	25.0
5	public area	0.0

(b) Building area criteria

The building area data is from digitization of building aerial photo in the project area. The criteria scores are as in Table 2

Table 2 Distance of impact score

Type	Description	Score
1	>200 m.	100.0
2	150-200 m.	75.0
3	100-150 m.	50.0
4	50-100 m.	25.0
5	<50 m.	0.0

(c) Sensitive area criteria

Sensitive area is the environmental and social impacted area. This data is from the environment and society study of the specialists in both fields to get the scores and to make the sensitive area map. In this research, there are five scoring levels for the evaluation as in Table 3

Table 3 Sensitive area score

Type	Description	Score	Remark
1	Level 1	100.0	Less impact
2	Level 2	75.0	
3	Level 3	50.0	
4	Level 4	25.0	
5	Level 5	0.0	High impact

4. Spatial Evaluations

In the evaluation process, the impacts from any coastal structure layouts are evaluated by spatial evaluation method. The calculated results are from the intersection between the polygon of landuse with the Polygon of land and sea areas.

In fact, Polygon of land and sea areas is from the shoreline change prediction by using Geo function named intersection. Intersect creates a new coverage by overlaying the features from the input coverage and intersect polygon coverage. The output coverage contains the input features or portions of the input features that overlap features in the intersect coverage. The output features have the attribute from the original feature from the input coverage and the feature in the intersect coverage, which they intersect.

Intersect is one of several Overlay tools available. The tool most similar to Intersect is Clip, which does not transfer any attribute from the overlay feature class to the output. Input Coverage features can be polygons, lines, or points. The intersect coverage must have polygon topology. Output coverage features resulting from the overlay are of the same type as the input coverage features. They are split when they intersect with the polygons of the intersect coverage. Topology is built for the output coverage as in Figure 28.

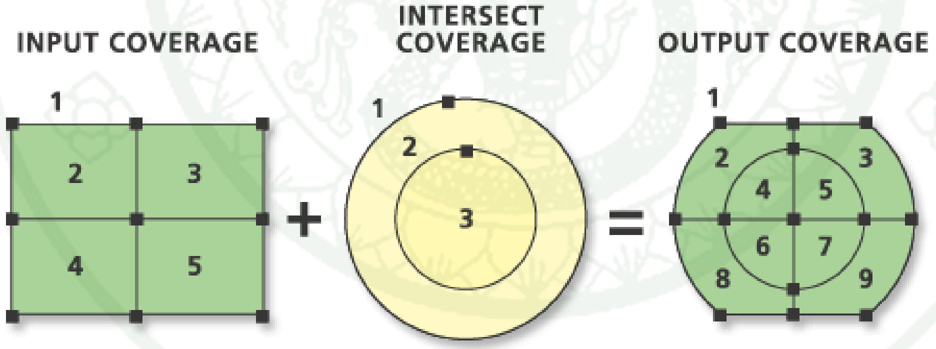
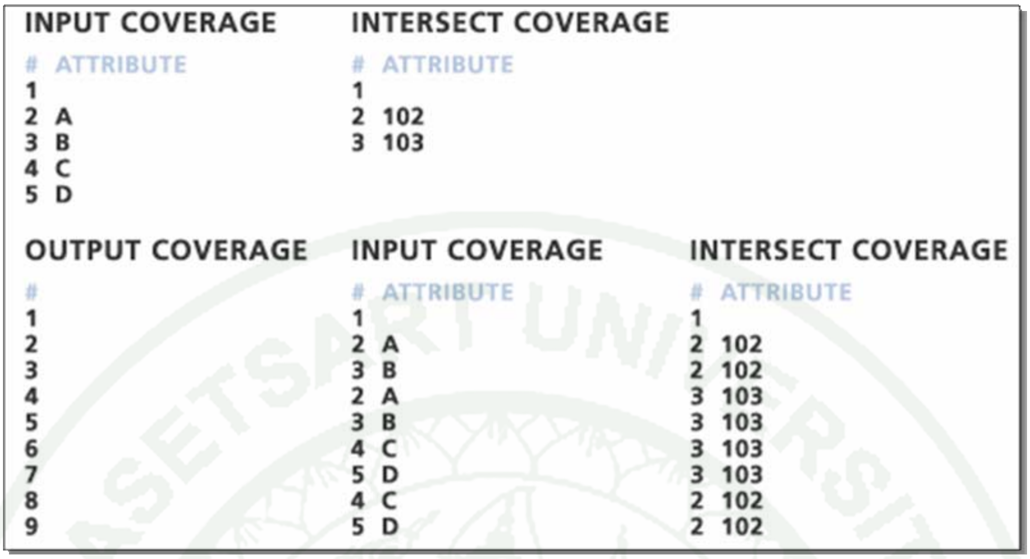


Figure 28 Polygon intersection

Attribute tables are updated. The attribute table for the output coverage contains items from both the input and intersects coverage attribute tables. Items are merged using the old internal number of each feature. The two tables below list the items that are written to the attribute table of the output coverage as in Figure 29.



INPUT COVERAGE		INTERSECT COVERAGE	
#	ATTRIBUTE	#	ATTRIBUTE
1		1	
2	A	2	102
3	B	3	103
4	C		
5	D		

OUTPUT COVERAGE	INPUT COVERAGE		INTERSECT COVERAGE	
#	#	ATTRIBUTE	#	ATTRIBUTE
1	1		1	
2	2	A	2	102
3	3	B	2	102
4	2	A	3	103
5	3	B	3	103
6	4	C	3	103
7	5	D	3	103
8	4	C	2	102
9	5	D	2	102

Table 29 Polygon intersection result table

C. Dialog base development

Graphic user interface (GUI) or dialogue base is the important part of DSS because it is the transition between the system and the users. In the dialogue base for DSS4CPD, GIS is used in order to integrate all three main models together. If considering the elements of DSS4CPD (as shown in Figure 30), it is found that the system operation requires GUI or dialog for the transition of all elements. The mentioned transition needs the designer decision; for example, the deep water wave representative, and baseline position. So, the transition of Dialog base with Data base and Model base is needed.

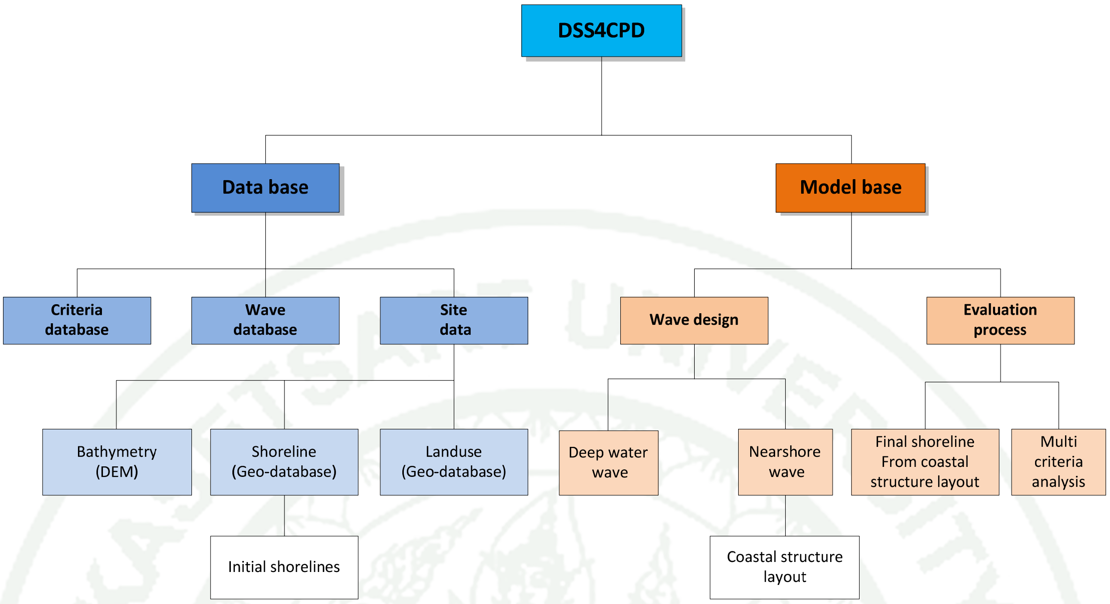


Figure 30 Component of DSS4CPD

1. Dialog base framework

Information technology continues to evolve, but one can identify various architectural patterns or styles that seem to reoccur in the development of computerized decision support systems. New systems seem to imitate or adopt prior patterns by incorporating updated hardware and networking technologies. It is likely historical architectural patterns will persist with service oriented and message-based implementations of decision support systems.

Advocates of a unified modeling approach to building systems perceive that design patterns or common architectural styles exist for classes of systems with similar purposes. Inadequate attention has been given to defining these patterns or styles for DSS, but some material that has been written on the topic.

An architecture for a computerized Decision Support System documents the plan for deploying the components of the envisioned DSS or how the components were actually deployed in an implemented decision support application. In general, DSS architecture specifications focus on the dialog/user interface, model base and data base components and how they are interconnected. "Architecture is the fundamental organization of a system embodied in its components, their relationships to each other, and to the environment, and the principles guiding its design and evolution (IEEE 1471-2000)."

According to Sprague and Carlson (1982), the components of the DSS technology framework include dialogue management, data base management, model base management, and DSS architecture. They argued the DSS architecture describes the mechanism and structure for the integration of the dialogue, data base and model management components.

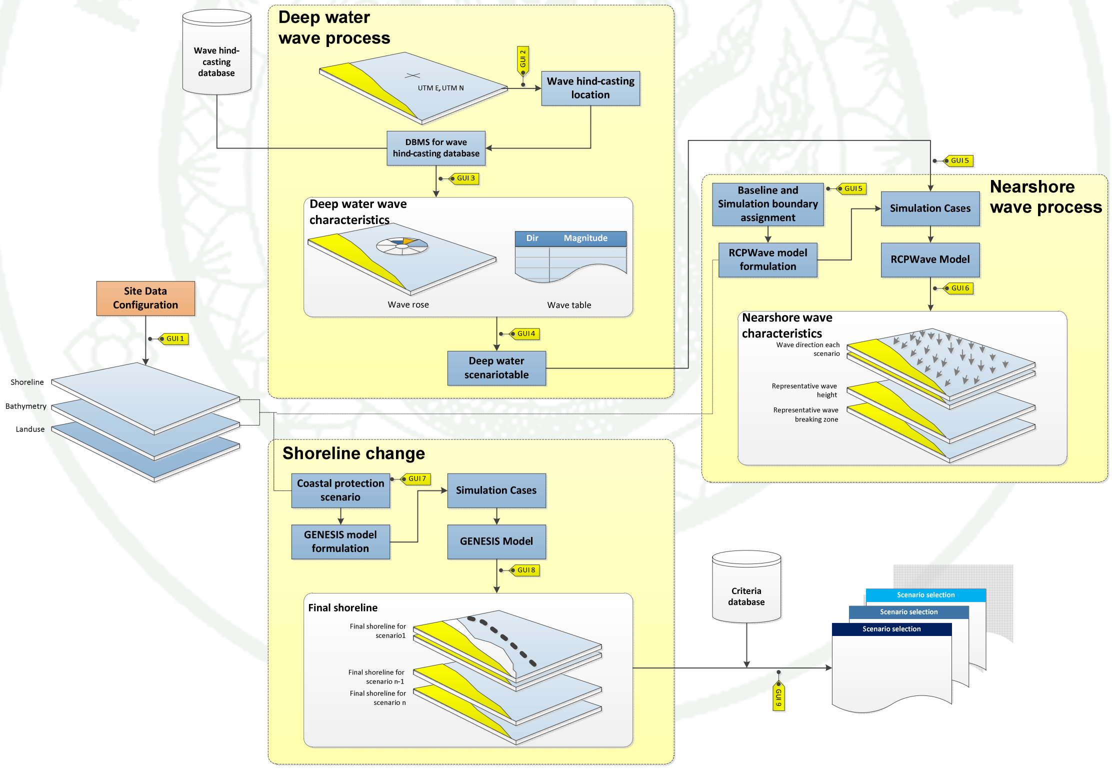


Figure 31 Dialog base framework

a) GUI 1 Site data

The database using in DSS4CPD consists of shoreline data, bathymetric data, and landuse data. Those data can be put in GIS. In this GUI 1 Site Data, it is designed to work on the list menu. As a result, DSS4CPD is required to have shoreline data, bathymetric data, and landuse data all in the system in order to be the alternatives in the list. The flowchart is as shown in Figure 32.

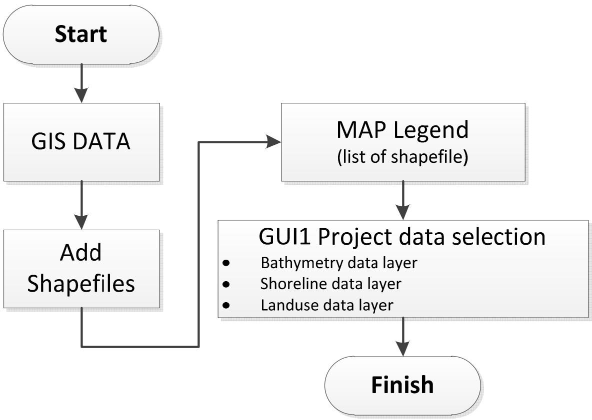


Figure 32 GUI-1 Framework

b) GUI 2 Deep water wave

Deep water wave data has already been in the database, and on grid system. So, in order to use such data, the location on grid of the deep water wave is needed. After that, the system will contact the database to get all data and to conclude them in the picture of table. The flowchart is as shown in Figure 33.

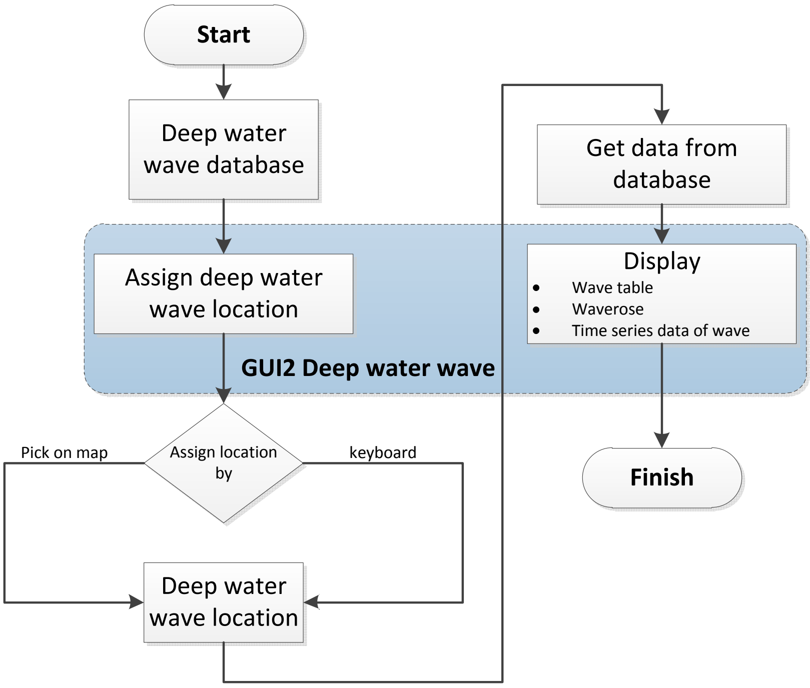


Figure 33 GUI-2 Framework

c) GUI 3 Wave design and wave scenario

Wave design is the wave representative of the deep water wave at the selected location for the calculation of wave transformation. In this study, wave direction is separated to 16 directions. For the wave design, wave height and wave frequency of the dominant waves, deep water wave data have been calculated to be the wave design at the return period of 50 year based on construction standard. Then, the system will create the wave scenarios and make the wave scenario table for the study area. The flowchart is as shown in Figure 34.

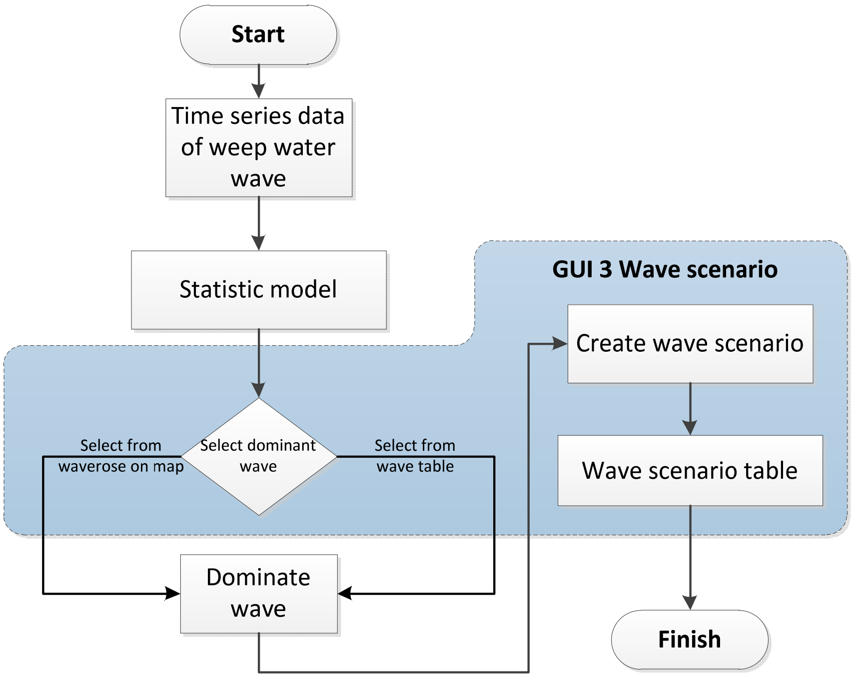


Figure 34 GUI-3 Framework

d) GUI 4 Nearshore wave model formulation

For the model formulation, the baseline is assigned. This baseline is referred as the axes in the wave transformation model by harvesting all data from the selected grid from GUI 1to work in the study case. At this point, all fundamental physical data are sufficient for wave transformation model calculation. After that, all possible wave scenarios from GUI 3 will be created as the model input data for further use. The flowchart is as shown in Figure 35.

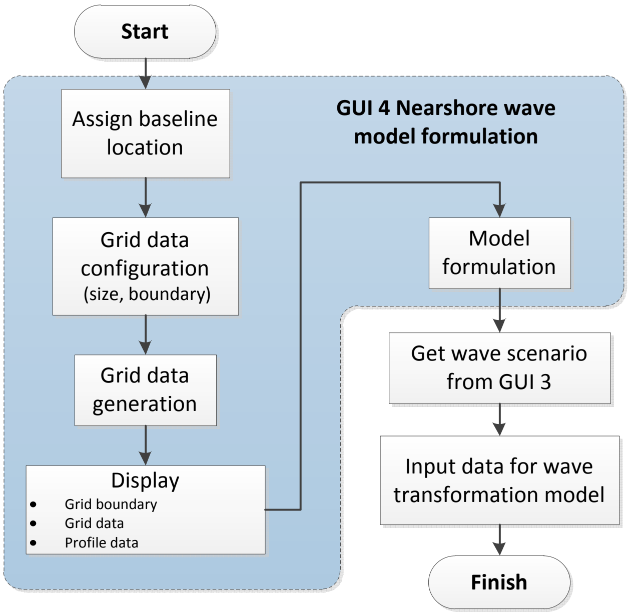


Figure 35 GUI-4 Framework

e) GUI 5 Nearshore wave simulation

After all cases have been simulated, the outputs from all cases are wave height data, wave direction data, wave breaking position data, and wave number data. All data are stored as grid data. To illustrate, the system will conclude the data in details in the whole all scenario picture and individual scenario. Both conclusions are presented in maps and tables in order the help the decision makers doing the coastal structure layout design. The flowchart of this GUI 5 is as shown in Figure 36.

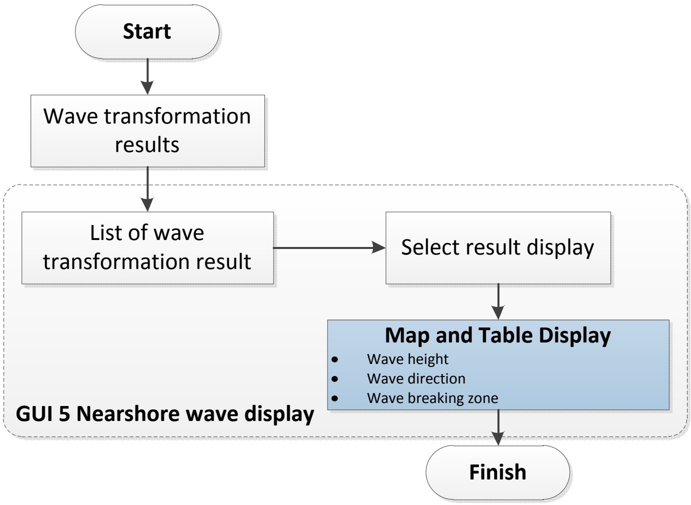


Figure 36 GUI-5 Framework

f) GUI 6 Coastal protection scenario

In order to make the coastal protection layout design, the system is always referred to the reference baseline. The designers have to design length and spacing of the designed coastal structures. Then, the system will create the coastal structure layouts as assigned, and will present all scenarios on maps. As a result, the decision makers can see and understand the combinations of spacing and length of the coastal structure layout. The flowchart of this GUI is as shown in Figure 37.

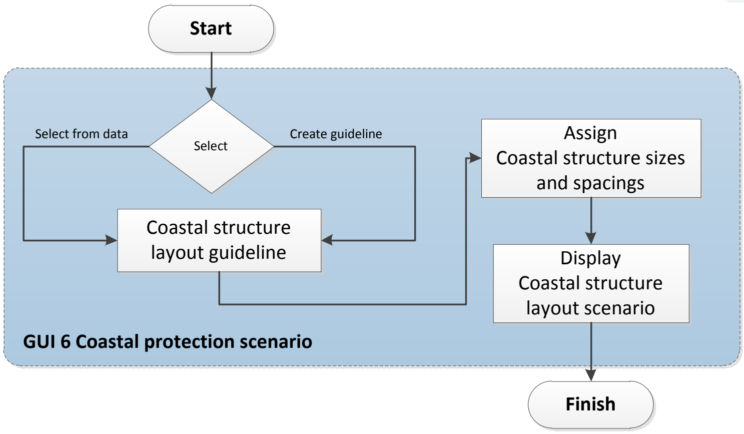


Figure 37 GUI-6 Framework

g) GUI 7 Shoreline change simulation and results display

After having many possible coastal structure layouts from all scenarios, all layouts are the inputs for the shoreline change model. The model will do the shoreline change analysis from all layout scenarios. The calculated results are presented in the pictures of yearly shorelines. When the yearly shorelines are overlayed with the initial shoreline, the erosion areas and the accumulation areas are presented. The system will present all the impacts with the layouts on maps and tables. The flowchart of this GUI is as shown in Figure 38.

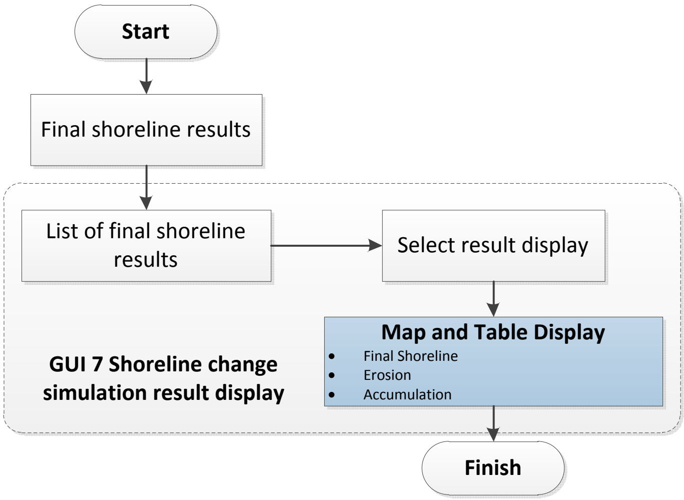


Figure 38 GUI-7 Framework

h) GUI 8 Scenario comparison and recommendation

Finally, the most important data that the decision makers need is the ranking list of the possible layouts which can be implemented in the project area. DSS4CPD is the tool to recommend the suitable layouts. In this study, the top 5 in scores of the possible layouts which can be implemented in the project area are presented to the decision makers to select which one is the most appropriate layout for the area. For the scoring process, spatial evaluation is the tool of this system. To illustrate, the system will analyze the erosion and accumulation of the 20 year (in this study) shoreline change together with the layout scenarios and score to see the impacts. Then, spatial evaluation will score and present the top 5 in scores of the possible layouts to the decision makers to choose the layout solution. The flowchart of this GUI is as shown in Figure 39.

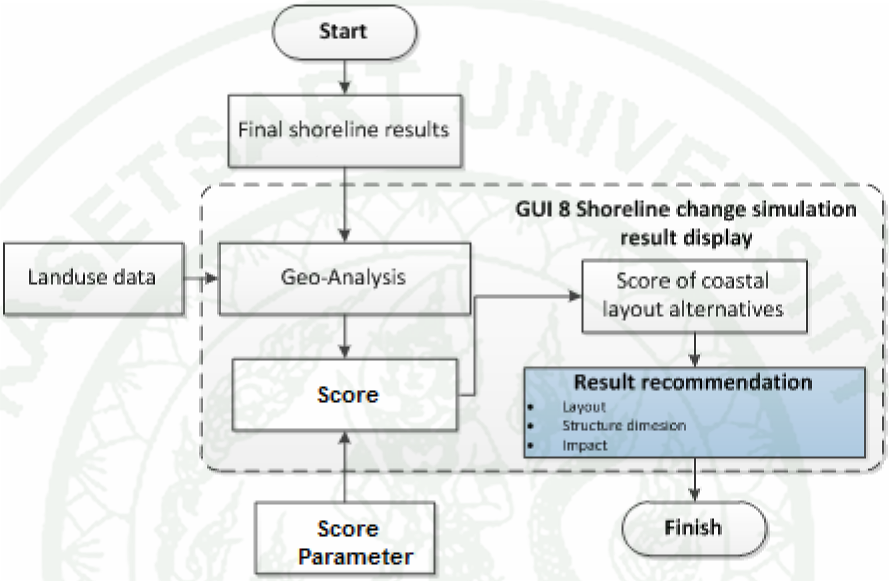


Figure 39 GUI-8 Framework

2. System integration

The DSS4CPD described herein is a MapWindow (Ames 2010) plug-in for the design of coastal protection design. The plug-in was developed in VB .NET and compiled as a dynamic link library (DLL file). MapWindow can connect to the DLL, or plug-in, with interfacing functions, and data and event commands. MapWindow GIS is an open-source GIS application and set of programmable mapping components. It has been adopted by the United States Environmental Protection Agency as the primary GIS platform for its BASINS (Better Assessment Science Integrating Point and Nonpoint Sources) watershed analysis and modeling software. MapWindow is distributed as an open source application under the Mozilla Public License, and it can be reprogrammed to perform different or more specialized tasks. Other plug-ins are also available to expand compatibility and functionality. The application is built upon

Microsoft .NET technology. For the advantage of the MapWindow, it is to be used as the developed DSS. For more details, those will be mentioned later.

The GIS is a computer system capable of holding and using data describing places on the earth's surface, while the more complex defines it as an organized collection of computer hardware, software, geographic data and personal designed to efficient capture, store, update, manipulate, analyze and display all forms of geographically referenced information.

A GIS can map any information stored in spreadsheets or databases that has a geographic component to allow you to see patterns, relationships, and trends that could not otherwise have been seen in a table or list format. It gives an entirely new, dynamic perspective on information and helps make better decisions.

A GIS is characterized by a unique ability of a user to overlay spatial layers information and perform spatial queries to create new information, the results of which are automatically tabulated and mapped. Graphical elements describing the location and shape of layer features are dynamically connected to databases, which describe the properties of the features.

RESULTS AND DISCUSSION

Decision Support System for Coastal Protection Design (DSS4CPD) has been developed in this research by using GIS program named Map Window for system integration. In this program, it consists of all data for coastal protection design, all models for each part of model calculations, and the interface. For the interface, it uses for the model input and output communication, display that designers use the results for coastal structure design decision.

There are two parts of the contributions in this research: 1) model development and 2) DSS4CPD Application from the integration of Data base, Model base, and User Interface. For model development and integration, there are three major elements: 1) Wave design, 2) Wave transformation and 3) Shoreline change. In this study, Langsuan beach in Chumporn province has been used as the case study, and the study details will be mentioned later.

1. DSS Developing Result

A. DSS4CPD Data Process

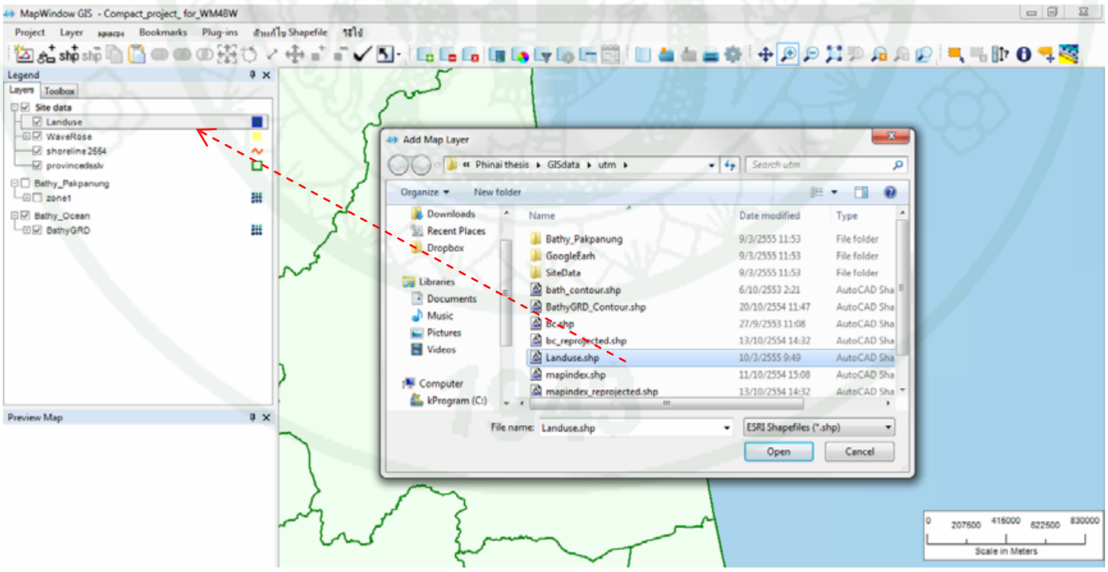
For the coastal protection design, the first considered data is wave coming to the coast. The wave statistics data let the designers know the dominant wave direction and wave frequency at site. After knowing the data, the designers can make the coastal structure layout to solve the erosion at site. For the wave height, it represents the wave energy attacking the beach; so, the coastal structure materials and sizes can be determined. Therefore, the wave data is a very important data in the model calculation. In this study, the wave data is simulated from the Wave Analysis Model (WAM) from Hydrographic Department, Royal Thai Navy. This wave data is used in the database and is presented as waverose pictures. In this research, there is the developed program to simulate waves, and to make the report suitable for the coastal structure designers in order to make the layout and wave design. The details of making the wave design are as followed:

1. Basic designing data

The basic data using for coastal protection design system in DSS4CPD consists of beach profile data, bathymetric data, and landuse data. All mentioned data are stored in GIS database. The details are as followed:

- Bathymetric Data is DEM (in the ESRI GRID Format)
- Shreline data is (line shape) by digitizing from aerial photo.
- Landuse data is shapefile (polygon shape)
- Beach profile data is the shapefile (line shape) by collecting every surveying time or every year by one layer per one year.

All data can be input by using tool in adding layer icon in DSS4CPD as shown in Figure 40.



Name	Date modified	Type
Bathy_Pakpanung	9/3/2555 11:53	File folder
GoogleEarh	9/3/2555 11:53	File folder
SiteData	9/3/2555 11:53	File folder
bath_contour.shp	6/10/2553 2:21	AutoCAD Sha
BathyGRD_Contour.shp	20/10/2554 11:47	AutoCAD Sha
Bc.shp	27/9/2553 11:08	AutoCAD Sha
bc_reprojected.shp	13/10/2554 14:32	AutoCAD Sha
Landuse.shp	10/3/2555 9:49	AutoCAD Sha
mapindex.shp	11/10/2554 15:08	AutoCAD Sha
mapindex_reprojected.shp	13/10/2554 14:32	AutoCAD Sha

File name: Landuse.shp

ESRI Shapefiles (*.shp)

Figure 40 Basic designing data adding

The user can add layer for each data for more than one layer such as every year shoreline data. Later on, the developed Plug-in can be used for selecting what year data or the data in many years in which layer to be calculated in the model. Although many GIS data in many layers might not be used in calculation, they help coastal engineers and designers understand the historical events at site. All data can be added in layers in order to be the information for site data.

2. Site data using in DSS4CPD

DSS4CPD is GIS Plug-in; thus, all data that DSS4CPD can use have to be added in GIS. All added data are stored subsequently in legend of the developed MapWindow Plug-in. The program will analyze all data in the legend and will make a list of the data such as beach profile year by year, bathymetric data in each surveying time, and landuse to help the designers in using those data.

In order to use the site data in MapWindow Plug-in, the user can click the icon as shown in Figure 41. In the case that there is no icon the users want, the users can select from Plug-in menu and open it from DSS4CPD Plug-in as shown in Figure 42. In this part of model development, it is the beginning work of DSS4CPD that has the complied code which is designed to work together with Mapwindow and coastal structure design by using interface capability between GIS and Mapwindow display for data input, model calculation, and result display. The details will be mentioned later.

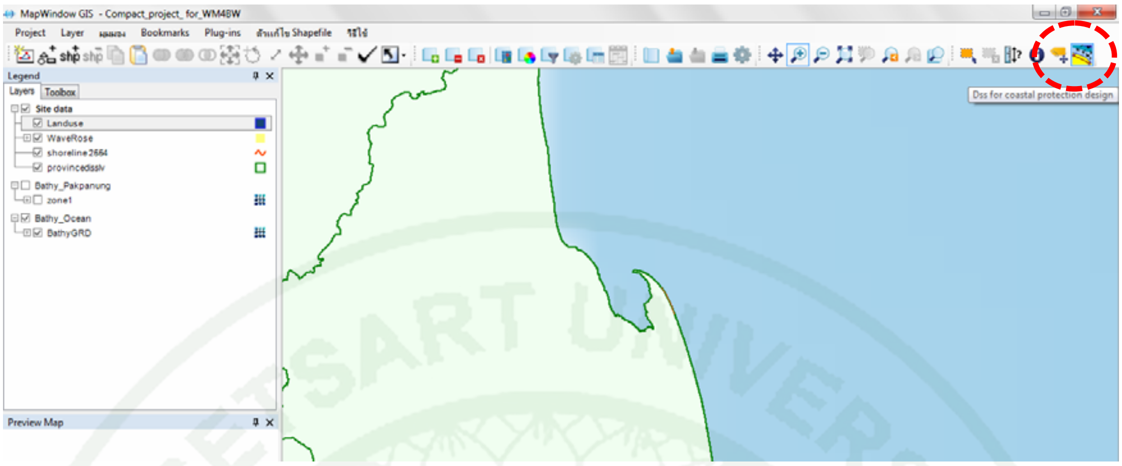
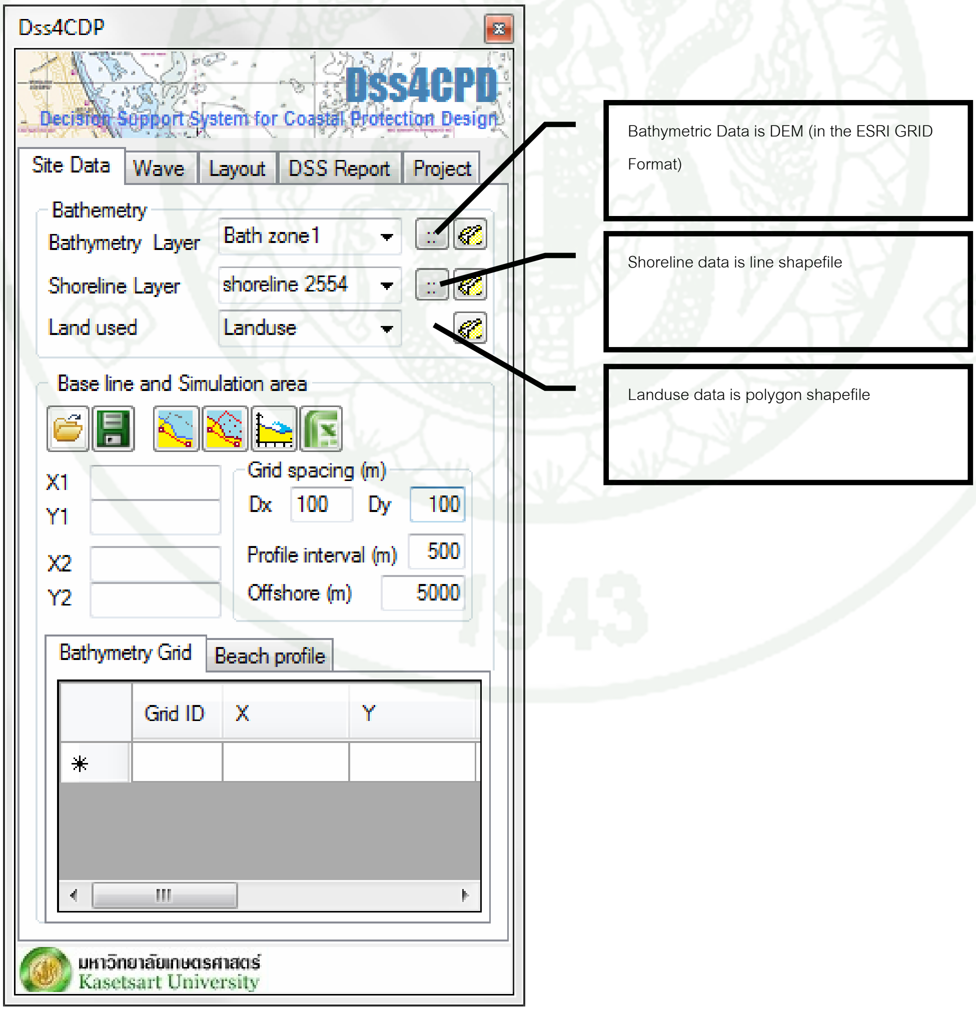


Figure 41 DSS4CPD Plug-in icon.



Bathymetry Layer: Bath zone1

Shoreline Layer: shoreline 2554

Land used: Landuse

Dx: 100 Dy: 100

Profile interval (m): 500

Offshore (m): 5000

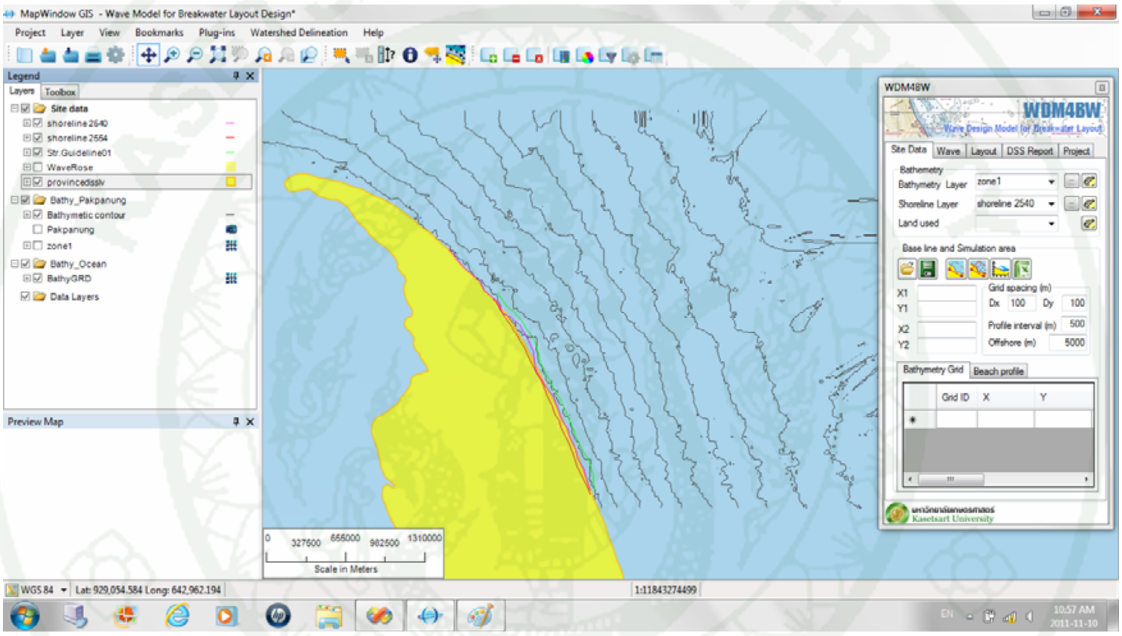
Bathymetric Data is DEM (in the ESRI GRID Format)

Shoreline data is line shapefile

Landuse data is polygon shapefile

Figure 42 Dialogue base for site data assignment

After that, the Plug-in will show the information in Window or dialogue base as shown in Figure 43. In this part, it explains the site data which consists of three important layers as mentioned before. The users can click at drop down menu of each parameters for example shoreline. In this part, dialogue base will show the list of layer involving shoreline information. In fact, all shoreline data are added in Map legend to be used in the menu for the further selection.



Bathymetry Layer: zone1
Shoreline Layer: shoreline 2540
Land used:
Dx: 100
Dy: 100
Profile interval (m): 500
Offshore (m): 5000
Lat: 929,054.584 Long: 642,962.194
1:11843274499

Figure 43 Main dialogue base of DSS4CPD

3. Data Processing

The data processing is to generate the data preparing for using in the models. In data processing, the boundary of mathematical model is needed by indicating the baseline along with the shoreline, having the distance offshore, and having grid size (Dx, Dy). For data preparation, the representative grid position is needed for calculation. Furthermore, the elevation of bathymetric data and elevation of any shoreline that separating water and earth are needed to see the whole picture of the topographic data at site. The procedure is:

Step 1Clickicon to indicate the baseline by selecting two determined points.

Step 2, 3 Pick the points on map and draw the line between two points clockwise as shown in Figure 44.

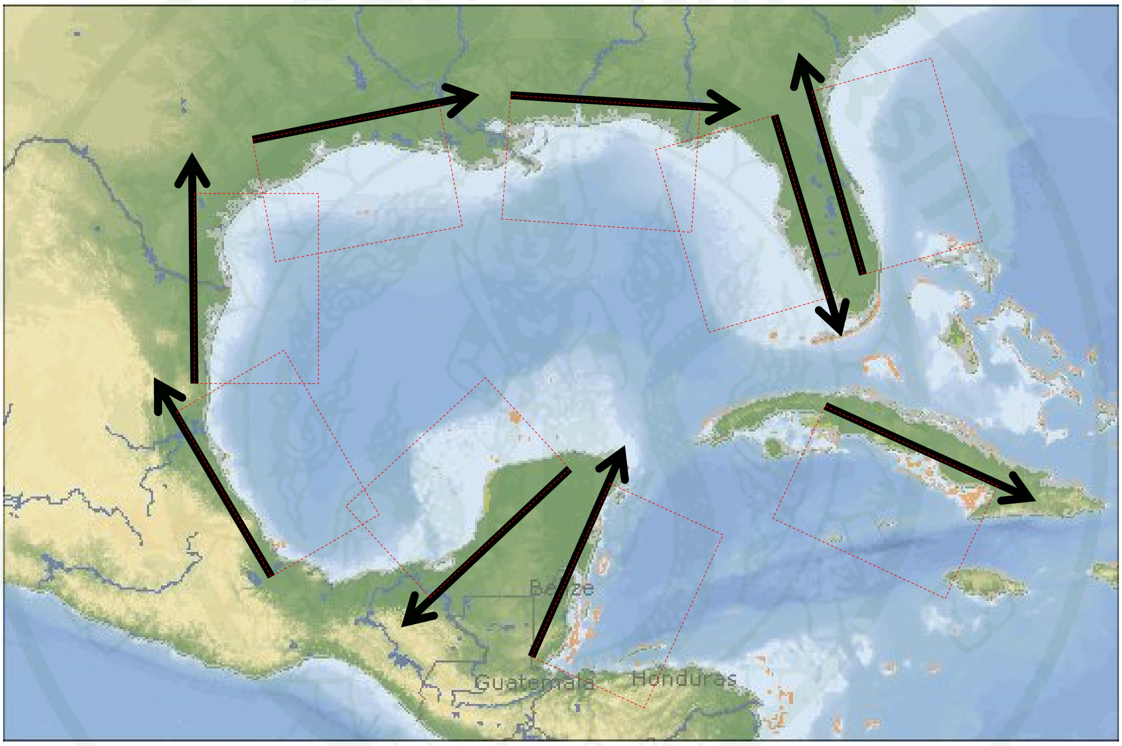
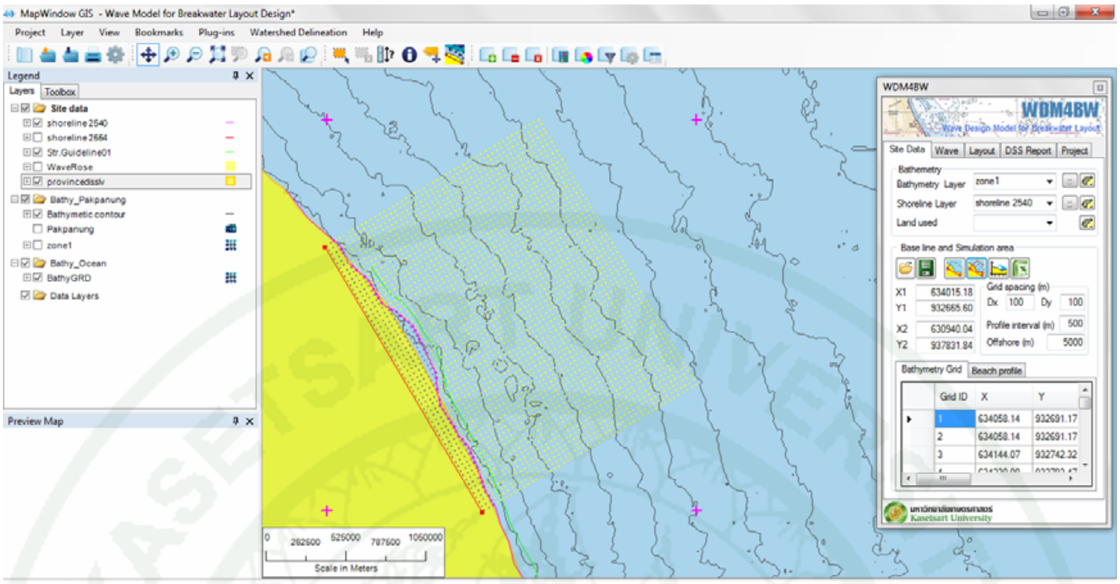


Figure 44 Baselinedirection (line between two points clockwise)

Step 4 Click icon to order the system to create the grid data and to get the elevation data.

Step5,6 The program will draw the line from points of grid on map and create x,y,z data. All data can be exported to excel. The procedure is as shown in Figure 45.



Bathymetry Layer: zone1
Shoreline Layer: shoreline 2540
Land used:

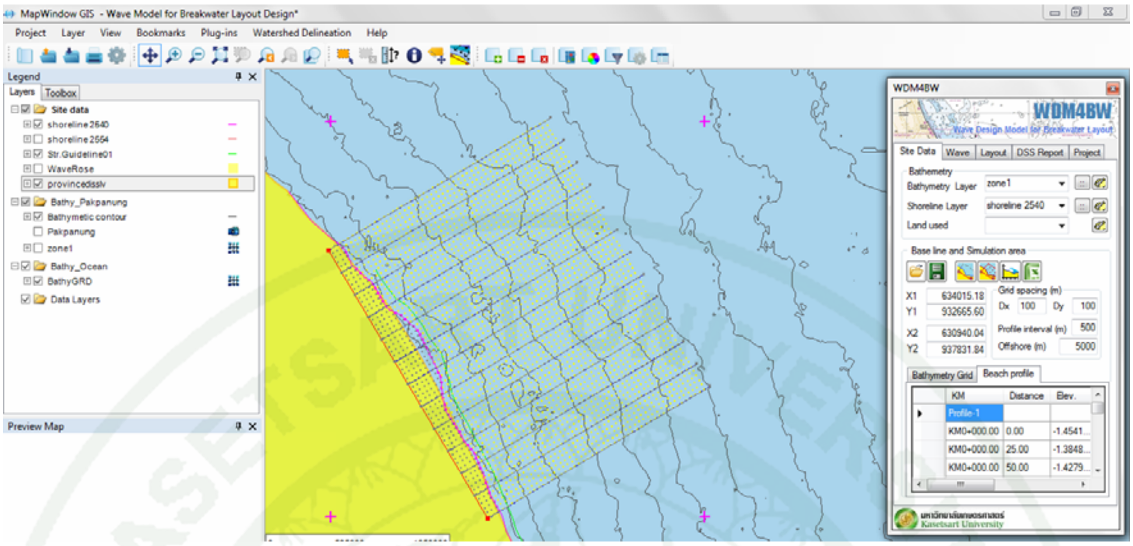
X1 634015.18
Y1 932665.60
X2 630940.04
Y2 937831.84

Grid spacing (m)
Dx 100 Dy 100
Profile interval (m) 500
Offshore (m) 5000

Grid ID	X	Y
1	634058.14	932691.17
2	634058.14	932691.17
3	634144.07	932742.32

Figure 45 Baseline and there bathymetric data (grid form)

Another important data is the beach profile data. Since the beach profile data is used for determining the shoreline for model calculation. For example, wave transformation model uses bathymetric data and beach profile data to see how the waves move and transform from deep water to the beach. Beach profile data is generated after grid generation. At this step, the beach profile interval 1) is required by clicking icon 2); then, the program will create the beach profile perpendicularly to the baseline according to the interval distance. In addition, program will draw the profile line and display the value of any single data point as shown 3), 4) in Figure 46.



Bathymetry Layer: zone1
Shoreline Layer: shoreline 2540
Land used:

X1 634015.18
Y1 932665.60
X2 630940.04
Y2 937831.84
Dx 100 Dy 100
Profile interval (m) 500
Offshore (m) 5000

KM	Distance	Elev.
Profile-1		
KM0+000.00	0.00	-1.4541...
KM0+000.00	25.00	-1.3848...
KM0+000.00	50.00	-1.4279...

Figure 46 Beach profile generation procedure.

B. DSS4CPDWave Hind-casing Process

For DSS4CPD, the DSS operation is to be presented starting from wave hind-casting: fetch map, dominant wave display, wave analysis table, and wave transformation: wave height map, wave direction map, and wave breaking map. In fact, they are all important data to be used in the decision making for coastal protection design. To illustrate, the deep water wave is the representative of the wave boundary in the project area. For the wave transformation, the wave height and wave direction are the indication for coastal structure layout position and sizes. In addition, the wave height in the near shore area determines the coastal structure size since the wave height is directly related to the wave force or wave energy going to the beach. Wave data is the important information for coastal structure design; therefore, the deep water wave representative point is important as well. To select the representative point or coordinate at the project boundary for deep water wave, the designers have to consider the major factors of the deep water wave representative such as water depth, distance from the project beach, and etc.

To use DSS4CPD, it is started from loading the design data base which is stored in the shape file pattern into Legend of Map Window and then, selecting the point of position the deep water wave to be calculated to be used in this project area as shown in Figure 47.

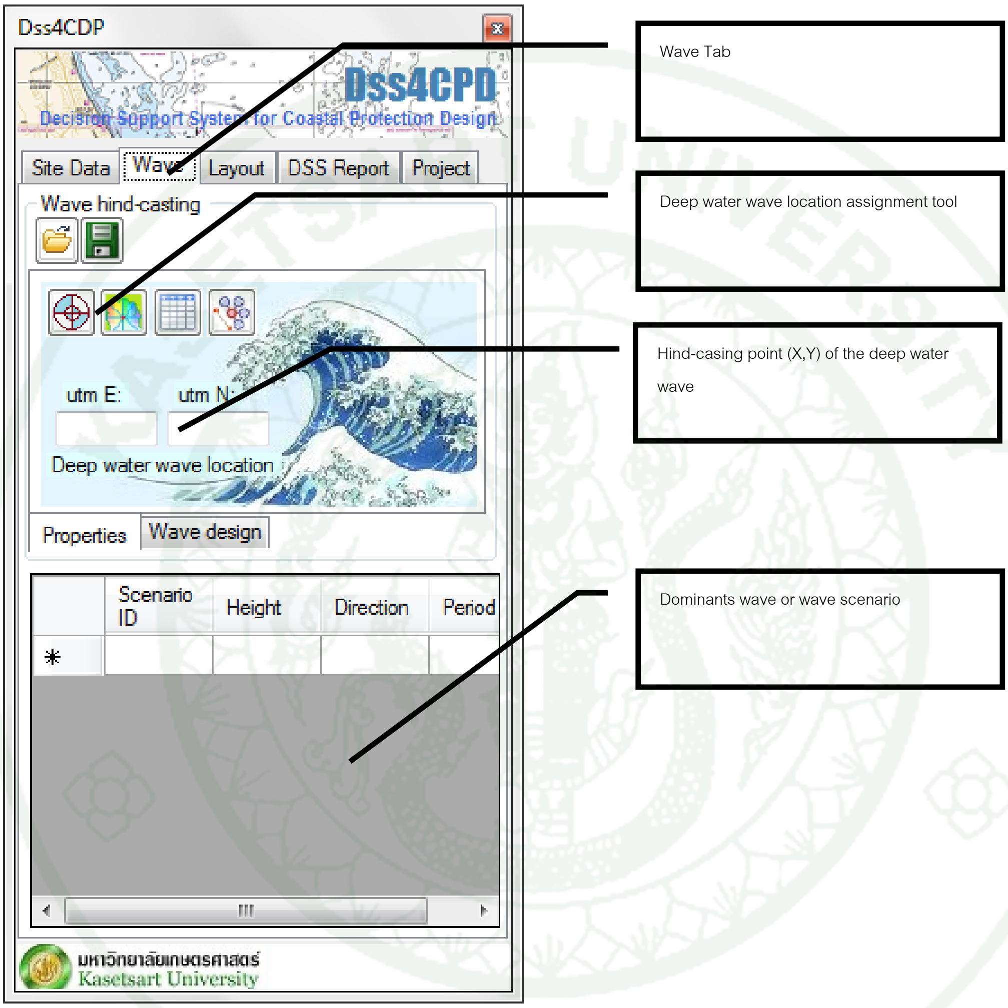


Figure 47 Dialogue base for wave properties

DSS4CPD will investigate the wind direction line and make it to be fetch length map. In order to have designer understand the wind and wave behaviors in the study area because the wave height and wave direction relies on the chosen positions which are impacted by the distance the wind coming on the water surface, wind speed and wind frequency (Figures 48 and 49).

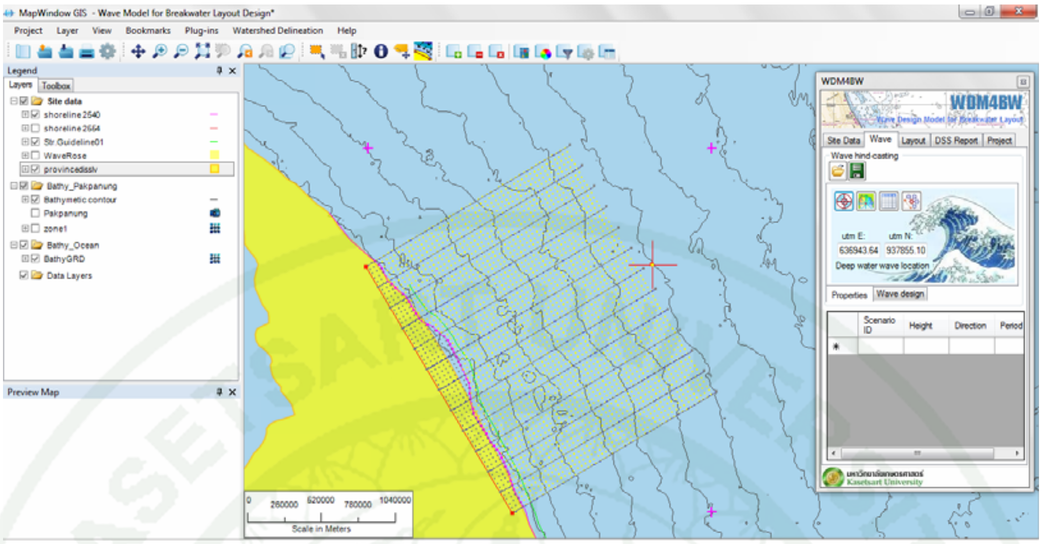


Figure 48 A wave hind-casting location

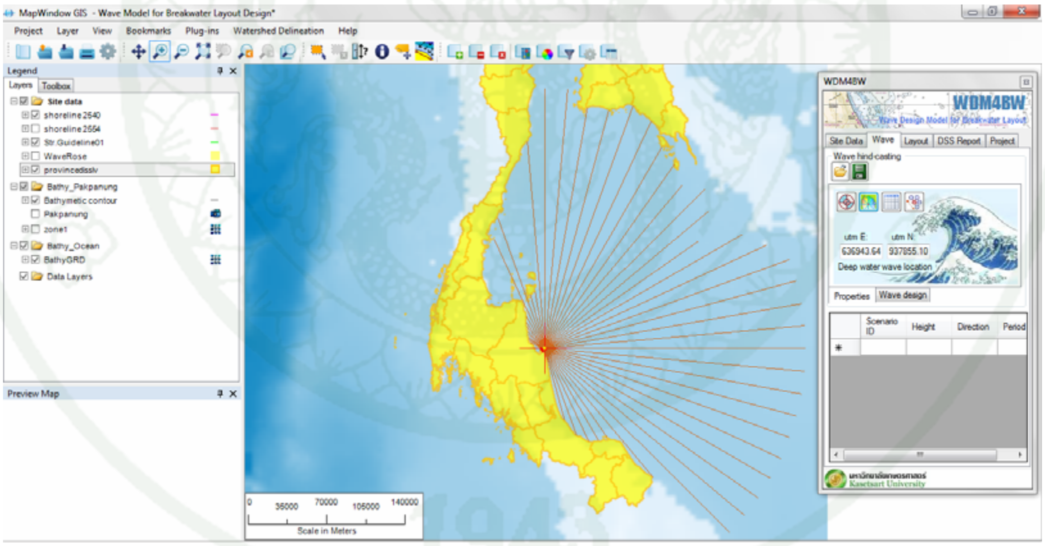
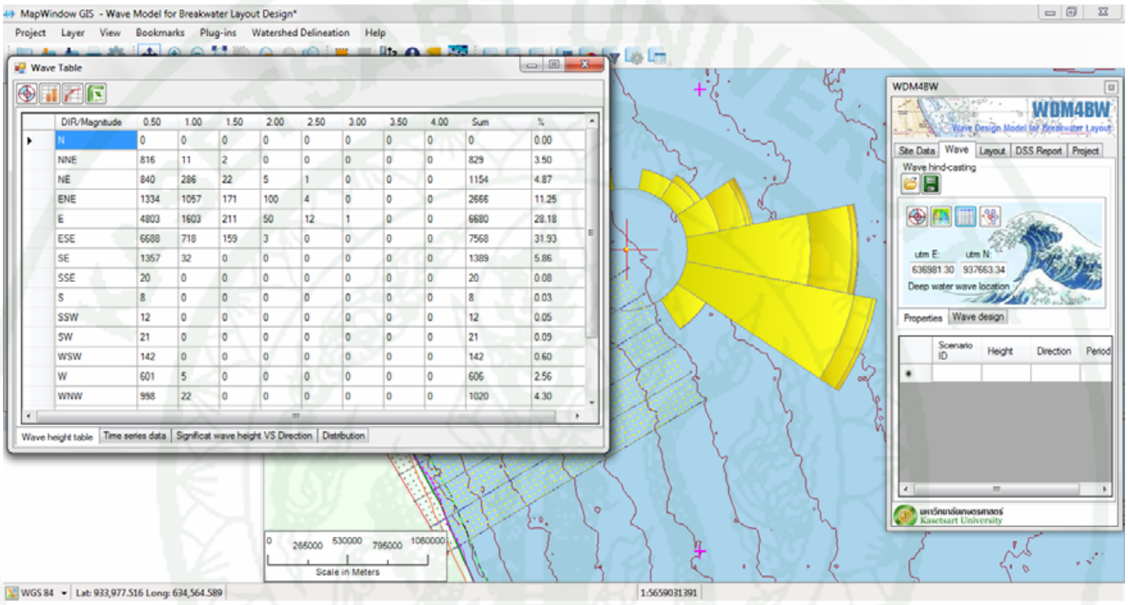


Figure 49 Fetch length of wave hind-casting point

After setting the information of wave, the system will be linked to database in the part of wave climate database and the hind cast result will be presented in the pictures of wave rose and wav e analysis table. For all data, they will be stored and be continuously evaluated in the wave transformation.

For the waverose generation and wave analysis table, they are created after the deep water at the boundary is generated by clicking icon ▦ 1). Program will display the window of wave analysis table 2), and will generate waverose on GIS map at the deep water wave representative point 3) as shown in Figure 50.



DIR/Magnitude	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Sum	%
N	0	0	0	0	0	0	0	0	0	0.00
NNE	816	11	2	0	0	0	0	0	829	3.50
NE	840	286	22	5	1	0	0	0	1154	4.87
ENE	1334	1057	171	100	4	0	0	0	2666	11.25
E	4803	1603	211	50	12	1	0	0	6680	28.18
ESE	6688	718	159	3	0	0	0	0	7568	31.93
SE	1357	32	0	0	0	0	0	0	1389	5.86
SSE	20	0	0	0	0	0	0	0	20	0.08
S	8	0	0	0	0	0	0	0	8	0.03
SSW	12	0	0	0	0	0	0	0	12	0.05
SW	21	0	0	0	0	0	0	0	21	0.09
WSW	142	0	0	0	0	0	0	0	142	0.60
W	601	5	0	0	0	0	0	0	606	2.56
WNW	998	22	0	0	0	0	0	0	1020	4.30

utm E: 636981.30 utm N: 937663.34
Deep water wave location

Scenario ID	Height	Direction	Period

Lat: 933,977.516 Long: 634,564.589

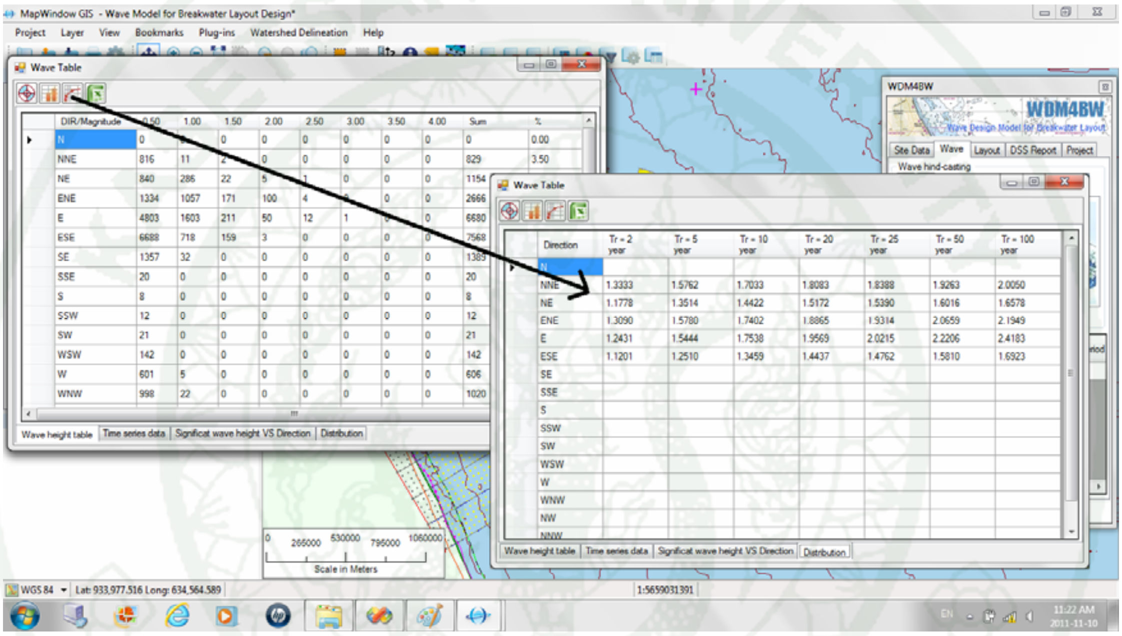
Figure 50 Waveanalysis table and waverose diagram.

1. Wave Design

For wave design analysis, it is time series analysis of deep water wave at the boundary point. The analysis gives the result of dominant wave height and dominant wave direction impacted on the study area. The analysis procedure uses statistics of chi-square including:

- Gambel
- Log Gambel
- Peason
- Peason Type III
- Log Peason

This is to calculate wave height and wave period of wave design at the returning years. In coastal engineering design, the 50 year returning period is used for being the representative of wave design returning period. In wave design calculation program, it starts by clicking icon, the system will use the lowest value of chi-square values in the study area analysis as shown in Figure 51.



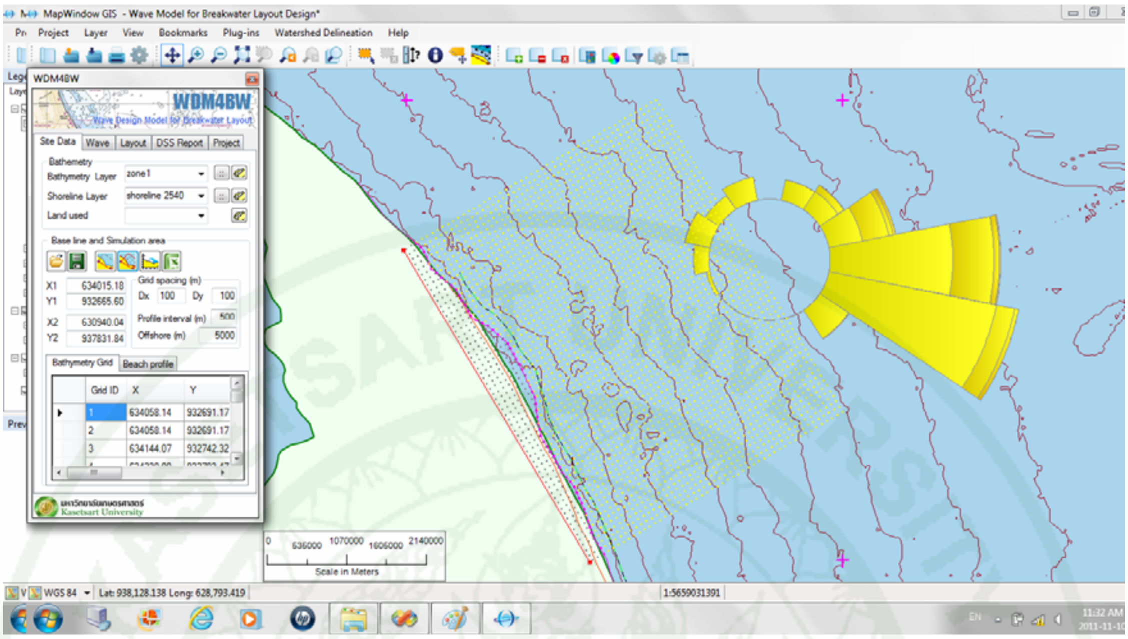
DIR/Magnitude	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Sum	%
N	0	0	0	0	0	0	0	0	0	0.00
NNE	816	11	2	0	0	0	0	0	829	3.50
NE	840	286	22	5	1	0	0	0	1154	
ENE	1334	1057	171	100	4	0	0	0	2666	
E	4803	1603	211	50	12	1	0	0	6680	
ESE	6688	718	159	3	0	0	0	0	7568	
SE	1357	32	0	0	0	0	0	0	1389	
SSE	20	0	0	0	0	0	0	0	20	
S	8	0	0	0	0	0	0	0	8	
SSW	12	0	0	0	0	0	0	0	12	
SW	21	0	0	0	0	0	0	0	21	
WSW	142	0	0	0	0	0	0	0	142	
W	601	5	0	0	0	0	0	0	606	
WNW	998	22	0	0	0	0	0	0	1020	

Direction	Tr = 2 year	Tr = 5 year	Tr = 10 year	Tr = 20 year	Tr = 25 year	Tr = 50 year	Tr = 100 year
N							
NNE	1.3333	1.5762	1.7033	1.8083	1.8388	1.9263	2.0050
NE	1.1778	1.3514	1.4422	1.5172	1.5390	1.6016	1.6578
ENE	1.3090	1.5780	1.7402	1.8865	1.9314	2.0659	2.1949
E	1.2431	1.5444	1.7538	1.9569	2.0215	2.2206	2.4183
ESE	1.1201	1.2510	1.3459	1.4437	1.4762	1.5810	1.6923
SE							
SSE							
S							
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							

Figure 51 Wave-rose overlay on GIS map.

2. Wave scenarios

Wave scenario is the dominant deep water wave at the site boundary being as the wave representatives in wave design and wave transformation calculation. To design wave scenarios is to select waves from dominant wave directions in site waverose such as in the directions: ENE, E, and ESE to be the dominant directions of the site wave scenarios. The wave scenario step starts by clicking icon and clicking at waverose for selected directions. To add more dominant directions is to click Ctrl + waverose as shown in Figure 52.



Bathymetry Layer: zone1

Shoreline Layer: shoreline 2540

Land used:

X1: 634015.18

Y1: 932665.60

X2: 630940.04

Y2: 937831.84

Grid spacing (m): Dx 100 Dy 100

Profile interval (m): 500

Offshore (m): 5000

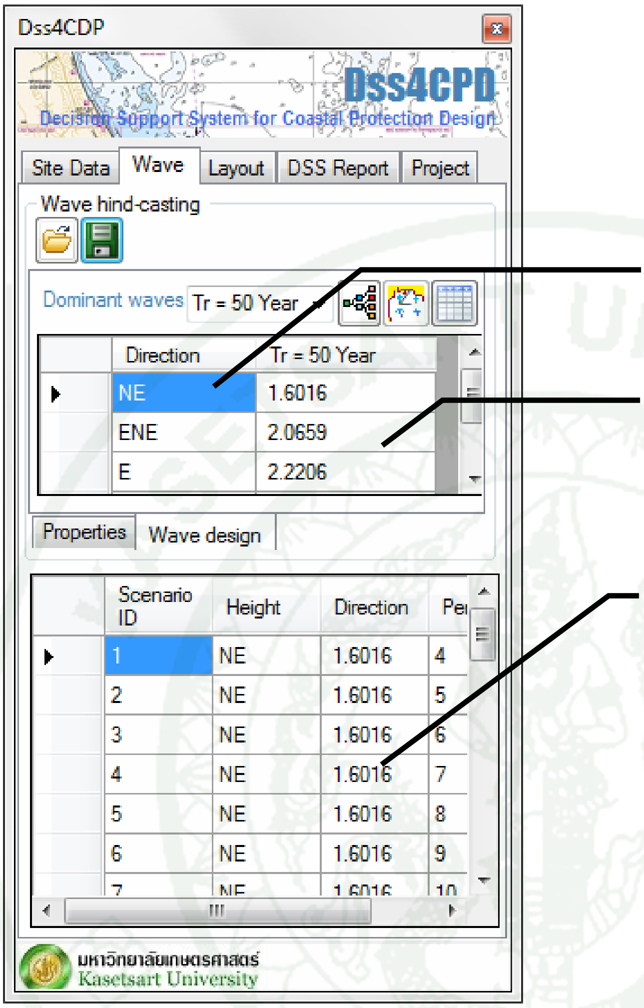
Grid ID	X	Y
1	634058.14	932691.17
2	634058.14	932691.17
3	634144.07	932742.32

WGS 84 Lat: 938,128.138 Long: 628,793.419

1:5650031391

Figure 52 Dominant wave directions for wave scenario selection

Wave scenarios are made from the relationship of dominant wave directions and wave periods. Generally, wave periods in the Gulf of Thailand and Andaman Sea are between 4-10 second. Thus, the number of wave scenarios is equal to “number of dominant wave directions multiply by 7” (7 is for 4 sec to 10 sec) the wave scenario as shown in Figure 53.



Dominant waves: Tr = 50 Year

	Direction	Tr = 50 Year
▶	NE	1.6016
	ENE	2.0659
	E	2.2206

	Scenario ID	Height	Direction	Pe
▶	1	NE	1.6016	4
	2	NE	1.6016	5
	3	NE	1.6016	6
	4	NE	1.6016	7
	5	NE	1.6016	8
	6	NE	1.6016	9
	7	NE	1.6016	10

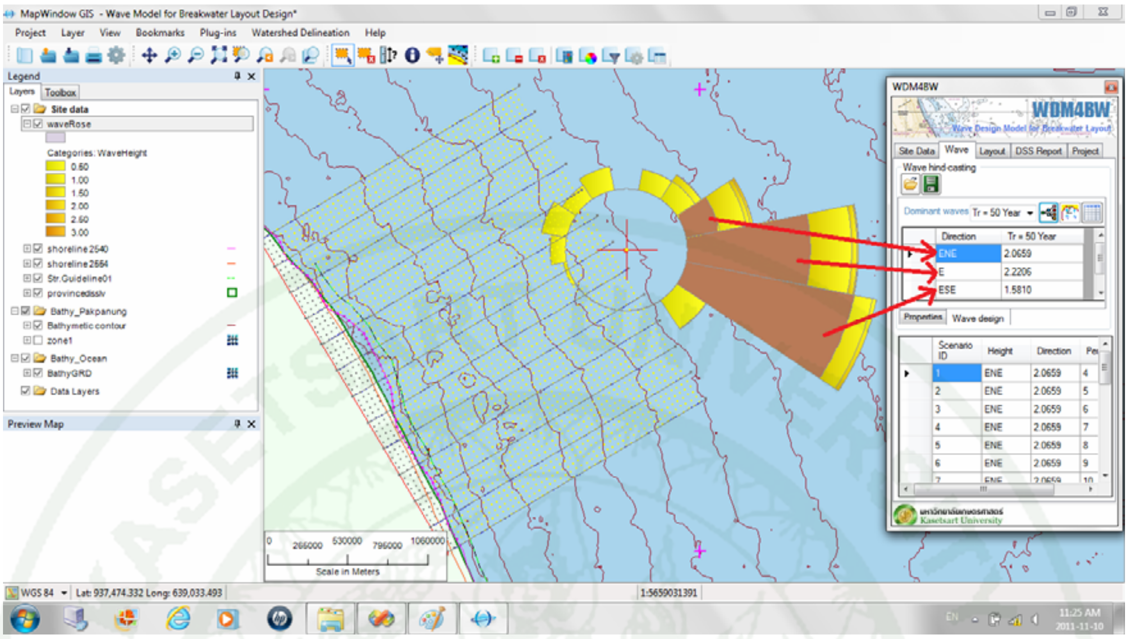
Dominant wave or wave selected direction

Wave design (Wave height at return period 50 year)

Combination of wave direction, height, and period (4-10 sec)

Figure 53 Wave scenario table

After having dominant wave directions, the next step of wave scenario selection is to choose the return period of the wave design 1), and then click icon 2), to get the wave scenario table 3) as shown in Figures 54 and 55.



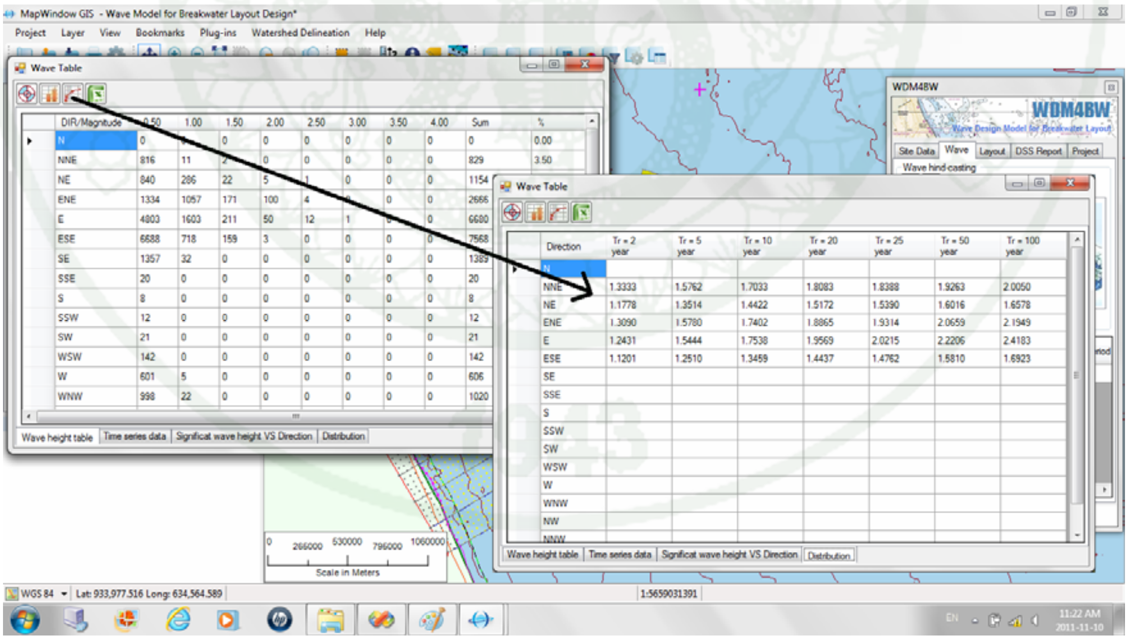
Lat: 937,474.332 Long: 639,033.493

Dominant waves Tr = 50 Year

	Direction	Tr = 50 Year
▶	ENE	2.0659
	E	2.2206
	ESE	1.5810

	Scenario ID	Height	Direction	Pe
▶	1	ENE	2.0659	4
	2	ENE	2.0659	5
	3	ENE	2.0659	6
	4	ENE	2.0659	7
	5	ENE	2.0659	8
	6	ENE	2.0659	9
	7	ENE	2.0659	10

Figure 54 Wave scenario selection



Lat: 933,977.516 Long: 634,564.589

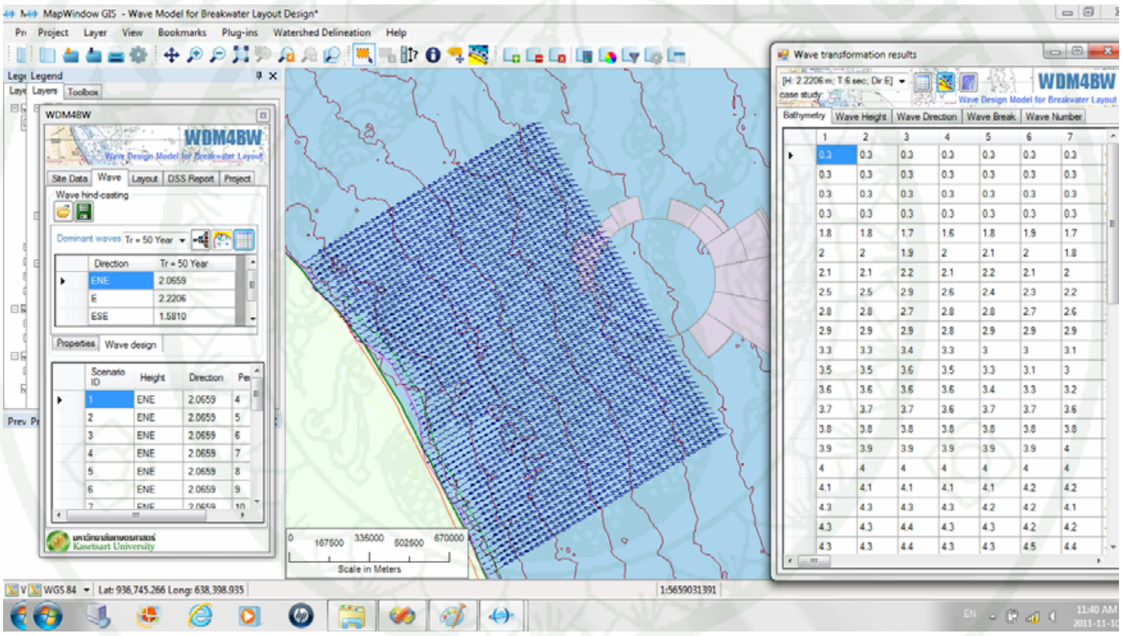
DIR/Magnitude	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Sum	%
N	0	0	0	0	0	0	0	0	0	0.00
NNE	816	11	2	0	0	0	0	0	829	3.50
NE	840	286	22	5	1	0	0	0	1154	
ENE	1334	1057	171	100	4	0	0	0	2666	
E	4803	1603	211	50	12	1	0	0	6680	
ESE	6688	718	159	3	0	0	0	0	7568	
SE	1357	32	0	0	0	0	0	0	1389	
SSE	20	0	0	0	0	0	0	0	20	
S	8	0	0	0	0	0	0	0	8	
SSW	12	0	0	0	0	0	0	0	12	
SW	21	0	0	0	0	0	0	0	21	
WSW	142	0	0	0	0	0	0	0	142	
W	601	5	0	0	0	0	0	0	606	
WNW	998	22	0	0	0	0	0	0	1020	

Direction	Tr = 2 year	Tr = 5 year	Tr = 10 year	Tr = 20 year	Tr = 25 year	Tr = 50 year	Tr = 100 year
N							
NNE	1.3333	1.5762	1.7033	1.8083	1.8388	1.9263	2.0050
NE	1.1778	1.3514	1.4422	1.5172	1.5390	1.6016	1.6578
ENE	1.3090	1.5780	1.7402	1.8865	1.9314	2.0659	2.1949
E	1.2431	1.5444	1.7538	1.9569	2.0215	2.2206	2.4183
ESE	1.1201	1.2510	1.3459	1.4437	1.4762	1.5810	1.6923
SE							
SSE							
S							
SSW							
SW							
WSW							
W							
WNW							
NW							
NNW							

Figure 55 Wave-rose overlay on GIS map

C. DSS4CPD Wave Transformation Process

For the calculation of wave transformation, the users must select the base line which is very important since that baseline is going to be used for analysis, design and evaluation of the coastal structure design in the project by referring to that baseline always. How to select the baseline, the users must select for the system, this should be perpendicular to the dominant wave direction. In fact, the baseline must draw clockwise only as shown in Figure 56.



Dominant waves: Tr = 50 Year

Direction	Tr = 50 Year
ENE	2.0659
E	2.2206
ESE	1.5810

Scenario ID	Height	Direction	Pe
1	ENE	2.0659	4
2	ENE	2.0659	5
3	ENE	2.0659	6
4	ENE	2.0659	7
5	ENE	2.0659	8
6	ENE	2.0659	9
7	ENE	2.0659	10

Lat: 936,745.266 Long: 638,398.935

[H: 2.2206 m; T:6 sec; Dir:E]

1	2	3	4	5	6	7
0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.3	0.3	0.3	0.3	0.3	0.3	0.3
0.3	0.3	0.3	0.3	0.3	0.3	0.3
1.8	1.8	1.7	1.6	1.8	1.9	1.7
2	2	1.9	2	2.1	2	1.8
2.1	2.1	2.2	2.1	2.2	2.1	2
2.5	2.5	2.9	2.6	2.4	2.3	2.2
2.8	2.8	2.7	2.8	2.8	2.7	2.6
2.9	2.9	2.9	2.8	2.9	2.9	2.9
3.3	3.3	3.4	3.3	3	3	3.1
3.5	3.5	3.6	3.5	3.3	3.1	3
3.6	3.6	3.6	3.6	3.4	3.3	3.2
3.7	3.7	3.7	3.6	3.7	3.7	3.6
3.8	3.8	3.8	3.8	3.8	3.8	3.8
3.9	3.9	3.9	3.9	3.9	3.9	4
4	4	4	4	4	4	4
4.1	4.1	4.1	4.1	4.1	4.2	4.2
4.3	4.3	4.3	4.3	4.2	4.2	4.1
4.3	4.3	4.4	4.3	4.3	4.2	4.2
4.3	4.3	4.4	4.3	4.3	4.5	4.4

Figure 56 Wave transformation result

Wave transformation model give the calculation results in the forms of Matrix or Grid. In fact, the results are wave height, wave direction, wave period and wave number. As mentioned above, all data are in grid form which have coordinates of x,y which also refer to size and number of grid in x and y axes. As a result, the data can be plotted as a map. For the wave transformation model, it has the baseline as its reference; thus, the model coordinates are rotated from the baseline to be the same coordinates as in GIS.

D. DSS4CPDLayout Design Process

Coastal structure or coastal protection layout for this research is always referred to the reference line so called layout guideline. Layout guideline is made by the coastal protection designers. The data used here is in the pattern of polyline or list of x, y that overlay on the map of study area. This line is polyline shapefile, and is used as a guide for coastal structure layout position (Figure 57). This means that any breakwater layout is from the results of appropriate spacing and length of each breakwaters. In case of sizes of breakwaters and their spacing are already done, the combination of the layout is from the number of different breakwater sizes multiply by number of breakwater spacing.

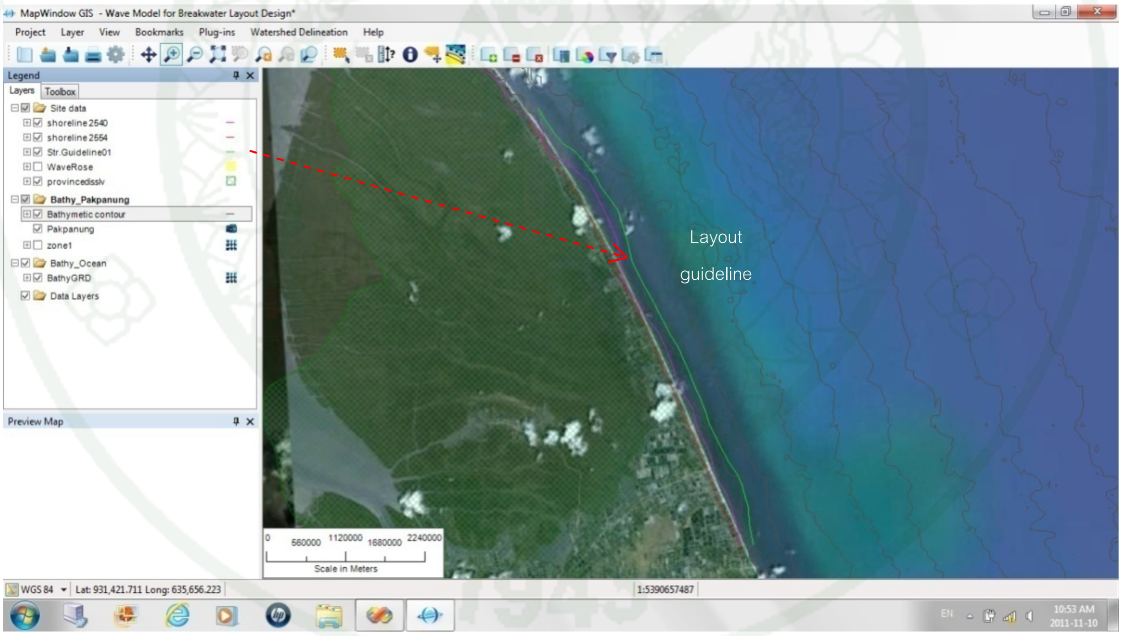
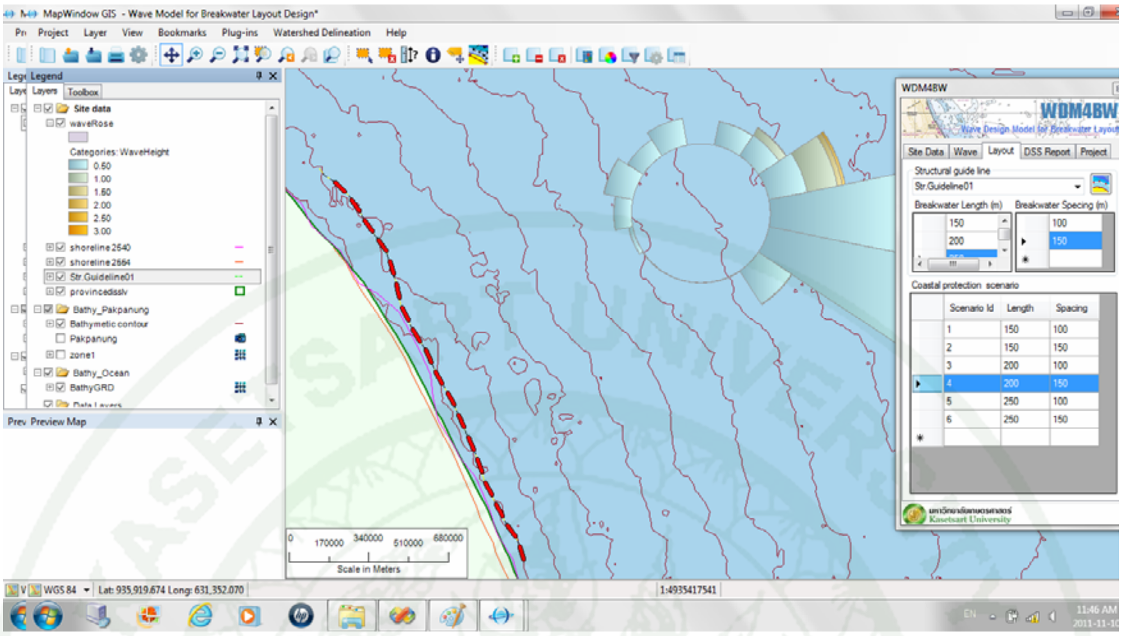


Figure 57 Layout guideline (Polyline shapefile)

In the example, there are three sizes of breakwaters which are150, 200, and 250 meters, and two breakwater spacing which are 100 and 150 meters. So, the combination of coastal protection layout is equal to 3 multiply by 2 = 6. DSS4CPD has prepared two tables for spacing table and size table of breakwater to make the coastal structure layout combination as shown in Figure 58.



Structural guide line: Str.Guideline01

Breakwater Length (m): 150, 200

Breakwater Specing (m): 100, 150

Coastal protection scenario

Scenario Id	Length	Spacing
1	150	100
2	150	150
3	200	100
4	200	150
5	250	100
6	250	150

Figure 58 Coastal protection layout for the combination number 4

2. Case Study

In this study, Langsuan beach in Chumporn province has been used as the case study because Chumporn is one of the provinces that have beach erosion problem. In Langsuan Chumporn, people over a hundred families are facing severe waves and high tides during monsoon. The results got from DSS4CPD help in making coastal structure layout decision for coastal structure designers and engineers. The objectives of this study are as followed.

A. Objective of DSS4CPD study

1. To study and analyze, and to find out cuases of the erosion problem in Bann Hualam, Ampur Langsuan, Chumporn Province, as shown in Figure 59.

2. To apply DSS4CPD in order to help in making solution of the erosion problem in Bann Hualam, Ampur Langsuan, Chumporn Province.

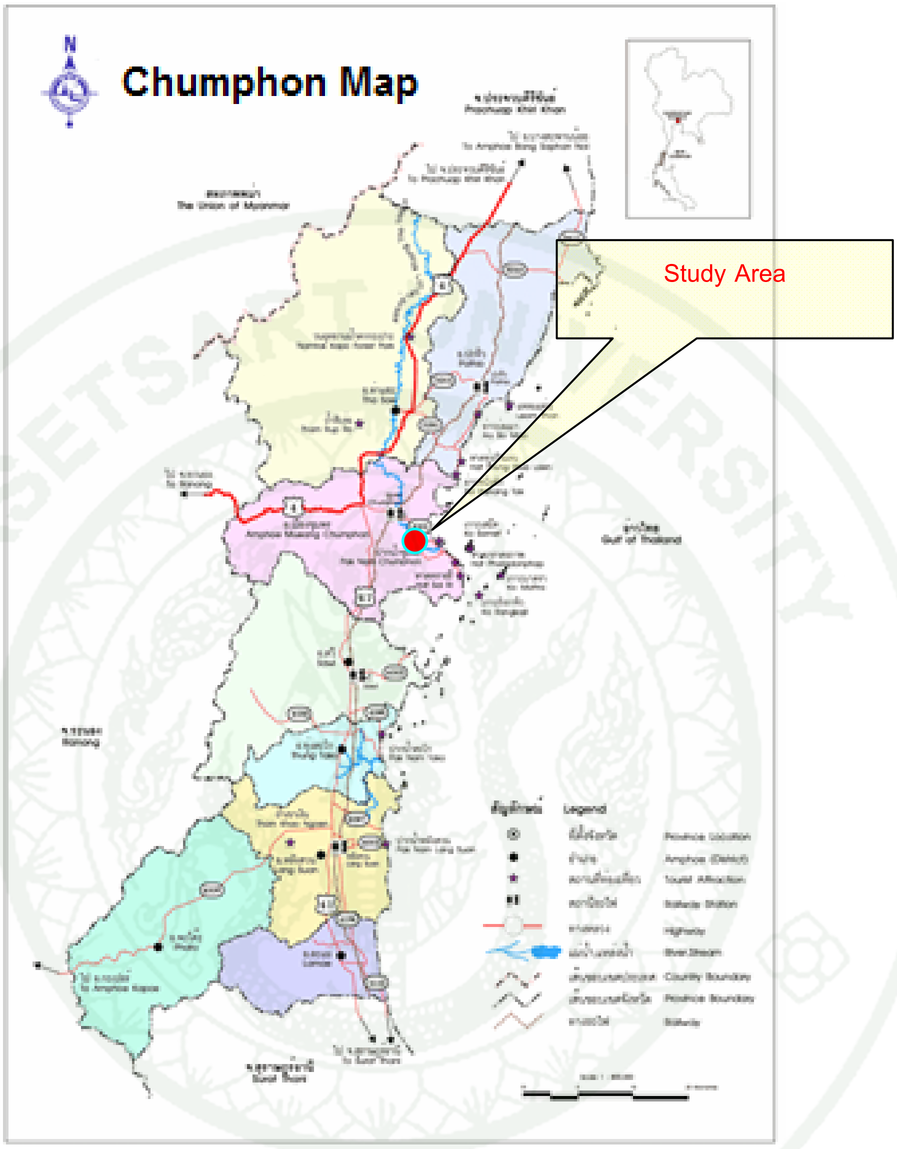


Figure 59 Study area map

B. Study Area

1. Project site

The study area is in Tambon Bangmapraw, Ampur Langsuan, Chumporn Province. In fact, it is the long beach in the south of Langsuan River with the 4.5 kilometers long as shown in Figure 60, and in the south of Chumporn province. For the site geographic condition, the jetties was built in both sides, north and south, of

Langsuan Estuary. One jetty on the north is 1,476 meters long, and the other jetty on the south is 1,330 meters long with spacing of 160 meters from each other. The navigation channel is about 2.5 meters deep. In the south of the estuary, rocks were dropped as the 500 meter long revetment to solve the erosion problem in the area. However, the 700 meters long erosion has still occurred next to the revetment. The causes of erosion are from the jetty reflecting the wave energy to the beach and high wave energy during the monsoon season. The site geographic condition is as shown in Figure 60.

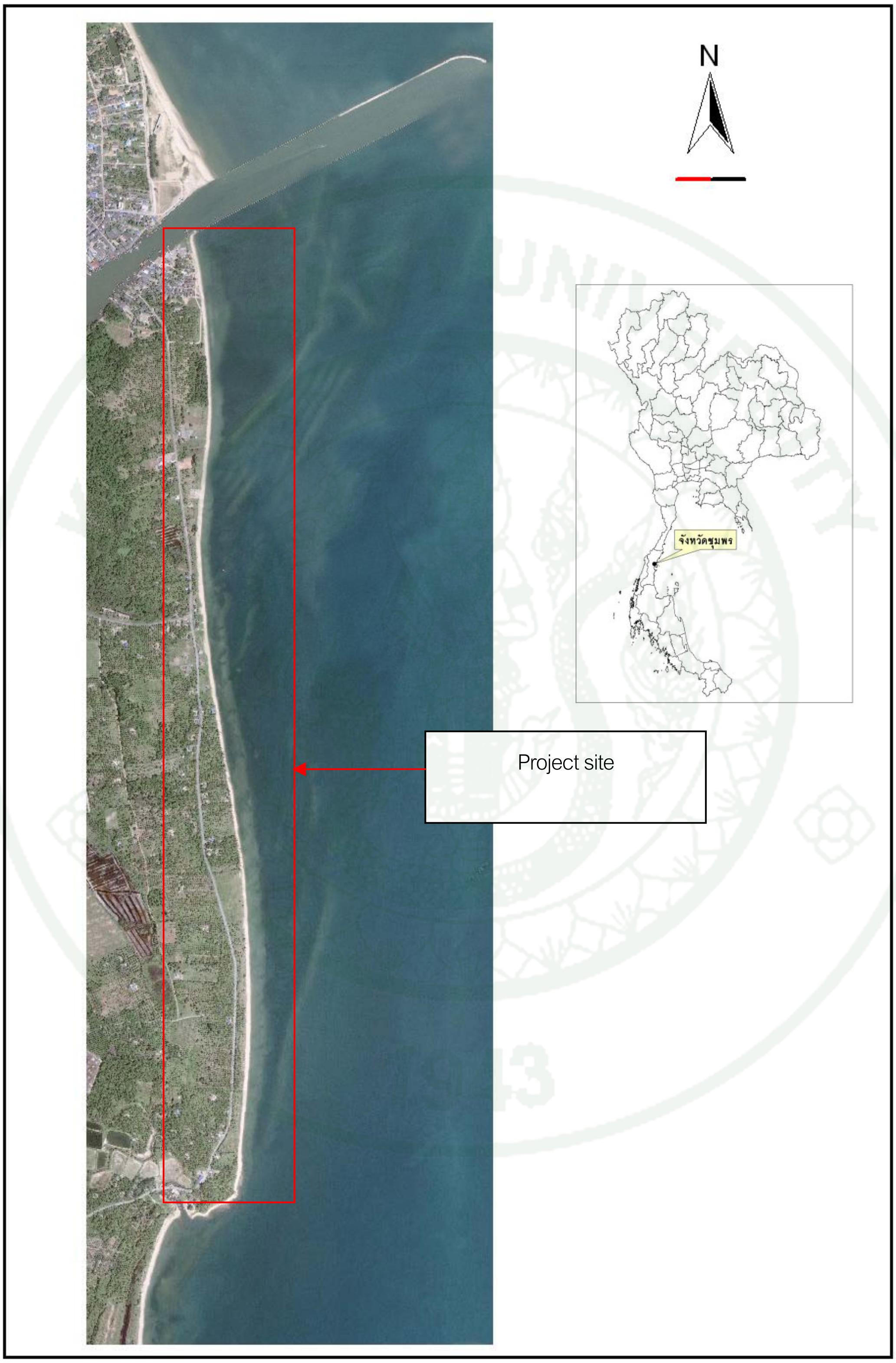


Figure 60 Project site

3. Geographic and Geomorphology

a) Geographic

Chumporn Geographic characteristics are separated in three parts 1) plain terrain in the middle of the province 2) high hills and mountains in west and 3) long shoreline in the east. The study area is in the 222 kilometer coast in the east side of Chumporn. In this study area, the coast consists of two crenulate bays:

1) First part starts from Ban Bangyee to Ban Fungkrajom with the length from north to south 12 kilometers long called “Langsuan Bay” with the Langsuan Estuary at the bay south. This bay is in the equilibrium condition.

2) The second part starts from Langsuan Estuary to Kao Nuer at south 13 kilometers long called “Bangmapraw Bay”

area has been changed, and jetties has blocked the sediment moving north and south in the area. In addition, because of the global warming and sea level rise, it causes the erosion in the area.

4. Tidal data

The nearest tidal station to the study site is Langsuan tidal station, in Chumporn Province. The tidal statistics data is as shown in Table 4.

Table 4 Tidal statistics data of Langsuan tidal station, in Chumporn Province

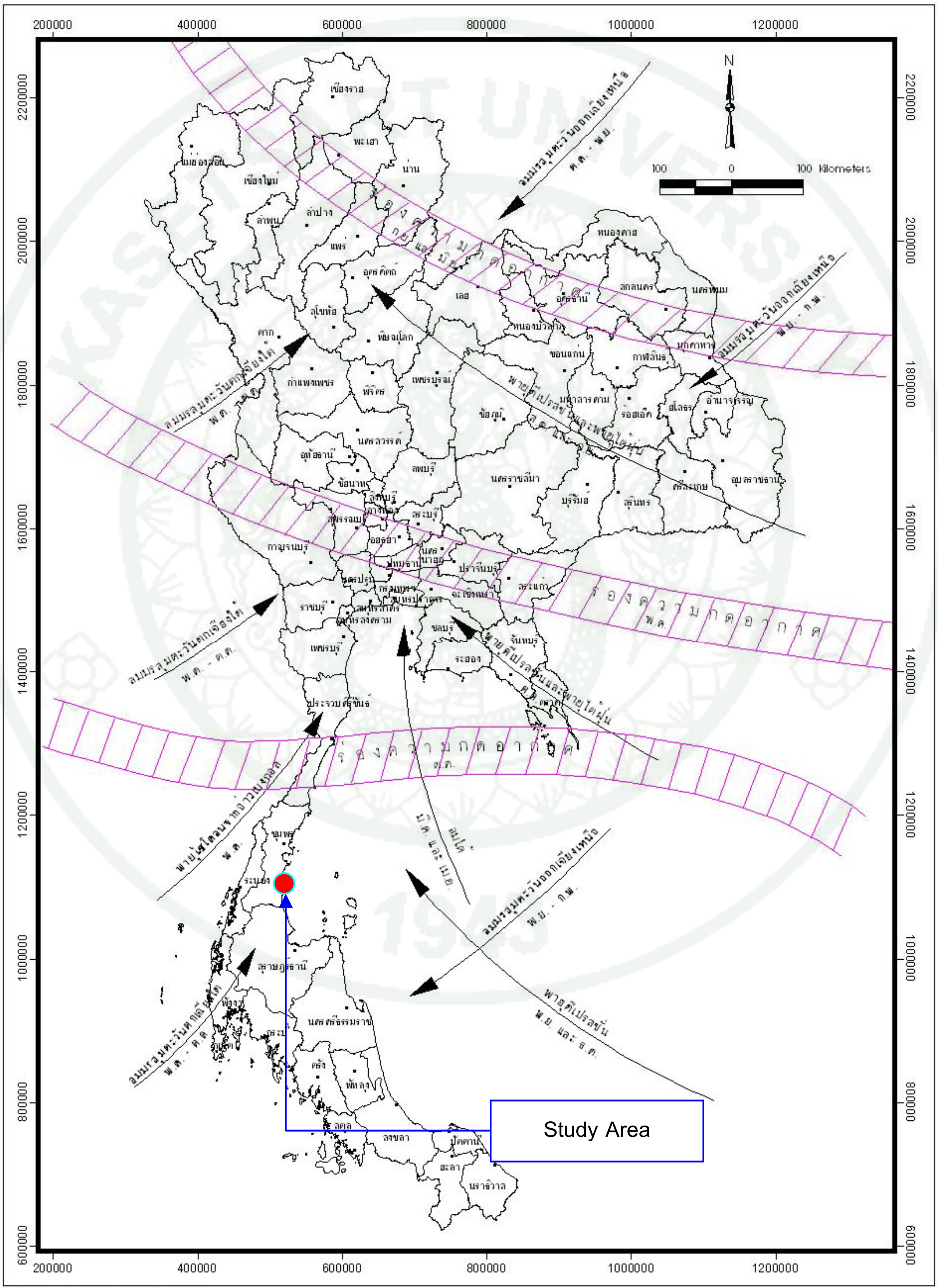
Water level	Langsuan tidal station, in Chumporn Province
Mean Highest High Water (MHHW)	+0.74 m. (MSL)
Mean High Water Spring (MHWS)	+0.79 m. (MSL)
Mean High Water (MHW)	+0.67 m. (MSL)
Mean High Water Neap (MHWN)	+0.65 m. (MSL)
Local Mean Sea Level (LMSL)	+0.06 m. (MSL)
Mean Low Water Neap (MLWN)	-0.43 m. (MSL)
Mean Low Water (MLW)	-0.43 m. (MSL)
Mean Low Water Spring (MLWS)	-0.46 m. (MSL)
Mean Lowest Low Water (MLLW)	-0.45 m. (MSL)

For the tidal type in this area is a mixed type which has diurnal type and semi-diurnal type together. The tidal range in the area is 0.89 m. during the spring tide and 0.60 m. during the neap tide.

The designed highest water level is the water level used for determining the height of the structures in coastal structure design. The water level also affects in wave energy level. If the water level is high nearshore, the high waves can also come very close to the beach before breaking. Especially, high waves in the study area are always occurred during the monsoon (November to January) which is the same time that the water level is high. As a result, Mean High Water Spring (MHWS) +0.79m. (from MSL) is used as designed highest water level in this study area.

5. Meteorological data

Because Chumporn province is in the south of Thailand, it is affected by the southwest monsoon during May to October which is the monsoon that moves pass the south of Indian Ocean. After that, during November to February, it is affected by Northeast monsoon that causes continuous rain in many months. In addition, during that time, because of the severe winds, they cause very high waves which directly affect in the erosion. For the directions and times of the monsoons, they are as shown in Figure 61.



BHAWIN:c:\project\thailand\04d067.apr\'wind'

Figure 61 The directions and times of the monsoons in Thailand**.**

C. Historical shoreline data

Generally, shoreline is continuously changed both eroded and accumulated until it becomes equilibrium because of the sediment transport. Actually, there are two major causes of shoreline change: 1) by nature and 2) by human.

The studies of shoreline changes have been done mostly by Aerial Photo Comparison. The records from those photos can interpret to shoreline changes by referring to the reference points and distortion that is now with the higher and higher technology, the data seem to be more accurate.

1. Spatial Analysis

The study and data analysis of this part is the four different time collection of Aerial photos and satellite photos of the study area, Tambon Bangmapraw, Ampur Langsuan, Chumporn. Such shoreline changed data are analyzed by Overlay Technique of Geographic Information System (GIS). In fact, the data of Aerial photos and satellite photos are process through Interpretation Method and Coordinate Transformation Method by using the map ratio 1:50,000 as a base map. Four data are as followed:

- Aerial photo (black and white) in 1975 ratio 1:15,000 (photo taken in July 1975)
- Aerial photo (black and white) in 1995 ratio 1:15,000 (photo taken in Febuary 1995)
- Aerial photo (color) in 2002 ratio 1:25,000 (photo taken in March 2002)
- SPOT Satellite Photo in 2006 (photo taken in December 2006)

The results of shoreline changes by Overlay Technique of Geographic Information System (GIS) are from the analysis of Aerial photos and satellite photos in four different times: Aerial photo in 1975, Aerial photo in 1995, Aerial photo in 2002, and SPOT Satellite Photo in 2006; so, the results are three comparison result data which are:

- Duration 20 years of shoreline change from the comparison of Aerial photo in 1975 and Aerial photo in 1995
- Duration 7 years of shoreline change from the comparison of Aerial photo in 1995 and Aerial photo in 2002
- Duration 4 years of shoreline change from the comparison of Aerial photo in 2002 and Aerial photo in 2006

For the shoreline change analysis of Duration 20 years from the comparison of Aerial photo in 1975and Aerial photo in 1995, it is shown in Figure 62. This result has been done by using Aerial photo in 1975 as Background, and using Aerial photo in 1995 (blue line) overlaid on it. The erosion areas are replaced by symbol “E1-”, and the accumulated areas are replaced by symbol “A1-” followed by the area amount or length of the shoreline.

For the shoreline change analysis of Duration 7 years from the comparison of Aerial photo in 1995and Aerial photo in 2002, it is shown in Figure 63. This result has been done by using Aerial photo in 1995 as Background, and using Aerial photo in 2002 (blue line) overlaid on it. The erosion areas are replaced by symbol “E2-”, and the accumulated areas are replaced by symbol “A2-” followed by the area amount or length of the shoreline.

For the shoreline change analysis of Duration 4 years from the comparison of Aerial photo in 2002 and Aerial photo in 2006, it is shown in Figure 64. This result has been done by using Aerial photo in 2002 as Background, and using Aerial photo in 2006 (blue line) overlaid on it. The erosion areas are replaced by symbol “E3-”, and the accumulated areas are replaced by symbol “A3-” followed by the area amount or length of the shoreline.

It is found that during 20 years (1975-1995), the erosion area and accumulation area are as followed:

Coastal area part 1
There are 4 accumulation areas (A1-1 to A1-4) totally 70.76 Rais
There are 3 erosion areas (E1-1 to E1-3) totally 26.93 Rais

Coastal area part 2
There is 1 accumulation area (A1-5) totally 33.83 Rais
There are 2 erosion areas (E1-4 to E1-5) totally 34.02 Rais

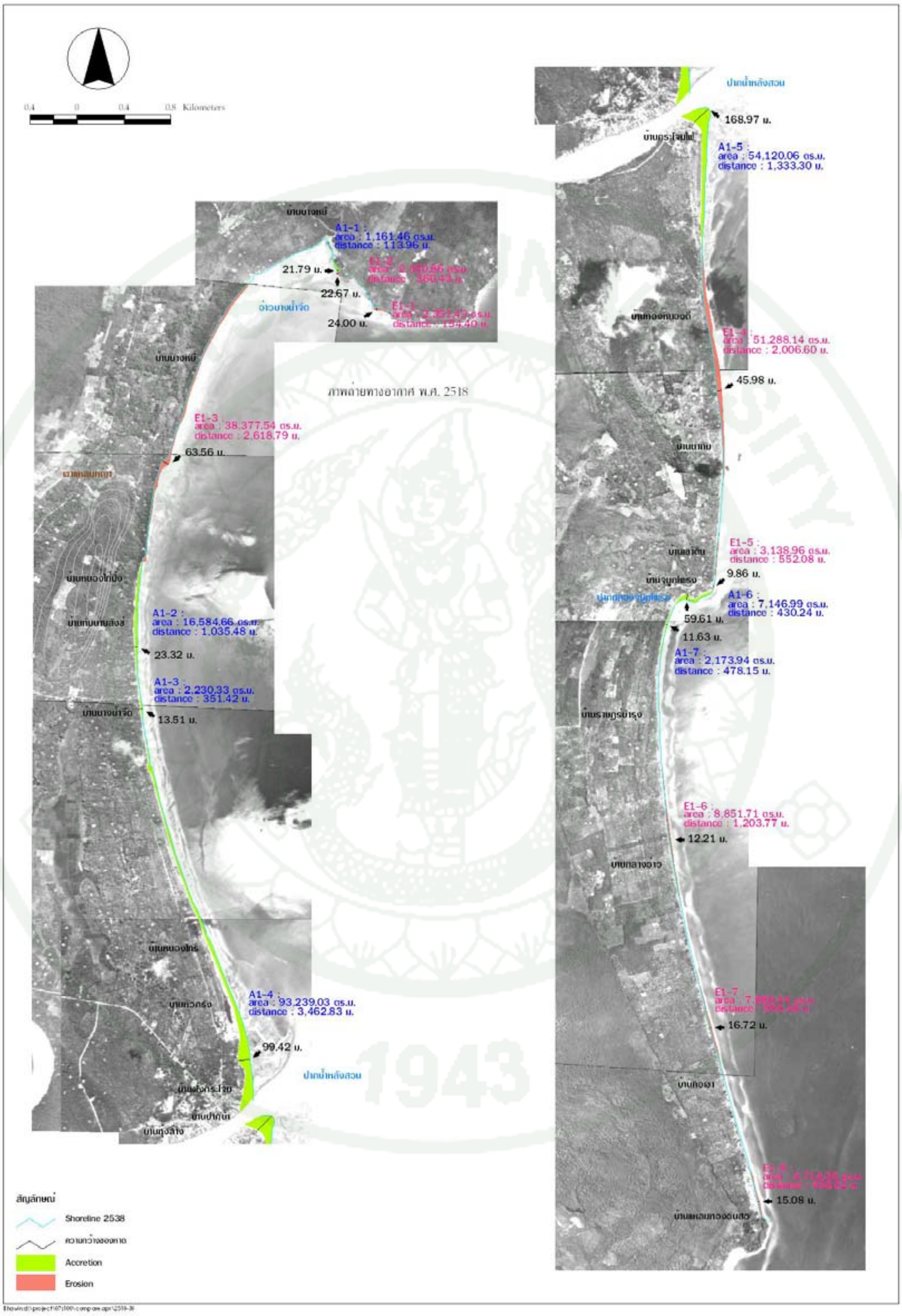


Figure 62 Duration 20 years of shoreline change from the comparison of Aerial photo in 1975 and Aerial photo in 1995

Figure 63 Duration 7 years of shoreline change from the comparison of Aerial photo in 1995 and Aerial photo in 2002

Figure 64 Duration 6 years of shoreline change from the comparison of Aerial photo in 2002 and SPOT Satellite Photo in 2006

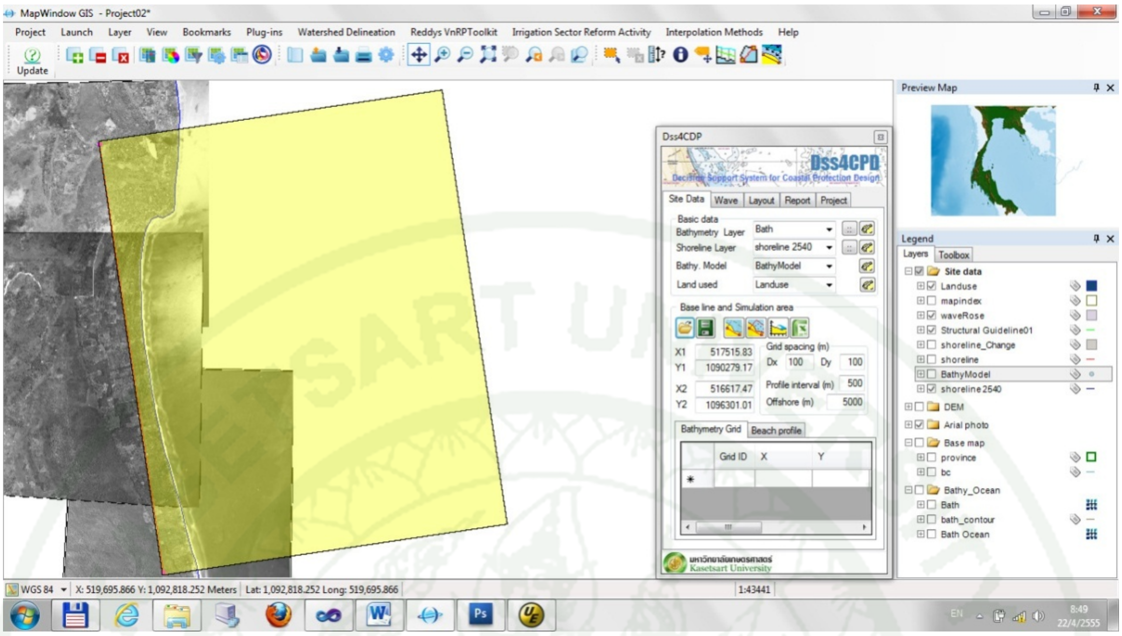
D. DSS4CPD Application

In the study case, the coastal structure design starts from preparing basic design data which consists of beach profile data and bathymetric data. The next step, the first decision making, is to make the study area baseline. In fact, the baseline is the straight line that covers the whole study area. For this study case, the baseline is the line between (517515.83, 1090279.17) and (516617.47, 1096301.01). For the Dialog Base, the designer can adjust as many orders as he wants such as distance from shoreline of the simulation area, and Grid spacing for the calculation. The examples are as shown in Figure 65.

```
Bathymetric Layer, Bath
Shoreline Layer, shoreline 2540
Land used Layer, Landuse
-----------------------------------------------
Baseline p1, 517515.83, 1090279.17
Baseline p2, 516617.47, 1096301.01
-----------------------------------------------
DX, 100
DY, 100
Offshore Length, 5000
```

Figure 65 The baseline data for coastal structure design

From the baseline assignment, DSS4CPD uses all above mentioned data to simulation process by creating data grid. To illustrate, the number of grids along the shoreline in this study is 68, and the number of grids from shoreline to the deep water in this study is 50 (DX =100 DY =100 m) as shown in Figures 66 and 67.

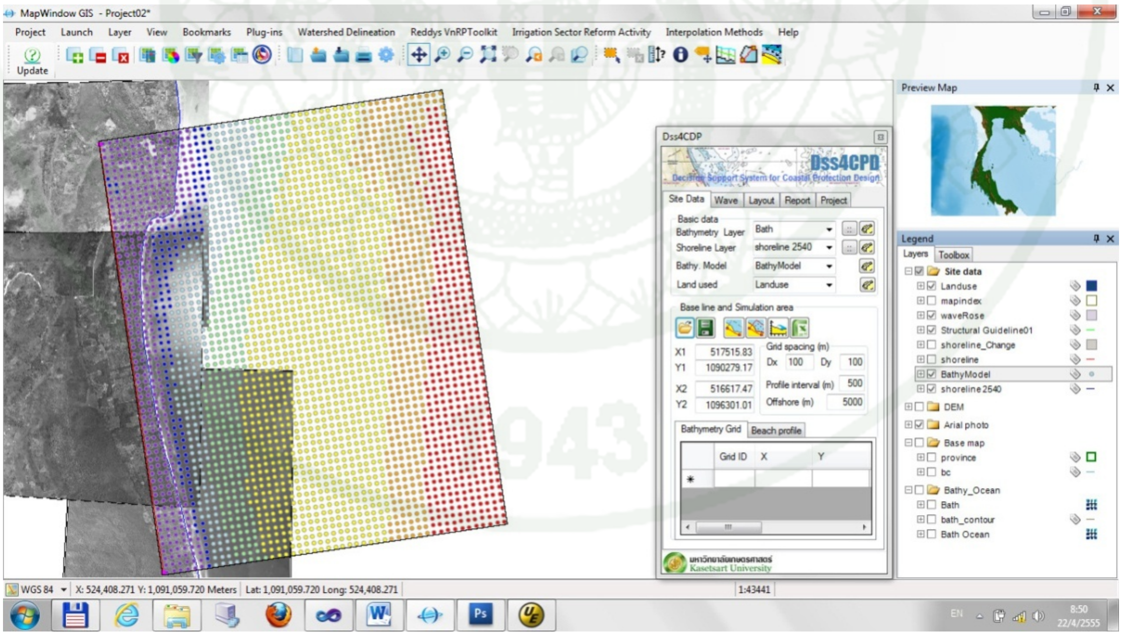


Basic data
Bathymetry Layer: Bath
Shoreline Layer: shoreline 2540
Bathy. Model: BathyModel
Land used: Landuse

Base line and Simulation area
X1 517515.83
Y1 1090279.17
X2 516617.47
Y2 1096301.01
Grid spacing (m) Dx 100 Dy 100
Profile interval (m) 500
Offshore (m) 5000

WGS 84 X: 519,695.866 Y: 1,092,818.252 Meters Lat: 1,092,818.252 Long: 519,695.866

Figure 66 Dialog base for Baseline Assignment, and grids for simulation.



Basic data
Bathymetry Layer: Bath
Shoreline Layer: shoreline 2540
Bathy. Model: BathyModel
Land used: Landuse

Base line and Simulation area
X1 517515.83
Y1 1090279.17
X2 516617.47
Y2 1096301.01
Grid spacing (m) Dx 100 Dy 100
Profile interval (m) 500
Offshore (m) 5000

WGS 84 X: 524,408.271 Y: 1,091,059.720 Meters Lat: 1,091,059.720 Long: 524,408.271

Figure 67 Dialog base for Baseline Assignment, and grids for simulation.

DSS4CPD uses the selected grid lines to be calculated relatively to the baseline. Points or grids from the bathymetric data or beach profiles are considered the positions if they are in the water, they can be directly read from DEM, but if they are in land, they are considered to be one constant value. The grid generation is as shown in Figure 68.

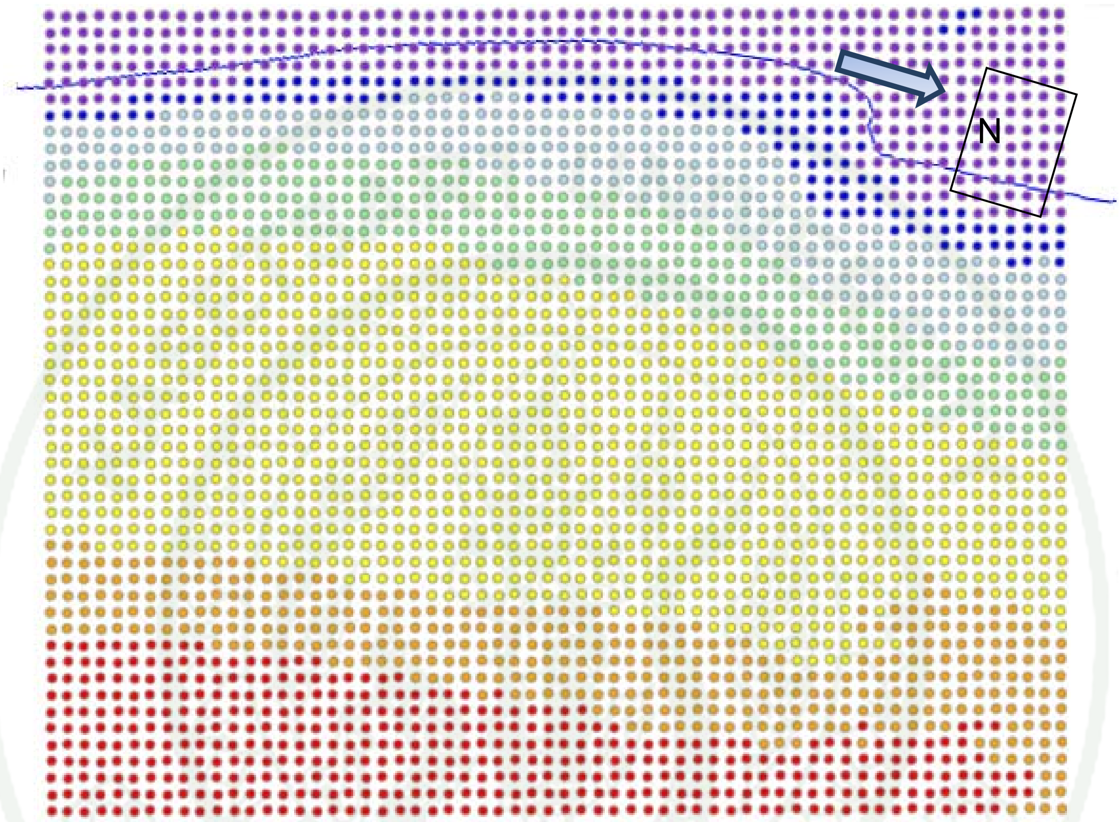
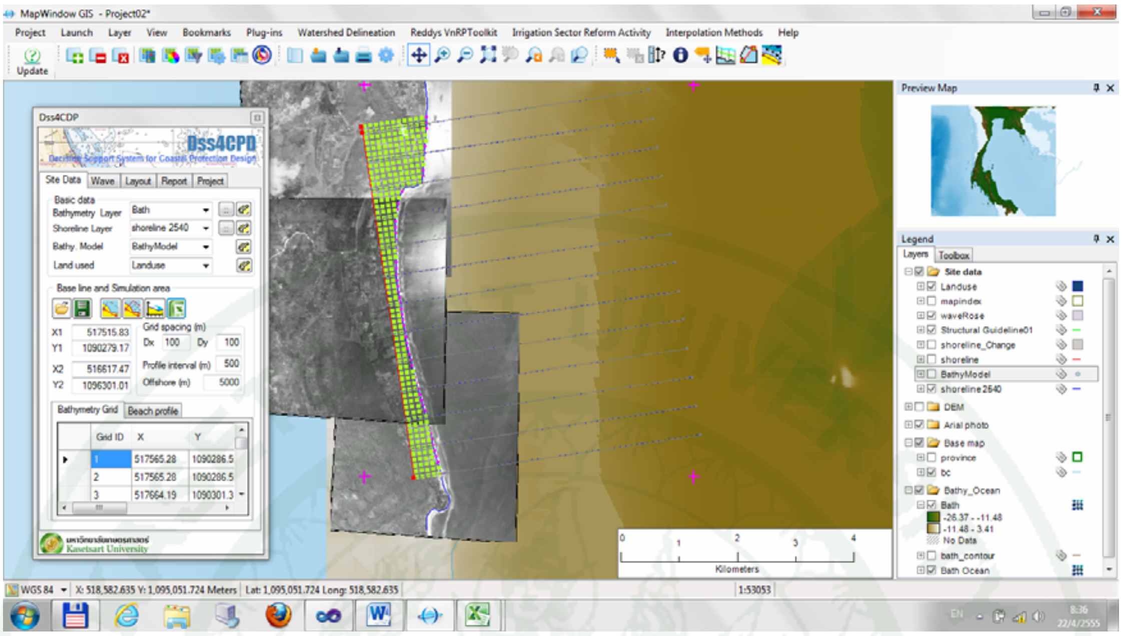


Figure 68 Bathymetry grid data generation

The other important data for DSS4CPD are water depth data and beach profile data. DSS4CPD has developed the tool that demonstrates such data to designers or decision makers in order to make any decision for the next working step as shown in Figures 69 and 70.

Beach profile data is very important for the designers to understand the distance from shore, MSL contour, or to get the calibration results, K_1 and K_2 in the shoreline change model, GENESIS.



Bathymetry Layer: Bath
Shoreline Layer: shoreline 2540
Bathy. Model: BathyModel
Land used: Landuse

X1: 517515.83
Y1: 1090279.17
X2: 516617.47
Y2: 1096301.01

Grid spacing (m): Dx 100 Dy 100
Profile interval (m): 500
Offshore (m): 5000

Grid ID	X	Y
1	517565.28	1090286.5
2	517565.28	1090286.5
3	517664.19	1090301.3

WGS 84 X: 518,582.635 Y: 1,095,051.724 Meters Lat: 1,095,051.724 Long: 518,582.635

Figure 69 Profile data of beach profiles and water depth data

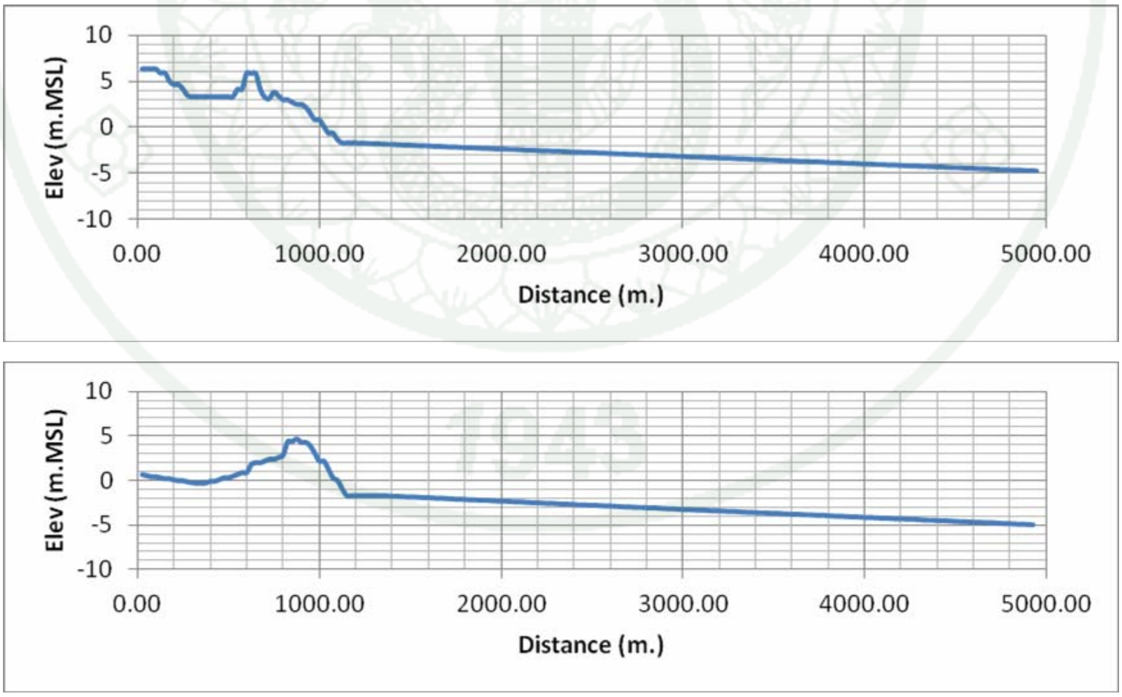
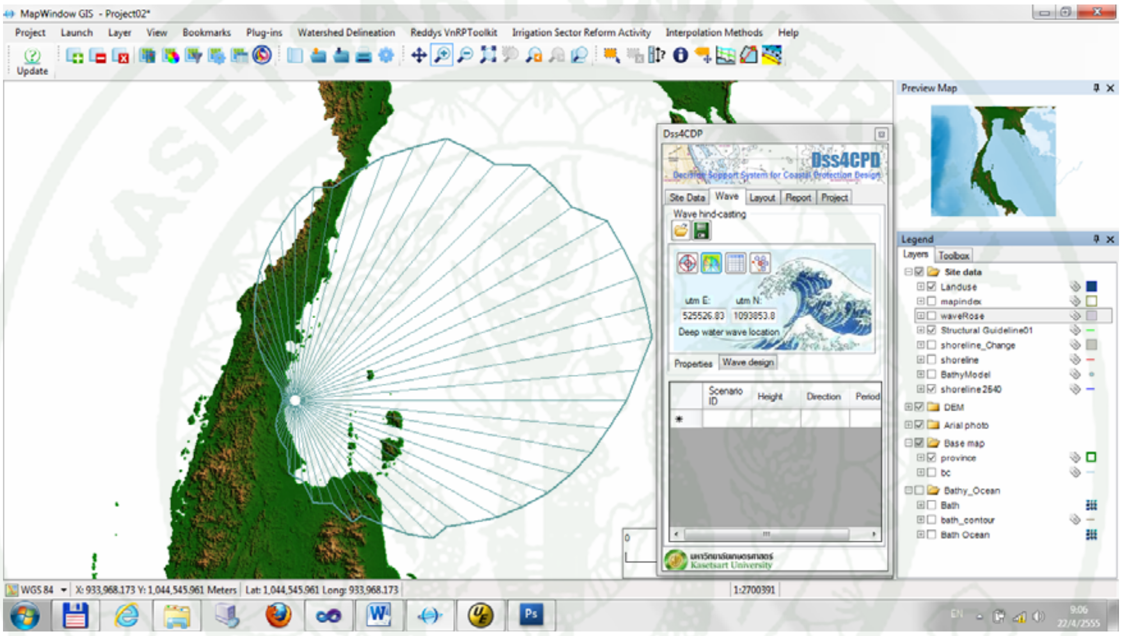


Figure 70 Example of water depth profile line KM 2+500 and KM 5+000

Deep water wave

After all basic data and information as the input data for DSS4CPD, the next step is the decision making to get the deep water wave origin position. In fact, the designers make the coordinate (N, E) of the wave hind-casting point. Then, the system will analyze all data and query wave data from deep water wave data base as shown in Figure 71.

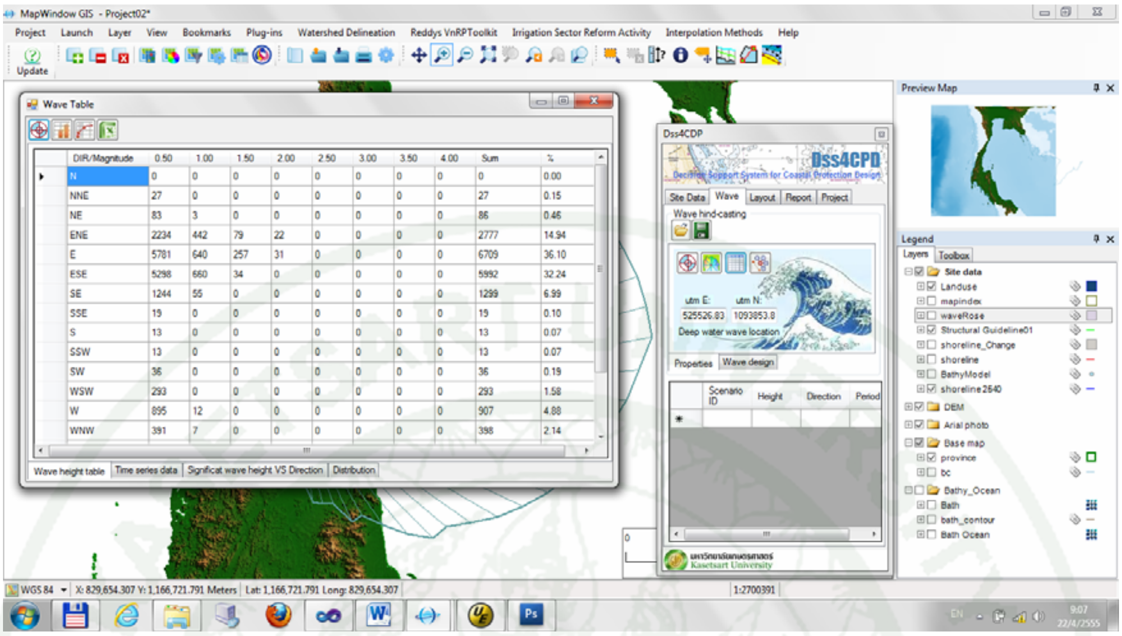


utm E: 525526.83
utm N: 1093853.8
Deep water wave location

WGS 84 | X: 933,968.173 Y: 1,044,545.961 Meters | Lat: 1,044,545.961 Long: 933,968.173 | 1:2700391

Figure 71 Fetch length of the study area

After querying wave data, all wave data results are analyzed for all directions and frequencies relatively to the study area. All results, frequency, height, and directions, are presented in table. For the directions, they are 16 major directions which are: N, NNE, NE, ENE, E, ESE, SE, SSE, S, SSW, SW, WSW, W, WNW, NW, and NNW as shown in Figures 72-74, and Table 5.



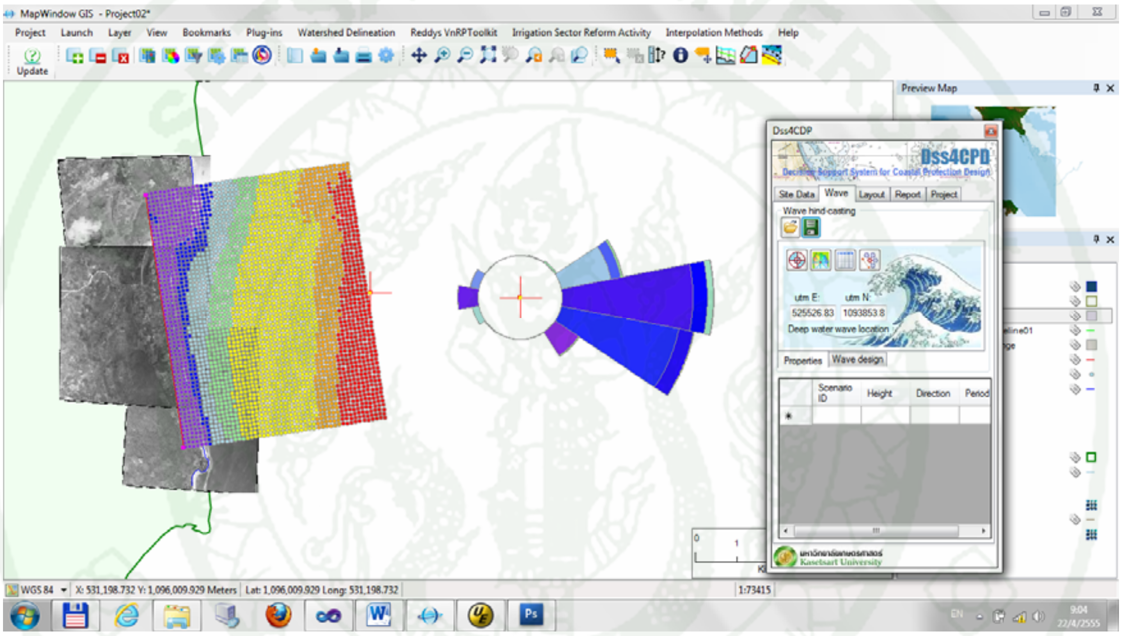
DIR/Magnitude	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Sum	%
N	0	0	0	0	0	0	0	0	0	0.00
NNE	27	0	0	0	0	0	0	0	27	0.15
NE	83	3	0	0	0	0	0	0	86	0.46
ENE	2234	442	79	22	0	0	0	0	2777	14.94
E	5781	640	257	31	0	0	0	0	6709	36.10
ESE	5298	660	34	0	0	0	0	0	5992	32.24
SE	1244	55	0	0	0	0	0	0	1299	6.99
SSE	19	0	0	0	0	0	0	0	19	0.10
S	13	0	0	0	0	0	0	0	13	0.07
SSW	13	0	0	0	0	0	0	0	13	0.07
SW	36	0	0	0	0	0	0	0	36	0.19
WSW	293	0	0	0	0	0	0	0	293	1.58
W	895	12	0	0	0	0	0	0	907	4.88
WNW	391	7	0	0	0	0	0	0	398	2.14

Figure 72 Wave table

Table 5 Wave table

	0.50	1.00	1.50	2.00	2.50	3.00	3.50	4.00	Sum	%
N	0	0	0	0	0	0	0	0	0	0
NNE	27	0	0	0	0	0	0	0	27	0.15
NE	83	3	0	0	0	0	0	0	86	0.46
ENE	**2234**	**442**	**79**	**22**	**0**	**0**	**0**	**0**	**2777**	**14.9**
E	**5781**	**640**	**257**	**31**	**0**	**0**	**0**	**0**	**6709**	**36.1**
ESE	**5298**	**660**	**34**	**0**	**0**	**0**	**0**	**0**	**5992**	**32.2**
SE	1244	55	0	0	0	0	0	0	1299	6.99
SSE	19	0	0	0	0	0	0	0	19	0.1
S	13	0	0	0	0	0	0	0	13	0.07
SSW	13	0	0	0	0	0	0	0	13	0.07
SW	36	0	0	0	0	0	0	0	36	0.19
WSW	293	0	0	0	0	0	0	0	293	1.58
W	895	12	0	0	0	0	0	0	907	4.88
WNW	391	7	0	0	0	0	0	0	398	2.14
NW	13	0	0	0	0	0	0	0	13	0.07
NNW	5	0	0	0	0	0	0	0	5	0.03
Summary	16345	1819	370	53	0	0	0	0	18587	100

From wave hind-casting result information, it is seen that the dominant wave directions are ENE, E, ESE, and SE. However, the directions E and ESE are the first and second high percentage of wave coming to the project area. For that reason, it can be stated that the net sediment transport are moved up north. As a result, the coastal structure layout guideline can be considered following the above information.



utm E: 525526.83

utm N: 1093853.8

WGS 84 | X: 531,198.732 Y: 1,096,009.929 Meters | Lat: 1,096,009.929 Long: 531,198.732 | 1:73415

Figure 73 Waverose overlay on map

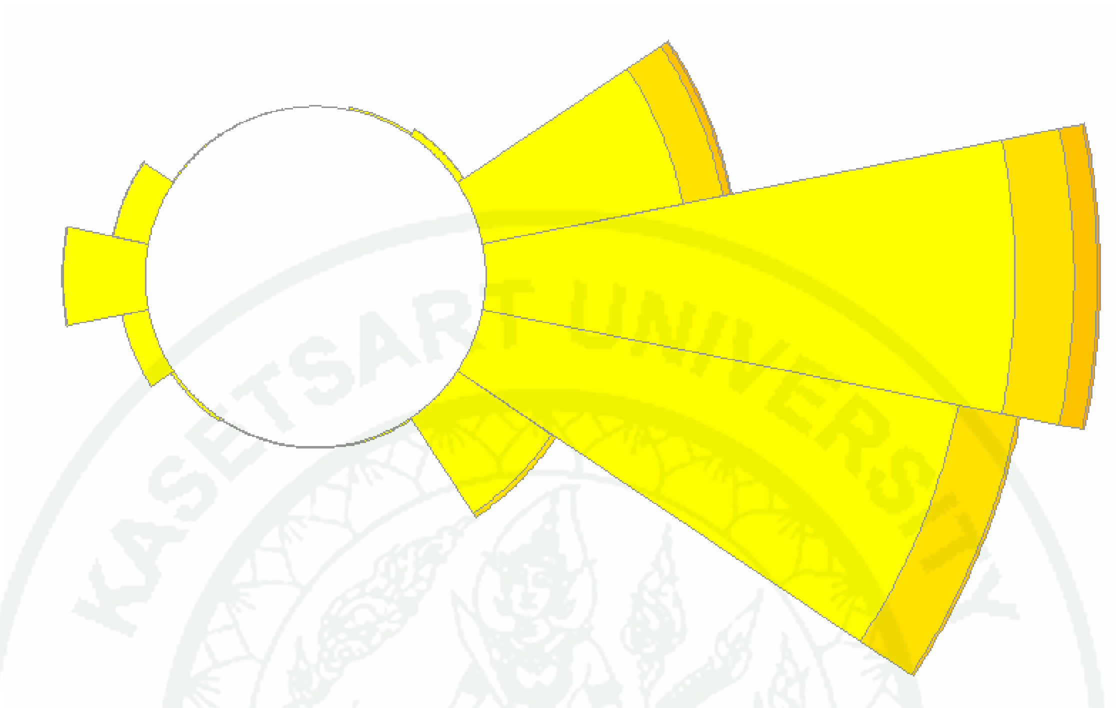
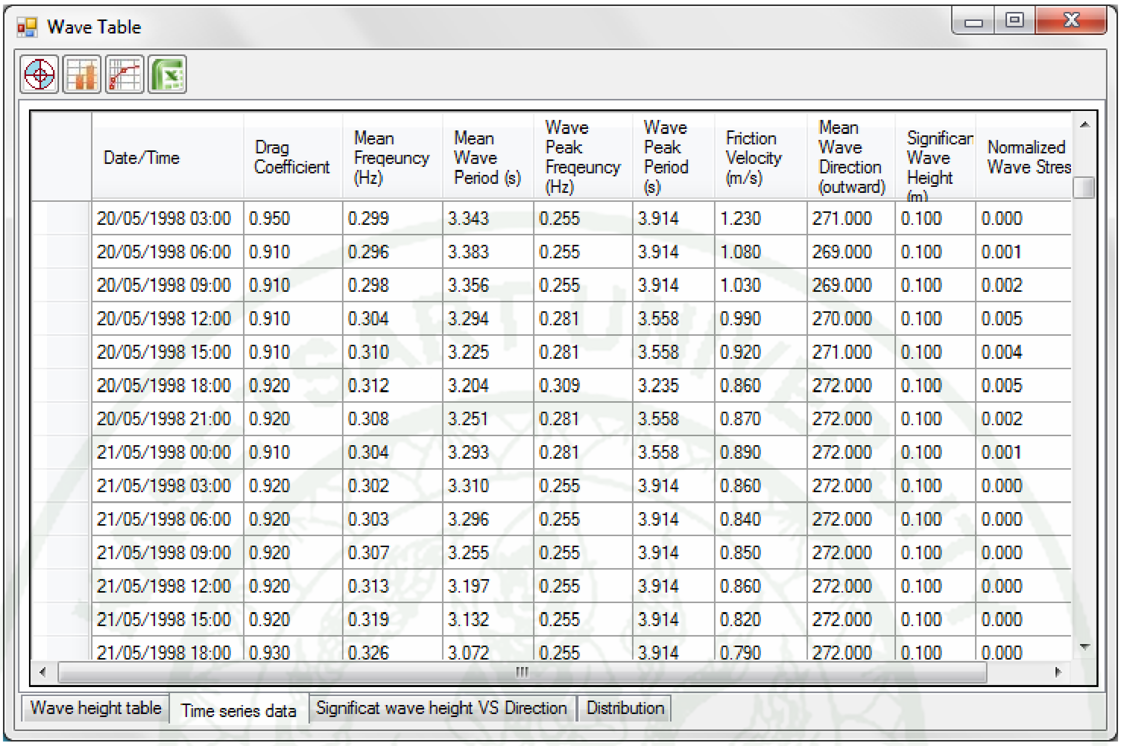


Figure 74 Chompron Waverose diagram

All wave parameters at the selected point are presented as the time series table as shown in Figure 10. Eight important parameters in the table are: Drag Coefficient, Mean Frequency (Hz), Mean Wave Period (s), Wave peak frequency (Hz), Wave peak period(s), Friction velocity (m/s), Mean wave direction, Significant wave height, and Normalize wave stress. The examples of the above mentioned data are as shown in Figures 75 to 83.



	Date/Time	Drag Coefficient	Mean Freqeuncy (Hz)	Mean Wave Period (s)	Wave Peak Freqeuncy (Hz)	Wave Peak Period (s)	Friction Velocity (m/s)	Mean Wave Direction (outward)	Significar Wave Height (m)	Normalized Wave Stres
	20/05/1998 03:00	0.950	0.299	3.343	0.255	3.914	1.230	271.000	0.100	0.000
	20/05/1998 06:00	0.910	0.296	3.383	0.255	3.914	1.080	269.000	0.100	0.001
	20/05/1998 09:00	0.910	0.298	3.356	0.255	3.914	1.030	269.000	0.100	0.002
	20/05/1998 12:00	0.910	0.304	3.294	0.281	3.558	0.990	270.000	0.100	0.005
	20/05/1998 15:00	0.910	0.310	3.225	0.281	3.558	0.920	271.000	0.100	0.004
	20/05/1998 18:00	0.920	0.312	3.204	0.309	3.235	0.860	272.000	0.100	0.005
	20/05/1998 21:00	0.920	0.308	3.251	0.281	3.558	0.870	272.000	0.100	0.002
	21/05/1998 00:00	0.910	0.304	3.293	0.281	3.558	0.890	272.000	0.100	0.001
	21/05/1998 03:00	0.920	0.302	3.310	0.255	3.914	0.860	272.000	0.100	0.000
	21/05/1998 06:00	0.920	0.303	3.296	0.255	3.914	0.840	272.000	0.100	0.000
	21/05/1998 09:00	0.920	0.307	3.255	0.255	3.914	0.850	272.000	0.100	0.000
	21/05/1998 12:00	0.920	0.313	3.197	0.255	3.914	0.860	272.000	0.100	0.000
	21/05/1998 15:00	0.920	0.319	3.132	0.255	3.914	0.820	272.000	0.100	0.000
	21/05/1998 18:00	0.930	0.326	3.072	0.255	3.914	0.790	272.000	0.100	0.000

Figure 75 Dialogue base of wave parameters

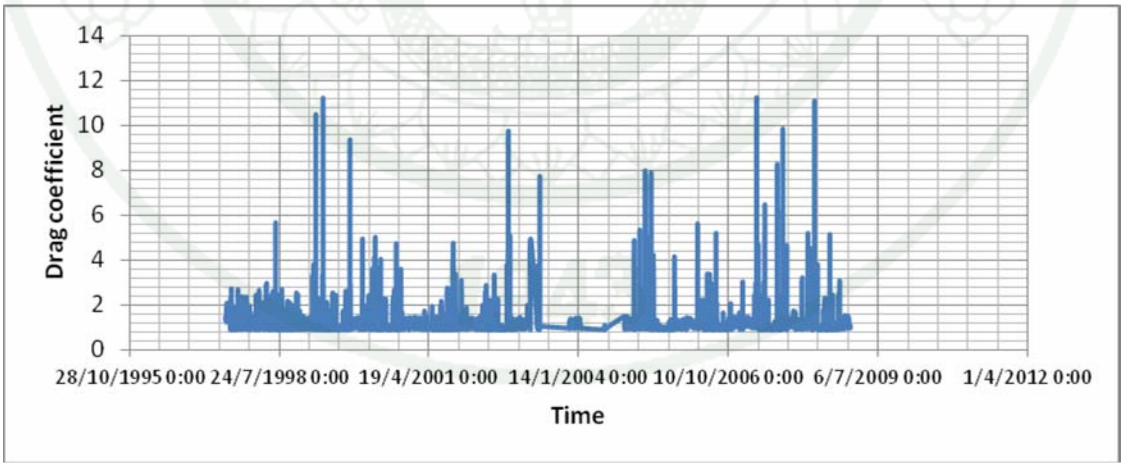


Figure 76 Time series of Drag coefficient

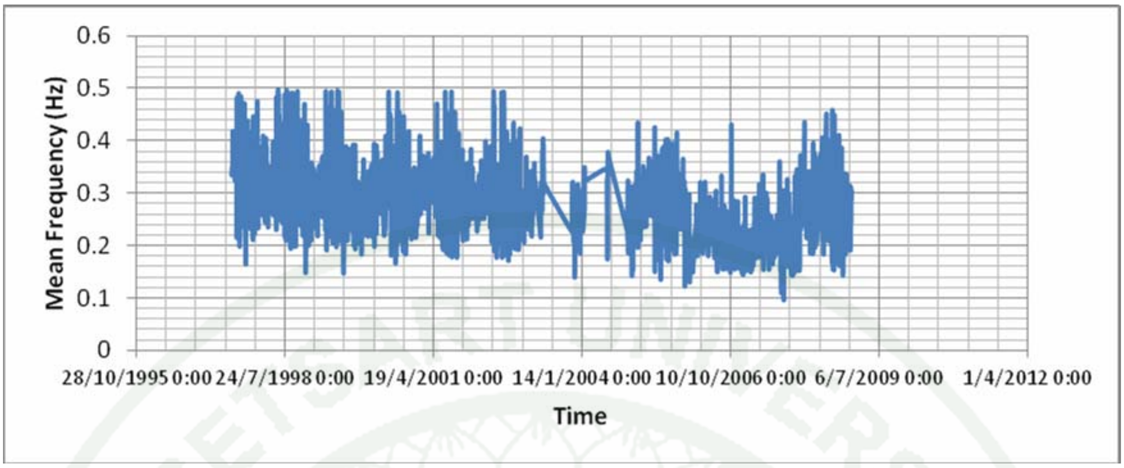


Figure 77 Time series of Mean frequency

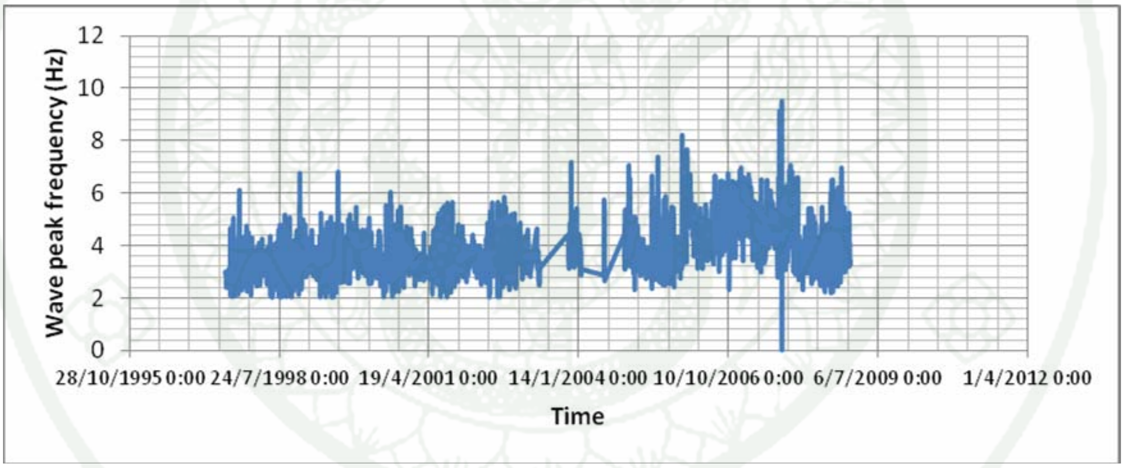


Figure 78 Time series of Wave peak frequency (Hz)

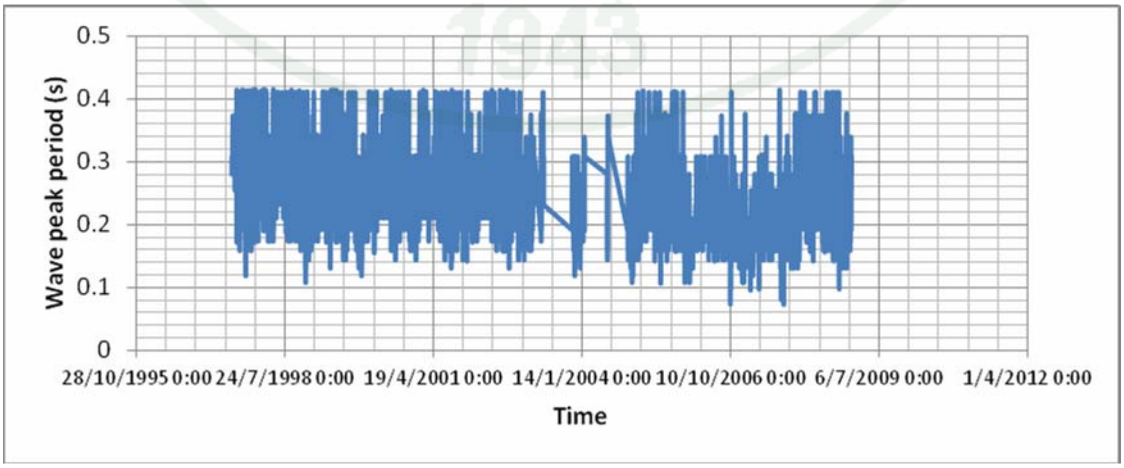


Figure 79 Time series of Wave peak period

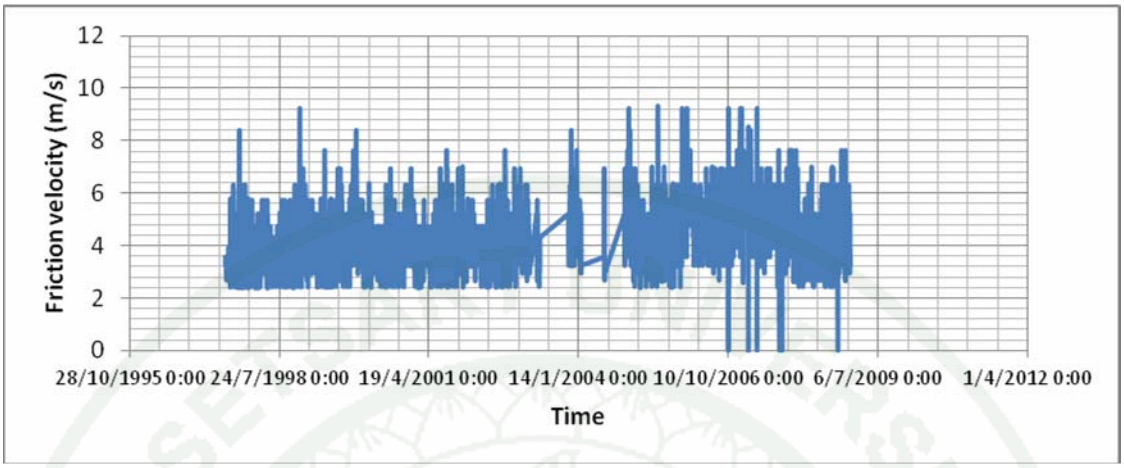


Figure 80 Time series of Friction velocity

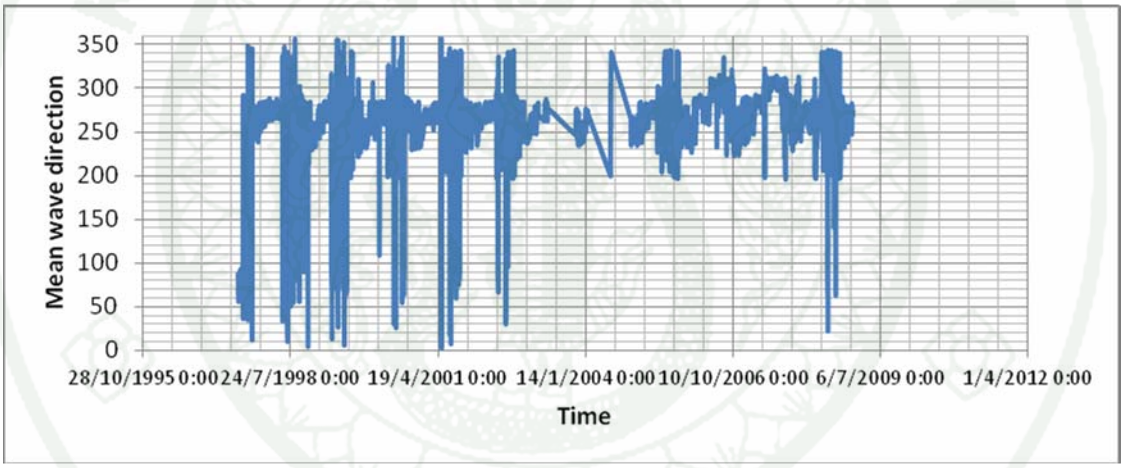


Figure 81 Time series of Mean wave direction

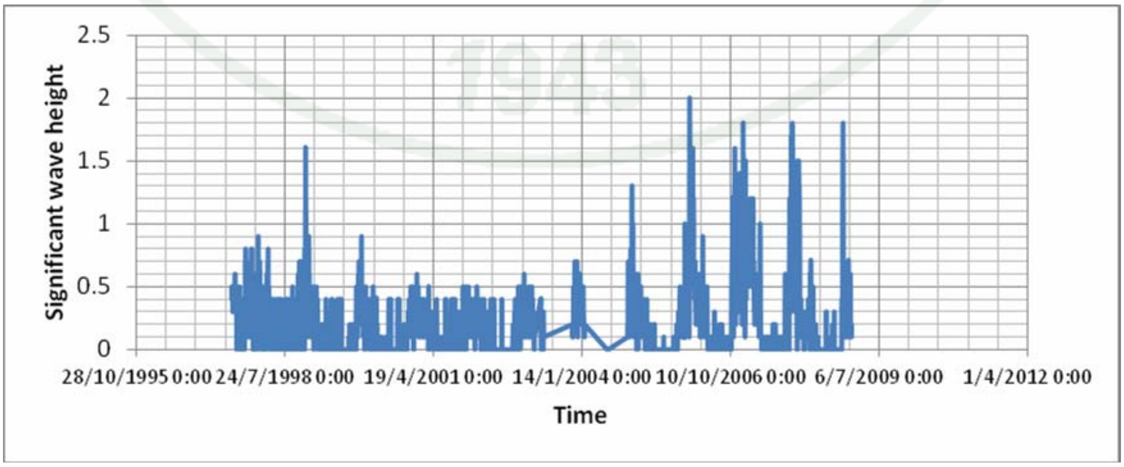


Figure 82 Time series of Significant wave height

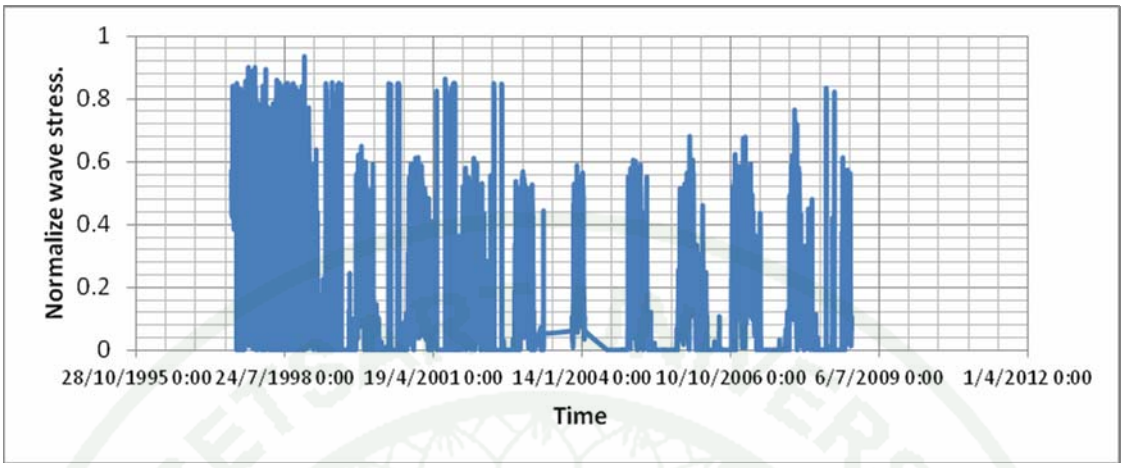


Figure 83 Time series of Normalize wave stress.

6. Wave design

For the analysis of deep water wave height and deep water wave period, the wave statistics from the wave calculation as in the above calculated result. From the results of wave and wind prediction in the study area, when the predicted highest wave heights in each year are analyzed for finding the significant wave height using for the coastal structure design, they use the 7 equations which are: 1. Normal, 2. Log-Normal, 3. Gumbel, 4. Log-Gumbel 5. Pearson-3, 6. Log-Pearson-3, and 7. Log-Normal-3. For each of equations, they give the different results relatively to wave data. The equation that has the minimum CHI-Square Standard Error is the best equation relative to the data as shown in Tables 6-8.

Table 6 Wave design in direction ENE

DISTRIBUTION	LOCATION	SCALE	SHAPE	RETURN PERIOD	
PARAMETER	PARAMETER	PARAMETER	STANDARD	5 Year	100 Year
NORMAL	1.276	0.224	0.000	1.464	1.796
LOG-NORMAL	0.229	0.172	0.000	1.453	1.876
GUMBEL	**1.175**	**0.175**	**0.000**	**1.437**	**1.978**
LOG-GUMBEL	0.151	0.134	0.000	1.423	2.157
PEARSON-3	0.416	0.058	14.743	1.456	1.881

Table 6 (Continued)

DISTRIBUTION	LOCATION	SCALE	SHAPE	RETURN PERIOD	
PARAMETER	PARAMETER	PARAMETER	STANDARD	5 Year	100 Year
LOG-PEARSON-3	-1.079	0.023	57.658	1.449	1.939
LOG-NORMAL-3	0.250	0.169	0.000	1.453	1.874

Table 7 Wave design in direction E

DISTRIBUTION	LOCATION	SCALE	SHAPE	RETURN PERIOD	
PARAMETER	PARAMETER	PARAMETER	STANDARD	5 Year	100 Year
NORMAL	1.242	0.214	0.000	1.423	1.741
LOG-NORMAL	0.203	0.164	0.000	1.406	1.793
GUMBEL	**1.146**	**0.167**	**0.000**	**1.397**	**1.915**
LOG-GUMBEL	0.130	0.128	0.000	1.378	2.047
PEARSON-3	0.824	0.110	3.807	1.403	1.896
LOG-PEARSON-3	-0.314	0.052	10.001	1.395	1.932
LOG-NORMAL-3	-0.480	0.312	0.000	1.396	1.870

Table 8 Wave design in directionESE

DISTRIBUTION	LOCATION	SCALE	SHAPE	RETURN PERIOD	
PARAMETER	PARAMETER	PARAMETER	STANDARD	5 Year	100 Year
NORMAL	1.049	0.062	0.000	1.101	1.193
LOG-NORMAL	0.047	0.058	0.000	1.100	1.198
GUMBEL	**1.022**	**0.048**	**0.000**	**1.094**	**1.243**
LOG-GUMBEL	0.021	0.045	0.000	1.092	1.255
PEARSON-3	0.920	0.029	4.385	1.096	1.235

Table 8 (Continued)

PARAMETER	LOCATION PARAMETER	SCALE PARAMETER	SHAPE STANDARD	RETURN PERIOD 5 Year	100 Year
LOG-PEARSON-3	-0.086	0.025	5.328	1.095	1.241
LOG-NORMAL-3	-1.652	0.289	0.000	1.094	1.225

In this research, Gumbel equation is the best equation relative to the data. As a result, this equation is used in analyzing the return period to get the significant wave height value for the design, and the best return period using in this research is 50 year and the wave height for the design are 1.7901, 1.7981 and 1.1762 m. (ENE, E and ESE)

From wave data in study area, there are three dominant directions which are ENE, E, and ESE. When those directions are combined with the possible wave periods in the Gulf of Thailand which is between 4 sec. to 9 sec., the wave scenarios in this is equal to 3(number of directions) multiply by 7(number of periods) = 21 scenarios as shown in Table 9.

Table 9 Wave scenario list

Scenario ID	Wave Direction	Height (m)	Period (sec)
1	ENE	1.7901	4
2	ENE	1.7901	5
3	ENE	1.7901	6
4	ENE	1.7901	7
5	ENE	1.7901	8
6	ENE	1.7901	9
7	ENE	1.7901	10
8	E	1.7981	4
9	E	1.7981	5
10	E	1.7981	6
11	E	1.7981	7
12	E	1.7981	8
13	E	1.7981	9
14	E	1.7981	10
15	ESE	1.1762	4
16	ESE	1.1762	5
17	ESE	1.1762	6
18	ESE	1.1762	7
19	ESE	1.1762	8
20	ESE	1.1762	9
21	ESE	1.1762	10

After that, DSS4CPD will do the wave transformation for all 21 scenarios, and make wave information maps such as wave direction maps, wave height maps, and wave breaking maps. All maps are presented on GIS in order to help coastal engineers or designers understand and can make the breakwater layout later on. The result of simulated nearshore waves are as shown in Figures 84- 90.

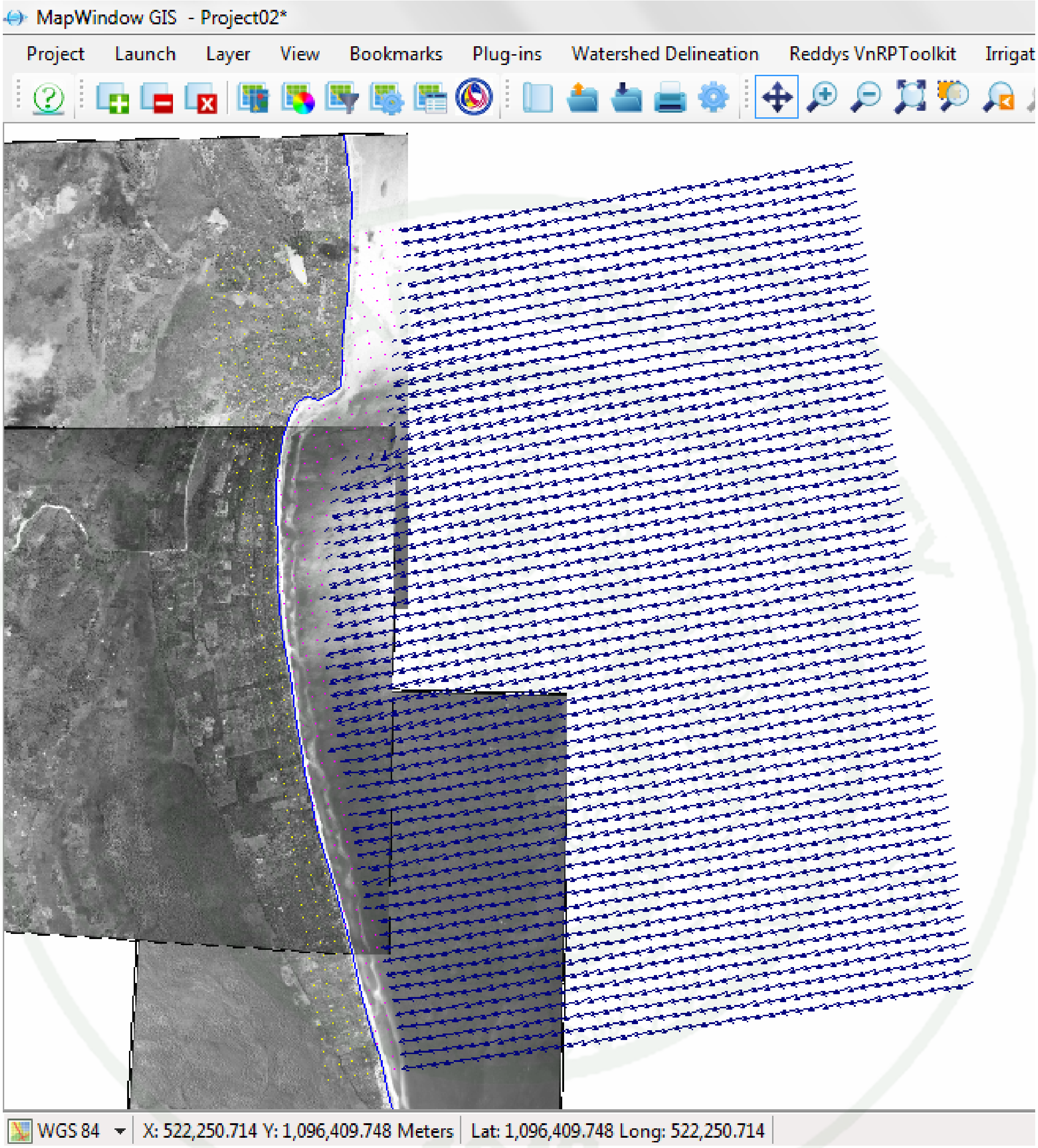
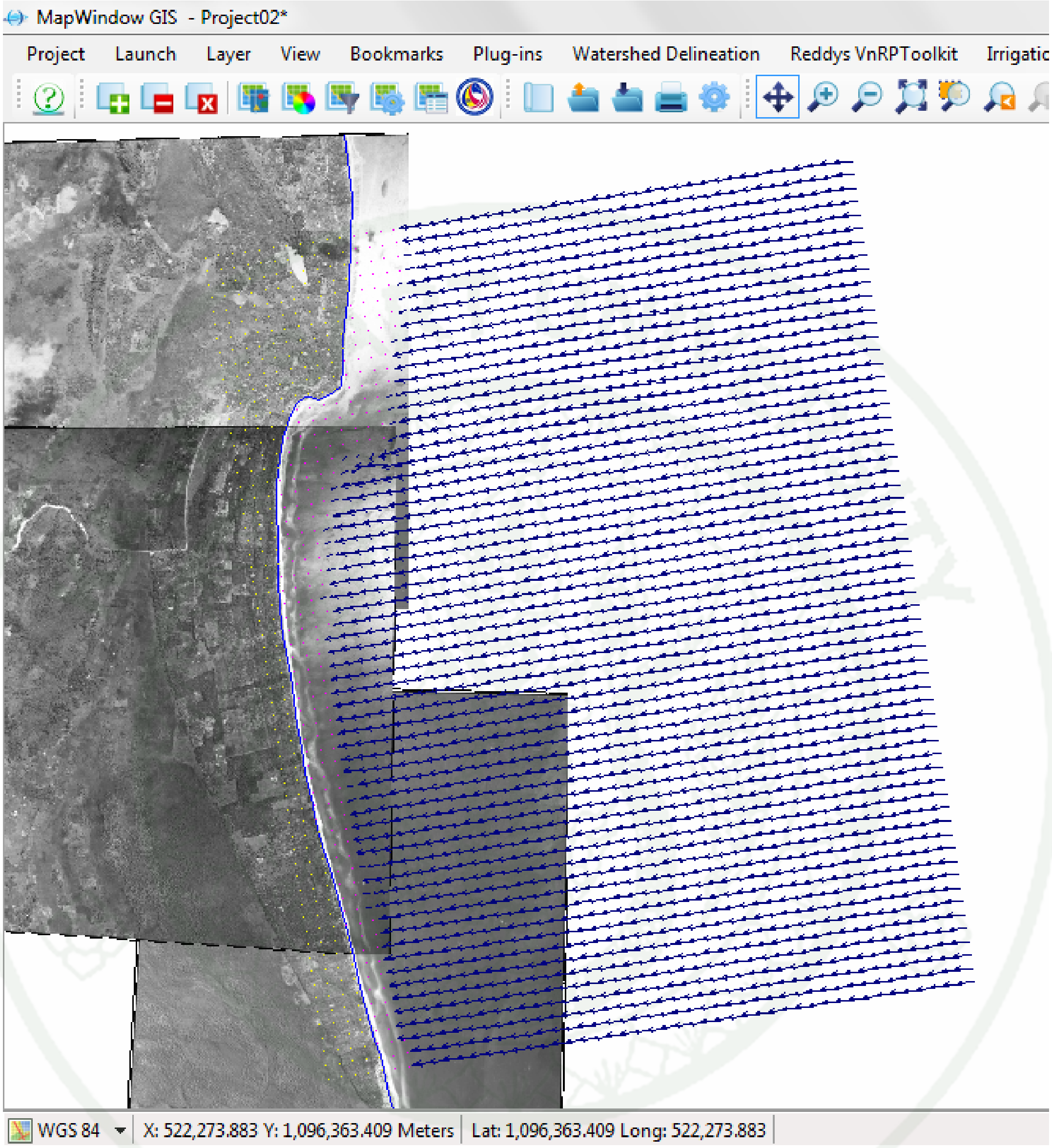


Figure 84 Wave direction map from deep water wave scenario period 7 sec/ ENE



WGS 84 | X: 522,273.883 Y: 1,096,363.409 Meters | Lat: 1,096,363.409 Long: 522,273.883

Figure 85 Wave direction map from deep water wave scenario period 7 sec/ E

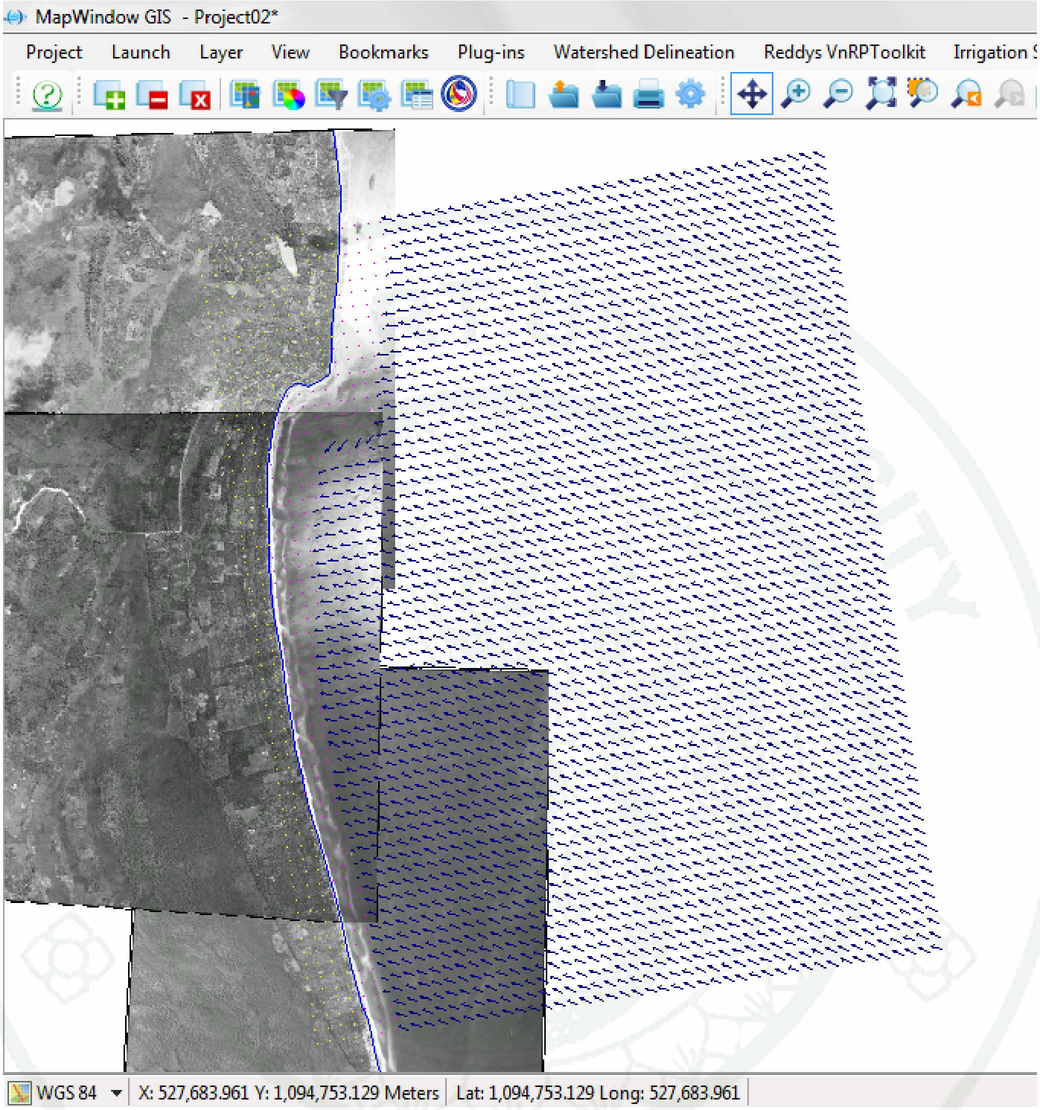
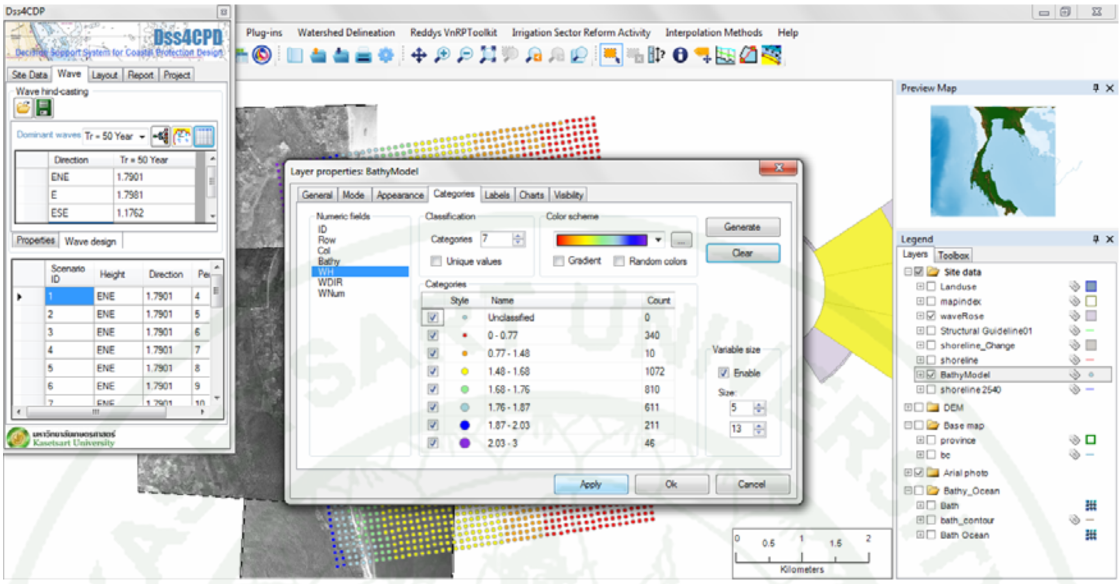


Figure 86 Wave direction map from deep water wave scenario period 7 sec/ ESE

From the wave transformation calculation result, it is found that when having the significant wave heights for all wave transformation scenario results, the water depth contour of two meter from mean sea water level (MSL) is appropriate for being the line of coastal structure alignment. For further study, this line of water depth is going to use for coastal structure detail design such as rock size, and structure dimensions.



Dominant waves: Tr = 50 Year

	Direction	Tr = 50 Year
	ENE	1.7901
	E	1.7981
	ESE	1.1762

	Scenario ID	Height	Direction	Pe
▸	1	ENE	1.7901	4
	2	ENE	1.7901	5
	3	ENE	1.7901	6
	4	ENE	1.7901	7
	5	ENE	1.7901	8
	6	ENE	1.7901	9
	7	ENE	1.7901	10

Layer properties: BathyModel

General | Mode | Appearance | Categories | Labels | Charts | Visibility

Numeric fields: ID, Row, Col, Bathy, WH, WDIR, WNum

Classification: Categories 7

☐ Unique values

Color scheme: ☐ Gradient ☐ Random colors

Generate | Clear

Categories

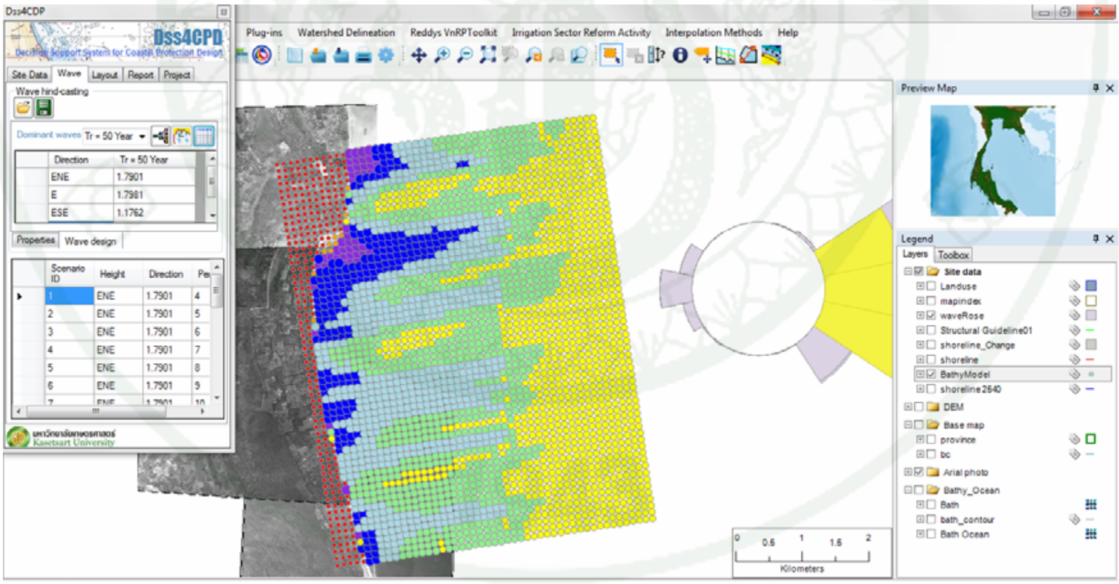
	Style	Name	Count
☑	●	Unclassified	0
☑	●	0 - 0.77	340
☑	●	0.77 - 1.48	10
☑	●	1.48 - 1.68	1072
☑	●	1.68 - 1.76	810
☑	●	1.76 - 1.87	611
☑	●	1.87 - 2.03	211
☑	●	2.03 - 3	46

Variable size: ☑ Enable

Size: 5, 13

Apply | Ok | Cancel

Figure 87 Wave height map colored scale generate dialogue.



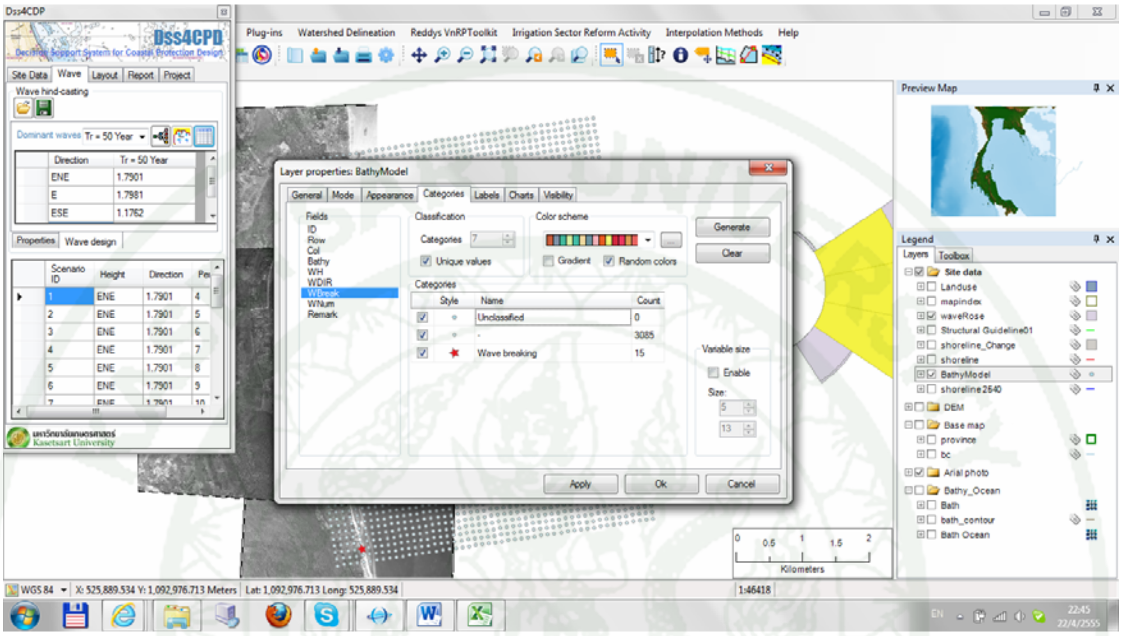
Dominant waves: Tr = 50 Year

	Direction	Tr = 50 Year
	ENE	1.7901
	E	1.7981
	ESE	1.1762

	Scenario ID	Height	Direction	Pe
▸	1	ENE	1.7901	4
	2	ENE	1.7901	5
	3	ENE	1.7901	6
	4	ENE	1.7901	7
	5	ENE	1.7901	8
	6	ENE	1.7901	9
	7	ENE	1.7901	10

Figure 88 Wave height map (case deep water wave scenario period 7 sec/ ESE)

The positions of wave breaking is important for the designers to now since this is the point that waves have changed their energy and have broken from their pattern. In addition, there are lots of sediment movements at the sea bed in this wave breaking area due to the wave energy at this point. To understand the wave behaviors as mentioned, the designers can make the appropriate coastal structure design in this project area suitably.



Dominant waves: Tr = 50 Year

	Direction	Tr = 50 Year
	ENE	1.7901
	E	1.7981
	ESE	1.1762

	Scenario ID	Height	Direction	Pe
▶	1	ENE	1.7901	4
	2	ENE	1.7901	5
	3	ENE	1.7901	6
	4	ENE	1.7901	7
	5	ENE	1.7901	8
	6	ENE	1.7901	9
	7	ENE	1.7901	10

Layer properties: BathyModel

General | Mode | Appearance | Categories | Labels | Charts | Visibility

Fields: ID, Row, Col, Bathy, WH, WDIR, WBreak, WNum, Remark

Classification: Categories 7; ☑ Unique values

Color scheme: ☐ Gradient ☑ Random colors

Generate | Clear

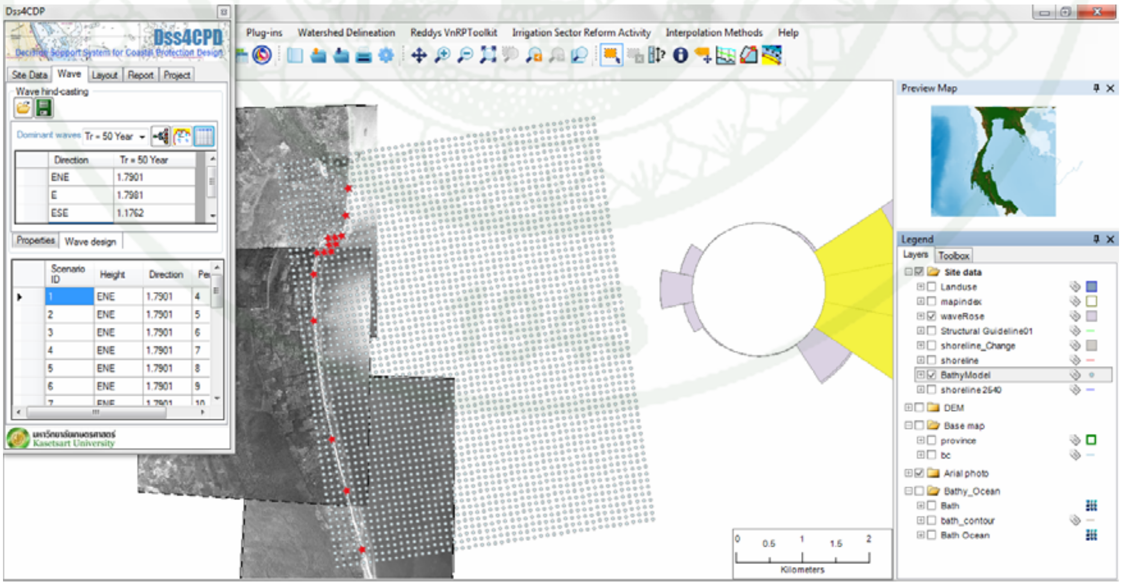
Categories

	Style	Name	Count
☑	•	Unclassified	0
☑	•	-	3085
☑	★	Wave breaking	15

Variable size: ☐ Enable; Size: 5, 13

Apply | Ok | Cancel

Figure 89 Wave breaking map generate dialogue.



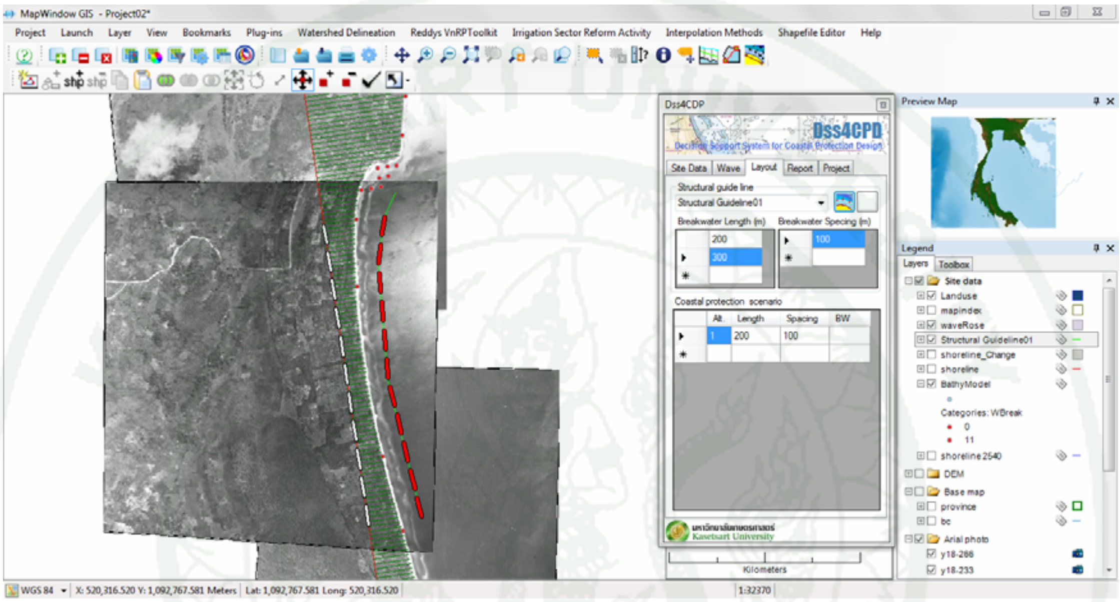
Dominant waves: Tr = 50 Year

	Direction	Tr = 50 Year
	ENE	1.7901
	E	1.7981
	ESE	1.1762

	Scenario ID	Height	Direction	Pe
▶	1	ENE	1.7901	4
	2	ENE	1.7901	5
	3	ENE	1.7901	6
	4	ENE	1.7901	7
	5	ENE	1.7901	8
	6	ENE	1.7901	9
	7	ENE	1.7901	10

Figure 90 Wave breaking map (case deep water wave scenario period 7 sec/ ESE)

After having breakwater guideline, two sizes of breakwater have been input which are the breakwater 200 and 300 meters long with the spacing of 100 meters. Then, the system will create the breakwater layout alternatives as shown in Figure 91.



X: 520,316.520 Y: 1,092,767.581 Meters
Lat: 1,092,767.581 Long: 520,316.520

Structural guide line: Structural Guideline01

Breakwater Length (m)
200
300

Breakwater Spacing (m)
100

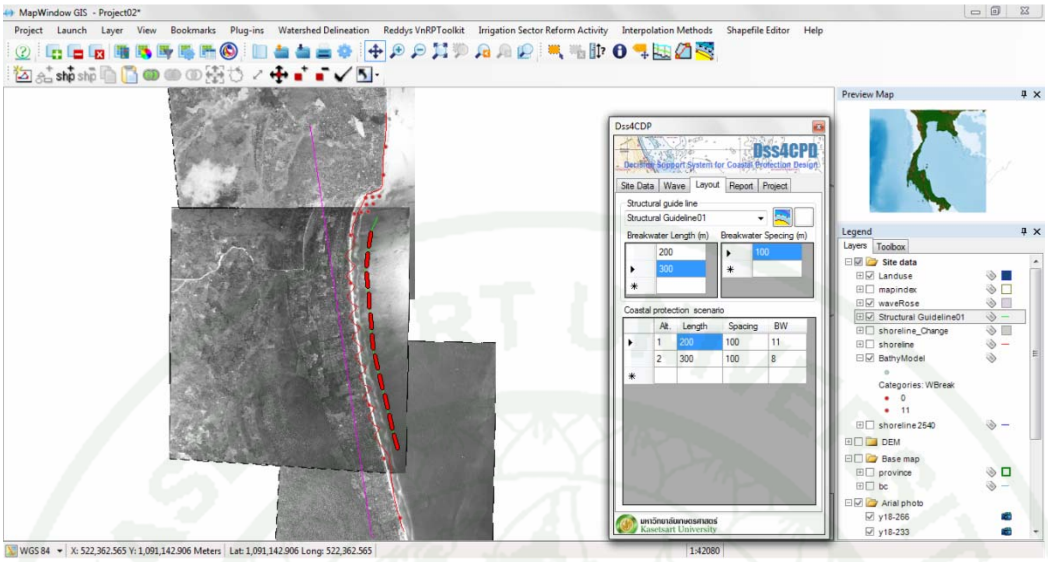
Coastal protection scenario

Alt.	Length	Spacing	BW
1	200	100	

Figure 91 Alternative 1 200 m breakwaters with spacing 100 m

From the coastal structure layouts, all breakwaters can be determined their positions, sizes, and spacings by relating to the project baseline based on Grid system as shown in figure 91. After that, all above data are used as the input files in the required format in Shoreline change model equally to the number of layout scenarios for the model calculation.

After calculating shoreline change by the model, the system created the new shoreline as shown in Figure 92. The shoreline calculation results for the model are different from each other affected from each sizes and spacing of the layouts. Then, the results are computed and compared in spatial decision support in GIS to see what the most appropriate layout (the layout with highest score) for the project is.



Structural guide line: Structural Guideline01

Breakwater Length (m): 200, 300

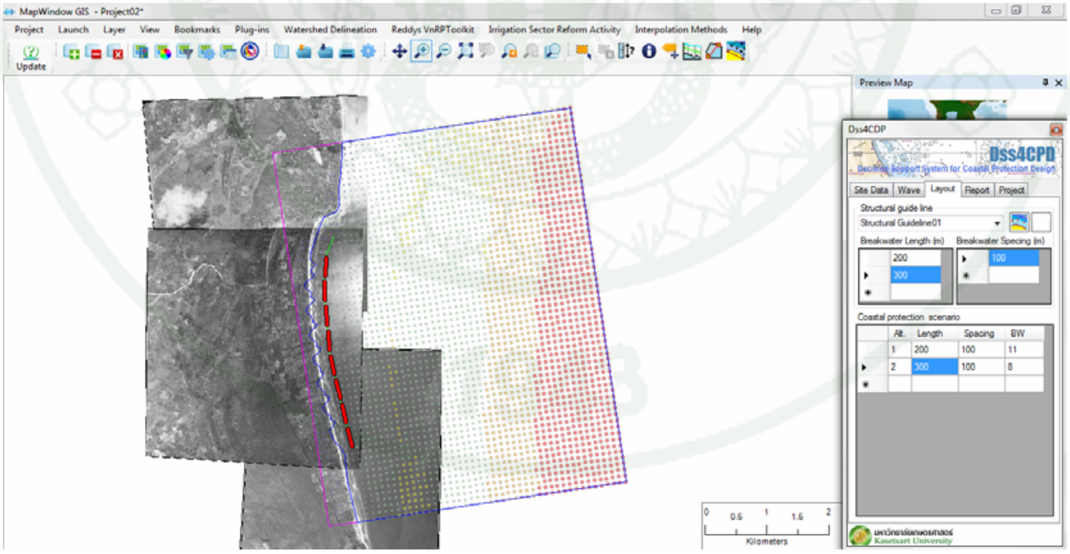
Breakwater Specing (m): 100

Coastal protection scenario

Alt.	Length	Spacing	BW
1	200	100	11
2	300	100	8

Figure 92 Final shoreline result for alternative 1

After that, DSS4CPD creates polygon map which separates land and sea as shown in Figure 93.



Structural guide line: Structural Guideline01

Breakwater Length (m): 200, 300

Breakwater Specing (m): 100

Coastal protection scenario

Alt.	Length	Spacing	BW
1	200	100	11
2	300	100	8

Figure 93 Polygon which demonstrate land and sea areas is the final shoreline result (Alternative 2)

From the alternatives, DSS4CPD used the above polygon data to intersect with landuse polygon, the result is the predicted shoreline change polygon which separated between sea area and land area. Both area polygons are input in GIS Attribute data. This data is used in evaluation score based on multi-criteria analysis (MCA) scoring method. Multi criteria analysis in this research consists of three major criteria layers which are: 1) landuse, 2) structure or building, and 3) impacted or sensitive area. All data in three layers are in polygon shape. Therefore, the polygons can be intersect and compare with the shorelines in order to get the evaluation scores as referred in chapter 9. The result is as shown in the table 10.

Table 10 Impact score

	Impact Score						
Alt.	Land use	Weight	Building	Weight	Sensitive area	Weight	Total
1	35	50	25	20	45	30	36
2	30	50	15	20	25	30	26

In this research, the evaluation process concludes the impact both in positive and negative to get the highest ranking score. In the study case, alternative 2 gets the highest score and to be the recommendation for the further details of design.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The decision support system for coastal protection design called DSS4CPD has been developed in this research. It consists of three major elements: 1) Data base, 2) Model base, and 3) Dialog base, all of which three parts working together in order to evaluate, analyze, and demonstrate all decisive information to help the coastal engineers or designers for finding the most appropriate coastal structure layout.

The database includes three components: physical information of study area, wave information in the project area, and the information of coastal protection structure. In the development process of database, there are three formats including shapefile, Grid file and image map file were used on GIS map

Three models have been integrated to work together with GIS. The wave models, WAM and wave transformation model,RCPWave have been used to demonstrate the wave condition which is directions and heights from deep water transforming to the beach, and to demonstrate the wave breaking zone map for making the coastal structure layout. The shoreline change model, GENESIS,by using Genetic Algorithm (GA) for finding the optimal coefficients, K1 and K2 in calibration process, has been used to show all shoreline change scenario results impacted from any coastal structure layouts, and then having the spatial evaluation (sDSS) and multi-criteria analysis (MCA) for finding the appropriate layout solution.

DSS4CPD has been developed by using GIS program named Map Window for system integration and for user interface in dialogbase. In this program, it consists of all data for coastal protection design, all models for each part of model calculations, and the interface. For the interface, it uses for the model input and output communication, display that designers use the results for coastal structure design decision.

In this research, the breakwater design in Langsuan, district, Chumporn province, Thailand, is used as the case study. The studied result is found the most appropriate layout of the breakwaters considering relative factors using DSS4CPD for the design process, and the study details of DSS4CPD components with a GIS interface for integrating what are as followed:

1. Spatial Data

In this research, the database used for the DSS4CPD can be divided into 3 components, i.e. physical information on study area, wave information in the required area, and the information on coastal protection structure (breakwater). In the development process of database, 3 formats(shape file, Grid file and image map file) of database were used including GIS map to do:

- Data integration
- Data transformation

2. Deep Water Wave (Wave hind-casting)

The development result is the Mapwindow Plug-in using for calculating deep water wave. In fact, the users can select the position they need to the deep water waves. Then, the system will calculate the selected position data and will show the result of wave height, wave direction and wave period in term of waverose and data in the table. Especially, for the waverose, the system can demonstrate the wave rose picture on GIS Map.

3. Nearshore wave

After having the dominant waves from waverose, the system generates combination of deepwater wave scenarios to get the wave transformation for each scenario. In this step, the system also gets the table of spatial wave properties such as:

+ Wave Height map
+ Wave Direction map
+ Wave breaking zone map
+Nearshore Significant wave height

As a result, the coastal structure designer can view and understand the wave behavior and there transformation from the deep water to the beach precisely.

4. Breakwater Layouts

From the previous step, all data is presented in the terms of Grid Table in direction X, (along shoreline), and Y (perpendicular to the shoreline). For the developed system, the interface is presented by gathering all data and demonstrating as the maps on GIS. For example, wave breaking position map, wave height and wave direction map. For wave breaking map, the system created one line of wave breaking in each wave scenario. Mostly, wave scenarios that have the same height of wave design always get the same wave breaking line. This line is the alignment of the breakwater layout, and this line can lead to the combinations of breakwater layout alternatives.

5. Shoreline change model

The shoreline change model, GENESIS, using Genetic Algorithm (GA) to get the optimal coefficients, K1 and K2 in model calibration, has been used to show all shoreline change scenario results impacted from any coastal structure layouts.. After having many possible coastal structure layouts from all scenarios, all layouts are the inputs for the shoreline change model. The model will do the shoreline change analysis to get the results impacted from all layout scenarios. Then, Geo-function for spatial impact evaluation is the next step for finding the layout solution.

6. Geo-function for spatial evaluation

When the final shorelines are overlayed with the initial shoreline, the erosion areas and the accumulation areas are presented. The system will present all the impacts with the layouts on maps and tables. The system will analyze the erosion and accumulation of the 20 year shoreline change together with the layout scenarios and scores to see the impacts. and then having the spatial evaluation (sDSS) and multicriteria analysis (MCA) for finding the most appropriate layout solution. In fact, DSS and MCA will do the ranking list of the possible layouts which can be implemented in the project area. As the data mentioned, all data are the information for decision making in order to help the designer of coastal structure system, to design the coastal structure layout.

Recommendations

For the design, this system can add more data and information in order to get the optimal solution in the points of engineering, environment, and economics purposes. To illustrate, in engineering concern, types of coastal structures such as groin, jetty, and seawall can be tested in the system. All coastal structure types can be compared and evaluated by using searching tool such as GA (Genetic Algorithm) for finding the optimal solution. In fact, GA can also be another tool in locating the layout. The number of population of each Generation can be used until getting the optimal layout. In addition, the construction cost will be increased depending on the difficulty of the construction. The research to be conducted in the future shall add the inshore wave movement section and the rock size calculation section which will enhance the effectiveness of this system. In this study, Hudson formula is used for calculating the coastal structure rock size which relies on the wave height. In fact, the wave transformation data result in any position is used by DSS4CPD in the calculation of the coastal structure outer layer since the outer rock size is relied upon the wave energy. Then, multicriteria analysis (MCA) can be used for finding the most appropriate layout solution considering all relative factors and relative concerns.

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1999-2000	Oceanographic Officer, Oceanographic Division, and Executive Officer of H.T.M.S.Suk (Oceanographic Survey Ship)
2000-2001	Oceanographic Officer, Oceanographic Division, and Captain of H.T.M.S.Suk (Oceanographic Survey Ship)
2001-2002	Chief of Oceanographic Station Section, Oceanographic Division, and Captain of H.T.M.S.Suk (Oceanographic Survey Ship)
2002-2003	Chief of Oceanographic Station Section, Oceanographic Division
2004-2006	Chief of Astronomical Section, Aids of Navigation Division
2011-Present	Vice Director of Hydrographic Division, Royal Thai Naval Academy