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PRELIMINARY EVALUATION OF DOSES FOLLOWING HYPOTHETICAL EXPLOSIONS OF RADIOLOGICAL DISPERSION DEVICES

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Science Program in Nuclear Technology
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วัตถุประสงค์ของงานวิจัยนี้คือการดำเนินการประเมินปริมาณรังสีเบื้องต้นจากการระเบิดสมมติของอุปกรณ์แพร่กระจายกัมมันตรังสี (RDDs) ที่พื้นที่การศึกษา (อนุสาวรีย์ชัยสมรภูมิ, สยามสแควร์และเมืองพัทยา) การคำนวณอยู่บนพื้นฐานการจำลองการแพร่กระจายโดยใช้โปรแกรมสำเร็จรูป Health Physics Codes program (Hotspot) ซึ่งใช้สมการการกระจายตัวแบบเกาส์เซียนพลูมและให้เส้นค่าระดับปริมาณรังสีสอดคล้องกับระดับปริมาณรังสีสมมูลย์ที่ร่างกายได้รับ (1,000, 250 and 5 mSv TEDE) พารามิเตอร์ที่ใช้ในการศึกษาครั้งนี้ ได้แก่ ชนิดนิวไคลด์กัมมันตรังสี (Co-60, Cs-137 และ Ir-192), ปริมาณของนิวไคลด์กัมมันตรังสี (100 Ci), น้ำหนักของระเบิด (10 และ 25 ปอนด์), ข้อมูลอุตุนิยมวิทยา (ทิศทางลมและความเร็วลม ข้อมูลย้อนหลัง 20 ปี) และข้อมูลประชากร สำหรับโปรแกรม ArcGIS 9.3 นำมาใช้ในการวิเคราะห์หาระยะทางมากที่สุดของการกระจายรังสี จำนวนประชากรและรายชื่อตำบลในพื้นที่ที่ได้รับผลกระทบจากการระเบิดของ RDDs ประโยชน์ของการวิเคราะห์นี้เพื่อวางแผนรับมือกับเหตุฉุกเฉินที่สามารถจัดทำและนำเสนอเพื่อลดและควบคุมสถานการณ์สมมุติ พื้นที่ที่ได้รับปริมาณรังสีสมมูลย์ (TEDE) มากกว่า 250 mSv ควรพิจารณาเป็นพื้นที่อพยพโดยทันที

ภาควิชา	วิศวกรรมนิวเคลียร์	ลายมือชื่อนิสิต	....
สาขาวิชา	เทคโนโลยีนิวเคลียร์	ลายมือชื่อ อ.ที่ปรึกษาหลัก	....
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KEYWORDS: RADIOLOGICAL DISPERSION DEVICE, RADIONUCLIDE, TOTAL EFFECTIVE DOSE EQUIVALENT

PORNTHIP KUASAKUL: PRELIMINARY EVALUATION OF DOSES FOLLOWING HYPOTHETICAL EXPLOSIONS OF RADIOLOGICAL DISPERSION DEVICES. ADVISOR: ASSOC. PROF. DR.DOONYAPONG WONGSAWAENG, 156 pp.

The objective of this research was to perform preliminary evaluation of doses following hypothetical explosions of radiological dispersion devices (RDDs) at the studied areas (Victory Monument, Siam Square and Pattaya city). Calculations were based on the plume dispersion computer code, Hotspot Health Physics Codes program, which implemented the Gaussian plume dispersion model and provide contour lines corresponding to specified radiation dose levels (1,000, 250 and 5 mSv TEDE). Parameters used in this study were radionuclide species (Co-60, Cs-137 and Ir-192), material at risk (100 Ci), high explosive (10 and 25 pounds), meteorological data (wind direction and wind speed period for the past 20 years) and population data. ArcGIS Desktop 9.3 was used to analyze further, Maximum distances of the plume dispersions and total number of populations and sub-district names of affected areas from explosions of RDDs. The benefit of this analysis is the subsequent emergency response plans that can be prepared and offered in order to mitigate and control the hypothetical situations. Areas receiving the total effective dose equivalent (TEDE) of more than 250 mSv should be considered immediate evacuation areas.

Department: Nuclear Engineering Student's Signature ....
Field of Study: Nuclear Technology Advisor's Signature ....
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CHAPTER 1
Introduction

1.1 Background and importance of the issue

In current era, international concerns over chemical, biological, radiological and nuclear (CBRN) weapons present special challenges to nuclear security. These four categories of weapons are often grouped together as “weapons of mass destruction” (WMD). However, all three categories except nuclear weapons could also be used in more limited ways. In addition to their physically destructive effects, CBRN weapons have great potential to cause psychological fear and panic. International efforts to control and eventually eliminate CBRN weapons are ongoing, but these control regimes have many limitations and gaps.

For this research work, the interest is only on radiological weapons. There are many kinds of radionuclides that can be used in several fields in Thailand such as industry, hospitalization, agriculture, environmental, education, research, etc. Some of them are the potential isotopes used in radiological dispersion devices (RDDs) [1] such as Cobalt-60, Cesium-137, Iridium-192, Americium-241, Californium-252, Plutonium-238, Polonium-210, Radium-226 and Strontium-90. Via RDDs detonations, they could release alpha, beta, or gamma radiation that can affect the body, risking both external and internal contamination, and could cause wide-area contamination. Theft and sabotage for radiological terrorism act by taking advantage of vulnerabilities in usage securities, import and export control systems.

A radiological terrorism is the use of radioactive materials to cause physical injury and psychological damage, destruction to property and the environment. Terrorists will use the radioactive material to make radiological dispersion devices (e.g., dirty bomb and other dispersal methods) [2] by mixing radioactive materials (potential isotopes used in RDDs) in powder or pellet forms with a conventional explosive, such as dynamite, and attacking the public. It can be made into a small device or a car bomb.

The purpose of this research work is to study the spread of radioactive materials in the air from the start to finish from hypothetical act of explosions of radiological dispersion devices in order to evaluate doses to the unshielded public. Emergency response plans will be offered in order to mitigate and control the studied hypothetical situations.

1.2 Objective of the thesis

The objective of this research work is to perform preliminary evaluation of doses following hypothetical explosions of radiological dispersion devices.

1.3 Scope of the thesis

The scope of this research work is as follows:

1. Study at least three potential sites for explosions of radiological dispersion devices.
2. Gather parameters for the above potential sites.
3. Calculate doses for unshielded people in the affected areas using an appropriate computer code.

1.4 Research Methodology

The methodologies of this research work are as follows:

1. Perform literature review of related research activities.
2. Study the regulations and practices relating to the calculation of restricted zone and the amount of radiation that has been receive around event areas.
3. Study the spread of radioactive substance in the atmosphere.
4. Select potential sites for hypothetical explosions of radiological dispersion devices in Thailand using data from related agencies.
5. Select the appropriate computer code and study how to use it.

6. Collect and analyze data such as meteorological data from ground stations, distribution of population in each potential site, etc.

7. Analyze doses for unshielded public in the affected areas using an appropriate computer code.

8. Analyze and discuss results of doses for people in the affected areas.

9. Write thesis and publication.

1.5 Expected Benefits

Gain knowledge on the resulting spread of radioactive materials following hypothetical explosions of radiological dispersion devices events from the beginning to the end of accidents and offer emergency evacuation plans in the affected areas in order to control and mitigate the situations as well.

CHAPTER 2

Literature Review

2.1 CBRN weapons

There is an international concern that terrorists can potentially use chemical, biological, radiological, or nuclear (CBRN) weapons to attack to cause many casualties. (The number of deaths is based on several factors.) Also, these events can cause long-lasting fear from threat and after the incident. Figure 2.1 shows all four categories of weapons which are often grouped together as "weapons of mass destruction" (WMD) [3].

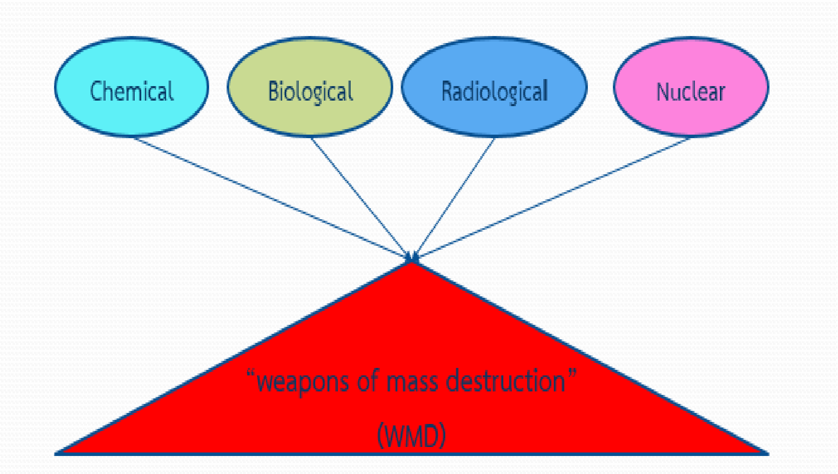


Figure 2.1 Categories of weapons of mass destruction

2.1.1 Chemical weapon

There are four main categories of chemical weapons that were developed for military use (choking agents, blister agents, blood agents and nerve agents). Classification of chemical weapons is shown in Table 2.1. However, any toxic chemical can be used as a chemical agent (e.g., pesticides, industrial chemicals and household chemicals). In addition, non-lethal agents could also be used (e.g., tear gas or fentanyl).

Table 2.1 Classification of chemical weapons [3]

Categories	Mode of receive	Physiological Effects	Distribution	Lethality	Examples
Choking agents	Inhalation	• Fluid builds up in lungs & victim chokes on own fluid • Dry land drowning • Victim dies of oxygen deficiency	Gas	Low to medium	• Chlorine gas • Chloropicrin (PS) • Diphosgene (DP) • Phosgene (CG) • Disulfur decafluoride • Perfluoroisobutene
Blister agents	Inhalation, Skin Contact	• Burns skin, mucous membranes, and eyes, causing large water blisters on exposed skin or in lungs • Primarily used to injure	Liquid, Aerosol, Vapor, Dust	Low to medium	• Sulfur mustard (H, HD) • Nitrogen mustard (HN) • Lewisite (L) and phosgene oxime (CX)
Blood agents	Inhalation	• Destroys ability of blood cells to utilize oxygen	Gas	Medium to high	• Hydrogen cyanide (AC) • Cyanogen chloride (CK) • Arsine (SA)
Nerve agents	Contact (VX), Inhalation (G-series)	• Causes seizures and loss of body control • Exhausts muscles, including heart and diaphragm • Lethal dose can cause death from respiratory failure in five minutes	Liquid, Vapor, Aerosol	High	• Sarin • Tabun • Cyclosarin

2.1.2 Biological weapon

Terrorists can use biological agents (e.g., viruses, bacteria, fungi, other microorganisms or associated toxins) to attack to cause effects to human health, animals or plants, which could also lead to many casualties [3].

2.1.3 Radiological weapon

A radiological weapon is any weapon that is designed to distribute radioactive material. Most radiological weapon is a radiation dispersal device (RDD) or dirty bomb to cause lethality, injury, damage and widespread destruction [4]. A radiological dispersal device (RDD) is any device that causes the spread of radioactive material (non-nuclear bomb) [5]. Dispersion methods can be explosion that produces radioactive and nonradioactive shrapnel and radioactive dust [5].

Although there are many radionuclides that can be used in several fields, these are the nine radionuclides to become of RDDs interest: cobalt-60 (Co-60), strontium-90 (Sr-90), cesium-137 (Cs-137), iridium- 192 (Ir- 192), polonium-210 (Po-210), radium-226 (Ra-226), plutonium-238 (Pu-238), americium-241 (Am-241) and californium-252 (Cf-252) [1].

2.1.4 Nuclear weapon

A nuclear weapon is an explosive device that obtains the explosive force from nuclear reactions. There are two types: fission bomb and fusion bomb. Both reactions produce large energy output from small nuclear material. The first uses of nuclear weapons for mass destruction was by the U.S. Army at Hiroshima and Nagasaki cities during World War II.

2.2 Radioactivity Dispersion in the Atmosphere

This section discusses the spread of radioactive material from a radiological dispersal device to assess the boundary of affected area and the radiation dose that people receive. Therefore, the theory of the spread of radioactive material in the atmosphere is required.

The spreading behavior of radioactive particles in the atmosphere in the case of accident or terrorism depends on the χ/Q factor (atmospheric dispersion factor) [6], which is required to calculate the quantity and the danger from the spread of radioactive particles from the beginning to the end for effective control and mitigation of the situation.

Calculation is based on the assumption that the spread of radioactive material particles in the air behaves like a smoke plume, which is distributed vertically and horizontally in the form of Gaussian distribution [7]. There is a maximum concentration at the center of the plume (plume centerline), and the distribution of the plume depends on many factors such as wind speed, wind direction, temperature, atmospheric stability and etc.

Gaussian distribution is a mathematical model that can be used to predict the concentration of pollutants in the direction of the wind (x-axis) from the point of origin, having the highest concentration at the center of the plume. The concentration also depends on the distribution of the wind direction in the transverse (y-axis) and vertical (z-axis) directions. Normally, when the plume is discharged from the release point, it will initially be floating up high in the air due to heat and exit velocity and subsequently move in the direction of the x-axis by the result of convection. It will then spread out in the directions of the y-axis and z-axis due to diffusion. The result of the diffusion process is shown in Figure 2.2.

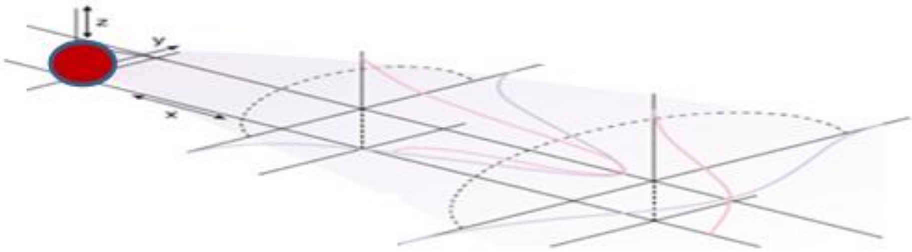


Figure 2.2 Distribution of particles from the source according to the Gaussian distribution

2.3 Radiation source

There are two common types of radiation sources: environmental radiation which are natural background radiation and man-made radioactivity.

2.3.1 Natural Background Radiation

Humans can receive natural radiation all the time from the environment. External radiation sources are such as cosmic rays, ground rays, etc. Internal radiation sources include food, air and water with the following details:

(1) External Radiation Sources

External radiation sources can be from cosmic rays. They consist of particles and photons from the sun and from space. When cosmic rays enter the atmosphere of the earth, they interact with oxygen and nitrogen in the atmosphere generating elementary particles down to the surface of the Earth, as well as radioisotopes such as carbon-14. Cosmic rays are a major source of external radiation. The level of cosmic rays depends on the elevation above the earth's surface and location on the earth's surface. Humans receive cosmic rays at approximately 0.45 mSv/year Human exposure to radiation from the ground are mostly from potassium-40, uranium, thorium and new elements of decomposition reactions (decay products). These sources usually emit gamma rays.

(2) Internal Radiation Sources

Internal radiation sources are from the consumption of plants and breathing. Plants will absorb potassium including the radionuclide potassium-40 from the ground. When humans eat vegetable, radioactive materials will accumulate in the body. Amounts of accumulation depend on age and sex of the consumer. In the atmosphere, there are radon-220 and radon-222 from the decay of thorium and uranium in the ground. When human breathes them into the lungs, they will circulate throughout the blood circulation system. Radioactive solids will persist in the lungs. This is one of the sources of alpha radiation in the body. There is also radioactive carbon-14, caused by the interaction of cosmic rays with nitrogen in the air and from the photosynthesis of plants. The average amount of dose due to the consumption of food, water and breathing is approximate 0.25 mSv/year.

2.3.2 Man-made radioactivity

(1) Radiation from medical uses

Nowadays, developments of radioactive materials for medical uses are such as the treatment of cancer or tumor, monitoring and diagnostics and sterile medical products. For example, for the treatment of cancer or tumor, the most widely used radioisotopes are such as cobalt-60, iridium- 192 and others for brachytherapy in the part of cancer in the body and teletherapy from gamma radiation from exterior into the part of cancer in the body. Iodine-131 is used to treat cancer in the thyroid gland, strontium-90 sheet is used to treat the skin tissues, phosphorus-32 liquid is used to treat conditions with red blood cell and leukemia, etc.

(2) Radiation from industrial uses

Currently, there are many industrial uses of radiation. For example radioisotopes are used to improve, inspect, and control the quality of goods, to control the thickness of material (e.g., paper, metal, plastics), to check oil and gas pipelines for leaks, to check defects in welds, to locate and quantify oil, natural gas and mineral deposits, to gauge the density of road surfaces and subsurface of construction and other applications. Radioactive materials authorized to possess in factory are available in 19 types [8] as shown in Table 2.2.

Table 2.2 Types of radioactive materials in industrial uses that are authorized to possess

Radioisotopes	Half-Life	Specific Activity (Ci/g)
1. Am-241 (Americium)	430 yr	3.5
2. Be-7 (Beryllium)	53.22 days	350,000
3. Cd-109 (Cadmium)	1.3 yr	2,600
4. Cf-252 (Californium)	2.6 yr	540
5. C-14 (Carbon)	5,700 yr	4.5
6. Cs-137 (Cesium)	30 yr	88
7. Co-60 (Cobalt)	5.3 yr	1,100
8. Cm-244 (Curium)	18 yr	82
9. Fe-55 (Iron)	2.7 years	2,200
10. Ir-192 (Iridium)	74 days	9,200
11. Kr-85 (Krypton)	11 yr	400
12. K-40 (Potassium)	1.3 billion	0.0000071
13. Ni-63 (Nickel)	96 yr	60
14. Po-210 (Polonium)	140 days	4,500

Table 2.2 Types of radioactive materials in industrial uses that are authorized to possess (continuous)

Radioisotopes	Half-Life	Specific Activity (Ci/g)
15. Pm-147 (Promethium)	2.62 yr	940
16. Ra-226 (Radium)	1,600 yr	1.0
17. Sr-90 (Strontium)	29 yr	140
18. Th-232 (Thorium)	14 billion yr	0.00000011
19. U-235 (Uranium)	700 million yr	0.0000022

These uses directly and indirectly influence to contaminate the environment and human can take into the body by eating food, drinking water or breathing air.

(3) Radiation from nuclear power plants

Radiation from nuclear power plants occur from the reactor to generate electricity. Radioactive materials are in fuel rods all the time, but sometimes there is a small leakage on the fuel rod, resulting in the release into the cooling system of a reactor core. Major radioisotopes of concern are tritium, krypton, xenon, iodine, cerium, strontium, etc.

(4) Radiation from atomic bomb testing in the air

Radiation from atomic bomb testing in the air can be very high from strontium-90, caesium-137 and carbon-14, for example, that remain in the air after the test and disperse throughout the world. Everyone will get these radioisotopes into their body.

(5) Other sources

There are other sources of man-made radiation such as agricultural uses to improve and preserve food and to control insect by sterilization and irradiation. This other sources also include jewelry work, some other consumer products, etc.

2.4 Hotspot Health Physics Codes

Hotspot Health Physics Codes were developed by The United States Department of Energy (DOE). It is a well-established Gaussian plume model, widely used since 1988 for evaluation the effect of radiation and the spread of radioactive substances in the air [9]. The main user interface screenshot of HotSpot is shown in Figure 2.3.+

In HotSpot, there are many atmospheric dispersion models: Plutonium Explosion, Uranium Explosion, Plutonium Fire, Uranium Fire, Plutonium Resuspension, Tritium Release, General Explosion, General Fire, General Resuspension and General Plume. ICRP Publication 60 and ICRP Publication 30 were adopted. HotSpot can be used to predict the effects of radiation in the distance of less than 10 kilometers. With meteorological data, the result of the radiation emergency since the start an incident (less than 1-2 hours) can be obtained.

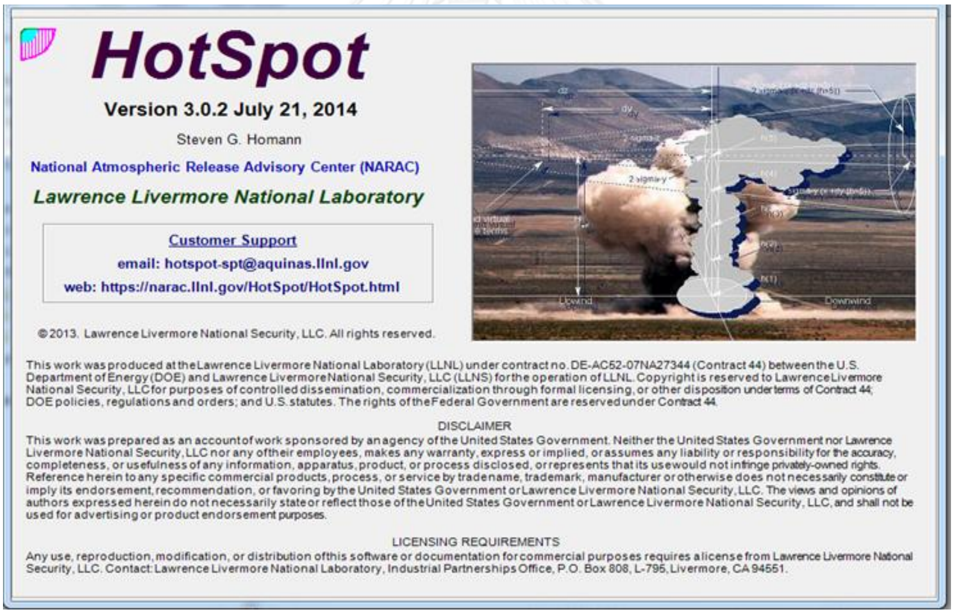


Figure 2.3 The main user interface screenshot of HotSpot

2.5 Related Research

Presented herein is a review of related researches.

2.5.1 Nithima Lojai (2011) [6] Research involves "Evaluation of Exclusion Area Boundary and Low Population Zone for Thailand Nuclear Power Plant." Calculations were done for the Total Effective Dose Equivalent (TEDE) for individuals at Exclusion Area Boundary (EAB) and Low Population Zone (LPZ), which requires that when an accident happens, the TEDEs at the EAB and LPZ distances must not exceed 25 Rem (0.25 Sv) within 2 hours and 30 days, respectively, of radioactive plume passing.

2.5.2. Seinfeld, J.H. Atmospheric Chemistry and Physics of Air Pollution (1986) [10] A detailed study of temperature at ground level (z = 0) and how it changes with height, which is called "Dry adiabatic lapse rate." There is a change of 5.4 degrees Fahrenheit (°F) per 100 feet or 1 degrees Celsius (°C) per 100 meters. In the atmosphere there is combination of 5 lapse rates: adiabatic (neutral condition), super adiabatic (unstable condition), sub adiabatic (stable condition), isothermal (stable) and inversion (extremely stable).

2.5.3 Peerasak Sangarun (1997) [11] studied the spread of radioactive materials within a radius of 20 km using meteorological data of Prachuap Khiri Khan Province and population data of Thap Sakae and Bang Saphan district as the studied areas using the assumption of 1% fuel defect in a 600 MW PWR. The simulation involved Kr-85m, Kr-85, Kr-87, Kr-88, Xe-133, Xe-135, I-129, I-131, I-133 and I-135. The highest dose was 0.91 mrem/year at the location 750 meters to the northwest towards the northand, and 0.73 mrem/year at the distance of 750 meters to the southwest towards the south. The standard requirement was no more than 500 mrem/year. Analysis results of tritium and carbon-14 were 0.1-0.4 and 0.1-0.3 Bq/m^3, respectively.

2.5.4 National Nuclear and Radiological Emergency Plan (2014) [12] Information for all radioactive materials, except for irradiated fuel (e.g., irradiated fuel in reactor or spent fuel), can be used to determine the threat category and provides a plain language statement of the risk to the public for an uncontrolled dangerous source.

CHAPTER 3

Research Methodology

The methodologies of this research work are as follows:

3.1 Study the regulations and practices relating to the calculation of restricted zone and the amount of radiation that has been received around event areas.

This research evaluates doses following hypothetical explosions of RDDs, which affect populations in studied areas (Victory Monument, Siam Square and Pattaya city). Evaluated doses are compared with the reference dose rate of The International Commission on Radiological Protection (ICRP).

This research adapted a suitable Total Effective Dose Equivalent (TEDE) levels that may be received by the population as a result of acute radiation exposure from hypothetical explosions of RDDs, which require urgent responses in order to mitigate and control the studied hypothetical situations.

The ICRP has compiled effects of 1-day acute radiation exposure to human (radiation symptom benchmarks) [13], as shown in Table 3.1.

Table 3.1 Effects from radiation (symptom benchmarks) from 1-day acute radiation exposure [13]

Dose (mSv)	Effects
2.2	Normal radiation level in nature each person receives
5	The maximum threshold allowed for the public
50	The maximum allowed for radiation workers
250	Does not show any symptoms both short and long terms
500	White blood cells will decrease
1,000	Fatigue, nausea and white blood cells will decrease
3,000	Vomiting, fatigue, white blood cells will decrease, hair loss, loss of appetite, dry throat, fever, short life and may die within 3-6 weeks

Table 3.1 Effects from radiation (symptom benchmarks) from 1-day acute radiation exposure (continued)

Dose (mSv)	effects
6,000	Vomiting, diarrhea, fatigue, white blood cells will decrease within 1-2 hours, rapid hair loss, fever and inflammation in the mouth and throat, severe bleeding and may die up to 50% within 2-6 weeks
10,000	Similar to the above symptoms, skin blistering, swelling, hair loss, death within 2-3 weeks

As can be seen in Table 3.1, as well as the limits in 10 Part 50 of CFR Section 50.67, the acute radiation exposure dose for the unshielded public of 250 mSv (25 Rem) TEDE [14] was chosen as a reference value for the evaluation of the boundaries of the evacuation areas, as people in areas receiving acute radiation dose more than 250 mSv will exhibit radiation sickness symptoms.

The TEDE dose in rem is calculated by the sum of the equivalent dose received from outside the body (Effective Dose Equivalent; D_{EDE}) due to the effects of the radioactive cloud and the equivalent dose received from a radioactive substance into the body by inhalation and collection at various organs within the body for 50 years (Committed Effective Dose Equivalent; D_{CEDE}), as shown in Equation (1) [6].

$$TEDE = D_{EDE} + D_{CEDE} \qquad (1)$$

One can calculate the amount of radiation received from outside the body (Effective Dose Equivalent; D_{EDE}) as the result of radioactive cloud from Equation (2) [6].

$$D_{EDE} = \sum_i DCF_i \sum_j R_{ij} (\chi/Q)_j \qquad (2)$$

Where D_{EDE} = Effective Dose Equivalent or dose from radioactive cloud (Rem)

DCF_i = EDE dose conversion factor of radioactive element i (Rem-m^3/Ci-s)

R_{ij} = Amount of radioactive element i released during period j (Ci)

$(\chi/Q)_j$ = Factor of the spread in the atmosphere (Atmospheric dispersion factor) during period j (s/m^3)

The amount of radiation that is absorbed into the body (Inhalation Dose or Committed Effective Dose Equivalent; D_{CEDE}) can be calculated from Equation (3) [6].

$$D_{CEDE} = \sum_i DCF_i \sum_j R_{ij}(BR)_j(\chi/Q)_j \quad (3)$$

where D_{CEDE} = Committed Effective Dose Equivalent (Rem)

DCF_i = CEDE dose conversion factor of radioactive element i (Rem-m^3/Ci-s)

R_{ij} = Amount of radioactive element i released during period j (Ci)

$(BR)_j$ = Respiratory rate during period j (m^3/s)

$(\chi/Q)_j$ = Factor of the spread in the atmosphere (Atmospheric dispersion factor) during period j (s/m^3)

3.2 Study the spread of radioactive substance in the atmosphere.

The study was based on the assumption that the spread of radioactive material particles in the air behaves like a smoke plume, which is distributed vertically and horizontally in the form of Gaussian distribution. There is a maximum concentration at the center of the plume (plume centerline) [7], and the distribution of the plume depends on many factors such as wind speed, wind direction, temperature, atmospheric stability and etc.

For this research, the Hotspot health physics computer program (HotSpot program) was applied for the simulation of the Gaussian distribution of the plume as well as the spreading behavior of radioactive particles in the atmosphere in case of explosions of radiological dispersion devices (RDDs). Factors of spread in the atmosphere were also adopted from FGR No.11 and 12. The formula that Hotspot uses to calculate the concentration of radioactive materials at the coordinate of affected area is shown in Equation (4) [3].

$$\chi(x,y,z,H)=\frac{Q}{2\pi u\sigma_y\sigma_z}\left\{\exp\left[-\left(\frac{y^2}{2\sigma_y^2}+\frac{(z+H)^2}{2\sigma_z^2}\right)\right]+\exp\left[-\left(\frac{y^2}{2\sigma_y^2}+\frac{(z-H)^2}{2\sigma_z^2}\right)\right]\right\}\exp\left[-\frac{\lambda x}{u}\right]DF(x) \quad (4)$$

where *(x,y,z)* = Coordinate to calculate concentration (m)

χ = Concentration of radioactive materials (Ci/m^3)

Q = Release rate (Ci/s)

H = Release height (h) + Plume rise (Δh)

u = Wind speed at the release point (m/s)

σ_y = Horizontal or y-axis diffusion coefficient

σ_z = Vertical or z-axis diffusion coefficient

λ = Radioactive decay constant

DF(x) = Plume depletion factor

There are many kinds of radionuclides that can be used in several fields in Thailand. Some of them are the potential isotopes used in RDDs (e.g., americium-241, californium-252, cesium-137, cobalt-60, iridium-192, plutonium-238, polonium-210, radium-226 and strontium-90) [1]. For this research, cobalt-60, cesium-137 and iridium-192 were chosen for evaluation.

The reason for choosing these three high-energy gamma-emitting radioisotopes is because they are used in several fields in Thailand such as industry, hospitalization, agriculture, environment, education and research. Because of their availability in several fields, they could be potential targets for theft or terrorists. Moreover, the long half-life of cobalt-60 (5.27 years) and cesium-137 (30 years) and the medium half-life of iridium-192 (73.83 days) make them suitable for a dirty bomb because they can contaminate the affected area for a long time.

Table 3.2 Properties of radionuclides chosen for this research

Isotope	Half-Life (years)	Emitted radiation	Specific Activity (Ci/g)
Cobalt-60	5.27	β, γ	1,100
Cesium-137	30	β, γ	88
Iridium-192	0.2 (73.83 d)	β, γ	9,200

3.3 Select potential sites for hypothetical explosions of radiological dispersion devices in Thailand.

For this research, three potential sites (Victory Monument, Siam Square and Pattaya city) were chosen as the areas for hypothetical explosions of RDDs because they have high population density and are the centers for tourists, transport hub, community, business and etc. All three potential sites as shown in Figure 3.1. These areas are very prime for acts of terrorism.

Figure 3.1 Pictures of three potential sites

3.3.1 Victory Monument

Location: Coordinates UTM 47P 1522260N 666307E

Victory Monument is a big military monument, which is considered the major transportation hub of Bangkok with several bus, vans and BTS Skytrain Station routes. It is located in Ratchathewi District as the center of a traffic circle at the intersection of Ratchathewi, Phahonyothin and Phaya Thai Roads.

There are many buildings located around, such as Rajvithi hospitals, Phramongkutklao College of Medicine, Phramongkutklao Hospital, Si Rat Expressway, Victory Monument BTS station and various fashion malls.

3.3.2 Siam Square

Location: Coordinates UTM 47P 1520115N 665900E

Siam Square is the main shopping center of Pathum Wan district, as shown in Figure 3.2. It is encircled by Rama 1, Phaya Thai and Henri Dunant Roads. It is considered the major interchange transportation of BTS SkyTrain system for both The Sukhumvit Line and The Silom Line.

There are many big buildings located around. Most of them are fashion malls that are located close to each other such as Siam Center, Siam Discovery Center, Siam Square One, Siam Paragon, MBK Center, Ratchaprasong shopping district and Phloen Chit Road and Sukhumvit Road.

3.3.3 Pattaya city

Location: Coordinates UTM 47P 1432335N 705360E

Although Pattaya City is small in size of about 22.2 km^2, it is a self-governing municipal area which covers all of Tambon Nong Prue and Naklua and some parts of Huai Yai and Nong Pla Lai. Pattaya is a popular beach for Thai and foreign tourists. It is on the east coast of the Gulf of Thailand, southeast of Bangkok. The city can easily connect with other cities via road, rail, bus, taxis and air.

3.4 Select the appropriate computer code and study how to use it.

Hotspot Health Physics Codes program was chosen for this research because it can evaluate radiation doses rapidly, facilitating quick emergency planning during radiological emergencies. It was adopted for the evaluation of the boundaries of the distance to be affected and safe areas from hypothetical explosions of RDDs.

Hotspot is a well-established Gaussian plume dispersion model. There are 6 parts of information that must be put into Hotspot as follows: 1) models, 2) source term, 3) meteorology, 4) receptor, 5) setup and 6) output.

3.5 Collect and analyze data such as meteorological data from ground stations, distribution of population in each potential site, etc.

After potential sites were selected, data in each site were collected and analyzed as follows:

3.5.1 Meteorological data

In the atmosphere, there is a combination of atmospheric stability. Atmospheric stability class is defined according to 5 lapse rates (unstable, neutral, stable, isothermal and inversion) [8] as shown in Figure 3.2. HotSpot allows users to explicitly select the atmospheric stability class, or the program can evaluate the stability class according to the data observed in studied areas which includes wind speed, sun position and time of the day as shown in Table 3.3.

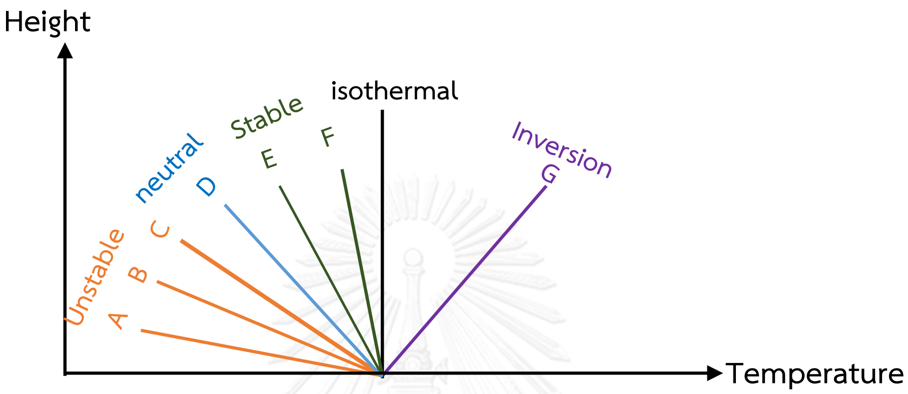


Figure 3.2 Types of atmospheric stability

Table 3.3 Atmospheric stability class according to atmospheric condition

Ground wind speed (m/s)	Sun high in sky	Sun low in sky or cloudy	Night time
<2	A	B	F
2-3	A	C	E
3-4	B	C	D
4-6	C	D	D
>6	C	D	D

Stability types:

A: Extremely Unstable

B: Moderately Unstable

C: Slightly Unstable

D: Neutral

E: Slightly Stable

F: Moderately Stable

For this research, the most conservative condition resulting in the largest spread of the radioactive material was assumed. The deposition velocity was set to 0 and the atmospheric stability class was F. The plume travel distances for stability class F was greater than for stability classes A - E.

In categorizing metrological data (wind direction and wind speed), it could be done by 1) collecting metrological data [15] in each month for 1 year, 2) finding the average for the year for the percentage of each range, and then 3) analyzing metrological data into wind rose map.

The wind rose map of a particular location gives information on the frequency of each wind speed range and direction. Example of collected frequency distribution of wind speed and wind direction at 1 atmospheric stability level and the associated in wind rose map are shown in Table 3.4 and Figure 3.3, respectively.

Table 3.4 Examples of collected frequency distribution of wind speed and wind direction at 1 atmospheric stability level

Site name: Pattaya

Pasquill stability Class: F

Period of record: January: 1995 - 2014

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.40	0.67	1.05	0.38	0.03	0.00	2.53
NNE		0.48	2.82	2.37	2.13	0.48	0.03	8.31
NE		0.27	4.14	2.93	2.85	0.62	0.27	11.08
ENE		0.32	1.94	1.86	1.13	0.24	0.05	5.54
E		0.67	0.65	1.13	0.05	0.00	0.00	2.50
ESE		0.22	0.24	0.77	0.11	0.00	0.00	1.34
SE		0.05	0.03	0.03	0.00	0.00	0.00	0.11
SSE		0.46	0.30	0.58	0.11	0.00	0.00	1.45
S		0.89	0.99	2.26	0.16	0.03	0.00	4.33
SSW		0.56	2.10	2.77	0.65	0.00	0.00	6.08
SW		0.38	1.13	0.89	0.40	0.08	0.00	2.88
WSW		0.22	2.31	2.52	0.38	0.00	0.00	5.43
W		0.43	2.23	2.35	0.16	0.00	0.05	5.22
WNW		0.30	1.18	1.32	0.26	0.00	0.00	3.06
NW		0.08	0.65	0.77	0.19	0.03	0.00	1.72
NNW		0.08	1.08	1.08	0.31	0.03	0.00	2.58
Total	35.84	5.81	22.46	24.68	9.27	1.54	0.40	64.16

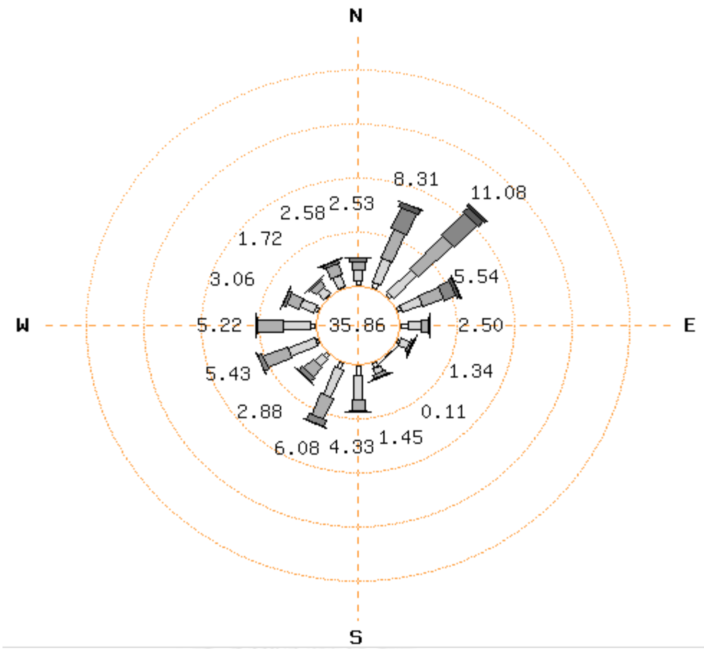


Figure 3.3 Example of wind rose map

Victory Monument:

Analysis of the meteorological data from 1995-2014 (20 years) into wind rose map at Bangkok Meteorological Station (Queen Sirikit National Convention Center) revealed that the wind speed of 1-6 knots (0.5-3.0 m/s) blowing from S and E directions occurred at the highest frequency (collected data of wind speed and wind direction shown in Tables A.1 - A.12 and presented in wind rose maps in Figures A.1 - A.12).

Siam Square:

Analysis of the meteorological data from 1995-2014 (20 years) into wind rose map at Bangkok Meteorological Station (Queen Sirikit National Convention Center) revealed that the wind speed of 1-6 knots (0.5-3.0 m/s) blowing from S and E directions occurred at the highest frequency (collected data of wind speed and wind direction shown in Tables A.1 - A.12 and presented in wind rose maps in Figures A.1 - A.12).

Pattaya City:

Analysis of the meteorological data from 1995-2014 (20 years) into wind rose map at Pattaya Meteorological Station revealed that the wind speed of 1-10 knots (0.5-5.0 m/s) blowing from SSW and NE directions occurred at the highest frequency (collected data of wind speed and wind direction shown in Tables A.13 - A.24 and presented in wind rose maps in Figures A.13A - 24).

3.5.2 Distribution of population data

Following studied hypothetical explosions of RDDs, HotSpot program provides contour lines corresponding to specified radiation levels. The results are stored as TEDE contour lines in a file with .kml extension, which can be directly displayed on Google Earth. ArcTools (ArcGIS Desktop 9.3) can be used to convert from .kml to .shp file for visual presentation of affected areas inside the contour lines representing the TEDE doses of 1,000, 250, and 5 mSv, as shown in Figure 3.4.

Population data of studied areas were obtained from the Department of Provincial Administration (the population in each district in year 2014) [16]. It was analyzed together with Hotspot. People who stay inside the 250 mSv TEDE contour line (receiving the dose of 250 mSv or more) will be considered immediate evacuation areas.

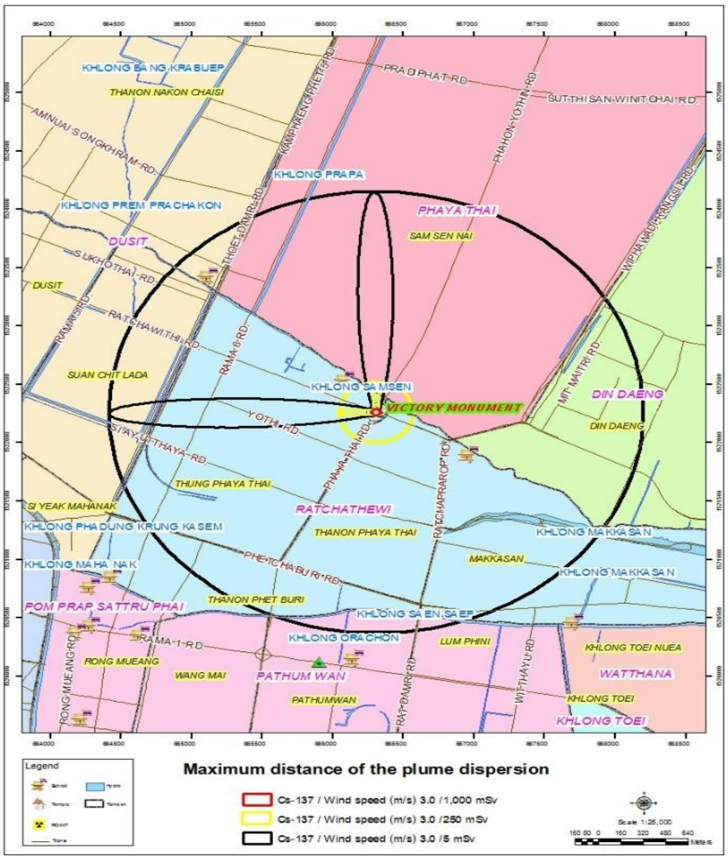


Figure 3.4 Example of analyzed affected areas inside the contour lines representing the TEDE doses of 1,000, 250, and 5 mSv at Victory Monument site on ArcGIS Desktop 9.3 program

3.6 Analyze doses for unshielded public in the affected areas using an appropriate computer code.

After potential sites were selected, data in each site were collected and analyzed. Doses for unshielded public in the affected areas were analyzed by HotSpot program. The following illustrates steps for data input:

3.6.1 Models

Atmospheric dispersion model was chosen with the General Explosion simulation, as shown in Figure 3.5.

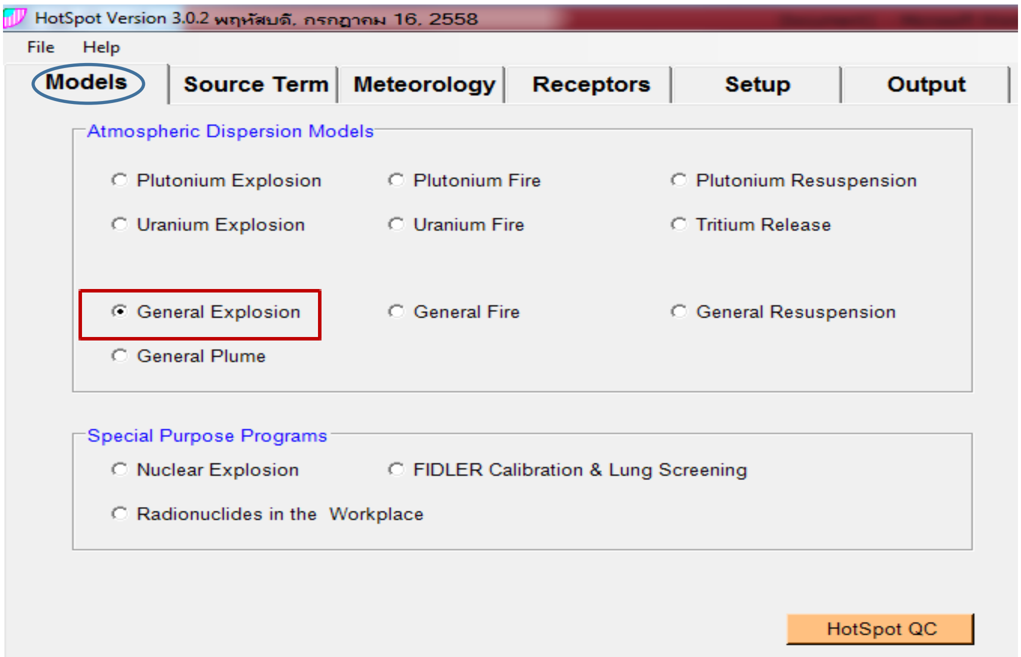


Figure 3.5 The 1st step, choose the type of the atmospheric dispersion model.

3.6.2 Source Term

For this research, the involved radioactive materials data were input into HotSpot program. Co-60, Cs-137 and Ir-192 were considered with the high explosives of 10 and 25 pounds (approximately equal to 4.5 and 11.33 kg, referring to hidden bomb and car bomb, respectively). Materials at risk were 100 Ci and other information were set automatically (damage ratio, leakpath factor, airborne fraction, respirable fraction and deposition velocity), as shown in Figure 3.6.

Details were set as follows:

- Radionuclide: the type of radioactive nuclide (input Co-60, Cs-137 and Ir-192),

- High Explosive: the weight of explosive (input 10, 25 pounds),

- Material at Risk (MAR): Total amount of radioactive nuclide-related situations (input 100 Ci).

Other information were set automatically as follows:

- Damage Ratio (DR): MAR fraction immediately affected by the situation,

- Leakpath Factor (LPF): MAR fraction that passes in storage or being carried out for the situation. Leakpath Factor is equal to 1,

- Airborne Fraction (AF): MAR fraction of the dust in the air,

- Respirable Fraction (RF): a fraction of small particles that can be breathed into the body (Aerodynamic Diameter (AD) ≤ 10 microns),

- Deposition Velocity: The ratio of the cumulative flow for breathing and concentration in the air near the surface to breathe.

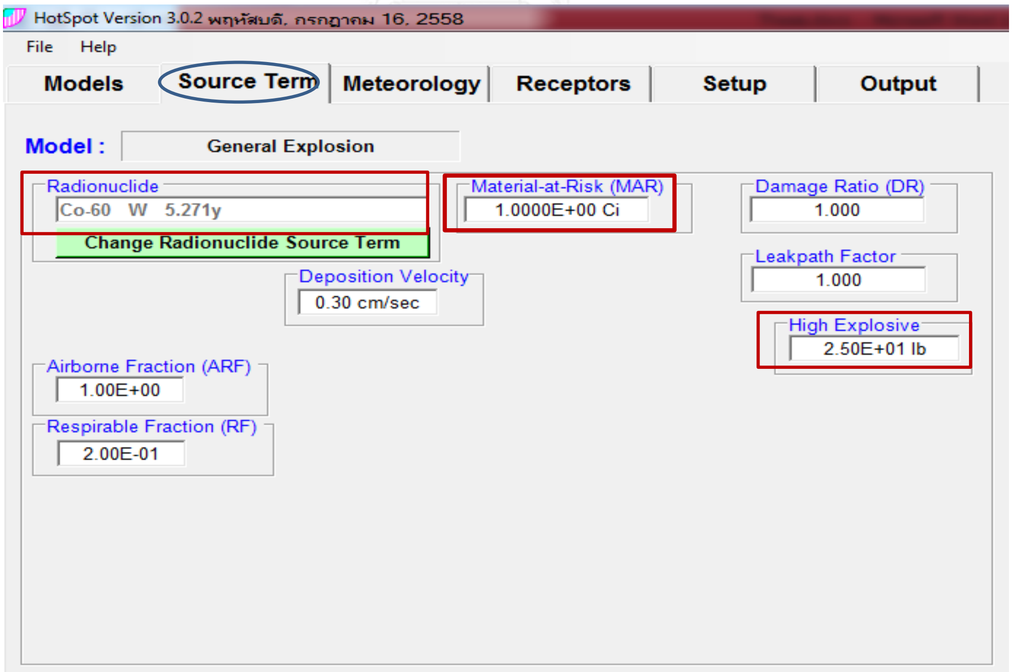


Figure 3.6 The 2nd step, input data of source term

3.6.3 Meteorology

The following meteorological data were input into HotSpot program, as shown in Figure 3.7: wind speed and wind direction from the wind rose map (the highest frequency was chosen), atmospheric stability class F and the wind speed at the 10-meter reference height.

Details were set as follows:

- Victory Monument site: wind speed of 1-6 knots (0.5-3.0 m/s) blowing from S and E directions occurred at the highest frequency,
- Siam Square site: wind speed of 1-6 knots (0.5-3.0 m/s) blowing from S and E directions occurred at the highest frequency,
- Pattaya City site: wind speed of 1-10 knots (0.5-5.0 m/s) blowing from SSW and NE directions occurred at the highest frequency.

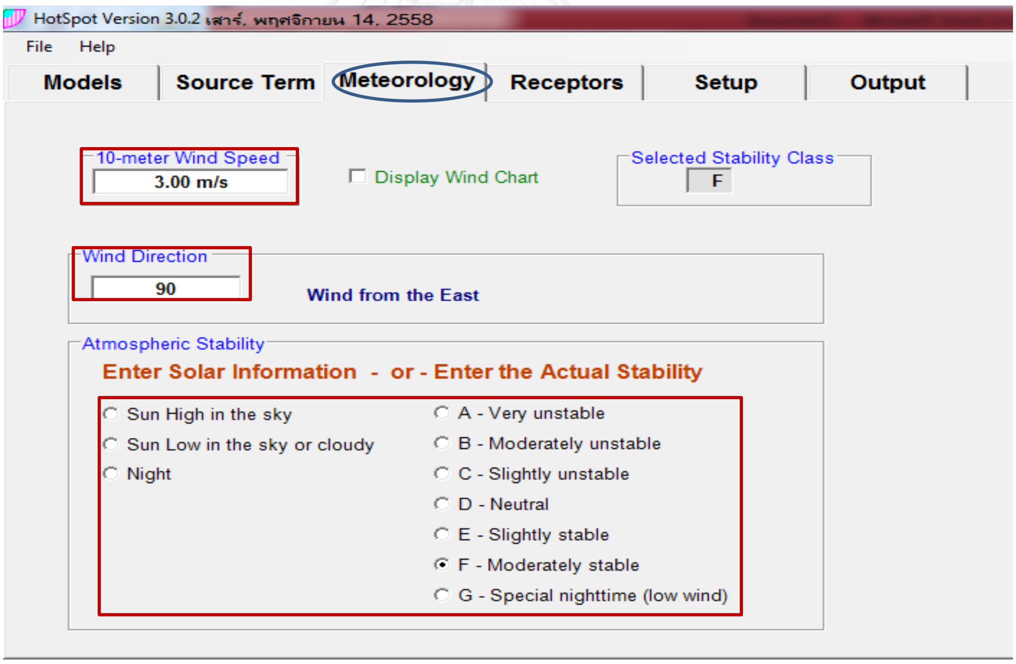


Figure 3.7 The 3rd step, input meteorological data

3.6.4 Receptor

The altitude of 0 m was chosen for the receptor height as shown in Figure 3.8.

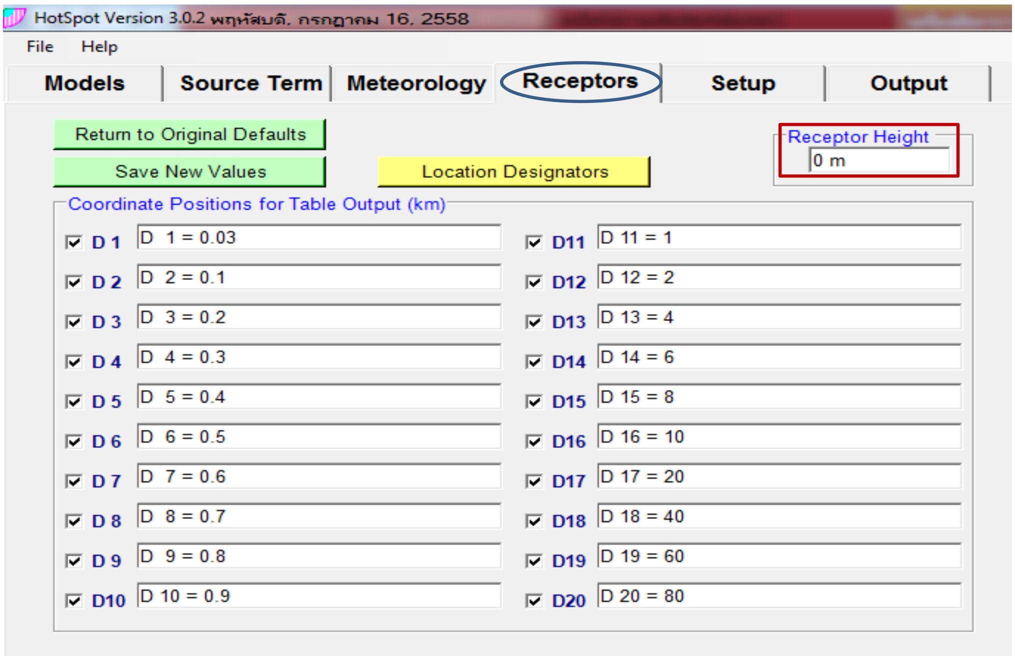


Figure 3.8 The 4th step, input data of receptor height

3.6.5 Setup

Details were set as follows:

- Terrain was set as City,

- Respiratory rate was set at 3.5 x 10^{-4} m^3/s in all cases,

- Height reference (Wind Reference Height) was set at 10 meters. This is the height that is used most frequently,

- Estimate the approximate value of the spread of the radioactivity (χ / Q),

- Dose conversion factor (DCF) adopted from FGR 11,

- Contour values were set for TEDE of 100, 25 and 0.5 rem, respectively.

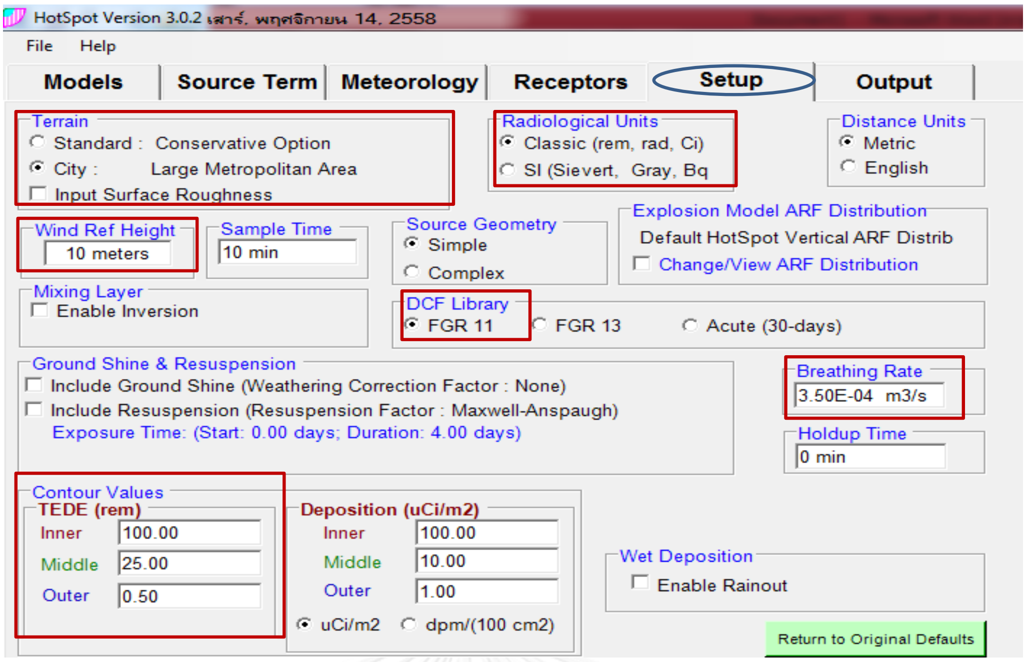


Figure 3.9 The 5th step, the settings of the program

3.6.5 Output

Details were set as follows:

- The coordinates of locations in the UTM WGS 84 format for Victory monument was 47P 1522200N 666300E, for Siam Square was 47P 1520115N 665900E and for Pattaya was 47P 1432335N 705360E,

- Results of analysis included distance to receive the highest dose (Maximum Dose Distance), maximum TEDE and the farthest distance of the plume (Exceeds dose out to). The Inner, Middle and Outer TEDE contours were set equal to 100, 25 and 0.5 rem (1,000 mSv, 250 mSv and 5 mSv), respectively, as shown in Figure 3.10.

- Results were saved as TEDE Contour Lines with the .kml extension, which can be directly displayed in Google Earth.

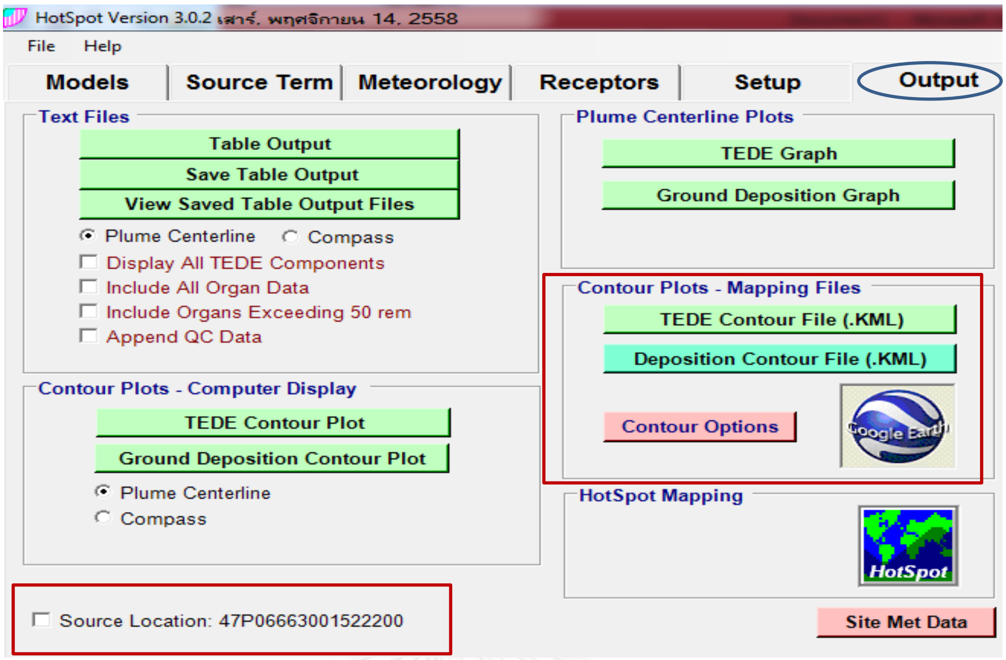


Figure 3.10 The 6th step, output setting

CHAPTER 4
Results

4.1 Preliminary evaluation of TEDE at potential sites were performed for hypothetical explosions of RDDs

After potential sites were selected (Victory Monument, Siam Square and Pattaya city), potential radionuclides used in RDDs (cobalt-60, cesium-137 and iridium-192) were chosen for evaluation. Next, data in each site were collected and analyzed (meteorological data from ground stations, distribution of population). Finally, all data were put into HotSpot program to analyze the doses for unshielded public in the affected areas.

The ICRP has compiled effects of 1-day acute radiation exposure to human as shown in Table 3.1 Doses resulting in 1-day acute radiation exposure were adopted as the Total Effective Dose Equivalent (TEDE). For this research, the acute radiation exposure doses for the unshielded public of 5 mSv (the maximum threshold allowed for the public), 250 mSv (does not show any symptoms both short and long terms) and 1,000 mSv (fatigue, nausea and white blood cells will decrease) of TEDE were chosen as reference values for the preliminary evaluation of doses following hypothetical explosions of RDDs in order to formulate emergency response plans, determine immediate evacuation areas, offer, mitigate and control the studied hypothetical situations.

The maximum Total Effective Dose Equivalent (TEDE) was analyzed by HotSpot program at various material at risks. Results are shown in Tables 4.1- 4.3.

Table 4.1 The maximum TEDE analyzed by HotSpot program at 10 min

Material at Risk (Ci)	High Explosive (lb)	Maximum TEDE at 10 min (mSv)		
		Co-60	Cs-137	Ir-192
1	1	12.5	2.7	3.9
10	1	125	27	39
100	1	1,250	270	390
1,000	1	12,500	2,700	3,900

Table 4.2 The maximum TEDE analyzed by HotSpot program at 1 hr

Material at Risk (Ci)	High Explosive (lb)	Maximum TEDE at 1 hr (mSv)		
		Co-60	**Cs-137**	**Ir-192**
1	1	8.7	1.9	2.7
10	1	87	19	27
100	1	870	190	270
1,000	1	8,700	1,900	2,700

Table 4.3 The maximum TEDE analyzed by HotSpot program at 24 hr

Material at Risk (Ci)	High Explosive (lb)	Maximum TEDE at 24 hr (mSv)		
		Co-60	**Cs-137**	**Ir-192**
1	1	4.6	0.997	1.4
10	1	46	9.97	14
100	1	460	99.7	140
1,000	1	4,600	997	1,400

Results in Tables 4.1-4.3 revealed that hypothetical explosions of RDDs of materials at risk of 1 and 10 Ci for all radiation exposure time of 10 min, 1 hr and 24 hr had the maximum TEDE not exceeding 250 mSv. Therefore, materials at risk of 1 and 10 Ci were not suitable for use in calculating the distance of impact of the affected area. However, for materials at risk of 100 and 1,000 Ci, the maximum TEDE was more than 250 mSv for most of the exposure time of 10 min, 1 hr and 24 hr. Therefore, materials at risk of 100 and 1,000 Ci were suitable for use in calculating the distance of impact of the affected area.

For this research, the material at risk of 100 Ci was selected for use in calculating the distance of impact for the affected area by HotSpot program because 100 Ci was the minimum amount of material at risk that results in the maximum TEDE of more than 250 mSv.

4.2 Maximum distances of the plume dispersion from explosions of radiological dispersion devices (RDDs) on affected areas

The spreading behavior of radioactive particles in the atmosphere in the case of explosions of radiological dispersion devices (RDDs) were analyzed by HotSpot program, which performed simulation of the Gaussian distribution of the plume. This program provides contour lines corresponding to specified radiation levels for visual presentation affected areas inside the contour line representing the TEDE doses of 1,000, 250, and 5 mSv. The results as TEDE contour lines were saved as .kml extension, which can be directly displayed on Google Earth. ArcTools (ArcGIS Desktop 9.3) can be used to convert from .kml to .shp file for further analysis, as shown in Figures 4.1 and 4.2. The distance from the point of hypothetical act to the Buffer Zone equals the maximum radioactive material dispersion distance from explosions of radiological dispersion devices (RDDs).

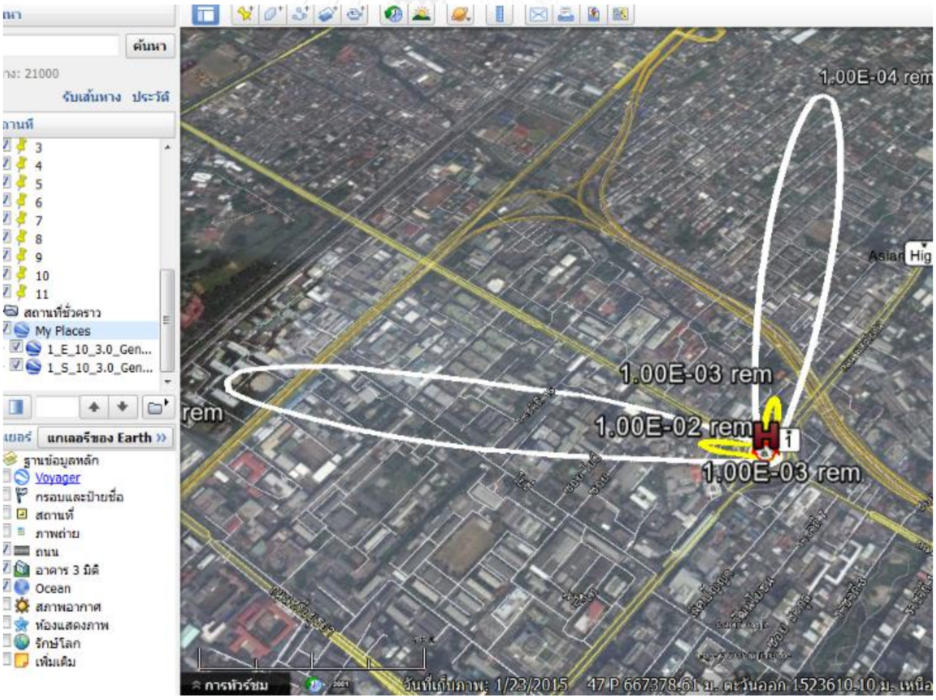


Figure 4.1 Example of results analyzed by HotSpot program showing the TEDE contour lines (.kml extension) of affected areas on Google Earth program (white line: 5 mSv, yellow line: 250 mSv and red line: 1,000 mSv)

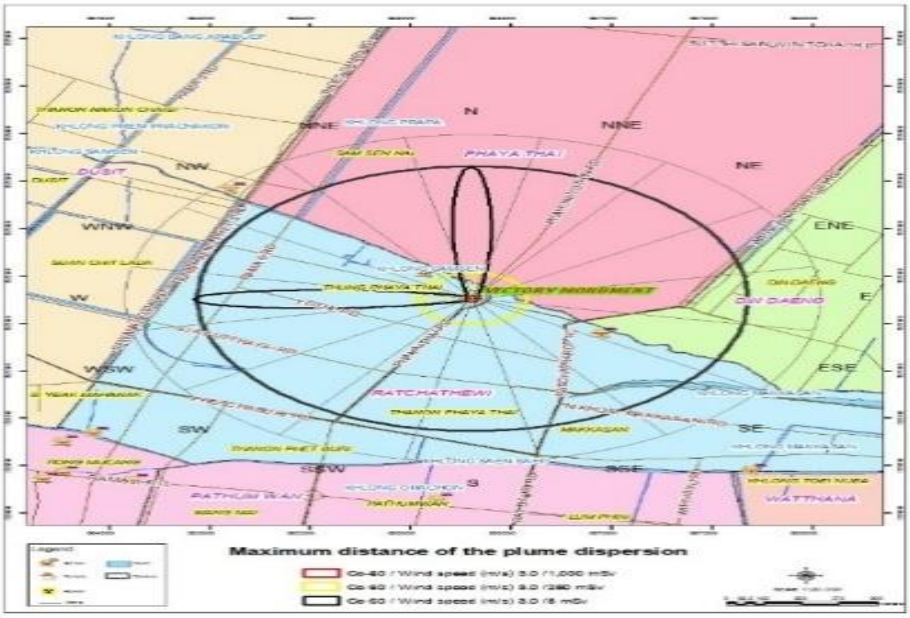


Figure 4.2 Example of conversion from .kml to .shp file which can be displayed on ArcGIS Desktop 9.3

4.2.1 Victory Monument site

Analysis was performed for the three radionuclides (Co-60, Cs-137 and Ir-192) with high explosive of 10 and 25 pounds and wind speed of 1 and 6 knots (0.5 and 3.0 m/s) blowing from S and E directions.

1) Co-60

For the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.06, 0.07 and 0.83 km, respectively, as shown in Figure 4.3.

For the case of Co-60 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 0.52 and 4.17 km, respectively, as shown in Figure 4.4.

For the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum

distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.27 and 1.38 km, respectively, as shown in Figure 4.5.

For the case of Co-60 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.99 and 7.64 km, respectively, as shown in Figure 4.6.

2) Cs-137

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.07 and 0.11 km, respectively, as shown in Figure 4.7.

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.26 and 1.89 km, respectively, as shown in Figure 4.8.

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 0.11 and 0.79 km, respectively, as shown in Figure 4.9

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 1.42 and 10.79 km, respectively, as shown in Figure 4.10.

3) Ir-192

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.06 and 0.09 km, respectively, as shown in Figure 4.11.

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum

distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.23 and 1.71 km, respectively, as shown in Figure 4.12.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.11, 0.11 and 0.69 km, respectively, as shown in Figure 4.13.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.08, 1.28 and 9.77 km, respectively, as shown in Figure 4.14.

4.2.2 Siam Square site

Analysis were performed for the three radionuclides (Co-60, Cs-137 and Ir-192) with high explosive of 10 and 25 pounds and wind speed of 1 and 6 knots (0.5 and 3.0 m/s) blowing from S and E directions.

1) Co-60

For the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.06, 0.07 and 0.83 km, respectively, as shown in Figure 4.15.

For the case of Co-60 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 0.52 and 4.17 km, respectively, as shown in Figure 4.16

For the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.27 and 1.38 km, respectively, as shown in Figure 4.17.

For the case of Co-60 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.99 and 7.64 km, respectively, as shown in Figure 4.18

2) Cs-137

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.07 and 0.11 km, respectively, as shown in Figure 4.19.

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.26 and 1.89 km, respectively, as shown in Figure 4.20.

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 0.11 and 0.79 km, respectively, as shown in Figure 4.21.

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.10, 1.42 and 10.79 km, respectively, as shown in Figure 4.22.

3) Ir-192

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.06 and 0.09 km, respectively, as shown in Figure 4.23.

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.23 and 1.71 km, respectively, as shown in Figure 4.24.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions, results revealed that the maximum

distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.11, 0.11 and 0.69 km, respectively, as shown in Figure 4.25.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.08, 1.28 and 9.77 km, respectively, as shown in Figure 4.26.

4.2.3 Pattaya City site

Analysis were performed for the three radionuclides (Co-60, Cs-137 and Ir-192) with high explosive of 10 and 25 pounds and wind speed of 1 and 10 knots (0.5 and 5.0 m/s) blowing from SSW and NE directions.

1) Co-60

For the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.06, 0.07 and 0.83 km, respectively, as shown in Figure 4.27.

For the case of Co-60 with high explosive of 10 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.06, 0.64 and 4.93 km, respectively, as shown in Figure 4.28.

For the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.11, 0.54 and 4.18 km, respectively, as shown in Figure 4.29.

For the case of Co-60 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.07, 0.92 and 6.10 km, respectively, as shown in Figure 4.30.

2) Cs-137

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum

distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.06 and 0.11 km, respectively, as shown in Figure 4.31.

For the case of Cs-137 with high explosive of 10 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.15 and 1.29 km, respectively, as shown in Figure 4.32.

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.11, 0.12 and 0.79 km, respectively, as shown in Figure 4.33.

For the case of Cs-137 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.08, 0.92 and 6.92 km, respectively, as shown in Figure 4.34.

3) Ir-192

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.05, 0.06 and 0.09 km, respectively, as shown in Figure 4.35.

For the case of Ir-192 with high explosive of 10 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.03 and 1.16 km, respectively, as shown in Figure 4.36.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions, results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.11, 0.12 and 0.70 km, respectively, as shown in Figure 4.37.

For the case of Ir-192 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions, results revealed that the maximum

distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.07, 0.83 and 6.25 km, respectively, as shown in Figure 4.38.

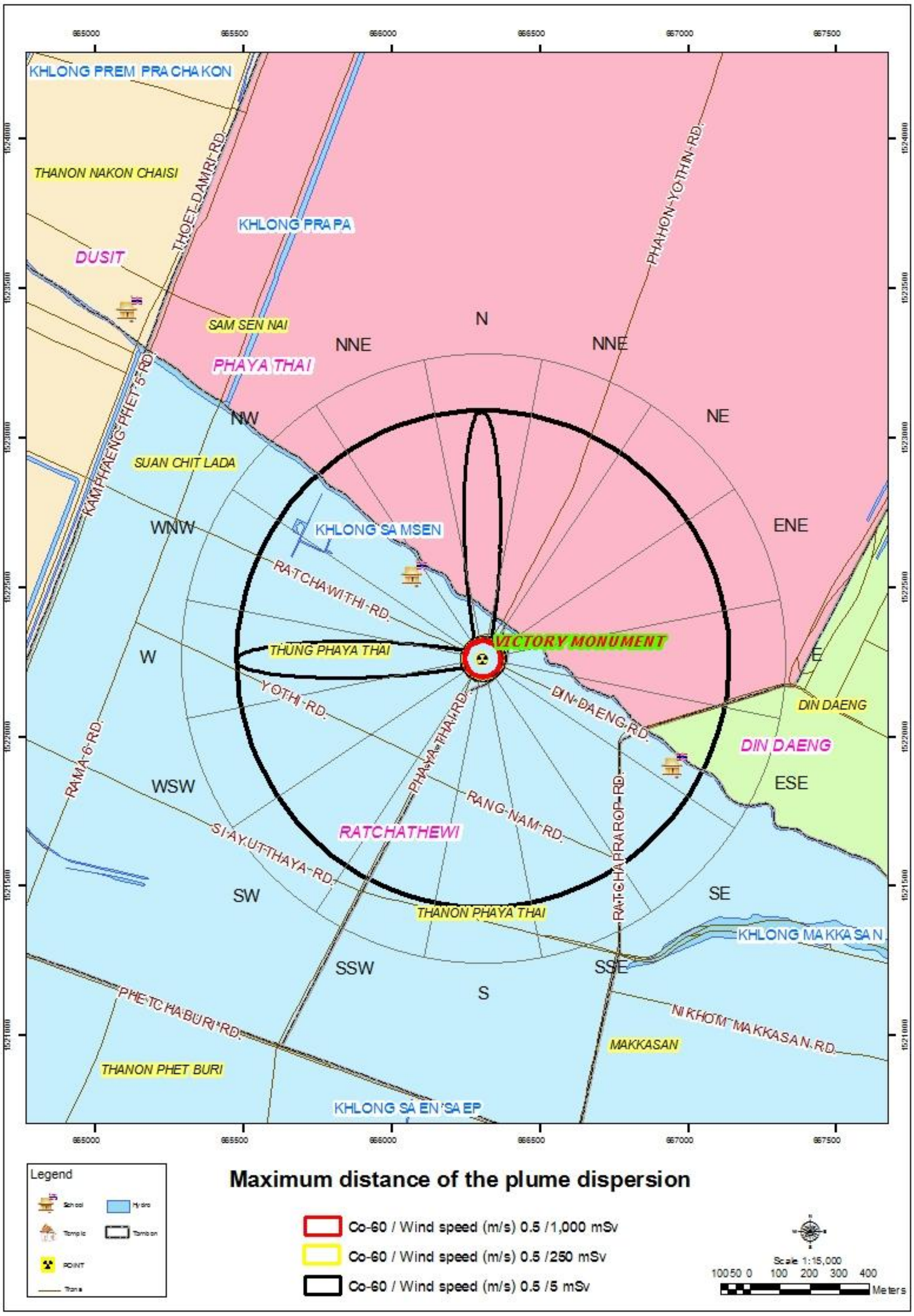


Figure 4.3 Boundary of affected areas at the Victory Monument site for the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

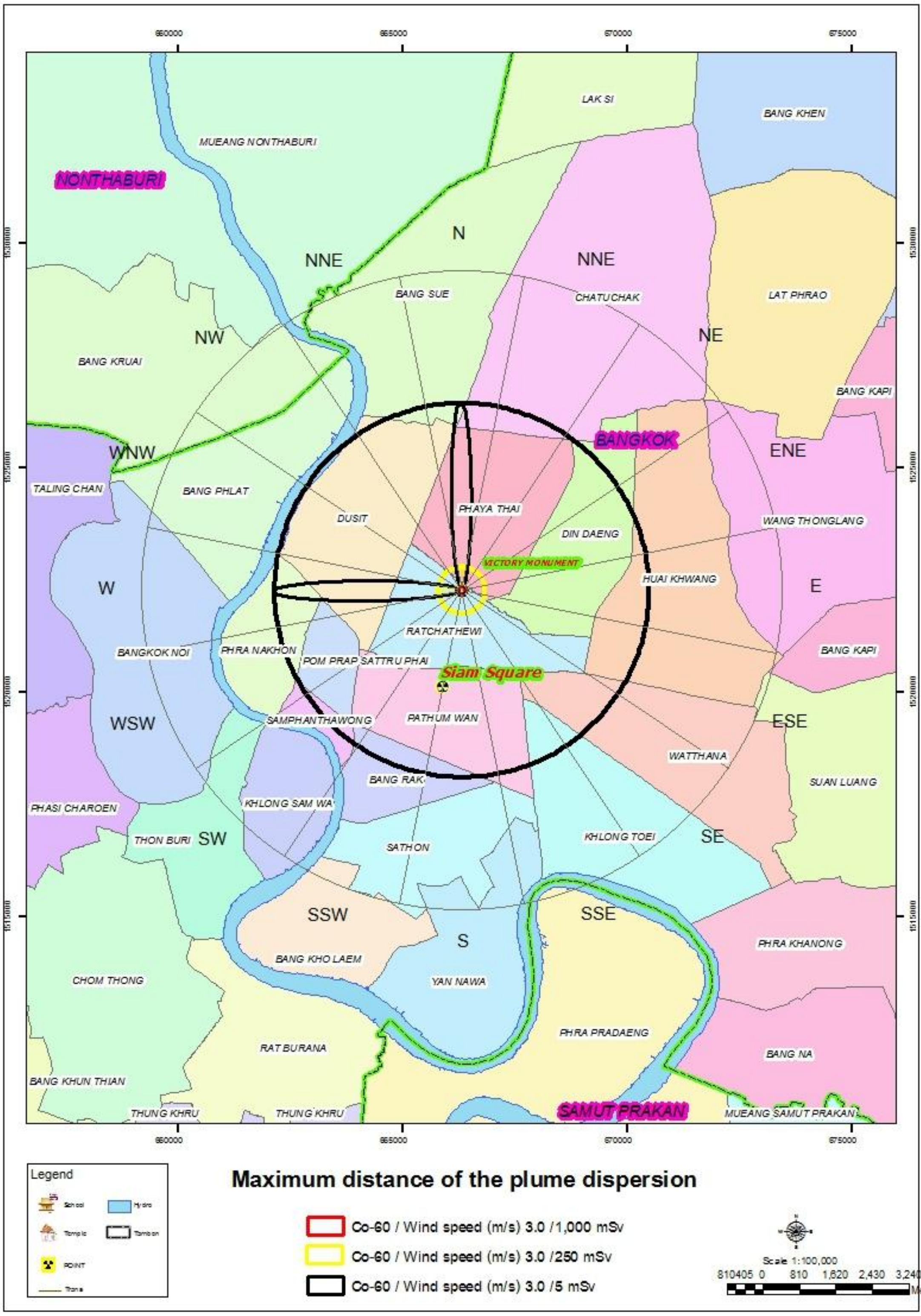


Figure 4.4 Boundary of affected areas at the Victory Monument site for the case of Co-60 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

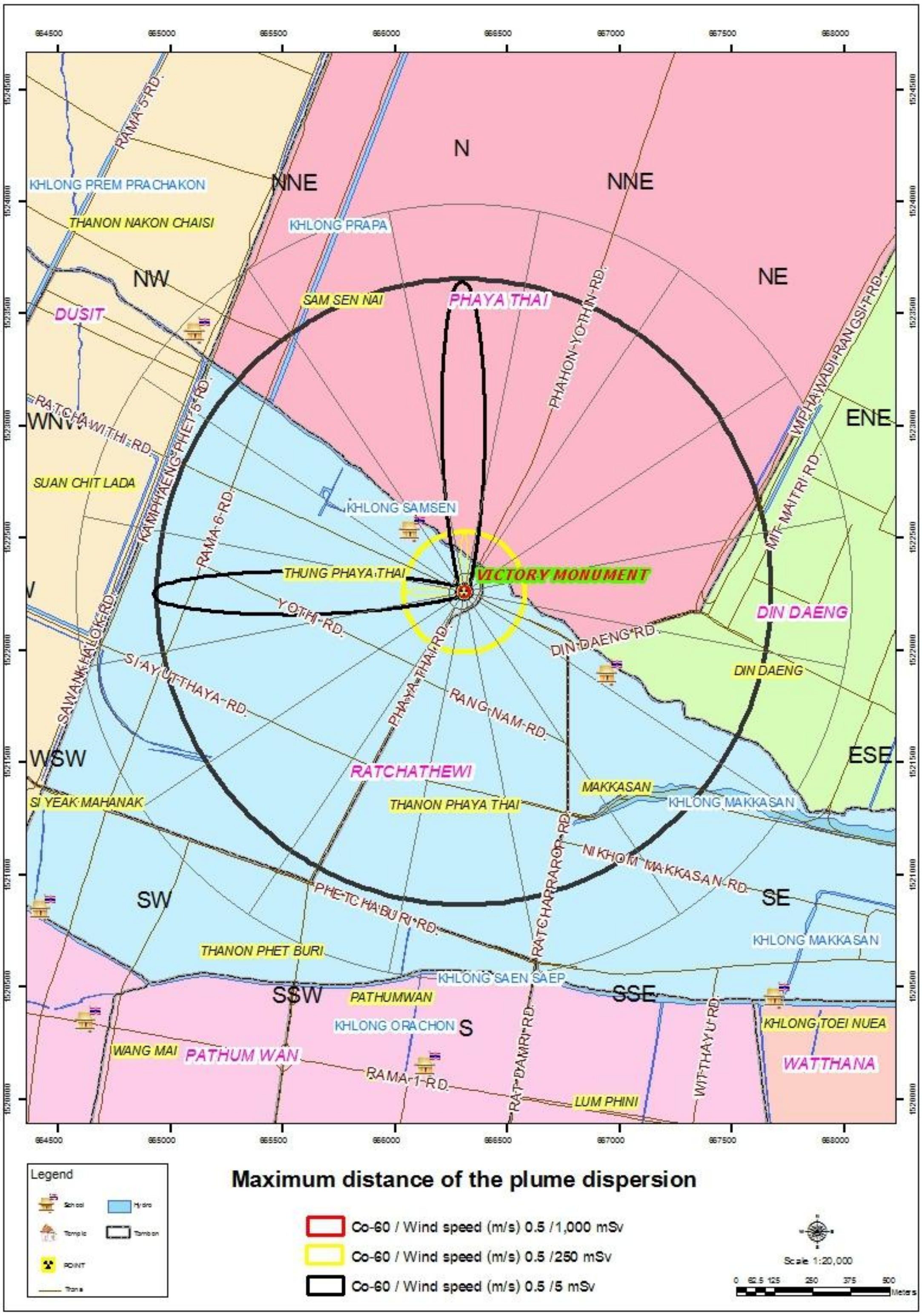


Figure 4.5 Boundary of affected areas at the Victory Monument site for the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

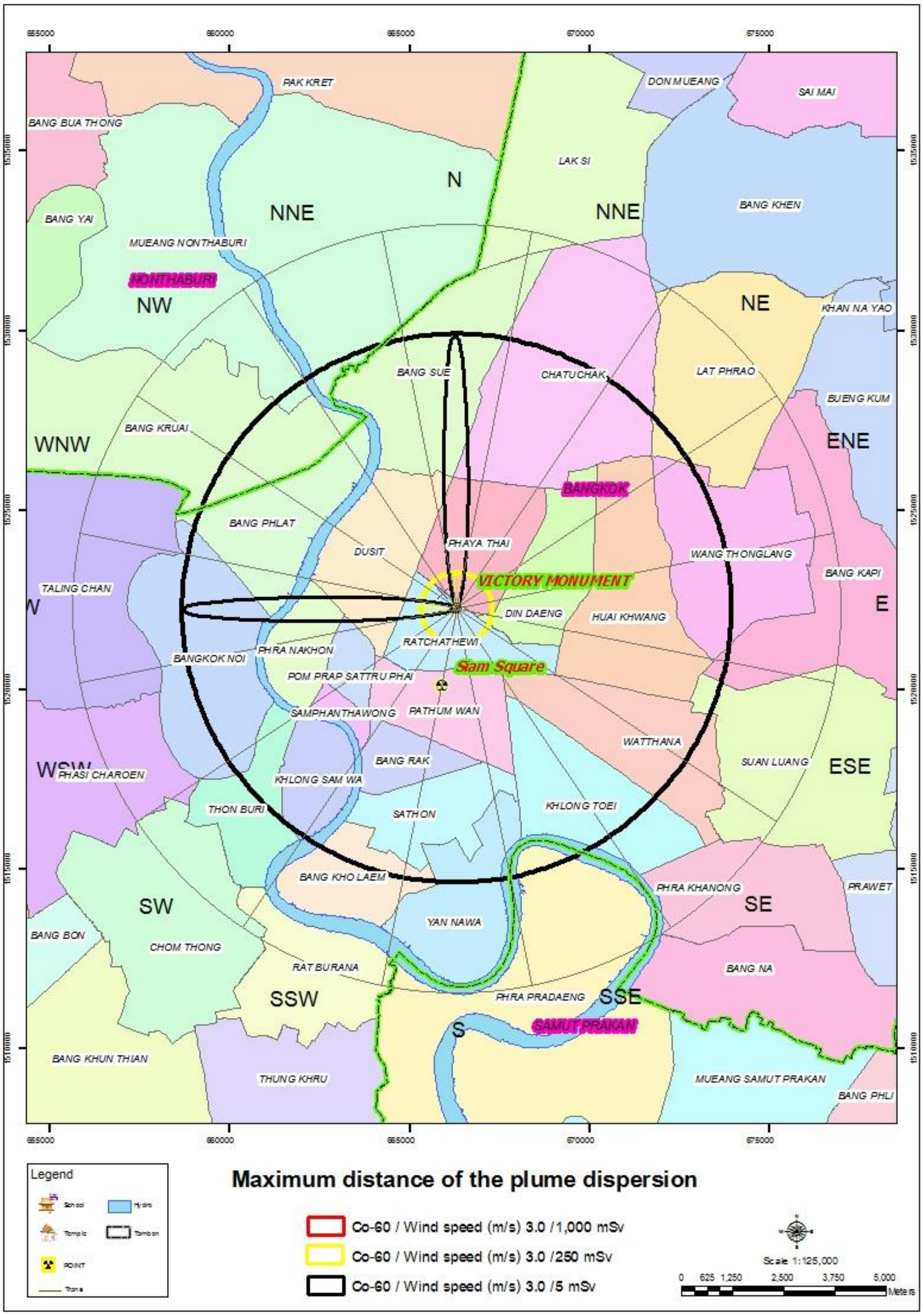


Figure 4.6 Boundary of affected areas at the Victory Monument site for the case of Co-60 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

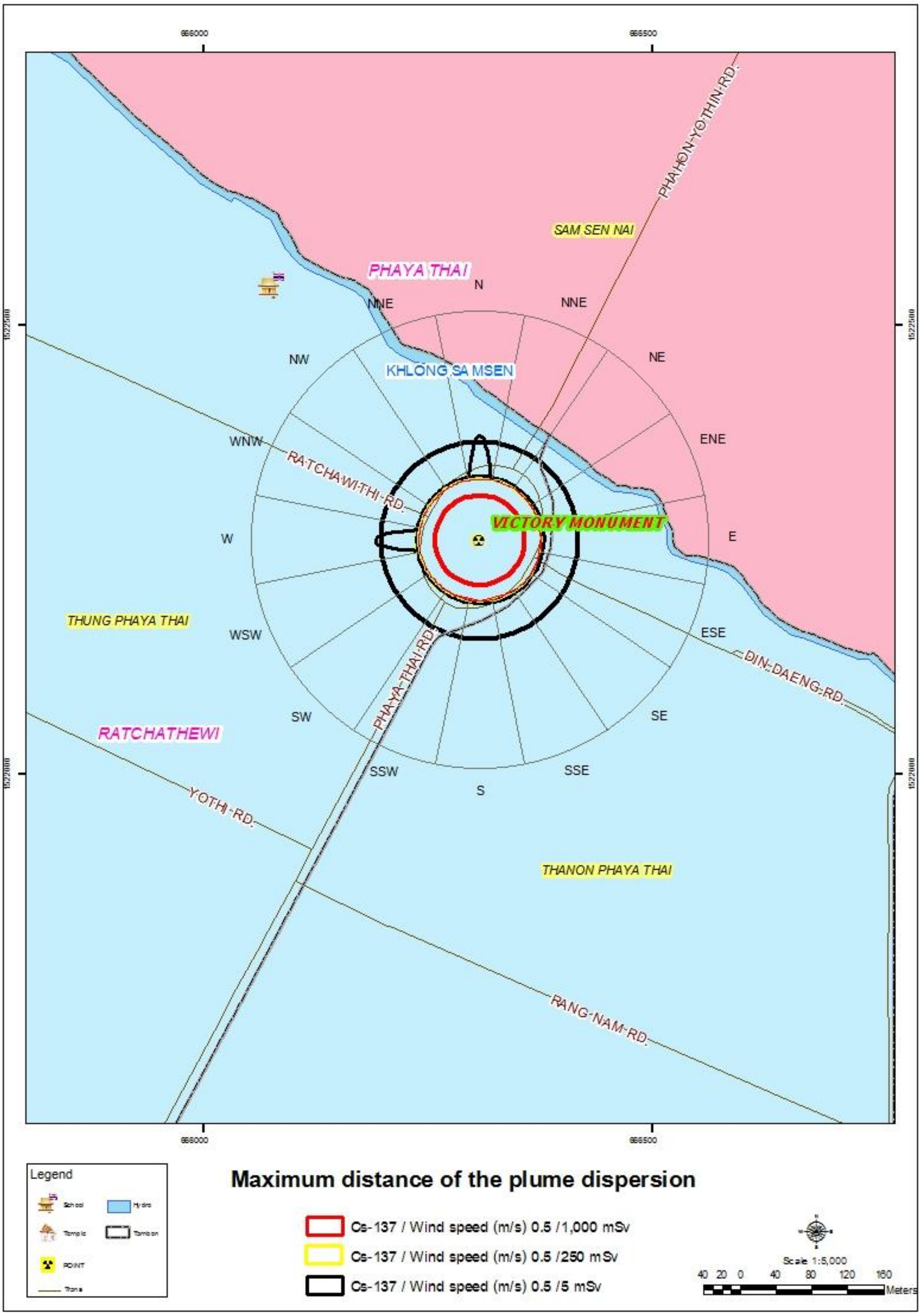


Figure 4.7 Boundary of affected areas at the Victory Monument site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

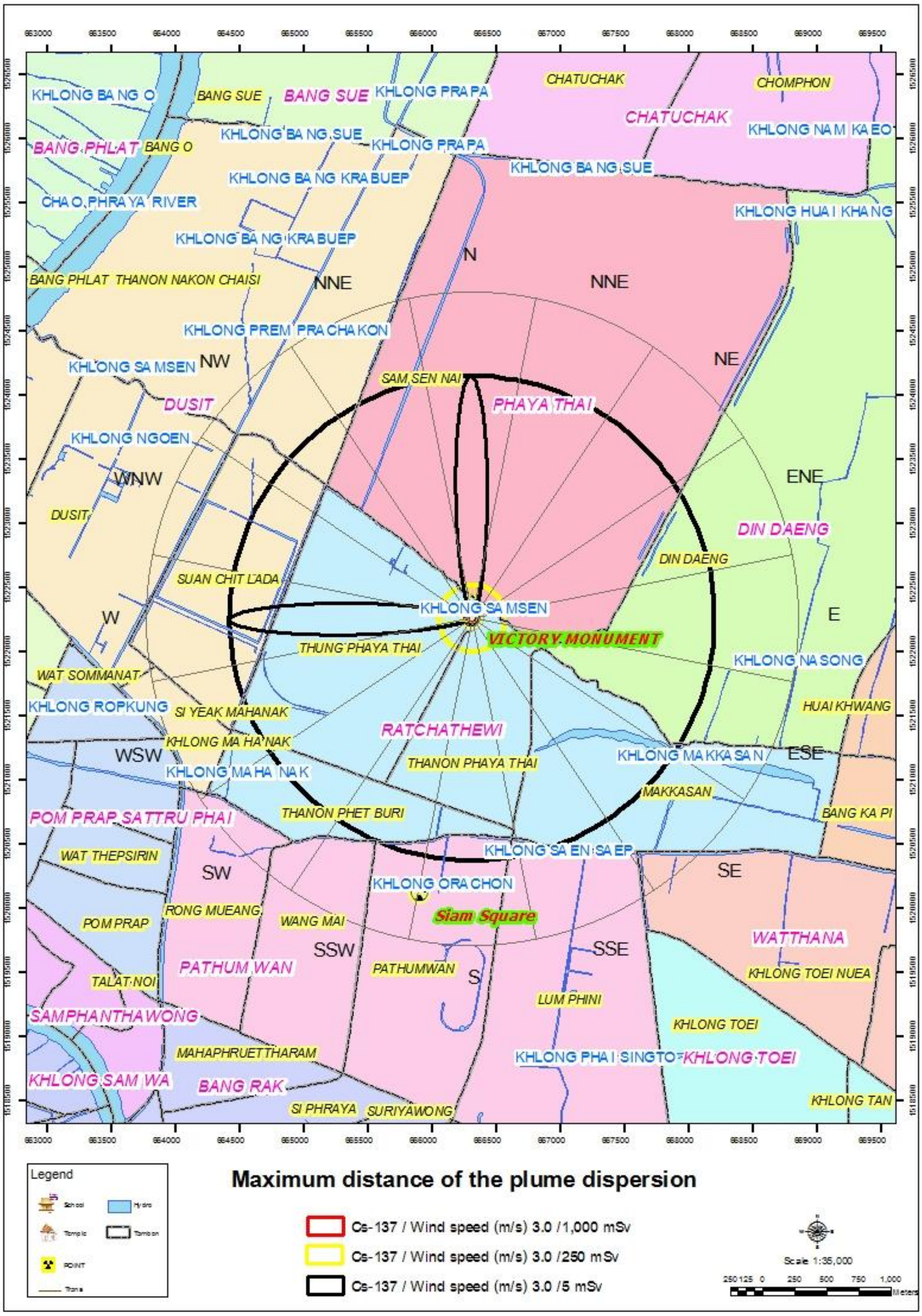


Figure 4.8 Boundary of affected areas at the Victory Monument site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

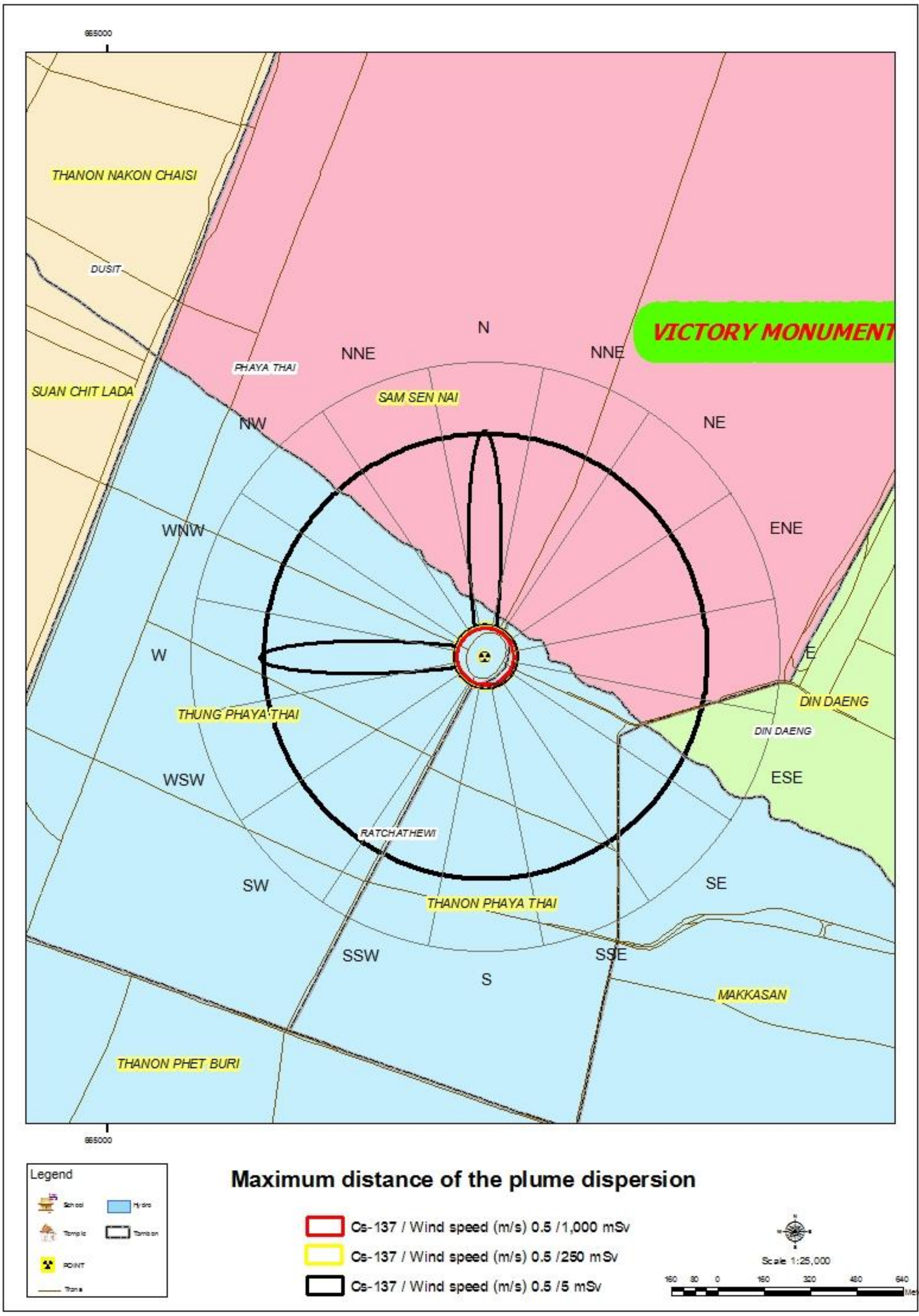


Figure 4.9 Boundary of affected areas at the Victory Monument site for the case of Cs-137 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

Figure 4.10 Boundary of affected areas at the Victory Monument site for the case of Cs-137 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

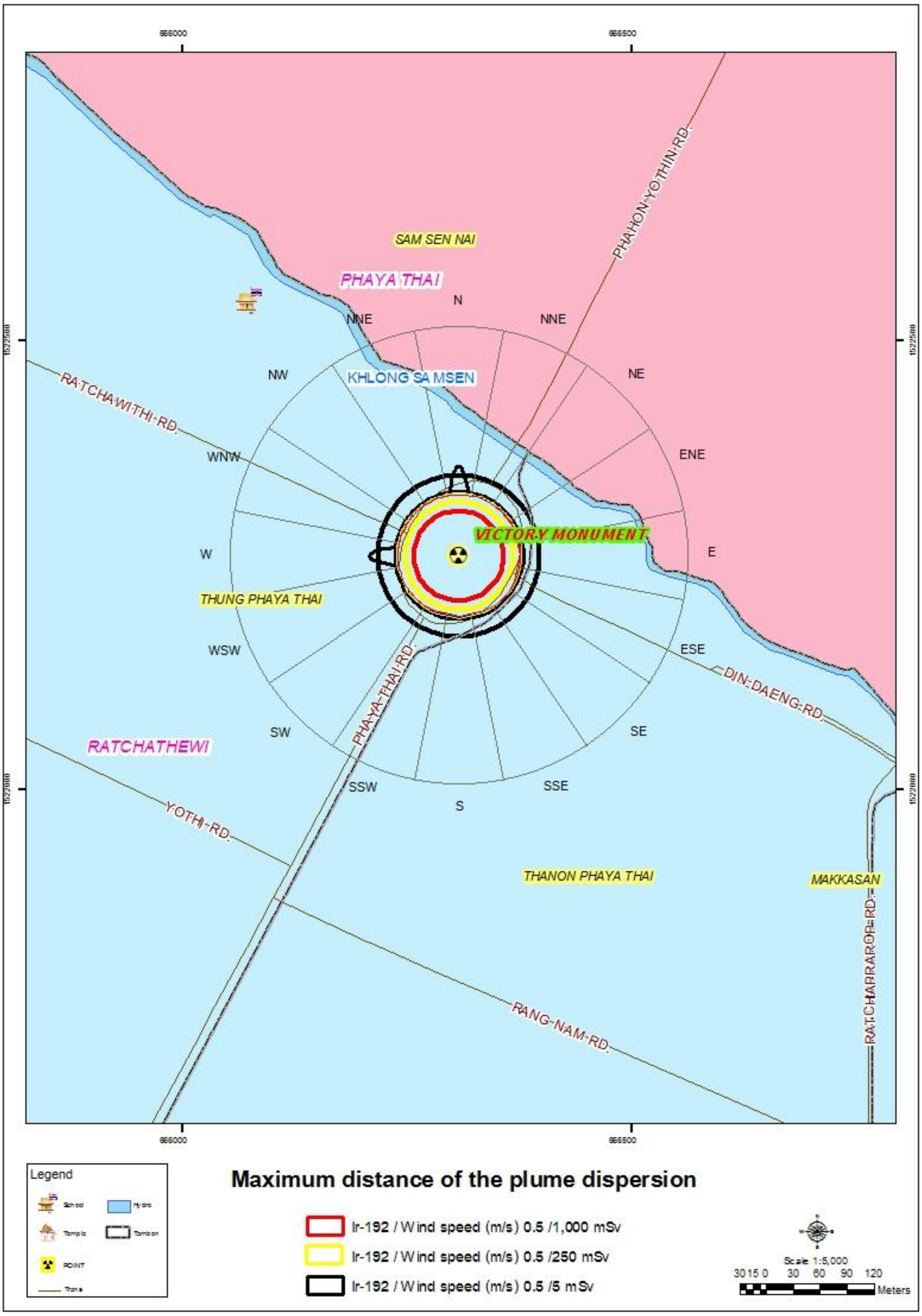


Figure 4.11 Boundary of affected areas at the Victory Monument site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

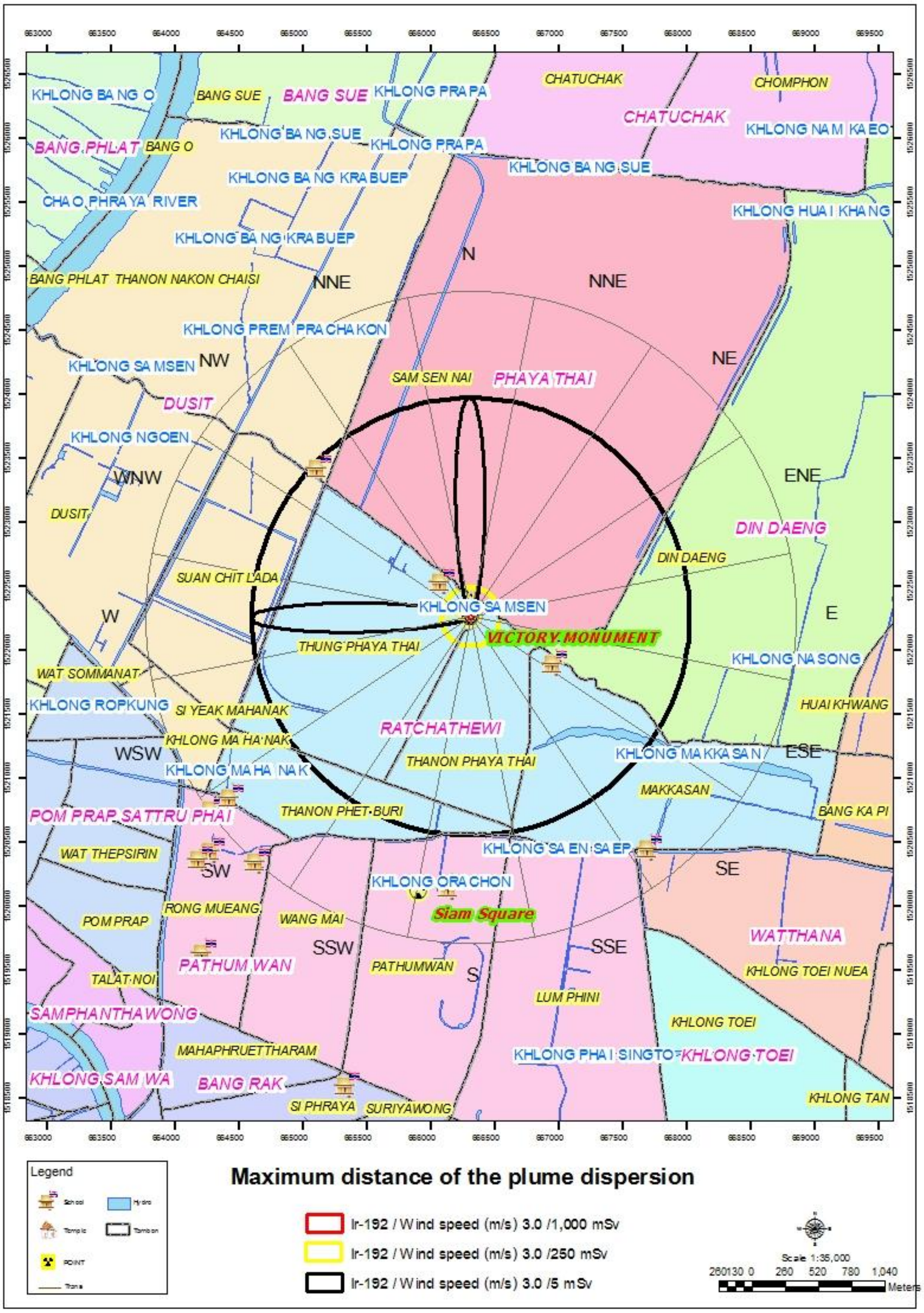


Figure 4.12 Boundary of affected areas at the Victory Monument site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

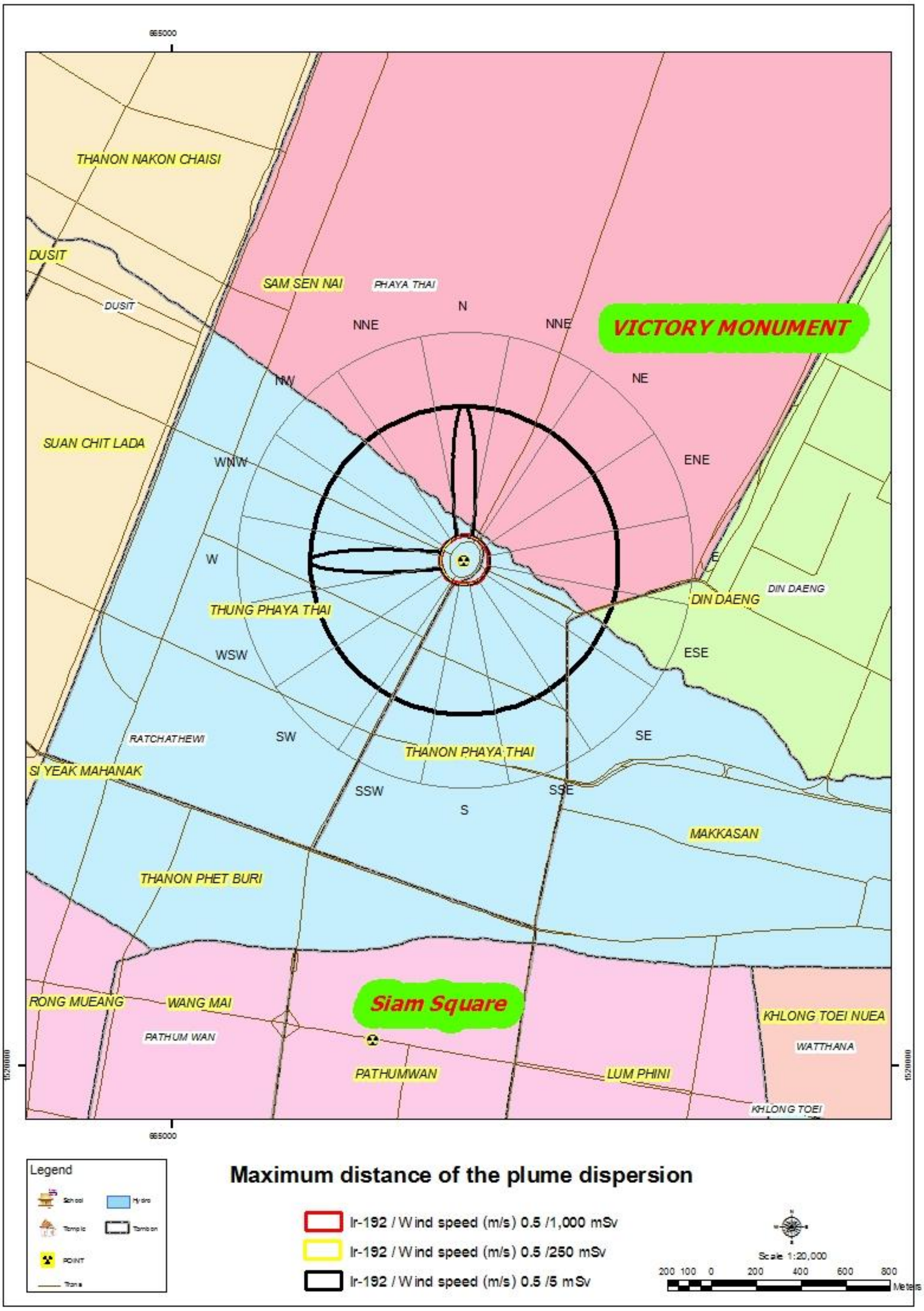


Figure 4.13 Boundary of affected areas at the Victory Monument site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

Figure 4.14 Boundary of affected areas at the Victory Monument site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

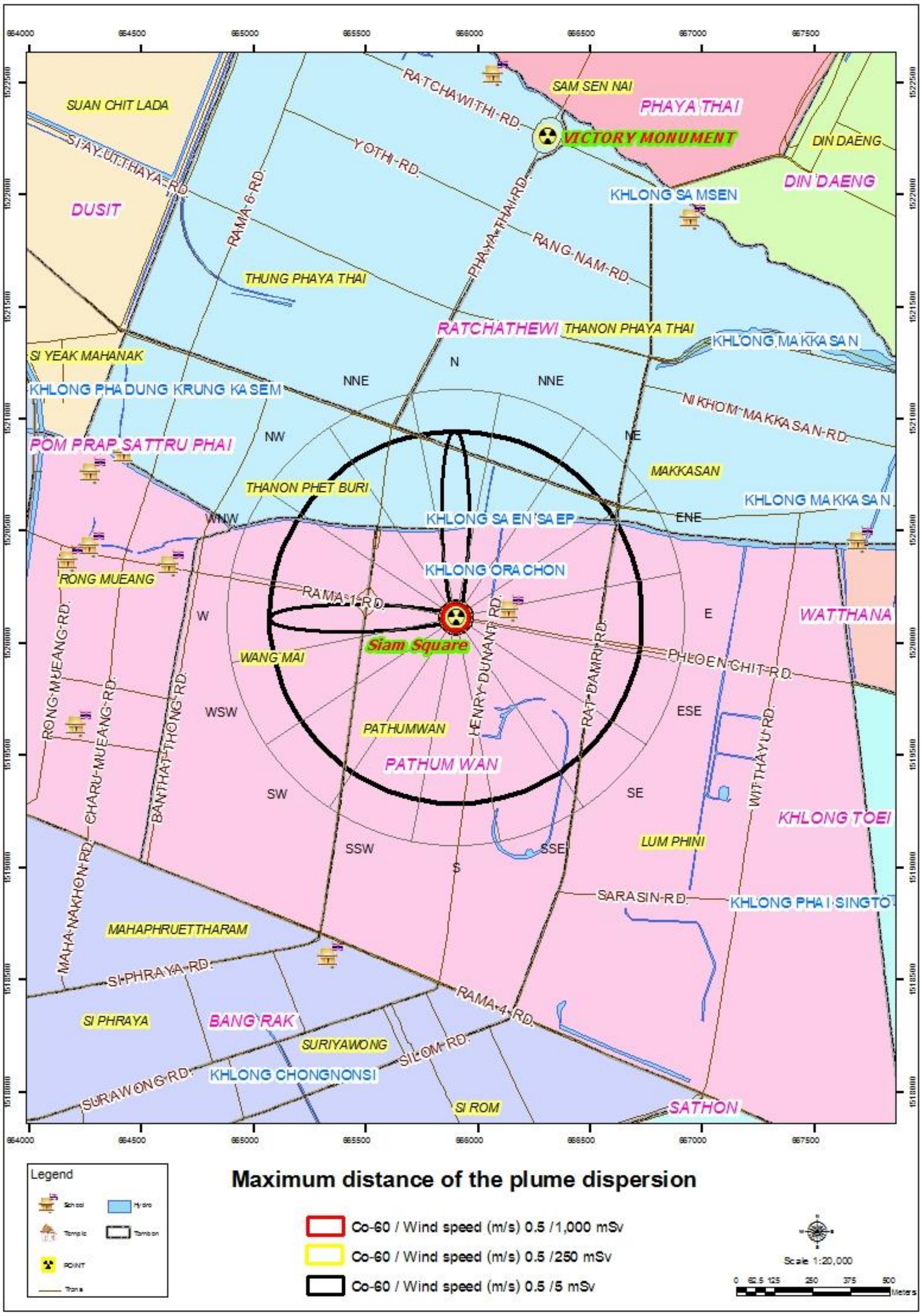


Figure 4.15 Boundary of affected areas at the Siam Square site for the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

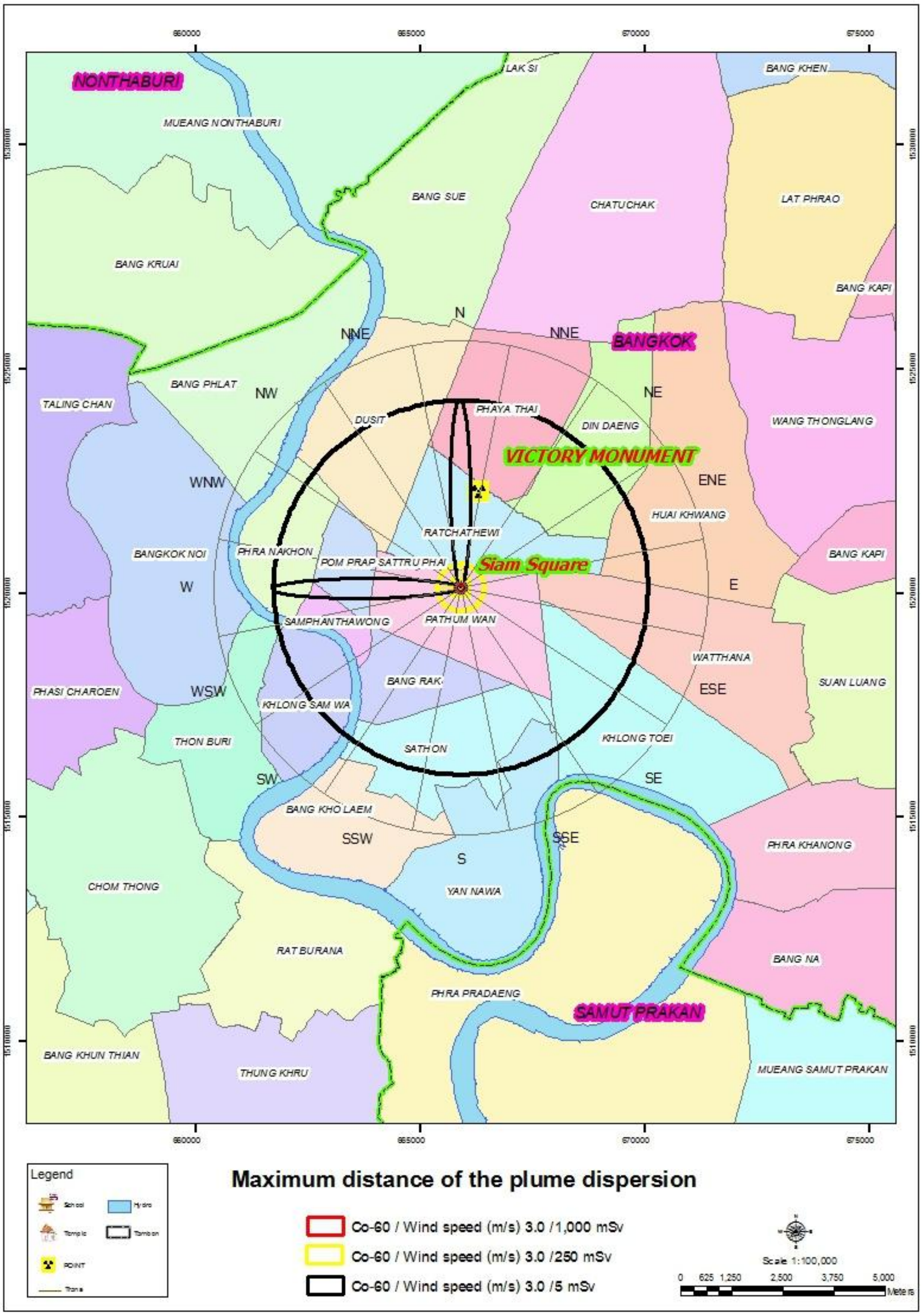


Figure 4.16 Boundary of affected areas at the Siam Square site for the case of Co-60 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

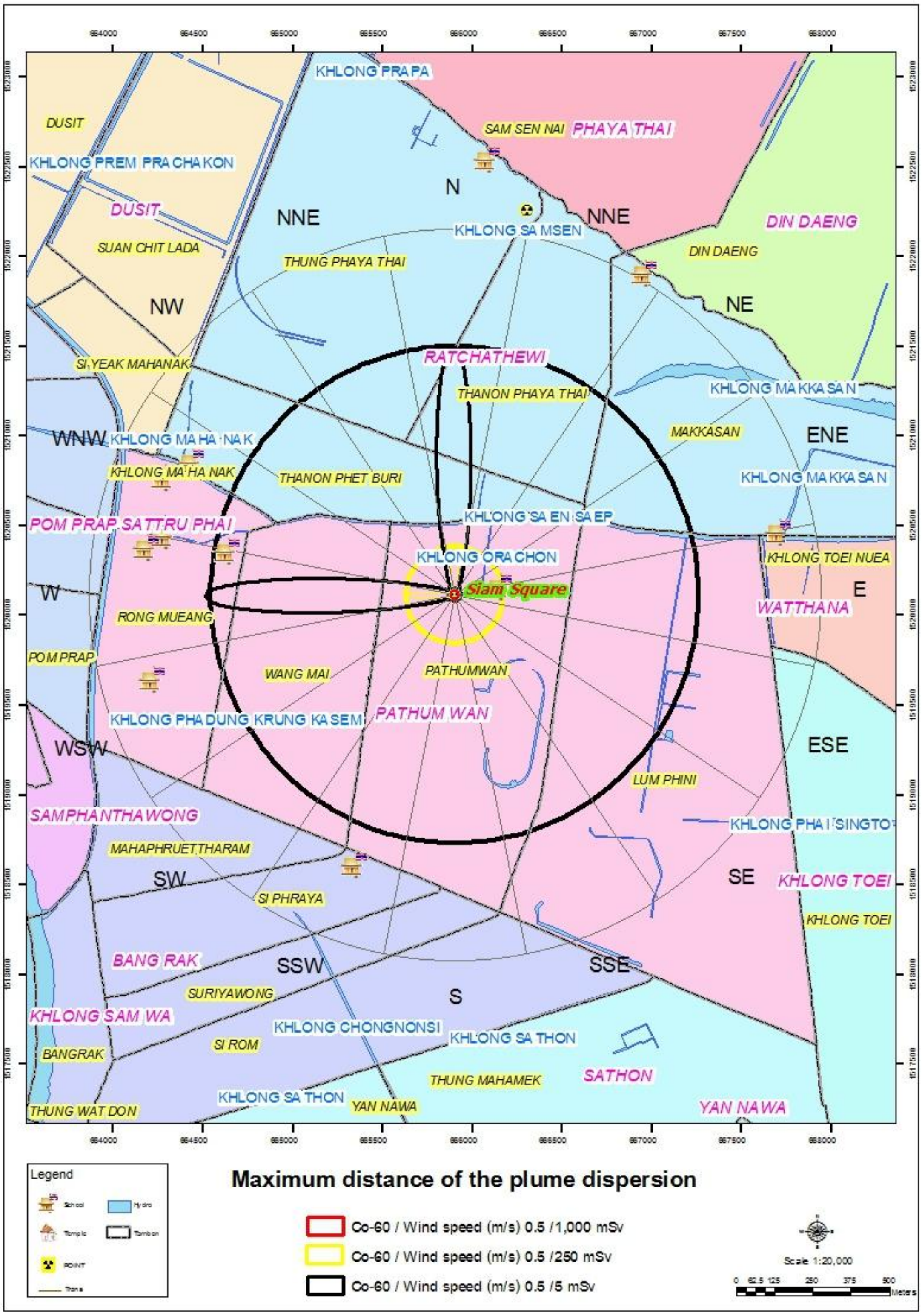


Figure 4.17 Boundary of affected areas at the Siam Square site for the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

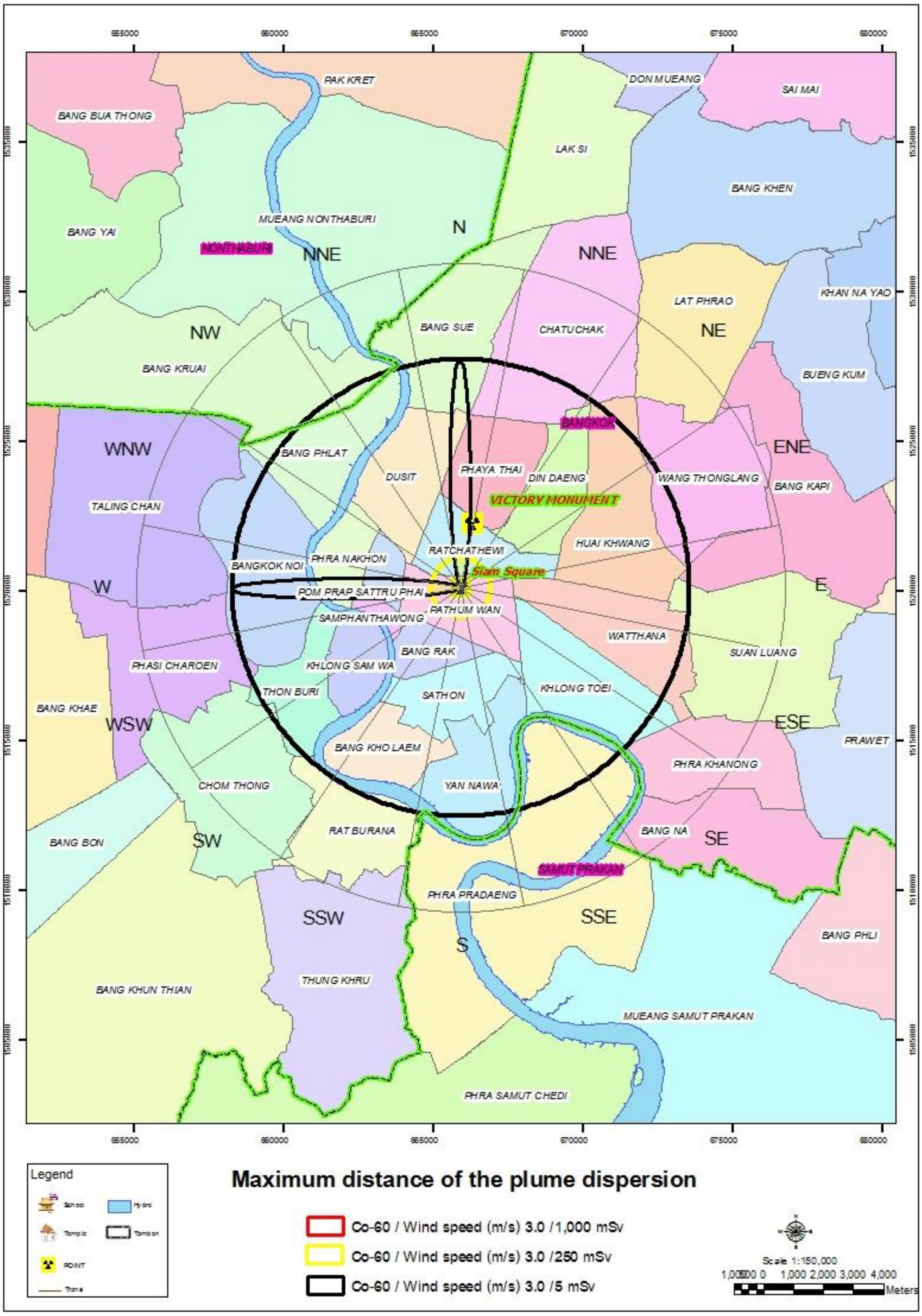


Figure 4.18 Boundary of affected areas at the Siam Square site for the case of Co-60 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

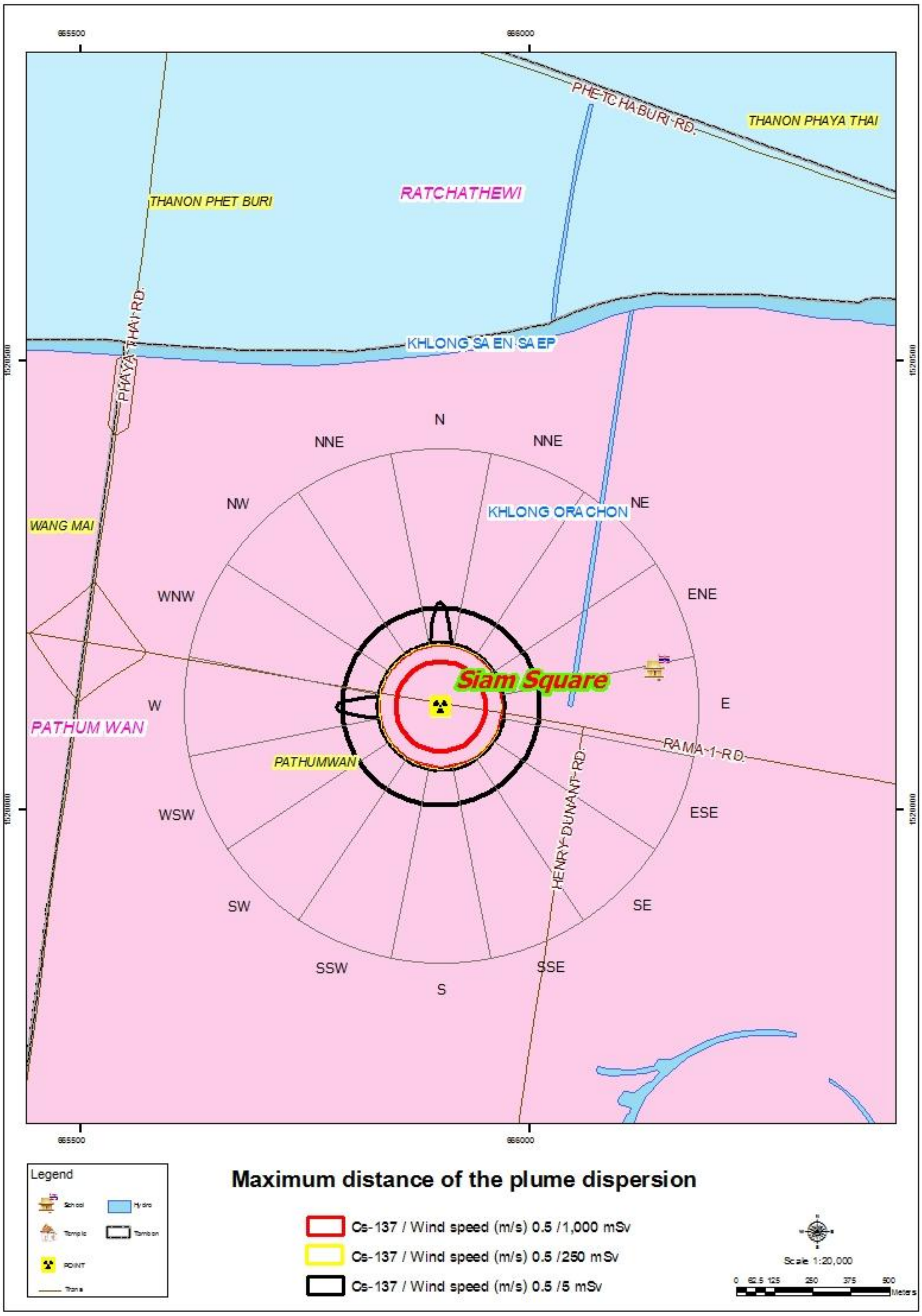


Figure 4.19 Boundary of affected areas at the Siam Square site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

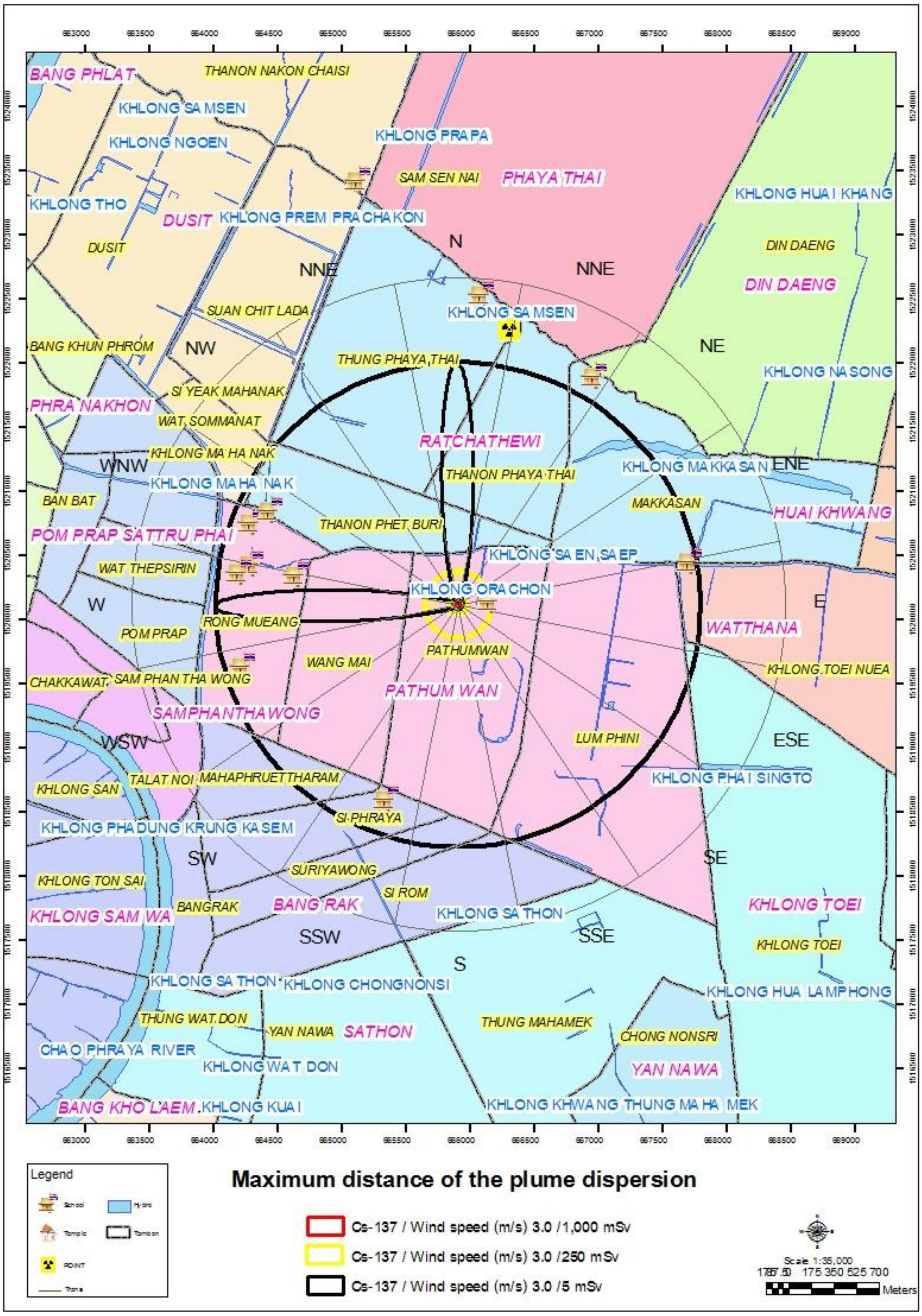


Figure 4.20 Boundary of affected areas at the Siam Square site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

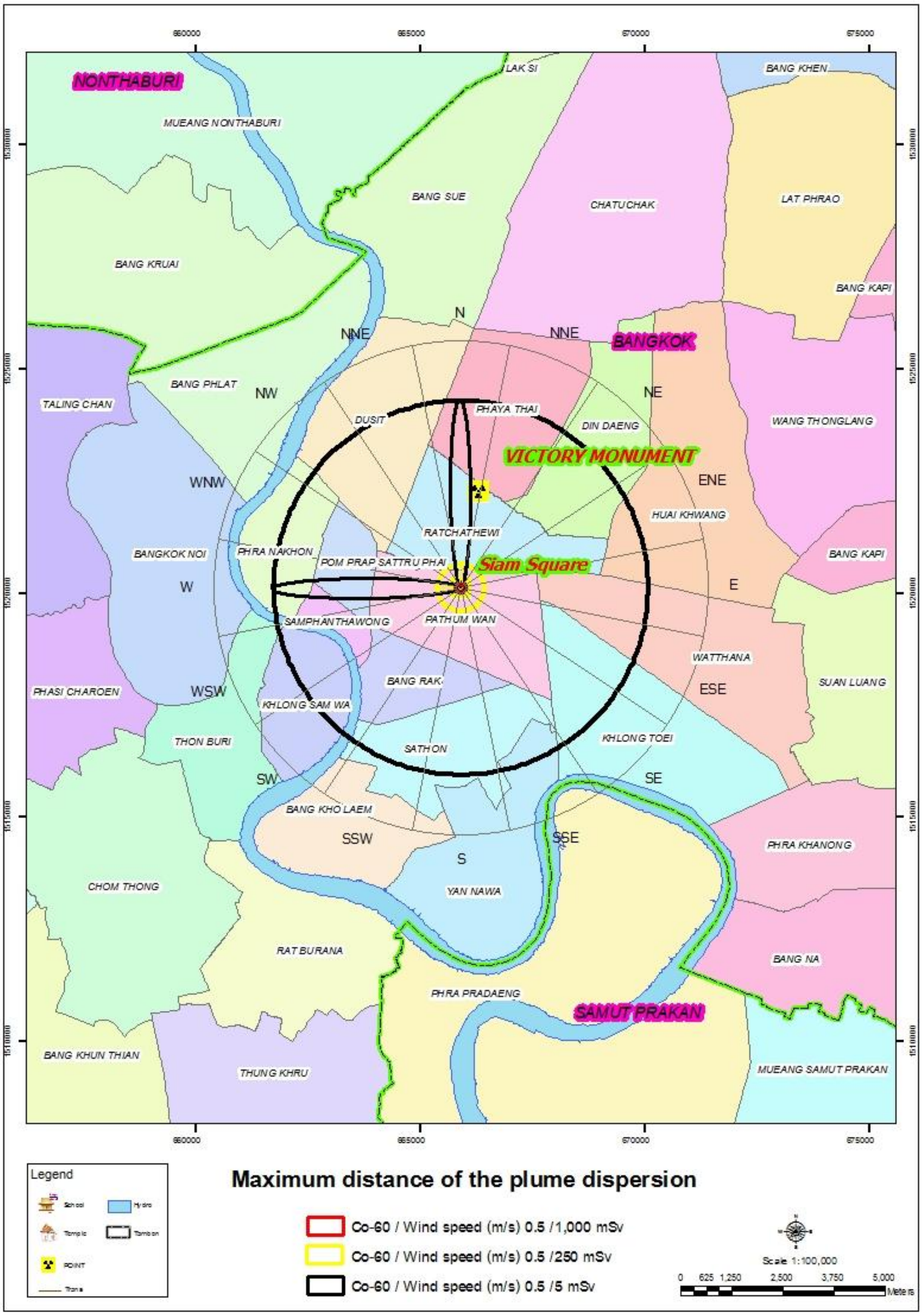


Figure 4.21 Boundary of affected areas at the Siam Square site for the case of Cs-137 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

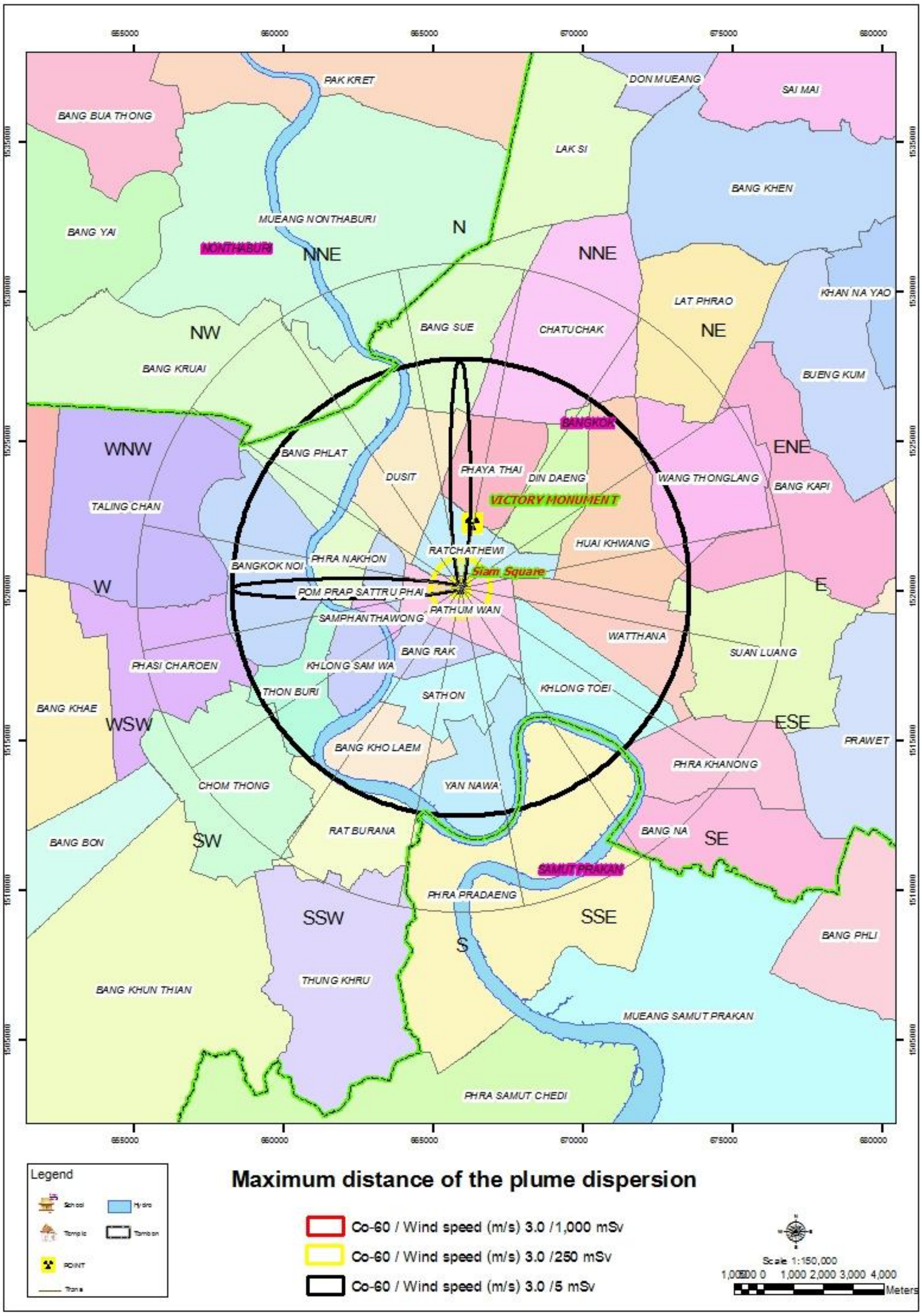


Figure 4.22 Boundary of affected areas at the Siam Square site for the case of Cs-137 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

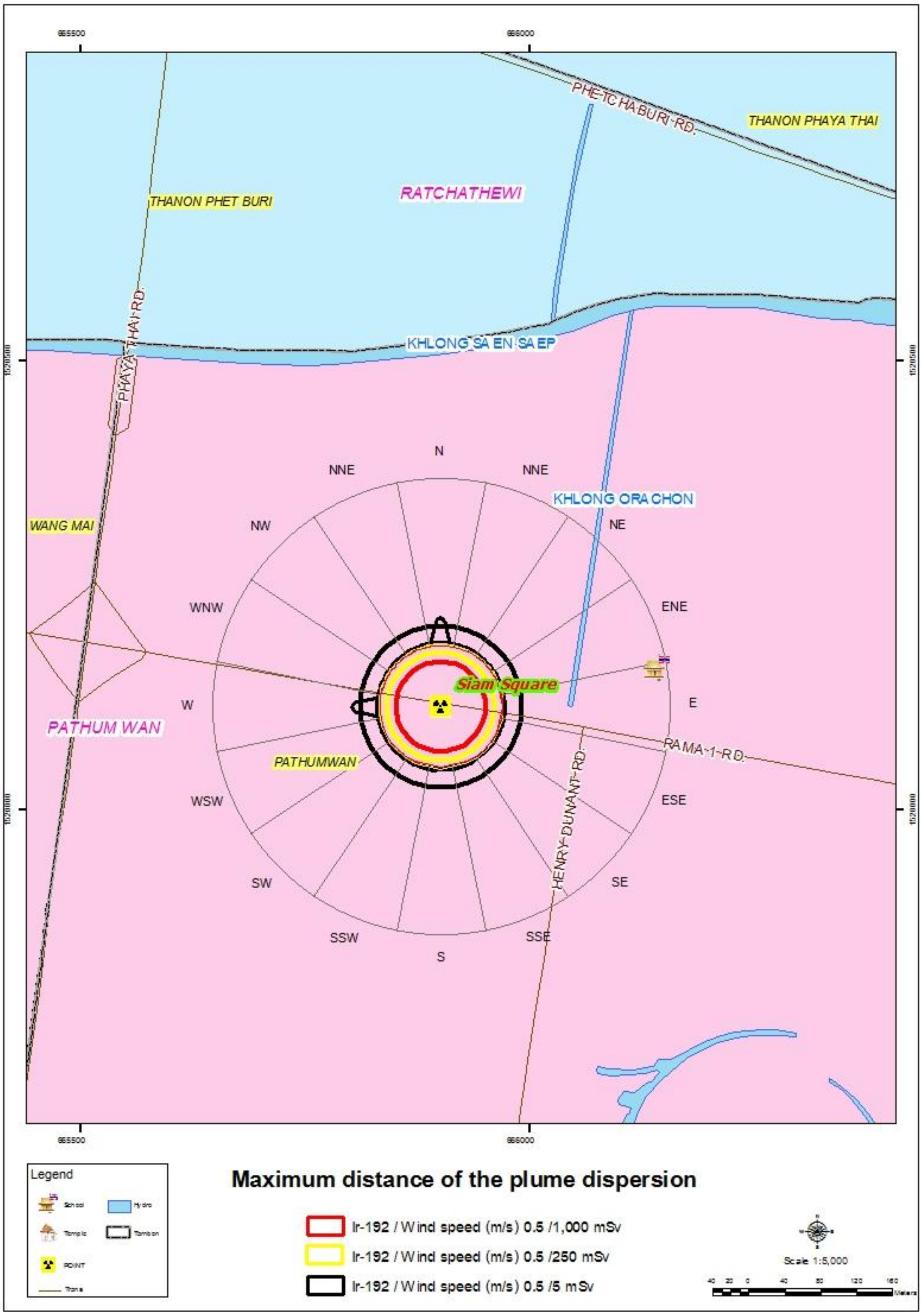


Figure 4.23 Boundary of affected areas at the Siam Square site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from S and E directions

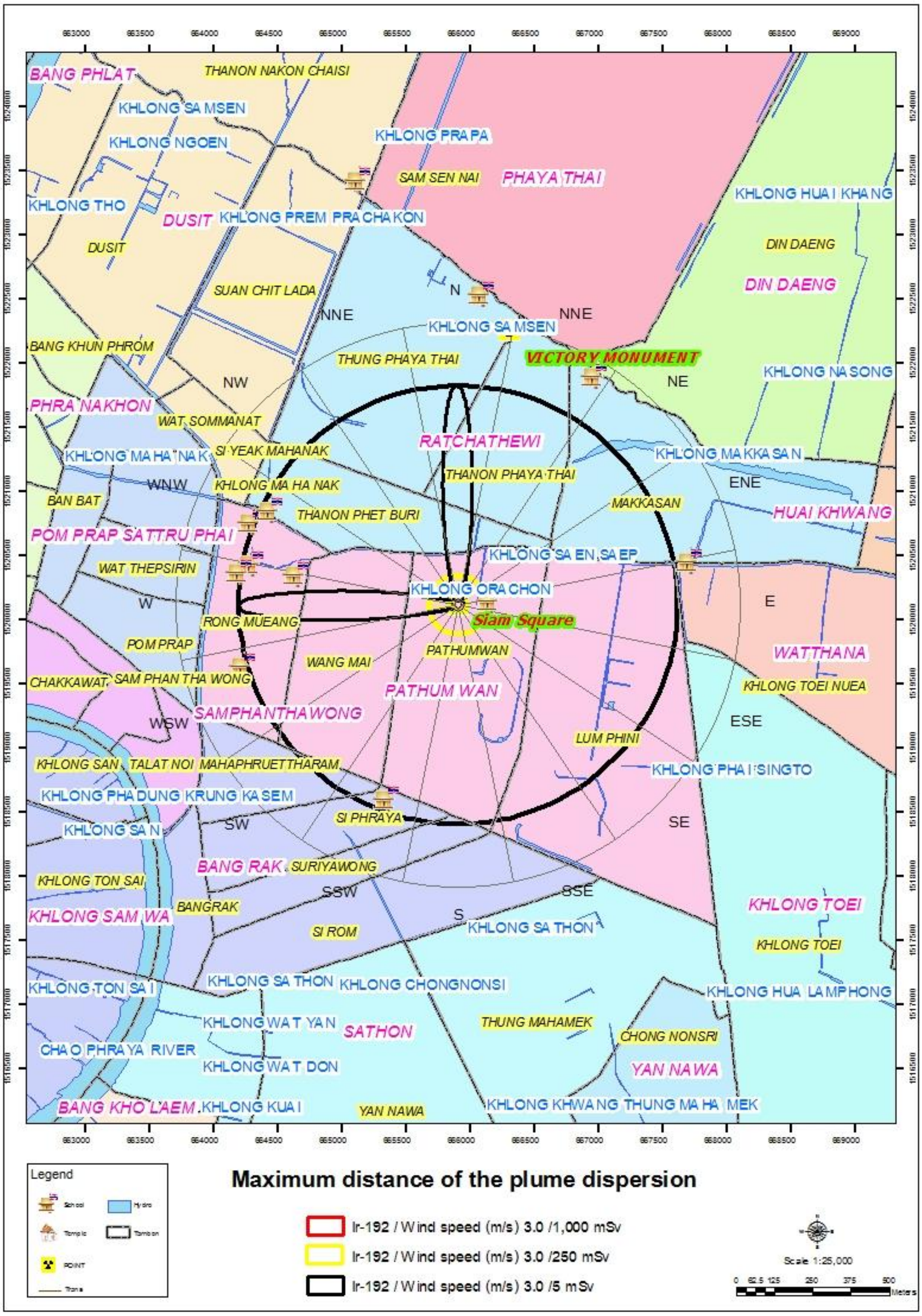


Figure 4.24 Boundary of affected areas at the Siam Square site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 3.0 m/s blowing from S and E directions

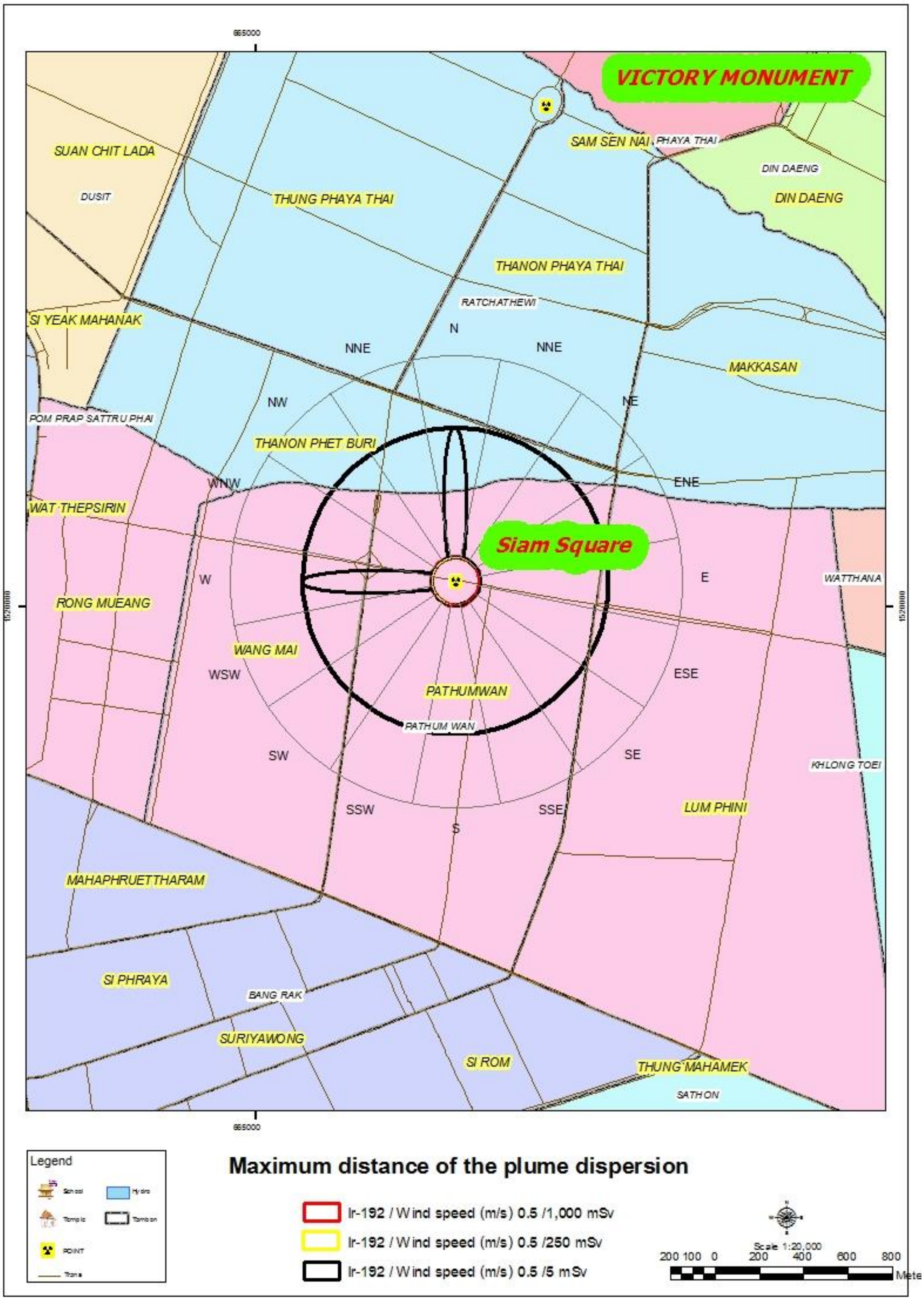


Figure 4.25 Boundary of affected areas at the Siam Square site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from S and E directions

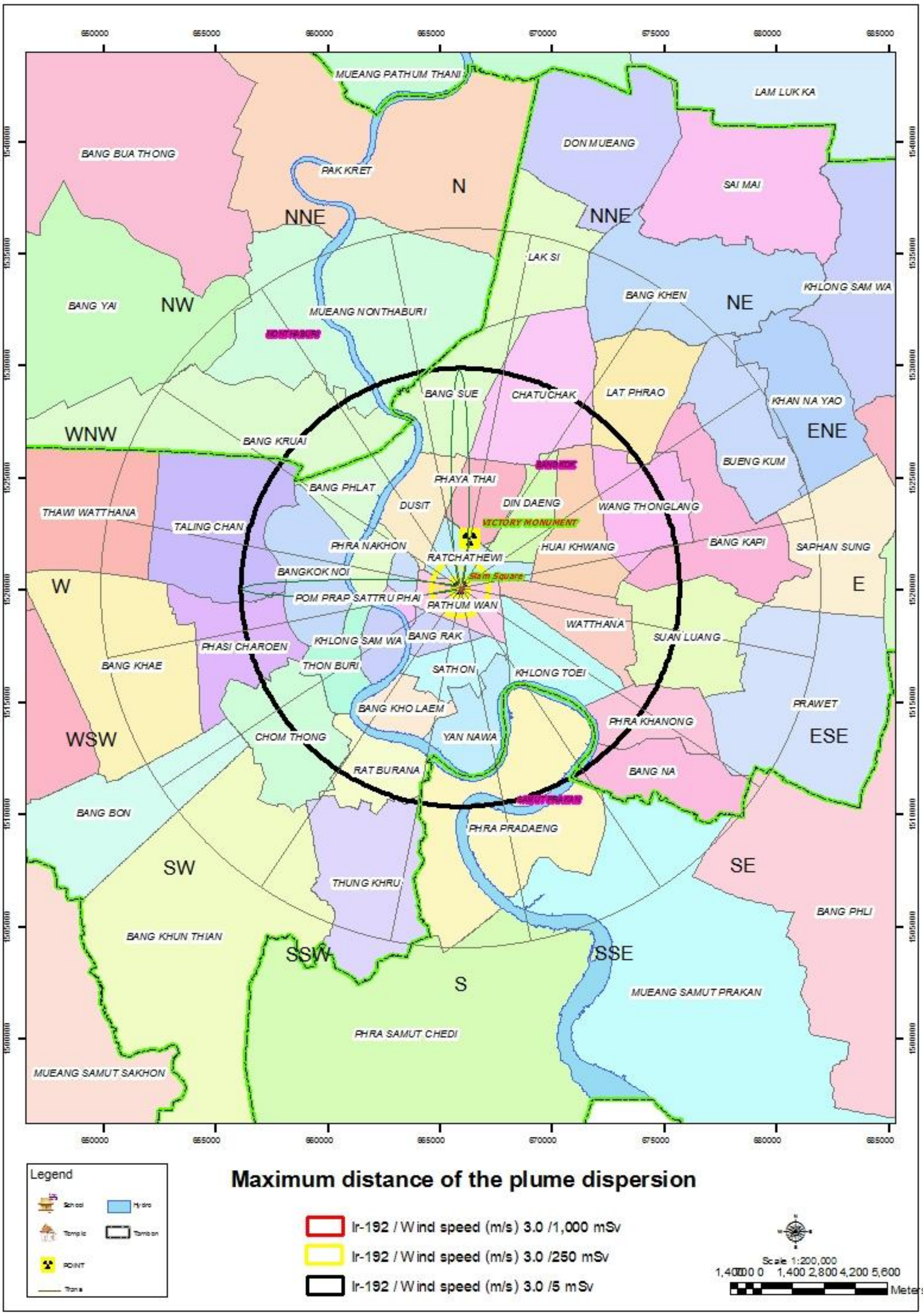


Figure 4.26 Boundary of affected areas at the Siam Square site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 3.0 m/s blowing from S and E directions

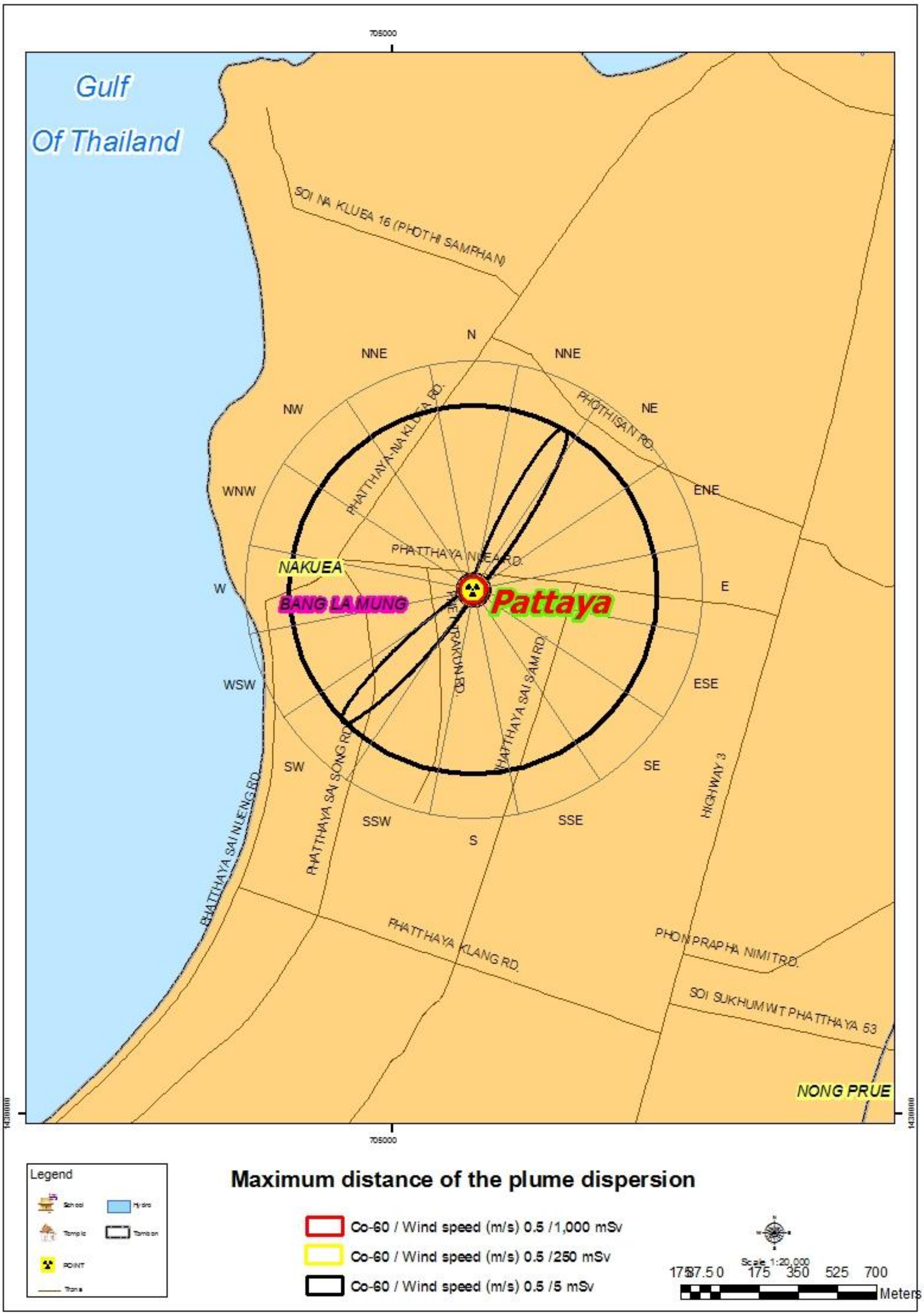


Figure 4.27 Boundary of affected areas at the Pattaya City site for the case of Co-60 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions

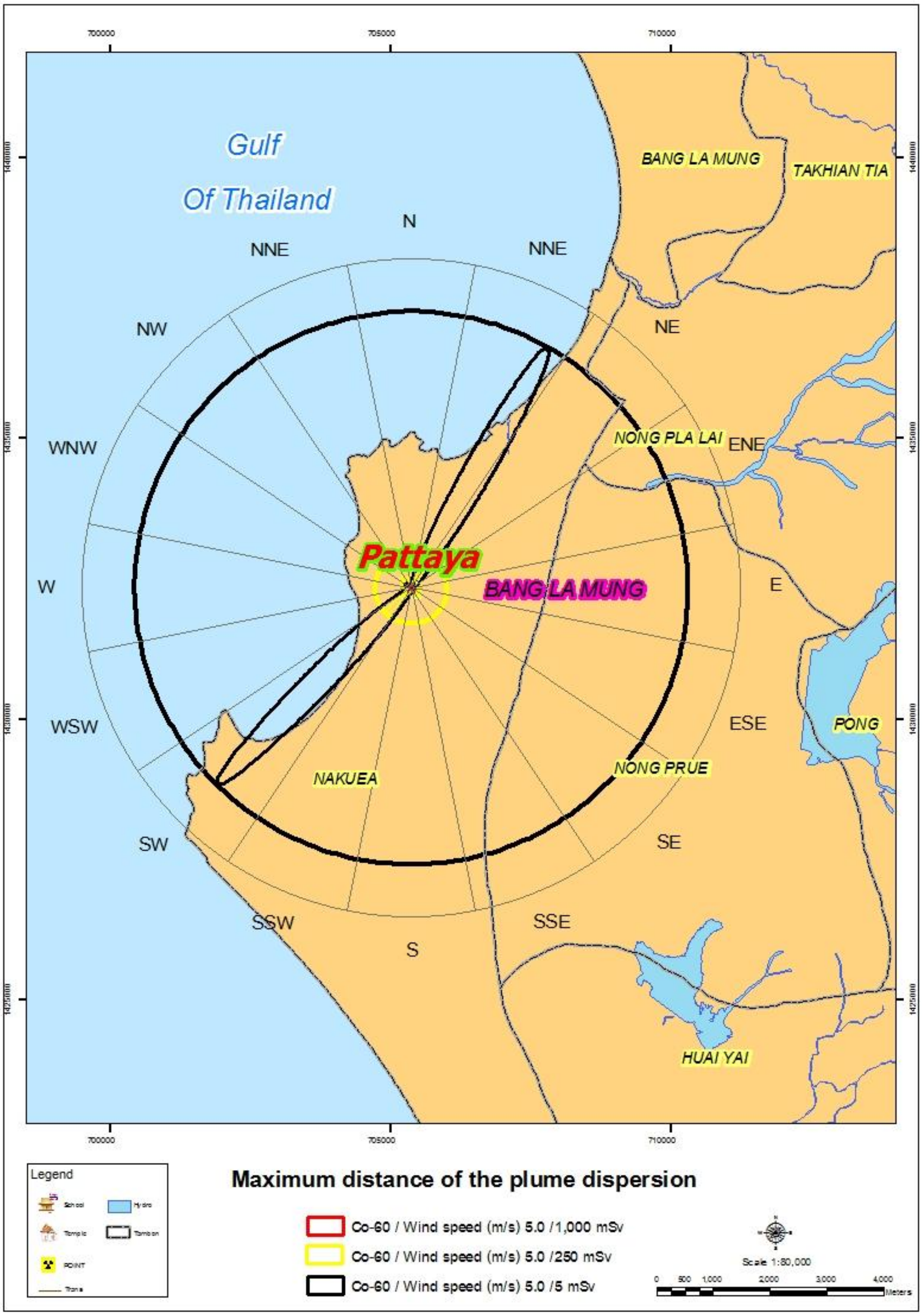


Figure 4.28 Boundary of affected areas at the Pattaya City site for the case of Co-60 with high explosive of 10 pounds and speed of 5.0 m/s blowing from SSW and NE directions

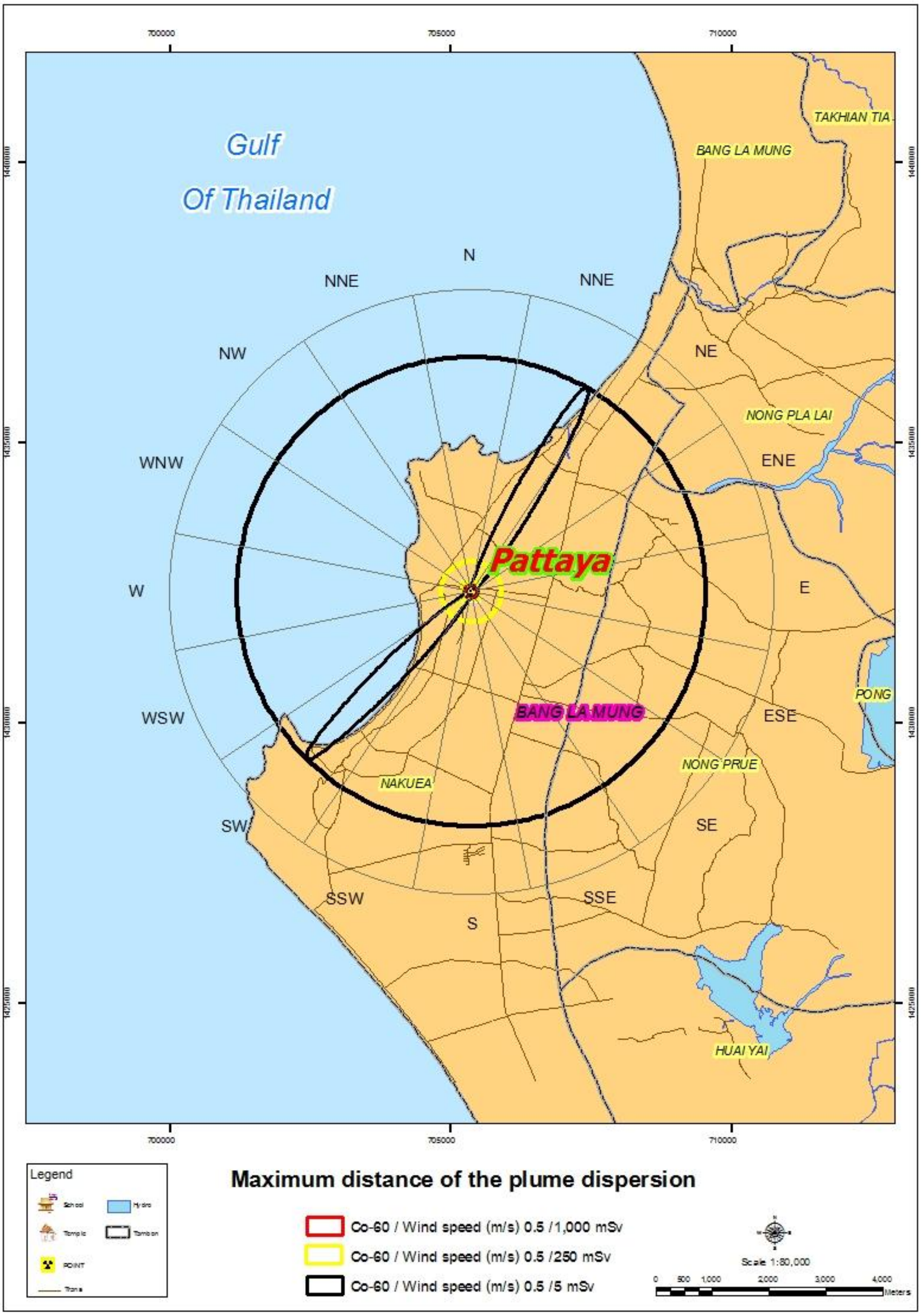


Figure 4.29 Boundary of affected areas at the Pattaya City site for the case of Co-60 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions

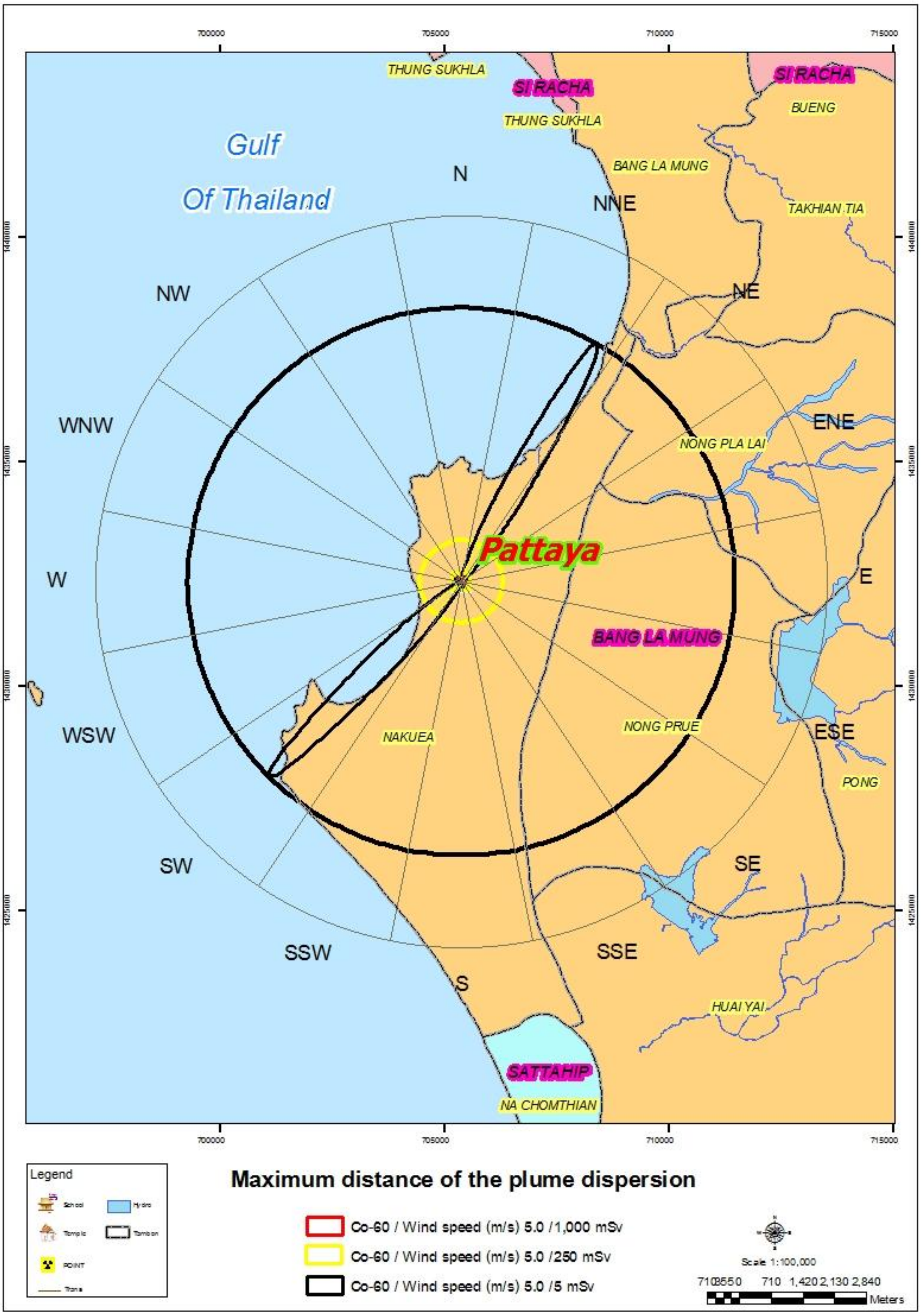


Figure 4.30 Boundary of affected areas at the Pattaya City site for the case of Co-60 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions

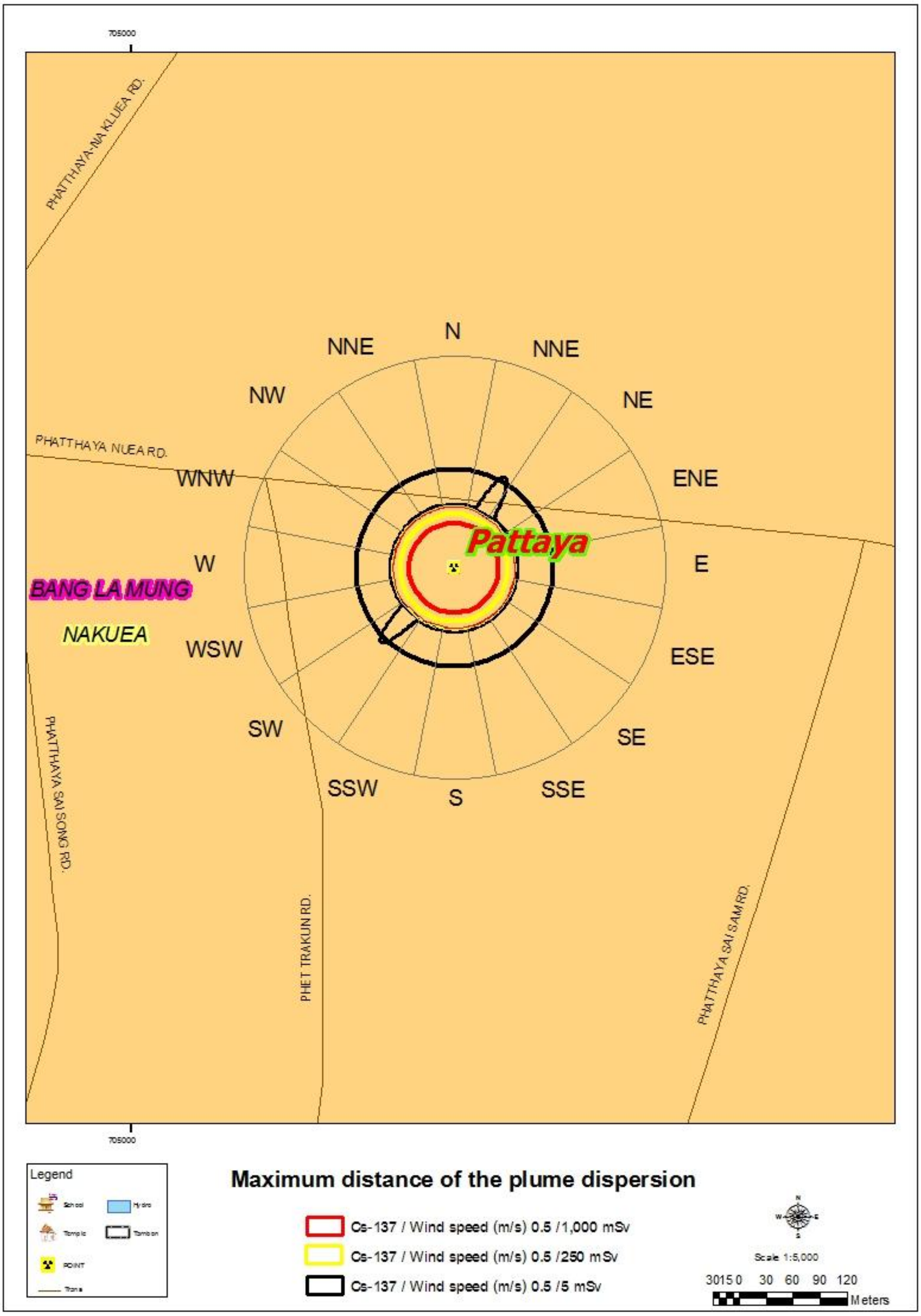


Figure 4.31 Boundary of affected areas at the Pattaya City site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions

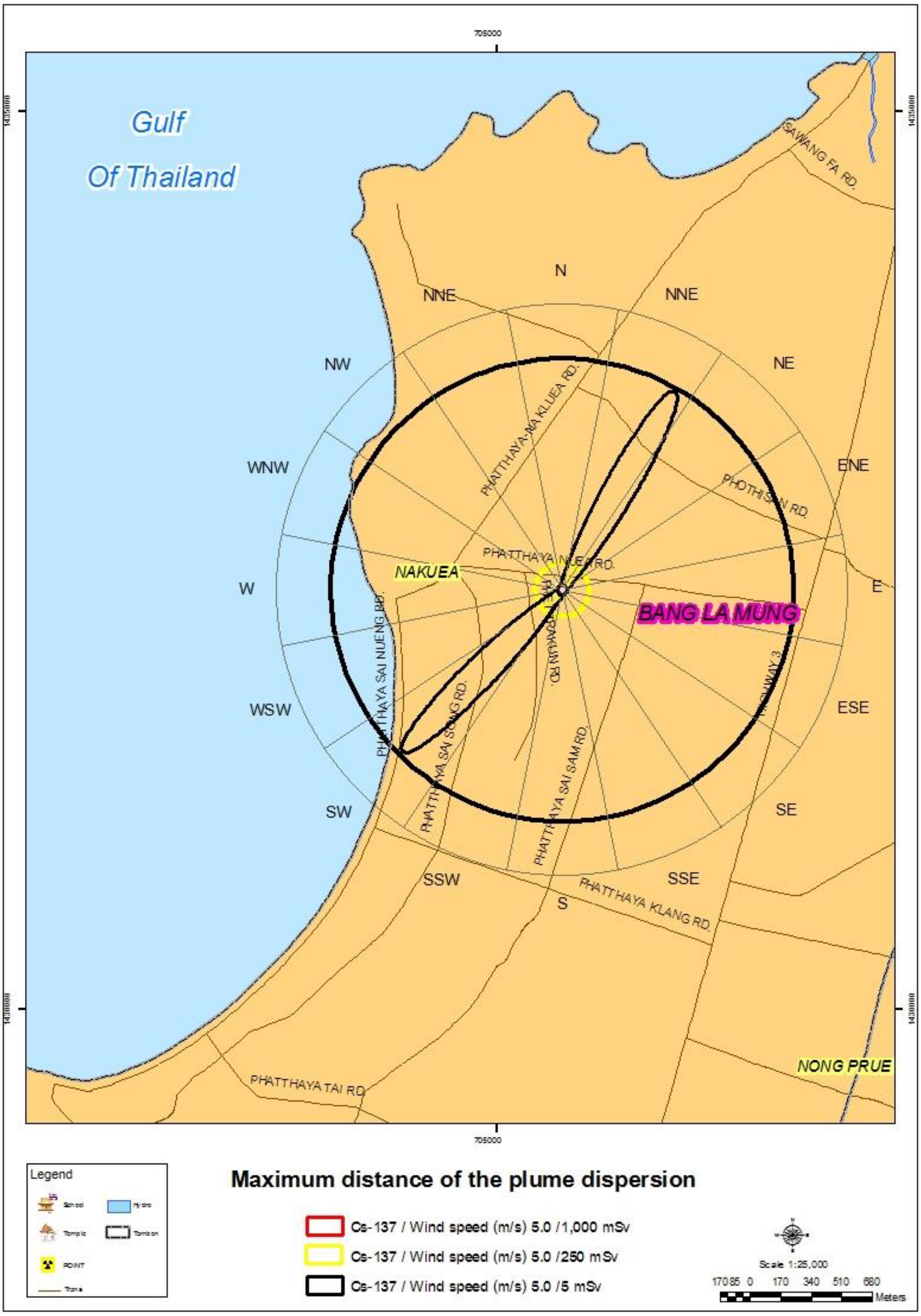


Figure 4.32 Boundary of affected areas at the Pattaya City site for the case of Cs-137 with high explosive of 10 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions

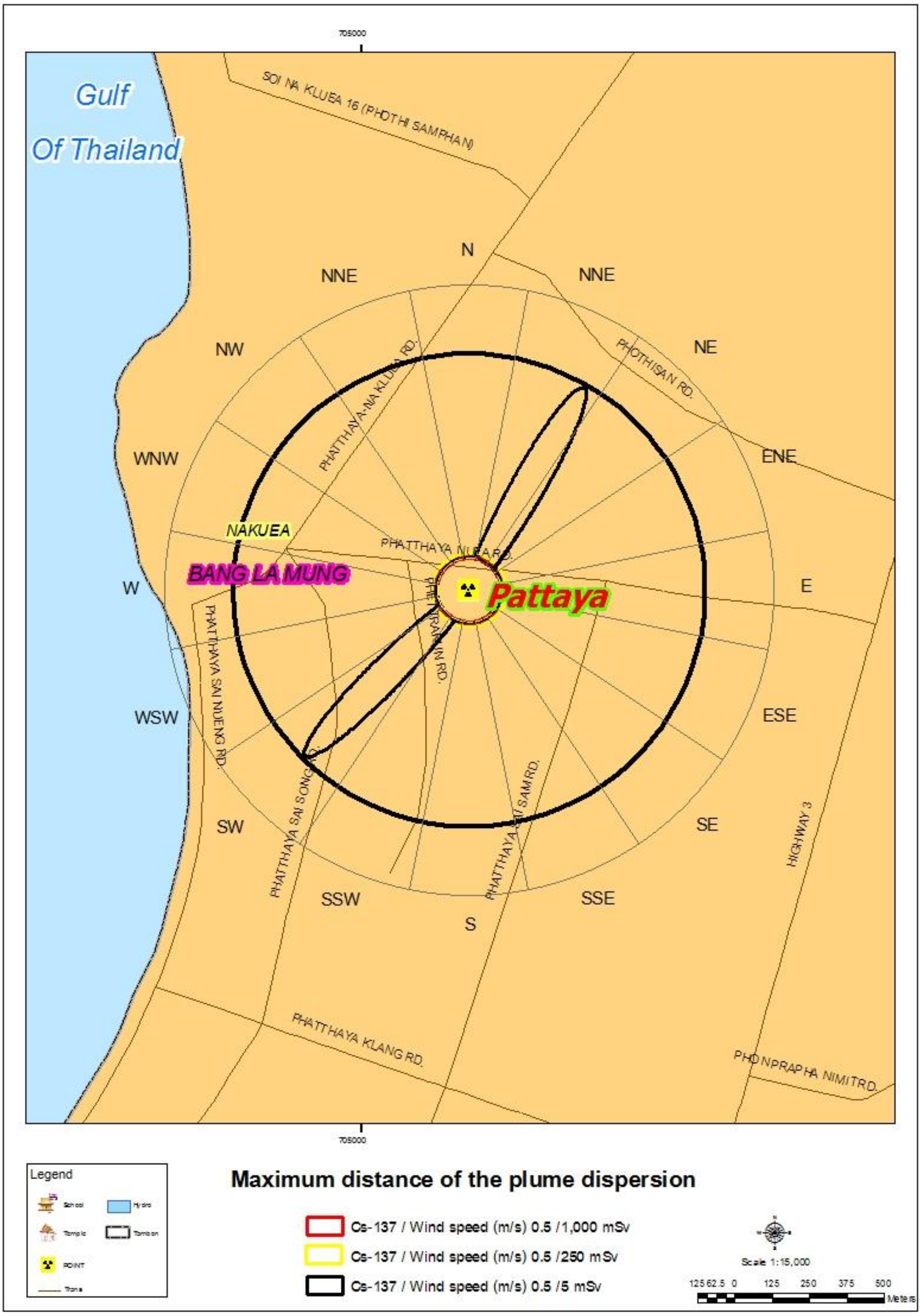


Figure 4.33 Boundary of affected areas at the Pattaya City site for the case of Cs-137 with high explosive of 25 pounds of wind speed of 0.5 m/s blowing from SSW and NE directions

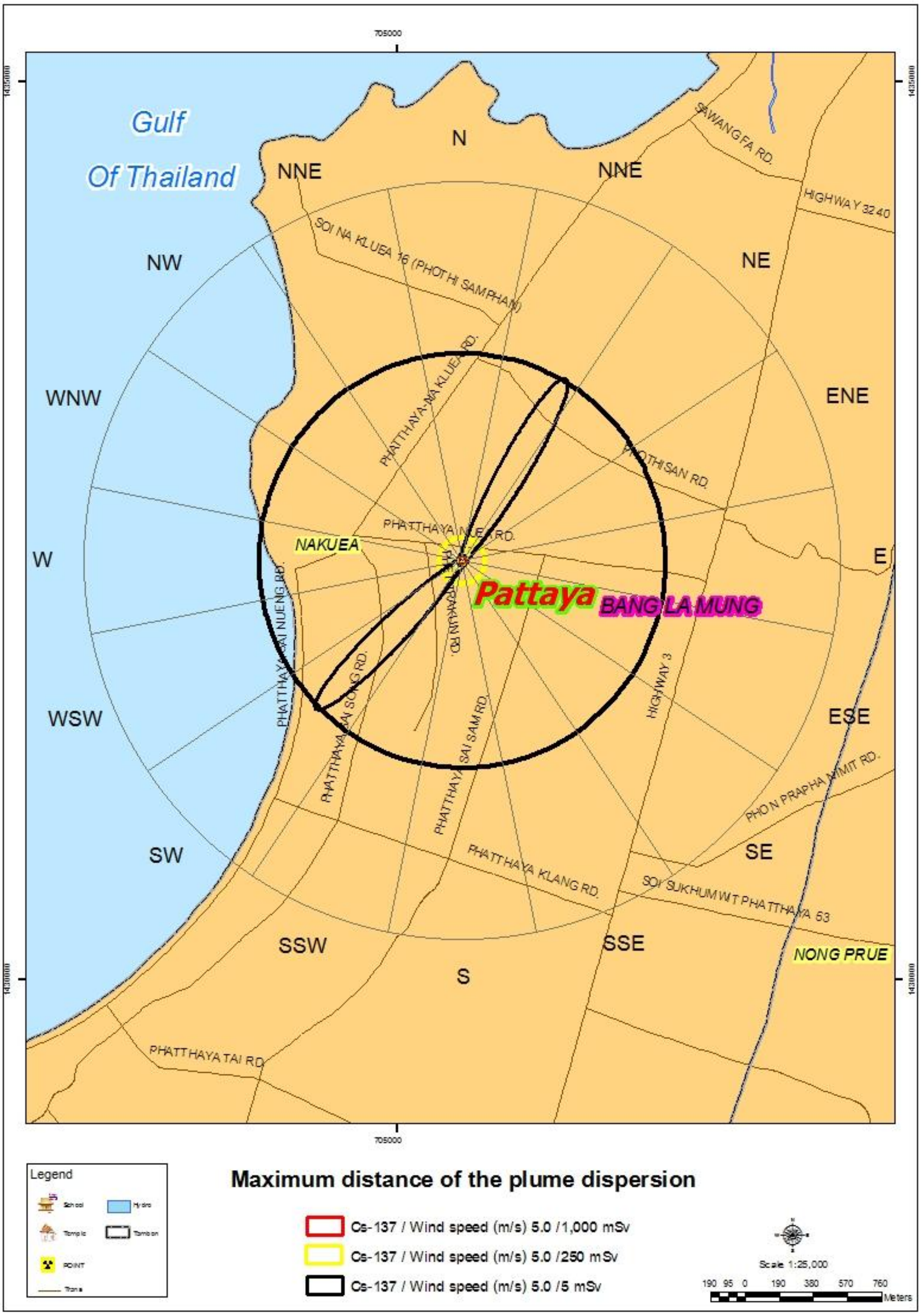


Figure 4.34 Boundary of affected areas at the Pattaya City site for the case of Cs-137 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions

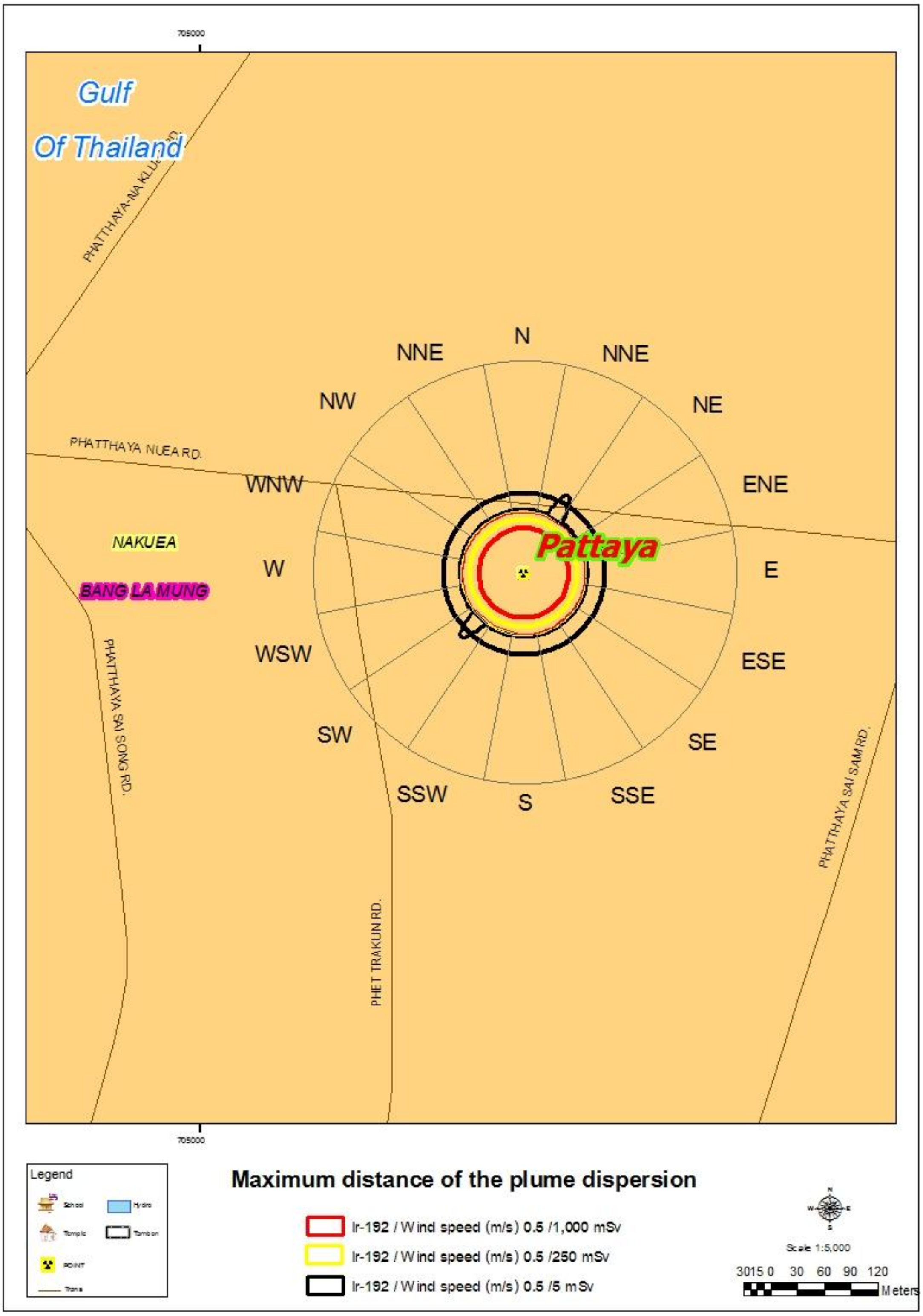


Figure 4.35 Boundary of affected areas at the Pattaya City site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions

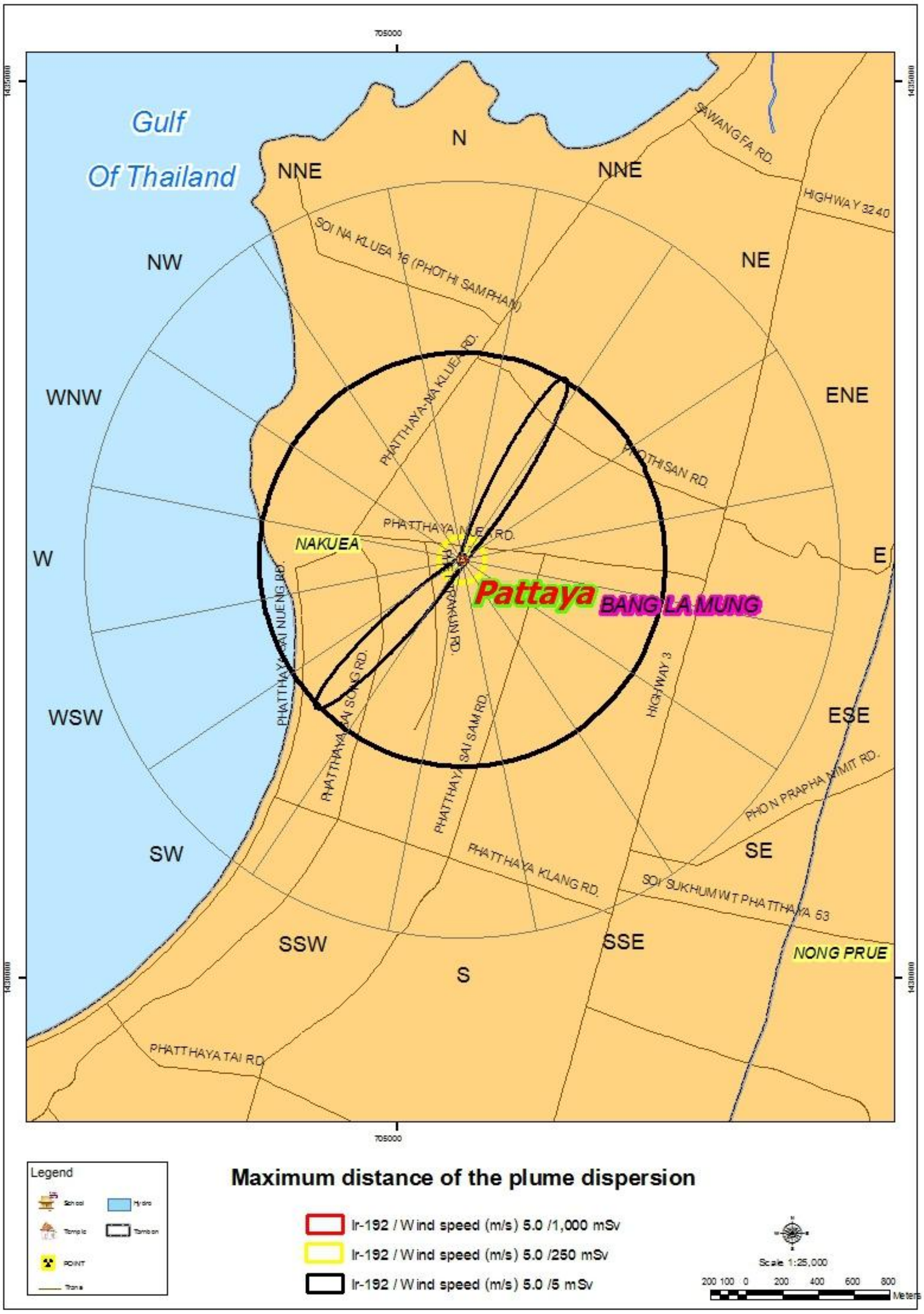


Figure 4.36 Boundary of affected areas at the Pattaya City site for the case of Ir-192 with high explosive of 10 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions

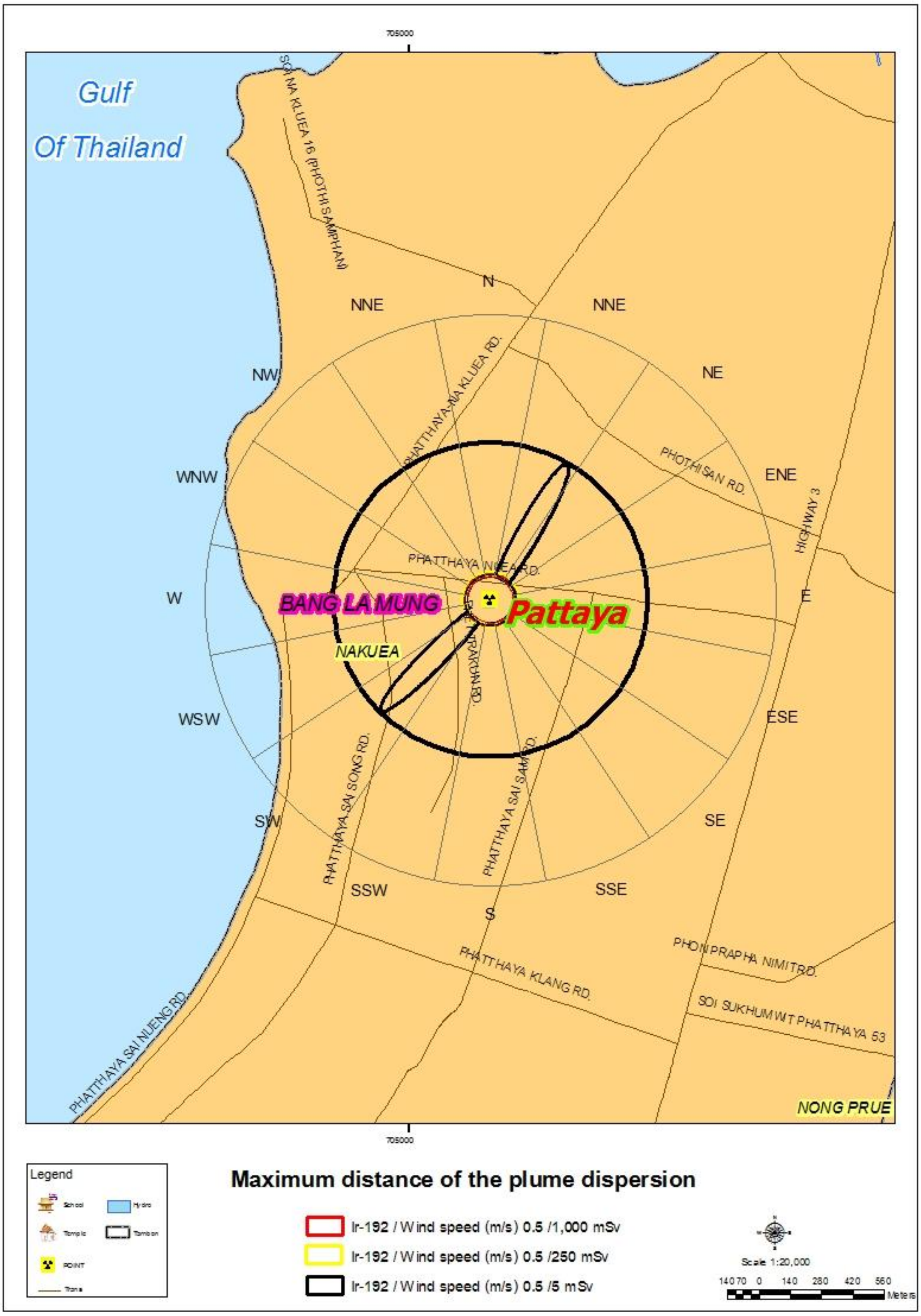


Figure 4.37 Boundary of affected areas at the Pattaya City site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 0.5 m/s blowing from SSW and NE directions

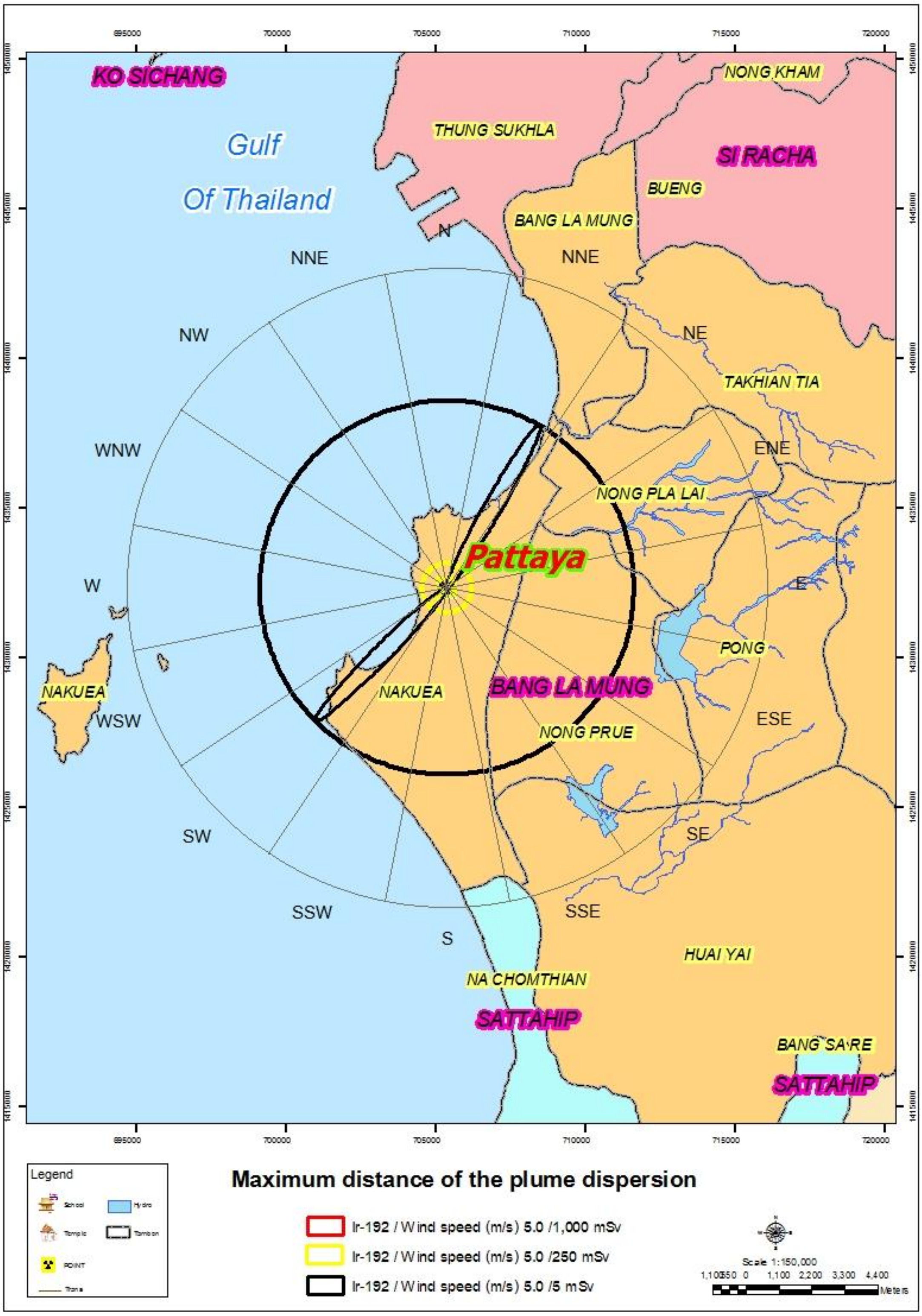


Figure 4.38 Boundary of affected areas at the Pattaya City site for the case of Ir-192 with high explosive of 25 pounds and wind speed of 5.0 m/s blowing from SSW and NE directions

From analysis of the spread of radiation following hypothetical explosions of RDDs at the three potential sites, results of the maximum plume dispersion distances for different explosives and different wind speed of each radionuclide are shown in Table 4.4 and Figures 4.39 - 4.41.

Table 4.4 The maximum plume dispersion distances for the material at risk of 100 Ci of each radionuclide at each potential site

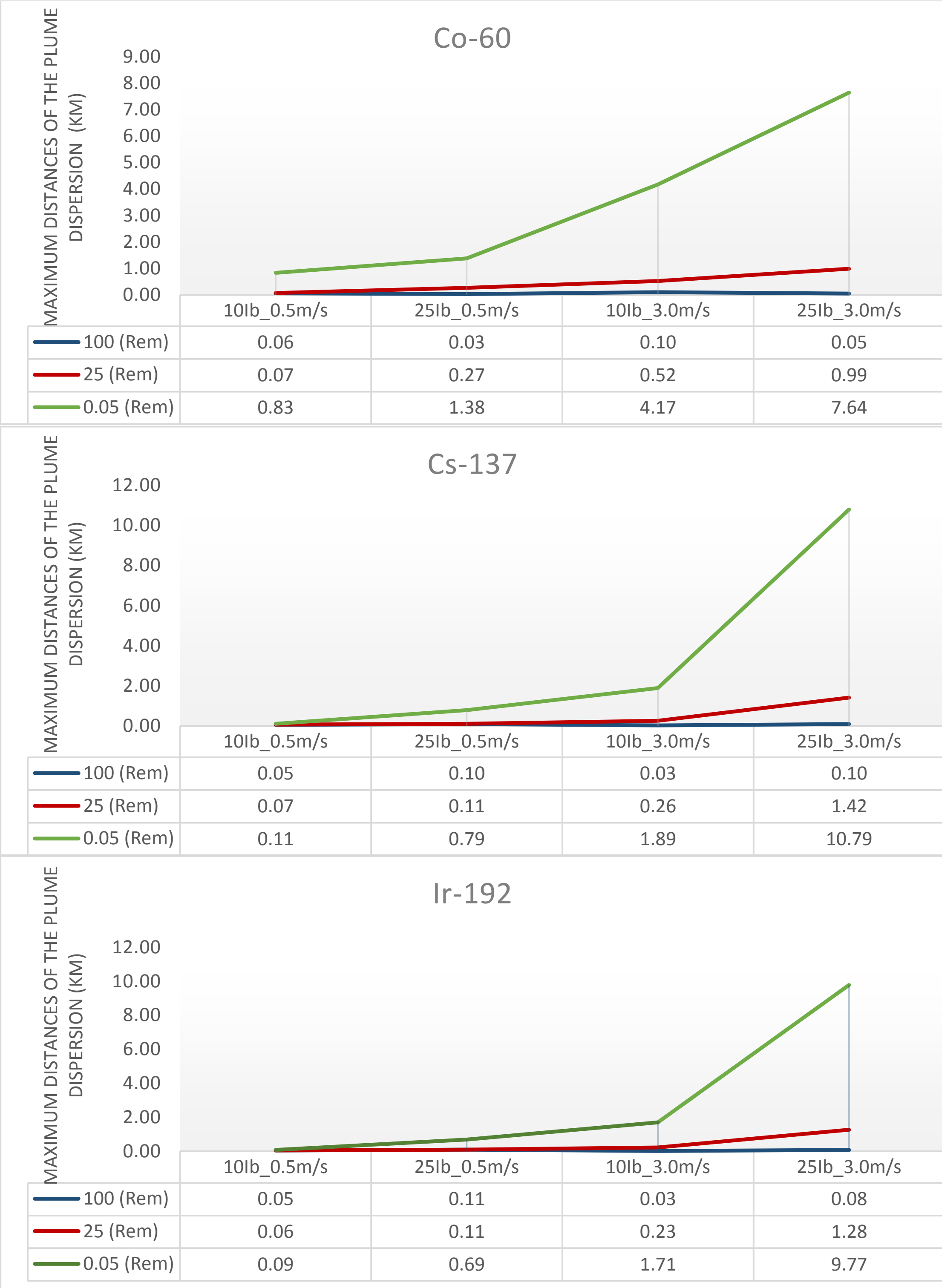
	Radionuclide	Wind direction	Explosive (lb)	Wind speed (m/s)	Maximum plume dispersion distance (km)		
					1,000 mSv	250 mSv	5 mSv
Victory Monument site	Co-60	S,E	10	0.5	0.06	0.07	0.83
				3.0	0.10	0.52	4.17
			25	0.5	0.03	0.27	1.38
				3.0	0.05	0.99	7.64
	Cs-137	S,E	10	0.5	0.05	0.07	0.11
				3.0	0.03	0.26	1.89
			25	0.5	0.10	0.11	0.79
				3.0	0.10	1.42	10.79
	Ir-192	S,E	10	0.5	0.05	0.06	0.09
				3.0	0.03	0.23	1.71
			25	0.5	0.11	0.11	0.69
				3.0	0.08	1.28	9.77
Siam Square site	Co-60	S,E	10	0.5	0.06	0.07	0.83
				3.0	0.10	0.52	4.17
			25	0.5	0.03	0.27	1.38
				3.0	0.05	0.99	7.64
	Cs-137	S,E	10	0.5	0.05	0.07	0.11
				3.0	0.03	0.26	1.89
			25	0.5	0.10	0.11	0.79
				3.0	0.10	1.42	10.79
	Ir-192	S,E	10	0.5	0.05	0.06	0.09
				3.0	0.03	0.23	1.71
			25	0.5	0.11	0.11	0.69
				3.0	0.08	1.28	9.77

Table 4.4 The maximum plume dispersion distances for the material at risk of 100 Ci of each radionuclide at each potential site (continued)

	Radionuclide	Wind direction	Explosive (lb)	Wind speed (m/s)	Maximum plume dispersion distance (km)		
					1,000 mSv	250 mSv	5 mSv
Pattaya City site	Co-60	SSW,NE	10	0.5	0.06	0.07	0.82
				5.0	0.06	0.64	4.93
			25	0.5	0.11	0.54	4.18
				5.0	0.07	0.92	6.10
	Cs-137	SSW,NE	10	0.5	0.05	0.06	0.11
				5.0	0.03	0.15	1.29
			25	0.5	0.11	0.12	0.79
				5.0	0.08	0.92	6.92
	Ir-192	SSW,NE	10	0.5	0.05	0.06	0.09
				5.0	0.03	0.03	1.16
			25	0.5	0.11	0.12	0.70
				5.0	0.07	0.83	6.25

With the same radionuclide and high explosive, but different wind speed (low and high), the study found that maximum distances of the plume dispersion on the affected areas of high wind speed were greater than that of low wind speed. For example, for Co-60 with high explosive of 10 pounds and wind speed of 0.5 and 3.0 m/s, the study found that the maximum distance of the plume dispersion on the affected areas for the case wind speed of 3.0 m/s was greater than the case wind speed of 0.5 m/s. For the cases of Cs-137 and Ir-192, results exhibited the same trend.

In addition, with the same radionuclide and wind speed, but different explosives (lower explosives and higher explosives), the study found that maximum distances of the plume dispersion on the affected areas of higher explosives were greater than that of lower explosives. For example, for Co-60 with 0.5 m/s wind speed and explosives of 10 and 25 pounds, the study found that the maximum distance of the plume dispersion on the affected areas for the case explosive of 25 pounds was greater than the case explosive of 10 pounds. For the cases of Cs-137 and Ir-192, results exhibited the same trend.



Co-60

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.06	0.03	0.10	0.05
25 (Rem)	0.07	0.27	0.52	0.99
0.05 (Rem)	0.83	1.38	4.17	7.64

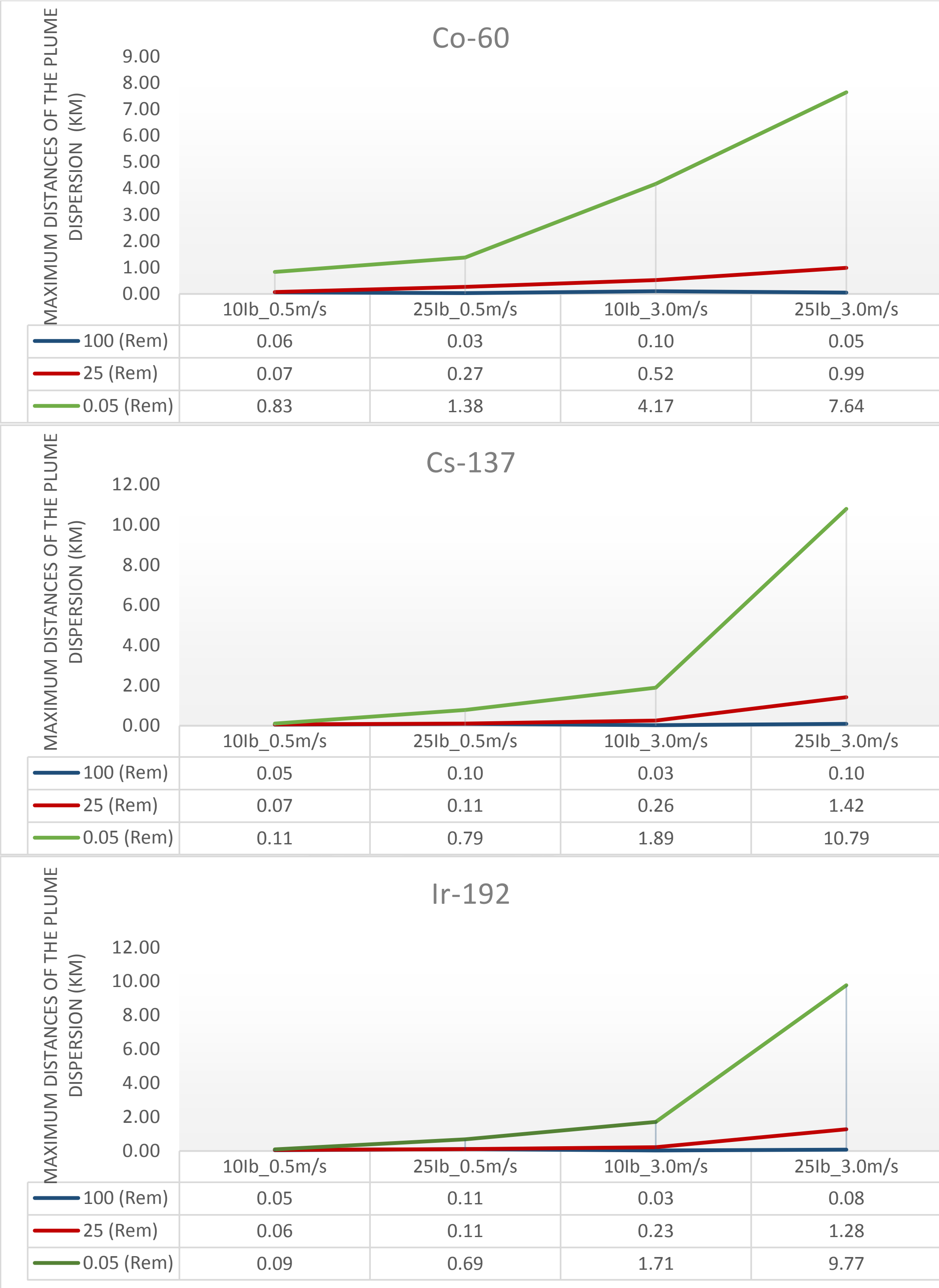
Cs-137

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.05	0.10	0.03	0.10
25 (Rem)	0.07	0.11	0.26	1.42
0.05 (Rem)	0.11	0.79	1.89	10.79

Ir-192

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.05	0.11	0.03	0.08
25 (Rem)	0.06	0.11	0.23	1.28
0.05 (Rem)	0.09	0.69	1.71	9.77

Figure 4.39 Comparison of maximum distances of the plume dispersion at the Victory Monument site for the three radionuclides between different explosives and different wind speed



Co-60

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.06	0.03	0.10	0.05
25 (Rem)	0.07	0.27	0.52	0.99
0.05 (Rem)	0.83	1.38	4.17	7.64

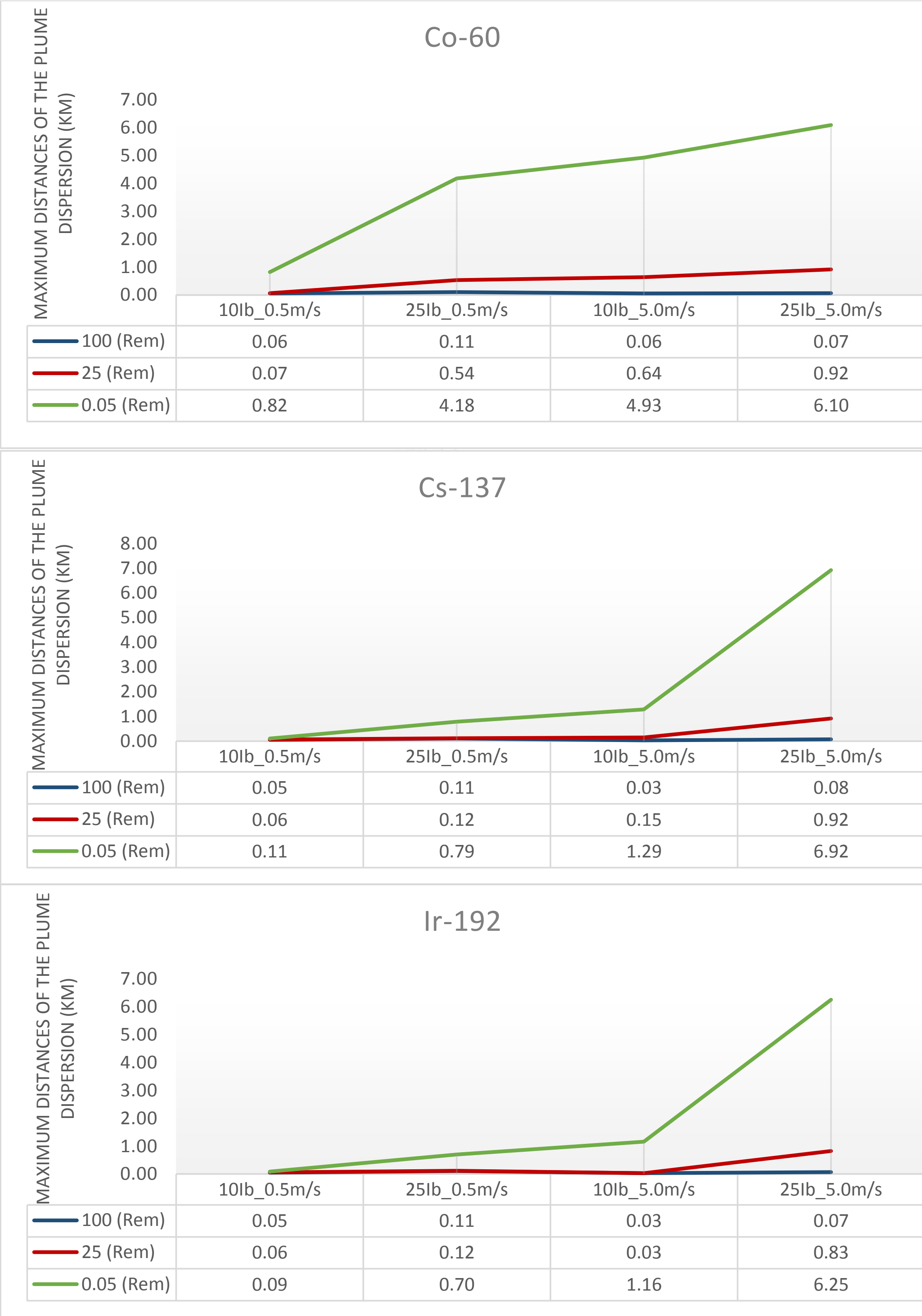
Cs-137

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.05	0.10	0.03	0.10
25 (Rem)	0.07	0.11	0.26	1.42
0.05 (Rem)	0.11	0.79	1.89	10.79

Ir-192

	10lb_0.5m/s	25lb_0.5m/s	10lb_3.0m/s	25lb_3.0m/s
100 (Rem)	0.05	0.11	0.03	0.08
25 (Rem)	0.06	0.11	0.23	1.28
0.05 (Rem)	0.09	0.69	1.71	9.77

Figure 4.40 Comparison of maximum distances of the plume dispersion at the Siam Square site for the three radionuclides between different explosives and different wind speed



Co-60

	10lb_0.5m/s	25lb_0.5m/s	10lb_5.0m/s	25lb_5.0m/s
100 (Rem)	0.06	0.11	0.06	0.07
25 (Rem)	0.07	0.54	0.64	0.92
0.05 (Rem)	0.82	4.18	4.93	6.10

Cs-137

	10lb_0.5m/s	25lb_0.5m/s	10lb_5.0m/s	25lb_5.0m/s
100 (Rem)	0.05	0.11	0.03	0.08
25 (Rem)	0.06	0.12	0.15	0.92
0.05 (Rem)	0.11	0.79	1.29	6.92

Ir-192

	10lb_0.5m/s	25lb_0.5m/s	10lb_5.0m/s	25lb_5.0m/s
100 (Rem)	0.05	0.11	0.03	0.07
25 (Rem)	0.06	0.12	0.03	0.83
0.05 (Rem)	0.09	0.70	1.16	6.25

Figure 4.41 Comparison of maximum distances of the plume dispersion at the Pattaya City site for the three radionuclides between different explosives and different wind speed

4.3 Total number of affected populations from explosions of radiological dispersion devices (RDDs) on affected areas

TEDE contour lines in the .kml file were converted into the .shp file in order to analyze the total number of affected populations in affected areas using ArcGIS Desktop 9.3 program. Instruction on how to use ArcGIS Desktop 9.3 is shown in Appendix B.

Results of total number of affected populations from explosions of radiological dispersion devices (RDDs) on affected areas at three potential site are as follows:

4.3.1 Victory Monument site

Three radionuclides (Co-60, Cs-137 and Ir-192), high explosives of 10 and 25 pounds and wind speed of 1 and 6 knots (0.5 and 3.0 m/s) blowing from S and E directions were analyzed. Table 4.5 shows the total number of population and sub-district names of the affected areas.

1) Co-60

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected population within TEDE contour lines of 1,000, 250 and 5 mSv were 142, 193 and 20,605 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected population within the TEDE contour lines of 1,000, 250 and 5 mSv were 375, 8,169 and 533,150 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected population within the TEDE contour line of 250 mSv were 432 and 666 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 35, 2,308 and 58,101 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 140 and 175 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 98, 29,428 and 1,426,827 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 1,600 and 2,362 persons, respectively.

2) Cs-137

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 98, 193 and 443 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 35, 2,150 and 109,771 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 131 and 166 persons, respectively.

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 375, 443 and 17,657 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 375, 61,685 and 2,358,498 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 3,223 and 5,000 persons, respectively.

3) Ir-192

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 98, 142 and 443 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 35, 1,708 and 90,454 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 109 and 128 persons, respectively.

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 443, 443 and 14,230 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 251, 38,301 and 2,035,472 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions. The total number of affected populations within the TEDE contour line of 250 mSv were 2,530 and 4,164 persons, respectively.

4.3.2 Siam Square site

Three radionuclides (Co-60, Cs-137 and Ir-192), high explosives of 10 and 25 pounds and wind speed of 1 and 6 knots (0.5 and 3.0 m/s) blowing from S and E directions were analyzed. Table 4.6 shows the total number of populations and sub-district names of the affected areas.

1) Co-60

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 34, 46 and 12,345 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 93, 3,226 and 491,014 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 414 and 225 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE clines of 1,000, 250 and 5 mSv were 8, 682 and 40,037 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 43 and 41 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 23, 18,611 and 1,454,286 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 1,898 and 1,083 persons, respectively.

2) Cs-137

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 23, 46 and 113 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 8, 632 and 91,780 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 39 and 40 persons, respectively.

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 93, 113 and 10,874 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 93, 43,664 and 2,386,129 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E of wind directions, the total number of affected populations within TEDE Contour Line of 250 mSv were 3,929 and 3,153 persons, respectively.

3) Ir-192

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 23, 34 and 76 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 8, 495 and 70,402 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 31 and 32 persons, respectively.

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the contour lines of 1,000, 250 and 5 mSv were 113, 113 and 7,578 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 3.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 60, 33,876 and 2,074,250 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 3,162 and 2,122 persons, respectively.

4.3.3 Pattaya City site

Three radionuclides (Co-60, Cs-137 and Ir-192), high explosive of 10 and 25 pounds and wind speed of 1 and 10 knots (0.5 and 5.0 m/s) blowing from SSW and NE directions were analyzed. Table 4.7 shows the total number of populations and sub-district names of the affected areas.

1) Co-60

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 9, 12 and 1,639 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Co-60, high explosive of 10 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 9, 998 and 43,637 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 62 and 62 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 29, 711 and 31,479 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 44 and 44 persons, respectively.

For the analyzed case of Co-60, high explosive of 25 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 12, 2,063 and 65,067 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 129 and 129 persons, respectively.

2) Cs-137

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 6, 9 and 29 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 10 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 2, 55 and 3,857 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 3 and 3 persons, respectively.

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 29, 35 and 1,521 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Cs-137, high explosive of 25 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 16, 2,063 and 80,330 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE Contour Line of 250 mSv were 129 and 129 persons, respectively.

3) Ir-192

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 6, 9 and 20 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 10 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 2, 40 and 3,129 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 3 and 3 persons, respectively.

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 0.5 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 29, 35 and 1,194 persons, respectively (for this case, the plume disperses outward equally in all directions).

For the analyzed case of Ir-192, high explosive of 25 pounds and wind speed of 5.0 m/s, the total number of affected populations within the TEDE contour lines of 1,000, 250 and 5 mSv were 12, 1,679 and 67,862 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the SSW and NE wind directions, the total number of affected populations within the TEDE contour line of 250 mSv were 105 and 105 persons, respectively.

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	424	THUNG PHAYA THAI	193	THUNG PHAYA THAI	142
			SAM SEN NAI	6,499				
			THUNG PHAYA THAI	9,183				
			THANON PHAYA THAI	3,957				
			MAKKASAN	543				
Total population				20,605		193		142
Co-60	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	106,654	SAM SEN NAI	2,223	THUNG PHAYA THAI	345
			THANON NAKON CHAISI	55,130	THUNG PHAYA THAI	4,016	THANON PHAYA THAI	30
			SAM SEN NAI	72,203	THANON PHAYA THAI	1,930		
			HUAI KHWANG	8,788				
			WACHIRA PHAYABAN	9,785				
			DUSIT	15,747				
			SUAN CHIT LADA	9,881				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	974				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,007				
			THANON PHAYA THAI	9,231				
			BANG KA PI	2,543				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			TALAT YOT	10				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	3,658				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			BAN BAT	7,502				
			SAOCHINGCHA	303				
			SAMRAN RAT	2,572				
			RONG MUEANG	18,338				
			WAT THEPSIRIN	7,667				
			PATHUMWAN	6,256				
			WANG MAI	8,128				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			LUM PHINI	16,533				
			KHLONG TOEI NUEA	7,877				
			WANG BURAPHA PHIROM	2				
			POM PRAP	16,330				
			KHLONG TAN NUEA	181				
			SAM PHAN THA WONG	4,682				
			CHAKKAWAT	45				
			KHLONG TOEI	9,186				
			TALAT NOI	2,214				
			MAHAPHRUETTHARAM	9,801				
			SI PHRAYA	4,614				
			SURIYAWONG	1,395				
			SI ROM	1,277				
			CHOMPHON	1,679				
			CHATUCHAK	2,866				
			BANG SUE	6,861				
Total population				533,150		8,169		375
Population from E Direction						666		
Population from S Direction						432		
Cs-137	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THUNG PHAYA THAI	392	THUNG PHAYA THAI	193	THUNG PHAYA THAI	98
			THANON PHAYA THAI	51				
Total population				443		193		98
Cs-137	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	17,417	SAM SEN NAI	300	THUNG PHAYA THAI	35
			THANON NAKON CHAISI	1,357	THUNG PHAYA THAI	1,309		
			SAM SEN NAI	29,617	THANON PHAYA THAI	541		
			SUAN CHIT LADA	3,545				
			THUNG PHAYA THAI	31,198				
			THANON PHAYA THAI	9,231				
			MAKKASAN	8,348				
			THANON PHET BURI	8,479				
			PATHUMWAN	421				
			LUM PHINI	158				
Total population				109,771		2,150		35
Population from E Direction						166		
Population from S Direction						131		

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THUNG PHAYA THAI	298	THUNG PHAYA THAI	142	THUNG PHAYA THAI	98
			THANON PHAYA THAI	13				
Total population				311		142		98
Ir-192	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	12,275	SAM SEN NAI	181	THUNG PHAYA THAI	35
			THANON NAKON CHAISI	353	THUNG PHAYA THAI	1,097		
			SAM SEN NAI	25,463	THANON PHAYA THAI	430		
			SUAN CHIT LADA	1,751				
			THUNG PHAYA THAI	29,925				
			THANON PHAYA THAI	9,231				
			MAKKASAN	6,569				
			THANON PHET BURI	4,870				
			PATHUMWAN	17				
Total population				90,454		1,708		35
Population from E Direction						128		
Population from S Direction						109		
Co-60	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	5,254	SAM SEN NAI	343	THUNG PHAYA THAI	35
			SAM SEN NAI	17,760	THUNG PHAYA THAI	1,385		
			THUNG PHAYA THAI	23,347	THANON PHAYA THAI	580		
			THANON PHAYA THAI	8,243				
			MAKKASAN	3,497				
Total population				58,101		2,308		35
Population from E Direction						175		
Population from S Direction						140		

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG SUE	23,478	DIN DAENG	1,182	THUNG PHAYA THAI	98
			LAT PHRAO	4,317	SAM SEN NAI	9,350		
			BANG O	26,007	THUNG PHAYA THAI	12,682		
			SAM SEN NOK	39,055	THANON PHAYA THAI	5,094		
			WANG THONG LANG	12,548	MAKKASAN	1,120		
			DIN DAENG	127,260				
			THANON NAKON CHAISI	58,759				
			BANG PHLAT	24,123				
			SAM SEN NAI	72,203				
			HUAI KHWANG	24,005				
			BANG BAM RU	18,867				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				
			DUSIT	15,747				
			SUAN CHIT LADA	9,881				
			HUA MAK	1,363				
			BANG KHUN SI	3,575				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,124				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	3,168				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	46,949				
			KHLONG TOEI	60,970				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				
			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				
			SI PHRAYA	11,392				
			BANGRAK	3,099				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				
			PHRA KHANONG NUEA	7,014				
			BANG YI RUEA	15,369				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	7,873				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	24,941				
			BUKKHALO	3,259				
			CHONG NONSRI	25,388				
			THUNG WAT DON	40,660				
			WAT PHRAYAKRAI	20,007				
			BANG KHO LAEM	540				
			LAT YAO	1,370				
			CHANTHARAKASEM	18,547				
			CHOMPHON	30,886				
			CHATUCHAK	25,065				
			WANG THONG LANG	24,860				
			SA PAN SONG	7,223				
			BUKKHALO	1,803				
			BANG SUE	84,008				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			SAMUT PRAKAN					
			BANG KA CHAO	1,582				
Total population				1,426,827		29,428		98
Population from E Direction						2,362		
Population from S Direction						1,600		
Cs-137	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	230	THUNG PHAYA THAI	392	THUNG PHAYA THAI	345
			SAM SEN NAI	5,523	THANON PHAYA THAI	51	THANON PHAYA THAI	30
			THUNG PHAYA THAI	7,986				
			THANON PHAYA THAI	3,548				
			MAKKASAN	370				
Total population				17,657		443		375
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG SUE	44,987	DIN DAENG	6,084	THUNG PHAYA THAI	345
			CHORA KHE BUA	10,312	SAM SEN NAI	18,541	THANON PHAYA THAI	30
			LAT PHRAO	72,421	THUNG PHAYA THAI	24,800		
			KHLONG CHUN	35,576	THANON PHAYA THAI	8,467		
			BANG O	26,007	MAKKASAN	3,793		
			SAM SEN NOK	39,055				
			WANG THONG LANG	45,388				
			DIN DAENG	127,260				
			CHIMPHLI	4,760				
			THANON NAKON CHAISI	58,759				
			TALING CHAN	20,426				
			BANG PHLAT	25,133				
			SAM SEN NAI	72,203				
			HUAI KHWANG	24,005				
			BANG BAM RU	19,363				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				
			DUSIT	15,747				
			KHLONG CHAK PHRA	10,848				
			BANG RA MAT	4,964				
			SUAN CHIT LADA	9,881				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			HUA MAK	24,226				
			BANG KHUN SI	34,264				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,364				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			BANG PHROM	8,483				
			BANG CHUEAK NANG	1,934				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	60,258				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	52,147				
			BANG WAEK	10,020				
			KHLONG TOEI	71,441				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				
			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				
			BANG CHAK	8,267				
			SI PHRAYA	11,392				
			BANG DUAN	1,236				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			BANGRAK	3,099				
			PAK KHLONG PHASI CHAROEN	15,765				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				
			PHRA KHANONG NUEA	22,764				
			BANG YI RUEA	22,874				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	24,131				
			BANGWA	5,198				
			TALAT PHLU	17,352				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	25,885				
			BUKKHALO	17,509				
			CHONG NONSRI	49,516				
			THUNG WAT DON	40,660				
			BANG KHO	35,614				
			WAT PHRAYAKRAI	27,898				
			BANG KHUN THIAN	1,343				
			BANG CHAK	31,061				
			BANG KHO LAEM	25,582				
			CHOM THONG	10,806				
			BANG PHONG PHANG	31,327				
			BANG PAKOK	21,425				
			BANG MOT	526				
			RAT BURANA	16,778				
			BANGNA	260				
			LAT YAO	41,666				
			SENA NIKHOM	18,229				
			CHANTHARAKASEM	39,181				
			CHOMPHON	30,886				
			CHATUCHAK	25,065				
			WANG THONG LANG	25,941				
			SA PAN SONG	12,749				
			DOA KA NONG	18,102				
			BUKKHALO	17,509				
			BANG SUE	84,008				
			NONTHABURI					
			BANG KRA SO	3,364				
			BANG KHEN	35,571				
			TALAT KHAN	41,450				
			BANG SI MUEANG	11,845				
			BANG SI THONG	9,924				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			BANG KHUN KONG	633				
			BANG KHA NUN	4,857				
			BANG KRUAI	27,453				
			WAT CHALO	14,405				
			SAMUT PRAKAN					
			BANG KA CHAO	5,173				
			BANG KO BUA	7,212				
			BANG NAM PHUENG	3,611				
			BANG YO	10,854				
			BANG PHUENG	5,098				
			BANG KRA SOP	392				
			SONG KHANONG	815				
Total population				2,358,498		61,685		375
Population from E Direction						5,000		
Population from S Direction						3,223		
Ir-192	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	67	THUNG PHAYA THAI	392	THUNG PHAYA THAI	392
			SAM SEN NAI	4,362	THANON PHAYA THAI	51	THANON PHAYA THAI	51
			THUNG PHAYA THAI	6,583				
			THANON PHAYA THAI	3,028				
			MAKKASAN	190				
Total population				14,230		443		443
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG SUE	43,815	DIN DAENG	3,915	THUNG PHAYA THAI	249
			CHORA KHE BUA	113	SAM SEN NAI	3,915	THANON PHAYA THAI	2
			LAT PHRAO	56,410	THUNG PHAYA THAI	20,416		
			KHLONG CHUN	2,053	THANON PHAYA THAI	7,336		
			BANG O	26,007	MAKKASAN	2,719		
			SAM SEN NOK	39,055				
			WANG THONG LANG	44,428				
			DIN DAENG	127,260				
			CHIMPHLI	1,260				
			THANON NAKON CHAISI	58,759				
			TALING CHAN	13,656				
			BANG PHLAT	25,133				
			SAM SEN NAI	72,203				
			HUAI KHWANG	24,005				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			BANG BAM RU	19,363				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				
			DUSIT	15,747				
			KHLONG CHAK PHRA	10,848				
			BANG RA MAT	1,361				
			SUAN CHIT LADA	9,881				
			HUA MAK	17,185				
			BANG KHUN SI	34,264				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,364				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			BANG PHROM	4,998				
			BANG CHUEAK NANG	335				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	33,757				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	52,147				
			BANG WAEK	3,856				
			KHLONG TOEI	71,441				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				
			BANG CHAK	1,342				
			SI PHRAYA	11,392				
			BANGRAK	3,099				
			PAK KHLONG PHASI CHAROEN	12,022				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				
			PHRA KHANONG NUEA	22,764				
			BANG YI RUEA	22,874				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	24,131				
			TALAT PHLU	17,352				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	25,885				
			BUKKHALO	17,509				
			CHONG NONSRI	49,328				
			THUNG WAT DON	40,660				
			BANG KHO	12,424				
			WAT PHRAYAKRAI	27,898				
			BANG CHAK	7,925				
			BANG KHO LAEM	25,582				
			BANG PHONG PHANG	21,226				
			BANG PAKOK	4,262				
			RAT BURANA	4,345				
			LAT YAO	29,190				
			SENA NIKHOM	9,870				
			CHANTHARAKASEM	39,181				
			CHOMPHON	30,886				
			CHATUCHAK	25,065				
			WANG THONG LANG	25,941				
			SA PAN SONG	12,749				
			DOA KA NONG	17,909				
			BUKKHALO	17,509				
			BANG SUE	84,008				
			NONTHABURI					
			BANG KHEN	25,578				
			TALAT KHAN	22,017				
			BANG SI MUEANG	1,797				
			BANG SI THONG	8,279				
			BANG KHA NUN	713				
			BANG KRUAI	27,453				
			WAT CHALO	14,226				

Table 4.5 Total number of population and sub-district names of affected areas at Victory Monument site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			SAMUT PRAKAN					
			BANG KA CHAO	5,173				
			BANG KO BUA	7,209				
			BANG NAM PHUENG	255				
			BANG YO	4,723				
			BANG PHUENG	12				
Total population				2,035,472		38,301		251
Population from E Direction						4,164		
Population from S Direction						2,530		

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THANON PHAYA THAI	530	PATHUMWAN	46	PATHUMWAN	34
			THANON PHET BURI	5,154				
			PATHUMWAN	3,764				
			WANG MAI	2,129				
			LUM PHINI	768				
Total Population				12,345		46		34
Co-60	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			DIN DAENG	52,769	ANON PHET BU	670	PATHUMWAN	93
			HUAI KHWANG	2,193				
			DUSIT	11,695				
			SUAN CHIT LADA	9,881				
			THUNG PHAYA THAI	31,586				
			BANG KHUN PHROM	4,526				
			BAN PHAN THOM	6,046				
			THANON PHAYA THAI	9,231				
			BANG KA PI	2,224				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			TALAT YOT	488				
			BOROM MAHARATCHAV	89				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,002				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	2,084				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,543				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	5,218				
			KHLONG TOEI	30,843				
			KHLONG SAN	15,120				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			MAHAPHRUETTHARAM	12,413				
			SOMDET CHAO PHRAYA	6,861				
			KHLONG TAN	1,985				
			SI PHRAYA	11,392				
			BANGRAK	3,099				
			KHLONG TON SAI	11,606				
			SI ROM	14,244				
			THUNG MAHAMEK	17,757				
			YAN NAWA	13,314				
			BANG LAM PHU LANG	1,767				
			CHONG NONSRI	5,192				
			THUNG WAT DON	21,247				
Total population				491,014		3,226		93
Population from E Direction						225		
Population from S Direction						414		
Cs-137	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			PATHUMWAN	113	PATHUMWAN	46	PATHUMWAN	23
Total Population				113		46		23
Cs-137	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THUNG PHAYA THAI	12,071	PATHUMWAN	632	PATHUMWAN	8
			THANON PHAYA THAI	7,842				
			MAKKASAN	6,731				
			SI YEAK MAHANAK	245				
			THANON PHET BURI	15,220				
			RONG MUEANG	14,433				
			PATHUMWAN	6,256				
			WANG MAI	8,128				
			LUM PHINI	12,402				
			KHLONG TOEI NUEA	379				
			KHLONG TOEI	150				
			MAHAPHRUETTHARAM	3,668				
			SI PHRAYA	3,084				
			SURIYAWONG	956				
			SI ROM	215				
Total population				91,780		632		8
Population from E Direction						40		
Population from S Direction						39		

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			PATHUMWAN	76	PATHUMWAN	34	PATHUMWAN	23
Total Population				76		34		23
Ir-192	10	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THUNG PHAYA THAI	8,210	PATHUMWAN	495	PATHUMWAN	8
			THANON PHAYA THAI	6,897				
			MAKKASAN	4,669				
			THANON PHET BURI	13,892				
			RONG MUEANG	9,355				
			PATHUMWAN	6,237				
			WANG MAI	8,094				
			LUM PHINI	10,157				
			MAHAPHRUETTHARAM	1,391				
			SI PHRAYA	1,399				
			SURIYAWONG	101				
Total population				70,402		495		8
Population from E Direction						32		
Population from S Direction						31		
Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THUNG PHAYA THAI	3026	PATHUMWAN	682	PATHUMWAN	8
			THANON PHAYA THAI	4800				
			MAKKASAN	1802				
			THANON PHET BURI	10803				
			RONG MUEANG	1943				
			PATHUMWAN	5554				
			WANG MAI	6559				
			LUM PHINI	5550				
Total population				40,037		682		8
Population from E Direction						41		
Population from S Direction						43		

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG O	25,830	THUNG PHAYA THAI	128	PATHUMWAN	23
			SAM SEN NOK	31,352	THANON PHAYA THAI	1,844		
			WANG THONG LANG	4,733	MAKKASAN	165		
			DIN DAENG	127,260	THANON PHET BURI	6,846		
			THANON NAKON CHAISI	58,759	PATHUMWAN	4,298		
			BANG PHLAT	21,994	WANG MAI	3,410		
			SAM SEN NAI	72,203	LUM PHINI	1,920		
			HUAI KHWANG	24,005				
			BANG BAM RU	15,030				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				
			DUSIT	15,747				
			SUAN CHIT LADA	9,881				
			HUA MAK	515				
			BANG KHUN SI	13,103				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,364				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	3,191				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			POM PRAP	16,330				
			KHLONG TAN NUEA	50,393				
			KHLONG TOEI	71,441				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				
			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				
			SI PHRAYA	11,392				
			BANGRAK	3,099				
			PAK KHLONG PHASI CHAROEN	1,573				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				
			PHRA KHANONG NUEA	14,097				
			BANG YI RUEA	22,874				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	18,189				
			TALAT PHLU	14,099				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	25,885				
			BUKKHALO	17,509				
			CHONG NONSRI	49,104				
			THUNG WAT DON	40,660				
			BANG KHO	1,650				
			WAT PHRAYAKRAI	27,898				
			BANG CHAK	43				
			BANG KHO LAEM	25,582				
			BANG PHONG PHANG	21,355				
			BANG PAKOK	2,609				
			RAT BURANA	4,830				
			CHANTHARAKASEM	53				
			CHOMPHON	14,635				
			CHATUCHAK	10,322				
			WANG THONG LANG	7,260				
			DOA KA NONG	15,313				
			BUKKHALO	17,509				
			BANG SUE	55,432				
			NONTHABURI					
			BANG KRUAI	7,847				
			WAT CHALO	421				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			SAMUT PRAKAN					
			BANG KA CHAO	5,171				
			BANG KO BUA	4,645				
			BANG YO	3,370				
			BANG PHUENG	54				
Total population				1,454,286		18,611		23
Population from E Direction						1,083		
Population from S Direction						1,898		
Cs-137	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THANON PHAYA THAI	278	PATHUMWAN	113	PATHUMWAN	93
			THANON PHET BURI	4,635				
			PATHUMWAN	3,617				
			WANG MAI	1,827				
			LUM PHINI	517				
Total Population				10,874		113		93
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG SUE	35,076	THUNG PHAYA THAI	3,515	PATHUMWAN	93
			LAT PHRAO	35,918	THANON PHAYA THAI	5,073		
			KHLONG CHUN	1,966	MAKKASAN	2,156		
			BANG O	26,007	THANON PHET BURI	11,295		
			SAM SEN NOK	39,055	RONG MUEANG	2,904		
			WANG THONG LANG	45,388	PATHUMWAN	5,666		
			DIN DAENG	127,260	WANG MAI	6,879		
			CHIMPHLI	4,139	LUM PHINI	6,176		
			THANON NAKON CHAISI	58,759				
			TALING CHAN	17,784				
			BANG PHLAT	25,133				
			SAM SEN NAI	72,203				
			HUAI KHWANG	24,005				
			BANG BAM RU	19,363				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				
			DUSIT	15,747				
			KHLONG CHAK PHRA	10,848				
			BANG RA MAT	5,670				
			SUAN CHIT LADA	9,881				
			HUA MAK	21,245				
			BANG KHUN SI	34,264				
			THUNG PHAYA THAI	31,586				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,364				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			BANG PHROM	9,847				
			BANG CHUEAK NANG	3,435				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	66,291				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	52,147				
			BANG WAEK	16,178				
			KHLONG TOEI	71,441				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				
			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				
			BANG CHAK	8,271				
			SI PHRAYA	11,392				
			BANG DUAN	12,966				
			BANGRAK	3,099				
			PAK KHLONG PHASI CHAROEN	15,765				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			PHRA KHANONG NUEA	22,764				
			BANG YI RUEA	22,874				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	24,131				
			BANGWA	16,885				
			TALAT PHLU	17,352				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	25,885				
			BUKKHALO	17,509				
			CHONG NONSRI	49,516				
			THUNG WAT DON	40,660				
			BANG KHO	35,829				
			WAT PHRAYAKRAI	27,898				
			BANG KHUN THIAN	20,215				
			BANG CHAK	56,222				
			BANG KHO LAEM	25,582				
			CHOM THONG	29,938				
			BANG PHONG PHANG	31,327				
			BANG PAKOK	48,200				
			BANG MOT	20,527				
			RAT BURANA	34,074				
			BANGNA	18,124				
			BANG MOT	9,636				
			LAT YAO	14,196				
			SENA NIKHOM	362				
			CHANTHARAKASEM	35,624				
			CHOMPHON	30,886				
			CHATUCHAK	25,065				
			WANG THONG LANG	25,941				
			SA PAN SONG	12,749				
			DOA KA NONG	18,102				
			BUKKHALO	17,509				
			BANG SUE	84,008				
			NONTHABURI					
			BANG KHEN	16,347				
			TALAT KHAN	2,845				
			BANG SI MUEANG	535				
			BANG SI THONG	7,171				
			BANG KHA NUN	739				
			BANG KRUAI	27,453				
			WAT CHALO	14,405				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Cs-137	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			SAMUT PRAKAN					
			BANG KA CHAO	5,173				
			BANG KO BUA	7,212				
			BANG NAM PHUENG	4,877				
			BANG YO	11,169				
			BANG PHUENG	22,157				
			BANG KRA SOP	2,839				
			SONG KHANONG	7,989				
			SAMRONG	6,555				
			TALAT	10,190				
			BANG YA PHRAEK	9,848				
			SAMRONG KLUANG	3,872				
			BANG KHRU	251				
Total population				2,386,129		43,664		93
Population from E Direction						3,153		
Population from S Direction						3,929		
Ir-192	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			THANON PHET BURI	3,079	PATHUMWAN	113	PATHUMWAN	113
			PATHUMWAN	3,206				
			WANG MAI	1,195				
			LUM PHINI	98				
Total population				7,578		113		113
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			BANGKOK					
			BANG SUE	23,540	THUNG PHAYA THAI	1,933	PATHUMWAN	60
			LAT PHRAO	11,227	THANON PHAYA THAI	4,083		
			BANG O	26,007	MAKKASAN	1,288		
			SAM SEN NOK	39,055	THANON PHET BURI	9,930		
			WANG THONG LANG	34,954	RONG MUEANG	875		
			DIN DAENG	127,260	PATHUMWAN	5,234		
			CHIMPHLI	965	WANG MAI	5,950		
			THANON NAKON CHAISI	58,759	LUM PHINI	4,583		
			TALING CHAN	9,749				
			BANG PHLAT	25,133				
			SAM SEN NAI	72,203				
			HUAI KHWANG	24,005				
			BANG BAM RU	19,363				
			WACHIRA PHAYABAN	12,071				
			BANG YI KHAN	26,284				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			DUSIT	15,747				
			KHLONG CHAK PHRA	10,848				
			BANG RA MAT	1,973				
			SUAN CHIT LADA	9,881				
			HUA MAK	14,174				
			BANG KHUN SI	34,264				
			THUNG PHAYA THAI	31,586				
			WAT SAMPHRAYA	3,086				
			BANG KHUN PHROM	5,029				
			BAN PHAN THOM	7,371				
			THANON PHAYA THAI	9,231				
			SIRIRAT	17,081				
			CHANASONGKHRAM	2,114				
			BANG KA PI	16,942				
			WAT SOMMANAT	7,524				
			MAKKASAN	17,673				
			BAN CHANG LO	34,364				
			TALAT YOT	2,763				
			PHRA BOROM MAHARATCHAWANG	4,422				
			SI YEAK MAHANAK	7,936				
			BOWONNIWET	5,465				
			BANG PHROM	6,889				
			BANG CHUEAK NANG	1,272				
			THANON PHET BURI	15,300				
			KHLONG MA HA NAK	10,182				
			SANCHAO PHOSUEA	3,459				
			BAN BAT	7,577				
			SAOCHINGCHA	2,497				
			RONG MUEANG	18,338				
			WAT RATCHA BOPHIT	3,544				
			SUAN LUANG	41,476				
			PATHUMWAN	6,256				
			LUM PHINI	18,835				
			KHLONG TOEI NUEA	8,609				
			POM PRAP	16,330				
			KHLONG TAN NUEA	52,147				
			BANG WAEK	8,904				
			KHLONG TOEI	71,441				
			KHLONG SAN	15,635				
			MAHAPHRUETTHARAM	12,413				
			HIRANRUCHI	13,083				
			SOMDET CHAO PHRAYA	14,458				
			KHLONG TAN	11,649				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			BANG CHAK	8,245				
			SI PHRAYA	11,392				
			BANG DUAN	1,531				
			BANGRAK	3,099				
			PAK KHLONG PHASI CHAROEN	15,765				
			KHLONG TON SAI	19,246				
			SI ROM	14,244				
			PHRA KHANONG NUEA	22,764				
			BANG YI RUEA	22,874				
			THUNG MAHAMEK	20,013				
			PHRA KHANONG	24,131				
			BANGWA	7,779				
			TALAT PHLU	17,352				
			YAN NAWA	21,759				
			BANG LAM PHU LANG	25,885				
			BUKKHALO	17,509				
			CHONG NONSRI	49,516				
			THUNG WAT DON	40,660				
			BANG KHO	35,829				
			WAT PHRAYAKRAI	27,898				
			BANG KHUN THIAN	6,551				
			BANG CHAK	33,706				
			BANG KHO LAEM	25,582				
			CHOM THONG	23,358				
			BANG PHONG PHANG	31,327				
			BANG PAKOK	35,249				
			BANG MOT	6,391				
			RAT BURANA	29,909				
			BANGNA	4,022				
			BANG MOT	529				
			LAT YAO	992				
			CHANTHARAKASEM	20,367				
			CHOMPHON	30,886				
			CHATUCHAK	25,003				
			WANG THONG LANG	25,941				
			SA PAN SONG	12,365				
			DOA KA NONG	18,102				
			BUKKHALO	17,509				
			BANG SUE	84,008				

Table 4.6 Total number of population and sub-district names of affected areas at Siam Square site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	3.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District (continued)			NONTHABURI					
			BANG KHEN	3,896				
			TALAT KHAN	150				
			BANG SI THONG	2,968				
			BANG KRUAI	27,453				
			WAT CHALO	10,803				
			SAMUT PRAKAN					
			BANG KA CHAO	5,173				
			BANG KO BUA	7,212				
			BANG NAM PHUENG	4,848				
			BANG YO	11,169				
			BANG PHUENG	15,063				
			BANG KRA SOP	1,772				
			SONG KHANONG	7,240				
			TALAT	5,463				
			BANG YA PHRAEK	1,409				
Total population				2,074,250		33,876		60
Population from E Direction						2,122		
Population from S Direction						3,162		

Table 4.7 Total number of population and sub-district names of affected areas at Pattaya City site

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	1,639	NAKUEA	12	NAKUEA	9
Total Population				1,639		12		9
Co-60	10	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NONG PLA LAI	617	NAKUEA	998	NAKUEA	9
			NAKUEA	23,501				
			NONG PRUE	19,519				
Total Population				43,637		998		9
Population from SSW Direction						62		
Population from NE Direction						62		
Cs-137	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	29	NAKUEA	9	NAKUEA	6
Total Population				29		9		6
Cs-137	10	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	3,857	NAKUEA	55	NAKUEA	2
Total Population				3,857		55		2
Population from SSW Direction						3		
Population from NE Direction						3		
Ir-192	10	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	20	NAKUEA	9	NAKUEA	6
Total Population				20		9		6
Ir-192	10	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	3,129	NAKUEA	40	NAKUEA	2
Total Population				3,129		40		2
Population from SSW Direction						3		
Population from NE Direction						3		

Table 4.7 Total number of population and sub-district names of affected areas at Pattaya City site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Co-60	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NONG PLA LAI	121	NAKUEA	711	NAKUEA	29
			NAKUEA	19,514				
			NONG PRUE	11,844				
Total Population				31,479		711		29
Population from SSW Direction						44		
Population from NE Direction						44		
Co-60	25	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NONG PLA LAI	2,621	NAKUEA	2,063	NAKUEA	12
			NAKUEA	29,139				
			NONG PRUE	33,307				
Total Population				65,067		2,063		12
Population from SSW Direction						129		
Population from NE Direction						129		
Cs-137	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	1,521	NAKUEA	35	NAKUEA	29
Total Population				1,521		35		29
Cs-137	25	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			BANG LA MUNG	125	NAKUEA	2,063	NAKUEA	16
			NONG PLA LAI	4,845				
			NAKUEA	32,075				
			NONG PRUE	43,284				
Total Population				80,329		2,063		16
Population from SSW Direction						129		
Population from NE Direction						129		

Table 4.7 Total number of population and sub-district names of affected areas at Pattaya City site (continued)

Radionuclide	Explosive (lb)	Wind speed (m/s)	Total of affected populations from RDD explosions					
Ir-192	25	0.5	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NAKUEA	1,194	NAKUEA	35	NAKUEA	29
Total Population				1,194		35		29
Ir-192	25	5.0	Sub Distric	5 mSv	Sub Distric	250 mSv	Sub Distric	1,000 mSv
Population of Sub District			CHON BURI					
			NONG PLA LAI	3,006	NAKUEA	1,679	NAKUEA	12
			NAKUEA	29,783				
			NONG PRUE	35,073				
Total Population				67,862		1,679		12
Population from SSW Direction						105		
Population from NE Direction						105		

CHAPTER 5
Conclusion

5.1 Discussion

5.1.1 Preliminary evaluation of TEDE at potential sites were performed for hypothetical explosions of RDDs

The results of this research indicate the amount of doses which are compared with the reference dose rate of The International Commission on Radiological Protection (ICRP) which adapted suitable Total Effective Dose Equivalent (TEDE) levels that may be received by the population as a result of acute radiation exposure from hypothetical explosions of RDDs. For this research, preliminary evaluation of TEDE doses of 1,000, 250 and 5 mSv at potential sites were performed for hypothetical explosions of RDDs using Hotspot program to provide contour lines corresponding to specified radiation dose levels (1,000, 250 and 5 mSv TEDE). The .kml output files can be directly displayed on Google Earth for visual presentation of the three affected distances. ArcTools (ArcGIS Desktop 9.3) was used to convert .kml file to .shp file in order to analyze further. Maximum distances of the plume dispersions, total number of populations and sub-district names of affected areas from explosions of radiological dispersion devices (RDDs) on affected areas were analyzed by ArcGIS Desktop 9.3. The benefit of this analysis is the subsequent emergency response plans that can be prepared and offered in order to mitigate and control the hypothetical situations.

From results are shown in Tables 4.1- 4.3, the maximum of Total Effective Dose Equivalent (TEDE) was analyzed by HotSpot program at various materials at risks. The results revealed that high material at risk resulted of TEDE were greater than low material at risk in case all radiation exposure time.

5.1.2 Maximum distances of the plume dispersion from explosions of radiological dispersion devices (RDDs) on affected areas

From the results presented in Figures 4.39 - 4.41, high wind resulted in greater affected distances. The same trend was observed for the case of explosives – higher explosives resulted in greater affected distances than lower explosives. These findings correspond with expectations as faster wind will blow radioactive materials to a greater distance and as higher explosives mean more radioactive materials being dispersed at the beginning of the postulated RDD explosion.

5.1.3 Total number of affected populations from explosions of radiological dispersion devices (RDDs) on affected areas

For this research, three potential sites (Victory Monument, Siam Square and Pattaya city) were representative of the areas for hypothetical explosions of RDDs. These areas are very prime for acts of terrorism because they have high population density and are the centers for tourists, transport hub, community, business and etc.

Table 5.1 Total number of affected population within TEDE of 250 mSv for the Victory Monument site

	Radionuclide	Wind direction	Explosive (lb)	Wind speed (m/s)	Affected population within TEDE of 250 mSv (persons)		
					Worse Case	S	E
Victory Monument site	Co-60	S,E	10	0.5	193	-	-
				3.0	8,169	432	666
			25	0.5	2,308	140	175
				3.0	29,428	1,600	2,362
	Cs-137	S,E	10	0.5	193	-	-
				3.0	2,150	131	166
			25	0.5	443	-	-
				3.0	61,685	3,223	5,000
	Ir-192	S,E	10	0.5	142	-	-
				3.0	1,708	109	128
			25	0.5	443	-	-
				3.0	38,301	2,530	4,164

Table 5.2 Total number of affected population within TEDE of 250 mSv for the Siam Square site

Site	Radionuclide	Wind direction	Explosive (lb)	Wind speed (m/s)	Affected population within TEDE of 250 mSv (persons)		
					Worse Case	S	E
Siam Square site	Co-60	S,E	10	0.5	46	-	-
				3.0	3,226	414	225
			25	0.5	682	43	41
				3.0	18,611	1,898	1,083
	Cs-137	S,E	10	0.5	46	-	-
				3.0	632	39	40
			25	0.5	113	-	-
				3.0	43,664	3,929	3,153
	Ir-192	S,E	10	0.5	34	-	-
				3.0	495	31	32
			25	0.5	113	-	-
				3.0	33,876	3,162	2,122

Table 5.3 Total number of affected population within TEDE of 250 mSv for the Pattaya City site

Site	Radionuclide	Wind direction	Explosive (lb)	Wind speed (m/s)	Affected population within TEDE of 250 mSv (persons)		
					Worse Case	SSW	NE
Pattaya City site	Co-60	SSW,NE	10	0.5	12	-	-
				5.0	998	62	62
			25	0.5	711	44	44
				5.0	2,063	129	129
	Cs-137	SSW,NE	10	0.5	9	-	-
				5.0	55	3	3
			25	0.5	35	-	-
				5.0	2,063	129	129
	Ir-192	SSW,NE	10	0.5	9	-	-
				5.0	40	3	3
			25	0.5	35	-	-
				5.0	1,679	105	105

For example, in the case of Victory Monument, if a hypothetical explosion of RDD occurred with the explosive of 10 pounds (4.5 kg) with 100 Ci Ir-192 and the assumed wind speed of 6 knots (3.0 m/s) blowing from S and E direction, results analyzed by HotSpot and ArcGIS Desktop 9.3 are shown in Figures 5.1-5.3.

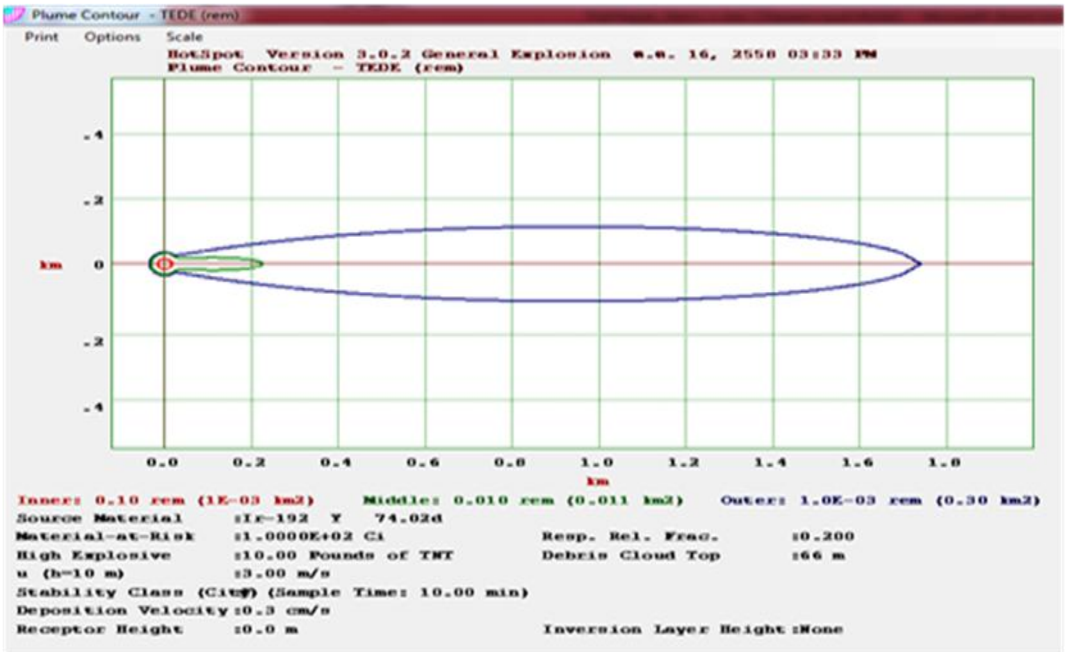


Figure 5.1 TEDE contour plot in HotSpot Program

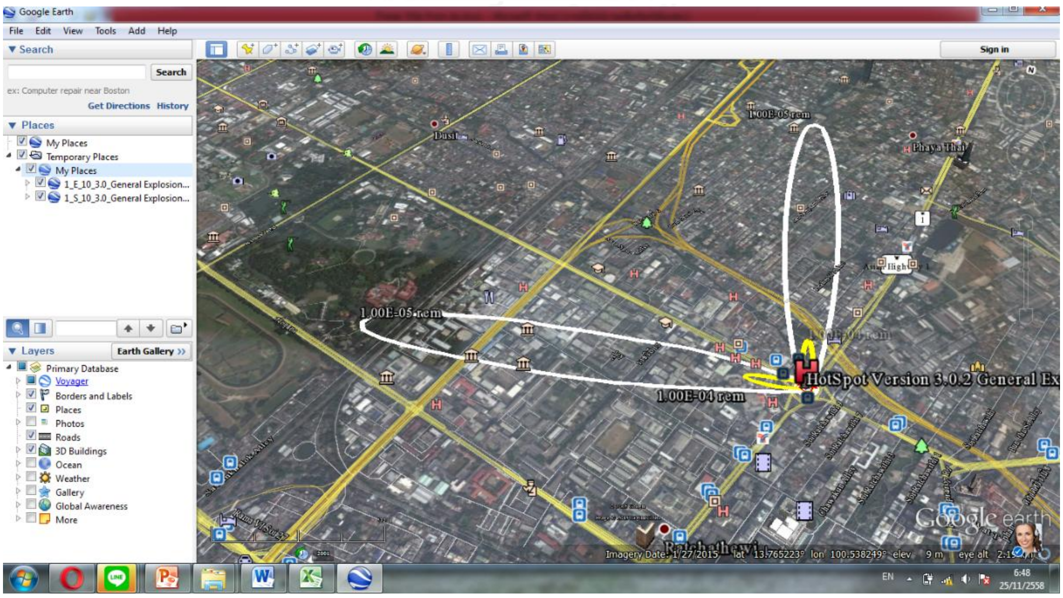


Figure 5.2 TEDE contour lines corresponding to specified radiation dose levels. The .kml output file is displayed on Google Earth

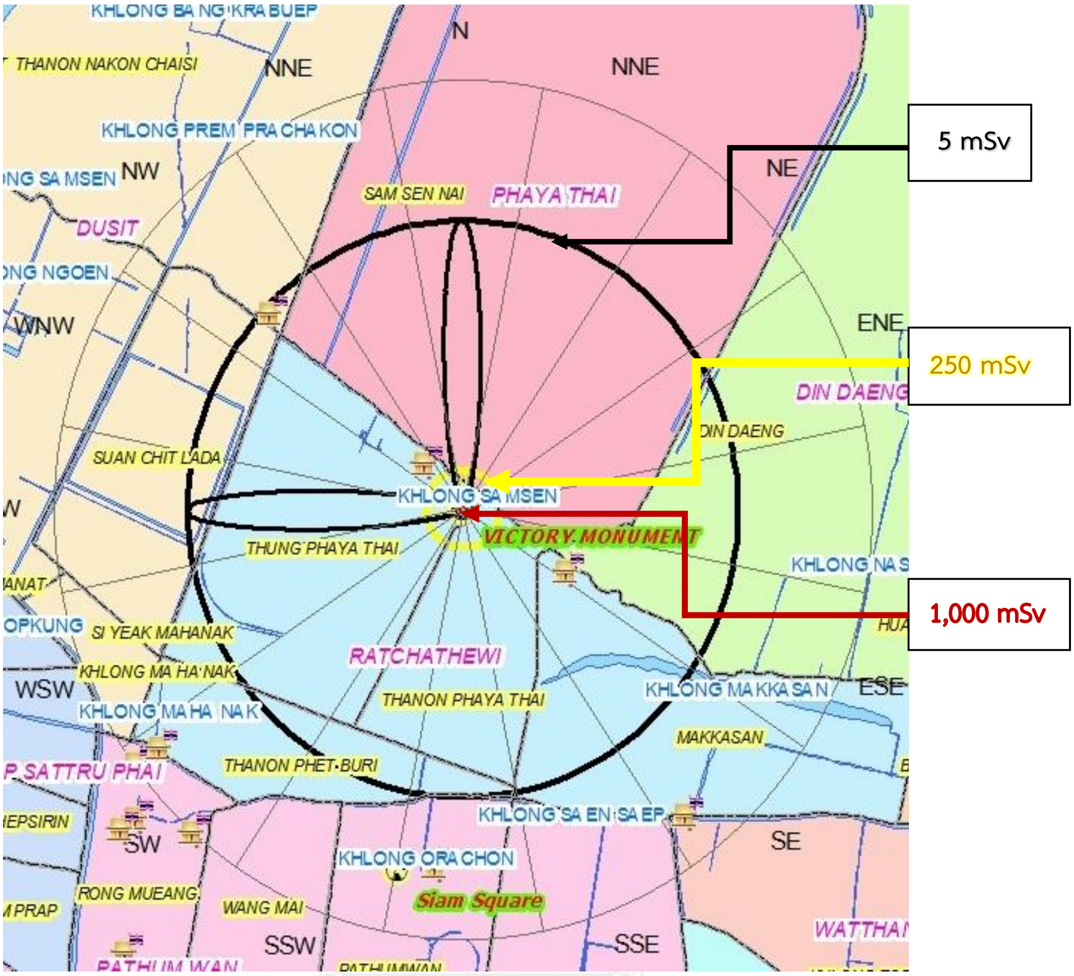


Figure 5.3 The Buffer Zone of radiation dose levels on ArcGIS Desktop 9.3

Results revealed that the maximum distances to receive the TEDE equal to 1,000, 250 and 5 mSv were 0.03, 0.23 and 1.71 km, respectively. The analyzed total number of affected population within TEDE contour lines of 1,000, 250 and 5 mSv were 35, 1,708 and 90,454 persons, respectively (counting, for the worst case estimate, all people staying within the entire range of each contour line in all compass directions irrespective of wind direction). In addition, for the area located opposite of the S and E wind directions, the total number of affected population within the TEDE contour line of 250 mSv were 109 and 128 persons, respectively.

Therefore:

- People who stay less than 0.03 km from the center of explosion (35 persons in Phayathai) will receive a TEDE of 1,000 mSv or more. This would result in the decrease in the number of white blood cells and possibly result in deaths. In addition, immediate medical assistance must be provided to victims to heal physical injuries from the explosive and radiation sickness,

- People who stay between 0.03 - 0.23 km from the center explosion (1,708 persons in Sam Sen Nai, Thung Phaya Thai and Phaya Thai Road), especially the area located opposite of the S and E wind directions (109 and 128 persons, respectively), must be evacuated immediately to avoid receiving a TEDE of 250 mSv or more to avoid radiation sickness,

- People who stay more than 0.23 km from the center of the explosion could still stay in the area because there will be no symptoms in both short and long terms.

5.2 Recommendation for Future Research

A computer program should be developed to analyze the characteristics of more complex plumes, such as those originated in the city area with numerous buildings, in order to realistically take into account complex city terrains. The program must also be designed in accordance with the ICRP Publication 103.

Although explosions of RDDs cannot cause mass casualties compared to a nuclear explosion, all or most immediate fatalities or injuries to persons will probably be due to the force of explosion. RDDs may affect small, localized areas (e.g., a street, single building, or city block) or large areas up to several square kilometers, depending on the nature of the dispersion and the amount and type of radioactive material. Other hazards may also be present (e.g., fire, smoke, shock, shrapnel from an explosion or chemicals). Furthermore, health and environmental consequences from RDDs will depend on the design of the device, type and quantity of radioactive material and the pattern of dispersion following the release. While large numbers of people in a densely populated area around the explosion of a RDD might become contaminated and require radioactive decontamination of persons and areas affected, few, if any, will be contaminated to a level requiring medical treatment.

After the knowledge on the resulting spread of radioactive materials following hypothetical explosions of RDDs from the beginning to the end of accidents was gained, emergency evacuation plans must be offered by authority in the affected areas. Public health authorities will have to assess the persons who were close to the point of release for the needed medical intervention when receiving an acute radiation dose of more than 250 mSv in order to control and mitigate the situation.

In an RDD event, the radiation will likely be coming from the ground and other horizontal surfaces where the radioactive materials will have been distributed by the blast. One must exercise the 3 golden rules for radiation protection: reduce time, increase distance, and use appropriate shielding.

• Time: The less time one spends near the radiation source, the lower the exposure will be.

• Distance: The greater the distance from the source, the less the exposure will be. Radiation exposure decreases with distance according to the inversed square law.

• Shielding: External exposure to radiation can be partially blocked by the use of shielding. Traditionally, shielding is made of lead or concrete. However, staying behind vehicles, buildings, or other objects will also decrease exposure.

REFERENCES

References

[1] John Peterson, Margaret MacDonell, Lynne Haroun, and Fred Monette. (2007). Human Health Fact Sheet, Argonne National Laboratory: Radiological and Chemical Fact Sheets to Support Health Risk Analyses for Contaminated Areas. Available August 15, 2015 from http://www.remm.nlm.gov/rdd.htm.

[2] National Academies. (2004). Radiological Attack: Dirty Bombs and Other Devices, (PDF - 591 KB). Available August 12, 2015

[3] Doonyapong Wongsawaeng. (2014). CBRN weapon: Weapon of Mass Destruction Nonproliferation Nuclear Engineering, Handouts of 2111651 (unpublished document). Department of Nuclear Engineering, Faculty of Engineering, Chulalongkorn University.

[4] Rickert, Paul (2005-12-31). "The Likely Effect of a Radiological Dispersion Device". Liberty University. pp. 2, 3. Retrieved 21 October 2014.

[5] John Peterson, Margaret MacDonell, Lynne Haroun, and Fred Monette. (2005). Radiological Dispersal Device (PDF - 2.34 MB) (Human Health Fact Sheet, Argonne National Laboratory:

[6] Nithima Lojai. (2011). Evaluation of Exclusion Area Boundary and Low Population Zone for Thailand Nuclear Power Plant. Master's Thesis. Department of Nuclear Engineering, Faculty of Engineering, Chulalongkorn University.

[7] Gardiner, C. W. (1985). The Gaussian distribution; Handbook of stochastic methods (Vol. 4). Berlin: Springer.

[8] Safety technology bureau. (2011). Instructions for reporting radioactive material. Manual.pdf. Department of Industrial Works.

[9] Homann, Steven G. (2014). Health Physics Codes Version 3.0.2 User's Guide: National Atmospheric Release Advisory Center Lawrence Livermore National Laboratory.

[10] Seinfeld, J.H. (1986). Atmospheric Chemistry and Physics of Air Pollution. Canada: John Wiley & Sons

[11] Peerasak Sangarun. (1986). Model the spread of radioactive substances in the atmosphere from Nuclear power plants. Master's Thesis. Department of Physics. Faculty of Science, Prince of Songkla University.

[12] National Nuclear and Radiological Emergency Plan. (2014). Dangerous Quantity of Radioactive Material. Office of Atoms for Peace.

[13] ICRP (1991a). (1990). Recommendations of the International Commission on Radiological Protection. ICRP Publication 60, Annals of the ICRP 21(1-3), Pergamon Press, Oxford.

[14] United States Nuclear Regulatory Commission Regulations. (1999). Code of Federation Regulation. Title 10 Part 50 Section 50.67. Accident Source Term.

[15] Meteorological Department. (2015). The average period of measurement data on wind speed and wind direction during the recorded period of 1995 - 2014.

[16] The Office for National Statistics. Department Ministry of the Interior. (2014). number of population from the register and the density of the population.

APPENDIX

APPENDIX A

Meteorological data of the studied areas

Table A.1 Collect data of wind speed and wind direction during the recorded period of January 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.97	1.41	0.08	0.00	0.00	0.00	2.46
NNE		1.29	0.85	0.28	0.00	0.00	0.00	2.42
NE		0.92	0.65	0.24	0.00	0.00	0.00	1.81
ENE		1.85	2.30	0.33	0.04	0.00	0.00	4.52
E		2.90	4.40	1.13	0.04	0.00	0.00	8.47
ESE		1.90	1.69	0.28	0.00	0.00	0.00	3.87
SE		0.32	0.52	0.13	0.00	0.00	0.00	0.97
SSE		0.93	1.21	0.08	0.00	0.00	0.00	2.22
S		1.69	3.31	0.52	0.04	0.00	0.00	5.56
SSW		1.05	2.22	0.32	0.00	0.00	0.00	3.59
SW		0.57	0.56	0.12	0.00	0.00	0.00	1.25
WSW		0.40	0.40	0.09	0.00	0.00	0.00	0.89
W		0.57	0.28	0.00	0.00	0.00	0.00	0.85
WNW		1.13	0.52	0.08	0.00	0.00	0.00	1.73
NW		0.97	1.01	0.28	0.00	0.00	0.00	2.26
NNW		1.57	2.38	0.12	0.04	0.00	0.00	4.11
Total	53.02	19.03	23.71	4.08	0.16	0.00	0.00	46.98

Source: Thai Meteorological Department, 2015

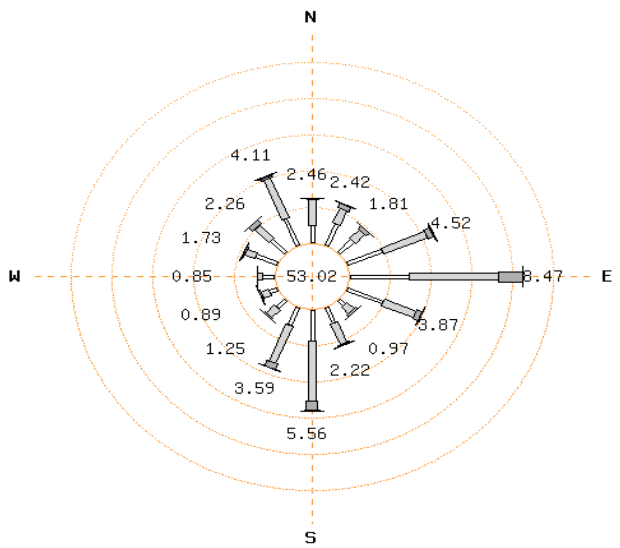


Figure A.1 Analyzed metrological data into wind rose map during the recorded period of January 1995 – 2014 at Bangkok Meteorological Statio

Table A.2 Collect data of wind speed and wind direction during the recorded period of February 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.44	0.27	0.04	0.00	0.00	0.00	0.75
NNE		0.31	0.31	0.00	0.00	0.00	0.00	0.62
NE		0.09	0.18	0.04	0.00	0.00	0.00	0.31
ENE		0.67	0.53	0.13	0.00	0.00	0.00	1.33
E		1.55	1.29	0.40	0.00	0.00	0.00	3.24
ESE		1.46	1.55	0.23	0.00	0.00	0.00	3.24
SE		1.73	1.29	0.13	0.00	0.00	0.00	3.15
SSE		2.84	2.83	0.27	0.00	0.00	0.00	5.94
S		6.12	13.16	3.15	0.40	0.00	0.00	22.83
SSW		3.01	6.21	2.22	0.13	0.00	0.00	11.57
SW		1.24	1.60	0.71	0.04	0.00	0.00	3.59
WSW		0.71	0.93	0.27	0.00	0.00	0.00	1.91
W		0.62	0.53	0.04	0.01	0.00	0.00	1.20
WNW		0.31	0.31	0.09	0.00	0.00	0.00	0.71
NW		0.22	0.40	0.04	0.00	0.00	0.00	0.66
NNW		0.53	0.49	0.04	0.00	0.00	0.00	1.06
Total	37.89	21.85	31.88	7.80	0.58	0.00	0.00	62.11

Source: Thai Meteorological Department, 2015

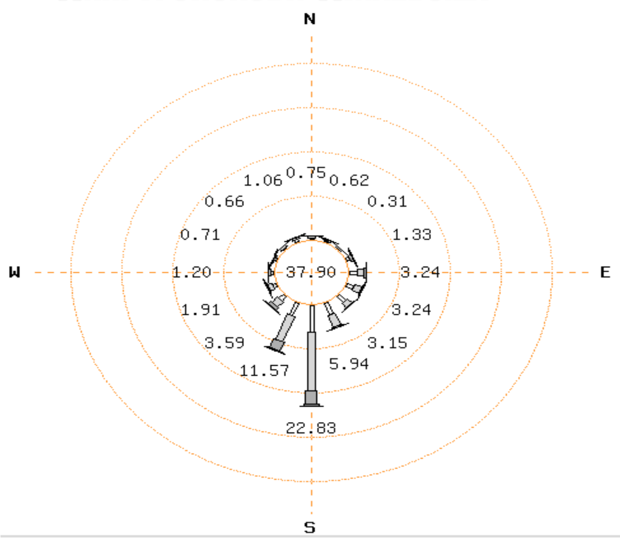


Figure A.2 Analyze metrological data into wind rose map during the recorded period of February 1995 – 2014 at Bangkok Meteorological Station

Table A.3 Collect data of wind speed and wind direction during the recorded period of March 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.37	0.24	0.08	0.00	0.00	0.00	0.69
NNE		0.53	0.28	0.04	0.00	0.00	0.00	0.85
NE		0.16	0.24	0.04	0.00	0.00	0.00	0.44
ENE		0.40	0.56	0.09	0.04	0.00	0.00	1.09
E		1.17	1.82	0.40	0.00	0.00	0.00	3.39
ESE		1.69	2.27	0.56	0.04	0.00	0.00	4.56
SE		1.33	0.97	0.24	0.00	0.00	0.00	2.54
SSE		2.90	3.91	0.93	0.04	0.00	0.00	7.78
S		6.09	14.48	4.23	0.20	0.00	0.00	25.00
SSW		3.23	7.34	1.97	0.16	0.00	0.00	12.70
SW		0.89	1.37	0.76	0.04	0.00	0.00	3.06
WSW		0.65	1.17	0.44	0.00	0.00	0.00	2.26
W		0.40	0.40	0.01	0.00	0.00	0.00	0.81
WNW		0.40	0.44	0.05	0.00	0.00	0.00	0.89
NW		0.32	0.48	0.21	0.00	0.00	0.00	1.01
NNW		0.56	1.01	0.24	0.04	0.00	0.00	1.85
Total	31.08	21.09	36.98	10.29	0.56	0.00	0.00	68.92

Source: Thai Meteorological Department, 2015

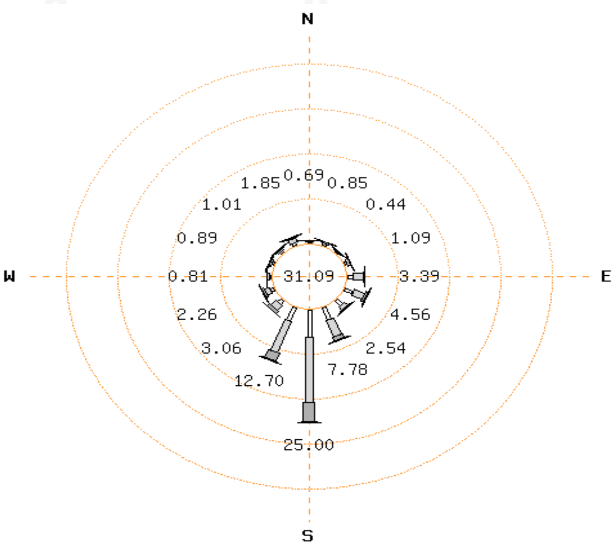


Figure A.3 Analyze metrological data into wind rose map during the recorded period of March 1995 – 2014 at Bangkok Meteorological Station

Table A.4 Collect data of wind speed and wind direction during the recorded period of April 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.29	0.46	0.08	0.00	0.00	0.00	0.83
NNE		0.37	0.21	0.00	0.00	0.00	0.00	0.58
NE		0.12	0.12	0.08	0.01	0.00	0.00	0.33
ENE		0.41	0.21	0.00	0.00	0.00	0.00	0.62
E		1.50	1.50	0.25	0.17	0.00	0.00	3.42
ESE		2.08	1.96	0.58	0.00	0.00	0.00	4.62
SE		1.17	1.46	0.16	0.00	0.00	0.00	2.79
SSE		2.92	3.96	0.95	0.00	0.00	0.00	7.83
S		6.42	12.12	3.84	0.08	0.00	0.00	22.46
SSW		2.67	6.62	2.17	0.04	0.00	0.00	11.50
SW		0.96	3.08	0.71	0.04	0.00	0.00	4.79
WSW		0.79	1.25	0.63	0.00	0.00	0.00	2.67
W		1.25	1.21	0.50	0.08	0.00	0.00	3.04
WNW		0.71	1.08	0.50	0.04	0.00	0.00	2.33
NW		0.38	0.67	0.24	0.04	0.00	0.00	1.33
NNW		0.67	0.88	0.24	0.00	0.00	0.00	1.79
Total	29.07	22.71	36.79	10.93	0.50	0.00	0.00	70.93

Source: Thai Meteorological Department, 2015

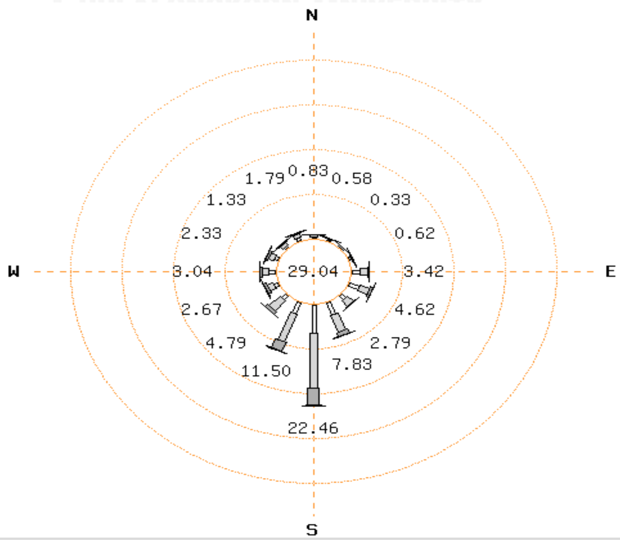


Figure A.4 Analyze metrological data into wind rose map during the recorded period of April 1995 – 2014 at Bangkok Meteorological Station

Table A.5 Collect data of wind speed and wind direction during the recorded period of May 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.08	0.25	0.04	0.04	0.00	0.00	0.41
NNE		0.16	0.08	0.00	0.04	0.00	0.00	0.28
NE		0.04	0.08	0.00	0.00	0.00	0.00	0.12
ENE		0.77	0.41	0.08	0.00	0.00	0.00	1.26
E		2.16	0.97	0.20	0.00	0.00	0.00	3.33
ESE		2.11	1.82	0.33	0.08	0.00	0.00	4.34
SE		0.53	1.09	0.04	0.00	0.00	0.00	1.66
SSE		1.66	2.51	0.53	0.00	0.00	0.00	4.70
S		4.18	8.72	3.16	0.08	0.00	0.00	16.14
SSW		3.41	5.31	2.39	0.04	0.00	0.00	11.15
SW		1.01	2.84	0.69	0.08	0.00	0.00	4.62
WSW		1.54	2.64	0.81	0.08	0.00	0.00	5.07
W		1.50	2.88	0.89	0.00	0.00	0.00	5.27
WNW		1.09	1.18	0.45	0.00	0.00	0.00	2.72
NW		0.28	0.57	0.04	0.00	0.00	0.00	0.89
NNW		0.81	0.24	0.08	0.01	0.00	0.00	1.14
Total	36.90	21.33	31.59	9.73	0.45	0.00	0.00	63.10

Source: Thai Meteorological Department, 2015

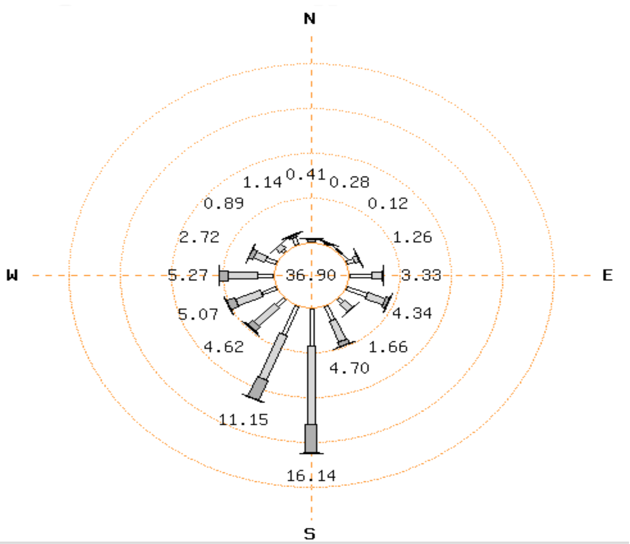


Figure A.5 Analyze metrological data into wind rose map during the recorded period of May 1995 – 2014 at Bangkok Meteorological Station

Table A.6 Collect data of wind speed and wind direction during the recorded period of June 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.08	0.08	0.05	0.00	0.00	0.00	0.21
NNE		0.04	0.04	0.00	0.00	0.00	0.00	0.08
NE		0.08	0.00	0.00	0.00	0.00	0.00	0.08
ENE		0.29	0.09	0.00	0.00	0.00	0.00	0.38
E		0.88	0.54	0.12	0.00	0.00	0.00	1.54
ESE		0.76	1.29	0.12	0.00	0.00	0.00	2.17
SE		0.38	0.58	0.21	0.00	0.00	0.00	1.17
SSE		1.29	2.04	0.42	0.00	0.00	0.00	3.75
S		4.25	8.38	2.67	0.12	0.00	0.00	15.42
SSW		3.88	6.62	2.46	0.04	0.00	0.00	13.00
SW		1.75	3.50	0.62	0.09	0.00	0.00	5.96
WSW		2.79	3.62	1.08	0.26	0.00	0.00	7.75
W		1.62	3.17	0.96	0.08	0.00	0.00	5.83
WNW		0.79	1.17	0.42	0.04	0.00	0.00	2.42
NW		0.29	0.50	0.04	0.00	0.00	0.00	0.83
NNW		0.46	0.25	0.04	0.04	0.00	0.00	0.79
Total	38.62	19.63	31.87	9.21	0.67	0.00	0.00	61.38

Source: Thai Meteorological Department, 2015

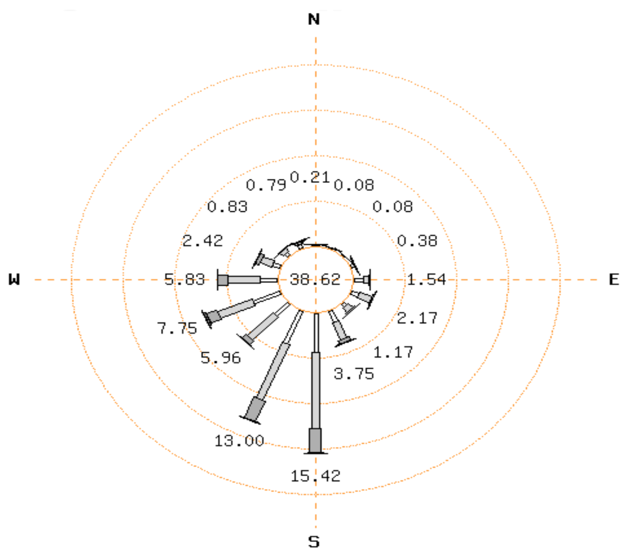


Figure A.6 Analyze metrological data into wind rose map during the recorded period of June 1995 – 2014 at Bangkok Meteorological Station

Table A.7 Collect data of wind speed and wind direction during the recorded period of July 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.20	0.00	0.00	0.00	0.00	0.00	0.20
NNE		0.08	0.04	0.00	0.00	0.00	0.00	0.12
NE		0.04	0.00	0.00	0.00	0.00	0.00	0.04
ENE		0.08	0.04	0.00	0.00	0.00	0.00	0.12
E		0.77	0.32	0.04	0.00	0.00	0.00	1.13
ESE		0.56	0.65	0.00	0.00	0.00	0.00	1.21
SE		0.16	0.40	0.00	0.00	0.00	0.00	0.56
SSE		0.89	1.13	0.24	0.00	0.00	0.00	2.26
S		3.47	5.97	1.77	0.08	0.00	0.00	11.29
SSW		3.31	5.08	1.73	0.12	0.00	0.00	10.24
SW		2.34	3.50	0.85	0.12	0.00	0.00	6.81
WSW		2.50	5.25	1.53	0.16	0.00	0.00	9.44
W		2.98	4.60	1.94	0.08	0.00	0.00	9.60
WNW		0.89	1.81	0.65	0.04	0.00	0.00	3.39
NW		0.52	0.65	0.28	0.04	0.00	0.00	1.49
NNW		0.52	0.24	0.20	0.01	0.00	0.00	0.97
Total	41.13	19.31	29.68	9.23	0.65	0.00	0.00	58.87

Source: Thai Meteorological Department, 2015

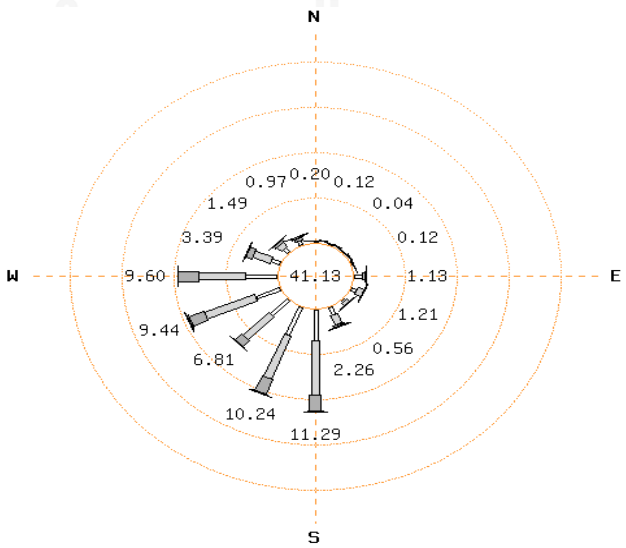


Figure A.7 Analyze metrological data into wind rose map during the recorded period of July 1995 – 2014 at Bangkok Meteorological Station

Table A.8 Collect data of wind speed and wind direction during the recorded period of August 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.04	0.24	0.00	0.00	0.00	0.00	0.28
NNE		0.04	0.00	0.00	0.00	0.00	0.00	0.04
NE		0.04	0.00	0.00	0.00	0.00	0.00	0.04
ENE		0.24	0.08	0.00	0.00	0.04	0.00	0.36
E		0.45	0.36	0.08	0.00	0.00	0.00	0.89
ESE		0.49	0.52	0.04	0.00	0.00	0.00	1.05
SE		0.28	0.20	0.04	0.04	0.00	0.00	0.56
SSE		1.13	0.89	0.20	0.04	0.00	0.00	2.26
S		2.75	4.03	1.73	0.12	0.00	0.00	8.63
SSW		3.63	4.96	1.21	0.20	0.00	0.00	10.00
SW		1.77	2.94	0.77	0.12	0.00	0.00	5.60
WSW		2.98	4.52	1.25	0.04	0.00	0.00	8.79
W		2.83	4.76	1.41	0.56	0.00	0.00	9.56
WNW		1.85	2.78	0.69	0.08	0.00	0.00	5.40
NW		0.52	0.69	0.24	0.04	0.00	0.00	1.49
NNW		0.52	0.89	0.08	0.04	0.00	0.00	1.53
Total	43.52	19.56	27.86	7.74	1.28	0.04	0.00	56.48

Source: Thai Meteorological Department, 2015

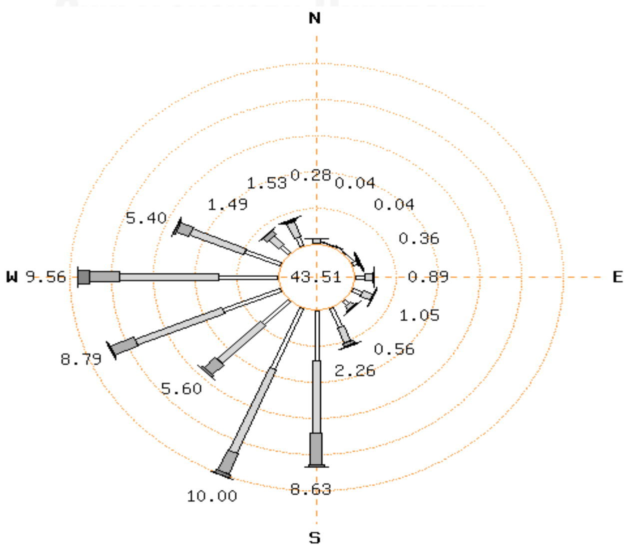


Figure A.8 Analyze metrological data into wind rose map during the recorded period of August 1995 – 2014 at Bangkok Meteorological Station

Table A.9 Collect data of wind speed and wind direction during the recorded period of September 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.17	0.25	0.12	0.00	0.00	0.00	0.54
NNE		0.29	0.12	0.04	0.01	0.00	0.00	0.46
NE		0.04	0.04	0.04	0.00	0.00	0.00	0.12
ENE		0.29	0.46	0.00	0.00	0.00	0.00	0.75
E		1.08	0.58	0.09	0.00	0.00	0.00	1.75
ESE		0.71	0.96	0.00	0.04	0.00	0.00	1.71
SE		0.21	0.25	0.04	0.00	0.00	0.00	0.50
SSE		0.92	0.96	0.16	0.00	0.00	0.00	2.04
S		2.29	3.29	1.46	0.08	0.00	0.00	7.12
SSW		2.71	3.12	0.88	0.04	0.00	0.00	6.75
SW		1.00	2.17	0.37	0.04	0.00	0.00	3.58
WSW		1.75	2.42	0.63	0.04	0.04	0.00	4.88
W		3.08	4.83	1.54	0.17	0.00	0.00	9.62
WNW		1.67	3.46	0.83	0.12	0.00	0.00	6.08
NW		1.00	1.88	0.37	0.04	0.00	0.00	3.29
NNW		0.96	0.83	0.34	0.04	0.00	0.00	2.17
Total	48.64	18.17	25.62	6.91	0.62	0.04	0.00	51.36

Source: Thai Meteorological Department, 2015

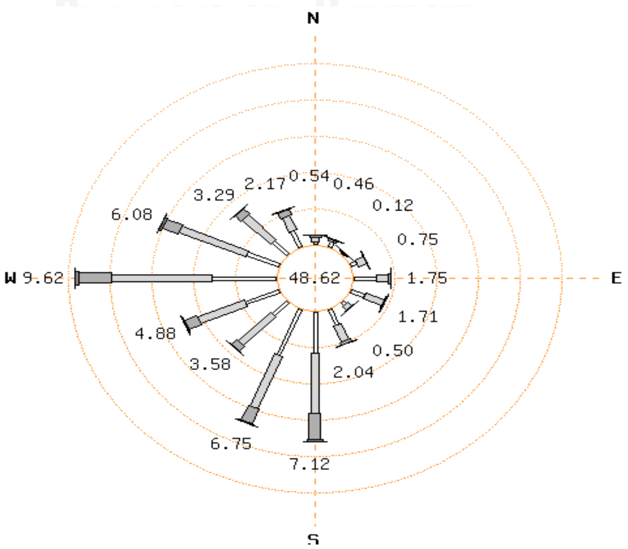


Figure A.9 Analyze metrological data into wind rose map during the recorded period of September 1995 – 2014 at Bangkok Meteorological Station

Table A.10 Collect data of wind speed and wind direction during the recorded period of October 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		1.21	1.21	0.08	0.00	0.00	0.00	2.50
NNE		1.21	1.25	0.04	0.00	0.00	0.00	2.50
NE		0.52	0.56	0.13	0.00	0.00	0.00	1.21
ENE		1.33	1.30	0.32	0.00	0.00	0.00	2.95
E		3.15	4.07	0.69	0.04	0.00	0.00	7.95
ESE		1.74	2.02	0.28	0.00	0.00	0.00	4.04
SE		0.52	0.41	0.08	0.00	0.00	0.00	1.01
SSE		0.49	0.52	0.00	0.00	0.00	0.00	1.01
S		0.97	1.21	0.44	0.00	0.00	0.00	2.62
SSW		1.13	1.13	0.08	0.04	0.00	0.00	2.38
SW		0.56	0.65	0.12	0.00	0.00	0.00	1.33
WSW		0.57	0.48	0.12	0.00	0.00	0.00	1.17
W		1.54	1.33	0.24	0.00	0.00	0.00	3.11
WNW		1.53	1.50	0.00	0.00	0.00	0.00	3.03
NW		1.21	1.21	0.04	0.00	0.00	0.00	2.46
NNW		1.69	1.57	0.33	0.00	0.00	0.00	3.59
Total	57.14	19.37	20.42	2.99	0.08	0.00	0.00	42.86

Source: Thai Meteorological Department, 2015

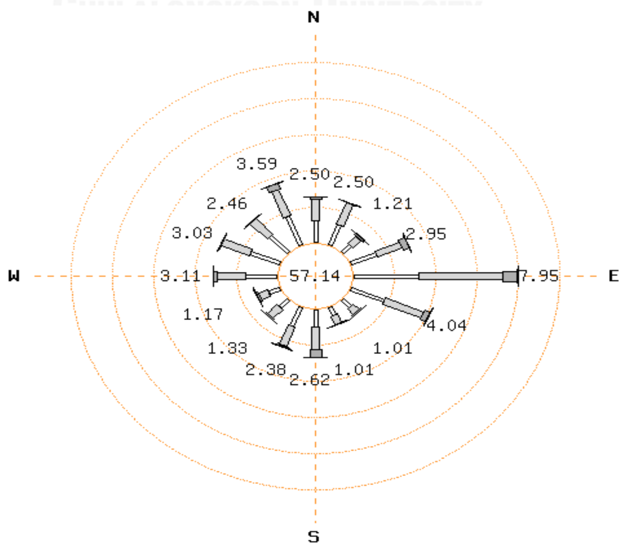


Figure A.10 Analyze metrological data into wind rose map during the recorded period of October 1995 – 2014 at Bangkok Meteorological Station

Table A.11 Collect data of wind speed and wind direction during the recorded period of November 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		1.29	1.88	0.29	0.00	0.00	0.00	3.46
NNE		1.62	1.38	0.17	0.00	0.00	0.00	3.17
NE		0.50	0.83	0.17	0.00	0.00	0.00	1.50
ENE		2.38	2.37	0.38	0.04	0.00	0.00	5.17
E		4.54	3.79	1.17	0.08	0.00	0.00	9.58
ESE		1.58	1.50	0.34	0.00	0.00	0.00	3.42
SE		0.42	0.25	0.00	0.00	0.00	0.00	0.67
SSE		0.29	0.17	0.00	0.00	0.00	0.00	0.46
S		1.00	1.08	0.04	0.05	0.00	0.00	2.17
SSW		0.58	9.46	0.04	0.00	0.00	0.00	10.08
SW		0.42	0.21	0.00	0.00	0.00	0.00	0.63
WSW		0.25	0.25	0.00	0.00	0.00	0.00	0.50
W		1.04	0.58	0.00	0.00	0.00	0.00	1.62
WNW		1.42	1.04	0.16	0.00	0.00	0.00	2.62
NW		1.67	1.92	0.16	0.00	0.00	0.00	3.75
NNW		2.79	2.58	0.21	0.00	0.00	0.00	5.58
Total	45.62	21.79	29.29	3.13	0.17	0.00	0.00	54.38

Source: Thai Meteorological Department, 2015

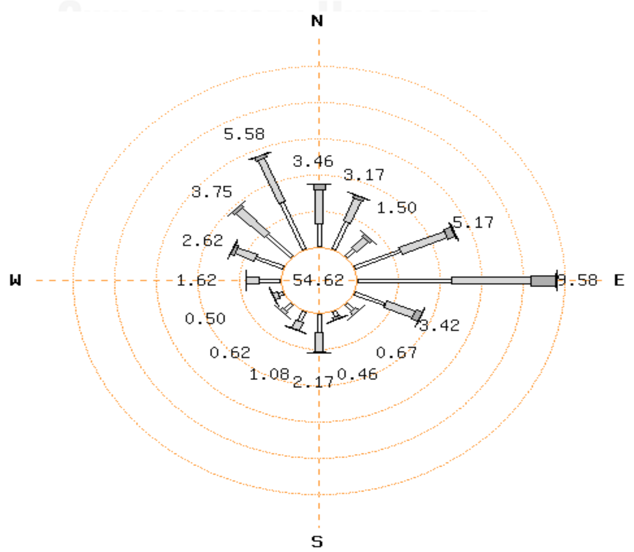


Figure A.11 Analyze metrological data into wind rose map during the recorded period of November 1995 – 2014 at Bangkok Meteorological Station

Table A.12 Collect data of wind speed and wind direction during the recorded period of December 1995 – 2014 at Bangkok Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		1.85	2.18	0.20	0.00	0.00	0.00	4.23
NNE		1.69	1.57	0.17	0.00	0.00	0.00	3.43
NE		1.09	0.73	0.12	0.00	0.00	0.00	1.94
ENE		1.81	2.78	0.25	0.04	0.00	0.00	4.88
E		2.82	4.76	1.09	0.00	0.00	0.00	8.67
ESE		1.41	1.69	0.25	0.00	0.00	0.00	3.35
SE		0.37	0.40	0.08	0.00	0.00	0.00	0.85
SSE		0.41	0.52	0.00	0.00	0.00	0.00	0.93
S		0.81	0.81	0.23	0.00	0.00	0.00	1.85
SSW		0.52	0.53	0.20	0.00	0.00	0.00	1.25
SW		0.24	0.16	0.08	0.00	0.00	0.00	0.48
WSW		0.28	0.16	0.00	0.00	0.00	0.00	0.44
W		0.53	0.28	0.04	0.00	0.00	0.00	0.85
WNW		0.97	1.05	0.12	0.00	0.00	0.00	2.14
NW		2.06	1.73	0.44	0.04	0.00	0.00	4.27
NNW		2.78	3.23	0.40	0.00	0.00	0.00	6.41
Total	54.03	19.64	22.58	3.67	0.08	0.00	0.00	45.97

Source: Thai Meteorological Department, 2015

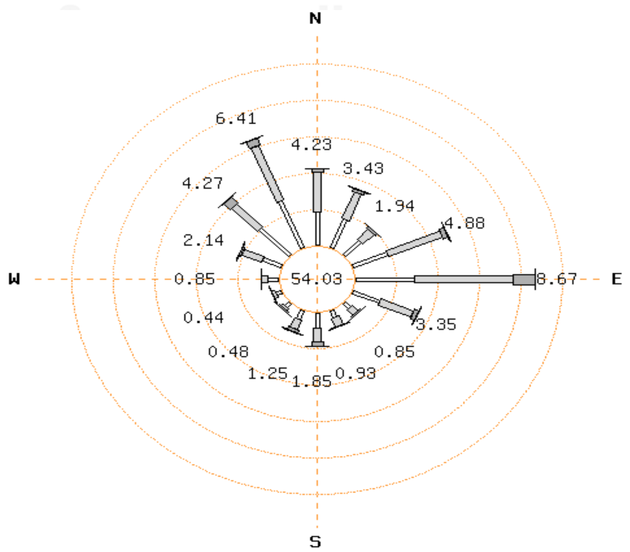


Figure A.12 Analyze metrological data into wind rose map during the recorded period of December 1995 – 2014 at Bangkok Meteorological Station

Table A.13 Collect data of wind speed and wind direction during the recorded period of January 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.40	0.67	1.05	0.38	0.03	0.00	2.53
NNE		0.48	2.82	2.37	2.13	0.48	0.03	8.31
NE		0.27	4.14	2.93	2.85	0.62	0.27	11.08
ENE		0.32	1.94	1.86	1.13	0.24	0.05	5.54
E		0.67	0.65	1.13	0.05	0.00	0.00	2.50
ESE		0.22	0.24	0.77	0.11	0.00	0.00	1.34
SE		0.05	0.03	0.03	0.00	0.00	0.00	0.11
SSE		0.46	0.30	0.58	0.11	0.00	0.00	1.45
S		0.89	0.99	2.26	0.16	0.03	0.00	4.33
SSW		0.56	2.10	2.77	0.65	0.00	0.00	6.08
SW		0.38	1.13	0.89	0.40	0.08	0.00	2.88
WSW		0.22	2.31	2.52	0.38	0.00	0.00	5.43
W		0.43	2.23	2.35	0.16	0.00	0.05	5.22
WNW		0.30	1.18	1.32	0.26	0.00	0.00	3.06
NW		0.08	0.65	0.77	0.19	0.03	0.00	1.72
NNW		0.08	1.08	1.08	0.31	0.03	0.00	2.58
Total	35.84	5.81	22.46	24.68	9.27	1.54	0.40	64.16

Source: Thai Meteorological Department, 2015

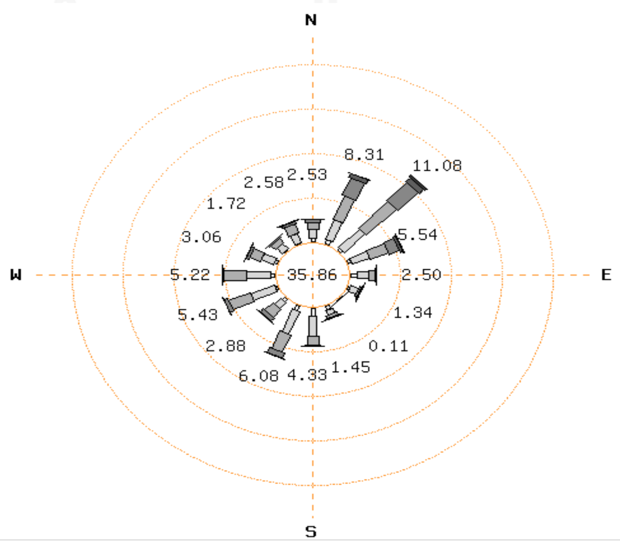


Figure A.13 Analyze metrological data into wind rose map during the recorded period of January 1995 – 2014 at Pattaya Meteorological Station

Table A.14 Collect data of wind speed and wind direction during the recorded period of February 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.18	0.15	0.35	0.12	0.03	0.00	0.83
NNE		0.09	1.21	0.62	0.58	0.15	0.00	2.65
NE		0.00	1.36	0.88	0.71	0.35	0.09	3.39
ENE		0.18	0.53	0.56	0.38	0.09	0.00	1.74
E		0.71	0.15	0.56	0.03	0.00	0.00	1.45
ESE		0.47	0.18	0.86	0.05	0.00	0.00	1.56
SE		0.20	0.00	0.09	0.00	0.00	0.00	0.29
SSE		0.47	0.35	0.95	0.09	0.00	0.00	1.86
S		1.98	2.03	4.51	0.80	0.06	0.00	9.38
SSW		0.86	5.10	5.57	1.86	0.15	0.03	13.57
SW		0.74	2.95	3.10	1.27	0.14	0.00	8.20
WSW		0.32	4.13	3.30	0.86	0.00	0.00	8.61
W		0.35	1.39	1.65	0.41	0.00	0.00	3.80
WNW		0.12	0.68	0.56	0.09	0.00	0.00	1.45
NW		0.03	0.53	0.35	0.12	0.00	0.00	1.03
NNW		0.02	0.27	0.47	0.18	0.00	0.00	0.94
Total	39.25	6.72	21.01	24.38	7.55	0.97	0.12	60.75

Source: Thai Meteorological Department, 2015

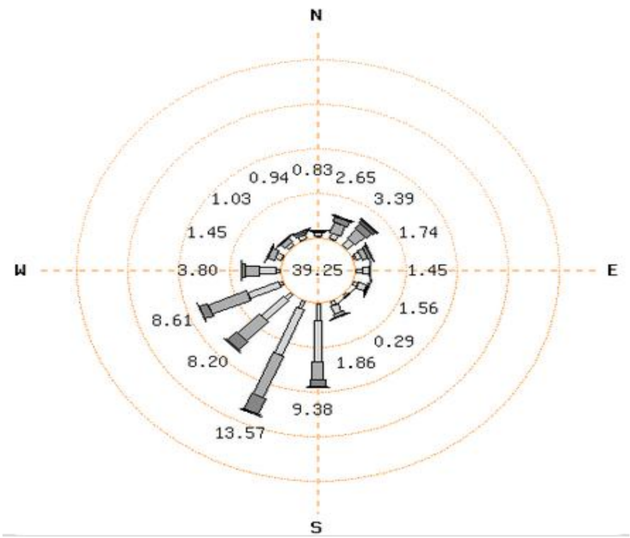


Figure A.14 Analyze metrological data into wind rose map in during the recorded period of February 1995 – 2014 at Pattaya Meteorological Station

Table A.15 Collect data of wind speed and wind direction during the recorded period of March 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.03	0.43	0.35	0.22	0.05	0.00	1.08
NNE		0.11	0.83	0.66	0.46	0.22	0.03	2.31
NE		0.13	1.48	0.86	0.41	0.14	0.05	3.07
ENE		0.13	0.59	0.38	0.16	0.00	0.03	1.29
E		0.48	0.22	0.62	0.08	0.00	0.00	1.40
ESE		0.57	0.10	0.65	0.00	0.00	0.00	1.32
SE		0.11	0.02	0.22	0.00	0.00	0.00	0.35
SSE		0.65	0.32	1.56	0.19	0.00	0.00	2.72
S		1.91	3.04	6.03	1.13	0.08	0.00	12.19
SSW		1.05	6.33	5.98	3.01	0.24	0.00	16.61
SW		0.22	2.77	2.61	1.51	0.16	0.00	7.27
WSW		0.51	3.64	2.91	1.05	0.05	0.00	8.16
W		0.46	1.18	1.48	0.40	0.03	0.00	3.55
WNW		0.13	0.19	0.62	0.08	0.00	0.00	1.02
NW		0.03	0.10	0.11	0.11	0.00	0.00	0.35
NNW		0.08	0.30	0.32	0.13	0.00	0.00	0.83
Total	36.48	6.60	21.54	25.36	8.94	0.97	0.11	63.52

Source: Thai Meteorological Department, 2015

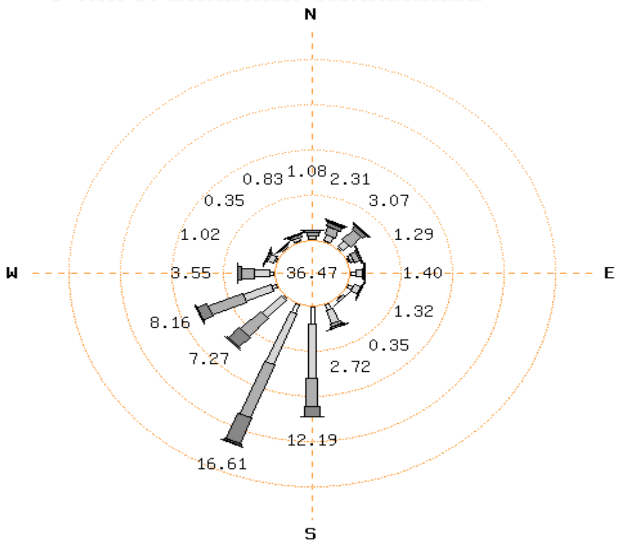


Figure A.15 Analyze metrological data into wind rose map during the recorded period of March 1995 – 2014 at Pattaya Meteorological Station

Table A.16 Collect data of wind speed and wind direction during the recorded period of April 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.00	0.06	0.19	0.08	0.00	0.00	0.33
NNE		0.11	0.22	0.50	0.11	0.00	0.03	0.97
NE		0.08	0.56	0.67	0.28	0.16	0.00	1.75
ENE		0.14	0.14	0.39	0.06	0.02	0.00	0.75
E		0.69	0.15	0.86	0.11	0.00	0.00	1.81
ESE		0.39	0.16	0.78	0.00	0.00	0.00	1.33
SE		0.22	0.03	0.19	0.00	0.00	0.00	0.44
SSE		0.97	0.28	1.58	0.00	0.00	0.00	2.83
S		2.20	2.45	6.67	0.93	0.06	0.00	12.31
SSW		1.00	6.25	6.17	2.67	0.20	0.00	16.29
SW		0.25	3.53	2.58	1.70	0.19	0.00	8.25
WSW		0.28	3.89	3.11	0.64	0.03	0.00	7.95
W		0.28	1.00	2.00	0.30	0.03	0.00	3.61
WNW		0.00	0.14	0.64	0.03	0.00	0.00	0.81
NW		0.00	0.08	0.14	0.00	0.00	0.00	0.22
NNW		0.06	0.03	0.11	0.02	0.00	0.00	0.22
Total	40.13	6.67	18.97	26.58	6.93	0.69	0.03	59.87

Source: Thai Meteorological Department, 2015

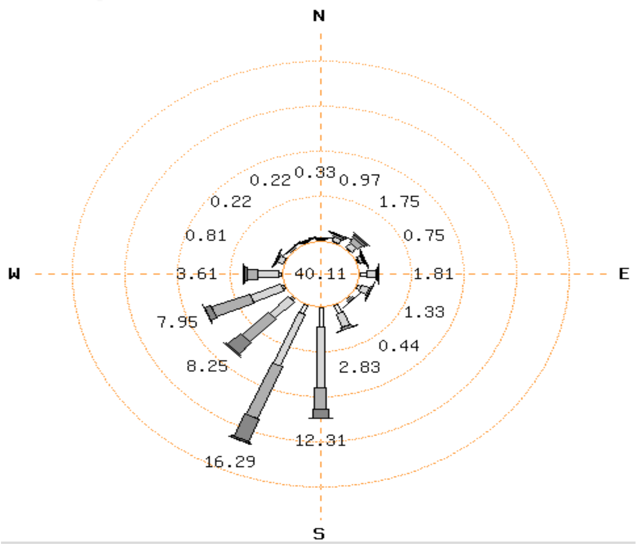


Figure A.16 Analyze metrological data into wind rose map during the recorded period of April 1995 – 2014 at Pattaya Meteorological Station

Table A.17 Collect data of wind speed and wind direction during the recorded period of May 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.13	0.17	0.24	0.00	0.00	0.00	0.54
NNE		0.05	0.05	0.30	0.08	0.03	0.00	0.51
NE		0.19	0.54	0.46	0.13	0.00	0.00	1.32
ENE		0.11	0.08	0.48	0.00	0.00	0.00	0.67
E		0.62	0.16	0.67	0.00	0.00	0.00	1.45
ESE		0.13	0.06	0.40	0.00	0.00	0.00	0.59
SE		0.08	0.03	0.19	0.00	0.00	0.00	0.30
SSE		0.45	0.27	0.89	0.00	0.00	0.00	1.61
S		1.86	3.12	5.76	1.23	0.03	0.00	12.00
SSW		1.61	8.12	7.07	2.70	0.19	0.08	19.77
SW		0.40	5.24	4.63	1.94	0.11	0.00	12.32
WSW		0.43	4.25	4.25	1.23	0.00	0.03	10.19
W		0.22	1.12	2.39	0.30	0.03	0.00	4.06
WNW		0.03	0.30	0.40	0.05	0.00	0.00	0.78
NW		0.05	0.04	0.13	0.00	0.00	0.00	0.22
NNW		0.05	0.06	0.11	0.00	0.00	0.00	0.22
Total	33.45	6.41	23.61	28.37	7.66	0.39	0.11	66.55

Source: Thai Meteorological Department, 2015

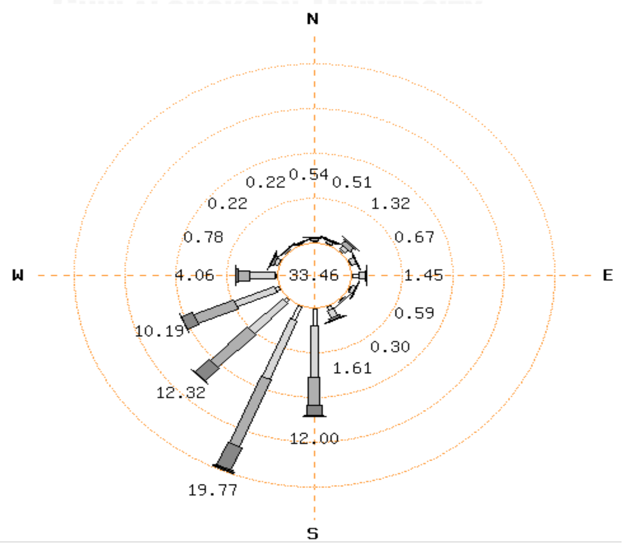


Figure A.17 Analyze metrological data into wind rose map during the recorded period of May 1995 – 2014 at Pattaya Meteorological Station

Table A.18 Collect data of wind speed and wind direction during the recorded period of June 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.00	0.08	0.03	0.03	0.00	0.00	0.14
NNE		0.00	0.11	0.06	0.00	0.00	0.00	0.17
NE		0.00	0.08	0.12	0.08	0.00	0.00	0.28
ENE		0.03	0.08	0.00	0.00	0.00	0.00	0.11
E		0.22	0.44	0.09	0.00	0.00	0.00	0.75
ESE		0.25	0.36	0.14	0.00	0.00	0.00	0.75
SE		0.06	0.08	0.00	0.00	0.00	0.00	0.14
SSE		0.31	0.94	0.14	0.03	0.00	0.00	1.42
S		1.56	5.30	2.89	0.94	0.14	0.00	10.83
SSW		1.31	9.02	9.39	3.36	0.22	0.06	23.36
SW		0.64	5.67	6.69	2.89	0.19	0.03	16.11
WSW		0.36	5.17	5.86	1.33	0.11	0.00	12.83
W		0.31	2.39	1.92	0.38	0.03	0.00	5.03
WNW		0.06	0.14	0.19	0.05	0.00	0.00	0.44
NW		0.00	0.06	0.00	0.00	0.00	0.00	0.06
NNW		0.00	0.05	0.06	0.00	0.00	0.00	0.11
Total	27.47	5.11	29.97	27.58	9.09	0.69	0.09	72.53

Source: Thai Meteorological Department, 2015

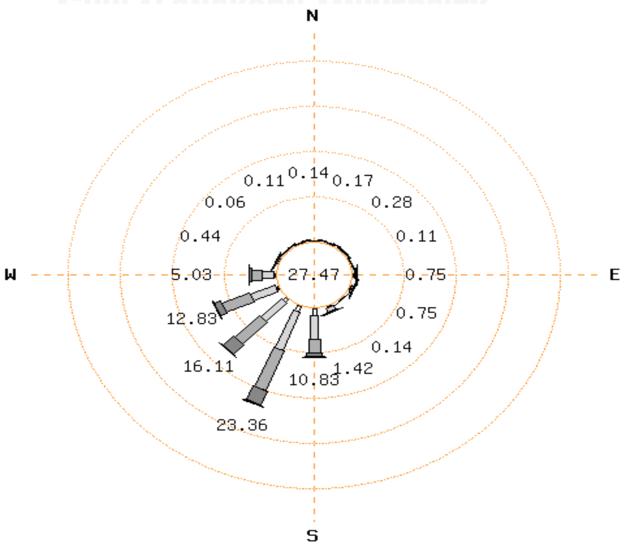


Figure A.18 Analyze metrological data into wind rose map during the recorded period of June 1995 – 2014 at Pattaya Meteorological Station

Table A.19 Collect data of wind speed and wind direction during the recorded period of July 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.06	0.08	0.05	0.03	0.00	0.00	0.22
NNE		0.01	0.05	0.05	0.00	0.00	0.00	0.11
NE		0.00	0.13	0.03	0.00	0.00	0.00	0.16
ENE		0.03	0.08	0.00	0.00	0.00	0.00	0.11
E		0.22	0.59	0.00	0.00	0.00	0.00	0.81
ESE		0.19	0.21	0.03	0.00	0.00	0.00	0.43
SE		0.08	0.03	0.00	0.00	0.00	0.00	0.11
SSE		0.22	0.49	0.24	0.00	0.00	0.00	0.95
S		1.46	3.36	2.60	1.19	0.14	0.00	8.75
SSW		1.35	8.88	9.86	4.05	0.27	0.00	24.41
SW		0.62	5.33	8.51	3.85	0.30	0.00	18.61
WSW		0.73	5.18	7.72	2.44	0.27	0.00	16.34
W		0.43	2.20	1.95	0.54	0.08	0.00	5.20
WNW		0.00	0.16	0.03	0.14	0.00	0.00	0.33
NW		0.00	0.05	0.00	0.03	0.00	0.00	0.08
NNW		0.05	0.11	0.03	0.00	0.00	0.00	0.19
Total	23.19	5.45	26.93	31.10	12.27	1.06	0.00	76.81

Source: Thai Meteorological Department, 2015

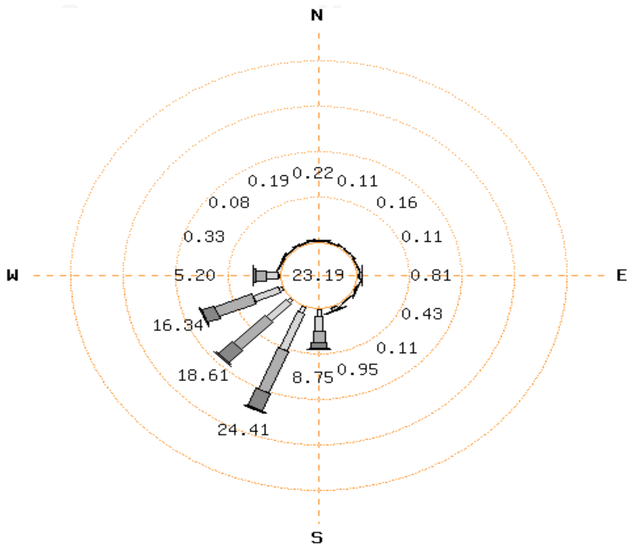


Figure A.19 Analyze metrological data into wind rose map during the recorded period of July 1995 – 2014 at Pattaya Meteorological Station

Table A.20 Collect data of wind speed and wind direction during the recorded period of August 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.05	0.05	0.12	0.00	0.00	0.00	0.22
NNE		0.08	0.00	0.05	0.00	0.00	0.00	0.13
NE		0.03	0.10	0.11	0.00	0.03	0.00	0.27
ENE		0.11	0.03	0.05	0.03	0.00	0.00	0.22
E		0.38	0.00	0.67	0.03	0.00	0.00	1.08
ESE		0.16	0.00	0.24	0.00	0.00	0.00	0.40
SE		0.11	0.00	0.08	0.05	0.00	0.00	0.24
SSE		0.35	0.03	0.48	0.13	0.00	0.00	0.99
S		1.34	2.23	3.36	0.81	0.08	0.00	7.82
SSW		1.24	9.57	8.68	3.92	0.27	0.00	23.68
SW		0.46	9.00	5.89	3.17	0.11	0.03	18.66
WSW		0.67	6.27	5.89	1.64	0.13	0.00	14.60
W		0.35	1.10	2.63	0.54	0.00	0.00	4.62
WNW		0.08	0.27	0.43	0.13	0.00	0.00	0.91
NW		0.00	0.11	0.19	0.00	0.00	0.00	0.30
NNW		0.05	0.11	0.19	0.03	0.00	0.00	0.38
Total	25.48	5.46	28.87	29.06	10.48	0.62	0.03	74.52

Source: Thai Meteorological Department, 2015

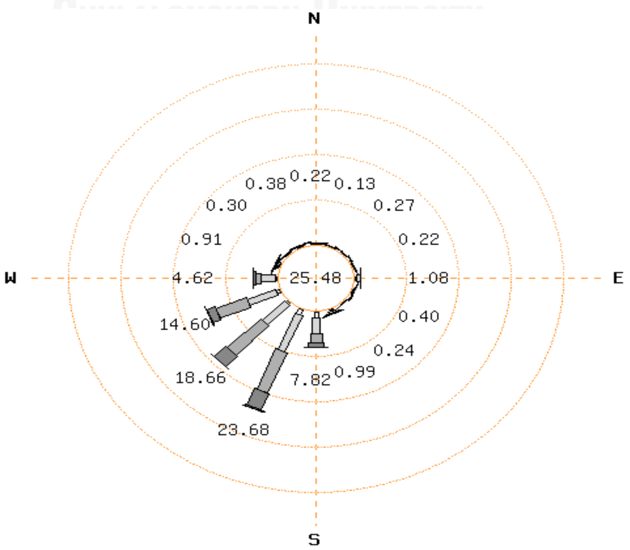


Figure A.20 Analyze metrological data into wind rose map during the recorded period of August 1995 – 2014 at Pattaya Meteorological Station

Table A.21 Collect data of wind speed and wind direction during the recorded period of September 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.11	0.17	0.25	0.03	0.00	0.00	0.56
NNE		0.03	0.08	0.47	0.06	0.00	0.00	0.64
NE		0.08	0.31	0.41	0.11	0.00	0.03	0.94
ENE		0.06	0.03	0.44	0.00	0.00	0.00	0.53
E		0.47	0.16	0.81	0.00	0.00	0.00	1.44
ESE		0.11	0.00	0.56	0.00	0.00	0.00	0.67
SE		0.11	0.00	0.03	0.03	0.00	0.00	0.17
SSE		0.47	0.06	0.33	0.00	0.03	0.00	0.89
S		1.35	1.05	3.14	0.27	0.05	0.00	5.86
SSW		1.25	5.75	8.00	1.69	0.11	0.03	16.83
SW		1.00	4.56	5.00	1.36	0.11	0.05	12.08
WSW		0.47	5.22	5.97	1.06	0.00	0.00	12.72
W		0.58	2.03	2.92	0.36	0.03	0.00	5.92
WNW		0.14	0.50	0.75	0.03	0.00	0.00	1.42
NW		0.00	0.08	0.28	0.06	0.00	0.00	0.42
NNW		0.08	0.17	0.53	0.08	0.00	0.00	0.86
Total	38.05	6.31	20.17	29.89	5.14	0.33	0.11	61.95

Source: Thai Meteorological Department, 2015

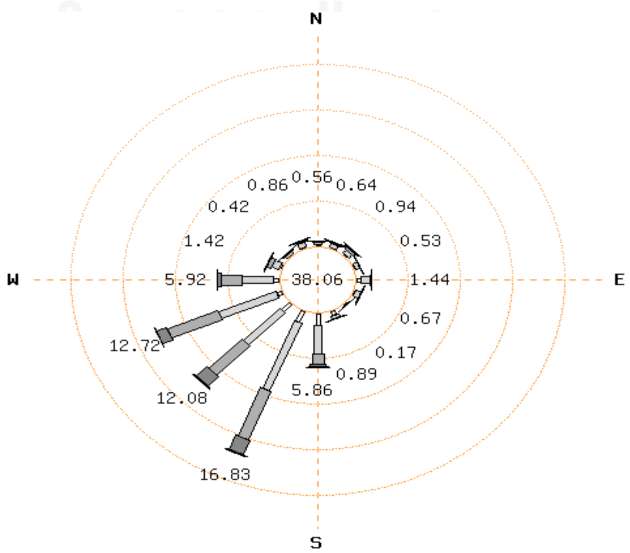


Figure A.21 Analyze metrological data into wind rose map during the recorded period of September 1995 – 2014 at Pattaya Meteorological Station

Table A.22 Collect data of wind speed and wind direction during the recorded period of October 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.19	0.62	1.00	0.23	0.03	0.00	2.07
NNE		0.48	2.45	2.58	1.29	0.24	0.03	7.07
NE		0.46	4.98	3.44	2.45	0.53	0.00	11.86
ENE		0.43	2.04	2.88	0.94	0.08	0.00	6.37
E		0.78	0.24	1.45	0.11	0.00	0.00	2.58
ESE		0.19	0.16	0.83	0.00	0.00	0.00	1.18
SE		0.06	0.00	0.13	0.00	0.00	0.00	0.19
SSE		0.32	0.03	0.56	0.03	0.00	0.00	0.94
S		1.05	0.43	1.64	0.16	0.03	0.00	3.31
SSW		0.75	1.34	2.40	0.32	0.03	0.00	4.84
SW		0.24	1.10	1.91	0.22	0.03	0.00	3.50
WSW		0.56	1.24	2.26	0.22	0.00	0.00	4.28
W		0.62	1.05	2.72	0.26	0.00	0.00	4.65
WNW		0.32	0.59	1.61	0.04	0.00	0.00	2.56
NW		0.06	0.56	0.70	0.08	0.03	0.00	1.43
NNW		0.38	0.54	1.08	0.12	0.00	0.00	2.12
Total	41.05	6.89	17.37	27.19	6.47	1.00	0.03	58.95

Source: Thai Meteorological Department, 2015

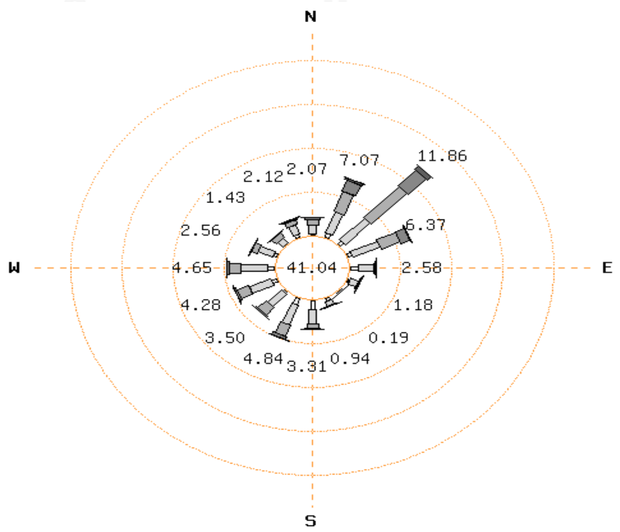


Figure A.22 Analyze metrological data into wind rose map during the recorded period of October 1995 – 2014 at Pattaya Meteorological Station

Table A.23 Collect data of wind speed and wind direction during the recorded period of November 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.27	1.39	1.39	0.42	0.06	0.00	3.53
NNE		0.47	3.86	6.22	4.42	0.58	0.06	15.61
NE		0.44	4.11	8.67	6.39	1.11	0.31	21.03
ENE		0.28	3.39	4.42	2.33	0.36	0.03	10.81
E		0.50	0.44	0.28	0.17	0.00	0.00	1.39
ESE		0.00	0.25	0.06	0.00	0.00	0.00	0.31
SE		0.05	0.03	0.00	0.00	0.00	0.00	0.08
SSE		0.17	0.22	0.00	0.00	0.00	0.00	0.39
S		0.53	0.64	0.03	0.08	0.00	0.00	1.28
SSW		0.34	1.44	0.72	0.19	0.00	0.00	2.69
SW		0.19	0.62	0.33	0.00	0.00	0.00	1.14
WSW		0.25	1.06	0.69	0.25	0.00	0.00	2.25
W		0.22	1.28	1.11	0.17	0.00	0.00	2.78
WNW		0.06	0.97	0.86	0.11	0.00	0.00	2.00
NW		0.06	0.82	0.75	0.06	0.00	0.00	1.69
NNW		0.36	1.67	1.61	0.33	0.00	0.00	3.97
Total	29.05	4.19	22.19	27.14	14.92	2.11	0.40	70.95

Source: Thai Meteorological Department, 2015

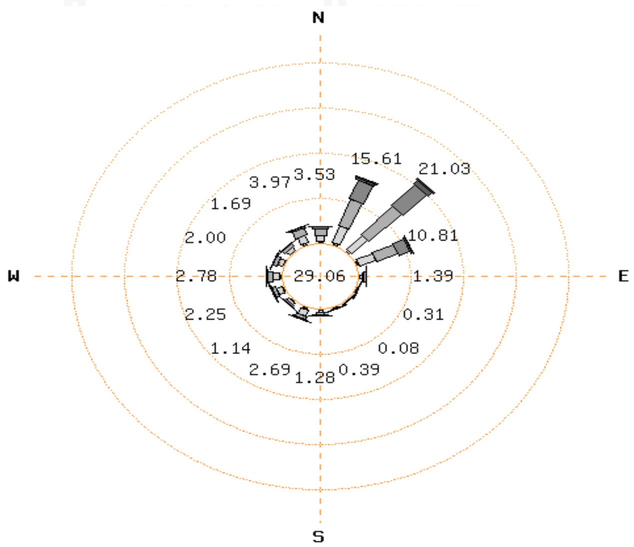


Figure A.23 Analyze metrological data into wind rose map during the recorded period of November 1995 – 2014 at Pattaya Meteorological Station

Table A.24 Collect data of wind speed and wind direction during the recorded period of December 1995 – 2014 at Pattaya Meteorological Station

Wind Direction	The percentage of wind speed (knots)							
	<1	1-3	4-6	7-10	11-16	17-21	22+	Total
N		0.32	2.04	1.26	0.73	0.00	0.00	4.35
NNE		0.54	4.41	5.40	4.01	0.67	0.08	15.11
NE		0.40	4.84	7.96	5.35	1.32	0.13	20.00
ENE		0.32	3.41	4.36	2.15	0.14	0.00	10.38
E		0.35	0.91	0.51	0.08	0.03	0.49	2.37
ESE		0.16	0.30	0.24	0.03	0.00	0.00	0.73
SE		0.00	0.11	0.05	0.00	0.00	0.00	0.16
SSE		0.13	0.27	0.25	0.00	0.00	0.00	0.65
S		0.73	1.13	0.30	0.05	0.02	0.00	2.23
SSW		0.22	1.05	0.32	0.16	0.00	0.00	1.75
SW		0.27	1.05	0.43	0.32	0.03	0.00	2.10
WSW		0.43	1.09	0.73	0.03	0.00	0.00	2.28
W		0.30	1.75	1.10	0.16	0.00	0.00	3.31
WNW		0.16	1.64	1.18	0.16	0.00	0.00	3.14
NW		0.05	0.97	0.94	0.51	0.05	0.00	2.52
NNW		0.22	1.88	2.93	0.86	0.00	0.00	5.89
Total	23.03	4.60	26.85	27.96	14.60	2.26	0.70	76.97

Source: Thai Meteorological Department, 2015

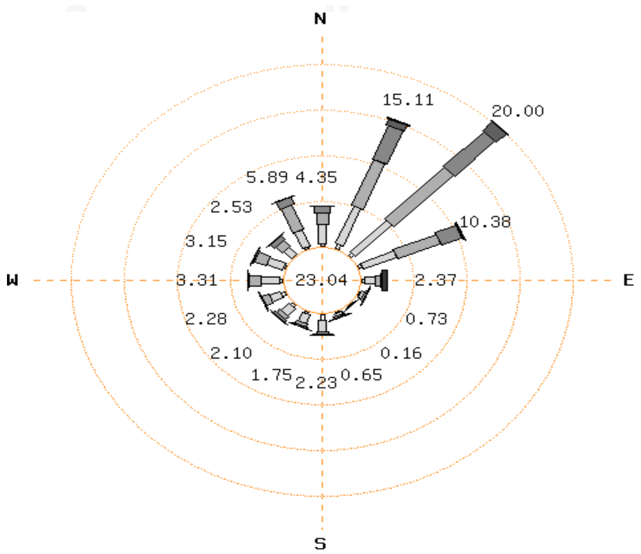


Figure A.24 Analyze metrological data into wind rose map during the recorded period of December 1995 – 2014 at Pattaya Meteorological Station

APPENDIX B

Procedure for using ArcGIS Desktop 9.3 to analyze the total number of affected population from hypothetical explosions of RDDs.

1. Adding layer data into ArcGIS Desktop 9.3 and select theme-specific options such as province, district boundaries, rivers, roads and the model of radiation dispersion as shown in Figure B.1 (.kml file from HotSpot analysis must be converted to .shp file).

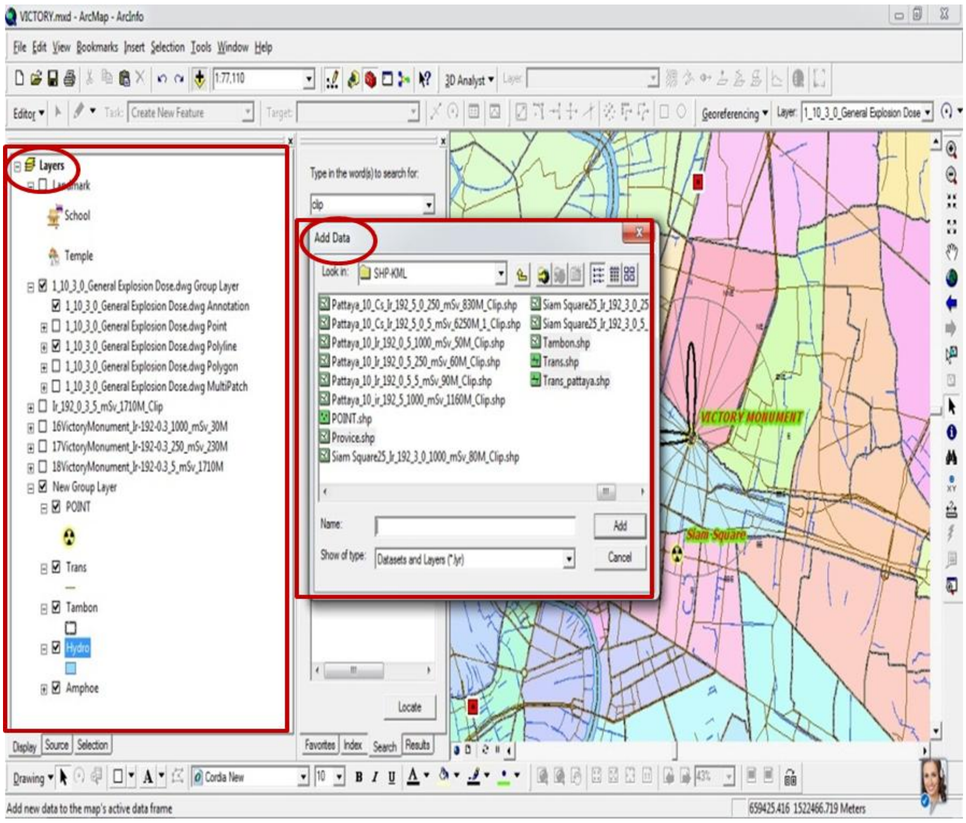


Figure B.1 Adding Layer data into ArcGIS Desktop 9.3

2. Using the "Buffer" command with all three distances based on the amount of radiation of 1,000, 250 and 5 mSv as shown in Figure B.2.

3. Using the "Clip" command to select the district area under the Buffer zone of each TEDE radiation level as shown in Figure B.3.

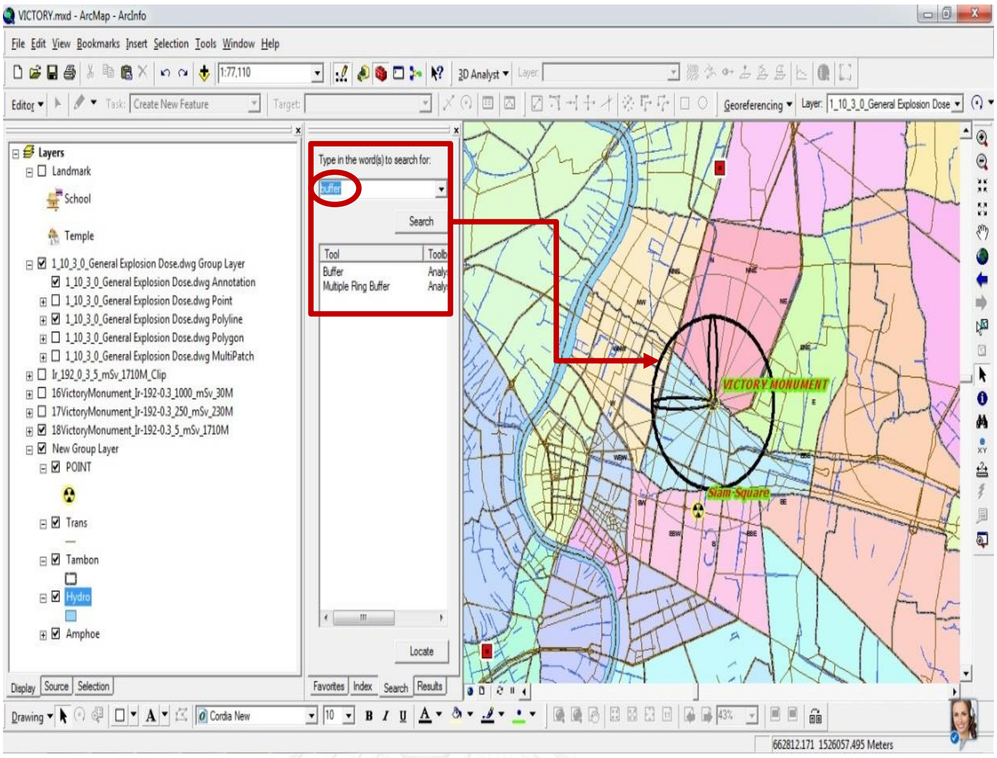


Figure B.2 Creating buffer zone

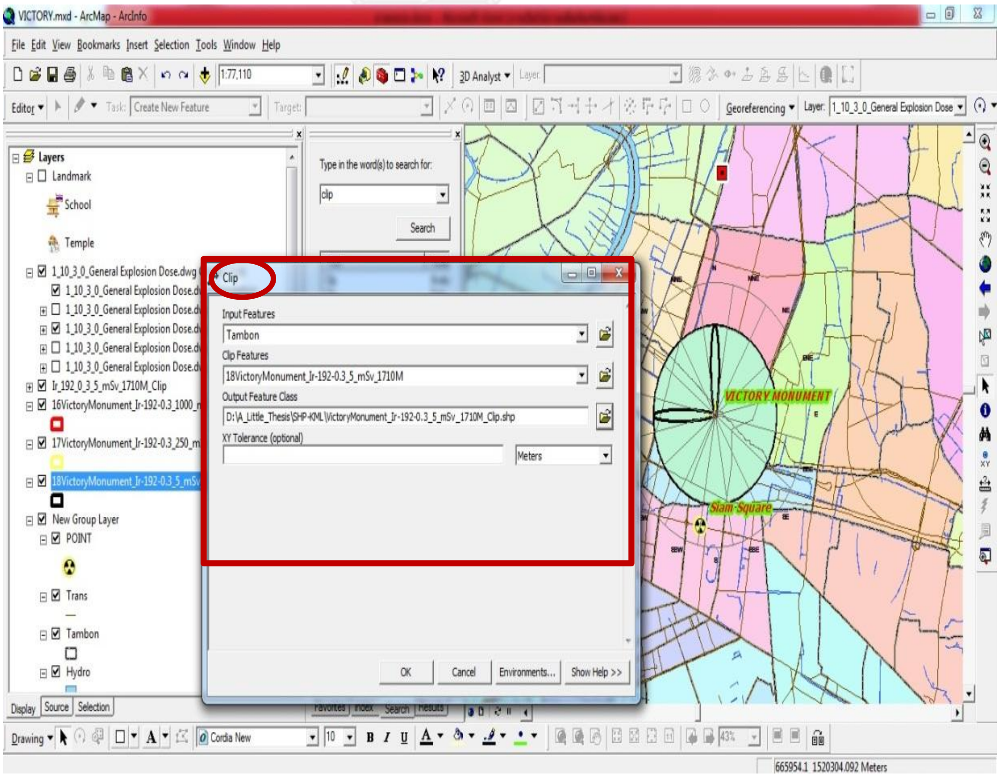


Figure B.3 Clipping the overlap area under the Buffer zone.

4. Determining the ratio of the clipped area to the total area of the district the clipped area is in as shown in Figure B.4.

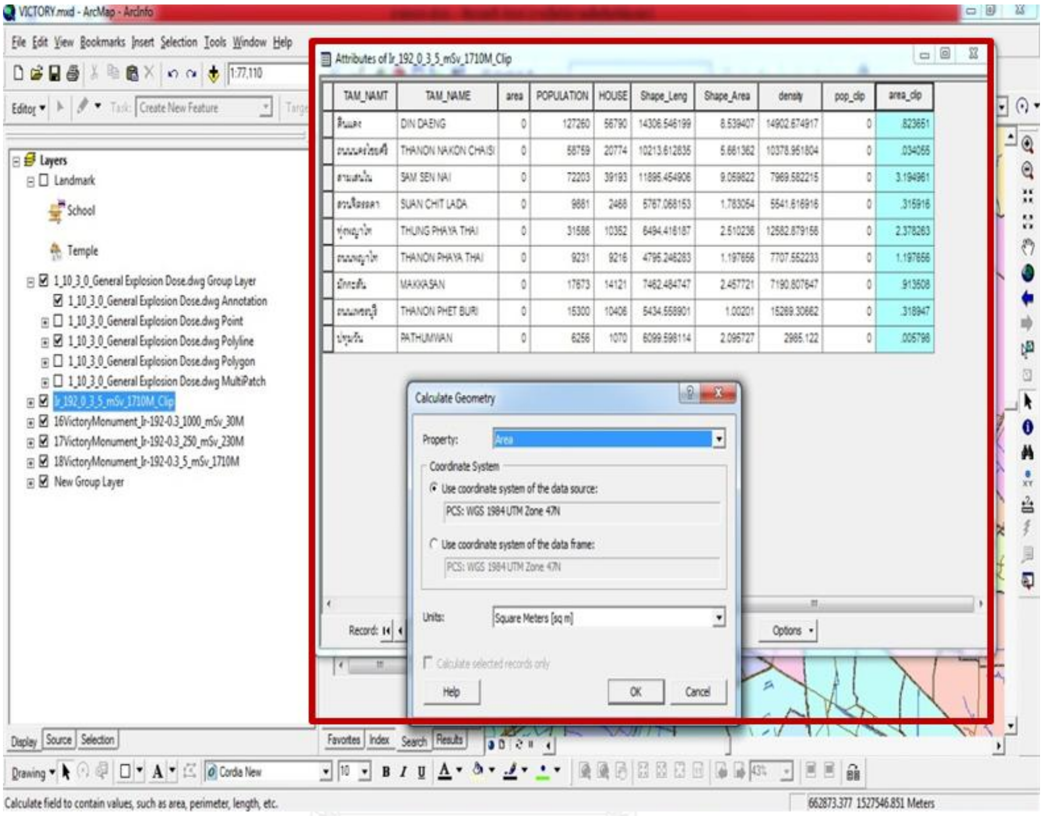


Figure B.4 Calculation of the clipped area to analyze the data.

5. Calculating the number of population in the affected area based on the ratio of areas determined in step 4 as shown in Figure B.5 (assuming that population is spatially distributed evenly in each district).

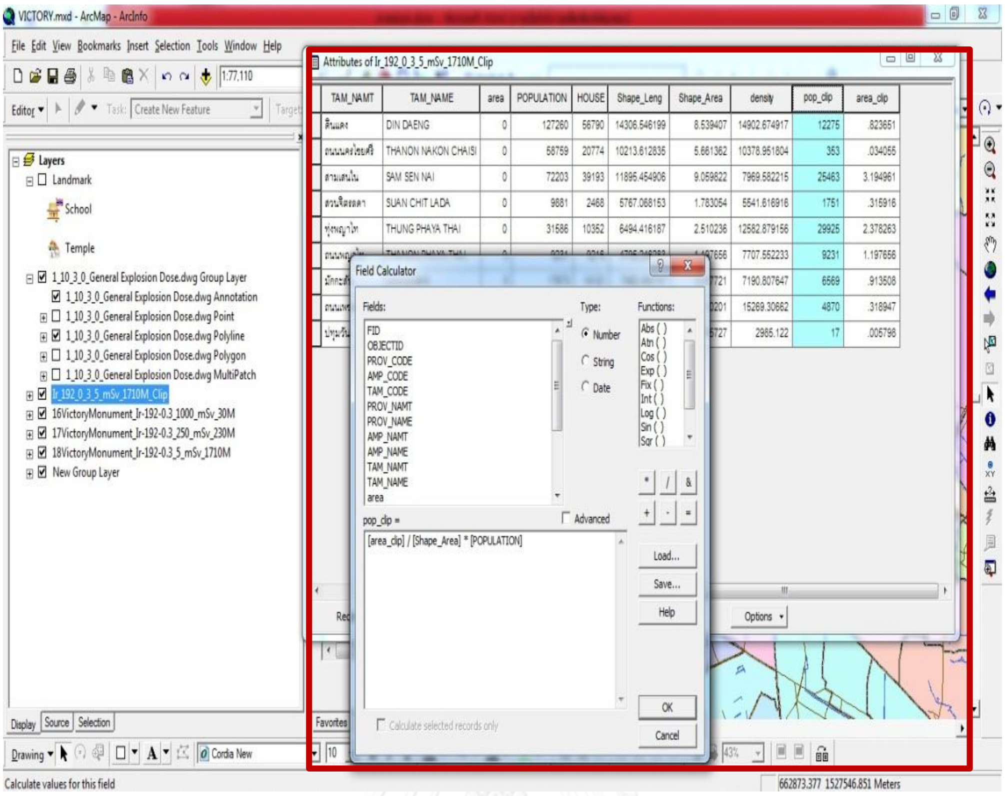


Figure B.5 Calculation of the number of population in affected area

VITA

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Date of Birth January 21, 2528

Place of birth Phuket, Thailand

History of education

Graduated with Bachelor's Degree in Engineering. Environmantal Engineering, Faculty of Engineering, Prince of Songkla University, 2008

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