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APPLICATION OF GOOGLE EARTH FOR UPDATING METROPOLITAN WATERWORKS AUTHORITY GIS

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A Thesis Submitted in Partial Fulfillment of the Requirements
for the Degree of Master of Engineering Program in Infrastructure in Civil Engineering
Department of Civil Engineering
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ระบบสารสนเทศทางภูมิศาสตร์เป็นระบบที่ถูกนำมาใช้อย่างแพร่หลายในหน่วยงานต่างๆ ไม่ว่าจะเป็นหน่วยงานราชการ หน่วยงานเอกชน หรือหน่วยงานรัฐวิสาหกิจ ทางการประปานครหลวงเป็นหน่วยงานรัฐวิสาหกิจที่สำคัญหน่วยงานหนึ่งที่ให้บริการทางด้านสาธารณูปโภค เพื่อการรองรับการเจริญเติบโตและการขยายตัวของผู้ใช้บริการ จึงได้นำระบบสารสนเทศทางภูมิศาสตร์เข้ามาใช้ในหน่วยงาน โดยพิจารณาถึงตำแหน่งและที่ตั้งเป็นสำคัญ กูเกิ้ล เอิร์ธจึงเป็นอีกทางเลือกหนึ่งเพื่อดำเนินการปรับปรุงแผนที่ของการประปานครหลวงให้มีความทันสมัยมากขึ้น

การวิจัยนี้มีวัตถุประสงค์เพื่อศึกษาเนื้อหาข้อมูลของการประปานครหลวงและกูเกิ้ล เอิร์ธ หาขบวนการความสัมพันธ์ค่าพิกัดพื้นหลักฐานของทั้งสองระบบ ปรับปรุงข้อมูลสารสนเทศภูมิศาสตร์ของการประปานครหลวงบนกูเกิ้ล เอิร์ธและนำข้อมูลไปประยุกต์ใช้ในระบบสารสนเทศภูมิศาสตร์ของการประปานครหลวง ในการดำเนินการวิจัยครั้งนี้เลือกสำนักงานการประปานครหลวง สาขาสมุทรปราการเป็นพื้นที่ทดลองในการปฏิบัติงานทางด้านการหากระบวนการปรับปรุงแผนที่ฐานของการประปานครหลวงมีพื้นที่จ่ายน้ำ 463.743 ตร.กม. ผู้ใช้น้ำ 149,473 ราย

ผลจากการวิจัย พบว่า กูเกิ้ล เอิร์ธมีเนื้อหาข้อมูลคล้ายคลึงกับระบบสารสนเทศภูมิศาสตร์ของการประปานครหลวง ขบวนการปรับแก้การซ้อนทับข้อมูลของทั้งสองระบบมีค่าเศษเหลือจากการแปลงค่าพิกัดพื้นหลักฐานน้อยมากสามารถนำขบวนการดังกล่าวไปใช้ในการปรับปรุงข้อมูลระบบสารสนเทศภูมิศาสตร์ของการประปานครหลวงได้ เพื่อช่วยในการตัดสินใจวางแผนงานโครงสร้างพื้นฐานและระบบการจัดการบริหารงานลดน้ำสูญเสีย อีกทั้งยังสามารถทำได้รวดเร็ว ถูกต้องและมีประสิทธิภาพ

ภาควิชา วิศวกรรมโยธา	ลายมือชื่อนิสิต
สาขาวิชาโครงสร้างพื้นฐานทางวิศวกรรมโยธา	ลายมือชื่ออ.ที่ปรึกษาวิทยานิพนธ์หลัก
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Geographic Information System (GIS) is a system widely used in many organizations such as government organizations, private organizations, and state enterprises. Metropolitan Waterworks Authority (MWA) is an important state enterprise providing public supply in order to support customer growth and rise. In order to support efficiently, MWA uses the Geometric Information System to develop the services focusing on positions and locations in particular. Accordingly, Google Earth is a choice for improving and keeping the map data of Metropolitan Waterworks Authority up to date.

The aim of the research is to study the map data of Metropolitan Waterworks Authority and Google Earth, examine the comparative study of datum coordinate of both systems and improve the GIS of MWA in Google Earth to apply the updated data to the GIS of MWA. In this research, the researcher selected Samutprakarn Branch Office of MWA as a test area to find an improving algorithm of MWA land base; the test area covers serviced areas approximately 463.743 Sq.km and there are customer connections around 149,473.

The result of the study reveals that Google Earth has the similarity of data to the GIS of MWA. The algorithm of editing the overlay of both data shows minimal residuals after performing the datum transformation which can be used to improve the GIS of MWA and help planning an infrastructure and water loss management system quickly, correctly and efficiently.

Department : Civil Engineering .... Student's Signature ....

Field of Study : Infrastructure in Civil Engineering Advisor's Signature ....

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CONTENTS

PAGE

PAGE

LIST OF TABLES

LIST OF FIGURES

FIGURE PAGE

FIGURE PAGE

FIGURE PAGE

FIGURE PAGE

LIST OF ABBREVIATIONS

SYMBOLS	MEANING
φ	geodetic latitude in local system
λ	geodetic longitude in local system
h	the distance of a point above or below the local ellipsoid measured along the ellipsoid normal through the point
a	semi-major axis of local ellipsoid
f	flattening of the local ellipsoid
ΔX	shifts between the centers of the local geodetic system and the WGS84 ellipsoid
ΔY	shifts between the centers of the local geodetic system and the WGS84 ellipsoid
ΔZ	shifts between the centers of the local geodetic system and the WGS84 ellipsoid
Δa	differences between the semi-major axis and the flattening of the local and WGS84 system
Δf	differences between the semi-major axis and the flattening of the local and WGS84 system
S	scale factor
θ	The rotation angle
x	coordinate system in x-axis
y	coordinate system in y-axis
x’	scaled coordinate system in x-axis
y’	scaled coordinate system in y-axis
X	coordinate system in x-axis has been superimposed on x’ , y’ system
Y	coordinate system in y-axis has been superimposed on x’ , y’ system
X’	rotated coordinate system in x-axis
Y’	rotated coordinate system in x-axis
T_x	Translation factors in x-axis

SYMBOLS	MEANING
Ty	Translation factors in y-axis
A	Matrix of A
X	Matrix of X
L	Matrix of L
V	Matrix of residuals value
t	The test statistic

CHAPTER I

INTRODUCTION

1.1 BACKGROUND AND PROBLEM STATEMENT

In the process of water loss management, there are many methods to reduce the water loss. Basic physical information system is one of successful and effective methods of Metropolitan Waterworks Authority (MWA) because the basic physical information system can manage the basic physical information of district metering area (DMA), for example, survey data, year of using material (such as pipe lines of water-supply materials).

In the future, the management of consumed water is necessary for supporting communities in any aspects such as lining the water main and serviced pipes to accommodations, factories and authorities because urbanized areas are rapidly expanding to rural areas and countryside and the number of populations are continuously rising as well. According to the civilization and population growth, it is necessary to use maps and geographic information system for analyzing, managing, and planning all water supply systems.

Nowadays, after improving the maps of Metropolitan Electricity Authority (MEA) which have divided to each branch, the information will be sent to the engineering standard and mapping department for processing in an applied program, Editor Tool, developed from Arc view program for easier using. Some maps used in this applied program are not appropriate to the area at present. Some areas in the program have not construction or road land base. The land base is still out of date data that cannot be improved. MWA has to wait for the new land base map information from the engineering standard and mapping department which will be delivered from MEA. According that some of information from the engineering standard and mapping department may be lost, not correct, or hard to verify again. For instance, some of water meters in some areas have not been recorded in the GIS of WMA because the system has no land base. Free orthophotographic map is a service of Google Earth Program that gives the similar data to the map showed in the applied program used by MWA. But the problem is how to compare the pipelines, road and other information from the applied program and the Google Earth Program; it is unclear whether both of the information is correct.

Method of bringing basic layer from MWA and processing in the Google Earth Program firstly shows that the layer of MWA is not the same as the information from Google Earth Program; especially in positions.

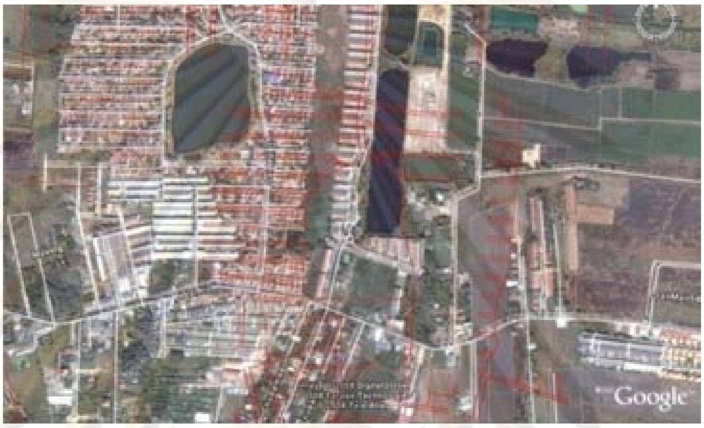


Figure 1.1 The layer of MWA is not overlaid with the Google Earth information.

Picture from the applied program used by MWA shows that the white areas in the map have incomplete building layer, The basic information system should be correct and complete in order to decide a plan for infrastructure of MWA in the rapidly expanding urbanized area, and take less time.

Figure 1.2 Google Earth Program can help to improve the information from MWA.

1.2 OBJECTIVES

1. To compare information contents of Metropolitan Waterworks Authority GIS and free map service application of Google Earth.
2. To determine the process for the relation of map reference between the two systems.
3. To update the Metropolitan Waterworks Authority GIS data overlaid on Google Earth and apply the developed method on the new data.
4. To evaluate the methodology and make a conclusion.

1.3 SCOPE

In order to complete this research successfully, it is necessary to focus on the scope of the research as following.

1. Specify the tested areas which are the Samutprakarn branch of Metropolitan Waterworks Authority; they are divided into 78 sub-areas in according to DMA. Collect the information and study layers of the areas with the help of Google Earth and the application of MWA.
2. The layers used for the research can be classified into various categories; the layer of building, the layer of curbside, the layer of surface water such as canals, ditches, ponds and etc. This research aims to improve the base map only in the scope of building layer.
3. Use the two-dimensional conformal coordinate transformation and two-dimensional affine coordinate transformation for calculating the systematic error and model building.
4. Use the principles of statistic called "NSSDA" (The National Standard for Spatial Data Accuracy to measure and report geographic data quality), which was studied and developed by the Governor's Council on Geographic Information, to assess the accuracy of information after improving the base map. According to the assessment of the improved base map by Google Earth, the NSSDA result must reach the particular standard which can be acceptable for mapping.

5. Google Earth program used for supporting this research is the version of 4.2 Google Earth which can be downloaded for free.

1.4 RATIONAL AND THEORY OR HYPOTHESIS

Free map services of Google Earth are available and have potential for updating MWA GIS that applying free map services to the MWA GIS could improve rapid updating of MWA data. Quite often there is more land base on Google Earth.

However, the aims of this thesis are to study the method of processing the MWA GIS by using the Google Earth, and analyzing how much difference of the both systems for updating and applying in the Geographic information system of MWA.

1.5 METHODOLOGY

1. Study details of MWA's map layers from the applied program, Editor Tools.
2. Study free map services from Google Earth program.
3. Study the relation of the Editor Tool and Google Earth.
4. Transform the information from MWA and compare to the information from Google Earth.
5. Evaluate adapting method and improving the information.

1.6 LITERATURE REVIEW

Definition of GIS

According to Britannica Concise Encyclopedia (2006), Computerized system that relates and displays data collected from a geographic entity in the form of a map. The ability of GIS to overlay existing data with new information and display it in colour on a computer screen is used primarily to conduct analyses and make decisions related to geology, ecology, land use, demographics, transportation, and other domains, most of which relate to the human use of the physical environment. Through the process of geocoding, geographic data from a database is converted into images in the form of maps.

Wikipedia the free encyclopedia (2009), A geographic information system (GIS) (also known as geographical information system, particularly in the UK, and geomatics in Canada) is a system for capturing, storing, analyzing and managing data and associated attributes which are spatially referenced to the earth. In the strictest sense, it is a computer system capable of integrating, storing, editing, analyzing, sharing, and displaying geographically-referenced information. In a more generic sense, GIS is a tool that allows users to create interactive queries (user created searches), analyze the spatial information, edit data, maps, and present the results of all these operations. Geographic information science is the science underlying the geographic concepts, applications and systems, taught in degree and GIS Certificate programs at many universities.

History of development

According to Wikipedia the free encyclopedia (2009), About 15,500 years ago, on the walls of caves near Lascaux, France, Cro-Magnon hunters drew pictures of the animals they hunted. Associated with the animal drawings are track lines and tallies thought to depict migration routes. While simplistic in comparison to modern technologies, these early records mimic the two-element structure of modern geographic information systems, an image associated with attribute information.

In 1854, John Snow depicted a cholera outbreak in London using points to represent the locations of some individual cases, possibly the earliest use of the geographic method. His study of the distribution of cholera led to the source of the disease, a contaminated water pump (the Broad Street Pump, whose handle he disconnected terminating the outbreak) within the heart of the cholera outbreak.

While the basic elements of topography and theme existed previously in cartography, the John Snow map was unique, using cartographic methods not only to depict but also to analyze clusters of geographically dependent phenomena for the first time.

The early 20th century saw the development of "photo lithography" where maps were separated into layers. Computer hardware development spurred by nuclear weapon research would lead to general purpose computer "mapping" applications by the early 1960s.

The year 1962 saw the development of the world's first true operational GIS in Ottawa, Ontario, Canada by the federal Department of Forestry and Rural Development. Developed by Dr. Roger Tomlinson, it was called the "Canada Geographic Information System" (CGIS) and was used to store, analyze, and manipulate data collected for the Canada Land Inventory (CLI) an initiative to determine the land capability for rural Canada by mapping information about soils, agriculture, recreation, wildlife, waterfowl, forestry, and land use at a scale of 1:50,000. A rating classification factor was also added to permit analysis. CGIS was the world's first "system" and was an improvement over "mapping" applications as it provided capabilities for overlay, measurement, and digitizing/scanning. It supported a national coordinate system that spanned the continent, coded lines as "arcs" having a true embedded topology, and it stored the attribute and locational information in separate files. As a result of this, Tomlinson has become known as the "father of GIS," particularly for his use of overlays in promoting the spatial analysis of convergent geographic data. CGIS lasted into the 1990s and built the largest digital land resource database in Canada. It was developed as a mainframe based system in support of federal and provincial resource planning and management. Its strength was continent-wide analysis of complex datasets. The CGIS was never available in a commercial form.

In 1964, Howard T Fisher formed the Laboratory for Computer Graphics and Spatial Analysis at the Harvard Graduate School of Design (LCGSA 1965-1991), where a number of important theoretical concepts in spatial data handling were developed, and which by the 1970s had distributed seminal software code and systems, such as 'SYMAP', 'GRID', and 'ODYSSEY' -- which served as literal and inspirational sources for subsequent commercial development to universities, research centers, and corporations worldwide.

By the early 1980s, M&S Computing (later Intergraph), Environmental Systems Research Institute (ESRI) and CARIS (Computer Aided Resource Information System) emerged as commercial vendors of GIS software, successfully incorporating many of the CGIS features, combining the first generation approach to separation of spatial and attribute information with a second generation approach to organizing attribute data into database structures. In parallel, the development of two public domain systems began in the late 1970s and early 1980s. MOSS, the Map Overlay and Statistical System project started in 1977 in Fort Collins, Colorado under the auspices of the Western Energy and Land Use Team (WELUT) and the US Fish and Wildlife Service. GIS was begun in 1982 by the U.S. Army Corp of Engineering Research Laboratory (USA-CERL) in Champaign, Illinois, a branch of the U.S. Army Corps of Engineers to meet the need of the United States military for software for land management and environmental planning. The later 1980s and 1990s industry growth were spurred on by the growing use of GIS on Unix workstations and the personal computer. By the end of the 20th century, the rapid growth in various systems had been consolidated and standardized on relatively few platforms and users were beginning to export the concept of viewing GIS data over the Internet, requiring data format and transfer standards. More recently, there are a growing number of free, open source GIS packages which run on a range of operating systems and can be customized to perform specific tasks.

Applications

According to Wikipedia the free encyclopedia (2009), Geographic information system technology can be used for scientific investigations, resource management, asset management, archaeology, environmental impact assessment, urban planning, cartography, criminology, geographic history, marketing, logistics, and other purpose. For example, GIS might allow emergency planners to easily calculate emergency response times in the event of a natural disaster, GIS might be use to find wetlands that need protection from pollution, or GIS can be use by a company to site a new business location to take advantage of a previously under-served market.

GIS software

According to Wikipedia the free encyclopedia (2009), Geographic information can be accessed, transferred, transformed, overlaid, processed and displayed using numerous software applications. Within industry, commercial offerings from companies such as Smallworld, Manifold system, ESRI, Intergraph, Mapinfo and Autodesk dominate, offering an entire suite of tools. Government and military departments often use custom software, open source products, such as GRASS, or more specialized products that meet a well defined need. Although free tools exist to view GIS database, public access to geographic information is dominated by online resources such as Google Earth and interactive web mapping.

GIS processing software is used for the task of preparing data for use within a GIS. This transforms the raw or legacy geographic data into a format usable by GIS products. For example an aerial photograph may need to be stretched (orthorectified) using photogrammetry so that its pixels align with longitude and latitude gradations (or whatever grid is needed). This can be distinguished from the transformations done within GIS analysis software by the fact that these changes are permanent, more complex and time consuming. Thus, a specialized high-end type of software is generally used by a person skilled in Remote Sensing and / or GIS processing aspects of computer science. In addition, AutoCAD, normally used for drafts of engineering projects, can be configured for the editing of vector maps, and has some products that have migrated towards GIS use. It is especially useful as it has strong support for digitization. Raw geographic data can be edited in many standard database and spreadsheet applications and in some cases a text editor may be used as long as care is taken to properly format data.

Free and open-source GIS software

Many GIS tasks can be accomplished with free or open-source software. With the broad use of non-proprietary and open data formats such as the shape file format for vector data and the Geotiff format for raster data, as well as the adoption of OGC standards for networked servers, development of open source software continues to evolve, especially for web and web service oriented applications. Well-know open source GIS software includes GRASS GIS, Quantum GIS, MapServer, uDig, OpenJump, gvSIG and many others (e.g., see OSGeo or MapTools).

Much open source GIS development has focused on the creation of libraries that provide functionality for third party applications. Such libraries include GDAL/OGR and GeoTools. These libraries are used by open source and proprietary software alike to provide basic functionality.

Map overlay

According to Wikipedia the free encyclopedia (2009), The combination of several spatial datasets (points, lines or polygons) creates a new output vector dataset, visually similar to stacking several maps of the same region. These overlays are similar to mathematical Venn diagram overlays. A union overlay combines the geographic features and attribute tables of both inputs into a single new output. An intersect overlay defines the area where both inputs overlap and retains a set of attribute fields for each. A symmetric difference overlay defines an output area that includes the total area of both inputs except for the overlapping area.

Data extraction is a GIS process similar to vector overlay, though it can be used in either vector or raster data analysis. Rather than combining the properties and features of both datasets, data extraction involves using a "clip" or "mask" to extract the features of one data set that fall within the spatial extent of another dataset.

In raster data analysis, the overlay of datasets is accomplished through a process known as "local operation on multiple rasters" or "map algebra," through a function that combines the values of each raster's matrix. This function may weigh some inputs more than others through use of an "index model" that reflects the influence of various factors upon a geographic phenomenon.

Chatchai N. (2007) has studied about the application of Google Earth as well as the water management and found that the Google Earth can be cooperated with the GIS efficiently; it not only offers more excellent potential for accessing the data, but also adding the value of the data as well. An obstacle of using the Google Earth helping for updating the base map of MWA is the need of comparison between the existing data layers of MWA and the orthophotos of Google Earth, in which the Indian-Datum-1975 data layers of MWA must be overlaid on the WGS 84 data layers of Google Earth.

In the study of Mahapatra et al. (2004) about updation and positional accuracy improvement with the help of transformation using weight proportional to the area of triangle. These methods have changed the notion that old vector data cannot be used for new mapping/updation. A set of rotation, scaling & translation factors were calculated based on least square method technique, which will transform original feature to the transformed feature. These parameters may be modified to take higher order transformation. But using higher order will allow bending of objects (which spans across several triangles), thus improving relative accuracy but geometric errors gets introduced. The original object is transformed with these rotation, scaling and translation parameters, to re-establish original geometry. Positional Accuracy Improvement (PAI) This process assumes existing data is relatively correct and Geometric/Absolute accuracy is within specified tolerance limits. In this process, attempt is made to improve the accuracy of existing data. The user must specify the amount of displacement required at several well distributed points throughout the map using the available information form ground survey or latest orthophoto or stereo model. Positional Accuracy Improvement (PAI) requires a special kind of transformation to the vector data to improve the overall accuracy with minimal change to the following accuracies. The allowable limit varies depending upon the scales of data sets, but the basic principles remains the same.

Relative accuracy: It is a measure of how close is the distance of a line measured on map agrees with the corresponding distance measured on ground.

Absolute accuracy: It is a measure of how close is the coordinate of a point on map agrees with the corresponding coordinate of the point measured on ground.

Geometric fidelity: It is a measure of how closely the feature on the map matches the real-world shape and alignment.

Figure 1.3 The left figure shows before PAI and right after PAI operations.

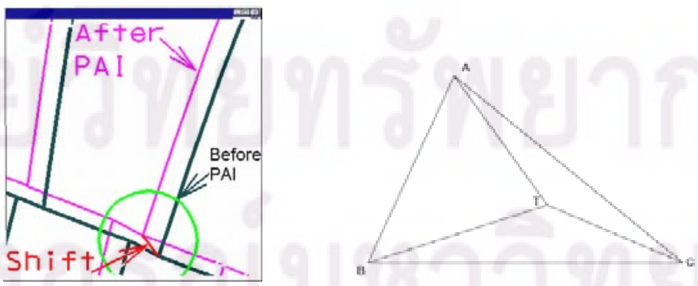


Figure 1.4 Transformation before and after PAI, The right figure shows Weight proportional to the area of triangle formed with two other vertices.

The problem of how the positional accuracy of legacy datasets can be improved through integrating new, higher accuracy data has been addressed with regards to land parcel databases (Merrit and Masters, 1999; Tamim and Schaffrin, 1995). The approach has been to use techniques based on least squares adjustment to obtain the optimal fit between the new data and the existing dataset. The advantage of such an approach is that positions are optimized taking into account all of the available information, including the quality of the data points. In addition, updated positional accuracy parameters are generated for each point, enabling reporting of local quality measures.

A further benefit of using a least squares based approach is that additional information can be incorporated into the adjustment. For example, it is possible to include constraints based on geometric properties of the dataset, such as parallel lines, right angles or known areas (Hesse et al., 1990; Tong et al., 2005). These geometric constraints provide additional information to the adjustment process, resulting in better feature positioning. Accordingly, software has been developed for positional accuracy improvement of well-defined feature sets, such as the land parcel database, using techniques based on the method of least squares. In addition to improving positional accuracy, this software also provides updated local positional accuracy parameters.

Tom Timms, Giles D'Souza and Rajesh Kalra (2003) explain the background and effects of Ordnance Survey's new positional accuracy improvement programme on your data, and outline ways you can handle the changes. Ordnance Survey's new programme OS 1:2,500 scale mapping in rural areas was derived from County Series maps reconciled to the National Grid by a manual overhaul procedure. Potential problems with this mapping have been known for many years, and absolute positional errors of up to 13 metres have been discovered. In April 2001, OS started the positional accuracy improvement (PAI) programme, with the aim of bringing all of the 1:2,500-scale data within a uniform resurvey specification within five years. This programme entails the manual editing of detail on OS maps; in some cases blocks of detail are shifted and rotated by several metres. In consultation papers, OS undertook to liaise closely with customers throughout the programme and advised that the overall timescale of the programme would be tailored to the needs of major users. The PAI programme was split into two parts – Rural Towns and Other Rural Areas. The Rural Towns programme covers some 2,300 1:2,500 map data tiles, while the Other Rural Areas account for some 155,000 1:2,500 map data tiles. PAI in these latter areas will be achieved by methods that involve resurveying or photogrammetric interpretation. The resulting data should have an absolute accuracy of +/- 1.1 metres RMSE (Root Mean-Square Error). Priority has been placed on those areas requiring the most urgent rural revision update. The full programme is planned to be completed in five years, coinciding with the rural revision cycle that also began in April 2001.

Sue Hope, Allison Kealy and Gary Hunter (2006) has studied about Improving positional accuracy and preserving topology through spatial data fusion. The least squares based techniques designed to improve positional accuracy of spatial datasets as higher quality data are integrated are limited in application to well-defined features. Extending them to features that are not well-defined will require the development of methods to match points across the feature representations. If done successfully, this will enable positional accuracy improvement of existing datasets, as well as the generation of measures reporting local variation in accuracy. In addition, it is proposed that some topological relations may be modelled as constraints in the adjustment process, resulting in the preservation of topology as datasets are adjusted. The left hand side of Figure 1.5 illustrates the current state of affairs with regards to positional accuracy improvement as applied to features that are well-defined points. The right hand side portrays the focus of the current research, in extending this methodology to datasets that are not necessarily well-defined points. Note that the current research assumes that corresponding features in the two datasets have already been identified. The tasks that are the focus of this research are firstly, to match points within these corresponding features and secondly, to develop constraints from topological relationships between features.

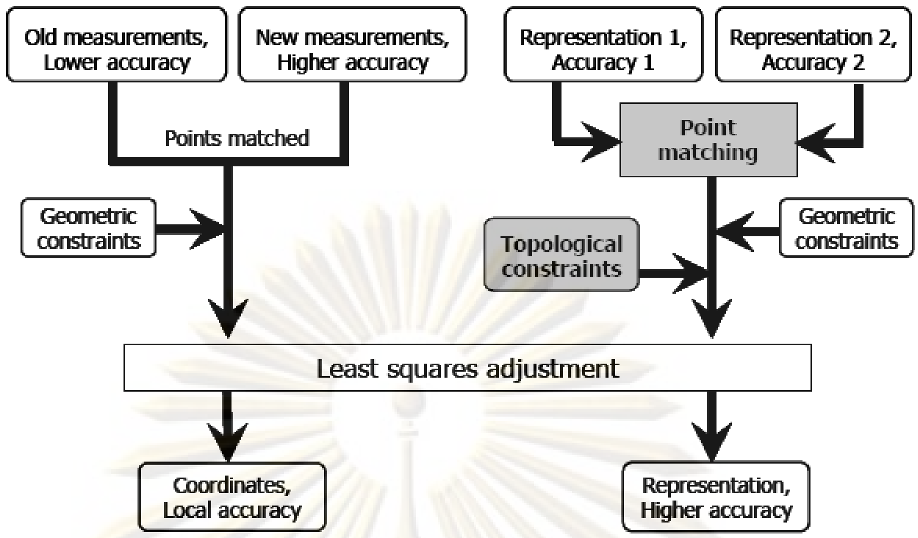


Figure 1.5 The methodology research of Improving positional accuracy and preserving topology through spatial data fusion.

Positional Accuracy

Ken Johnson, Mike Lalla and Mike Schauer, (1999) applying the NSSDA to large-scale data set. This project evaluates the accuracy of topographic and digital terrain model data sets created using photogrammetric techniques. The Minnesota Department of Transportation's photogrammetric unit produces these data sets, which are used within the agency to plan and design roadways and roadway improvements. The horizontal accuracy of the topographic data set was tested. Although the elevation contours of the topographic data set do record vertical data, a different data set, a Digital Terrain Model, was used to test vertical accuracy, as DTMs tend to be more accurate. DTMs are used to compute complex solutions dealing with design issues such as material quantities and hydraulics. To rely on these solutions, understanding the accuracy of the DTM is crucial.

Point number	z (test) Photo elev	z (independent) Field elev	diff in z Photo field	(diff in z)^2
100	293.755	293.79	-0.035	0.001202
101	293.671	293.71	-0.039	0.001515
102	293.87	293.9	-0.03	0.000913
103	293.815	293.85	-0.035	0.001241
104	294.609	294.62	-0.011	0.000113
105	295.238	295.3	-0.062	0.003834
106	295.54	295.56	-0.02	0.000394
107	295.28	295.3	-0.02	0.000385
108	294.933	295	-0.067	0.004465
109	294.431	294.46	-0.029	0.000847
110	293.994	294.02	-0.026	0.000664
111	293.736	293.77	-0.034	0.001131
112	293.537	293.58	-0.043	0.001886
113	293.478	293.55	-0.072	0.005164
114	293.671	293.7	-0.029	0.000858
590	261.801	261.84	-0.039	0.001513
592	263.428	263.42	0.008	0.00007
593	256.949	256.93	0.019	0.000352
594	256.853	256.82	0.033	0.001105
595	255.766	255.72	0.046	0.002095
596	256.411	256.39	0.021	0.000441
597	256.12	256.14	-0.02	0.000414
598	258.249	258.3	-0.051	0.002645
599	258.395	258.46	-0.065	0.004161
600	258.414	258.46	-0.046	0.002159
			sum	1.375
			average	0.005
			RMSEz	0.068
			NSSDA	0.134

Table 1.1 Vertical accuracy statistic worksheet.

(Ken Johnson, Mike Lalla and Mike Schauer,1999: 10)

Point number	Point description	x (independent)	x (test)	diff in x	(diff in x)^2	y (independent)	y (test)	diff in y	(diff in y)^2	(diff in x)^2 + (diff in y)^2
1	TP1A	178247.28	178247.37	-0.089	0.007921	48326.078	48326.138	-0.06	0.0036	0.011521
2	TP2	178249.23	178249.17	0.055	0.003025	48287.228	48287.171	0.057	0.003249	0.006274
3	TP3A	178456.79	178456.73	0.06	0.0036	48337.408	48337.283	0.125	0.015625	0.019225
4	TP4	178715.82	178715.88	-0.054	0.002916	48542.511	48542.543	-0.032	0.001024	0.00394
5	TP5	179047.54	179047.65	-0.104	0.010816	48657.388	48657.44	-0.052	0.002704	0.01352
6	TP6	179227.76	179227.8	-0.016	0.000256	48336.177	48336.147	0.03	0.0009	0.001156
7	TP7	179238.56	179238.69	-0.132	0.017424	48671.457	48671.48	-0.023	0.000529	0.017953
9	TP9	180257.36	180257.39	-0.033	0.001089	48337.972	48337.97	0.002	4E-06	0.001093
10	SWK	180426.36	180426.36	0.005	2.5E-05	48445.001	48444.917	0.084	0.007056	0.007081
11	DI	180568.35	180568.48	-0.128	0.016384	48523.693	48523.696	-0.003	9E-06	0.016393
12	TP12A	180680.73	180680.78	-0.053	0.002809	48275.075	48274.978	0.097	0.009409	0.012218
13	SW	180676.31	180676.38	-0.076	0.005776	48413.085	48413.154	-0.069	0.004761	0.010537
14	TP14	180654.46	180654.47	-0.01	0.0001	47955.055	47954.992	0.063	0.003969	0.004069
15	MH	180843.48	180843.56	-0.083	0.006889	48505.391	48505.548	-0.157	0.024649	0.031538
17	TP17	181338.97	181339.11	-0.141	0.019881	48313.103	48313.244	-0.141	0.019881	0.039762
18	TP18	181283.2	181283.25	-0.051	0.002601	48174.063	48174.057	0.006	3.6E-05	0.002637
19	TP19	181075.07	181075.09	-0.018	0.000324	48171.737	48171.637	0.1	0.01	0.010324
20	TP20A	181495.79	181495.85	-0.057	0.003249	48043.414	48043.497	-0.083	0.006889	0.010138
21	TP21	181676.58	181676.59	-0.009	8.1E-05	48242.779	48242.744	0.035	0.001225	0.001306
22	TP22	181673.86	181673.82	0.044	0.001936	48579.533	48579.693	-0.16	0.0256	0.027536
24	TP24	181937.26	181937.3	-0.045	0.002025	48136.264	48136.256	0.008	6.4E-05	0.002089
26	TP26	182085.95	182085.96	-0.004	1.6E-05	48127.717	48127.778	-0.061	0.003721	0.003737
27	TP27	182243.61	182243.57	0.041	0.001681	48032.915	48032.879	0.036	0.001296	0.002977
28	TP28	182289.49	182289.56	-0.065	0.004225	48729.272	48729.211	0.061	0.003721	0.007946
29	TP29	182259.51	182259.63	-0.122	0.014884	48930.614	48930.707	-0.093	0.008649	0.023533
30	TP30	182277.52	182277.57	-0.053	0.002809	48410.278	48410.398	-0.12	0.0144	0.017209
32	TP32	182590.79	182590.88	-0.095	0.009025	48437.482	48437.633	-0.151	0.022801	0.031826
33	TP33	182494.13	182494.22	-0.099	0.009801	48422.78	48422.862	-0.082	0.006724	0.016525
34	TP34	182410.21	182410.24	-0.027	0.000729	48672.544	48672.564	-0.02	0.0004	0.001129
35	TP35	182740.18	182740.15	0.027	0.000729	48307.436	48307.447	-0.011	0.000121	0.00085
36	TP36	182771.78	182771.77	0.015	0.000225	47967.3	47967.292	0.008	6.4E-05	0.000289
37	TP37	183067.28	183067.27	0.014	0.000196	48044.513	48044.539	-0.026	0.000676	0.000872
38	TP38	183242.23	183242.18	0.048	0.002304	47982.797	47982.798	-0.001	1E-06	0.002305
39	TP39	183458.2	183458.24	-0.035	0.001225	47885.194	47885.162	0.032	0.001024	0.002249
40	TP40	183778.2	183778.26	-0.059	0.003481	48230.799	48230.753	0.046	0.002116	0.005597
41	TP41	183886.38	183886.4	-0.019	0.000361	47924.349	47924.264	0.085	0.007225	0.007586
42	TP42	184394.5	184394.54	-0.031	0.000961	48083.648	48083.657	-0.009	8.1E-05	0.001042
43	TP43A	184644.38	184644.44	-0.059	0.003481	48068.904	48068.751	0.153	0.023409	0.02689
44	TP44	184804.19	184804.35	-0.16	0.0256	48192.963	48192.891	0.072	0.005184	0.030784
45	TP45	185120.62	185120.67	-0.054	0.002916	48201.523	48201.505	0.018	0.000324	0.00324
									sum	0.436896
									average	0.0109224
									RMSE	0.10451029
									NSSDA	0.1808864

Table 1.2 Horizontal accuracy statistic worksheet.

(Ken Johnson, Mike Lalla and Mike Schauer,1999: 11)

The positional accuracy statistic

The vertical root mean square error is shown as a linear error. In table 1.1 the vertical RMSE is 0.068 m. The horizontal RMSE deals with two dimensions giving x and y coordinates. Using the equation of a circle: $x^2 + y^2 = r^2$ and modifying it slightly into

$$(X\ \text{independent} - X\ \text{test})^2 + (Y\ \text{independent} - Y\ \text{test})^2 = r_{\text{error}}^{2}$$

the error radius is found for each coordinate. The horizontal RMSE is calculated by adding up the radius errors, averaging them and taking the square root. This gives a circular error defined by the radius. The horizontal RMSE in table 1.2 is a circle defined by a radius of 0.105 m. The NSSDA requires a 95 percent confidence level. To attain this, the vertical RMSE is multiplied by 1.96 and the horizontal RMSE is multiplied by 1.7308, resulting in horizontal and vertical accuracies of 0.181 and 0.134 meters respectively.

The accuracy statement and metadata

Table 1.1 contains formal NSSDA reports for both the horizontal and vertical positional accuracy measured for this project.

Observations and comments

A couple of concerns were raised in applying the NSSDA to this data set. First, the field test shots need to be points that have been placed on the map. For this project, the field crew substituted a few points that had not been originally placed on the topographic maps, so these were not considered. The second concern dealt with map symbol placement, origin and scale. For example, with a map symbol such as a catch basin, the origin is the lower left corner. The field crew may have collected the control point using the center of the catch basin, and even if they used the correct corner, the scaled size may be different. This type of systematic error could have a major impact on the accuracy statement of this project.

Positional accuracy statements as reported in metadata.

Horizontal positional accuracy

Using the National Standard for Spatial Data Accuracy, the data set tested 0.181 meters horizontal accuracy at 95% confidence level.

Vertical positional accuracy

Using the National Standard for Spatial Data Accuracy, the data set tested 0.134 meters vertical accuracy at 95% confidence level.

Don Elwood , Tara Mugan and Lisa Zick , (1999) applying the NASSDA to contract service work. The city of Minneapolis uses its planimetric database for a variety of engineering and planning purposes. In this project, it provided a photo control to produce a digital orthophoto database for the city. Presently, about two thirds of Minneapolis is covered with high-resolution color digital orthophotographs. The primary use for this database is to identify changes over time and transfer them to the planimetric database. Updated planimetry is digitized from digital orthophotos into the planimetric database. A precise match between the orthophoto products and the planimetric database is critical as design crews use the planimetric database and orthophotos for street design plans. For this reason, it was a worthwhile investment to develop a positional accuracy estimate for digital orthophotos using the NSSDA.Shown in figure 1.6 Portion of a Minneapolis control quality map identifying the magnitude and direction of differences between city monuments and corresponding vendor supplied data.

Point number	x (inde-pendent)	x (test)	diff in x	(diff in x)^2	y (inde-pendent)	y (test)	diff in y	(diff in y)^2	(diff in x)^2 + (diff in y)^2
3234	542850.895	542850.872	0.023	0.000529	152223.812	152223.840	-0.028	0.000784	0.001313
3062	522260.248	522260.211	0.037	0.001369	138937.691	138937.700	-0.009	8.1E-05	0.00145
118	541542.816	541542.781	0.035	0.001225	141704.350	141704.309	0.041	0.001681	0.002906
230A	540484.021	540484.057	-0.036	0.001296	148882.295	148882.347	-0.052	0.002704	0.004
441	535191.599	535191.550	0.049	0.002401	161295.030	161295.075	-0.045	0.002025	0.004426
811	539143.822	539143.898	-0.076	0.005776	173109.161	173109.161	0	0	0.005776
2215A	535233.433	535233.408	0.025	0.000625	148235.180	148235.075	0.105	0.011025	0.01165
334A	540460.246	540460.317	-0.071	0.005041	156140.475	156140.383	0.092	0.008464	0.013505
3325	542852.905	542852.843	0.062	0.003844	154853.051	154852.845	0.206	0.042436	0.04628
310	535172.307	535171.633	0.674	0.454276	157367.845	157367.914	-0.069	0.004761	0.459037
821	545478.707	545478.821	-0.114	0.012996	173183.409	173182.379	1.03	1.0609	1.073896
125	532263.602	532262.676	0.926	0.857476	141665.163	141665.682	-0.519	0.269361	1.126837
126	531934.210	531933.463	0.747	0.558009	141661.771	141662.617	-0.846	0.715716	1.273725
2117	542896.486	542897.629	-1.143	1.306449	141706.605	141706.675	-0.07	0.0049	1.311349
3035	545524.703	545523.756	0.947	0.896809	139073.949	139073.149	0.8	0.64	1.536809
431	527338.530	527339.579	-1.049	1.100401	162558.097	162558.762	-0.665	0.442225	1.542626
544	530126.997	530127.929	-0.932	0.868624	168401.063	168401.941	-0.878	0.770884	1.639508
2055	519318.325	519319.943	-1.618	2.617924	136413.556	136413.553	0.003	9E-06	2.617933
								sum	41.952161
								average	0.332953659
								RMSE	0.577021368
								NSSDA	0.998708583

Table 1.3 Horizontal positional accuracy worksheet.

(Don Elwood , Tara Mugan and Lisa Zick , 1999)

Observations and comments

Once test data was received from the vendor, the results were mapped. The project team noticed large random errors where good control was expected. It investigated those points and found monuments incorrectly painted or monuments not properly labeled. In areas of significant elevation change, errors were larger. To compensate, some points were thrown out because adequate control was not available. In areas of large elevation change, additional control data was given to the vendor who then was able to return updated coordinate data with improved results.

Positional accuracy statements as reported in metadata.

Horizontal positional accuracy

Using the National Standard for Spatial Data Accuracy, the data set tested 1 foot horizontal accuracy at 95% confidence level.

Vertical positional accuracy

Not applicable

1.7 BENEFITS OF THE STUDY

1. This study shows you the similarity and difference within the scope of information contents of MWA and Google Earth, limitations on the use of both information contents and the potential and benefits of using Google Earth to support the improving process of the base map.
2. This study provides you the methods and processes of map reference from MWA and Google Earth. It shows how both of them process in relation of each other. The benefits of relational operations are useful to help editing the base map to be more accurate.
3. This study gives an idea of geographical layer accuracy and residual causing after operating the process for updating the layers of MWA. The residual will be considered whether it reaches the acceptable standard.
4. This study shows the introduction of improving method by Google Earth for editing the layers of MWA and shows how to process the operations for practical uses.
5. To use benefits of free map service from Google Earth in order to verify and update waterworks information layers from a MWA's applied program, Editor Tool for checking in short time, and reducing work.

CHAPTER II

COORDINATE TRANSFORMATION AND POSITIONAL ACCURACY

In this chapter, it presents a key basic knowledge of coordinate transformation and the thesis theory and methodology Molodensky equations, Two dimensional conformal coordinate transformations, Two dimensional affine coordinate transformation, Statistically valid parameters, positional accuracy.

2.1 Introduction about coordinate transformation

The World Geodetic System 1984 (WGS84) is used by the US Department of Defense for GPS and is suitable for charting and navigation. The International Terrestrial Reference Frame (ITRF) is a based on many GPS, Satellite Laser Ranging (SLR),Very Long Baseline Interferometry (VLBI) stations worldwide and is recommended by the International Association of Geodesy & PCGIAP for regional datums and scientific applications. (Working Group 1 Resolution of 1999)

The difference between positions in terms of an individual local datum and positions in terms of a global datum may be of the order of several hundred metres, and may vary considerably even for a single local datum. If the local survey network has variable quality or does not have a continuous landmass, a country may effectively have a number of local datums, requiring a number of different transformations to the global datum. (Shigeru, M., et al.,2006: 1)

With the increasing exchange of geographic information local and globally, positions need to be available in terms of both a local and global datums. The process of mathematically converting positions from one datum to the other is known as transformation. (Shigeru, M., et al.,2006: 1)

2.1.1 Transforming Positions

There are a number of ways to mathematically transform positions from one datum to another, but they all require "common points". Common points are surveyed points that have known positions in terms of both the local and the global datum. The achievable accuracy of the datum transformation will be determined by the number, distribution and accuracy of these common points and the transformation technique adopted. Generally speaking, the greater the accuracy required, the more common points are needed. (Shigeru, M., et al.,2006: 1)

The common points chosen should be a good sample of the true relationship between the local and global datums. If the local survey network was entirely consistent and regular and was merely offset from the global datum, a single common point would be sufficient to determine this block shift. However, this is a highly unlikely scenario and the more irregular the local survey network, the more common points will be required. A good understanding of the local datum and survey framework is required before a datum transformation can be produced. (Shigeru, M., et al.,2006: 1)

Obtaining Common Points

Ideally, global datum positions should be determined for the local datum origin points and the local survey network recomputed in terms of the global datum. Different locations could be used for the global positions, provided they were accurately connected to the survey network. After the re-computation, every point in the survey network would be a "common point" and, provided the new positions for the origin points were of suitable quality, would probably also give an improved survey network in terms of the global datum. (Shigeru, M., et al.,2006: 2)

A re-computation of the survey network in terms of the global datum assumes that all the original observations are available, but this may not be the case. An alternative strategy would be to obtain sample common points at suitable existing survey network sites. These sites should be chosen to represent the characteristics of the network, so where the survey network is consistent only a few would be required, but where it is inconsistent, many more would be required. Of course any isolated areas (e.g. unconnected islands) would need their own set of common points. These common points are then be used to determine a transformation model for the other points in the survey network and the many derived spatial data sets that depend on the local datum but are not directly connected to the survey network. (Shigeru, M., et al.,2006: 2)

It is wise to obtain far more than the minimum number of common points. The redundant points will give a much better idea of the consistency of the survey network and the derived transformation parameters. A number of the redundant common points ("check points") can be reserved from the initial transformation modelling and later can be used as an independent check of the quality of the transformation process, by comparing actual and transformed positions. If the difference between the actual and transformed positions (residuals) is not acceptable, then (i) the derivation of the transformation process can be repeated using a different selection of common points, or (ii) more common points can be obtained, or (iii) a different transformation method can be used. (Shigeru, M., et al.,2006: 2)

2.2 Transformation Methods.

There are many ways of modelling the transformation between two datums, but those in commonly use Molodenskys.

Mathematically a datum transformation is feasible via 3 dimensional geocentric co-ordinates, implying a 3D similarity transformation defined by 7 parameters: 3 shifts, 3 rotations and a scale difference. This transformation is combined with transformations between the geocentric co-ordinates and ellipsoidal latitude and longitude co-ordinates in both datum systems. (Richard Knippers , Jan Hendrikse : Webpage)

$$(\varphi,\lambda,h)_{Datum\ a} \rightarrow (X,Y,Z)_{Datum\ a} \rightarrow (X,Y,Z)_{Datum\ b} \rightarrow (\varphi,\lambda,h)_{Datum\ b}$$

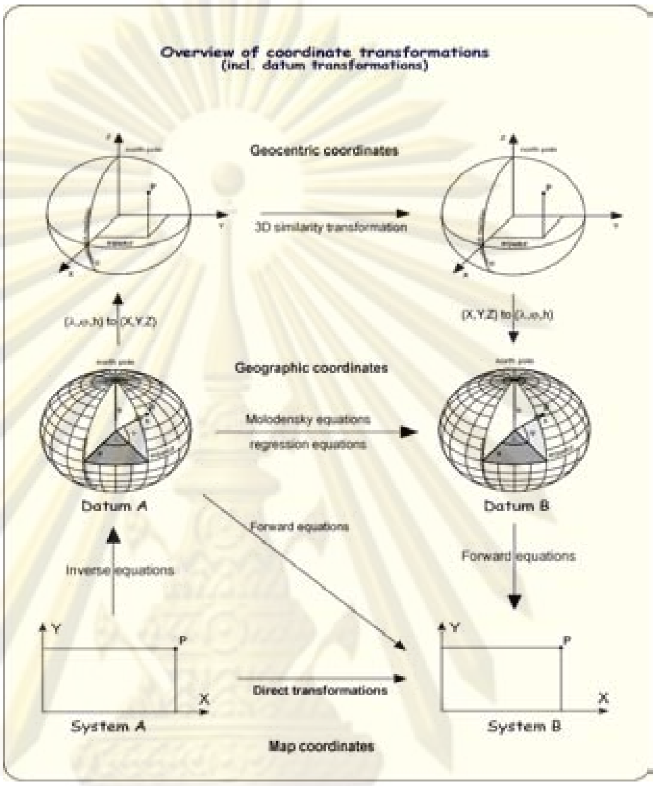


Figure 2.1 Overview of coordinate transformations.

(Richard Knippers , Jan Hendrikse : Webpage)

However a good approximation of this datum transformation make use of the Molodensky and the regression equations, relating directly the ellipsoidal latitude and longitude, and in case of Molodensky also the height, of both datum systems.

Molodensky equations The standard Molodensky equations relate ellipsoidal latitude and longitude co-ordinates and ellipsoidal height of a local geodetic datum to those of the WGS84 datum. (NIMA report, 1997).

Molodensky formula

$$\varnothing_{WGS84} = \varnothing_{Indian1975} + \Delta\varnothing$$
$$\lambda_{WGS84} = \lambda_{Indian1975} + \Delta\lambda \qquad (2.1)$$
$$h_{WGS84} = h_{Indian1975} + \Delta h$$

$$\Delta\varnothing = \{-\Delta X \sin\varnothing \cos\lambda - \Delta Y \sin\varnothing \sin\lambda + \Delta Z \cos\varnothing + \Delta a\left(\frac{R_n e^2 \sin\cos}{a}\right) + \Delta f$$
$$[R_M\left(\frac{a}{b}\right) + R_N\left(\frac{b}{a}\right)]\sin\varnothing\cos\varnothing\}\bullet[(RM + h)\sin 1'']^{-1}$$
$$\Delta\lambda = [-\Delta X \sin\lambda + \Delta Y \cos\lambda] \bullet [(R_N + h)\cos\varnothing \sin 1'']^{-1}$$
$$\Delta h = \Delta X \cos\varnothing \cos\lambda + \Delta Y \cos\varnothing \sin\lambda + \Delta Z \sin\varnothing - \Delta a\left[\frac{a}{R_N}\right] + \Delta f\left[\frac{b}{a}\right] R_N \sin^2\varnothing$$

(φ = geodetic latitude in local system; λ = geodetic longitude in local system; h = the distance of a point above or below the local ellipsoid measured along the ellipsoid normal through the point; a = semi-major axis of local ellipsoid; f = flattening of the local ellipsoid; $\Delta X, \Delta Y, \Delta Z$ = shifts between the centers of the local geodetic system and the WGS84 ellipsoid; Δa, Δf = differences between the semi-major axis and the flattening of the local and WGS84 system; all Δ quantities are obtained by subtracting local geodetic system ellipsoid values from WGS84 ellipsoid values) (Richard Knippers , Jan Hendrikse : Webpage)

Simplified: $\Delta\varphi = f(\Delta x, \Delta y, \Delta z, \Delta a, \Delta f)$

$$\Delta\lambda = f(\Delta x, \Delta, \Delta z, \Delta a, \Delta f)$$

$$\Delta h = f(\Delta x, \Delta y, \Delta z, \Delta a, \Delta f)$$

($\Delta x, \Delta y, \Delta z$:Centre offset $\Delta a, \Delta f$:differences in ellipsoid size and shape)

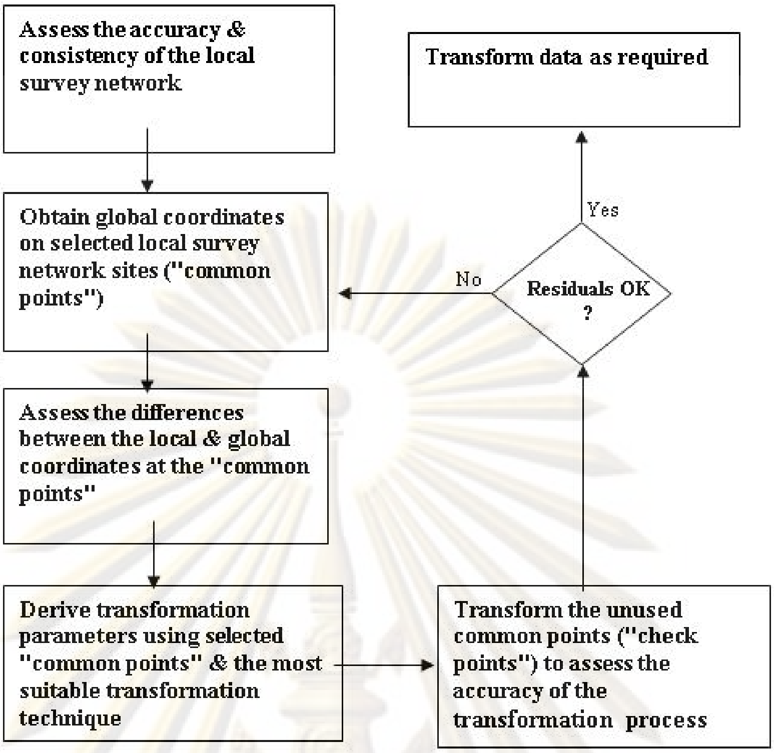


Figure 2.2 General Transformation Procedure.

(Richard Knippers , Jan Hendrikse : Webpage)

2.2.1 Direct transformations

If the underlying projection of a coordinate system is unknown we may relate the coordinate system to a known coordinate system on the basis of a set of selected points whose coordinates are known in both systems. These points may be ground control points or common points such as corners of houses or road intersections, as long as they have know coordinates in both systems. (Richard Knippers , Jan Hendrikse : Webpage)

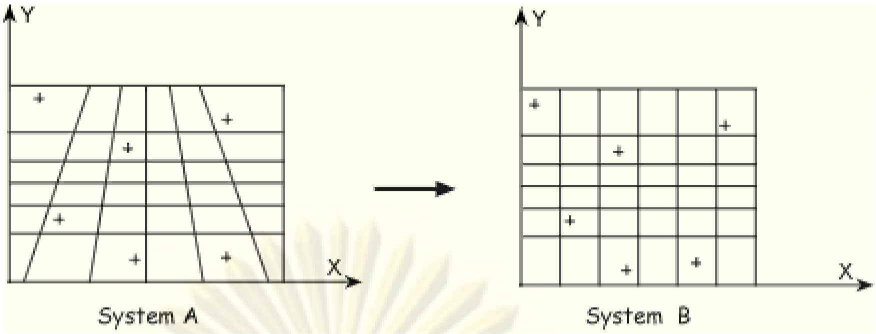


Figure 2.3 Co-ordinate transformation performed on the basis of selected points. Here six points were chosen. (Richard Knippers , Jan Hendrikse : Webpage)

Image and scanned data are usually transformed by this method. The transformations may be conformal, affine, projective, polynomial or of another type, depending on the geometric errors in the data set. Linear conformal or affine transformations can be used to rectify distortions such as a shift (or translation), a rotation or a linear scale difference. Non-linear polynomial transformations can be used to correct variable scale differences. Direct transformations are also used to match vector data layers that don't fit exactly by stretching or rubber sheeting them over the most accurate data layer. Moreover, affine transformations are used in map digitising for the registration of a paper or scanned map. (Richard Knippers , Jan Hendrikse : Webpage)

2.2.1.1 Two dimensional conformal coordinate transformations

The two-dimensional conformal coordinate transformation, also known as the four parameter similarity transformation, has the characteristic that true shape is retained after transformation. It is typically used in surveying when converting separate surveys into a common reference coordinate system. (Paul R.Wolf , Charles D.Ghilani.,1997: 335-342) This transformation is a three-step process that involves:

1. Scaling to create equal dimensions in the two coordinate systems
2. Rotation to make the reference axes of the two systems parallel
3. Translations to create a common origin for the two coordinate systems

Scaling and rotation are each defined by one parameter, and translation involves two parameters. Thus there are a total of four parameters in this transformation. The transformation requires a minimum of two points, called control points, that are common to both systems. With the minimum of two points, the four parameters of the transformation can be determined uniquely. If more than two control points are available, a least-squares adjustment is possible. After determining the values of the transformation parameters, any points in the original system may be transformed.

Equation development

Figure 2.4(a) and 2.4(b) illustrate two independent coordinate systems. In these systems, three common control points, A, B, and C exist (i.e., their coordinates are known in both systems). Points 1 through 4 have their coordinates known only in the xy system of Figure 2.4(b) The problem is to determine their X and Y coordinates in the system of Figure 2.4(a) The necessary equations are developed as follows:

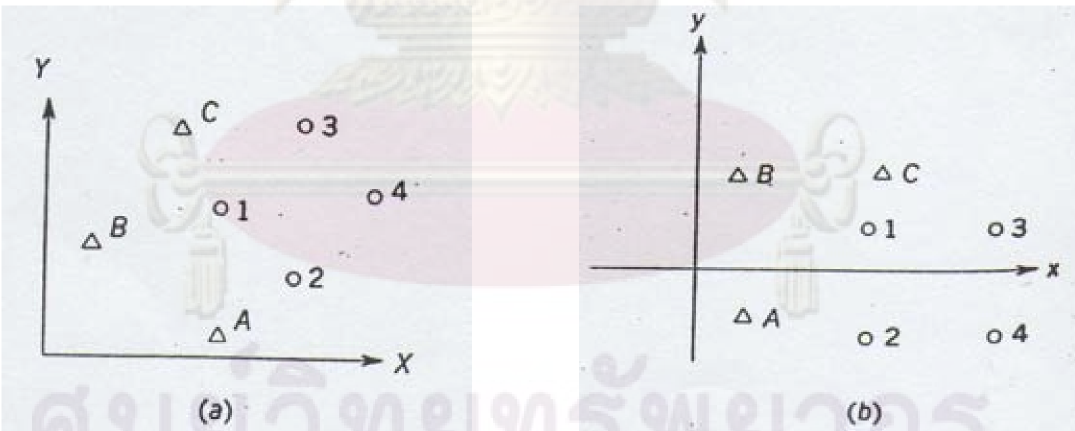


Figure 2.4 Two-dimensional coordinate systems. (Paul R.Wolf , Charles D.Ghilani.,1997: 336)

Step 1: Scaling. To make line lengths as defined by the (x,y) coordinate system equal to their lengths in the (X,Y) system, it is necessary to multiply (x,y) coordinates by a scale factor, S Thus scaled coordinate x' and y' are

$$x' = Sx$$
$$y' = Sy \qquad (2.2)$$

step 2: Rotation. In Figure 2.5 the (X,Y) coordinate system has superimposed on the scaled (x',y') system. The rotation angle, θ, is shown between the y' and Y axes. To analyze the effects of this rotation, an (X',Y') system was constructed parallel to the (X,Y) system such that its origin is common with that of the x'y' system. Expressions that give the (X',Y') rotated coordinates for any point (such as point 4 shown) in terms of its (x',y') coordinates are

$$X' = x'\cos(\theta) - y'\sin(\theta)$$
$$Y' = x'\sin(\theta) + y'\cos(\theta) \qquad (2.3)$$

Step 3: Translation. To finally arrive at X and Y coordinates for a point, it is necessary to translate the origin of the (X',Y') system to the origin of the (X,Y) system. Referring to figure 2.5 it can be seen that this translation is accomplished by adding translation factor as follows

$$X = X' + T_x \text{ and } Y = Y' + T_y \qquad (2.4)$$

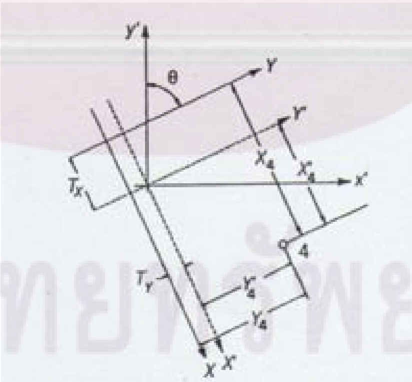


Figure 2.5 Super-imposed coordinate systems. (Paul R.Wolf , Charles D.Ghilani.,1997: 337)

If Equations (2.2), (2.3), and (2.4) are combined, a single set of equations results that transform the points from (x,y) coordinates of Figure 2.4(b) directly into (X,Y) coordinates of Figure 2.4(a) as

$$X = (S\cos\theta)x - (S\sin\theta)y + T_X$$

$$Y = (S\sin\theta)x + (S\cos\theta)y + T_y \qquad (2.5)$$

Now let $S\cos\theta = a$, $S\sin\theta = b$, $T_X = c$, and T, = d, and add residuals to make redundant equations consistent. Then Equations (2.5) can be written as

$$ax - by + c = X + v_x$$

$$ay + bx + d = Y + v_Y \qquad (2.6)$$

2.2.1.1.1 Application of least squares

Equations (2.6) represent the basic observation equations for a two dimensional conformal coordinate transformation that have four unknowns a, b, c, and d. The four unknowns embody the transformation parameters S, θ, T_x, and T_y. Since two equations can be written for every control point, only two control points are needed for a unique solution. When more than two are present, a redundant system exists for which a least-squares solution can be found. As an example, consider the equations that could be written for the situation illustrated in Figure 2.4 There are three control points, A, B, and C, and thus the following six equations can be written

$$ax_a - by_a + c = X_A + v_{x_A}$$

$$ay_a + bx_a + d = Y_A + v_{y_A}$$

$$ax_b - by_b + c = X_B + v_{x_B}$$

$$ay_b + bx_b + d = Y_B + v_{y_B}$$

$$ax_c - by_c + c = X_C + v_{x_C}$$

$$ay_c + bx_c + d = Y_C + v_{y_C} \qquad (2.7)$$

Equations (2.7) can be expressed in matrix form as

$$AX = L + V \tag{2.8}$$

Where

$$A = \begin{bmatrix} xa & -ya & 1 & 0 \\ ya & xa & 0 & 1 \\ xb & -yb & 1 & 0 \\ yb & xb & 0 & 1 \\ xc & -yc & 1 & 0 \\ yc & xc & 0 & 1 \end{bmatrix} \quad X = \begin{bmatrix} a \\ b \\ c \\ d \end{bmatrix} \quad L = \begin{bmatrix} XA \\ YA \\ XB \\ YB \\ XC \\ YC \end{bmatrix} \quad V = \begin{bmatrix} vxA \\ vyA \\ vxb \\ vyB \\ vxC \\ vyC \end{bmatrix}$$

Having obtained the most probable values for the coefficients from the least-squares solution, the (X,Y) coordinates of any additional points whose coordinates are known in the (x,y) system can then be obtained by applying Equations (2.6) (where the residuals are now considered to be zeros).

After the adjustment, the scale factor S and rotation angle θ can be computed with the following equations.

$$\theta = \tan^{-1}\left(\frac{b}{a}\right) \tag{2.9}$$

$$S = \frac{a}{\cos(\theta)} \tag{2.10}$$

2.2.1.2 Two dimensional affine coordinate transformations

The two-dimensional affine coordinate transformation is also known as the six parameter transformation. It is a slight variation from the two-dimensional conformal transformation. In the affine transformation there is the additional allowance for two different scale factors, one in the x direction and the other in the y direction. This transformation is commonly used in photogrammetry to transform photo coordinates from an arbitrary measurement photo coordinate system to the camera fiducial system, and to account for differential shrinkages that occur in the x and y directions. As in the conformal transformation, the affine transformation also applies two translations of the origin, and a rotation about the origin, plus a small nonorthogonality correction between the x and y axes. This results in a total of six unknowns. The mathematical model for the affine transformation is

$$\begin{aligned} ax+by+c &= X+V_X \\ dx+ey+f &= Y+V_y \end{aligned} \qquad (2.11)$$

These equations are linear and can be solved uniquely when three control points exist (i.e., points whose coordinates are known in the both systems). This is because for each point, an equation set in the form of Equations (2.11) can be written and three points yields 6 equations involving the 6 unknowns. If more than three control points are available, a least-squares solution can be obtained. Assume, for example, that four common points (1, 2, 3, 4) exist. Then the equation system would be

$$\begin{aligned} ax_1+by_1+c &= X_1+V_{X1} \\ dx_1+ey_1+f &= Y_1+V_{Y1} \\ ax_2+by_2+c &= X_2+V_{X2} \\ dx_2+ey_2+f &= Y_2+V_{Y2} \\ ax_3+by_3+c &= X_3+V_{X3} \\ dx_3+ey_3+f &= Y_3+V_{Y3} \\ ax_4+by_4+c &= X_4+V_{X4} \\ dx_4+ey_4+f &= Y_4+V_{Y4} \end{aligned} \qquad (2.12)$$

In matrix notation, Equations (2.12) are expressed as AX = L + V, where

$$\begin{bmatrix} x1 & y1 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x1 & y1 & 1 \\ x2 & y2 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x2 & y2 & 1 \\ x3 & y3 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x3 & y3 & 1 \\ x4 & y4 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & x4 & y4 & 1 \end{bmatrix} \begin{bmatrix} a \\ b \\ c \\ d \\ e \\ f \end{bmatrix} = \begin{bmatrix} X1 \\ Y1 \\ X2 \\ Y2 \\ X3 \\ Y3 \\ X4 \\ Y4 \end{bmatrix} + \begin{bmatrix} vx1 \\ vy1 \\ vx2 \\ vy2 \\ vx3 \\ vy3 \\ vx4 \\ vy4 \end{bmatrix}$$

They are then used to transfer the remaining points from the (x,y) coordinate system to the (X,Y) coordinate system.

2.3 Statistically valid parameters

Besides the coordinate transformations described in preceding sections, it is possible to develop numerous others. For example, polynomial equations of various degrees could be used to transform data. As additional terms are added to a polynomial. the resulting equation will force better fits on any given data set However, caution should be exercised when doing this since the resulting transformation parameters may not be statistically significant. (Paul R.Wolf , Charles D.Ghilani.,1997: 353-354)

As an example. when using a two-dimensional conformal coordinate transformation with a data set having four control points, nonzero residuals would be expected. However. if a projective transformation were used, this data set would yield a unique solution and thus the residuals would be zero. Is the projective a more appropriate transformation for this data set? Is this truly a better fit? Guidance in, the answers to these questions can be obtained by checking the statistical validity of the parameters.

The adjusted parameters divided by their standard deviations represent a t statistic with v degrees of freedom. If a parameter is to be judged as statistically different from zero, and thus significant, the computed t value (the test statistic) must be greater than $t_{\alpha/2,v}$. Simply stated, the test statistic is

$$t = \frac{|parameter|}{S} \qquad (2.13)$$

2.4 Positional accuracy

Christopher Cialek, chair, Don Elwood et al, (1999: 1-8) Using the National Standard for Spatial Data Accuracy to measure and report geographic data quality. The National Standard for Spatial Data Accuracy describes a way to measure and report positional accuracy of features found within a geographic data set. Approved in 1998 the National Standard for Spatial Data Accuracy (NSSDA) recognizes the growing need for digital spatial data and provides a common language for reporting accuracy.

How the positional accuracy of map features is best estimated has been debated since the early days of cartography. The question remains a significant concern today with the proliferating use of computers, geographic information systems and digital spatial data. Until recently, existing accuracy standards such as the National Map Accuracy Standards focused on testing paper maps, not digital data. Today, use of digital GIS is replacing traditional paper maps in more and more applications. Digital geographic data sets are being generated by federal, state and local government agencies, utilities, businesses and even private citizens. Determining the positional accuracy of digital data is difficult using existing standards.

A variety of factors affect the positional accuracy of digital spatial data. Error can be introduced by: digitizing methods, source material, generalization, symbol interpretation, the specifications of aerial photography, aerotriangulation technique, ground control reliability, photogrammetric characteristics, scribing precision, resolution, processing algorithms and printing limitations. Individual errors derived from any one of these sources is often small; but collectively, they can significantly affect data accuracy, impacting how the data can be appropriately used. The NSSDA helps to overcome this obstacle by providing a method for estimating positional accuracy of geographic data, in both digital and printed form. The National Standard for Spatial Data Accuracy is one in a suite of standards dealing with the accuracy of geographic data sets and is one of the most recent standards to be issued by the Federal Geographic Data Committee. Minnesota was represented in the latter stages of the standard's development through the Governor's Council on Geographic Information and the state's Department of Transportation.

How the NSSDA works.

There are seven steps in applying the NSSDA:

1. Determine if the test involves horizontal accuracy, vertical accuracy or both.
2. Select a set of test points from the data set being evaluated.
3. Select an independent data set of higher accuracy that corresponds to the data set being tested.
4. Collect measurements from identical points from each of those two sources.
5. Calculate a positional accuracy statistic using either the horizontal or vertical accuracy statistic worksheet.
6. Prepare an accuracy statement in a standardized report form.
7. Include that report in a comprehensive descriptionof the data set called metadata.

Steps in detail (Positional Accuracy Handbook 1999)

1. Determining which test to use. The first step in applying the NSSDA is to identify the spatial characteristics of the data set being tested. If planimetric accuracy the x,y accuracy of the data set is being evaluated, use the horizontal accuracy statistic worksheet see table 2.1

2. Selecting test points. A data set's accuracy is tested by comparing the coordinates of several points within the data set to the coordinates of the same points from an independent data set of greater accuracy. Points used for this comparison must be well-defined. They must be easy to find and measure in both the data set being tested and in

the independent data set. For data derived from maps at a scale of 1:5,000 or smaller, points found at right-angle intersections of linear features work well. These could be right-angle intersections of roads, railroads, canals, ditches, trails, fences and pipelines. For data derived from maps at scales larger than 1:5,000 plats or property maps, for example features like utility access covers, intersections of sidewalks, curbs or gutters make suitable test points. For survey data sets, survey monuments or other well-marked survey points provide excellent test points. Twenty or more test points are required to conduct a statistically significant accuracy evaluation regardless of the size of the data set or area of coverage. Twenty points make a computation at the 95 percent confidence level reasonable. The 95 percent confidence level means that when 20 points are tested, it is acceptable that one point may exceed the computed accuracy. If fewer than 20 test points are available, another

Federal Geographic Data Committee standard, the Spatial Data Transfer Standard, describes three alternatives for determining positional accuracy: 1) deductive estimate, 2) internal evidence and 3) comparison to source.

3. Selecting an independent data set. The independent data set must be acquired separately from the data set being tested. It should be of the highest accuracy available. In general, the independent data set should be three times more accurate than the expected accuracy of the test data set. Unfortunately, this is not always possible or practical. If an independent data set that meets this criterion cannot be found, a data set of the highest accuracy feasible should be used. The accuracy of the independent data set should always be reported in the metadata. The areal extent of the independent data set should approximate that of the original data set. When the tested data set covers a rectangular area and is believed to be uniformly accurate, an ideal distribution of test points allows for at least 20 percent to be located in each quadrant see figure 2.7 Test points should be spaced at intervals of at least 10 percent of the diagonal distance across the rectangular data set; the test points shown in figure 2.8 comply with both these conditions. It is not always possible to find test points that are evenly distributed. When an independent data set covers only a portion of a tested data set, it can still be used to test the accuracy of the overlapping area. The goal in selecting an independent

data set is to try to achieve a balance between one that is more accurate than the data set being tested and one which covers the same region. Independent data sets can come from a variety of sources. It is most convenient to use a data set that already exists, however, an entirely new data set may have to be created to serve as control for the data set being tested. In all cases, the independent and test data sets must have common points. Always report the specific characteristics of the independent data set, including its origin, in the metadata.

Figure 2.6 Ideal test point distribution. Figure 2.7 Ideal test point spacing.

(Christopher Cialek, chair, Don Elwood et al, 1999: 3)

4. Recording measurement values. The next step is to collect test point coordinate values from both the test data set and the independent data set. When collecting these numbers, it is important to record them in an appropriate and similar numeric format. For example, if testing a digital database with an expected accuracy of about 10 meters, it would be overkill to record the coordinate values to the sixth decimal place; the nearest meter would be adequate. Use similar common sense when recording the computed accuracy statistic.

5. Calculating the accuracy statistic. Once the coordinate values for each test point from the test data set and the independent data set have been determined, the positional accuracy statistic can be computed using the appropriate accuracy statistic worksheet. Illustrations of filled out worksheets can be found in the handbook's case studies. The NSSDA statistic is calculated by first filling out the information requested in the appropriate table and then computing three values: The sum of the set of squared differences between the test data set coordinate values and the independent data set coordinate values, the average of the sum by dividing the sum by the number of test points being evaluated, and the root mean square error statistic, which is simply the square root of the average. The NSSDA statistic is determined by multiplying the RMSE by a value that represents the standard error of the mean at the 95 percent confidence level: 1.7308 when calculating horizontal accuracy.

A Point number	B Point description	C x (inde-pendent)	D x (test)	E diff in x	F (diff in x) ^{2}	G y (inde-pendent)	H y (test)	I diff in y	J (diff in y) ^{2}	K (diff in x) ^{2} + (diff in y) ^{2}
									sum	
									average	
									$RMSE_r$	
									NSSDA	

Table 2.1 Horizontal accuracy statistic worksheet.

(Christopher Cialek, chair, Don Elwood et al, 1999: 5)

Column	Title	Content
A	Point number	Designator of test point
B	Point description	Description of test point
C	x (independent)	x coordinate of point from independent data set
D	x (test)	x coordinate of point from test data set
E	diff in x	x (independent) - x (test)
F	$(\text{diff in x})^2$	Squared difference in x = $(x (\text{independent})-x(\text{test}))^2$
G	Y (independent)	y coordinate of point from independent data set
H	y (test)	y coordinate of point from test data set
I	diff in y	y (independent) -y (test)
J	$(\text{diff in y})^2$	Squared difference in y =$(y (\text{independent})-y(\text{test}))^2$
K	$(\text{diff in } x^2)+(\text{diff in } y^2)$	Squared difference in x plus squared difference in y = $(\text{error radius})^2$
	Sum	$\sum[(\text{diff in x})^2 + (\text{diff in y})^2]$
	average	sum / number of points
	RMSE	Root Mean Square Error (radial) = $\text{average}^{1/2}$
	NSSDA	National Standard for Spatial Data Accuracy statistic = 1.7308 * RMSE

6. Preparing an accuracy statement. Once the positional accuracy of a test data set has been determined, it is important to report that value in a consistent and meaningful way. To do this one of two reporting statements can be used:

Tested (meters, feet) (horizontal, vertical) accuracy at 95% confidence level Compiled to meet (meters, feet) (horizontal, vertical) accuracy at 95% confidence level A data set's accuracy is reported with the tested statement when its accuracy was determined by comparison with an independent data set of greater accuracy as described in steps 2 through 5. For example, if after comparing horizontal test data points against those of an independent data set, the NSSDA statistic is calculated to be 34.8 feet, the proper form for the positional accuracy report is: Positional Accuracy: Tested 34.8 feet horizontal accuracy at 95% confidence level This means that a user of this data set can be confident that the horizontal position of a well defined feature will be within 34.8 feet of its true location, as best as its true location has been determined, 95 percent of the time. When the method of compiling data has been thoroughly tested and that method produces a consistent accuracy statistic, the compiled to meet reporting statement can be used. Expanding on the same example, suppose the method of data collection consistently yields a positional accuracy statistic that was no worse that is, no less accurate than 34.8 feet for eight data sets tested. It would be appropriate to skip the testing process for data set nine, and assume that its accuracy is consistent with previously tested data. Report this condition using the following format: Positional Accuracy: Compiled to meet 34.8 feet horizontal accuracy at 95% confidence level to appropriately use the compiled to meet reporting statement, it is imperative that the data set compilation method consists of standard, well documented, repeatable procedures. It is also important that several data sets be produced and tested. Finally, the NSSDA statistics computed in each test must be consistent. Once all these criteria are met, future data sets compiled by the same method do not have to be tested. The largest or worst case NSSDA statistic from all tests is always reported in the compiled to meet statement.

7. Including the accuracy report in metadata. The final step is to report the positional accuracy in a complete description of the data set. Often described as data about data, metadata lists the content, quality, condition, history and other characteristics of a data set.

CHAPTER III

Geographic information systems of Metropolitan Waterworks Authority

In this chapter, it is roughly stated about the introduction and history of information system of Metropolitan Waterworks Authority and the application operated in the process in this study and indicated benefits of Google Earth application as a supporting part of development for up-to-date information system of MWA.

3.1 Mapping and system management project GIS AM/FM

Objective of the project

1. To change the pipe water supply system map into the digital map that can be rectified and collected effectively.
2. To support the convenient and effective services for water user
3. To support the call center service.
4. To support the use of the GIS data system for applying to the works of all institutes of the Metropolitan Waterworks Authority.

Operating period

At the beginning

The plan would be operated within 7 years between 2543 B.E. to 2549 B.E. and divided in 5 periods.

Later, the operation plan was increased by 1 period (following the adviser's suggestion in the marketing strategy plan). As a result, the plan was operated in 6 periods and will be finished in 2552 B.E. (For any institutes where need to use and would not edit the data, the use of GIS Web Application can reduce the high budget of software (Arc View)).

The financial operating in each period as follows

Period 1 project operate fiscal in 2543 B.E. use the budget for

1.	Base map value at Bangkok area	12,000,000 Bath
2.	Software	8,400,000 Bath
3.	Computer and equipments	6,377,000 Bath
	Total	26,777,000 Bath

Period 2 project operate fiscal in 2544-2546 B.E. use the budget for

1.	Base map at Bangkok area	20,000,000 Bath
2.	Base map at boundary area	800,000 Bath
3.	Software	16,100,000 Bath
4.	Computer and equipments	4,800,000 Bath
	Total	48,900,000 Bath

Period 3 project operate fiscal in 2547-2548 B.E. use the budget for

Period 3.1 in 2547 B.E.

1.	Base map at boundary area	12,000,000 Bath
2.	Software	8,900,000 Bath
3.	Computer and equipments	3,710,000 Bath
	Total	24,610,000 Bath

Period 3.2 in 2548 B.E.

1. Computer and equipments 4,877,000 Bath
2. Software and application program 17,330,000 Bath

Total 22,207,000 Bath

Period 4 project operate fiscal in 2549 B.E. use the budget for

1. Computer and equipments 2,780,000 Bath
2. Software and application program 5,000,000 Bath

Total 7,780,000 Bath

Period 5 project operate fiscal in 2550 B.E. use the budget for

1. Computer for the backup GIS system 1,915,000 Bath
2. make the backup GIS system for applied program 5,280,000 Bath

Total 7,195,000 Bath

Period 6 project operate fiscal in 2551 B.E. use the budget for

1. Computer and equipments replace originally 4,231,000 Bath
2. Administration database software 2,950,000 Bath

Total 7,181,000 Bath

Period 7 project operate fiscal in 2552 B.E. use the budget for

1. External harddrive 1,500,000 Bath
2. GIS Web Application (on internet) 4,000,000 Bath

Total 5,500,000 Bath

Total cost of Mapping and GIS AM/FM system management project is around 149,310,000 Bath.

According to the project, it is obvious that base map price is quite high and the compilation of base map takes a long time to complete. However, Google Earth is an application that is effective enough to help updating the base map as well.

3.2 Data of Mapping and system management project GIS AM/FM as follows

1. System pipe water supply database.
2. Customer database.
3. As-built drawings link with pipe water supply data in GIS.
4. Gate Valve drawings link with water gate data in GIS.
5. Base map 1:1,000
6. Conspiracy market database and serve.
7. The database of the project adjusts water supply system for decreases the water loses. (District Metering Area data, repair a pipe data, location of Remote Terminal Unit data)
8. Route reading meter database.

3.3 Introduction GIS/AM/FM of Metropolitan waterworks authority

The AM/FM/GIS system data model allows GIS architects to define a relationship model which consists of all the database tables and their dependencies. This is often combined with business rules to make the system more intelligent so that it can be utilized in running various analyses on the data. e.g. a pipeline GIS system can let users perform detailed analysis of all the pressure points or valves located on the pipe at different intervals. This can be possible by defining a relationship between a pipeline entity or object and the pressure valve object. Designing a data model for any utility company could be an extensive task which involves requirements gathering and analysis, designing specifications and implementation. Implementation mostly deals with development of functional tools to assist users in managing and analyzing the system. These functional tools might include object placement tools, analysis tools, reporting tools etc. The functional tool development is generally done using a supporting programming language. An advanced AM/FM/GIS software is always equipped with pre defined functions and procedures to carry out common GIS operations.

AM is an acronym for Automated Mapping system. It is the mapping construction and maintenance using integrated computer software in stead of hand-drawing. This system was developed and duplicated from the method of drawing and editing data by hands. In those days, mapping offices needed to record spatial data on paper sheets which were difficult to be edited according to their limitations on the maintenance, improvement to be up to date and application of data for further uses. When the GIS/AM/FM systems are used in organizations, the whole operation of data recording, editing or printing will be performed by computers which can make the processing become much faster, more effective and accurate.

FM system or Facility Management is the management of public supply system by using mapping data imported and maintained by AM system to analyze and design facilities.

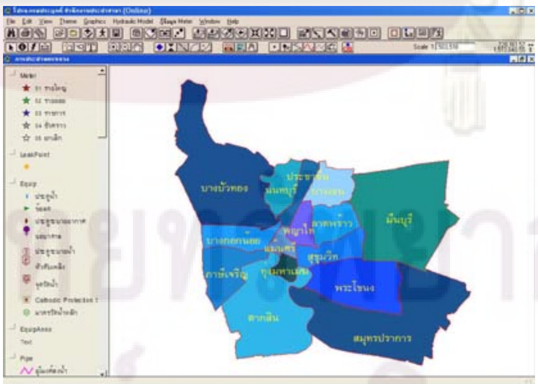


Figure 3.1 GIS/AM/FM of Metropolitan waterworks authority.

Advantages

GIS technology has given many organizations a chance to stow away the clumsy torn maps and go digital. A complete AM/FM/GIS tool not only provides digital maps but also numerous time-saving and cost cutting tools.

The public utility companies have changed significantly in the past decade. With increasing demand, there is tremendous pressure on the utility companies to improve their business. Companies have been looking at information systems to reorganize their business processes and benefit from it. Some AM/FM/GIS systems offer full fledged solutions to companies by supporting their existing business processes. Some of these solutions are :

- Utilizing an existing GIS system.
- Supporting Workflow Management Systems (WMS)
- Integration with Customer Information Systems
- Integration with Operations Support Systems (OSS)
- Integration with Planning and Engineering
- Cost analysis
- Inventory Management

Investing in AM/FM/GIS systems with good planning can help businesses benefit in the long run.

At Mapping department

An applied program for mapping department is a program developed on new technology by the new version of ArcInfo program. The ArcInfo program has been developed and designed the character for easy using and adapted by users proposes. The program was developed by Object Oriented which is one of popular tools, for example, Visual Basic for Application, Visual Basic, Visual C++ etc. Besides, the

Technology of Geodatabase can make users change from developing the program to improving the database.

At branch

The applied program for branches is the program developed on ArcView version 3.3. The applied program of the Metropolitan Waterworks Authority has been added more abilities to update new data all the time. The applied program used in this branch can be used by both of AM/FM.

The data which are important for the system GIS/AM/FM.graphic data of the Metropolitan Waterworks Authority are classified as two groups as following:

1. Base map data

Basic map data is basic data used to refer pipe system data, because the data collection of pipe water supply system must be referred with basic map data as follows Roadedge, Building, Landmark and Land edge, Hydrology, Road Centerline, Master Grid, MWA District, MWA Admin.

2. Pipe Map data

Pipes Map data shows the line of water supply pipes and positions of equipments in pipe water supply system in areas of the Metropolitan Waterworks Authority, including main pipes, tunnels, and other equipments in pipe water supply system for example gate valve and fire hydrant.

3.4 Transmitting data between mapping department and branch

Because GIS of The Metropolitan Waterworks Authority has been updated all the time, so it is necessary to consider in data system administration. The sent data have to be improved from each branch before being sent to mapping department to improve again. The most GIS data are used in the branches of the Metropolitan Waterworks Authority. The leakage survey division of each branch will check and modify piping system all the time by transmitting data between mapping department and branches by FTP (File Transfer Protocol).

In case, the branches of Metropolitan Waterworks Authority update any information of MWA which have no land base (base map), the information will be sent to Mapping Department in order to make as-built drawing. Mapping Department will correct image coordinates and search for the orthophotos from Google Earth and Pointasia Program. In case of unfound orthophotos, Mapping Department will copy the information and compile it for Metropolitan Electricity Authority. Whenever the Mapping Department gets the orthophotos, they will be made for georeferencing; printed, compiled for MEA (Metropolitan Electricity Authority) and imported to raster dataset. (see figure 3.2)

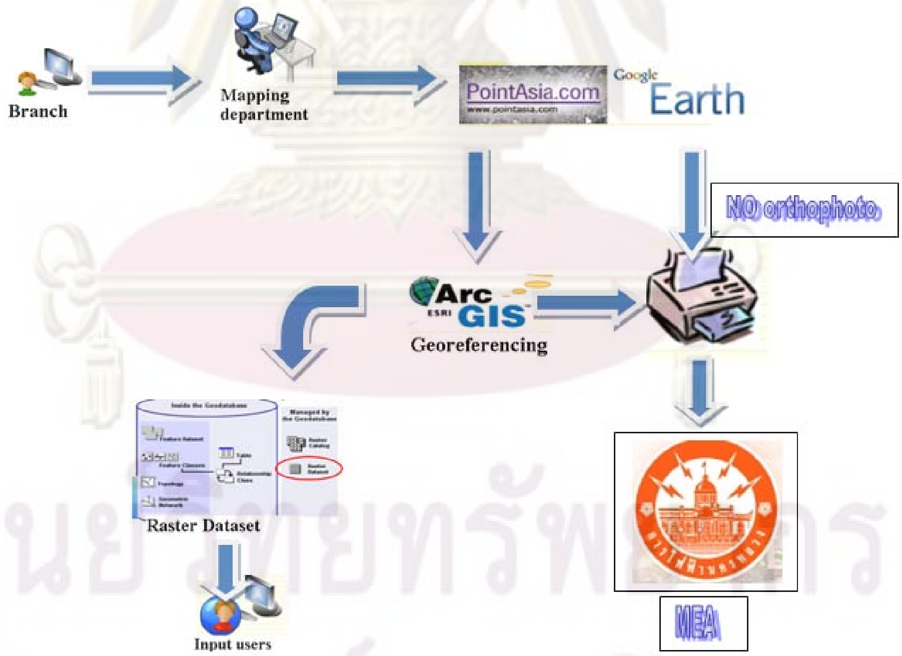


Figure 3.2 Flowchart of sending AS-built drawing data with no land base information.

3.5 Introduction applied program "Editor Tool"

Editors Tools Program is equipment for adding, editing data which can work with piping line data, plumping equipment, water meters, serviced pipes and routing boundary for example. The main application features for piping line and plumbing equipment management started by creating a job on the application. The user had to cut some selected sections from the previous database and pasted them on the job. The user was able to edit the data on the job such as installing new piping lines and gate data or abandoning the use of piping line or gate valve. Moreover, the user could edit the water pipe lines to be more suitable by using editing tools in the application, for example, in order to curve a pipe line in the position of pipe crossing, use the tool "Curve".

After editing the data completely, the user had to export the data to be share file in order to send to Mapping Department and then compiled with the main database. However, there were some types of data which could be edited without creating a job on the application such as water meter data, serviced pipes, free base map; the user was able to add or edit through the theme of data and could preview the edited data immediately after editing.

Logging into Editor Tool

To log into Editor Tool, the user took double click on the icon with a cursor to launch the software. There should be an icon on the desktop. (figure 3.3)

Figure 3.3 Editor Tools Icon.

When the user accessed the application software of Metropolitan Waterworks Authority, there were 2 optional statuses appearing on the screen; editor tools online and editor tools offline. Editor tools online was editing online data; editor tools offline was viewing the online data only as shown in picture 3.4

Figure 3.4 Selecting the work function.

User interface of Editor Tools

Editor Tools run on the environment of ArcView 3.3, thus the character of GUI (Graphical User Interface) has the same as ArcView. GUI of the Editor Tools program consists of menu, button and tool

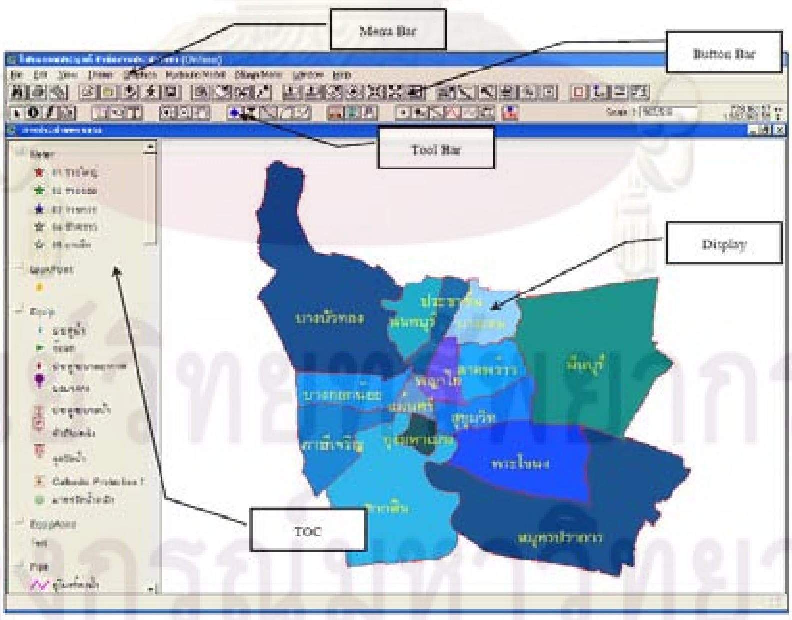


Figure 3.5 The following diagram describes some of the features available in the main window of Editor Tools.

Toc: This part is used for explaining all data, and also controlling the data display.

Menu bar: This part is used for controlling such as zoom in, zoom out

3.5.1 Base map data improvement

Due to rapidly increasing of water users in some areas, the base map of Metropolitan Waterworks Authority (WMA) can't be updated in real-time. Accordingly, Mapping Department prepares data layers of base map improvement for WMA branch offices in order to urgently improve piping data.

In the process of base map improvement by using editor tools, the user started with "editing" on the button bar and selected what needed to be improved as poly line, polygon, rectangular, circle. Poly line feature represented for street and sidewalk illustrating. Polygon feature was used for building creating as same as rectangular feature. Circle feature was used for round buildings creating.

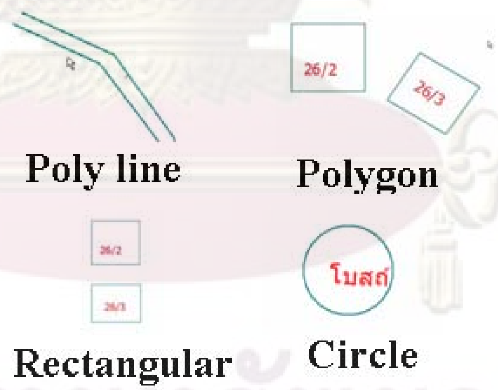


Figure 3.6 Sample of making the geometric basic map.

In addition, poly line can build the character identifying the road line as the figure 3.7

Figure 3.7 Building the character identifying the road line.

In addition, Google Earth helps searching for names of streets or looking for nearly streets which can make the improvement to be easier as shown in figure 3.8.

Figure 3.8 Names of roads and streets shown on Google Earth.

However, the base map compilation in the editor tools application by drawing with no consideration of actual coordinates of the building can not represent the facts as shown in the figure 3.9. There is no reference for the created buildings to refer to real types of building because the application shows only white screen displays, whereas Google Earth shows orthophotos which gives an accurate description of building. As shown in the figure 3.8. (In case of having no base map in the application of Metropolitan Waterworks Authority, Google Earth can give the orthophotos.) Moreover, Google Earth can create polygon and line, as shown in the figure 3.10.

Figure 3.9 Building digitizing without knowing of types of accommodations.

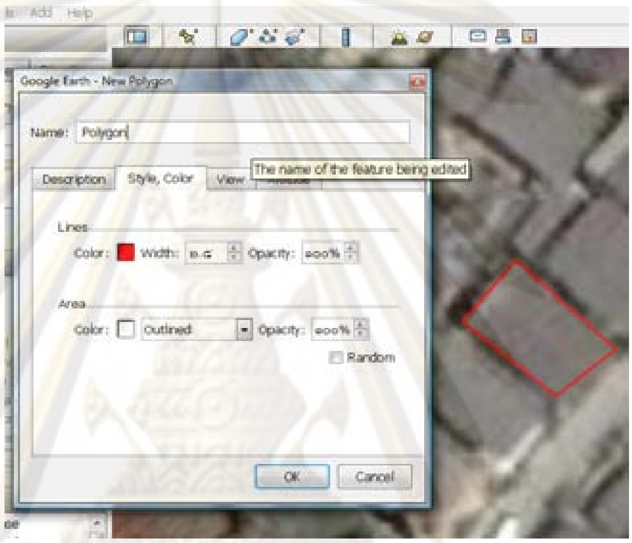


Figure 3.10 Building polygon by Google Earth.

Google Earth application can also create vector data as same as Geographic Information System (GIS) but the data will be stored with the new markup language, XML (Extensive Markup Language). For more convenient in using through the internet, providers can create their own languages by Keyhole named KML (Keyhole Markup Language) that displays the data on Google Earth Client. KML has version 2.0 at present which can work with Google Earth client version3 and upper versions which supports displaying 3 types of vector data the same as GIS; point or placemark is a point feature which users can create from the prepared tools in every version of Google Earth and can fix any point details according to the optional icons of the application. KML is in the tag named <icon> line consisting of a set of more than 2 points. To create vector data, the user can use the tag “Linestring” from Google Earth application.

The users have to buy Google Earth Plus application before using these commands or creating the vector data by writing KML. Polygon consists of sets of arc and sets of point in combination. KML can display both of simple and complex polygons. In Google Earth application, the users can not create polygon data; they have to buy Google Earth Plus application or create the polygon data by writing KML only.

3.5.2 The improvement of water user data

The updating of water user data is useful for searching for the information of water users, calculating the quantity of water in targeted areas and keeping track of water users in any cases. The process of map data updating starts with editing, select required data and convert them to be meter, then use "Locator tools" to search for the location and fill the information of location as needed.

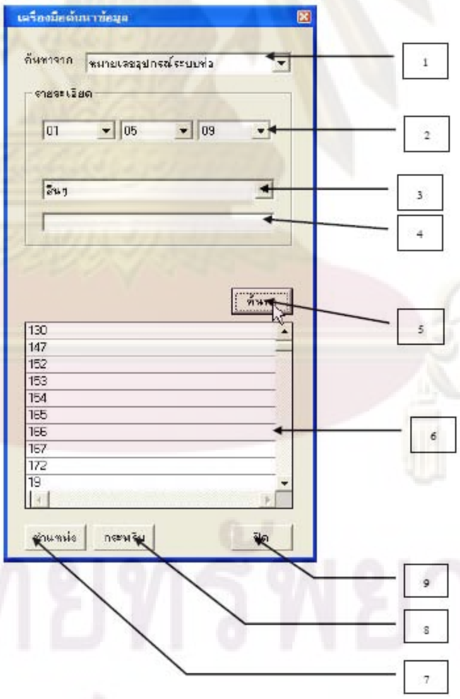


Figure 3.11 Searching location by the Locator Tools window.

Firstly, select an data type to specify the information for searching, for example, finding the data from an important place or street, then select sub elements in Branch-Zone-

Block for advanced searching, anyway, some data types can not specify sub elements but some can, for example, serial number of piping equipment can be specified to types of gate valve, fire hydrant. After that, fill other additional detail and click the button “Search” for searching. Click the button “Position” to zoom into the selected area from the result lists or click the button “Kraprib” to show the position of the found data and the data will be blinking, then, click the button “Add Meter” to access the screen display for the updating of water user as shown in the picture 3.13 and blue point will appear on the screen as shown in the figure 3.14.

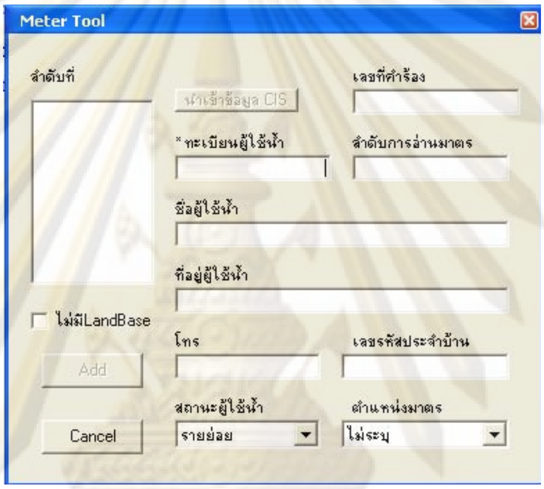


Figure 3.12 Window shows the improvement of water user information.

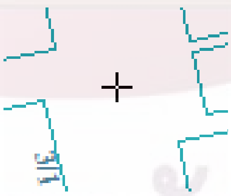


Figure 3.13 The curcer is changed to cross sign for showing data of water user on the needed position.

Figure 3.14 The data of water user shown in blue spot.

To input the data of water user, at the present Metropolitan Waterworks Authority has only installed water meters within building areas with no consideration of the positions of water meters which may have an impact on an analysis of solving water resource problem in the future. Nowadays, the data in Geographic Information System are still inaccurate; which of water pipes that flows through each of water meters is unclear. In the future, Metropolitan Waterworks Authority is going to input serviced pipe data into GIS and it will be more difficult to input the water user data without the base map. Anyway, Google Earth application has “Add placemark” which has the same application features as the input of Metropolitan Waterworks Authority as shown in the figure 3.15.

Figure 3.15 Placemark of GE can also show the data.

3.5.3 Piping line illustration

Piping line illustration consists of 2 parts; water pipe and piping equipment. Water pipe is classified into 3 types which are Main pipe, Distribute pipe and Tunnel, whereas plumbing equipment consists of Reducer Fire Hydrant, Air Valve, Well, Gauging Point, Blow Off, Master Meter and Cathodic Protection.

Figure 3.16 Symbols represent pipe and pipe equipment in editor tools.

In order to illustrate piping line, the user started opening a new job by using Job Management on the button bar, selected theme to be edited by choosing as pipe and then named the job according to Mapping Department's requirements. The job should have be named as a branch code name, sheet name 1:4000 (Name of contract – Ref . No.) and an officer code according to each branch. For example, 06G-22(PTT-202-001)024 means that the job of Mansri branch office locates in the sheet of G-22, PTT-202 Contract with Ref No. 001 and Mr. Somkid is an officer for this job as shown in the figure 3.17

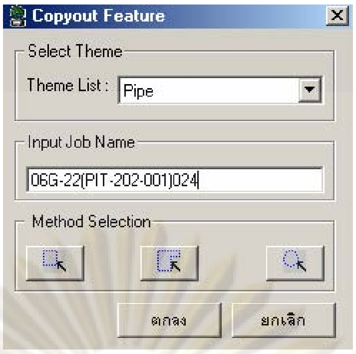


Figure 3.17 Window shows naming the job.

Then, the user used the tool “Method Selection” to select required data for improving map data. “Method Selection” can be used with 3 choices for working area selection; those are by using Square, Polygon and Circle. After that, the application would display the number of pipes in the selected area and the user could copy the data for further working. The user had to select “Theme” and change to “Equip” in order to copy the plumbing equipment data.

3.5.3.1 Piping Abandon Process

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; some pipes are abandoned, the branch office can inform Mapping and Printing Department of the pipe abandon in GIS. After being informed, Mapping Department is responsible for deleting the data from the database by using the tool “Abandon”.

Figure 3.18 The cancelled pipe line shown in light orange color.

3.5.3.2 **Piping Replacement Process**

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; the data of sizes, materials, pipe contract and installation year of existing pipes are not compatible with the field data, the branch office can inform Mapping Department of the piping replacement in GIS. After being informed, Mapping Department will edit the data in GIS to be compatible with the field data of the branch office. In order to edit the data, the users can select the pipe and use the tools "Replace" to enter the editing window as shown in the figure 3.19. After editing, click the button "Update" to confirm the replacement.

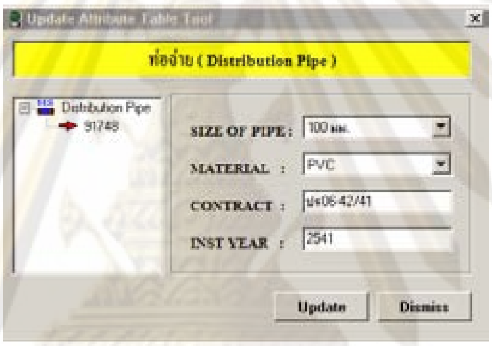


Figure 3.19 Window editing pipe data.

3.5.3.3 **Piping Installation Process**

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; some pipes for which the branch office is responsible are not shown in GIS or incomplete, the branch office is able to inform Mapping Department of piping installation. Mapping Department will edit the GIS data to be compatible with the field data by clicking the button "DIS" and installing the pipe line as required. In case of lacking Land base, the branch office is unable to update the new data, and the as –built will be sent to Mapping Department. However, building-detailed orthophotos from Google Earth can be used for creating the Land Base on the application software of MWA which makes it more convenient to update the data directly and the data must not be forwarded to Mapping Department. Figure 3.20 shown is the map which has no landbase, so it cannot update the new data. The orthophoto from Google Earth which has the missing house and construction photo.

Figure 3.20 The orthophoto from Google Earth has the missing house.

3.5.3.4 **Piping Equipment Editing**

Old Piping Equipment Abandon Process

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; some old pipes are abandoned, the branch office can inform Mapping Department of the piping equipment abandon in GIS. After being informed, Mapping Department is responsible for deleting the data from the database by using the tool “Abandon”, selecting the piping equipment as required and finally confirming the abandon; the abandon equipment will be turned to red.

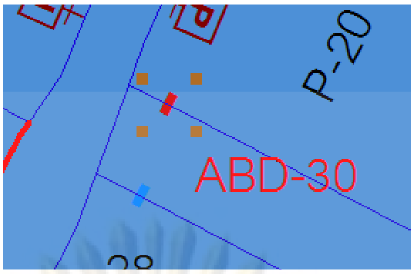


Figure 3.21 The cancelled pipe equipment shown in red color.

3.5.3.5 Piping Replacement Process

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; the piping equipment such as gate valve is improved and type of gate valve has changed and been not compatible with the field data, the branch office can inform Mapping Department of the piping equipment replacement in GIS. After being informed, Mapping Department will edit the data in GIS to be compatible with the field data of the branch office. In order to replace the data, the users have to select the tool "Replace" and select the old piping equipment and then the users will enter the editing window as shown in the figure 3.22. After editing, click the button "Update" to confirm the replacement.

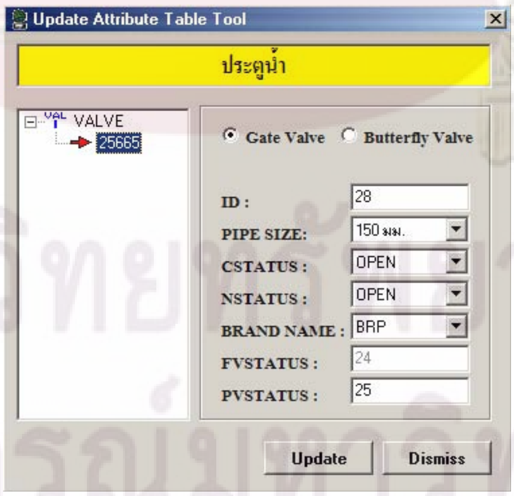


Figure 3.22 Window editing pipe equipment data.

3.5.3.6 New Piping Equipment Installation Process

Whenever a branch office of MWA finds that GIS data of the branch office are incompatible with field data; some piping equipment for which the branch office is responsible are not shown in GIS or incomplete, the branch office is able to inform Mapping Department of piping equipment installation. Mapping Department will edit the GIS data to be compatible with the field data. There are 9 optional types of piping equipment; Reducer, Fire Hydrant, Air Valve, Gate Valve, Well, Gauging Point, Blow Off, Master Meter and Cathodics Protection. Users have to choose the required piping equipment to illustrate the piping line, and digitize gate valve line along the piping line. Whenever the piping equipment is installed, Gate valve number always shows 00. After sending the data to Mapping and Printing Department already, the Department will set codes of equipment and distribute them to the branch office for use.

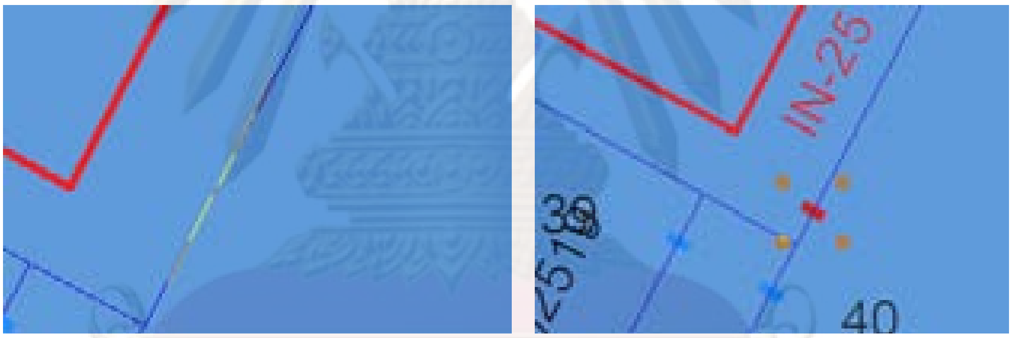


Figure 3.23 The figure is the line of the gate valve installation along the pipe line.

Google Earth can be used as an assistant for piping installation design and survey. For an additional installation of piping, the officers need to survey and measure the features and distance which sometimes get incorrect information; they can use Google Earth to measure the distance instead (in case the Editor Tools has no Land base); for example, air valve needs to be installed for piping installation across canal; in case of not having Land Base, the position of gate valve installation is unpredictable.

Figure 3.24 GE helps for designing the piping and pipe equipment installation.

CHAPTER IV

Research Methodology

Research methodology of this thesis is a development and an improvement of mapping data of Metropolitan Waterworks Authority to be more accurate and up to date in order to support the civilization in our society nowadays. Metropolitan Waterworks Authority is considered as an important public utility to provide services for the public.

The civilization and increasingly urbanized societies have been developing towards the out skirt of the town such as Samutprakarn Province which has the increasing number of population, in addition, the numbers of water requesters have increased as well. Thus, in response to basic human needs, the number of accommodation such as commercial buildings, town houses, single family homes, town home villages are expected to increase, too.

4.1 Equipment and Tools

1. GIS data of Metropolitan Waterworks Authority.
2. Google Earth.
3. Other programs such as ArcView , Editor Tools , FWTools , Openjump , Octave.
4. Computer.

4.2 Program for Research

1. Google Earth displays satellite images of varying resolution of the Earth's surface, allowing users to visually see things like cities and houses looking perpendicularly down or at an oblique angle, with perspective (see also bird's eye view). The degree of resolution available is based somewhat on the points of interest and popularity, but most land (except for some islands) is covered in at least 15 meters of resolution.

2. ArcView is a geographic information system software product produced by ESRI. ArcView GIS is a powerful software that provides for visualizing, querying, exploring, and analyzing data geographically. ArcView is a powerful GIS tool that can display information (which resides locally or over a distributed network), read spatial and tabular information from a variety of data formats, access external databases, produce thematic maps (use colors and symbols to represent features as well to represent features based on their attributes), perform spatial queries, connect spatial information to database attributes, provide several analytical tools, and allows for a high degree of customization using Avenue.
3. Editor tools is the applied program working as the same as Arc View which was built for easier using.
4. FWTools is a set of open source programs for geographical information systems bundled by Frank Warmerdam (initials FW). The graphical GIS toolset is made for Microsoft Windows and Linux platforms, and includes several popular subpackages: openEV , Mapserver , Gdal/OGR , Proj.4 , OGDI , Python programming language
5. Openjump is an open source GIS software written in Java. It is based on JUMP GIS by Vivid Solutions.
6. Octave is a high-level language, primarily intended for numerical computations. It provides a convenient command line interface for solving linear and nonlinear problems numerically, and for performing other numerical experiments using a language that is mostly compatible with Matlab. It may also be used as a batch-oriented language.

   Octave has extensive tools for solving common numerical linear algebra problems, finding the roots of nonlinear equations, integrating ordinary functions, manipulating polynomials, and integrating ordinary differential and differential-algebraic equations. It is easily extensible and customizable via user-defined functions written in Octave's own language, or using dynamically loaded modules written in C++, C, Fortran, or other languages.

GNU Octave is also freely redistributable software. You may redistribute it and/or modify it under the terms of the GNU General Public License (GPL) as published by the Free Software Foundation.

4.3 Methodology

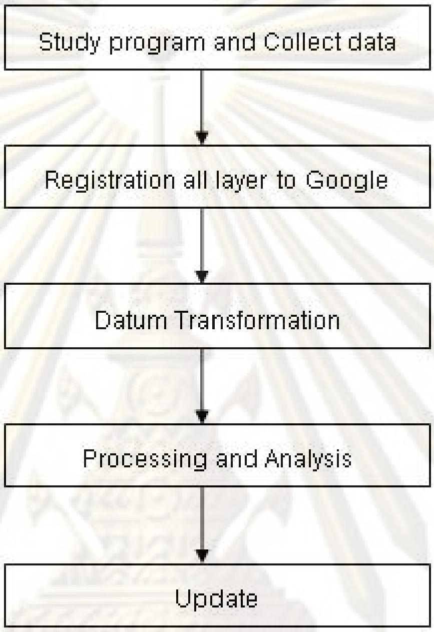


Figure 4.1 Methodology plan.

4.3.1 Collect data

Firstly, the researcher studied the services of the free map program, Google Earth, and analyzed how to use them and their functions; secondly, analyzed the MWA's maps in the applied program, Editor Tool, then studied the collected information from the programs and after that, analyzed the processes and the information layers of the programs. The information layers were divided by selecting only needed parts which were minimized for easier analyzing. Then, the relations of the information from the applied program and Google Earth were analyzed, including how to process the applied program into Google Earth for comparing and how relative the positions from the applied program and Google Earth were. After roughly studying the relations and some problems of these positions, the selected areas finally would finally be studied. These areas were containing all the distribution of the control points. The coordination was converted from Indian datum 1975 coordinate system into the WGS84.

To collect data, the researcher started with collecting required files and separating into different zones in order to minimize the files which could be easily used by Arc View GIS and then, access a new window as shown in the figure 4.2

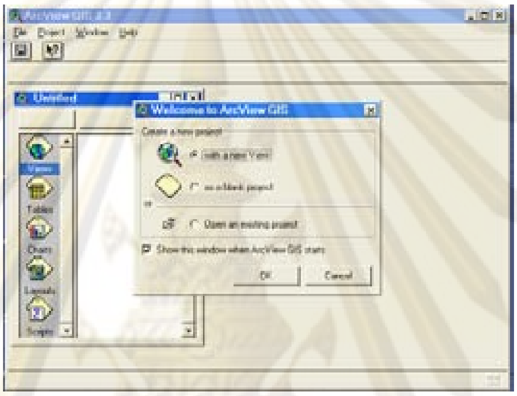


Figure 4.2 ArcView GIS window.

The researcher opened a new file, dragged a required data layer and selected required themes which were land Base and Zone for clipping, after that used the tool “Select Feature” to choose areas, the selected area would be yellow as shown in the figure 4.4, then went to the Menu “Extensions” to close Geoprocessing and a new window would appear on the screen. Next, the researcher went to “Clip one theme based on another” and selecte required files for clipping, changed “Building” to “Input theme” and changed “Zone” to “Overlay theme” an finally, outputed the clipped files, as shown in the figure 4.5, and got a new theme, as shown in the figure 4.6.

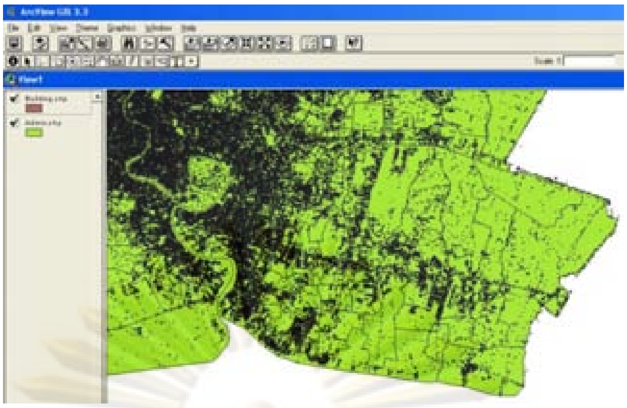


Figure 4.3 The two information layers needed to be clipped.

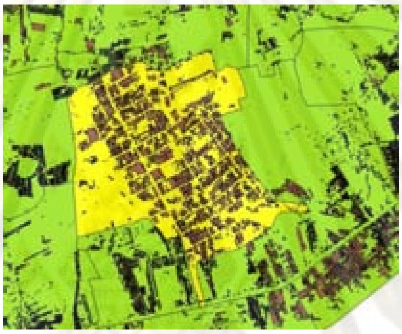


Figure 4.4 The area needed to be cut data.

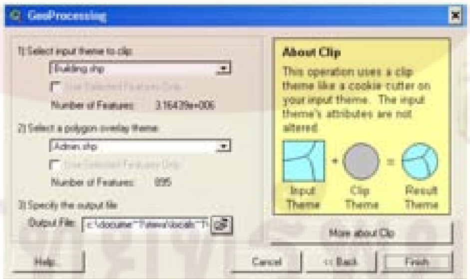


Figure 4.5 Selecting the file needed to be clipped.

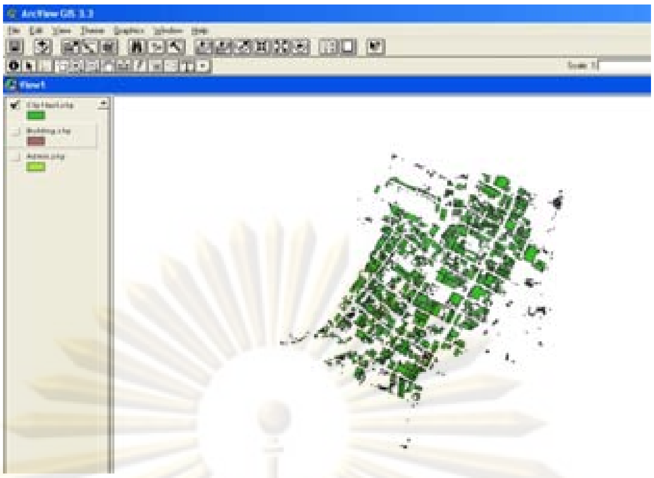


Figure 4.6 Selecting only the needed part from the file which was already clipped.

In this thesis, file clipping was made in every data layer such as building layer, hydrology layer, meter layer, pipe layer and road edge layer. According to DMA, there were totally 78 areas for the experiment. Clipped files were consisted of 3 files with different types which were .dbf, .shp, .shx as shown in the figure 4.7. In some data layers such as an annotation layer could not be clipped, however, there were still enough clipped layers for doing the research.

Figure 4.7 The files in different types after clipping.

4.3.2 Registration

After collecting and saving the files, then the shape files were transformed to kml files by transforming the information layers to kml files for processing in Google Earth.

The researcher started transforming the file typed as shape file into KML file by using FWTools application which the window would appear as shown in figure 4.8.

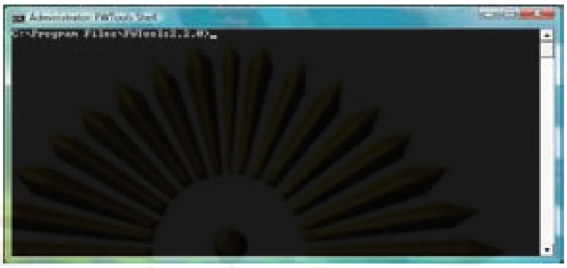


Figure 4.8 Sample of FW Tools.

The researcher used the code "ogr2ogr" to transform the type of files from share file into KML by saving the shape file in a Drive such as c:\, d:\ and then entered the code "ogr2ogr -f KML -s_srs epsg:32647 -t_srs epsg:4326 output file.kml input file.shp" (see figure 4.9). After the application has already processed, the window would appear as shown in the figure 4.10. In the drive, in which the shape file was saved, showed another file as typed KML (see figure 4.11) Then, double clicked on the KML file to open with Google Earth and compare between the data of MWA and orthophotos from Google Earth as shown in the figure 4.12.

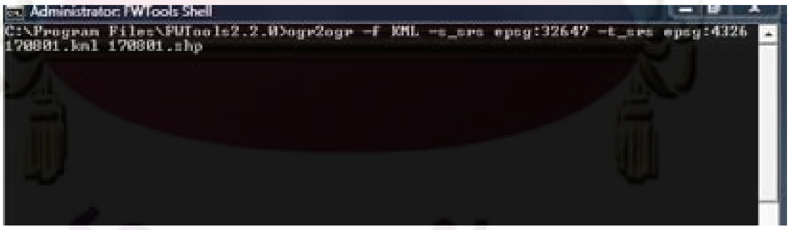


Figure 4.9 Inputting orders to change shape file to KML file.

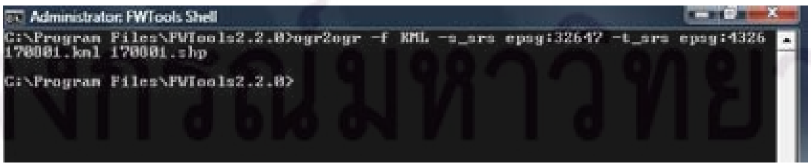


Figure 4.10 Program was running.

Figure 4.11 KML file after being changed from the shape file.

Figure 4.12 The red line was MWA data which was adapted to KML file.

It s found that the information of MWA and orthophotos from Google Earth have the greatly different coordinate value. The magnitude of the coordinate value difference is approximately 440 meters. (see figure 4.13)

Figure 4.13 The MWA information layer was not overlay on the data from Google Earth.

4.3.3 Datum Transformation.

After the shape files were transformed to kml files, the researcher processed the information layers in Google Earth in order to see whether there were any differences after overlaying with the information layers in Google Earth; if yes, how much was that difference. The information layers from MWA were Indian datum 1975, while the layers from Google Earth were WGS84, so the position value had to be transformed, because the two information layers were very different from each other.

According to the coordinate value difference, the Molodensky formula could be used for datum transformation between Indian datum 1975 and World Geodetic System 1984. (Reference: memorandum of Royal Thai Survey Department; The Variable Optimization for Datum Transformation; 10 January 2008)

$$\Delta X = -204.5 \text{ meter}$$
$$\Delta Y = -837.9 \text{ meter}$$
$$\Delta Z = -294.8 \text{ meter}$$

In addition, the FWTools application was used for supporting this research. For the shape file transformation, from Indian 1975 Datum to WGS84, it required the code "ogr2ogr" and parameters from Royal Thai Survey Department; the syntax for the transformation was "ogr2ogr -f "kml" -s_srs "+proj=tmerc +ellps=evrst30 +lon_0=99 +x_0=500000 +k=0.9996 +towgs84=204.5,837.9,294.8" -t_srs epsg:4326 output file.kml input file.shp." (see figure 4.14)

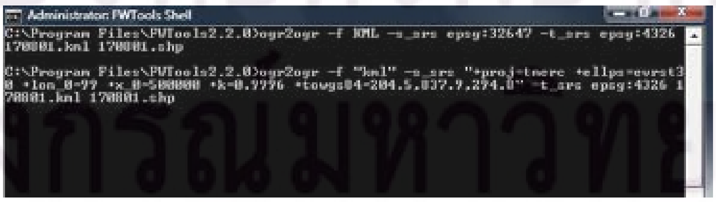


Figure 4.14 Inputting parameter from the Royal Thai Survey Department.

The result of the transformation was creating a new KML file which was recorded the edited parameter. The KML file could be basically tested for accuracy by visual inspection or using the tool “ruler” from Google Earth application. In this research, there were 78 zones (as mentioned above) that have been transformed from shape files into KML files. (The stated 78 zones were located in Samutprakarn only.) After using the tool “ruler”, it indicated that the difference of the information layers in each zone has reduced to approximately 14-20 meters. (see also figure 4.16)

Figure 4.15 The information layer of MWA after inputting parameter from the Royal Thai Survey Department.

Figure 4.16 The information layer from MWA is near with Google Earth.

4.3.4 Processing.

After transforming the datum of the information layers, the transformed layers would be processed in Google Earth in order to find out if the layers from MWA were overlaid with the information from Google Earth. The differences in the both information could be checked by visual inspection. And when the researcher has checked by visual inspection, it showed that the overlay of the information caused modeled systematic error. Finally, they would be processed in an accuracy analysis.

4.3.5 Analysis.

Accuracy Analysis by RMSE

In order to search for the coordinates of the layers of MWA, the researcher opened the datum-transformed KML files, selected the icon “Placemark” on the Toolbar menu and converted the icon “Placemark” from “Pushpin” to “Cross-hairs” icon, then, added “Placemark” on 20 points all around the zone at random. (see figure 4.17)

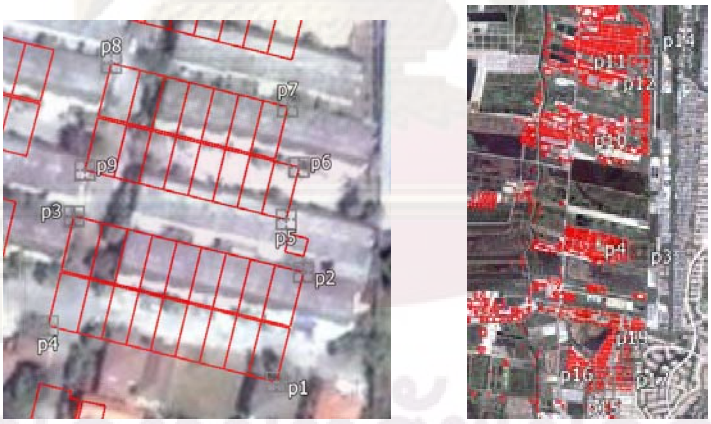


Figure 4.17 Picture shows positions of the MWA information layer added by Placemark at random.

After that, added “Placemark” onto the layers of Google Earth in the same way as the layers of MWA. The alphabet P in the figure 4.18 indicated the Placemark on the layers of MWA; the alphabet G indicated the Placemark on the layers from Google Earth. (see also figure 4.18)

Figure 4.18 Picture shows positions of the MWA and Google Earth information layer added by Placemark at random.

It was shown that the coordinate-transformed layers of MWA were still inaccurate, however; P1 and G1 coordinates should have appeared in the same position as shown in the picture 4.19. From the visual inspection and the use of the tool "Ruler" to roughly measure the coordinates of both layers revealed the systematic error.

Figure 4.19 Picture shows the position of MWA information layer in comparation with Google Earth information layer.

From the layers above, the coordinates of both layers were shown in the table 4.1.

	MWA		Google Earth	
point number	E	N	E	N
1	686900.33	1501329.84	686917.14	1501340.80
2	686906.62	1501355.92	686923.44	1501366.92
3	686852.19	1501368.90	686868.68	1501378.79
4	686845.94	1501343.07	686861.61	1501353.44
5	686902.43	1501368.40	686921.47	1501381.21
6	686905.42	1501380.72	686923.78	1501391.01
7	686902.69	1501395.00	686920.56	1501405.41
8	686860.87	1501404.93	686877.36	1501415.42
9	686854.77	1501379.72	686871.22	1501391.12
10	686842.38	1502335.62	686858.16	1502347.38
11	686845.77	1502906.39	686862.84	1502920.18
12	686848.86	1502917.33	686865.47	1502929.20
13	686941.69	1503055.04	686957.19	1503067.14
14	686942.40	1503078.72	686957.23	1503088.00
15	686562.94	1500215.68	686580.54	1500226.53
16	686572.57	1500296.23	686585.08	1500306.45
17	686731.58	1500347.43	686745.49	1500356.94
18	686806.68	1500386.70	686820.49	1500397.73
19	686796.78	1500504.75	686811.76	1500515.66
20	686790.14	1500546.59	686806.40	1500554.73

Table 4.1 Coordinate from MWA and Google Earth.

The coordinates in the table 2.1 can be used to carry out an accuracy analysis by RMSE (see also the table 2.1) to find out NSSDA.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686900.33	686917.14	-16.81	282.58	1501329.84	1501340.80	-10.96	120.1216	402.7
686906.62	686923.44	-16.82	282.91	1501355.92	1501366.92	-11.00	121	403.9
686852.19	686868.68	-16.49	271.92	1501368.90	1501378.79	-9.89	97.8121	369.7
686845.94	686861.61	-15.67	245.55	1501343.07	1501353.44	-10.37	107.5369	353.1
686902.43	686921.47	-19.04	362.52	1501368.40	1501381.21	-12.81	164.0961	526.6
686905.42	686923.78	-18.36	337.09	1501380.72	1501391.01	-10.29	105.8841	443.0
686902.68	686920.56	-17.88	319.69	1501395.00	1501405.41	-10.41	108.3681	428.1
686860.87	686877.36	-16.49	271.92	1501404.93	1501415.42	-10.49	110.0401	382.0
686854.77	686871.22	-16.45	270.60	1501379.72	1501391.12	-11.40	129.96	400.6
686842.38	686858.16	-15.78	249.01	1502335.62	1502347.38	-11.76	138.2976	387.3
686845.77	686862.84	-17.07	291.38	1502906.39	1502920.18	-13.79	190.1641	481.5
686848.86	686865.47	-16.61	275.89	1502917.33	1502929.20	-11.87	140.8969	416.8
686941.69	686957.19	-15.50	240.25	1503055.04	1503067.14	-12.10	146.41	386.7
686942.40	686957.23	-14.83	219.93	1503078.72	1503088.00	-9.28	86.1184	306.0
686562.94	686580.54	-17.60	309.76	1500215.68	1500226.53	-10.85	117.7225	427.5
686572.57	686585.08	-12.51	156.50	1500296.23	1500306.45	-10.22	104.4484	260.9
686731.58	686745.49	-13.91	193.49	1500347.43	1500356.94	-9.51	90.4401	283.9
686806.68	686820.49	-13.81	190.72	1500386.70	1500397.73	-11.03	121.6609	312.4
686796.78	686811.76	-14.98	224.40	1500504.75	1500515.66	-10.91	119.0281	343.4
686790.14	686806.40	-16.26	264.39	1500546.59	1500554.73	-8.14	66.2596	330.6
							SUM	7647
							Average	382
							RMSE	20
							NSSDA	34

Table 4.2 Accuracy report.

From the table 4.2, the coordinates of the layer of MWA and Google Earth could be used for conformal coordinate transformation and affine coordinate transformation according to the function mentioned in Chapter 2 for which conformal coordinate transformation had to be performed first. (see calculating process thoroughly in Appendix) For that transformation, the researcher used an application of least squares to support for finding out the parameters.

$$AX = L + V$$

$$A = \begin{bmatrix}
6.8692e{+}005 & -1.5013e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5013e{+}006 & 6.8692e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8692e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8692e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8687e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8687e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8686e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8686e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8692e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8692e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8692e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8692e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8692e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8692e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8688e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8688e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8687e{+}005 & -1.5014e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5014e{+}006 & 6.8687e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8686e{+}005 & -1.5023e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5023e{+}006 & 6.8686e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8686e{+}005 & -1.5029e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5029e{+}006 & 6.8686e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8687e{+}005 & -1.5029e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5029e{+}006 & 6.8687e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8696e{+}005 & -1.5031e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5031e{+}006 & 6.8696e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8696e{+}005 & -1.5031e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5031e{+}006 & 6.8696e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8658e{+}005 & -1.5002e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5002e{+}006 & 6.8658e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8659e{+}005 & -1.5003e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5003e{+}006 & 6.8659e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8675e{+}005 & -1.5004e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5004e{+}006 & 6.8675e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8682e{+}005 & -1.5004e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5004e{+}006 & 6.8682e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8681e{+}005 & -1.5005e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5005e{+}006 & 6.8681e{+}005 & 0.0000e{+}000 & 1.0000e{+}000 \\
6.8681e{+}005 & -1.5006e{+}006 & 1.0000e{+}000 & 0.0000e{+}000 \\
1.5006e{+}006 & 6.8681e{+}005 & 0.0000e{+}000 & 1.0000e{+}000
\end{bmatrix}
\quad
X = \begin{bmatrix}
9.9933e{-}001 \\
3.2776e{-}004 \\
9.3834e{+}002 \\
7.7477e{+}002
\end{bmatrix}$$

$$L = \begin{bmatrix}
6.8690e{+}005 \\ 1.5013e{+}006 \\ 6.8691e{+}005 \\ 1.5014e{+}006 \\ 6.8685e{+}005 \\ 1.5014e{+}006 \\ 6.8685e{+}005 \\ 1.5013e{+}006 \\ 6.8690e{+}005 \\ 1.5014e{+}006 \\ 6.8691e{+}005 \\ 1.5014e{+}006 \\ 6.8690e{+}005 \\ 1.5014e{+}006 \\ 6.8686e{+}005 \\ 1.5014e{+}006 \\ 6.8685e{+}005 \\ 1.5014e{+}006 \\ 6.8684e{+}005 \\ 1.5023e{+}006 \\ 6.8685e{+}005 \\ 1.5029e{+}006 \\ 6.8685e{+}005 \\ 1.5029e{+}006 \\ 6.8694e{+}005 \\ 1.5031e{+}006 \\ 6.8694e{+}005 \\ 1.5031e{+}006 \\ 6.8656e{+}005 \\ 1.5002e{+}006 \\ 6.8657e{+}005 \\ 1.5003e{+}006 \\ 6.8673e{+}005 \\ 1.5003e{+}006 \\ 6.8681e{+}005 \\ 1.5004e{+}006 \\ 6.8680e{+}005 \\ 1.5005e{+}006 \\ 6.8679e{+}005 \\ 1.5005e{+}006
\end{bmatrix}
\quad
V = \begin{bmatrix}
0.656992 \\ 0.206876 \\ 0.654190 \\ 0.231358 \\ 0.357162 \\ -0.904581 \\ -0.449769 \\ -0.409833 \\ 2.870832 \\ 2.031092 \\ 2.186065 \\ -0.494748 \\ 1.703513 \\ -0.385497 \\ 0.339313 \\ -0.326395 \\ 0.311411 \\ 0.597951 \\ -0.663221 \\ 0.309939 \\ 0.435888 \\ 1.955877 \\ -0.028839 \\ 0.030667 \\ -1.245794 \\ 0.197871 \\ -1.922658 \\ -2.636158 \\ 2.038796 \\ 0.736653 \\ -3.080454 \\ 0.054340 \\ -1.804987 \\ -0.637072 \\ -1.968845 \\ 0.880051 \\ -0.831621 \\ 0.677802 \\ 0.439182 \\ -2.120256
\end{bmatrix}$$

Figure 4.20 Example of results from calculating parameter of conformal coordinate transformations.

Then, the researcher used the coordinates from the table 4.2 for affine coordinate transformation according to the function mentioned in Chapter 2. (see calculating process thoroughly in Appendix) and used the application of least squares to support for finding out the parameters.

$$
A = \begin{bmatrix}
6.8692e+005 & 1.5013e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8692e+005 & 1.5013e+006 & 1.0000e+000 \\
6.8692e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8692e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8687e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8687e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8686e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8686e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8692e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8692e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8692e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8692e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8692e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8692e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8688e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8688e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8687e+005 & 1.5014e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8687e+005 & 1.5014e+006 & 1.0000e+000 \\
6.8686e+005 & 1.5023e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8686e+005 & 1.5023e+006 & 1.0000e+000 \\
6.8686e+005 & 1.5029e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8686e+005 & 1.5029e+006 & 1.0000e+000 \\
6.8687e+005 & 1.5029e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8687e+005 & 1.5029e+006 & 1.0000e+000 \\
6.8696e+005 & 1.5031e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8696e+005 & 1.5031e+006 & 1.0000e+000 \\
6.8696e+005 & 1.5031e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8696e+005 & 1.5031e+006 & 1.0000e+000 \\
6.8658e+005 & 1.5002e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8658e+005 & 1.5002e+006 & 1.0000e+000 \\
6.8659e+005 & 1.5003e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8659e+005 & 1.5003e+006 & 1.0000e+000 \\
6.8675e+005 & 1.5004e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8675e+005 & 1.5004e+006 & 1.0000e+000 \\
6.8682e+005 & 1.5004e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8682e+005 & 1.5004e+006 & 1.0000e+000 \\
6.8681e+005 & 1.5005e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8681e+005 & 1.5005e+006 & 1.0000e+000 \\
6.8681e+005 & 1.5006e+006 & 1.0000e+000 & 0.0000e+000 & 0.0000e+000 & 0.0000e+000 \\
0.0000e+000 & 0.0000e+000 & 0.0000e+000 & 6.8681e+005 & 1.5006e+006 & 1.0000e+000
\end{bmatrix}
\quad
X = \begin{bmatrix}
9.9278e-001 \\
1.4899e-004 \\
4.7206e+003 \\
1.8792e-003 \\
9.9926e-001 \\
-1.9428e+002
\end{bmatrix}
$$

$$
L = \begin{bmatrix}
6.8690e+005 \\ 1.5013e+006 \\ 6.8691e+005 \\ 1.5014e+006 \\ 6.8685e+005 \\ 1.5014e+006 \\ 6.8685e+005 \\ 1.5013e+006 \\ 6.8690e+005 \\ 1.5014e+006 \\
6.8691e+005 \\ 1.5014e+006 \\ 6.8690e+005 \\ 1.5014e+006 \\ 6.8686e+005 \\ 1.5014e+006 \\ 6.8685e+005 \\ 1.5014e+006 \\ 6.8684e+005 \\ 1.5023e+006 \\
6.8685e+005 \\ 1.5029e+006 \\ 6.8685e+005 \\ 1.5029e+006 \\ 6.8694e+005 \\ 1.5031e+006 \\ 6.8694e+005 \\ 1.5031e+006 \\ 6.8656e+005 \\ 1.5002e+006 \\
6.8657e+005 \\ 1.5003e+006 \\ 6.8673e+005 \\ 1.5003e+006 \\ 6.8681e+005 \\ 1.5004e+006 \\ 6.8680e+005 \\ 1.5005e+006 \\ 6.8679e+005 \\ 1.5005e+006
\end{bmatrix}
\quad
V = \begin{bmatrix}
0.130373 \\ 0.305901 \\ 0.106765 \\ 0.338476 \\ 0.174015 \\ -0.883184 \\ -0.598702 \\ -0.397774 \\ 2.343122 \\ 2.134235 \\
1.647899 \\ -0.308651 \\ 1.193299 \\ -0.285322 \\ 0.116705 \\ -0.293087 \\ 0.117508 \\ 0.622496 \\ -0.315701 \\ 0.252712 \\
1.025839 \\ 1.869067 \\ 0.548189 \\ -0.052643 \\ -1.203669 \\ 0.247908 \\ -1.870850 \\ -2.587321 \\ 3.193312 \\ 0.385130 \\
-1.917569 \\ -0.295279 \\ -1.660540 \\ -0.741070 \\ -2.304119 \\ 0.889788 \\ -1.053500 \\ 0.666409 \\ 0.271031 \\ -2.142477
\end{bmatrix}
$$

Figure 4.21 Example of results from calculating parameter of affine coordinate transformations.

From figure 4.20 and figure 4.21, it revealed that there are only a-few-meter matrix residuals from conformation transformation and affine transformation. From the table 4.2, the differences in the vertical and horizontal axis were systematic sizes and directions.

4.3.6 Update.

The next process was an update. The land base or the information layers were processed in Google Earth by digitizing in Google Earth, and then the lines which were kml file have been transformed to shape file to be able to use in the program of MWA.

In the process of update, firstly, the researcher opened the datum-transformed file of MWA with Google Earth, and used the tool “Add Path”  to create “Building” standing for buildings on the orthophotos from Google Earth. (see also figure 4.22)

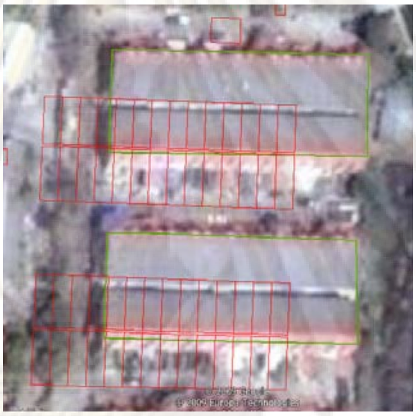


Figure 4.22 Digitize rectangular on GE by add path. (green line)

Then, the researcher selected “Save Place as” to save the file of “Building” and changed file type as KML. (as shown in figure 4.23)

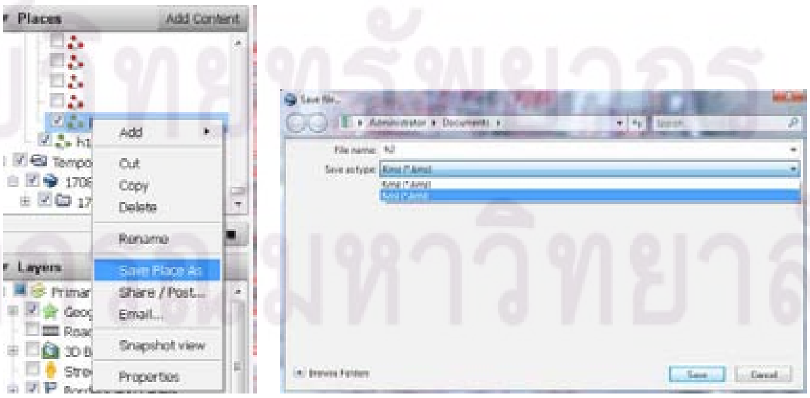


Figure 4.23 Saving file as KML file on Google earth.

Actually, the researcher could create KML file with the use of GE tools. The KML file was able to be converted to shape file through the FWTools application by entering the code “ogr2ogr ogroutput.shp input.kml” The shapefile that was converted from the KML file would be separated into 4 different file types; .shp .shx .dbf .prj. (see figure 4.24)

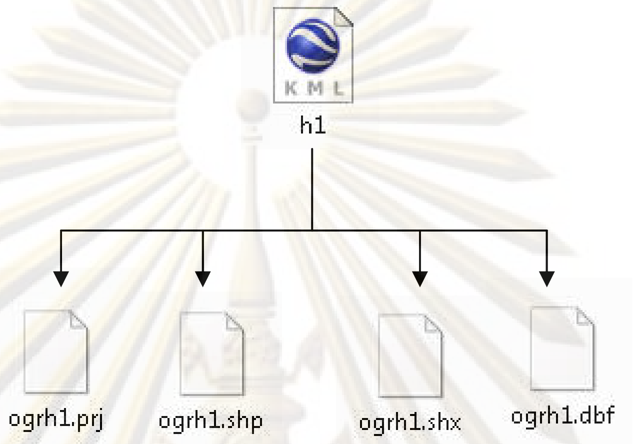


Figure 4.24 Changing one kml file to four files.

After that, the researcher opened the shapefile which was transformed the datum, with Openjump program (see figure 4.25) and then converted the shapefile of “Building” created in Google Earth to UTM by the FWTools application with the code : ogr2ogr -f "Esri shapefile" -s_srs epsg:4326 -t_srs "+proj=tmerc +ellps=evrst30 +lon_0=99 +x_0=500000 +k=0.9996 +towgs84=204.5,837.9,294.8" output.shp input.shp

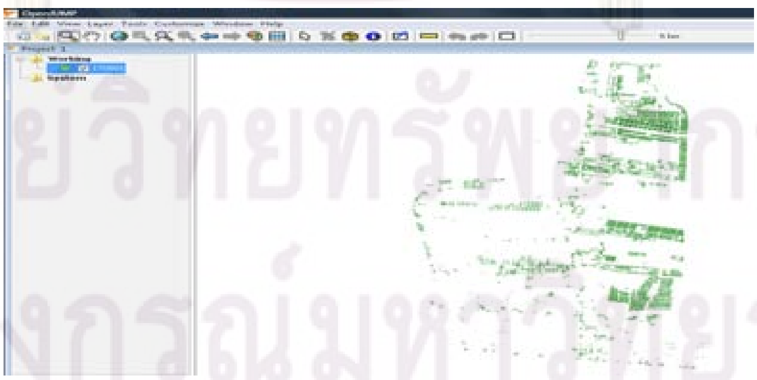


Figure 4.25 The MWA information layer opened by Openjump Program.

In the next step, the researcher opened the shapefile created on Google Earth with the Openjump application in the same way as the shapefile of MWA as shown in figure 4.26. The green line represents the MWA information layer. The blue line represents construction built by Google Earth opened in Openjump Program.

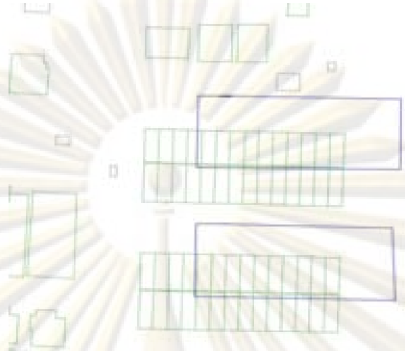


Figure 4.26 The blue line represents construction built by Google Earth.

4.3.6.1 **Geometric Transformations**

4.3.6.1.1 **Warping**

A warp is an algorithm for modifying all of the features in a layer, usually according to some parameters that are easy to specify, such as vectors.

4.3.6.1.1.1 **Applying an Affine Transform**

An affine transform is a linear transformation that is defined by the initial and final positions of three points. The affine transform will translate, rotate, scale, flip, and shear the dataset so that the initial three locations are mapped to the final three locations.

Affine transforms can be tricky to apply properly sometimes you get results that you don’t expect! However, they are safe to use because the original layer is not modified; rather, a new layer is created.

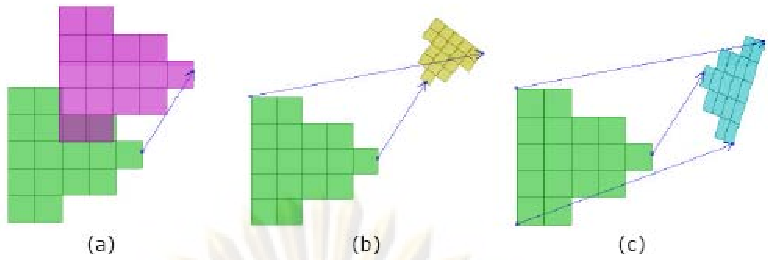


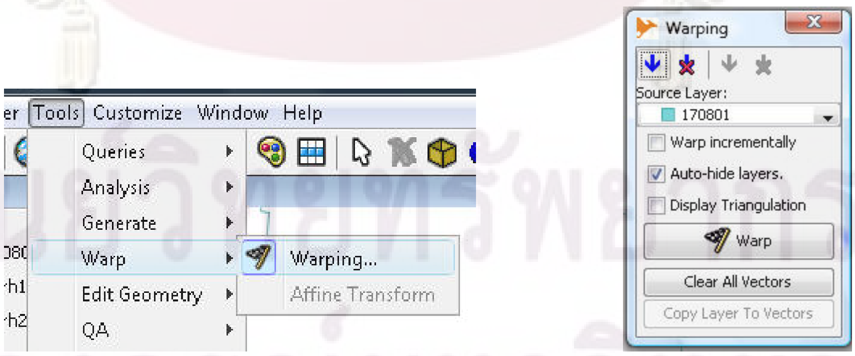
Figure 4.27 Applying an affine transform, specifying (a) one point (b) two points (c) three points.

The simplest use of an affine transform is to move all the features of a layer. This usage involves one vector. The layer will not be rotated, scaled, flipped, or sheared – just translated (see Figure 4.27a above).

When you supply two vectors, the layer will be translated, rotated, and scaled, but not flipped or sheared (see Figure 4.27b above).

When you supply three vectors, the layer will be translated, rotated, scaled, flipped, and sheared (see Figure 4.27c above).

The next process was a warp which helped for geometric corrections in the files that have still remained some errors. Firstly, the researcher run the Openjump application, selected the tool "warp" and "warping" (see figure 4.28(a)) and then selected source layer for warping. (see figure 4.28(b))



(a) (b)

Figure 4.28 Choose source layer.

After selecting the source layer, the researcher selected green lines which were required to warp and blue lines which needed to be replaced by the green lines. (see figure 4.29)

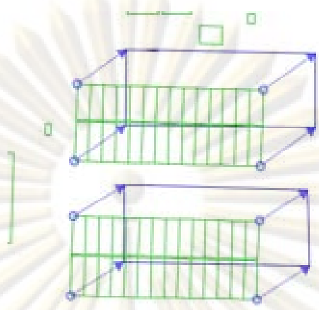


Figure 4.29 Selecting a point to warp.

When the warping has finishes, the researcher clicked to right on the mouse and went to “Save Data” to save the warped shape file, then converted the file to KML file with the FWTools program by entering the code;

“ogr2ogr -f "kml" -s_srs "+proj=tmerc +ellps=evrst30 +lon_0=99 +x_0=500000 +k=0.9996 +towgs84=204.5,837.9,294.8" -t_srs epsg:4326 output.kml input.shp”

The warped file had to be run with Google Earth again in order to examine how it was accurate. (see figure 4.30)

Figure 4.30 The file after warpping and comparing with the orthophoto from Google Earth.

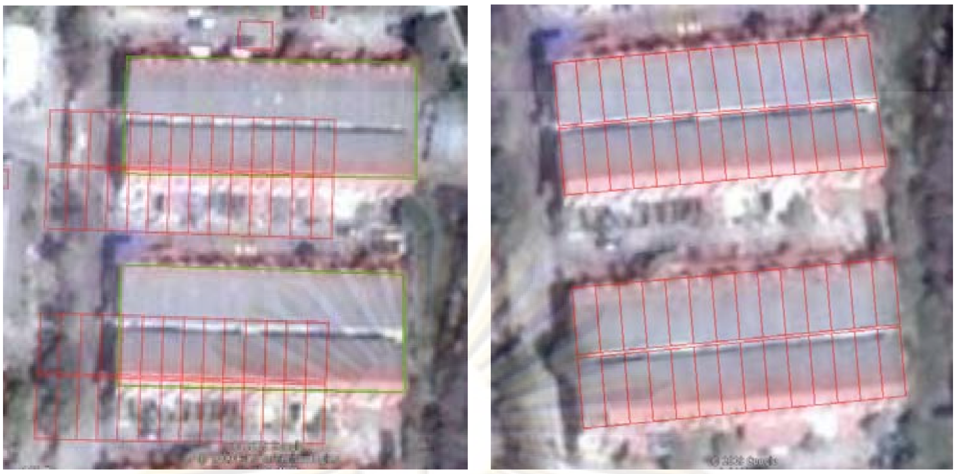


Figure 4.31 The left picture is before warpping. The right one is after warpping.

Figure 4.32 All zone after Geomatric transform.

According to the visual inspection and the use of “Ruler Tool” for measuring the difference of coordinates all around the zones, it was shown that the warped file was rather completely overlaid with the orthophotos from Google Earth; that was the overlay was rather perfect except for a few buildings. Moreover, the warped file gave the detailed data which were accurate enough for map updating later.

The examination of Land Base information layer of MWA

According to the examination of land base information layer of MWA for layer updating, it was found that the information of just-built village has not been found in the information of MWA but could be found in Google Earth. The red line represented the information of MWA and the just-built village which MWA had no land base stood in the green circle. (see also figure 4.33)

Figure 4.33 Houses in green circles does not exist on the MWA information layer.

The researcher could update the building information layer of MWA with the orthophotos from Google Earth. Firstly, the researcher used the tool “add path ” in Google Earth to digitize the building layer in the area of just-built village. (see figure 4.34)

Figure 4.34 The left picture is before update. The right one is after digitizing houses.

After digitizing the building in Google Earth, the use saved the building file as KLM type and converted to shape file by using the FWTools application and then merged the warped shape file of MWA and the shape file which was digitized in Google Earth into the same shape file (that meant there were 2 shape files merging into 1 file.) However, the shape file of MWA was UTM, the digitized shape file was lat, lon which had to be converted to UTM before. The conversion could be made with FWTools by entering the code "ogr2ogr -f "Esri shapefile" -s_srs epsg:4326 -t_srs "+proj=tmerc +ellps=evrst30 +lon_0=99 +x_0=500000 +k=0.9996 +towgs84=204.5,837.9,294.8" output.shp input.shp"

And the file could be merged with the FWTools by entering the code

"ogr2ogr file_merged.shp first file.shp

ogr2ogr -update -append file_merged.shp second file.shp -nln file_merged"

The warped file of MWA should have been the first file and the other should have been the second file. (see figure 4.35)

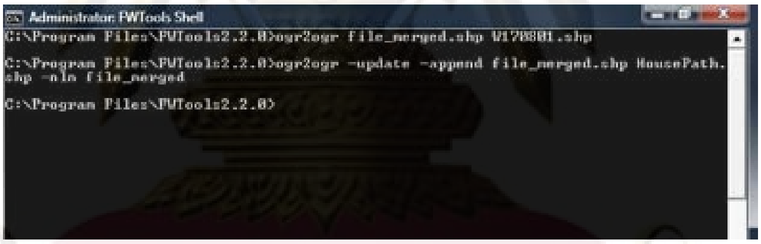


Figure 4.35 Sample of file merging order by FWTools Program.

Figure 4.36 left figure is a file before merge right figure is a file after merge.

After that, the researcher opened the original file of MWA (which was not transformed the parameter from Royal Thai Survey Department) in Google Earth (it was possible to open in Openjump or others, due to the great number of the transformed files and untransformed files, the searcher opened the file in Google in order not to misunderstand) and opened the merged file in Google Earth as shown in figure 4.37

Figure 4.37 Red layer is a MWA file green layer is a digitized file on GE.

The Overlay of the MWA layer and the building-updated file caused a lot of errors because of the last warping. Therefore, the researcher had to process the affine transformation one more time to move the updated file to the previous coordinate of MWA. Differ average is about 20 meters after affine transformation.

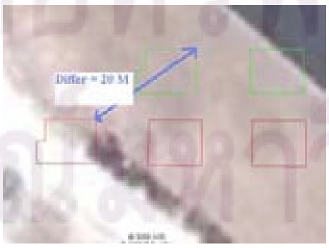


Figure 4.38 Green layers are updated files red layers are MWA files.

In the next step, the researcher has found the coordinates of the untransformed layer of MWA and the updated layer by selecting 20 points on the layers at random to find the difference. (see figure 4.39)

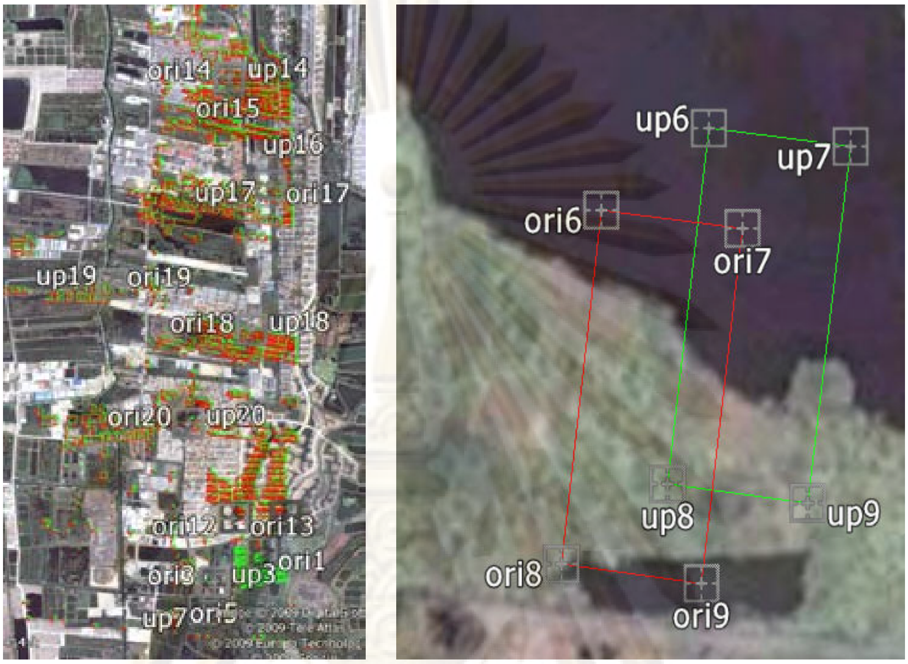


Figure 4.39 Find coordinate between MWA data and updated file.

Then, the researcher could get the coordinates of the information layer of MWA and the updated file layer as table 4.3.

	update		MWA	
point number	E	N	E	N
1	686971.64	1499685.35	686955.67	1499675.19
2	686991.66	1499695.23	686975.68	1499685.05
3	686629.71	1499496.37	686613.76	1499486.20
4	686638.36	1499471.44	686622.40	1499461.25
5	686637.72	1499462.84	686621.74	1499452.65
6	686524.05	1499309.52	686508.09	1499299.34
7	686544.27	1499306.24	686528.31	1499296.05
8	686516.01	1499262.26	686500.07	1499252.06
9	686536.32	1499258.86	686520.38	1499248.64
10	687134.38	1499925.38	687118.41	1499915.16
11	687142.40	1499925.02	687126.43	1499914.81
12	686785.47	1499927.82	686769.51	1499917.61
13	686793.27	1499927.47	686777.34	1499917.24
14	686883.04	1502913.91	686867.34	1502903.61
15	686880.53	1502876.84	686864.78	1502866.46
16	687278.43	1502268.37	687262.53	1502258.13
17	687129.75	1502171.38	687113.84	1502161.13
18	686957.99	1501196.40	686942.09	1501186.18
19	686022.64	1501545.78	686006.92	1501535.47
20	686500.91	1500580.01	686485.03	1500569.79

Table 4.3 Shown coordinates of MWA and updated file.

The coordinates shown in the table 4.5 could be used for doing the accuracy analysis by RMSE. (see table 4.4) The result of the analysis showed that the NSSDA was fairly similar to the result of the first process; that meant the process was systematic.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686971.64	686955.67	15.97	255.04	1499685.35	1499675.19	10.16	103.2256	358.3
686991.66	686975.68	15.98	255.36	1499695.23	1499685.05	10.18	103.6324	359.0
686629.71	686613.76	15.95	254.40	1499496.37	1499486.20	10.17	103.4289	357.8
686638.36	686622.40	15.96	254.72	1499471.44	1499461.25	10.19	103.8361	358.6
686637.72	686621.74	15.98	255.36	1499462.84	1499452.65	10.19	103.8361	359.2
686524.05	686508.09	15.96	254.72	1499309.52	1499299.34	10.18	103.6324	358.4
686544.27	686528.31	15.96	254.72	1499306.24	1499296.05	10.19	103.8361	358.6
686516.01	686500.07	15.94	254.08	1499262.26	1499252.06	10.20	104.0400	358.1
686536.32	686520.38	15.94	254.08	1499258.86	1499248.64	10.22	104.4484	358.5
687134.38	687118.41	15.97	255.04	1499925.38	1499915.16	10.22	104.4484	359.5
687142.40	687126.43	15.97	255.04	1499925.02	1499914.81	10.21	104.2441	359.3
686785.47	686769.51	15.96	254.72	1499927.82	1499917.61	10.21	104.2441	359.0
686793.27	686777.34	15.93	253.76	1499927.47	1499917.24	10.23	104.6529	358.4
686883.04	686867.34	15.70	246.49	1502913.91	1502903.61	10.30	106.0900	352.6
686880.53	686864.78	15.75	248.06	1502876.84	1502866.46	10.38	107.7444	355.8
687278.43	687262.53	15.90	252.81	1502268.37	1502258.13	10.24	104.8576	357.7
687129.75	687113.84	15.91	253.13	1502171.38	1502161.13	10.25	105.0625	358.2
686957.99	686942.09	15.90	252.81	1501196.40	1501186.18	10.22	104.4484	357.3
686022.64	686006.92	15.72	247.12	1501545.78	1501535.47	10.31	106.2961	353.4
686500.91	686485.03	15.88	252.17	1500580.01	1500569.79	10.22	104.4484	356.6
							SUM	7154
							Average	358
							RMSE	19
							NSSDA	33

Table 4.4 Accuracy between MWA layer and Updated file layer.

Because the affine transformation always caused the errors; thus, the researcher divided the zone into 3 sub-zones to test the warping. (see figure 4.40) The first zone covered the area about 3 square meters; the second zone covered 2.64 square meters; and the third zone covered 3.12 square meters. From the test, the warping in the second zone caused some errors as same as the warping in the third zone; but the second zone showed only a few errors. According to the test, the warping on the second zone caused some errors; the first and the third zone had quite a few distortions. Thus, the researcher used the warping on 20 points all around the zone at random.

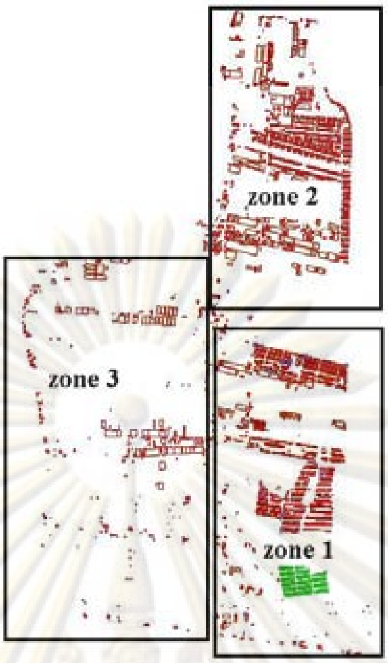


Figure 4.40 Divided 3 zone.

The researcher has marked on 20 warping points at random. (see figure 4.41)

Figure 4.41 Blue point is a warping point.

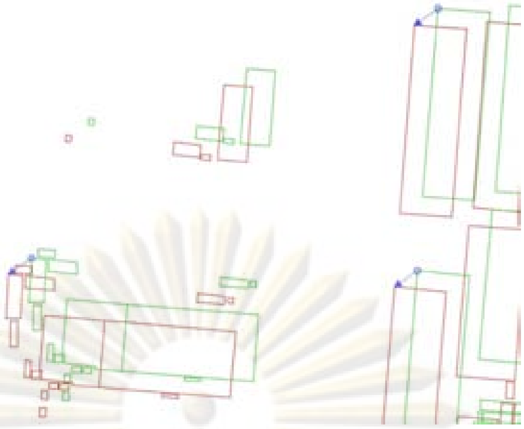


Figure 4.42 Zoom to warping point between MWA layer and updated layer.

After marking the warping points, then, the researcher selected the tool “Warping” in the Openjump. The result would appear as shown in figure 4.43.

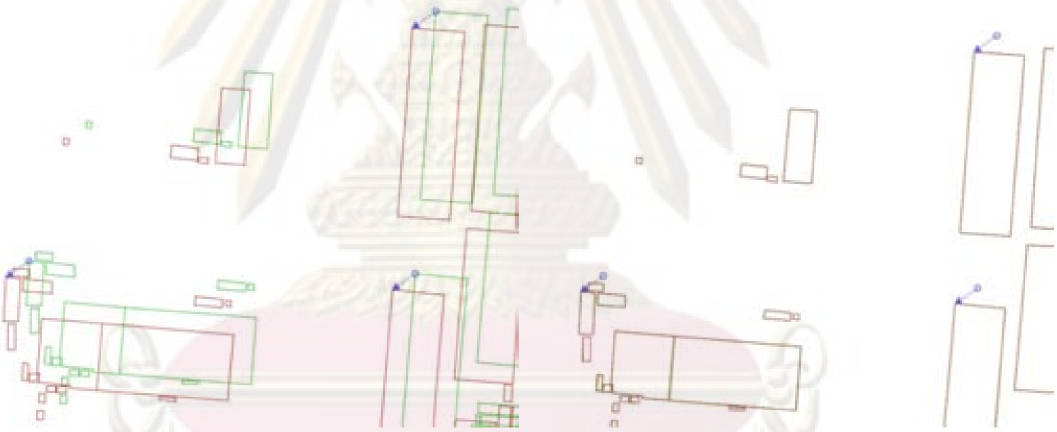


Figure 4.43 The left picture is before wrapping. The right one is after wrapping.

In the next step, select a warping point at random (see figure 4.44) in order to find the NSSDA of all three zones and then compare it with the NSSDA of the multiple warping points and find out whether the NSSDA of the multiple warping points are less than the other.

Figure 4.44 Marking a warping point at random.

After completion of Geometric Transformation, convert the updated shape file to Indian 1975 and then open with the Editor Tools of WMA for further use.

The method and process by using Google Earth for updating the base map of MWA consist of multi-reversion of datum transformation which may cause some mistakes and confused. Therefore, the researcher has drawn the flow chart to make the process easier to understand. In addition, it has been used in the research which helped operating completely as shown in Figure 4.45.

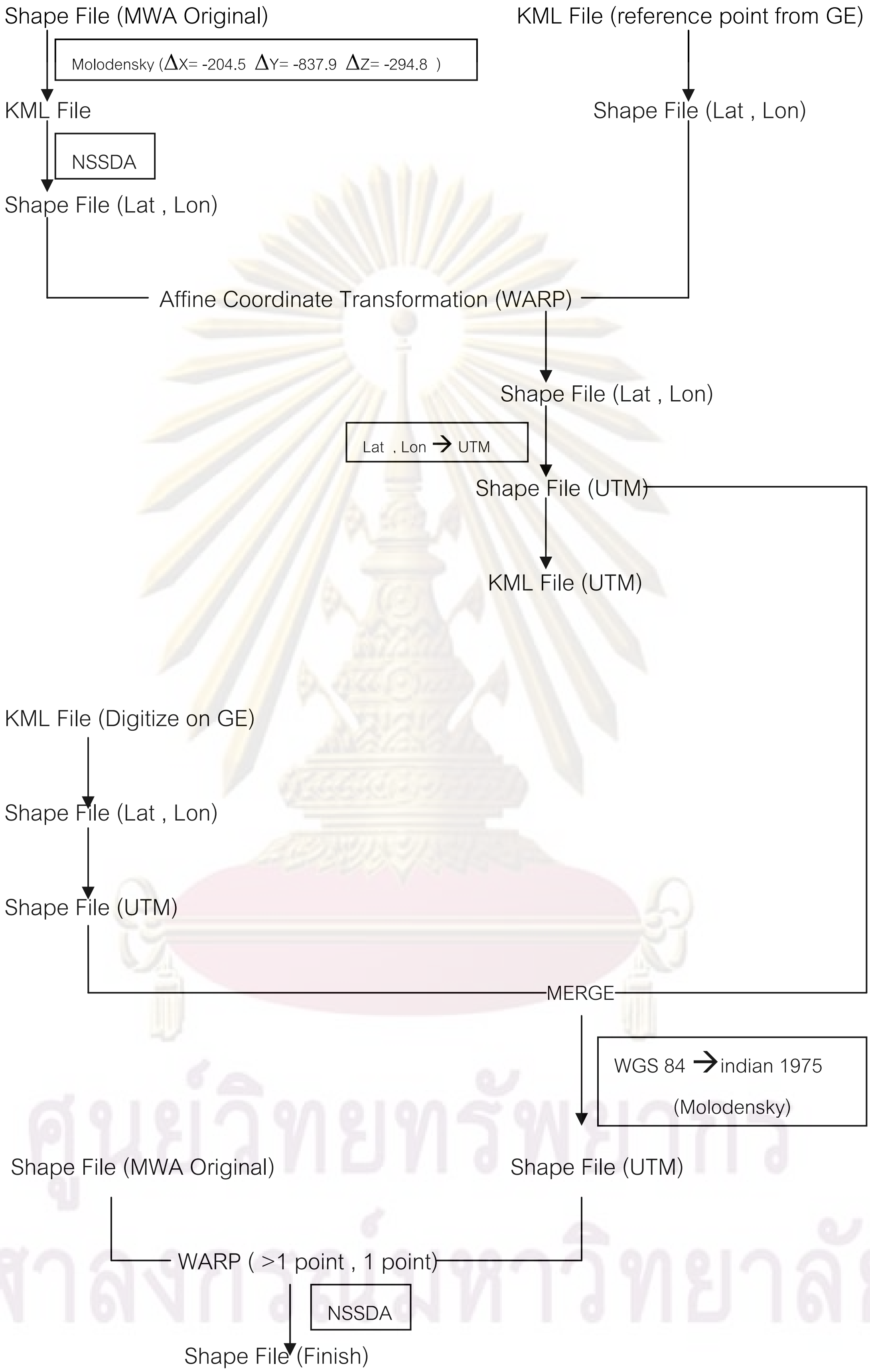


Figure 4.45 Flow chart of Updating methodology.

CHAPTER V

Research Results

This chapter discusses research results. The results of the study will be discussed and explained step by step through the process of research as mentioned in chapter 4; namely Study program and Collect data, Registration layer to Google Earth, Datum Transformation, Analysis and Update respectively.

5.1 Study program and Collect data.

According to the study of Google Earth and Editor Tools of MWA, it is found that Google Earth is an application that can assist users to work with data easier and also help users to edit the base map of WMA efficiently. The researcher has chosen the experimental site of DMA 17-08-01 covering on the area of approximately 5X5 square kilometers for the experiment.

First of all, divide the data layer of WMA into 78 DMA (as shown in figure 5.1).The DMA layer can be separated by its characteristic into 3 types; vertical layer, horizontal layer and square layer as shown in figure 5.2

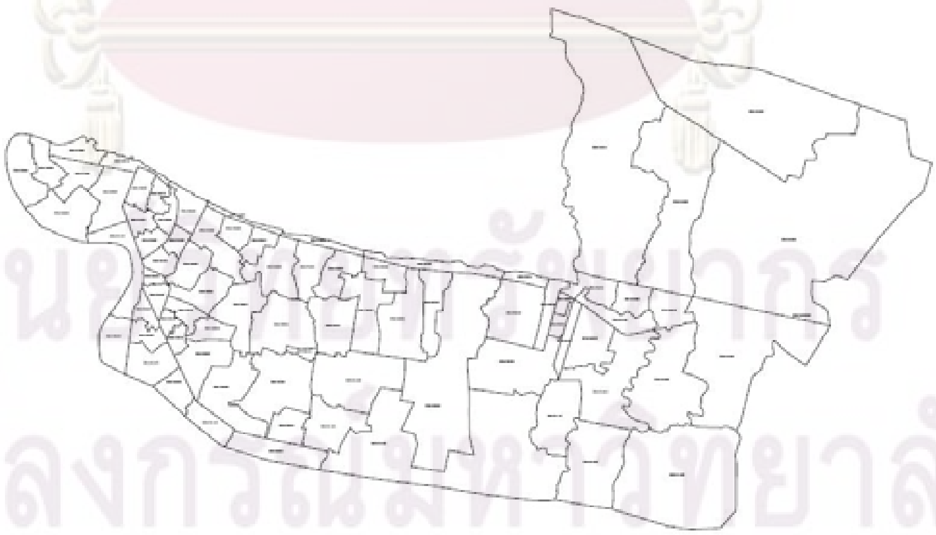


Figure 5.1 Data layer divided into 78 DMA.

Figure 5.2 3 characteristics of DMA layer; horizontal , vertical and square layer.

Figure 5.3 A sample of edited building layer of MWA.

Figure 5.4 A sample of edited road-data layer of MWA.

5.2 Registration.

After importing the data layer of MWA without inputting the parameters from Royal Thai Survey Department, it is obvious that the data layers of MWA and Google Earth are not overlaid; there are namely a lot of errors as shown in figure 5.5.

Figure 5.5 Data layers of MWA and Google Earth are not overlaid.

5.3 Datum Transformation.

When the researcher used Molodensky formula by inputting the parameters from Royal Thai Survey Department, the result shows that the layers of MWA and Google Earth are closer and nearly overlaid. (see figure 5.6)

Figure 5.6 The layers of MWA and Google Earth are almost overlaid.

The layers of both systems, however, are incompletely overlaid when the researcher randomly tested the positional accuracy by using the tool "Ruler"; the magnitude of layer difference is approximately 20-30 meters.

5.4 Analysis.

After inputting the parameters from Royal Thai Survey Department, the datum coordinates of MWA and Google Earth appear as shown in table 5.1. And the coordinates below can be calculated for the NSSDA as shown in table 5.2.

	MWA		Google Earth	
point number	E	N	E	N
1	686900.33	1501329.84	686917.14	1501340.80
2	686906.62	1501355.92	686923.44	1501366.92
3	686852.19	1501368.90	686868.68	1501378.79
4	686845.94	1501343.07	686861.61	1501353.44
5	686902.43	1501368.40	686921.47	1501381.21
6	686905.42	1501380.72	686923.78	1501391.01
7	686902.68	1501395.00	686920.56	1501405.41
8	686860.87	1501404.93	686877.36	1501415.42
9	686854.77	1501379.72	686871.22	1501391.12
10	686842.38	1502335.62	686858.16	1502347.38
11	686845.77	1502906.39	686862.84	1502920.18
12	686848.86	1502917.33	686865.47	1502929.20
13	686941.69	1503055.04	686957.19	1503067.14
14	686942.40	1503078.72	686957.23	1503088.00
15	686562.94	1500215.68	686580.54	1500226.53
16	686572.57	1500296.23	686585.08	1500306.45
17	686731.58	1500347.43	686745.49	1500356.94
18	686806.68	1500386.70	686820.49	1500397.73
19	686796.78	1500504.75	686811.76	1500515.66
20	686790.14	1500546.59	686806.40	1500554.73

Table 5.1 The datum coordinates of WMA and Google Earth.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686900.33	686917.14	-16.81	282.58	1501329.84	1501340.80	-10.96	120.1216	402.7
686906.62	686923.44	-16.82	282.91	1501355.92	1501366.92	-11.00	121	403.9
686852.19	686868.68	-16.49	271.92	1501368.90	1501378.79	-9.89	97.8121	369.7
686845.94	686861.61	-15.67	245.55	1501343.07	1501353.44	-10.37	107.5369	353.1
686902.43	686921.47	-19.04	362.52	1501368.40	1501381.21	-12.81	164.0961	526.6
686905.42	686923.78	-18.36	337.09	1501380.72	1501391.01	-10.29	105.8841	443.0
686902.68	686920.56	-17.88	319.69	1501395.00	1501405.41	-10.41	108.3681	428.1
686860.87	686877.36	-16.49	271.92	1501404.93	1501415.42	-10.49	110.0401	382.0
686854.77	686871.22	-16.45	270.60	1501379.72	1501391.12	-11.40	129.96	400.6
686842.38	686858.16	-15.78	249.01	1502335.62	1502347.38	-11.76	138.2976	387.3
686845.77	686862.84	-17.07	291.38	1502906.39	1502920.18	-13.79	190.1641	481.5
686848.86	686865.47	-16.61	275.89	1502917.33	1502929.20	-11.87	140.8969	416.8
686941.69	686957.19	-15.50	240.25	1503055.04	1503067.14	-12.10	146.41	386.7
686942.40	686957.23	-14.83	219.93	1503078.72	1503088.00	-9.28	86.1184	306.0
686562.94	686580.54	-17.60	309.76	1500215.68	1500226.53	-10.85	117.7225	427.5
686572.57	686585.08	-12.51	156.50	1500296.23	1500306.45	-10.22	104.4484	260.9
686731.58	686745.49	-13.91	193.49	1500347.43	1500356.94	-9.51	90.4401	283.9
686806.68	686820.49	-13.81	190.72	1500386.70	1500397.73	-11.03	121.6609	312.4
686796.78	686811.76	-14.98	224.40	1500504.75	1500515.66	-10.91	119.0281	343.4
686790.14	686806.40	-16.26	264.39	1500546.59	1500554.73	-8.14	66.2596	330.6
							SUM	7647
							Average	382
							RMSE	20
							NSSDA	34

Table 5.2 The coordinates can be calculated for the NSSDA.

According to the table of calculating the NSSDA above, the result shows NSSDA = 34; that means:

Positional Accuracy: Tested 34 meter horizontal

accuracy at 95% confidence level

This means that a user of this data set can be confident that the horizontal position of a well defined feature will be within 34 meter of its true location, as best as its true location has been determined, 95 percent of the time.

After that, when the researcher used the coordinates from the table 5.1 to operate the conformal coordinate transformation and affine coordinate transformation. The results of residuals value are indicated as shown in figures 5.7 and 5.8

$$\mathbf{V} = \begin{bmatrix} 0.656992 \\ 0.206876 \\ 0.654190 \\ 0.231358 \\ 0.357162 \\ -0.904581 \\ -0.449769 \\ -0.409833 \\ 2.870832 \\ 2.031092 \\ 2.186065 \\ -0.494748 \\ 1.703513 \\ -0.385497 \\ 0.339313 \\ -0.326395 \\ 0.311411 \\ 0.597951 \\ -0.663221 \\ 0.309939 \\ 0.435888 \\ 1.955877 \\ -0.028839 \\ 0.030667 \\ -1.245794 \\ 0.197871 \\ -1.922658 \\ -2.636158 \\ 2.038796 \\ 0.736653 \\ -3.080454 \\ 0.054340 \\ -1.804987 \\ -0.637072 \\ -1.968845 \\ 0.880051 \\ -0.831621 \\ 0.677802 \\ 0.439182 \\ -2.120256 \end{bmatrix}$$

(a)

$$\mathbf{V} = \begin{bmatrix} 0.138373 \\ 0.305901 \\ 0.106765 \\ 0.338476 \\ 0.174015 \\ -0.883184 \\ -0.598702 \\ -0.397774 \\ 2.343122 \\ 2.134235 \\ 1.647899 \\ -0.388651 \\ 1.193299 \\ -0.285322 \\ 0.116785 \\ -0.293887 \\ 0.117508 \\ 0.622496 \\ -0.315701 \\ 0.252712 \\ 1.025839 \\ 1.869067 \\ 0.548189 \\ -0.052643 \\ -1.203669 \\ 0.247988 \\ -1.870850 \\ -2.587321 \\ 3.193312 \\ 0.385130 \\ -1.917569 \\ -0.295279 \\ -1.668540 \\ -0.741070 \\ -2.304119 \\ 0.889788 \\ -1.053500 \\ 0.666409 \\ 0.271031 \\ -2.142477 \end{bmatrix}$$

(b)

Figure 5.7 (a) Shows the residual values after operating the conformal coordinate transformation. (b) Shows the residual values after operating the affine coordinate transformation.

It clearly shows that the residual values are only a few meters, so it prefers to conduct the affine coordinate transformation.

5.5 Update.

In the process of updating the MWA base map by using Google Earth, the researcher has operated the process step by step of the flow chart 4.45 being proved that it was practical as mentioned in Chapter 4. The result of the experiment has shown as following:

5.5.1 Use multiple warping points

From the figure 4.43, it is apparently shown that the layer of MWA and the updated layer are overlaid with a few errors as figure 5.8 – 5.9. From the visual inspection, the overlays of the first and the third zone hardly appear the error, whereas the overlay of the second zone apparently causes the errors. Then, use the both of layers to do the accuracy analysis by RMSE again which causes the result as shown in the table 5.3 – 5.5.

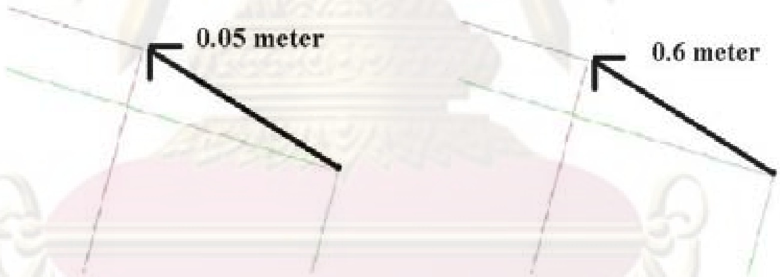


Figure 5.8 The information layer from the zone 1(left) and zone 2(right).

Figure 5.9 The information layer from the zone 3.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686769.525682	686769.525681	0.000000	0.000000	1499917.590419	1499917.590419	0.000000	0.000000	0.000000
686856.787106	686856.787106	0.000000	0.000000	1499914.412459	1499914.412459	0.000000	0.000000	0.000000
686508.087274	686508.088372	-0.001098	0.000001	1499299.330657	1499299.330096	0.000561	0.000000	0.000002
686955.671693	686955.671693	0.000000	0.000000	1499675.178516	1499675.178516	0.000000	0.000000	0.000000
686859.486858	686859.487371	-0.000513	0.000000	1499097.372292	1499097.372030	0.000262	0.000000	0.000000
687002.783445	687002.780095	0.003350	0.000011	1499805.191166	1499805.192877	-0.001711	0.000003	0.000014
686778.871269	686778.871269	0.000000	0.000000	1500027.502860	1500027.502860	0.000000	0.000000	0.000000
686630.572692	686630.572692	0.000000	0.000000	1500178.459743	1500178.459744	0.000000	0.000000	0.000000
687058.163479	687058.159093	0.004386	0.000019	1500322.688558	1500322.690799	-0.002241	0.000005	0.000024
686942.116905	686942.075193	0.041713	0.001740	1501186.159035	1501186.171607	-0.012572	0.000158	0.001898
686583.049085	686583.023785	0.025300	0.000640	1501270.453838	1501270.461464	-0.007625	0.000058	0.000698
687239.545987	687239.459038	0.086949	0.007560	1501116.201014	1501116.254085	-0.053071	0.002816	0.010377
687233.057104	687233.054059	0.003045	0.000009	1501026.935128	1501026.936538	-0.001410	0.000002	0.000011
686777.759828	686777.725703	0.034125	0.001165	1501161.977824	1501161.988109	-0.010285	0.000106	0.001270
686772.404102	686772.372523	0.031580	0.000997	1501139.763282	1501139.772800	-0.009518	0.000091	0.001088
686820.989398	686820.954223	0.035175	0.001237	1501127.937157	1501127.947758	-0.010601	0.000112	0.001350
686826.402696	686826.364949	0.037748	0.001425	1501150.390497	1501150.401874	-0.011377	0.000129	0.001554
686666.801332	686666.784136	0.017195	0.000296	1501093.579977	1501093.585160	-0.005183	0.000027	0.000323
686672.285401	686672.267804	0.017597	0.000310	1501092.200952	1501092.206256	-0.005304	0.000028	0.000338
686671.986537	686671.969119	0.017418	0.000303	1501090.558237	1501090.563487	-0.005250	0.000028	0.000331
							SUM	0.019277873
							Average	0.000963894
							RMSE	0.031046637
							NSSDA	0.053735519

SUM	0.019277873
Average	0.000963894
RMSE	0.031046637
NSSDA	0.053735519

Table 5.3 NSSDA value of zone 1.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686839.6768139	686839.5843396	0.092474	0.008551	1501996.6289434	1501996.6568150	-0.027872	0.000777	0.009328
686852.1888721	686852.0979125	0.090960	0.008274	1501994.1782877	1501994.2057028	-0.027415	0.000752	0.009025
687211.5822718	687211.1632127	0.419059	0.175611	1502220.5925558	1502220.8521689	-0.259613	0.067399	0.243010
687221.0795225	687220.7199861	0.359536	0.129266	1502220.4036896	1502220.6278315	-0.224142	0.050240	0.179506
687221.0380872	687220.6751186	0.362969	0.131746	1502214.0304899	1502214.2566492	-0.226159	0.051148	0.182894
687212.9722322	687212.5541046	0.418128	0.174831	1502204.9344288	1502205.1934180	-0.258989	0.067075	0.241906
687225.0109708	687224.6683244	0.342646	0.117407	1502204.7550723	1502204.9690806	-0.214008	0.045800	0.163206
687252.5692348	687252.4051275	0.164107	0.026931	1502215.9023820	1502216.0100457	-0.107664	0.011591	0.038523
687261.1968134	687261.0868799	0.109934	0.012085	1502215.9346646	1502216.0100457	-0.075381	0.005682	0.017768
687261.1340338	687261.0179771	0.116057	0.013469	1502204.4242992	1502204.5032786	-0.078979	0.006238	0.019707
687012.4101646	687011.8501764	0.559988	0.313587	1502809.3016493	1502809.6340814	-0.332432	0.110511	0.424098
687079.1094761	687078.5190921	0.590384	0.348553	1502802.6184432	1502802.9814058	-0.362963	0.131742	0.480295
687077.3976411	687076.8105508	0.587090	0.344675	1502785.3658079	1502785.7249733	-0.359165	0.129000	0.473675
687010.7417049	687010.1892327	0.552472	0.305226	1502792.5311155	1502792.8583891	-0.327274	0.107108	0.412334
686843.8511778	686843.4632191	0.387959	0.150512	1502919.6027963	1502919.8372983	-0.234502	0.054991	0.205503
687064.5218187	687064.7691689	-0.247350	0.061182	1502922.1101796	1502922.1634274	-0.053248	0.002835	0.064017
687075.2909489	687075.5263923	-0.235443	0.055434	1502932.5107247	1502932.5614093	-0.050685	0.002569	0.058003
686858.8643576	686858.8494994	0.014858	0.000221	1503629.3708347	1503629.3607664	0.010068	0.000101	0.000322
686829.4186988	686829.4186978	0.000001	0.000000	1503631.2633174	1503631.2633174	0.000000	0.000000	0.000000
686446.3714647	686446.3714651	0.000000	0.000000	1503698.6321273	1503698.6321271	0.000000	0.000000	0.000000
							SUM	3.223119519
							Average	0.161155976
							RMSE	0.401442369
							NSSDA	0.694816453

SUM	3.223119519
Average	0.161155976
RMSE	0.401442369
NSSDA	0.694816453

Table 5.4 NSSDA value of zone 2.

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
685342.0298307	685342.0982379	-0.068407	0.004680	1501855.0470002	1501855.1416656	-0.094665	0.008962	0.013641
685341.0622016	685341.1313716	-0.069170	0.004784	1501842.2495717	1501842.3431077	-0.093536	0.008749	0.013533
685342.4226674	685342.4913567	-0.068689	0.004718	1501819.9703388	1501820.0619876	-0.091649	0.008399	0.013118
685419.9569840	685419.9802764	-0.023292	0.000543	1501775.3703208	1501775.4601285	-0.089808	0.008065	0.008608
685280.1296831	685280.2333551	-0.103672	0.010748	1501539.7821456	1501539.8503115	-0.068166	0.004647	0.015394
685278.1543450	685278.2563378	-0.101993	0.010403	1501498.2671126	1501498.3329476	-0.065835	0.004334	0.014737
685712.3482895	685712.3132956	0.034994	0.001225	1500506.9148477	1500506.9253793	-0.010532	0.000111	0.001335
686050.0144580	686050.0018714	0.012587	0.000158	1499861.6339864	1499861.6357945	-0.001808	0.000003	0.000162
686085.6375975	686085.6249889	0.012609	0.000159	1499855.0663647	1499855.0684411	-0.002076	0.000004	0.000163
685584.8786847	685584.8082417	0.070443	0.004962	1501488.0432765	1501488.1125611	-0.069285	0.004800	0.009763
685624.2942610	685624.2012223	0.093039	0.008656	1501432.5323829	1501432.5978980	-0.065515	0.004292	0.012948
685989.2853792	685989.2403738	0.045005	0.002025	1500641.5298710	1500641.5434355	-0.013564	0.000184	0.002209
685999.0191996	685998.9748743	0.044325	0.001965	1500641.3096722	1500641.3230317	-0.013360	0.000178	0.002143
686014.5272376	686014.4840956	0.043142	0.001861	1500569.3703238	1500569.3833266	-0.013003	0.000169	0.002030
686028.3326385	686028.2904955	0.042143	0.001776	1500544.2386624	1500544.2513642	-0.012702	0.000161	0.001937
686016.5764451	686016.5334831	0.042962	0.001846	1500542.8362031	1500542.8491517	-0.012949	0.000168	0.002013
685935.1882320	685935.1396170	0.048615	0.002363	1500520.6704587	1500520.6851111	-0.014652	0.000215	0.002578
685926.4022886	685926.3531258	0.049163	0.002417	1500513.7941287	1500513.8089462	-0.014818	0.000220	0.002637
685886.2824924	685886.2307937	0.051699	0.002673	1500510.1358465	1500510.1514283	-0.015582	0.000243	0.002916
685775.8638337	685775.8181059	0.045728	0.002091	1500506.5702846	1500506.5840668	-0.013782	0.000190	0.002281
							SUM	0.124147922
							Average	0.006207396
							RMSE	0.07878703
							NSSDA	0.136364592

SUM	0.124147922
Average	0.006207396
RMSE	0.07878703
NSSDA	0.136364592

Table 5.5 NSSDA value of zone 3.

5.5.2 Use one warping point

From the result of using one warping point, it indicates that the layer of MWA and the updated layer from Google Earth are quite overlaid because the NSSDA values of all 3 zones are less than 0.001 meter as shown in tables 5.6-5.8. So, In conclusion of using one warping point option, the NSSDA value is minimized in comparison with multiple warping point option; it indicates higher accuracy. However, a selected warping point for one warping point option must be suitable and be able to be the represented point for the whole layer which is quite difficult to single out it. Moreover, an unsuitable warping point can cause higher NSSDA value in compared to the multiple warping point process. As a result of that, the multiple warping points (Affine transformations) are widely used in practical way.

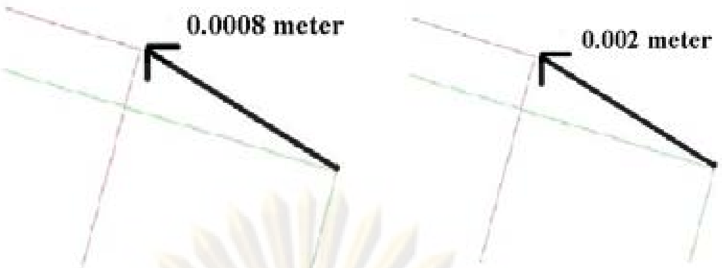


Figure 5.10 The information layer from the zone 1(left) and zone 2(right) (one warping point).

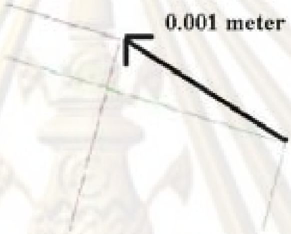


Figure 5.11 The information layer from the zone 3 (one warping point).

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686813.2081543	686813.2078162	0.000338	0.000000	1500072.4573110	1500072.4571411	0.000170	0.000000	0.000000
686828.4199368	686828.4195733	0.000363	0.000000	1500022.3715580	1500022.3713826	0.000175	0.000000	0.000000
686884.0990431	686884.0986710	0.000372	0.000000	1499977.7671936	1499977.7669878	0.000206	0.000000	0.000000
686890.5563391	686890.5559589	0.000380	0.000000	1499961.0310333	1499961.0308247	0.000209	0.000000	0.000000
686842.2219623	686842.2215380	0.000424	0.000000	1499914.8098797	1499914.8097039	0.000176	0.000000	0.000000
686924.5399880	686924.5395096	0.000478	0.000000	1499781.0778560	1499781.0776402	0.000216	0.000000	0.000000
686945.2754540	686945.2749410	0.000513	0.000000	1499712.9083216	1499712.9080983	0.000223	0.000000	0.000000
687058.2838756	687058.2836364	0.000239	0.000000	1500101.4260277	1500101.4257072	0.000321	0.000000	0.000000
687070.6238325	687070.6235340	0.000298	0.000000	1499998.6685083	1499998.6681879	0.000320	0.000000	0.000000
687086.5978329	687086.5975220	0.000311	0.000000	1499968.1738083	1499968.1734805	0.000328	0.000000	0.000000
687107.0196305	687107.0192943	0.000336	0.000000	1499915.5197184	1499915.5193821	0.000336	0.000000	0.000000
686936.4520854	686936.4524516	-0.000366	0.000000	1501162.0560122	1501162.0556067	0.000326	0.000000	0.000000
686990.9558599	686990.9562364	-0.000377	0.000000	1501149.9947500	1501149.9943924	0.000358	0.000000	0.000000
687053.3311802	687053.3315682	-0.000388	0.000000	1501135.2232069	1501135.2228934	0.000394	0.000000	0.000000
687119.5019144	687119.5023147	-0.000400	0.000000	1501119.5545346	1501119.5541022	0.000432	0.000000	0.000000
687114.1502169	687114.1505390	-0.000323	0.000000	1500995.3207339	1500995.3203141	0.000420	0.000000	0.000000
687137.6136021	687137.6139295	-0.000327	0.000000	1500990.1084389	1500990.1080053	0.000434	0.000000	0.000000
686964.7219632	686964.7219563	0.000007	0.000000	1500534.3256611	1500534.3253651	0.000296	0.000000	0.000000
687004.2676413	687004.2676177	0.000024	0.000000	1500485.3474241	1500485.3471078	0.000316	0.000000	0.000000
687007.1462237	687007.1461911	0.000033	0.000000	1500468.9100594	1500468.9097426	0.000317	0.000000	0.000000
							SUM	0.000004284
							Average	2.14178E-07
							RMSE	0.000462793
							NSSDA	0.000801002

SUM	0.000004284
Average	2.14178E-07
RMSE	0.000462793
NSSDA	0.000801002

Table 5.6 NSSDA value of zone 1(one warping point).

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
686595.9082614	686595.9099136	-0.001652	0.000003	1503458.9886391	1503458.9883494	0.000290	0.000000	0.000003
686631.4962663	686631.4978506	-0.001584	0.000003	1503328.2150281	1503328.2147264	0.000302	0.000000	0.000003
686653.1158382	686653.1173595	-0.001521	0.000002	1503212.9806196	1503212.9803135	0.000306	0.000000	0.000002
686716.2677497	686716.2692690	-0.001519	0.000002	1503175.3534449	1503175.3531033	0.000342	0.000000	0.000002
686698.5193631	686698.5208267	-0.001464	0.000002	1503093.7481764	1503093.7478516	0.000325	0.000000	0.000002
686864.8088484	686864.8102287	-0.001380	0.000002	1502866.4550774	1502866.4546686	0.000409	0.000000	0.000002
686937.0644458	686937.0658460	-0.001400	0.000002	1502859.6775669	1502859.6771148	0.000452	0.000000	0.000002
687015.9000442	687015.9014650	-0.001421	0.000002	1502850.5529867	1502850.5524874	0.000499	0.000000	0.000002
687087.5747544	687087.5761943	-0.001440	0.000002	1502843.7121353	1502843.7115919	0.000543	0.000000	0.000002
687164.9288768	687164.9303328	-0.001456	0.000002	1502828.1800773	1502828.1794879	0.000589	0.000000	0.000002
686552.0832572	686552.0845137	-0.001256	0.000002	1502833.4132582	1502833.4130416	0.000217	0.000000	0.000002
686621.8280105	686621.8292776	-0.001267	0.000002	1502812.8780731	1502812.8778158	0.000257	0.000000	0.000002
686642.1992674	686642.2005377	-0.001270	0.000002	1502807.0395930	1502807.0393238	0.000269	0.000000	0.000002
686702.6687637	686702.6700416	-0.001278	0.000002	1502786.6357740	1502786.6354696	0.000304	0.000000	0.000002
686733.2581341	686733.2594168	-0.001283	0.000002	1502777.9449788	1502777.9446565	0.000322	0.000000	0.000002
686850.7354720	686850.7367512	-0.001279	0.000002	1502708.1312077	1502708.1308193	0.000388	0.000000	0.000002
686895.0759447	686895.0772238	-0.001279	0.000002	1502683.8199833	1502683.8195698	0.000413	0.000000	0.000002
686953.7371939	686953.7383978	-0.001204	0.000001	1502529.1262627	1502529.1258243	0.000438	0.000000	0.000002
687035.1760867	687035.1773052	-0.001218	0.000001	1502508.8498413	1502508.8493548	0.000486	0.000000	0.000002
687116.6854414	687116.6866741	-0.001233	0.000002	1502488.0509892	1502488.0504548	0.000534	0.000000	0.000002
							SUM	0.000041057
							Average	2.05284E-06
							RMSE	0.001432775
							NSSDA	0.002479847

SUM	0.000041057
Average	2.05284E-06
RMSE	0.001432775
NSSDA	0.002479847

Table 5.7 NSSDA value of zone 2(one warping point).

X(independent)	X(test)	diff in X	(diff in X)^2	Y(independent)	Y(test)	diff in Y	(diff in Y)^2	((diff in X)^2)+((diff in Y)^2)
685010.3822222	685010.3823439	-0.000122	0.000000	1501812.6519496	1501812.6527437	-0.000794	0.000001	0.000001
685105.8686874	685105.8687985	-0.000111	0.000000	1501743.1921783	1501743.1929196	-0.000741	0.000001	0.000001
685128.3440728	685128.3440708	0.000002	0.000000	1501544.8206872	1501544.8214294	-0.000742	0.000001	0.000001
685280.2333096	685280.2333551	-0.000045	0.000000	1501539.8496610	1501539.8503115	-0.000651	0.000000	0.000000
685321.2301991	685321.2302574	-0.000058	0.000000	1501538.4081917	1501538.4088175	-0.000626	0.000000	0.000000
685761.2374813	685761.2376505	-0.000169	0.000000	1501480.3947558	1501480.3951192	-0.000363	0.000000	0.000000
685852.7366195	685852.7368163	-0.000197	0.000000	1501475.5206014	1501475.5209097	-0.000308	0.000000	0.000000
685882.8491997	685882.8494049	-0.000205	0.000000	1501472.9536974	1501472.9539876	-0.000290	0.000000	0.000000
685943.2057991	685943.2060213	-0.000222	0.000000	1501467.9482972	1501467.9485512	-0.000254	0.000000	0.000000
685971.1050806	685971.1053108	-0.000230	0.000000	1501465.8886349	1501465.8888721	-0.000237	0.000000	0.000000
685458.4417610	685458.4413640	0.000397	0.000000	1500714.9621108	1500714.9627139	-0.000603	0.000000	0.000001
685482.8239229	685482.8234885	0.000434	0.000000	1500640.1250459	1500640.1256397	-0.000594	0.000000	0.000001
685500.0164606	685500.0160607	0.000400	0.000000	1500643.7573097	1500643.7579244	-0.000535	0.000000	0.000000
685669.7436496	685669.7432027	0.000367	0.000000	1500640.9083740	1500640.9088547	-0.000480	0.000000	0.000000
685756.8033433	685756.8030053	0.000338	0.000000	1500640.9086273	1500640.9090545	-0.000427	0.000000	0.000000
685832.7066593	685832.7063430	0.000316	0.000000	1500643.1589613	1500643.1593430	-0.000382	0.000000	0.000000
685955.6908136	685955.6905015	0.000312	0.000000	1500502.6550348	1500502.6553466	-0.000312	0.000000	0.000000
685776.7658618	685776.7650065	0.000775	0.000001	1499918.5989008	1499918.5993700	-0.000469	0.000000	0.000001
685699.1392055	685699.1383034	0.000902	0.000001	1499752.4771519	1499752.4776803	-0.000528	0.000000	0.000001
685775.4830050	685775.4818117	0.001193	0.000001	1499231.6635797	1499231.6641003	-0.000521	0.000000	0.000002
							SUM	0.000009442
							Average	4.72093E-07
							RMSE	0.00068709
							NSSDA	0.001189216

SUM	0.000009442
Average	4.72093E-07
RMSE	0.00068709
NSSDA	0.001189216

Table 5.8 NSSDA value of zone 3(one warping point).

The shape file updated by Google Earth can be used in Editor Tool of MWA efficiently and can also import water meter, piping line and piping equipment data as shown in figure 5.15.

Figure 5.12 The left is data layer of MWA before updating; the right is updated data layer of MWA.

Chapter VI

Conclusion and Recommendation

The aim of this chapter is to conclude the use of Google Earth which is a free map service to support the update on GIS of MWA and the relationship between Google Earth and GIS of MWA. Both of the information layers were used to analyze and compare in any aspects of the information in order to help developing the GIS of MWA to meet the required accuracy and keep up to date as mentioned in the chapter 4.

The process of the study of application software of MWA and Google has quite similar features, however, the layers of Google Earth is less accurate than the layers of MWA due to the insufficient detail in the orthophotos of Google Earth.

In the process of layer import from MWA to Google Earth, firstly, the researcher selected the land base layer of WMA-which is called as building layer according to the application software of MWA, then imported the building layer into Google Earth. In the process of shape file to KML file transformation, it spent quite a long time to process the operation and caused an error. Consequently, the layer had to be clipped to minimize size of the file from the provincial scale to the scale of zone. The stated zone was not divided into Ampur or Khet but according to DMA of MWA which could be divided into 78 DMA. When the file was minimized, the processing of the computer run faster and there was no error. The minimized file was available for further step.

After having the test file as required, display it in Google Earth. The layer of test file of MWA was defined as Indian datum 1975; while the layer of Google Earth was defined as WGS84 which made the both layers unoverlaid. Accordingly, the both layers had to be converted from Indian datum 1975 into WGS84 by using the edited parameter of Royal Thai Survey Department. The transformation gave better result but it remained some errors. According to the test, it was found that the NSSDA of every zone had similar value; namely about 33-34, which was systematic error. Then, select a test area for this research; used the coordinate of the test area to perform the conformal transformation and affine transformation. According to the affine transformation, it caused minimal residuals, thus, it was possible to operate Geometric Transformation. The use of Google Earth to help updating the information of MWA implied that after transforming the Datum from Indian datum 1975 into WGS 84, the file still remained errors which had to be totally eliminated before digitizing the land base in Google Earth by operating the affine transformation.

Firstly, mark reference points in Google Earth to perform the Geometric transformation of the MWA layer to overlay the layer of Google Earth. Form the visual inspection, it was obvious that the both of test layers were overlaid with only a few errors. As a result, the NSSDA were not required. In this step, the researcher got the shape file of MWA overlaid with the layer of Google Earth; the overlay caused only a few errors.

At this time, the researcher was able to digitize the land base in Google Earth; the digitized land base was classified as KML file, so it had to be converted to shapefile in order to be able to be merged with the geometric transformed file; accordingly, the researcher would have the updated file with the help of Google Earth. After that, transform the WGS 84-datum file into the Indian datum 1975 file with datum transformation algorithm and then perform the geometric transformation one more time. (In this step, the raw layer of MWA and the updated layer were operated the geometric transformation.) Then find the NSSDA of the both of files again by dividing the zone into 3 areas, the result indicated that NSSDA of the 1st area was 0.053, the second was 0.69 and the third was 0.13. The NSSDA above were considered to meet the required standard for practical use.

Recommendation

1. Some figures of areas shown in the orthophotos of Google Earth are rough geometric figures and are covered with grey cloud which can be used to update the GIS of MWA.
2. Some figures of street lines shown in the orthophotos of Google Earth are covered with shadow of surrounding buildings.

3. Some figures of join-roofed buildings like town house shown in the orthophotos of Google Earth cannot be specified the exact number of houses; accordingly, field data must be used for the updating.
4. In the process of geometric transformation, the smaller area the zone is divided into, the less error appears.
5. Label in the GIS of MWA cannot be clipped and opened with Google Earth.

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APPENDICES

APPENDIX A

TWO-DIMENSIONAL CONFORMAL COORDINATE TRANSFORMATION

A =

6.8692e+005	-1.5013e+006	1.0000e+000	0.0000e+000
1.5013e+006	6.8692e+005	0.0000e+000	1.0000e+000
6.8692e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8692e+005	0.0000e+000	1.0000e+000
6.8687e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8687e+005	0.0000e+000	1.0000e+000
6.8686e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8686e+005	0.0000e+000	1.0000e+000
6.8692e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8692e+005	0.0000e+000	1.0000e+000
6.8692e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8692e+005	0.0000e+000	1.0000e+000
6.8692e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8692e+005	0.0000e+000	1.0000e+000
6.8688e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8688e+005	0.0000e+000	1.0000e+000
6.8687e+005	-1.5014e+006	1.0000e+000	0.0000e+000
1.5014e+006	6.8687e+005	0.0000e+000	1.0000e+000
6.8686e+005	-1.5023e+006	1.0000e+000	0.0000e+000
1.5023e+006	6.8686e+005	0.0000e+000	1.0000e+000
6.8686e+005	-1.5029e+006	1.0000e+000	0.0000e+000
1.5029e+006	6.8686e+005	0.0000e+000	1.0000e+000
6.8687e+005	-1.5029e+006	1.0000e+000	0.0000e+000
1.5029e+006	6.8687e+005	0.0000e+000	1.0000e+000
6.8696e+005	-1.5031e+006	1.0000e+000	0.0000e+000
1.5031e+006	6.8696e+005	0.0000e+000	1.0000e+000
6.8696e+005	-1.5031e+006	1.0000e+000	0.0000e+000
1.5031e+006	6.8696e+005	0.0000e+000	1.0000e+000
6.8658e+005	-1.5002e+006	1.0000e+000	0.0000e+000
1.5002e+006	6.8658e+005	0.0000e+000	1.0000e+000
6.8659e+005	-1.5003e+006	1.0000e+000	0.0000e+000
1.5003e+006	6.8659e+005	0.0000e+000	1.0000e+000
6.8675e+005	-1.5004e+006	1.0000e+000	0.0000e+000
1.5004e+006	6.8675e+005	0.0000e+000	1.0000e+000
6.8682e+005	-1.5004e+006	1.0000e+000	0.0000e+000
1.5004e+006	6.8682e+005	0.0000e+000	1.0000e+000
6.8681e+005	-1.5005e+006	1.0000e+000	0.0000e+000
1.5005e+006	6.8681e+005	0.0000e+000	1.0000e+000
6.8681e+005	-1.5006e+006	1.0000e+000	0.0000e+000
1.5006e+006	6.8681e+005	0.0000e+000	1.0000e+000

L =

6.8690e+005
1.5013e+006
6.8691e+005
1.5014e+006
6.8685e+005
1.5014e+006
6.8685e+005
1.5013e+006
6.8690e+005
1.5014e+006
6.8691e+005
1.5014e+006
6.8690e+005
1.5014e+006
6.8686e+005
1.5014e+006
6.8685e+005
1.5014e+006
6.8684e+005
1.5023e+006
6.8685e+005
1.5029e+006
6.8685e+005
1.5029e+006
6.8694e+005
1.5031e+006
6.8694e+005
1.5031e+006
6.8656e+005
1.5002e+006
6.8657e+005
1.5003e+006
6.8673e+005
1.5003e+006
6.8681e+005
1.5004e+006
6.8680e+005
1.5005e+006
6.8679e+005
1.5005e+006

$$N = \begin{bmatrix} 5.4523e+013 & 0.0000e+000 & 1.3737e+007 & 3.0029e+007 \\ 0.0000e+000 & 5.4523e+013 & -3.0029e+007 & 1.3737e+007 \\ 1.3737e+007 & -3.0029e+007 & 2.0000e+001 & 0.0000e+000 \\ 3.0029e+007 & 1.3737e+007 & 0.0000e+000 & 2.0000e+001 \end{bmatrix}$$

$$n = \begin{bmatrix} 5.4522e+013 \\ 3.3568e+008 \\ 1.3737e+007 \\ 3.0029e+007 \end{bmatrix}$$

$$Qxx = \begin{bmatrix} 5.7177e-008 & -7.1937e-018 & -3.9272e-002 & -8.5849e-002 \\ -7.1937e-018 & 5.7177e-008 & 8.5849e-002 & -3.9272e-002 \\ -3.9272e-002 & 8.5849e-002 & 1.5587e+005 & -0.0000e+000 \\ -8.5849e-002 & -3.9272e-002 & -0.0000e+000 & 1.5587e+005 \end{bmatrix}$$

a = 0.99933

b = 3.2776e-004

c = 938.34

d = 774.77

V =	0.656992
	0.206876
	0.654190
	0.231358
	0.357162
	-0.904581
	-0.449769
	-0.409833
	2.870832
	2.031092
	2.186065
	-0.494748
	1.703513
	-0.385497
	0.339313
	-0.326395
	0.311411
	0.597951
	-0.663221
	0.309939
	0.435888
	1.955877
	-0.028839
	0.030667
	-1.245794
	0.197871
	-1.922658
	-2.636158
	2.038796
	0.736653
	-3.080454
	0.054340
	-1.804987
	-0.637072
	-1.968845
	0.880051
	-0.831621
	0.677802
	0.439182
	-2.120256

TWO-DIMENSIONAL AFFINE COORDINATE TRANSFORMATION

A =

6.8692e+005	1.5013e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8692e+005	1.5013e+006	1.0000e+000
6.8692e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8692e+005	1.5014e+006	1.0000e+000
6.8687e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8687e+005	1.5014e+006	1.0000e+000
6.8686e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8686e+005	1.5014e+006	1.0000e+000
6.8692e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8692e+005	1.5014e+006	1.0000e+000
6.8692e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8692e+005	1.5014e+006	1.0000e+000
6.8692e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8692e+005	1.5014e+006	1.0000e+000
6.8688e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8688e+005	1.5014e+006	1.0000e+000
6.8687e+005	1.5014e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8687e+005	1.5014e+006	1.0000e+000
6.8686e+005	1.5023e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8686e+005	1.5023e+006	1.0000e+000
6.8686e+005	1.5029e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8686e+005	1.5029e+006	1.0000e+000
6.8687e+005	1.5029e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8687e+005	1.5029e+006	1.0000e+000
6.8696e+005	1.5031e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8696e+005	1.5031e+006	1.0000e+000
6.8696e+005	1.5031e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8696e+005	1.5031e+006	1.0000e+000
6.8658e+005	1.5002e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8658e+005	1.5002e+006	1.0000e+000
6.8659e+005	1.5003e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8659e+005	1.5003e+006	1.0000e+000
6.8675e+005	1.5004e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8675e+005	1.5004e+006	1.0000e+000
6.8682e+005	1.5004e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8682e+005	1.5004e+006	1.0000e+000
6.8681e+005	1.5005e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8681e+005	1.5005e+006	1.0000e+000
6.8681e+005	1.5006e+006	1.0000e+000	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	6.8681e+005	1.5006e+006	1.0000e+000

L =

6.8690e+005
1.5013e+006
6.8691e+005
1.5014e+006
6.8685e+005
1.5014e+006
6.8685e+005
1.5013e+006
6.8690e+005
1.5014e+006
6.8691e+005
1.5014e+006
6.8690e+005
1.5014e+006
6.8686e+005
1.5014e+006
6.8685e+005
1.5014e+006
6.8684e+005
1.5023e+006
6.8685e+005
1.5029e+006
6.8685e+005
1.5029e+006
6.8694e+005
1.5031e+006
6.8694e+005
1.5031e+006
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1.5002e+006
6.8657e+005
1.5003e+006
6.8673e+005
1.5003e+006
6.8681e+005
1.5004e+006
6.8680e+005
1.5005e+006
6.8679e+005
1.5005e+006

N =

9.4352e+012	2.0625e+013	1.3737e+007	0.0000e+000	0.0000e+000	0.0000e+000
2.0625e+013	4.5087e+013	3.0029e+007	0.0000e+000	0.0000e+000	0.0000e+000
1.3737e+007	3.0029e+007	2.0000e+001	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	9.4352e+012	2.0625e+013	1.3737e+007
0.0000e+000	0.0000e+000	0.0000e+000	2.0625e+013	4.5087e+013	3.0029e+007
0.0000e+000	0.0000e+000	0.0000e+000	1.3737e+007	3.0029e+007	2.0000e+001

n =

9.4349e+012
2.0625e+013
1.3737e+007
2.0625e+013
4.5087e+013
3.0029e+007

Qxx =

8.1906e-006	-5.7855e-007	-4.7570e+000	0.0000e+000	0.0000e+000	0.0000e+000
-5.7855e-007	9.8733e-008	2.4913e-001	0.0000e+000	0.0000e+000	0.0000e+000
-4.7570e+000	2.4913e-001	2.8933e+006	0.0000e+000	0.0000e+000	0.0000e+000
0.0000e+000	0.0000e+000	0.0000e+000	8.1906e-006	-5.7855e-007	-4.7570e+000
0.0000e+000	0.0000e+000	0.0000e+000	-5.7855e-007	9.8733e-008	2.4913e-001
0.0000e+000	0.0000e+000	0.0000e+000	-4.7570e+000	2.4913e-001	2.8933e+006

a = 0.99278

b = 1.4899e-004

c = 4720.6

d = 0.0018792

e = 0.99926

f = -194.28

v =

0.138373
0.305901
0.106765
0.338476
0.174015
-0.883184
-0.598702
-0.397774
2.343122
2.134235
1.647899
-0.388651
1.193299
-0.285322
0.116785
-0.293887
0.117508
0.622496
-0.315701
0.252712
1.025839
1.869067
0.548189
-0.052643
-1.203669
0.247988
-1.870850
-2.587321
3.193312
0.385130
-1.917569
-0.295279
-1.668540
-0.741070
-2.304119
0.889788
-1.053500
0.666409
0.271031
-2.142477

APPENDIX B

Editor Tools User Guide.

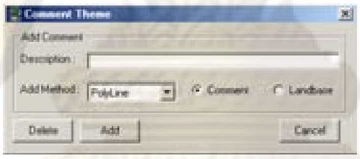
1. Updating Base Map of MWA Program.

1. Select start edit 

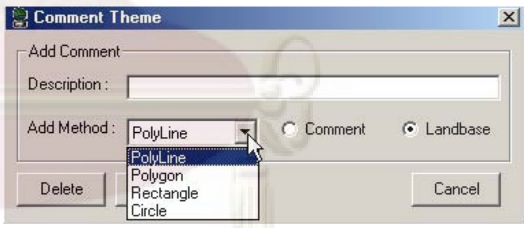
2. Select theme selected as comment

3. Notice dot line at comment

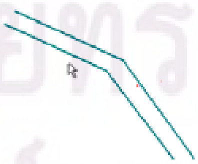
4. Select Tool add comment theme



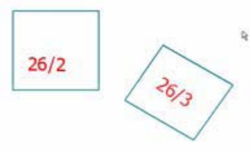
5. Appear tool



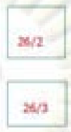
6. Select type of data as landbase
7. User can use type in 4 type poly line , polygon , rectangular , circle



Poly line



Polygon

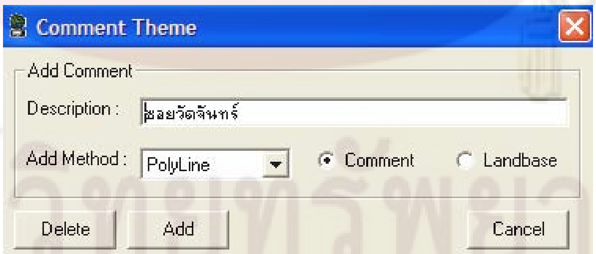


Rectangular

Circle

8. Crate road edge line

Select poly line and put description

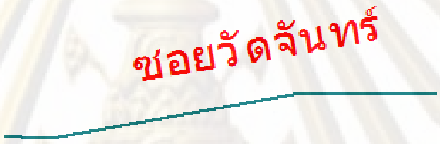


Click add button

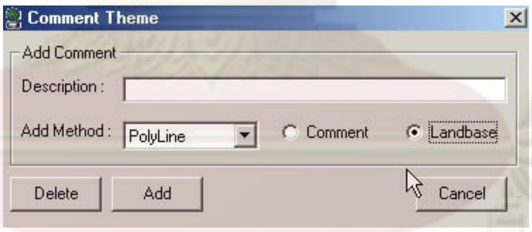
Draw road edge line and click “OK”

Draw label line

Get the road edge one side yet



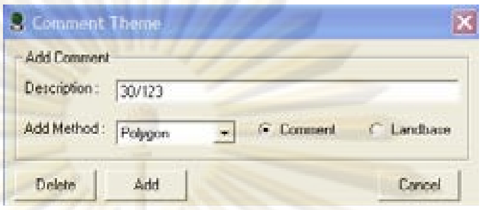
Crate another side again



Finish

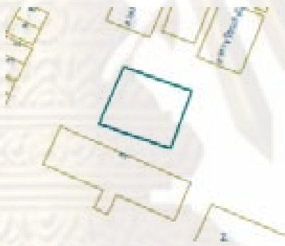
9. Create building line

Select method polygon , rectangular or circle put description house order as 30/123



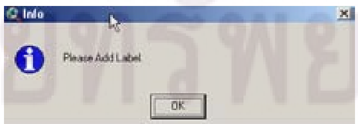
Click add button

Draw building line

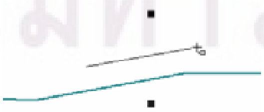


Figure…

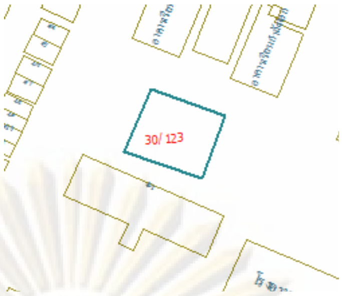
Click “OK”



Draw label line

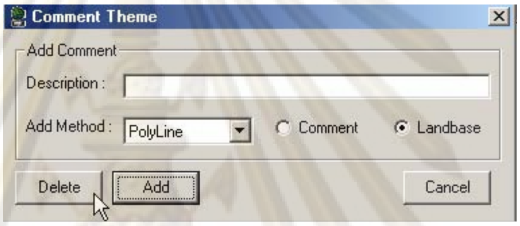


Finish

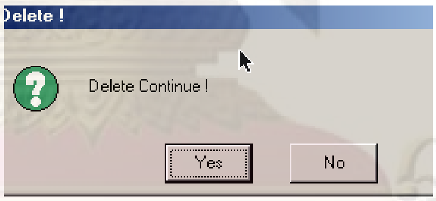


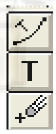
10. Deletion

Select delete



Select line you want deleted click “YES” for confirm





11. Deletion and edit address or road edge annotation

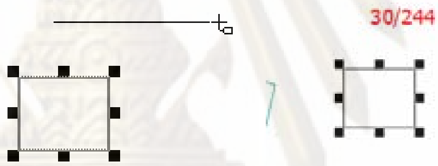
Select Delete Feature Label 

Click annotation you want deleted.

Click "YES"

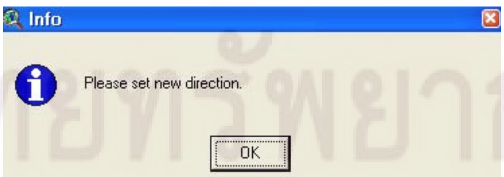
Add annotation use (Add feature label)

Click on building or road you want Add

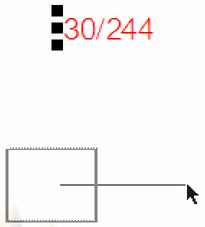


Reposition Label use (Tool Reposition Label)

Click on annotation you want reposition click "OK"



Draw new annotation line



Get the new position

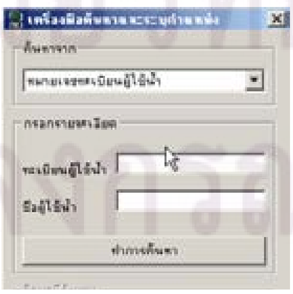
2. Updating Water Meter of MWA

1. Select start editing 

2. Select Meter

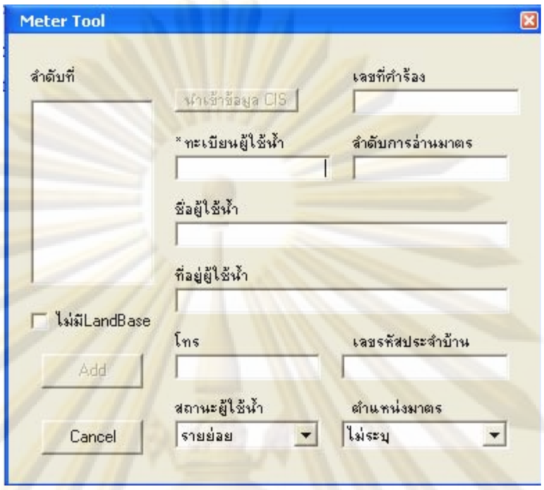
3. Use Locator Tools 

find area and place where you want edit



4. Click Add Meter 

You get new window this below and put information detail



After that click 

curser changing to cross

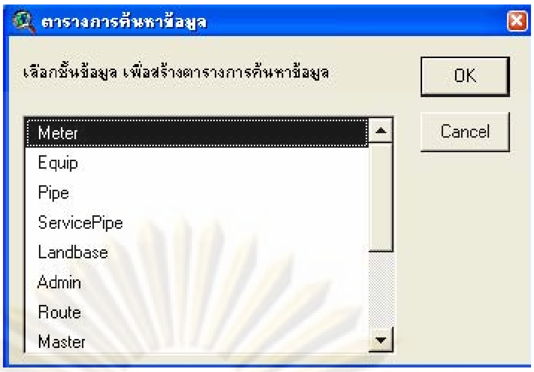
Click on area you want add meter

In case you want deleted Meter : use 

click on Meter and press delete button on your computer

After edit yet you must save click on Stop Editing 

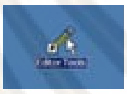
and press Update Locator Table button 

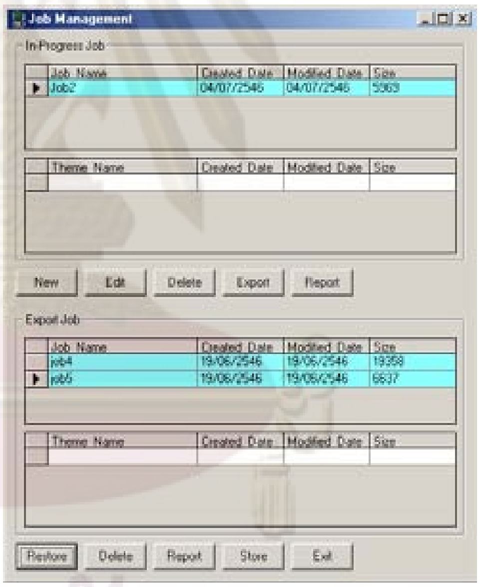
choose Meter 

and click “OK”

finish.

3. Updating Piping Line

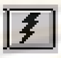
1. Start double click Editor Tools on desktop 



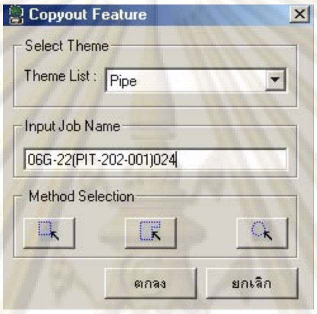
2. Select Job Management 

3. Select New 

4. Choose Select Theme as pipe

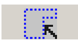
5. Use Map Tip  for information 

6. Input Job Name



7. Choose area you want edit by Method Selection

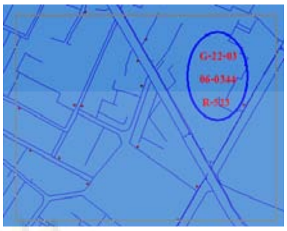
 choose area by rectangular

 choose area by polygon

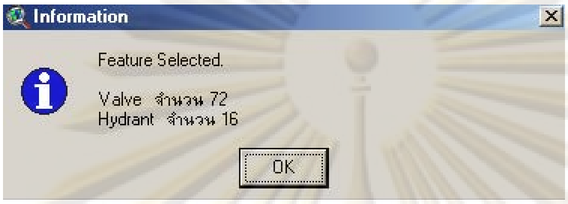
 choose area by circle

8. Computer prepare information copy click “OK”

9. Change Select Theme from pipe to equip

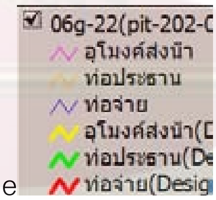
10. Choose area you want edit 

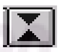
11. Computer prepare information copy click “OK”

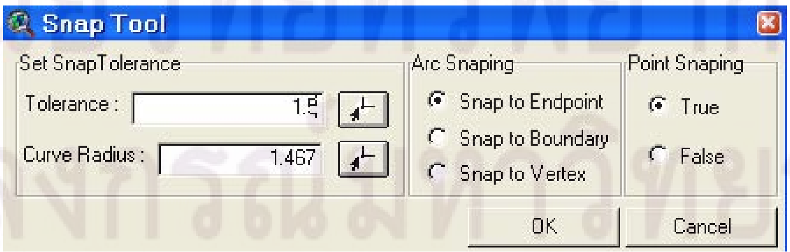


12. Click start editing 

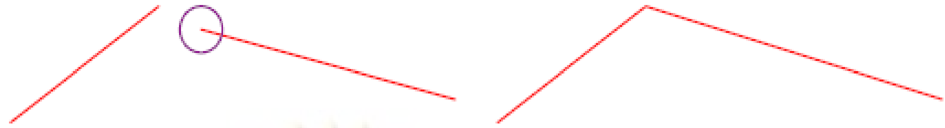
13. Choose data 

14. Appear dot line in front of name 

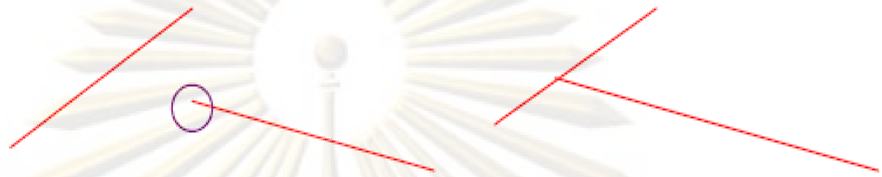
Set up snap tool 



Snap to end point

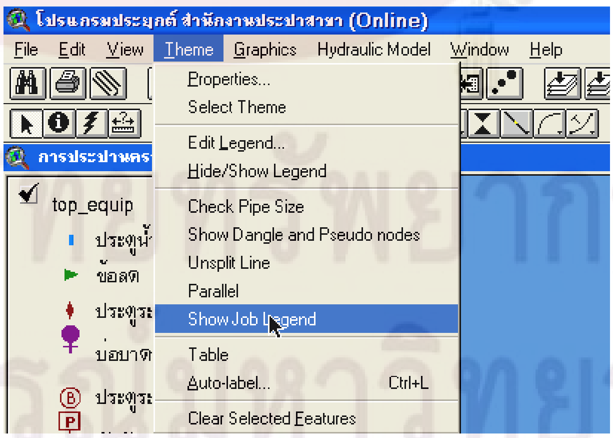


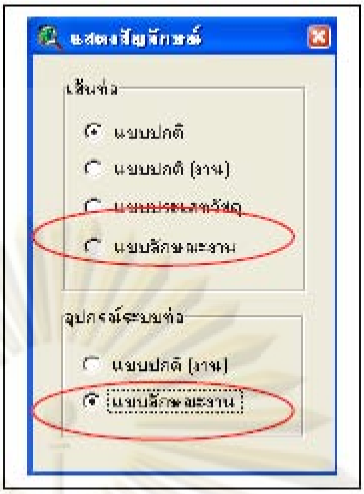
Snap to boundary



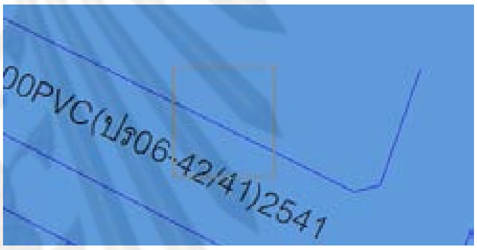
Snap to vertex

15. User should be change attribute display example red color represent install new pipe , green color represent replace pipe , yellow color represent abandon pipe. Click at menu→theme→show job legend , choose from figure below in red circle.

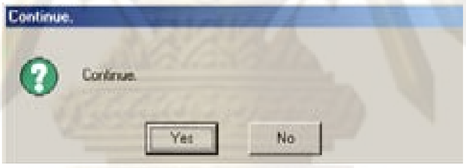




16. Abandon pipe click 



17. Choose pipe you want abandon

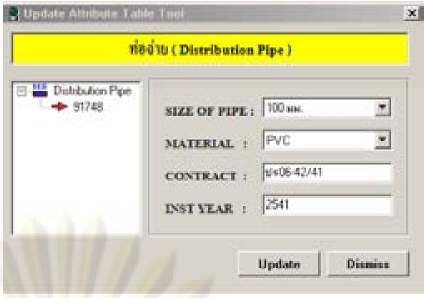


18. Click “YES”

19. Color pipe change is orange color

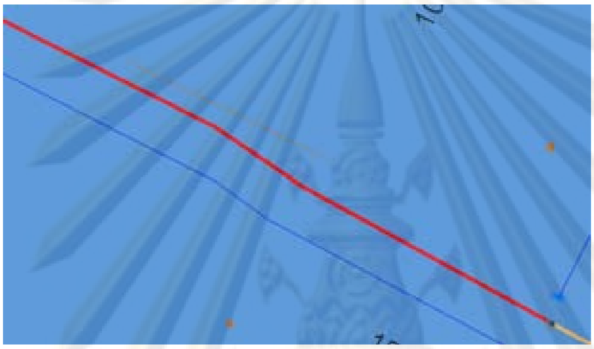
20. Replace pipe click 

21. Choose pipe you want replace pipe

22. After that new windows  you can change new information

23. Click “update” is finish

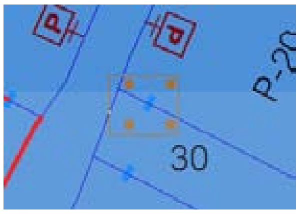
24. Install new pipe click DIS button draw new pipe as you want



25. Draw annotation 

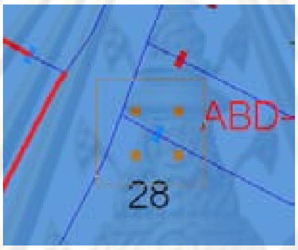
26. Edit equip click  Choose data 

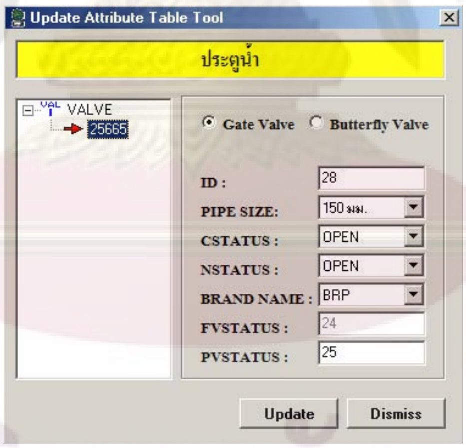
27. Abandon equip click 

28. Choose equip you want abandon 

29. Click “YES” 

30. Replace equip click 

31. Choose equip 

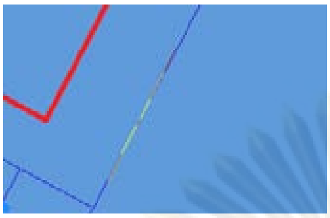
32. New window 

you can change information

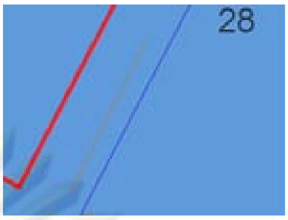
33. Click “Update” is finish

Install new equip  Choose equip

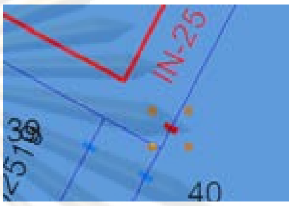
you want to add example valve click equip on to position you want



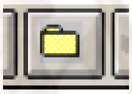
add label



click "OK"

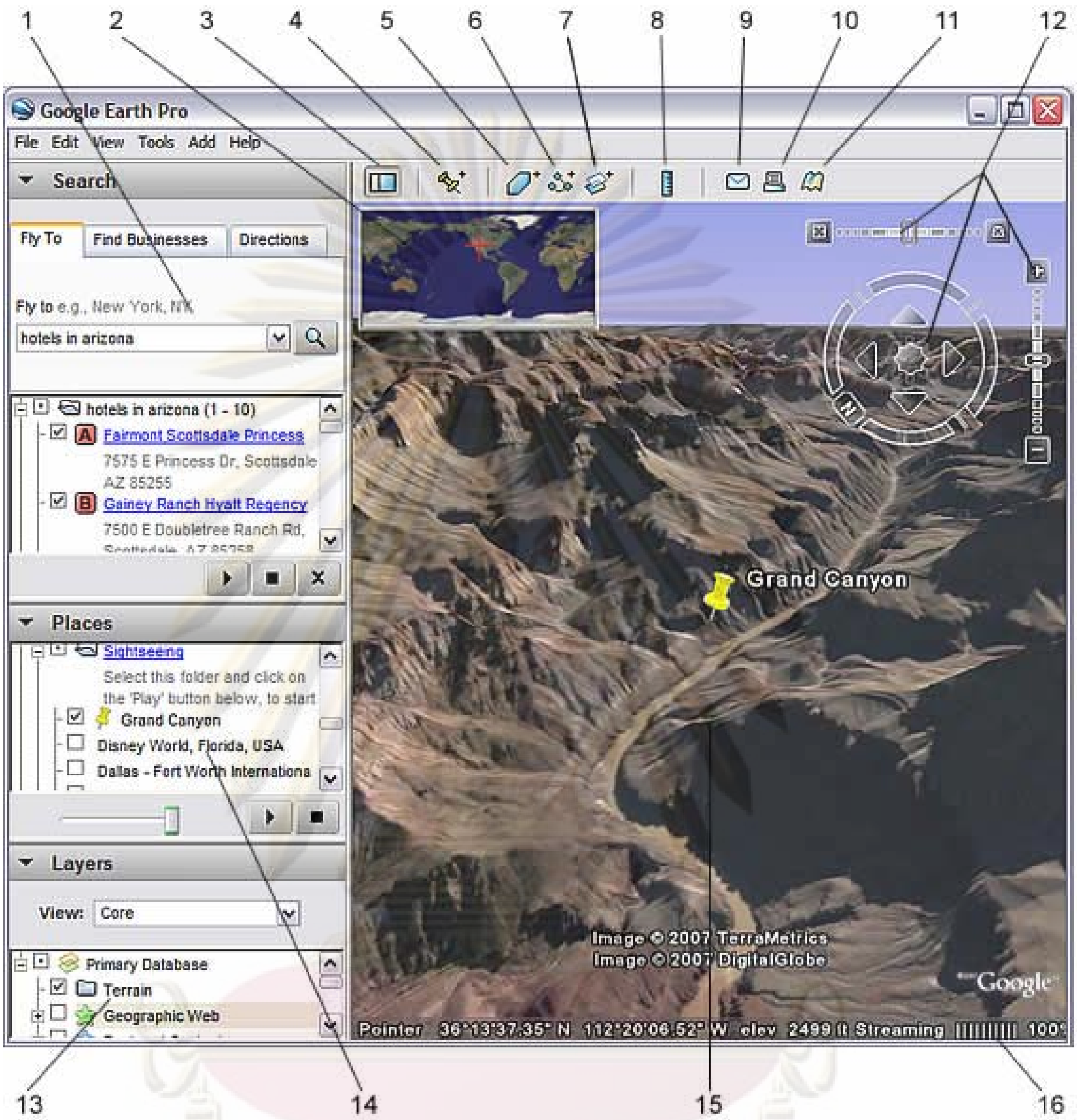


34. Saving click 

and 

click "YES" 

Google Earth User Guide.



1. **Search panel** - Use this to find places and directions and manage search results.

Google Earth EC

may display additonal tabs here.

2. **Overview map** - Use this for an additional perspective of the Earth.

3. **Hide/Show sidebar** - Click this to conceal or the display the side bar (Search, Places

and Layers

panels).

4. **Placemark** - Click this to add a placemark for a location.

5. **Polygon** - Click this to add a polygon.

6. **Path** - Click this to add a path (line or lines).

7. **Image Overlay** - Click this to add an image overlay on the Earth.

8. **Measure** - Click this to measure a distance or area size.

9. **Email** - Click this to email a view or image.

10. **Print** - Click this to print the current view of the Earth.

11. **Show in Google Maps** - Click this to show the current view in Google Maps in your web browser

12. **Navigation controls** - Use these to tilt, zoom and move around your viewpoint (see below).

13. **Layers panel** - Use this to display points of interest.

14. **Places panel** - Use this to locate, save, organize and revisit placemarks.

Marking Places

When you first start Google Earth, the Places panel contains an empty My Places folder to hold places that you want to save. (If you are upgrading from a previous version of Google Earth, Google Earth imports your saved places.) Every item located in the My Places folder is saved for subsequent Google Earth sessions. Items located in the Places panel but not saved in the My Places folder are located in the Temporary Places folder and are unavailable in the next Google Earth session if you do not move or save them to your My Places folder. You can use the Places panel to save and organize places that you visit, address or listing searches, natural features, and more. This section covers the basic ways to add a placemark to the My Places folder:

Creating a New Placemark.

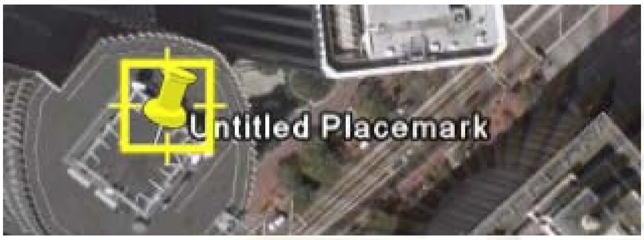
Follow these instructions to add a new placemark to any spot in the viewer.

1. Position the viewer to contain the spot you want to placemark. Consider zooming into the best viewing level for the desired location. Choose any one of the following methods:

Select *Placemark* from the *Add* Menu.

Click the Pushpin icon on the toolbar menu at the the top of the screen

The *New Placemark*dialog box appears and a *New Placemark*icon is centered in the viewer inside a flashing yellow square. Position the placemark. To do this, position the cursor on the placemark until the cursor changes to a pointing finger and drag it to the desired location. The cursor changes to a finger pointing icon to indicate that you can move the placemark.



You can also lock the placemark position or set advanced coordinates for its position.

Set the following properties for the new placemark:

-**Name** for the placemark

-**Description**, including HTML text

-**Style, Color** - Choose a color, scale (size) and opacity for the placemark icon

- **View** - Choose a position for the placemark. For explanation of terms in this tab, mouse over each field.

-**Altitude** - Choose the height of the placemark as it appears over terrain with a numeric value or the slider. Choose *Extend to ground* to show the placemark attached to a line anchored to the ground.

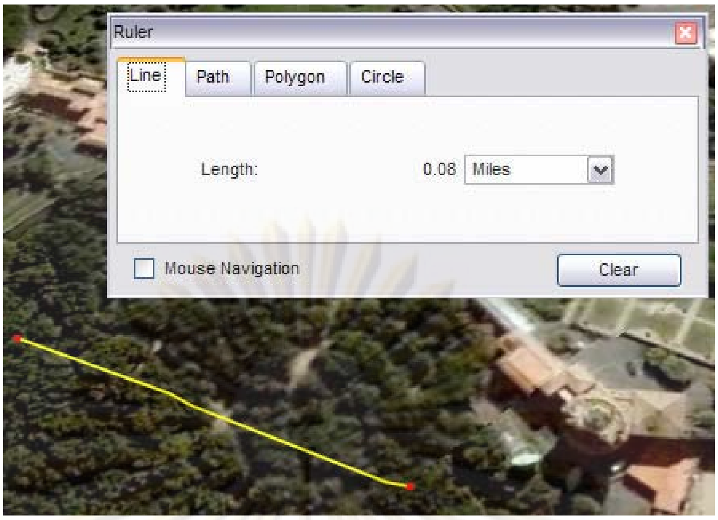
- **(Icon)** - Click the icon for the placemark (top right corner of the dialog box) to choose an alternate icon.

2. Click **OK** to apply the information you entered in the placemark
dialog box.

Measuring Distances and Areas

Google Earth offers a number of tools that you can use to measure distances and estimate sizes. Depending upon which version of Google Earth you are using, you have access to the following measuring tools:

- Measuring with a line or path (all Google Earth versions)
- Measuring with a circle radius or polygon (Google Earth PRO)



Use the Ruler window (Tools menu) to measure length, area, and circumference as follows:

1. Position the imagery you want to measure within the 3D viewer and make sure you are viewing the earth from top-down (type U) and with terrain turned off for best accuracy. Measuring is calculated using the lat/lon coordinates from point to point and does not consider elevation.

2. From the Tools menu, select Ruler. The Ruler dialog box appears. Consider moving the dialog box to a region of your screen that doesn't obstruct the 3D viewer.

3. Choose the type of shape you want to measure with. All versions of Google Earth can measure with Line or Path. Google Earth PRO users can also measure using a polygon or circle.

4. Choose the unit of measure for length, perimeter, area, radius, or circumference, as applicable. See the table below for a list of supported units of measure.

5. Click in the 3D viewer to set the beginning point for your shape and continue clicking until the line, path, or shape measures the desired region. (For circle, click in the center and drag out to define the circle.) A red dot indicates the beginning point of your shape, and a yellow line connects to it as you move the mouse. Each additional click adds a new line to the shape, depending upon the tool you chose. The total units for the shape are defined in the Ruler dialog box, and you can choose other units of measure for the existing shape.

Biography

Name-Username	Mr. Tirawat Chaivanisphol
Birth	5 November 1984
Birthplace	Bangkok
Education	Bachelor Degree in Civil Engineering from Mahidol University