The Kingdom of Thailand

NCDC Management Working Group

The Kingdom of Thailand
The project for capacity development and promotion of utilization of National CORS Data Center
Project Completion Report (2nd and 3rd Terms)

February 2024

Japan International Cooperation Agency (JICA)

PASCO CORPORATION

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Abbreviations

Abbreviation	Description
CORS	Continuously Operating Reference Station
C/P	Counter Part
DGA	Digital Government Development Agency
DOF	Department of Fishery
DOL	Department of Lands
DPT	Department of Public Works and Town & Country Planning
GGRF	Global Geodetic Reference Frame
GISTDA	Geo-Informatics and Space Technology Development Agency
GLONASS	Global Navigation Satellite System
GNSS	Global Navigation Satellite System
GSI	Geospatial Information Authority of Japan
GPS	Global Positioning System
HII	Hydro Informatics Institute
IGS	International GNSS Service
ITRF	International Terrestrial Reference Frame
JAS	Japan Association of Surveyors
JPT	JICA Project Team
MGA	Multi GNSS Asia
MHESI	Ministry of Higher Education Science Research and Innovation
MOAC	Ministry of Agriculture and Cooperatives
MOT	Ministry of Transport
NCDC	National CORS Data Center
NICT	National Institute of information and communications technology
NIMT	National Institute of Metrology (Thailand)
OJT	On the Job Training
QZSS	Quasi-Zenith Satellite System
PCRG	Promotion Council of Real Time Positioning using GPS-based Control Stations
R/D	Record of Discussion
RINEX	Receiver INdependent Exchange Format
RTK	Real Time Kinematic
RTSD	Royal Thai Survey Department
SKP	Space Krenovation Park
SLA	Service Level Agreement
TOR	Terms of Reference
TPT	Thai Project Team

1. Project Outline

(1) Project background

Continuously Operating Reference Station (CORS) refers to a reference point that continuously receives radio signals that contain positional information from the Global Navigation Satellite System (GNSS). If a CORS network is managed and operated in an integrated manner, and accurate position and correction data from the CORS network are appropriately analyzed and distributed by the National CORS Data Center (NCDC), you can determine three dimensional positions on the Earth accurately (i.e., precise positioning). Using these precise positioning data from NCDC, the efficient infrastructure development using ICT (i-Construction), automatic operation of agricultural machinery, as well as industrial promotion through autonomous driving technologies are expected.

In Thailand, several government agencies have set up CORS across the country. However, since each agency has set up its own CORS according to its purpose of use, the specifications are not always unified, and the acquired information could not be shared and utilized effectively.

Giving consideration to this situation, in March 2017, with the aim of utilization of precise positioning data by private sectors through disclosing it to the public in a unified way, the Government of Thailand decided to form a network of approx. 240 CORSs across the country constructed by government agencies and to establish NCDC. NCDC integrates, analyzes, and distributes data from the CORS network. The Government of Thailand asked the Government of Japan to carry out this project (hereinafter, "the Project") on technical support for capacity development of operation and maintenance of NCDC for stable distribution of precise positioning data from NCDC and promotion of utilization of the distributed precise positioning data.

(2) Project Name

The project for capacity development and promotion of utilization of national CORS data center

(3) Goals of the Project and its expected outputs

Keeping in mind that development of CORS and its utilization are closely related to the realization of Thailand 4.0, the implementing agency, Thailand Project Team (TPT), together with JICA Project Team (JPT) will aim to produce the project outputs and achieve the project goals by implementing activities based on Record of Discussions R/D).

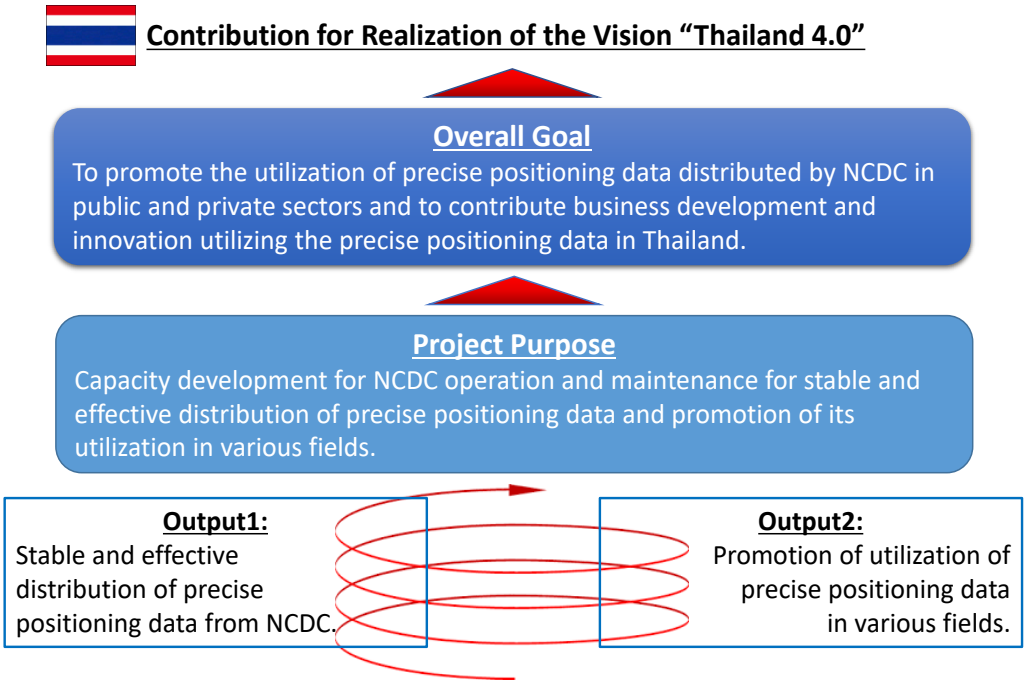


Figure 1-1 Goals of the project and expected outputs

(4) Target area

All over Thailand

(5) Implementing agency and main counterparts (C/P)

[Implementing agency]

NCDC Management Working Group

Chairperson: RTSD Director General

Secretary: RTSD

Assistant Secretary: GISTDA

Members: DOL, DPT, DGA, GISTDA, HII, MOT, NIMT, RTSD and Thai advisors

[Main counterparts]

For Output 1: Chairperson of NCDC Management Working Group or his/her designated person (RTSD)

For Output 2: Executive Director of GISTDA or his/her designated person (GISTDA)

(6) Joint Working Group on the Project for Capacity Development and Promotion of Utilization of National CORS Data Center

Joint Working Group on the Project for Capacity Development and Promotion of Utilization of National CORS Data Center (hereinafter "Joint WG on NCDC") set up by GNSS Sub-Committee will play vital roles in implementing the Project as follows:

1) to approve an annual work plan
2) to evaluate the Project
3) to decide key issues related to the framework of the Project including modifications of PDM

4) to review the progress and share the current status among stakeholders
5) to support the execution of the Project
6) to make a decision on the Project issues that arise during the implementation of the Project

Chairperson: Professor Dr. Chalermchon Satirapod
Co-chair: Chief Representative of JICA Thailand Office
Co-Secretary: RTSD and GISTDA
Members: RTSD, GISTDA, DOL, DPT, HII, NIMT, DOF, NSTDA, and experts from academic institutions

(7) Project period and terms

Project period (The 1st term to the 3rd term)

From November 2020 to February 2024 (The 2nd term started from November 2022)

Classification of project period into three terms

This project consists of three terms as shown in Table 1-1: the 1st term was from start of the project to launch of trial data distribution from NCDC, the 2nd term was from launch of trial data distribution from NCDC to before launch of pilot projects, and the 3rd term was from launch of the pilot projects to completion of the project. In the 1st term, the project focused on the activities 1-1, 1-2, 1-3, and 2-1 described in chapter 3 and the term ended in October 2021.

The 2nd term started in the middle of November 2021. Although the budget for the full scale NCDC had not been approved, the project moved into its 3rd term when NCDC launched its service to the public in March 2022. This report reports the activities carried out during the 2nd term and 3rd term and overall achievement of the project.

Table 1-1 Main activities and period of each term

Term	Period	Main activities
1st term	From start of the project to October 2021	Establishment of NCDC, establishment of organizational structure for operation and maintenance, preparation of operation plan / quality requirements draft / manual, unification of geodetic reference systems of the existing CORS, data distribution test, proposal of framework for promotion of utilization, implementation of 1st seminar, formulation of a pilot project plan, and so forth.
2nd term	From November 2021 to March 2022	Trial data distribution, improvement of the organizational structure for operation and maintenance that meets quality requirements, building of data distribution monitoring and user support system, 1st training in Japan, determination of pilot projects and contractors, implementation of 2nd seminar and so forth.
3rd term	From April 2022 to February 2024	Data distribution start, update of manual, implementation of pilot projects / business matching / regional workshop / 3rd seminar / market research / 2nd training in Japan, and so forth.

2. NCDC operation and maintenance status

The requested budget of TPT was partially allocated in October 2020 (about 28 million baht), and the interim NCDC was established in August 2021 accordingly. After the trial data distribution in the 2nd term, the precise positioning service from the interim NCDC has become available for general use in Thailand in the 3rd term from March 2022.

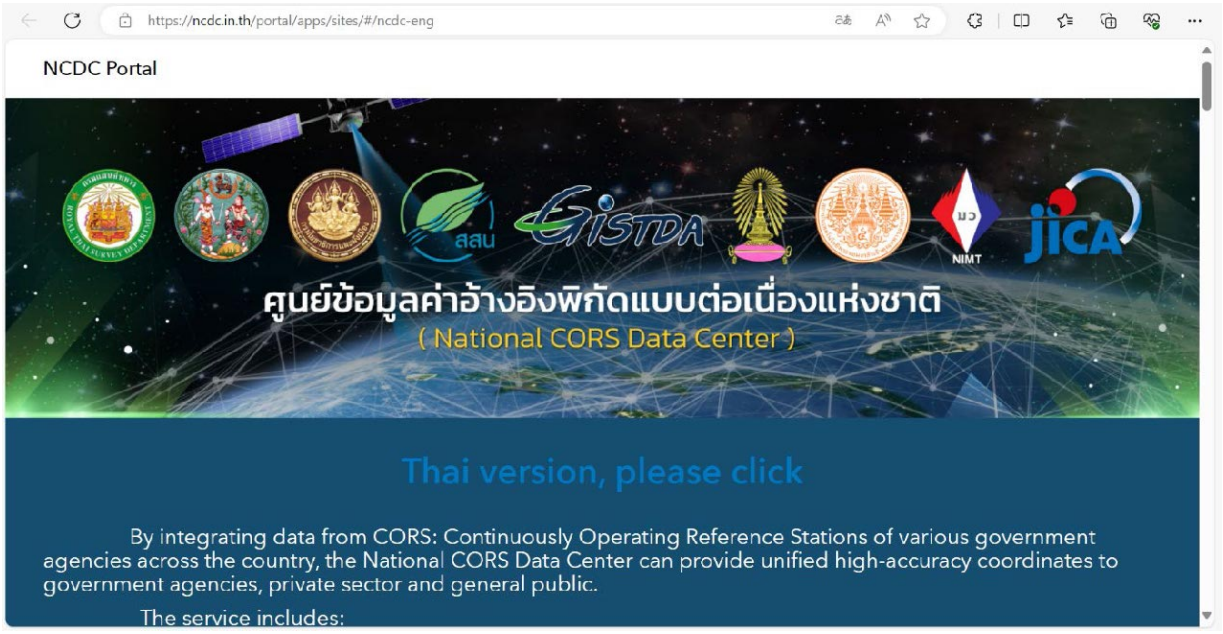


Figure 2-1 Top page of the NCDC website (in English)

The interim NCDC is RTSD's data center (located at the 3rd floor of annex building, Ladprao office) with enhanced servers, networking equipment, data storage (200TB), GIS software, and so on, and in the future, the data center will be completely shaped as NCDC. The data center has been using Spider software from Leica Company to generate the correction data. As of December 2023, it collects GNSS data from 238 CORS stations in Thailand, of which 171 stations are used to generate correction data. RTSD staff are in charge of NCDC, but equipment maintenance and daily operation are outsourced to Leica's local distributor, GIS Company.

In general, correction data from NCDC includes GPS, Quasi-Zenith Satellite System (QZSS), GLONASS, Galileo, and BeiDou, but some of CORS operated by DOL use a slightly dated receiver (CHCNAV N72), which is not compatible with QZSS. DOL has established 53 new CORS stations after 2021, whose receivers (CHCNAV P5E-Net) are compatible with QZSS.



Figure 2-2 Operation room of Interim NCDC, Monitoring screen of Spider software, the entrance of server room (source: RTSD)

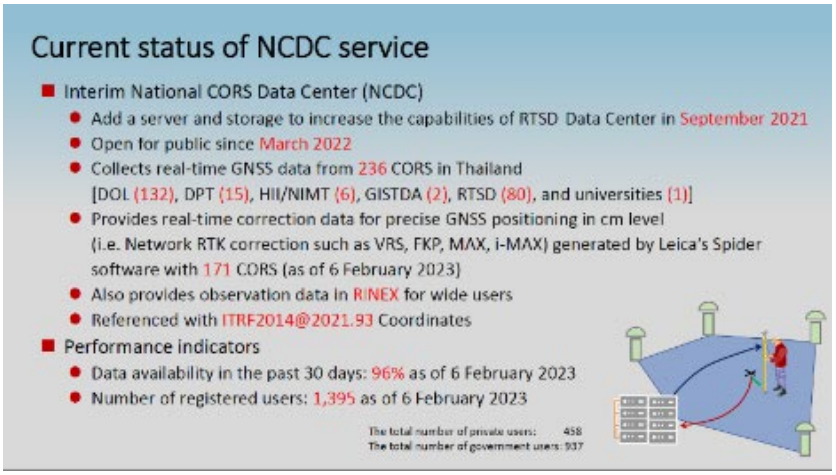


Figure 2-3 Current status of interim NCDC (6th Joint WG on NCDC meeting material, February 2023)

Overview of NCDC and service guideline are introduced in the NCDC website (https://www.ncdc.in.th). Acquisition rate of observation data (RINEX format) is about 95%, with some room for improvement (Figure 2-4). The service is currently provided free of charge, and the number of registered users has steadily increased to 1,395 as of February 2023 and 1,756 as of July 2023 (Table 2-1). The number reached 2,123 as of December 2023.

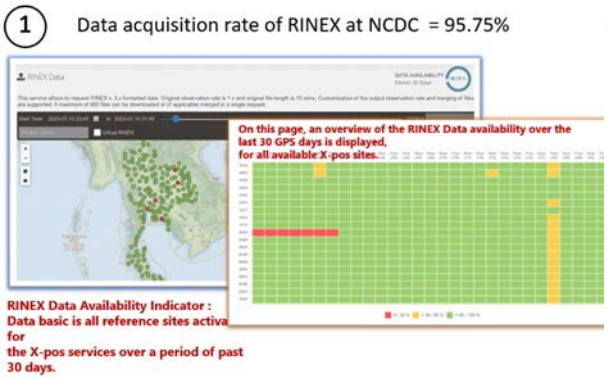


Figure 2-4 Web page of NCDC

2 The total number of the registered NCDC users

Month	Private user		Government users	Total
	Unexpired Paid users	NCDC users (free of charge)		
Aug 2022	62	216	931	1,209
Sep 2022	64	245	934	1,243
Oct 2022	69	277	934	1,280
Nov 2022	53	330	937	1,320
Dec 2022	70	354	937	1,361
Jan 2023	65	368	937	1,370
Feb 2023	68	390	937	1,395
Mar 2023	68	454	964	1,486
Apr 2023	58	557	977	1,592
May 2023	60	578	977	1,615
Jun 2023	50	652	977	1,679
Jul 2023	66	711	979	1,756

+77

Table 2-1 Number of registered users

(7th Joint WG on NCDC meeting material, July 2023)

Field VRS surveys by RTSD with NCDC corrections in Bangkok, Lumpang, Chonburi yielded the desired cm precision. On the other hand, there are several reports from pilot project users working on the control of agricultural and construction machinery that the precision has deteriorated during observation (Figure 2-5 Left). In addition, according to the "deemed rover method" (i.e. a method of treating CORS as a rover and performing VRS positioning and evaluating the accuracy of correction data based on its accuracy), the FIXed solution cannot be obtained depending on the region and time (Figure 2-5 Right). The members have made possible improvements in consultation with manufacturers. However, since ionospheric disturbances due to solar activity will increase in the future, it is important to continue monitoring the precision.

Unfortunately, the interim NCDC cannot generate correction data using all CORS in Thailand due to restrictions such as Spider's license option and server capacity. It is known that the higher the density of used CORS, the better the stability and accuracy of network RTK positioning. For this reason, TPT has been requesting a budget for full-scale NCDC development, but due to the influence of COVID-19, the budget has not been approved yet as of in December 2023.

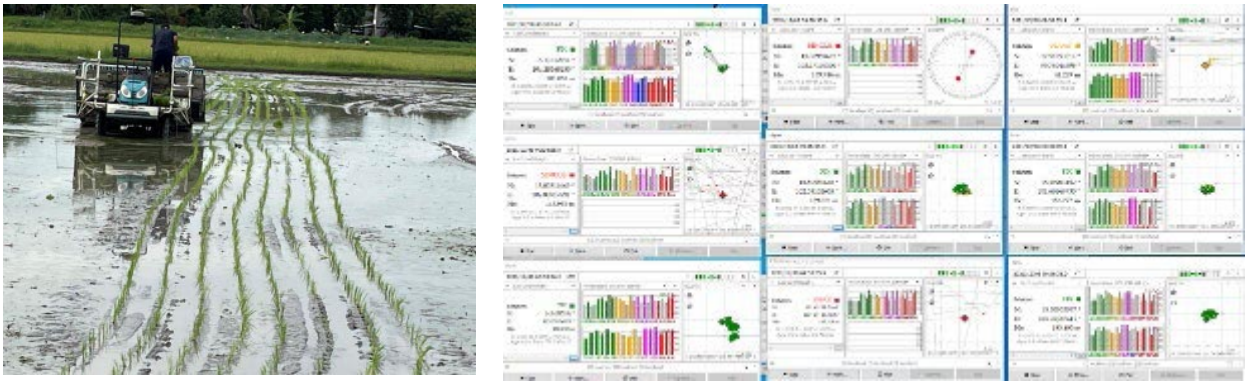


Figure 2-5 Left: Example of reduced precision: meandering of agricultural machinery, Right: Example of deemed rover results (6th Joint WG on NCDC meeting material, February 2023)

3. Activities conducted

3.1. How this project was implemented

During the 1st term, the project activities were mainly carried out online due to the travel restrictions from COVID-19. With the relaxation of these restrictions, project activities were conducted both face-to-face and online in the 2nd and 3rd terms. As shown in Table 3-1, the progress of the entire project were discussed and confirmed at Monthly Meeting attended by the chairman of the Joint WG on NCDC, JPT members, and TPT members, and in the meantime, Output1 and Output2 meetings were held at least once a month, while the activities were implemented accordingly. Also, the Technical Transfer Sessions related to Output1 and Output2 were conducted.

Table 3-1 Project implementation

Meeting	Main contents	Main participants	Remarks
Monthly Meeting	Confirm the progress of the entire project (such as report of Output1 and Output2 Meeting) Confirm agreement of meeting members or discuss about topics related to the project	Chairperson, TPT, JPT	Once a month in principle. 30 sessions
Output1 Meeting	1) Introduce case studies from Japan (such as coordinates system, SLA, user supports, MADOCA, private CORS, accuracy evaluation by deemed rover method etc.) 2) Introduce case studies from the world (such as IGS, ITRF2020, international meetings, etc.) 3) Questions and discussion (Evaluation of NCDC precision, Data delay, Ionospheric disturbance, Radio Interference, Pilot users' comments, etc.), 4) Activity plan of Output1 and others	Person in charge of TPT and JPT	Once a month in principle. 34 sessions
Output2 Meeting	Discuss topics related to Output2 (such as drafting utilization promotion plan, considering the framework, implementing pilot project, organizing site tours, providing GNSS training, creating PR tools, hosting seminars), confirm work progress, share information and others	Person in charge of TPT and JPT	Once a month in principle. 41 sessions
Output1 Technical Transfer Session	Discuss the necessary technologies for NCDC operation (plan, monitoring, security, analysis, services, facility management, PR), case studies of Japan, and current situation in Thailand, in order to support TPT to create the draft manual for NCDC	JPT and person in charge of interim NCDC's operation (RTSD staff etc.)	JPT members visit NCDC in principle. 56 sessions and 8 online sessions
Output2 Technical Transfer Session	Explain and discuss the methods for economic impact analysis	JPT and person in charge of GISTDA	4 face-to-face sessions and online sessions

The project members nicknamed the project "TIGORS," meaning "Tie GNSS CORS in Thailand, and used in documents and events related to the project. TIGORS" is also used in this report.



3.2. Flow Chart of the Project

Figure 3-1 shows the overall flow of the Project.

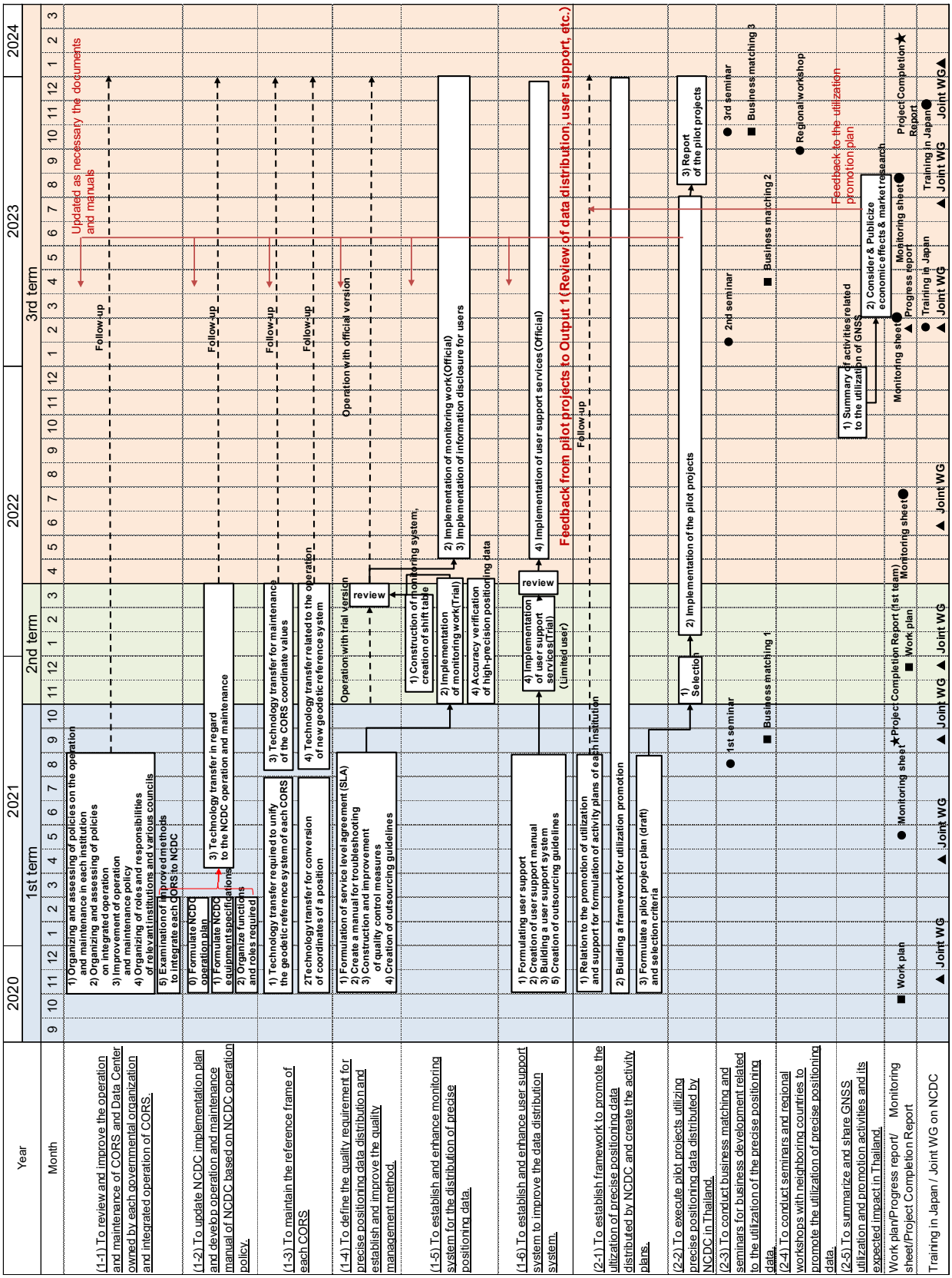


Figure 3-1 Flow chart of the Project

3.3. Project schedule

The Project has been implemented as shown in Table 3-2.

Table 3-2 Project schedule

Activities	Year	2020	2021				2022				2023				2024
Sub-Activities	Month	10	1	4	7	10	1	4	7	10	1	4	7	10	1
Output 1: Stable distribution of precise positioning data from NCDC															
1.1To review and improve the operation and maintenance of CORS and Data Center owned by each governmental organization and integrated operation of CORS.	Plan	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■			■	■		■		■	
	Actual	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■
1.2 To update NCDC implementation plan and develop operation and maintenance manual of NCDC based on NCDC operation policy.	Plan	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■			■	■		■		■	
	Actual	■ ■	■		■	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
1.3 To maintain the reference frame of each CORS.	Plan	■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■		■			■			
	Actual	■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■
1.4 To define the quality requirement for real time data and establish and improve the quality management method.	Plan	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■		■		■				■	■
	Actual	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
1.5 To establish and enhance monitoring system for the distribution of precise positioning data.	Plan					■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
	Actual		■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
1.6 To establish and enhance user support system to improve the data distribution system.	Plan	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
	Actual		■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				
Output 2: Promotion of utilization of precise positioning data in various fields															
2.1 To establish framework to promote the utilization of precise positioning data distributed by NCDC and create the activity plans.	Plan	■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■			■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■				
(1) Planning	Actual	■ ■	Planning was completed at the end of De				Execution started from Jan. 2022.								
(2) Framework					■					■ ■	■ ■			■	
(3) Pilot Project		Planning and selection was completed at the end of Dec. 2021.					■ ■ ■ ■ ■ ■ ■ ■								
2.2 To execute pilot projects utilizing precise positioning data distributed by NCDC in Thailand.	Plan					■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■				
	Actual						■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■ ■				■
2.3 To conduct business matching and seminars for business development related to the utilization of the precise positioning data.	Plan	■		■ ■		■			■	■			■		
	Actual			1st seminar ■						2nd seminar	■		■	■	3rd seminar
2.4 To conduct seminars and regional workshop with neighboring countries to promote the utilization of precise positioning data.	Plan										Agri DEMO DAY		■		
	Actual													■	■
2.5 To summarize and share GNSS utilization and promotion activities and its expected impact in Thailand.	Plan									■ ■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■				
	Actual									■ ■ ■	■ ■ ■ ■ ■ ■ ■ ■ ■ ■				

3.4. Assignment of JPT members

JPT members have been assigned in the Project as shown in Table 3-3.

Table 3-3 Assignment of JPT members

	Name/ Role	Year	2021		2022												2023												2024	
		Month	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2
In Thailand	TSUJI Hiromichi, Team leader/ NCDC and CORS management plan/utilization promotion support	Plan																												
		Actual																												
	SEIMIYA Nami, Deputy team leader/ NCDC and CORS management plan/utilization promotion support	Plan																												
		Actual																												
	CHIBA Zenichi, NCDC operation and maintenance	Plan																												
		Actual																												
	TSUJI Hiromichi, Reference system management	Plan																												
		Actual																												
	HOSOYA Motoyuki, Quality control/data distribution support	Plan																												
		Actual																												
	ISOBE Kohei, Pilot project/business development support (1)	Plan																												
		Actual																												
	SEIMIYA Nami, Pilot project/business development support (2)	Plan																												
		Actual																												
	NAKATANI Ryusuke, Training in Japan/seminar plan	Plan																												
		Actual																												
	YAJIMA Makoto, Market research/economic analysis	Plan																												
		Actual																												
In Japan	TSUJI Hiromichi, Team leader/ NCDC and CORS management plan/utilization promotion support	Plan																												
		Actual																												
	SEIMIYA Nami, Deputy team leader/ NCDC and CORS management plan/utilization promotion support	Plan																												
		Actual																												
	CHIBA Zenichi, NCDC operation and maintenance	Plan																												
		Actual																												
	TSUJI Hiromichi, Reference system management	Plan																												
		Actual																												
	HOSOYA Motoyuki, Quality control/data distribution support	Plan																												
		Actual																												
	ISOBE Kohei, Pilot project/business development support (1)	Plan																												
		Actual																												
	SEIMIYA Nami, Pilot project/business development support (2)	Plan																												
		Actual																												
	NAKATANI Ryusuke, Training in Japan/seminar plan	Plan																												
		Actual																												
	YAJIMA Makoto, Market research/economic analysis	Plan																												
		Actual																												

3.5. Activities related to overall project

[1] Preparation of Draft Work Plan

JPT reviewed the existing relevant materials, information, and data, and examine basic policies, methods, items, contents, implementation systems, schedules, and so forth regarding the implementation of the Projects. Based on these, JPT prepared the draft Work Plan for the 2nd and 3rd terms and obtained JICA's consent for the contents.

[2] Discussion of Work Plan (draft) and confirmation of PDM

The draft Work Plan mentioned above was reached agreement at the 4th Joint WG on NCDC meeting.

[3] Implementation of trainings in Japan

The 1st Training in Japan

This was held from 13th February 2023 (arrival to Japan) to 25th February 2023 (departure from Japan) aiming the goals below.

Output1: Learn how to solve the problems in operation management of NCDC as well as each agency's CORS from the cases of Japan.

Output2: Learn many examples of utilization of CORS as a reference for planning and implementation of promotion activities in Thailand.

JPT coordinated with the training host organizations listed below regarding the training contents and schedule. JPT also prepared the training materials. When making the training program, JPT took the flow of "CORS operation and maintenance (Output1)" - "CORS utilization (Output2)" - "touching new technologies" into consideration. As for the utilization, the technologies related to the pilot projects, as well as those which have been put into practical use and used commercially in Japan. The program and the participants are as follows.

Table 3-4 Outline of the 1st training in Japan

Date	Time	Contents	Host Organization	Training Items*
13th (Mon)	7:40	Arrival in Japan (at Narita, TG642)		-
14th (Tue)	9:30-12:00	Briefing	JICA Tsukuba	-
	13:15-16:00	Courtesy visit, overview of the GSI	GSI	[1] [2]
15th (Wed)	9:30-12:00	Lecture on quality control of GNSS data, equipment certification, and explanation of PCRG	Japan Association of Surveyors (JAS)	[1] [2] [3]
	13:45-16:45	Lectures and observations on operation and inspection of GNSS CORSs	GSI	[1] [2] [3]
16th (Thu)	13:30-16:00	Observation of CORS data utilization [Agricultural field]	YAMAHA	[4]
17th (Fri)	10:00-12:00	Lecture on GNSS survey and CORS data quality Lecture on CORS data utilization [Surveying field]	Jenoba Topcon	[1] [3] [4]
	13:00-16:00	Lecture and observation on CORS data utilization [Construction field]	Nishio Rent All	[3] [4]
18th (Sat)		Japanese culture tour		
19th (Sun)				
20th (Mon)	10:00-12:00	Lecture on data center operation and user management	Jenoba	[1] [3]
21st (Tue)	10:00-12:00	Lecture on training for users of GNSS CORSs	JAS	[5]
	14:00-16:00	Lecture on CORS data utilization [Precise 3D data and snow removal support system]	Dynamic Map Platform (DMP)	[4]
22nd (Wed)	10:00-12:00	Observation of examples of utilization of spatial information [Advanced case]	SECOM	[6]
	13:30-16:00	A lecture on space weather and a tour of the NICT exhibition room	National Institute of Information and Communications Technology (NICT)	[1] [3]
23rd (Thu)		National holiday		
24th (Fri)	9:30-12:00	Summarize of training report	Pasco	-
	14:00-17:00	Training debriefing session and training evaluation session	JICA HQ	-
25th (Sat)	11:45	Departure from Japan (from Narita, TG643)		-

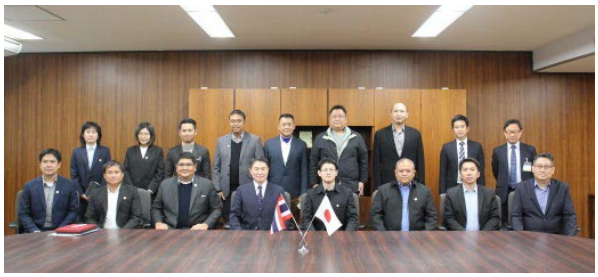
* Training items: [1] Operation of CORS, [2] Maintenance and management of CORS, [3] Stable delivery of CORS data, [4] Utilization of CORS data, [5] Education of CORS users, [6] New technology on CORS

Table 3-5 The participants of the 1st Training in Japan

No	Photo	Name	Position	Organization
1		Mr. Phuritat Sansuttawijit	Civil Engineer Practitioner Level	DPT
2		Ms. Kanyuta Jekchantuek	Civil Engineer Officer	DPT
3		Dr. Peera Yomwan	Acting Specialist in Surveying for Mapping	DOL

No	Photo	Name	Position	Organization
4		Mr. Norasi Nilphetploy	Senior Professional Survey Engineer	DOL
5		Mr. Pongsak Jindasee	Researcher	HII
6		Mr. Ratchanon Naksomboon	Geoinformatics Specialist	HII
7		Mr. Suwat Sreesawet	Engineer	GISTDA
8		Mr. Pranatpol Thaicharoen	Innovation Development Officer	GISTDA
9		Col. Rungkrai Kraimark	Deputy Director	RTSD
10		Col. Parinya Thaweewat	Chief of Geodesy Section	RTSD
11		Prof. Dr. Chalermchon Satirapod	Professor and Head of Survey Engineering Department	Chulalongkorn University
12		Asst. Prof. Nuksit Noomwongs	Assistant Professor of Mechanical Engineering Department	Chulalongkorn University
13		Asst. Prof. Dr. Soravis Supavetch	Assistant Professor of Civil Engineering Department	Kasetsart University
14		Assoc. Prof. Chattichai Waisurasingha	Associate Professor of Civil Engineering Department	Khon Kaen University

At the reporting session held on the last day of the training, the participants expressed that they gained plenty of knowledge and awareness about the operation and maintenance of CORS, the quality control of distributed data, efforts for and practical cases of utilization of CORS in various fields, and the technologies behind through this training.



GSI (14th Feb)



GSI (14th Feb)



JAS (15th Feb)



YAMAHA (16th Feb)



Topcon (17th Feb)



Nishio Rent All (17th Feb)



Jenoba (20th Feb)



JAS (21st Feb)



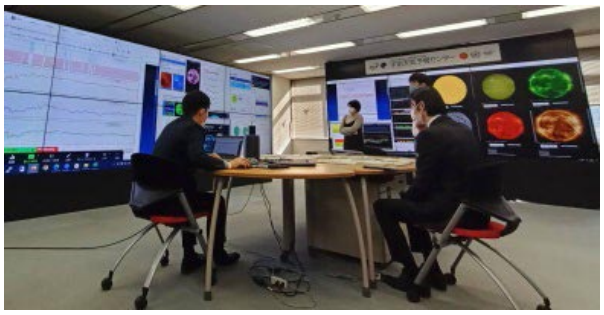
DMP (21st Feb)



SECOM (22nd Feb)



NICT (22nd Feb)



NICT (22nd Feb)



JICA (24th Feb)



JICA (24th Feb)

Figure 3-2 Photos of the 1st Training in Japan

The 2nd Training in Japan

This was held from 27th November 2023 (arrival to Japan) to 9th December 2023 (departure from Japan) aiming the goals below.

Output1: Learn how to solve the problems in operation and data distribution of NCDC from the cases of Japan.

Output2: Learn many examples of utilization of CORS as a reference for planning and implementation of promotion activities in Thailand.

JPT coordinated with the training host organizations listed below regarding the training contents and schedule. JPT also prepared the training materials. When making the training program, JPT took the flow of "CORS operation and maintenance (Output1)" - "CORS utilization (Output2)" - "touching other CORS related technologies as well as new technologies" into consideration. As for the utilization, the technologies related to the pilot projects, as well as those which have been put into practical use and used commercially in Japan. The program and the participants are as follows.

Table 3-6 Outline of the 2nd training in Japan

Date	Time	Contents	Host Organization	Training Items*
27th (Mon)	13:05	Arrival in Japan (at Narita, NH806)		
28th (Tue)	10:00-12:00	Briefing	JICA Tsukuba	
	14:00-16:00	Courtesy visit, overview of the GSI	GSI	[1] [2] [3]
29th (Wed)	9:30-12:00	Lectures on overview of CORS and GEONET	GSI	[1] [2] [3]
	13:30-15:45	Lectures and observations on operation, inspection, and O&M of GNSS CORSs	GSI	[1] [2]
30th (Thu)	9:30-10:30	Lecture on Very Long Baseline Interferometry (VLBI)	GSI	[4]
	13:30-14:30	Site visit of VLBI facility in Ishioka-city	GSI	[4]
1st (Fri)	9:30-12:00	Lecture on quality control of GNSS real time data	JAS	[2] [3]
	13:30-15:00	Lectures and observations on equipment certification	JAS	[4]
2nd (Sat)				
3rd (Sun)	6:30	2 participants arrival in Japan		
4th (Mon)	9:30-11:30	Lecture on CORS data distribution	Jenoba	[1] [2]
	14:00-16:00	Lecture on CORS data utilization [Surveying and other applications]	Nikon Trimble	[3] [4]
5th (Tue)	11:15-15:15	Observation of CORS data utilization [Agricultural field]	Yanmar Agri Business	[3] [4]
6th (Wed)	9:30-11:30	Lecture on CORS data utilization [UAV and laser survey]	Pasco	[3] [4]
	13:30-16:00	A lecture on space weather and a tour of the NICT exhibition room	NICT	[3] [4]
7th (Thu)	10:00-16:00	Observation of CORS data utilization [Surveying and construction field]	Topcon	[3]
8th (Fri)	9:30-12:00	Summarize of training report	JICA Tokyo	
	14:00-17:00	Training reporting session		
9th (Sat)	11:45	Departure from Japan (from Haneda, NH805)		

* Training items: [1] Maintenance and management of CORS, [2] Stable delivery of CORS data, [3] Utilization of CORS data, [5] CORS related technologies and new technologies on CORS

Table 3-7 The participants of the 2nd Training in Japan

No	Photo	Name	Position	Organization
1		Prof. Dr. Chalermchon Satirapod	Professor and Head of Survey Engineering Department	Chulalongkorn University
2		Mr. Miti Nuntatikul	Survey Engineer, Senior Professional Level	DOL
3		Mr. Thunpravee Tuntreeboon	Survey Engineer, Practitioner Level	DOL
4		Mr. Nakarin Plangpongpan	Expert on Survey and Map	DPT
5		Mr. Chaiwat Panachat	Surveyor, Experienced Level	DPT
6		Mr. Chinnatat Keawkaew	Director of Aerospace Industry Promotion Center	GISTDA
7		Ms. Nimnoi Anothai	Innovation Development Officer	GISTDA
8		Mr. Jirapaht Thieankhwan	Innovation Development Officer	GISTDA
9		Mr. Manorot Tangseveephan	Director of Technology and Digital Division	HII
10		Mr. Amnat Sompan	Research Associate	HII
11		Dr. Sompoch Puntavungkoon	Deputy Director of Map Information Center	RTSD
12		Mr. Thaweechai Choocherd	Geophysicist	RTSD
13		Mr. Chanachon Paijitprapaporn	Officer	RTSD
14		Dr. Thayathip Thongtan	Senior Electrical Metrologist	NIMT

The participants gained plenty of knowledge and awareness about the operation and maintenance of CORS, the quality control of distributed data, practical cases of utilization of CORS in various fields, and the technologies behind through this training.



GSI (28th Nov)



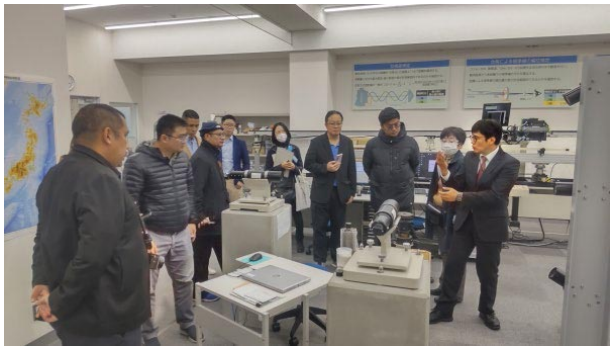
GSI (29th Nov)



GSI (29th Nov)



GSI (30th Nov)



JAS (1st Dec)



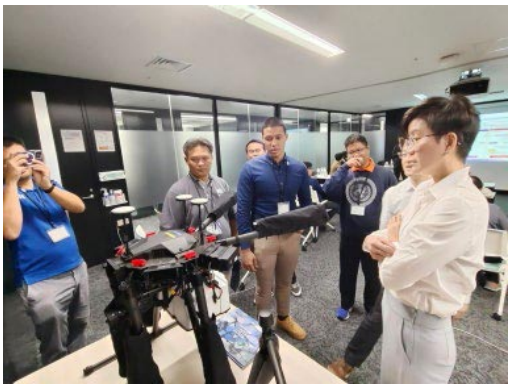
Jenoba (4th Dec)



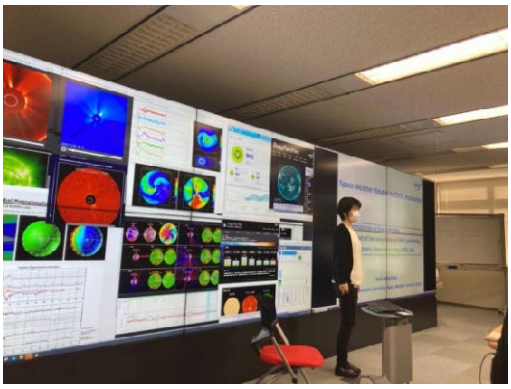
Nikon Trimble (4th Dec)



Yanmar Agri (5th Dec)



Pasco (6th Dec)



NICT (6th Dec)



Topcon (7th Dec)



Topcon (7th Dec)



JICA Tokyo (8th Dec)



JICA Tokyo (8th Dec)

Figure 3-3 Photos of the 2nd training in Japan

[4] Holding of Joint WG on NCDC meetings

TPT and JPT jointly held the 4th - 8th Joint WG on NCDC meetings. (The 1st - 3rd meetings were held in the 1st term.)

Table 3-8 Outline of Joint WG on NCDC meetings

No.	Date	Agenda
4th	23rd December 2021 (In the middle of the 2nd term)	- Confirmation of work plan (2nd term and 3rd term) - Confirmation of the persons subject to technology transfer - Report on the result of the selection of the pilot projects
5th	24th June 2022 (After the start of the 3rd term)	- Confirmation of progress of each activity / Confirmation of preparation status of pilot projects - Summarizing of the 2nd term activities, and planning of the 3rd term - Setting of Key Performance indicators (*) - Confirmation and agreement on the monitoring sheet Ver.3
6th	7th February 2023 (Middle of the 3rd term)	- Confirmation of progress of each activity - Confirmation of the plan of the 1st training in Japan - Report on the 2nd project seminar - Setting of the PDM indicators - Confirmation and agreement on the monitoring sheet Ver.4
7th	24th July 2023 (Middle of the 3rd term)	- Confirmation of progress of each activity - Report of the training 1st training in Japan/ Plan for the 2nd training in Japan - Plan for the regional workshop/ the 3rd project seminar - Confirmation and agreement on the monitoring sheet Ver.5
8th	25th January 2024 (Late stage of the 3rd term)	- Report of the activities conducted after 7th meeting (including 3rd Seminar / Regional Workshop / 2nd training in Japan, etc.) - Confirmation of the points of project completion report and conclusion of the project (including project evaluation / confirmation of issues to be addressed to achieve the overall goal / exchange opinions and plans for the coming 3 years, etc.)

* Key Performance indicators

The following indicators were set and monitored on monthly basis.

- Data acquisition rate of RINEX at NCDC
- The total number of the registered NCDC users
- The total number of visitors to the NCDC website
- The number of participants in NCDC related promotion events





The 5th Joint WG on NCDC meeting (24th June 2022)




The 6th Joint WG on NCDC meeting (7th February 2023)




The 7th Joint WG on NCDC meeting (24th July 2023)




The 8th Joint WG on NCDC meeting (25th January 2024)

Figure 3-4 Photos of the Joint WG on NCDC meetings

3.6. Output1: Stable and effective distribution of precise positioning data from NCDC

3.6.1. Common subject matter

Activities were performed through online Output1 meetings, Technical Transfer sessions at NCDC, and other individual meetings.

Representatives from 5 CORS operating agencies which are TPT members, including RTSD which is the C/P of Output1, attended in Output1 meetings. The duration of each session was about 1 to 1.5 hours.

The technical transfer sessions were held at NCDC in principle when JPT members traveled from Japan, and 5 - 6 RTSD staff members who operate NCDC participated. Other CORS operating agencies were visited as necessary, and companies outsourced by each agency also participated when appropriate. The duration of

each session was approximately 2 to 3 hours.

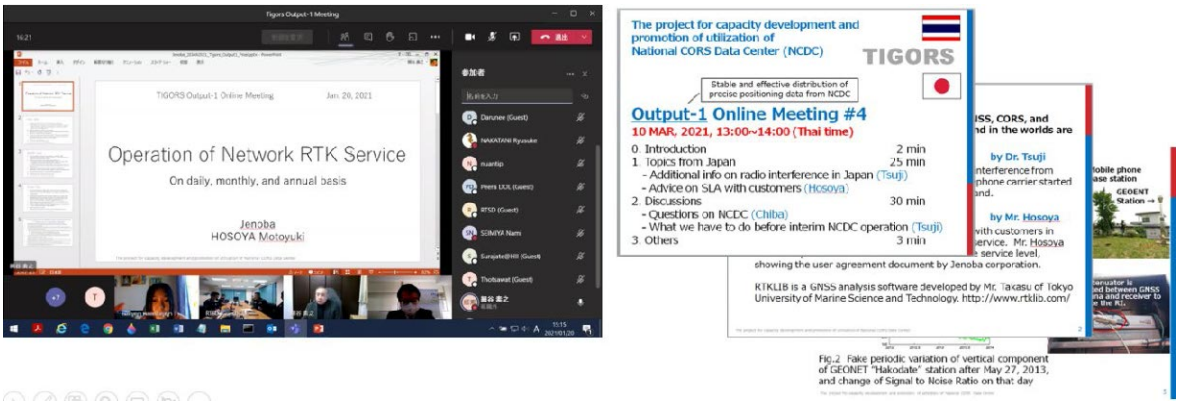


Figure 3-5 Photos of the Output1 meetings

Table 3-9 Output1 meetings in 2nd and 3rd terms

No.	Date	Main contents
Output1-11	9th Dec 2021	1. Topics from Japan : Peera-san's report on his participation to JICA online training course at GSI Japan 2. Status and actions for the improvement of NCDC service 3. Preparation for the next Joint WG on NCDC
Output1-12	24th Jan 2022	1. Topics from the world : A report on Geospatial Capacity Development Conference on GNSS applications and Disaster Risk Reduction 2. Results of NCDC tuning in Dec. 2021 and Jan. 2022 3. Current status of NCDC service
Output1-13	17th Feb 2022	1. Topics from the world : Pilot Project on CORS Utilization: UAV Photogrammetry Using CORS for Construction Survey in the Philippines 2. Report of NRTK surveys in the field (Bangkok, Lumpang) 3. Towards the improvement of NCDC service (focusing on Spider)
Output1-14	17th Mar 2022	1. Topics from Japan : Realization of semi dynamic reference frame in Japan 2. Towards the improvement of NCDC service (focusing on data gap) 3. Confirmation of homework on NCDC O&M 4. Review of our activity in accordance with TIGORS work plan
Output1-15	20th Apr 2022	1. Topics from Japan : Performance standards and registration procedures for private CORS in Japan 2. Follow up of NCDC action plan (Deemed rover analysis at NCDC) 3. Recent results of Deemed Rover analysis by JPT
Output1-16	19th May 2022	1. Topics from Japan : Requirement of GNSS precision for ICT construction in Japan 2. Results of deemed rover analysis at NCDC 3. Postmortem on a recent NCDC pilot result at ATTRIC (Nishio Rent All)
Output1-17	16th Jun 2022	1.Topics from the world : Notes on ITRF2020 2. Planning of increasing the number of Deemed Rovers 3. Preparation for the next Joint WG on NCDC meeting
Output1-18	21st Jul 2022	1.Topics from Japan : How GSI Japan maintains sky photographs over CORS 2.Topics from Japan : Note on a MIRAI project by CAO Japan 3. Report of Key Performance Indicators 4. 2nd result of ATTRIC test 5. Hosoya's notes on his recent visit to NCDC
Output1-19	22h Aug 2022	1.Topics from Japan : TKY2JGD: The coordinate transformation tool in Japan 2. Report of Key Performance Indicators 3. Report from the pilot project by Yanmar Agri 4. Analysis of RINEX data at Master stations of Spider

No.	Date	Main contents
Output1-20	21st Sep 2022	1. Topics from the world: Brief review of IGS 2022 virtual workshop 2. Topics from the world: Switch to ITRF2020 of IGS products 3. Report of Key Performance Indicators and NCDC activities
Output1-21	21st Oct 2022	1. Topics from world: Review of IGS 2022 virtual workshop (continued) 2. Topics from Japan: Research Consortium for using Private CORS in Japan 3. Topics from Japan: Development of QC software "RINGO" by GSI Japan 4. Feedback from a pilot project user (Yanmar Agri) 5. Availability of Bernese ver.5.4 6. Report of KPI and NCDC activities (including firmware version)
Output1-22	21st Nov 2022	1. Topics from the world: Review of the United Nations ICG 16th meeting 2. Feedback from a pilot project user (Topcon) 3. Analysis of data delay and signal using DOL account 4. Report of KPI and NCDC action items (with survey report at Chonburi)
Output1-23	21st Dec 2022	1. Topics from Japan: Advancement of Space Weather Forecasting in Japan 2. Examples of Ionospheric disturbance on NRTK 3. Data suspension and delay in NCDC network 4. Report of KPI and NCDC action items
Output1-24	19th Jan 2023	1. Topics from Japan: Recent news on GEONET - Good and Bad news – (Application of REGARD, Correction of CORS coordinates) 2. Feedback from users: Yamaha 3. Plan of NCDC data delay test from 16th -31st Jan. 2023 4. Recommendation on RTKLIB setting, KPI and NCDC action items (including report to National Geo-informatics Board) 5. Review and discussion on Output1 activities so far
Output1-25	26th Mar 2023	1. Topics from Japan: Review of 1st Training in Japan 2. KPI report 3. Issues of interim NCDC, and NCDC action plans
Output1-26	24th Apr 2023	1. Topics from the world: The Tour de I'IGS 5th Stop: GNSS for Natural Hazards in the South Pacific 2. KPI report with draft Action items of NCDC 3. Story of our next JICA project
Output1-27	18th May 2023	1. Topics from Japan: Release of RINGO software from GSI 2. Report of KPI and NCDC Action items 3. Report of JPT visit to NCDC 4. Radio Interference test at SBKK 5. Feedback to the last month discussion
Output1-28	15th Jun 2023	1. Topics from the world: Technical news on GNSS software 2. Report of KPI and NCDC Action items 3. Initial look at RINGO results 4. More discussions on Radio Interference test 5. What's new in TIGORS2
Output1-29	14th Jul 2023	1. Topics from Japan/the world: New IGS Analysis Center Candidate JGX 2. Report of KPI and NCDC Action items 3. Discussion on SLA and guidelines for outsourcing 4. Preparation to 7th Joint WG on NCDC
Output1-30	21st Aug 2023	1. Topics from the world: Brief look at IUGG 2023 2. Report of KPI and NCDC Action items 3. Follow up of discussions on SLA, Outsourcing, and RI 4. Jenoba's reporting system for CORS operation
Output1-31	14th Sep 2023	1. Topics from the world: UNGGIM 13th session in August 2023 2. Report of KPI and NCDC Action items 3. Follow up of discussions on NCDC 4. Jenoba's comment on Deemed rover analysis 5. Preparation to the regional workshop
Output1-	12th Oct	1. Topics from the world: ION GNSS+ 2023 meeting

No.	Date	Main contents
32	2023	2. Report of KPI and NCDC Action items 3. Understanding issues and countermeasures for stable distribution
Output1-33	9th Nov 2023	1. Topics from the world : Brief look at 17th meeting of ICG 2. Report of KPI and NCDC Action items 3. Review of RTSD/DOL/JPT meeting on 1st Nov. 4. To clarify NCDC problem using JENOBA's Server and Spider
Output1-34	19th Dec 2023	1. Topics from Japan : Review of 2nd training in Japan 2. Report of KPI and NCDC Action items 3. Discussion on the effects of technology transfer 4. Concluding remarks from JPT

Table 3-10 Technical transfer in 2nd and 3rd terms. 56 sessions at NCDC, 8 sessions online in total.

Month	Target group, number of sessions (Topics)
Dec 2021	RTSD: 4, online 3 (NCDC precision evaluation and improvement) DOT: 1, DOL:1, HII 1 (Information exchange and site visit)
Jan 2022	RTSD:3 (Operation and maintenance, Equipment update plan, Trouble shooting) RTSD and DOL online 2 (Data delay at DOL)
Feb 2022	RTSD and HII online 2 (Data delay at HII)
Mar 2022	RTSD 4 (Activity plan, Deemed rover method, Coordinate system, Manual, User support) DPT, DOL, HII, and GISTDA online 1 (Individual discussion)
May 2022	RTSD 3 (Operation and maintenance, Rinex data application in Japan) RTSD 3 (Coordinate system in Japan, ITRF2020, Quality control of NCDC)
Jun 2022	RTSD 4 (KPI, Advice on transfer to ITRF2014, Quality control of NCDC, Spider setting)
Jul 2022	RTSD 3 (Spier setting, CORS site visit) DOL 1, DPT 1, HII 1 (Information exchange and site visit)
Aug 2022	RTSD 4 (Japan's CORS regular inspection, security measures, system redundancy, work regulations case study) DOL 1 (Precision improvement)
Oct 2022	RTSD 3 (Briefing to new director, Case study of Japan, NCDC evaluation, feedback from pilot project) DOL 1 (Precision improvement)
Dec 2022	RTSD 4 (Budget/procurement, Equipment inspection/registration, Confirmation of manuals and progress)
Mar 2023	RTSD 2(Progress of NCDC, NCDC Manual)
Apr 2023	RTSD 3(NCDC activity plan, Observation and analysis of radio interference, SLA, Update of Bernese software)
Jul 2023	RTSD 2(Spectrum analysis, Indication of precision in SLA, Improvement of deemed rover method, Note on outsourcing etc.)
Aug 2023	RTSD 3(Feedback to NCDC manual)
Nov 2023	RTSD 1(Quality control, Data delay, Spider setting, Plasma bubble, Radio interference, Unification of observation signal, Manual, Response to the user meeting etc.)
Dec 2023	RTSD 3(Feedback to NCDC manual, Advise to RTSD)



Figure 3-6 Photos of the technical transfer sessions

3.6.2. Details of each activity and results

[1-1] To review and improve the operation and maintenance of CORS and Data Center owned by each governmental organization and integrated operation of CORS

Activity 1-1 was conducted primarily in 1st term (November 2020 - October 2021). The activities of 1st term are described in the Project Completion Report (1st term), but in order to determine the level of achievement over the entire period, the activities of 1st term are also described here, along with 2nd and 3rd terms (November 2021 - March 2022, and April 2022 - February 2024 respectively).

The interim NCDC was limited by the inability to generate correction data using all CORS in Thailand, and the early development of a full-scale NCDC that can use all CORS was a challenge to ensure stable accuracy even during ionospheric disturbances. Unfortunately, the interim NCDC was not expanded during the project period due to government budget constraints caused by COVID-19, but related organizations will continue to make budget requests for the realization of the full-scale NCDC.

Table 3-11 Activity 1-1

NO.	Items	Activities
1)	Review of policies on the operation and maintenance of CORS and data center in each agency	- The current status and plans of each CORS/DC were confirmed for the 5 CORS agencies. - Operation policies of each DC after the establishment of NCDC are as follows. - RTSD, the hosting agency of NCDC, will use NCDC as RTSD's DC. - DOL and DPT will continue their precise positioning services in their own fields. - GISTDA and HII will operate for research purpose only. - Since private use will be integrated into NCDC, it can be evaluated that the philosophy of NCDC has been realized.
2)	Review of policies on integrated operation of CORS data (including data collection and distribution schemes)	- The policy was confirmed through interviews with the 5 agencies. - Interim NCDC uses a method in which CORS data from each agency is collected at each agency's data center (DC) and then transferred to NCDC from each DC. Although this is a cost-effective method that allows the use of existing facilities, the analysis by the "deemed rover method" and network analysis tools revealed simultaneous delays occurring in the Government Information Network (GIN) connecting each DC to NCDC, and sporadic delays in the commercial Internet lines connecting each CORS to DC. - In the implementation of a full-scale NCDC, it is important

NO.	Items	Activities
		to consult and coordinate with GIN experts and Internet service providers in order to minimize these delays and achieve stable service.
3)	Improvement of operation and maintenance policy from the viewpoint of promoting utilization of precise positioning data, and meeting the service level to be presented to users	- JPT explained the importance of stable service implementation and clarification of service levels to users in promoting utilization.
4)	Review of roles and responsibilities of relevant agencies and various councils to promote the above, and operation of the various councils.	- Matters that need to be agreed upon by the TPT as a whole, such as the management policy of NCDC and unification of coordinate systems, are discussed technically in the NCDC Management WG, one of the Thai side councils, and then decided by the Sub-Committee on Management of GNSS Infrastructure of Thailand. - Project implementation and progress management are conducted by the Thai-Japan Joint WG on NCDC. The status of NCDC is also reported in the National Geo-informatics Board, the upper body of the Sub-Committee. - These councils are still in operation in 2nd and 3rd terms.

For example, at the online meeting of the National Geo-informatics Board on 9th January 2023, RTSD reported on the current status of the NCDC as shown in Figure 3-7. According to the NCDC logs for December 2022, users' GNSS receivers (rovers) performed 35,334 precise real-time positioning using NCDC corrections, or 1,139 times per day.

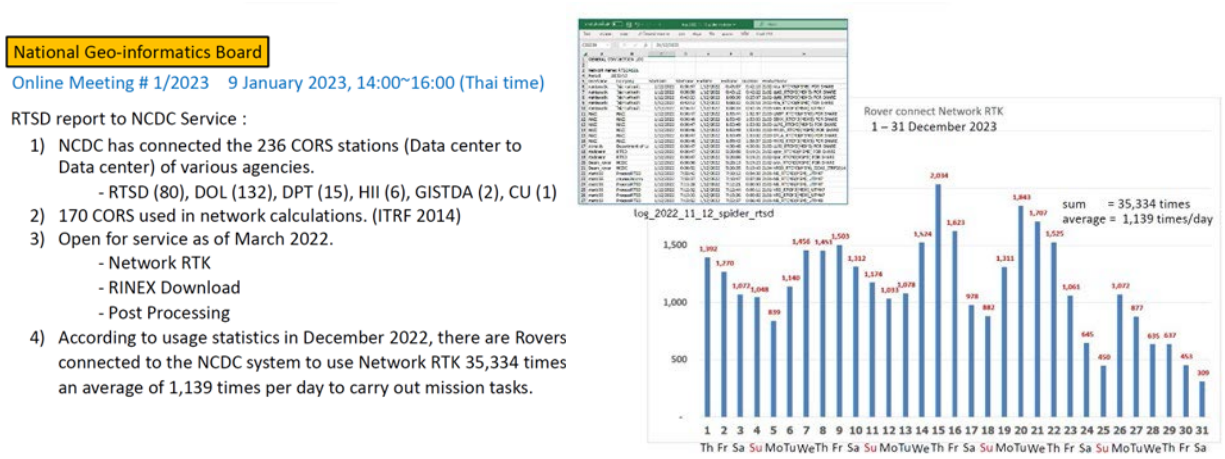


Figure 3-7 The status of NCDC reported at National Geo-informatics Board (Output1 meeting, January 2023)

[1-2] To update NCDC implementation plan and develop operation and maintenance manual of NCDC based on NCDC operation policy

In Activity 1-2, the NCDC Operation and Maintenance Manual (in Thai) has been prepared and updated through technology transfer sessions for RTSD staff in charge of NCDC planning, operation and maintenance, where the current status of NCDC was discussed using Japanese case studies as material. During the project period, the manager in charge of NCDC (Director of Geodesy and Geophysics Division

of RTSD) was replaced twice, but about 5 to 6 staff members, including the 3 core technical officers, participated in the technology transfer sessions each time.

Table 3-12 Activity 1-2

NO.	Items	Activities
0)	Formulation/update NCDC operation policy and operation plan (maintenance management plan)	- The draft NCDC Service Guidelines (in Thai), which were discussed by TPT at NCDC Management WG in November 2020 regarding NCDC's operational policies and plans, were shared with JPT for comment, and an English translation was provided for reference (Appendix 1). - The revised service guidelines (in Thai) are posted on the NCDC web page*.
1)	Formulation of NCDC equipment specifications - CORS and NCDC quality requirements - CORS and NCDC equipment specifications that meet the service level	- The interim NCDC specifications were prepared by TPT in 1st term and shared with JPT after the bidding. JPT commented on them based on the Japanese case study for reference in the next round. - In 2nd and 3rd terms, JPT was to advise on the specific specifications for the full-fledged NCDC, but since the budget for the full-scale NCDC was not approved, JPT advised on the issues of interim NCDC based on the operational status.
2)	Review of functions and roles required for NCDC - Preparation and finalization of NCDC functions and roles for stable data distribution by NCDC that meet the service level agreement (SLA)	- In the technology transfer session of 1st term, the expected functions and roles of NCDC** (A: Planning Management / Cooperation, B: Monitoring / Troubleshooting, C: Security, D: Analysis / Data Processing, E: Positioning Service / User Management, F: Equipment Maintenance, G: Public Relations) were explained. JPT advised to construct NCDC in accordance with the actual situation in Thailand. - The concept of SLA was explained at Output1 meeting, as well as the need of statistical information to support the numerical description of SLA. - JPT explained trouble shooting, information security, and equipment maintenance at the technology transfer sessions in 2nd and 3rd terms.
3)	NCDC operation and maintenance - Technologies in regard to the NCDC operation and maintenance (including technologies for outsourcing) - Formulation of manuals and guidelines for NCDC operation and maintenance (including user support system) - Maintenance of reports/record forms, etc.	- During technology transfer sessions in 1st term, JPT explained examples of manuals in Japan and emphasized the importance of having the staff members themselves prepare the manual and update it through their work. TPT prepared the framework of the manual (in English), referring to the Japanese case study. - In 2nd and 3rd terms, TPT prepared a draft manual in Thai with comprehensive contents including operation and maintenance management, coordinate reference system, and quality control, and updated it based on advice from JPT and operational experience in Thailand. In 3rd term, the draft manual was updated with reference to feedback from the pilot project users (Appendix 2).

* https://ncdc.in.th/portal/apps/sites/#/ncdc-eng/datasets/6f3d1e2b9ec14d19a749f315dadb1df1

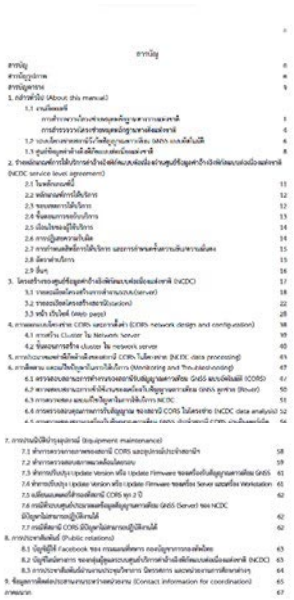
** Table 3-10, Project completion report (1st term)



National CORS Data Center Operation and Maintenance Manual

INTRODUCTION
(Describe the propose of this manual)
BACKGROUND
(Describe the background of NCDC, Formation, establishment, coordinated agencies)
ORGANIZATION STRUCTURE
(Describe the related committees in NCDC)
NCDC Service Guideline (Draft)/Service Level Agreement (to be updated)
(Insert Draft Service guideline which has been presented in GNSS Sub Committee Meeting on 5 August 2021)
NCDC infrastructure and Streaming Scenario
(Describe NCDC infrastructure (Hardware/Software, Firewall, Network/Internet connection) and Diagram showing the flow of GNSS data streaming and Backup)
CORS network design and configuration
(Describe CORS location, Clusters Design, Auto Cell Setting, Mount Point Configuration)
REFERENCE FRAME Determination
(Brief explanation of Reference Frame (Coordinate system))
SERVICES for users/customers
(User Registration, NRTK, RINEX Download, Post Processing)
Quality Control
(Daily Tasking, Periodical Tasking, personnel assignment)
Troubleshooting/FAQs
(Solving problems that may occur with users)
Maintenance
(Maintenance Schedule)
Public Relation
(Web developing, Promoting NCDC, Seminar)
Contact information of each agency





Framework of NCDC Manual
(1 page in English)

NCDC manual version 5 Revised
(92 pages in Thai)

Figure 3-8 Progress of NCDC manual

Table 3-13 Content of NCDC Manual Version 5 Revised

1. Basic information (about this manual)
1.1 Geodetic Reference System in Thailand
Surveys for the National Horizontal Reference Point Network 1
Surveys for the National Vertical Reference Point Network 4
1.2 CORS Network 6
1.3 National CORS Data Center (NCDC) 8
2 NCDC Draft Standards for the Provision of Precise Positioning Services (NCDC Service Level Agreement)
2.1 Definition of Terms 11
2.2 Terms of Service Provision 12
2.3 Scope of Service 12
2.4 Service Request Procedures 13
2.5 Terms and Conditions of Service Use 14
2.6 Disclaimer 14
2.7 Confidentiality of Service 15
2.8 Service Fees 15
2.9 Others 16
3. Configuration of NCDC 17
3.1 System Structure (Server) 18
3.2 CORS Station Structure 22
3.3 Web page 28
4. CORS Network Structure 41
4.1 Creating a Cluster on a Network Server 42
4.2 Procedure for Creating a Cluster on a Network Server 43
5. Calculation of reference coordinates of CORS stations 46
6. Service monitoring and troubleshooting 51
6.1 Automatic Checking of CORS Station Operation Status 51
6.2 Checking the Access Status of User's GNSS Receiver (Rover) 54

6.3 Checking and Resolving Troubles When Using NCDC Services 55
6.4 Checking the Received Signal Quality at CORS 56
6.5 Checking the status of GNSS receiver at CORS station via the Internet 60
6.6 In case of NCDC server problems 62
6.7 In case of CORS station problems 62
7. Maintenance of equipment
7.1 Perform physical inspection of CORS stations and equipment 63
7.2 Inspecting the surrounding environment 64
7.3 Update GNSS receivers and firmware 66
7.4 Update servers and workstations, firmware updates 66
7.5 Replace spare batteries at CORS stations every two years 67
8. Public Relations
8.1 LINE official account administrator 68
8.2 PR through Conferences, Exhibitions, Various Educational Institutions, etc. 69
9. Contact information for coordination among NCDC agencies 70
Appendix: Reference Coordinates for NCDC CORS 71
Trouble shooting of Leica Spider 81

[1-3] To maintain the reference system of each CORS

In Activity 1-3, JPT shared the examples of reference coordinate system management in Japan and around the world in Output1 meetings. RTSD staff with experience in GNSS baseline analysis took the lead in learning the analysis software "Bernese" to obtain the reference coordinate values. Based on the joint research with Chulalongkorn University and others (Project Completion Report (1st term), Figure 3-7) and advice from JPT, RTSD determined the reference coordinate values for CORS (ITRF2014, reference epoch: 2021.93) and used those values in the NCDC service from March 2022.

For conversion from the conventionally used reference coordinate values (ITRF2005 and ITRF2008), it was decided to use a simple 3-parameter (the amount of shift in each axis direction in a 3-dimensional Cartesian coordinate system), and the method is provided to users on the NCDC website (Figure 3-7). It can be applied for mapping tasks that do not require mm-level accuracy. The transformation parameters to TRF2014@2021.93 are as follows:

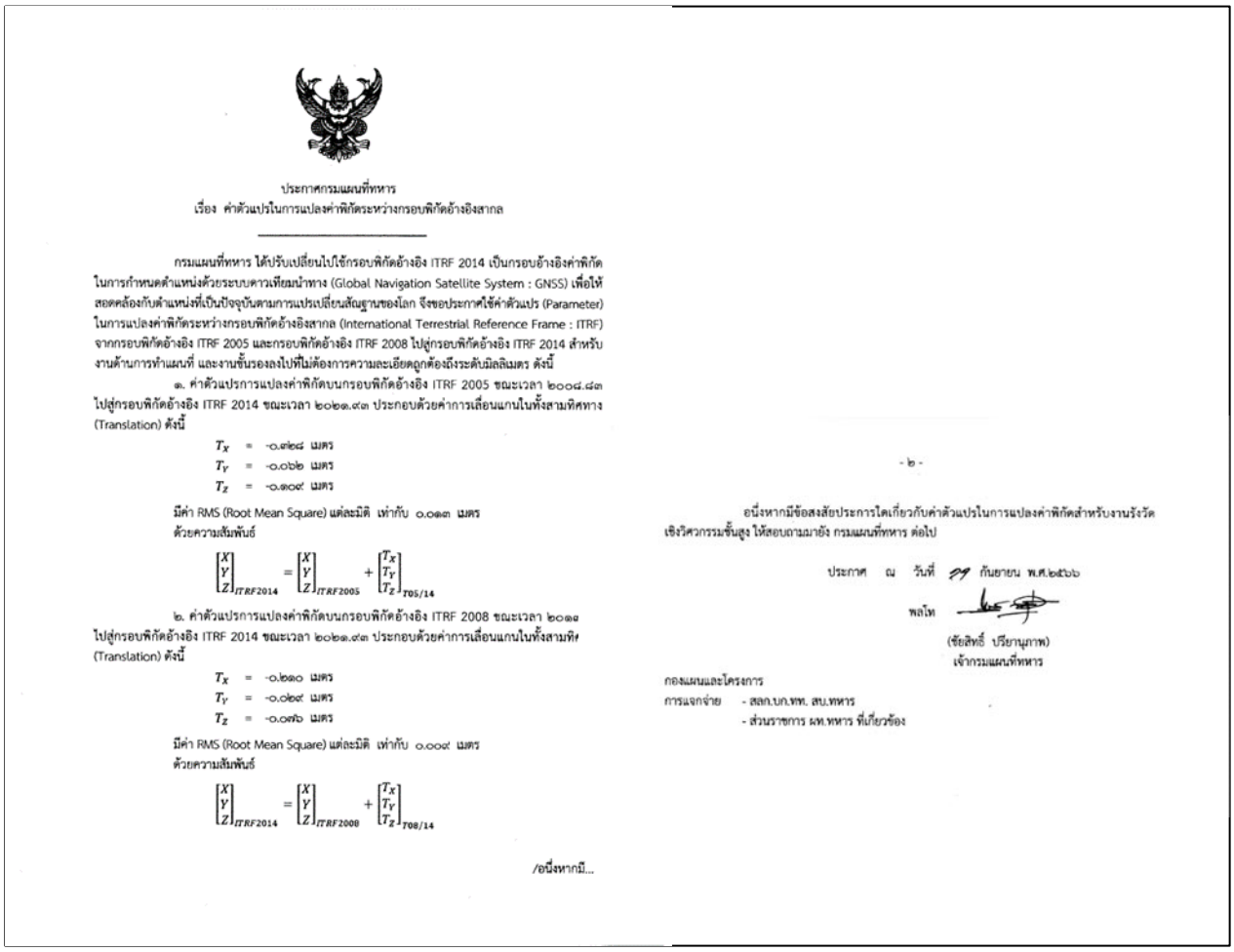
From ITRF2005@2008.43 Tx= -0.328 m, Ty= -0.062 m, Tz= -0.002 m,

From ITRF2008@2013.81 Tx= -0.210 m, Ty= -0.029 m, Tz= -0.076 m.

Table 3-14 Activity 1-3

NO.	Items	Activities
1)	Technologies required to unify the geodetic reference system of each CORS - CORS daily coordinate calculation based on the international standards (ITRF2014) (assuming the use of Bernese software) - Accuracy verification of coordinates of each agency's CORS (compare with calculation results of the same data by Bernese) - Understand Japanese geodetic reference system and its	- JPT introduced Japan's geodetic standards and GSI's method for reference coordinate system management in 1st term. - A license for the precise GNSS analysis software Bernese ver. 5.2, which can calculate ITRF coordinates for CORS, was procured along with a laptop PC, and provided to NCDC for training purposes. The software and PC were loaned in advance to DOL interested in Bernese analysis, and NCDC staff with Bernese skills provided guidance on the ITRF 2014 analysis using tutorial data. - Through joint research between Chulalongkorn University, DOL, RTSD and others, the ITRF2014

NO.	Items	Activities
	management methods of the Geospatial Information Authority of Japan	coordinate values for CORS in Thailand and the transformation parameters from the conventional coordinate system were determined on a trial basis, and shared at the Output1 meeting. - Based on this result, the coordinate values for CORS in Thailand were to be unified to ITRF2014 (epoch: 2020.17) from January 2022. However, RTSD found a mistake in the above coordinate values after a close examination, and the coordinate values for NCDC were changed to ITRF2014 (epoch: 2021.93). This value is used for NCDC services from March 2022. ITRF2014 in Thailand is realized by fixing 12 IGS stations around Thailand. - In 2nd and 3rd terms, technical information was shared on ITRF2020, the latest ITRF coordinate system that is expected to be used in the future. In addition, Bernese software is updated to ver. 5.4, which allows ITRF2020 calculations to be easily performed. - RTSD estimated coordinate transformation parameters from the previously used ITRF2005 and ITRF2008 to ITRF2014, and after sharing the results at the Output1 meeting, RTSD decided to use a simple 3-parameter, and the method was published on the NCDC website.
2)	Technologies for transformation of coordinates due to changes in geodetic reference system - ITRF coordinate transformation method - Method for estimating coordinate transformation parameters due to change of geodetic reference system - Estimating coordinate transformation parameters using Bernese utility program	
3)	Technologies for maintenance of the CORS coordinates - CORS daily coordinate monitoring method (time series data monitoring) - Presentation on cases in Japan regarding the timing of coordinate revision.	- JPT explained in the technology transfer sessions in 2nd and 3rd terms that 1) the relative accuracy of CORS coordinate values for generating NCDC corrections should be kept within 1 cm, 2) daily monitoring of coordinate values by Bernese or others are desirable to confirm this, and 3) examples of crustal deformation monitoring in Japan. - However, daily monitoring requires some resources and has not yet been implemented at NCDC. - The timing of coordinate revision in Japan (during normal times and earthquakes) was explained at the Output1 meeting and the training in Japan in 3rd term.
4)	Technologies related to the operation of new geodetic reference system - Understanding the concept of semi-dynamic correction and study of its introduction in Thailand - Transformation parameters - Creation of operational guidelines	- JPT explained "semi-dynamic correction" and "dynamic correction," which are coordinate system management methods in Japan, where crustal movement is remarkable, at the Output1 meetings and the training in Japan in 3rd term. Although the coordinate values in Thailand also change by several cm per year due to plate motions, the relative changes are small, so there is no problem for the time being in using the reference epoch's coordinate values. However, after more than 10 years since the coordinate values were determined, the discrepancy between the physical location and the coordinate values may become a problem.



ประกาศกรมแผนที่ทหาร
เรื่อง ค่าตัวแปรในการแปลงค่าพิกัดระหว่างกรอบพิกัดอ้างอิงสากล

กรมแผนที่ทหาร ได้ปรับเปลี่ยนไปใช้กรอบพิกัดอ้างอิง ITRF 2014 เป็นกรอบอ้างอิงค่าพิกัดในการกำหนดตำแหน่งด้วยระบบดาวเทียมนำทาง (Global Navigation Satellite System : GNSS) เพื่อให้สอดคล้องกับตำแหน่งที่เป็นปัจจุบันตามการแปรเปลี่ยนสัณฐานของโลก จึงขอประกาศใช้ค่าตัวแปร (Parameter) ในการแปลงค่าพิกัดระหว่างกรอบพิกัดอ้างอิงสากล (International Terrestrial Reference Frame : ITRF) จากกรอบพิกัดอ้างอิง ITRF 2005 และกรอบพิกัดอ้างอิง ITRF 2008 ไปสู่กรอบพิกัดอ้างอิง ITRF 2014 สำหรับงานด้านการทำแผนที่ และงานชั้นรองลงไปที่ไม่ต้องการความละเอียดลงถึงระดับมิลลิเมตร ดังนี้

๑. ค่าตัวแปรการแปลงค่าพิกัดบนกรอบพิกัดอ้างอิง ITRF 2005 ขณะเวลา ๒๐๐๕.๘๓ ไปสู่กรอบพิกัดอ้างอิง ITRF 2014 ขณะเวลา ๒๐๒๑.๙๓ ประกอบด้วยค่าการเลื่อนแกนในทั้งสามทิศทาง (Translation) ดังนี้

T_X = -๐.๗๒๘ เมตร
T_Y = -๐.๐๖๖ เมตร
T_Z = -๐.๑๐๔ เมตร

มีค่า RMS (Root Mean Square) แต่ละมิติ เท่ากับ ๐.๐๑๓ เมตร
ด้วยความสัมพันธ์

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2014} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2005} + \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix}_{T05/14}$$

๒. ค่าตัวแปรการแปลงค่าพิกัดบนกรอบพิกัดอ้างอิง ITRF 2008 ขณะเวลา ๒๐๑๐ ไปสู่กรอบพิกัดอ้างอิง ITRF 2014 ขณะเวลา ๒๐๒๑.๙๓ ประกอบด้วยค่าการเลื่อนแกนในทั้งสามทิศ (Translation) ดังนี้

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มีค่า RMS (Root Mean Square) แต่ละมิติ เท่ากับ ๐.๐๐๔ เมตร
ด้วยความสัมพันธ์

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2014} = \begin{bmatrix} X \\ Y \\ Z \end{bmatrix}_{ITRF2008} + \begin{bmatrix} T_X \\ T_Y \\ T_Z \end{bmatrix}_{T08/14}$$

/อนึ่งหากมี...

- ๒ -

อนึ่งหากมีข้อสงสัยประการใดเกี่ยวกับค่าตัวแปรในการแปลงค่าพิกัดสำหรับงานรังวัดเชิงวิศวกรรมชั้นสูง ให้สอบถามมายัง กรมแผนที่ทหาร ต่อไป

ประกาศ ณ วันที่ ๒๙ กันยายน พ.ศ.๒๕๖๖

พลโท
(ชัยสิทธิ์ ปริยานุภาพ)
เจ้ากรมแผนที่ทหาร

กองแผนและโครงการ
การแจกจ่าย - สลก.บก.ทท. สบ.ทหาร
- ส่วนราชการ ผท.ทหาร ที่เกี่ยวข้อง

Figure 3-9 Coordinate transformation parameters for CORS published on the NCDC website (RTSD, September 2023)
(https://ncdc.in.th/portal/apps/sites/#/ncdc-eng/datasets/7f303b180b914fadb29a5b68e64f4fd9)

[1-4] To define the quality requirement for precise positioning data distribution and establish and improve the quality management method

Activities 1-4 through 1-6 were related to services for real-time precise positioning data provided by NCDC, and were led by JPT experts who have been working on similar services in Japan for many years. In addition to sharing Japan's experience, knowledge, and case studies at the Output1 meeting, various analyses were conducted using real-time data from NCDC by JPT, and based on the results, the quality and latency of data observed at CORS and precise positioning data (network RTK correction data) generated by NCDC were evaluated, and discussed with RTSD staff in charge of NCDC operations and operators to whom RTSD outsources NCDC operations, in order to resolve issues. When necessary, staff members in charge of non-RTSD agencies such as DOL and their outsourced operators also participated.

Table 3-15 Activity 1-4

NO.	Items	Activities
1)	Formulation of Service Level Agreement (SLA) for precise positioning data distribution (Positioning accuracy, area, available time, delay time, problem response time, etc.) and understanding necessity of SLA	- The draft NCDC service guideline prepared by the Thai side at the beginning of the project is evaluated as equivalent to SLAs for free services. - In 1st term, JPT introduced ISO quality control, general SLA concepts, and membership rules of Japanese distributors, explaining that liability must be taken into account in the case of paid services, to deepen understanding of quality requirements of TPT. However, it was noted that Japanese distributors do not guarantee positioning accuracy. - In 3rd term, RTSD conducted a daytime VRS survey using NCDC service on reference points with known coordinates, and confirmed that the results are generally accurate to 3 cm horizontally and 10 cm vertically. This is considered typical accuracy obtained from daytime surveys and will be posted on the NCDC web as a reference value for the SLA.
2)	Creation of a manual for troubleshooting	- In 1st term, various examples of trouble shooting in Japan (e.g., signal reception problems due to tree growing, equipment failure due to lightning, data delay due to additional satellite systems, and radio interference from cellular phone base stations) were introduced. - In 2nd and 3rd terms, TPT prepared a comprehensive draft manual in Thai, including trouble shooting, and updated it based on advice from JPT and operational experience in Thailand.
3)	Formulation and improvement of quality control measures (maintenance and update of quality control manuals and guidelines)	- In 1st term, the contents of quality control in Japan, examples of manuals, and software that can be used for quality control were introduced. - In order to obtain statistical information on the precision obtained from the service, JPT transferred technology on how to evaluate precision using the "deemed rover method" (JPT also provided a batch file that runs on Windows). - In 2nd and 3rd terms, TPT prepared a comprehensive draft manual in Thai, including quality control, and updated it based on advice from JPT and operational experience in Thailand.
4)	Creation of outsourcing guidelines (Selection of outsourced tasks, Terms of Reference (TOR), instruction/supervision methods, etc.)	- Inquiry was made to TPT regarding the existing documents on quality in 1st term, but nothing other than the general specifications for outsourcing could be confirmed. - JPT confirmed that the outsourced work at NCDC was based on the specifications for the interim NCDC procurement. While the contents of the outsourced work were generally appropriate, JPT advised that rules and regulations regarding the preparation of reports would be required.

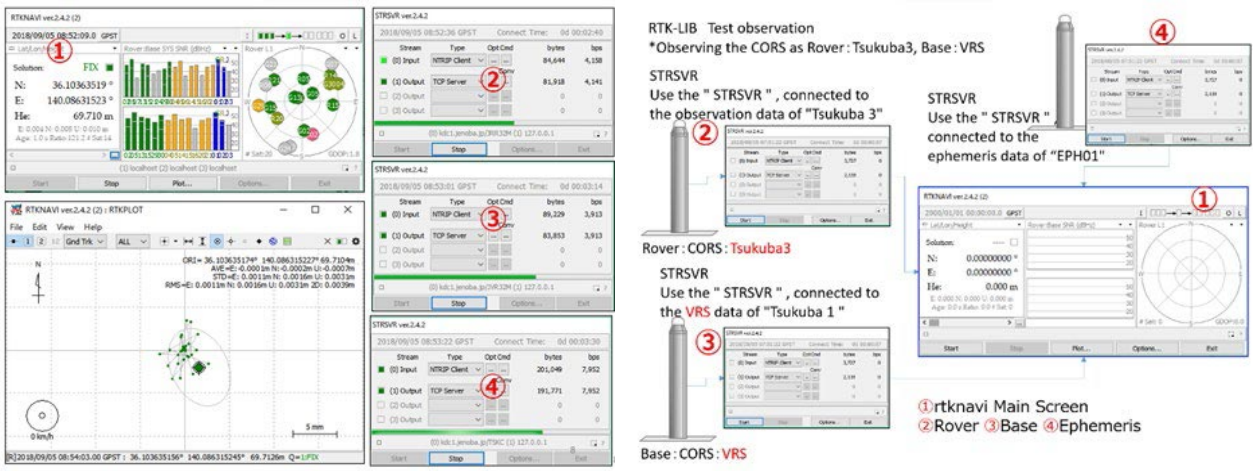


Figure 3-10 The "deemed rover method". This is a precision verification method transferred from Japan, in which CORS is regarded as a rover for VRS positioning and the precision of NCDC corrections is evaluated based on the precision of VRS positioning. It uses RTKLIB, an open-source software developed in Japan. (Output1 meeting August 2021, prepared by Jenboa)

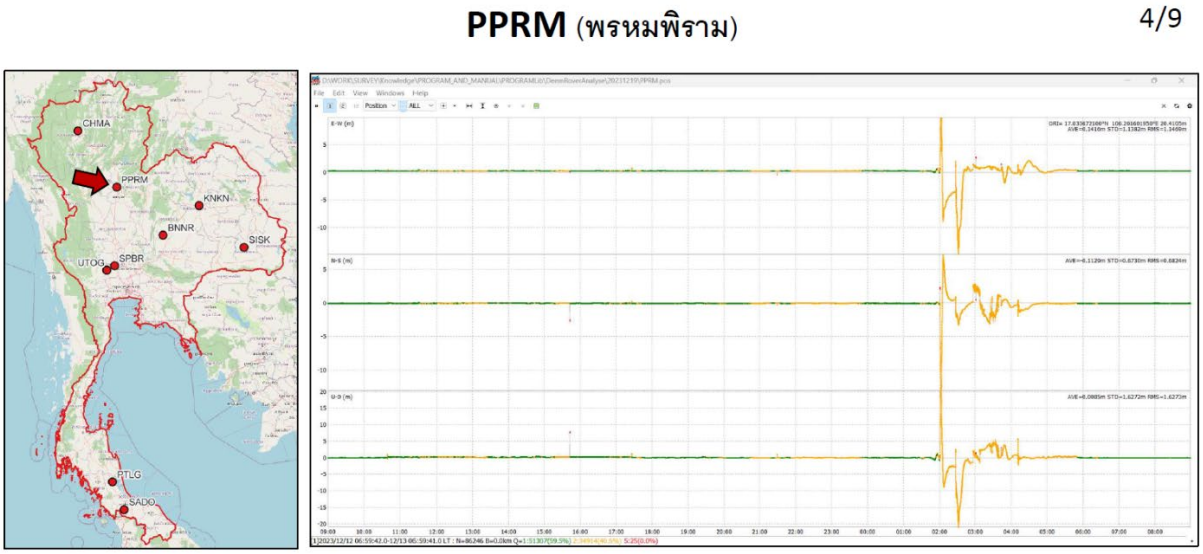


Figure 3-11 Results of the "deemed rover method" by NCDC (December 13, 2023, for 24 hours). Precision is greatly reduced during the nighttime. This is considered to be caused by ionospheric disturbances by plasma bubbles (regions of low electron density) formed in the evening near the equator and moving over Thailand (Output1 meeting, December 2023).

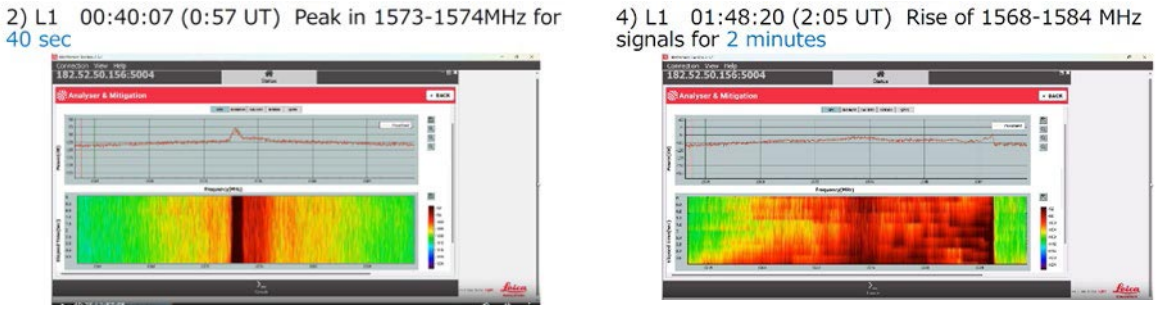


Figure 3-12 Example of radio interference observed at CORS in Bangkok. The interference occurred only for a short time, but it is at a level that could affect VRS positioning, so care should be taken. Leica Interference Tool was used. (Output1 meeting, August 2023).

[1-5] To establish and enhance monitoring system for the distribution of precise positioning data

Activities 1-5 were proceeded mainly in the 2nd and 3rd terms after the test distribution of precise positioning data started.

Table 3-16 Activity 1-5

NO.	Items	Activities
1)	Establishment of monitoring system, creation of shift table for the staff of each position	- In 2nd term, TPT prepared a comprehensive draft manual including monitoring system of precise positioning data distribution, with the support of JPT.
2)	Implementation of monitoring work based on the quality control manual (OJT)	- Based on the comprehensive manual, NCDC staff conducted daily operations, including information disclosure to users, and continued to report on the data acquisition rate and accuracy of the "deemed rover method" at the project monthly meetings. - Based on feedback from pilot project users, NCDC staff worked with JPT to resolve issues in data distribution and reflected them in the manual as necessary.
3)	Implementation of information disclosure for users (OJT)	
4)	Accuracy verification of precise positioning data	- In 1st term, the precision verification method using the "deemed rover method" was introduced, and the technology was transferred in 2nd and 3rd terms. The Thai side continued the precision verification using the "deemed rover method" every month from April 2023. It was found that the precision decreased at night due to increased solar activity. - In 2nd term, RTSD repeated VRS survey using NCDC correction data at the same location, and confirmed that the precision (repeatability) was generally about 3 cm horizontally and 10 cm vertically. - In 3rd term, RTSD conducted VRS surveying on reference points with known coordinates and confirmed that it could obtain a precision (accuracy) of approximately 3 cm horizontally and 10 cm in height.

Onsite VRS survey with NCDC data

PID	JDN	NRTK			Reference			ΔE	ΔN	ΔElev	RMSE			
		Easting (m)	Northing (m)	Ellipsoidal height (m)	Easting (m)	Northing (m)	Ellipsoidal height (m)				Horizontal (m)	Vertical (m)	Horizontal (m)	Vertical (m)
CHTB	320	197934.133	1378450.342	-16.947	197934.136	1378450.337	-16.942	-0.003	0.005	-0.005	0.016	0.015	0.036	0.070
	321	197934.115	1378450.348	-16.937				-0.021	0.011	0.005				
	322	197934.118	1378450.352	-16.943				-0.019	0.015	-0.001				
	323	197934.129	1378450.338	-16.942				-0.008	0.001	0.000				
	324	197934.129	1378450.334	-16.957				-0.007	-0.003	-0.015				
	325	197934.131	1378450.342	-16.973				-0.005	0.006	-0.032				
NKPH	320	445083.476	1949590.119	120.372	445083.401	1949590.004	120.549	0.075	0.115	-0.177	0.078	0.141		
	321	445083.376	1949589.993	120.613				-0.026	-0.010	0.064				
	322	445083.371	1949589.997	120.583				-0.030	-0.007	0.034				
	323	445083.470	1949589.950	120.812				0.069	-0.054	0.263				
	324	445083.371	1949589.983	120.559				-0.030	-0.021	0.009				
	325	445083.385	1949589.978	120.664				-0.016	-0.026	0.115				
SRIS	320	437180.235	1647472.559	115.076	437180.221	1647472.576	115.051	0.014	-0.017	0.025	0.025	0.052		
	321	437180.234	1647472.554	115.076				0.013	-0.022	0.025				
	322	437180.230	1647472.558	115.116				0.009	-0.018	0.064				
	323	437180.229	1647472.551	115.105				0.008	-0.025	0.054				
	324	437180.225	1647472.553	115.109				0.004	-0.023	0.058				
	325	437180.232	1647472.560	115.118				0.011	-0.016	0.066				
HUAH	320	605962.547	1383861.837	-27.465	605962.554	1383861.850	-27.490	-0.008	-0.013	0.025	0.022	0.025		
	321	605962.563	1383861.836	-27.489				0.009	-0.014	0.001				
	322	605962.542	1383861.830	-27.494				-0.013	-0.020	-0.004				
	323	605962.532	1383861.834	-27.456				-0.022	-0.016	0.034				
	324	605962.546	1383861.831	-27.463				-0.009	-0.019	0.027				
	325	605962.547	1383861.849	-27.454				-0.007	-0.001	0.036				
OTRI	320	539223.356	2027326.797	240.091	539223.357	2027326.807	240.057	-0.001	-0.010	0.034	0.013	0.028		
	321	539223.370	2027326.792	240.094				0.013	-0.015	0.037				
	322	539223.364	2027326.794	240.099				0.007	-0.012	0.042				
	323	539223.356	2027326.802	240.067				-0.001	-0.005	0.010				
	324	539223.363	2027326.807	240.057				0.006	0.000	0.000				
	325	539223.361	2027326.801	240.076				0.004	-0.006	0.019				

Figure 3-13 Field VRS survey results by RTSD in November 16-21, 2023.
RMSE is 3.6 cm in horizontal and 7.0 cm in height (Output1 meeting, December 2023).

[1-6] To establish and enhance user support system to improve the data distribution system

Activities 1-6 are as follows.

Table 3-17 Activity 1-6

NO.	Items	Activities
1)	Formulation of user support contents (such as responses to inquiries from users, notifications/communication to users, posting of FAQs, etc.)	- Inquiry was made to RTSD in 1st term regarding existing documents and activities related to user support, but it was found that no specific manual was available. - JPT introduced the contents and examples of user support in Japan at Output1 meetings and advised the importance of creating a manual.
2)	Creation of user support manual (including matters related to user (NCDC user) management)	
3)	Building a user support system	- A comprehensive draft manual, including user support, has been developed and updated in 2nd and 3rd terms. - Services, including user support, are in place.
4)	Implementation of user support services (OJT)	
5)	Creation of outsourcing guidelines (selection of outsourced tasks, TOR, instruction/supervision methods, etc.)	- For technical problems reported by users, the staff directly advises and tries to solve them. When problems cannot be resolved by staff alone, they are handled with the assistance of outsourced service providers. - While the content of the outsourced services is generally appropriate, JPT advised that rules and regulations regarding the preparation of reports are needed in future update.

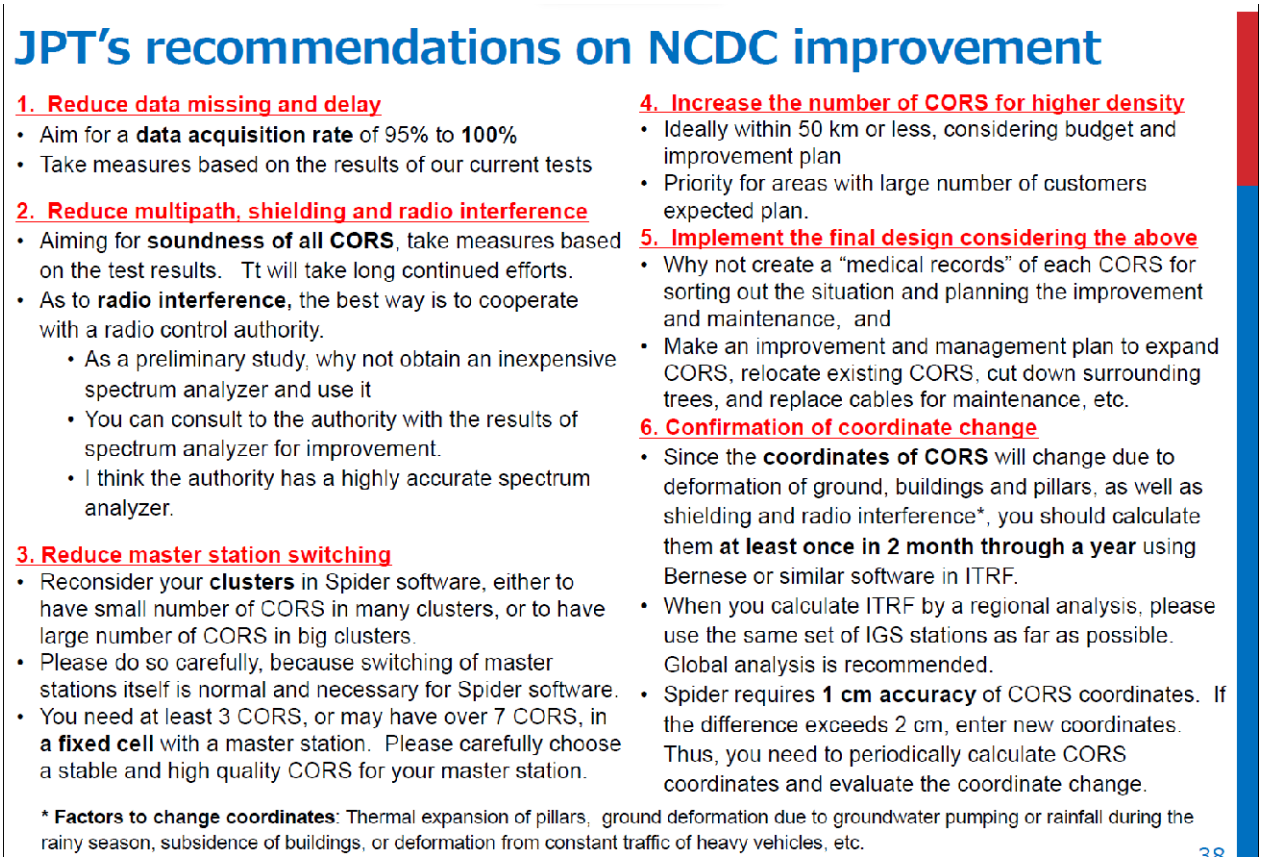


Figure 3-14 Summary of advice from JPT regarding Output1. Although JPT supported the improvement of NCDC services through activities 1-1 to 1-6, there is still room for improvement for NCDC service compared to the quality obtained in Japanese services. These are items that NCDC should focus on in the future (6th Joint WG on NCDC meeting material, February 2023).

3.6.3. Achievements

This section describes the status of achievement of the evaluation items and targets for each activity related to Output1, including 1st term. As shown in Table 3-18, with the exception of Activity 1-2, the development of equipment specifications for a full-scale NCDC, the indicators and objectives set for all activities are considered to have been achieved.

Table 3-18 Evaluation method for each activity related to Output1 and results

Activities	NO.	Evaluation item	Indicator/objective	Results
1-1	1	Improvement of the operation and maintenance policy of each institution's CORS data center	Publication of the operation and maintenance policy of each institution's CORS data center	Achieved - The NCDC web describes the collaborative efforts of the agencies
	2	Improvement of the operation and maintenance of each agency's CORS data center	Rate of missing observation data of CORS of each agency	Achieved - NCDC's overall data acquisition rate is monitored monthly
	3	Improvement of CORS data integration operation policy	Documenting policy for unified CORS data operation	Achieved - Service guidelines published on the NCDC web

Activities	NO.	Evaluation item	Indicator/objective	Results
	4	Promotion to utilize precise positioning data and sufficiency of SLA for users	・ Number of NCDC users ・ Sufficiency of positioning accuracy, area, available time, etc.	Achieved - Number of NCDC users: 2,123 (996 public, 1,127 private) (December 2023) - Accuracy is indicated on the NCDC web
1-2	1	Formulation of NCDC management policy and management plan	Publication of NCDC management policy and management plan	Achieved - Service guidelines published on the NCDC web
	2	Formulation of NCDC equipment specifications	Thai government's procurement will be carried out based on the specifications on the left	Partially achieved - Interim NCDC completed - Full-scale NCDC not yet completed (no Budget so far)
	3	Review of NCDC functions and roles	Publication of a document stating the functions and roles of NCDC	Achieved - Service guidelines published on the NCDC web
	4	Preparation of manuals, guidelines, and forms related to the operation and maintenance	Preparation of manuals, guidelines, and forms	Achieved - NCDC staff prepared a draft comprehensive manual, being updated based on operational experience
1-3	1	Coordinate calculation based on the international standards (ITRF) for CORS	Number of NCDC staff who can perform global analysis with Bernese and calculate the coordinate values of ITRF2014	Achieved - Increased from 1 to 4
	2	Unification of CORS geodetic reference systems	Unification of CORS geodetic reference systems used in NCDC	Achieved - RTSD determined the CORS reference coordinate values ITRF2014 (epoch: 2021.93) and used them in the service starting March 2022
	3	Calculation of coordinate transformation parameters	Transformation parameters are created between ITRF2014 and the reference system of each agency's CORS.	Achieved - RTSD determined and published 3-parameters from ITRF2005 and ITRF2008 coordinates to ITRF2014 coordinates
	4	Operation of new geodetic reference systems	Formulation of operational guidelines	Achieved - RTSD published the coordinate transformation method
1-4	1	Formulation of service level agreement (SLA) for precision positioning data	SLA is formulated	Achieved - Service guidelines and indication of precision published on the NCDC web
	2	A quality control manual	Manual is created	Achieved - NCDC staff prepared a draft comprehensive manual, being updated based on operational experience
1-5	1	A manual for troubleshooting	Manual is created	ditto
	2	Outsourcing guidelines	Outsourcing guidelines are	ditto

Activities	NO.	Evaluation item	Indicator/objective	Results
			created	
1-6	1	Formulation of user support	User support components are created	ditto
	2	A manual for inquiry responses, notification and communication	Manual is created	ditto
	3	Outsourcing guidelines	Outsourcing guidelines are created	ditto
	4	Implementation status of user support	Number of inquiries, user satisfaction, response time	Achieved - Number and summary of inquiries are recorded at NCDC
Overall	1	Technical level of staff in charge	Technical level is improved	Staff in charge feel that the technical level has improved - NCDC staff confirmed self-assessment of skill sheets

Table 3-19 shows a self-assessment of skill level by NCDC staff (i.e., 4 RTSD and 1 HII person) before and after the Output1 activities. Although the evaluation criteria differ from person to person, it is clear that the staff members in charge of NCDC feel that their technical skills have improved.

Table 3-19 Review of skill sheets by NCDC staff

1. Skill sheet for NCDC officer (ver.1) Before/After Date: Dec 2023

Planning and management / Cooperation with related agencies	Making NCDC plans / Budget planning and execution	1/2	3/4	0/4	3/4	1/3
	Liaison with supervisors and other agencies	2/3	3/4	4/4	3/4	2/4
Monitoring / Trouble shooting	Monitoring of CORS and DC operations	2/4	4/4	0/4	2/4	2/4
	Quality check of correction data (precision of NRTK positioning)	2/4	3/4	0/4	1/3	2/3
	Detection of troubles	2/4	3/4	0/4	1/3	1/3
	Interaction with contractors and agencies in case of trouble	2/4	4/4	0/4	2/4	2/4
Information security	Protecting DC from hacking	1/3	2/4	0/4	1/3	1/1
Data analysis	ITRF coordinates calculation using Bernese software	3/5	2/3	0/4	1/3	2/3
NRTK service / User management	User database management / Interaction with users / FAQ for users	2/4	3/4	0/4	2/4	2/3
Equipment maintenance	Regular maintenance of DC (and CORS)	2/3	4/4	0/4	1/3	2/4
	Update and repair of DC (and CORS)	2/3	3/3	0/4	1/3	2/4
	Administration of land occupancy and relocation of CORS	2/3	3/4	0/4	1/4	1/4
	Interaction with contractors and agencies in case of trouble	2/4	4/4	0/4	1/4	2/4
Public relations / Awareness rising	FAQ for non-users / Introductory Web Contents	2/3	4/5	0/4	2/4	2/2

Please fill in your skill levels based on your feeling when you joined NCDC, and compare how they change after the series of Tigors Output-1 sessions. Thank you.

The project for capacity development and promotion of utilization of National CORS Data Center

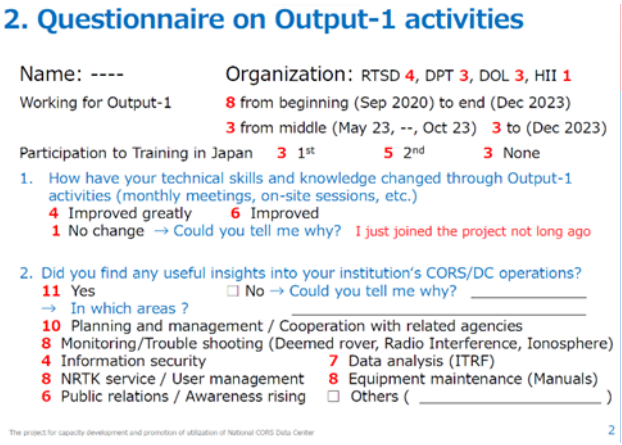
1. Have no knowledge
2. Have knowledge, but can not do
3. Can do with a supervisor
4. Can do
5. Can teach

1

Table 3-20 shows a result of questionnaire for those who participated in Output1 activities about the

change in their technical skills, and it is clear that all rated the change positively.

Table 3-20 Results of a questionnaire for those who participated in Output1 activities



2. Questionnaire on Output-1 activities

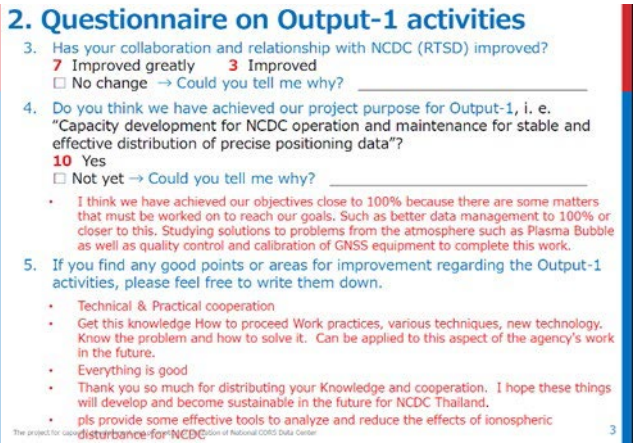
Name: ---- Organization: RTSD 4, DPT 3, DOL 3, HII 1

Working for Output-1
8 from beginning (Sep 2020) to end (Dec 2023)
3 from middle (May 23, --, Oct 23) 3 to (Dec 2023)

Participation to Training in Japan 3 1st 5 2nd 3 None

1. How have your technical skills and knowledge changed through Output-1 activities (monthly meetings, on-site sessions, etc.)
4 Improved greatly 6 Improved
1 No change → Could you tell me why? I just joined the project not long ago

2. Did you find any useful insights into your institution's CORS/DC operations?
11 Yes ☐ No → Could you tell me why? _____
→ In which areas ? _____
10 Planning and management / Cooperation with related agencies
8 Monitoring/Trouble shooting (Deemed rover, Radio Interference, Ionosphere)
4 Information security 7 Data analysis (ITRF)
8 NRTK service / User management 8 Equipment maintenance (Manuals)
6 Public relations / Awareness rising ☐ Others (_____)



2. Questionnaire on Output-1 activities

3. Has your collaboration and relationship with NCDC (RTSD) improved?
7 Improved greatly 3 Improved
☐ No change → Could you tell me why? _____

4. Do you think we have achieved our project purpose for Output-1, i. e. "Capacity development for NCDC operation and maintenance for stable and effective distribution of precise positioning data"?
10 Yes
☐ Not yet → Could you tell me why? _____

- I think we have achieved our objectives close to 100% because there are some matters that must be worked on to reach our goals. Such as better data management to 100% or closer to this. Studying solutions to problems from the atmosphere such as Plasma Bubble as well as quality control and calibration of GNSS equipment to complete this work.

5. If you find any good points or areas for improvement regarding the Output-1 activities, please feel free to write them down.

- Technical & Practical cooperation
- Get this knowledge How to proceed Work practices, various techniques, new technology. Know the problem and how to solve it. Can be applied to this aspect of the agency's work in the future.
- Everything is good
- Thank you so much for distributing your Knowledge and cooperation. I hope these things will develop and become sustainable in the future for NCDC Thailand.
- pls provide some effective tools to analyze and reduce the effects of ionospheric disturbance for NCDC

The "deemed rover method" transferred from Japan was used in a study conducted by Chulalongkorn University, and the results were published in Survey Review in October 2023 as "Performance assessment of continuously operating reference stations Using the deemed rover analysis approach with NRTK GNSS technique in Thailand" was published in Survey Review in October 2023 (Survey Review, DOI: 10.1080/00396265.2023.2268411).

Judging from the above, although the detailed specifications of equipment of the full-scale NCDC was not developed because the budgeting of the Thai side has not been achieved, each of the activity in Output1, which aimed to improve the technical capacity of the Thai side, has largely been achieved and has been effective.

As a result, the acquisition rate of observation data, which is the indicator used to evaluate the achievement level of Output1, as described in Chapter 4, has reached more than 95%, and thus, it can be concluded that Output1 "Stable and effective distribution of precise positioning data by NCDC" has been achieved, and among the project goals, "NCDC's operation and maintenance management capacity for stable and effective distribution of precise positioning data has been strengthened" has also been achieved.

3.7. Output2: Promotion of utilization of precise positioning data in various fields

3.7.1. Common subject matter

In accordance with the plan for utilization promotion plan formulated during the 1st term, TPT and JPT made a detailed plan for each promotion activity and carried them out.

Table 3-21 Output2 meetings

No.	Date	Main contents
Output2-16	25th Nov 2021	1. Preparation of the selection of the pilot projects - Progress and current status - Receipt of the application forms 2. Progress of the data receiving test and its outcomes 3. Time schedule for selection 4. Appointment of the selection board members 5. Guidance for the selection board members
Output2-17	17th Jan 2022	0. Overall plan of promotion of utilization of NCDC data 1. Creation of NCDC leaflet 2. Preparation for the other activities 3. Progress of JICA Pilot Project 4. Others
Output2-18	14th Feb 2022	0. Overall plan of promotion of utilization of NCDC data 1. Creation of NCDC leaflet 2. Preparation for the GNSS training and workshop 3. Progress of JICA Pilot Project 4. Others
Output2-19	14th Mar 2022	0. Overall plan of promotion of utilization of NCDC data 1. Creation of NCDC leaflet 2. Preparation for the GNSS training and workshop 3. Progress of JICA Pilot Project 4. Others
Output2-20	30th Mar 2022	0. Overall plan of promotion of utilization of NCDC data 1. Creation of NCDC leaflet 2. Preparation for the GNSS training and workshop 3. Others
Output2-21	26th Apr 2022 *Face-to-face	1. Review of the rehearsal and discussion for improvement 2. Discussion on the overall plan of GNSS training and WS 3. Report on the progress of creation of the NCDC leaflet
Ad hoc	24th May 2022	1. Creation of NCDC leaflet 2. Obtainment of NBTC letters 3. Invitation to the construction site tour to be held on 22nd June 4. Preparation for the 1st GNSS training
Output2-22	26th May 2022	1. Preparation for the 1st GNSS training 2. Discussion on the overall plan of GNSS training and WS
Output2-23	10th Jun 2022	1. Preparation for the 5th Joint WG on NCDC 2. Preparation for the 1st GNSS Training 3. Preparation for the 5th Joint WG on NCDC meeting
Output2-24	18th Jul 2022	1. Finalization and distribution of the NCDC leaflet 2. Preparation for the 1st GNSS Training 3. Preparation for the 1st GNSS Workshop 4. Progress of the JICA Pilot Project
Output2-25	17th Aug 2022	1. Distribution of the NCDC leaflet 2. Preparation for the 1st GNSS Training and the 1st GNSS Workshop 3. Progress of the JICA Pilot Project 4. Discussion on LINE Stickers
Output2-26	16th Sep 2022	1. Distribution of the NCDC leaflet 2. Preparation for the 1st GNSS Training and the 1st GNSS Workshop 3. Progress of the JICA Pilot Project 4. Discussion on LINE Stickers
Output2-27	19th Oct 2022	1. Distribution of the NCDC leaflet 2. Review of the 1st GNSS training and the 1st GNSS workshop

No.	Date	Main contents
		3. Discussion on creation of leaflets of use cases 4. Progress of the Pilot Project 5. Discussion on LINE stickers 6. Preparation for Activity 2-5
Ad hoc	31st Oct 2022	Discussion and preparation for Activity 2-5
Output2-28	29th Nov 2022	1. Progress of Activity 2-5 2. Progress of the Pilot Project 3. Preparation for the 2nd project seminar in MGA 4. Opinion exchange regarding further promotion
Ad hoc	20th Dec 2022	Discussion and preparation for web-questionnaire
Output2-29	23rd Dec 2022	1. Progress of Activity 2-5 2. Progress of the Pilot Project 3. About further promotion of utilization of NCDC
Output2-30	23rd Jan 2023	1. Progress of Activity 2-5 2. Progress of the Pilot Project 3. Review and discussion on Output2 activities so far/ Preparation for the 6th Joint WG on NCDC 4. About further promotion of utilization of NCDC
Output2-31	28th Feb 2023	1. Distribution of NCDC utilization leaflet 2. Progress of Activity 2-5 3. Progress of the Pilot Project 4. Preparation for the Agriculture DEMO DAY 5. Plan for the next GNSS trainings 6. About “Economic Driving Workshop” 7. About further promotion of utilization of NCDC and after TIGORS
Output2-32	28th Mar 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the Agri DEMO DAY 4. Preparation for the next GNSS trainings 5. Creation of use case leaflets
Output2-33	27th Apr 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the Agri DEMO DAY 4. Preparation for the next GNSS trainings 5. Creation of use case leaflets
Output2-34	23rd May 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the Agri DEMO DAY 4. Preparation for the next GNSS trainings 5. Creation of use case leaflets
Output2-35	16th Jun 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the Agri DEMO DAY 4. Creation of use case leaflets 5. Preparation for the next GNSS trainings
Output2-36	18th Jul 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Review of the Agri DEMO DAY 4. Creation of use case leaflets 5. Preparation for the next GNSS training 6. Preparation for the regional workshop 7. Preparation for the final JICA seminar 8. Preparation for the NCDC user meeting 9. Review of the monitoring sheet and presentation material for the 7th Joint WG on NCDC meeting
Output2-	21st Aug 2023	1. Progress of Activity 2-5

No.	Date	Main contents
37		2. Progress of the pilot projects 3. Creation of the use case leaflets 4. Preparation for the regional workshop 5. Preparation for the final JICA seminar 6. Preparation for the NCDC user meeting 7. Preparation for the next GNSS training 8. LINE stickers
Output2-38	14th Sep 2023	1. Progress of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the regional workshop 4. Preparation for the final JICA seminar and the NCDC user meeting 5. Preparation for the next GNSS training 6. LINE stickers
Output2-39	20th Oct 2023	1. Report of Activity 2-5 2. Progress of the pilot projects 3. Preparation for the session in Thailand Space Week 4. Preparation for the final JICA seminar and the NCDC user meeting 5. Preparation for the next GNSS training 6. LINE stickers
Output2-40	17h Nov 2023	1. Progress of the pilot projects 2. Review of the presentations Thailand Space Week 3. Review of the final JICA seminar and the NCDC user meeting 4. Preparation for the next GNSS training 5. LINE stickers
Output2-41	19th Dec 2023	1. Progress of the pilot projects 2. Discussion on the future GNSS trainings 3. LINE stickers 4. Review of the Output2 activities

3.7.2. Details of each activity and results

[2-1] To establish framework to promote the utilization of precise positioning data distributed by NCDC and create the activity plans

(1) Confirmation of roles and responsibilities of each government agency in relation to the promotion of utilization and formulation of a utilization promotion activity plan of each agency

Based on the utilization promotion activity plan developed in the 1st term, the members implemented the activities to raise awareness, acquire users, and promote utilization of NCDC.

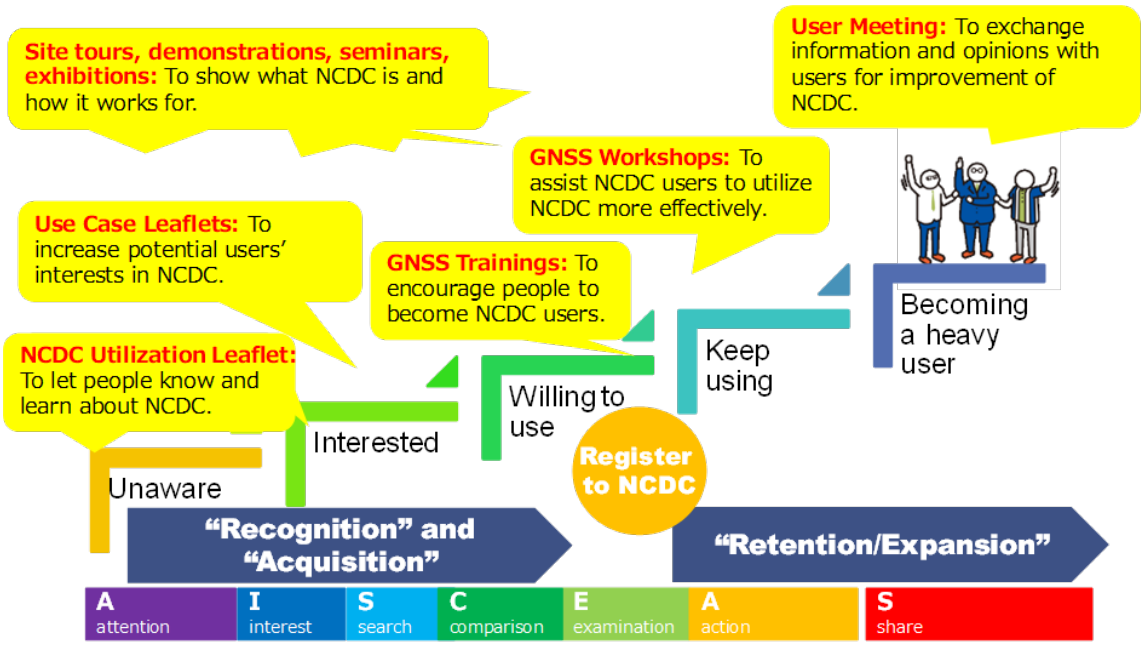
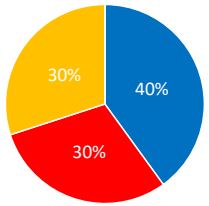
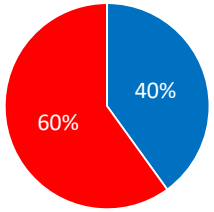
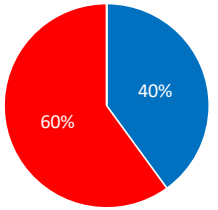


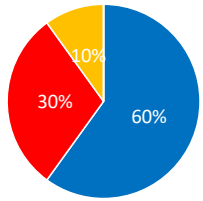
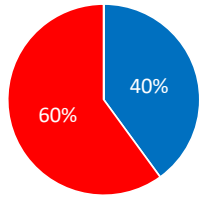
Figure 3-15 Steps from recognition to becoming a heavy user

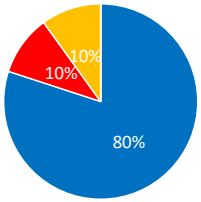
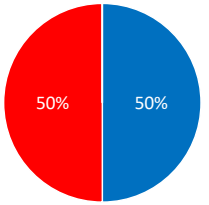
Table 3-22 shows the plan (Purpose, expected outcome, and timing of each activity), the actual performance of the activities, and the self-evaluations of TPT members (a total of 10 people from the 5 organizations responded). The self-evaluations were made in response to the question "Do you think that the following promotion activities contributed to increase awareness of GNSS/NCDC and to increase the number of NCDC users? (Members who did not participate in the activities may chose "Not sure"). The answer choices and the legend of the graph are as follows.

■ Very much "Yes" ■ Yes ■ Not sure ■ No ■ Very much "No"

Table 3-22 Activity plan of promotion utilization of NCDC and actual performance

Activities	Main Target				Purpose and expected outcome	When (Plan)	Actual performance	Self-evaluation
	Recognition	Acquisition	Retention	Expansion				
[A] Distribution of a leaflet for introduction of NCDC	■	■			[Purpose] To raise awareness about NCDC [Expected outcome] The public have interests about NCDC	Start distribution from Mar. 2022.	Created the leaflet and a banner and presented them at several events.	
[B] Introduction of NCDC at 1st and 2nd JICA seminar	■	■			[Purpose] To raise awareness about NCDC [Expected outcome] The public have interests about NCDC	In Sep. 2021 and Aug. 2022	Presented NCDC at the project seminars, site tours, Agri DEMO DAY, TSW, KU, and the regional workshop.	
[C] GNSS trial at JICA seminars		■			[Purpose] To provide opportunities to try GNSS [Expected outcome] The potential users decide to become a user	In Aug. 2022 and Aug. 2023	Provided the GNSS trial session at the GNSS training [H].	N/A
[D] JICA Pilot Project	■	■	■	■	[Purpose] To raise awareness about NCDC [Expected outcome] The potential users decide to become a user. The users get hints to use NCDC more effectively.	From Feb. 2022 to Jul. 2023	Thai-Japanese companies performed 8 pilot projects and held site tours 3 times. TIGORS organized Agri DEMO DAY.	

Activities	Main Target				Purpose and expected outcome	When (Plan)	Actual performance	Self-evaluation
	Recognition	Acquisition	Retention	Expansion				
[E] Distribution of leaflets of use cases of NCDC	■	■	■	■	[Purpose] To introduce the benefits of use of NCDC [Expected outcome] The potential users decide to become a user. The users get hints to use NCDC more effectively.	From Aug. 2022	TPT agencies created 5 and the companies created 8 uses case leaflets (webpages).	
[F] Introduction of use cases of NCDC at 3rd JICA seminar	■	■	■	■	Same as the above	In Aug. 2023	DOL and HII introduced their use of NCDC at 2nd seminar and the companies and DPT did it at 3rd seminar.	
[G] Establishment of a council for promotion of utilization of NCDC			■	■	[Purpose] To make a place where NCDC service provider (TPT), GNSS manufactures, and the users can communicate and discuss for improvement of NCDC [Expected outcome] The NCDC service will be improved, and users' satisfaction will be increased.	By Aug. 2023	Decided not to establish a new framework but organized the NCDC User Meeting instead.	N/A

Activities	Main Target				Purpose and expected outcome	When (Plan)	Actual performance	Self-evaluation
	Recognition	Acquisition	Retention	Expansion				
[H] GNSS training	■	■	■	■	[Purpose] To introduce the benefits of use of NCDC [Expected outcome] The potential users decide to become a user. The users get hints to use NCDC more effectively.	Every 3 months from Jan. 2022	Provided the GNSS training for beginners.	
[I] GNSS workshop			■	■	[Purpose] To provide useful information to encourage the NCDC users to use more. [Expected outcome] The participants get hints to use NCDC more effectively.	Every 3 to 4 months from Apr. 2022	Provided the GNSS workshop for construction.	
[J] Introduction of NCDC on 5 agencies' website/ SNS	■	■			[Purpose] To raise awareness about NCDC [Expected outcome] The public have interests about NCDC	Anytime	The agencies introduce NCDC when they have opportunities.	N/A

Although there were some delays and revisions to some activities, they were generally implemented as originally planned. The following is a summary of the main activities.

1) Creation of NCDC Utilization Leaflet

The members created NCDC utilization leaflet. The 5 agencies provided ideas and materials, and GISTDA did the design work. The leaflet exhibited at National Science and Technology Fair, DPT's training, Economic Driving with NCDC seminar, the ICT construction lecture at Kasetsert University, and the 3rd project seminar. The leaflet will be updated by TPT when appropriate.

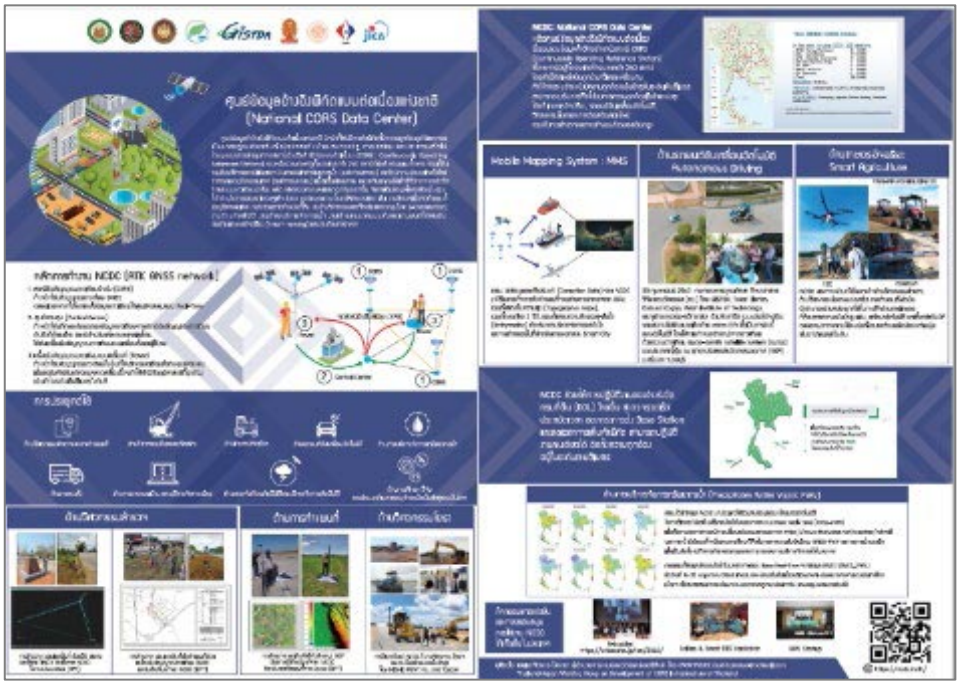


Figure 3-16 NCDC Utilization leaflet

2) Provision of GNSS Training and GNSS Workshop

The members provided a GNSS Training for beginners and a GNSS Workshop for construction on 28th September 2022. Over 40 people from various organizations participated. TPT members from 5 agencies as well as some invited speakers gave lectures and presentations. In the Output2 meeting held after the training and workshop, the members reviewed them and discussed things to be improved for future trainings and workshops.

Table 3-23 The program of the GNSS Training

Time	Activity
8.30 – 9.00	Reception
9.00 – 9.05	**Welcome / Introduction** By Prof. Dr. Chalermchon Satirapod, Department of Survey Engineering, Chulalongkorn University and Chief of Thailand-Japan working Group on Development of CORS Infrastructure of Thailand
9.05 – 9.30	**What is the GPS - GNSS system and operation.** By Dr. Chaiyut Charoenphon, Department of Survey Engineering, Chulalongkorn University
9.30 – 10.00	**What is the NCDC and How to utilize NCDC** By Lt. Col. Parinya Thaweewat, Royal Thai Survey Department
10.00 – 10.15	Break
10.15 – 10.25	**Use cases-01: NCDC for Land Surveying Operation** By Dr. Peera Yomwan, Department of Land
10.25 – 10.35	**Use cases-02: NCDC for Surveying and Mapping for Urban Planning** By Mr. Chaiwat Panachat, Department of Public Works and Town & Country Planning
10.35 – 10.45	**Use cases-03: NCDC for UAV Mapping in the Kok Nhong na model** By Mr. Rattawat Wasuhiranyrith, GISTDA
10.45 – 10.55	**Use cases-04: NCDC for Hydrographic Survey for Water Management** By Ms. Nuantip Chaladlert, Hydro Informatics Institute
10.55 – 11.50	**GNSS Trial (In the rooftop)**
11.50 – 12.00	Closing

Table 3-24 The agenda of the GNSS Workshop

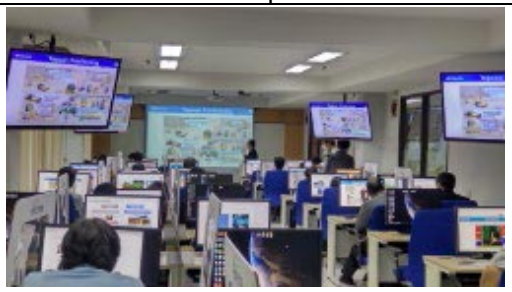
Time	Activity
13.30 – 14.00	Reception
14.00 – 14.05	**Welcome / Introduction**
14.05 – 14.20	**Presentation-01: Digital Transformation for i-Construction and i-Agriculture** By Mr. Kroekits leewongcharoen, Adviser to Minister of Digital Economy and Society, Ministry of Digital Economy and Society
14.20 – 14.35	**Presentation-02: Current situations of construction in Thailand** By Mr. Terdsak Prasenmool, CH. Karnchang Public Company Limited
14.35 – 15.00	**Presentation-03: Introduction of ICT construction and its benefits** By Nishio Rent All (Thailand) Co., Ltd., Topcon Instruments (Thailand), NISHIO RENT ALL CO., LTD., Topcon Corporation
15.00 – 15.15	Break
15.15 – 15.50	**Discussion: Benefits and challenges of use of NCDC and introducing ICT construction in the construction field in Thailand** Facilitated by Prof. Dr. Chalermchon Satirapod
15.50 – 16.00	Conclusion



Greeting from Prof. Dr. Chalermchon Satirapod



GNSS Trial



The training room



Group photo



Discussion in the secretariat team



Rehearsal held in April

Figure 3-17 Photos of the GNSS Training and GNSS Workshop

When the utilization promotion plan was formulated, GNSS trainings and GNSS workshops were planned to be held on a regular basis, but due to difficulties in arranging personnel and budget, they were not held. However, since there is a high need for training for beginners, Prof. Dr. Chalermchon Satirapod and TPT members discussed the matter, and as a result, it was decided that GISTDA will take the lead in holding training sessions on a continuous and regular basis after the completion of this project, in cooperation with the 5 agencies. In the future, GISTDA is considering making this a part of its annual training menu.

3) Creation of NCDC use case leaflets

The 5 agencies created use case leaflets showing how they are utilizing NCDC data for their projects and daily work. The companies who performed the 8 pilot projects also created leaflets explaining how NCDC can be used based on the activities and results of their pilot projects. All the leaflets are published on the NCDC website.

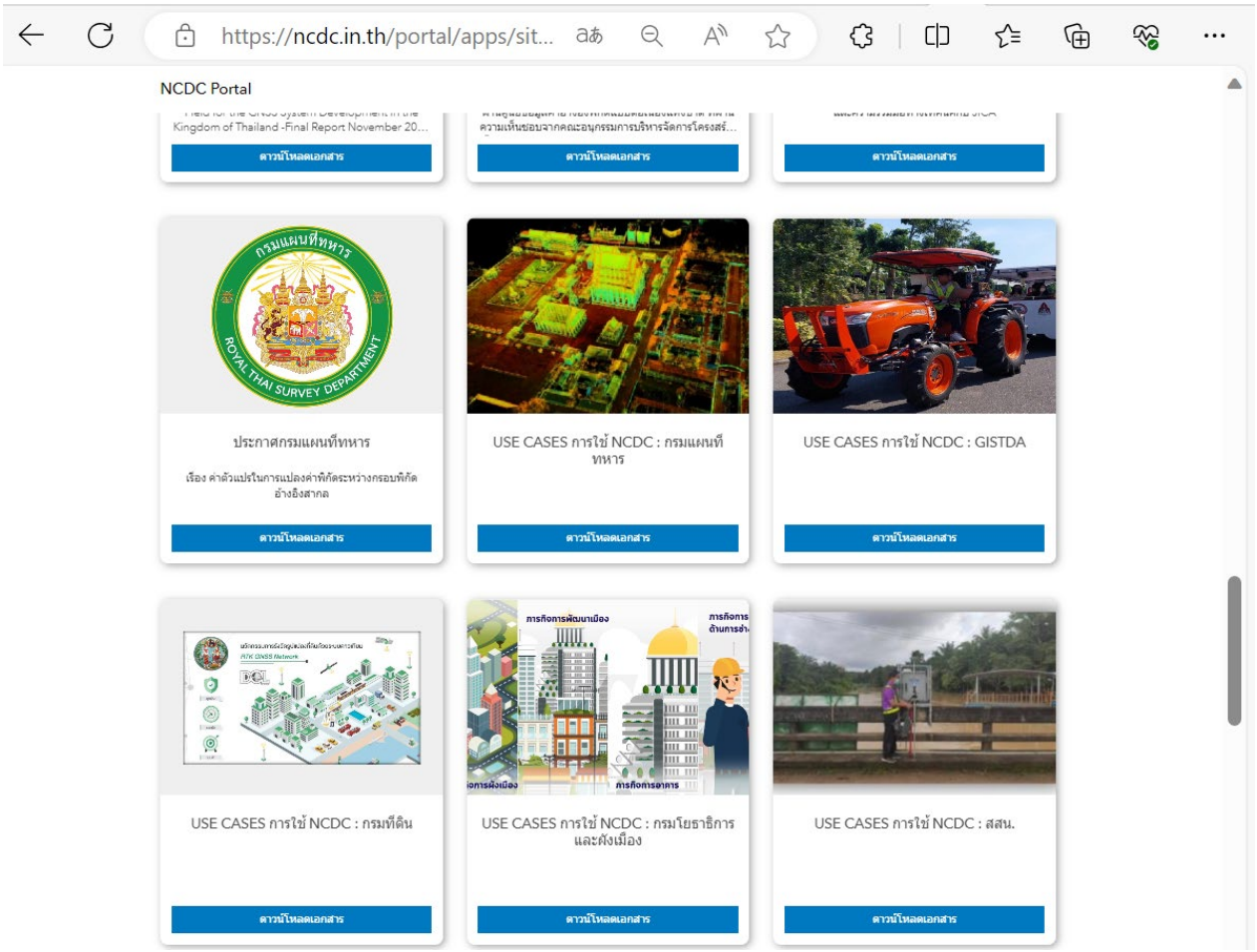


Figure 3-18 Use case leaflets on the NCDC website

4) Others (Additional activities)

In addition to the pre-planned activities, the members participated in events whenever there was an opportunity that was considered good for promoting NCDC and its utilization. Although it is difficult to measure the effects of individual activities, the members believe that the continuation of these steady activities contributed to the increase in the number of registered users as described below. The following is a list of major activities.

Table 3-25 Examples of additional PR activities

Date	Activity
18th Jan 2022	Introduction of NCDC in the international conference of Geospatial Capacity Development Conference on GNSS applications and DRR (hosted by GSI) (GISTDA)
11th Mar 2022	Introduction of NCDC and JICA Pilot Project in Multi GNSS Asia Annual Conference in 2022 (DOL, GISTDA etc.)
14th Mar 2022	Introduction of NCDC in i-Construction seminar (hosted by MLIT) (RTSD)
Aug 2022	Introduction of NCDC, JICA Pilot Project, and the construction pilot project in NST 2022
Nov 2022	Introduction of NCDC at the SDGs seminar (organized by a JICA project)

Date	Activity
	(GISTDA)
Nov 2022	Introduction of NCDC at a FOSS4G event (GISTDA)
21st Apr 2023	Introduction of NCDC at Economic Driving with NCDC seminar (RTSD, GISTDA, and JPT)
8th Sep 2023	Introduction of NCDC in a lecture on i-Construction at Kasetsart University (RTSD)
26th Oct 2023	Introduction of NCDC in Thailand Space Week (RTSD, JPT)
From Oct 2023-	Introduction of NCDC and JICA Pilot Project in Japan Pavilion in GISTDA SKP
Nov 2023	Introduction of NCDC and JICA Pilot Project in Geo Activity Contest (organized by GSI in Japan) (JPT)



Economic Driving with NCDC



Economic Driving with NCDC



Lecture on i-Construction at Kasetsart University



Thailand Space Week



Thailand Space Week

Figure 3-19 Photos of PR activities of NCDC

(2) Establishment of a framework for utilization promotion

The point of having a framework was to provide a place where stakeholders of NCDC (e.g., the 5 agencies, users, GNSS manufactures, academics, and so on) can discuss the issues and ideas for improvement of NCDC. Having considered that Japan's "Promotion Council of Real Time Positioning using GPS-based Control Stations (PCRG)" as a model case, JPT and TPT received online and face-to-face lectures regarding the history of establishment, structure, and activities from the council.

JPT and TPT discussed several times and decided to organize a meeting where TPT members, NCDC uses, and other GNSS related companies discuss and exchange opinions regarding improvement and further utilization of NCDC before the Project ends instead of establishing a new framework (and actually organized "NCDC User Meeting" later). The reasons were; 1) Thailand already has several working groups related to GNSS, 2) a new organization would be a long-time burden for TPT, especially for the secretariat, and 3) on the other hand, everybody in Thai-Japan Joint WG is open enough to allow users and others to join seminars or activities. Thai-Japan Joint WG will continue working as it is and move step by step to be like the council in future.

[2-2] To execute pilot projects utilizing precise positioning data distributed by NCDC in Thailand

(1) Selection of pilot projects

According to the selection method (Table 3-26), application requirements and conditions, and selection criteria determined in the pilot project plan, JPT and TPT together with the cooperation of the selection committee evaluated the submitted proposals. As a result, the 8 pilot projects listed in Table 3-27 were selected and then approved at the 4th Joint WG on NCDC meeting held on 23rd December 2021.

Table 3-26 Evaluation process of the pilot project

Date	Activity
30th Nov 2021	Deadline for submission of proposal
1st Dec 2021	Start evaluation Selection members: Check the proposals and list up questions. Secretariat members: Check all the submitted documents.
8th and 9th Dec 2021	Hearing
15th Dec 2021	Deadline for scoring by the selection board members
16th Dec 2021	Aggregate the score and make ranking for each sector
23rd Dec 2021	Selection board meeting: confirm the result of evaluation and agree on the selection

Table 3-27 Result of the selection of the pilot project

Field	Title and Company
Survey	Title: Accuracy verification from N-RTK / STATIC survey Company: Topcon Corporation, TOPCON Positioning Asia, Topcon Instruments (Thailand)*
Construction	Title: Road construction using ICT construction machineries Company: NISHIO RENT ALL, Nishio Rent All (Thailand) Co., Ltd., Topcon Corporation, TOPCON Positioning Asia, Topcon Positioning Asia (Malaysia),

Field	Title and Company
	Topcon Instruments (Thailand)*
Agriculture	Title: Smart Farm in BIO Hub EEC Area Company: Impress Green Energy Co., Ltd.**
	Title: Utilization of NCDC Data Application in Agriculture Company: QUANTUM MOTUS
	Title: Benefits of Autosteering for Rice Production in Thailand Company: Topcon Corporation, Topcon Instruments (Thailand)*
	Title: Development of Precision pesticide spray method by using auto piloted Yamaha Unmanned Helicopter Company: Siam Yamaha Motor Robotics Co., Ltd., Thai Yamaha Motor Co., Ltd., Yamaha Motor Co., Ltd.,
	Title: Smart Agriculture utilizing Autonomous and Telematics Technology in Thailand Company: YANMAR AGRIBUSINESS Co., Ltd, YANMAR S.P. Co., Ltd
Autonomous driving	Title: Intelligent driving vehicle in Thailand Company: Asia Technology Industry Co., Ltd., Tokai Clarion. LTD, CORE CORPORATION, Chulalongkorn University

* Topcon Instruments (Thailand) changed its name to Topcon Positioning Asia (Thailand) later.

** Impress Green Energy changed its name to Bio Mat Link Co., Ltd. later.

(2) Performance of the pilot projects

1) Progress monitoring and implementation assistance

PASCO Corporation and the selected companies mentioned above signed the contracts and the pilot projects started one by one. JPT and TPT monitored the progress the progress of the pilot projects on a monthly basis and assisted in their smooth implementation. A summary of the implementation of each project is provided below (for details, see the Pilot Project Implementation Reports in the appendix).

Table 3-28 Summary of the pilot projects

NO.	Name and implementor	Summary
1	[Survey] Evaluation of N-RTK Survey Results Compared to Static Survey in Thailand (Topcon)	The accuracy and stability of Network RTK using NCDC data at 6 locations across Thailand were verified at different distances between observation points and CORS. Observation points were set up and verified at locations where the distance to CORS was within (less than) 30 km and at locations where the distance to CORS was more than 30 km. The results of the validation showed that no significant differences in the accuracy of Network RTK occurred due to differences in the distance. Positioning stability was better when the distance between the observation points and CORS was closer.
2	[Construction] Road construction using ICT construction machineries utilizing NCDC (Nishio Rent All & Topcon)	ICT construction using NCDC data and ICT construction machinery (e.g., Machine Control (MC) and Machine Guidance (MG)) was carried out in ATTRIC, an actual construction site, in Thailand. It was confirmed that the use of NCDC data and ICT construction could reduce the initial installation costs of the work and shorten the work time. It was also found that safety could be improved by reducing the manual work required in conventional construction.
3	[Agriculture] Using NCDC to increase	Equipment capable of using NCDC data was attached to farm machinery at each stage of the cassava process, from planting to harvesting and

NO.	Name and implementor	Summary
	the product yield in supply chain management in the cassava industry (Bio Mat Link)	transportation, and a comparison of work efficiency and productivity between farming methods that utilize this data and conventional farming methods was conducted. The use of NCDC data enabled farm machinery and planting positions to be determined with precise, resulting in higher yields with fewer man-hours than the conventional method.
4	[Agriculture] Utilization of National CORS Data Center Application in Agriculture (Quantum Motus)	The work efficiency, cost and productivity of farming methods using agricultural drones with NCDC data and sensors to monitor growth conditions were compared with commonly practiced farming methods on rice farms in Thailand. It was confirmed that the use of agricultural drones and sensors using NCDC data enabled more efficient fertilizer application and pest control than conventional methods, which resulted in reduced costs, improved work efficiency and increased yields.
5	[Agriculture] AUTO PILOT system by network RTK provided by NCDC (SYMR)	Fertilizer was applied using an unmanned agricultural helicopter and NCDC data, and a comparison was made with a normal GNSS-only flight and fertilizer application. It was confirmed that while the conventional method can fly 200 meters and apply 100 rai of fertilizer per day, using NCDC data can fly 400 meters and apply 150 rai per day, thereby improving productivity. It was also confirmed that using NCDC data contributed to improved safety by enabling highly accurate autonomous flight and reducing the pilot's workload.
6	[Agriculture] Benefits of Autosteering for Rice Production in Thailand (Topcon)	Rice planting operations were carried out in rice paddies at the Thai Rice Science Institute (TRSI) using the conventional method (manual operation) and the automatic steering method using NCDC data, and a comparison was made in terms of productivity. Using automatic steering, rice planting operations could be carried out with higher accuracy (straightness) than manual operation. In addition, the time required for rice planting could be reduced by 25% compared to the conventional method, due to factors such as the fact that the operator was freed from the tractor steering work and could concentrate on other tasks in parallel with the rice planting work. These facts confirm the significance of the automatic steering method using NCDC data in terms of productivity.
7	[Agriculture] Smart Agriculture utilizing Telematics and Autonomous Technology in Thailand (Yanmar Agri Business)	The applicability and effectiveness of the introduction of 2 smart farming technologies, “manpower and labour saving by automatic farm machinery” and “visualization of harvesting and operation track information”, were evaluated for several major crops in Thailand. As for evaluation of manpower and labour saving by automated farm machinery, it was confirmed that significant labour saving (about 1.6 times of work efficiency) could be achieved through co-operative work by robot tractors and straight-assist tractors. It was also found that even an inexperienced operator can work at high speed (about 1.4 times) while maintaining the same accuracy as a skilled operator by using a straight-assist tractor. Interviews with farmers about the use of the labour-saving and visualized information from the automatic steering of the auto rice transplanter and straight-assist combine harvester confirmed that the introduction of the technologies was effective in reducing workload, monitoring work progress in real time and providing yield results at a glance.
8	[Autonomous Driving] Intelligent	An autonomous driving system using a micro-vehicle was demonstrated using NCDC data and a multi-GNSS satellite system.

NO.	Name and implementor	Summary
	driving vehicle in Thailand (Asia Technology Industry)	It was confirmed that the use of NCDC data enables autonomous driving of micro-vehicles even in poor satellite signal reception conditions.





Survey (Topcon Corporation)





Construction (Nishio Rent All, Topcon Corporation)





Agriculture (Bio Mat Link)




Agriculture (Quantum Motus)




Agriculture (Siam Yamaha Motor Robotics)




Agriculture (Topcon Corporation)




Agriculture (Yanmar Agribusiness)





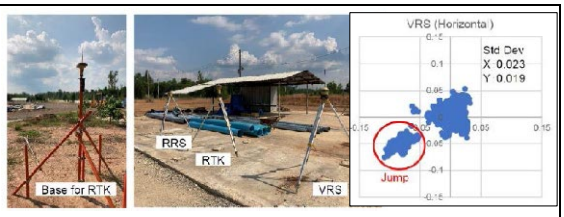
Autonomous driving (Asia Technology Industry)

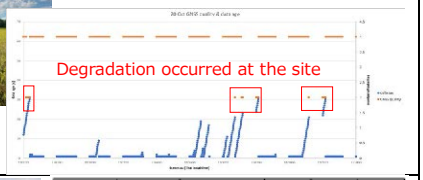
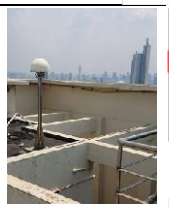
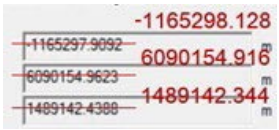
Figure 3-20 Photos of performance of the pilot projects

2) Feedback to NCDC

NCDC was improved based on inquiries and suggestions given from the companies. Table 3-29 shows some examples of the feedback and status of the improvement. Through the use of NCDC data at various locations and times in Thailand, it became clear that the configuration of the CORS used for correction data generation caused a degradation of positioning accuracy and that the stability deteriorated depending on the time of day (mainly at night), which was recognized as a medium- to long-term issues for consideration.

Table 3-29 Examples of the feedback to NCDC

NO.1	**Optimization of network configuration for VRS correction** Nishio & Topcon compared results obtained from RTK (local base) and RRS/VRS* (NCDC), finding jumps in VRS solutions. NCDC added 3 CORS for VRS calculation to have better network configuration. *RRS/VRS: Correction methods of NCDC using 1 CORS or several CORS, respectively	 Nishio & Topcon (Construction)
NO.2	**Recognition of positioning error** One of the planting machines didn't run straight while other with IMU* run straight. Both using NCDC correction. This taught us there is a room for improvement of NCDC precision, and results depend on the performance of total equipment. *IMU: Inertial Measurement Unit	 Without IMU  With IMU Yanmar Agri and Topcon (Agriculture)

NO.3	**Recognition of problem caused by switching of a master station** Yanmar Agri experienced degradation of NCDC correction data associated with a switching of a master station of VRS. NCDC solved this problem by providing correction data with a fixed master station.	 Yanmar Agri (Agriculture) 
NO.4	**Correction of CORS coordinates** Topcon noticed inconsistency between official coordinates and estimated coordinates at "BPLE". NCDC confirmed that newly added 3 CORS including "BPLE" were using ITRF2008 coordinates instead of ITRF2014, and corrected them.	 Topcon (Surveying) Number / Station ID / Distance [km] / N / E / H 6 / SBKK / 13.1 / 0.0 / 0.0 / 0.0 236 / BPLE / 38.7 / 9.9 / -22.6 / 3.5 166 / CNBR / 64.2 / -0.2 / 1.2 / 1.7 108 / OKRK / 67.4 / 0.0 / 0.8 / 2.9 150 / PTBR / 90.6 / -0.1 / 1.0 / 1.8 20 cm gap in BPLE coordinates! 

(3) PR of the pilot projects

1) Construction site tour on 22nd June 2022 by Nishio Rent All & Topcon

https://www.jica.go.jp/Resource/project/thailand/031/news/20220809.html

The construction site tour was held on 22nd June at Automotive and Tyre Testing, Research and Innovation Center (ATTRIC) in Chachoengsao Province by Nishio Rent All & Topcon with generous cooperation of Nippon Road Co., Ltd., and Thai Nippon Road Co., Ltd. Thanks to collaboration between TIGORS members and Nishio & Topcon, over 90 participants could see ICT construction and learned about NCDC.









Figure 3-21 Photos of the construction site tour

2) Agriculture site tour on 10th November 2022 by Yanmar Agri Business

https://www.jica.go.jp/Resource/project/thailand/031/news/20221128.html

The agricultural site tour was organized in Saraburi Province by Yanmar Agri Business. Around 60 participants including TIGORS members participated and experienced the 4 models of agricultural machinery using NCDC data.



Figure 3-22 Photos of the agriculture site tour

3) Agri DEMO DAY on 23rd June 2023 by the companies who performed the 5 Agriculture pilot projects

https://www.jica.go.jp/oda/project/1900527/news/20230622.html

[Video] https://fb.watch/lVymZLRjim/

[Photos] https://shorturl.asia/hnBkU

JPT and TPT organized a joint demonstration event named "Agri DEMO DAY" at a farm in Samut Prakan Province to promote the utilization of NCDC and to publicize the results of 5 agricultural pilot projects. Approximately 160 people from Thai government agencies, Japanese and Thai private companies, universities, media, and the Embassy of Japan in Thailand participated in the event.

At this event, the implementing companies demonstrated some of the farm machines and technologies they are using in their own pilot projects. Participants were divided into 5 groups and toured the 5 sites in turn. Test rides were also given of a straight-line assist farm machine and an auto steering farm machine.


AGRI DEMO DAY
การสาธิตการใช้ประโยชน์ศูนย์ข้อมูลสถานีค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC) ด้านเทคโนโลยีการเกษตร
22 มิถุนายน 2566
รอบเวลาการสาธิต 9:00 น. - 15:00 น.
5 โครงการนำร่องด้านการเกษตร Tie Gnss cORS in Thailand (TIGORS)
โดยคณะทำงานร่วมไทย-ญี่ปุ่น ในการดำเนินโครงการพัฒนาศักยภาพและส่งเสริมการใช้ประโยชน์ศูนย์ข้อมูลสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (CORS) แห่งชาติ
Quantum Motus
Siam Yamaha Motor Robotics Co., Ltd., Dep. of agriculture
BioMatLink Co., Ltd.
Topcon Corporation, Topcon Positioning Asia (Thailand)
YANMAR AGRIBUSINESS Co., Ltd, YANMAR S.P. Co., Ltd
Entrance
YANMAR
TOPCON
SYMR
Register
Location




























GROUP



Figure 3-23 Photos of Agri DEMO DAY

About 70 participants answered the questionnaire after the event. 97% of them were either “Very satisfied” or “Satisfied” with the event, and 91% of them “Well understood” or “Understood” NCDC. The participants gave a lot of positive comments; “I got ideas and knowledge to use NCDC data to apply for benefits.”, “If possible, I would like to watch more demonstrations of applications in other fields.”, and “There should be more publicity to reach more target groups”.

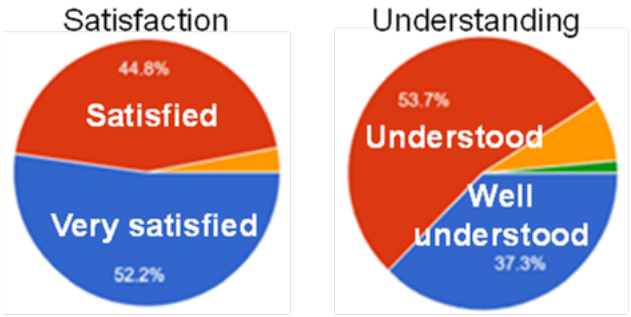


Figure 3-24 Results of the questionnaire



Figure 3-25 Photos of the Agri DEMO DAY

Agri DEMO DAY news was published on two major Thai online news sites (MGR Online, Siamrath Online) and one Japanese newspaper (The Daily NNA Thailand), and was also featured on two Japanese TV programs of TV Asahi who described that the technologies demonstrated in the event could be solutions for Thailand's serious problem of declining birthrate and aging population. This event became a good opportunity for NCDC and precise positioning technology to be widely known in Japan and Thailand.

It was a tough challenge, but the members worked hard and are satisfied with the results. The project members took another big step forward together and were sincerely grateful for the support and cooperation of all the companies that provided demonstrations and of all the participants.

4) Demonstration of Autonomous Driving Vehicle on 26th September 2023 by Asia Technology Industry

https://www.facebook.com/share/p/gwbc2vSisGzBdaeq/?mibextid=WC7FNe

Asia Technology Industry (ATI) conducted an autonomous driving demonstration of an electric golf cart using NCDC data at GISTDA's Space Krenovation Park in Chonburi province. Participants in the regional workshop watched the autonomous driving and had a test drive.



Figure 3-26 Photos of the demonstration

5) Report, use case leaflet, and video introducing the pilot projects

In addition to the above activities, with the understanding and great cooperation of the implementing companies, the content and results of the pilot project were publicized at the events inside and outside the project shown in Table 3-30.

Table 3-30 PR of the pilot projects

Timing	Place/contents
Aug 2022, Aug 2023	Panel and video exhibits at National Science and Technology Fair
31st Jan 2023	Presentations by the companies on overview, progress, and future prospects of each pilot project at the 2nd project seminar
21st Apr 2023	Panels and video exhibits at Economic Driving with NCDC seminar
25th Sep 2023	Presentations by the companies at the regional workshop on the content and results of each pilot project
From Oct 2023	Panel and video exhibits at the Japan Pavilion in GISTDA SKP
31st Oct 2023	Presentations by the companies on the results of each pilot project at the 3rd project seminar
Jan 2024-	Published the user case leaflets and videos on the NCDC website

In addition, the companies prepared an implementation report (Appendix 3), a leaflet introducing case studies of the use of NCDC, and a video introducing the pilot project. The use case leaflets and

videos are published on the NCDC website (https://ncdc.in.th/portal/apps/sites/#/ncdc).

(4) Summary of pilot project

The pilot projects are summarized based on the implementation reports of the 8 pilot projects submitted by each company.

First, the benefits of using NCDC suggest that the realization of precise positioning using NCDC in all fields will boost further business development in the future. In addition, it was found that users can receive a variety of benefits, as high accuracy positioning not only improves work accuracy, but also contributes to reducing workload and improving work safety as a result.

Table 3-31 Benefits of using NCDC

Survey	- The fact that the NCDC enables precise network RTK surveying to be conducted anytime, by anyone, anywhere is expected to be utilized in many fields in the future. - The establishment of the NCDC is significant in that CORS will operate with a unified coordinate system.
Construction	- The cost and work time required for the installation of fixed stations for RTK surveying, which was necessary for conventional works, could be reduced. - The radio equipment required for conventional RTK surveying is no longer necessary, leading to a reduction in costs. The range of use of ICT construction was expanded, as it was no longer necessary to consider buildings and terrain that would be an obstacle to radio signals.
Agriculture	- It was confirmed that the NCDC could enable operations of automatic farm machines, agricultural helicopters, and drones, which require precise positioning. The results show promise for the spread of smart agriculture. - It was confirmed that the NCDC's precise positioning also contributes to reducing the workload and improving safety. - It was also confirmed that the NCDC can be used to monitor the growth of crops and the operating status of farm machinery, contributing to improved productivity and increased yields. - The availability of NCDC data free of charge is appreciated.
Autonomous driving	- As the NCDC supports all necessary positioning satellites, it was confirmed that autonomous driving is possible with highly accurate position information using network RTK, even in locations where signal reception is difficult.

On the other hand, a common issue faced by all fields in using the NCDC was that the data delivered by the NCDC was unstable depending on the location or time of use. As the current NCDC is an interim version, the number of CORS used to generate the correction data to be delivered is limited. As a result, data instability and degradation of positioning accuracy have occurred, especially when the distance between the location of use and the CORS is far away. In addition, as described in Chapter2. NCDC operation and maintenance status, it was reported that there is a degradation of positioning accuracy at night due to ionospheric disturbances, which poses a problem for the use of the NCDC. Furthermore, in agricultural projects, it was reported that NCDC data could not be received in rural areas due to low mobile communication signal strength and that it took time to connect. Although not directly related to NCDC, some of the companies mentioned that import/export procedures for equipment took much longer time than expected.

Table 3-32 Issues faced during use of NCDC and concerns

Survey	- Network RTK became instable when using at some distances from CORS. - The number of satellites included in NCDC data tended to decrease significantly at night.
Construction	- There were problems with positioning stability depending on the time of day. - Construction works are taking place in various locations, but at present the NCDC CORS does not cover all of Thailand.
Agriculture	- Positioning accuracy sometimes decreased during the work. One of the reasons for this is the poor signal strength of mobile communications. - Temporary instability of Network RTK sometimes affects the accuracy of automatic steering. - Connection to the NCDC sometimes takes a long time. - Some rural areas where agriculture takes place are not well serviced by NCDC. - The processing of documents such as import/export permits took much longer than initially planned.
Autonomous driving	- During nighttime autonomous driving, the Network RTK sometimes did not become FIX, resulting in deteriorated position accuracy. - Export/import procedures for equipment took more than six months.

As one of the solutions to the above-mentioned technical issues, the companies expressed their expectations for installation of more CORS for stable delivery of NCDC data (increased density of CORS in high-demand areas, such as large-scale infrastructure development, and expanded coverage in rural areas). On the operational side, there is a need for improved user support, such as the establishment of a help desk to promptly respond to user enquiries and consultations, and the provision of technical information and related trainings. In addition, prior notification of NCDC maintenance and immediate communication in the event of failures are also important for the use of NCDC in daily operations and businesses. Furthermore, some companies suggested that the promotion of understanding of new technologies in government agencies could help smooth procedures for importing and exporting equipment, etc.

As described above, the pilot project confirmed the usefulness of NCDC in various fields, solved some technical issues based on feedback from the companies, and identified further technical and operational issues. It was important to be able to evaluate NCDC from the user's perspective, and this pilot project was significant. The project members would like to sincerely thank the companies and all stakeholders who supported and cooperated with the activities.

[2-3] To conduct business matching and seminars for business development related to the utilization of the precise positioning data

(1) Holding JICA project seminar

The 2nd JICA Project Seminar

The 2nd JICA project seminar was held as one of the sessions on the first day of the 13th Multi-GNSS Asia (MGA) Annual Conference held in Chiang Mai from 31st January to 2nd February 2023. JPT and GISTDA made preparations including coordinating with the conference organizer, making the agenda, and arranging presenters, setting up the venue, and testing connections with online presenters. At the seminar, RTSD gave

a presentation on the project and NCDC, and the companies participating in the pilot project and TPT members explained how they were using NCDC to the participants of 39 on-site and 22 online.

Table 3-33 Overview of the 2nd JICA Seminar

Title	Applications of N-RTK provided by Thailand National CORS Data Center
Date/Time	31st January 2023, 16:15-18:00 (Thai time), 18:15-20:00 (Japan time)
Place	13th Multi-GNSS Asia Annual Conference (held in Royal Park Ratchaphruek, Chiang Mai & Hybrid)
Goals	By introducing examples of utilization of precise positioning data, potential users will recognize its usefulness, leading to the discovery and increase of new users. By explaining and disseminating the current status of NCDC and the usefulness of precise positioning data, the number of users of the distribution data will be increased.
Contents	1. Opening remarks: Applications of N-RTK provided by Thailand National CORS Data Center (Prof. Dr. Chalermchon Satirapod) 2. Introduction of NCDC and Data Distribution (Col. Kriengkrai Boonterm, RTSD) 3. Use cases of NCDC data - JICA TIGORS Pilot Project [Survey] (Mr. Naoyuki Tamaki, Topcon) - Road construction using ICT construction machineries utilizing NCDC (Mr. Takashi Ogawa, Topcon) - Collaborative Value Chain Management Platform from Farm to Factory (Dr. Thanika Chintanapunt, Bio Mat Link) - Utilization of National CORS Data Center Application in Agriculture (Dr. Witaya Lerdpiriyakamol, Quantum Motus) - Unmanned Helicopter "Fazer R RTK" by NCDC (Mr. Teerasak Charoensettakul, Siam Yamaha Motor Robotics) - TIGORS Pilot Project [Agriculture] (Mr. Naoyuki Tamaki, Topcon) - YANMAR JICA Pilot Project details (Mr. Seungkyu Lee, Yanmar Agribusiness) - Intelligent driving vehicle in Thailand, Low-cost autonomous vehicle (Mr. Kanin Kiataramgul, Asia Technology Industry) - CORS Network for Cadastral Surveying (Dr. Peera Yomwan, DOL) - Using the NCDC with Hydrographic Survey for Water Management (Ms. Nuantip Chaladlert, HII) 4. Closing remarks Speech (Mr. Kenichiro Koiwa, JICA Thailand Office)
Participants	On-site: 39 people, On-line: 22 people



Figure 3-27 Photos of the 2nd seminar

The 3rd JICA Project Seminar

[Video] https://www.facebook.com/skp.gistda/videos/883625566613428/

[Photos] https://www.facebook.com/share/v/wMjxHfR87RfnSfuX/?mibextid=WC7FNe

The members organized the final seminar of the project to widely publicize the results of the project and examples of use cases of NCDC on 31st October 2023 in Bangkok.

Table 3-34 Overview of the 3rd /final JICA Seminar

Title	TIGORS Final Seminar
Date/Time	31st October 2023, 9:10-12:00 (Thai time), 11:10-14:00 (Japan time)
Place	Jasmine City Hotel in Bangkok
Goals	To promote the achievements of the project and use cases of NCDC
Contents	1. Opening remark (Ms. Yuki Kitagawa, Senior Representative of JICA Thailand Office) 2. Overview of TIGORS Project (Dr. Hiromichi Tsuji, JICA Project Team Leader) 3. National CORS Data Center (NCDC) (Col. Sompoch Puntavungkoon, RTSD) 4. Use cases of NCDC data - Report of JICA TIGORS Pilot Project [Survey] (Mr. Naoyuki Tamaki, Topcon) - Road construction using ICT construction machineries utilizing NCDC (Mr. Takashi Ogawa, Topcon) - Agriculture Solutions (Ms. Tanista Ketkaew, Topcon) - Utilization of NCDC in Agriculture (Dr. Witaya Lerdpiriyakamol, Quantum Motus) - AUTO PILOT system by Network-RTK provided by NCDC (Mr. Teerasak Charoensettakul, Siam Yamaha Motor Robotics) - Using NCDC to increase the product yield in supply chain management in the cassava industry (Mr. Chaiwat Bootchai, Bio Mat Link) - Smart Agriculture utilizing Autonomous and Telematics Technology in Thailand (Mr. Seungkyu Lee, YANMAR AGRIBUSINESS) - Low-cost autonomous driving vehicle using high-accuracy GNSS (Mr. Sitthisak Khamkasem, Asia Technology Industry) - Utilization of NCDC Data (Mr. Chaiwat Panachat, DPT) 5. Way Forward - Dr. Peera Yomwan (DOL) - Mr. Chaiwat Panachat (DPT) - Dr. Acharaporn Bumrungkit (GISTDA) - Ms. Nuantip Chaladlert (HII) - Mr. Sarayut Yousamran (RTSD) 6. Closing remarks (Prof. Dr. Chalermchon Satirapod)
Participants	122 from Thai government agencies, Thai and Japanese private companies, and universities, etc.

At first JPT and RTSD reported on the achievements of this project, and then the implementing companies of the 8 pilot projects and DPT presented use cases of NCDC applications in the fields of surveying, construction, agriculture, and autonomous driving. Exhibition booths were set up where NCDC's services and the results of each company's pilot project, technologies, and products were presented. Through the presentations and face-to-face communications at the booths, TPT and JPT believe that the usefulness and potential of NCDC were conveyed to the participants.

In the "Way Forward" session at the end of the seminar, representatives from each of the 5 TPT agencies spoke strongly about their aspirations for further improvement of NCDC services and promotion of utilization of NCDC, while also describing how NCDC has become an integral part of their business and providing specific examples of future developments using NCDC.

Topcon and Topcon Positioning Asia (Thailand) distributed bags of the rice grown and harvested through their pilot project to everyone participated in the seminar, a wonderful memento of the results of NCDC's utilization.








Forwa




The project for capacity development and promotion of utilization of National CORS Data Center (NCDC)
NCDC USER MEETING
31 October 2023
JICA









Figure 3-28 Photos of the 3rd seminar

(2) Holding the NCDC user meeting

The members organized the NCDC user meeting on the afternoon of 31st October 2023, the same day that the above seminar was held. About 50 people, Prof. Dr. Chalermchon Satirapod, TPT, users (i.e., the companies who performed the 8 pilot projects), and JPT attended the meeting and exchanged opinions and ideas on further improvement and promotion of NCDC.

Table 3-35 Overview of the NCDC user meeting

Title	NCDC User Meeting
Date/Time	31st October 2023, 13:30-16:00 (Thai time), 15:30-18:00 (Japan time)
Place	Jasmine City Hotel in Bangkok
Purpose	To listen to the feedback from the users and exchange opinions and ideas with the users for improvement of NCDC
Contents	1. Opening remark (Col. Sarayut Yousamran, Director of Geodesy and Geophysics Division, RTSD) 2. Self-Introduction 3. Introduction of operation of NCDC (Col. Parinya Thaweewat Chief of Geodesy Section, Geodesy and Geophysics Division, RTSD) 4. Comments from the NCDC users - Survey field [Topcon] - Construction field [Nishio Rent All & Topcon] - Agriculture field [Topcon] - Agriculture field [Quantum Motus] - Agriculture field [Siam Yamaha Motor Robotics] - Agriculture field [Bio Mat Link] - Agriculture field [YANMAR Agribusiness] - Autonomous Driving field [Asia Technology Industry] 5. Opinion Exchange Prof. Dr. Chalermchon Satirapod 6. Closing Remarks (Prof. Dr. Chalermchon Satirapod) 7. Group photo
Participants	About 50; Prof. Dr. Chalermchon Satirapod, TPT, users (companies implementing pilot projects), and JPT

While the final seminar focused on sharing the achievements, this meeting provided an opportunity for TPT members as service providers and the implementing companies in JICA pilot project as users to share

information and exchange opinions on issues of the current NCDC and requests for future improvement.

First, RTSD, the organization responsible for NCDC, explained to the users the status of NCDC's data quality monitoring and the details of efforts for improvement. Following this, representatives from each company shared their thoughts and opinions about the benefits, satisfaction level, issues, requests for improvement, and expectations for the future based on their experience using NCDC's services for several months to over a year. The satisfaction levels of the users were as shown below: "Very much satisfied" was 1 response, while "ok" was 3 responses, indicating that NCDC needs to continue its efforts for improvement.

Please tell us level of satisfaction on NCDC by writing "5", "4", "3", "2", or "1",
where
5:Very much satisfied, 4:Satisfied, 3:ok, 2:Dissatisfied, 1:Very much dissatisfied

- **4** [Survey (Topcon)]
- **3** [Nishio rentall & Topcon (Construction)]
- **4** [Topcon (Agriculture)]
- **5** [QUANTUM MOTUS (Agriculture)]
- **5** [Siam Yamaha Motor Robotics (Agriculture)]
- **4** [BioMatLink (Agriculture)]
- **3** [Yanmar Agri Business (Agriculture)]
- **3** [Asia Technology Industry (Autonomous Driving)]

In the latter half of the meeting, all participants exchanged opinions on common issues and requests of users under the facilitation of Prof. Dr. Chalermchon Satirapod. TPT members had had very limited opportunities for direct dialogue with users, but the face-to-face exchange provided an opportunity to hear candid opinions that will serve as hints for future improvement of NCDC.



Figure 3-29 Photos of the NCDC User Meeting

(3) Business matching

With a view to contributing to the development of businesses that utilize the precise positioning data distributed from NCDC, the project members sought to create contact points between companies implementing the pilot projects and their potential customers/ potential business partners through the following activities.

- Support for implementation of site tours and demonstrations, and PR
- Holding and promoting Agri DEMO DAY
- Holding project seminars (presentations, exhibitions)
- Introduction of GNSS-related events
- Collaboration with universities
- Dissemination of information at GNSS-related events not organized by this project, websites (NCDC, JICA, etc.), SNS, etc.
- Others

It is difficult to evaluate the results of the above efforts at this point, since full-scale business development of services and products utilizing NCDC is yet to begin, but the companies that implemented the pilot projects commented positively, “We were able to obtain opportunities and triggers that could not be obtained through individual corporate efforts alone”.

(4) Presentations in the 14th Multi-GNSS Asia Annual Conference

In order to raise awareness and increase the number of users of NCDC, Prof. Dr. Chalermchon Satirapod, TPT, JPT and NIMT hosted “Thailand-Japan Special Session” in the 14th MGA Annual Conference held in Chiang Rai from 30th January to 2nd February 2024, and presented the activities and achievements of the project, the current status and future of NCDC, and the results of the pilot project (examples of NCDC applications) to GNSS stakeholders in Thailand and other countries. The session was attended by about 40 participants face-to-face and 20 participants online.

Table 3-36 Overview of the Thailand-Japan special session in MGA

Title	Thailand-Japan Special Session
Date/Time	31st January 2024, 15:30-16:30 (Thai time), 17:30-18:30 (Japan time)
Place	The 14th Multi-GNSS Asia Annual Conference at Mae Fah Luang University, Chiang Rai and online
Purpose	To publicize the activities and achievements of the project to GNSS stakeholders in Thailand and other countries. Explain and disseminate the current status, future prospects and examples of utilization of NCDC, to increase the number of users.
Contents	Chair: Prof. Dr. Chalermchon Satirapod, Chulalongkorn University Co-Chair: Mr. Chinnatat Keawkaew, GISTDA 1. Greeting *video message (Mr. Kazuya Suzuki, the Chief Representative, JICA Thailand Office) 2. Overview and achievements of JICA TIGORS Project (Dr. Hiromichi Tsuji, Team Leader of JICA Project Team (PASCO Corporation)) 3. Operation and Maintenance of NCDC (Col. Dr. Sompoch Puntavungkoon, RTSD) 4. GNSS test and calibration facilities at NIMT (Dr. Thayathip Thongtan, NIMT) 5. Results of the 8 Pilot Project (Ms. Nami Seimiya, Deputy Team Leader of JICA Project Team (PASCO Corporation))
Participants	On-site: approx.40 people, On-line: approx.20 people



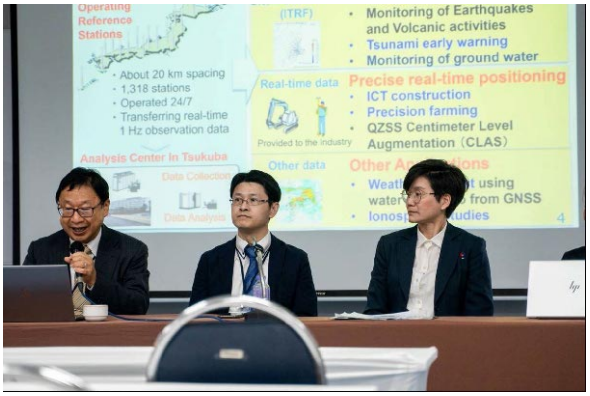


Figure 3-30 Photos of the Thailand-Japan special session

[2-4] To conduct seminars and a regional workshop with neighboring countries to promote the utilization of precise positioning data

(1) Regional Workshop in Bangkok

JPT and TPT organized the regional workshop inviting representatives from 6 Asian countries as described below.

Table 3-37 Outline of the regional workshop

Dates	On 21st, 22nd, 25th, 26th, and 27th September 2023
Venue	Grande Centre Point Hotel in Bangkok and the pilot project sites in Thailand
Participants	Government officials responsible for GNSS/CORS from Bangladesh, Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Viet Nam
Purpose	To encourage further utilization of GNSS/CORS in the Asian countries by introducing key activities of JICA CORS project in Thailand (TIGORS), as well as providing an opportunity for the participants to share ideas and exchange technologies in the field of GNSS/CORS among participating countries.

Table 3-38 Programme of the regional workshop

Day	Details	Location
-	(Travel, from each country to Bangkok)	
Day 1	- Greetings and Self-introduction - Introduction of JICA's Cooperation on CORS in Asia - Introduction of the current situation and issues regarding CORS in each country - Reception	Bangkok
Day 2	- Introduction of NCDC and TIGORS project - Summary and discussion on the current situation and issues - Site visit #1: NCDC (RTSD)	Ditto
Day 3	- Overview of the pilot project and presentations from the participating companies - Opinion exchange "What we will do to move forward" and wrap-up	Ditto
Day 4	Site visit #2: Autonomous Driving pilot project (Asia Technology Industry)	Chonburi
Day 5	Site visit #3: Agriculture pilot project (Siam Yamaha Motor Robotics)	Samut Prakan
-	(Travel, from Bangkok to each country)	

Table 3-39 List of participants of the regional workshop

Country	Participants
Bangladesh	Mr. M J Arif Begg (Ministry of Defence / Deputy Secretary) Mr. Mohammed Abdur Rouf Howlader (Survey of Bangladesh / Director)
Cambodia	Mr. Sin Sotheany (General Department of Cadastre and Geography / Deputy Director General) Mr. Chharom Chin (General Department of Cadastre and Geography / Geography Dept., Deputy Director) *Until 25th Sep.
Indonesia	Dr. Gatot Haryo Pramono (Geospatial Information Agency / Head of Center for Geodetic Control Network and Geodynamics) Mr. Yuandhika Galih Wismaya (Geospatial Information Agency / Staff)
Lao PDR	Dr. Ammala Keonuchan (National Geographic Department / Director General) Mr. Daeng Phanhpheng (National Geographic Department / Deputy Director of Survey and Border-Joining Zone Division)
Philippines	Ms. Charisma Victoria D. Cayapan (National Mapping and Resource Information Authority / Geophysicist IV) Mr. Donnie T. Mancera (National Mapping and Resource Information Authority / Engineer II)

Country	Participants
Thailand	Chulalongkorn University: Prof. Dr. Chalermchon Satirapod Royal Thai Survey Department: Col. Kriengkrai Boonterm, Col. Dr. Sompoch Panthawangkun, Col. Rungkrai Kraimark, and some others Department of Lands: Dr. Peera Yomwan, Mr. Norasi Nilphetploy, Mr. Miti Nuntatikul Department of Public Works and Town & Country Planning: Mr. Nakarin Plangpongpan, Mr. Chaiwat Panachat Geo-Informatics and Space Technology Development Agency: Mr. Chinnatat Keawkaew, Mr. Pranatpol Thaicharoen, Ms. Supasiri Reungthummawat Hydro-Informatics Institute: Ms. Nuantip Chaladlert, Ms. Patsharawadee Chitsutti, Ms. Jittraphon Yuthai, Mr. Phisitchai Hanpadungkit, Mr. Tullatorn Arak
Viet Nam	Mr. Nguyen Dai Dong (Department of Survey and Mapping of Vietnam / Deputy Director of Technology of survey, mapping and geo-information Division) Mr. Do Anh Tuan (Department of Survey and Mapping of Vietnam / Engineer, Technology of survey, mapping and geo-information Division)
Japan *Organizer	JICA Thailand Office: Ms. Yuki Kitagawa, Mr. Yasuyuki Endo, Dr. Kobchai Songsrisanga JICA project team: Dr. Hiromichi Tsuji, Ms. Nami Seimiya, Mr. Ryusuke Nakatani of PASCO Corporation

Based on the presentations given by each country, the results of preliminary questionnaires, and the information shared through the series of opinion exchange and discussions held during the regional workshop, the participants confirmed that the participated countries are having the following common issues and challenges.

- Damages caused by lightening, radio interference, deformation monitoring
- Integration of various CORS within a country
- Pricing, securing budget, HR capacity building, marketing and PR

Although the time was very limited, every participant gained valuable information and insights which can be of great help in their countries from other participants.

The participants witnessed how CORS can contribute to solve social issues by assisting agriculture work and through implementation of autonomous driving from the site visits on 26th and 27th September.

Since GNSS/CORS is a highly specialized technology, it is not very easy nor efficient for the agencies in charge in each country to gain experience and find solutions to the issues on their own. As one of the most important outcomes of this workshop, the participants recognized that information sharing and discussions across countries is effective for improving and promoting the utilization of CORS in each country. During the concluding discussion named “What can we do to move forward?”, they then came up with the idea of holding a regular online meeting in every 3 months to continue information exchange of CORS of each country (Appendix 4).














Figure 3-31 Photos of the Regional Workshop

11 participants responded to the questionnaire at the end of the workshop. The following comments were given on the overall impression.

- The content and schedule of each day were well considered, managed, and implemented.
- Very useful information was obtained on how participating countries can develop in the CORS field.
- The content of this workshop would be useful for capacity building and promoting the use of CORS in Asian countries.
- I look forward to implementing what I learnt here in my work in my country.

Among the presentations from each country that left a particularly strong impression were those on heat management in Thailand, the integration of CORS of several institutions in Thailand, the design (appearance) of CORS in Cambodia, and measures to secure support from the government in Indonesia. The following comments were also made as ideas for technical assistance required in each country.

- Development of open-source CORS management software (Thailand)
- Operation and maintenance of NCDC (Thailand)
- Projects to expand the CORS network and acquire users (Philippines)
- Addressing issues of geodetic reference systems (e.g., strengthening of geodetic infrastructure, coordinate transformation parameters, etc.) and integration of CORS network and utilization (Philippines)
- Application of CORS to land subsidence (Vietnam)
- Technical cooperation on data utilization (Indonesia)
- Establishment of CORS-based geodetic networks and establishment of data centres (Lao PDR)

(2) Follow-up/ reunion meeting

JPT, TPT and the participants in the regional workshops mentioned above held their first follow-up meeting on 29th January 2024 at a venue in Chiang Rai and an online hybrid. The director of the international division of Geospatial Information Authority of Japan (GSI) attended the meeting as an observer.

Table 3-40 Outline of the follow-up meeting

Date/ time	On 29th January 2024 at 14:00-15:15 (Thai time), 16:00-17:15 (Japan time)
Venue	Mae Fah Luang Univ. in Chiang Rai & online
Participants	Government officials responsible for GNSS/CORS from Bangladesh, Cambodia, Indonesia, Lao PDR, Philippines, Thailand, and Viet Nam JPT members
Observer	GSI, Japan
Purpose	To continue exchanging information on CORS operation, maintenance, and utilization in each country.
Agenda	1. Introduction 2. Greeting/Presentation from each country - Bangladesh: Greeting - Cambodia: Greeting - Indonesia: Online services based on CORS data - Lao PDR: Work progress and proposal about CORS - Philippines: Greeting - Thailand: Greeting from DOL, NCDC manual from RTSD

	- Viet Nam: Greeting - Japan: News from GSI website (Noto Peninsula earthquake) 3. Q & A, opinion/information exchange 4. Plan of next session

Table 3-41 List of participants

Country	Participants
Bangladesh	Mr. Mohammed Abdur Rouf Howlader (Survey of Bangladesh / Director)
Cambodia	Mr. Sin Sotheany (General Department of Cadastre and Geography / Deputy Director General) Mr. Chharom Chin (General Department of Cadastre and Geography / Geography Dept., Deputy Director) Mr. So Vanna (General Department of Cadastre and Geography / Director)
Indonesia	Dr. Gatot Haryo Pramono (Geospatial Information Agency / Head of Center for Geodetic Control Network and Geodynamics)
Lao PDR	Dr. Ammala Keonuchan (National Geographic Department / Director General) Mr. Daeng Phanhpheng (National Geographic Department / Deputy Director of Survey and Border-Joining Zone Division)
Philippines	Ms. Charisma Victoria D. Cayapan (National Mapping and Resource Information Authority / Geophysicist IV)
Thailand	Prof. Dr. Chalermchon Satirapod (Chulalongkorn University) Col. Dr. Sompoch Panthawangkun (RTSD) Mr. Miti Nuntatikul (DOL) Ms. Patsharawadee Chitsutti (HII)
Viet Nam	Mr. Nguyen Dai Dong (Department of Survey and Mapping of Vietnam / Deputy Director of Technology of survey, mapping and geo-information Division)
Japan *Observer	Mr. Yudai Sato (International Division, GSI / Director)
Japan *Organizer	Dr. Hiromichi Tsuji, Ms. Nami Seimiya, Mr. Ryusuke Nakatani (JPT, PASCO Corporation)

Representatives from the participating countries shared information on their activities conducted since October 2023, where Indonesia provided information on their online services using CORS data, Lao PDR on the plan of integration of CORS, and Thailand on the development of operation and maintenance manuals, each through a 10-minute presentation. JPT introduced GSI's responses after the Noto Peninsula earthquake.

The participants discussed and agreed to continue the online information exchange meetings every 6 months. The next meeting will be chaired by the Philippines in July 2024, and the agenda and topics will be decided around June, depending on progress and interests in each country.

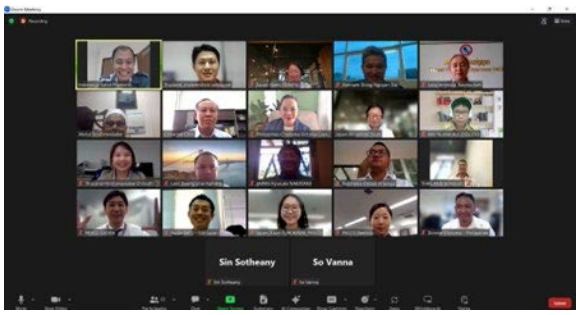




Figure 3-32 Photos of the follow-up meeting of regional workshop

[2-5] To summarize and share GNSS utilization and promotion activities and its expected impact in Thailand

(1) Review of activities related to the utilization of GNSS in Thailand

1) Interview surveys

Interview surveys were conducted with the related parties to collect information about their activities for utilization of CORS and GNSS carried out so far in Thailand. The interviewees, schedule of the interview survey, and comments/opinions obtained are summarized below.

Table 3-42 Schedule of interview survey

Date	Organization and Company	Respondents
31st Oct. 2022	Chulalongkorn University	Prof. Dr. Chalermchon Satirapod
1st Nov. 2022 2nd Nov. 2022	Hydro Informatics Institute (HII)	Ms. Nuantip, and 1 person
	Department of Public Works and Town & Country Planning (DPT)	Mr. Chaiwat, and 5 persons
3rd Nov. 2022 4th Nov. 2022	Department of Lands (DOL)	Dr. Peera, and 2 persons
	Royal Thai Survey Department (RTSD)	Col. Kriengkrai, Dr. Sompoch, and 4 persons
7th Nov. 2022	Bio Mat Link Co., Ltd. (BML)	Dr. Chintanapunt, and 2 persons
	Geo-Informatics and Space Technology Development Agency (GISTDA)	Dr. Nattawat (on-line), Mr. Thotsawat
31st Oct. 2022	Ministry of Digital Economy and Society (MDES)	Mr. Kroekits, Advisor to the minister
1st Nov. 2022	Thai Nippon Road	Mr. Katsuji Kawamura, President
2nd Nov. 2022	Topcon Thailand	Mr. Samniang Suttara, Ms. Tanista Ketkaew, Mr. Takashi Ogawa

Table 3-43 Comments/opinions obtained from the interview survey

Interviewees	Comments/Opinions
Chulalongkorn University	- He is satisfied with what the TIGORS has achieved so far. All WG members are actively participating in approaching potential users of NCDC. - Since about 80% of the rural population is engaged in agriculture, He personally believes that agriculture is the number one target sector.
Hydro Informatics	- HII held workshops in rural areas. Local government officials also participated in

Interviewees	Comments/Opinions
Institute (HII)	the workshops. Since rural areas do not have the budget to purchase GNSS receivers, they asked HII to introduce low-cost GNSS receivers. - HII also introduce NCDC in their lectures and workshops. - HII expressed that they would continue the CORS courses and workshops.
Department of Public Works and Town & Country Planning (DPT)	- DPT conducted trainings on the use of GNSS receivers as new equipment was introduced. They were implemented for the staff members of DPT offices in 76 prefectures nationwide. - CORS density is not a big problem for 1/4,000 DPT mapping jobs. It is necessary to make it denser for surveying. - Data may be unstable when using data from NCDC. DPT deals with it in post-processing because DPT has technical capabilities. So, such responses would be difficult for ordinary users which do not have such technical capabilities.
Department of Lands (DOL)	- It conducted trainings for government agencies and the private sector, with a cumulative total of over 3,000 participants. - Since 2012, CORS has been installed on a pilot basis, and since 2017, the area has been expanded in earnest. It is expected to cover the whole country in 2023.
Royal Thai Survey Department (RTSD)	- They are not satisfied with the current number of users. They do not think they have been able to recover their investment, but recovery is not the primary purpose of RTSD. Since NCDC is a national infrastructure, it is important that it is used effectively for Thailand. They requested to continue the activity of the Output2 of TIGORS to promote utilization. - Since Thailand is an agricultural country, they think that CORS will be mainly used in agriculture, but because of the cost of installing GNSS receivers, it is likely that agricultural corporations with financial resources will be users more and more rather than general farmers.
Bio Mat Link Co., Ltd. (BML)	- BML's business is to connect among farmers, logistics companies, and food processing companies (Collaborative Value Chain Management). - Major crops in Thailand are rice, cassava, and sugar cane. Among them, cassava is the first target crop for IGE's business because of its potential and ease of starting a business. In the future, they plan to expand the target crops to include rice and corn. - Waste after cassava processing is collected and used as agricultural chemicals and feeds (recycling). GNSS location information of transport vehicles is required for waste traceability. - Currently, a pilot project is being implemented in Chachoengsao Province. In addition, the business area is being expanded to eight prefectures. Ultimately (in 2025), it plans to expand to 54 prefectures. They plan to use GPS and NCDC data in all areas. Precise positioning by NCDC is necessary for cross-checking of GPS for explaining its advantages to investors.
Geo-Informatics and Space Technology Development Agency (GISTDA)	- Domestic and international efforts are being made to promote the use of GNSS. Activities in collaboration with Japan's JICA (this project) and the Cabinet Office are included. They will also promote the utilization of CORS data from GISTDA. In addition, as infrastructure development, CORS data is aggregated in SKP, and data is provided from SKP. - They are holding an idea competition for university students in collaboration with Japanese government partners. They are also collaborating with European partners through MGA (Galileo related). - Several projects related to Japan are being implemented, but the directions are various. It is expected that related organizations on the Japanese side (for example, JICA and the Cabinet Office) would cooperate with each other if possible. It would be nice if experts could work in the same direction.
Ministry of Digital Economy and Society (MDES)	- Precise positioning using GNSS is a new technology for general Thai people, so the benefits are not yet understood. Since Thailand is an agricultural country, cost reduction and profit improvement in agriculture are important points. It would be

Interviewees	Comments/Opinions
	nice if it is presented that NCDC can help with that to the people. - Government interest is important. It is also important to persuade the politician and to make the politician to think it will improve his/her approval rating. To that end, it is necessary to show the effects of using NCDC not only in theory but also in actual results. - There are only four major general contractors in Thailand. These four companies will basically enjoy the benefits of NCDC in the construction sector. Therefore, it is inferred that the government and politicians do not attach importance to the diffusion of the construction sector due to the narrow scope of influence. - There are barriers to the current widespread use of GNSS/CORS, such as the high cost of GNSS receivers and the lack of Internet access in some areas.
Thai Nippon Road	- ICT construction using satellite data started four years ago. The first example is the pavement of an automobile test course in Thailand in cooperation with Nikon-Trimble. For this construction, precision in millimeters was required for flatness, which was impossible without GNSS. The second example is JICA's pilot project. - At Thai Nippon Road, three Japanese engineers stayed for 6 months and provided technical guidance to young local engineers for the first ICT construction. The young engineers in Thailand were very understanding and mastered the techniques well in a short period of time. - Precise positioning has not yet been fully recognized by the bureaucrats of the Road Department of Thailand. It is important that they recognize that need. JICA's pilot project was inspected by construction officials from the Road Department, contributing to raising their awareness.
Topcon Thailand	- Topcon is developing business in three sectors: surveying, construction (i-Construction), and agriculture (Smart Agriculture). Regarding the spread of GNSS/CORS, they are participating in JICA's pilot project in these three sectors. Other than that, they dispatch instructors to GISTDA workshops. - If the spread is still insufficient, the government's backup that fulfills the prerequisites such as increasing the number of CORS and improving the Internet environment is necessary for further spread. - About 10 years ago, Chinese companies entered the field of surveying and became a formidable competitor. The advantage of Chinese products is their low prices. Topcon's strategy is not to be easily involved in price competition, but to compete with the quality of the product package (durability of the product itself, generous service such as maintenance).



Chulalongkorn University



HII



DPT



DOL



RTSD



Bio Mat Link

Figure 3-33 Photos of the interviews

2) Lessons Learned

The lessons learned from considerations on the results of past activities for the spread of GNSS/CORS are summarized briefly as follows:

- One of the keys to the diffusion of the latest technology is that its merits are fully understood not only by specialists but also by the general public.
- If the price of the necessary equipment such as GNSS receivers does not drop, it will be difficult to see widespread use, but on the other hand, it is also true that manufacturing costs will not decrease unless they become widespread. Therefore, it is important for the government and aid partners to take the initiative in promoting investment.
- Several organizations have pointed out that it takes time for the positioning results to stabilize because an internet environment is still insufficient, especially in rural areas, and that the density of CORSs is low. Improvement on this point will be necessary for popularization of GNSS.
- When it comes to precise positioning, the first thing that comes to mind is automatic driving of heavy machinery and vehicles. It was presented that there are unexpected applications such as identification of toll road vehicles, traceability of waste transportation, and high-precision road paving. In the future, as it becomes more popular, it is highly possible that completely unexpected uses will be developed that will lead to business. For this reason, it can be said that the idea competition for students that GISTDA is conducting in collaboration with partners such

as the Japanese government is a wonderful initiative.

- Most of interviewees expressed their expectation that the Japanese government and JICA to provide technical support, such as expanding the usable area, improving accuracy, and ensuring the stability of measurement results.

(2) Market research of businesses utilizing CORS and GNSS, and their economic effects

1) Market research of business utilizing CORS and GNSS

Make a market research plan

The market research plan was discussed at several Output 2 meetings based on the JPT's proposal, and the following was agreed at the end of 2022. It was decided that the details would be worked out as the project progresses.

[Web Survey Plan]

*This survey intends to gather personal opinions from various kinds of people

NOTE: We will set the target groups and prepare questions for each group. At the beginning of the questionnaire, an answerer will select which group he/she belongs to, and then, answer the questions prepared for the selected group.

No.	Group	Description
1	Policy group (the person who is setting up the policy or the road map in Thailand)	*Details will be discussed and decided together.
2	Technician or surveyor group (the person who used the GNSS in his career way)	This group includes government officers (excluding TPT members), local government officers, engineers working for survey companies, and students. *Details will be discussed and decided together.
3	Future group (the person who are interested and come to joint in the future)	This group includes people working for agriculture and construction companies. *Details will be discussed and decided together.
4	End user group such as people who used the GNSS for car navigation and anything in his life	This group includes people working for other companies than agriculture and construction companies. *Details will be decided after discussing with GISTDA.
5	Industry group	−

How we distribute the URL

*Details will be discussed and decided together

- To send emails to the participants in the GNSS Training and the site tours
- To extract suitable people from GISTDA's emailing list and send emails?
- To send emails to the people who have registered to NCDC (Government officers 900, general users 300)
- To post the URL on Facebook etc.

<Implementation procedure>

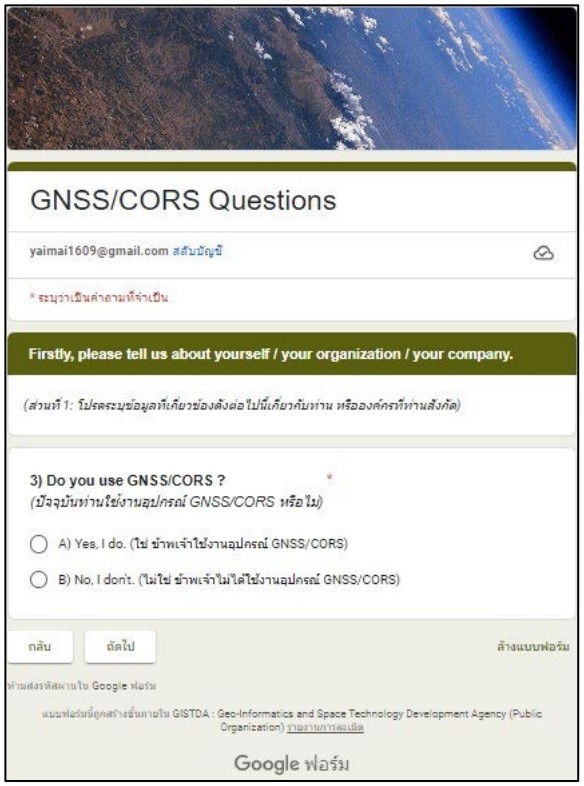
- December to January: Prepare the questionnaire *Let's have online meetings。
- February to March: Open the questionnaire web page
- The end of March: Close the web page, aggregate and evaluate the results

Design and formulate a questionnaire sheet

The questions to be asked in the questionnaire were drafted by GISTDA members and discussed within TPT. The outline of the question items is as follows.

- GNSS/CORS usages
- Interest in GNSS/CORS training
- Expected spread of GNSS/CORS in Thailand
- Awareness of NCDC
- Interest in NCDC training

The survey was conducted using Google's web survey service (free of charge), and experienced GISTDA members created the web page.



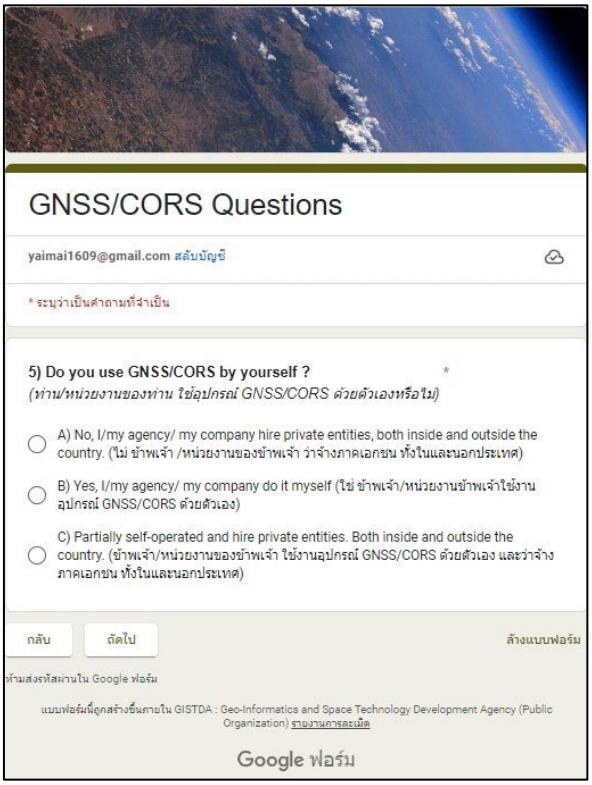


Figure 3-34 Screenshot of web survey

Conduct a questionnaire survey (web)

The questionnaire survey was conducted with the activities and the schedule below.

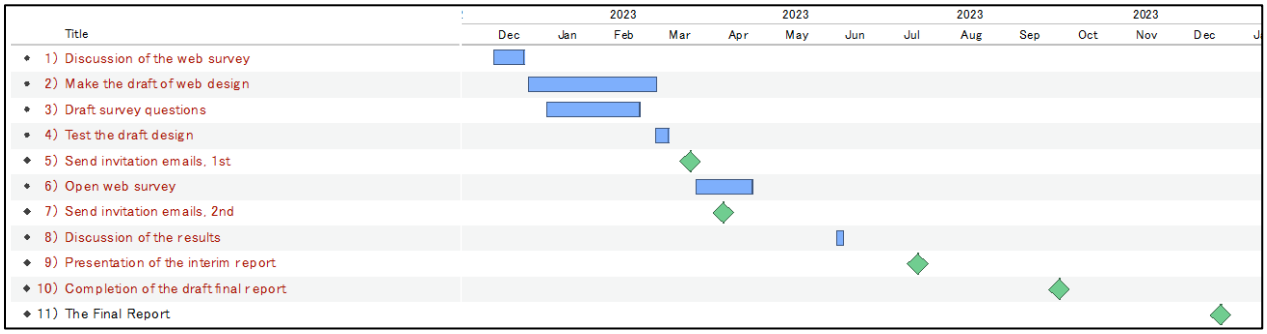


Figure 3-35 Time schedule of the questionnaire survey

Summarize the questionnaire survey results

The results of the questionnaire survey are as follows.

- Website opening period: 24th March 2023 - 21st April 2023
- The number of email invitations to participate in the survey: 300 (The mailing list was created based on the mailing lists of TPT and lists of participants in the project events. In addition to emails, invitations were also sent from the LINE Group, and the website was opened to external parties such as government agencies and universities.)
- The number of valid responses: 100

The main findings obtained from the questionnaire survey are as follows.

- Almost a half of the respondents are technicians or surveyors working in a private company.
- More than 80% use GNSS/CORS technology.
- The most common reason cited by respondents who do not use is that they do not have necessary equipment (i.e., GNNS receiver).
- More than 80% of who do not use GNSS/CORS now will use in future.
- Presently, GNSS/CORS technology are being used mostly for surveying and mapping.
- Almost all the users expect the millimeter or centimeter level accuracy.
- More stability and wider coverage, and lower cost (free of charge) for the uses of GNSS/CORS and NCDC are requested by many respondents.
- 83% know NCDC but a third of them do not register to NCDC yet.
- Majority of the respondents have an interest in the training on use of GNSS/CORS and NCDC technology.

2) Economic effects of businesses utilizing CORS and GNSS

The research and analysis regarding economic effects was basically carried out using the following steps.

1. Based on the results of "(1) Review of activities related to the utilization of GNSS in Thailand," we assumed agriculture, construction, and transportation as industries that would be significantly affected.

2. Identify what impacts are measurable in monetary terms and what are not by interviews to the specialists of each sector.
3. Estimate what the direct impact (increase in production) will be that can be measured in monetary terms with interviews to the experts of each sector and existing researches.
4. Based on the above, the spillover effect on the entire economy of Thailand will be estimated by input-output analysis.

The research/analysis was conducted according to the schedule below.

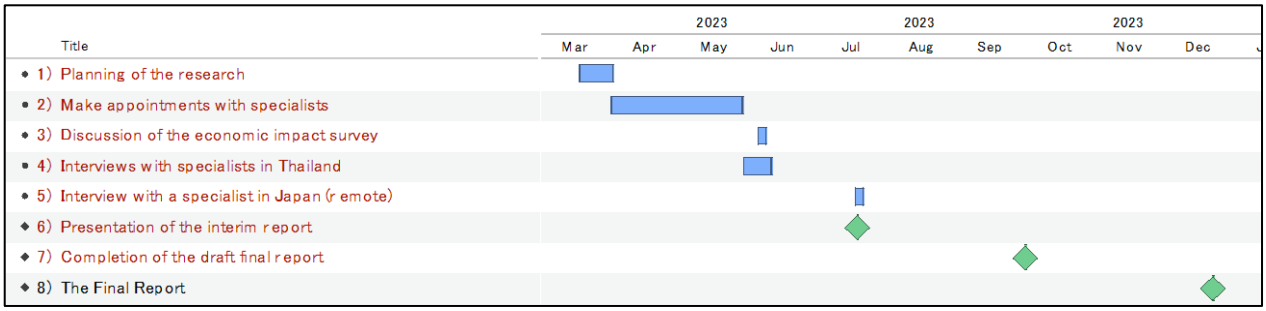


Figure 3-36 Time schedule of the research and analysis regarding economic effects

Preliminary survey and make a list of economic-related keypersons

The survey on "(1) Review of activities related to the utilization of GNSS in Thailand" was conducted as a preliminary survey for this project, and the knowledge obtained there was utilized for the analysis. The list of economic-related key persons was made as below with the assistance and recommendations from Prof. Dr. Chalermchon Satirapod.

Table 3-44 The list of economic-related key persons

Keyperson	Purposes
Asst. Prof. Pacharasut Sujarittanonta of Chulalongkorn University (Economics)	To ask about the methodology of economic effects. Author of the economic impact report provided by Prof. Dr. Chalermchon.
Ms. Kingkamon Lertthitinunkul of NESDC (I-O table)	To ask about input-output tables, which are commonly used to calculate economic effects. NESDC is the government agency creating input-output tables in Thailand.
Asst. Prof. Dr. Soravis Supavetch and Asst. Prof. Dr. Poonphipop Kasemsub of Kasetsart University (Agriculture)	To ask about the economic impact on the agricultural sector, which is one of the industries expected to be greatly affected.
Assoc. Prof. Dr. Saksit Chalermpong, Department of Civil Engineering, Faculty of Engineering and Deputy Director, Transportation Institute, Chulalongkorn University (Transportation)	To ask about the economic impact on the transportation sector, which is one of the industries expected to be greatly affected.
Dr. Damrongrit Niammuad, Deputy Executive Director, GISTDA	To confirm the research content and methodology with who have proposed conducting economic impact research and analysis for this project.
Dr. Vanida Khumnirdpetch, Director, Bureau of Foreign Agricultural Affairs, MOAC (Agriculture)	To ask about the economic impact and the government policy in the agricultural sector, which is one of the industries expected to be greatly affected.

Keyperson	Purposes
Prof. Chattichai Waisurasingha of Khon Kaen University (Construction)	To ask about the economic impact on the construction sector, which is one of the industries expected to be greatly affected.

Discuss with economic-related keypersons

The main points of the discussions are as follows.

Table 3-45 The main points of the discussions

Date	Interviewees	Summary of Interviews on Economic Impacts
29th May	Asst. Prof. Pacharasut Sujarittanonta of Chulalongkorn University (Economics)	• The paper on economic impact provided by Prof. Dr. Chon to JPT is a much earlier paper prepared by Asst. Prof. Pacharasut in 2016. • The paper used a model with I-O analysis. Popularization of technology means that it becomes available to general consumers. Therefore, the idea is to target final demand (demand including general consumers directly or via companies). • With reference to overseas cases, adjustments were made to the economic model, using various parameters (CPI, effective exchange rate, GDP) and the model was applied to Thailand by extrapolation for each industry sector.
29th May	Ms. Kingkamon Lertthitinunkul of NESDC (I-O table)	• The current latest I-O table is the 2015 edition. Originally, they would have been working on creating the 2020 version, but due to the impact of COVID-19, they were unable to obtain sufficient data, so they started creating the 2021 version. It is scheduled to be completed in 2025. • The budget for creating I-O tables may change depending on the intentions of the current government, so if the budget is reduced, adjustments are made by reducing the number of samples to be collected, etc. However, the impact of budget cuts is being minimized by focusing on securing data in the industrial and service sectors, which are subject to large fluctuations. • The Leontief inverse matrix table used for calculating the spillover effects is not open to the public. It is available upon request. (JPT requested Leontief's inverse matrix for 16 sectors and obtained it.)
30th May	Prof. Chalermchon Satirapod of Chulalongkorn University	• Prof. Chalermchon advised that the traveling cost of surveys for resolving land boundary disputes can be reduced up to 80,000 Million Baht. (Detailed explanation for this benefit was provided by DOL.)
31st May	Asst. Prof. Dr. Soravis Supavetch and Asst. Prof. Dr. Poonphipop Kasemsub of Kasetsart University (Agriculture)	• In 2022, they tried RTK using a GNSS receiver, but the receiver settings and operations were difficult to understand. In this situation, they felt that it would be difficult for farmers to use it, let alone for surveyors. • The price of GNSS receiver is important for future widespread use. There is no problem if it costs tens of thousands of baht per unit, but if it costs hundreds of thousands of baht, it will be difficult to popularize it. Looking at the graph of the spread of GNSS guidance systems and straight-line assist for agricultural machinery in Japan, interviewees impression is that they will spread to the same extent in Thailand. • In Thailand, as in Japan, there are few young people who want to work in the agricultural field, and the farmers currently engaged in the field are aging. They have high hopes that the spread of GNSS/CORS technology will help alleviate this labor shortage. However, the actual effects are still unknown, so future research is desired, and they are also looking forward to technical cooperation from Japan. (JPT requested them to introduce research on the effects of labor shortages in the agricultural field.)

Date	Interviewees	Summary of Interviews on Economic Impacts
1st June	Assoc. Prof. Dr. Saksit Chalermpong, Department of Civil Engineering Faculty of Engineering and Deputy Director, Transportation Institute, Chulalongkorn University (Transportation)	• In the tracking systems currently in general use, the accuracy of several meters of GPS is sufficient. If the technology with an accuracy of several tens of centimeters becomes widespread, it could be used for things such as identifying parking areas for bicycles and motorcycles in micro-mobility, and it is conceivable that the system would become even more efficient. Also, if the price of GNSS receivers falls, it will lead to the introduction of auto steering for Share Mobility (buses and ambulances). • As research on the economic aspect, the following items are being carried out: ✓ Consideration of ride-sharing pricing -> Setting appropriate income for riders ✓ Examining the effects of reducing time costs and driving costs (fuel, consumables, and other maintenance and management costs) (JPT asked for the introduction of research examples of economic effects.) • Looking at the current level of technology dissemination, it is hard to imagine that the state of society from a transportation perspective will change significantly within the next five years, but if you think about it in ten years, it will likely change significantly.
2nd June	Dr. Damrongrit Niammuad, Deputy Executive Director, GISTDA	• When evaluating government projects in Thailand, it is necessary to issue a Social Return on Investment (SROI). If the effect can be shown with concrete figures, the explanation of the evaluation results can be persuasive. SROI also serves as explanatory material for future business needs. NCDC is Thailand's basic infrastructure. The results of the research on economic impacts will also serve as a reference when considering future activities related to NCDC. • (For the research on economic impacts, since the research period and human resources invested are extremely limited, JPT would like to hear the opinions of experts in each field after focusing the industrial fields that will be affected. JPT asked for his understanding that JPT will update the existing survey by calculating the approximate value including the spillover effect.) He understands that the contents of this research are extremely limited. In the results of the survey, he would like JPT to describe the input items and models that will be necessary for further detailed surveys in the future as Recommendations for the future. • Thailand's GNSS efforts have just begun, so there is a lack of economic knowledge. He would like to request the dispatch of economic experts.
9th June	Dr. Vanida Khumnirdpetch, Director, Bureau of Foreign Agricultural Affairs, MOAC (Agriculture)	• It remains to be seen how much the improvement in positioning accuracy from a few meters to a few centimeters will affect agriculture. The majority of farmers in Thailand are small-scale and have low incomes. Therefore, regarding the dissemination of GNSS/CORS technology, since the price of receivers is high, the problem is how to inform farmers about the cost-effectiveness and disseminate it, and who will make the investment. • The aging and decreasing number of agricultural workers is a serious problem in Thailand as well. However, with the recent spread of IT technology, there is a tendency for young people to engage in agriculture. Therefore, it is highly anticipated that GNSS/CORS technology will lead to the spread of Smart Agriculture and provide a clue to solving this problem. • MOAC believe that the introduction of GNSS/CORS is an important policy item, but MOAC cannot yet predict its effects, and at this point there are still many unknowns regarding future application development, and MOAC has not yet decided how to do it specifically. It seems that a large amount

Date	Interviewees	Summary of Interviews on Economic Impacts
		of investment will be required.
18th July	Prof. Chattichai Waisurasingha of Khon Kaen University (Construction)	• GNSS/CORS is already in use in Thailand for land surveying. It will also be used for road construction and railway construction. It leads to work efficiency. There is an example of use in railway construction. • GNSS/CORS improves work efficiency. According to an Italian company in Thailand, the cost of road surveying is 20,000 baht/km with the conventional method, but with GNSS, it is 2,000-3,000 baht/km, which can greatly reduce the cost. • When it comes to high-precision construction, railway construction in particular requires precision. According to the policy of the Thai government, the railway construction is expected to increase in the future. The construction of high-speed railways will also increase. Compared to road construction, railway construction requires a larger budget scale. Therefore, it is easy to secure the introduction cost of the new technology for railway construction. On the other hand, road projects need discussions with politicians, and it is not easy to have investment for introduction of new technologies.

The results obtained from the discussions were summarized below. It should be noted that the members in advance that agriculture, construction, and transportation would be the industries that would be significantly affected, and this assumption can be said reasonable.

- It was found that some studies have already been conducted on the economic effects of GNSS/CORS technology diffusion.
- None of the experts interviewed pointed out concerns about our methodology for economic analysis, and the members believe that they have understood it.
- The members received some ideas from the keypersons regarding future applications in each industrial field and pointing out what kind of economic effects there are.
- Unfortunately, none of the keypersons provided specifics on the quantifiable impact (such as monetary value).



Chulalongkorn University (Economics)



NESDC



Kasetsart University



Chulalongkorn University (Transportation)



GISTDA



MOAC

Figure 3-37 Photos of the discussions with the keypersons

Consider economic effects

At the start of the study, it was assumed that an input-output analysis would be conducted for the survey and analysis of economic effects, but as specific figures regarding the direct impact on the industry needed for this analysis could not be obtained, the method was reviewed and existing research in Australia[1] was utilized. This research adopted the CGE (Computable General Equilibrium) model, which is said to be able to calculate direct and indirect economic effects, remove the constraints of input-output analysis, and obtain more sophisticated results.

The results of the above survey in Australia show how much the spread of GNSS/CORS technology will ultimately have in increasing production (excluding intermediate inputs) in each industrial sector. Based on this result, the table below calculates the percentage expansion effect that will ultimately have on the total GDP in Thailand, taking into account differences in industrial structure (differences in the share of each industrial sector) between Australia and Thailand.

[1] The Value of Augmented GNSS in Australia, June 2013 by ACIL Allen Consulting

Table 3-46 Production value expansion effect in Thailand (relative to GDP)

Industrial Sector	Production increase	
	Low case	High case
Crop	0.578%	1.050%
Construction	0.008%	0.013%
Land transport	0.014%	0.025%
Water transport	0.004%	0.006%
Air transport	0.002%	0.002%
Total	0.605%	1.095%

Note: It is assumed that GNSS/CORS technology will spread in Thailand at a level equivalent to the level of GNSS/CORS technology expected to spread in Australia in 2020.

Source: Calculated by JPT based on the results of The Value of Augmented GNSS in Australia, June 2013 by ACIL Allen.

The results of applying the above production value expansion effect to Thailand are as follows. If GNSS/CORS technology spreads to the three industrial sectors of agriculture, construction, and transportation to the extent expected in Australia in 2020, the production value of the entire Thai economy (excluding intermediate inputs) will increase in the low case by 0.6% (For example, as the GDP in 2021 is approximately 16,166.6 billion baht, it will increase by 97,829 million baht), and in high case, it will increase by 1.1% (also 177,081 million baht).

Publicize the survey and research results

The results of the survey and analysis regarding the economic effects were discussed with TPT members and it was decided that they would not be presented at seminars, etc. in order to avoid misunderstandings caused by inadvertently citing specific figures such as increases in production value.

3) Technology transfer

Technology transfer was conducted 4 times as shown below.

Table 3-47 Technology transfer session regarding Activity2-5

NO.	Date	Contents	Target	# of participants
1	8th Dec 2022	Explanation and Q&A regarding web-based market research	GISTDA members	3
2	9th Dec 2022	Explanation on creating questionnaires for questionnaire surveys, extraction of problems (brainstorming format)	GISTDA members	2
3	6th Jun 2023	Analyzing method for questionnaire survey results	GISTDA members	2
4	7th Jun 2023	Economic impact analysis method	GISTDA members	1




Figure 3-38 Photos of the technology transfer sessions for market research and economic impact analysis

3.7.3. Achievements

All the activities of Output2 were completed as shown on Table 3-48.

Table 3-48 Evaluation method for each activity related to Output2 and results

Activities	NO.	Evaluation item	Indicator	Result
2-1	1	Utilization promotion activity plan	A plan is created	Achieved - The promotion activies were conducted based on the plan.
	2	Use case reports of NCDC data	Number of reports	Achieved - 13 (5 from TPT and 8 from the pilot projects) of use case leaflets were created and posted on the NCDC website.
	3	Establishment of a framework (e.g., council)	The framework (council) is established	Achieved - The NCDC user meeting was held instead.
2-2	1	Implementation of JICA Pilot Project	Number of pilot projects	Achieved - 8 pilot projects were completed.
	2	Feedback to NCDC	Number of feedback items from the companies	Achieved - 8 feedback
	3	JICA Pilot Project plan	Pilot project plan is created	Achieved - The pilot project was conducted based on the plan
	4	JICA Pilot Project application guideline	Pilot project application guideline	Achieved - 8 pilot project were selected based on the guideline
2-3	1	Participants of each seminar	Number of participants including participants online	1st seminar: 100+ 2nd seminar: approx. 40 3rd seminar: 122
	2	Participants of GNSS	Number of participants in	Approx.40

Activities	NO.	Evaluation item	Indicator	Result
		survey trial	GNSS survey trial	
	3	Business matching	Number of offered occasions for business matching	3 face-to-face meetings
2-4	1	Responses to a questionnaire	Full understanding of NCDC and distributed data Technical exchange between participating countries is carried out Satisfied with attending the workshop	Achieved - 11 responces showing full understanding of NCDC and satisfactions on the regional workshop
2-5	1	Market research plan	A plan is created	Achieved - The research was conducted based on the plan
	2	Market research report	A report is created	Achieved - The report is attached (Appendix 5)
	3	Economic analysis consideration report	A report is created	Achieved - The report is attached (Appendix 6)
Overall	2	NCDC registered users	Number of NCDC registered users	2,123 as of Dec 2023

4. Evaluation of the project

4.1. Achievement level of project purpose

Contrary to the initial assumption at the beginning of the project, all activities were carried out using the interim NCDC. However, as described below, the indicators for Output1 and Output2 were achieved, and since the number of registered users of NCDC, which is the indicator for the project purpose, is on an increasing trend, the members consider that the project purpose has been achieved.

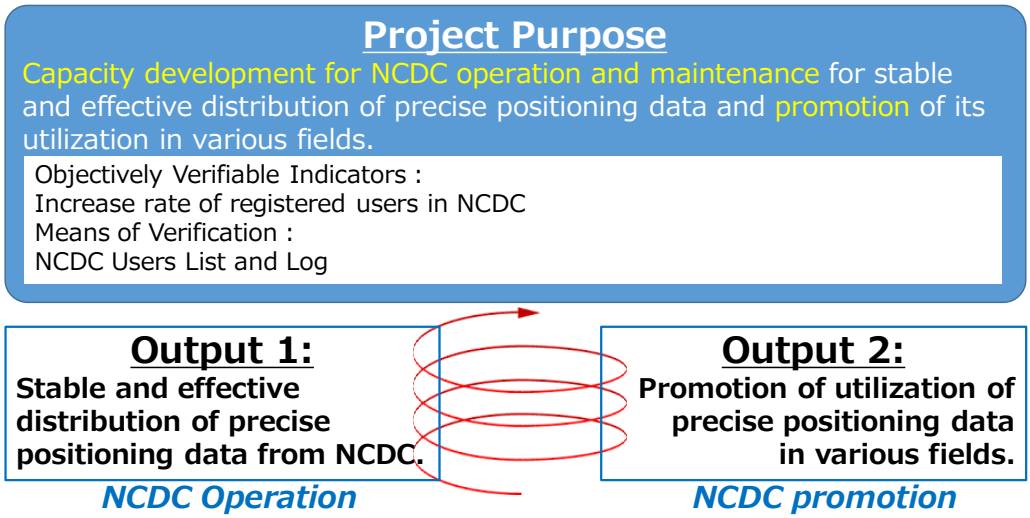


Figure 4-1 The project purpose and 2 outputs

(1) Achievement level of Output1

The indicators and means of verification for Output1 (Stable and effective distribution of precise positioning data from NCDC) are as follows.

Indicators: The number of troubles related to the distribution of precise positioning data from NCDC and required time for the troubleshooting
Means of verification: Acquisition and failure rate of precise positioning data

Among the indicators, “time required for resolution” is difficult to clearly define, and since there is no specific record of this indicator except for the pilot projects, it was decided at the 6th Joint WG on NCDC meeting held in February 2023 to use the “number of complaints received from NCDC registered users” as an indicator.

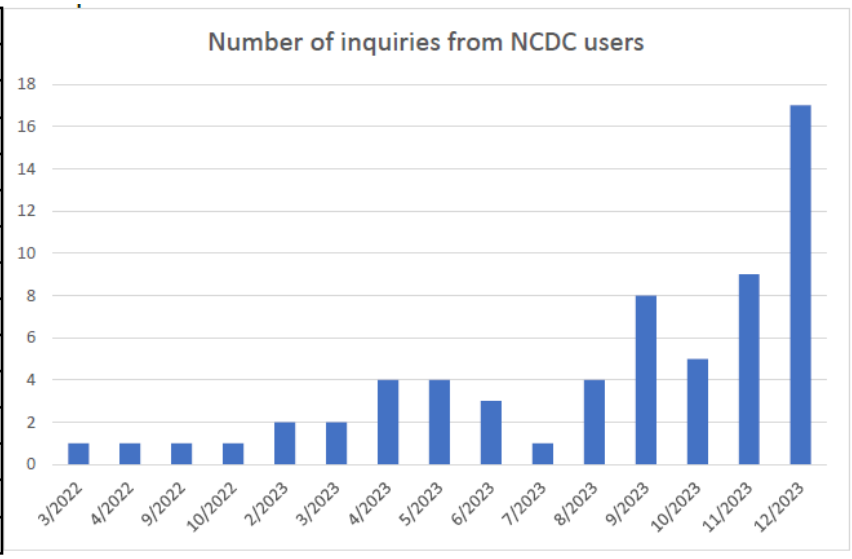
NCDC has been recording the inquiries received by phone or email from registered users since the service was launched in March 2022. In response to requests from the companies who performed the pilot projects, a help desk on LINE was also established in November 2023.

Table 4-1 summarizes the number of inquiries received per month based on the logs stored at NCDC. The number of inquiries was small at the beginning of the operation, but now exceeds 10 per month, indicating that NCDC staff members are responding well to users as the use of NCDC becomes popular and the number of users increases.

According to the staff member in charge, most of the inquiries are about how to use the NCDC's correction data rather than complaints, and there are not many inquiries from the same person afterwards. This suggests that there are few users who have major problems in using the NCDC.

Table 4-1 Number of inquiries from users to NCDC (source: RTSD)

3/2022	1
4/2022	1
9/2022	1
10/2022	1
2/2023	2
3/2023	2
4/2023	4
5/2023	4
6/2023	3
7/2023	1
8/2023	4
9/2023	8
10/2023	5
11/2023	9
12/2023	17



On the other hand, the indicator verification method is "Acquisition and failure rate of precise positioning data". At the Joint WG on NCDC meeting in February 2023, this was decided to be monitored by "monthly average acquisition rate of CORS observation data (RINEX format) provided from NCDC", and a numerical target of "95% or more" was set. Although precise positioning data strictly refers to the correction data generated from CORS observation data, not the observation data itself, it is considered to be an appropriate verification method because the acquisition rate of observation data provided from NCDC also drops when a problem occurs at CORS or NCDC. A similar indicator is used as a Key Performance Indicator (KPI) for CORS in Japan, and GSI has set 99.5% as its numerical target. Figure 4-2 shows the results reported by RTSD at monthly Output1 meetings and others.

At the end of the project, the target of 95% has been met, and it can be said that Output1 (i.e., stable and effective delivery of precise positioning data) has been achieved.

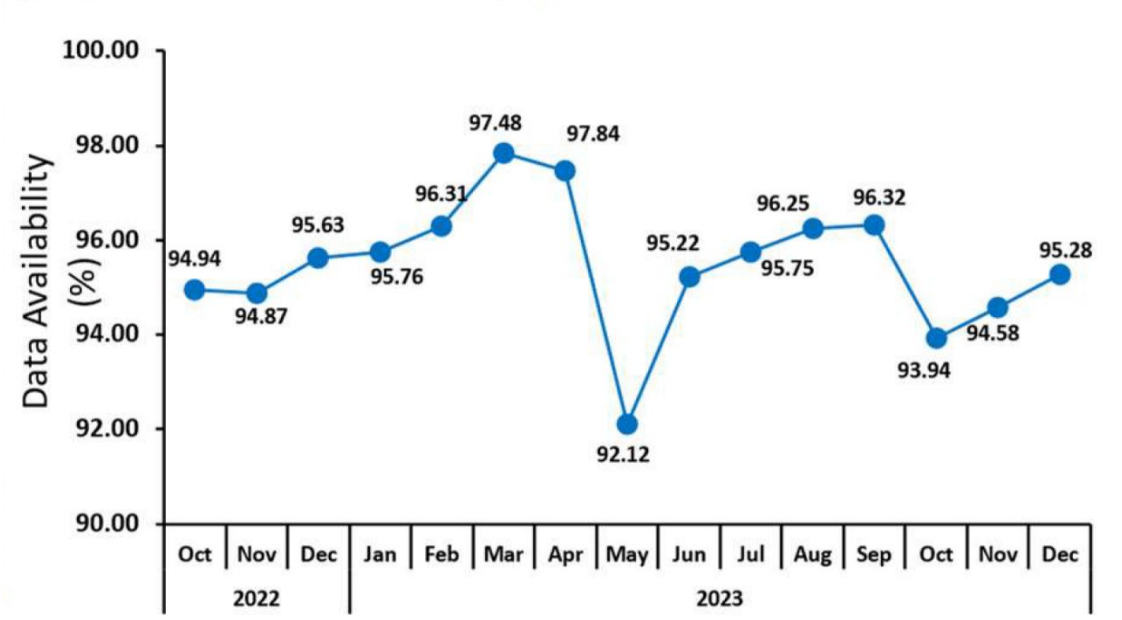


Figure 4-2 The acquisition rate of observation data (RINEX) for CORS in Thailand provided from NCDC. Generally, it is above the target of 95%. The drop to 92% in May 2023 occurred due to overhaul of NCDC server carried out from May 8 to 15, 2023. At that time, RTSD alerted users on the NCDC website.

(2) Achievement level of Output2

The indicators and means of verification for Output2 (promotion of utilization of precise positioning data in various fields) are as follows.

Indicators: The number of companies or organizations utilizing the precise positioning data from NCDC Means of verification: The number of registered users

TPT and JPT discussed setting of the specific target values and concluded as follows, which was approved at the 6th Joint WG on NCDC meeting held in February 2023.

- "The number of companies or organizations utilizing the precise positioning data from NCDC" shall be verified from "The number of registered users" is one of the KPIs which is monitored every month and the result from the web questionnaire which is going to be conducted.
- Since NCDC is still on "the introduction stage of the service life cycle", TPT and JPT found it unreasonable to set the target value during the project and agreed that our target will be to make steady increase and have as many registered uses as possible until the end of the project.

Although no target was set for the number of registered users as mentioned above, TPT and JPT made efforts to raise awareness of NCDC and acquire users through the events inside and outside the project during the project period. As a result, as shown in Figure 4-3, the number of registered users as of December 2023 had doubled to 2,123 in a year and a half since June 2022, when this indicator was set as a KPI. Therefore,

it can be said that Output2 (promotion of utilization of precise positioning data in various fields) has been achieved.

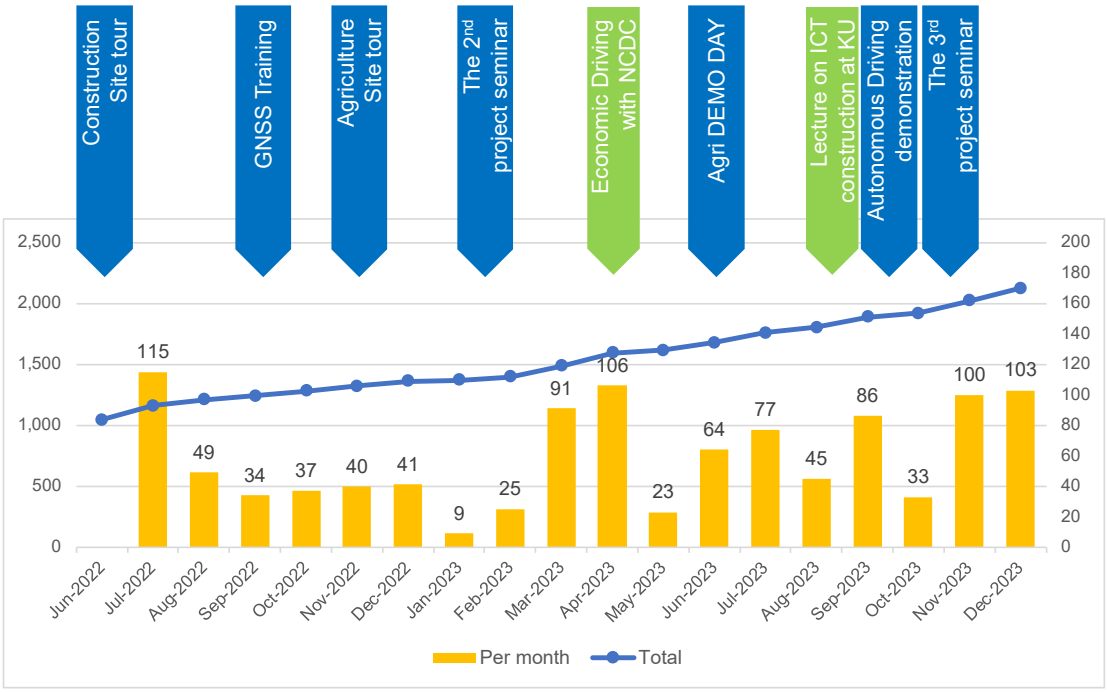


Figure 4-3 The numbers of registered users of NCDC

4.2. Self-evaluation based on the 6 DAC Evaluation Criteria by the project members

The project members evaluated the project results based on the 6 DAC Evaluation Criteria, the international ODA evaluation perspective of the Organization for Economic Co-operation and Development/Development Assistance Committee (OECD-DAC), as follows.

■ Relevance

The NCDC's precise positioning services were launched through close collaboration between 5 CORS-holding organizations in Thailand, which assist businesses that require precise positioning, such as surveying and mapping, smart agriculture, ICT construction and autonomous vehicle driving. This contributes to the realization of Thailand 4.0 and can be regarded as highly relevant.

■ Coherence

Five-Year Joint Action Plan on Japan-Thailand Strategic Economic Partnership (2022-2026) includes the cooperation in the field of the GNSS. In addition, NCDC is a national infrastructure to realize Global Geodetic Reference Frame in Thailand recommended by the United Nations General Assembly in 2015. Moreover, this project is in line with SDG Goal 9 “to build resilient infrastructure, promote sustainable industrialization and foster innovation”.

As described above, the project is in line with the cooperation policy and international initiatives of Japan

and Thailand.

■ Effectiveness

NCDC service is operational and open to the public since March 2022 with the acquisition rate of precise positioning data above 95% as of December 2023. The number of registered users as of December 2023 has doubled to 2,123 in the recent 1.5 year. In the meantime, the 8 pilot projects using NCDC service were implemented in the fields of survey, construction, agriculture, and autonomous vehicle driving, which strongly showed the benefits of use of NCDC to the public.

■ Impact

NCDC will contribute to implementation of smart agriculture and ICT construction, which will be one of the counter measures to the declining birthrate and aging population in Thailand. On the other hand, it has no adverse effects on human rights, gender, or the environment.

■ Efficiency

Although JPT members' visits to Thailand and trainings in Japan were later than initially planned due to the impact of COVID-19, the project was implemented without increasing the project duration and cost through effective use of online discussions as well as technology transfer sessions.

■ Sustainability

NCDC staffs' capacity and collaboration mindset of the 5 agencies obtained in this project will enable stable operation of NCDC provided that Thai Government will secure budget allocation for CORS and NCDC.

4.3. Other evaluations

■ JPT and GISTDA members awarded "Honorary Aerial Photo Navigator Badge" from RTSD (October 2022)
https://www.jica.go.jp/Resource/project/Thailand/031/news/20221122.html

In October 2022, 6 JPT members and 2 GISTDA members received the "Honorary Aerial Photo Navigator Badge" from RTSD. This badge is awarded annually to those who have provided outstanding cooperation and support to RTSD's surveying projects. The JPT and GISTDA members received the badge in recognition of their activities since November 2020 through the project to provide technical support for the stable operation of NCDC and to promote its utilization.



Figure 4-4 Award of “Honorary Aerial Photo Navigator Badge”

■ The project received “International Cooperation Award” at Geo Activity Contest hosted by GSI (November 2023)

The Geo Activity Contest is an event that aims to promote the use of geospatial information by fostering and disseminating good practices, creating new services, etc., through the introduction of various "initiatives," "ideas," and "services" related to the utilization of geospatial information through exhibitions and presentations, and through interaction with participants and visitors. (Adapted from 'https://www.g-expo.jp/2023/geocon/')

Pasco Corporation and JICA jointly applied to the 2023 contest as the "TIGORS Project Team" with the concept of "contributing to the development of society through geospatial information by utilizing Japan's long-cultivated CORS technology overseas," and received the "International Cooperation Award" after the screening process.





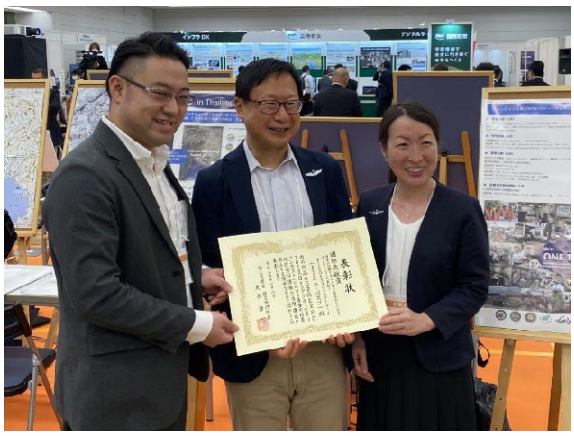




Figure 4-5 "International Cooperation Award" in Geo Activity Contest

5. Towards achievement of the overall goal

5.1. Issues and countermeasures

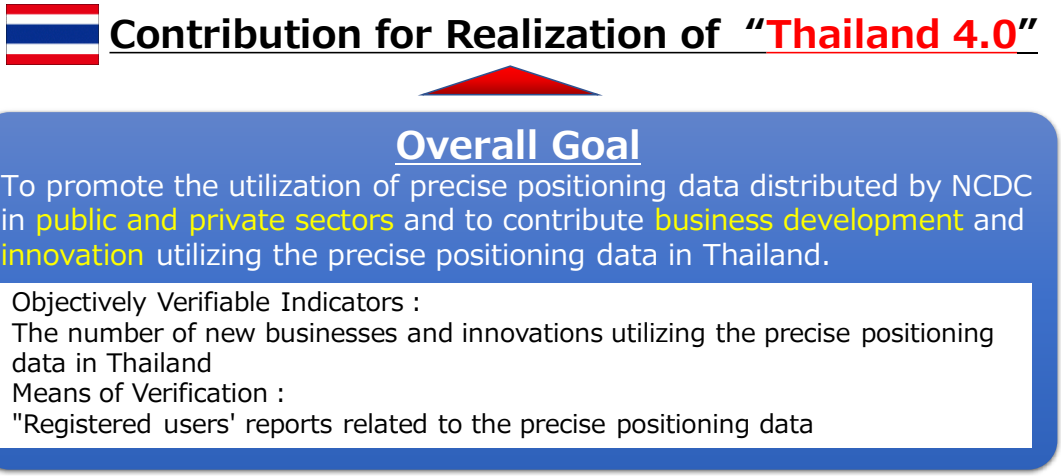


Figure 5-1 Overall goal of the project

As reported above, this project has achieved the expected outputs by effectively combining online and on-site activities. However, there are issues that have emerged as the project has progressed. These issues, which need to be resolved in order to achieve the overall project goal, and the measures to address them are described below.

Issue 1: Issues related to the stability of precise positioning services and NCDC's processing capacity

NCDC launched its precise positioning service in March 2022, and the pilot projects using the service have been implemented smoothly. However, according to monitoring results, centimeter-level accuracy cannot be ensured 24 hours a day, 7 days a week.

(i) Service Instability

GNSS radio waves are delayed as they pass through the Earth's ionosphere, but this effect can usually be compensated by using nearby CORS. However, in low-latitude areas such as Thailand, it has been found that even with the use of nearby CORS, positioning accuracy can be degraded for several hours on days when the ionosphere is disturbed by active solar activity. Since solar activity will reach its next peak around 2025, this will be a serious obstacle to the utilization of NCDC. In order to provide appropriate advice to users, it is necessary to transfer technology related to ionospheric monitoring and impact mitigation measures using CORS networks.

(ii) Constraints on NCDC's processing capacity

The processing capacity of the interim NCDC, which was developed by the Thai side under the austerity budget associated with the COVID-19, is limited, and it is not possible to provide services using all the CORS installed in Thailand. This also leads to service instability. In light of the settlement of the COVID-19, the Thai side has requested a budget for the expansion of NCDC, and it is necessary to transfer technology related to the formulation of its specifications and system tuning after the development of full-scale NCDC.

(iii) Problems with the environment surrounding each CORS

The quality of observation data is changing due to the aging of equipment and changes in the environment at each CORS station, leading to service instability. It is necessary to thoroughly control the quality of observation data, which is the basis of precise positioning services, such as the presence or absence of radio wave interference.

Issue 2: Issues related to raising the visibility of NCDC and expanding the number of users

Based on the activity plan of promotion utilization of NCDC formulated in Activity 2-1, efforts have been made to improve the recognition of NCDC and increase the number of users by communicating the content and benefits of the services provided by NCDC through the websites, leaflets, seminars, pilot project site tours, etc. This has contributed to more than 23,000 accesses to the NCDC website (as of December 2023) and the number of registered users (2,123 users, as of December 2023). However, NCDC has not yet reached all of targets, in other words its potential users targets, as there is still a wide range of both public and private sectors to which the NCDC should appeal. In addition, the following issues were identified through the implementation of the utilization promotion activities.

- It is difficult to overcome the technical concerns of potential users and to encourage them to "actually use" the NCDC by providing only documents and simple explanations.
- In order for new technologies to be implemented in Thailand, it is necessary to show the expected benefits based on actual cases.
- There are potential users who have a need for NCDC but have not yet used it because they cannot afford expensive GNSS receivers or because they lack the technical knowledge and ability.
- Governmental support and promotion (e.g., formulation of guidelines) is needed, as has been done in Japan.

In the future, it will be necessary to further increase awareness and expand the number of users in cooperation with Thai government agencies, experts, and Japanese and Thai companies with experience in GNSS utilization that are closely related to the utilization of NCDC, while addressing the above issues.

Issue 3: Issues related to GNSS surveying instruments used by NCDC users

The NCDC's precise positioning service is realized by providing correction data generated from the surrounding CORS network to observation data acquired by users' GNSS surveying instruments. Therefore, proper use of the service requires that the user's equipment is in good working order. In Japan, there is an equipment certification system whereby certification bodies registered at GSI inspect and endorse equipment used in official surveys.

Currently, there is no such certification system in Thailand, and this is not an environment where NCDC users can use GNSS surveying equipment with confidence. TPT members learned about the Japanese certification system through training in Japan, and is expected to establish such a system in the NCDC as a measure to promote its use in the future.

5.2. Recommendations from JPT to TPT

As mentioned above, the goals set for this project have mostly been achieved through TPT's diligent efforts over the 3.5 years of the project. However, from the point of view of customers who pay for precise positioning services in Japan, "stable and effective distribution of precise positioning data (Ouput1)" has not been completed in Thailand as technical issues, the fact that observation data are lost albeit slightly somewhere in the NCDC network, that there are concerns about the effects of radio interference to the CORS located in urban areas, and that it is sometimes impossible to survey at night due to ionospheric disturbances caused by increased solar activity, still remain. The “promotion of utilization of precise positioning data in various fields (Output2)” is also a halfway point, as it is believed that there are apparently a substantial number of potential users who have yet to be approached.

Now that full-fledged social implementation of NCDC has started with the implementation of this project, the importance of stable operation of NCDC and promotion of its utilization has increased even further: the NCDC, as an important national infrastructure, must always continue to provide high quality services and develop according to the needs of its users. Therefore, the following recommendations are made in view of the sustainability and development of NCDC after this project has been completed.

Commitment of the Thai Government

Firstly, it is important to note the continued commitment of the Thai Government to the NCDC. Based on the considerations and decisions made by the National GIS Board and the GNSS Sub-Committee, all the necessary budget and human resources for the operation and maintenance of the CORS and data centres comprising the NCDC and the widespread use of precise positioning data must be properly allocated. The earliest possible realization of a full-scale NCDC is also required in order to improve stability.

Continued spiral-up of NCDC

The next important thing is to continue the NCDC spiral-up activities fostered in the project: it is important not to stop monitoring, promoting utilization, and improving the precise positioning services through close collaboration among the TPT agencies, and to update the maintenance manual based on the results of daily operations and user responses. The monitoring of KPIs and the progress of improvement activities, which were carried out monthly in the second half of the project, should also be continued with the cooperation among TPT members. As long as NCDC and its users continue to exist, these efforts to solve operational issues and promote utilization will probably never end. However, TPT members will find that the NCDC's service standards are improving as it spirals up in operation and utilization promotion, and will eventually see Thailand 4.0 realized, supported by the world's highest standard of precise positioning environment.

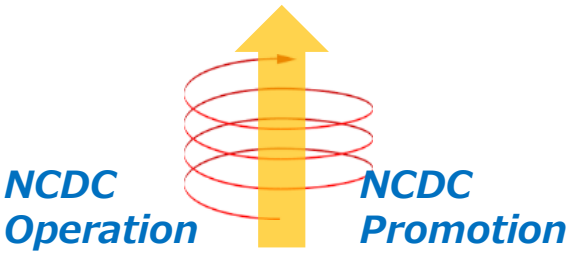


Figure 5-2 Spiral-up of NCDC

6. Ideas applied and lessons learned during project implementation

■ What JPT tried to do and what JPT tried to keep in mind

At the start of the project, due to travel restrictions imposed by the expansion of COVID-19, JPT was forced to use an online conference tool (Teams) for discussions and technology transfer with TPT. At the beginning, there were some problems, such as a delay of the meeting waiting for members who have trouble in connection, and a switch to another tool (Zoom) when the Teams system went down. However, as both parties became familiar with the online conferencing, the advantages of online conferencing (e.g., easy listening, easy viewing of screen-shared documents, and easy recording of meetings) were demonstrated, and high-quality information exchange was possible. In addition, 3 types of meetings were held online on a regular monthly basis, which kept both parties motivated and able to continue working on the project. Because of these advantages, online meetings are continued at the same frequency even after travel resumed and face-to-face meetings on-site became possible, contributing to the formation of a sense of "one team" between the Thai and Japanese sides.



Figure 6-1 TIGORS One Team

This project included the technical activity of operating NCDC (Output1) and the social activity of promoting NCDC (Output2), and two relatively independent teams for each activity were established. Although the two teams included Japanese and Thai members each, as the project progressed, there was not only a sense of Japan and Thailand side, but also a sense of the provider side (the agencies responsible of CORS (i.e. RTSD, DOL, and etc.), Japanese GNSS/CORS experts (i.e. members from JPT), and outsourcing

agents) and users side (the agencies in charge of PR (i.e. GISTDA and others), Japanese consultants (i.e. members from JPT), and the companies who performed the pilot projects). The project was able to move forward with both teams' close collaboration while they were stimulated by each other's activities as if in competition. This spiral-up structure (Figure 1-1) which was not a simple model of implementing Output2 using the NCDC released in Output1, but feedback from Output2 improves Output1 and both teams aim even higher, seems to have been effective. The concept of the spiral-up structure was shared by all members as a basic policy for project implementation, and then constantly emphasized during the project. Of course, for the activities inviting participants from outside the project such as GNSS training, Agri DEMO DAY, the final seminar and user meetings, the members shared roles across teams and worked together as one team.

■ Lessons Learned

One of the utilization promotion activities, the provision of GNSS training for beginners and GNSS workshops, was intended to be provided once every 3 to 4 months when the plan was formulated during the 1st term, but as a result, both were made once only. The reason for this was that the initial idea to use GISTDA's facilities the same as the first training and workshop became difficult, and alternative ways of conducting the training were considered but necessary arrangements could not be made in time. The alternative was to invite corporate sponsors for the training and ask them to provide refreshments and water for the participants, but the other project events (Agri DEMO DAY, regional workshops, final seminar, and user meeting) were taking place at the same time and these events had to be prioritized. Therefore, the GNSS training and GNSS workshops could not be provided again during the project period. In the future, it would be desirable to have as many plans as possible for securing personnel and budget from the initial stage, and to start coordination with related parties (e.g. within the 5 organizations and with potential sponsors) in a timely manner when it becomes clear that reconsideration and rearrangements of the plan is needed.

7. Others

7.1. Subcontracting work

JPT (PASCO CORPORATION) made contracts with the companies who performed the 8 selected pilot projects (activity [2-2]) and confirmed that all work has been successfully completed by the end of December 2023 and reports from each project had been submitted.

7.2. Procurement of equipment

JPT (PASCO Corporation) procured the items listed in Table 7-1 and hand them over to TPT. The items listed in Table 7-2 were not procured because it was found that TPT had enough equipment for these.

Table 7-1 Equipment procured and handed over

Equipment	Quantity	Specification	Procurement location	Applications, etc.	Remarks
Low-cost NSS receiver	10 receivers	Dual-Frequency RTK GNSS with centimeter accuracy	Japan	Used at a GNSS survey trial	
Peripheral equipment for the Low-cost GNSS receivers	10 sets	Android smartphone, battery, storage case, leveling instrument, pole	Thai	Same as above	
GNSS receiver for surveying	1 set	GPS, GLONASS, Galileo, QZSS compatible, 452 channels	Thai	Used for accuracy evaluation and troubleshooting of delivered data	Compatible with both fixed and mobile stations
GNSS analysis software	1 license	Precision analysis for long baseline	Third country (Switzerland)	Long baseline analysis	
PC for analysis processing	1 set	Intel i7, 16GB RAM, 512GB SSD	Thai	Long baseline analysis processing	
Security software	1 license (4 years)	Antivirus, real-time protection, GPS tracking, data erasure	Thai	Daily information security measures	

Table 7-2 Equipment not procured

Equipment	Quantity	Specification	Procurement location	Applications, etc.	Remarks
Projector	1 set	Full HD, 3000 lumens	Thai	For showing presentation materials during meetings	
Laser pointer	1 set	Green Laser, slide control	Thai	For pointing at presentation materials during meeting	
Web conferencing	1 set	Intel i5, 16GB RAM, 512GB SSD, 14inch	Thai	Web conference, web broadcasting,	Including MS-Office

Equipment	Quantity	Specification	Procurement location	Applications, etc.	Remarks
PC				document creation	
Microphone/speaker	1 set	360° omnidirectional microphone, Bluetooth	Thai	Conducting a web conference	
Camera for web broadcasting	1 set	HD 50 Mbps, OPTICAL ZOOM	Thai	Web broadcasting and recording of seminars, etc.	Including tripod
Video capture box	1 set	USB3.0, Bus Power, FullHD, 60p, HDMI	Thai	Web broadcasting	
Security software	1 license (4 years)	Antivirus, real-time protection, GPS tracking, data erasure	Thai	Daily information security measures	For the Web conferencing PC

Appendix

1) Draft NCDC Service Guidelines (English translation for reference)
2) NCDC Manual Ver. 5 Revised (in Thai)
3) Pilot Project Implementation Report (in English or in Thai and English)
4) Regional Workshop Summary (in English)
5) Market Research Report (in English)
6) Research Report on Economic Impact of Business Utilizing GNSS/CORS (in English)
7) Project Monitoring Sheet (Project Design Matrix and Plan of Operation) (in English)

1) Draft NCDC Service Guidelines (English translation for reference)

(Draft) Terms and Conditions of the National CORS Data Center's Service Charges
B.E. ……..

In order to make the provided CORS data from each government agency have the integrated coordinates through the National CORS Data Center, to mutually use the data for the national development and management, and to provide the service efficiently, by the authority of the Office of the Prime Minister on the National Geospatial Committee Order 2015, the Terms and Conditions the National CORS Data Center's Service Charges was considered as follows.

1. In this Terms and Conditions

"Global Navigation Satellite System (GNSS)" refers to a satellite navigation system using an electronic device as a receiver to perform positional processing at the point where the receiver is located.

"Real Time Kinematics: RTK" refers to a technique to receive kinetic satellite signals and obtaining the coordinates at the time of survey in real-time from the survey network system with kinetic satellite.

"Continuously Operating Reference Stations; CORS" refers to the survey stations that continuously store the Global Navigation Satellite System (GNSS) data and continuously link data to the CORS stations.

"Providing services" refers to the services provided from Continuously Operating Reference Stations (CORS) to the government agencies and general users either with or without charge according to the Terms and Conditions that the participating agencies have jointly established.

"National CORS Data Center" refers to the data center that tracks, collects, links, stores, processes and disseminates data as services for users.

"Government agencies" refers to ministries, bureaus, departments, offices or government agencies known otherwise and having the status of department, provincial government, local government, state enterprise, educational institution, organization or public organization established by an act or royal decree, and it shall include other government agencies that have royal decree defining as state agencies.

"Non-governmental users" refers to the private sector and people who receive the services of the National CORS Data Center.

"Service provider" refers to the agency who owns the Continuously Operating Reference Stations (CORS) and perform data streaming to the National CORS Data Center for the provision of integrated services.

"Users" refers to government agencies, private sector and people who receive the services of the National CORS Data Center.

"National CORS Data Center Service System" refers to CORS data services providing system through website platform.

2. Conditions of Services Provision

Users can take data retrieved from CORS station to use in their missions such as surveying or further analysis. However, users' activity must not cause any damages to the service provider, and must refer the source of data to the service provider in the work that users have developed or created, in order to identify the source of the information. Also, to copying information to third parties or other entities is strictly prohibited.

3. Scope of Services

3.1 Service provider can provide services from CORS stations to users through National CORS Data Center as follows.

3.1.1 Surveying service by Network Real Time Kinematics typed GNSS system

3.1.2 Satellite navigation data service for Continuously Operating Reference Stations (CORS) in RINEX file format

3.1.3 Coordinates Post processing service

๓.๒ Accuracy levels of provided data for each usage are as follows.

Accuracy	Usage
1 centimeter or less	Tracking the tectonic movement and faults
1 – 10 centimeters	Surveying (Ground survey, laser surveying, MMS), Smart Agriculture (precision agriculture, autonomous operation of agricultural machinery), Construction (i-Construction,3D surveying, construction machine control), Autonomous driving vehicle
10 centimeters – 1 meter	Mapping for autonomous driving vehicle
1 meter above	Satellite-based Augmentation System (SBAS), Maritime Surveying, Buoy Tracking, Public Transport Management

4. Service Request Process

In order to use CORS data from National CORS Data Center, the following steps are required.

4.1 Users log in to the services providing system of National CORS Data Center through online system

4.2 Users submit the request form by specifying user's details such as address, usage type, and must accept the End User License Agreement (EULA) or Terms and Conditions of Services

4.3 In case the service charge is required, users must make payment of the service charge, and attach the proof of payment into the system.

๔.๔ Service provider or system administrator review and consider the request, and when the service provider or the system administrator approve, users will be consequently notified of the approval result.

5. Terms of Use

5.1 Users shall provide their information such as the correct, true and up-to-date personal identification or contact details to the National CORS Data Center as a part of the service registration process or the continued use of the service.

5.2 Users shall be attentive when downloading large amounts of data for collection purposes, in order to avoid excessive traffic.

5.3 Users shall use the services for the purposes permitted by the provisions of National CORS Data Center, and must not violate laws, rules, regulations, or generally accepted practices.

5.4 Users shall not access or attempt to access to any services by using other methods including the automated access (Script), unless the users are clearly authorized by National CORS Data Center to do so.

5.5 Users shall not do or participate in interrupting or interfering the service of National CORS Data Center, including the server and network connected to the service.

5.6 Users shall not copy, duplicate, reproduce, sell, trade or re-sell the service for any purpose, unless users have clearly obtained permission from National CORS Data Center to do so.

5.7 Users shall have responsibility to maintain the confidentiality of the password associated with any accounts used to access the services.

5.8 In case there are any damages resulting from the violation of these terms, the user shall solely responsible for the affected person, including the National CORS Data Center.

5.9 If the user has used the information and fails to comply to these terms and conditions, the service provider can take legal action as necessary, o cease the data provision from here on.

6. Disclaimer

The National CORS Data Center shall not be liable for any damages of the users occurred from the quality or the loss of data received from the National CORS Data Center, including damages, losses, or expenses incurred, either directly or indirectly, as a result or a consequence of the user accessing the service, or damages, losses, or expenses caused by operation failure, mistake, omission, interruption, defect, system imperfection, or computer virus, even though the National CORS Data Center may be notified that damages may be occurred. In addition, the National CORS Data Center shall not be liable to website users or individuals for any claims regarding the website or any contents, including any decisions or actions caused by the user's trust in the contents, or in either direct or indirect damages that may occur. The user acknowledges and recognizes that the National CORS Data Center shall not be liable for any actions of the user.

7. Eligibility of services and the classification of confidentiality/security

7.1 The National CORS Data Center or the licensors have the sole legal rights to own all rights, including the intellectual property rights contained in the services created by the National CORS Data Center or the licensors, whether those rights are registered or not.

7.2 The classification of the confidentiality and the security of CORS data services through the National CORS Data Center is not considered as classified (Unclassified), except the National CORS Data Center or the licensors consider the service may affect the national security or the national interests, the service shall be suspended on a specific case basis.

7.3 The user must not disclose confidential information that the National CORS Data Center imposes without prior written consent.

7.4 The user must not use a trade name, trademark, service mark, logo, or domain name of the National CORS Data Center without prior written consent.

8. Service Charges

8.1 The CORS data services provided to the government agencies through the National CORS Data Center are free of charge.

8.2 The service charges rate of the CORS data services provided to the non-governmental agencies through the National CORS Data Center shall be in accordance with the announcement of the National Geospatial Committee.

9. Transitional provision

9.1 The administrator of the National CORS Data Center is designated as the coordinator until any changes are considered.

9.2 If there are any changes in services or the eligibility for services, it shall be processed under the consideration of the National Geospatial Committee.

10. The Governing Law

Interpretation and enforcement of this terms and conditions must be complied with the Laws of Thailand.

Revised: December 4th, 2020

2) NCDC Manual Ver. 5 Revised (in Thai)



คู่มือการปฏิบัติงาน

ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ

(National CORS Data Center)



สารบัญ

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สารบัญตาราง จ
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1. ประวัติงานสำรวจกรมแผนที่ทหาร (History of surveying RTSD[1])

1.1 งานยีออเดซี

การสำรวจวางโครงข่ายหมุดหลักฐานทางราบแห่งชาติ

ค่าพิกัดทางราบนั้นใช้อ้างอิงในหลากหลาขวัตถุประสงค์ และมีความสำคัญที่สุดในการอ้างอิงค่าพิกัด เช่น การอ้างอิงกรรมสิทธิ์ถือครองที่ดิน การอ้างอิงแนวเขตแดนของประเทศ เป็นต้น ในอดีตที่ผ่านมา ประเทศไทย ได้มีการโยงค่าพิกัดทางราบมาตั้งแต่สมัยรัชกาลที่ 5 โดยใช้ค่าพิกัดจากการขยายโครงข่ายสามเหลี่ยมใหญ่มาจากภูเขากะเลียนเปอร์ประเทศอินเดีย ผ่านประเทศพม่าเข้ามาในประเทศไทย และมีการวิวัฒนาการในวิธีการรังวัดเรื่อยมา เริ่มตั้งแต่ การรังวัดโดยการสามเหลี่ยมชั้นที่ 1 การวงรอบชั้นที่ 1 การรังวัดสัญญาณจากคาวเทียมระบบ ดอเปลอร์ (Doppler หรือเรียกอีกชื่อหนึ่งว่าระบบทรานสิท (Transit)จนในปัจจุบัน ใช้วิธีการรังวัดสัญญาณจากดาวเทียม NAVSTAR GPS (Navigation Satellite Timing And Ranging Global Positioning System) หรือเรียกสั้นๆว่า ดาวเทียม GPS ซึ่งเป็นการรังวัดโดยใช้ข้อมูลจากดาวเทียมที่ อ้างอิงกับระบบวงโคจรของคาวเทียมและจุดศูนย์กลางของโลก

ค่าพิกัดทางราบนั้น มีความเกี่ยวข้องกับพื้นหลักฐานอ้างอิงมาก การพัฒนาพื้นหลักฐานอ้างอิงในประเทศไทยนั้น มีการวิวัฒนาการดังนี้

- การรังวัดขยายโครงข่ายสามเหลี่ยม เป็นวิธีการหาค่าพิกัดโดยอาศัยมุมของแต่ละหมุดในโครงข่ายเพื่อคำนวณหาค่าพิกัด หมุดหลักฐานของโครงข่ายสามเหลี่ยม มักอยู่บนที่สูงเพื่อให้สามารถส่องเห็นได้จาระยะไกล หมุดหลักฐานงาน โครงข่ายสามเหลี่ยมมี 2 ชนิดคือ หมุดสามเหลี่ยมใหญ่ (ความคลาดเคลื่อนไม่เกิน : ±1.7" และหมุดลาพลาช (ความคลาดเคลื่อน ไม่เกิน ±0.5" ในปี 2527 มีจำนวนหมุดทั้งสิ้น362 สถานี ดังภาพที่ 1.1

- การรังวัดด้วยการทำวงรอบชั้นที่ 1 การทำวงรอบชั้นที่ 1 เป็นการรังวัดมุมและระยะคล้ายกับงานโครงข่ายสามเหลี่ยม การทำงานไม่เป็นโครงข่าย แต่จะเป็นวงรอบเข้าบรรจบตัวเอง การหาระยะโคยใช้เครื่อง EDM (Electronic Distance Measurement) โดยกระจายค่าความคลาดเคลื่อนให้แก่หมุดต่างๆที่อยู่ในวงรอบ การหาค่าพิกัดทางราบชนิดนี้เป็นการวางหมุดหลักฐานเพิ่มเติมจากการทำโครงข่ายสามเหลี่ยมตั้งแต่ปี 2519 จบถึงปี 2529 มีจำนวนหมุดทั้งสิ้น 154 สถานี ดังภาพที่ 1.1

- การรังวัดด้วยดาวเทียม ระบบดอปเปลอร์ (Doppler) เป็นวิธีการกำหนดตำแหน่งระหว่างเครื่องรับสัญญาณดาวเทียมกับจุดศูนย์กลางของวงโคจรดาวเทียม จุดศูนย์กลางของโลก) โคยมีการรังวังใน 2 ช่วงคือ ประมาณปี พ.ศ.2514 ถึง พ.ศ. 2522 เป็นการรังวัดค่าพิกัดทางราบด้วยดาวเทียมครั้งแรก โดยความร่วมมือของไทยกับประเทศสหรัฐอเมริกา มีการสร้างหมุดใหม่และรังวัดบนหมุด โครงข่ายสามเหลี่ยมเดิมจุดประสงค์หลักเพื่อปรับปรุงพื้นหลักฐาน Indian 1954 ร่วมกับ WGS 72 จนกลายมาเป็น Indian 1975 มีจำนวนหมุด 19 สถานี แต่ก็มีการรังวัดขยายโครงข่ายต่อเนื่องจนถึงปี พ.ศ. 2533 จนมีจำนวนหมุดมากกว่า 120 สถานี ดังภาพที่ 1.2

- การรังวัดด้วยดาวเทียม GPS เป็นวิธีการกำหนดตำแหน่งระหว่างเครื่องรับสัญญาณคาวเทียมกับจุดศูนย์กลางของวงโคจรดาวเทียม (จุดศูนย์กลางของโลก) เริ่มการรังวัดเมื่อปี พ.ศ. 2533 โดยอาศัยหมุดหลักฐานเดิมและมีการสร้างหมุดใหม่ด้วย การบริการข้อมูลให้ทั้งบนพื้นหลักฐาน Indian 1975 และWGS 84 การรังวัดวิธีนี้เป็นวิธีการรังวัดที่ใช้ในการปรับปรุงข้อมูลหมุดหลักฐานในปัจจุบันให้ทันสมัย ดังภาพที่ 1.3

[1] Royal Thai Survey Department

วิวัฒนาการโครงข่ายหมุดหลักฐานทางราบ

ค.ศ.

1999 - มีการรังวัดค่าพิกัดด้วยดาวเทียม GPS เส้นฐานระยะยาวประมาณ 250 กม.
- โครงข่ายอ้างอิง 7 หมุด (THAICA 5,GEODYSSEA 2) โครงข่ายหลัก 11 หมุด รวมเป็น 18 หมุด บนกรอบอ้างอิง ITRF1994 epoch 1996.3

ขยายโครงข่ายทั่วประเทศ

2002 - โครงชายสามเหลี่ยมทั่วประเทศ เส้นฐานระยะยาวประมาณ 30 - 50 กม.
- ปรับแก้โดยใช้ข้อมูลการรังวัดปี 2534 - 2544 เรียกว่าโครงข่ายเสริม (เติม) รวม 692 หมุด บนกรอบอ้างอิง ITRF2000 epoch 2003.11

เกิดซึนามิ - ยกเลิกโครงข่ายเสริม (เติม) 692 หมุด

2006 - คัดเลือกหมุดที่มั่นคงแข็งแรงออกแบบเป็นโครงชายสามเหลี่ยมเส้นฐานระยะยาว ประมาณ 100 กม. ปรับแก้โดยใช้ข้อมูลการรังวัดปี 2548 - 2550
- เรียกว่าโครงข่ายรอง รวม 94 หมุด บนกรอบอ้างอิง ITRF2000 epoch 2005.7

งานซ่อมโครงข่าย ปี 53

2010 - รังวัดซ่อมโครงข่ายเสริม (เติม) จำนวน 692 หมุด เพื่อปรับแก้ค่าพิกัดที่ได้รับผลกระทบจากซึนามิ บนกรอบอ้างอิง ITRF2005 epoch 2008.11
- ยังไม่มีการประกาศใช้งานโครงข่ายเสริมนี้

งานซ่อมแซมหมุดฯ ปี 56

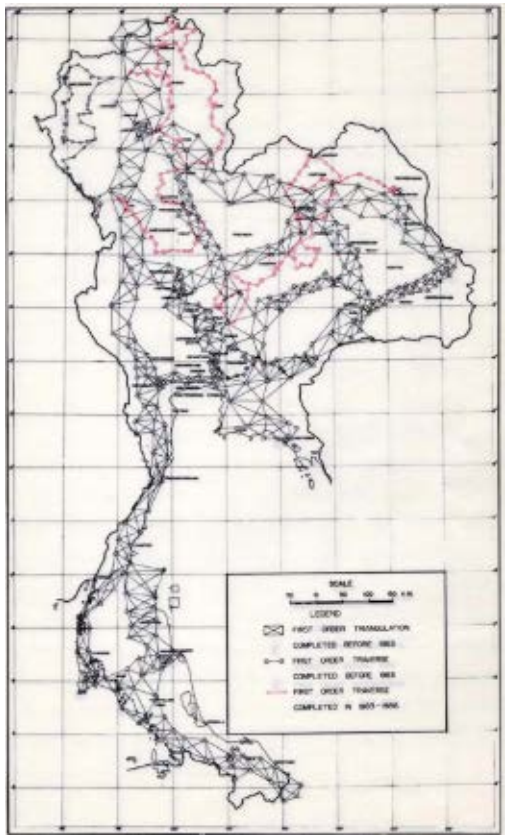
2013 - ตรวจสอบความน่าเชื่อถือของโครงข่ายเสริม (เติม) 694 หมุด ที่ปรับแก้ในปี 53 รังวัดจำนวน 60 หมุด บนกรอบอ้างอิง ITRF2000 epoch 2008.11

รังวัดโครงข่ายรองใหม่ ปี 57

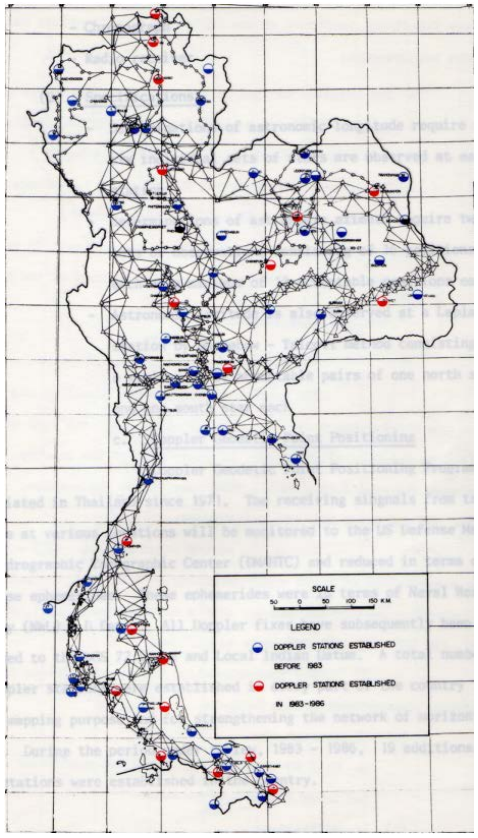
2014 - รังวัดและปรับแก้โครงข่ายรองพร้อมกันทั้งประเทศเพื่อลดผลกระทบจากความบิดเบี้ยวของโครงข่าย ได้โครงข่ายรองใหม่ จำนวน 94 หมุด
- บนกรอบอ้างอิง ITRF2008 epoch 2013.10

รังวัดโครงข่ายเสริมใหม่ ปี 58

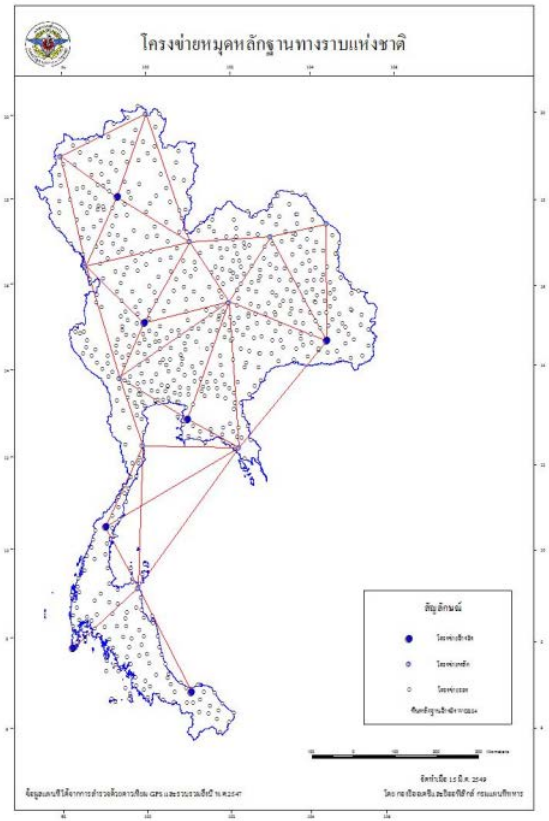
2015 - รังวัดและปรับแก้โครงชายเสริมพร้อมกันทั้งประเทศเพื่อลดผลกระทบจากความบิดเบี้ยวของโครงข่าย ได้โครงข่ายเสริมใหม่ จำนวน 381 หมุด
- บนกรอบอ้างอิง ITRF2008 epoch 2013.10



ภาพที่ 1.1 การกระจายตัวของโครงข่ายสามเหลี่ยมและวงรอบชั้นที่ 1



ภาพที่ 1.2 การกระจายตัวของหมุดดาวเทียมดอปเปลอร์และโครงข่ายสามเหลี่ยม



ภาพที่ 1.3 โครงข่ายหมุดหลักฐานดาวเทียม GPS

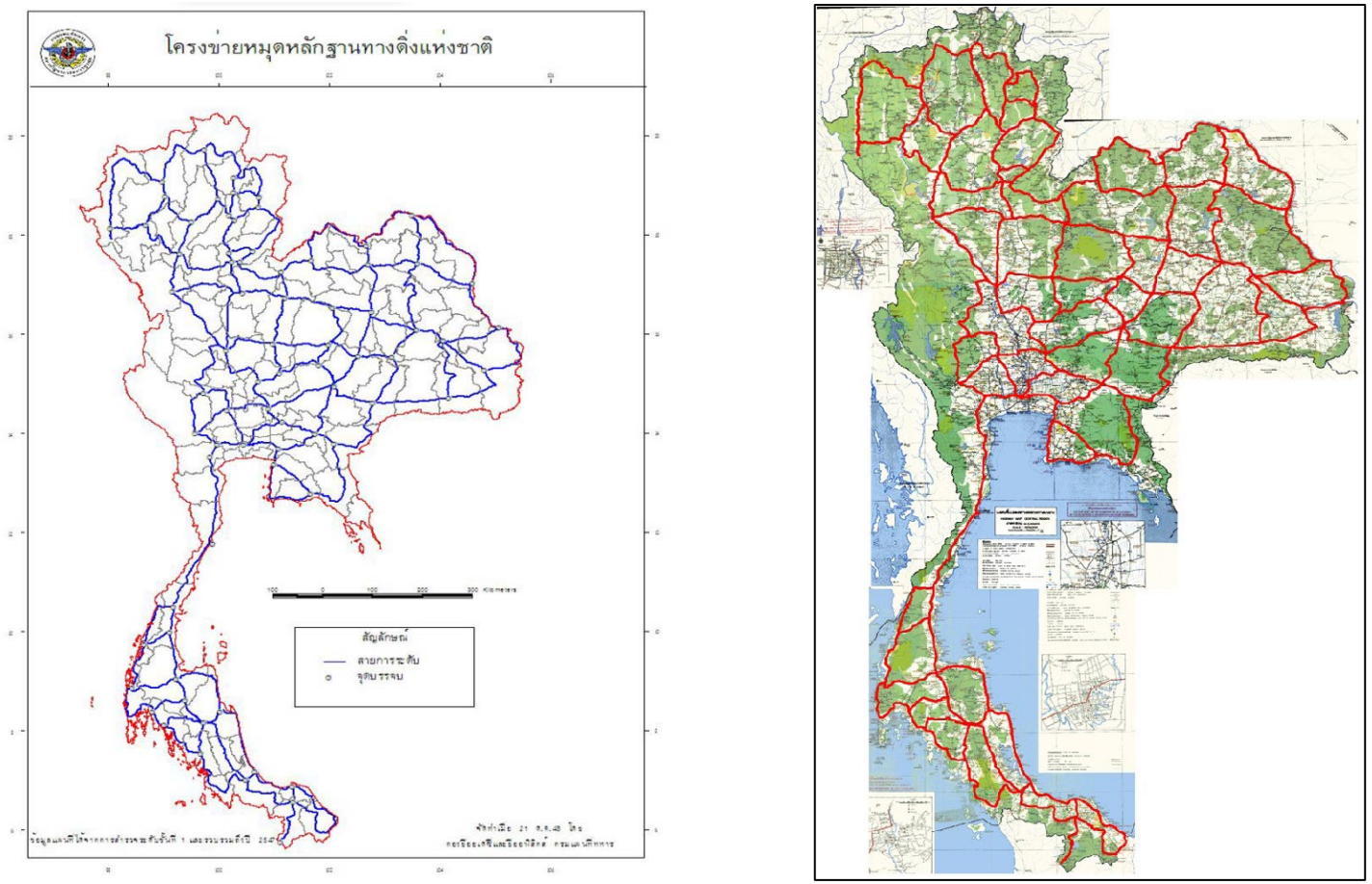
การสำรวจวางโครงข่ายหมุดหลักฐานทางดิ่งแห่งชาติ

ค่าระดับสูง (Elevation) ที่ใช้ในการสำรวจและการทำแผนที่จะเป็นค่า Orthometric Height ซึ่งในทางทฤษฎีอ้างอิงกับพื้นผิวศักย์สมดุล (Equipotential Surface) หรือพื้นผิวระดับ (Level Surface) ที่เรียกว่า ยีออยด์ (Geoid) โดยที่ยีออยด์ถือว่าเป็นสัณฐานของโลกอย่างแท้จริง อันเป็นผลมาจากปรากฏการณ์ธรรมชาติ อาทิ สนามความถ่วงพิภพ เป็นสำคัญ อย่างไรก็ดีในทางปฏิบัติ เนื่องจากการหายีออยด์ให้มีความละเอียดถูกต้องสูง กระทำได้ยากและสลับซับซ้อนจึงนิยมใช้ระดับทะเลปานกลาง (รทก. หรือ MeanSea Level : MSL) เป็นพื้นผิวระดับที่มีค่าระดับเป็นศูนย์ เพื่อใช้ในการอ้างอิงในการหาค่าระดับสูง หรือกล่าวโดยสรุปเป็นพื้นหลักฐานทางดิ่ง

รทก. ของประเทศไทยได้มีการรังวัดในรัชสมัยรัชกาลที่ 6 ระหว่างปี 2453 - 2458 เป็นเวลา 5ปี (วงรอบที่เหมาะสมควรเป็น 19 ปี) ณ สถานีวัดน้ำ กรมอุทกศาสตร์ กองทัพเรือ ต.เกาะหลัก อ.เมือง จ.ประจาบคีรีขันธ์

โดย Mr. S W Masterman รังวัดด้วยเครื่อง The Lord Kevin Vertical Type โดยบันทึกการขึ้นลงของระดับทะเลแล้วนำมาเฉลี่ยเพื่อหาค่าระดับทะเลปานกลาง จากนั้นจึงได้โยงค่า รทก. มายังบริเวณ โขดหินชายฝั่งแล้วกำหนดให้เป็นหมุดหลักอ้างอิงทางดิ่งหมุดแรกหรือเป็นจุดศูนย์กำเนิด มีชื่อว่า"BMA." ได้ค่า 1.4477 เมตร และเรียก รทก นี้ว่า " พื้นหลักฐานทางดิ่งเกาะหลัก 2458 "(Kolak 1915 Vertical Datum)

นับจากนั้นจึงได้มีการสำรวจวางโครงข่ายหมุดหลักฐานทางดิ่งแห่งชาติ แผ่ขยายออกไปทั่วทั้งภูมิภาคของประเทศไทย เข้าสู่พื้นที่สำคัญในการพัฒนาโครงสร้างพื้นฐานของประเทศ โดยอาศัยเส้นทางหลักของการคมนาคมทางบก อาทิ ทางหลวงแผ่นดิน ทางรถไฟ เป็นต้น เพื่อเป็นหมุดหลักฐานอ้างอิงอันเป็นคุโณปการในการหาค่าระดับสูงแก่การสำรวจการทำแผนที่ และภูมิสารสนเทศให้กับหน่วยงานที่เกี่ยวข้องทั้งภาครัฐและเอกชน

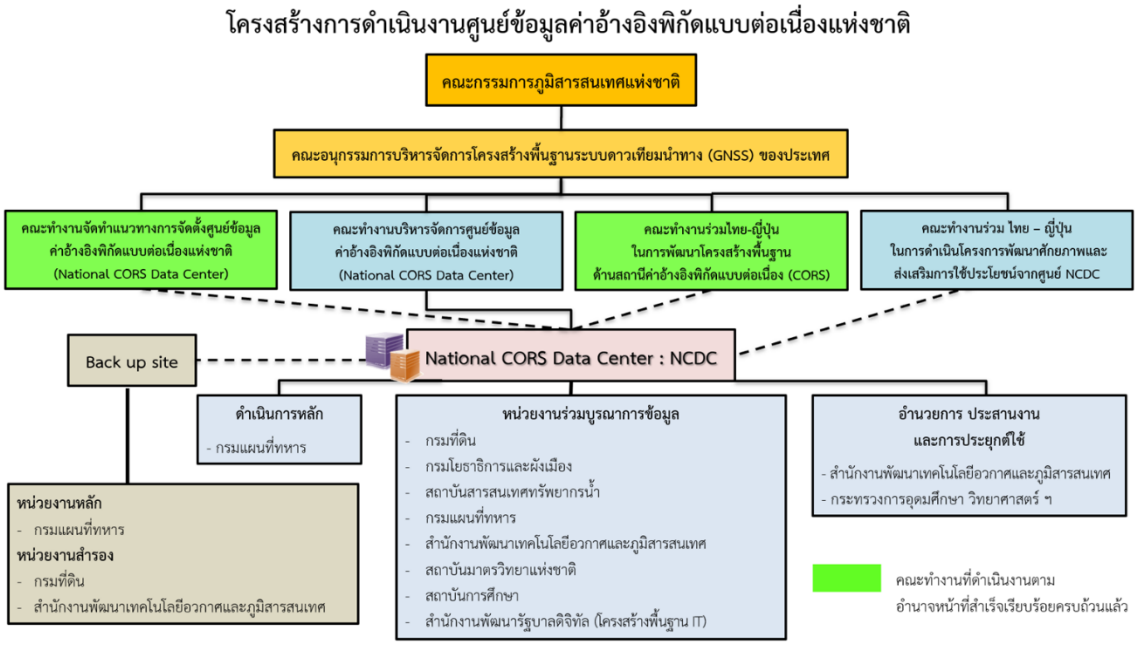


ภาพที่ 1.4 โครงข่ายระดับชั้น 1 ของประเทศไทย

1.2 ระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ

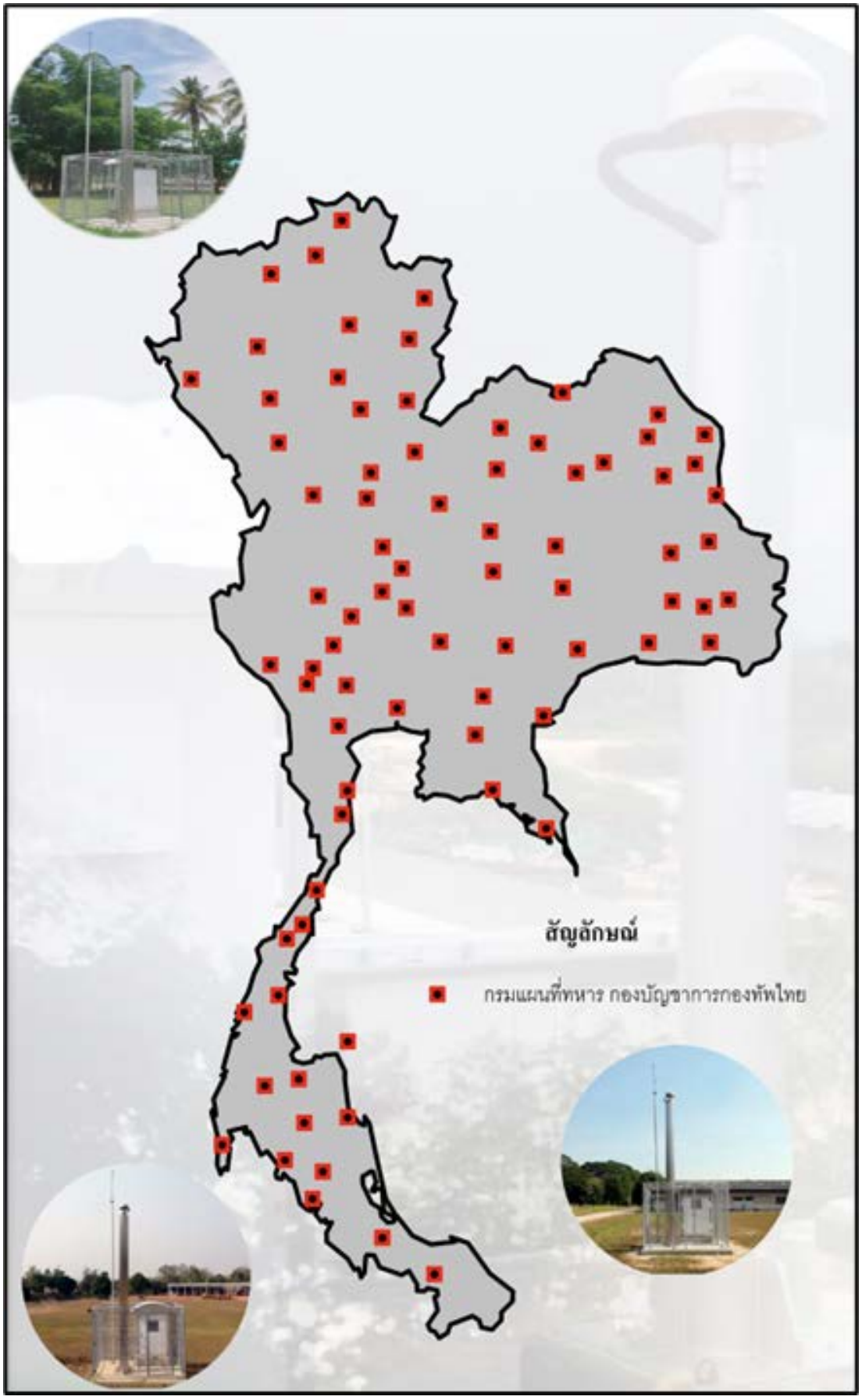
วัตถุประสงค์

เพื่อเพิ่มขีดความสามารถการปฏิบัติงานสำรวจและการทำแผนที่ ให้สามารถตอบสนองต่อการประเมินและป้องกันด้านอุทกภัยและภัยพิบัติธรรมชาติอื่นๆ รวมทั้งทำให้การสำรวจหาค่าพิกัด ทั้งทางราบและค่าความสูงเหนือระดับทะเลปานกลาง โดยการประยุกต์ใช้ร่วมกับแบบจำลองยีออยด์ท้องถิ่นความละเอียดสูง (TGM2017) ในเวลาอันรวดเร็วแบบทันที (Realtime) สามารถให้ค่าพิกัดที่มีความละเอียดถูกต้องในระดับ 3-5 เซนติเมตร



หน่วยงาน	จำนวนสถานี
กรมแผนที่ทหาร (ลาดพร้าว)	1
กรมการสื่อสารทหาร	20
หน่วยบัญชาการทหารพัฒนา	20
ที่ว่าการอำเภอ	4
การศึกษานอกโรงเรียน (กศน.)	1
สำนักงานเทศบาล	3
กรมที่ดิน	26
องค์การบริหารส่วนตำบล	5
รวม	80

ตารางที่ 1.1 สถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS) แบบต่อเนื่อง ของกรมแผนที่ทหาร



ภาพที่ 1.5 สถานีอ้างอิงค่าพิกัดแบบต่อเนื่อง(CORS) กรมแผนที่ทหาร กองบัญชาการกองทัพไทย 80 สถานี

1.3 ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ

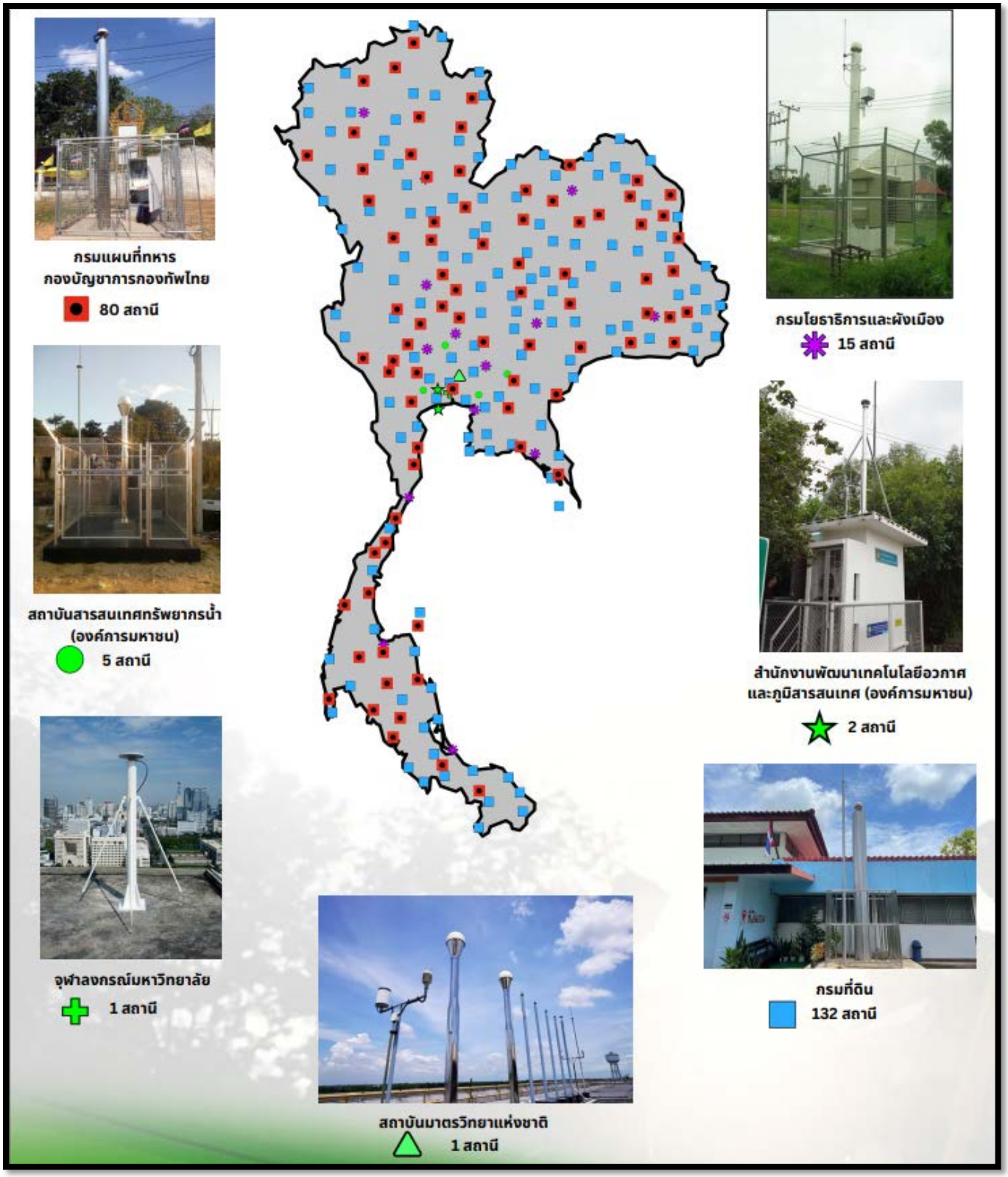
ในปัจจุบันหน่วยงานภาครัฐหลายหน่วยงาน ได้มีการจัดตั้งสถานีอ้างอิงพิกัดแบบต่อเนื่อง หรือ CORS (Continuously Operating Reference Stations) สำหรับให้บริการค่าปรับแก้จากการรังวัดด้วยระบบดาวเทียมนำร่อง Global Navigation Satellite System (GNSS) เพื่อให้สามารถรังวัดค่าพิกัดแบบทันทีที่มีความถูกต้องสูงไว้ใช้ในภารกิจเฉพาะหน่วยงาน แต่ยังไม่มีการบูรณาการร่วมกัน

ต่อมาคณะกรรมการภูมิสารสนเทศแห่งชาติ (กภช.)[2] จึงได้มีมติเห็นชอบให้มีการจัดตั้งศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center: NCDC) เพื่อบูรณาการข้อมูลดังกล่าวให้มีความเป็นเอกภาพเป็นระบบเดียวกันทั่วประเทศ พร้อมทั้งให้บริการค่าปรับแก้เพื่อการรังวัดค่าพิกัดที่มีความถูกต้องสูงและมีมาตรฐานเดียวกันสนับสนุนแก่หน่วยงานของรัฐและเอกชน

ผลของการจัดตั้งศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ จะทำให้มีการให้บริการข้อมูลค่าพิกัดอ้างอิงจากโครงข่ายสถานี CORS ที่มีความถูกต้องสูงและมีเสถียรภาพ ส่งผลให้ค่าพิกัดจากการรังวัดด้วยระบบดาวเทียมนำร่อง หรือ GNSS มีความละเอียดถูกต้องมากขึ้น จึงถือเป็นข้อมูลโครงสร้างพื้นฐานที่สำคัญในการพัฒนาเศรษฐกิจ สังคม และรักษาความมั่นคงให้กับประเทศ เช่น งานสำรวจเพื่อจัดทำแผนที่และภูมิสารสนเทศ งานรังวัดและจัดทำแปลงที่ดิน งานด้านวิศวกรรมและก่อสร้างสาธารณูปโภค (i-Construction) งานด้านภัยพิบัติ งานด้านบริหารจัดการน้ำ งานด้านคมนาคมขนส่งและยานยนต์ไร้คนขับ งานด้านเกษตรอัจฉริยะ (Smart Farming) และงานด้านการทหาร

ปัจจุบัน มีองค์การความร่วมมือระหว่างประเทศแห่งญี่ปุ่น (Japan International Cooperation Agency) หรือ JICA ซึ่งเป็นหน่วยงานของรัฐบาลญี่ปุ่น คอยให้คำปรึกษาตลอดจนความช่วยเหลือด้านการพัฒนาประเทศอย่างเป็นทางการในนามของรัฐบาลญี่ปุ่นแก่ประเทศกำลังพัฒนา ทั้งการพัฒนาในด้านเศรษฐกิจและด้านสังคม รวมถึงส่งเสริมการยกระดับความร่วมมือระหว่างประเทศ เข้ามามีส่วนร่วมในการให้คำปรึกษาในการพัฒนาการจัดตั้งศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ ตามภาพที่ 1.6

[2] คณะกรรมการภูมิสารสนเทศแห่งชาติ (กภช.) มีหน้าที่เพื่อดำเนินการด้านนโยบายเกี่ยวกับการจัดทำภูมิสารสนเทศ การจัดทำแผนที่ และการสำรวจข้อมูลระยะไกล เป็นไปอย่างมีมาตรฐาน ลดความซ้ำซ้อน บูรณาการข้อมูลให้สามารถแลกเปลี่ยน ประสานและเชื่อมโยงข้อมูลที่เกี่ยวข้องกันได้อย่างเป็นระบบสามารถตอบสนองความต้องการใช้งานภูมิสารสนเทศในการบริหารราชการอย่างมีประสิทธิภาพ



ภาพที่ 1.6 สถานีอ้างอิงค่าพิกัดแบบต่อเนื่อง(CORS) ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ(NCDC)

ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC) บูรณาการข้อมูลจาก 8 หน่วยงาน ดังนี้

1. กรมแผนที่ทหาร กองบัญชาการกองทัพไทย (Royal Thai Survey Department)
2. กรมที่ดิน (Department of Lands)
3. กรมโยธาธิการและผังเมือง (Department of Public Works and Town & Country Planning)
4. สถาบันสารสนเทศทรัพยากรน้ำ (องค์การมหาชน) (สสน.)(Hydro Informatics Institute)
5. สำนักงานพัฒนาเทคโนโลยีอวกาศและภูมิสารสนเทศ (องค์การมหาชน) GISTDA (Geo-Informatics and Space Technology Development Agency)
6. จุฬาลงกรณ์มหาวิทยาลัย (Chulalongkorn University)
7. สถาบันเทคโนโลยีพระจอมเกล้าเจ้าคุณทหารลาดกระบัง (King Mongkut's Institute of Technology Ladkrabang)
8. สถาบันมาตรวิทยาแห่งชาติ (National Institute of Metrology)

หน่วยงาน	**จำนวน CORS**
กรมแผนที่ทหาร	80
กรมที่ดิน	132
กรมโยธาธิการและผังเมือง	15
สถาบันสารสนเทศทรัพยากรน้ำ(องค์การมหาชน)	5
GISTDA	2
จุฬาลงกรณ์มหาวิทยาลัย	1
สถาบันมาตรวิทยาแห่งชาติ	1
รวม	**236**

ตารางที่ 1.2 หน่วยงานที่ร่วมบูรณาการข้อมูล

2. ร่างหลักเกณฑ์การให้บริการค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC service level agreement)

เพื่อให้การบริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) เกิดการบูรณาการร่วมกันของหน่วยงานภาครัฐ ในการให้บริการข้อมูลจากสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง และใช้ประโยชน์ร่วมกันในการพัฒนาและบริหารจัดการประเทศ รวมทั้งให้บริการได้อย่างมีประสิทธิภาพ อาศัยอำนาจตามความในข้อ 10 (2)[3] เสนอแนะต่อคณะรัฐมนตรี ในการกำหนดแนวทางการปฏิบัติงานด้านข้อมูลภูมิสารสนเทศของหน่วยงานของรัฐเพื่อให้การบริหารจัดการระบบข้อมูลภูมิสารสนเทศในทุกมิติที่เกี่ยวข้องเป็นไปอย่างมีประสิทธิภาพแห่งระเบียบสำนักนายกรัฐมนตรี ว่าด้วยคณะกรรมการภูมิสารสนเทศแห่งชาติ พ.ศ. 2558 จึงได้กำหนดหลักเกณฑ์การให้บริการข้อมูล ค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ ดังต่อไปนี้

2.1 ในหลักเกณฑ์นี้

“ระบบดาวเทียมเพื่อการนำทาง (Global Navigation Satellite System: GNSS)” หมายถึง ระบบนำทางด้วยดาวเทียม โดยใช้อุปกรณ์อิเล็กทรอนิกส์เป็นตัวรับสัญญาณเพื่อประมวลผลเชิงตำแหน่ง ณ จุดที่อุปกรณ์รับสัญญาณตั้งอยู่

“การรังวัดสัญญาณดาวเทียมแบบจลน์ (Real Time Kinematics: RTK)” หมายถึง การรับสัญญาณดาวเทียมแบบจลน์ ได้ค่าพิกัดฉากทันที ณ เวลาทำการรังวัดจากระบบโครงข่ายการรังวัด ด้วยดาวเทียมแบบจลน์

“สถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (Continuously Operating Reference Stations; CORS)” หมายถึง สถานีรังวัดและจัดเก็บข้อมูลสัญญาณดาวเทียมเพื่อการนำทาง หรือ Global Navigation Satellite System (GNSS) อย่างต่อเนื่อง และเชื่อมโยงข้อมูลมายังศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ

“ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center: NCDC)” หมายถึง ศูนย์ข้อมูลที่ทำหน้าที่ ติดตาม รวบรวม เชื่อมโยง จัดเก็บ ประมวลผล และเผยแพร่ เพื่อให้บริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องไปยังผู้ใช้บริการ

“ระบบให้บริการศูนย์ข้อมูลค่าอ้างอิงค่าพิกัดแบบต่อเนื่องแห่งชาติ” หมายถึง ระบบบริการข้อมูลค่าอ้างอิงค่าพิกัดแบบต่อเนื่องของประเทศผ่านเว็บไซต์

“การให้บริการ” หมายถึง การให้บริการข้อมูลจากสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง หรือ Continuously Operating Reference Stations (CORS) แก่หน่วยงานของรัฐและผู้ใช้งานทั่วไป โดยไม่คิดค่าใช้จ่าย หรือคิดค่าใช้จ่ายตามหลักเกณฑ์ที่หน่วยงานที่ร่วมบูรณาการได้กำหนดร่วมกัน

“หน่วยงานของรัฐ” หมายถึง กระทรวง ทบวง กรม ส่วนราชการที่เรียกชื่ออย่างอื่น และมีฐานะเป็นกรม ราชการส่วนท้องถิ่น รัฐวิสาหกิจ สถาบันการศึกษา องค์กร หรือองค์การมหาชน ที่ตั้งขึ้น โดยพระราชบัญญัติหรือพระราชกฤษฎีกา และให้หมายความรวมถึงหน่วยงานอื่นของรัฐที่มีพระราชกฤษฎีกากำหนดให้เป็นหน่วยงานของรัฐ หรือ หน่วยงานอื่นของรัฐในฝ่ายบริหาร

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[3] อำนาจตามความในข้อ 10 (2) ตามราชกิจจานุเบกษา 23 กันยายน 2558 เรื่อง ระเบียบสำนักนายกรัฐมนตรี ว่าด้วยคณะกรรมการภูมิสารสนเทศแห่งชาติ พ.ศ 2558

“ผู้ใช้งานที่ไม่ใช่หน่วยงานของรัฐ” หมายถึง ภาคเอกชน และภาคประชาชน ที่เข้ามาใช้บริการของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center)

“ผู้ให้บริการ” หมายถึง หน่วยงานผู้เป็นเจ้าของสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (CORS) และเชื่อมโยงข้อมูล (data streaming) มายังศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ เพื่อร่วมบูรณาการให้บริการต่อไป

“ผู้ดูแลระบบ” หมายถึง ผู้แทนกรมแผนที่ทหาร ปฏิบัติหน้าที่บริหาร หรือผู้มีสิทธิเข้าถึงจัดการระบบคอมพิวเตอร์ โดยดูแลการติดตั้งและบำรุงรักษาระบบปฏิบัติการ การติดตั้งฮาร์ดแวร์ การติดตั้งและการปรับปรุงซอฟต์แวร์ สร้าง ออกแบบและบำรุงรักษาบัญชีผู้ใช้บริการค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) ในการเข้าสู่อินเทอร์เน็ตหรือให้สามารถติดต่อถึงกันโดยประการอื่น โดยผ่านทางระบบคอมพิวเตอร์

“ผู้ให้อนุญาต” หมายถึง หน่วยงานผู้เป็นเจ้าของสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (CORS) หรือข้อมูลที่เกี่ยวข้อง ที่ให้อนุญาตแก่ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ ใช้ข้อมูลเพื่อให้บริการในระบบให้บริการศูนย์ข้อมูลค่าอ้างอิงค่าพิกัดแบบต่อเนื่องแห่งชาติ

“ผู้ใช้บริการ” หมายถึง หน่วยงานของรัฐ ภาคเอกชน และภาคประชาชน ที่เข้ามาใช้บริการของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ

2.2 หลักเกณฑ์การให้บริการ

ผู้ใช้บริการจะนำข้อมูลจากสถานีค่าอ้างอิงพิกัดแบบต่อเนื่องไปใช้ในภารกิจของผู้ใช้บริการ อาทิเช่นการสำรวจรังวัด การวิเคราะห์ต่อยอดการวิจัย พัฒนานวัตกรรม และประยุกต์ใช้ข้อมูลดังกล่าวรองรับการใช้งานของทั้งหน่วยงานของรัฐ สถาบันการศึกษา ภาคเอกชน และภาคประชาชน โดยการดำเนินงานดังกล่าวต้องไม่ก่อให้เกิดความเสียหายใด ๆ แก่ผู้ให้บริการและผู้ใช้บริการ และต้องอ้างอิงแหล่งที่มาแก่ผู้ให้บริการในงานที่ผู้ใช้บริการได้พัฒนาหรือได้จัดทำขึ้นเพื่อเป็นการแจ้งแหล่งที่มาของข้อมูล รวมถึงห้ามนำสำเนาข้อมูลให้แก่บุคคลที่สามหรือหน่วยงานอื่น

2.3 ขอบเขตการให้บริการ

2.3.1 ผู้ให้บริการพิจารณาให้บริการข้อมูลจากสถานีอ้างอิงค่าพิกัดแบบต่อเนื่อง ผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) แก่ผู้ใช้บริการดังนี้

(ก) บริการรังวัดด้วยระบบโครงข่ายการรังวัดสัญญาณดาวเทียม GNSS แบบจลน์ (Network Real Time Kinematics)

(ข) บริการข้อมูลสัญญาณดาวเทียมเพื่อการนำทางของสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (Continuously Operating Reference Stations; CORS) ในรูปแบบ RINEX file

(ค) บริการประมวลผลค่าพิกัดแบบภายหลัง (Post processing)

2.3.2 คำแนะนำค่าความถูกต้องของข้อมูลที่ให้บริการ สำหรับในการใช้งานประเภทต่างๆ ดังนี้

ค่าความถูกต้อง	การใช้งาน
1 เซนติเมตรหรือน้อยกว่า	การติดตามการเคลื่อนตัวของเปลือกโลกและรอยเลื่อน
1 เซนติเมตร – 10 เซนติเมตร	การสำรวจ (ground survey, laser surveying, MMS), เกษตรอัจฉริยะ (precision agriculture, autonomous operation of agricultural machinery), การก่อสร้าง (i-Construction,3D surveying, construction machine control), ยานยนต์อัตโนมัติ
10 เซนติเมตร – 1 เมตร	แผนที่สำหรับการขับขี่แบบอัตโนมัติ
มากกว่า 1 เมตร ขึ้นไป	Satellite-based Augmentation System (SBAS), การสำรวจทางทะเล, การติดตามทุ่น, การจัดการขนส่งสาธารณะ

ตารางที่ 2.1 ค่าความถูกต้องของข้อมูลที่ให้บริการ

2.4 ขั้นตอนการขอรับบริการ

ในการขอใช้บริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) มีขั้นตอน ดังต่อไปนี้

2.4.1 ผู้ใช้บริการเข้าสู่ระบบบริการของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติผ่านระบบออนไลน์

2.4.2 กรอกแบบฟอร์มลงทะเบียนขอใช้ระบบ โดยระบุรายละเอียดของผู้ใช้บริการ เช่น ที่อยู่ ประเภทการใช้งาน ทั้งนี้จะต้องยอมรับข้อตกลงการใช้งาน (End User License Agreement : EULA) หรือหลักเกณฑ์การให้บริการ

2.4.3 กรณีที่ต้องมีการชำระค่าบริการ ให้ผู้ใช้บริการชำระค่าบริการให้เรียบร้อยพร้อมแนบหลักฐานการชำระเงินลงในระบบ

2.4.4 ผู้ให้บริการหรือผู้ดูแลระบบ ตรวจสอบและพิจารณาคำขอ และเมื่อผู้ให้บริการหรือผู้ดูแลระบบพิจารณาอนุมัติให้ใช้ข้อมูลแล้ว ผู้ใช้บริการจะได้รับการตอบกลับผลการอนุมัติการขอใช้ข้อมูลต่อไป

2.5 เงื่อนไขของผู้ใช้บริการ

2.5.1 ผู้ใช้บริการจะต้องให้ข้อมูลเกี่ยวกับตนเอง เช่น ข้อมูลระบุตัวตนหรือรายละเอียดการติดต่อที่ถูกต้องเป็นจริง และเป็นปัจจุบันเสมอแก่ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) อันเป็นส่วนหนึ่งของกระบวนการลงทะเบียนใช้บริการที่ต่อเนื่อง

2.5.2 ผู้ใช้บริการจะต้องระมัดระวังในการดาวน์โหลดข้อมูลจำนวนมากเพียงเพื่อการเก็บสะสม ทั้งนี้เพื่อหลีกเลี่ยงการจราจรข้อมูลที่มากเกินความจำเป็น

2.5.3 ผู้ใช้บริการจะต้องใช้บริการนี้ เพื่อวัตถุประสงค์ที่ได้รับอนุญาตตามข้อกำหนดของ ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) และไม่ขัดต่อกฎหมาย กฎระเบียบ ข้อบังคับ หลักปฏิบัติที่เป็นที่ยอมรับโดยทั่วไป

2.5.4 ผู้ใช้บริการจะต้องไม่เข้าใช้หรือพยายามเข้าใช้บริการหนึ่งบริการใดโดยวิธีอื่น รวมถึงการใช้วิธีการอัตโนมัติ (การใช้สคริปต์) นอกจากช่องทางที่ ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) จัดเตรียมไว้ให้ เว้นแต่ผู้ใช้บริการจะได้รับอนุญาตจาก ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) โดยชัดแจ้งให้ทำเช่นนั้นได้

2.5.5 ผู้ใช้บริการจะต้องไม่ทำหรือมีส่วนร่วมในการขัดขวางหรือรบกวนการบริการของ ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) รวมทั้งเครื่องแม่ข่ายและเครือข่ายที่เชื่อมต่อกับบริการ

2.5.6 ผู้ใช้บริการจะต้องไม่ทำสำเนา คัดลอก ทำซ้ำ ขาย แลกเปลี่ยน หรือขายต่อบริการเพื่อวัตถุประสงค์ใด ๆ เว้นแต่ผู้ใช้บริการจะได้รับอนุญาตจาก ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ โดยชัดแจ้งให้ทำเช่นนั้นได้

2.5.7 ผู้ใช้บริการจะต้องรักษาความลับของรหัสผ่านที่เชื่อมโยงกับบัญชีใด ๆ ที่ใช้ในการเข้าถึงบริการ

2.5.8 ผู้ใช้บริการจะต้องเป็นผู้รับผิดชอบแต่เพียงผู้เดียวต่อบุคคลใด ๆ รวมถึง ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) ในความเสียหายอันเกิดจากการละเมิดข้อกำหนด

2.5.9 หากผู้ใช้บริการได้นำข้อมูลไปใช้และไม่ปฏิบัติ ตามหลักเกณฑ์นี้ ผู้ให้บริการสามารถที่จะดำเนินการตามกฎหมายได้ตามความจำเป็นเหมาะสม หรืองดการให้บริการข้อมูลครั้งต่อไป

2.6 การปฏิเสธความรับผิด

ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) จะไม่รับผิดชอบต่อความเสียหายใด ๆ ของผู้ใช้บริการที่เกิดจากคุณภาพ หรือการสูญเสียของข้อมูลจากสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง รวมถึงความเสียหาย สูญเสียและค่าใช้จ่าย ที่เกิดขึ้นไม่ว่าโดยตรงหรือโดยอ้อม ที่เป็นผลหรือสืบเนื่องจากการที่ผู้ใช้บริการเข้าใช้บริการ หรือต่อความเสียหาย สูญเสียหรือค่าใช้จ่ายที่เกิดจากความล้มเหลวในการใช้งาน ความผิดพลาด การละเว้น การหยุดชะงัก ข้อบกพร่องความไม่สมบูรณ์ คอมพิวเตอร์ไวรัส ถึงแม้ว่าศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) จะได้รับแจ้งว่าอาจจะเกิดความเสียหาย สูญเสียหรือค่าใช้จ่ายดังกล่าวขึ้น นอกจากนี้ ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ ไม่รับผิดต่อผู้ใช้เว็บไซต์หรือบุคคลจากการเรียกร้องใด ๆ ที่เกิดขึ้นจากบนเว็บไซต์ หรือเนื้อหาใด ๆ ซึ่งรวมถึงการตัดสินใจหรือการกระทำใด ๆ ที่เกิดจากความเชื่อถือในเนื้อหาดังกล่าวของผู้ใช้เว็บไซต์ หรือในความเสียหายใด ๆ ไม่ว่าความเสียหายทางตรง หรือทางอ้อม รวมถึงความเสียหายอื่นใดที่อาจเกิดขึ้นได้ ผู้ใช้บริการยอมรับและตระหนักดีว่า ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) จะไม่ต้องรับผิดชอบต่อการกระทำใดของผู้ใช้บริการทั้งสิ้น

2.7 การกำหนดสิทธิ์การให้บริการ และการกำหนดชั้นความลับ/ความมั่นคง

2.7.1 ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) หรือผู้ให้อนุญาต เป็นผู้มีสิทธิ์ตามกฎหมายแต่เพียงผู้เดียวใน กรรมสิทธิ์ ผลประโยชน์ทั้งหมด รวมถึงสิทธิ์ในทรัพย์สินทางปัญญาใด ๆ ที่มีอยู่ในบริการซึ่งศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ หรือผู้ให้อนุญาตแก่ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) เป็นผู้จัดทำขึ้น ไม่ว่าสิทธิ์เหล่านั้นจะได้รับการจดทะเบียนไว้หรือไม่ก็ตาม

2.7.2 การกำหนดชั้นความลับ และความมั่นคงในการบริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) ไม่จัดอยู่ในชั้นความลับ (Unclassified) ยกเว้นศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) หรือผู้ให้อนุญาตพิจารณาเห็นแล้วว่ามีผลกระทบต่อความมั่นคงหรือส่งผลเสียหายต่อผลประโยชน์ของชาติ

จะงดให้บริการเป็นเฉพาะกรณีไป

2.7.3 ผู้ใช้บริการจะต้องไม่เปิดเผยข้อมูลที่ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) กำหนดให้เป็นความลับ โดยไม่ได้รับความยินยอมเป็นลายลักษณ์อักษรล่วงหน้า

2.7.4 ผู้ใช้บริการจะต้องไม่ใช้ชื่อทางการค้า เครื่องหมายการค้า เครื่องหมายการบริการ ตราสัญลักษณ์ชื่อโดเมนของ ศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) โดยไม่ได้รับความยินยอมเป็นลายลักษณ์อักษร

2.8 อัตราค่าบริการ

2.8.1 การให้บริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) แก่หน่วยงานของรัฐเป็นการให้บริการโดยไม่คิดค่าใช้จ่าย

2.8.2 อัตราค่าบริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) แก่ผู้ใช้งานที่ไม่ใช่หน่วยงานของรัฐ ให้เป็นไปตามแนบท้ายหลักเกณฑ์การให้บริการค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) พ.ศ. 2565

2.9 อื่นๆ

2.9.1 ผู้ดูแลระบบศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) เป็นเป็นผู้แทนกลางในการติดต่อประสานงาน จนกว่าจะมีการเปลี่ยนแปลงใดๆ

2.9.2 หากมีการเปลี่ยนแปลงการให้บริการ และการกำหนดสิทธิ์การรับบริการให้สามารถทำได้โดยผ่านการพิจารณาของคณะกรรมการภูมิสารสนเทศแห่งชาติ

2.9.3 กรณีมีปัญหาในการตีความ และการบังคับใช้ตามประกาศเรื่อง หลักเกณฑ์การให้บริการค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) พ.ศ. 2564 ฉบับนี้ ให้เป็นไปตามกฎหมายไทย

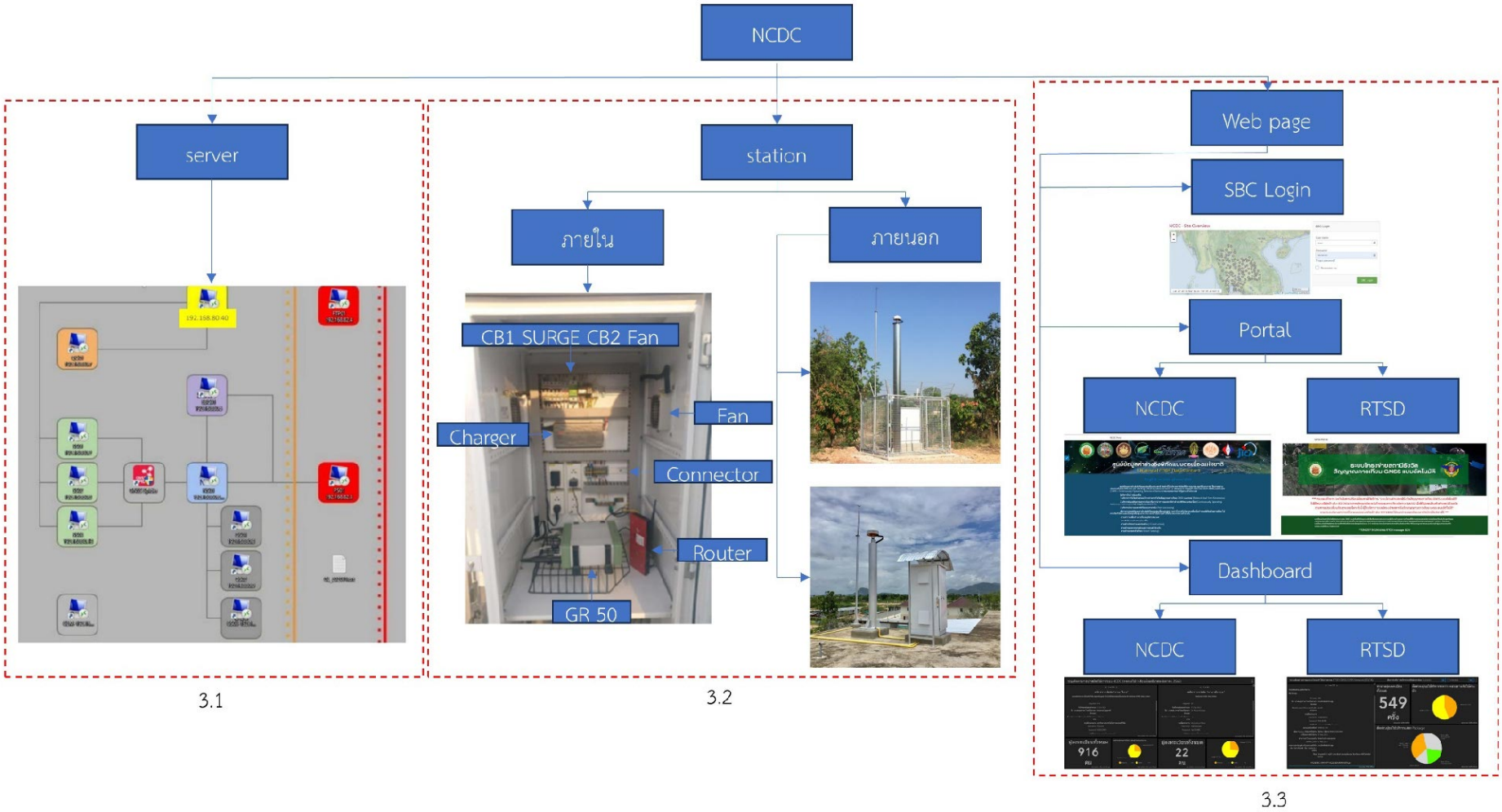
รายการ	ราคาหน่วยงานของรัฐ(บาท)	ราคาภาคเอกชน (บาท)
บริการรังวัดค่าพิกัดด้วยระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ ราย 2 สัปดาห์	ไม่คิดค่าบริการ	
บริการรังวัดค่าพิกัดด้วยระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ รายเดือน	ไม่คิดค่าบริการ	
บริการรังวัดค่าพิกัดด้วยระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ ราย 6 เดือน	ไม่คิดค่าบริการ	
บริการรังวัดค่าพิกัดด้วยระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ รายปี	ไม่คิดค่าบริการ	

ตารางที่ 2.2 ค่าบริการของข้อมูลที่ให้บริการ

หมายเหตุ

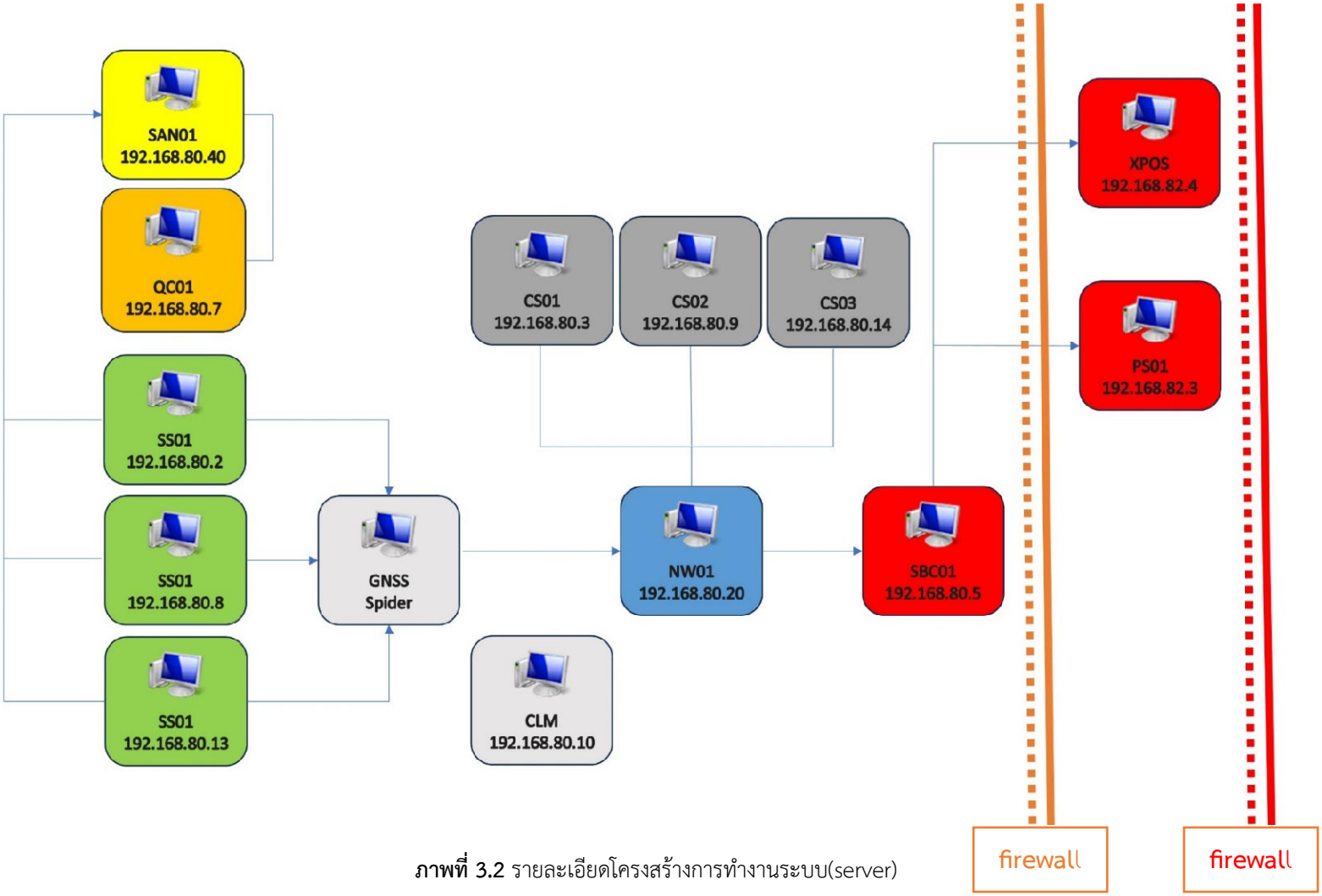
- อัตราค่าบริการของภาคเอกชน ระยะแรกให้บริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องโดยไม่คิดค่าใช้จ่าย เพื่อส่งเสริมการใช้งานข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องและให้ทบทวนนโยบายการให้บริการข้อมูลแบบไม่คิดมูลค่าทุก 6 เดือน (ตามมติที่ประชุมคณะอนุกรรมการบริหารจัดการโครงสร้างพื้นฐานระบบดาวเทียมนำทาง (GNSS) ของประเทศ ครั้งที่ 1/2563 เมื่อวันจันทร์ที่ 6 มกราคม 2563)
- การทบทวนนโยบายการให้บริการข้อมูลมูลค่าอ้างอิงพิกัดแบบต่อเนื่องผ่านศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ ให้เป็นไปตาม คำสั่งคณะอนุกรรมการบริหารจัดการโครงสร้างพื้นฐานระบบดาวเทียมนำทาง (GNSS) ของประเทศ ที่ 2/ 2560 เรื่อง การแต่งตั้งคณะทำงานบริหารจัดการศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่อง (National CORS Data Center) คณะทำงานบริหารจัดการศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) อำนาจหน้าที่ (1) ศึกษา แนวทางการจัดตั้งศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) แนวทางการให้บริการข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ แนวทางการเชื่อมโครงข่ายสถานี CORS ของหน่วยงานต่างๆ เข้าสู่ศูนย์ข้อมูลอ้างอิงค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center) และจัดทำเป็นแผนปฏิบัติ หรือหลักเกณฑ์ประกอบการดำเนินงานของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Cent

3. โครงสร้างของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC)



ภาพที่ 3.1 โครงสร้างของศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC)

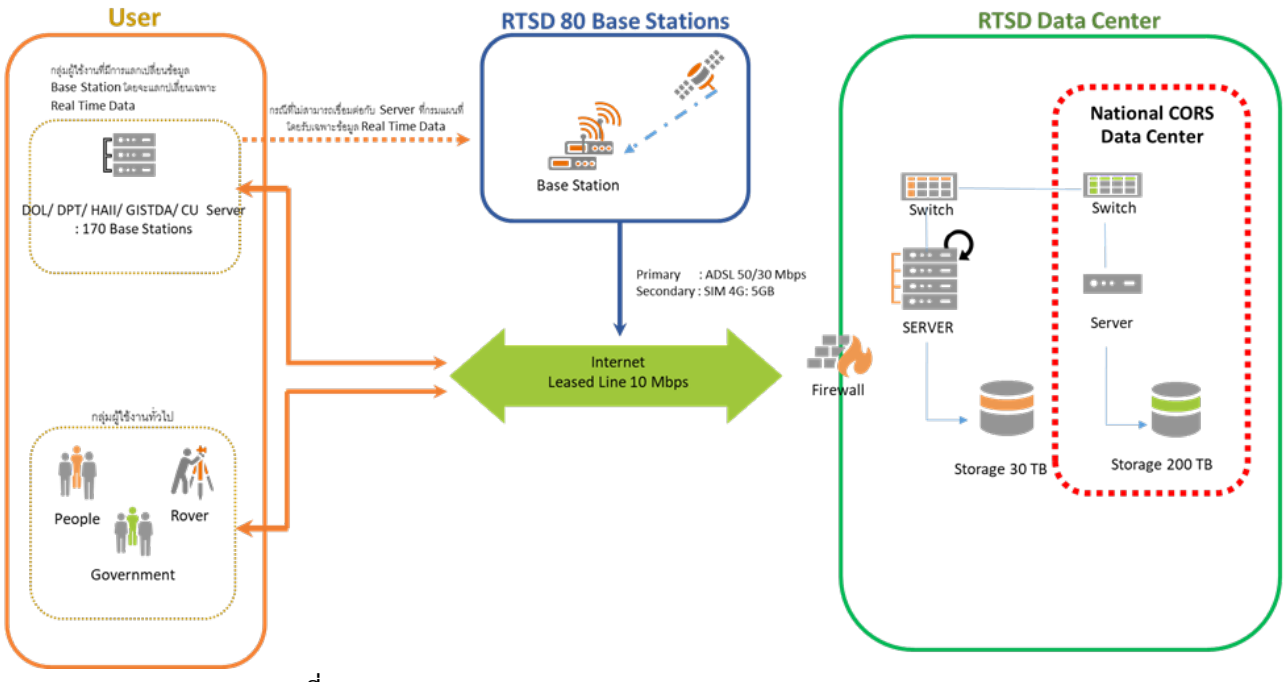
3.1 รายละเอียดโครงสร้างการทำงานระบบ(server)



ภาพที่ 3.2 รายละเอียดโครงสร้างการทำงานระบบ(server)

SAN01 = HARDDISK (ที่เก็บข้อมูล rinex, Hatanaka)
QC01 = SPIDER QC SERVER
SS01 = RTSD 80 CORS SITE SERVER (เชื่อมต่อ CORS กรมแผนที่ทหาร จำนวน 80 CORS)
SS02 = 90 CORS SITE SERVER (เชื่อมต่อ CORS กรมที่ดิน จำนวน 90 CORS)
SS03 = 66 CORS SITE SERVER (เชื่อมต่อ CORS หน่วยงานอื่นๆ จำนวน 66 CORS)
NW01 = NETWORK SERVER
CS01,02,03 = CLUSTER SERVER (ทำงานร่วมกับNW01)
CLM = Customer License Manager
SBC01 = Spider Business Center (ทำหน้าที่จัดการ บริหาร rtk user)
XPOS = X POS SERVER
(ทำงานร่วมกับSBCคำนวณcoordinate online, download RINEX)
PS01 = PROXY SERVER
(จัดการเรื่อง internet RTK ROVER)

3.1.1 โครงสร้างการทำงานของ NCDC (NCDC infrastructure)



ภาพที่ 3.3 GNSS 80 Base + National CORS Data Center Phrase 1 Diagram

Hardware

- เครื่องคอมพิวเตอร์แม่ข่าย (Server) หลัก ยี่ห้อ Dell รุ่น PowerEdge R740 4 เครื่อง
- เครื่องคอมพิวเตอร์สำหรับงานประมวลผล (WorkStation) ยี่ห้อ Dell รุ่น Precision Tower 3620 จำนวน 8 ชุด
- อุปกรณ์กระจายสัญญาณและสลับเครือข่าย ยี่ห้อ Juniper รุ่น EX3400 (Core Switch) จำนวน 2 ชุด
- อุปกรณ์เครือข่ายสำหรับบริการเชื่อมโยงการจัดเก็บข้อมูล SAN Switch (Storage Area Network Switch) ยี่ห้อ EMC รุ่น DS300B จำนวน 2 ชุด
- อุปกรณ์เครือข่ายสำหรับจัดเก็บข้อมูลแบบเครือข่าย (SAN Storage) ยี่ห้อ EMC รุ่น Unity 300 จำนวน 1 ชุด
- อุปกรณ์สำรองไฟฟ้า (UPS) ขนาด 20 kVA ยี่ห้อ APC รุ่น SURT20KRMXLI จำนวน 1 ชุด
- อุปกรณ์สำรองไฟฟ้า (UPS) ขนาด 1 KVA ยี่ห้อ APC รุ่น BX1100LI-MS จำนวน 1 ชุด
- ตู้ Rack ขนาด 42U ยี่ห้อ Dell รุ่นNetshelter SX 42U จำนวน 1 ชุด
- อุปกรณ์ Firewall ยี่ห้อ Fortinet รุ่น Fortigate 500E จำนวน 1 ชุด

Software

- โปรแกรมระบบบริหารจัดการเครื่องคอมพิวเตอร์เสมือน สำหรับติดตั้งบนเครื่องคอมพิวเตอร์แม่ข่าย ยี่ห้อ VMware รุ่น VMware vSphere standard Edition จำนวน 1 ชุด
- โปรแกรมระบบบริการข้อมูลภูมิสารสนเทศสำหรับศูนย์ประมวลผลข้อมูลดาวเทียม GNSS ยี่ห้อ ArcGIS รุ่น ArcGIS GIS Server Standard Enterprise จำนวน 1 ชุด
- โปรแกรมจัดการฐานข้อมูลภูมิสารสนเทศสำหรับศูนย์ประมวลผลข้อมูลดาวเทียม GNSS ยี่ห้อ ArcGIS รุ่น ArcGIS Desktop Standard จำนวน 1 ชุด
- โปรแกรมระบบจัดการฐานข้อมูลเชิงสัมพันธ์ (RDBMS) ยี่ห้อ Microsoft รุ่น SQL Server จำนวน 1 ชุด

3.1.2 การทำงานของระบบ NCDC



ภาพที่ 3.4 การทำงานของระบบ NCDC

เครื่องคอมพิวเตอร์แม่ข่าย 1
SBC[4] server
- บริการ download RINEXE FILE จัดเก็บที่ storage 200TB เป็นระยะเวลา 5 ปี
- บริการคำนวณ baseline processing online
- บริการค่าปรับแก้สำหรับ RTK GNSS

FTP server for other เก็บข้อมูลสำหรับนำไปใช้งาน
Web Map Server สำหรับให้บริการ Web Portal
vCenter Server บริหารจัดการ Host และ VM

เครื่องคอมพิวเตอร์แม่ข่าย 2
Site Server 2 รับข้อมูลจาก 90 Base Station ของกรมที่ดินและหน่วยงานอื่นๆ ใช้ในการคำนวณระบบ Network RTK
Site Server 3 รับข้อมูลจาก 66 Base Station ของกรมที่ดินและหน่วยงานอื่นๆ เพื่อเก็บข้อมูล Rinex file เท่านั้น
Proxy Server ตรวจสอบสิทธิ์การให้บริการหน้าเว็บ ให้กับผู้ใช้งาน
FTP (XPOS) ให้บริการข้อมูลหลังประมวลผลเรียบร้อยแล้ว ของผู้ใช้งานภายนอก
Share Drive สำหรับ Backup ข้อมูล
CLM Server ใช้เก็บ license ของ spider software

เครื่องคอมพิวเตอร์แม่ข่าย 3
Network Server สำหรับประมวลผลข้อมูล network GNSS
Cluster Server 3 สำหรับประมวลผลข้อมูลแบบ cluster ของ Site Server 3
Bernese Server สำหรับประมวลผลข้อมูลด้วย Bernese software

เครื่องคอมพิวเตอร์แม่ข่าย 4
Site Server 1 รับข้อมูลจาก 80 Base Station ของกรมแผนที่ทหาร
QC Server ตรวจสอบข้อมูล GNSS จาก Base Station ของกรมแผนที่ทหาร
Database Server สำหรับติดตั้งฐานข้อมูลของ Web Portal
Zabbix Server สำหรับ monitor การใช้งานของ Host และ VM

เครื่องคอมพิวเตอร์แม่ข่าย 5
Cluster Server 1 สำหรับประมวลผลข้อมูลแบบ cluster ของ Site Server 1
Cluster Server 2 สำหรับประมวลผลข้อมูลแบบ cluster ของ Site Server 2

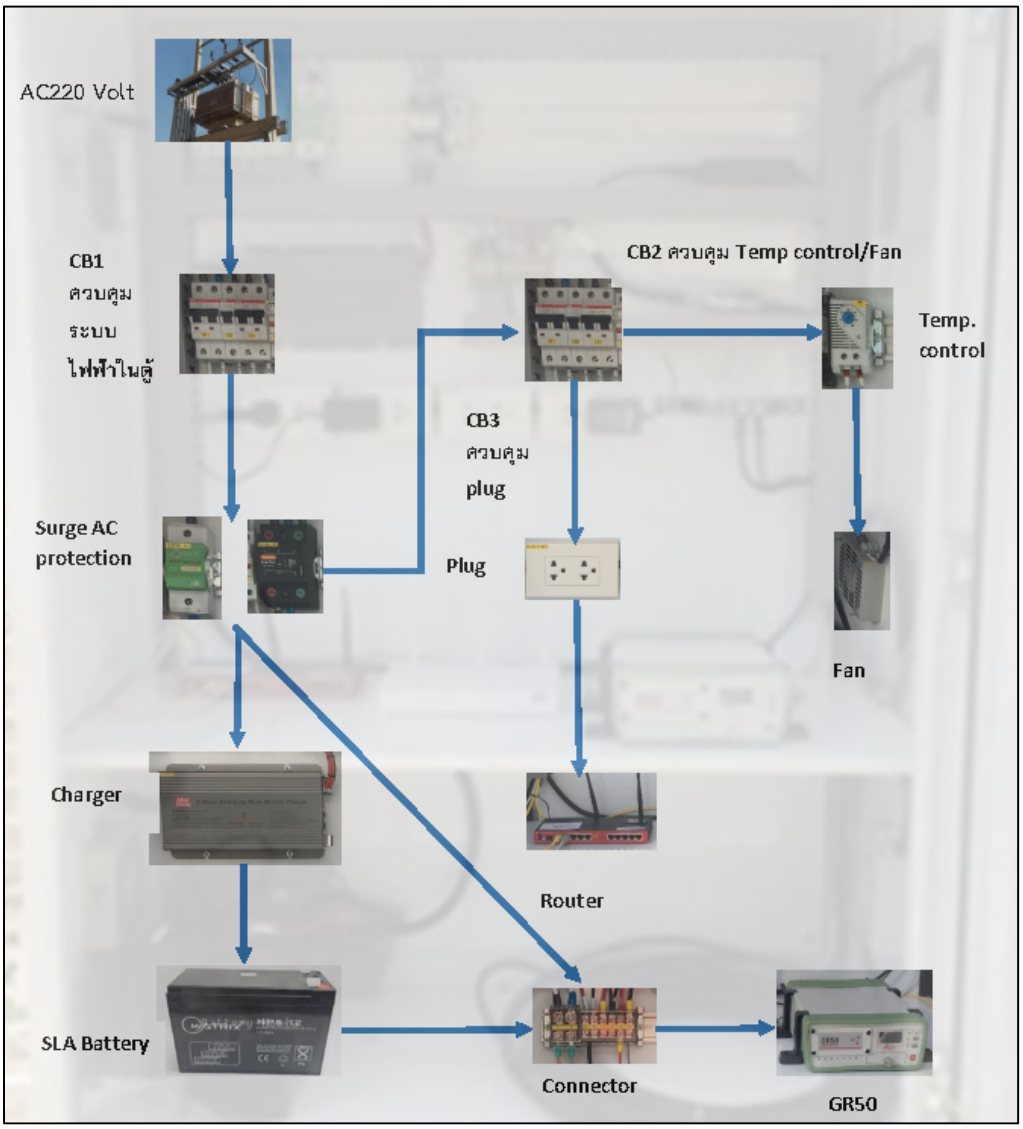
[4] SBC **ย่อมาจาก** Spider Business Center

3.2 รายละเอียดโครงสร้างสถานี(CORS)

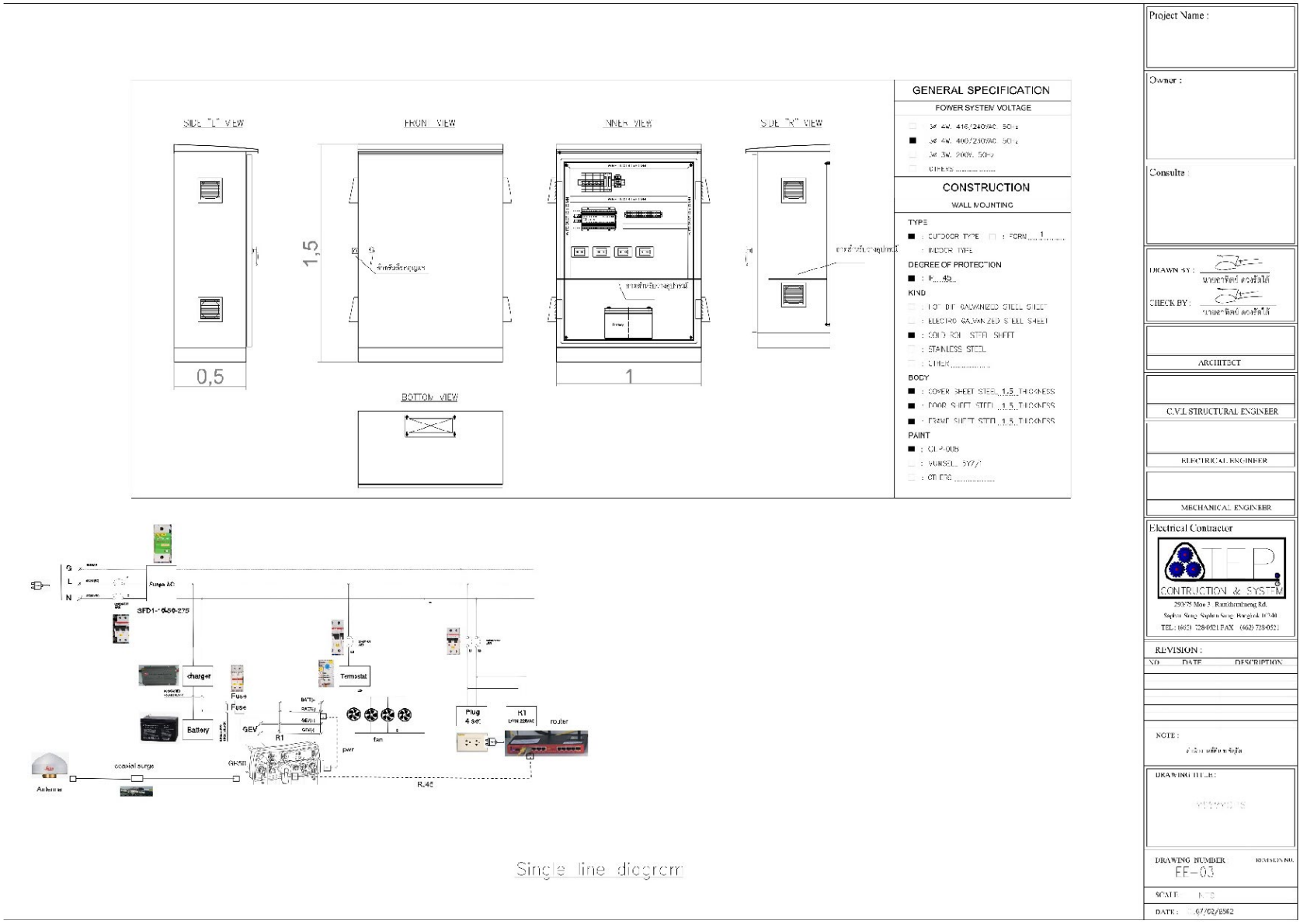
3.2.1 โครงสร้างภายในสถานี

อุปกรณ์ภายในตู้ CORS มีการเชื่อมต่อกันดังแสดงในรูปที่ 31 ซึ่งสามารถตรวจสอบสถานะการทำงานระบบไฟฟ้าในสภาวะปกติได้ดังนี้

- สวิทช์ CB1 CB2 และ CB3 จะต้องอยู่ในตำแหน่ง ON ดังแสดงในรูปที่ 1.9
- Surge AC protection ไฟตำแหน่งซ้ายมือ สีเขียว ไฟด้านขวา สีแดง สำหรับ novaris และไม่มีไฟสำหรับ starbel
- Relay เพื่อตรวจสอบระบบ จ่ายไฟจากแบตแตอรี่ เมื่อระบบไฟ AC ดับ ต้องมีไฟสีแดง



ภาพที่ 3.5 รายละเอียดโครงสร้างภายในตู้ของสถานี



ภาพที่ 3.6 รายละเอียดโครงสร้างระบบไฟฟ้าภายในสถานี

3.2.2 โครงสร้างภายนอกสถานี

โครงสร้างสถานี CORS ประเภทที่ 1

ตัวอย่างสถานี CORS ดังแสดงในภาพที่ 3.7 เป็นสถานี CORS ที่ติดตั้งบนพื้นดินโดยมีแบบแปลนดังแสดงในภาพที่ 3.8



สถานี LKPT



สถานี BORI

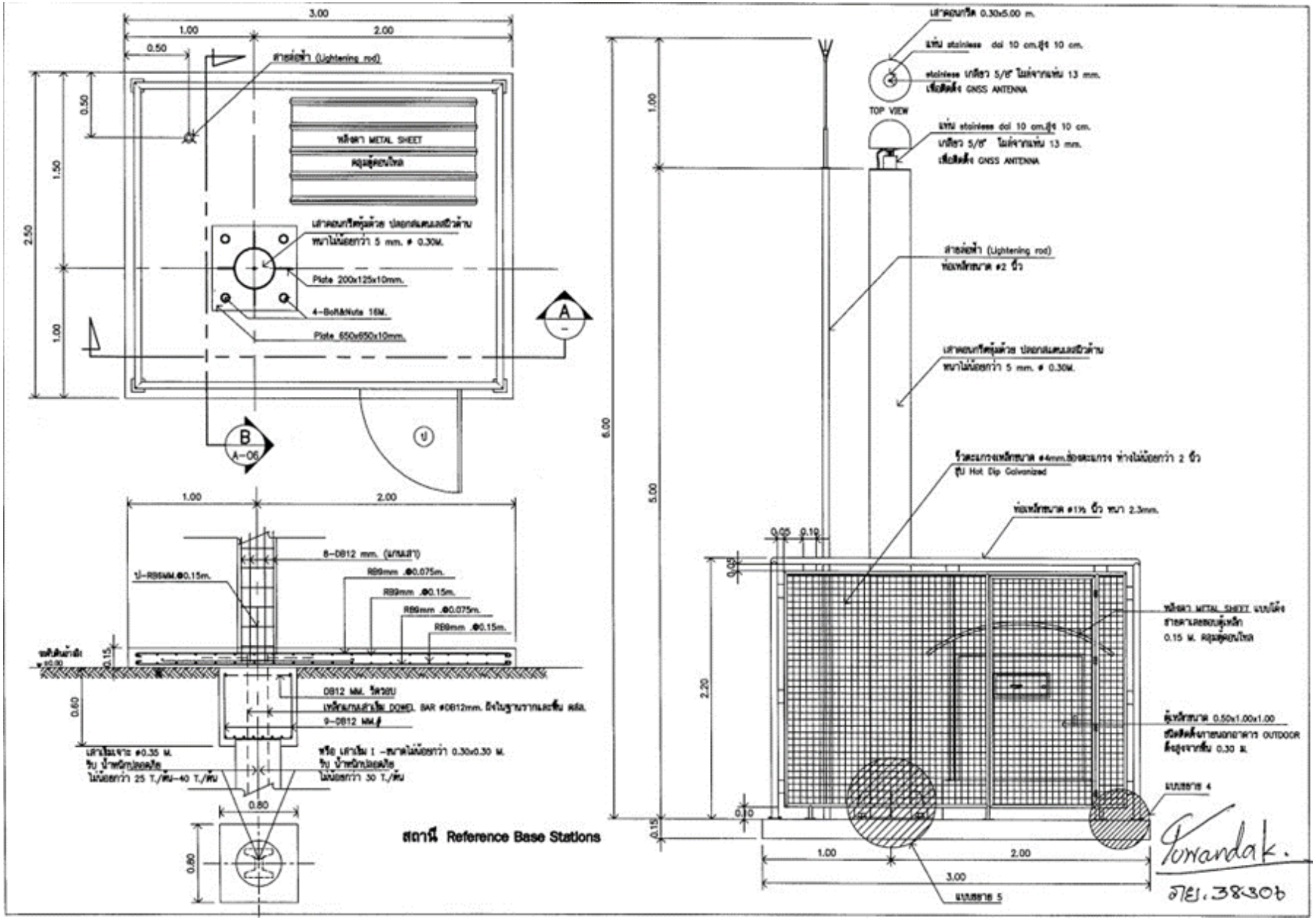


สถานี DOL



สถานี DPT

ภาพที่ 3.7 ตัวอย่างสถานี CORS ประเภทที่ 1



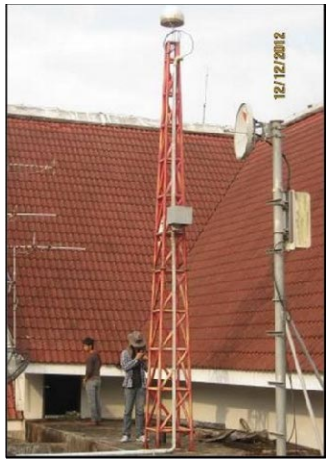
ภาพที่ 3.8 แบบแปลนสถานี CORS ประเภทที่ 1 สถานี LKPT

โครงสร้างสถานี CORS ประเภทที่ 2

ตัวอย่างสถานี CORS ดังแสดงในภาพที่ 3.9 เป็นสถานี CORS ที่ติดตั้งบนอาคารโดยมีแบบแปลนดังแสดงในภาพที่ 3.10



สถานี LPBI



สถานี CHAN

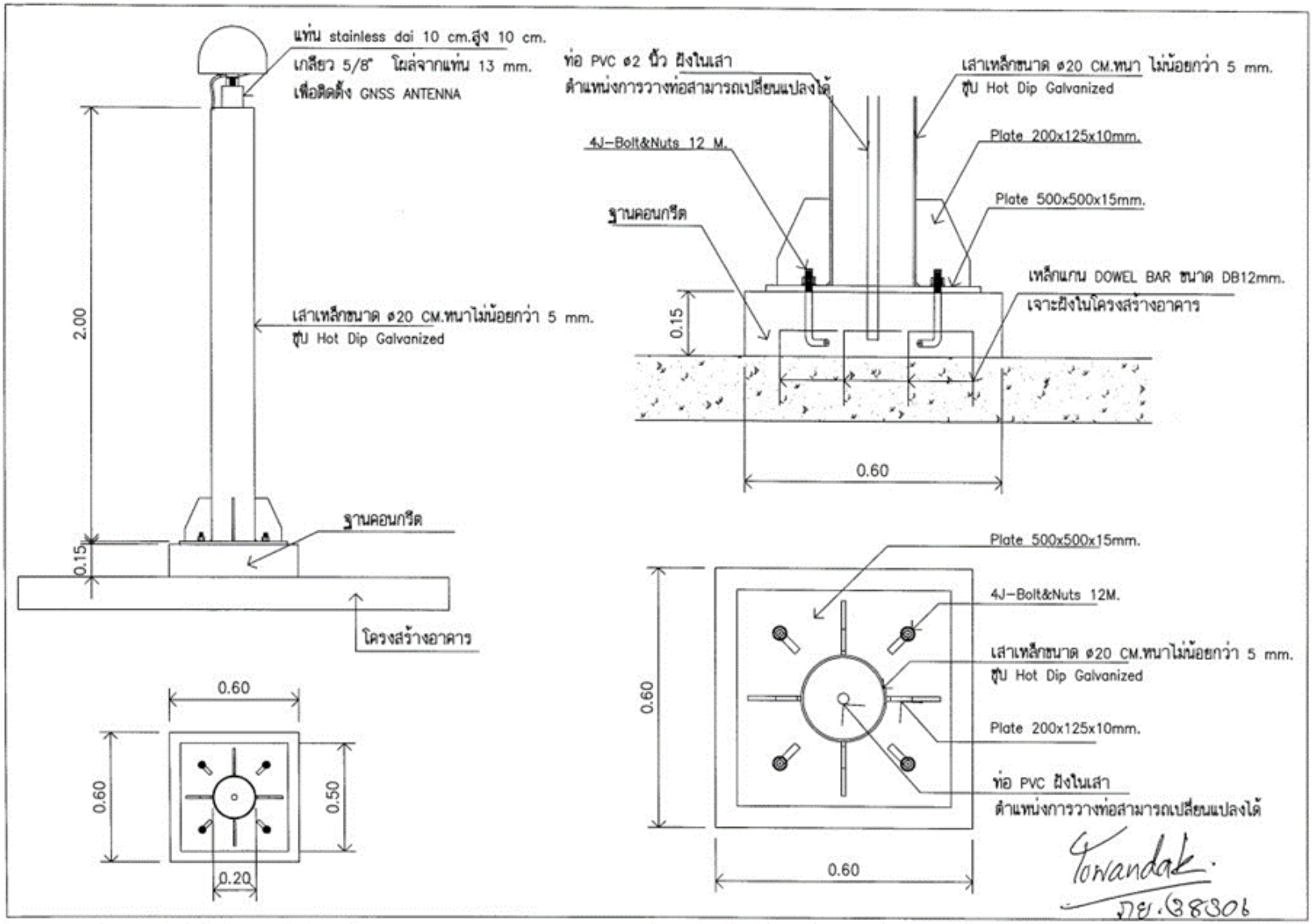


สถานี CU



สถานี NIMT

ภาพที่ 3.9 ตัวอย่างสถานี CORS ประเภทที่ 2



ภาพที่ 3.10 แบบแปลนสถานี CORS ประเภทที่ 2 สถานี LPBI

3.3 หน้า เว็บไซต์ (Web page)

3.3.1 SBC Login

SBC หมายถึง Spider Business Center มีหน้าที่ในการให้บริการในระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียมGNSSแบบอัตโนมัติ สำหรับผู้ใช้งานที่ลงทะเบียนเรียบร้อยแล้ว ซึ่งมีการเข้าใช้งาน(Login) ประกอบด้วยผู้ใช้ 2 ประเภท

1. User สามารถเข้าถึง ข้อมูลที่ให้บริการแก่ผู้ใช้ (User service) ได้

มีบริการ 2 รูปแบบ คือ

- RTSD User เป็นบริการแบบเสียค่าใช้จ่าย(ปัจจุบันให้บริการเฉพาะหน่วยงานรัฐ)
- NCDC User เป็นบริการแบบไม่เสียค่าใช้จ่าย

2. Admin สามารถเข้าถึง การบริหารจัดการบัญชีผู้ใช้งาน (User management)

<u>ข้อมูลที่ให้บริการแก่ผู้ใช้ (User service)</u>

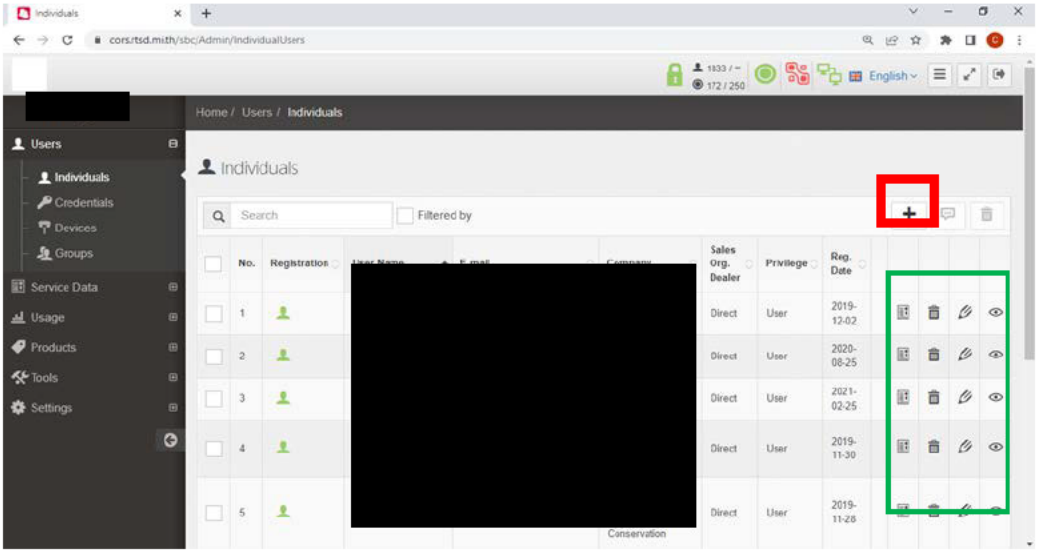
- การให้บริการค่าตัวแก้ความคลาดเคลื่อนทางตำแหน่งสำหรับการสำรวจค่าพิกัดด้วยการรังวัดสัญญาณดาวเทียม GNSS ผ่านเครือข่ายอินเตอร์เน็ตไปยังผู้ใช้ได้อย่างทันทีทันใดทั้ง 4 วิธี ได้แก่ VRS, FKP, MAX, และ i-MAX โดยจะให้บริการ 2 พอร์ต ได้แก่ 2101 และ 2105 ซึ่งจะทำให้ผู้ใช้บริการได้ค่าพิกัดในกรอบพิกัดอ้างอิง ITRF2008 และ ITRF2014 ตามลำดับ

- การให้บริการดาวน์โหลดข้อมูลรังวัดสัญญาณดาวเทียม GNSS ของสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS) ทุกสถานีในโครงข่าย ในรูปแบบไฟล์ RINEX และสามารถดาวน์โหลดข้อมูล Virtual RINEX ณ พิกัดสามมิติที่ผู้ใช้บริการกำหนดได้ ซึ่งผู้ใช้การสามารถดาวน์โหลดข้อมูลทั้งสองประเภทย้อนหลังได้ไม่เกิน 30 วันนับจากวันปัจจุบัน

- การให้บริการประมวลผลภายหลัง (Post-processing) ข้อมูลรังวัดสัญญาณดาวเทียม GNSS ผู้ใช้บริการสามารถอัปโหลดข้อมูลรังวัดสัญญาณดาวเทียม GNSS ในรูปแบบไฟล์ RINEX บน SBC ได้ ซึ่งจะสามารถประมวลผลข้อมูลย้อนหลังได้ไม่เกิน 30 วันนับจากวันปัจจุบัน โดยที่ SBC จะประมวลผลข้อมูลโดยใช้สถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS) ที่อยู่บริเวณโดยรอบเป็นสถานีอ้างอิง เมื่อประมวลผลเสร็จสิ้น ผู้ใช้บริการจะสามารถตรวจสอบผลการประมวลผลบน SBC ได้

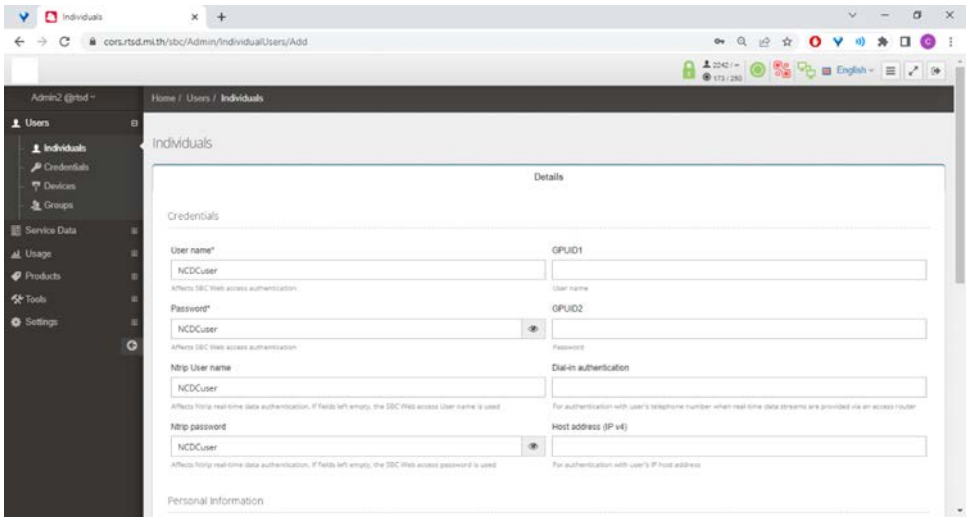
การบริหารจัดการบัญชีผู้ใช้งาน (User management)

ผู้ดูแลระบบจะต้องเข้าสู่ระบบ SBC ด้วยบัญชีผู้ใช้ของผู้ดูแลระบบและกดเข้าไปที่ Users > Individuals ที่แถบด้านซ้ายของหน้าเว็บไซต์ก็จะปรากฏข้อมูลเบื้องต้นของบัญชีผู้ใช้บริการทั้งหมด ดังแสดงใน ภาพที่ 3.11 ซึ่งไอคอน + ในกรอบสีแดงมีหน้าที่ในการเพิ่มบัญชีผู้ใช้บริการใหม่ และไอคอน ในกรอบสีเขียวมีหน้าที่ในการเพิ่ม package ใหม่ให้กับผู้ใช้บริการเดิม, ลบบัญชีผู้ใช้บริการ, แก้ไขข้อมูลบัญชีผู้ใช้บริการแต่ละบัญชี, และเข้าไปตรวจดูข้อมูลบัญชีผู้ใช้บริการแต่ละบัญชี ตามลำดับ

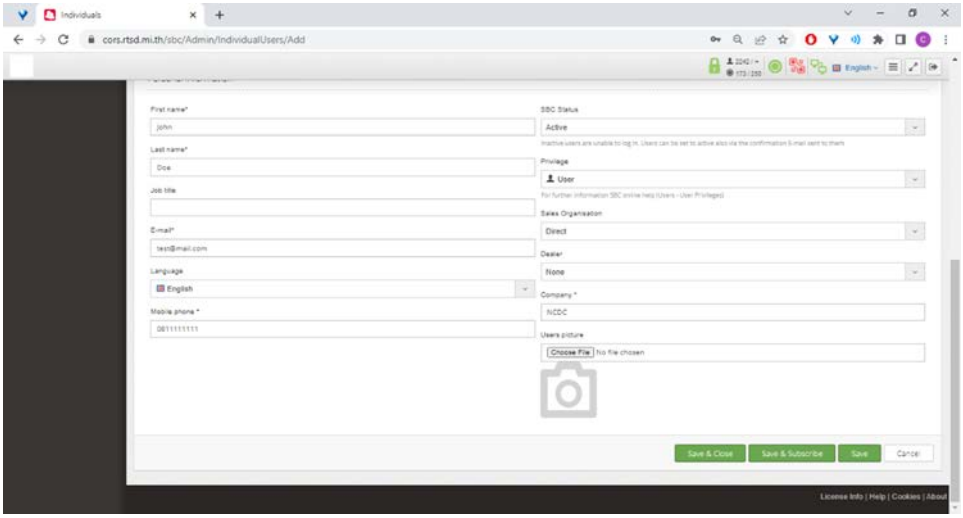


ภาพที่ 3.11 ข้อมูลบัญชีผู้ใช้บริการทั้งหมด

การเพิ่มบัญชีผู้ใช้บริการใหม่นั้นจะกระทำได้โดยการกดไอคอน + ในกรอบสีแดง ภาพที่ 3.11 ก็จะปรากฏหน้าต่างขึ้นมาให้ผู้ดูแลระบบจะต้องการกรอกข้อมูลของบัญชีผู้ใช้บริการใหม่ในหัวข้อต่างๆ ดังแสดงในภาพที่ 3.12 เมื่อกรอกข้อมูลจนครบแล้ว จะมีปุ่มที่มีข้อความว่า Save & Close, Save & Subscribe, Save, และ Cancel ซึ่งหมายถึง บันทึกข้อมูลบัญชีผู้ใช้บริการและกลับไปยังหน้าต่างดังแสดงในภาพที่ 3.11 แต่ยังไม่มีการอนุมัติบัญชีผู้ใช้บริการตาม Package ที่ผู้ใช้ได้ระบุไว้, บันทึกข้อมูลบัญชีผู้ใช้บริการและดำเนินการอนุมัติบัญชีผู้ใช้บริการตาม Package ที่ผู้ใช้ได้ระบุไว้, บันทึกข้อมูลบัญชีผู้ใช้บริการ แต่ยังคงอยู่ที่หน้าต่างเดิม เพื่อให้ผู้ดูแลระบบสามารถแก้ไขข้อมูลผู้ใช้บริการได้, และยกเลิกการเพิ่มบัญชีผู้ใช้บริการนี้ตามลำดับ



(ก)



(ข)

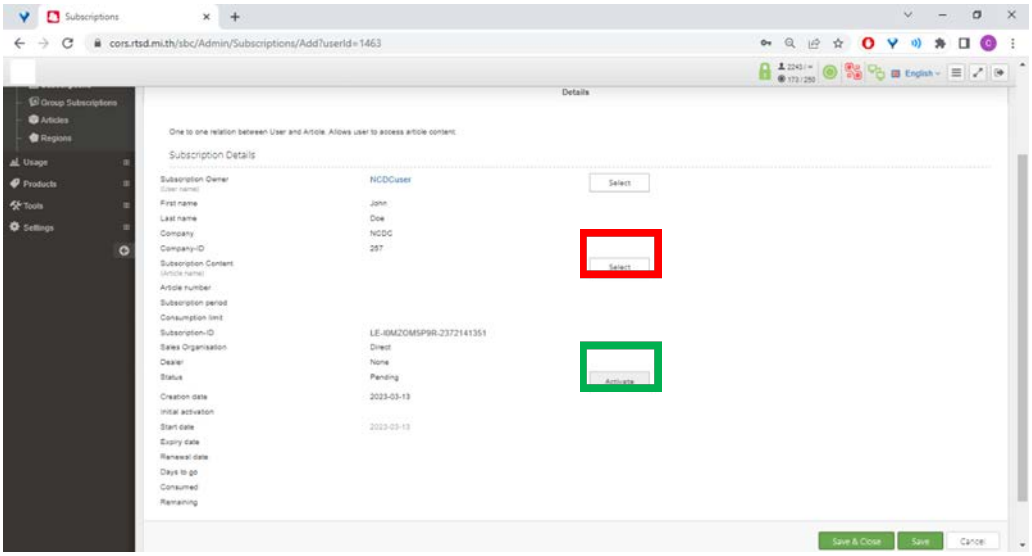
ภาพที่ 3.12 หน้าต่างข้อมูลบัญชีผู้ใช้บริการ

เมื่อผู้ดูแลระบบเพิ่มบัญชีผู้ใช้บริการแล้วก็จะต้องกรอกข้อมูล Package ตามที่ผู้ใช้ได้โดยแบ่งออกเป็น 3 กรณี จากหน้าต่างข้อมูลบัญชีผู้ใช้บริการ ดังแสดงในภาพที่ 3.12 ดังนี้

1. กดปุ่ม Save & Close – เมื่อกลับมายังหน้าต่างเว็บไซต์ ดังแสดงในภาพที่ 3.10 แล้ว ให้ผู้ดูแลระบบค้นหาบัญชีผู้ใช้บริการที่ต้องการกรอกข้อมูล Package และกดไอคอน ในกรอบสีเขียว ดังแสดงในภาพที่ 3.11 และกดปุ่ม Save & Subscribe เพื่อเข้าสู่หน้าต่างการกรอกข้อมูล Package ดังแสดงในภาพที่ 3.13

2. กดปุ่ม Save & Subscribe – จะเป็นการเข้าสู่หน้าต่างการกรอกข้อมูล Package ดังแสดงในภาพที่ 3.13

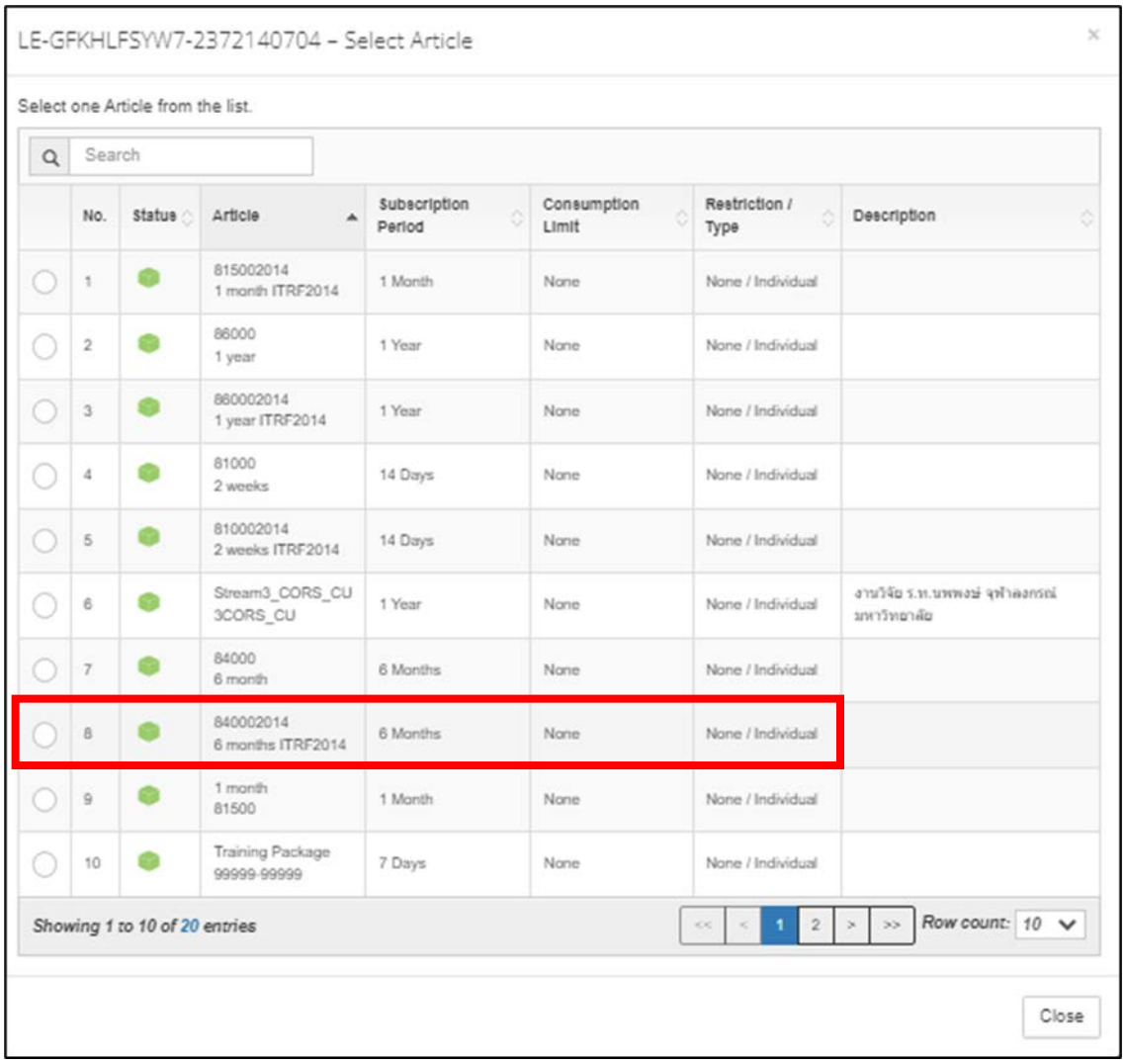
3. กดปุ่ม Save – ผู้ดูแลระบบสามารถกดปุ่ม Save & Subscribe เพื่อเข้าสู่หน้าต่างการกรอกข้อมูล Package ดังแสดงใน ภาพที่ 3.13



ภาพที่ 3.13 หน้าต่างการกรอกข้อมูล Package

เมื่อเข้าสู่หน้าต่างการกรอกข้อมูล Package ดังแสดงในภาพที่ 3.13 ให้ผู้ดูแลระบบกรอกข้อมูล Package ตามที่ผู้ใช้บริการสมัครได้โดยการกดปุ่ม Select ในกรอบสีแดง ดังแสดงในภาพที่ 3.13 ก็จะปรากฏหน้าต่างที่จะให้ผู้ดูแลระบบเลือก Package ดังแสดงในภาพที่ 3.14

เมื่อผู้ดูแลระบบเลือก Package เรียบร้อยแล้วให้กดปุ่ม close ก็จะปรากฏรายละเอียดของ Package ที่เลือกไว้ข้างต้น ซึ่งผู้ดูแลระบบสามารถอนุมัติบัญชีผู้ใช้ได้ โดยการกดปุ่ม Activate ในกรอบสีเขียวดังแสดงในภาพที่ 3.13 แต่จะต้องอนุมัติตามวันที่ผู้ใช้บริการระบุไว้เสียก่อนจึงจะดำเนินการได้ หากยังไม่ถึงวันที่กำหนด ให้ผู้ดูแลระบบกด Save & Close จะเป็นการบันทึก Package ของผู้ใช้บริการแต่จะยังไม่ได้อนุมัติการใช้บริการ Package ข้างต้นให้กับบัญชีผู้ใช้บริการ

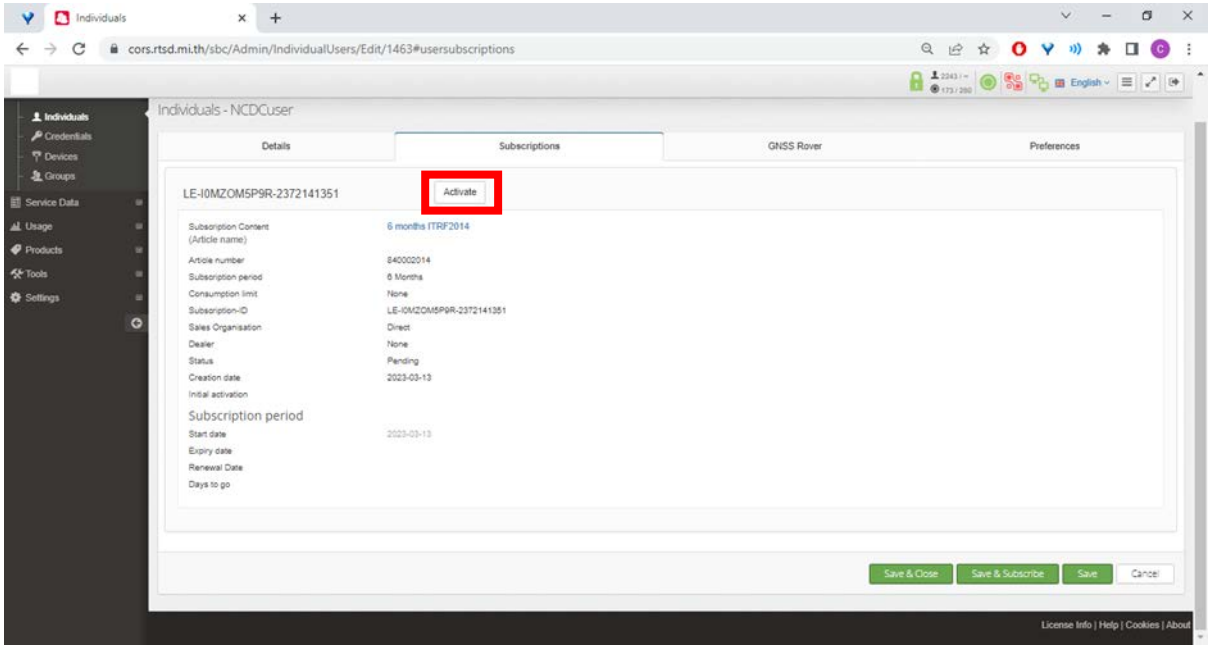


ภาพที่ 3.14 หน้าต่างบัญชีรายชื่อ Package

เมื่อถึงวันที่ผู้ใช้บริการระบุไว้ในแบบฟอร์มแล้ว ให้ผู้ดูแลระบบเข้าสู่ระบบด้วยบัญชีผู้ใช้ของผู้ดูแลระบบในเว็บไซต์ SBC เพื่ออนุมัติบัญชีผู้ใช้บริการ ซึ่งสามารถดำเนินการได้สองวิธี ได้แก่

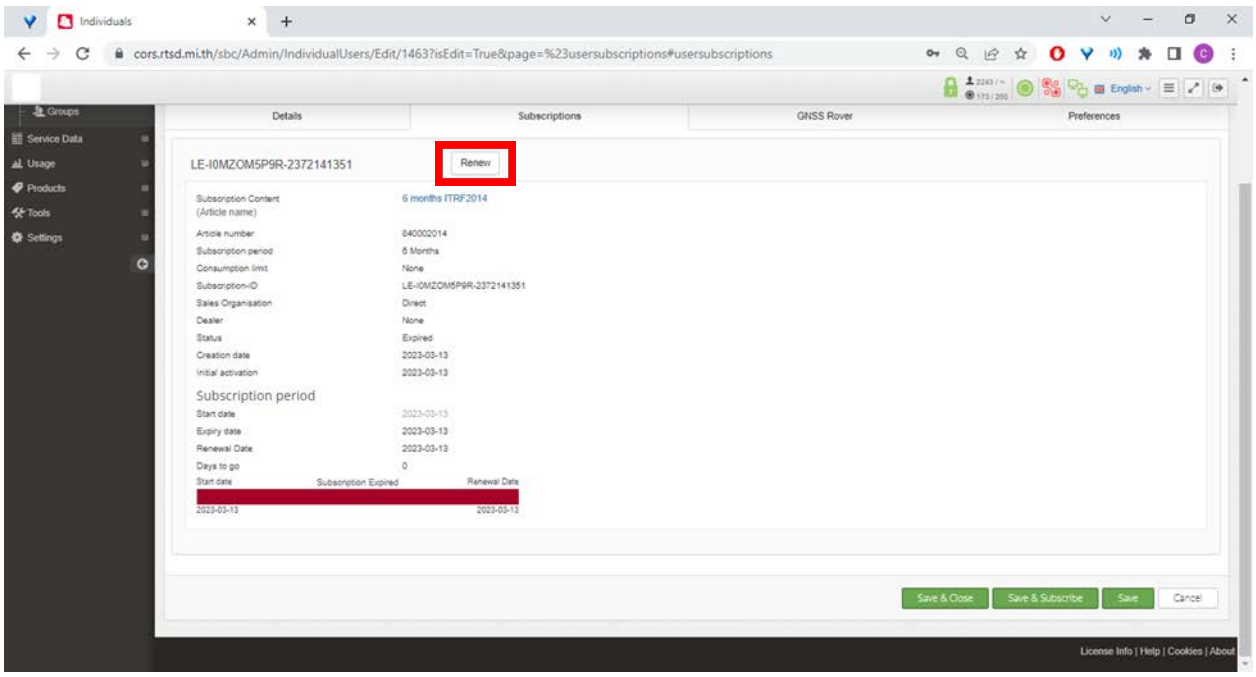
1) กดเข้าไปที่ Service Data > Subscriptions ที่แถบด้านซ้ายของหน้าเว็บไซต์ และค้นหาบัญชีผู้ใช้ที่ต้องการอนุมัติ แล้วกดไอคอน ที่อยู่บริเวณด้านขวาของข้อมูลบัญชีผู้ใช้บริการ ก็จะปรากฏหน้าต่างดังแสดงในภาพที่ 3.13 ให้ผู้ดูแลระบบกดปุ่ม Activate ในกรอบสีเขียว ดังแสดงในภาพที่ 3.13

2) กดเข้าไปที่ Users > Individuals ที่แถบด้านซ้ายของหน้าเว็บไซต์ และค้นหาบัญชีผู้ใช้ที่ต้องการอนุมัติ แล้วกดไอคอน ในกรอบสีเขียว ดังแสดงในภาพที่ 3.11 จะปรากฏข้อมูลของบัญชีผู้ใช้บริการขึ้นมา ให้ผู้ดูแลระบบกดแท็บ Subscriptions ที่อยู่บริเวณส่วนบนของหน้าต่าง และกดปุ่ม Activate ในกรอบสีแดง ดังแสดงในภาพที่ 3.15



ภาพที่ 3.15 หน้าต่างการอนุมัติบัญชีผู้ใช้บริการ

เมื่อ package ที่ผู้ใช้บริการสมัครหมดอายุ กล่าวคือ ถึงวันครบกำหนดแล้ว ผู้ใช้บริการสามารถต่ออายุ package เดิมได้ โดยผู้ดูแลระบบจะต้อง กดเข้าไปที่ Users > Individuals ที่แถบด้านซ้ายของหน้าเว็บไซต์ และค้นหาบัญชีผู้ใช้ที่ต้องการต่ออายุแล้วกดไอคอน ในกรอบสีเขียว ดังแสดงในภาพที่ 3.11 จะปรากฏข้อมูลของบัญชีผู้ใช้บริการขึ้นมา ให้ผู้ดูแลระบบกดแท็บSubscriptions ที่อยู่บริเวณส่วนบนของหน้าต่าง และกดปุ่ม Renew ในกรอบสีแดง ดังแสดงในภาพที่ 3.16 แล้วกด Save



ภาพที่ 3.16 การต่ออายุ package

กรณีผู้ดูแลระบบมีการแก้ไขรายละเอียดของบัญชีผู้ใช้บริการ นอกจาก Username สามารถทำได้โดยกดเข้าไปที่ Users > Individuals ที่แถบด้านซ้ายของหน้าเว็บไซต์ และค้นหาบัญชีผู้ใช้ที่ต้องการต่ออายุ แล้วกดไอคอน ในกรอบสีเขียว ดังแสดงในภาพที่ 3.11 จะปรากฏข้อมูลของบัญชีผู้ใช้บริการขึ้นมาให้ผู้ดูแลระบบแก้ไขและกด Save

เมื่อเกิดข้อผิดพลาดขึ้น เช่น Username ที่ผู้ใช้บริการสมัครซ้ำกับ Username อื่นที่ได้ลงทะเบียนในระบบแล้ว ผู้ดูแลระบบจะต้องติดต่อผู้ใช้บริการทางช่องทางที่ผู้ใช้บริการได้ลงทะเบียนไว้เช่น เบอร์ติดต่อหรืออีเมลเป็นต้น หรือในกรณีที่ผู้ใช้บริการมีข้อสงสัยสามารถติดต่อสอบถามผ่านทาง Line Official ชื่อว่า NCDC_Thailand ซึ่งจะมีผู้ดูแลระบบให้ข้อมูลและตอบข้อสงสัยกับผู้ใช้บริการ

3.3.2 Portal[5]

ศูนย์อ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center : NCDC)

มีหน้าที่ให้บริการค่าพิกัดที่มีความถูกต้องสูงที่มีเอกภาพ เป็นมาตรฐานเดียวกันทั้งประเทศแก่หน่วยงานภาครัฐ ภาคเอกชน และประชาชนทั่วไป โดยบูรณาการข้อมูลจากสถานีอ้างอิงค่าพิกัดแบบต่อเนื่อง (CORS : Continuously Operating Reference Stations) ของหน่วยงานภาครัฐต่างๆ ทั่วประเทศ มีการประชาสัมพันธ์ และเผยแพร่ข้อมูลการให้บริการของ NCDC ผ่านทางหน้าเว็บไซต์ที่ลิงก์ https:// www.ncdc.in.th ดังแสดงในภาพที่ 3.17

มีบริการใน 3 รูปแบบคือ

- บริการการรังวัดด้วยระบบโครงข่ายการรังวัดสัญญาณดาวเทียม GNSS แบบจลน์ (Network Real Time Kinematics)
- บริการข้อมูลสัญญาณดาวเทียมเพื่อการนำทางของสถานีค่าอ้างอิงพิกัดแบบต่อเนื่อง (Continuously Operating Reference Stations; CORS) ในรูปแบบ RINEX file
- บริการประมวลผลค่าพิกัดแบบภายหลัง (Post processing)

บริการจากศูนย์ข้อมูลค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ จะทำให้การรังวัดจากเครื่องมือกำหนดพิกัดด้วยดาวเทียม ได้ค่าพิกัดที่มีความละเอียดถูกต้องสูงมาก สามารถนำไปประยุกต์ใช้ได้ในหลากหลายด้าน เช่น งานสำรวจเพื่อทำแผนที่และภูมิสารสนเทศ,งานรังวัดและสำรวจแปลงที่ดิน,งานด้านวิศวกรรมและก่อสร้าง (i-Construction),งานด้านคมนาคมขนส่งและยานยนต์ไร้คนขับ,งานด้านเกษตรอัจฉริยะ (Smart Farming)

[5] **อ้างอิงจาก คู่มือการตั้งค่า** ArcGIS Enterprise Sites



ภาพที่ 3.17 ศูนย์อ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center : NCDC)

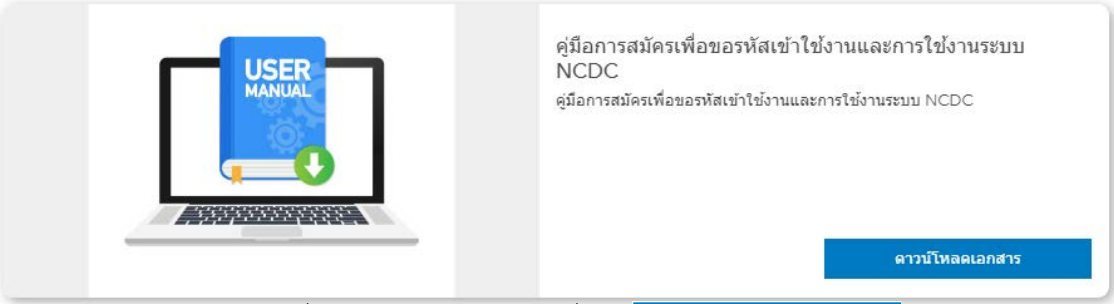
ระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (RTSD)

มีวัตถุประสงค์เพื่อเพิ่มขีดความสามารถการปฏิบัติงานสำรวจและการทำแผนที่ให้สามารถตอบสนองต่อการประเมินและป้องกันด้านอุทกภัยและภัยพิบัติธรรมชาติอื่นๆ รวมทั้งทำให้การสำรวจหาค่าพิกัดทั้งทางราบและค่าความสูงเหนือระดับทะเลปานกลาง โดยการประยุกต์ใช้ร่วมกับแบบจำลองยีออยด์ท้องถิ่นความละเอียดสูง (TGM2017*) ในเวลาอันรวดเร็วแบบทันที (Realtime) สามารถให้ค่าพิกัดที่มีความละเอียดถูกต้องในระดับ 3-5 เซนติเมตร อันจะเป็นการยกระดับการสำรวจในประเทศไทย ให้เป็นมาตรฐานสากลและรองรับการเข้าสู่ประชาคมเศรษฐกิจอาเซียน ภายใต้โมเดล Thailand 4.0 เผยแพร่ข้อมูลการให้บริการของ RTSD ผ่านทางหน้าเว็บไซต์ที่ลิงก์ https://www.rtsd.mi.th ดังแสดงในภาพที่ 3.18



ภาพที่ 3.18 ระบบโครงข่ายสถานีรังวัดสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (RTSD)

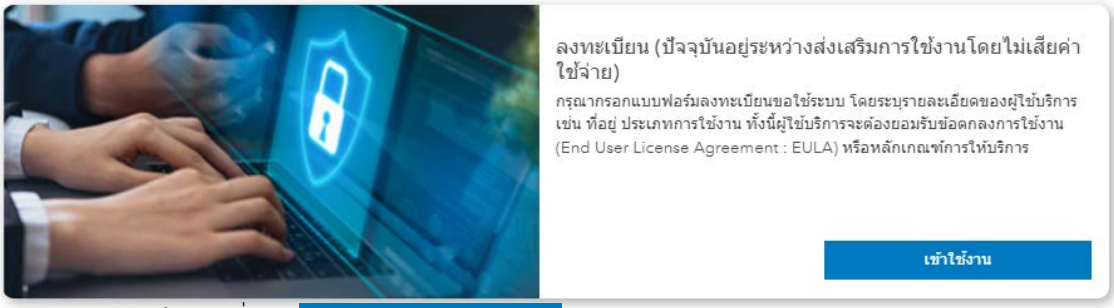
วิธีการใช้งาน Portal ผ่านทาง https://ncdc.in.th



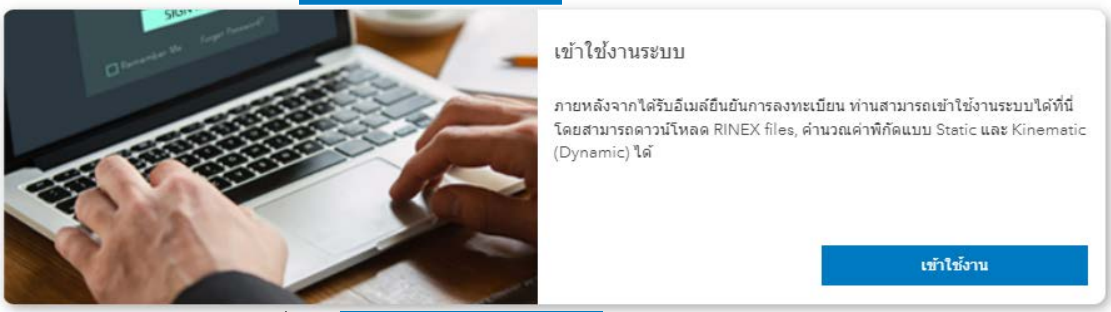
- ดาวน์โหลดคู่มือการสมัครเพื่อขอรหัสเข้าใช้งาน โดยกดที่ ช่อง **ดาวน์โหลดเอกสาร**



- ดาวน์โหลดคู่มือการใช้งาน โดยกดที่ ช่อง **ดาวน์โหลดเอกสาร**



- ลงทะเบียน โดยกดที่ ช่อง **เข้าใช้งาน**

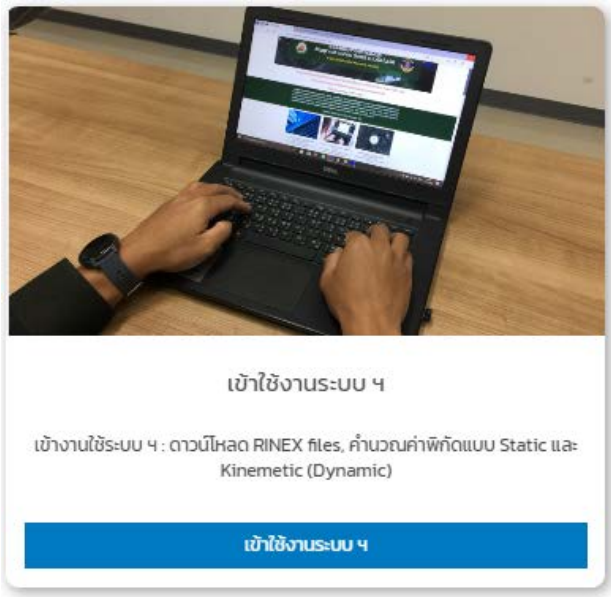


- เข้าใช้งานระบบ โดยกดที่ ช่อง **เข้าใช้งาน**

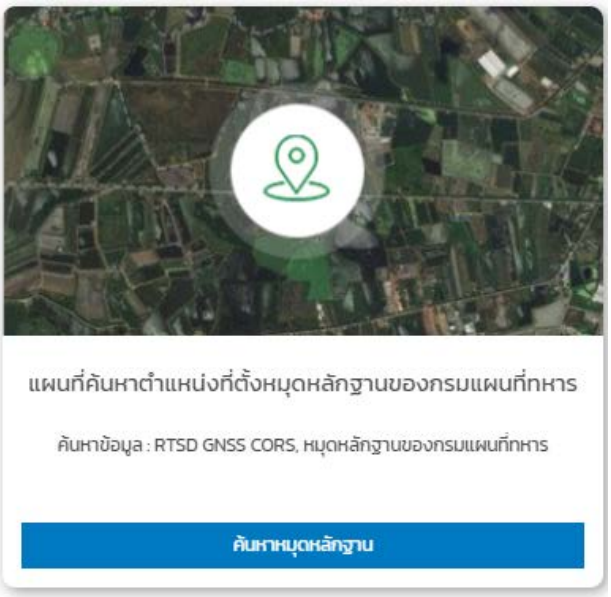


- ตรวจสอบตำแหน่ง CORS โดยกดที่ ช่อง **เข้าใช้งาน**

วิธีการใช้งาน Portal ผ่านทาง https://www.rtsd.mi.th



- เข้าใช้งานระบบ โดยกดที่ ช่อง เข้าใช้งาน



- ค้นหาตำแหน่งหมุดหลักฐาน โดยกดที่ ช่อง ค้นหาหมุดหลักฐาน



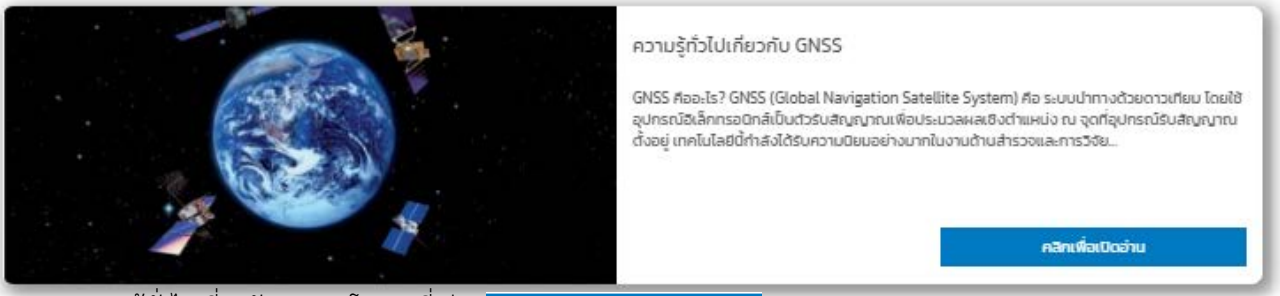
- ดาวน์โหลด TGM2017 โดยกดที่ ช่อง ดาวน์โหลดเอกสาร



- ดาวน์โหลดคู่มือการใช้งานระบบ โดยกดที่ ช่อง ดาวน์โหลดเอกสาร



- ดาวน์โหลดคู่มือการใช้งาน Leica GS10 โดยกดที่ ช่อง ดาวน์โหลดเอกสาร



- หาความรู้ทั่วไปเกี่ยวกับ GNSS โดยกดที่ ช่อง คลิกเพื่อเปิดอ่าน



- หาข้อมูลระบบดาวเทียม GNSS โดยกดที่ ช่อง คลิกเพื่อเปิดอ่าน



- ตรวจสอบตำแหน่ง CORS โดยกดที่ ช่อง คลิกเพื่อเปิดอ่าน

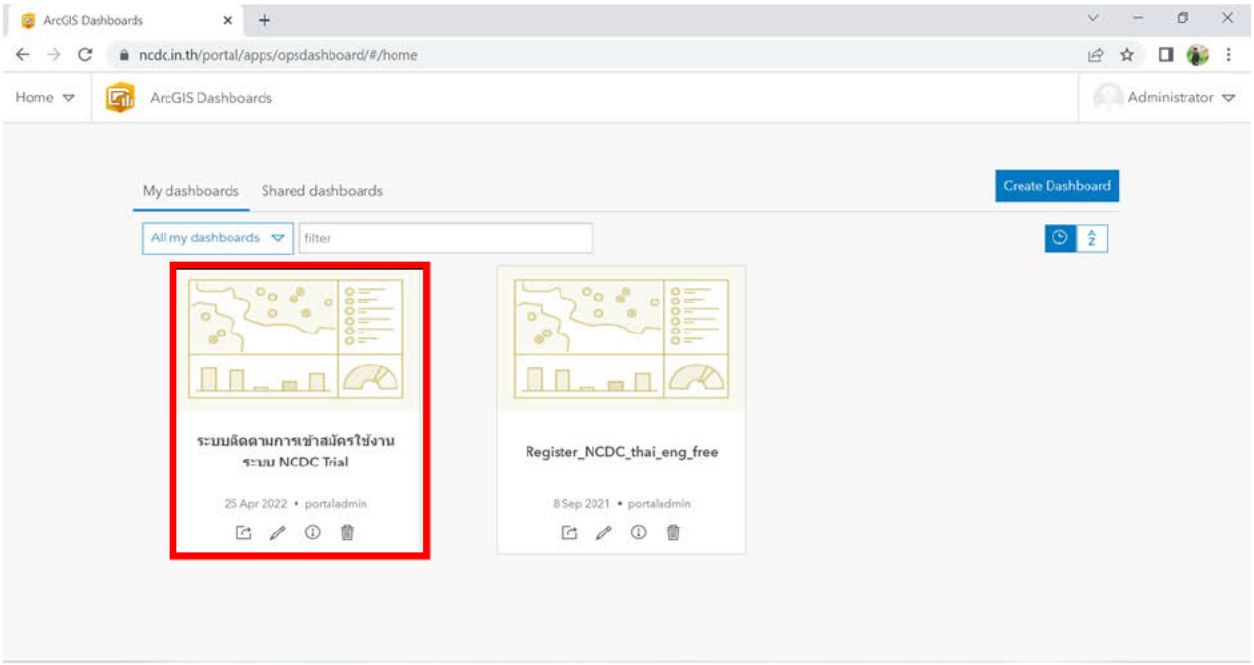


- อ่านเอกสารการประเมินความถูกต้องค่าระดับความสูงภูมิประเทศโดยใช้แบบจำลองยีออยด์ โดยกดที่ ช่อง คลิกเพื่อเปิดอ่าน

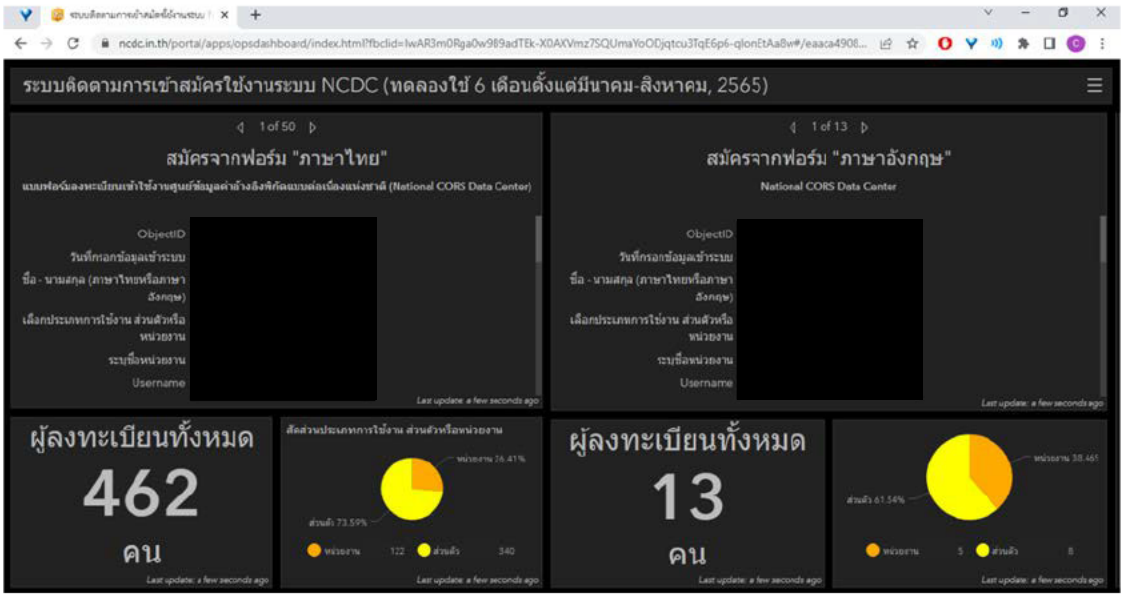
3.3.3 Dashboards

<u>ตรวจสอบข้อมูลการสมัครใช้บริการ NCDC ของผู้ใช้ใหม่</u>

Admin สามารถตรวจสอบข้อมูลของผู้ที่สมัครเข้ามาใช้บริการด้วยระบบติดตามการลงทะเบียนเข้าใช้งานระบบ NCDC ได้ที่ ArcGIS Dashboards ผ่านลิงก์ https://ncdc.in.th/portal/apps/opsdashboard/#/home และคลิกเลือก ระบบติดตามการเข้าสมัครใช้งานระบบ NCDC Trial ในกรอบสีแสดงดังแสดงในภาพที่ 3.19 ก็จะปรากฏข้อมูลของผู้สมัครทั้งหมดและสถิติของการสมัคร ได้แก่ จำนวนผู้ลงทะเบียนทั้งหมด สัดส่วนผู้ขอใช้บริการระหว่างหน่วยงานกับใช้ส่วนตัว ดังแสดงในภาพที่ 3.20



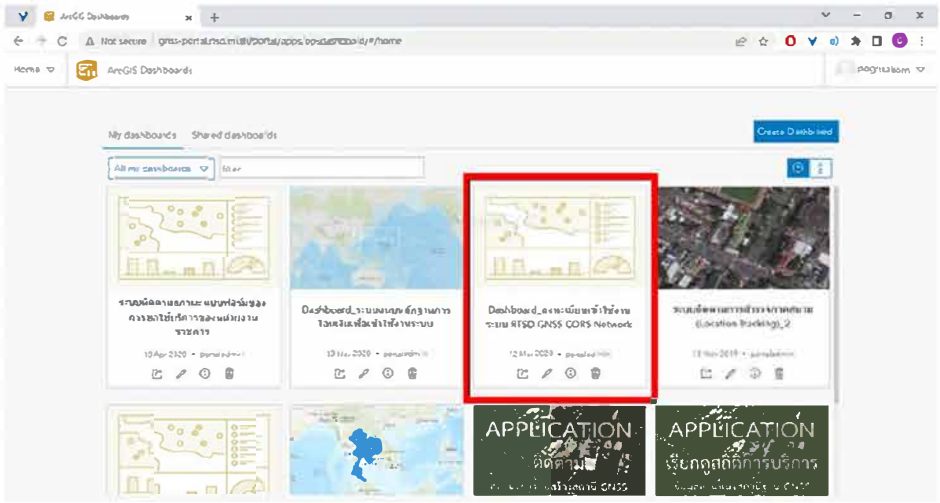
ภาพที่ 3.19 ArcGIS Dashboards (NCDC)



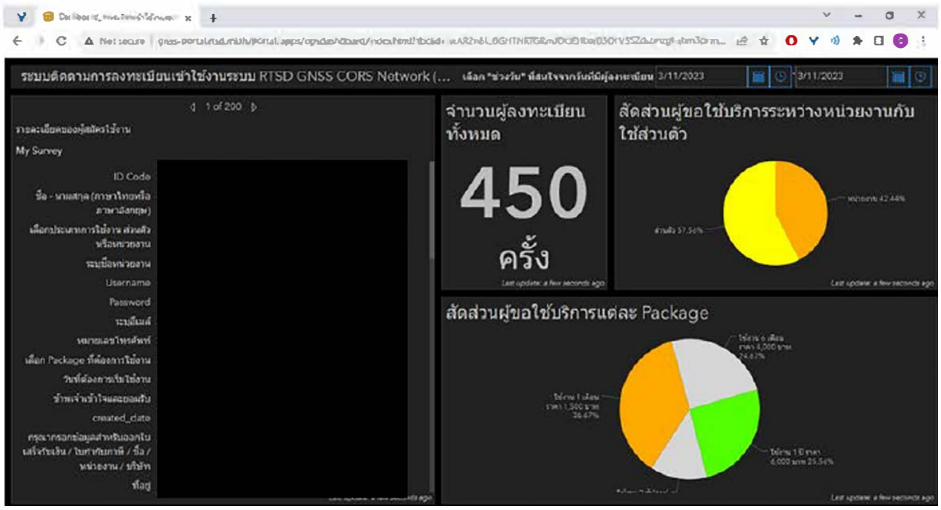
ภาพที่ 3.20 Dashboards ณ วันที่ 11 มีนาคม 2566 เวลา 16:45 น.

ตรวจสอบข้อมูลการสมัครใช้บริการ RTSD CORS ของผู้ใช้ใหม่

Admin สามารถตรวจสอบข้อมูลของผู้ที่สมัครเข้ามาใช้บริการด้วยระบบติดตามการลงทะเบียนเข้าใช้งานระบบ RTSD CORS ได้ที่ ArcGIS Dashboards ผ่านลิงก์ http://gnss-portal.rtsd.mi.th/portal/apps/opsdashboard/#/home และคลิกเลือก Dashboard_ลงทะเบียนเข้าใช้งานระบบ RTSD GNSS CORS Network ในกรอบสีแดงดังแสดงภาพที่ 3.21 จะแสดงข้อมูลของผู้สมัครทั้งหมด และสถิติของการสมัคร ดังแสดงในภาพที่ 3.22



ภาพที่ 3.21 ArcGIS Dashboards (RTSD)



ภาพที่ 3.22 RTSD Dashboards ณ วันที่ 11 มีนาคม 2566 เวลา 16:45 น.

Admin จะนำข้อมูลผู้สมัครใช้บริการใหม่ไปตรวจสอบคุณสมบัติ และทำการสร้างบัญชีผู้ใช้ใหม่ ทำการต่ออายุบัญชีผู้ใช้ หรือแก้ไขรายละเอียดบัญชีผู้ใช้ รายละเอียดตามที่ได้กล่าวไปแล้วในหัวข้อที่ 3.3.1.2

4. การออกแบบโครงข่าย CORS และการตั้งค่า (CORS network design and configuration)

วัตถประสงค์

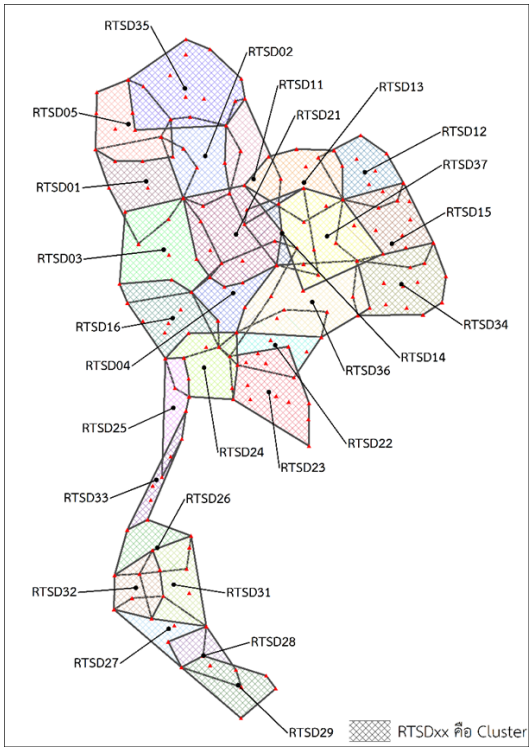
เนื่องจากปริมาณข้อมูลที่ได้รับจาก CORS มีปริมาณมาก และ มาจากหลายหน่วยงาน เช่น กรมที่ดิน ที่จะส่ง ข้อมูลของ CORS กรมที่ดิน มาพร้อมกันทั้งหมด ทำให้ข้อมูลอัพโหลดได้ล่าช้า จึงจำเป็นต้องมีการออกแบบโครงข่าย CORS เพื่อให้ส่วนของ Server สามารถประมวลผลได้อย่างมีประสิทธิภาพ

สาเหตุ

แรกเริ่มเดิมที NCDC ได้แบ่ง Cluster เป็น 4 Cluster ผลที่ได้คือ Rover ไม่สามารถ Fix ค่าพิกัดได้ซึ่งสาเหตุ มาจากการที่ปริมาณข้อมูลมีมากเกินไปทำให้ส่งข้อมูลได้ไม่เต็มประสิทธิภาพ จึงได้แก้ปัญหาโดยการแบ่ง Cluster โดย 1 Cluster มี 8-15 CORS ผลที่ได้คือ Rover สามารถ Fix ค่าได้

หลักการออกแบบ

- ออกแบบโครงข่ายให้มีระยะระหว่าง CORS ประมาณ 50-100 กม.
- ออกแบบ Cluster/Auto cell ให้มีจำนวน CORS ต่อ Cluster ประมาณ 8-15 CORS เพื่อไม่ให้ load ต่อการทำงานของ CPU/RAM ของ computer
- ออกแบบ Cluster/Auto cell ให้มีระยะ overlap ประมาณ 20-30% เพื่อให้เป็น redundant ในกรณี Cluster/Auto cell นั้นไม่สามารถ fixed ambiguity ได้ ระบบจะย้ายไปที Cluster/Auto cell อื่นแทน
- ระบบจำทำการส่งค่าปรับแก้แบบ NRTK ให้ หากไม่สามารถสร้างค่าปรับแก้แบบ NRTK ได้ ระบบจะทำการส่งค่าปรับแก้แบบ Single base ให้แทนโดยเลือกสถานี Base จากที่มีจำนวนดาวเทียม fixed ร่วมกับสถานี rover ได้มากที่สุด และเมื่อระบบ NRTK กลับมาทำงานได้ ระบบจะย้ายกลับมาทำงานแบบ NRTK เองแบบอัตโนมัติ



ภาพที่ 4.1 การออกแบบโครงข่าย CORS (Cluster)

4.1 การสร้าง Cluster ใน Network Server

การออกแบบ cluster จะคำนึงถึง

- 1 cluster ไม่ควรมีจำนวน CORS เกิน 35 CORS
- Cluster ควรมีพื้นที่ overlap กับแต่ละ cluster ข้างเคียงประมาณ 20-30 %

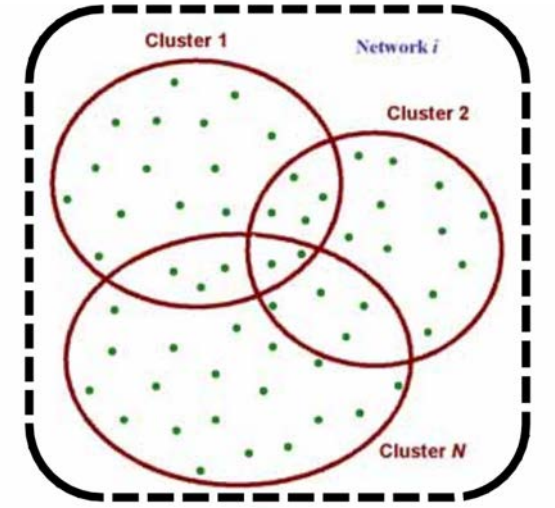
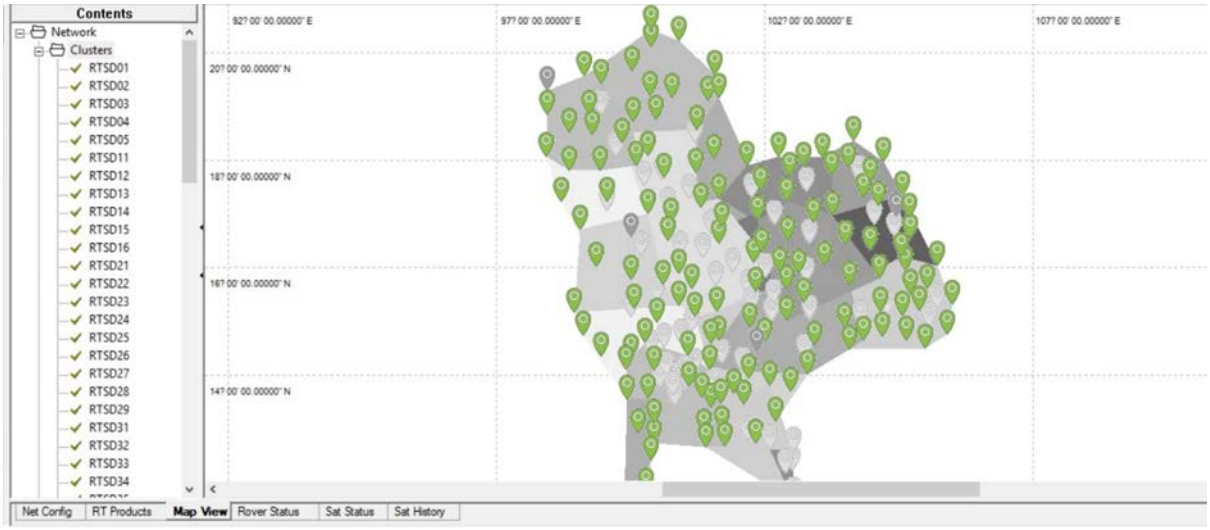


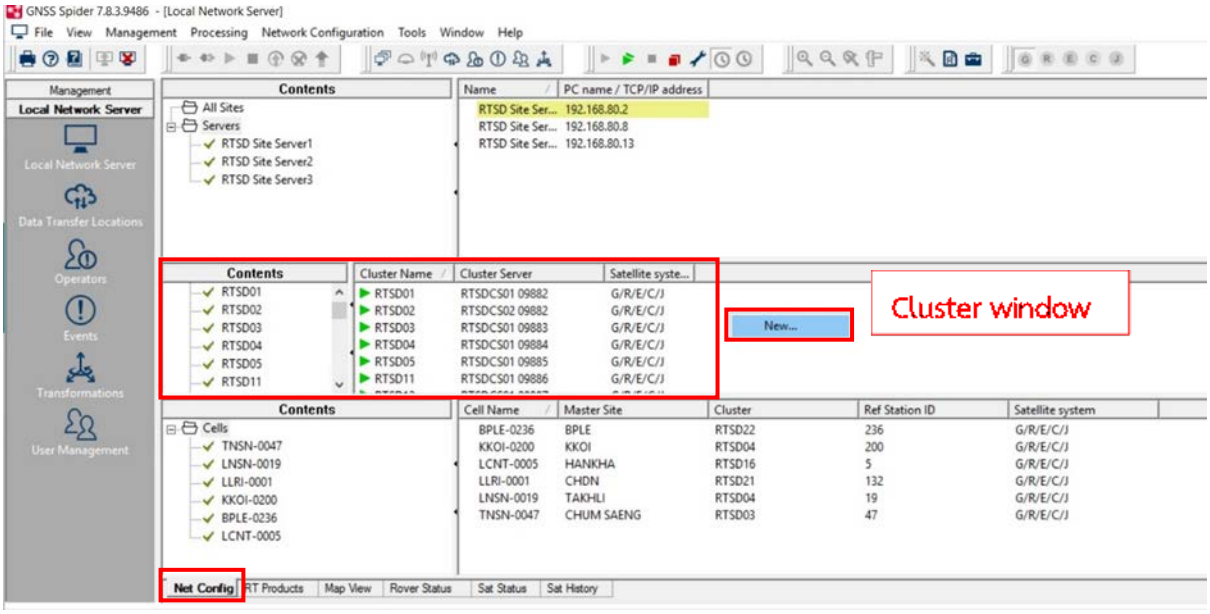
Figure 2:
A reference network comprising a number of clusters.



ภาพที่ 4.2 การออกแบบ cluster ใน NCDC network server

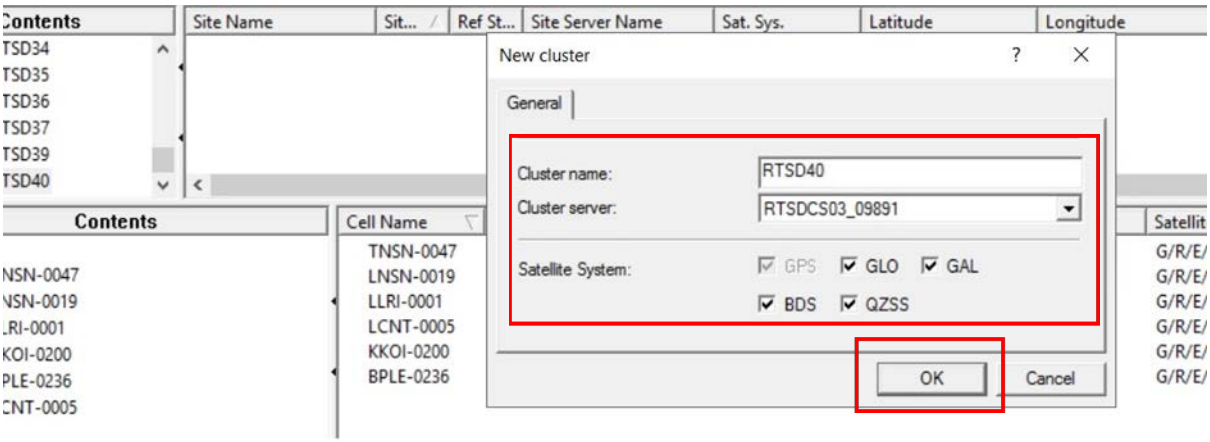
4.2 ขั้นตอนการสร้าง cluster ใน network server

1. ที่เครื่อง network server เปิด โปรแกรม GNSS spider เลือก Net Config tab, ที่ cluster window ให้ click mouse ขวา แล้ว เลือก new



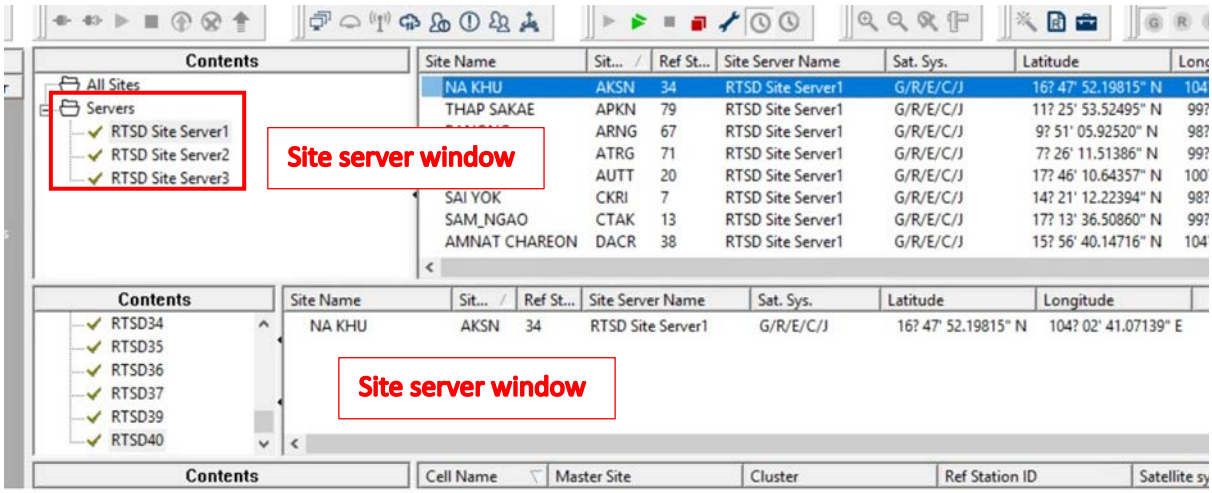
ภาพที่ 4.3 การสร้าง cluster ใน NCDC network server (1)

2. ป้อนชื่อ Cluster name, เลือก Cluster server, เลือก Satellite systems แล้ว กด OK (cluster server จะมี 3 Server คือ CS01 CS02 CS03 ในแต่ละ CS จะมี sub cluster อีก 10 sub cluster ทำให้ ระบบ NCDC มี sub cluster ทั้งหมด 30 sub cluster การสร้าง cluster ใหม่ ให้เลือก sub cluster ที่ยังไม่ได้เปิดใช้ หรือ กำลัง stop)



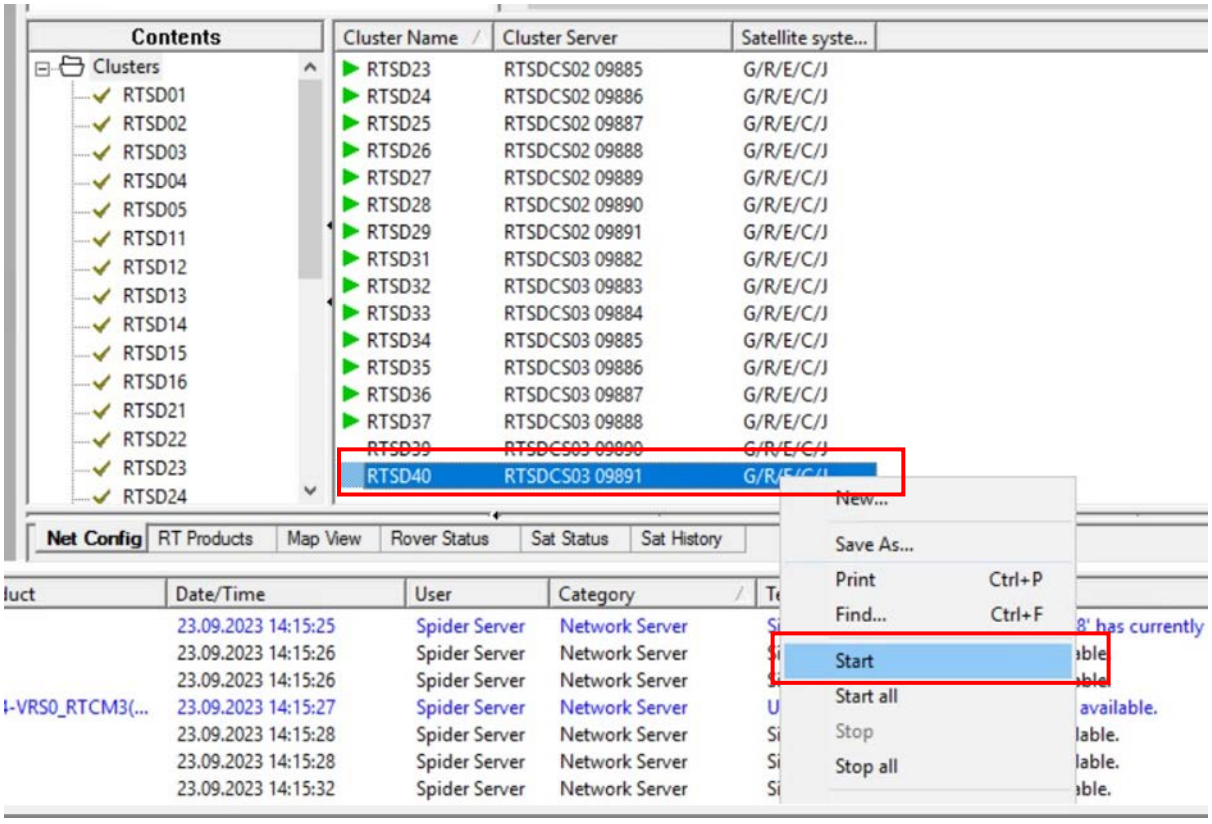
ภาพที่ 4.4 การสร้าง cluster ใน NCDC network server (2)

3. ที่ site server window ให้เลือก Site server (SS01 or SS02) ที่เชื่อมต่อกับ CORS ที่จะให้อยู่ใน Cluster, พื้นที่ด้านขวาของ site server window จะแสดงรายชื่อ CORS ที่อยู่ใน Site server ให้ทำการ drag and drop ที่ละ CORS จาก site server window ไปไว้ใน cluster window จนครบทุก CORS ที่ต้องการ



ภาพที่ 4.5 การสร้าง cluster ใน NCDC network server (3)

4. ที่ cluster window ให้เลือก cluster ที่สร้างใหม่ แล้ว click mouse ขวา เลือก start เพื่อเปิดการทำงานของ cluster



ภาพที่ 4.6 การสร้าง cluster ใน NCDC network server (4)

5. เลือก Map View tab , ที่ cluster window เลือก cluster ที่ต้องการดู ด้านขวาของจอจะแสดงขอบเขตของ cluster นั้น



(ก)

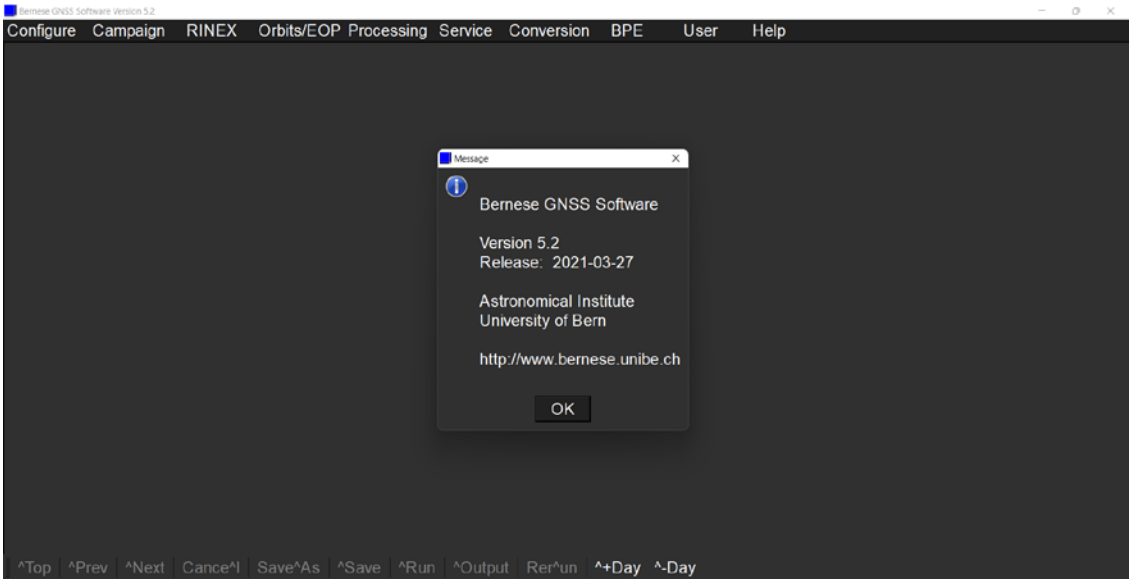


(ข)

ภาพที่ 4.7 การสร้าง cluster ใน NCDC network server (5)

5. การประมวลผลค่าพิกัดอ้างอิงของสถานี CORS ในโครงข่าย (NCDC data processing)

การประมวลผลค่าพิกัดสถานีรับสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS) ปัจจุบันใช้โปรแกรม Bernese เวอร์ชั่น 5.2 ดังแสดงในภาพที่ 5.1 โดยเลือกกรอบอ้างอิงในการประมวลผลคือกรอบพิกัดอ้างอิง ITRF2014 ซึ่งเป็นกรอบอ้างอิงล่าสุดในปัจจุบันและกรอบพิกัดอ้างอิง ITRF2008 (อันเดิมที่ยังใช้อยู่) โดยเลือกวิธีการโยงยึดค่าพิกัด (Mapping) ด้วยสถานี IGS จำนวน 12 สถานี ดังแสดงในภาพที่ 5.2 ซึ่งจะได้ค่าพิกัดสถานี CORS ของ NCDC ดังแสดงในตารางที่ 5 ในส่วนของภาคผนวก

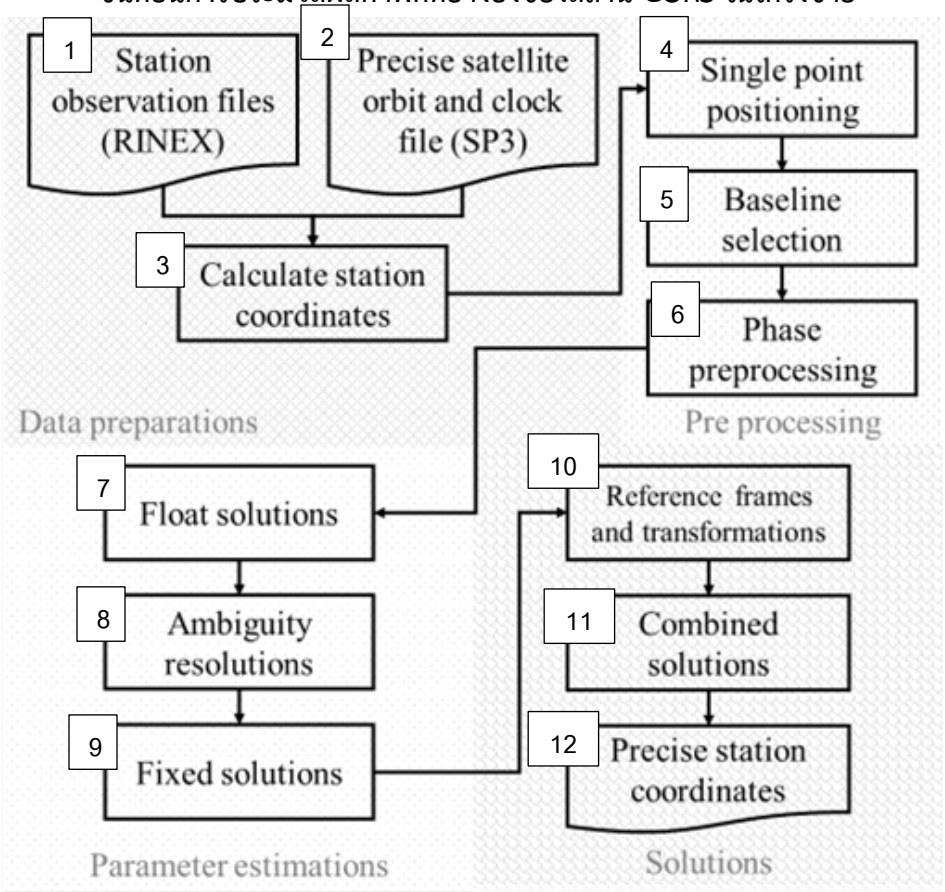


ภาพที่ 5.1 โปรแกรม Bernese เวอร์ชั่น 5.2



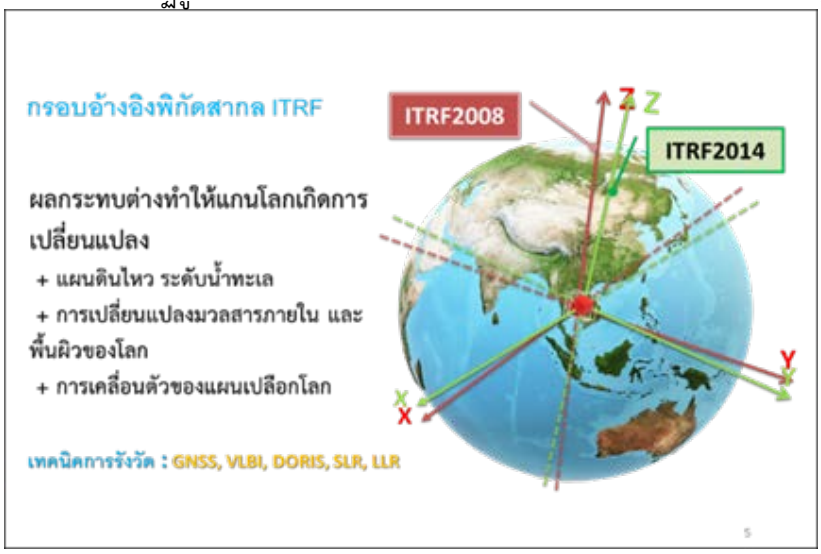
ภาพที่ 5.2 ตำแหน่งสถานี IGS ทั้ง 12 สถานี ที่ใช้ในการโยงยึดค่าพิกัด

ขั้นตอนการประมวลผลค่าพิกัดอ้างอิงของสถานี CORS ในโครงข่าย



1. การเตรียมข้อมูลสถานี CORS จำนวน 23 สถานี
2. การเตรียมข้อมูลค่าแก้ที่มีความละเอียด
3. คำนวณค่าพิกัดสถานีเริ่มต้น
4. ประมวลผลจุดเดี่ยว
5. คำนวณการเลือกเส้นฐาน(Baseline)
6. เตรียมข้อมูลก่อนการปรับแก้ค่าพิกัด
7. คำนวณจำนวนลูกคลื่นที่เป็นไม่จำนวนเต็มลูกคลื่น
8. คำนวณจำนวนลูกคลื่นที่เป็นจำนวนเต็มลูกคลื่น
9. เลือกค่าพิกัดที่สมบูรณ์ ไปใช้งานในขั้นต่อไป
10. เลือกกรอบอ้างอิง และตรวจสอบค่าผิดปกติ
11. รวมข้อมูลหลักการปรับแก้(Mapping)
12. ได้ค่าพิกัดความละเอียดสูง

เนื่องจากผลกระทบต่างๆทำให้แกนโลกเกิดการเปลี่ยนแปลง NCDC จึงเลือกใช้กรอบพิกัดอ้างอิง ITRF2014 ที่ใช้อยู่ในปัจจุบันแทนกรอบพิกัดอ้างอิง ITRF2008 (อันเดิมที่ยังใช้อยู่เพราะยังมีหน่วยงานราชการที่ยังคงใช้งานอยู่ ยกตัวอย่างเช่น สำนักงานการปฏิรูปที่ดินเพื่อเกษตรกรรม ต้องใช้เพื่อการทำงานเกี่ยวกับที่ดิน)



ภาพที่ 5.3 กรอบพิกัดอ้างอิง ITRF2008 (อันเดิม) และITRF2014 (อันใหม่)

```
================================================================================
RNX2SNX BPE PROCESSING SUMMARY FOR YEAR-SESSION 21-3070
================================================================================


Summary file generated at 24-Dec-2021 11:21:56 by R2S_SUM

General files:
   Antenna phase center eccentricity file:   PCV.I14
   Satellite information file:               SATELLIT.I14
   Satellite problem file:                   SAT_2021.CRX
   Receiver characterization file:           RECEIVER.
   Orbit, ERP and clock products used from:  ${D}/IGS

Observation file selection:
   RINEX 2 files copied from:                ${D}/RTSD/
   RINEX 3 files copied from:                ${D}/RTSD3/
   Station selection:                        all stations

Reference frame and station related files:
   Station related files used from:          ${D}/REF52/
   External reference frame file series:     ITRF2014_R.(CRD|VEL)
   Project specific station file series:     RTSD
      Station information file:              STA/RTSD.STA
      RINEX inconsistency file:
      Ocean tidal loading table:             STA/RTSD.BLQ
      Atmosphere tidal loading table:        STA/RTSD.ATL
```

ภาพที่ 5.4 ตัวอย่างผลการประมวล โปรแกรม Bernese เวอร์ชัน 5.2 บนกรอบพิกัดอ้างอิง ITRF2014

```
Other options from PCF:
   Antenna phase center model updated with:  I14.ATX
   RINEX 3 observation type selection:       OBS.SEL
   Satellite system(s) included:             GPS/GLO
   Sampling rate for final solution:         180 seconds
   Higher order ionosphere based on:         HOI213070
   Session scheme:                           daily
   Maximum number of files per cluster:      10
   Max. number of files per GPSEDT cluster:  10

Ambiguity resolution options from PCF:
   GNSS to be used for ambiguity resolution: ALL
   Maximum baseline length for MW/L3 AR:     6000 km
   Maximum baseline length for QIF AR:       2000 km
   Maximum baseline length for L5/L3 AR:     200 km
   Maximum baseline length for L1&L2 AR:     20 km

Storing the results:
   Results files saved to:                   ${S}/RTSD14_REL/2021/
      Preliminary (ambiguity-float) results: P1_213070
      Final (ambiguity-fixed) results:       F1_213070
      Size-reduced NEQ information:          R1_213070
      SINEX header information from:         SINEX.RNX2SNX
   Observation files saved to:               ${S}/RTSD14_REL/2021/OBS/213070/
```

ภาพที่ 5.5 ตัวอย่างผลการประมวล โปรแกรม Bernese เวอร์ชั่น 5.2 (2)

```
--------------------------------------------------------------------------------------------------------------------------------------------------------
MEAN VALUES OF GEOCENTRIC X,Y,Z - COORDINATES
RMS1: RMS OF UNWEIGHTED AVERAGE OF EACH COORDINATE COMPONENT
RMS2: FORMAL ACCURACY OF EACH COORDINATE COMPONENT FROM COMBINED SOLUTION USING EQUAL WEIGHTS
--------------------------------------------------------------------------------------------------------------------------------------------------------

NUM  STATION         #FIL FLG        X (M)      RMS1   RMS2         Y (M)      RMS1   RMS2        Z (M)      RMS1    RMS2
--------------------------------------------------------------------------------------------------------------------------------------------------------

 23  AKSN AKSN          3  M   -1482252.35840 0.00149 0.00216  5925273.06653 0.00265 0.00216  1831476.09235 0.00081 0.00216
 47  APKN APKN          3  M   -1037945.15996 0.00066 0.00216  6165673.98551 0.00207 0.00216  1255828.59586 0.00028 0.00216
 51  ARNG ARNG          3  M    -941903.93554 0.00356 0.00216  6213713.60107 0.00300 0.00216  1084084.33814 0.00107 0.00216
 58  ATRG ATRG          3  M   -1044225.20331 0.00207 0.00216  6238038.70774 0.00199 0.00216   820027.00264 0.00029 0.00216
 64  AUTT AUTT          3  M   -1130743.79125 0.00043 0.00216  5969730.38651 0.00240 0.00216  1934162.40612 0.00068 0.00216
 71  BAKO 23101M002     3  M   -1836969.51545 0.00166 0.00216  6065616.91940 0.00252 0.00216  -716257.93140 0.00008 0.00216
 94  BJFS 21601M001     3  M   -2148744.61844 0.00068 0.00216  4426641.15603 0.00051 0.00216  4044655.79641 0.00018 0.00216
174  CKRI CKRI          3  M    -962275.44457 0.00059 0.00216  6105152.83652 0.00540 0.00216  1570943.99785 0.00097 0.00216
201  CTAK CTAK          3  M    -960118.23226 0.00058 0.00216  6017800.90665 0.00434 0.00216  1876856.68365 0.00127 0.00216
208  CUSV 21904S001     3  M   -1132915.02852 0.00165 0.00216  6092528.51055 0.00021 0.00216  1504633.16543 0.00160 0.00216
211  DAEJ 23902M002     3  M   -3120042.46508 0.00163 0.00216  4084614.65909 0.00025 0.00216  3764026.78113 0.00093 0.00216
219  DBRM DBRM          3  M   -1381901.78942 0.00093 0.00216  6018323.34670 0.00324 0.00216  1592491.71267 0.00056 0.00216
220  DCMI DCMI          3  M    -937854.38708 0.00082 0.00216  5944574.22207 0.00135 0.00216  2106753.02830 0.00101 0.00216
221  DCRI DCRI          3  M   -1028340.64458 0.00112 0.00216  5903260.16586 0.00335 0.00216  2179044.39184 0.00173 0.00216
229  DLEI DLEI          3  M   -1258695.11838 0.00065 0.00216  5956128.15991 0.00195 0.00216  1897416.43421 0.00080 0.00216
230  DMSN DMSN          3  M    -837150.69068 0.00079 0.00216  6008179.31130 0.00122 0.00216  1964076.81299 0.00067 0.00216
231  DNAN DNAN          3  M   -1145278.74943 0.00070 0.00216  5919706.33972 0.00508 0.00216  2073937.25235 0.00223 0.00216
232  DNPM DNPM          3  M   -1522984.92315 0.00051 0.00216  5909676.07268 0.00255 0.00216  1848124.03087 0.00130 0.00216
234  DPLK DPLK          3  M   -1087333.00240 0.00198 0.00216  6008757.71883 0.00127 0.00216  1835935.63204 0.00094 0.00216
235  DPNB DPNB          3  M   -1182920.92965 0.00097 0.00216  6003701.73871 0.00372 0.00216  1793446.82105 0.00195 0.00216
239  DSNI DSNI          3  M   -1020697.52886 0.00164 0.00216  6217118.59769 0.00219 0.00216   989737.15279 0.00262 0.00216
240  DSNK DSNK          3  M   -1457051.87860 0.00094 0.00216  5914549.01564 0.00204 0.00216  1885146.08237 0.00093 0.00216
241  DSSK DSSK          3  M   -1505872.02776 0.00081 0.00216  5970251.56514 0.00215 0.00216  1658989.43052 0.00060 0.00216
243  DUDN DUDN          3  M   -1400643.00871 0.00035 0.00216  5939284.86282 0.00140 0.00216  1850039.24458 0.00117 0.00216
247  DUTI DUTI          3  M   -1024115.78848 0.00048 0.00216  6069399.87934 0.00160 0.00216  1666393.49228 0.00159 0.00216
249  DYLA DYLA          3  M   -1218007.58246 0.00099 0.00216  6219834.42578 0.00321 0.00216   712783.90435 0.00033 0.00216
252  ECMI ECMI          3  M    -924694.46930 0.00060 0.00216  5980687.25665 0.00116 0.00216  2008262.93290 0.00065 0.00216
358  HKSL 23015M001     3  M   -2393383.13407 0.00032 0.00216  5393860.93441 0.00081 0.00216  2412592.17582 0.00068 0.00216
381  HYDE 22307M001     3  M    1208443.87004 0.00102 0.00216  5966805.96958 0.00144 0.00216  1897077.45368 0.00080 0.00216
389  IISC 22306M002     3  M    1337935.72332 0.00123 0.00216  6070317.10557 0.00283 0.00216  1427877.37131 0.00112 0.00216
487  LCNT LCNT          3  M   -1070784.28105 0.00127 0.00216  6069037.63430 0.00121 0.00216  1637875.96271 0.00044 0.00216
```

ภาพที่ 5.6 ตัวอย่างผลการประมวล โปรแกรม Bernese เวอร์ชั่น 5.2 (3)

```
 488  LCPM LCPM          3  M   -1261224.61499 0.00066 0.00216  6015257.42682 0.00042 0.00216  1699797.78066 0.00015 0.00216
 499  LKPT LKPT          3  M   -1010663.20165 0.00141 0.00216  6031473.96916 0.00267 0.00216  1805406.56953 0.00130 0.00216
 500  LKRI LKRI          3  M   -1021280.07596 0.00096 0.00216  6096687.99515 0.00120 0.00216  1565943.73391 0.00119 0.00216
 502  LLEI LLEI          3  M   -1257391.85325 0.00084 0.00216  5974248.63029 0.00512 0.00216  1840688.84169 0.00106 0.00216
 504  LLPG LLPG          3  M   -1046898.29774 0.00084 0.00216  5950358.39625 0.00319 0.00216  2037915.10539 0.00107 0.00216
 505  LLPN LLPN          3  M    -945162.17940 0.00051 0.00216  6001074.39713 0.00178 0.00216  1937646.34849 0.00033 0.00216
 506  LLRI LLRI          3  M   -1145246.53147 0.00104 0.00216  6052214.04694 0.00183 0.00216  1649689.07139 0.00038 0.00216
 507  LMDH LMDH          3  M   -1554648.96785 0.00114 0.00216  5914873.37903 0.00024 0.00216  1804870.49154 0.00085 0.00216
 510  LNAN LNAN          3  M   -1128247.24256 0.00053 0.00216  5942056.56479 0.00268 0.00216  2018483.89542 0.00126 0.00216
 511  LNBP LNBP          3  M   -1311175.42627 0.00063 0.00216  5951371.53182 0.00291 0.00216  1876583.43617 0.00109 0.00216
 512  LNKI LNKI          3  M   -1339229.20912 0.00054 0.00216  5922621.66745 0.00073 0.00216  1945761.57145 0.00059 0.00216
 513  LNMA LNMA          3  M   -1356900.39073 0.00136 0.00216  6000717.53755 0.00225 0.00216  1677331.66670 0.00102 0.00216
 514  LNSN LNSN          3  M   -1111112.13210 0.00072 0.00216  6052437.91876 0.00284 0.00216  1672093.63158 0.00050 0.00216
 519  LPBI LPBI          3  M   -1075534.16656 0.00045 0.00216  6128876.26883 0.00310 0.00216  1395510.33319 0.00087 0.00216
 520  LPCT LPCT          3  M   -1083659.54149 0.00152 0.00216  6020119.68260 0.00459 0.00216  1800763.96568 0.00109 0.00216
 523  LPLK LPLK          3  M   -1145387.98043 0.00076 0.00216  5989310.64709 0.00238 0.00216  1864348.91692 0.00039 0.00216
 525  LPRE LPRE          3  M   -1035726.41803 0.00101 0.00216  5976349.13162 0.00253 0.00216  1966343.75955 0.00072 0.00216
 527  LSN1 LSN1          3  M   -1088138.31338 0.00254 0.00216  6196940.80355 0.00118 0.00216  1042730.25269 0.00062 0.00216
 528  LSN2 LSN2          3  M    -973259.74696 0.00160 0.00216  6226268.94884 0.00416 0.00216   980242.18008 0.00023 0.00216
 529  LSNK LSNK          3  M   -1468571.71115 0.00093 0.00216  5901750.33712 0.00154 0.00216  1915781.36008 0.00053 0.00216
 530  LSRN LSRN          3  M   -1477946.34388 0.00155 0.00216  5993065.70043 0.00220 0.00216  1601258.11796 0.00097 0.00216
 531  LSSK LSSK          3  M   -1561088.45624 0.00192 0.00216  5971825.25485 0.00255 0.00216  1601693.93731 0.00101 0.00216
 532  LTRG LTRG          3  M   -1057745.06585 0.00105 0.00216  6230578.04533 0.00396 0.00216   858627.22698 0.00053 0.00216
 533  LTRT LTRT          3  M   -1352218.00702 0.00145 0.00216  6085818.37975 0.00074 0.00216  1342643.80482 0.00119 0.00216
 536  LYST LYST          3  M   -1499624.85796 0.00053 0.00216  5952705.80389 0.00195 0.00216  1725794.87123 0.00086 0.00216
 587  MKRI MKRI          3  M   -1047824.35402 0.00168 0.00216  6083730.35323 0.00065 0.00216  1598072.09782 0.00160 0.00216
 590  MNSN MNSN          3  M   -1136318.46615 0.00077 0.00216  6038710.86369 0.00059 0.00216  1704194.92936 0.00114 0.00216
 603  MRBR MRBR          3  M   -1059873.89443 0.00083 0.00216  6110212.56340 0.00240 0.00216  1485747.89666 0.00110 0.00216
 628  NKBI NKBI          3  M   -1004107.38955 0.00148 0.00216  6237146.34769 0.00488 0.00216   874718.71203 0.00057 0.00216
 745  PCCO PCCO          3  M   -1248697.12293 0.00098 0.00216  6077550.79101 0.00300 0.00216  1473351.78664 0.00113 0.00216
 747  PCPM PCPM          3  M   -1253922.87524 0.00159 0.00216  6000701.40766 0.00097 0.00216  1755580.34015 0.00028 0.00216
 748  PCRI PCRI          3  M    -996241.56816 0.00056 0.00216  5925989.52765 0.00553 0.00216  2132025.29439 0.00252 0.00216
 759  PIMO 22003M001     3  M   -3186293.50445 0.00067 0.00216  5286624.44909 0.00096 0.00216  1601158.41002 0.00042 0.00216
 771  PNST PNST          3  M   -1030041.78965 0.00214 0.00216  6225236.02689 0.00211 0.00216   927766.87332 0.00068 0.00216
 861  SBKK SBKK          3  M   -1139278.64145 0.00028 0.00216  6089742.30440 0.00119 0.00216  1510744.31291 0.00105 0.00216
 957  TCP1 TCP1          3  M    -998580.61278 0.00071 0.00216  6185787.50823 0.00185 0.00216  1187602.13032 0.00007 0.00216
 958  TCP2 TCP2          3  M    -988846.32647 0.00061 0.00216  6202198.63308 0.01608 0.00216  1107854.06572 0.00509 0.00216
 959  TCTI TCTI          3  M   -1275980.97014 0.00198 0.00216  6090015.75232 0.00306 0.00216  1396880.01049 0.00083 0.00216
 987  TKK1 TKK1          3  M   -1364654.01143 0.00089 0.00216  5952327.71586 0.00211 0.00216  1835839.96579 0.00089 0.00216
 988  TKK2 TKK2          3  M   -1343631.38843 0.00027 0.00216  5987078.44704 0.00331 0.00216  1735623.26211 0.00209 0.00216
 989  TKRI TKRI          3  M   -1013658.09378 0.00184 0.00216  6103489.75151 0.00349 0.00216  1544279.85595 0.00176 0.00216
 995  TNPM TNPM          3  M   -1532978.17396 0.00043 0.00216  5894327.60139 0.00181 0.00216  1888232.69592 0.00089 0.00216
 996  TNPT TNPT          3  M   -1068059.87755 0.00038 0.00216  6094630.92785 0.00418 0.00216  1542424.29342 0.00181 0.00216
 997  TNSN TNSN          3  M   -1108936.32873 0.00105 0.00216  6035226.51006 0.00031 0.00216  1733982.22484 0.00061 0.00216
 998  TNST TNST          3  M   -1090749.76837 0.00263 0.00216  6213696.80736 0.00310 0.00216   935325.97351 0.00078 0.00216
   7  TPK1 TPK1          3  M   -1069622.71255 0.00155 0.00216  6137421.50764 0.00137 0.00216  1362359.49386 0.00009 0.00216
   8  TPK2 TPK2          3  M   -1019361.90155 0.00109 0.00216  6178593.43760 0.00233 0.00216  1207649.46925 0.00099 0.00216
   9  TPKT TPKT          3  M    -914875.25029 0.00191 0.00216  6247977.47885 0.00307 0.00216   896544.39265 0.00051 0.00216
  10  TPRI TPRI          3  M   -1256831.60214 0.00148 0.00216  6062465.45281 0.00695 0.00216  1527009.10568 0.00140 0.00216
  20  TSKA TSKA          3  M   -1143697.00202 0.00007 0.00216  6227724.30701 0.00494 0.00216   764312.72980 0.00060 0.00216
  22  TSKW TSKW          3  M   -1340690.90294 0.00246 0.00216  6051254.12184 0.00210 0.00216  1500217.89272 0.00128 0.00216
  23  TSRI TSRI          3  M   -1194168.76244 0.00440 0.00216  6055887.81990 0.00067 0.00216  1602984.57152 0.00073 0.00216
  24  TSSK TSSK          3  M   -1549340.54146 0.00083 0.00216  5961235.34306 0.00288 0.00216  1651359.41513 0.00121 0.00216
  26  TUBN TUBN          3  M   -1581409.48595 0.00172 0.00216  5950175.88853 0.00179 0.00216  1660747.17915 0.00075 0.00216
  30  TUTT TUTT          3  M   -1068725.88894 0.00077 0.00216  5984703.26590 0.00542 0.00216  1922897.11604 0.00216 0.00216

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 ---------------------------------------------------------------
 >>> CPU/Real time for pgm "COMPAR": 0:00:00.000 / 0:00:00.052
 >>> Program finished successfully
```

ภาพที่ 5.7 ตัวอย่างผลการประมวล โปรแกรม Bernese เวอร์ชั่น 5.2 (4)

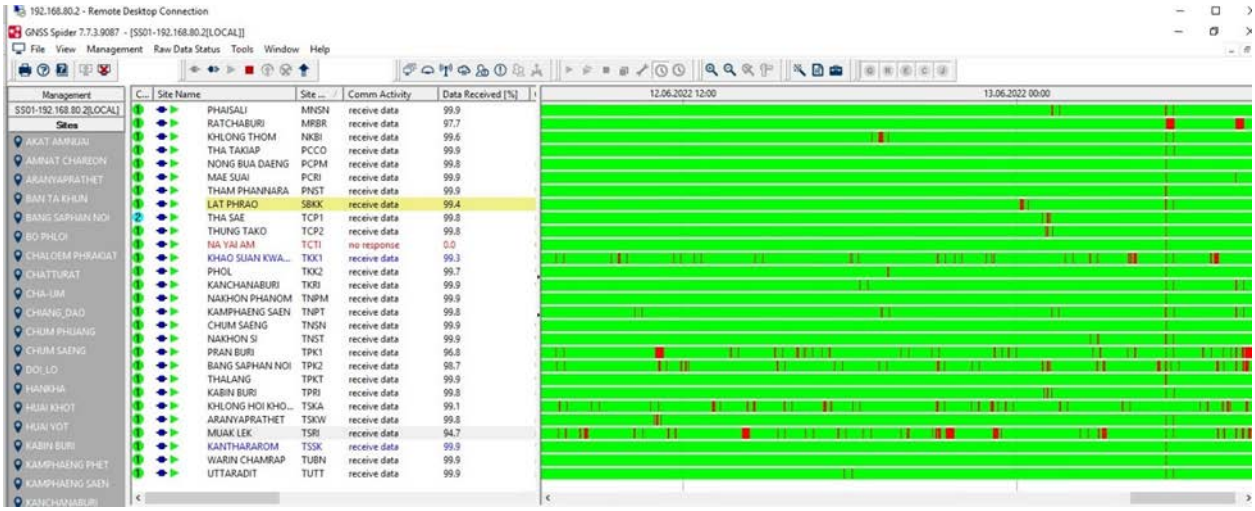
6. การติดตาม และแก้ไขปัญหาในการให้บริการ (Monitoring and Troubleshooting)

Admin หรือ ผู้ที่มีหน้าที่ควบคุมดูแลการให้บริการของ NCDC ต้องดำเนินการตรวจสอบสถานะการทำงานของระบบ NCDC การเข้าใช้งานของเครื่อง Rover การสมัครใช้บริการของผู้ใช้ใหม่ และการแก้ไขปัญหาต่างๆ ของผู้ใช้บริการ ดังนี้

6.1 ตรวจสอบสถานะการทำงานของสถานีรับสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS)

ในวันทำการ ใช้เครื่อง Workstation หมายเลข 02 ที่ศูนย์ประมวลผลข้อมูลสถานี CORS เพื่อทำการเชื่อมต่อ (remote) เข้ากับ Virtual server ชื่อ SS01 , SS02 , SS03 แล้วเรียกดูข้อมูลสถานะการรับสัญญาณ (Streaming) ของ CORS แต่ละสถานี ผ่านโปรแกรม GNSS Spider ดังนี้

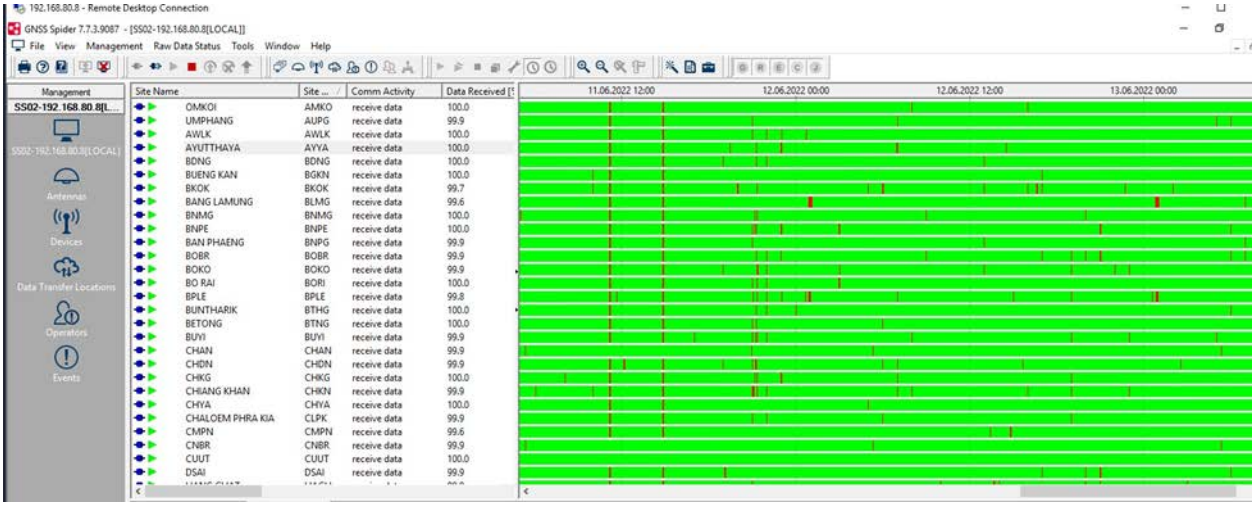
- SS01 สถานะข้อมูลการ Streaming จาก CORS จำนวน 80 สถานีของกรมแผนที่ทหาร



ภาพที่ 6.1 ตัวอย่างสถานะข้อมูลการ streaming จาก CORS จำนวน 80 สถานีของ SS01

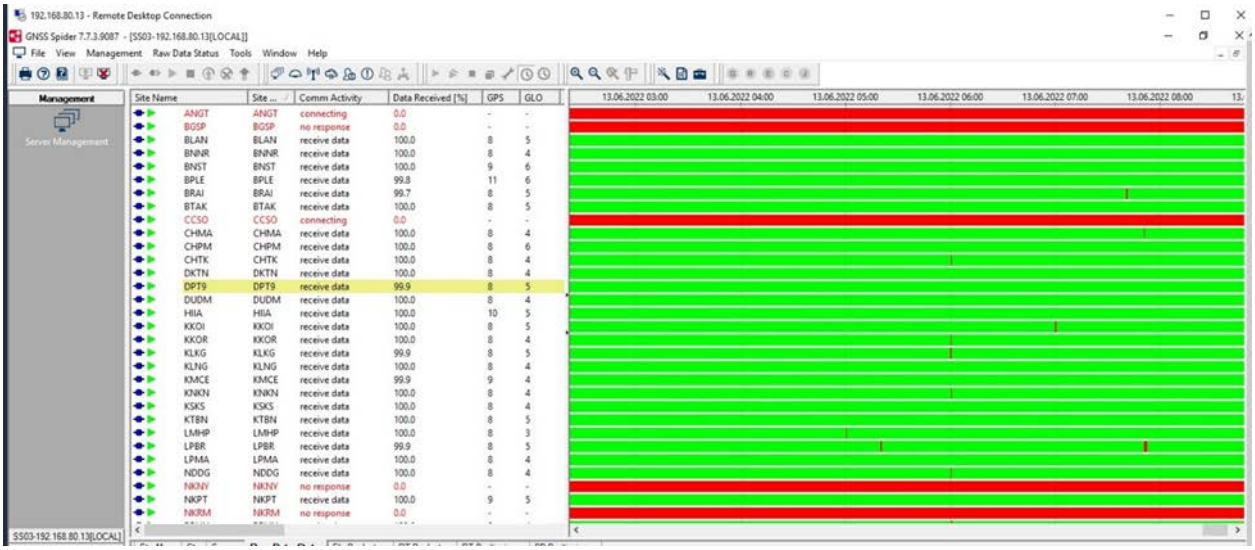
- สถานะข้อมูลการ Streaming จาก CORS ปกติ
- สถานะข้อมูลการ Streaming จาก CORS ไม่ปกติ
  (ไม่เกิดผลกระทบเกิดจากข้อมูลขาดหายไปบางช่วง)
  การขาดหายเวลาเดิมซ้ำๆหลายCORSพร้อมกันเกิดจากหน่วยอื่นๆส่งข้อมูลได้ล่าช้า เพราะปริมาณข้อมูลมากและถูกส่งมาพร้อมกัน
  หากขาดหายยาวให้ตรวจสอบตามคู่มือการแก้ปัญหาการใช้งาน Leiga Spider

- SS02 สถานะข้อมูลการ Streaming จาก CORS จำนวนทั้งหมด 92 สถานี โดยแบ่งเป็นสถานี CORS ของกรมที่ดิน 85 สถานี, กรมโยธาธิการและผังเมือง 4 สถานี, สสน. 1 สถานี, จุฬาลงกรณ์มหาวิทยาลัย 1 สถานีและ GISTDA 1 สถานี



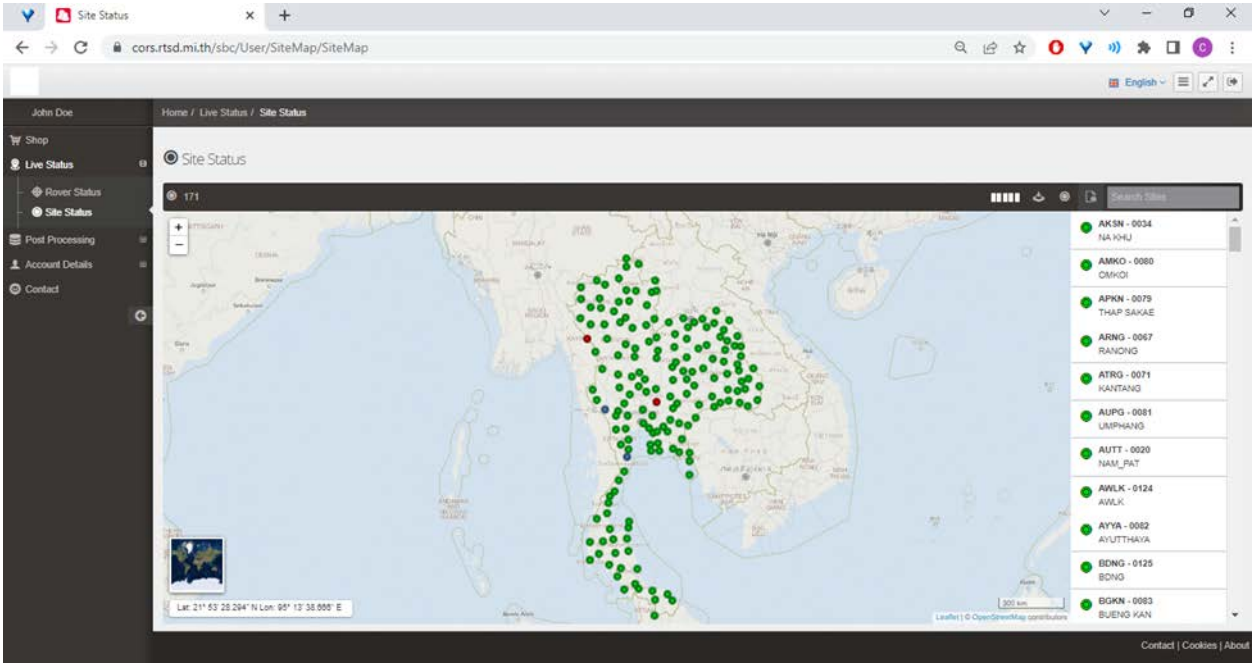
ภาพที่ 6.2 ตัวอย่างสถานะข้อมูลการ streaming จาก CORS จำนวน 92 สถานีของ SS02

- SS03 สถานะข้อมูลการ Streaming จาก CORS จำนวนทั้งหมด 64 สถานี โดยแบ่งเป็นสถานี CORS ของกรมที่ดิน 47 สถานี, กรมโยธาธิการและผังเมือง 11 สถานี, สสน. 5 สถานีและGISTDA 1 สถานี



ภาพที่ 6.3 ตัวอย่างสถานะข้อมูลการ streaming จาก CORS จำนวน 64 สถานีของ SS03

นอกวันทำการ เจ้าหน้าที่ที่รับผิดชอบในวันนั้นทำการตรวจสอบสถานะการรับสัญญาณของ CORS แต่ละสถานี ผ่านโปรแกรม Spider Business Center (SBC) ผ่านทางเว็บบราวเซอร์ที่ https://cors.rtsd.mi.th/sbc/spider-business-center เมื่อ login เข้าระบบแล้วให้ไปที่เมนู Usage เลือกหัวข้อย่อย Site Status ดังแสดงในภาพที่ 6.4



ภาพที่ 6.4 ตัวอย่างสถานะข้อมูลการ Streaming จาก CORS แต่ละสถานี(ก) ส่วนที่หนึ่ง (ข) ส่วนที่สอง

สถานะข้อมูลการ Streaming จาก CORS แต่ละสถานี มีรายละเอียด ดังนี้

- สถานะข้อมูลการ Streaming จาก CORS ปกติ ข้อมูลสามารถนำมาคำนวณ Ambiguity fixed ในโครงข่ายได้
- สถานะข้อมูลการ Streaming จาก CORS ปกติ ข้อมูลยังไม่สามารถนำมาคำนวณ Ambiguity fixed ในโครงข่ายได้
- สถานะข้อมูลการ Streaming จาก CORS ไม่ปกติ ไม่สามารถเชื่อมต่อกับสถานีได้

สำหรับการตรวจสอบตามข้อ 6.1 หากตรวจพบสถานี CORS มีปัญหา ให้ดำเนินการแจ้งผู้รับผิดชอบของแต่ละหน่วยงานตามข้อมูลการติดต่อในหัวข้อที่ 9 เพื่อดำเนินการตรวจสอบ และแก้ไขต่อไป

- ในกรณีข้อมูลที่มีปัญหา ขึ้นกับสถานะสีแดง

  ตรวจสอบว่าสถานีดังกล่าวเป็นของหน่วยงานใด

  1. ถ้าเป็นหน่วยงานอื่นจะประสานผ่านโทรศัพท์ให้ตรวจสอบ
  2. ถ้าเป็นหน่วยงานของกรมแผนที่ ให้ดำเนินการดังนี้

     2.1 Login ผ่าน Web interface

     2.1.1 ผ่าน Fiber Obtic

     2.1.2 ผ่าน Sim AIS

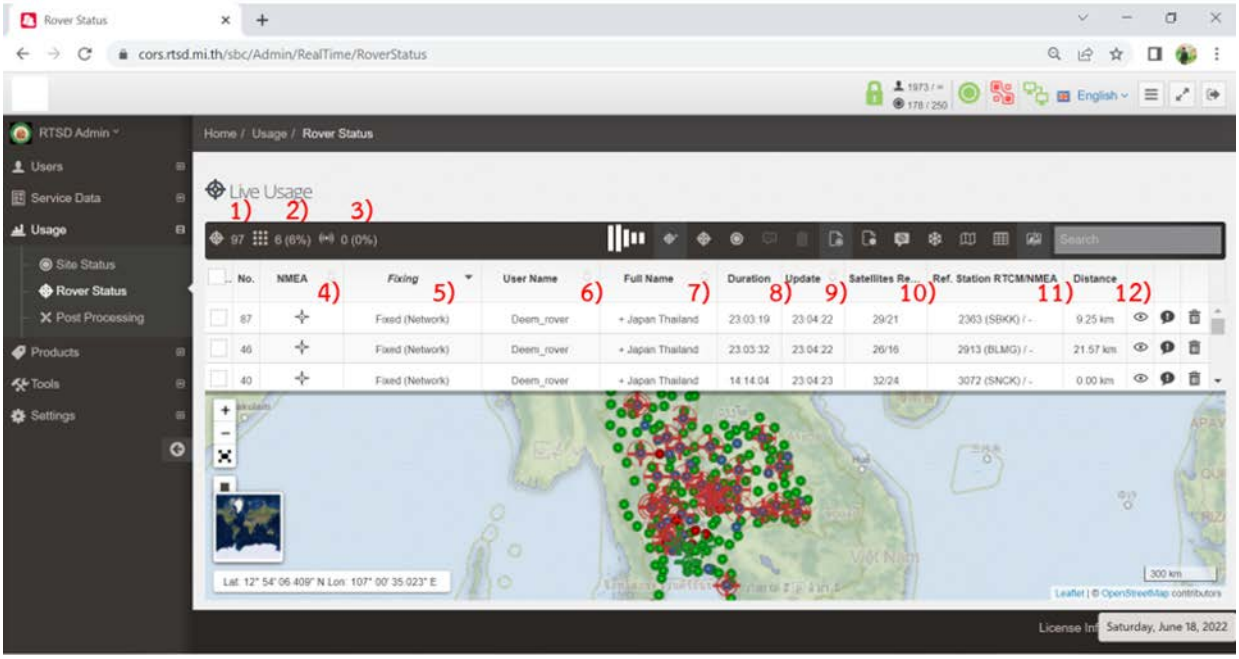
     2.2 ตรวจสอบผ่าน Spider Software

     2.3 ตรวจสอบผ่าน เจ้าหน้าที่(GIS)

     2.4 ประสาน เจ้าหน้าที่ ในพื้นที่ให้เปิดตู้และรายงาน

6.2 ตรวจสอบสถานะการเข้าใช้งานของเครื่องรับสัญญาณดาวเทียม GNSS ลูกข่าย (Rover)

ทำการตรวจสอบสถานะการเข้าใช้งานของเครื่องรับสัญญาณดาวเทียม GNSS ลูกข่าย (Rover) ผ่านโปรแกรม Spider Business Center (SBC) ผ่านทางเว็บบราวเซอร์ที่ https://cors.rtsd.mi.th/sbc/spider-business-center เมื่อ login เข้าระบบแล้วให้ไปที่เมนู Usage เลือกหัวข้อย่อย Rover Status ดังแสดงในภาพที่ 6.5



ภาพที่ 6.5 ตัวอย่างสถานะการเข้าใช้งานของเครื่องรับสัญญาณดาวเทียม GNSS ลูกข่าย (Rover)

รายละเอียดข้อมูลที่ตรวจสอบได้มี ดังนี้

1. จำนวนเครื่องรับสัญญาณดาวเทียม GNSS ลูกข่าย (Rover) ที่ใช้งาน
2. จำนวน Rover ที่รังวัดค่าพิกัดได้ด้วยวิธี Network RTK
3. จำนวน Rover ที่รังวัดค่าพิกัดได้ด้วยวิธี Single RTK
4. สถานะการรังวัดค่าพิกัดของ Rover ที่ได้จากข้อมูล NMEA message
5. สถานะการ fixing ambiguity ในการรังวัดค่าพิกัดของ Rover
6. ชื่อบัญชีของผู้ใช้งาน
7. ชื่อเจ้าของบัญชีผู้ใช้งาน
8. ระยะเวลาที่เข้าใช้งานระบบ
9. เวลาล่าสุดที่ส่งข้อมูลเข้ามาในระบบ
10. จำนวนดาวเทียม GNSS ที่รับข้อมูลได้ของ Reference station/Rover
11. Reference station ที่ใช้ในการรังวัด
12. ระยะห่างจาก Reference station ที่ใช้ในการรังวัด

6.3 การตรวจสอบ และแก้ไขปัญหาในการใช้บริการ NCDC

ในการให้บริการของ NCDC อาจมีปัญหาการใช้งานที่เกิดจากความผิดพลาดของระบบ NCDC ปัญหาจากสถานี CORS หรือ ปัญหาจากเครื่องรับสัญญาณฯ Rover ที่ Admin จะต้องทำการตรวจสอบ และแก้ไขในหลายกรณี ยกตัวอย่างได้ ดังนี้

6.3.1 มีผู้ใช้บริการ NCDC จำนวนมากแจ้งปัญหาการไม่สามารถรังวัดค่าพิกัด หรือใช้บริการออนไลน์ได้พร้อมๆกัน

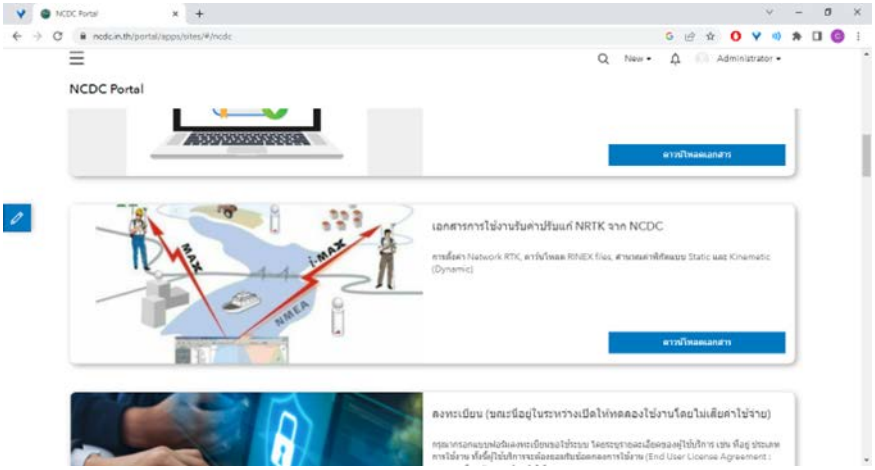
- สิ่งที่ควรตรวจสอบ ทำการตรวจสอบสถานะการทำงานของสถานีรับสัญญาณดาวเทียม GNSS แบบอัตโนมัติ (CORS) ตามข้อ 6.1 ว่ามีการขาดหายของข้อมูลเป็นจำนวนมากหรือไม่ เพราะจะทำให้ GNSS Spider ไม่สามารถคำนวณค่าแก้ในโครงข่ายได้

- การแก้ไข ทำการรีสตาร์ท Server และการเชื่อมต่อ internet ใหม่ เพื่อเคลียร์ข้อมูล cache file ที่อาจกินทรัพยากรของ Server จนทำให้ขีดความสามารถในการทำงานลดลง

6.3.2 ผู้ใช้บริการ NCDC ไม่สามารถทำการตั้งค่าเครื่องมือของ Rover ให้รังวัดในระบบ Network RTK ได้

- สิ่งที่ควรตรวจสอบ ขอรายละเอียดเครื่องรับสัญญาณดาวเทียม GNSS จากผู้ใช้บริการ เพื่อทำการตรวจสอบว่ารองรับการทำงานในระบบ Network RTK หรือไม่

- การแก้ไข หากเครื่องมือของผู้ใช้บริการรองรับการทำงานแบบ Network RTK ให้แนะนำตัวอย่างการตั้งค่าเครื่องมือที่ถูกต้องให้กับผู้ใช้ โดยสามารถดาวน์โหลดเอกสารได้ผ่านลิงก์ https://ncdc.in.th ในกรอบสีแดงดังแสดงในภาพที่ 6.6



ภาพที่ 6.6 การดาวน์โหลดตัวอย่างการตั้งค่าเครื่องมือ

6.3.3 ผู้ใช้บริการ NCDC ไม่สามารถทำการประมวลผลค่าพิกัดแบบ Online ได้

- สิ่งที่ควรตรวจสอบ ขอรายละเอียดข้อมูล RINEX ที่ผู้ใช้บริการส่งเข้ามาประมวลผล

- การแก้ไข

1) หากข้อมูล RINEX ของผู้ใช้บริการต่ำกว่า Version 3.XX ให้แนะนำวิธีการแปลงไฟล์ RINEX เป็น Version 3.XX ขึ้นไป

2) ตรวจสอบว่าข้อมูล RINEX ต้องมีขนาดไม่เกิน 150 MB

6.4 การตรวจสอบคุณภาพการรับสัญญาณ ของสถานี CORS ในโครงข่าย (NCDC data analysis)

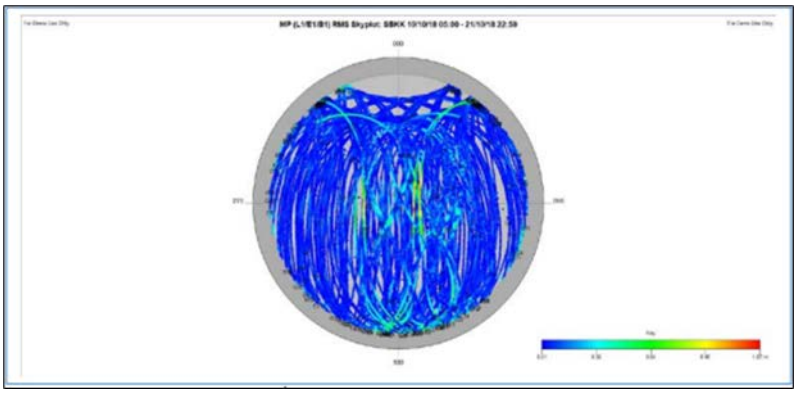
- แสดงข้อมูลการตรวจสอบคุณภาพสัญญาณ CORS โดย Spider QC

จะแบ่งออกเป็น 4 ขั้นตอน ดังนี้

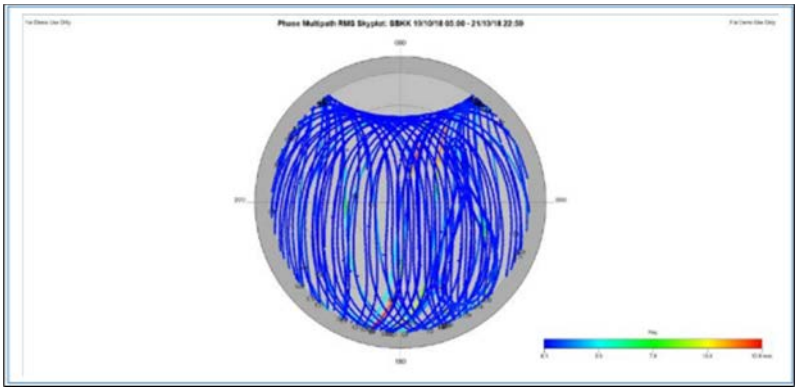
6.4.1 การตรวจสอบคลื่นหลายวิถี (Multipath) ตัวอย่างจากสถานี SBKK

Code Multipath โดยเฉลี่ยสูงสุด 0.232 เมตร ไม่เกิน 50 เซนติเมตรตามข้อกำหนด

Phase Multipath โดยเฉลี่ยสูงสุด 1.371 มิลลิเมตร ซึ่งไม่เกิน 5 มิลลิเมตรตามข้อกำหนด



(ก)



(ข)

ภาพที่ 6.7 ตัวอย่างการตรวจสอบคลื่นหลายวิถี

(ก) Code Multipath (ข) Phase Multipath

6.4.2 การตรวจสอบความสมบูรณ์ของข้อมูลรังวัด ตัวอย่างจากสถานี SBKK ในการรับสัญญาณดาวเทียมนั้นสามารถบันทึกข้อมูลได้ epoch with data 100 % โดยสามารถจำแนกตามประเภทดาวเทียมได้ดังนี้

Tracking Summary:

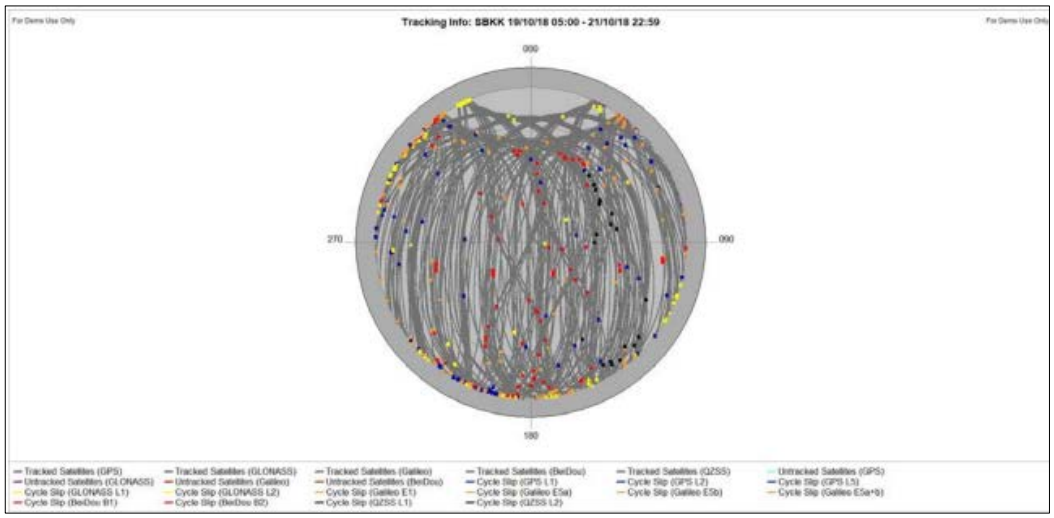
GPS Completeness: 99.9%

GLONASS Completeness: 99.8 %

Galileo Completeness: 99.8 %

BeiDou Completeness: 99.7 %

QZSS Completeness: 100.0 %



ภาพที่ 6.8 ตัวอย่าง GNSS Tracking Information

6.4.3 การตรวจสอบการขาดหายข้อมูลรังวัด (Cycle-Slip) ตัวอย่างจากสถานี SBKK

Cycle Slip ของสัญญาณดาวเทียม GPS น้อยกว่า 0.2 slip ต่อ 1000 observation

Cycle Slip ของสัญญาณดาวเทียม GLONASS น้อยกว่า 0.2 slip ต่อ 1000 observation

Cycle Slip ของสัญญาณดาวเทียม BEODOU น้อยกว่า 0.2 slip ต่อ 1000 observation

Cycle Slip ของสัญญาณดาวเทียม GALILEO น้อยกว่า 0.2 slip ต่อ 1000 observation

Cycle Slip ของสัญญาณดาวเทียม QZSS น้อยกว่า 0.1 slip ต่อ 1000 observation

โดยมีรายละเอียดจำนวนการขาดหายของสัญญาณ (Cycle Sip) ดังแสดงในภาพที่ 6.9

Cycle Slip Summary:

Satellite System	L1/E1/B1	L2	L5/E5a	E5b/B2	E5a+b
GPS	139	154	35	-	-
GLONASS	77	108	-	-	-
Galileo	116	-	91	52	65
BeiDou	374	-	-	32	-
QZSS	19	34	-	-	-
GPS+QZSS	158	188	35	-	-
All	725	296	126	84	65

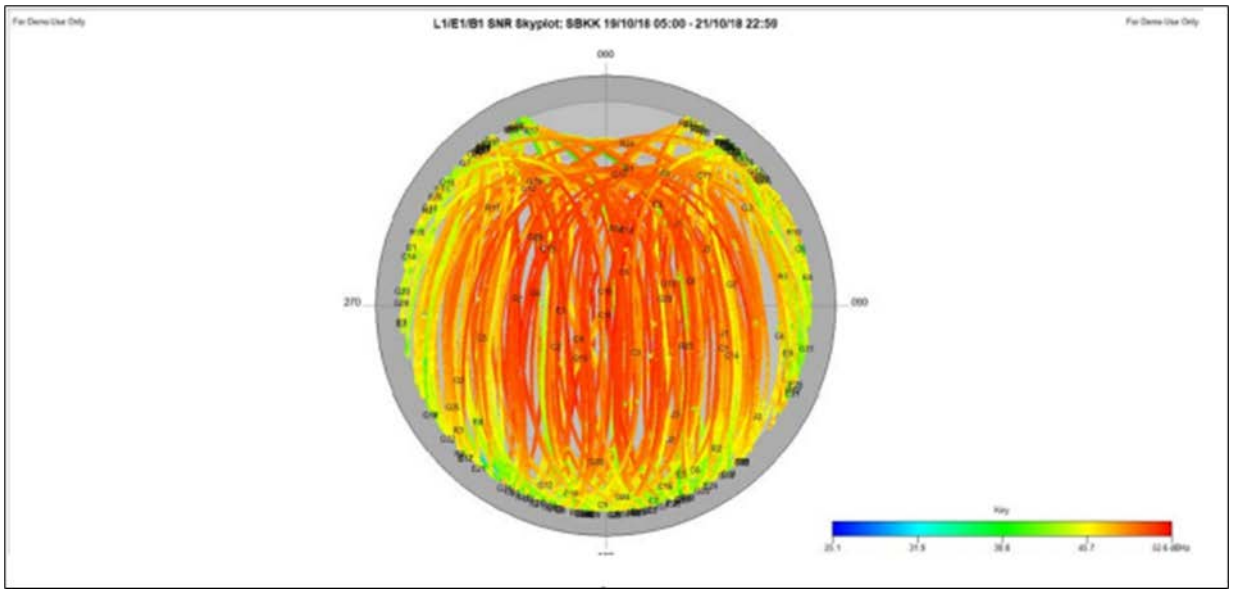
ภาพที่ 6.9 ตัวอย่างจำนวนการขาดหายของสัญญาณ (Cycle Slip)

6.4.4 การตรวจสอบการกระจายความเข้มของสัญญาณ(SNR) ตัวอย่างจากสถานี SBKK

ในการวิเคราะห์ตรวจสอบความเข้มของสัญญาณ จากค่า Signal to Noise Ratio (SNR) พบว่าสัญญาณดาวเทียมที่รับได้มีค่า SNR ที่ใช้ได้ คือ มีค่าเฉลี่ยมากกว่า 40 dB-Hz ดังแสดงในตารางที่ 6.1

	L1/E1B1 (dB-Hz)	L2 (dB-Hz)	L5/E5a (dB-Hz)	E5b/B2 (dB-Hz)	E5a+b (dB-Hz)
Average GPS:	48.8	44.5	48.6	-	-
Average GLONASS:	47.6	44.1	-	-	-
Average Galileo:	48.7	-	46.6	47.7	48.4
Average BeiDou:	45.7	-	-	46.6	-
Average QZSS:	47.5	47.2	48.1	-	-
Average All:	47.9	44.5	47.5	47.2	48.4

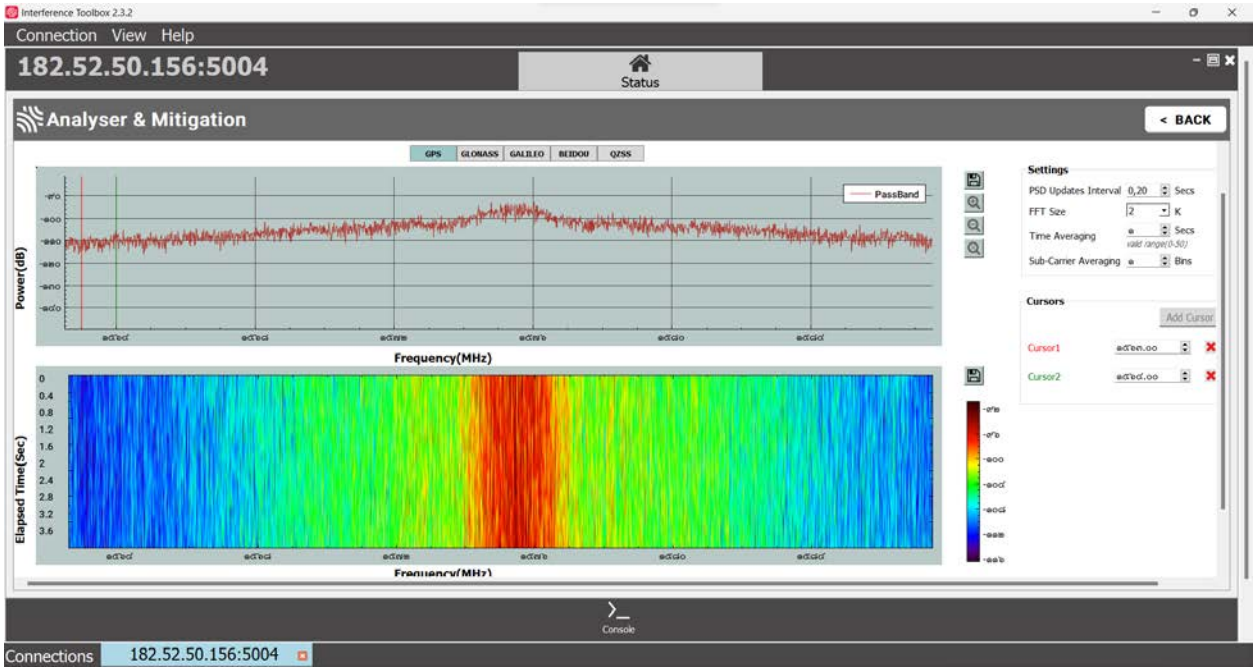
ตารางที่ 6.1 ตัวอย่างความเข้มของสัญญาณดาวเทียมโดยเฉลี่ย



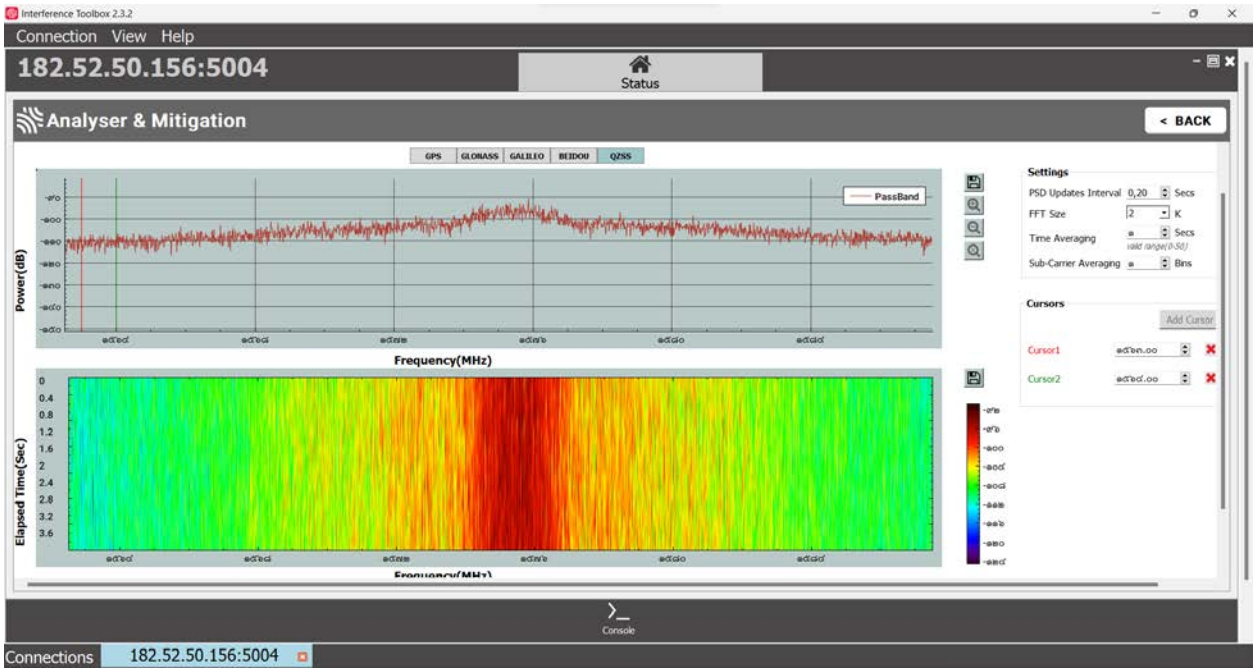
ภาพที่ 6.10 ตัวอย่าง SNR skyplot

ดังนั้นในการทดสอบ สถานีรับสัญญาณดาวเทียม GNSS แบบอัตโนมัติ จะมีการทดสอบทุกสถานี เพื่อใช้ในการวิเคราะห์ค่าความคลาดเคลื่อนทุกประเภท เพื่อที่จะใช้ในการวางแผนการจัดระบบ ในส่วนการสร้างโครงข่ายใหญ่(Network) โครข่ายรอง(Cluster) และโครงข่ายย่อย(Cell) ได้

- แสดงข้อมูลการตรวจสอบคุณภาพสัญญาณ CORS โดย Interence Toolbox 2.3 (GR 50)



(ก)



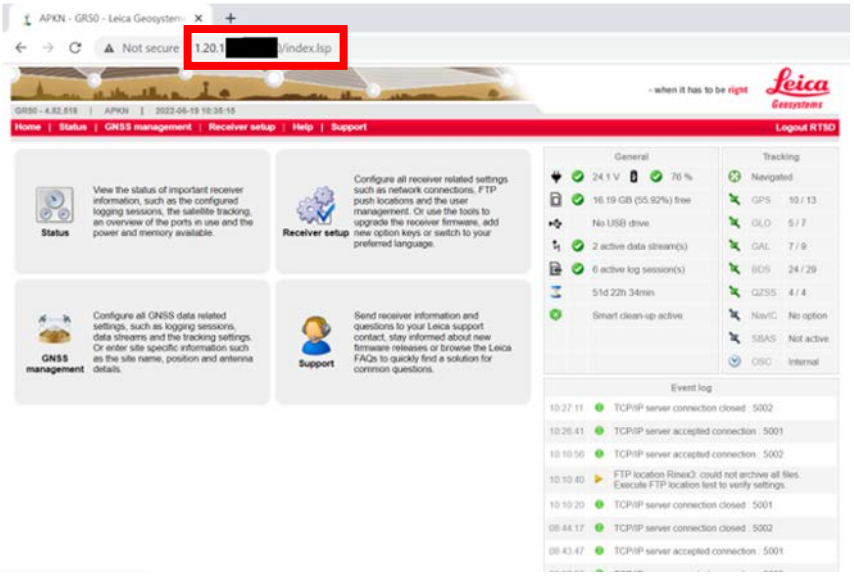
(ข)

ภาพที่ 6.11 ตัวอย่างการตรวจสอบคุณภาพสัญญาณ CORS โดย Interence Toolbox 2.3 (GR 50)

(ก) ดาวเทียม GPS (ข) ดาวเทียม QZSS

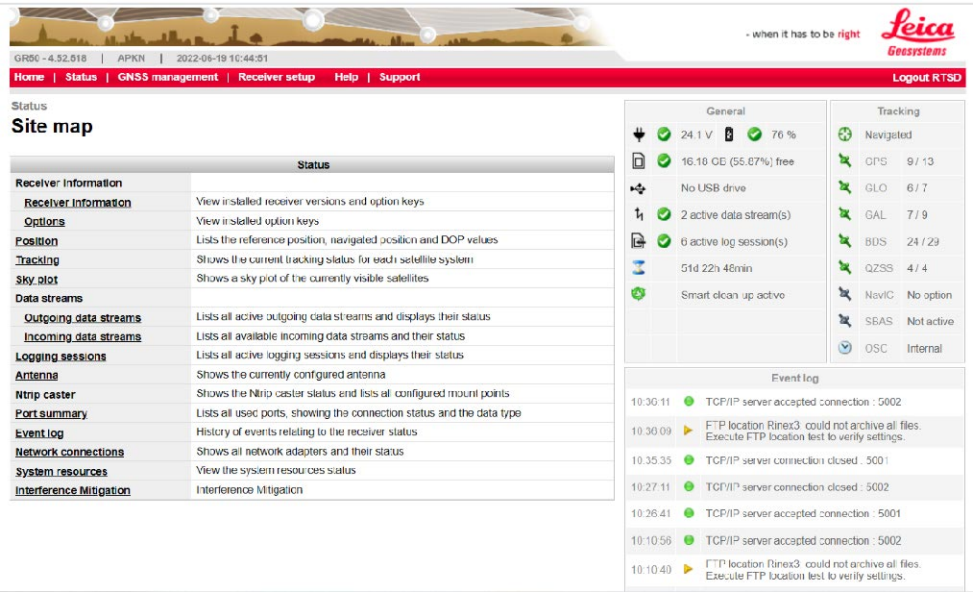
6.5 การตรวจสอบสถานะเครื่องรับสัญญาณดาวเทียม GNSS ประจำสถานี CORS ผ่านอินเตอร์เน็ต

เครื่องรับสัญญาณดาวเทียม GNSS ที่ประจำอยู่ในแต่สถานี CORS สามารถตรวจสอบสถานะได้ผ่านทาง internet ในสองรูปแบบคือ ผ่านทาง ADSL ดังแสดงในภาพที่ 6.12 และผ่านทางสัญญาณโทรศัพท์ โดยการตรวจสอบสถานะได้ผ่านทาง internet ในสองรูปแบบ จะเหมือนกันทุกอย่างในแต่ละเครื่องรับฯ แต่จะมีที่อยู่ IP ที่แตกต่างกัน ในแต่ละช่องทางการเชื่อมต่อ internet

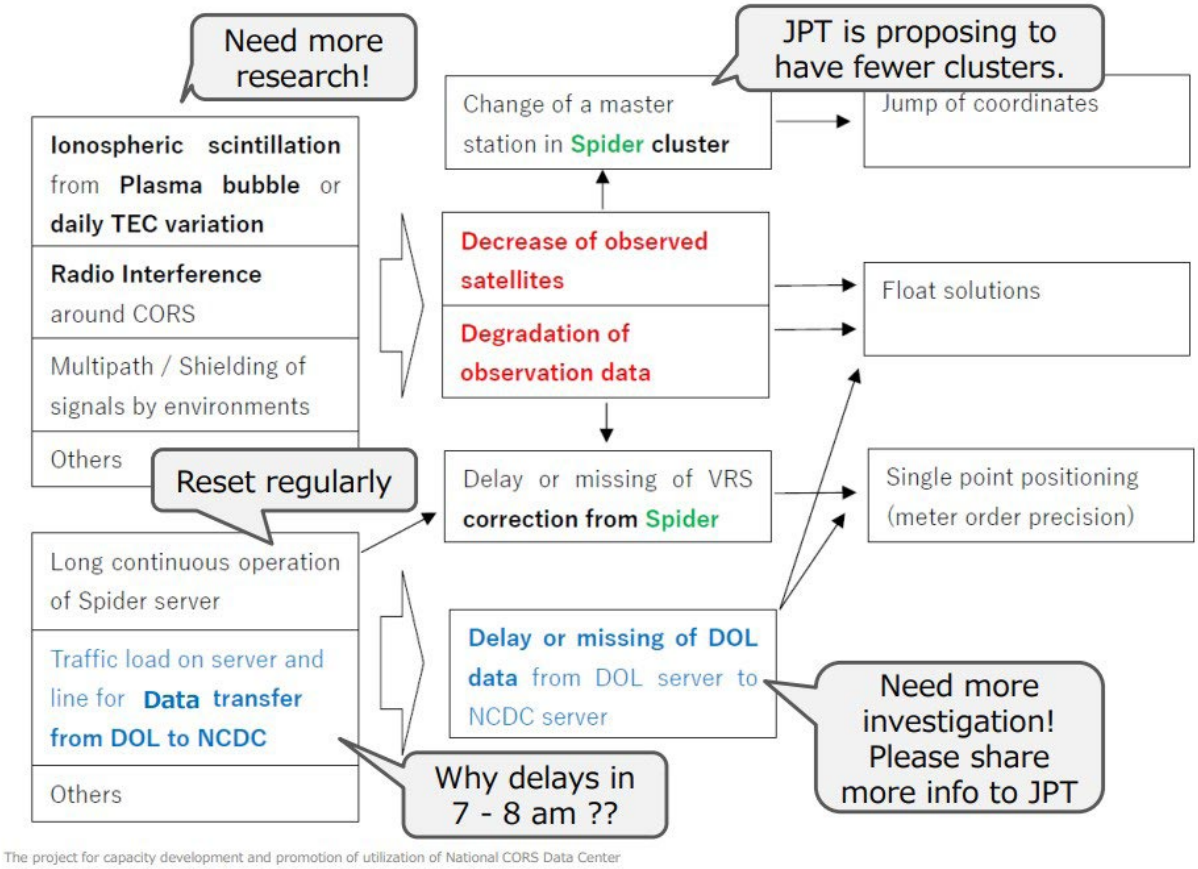


ภาพที่ 6.12 ตัวอย่างการเชื่อมต่อผ่านทาง ADSL สถานี APKN

เมื่อเข้าสู่หน้า Home ของเครื่องรับสัญญาณดาวเทียม GNSS ประจำสถานี CORS เราสามารถตรวจสอบข้อมูลสถานะทั่วไปได้ที่หน้าต่าง General และตรวจสอบจำนวนดาวเทียมในแต่ละระบบที่รังวัดได้ในขณะเวลาจริงที่หน้าต่าง Tracking นอกจากนี้ในเมนู Status สามารถเรียกดูข้อมูลสถานะเพิ่มเติมได้โดยมีรายละเอียดดังแสดงในภาพที่ 6.13



ภาพที่ 6.13 ตัวอย่างข้อมูลสถานะเพิ่มเติม



ภาพที่ 6.14 ตัวอย่างปัญหาในการทำงาน

6.6 กรณีที่ระบบศูนย์ประมวลผลข้อมูลสัญญานดาวเทียม GNSS (Server) ของ NCDC มีปัญหาไม่สามารถปฏิบัติงานได้ ต้องได้รับการแก้ไขให้สามารถกลับมาปฏิบัติงานได้ภายใน 24 ชั่วโมง โดยบริษัท

6.7 กรณีที่สถานี CORS มีปัญหาไม่สามารถปฏิบัติงานได้ ต้องได้รับการแก้ไขให้สามารถกลับมาปฏิบัติงานได้ภายใน 3 วัน หากเป็นสถานีฯ ที่อยู่ในเขตกรุงเทพ และปริมณฑล และภายใน 5 วัน สำหรับพื้นที่อื่นๆ โดยบริษัท

ขั้นตอนในการแก้ปัญหา

ในกรณีที่ปัญหาเป็น CORS ของกรมแผนที่ทหาร

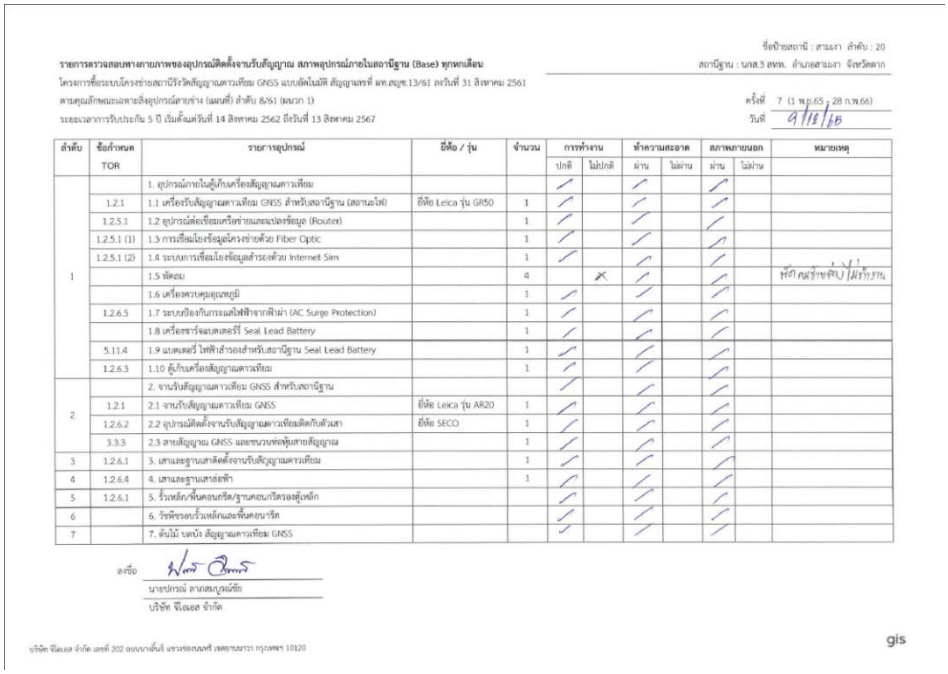
1. เมื่อเกิดปัญหาตามหัวข้อที่ได้กล่าวไว้ข้างต้นให้ผู้ดูแลระบบทำการแก้ปัญหาตาม คู่มือการแก้ปัญหาการใช้งาน Leiga Spider (Trouble Shooting) ในภาคผนวก หากปัญหาไม่สามารถแก้ได้หรืออยู่นอกเหนือจากคู่มือให้ปฏิบัติขั้นตอนต่อไป
2. ทำการติดต่อบริษัทให้ทำการตรวจสอบ และ แก้ไข
   ในกรณีที่แก้ไขได้ให้บริษัทแจ้งสาเหตุของปัญหา วิธีการแก้ ผลที่ได้ มาใน รายงาน
   ในกรณีที่ปัญหาไม่สามารถแก้ได้หรืออยู่นอกเหนือจากคู่มือให้ปฏิบัติขั้นตอนต่อไป
3. บริษัทต้องติดต่อกับทาง Leiga ให้ทำการตรวจสอบ และ แก้ไข
   ในกรณีที่แก้ไขได้ให้บริษัทแจ้งสาเหตุของปัญหา วิธีการแก้ ผลที่ได้ มาใน รายงาน
   ในกรณีที่ปัญหาไม่สามารถแก้ได้หรืออยู่นอกเหนือจากคู่มือให้ปฏิบัติขั้นตอนต่อไป
4. ทำการติดต่อหน่วยงานที่รับผิดชอบพื้นที่ที่เกิดปัญหาให้ส่งคนไปตรวจสอบ CORS ว่าเกิดอะไรกับ CORS รึมั้ยที่อาจทำให้ CORS เกิดปัญหา แล้วแจ้งทางเราเพื่อหาแนวทางต่อไป
   หากไม่พบปัญหาให้ทางหน่วยงานที่รับผิดชอบพื้นที่ที่เกิดปัญหาทำการสับคัตเอาท์
   ในกรณีที่ปัญหาไม่สามารถแก้ได้หรืออยู่นอกเหนือจากคู่มือให้ปฏิบัติขั้นตอนต่อไป
5. ผู้ดูแลระบบทำการลงพร้อมกับบริษัทภายใต้ความเห็นชอบจากผู้บังคับบัญชาเพื่อแก้ไขปัญหา

ในกรณีที่ปัญหาเป็น CORS ของกรมแผนที่ทหาร

ทำการประสานหน่วยงานอื่นให้ทราบถึงปัญหาและดำเนินการตามแนวทางการปฏิบัติของหน่วยงานนั้น

7. การปรนนิบัติบำรุงอุปกรณ์ (Equipment maintenance)

ผู้ดูแลระบบจะต้องควบคุมการปฏิบัติให้บริษัททำการปรนนิบัติบำรุงอุปกรณ์ตามวงรอบ 6 เดือนตาม รายงานตรวจสอบทางกายภาพ สภาพอุปกรณ์ภานในสถานีฐาน (Base)



รายการตรวจสอบทางกายภาพของอุปกรณ์ติดตั้งจานรับสัญญาณ สภาพอุปกรณ์ภายในสถานีฐาน (Base) ทุกหกเดือน

โครงการซื้อระบบโครงข่ายสถานีวิจัยสัญญาณดาวเทียม GNSS แบบยั่งยืน สัญญาเลขที่ พท.สอยฯ.13/61 ลงวันที่ 31 สิงหาคม 2561

ตามคุณลักษณะเฉพาะสิ่งอุปกรณ์สายช่าง (แผนที่) ลำดับ 8/61 (แนวเว 1)

ระยะเวลาการรับประกัน 5 ปี เริ่มตั้งแต่วันที่ 14 สิงหาคม 2562 ถึงวันที่ 13 สิงหาคม 2567

ชื่อป้ายสถานี : สามเงา ลำดับ : 20

สถานีฐาน : นกส.3 สทพ. อำเภอสามเงา จังหวัดตาก

ครั้งที่ 7 (1 พ.ย.65 - 28 ก.พ.66)

วันที่ 9/12/66

ลำดับ	ข้อกำหนด TOR	รายการอุปกรณ์	ยี่ห้อ / รุ่น	จำนวน	การทำงาน		ทำความสะอาด		สภาพภายนอก		หมายเหตุ
					ปกติ	ไม่ปกติ	ผ่าน	ไม่ผ่าน	ผ่าน	ไม่ผ่าน	
1		1. อุปกรณ์ภายในตู้เก็บเครื่องสัญญาณดาวเทียม			/		/		/		
	1.2.1	1.1 เครื่องรับสัญญาณดาวเทียม GNSS สำหรับสถานีฐาน (สถานะไฟ)	ยี่ห้อ Leica รุ่น GR50	1	/		/		/		
	1.2.5.1	1.2 อุปกรณ์ต่อเชื่อมเครือข่ายและแปลงข้อมูล (Router)		1	/		/		/		
	1.2.5.1 (1)	1.3 การเชื่อมโยงข้อมูลโครงข่ายด้วย Fiber Optic		1	/		/		/		
	1.2.5.1 (2)	1.4 ระบบการเชื่อมโยงข้อมูลสำรองด้วย Internet Sim		1	/		/		/		
		1.5 พัดลม		4		X	/		/		พังทุกตัวเลย ไม่ทำงาน
		1.6 เครื่องควบคุมอุณหภูมิ		1	/		/		/		
	1.2.6.5	1.7 ระบบป้องกันกระแสไฟฟ้าจากฟ้าผ่า (AC Surge Protection)		1	/		/		/		
		1.8 เครื่องชาร์จแบตเตอรี่ Seal Lead Battery		1	/		/		/		
	5.11.4	1.9 แบตเตอรี่ ไฟฟ้าสำรองสำหรับสถานีฐาน Seal Lead Battery		1	/		/		/		
	1.2.6.3	1.10 ตู้เก็บเครื่องสัญญาณดาวเทียม		1	/		/		/		
2		2. จานรับสัญญาณดาวเทียม GNSS สำหรับสถานีฐาน			/		/		/		
	1.2.1	2.1 จานรับสัญญาณดาวเทียม GNSS	ยี่ห้อ Leica รุ่น AR20	1	/		/		/		
	1.2.6.2	2.2 อุปกรณ์ติดตั้งจานรับสัญญาณดาวเทียมติดกับตัวเสา	ยี่ห้อ SECO	1	/		/		/		
	3.3.3	2.3 สายสัญญาณ GNSS และขนวนหัวต่อสายสัญญาณ		1	/		/		/		
3	1.2.6.1	3. เสาและฐานเสาติดตั้งจานรับสัญญาณดาวเทียม		1	/		/		/		
4	1.2.6.4	4. เสาและฐานเสาล่อฟ้า		1	/		/		/		
5	1.2.6.1	5. รั้วเหล็ก/พื้นคอนกรีต/ฐานคอนกรีตรองตู้เหล็ก			/		/		/		
6		6. วัสดีรอบรั้วเหล็กและพื้นคอนกรีต			/		/		/		
7		7. ต้นไม้ บดบัง สัญญาณดาวเทียม GNSS			/		/		/		

ลงชื่อ

นายปกรณ์ ลาภสมบูรณ์ชัย

บริษัท จีเอเอส จำกัด

บริษัท จีเอเอส จำกัด เลขที่ 202 ถนนงามวงศ์วาน แขวงบางเขน เขตบางเขน กรุงเทพฯ 10120

gis

ภาพที่ 7.1 รายงานตรวจสอบทางกายภาพ สภาพอุปกรณ์ภานในสถานีฐาน (Base) ทุกหกเดือน

7.1 ทำการตรวจกายภาพของสถานี CORS และอุปกรณ์ประจำสถานีฯ ทุก 6 เดือน ตัวอย่างเช่น เครื่องรับสัญญาณดาวเทียม GNSS อุปกรณ์เชื่อมต่อ internet พัดลมระบายความร้อน ระบบวงจรไฟฟ้า ระบบป้องกันไฟฟ้ากระชาก แบตเตอรี่ภายนอก สายสัญญาณของเครื่องรับสัญญาณดาวเทียม GNSS และจานรับสัญญาณดาวเทียม GNSS เป็นต้น ดังแสดงในภาพที่ 7.2 เป็นการเปลี่ยนพัดลมระบายอากาศ ณ สถานี TPK2 ในการปรนนิบัติบำรุงครั้งที่ 5



ภาพที่ 7.2 การเปลี่ยนพัดลมระบายอากาศ ณ สถานี TPK2

7.2 ทำการตรวจสอบสภาพแวดล้อมโดยรอบ บริเวณสถานี CORS ทุก 6 เดือน พร้อมกันกับการปฏิบัติในข้อ 7.1 หากมีสิ่งบดบังการรับสัญญาณสัญญาณฯ ให้ดำเนินการแก้ไขทันที ดังแสดงในภาพที่ 7.3 - 7.5 เป็นการแก้ไขสิ่งบดบังการรับสัญญาณ ณ สถานี TCP2 ในการปรนนิบัติบำรุงครั้งที่ 7



ภาพที่ 7.3 ภาพก่อนการตัดต้นไม้

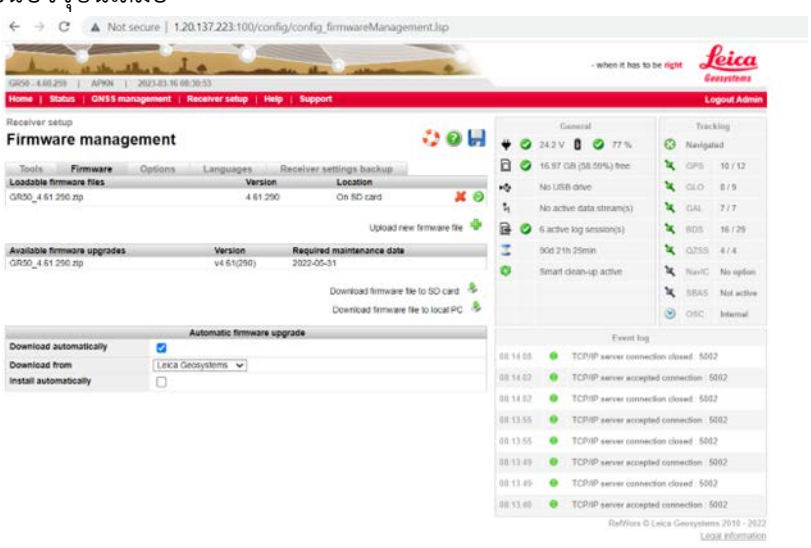


ภาพที่ 7.4 ภาพระหว่างดำเนินการตัดต้นไม้



ภาพที่ 7.5 ภาพหลังตัดการต้นไม้

7.3 **ทำการปรับปรุง Update Version หรือ Update Firmware ของเครื่องรับสัญญาณดาวเทียม GNSS** ที่สถานี CORS ให้เป็นปัจจุบันเสมอ



ภาพที่ 7.6 การ Update Firmware ของเครื่องรับสัญญาณฯ

7.4 ทำการปรับปรุง Update Version หรือ Update Firmware ของเครื่อง Server และเครื่อง Workstation รวมทั้งโปรแกรมอื่นๆ ที่เกี่ยวข้อง เช่น GNSS Spider และ Microsoft Windows Server ให้เป็นปัจจุบันเสมอ



ภาพที่ 7.7 การ Update Firmware ของ GNSS Spider

7.5 เปลี่ยนแบตเตอรี่สำรองที่สถานี CORS ทุก 2 ปี ทุก 6 เดือน จะต้องมีการตรวจสอบสภาพแบตเตอรี่สำรอง หากพบความเสียหาย หรือการทำงานให้ทำการเปลี่ยน หากไม่มีเหตุผิดปกติ ให้เปลี่ยนแบตเตอรี่ตามวงรอบ ทุก 2 ปี ตามปกติ ดังแสดงในภาพที่ 7.8 เป็นการเปลี่ยนแบตเตอรี่สำรอง ณ สถานี LNSN ในการปรนนิบัติบำรุงครั้งที่ 6



ภาพที่ 7.8 การเปลี่ยนแบตเตอรี่สำรอง ณ สถานี LNSN

8. การประชาสัมพันธ์ (Public relations)

เพื่อส่งเสริมการใช้บริการศูนย์บริการค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (National CORS Data Center : NCDC) ให้เป็นไปอย่างกว้างขวาง และเกิดประโยชน์สูงสุดในการพัฒนาด้านการสำรวจ เทคโนโลยี เศรษฐกิจ และสังคม ของประเทศไทย จึงจำเป็นต้องมีการประชาสัมพันธ์ เพื่อส่งเสริมการใช้งานของ NCDC ให้หน่วยงานภาครัฐ หน่วยงานเอกชน สถาบันการศึกษา และประชาชนทั่วไป ให้ได้รับทราบรายละเอียดการให้บริการอย่างแพร่หลาย โดยในปัจจุบันมีช่องทาง ดังนี้

8.1 บัญชีไลน์ทางการ ของกลุ่มผู้ดูแลระบบศูนย์บริการค่าอ้างอิงพิกัดแบบต่อเนื่องแห่งชาติ (NCDC)

กลุ่มผู้ดูแลระบบ NCDC ในส่วนของ กรมแผนที่ทหาร ได้มีการสร้างบัญชีไลน์ทางการ (Line Official Account :Line OA) เพื่อให้บริการในการติดต่อสอบถามข้อมูลเกี่ยวกับการให้บริการของ NCDC การสมัครใช้บริการ และการติดต่อเพื่อแก้ไขปัญหาในการใช้งานระบบฯ โดยสามารถติดต่อได้ที่บัญชี Line OA ดังนี้ @891wliii หรือที่ QR code ดังแสดงในภาพที่ 8.1

ภาพที่ 8.1 QR code บัญชีไลน์ทางการ ของกลุ่มผู้ดูแลระบบ

หน้าที่ผู้ดูแลระบบ

- ดูแลระบบ และบัญชีUser ของลูกค้า
- ตอบคำถามและแก้ไขปัญหาให้กับลูกค้า
- ติดตาม และแก้ไขปัญหาในการให้บริการ
- ตรวจสอบการปรนนิบัติบำรุงอุปกรณ์ตามวงรอบ และเมื่อเกิดปัญหา (ผู้ดูแลระบบตรวจสอบบริษัทที่ทำการปรนนิบัติบำรุงอุปกรณ์)
- แจ้งเตือนลูกค้าเมื่อเกิดปัญหา เช่น การซ่อมบำรุง

8.2 การประชาสัมพันธ์ผ่านงานประชุมวิชาการ นิทรรศการ และหน่วยงานการศึกษาต่างๆ

ส่งเสริมให้มีการเผยแพร่ข้อมูลการให้บริการของ NCDC ผ่านการเข้าร่วมนำเสนอข้อมูลในงานวิชาการ นิทรรศการ ที่จัดโดยหน่วยงานการศึกษาต่างๆ รวมทั้งกิจกรรมที่จัดโดยหน่วยงานภาครัฐ และเอกชน ที่มีส่วนเกี่ยวข้องกับการให้บริการ หรือใช้บริการของ NCDC ดังแสดงในภาพที่ 8.2 – 8.3



ภาพที่ 8.2 การนำเสนอผลงานในงานสัปดาห์วิชาการฯ ณ รร.จปร.



ภาพที่ 8.3 การนำเสนอผลงานในงานสัปดาห์วิชาการฯ ณ รร.จปร.(2)

9. ข้อมูลการติดต่อประสานงานระหว่างหน่วยงาน (Contact information for coordination)

หน่วยงาน	ตำแหน่ง	ชื่อ - สกุล	ช่องทางติดต่อ
กรมแผนที่ทหาร	ตัวแทน กรมแผนที่ทหาร	พ.อ. ศรายุทธ อยู่สำราญ	โทร 064-9734231 เมล์ sarayut.yo@rtarf.mi.th ไลน์ -
	Admin RTSD CORS	พ.อ. ปริญญา ทวีวัฒน์	โทร 089-6928738 เมล์ rtsd4354@hotmail.com ไลน์ beer4354
	Admin RTSD CORS	พ.ต. เสริม ชินรัตน์	โทร 063-2285455 เมล์ sermsurvey4960@gmail.com ไลน์ 0632285455
	Admin RTSD CORS	ร.อ. ณัฐนนท์ ดวงดี	โทร 087-3515141 เมล์ 0608ntn@gmail.com ไลน์ 0873515141
	Admin RTSD CORS	ร.อ. ชนะชล ไพจิตรประภาภรณ์	โทร 086-6650677 เมล์ chanachon.p5465@gmail.com ไลน์ 0866650677
กรมที่ดิน	ตัวแทนกรมที่ดิน	นายนรสีห์ นิลเพชร์พลอย	โทร 086-3279969 เมล์ norasi78@gmail.com ไลน์ norasi78
	Admin DOL CORS	นายธัญประวีณ์ ตัณตรีบูรณ์	โทร 087-3984484 เมล์ t.thunpravee@gmail.com ไลน์ skstickerz
GISTDA	ตัวแทน GISTDA	นางสาวดรุณี พรมโชติ	โทร 089-5085816 เมล์ darunee@gistda.or.th ไลน์ faii

ตารางที่ 9.1 ข้อมูลการติดต่อประสานงานระหว่างหน่วยงาน

หน่วยงาน	ตำแหน่ง	ชื่อ - สกุล	ช่องทางติดต่อ
สสน.	ตัวแทน สสน.	นางสาวนวลทิพย์ ฉลาดเลิศ	โทร 081-9312829 เมล์ nuantip@hii.or.th ไลน์ nuantip1234
กรมโยธาธิการและผังเมือง	ตัวแทนกรมโยธาธิการและผังเมือง	นายชัยวัฒน์ ปานะชาติ	โทร 081-3497752 เมล์ pig2513@gmail.com ไลน์ pig.2513
	Admin DPT CORS 1	นายชัยวัฒน์ ปานะชาติ	โทร 081-3497752 เมล์ pig2513@gmail.com ไลน์ pig.2513
	Admin DPT CORS 2	นายภูริทัต แสนสุทธวิจิตร	โทร 086-2311819 เมล์ phuritat.san@gmail.com ไลน์ 0862311819

ตารางที่ 9.2 ข้อมูลการติดต่อประสานงานระหว่างหน่วยงาน (ต่อ)

ภาคผนวก

ตารางที่ 1 ค่าพิกัดสถานี CORS ของ NCDC

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
AKSN	RTSD	-1482252.3667	5925273.0745	1831476.0756	16°47'52.19514"N	104°02'41.07950"E	173.388	48N	398207.150	1857435.669	198.783
APKN	RTSD	-1037945.1642	6165673.9906	1255828.5847	11°25'53.52185"N	99°33'20.59760"E	-2.456	47N	560620.023	1263753.285	26.252
ARNG	RTSD	-941903.9433	6213713.6036	1084084.3255	9°51'05.92210"N	98°37'10.35779"E	-4.112	47N	458284.648	1089033.613	23.934
ATRG	RTSD	-1044225.2063	6238038.7163	820026.9928	7°26'11.51106"N	99°30'10.79227"E	-9.570	47N	555504.092	822037.827	9.332
AUTT	RTSD	-1130743.7976	5969730.3934	1934162.3935	17°46'10.64094"N	100°43'31.78525"E	143.211	47N	682923.899	1965538.577	177.149
CKRI	RTSD	-962275.4427	6105152.8399	1570943.9881	14°21'12.22208"N	98°57'25.54531"E	214.029	47N	495373.922	1586811.044	248.825
CTAK	RTSD	-960118.2407	6017800.9175	1876856.6675	17°13'36.50616"N	99°03'53.75640"E	114.009	47N	506903.242	1904647.026	151.579
DACR	RTSD	-1549651.3552	5935497.4591	1740863.8863	15°56'40.14435"N	104°37'56.16386"E	152.798	48N	460644.671	1762829.275	176.207
DBRM	RTSD	-1381901.8128	6018323.3452	1592491.7106	14°33'16.45752"N	102°55'54.67022"E	184.834	48N	277162.595	1610071.580	209.393
DCMI	RTSD	-937854.3934	5944574.2301	2106753.0162	19°24'50.08953"N	98°57'55.63858"E	409.278	47N	496373.244	2146627.489	447.865
DCRI	RTSD	-1028340.6498	5903260.1783	2179044.3785	20°06'27.63450"N	99°52'54.10693"E	436.362	47N	592169.971	2223640.654	473.821
DLEI	RTSD	-1258695.1231	5956128.1714	1897416.4238	17°25'15.33479"N	101°55'57.43391"E	281.901	47N	811564.828	1928509.661	312.913
DMSN	RTSD	-837150.6991	6008179.3267	1964076.8010	18°03'13.04126"N	97°55'56.09061"E	157.084	47N	386993.804	1996444.504	197.202
DNAN	RTSD	-1145278.7516	5919706.3503	2073937.2432	19°06'00.62270"N	100°56'58.81101"E	325.896	47N	705110.743	2113053.667	359.735
DNPM	RTSD	-1522984.9268	5909676.0836	1848124.0204	16°57'18.50084"N	104°27'04.56987"E	133.579	48N	441576.715	1874673.900	158.638
DPLK	RTSD	-1087333.0092	6008757.7246	1835935.6158	16°50'25.28973"N	100°15'25.68130"E	16.223	47N	633935.156	1862320.534	50.957
DPNB	RTSD	-1182920.9338	6003701.7470	1793446.8095	16°26'21.92454"N	101°08'46.76013"E	96.689	47N	729175.110	1818758.144	128.174
DSNI	RTSD	-1020697.5325	6217118.6055	989737.1379	8°59'13.06150"N	99°19'24.17339"E	-4.931	47N	535545.602	993426.350	18.359
DSNK	RTSD	-1457051.8821	5914549.0286	1885146.0747	17°18'18.44614"N	103°50'21.37966"E	155.577	48N	376643.048	1913681.592	183.016
DSSK	RTSD	-1505872.0362	5970251.5739	1658989.4097	15°10'35.32099"N	104°09'23.01548"E	134.605	48N	409377.934	1678020.064	158.253
DUDN	RTSD	-1400643.0141	5939284.8739	1850039.2340	16°58'23.41540"N	103°16'09.98448"E	155.653	48N	315744.018	1877399.569	183.655
DUTI	RTSD	-1024115.7908	6069399.8916	1666393.4809	15°14'45.18709"N	99°34'39.16881"E	108.041	47N	562019.994	1685604.493	142.699
DYLA	RTSD	-1218007.5851	6219834.4248	712783.8923	6°27'34.35601"N	101°04'47.33357"E	57.703	47N	730021.408	714473.756	68.691
ECMI	RTSD	-924694.4736	5980687.2699	2008262.9218	18°28'25.26380"N	98°47'20.76579"E	262.496	47N	477734.072	2042606.417	301.260
ENMA	RTSD	-1283834.4135	6038812.3984	1597051.9584	14°35'49.58916"N	102°00'08.01352"E	205.259	48N	176991.859	1615896.148	231.919

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
LCNT	RTSD	-1070784.2861	6069037.6482	1637875.9529	14°58'45.16606"N	100°00'21.39833"E	-9.198	47N	608161.778	1656272.273	24.033
LCPM	RTSD	-1261224.6319	6015257.4361	1699797.7786	15°33'31.88285"N	101°50'30.19222"E	169.521	47N	804805.936	1722168.200	199.262
LKPT	RTSD	-1010663.1997	6031473.9763	1805406.5680	16°33'07.89885"N	99°30'44.59571"E	74.222	47N	554668.685	1830087.236	110.191
LKRI	RTSD	-1021280.0802	6096688.0122	1565943.7252	14°18'25.63385"N	99°30'34.37098"E	54.263	47N	554953.207	1581753.130	88.186
LLEI	RTSD	-1257391.8575	5974248.6381	1840688.8266	16°53'04.68134"N	101°53'07.77297"E	236.610	47N	807437.230	1869042.555	267.432
LLPG	RTSD	-1046898.3026	5950358.4055	2037915.0902	18°45'22.98258"N	99°58'42.32050"E	252.123	47N	603131.786	2074155.402	288.608
LLPN	RTSD	-945162.1840	6001074.4062	1937646.3348	17°48'06.74810"N	98°57'01.77521"E	420.868	47N	494753.249	1968266.619	458.765
LLRI	RTSD	-1145246.5371	6052214.0679	1649689.0628	15°05'23.00444"N	100°42'54.91140"E	5.371	47N	684349.375	1668968.363	36.782
LMDH	RTSD	-1554648.9700	5914873.3909	1804870.4780	16°32'49.25622"N	104°43'34.96433"E	120.754	48N	470805.738	1829464.601	144.248
LNAN	RTSD	-1128247.2483	5942056.5758	2018483.8846	18°34'16.92500"N	100°45'03.77126"E	163.186	47N	684787.408	2054300.868	197.710
LNBP	RTSD	-1311175.4325	5951371.5431	1876583.4259	17°13'26.23914"N	102°25'28.64379"E	209.369	48N	226119.664	1906153.872	239.639
LNKI	RTSD	-1339229.2141	5922621.6788	1945761.5610	17°52'46.91567"N	102°44'29.41147"E	145.336	48N	260697.377	1978324.540	176.521
LNMA	RTSD	-1356900.3967	6000717.5515	1677331.6556	15°20'53.99310"N	102°44'29.80600"E	122.333	48N	257549.657	1698118.799	150.255
LNSN	RTSD	-1111112.1381	6052437.9334	1672093.6229	15°17'57.90981"N	100°24'09.29419"E	53.573	47N	650589.173	1691929.964	86.046
LPBI	RTSD	-1075534.1712	6128876.2799	1395510.3223	12°43'22.24363"N	99°57'11.81317"E	-12.501	47N	603492.987	1406676.194	17.624
LPCT	RTSD	-1083659.5466	6020119.6909	1800763.9538	16°30'30.97657"N	100°12'15.56659"E	10.411	47N	628529.514	1825579.609	44.949
LPLK	RTSD	-1145387.9869	5989310.6582	1864348.9058	17°06'29.97847"N	100°49'35.22352"E	183.867	47N	694328.719	1892450.213	216.883
LPRE	RTSD	-1035726.4227	5976349.1459	1966343.7506	18°04'31.08896"N	99°49'54.99684"E	110.717	47N	588036.784	1998715.067	147.316
LSN1	RTSD	-1088138.3167	6196940.7935	1042730.2414	9°28'20.48841"N	99°57'33.11653"E	8.052	47N	605293.749	1047220.487	31.150
LSN2	RTSD	-973259.7514	6226268.9615	980242.1723	8°54'00.02565"N	98°53'03.47727"E	29.682	47N	487279.387	983799.261	54.166
LSNK	RTSD	-1468571.7150	5901750.3457	1915781.3469	17°35'43.24142"N	103°58'24.56945"E	131.817	48N	391081.169	1945711.961	160.002
LSRN	RTSD	-1477946.3499	5993065.7111	1601258.1051	14°38'11.53507"N	103°51'11.73099"E	144.070	48N	376503.721	1618438.380	166.447
LSSK	RTSD	-1561088.4591	5971825.2655	1601693.9251	14°38'26.23215"N	104°38'59.29618"E	139.169	48N	462289.019	1618606.727	158.864
LTRG	RTSD	-1057745.0701	6230578.0514	858627.2159	7°47'18.96631"N	99°38'06.20412"E	39.603	47N	570019.700	860980.155	58.930
LTRT	RTSD	-1352218.0109	6085818.3929	1342643.7934	12°14'00.20227"N	102°31'37.69786"E	-8.695	48N	230963.782	1353592.377	12.400
LYST	RTSD	-1499624.8622	5952705.8163	1725794.8625	15°48'10.88651"N	104°08'23.66642"E	108.960	48N	407884.755	1747335.489	134.186
MKRI	RTSD	-1047824.3603	6083730.3591	1598072.0882	14°36'25.54449"N	99°46'20.62169"E	9.824	47N	583190.118	1615011.194	43.515

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
MNSN	RTSD	-1136318.4728	6038710.8744	1704194.9172	15°36'01.59535"N	100°39'24.71671"E	36.899	47N	677639.984	1725430.312	68.707
MRBR	RTSD	-1059873.8947	6110212.5483	1485747.8718	13°33'37.68366"N	99°50'26.07741"E	-21.767	47N	590947.362	1499273.518	10.119
NKBI	RTSD	-1004107.3918	6237146.3591	874718.7020	7°56'07.95122"N	99°08'43.72302"E	-9.078	47N	516034.150	877174.742	12.234
PCCO	RTSD	-1248697.1267	6077550.8021	1473351.7761	13°26'42.29843"N	101°36'37.61662"E	49.535	47N	782655.521	1487854.533	75.852
PCPM	RTSD	-1253922.8824	6000701.4118	1755580.3409	16°04'57.49268"N	101°48'10.24443"E	230.593	47N	799859.236	1780109.208	260.500
PCRI	RTSD	-996241.5733	5925989.5312	2132025.2813	19°39'21.95935"N	99°32'34.74923"E	421.893	47N	556922.157	2173516.775	459.599
PNST	RTSD	-1030041.7950	6225236.0302	927766.8632	8°25'12.23059"N	99°23'42.60593"E	36.883	47N	543501.821	930759.028	58.526
SBKK	RTSD	-1139278.6433	6089742.3135	1510744.2972	13°47'34.59825"N	100°35'47.37945"E	1.246	47N	672579.832	1525400.479	31.573
TCP1	RTSD	-998580.6188	6185787.5175	1187602.1182	10°48'10.39387"N	99°10'12.81932"E	31.592	47N	518608.588	1194189.899	60.034
TCP2	RTSD	-988846.3260	6202198.6498	1107854.0524	10°04'11.35516"N	99°03'31.31681"E	5.159	47N	506431.782	1113132.726	32.229
TCTI	RTSD	-1275980.9736	6090015.7604	1396879.9973	12°44'07.72372"N	101°50'00.39865"E	16.628	47N	807698.702	1409561.875	41.119
TKK1	RTSD	-1364654.0159	5952327.7263	1835839.9564	16°50'18.43549"N	102°54'45.73075"E	382.194	48N	277590.664	1862858.090	410.951
TKK2	RTSD	-1343631.3938	5987078.4582	1735623.2491	15°53'42.44824"N	102°38'55.86634"E	196.889	48N	248255.696	1758749.896	226.017
TKRI	RTSD	-1013658.0967	6103489.7628	1544279.8435	14°06'18.74401"N	99°25'46.29870"E	25.944	47N	546364.206	1559404.046	59.732
TNPM	RTSD	-1532978.1845	5894327.6152	1888232.6827	17°20'03.65004"N	104°34'42.02661"E	152.065	48N	455197.232	1916591.925	178.094
TNPT	RTSD	-1068059.8918	6094630.9417	1542424.2778	14°05'16.86335"N	99°56'23.72163"E	-19.354	47N	601468.269	1557663.252	13.281
TNSN	RTSD	-1108936.3355	6035226.5249	1733982.2130	15°52'48.74593"N	100°24'41.82294"E	1.986	47N	651133.919	1756194.143	35.067
TNST	RTSD	-1090749.7707	6213696.8056	935325.9620	8°29'21.21461"N	99°57'22.46451"E	-10.812	47N	605252.151	938512.893	9.231
TPK1	RTSD	-1069622.7153	6137421.5197	1362359.4852	12°24'56.90812"N	99°53'10.13675"E	-5.008	47N	596318.517	1372693.692	24.639
TPK2	RTSD	-1019361.9050	6178593.4385	1207649.4577	10°59'14.16326"N	99°22'06.34104"E	135.617	47N	540250.483	1214596.268	163.799
TPKT	RTSD	-914875.2536	6247977.4949	896544.3827	8°08'04.38019"N	98°19'49.69999"E	219.238	47N	426241.353	899233.597	244.629
TPRI	RTSD	-1256831.6058	6062465.4664	1527009.0975	13°56'39.76206"N	101°42'44.21557"E	-3.662	47N	793069.175	1543247.359	23.102
TSKA	RTSD	-1143697.0044	6227724.3133	764312.7196	6°55'43.47576"N	100°24'22.29070"E	5.671	47N	655354.022	766101.706	20.343
TSKW	RTSD	-1340690.9096	6051254.1297	1500217.8813	13°41'41.79607"N	102°29'32.71345"E	25.005	48N	228773.732	1515394.802	48.927
TSRI	RTSD	-1194168.7670	6055887.8382	1602984.5647	14°39'06.77687"N	101°09'18.41559"E	475.099	47N	732109.639	1620927.788	504.179
TSSK	RTSD	-1549340.5447	5961235.3440	1651359.3994	15°06'18.29439"N	104°34'08.35912"E	118.953	48N	453685.386	1669993.954	140.809
TUBN	RTSD	-1581409.4915	5950175.9027	1660747.1698	15°11'34.73677"N	104°53'01.40300"E	116.535	48N	487510.634	1679674.210	137.433

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
TUTT	RTSD	-1068725.8920	5984703.2849	1922897.1121	17°39'46.92040"N	100°07'29.78245"E	52.481	47N	619319.486	1953260.958	88.160
AMKO	DOL	-883144.2953	6010907.0266	1937627.2863	17°48'02.29449"N	98°21'29.89466"E	785.030	47N	431991.297	1968245.488	823.227
AUPG	DOL	-944812.8421	6059318.7494	1748565.9090	16°00'58.19902"N	98°51'45.38210"E	428.846	47N	485301.185	1770728.476	464.944
AWLK	DOL	-956898.4688	6237553.7306	923074.1755	8°22'38.03845"N	98°43'18.14507"E	-7.207	47N	469361.069	926012.759	16.828
AYYA	DOL	-1134356.4462	6075002.9932	1572057.2383	14°21'51.51561"N	100°34'36.36078"E	-14.575	47N	670023.566	1588598.288	16.439
BDNG	DOL	-1394062.2638	5916172.5843	1926911.2146	17°42'02.97089"N	103°15'32.65323"E	147.844	48N	315369.025	1957939.556	177.495
BGKN	DOL	-1429610.4610	5884459.1058	1996199.6147	18°21'33.15768"N	103°39'18.97007"E	131.810	48N	357923.790	2030453.145	161.663
BGSP	DOL	-1025844.6227	6171496.2139	1237207.9414	11°15'35.37865"N	99°26'15.31429"E	7.105	47N	547761.795	1244744.531	35.747
BKOK	DOL	-1164774.7377	5954584.5484	1961139.5774	18°01'29.97240"N	101°04'04.29936"E	402.386	47N	718917.007	1994173.378	435.562
BLAN	DOL	-1092605.7953	6093002.9260	1531704.7263	13°59'17.31950"N	100°09'58.71018"E	-17.908	47N	625964.739	1546725.060	13.852
BLMG	DOL	-1173899.7645	6106033.7100	1416075.3664	12°54'48.56024"N	100°52'56.90337"E	-12.487	47N	704241.730	1428318.845	15.879
BNMG	DOL	-1424892.3817	5903605.3926	1942688.8156	17°51'02.02075"N	103°34'09.74007"E	134.659	48N	348410.061	1974232.569	164.232
BNNR	DOL	-1245302.5872	6020376.3487	1693509.5529	15°29'59.40208"N	101°41'12.11829"E	186.656	47N	788249.554	1715418.074	216.403
BNPE	DOL	-1312990.6639	5935131.9592	1925599.1807	17°41'18.06256"N	102°28'27.35918"E	158.778	48N	232082.242	1957501.496	189.823
BNPG	DOL	-1490328.0205	5883321.5278	1954981.0043	17°58'02.26711"N	104°12'53.33544"E	127.501	48N	416860.870	1986743.088	155.262
BNST	DOL	-1237503.6134	6218448.7340	691007.1192	6°15'41.10484"N	101°15'18.41834"E	46.810	47N	749514.286	692638.178	56.479
BOBR	DOL	-1391662.8698	5971556.5906	1750910.6012	16°02'20.15193"N	103°07'06.77768"E	151.351	48N	298708.801	1774155.088	179.769
BOKO	DOL	-1166457.8822	5914134.5184	2079169.6041	19°08'56.38552"N	101°09'26.52785"E	709.961	47N	726902.342	2118715.389	742.543
BORI	DOL	-1351917.6926	6077445.2264	1380185.5132	12°34'50.96744"N	102°32'28.15386"E	11.015	48N	232844.244	1392030.595	32.596
BPLE	DOL	-1165298.1278	6090154.9157	1489142.3437	13°35'31.28633"N	100°49'55.63813"E	-18.412	47N	698226.552	1503351.928	10.799
BRAI	DOL	-1018998.5516	6075037.4881	1649079.8575	15°05'01.42441"N	99°31'18.79726"E	125.331	47N	556085.655	1667653.299	159.972
BTAK	DOL	-961971.4525	6023304.4276	1858216.1635	17°03'02.19031"N	99°04'26.32003"E	93.439	47N	507872.320	1885155.096	130.824
BTHG	DOL	-1639450.2545	5947411.6276	1614110.0730	14°45'23.86249"N	105°24'40.61995"E	139.562	48N	544265.975	1631448.777	156.888
BTNG	DOL	-1218862.8794	6227967.1968	639033.0214	5°47'18.96619"N	101°04'23.81560"E	288.931	47N	729585.216	640255.319	297.756
BUYI	DOL	-1321931.4407	6001461.3932	1702320.6414	15°34'57.31835"N	102°25'19.48128"E	143.887	48N	223538.401	1724436.053	172.983
CHDN	DOL	-1186344.0160	6041578.7578	1659611.9375	15°10'57.26743"N	101°06'33.97202"E	25.776	47N	726631.107	1679612.642	56.215
CHKG	DOL	-1081312.0737	5889457.7616	2190327.4167	20°12'59.76497"N	100°24'13.35940"E	327.863	47N	646644.857	2236071.565	364.266

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
CHKN	DOL	-1227549.6381	5946180.3904	1947708.6334	17°53'52.97816"N	101°39'52.08659"E	191.483	47N	782312.364	1980924.595	223.594
CHPM	DOL	-1279552.5120	6003831.9896	1726072.7253	15°48'19.82110"N	102°01'51.70147"E	158.925	48N	181917.515	1749667.858	188.723
CHTK	DOL	-1120651.1627	5988384.8908	1882119.9628	17°16'35.16063"N	100°35'58.51550"E	174.795	47N	670032.017	1910840.919	208.680
CHYA	DOL	-1002385.5660	6212541.2504	1035825.1989	9°24'32.70640"N	99°09'56.18877"E	-1.654	47N	518181.748	1040084.291	23.189
CLPK	DOL	-1155477.1066	5899960.0589	2124054.7075	19°34'46.20401"N	101°04'51.01552"E	473.204	47N	718276.103	2166278.671	506.836
CMPN	DOL	-994847.7121	6192799.9946	1153707.2243	10°29'28.17614"N	99°07'34.87775"E	-9.951	47N	513826.642	1159720.463	17.966
DKTN	DOL	-1255359.7292	6026997.7083	1662480.8318	15°12'32.50557"N	101°45'57.15489"E	193.368	47N	797161.751	1683328.492	222.440
DSAI	DOL	-1177823.3192	5977435.6285	1882542.8989	17°16'47.98607"N	101°08'49.33945"E	331.119	47N	728239.970	1911800.728	363.191
DUDM	DOL	-1602826.6589	5952860.2183	1630520.6068	14°54'36.39161"N	105°04'10.87120"E	116.116	48N	507494.935	1648384.838	135.290
HACH	DOL	-983713.4120	5976430.9164	1992894.7537	18°19'38.64786"N	99°20'49.22281"E	249.458	47N	536666.793	2026443.577	287.357
JAHM	DOL	-1003279.9085	5959660.1598	2032774.3431	18°42'26.19139"N	99°33'21.12378"E	274.940	47N	558607.296	2068529.814	312.279
JKRT	DOL	-1324558.7104	6017890.4940	1641619.3834	15°00'49.87048"N	102°24'47.06747"E	149.440	48N	221821.689	1661485.823	177.014
KBCG	DOL	-1451929.9443	6004093.4025	1583920.6594	14°28'28.42329"N	103°35'40.10102"E	181.775	48N	348519.256	1600676.020	204.238
KHJM	DOL	-1643844.7534	5929414.4936	1674145.7503	15°19'06.76735"N	105°29'42.96277"E	94.318	48N	553165.879	1693619.850	113.126
KHMR	DOL	-1610363.4258	5916201.4465	1751219.4712	16°02'30.91105"N	105°13'36.32169"E	118.847	48N	524255.973	1773585.576	140.270
KKJN	DOL	-1042150.3237	6130097.9586	1415474.6696	12°54'28.05144"N	99°38'54.06426"E	48.460	47N	570335.312	1427027.729	79.726
KKOI	DOL	-1177854.3330	6060476.1875	1595852.1013	14°35'10.99557"N	100°59'54.00165"E	-0.897	47N	715281.563	1613525.202	28.941
KKOR	DOL	-1166142.7907	6001730.3216	1813679.0414	16°37'40.56585"N	100°59'44.25613"E	911.005	47N	712871.886	1839457.232	942.098
KLNG	DOL	-1260306.0090	6092119.7119	1401768.0123	12°46'51.01701"N	101°41'17.42534"E	-11.084	47N	791860.149	1414415.087	13.964
KMCE	DOL	-1522611.5173	5922257.9807	1808079.6465	16°34'37.79202"N	104°25'06.45854"E	159.741	48N	437961.048	1832869.648	183.972
KNKN	DOL	-1359634.0156	5966157.8308	1793620.7535	16°26'27.42141"N	102°50'16.61709"E	138.654	48N	269146.597	1818945.036	167.696
KNSN	DOL	-1430048.1244	5950286.0855	1791563.7588	16°25'17.75211"N	103°30'49.51530"E	128.765	48N	341306.898	1816153.061	155.705
KNSW	DOL	-1304888.2403	5994466.1742	1739513.9196	15°55'54.41451"N	102°16'50.46453"E	158.956	48N	208864.193	1763286.928	188.542
KNYM	DOL	-835485.6531	5981025.4754	2046761.0097	18°50'23.12719"N	97°57'07.75345"E	590.406	47N	389604.250	2083423.141	630.309
KOGD	DOL	-1356671.1030	6098368.0483	1280387.7103	11°39'29.02599"N	102°32'31.34970"E	35.986	48N	232020.376	1289905.392	55.825
KPNG	DOL	-1091258.7810	6191726.6765	1069785.4116	9°43'13.69469"N	99°59'43.53249"E	-11.981	47N	609191.347	1074667.170	11.653
KSKS	DOL	-1297233.8258	6014497.4791	1675341.9093	15°19'46.52560"N	102°10'16.89798"E	160.718	48N	196264.070	1696764.002	189.651

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
KSSB	DOL	-1268451.5312	5991382.3150	1776614.8233	16°16'50.21768"N	101°57'13.43014"E	206.292	47N	815698.102	1802258.699	236.287
KSWS	DOL	-1442358.3598	5971380.7925	1710148.3908	15°39'22.00185"N	103°34'45.89563"E	115.406	48N	347738.771	1731406.427	142.175
KUKN	DOL	-1513557.9966	5981932.9222	1609518.4822	14°42'49.40908"N	104°11'56.63829"E	137.662	48N	413777.683	1626816.149	159.353
LAGU	DOL	-1076507.0345	6240273.6746	759452.8101	6°53'04.16787"N	99°47'15.85351"E	-7.287	47N	587030.271	761051.503	9.476
LGNT	DOL	-1539633.5433	5929778.8195	1768790.5711	16°12'25.70665"N	104°33'18.45851"E	142.802	48N	452451.318	1791899.874	166.536
LMHP	DOL	-1338442.4009	6090317.1834	1336050.0767	12°10'20.70230"N	102°23'40.59416"E	-14.119	48N	216471.453	1346979.264	7.300
LOMS	DOL	-1186805.2352	5992762.8148	1827068.9980	16°45'22.81049"N	101°12'06.83086"E	137.933	47N	734726.352	1853900.848	169.798
LPMA	DOL	-1369203.2824	6007554.5995	1642821.6493	15°01'30.40789"N	102°50'21.03359"E	145.012	48N	267674.420	1662239.747	171.646
MEJM	DOL	-879958.6447	5986692.6609	2011006.6870	18°29'57.44621"N	98°21'42.44097"E	437.901	47N	432628.900	2045545.607	476.901
MHGS	DOL	-834433.8674	5964347.3757	2093791.5908	19°17'25.69504"N	97°57'51.10218"E	203.496	47N	391167.535	2133292.929	243.945
MSAI	DOL	-1026415.1523	5891082.1268	2212260.2712	20°25'39.66946"N	99°53'00.76408"E	378.029	47N	592174.088	2259058.252	415.590
MSOD	DOL	-910899.7963	6042331.6789	1822373.6867	16°42'42.90144"N	98°34'22.64468"E	180.799	47N	454474.916	1847735.099	219.135
MSSB	DOL	-1562766.5272	5945493.5347	1694592.7925	15°30'36.59845"N	104°43'37.21781"E	117.495	48N	470721.639	1714772.570	140.043
MWOG	DOL	-1015276.7863	6054806.6501	1723480.9142	15°46'52.76028"N	99°31'07.91797"E	97.519	47N	555574.928	1744815.152	132.523
NAMY	DOL	-1598658.7600	5966273.1825	1585475.6351	14°29'20.77564"N	105°00'00.02190"E	169.934	48N	500000.656	1601819.920	187.738
NANO	DOL	-1125627.5376	5951335.1206	1992890.4379	18°19'38.50744"N	100°42'37.18014"E	248.766	47N	680744.434	2027252.803	282.991
NDDG	DOL	-1363561.2510	6029293.9968	1566955.3702	14°18'58.13435"N	102°44'36.28469"E	231.266	48N	256590.572	1583876.915	255.582
NROA	DOL	-1317071.0218	5974071.1009	1799116.5360	16°29'33.51864"N	102°25'58.09861"E	172.796	48N	225937.448	1825174.063	202.502
NRTW	DOL	-1298692.5052	6203821.3153	709432.9476	6°25'44.77484"N	101°49'24.31066"E	4.437	47N	812337.312	711501.290	13.202
NSHO	DOL	-1360065.4557	5988322.0602	1718374.6715	15°43'59.71207"N	102°47'45.32813"E	145.736	48N	263822.155	1740661.944	174.430
OKRK	DOL	-1178265.2285	6073650.6267	1544929.8269	14°06'40.88906"N	100°58'43.65370"E	-15.413	47N	713625.737	1560941.664	13.878
PBHN	DOL	-1616951.3152	5939039.4969	1666309.6581	15°14'42.35199"N	105°13'48.33300"E	109.002	48N	524708.318	1685448.233	128.677
PDCP	DOL	-1215054.3672	6014245.7061	1736656.8187	15°54'16.92453"N	101°25'18.09064"E	249.222	47N	759289.125	1759896.279	279.339
PKET	DOL	-922365.1356	6250473.3511	869690.3622	7°53'22.65806"N	98°23'39.83216"E	0.140	47N	433244.102	872144.432	24.737
PKKT	DOL	-1132704.5879	6087759.8146	1523587.2391	13°54'44.91033"N	100°32'24.27438"E	13.343	47N	666394.622	1538584.309	44.003
PKNK	DOL	-1118572.2852	6211237.0908	918761.0840	8°20'16.16045"N	100°12'31.98392"E	-11.801	47N	633115.640	921848.603	6.945
PLDG	DOL	-1209062.8884	6097744.5582	1422375.3093	12°58'18.53685"N	101°12'54.58235"E	37.365	47N	740296.436	1435062.028	64.770

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
PNNK	DOL	-1203243.4353	6086106.9225	1475570.3542	13°27'57.00913"N	101°11'00.04872"E	-12.347	47N	736367.086	1489700.788	15.381
PNPS	DOL	-1373244.1679	5909347.2371	1962218.3151	18°02'09.63443"N	103°04'56.95040"E	141.258	48N	297017.371	1995221.425	171.980
PNTG	DOL	-1479558.1557	5941540.0297	1780479.1883	16°19'01.79001"N	103°59'00.04830"E	143.398	48N	391395.084	1804289.529	169.081
PONG	DOL	-1075183.2705	5930943.3880	2079127.6399	19°08'59.96535"N	100°16'30.71723"E	265.023	47N	634102.616	2117913.292	300.893
PPRM	DOL	-1080405.8426	6003678.7529	1856402.6394	17°02'01.21719"N	100°12'05.77504"E	20.406	47N	627887.595	1883672.818	55.544
PTBR	DOL	-1072925.1106	6119632.1121	1437164.0952	13°06'32.91513"N	99°56'39.54429"E	-16.103	47N	602362.367	1449396.830	14.736
PTLG	DOL	-1105618.7291	6224823.3073	839659.5397	7°36'56.10805"N	100°04'17.50035"E	-2.660	47N	618196.163	841947.115	14.766
PYAO	DOL	-1034057.8853	5936806.2080	2083569.7403	19°11'31.62053"N	99°52'49.84329"E	378.713	47N	592569.796	2122318.818	415.519
RAND	DOL	-1132675.5083	6217668.0257	856322.4420	7°46'03.44066"N	100°19'27.78236"E	-4.075	47N	646040.104	858836.444	12.759
RATP	DOL	-1126888.8185	6227967.6390	786903.8855	7°08'04.39854"N	100°15'22.08999"E	17.141	47N	638712.243	788812.388	32.640
RAYG	DOL	-1216734.6593	6103746.8165	1389703.6148	12°40'08.55509"N	101°16'25.28900"E	-13.418	47N	746943.792	1401611.937	13.137
SADO	DOL	-1148836.0896	6229446.5729	742561.6239	6°43'50.28740"N	100°26'56.74842"E	24.401	47N	660160.970	744209.123	38.242
SAKW	DOL	-1298270.8079	6057510.4208	1512153.9007	13°48'21.63253"N	102°05'48.70646"E	25.709	48N	186106.929	1528170.946	50.954
SAMG	DOL	-916785.9486	5968686.5611	2047599.0558	18°50'53.25659"N	98°43'56.43796"E	470.369	47N	471803.681	2084044.435	508.639
SATN	DOL	-1107406.4637	6238298.9187	730921.7285	6°37'28.89925"N	100°03'58.08453"E	-4.859	47N	617853.898	732386.947	10.275
SBRI	DOL	-1275756.5242	6205019.4075	739691.3133	6°42'16.29262"N	101°37'05.35266"E	1.542	47N	789454.487	741857.923	11.905
SCHP	DOL	-1289380.0789	5970108.0775	1831833.2468	16°48'04.27336"N	102°11'13.69017"E	179.313	48N	200174.772	1859690.150	209.819
SDAN	DOL	-1154290.8156	6017173.1132	1766859.2679	16°11'20.92092"N	100°51'33.41727"E	75.155	47N	698769.009	1790757.104	106.926
SDAO	DOL	-1314806.3577	6071793.0585	1440225.3103	13°08'13.30183"N	102°13'06.14398"E	233.836	48N	198416.002	1453954.067	257.407
SGNN	DOL	-1252681.6925	6036861.3564	1628666.9394	14°53'33.15205"N	101°43'22.15520"E	212.218	47N	792965.614	1648230.797	240.485
SICN	DOL	-1083287.8024	6206159.0681	991943.7671	9°00'25.80562"N	99°54'04.50418"E	-9.796	47N	599062.069	995766.661	12.067
SISA	DOL	-1031456.0103	5996166.4208	1907542.7936	17°31'03.10662"N	99°45'37.62771"E	41.089	47N	580721.493	1936969.456	77.677
SKBR	DOL	-905237.4051	6090994.9983	1656706.5535	15°09'18.02463"N	98°27'12.11037"E	173.800	47N	441274.321	1675543.794	210.941
SKNK	DOL	-1488626.6744	5911749.0181	1869297.9977	17°09'18.72602"N	104°08'01.34887"E	155.084	48N	407862.393	1896929.815	181.400
SKOM	DOL	-1289316.1985	5927263.3053	1965132.9090	18°03'49.23414"N	102°16'19.12648"E	151.133	48N	211219.704	1999363.302	182.325
SKPM	DOL	-1469423.1356	5986139.9920	1634345.1321	14°56'45.13543"N	103°47'30.30133"E	119.955	48N	370063.116	1652692.478	143.809
SKTH	DOL	-1041316.4918	6011521.1695	1853388.5796	17°00'18.65483"N	99°49'38.16149"E	23.115	47N	588057.119	1880314.210	59.319

ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
SMNM	DOL	-974577.8100	5987074.6953	1965312.3180	18°03'54.71630"N	99°14'43.91640"E	212.938	47N	525983.192	1997416.192	250.752
SNCK	DOL	-1229477.6193	6075764.8714	1496301.0132	13°39'30.88076"N	101°26'23.14441"E	-7.188	47N	763927.508	1511294.751	19.989
SPDI	DOL	-1305397.8785	6206671.0463	671589.7556	6°05'05.40811"N	101°52'38.76211"E	21.168	47N	818526.202	673430.859	28.537
SPUG	DOL	-1017286.8776	6117912.6562	1484364.8010	13°32'50.42995"N	99°26'26.76677"E	100.678	47N	547691.050	1497708.435	133.652
STHP	DOL	-1177361.2253	6111613.6261	1389031.0721	12°39'46.15181"N	100°54'14.64229"E	-17.280	47N	706789.480	1400602.158	10.393
SURN	DOL	-1438061.2287	5995700.0528	1627265.5096	14°52'46.69247"N	103°29'15.14249"E	129.068	48N	337292.096	1645564.916	153.596
TAPY	DOL	-1371960.2855	6035820.4090	1533662.4198	14°00'22.35015"N	102°48'21.30177"E	58.310	48N	263014.164	1549511.528	81.964
TEPA	DOL	-1204574.6259	6217562.7227	753451.1808	6°49'47.37217"N	100°57'52.20922"E	-2.409	47N	717100.599	755379.482	10.230
TGSG	DOL	-1060808.5551	6224765.0056	895963.6601	8°07'46.10714"N	99°40'16.64329"E	42.611	47N	573953.699	898672.735	62.569
THKP	DOL	-914616.1701	6235615.3210	977034.8302	8°52'14.58312"N	98°20'39.92854"E	-14.098	47N	427916.184	980622.713	12.770
THPP	DOL	-925142.0888	6099791.1940	1612846.7267	14°44'41.53668"N	98°37'27.11806"E	118.719	47N	459550.877	1630141.704	155.111
THSY	DOL	-871885.6820	6031205.6988	1876842.3345	17°13'36.16209"N	98°13'32.98945"E	99.725	47N	417692.523	1904799.981	138.843
TKPP	DOL	-1594093.5605	5934256.2579	1704736.9963	15°36'19.09163"N	105°02'10.16442"E	126.501	48N	503875.974	1725277.343	147.968
TPHN	DOL	-1108846.3215	6024716.9163	1769997.6421	16°13'07.85645"N	100°25'42.79250"E	10.052	47N	652689.147	1793675.220	43.475
TPNM	DOL	-1549746.8137	5903314.7781	1846192.0164	16°56'12.87957"N	104°42'34.03509"E	125.783	48N	469062.924	1872598.688	150.320
UTHI	DOL	-1069154.1356	6058114.3655	1678632.5902	15°21'38.97272"N	100°00'31.20802"E	0.519	47N	608260.300	1698488.008	34.094
UTOG	DOL	-1061726.5330	6087755.9159	1573446.4362	14°22'38.17069"N	99°53'35.11036"E	-13.903	47N	596289.100	1589637.459	19.210
VCBR	DOL	-1183380.7306	6027944.4613	1710264.1785	15°39'26.54502"N	101°06'24.54855"E	46.194	47N	725835.770	1732157.505	77.311
WGCN	DOL	-1012833.8015	5986317.4986	1947860.2513	17°53'59.40785"N	99°36'10.85267"E	72.741	47N	563873.616	1979207.100	109.800
WHAG	DOL	-902983.5412	5944738.3716	2122260.3822	19°33'41.59199"N	98°38'13.17481"E	705.681	47N	461923.344	2163004.375	744.428
WNKH	DOL	-1268879.7194	6047266.3612	1577808.3210	14°25'01.22872"N	101°51'01.02574"E	400.611	47N	807353.164	1595750.678	426.771
WNNW	DOL	-1445454.8061	5906211.3390	1919621.4040	17°37'54.17652"N	103°45'07.05416"E	142.740	48N	367599.009	1949877.596	171.356
WSPG	DOL	-1242445.0366	5963540.4968	1884709.2000	17°18'02.81852"N	101°46'07.19152"E	228.965	47N	794326.381	1914945.620	260.117
KLKG	DOL	-1033372.7334	6038317.2726	1769416.2787	16°12'47.93094"N	99°42'40.63131"E	34.273	47N	576022.052	1792662.993	69.525
KTBN	DOL	-1108230.1080	6099966.6030	1492516.6010	13°37'24.26041"N	100°17'49.46958"E	-19.306	47N	640307.942	1506451.605	11.547
CHAN	DPT	-1305191.1948	6086920.6015	1383367.9637	12°36'37.10719"N	102°06'08.69825"E	7.777	48N	185176.797	1395780.800	31.207
CNBR	DPT	-1183806.8748	6091488.4952	1469134.4219	13°24'21.65676"N	100°59'51.56414"E	-7.729	47N	716310.435	1482910.729	20.786

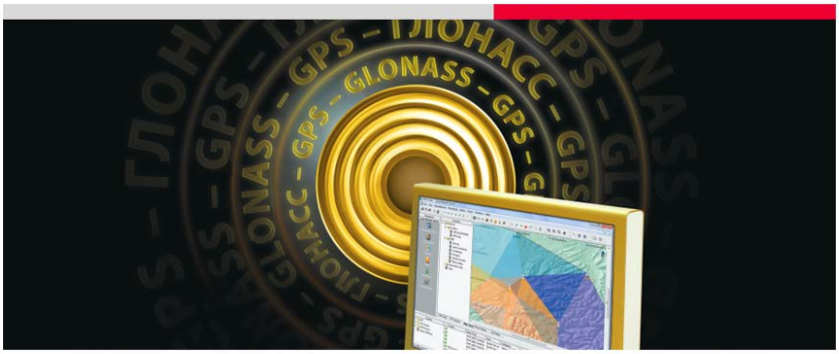
ตารางที่ 5 ค่าพิกัดสถานี CORS ของ NCDC (ต่อ)

STA	AGENCY	X (m)	Y (m)	Z (m)	Latitude	Longitude	h (m)	Zone	Easting (m)	Northing (m)	Elevation (m)
DPT9	DPT	-1136984.5432	6091176.4999	1506866.8508	13°45'24.40238"N	100°34'23.53672"E	37.946	47N	670087.834	1521382.869	68.298
LPBR	DPT	-1140009.4021	6061593.3007	1618813.9382	14°48'03.25717"N	100°39'04.50763"E	9.640	47N	677706.659	1636959.669	41.015
NKNY	DPT	-1201408.9760	6066337.4366	1555734.1665	14°12'43.44525"N	101°12'07.91192"E	-13.928	47N	737649.158	1572301.872	14.703
NKRM	DPT	-1294882.7280	6024986.5170	1639293.2110	14°59'31.49211"N	102°07'45.95493"E	152.468	48N	191268.497	1659451.988	180.301
NKSW	DPT	-1078589.9392	6046539.2817	1713801.0361	15°41'26.28267"N	100°06'50.82505"E	21.209	47N	619389.393	1735029.481	54.828
PJRK	DPT	-1062387.6410	6152905.1408	1297009.2181	11°48'41.82273"N	99°47'46.86126"E	-11.922	47N	586752.281	1305846.211	16.723
SISK	DPT	-1519763.8938	5968501.7029	1652534.8706	15°06'58.03015"N	104°17'08.46163"E	104.981	48N	423245.542	1671294.164	127.983
SOKA	DPT	-1163641.9549	6220193.9392	794819.0972	7°12'24.08010"N	100°35'46.04068"E	18.707	47N	676236.876	796905.718	33.466
SPBR	DPT	-1086264.4619	6079455.0886	1588618.4139	14°31'07.93889"N	100°07'50.10658"E	-13.320	47N	621820.815	1605413.550	19.258
SRTN	DPT	-1021155.5732	6214494.4589	1005605.0125	9°07'55.99598"N	99°19'52.90052"E	9.813	47N	536408.109	1009486.936	33.448
UDON	DPT	-1346748.8144	5936987.3497	1896511.3585	17°24'45.82620"N	102°46'50.56345"E	150.093	48N	264246.249	1926580.988	180.148
UTTD	DPT	-1065933.0100	5986322.6279	1919422.2986	17°37'48.32866"N	100°05'46.85971"E	51.072	47N	616307.892	1949598.110	86.794
CUUT	CU	-1132916.0044	6092526.3545	1504641.4386	13°44'09.56594"N	100°32'02.17122"E	74.316	47N	665856.049	1519055.754	104.757
MHDU	GISTDA	-1110093.2814	6095068.7867	1510924.1924	13°47'40.75051"N	100°19'19.65054"E	-14.384	47N	642914.508	1525409.351	16.755

<u>หมายเหตุ</u>

สถานี CORS จำนวน 8 สถานีที่ไม่ได้ปรากฏในตาราง ได้แก่ สถานี CORS ของกรมโยธาธิการและผังเมืองจำนวน 1 สถานี คือ CHMA, สถานี CORS ของ GISTDA จำนวน 1 สถานี คือ SMSK, และสถานี CORS ของสสน. จำนวน 6 สถานี คือ ANGT, CCSO, HIIA, NKPT, PCBR และ THAI อยู่ในระหว่างดำเนินการ

การแก้ปัญหาการใช้งาน Leica Spider
(Trouble Shooting)



คู่มือการใช้งาน Leica GNSS Spider

GNSS Networks
powered by Leica Geosystems

- when it has to be right Leica Geosystems

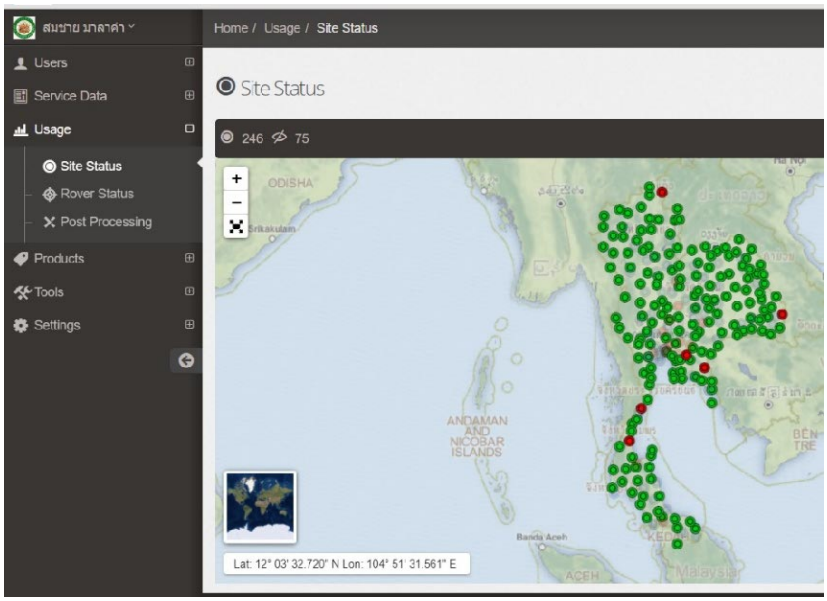
สารบัญ

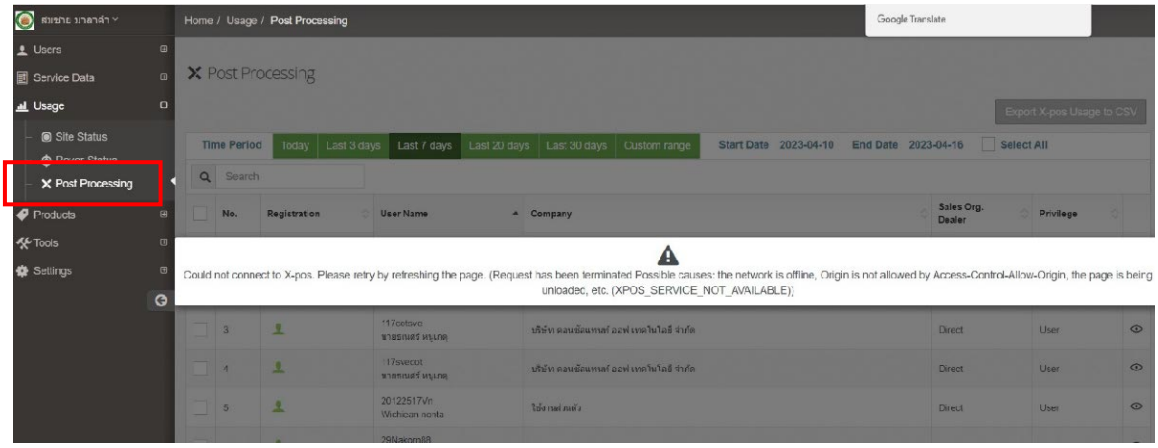
		หน้าที่
1.	SBC X-POS หยุดทำงาน	2
2.	CORS ใน SBC ขึ้นสีแดง disconnect	5
3.	CLUSTER stop การทำงาน	10

1. SBC X-POS หยุดทำงาน

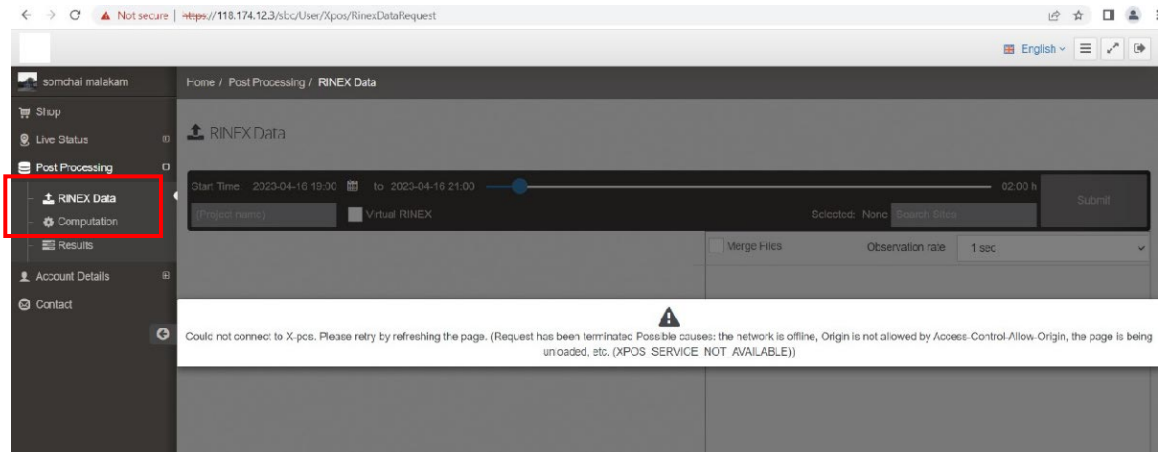
X-POS error message แสดงจากการเข้าสู menu

1.1 เลือก Post Processing แล้วแสดง error message



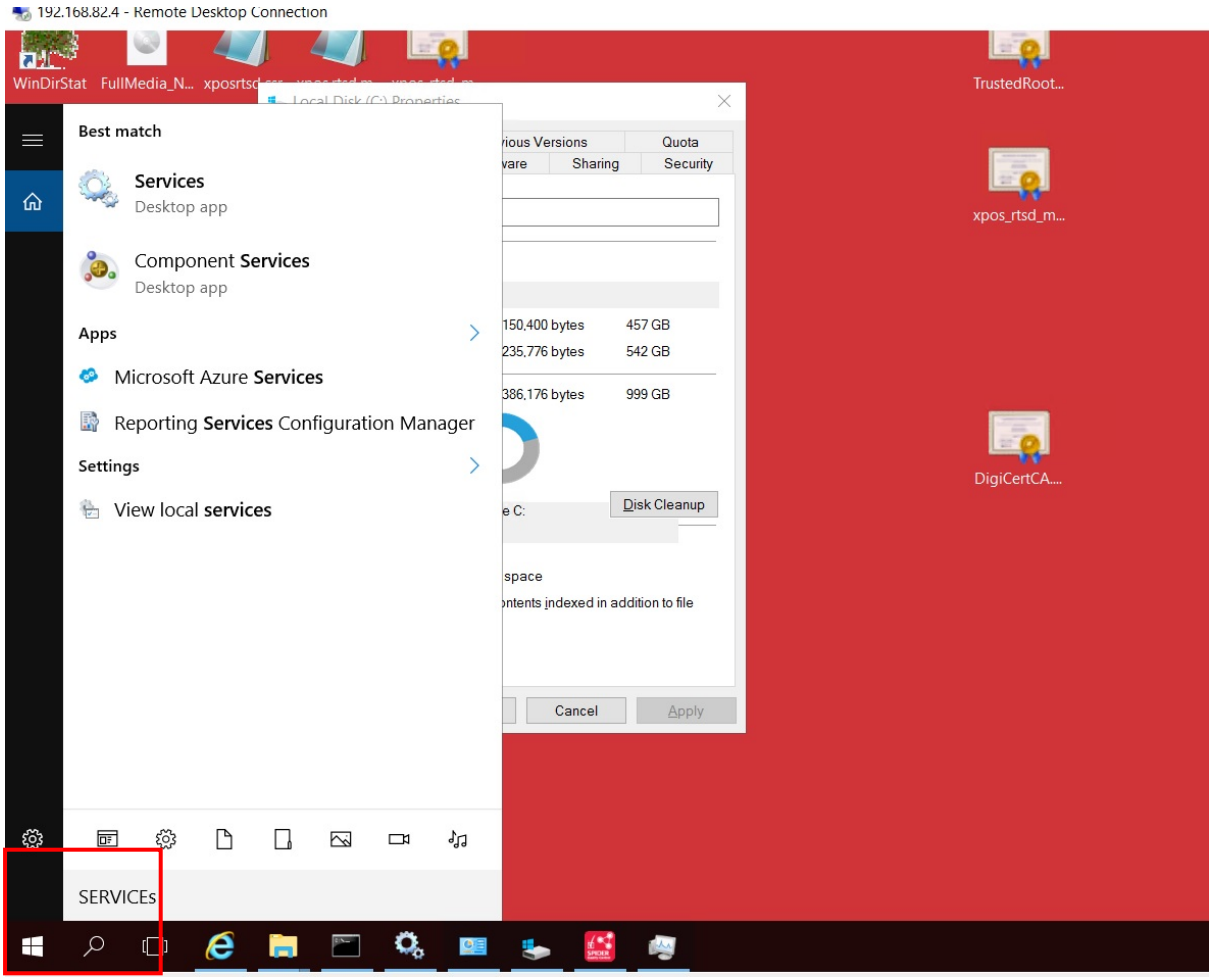


1.2 เลือก RINEX DOWNLOAD หรือ Computation แล้วแสดง error message

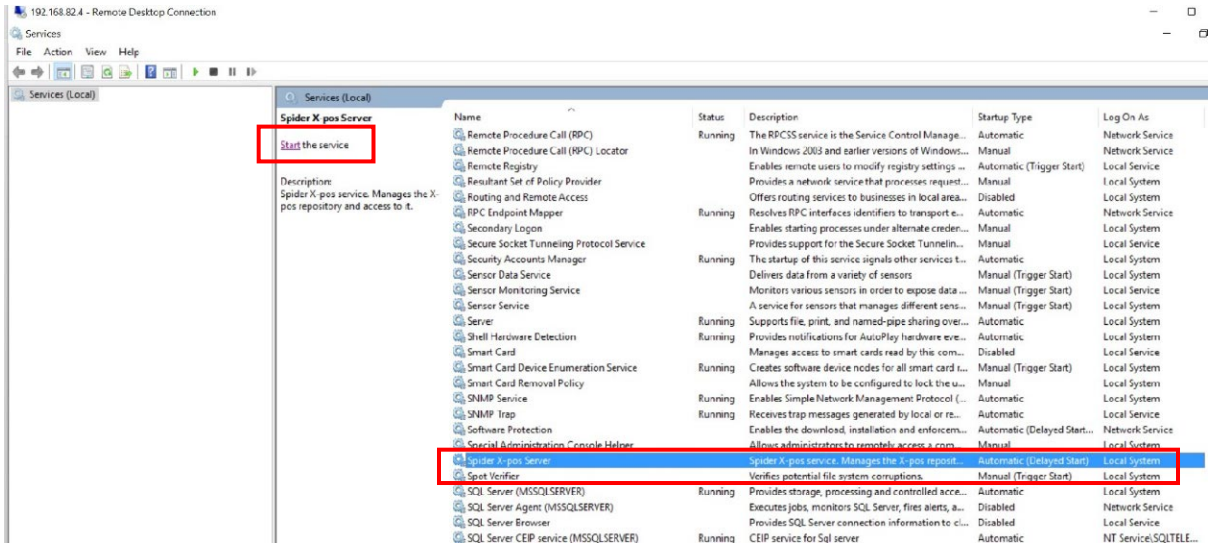


วิธีแก้ไข SBC X-POS หยุดทำงาน

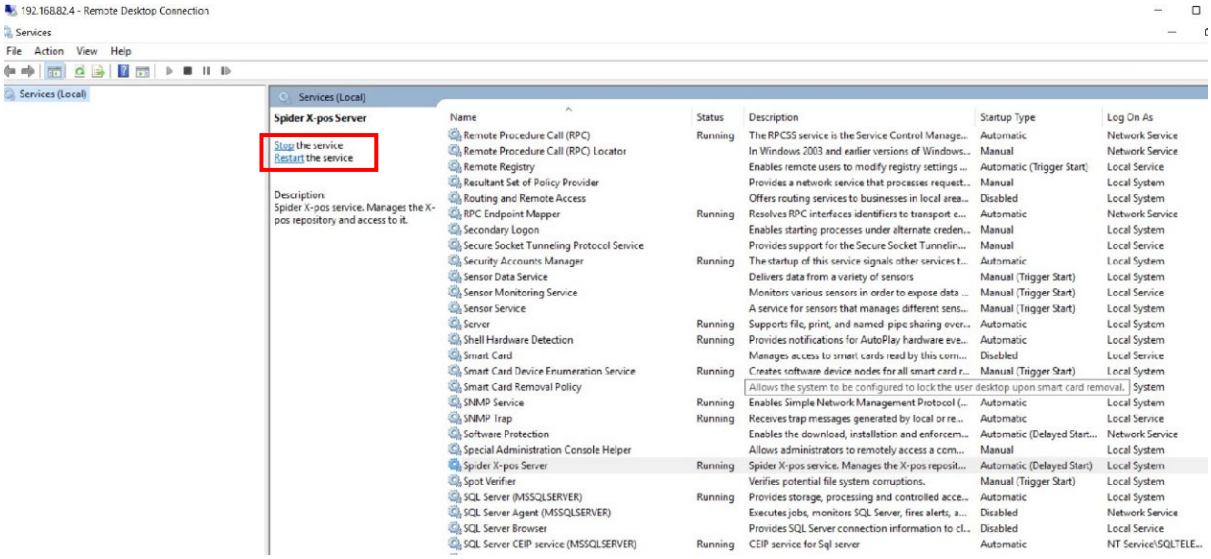
a1. เปิด XPOS server 192.168.82.4 เลือก windows icon ที่มุมล่างซ้าย พิมพ์ค้นหาโปรแกรม SERVICES



a2. ที่หน้าจอ Service windows ตรวจสอบ สถานะ Spider X-pos Server ว่าเป็น Start?

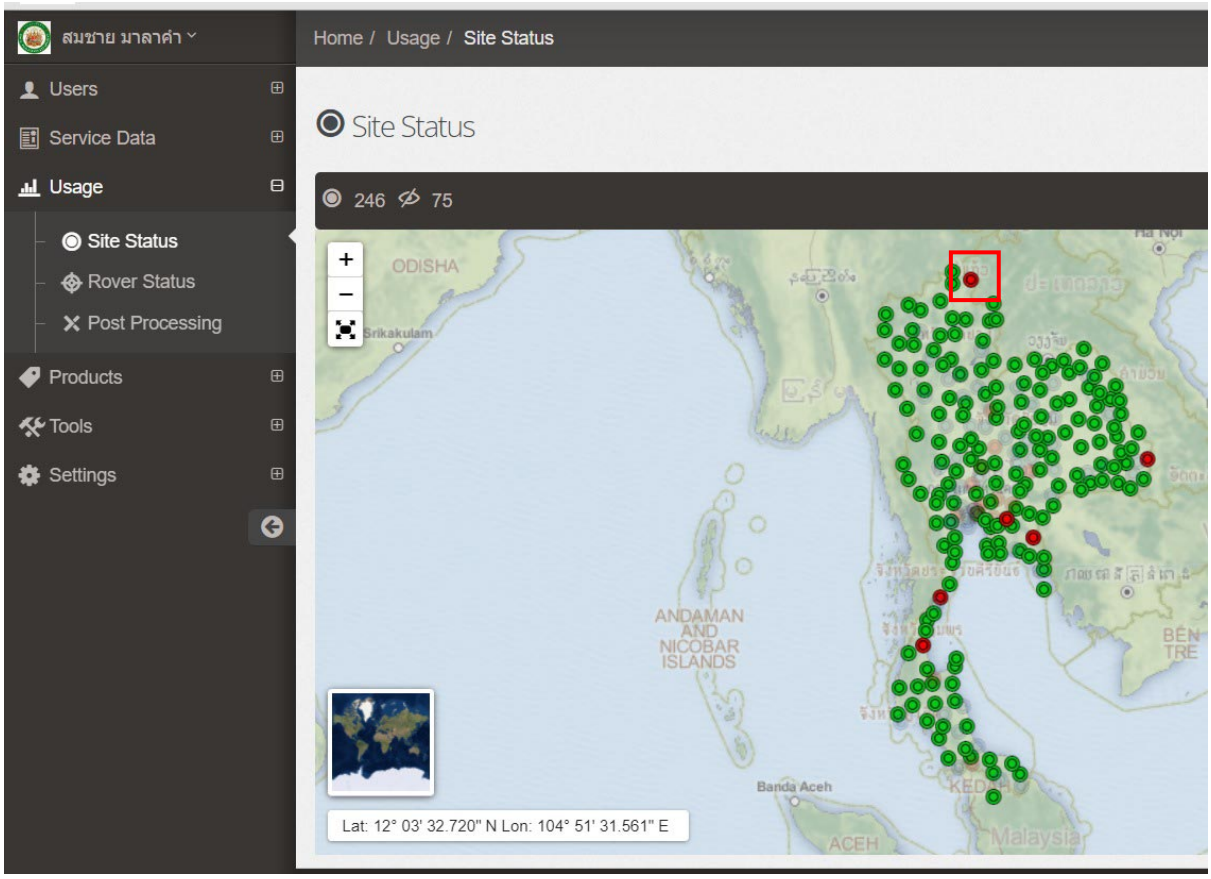


a3. ถ้าเป็น Start แสดงว่าระบบ XPOS stop การทำงานอยู่ ให้ click ที่ Restart เพื่อ เปิดการทำงานของ XPOS ดังรูปข้างล่าง



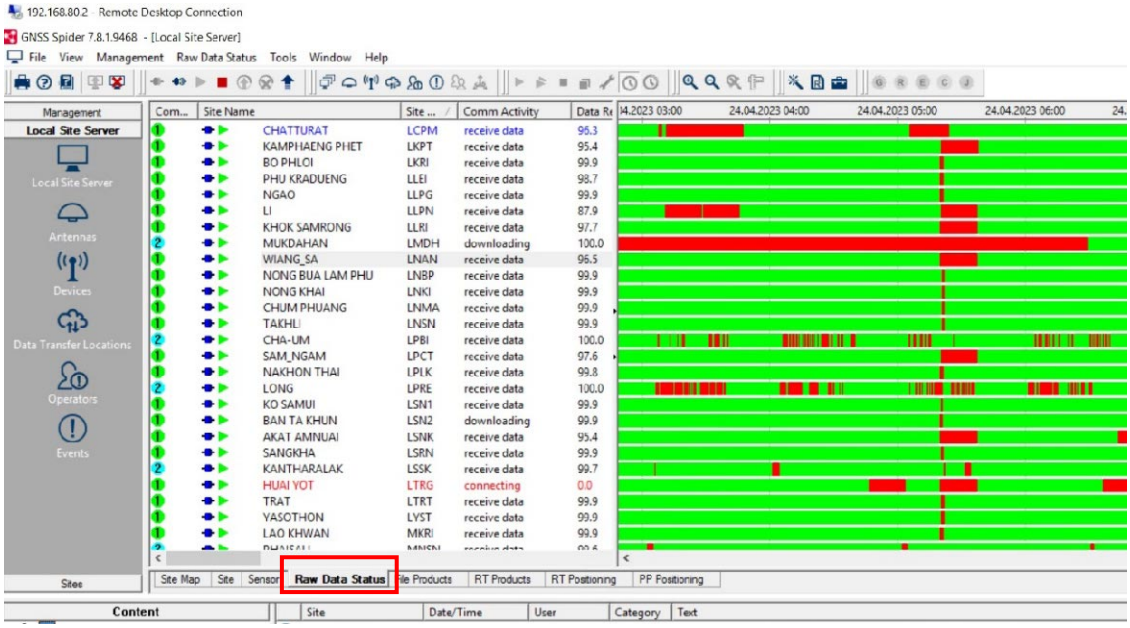
2. CORS ใน SBC ขึ้นสีแดง disconnect

เปิดหน้าจอ SBC ถ้ามี CORS สีแดงตามภาพ แสดงว่า สถานีนั้นมีการ disconnect กับ server

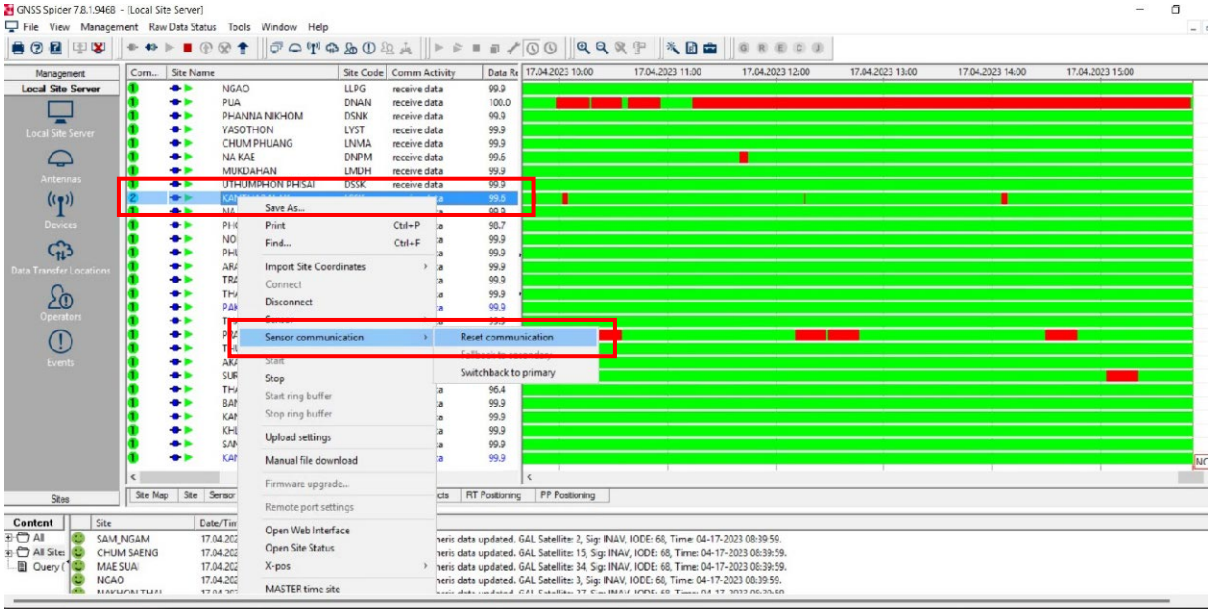


วิธีแก้ไข CORS disconnect

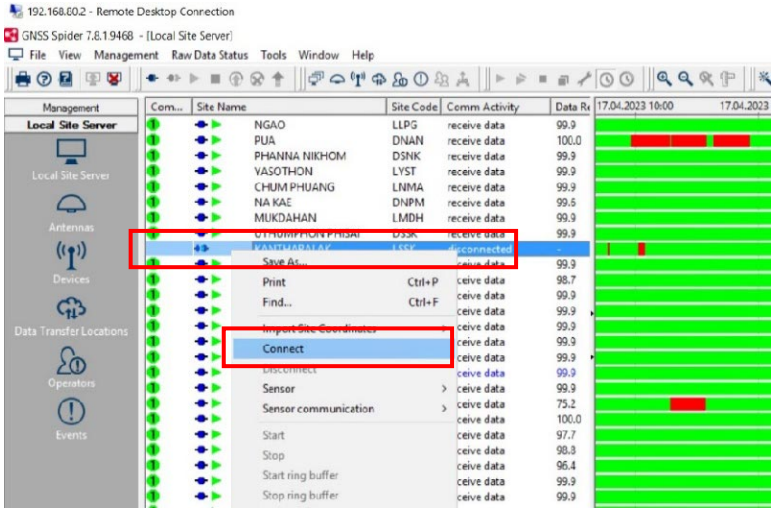
a1. เปิด Server ที่ connect กับ สถานีนั้น เช่น SS01 หรือ SS02 เลือก raw data status



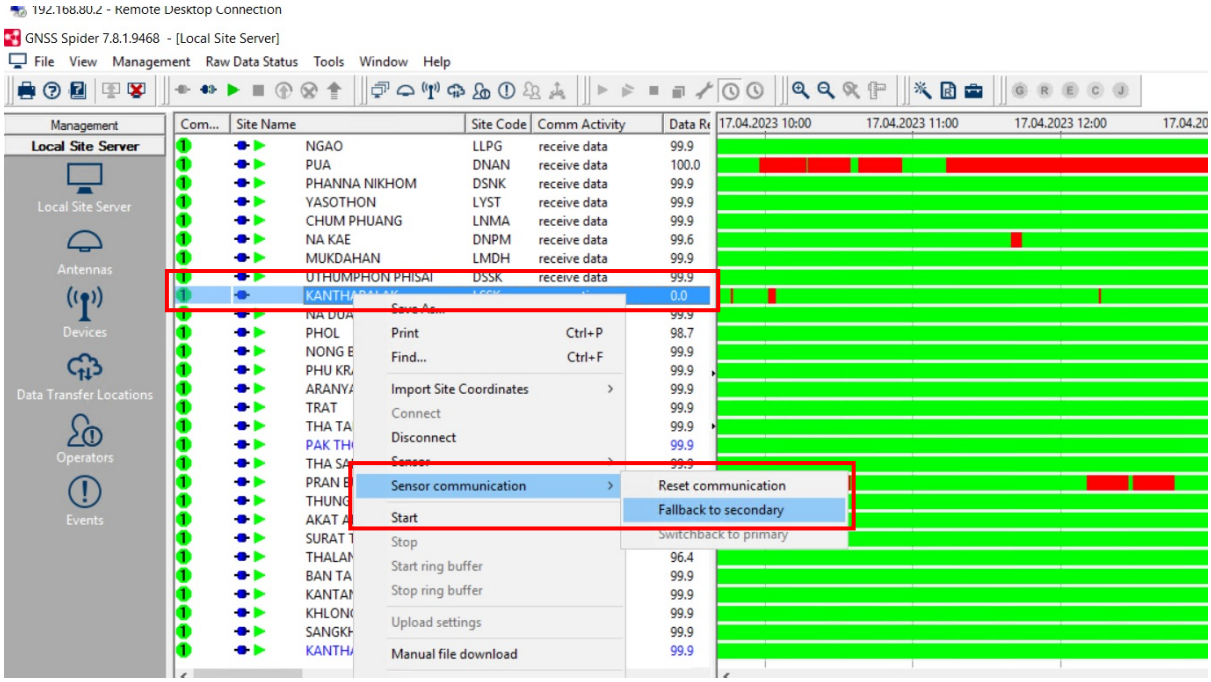
a2. เลือกสถานีที่ disconnect แล้ว click ขวา เลือก Sensor communication\Reset communication



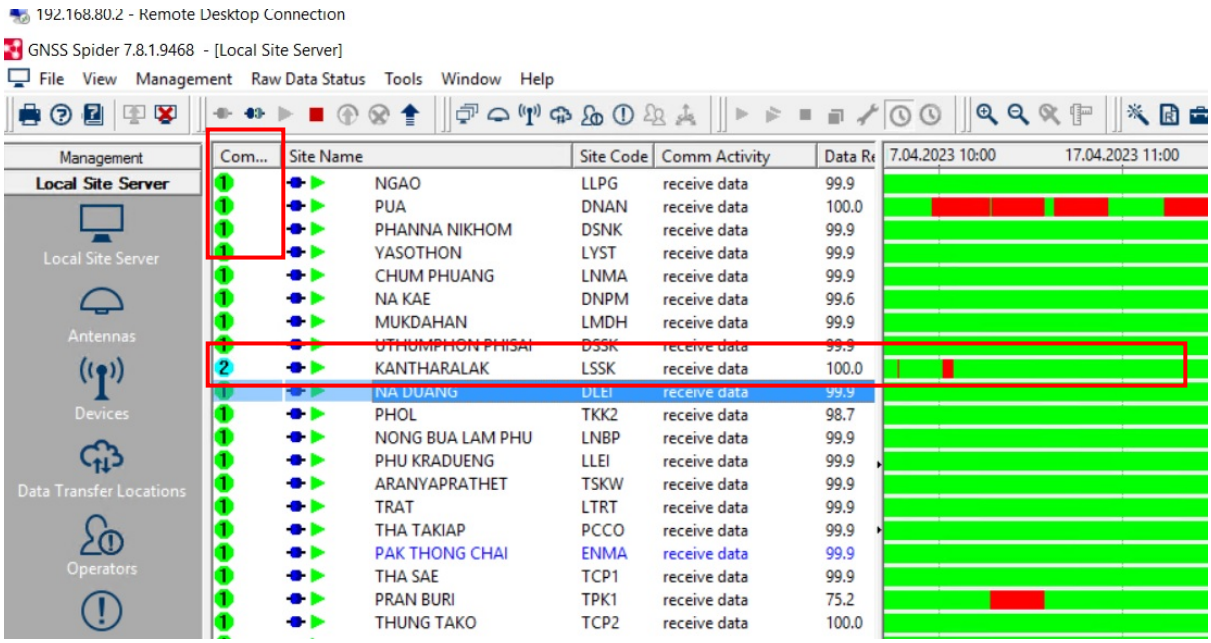
a3. หลังจาก reset comm. แล้ว ให้ click ขวา เลือก Connect



a4. หากสถานีสามารถเชื่อต่อด้วย fiber optic internet ได้เอง ก็ไม่ต้องดำเนินการอะไรต่อ แต่หากยังไม่เชื่อมต่อ ให้ดำเนินการดังนี้ ที่สถานีเดิม click ขวา เลือก Sensor Comm.\Fallback to secondary เพื่อเปลี่ยน การเชื่อมต่อจาก fiber optic internet เป็น sim internet ในกรณีที่ สถานี disconnect จาก fiber optic internet

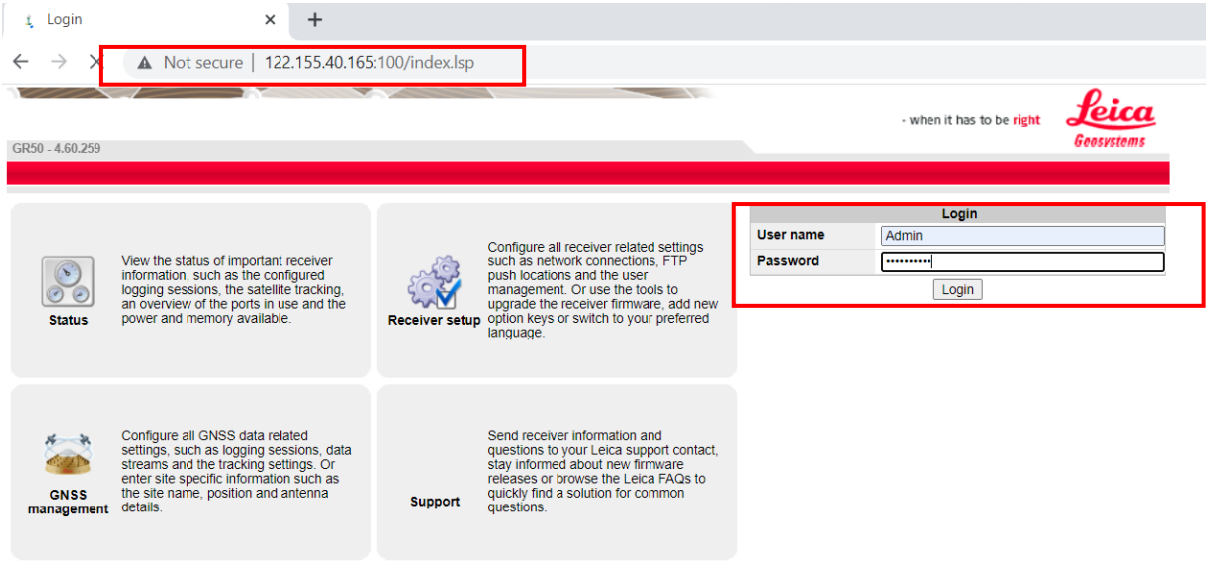


a5. Comm = 1 คือการต่อด้วย fiber optic internet Comm = 2 คือการต่อด้วย sim internet หาก สถานีเชื่อมต่อได้ปกติ จะปรากฏแถบข้อมูลสีเขียวแทนสีแดง
หากยังไม่สามารถ connect ได้ ข้อมูลแถบยังคงเป็นสีแดง ให้ทำการ reboot GR50 เพื่อ re-initial GR50/sim

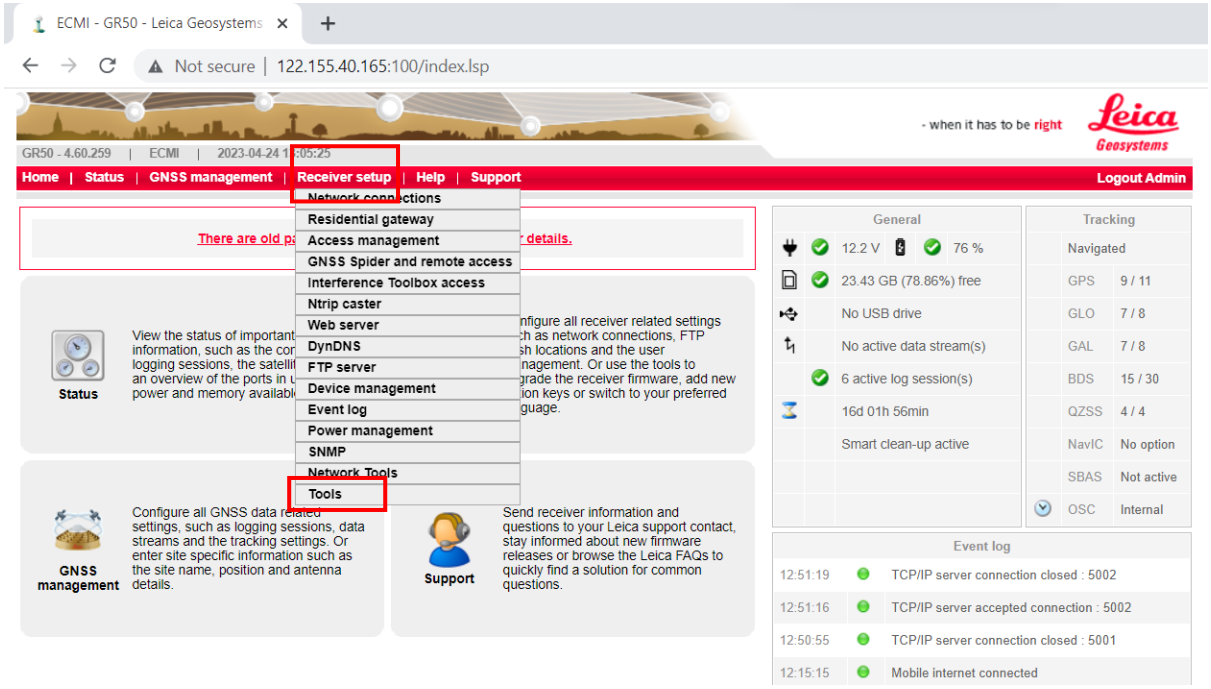


a6. การ re-initial GR50/sim

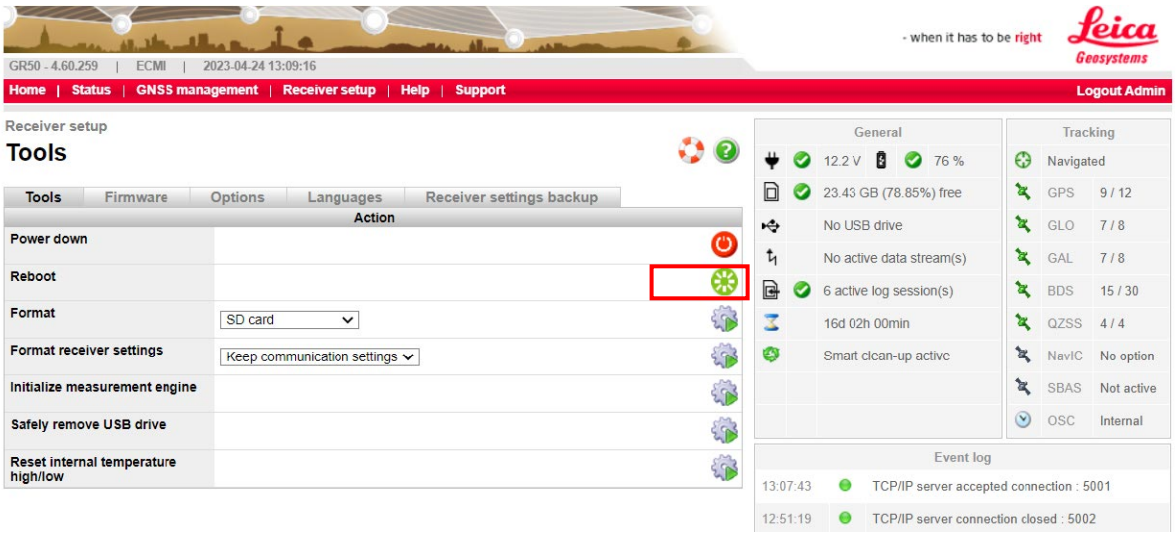
a6.1. เข้า Web Interface ของ GR50 ด้วย IP port100 ป้อน User name/Password กด Login



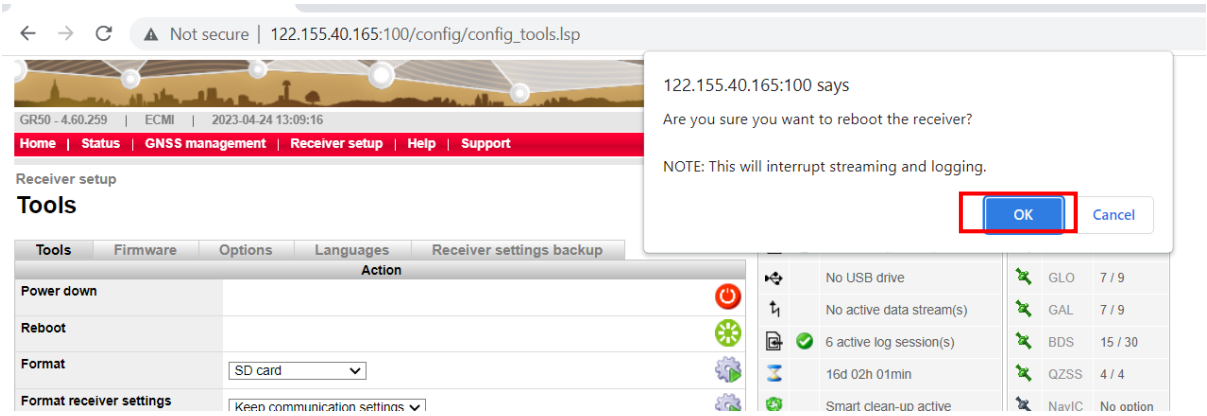
a6.2. เลือก Receiver setup/Tools



a6.3. เลือก Reboot



a6.4. เลือก OK

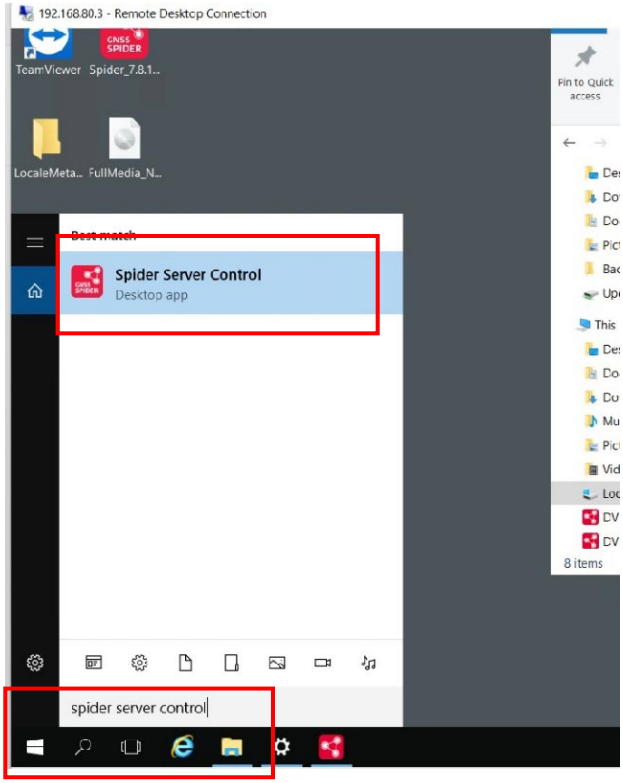


จะ reboot ใช้เวลาประมาณ 2-3 นาที

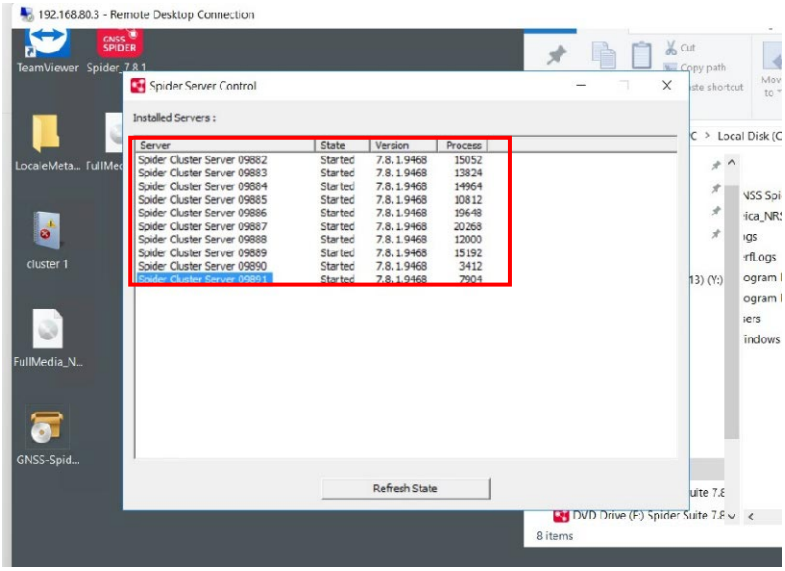
หาก Re-initial GR50/sim แล้ว ยังไม่สามารถ connect สถานีได้ ต้องเข้าดำเนินการเปิดตู้ที่สถานีเพื่อแก้ไข

3. CLUSTER stop การทำงาน และการแก้ไข

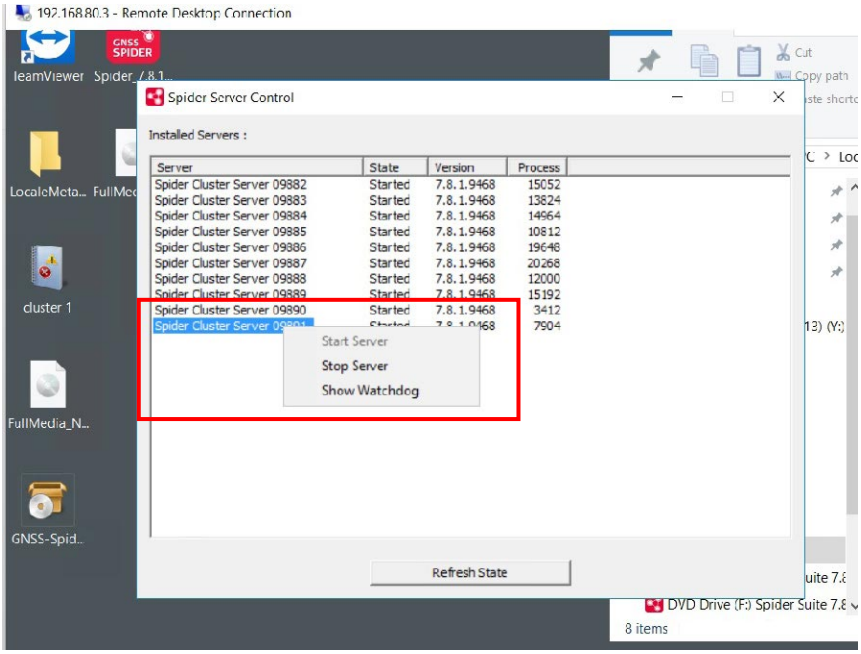
1. เปิด server CS01 or CS02 or CS03 เมื่อเปิด cluster ได้แล้ว ให้ click ที่มุมล่างซ้าย พิมพ์ค้นหาโปรแกรม Spider server control



2. ที่หน้าต่าง Spider server control ตรวจสอบสถานะการทำงานของแต่ละ cluster ใด ว่า stop หรือไม่



3. หาก สถานะเป็น stop ให้ เลือก cluster นั้น แล้ว click ขวา เลือก start server เพื่อให้กลับมาทำงานแบบปกติ



3) Pilot Project Implementation Report (in English or in Thai and English)

The project for capacity development and promotion of utilization of National CORS Data Center

JICA Pilot Project

Implementation Report

November 2023

Topcon Corporation

Topcon Positioning Asia

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1. Overview of the pilot project

1.1. Name of the pilot project

EN: Evaluation of N-RTK Survey Results Compared to Static Survey in Thailand.

TH: การตรวจสอบค่าความแม่นยำจากการสำรวจแบบ N-RTK / STATIC ในประเทศไทย

1.2. Background and purpose of the pilot projenct

CORS have been established throughout Thailand and the data has been consolidated. This is the background against which it was decided to evaluate the N-RTK survey using the data distributed from NCDC to check the differences in accuracy and stability depending on the distance between the observation point and the CORS. In addition, based on the evaluation results and findings, advice and feedback will be shared regarding the operation and management of the data distribution from NCDC.

1.3. Brief description of the pilot project

- 6 observation points were set in total

3 observation points that are less than 30 km from the nearest CORS(Close points)

3 observation points that are 30 km or more away from all of the nearest CORS(Wide points).

- Static and N-RTK surveys were performed for 2 days (about 10 hours per day) at each of the 6 observation points.

- The results showed no significant difference in the observation accuracy of the N-RTK survey between close points and wide points.

- On the other hand, the positioning stability of N-RTK surveying was more stable at close points than at wide points.

- An additional long-term survey was performed, and there were times when the number of GNSS involved in the correction information delivered from NCDC decreased significantly at night, showing that there is room for improvement.

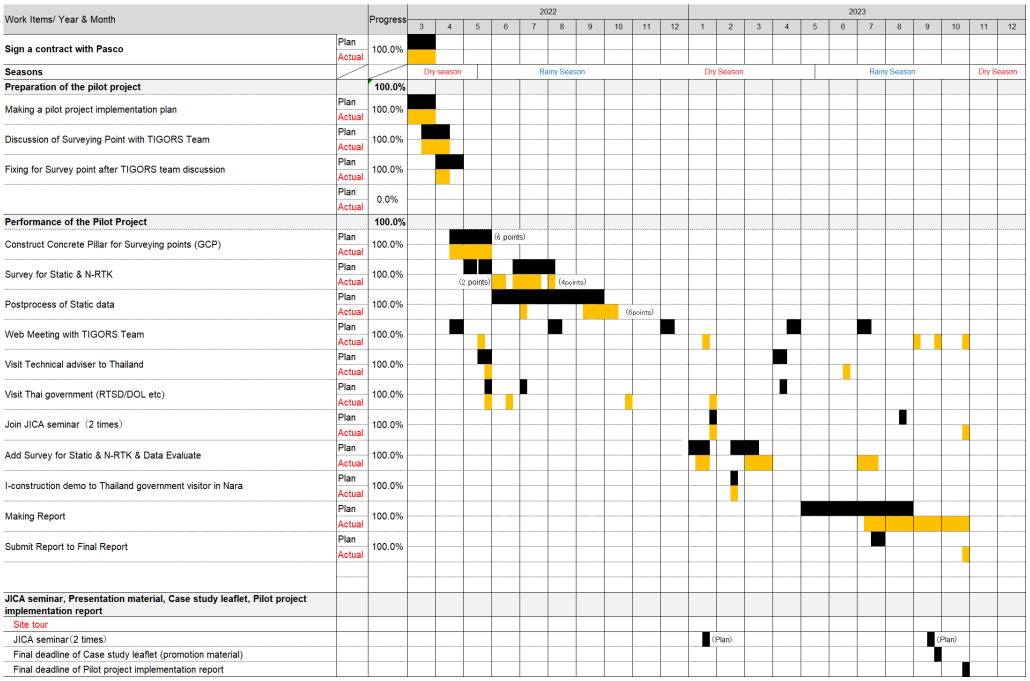
1.4. Implementation period

Preparation: March 2022 – July 2022

Work at the site: June 2022 – September 2022

Reporting: December 2022 – September 2023

Table 1-1 Plan and actual of the schedule



1.5. Location of the pilot project site

The 6 observation points.

CP-1 Location : Thawi Watthana, Bangkok, Thailand.

Coordinates : X: -1117485.896, Y: 6094816.363

CP-2 Location : Phachi, Phra Nakhon Si Ayutthaya, Thailand.

Coordinates : X: -1148627.338, Y: 6068853.873

CP-3 Location : Ban Bueng, Chonburi, Thailand.

Coordinates : X: -1209483.303, Y: 6091185.274

CP-4 Location : Song, Phrae, Thailand.

Coordinates : X: -1072545.389, Y: 5959318.032

CP-5 Location : Nong Ki, Buriram, Thailand.

Coordinates : X: -1349794.467, Y: 6019474.592

CP-6 Location : Lamae, Chumphon, Thailand.

Coordinates : X: -994443.558, Y: 6207650.044



Figure 1-1 Location of the pilot project site (Source from Google Map)

1.6. Members/ Technical instructors

The members listed below performed the pilot project.

Table 1-2 List of members/technical instructors

NO.	Name	Company	Role
1	N.Tamaki	TOPCON CORPORATION	Project Manager
2	M.Sonoda(Mibayashi)	TOPCON CORPORATION	Support field survey & data calculation
3	K.Ogawa	TOPCON Positioning Asia	Support data calculation & evaluation
4	K.Fuse	TOPCON Positioning Asia	Support data calculation & evaluation
5	S.Takahashi	TOPCON Positioning Asia	Data calculation & evaluation
6	S.Samniang	TOPCON Positioning Asia (Thailand)	Prepare equipment & leader of field survey
7	N.parinya	TOPCON Positioning Asia (Thailand)	Field Survey
8	S.Pittawat	TOPCON Positioning Asia (Thailand)	Field Survey
9	M.Purit	TOPCON Positioning Asia (Thailand)	Field Survey

1.7. Equipment used for the pilot project

The equipment listed below were used for the pilot project.

Table 1-3 List of equipment used

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
1	TOPCON GNSS Receiver HiPerHR	1	GNSS Receiver
2	TOPCON Field Controller FC-5000	1	Field computer
3	GNSS External Battery & Tripod	1	Survey accessories
4	WIFI router	1	Data communication
5	TOPCON Magnet Tools (Calculation Software)	1	Calculation software

GNSS receiver HiPerHR

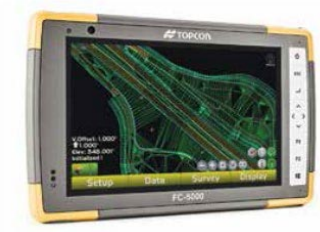


GNSS Tracking	
Number of Channels	452 with patented Universal Tracking Channel Technology
GPS	L1 C/A, L1C, L1P(Y), L2P(Y), L2C, L5
GLONASS	L1 C/A, L1P, L2 C/A, L2P, L3C
Galileo	E1, E5a, E5b, E5AltBOC, E6
BeiDou	B1, B2, B3 with ICD availability
IRNSS	SPS-L5
SBAS	WAAS/EGNOS/MSAS
QZSS	L1 C/A, L1C, L2C, L5, LEX
L-band	1525-1560 MHz
Satellites Tracked	All in view
Accuracy	
(L1 + L2)	H: 3.0 mm + 0.3 ppm V: 5.0 mm + 0.5 ppm
Precision Static*	H: 3.0 mm + 0.1 ppm V: 3.5 mm + 0.4 ppm
RTK, TILT Compensated**	H: 1.3 mm/°Tilt; Tilt ≤ 10° H: 1.8 mm/°Tilt; Tilt > 10° Maximum recommended angle for tilt compensation is 15°
Data Update / Output Rate	Up to 20 Hz

Communication	
Optional Radio Type	UHF (410-470 MHz) SS (915 MHz)
UHF radio range	5-7km typical; 15km in optimal** conditions
Cellular	Integrated HSPA+/CDMA
Additional Communications	Internal cellular modem Wi-Fi Bluetooth® LongLink™
Data and Memory	
Real Time Data Output	TPS, RTCM SC104 v2.x, 3.x, CMR/CMR+, RINEX
NMEA 0183 Output	Version 2.x, 3.x and 4.x
On-board Memory	8GB Internal
Power	
Power Source	External power 6 to 28 VDC 1x internal battery (3.7 V, 5200 mAh) 1x removable battery (7.2 V, 2900 mAh)
Operating Time	Up to 9 hours with included batteries
Environmental and Physical	
Dimensions (w x h)	115 x 132 mm
Operating Temp.	-40°C to 80°C
Water/Dust Rating	IP67
Drop and Topple	2 meter pole-drop
Weight	1.172 g (including internal and hot swappable external batteries)

Figure 1-2 Used survey equipment (TOPCON GNSS Receiver)

Field computer FC-5000



Hardware	
CPU	Intel® Atom™ Z3745 Processor
OS	Windows® 10
Memory	4 GB LPDDR3 RAM, SD slot, user accessible
Display	7 in. Sharp screen, Wide XGA at 1280 x 800
GPS	Type: uBlox NEO M8M Accuracy: 2-5 m Channels: 72 Update Rate: 5 Hz
Camera	Rear: 8 megapixel with LED Illumination Front: 2 megapixel
Wireless Connectivity	
Bluetooth®	Long-range Bluetooth Smart Ready wireless technology, v4.0 +EDR, Class 1.5, BLE support
Wi-Fi	802.11 a/b/g/n 2.4 GHz and 5 GHz
Cellular (optional)	Internal GSM 4G LTE

Environmental	
Water/Dust Rating	IP68 certified
Operating Temp	-20°C to 50°C
Temperature Shock	MIL-STD 810G
MIL-STD 810G	Drop 4 ft. (1.2 m), vibration, humidity, tumble spec: 1,000 1.6 ft. / 0.5 m tumbles (2,000 drops)
Dimensions (l x w x h)	13.71 x 3.45 x 21.5 cm
Operating Time	Up to 15 hours (5 hours internal batteries, 10 hours with swappable batteries)

Figure 1-3 Used survey equipment (TOPCON Field computer)

2. Details of the work

2.1. Work performed

2.1.1. Preparation

In consideration of the locations of CORS, observation points that satisfied the following two conditions were selected.

[1] The distance between the observation point and the nearest CORS is less than 30 km. (CP-1 to CP-3: Close points)

[2] The distances between the observation point and the nearest CORS is 30 km or more. (CP-4 to CP-6 :Wide points)

The selection of the 6 observation points was completed by March 2022.

1) Measurement reference marks were constructed and installed in coordination with the landowners.
2) Negotiations were started on the implementation of the long-term measurement after the installation.

Discussions with the JICA Project Team and the Thailand Working Group (WG) were held, and a support letter for the negotiations was provided by the WG. With positive responses from landowners throughout the negotiations, the observation points were set almost as planned.

Measuring instruments and observation point's piles were prepared in cooperation with Topcon Positioning Asia (Thailand), our subsidiary in Thailand.

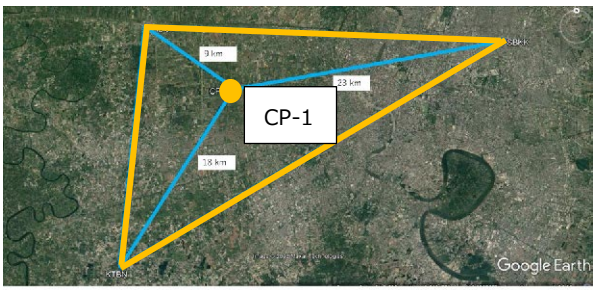


Figure 2-1 Location at CP-1 (Bangkok) (Source from Google earth)

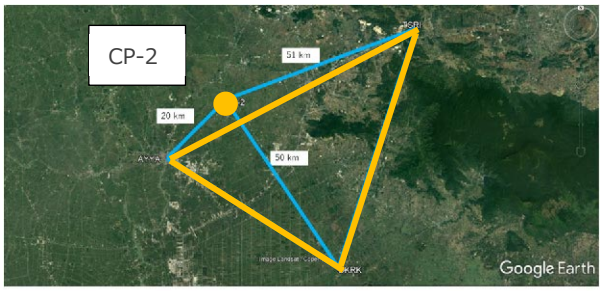


Figure 2-2 Location at CP-2 (Ayutthaya) (Source from Google earth)

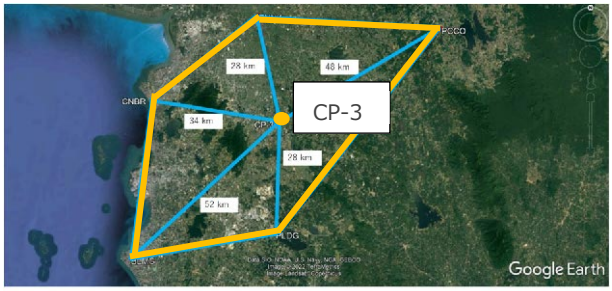


Figure 2-3 Location at CP-3 (Chonburi) (Source from Google earth)

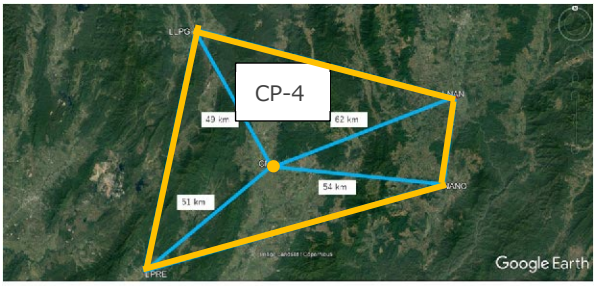


Figure 2-4 Location at CP-4 (Phrae) (Source from Google earth)

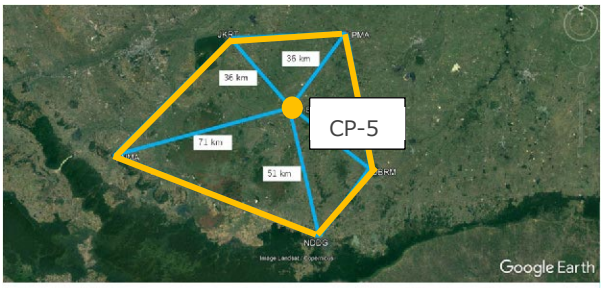


Figure 2-5 Location at CP-5 (Buriram) (Source from Google earth)

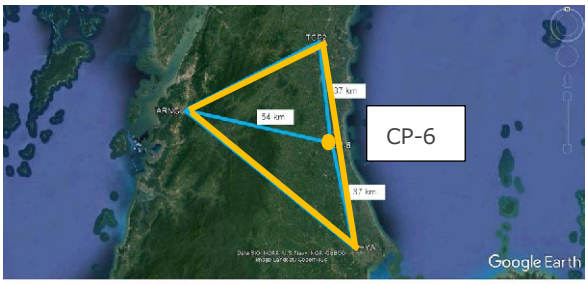


Figure 2-6 Location at CP-6 (Chumphon) (Source from Google earth)

2.1.2.Implementation

1. Construction of 6 observation points

Installation started in March 2022. After 6 excavated, earth retaining work, and foundation and concrete casting, the installation of all 6 observation points was completed at the end of June 2022.



Figure 2-7 Construction of CP points

CP-1





CP-2





CP-3





CP-4





CP-5





CP-6





Figure 2-8 Installed CP-1 to CP-6

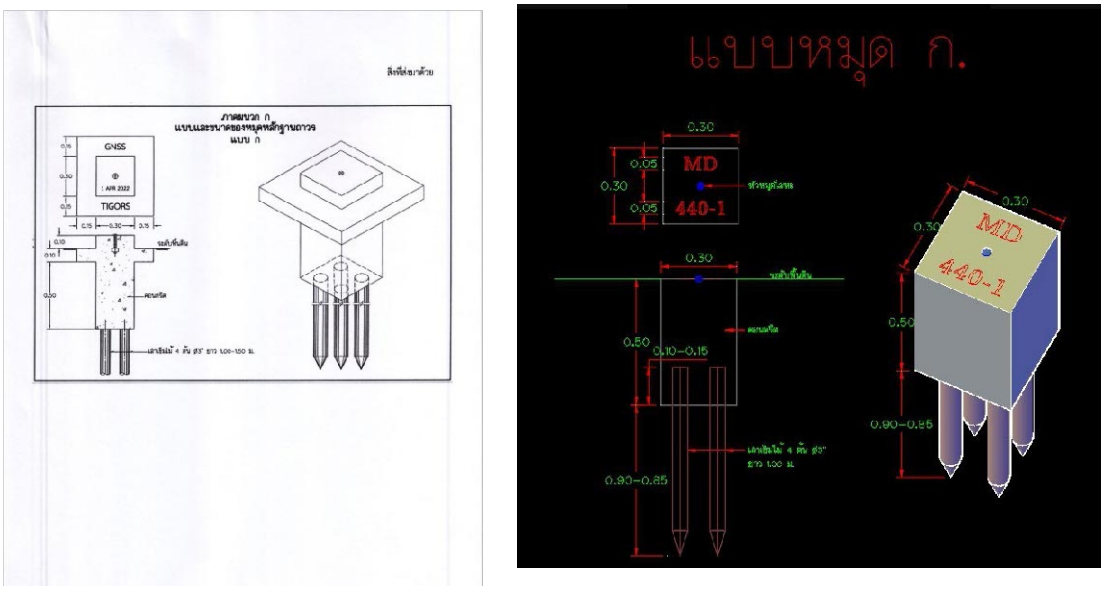


Figure 2-9 Design of CP points

2. Measurement

Measurement was carried out under the following conditions.

Receiver used: GNSS receiver (TOPCON, HiPerHR): 1 unit

Observation: Two kinds of surveys—static and N-RTK surveys—were performed simultaneously.

Observation conditions: Observation was performed twice on two different days at the same measurement point.

Each observation was 10 hours in length.

In both the static and N-RTK surveys, data was obtained at an observation frequency of once per second.

Satellite systems used: GPS, GLONASS, QZSS, GALILEO, and BEIDOU

Observational conditions for N-RTK survey: See 2.2.1 “Use of NCDC data.”

Equipment prepared by Topcon Positioning Asia (Thailand)



Survey at CP-2



Survey at CP-6



Figure 2-10 Preparation for survey & surveying CP points

3. Calculation after data acquisition and evaluation

All the data of the static and N-RTK surveys was downloaded from GNSS receivers, and then the procedures below were carried out.

1) A baseline analysis was performed with the static survey data, and the three-dimensional coordinates of CP-1 through CP-6 were obtained.

2) The positioning coordinate results, N-RTK positioning status, and other information were extracted from the NMEA data obtained at CP-1 through CP-6 in the N-RTK survey, and converted to Excel format. The data was analyzed in Excel.

3) This project was evaluated based on the results of 1) and 2) above.

*Details such as calculation results and analysis are given in 2.1.3 “Results.”

2.1.3.Results

1) Difference in survey accuracy

The calculation results of the static survey were as follows.

Table 2-1 Result of Static calculation of CP points

Point Name	Survey Date	X	Y	Z	Instrument Height(m)	B	L	H
CP-1	11-Jul-22	-1117485.896	6094816.363	1506457.629	1.408	134511.221	1002323.257	-28.300
CP-2	10-Jun-22	-1148627.338	6068853.873	1585263.611	1.299	142915.278	1004302.527	-23.671
CP-3	2-Jun-22	-1209483.303	6091185.274	1449635.189	1.277	131329.347	1011350.652	28.307
CP-4	5-Jul-22	-1072545.389	5959318.032	1997953.838	1.414	182233.077	1001209.885	150.135
CP-5	20-Jul-22	-1349794.467	6019474.592	1615308.531	1.557	144603.908	1023819.740	171.983
CP-6	3-Aug-22	-994443.558	6207650.044	1071869.801	1.267	94422.525	990604.507	-11.493

The differences in results between the static survey and the N-RTK survey were as follows.

Table 2-2 Result of difference between Static calculation / N-RTK survey

Unit :m

	Point Name	Survey Date	Horizontal				Vertical	
CP-1 to CP-3 (Close points)	CP-1	11-Jul-22	N	0.021	E	0.031	H	0.002
		12-Jul-22	N	0.017	E	0.031	H	0.063
	CP-2	10-Jun-22	N	0.011	E	0.003	H	0.063
		30-Jun-22	N	0.008	E	0.002	H	0.053
	CP-3	2-Jun-22	N	0.026	E	0.007	H	0.009
		7-Jun-22	N	0.021	E	0.000	H	0.020
CP-4 to CP-6 (Wide points)	CP-4	5-Jul-22	N	0.004	E	0.007	H	0.065
		6-Jul-22	N	0.010	E	0.009	H	0.044
	CP-5	20-Jul-22	N	0.013	E	0.011	H	0.005
		21-Jul-22	N	0.028	E	0.008	H	0.013
	CP-6	3-Aug-22	N	0.004	E	0.017	H	0.031
		4-Aug-22	N	0.028	E	0.008	H	0.074

[Results on the accuracy of the N-RTK survey]

- Table 2-2 shows the differences in accuracy of the N-RTK survey from the measurement results of the static survey.

- The differences in accuracy between the close points and the wide points are calculated based on the results of the N-RTK survey in Table 2-2.
  The average difference is 2.8 cm in the N direction, 2.3 cm in the E direction, and 2.1 cm in the height direction.
  The differences in accuracy of the N-RTK survey can be evaluated as within the acceptable range.

*In Table 2-2, the values enclosed in red (close points) or in blue (wide points) boxes show the largest differences in the horizontal (N/E) and height (H) directions from the calculation results of the static survey.

**For charts showing the differences at all measurement points, see 5. “References (Data)” .

2) Difference in stability

The positioning status in the observations by the N-RTK survey are as follows.

Table 2-3 Result of N-RTK survey status

CP-1 to CP-3 (Close points)	Fixed ratio : Approximately 87%
	Float ratio : Approximately 5%
CP-4 to CP-6 (Wide points)	Fixed ratio : Approximately 76%
	Float ratio : Approximately 22%

[Results on the positioning stability of N-RTK survey]

- The observation status results of the N-RTK survey show that in observations at close points, 87% were fix solutions, and approx. 5% were float solutions. On the other hand, in observations at wide points, 76% were fix solutions and approx. 22% were float solutions (red boxes).
  In the N-RTK survey, the positioning stability at close points was higher than that at wide points.

○ Example: N-RTK survey status at CP-6 (wide points)

Days 1 and 2 (Left: August 3, 2022; right: August 4, 2022.)

Table 2-4 Status of N-RTK survey at CP-6 (2 days)

	Rate	%
Autonomous	564	1.6
DGPS	18	0.1
Float	10064	28.0
Fixed	24852	69.2
Mis fixed	399	1.1
Total	35897	100.0

	Data	%
Autonomous	87	0.2
DGPS	34	0.1
Float	13574	37.7
Fixed	22134	61.5
Mis Fixed	144	0.4
Total	35973	100.0

Measurement was performed at CP-6 (wide points) for two days, and the float solutions occurred at 28% on the first day (August 3), and at 38% on the second day (August 4). That indicates unstable positioning.

** For data on positioning status at all points, see 5. “References (Data)” .

3) Additional measurements

Additional measurements were carried out to gain a deeper understanding of the accuracy and positioning, such as how the correction information from NCDC changes during long-term measurement at the same measurement point, and how the analysis fixed point, which is said to affect accuracy, changes.

Since it is not feasible to keep GNSS receivers at 6 observation points for a long period of time (not feasible to have staff present at receivers to ensure security), the following additional measurement was performed using a GNSS receiver and antenna installed on the rooftop of the Topcon Positioning Asia (Thailand) building (in the city of Bangkok).

- Long period measurement (1st)

Measurement dates: November 24 to 30, 2022 (about 1 week)

Receiver used: Topcon NET-G5

GNSS antenna used: Topcon choke ring antenna CR-G5

Mounting point: VRS_MSM5_UTM47_ITRF2014

Satellite systems: GPS, GLONASS, QZSS, GALILEO, and BEIDOU



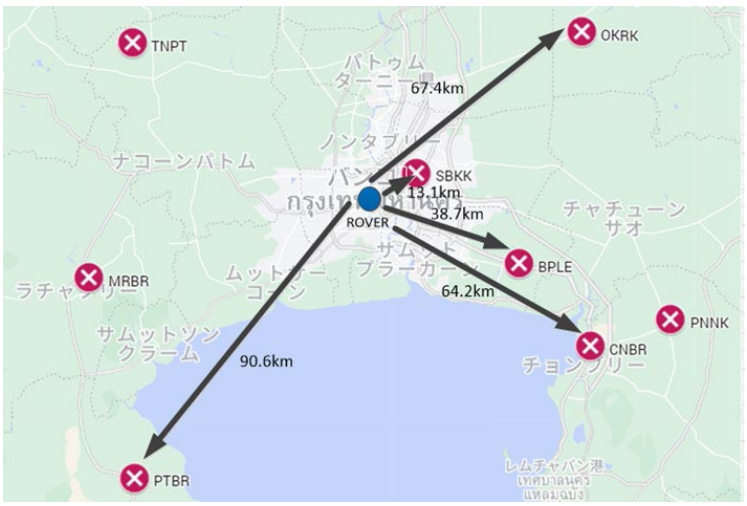


Figure 2-11 Location of long period survey (Right: Source from Google Map)

Table 2-5 N-RTK status of long period survey (24 Nov 2022 to 30 Nov 2022)

	Data	%
Antonomous	2890	0.5
DGPS	14	0.0
Float	4078	0.7
Fixed	542026	89.6
Mis fixed	55771	9.2
Total	604779	100.0

Table 2-6 Difference of changed analysis fixed CORS point (24 Nov 2022 to 30 Nov 2022)

unit : cm

Number	Station ID	Distance [km]	N	E	H
6	SBKK	13.1	0.0	0.0	0.0
236	BPLE	38.7	9.9	-22.6	3.5
166	CNBR	64.2	-0.2	1.2	1.7
108	OKRK	67.4	0.0	0.8	2.9
150	PTBR	90.6	-0.1	1.0	1.8

- Both of the accuracy and positioning were stable during the N-RTK survey using the correction information delivered from NCDC, which is the objective of the measurement.

- Regarding the change in the analysis fixed point, the measurement results show that the CORS station "6: SBKK," which was the closest to the observation point was selected in about 60% of the cases, and that points that were more than 100 km away from the observation point were not selected in any cases.

*However, when the No. 236 BPLE CORS station was selected as the analysis fixed point, there was a significant difference in the accuracy of the N-RTK survey. The positioning was also evaluated as an error. (Supplementary information below.)

[Supplement]

- Regarding the case where No. 236 BPLE CORS station was selected as the analysis fixed point, the fact that the accuracy and positioning of the solution for the N-RTK survey occurred error was officially reported to the TIGORS Secretariat on January 24, 2023. This information was reported to the Thai government through the JICA project team.

- Thereafter, the Thai government analyzed the problem and found that there was an error in the set coordinates of the CORS, and then corrected the coordinates.

- Long period measurement (2nd)

Measurement dates: March 27 to April 3, 2023 (about 1 week)

Receiver used: Topcon NET-G5

GNSS antenna used: Topcon choke ring antenna CR-G5

Mounting point: VRS_MSM5_UTM47_ITRF2014

Satellite systems: GPS, GLONASS, QZSS, GALILEO, and BEIDOU

*The observation setup was the same as for the observation in November 2022.

Table 2-7 Difference of changed analysis fixed CORS point (27 Mar 2023 to 3 Apr 2023)

units : cm

Number	Station ID	Distance [km]	N	E	H
6	SBKK	13.1	0.0	0.0	0.0
236	BPLE	38.7	0.6	-0.7	0.2
166	CNBR	64.2	-0.2	1.6	3.4
0	MRDR	73.5	-	-	-
150	PTBR	90.6	-1.3	3.8	-7.7
84	BLMG	98.6	-0.7	0.8	0.1
117	SPUG	116.2	-0.1	0.2	2.5

*Since the coordinate values of the BPLE were corrected, the accuracy of the N-RTK survey was good and stable even when the BPLE was selected as the analysis fixed point, confirming that the corrected coordinate values were appropriate.

- Events identified during the long period measurement that should be noted

Through the second long period observation in March 2023, it was revealed that there were changes in the positioning status and that the percentage of float solutions was on the increase. (Shown in the blue box in Table 2-8.)

Table 2-8 N-RTK status of long period survey (27 Mar 2023 to 3 Apr 2023)

	Data	%
Autonomous	27671	4.6
DGPS	26	0.0
Float	137223	22.7
Fixed	417117	69.0
Mis fixed	22757	3.8
Total	604794	100.0

After receiving these positioning results, we analyzed the correction information of the NCDC server and found that the number of satellites involved in the correction information decreased significantly at night. (See Figure 2-12)

Although the cause of this problem is unknown, it is difficult to obtain fix solutions in the N-RTK survey during this time period. Nighttime operation and management should be reviewed or revised, or the users should be alerted.

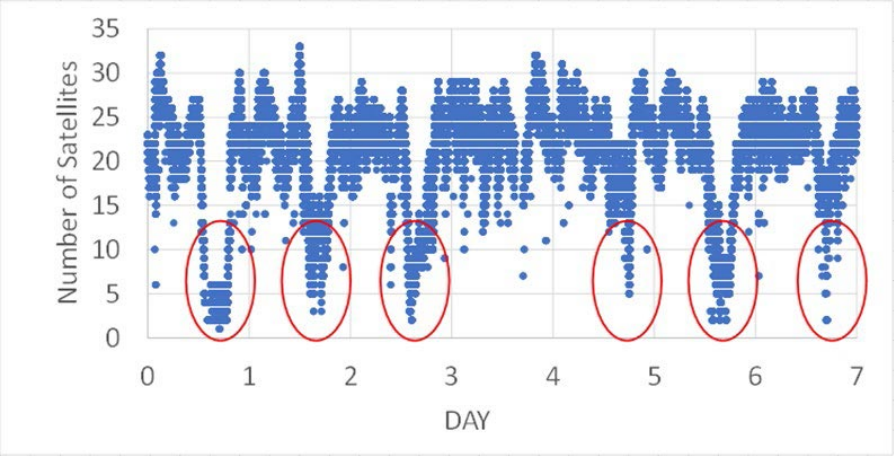


Figure 2-12 Number of GNSS satellite data from NCDC (27 Mar 2023 to 3 Apr 2023)

For reference, the data obtained through the first long period observation in November 2022 showed similar trends where the number of correction satellites decreased, but it did not last long enough to affect the observation. (See Table 2-5 for positioning details.)

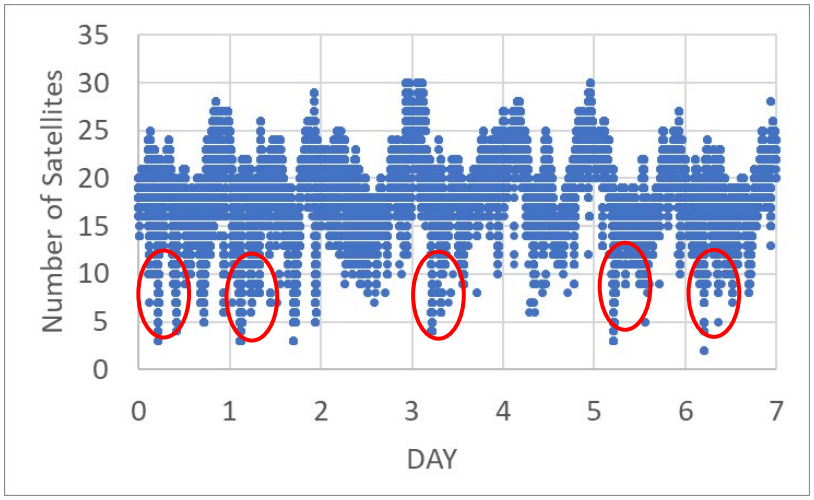


Figure 2-13 Number of GNSS satellite data from NCDC (24 Nov 2022 to 30 Nov 2022)

4) Discussion and advice based on the results

- The observation results of all 6 points show that Close Points has stable N-RTK status than Wide Points.

=> Since N-RTK positioning stability is important for the utilization of CORS, it is desirable to increase the number of CORS in order to shorten the distance from observation points to CORS.

- Long period observations showed that the accuracy of N-RTK surveys was stable when the analysis fixed point for N-RTK surveys remained unchanged and the CORS closest to the observation point was selected.

=> Since stable accuracy of N-RTK surveying is important for promoting the utilization of CORS, settings for CORS management software (settings such that the analysis fixed point does not select a point far from the observation point) It is necessary to take these countermeasures and maintain to stabile N-RTK accuracy.

2.2. Use of NCDC

2.2.1. Details of the NCDC data used

NCDC was used as follows.

Table 2-9 NCDC data used

IP address	118.174.12.3
Port	2105
Mount point	VRS_MSM5_UTM47_ITRF2014
User name	ntamaki
Period of use	02 Jun 2022 – 02 Jun 2022 (Survey at CP-3) 07 Jun 2022 – 07 Jun 2022 (Survey at CP-3) 10 Jun 2022 – 10 Jun 2022 (Survey at CP-2) 30 Jun 2022 – 30 Jun 2022 (Survey at CP-2) 05 Jul 2022 – 05 Jul 2022 (Survey at CP-4) 06 Jul 2022 – 06 Jul 2022 (Survey at CP-4) 11 Jul 2022 – 11 Jul 2022 (Survey at CP-1) 12 Jul 2022 – 12 Jul 2022 (Survey at CP-1) 20 Jul 2022 – 20 Jul 2022 (Survey at CP-5) 21 Jul 2022 – 21 Jul 2022 (Survey at CP-5) 03 Aug 2022 – 03 Aug 2022 (Survey at CP-6) 04 Aug 2022 – 04 Aug 2022 (Survey at CP-6)
RTK/ Post processing	RTK/ Post processing both
Satellite systems used	GPS･GLONASS･QZSS･GALILEO･BEIDOU

2.2.2. Problems occured and solutions

No problems have arisen so far.

2.3. Other related activities

1) Training in Japan

Representatives from Thai government agencies came to Japan to gain a deeper understanding of the operation and use of CORS. At that time, in cooperation with the TIGORS project team, Nishio Rent All Co., Ltd., and JENOBA CO., LTD., classroom training was provided to share how NCDC is operated at CORS in Thailand and to give an interim report on the results of the survey project. In the field training, to understand the accuracy and stability of CORS in Japan and to observe how they are utilized, demonstrations were

performed to show the VRS survey, ICT/unmanned constructions (Excavator), and drone and automated sweepers. The details are as follows.

Training date : February 17, 2023

Training venue : Kansai Machinery Center, Nishio Rent All Co., Ltd.
432-1 Nakamachi, Tenri City, Nara, Japan

Training objectives : To understand the importance of stable distribution of data in operating and utilizing CORS, and to experience the effectiveness of CORS data in the construction and survey fields.
(Part of the activities of the TIGORS Project)

Participants : 14 participants from Thai government agencies (DPT, DOL, HII, GISTDA, RTSD,
Chulalongkorn University, Kasetsart University, and Khon Kaen University)

Training contents : Report by JENOBA CO., LTD. on the ongoing technical cooperation for the stable operation of NCDC

Interim reports by Topcon Corporation on the survey project

Field demonstration by Nishio Rent All Co., Ltd. and Topcon Corporation

1: In the VRS survey demonstration, demonstrate how accurate the delivered data is and how fast the data is provided.

2: In the ICT construction (Excavator) demonstration, demonstrate how productivity will be improved in the ICT construction (automation in construction).

3: Experience the remote operation of unmanned construction (Excavator).

4: Demonstrate self-driving using an automatic sweeper.



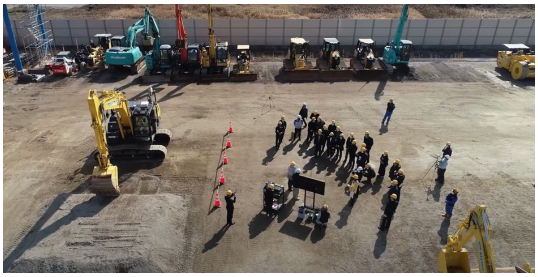








Figure 2-14 Photos of ICT Training in Nara pref (Feb 17, 2023)

Nishio Rent All Co., Ltd. produced a video of this observation visit, which was provided to JICA and government officials in Japan and Thailand.

https://www.youtube.com/watch?v=gSR8B7UVrq0__;!!Nbma_1s!sxXydp4lohrHgpkcBW-Jxc76Fb7zCShtUkhpZ_ilvlNnyg21vD0G6UVbl55z13WX4GtcM-7bSYR1Q7lQ5oqH$

Training outcome: It seems as if the objectives of the training were successfully achieved. One participant commented, "As the aging of the population is becoming more evident in my own country, I felt that it is essential to take measures like manpower reduction in the field of construction as well. We would like to take Japan's excellent technology home to our country and develop

personnel who can use it so we can contribute to the national development."

2: Explanation of the pilot project at the 2nd JICA seminar

There was a session on NCDC at the GNSS conference MGA, which is held every year in Asian, and there was a presentation to announce the details of the JICA pilot project.

MGA dates: January 31 to February 2, 2023

Presentation date: January 31, 2023

MGA venue: Chiang Mai University, Chiang Mai, Thailand

Presentation overview: As an example case where the highly accurate position correction data service from NCDC is utilized in Thailand, a time frame was allocated for the presentation of the JICA pilot project, and an interim report on the project was provided.

Presentation details: The presentation covered the outline and objective of the JICA pilot project (Survey) and the measurement conducted.
However, in terms of results, it only mentioned that results were under analysis as data compilation was still ongoing.







Figure 2-15 Photos of presentation MGA in Chiang Mai pref. (Jan 31, 2023)

3: Report in the JICA Regional workshop

At the JICA Regional Workshop held from September 21 to 27, there was a presentation to report the details and results of the JICA pilot project.

Workshop dates: September 21 to 27, 2023

Presentation date: September 25, 2023

Presentation format: Online

Presentation details: The presentation gave a summary of the JICA pilot project and included discussions and advice based on the results.





Figure 2-16 Photos of presentation JICA Region workshop in Bangkok (Sep 25 2023)

4:TIGORS Final Seminar & NCDC User Meeting

TIGORS Final Seminar (morning session) & NCDC User Meeting (afternoon session) were held on at Jasmine City Hotel, Bangkok which inviting approx.130 participants from government agencies and private companies.

Seminar Date: October 31, 2023

Location: Jasmine City Hotel, Bangkok

Purpose: Present the achievements of This Pilot project and discuss about way forward for NCDC.

Details: The purposes of the events are to present the achievements of TIGORS, the results of the pilot projects, and way forward in the morning session by each companies who had done the experiments for 8 pilot projects using CORS network from NCDC. In the afternoon session, NCDC users (the companies participated in 8 Pilot Project and some others) and

members of Thai-Japan Joint Working Group on NCDC exchanged the opinions and ideas for further improvement of NCDC in Thailand. Topcon presented 3 TIGORS pilot projects which are Survey, ICT Construction and Smart Agriculture. In addition, Topcon had booths to display the products and distribute the TIGORS rice packages as thank you gifts to Thai-Japan Joint Working Group on NCDC member and JICA TIGORS project and the participants.













Figure 2-17 Photos of JICA TIGORS Final Seminar & NCDC User Meeting in Bangkok (Oct 31 2023)

3. Way forward

3.1. Future outlook of the business using NCDC

Through this JICA pilot project, we at Topcon would like to suggest that our customers utilize NCDC's real-time data in the fields of land survey, construction, and agriculture.

3.2. About NCDC

1) Good points using NCDC

With the data distributed by NCDC, highly accurate N-RTK surveys can be utilized by anyone, anytime, and anywhere. The data is expected to be utilized in a large number of applications. It also makes it possible to standardize the coordinate system for CORS, which is very significant.

2) Issues to be solved

In the survey in the area with the wide points, although there was no significant difference in the observation accuracy, there were times when the N-RTK survey became unstable. The stability of N-RTK survey needs to improve.

- The number of satellites involved in the correction information delivered from NCDC tended to decrease significantly at nighttime.

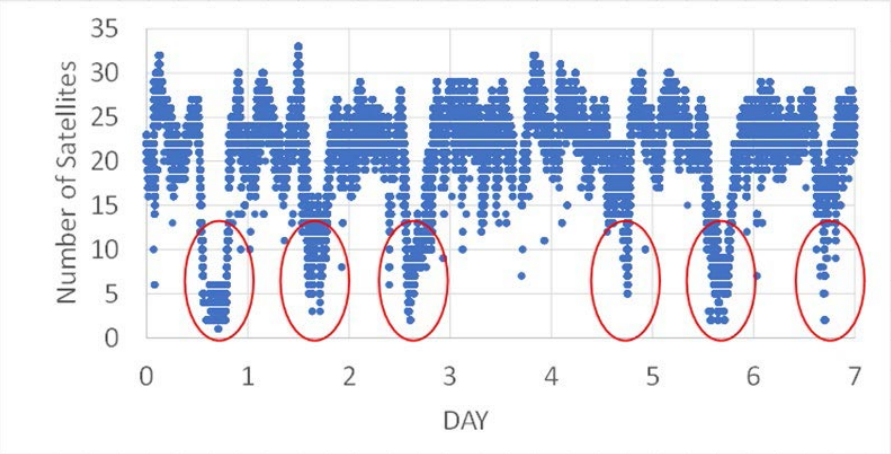


Figure 3-1 Number of GNSS satellite data from NCDC (Same as Figure 2-12)

3) Request for improvement

- We request that measures be taken to resolve the issues mentioned in 3.2.2) above and to alert users to these issues: the positioning instability of the N-RTK survey, and the decrease in the number of satellites involved in correction information from NCDC at nighttime.

- We request that users should be received email alerts when the use environment changes due to the maintenance or upgrading of the CORS management software.

4. Conclusion

A pilot project (Survey) was implemented regarding the utilization of the highly accurate positioning data.

Keeping in mind that ensuring the stability of the N-RTK survey is the key to promoting the utilization of the NCDC data, observations were performed with different distances between stations. The observations revealed that the positioning stability should be improved by increasing the density of the CORS. In addition, measures should also be taken to improve the situation where the number of satellites involved in correction information from NCDC decreases at nighttime.

We hope that the results of this pilot project (Survey) and the advice based on discussions using measurement results will contribute to the stable operation of NCDC. We would like to reiterate our gratitude to the NCDC officials, the Thai and Japanese government agencies, the WG members, and the pilot project team members involved in the implementation of this project.

5. References (Data)

1: Detailed observation results and positioning status data at CP-1 to CP-6 are attached.

1: Static calculation results

Table 5-1 Result of Static calculation of CP points (Same as Table 2-1)

Point Name	Survey Date	X	Y	Z	Instrument Height(m)	B	L	H
CP-1	11-Jul-22	-1117485.896	6094816.363	1506457.629	1.408	134511.221	1002323.257	-28.300
CP-2	10-Jun-22	-1148627.338	6068853.873	1585263.611	1.299	142915.278	1004302.527	-23.671
CP-3	2-Jun-22	-1209483.303	6091185.274	1449635.189	1.277	131329.347	1011350.652	28.307
CP-4	5-Jul-22	-1072545.389	5959318.032	1997953.838	1.414	182233.077	1001209.885	150.135
CP-5	20-Jul-22	-1349794.467	6019474.592	1615308.531	1.557	144603.908	1023819.740	171.983
CP-6	3-Aug-22	-994443.558	6207650.044	1071869.801	1.267	94422.525	990604.507	-11.493

2: Comparison of static survey calculation results with N-RTK survey

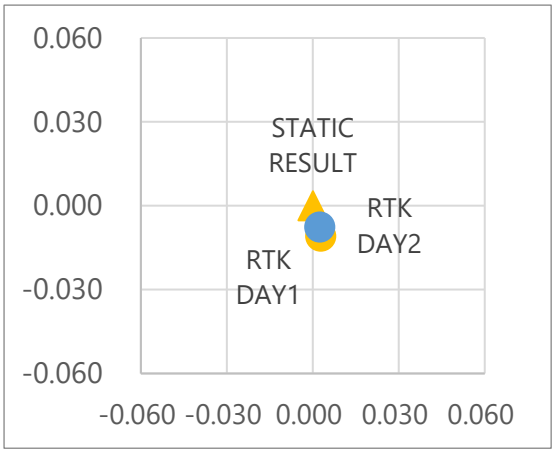
Table 5-2 Result of difference between Static calculation / N-RTK survey & N-RTK status for CP-1 & CP-2

CP-1 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	0.021	-0.031	-0.002
RTK DAY2	0.017	-0.033	0.063

CP-2 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	-0.011	0.003	0.063
RTK DAY2	-0.008	0.002	0.053



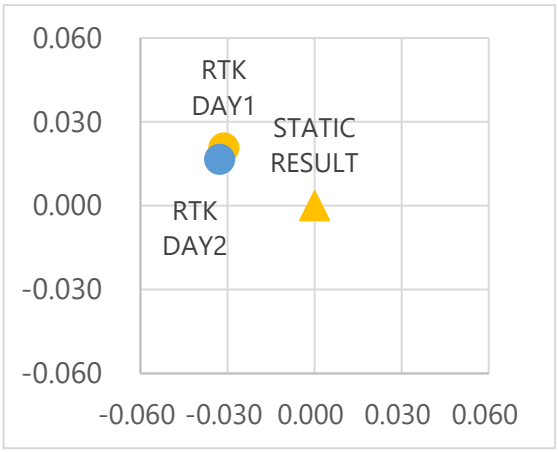


Figure 5-1 Difference between Static calculation / N-RTK survey Difference CP-1 & CP-2(Horizontal direction)

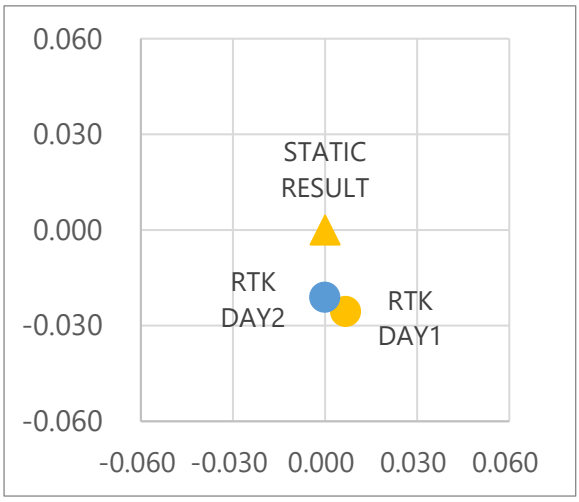
Table 5-3 Result of difference between Static calculation / N-RTK survey & N-RTK status for CP-3 & CP-4

CP-3 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	-0.026	0.007	0.009
RTK DAY2	-0.021	0.000	0.020

CP-4 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	0.004	-0.007	0.065
RTK DAY2	0.010	-0.009	0.044



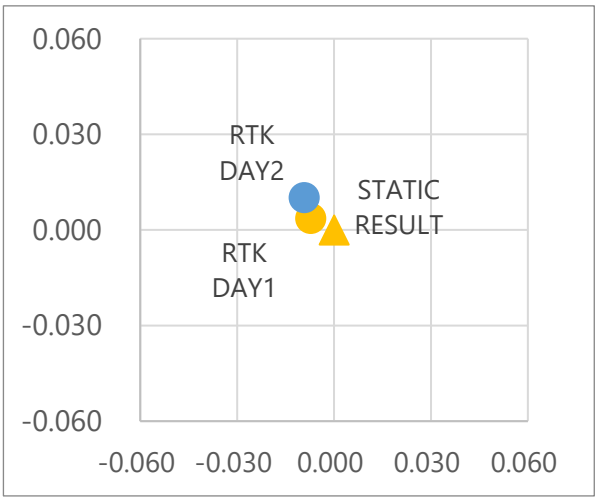


Figure 5-2 Difference between Static calculation / N-RTK survey Difference CP-3 & CP-4(Horizontal direction)

Table 5-4 Result of difference between Static calculation / N-RTK survey & N-RTK status for CP-5 & CP-6

CP-5 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	-0.013	0.011	0.005
RTK DAY2	-0.028	0.008	-0.013

CP-6 Units:m

	ΔN	ΔE	ΔH
STATIC RESULT	0.000	0.000	0.000
RTK DAY1	-0.004	-0.017	-0.031
RTK DAY2	-0.002	-0.021	-0.074

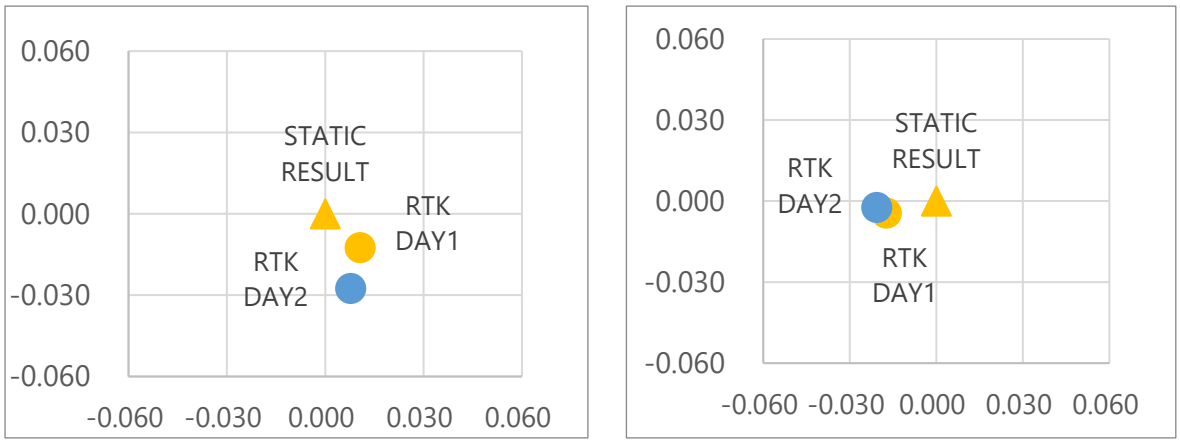


Figure 5-3 Difference between Static calculation / N-RTK survey Difference CP-5 & CP-6(Horizontal direction)

3: N-RTK survey positioning status

CP-1

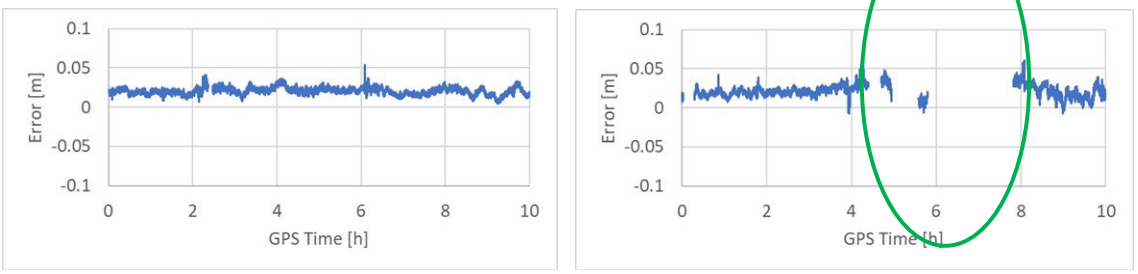
Days 1 and 2 (Left: July 11, 2022; right: July 12, 2022)

Table 5-5 N-RTK status CP-1

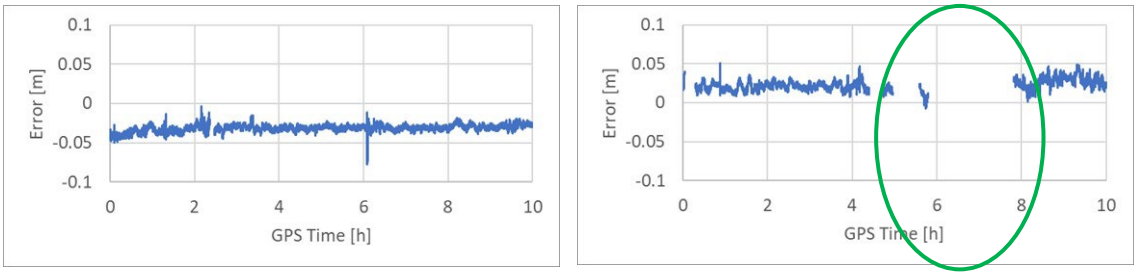
	Data	%
Autonomous	305	0.8
DGPS	0	0.0
Float	222	0.6
Fixed	35473	98.5
Mis fixed	0	0.0
Total	36000	100.0

	Data	%
Autonomous	22	0.1
DGPS	0	0.0
Float	11650	32.4
Fixed	24294	67.5
Mis fixed	0	0.0
Total	35966	100.0

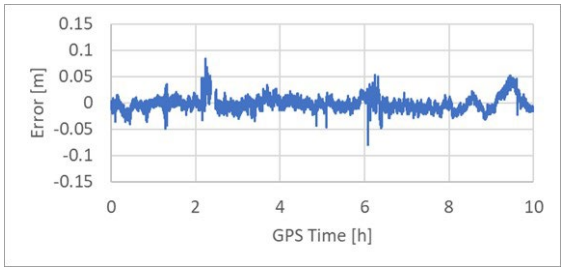
Difference in the N-S direction

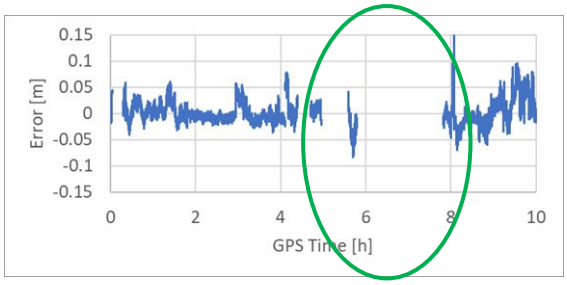


Difference in the E-W direction



Difference in the H direction

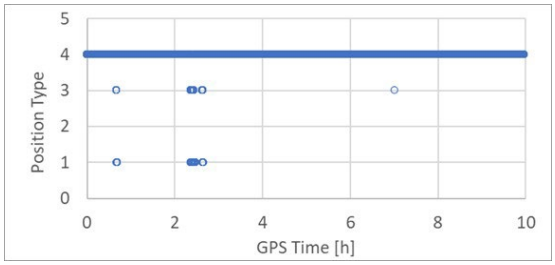


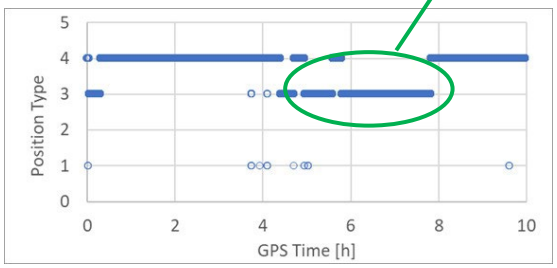


N-RTK survey positioning status

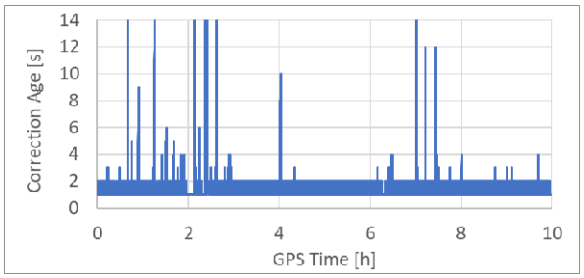
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value

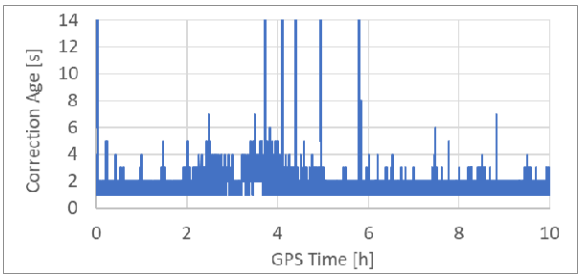
Data missing due to Float.



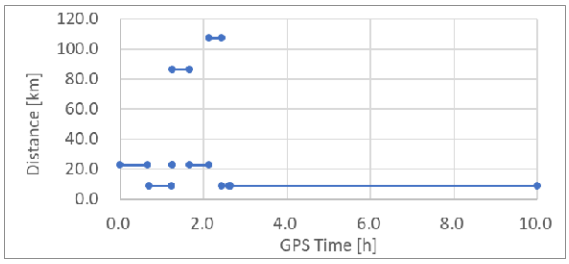


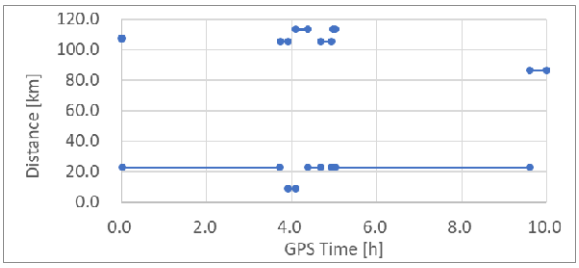
Correction information extrapolation time



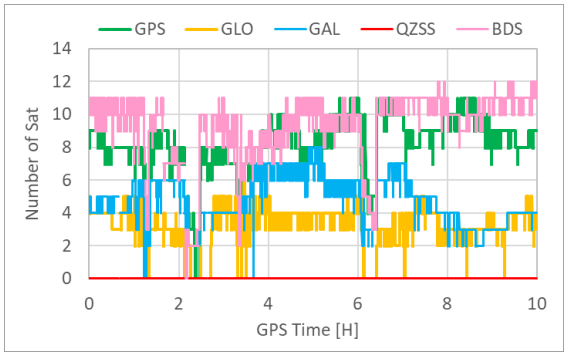


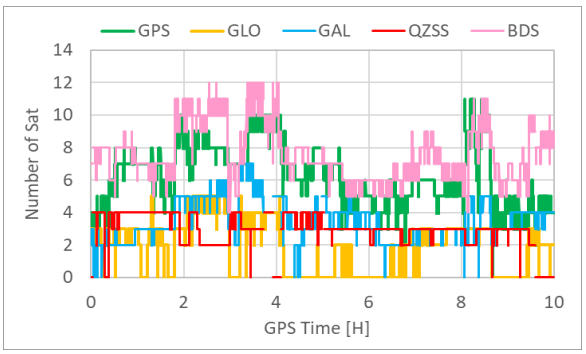
Distance from analysis fixed point in N-RTK survey





Changes in the number of satellites involved in the correction information from the NCDC server.





CP-2

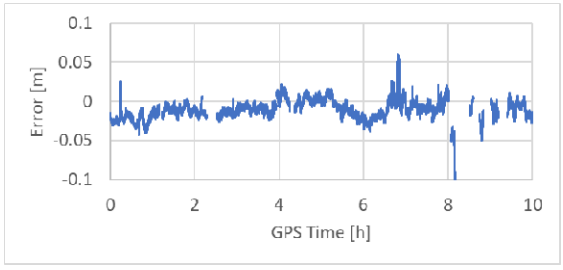
Days 1 and 2 (Left: June 10, 2022; right: June 30, 2022)

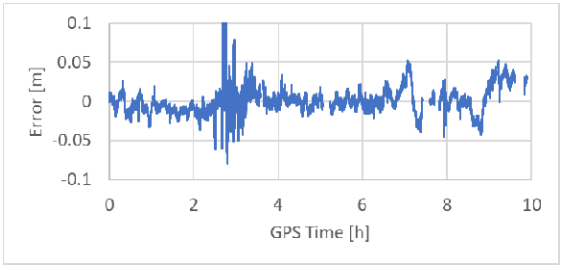
Table 5-6 N-RTK status CP-2

	Data	%
Autonomous	85	0.2
DGPS	0	0.0
Float	4171	11.7
Fixed	30171	84.8
Mis fixed	1134	3.2
Total	35561	100.0

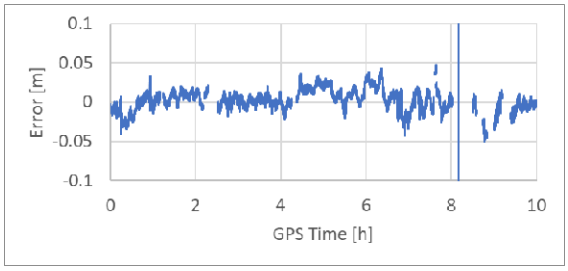
	Data	%
Autonomous	418	1.2
DGPS	0	0.0
Float	2590	7.2
Fixed	32066	89.2
Mis fixed	887	2.5
Total	35961	100.0

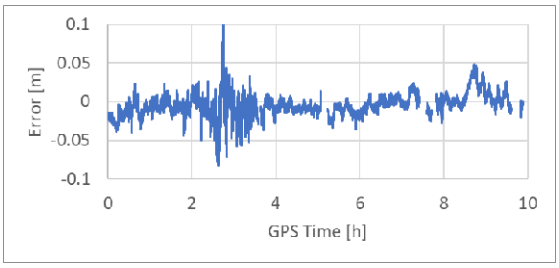
Difference in the N-S direction



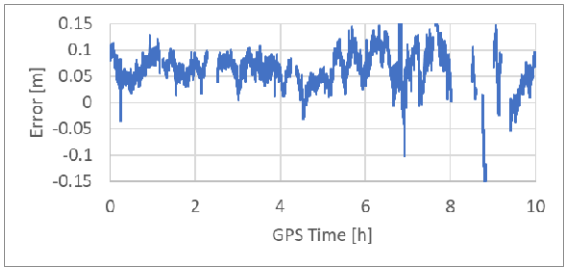


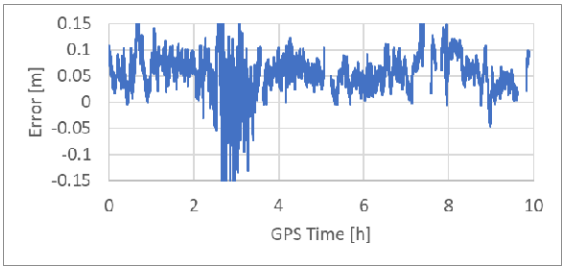
Difference in the E-W direction





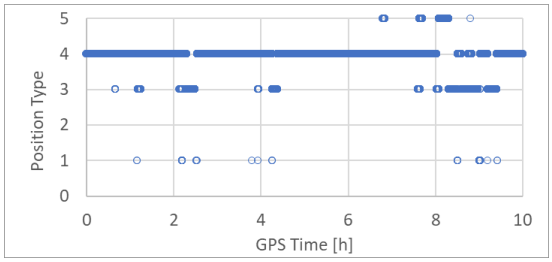
Difference in the H direction

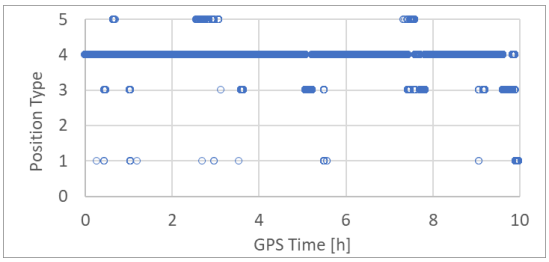




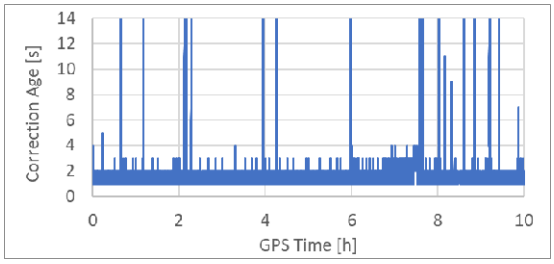
N-RTK survey positioning status

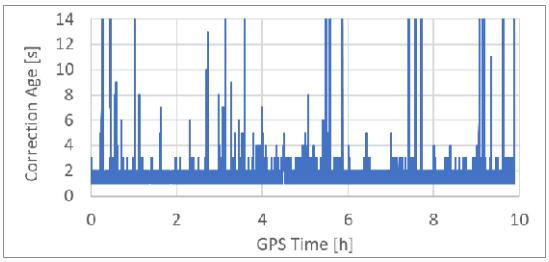
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value



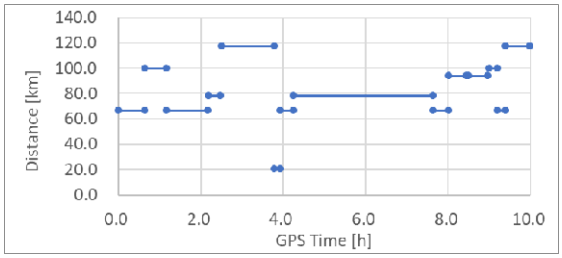


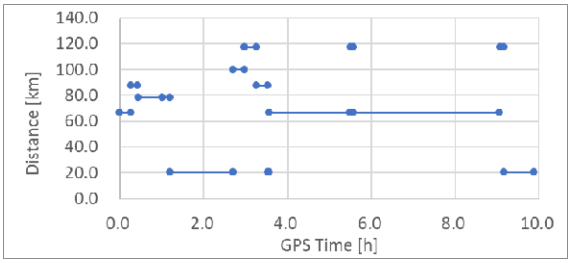
Correction information extrapolation time





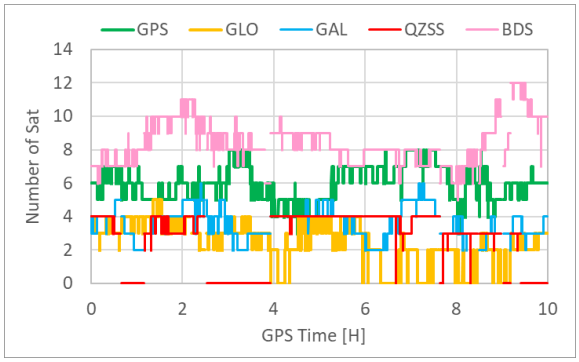
Distance from analysis fixed point in N-RTK survey

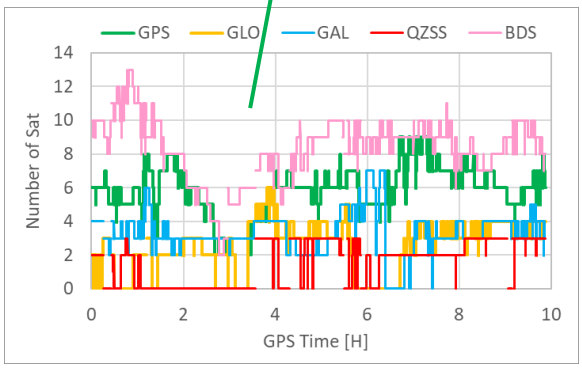




Changes in the number of satellites involved in the correction information from the NCDC server.

Some time zones have fewer GNSS satellites.





CP-3

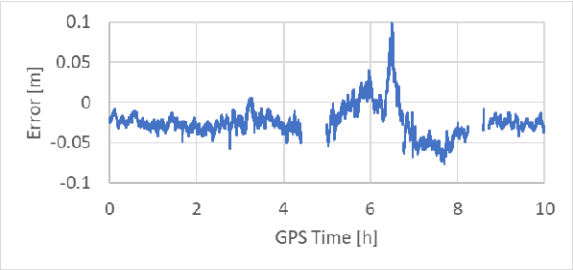
Days 1 and 2 (Left: June 2, 2022; right: June 7, 2022)

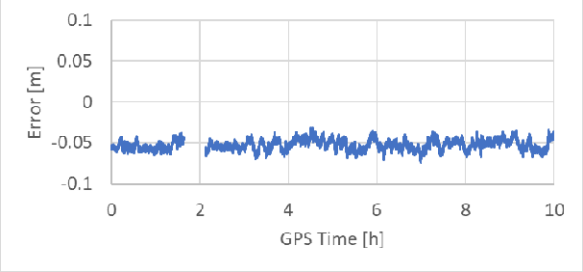
Table 5-7 N-RTK status CP-3

	Data	%
Autonomous	3558	9.9
DGPS	2	0.0
Float	163	0.5
Fixed	32112	89.5
Mis fixed	30	0.1
Total	35865	100.0

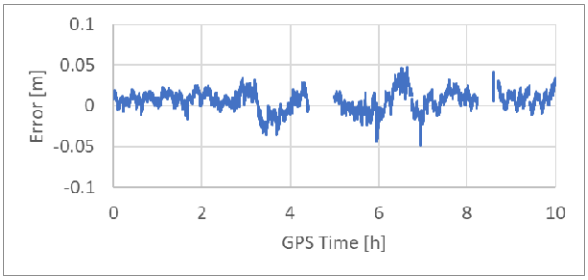
	Data	%
Autonomous	1,729	4.8
DGPS	0	0.0
Float	30	0.1
Fixed	34,240	95.1
Mis fixed	1	0.0
合計	36,000	100.0

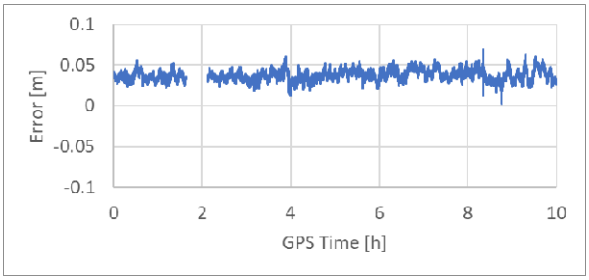
Difference in the N-S direction



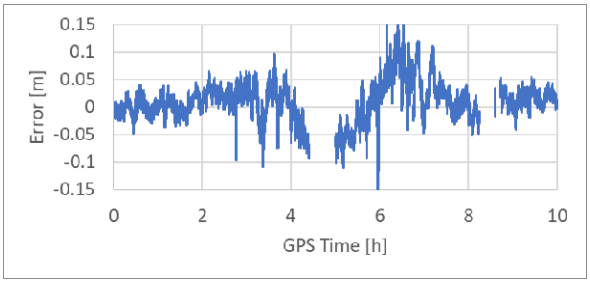


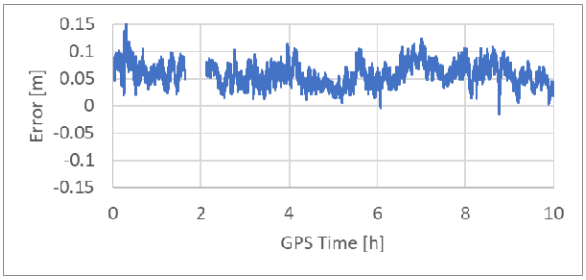
Difference in the E-W direction





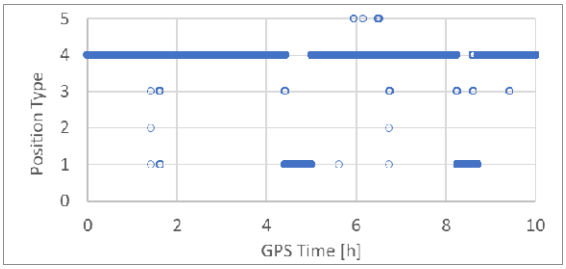
Difference in the H direction

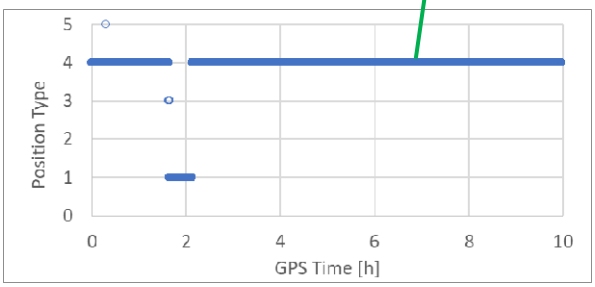




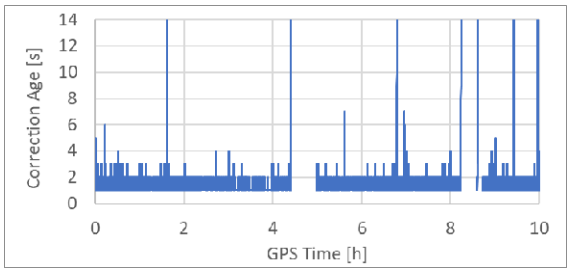
N-RTK survey positioning status

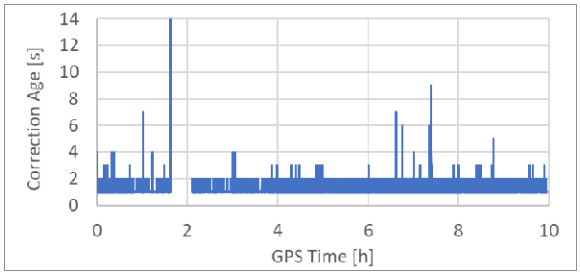
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value



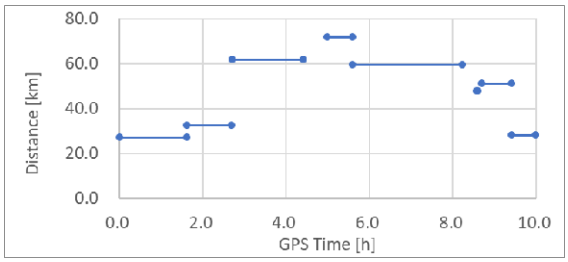


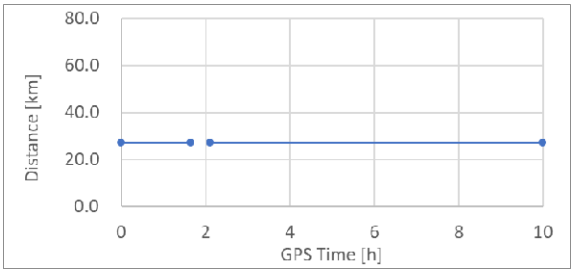
Correction information extrapolation time



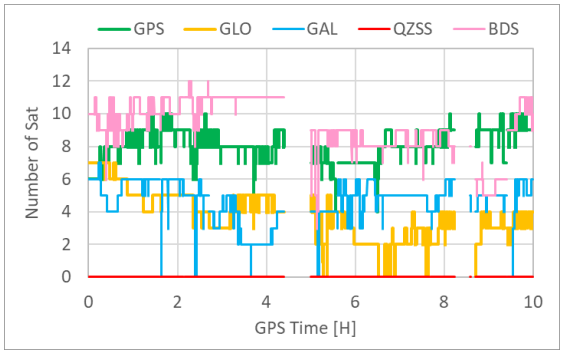


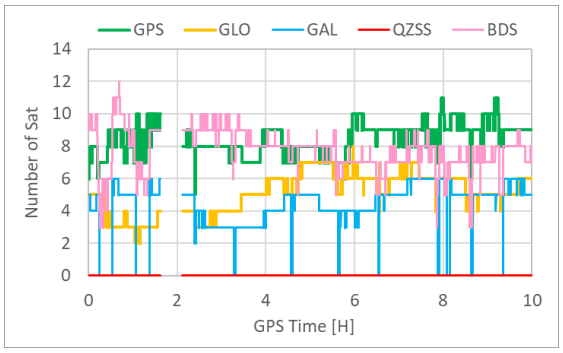
Distance from analysis fixed point in N-RTK survey





Changes in the number of satellites involved in the correction information from the NCDC server.





CP-4

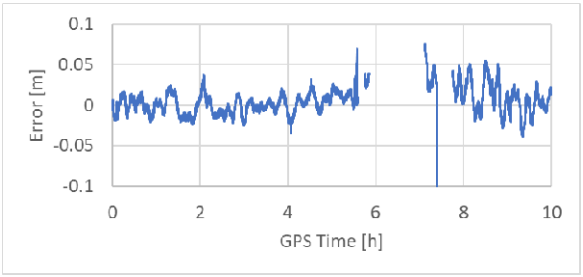
Days 1 and 2 (Left: July 5, 2022; right: July 6, 2022)

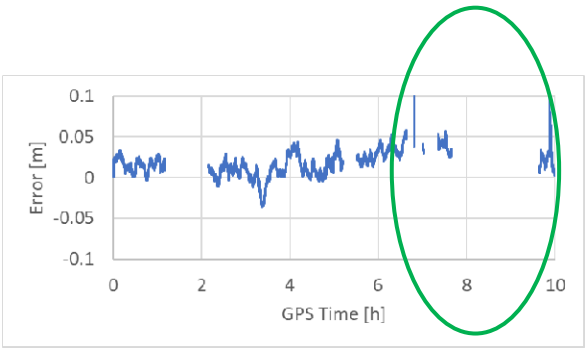
Table 5-8 N-RTK status CP-4

	Data	%
Autonomous	5	0.0
DGPS	2	0.0
Float	5982	16.6
Fixed	29111	80.9
Mis fixed	897	2.5
Total	35997	100.0

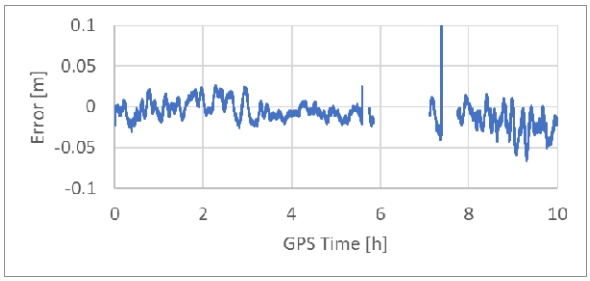
	Data	%
Autonomous	5	0.0
DGPS	1	0.0
Float	14324	39.8
Fixed	21479	59.7
Mis fixed	191	0.5
Total	36000	100.0

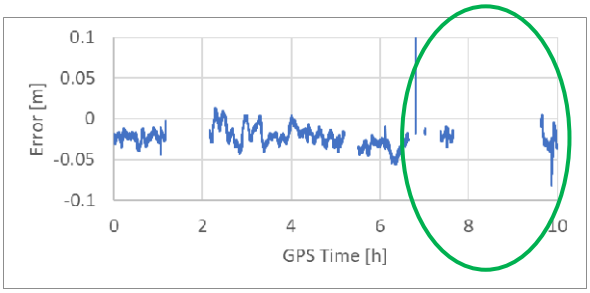
Difference in the N-S direction



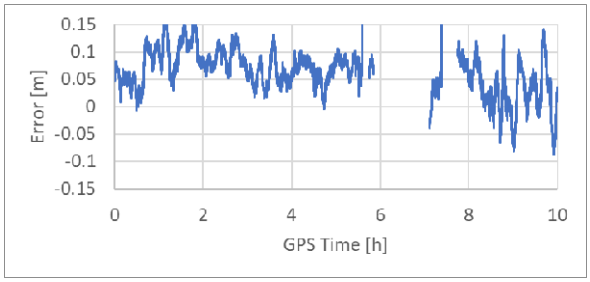


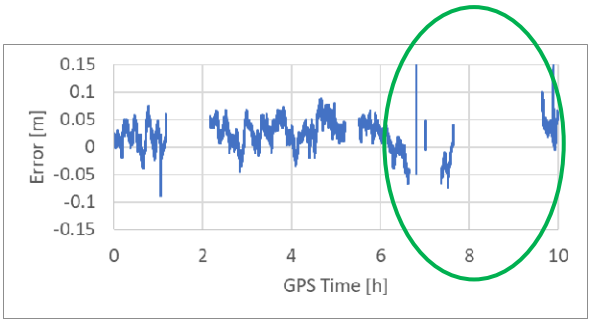
Difference in the E-W direction





Difference in the H direction

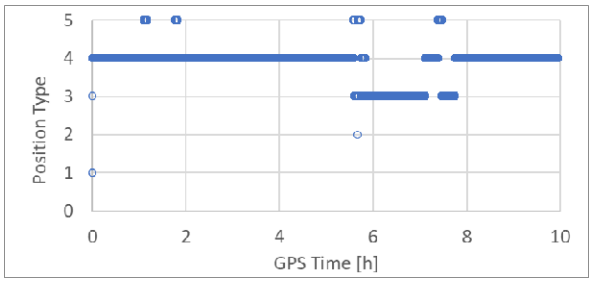


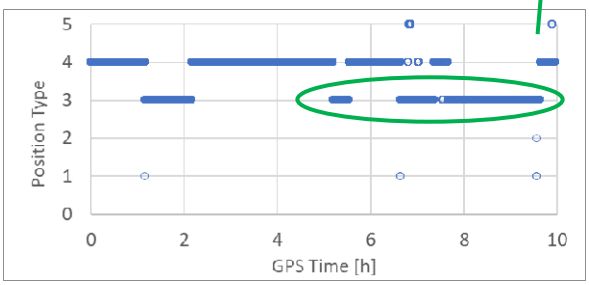


N-RTK survey positioning status

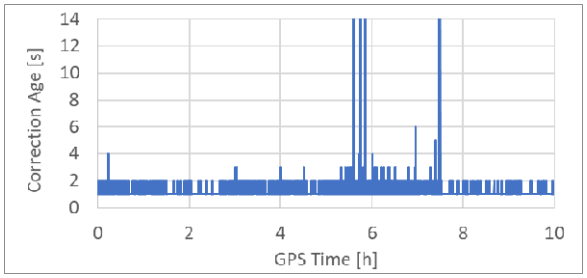
Data missing due to Float.

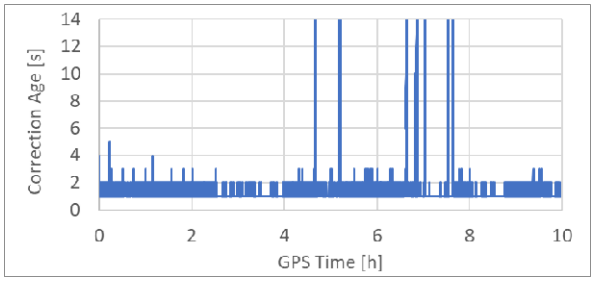
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value



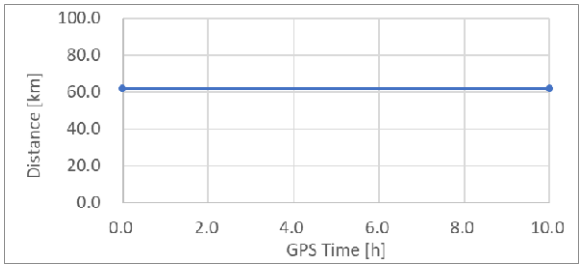


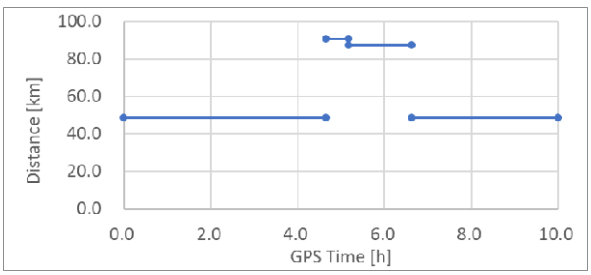
Correction information extrapolation time



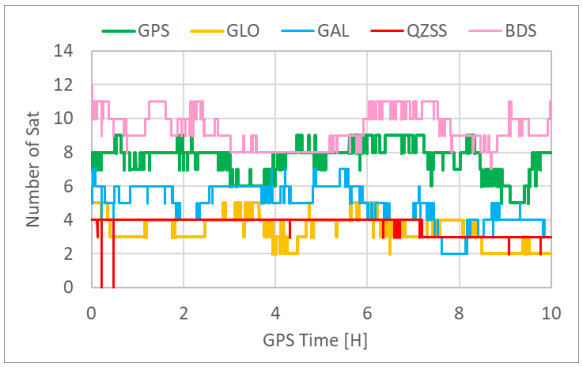


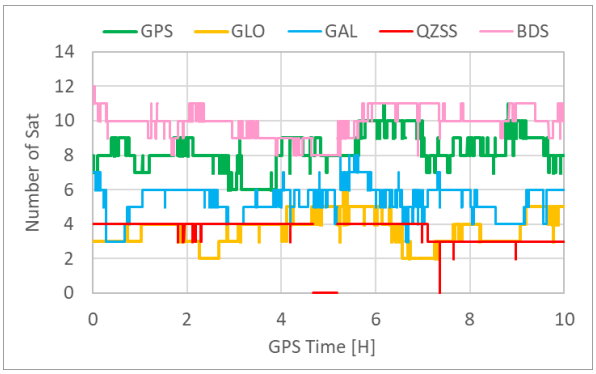
Distance from analysis fixed point in N-RTK survey





Changes in the number of satellites involved in the correction information from the NCDC server.





CP-5

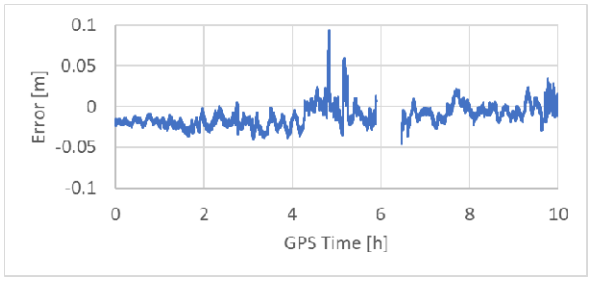
Days 1 and 2 (Left: July 20, 2022; right: July 21, 2022)

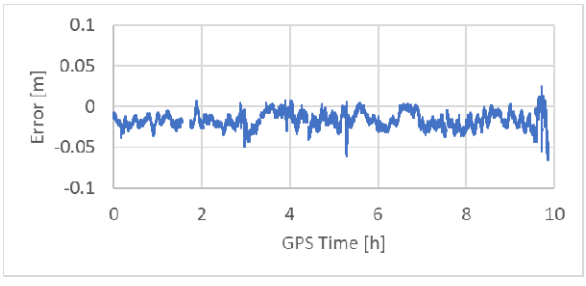
Table 5-9 N-RTK status CP-5

	Data	%
Autonomous	8	0.0
DGPS	1	0.0
Float	2340	6.5
Fixed	32186	89.4
Mis fixed	1464	4.1
Total	35999	100.0

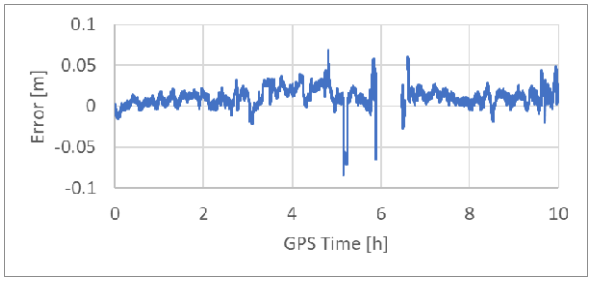
	Data	%
Autonomous	1316	3.7
DGPS	0	0.0
Float	473	1.3
Fixed	33905	94.6
Mis fixed	129	0.4
Total	35823	100.0

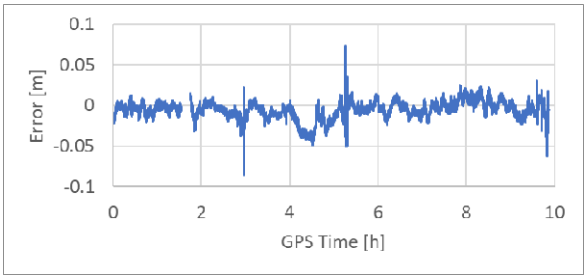
Difference in the N-S direction



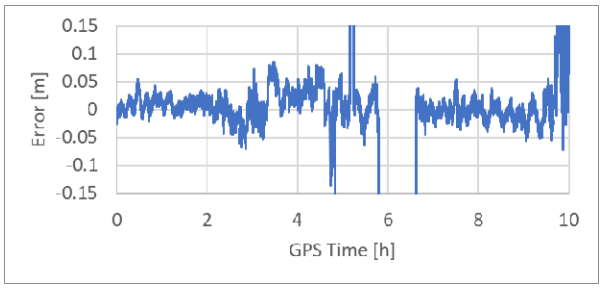


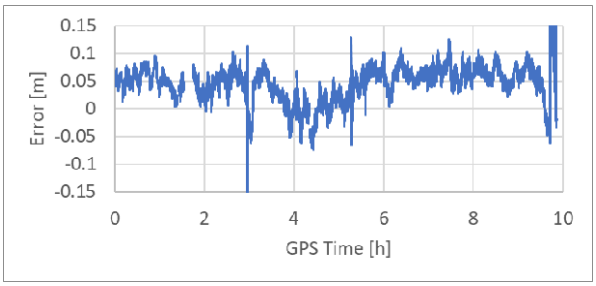
Difference in the E-W direction





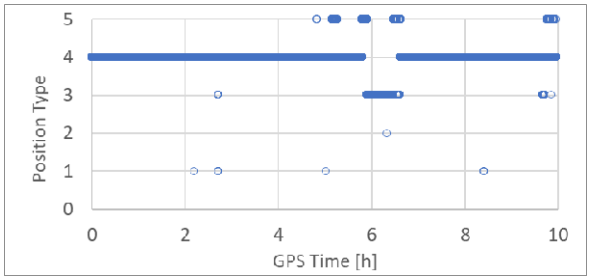
Difference in the H direction

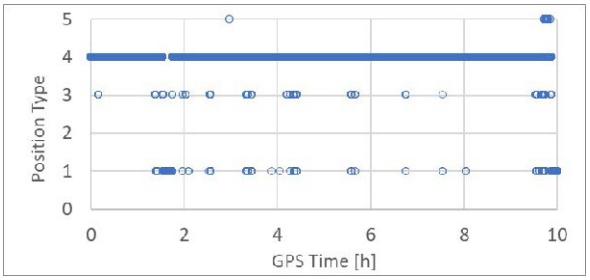




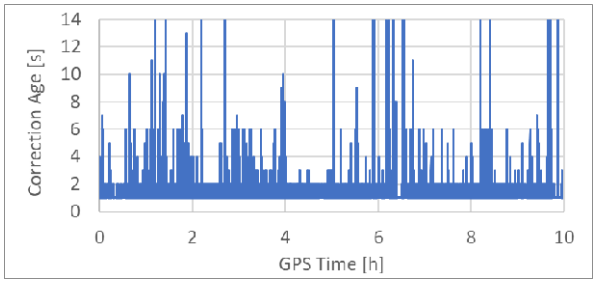
N-RTK survey positioning status

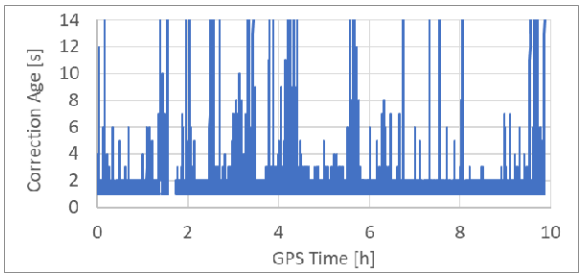
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value



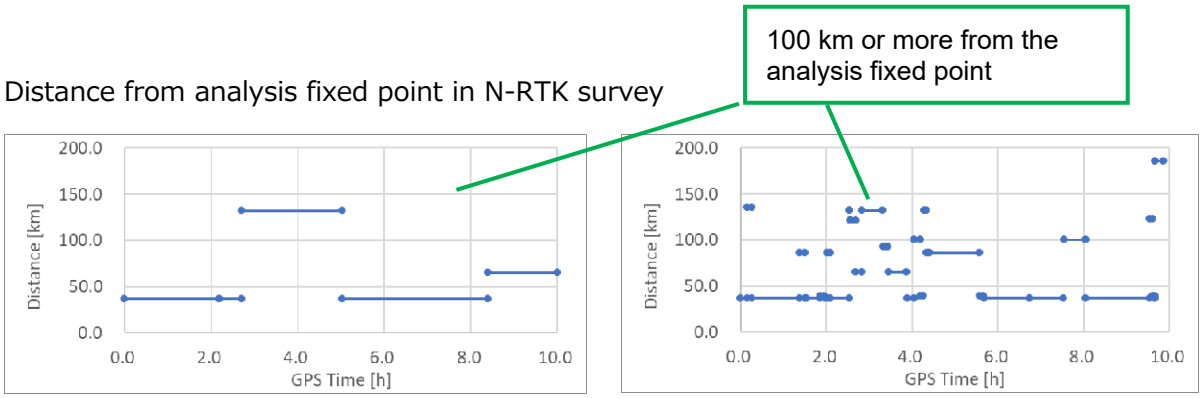


Correction information extrapolation time

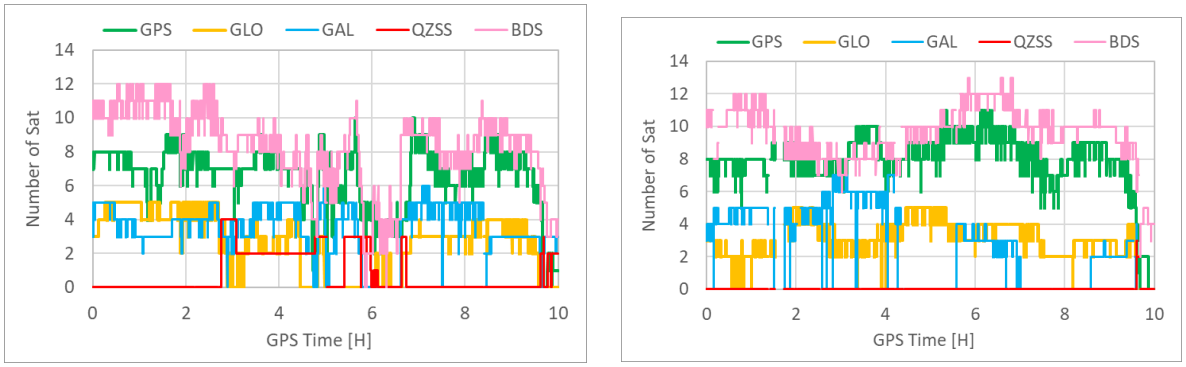




Distance from analysis fixed point in N-RTK survey



Changes in the number of satellites involved in the correction information from the NCDC server.



CP-6

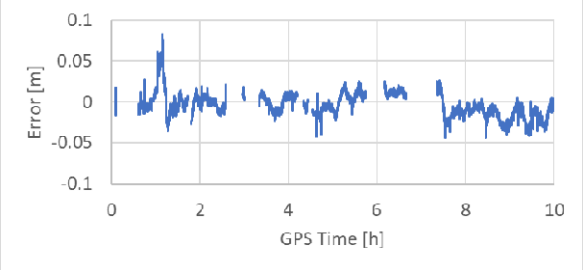
Days 1 and 2 (Left: August 3, 2022; right: August 4, 2022.)

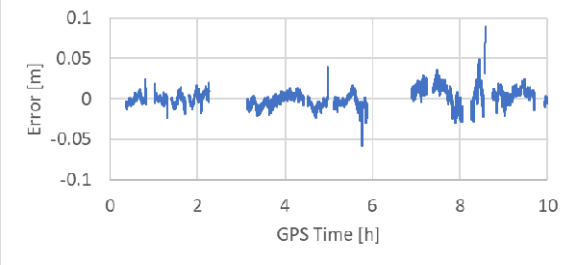
Table 5-10 N-RTK status CP-6

	Data	%
Autonomous	564	1.6
DGPS	18	0.1
Float	10064	28.0
Fixed	24852	69.2
Mis fixed	399	1.1
Total	35897	100.0

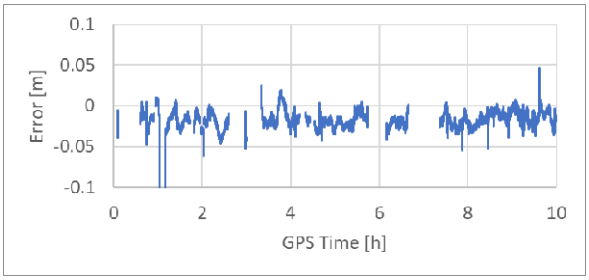
	Data	%
Autonomous	87	0.2
DGPS	34	0.1
Float	13574	37.7
Fixed	22134	61.5
Mis Fixed	144	0.4
Total	35973	100.0

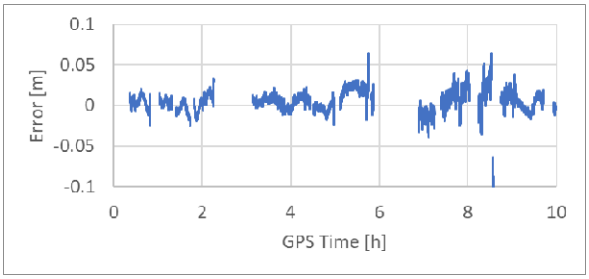
Difference in the N-S direction



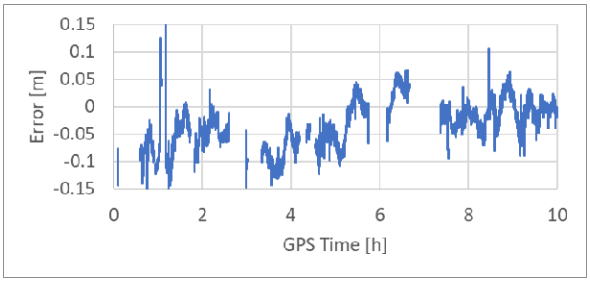


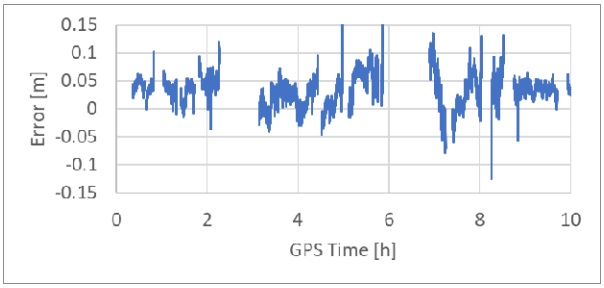
Difference in the E-W direction





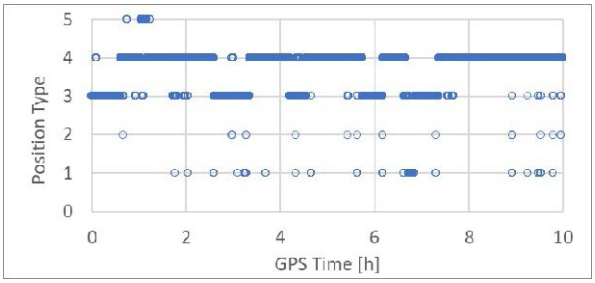
Difference in the H direction

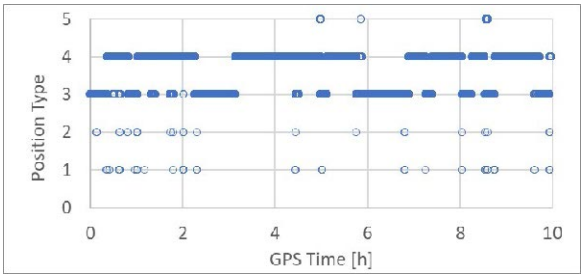




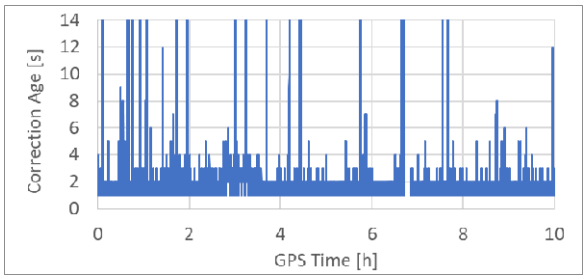
N-RTK survey positioning status

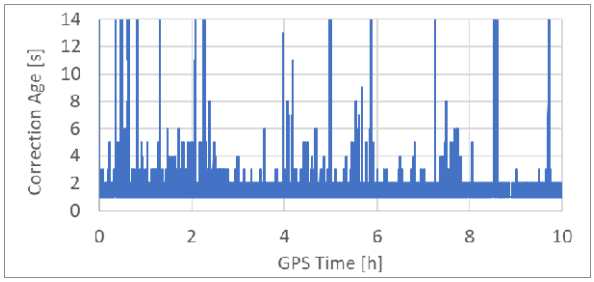
1: Single-point positioning　2: D-GPS　3: Float　4: Fix　5: Abnormal value



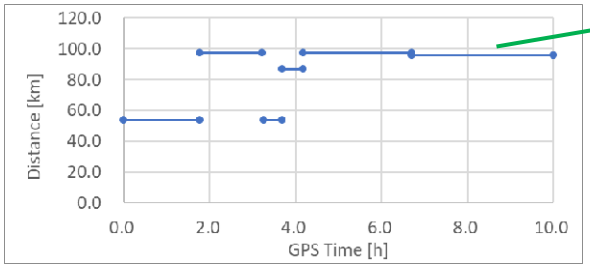


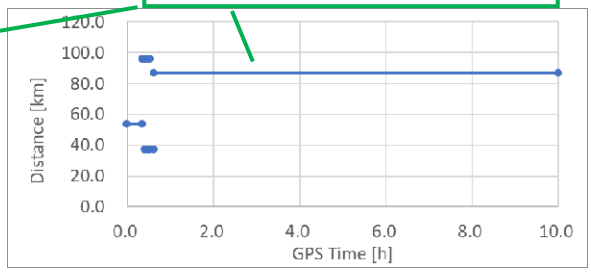
Correction information extrapolation time





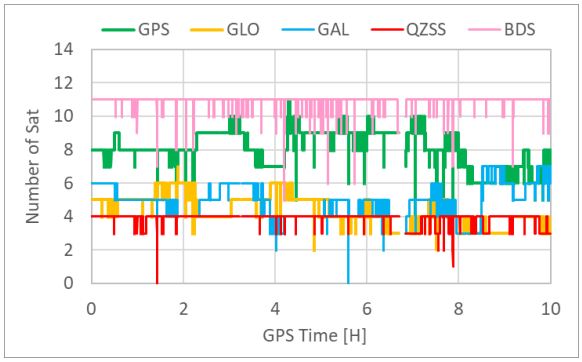
Distance from analysis fixed point in N-RTK survey

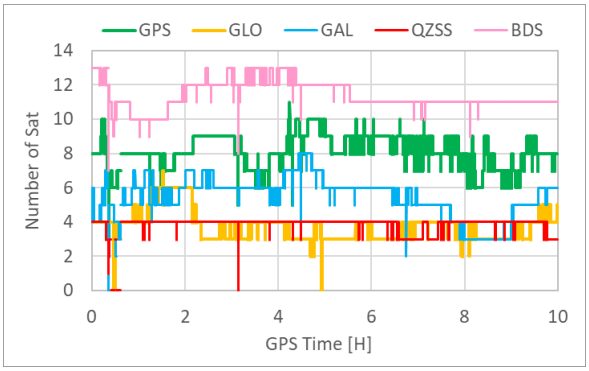




Close to 100 km from the analysis fixed point

Changes in the number of satellites involved in the correction information from the NCDC server.





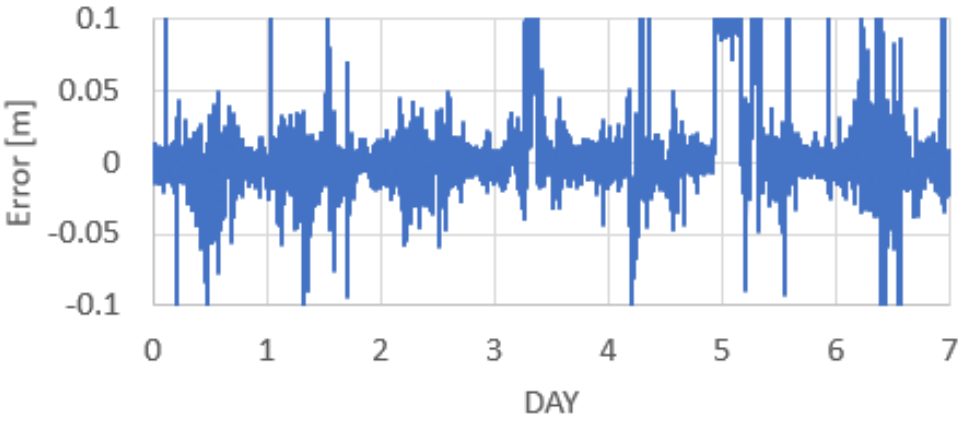
4: N-RTK survey of a long period observation at the point on the rooftop of the Topcon Positioning Asia (Thailand) building

4-1: November 24 to 30, 2022 (about 1 week)

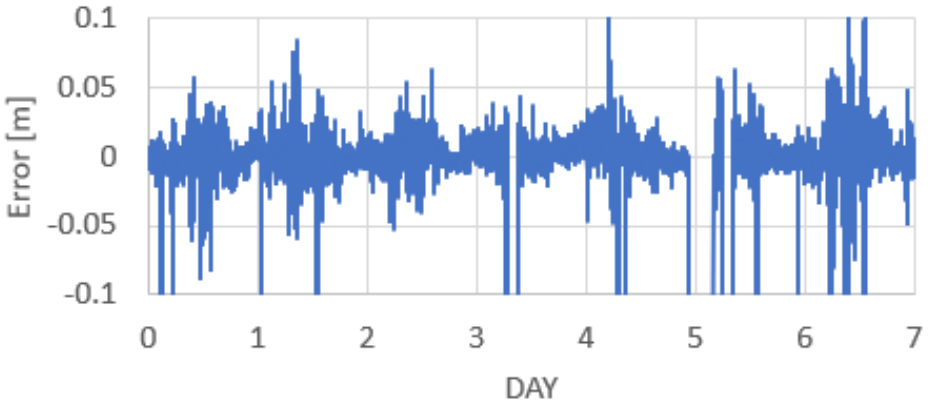
Table 5-11 N-RTK status for long period survey

	Data	%
Antonomous	2890	0.5
DGPS	14	0.0
Float	4078	0.7
Fixed	542026	89.6
Mis fixed	55771	9.2
Total	604779	100.0

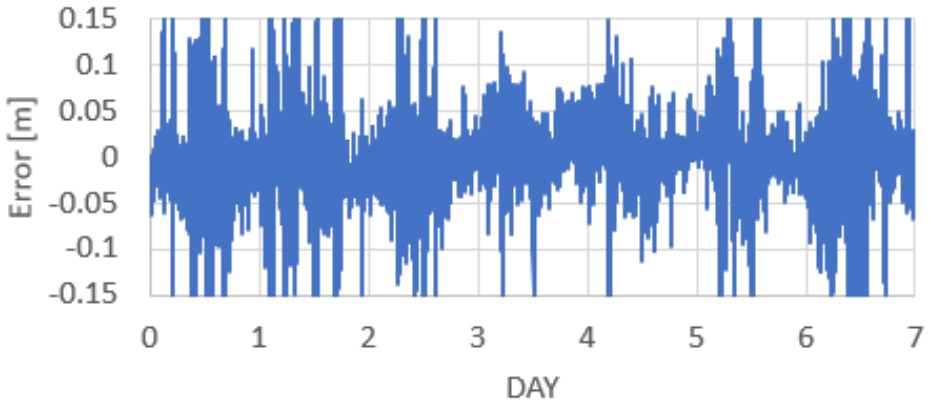
Difference in the N-S direction



Difference in the E-W direction

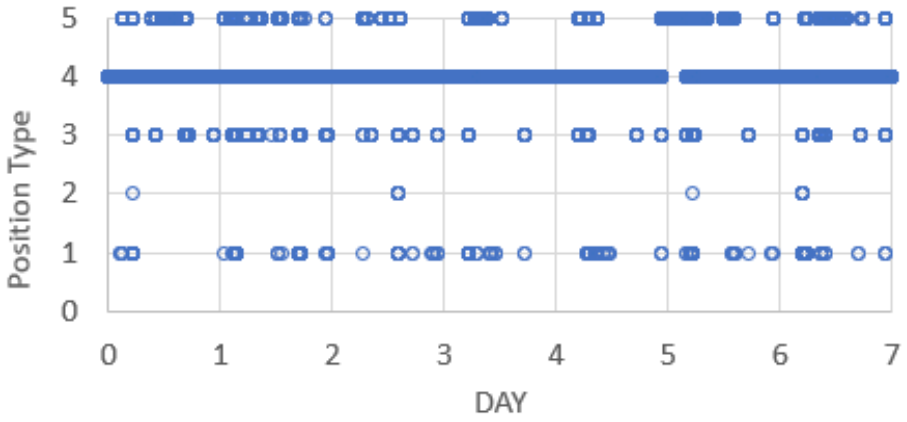


Difference in the H direction

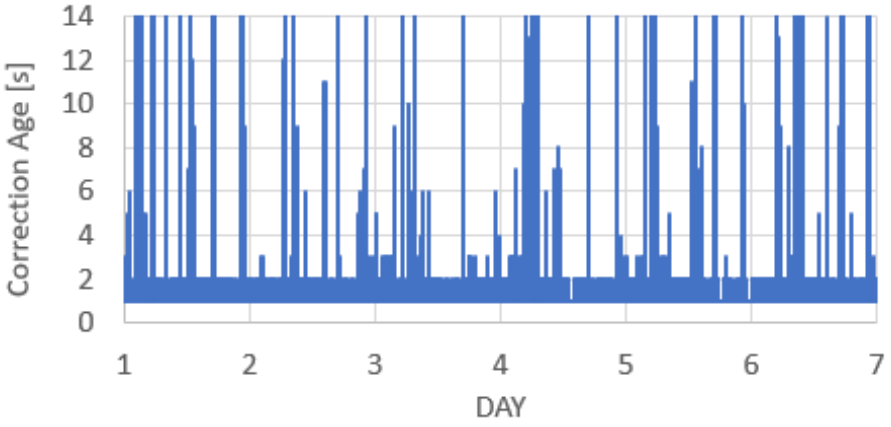


N-RTK survey positioning status

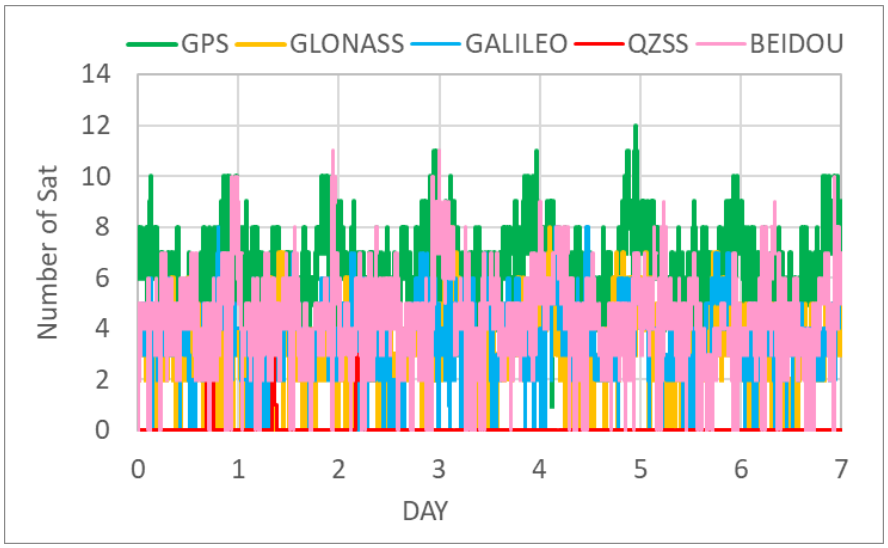
1: Autonomous　2: D-GPS　3: Float　4: Fixed　5: Mis fixed



Correction information extrapolation time



Changes in the number of satellites involved in the correction information from the NCDC server.

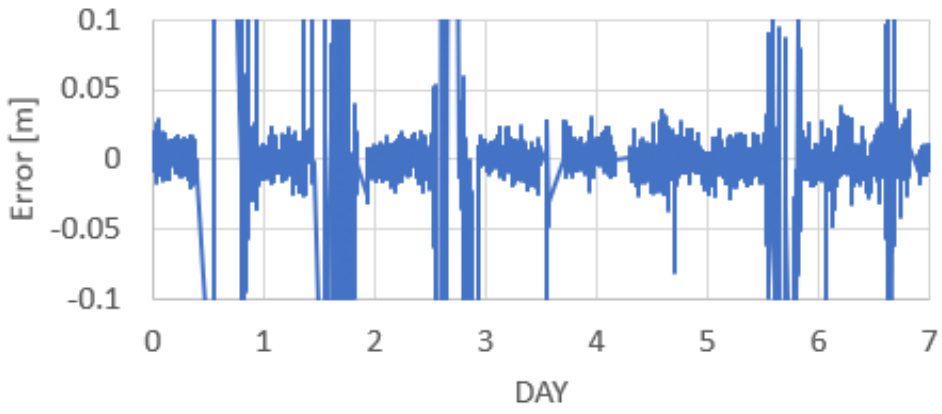


4-2: March 27 to April 3, 2023 (about 1 week)

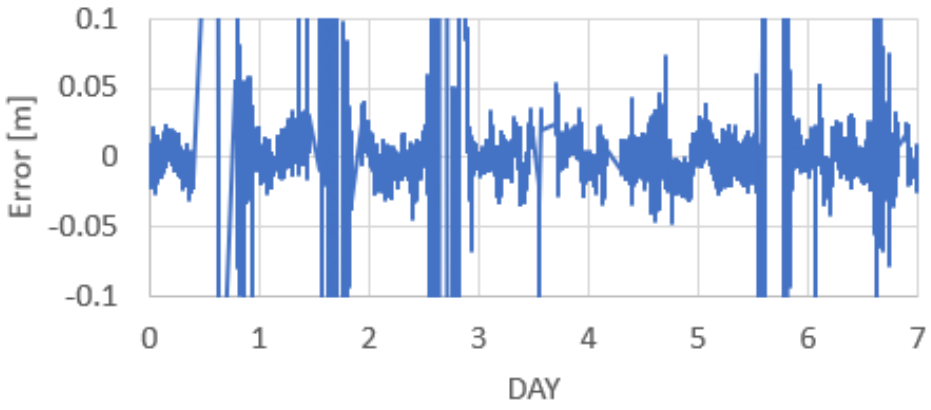
Table 5-12 N-RTK status for long period survey

	Data	%
Autonomous	27671	4.6
DGPS	26	0.0
Float	137223	22.7
Fixed	417117	69.0
Mis fixed	22757	3.8
Total	604794	100.0

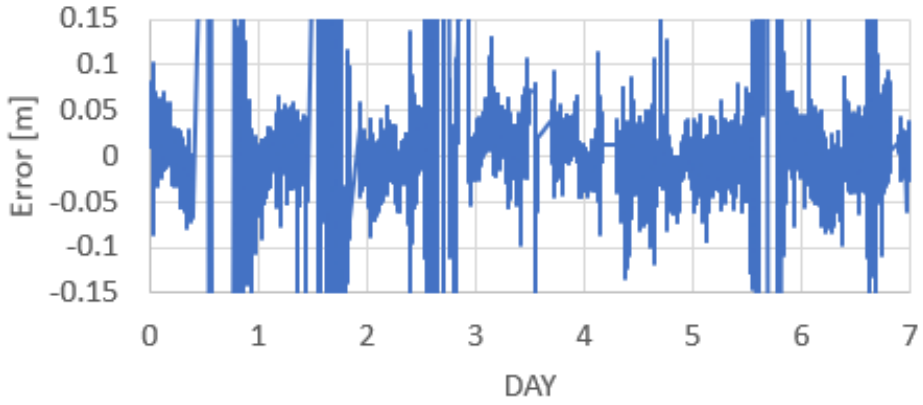
Difference in the N-S direction



Difference in the E-W direction

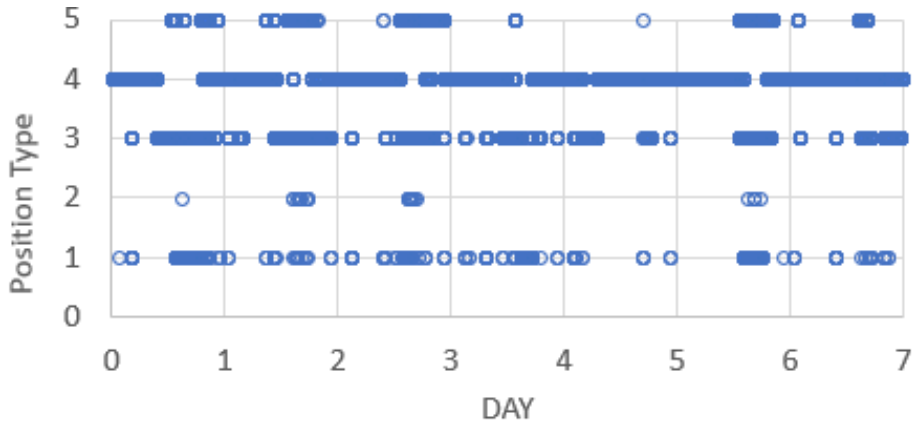


Difference in the H direction

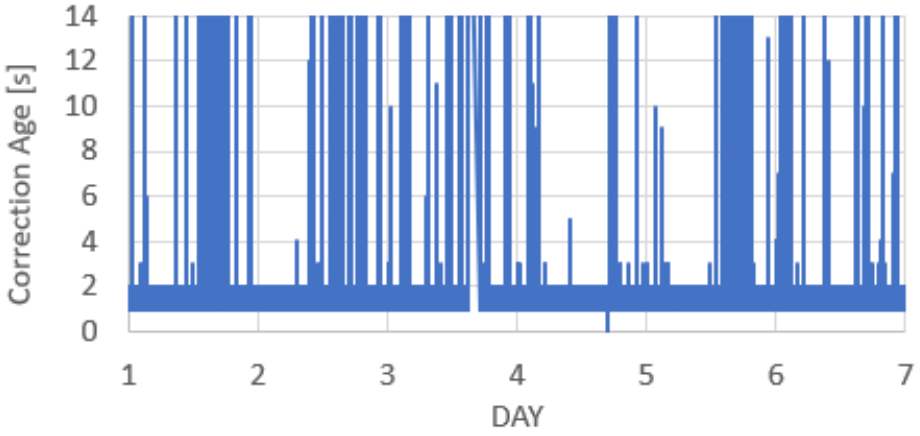


N-RTK survey positioning status

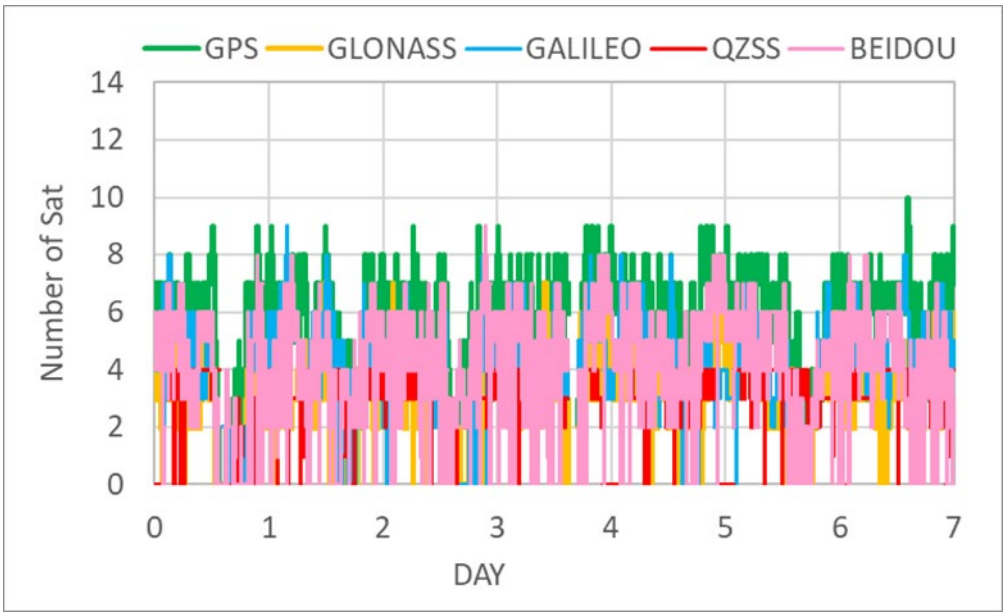
1: Autonomous　2: D-GPS　3: Float　4: Fixed　5: Mis fixed



Correction information extrapolation time



Changes in the number of satellites involved in the correction information from the NCDC server.



5: Explanation of terms

○ N-RTK survey positioning status

- Autonomous (Single-point positioning)

Positioning by a single observing receiver without GNSS correction information

- D-GPS

Differential positioning

Calculations are performed with GNSS correction information. The positioning accuracy is in units of meters.

- Float

Calculations are performed with GNSS correction information. The positioning accuracy is in units of under 1 meter.

- Fixed

Calculation is performed with GNSS correction information successfully correct positioning. The positioning accuracy is in units of 2 to 3 centimeters.

- Mis fixed

A mis fix or other situation where it is judged as a fix, but the accuracy actually deteriorates greatly due to the effect of noise, resulting in a solution that is different from the correct possition.

- Correction information extrapolation time

The transmission delay time for sending correction information from the server to a rover. A delay of 10 seconds or more clearly indicates deteriorated accuracy.

When a Topcon GNSS receiver is used, a delay of 30 seconds or more will lead to float solutions, and a delay of 60 seconds or more to autonomous (single-point positioning).

End of References

The project for capacity development and promotion of utilization of National CORS Data Center

JICA Pilot Project

Implementation Report

November 2023

NISHIO RENT ALL CO., LTD.

Topcon Corporation

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1. Overview of the pilot project

1.1. Name of the pilot project

JP：NCDC を活用した ICT 建機を用いた道路施工

EN: Road construction using the ICT construction machineries utilizing NCDC

TH: การใช้เทคโนโลยี ICT ในงานสร้างถนนโดยรับสัญญาณจาก NCDC

1.2. Background and purpose of the pilot projenct

This Pilot project verifies the use of RTK correction data provided to construction sites from the National CORS Data Center (NCDC), which integrated CORS located all over Thailand. Actual ICT construction machines are used to lay out the operation of machine control (MC) and machine guidance (MG) and points to be noted when using NCDC data at construction sites to facilitate the use of NCDC data at construction sites. In addition, the advantages of using NCDC data at construction sites will also be considered.

1.3. Brief description of the pilot projenct

The following construction work was performed: slope work with a 3DMG backhoe, subbase work with a 3DMC mmGPS motor grader, and paving work with a 3DMC mmGPS paver. Since the distance between NCDC reference points and the construction site may affect the stability of the positioning results, we conducted continuous observation tests within the construction site beforehand. It has been confirmed that utilizing NCDC data and the ICT- construction system reduced the initial introduction cost and working time.

1.4. Implementation period

Preparation:	January 2022 - April 2022
Work at the site:	April 2022 - June 2022
Reporting:	July 2022 - November 2023

Table 1-1 Plan and actual of the schedule

Work Items/ Year & Month		Progress	2022										2023											
			3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12
Sign a contract with Pasco	Plan	100.0%																						
	Actual																							
Preparation of the pilot project		**100.0%**																						
Making a pilot project implementation plan	Plan	100.0%																						
	Actual																							
Export/import of equipment	Plan	100.0%																						
	Actual																							
Obtainment of necessary permits	Plan	100.0%																						
	Actual																							
Localization for jobsite	Plan	100.0%																						
	Actual																							
Generate design data	Plan	100.0%																						
	Actual																							
Installation and calibration of Machine Control system for motor grader	Plan	100.0%																						
	Actual																							
Training of ICT construcion to local operators	Plan	100.0%																						
	Actual																							
Installation and calibration of Machine Guidance system for excavator	Plan	100.0%																						
	Actual																							
Installation and calibration of Machine Control system for asphalt finisher	Plan	100.0%																						
	Actual																							
Performance of the Pilot Project		**82.3%**																						
Roadbed construction	Plan	100.0%																						
	Actual																							
Slope shaping (if it is during roadbed construction term)	Plan	100.0%																						
	Actual																							
Pavement construction (depend on Roadbed construction status)	Plan	100.0%																						
	Actual																							
Collect ICT construction performance	Plan	100.0%																						
	Actual																							
Hearing ICT construction merit from local operators	Plan	100.0%																						
	Actual																							
Making seminar presentation	Plan	100.0%																						
	Actual																							
Join JICA seminar	Plan	50.0%																						
	Actual																							
On-site Site Tour	Plan	100.0%																						
	Actual																							
I-construction demo to Thailand government visitor in Nara	Plan	100.0%																						
	Actual																							
Making Final report	Plan	20.0%																						
	Actual																							
Submit Final report	Plan	0.0%																						
	Actual																							
Prepare Construction Workshop	Plan	100.0%																						
	Actual																							
Construction Workshop	Plan	100.0%																						
	Actual																							
JICA seminar, Presentation material, Case study leaflet, Pilot project implementation report																								
Site tour	Plan	100.0%																						
	Actual																							

1.5. Location of the pilot project site

Address: Khlong Takrao, Tha Takiap District, Chachoengsao 24160, Thailand

Coordinates: 13° 30' 00" north latitude, 101° 32' 05" east longitude

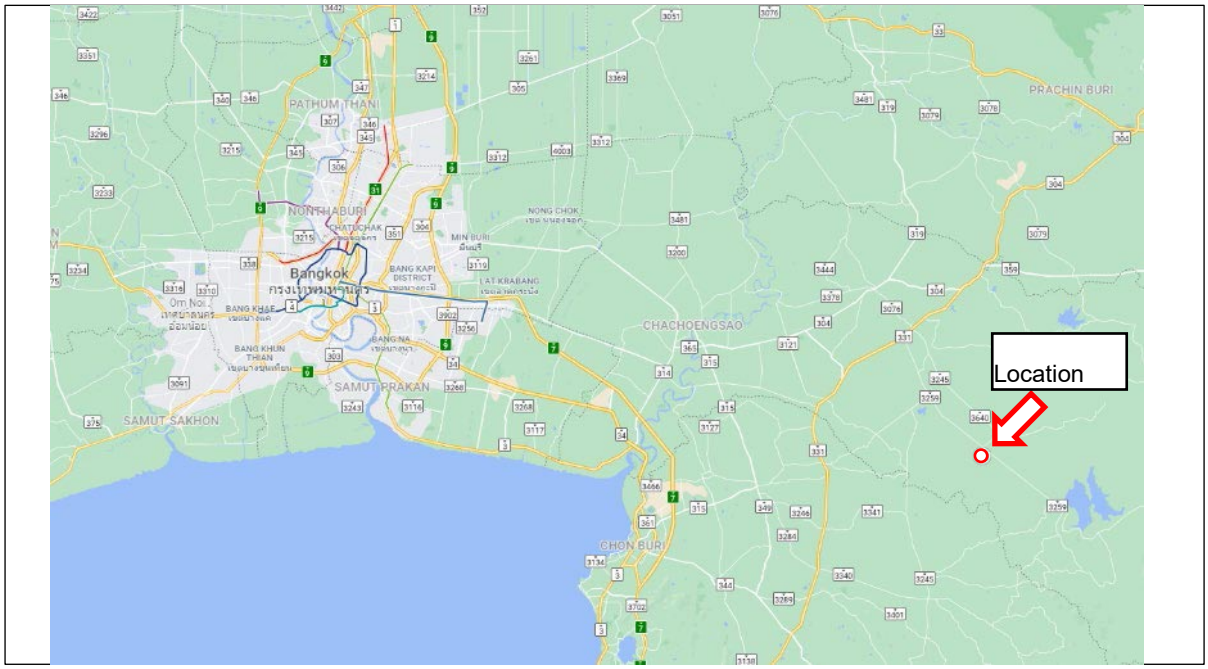


Figure 1-1 Location of the pilot project site (Source from Google Map)

1.6. Members/ Technical instructors

The members listed below performed the pilot project.

Table 1-2 List of members/technical instructors

NO.	Name	Company	Role
1	Takashi Ogawa	Topcon Positioning Asia (Thailand)	PJ coordination
2	Eric Lee Wei Chun	Topcon Positioning Asia (Malaysia)	MC/MG technical support
3	Muhammad Shahril Bin Mohamad Sabar	Topcon Positioning Asia (Malaysia)	MC/MG technical support
4	Muhammad Sharul Aqwa bin Mohamad Fauzi	Topcon Positioning Asia (Malaysia)	MC/MG technical support
5	Shigeki Hiraoka	Topcon Positioning Asia	MC/MG technical support
6	Akira Sugimoto	Topcon Positioning Asia	MC/MG technical support
7	Kiatkamol Boonsiriseth	Topcon Positioning Asia (Thailand)	Measurement technical support
8	Parinya Noinual	Topcon Positioning Asia (Thailand)	MC/MG technical support
9	Prathompong Phleejattu	Topcon Positioning Asia (Thailand)	Measurement technical support
10	Purit Mudthong	Topcon Positioning Asia (Thailand)	Measurement technical support
11	Hideki Yamaguchi	NISHIO RENT ALL	MC/MG equipment preparation
12	Tomohiko Kajiwara	NISHIO RENT ALL	MC/MG equipment preparation
13	Tomoki Kagoyama	NISHIO RENT ALL	MC/MG equipment preparation
14	Yuuki Manome	NISHIO RENT ALL	MC/MG equipment preparation
15	Shingo Iwasaki	NISHIO RENT ALL (Thailand)	MC/MG technical support
16	Somchai Maluleem	NISHIO RENT ALL (Thailand)	MC/MG technical support
17	Daisuke Okamoto	NISHIO RENT ALL	MC/MG technical support
18	Kittikul Prawanwimuth	NISHIO RENT ALL (Thailand)	MC/MG technical support
19	Chalermsak Pungpak	NISHIO RENT ALL (Thailand)	MC/MG technical support
20	Anu Sathaisong	NISHIO RENT ALL (Thailand)	MC/MG technical support
21	Preecha Lumta	NISHIO RENT ALL (Thailand)	MC/MG technical support
22	Kobkarn No-jit	NISHIO RENT ALL (Thailand)	MC/MG technical support

1.7. Equipment used for the pilot project

The equipment listed below were used for the pilot project.

Table 1-3 List of equipment used

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
1	TOPCON GNSS Receiver GR-5	2	Measuring instrument
2	TOPCON GNSS Receiver HiPer HR	2	Measuring instrument
3	TOPCON mmGPS Laser Transmitter PZL-1	1	Measuring instrument
4	TOPCON mmGPS Laser Detector PZS-1	1	Measuring instrument
5	TOPCON Field Controller FC-500	2	Measuring instrument
6	TOPCON Total Station DS	1	Measuring instrument
7	TOPCON 3D-Office application	1	Field management software
8	TOPCON Pocket-3D software	1	Survey software
9	TOPCON RTK Machine Guidance System (Excavator)	1	Machine Guidance
10	TOPCON mmGPS Machine Control System (Motor Grader)	1	Machine Control
11	TOPCON mmGPS Machine Control System (Asphalt Finisher)	1	Machine Control
12	KOMATSU PC-200	1	Construction machine
13	VOLVO G930	1	Construction machine
14	Voegele Super 1803-2	1	Construction machine

(1) GNSS receiver GR-5



GNSS	
GPS	L1, L1C*, L2, L2C, L5*
GLONASS	L1, L2
Galileo*	E1, E5a, E5b, AltBOC
BeiDou*	B1, B2
SBAS	L1 C/A WAAS/MSAS/ EGNOS
QZSS	L1 C/A, L1C*, L2C
Number of Channels	226-Channel Vanguard Technology™ with Universal Tracking Channels
Antenna Type	Integrated Fence Antenna™ † with Ground Plane
Accuracy (RMS)* *	
RTK	H: 5 mm + 0.5 ppm V: 10 mm + 0.8 ppm
Static †	H: 3.0 mm + 0.1 ppm V: 3.5 mm + 0.4 ppm
Communication	
Optional Radio Type	Integrated UHF/FH915
Base Radio Output	1.0 W, user selectable
Optional Cellular	Integrated HSPA/CDMA
I/O Communications	Class 2 *Bluetooth*® USB and Serial
Data and Memory	
Memory	Removable SD/SDHC
Data Update/ Output Rate	1 Hz – 50 Hz Selectable
Real Time Data Output	TPS, RTCM 2.x, 3.x, CMR, CMR+
ASCII Output	NMEA 0183 version 2.x and 3.0
Environmental	
Enclosure	Dust and water ingress protected magnesium I-Beam housing
Operating Temp	-30°C to 70°C††
Shock Rating	2 m pole drop to concrete IEC 60068-2-29, IEC 60068-2-27
Vibration Rating	Compliance with MIL-STD 810F - 514.5 - Cat.24

(2) GNSS receiver HiPer HR



GNSS Tracking	
Number of Channels	452 with patented Universal Tracking Channel Technology
GPS	L1 C/A, L1C, L1P(Y), L2P(Y), L2C, L5
GLONASS	L1 C/A, L1P, L2 C/A, L2P, L3C
Galileo	E1, E5a, E5b, E5AltBOC, E6
BeiDou	B1, B2, B3 with ICD availability
IRNSS	SPS-L5
SBAS	WAAS/EGNOS/MSAS
QZSS	L1 C/A, L1C, L2C, L5, LEX
L-band	1525-1560 MHz
Satellites Tracked	All in view
Accuracy	
(L1 + L2)	H: 3.0 mm + 0.3 ppm V: 5.0 mm + 0.5 ppm
Precision Static*	H: 3.0 mm + 0.1 ppm V: 3.5 mm + 0.4 ppm
RTK	H: 5.0 mm + 0.5 ppm V: 10.0 mm + 0.8 ppm
RTK, TILT Compensated**	H: 1.3 mm/°Tilt; Tilt ≤ 10° V: 1.8 mm/°Tilt; Tilt > 10° Maximum recommended angle for tilt compensation is 15°
Data Update / Output Rate	1 Hz standard 1C, 20 Hz optional
Communication	
Optional Radio Type	UHF (410-470 MHz) SS (915 MHz)
UHF radio range	5-7km typical, 15km in optimal*** conditions
Cellular	Integrated HSPA+/CDMA
Additional Communications	Internal cellular modem Wi-Fi, Bluetooth®, LongLink™
Data and Memory	
Real Time Data Output	TPS, RTCM SC104 v2.x, 3.x, CMR/CMR+, RINEX
NMEA 0183 Output	Version 2.x, 3.x and 4.x
On-board Memory	8GB Internal
Power	
Power Source	External power 6 to 28 VDC 1x internal battery (3.7 V, 5200 mAh) 1x removable battery (7.2 V, 2900 mAh)
Operating Time	Up to 9 hours with included batteries
Environmental and Physical	
Dimensions (w x h)	115 x 132 mm
Operating Temp.	-40°C to 80°C
Water/Dust Rating	IP67
Drop and Topple	2 meter pole-drop
Weight	1.1/1.2 g (including internal and hot swappable external batteries)

(3) mmGPS laser transmitter PZL-1



PZL-1 TRANSMITTER:

Zone Width	±10° (0-30m), ±5m (30-300m)
Zone Radius	300 meters (985 feet)
Lazer Zone Accuracy	Vertical: 1 arc second resolution
RTK GPS+ Accuracy	Horizontal: 10mm + 1ppm
Self-Leveling Range	±5°
Rotation Speed	600 rpm
Laser Class	Class 1
Channels	4
Plumb Beam	YES
Bluetooth	YES
I/O port	RS-232C
Power Supply	Rechargeable Ni-MH (w/runcharge) 4 D-Cell Alkaline
Operating Time	about 20 hours (Alk), 15 hours Ni-MH
Waterproof	IPX6
Operating Temp	-20° to +50° C

(4) mmGPS laser detector PZS-1



PZS-1 ROVER SENSOR:

Beam Detection	±10° by ±10° window
Channels	4
I/O port	RS-232C
Mounting	5/8x11 Thread
Waterproof	IPX6
Operating Temp	-20° to +50° C
Power Supply	BT-59Q Camcorder battery
Operating Time	about 8 hours
Weight	about 1kg

(5) Field computer FC-500



Hardware	
Processor	1 GHz ARM Cortex A8 i.MX53
Operating System	Microsoft® Windows Mobile 6.5
Memory and Data Storage	512 MB RAM 8 GB flash storage Micro-USB
Camera (Geo, Geo 3G)	5 megapixel resolution with autofocus and LED flash with video capture
Power	12/24V DC power input Intelligent Li-Ion battery 3.6V DC at 10800 mAh
Communication	
Ports	COM1 RS-232C (D-sub 9pin) 5V DC Power USB Host (Full A) USB Client (Micro)
Wireless Connection	*Bluetooth*® Wi-Fi 802.11 b/g/n
Cellular Connectivity (Geo 3G only)	Integrated Worldwide, 800/850, 900, 1800, 1900, 2100 MHz, UMTS/HSPA+

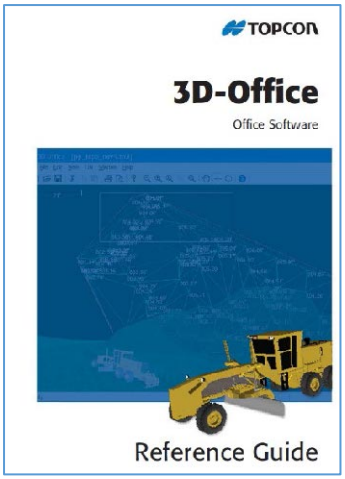
(6) Total station DS



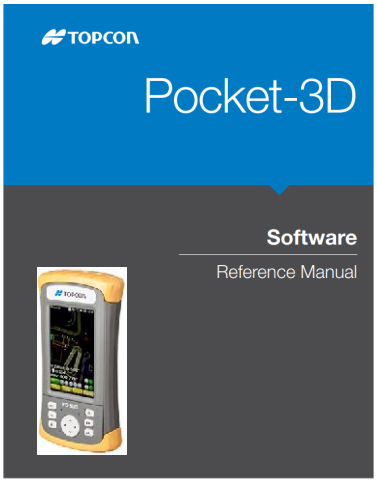
SPECIFICATIONS

Model		DS-101AC	DS-102AC	DS-103AC	DS-105AC
Telescope					
Magnification / Resolving power		30x / 2.5"			
Length - Hallmm (Lulin.), Objective aperture: 45mm (1.8in.) (50mm (2.0in.) for EDM), Image: Erect, Field of view: 1°30' (26m/1,000m), Minimum focus: 1.3m (4.3ft.), Reticle illumination: 5 brightness levels					
Angle measurement					
Display resolutions		0.5" / 1" (0.0001 / 0.0002gon, 0.002 / 0.005mil)		1" / 5" (0.0002 / 0.001gon, 0.005 / 0.02mil)	
Accuracy (ISO 17123-3:2001)		1"	2"	5"	5"
Advanced angle encoder technology		Provided			
Dual-axis compensator / Collimation compensation		Dual-axis liquid tilt sensor, working range: ±6' / Collimation compensation available			
Distance measurement					
Laser output		Reflectorless mode: Class 3R / Prism/sheet mode: Class 1			
Measuring range (under average conditions*1)	Reflectorless*2	0.3 to 800m (1 to 2,620ft) / Under good conditions*3: to 1,000m (3,280ft.)			
	Reflective sheet*4	RS90N-K: 1.3 to 500m (4.3 to 1,640ft.), RS50N-K: 1.3 to 300m (4.3 to 980ft.), RS10N-K: 1.3 to 100m (4.3 to 320ft.)			
	360°prism*5,6,7	1.3 to 1,000m (4.3 to 3,280ft.) Under good conditions*3			
	Mini prism*5,8	1.3 to 500m (4.3 to 1,640ft.)			
	One prism*5,9	1.3 to 5,000m (4.3 to 16,400ft.) / Under good conditions*3: 6,000m (16,680ft.)			
	Three prisms*5,10	to 6,000m (26,240ft.) / Under good conditions*3: to 10,000m (32,800ft.)			
Display resolution		Fine: 0.0001 / 0.001m (0.001 / 0.01ft., 1/16 / 1/8in.) / Rapid: 0.001m / 0.01ft. / 1/8in. Tracking: 0.01m / 0.1ft. / 1/2in.			
Accuracy*11 (ISO 17123-4:2001) (D=measuring distance in mm)	Reflectorless*2	(2 + 2ppm x D) mm*12			
	Reflective sheet*4	(2 + 2ppm x D) mm			
	Prism	(1.5 + 2ppm x D) mm			
Measuring time*13		Fine: 0.9s (initial 1.5s), Rapid: 0.6s (initial 1.3s), Tracking: 0.3s (initial 1.3s)			
Auto-Collimating, Auto-Tracking*14 and Motor					
Working range*15	360°prism*5,6,7	2 to 600m (6.6 to 1,960ft.)			
	One prism*5,9	1.3 to 1,000m (4.3 to 3,280ft.)			
	Reflective sheet*4	1.3 to 50m (16 to 160ft.)			
	Mini prisms*5,8	1.3 to 500m (4.3 to 1,640ft.)			
Rotation speed / Auto-Tracking speed*16		90°/s / 15°/s			
Motor type		DC Servo motor			
OS, Interface and Data management					
Operating system / Application		Microsoft Windows CE 6.0 / MAGNET FIELD			
Display / Keyboard		3.5inch, Semi-transmissive TFT QVGA color LCD with LED backlight, Touch screen, Automatic brightness control / 26 keys with backlight			
Control panel location*17		On both faces (Face 2 is only touch screen display)			
Tribrach		On right instrument support			
Data storage	Internal memory	500MB internal memory			
	Plug-in memory device	2GB flash memory (max. 8GB)			
Interface		Serial RS-232C, USB2.0 (Type A / mini B)			
Bluetooth modem (option)*18		Bluetooth Class 1, Ver.2.1+EDR, Operating range: up to 300m (980ft.)*19			
General					
Laser pointer*20		Coaxial red laser using EDM beam			
Guide light*21		Green LED (524nm) and Red LED (626nm), Operating range: 1.3 to 150m (4.3 to 490ft.)			
Levels	Graphic / Circular level	6' (Inner Circle) / 10' / 2mm			
Optical plummet		Magnification: 3x, Minimum focus: 0.5m (1.6ft.) from tribrach bottom			
Laser plummet (option)		Red laser diode (635nm±10nm), Beam accuracy: 51.0mm@1.5m, Class 2 laser product			
Dust and water protection / Operating temperature		IP65 (IEC 60529:2001) / -20 to +50°C (-4 to +122°F)			
Size with handle		W207 (W) X 190 (D) X 372 (H) mm (W8.1 x D7.5 x H14.6in.)			
Weight with battery & tribrach		Approx. 6.1kg (13.4lb.)			
Power supply					
Battery	BDC70 detachable battery	Li-ion rechargeable battery			
Operating time (20°C)	BDC70	Approx.5hours (Fine distance measurement (single) using Auto-Collimating, repeated every 30 seconds)			
	External battery (option)	BT-75Q: approx. 14.5hours (Fine distance measurement (single) using Auto-Collimating, repeated every 30 seconds)			

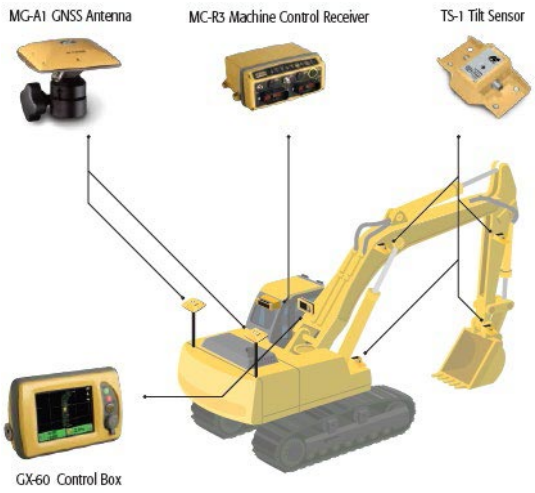
(7) Field management software 3D-Office



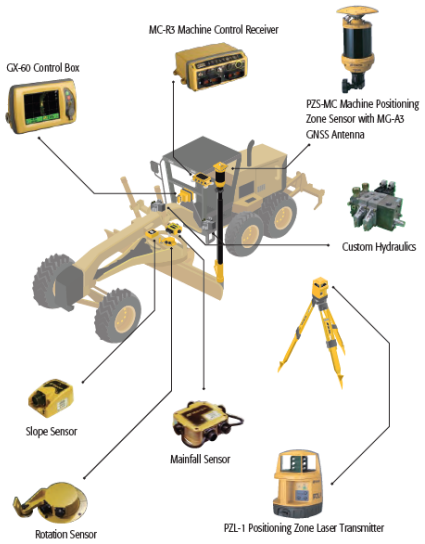
(8) Survey software Pocket-3D



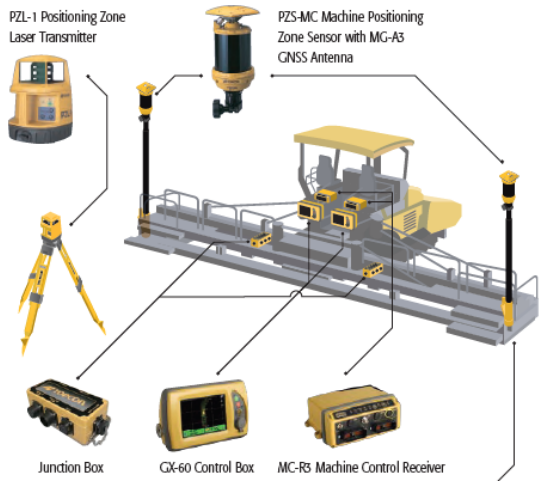
(9) 3DMG backhoe system



(10) 3DMC mmGPS motor grader system



(11) 3DMC mmGPS paver system



(12) Construction machine KOMATSU PC-200



(13) Construction machine VOLVO G930



(14) Construction machine Voegele Super 1803-2



2. Details of the work

2.1. Work performed

2.1.1.Preparation

(1) NCDC data reception test

Prior to the start of the pilot project, a NCDC data reception test was carried out in the construction site as follows.

Date:	Thursday, October 14, 2021
Location:	ATTRIC (Automotive and Tyre Testing, Research and Innovation Center) Sanam Chai Khet District, Chachoengsao Province
Equipment:	Topcon HiPerHR (GNSS receiver) Topcon FC-500 (Controller)
NCDC:	IP Address 118.174.12.3 Port number 2021 Mount Point MAX_RTCM3(MSM)_UTM48
Observation points:	7 reference points in the construction site Point Name: TND16, TND18, TND22, TND24, TND26, TND28, TND30

The reception test verified that the NCDC data could be received in the construction site, enabling VRS-RTK positioning. On the other hand, there were large errors between the current coordinates of reference points and those measured by VRS-RTK. The following pictures and table show the status of the reception test and the results obtained. The results of the reception test were reported to the JICA project team and improvements were made before the start of the pilot project. Reception test after improved is described in “2.2.2. Problems occurred and solutions''.

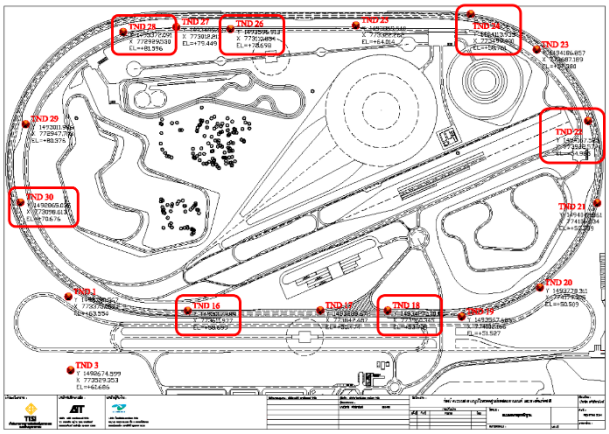


Figure 2-1 Layout of the construction reference points



Figure 2-2 Measurement work

Table 2-1 Results of the reception test

	Coordinates measured by VRS-RTK			Coordinates of reference points in construction site			Differences		
	Y	X	EL	Y	X	EL	dY	dX	dEL
TND16	1493017.289	773611.676	58.366	1493017.889	773611.977	58.699	-0.600	-0.301	-0.333
TND18	1493426.572	773960.462	53.437	1493427.170	773960.345	53.705	-0.598	0.117	-0.268
TND22	1494167.312	773923.026	54.675	1494167.525	773922.577	54.985	-0.213	0.448	-0.310
TND24	1494113.930	773499.607	58.470	1494113.935	773499.400	58.761	-0.005	0.207	-0.291
TND26	1493596.857	773110.591	73.376	1493596.913	773110.834	73.698	-0.056	-0.243	-0.322
TND28	1493372.017	772929.081	81.279	1493372.091	772929.530	81.596	-0.074	-0.449	-0.317
TND30	1492864.577	773097.984	70.395	1492865.035	773098.613	70.676	-0.458	-0.629	-0.281

(2) Installation of backup GNSS RTK base station

In view of the case where the provided data from NCDC stops during this pilot project, a backup GNSS RTK station was installed in the construction site. Since this GNSS RTK base station needs to be retained until the end of this pilot project, single pipes were used to make it resilient. The coordinates of the GNSS RTK base station was determined by VRS-RTK using NCDC data to ensure the consistency with NCDC data.

Date: Friday, April 1, 2022
Equipment: Topcon GR-5 (GNSS receiver)
Topcon FC-500 (Controller)
NCDC: IP Address 118.174.12.3
Port number 2021
Mount Point VRS_RTCM3.1_UTM48



Figure 2-3 Installation of backup GNSS RTK base station

Table 2-2 Coordinates of the GNSS RTK base station determined by VRS-RTK

Station name	BASEGR5
Latitude	13 ° 29' 59.68045 "
Longitude	101 °32' 04.96802 "
Ellipsoid height	16.2203 m

(3) Site localization [1]

In order to apply VRS-RTK at the construction site, localization was performed to determine the correlation between the site coordinate system and GNSS coordinate system. For the first localization, an NCDC mount point VRS_RTCM3.1_UTM48 was used. However, since there were large errors at some measurement points, the mount point was changed to NB_RTCM3.1_UTM48 to use the data of the nearby CORS stations. Then, localization was performed again. Finally good localization results were obtained.

Date:	Saturday, April 2, 2022	
Equipment:	Topcon GR-5 (GNSS receiver)	
	Topcon FC-500 (Controller)	
NCDC:	IP Address	118.174.12.3
	Port number	2021
	Mount Point	VRS_RTCM3.1_UTM48,
		⇒NB_RTCM3.1_UTM48
Measurement points:	16 reference points in the site	
	TND01, TND16, TND17, TND18, TND20, TND21, TND22, TND23,	
	TND24, TND25, TND26, TND27, TND28, TND29, TND30, BASEGR5	

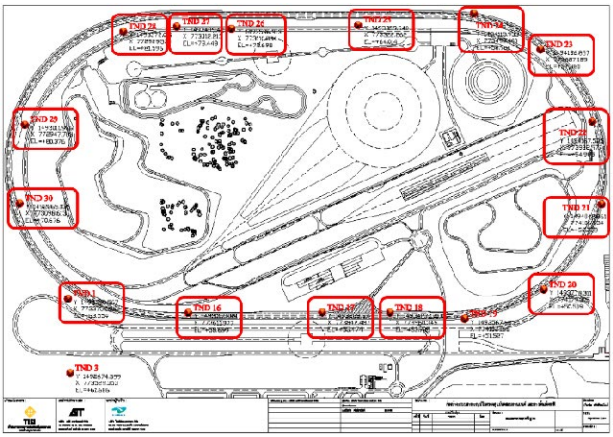


Figure 2-4 Layout of localization points



Figure 2-5 Localization work

Table 2-3 Localization results

Measurement point	Horizontal error	Vertical error
TND01	0.017 m	-0.005 m
TND16	0.024 m	-0.000 m
TND17	0.014 m	0.005 m
TND18	0.027 m	-0.011 m
TND20	0.014 m	-0.001 m
TND21	0.014 m	-0.000 m
TND22	0.017 m	0.004 m
TND23	0.006 m	-0.011 m

Measurement point	Horizontal error	Vertical error
TND24	0.006 m	0.000 m
TND25	0.022 m	-0.001 m
TND26	0.017 m	-0.003 m
TND27	0.015 m	0.009 m
TND28	0.009 m	0.005 m
TND29	0.005 m	0.000 m
TND30	0.006 m	-0.000 m
BASEGR5	0.004 m	0.10

[1] The process of determining coordinate conversion parameters between site coordinates and GNSS coordinates.

(4) Installation on backhoe and adjustment

3DMG backhoe system[2]was installed to the backhoe[3]used in the slope work, and the operation was checked and adjusted. The installation work was completed in one day; the work included the welding of the sensor base and GNSS poles, and the installation and wiring of equipment. After the installation, geometry measurement and accuracy check were conducted, and it could confirm to use for 3DMG backhoe system to the slope work.

Date:	Sunday, April 3, 2022 - Monday, April 4, 2022
Equipment:	3DMG backhoe system
	GNSS antennas (2 units)
	Tilt sensors (4 units)
	GNSS control box (1 unit)
	Monitor (1 unit)
Construction machine:	KOMATSU PC-200



Figure 2-6 Installation equipment



Figure 2-7 Welding sensor base



Figure 2-8 Installing GNSS poles



Figure 2-9 Body sensor



Figure 2-10 Tilt sensor



Figure 2-11 Monitor and control box



Figure 2-12 GNSS antenna



Figure 2-13 After installing the 3DMG backhoe system

[2] A guidance system that displays information on the difference between the bucket cutting edge and 3D design data to the operator.

[3] A type of Backhoe with a bucket attached facing the operator.




Figure 2-14 Geometry measurement and sensor adjustment



Figure 2-15 Accuracy check

(5) Installation on motor grader and adjustment

3DMC mmGPS motor grader system[4]was installed to the motor grader[5] to be used for the subbase work, and the operation was checked and adjusted. Since a motor grader equipped with hydraulic equipment and system wiring was used for installation, hydraulic piping and welding work were not needed, and as a result, the installation of equipment was completed in half a day. After the installation, geometry measurement and accuracy check were conducted, and it could confirm to use for 3DMC mmGPS motor grader system to the subbase work. As regards the hydraulic pressure adjustment, only the initial setting was conducted, and the final adjustment was made before the construction while listening to the opinions of operators.

Date:	Wednesday, April 27, 2022
Equipment:	3DMC mmGPS motor grader system
	GNSS antenna (1 unit)
	mmGPS laser detector (1 unit)
	Mainfall sensor (1 unit)
	Rotary sensor (1 unit)
	Slope sensor (1 unit)
	GNSS control box (1 unit)
	Monitor (1 unit)
Construction machine:	VOLVO G930



Figure 2-16 Monitor



Figure 2-17 Control box

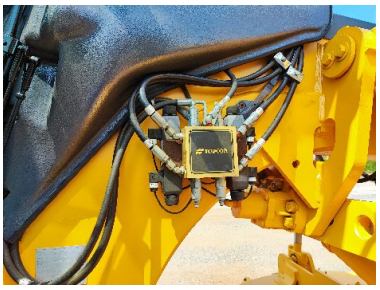


Figure 2-18 Hydraulic valve

[4] A system that automatically controls the height of machine blade based on the difference between the machine blade edge and 3D design data.

[5] A type of construction machine used for land grading.



Figure 2-19 mmGPS laser detector



Figure 2-20 Mainfall sensor

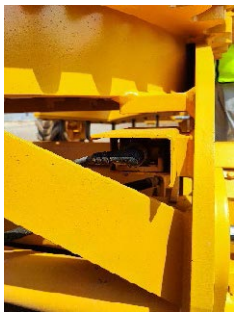


Figure 2-21 Slope sensor

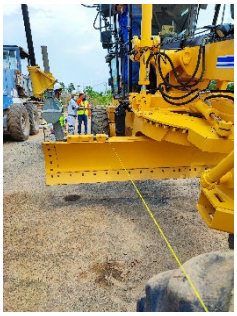


Figure 2-22 Blade rotation check

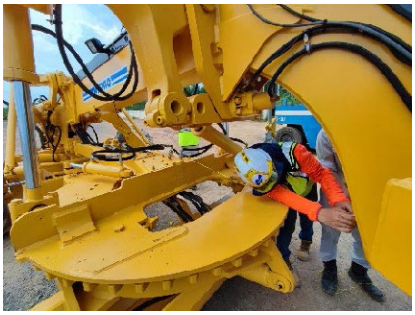


Figure 2-23 Drawbar center check



Figure 2-24 Geometry measurement



Figure 2-25 System operation check



Figure 2-26 System accuracy check

(6) Installation on paver and adjustment

The 3DMC mmGPS paver[6] system was installed to the asphalt paver[7] to be used for the paving work, and the operation was checked and adjusted. Since a paver equipped with a pole base for the installation of GNSS antennas was used, welding work was not needed, and as a result, the installation of equipment was completed in one day. After the installation, geometry measurement and accuracy check were conducted, it could confirm to use for 3DMC mmGPS paver system to pave work. In adjusting the hydraulic pressure, the operation was checked with the initial setting, and then adjusted so that the left and right control speeds were the same.

[6] A system that automatically controls the height of machine screed based on the difference between the machine blade edge and 3D design data.

[7] A type of construction machine used for asphalt paving work for road.

Date:	Wednesday, June 15, 2022
Equipment:	3DMC mmGPS paver system
	GNSS antennas (2 units)
	mmGPS laser detector (2 units)
	GNSS control box (1 unit)
	Monitor (1 unit)
Construction machine:	Voegele Super 1803-2



Figure 2-27 Installing antenna poles

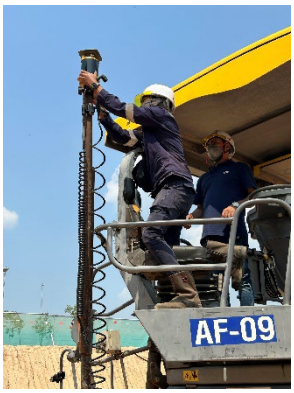


Figure 2-28 Installing mmGPS laser detector

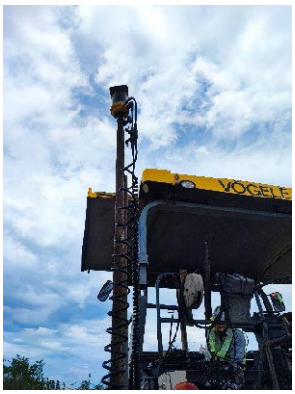


Figure 2-29 After installing mmGPS laser detector



Figure 2-30 Installing controller



Figure 2-31 Connecting the left control connector



Figure 2-32 Connecting the right control connector



Figure 2-33 Measuring the left screed



Figure 2-34 Measuring the right screed

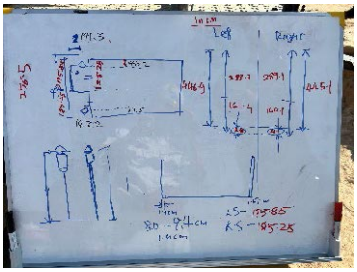


Figure 2-35 Geometry measurement results



Figure 2-36 Left control gauge



Figure 2-37 Right control gauge

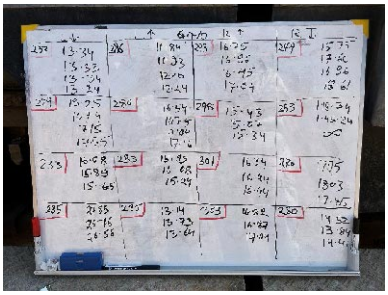


Figure 2-38 Right and left control speed adjustment work

(7) Preparation of 3D design data

3D design data to be used in the slope, subbase and paving work were prepared on the base of changing point data in design values. 3D design data for the slope construction was created from 326 changing points data, and had a width of 86 m, a slope length of 7 m, and 2 steps slope.

3D design data for roadbed work and pavement work was based on the surface layer design data, and the construction target height was set for each using the height offset function of the 3DMC software, and the common 3D design data was created from the 189 changing points data.

The surface design data was a wide of 8m, total length of 62m with slope of 2.5%.

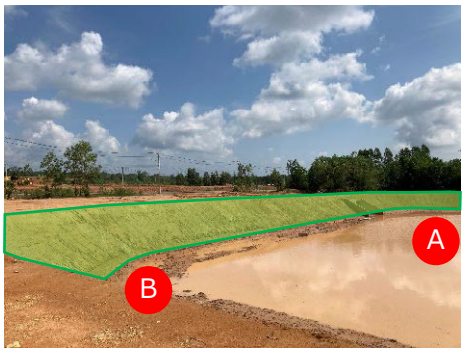


Figure 2-39 Slope work area

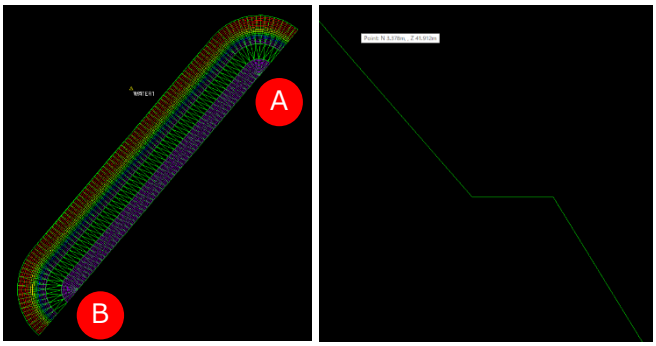


Figure 2-40 3D design data for the slope work

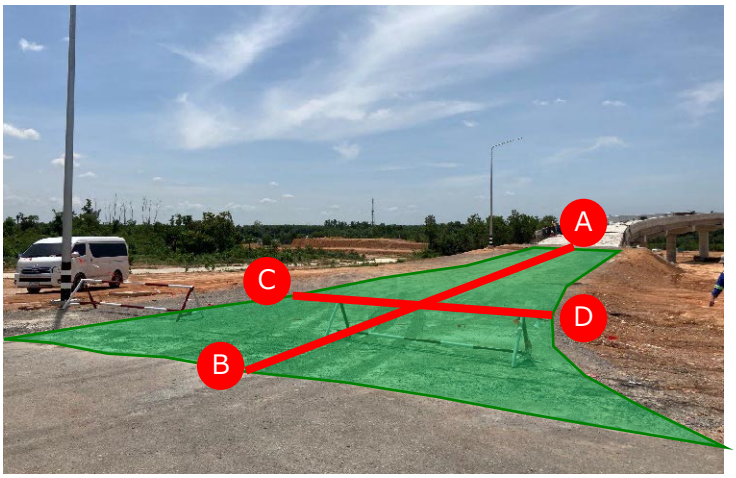


Figure 2-41 Subbase and paving work area

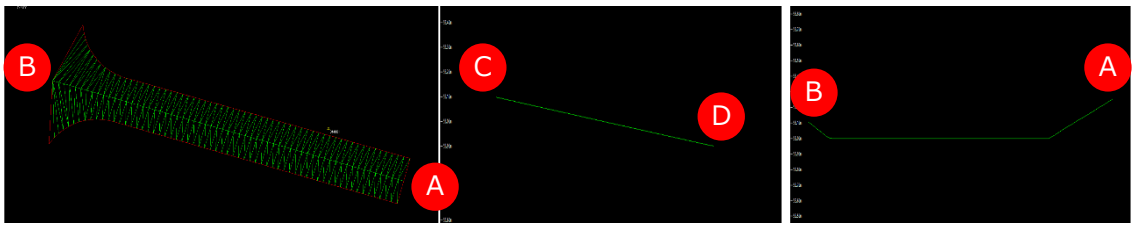


Figure 2-42 3D design data for the slope and paving work

2.1.2.Implementation

(1) Slope work

There was a regulating reservoir at the site, and the slope of the regulating reservoir was shaped using 3DMG backhoe system. In the conventional method, reference stakes are set to indicate the cutting position and the gradient and length of the slope for the operator before slope shaping. 3DMG backhoe system used this time has a GNSS receiver installed in the backhoe and obtains the coordinates of the bucket edge[8] through RTK real time positioning. Based on the bucket edge coordinates and the 3D design data, those differences are calculated and displayed on the display. The operator checked this displayed data and could operate the backhoe and shape the slope even without reference stakes.

Date:	Monday, April 25, 2022 - Wednesday, April 27, 2022
System used:	3DMG backhoe system
Design data:	3D design data for the slope work
Construction machine:	KOMATSU PC-200

The operation of the 3DMG backhoe system was checked before the slope shaping.

[8] The backet edge of backhoe.

With the check pile installed in the site at the cutting position, the bucket edge coordinates were confirmed to be appropriate.

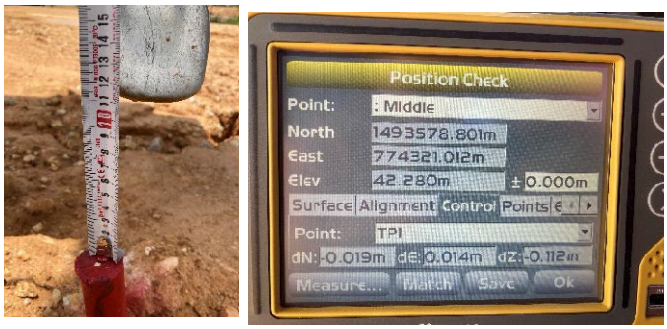


Figure 2-43 confirm of bucket edge coordinate



Figure 2-44 confirm of cutting position on the slope shoulder

After the instruction of 3DMG backhoe operation to the operator, the slope shaping work was started.



Figure 2-45 System instruction



Figure 2-46 Operation instruction



Figure 2-47 Slope shaping 1



Figure 2-48 Slope shaping 2

The slope shaping was performed smoothly without reference stakes.
Furthermore, it was found that omitting stake implementation could lead to reduced working hours.



Figure 2-49 After slope shaping 1



Figure 2-50 After slope shaping 2



Figure 2-51 After slope shaping 3

The subbase work was performed on the access road between facilities using 3DMC mmGPS motor grader system.
In conventional method, reference stakes should be set to indicate the target height for the operator. In the 3DMC mmGPS motor grader system used this time, GNSS receiver and a laser detector for improving height accuracy are installed on the motor grader, and horizontal coordinates are measured by RTK measurement and the elevation by laser measurement to obtain highly accurate blade edge[9] position data in real time. Then, the design gap is calculated from the blade edge position and the 3D design data, displayed on the monitor. And the blade edge height is adjusted by controlling the hydraulic valve so that the design gap will be zero. The operator checked this data and could shape the subbase while monitoring the design gap without reference stakes.

Date:	Friday, April 29, 2022 - Saturday, April 30, 2022
System used:	3DMC mmGPS motor grader system
Design data:	Surface layer 3D data
Construction machine:	VOLVO G930

The 3DMC mmGPS motor grader system was inspected before shaping the subbase.
After checked that there was no problem through the inspection, mmGPS laser transmitter[10] was set up in the construction site, and then the construction was started.



Figure 2-52 Pre-construction inspection



Figure 2-53 mmGPS laser transmitter



Figure 2-54 Start of the subbase work

To shape the subbase, crushed stones were spread and then cut off 8 cm. The operator could concentrate on checking the safety of the surroundings and the movement of the blade.
The subbase was shaped appropriately without reference stakes.
Furthermore, it was found that omitting stake process could lead to reduced working time and enhanced safety.

[9] Both ends of motor grader's blade.

[10] A type of rotating laser that emits a wide laser beam in the vertical direction.

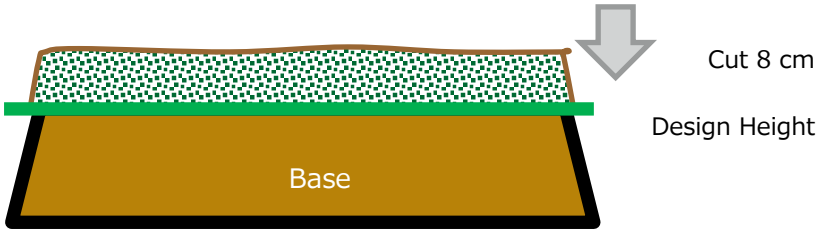


Figure 2-55 Grading crushed stones and shaping the subbase



Figure 2-56 Subbase work (Grading)



Figure 2-57 Subbase work (Operator)



Figure 2-58 Subbase work (Shaping)



Figure 2-59 Completion of the subbase work



Figure 2-60 Shaped subbase

After completing the work, the shaped subbase surface was checked. With conventional method, the checking can be conducted only at positions where the design height has been calculated beforehand. With the use of the 3D design data, however, the checking could be performed at any positions. This also turned out to contribute to the shortening of working time.



Figure 2-61 Grading check 1



Figure 2-62 Grading check 2



Figure 2-63 Grading check 3

(3) Paving work

The paving work was performed using the 3DMC mmGPS paver system on the access road where the subbase work was performed. In conventional construction, guidelines to show the reference height of the screed[11] were needed to set up before starting the paving work. In the 3DMC mmGPS paper system used this time, GNSS receivers and laser detectors for improving height accuracy are installed on the right and left edges of the screed, and the horizontal coordinates are measured by RTK measurement and the elevation by laser measurement. Thus, the real time positions of the right and left edges of the screed are obtained with high accuracy. Then, the design gap is calculated from the edge positions and the 3D design data, displayed on the monitor, and sent to the paver as height control data. With this height control data, the paving work was carried out successfully without the guidelines.

Date:	Monday, June 27, 2022
System used:	3DMC mmGPS paver system
Design data:	Surface layer 3D data
Construction machine:	Voegele Super 1803-2

A mmGPS laser transmitter was set up in the paving site, and the 3DMC mmGPS paver system was inspected. After checked that there was no problem, the paving work was started.



Figure 2-64 Subbase before being paved



Figure 2-65 mmGPS laser transmitter



Figure 2-66 Guide line

8-meter-wide lane was divided into two lanes, Lanes # 1 and #2, and paved 4 meter wide each.

[11] The part of a paver machine that paves the asphalt materials.

For paving Lane # 1, mmGPS was used on both of the right and left sides of the screed to precisely control the height. For Lane # 2, the height of the finished Lane # 1 as well as mmGPS on the opposite side were used to precisely control the height.

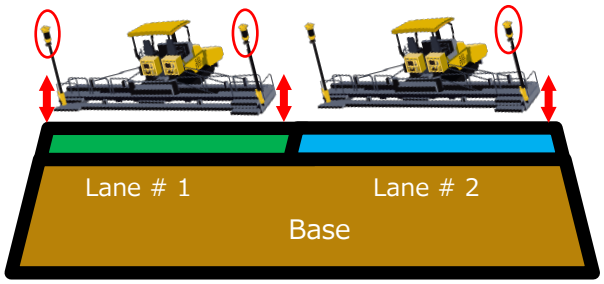


Figure 2-67 Height control for Lanes # 1 and # 2



Figure 2-68 Start of the paving



Figure 2-69 Paving of Lane # 1



Figure 2-70 Paving of Lane # 1 finished



Figure 2-71 Checking Paved height



Figure 2-72 Paving of Lane # 2



Figure 2-73 Paving of Lane # 2 finished



Figure 2-74 Compaction work 1



Figure 2-75 Compaction 2



Figure 2-76 Paving finished

The paving work was carried out successfully, revealing that the work can be performed smoothly without set up guidelines.
It was also found that omitting set up guidelines could lead to reduced working time.
Furthermore, it was found that without the guidelines set up around the feet, the safety and work efficiency are also expected to improve.

2.1.3. Results

It was confirmed that the use of the ICT construction was expected to have the following three advantages.

(1) Reduced working time

The construction workflow of the ICT construction is different from that of the conventional method in the following points. In conventional construction, the design data is presented in a form of a printed materials or printable CAD data. Then, reference stakes are set to indicate the design data in the field before starting construction. The quality and working time vary depending on the operator's skill, and construction works repeated of those process. On the other hand, in the ICT construction, design data is presented in a form of 3D digital data. Then, this design data is sent to the ICT construction machine, enabling the real time provision of operation instructions to the operator and the automatic control of the blade in operation.

Therefore, the process to install reference stakes to indicate the design data, which used to be required in conventional construction, can be omitted. Furthermore, construction checking is also performed simultaneously.

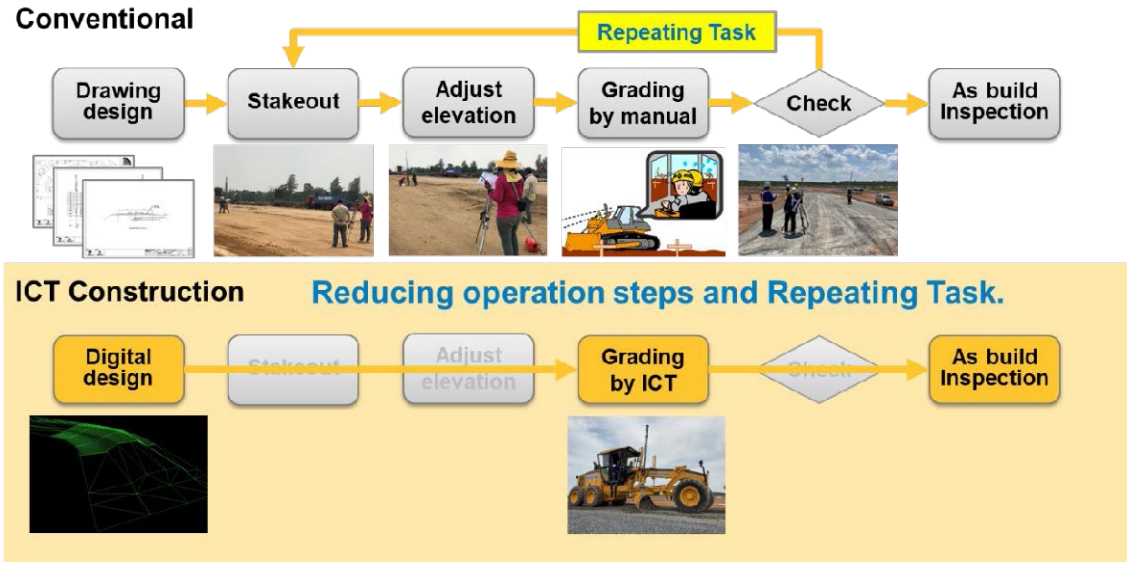


Figure 2-77 Comparison of construction workflows

The table below compares the workflows between conventional construction and the ICT construction for slope work, subbase work and paving work.

Table 2-4 Comparison of the workflow for slope work using 3DMG backhoe system

Workflow	Conventional construction	ICT construction
Design data	Printed materials or printable CAD data	3D data
Setting slope stakes	Required	Not required
Slope shaping	Shaped in accordance with slope stakes Operators intuitively slope construction between slope stakes.	Shaped in accordance with the displayed design differences The design differences can be displayed anywhere.
Checking	Required survey workers	Design differences can be confirmed anytime.

Table 2-5 Comparison of workflows for subbase work using 3DMC mmGPS motor grader system

Workflow	Conventional construction	ICT construction
Design data	Printed materials or printable CAD data	3D data
Setting reference stakes	Required	Not required
Subbase grading	graded in accordance with reference stakes Operators intuitively grade construction between reference stakes.	The system automatically controls the blades. Can be graded same level of quality anywhere.
Checking	Required survey workers	Design differences are always displayed on the monitor.

Table 2-6 Comparison of the workflow for paving work using 3DMC mmGPS paver system

Workflow	Conventional construction	ICT construction
Design data	Printed materials or printable CAD data	3D data
Setting guidelines	Required	Not required
Paving	Automatic control based on guidelines	The system automatically controls the screed.
Checking	Required survey workers	Design differences are always displayed on the monitor.

Using the ICT construction will cut the processes of setting slope or reference stakes and guidelines, and the project term is expected to be shortened. It is generally thought that a reduction of construction terms about 30% can be expected.



Figure 2-78 Shorten of project term

(2) Reducing initial implementation costs

It was confirmed that by receiving RTK correction data from NCDC, RTK positioning can be performed without the user having to prepare GNSS RTK base station.

If the user does not prepare GNSS RTK base station, it can be expected that the initial cost and maintenance cost required for GNSS RTK base station equipment will be reduced.

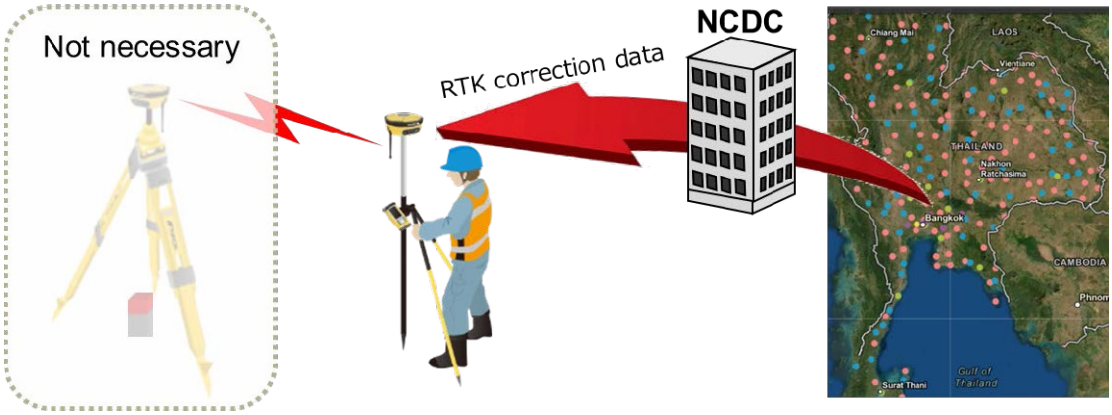


Figure 2-79 Reduce initial implementation cost

(3) Enhanced work safety

Since the work to set up reference stakes, which needs to be carried out in conventional construction, is omitted, contact accidents between workers and construction machines are avoided. In addition, this contributes to the prevention of infections including COVID-19 by reducing opportunities for workers to contact one another. The safety in the construction field is likely to improve as a result.

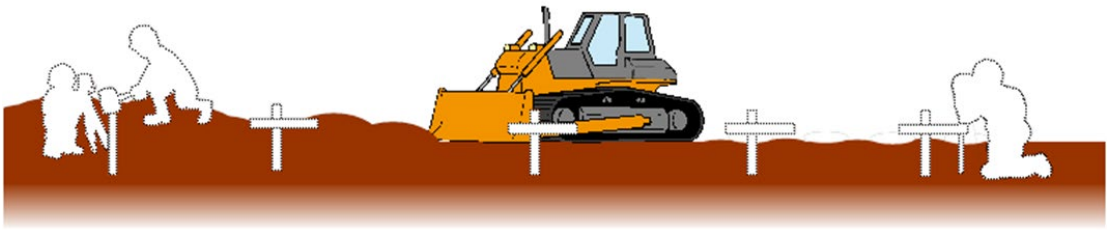


Figure 2-80 Enhanced work safety

2.2. Use of NCDC

2.2.1. Details of the NCDC data used

NCDC was used as follows.

Table 2-7 NCDC data used

IP address	118.174.12.3
Port	2101
Mount point	MAX_RTCM3(MSM)_UTM48 VRS_MSM5_UTM48 NB_RTCM3.1_UTM48
User name	togawa
Period of use	October 14, 2021 - October 14, 2021 April 1, 2022 - May 4, 2022 June 13, 2022 - June 30, 2022
RTK/ Post processing	Real time
Satellite systems used	GPS, GLONASS

2.2.2. Problems occured and solutions

In the NCDC data reception test on Thursday, October 14, 2021, large errors were found in coordinates measured by VRS-RTK. Therefore, the NCDC data reception test was conducted again.

In addition to VRS-RTK, measurement was performed by RRS-RTK and Local-RTK at the same time in this data reception test to confirm the stability of VRS-RTK.

Date:	Tuesday, April 26, 2022
Location:	ATTRIC
	Sanam Chai Khet District, Chachoengsao Province
Equipment:	Topcon HiPerHR (GNSS receiver)
	Topcon GR-5 (GNSS receiver)
NCDC:	IP Address 118.174.12.3
	Port number 2021
	Mount Point MAX_RTCM3(MSM)_UTM48
Observation points:	3 points in the site
Observation method:	RTK (Baseline 38 m)
	RRS-RTK (Baseline 10,640 m)
	VRS-RTK



Figure 2-81 Observation status

The simultaneous observations were continued for about 1 hour and 30 minutes, and the horizontal coordinates and heights measured by each method were recorded. The following figures show the results of the observations.

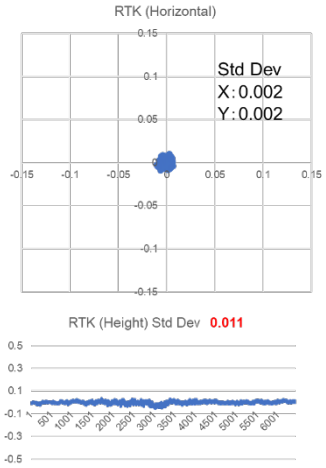


Figure 2-82 Results of Local-RTK

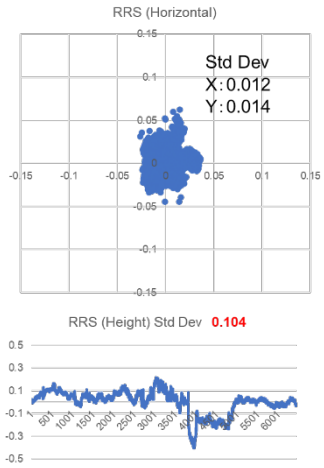


Figure 2-83 Results of RRS-RTK

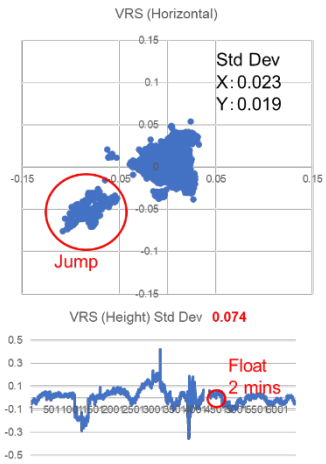


Figure 2-84 Results of VRS-RTK

The standard deviations in the RRS-RTK and VRS-RTK positioning were approximately 7 to 10 times larger than those in the Local-RTK positioning. In addition, in the VRS-RTK positioning, the solution resulted in float, and it found that jumps were occurred in the horizontal coordinates.

Results were reported to NCDC WG, then and 3 new CORS stations (BPLE, PNNK, SNCK) close to the construction site of use were added to the network for improvement.

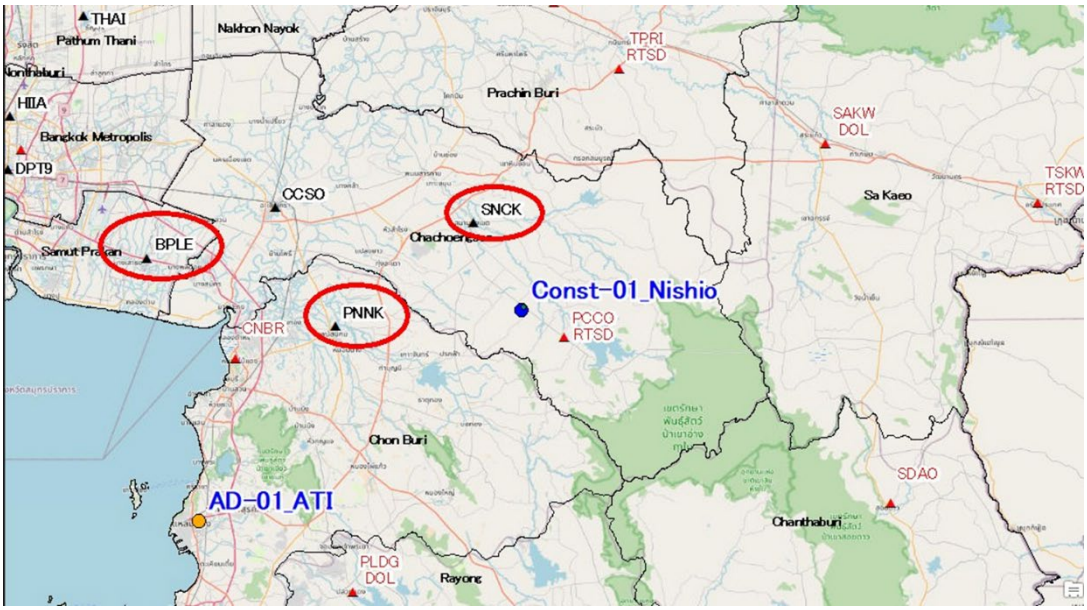


Figure 2-85 3 CORS stations added (Source from Open Street Map)

The NCDC data reception test was performed again with the improved network.

Date:	Thursday, June 16, 2022	
Location:	ATTRIC	
	Sanam Chai Khet District, Chachoengsao Province	
Equipment:	Topcon HiPerHR (GNSS receiver)	
	Topcon GR-5 (GNSS receiver)	
NCDC:	IP Address	118.174.12.3
	Port number	2104
	Mount Point	VRS_MSM5_UTM48
		NB_RTCM3.1_UTM48
Observation points:	3 points in the site	
Observation method:	RTK (Baseline 38 m)	
	RRS-RTK (Baseline 10,640 m)	
	VRS-RTK	



Figure 2-86 Observation status

The standard deviations in the RRS-RTK and VRS-RTK positioning were improved to approximately 5 times those in the Local-RTK positioning, and VRS-RTK positioning, fixed solutions were obtained constantly.

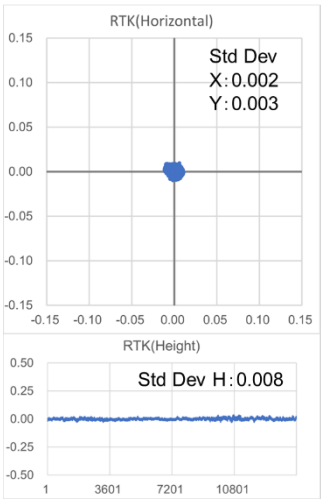


Figure 2-87 Results of Local-RTK

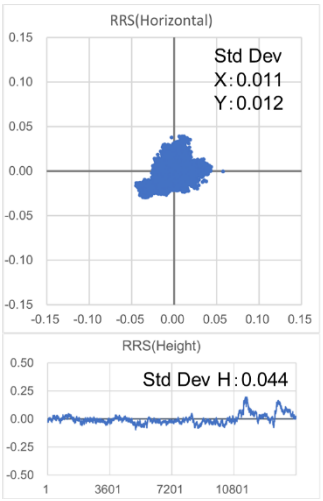


Figure 2-88 Results of RRS-RTK

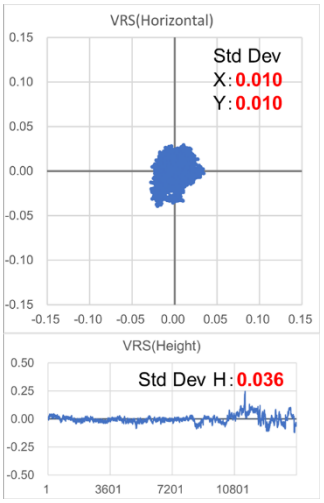


Figure 2-89 Results of VRS-RTK

This data reception test has verified that RTK positioning will be stabilized when the number of CORS stations increases in NCDC CORS network.

Continuous and stable RTK positioning is required for the ICT construction. Therefore, when using NCDC data to ICT construction, a reception test should be performed in advance to verify the stability of RTK positioning.

2.3. Other related activities

A site tour was held to introduce ICT construction and NCDC to government officials and private companies. A larger number of people than expected applied to the site tour, indicating a high level of interest. In the site tour, introduced ICT construction and NCDC were introduced, and ICT construction equipment actually used in this project was demonstrated.

Date:	Wednesday, June 22, 2022
Location:	ATTRIC
	Sanam Chai Khet District, Chachoengsao Province
Participants:	92 people
	Government agency 12 organizations
	Academic institution 2 universities
	Private companies 21 companies
Equipment:	Topcon GR-5 (GNSS receiver)
	Topcon 3DMG backhoe system
	Topcon 3DMC mmGPS motor grader system
	Topcon 3DMC mmGPS paver system



Figure 2-90 Presenters at the site tour



Figure 2-91 Scenes at the site tour seminar



Figure 2-92 Demonstration with real ICT Construction machines



Figure 2-93 Group Photo



Figure 2-94 Leaflet of this site tour (Source from Google Map in the right-side leaflet)

ICT Construction seminar was held at Kasetsart University for civil engineering graduate students, graduates, and general participants. Audiences were solicited as part of Kasetsart University's 20th anniversary event, and this seminar was attended by a larger number of people than expected. The seminar introduced ICT construction and NCDC / CORS network as well as new technologies used in ICT construction.

Nishio rent all & Topcon presented on ICT construction and prepared actual equipment for ICT construction, then explained more details to participants.

In addition, also prepared equipment such as GNSS, robotic total station and Laser Scanner that will be do hand-on session, participants experienced new ICT construction products.

Date : Saturday , September 9 2023
Location : Kasetsart University
50 Ngamwongwan Rd, Chatuchak Bangkok 10900 Thailand
Participants : 121 people
Government agency 9 organizations
Academic institution 2 universities
Private companies 4 companies
Equipment: Topcon HiPerHR (GNSS receiver)
Topcon LN-150 (Robotic Total Station)
Topcon GLS-2000(3D Laser Scanner)
Topcon IP-S3 (Mobile Mapping System)
TOPCON 3DMC/3DMG (Machine Control System/Machine Guidance System)

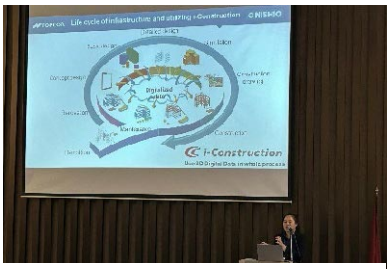


Figure 2-95 Explanation of ICT-Construction


Figure 2-96 Explanation of GNSS


Figure 2-97 Explanation of 3DMC


Figure 2-98 Explanation of 3D Laser Scanner


Figure 2-99 Explanation of MMS


Figure 2-100 Explanation of Robotic Total Station



Figure 2-101 Group Photo

3. Way forward

3.1. Future outlook of the business using NCDC

The advantages of utilizing NCDC data for users are that they do not need to make an initial investment necessary for the installation of GNSS RTK base stations and can cut working time. Users can easily understand the advantage of not requiring initial investment, since they need to initially make investments in the ICT construction machines for utilizing the ICT construction and want to keep the initial investment cost as low as possible. As for the working time, field workers who perform daily preparation work realize the advantage. In addition, not installing GNSS RTK base stations will bring about unexpected benefits: such as in the transportation of equipment and materials, charging of batteries, securing storage sites, and occupation of construction reference points.

Since ICT construction has not yet been introduced to the Thai market, we would like to first explain its benefits to private companies and construction companies and use it in promotional activities to introduce ICT construction. During the awareness promotion, we would like to look for users who are interested and who are willing to collaborate with us on trials, and we will make ICT implementation results with them. At that time, we would like to consider renting ICT construction equipment and providing technical support as a means of reducing initial investment. We believe that it will take time for ICT construction to become commonplace, but we hope that it will gradually become more widespread ICT construction as the working population decreases, NCDC becomes more common, and human resources development progresses.

3.2. About NCDC

1) Good points using NCDC

There were three main advantages of using NCDC.

(1) Not requiting GNSS RTK base stations

Since it was not necessary to establish GNSS RTK base station, the initial investment cost and working time for the installation of the GNSS RTK base station were cut out.

(2) Not requiring radio equipment

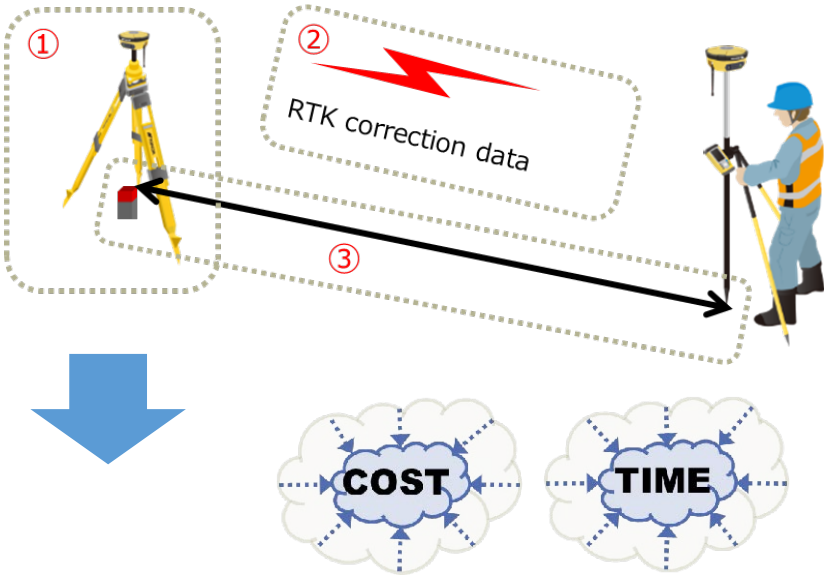
Since there is no need radio equipment to send/receive RTK correction data, costs can be reduced and the risk of radio interference can be eliminated.

(3) Applicable in a wide area

Since NCDC can be used wherever mobile networks are available, there was no need to take into consideration buildings or terrain that could interfere radio waves.

Case of without using NCDC data

① Set up GNSS RTK base in the construction aera.
② Transmit GNSS correction data from GNSS RTK base to RTK rover.
③ Take into consideration buildings or terrain that could interfere radio waves.



Case of using NCDC data

① No need to set up GNSS RTK base in the construction aera.
② Can receive GNSS correction data via mobile network.
③ No need to take into consideration buildings or terrain that could interfere radio waves.

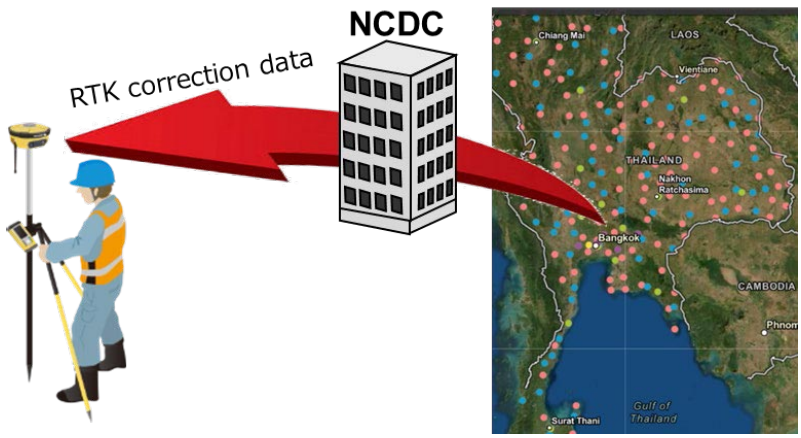


Figure 3-1 Advantages of using NCDC

2) Issues to be solved

NCDC is indispensable infrastructure for Thailand to develop further. In order to make NCDC available to as many users as possible, the following three points should be covered.

(1) NCDC data should be available anywhere in Thailand

Construction work is being carried out in various locations in Thailand.
CORS do not cover all of Thailand. By increasing the number of CORS and making it available anywhere in Thailand, it is expected that the number of users using NCDC will increase.

(2) GNSS correction data should be available at any time in a stable

Construction work is carried out day and night depending on the site environment and conditions. It is necessary to solve the problem that accuracy getting worse depending on the time of day. It is expected that the number of users using NCDC will increase when it can be used with stable accuracy at any time.

(3) Creating the ICT construction opportunities for everyone

The site tour and the ICT construction seminar have revealed the high interests in it, the reality is that ICT construction has not been introduced yet in Thailand (Only a few cases have been used in Thailand). If the ICT construction opportunities are provided cooperate from Government/Private/Academic sectors, the number of GNSS used case will increase, and NCDC users will also increase accordingly.

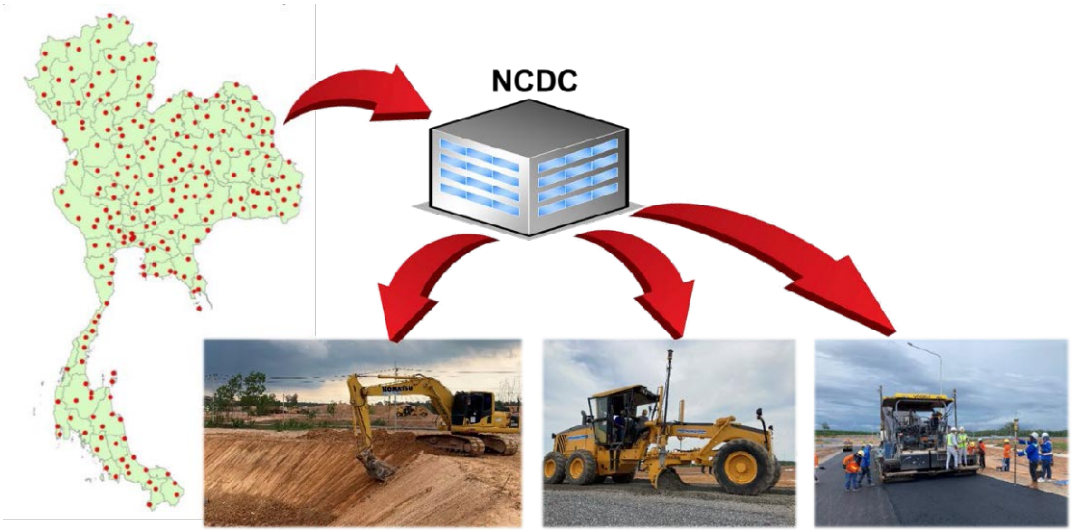


Figure 3-2 Case of using NCDC DATA to the construction sector

3) Request for improvement

At construction sites, constantly stable positioning is required. The GNSS data reception tests conducted this time confirmed that increasing the number of reference stations (CORS base stations) in the VRS network increases stability. Although, it is difficult to increase the number of CORS stations immediately, the desirable way is to increase the number of CORS stations starting with areas where periodic maintenance is required, such as areas where large-scale construction work is underway, airports, and highways.

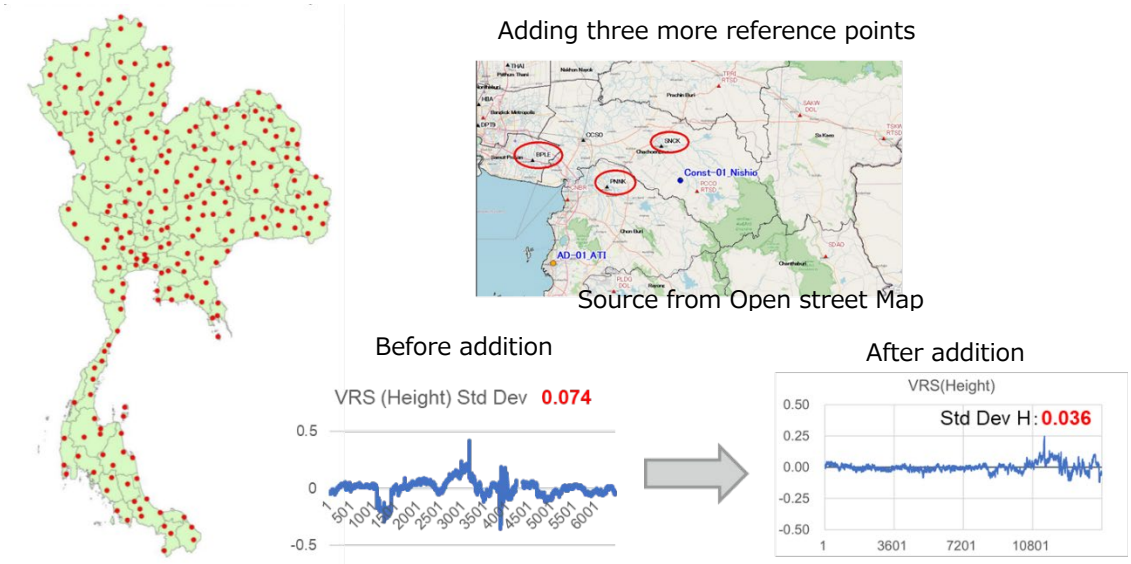


Figure 3-3 Effects of increasing CORS stations

4. Conclusion

In this pilot project, the ICT construction was performed using GNSS correction data distributed from NCDC, and the difference in work efficiency from conventional construction was evaluated. In conventional construction, reference stakes should be placed to indicate the design data before starting the construction. Furthermore, the construction status should be checked during work manually. The construction and checking are carried out repeatedly, and this repetitive work depends on the skill of operators. On the other hand, in the ICT construction, since the design data is registered in the ICT construction machine, the staking process for indicating the design data can be omitted. In addition, since checking is carried out at the same time while the construction work is in progress automatically, repetitive work does not occur. This shows it is expected that the reduction in working time for the staking will shorten the construction term. The ICT construction is expected to work effectively in solving conceivable problems of decreasing working population and lack of skilled operators in Thailand. The more the ICT construction is applied, the more people use NCDC, and that will expand CORS network. We are confident that this continuous positive spiral will promote the infrastructure development in Thailand while bolstering the productivity of construction work, and that the Thailand 4.0, Thailand policy, will be achieved as a result.
In order to spread the ICT construction, which is the catalyst for this positive spiral, we consider it is essential to deepen the understanding about the ICT construction by establishing systems under the support from the government and by developing human resources. We will continue initiatives to raise awareness about the ICT construction to contribute to the spread.

In conclusion, we would like to express our heartfelt gratitude to The Nippon Road Co., Ltd. and Thai Nippon Road Co., Ltd., which have provided significant cooperation in implementing this pilot project.

End of Report

The project for capacity development and promotion of utilization of National CORS Data Center

JICA Pilot Project

Implementation Report

November 2023

BIOMATLINK CO., LTD.

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1. Overview of the pilot project

1.1. Name of the pilot project

EN: Using NCDC* to increase the product yield in supply chain management in the cassava industry

TH: การใช้ NCDC* เพื่อเพิ่มผลผลิตในการจัดการห่วงโซ่อุปทานในอุตสาหกรรมมันสำปะหลัง

1.2. Background and purpose of the pilot project

Cassava is one of main economic crop for Thailand. It is harvested and produced from area covering around 8.75 million [Rai] with production capacity of 31.104 million tons. Therefore, the production of cassava per [Rai] is 3.56 tons. From 2019-2020, it is reported that the production area of cassava in Thailand increases gradually but the production per area [Rai] also gradually decrease around 1 percent also. Thus, agricultural precision technology is needed to manage the growth quality of cassava, the harvesting and logistics from cassava farm to factory.

The pilot ideas for utilizing the Data from NCDC for cassava farming by developing the BIOMATLINK-BOX module that receive and incorporate the data from NCDC in order to utilizing the high precision for smart cassava farming application. Then, the data will be collected and analyzed in data management system in cloud database server for whole chain total solution of cassava plantation from the field as “Whole Chain Total Solution,” where the data will be collected from planting stage to harvesting stage.

Therefore, the scope of our pilot project to implement NCDC data can be divided into 3 main stage, which are (1) planting stage (2) treatment stage, and (3) logistic stage where the planting stage will use NCDC data along with GNSS receiver in cassava farming activities such as specify the cassava plant location during planting or even tracking the route path of the tractor by mean of high precision point from NCDC through GNSS receiver. Thus, near-real time farm data visualization and monitoring will develop to display the data.

As for the treatment stage, the high precision from planting stage can be used for fertilizing, surveying, and treatment cassava. The NCDC data will be used for navigating to the cassava location for treatment services such as fertilizing, health checking, and data collecting. All data collected in this stage will be visualized in the central monitor.

In logistic stage, harvested cassava transportation at the purchasing point and tracking of truck route will implement the NCDC data to manage the logistics of the fleet for estimation of cost and time for efficient transport of cassava. In addition, the application for tracking and notifying along the transportation process will be developed when the truck arrives at the specific area, it will be alert to the driver or central monitor.

The outcome of the pilot project is the data that can provide yield increased from the use of these services and can be used to inform the estimated earnings on the day of harvesting. Thus, the whole value chain of smart farming can be realized by the implementation of NCDC data.

1.3. Brief description of the pilot project

To develop the module named BIOMATLINK-BOX that used NCDC data in supply chain management from the planting stage to harvest logistic stage. Data from all stages will be collected and displayed on sever dashboards.

(1) Planting Stage: used NCDC for identifying the cassava tree location, tractor route, count the cassava tree and estimate the yield in the field.
(2) Treatment Stage: used NCDC for navigating to the cassava tree for treatment service and data collection.
(3) Logistic Stage: used NCDC for tracking the harvested cassava in our own digital purchasing point area.

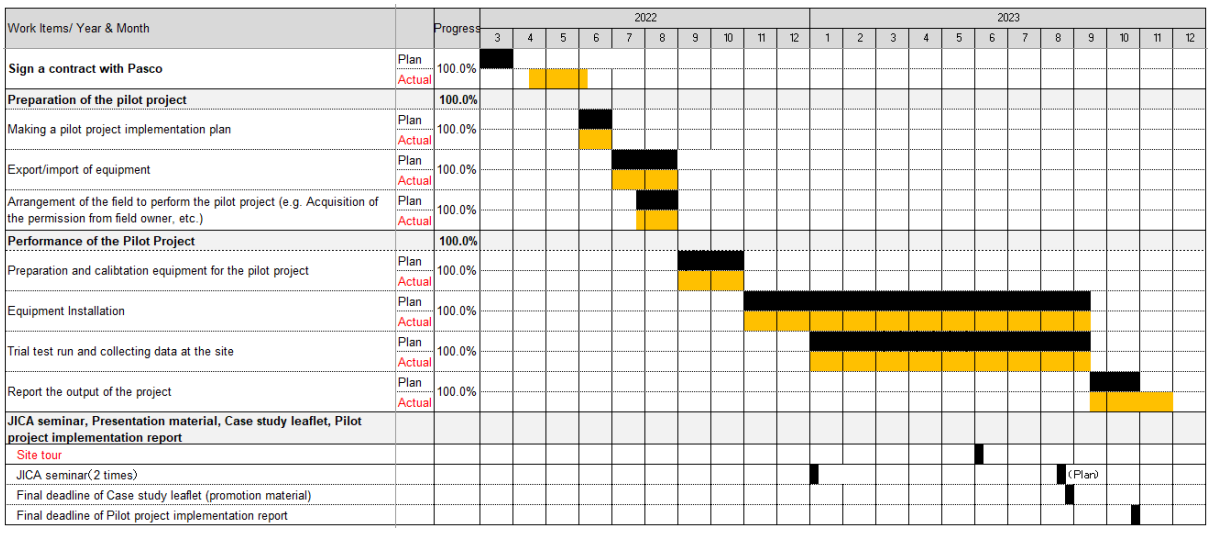
1.4. Implementation period

Preparation: JUN 2022 – MAR 2023

Work at the site: JAN 2023 – OCT 2023

Reporting: SEP 2023 – NOV 2023

Table 1-1 Plan and actual of the schedule



1.5. Location of the pilot project site

Address: BIOMATLINK DIGITAL PURCHASING POINT, 449/1 Moo 3, Tung Pra Ya sub-district, Sanam Chai Khet district, Chachoengsao province 24016

Google Map URL: https://maps.app.goo.gl/ZoZodx65LGUnFbLZA

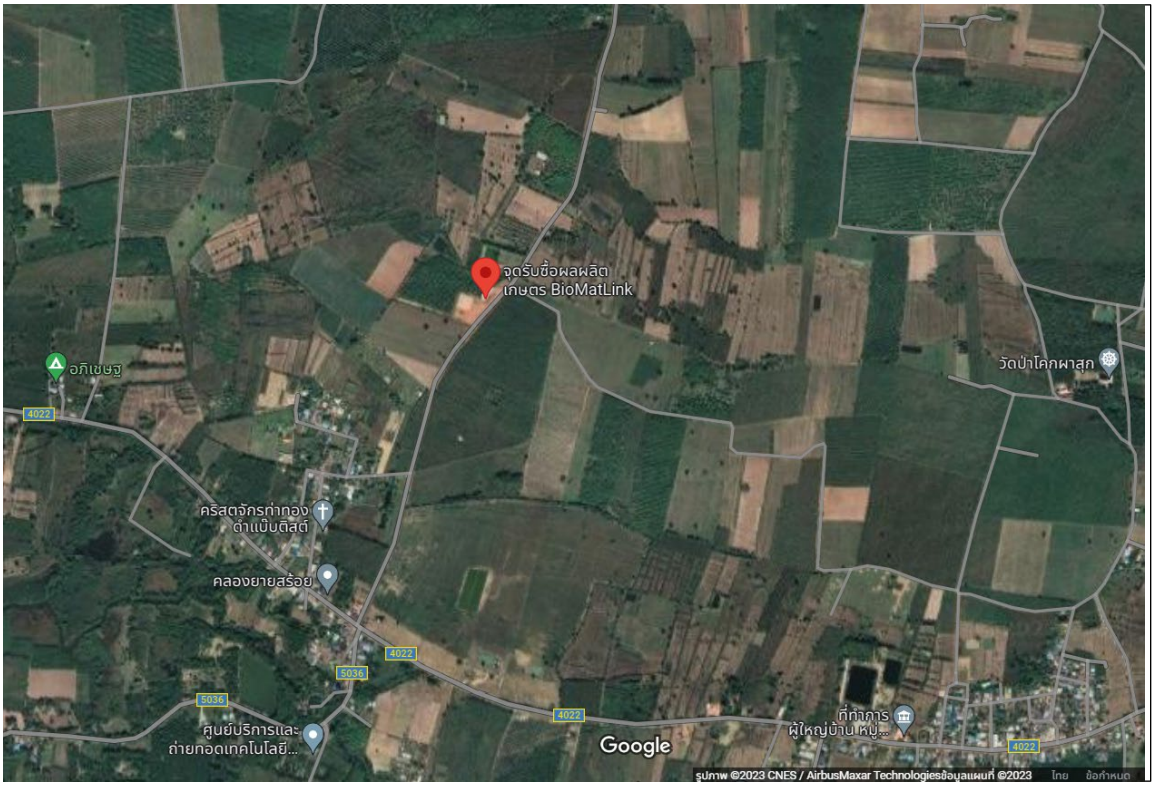


Image Source: Google Maps

Figure 1-1 Location of the pilot project site

1.6. Members/ Technical instructors

The members listed below performed the pilot project.

Table 1-2 List of members/technical instructors

NO.	Name	Company	Role
1	Dr. Thanika Chintanapunt	BIOMATLINK Co., Ltd.	Project Owner
2	Mr. Chaiwat Bootchai		Technical Leader/ Project Manager
3	Mr. Surached Teebuaban		Operation Engineer
4	Ms. Walaiphan Wattanabenjaphat		Project Coordinator
5	Mr. Nisit Chobdamrongtham		Project Coordinator
6	Mr. Nattayut Phengcharoon		Logistic
7	Mr. Nonthawat Kittiwatcharapong		Data Collection
8	Mr. Karintorn Srichankum		Data Collection
9	Mr. Narat Kilnchajon		Farmer Coordinator
10	Dr. Suparat Bootchai	Technical Education, Rajamangala University of Technology Thanyaburi	Research Consultant
11	Mr. Pharan Chawaphan		Mechatronics Consultant
12	Mr. Tawan Katduang		Electrical Device Consultant
13	Dr. Ananchai Ukaew	DRIVE Center, Naresuan University	Consultant of Connected Vehicle technology, Robot Farming
14	Mr. Prasert Wiangsukphaiboon	Nakra Microtek Co.,Ltd.	Consultant of GNSS RTK products R&D include Low cost RTK survey rover, RTK base station, supported QZSS, GPS, Glonass, Galileo.

1.7. Equipment used for the pilot project

For the pilot project we developed two BIOMATLINK-BOX to solve our problems. The equipment listed below was used for the pilot project.

Table 1-3 List of equipment used.

NO.	Name	Quantity	Remarks (specifications, usage, etc.)
1	Pocket WIFI + SIM CARD	2	
2	Yearly sim card	2	
3	Battery	8	
4	Battery board	4	
5	Mini fan	6	
6	Step down dc-2-dc	2	
7	Power switch	2	
8	IR Sensor	2	Detecting the cassava tree
9	Cassava tree planter machine	1	Tractor equipment for ridging tillage with planting the cassava tree
10	Node MCU v2	4	Communicate between RTK module
11	U-Blox GNSS module	2	Antenna
12	GNSS RTK Module	2	PANTAI RTK – PRML2
13	Miscellaneous	2	

2. Details of the work

2.1. Work performed

2.1.1. Preparation

To perform the pilot project work, we had prepared the following sections: BIOMATLINK-BOX, Planter Machine, Central Monitor, and Pilot Field Area.

BIOMATLINK-BOX

To make use of the NCDC data, we developed a device named BIOMATLINK-BOX for receiving the precise coordinate data from NCDC and transmitting coordinate data to our cloud database then displaying the device status. The main component of BIOMATLINK-BOX contains (1) GNSS RTK Module that can communicate to NCDC, (2) GNSS Antenna which is installed on the tractor or tripod for route tracking, (3) Node MCU which is the IoT programmable device for communicating between RTK Module via REST and central monitoring via API, and (4) the cassava tree counter sensor (optional) which is the optional when the job needs to count the cassava tree then we can connect the sensor to the BOX. All components are shown in Figure 2-1. And the example of developed BIOMATLINK-BOX module is shown in Figure 2-2.

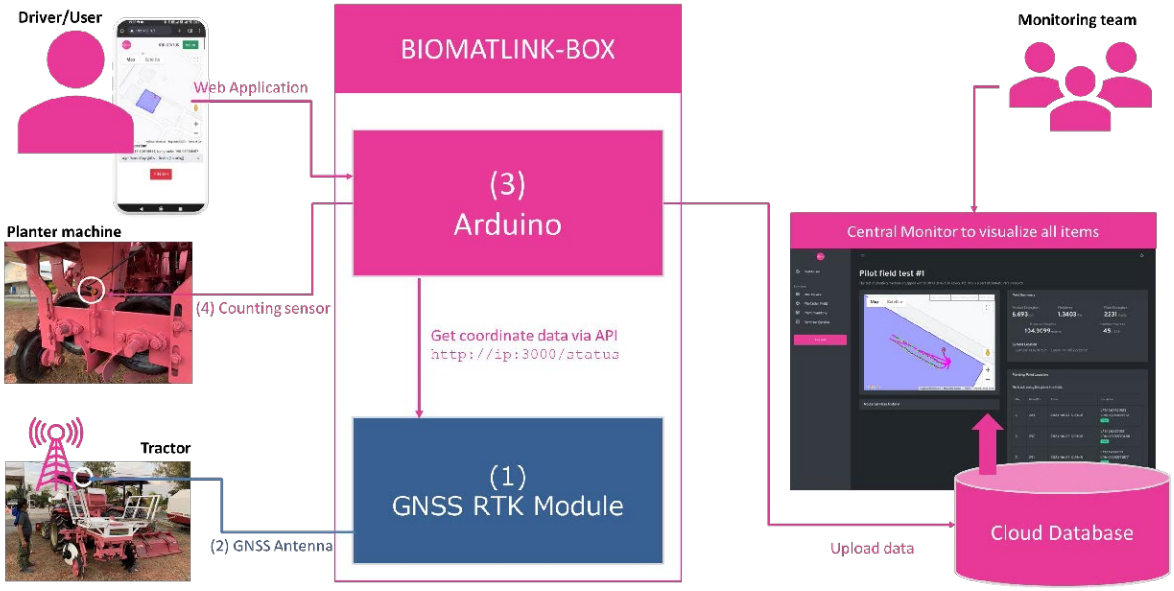


Figure 2-1 BIOMATLINK-BOX components.



Figure 2-2 BIOMATLINK-BOX module.

Planter Machine

We developed the ridge tillage with cassava tree planter machine that can be equipped to any tractor as shown in Figure 2-3.



Figure 2-3 Developing the ridge tillage with cassava planter machine (planter machine).

This machine will connect with the tractor like the sugarcane planter, but it is designed for cassava planting. To receive the NCDC data, we must install the antenna of BIOMATLINK-BOX on the tractor and if we want to count the cassava tree, we must install the cassava tree counter sensor on the planter machine.

A.



B.



Figure 2-4 (A) Installing the antenna of BIOMATLINK-BOX on tractor, and (B) Installing cassava tree counter sensor of BIOMATLINK-BOX on planter machine.

Central Monitor

We developed the central monitoring of the data collected from BIOMATLINK-BOX at https://senku.biomatlink.com. Once the BIOMATLINK-BOX is active, it will be sent the device status and location data to the could database via API. Then the dashboard will visualize the data that is stored on cloud server as shown in Figure 2-5.

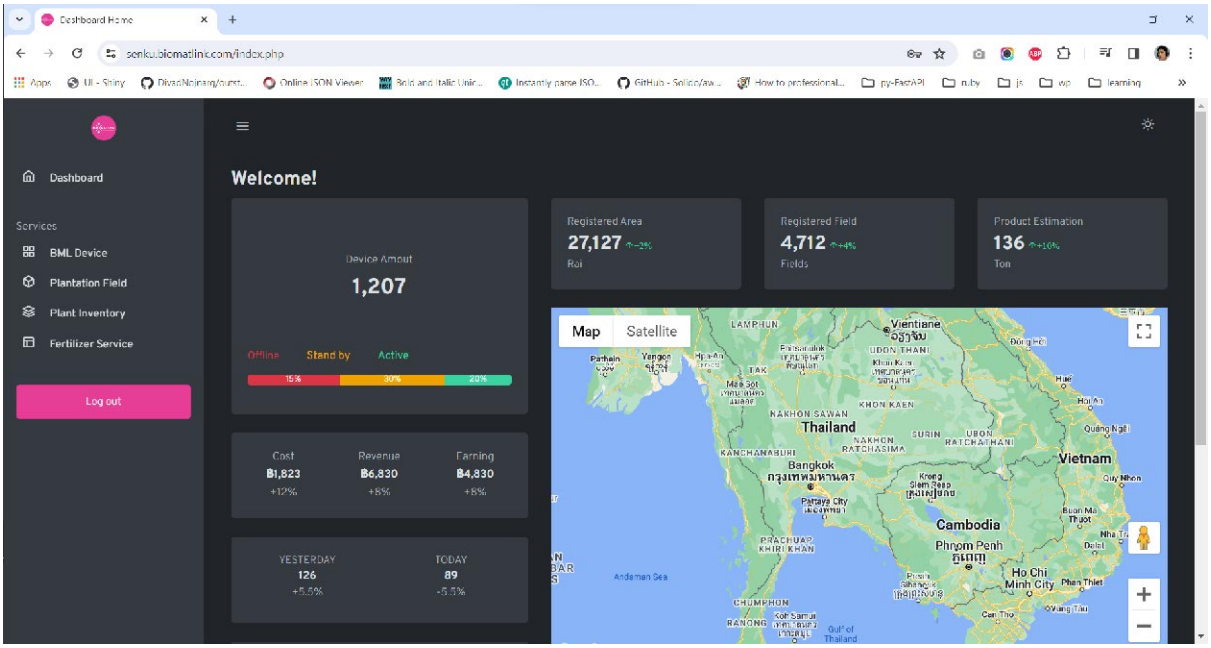


Figure 2-5 Central monitor dashboard site.

Pilot Field Area

We had 2 sites for comparison on the same pilot site area. (1) Conventional field which used of conventional method survey by using mobile GPS device, and (2) BIOMATLINK field which used of NCDC data. Both sites used 1 rai area for cassava planting. The arrangement of the field area is shown in Table 2-1.

Table 2-1 Field arrangement.

Conventional Field	BIOMATLINK Field
• Soil preparation • Cassava cutting preparation • Ridge tillage • Planting cassava by human	• Soil preparation • Ridge tillage + Planting cassava tree by planter machine
Humans collect the coordinate by using Mobile GPS	BIOMATLINK-BOX receive the coordinate location from NCDC CORS

We started land clearing from the rubber tree forest in January 2023. Then, prepared soil preparation for the cassava field in April 2023, and started planting in May 2023. All pilot field areas are located in the BIOMATLINK Cassava Demonstration Field. The conventional field (A) and BIOMATLINK field (B) are shown in Figure 2-6, they are on the same area of 1 Rai.

The BIOMATLINK's Cassava demonstration field (C) in Figure 2-6 is the cassava planting field before applying the NCDC. This field was prepared for research and demonstration to the farmers in Sanam Chai Khet sub-district. We used this area under different conditions of treatment. This area is split into 6 fields of 1 Rai each.

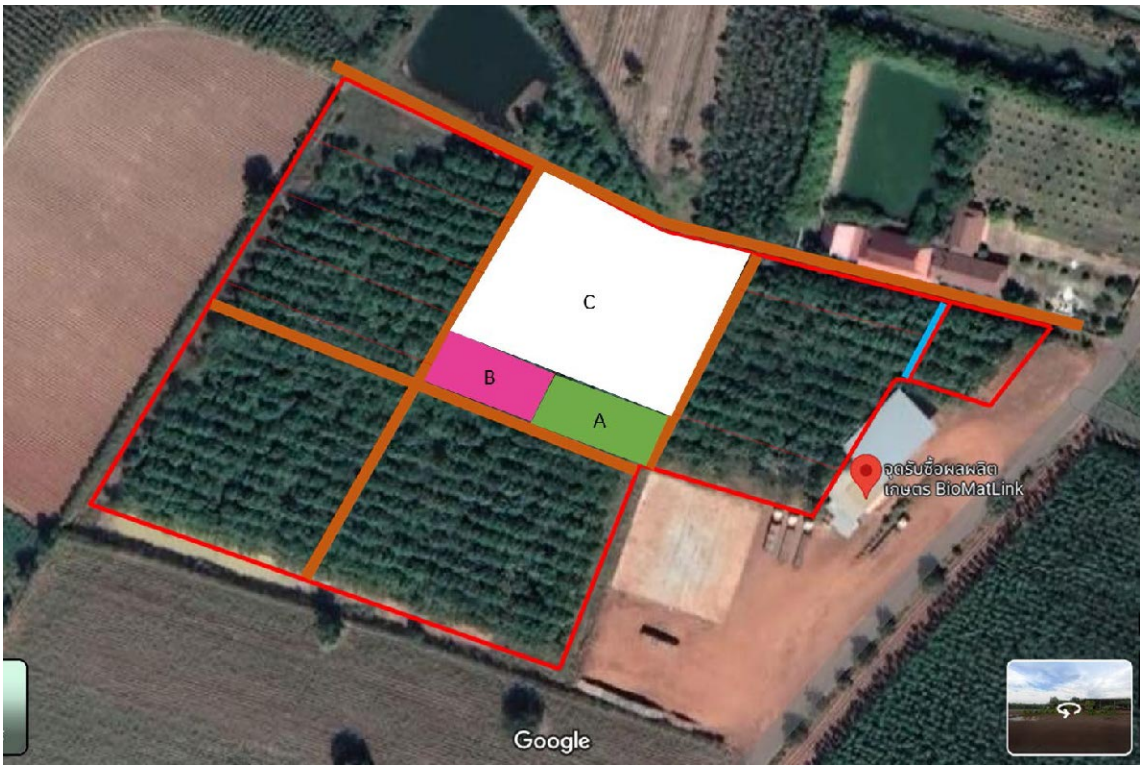


Figure 2-6 Pilot field area (A) Conventional field (B) BIOMATLINK field, and (C) BIOMATLINK's Cassava demonstration field.

2.1.2. Implementation

We implemented this pilot project by applying the BIOMATLINK-BOX that used NCDC data along in the supply chain into 3 stages: (1) Planting Stage (2) Treatment Stage, and (3) Logistic Stage. The BIOMATLINK-BOX had a user interface for interacting and communicating with the central monitor. For each stage, we used central monitoring to visualize the coordinates data from BIOMATLINK-BOX. The overall use of NCDC data by BIOMATLINK-BOX and its' application is shown in the following Figure 2-7.

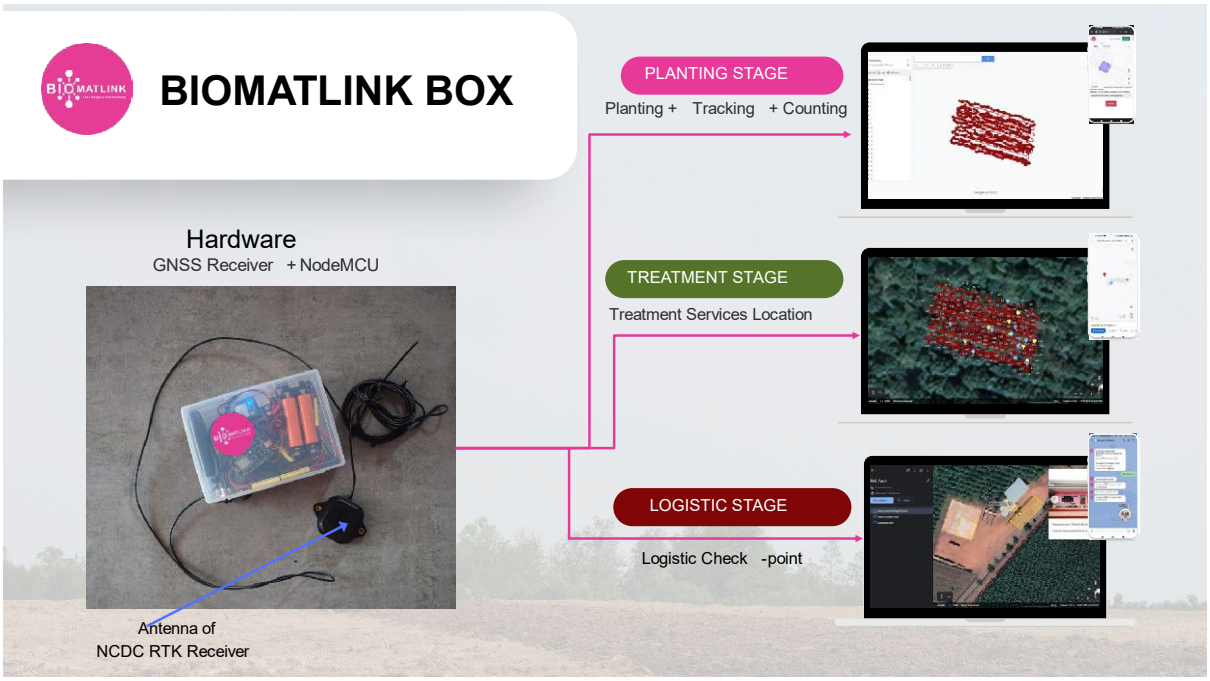


Figure 2-7 The use of NCDC data by BIOMATLINK-BOX in each implementation stage.

(1) Planting Stage

We equipped the BIOMATLINK-BOX with the cassava tree counter sensor into the planter machine and put the GNSS antenna on the tractor. Then we set up the working field on web application in the mobile phone that connects to the BIOMATLINK-BOX. The tractor driver pressed the start button on the web application and then started cassava planting. The web application of BIOMATLINK-BOX is shown as BIOMATLINK BOX Interface in Figure 2-8, and the setup of this stage is also shown in Figure 2-8.

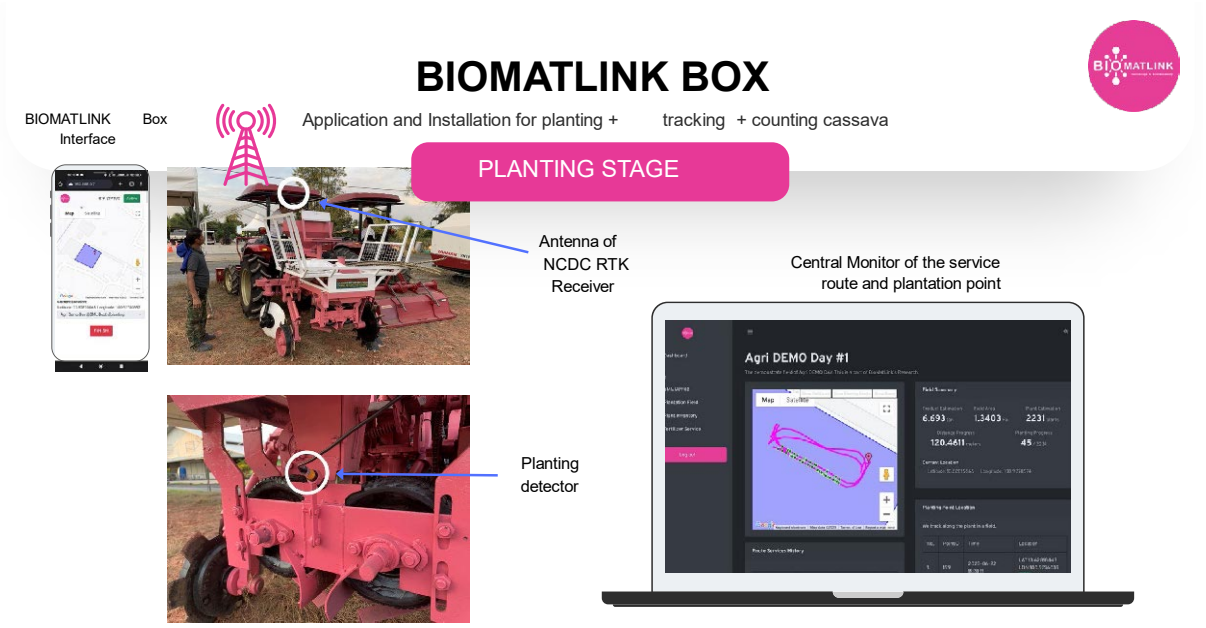


Figure 2-8 The use of NCDC data for planting stage.

In this stage, the BIOMATLINK-BOX communicates with the GNSS receiver to get the data from NCDC and then transmits the data to the cloud database. The data that this stage collected are:

- *Route coordinates.* It will be shown as a near real-time working route path on the central monitor.
- *Planting point coordinates.* They represent the cassava tree location stored as latitude and longitude when it was planted. The cassava tree location will be shown as a near real-time green dot over the route path on the central monitor. These coordinates will be counted as planted cassava for yield estimation on the central monitor.
- *Planting point locations.* They are labeled cassava trees by number. This will guide the treatment team in the treatment stage for cassava services.

Once the planting machine is working, the central monitor will calculate the useful information for the monitoring team. The calculated data attributes are:

- *Planting progress*. We had pre-calculated the number of cassava trees by area, thus in the central monitoring we can show the planting progress for the monitoring team.
- *Distance progress*. From the coordinates data, we can calculate the working distance of our driver as well.
- *Yield estimates*. Once the cassava is planted, we can calculate the yield estimates for our monitoring team. This will be summarized for the whole cassava field that we managed.

All visualized items were shown in the central monitor developed by BIOMATLINK team. The sample of central monitor screen is shown in Figure 2-9.

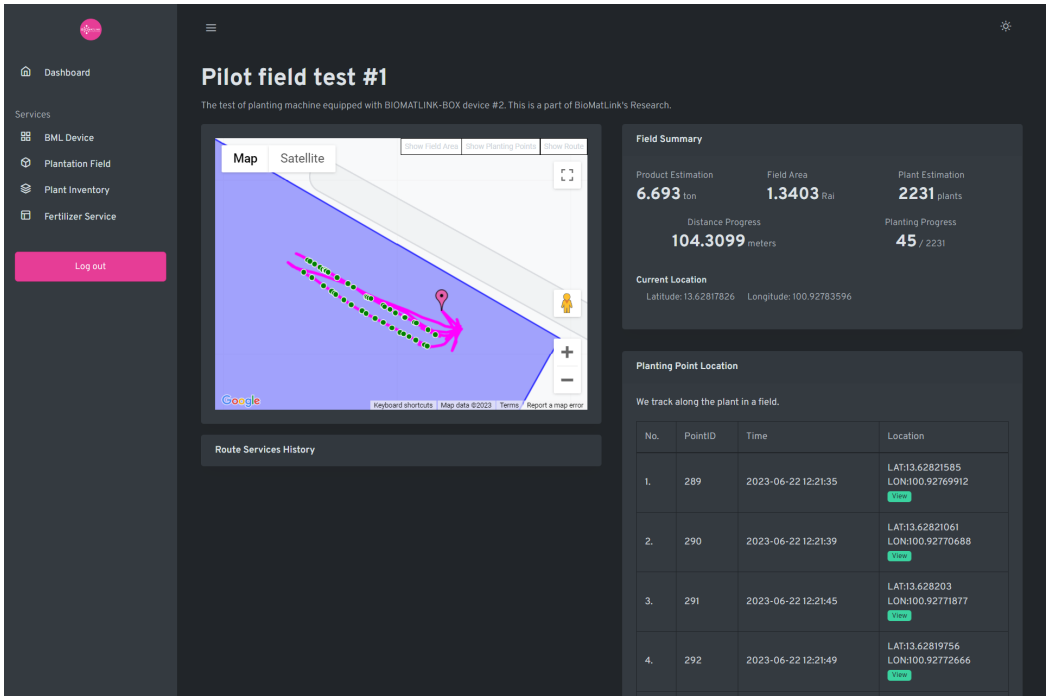


Figure 2-9 The central monitor displays tractor and cassava planting locations from BIOMATLINK-BOX.

(2) Treatment Stage

The ideal for this stage is to navigate to the assigned cassava tree location for treatment, data collection, and health monitoring. From the planting stage, we already had the precise cassava planted location. To increase the yield of cassava, we have to make sure that the growth of cassava will grow properly. Thus, the treatment team has to survey and collect the data in the cassava field for health and treatment monitoring.

In this stage, BIOMATLINK-BOX will be used to represent the treatment team to navigate to the randomly assigned cassava location point. Once finished the setup of BIOMATLINK-BOX is shown in Figure 2-10, the treatment team will connect the web application via mobile phone to the BIOMATLINK-BOX that will use the NCDC data as a point for navigating to the cassava location.

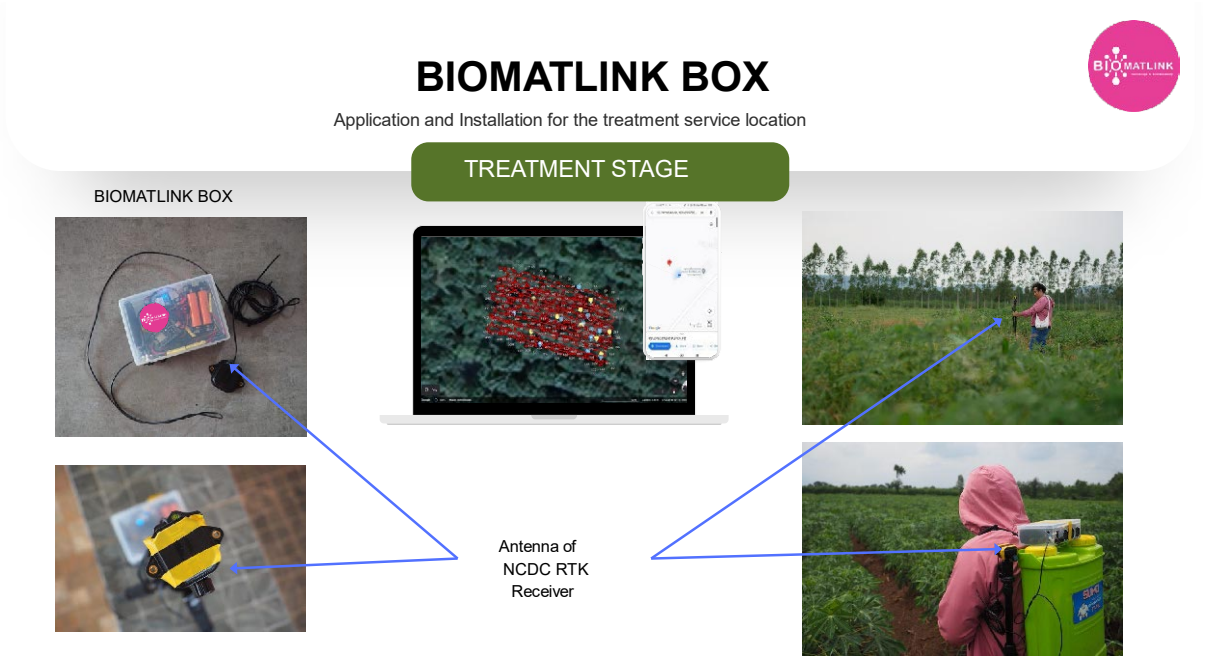


Figure 2-10 The use of NCDC data in the treatment stage.

Figure 2-10, The installation of BIOMATLINK-BOX, tested, and used in treatment services. Our treatment team could go to the randomly assigned location of the cassava plants to check their health and collect data including providing fertilizer. When guided by the application, the treatment team can work properly in the field boundary.

The treatment team will fill in the treatment form and then submit the data in the application. Thus, we can see the overall cassava health via the visualized application as shown in Figure 2-11.

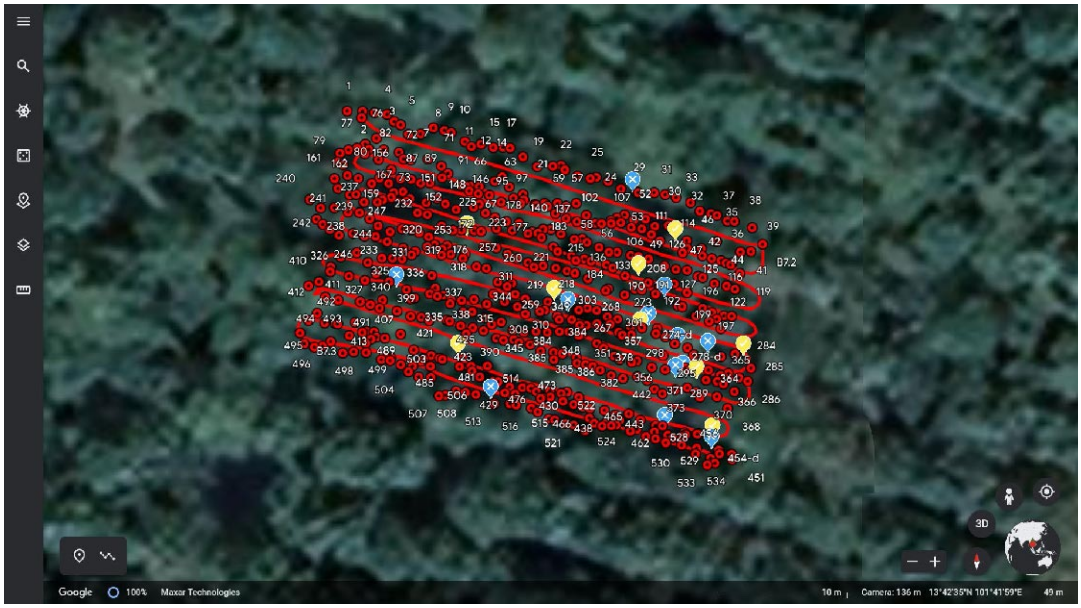


Figure 2-11 The record of cassava locations in the BIOMATLINK field.

(3) Logistic Stage

In the logistic stage, we tested by establishing the check-in area at the BIOMATLINK digital purchasing point station (pilot site). The check-in areas are (1) Queue area (2) Weight measurement area, (3) Cassava dump area, (4) Repeat the weight measurement area for calculating the total of harvested cassava. The designed workflow and application are shown in Figure 2-12.

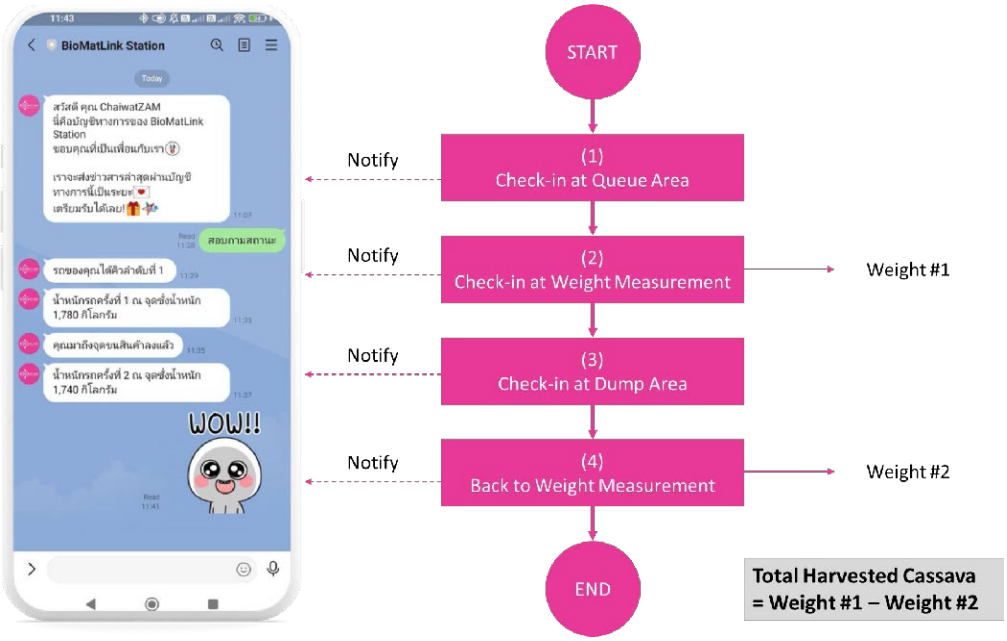


Figure 2-12 The designed workflow and application of the logistic stage.

To calculate the total harvested cassava, we employed the following equation:

$$\textit{Total Harvested Cassava} = \textit{Weight Before Dump (Weight \#1)} - \textit{Weight After Dump (Weight \#2)}$$

The weight before dump (Weight #1) was obtained from step (2) in Figure 2-12, while the weight after dump (Weight #2) was acquired from step (4) in the same figure. The program then automatically calculated the total harvested cassava, ensuring an efficient and accurate determination of the harvested cassava weight.

The NCDC data in this stage is used to represent the tracker for each check-in point area. When the seller drove the truck through each stage, the program listener will send the notification to the seller via callback service. We used the LINE application as a communication application between the seller and the BIOMATLINK team.

For testing, we used the harvested cassava of about 40 kg and a tractor in the workflow process. We installed the BIOMATLINK-BOX module on the tractor and the antenna on the top roof of the tractor. Then our team drove the tractor along to each point area. Once the tractor is in the check-in boundary, the notification will sent to the driver as soon as possible.

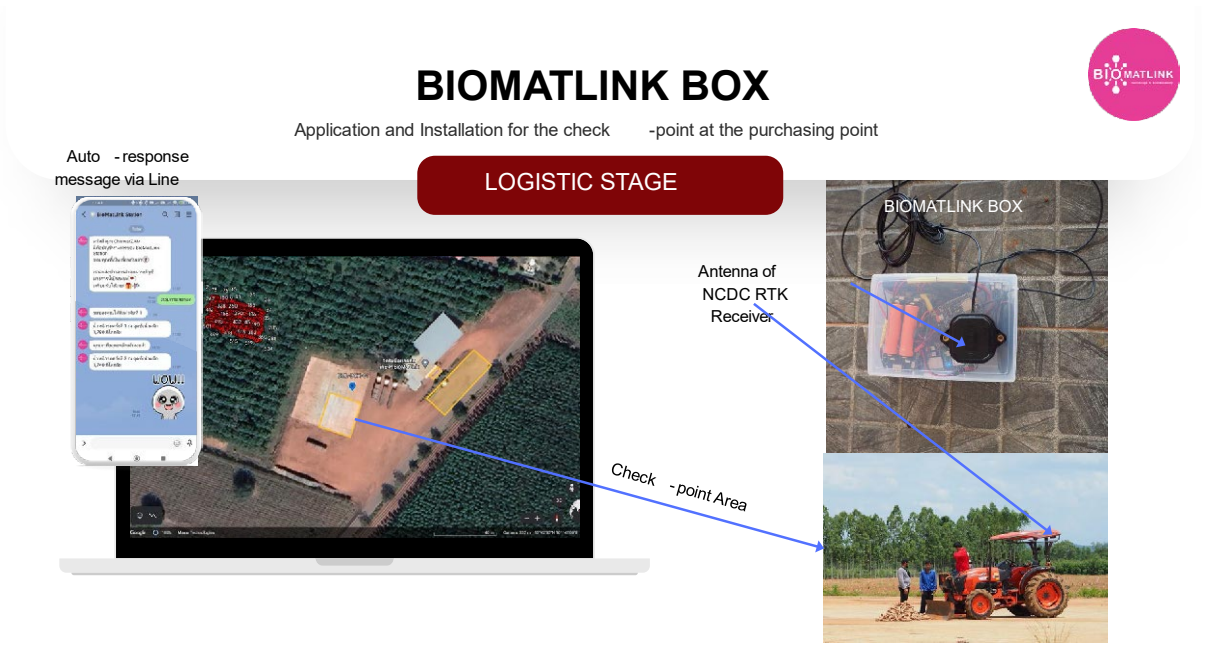


Figure 2-13 The use of NCDC data in the logistic stage.

In this stage, the NCDC data from BIOMATLINK-BOX could represent the tractor and coordinate as well as shown in Figure 2-13.

2.1.3. Results

(1) Planting Stage

In the planting stage, the results of the use of NCDC data compared to Mobile GPS data in the BIOMATLINK Field and conventional field are shown in Figure 2-14. We found that the accuracy of coordinates from NCDC was better than using mobile GPS to collect the coordinates.

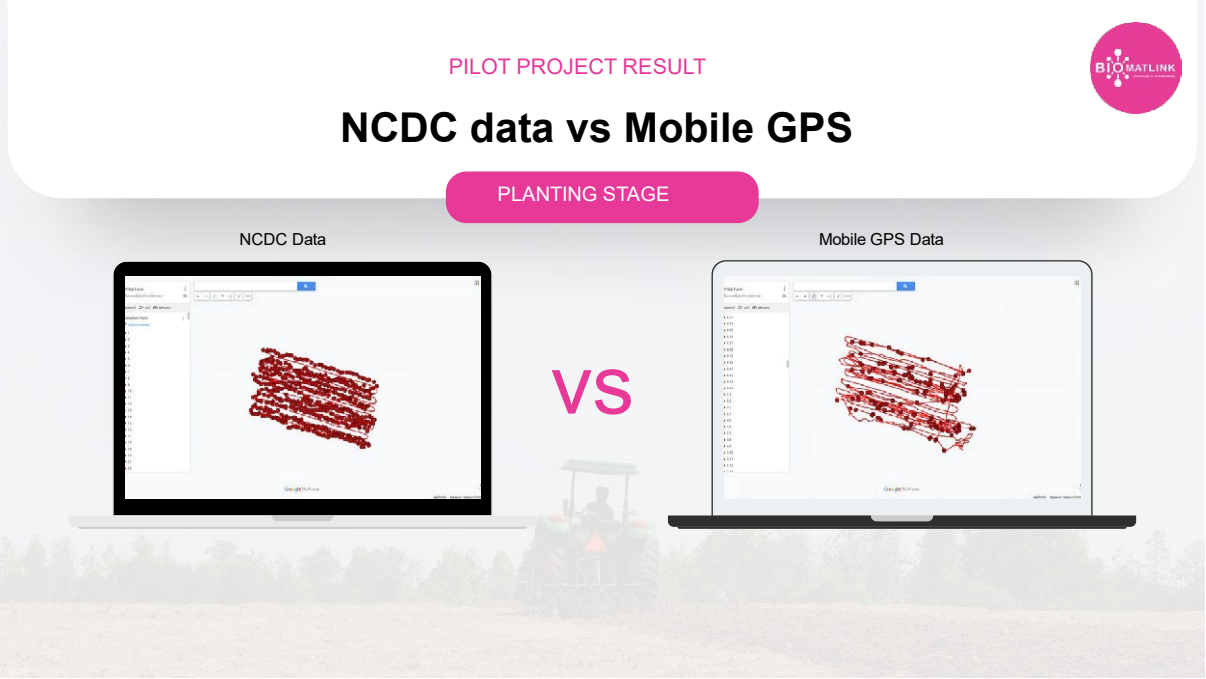


Figure 2-14 The cassava tree point collected by NCDC and Mobile GPS data.

The overall data in the planting stage can be usable even though we got a low fix rate of 1.7% from the NCDC. We also found that the cassava point coordinate of the first version of BIOMATLINK-BOX cannot align on the tractor route path. The reason because the tractor is not equipped with a planter machine, so we have to use the BIOMATLINK-BOX version 1 to manually collect the cassava point coordinates. Thus, we had to implement a new version (BIOMATLINK-BOX version 2) of BIOMATLINK-BOX that can improve the cassava point coordinates align on the tractor route path and equip the planting machine that demonstrates in the Agri Demo Day on 22 June 2023.

(2) Treatment Stage

As a result of the treatment stage, the treatment team used BIOMATLINK-BOX as a navigating device. They were able to quickly reach the location of the assigned cassava point locations and can fill in the record field survey data more quickly. When the

treatment team reached the location, there was an error of 0.5 - 1.0 m of the nearby cassava point location. This made the treatment team's work easier than counting the rows and trees in a field.

The record of survey from the treatment team is shown in Figure 2-15.

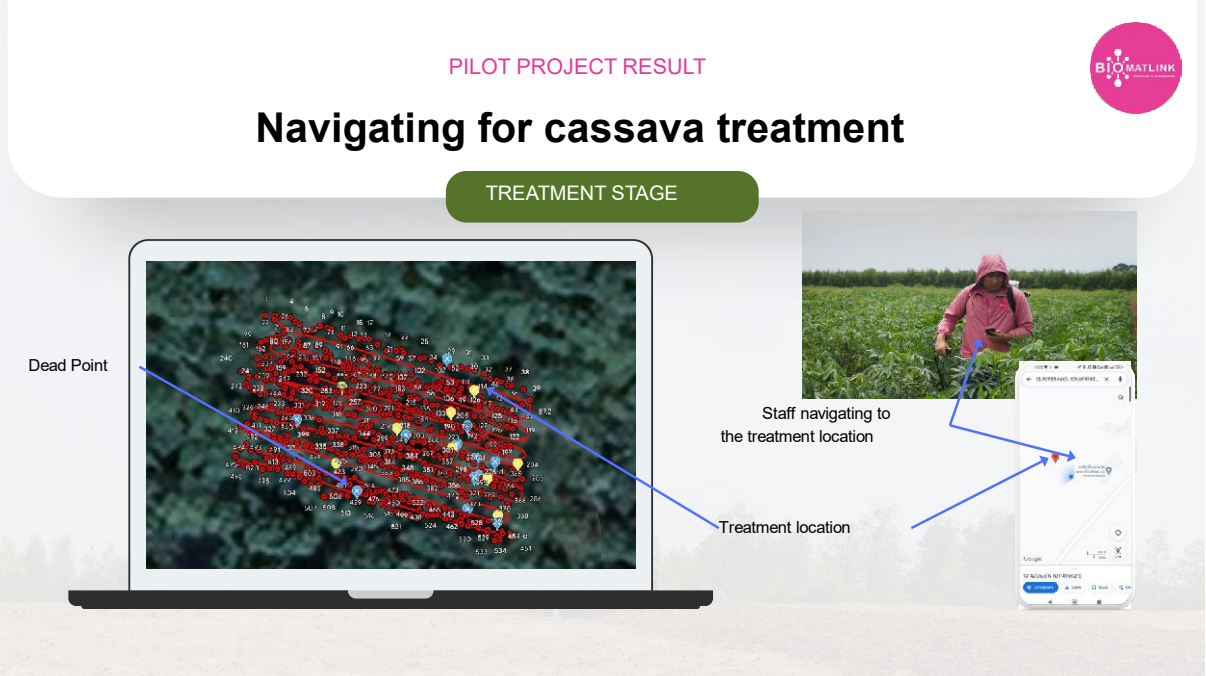


Figure 2-15 The record of survey cassava point location in treatment stage by using NCDC data.

(3) Logistic Stage

Results of use in the logistic stage, we found a good point that the system can specify coordinates in small check-point areas and slightly hidden corners, such as weighing measurement area. It was found that if the BIOMATLINK-BOX which connected to GNSS receiver stays in a confined area for a long time, there may be some movement of position. This may be due to the distance from the nearby CORS and the pilot site.

The setting up of the area, use of NCDC data, and result of the logistic stage were shown in the Figure 2-16.

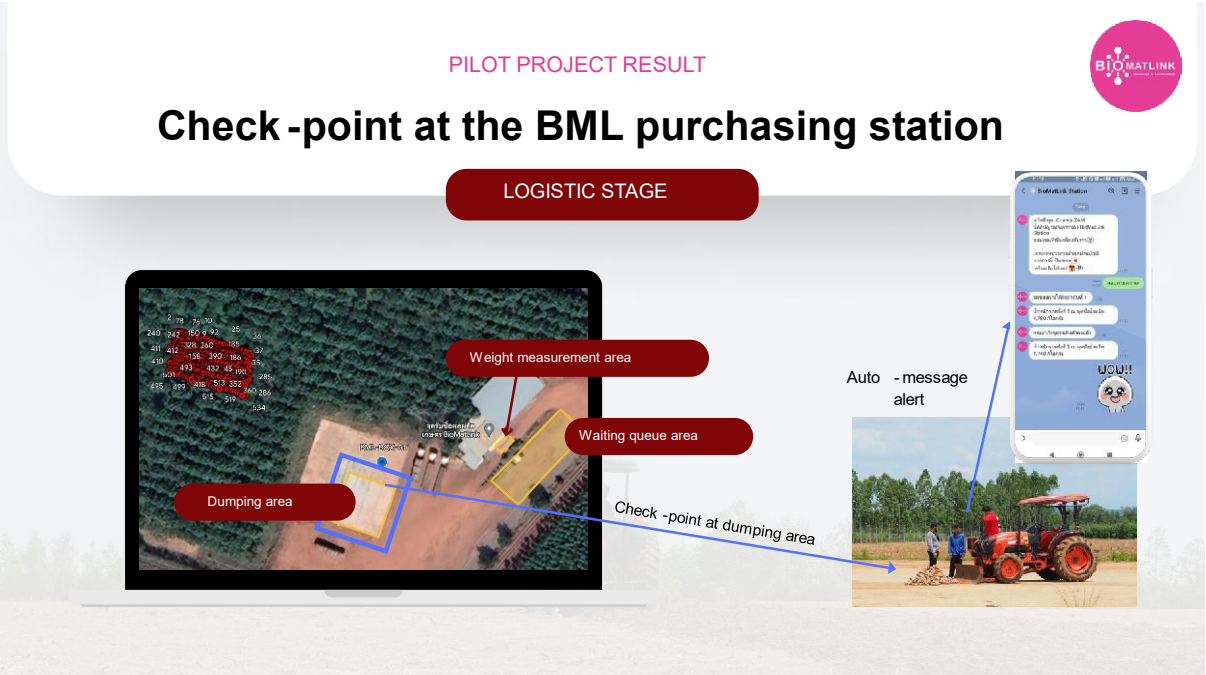


Figure 2-16 The setting up area for using NCDC data in logistic stage.

The result comparison of the conventional method and BIOMATLINK method by using precise agriculture with NCDC is shown in Table 2-2.

Table 2-2 Result comparison between conventional and BIOMATLINK method.

Item	Conventional	BIOMATLINK using NCDC
Area (Rai)	1	1
Average cassava plants	3,200	1,600 (-50%)
Workload (person)	12	6 (-50%)
Yield (Ton)	3	6 (+100%)
Cassava plant coordinates	LOW	PRECISE
Cost (Baht)	5,000	5,000

In the Table 2-2, can be described of each item below:

- **Area:** The cultivated area remains the same for both methods.

- **Average Cassava Plants:** BIOMATLINK demonstrates a significant improvement by reducing the average cassava plants by 50%, indicating more efficient planting strategies.
- **Workload:** The BIOMATLINK approach reduces the required workforce by 50%, showcasing enhanced automation and efficiency in cassava cultivation.
- **Yield:** BIOMATLINK achieves a 100% increase in yield, suggesting improved productivity and resource utilization.
- **Cassava Plant Coordinates:** BIOMATLINK provides precise coordinates, ensuring accurate tracking and monitoring of cassava plants compared to the conventional method.
- **Cost:** The cost remains constant at 5,000 Baht for both methods, emphasizing cost-effectiveness in adopting the BIOMATLINK approach.

Overall, the BIOMATLINK method, utilizing NCDC data, demonstrates superior efficiency and productivity in cassava cultivation compared to conventional methods.

2.2. Use of NCDC

2.2.1. Details of the NCDC data used

NCDC was used as follows.

Table 2-3 NCDC data used.

IP address	118.174.12.3
Port	2105
Mount point	VRS_MSM5_UTM47, VRS_MSM5_UTM48_ITRF2014
User name	biomatlink1, biomatlink2 and biomatlink3
Period of use	May 2023 – October 2023
RTK/ Post processing	-
Satellite systems used	QZSS, GPS, Glonass, Galileo

2.2.2. Problems occurred and solutions

Stability

Problem: We found that the fix rate is not stable when used in the field far from the nearby CORS. It might be of our pilot's site is far from the nearby CORS named SNCK, distance about 30 km compared to the site close to the nearby CORS named SBKK about 7 km. The fix rate of our pilot site was 1.7% compared to the test site where 7 km close to the nearby CORS was 96.7%. Each area is used and tested by using the same pocket Wi-Fi and internet provider. Thus, the internet

connection might be unstable in the pilot site located in the rural area causing the low fix rate.
Solution: We expect the coverage of the CORS will solve this problem.

- **Coverage**
  Problem: The fix rate in the rural area is very low. We got a 1.7% fix rate at our pilot site where the distance between the nearby CORS and the site is about 30 km. If the coverage of CORS covers the rural area (countryside), we expect that the fixed rate will be better than we found. Another reason might be the internet connection in the rural areas. Thus, the communication between mount point and the receiver did not work properly.
  Solution: Increase the number of CORS to cover the rural area.
- **User support**
  Problem: We cannot find an online channel to seek assistance, especially during times when we encounter issues. We are unsure whether the low FIX rate is due to our GNSS receiver's inability to connect to the NCDC server, issues with the mount point, problems with nearby CORS stations, or even user configuration issues. To pinpoint these problems, we need assistance from NCDC service personnel, sometimes requiring the quickest guidance possible. A feasible solution in today's era is to have a channel for online chat support, enabling us to inquire and receive prompt troubleshooting advice.
  Solution: Increase the online support channel including the technical channel.

2.3. Other related activities

To confirm the connection of the NCDC server, we used the GNSS Receiver in 4 related activities (1) The site area where 7 km close to the nearby CORS, (2) The visiting site area in Udon Thani province where 40 km far from the nearby CORS, (3) The survey of pilot site area where 30 km far from the nearby CORS, and (4) Agri Demo Day.

(1)The site area where 7 km close to the nearby CORS.

We used the NCDC data for collecting data log in rover mode by car. The test site is Vachirabenjatas Park. It is about 7 km close to the nearby CORS named SBKK. On this site, we got the highest fix rate of 96.7%. The visualized log is shown in Figure 2-17.

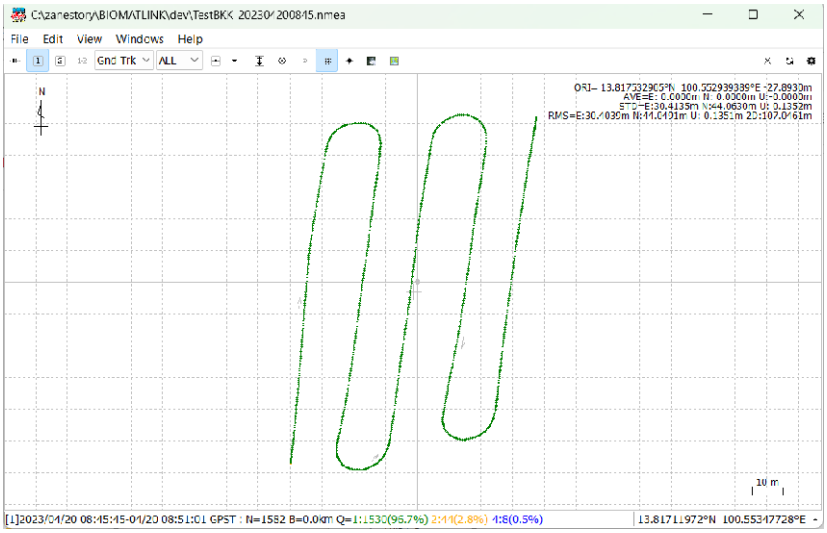


Figure 2-17 RTKPlot of Vachirabenjatas Park in Bangkok.



Figure 2-18 The use of NCDC for testing in Vachirabenjatas Park.
(1) Testing Site Overview. (2) GNSS Antenna Installation.
(3) Data Collection. (4) Validation.

(2) The visiting site area in Udon Thani where 40 km far from the nearby CORS.

We used the NCDC data for collecting data logs during the trip to Udon Thani province. The distance between the cassava field area and the nearby CORS named BDMG is about 40 km, but the fixed rate is better than our pilot site area. The fixed rate of the visiting site is about 21.5%. This data was collected by using the GNSS Receiver log and visualized on the RTKPlot as shown in Figure 2-19, and the activities are shown in Figure 2-20.

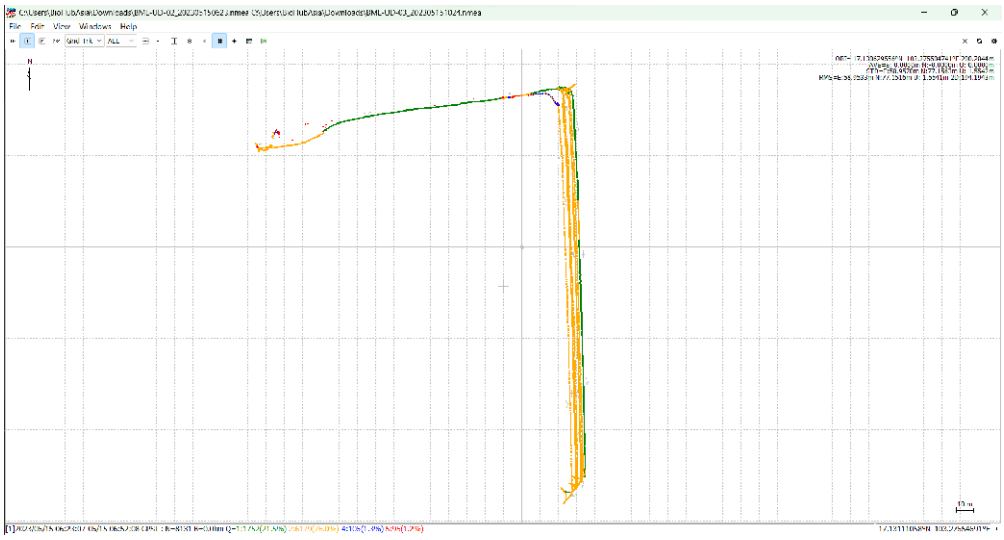


Figure 2-19 RTKPlot of visiting site in Udon Thani province.



Figure 2-20 The use of NCDC in visiting site in Udon Thani province.
(1) Installing the GNSS Antenna. (2) Collecting GPS log.
(3) GNSS RTK Module. (4) Visiting Field Area.

(3) The survey of pilot site area where 30 km far from the nearby CORS.

We used the NCDC data for collecting data log while surveying the pilot site area. The distance between the pilot site and the nearby CORS named SNCK is about 30 km in Chachoengsao province. The data log shows that the fix rate in the pilot site is very low, we got only 1.7%. This data log was collected by using GNSS Receiver and visualized on the RTKPlot software as shown in Figure 2-21.



Figure 2-21 RTKPlot of surveying in pilot site area.

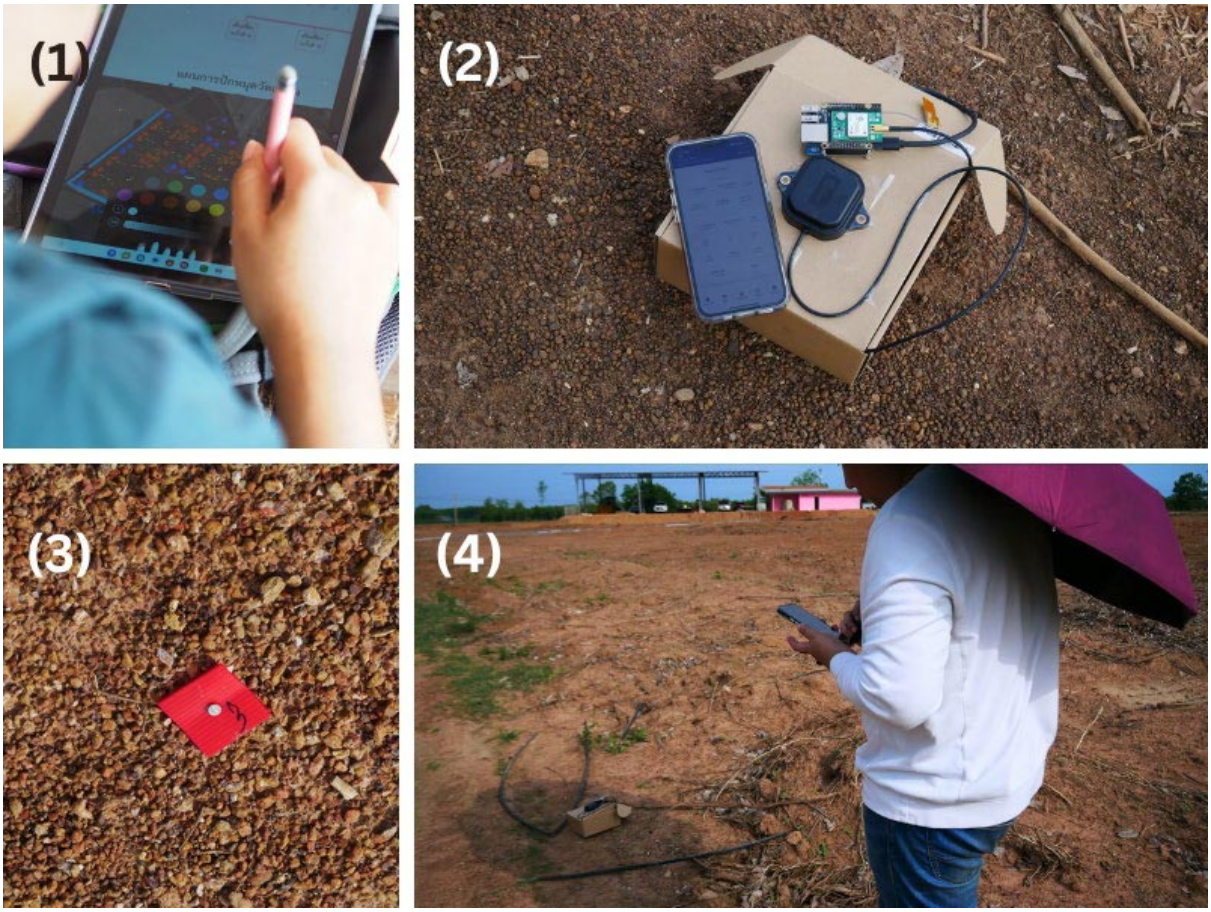


Figure 2-22 The use of NCDC for surveying in the pilot site area.
(1) Planning (2) GNSS RTK Receiver (3) Reference Point (4) Log Record

(4) Agri Demo Day.

We showcased the BIOMATLINK-BOX Version 2 connected to a planting detector installed on a tractor equipped with a planting machine. The GNSS receiver obtained data from NCDC, facilitating communication with the BIOMATLINK-BOX for route paths, device locations, and planting coordinates. All the data were visualized on the central monitor. The setup of this installation and software interface are shown in Figure 2-8.

During the Agri Demo Day, we presented an overview of the system's workflow, functionality, and benefits to the audience, as shown in Figure 2-23.



Figure 2-23 The demonstration of system work.
(1) Tractor equipped with planting machine and BIOMATLINK-BOX.
(2) Validate the data before Agri Demo Day.
(3) Demonstrate the system work.
(4) Near real-time route tracking and planting detector.

In summary, our observations indicate that the GNSS receiver's connectivity to NCDC is robust, with fixed rates influenced by proximity to nearby CORS and internet connectivity. Despite a low fix rate at our pilot site, the acquired coordinates prove more

accurate than conventional mobile GPS data, affirming the viability of incorporating this data into our ongoing pilot project.

3. Way forward

3.1. Future outlook of the business using NCDC

Currently, we leverage NCDC data in three crucial stages to amplify cassava yield. In the first stage, NCDC assists in precisely identifying cassava tree plantation points during the planting phase, while also delineating optimal routes for our machinery. The second stage involves utilizing NCDC to guide staff through assigned treatment locations for cassava trees, facilitated by a user-friendly application. This enhances the efficiency of tree care procedures. The third stage focuses on implementing NCDC for small-scale check-ins at our digital purchasing station, streamlining operations, and ensuring accuracy.

Looking ahead to this year, we have strategic plans to upgrade the BIOMATLINK-BOX and enhance its capabilities. In addition to augmenting the sensor suite on equipment arms for monitoring tasks such as plowing, fertilizing, and harvesting, we are set to equip 10 agricultural machines with the BIOMATLINK-BOX. This integration will significantly improve precision and efficiency in cassava cultivation. Furthermore, we anticipate that 50 users will be utilizing these upgraded agricultural machines equipped with the BIOMATLINK-BOX through a dedicated platform, contributing to improved yield outcomes.

Moreover, our vision includes the incorporation of new features on the central monitor, encompassing health monitoring, farm surveillance, and yield monitoring. Looking into the future, we foresee harnessing NCDC data for fertilizing stages using UAV drones, which will follow specific location or route path patterns. These drones will operate autonomously, and their activities can be seamlessly monitored from the central monitoring dashboard. This holistic approach promises a significant leap in efficiency and precision across our cassava cultivation processes.

3.2. About NCDC

1) Good points using NCDC

- **Precision agriculture:** NCDC can be used to guide agricultural machinery and collect data on crop growth and yield. This can help farmers to improve their productivity and reduce their environmental impact.
- High accuracy of coordinated data.
- Able to widen applications that need accurate location data.

2) Issues to be solved

- Not stable server and slow connection sometimes. This might be the internet connection in the rural area or the site.

- There are some errors when the distance between the site and the CORS is more than 30 km.

3) Request for improvement

- Coverage of CORS in the rural area.
- Online helpdesk support for usage and technical users.

4. Conclusion

In conclusion, our exploration into the use of NCDC data has revealed valuable insights. We observed that in areas near the CORS, the NCDC server demonstrated quicker responses and higher FIX rates compared to areas positioned more than 30 km away from the CORS. Our experience suggests that the application of NCDC data extends beyond our current use, showing potential for integration into various precision technology tools in the agriculture sector. Given the opportunity, we aspire to expand the utilization of NCDC in future projects.

Recognizing the significance of precise coordinates like those provided by NCDC, we advocate for establishing such technologies as fundamental infrastructures in the country. To facilitate this, workshops or training sessions, ranging from beginner to developer levels, could greatly enhance the understanding and utilization of NCDC. However, challenges such as the cost of GNSS receivers and limited knowledge about NCDC technology hinder us from fully exploiting its capabilities. We look forward to improving our team's readiness to harness this technology efficiently.

This pilot project has demonstrated the successful application of NCDC data in three crucial stages: (1) the planting stage, (2) the treatment stage, and (3) the logistic stage, effectively increasing cassava yield in the designated pilot site area. This achievement was made possible through the development of the BIOMATLINK-BOX and the central monitor, which visualizes the NCDC data coordinates. As shown in Figure 4-1 an illustration of the pilot site is used in this project.



Image source: Google Maps

Figure 4-1 The pilot site area covers (A) BIOMATLINK field for planting stage and treatment stage (B) The BIOMATLINK-BOX that used of NCDC data (C) The area for checking-in in the logistic stage.

5. Acknowledgement

We extend our sincere appreciation to the TIGORS project for their unwavering support and the Japan International Cooperation Agency (JICA) for providing the opportunity for our pilot project. Special thanks to Nakra Microtek Co., Ltd., for supplying the GNSS Receiver and offering technical consultation on NCDC. The acquisition of the GNSS Receiver toolkit from this company significantly contributed to the success of our project. We also express our gratitude to the DRIVE Center at Naresuan University, who provided valuable consultation at the project's inception. A heartfelt thank you to the consultant team from the Industrial Engineering and Mechatronics and Robotics Engineering Department at Rajamangala University of Technology Thanyaburi for their technical guidance and contribution to the development of the BIOMATLINK-BOX hardware.

Last but not least, immense thanks to our dedicated BIOMATLINK team whose unwavering support has been instrumental throughout this pilot project.