SOCIALIST REPUBLIC OF VIET NAM
MINISTRY OF TRANSPORT

# THE DETAILED DESIGN STUDY OF LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION PROJECT

# FINAL REPORT ON PORT PORTION OF THE PROJECT

March 2013

Japan International Cooperation Agency (JICA)

ORIENTAL CONSULTANTS CO., LTD. (OC)
NIPPON KOEI CO., LTD. (NK)
PADECO CO., LTD. (PADECO)
JAPAN BRIDGE & STRUCTURE INSTITUTE, INC. (JBSI)

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| CR(10) |
| 13-067 |

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Exchange Rate (As of March, 2010)
VND 1 = JPY 0.00528
USD 1 = JPY 89.60

This final report consists of 29 chapters and related appendices. The chapters related to each construction package are summarized as shown in the following table.

Construction Packages are as follows:

Package 6 : Infrastructure Construction Behind the Container Terminal
Package 8 : Channel Dredging and Disposal Works Part A
Package 9 : Channel Dredging and Disposal Works Part B
Package 10 : Breakwater and Sand Protection Dyke Works

| Title of Chapter / Appendices | | Package No. | | | |
|---|---|---|---|---|---|
| | | 6 | 8 | 9 | 10 |
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| 2 | Survey and Study on Natural Conditions | + | + | + | + |
| 3 | Survey on Environmental Conditions | + | + | + | + |
| **Division – I: Review of Previous FS Study** | | | | | |
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| 6 | Review of Port Planning and General Layouts | + | + | + | + |
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| 12 | Channel Dredging and Dredged Soil Disposal | | + | + | |
| 13 | Preliminary Construction Plan | + | + | + | + |
| 14 | Preliminary Cost Estimation | + | + | + | + |
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| 15 | Channel Dredging | | + | + | |
| 16 | Terminal Area and Access Road Area | + | | | |
| 17 | Outer Revetment | + | | | + |
| 18 | Public Related Area | + | | | |
| 19 | Sand Protection Dyke | | | | + |
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| Title of Chapter / Appendices | | Package No. | | | |
|---|---|---|---|---|---|
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# LIST OF ABBREVIATIONS

| | | |
|---|---|---|
| A | AASHTO | American Association of State Highway and Transportation Officials |
| | ACL | American Container Line, Inc. |
| | AIDS | Acquired Immune Deficiency Syndrome |
| | AIS | Automatic Identification System |
| | ALiCC | Arch action Low improvement ratio Cement Column |
| | APL | American President Lines |
| | ADCP | Acoustic Doppler Current Profiler |
| | ADB | Asian Development Bank |
| | ASEAN | Association of South East Asian Nations |
| B | B/C | Cost-Benefit Ratio |
| | BDS | Basic Design Study |
| | BKK | Bangkok |
| | BLT | Build - Lease - Transfer |
| | BOD | Biological Oxygen Demand |
| | BOO | Build-Operate-Own |
| | BOR | Berth Occupancy Ratio |
| | BOT | Build-Operate-Transfer |
| | BRICs | Brazil, Russia, India and China |
| | BS | British Standard |
| | BT | Built – Transfer |
| | BTO | Build - Transfer - Operate |
| C | CARB | Compensation, Assistance, and Resettlement Board |
| | CBR | California Bearing Ratio |
| | CBTA | Cross Border Transport Agreement |
| | CD | Chart Datum |
| | CDL | Chart Datum Level |
| | CDM | Cement Deep Mixing, Channel Depth Monitoring |
| | CFS | Container Freight Station |
| | CHE | Cargo Handling Equipment |
| | CIF | Cost, Insurance and Freight |
| | CIPs | Construction Investment Projects |
| | CIQ | Customs, Immigration, Quarantine |
| | CKYH | Coscon, "K"LINE, Yang Ming, Hanjin Shipping |
| | CNC | CNC Lines |
| | COSCO | China Ocean Shipping Company |
| | COSCON | COSCO Container Lines Co., Ltd |
| | CSD | Cutter Suction Pump Dredger (Pump Dredger) |
| | CTP | China-Transpacific Service |
| | CY | Container Yard |
| D | DAP | Diammonia Phosphate Fertilizer |
| | DCEZ | Dinh Vu-Cat Hai Economic Zone |
| | DD | Detailed Design |
| | DO | Dissolved Oxygen |
| | DONRE | Department of Natural Resource and Environment, HPPC |
| | DSCR | Debt Service Coverage Ratio |
| | DVIZ | Dinh Vu Industrial Zone |
| | DWT | Deadweight Tonnage |

| | | |
|---|---|---|
| E | ECD | Empty Container Depot |
| | ECDIS | Electronic Chart Display and Information System |
| | EHS | Environment, Health and Safety |
| | EIA | Environmental Impact Assessment |
| | EIR | Equipment Interchange Receipt |
| | EIRR | Economic Internal Rate of Return |
| | EMP | Environmental Management Plan |
| | E/N | Exchange of Notes |
| F | FC | Full Container Ship |
| | FDI | Foreign Direct Investment |
| | FEU | Forty-Foot Equivalent Unit |
| | FIRR | Financial Internal Rate of Return |
| | FOB | Free On Board |
| | F/S | Feasibility Study |
| | FTA | Free Trade Agreement |
| G | GC | General Cargo |
| | GD | Grab Dredger |
| | GL | Ground Level |
| | GOJ | The Government of Japan |
| | GOV | The Government of Socialist Republic of Viet Nam |
| | GDP | Gross Domestic Product |
| | GMS | Greater Mekong Subregion |
| | GPS | Global Positioning System |
| | GSO | General Statistics Office of Vietnam |
| | GT | Gross Tonnage |
| H | HAPACO | Hai Phong Industrial Zone Joint Stock Company |
| | HCM | Ho Chi Minh |
| | HECO | Highway Engineering Consultants |
| | HHWL | Highest High Water Level |
| | HIV | Human Immunodeficiency Virus |
| | HK | Hong Kong |
| | HP | Haiphong |
| | HPH | Hutchison Port Holdings |
| | HPPC | Haiphong People's Committee |
| | HWL | High Water Level |
| | HYMENET | The Center fot Hydrometeorological and Environmental Station Network |
| | HYMETEC | Technology Application and Training Center for Hydro-Meteorology and Environment |
| I | ICB | Interlocking Concrete Block |
| | IDC | Interest During Construction |
| | IMER | Institute of Marine Environment and Resources |
| | IMF | International Monetary Fund |
| | IMO | International Maritime Organization |
| | IP | Industrial Park |
| | IRP | Income Restoration Program |
| | IRR | Internal Rate of Return |
| | ISL | Institute of Shipping Economics and Logistics |
| | IT | Information Technology |
| | IUCN | International Union for Conservation of Nature |
| | IZ | Industrial Zone |

| | | |
|---|---|---|
| J | JBIC | Japan Bank for International Cooperation |
| | JBSI | Japan Bridge & Structure Institute, Inc. |
| | JCC | Joint Coordination Committee |
| | JETRO | Japan External Trade Organization |
| | JICA | Japan International Cooperation Agency |
| | JIS | Japanese Industrial Standards |
| | JIT | Just in Time |
| | JOPCA | Japan Overseas Ports Cooperation Association |
| | JPY | Japanese Yen |
| | JV | Joint Venture |
| L | L/A | Loan Agreement |
| | LC | Laem Chabang |
| | LCP | Laem Chabang Port |
| | LCL | Less than Container Load |
| | LDC | Land Resource Development Center, Cat Hai District PC |
| | LED | Light Emitting Diode |
| | LIBOR | London Interbank Offered Rate |
| | LLWL | Lowest Low Water Level |
| | Loa | Length Over All |
| | LWL | Low Water Level |
| M | MARPOL | International Convention for the Prevention of Pollution from Ships |
| | METI | Ministry of Economy, Trade and Industry |
| | MLWL | Mean Low Water Level |
| | MOC | Ministry of Construction |
| | MOM | Minutes of Meeting |
| | MONRE | Ministry of Natural Resources and Environment |
| | MOT | Ministry of Transport |
| | MOU | Memorandum of Understanding |
| | MP | Multi Purpose Ship |
| | MPA | Maritime and Port Authority of Singapore |
| | MPI | Ministry of Planning and Investment |
| | MPMU | Maritime Project Management Unit |
| | MSC | Mediterranean Shipping Company S.A. |
| | MSC No.1 | Maritime Safety Company No.1 |
| | MSL | Mean Sea Level |
| | MWL | Mean Water Level |
| N | N.A. | Not Applicable |
| | NCPFP | National Committee for Population and Family Planning |
| | NK | Nippon Koei Co., Ltd |
| | NM | Nautical Mile |
| | NPV | Net Present Value |
| | NYK | Nippon Yusen Kabushiki Kaisha |
| O | ODA | Official Development Assistance |
| | OJT | On the Job Training |
| | O/M | Operation and Maintenance |
| | OOCL | Orient Overseas Container Line |
| P | PAB | Project Affected Fishing Boats |
| | PACs | Potentially Project Affected Communes |

| | | |
|---|---|---|
| | PAH | Project Affected Household |
| | PAP | Project Affected People |
| | PAT | The Port Authority of Thailand |
| | PC | Prestressed Concrete |
| | PC | The People’s Committee |
| | PCU | Passenger Car Unit |
| | PDA | Pile Driving Analyzer |
| | PHC | Prestressed High-strength Concrete |
| | PIANC | Permanent International Association of Navigation Congress |
| | PIL | Pacific International Lines (Pte) Ltd . |
| | PM | Prime Minister |
| | PMB | Port Management Body |
| | PMU | Project Management Unit |
| | POC | Port Operating Company |
| | PPP | Public Private Partnership |
| | PRC | People's Republic of China |
| | PSA | Port of Singapore Authority |
| | PTI | Pre Trip Inspection |
| | PVD | Prefabricated Vertical Drain |
| Q | QGC | Quay Gantry Crane |
| R | RAP | Resettlement Assistance Program |
| | RC | Reinforced Concrete |
| | RCL | Regional Container Lines |
| | R/D | Record of Discussion |
| | RO | Rehabilitate – Own |
| | ROE | Return on Equity |
| | RORO | Roll-On/Roll-Off ship |
| | ROT | Rehabilitate - Operate - Transfer |
| | RTG | Rubber Tyred Gantry (Crane) |
| S | SAPROF | Special Assistance for Project Formation |
| | SAPROF EIA | Supplemental Report – Environmental Impact Assessment Report for Lach Huyen Gateway Port Construction Project (2010-2015), May 2010 |
| | SC | Slot Charter |
| | SCF | Standard Conversion Factor |
| | SDIZ | South Dinh Vu Industrial Zone |
| | SDVDC | South Dinh Vu Development Joint Stock Company |
| | SHB | Split Hopper Barge |
| | SITC | SITC Container Lines Co., Ltd |
| | SMEWW | Standard Methods for the Examination of Water and Wastewater |
| | SP | Singapore |
| | SPC | Special-Purpose Company |
| | SPP | Steel Pipe Pile |
| | SPT | Standard Penetration Test |
| | SS | Suspended Solid |
| | SSPP | Steel Sheet Pipe Pile |
| | STEP | Special Terms for Economic Partnership |
| T | TCVN | Vietnam Standards (Tiêu Chuẩn Việt Nam) |
| | TCXDVN | Vietnamese Construction Standard (Tiêu chuẩn Xây dựng Việt Nam) |
| | TDSI | Transport Development and Strategy Institute |
| | TEDI | Transport Engineering Design Incorporated |

| | | |
|---|---|---|
| | TEDIPORT | Port & Waterway Engineering Consultant Joint Stock Company |
| | TEQ | Toxic Equivalency Quantity |
| | TEU | Twenty-foot Equivalent Unit |
| | TNWA | The New World Alliance |
| | TSHD | Trailing Suction Hopper Dredger |
| | TSP | Total Suspended Particles |
| | TSS | Total Suspended Solids |
| U | UKC | Under Keel Clearance |
| | UNCTAD | United Nations Conference on Trade and Development |
| | UNESCO | United Nations Educational, Scientific and Cultural Organization |
| | USA | United States of America |
| | USEPA | United States Environmental Protection Agency |
| | UXO | Unexploded Ordnance |
| V | VAT | Value-Added Tax |
| | VHF | Very High Frequency |
| | VIDIFI | Vietnam Infrastructure Development and Financial Investment |
| | VINALINES | Vietnam National Shipping Lines |
| | VINAMARINE | Vietnam National Maritime Bureau |
| | VINASHIN | Vietnam Shipbuilding Industry Corporation |
| | VITRANSS | National Transport Development Strategy in the Socialist Republic of Vietnam |
| | VMS | Vietnam Maritime Safety Agency |
| | VND | Vietnamese Dong |
| | VNHC | Vietnam National Hydrographic Center |
| | VOC | Volatile Organic Compound |
| | VPA | Vietnam Seaports Association |
| | VTS | Vessel Traffic Service |
| W | WACC | Weighted Average Cost of Capital |
| | WB | The World Bank |
| | WB OP-4.12 | WB Operational Policy 4.12 - Involuntary Resettlement |
| | WTO | World Trade Organization |

# 1. INTRODUCTION

This report covers the Detailed Design of Design Study for the Port Portion of the Project carried out in a series of Detailed Design Study initiated from the first ($1^{st}$) basic design to the second ($2^{nd}$) detailed design stages. The Detailed Design Work is carried out according to the "Record of Discussions" agreed upon and signed by JICA Mission and MOT of GOV on June 18, 2010 in Hanoi.

## 1.1 Background

Owing to the Government's policy "Doi Moi", Vietnam economy has remarkably expanded and, sea-borne trade through the ports in the north of Vietnam has experienced a significant increase both in quantities and kinds of commodities.

Along the area connecting Hai Phong in the northern coastal region of Vietnam and Hanoi, there exist various enterprises that contribute to the development of the region. Major ports supporting commercial activities of these enterprises include Hai Phong and Cai Lan Port, which received JICA's loan assistance in the past for rehabilitation and expansion works. While the capacity of these ports and other ports in the region is planned to cope with total 40.2 million tons of containerized cargo in 2015, the demand is expected to surpass this figure in 2015 and expand to 58.9 million in 2020, making it necessary to build a new port with enough capacity to cover the demand that would overflow. Against this backdrop, the Government of The Socialist Republic of Vietnam (hereinafter referred to as "GOV") carried out a feasibility study on the Lach Huyen Port Infrastructure Construction Project, based on which GOV requested the government of Japan (hereinafter called as "GOJ) to provide a Japanese ODA Yen loan in order to enforce the development plan proposed in its feasibility study.

In response to the request of GOV, the Japan International Cooperation Agency (hereafter referred to as "JICA") conducted the Preparatory Survey for Lach Huyen Port Infrastructure Construction in Vietnam from October 2009 to June 2010. The survey team recommended the development of Lach Huyen Port Infrastructure Construction Project as a priority project under the finance by Japanese Government ODA Loan Project (hereinafter referred to as "the Project")

Responding to the recommendation of the JICA study, GOV requested GOJ to provide an ODA loan for the Project by JICA, and to conduct the Detailed Design Study for Lach Huyen Port Infrastructure Construction Project (hereafter referred to as "the Design Study") by the technical cooperation program of GOJ in June 2010.

GOJ decided to extend Design Study, and JICA and the Ministry of Transport of GOV (hereinafter referred to as "MOT"), a responsible organization for the Design Study in GOV, have agreed that both sides shall sincerely cooperate with each other in implementing the Design Study and confirmed the implementation details of the Design Study.

## 1.2 Outline of Design Study

The Design Study is intended to assist the implementing agencies for the Project, Maritime Project Management Unit II (MPMU II) under Vietnam Maritime Administration for the port portion to implement smoothly and successfully Lach Huyen Port Infrastructure Project. The objectives of the Design Study are to prepare the tendering documents and detailed design for the Project. It is confirmed by MOT that the drawing and documents formulated by the Design Study (hereinafter referred to as "the Design Documents") shall be fully utilized for the procurement procedure of the Project.

The Lach Huyen Port Infrastructure Construction Project (under the finance by Japanese Government ODA Loan) consists of the construction of land reclamation for two (2) berths of international container terminal and the related port and access road/bridge infrastructures. The following port facilities and equipment are to be provided for the port portion of the Project.

(Port Portion)

(1) Construction of land reclamation for container terminal yard, public related area and access road area,

(2) Construction of access roads behind container terminal yard and public related area,

(3) Earth retaining wall behind container berth and Revetment at the land reclamation area,

(4) Dredging Access channel and turning basin to CDL-14.0m and public port basin to CDL-4.0m

(5) Construction of Outer Revetment and Sand Protection Dyke extended to offshore

(6) Construction of harbor crafts berth and required utilities for access road and public related area

(7) Installation of beacon markers if required,

(8) Others.

The construction of container terminal including container berth, barge berth, container yard, terminal facilities and the procurement of container handling equipment will be executed by the VINALINES who will be given operation right of the terminal by the Prime Minister Decision No. 412/QD-TTg dated 11 April, 2007.

## 1.3 Scope of Design Study and Work Activities

In order to achieve the objectives mentioned above, the Study shall cover the following study works.

**1) Review of Previous Studies and Plans**

i) Review previous master plans, feasibility studies, Environmental Impact Assessment (EIA), Resettlement Action Plan (RAP), and other records and data related to the Project based on the latest information on traffic data, social and economic conditions, traffic forecast of the target year of 2015 in short term and 2020 in medium term among others, and

ii) Review plans, scope, scale, location or layout, if necessary and appropriate, and operation and maintenance system for the Project.

**2) Establishment of Design Study Framework**

i) Establish and agree with MPMU II design criteria and design/technical standards to be applied for the Project.

ii) Recommend and agree with MPMU II the format and content for the Bills of Quantities and cost estimate for construction of each contract package of the Project.

iii) Recommend and agree with MPMU II the division of each categorized package for construction,

iv) Recommend and agree with MPMU II the format and content for prequalification and tender documents for each package of construction,

v) Recommend and agree with MPMU II the time schedule for implementation of the detailed design, the Bills of Quantities, cost estimate, prequalification documents and bidding documents to allow the tendering of works and construction for each contract package to commence immediately after the completion of necessary design and documentation work and the gaining of necessary approvals,

vi) Agree with GOV the schedule, item and content of technical aspect for authorization of Design Study and Design Documents by Technical Advisory Committee, and

vii) Establish and agree with MPMU II and/or Technical Advisory Committee technical verification format, content and schedule for assessment of suitability of the Design Study and Design Documents.

**3) Design Study**

i) Conduct the following investigations and analyses required for the Port Portion of Design Study (Basic and Detailed design both inclusive):

(Field Survey and Investigation)

- Soil investigation of the new container terminal development areas, port structures areas and channel/basin dredging areas at Lach Huyen port,
- Topographic survey for Public Related Facility area and Hydrographic surveys for Container Terminal development area and the Channel and Turning Basin development areas including Port Protection Facility area,
- Magnetic hydrographic survey and analysis for removal of UXOs for dredging works (Deleted form the scope of the Design Study),
- Re-evaluation survey on disposal of dredged materials including needed installment at relative site,
- Re-evaluation survey on availability and suitability of the construction material source for rock, river and sea sand,
- Maritime observation (Tide, current and wave) and environmental survey
- Environmental baseline survey for seabed material and water quality
- Ecosystem (Fauna and flora, others) survey in the area concerned

(Simulation Analysis)

- Simulation of the wave hind-casting and harbor calmness assessment for planning the new container terminal development, outer & inner revetment and sand protection dyke
- Ship maneuvering simulation for assessment of suitable ship navigation for the safe passage of vessels through the channel and berthing/de-berthing ship handling as well as the acceptable limits of critical wind speed, etc (to be carried out under the presence of Vietnamese pilots).
- Advection Diffusion of suspended solid (SS) agitated by channel dredging, reclamation including temporary causeway for construction of inner & outer revetment, sand protection dyke, and dumped soil, and
- Sedimentation simulation for access channel by applying additional survey data.

(Satellite Photograph)

Satellite photograph will be furnished at the beginning of the project (at the time of starting construction works and completion of works as well in later stage) as part of environmental monitoring.

ii) Conduct Basic/Detailed Engineering Design on mainly following items of works for the Project.

- Channel Dredging and Disposal Works
  1) Comparative Study on Channel Dredging method and Disposal Sites for Dredged Soil
  2) In-depth Study on Disposal method at South Dinh Vu Industrial Zone
  3) Design for channel and turning basin
- Port Facilities
  1) Design for the reclamation for terminal area, access road area and public related area

2) Soil improvement related to the new container terminal and access road area for two cases of detailed design of PVD and CDM method
3) Design for revetment of reclamation (Inner Revetment) and earth retaining wall behind the container berth and barge berth
4) Design for breakwater (Outer Revetment A & B) and sand protection dyke
5) Study on utilities for container terminal and public related area as required,
6) Design for access road immediately behind container terminal area
7) Design for service boat berth at public related area.

iii) Prepare the construction method and plan of the channel and basin dredging and port facility construction works by maintaining the calmness in the channel and basin required for the present ship operation in the harbor. Regarding the plan of the channel and basin dredging, prepare the plan (Channel Dredging Plan) inconsideration of sedimentation analysis during construction period in order to minimize the dredging volume and complete the channel dredging as scheduled.

iv) Review the previous cost estimate of the Project and update and prepare the project cost based on the Bills of Quantities for each package for construction of the Project.

v) Prepare pre-qualification documents and tender documents required for the respective packaged works based on the GOV regulations and Guidelines for procurement under Japanese ODA loans, March 2009 (herein after called JICA Guidelines).

vi) Conduct EIA and prepare draft supplementary EIA report including additional ecosystem survey, and proposed dumping site survey behind the terminal (where a logistic park is expected to be built in future) in compliance with the Vietnamese laws and JBIC Environmental Guidelines. Also, conduct necessary explanation, revision in accordance with the comments required by competent authorities with VINAMARINE until EIA approved.

vii) Prepare the environmental management and monitoring program based on the approval of EIA report and supplementary EIA report for implementing the Project

viii) Monitor the progress of land acquisition and compensation for affected people, which is indicated in the land acquisition plan for being implemented by the local government. Report the progress to JICA.

ix) Prepare channel depth monitoring (CDM) and Maintenance Dredging Program during construction period in order to minimize the dredging volume and complete the channel as scheduled. CDM and Maintenance Dredging program is based on the Channel Dredging Plan mentioned above and planned to be conducted by a supervision consultant to be procured by MPMU II.

x) Formulate work safety program with recommendation for necessary countermeasures for construction.

xi) Formulate port management plan for Lach Huyen Port as for:

- The Plan for setting up port management body
- Management scheme
- Inspection and maintenance plan of port facilities including the channel maintenance

xii) Prepare HIV/AIDS prevention program together with the People's Committee of Hai Phong City.

xiii) Conduct overall evaluation of the Project in terms of EIRR, B/C, NPV and financial viability of the Project.

**4) Work Schedule and Activities**

The Design Study was originally scheduled to carry out within 11-month period subject to obtaining comments in time from Technical Advisory Committee to be established by GOV.

The Design Study was commenced in March 2011 and the Inception Report (IC/R) for the design study was submitted. The Basic Design has been carried out in the 1st Work in Vietnam and the 1st Work in Japan as shown in Figure 1.3.1: the Design Study Schedule for which the Basic Design Report (CD/R) in English and Vietnamese was submitted in July and August, 2011 respectively. In executing Design work, the Study Team had several meeting with counterpart organizations of MPMU II, VINAMARINE, MOT and such other related organization as Hai Phong PC, etc. The following field surveys on natural and environmental Conditions were carried out under the subcontract to Vietnamese consultants.

TEDI Port (Port & Waterway Engineering Consultant)

- Soil Investigation Part A
- Topographic and Bathymetric Survey

Portcoast (Portcoast Consultant Corporation):

- Soil Investigation Part B
- Current, Turbidity and Current Observation

HYMETEC (Technology Application and Training Center for Hydro-Meteorology and Environment)

- Biological Environment Survey and EIA Preparation Support
- Natural Environment Survey and EIA Preparation Support
- Social Environment and Land Acquisition Support

Immediately after completion of the Basic Design, Detailed Design on the proposed facilities for the Project was succeeded in the 2nd Work in Vietnam as shown in Figure 1.3.1: the Design Study Schedule. The work of this Detailed Design stage includes the detailed design of the proposed facilities as well as the preparation of prequalification documents, draft EIA report and bid documents for construction of the port facilities for the Project.

Several meetings with MPMU II, VINAMARINE, MOT and Technical Advisory Committee (Working Team) which was established for the Project in June 21, 2011 by MOT Decision were held. The results of Detailed Design work were presented in this draft final report (DF/R).

This Detailed Design report (DF/R) with the relevant supporting documents as listed below covers the detailed design for the port portion of the Project and summarize all the results of the Basic Design and Detailed Design including Pre-qualification Document, Bid Documents and draft EIA report.

### 5) Output Documents for Port Portion of the Project:

#### a) Draft Detailed Design Report

- Draft Detailed Design Report (DF/R) in English & Vietnamese
- Executive Summary in English & Vietnamese
- Design Calculation Sheet
- Work Quantity Calculation Sheet
- Construction Cost Breakdown Sheet

#### b) Prequalification Documents

- Draft PQ Document in English & Vietnamese
- Evaluation Criteria

For the following Package of Construction

Package 6: Infrastructure Construction Behind the Container Terminal
(Without Pre-qualification)
Package 8: Channel Dredging and Disposal Works Part A
Package 9: Channel Dredging and Disposal Works Part B
Package 10: Breakwater and Sand Protection Dyke Works

**c) Bid Documents**

- Draft Bid Document in English comprising of

  Volume I: Invitation for Bid, Instruction to Bidders and General and Special Conditions of Contract
  Volume II: Technical Specifications
  Volume III: Bill of Quantities
  Volume IV: Drawings
- Priced Bill of Quantities
- Bid Evaluation Criteria

For the following Package of Construction

Package 6: Infrastructure Construction Behind the Container Terminal
Package 8: Channel Dredging and Disposal Works Part A
Package 9: Channel Dredging and Disposal Works Part B
Package 10: Breakwater and Sand Protection Dyke Works

| TIME | TASK | REPORTS |
|---|---|---|
| March 2011 | **Preparatory Work in Japan**<br>★Collection & analysis of existing data / information<br>★Preparation of Inception Report (IC/R) & Questionnaires | |
| April 2011<br>June 2011 | **1st Work in Viet Nam**<br>★Presentation / Discussion of Inception Report (IC/R)<br>★Existing Data Collection and Review of Previous Studies and Plans<br>★Review of EIA and monitor land aquisition, etc.<br>★Estabilshment of Framework for Design Study<br>★Field Surveys for Natural & Environmental Conditions, and sorces and availability of construction mateiral<br>★Review of plan, scope, location or layout if appropriate<br>★Basic Design: Channel and truning basin, Reclamation and Soil Improvement, Port Facilities<br>★Review of the Existing Simulation Data on Channel Sedimentation and Execution of Further Study<br>★Re-evaluation of disposal of dredged soils<br>★Construction Planning & Time Schedule<br>★Rough Cost Estimate of Construction and Procurement Package for Construction | **Inception Report (IC/R)** |
| July 2011 | **1st Work in Japan**<br>★Preparation/Finalization of Basic Design Report (CD/R) | **Basic Design Report (CD/R)** |
| August 2011<br>October 2011 | **2nd Work in Viet Nam**<br>★Presentation / Discussion of Basic Design Report (CD/R)<br>★Preparation of Confirmation of Details on Design Contents<br>★Preparation of Prequalification Documents (PQ)<br>★Detaild Design<br>★Ship Maneuvering Simulation<br>★Channel Dredging Plan<br>★Channel Depth Monitoring and Maintenance Dredging Program<br>★Simulation on Advection Diffusion of Suspended Solid<br>★Detailed Construction Planning<br>★Detailed Project Cost Estimates<br>★Procurement Program of Construction Materials and Equipment<br>★Overall Project Evaluation by Economic Analysis and Financial Analysis of Whole Project<br>★Formulation of Construction Work Safety Program<br>★Preparaion of Tender Documents<br>★Preparation of Draft Supplemental EIA report (EIA) and Environmental Management/Monitoring Plan<br>★Preparation of HIV/AIDS Prevention Program<br>★Port Operation and Management Plan<br>★Preparation of Draft Final Report and Draft Tender Documents (DF/R) | **Prequalification Documents (PQ)**<br>**Draft Supplemental EIA Report (EIA)**<br>**Draft Final Report (DF/R)** |
| December 2011 | **2nd Work in Japan**<br>★Follow-up GOV Comments on DF/R | |
| January 2012 | **3rd Work in Viet Nam**<br>★Finalization of Final Report and Revised Tender Documents (F/R) | **Final Report (F/R)** |

**Figure 1.3.1 Work Schedule of Design Study of Port Portion for the Project**

Notes: Time Schedule for the detailed design works (from 2nd Work in Vietnam to the 3rd Work in Vietnam) was extended till May 2012 due to outstanding pending issues of channel dredged soil disposal site, soil improvement method and construction time schedule.

## 1.4 Principles of Design Study

In carrying out the Design Study, the following terms are set as basic principles:

(1) The Project is intended to be executed under the Japanese Government ODA loan finance. The Design Study is carried out within the framework of the Agreement on Technical Cooperation signed on October 20, 1998 (hereinafter called as "the Agreement" between GOJ and GOV and the Notes Verbal exchanged to jointly constitute an agreement between both governments.

(2) The execution of the Project shall follow, besides the laws and regulations of GOV, the guidelines of JICA, Record of Discussion ("R/D") agreed upon between JICA and GOV and, after signing of the Loan Agreement ("L/A"), provisions of the Exchange of Notes ("E/N") and L/A.

(3) The directions and contents of the Project will be basically decided by GOV based on the above items 1) and 2). If views and opinions, such as technical judgments, were different between GOV and the Study Team, the issue should be settled in consultation with JICA

(4) The contents of the reports of this Design Study, such as specifications and cost estimates, shall be treated to be confidential until finalization of tender procedures. General information on the Project, however, can be released to the stakeholders in such occasions as public hearing.

## 1.5 Legal Basis

### 1.5.1 General

(1) Decision No. 1741/QD-BGTVT dated 03/08/2011 of the Minister of the MOT on approval on detail planning of Port Group No. 1 until 2020, orientation up to 2030.

(2) Decision No. 1594 / QĐ-BGTVT dated 20/07/2011 of the Minister of the MOT on approval of replacing and supplementing a number of applicable standards for Lach Huyen Gateway Port Construction Investment Project

(3) Decision No. 476/ QD-BGTVT dated 13/03/2011 of the Minister of the MOT on approval for adjustment of Hai Phong international gateway port construction investment project- Starting stage

(4) Document No. 1346/TTg-KTN dated 03/08/2010 of the Prime Minister regarding adjustment of Hai Phong international gateway port project and Tan Vu- Lach Huyen highway project

(5) Based on MOD signed on 18/06/2010 among ministries, sectors of the Vietnam Government including MOT, MPI, MOF, VINAMARINE, MPMU II and JICA Appraisal mission; Final report of SAPROF Consultant

(6) Decision No. 2190/QD-TTg dated 24/12/2009 of the Prime Minister on approval on Master Plan of VN seaport system until 2020, orientation up to 2030

(7) Decision No.1448/QD/TTG dated 16/09/2009, approving adjustment on general plan on developing Hai Phong city up to 2025 and vision to 2050

(8) Decision No.1808/QD-CT dated 11/09/2009 of Hai Phong City People Committee, approving steering committee establishment of the city on Hai Phong International Gateway Port Project

(9) Decision No.34/2009/QD-TTG dated 02/03/2009, approving the Master Plan on Development of the Tonkin Gulf Coastal Economic Belt up to 2020

(10) Decision No. 3793/QD-BGTVT dated 22/12/2008 of MOT regarding approval on Hai Phong international gateway port project construction investment project (Lach Huyen port)

(11) Decision No 2231/QD-BTNMT dated 31/10/2008 of Ministry of Natural Resources and Environment, approving environmental impact assessment of Lach Huyen International Gateway Port Project, Hai Phong.

(12) Decision No. 1386/QD-BGTVT dated 19/05/2008 of the Ministry of Transport on approval of List of Construction standards applied for Lach Huyen Gateway Port Construction Investment Project

(13) Decision No.06/2008/QD-TTG dated 10/01/2008 establishing and promulgating regulation on operation of Dinh Vu-Cat Hai Economic Zone

(14) Letter No.8327/TTr-BGTVT dated 25/12/2007 of the Ministry of Transport on proposal for approving in principle the investment of Lach Huyen Gateway Port Project.

(15) Decision No.694/QD-CHHVN dated 23/10/2007 of Vietnam Maritime Administration on transfer of projects from the Maritime PMU I to Maritime PMU III.

(16) Decree No.131/2006/ND-CP on Issuance of Regulation on Management and Utilization of Official Development Assistance dated 09/11/2006

(17) Decree No.71/2006/ND-CP on seaport management and maritime navigation channel dated 25/07/2006

(18) Decision No.2570/QD-BGTVT dated 27/07/2005 of the Ministry of Transport on approval of outline, cost estimation for survey and FS preparation for Lach Huyen Gateway Port

Construction Project.

(19) Decision No.766/QD-CHHVN dated 31/12/2004 of the Vietnam Maritime Administration on assigning the representatives of the Project Owner for making Feasibility Study for the Lach Huyen Gateway Port Construction Project.

(20) Decision No.2561/QD-BGTVT dated 25/08/2004 of the Ministry of Transport on allowing the preparation of Feasibility Study for Lach Huyen Gateway Port Construction Project.

(21) Decision No.885/QD-TTg dated 22/08/2004 of the Prime Minister on approval of the detailed planning for northern seaport group (Group 1) to 2010 and orientation for development to 2020.

(22) Resolution No.32/NQ-TW dated 05/08/2003 of the Politburo on constructing and developing Hai Phong city in the process of industrialization and modernization.

(23) Decision No.04/2001/QD-TTg dated 10/01/2001 of the Prime Minister on approval of revised planning of Hai Phong city to 2020.

(24) Decision No.202/QD-TTg dated 12/10/1999 of the Prime Minister on approval of Master Plan for Vietnam seaports system to 2010.

### 1.5.2 Decrees/ Circulars related to Cost Estimates in Vietnam (as of September 2011)

(1) Construction Law No. 16/2003/QH11 dated 26 December 2003.

(2) Law No. 38/2009/QH12 dated 19 June 2009 amending and supplementing a number of articles of the Laws concerning capital construction investment.

(3) Decree No. 131/2006/ND-CP dated 09 November 2006 of the Government on Issuance of Regulation on Management and Utilization of Official Development Assistance

(4) Decree No. 12/2009/ND-CP dated 10 February 2009 of the Government on Management of Construction Investment Projects (CIPs)

(5) Decree No. 83/2009/ND-CP dated 15 October 2009 of the Government on Amending and supplementing a number of Articles of Decree No. 12/2009/ND-CP dated 10 February 2009 of Government on Management of Construction Investment Projects.

(6) Decree No. 112/2009/ND-CP dated 19 December 2009 of the Government on Management of work Construction Investment expenses

(7) Decree No. 209/2004/ND-CP dated 16 December 2004 of Government on quality management of construction works.

(8) Decree No. 49/2008/ND-CP dated 18 April 2008 of the Government on Amending and supplementing a number of Articles of Decree No. 209/2004/ND-CP dated 16 December 2004 of the Government on quality management of construction works.

(9) Decree No. 123/2008/ND-CP dated 08 December 2008 of the Government detailing and guiding the implementation of a number of articles of the Low on Value-Added Tax.

(10) Circular No. 04/2010/TT-BXD dated 26 May 2010 of the Ministry of Construction on guiding the marking and Management of work Construction Investment expenses

(11) Circular No. 129/2008/TT-BTC of December 26, 2008, guiding the implementation of a number of articles of the Value-Added Tax Law and guiding the implementation of the Government's Decree No. 123/2008/ND-CP of December 8, 2008, detailing and guiding the implementation of a number of articles of the Value-Added Tax Law

(12) Decree No. 87/2010/ND-CP of August 13, 2010, detailing a number of articles of the Law on Import Duty and Export Duty

(13) Construction Quantum - Construction Part in the announcement of the document No. 1776/BXD-VP dated 16 August 2007 of the Ministry of Construction.

(14) Construction Quantum - Installation Part in the announcement of the document No. 1777/BXD-VP dated 16 August 2007 of the Ministry of Construction.

(15) Construction Quantum - The waste material in the publication of the document No. 1784/BXD-VP dated 16 August 2007 of the Ministry of Construction.

(16) Construction Quantum on Sea and Inland following Decision No. 19/2000/QD-BXD dated 19 October 2000 of the Ministry of Construction.

(17) Decree No. 205/2004/ND-CP dated 14 December 2004 of the Government on decision salary grade systems in Vietnamese

(18) Decree No. 107/2010/ND-CP dated 29 October 2010 of the Government on decision minimum wage with the Vietnamese labor working in the foreign-Invested enterprise.

(19) Decision No. 131/QD-UBND dated 26 January 2011 of Hai Phong Committee on contraction equipment unit price (working shift) in Hai Phong province

(20) Material unit price Quotation of Hai Phong City Constructional - Financial Service at the present

## 1.6 Design Standard

In line with the Decision No. 1386 / QĐ-BGTVT dated May 19, 2008 approved by Ministry of Transport, the following design standards and codes are applied to this study.

### 1.6.1 Vietnamese Standards

#### 1) Standards for Topography, soil, hydrographic and ocean surveys

**Table 1.6.1 Standards for Topography, soil, hydrographic and ocean surveys**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Standard for "Land surveying in construction- General Requirements" | TCXDVN 309:2004 |
| 2 | Technical specifications for Engineering surveys - GPS monitoring and processing | TCXDVN 364:2006 |
| 3 | Building surveys - Basic principles | TCVN 4419:1987 |
| 4 | Surveying and Mapping regulations | 96TCN 43-90 |
| 5 | Surveying and Mapping from 1/500 to 1/25,000 scales | 96TCN 42-90 |
| 6 | Highway Survey procedures | 22TCN 263:2000 |
| 7 | Standard for soil investigation for Waterway works | 22 TCN 260:2000 |
| 8 | Soil investigation procedures | 22 TCN 259:2000 |
| 9 | River water level and temperature observation procedures | 94 TCN 1-88 |
| 10 | Code for observation of river water level discharge in tidal area | 94 TCN 17-99 |
| 11 | Code for observation of river suspended solid in non-tidal area | 94 TCN 13-96 |
| 12 | Code for maintenance and keeping conditions of hydrographic observation equipment and facilities | 94 TCN 15-97 |
| 13 | Code for onshore hydrographical observation | 94TCN 8:2006 |
| 14 | Method of soil physical property determination | TCVN 4195:1995 to TCVN 4199:1995 |

#### 2) Design Standards

**Table 1.6.2 General Design Standards**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Load and Actions- Design specifications | TCVN 2737:1995 |
| 2 | Concrete and reinforced concrete structures – Design specifications | TCVN 356:2005 |
| 3 | Steel structures – Design specifications | TCVN 338:2005 |
| 4 | Pile foundation - Design specifications | TCXD 205:1998 |
| 5 | Design of Structures for Earthquake Resistance | TCXDVN 375:2006 |
| 6 | Paint coating for steel bridge and steel structures coating - working and acceptance procedures | 22 TCN 253-98 |
| 7 | Concrete and reinforced concrete structures – Requirements of protection from corrosion under marine environment | TCXDVN 327:2004 |

**Table 1.6.3 Design Standards for Maritime Works**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Technical Standards for Port and Harbor Facilities | 22TCN 207-92 |
| 2 | Load and Actions (generated by wave and ship) to maritime work - Design specifications | 22 TCN 222-95 |
| 3 | Foundations of maritime structures - Design specifications | TCVN 4253:1986 |
| 4 | Concrete and Reinforced concrete of maritime works - Design specifications | TCVN 4116:1895 |
| 5 | Sea dykes - Design procedures | Decision No. 115-QD/KT4 on Jan. 12, 1976 of MOT |
| 6 | Guidance on sea dykes design by MARD | 14 TCN 130:2002 |
| 7 | Rules for waterway navigation signaling in Vietnam | Decision No. 4099/2000/QD-BGTVT on Dec. 28, 2000 |

**Table 1.6.4 Design standards for Buildings**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Grades for dwellings and civil works - General principles | TCXD 13:1991 |
| 2 | Warehouse - Basic Design Principles | TCXD 4317:1986 |
| 3 | High buildings - Single-unit reinforced concrete structure | TCXD 198:1997 |
| 4 | Office - Design specifications | TCVN 4601:1988 |
| 5 | Public works - Basic Design Principles | TCXDVN 276:2003 |
| 6 | Residence - Basic rules for design | TCVN 4451:1987 |
| 7 | Building structures and foundations - Basic rules for calculations | TCXD 40:1987 |
| 8 | Masonry and reinforced masonry structures - Design specifications | TCVN 5573:1991 |

**Table 1.6.5 Design Standards for Power Supply Utility**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Artificial outdoor lighting for public buildings and urban infrastructure-Design specifications | TCXDVN 333:2005 |
| 2 | Artificial lighting Standard in building | TCXD 16:1986 |
| 3 | Natural lighting standard in building | TCXD 29:1991 |
| 4 | Installation of electric equipments in dwellings and public building - Design specifications | TCXD 27:1991 |
| 5 | Thunder light prevention for construction works - Design and construction standards | TCXD 46:1984 |
| 6 | Complete unit of transformer up to 1000KVA, voltage up to 20KV | TCVN 3715:1982 |
| 7 | Code of electrical equipment - Part III - Distribution Facilities and Transformer | 11 TCN 20:2006 |
| 8 | Code of electrical equipment - Part IV: Protection and Automation | 11 TCN 21:2006 |

**Table 1.6.6 Design Standards for Water Supply and Drainage Utility**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Internal water supply – Design specifications | TCVN 4513-1988 |
| 2 | Water Supply - Distribution System and Facilities. Design specifications | TCXDVN 33:2006 |
| 3 | Drainage, External drainage system - Design specifications | TCXD 51:1974 |
| 4 | Internal Drainage – Design specifications | TCVN 4474:1987 |
| 5 | Fire protection equipment – Fire hydrant - Technical requirements | TCVN 6379:1998 |

**Table 1.6.7 Design Standards for Fire Prevention**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Fire prevention and protection for building and structure - Design requirements | TCVN 2622:1995 |
| 2 | Standard for fire protection in building design. Terminology - Definitions | TCVN 6160:1996 |
| 3 | Fire extinguishing system. General requirement for design, installation and use | TCN 5760:1993 |
| 4 | Fire prevention in building design and construction. Terminology - Definitions | TCVN 3991:1985 |

**Table 1.6.8 Design Standards for Highway**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Highway - Design specifications | TCVN 4054-05 |
| 2 | Flexible pavement - Design requirements and guidance | 22 TCN 211 - 06 |
| 3 | Survey and Design procedures for motorway embankment on soft soil foundation | 22 TCN 262:2000 |
| 4 | Rigid pavement - Design specifications | 22 TCN 223:1995 |

### 3) Standards for materials and testing

**Table 1.6.9 Standards for Materials**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Cements. Classification | TCVN 5493:2004 |
| 2 | Methods of taking and preparing samples of cement | TCVN 4787:2001 |
| 3 | Masonry cement | TCXDVN 324:2004 |
| 4 | Solid clay bricks | TCVN 1451:1998 |
| 5 | Concrete. Classification by compressive strength | TCVN 6025:1995 |
| 6 | Soil - Classification for civil engineering | TCVN 5747:1993 |
| 7 | Lightweight aggregates for concrete – Expanded clay, gravel and sand – Technical requirements | TCVN 6220:1997 |
| 8 | Mass concrete -Code of practice of construction and acceptance | TCXDVN 305:2004 |
| 9 | “Chemical admixtures for concrete | TCXDVN 325:2004 |
| 10 | Hot-rolled carbon steel for building. Specifications | TCVN 5709:1993 |
| 11 | Cold reduced steel wire for the reinforcement of concrete | TCVN 6288:1997 |
| 12 | Steel for the reinforcement of concrete. Ribbed bars | TCVN 6285:1997 |
| 13 | Steel for the reinforcement of concrete. Welded fabric | TCVN 6286:1997 |
| 14 | Mortar for masonry. Specifications | TCVN 4314:2003 |
| 15 | Test method for determination of aggregates | TCVN 7572:2006 |
| 16 | Traffic signs fluid painting on asphalt concrete pavement | 64 TCN 92:1995 |

**Table 1.6.10 Standards for Testing**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Soil / rock physical properties testing procedure | 22 TCN 57-84 |
| 2 | Cement concrete testing procedure | 22 TCN 60-84 |
| 3 | Asphalt concrete testing procedure | 22 TCN 62-84 |
| 4 | Sand for construction works - Method for determination of mica content | TCVN 4376:1986 |
| 5 | Concrete - Resistance testing and evaluating - General regulations | TCVN 5440:1991 |
| 6 | Steel bars for reinforcement of concrete. Bend and rebend tests | TCVN 6287:1997 |
| 7 | Heavy concrete. Curing requirements under natural humidity conditions | TCVN 5592:1991 |
| 8 | Heavy weight concrete. Determination of prismatic compressive strength and static modulus of elasticity in compression | TCVN 5726:1993 |
| 9 | Heavyweight concrete compounds - Slump test | TCVN 3106:1993 |
| 10 | Soil physical property determination method | TCVN 4195:1995 to TCVN 4199:1995 |

### 1.6.2 Foreign Standards

**Table 1.6.11 Foreign Standards and Reference Documents**

| No. | Name of the Standard | No. of the Standard |
|---|---|---|
| 1 | Guidance for design of local ship channels | UNDP |
| 2 | Approach channels - A guide for design | PIANC, 2000 |
| 3 | Dredging a handbook for engineers | R.N Bray & A.D. Bates & J.M.Land Amold.USA |
| 4 | British standard code for maritime structures | BS 6349 |
| 5 | Technical standard and commentaries for port and harbors facilities in Japan | OCDI-2002 |
| 6 | Handbook of port and harbor engineering | Gregory P.Tsinder 2003 |

# 2. SURVEY AND STUDY ON NATURAL CONDITIONS

## 2.1 Subsoil Investigation Survey

### 2.1.1 General Conditions

The Lach Huyen Port Development area is located in the lower reaches of the Red River (Song Cai River). Large amounts of soil and sand now in from the Chua Nam Trieu River and the Lach Huyen River, resulting in a thick built-up of a soft clay layer.

This project area belongs to Cat Hai district, Haiphong city. It is situated on the right of Lach Huyen river. The right bank of the river, beginning from stone jetty in the south of Cat Hai island, is a big sand bar with the length of about 6,000m and the width of 1,000m, its altitude is from 0 to +1.0m. The opposite bank is Cat Ba Island.

### 2.1.2 Geological Characteristics

In this region, the Feasibility Study Report for Hai Phong International Gateway Port Project, a geological and property survey was conducted by TEDI in 2007. And later on, five additional borings (PBH-1 to 5) and indoor soil property tests were conducted in 2008 by Nippon Koei. And also in 2010, 10 borings with soil property tests were carried out under THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM by JICA (hereinafter, JICA SAPROF (Special Assistance for Project Formation) Study).

According to JICA SAPROF Study result, the geological layers in this region are broken down into formations in the order of newer generations (Layer-1, Layer-2, Layer-8, etc.). The geological status for each layer, as well as the N-value distribution conditions, is shown in Table 2.1.1.

### 2.1.3 Subsoil Investigation Survey in this Study

The following subsoil investigation borings have been carried out with soil property tests in this Study to check the existing data and obtain the latest information for design of port structures.

The name of each area is shown in Figure 2.1.1. And quantities of boring investigations are shown in Table 2.1.2.

Details of quantities for this subsoil investigation survey are shown in Table 2.1.3 to Table 2.1.8.

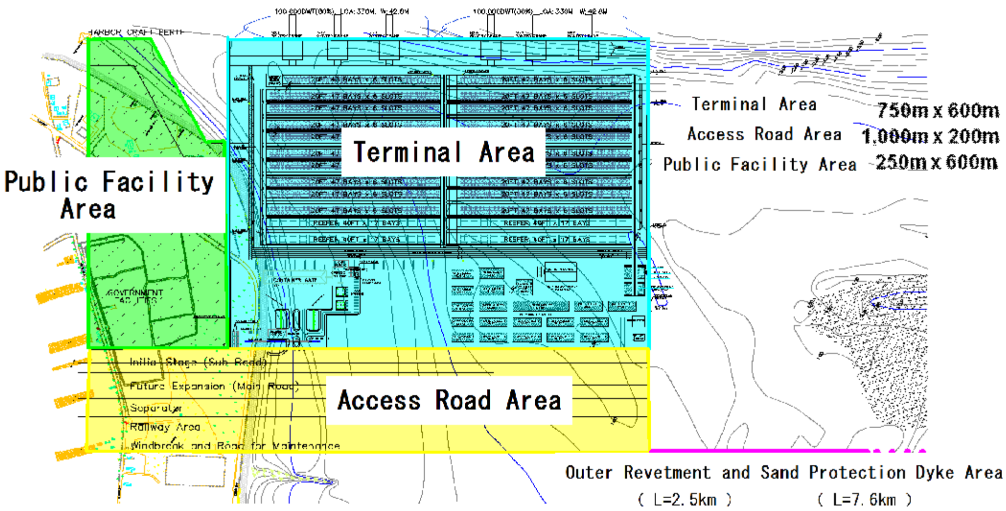



**Figure 2.1.1 Areas for Port Construction**

**Table 2.1.1 Soil Stratification at Project Site with N-value**

| Layer Name | | Average N-Value | Areas |
|---|---|---|---|
| 1a | Loose sand, clayey sand (SP/SP-SC) | 4.1 | 1. Reclamation area |
| | Grey, light grey | 5.7 | 2. Outer revetment B area |
| | | 4.8 | 3. Sand protection dyke area |
| 1b | Sandy clay (CL/SC) | 0.7 | 1. Reclamation area |
| | blackish grey, brownish grey, grey | 4.7 | 2. Outer revetment B area |
| | | 4.5 | 3. Sand protection dyke area |
| 2 | Fat clay with sand (CH) | 1.0 | 1. Reclamation area |
| | Grey, brownish and yellowish grey | 0.7 | 2. Outer revetment B area |
| | | 0.8 | 3. Sand protection dyke area |
| 3a | Sand (SP) | 4.4 | 1. Reclamation area |
| | Light grey and greenish grey | 4.5 | 2. Outer revetment B area |
| | | - | 3. Sand protection dyke area |
| 3b | Clayey sand/ Sandy clay (CL/SC) | 4.8 | 1. Reclamation area |
| | Yellowish grey, grey | 5.5 | 2. Outer revetment B area |
| | | 7.8 | 3. Sand protection dyke area |
| 3c | Sand (SP/SP-SC) | 5.8 | 1. Reclamation area |
| | Yellowish grey, grey | 21.0 | 2. Outer revetment B area |
| | | - | 3. Sand protection dyke area |
| 4 | Sandy lean clay (CL) | 10.3 | 1. Reclamation area |
| | Reddish brown, yellowish brown | - | 2. Outer revetment B area |
| | | 10.7 | 3. Sand protection dyke area |
| 5 | Fat clay with sand (CH) | 5.7 | 1. Reclamation area |
| | Grey, yellowish grey | 4.8 | 2. Outer revetment B area |
| | | 6.0 | 3. Sand protection dyke area |
| 6 | Lean clay (CL) | - | 1. Reclamation area |
| | Grey, reddish brown and bluish grey | 12.1 | 2. Outer revetment B area |
| | | 13.2 | 3. Sand protection dyke area |
| 7 | Silty, clayey sand (SC-SM) | - | 1. Reclamation area |
| | Light grey and yellowish grey | - | 2. Outer revetment B area |
| | | 15.9 | 3. Sand protection dyke area |
| 8a | Sand | 6.0 | 1. Reclamation area |
| | Yellowish grey, light grey | 6.9 | 2. Outer revetment B area |
| | | - | 3. Sand protection dyke area |
| 8b | Poorly-graded sand with silt (SP-SM) | - | 1. Reclamation area |
| | Light grey | 17.0 | 2. Outer revetment B area |
| | | 23.4 | 3. Sand protection dyke area |
| 8c | Silty Sand (SM/ SC-SM) | - | 1. Reclamation area |
| | Bluish grey, yellowish grey, light grey | 43.7 | 2. Outer revetment B area |
| | | 48.3 | 3. Sand protection dyke area |
| 9 | Completely weathered sandstone | - | 1. Reclamation area |
| | (Sandy clay with fragment) | - | 2. Outer revetment B area |
| | Reddish brown, yellowish brown | - | 3. Sand protection dyke area |
| 10 | Moderately weathered silt/claystone | - | 1. Reclamation area |
| | Reddish brown, yellowish brown | - | 2. Outer revetment B area |
| | | - | 3. Sand protection dyke area |

**Table 2.1.2 Quantities of Boring Investigation**

| Area | Nos. of Offshore Borings | Nos. of Onshore Borings | Sub Total | Total |
|---|---|---|---|---|
| Terminal Area | 50 | 2 | 52 | 211 |
| Access Road Area | 21 | 6 | 27 | |
| Public Facility Area | 6 | 4 | 10 | |
| Outer Revetment Area | 24 | - | 24 | |
| Sand Protection Dyke Area | 26 | - | 26 | |
| Channel Area | 72 | - | 72 | |

**Table 2.1.3 Quantities of Boring Investigation (Terminal, Access Road and Public Facility Area)**

| Survey Area | General Arrangement | Preceding Boring (Nr) | Following Boring (Nr) |
|---|---|---|---|
| Terminal Area (800m x600m) | @100m cross interval (@50m interval along face-line of berth) | 29 (offshore 27 & onshore 2) | 23 (Offshore) |
| Access Road Area (200m x1050m) | (@ 100m interval in 3 lines) | 13 (offshore 10 & onshore 3) | 14 (offshore 11 & onshore 3) |
| Public Facility Area (250m x 600m) | (@ 50m interval along Berth) | 3 (offshore 1 & onshore 2) | 7 (offshore 5 & onshore 2) |
| | Sub-total | 45 | 44 |
| | Total | 89 | |

**Table 2.1.4 Quantities of In-situ Sampling and Tests (Terminal, Access Road and Public Facility Area)**

| Item | Frequency | Survey Area | Preceding Boring (Nr) | Following Boring (Nr) |
|---|---|---|---|---|
| Standard Penetration Test (SPT) | One (1) m interval of boring except the depth where undisturbed soil sampling or In-situ Vane Shear Test are carried out | Terminal Area<br>Access Road Area<br>Public Area | 533<br>258<br>63 | 409<br>290<br>113 |
| | | Total | 854 | 812 |
| Undisturbed Sampling | Every three (3) or four (4) m interval in clay layer by either thin wall sampler (N<4) or rotary double tube sampler (N=4 to 15) and as designated by the Employer | Terminal Area<br>Access Road Area<br>Public Area | 184<br>81<br>12 | 112<br>77<br>32 |
| | | Total | 277 | 221 |
| In-situ Vane Shear Test | Four (4) meter interval at upper & lower clay layer and one (1) time at middle clay layer for every four (4) boring holes and as designated by the Employer | Terminal Area<br>Access Road Area<br>Public Area | 32<br>22<br>3 | 32<br>19<br>22 |
| | | Total | 57 | 73 |

**Table 2.1.5 Quantities of Soil Property Tests (Terminal, Access Road and Public Facility Area)**

| **Item** | **Frequency** | **Survey Area** | **Preceding Boring (Nr)** | **Following Boring (Nr)** |
|---|---|---|---|---|
| Physical Tests | | | | |
| Grains size analysis | For all disturbed and undisturbed samples | Terminal Area<br>Access Road Area<br>Public Area | 37316334 | 522360146 |
| | | Total | 570 | 1,028 |
| Specific gravity | For all disturbed and undisturbed samples | Terminal Area<br>Access Road Area<br>Public Area | 37316334 | 522360146 |
| | | Total | 570 | 1,028 |
| Water contents | For all undisturbed samples | Terminal Area<br>Access Road Area<br>Public Area | 2297011 | 1177532 |
| | | Total | 310 | 219 |
| Atterberg Limits (LL/PL) | For all undisturbed samples of cohesive soil | Terminal Area<br>Access Road Area<br>Public Area | 33914128 | 464326135 |
| | | Total | 508 | 925 |
| Unit weight | For all undisturbed samples | Terminal Area<br>Access Road Area<br>Public Area | 1616811 | 1107232 |
| | | Total | 240 | 214 |
| Mechanical Tests | | | | |
| Uni-axial Compression | Two (2) tests per each undisturbed sample | Terminal Area<br>Access Road Area<br>Public Area | 2819914 | 19612959 |
| | | Total | 394 | 384 |
| Tri-axial Compression (UU) | One half (1/2) of undisturbed sample | Terminal Area<br>Access Road Area<br>Public Area | 99547 | 936430 |
| | | Total | 160 | 187 |
| Tri-axial Compression (CU) | One half (1/2) of undisturbed sample | Terminal Area<br>Access Road Area<br>Public Area | 97345 | 502620 |
| | | Total | 136 | 96 |
| Consolidation | Four (4) undisturbed samples at every bored hole | Terminal Area<br>Access Road Area<br>Public Area | 1365611 | 1016529 |
| | | Total | 203 | 195 |

**Table 2.1.6 Quantities of Boring Investigation (Outer Revetment, Sand Protection Dyke and Channel Area)**

| **Survey Area** | **General Arrangement** | **Preceding Boring (Nr)** | **Following Boring (Nr)** |
|---|---|---|---|
| Outer Revetment (Breakwater) Area | @100m interval, 1 lines | 12 (Offshore) | 12 (Offshore) |
| Sand Protection Dyke Area | @ 300m interval, 1 lines | 13 (Offshore) | 13 (Offshore) |
| Channel Area and Ship Turning Basin | @ 500m interval, 2 lines | 35 (Offshore) | 37 (Offshore) |
| | Sub-total | 60 | 62 |
| | Total | 122 | |

**Table 2.1.7 Quantities of In-situ Sampling and Test Schedule (Outer Revetment, Sand Protection Dyke and Channel Area)**

| Item | Frequency | Survey Area | Preceding Boring (Nr) | Following Boring (Nr) |
|---|---|---|---|---|
| Standard Penetration Test (SPT) | One (1) m interval of boring except at the depth where undisturbed soil samples are taken | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 326<br>390<br>227 | 278<br>296<br>246 |
| | | Total | 943 | 820 |
| Undisturbed Sampling | Every three (3) or four (4) m interval in clay layer by either thin wall sampler (N<4) or rotary double tube sampler (N=4 to 15) and as designated by the Employer | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 58<br>43<br>76 | 40<br>47<br>80 |
| | | Total | 177 | 167 |

**Table 2.1.8 Quantities of Soil Property Tests (Outer Revetment, Sand Protection Dyke and Channel Area)**

| Item | Frequency | Survey Area | Preceding Boring (Nr) | Following Boring (Nr) |
|---|---|---|---|---|
| Physical Tests | | | | |
| Grains size analysis | For all disturbed and undisturbed samples | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 194<br>167<br>282 | 199<br>144<br>291 |
| | | Total | 643 | 634 |
| Specific gravity | For all disturbed and undisturbed samples | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 195<br>167<br>282 | 199<br>144<br>291 |
| | | Total | 644 | 634 |
| Water contents | For all undisturbed samples | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 53<br>42<br>72 | 41<br>47<br>79 |
| | | Total | 245 | 167 |
| Atterberg Limits (LL/PL) | For all undisturbed samples of cohesive soil | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 109<br>124<br>181 | 120<br>102<br>184 |
| | | Total | 414 | 406 |
| Unit weight | For all undisturbed samples | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 53<br>42<br>70 | 39<br>47<br>78 |
| | | Total | 165 | 164 |
| Mechanical Tests | | | | |
| Uni-axial Compression | Two (2) tests per each undisturbed sample | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 58<br>70<br>130 | 71<br>92<br>141 |
| | | Total | 258 | 304 |
| Tri-axial Compression (UU) | One half (1/2) of undisturbed sample | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 28<br>40<br>Nil | 35<br>26<br>Nil |
| | | Total | 68 | 61 |
| Tri-axial Compression (CU) | One half (1/2) of undisturbed sample | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 34<br>39<br>Nil | 37<br>35<br>Nil |
| | | Total | 73 | 72 |
| Consolidation | Four (4) Undisturbed samples at every bored hole | Outer Revetment<br>Sand Protection Dyke<br>Channel and Ship Basin | 48<br>41<br>Nil | 39<br>35<br>Nil |
| | | Total | 89 | 74 |

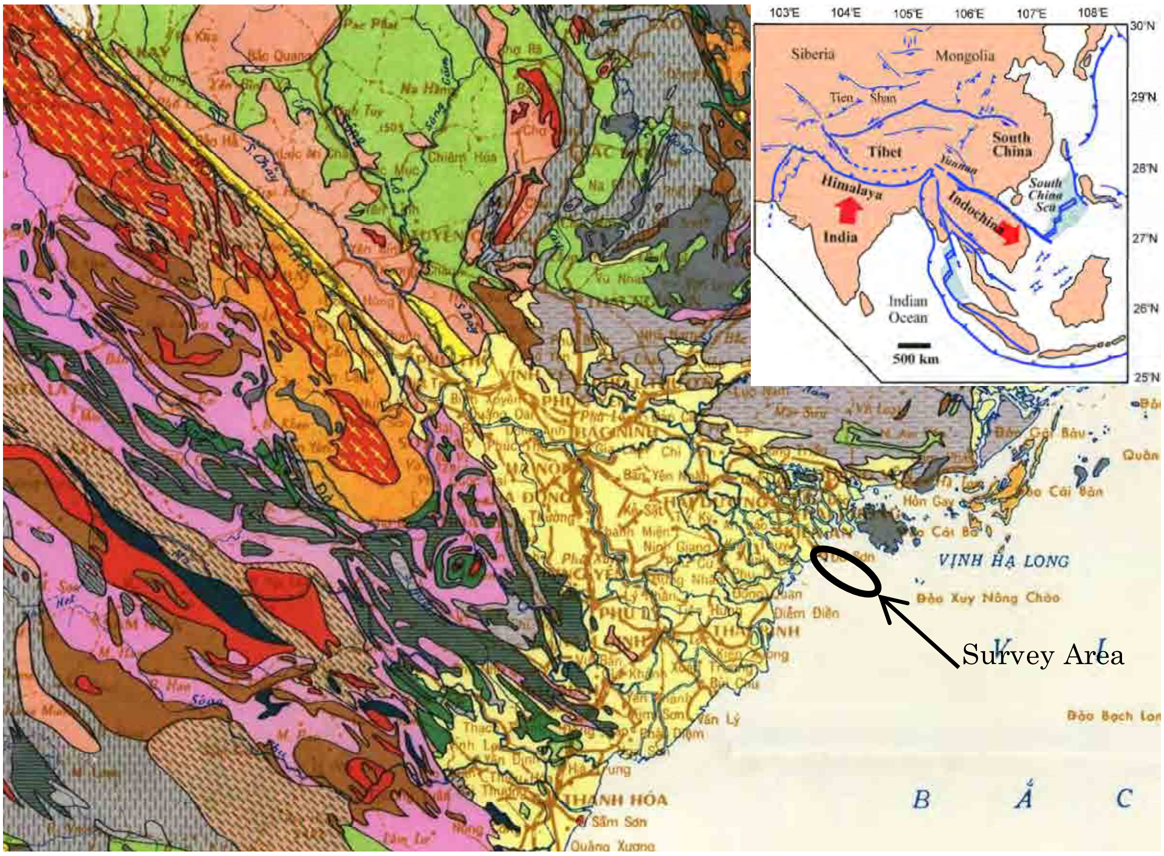
### 2.1.4 Location, Topography and Geology

Hai Phong is a port city, located in the east of northern coastal area, approximately 120 km away from Hanoi Capital. The investigation area locates in Cat Hai Island that is 13 km away from Hai Phong downtown in the east.

Location of the project site is shown in Figure 2.1.2 and Figure 2.1.3.

Survey area is located at the sea side of south end of Cat Hai Island which is at the front end of delta area of Red River. Large amount of soil and sand flow in from the Chua Nam Trieu River and Lach Huyen River, resulting in a thick buildup of a soft clay layer. At ground surface, sand can be seen in Cat Hai Island and at its surrounding areas and shellfish which lives in seabed sand are landed at Ben Got Jetty of Cat Hai Island as shown in Figure 2.1.4

As shown in Figure 2.1.2, geological structure can be seen from north west to south east direction. Because the boundary of tectonic plate exists around this area from north west to south east direction as shown in the upper right map of Figure 2.1.2. Therefore some geological and structural boundary may exist between Cat Hai Island and Cat Ba Island. One symptom of this is outcrops observed in Cat Ba Island. Weathered lime stone which is main bed rock of Cat Ba Island can be seen as shown in Figure 2.1.4. However only silt/clay stone is identified as a bed rock of Lach Huyen survey area according to survey results including existing ones. It means Lach Huyen River is flowing along the geological or structural boundary between Cat Hai Island and Cat Ba Island.




(Extracted from Geological Map Vietnam_Cambodia_Laos. 1971)

**Figure 2.1.2 Location of Survey Area on Geological Map**


(Extracted from Google Earth)

**Figure 2.1.3 Location of Survey Area**

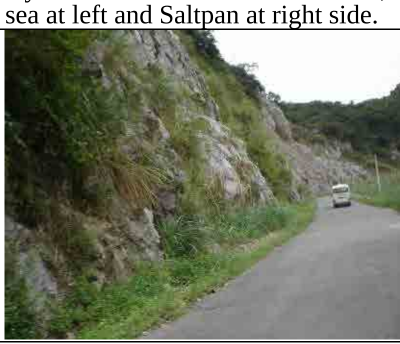
| | | |
|---|---|---|
|  |  |  |
| Sand beach near Ben Got Jetty at low tide | Stone revetment and sand beach in port reclamation area at low tide | Port reclamation area (view from sea side to land side) |
|  |  |  |
| Sand shoal at port reclamation area between SBH-1 and SBH-3 | Dyke at east side of Cat Ba Island; sea at left and Saltpan at right side. | Wide saltpan area inside the Cat Hai Island |
|  |  |  |
| Shellfish living in sandy place is collected at Ben Got Jetty. | Outcrops of hard lime stone seen at the west seaside of Cat Ba Island. | Inclined outcrop of lime stone seen at the west seaside of Cat Ba Island |

**Figure 2.1.4 Photos at and near Survey Area**

(Extracted from Report on "THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM", 2010 by JICA)

### 2.1.5 Boring Investigation

#### 1) Location and co-ordinates of boring points

Totally 211 offshore and onshore borings has been carried out at the planned port construction area, outer revetment area, sand protection dyke area and along the planned navigation channel from April to July 2011. The locations of boring points are tabulated in Table 2.1.9 and Table 2.1.10, and shown in the Figure 2.1.5 and Figure 2.1.6.

**Table 2.1.9 Co-ordinates of the boring locations for Terminal Area, Access Road Area and Public Facility Area**

| No. | BH No. | Actual Coordinates (m) – VN2000 | | No. | BH No. | Actual Coordinates (m) – VN2000 | |
|---|---|---|---|---|---|---|---|
| | | Northing | Easting | | | Northing | Easting |
| 1 | T2 | 2301469 | 620145 | 46 | T56 | 2301109 | 619835 |
| 2 | T3 | 2301426 | 620170 | 47 | T57 | 2301023 | 619887 |
| 3 | T4 | 2301383 | 620196 | 48 | T58 | 2300937 | 619937 |
| 4 | T5 | 2301339 | 620221 | 49 | T59 | 2300852 | 619989 |
| 5 | T6 | 2301297 | 620247 | 50 | T60 | 2300766 | 620040 |
| 6 | T8 | 2301211 | 620299 | 51 | T61 | 2300680 | 620091 |
| 7 | T9 | 2301168 | 620324 | 52 | T62 | 2300594 | 620143 |
| 8 | T10 | 2301125 | 620350 | 53 | B1 | 2301420 | 619533 |
| 9 | T11 | 2301082 | 620376 | 54 | B2 | 2301230 | 619647 |
| 10 | T13 | 2300996 | 620427 | 55 | B4 | 2301058 | 619750 |
| 11 | T14 | 2300953 | 620452 | 56 | B5 | 2300972 | 619801 |
| 12 | T15 | 2300910 | 620478 | 57 | B7 | 2300800 | 619903 |
| 13 | T17 | 2301460 | 620092 | 58 | B8 | 2300715 | 619955 |
| 14 | T18 | 2301400 | 620128 | 59 | B9 | 2300629 | 620006 |
| 15 | T19 | 2301314 | 620178 | 60 | B10 | 2300543 | 620057 |
| 16 | T20 | 2301228 | 620230 | 61 | B11 | 2301410 | 619461 |
| 17 | T21 | 2301142 | 620281 | 62 | B12 | 2301382 | 619630 |
| 18 | T22 | 2301057 | 620333 | 63 | B13 | 2301093 | 619612 |
| 19 | T23 | 2300971 | 620384 | 64 | B14 | 2301007 | 619664 |
| 20 | T24 | 2300885 | 620435 | 65 | B15 | 2300921 | 619715 |
| 21 | T25 | 2300799 | 620486 | 66 | B16 | 2300835 | 619766 |
| 22 | T26 | 2301435 | 620049 | 67 | B17 | 2300749 | 619817 |
| 23 | T27 | 2301409 | 620005 | 68 | B18 | 2300663 | 619869 |
| 24 | T29 | 2301263 | 620093 | 69 | B19 | 2300577 | 619920 |
| 25 | T30 | 2301177 | 620144 | 70 | B20 | 2301308 | 619546 |
| 26 | T32 | 2301005 | 620247 | 71 | B21 | 2301127 | 619475 |
| 27 | T33 | 2300919 | 620298 | 72 | B22 | 2301041 | 619527 |
| 28 | T34 | 2300834 | 620349 | 73 | B23 | 2300955 | 619578 |
| 29 | T35 | 2300748 | 620400 | 74 | B24 | 2300870 | 619629 |
| 30 | T37 | 2301298 | 619956 | 75 | B25 | 2300784 | 619680 |
| 31 | T38 | 2301212 | 620007 | 76 | B26 | 2300698 | 619732 |
| 32 | T40 | 2301040 | 620110 | 77 | B27 | 2300612 | 619783 |
| 33 | T41 | 2300954 | 620161 | 78 | B28 | 2300526 | 619834 |
| 34 | T43 | 2300782 | 620263 | 79 | B29 | 2300440 | 619885 |
| 35 | T45 | 2301332 | 619818 | 80 | G1 | 2301752 | 620034 |
| 36 | T46 | 2301246 | 619870 | 81 | G2 | 2301705 | 620062 |
| 37 | T47 | 2301160 | 619921 | 82 | G3 | 2301657 | 620091 |
| 38 | T48 | 2301075 | 619972 | 83 | G4 | 2301610 | 620060 |
| 39 | T49 | 2300989 | 620024 | 84 | G5 | 2301563 | 620030 |
| 40 | T50 | 2300903 | 620074 | 85 | G6 | 2301516 | 620000 |
| 41 | T51 | 2300817 | 620126 | 86 | G7 | 2301477 | 619965 |
| 42 | T52 | 2300731 | 620177 | 87 | G8 | 2301701 | 619948 |
| 43 | T53 | 2300645 | 620228 | 88 | G9 | 2301692 | 619836 |
| 44 | T54 | 2301281 | 619733 | 89 | G10 | 2301503 | 619832 |
| 45 | T55 | 2301195 | 619784 | - | - | - | - |

*T-xx series borings for Terminal Area, B-xx series borings for Access Road Area and G-xx series borings for Government Facility Area.

**Table 2.1.10 Co-ordinates of the boring locations for Outer Revetment Area, Sand Protection Dyke Area and Navigation Channel Area**

| No. | BH No. | Actual Coordinates (m) – VN2000 | | No. | BH No. | Actual Coordinates (m) – VN2000 | |
|---|---|---|---|---|---|---|---|
| | | Northing | Easting | | | Northing | Easting |
| 1 | O-01 | 2300312 | 619962 | 62 | C-12 | 2299382 | 621632 |
| 2 | O-02 | 2300228 | 620012 | 63 | C-13 | 2299415 | 621877 |
| 3 | O-03 | 2300138 | 620064 | 64 | C-14 | 2298992 | 621934 |
| 4 | O-04 | 2300054 | 620114 | 65 | C-15 | 2298908 | 622278 |
| 5 | O-05 | 2299967 | 620168 | 66 | C-16 | 2298592 | 622237 |
| 6 | O-06 | 2299882 | 620218 | 67 | C-17 | 2298503 | 622559 |
| 7 | O-07 | 2299797 | 620271 | 68 | C-18 | 2298185 | 622530 |
| 8 | O-08 | 2299711 | 620324 | 69 | C-19 | 2298097 | 622857 |
| 9 | O-09 | 2299625 | 620373 | 70 | C-20 | 2297789 | 622833 |
| 10 | O-10 | 2299537 | 620423 | 71 | C-21 | 2297694 | 623155 |
| 11 | O-11 | 2299453 | 620476 | 72 | C-22 | 2297382 | 623125 |
| 12 | O-12 | 2299369 | 620527 | 73 | C-23 | 2297294 | 623451 |
| 13 | O-13 | 2299281 | 620578 | 74 | C-24 | 2296980 | 623425 |
| 14 | O-14 | 2299198 | 620631 | 75 | C-25 | 2296892 | 623751 |
| 15 | O-15 | 2299108 | 620681 | 76 | C-26 | 2296580 | 623722 |
| 16 | O-16 | 2299028 | 620733 | 77 | C-27 | 2296491 | 624050 |
| 17 | O-17 | 2298948 | 620796 | 78 | C-28 | 2296181 | 624025 |
| 18 | O-18 | 2298868 | 620862 | 79 | C-29 | 2296090 | 624348 |
| 19 | O-19 | 2298792 | 620922 | 80 | C-30 | 2295777 | 624323 |
| 20 | O-20 | 2298716 | 620988 | 81 | C-31 | 2295687 | 624654 |
| 21 | O-21 | 2298635 | 621048 | 82 | C-32 | 2295381 | 624616 |
| 22 | O-22 | 2298556 | 621107 | 83 | C-33 | 2295290 | 624949 |
| 23 | O-23 | 2298474 | 621169 | 84 | C-34 | 2294979 | 624915 |
| 24 | O-24 | 2298403 | 621235 | 85 | C-35 | 2294878 | 625247 |
| 25 | D-01 | 2298164 | 621412 | 86 | C-36 | 2294571 | 625123 |
| 26 | D-02 | 2297929 | 621589 | 87 | C-37 | 2294488 | 625545 |
| 27 | D-03 | 2297695 | 621758 | 88 | C-38 | 2294176 | 625516 |
| 28 | D-04 | 2297463 | 621932 | 89 | C-39 | 2294082 | 625839 |
| 29 | D-05 | 2297231 | 622103 | 90 | C-40 | 2293769 | 625810 |
| 30 | D-06 | 2296998 | 622278 | 91 | C-41 | 2293680 | 626137 |
| 31 | D-07 | 2296764 | 622451 | 92 | C-42 | 2293367 | 626107 |
| 32 | D-08 | 2296533 | 622624 | 93 | C-43 | 2293315 | 626474 |
| 33 | D-09 | 2296297 | 622795 | 94 | C-44 | 2292970 | 626410 |
| 34 | D-10 | 2296064 | 622968 | 95 | C-45 | 2292914 | 626777 |
| 35 | D-11 | 2295832 | 623144 | 96 | C-46 | 2292566 | 626704 |
| 36 | D-12 | 2295602 | 623314 | 97 | C-47 | 2292512 | 627075 |
| 37 | D-13 | 2295366 | 623487 | 98 | C-48 | 2292163 | 627002 |
| 38 | D-14 | 2295133 | 623661 | 99 | C-49 | 2292110 | 627373 |
| 39 | D-15 | 2294902 | 623832 | 100 | C-50 | 2291762 | 627300 |
| 40 | D-16 | 2294668 | 624005 | 101 | C-51 | 2291709 | 627671 |
| 41 | D-17 | 2294435 | 624178 | 102 | C-52 | 2291367 | 627603 |
| 42 | D-18 | 2294202 | 624352 | 103 | C-53 | 2291308 | 627969 |
| 43 | D-19 | 2293971 | 624522 | 104 | C-54 | 2290960 | 627896 |
| 44 | D-20 | 2293738 | 624697 | 105 | C-55 | 2290906 | 628268 |
| 45 | D-21 | 2293504 | 624871 | 106 | C-56 | 2290558 | 628194 |
| 46 | D-22 | 2293271 | 625045 | 107 | C-57 | 2290505 | 628565 |
| 47 | D-23 | 2293038 | 625216 | 108 | C-58 | 2290157 | 628492 |
| 48 | D-24 | 2292806 | 625389 | 109 | C-59 | 2290101 | 628859 |
| 49 | D-25 | 2292572 | 625561 | 110 | C-60 | 2289756 | 628790 |
| 50 | D-26 | 2292291 | 625770 | 111 | C-61 | 2289704 | 629160 |
| 51 | C-01 | 2301646 | 620270 | 112 | C-62 | 2289354 | 629089 |
| 52 | C-02 | 2301541 | 620577 | 113 | C-63 | 2289299 | 629459 |
| 53 | C-03 | 2301221 | 620524 | 114 | C-64 | 2288952 | 629386 |
| 54 | C-04 | 2301114 | 620838 | 115 | C-65 | 2288899 | 629755 |
| 55 | C-05 | 2300788 | 620782 | 116 | C-66 | 2288551 | 629684 |
| 56 | C-06 | 2300687 | 621092 | 117 | C-67 | 2288497 | 630056 |
| 57 | C-07 | 2300359 | 621037 | 118 | C-68 | 2288155 | 629986 |
| 58 | C-08 | 2300252 | 621345 | 119 | C-69 | 2288095 | 630355 |
| 59 | C-09 | 2299929 | 621292 | 120 | C-70 | 2301041 | 621297 |
| 60 | C-10 | 2299701 | 621674 | 121 | C-71 | 2301756 | 620635 |
| 61 | C-11 | 2299600 | 621490 | 122 | C-72 | 2301411 | 620841 |

*O-xx series borings for Outer Revetment Area, D-xx series borings for Sand Protection Dyke and C-xx series borings for Channel Area

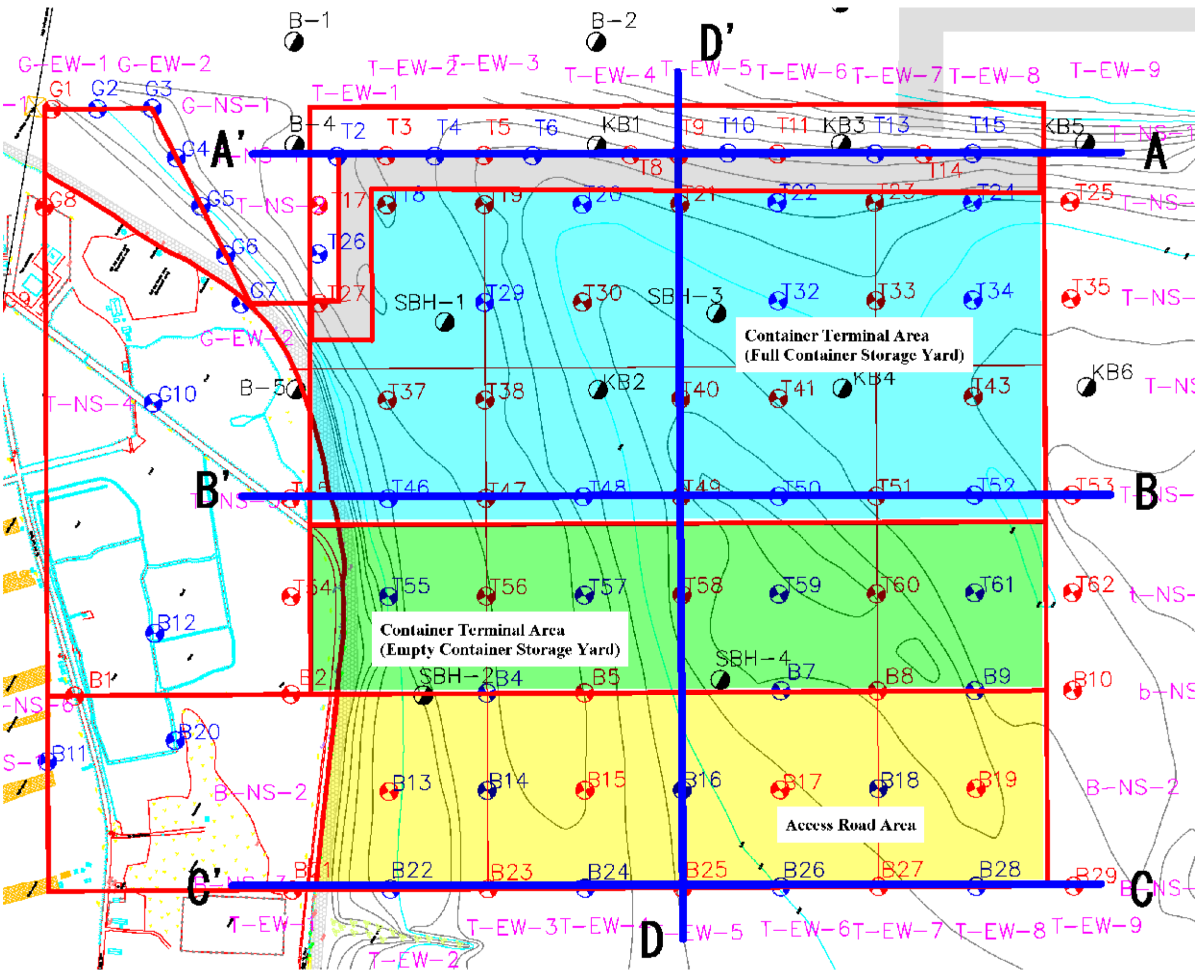



**Figure 2.1.5 Location of Boring Points for Terminal Area, Access Road Area and Public Facility Area**

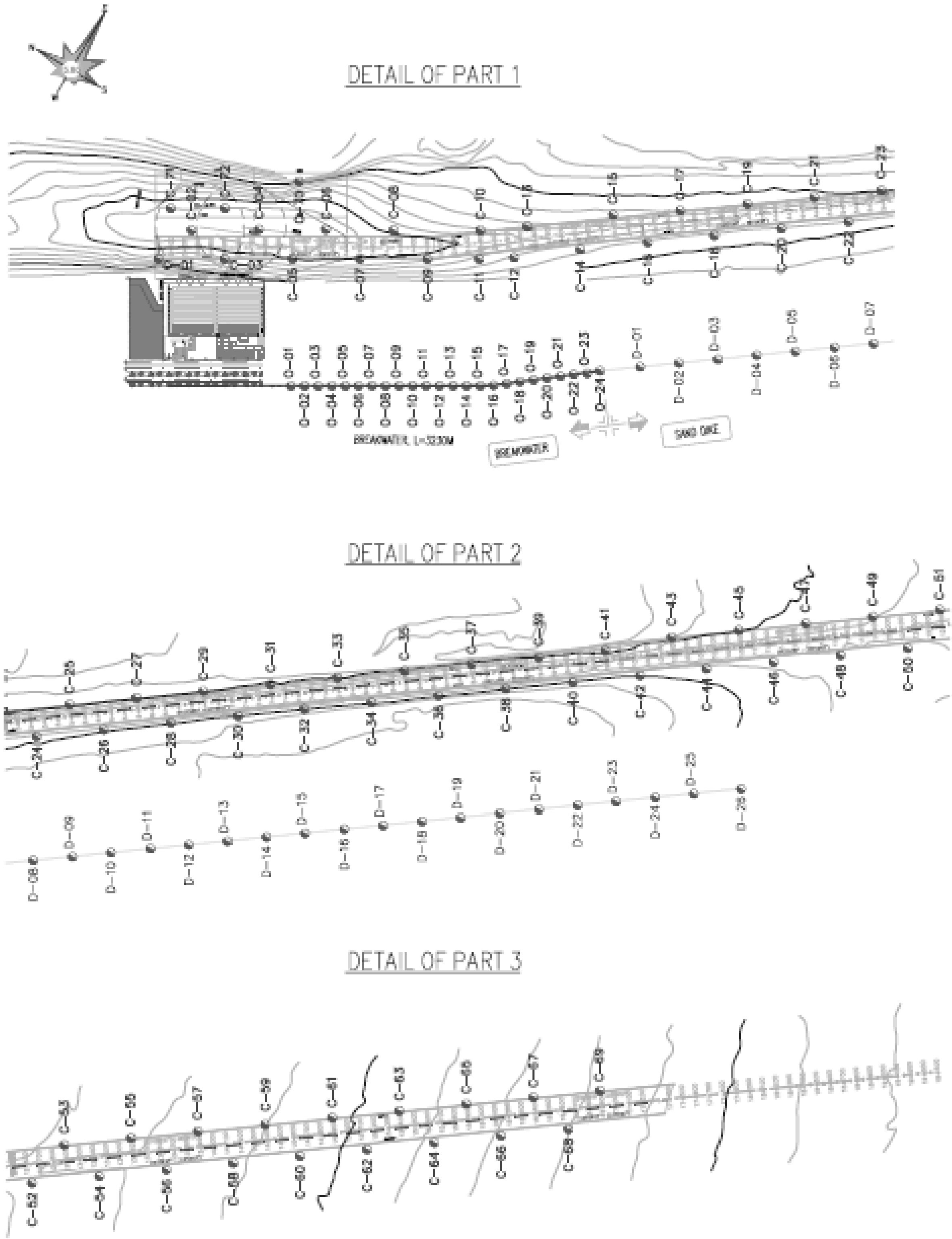



**Figure 2.1.6 Location of Boring Points for Outer Revetment Area, Sand Protection Dyke Area and Navigation Channel Area**

## 2) Boring Investigation Result

### a) Soil stratifications at Site

Boring investigation has been carried out in this Study. According to the soil investigation result in this study, soil stratifications have been identified are tabulated as shown in Table 2.1.1.

As shown in Table 2.1.1, soil layers including bed rock at the site can be classified into 10 main layers with 5 sub layers and distribution of each layer at 3 areas (Reclamation Area, Outer Revetment B Area and Sand Protection Dyke Area) can be summarized in Table 2.1.11.

**Table 2.1.11 Distribution of Soil Layers at Boring Investigation Area**

| Layer Name | | Average N-Value | Distributed Area | | Distributed Depth C.D.L (m) | Distributed thickness (m) |
|---|---|---|---|---|---|---|
| 1a | Loose sand, clayey sand (SP/SP-SC) | 4.1 | 1. Reclamation area | Distributed at almost whole reclamation area . | GL to -1.4m | 0.3m to 4.5m |
| | Grey, light grey | 5.7 | 2. Outer revetment B area | Ditributed at O-01 to 06, 09, 14 to 16, 19 to 21 and 24. | GL to -1.6m | 0.8m to 3.6m |
| | | 4.8 | 3. Sand protection dyke area | Distributed at D-01, 02, 03, 05, 11 to 16, 18, 19 and 22. | GL to -3.5m | 0.7m to 4.8m |
| 1b | Sandy clay (CL/SC) | 0.7 | 1. Reclamation area | Distributed at some places in reclamation area . | -0.8m to -0.4m | 1.2m to 7.8m |
| | blackish grey, brownish grey, grey | 4.7 | 2. Outer revetment B area | Ditributed at O-05, 07 to 08, 10 to 13, 17 to 18 and 23. | 0.3m to -2.3m | 0.7m to 4.6m |
| | | 4.5 | 3. Sand protection dyke area | Distributed at D-04, 06 to 10,17, 20 and 21. | -2.2m to -5.2m | 0.9m to 4.6m |
| 2 | Fat clay with sand (CH) | 1.0 | 1. Reclamation area | Distributed at whole reclamation area . | -2.7m to -8.0m | 2.2m to 11.3 |
| | Grey, brownish and yellowish grey | 0.7 | 2. Outer revetment B area | Distributed along the whole Outer Revetment B. | -1.8m to -8.8m | 5.8m to 9.0m |
| | | 0.8 | 3. Sand protection dyke area | Distributed along the whole Sand Protection Dyke. | -4.2m to -12.7m | 6.5m to 16.9m |
| 3a | Sand (SP) | 4.4 | 1. Reclamation area | Distributed at some places in reclamation area . | -7.5m to -9.7m | 1.2m to 4.8m |
| | Light grey and greenish grey | 4.5 | 2. Outer revetment B area | Identified at only Borehole O-01 | -7.7m to -9.6m | 1.9m |
| | | - | 3. Sand protection dyke area | Not distributed | - | - |
| 3b | Clayey sand/ Sandy clay (CL/SC) | 4.8 | 1. Reclamation area | Distributed at almost whole area except small area. | -8.2m to -12.2m | 0.8m to 8.7m |
| | Yellowish grey, grey | 5.5 | 2. Outer revetment B area | Ditributed along the Outer Revetnebt B excpt at O-10, 16 and 19. | -8.9m to -12.1m | 1.1m to 5.6m |
| | | 7.8 | 3. Sand protection dyke area | Distributed along the Sand Protection Dyke except at D-19 to 23 and D-26. | -12.1m to -17.0m | 2.8m to 7.5m |
| 3c | Sand (SP/SP-SC) | 5.8 | 1. Reclamation area | Distributed at almost whole area except some areas. | -10.9m to -14.4m | 0.5m to 7.2m |
| | Yellowish grey, grey | 21.0 | 2. Outer revetment B area | Identified at only Borehole O-01 | -11.9m to -14.1m | 2.2m |
| | | - | 3. Sand protection dyke area | Not distributed | - | - |
| 4 | Sandy lean clay (CL) | 10.3 | 1. Reclamation area | Distributed at almost whole area except some of road areas. | -12.0m to -15.6m | 0.5m to 9.5m |
| | Reddish brown, yellowish brown | - | 2. Outer revetment B area | Not distributed | - | - |
| | | 10.7 | 3. Sand protection dyke area | Identified at D-10, 13 and D-20 to 22. | -15.4m to -20.8m | 2.8m to 10.0m |
| 5 | Fat clay with sand (CH) | 5.7 | 1. Reclamation area | Distributed at whole reclamation area . | -15.3m to -26.2m | 3.9m to 18.3m |
| | Grey, yellowish grey | 4.8 | 2. Outer revetment B area | Ditributed along the Outer Revetnebt B excpt at O-02 to 04, 13, 14, 18, 19. | -11.3m to -17.3m | 1.8m to 12.6m |
| | | 6.0 | 3. Sand protection dyke area | Identified at D-01 to 03, 08, 14 to 18, D-20 to 24. | -17.3m to -24.1m | 2.0m to 13.1m |
| 6 | Lean clay (CL) | - | 1. Reclamation area | Not distributed | - | - |
| | Grey, reddish brown and bluish grey | 12.1 | 2. Outer revetment B area | Ditributed along the Outer Revetnebt B excpt at O-01. | -15.9m to -24.2m | 3.8m to 15.8m |
| | | 13.2 | 3. Sand protection dyke area | Distributed along the Sand Protection Dyke except at D-22 to 24. | -20.4m to -31.7m | 1.0m to 22.2m |
| 7 | Silty, clayey sand (SC-SM) | - | 1. Reclamation area | Not distributed | - | - |
| | Light grey and yellowish grey | - | 2. Outer revetment B area | Not distributed | - | - |
| | | 15.9 | 3. Sand protection dyke area | Identified at D-08, 14, 17, 19 to 21, 24 and 26. | -26.4m to -29.1m | 0.8m to 8.8m |
| 8a | Sand | 6.0 | 1. Reclamation area | Identified at only Borehole T-09 and T-54. | -27.6m to -29.7m | 1.4m to 3.6m |
| | Yellowish grey, light grey | 6.9 | 2. Outer revetment B area | Identified at Borehole No. O-03 and O-13 only. | -21.9m to -27.2m | 2.4m to 8.2m |
| | | - | 3. Sand protection dyke area | Not distributed | - | - |
| 8b | Poorly-graded sand with silt (SP-SM) | - | 1. Reclamation area | Not distributed | - | - |
| | Light grey | 17.0 | 2. Outer revetment B area | Identified at Borehole No. O-02, 12, 14, 17, 19, 23 and 24. | -23.2m to -27.4m | 2.3m to 7.5m |
| | | 23.4 | 3. Sand protection dyke area | Identified at D-05, 07, 08 and 10. | -31.5m to -32.8m | 0.7m to 2.7m |
| 8c | Silty Sand (SM/ SC-SM) | - | 1. Reclamation area | Not distributed | - | - |
| | Bluish grey, yellowish grey, light grey | 43.7 | 2. Outer revetment B area | Identified along the Outer Revetment B except at No. O-01, 13 and 24. | -26.2m to -29.1m | 0.5m to 10.9m |
| | | 48.3 | 3. Sand protection dyke area | Identified at D-01, 03, 05, 07, 08, 11 and 13. | -34.6m to -36.7m | 0.8m to 7.0m |
| 9 | Completely weathered sandstone | - | 1. Reclamation area | Identified at Borehole T-02, 03, 10, B-04, B-20 and KB-02, 03, 04, 06. | -26.0m to -27.9m | 0.2m to 5.0m |
| | (Sandy clay with fragment) | - | 2. Outer revetment B area | Identified at Borehole No. O-03, 05, 07, 09 and 11. | -29.7m to -30.9m | 0.4m to 3.0m |
| | Reddish brown, yellowish brown | - | 3. Sand protection dyke area | Not distributed | - | - |
| 10 | Moderately weathered silt/claystone | - | 1. Reclamation area | Distributed at whole reclamation area . | -26.6m to -29.7m | 2.5m to 5.5m |
| | Reddish brown, yellowish brown | - | 2. Outer revetment B area | Not distributed | - | - |
| | | - | 3. Sand protection dyke area | Not distributed | - | - |

Boring work conditions with surrounding situations are shown in Figure 2.1.7.

| | |
|---|---|
|  |  |
| Tower of high tension lines located at corner of north-east end of future reclamation area (Height of Tower >80m) | Revetment under repair at existing shore line in reclamation area (Photo at low tide) |
|  |  |
| Under boring works on the jack-up pontoon and steel trestle in the Terminal area | Under boring works on the jack-up pontoon and steel trestle in the Terminal and Access Road area |
|  |  |
| Under boring works on the jack-up pontoon and steel trestle in the Terminal and Access Road area | Under boring works on the jack-up pontoon in the Outer Revetment (Breakwater) area |

**Figure 2.1.7 Photos of Site Conditions and Boring Works**

Boring investigations have been carried out at 4 areas such as 1.Reclamation Area (Terminal Area, Access Road Area and Public Facility Area), 2.Outer Revetment Area, 3.Sand Protection Dyke Area, and 4.Navigation Channel Area. Subsoil investigation results are described separately about these 4 areas in the following section.

### 2.1.6 Sub soil investigation result at Reclamation Area (Terminal Area, Access Road Area and On-land Area (Public Facility and Road Area))

#### 1) Boring Result

Totally 89 boreholes have been drilled and investigated at Reclamation Area (Terminal Area, Access Road Area and On-land Area (Public Facility and Road Area)). Soil stratification identified in this Area is tabulated as shown in Table 2.1.12

**Table 2.1.12 Soil Stratification identified at Reclamation Area**

| Layer Name | | Color | Average N-Value | Distributed Depth C.D.L (m) | Distributed thickness (m) |
|---|---|---|---|---|---|
| 1a | Loose sand, clayey sand (SP/SP-SC) | Grey, light grey | 4.1 | GL to -1.4m | 0.3m to 4.5m |
| 1b | Sandy clay (CL/SC) | blackish grey, brownish grey, grey | 0.7 | -0.8m to -0.4m | 1.2m to 7.8m |
| 2 | Fat clay with sand (CH) | Grey, brownish and yellowish grey | 1.0 | -2.7m to -8.0m | 2.2m to 11.3 |
| 3a | Sand (SP) | Light grey and greenish grey | 4.4 | -7.5m to -9.7m | 1.2m to 4.8m |
| 3b | Clayey sand/ Sandy clay (CL/SC) | Yellowish grey, grey | 4.8 | -8.2m to -12.2m | 0.8m to 8.7m |
| 3c | Sand (SP/SP-SC) | Yellowish grey, grey | 5.8 | -10.9m to -14.4m | 0.5m to 7.2m |
| 4 | Sandy lean clay (CL) | Reddish brown, yellowish brown | 10.3 | -12.0m to -15.6m | 0.5m to 9.5m |
| 5 | Fat clay with sand (CH) | Grey, yellowish grey | 5.7 | -15.3m to -26.2m | 3.9m to 18.3m |
| 9 | Completely weathered sandstone | Reddish brown, yellowish brown | - | -26.0m to -27.9m | 0.2m to 5.0m |
| 10 | Moderately weathered silt/clay stone | Reddish brown, yellowish brown | - | -26.6m to -29.7m | 2.5m to 5.5m |

: Sand Layer, : Clay Layer, : Weathered Rock

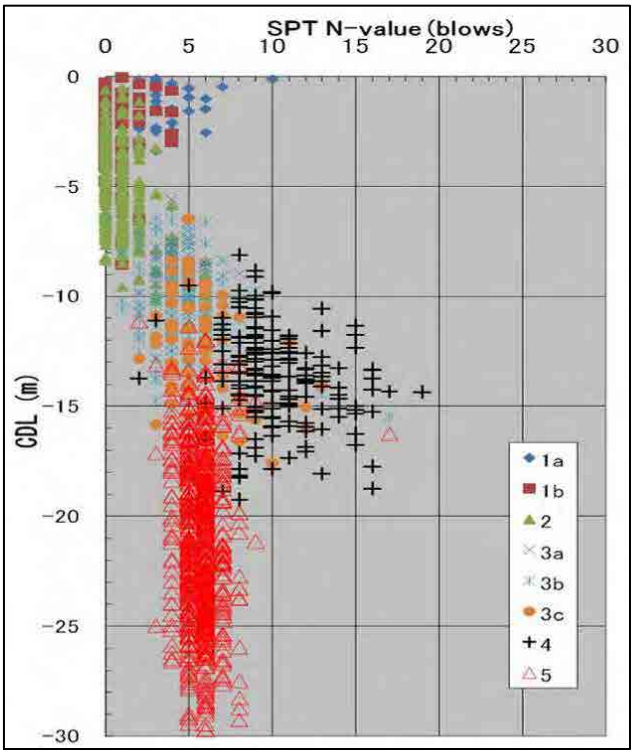
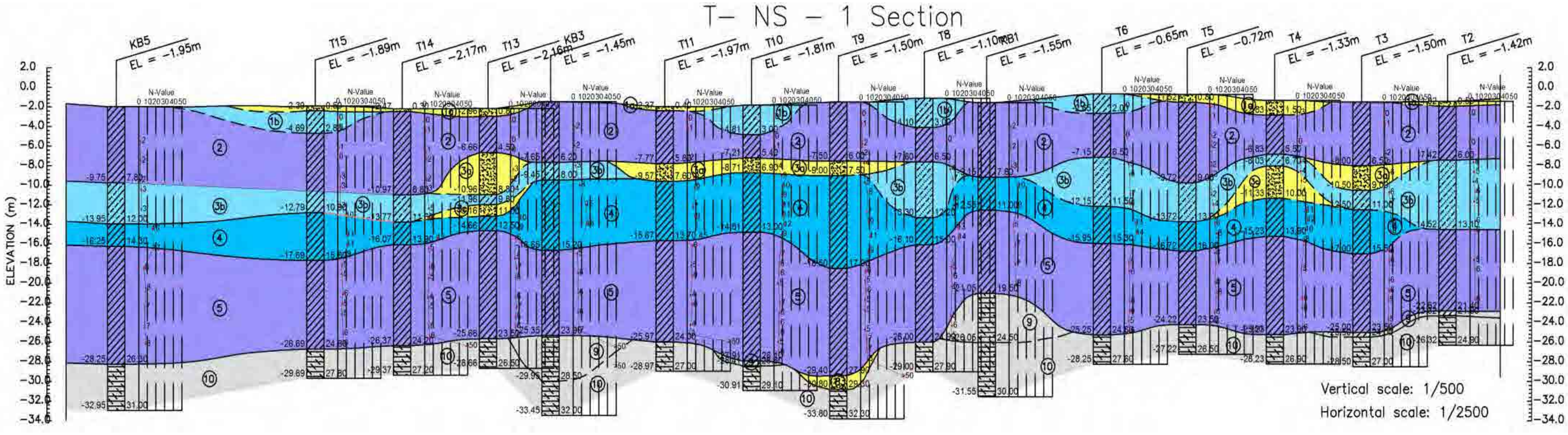



**Figure 2.1.8 SPT N-value Distribution with Depth**

Representative soil profiles with SPT-N values based on Study result are shown in Figure 2.1.9 to Figure 2.1.10 (Refer to Figure 2.1.5 for locations of soil profile sections). All other soil profiles are shown in Appendix.

SPT–N value distributions with depth including existing boring results are shown in Figure 2.1.8. Intermediate layers such as Layer 4 (Clay) and a part of Layer 3 have more than 8 to 10 of SPT N-values between two soft and firm clay layers, Layer 2 and Layer 5 which has an average SPT N-value 1 and 6 respectively. Average SPT N-value for each layer is as follows;

Layer 1a: N= 4.1, Layer 1b: N=0.7, Layer 2: N=1.0, Layer 3a: N=4.4, Layer 3b: N=4.8, Layer 3c: N=5.8, Layer 4: N=10.3, Layer 5: N=5.7



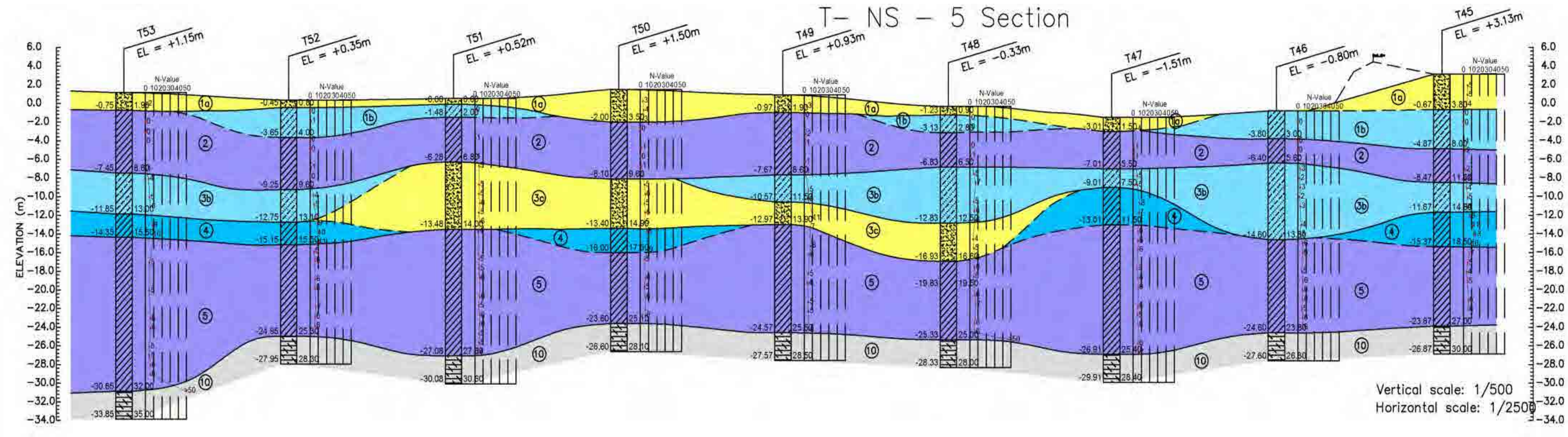




**Figure 2.1.9 Soil Profile (A-A' and B-B' Section)**

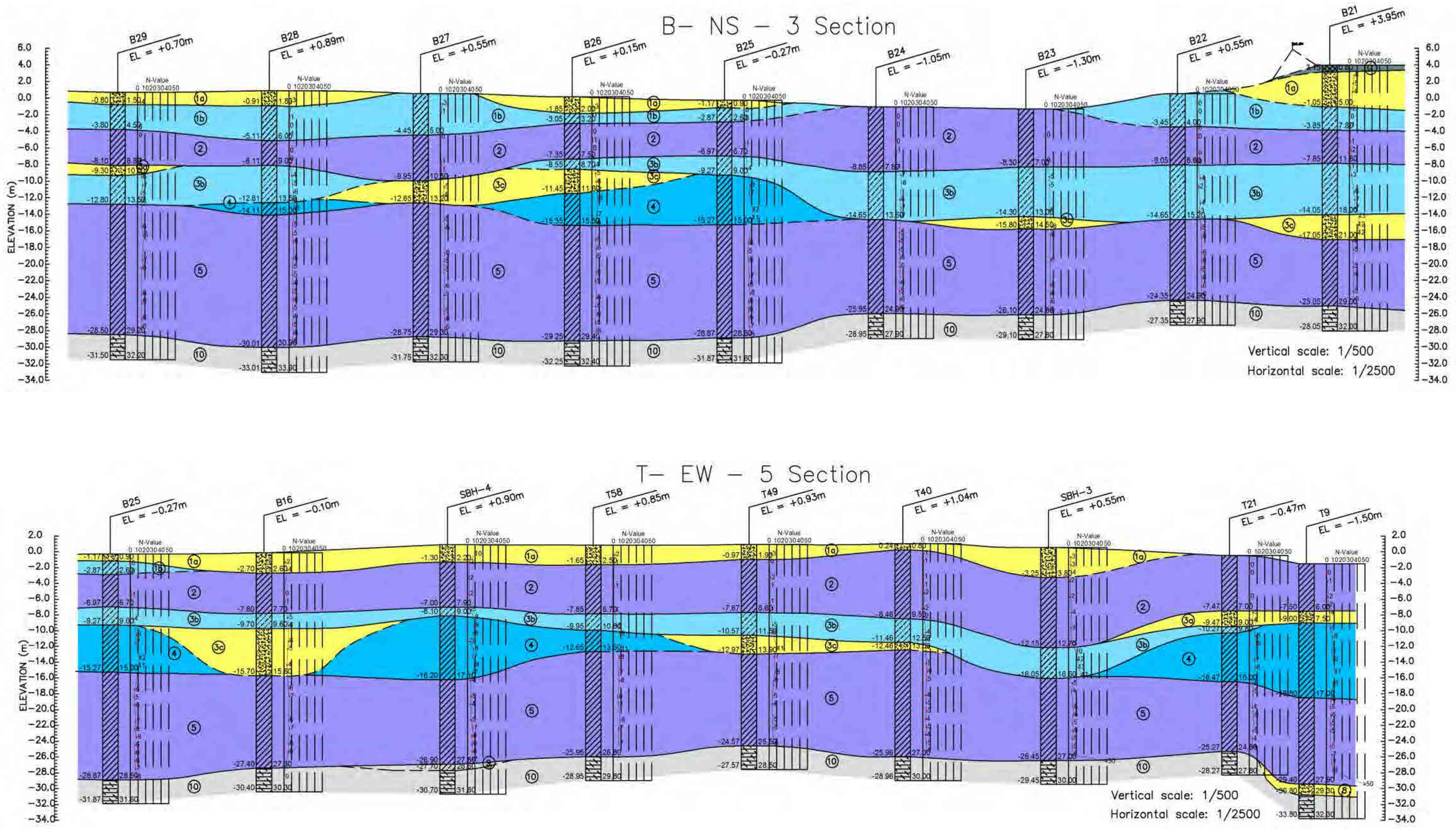
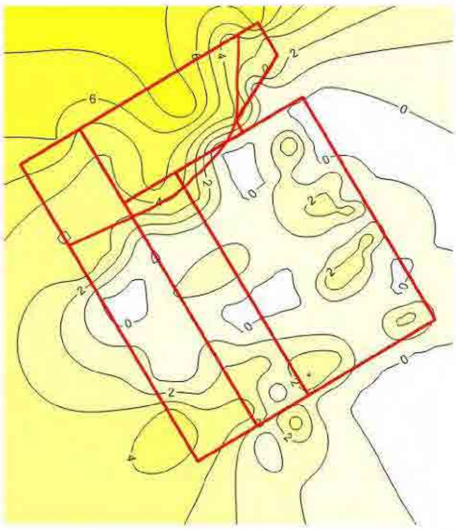


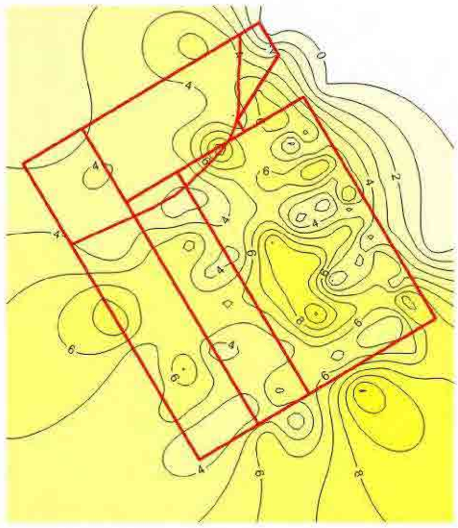

**Figure 2.1.10 Soil Profile (C-C' and D-D' Section)**

Distribution of fine soils such as Layer 1b (Sandy Clay), Layer 2 (Fat Clay or Fat Clay with Sand), Layer 3b (Sandy Clay), Layer 4 (Lean Clay or Sandy Lean Clay), Layer 5 (Fat Clay or Fat Clay with Sand), total fine soil thickness and bottom level of fine soil layers at Reclamation Area (Terminal Area, Access Road Area and Government Facility and Road Area) are shown in Figure 2.1.11 as contour maps of soil layer thickness and bottom level.

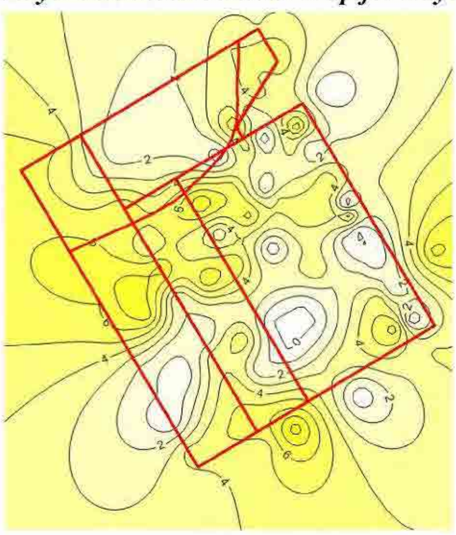
According to contour map for soil layer thickness obtained in this Survey result, 4 to 10m thick soft fine soil (Layer 2) including sandy clay (Layer 1b) are distributed in the port construction area. And also 8 to 17m thick firm clay layer (Layer 5) is distributed as well. Totally 20 to 30m or thicker fine soil (Clay, Silt and sandy Clay) layers including intermediate stiff clay layer (Layer 4) are distributed in port construction area. Firm soil layers which has more than 8 of SPT N value is distributed mainly at Full Container Storage Yard and center of Vacant Container Storage Yard and Access Road Area. Bottom level of those clay layers are between 24 m and 30 m.



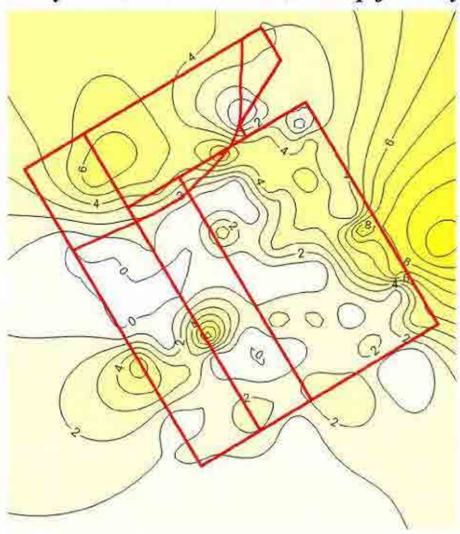
***Soil layer thickness Contour Map for Layer 1b***



***Soil layer thickness Contour Map for Layer 2***

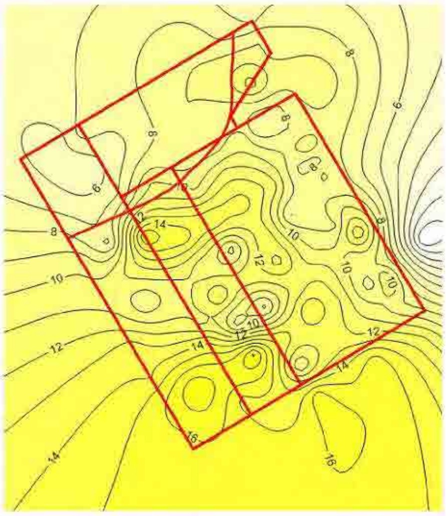


***Soil layer thickness Contour Map for Layer 3b***

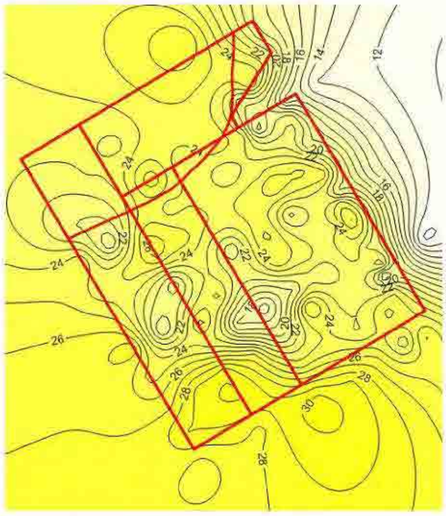


***Soil layer thickness Contour Map for Layer 4***

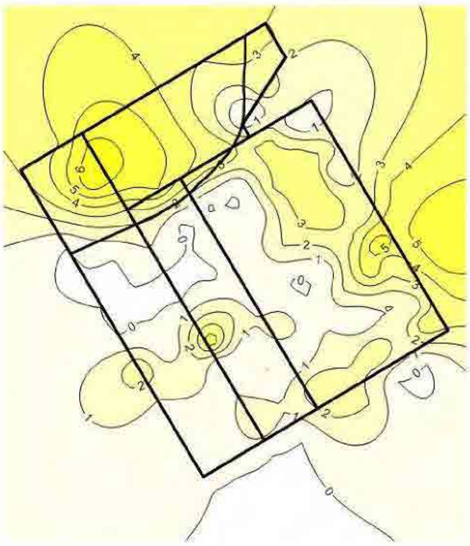
**Figure 2.1.11 Soil Layer Thickness Contour Map for Clay Layers (Layer 1b, 2, 3b and 5)**



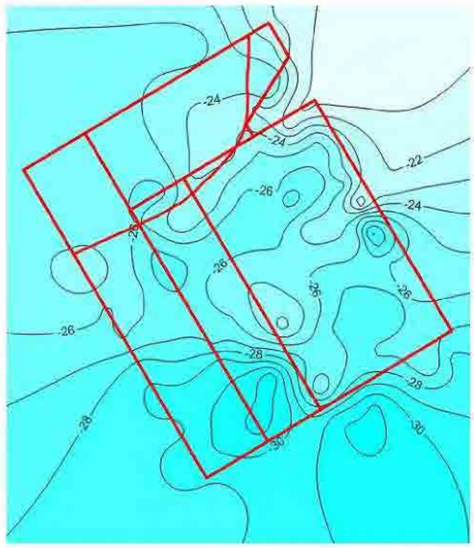
*Soil layer thickness Contour Map for Layer 5*



*Soil layer thickness Contour Map for Total thickness clay layer*



*Thickness Intermediate firm layer (N≥8)*



*Bottom level of clay layer (layer 5)*

**Figure 2.1.12 Soil Layer Thickness Contour Map for Clay Layers (Layer 5, Total thickness of clay layers and Intermediate layers (N>8)) and Bottom Level Contour Map for clay layers**

#### 2) Bed Rock Conditions at survey Area

Bed rock identified in the reclamation area is sand/silt/clay stone which is highly to moderately weathered, and completely weathered one. Bed rock is identified in the within about 2km from shore line of south end of Cat Hai Island.

According to JICA SAPROF Study Report (2010), top level of highly to moderately weathered rock is changing depending on the distance from shore line as follows;

**Table 2.1.13 Distribution of bed rock (Weathered rock)**

| Distance from Shore Line | | Top Level of Weathered Rock (DL; m) |
|---|---|---|
| 0.0 to 1.5 km | Port Area | 20 m to 35 m |
| 1.5 to 3.0 km | | 30 m to 40 m |
| 3.0 to 5.5 km | Off-shore Area | 35 m to 40 m |
| 5.5km and more far | | 40m to more than 55m |

(Extracted from Report on "THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM", 2010 by JICA)

According to boring investigation results of this Study, top level of weathered rock is identified as distributed between 20m and 31m within 0.8 km from shore line at reclamation area.

Although compression tests have not been carried out in this Study, however results of rock core samples are described in SAPROF Study Report as shown in Figure 2.1.13. As shown in this figure, compression strength is ranging from Ru = 50 to 800kgf/cm$^2$ depending on location and weathered conditions. Average compression strength of rock core samples is about 350 kgf/cm$^2$.Bulk density of rock core samples are shown in Figure 2.1.13. Bulk density plots with depth are ranging between 2.4 and 2.7 g/cm$^3$. Average bulk density is 2.60 g/cm$^3$ (Data from JICA SAPROF Study Report, 2010).

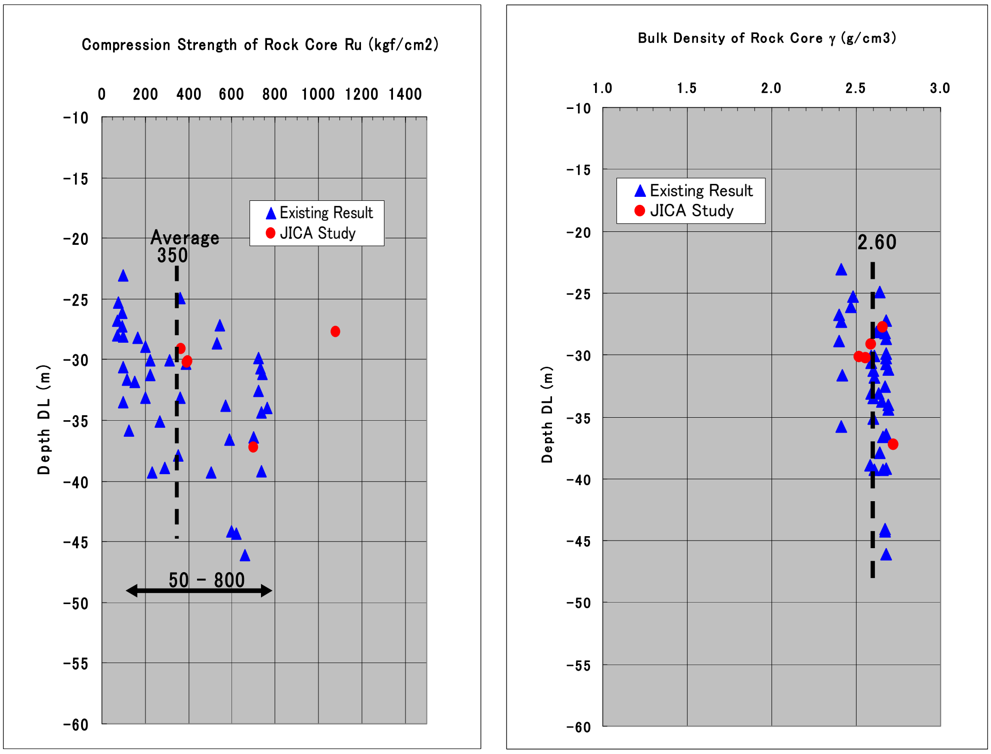



**Figure 2.1.13 Ru and γ of Rock Core Sample with Depth (DL)**

(Extracted from Report on "THE PREPARATORY SURVEY ON LACH HUYEN PORT INFRASTRUCTURE CONSTRUCTION IN VIET NAM", 2010 by JICA)

### 3) Soil Properties

Laboratory test results including existing results are shown as a relationship between depth and each value in Appendix 2.1.

Soil properties obtained from subsoil investigation surveys which have been carried out this time and from existing soil investigation results are tabulated in Table 2.1.14 also in Appendix which shows the soil properties of each layer at Reclamation Area.

**Table 2.1.14 Soil Properties of each Layer at Reclamation Area**

| Layer | Soil Type | Field Test Result | | Fine Content (%) | Natural moisture content W (%) | Atterberg Limits | | | | Bulk density (KN/m³) | | Specific Gravity | Initial void ratio eo | Consolidation test | | | | | | Unconfined compression test | | Tri-xial test (UU) | | Tri-xial test (CU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | SPT | Field Vane | | | Liquid limit $W_L$(%) | Plastic limit Wp(%) | Plasticity index Ip (%) | Liquidity index | Natural | Dry | | | Over consolidated | Nomally consolidated | Compression Index | Re-Compression Index | Swelling Index | Consolidation yield stress | | | | | | |
| | | N Blows | Su (KG/cm²) | | | | | | | | | | | Cv(o) ($10^{-3}$cm²/s) | Cv(n) ($10^{-3}$cm²/s) | Cc | Cr | Cs | Pc (KN/m²) | $q_u$ (KN/m²) | εf (%) | Cuu (KN/m²) | φuu (deg.) | Ccu (KN/m²) | φcu (deg.) |
| **1a** | **SP** | 4.1 | | 6.21 | | | | | | | | 2.65 | | | | | | | | | | | | | |
| **1b** | **SC/ CS** | 0.7 | 0.14 | 68.60 | 37.48 | 38.20 | 18.92 | 19.28 | 1.05 | 17.84 | 13.01 | 2.68 | 1.026 | 1.079 | 1.171 | 0.289 | 0.072 | 0.051 | 0.983 | 0.282 | 3.851 | 15.989 | 1.08 | | |
| **2** | **CH** | 1.0 | 0.15 | 91.66 | 51.60 | 61.72 | 24.78 | 36.93 | 0.72 | 16.58 | 10.96 | 2.70 | 1.441 | 0.964 | 0.726 | 0.551 | 0.114 | 0.088 | 0.914 | 0.328 | 3.487 | 15.414 | 0.80 | 24.600 | 19.58 |
| **3a** | **SP** | 4.4 | | 8.42 | | 24.40 | 12.36 | 12.04 | | | | 2.65 | | | | | | | | | | | | | |
| **3b** | **SC/ CS** | 4.8 | 0.27 | 56.85 | 28.05 | 34.00 | 16.18 | 17.83 | 0.73 | 19.20 | 15.13 | 2.68 | 0.790 | 1.973 | 2.118 | 0.201 | 0.043 | 0.039 | 1.446 | 0.446 | 7.603 | 25.300 | 0.73 | 17.083 | 24.10 |
| **3c** | **SP** | 5.8 | | 11.19 | | 23.86 | 12.00 | 11.86 | | | | 2.65 | | | | | | | | | | | | | |
| **4** | **CH** | 10.3 | | 82.10 | 31.71 | 49.10 | 20.80 | 28.30 | 0.41 | 18.67 | 14.25 | 2.70 | 0.875 | 1.262 | 0.950 | 0.361 | 0.043 | 0.071 | 2.493 | 0.809 | 4.988 | 49.185 | 0.68 | 11.043 | 22.06 |
| **5** | **CH** | 5.7 | 0.42 | 94.64 | 44.18 | 58.71 | 22.83 | 35.88 | 0.57 | 17.23 | 11.97 | 2.70 | 1.217 | 2.210 | 0.890 | 0.586 | 0.083 | 0.102 | 2.440 | 0.838 | 4.193 | 47.861 | 1.04 | 7.238 | 21.75 |

The following existing soil laboratory test results are referred as existing soil investigation for Reclamation Area.

- SBH-1 to 4 (by JICA SAPROF Study), B-1 to 5 (by Nippon Koei), KB-1-6 (by TEDIPORT) ; Total 15 boreholes

Characteristics of soil properties of soil layers are described as follows;

**a) Physical properties**

i) Specific Gravity of Soil Gs (Refer to Figure 2.1.14)

Specific gravity of soil shows 2.7 in average through all soil layers at Reclamation area and ranging between 2.65 and 2.70. This value shows that all soil layers at Reclamation Area are composed of inorganic soils.

ii) Fine Content Fc (Weight percentage passing 74μm Sieve) (Refer to Figure 2.1.14)

Fine content is one of the indices obtained from sieve analysis test. When it is more than 50%, we classify the soil as fine soil like silt or clay.

According to sieve analysis test result, Layer 1b, 2, 3b, 4, 5 can be classified as fine soil, however Layer 1a, 3a and 3c are classified as coarse soil which has about 10% of fine content. Horizontal continuity is generally poor for these coarse soil layers except Layer 1a. Therefore they should not be considered as permeable layer for consolidation settlement from conservative point of view.

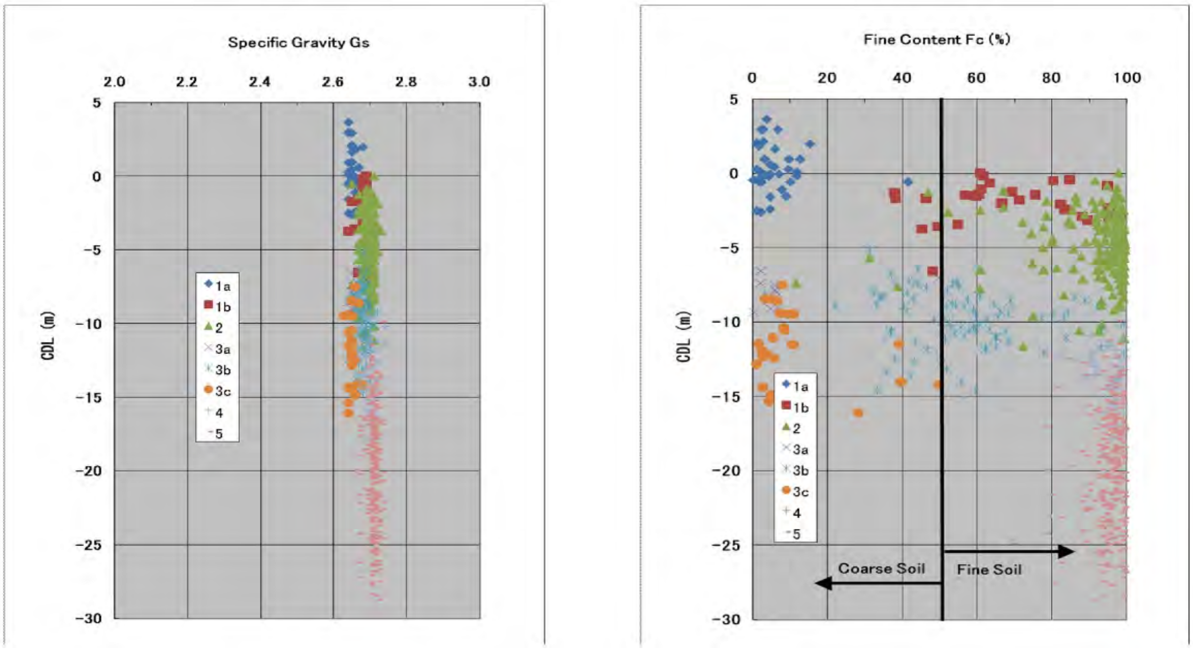



**Figure 2.1.14 Specific Gravity and Fine Content with Depth**

iii) Natural Water Content and Atterberg's Limits (Refer to Figure 2.1.15 and Figure 2.1.16)

Layer 2 and Layer 5 which has considerable thickness and horizontal distribution can be main subject layers for consolidation settlement. Average natural water content Layer 2 and Layer 5 at Reclamation Area is 50% and 45% respectively. Other clay layers such as Layer 1b, 3b and 4 have 35%, 30% and 30% of average natural water content respectively.

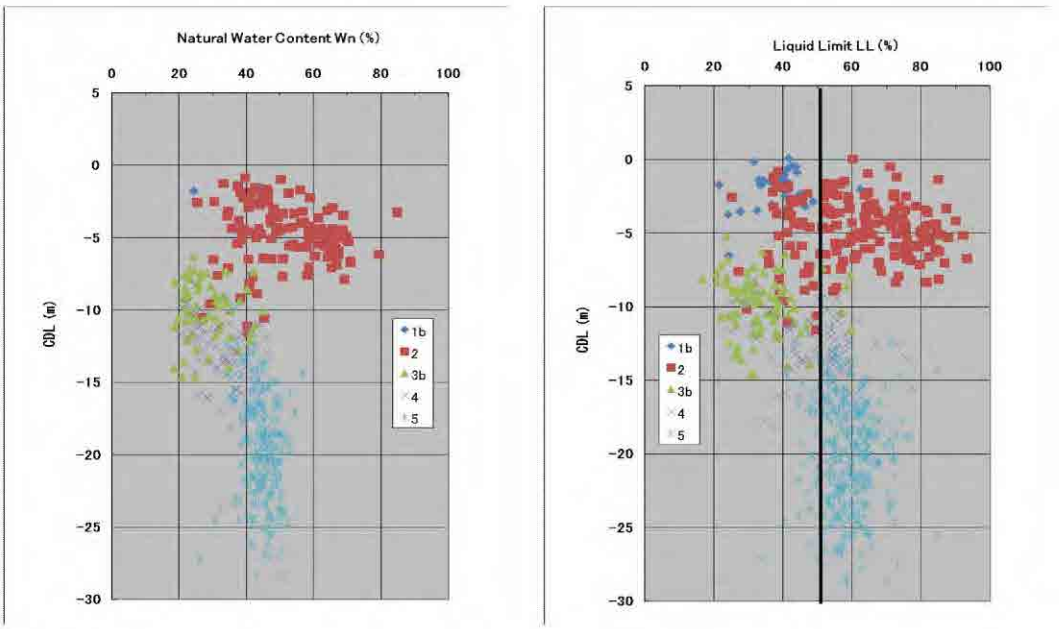



**Figure 2.1.15 Natural Water Content and Liquid Limit with Depth**

According to liquid limit test result as shown in the right end of Figure 2.1.15, liquid limits of soil layers (Layer 2, 4 and 5 except Layer 1b and 3b which have much sand content) are more than 50% in average, which shows high plasticity. Therefore clays of only these three layers have high plasticity.

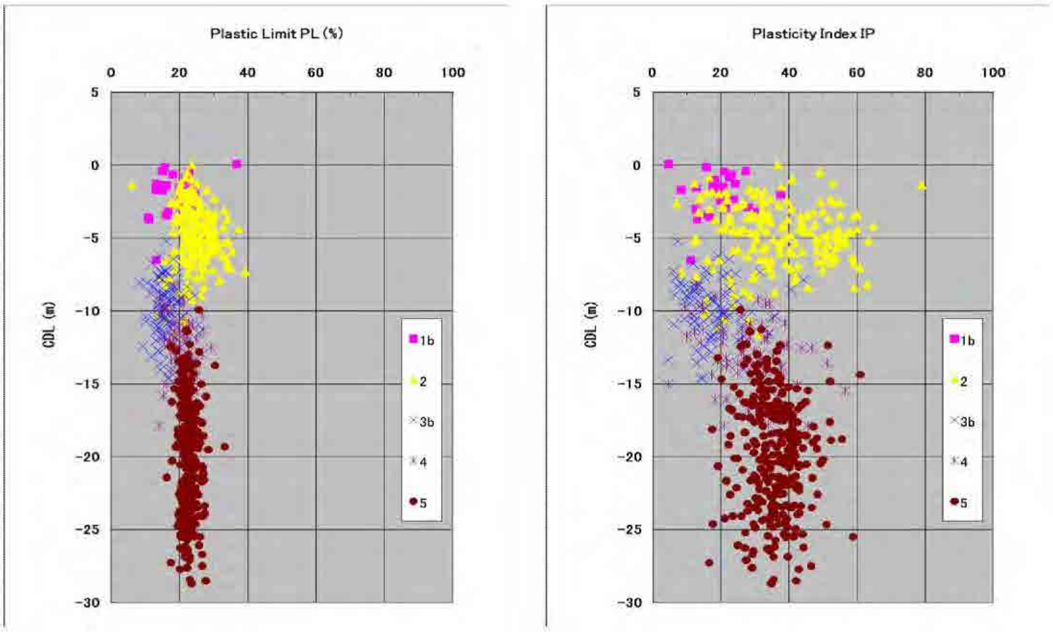



**Figure 2.1.16 Plastic Limit and Plasticity Index**

iv) Bulk Density (Unit Weight) and Void Ratio (Refer to Figure 2.1.17)

As shown in Figure 2.1.17, average value of bulk density and void ratio for each layer are as shown in Table 2.1.15.

**Table 2.1.15 Bulk Density and Void Ratio**

| Layer Name | Bulk Density γ (kN/m$^3$) | Void Ratio $e_0$ |
|---|---|---|
| Layer 1b | 17.9 | 1.0 |
| Layer 2 | 16.6 | 1.4 |
| Layer 3b | 19.3 | 0.8 |
| Layer 4 | 18.7 | 0.9 |
| Layer 5 | 17.2 | 1.2 |

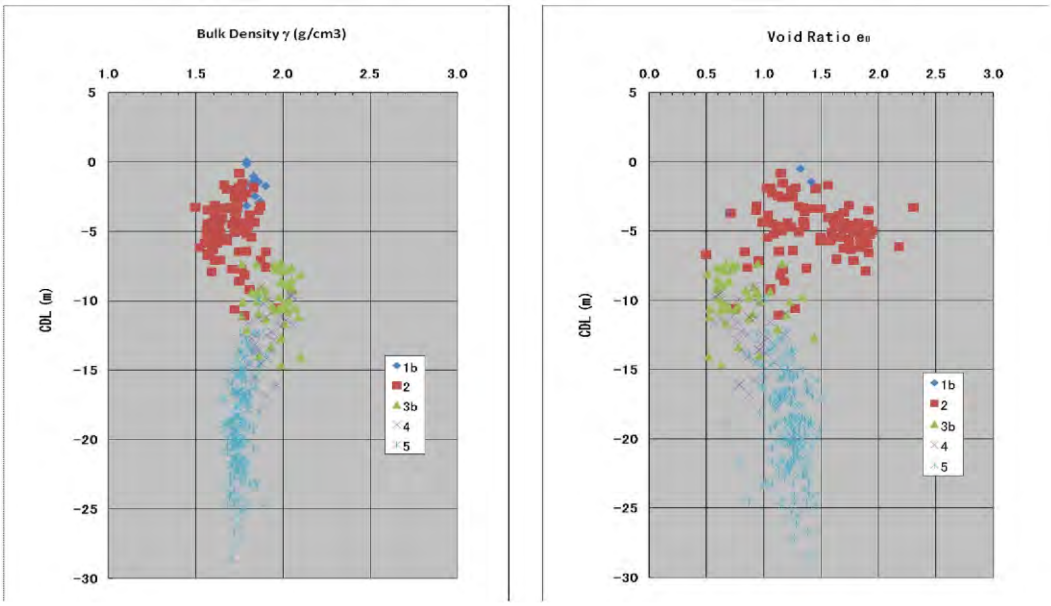



**Figure 2.1.17 Bulk Density and Initial Void Ratio with Depth**

**b) Mechanical Properties of Cohesive Soil**

i) Shear Strength of Cohesive Soil

Unconfined compression test, tri-axial test and field vane shear test have been carried out in this survey to identify the undrained shear strength under the ground.

Unconfined compression strength and that failure strain are shown in Figure 2.1.18. Average unconfined compression strength of each layer at Reclamation Area is as follows;

- Layer 1b: qu = 28kN/$m^2$, Layer 2: qu = 30kN/$m^2$, Layer 3b: qu = 43kN/$m^2$,
- Layer 4: qu = 79kN/$m^2$, Layer 5: qu = 82kN/$m^2$

As shown in Figure 2.1.18, more than half of failure strains (strain at peak strength of unconfined compression test) of samples in Layer 2 show more than 7%. It means that about half of samples are disturbed during sampling, transportation and testing process. Therefore strength of half of samples shows the smaller strength than actual in-situ strength. Therefore the above average unconfined compression strength (qu) can be estimated to give a little smaller values than completely undisturbed one.

However failure strains of Layer 5 which has medium consistency (average N is 5.7) show that only less than 10% of sample are disturbed.

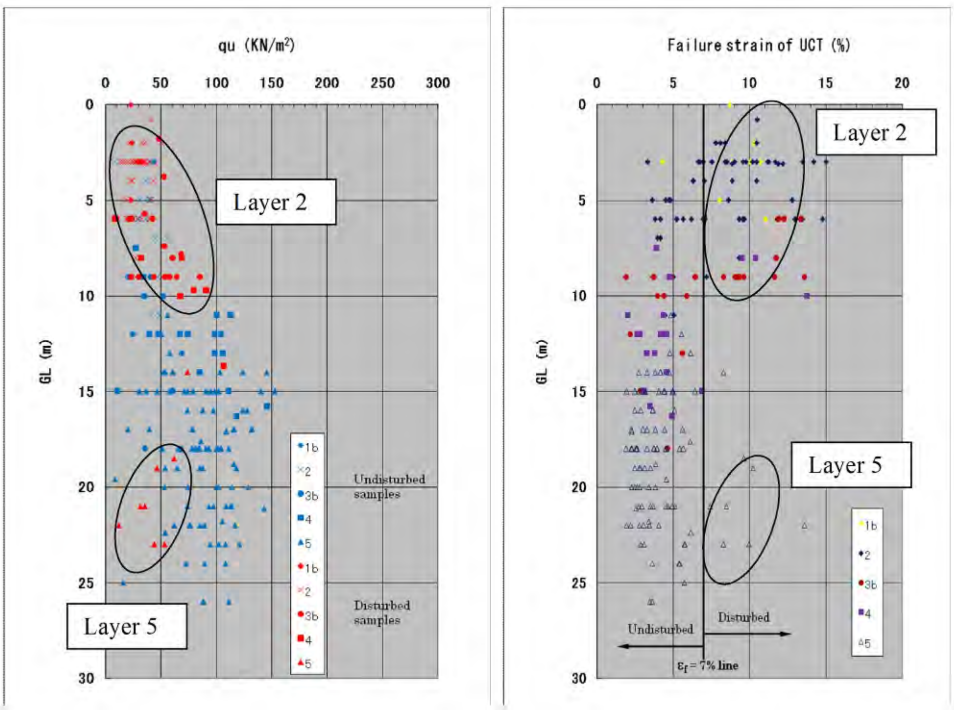



**Figure 2.1.18 Unconfined Compression Strength and Failure Strain with Depth**

Comparison of undrained shear strengths from unconfined compression strength test ($C_u$), tri-axial compression strength test ($C_{uu}$) and field vane shear strength test ($S_{ufv}$) is shown in Figure 2.1.19.

The distribution of undrained shear strength with depth of Cu and $C_{uu}$ is very similar each other.

$S_{ufv}$ from field vane shear test has small variation in its distribution with depth compared to those of Cu and $C_{uu}$. The average value of $S_{ufv}$ is plotted at a little smaller side than average of Cu and $C_{uu}$.

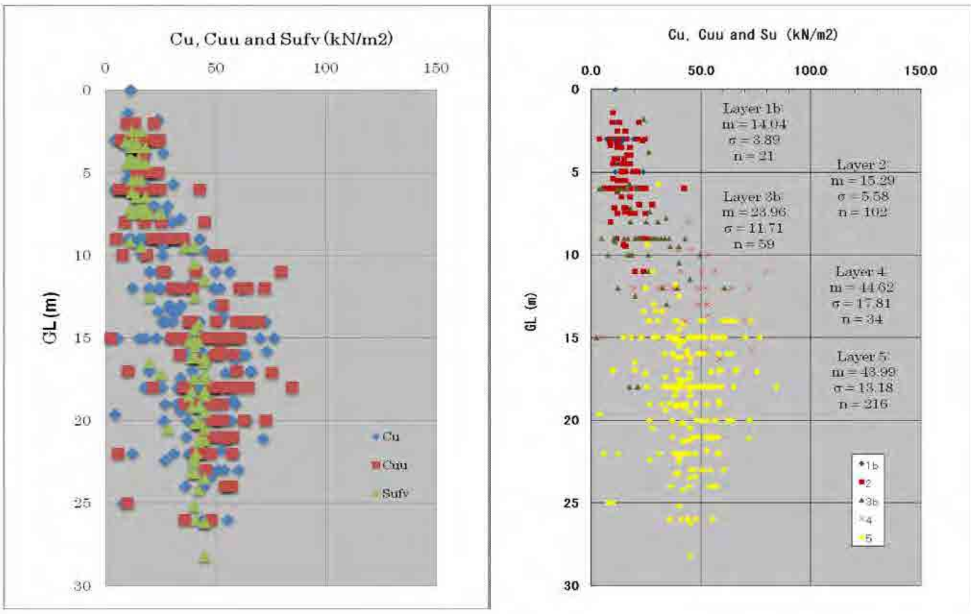



**Figure 2.1.19 Cu, Cuu and Sufv with Depth**

ii) Consolidation Characteristics of Cohesive Soil

<u>Preconsolidation Pressure Pc</u>

Preconsolidation pressure Pc is distributing with depth as shown in Figure 2.1.20.

Possible consolidation settlement layers are Layer 1b, 2, 3b, 4 and 5 in Reclamation Area. Remarkable point of these clay layers is that they are a little over consolidated. Even uppermost Layer 1b and Layer 2 are also over-consolidated as shown in Figure 2.1.20.

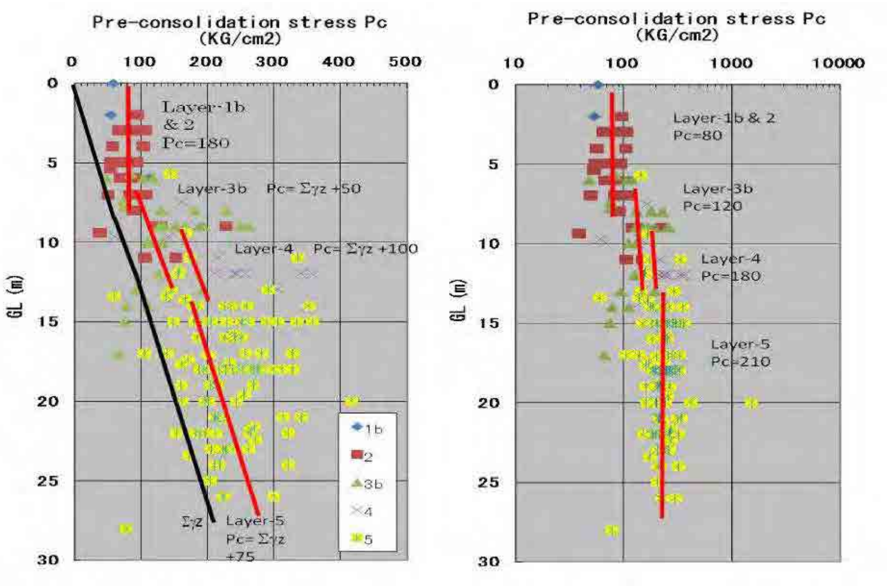



**Figure 2.1.20 Preconsolidation Pressure (Pc) with Depth**

According to Figure 2.1.20, preconsolidation pressure for each layer can be described as follows;

- Layer 1b and Layer 2 : Pc = 80kN/m$^2$
- Layer 3b : Pc = Σγz + 50 kN/m$^2$
- Layer4 : Pc = Σγz + 100 kN/m$^2$
- Layer 5 : Pc = Σγz + 75 kN/m$^2$

However even though above soil layers are over-consolidated, finally construction load about 120 to 140 kN/m$^2$ will be working on them beyond the average Pc lines. Accordingly some extent of consolidation settlement due to above layers will be anticipated.

Increase Ratio of Undrained Shear Strength (Cu/P) and Over Consolidation Ratio (OCR)

From relationship between unconfined strength (Cu= qu/2), tri-axial compression strength ($C_{uu}$) and pre-consolidation pressure Pc, increase ratio of undrained shear strength (Cu/P) has been estimated.

As shown in Figure 2.1.21, the plotted data are distributed with depth between Cu/P =0.1 and 0.3. Average value of Cu/Pc of clay layers are almost same values which is about Cu/P=0.2.

From the relation between above preconsolidation pressure (Pc) and overburden pressure (Σγz), over consolidation ratios (OCR=Pc/Σγz) with depth are plotted as shown in Figure 2.1.21. According to this graph, average value and distributed range of OCR for each layer can be described as follows;

- Layer 1b : OCR=3.8 (1to 5)
- Layer 2 : OCR=2.2 (1 to 4)
- Layer 3b : OCR= 2.3 (1 to 4)
- Layer4 : OCR=2.7 (1 to 4)
- Layer 5 : OCR=1.9(1 to 3)

As described above, average over consolidation ratio (OCR) for each layer is approximately between 2 and 3 from Pc/Σγz – depth relation.

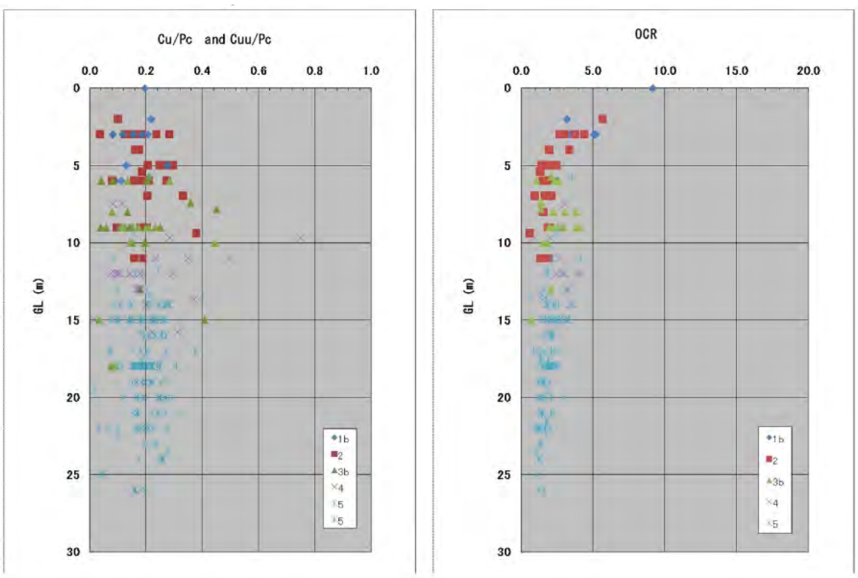



**Figure 2.1.21 Cu/Pc, Cuu/Pc and OCR(Pc/Σγz) with Depth**

<u>Compression Index Cc and Recompression Index Cr</u>

Compression Index Cc and Recompression Index Cr are distributed with depth as shown in Figure 2.1.22.

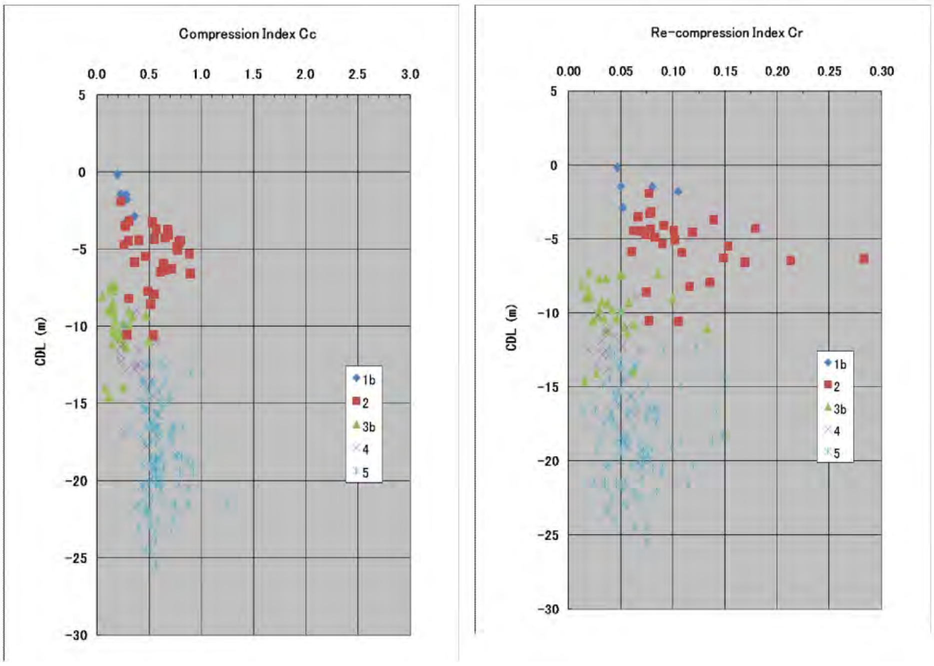



**Figure 2.1.22 Cc and Cr with Depth**

According to consolidation test results, Compression Index Cc and Re-compression Index Cr are obtained as shown in Figure 2.1.22. Average values of Cc and Cr for each layer at Reclamation Area are described as follows;

- Layer 1b : Cc = 0.3, Cr = 0.07
- Layer 2 : Cc = 0.6, Cr = 0.12
- Layer 3b : Cc = 0.3, Cr = 0.05
- Layer 4 : Cc = 0.4, Cr = 0.04
- Layer 5 : Cc = 0.6, Cr = 0.06

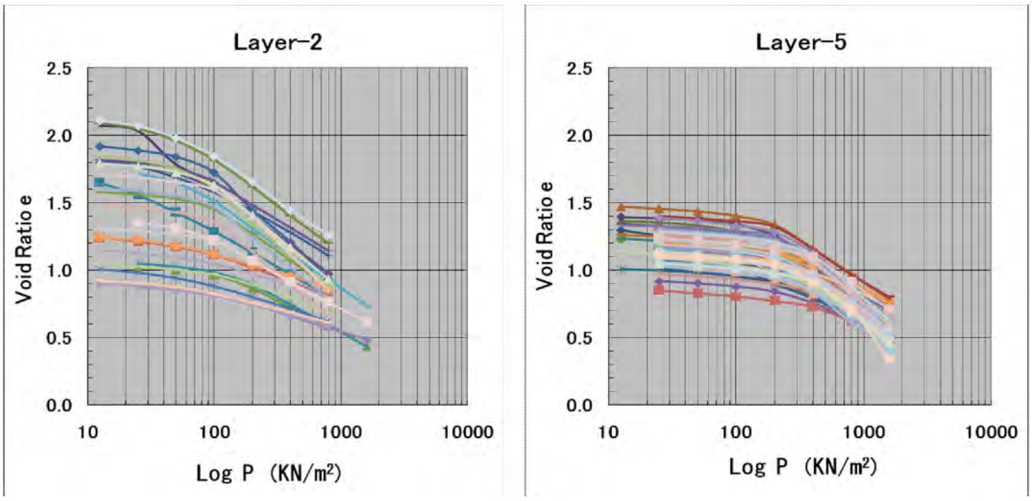



**Figure 2.1.23 e-Log P Curves for Layer 2 and Layer 5**

<u>Coefficient of Consolidation Cv</u>

Coefficient of consolidation Cv is one of the important consolidation factors which show the speed of consolidation settlement. In Figure 2.1.24, Cv (OC) and Cv (NC) are plotted with depth. (Cv (OC): Average value of Cv in over consolidation range, Cv (NC): Average value of Cv in normal consolidation range.)

Average Cv (NC) and average Cv (OC) for each layer is as follows;

- Layer 1b: Cv(NC)=1.2 x $10^{-3}$cm/sec=104cm$^2$/day, Cv(OC)= 1.2 x $10^{-3}$cm/sec=104cm$^2$/day
- Layer 2: Cv(NC)=0.6 x $10^{-3}$cm/sec=52cm$^2$/day, Cv(OC)= 1.0 x $10^{-3}$cm/sec=86cm$^2$/day
- Layer 3b: Cv(NC)=1.2 x $10^{-3}$cm/sec=104cm$^2$/day, Cv(OC)= 1.2 x $10^{-3}$cm/sec=104cm$^2$/day
- Layer 4 : Cv(NC)=0.8 x $10^{-3}$cm/sec=69cm$^2$/day, Cv(OC)= 1.2 x $10^{-3}$cm/sec=104cm$^2$/day
- Layer 5 : Cv(NC)=0.8 x $10^{-3}$cm/sec=69cm$^2$/day, Cv(OC)= 2.2 x $10^{-3}$cm/sec=190cm$^2$/day

Above average values are selected based on Cv-Log P lines for each layer.

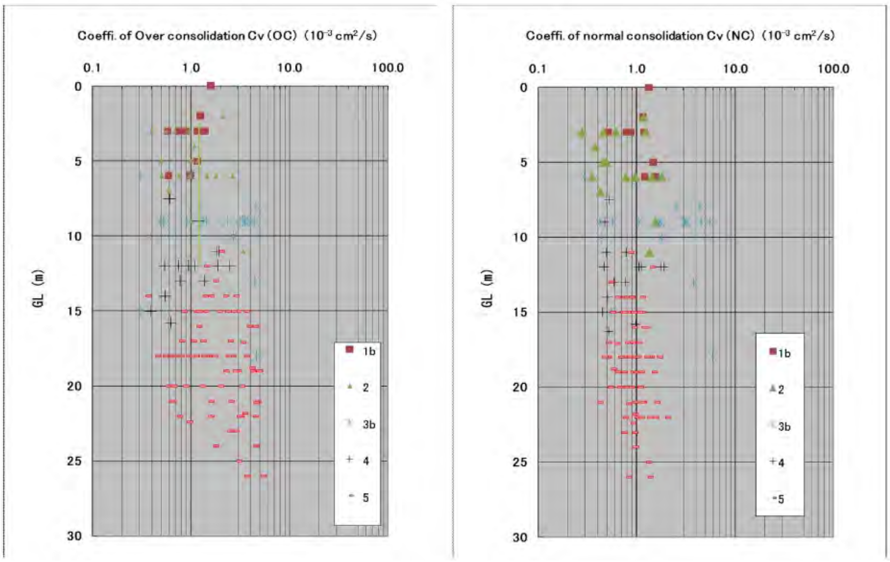



**Figure 2.1.24 Cv (OC) and Cv (NC) with Depth**

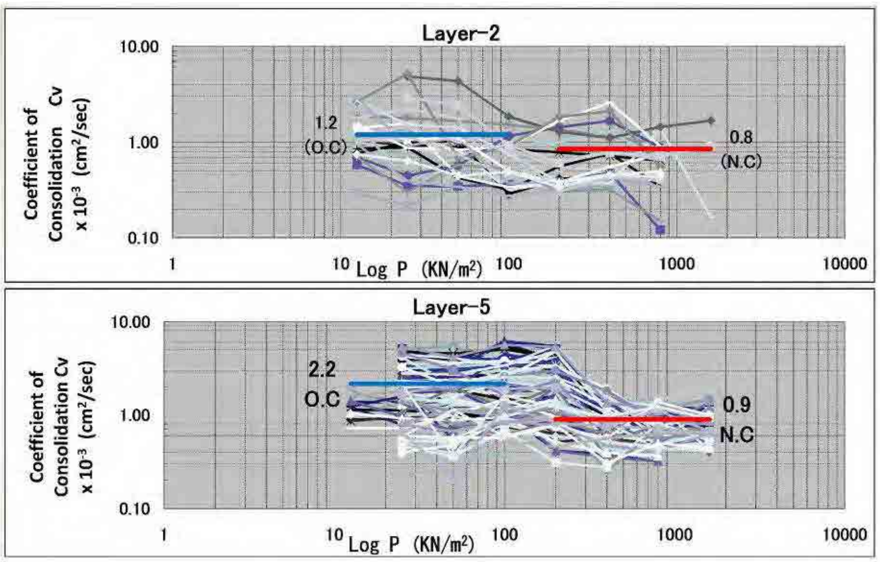



**Figure 2.1.25 Log Cv – Log P Curves for Layer 2 and Layer 5**

Rate of Secondary Compression Cα (= Δe/Δlog t)

In this study and existing investigation results, there has not been carried out any special consolidation tests for the evaluation of Secondary Compression Index Cα.

Therefore the following formula is applied for the evaluation of Cα;

Cα(NC)/ Cc = 0.04± 0.01 (after Ladd et al, 2003)

Adopted here, Cα(NC)/ Cc = 0.03

Rate of Secondary Compression Cα ( Cαε= Cα /(1+$e_0$) ) obtained from average Cc for each layer and above formula is as follows;

- Layer 1b: Cα(NC) =0.04xCc=0.03x0.3= 0.009, Cαε= Cα /(1+$e_0$) = 0.009/(1+1.0)= 0.005
- Layer 2 : Cα(NC) =0.04xCc=0.03x0.6= 0.018, Cαε= Cα /(1+$e_0$) = 0.018/(1+1.4)= 0.008
- Layer 3b : Cα(NC) =0.04xCc=0.03x0.3= 0.009, Cαε= Cα /(1+$e_0$) = 0.009/(1+0.8)= 0.005
- Layer 4 : Cα(NC) =0.04xCc=0.03x0.4= 0.012, Cαε= Cα /(1+$e_0$) = 0.012/(1+0.9)= 0.006
- Layer 5 : Cα(NC) =0.04xCc=0.03x0.6= 0.018, Cαε= Cα /(1+$e_0$) = 0.018/(1+1.2)= 0.008

### 4) Soil parameters for each layer at Reclamation Area

Soil parameters for design purpose, those values are recommended and tabulated based on average values of soil property test results at Reclamation Area as shown in Table 2.1.16.

**Table 2.1.16 Soil Parameters recommended for Reclamation Area**

| Layer No. | Typical Soil Type | SPT-N | γ ($kN/m^3$) | γ' ($kN/m^3$) | Cu ($kN/m^2$) | φ (°) | Cc | Cr | Pc ($kN/m^2$) | e0 | Cv (OC) x $10^{-3}$ ($cm^2/s$) | Cv (NC) x $10^{-3}$ ($cm^2/s$) | Cu/P for NC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | SP, SP-SC | 4 | 18.0 | 8.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 1b | CL | 1 | 18.0 | 8.0 | 15 | 0.0 | 0.30 | 0.07 | 80 | 1.05 | 1.20 | 1.20 | 0.20 |
| 2 | CH | 1 | 17.0 | 7.0 | 15 | 0.0 | 0.60 | 0.12 | 80 | 1.45 | 1.00 | 0.60 | 0.20 |
| 3a | SP | 4 | 19.0 | 9.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 3b | CL,SC | 5 | 19.0 | 9.0 | 25 | 0.0 | 0.25 | 0.05 | Σγ'z+50 | 0.80 | 1.20 | 1.20 | 0.20 |
| 3c | SP, SP-SC | 6 | 19.0 | 9.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 4 | CH, CL | 10 | 19.0 | 9.0 | 50 | 0.0 | 0.35 | 0.04 | Σγ'z+100 | 0.85 | 1.20 | 0.80 | 0.20 |
| 5 | CH | 6 | 17.5 | 7.5 | 40 | 0.0 | 0.60 | 0.08 | Σγ'z+75 | 1.20 | 2.20 | 0.80 | 0.20 |
| Fill,Emb. | S | - | 18.0 | 10.0 | 0 | 30.0 | - | - | - | - | - | - | - |

*NC: Normaly conslidated State OC: Over consolidated State z: Depth (m)

## 2.1.7 Sub soil investigation result at Outer Revetment B Area

### 1) Boring Result

Totally 24 boreholes have been drilled and investigated along Outer Revetment B. Soil stratification identified in this Area is tabulated as shown in Table 2.1.17.

**Table 2.1.17 Soil Stratification identified at Outer Revetment B Area**

| Layer Name | | Color | Average N-Value | Distributed Depth C.D.L (m) | Distributed thickness (m) |
|---|---|---|---|---|---|
| 1a | Loose sand, clayey sand (SP/SP-SC) | Grey, light grey | 5.7 | GL to -1.6m | 0.8m to 3.6m |
| 1b | Sandy clay (CL/SC) | blackish grey, brownish grey, grey | 4.7 | 0.3m to -2.3m | 0.7m to 4.6m |
| 2 | Fat clay with sand (CH) | Grey, brownish and yellowish grey | 0.7 | -1.8m to -8.8m | 5.8m to 9.0m |
| 3a | Sand (SP) | Light grey and greenish grey | 4.5 | -7.7m to -9.6m | 1.9m |
| 3b | Clayey sand/ Sandy clay (CL/SC) | Yellowish grey, grey | 5.5 | -8.9m to -12.1m | 1.1m to 5.6m |
| 3c | Sand (SP/SP-SC) | Yellowish grey, grey | 21.0 | -11.9m to -14.1m | 2.2m |
| 5 | Fat clay with sand (CH) | Grey, yellowish grey | 4.8 | -11.3m to -17.3m | 1.8m to 12.6m |
| 6 | Lean clay (CL) | Grey, reddish brown and bluish grey | 12.1 | -15.9m to -24.2m | 3.8m to 15.8m |
| 8a | Sand | Yellowish grey, light grey | 6.9 | -21.9m to -27.2m | 2.4m to 8.2m |
| 8b | Poorly-graded sand with silt (SP-SM) | Light grey | 17.0 | -23.2m to -27.4m | 2.3m to 7.5m |
| 8c | Silty Sand (SM/ SC-SM) | Bluish grey, yellowish grey, light grey | 43.7 | -26.2m to -29.1m | 0.5m to 10.9m |
| 9 | Completely weathered sandstone | Reddish brown, yellowish brown | - | -29.7m to -30.9m | 0.4m to 3.0m |
| 10 | Moderately weathered silt/claystone | Reddish brown, yellowish brown | - | - | - |

[yellow]: Sand Layer, [light blue]: Clay Layer, [orange]: Weathered Rock

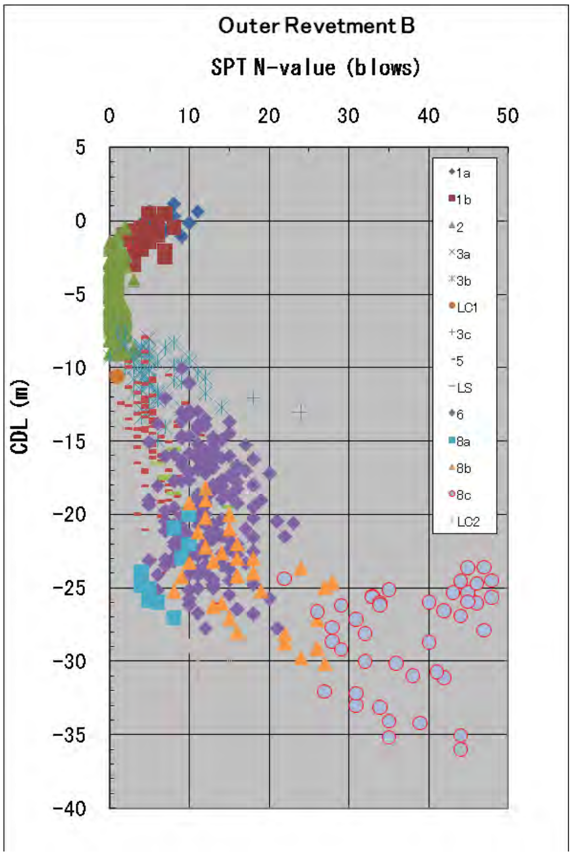



**Figure 2.1.26 SPT N-value Distribution with Depth**

Representative soil profiles with SPT-N values based on this Study result are shown in Figure 2.1.27.

SPT –N value distributions with depth along the Outer Revetment B are shown in Figure 2.1.26. Average SPT N-value for each layer is as follows;

Layer 1a: N = 5.7
Layer 1b: N = 4.7
Layer 2 : N = 0.7
Layer 3a : N = 4.5
Layer 3b : N = 5.5
Layer 3c : N = 21.0
Layer 5 : N = 4.8
Layer 6 : N = 12.1
Layer 8a : N = 6.9
Layer 8b : N = 17.0
Layer 8c : N = 43.7

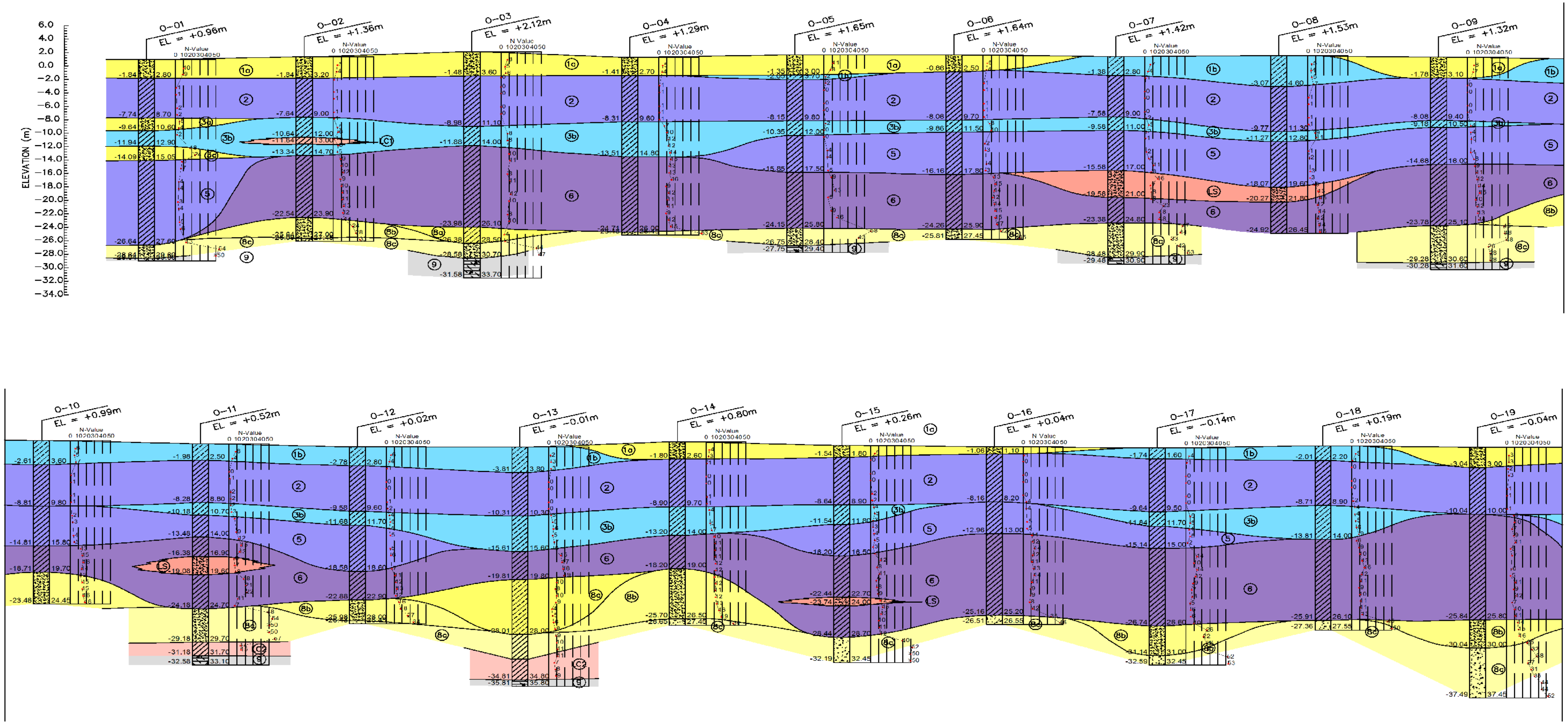



**Figure 2.1.27 Soil Profile along the Outer Revetment B**

### 2) Soil Properties

Laboratory test results are shown as a relationship between depth and each value in Appendix.

Soil properties obtained from subsoil investigation surveys at Outer Revetment B Area, which have been carried out this time are tabulated in Table 2.1.18.

**Table 2.1.18 Soil Properties of each Layer at Outer Revetment B Area**

| Layer | Soil Type | SPT | Fine content (%) | Natural moisture content w (%) | Atterberg Limits | | | Bulk density (KN/m³) | | Specific Gravity | Initial Void ratio | Consolidation test | | | | | | Unconfined compression test | | | | Tri-xial test (UU) | | Tri-xial test (UU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Liquid limit $W_l$(%) | Plastic limit Wp(%) | Plasticity index Ip (%) | Natural | Dry | | | Log Average in Over consolidated | Log Average in Normal consolidated | Compression Index | Re-Compression Index | Swelling Index | Over consolidation stress | $q_u$ (KN/m²) | | Failure Strain of (%) | | | | | |
| | | N_Value (blows) | | | | | | | | | eo | Cv(o) ($10^{-3}$cm²/s) | Cv(n) ($10^{-3}$cm²/s) | Cc | Cr | Cs | Pc (KN/m²) | A | B | A | B | Cuu (KN/m²) | φuu (deg.) | Ccu (KN/m²) | φcu (deg.) |
| 1a | SP/SP-SM | 5.7 | 5.0 | | | | | | | 2.69 | | | | | | | | | | | | | | | |
| 1b | SM/SC-SM | 4.7 | 31.8 | | | | | | | 2.69 | | | | | | | | | | | | | | | |
| 2 | CH | 0.7 | 96.6 | 55.73 | 59.09 | 28.37 | 30.72 | 16.41 | 10.59 | 2.70 | 1.525 | 1.35 | 0.85 | 0.586 | 0.059 | 0.081 | 60.80 | 38.96 | 39.80 | 7.49 | 7.69 | 22.54 | 0°29' | 16.72 | 12°43' |
| 3a | SP/SP-SM | 4.5 | 13.5 | | | | | 16.41 | | 2.66 | | | | | | | | | | | | | | | |
| 3b | SM/SC-SM | 5.5 | 50.2 | 29.81 | 31.72 | 17.57 | 14.15 | 18.82 | 14.57 | 2.69 | 0.828 | 1.91 | 1.54 | 0.187 | 0.017 | 0.022 | 102.07 | 42.26 | 42.15 | 6.01 | 9.39 | 47.79 | 1°44' | 22.85 | 16°31' |
| 3c | SM | 21.0 | 28.4 | | | | | | | 2.66 | | | | | | | | | | | | | | | |
| 5 | CL | 4.8 | 93.8 | 42.02 | 46.94 | 22.59 | 24.36 | 17.59 | 12.48 | 2.71 | 1.158 | 2.03 | 1.18 | 0.475 | 0.038 | 0.067 | 160.16 | 68.77 | 64.37 | 6.57 | 7.24 | 46.99 | 0°51' | 28.02 | 13°42' |
| 6 | CL | 12.1 | 84.1 | 28.67 | 39.10 | 20.24 | 18.86 | 19.22 | 15.03 | 2.71 | 0.789 | 1.65 | 1.11 | 0.244 | 0.013 | 0.053 | 163.76 | 139.13 | 125.34 | 10.32 | 11.57 | 45.61 | 0°45' | 23.52 | 16°4' |
| 8a | SM | 6.9 | 28.6 | | | | | | | 2.68 | | | | | | | | | | | | | | | |
| 8b | SC-SM or SP-SM | 17.0 | 32.5 | | | | | | | 2.69 | | | | | | | | | | | | | | | |
| 8c | SM/SC-SM | 43.7 | 21.4 | | | | | | | 2.68 | | | | | | | | | | | | | | | |
| LS | SC/SC-SM | 10.0 | 38.0 | | 25.8 | 14.0 | 11.8 | | | 2.70 | | | | | | | | | | | | | | | |
| LC1 | CL | 1.0 | 92.8 | | | | | | | 2.71 | | | | | | | | | | | | | | | |
| LC2 | CL | 10.4 | 78.3 | | 40.2 | 22.2 | 17.9 | | | 2.70 | | | | | | | | | | | | | | | |

Characteristics of soil properties of soil layers are described as follows;

#### a) Physical properties

i) Specific Gravity of Soil Gs (Refer to Figure 2.1.28)

Specific gravity of soil shows 2.7 in average through all soil layers at Reclamation area and ranging between 2.66 and 2.71. This value shows that all soil layers at Outer Revetment B Area are composed of inorganic soils.

ii) Fine Content Fc (Weight percentage passing 74μm Sieve) (Refer to Figure 2.1.28)

Fine content is one of the indices obtained from sieve analysis test. When it is more than 50%, we classify the soil as fine soil like silt or clay.

According to sieve analysis test result, Layer 2, 3b, 5, 6 can be classified as fine soil, however Layer 1a, 1b, 3a, 3c, 8a, 8b and 8c are classified as coarse soil which has about 5% to 30% of fine content.

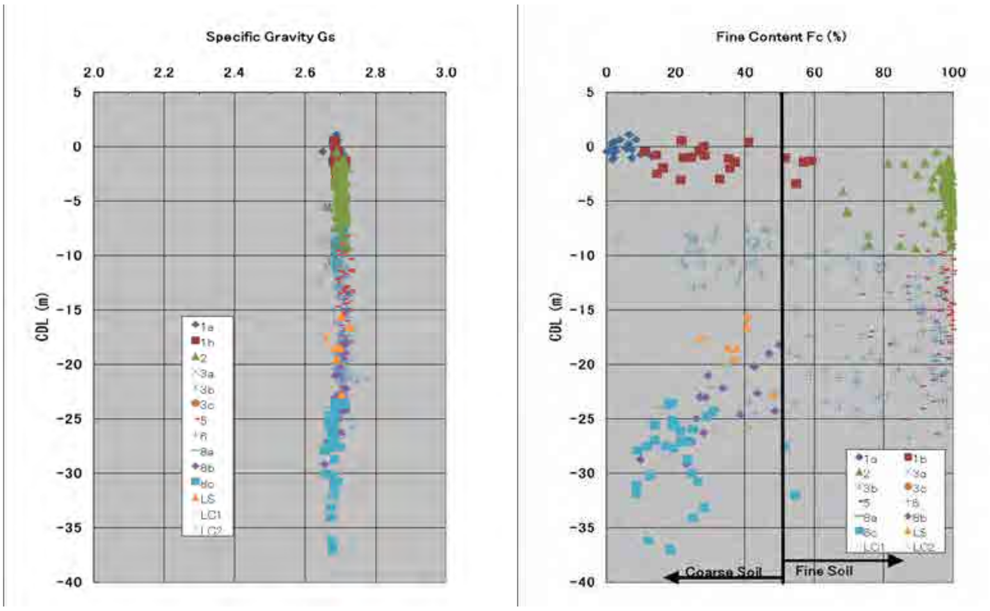



**Figure 2.1.28 Specific Gravity and Fine Content with Depth**

iii) Natural Water Content and Atterberg's Limits (Refer to Figure 2.1.29)

Layer 2 and Layer 5 which has considerable thickness and horizontal distribution can be main subject layers for consolidation settlement. Average natural water content Layer 2 and Layer 5 at Outer Revetment B Area is 56% and 42% respectively. Other clay layers such as Layer 3b and Layer 6 have 30% and 29% of average natural water content respectively.

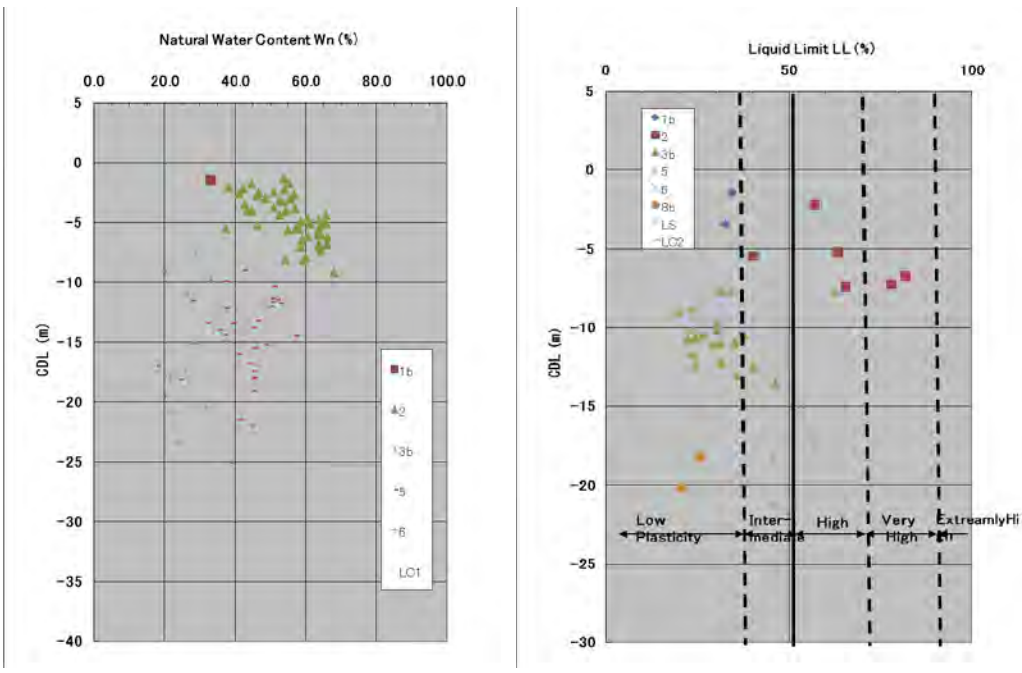



**Figure 2.1.29 Natural Water Content and Liquid Limit with Depth**

According to liquid limit test result as shown in the right side of Figure 2.1.29, liquid limits of fine soil layers, Layer 2, layer 3b, Layer 5 and Layer 6 are 59%, 32%, 47% and 29% in average, only Layer 2 shows high plasticity in average.

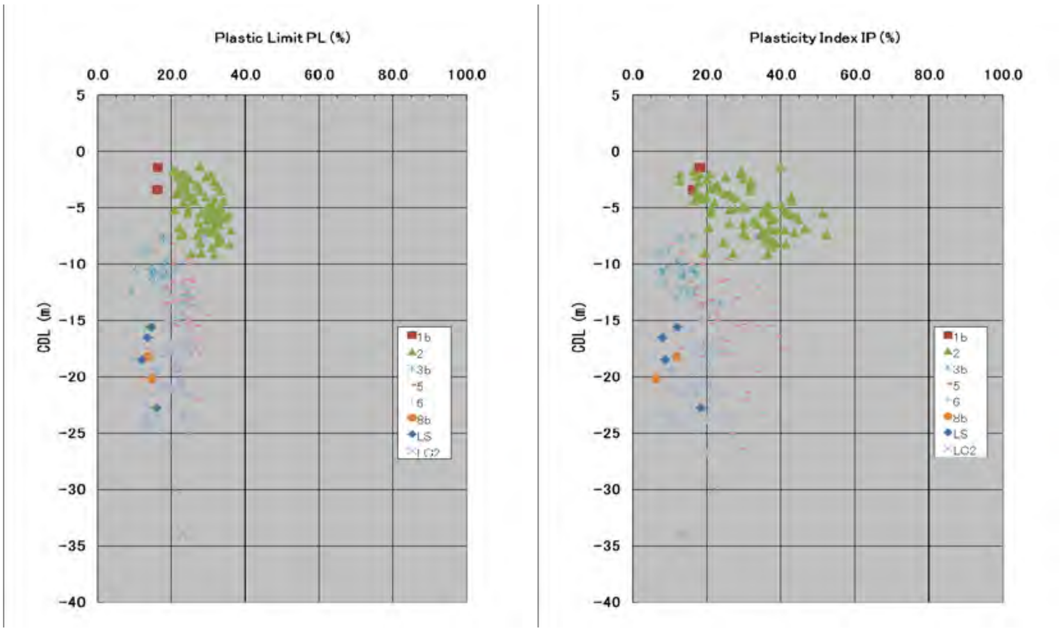



**Figure 2.1.30 Plastic Limit and Plasticity Index**

iv) Bulk Density (Unit Weight) and Void Ratio (Refer to Figure 2.1.31)

As shown in Figure 2.1.31, average value of bulk density and void ratio for each layer are as shown in Table 2.1.19.

**Table 2.1.19 Bulk Density and Void Ratio**

| Layer Name | Bulk Density $\gamma$ (kN/m$^3$) | Void Ratio $e_0$ |
|---|---|---|
| Layer 2 | 16.4 | 1.5 |
| Layer 3b | 18.8 | 0.8 |
| Layer 5 | 17.6 | 1.2 |
| Layer 6 | 19.2 | 0.8 |

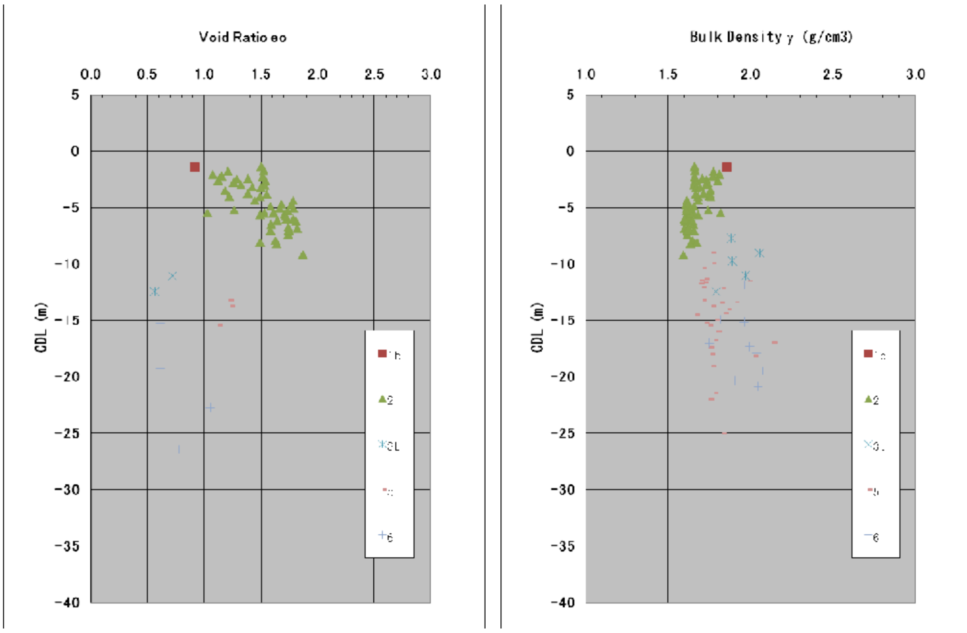



**Figure 2.1.31 Bulk Density and Initial Void Ratio with Depth**

**b) Mechanical Properties of Cohesive Soil**

i) Shear Strength of Cohesive Soil

Unconfined compression test and tri-axial test have been carried out in this survey to identify the undrained shear strength under the ground.

Unconfined compression strength and that failure strain are shown in Figure 2.1.32. Average unconfined compression strength of each layer at Reclamation Area is as follows;

- Layer 2 : qu = 39kN/m$^2$, Layer 3b : qu = 42kN/m$^2$,
- Layer 5 : qu = 66kN/m$^2$, Layer 6 : qu = 132kN/m$^2$

As shown in Figure 2.1.32, more than half of failure strains (strain at peak strength of unconfined compression test) of samples in Layer 2 show more than 7%. It means that about half of samples are disturbed during sampling, transportation and testing process. Therefore strength of half of samples might be showing the smaller strength than actual in-situ strength. Therefore the above average unconfined compression strength (qu) can be estimated to give a little smaller values than completely undisturbed one.

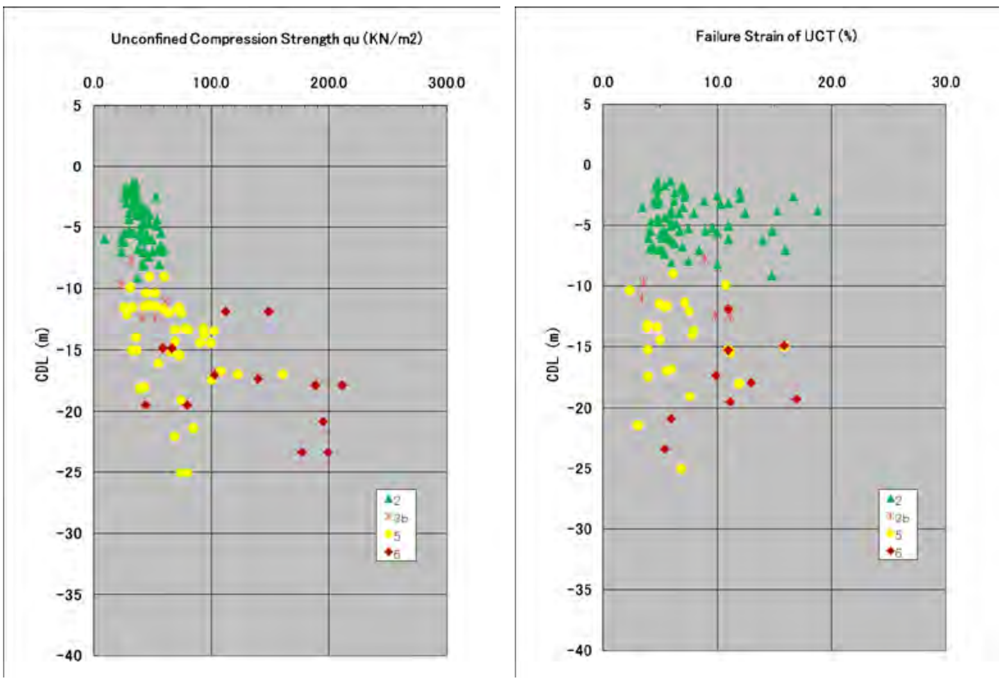



**Figure 2.1.32 Unconfined Compression Strength and Failure Strain with Depth**

Comparison of undrained shear strengths from unconfined compression strength test (Cu) and tri-axial compression strength test (Cuu) is shown in Figure 2.1.33.

The distribution of undrained shear strength with depth of Cu and Cuu is very similar each other.

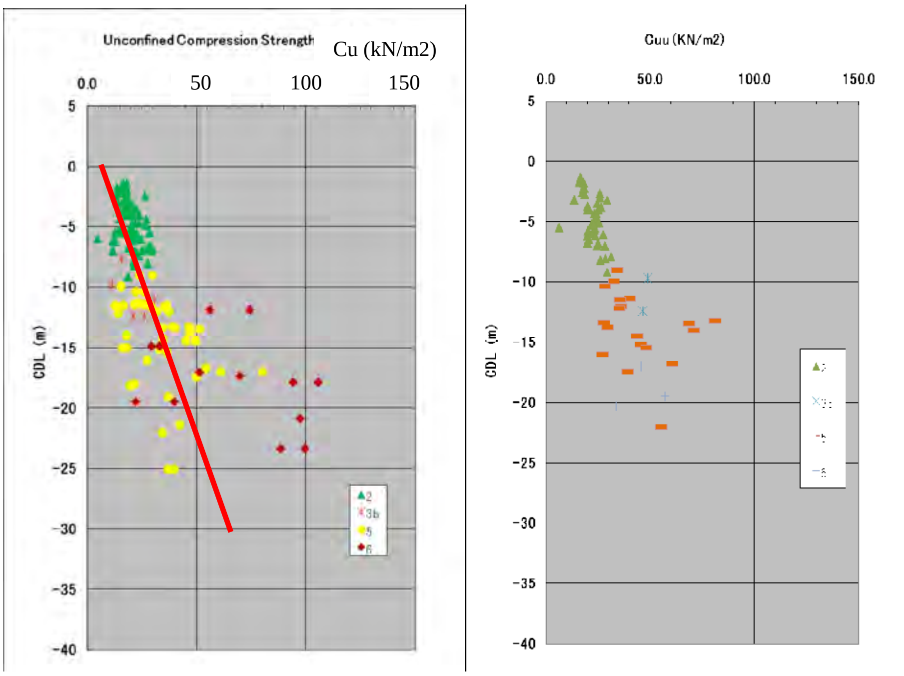



**Figure 2.1.33 Cu and Cuu with Depth**

ii) Consolidation Characteristics of Cohesive Soil

<u>Preconsolidation Pressure Pc</u>

Preconsolidation pressure Pc is distributing with depth as shown in Figure 2.1.34.

Possible consolidation settlement layers are Layer 1b, 2, 3b, 5 and 6 at Outer Revetment B Area. Remarkable point of these clay layers is that they are a little over consolidated. Even uppermost Layer 2 is also over-consolidated as shown in Figure 2.1.34.

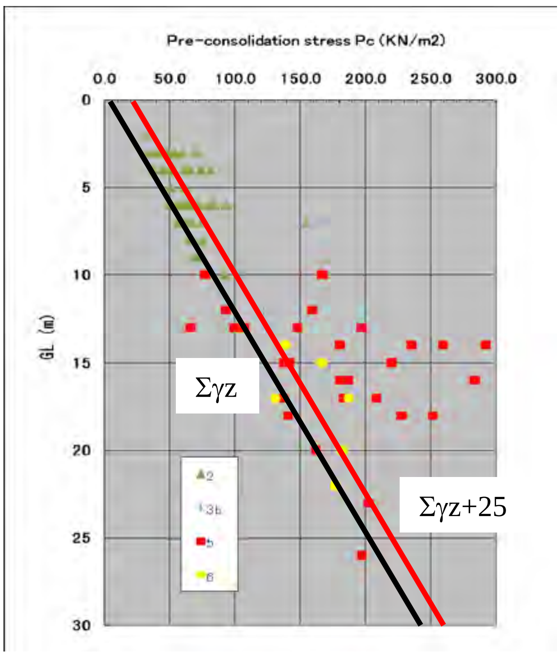



**Figure 2.1.34 Preconsolidation Pressure (Pc) with Depth**

According to Figure 2.1.34, preconsolidation pressure for each layer can be described as follows;

- Layer 1b, Layer 2 and Layer 3b : Pc = $\Sigma\gamma z$ + 25 kN/m$^2$
- Layer 5: Pc = $\Sigma\gamma z$ + 50 kN/m$^2$
- Layer 6 : Pc = $\Sigma\gamma z$ + 100 kN/m$^2$

However even though above soil layers are over-consolidated, finally construction load in future about 50 to 100 kN/m$^2$ will be working on them beyond the average Pc lines except Layer 6. Accordingly some extent of consolidation settlement due to above layers will be anticipated.

<u>Compression Index Cc and Recompression Index Cr</u>

Compression Index Cc and Recompression Index Cr are distributed with depth as shown in Figure 2.1.35.

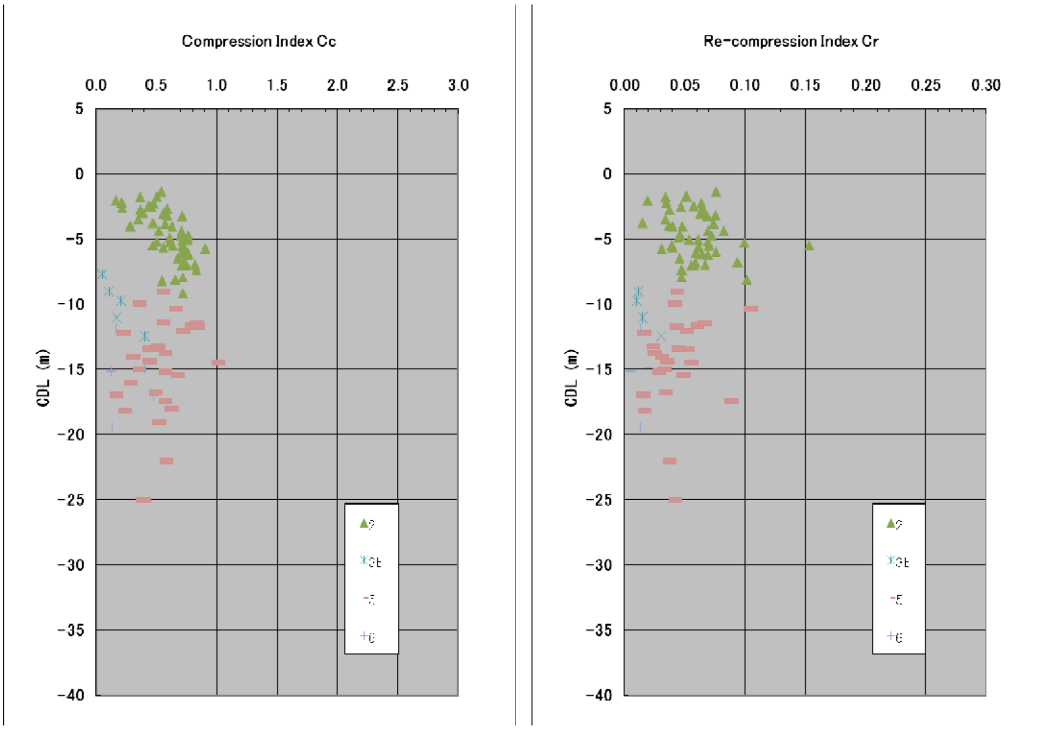



**Figure 2.1.35 Cc and Cr with Depth**

According to consolidation test results, Compression Index Cc and Re-compression Index Cr are obtained as shown in Figure 2.1.36. Average values of Cc and Cr for each layer at Outer Revetment B Area are described as follows;

- Layer 2 : Cc = 0.60, Cr = 0.06
- Layer 3b : Cc = 0.25, Cr = 0.05
- Layer 5 : Cc = 0.55, Cr = 0.04
- Layer 5 : Cc = 0.15, Cr = 0.01

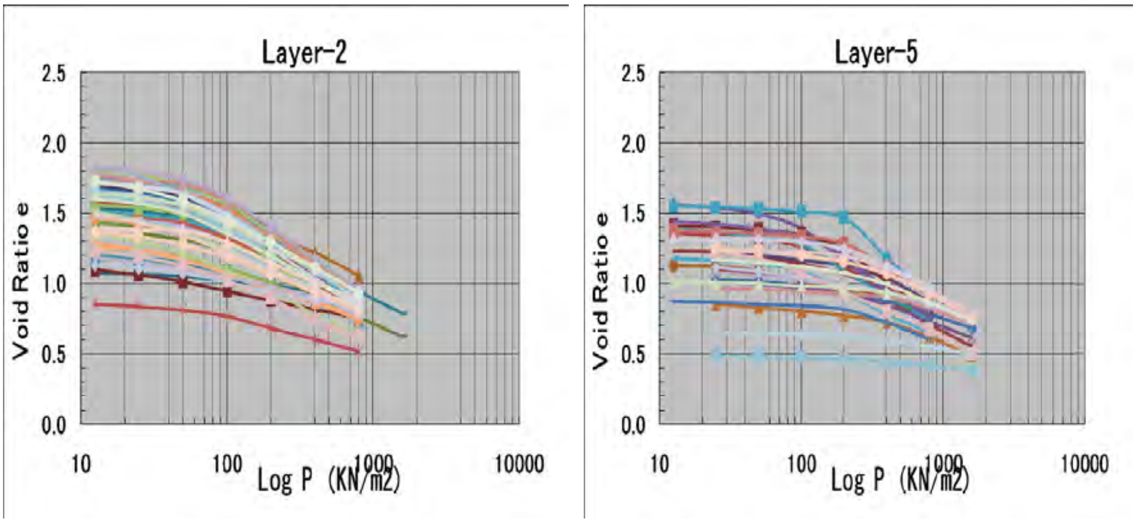



**Figure 2.1.36 e-Log P Curves for Layer 2 and Layer 5**

Coefficient of Consolidation Cv

Coefficient of consolidation Cv is one of the important consolidation factors which show the speed of consolidation settlement. In Figure 2.1.37, Cv (OC) and Cv (NC) are plotted with depth. (Cv (OC): Average value of Cv in over consolidation range, Cv (NC): Average value of Cv in normal consolidation range.)

Average Cv (NC) and average Cv (OC) for each layer is as follows;

- Layer 2 : Cv(NC)=0.60 x $10^{-3}$cm/sec=52cm$^2$/day, Cv(OC)= 1.0 x $10^{-3}$cm/sec=86cm$^2$/day
- Layer3b: Cv(NC)=1.20 x $10^{-3}$cm/sec=104cm$^2$/day, Cv(OC)= 1.2 x $10^{-3}$cm/sec=104cm$^2$/day
- Layer 4 : Cv(NC)=0.2 x $10^{-3}$cm/sec=17cm$^2$/day, Cv(OC)= 0.3 x $10^{-3}$cm/sec=26cm$^2$/day
- Layer 5 : Cv(NC)=0.15 x $10^{-3}$cm/sec=13cm$^2$/day, Cv(OC)= 0.3 x $10^{-3}$cm/sec=26cm$^2$/day

Above average values are selected based on Cv-Log P lines for each layer.

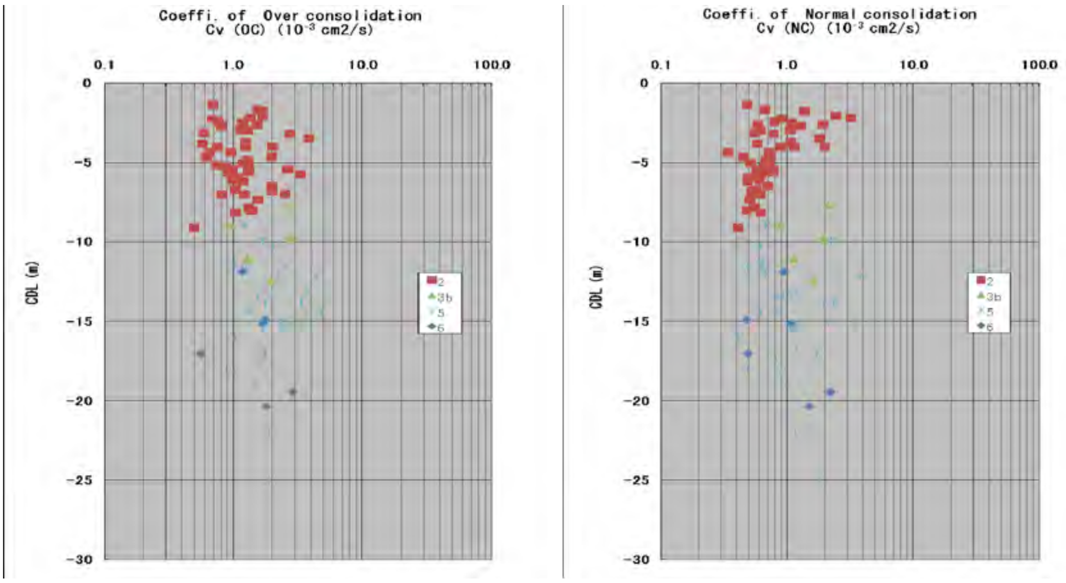



**Figure 2.1.37 Cv (OC) and Cv (NC) with Depth**

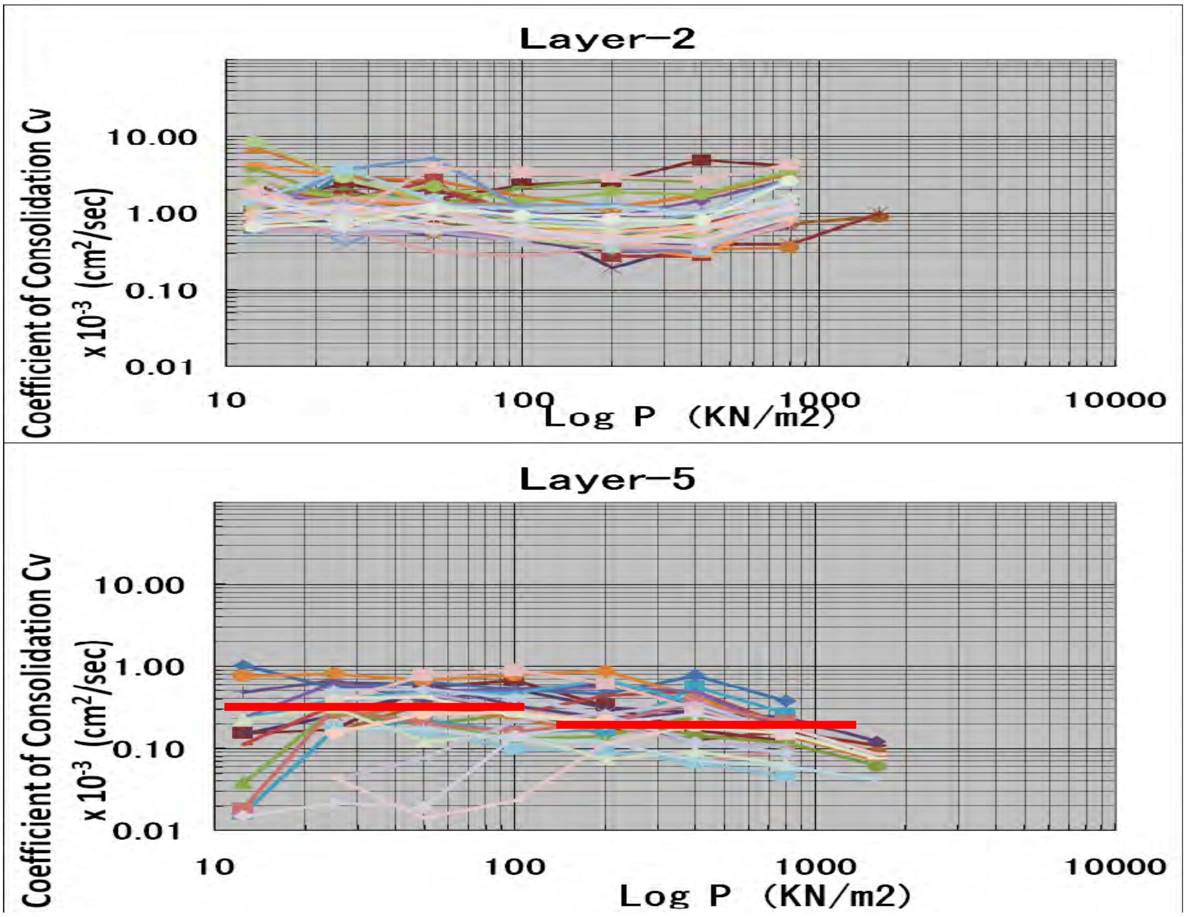



**Figure 2.1.38 Log Cv – Log P Curves for Layer 2 and Layer 5**

Rate of Secondary Compression Cα (= Δe/Δlog t)

In this study and existing investigation results, there has not been carried out any special consolidation tests for the evaluation of Secondary Compression Index Cα.

Therefore the following formula is applied for the evaluation of Cα;

$$C\alpha(NC)/\ Cc = 0.04 \pm 0.01 \text{ (after Ladd et al, 2003)}$$

$$\text{Adopted here, } C\alpha(NC)/\ Cc = 0.03$$

Rate of Secondary Compression Cα ( $C\alpha\varepsilon = C\alpha /(1+e_0)$ ) obtained from average Cc for each layer and above formula is as follows;

- Layer2 : Cα(NC) =0.03xCc=0.03x0.6= 0.018, $C\alpha\varepsilon = C\alpha /(1+e_0) = 0.018/(1+1.55) = 0.007$
- Layer3b: Cα(NC) =0.03xCc=0.03x0.25= 0.008, $C\alpha\varepsilon = C\alpha /(1+e_0) = 0.008/(1+0.80) = 0.004$
- Layer5: Cα(NC) =0.03xCc=0.03x0.55= 0.017, $C\alpha\varepsilon = C\alpha /(1+e_0) = 0.017/(1+1.15) = 0.008$
- Layer6: Cα(NC) =0.03xCc=0.03x0.15= 0.005, $C\alpha\varepsilon = C\alpha /(1+e_0) = 0.005/(1+0.80) = 0.003$

**3) Soil parameters for each layer at Outer Revetment B Area**

Soil parameters for design purpose, those values are recommended and tabulated based on average values of soil property test results at Outer Revetment B Area as shown in Table 2.1.20.

**Table 2.1.20 Soil Parameters recommended for Outer Revetment B**

| Layer No. | Typical Soil Type | SPT-N | γ (kN/m³) | γ' (kN/m³) | Cu (kN/m²) | φ (°) | Cc | Cr | Pc (kN/m²) | e0 | Cv (OC) x 10⁻³ (cm²/s) | Cv (NC) x 10⁻³ (cm²/s) | Cu/P for NC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | SP, SP-SM | 6 | 18.0 | 8.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 1b | SM, SC-SM | 5 | 18.0 | 8.0 | 10 + 2Z | 0.0 | 0.30 | 0.07 | γ'z + 25 | 1.05 | 1.20 | 1.20 | 0.20 |
| 2 | CH | 1 | 16.5 | 6.5 | 10 + 2Z | 0.0 | 0.60 | 0.06 | γ'z + 25 | 1.55 | 1.00 | 0.60 | 0.20 |
| 3a | SP, SP-SM | 5 | 19.0 | 9.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 3b | SM, SC-SM | 6 | 19.0 | 9.0 | 10 + 2Z | 0.0 | 0.25 | 0.05 | γ'z + 25 | 0.80 | 1.20 | 1.20 | 0.20 |
| 3c | SM | 21 | 19.0 | 9.0 | 0 | 33.0 | - | - | - | - | - | - | - |
| 5 | CL | 5 | 17.5 | 7.5 | 10 + 2Z | 0.0 | 0.55 | 0.04 | γ'z + 50 | 1.15 | 0.30 | 0.20 | 0.20 |
| 6 | CL | 12 | 19.0 | 9.0 | 50 | 0.0 | 0.15 | 0.01 | γ'z + 100 | 0.80 | 0.30 | 0.15 | 0.20 |
| 8a | SM | 7 | 18.0 | 8.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 8b | SC-SM, SP-SM | 17 | 19.0 | 9.0 | 0 | 30.0 | - | - | - | - | - | - | - |
| 8c | SM, SC-SM | 44 | 20.0 | 10.0 | 0 | 35.0 | - | - | - | - | - | - | - |
| Fill,Emb | S | - | 18.0 | 10.0 | 0 | 30.0 | - | - | - | - | - | - | - |

*NC: Normal conslidated State, OC: Over consolidated State * z : Depth (m)

## 2.1.8 Sub soil investigation result at Sand Protection Dyke Area

### 1) Boring Result

Totally 26 boreholes have been drilled and investigated along Outer Revetment B. Soil stratification identified in this Area is tabulated as shown in Table 2.1.21.

**Table 2.1.21 Soil Stratification identified at Reclamation Area**

| Layer Name | | Color | Average N-Value | Distributed Depth C.D.L (m) | Distributed thickness (m) |
|---|---|---|---|---|---|
| 1a | Loose sand, clayey sand (SP/SP-SC) | Grey, light grey | 4.8 | GL to -3.5m | 0.7m to 4.8m |
| 1b | Sandy clay (CL/SC) | blackish grey, brownish grey, grey | 4.5 | -2.2m to -5.2m | 0.9m to 4.6m |
| 2 | Fat clay with sand (CH) | Grey, brownish and yellowish grey | 0.8 | -4.2m to -12.7m | 6.5m to 16.9m |
| 3b | Clayey sand/ Sandy clay (CL/SC) | Yellowish grey, grey | 7.8 | -12.1m to -17.0m | 2.8m to 7.5m |
| 4 | Sandy lean clay (CL) | Reddish brown, yellowish brown | 10.7 | -15.4m to -20.8m | 2.8m to 10.0m |
| 5 | Fat clay with sand (CH) | Grey, yellowish grey | 6.0 | -17.3m to -24.1m | 2.0m to 13.1m |
| 6 | Lean clay (CL) | Grey, reddish brown and bluish grey | 13.2 | -20.4m to -31.7m | 1.0m to 22.2m |
| 7 | Silty, clayey sand (SC-SM) | Light grey and yellowish grey | 15.9 | -26.4m to -29.1m | 0.8m to 8.8m |
| 8b | Poorly-graded sand with silt (SP-SM) | Light grey | 23.4 | -31.5m to -32.8m | 0.7m to 2.7m |
| 8c | Silty Sand (SM/ SC-SM) | Bluish grey, yellowish grey, light grey | 48.3 | -34.6m to -36.7m | 0.8m to 7.0m |

: Sand Layer, : Clay Layer, : Weathered Rock

Representative soil profiles with SPT-N values based on this Study result are shown in Figure 2.1.41 and Figure 2.1.42.

SPT –N value distributions with depth along the Sand Protection Dyke are shown in Figure 2.1.39. Average SPT N-value for each layer is as follows;

Layer 1a: N = 4.8
Layer 1b: N = 4.5
Layer 2 : N = 0.8
Layer 3b : N = 7.8
Layer 4 : N = 10.7
Layer 5 : N = 6.0
Layer 6 : N = 13.2
Layer 7 : N = 15.9
Layer 8b : N = 23.4
Layer 8c : N = 48.3

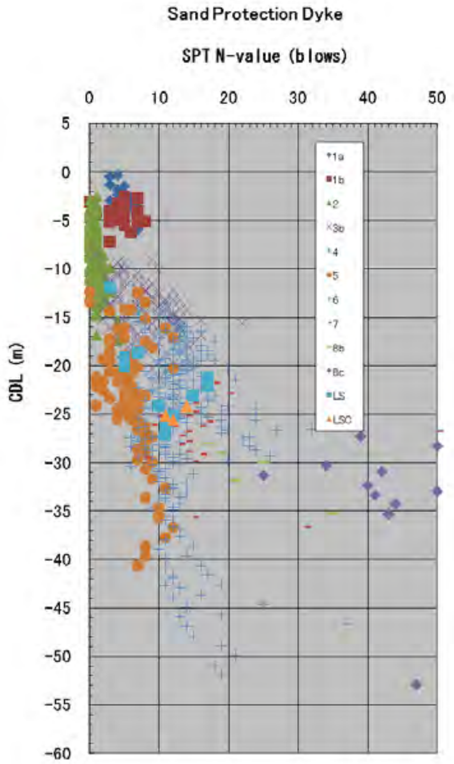



**Figure 2.1.39 SPT N-value Distribution with Depth**

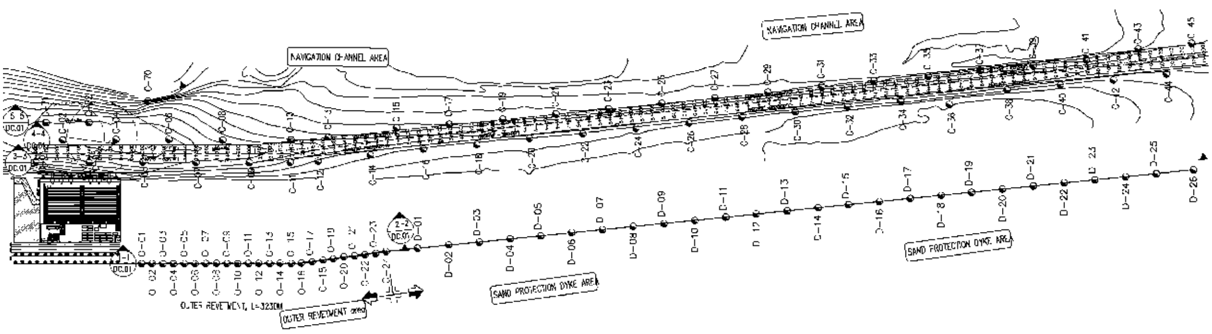


**Figure 2.1.40 Boring Location Map for Sand Protection Dyke Area**

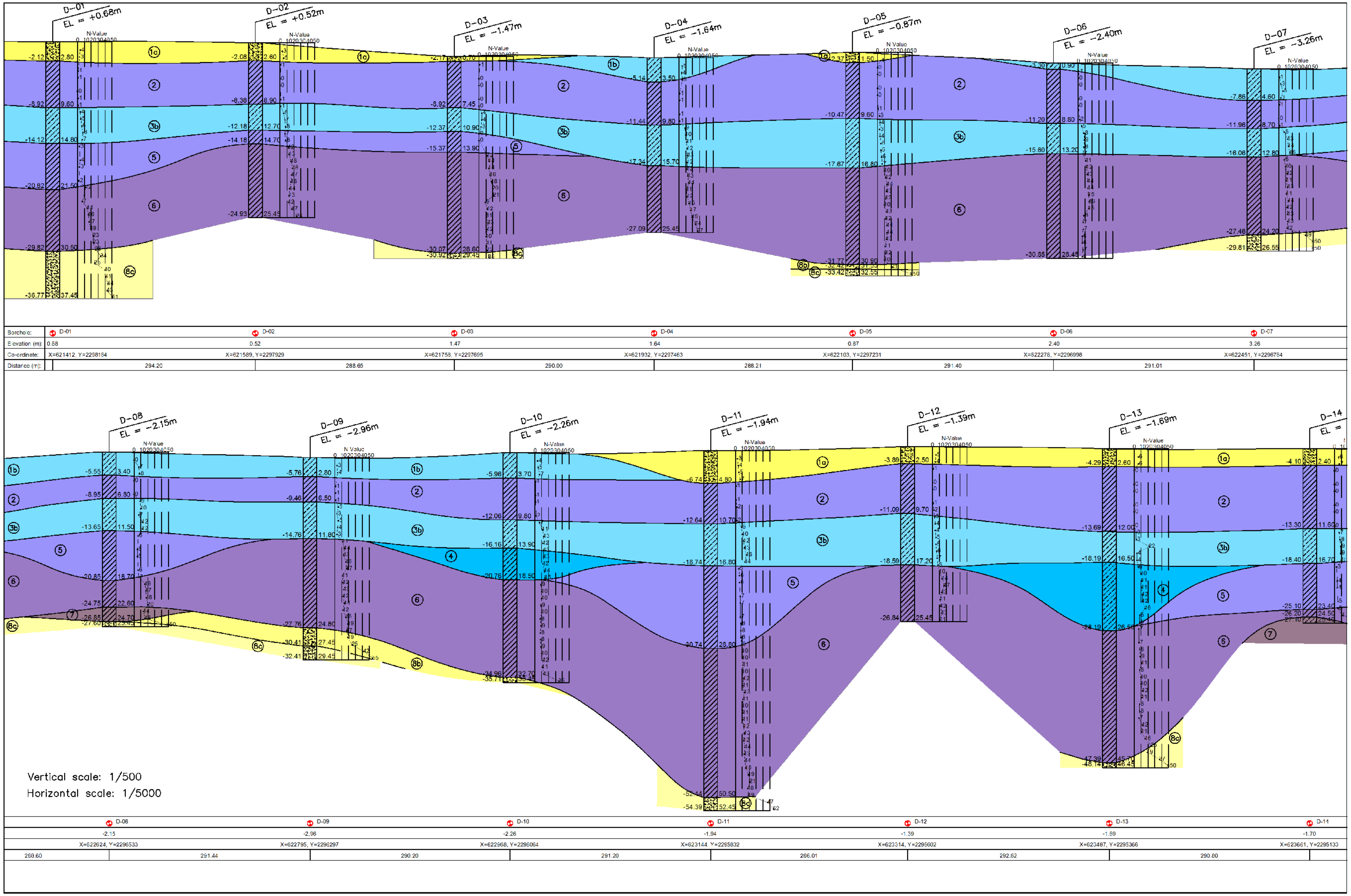



**Figure 2.1.41 Soil Profile along the Sand Protection Dyke (1/2)**

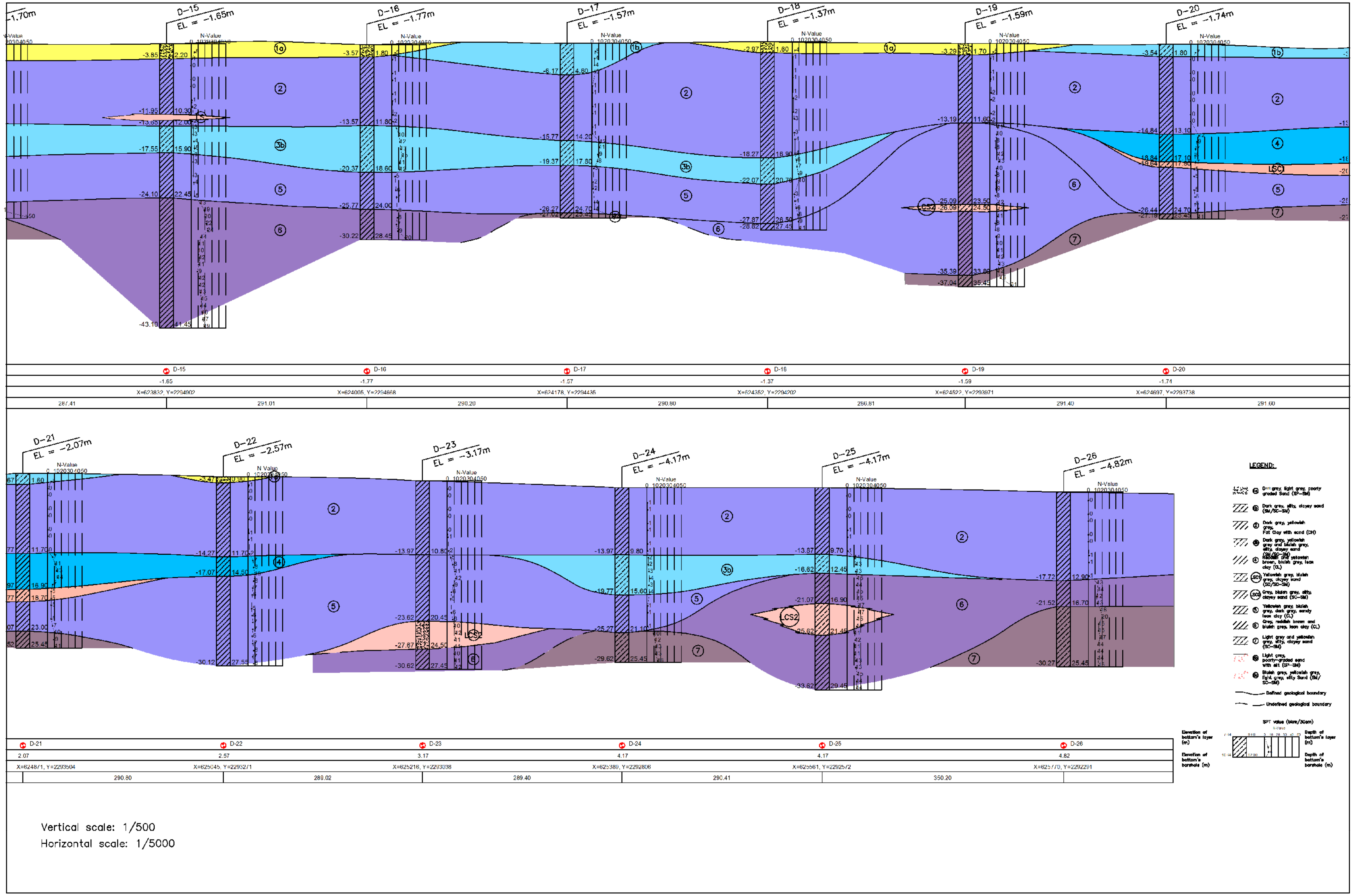



**Figure 2.1.42 Soil Profile along the Sand Protection Dyke (2/2)**

## 2) Soil Properties

Laboratory test results are shown as a relationship between depth and each value in Appendix.

Soil properties obtained from subsoil investigation surveys at Sand Protection Dyke Area which have been carried out this time are tabulated in Table 2.1.22.

**Table 2.1.22 Soil Properties of each Layer at Sand Protection Dyke Area**

| Layer | Soil Type | SPT | Fine content (%) | Natural moisture content w (%) | Atterberg Limits | | | Bulk density (KN/m$^3$) | | Specific Gravity | Void ratio e0 | Consolidation test | | | | | | Unconfined compression test | | | | Tri-xial test (UU) | | Tri-xial test (CU) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Liquid limit $W_L$(%) | Plastic limit Wp(%) | Plasticity index Ip (%) | Natural | Dry | | | Log Average in Over consolidated | Log Average in Nomal consolidated | Compression Index | Re-Compression Index | Swelling Index | Over consolidation stress | $q_u$ (KN/m$^2$) | | Failure Strain of (%) | | | | | |
| | | N_Value (blows) | | | | | | | | | | Cv(o) ($10^{-3}$cm$^2$/s) | Cv(n) ($10^{-3}$cm$^2$/s) | Cc | Cr | Cs | Pc (KN/m$^2$) | A | B | A | B | Cuu (KN/m$^2$) | φuu (deg.) | Ccu (KN/m$^2$) | φcu (deg.) |
| 1a | SP-SM | 4.8 | 8.9 | | | | | | | 2.69 | | | | | | | | | | | | | | | |
| 1b | SM/SC-SM | 4.5 | 31.3 | | 35.14 | 18.89 | 16.25 | | | 2.69 | | | | | | | | | | | | | | | |
| 2 | CH | 0.8 | 97.1 | 65.64 | 68.20 | 31.82 | 36.44 | 15.69 | 9.50 | 2.70 | 1.805 | 0.95 | 0.56 | 0.714 | 0.092 | 0.110 | 58.03 | 25.09 | 25.90 | 8.59 | 8.98 | 17.18 | 0°44' | 14.19 | 12°23' |
| 3b | SM/SC-SM | 7.8 | 37.1 | | 30.16 | 16.89 | 13.26 | | | 2.69 | | | | | | | | | | | | | | | |
| 4 | CL | 10.7 | 91.5 | | 42.39 | 22.71 | 19.67 | | | 2.71 | | | | | | | | | | | | | | | |
| 5 | CL | 6.0 | 87.2 | 42.02 | 44.71 | 23.18 | 21.53 | 17.55 | 12.43 | 2.71 | 1.155 | 1.94 | 1.08 | 0.430 | 0.037 | 0.063 | 159.11 | 60.78 | 57.01 | 7.24 | 8.23 | 30.78 | 1°8' | 23.21 | 13°51' |
| 6 | CL | 13.2 | 90.9 | 44.16 | 46.77 | 23.87 | 22.90 | 17.73 | 12.58 | 2.71 | 1.198 | 1.23 | 0.58 | 0.513 | 0.043 | 0.118 | 189.39 | 96.69 | 80.20 | 3.33 | 3.99 | 48.91 | 2°23' | 32.94 | 17°39' |
| 7 | SC/SC-SM | 15.9 | 46.6 | | 26.61 | 15.51 | 11.10 | | | 2.69 | | | | | | | | | | | | | | | |
| 8b | SP-SM | 23.4 | 14.0 | | | | | | | 2.67 | | | | | | | | | | | | | | | |
| 8c | SM/SC-SM | 48.3 | 18.3 | | | | | | | 2.68 | | | | | | | | | | | | | | | |
| LSC1 | SC/SC-SM | 5.7 | 35.2 | | 30.88 | 18.23 | 12.65 | | | 2.67 | | | | | | | | | | | | | | | |
| LSC2 | SC/SC-SM | 13.0 | 39.8 | | 42.35 | 16.61 | 25.74 | | | 2.71 | | | | | | | | | | | | | | | |

Characteristics of soil properties of soil layers are described as follows;

### a) Physical properties

i) Specific Gravity of Soil Gs (Refer to Figure 2.1.43)

Specific gravity of soil shows 2.7 in average through all soil layers at Reclamation area and ranging between 2.67 and 2.71. This value shows that all soil layers at Sand Protection Dyke Area are composed of inorganic soils.

ii) Fine Content Fc (Weight percentage passing 74μm Sieve) (Refer to Figure 2.1.43)

Fine content is one of the indices obtained from sieve analysis test. When it is more than 50%, we classify the soil as fine soil like silt or clay.

According to sieve analysis test result, Layer 2, 4, 5, 6 can be classified as fine soil, however Layer 1a, 1b, 3b, 7, 8b and 8c are classified as coarse soil which has about 10% to 50% of fine content.

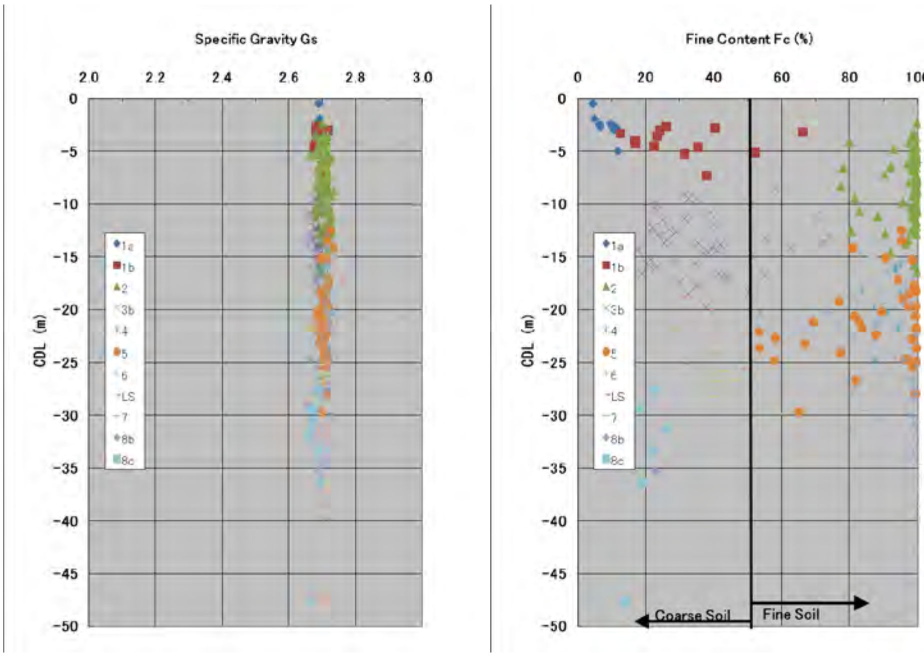



**Figure 2.1.43 Specific Gravity and Fine Content with Depth**

iii) Natural Water Content and Atterberg's Limits (Refer to Figure 2.1.44)

Layer 2 and Layer 5 which has considerable thickness and horizontal distribution can be main subject layers for consolidation settlement. Average natural water content Layer 2 and Layer 5 at Sand Protection Dyke Area is 66% and 42% respectively. Other clay layer such as Layer 6 has 44% of average natural water content.

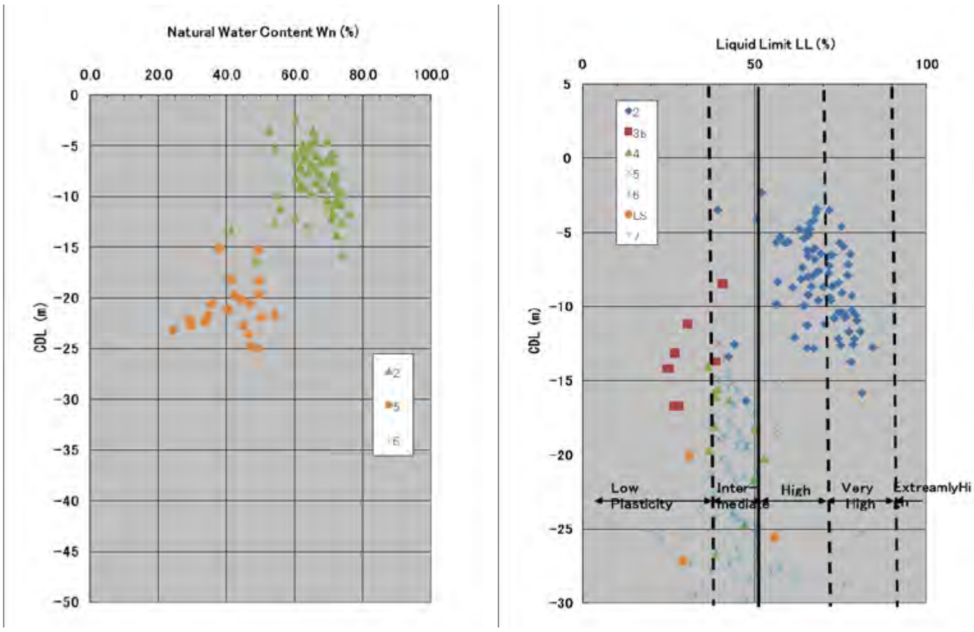



**Figure 2.1.44 Natural Water Content and Liquid Limit with Depth**

According to liquid limit test result as shown in the right side of Figure 2.1.44, liquid limits of fine soil layers, Layer 2, Layer 5 and Layer 6 are 68%, 45% and 47% in average, only Layer 2 shows high plasticity in average.

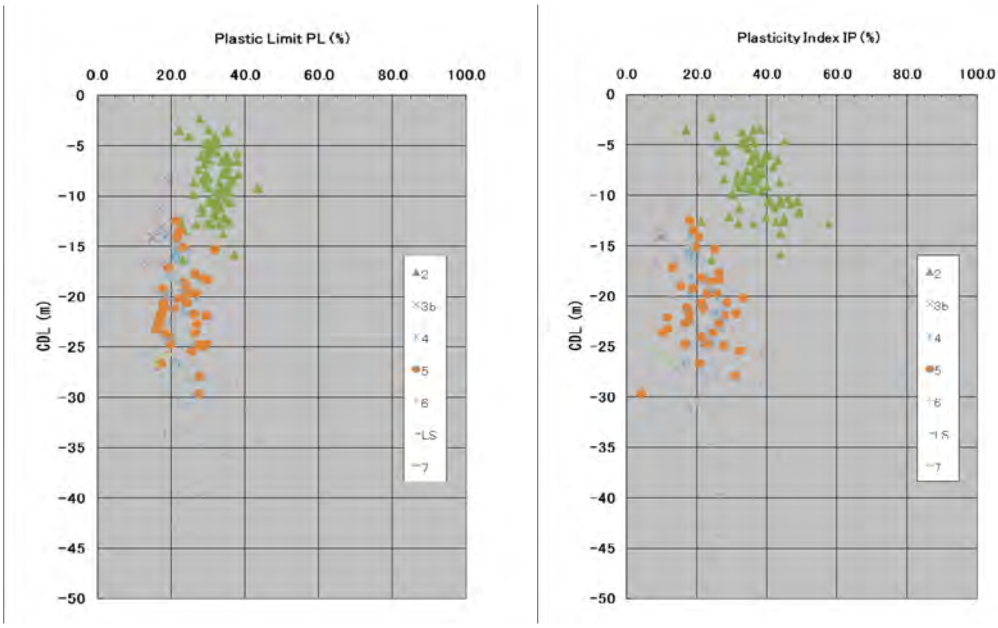



**Figure 2.1.45 Plastic Limit and Plasticity Index**

iv) Bulk Density (Unit Weight) and Void Ratio (Refer to Figure 2.1.46)

As shown in Figure 2.1.46, average value of bulk density and void ratio for each layer are as shown in Table 2.1.23.

**Table 2.1.23 Bulk Density and Void Ratio**

| Layer Name | Bulk Density γ (kN/m$^3$) | Void Ratio $e_0$ |
|---|---|---|
| Layer 2 | 15.7 | 1.8 |
| Layer 5 | 17.6 | 1.2 |
| Layer 6 | 17.7 | 1.2 |

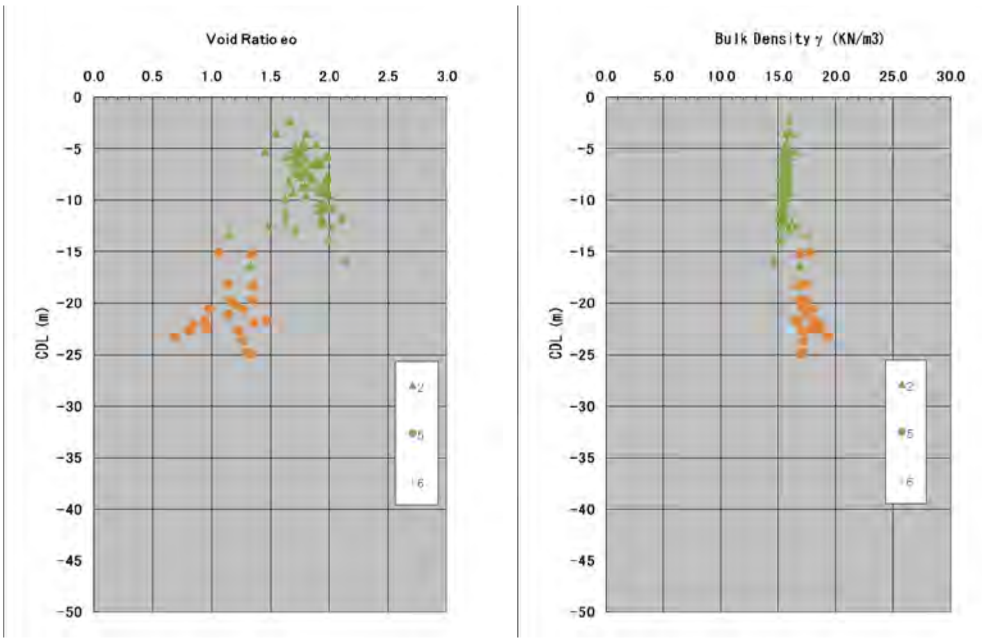



**Figure 2.1.46 Bulk Density and Initial Void Ratio with Depth**

**b) Mechanical Properties of Cohesive Soil**

i) Shear Strength of Cohesive Soil

Unconfined compression test and tri-axial test have been carried out in this survey to identify the undrained shear strength under the ground.

Unconfined compression strength and that failure strain are shown in Figure 2.1.47. Average unconfined compression strength of each layer at Reclamation Area is as follows;

Layer 2: qu = 25kN/m$^2$,      Layer 5: qu = 59kN/m$^2$,      Layer 6: qu = 89kN/m$^2$

As shown in Figure 2.1.47, most of failure strains (strain at peak strength of unconfined compression test) of samples in Layer 2 and Layer 5 show more than 7%. It means that more than half of these samples are disturbed during sampling, transportation and testing process. Therefore strength of these samples might be showing the smaller strength than actual in-situ strength. Therefore the above average unconfined compression strength (qu) can be estimated to give a little smaller values than completely undisturbed one.

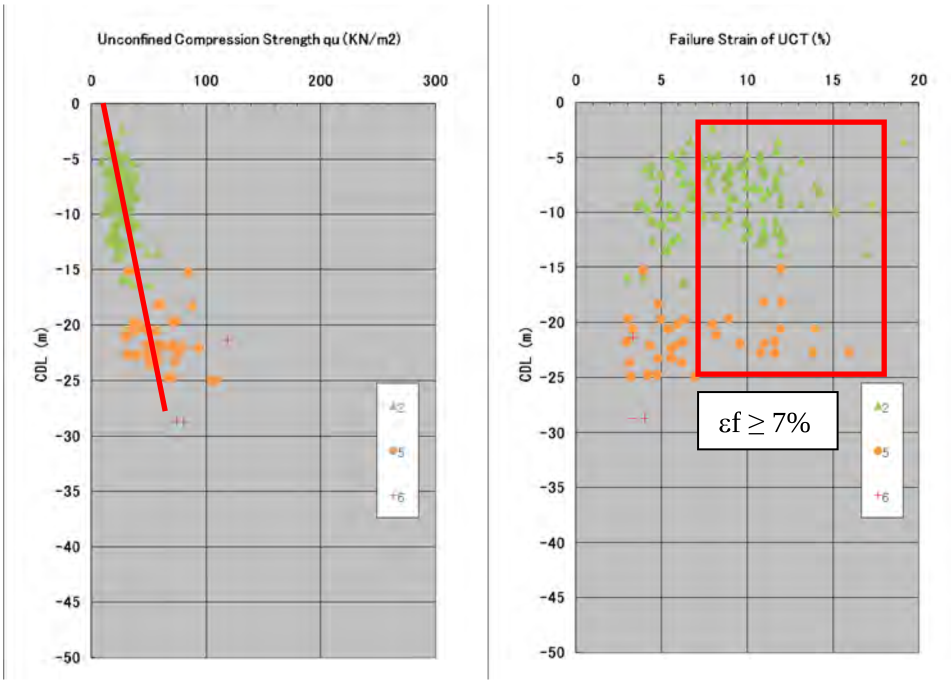



**Figure 2.1.47 Unconfined Compression Strength and Failure Strain with Depth**

Comparison of undrained shear strengths from unconfined compression strength test (Cu) and tri-axial compression strength test (Cuu) is shown in Figure 2.1.48.

The distribution of undrained shear strength with depth of Cu and Cuu is very similar each other.

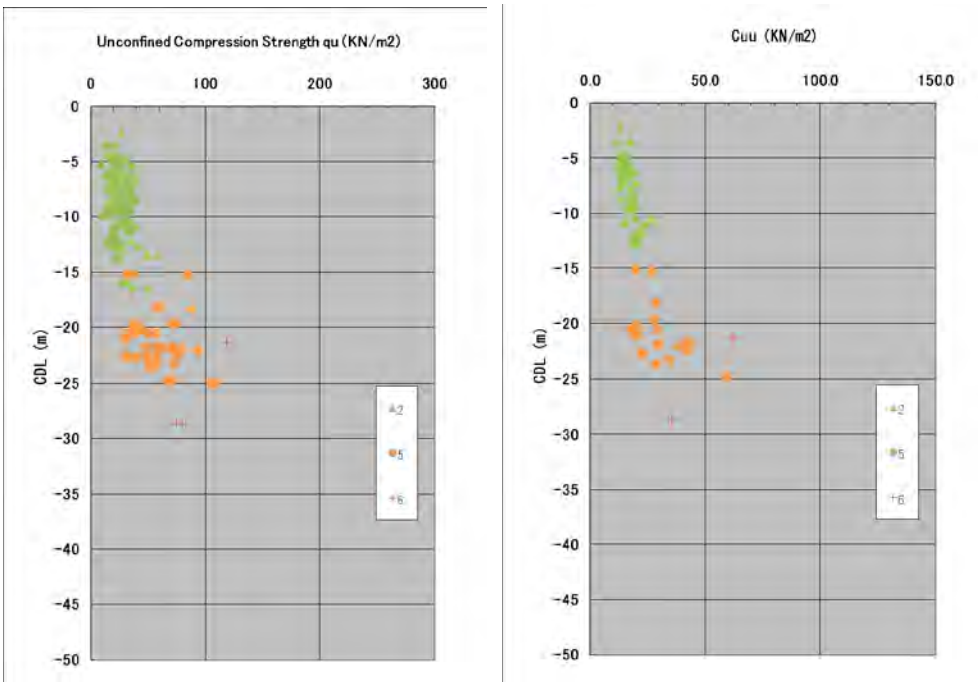



**Figure 2.1.48 Cu and Cuu with Depth**

ii) Consolidation Characteristics of Cohesive Soil

<u>Preconsolidation Pressure Pc</u>

Preconsolidation pressure Pc is distributing with depth as shown in Figure 2.1.49.

Possible consolidation settlement layers are Layer 1b, 2, 3b and 5 at Sand Protection Dyke Area. These clay layers are that they are slightly over consolidated. Even uppermost Layer 2 is also over-consolidated as shown in Figure 2.1.49.

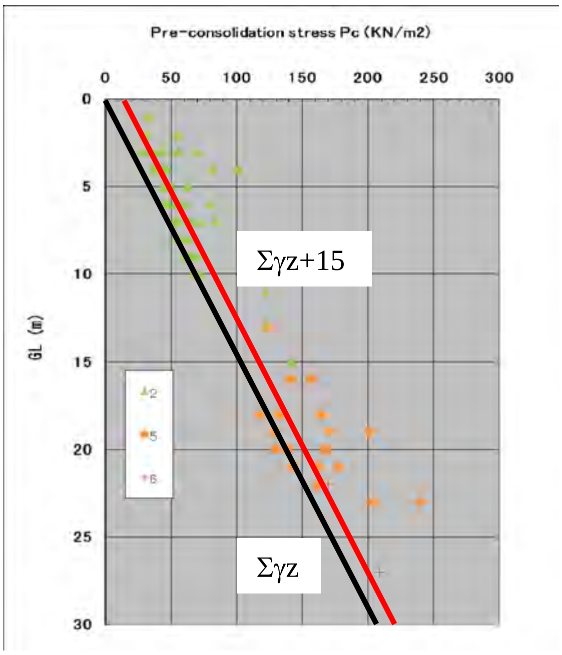



**Figure 2.1.49 Preconsolidation Pressure (Pc) with Depth**

According to Figure 2.1.49, preconsolidation pressure for each layer can be described as follows;

- Layer 2, Layer 5, Layer 6: $Pc = \Sigma\gamma z + 15$ kN/m$^2$

However even though above soil layers are slightly over-consolidated, finally construction load in future about 20 to 40 kN/m$^2$ will be working on them beyond the average Pc lines. Accordingly some extent of consolidation settlement due to above layers will be anticipated.

<u>Compression Index Cc and Recompression Index Cr</u>

Compression Index Cc and Recompression Index Cr are distributed with depth as shown in Figure 2.1.50.

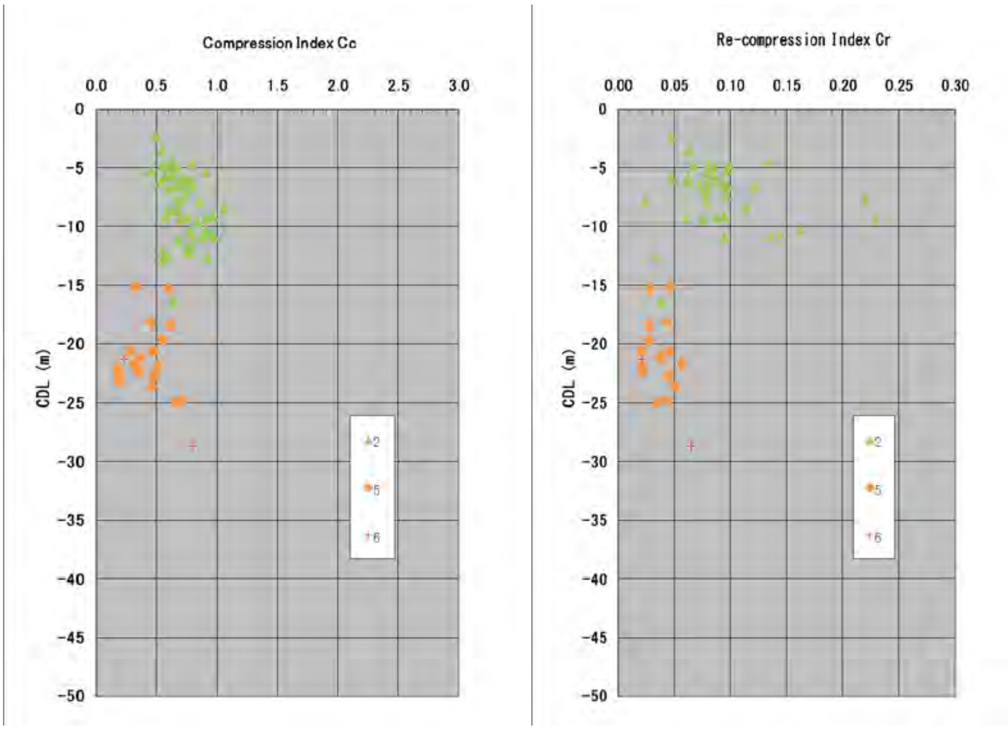



**Figure 2.1.50 Cc and Cr with Depth**

According to consolidation test results, Compression Index Cc and Re-compression Index Cr are obtained as shown in Figure 2.1.51. Average values of Cc and Cr for each layer at Sand Protection Dyke Area are described as follows;

- Layer 2 : Cc = 0.70, Cr = 0.09
- Layer 5 : Cc = 0.45, Cr = 0.04
- Layer 6 : Cc = 0.50, Cr = 0.04

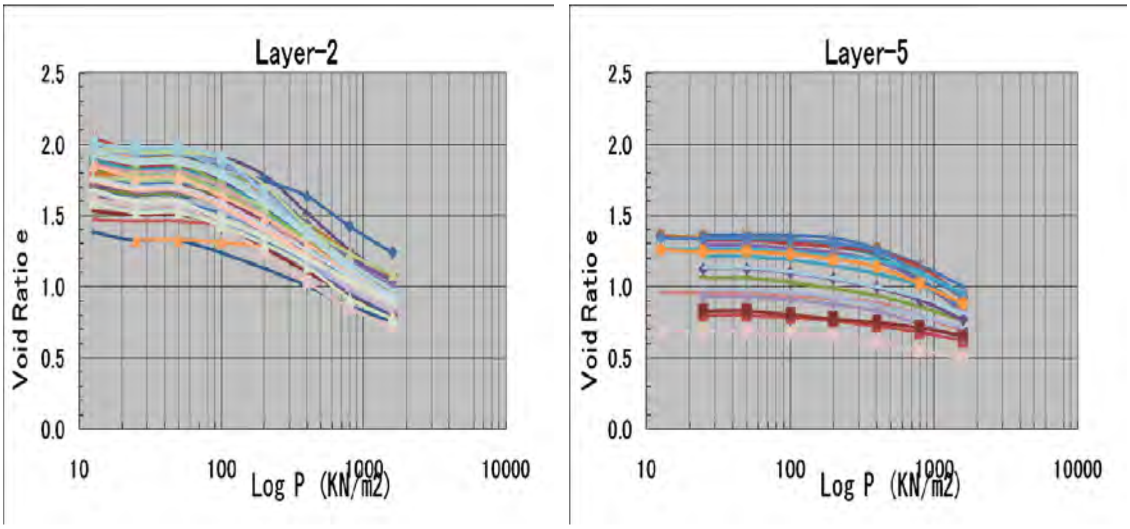



**Figure 2.1.51 e-Log P Curves for Layer 2 and Layer 5**

Coefficient of Consolidation Cv

Coefficient of consolidation Cv is one of the important consolidation factors which show the speed of consolidation settlement. In Figure 2.1.52, Cv (OC) and Cv (NC) are plotted with depth. (Cv (OC): Average value of Cv in over consolidation range, Cv (NC): Average value of Cv in normal consolidation range.)

Average Cv (NC) and average Cv (OC) for each layer is as follows;

- Layer 2 : Cv(NC)=0.60 x $10^{-3}$cm/sec=52cm$^2$/day, Cv(OC)= 1.0 x $10^{-3}$cm/sec=86cm$^2$/day
- Layer3b: Cv(NC)=1.20 x $10^{-3}$cm/sec=104cm$^2$/day, Cv(OC)= 1.2 x $10^{-3}$cm/sec=104cm$^2$/day
- Layer 4 : Cv(NC)=0.2 x $10^{-3}$cm/sec=17cm$^2$/day, Cv(OC)= 0.3 x $10^{-3}$cm/sec=26cm$^2$/day
- Layer 5 : Cv(NC)=0.15 x $10^{-3}$cm/sec=13cm$^2$/day, Cv(OC)= 0.3 x $10^{-3}$cm/sec=26cm$^2$/day

Above average values are selected based on Cv-Log P lines for each layer.

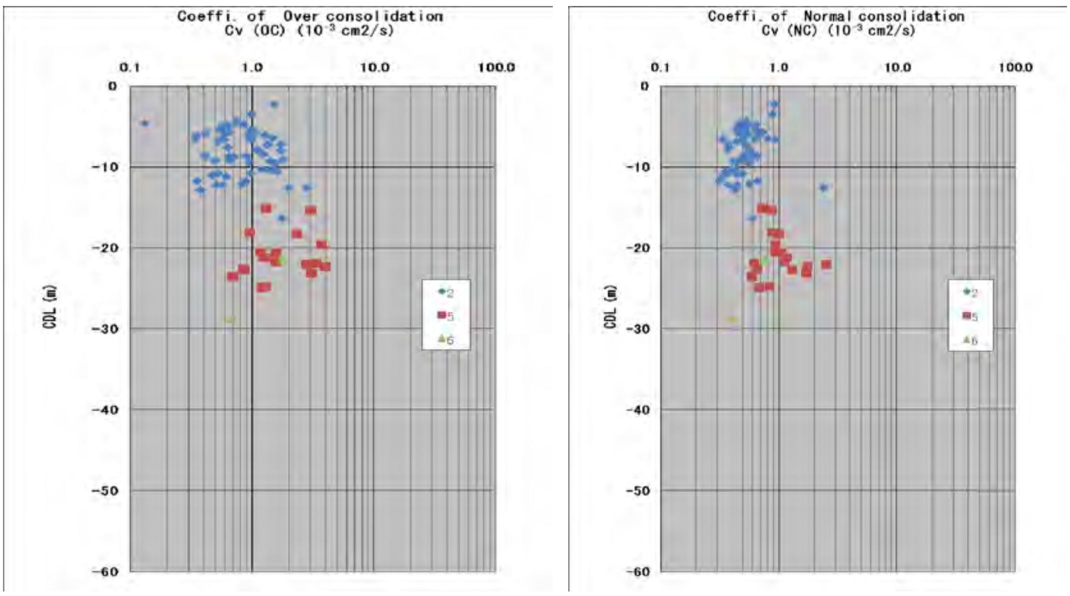



**Figure 2.1.52 Cv (OC) and Cv (NC) with Depth**

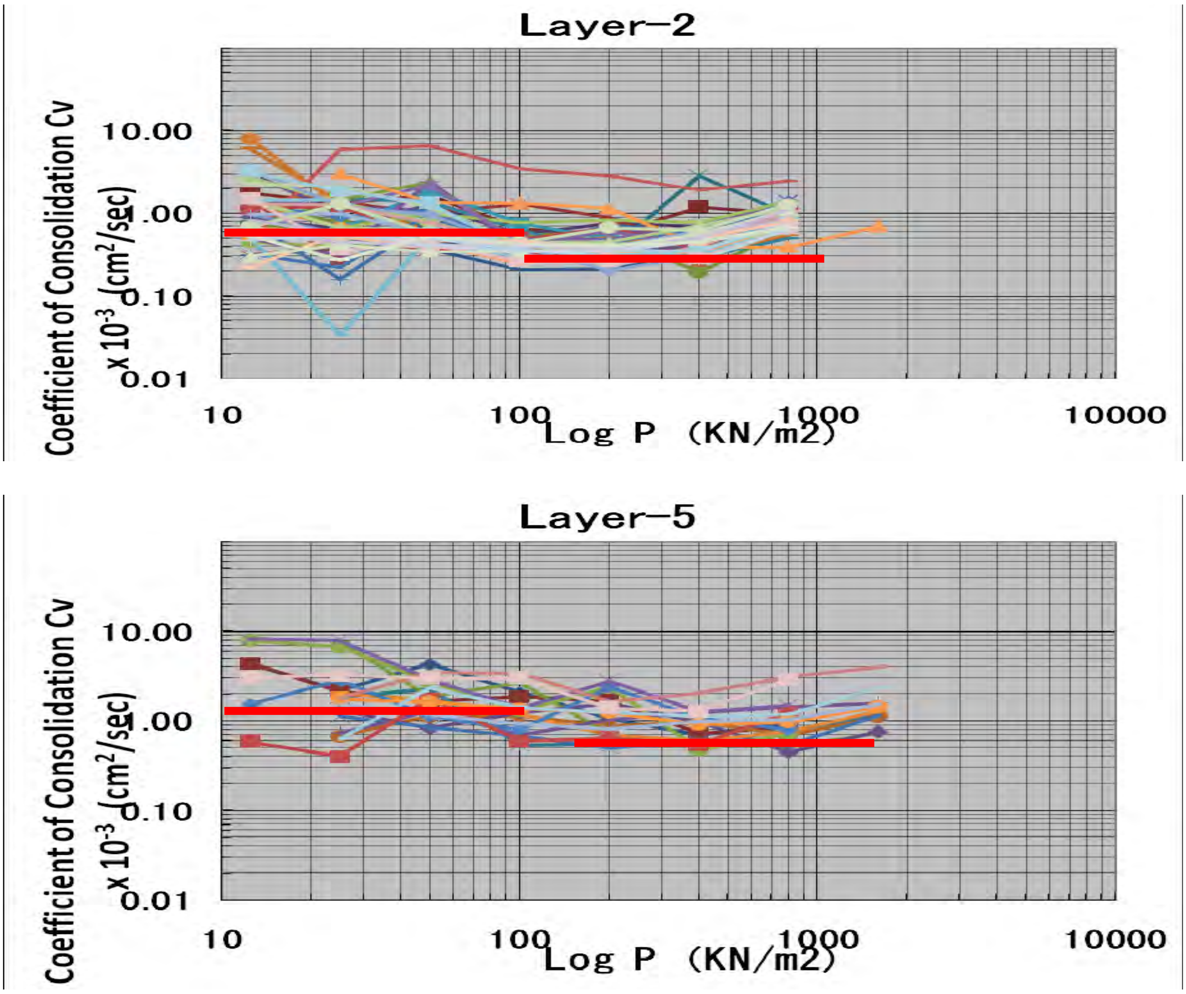



**Figure 2.1.53 Log Cv – Log P Curves for Layer 2 and Layer 5**

<u>Rate of Secondary Compression Cα (= Δe/Δlog t)</u>

In this study and existing investigation results, there has not been carried out any special consolidation tests for the evaluation of Secondary Compression Index Cα.

Therefore the following formula is applied for the evaluation of Cα;

$$C\alpha(NC)/ Cc = 0.04 \pm 0.01 \text{ (after Ladd et al, 2003)}$$

$$\text{Adopted here, } C\alpha(NC)/ Cc = 0.03$$

Rate of Secondary Compression Cα ( $C\alpha\varepsilon = C\alpha/(1+e_0)$ ) obtained from average Cc for each layer and above formula is as follows;

- Layer2 : Cα(NC) =0.03xCc=0.03x0.70= 0.021, $C\alpha\varepsilon = C\alpha/(1+e_0) = 0.021/(1+1.80) = 0.008$
- Layer5: Cα(NC) =0.03xCc=0.03x0.45= 0.014, $C\alpha\varepsilon = C\alpha/(1+e_0) = 0.014/(1+1.20) = 0.006$
- Layer6: Cα(NC) =0.03xCc=0.03x0.60= 0.018, $C\alpha\varepsilon = C\alpha/(1+e_0) = 0.018/(1+1.20) = 0.008$

**3) Soil parameters for each layer at Sand Protection Dyke Area**

Soil parameters for design purpose, those values are recommended and tabulated based on average values of soil property test results at Sand Protection Dyke Area as shown in Table 2.1.24.

**Table 2.1.24 Soil Parameters recommended for Sand Protection Dyke Area**

| Layer No. | Typical Soil Type | SPT-N | γ (kN/m³) | γ' (kN/m³) | Cu (kN/m²) | ϕ (°) | Cc | Cr | Pc (kN/m²) | e0 | Cv (OC) x 10⁻³ (cm²/s) | Cv (NC) x 10⁻³ (cm²/s) | Cu/P for NC |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1a | SP-SM | 5 | 18.0 | 8.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 1b | SM/SC-SM | 5 | 18.0 | 8.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 2 | CH | 1 | 15.5 | 5.5 | 13 | 0.0 | 0.70 | 0.09 | γ'z + 15 | 1.80 | 1.00 | 0.40 | 0.20 |
| 3b | SM/SC-SM | 8 | 19.0 | 9.0 | 0 | 25.0 | - | - | - | - | - | - | - |
| 4 | CL | 11 | 19.0 | 9.0 | 75 | 0.0 | 0.25 | 0.05 | γ'z + 15 | 1.20 | 2.00 | 1.00 | 0.20 |
| 5 | CL | 6 | 17.5 | 7.5 | 30 | 0.0 | 0.45 | 0.04 | - | - | - | - | - |
| 6 | CL | 13 | 17.5 | 7.5 | 85 | 0.0 | 0.50 | 0.04 | γ'z + 15 | 1.20 | 1.20 | 0.60 | 0.20 |
| 7 | SC/SC-SM | 16 | 19.0 | 9.0 | 100 | 0.0 | - | - | - | - | - | - | - |
| 8b | SP-SM | 23 | 18.0 | 8.0 | 0 | 30.0 | - | - | - | - | - | - | - |
| 8c | SM/SC-SM | 48 | 19.0 | 9.0 | 0 | 30.0 | - | - | - | - | - | - | - |
| Fill,Emb. | S | - | 18.0 | 10.0 | 0 | 30.0 | - | - | - | - | - | - | - |

*NC: Normal conslidated State, OC: Over consolidated State        * z : Depth (m)

## 2.1.9 Sub soil investigation result along the Navigation Channel

### 1) Boring Result

Totally 72 boreholes have been drilled and investigated along Navigation Channel and at Turning Basin Area. Soil stratification identified in this Area is tabulated as shown in Table 2.1.25.

**Table 2.1.25 Soil Stratification identified at Reclamation Area**

| Layer Name | | Color | Average N-Value |
|---|---|---|---|
| 1b | Silty/ Clayey Sand (SC/SM) | Dark grey | 5.3 |
| 2 | Fat clay with sand (CH) | Grey, brownish and yellowish grey | 0.5 |
| 3b | Silty/ Clayey Sand (SC/SM) | Yellowish grey, grey | 12.9 |
| 4a | Lean clay (CL) | Bluish and Yellowish Grey | 5.5 |
| 4 | Lean clay (CL) | Reddish brown, Yellowish brown | 12.2 |

[yellow]: Sand Layer, [light blue]: Clay Layer

Representative soil profiles with SPT-N values based on this Study result are shown in Figure 2.1.56.

SPT –N value distributions with depth along the Navigation Channel and Turning Basin are shown in Figure 2.1.54. Average SPT N-value for each layer is as follows;

Layer 1b: N = 5.3
Layer 2: N = 0.5
LC2: N=5.8
LS2: N=6.3
Layer 3b : N =12.9
Layer 4a : N = 5.5
Layer 4 : N = 12.2
LS4: N=16.9

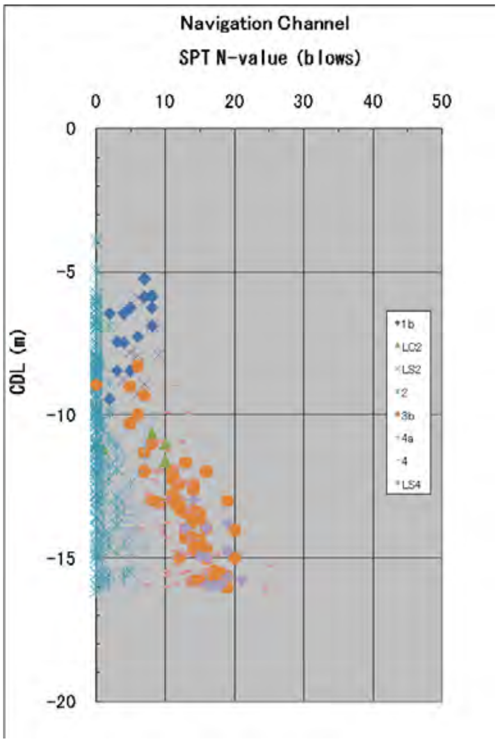



**Figure 2.1.54 SPT N-value Distribution with Depth**

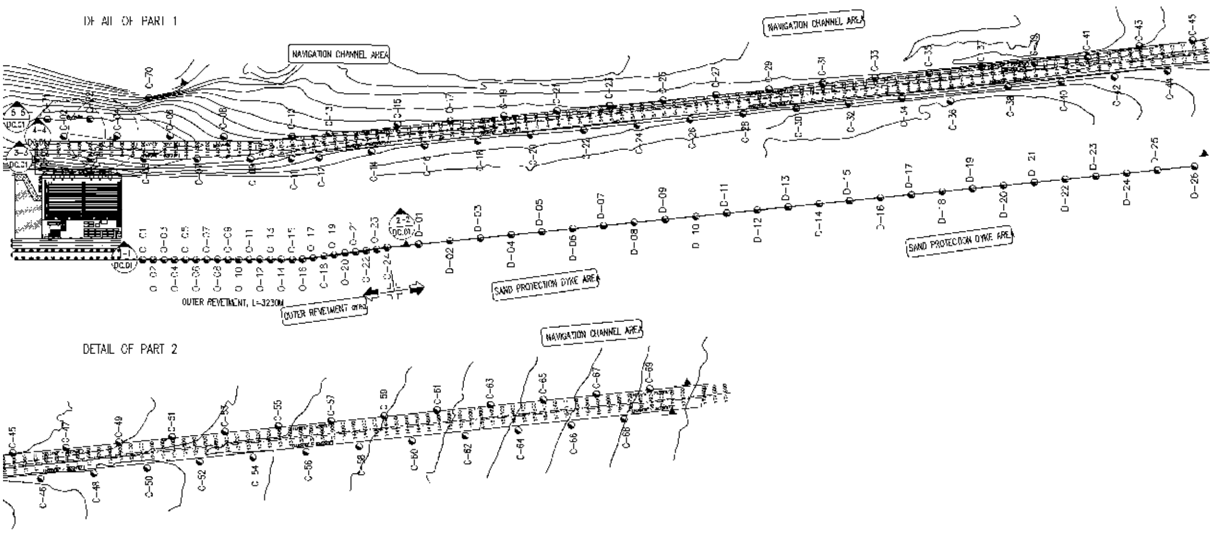



**Figure 2.1.55 Boring Location Map along Navigation Channel and at Turning Basin (C-series)**

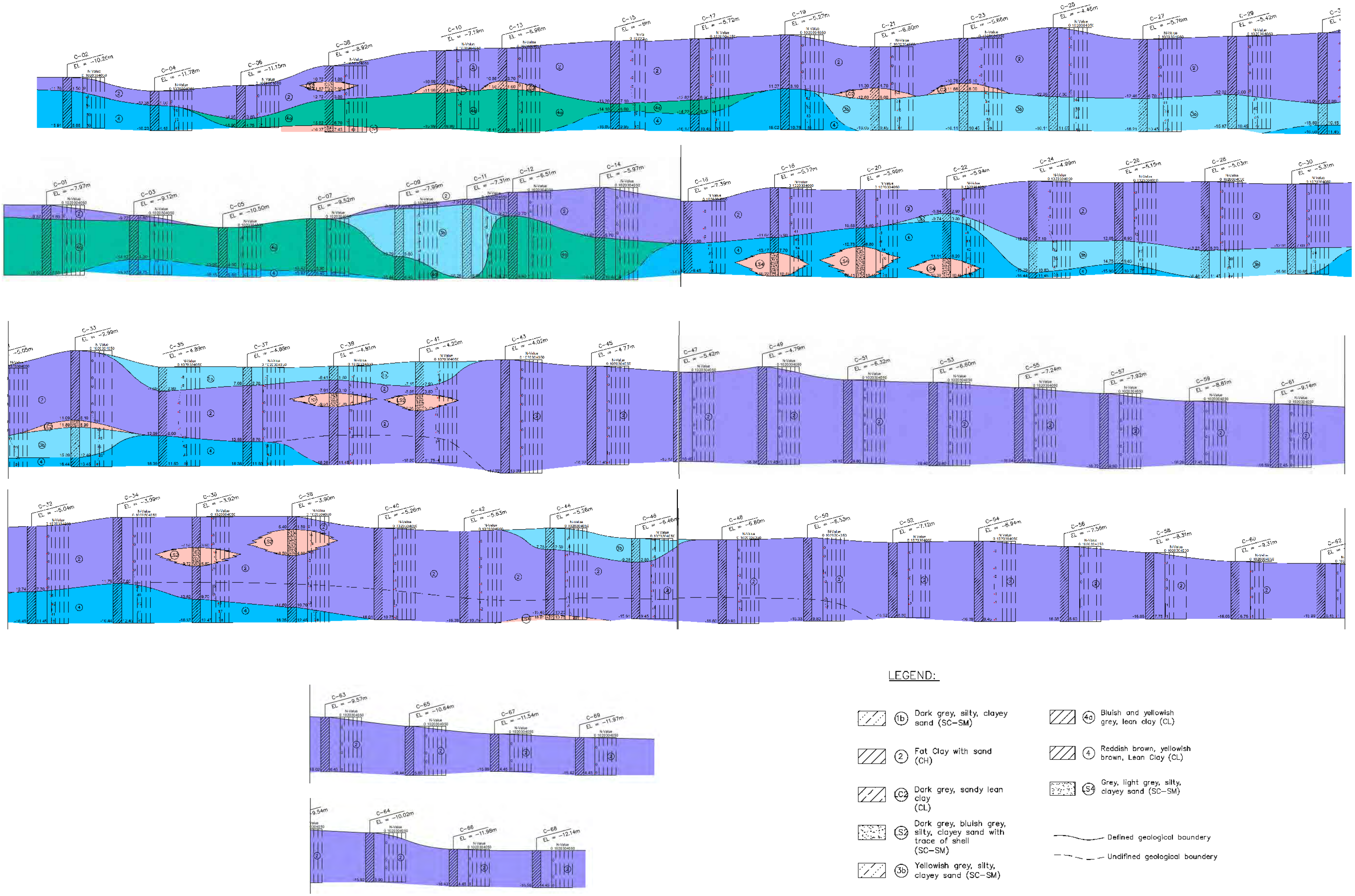



Figure 2.1.56 Soil Profile along the Navigation Channel

## 2) Soil Properties

Laboratory test results including existing results are shown as a relationship between depth and each value in Appendix 2.1.

Soil properties obtained from subsoil investigation surveys along the Navigation Channel and Turning Basin Area which have been carried out this time are tabulated in Table 2.1.26.

**Table 2.1.26 Soil Properties of each Layer at Sand Protection Dyke Area**

| Layer | Soil Type | SPT N_Value (blows) | Fine content Fc (%) | Natural moisture content w (%) | Atterberg Limits: Liquid limit $W_L$(%) | Atterberg Limits: Plastic limit Wp(%) | Atterberg Limits: Plasticity index Ip (%) | Bulk density ($KN/m^3$): Natural | Bulk density ($KN/m^3$): Dry | Specific Gravity | Void ratio eo | Unconfined compression test: $q_u$ ($KN/m^2$) A | Unconfined compression test: $q_u$ ($KN/m^2$) B | Unconfined compression test: Failure Strain εf (%) A | Unconfined compression test: Failure Strain εf (%) B |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1b | SC-SM | 5.3 | 31.5 | | | | | | | 2.68 | | | | | |
| 2 | CH | 0.5 | 94.2 | 64.92 | 61.64 | 29.28 | 32.37 | 15.82 | 9.63 | 2.69 | 1.77 | 13.06 | 13.31 | 12.39 | 12.16 |
| LC2 | CL | 5.8 | 68.7 | | 32.59 | 18.96 | 13.63 | | | 2.71 | | | | | |
| LS2 | SC-SM | 6.3 | 26.1 | 32.98 | | | | 18.06 | 13.58 | 2.68 | 0.945 | 8.94 | 9.07 | 14.85 | 10.93 |
| 3b | SC/SC-SM | 12.9 | 37.5 | | 23.26 | 15.10 | 8.16 | | | 2.69 | | | | | |
| 4a | CL | 5.5 | 90.1 | 38.46 | 41.29 | 20.84 | 20.45 | 17.94 | 13.00 | 2.71 | 1.060 | 38.53 | 39.72 | 12.50 | 12.30 |
| 4 | CL | 12.2 | 85.4 | 35.50 | 39.95 | 20.89 | 19.06 | 18.15 | 13.39 | 2.71 | 0.983 | 51.55 | 57.00 | 11.98 | 15.00 |
| LS4 | SC-SM | 16.9 | 32.5 | | | | | | | 2.68 | | | | | |

Characteristics of soil properties of soil layers are described as follows;

### a) Physical properties

i) Specific Gravity of Soil Gs (Refer to Figure 2.1.58)

Specific gravity of soil shows 2.7 in average through all soil layers at Reclamation area and ranging between 2.68 and 2.71. This value shows that all soil layers at Sand Protection Dyke Area are composed of inorganic soils.

ii) Fine Content Fc (Weight percentage passing 74μm Sieve) (Refer to Figure 2.1.58)

Fine content is one of the indices obtained from sieve analysis test. When it is more than 50%, we classify the soil as fine soil like silt or clay.

According to sieve analysis test result, Layer 2, LC2, 4a and 4 can be classified as fine soil, however Layer 1b, LS2, 3b and LS4 are classified as coarse soil which has about 25% to 35% of fine content.

Fine content with depth for every 1km interval are shown in Figure 2.1.57.

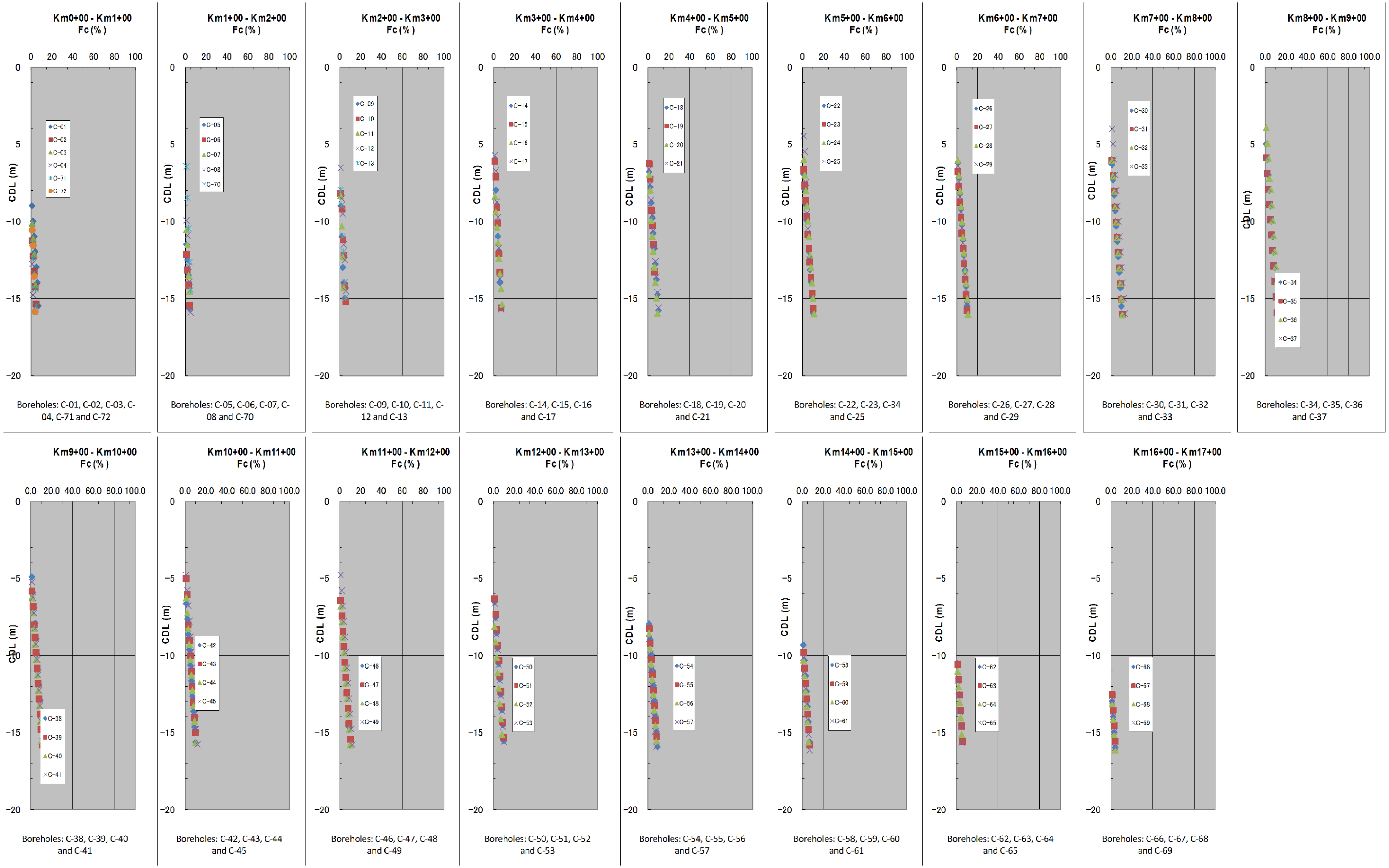



**Figure 2.1.57 Fine content with depth in every 1km interval**

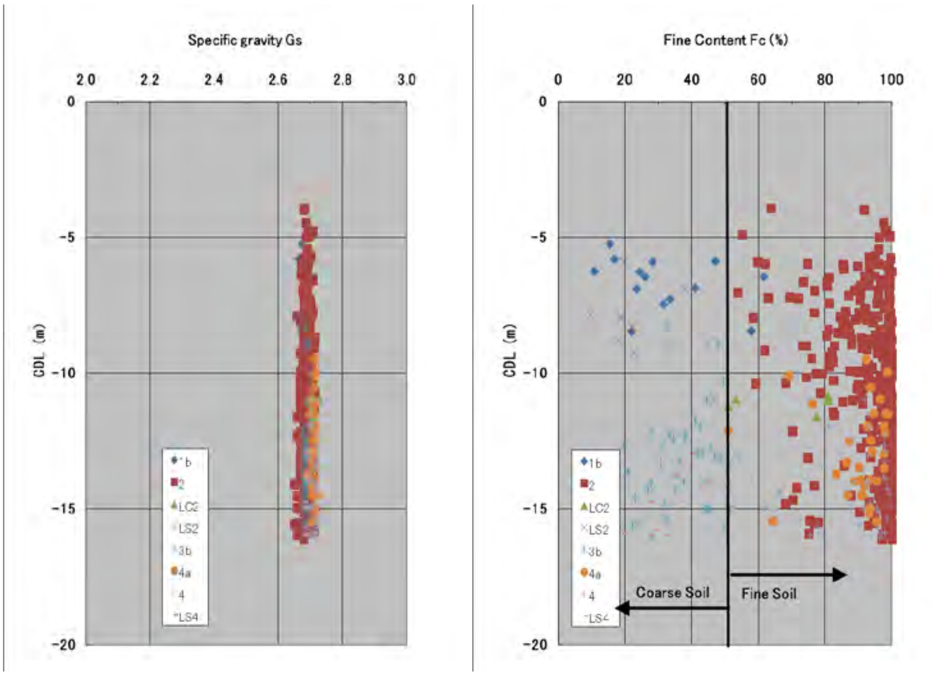



**Figure 2.1.58 Specific Gravity and Fine Content with Depth**

iii) Natural Water Content and Atterberg's Limits (Refer to Figure 2.1.59)

Average natural water content of fine soil layers such as Layer 2, LC2, Layer 4a and Layer 4 along the Navigation Channel and Turning Basin Area are 65%, 69%, 90% and 85% respectively.

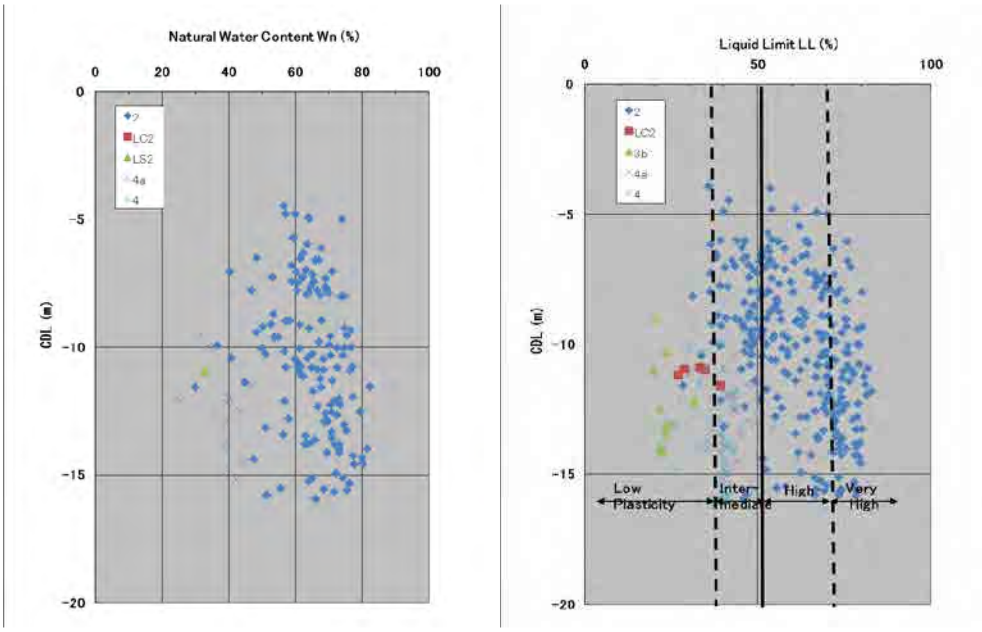



**Figure 2.1.59 Natural Water Content and Liquid Limit with Depth**

According to liquid limit test result as shown in the right side of Figure 2.1.59, liquid limits of fine soil layers, Layer 2, LC2, Layer 4a and Layer 4 are 62%, 33%, 23%, 41% and 40% in average, only Layer 2 shows high plasticity in average.

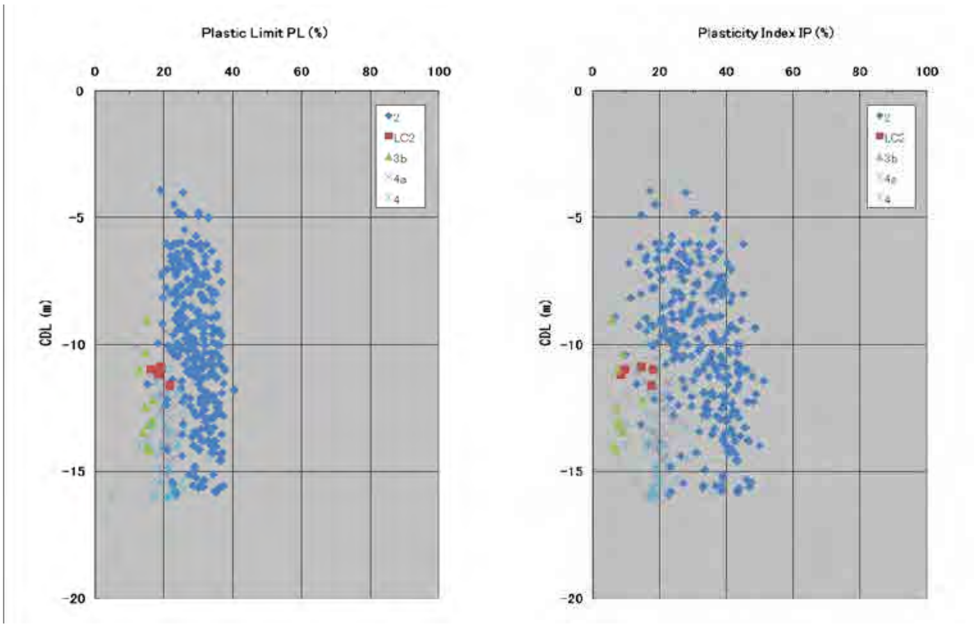



**Figure 2.1.60 Plastic Limit and Plasticity Index**

iv) Bulk Density (Unit Weight) and Void Ratio (Refer to Figure 2.1.61)

As shown in Figure 2.1.61, average value of bulk density and void ratio for each layer are as shown in Table 2.1.27.

**Table 2.1.27 Bulk Density and Void Ratio**

| Layer Name | Bulk Density γ (kN/m$^3$) | Void Ratio $e_0$ |
|---|---|---|
| Layer 2 | 15.8 | 1.77 |
| LS2 | 18.1 | 0.95 |
| Layer 4a | 17.9 | 1.06 |
| Layer 4 | 18.2 | 0.98 |

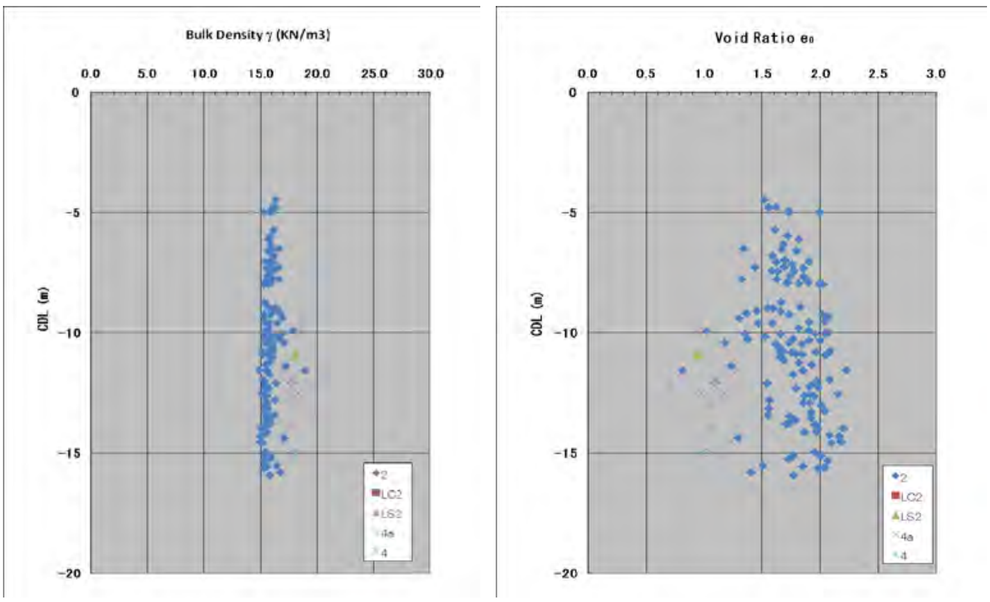



**Figure 2.1.61 Bulk Density and Initial Void Ratio with Depth**

**b) Mechanical Properties of Cohesive Soil**

i) Shear Strength of Cohesive Soil

Unconfined compression test and tri-axial test have been carried out in this survey to identify the undrained shear strength under the ground.

Unconfined compression strength and that failure strain are shown in Figure 2.1.62. Average unconfined compression strength of each layer at Reclamation Area is as follows;

- Layer 2: qu = 13kN/m$^2$, LS2: qu = 9kN/m$^2$,
- Layer 4a: qu = 39kN/m$^2$, Layer 4: qu = 54kN/m$^2$

As shown in Figure 2.1.62, most of failure strains (strain at peak strength of unconfined compression test) of samples in Layer 2 show more than 7%. It means that most of these samples are disturbed during sampling, transportation and testing process. Therefore strength of these samples might be showing the smaller ones than actual in-situ strength. Therefore the above average unconfined compression strength (qu) can be estimated to give a smaller values than completely undisturbed one.

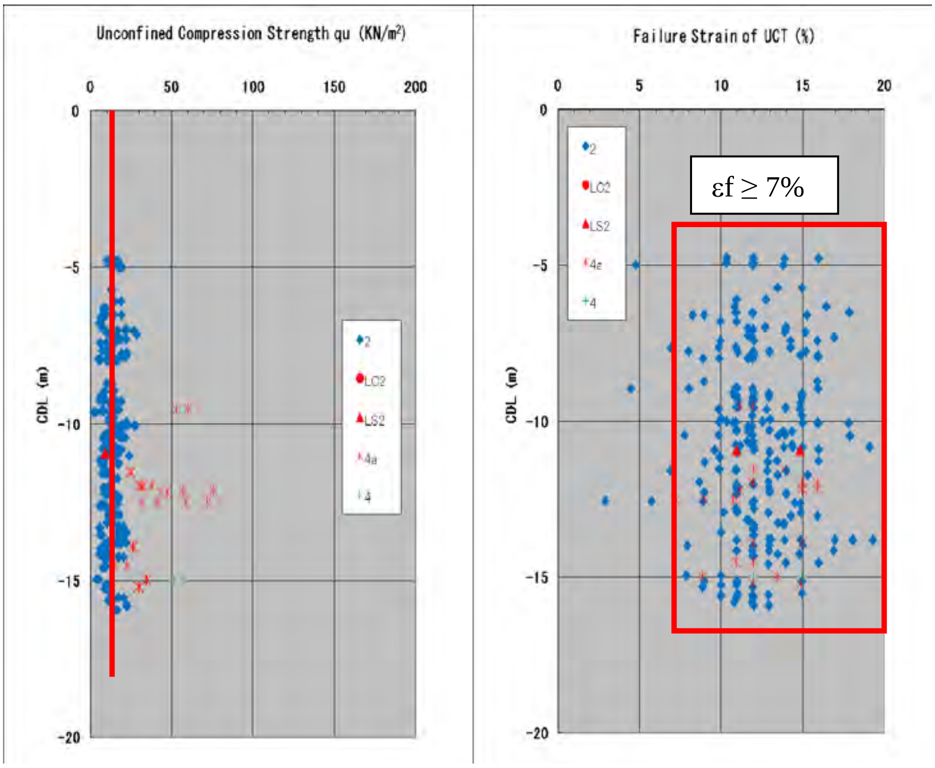



**Figure 2.1.62 Unconfined Compression Strength and Failure Strain with Depth**

Unconfined compression strength with depth for every 1km interval is shown in Figure 2.1.63.

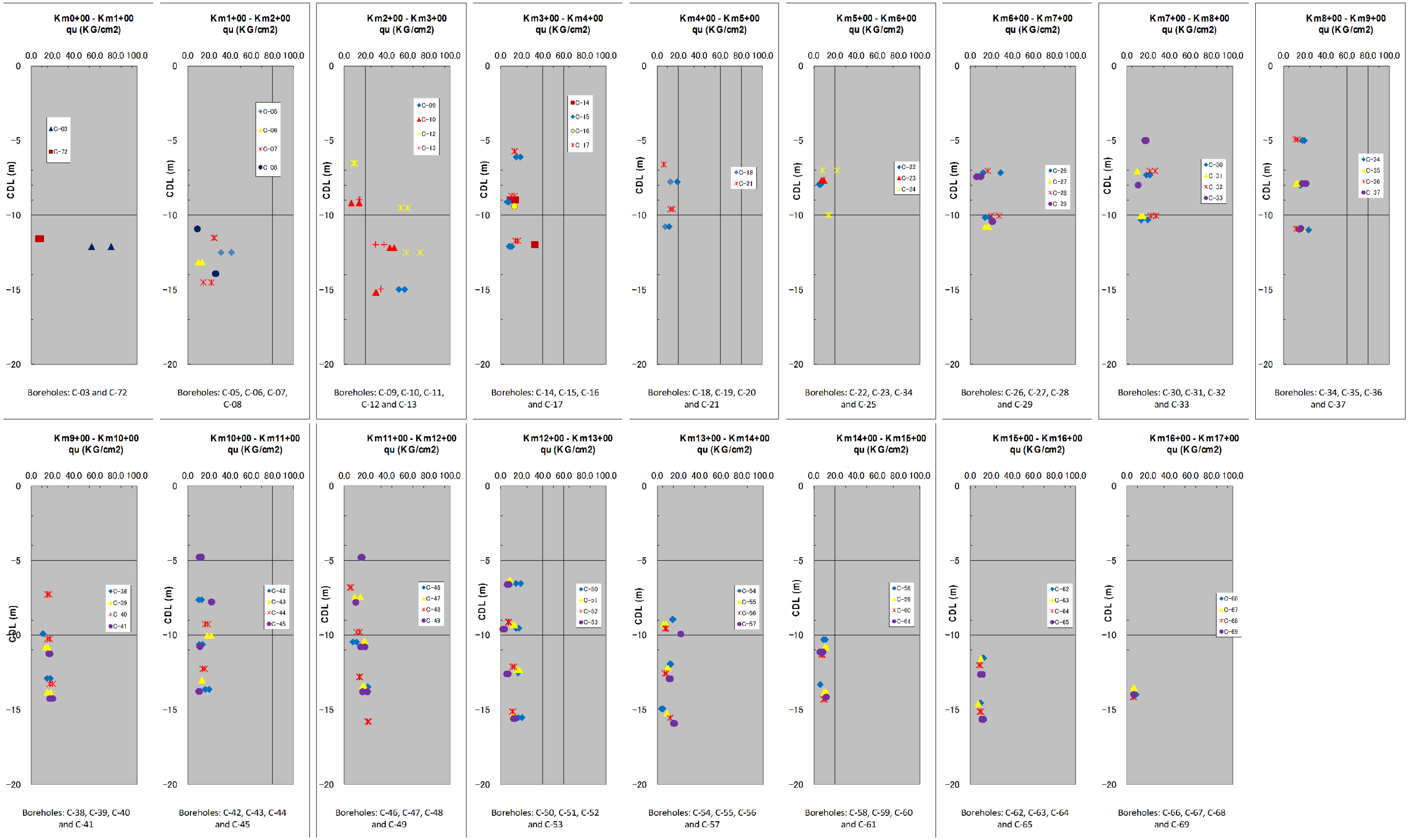



**Figure 2.1.63 Unconfined compression strength with depth in every 1km interval**

### 3) Soil parameters for each layer at Navigation Channel and Turning Basin Area

Soil parameters for design purpose, those values are recommended and tabulated based on average values of soil property test results along the Navigation Channel and Turning Basin Area as shown in Table 2.1.28.

**Table 2.1.28 Soil Parameters recommended for Navigation Channel and Turning Basin Area**

| Layer No. | Typical Soil Type | SPT-N | $\gamma$ (kN/m$^3$) | $\gamma'$ (kN/m$^3$) | Cu (kN/m$^2$) | $\phi$ (°) |
|---|---|---|---|---|---|---|
| 1b | SC-SM | 5 | 18.0 | 8.0 | 0 | 25.0 |
| 2 | CH | 1 | 16.0 | 6.0 | 7 | 0.0 |
| LC2 | CL | 6 | 18.0 | 8.0 | 40 | 0.0 |
| LS2 | SC-SM | 6 | 18.0 | 8.0 | 0 | 25.0 |
| 3b | SC/SC-SM | 13 | 19.0 | 9.0 | 0 | 30.0 |
| 4a | CL | 6 | 18.0 | 8.0 | 40 | 0.0 |
| 4 | CL | 12 | 18.0 | 8.0 | 80 | 0.0 |
| LS4 | SC-SM | 17 | 18.0 | 8.0 | 0 | 30.0 |
| Fill,Emb. | S | - | 18.0 | 10.0 | 0 | 30.0 |

*NC: Normal conslidated State, OC: Over consolidated State

## 2.2 Topographic / Bathymetric Survey

The objectives of the topographic and bathymetric surveys are to confirm the topographic and hydrographical changes of the area, and to create drawings with the Universal Transverse Mercator (UTM) coordinate system and appropriate elevation for the detailed design study of the Lach Huyen Port Infrastructure Construction Project. The survey had been done from 15 April to 13 May 2011 in/around the Lach Huyen Port Infrastructure Construction Project sites in Vietnam.

The bathymetric survey along the navigational channel had been carried out with two kinds of echo frequencies, i.e. high frequency of 200 kHz and low frequency of 30 kHz, in order to identify the thickness of the low density subsoil layer on the seabed.

The topographic and bathymetric surveys have been done in compliance with the following: 1) technical standards on establishing horizontal and vertical control networks issued by the Vietnam National Land Administration Department (VNLAD); 2) technical standards on topographic surveying with scales of 1/500, 1/1000, 1/2000, 1/5000 (96TCN43-90) issued by VNLAD; 3) technical standards on GPS measurement and processing for surveying in construction (TCXDVN 364: 2006) issued by the Ministry of Construction; and 4) technical standards on hydrographic surveying issued by the National Hydro Meteorological Department.

The third order of horizontal control points in the VN2000 coordinate system established by VNLAD are used for developing the fourth order network. The third order benchmark is used for the development of the fourth order vertical control network (benchmarks). Table 2.2.1 shows the original control points provided by VNLAD used for this survey.

**Table 2.2.1 Original Control Points**

| No. | Point Name | Coordinates in VN2000 | | Elevation (m) | Remark |
|---|---|---|---|---|---|
| | | X (m) | Y (m) | | |
| 1 | 118528 | 2301037.136 | 695802.579 | | Third order coordinate point |
| 2 | 118511 | 2301801.859 | 692325.001 | | Third order coordinate point |
| 3 | AKS.6 | | | 5.238 | |

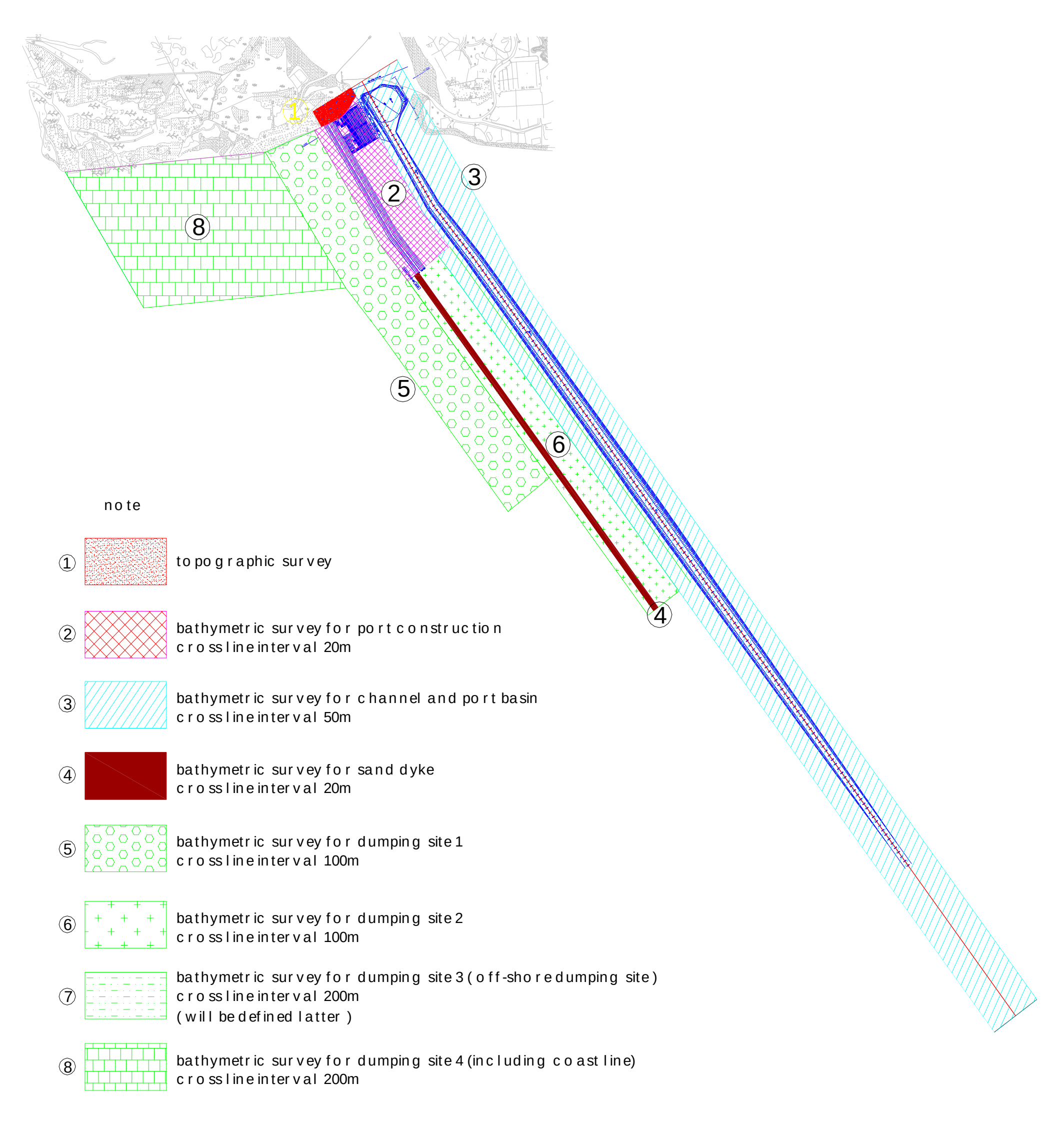
Tide observation at Ben God Ferry Terminal, which is located near Lach Huyen Strait, was done and the hourly water level observation was carried out. Consecutive harmonic analysis and comparison of data with Hon Dau National Hydrological Station have also been done for processing of bathymetric survey data and other consecutive design works.

### 2.2.1 Survey Areas

The topographic and hydrographic bathymetric surveys were done to cover the areas shown in Figure 2.2.1

The topographic survey was done for the terminal, port road and public facilities area at Cat Hai Island. The bathymetric survey of the navigational channel was done from station Km. 26+000 to station Km. 47+000 from Hai Phong Port with a width of 500 m offset from the center line of the channel to both sides. The bathymetric surveys for the terminal, port road and sand protection training dyke area were also done in the sea area. The alternative dumping sites 1 to 4 were selected for the comparative study for the selection of the dredged material dumping sites.

The survey areas and quantities of the work are shown in Table 2.2.2.




Note: The offshore dumping site is located outside this figure.

**Figure 2.2.1 Topographic and Hydrographic Bathymetric Survey Area**

**Table 2.2.2 Survey area and survey quantity**

| Survey Area | Survey Volume | Remarks |
|---|---|---|
| For terminal, port road and public facilities areas at Cat Hai Island | 28.8 ha | |
| For channel and port basin | 2,150 ha; cross line interval @50 m | 200 kHz and 30 kHz |
| For terminal and port road | 320 ha; cross line interval @20 m | 200 kHz |
| For sand protection training dyke | 70 ha; cross line interval @20 m | 200 kHz |
| For dumping site 1 (logistic park) | 778 ha; cross line interval @100 m | 200 kHz |
| For dumping site 2 (inner seawater area of sand protection training dyke) | 560 ha; cross line interval @100 m | 200 kHz |
| For dumping site 3 (offshore site) | 2,500 ha; cross line interval @500 m | 200 kHz |
| For dumping site 4 (south of Cat Hai Island) | 996 ha; cross line interval @500 m | 200 kHz |

### 2.2.2 Methodology of Survey

Survey equipment that was used for surveying works is shown in Appendix 2-2. The VN2000 coordinate system with central Meridian 105° 45', zone 3° (Ko=0.9999). The detailed parameters of the coordinate system are as follows:

- Spheroid : WGS 84
- Semimajor axis : 6,378,137 m
- 1/flattening : 298.25723563
- Projection : UTM
- Central meridian (CM) : 105° 45' E
- False easting : 500 km
- False northing : 0.000
- Scale factor at CM : 0.9999

The GPS static measurement method was used for the establishment of fourth order and grade 2 traverse networks. The network was measured in three sessions by using four sets of Trimble R3 equipment. The network was connected to two third order national control points, i.e. 118528 and 118511. The detailed procedure of establishing fourth order and grade 2 traverse networks are shown in Appendix 2-3.

The objects of the topographic map include all existing surface features such as roads, ponds, culverts, houses, electric poles and other natural objects with a map scale of 1/1000. They were measured by using total station equipment.

The water levels were observed by using a self-recording tide gauge located at Ben Got Jetty and the water levels collected at Hon Dau National Hydrological Station were used to reduce the surveyed depths into a chart datum. Water level data with recording intervals of 10 minutes were inputted for data processing. Tidal observation at Ben Got Jetty was done from 29 April to 13 May 2011 with a total duration of 30 days so that tidal harmonic analysis can be done. Figure 2.2.2 shows the observed results of sea surface elevation at Ben Got Jetty. Sea surface elevation data at Hon Dau National Hydrological Station were also indicated in this figure.

Figure 2.2.3 shows the correlation of water levels between Ben Got Jetty and Hon Dau National Hydrological Station. The correlation equation is established as follows:

(Water level at Ben Got) = 1.01 x (Water level at Hon Dau) + 10.02 (cm)

The correlation coefficient R is 0.99.

The results of harmonic analysis are shown in Appendix 2-4.

The processing of bathymetric surveyed data at Lach Huyen Channel in this project was divided into two segments: using the water levels observed at Ben Got Jetty and water level collected at Hon Dau National Hydrological Station's tide gauges. Along the Lach Huyen Channel, from Km. 26+000 to Km. 34+800, both water levels observed at Ben Got and Hon Dau were used to process the surveyed depth to a chart datum. The bathymetric surveyed data of the segment from Km. 34+800 to the end of Lach Huyen Channel (Km. 42+000) was processed based on the water levels of Hon Dau Station only. The bathymetric surveyed data for the sand dyke and dumping sites were processed based on the water levels observed at Ben Got and Hon Dau. A detailed procedure on the survey and data processing is shown in Appendix 2-5.

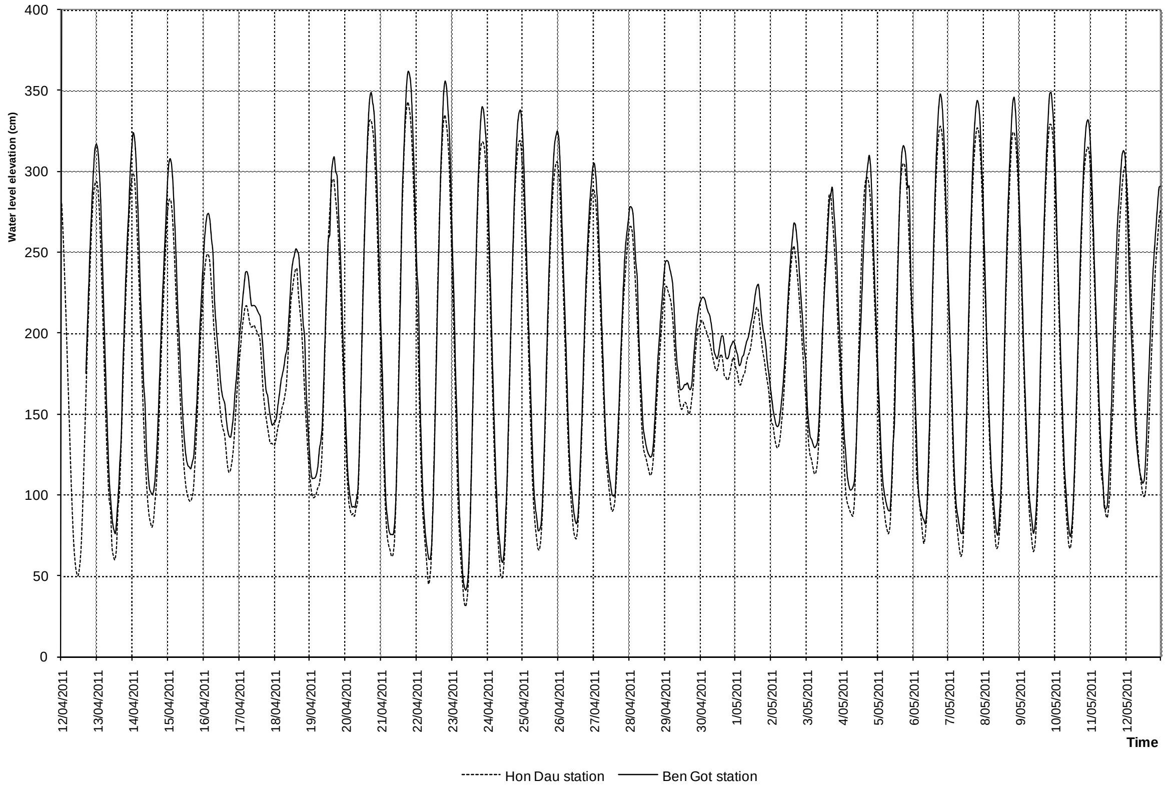



**Figure 2.2.2 Tidal Observation Results at Ben Got Jetty and Hon Dau**

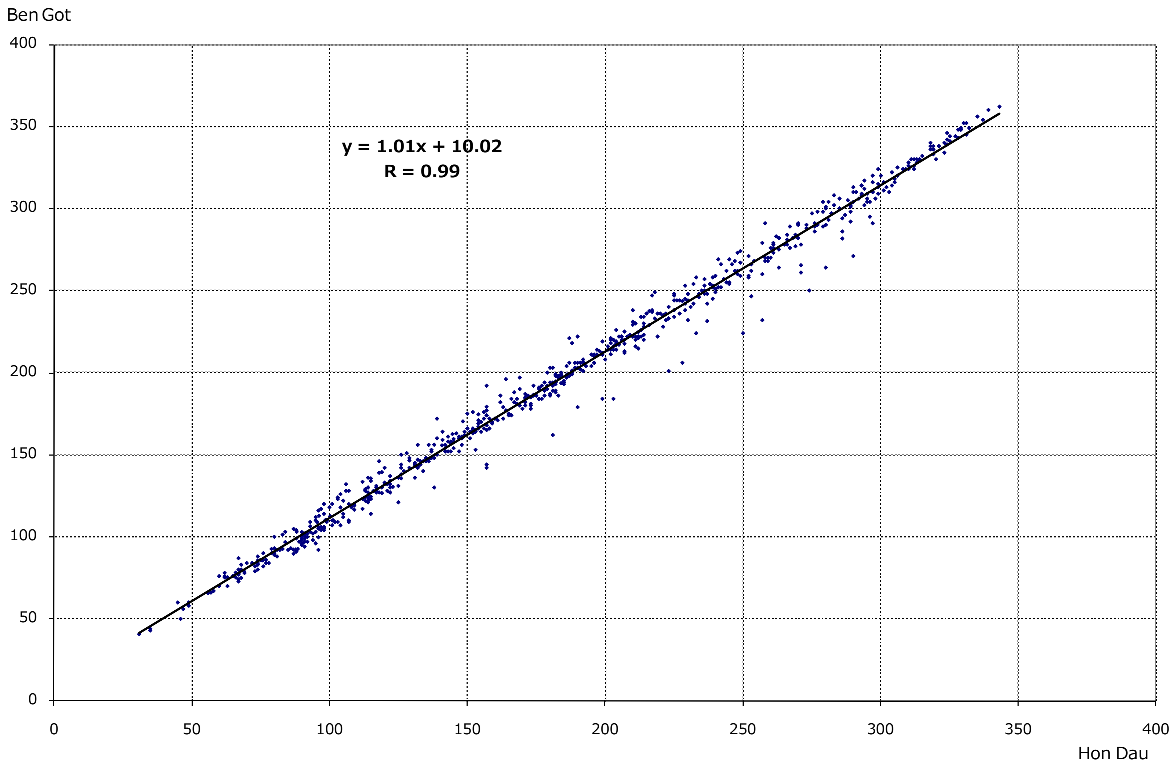



**Figure 2.2.3 Correlation between the Water Levels at Ben Got and Hon Dau**

### 2.2.3 Survey Results

Processed data of the topographic and bathymetric surveys of the terminal and port road, bathymetric survey of sand protection training dyke, bathymetric surveys of candidate dumping sites 1 (logistic park), 2 (inner area of sand protection training dyke), site 3 (off-shore dumping site), and site 4 (south of Cat Hai Island) are shown in Figure 2.2.4 to Figure 2.2.9, respectively.

Seabed contour maps for the navigational channel and turning basin by dual frequencies are shown in Figure 2.2.10. Figure 2.2.11 and Figure 2.2.12 show the comparison of the longitudinal cross sections along the navigational channel obtained by dual frequencies. Figure 2.2.13 to Figure 2.2.19 show the comparison of the cross sections of the navigational channel by dual frequencies.

As shown in Figure 2.2.10, clear dredging traces have been identified along the navigational channel, between Km. 26+000 and Km. 39+000, and were maintained for the channel at Hai Phong Port.

Characteristics of the longitudinal profile of the navigational channel are the same as before, that is to say, water depths from Km. 26+500 to Km. 28+500 show deeper values as compared with the other sections of the channel due to the rapid tidal current condition induced by the narrow strait between Cat Ba and Cat Hai Islands. A constant navigational channel water depth of around CDL -8.00 m was maintained until Km. 36+000 m. From Km. 37+000 to Km. 40+000, water depth is shallower than CDL -8.00 m. The original sea bottom slope of 1/200 appears from Km. 41+000 towards the offshore.

According to the dual frequency sounding (200k Hz and 30 kHz) survey results shown in Figure 2.2.10, low density subsoil layer with thickness between 20 cm and 50 cm can be recognized along the navigational channel, specifically, it is prominent from Km. 36+000 towards the offshore. This is consistent with the results of the previous SAPROF study.

Comparisons with previous bathymetric survey data were done in other chapters such as channel sedimentation.

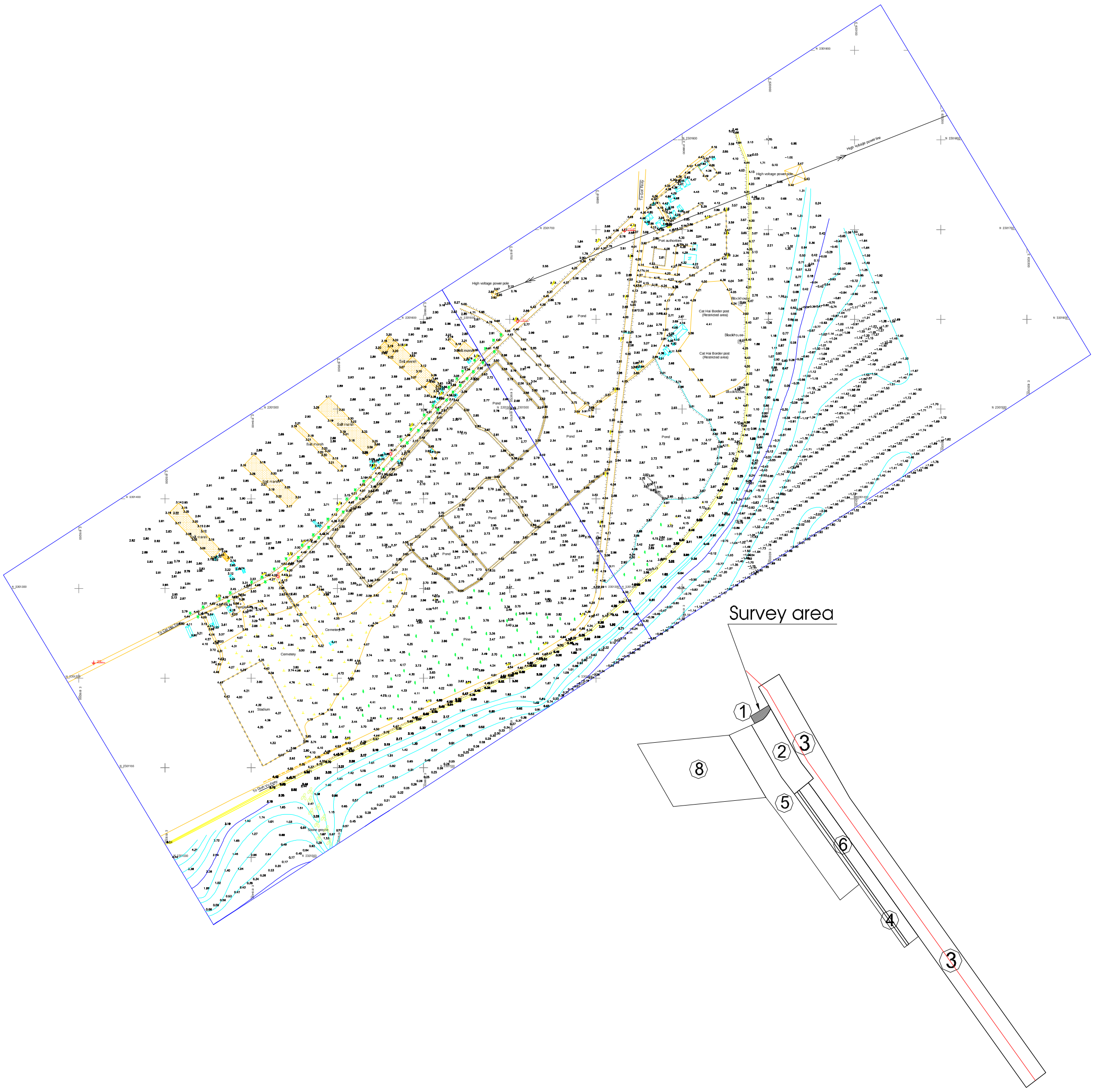



**Figure 2.2.4 Topographic Survey Results**

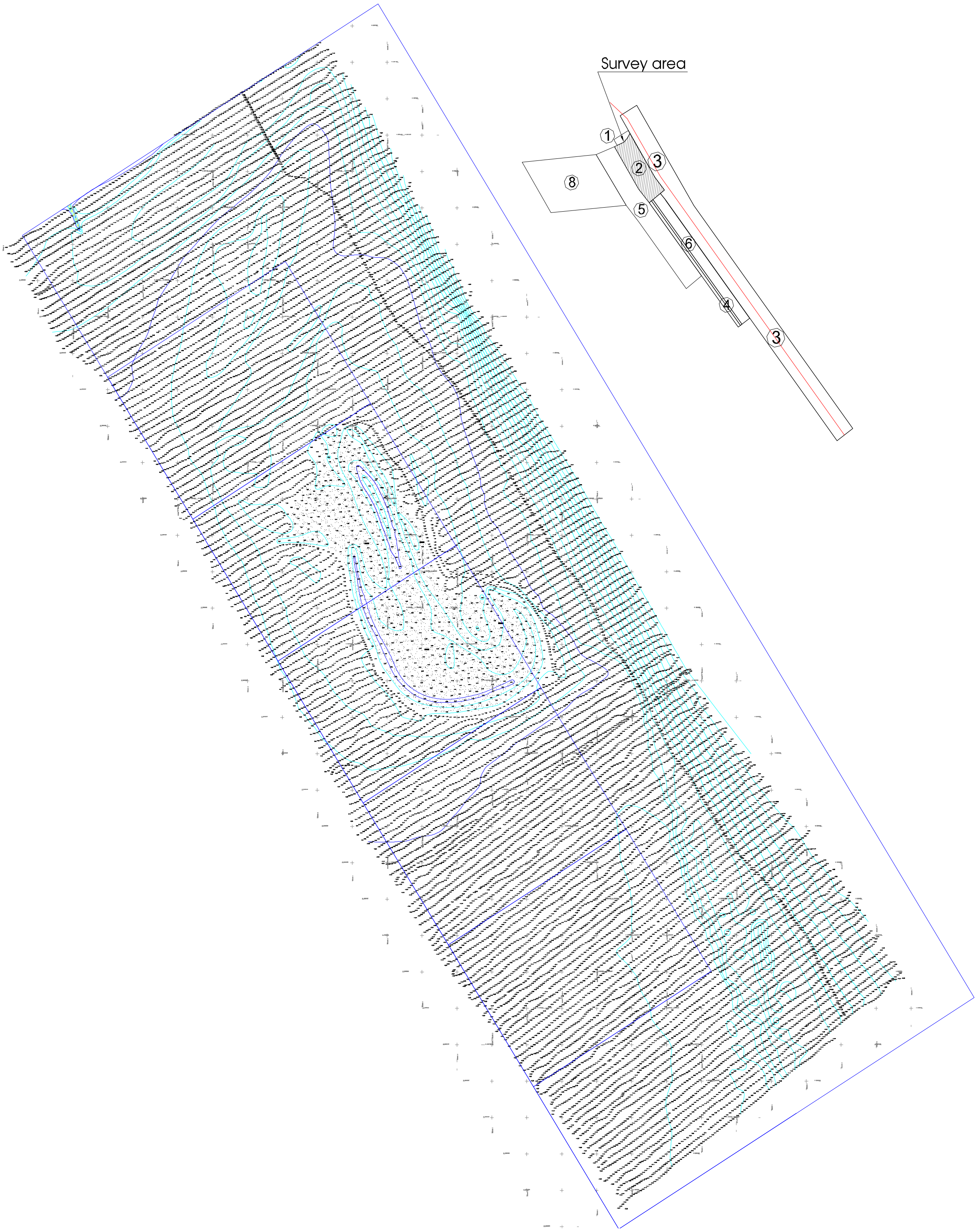



**Figure 2.2.5 Bathymetric Survey Results of the Terminal and Port Road**

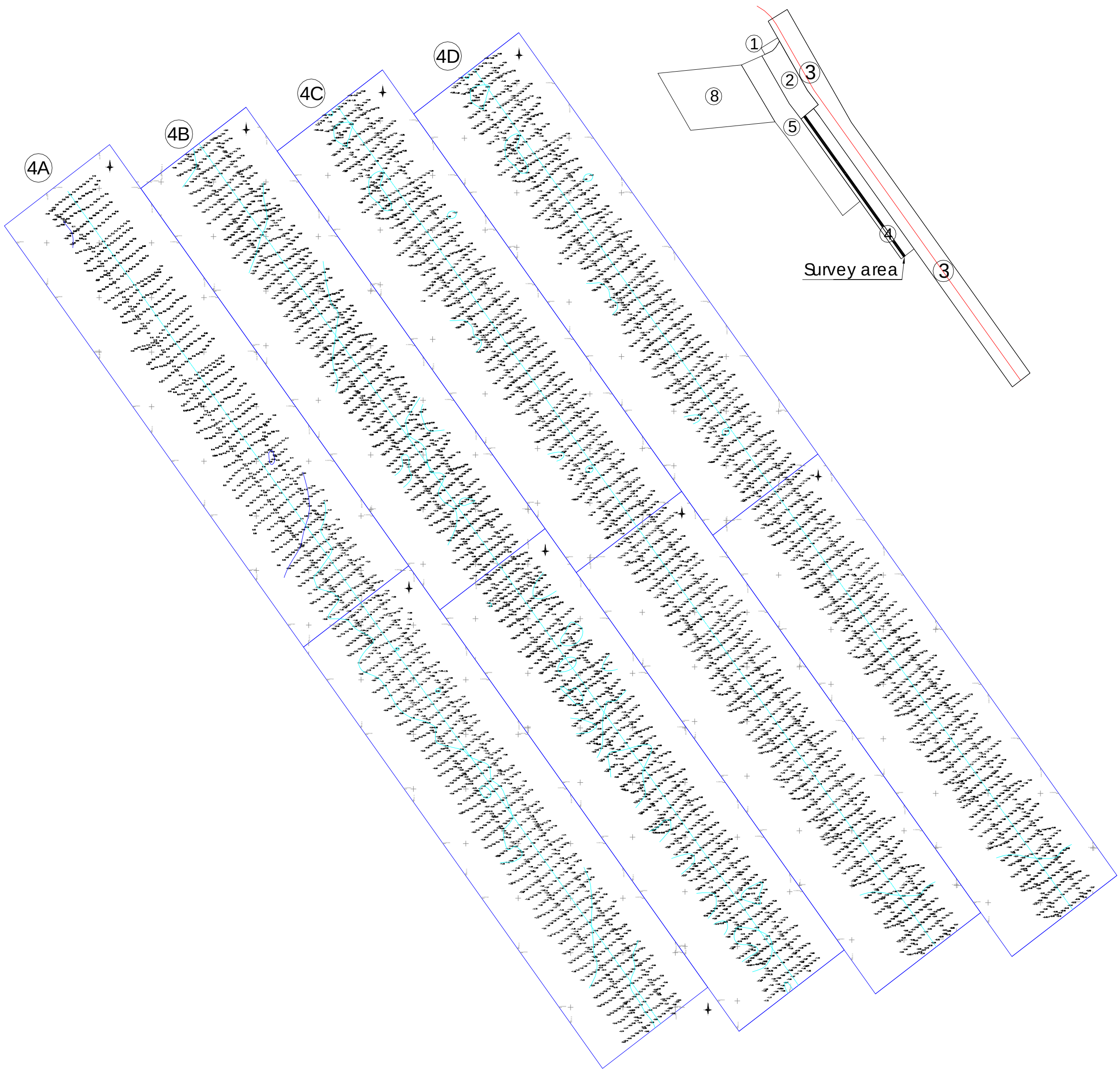



**Figure 2.2.6 Bathymetric Survey Results of the Sand Protection Training Dyke**

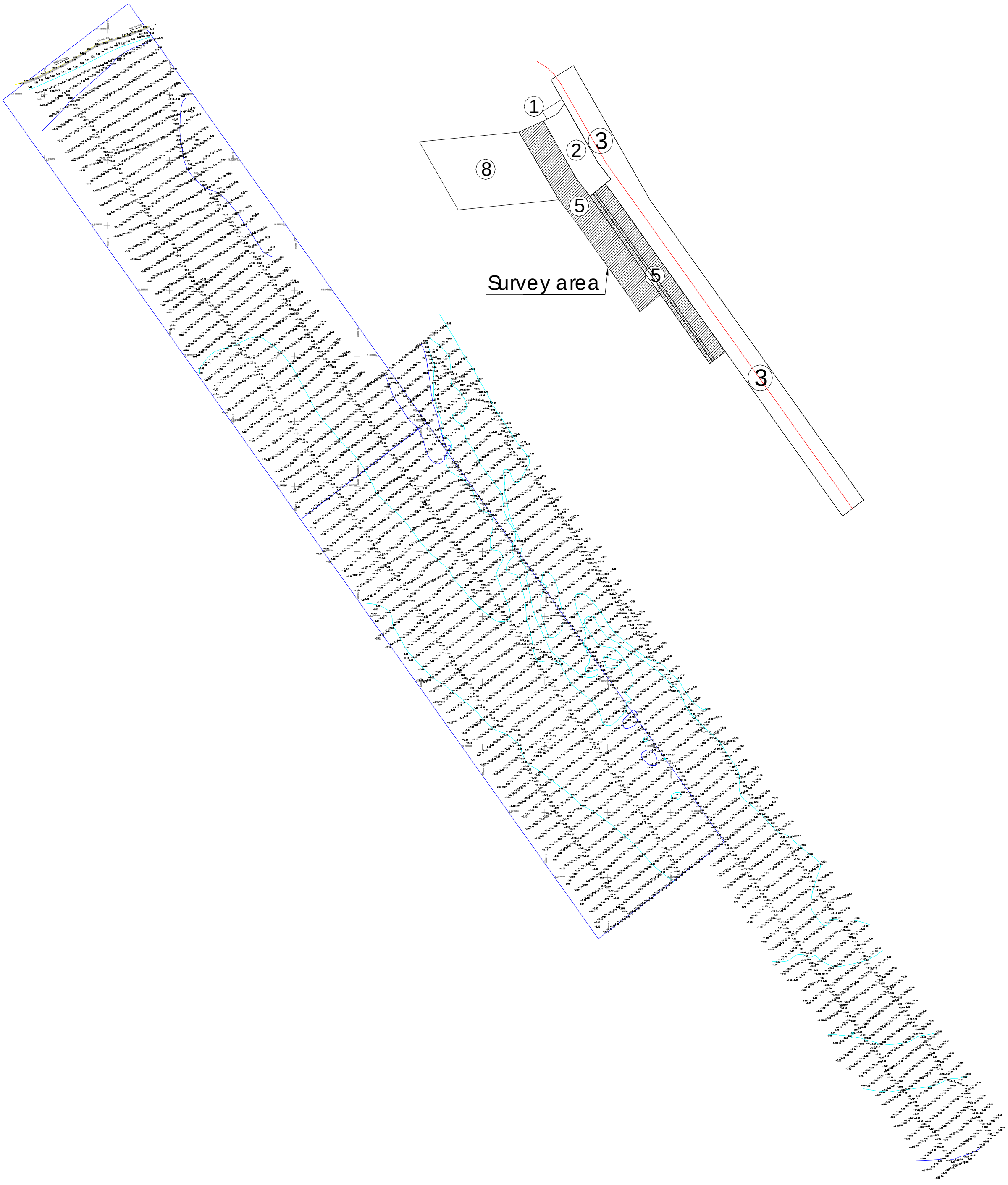



**Figure 2.2.7 Bathymetric Survey Results of Candidate Dumping Sites 1 and 2 (Logistic Park and Inner Seawater Area of the Sand Protection Training Dyke)**

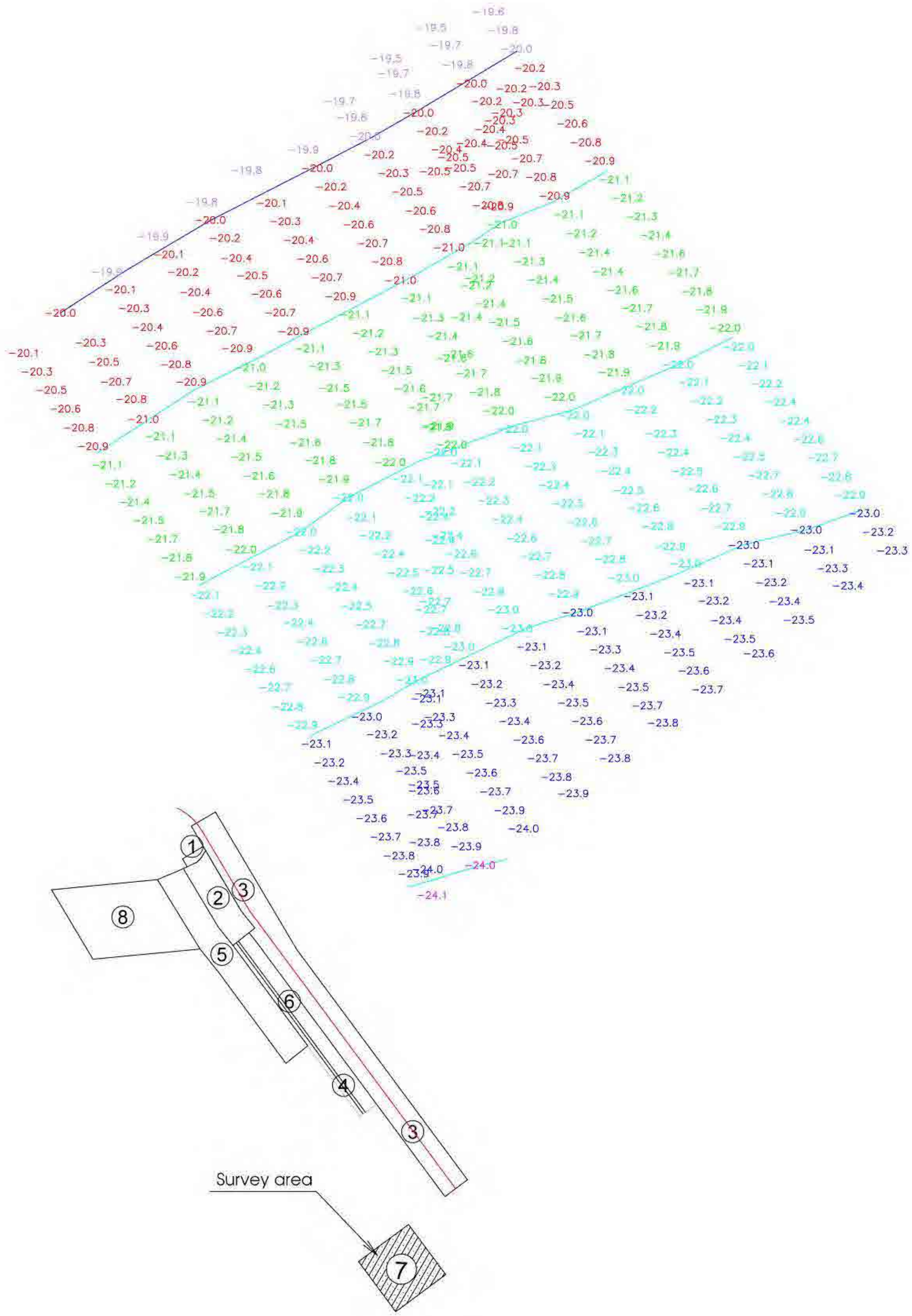



**Figure 2.2.8 Bathymetric Survey Results of Candidate Dumping Site 3 (Off-shore Dumping Site)**

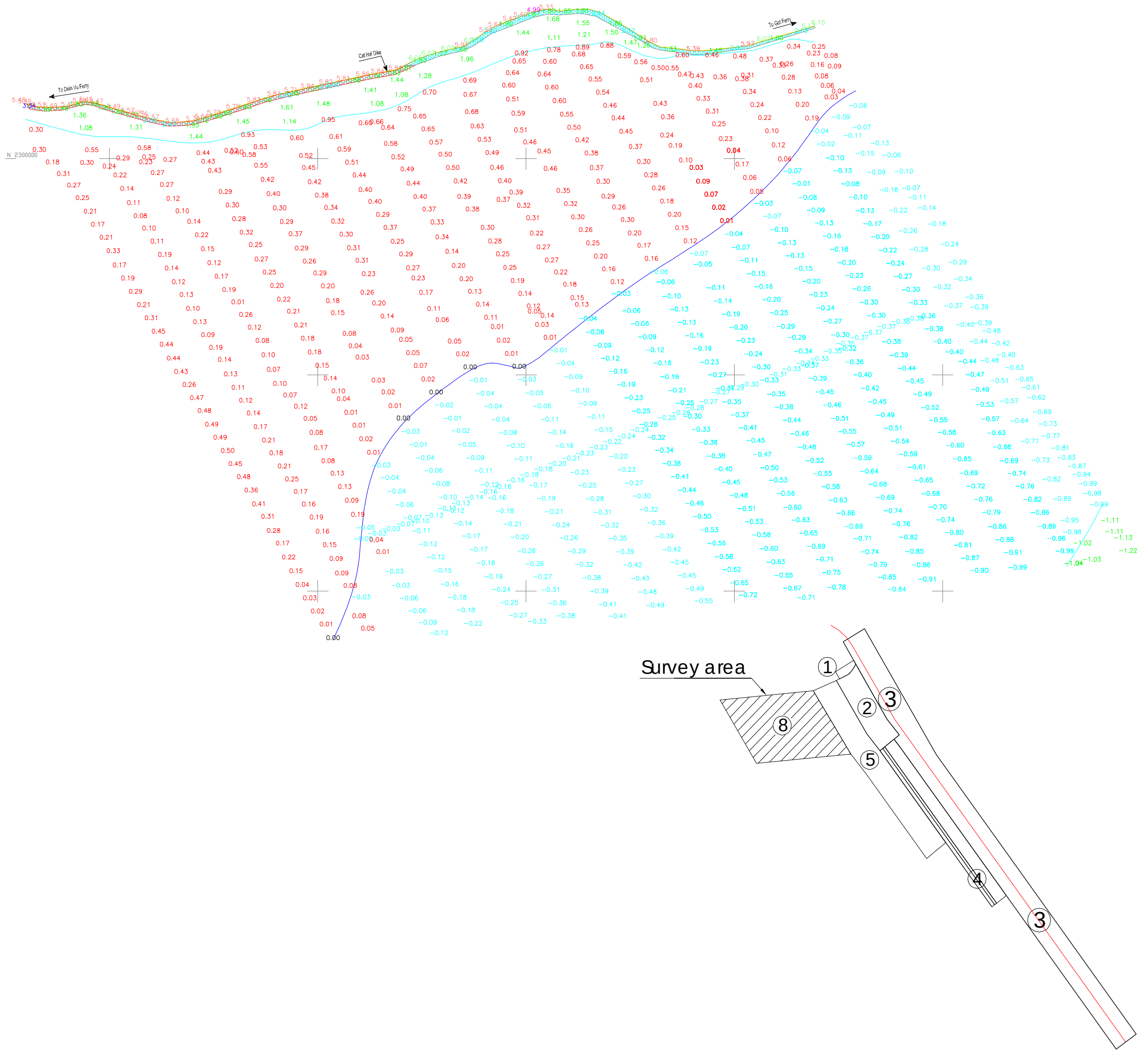



**Figure 2.2.9 Bathymetric Survey Results of Candidate Dumping Site 4 (South of Cat Hai Island)**

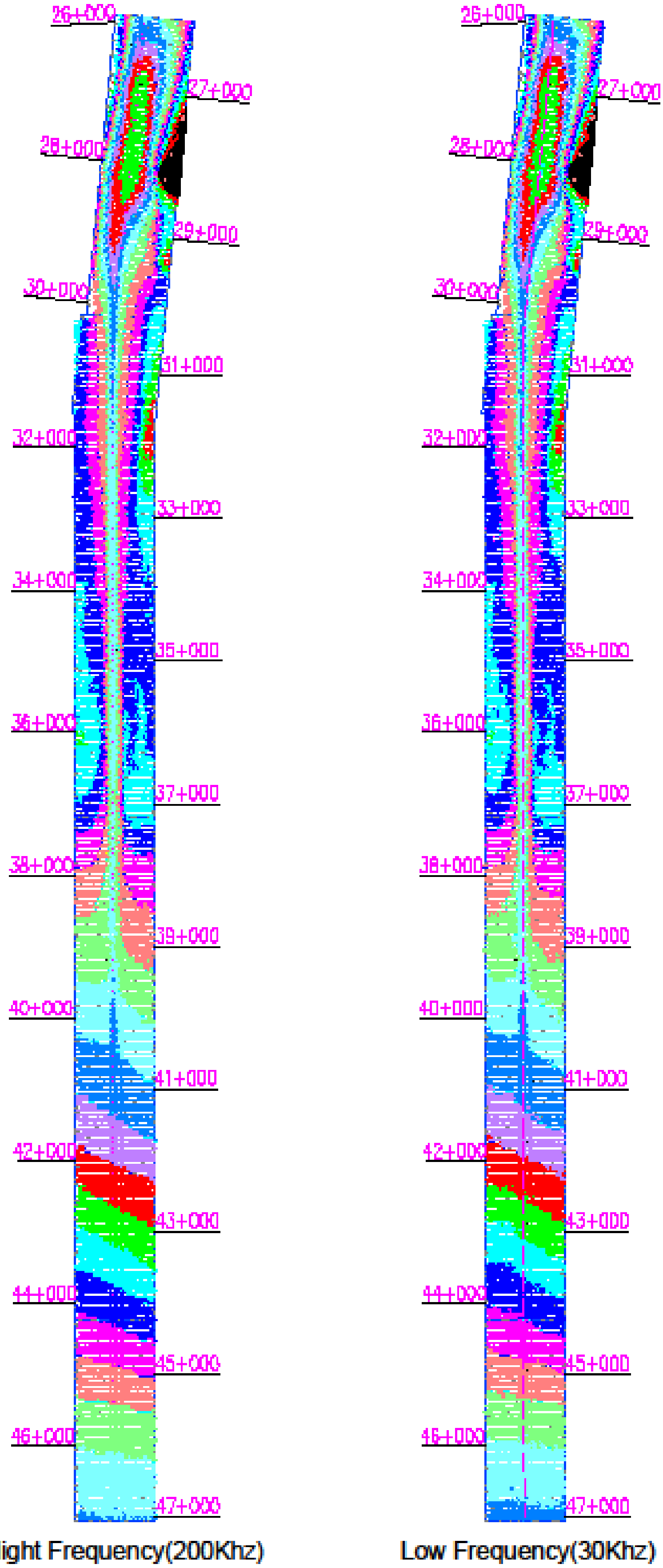
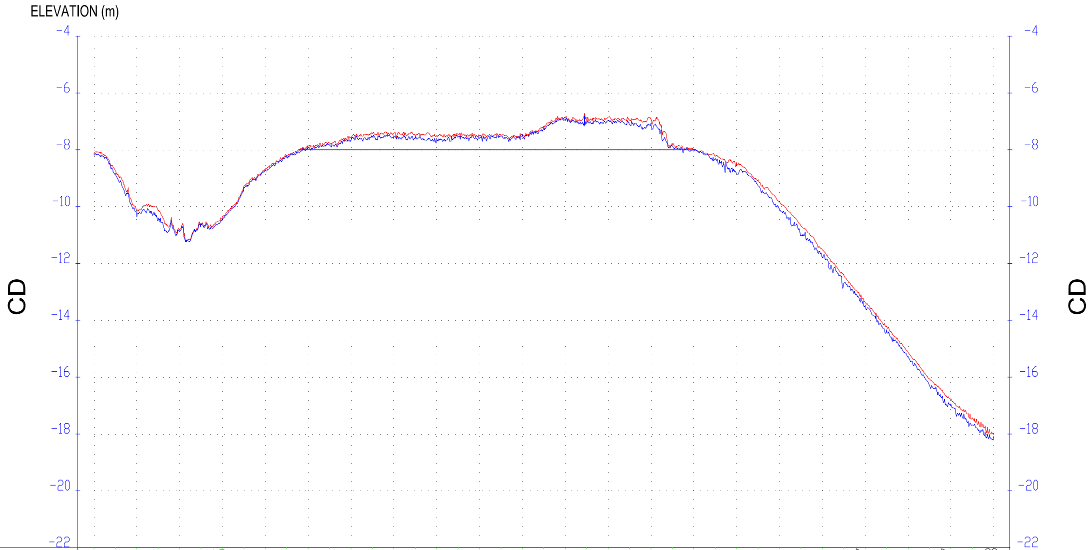



**Figure 2.2.10 Seabed Contour Maps of the Navigational Channel by Dual Frequencies**




| | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION(m) (FREQUENCY 200KHz) | -8.12 | -10.15 | -10.81 | -10.35 | -8.68 | -7.87 | -7.58 | -7.42 | -7.50 | -7.50 | -7.44 | -6.88 | -6.85 | -6.92 | -8.00 | -8.45 | -9.83 | -11.52 | -13.37 | -15.12 | -16.77 | -17.98 |
| ELEVATION(m) (FREQUENCY 30KHz) | -8.17 | -10.31 | -10.86 | -10.44 | -8.71 | -7.92 | -7.67 | -7.52 | -7.62 | -7.56 | -7.47 | -6.96 | -6.97 | -7.08 | -8.04 | -8.86 | -10.09 | -11.79 | -13.48 | -15.27 | -16.94 | -18.14 |
| STATION (m) | 26+000 | 27+000 | 28+000 | 29+000 | 30+000 | 31+000 | 32+000 | 33+000 | 34+000 | 35+000 | 36+000 | 37+000 | 38+000 | 39+000 | 40+000 | 41+000 | 42+000 | 43+000 | 44+000 | 45+000 | 46+000 | 47+000 |

**Figure 2.2.11 Comparison of the Longitudinal Cross Section along the Navigational Channel Obtained by Dual Frequencies**

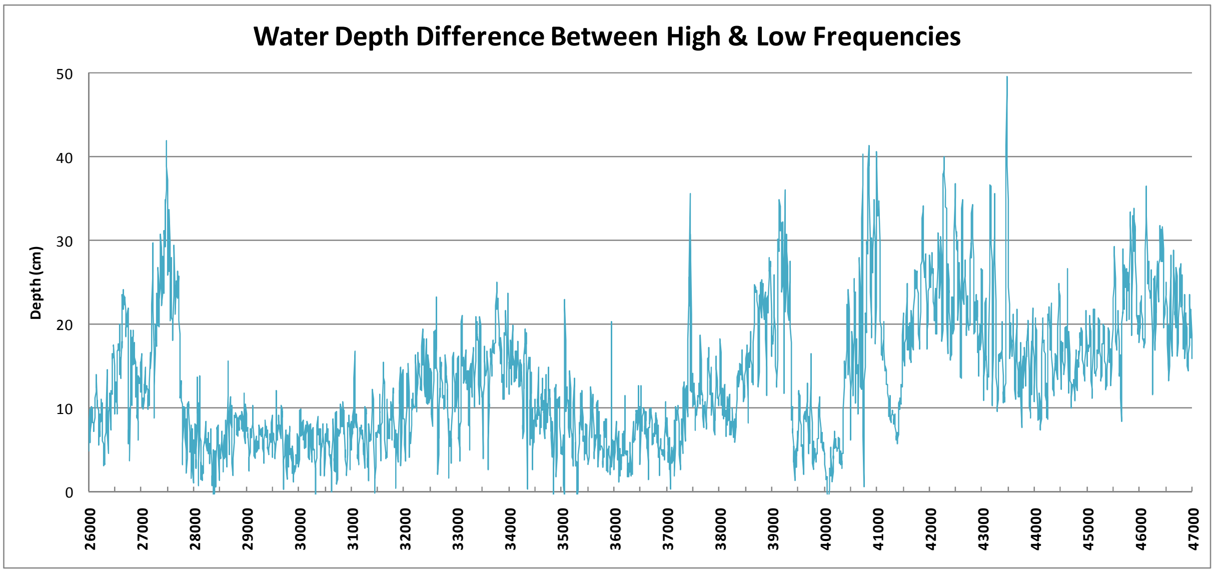
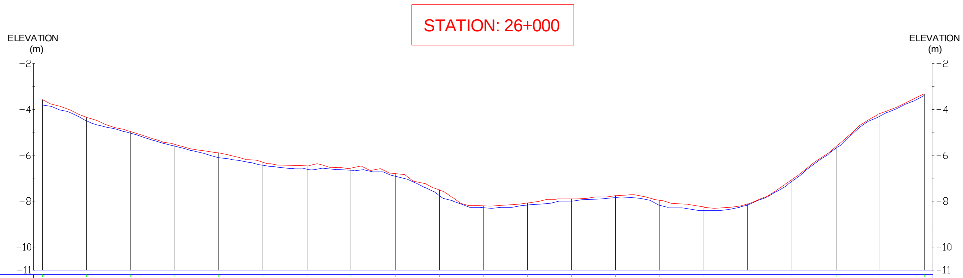
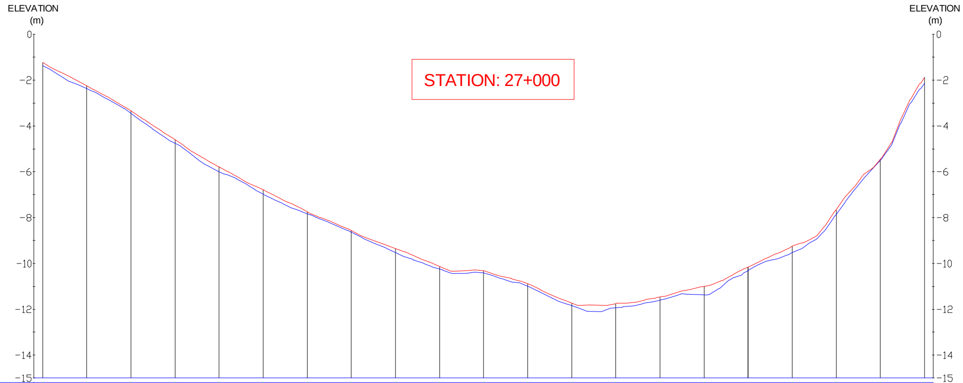



**Figure 2.2.12 Depth Difference along the Navigational Channel Obtained by Dual Frequencies**




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -3.58 | -4.34 | -4.97 | -5.53 | -5.91 | -6.31 | -6.46 | -6.56 | -6.80 | -7.51 | -8.21 | -8.09 | -7.90 | -7.76 | -7.97 | -8.26 | -8.12 | -7.06 | -5.62 | -4.19 | -3.32 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -3.79 | -4.51 | -5.04 | -5.61 | -6.11 | -6.43 | -6.60 | -6.65 | -6.91 | -7.76 | -8.29 | -8.18 | -8.00 | -7.85 | -8.19 | -8.41 | -8.17 | -7.14 | -5.70 | -4.29 | -3.39 |
| CUM. DISTANCE ( m) | -800 | -750 | -700 | -650 | -600 | -550 | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 |

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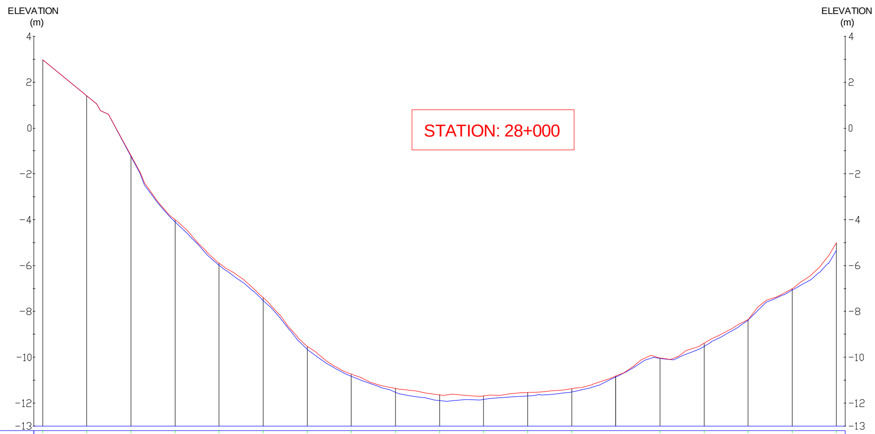
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -1.23 | -2.26 | -3.34 | -4.60 | -5.78 | -6.80 | -7.74 | -8.57 | -9.35 | -10.14 | -10.32 | -10.88 | -11.74 | -11.75 | -11.47 | -11.00 | -10.15 | -9.25 | -7.67 | -5.45 | -1.88 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -1.38 | -2.38 | -3.45 | -4.76 | -6.00 | -6.99 | -7.83 | -8.64 | -9.52 | -10.25 | -10.42 | -10.99 | -11.84 | -11.93 | -11.60 | -11.37 | -10.31 | -9.52 | -7.87 | -5.49 | -2.15 |
| CUM. DISTANCE ( m) | -800 | -750 | -700 | -650 | -600 | -550 | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 |

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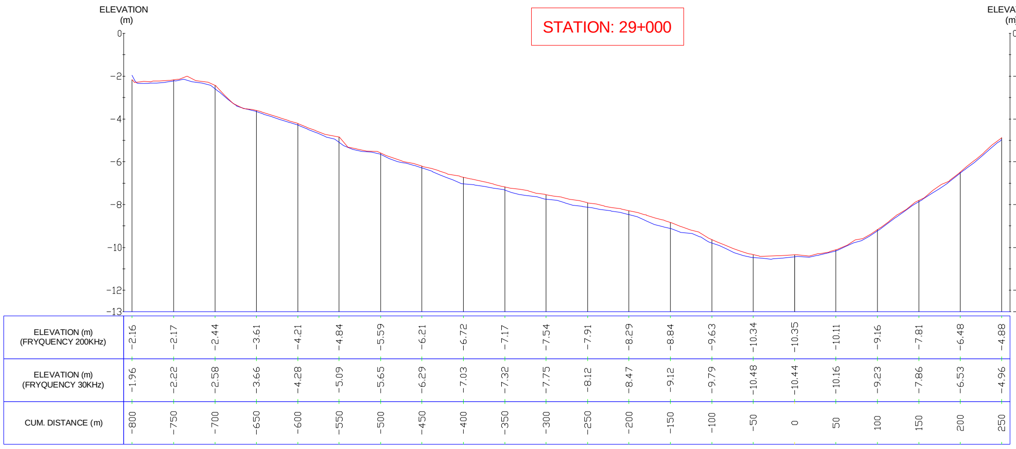
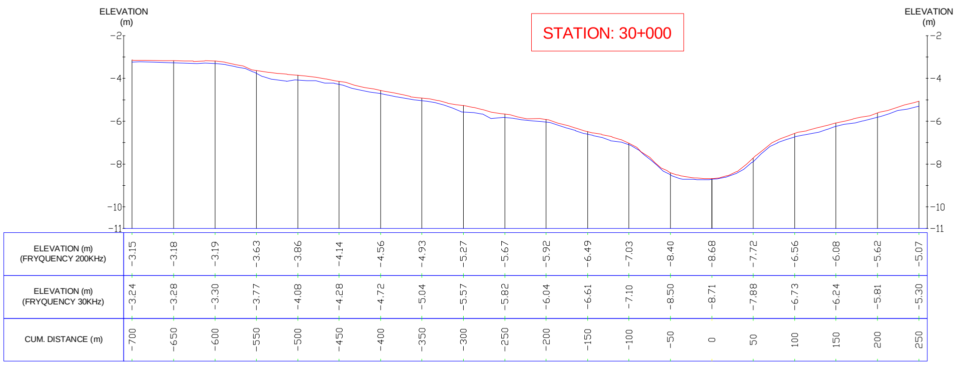
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | 2.97 | 1.40 | -1.21 | -4.00 | -5.89 | -7.40 | -9.53 | -10.73 | -11.36 | -11.64 | -11.68 | -11.53 | -11.37 | -10.81 | -10.04 | -9.39 | -8.36 | -7.00 | -4.99 |
| ELEVATION (m) (FRYQUENCY 30KHz) | 2.97 | 1.40 | -1.26 | -4.09 | -6.00 | -7.52 | -9.65 | -10.83 | -11.53 | -11.89 | -11.84 | -11.69 | -11.51 | -10.86 | -10.04 | -9.52 | -8.38 | -7.07 | -5.34 |
| CUM. DISTANCE ( m) | -650 | -600 | -550 | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 |

Legend
Hight frequency line
Low frequency line
Hight frequency lines

**Figure 2.2.13 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**



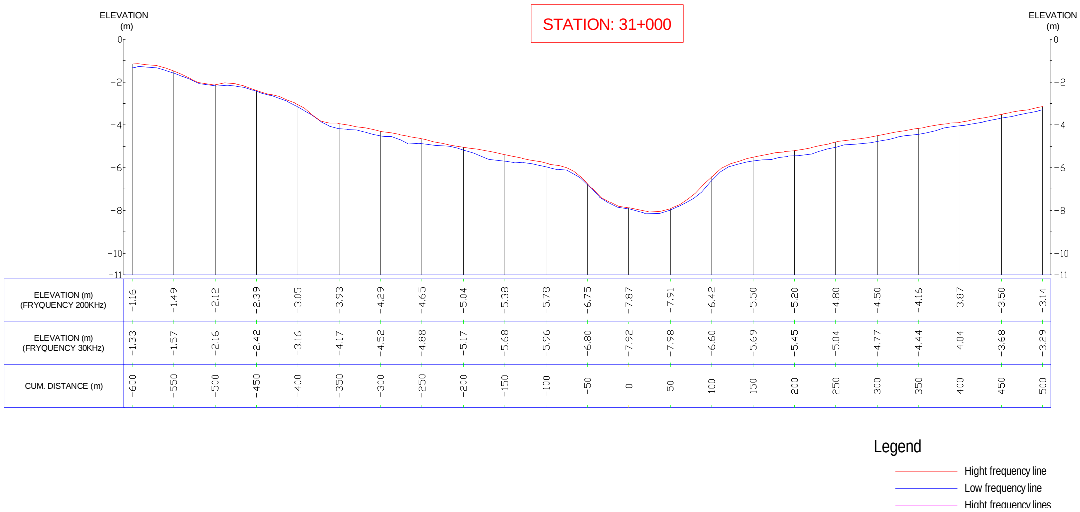
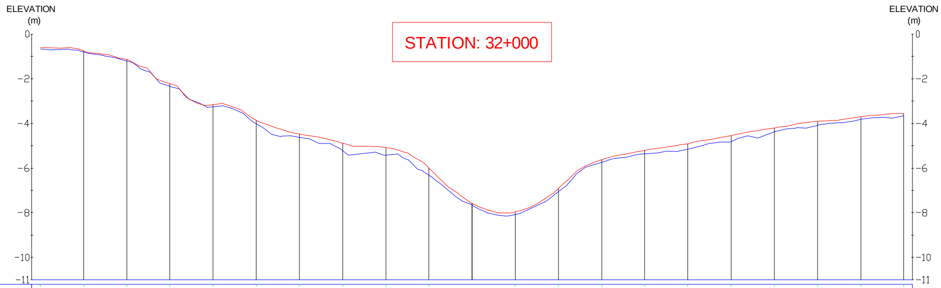




**Figure 2.2.14 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**

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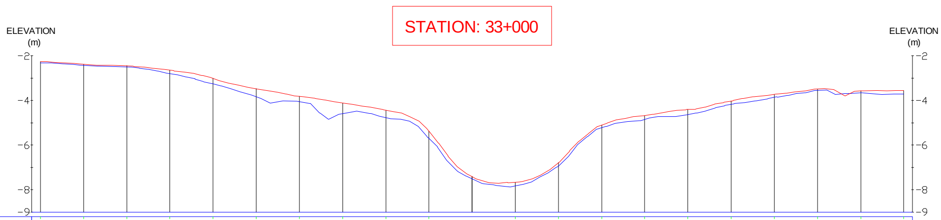
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -0.61 | -0.76 | -1.13 | -2.22 | -3.16 | -3.86 | -4.47 | -4.88 | -5.08 | -6.00 | -7.58 | -7.96 | -6.91 | -5.62 | -5.21 | -4.91 | -4.55 | -4.20 | -3.90 | -3.70 | -3.56 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -0.67 | -0.80 | -1.20 | -2.34 | -3.26 | -4.02 | -4.62 | -5.21 | -5.41 | -6.33 | -7.67 | -8.08 | -7.05 | -5.74 | -5.37 | -5.15 | -4.82 | -4.38 | -4.09 | -3.82 | -3.66 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

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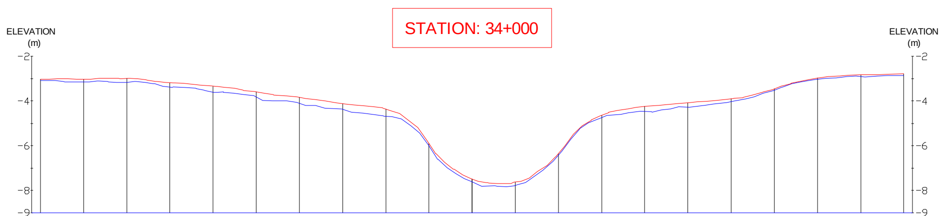
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -2.26 | -2.37 | -2.44 | -2.64 | -3.00 | -3.47 | -3.81 | -4.11 | -4.43 | -5.37 | -7.42 | -7.67 | -6.79 | -5.10 | -4.67 | -4.40 | -4.02 | -3.72 | -3.48 | -3.57 | -3.54 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -2.32 | -2.42 | -2.49 | -2.80 | -3.26 | -3.83 | -4.06 | -4.60 | -4.76 | -5.70 | -7.52 | -7.83 | -6.94 | -5.22 | -4.85 | -4.63 | -4.17 | -3.86 | -3.55 | -3.64 | -3.70 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

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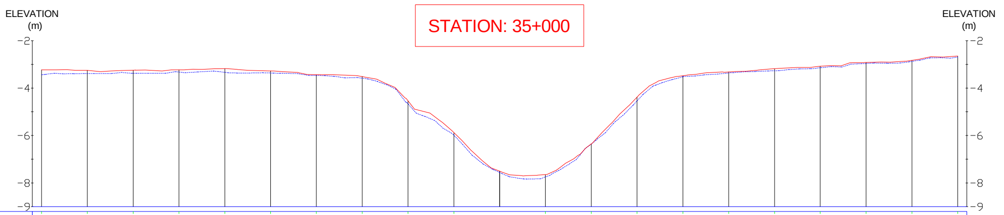
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -3.03 | -3.02 | -2.99 | -3.18 | -3.34 | -3.60 | -3.83 | -4.12 | -4.36 | -5.89 | -7.50 | -7.63 | -6.35 | -4.63 | -4.24 | -4.09 | -3.90 | -3.45 | -2.97 | -2.81 | -2.78 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -3.08 | -3.14 | -3.17 | -3.37 | -3.60 | -3.83 | -4.10 | -4.36 | -4.69 | -6.00 | -7.62 | -7.79 | -6.42 | -4.75 | -4.48 | -4.28 | -4.03 | -3.52 | -3.03 | -2.90 | -2.87 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

Legend
- Hight frequency line
- Low frequency line
- Hight frequency lines

**Figure 2.2.15 Comparison of Cross Sections of Navigational Channel Obtained by Dual Frequencies**

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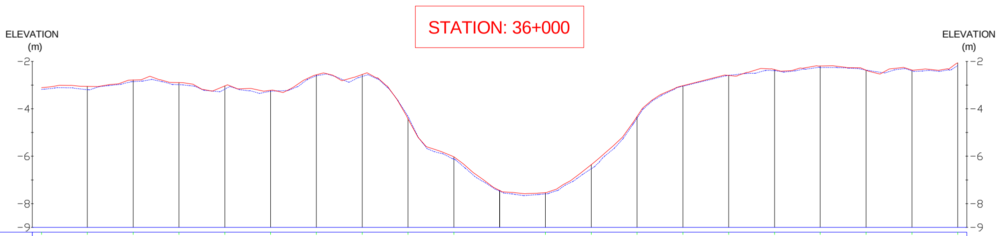
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -3.23 | -3.25 | -3.24 | -3.23 | -3.17 | -3.28 | -3.43 | -3.51 | -4.54 | -5.88 | -7.50 | -7.65 | -6.35 | -4.37 | -3.48 | -3.32 | -3.18 | -3.07 | -2.92 | -2.83 | -2.65 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -3.44 | -3.38 | -3.37 | -3.32 | -3.33 | -3.36 | -3.47 | -3.58 | -4.66 | -5.99 | -7.56 | -7.74 | -6.36 | -4.54 | -3.52 | -3.36 | -3.27 | -3.14 | -2.96 | -2.87 | -2.69 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

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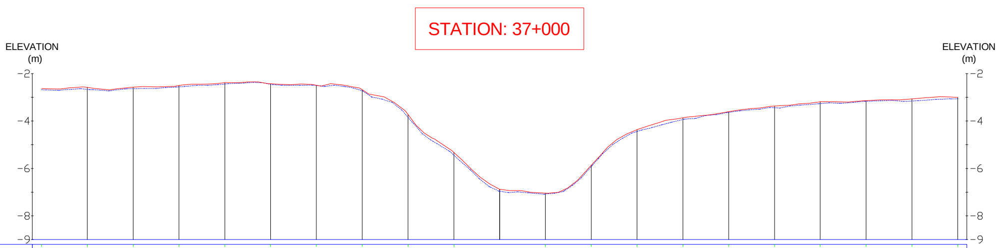
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -3.11 | -3.06 | -2.79 | -2.90 | -3.04 | -3.22 | -2.56 | -2.56 | -4.43 | -6.03 | -7.44 | -7.54 | -6.35 | -4.32 | -3.03 | -2.59 | -2.35 | -2.20 | -2.37 | -2.37 | -2.06 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -3.18 | -3.19 | -2.85 | -2.98 | -3.17 | -3.26 | -2.61 | -2.64 | -4.32 | -6.12 | -7.47 | -7.59 | -6.53 | -4.40 | -3.05 | -2.59 | -2.38 | -2.26 | -2.37 | -2.40 | -2.17 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

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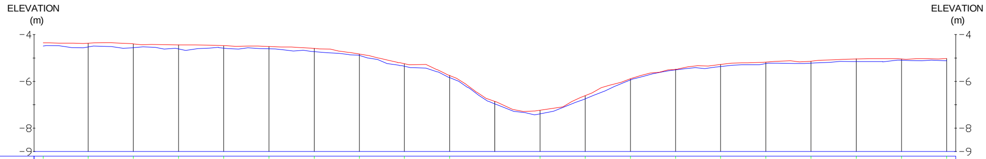
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -2.63 | -2.58 | -2.57 | -2.51 | -2.38 | -2.43 | -2.49 | -2.69 | -3.73 | -5.33 | -6.88 | -7.04 | -5.87 | -4.37 | -3.87 | -3.61 | -3.37 | -3.19 | -3.14 | -3.07 | -3.01 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -2.69 | -2.67 | -2.64 | -2.56 | -2.44 | -2.45 | -2.50 | -2.73 | -3.85 | -5.44 | -6.96 | -7.08 | -5.92 | -4.44 | -3.94 | -3.64 | -3.44 | -3.27 | -3.17 | -3.16 | -3.07 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

Legend
Hight frequency line
Low frequency line
Hight frequency lines

**Figure 2.2.16 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**

STATION: 38+000

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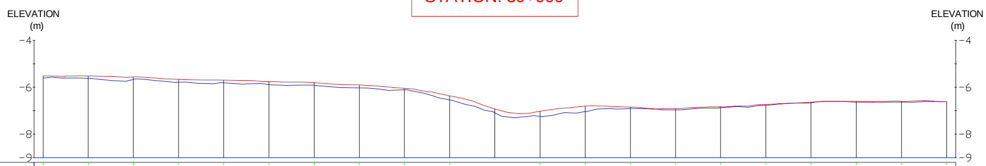
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -4.35 | -4.37 | -4.39 | -4.44 | -4.47 | -4.51 | -4.59 | -4.83 | -5.24 | -5.75 | -6.85 | -7.23 | -6.61 | -5.89 | -5.48 | -5.28 | -5.17 | -5.14 | -5.04 | -5.04 | -5.02 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -4.48 | -4.53 | -4.56 | -4.62 | -4.58 | -4.61 | -4.73 | -4.88 | -5.35 | -5.84 | -6.96 | -7.38 | -6.75 | -5.94 | -5.50 | -5.37 | -5.24 | -5.22 | -5.15 | -5.10 | -5.12 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 39+000

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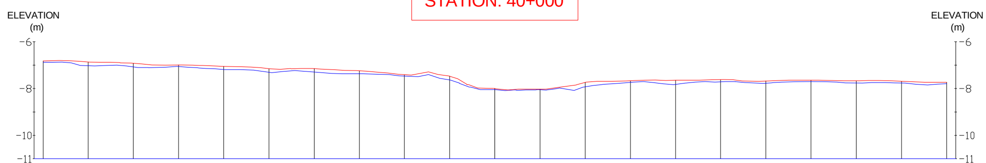
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -5.52 | -5.52 | -5.56 | -5.66 | -5.70 | -5.76 | -5.80 | -5.90 | -6.04 | -6.37 | -6.92 | -7.02 | -6.80 | -6.84 | -6.90 | -6.83 | -6.73 | -6.63 | -6.60 | -6.60 | -6.60 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -5.61 | -5.62 | -5.66 | -5.79 | -5.80 | -5.89 | -5.92 | -6.02 | -6.10 | -6.54 | -7.08 | -7.24 | -7.03 | -6.90 | -6.96 | -6.88 | -6.77 | -6.66 | -6.63 | -6.63 | -6.61 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 40+000

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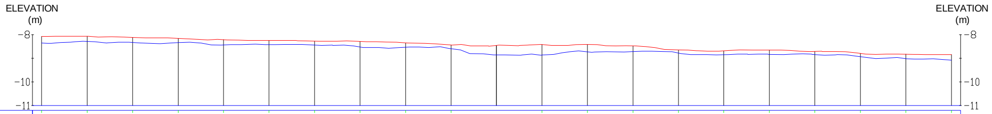
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -6.81 | -6.86 | -6.92 | -6.98 | -7.05 | -7.15 | -7.14 | -7.24 | -7.40 | -7.47 | -8.00 | -8.02 | -7.73 | -7.66 | -7.64 | -7.61 | -7.67 | -7.64 | -7.66 | -7.68 | -7.73 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -6.88 | -7.02 | -7.07 | -7.06 | -7.18 | -7.30 | -7.29 | -7.36 | -7.46 | -7.63 | -8.04 | -8.05 | -7.92 | -7.73 | -7.82 | -7.71 | -7.77 | -7.70 | -7.76 | -7.76 | -7.78 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

Legend
Hight frequency line
Low frequency line
Hight frequency lines

**Figure 2.2.17 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**

STATION: 41+000

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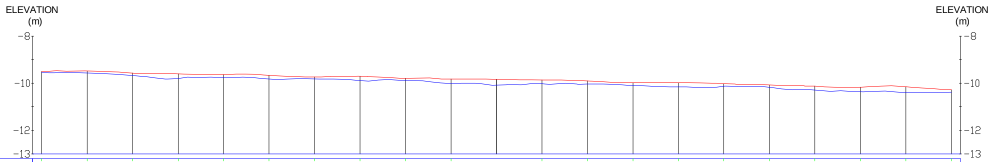
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -8.08 | -8.07 | -8.12 | -8.16 | -8.21 | -8.24 | -8.28 | -8.29 | -8.35 | -8.44 | -8.46 | -8.42 | -8.41 | -8.48 | -8.65 | -8.69 | -8.66 | -8.71 | -8.79 | -8.82 | -8.84 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -8.35 | -8.29 | -8.33 | -8.34 | -8.44 | -8.42 | -8.44 | -8.53 | -8.53 | -8.59 | -8.86 | -8.86 | -8.73 | -8.71 | -8.78 | -8.85 | -8.83 | -8.84 | -8.93 | -9.02 | -9.08 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 42+000

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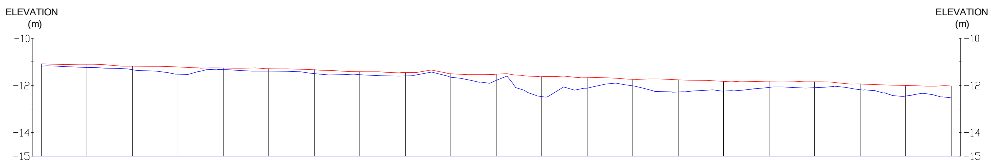
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -9.50 | -9.49 | -9.57 | -9.61 | -9.64 | -9.67 | -9.74 | -9.70 | -9.79 | -9.83 | -9.83 | -9.87 | -9.91 | -9.98 | -9.98 | -10.02 | -10.08 | -10.13 | -10.17 | -10.16 | -10.29 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -9.55 | -9.57 | -9.68 | -9.80 | -9.77 | -9.82 | -9.82 | -9.89 | -9.89 | -10.02 | -10.09 | -10.03 | -10.04 | -10.10 | -10.16 | -10.14 | -10.18 | -10.30 | -10.36 | -10.40 | -10.39 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 43+000

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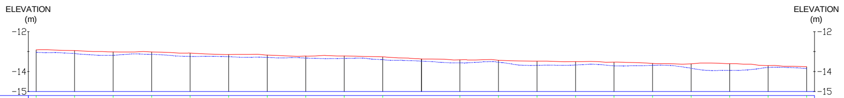
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | -11.08 | -11.10 | -11.17 | -11.21 | -11.25 | -11.29 | -11.33 | -11.42 | -11.45 | -11.50 | -11.52 | -11.62 | -11.67 | -11.74 | -11.76 | -11.82 | -11.82 | -11.84 | -11.94 | -12.00 | -12.02 |
| ELEVATION (m) (FRYQUENCY 30KHz) | -11.18 | -11.23 | -11.33 | -11.52 | -11.32 | -11.39 | -11.49 | -11.54 | -11.59 | -11.65 | -11.79 | -12.47 | -12.12 | -12.01 | -12.27 | -12.23 | -12.08 | -12.09 | -12.17 | -12.45 | -12.53 |
| CUM. DISTANCE (m) | -500 | -450 | -400 | -350 | -300 | -250 | -200 | -150 | -100 | -50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

Legend
- Hight frequency line
- Low frequency line
- Hight frequency lines

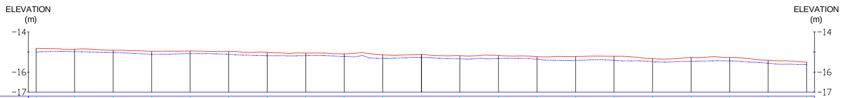
**Figure 2.2.18 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**

STATION: 44+000



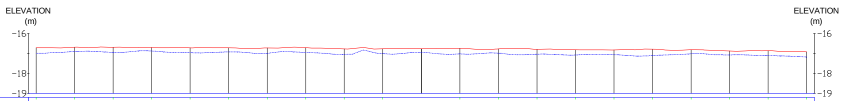

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | −12.92 | −12.95 | −13.01 | −13.02 | −13.08 | −13.15 | −13.18 | −13.23 | −13.22 | −13.27 | −13.37 | −13.42 | −13.43 | −13.48 | −13.51 | −13.53 | −13.60 | −13.62 | −13.61 | −13.71 | −13.76 |
| ELEVATION (m) (FRYQUENCY 30KHz) | −13.04 | −13.10 | −13.19 | −13.14 | −13.24 | −13.26 | −13.30 | −13.33 | −13.34 | −13.41 | −13.48 | −13.57 | −13.53 | −13.69 | −13.67 | −13.73 | −13.69 | −13.84 | −13.94 | −13.80 | −13.85 |
| CUM. DISTANCE (m) | −500 | −450 | −400 | −350 | −300 | −250 | −200 | −150 | −100 | −50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 45+000



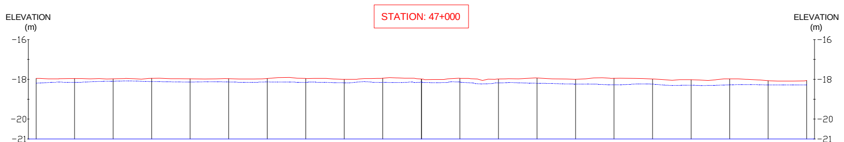

| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | −14.82 | −14.86 | −14.92 | −14.97 | −14.95 | −14.97 | −15.02 | −15.06 | −15.09 | −15.14 | −15.12 | −15.19 | −15.18 | −15.24 | −15.22 | −15.21 | −15.33 | −15.28 | −15.27 | −15.41 | −15.51 |
| ELEVATION (m) (FRYQUENCY 30KHz) | −15.01 | −14.98 | −15.03 | −15.12 | −15.08 | −15.12 | −15.18 | −15.18 | −15.22 | −15.32 | −15.27 | −15.35 | −15.32 | −15.36 | −15.42 | −15.42 | −15.48 | −15.47 | −15.45 | −15.56 | −15.63 |
| CUM. DISTANCE (m) | −500 | −450 | −400 | −350 | −300 | −250 | −200 | −150 | −100 | −50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 46+000




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | −16.71 | −16.69 | −16.70 | −16.71 | −16.72 | −16.71 | −16.72 | −16.71 | −16.77 | −16.77 | −16.77 | −16.74 | −16.78 | −16.80 | −16.82 | −16.83 | −16.79 | −16.81 | −16.88 | −16.86 | −16.92 |
| ELEVATION (m) (FRYQUENCY 30KHz) | −17.00 | −16.90 | −16.95 | −16.88 | −16.97 | −16.92 | −17.00 | −16.95 | −17.04 | −17.01 | −16.94 | −17.02 | −16.99 | −17.04 | −17.08 | −17.07 | −17.11 | −17.02 | −17.08 | −17.11 | −17.18 |
| CUM. DISTANCE (m) | −500 | −450 | −400 | −350 | −300 | −250 | −200 | −150 | −100 | −50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |

STATION: 47+000




| | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ELEVATION (m) (FRYQUENCY 200KHz) | −17.95 | −17.96 | −17.97 | −17.94 | −17.97 | −17.97 | −17.95 | −17.95 | −18.00 | −17.94 | −17.98 | −17.95 | −17.98 | −17.94 | −18.00 | −17.94 | −17.98 | −18.02 | −17.98 | −18.07 | −18.06 |
| ELEVATION (m) (FRYQUENCY 30KHz) | −18.19 | −18.15 | −18.10 | −18.11 | −18.14 | −18.13 | −18.13 | −18.14 | −18.17 | −18.15 | −18.14 | −18.14 | −18.17 | −18.20 | −18.24 | −18.27 | −18.24 | −18.30 | −18.27 | −18.28 | −18.28 |
| CUM. DISTANCE (m) | −500 | −450 | −400 | −350 | −300 | −250 | −200 | −150 | −100 | −50 | 0 | 50 | 100 | 150 | 200 | 250 | 300 | 350 | 400 | 450 | 500 |



**Figure 2.2.19 Comparison of Cross Sections of the Navigational Channel Obtained by Dual Frequencies**

## 2.3 Current, Turbidity and Waves Observation

Lach Huyen Port construction area is the area where sedimentation in the access channel is expected to be severe. The most of sediment around the access channel of the port consists of mud (silt or clay) which is easy to move by waves and current. The mud transport and sedimentation are complex phenomenon and needed careful estimation for the maintenance dredging volume and effectiveness of siltation protection works.

This section describes the results of field survey carried out in May to June, 2011. In the survey, a simultaneous observation of current, waves, and turbidity for one month has been conducted in order to collect useful information for sedimentation simulations. The observation were conducted at 6 stations near the Lach Huyen channel, to collect fundamental data for the relation between the forcing condition (current and waves) and suspended sediment (turbidity). Also, observation of current and suspended sediment has been carried out at 5 stations in the rivers and canals to obtain the basic information of the sediment inflow supplied from rivers.

### 2.3.1 Observation Method

#### 1) Survey Stations

The locations of the observation stations are shown in Figure 2.3.1. The observation is divided into two series which are the channel section of C1 to C6 and the river section of R1 to R5. The observation stations for the channel section are located along the Lach Huyen channel for C1 to C4 and C6 and located at the offshore of the river mouth of Bach Dang River for C5. The observation stations for the river section of R1 to R5 are positioned in the rivers connected to Lach Huyen estuary. Also, T1 and T2 are tide stations for the survey. The coordinates of the stations, the water depth, and name of equipment are summarized in Table 2.3.1 to Table 2.3.3.

#### 2) Method of the observation

For the channel section of C1 – C6, 30 day consecutive observation of wave, current, and turbidity were conducted from April 30, 2011 to May 31, 2011. Current and turbidity were measured at stations of C1, C3, C4, and C5, wave and turbidity at C2, and wave and current at C6. Current velocities were measured in multi-layers with the ADCP-type equipment, and waves of wave height, period, and direction were measured by wave meters. The current meters and wave meters were installed on the sea bed as shown in Figure 2.3.3. Turbidity was measured with a turbidity meter by raising it from the sea bed to water surface to obtain the vertical distribution of suspended sediment as shown in Figure 2.3.4. All data of the observation were recorded every one hour.

For the river section of R1 – R5, 52 hour consecutive observation of current, and suspended sediment has been conducted in the period of neap tide from 10 am 27, May 2011 to 02 pm 29, May 2011 and in spring tide from 10 am 02, June 2011 to 02 pm 04, June 2011. Current velocities were measured in multi-layers with the ADCP-type equipment, and suspended sediment was measured by sampling water. The time step to get data is every one hour.


**Figure 2.3.1 Survey stations**

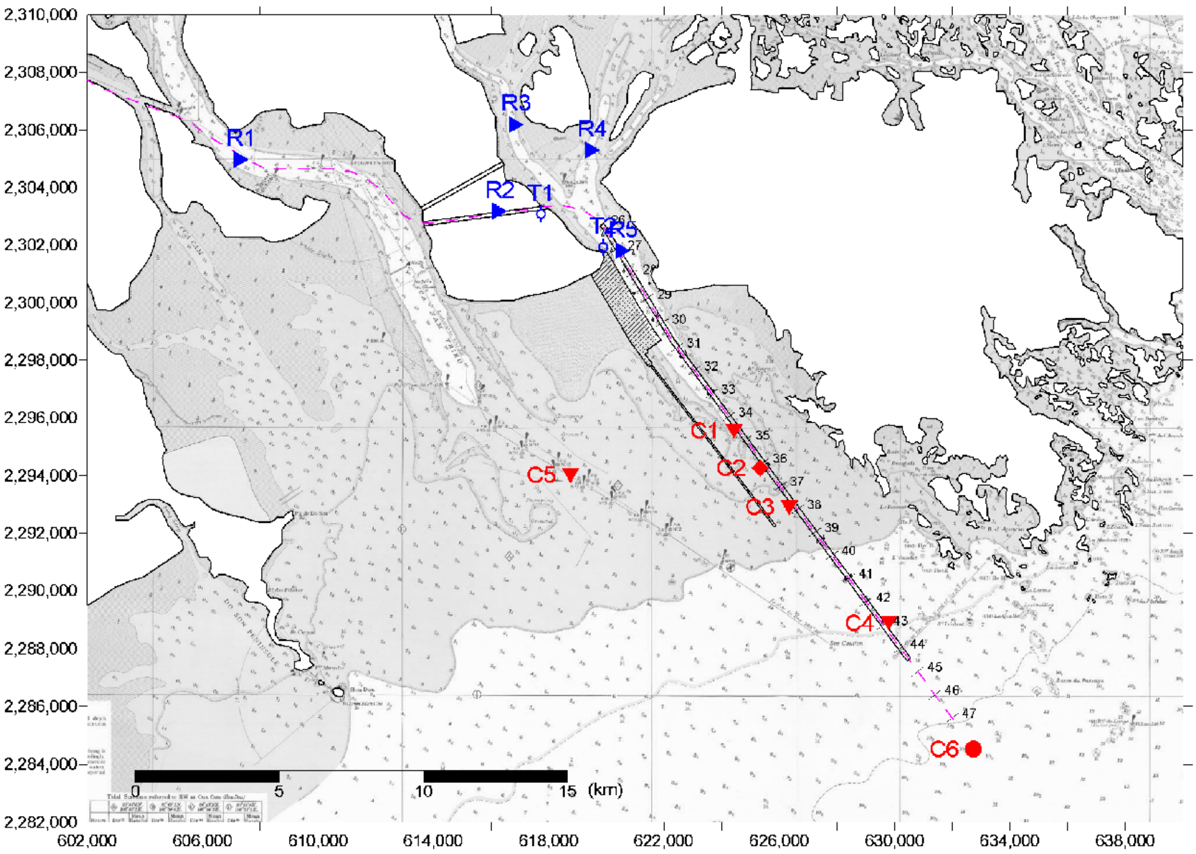



**Figure 2.3.2 Locations of Survey stations**

**Table 2.3.1 Coordinates of survey stations for channel section (C1 – C6)**

| Station | VN2000 | | WGS84 | | Depth | Measurement | Name of Equipment |
|---|---|---|---|---|---|---|---|
| | Y(Easting) | X(Northing) | Longitude | Latitude | (m, CD) | | |
| C1 | 624436 | 2295549 | 106$^0$56’48.470” | 20$^0$44’53.816” | 4.1 | C, (W),T | Argonaut, OBS3A |
| C2 | 625343 | 2294265 | 106$^0$57’19.490” | 20$^0$44’11.877” | 3.6 | W,T | Triton, OBS3A |
| C3 | 626343 | 2292896 | 106$^0$57’53.683” | 20$^0$43’27.104” | 5.2 | C, (W),T | Argonaut, OBS3A |
| C4 | 629799 | 2288883 | 106$^0$59’52.058” | 20$^0$41’15.780” | 11.6 | C, (W),T | Argonaut, OBS3A |
| C5 | 618766 | 2294011 | 106$^0$53’32.112” | 20$^0$44’05.154” | 2.9 | C, (W),T | Argonaut, OBS3A |
| C6 | 632738 | 2284517 | 107$^0$01’32.404” | 20$^0$38’53.106” | 19.0 | W,C | AWAC |

Observation period: Consecutive 30 days (from April 30, 2011 to May 31, 2011)
C: Current observation (multi-layers) by current meter
W: Wave observation (wave height, period, and direction) by wave meter
(W): Wave height and period are measured by current meter with optional function to measure wave.
T: Turbidity observation by the turbidity meter

**Table 2.3.2 Coordinates of survey stations for river section (R1 – R5)**

| Station | VN2000 | | WGS84 | | Depth | Measurement | Name of Equipment |
|---|---|---|---|---|---|---|---|
| | Y(Easting) | X(Northing) | Longitude | Latitude | (m, CD) | | |
| R1 | 607339 | 2304983 | 106$^0$46’59.600” | 20$^0$50’04.400” | 6.1 | C,SS | Flow Quest, Water Sampler |
| R2 | 616303 | 2303188 | 106$^0$52’09.173” | 20$^0$49’04.104” | 6.1 | C,SS | Flow Quest, Water Sampler |
| R3 | 616876 | 2306198 | 106$^0$52’29.715” | 20$^0$50’41.817” | 4.6 | C,SS | Flow Quest, Water Sampler |
| R4 | 619524 | 2305305 | 106$^0$54’01.074” | 20$^0$50’12.196” | 8.6 | C,SS | Flow Quest, Water Sampler |
| R5 | 620578 | 2301801 | 106$^0$54’36.677” | 20$^0$48’17.996” | 13.6 | C,SS | Flow Quest, Water Sampler |

Observation period: 52 hours in neap tide (From 10AM 27, May 2011 to 02PM 29, May 2011), and 52 hours in spring tide (From 10AM 02, June 2011 to 02PM 04, June 2011).
C: Current observation (multi-layers) by the current meter
SS: Suspended sediment concentration by water sampling (3 layers of 0.2H, 0.6H, and Bed. H is the water depth)

**Table 2.3.3 Coordinates of tide observation stations (T1 and T2)**

| Station | VN2000 | | WGS84 | | Depth | Measurement | Name of Equipment |
|---|---|---|---|---|---|---|---|
| | Y(Easting) | X(Northing) | Longitude | Latitude | (m, CD) | | |
| T1 | 617727 | 2303089 | 106$^0$52’58.410” | 20$^0$49’00.541” | - | Tide | Level2000 |
| T2 | 619883 | 2301926 | 106$^0$54’12.662” | 20$^0$48’22.230” | - | Tide | Level2000 |

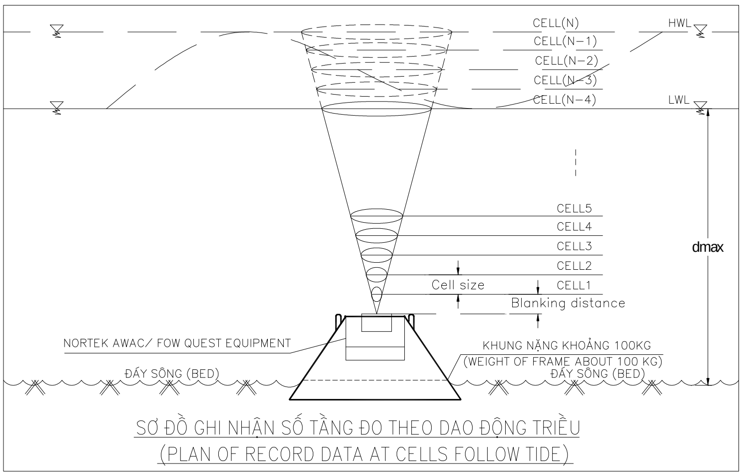



**Figure 2.3.3 Image installing the current meter on to seabed**

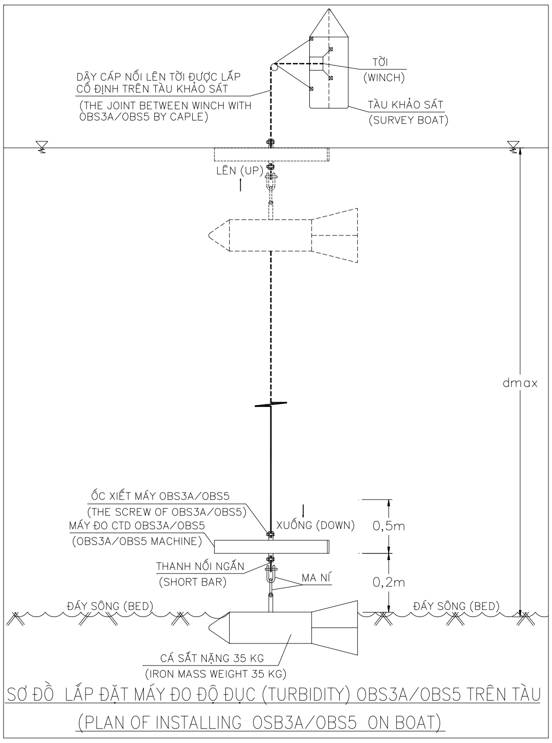



**Figure 2.3.4 Method of turbidity observation**

### 2.3.2 Results of Observation of channel section (C1 – C6)

#### 1) Time Series of observed data

As the results of the observation at C1 – C6, time series of tide level (at T2), current vectors of the depth-averaged current, current speed, current components in the eastern and northern direction, wave height and period, turbidity of 3 layer-averaged, and turbidity of 3 layers of 0.2m, 0.7m, and 1.7 m above sea bed are shown. The turbidity shown in the figure is the value converted to suspended load concentration by using the result of water sampling at each station. Also, as the multi-layer current observation was conducted, current velocity of each layer is shown in Figure 2.3.10 to Figure 2.3.13.

In the observation, the data of current, wave, and turbidity have been obtained simultaneously although there is some lack of data. According to the variation of wave height, high wave over 1.0 m came twice from 7, May to 12, May and from 22, May to 24, May. The time variation of the turbidity looks follow the variation of wave height. However, in the both period of high wave, the tidal current is also strong because of spring tide. Therefore, both wave and current seem to influence the suspended sediment concentration.

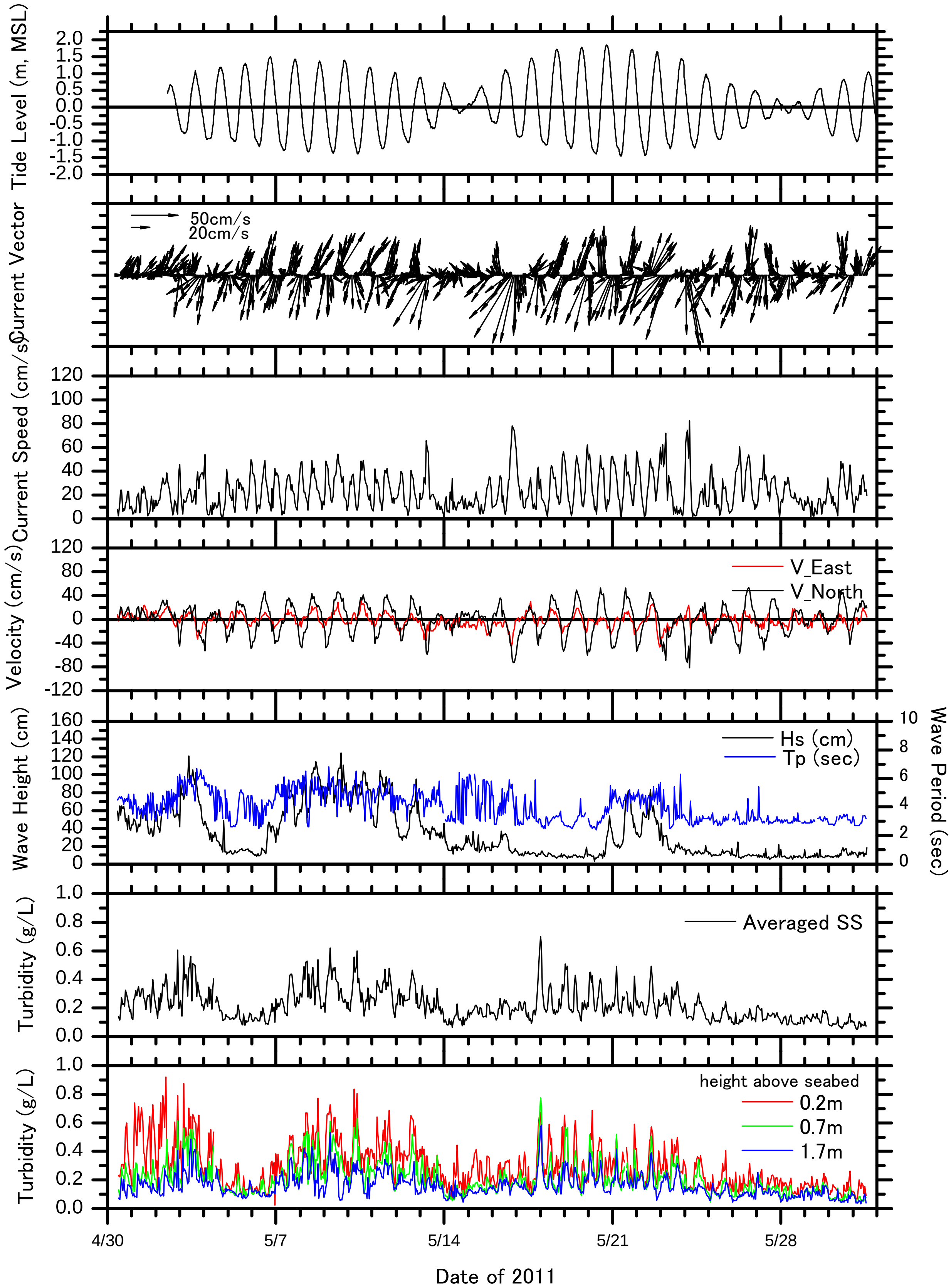



**Figure 2.3.5 Time series of Current, wave, and Turbidity at C1**

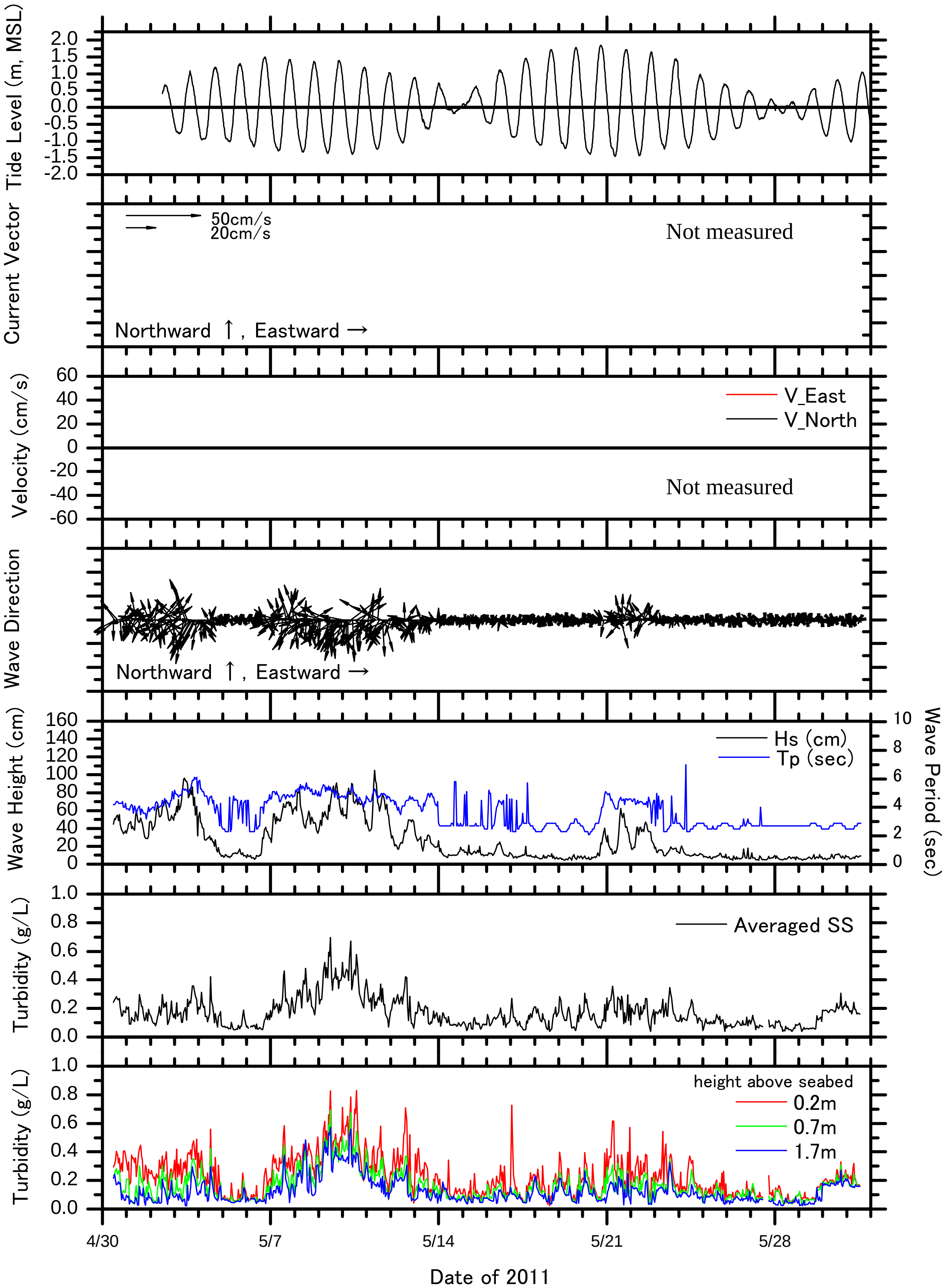



**Figure 2.3.6 Time series of Current, wave, and Turbidity at C2**

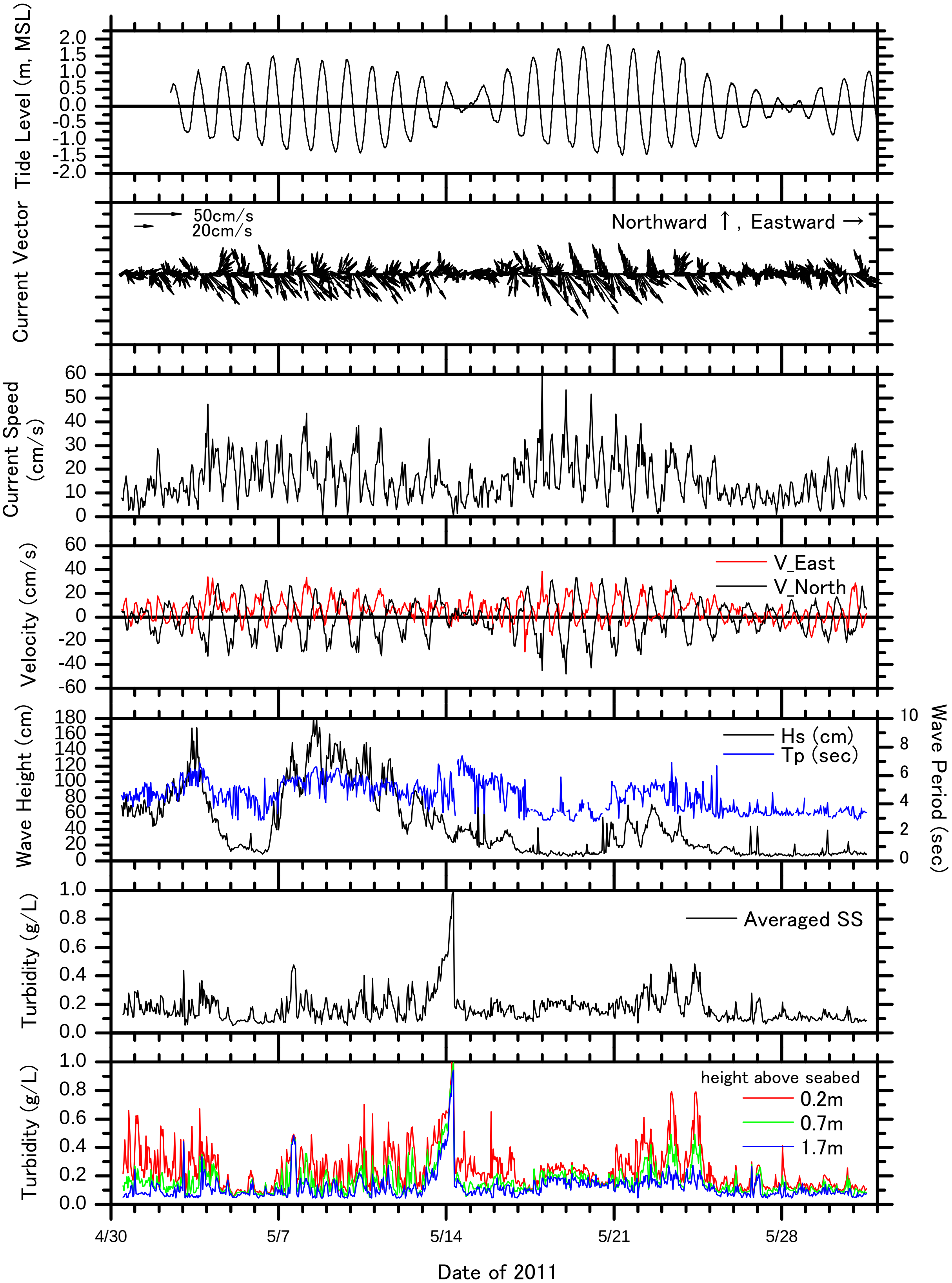



**Figure 2.3.7 Time series of Current, wave, and Turbidity at C3**

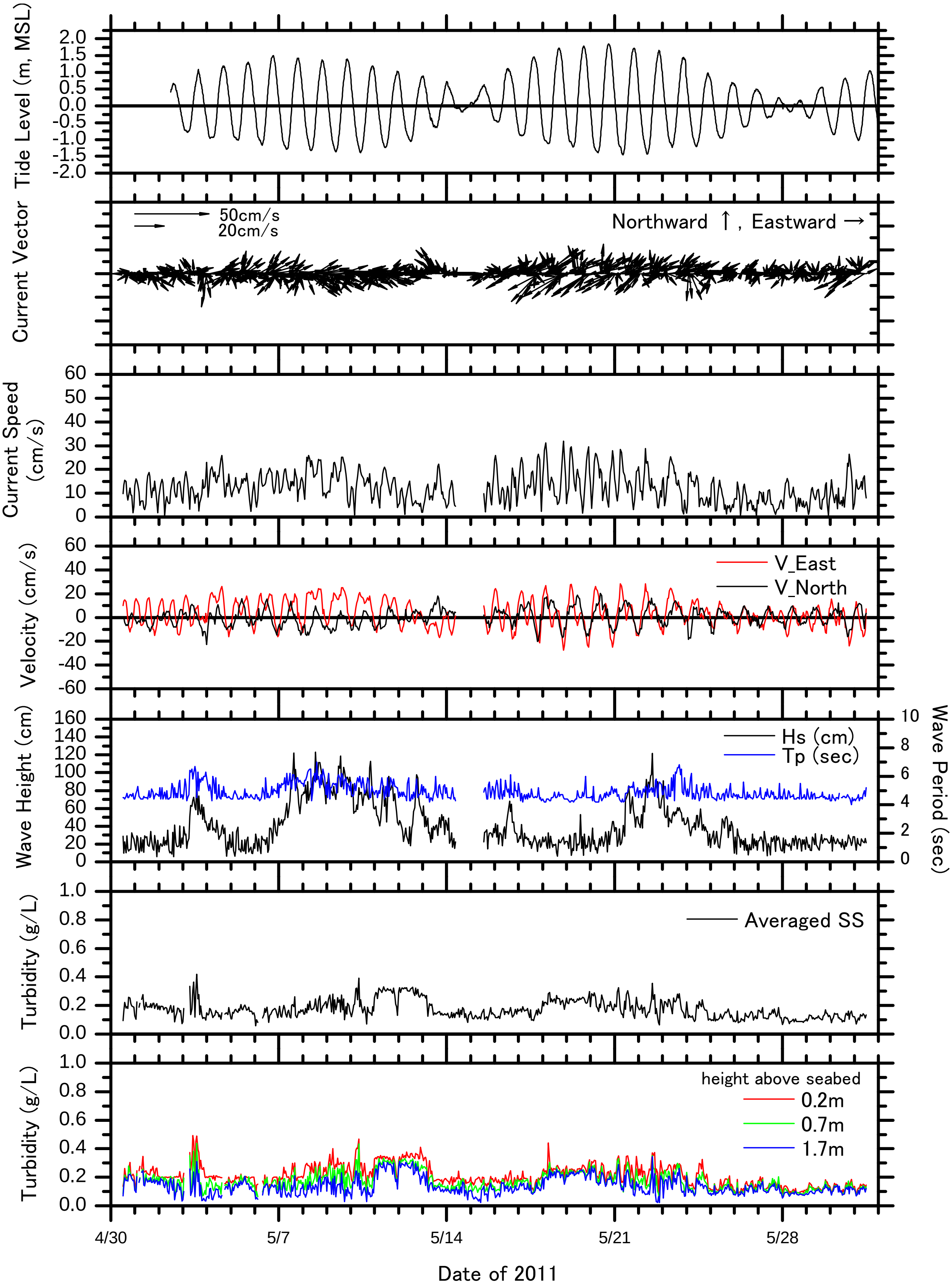



**Figure 2.3.8 Time series of Current, wave, and Turbidity at C4**

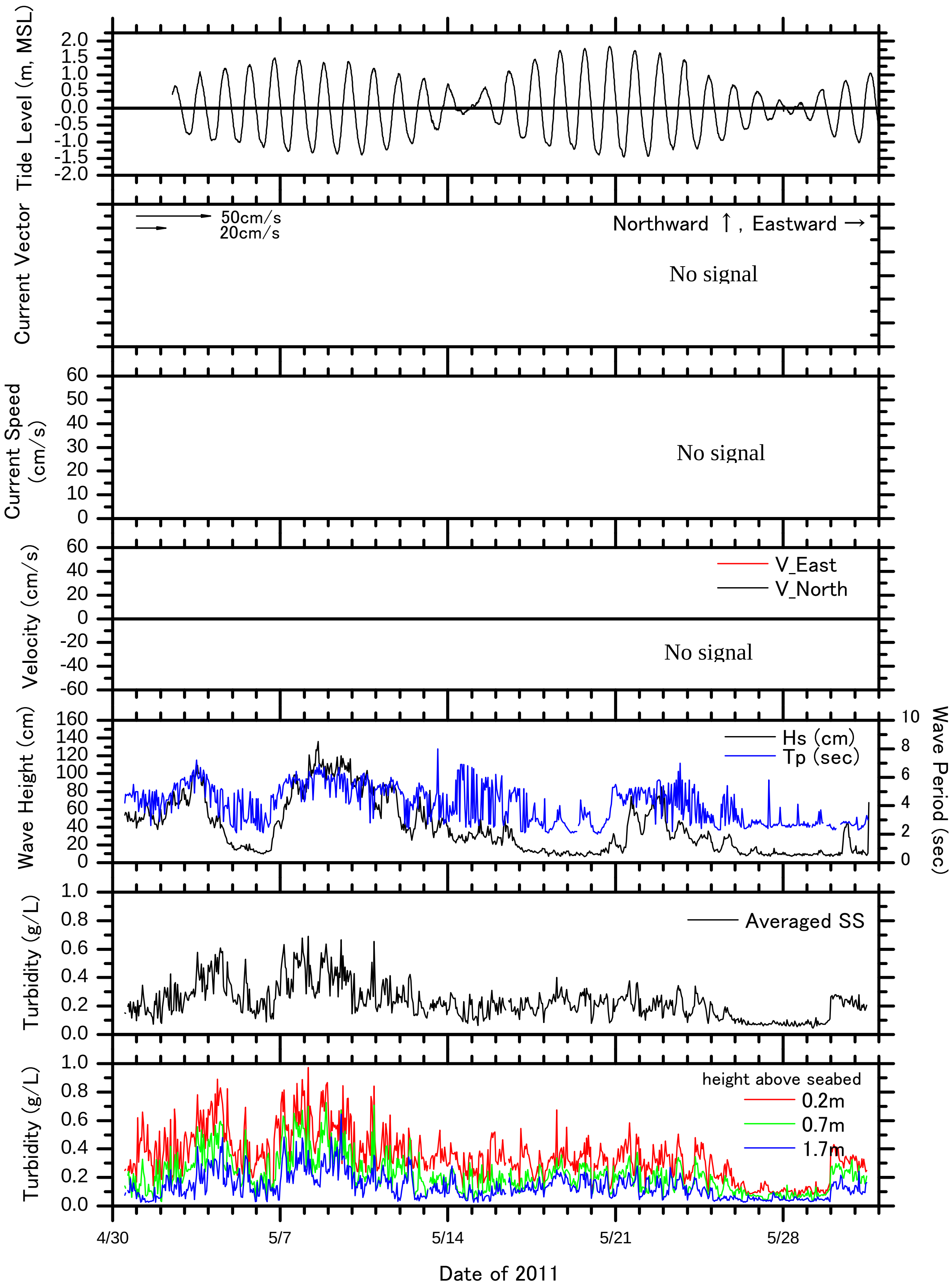



**Figure 2.3.9 Time series of Current, wave, and Turbidity at C5**

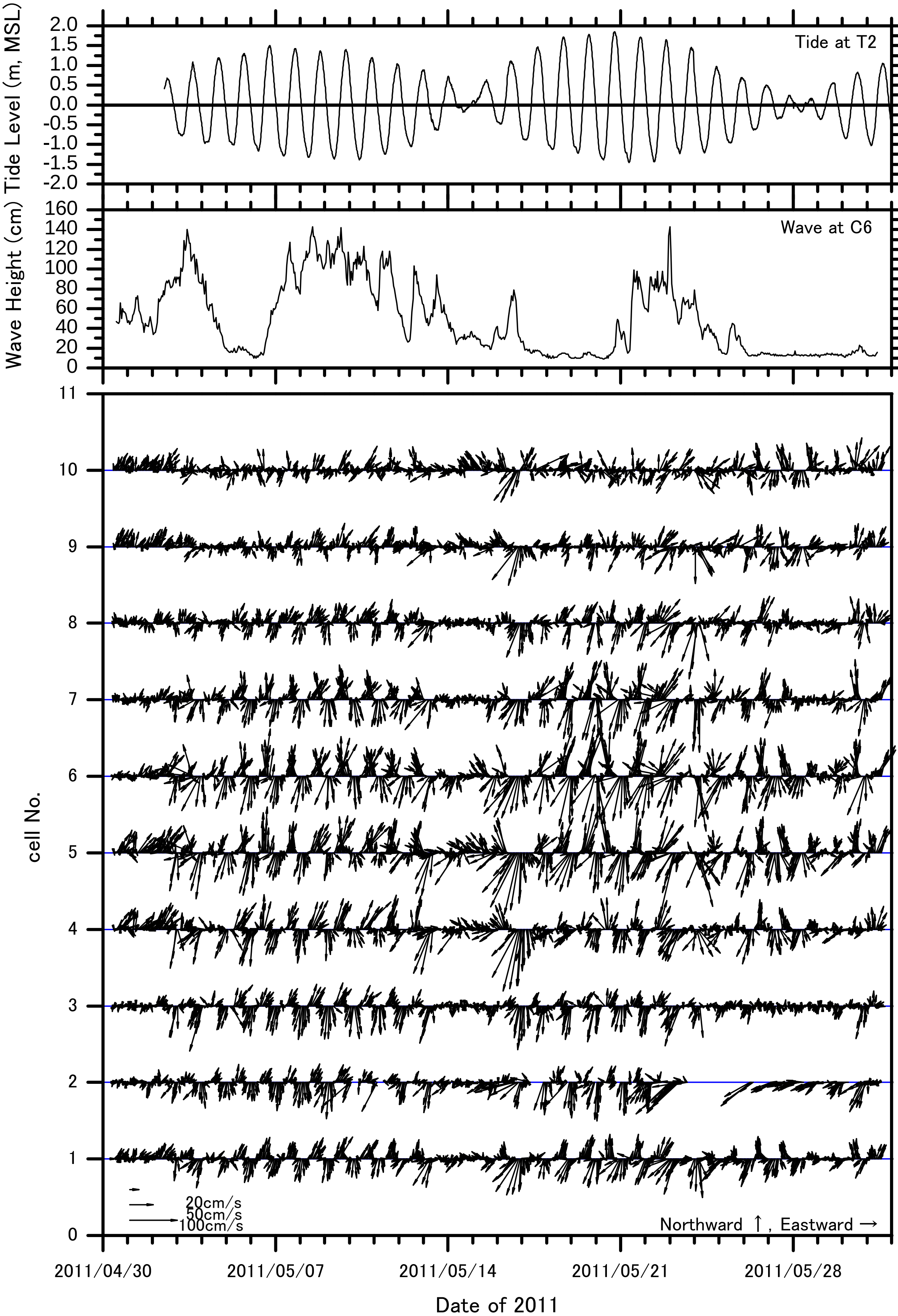



**Figure 2.3.10 Result of Current observation at C1**

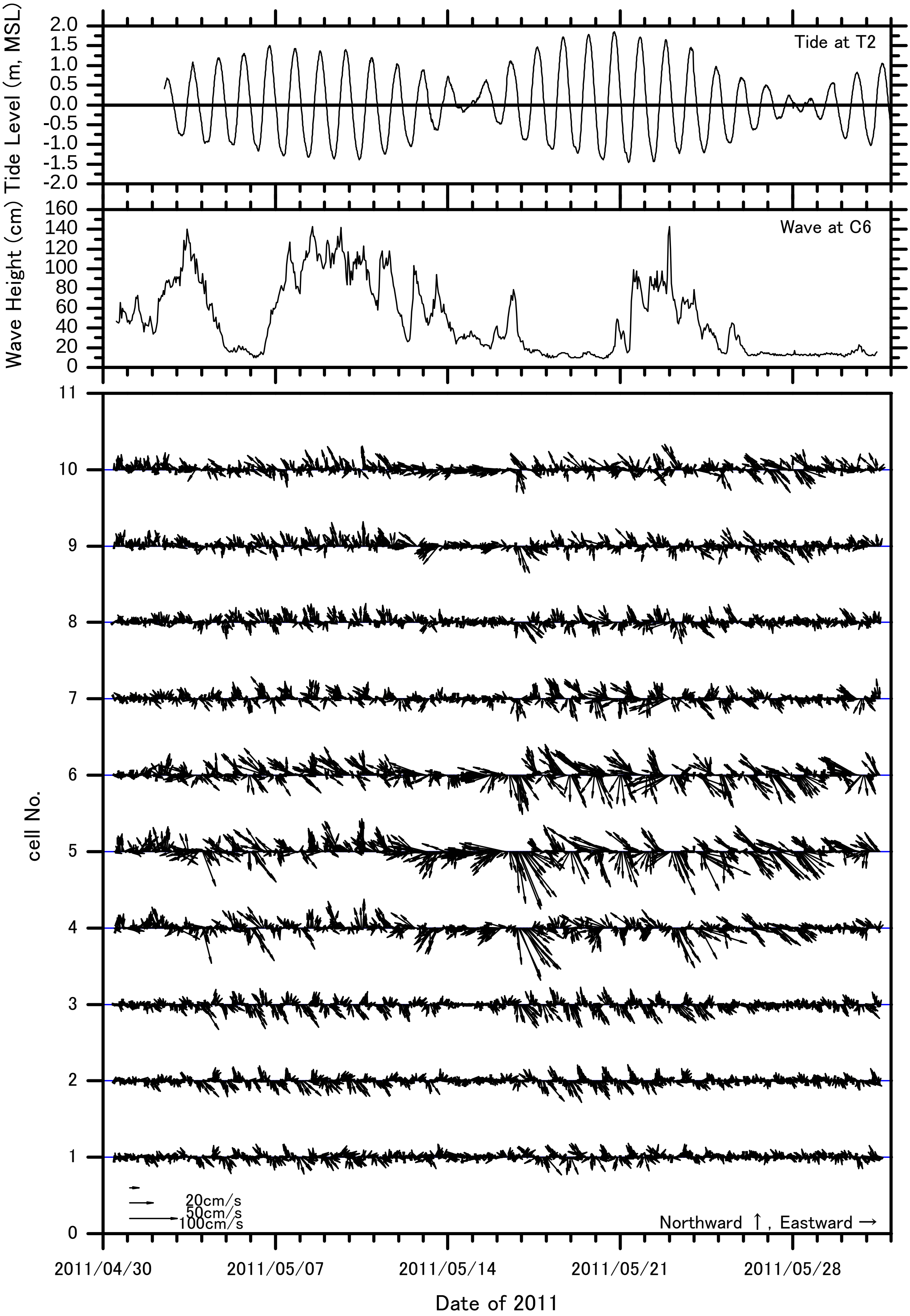



**Figure 2.3.11 Result of Current observation at C3**

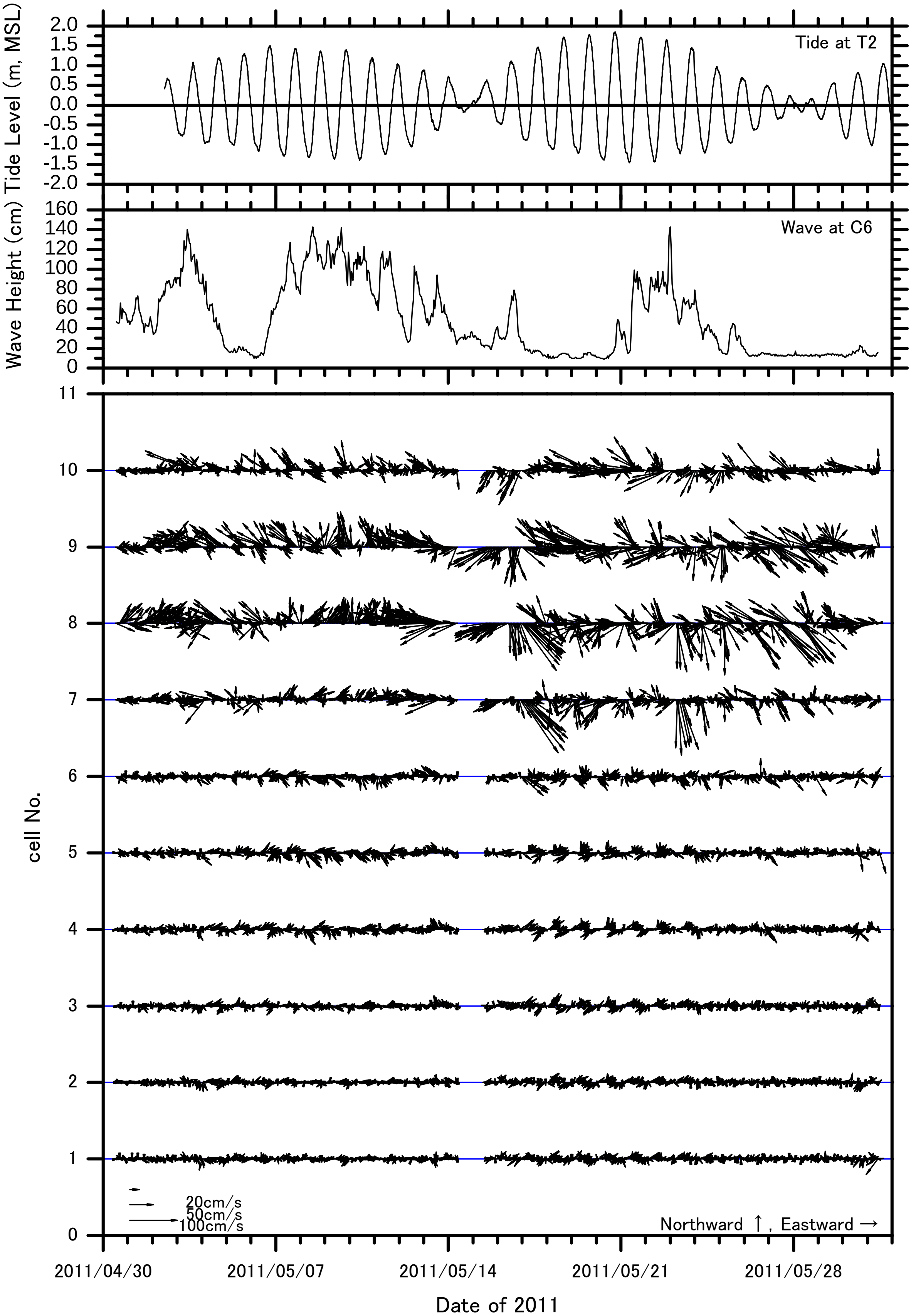



**Figure 2.3.12 Result of Current observation at C4**

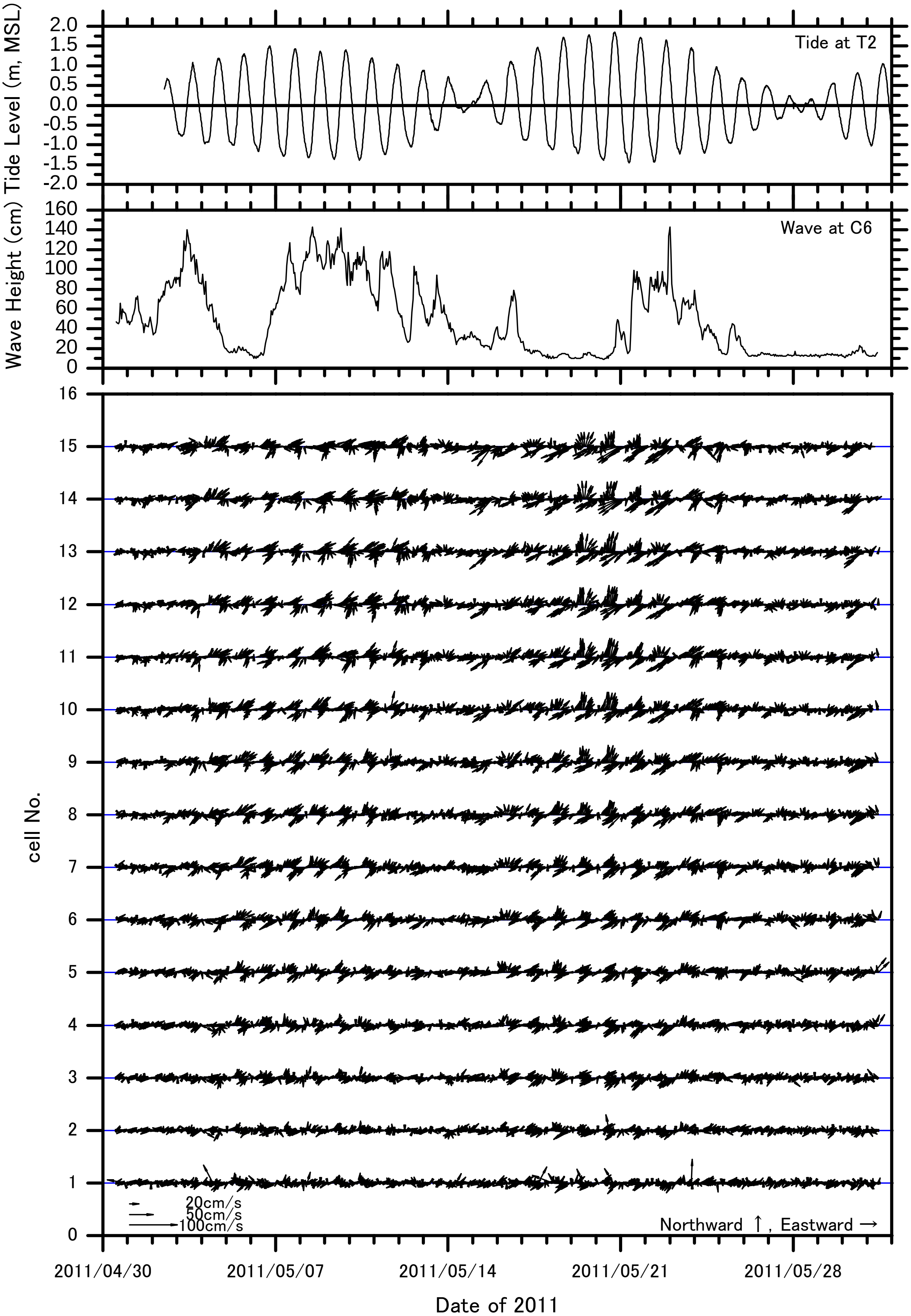



**Figure 2.3.13 Result of Current observation at C6**

### 2) Current Rose

Figure 2.3.14 shows current roses of the stations of C1, C3, C4, and C6. The stations are located along the channel. The current roses are made by the frequency analysis from the depth-averaged current velocity data. From the figure, current direction from S to WSW seems prevail at the station C1. For the station C3, current direction seems dominant along the channel. For the station C4 and C6, current direction seems dominant in ENE and SW.

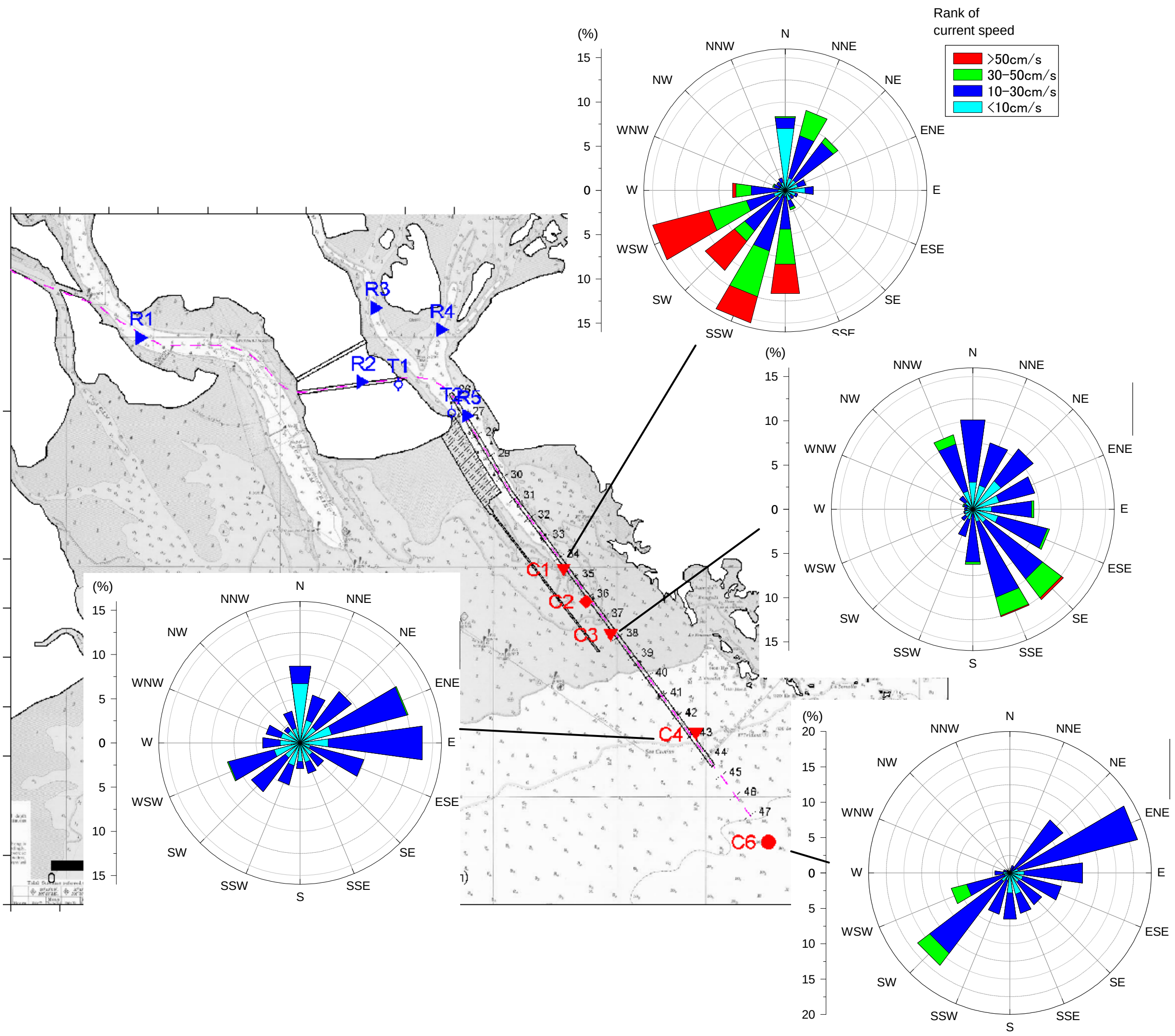



**Figure 2.3.14 Current Rose at C1, C3, C4, and C6**

### 3) Mean velocity

Table 2.3.4 is layer averaged velocities obtained from the whole observation record. Figure 2.3.15 shows velocity components in vertical distributions. The magnitude of the mean velocity is small in the range of approximately 5 cm/s, and some difference in direction from top to bottom is seen in the figure.

**Table 2.3.4 Layer-averaged current velocity as the mean velocity of whole record**

| | | Layer-averaged velocity | | | Depth averaged |
|---|---|---|---|---|---|
| | | bottom | middle | top | |
| C1 | Vel (cm/s) | 7.45 | 2.32 | 3.22 | 1.44 |
| | Dir (deg.) | 205.5 | 309.7 | 10.7 | 256.4 |
| C3 | Vel (cm/s) | 4.44 | 5.67 | 5.21 | 2.27 |
| | Dir (deg.) | 110.8 | 269.6 | 309.7 | 282.7 |
| C4 | Vel (cm/s) | 2.26 | 3.55 | 10.81 | 1.38 |
| | Dir (deg.) | 70.7 | 124.6 | 280.8 | 271.1 |
| C6 | Vel (cm/s) | 1.09 | 1.28 | 1.23 | 0.94 |
| | Dir (deg.) | 44.7 | 52.6 | 117.7 | 68.3 |

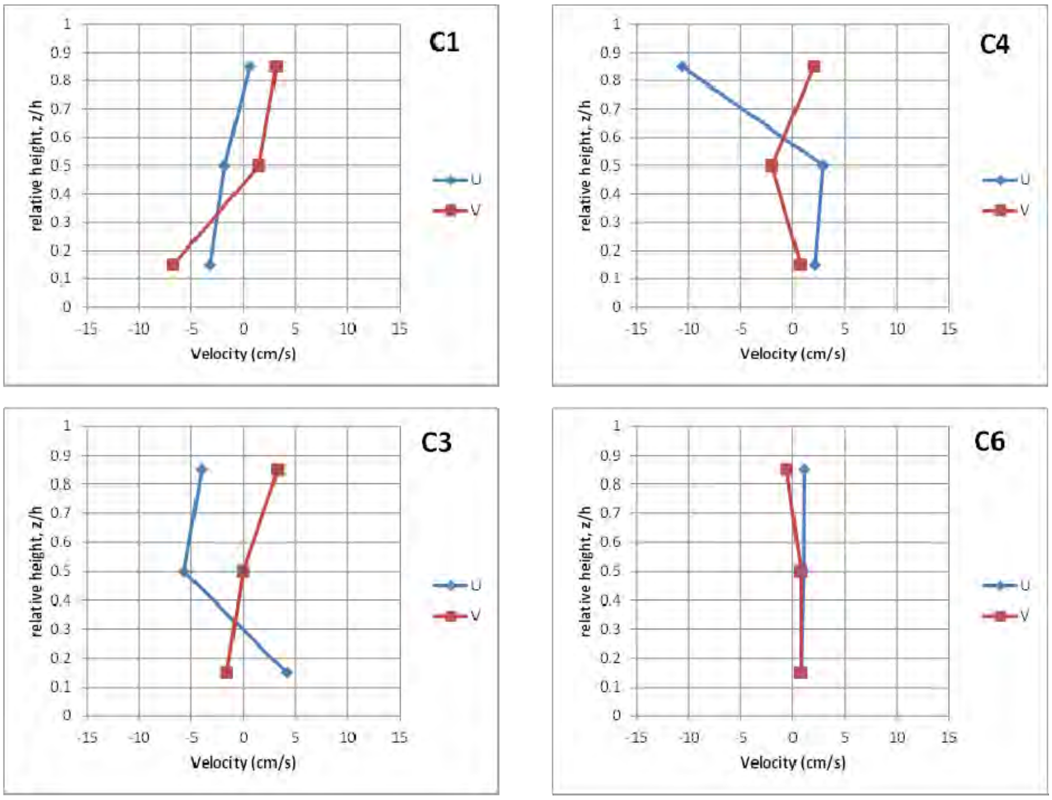



**Figure 2.3.15 Layer averaged velocity components for 3 layers of Bottom, Middle, and Top. (U=Eastward, V=Northward)**

### 4) Correlation of waves

Waves were measured at Station C1 to C6 by using wave meter or optional function of current meter. Figure 2.3.16 shows a comparison of time series of wave height and Figure 2.3.18 shows the results of correlation analysis of wave height between C6 (located at the most offshore) and the other. Figure 2.3.17 shows a wave rose from the observation data at C6. During the survey period, it is confirmed that dominant wave direction was from SSE.

The correlation of wave height between the data of C6 and the others is high and the reduction rate of wave height varies location to location. As the locations of C1, C2, and C3 are on the complex topography between the channel and the sand bar extending at the west side of the channel, it is possible that the waves are influenced by the complex topography.

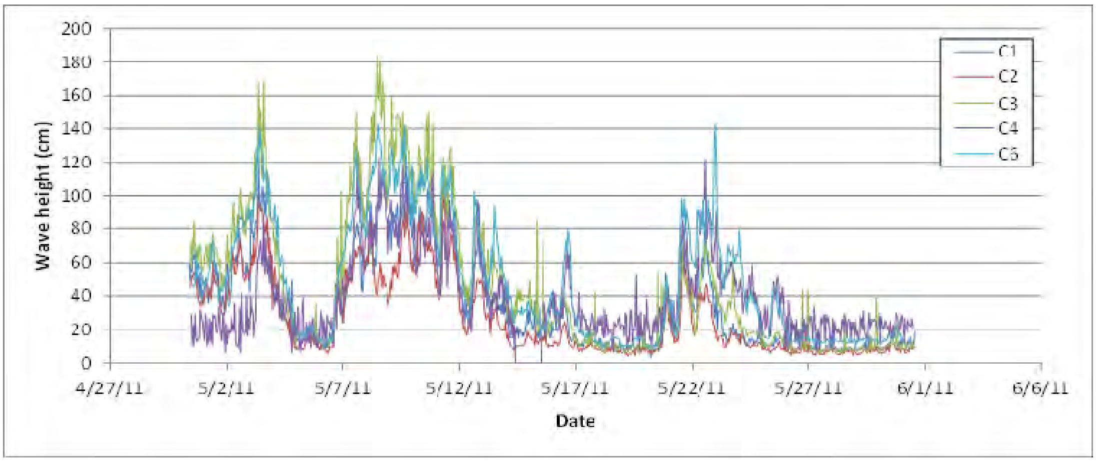



**Figure 2.3.16 Time series of wave height at stations of C1-C6**

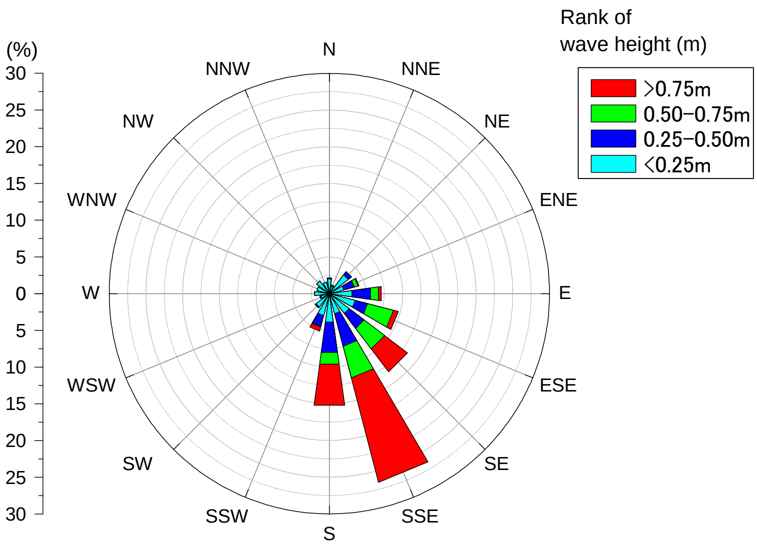



**Figure 2.3.17 Wave Rose from the observation data at C6**

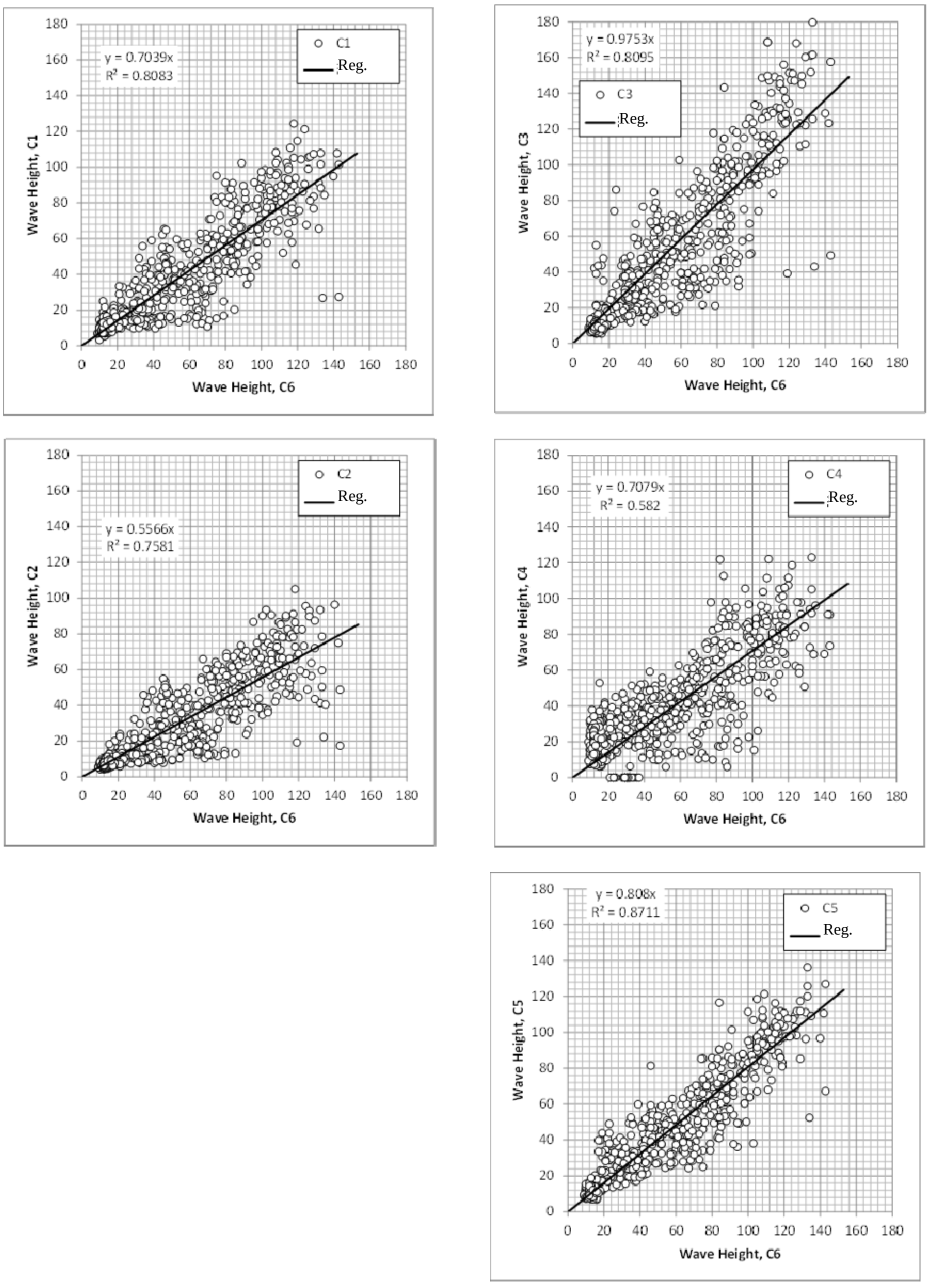



**Figure 2.3.18 Correlation of wave height between the offshore station of C6 and others**

### 2.3.3 Results of Observation of river section (R1 – R5)

As the results of the observation at R1 – R6, time series of tide level (at T2), current vectors of the depth-averaged current, current speed, current components in the east and north direction, suspended sediment concentration of 3 layer-averaged, and suspended sediment of 3 layers of 0.2H, 0.6H, and just above the sea bed (Bed) are shown, where H is the water depth. The suspended sediment concentration for the river section is directly measured by water sampling at each station. Also, Figure 2.3.10 to Figure 2.3.13 show current velocity vectors of each observation layer.

In the observation of river section, the dominant current direction is along the river and changes oscillatory with flood and ebb tide. In particular, R1 and R5 where are located in the mouth of Bach Dang River and Lach Huyen Estuary, strong tidal current has occurred during spring tide. While, the current speed at R2, located in Ha Nam canal, is slower than other stations indicating that the sediment from Bach Dang River is not supplied into Lach Huyen Port area directly.

On suspended sediment concentration, the variation of concentration is not so significant in all stations of R1 – R5. The range of concentration was approximately 0.1 – 0.3 g/L at all stations.

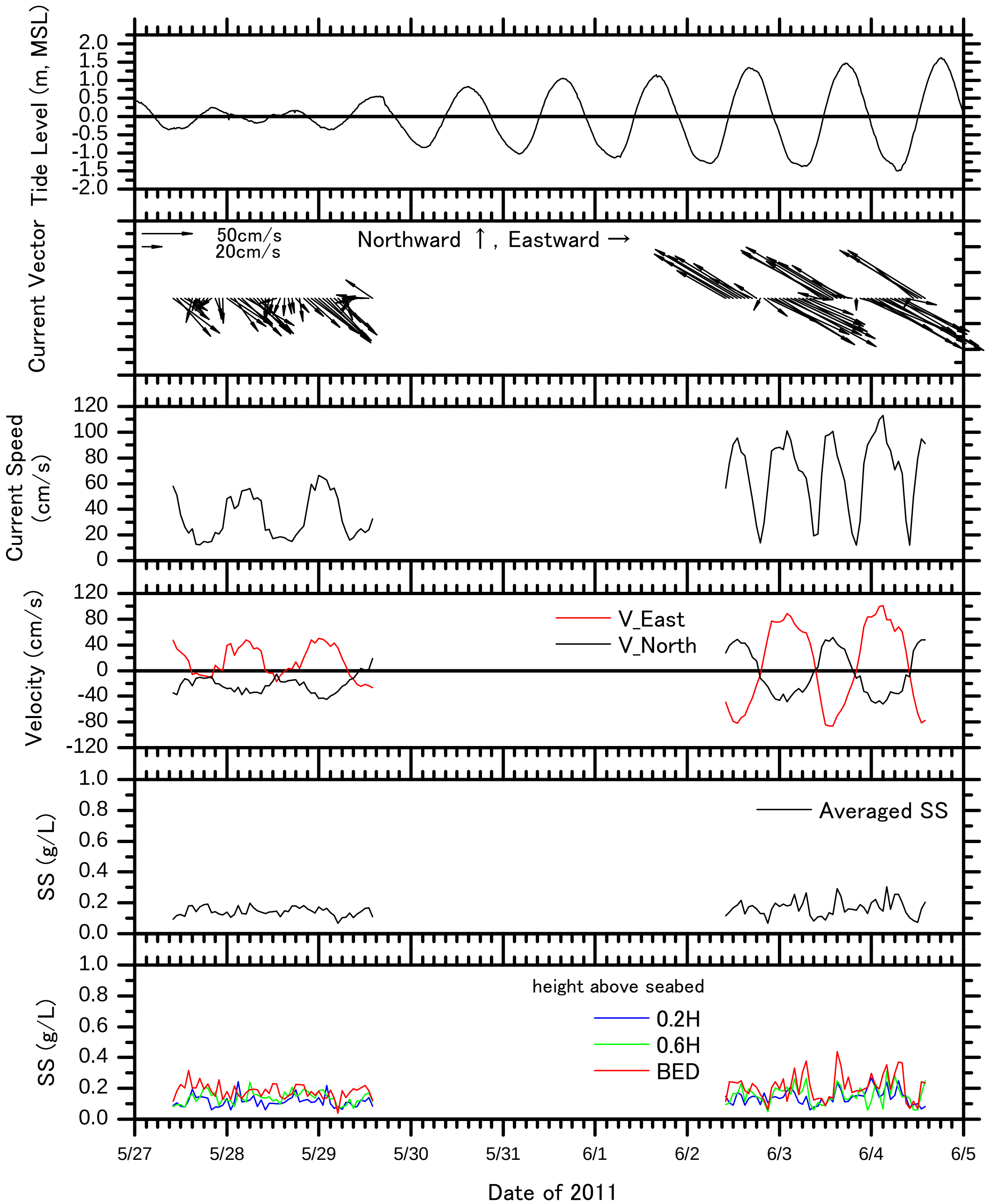



**Figure 2.3.19 Time series of Current and SS-concentration at R1**
**(52 hour observation for Neap and Spring Tide)**

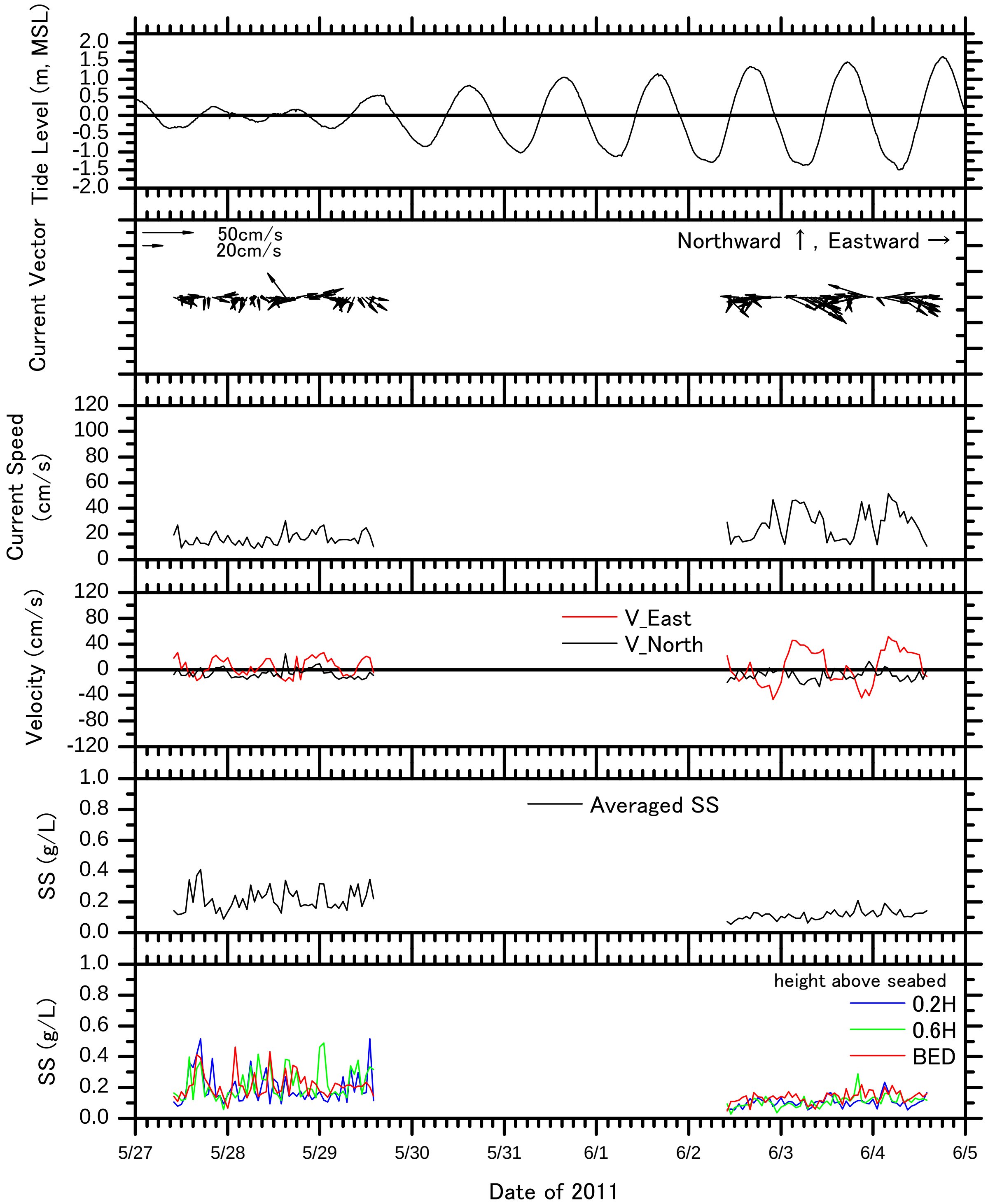



**Figure 2.3.20 Time series of Current and SS-concentration at R2**
**(52 hour observation for Neap and Spring Tide)**

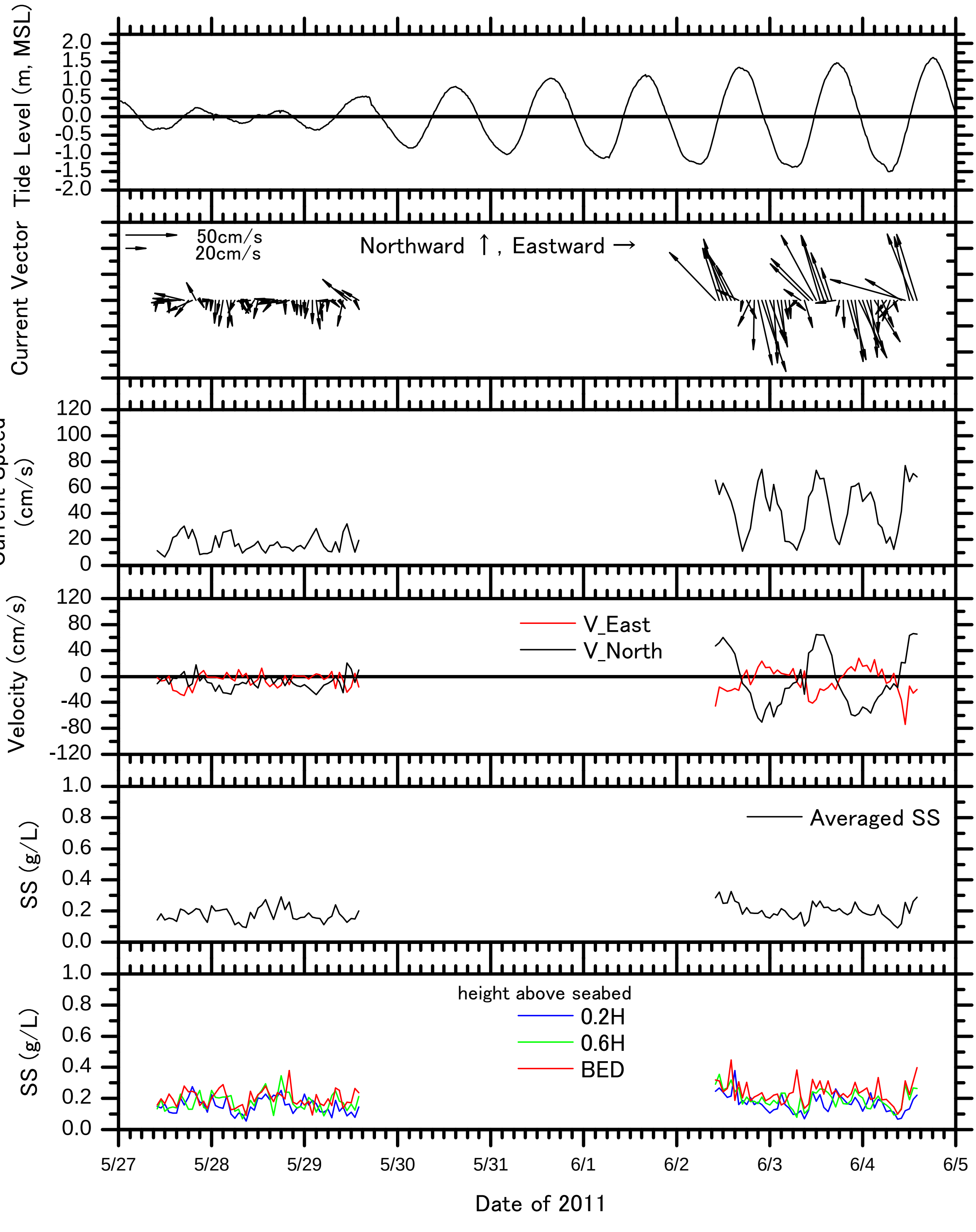



**Figure 2.3.21 Time series of Current and SS-concentration at R3**
**(52 hour observation for Neap and Spring Tide)**

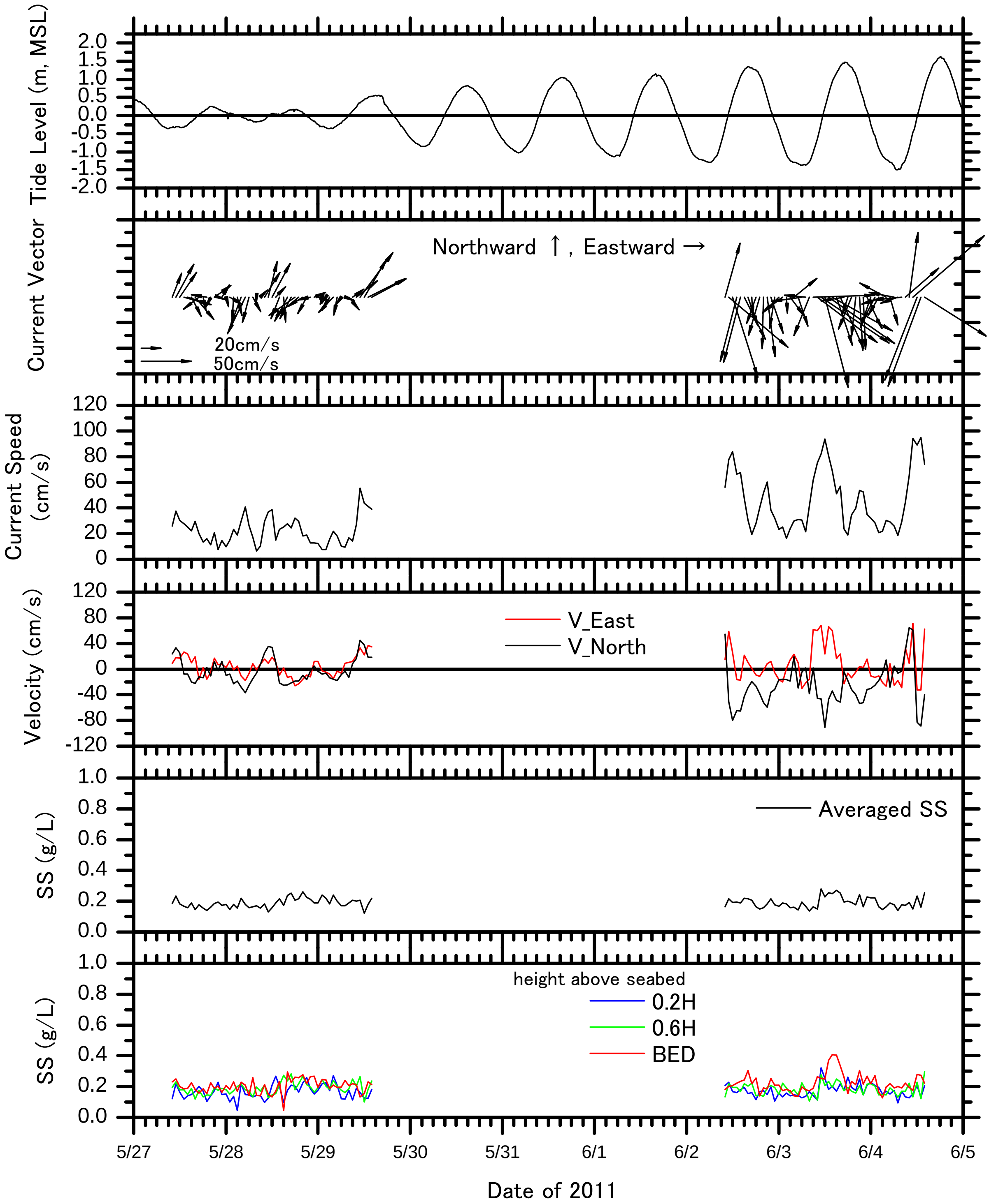



**Figure 2.3.22 Time series of Current and SS-concentration at R4 (52 hour observation for Neap and Spring Tide)**

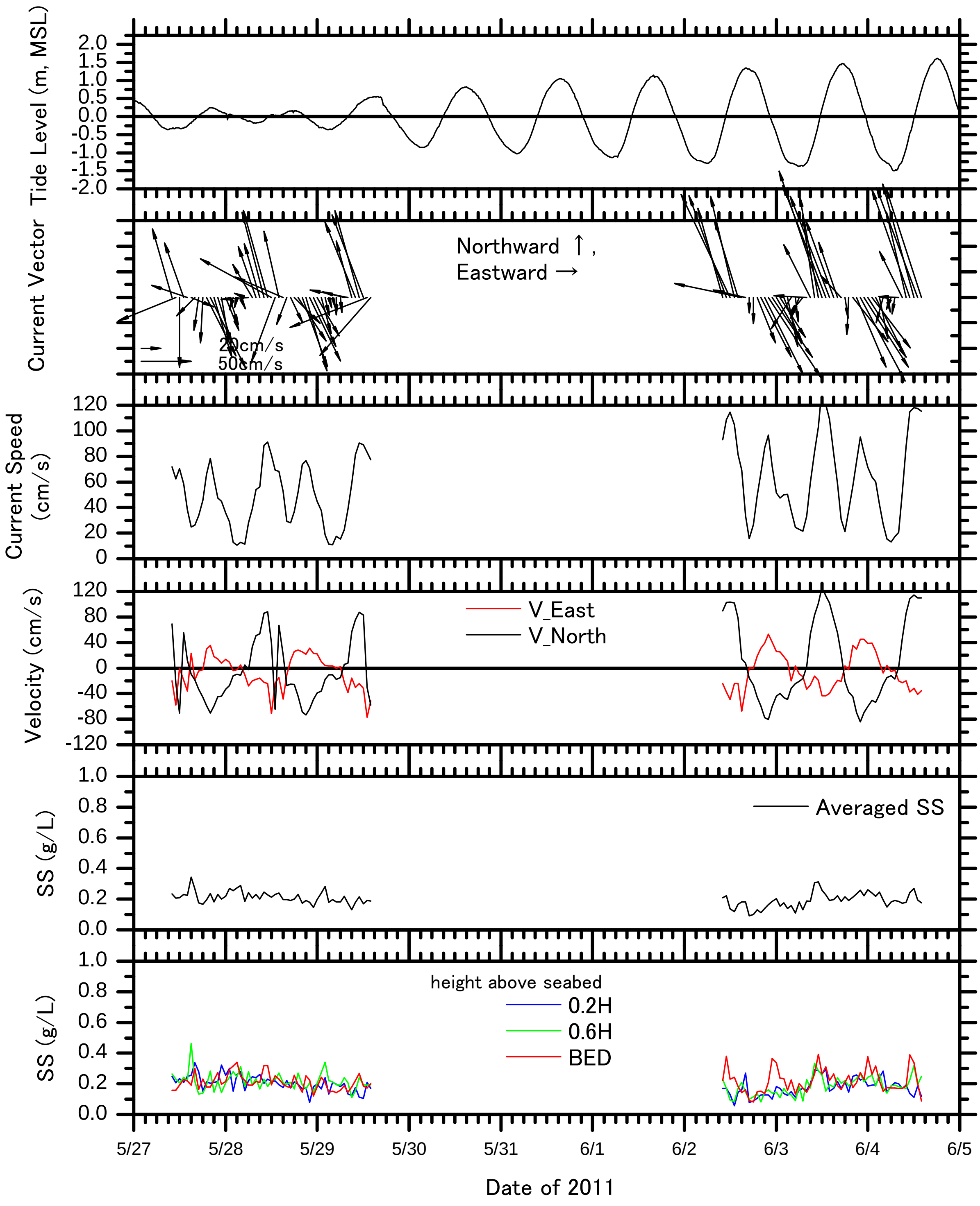



**Figure 2.3.23 Time series of Current and SS-concentration at R5**
**(52 hour observation for Neap and Spring Tide)**

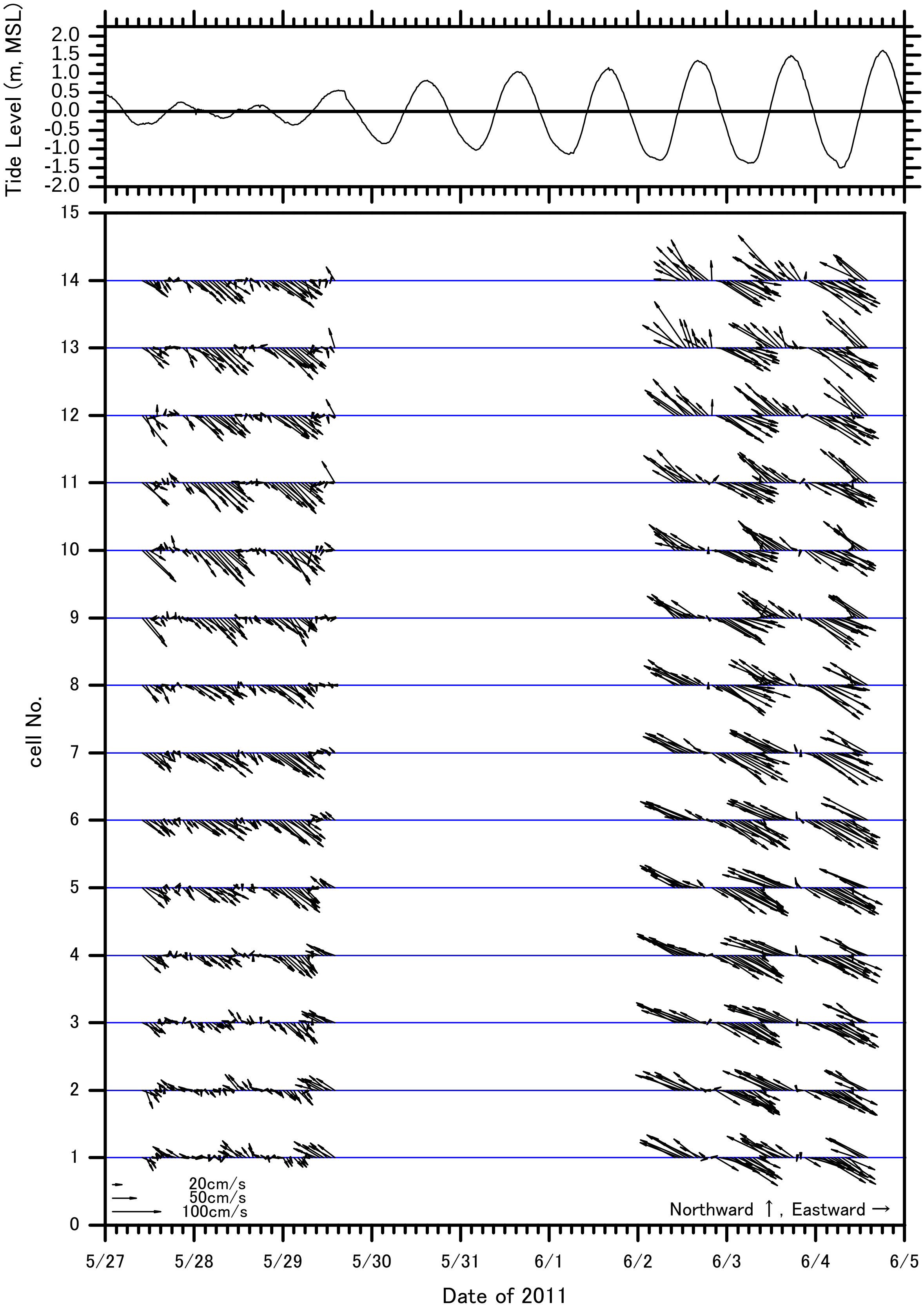



**Figure 2.3.24 Time series of multi-layer current vectors at R1**

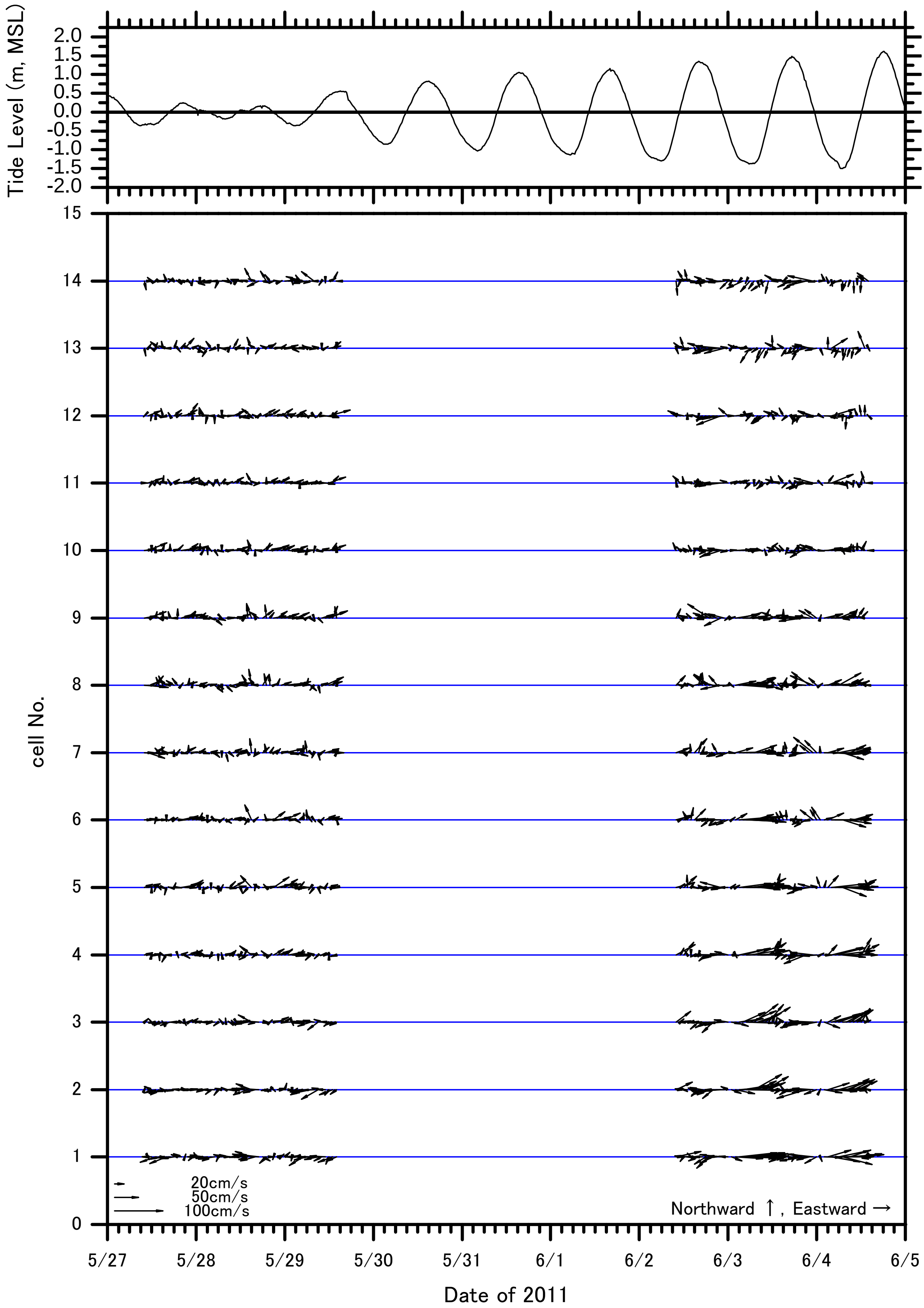



**Figure 2.3.25 Time series of multi-layer current vectors at R2**

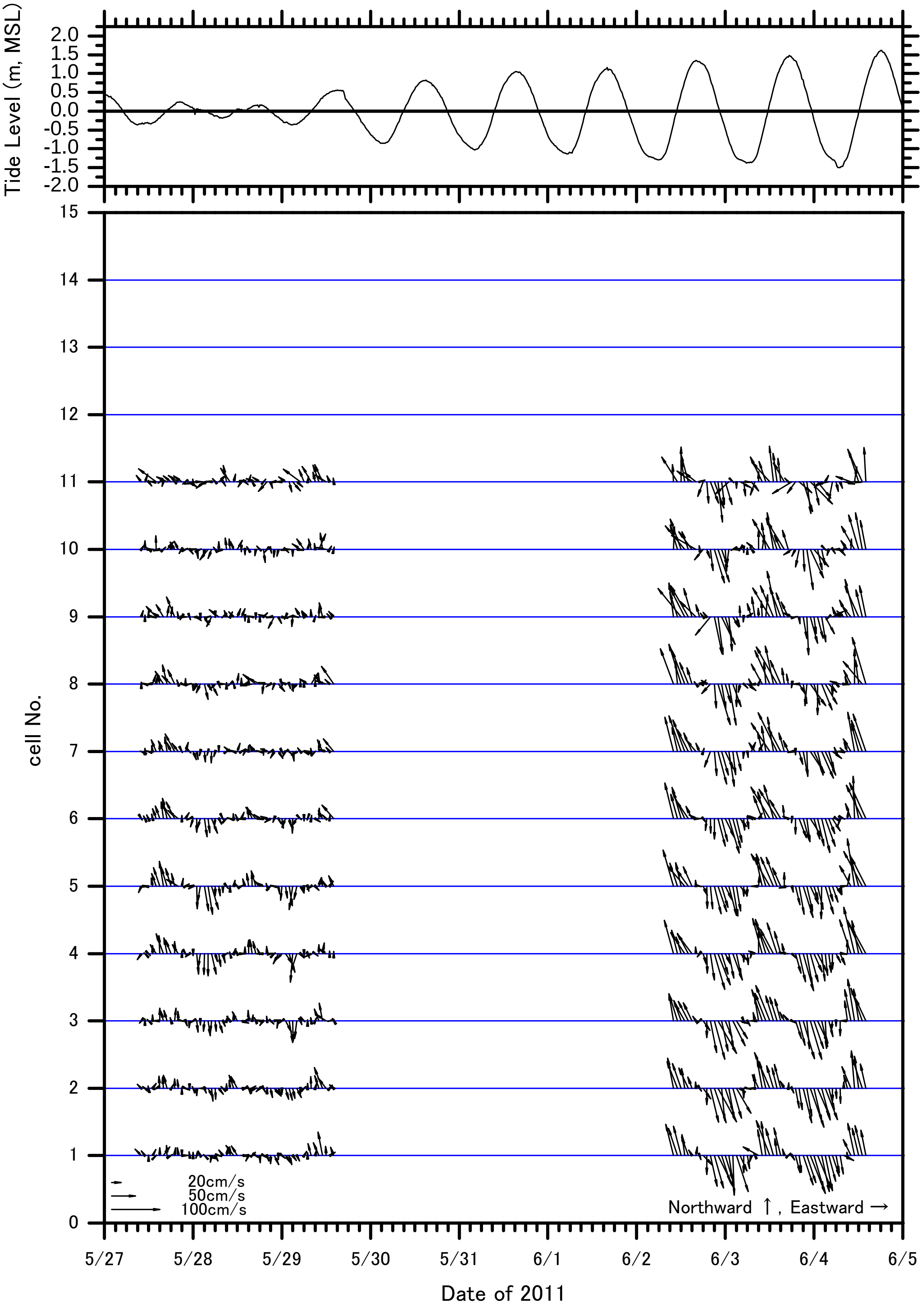



**Figure 2.3.26 Time series of multi-layer current vectors at R3**

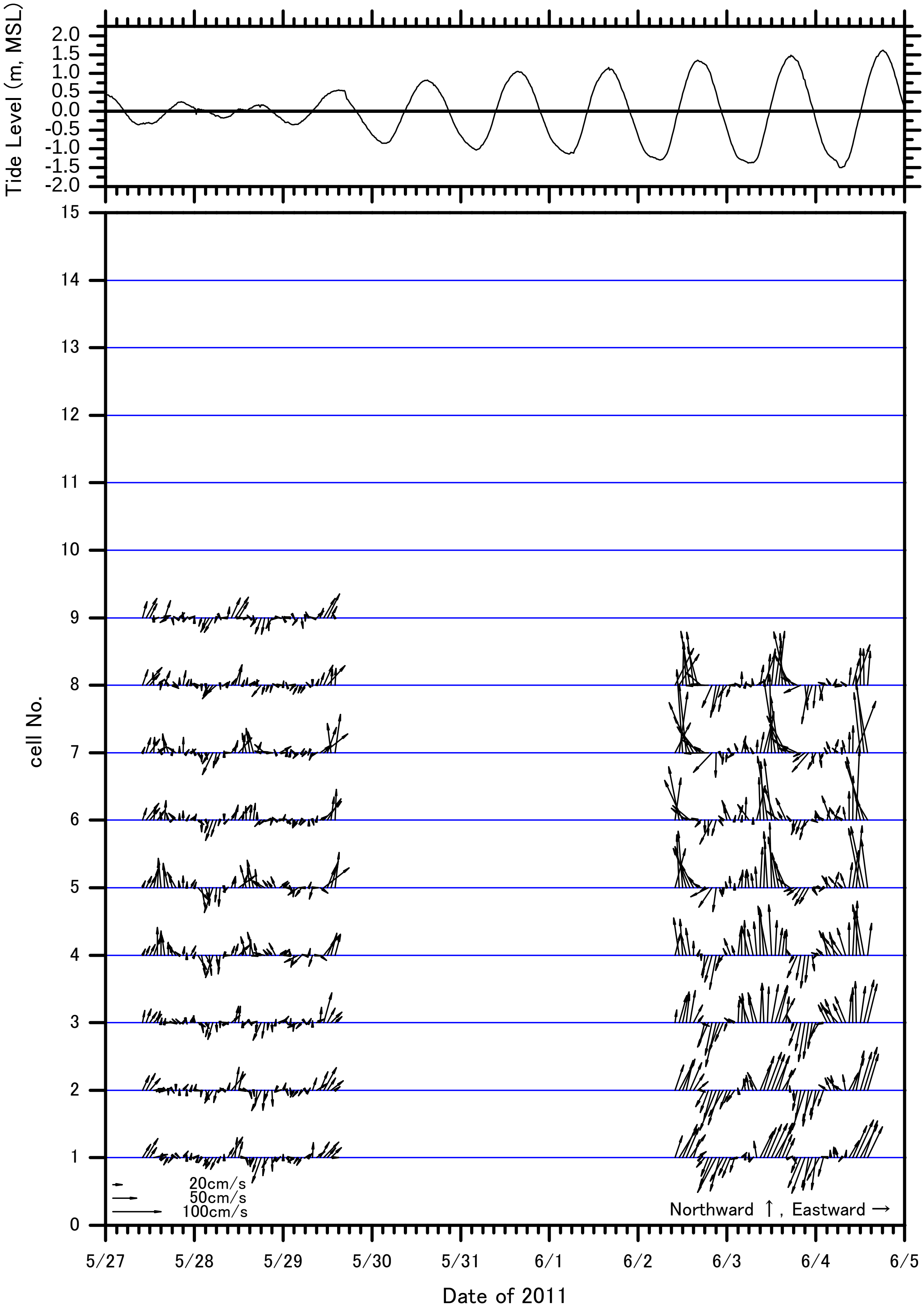



**Figure 2.3.27 Time series of multi-layer current vectors at R4**

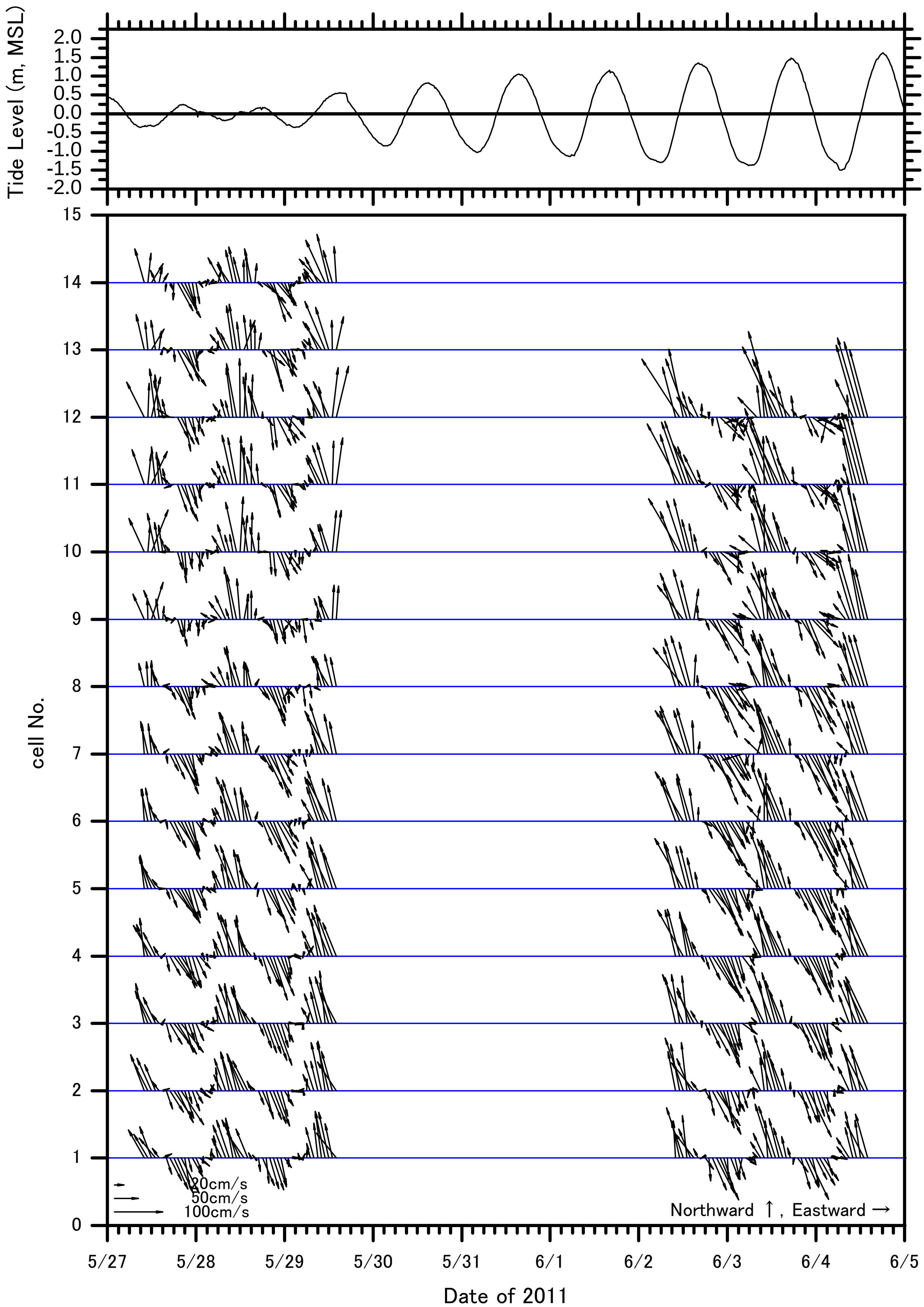



**Figure 2.3.28 Time series of multi-layer current vectors at R5**

### 2.3.4 Summary of the observation

In this study, simultaneous observation of current, wave, and turbidity were carried out to obtain useful information for sedimentation simulations. The survey was conducted with 6 stations in the sea and 5 stations in the river connected to Lach Huyen Port area, in May, 2011. At the stations of C1 to C6 in the sea area, 30 day consecutive observation was carried out. At the stations of R1 to R5 in the rivers 52 hour consecutive observation for high (Spring) tide and Low (Neap) tide were conducted.

Table 2.3.5 and Table 2.3.6 are summarized tables of the observation. The mean and maximum values of wave height, current velocity for depth-averaged value, and the depth averaged suspended sediment (turbidity) are shown in Table 2.3.5. Also, the values for current and suspended sediment are shown in Table 2.3.6 for high and low tide, respectively.

In the wave observation, the mean wave height is approximately 0.4 m, and the maximum wave height is observed 1.43 m at the most offshore station of C6, and 1.83m at the station C3. The dominant direction of the offshore wave was in the SSE direction during the survey period. The maximum current velocity was 1.15 m/s at the station C1, and has a tendency that the maximum velocity decreases with the distance from the Lach Huyen Port area. On the suspended sediment concentration, the range of mean concentration is 0.17 – 2.2 g/L and that of maximum is 0.4 – 1.0 g/L.

In the observation for the rivers, maximum current velocity of 1.33 m/s is obtained at R5 located at the mouth of Lach Huyen estuary during the high tide and the next is 1.1m/s at R1 located at the mouth of Bach Dang River. On the suspended concentration, the range of mean concentration is obtained 0.15 – 0.21 g/L and the value is in the same order as that of sea area. Also, the range of maximum concentration is 0.2 – 0.4 g/L and is lower than the range of maximum concentration in the sea area.

Thus, from the simultaneous observation, the data on relation between forcing conditions of wave and current and suspended sediment have been obtained. These data are helpful for verification of simulation study of sediment transport around the Lach Huyen Port area.

**Table 2.3.5 Mean and Maximum values at C1-C6 over whole recording period.**

| Station | Wave Height (cm) | | Current velocity (cm/s) | | Suspended Sediment (g/L) | | |
|---|---|---|---|---|---|---|---|
| | Mean | Max | Mean | Max | Mean | Max | Min |
| C1 | 33.9 | 124.4 | 30.14 | 114.59 | 0.220 | 0.699 | 0.050 |
| C2 | 26.7 | 105.0 | − | − | 0.171 | 0.697 | 0.038 |
| C3 | 45.5 | 183.4 | 15.71 | 59.16 | 0.174 | 0.990 | 0.053 |
| C4 | 39.4 | 122.9 | 12.29 | 31.94 | 0.173 | 0.418 | 0.059 |
| C5 | 39.5 | 136.2 | − | − | 0.230 | 0.691 | 0.045 |
| C6 | 48.3 | 143.0 | 16.31 | 43.53 | − | − | − |

**Table 2.3.6 Mean and Maximum values of observation at R1-R5 over whole recording period.**

| Station | Current velocity (cm/s) | | | | Suspended Sediment (g/L) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Low tide (Neap tide) | | High tide (Spring tide) | | Low tide (Neap tide) | | | High tide (Spring tide) | | |
| | Mean | Max | Mean | Max | Mean | Max | Min | Mean | Max | Min |
| R1 | 33.75 | 66.30 | 69.00 | 113.25 | 0.143 | 0.199 | 0.066 | 0.167 | 0.304 | 0.067 |
| R2 | 16.26 | 30.29 | 27.53 | 51.43 | 0.216 | 0.41 | 0.087 | 0.115 | 0.211 | 0.055 |
| R3 | 16.88 | 32.04 | 43.75 | 76.87 | 0.177 | 0.292 | 0.094 | 0.202 | 0.325 | 0.091 |
| R4 | 22.37 | 55.43 | 46.60 | 94.70 | 0.187 | 0.26 | 0.121 | 0.191 | 0.281 | 0.138 |
| R5 | 48.85 | 91.22 | 64.98 | 133.91 | 0.213 | 0.342 | 0.131 | 0.191 | 0.312 | 0.091 |