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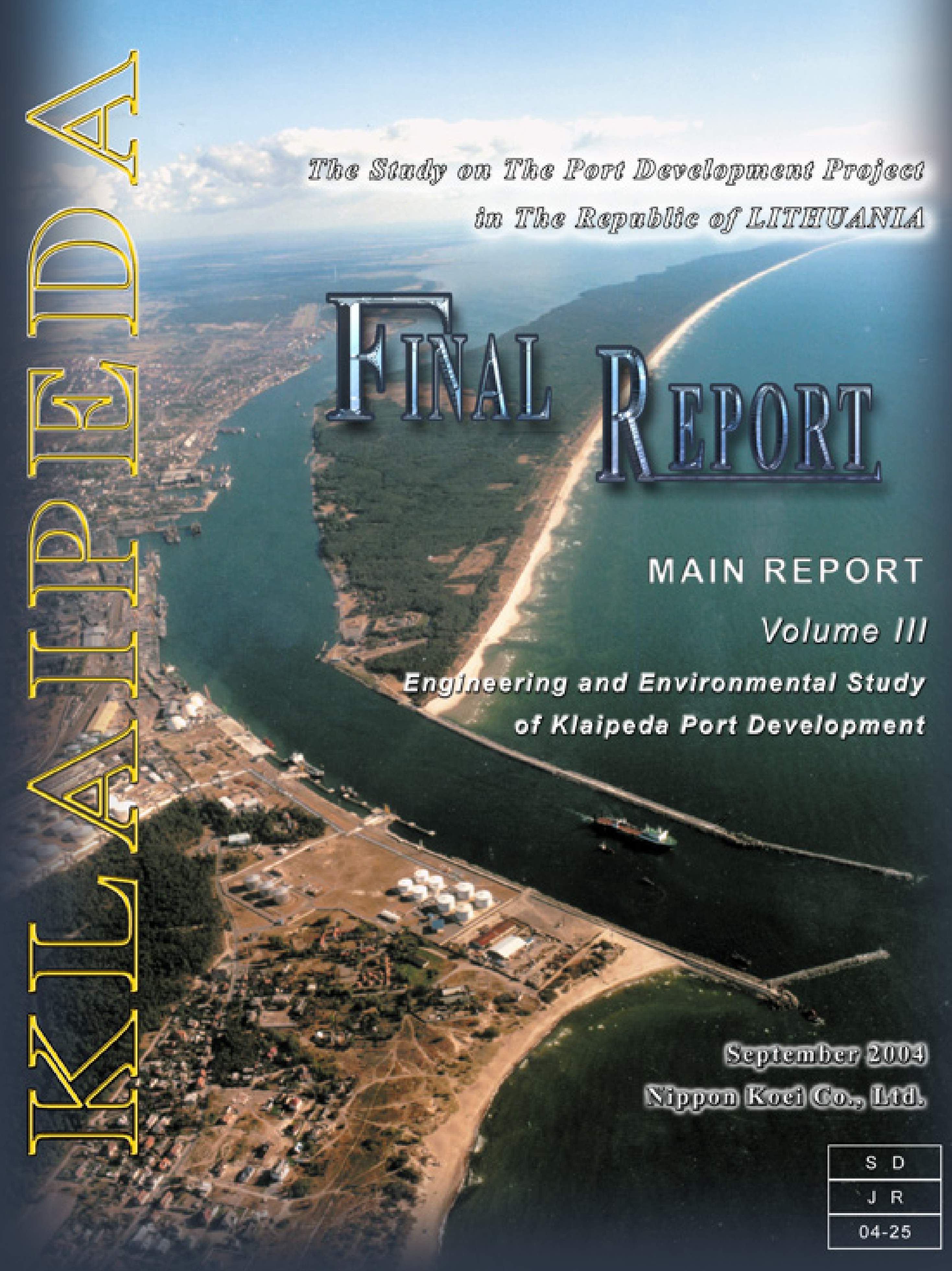

KLAIPEDA

*The Study on The Port Development Project in The Republic of LITHUANIA*

# FINAL REPORT

## MAIN REPORT

*Volume III*

***Engineering and Environmental Study of Klaipeda Port Development***

September 2004
Nippon Koei Co., Ltd.

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THE PORT DEVELOPMENT PROJECT
IN THE REPUBLIC OF LITHUANIA

# VOLUME III

# MAIN REPORT
## *ENGINEERING AND ENVIRONMENT STUDY OF KLAIPEDA PORT DEVELOPMENT*

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# ABBREVIATIONS TABLE

| | |
|---|---|
| 'E' | Road European Road Number |
| 2K | Project K is the initial of Klaipeda Port and Kaliningrad Port |
| APEC | Asia Pacific Economic Cooperation |
| AIS | Automatic Identification System |
| BAF | Bunker Adjustment Fee |
| BBT | Baltic Bulk Terminal |
| BC | Belarusian Railways |
| B/C | Benefit/Cost |
| BOD | Biochemical Oxygen Demand |
| BOT | Build, Operate and Transfer |
| Bpd | Barrels per day |
| BSL | Baltic Sea Level |
| CARs | The Central Asian Republics |
| CD | Chart Datum |
| CEDA | Central Dredging Association |
| CFC | Standard Conversion Factor |
| CFS | Container Freight Station |
| CFSL | Conversion Factor for Skilled Labour |
| CFUL | Conversion Factor for Unskilled Labour |
| CIF | Cost, Insurance and Freight |
| CIM | Uniform Rules Concerning the Contract for International Carriage of Goods by Rail |
| CIS | Commonwealth of Independent States |
| CMR | Centre of Marine Research, Ministry of Environment |
| CNC | Compagnie Nouvelle de Conteneurs |
| DAP | Diammonium Phosphate |
| DEP | Department of Environment Protection |
| DGPS | Differential Global Positioning System |
| DIN | Deutsches Institut fur Normung e.V |
| DWT | Dead Weight Tonne |
| EBRD | European Bank for Reconstruction and Development |
| EC | European Communities |
| ECE | Economic Commission for Europe |
| EDI | Electronic Data Interchange |
| EIA | Environmental Impact Assessment |
| EIB | European Investment Bank |
| EIRR | Economic Internal Rate of Return |
| EIU | Economist Intelligence Unit |
| EPD | Environmental Protection Department |
| ERR | Economic Rate of Return |
| ESN | European Shortsea Network |
| ESTO | European Sea Ports Organization |
| ETSNG | Unified Cargo Nomenclature of CIS (Russian Abbreviation) |
| EU | European Union |
| EVR | Estonian Railway |
| F/S | Feasibility Study |

| | |
|---|---|
| FAO | Food & Agriculture Organisation |
| FEC | Federal Energy Commission |
| FEZ | Free Economic Zone |
| FIRR | Financial Internal Rate of Return |
| FOB | Free on Board |
| FSU | Former Soviet Union |
| GDP | Gross Domestic Product |
| GOJ | Government of Japan |
| GTA | Global Trade Atlas |
| HKN | Harmonized Cargo Classifier (Russian Abbreviation) |
| IADC | International Association Dredging Companies |
| IBRD | International Bank for Reconstruction and Development |
| ICD | Inland Container Depot |
| ICF | Intercontainer-Interfrigo |
| IEE | Initial Environmental Examination |
| IMDG | International Maritime Dangerous Goods |
| IMF | International Monetary Fund |
| IMO | International Maritime Organisation |
| IPC | Implementation Provisions of the Community |
| IRR | Internal Rate of Return |
| ISPA | Instrument for Structural Policies for Pre-Accession |
| ISPS | International Ship and Port Facility Security |
| IT | Information Technology |
| JICA | Japan International Cooperation Agency |
| KSSA | Klaipeda State Seaport Authority |
| KUBIS | Klaipeda Port Community Information System |
| KZH | Kazakhstan Railways |
| LAN | Local Area Network |
| LCL | less-than-carload |
| LDZ | Latvian Railway |
| LEI | Lithuanian Energy Institute |
| LG | Lithuanian Railways |
| LINAVA | Lithuanian National Road Carriers Association |
| LOA | Length Overall |
| LRP | Level Repayment Principle |
| MLA | Multi-Lateral Agreement |
| MOE | Ministry of Environment |
| MOF | Ministry of Finance |
| MOTC | Ministry of Transport and Communications |
| MTT | International Transit Tariff (Russian Abbreviation) |
| N/A | Not available |
| NATO | North Atlantic Treaty Organisation |
| NCC | National Container Company |
| NEN | North European Network |
| NIB | Nordic Investment Bank |
| NMBS | Belgian National Railways |
| NPV | Net Present Value |
| OCJD | Organization of Cooperation of Railways (Russian Abbreviation) |
| OD | Origin and Destination |
| OECD | Organization for Economic Co-operation and Development |

| | |
|---|---|
| OSJD | Organization for Railway Cooperation |
| PAHs | Polycyclic Aromatic Hydrocarbons |
| PHARE | Poland, Hungary, Aid of Economic Reconstruction |
| PIANC | Permanent International Association of Navigation Congresses |
| PTMS | Port Traffic Management System |
| RF | Russian Federation |
| Ro/Ro | Roll on Roll off |
| RTG | Rubber-Tire Gantry Cranes |
| RZD | Russian Railways |
| SCF | Standard Conversion Factor |
| SMGS | Agreement on International Goods Transports by Rail |
| SOLAS | Safety of Life at Sea |
| SPM | Single Point Mooring Buoy |
| TACIS | Technical Assistance of the Commonwealth of Independent States |
| TBT | Tributyl Tin |
| TEN | Trans-European Network |
| TEU | Twenty Foot Equivalent Unit |
| TINA | Transport Infrastructure Needs Assessment |
| TIR | Carnet TIR (Transport Internationaux Routiers:French; International Road Transport) |
| TOR | Terms of Reference |
| TRACECA | Transport Corridor Europe Caucasus Asia |
| UAIS | Universal Automatic Identification System |
| UAN | Urea Ammonium Nitrate |
| UIC | International Union of Railways (French abbreviation of Union Internationale Des Chemins de Fer) |
| UN | United Nations |
| USD | United States Dollars |
| VAT | Value Added Tax |
| VLCC | Very Large Crude Carrier |
| VTS | Vessel Traffic System |
| VTT | Technical Research Centre of Finland |
| WGS 84 | World Geodetic System 1984 |
| WTO | World Trade Organization |

## Abbreviation of Common Weights Measures and Technical Terms

| | |
|---|---|
| % | Percentage |
| $^0/_{00}$ | Parts per thousand |
| $\_^2$, $m^2$, sq. m | Square e.g. square metre(s) |
| $\_^3$, $m^3$, cu. m | Cubic e.g. cubic metre(s) |
| Bn or $10^9$ | Billion |
| GT | Gross ton(s) |
| HP, PS | Horsepower |
| hr or h | Hour(s) |
| Hz | Hertz |
| In. | Inch(es) |
| Kl | kilolitre(s) |
| knots | Marine speed measurement |
| Kph | Kilometres Per Hour |
| l | Litre |
| mg O/l | Milligrams of Oxygen per litre |
| Mill | Million |
| NM | Nautical mile(s) |
| No | Number (serial number) |
| no(s) | (units) |
| $^0$ | Degrees of latitude or longitude |
| $^oC$ | Celsius Degrees (Centigrade) |
| ppm | Parts per million |
| Psi | Pound per square inch |
| rpm | Revolutions per minute |
| W | Width |

# MEASUREMENT UNITS TABLE

| | |
|---|---|
| **Extent** | |
| $cm^2$ | Square-centimetres (1.0 cm x 1.0 cm) |
| $m^2$ | Square-metres (1.0 m x 1.0 m) |
| $km^2$ | Square-kilometres (1.0 Km x 1.0 Km) |
| ha. | Hectares (10,000 $m^2$ ) |
| **Length** | |
| mm | Millimetres |
| cm | Centimetres (10 mm) |
| m | Metres (100 cm) |
| km | Kilometres (1,000 m) |
| **Currency** | |
| US$ | United State Dollars |
| J¥ | Japanese Yen |
| ∈ | EURO |
| Lt. | Litas (3.4528Lt/∈) |
| **Weight** | |
| mg | Milligram (s) |
| g | Gram (s) (1,000 mg) |
| Kg | Kilogram (s) (1,000 g) |
| Ton, t or MT | Metric tonne (1,000 kg) |
| **Time** | |
| sec. | Seconds |
| min. | Minute (60 Sec.) |
| hr. | Hours (60 Min.) |

**Standard Conversions**

1 inch = 25.4 mm
1 feet = 0.3048 m

# CHAPTER 1 NATURAL CONDITIONS

# CHAPTER 1 NATURAL CONDITIONS

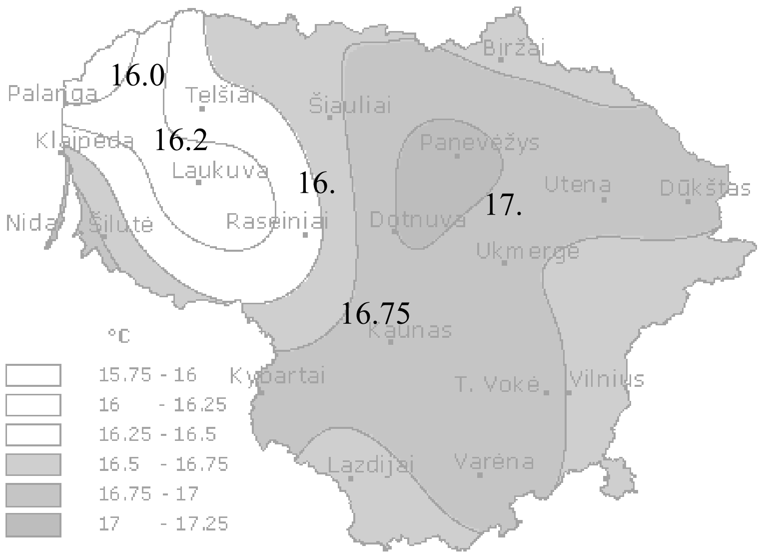
## 1.1 Meteorological Condition

### (1) Climate

Lithuania is located between the latitude of 54 and 56 degrees N and between the longitude of 21 and 26 degrees E. Lithuania holds two climate patterns such as maritime and continental weather. The maritime climate prevails in the 12-15 km wide coastal zone, and the continental in the eastern part of the country. The weather is generally changeable across the country. There is significant variation in the rainfall patterns and minimum temperature between the east and west of the country. The eastern half of the country experiences colder winter and the western coastal areas experience higher precipitation due to the maritime influence from the Baltic Sea.

### (2) Temperature

Figure III.1.1-1 shows a typical monthly summer average temperature (in July) covering of the whole area of Lithuania, which shows that the temperature in the western part of the country (coastal zone, including Klaipeda) is comparatively lower.




Source: Lithuanian Hydrometeorological Service
Note: Average temperature of July

**Figure III.1.1-1 Monthly Average of Summer Temperature (1960-1990)**

The monthly average of maximum, mean, and minimum temperatures at Klaipeda from 1961 to 1990 are summarised in Table III.1.1-1. In June, July, and August, a temperature is relatively high. The monthly average low is –5.2 °C in January.

The absolutely minimum and maximum temperatures recorded in the hyrdometeorology station in Klaipeda were –33.4 °C in February 1956 and 34.0 °C in August 1896,1917 and 1954 respectively.

**Table III.1.1-1 Monthly Maximum, Mean, and Minimum Temperatures in Klaipeda (1961-1990)**

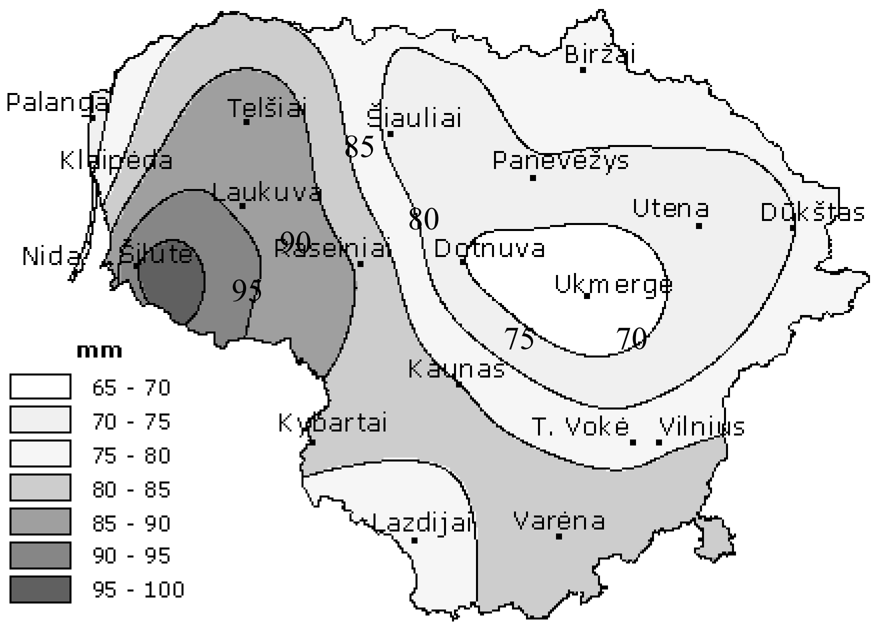
(Unit: °C)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Monthly Ave. Max. Temperature | -0.4 | -0.4 | 3.2 | 8.9 | 15.0 | 18.3 | 19.9 | 20.1 | 16.4 | 11.5 | 6.2 | 2.3 |
| Monthly Ave. Mean Temperature | -2.8 | -2.6 | 0.3 | 5.0 | 10.6 | 14.3 | 16.6 | 16.8 | 13.3 | 9.0 | 3.9 | -0.1 |
| Monthly Ave. Min. Temperature | -5.2 | -5.1 | -2.2 | 2.0 | 6.9 | 10.9 | 13.6 | 13.6 | 10.2 | 6.4 | 1.7 | -2.5 |

Source : Lithuanian Hydrometeorological Service

### (3) Precipitation

The average annual precipitation at Lithuania is 626mm; most rain falls in summer. Figure III.1.1-2 shows the monthly summer average precipitation in Lithuania. It shows comparatively high precipitation in the south-eastern part of the country.




Source: Lithuanian Hydrometeorological Service
Note: Average precipitation of July

**Figure III.1.1-2 Monthly Average of Summer Precipitation Isobath Map (1960-1990)**

The monthly average precipitation and number of days with rain in Klaipeda from 1961 to 1990 is shown in Table III.1.1-2. Though the precipitation is distributed around the year, but comparatively higher from August to November. Total precipitation is 735mm/year and the number of days with rain is 126 days.

**Table III.1.1-2 Monthly Average Precipitation and Number of Rainy Days in Klaipeda (1961-1990)**

(Unit: mm/day)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Average Precipitation | 50 | 31 | 39 | 36 | 39 | 56 | 74 | 83 | 89 | 80 | 90 | 68 | 735 |
| Number of Days with Rain/Snow | 12 | 8 | 9 | 7 | 7 | 8 | 10 | 11 | 13 | 12 | 15 | 14 | 126 |

Note : Days with rain at least 1.0mm.
Source : Lithuanian Hydrometeorological Service

### (4) Wind

The maximum and mean velocity of average monthly winds during the period of 10 years are shown in Appendix E 1 and summarized in Table III.1.1-3. According to this information, the monthly average wind velocity is slightly stronger in winter season and the velocity varies between 4.0 and 6.0 m/sec throughout the year. The prevailing average wind direction is easterly in autumn, westerly to southerly in winter, westerly to northerly in spring, and from westerly in summer. The maximum wind velocity was recorded at 38 m/sec in December 1999 with a direction of W.

**Table III.1.1-3 Mean and Maximum of Average Wind Velocity (1993-2002)**

(Unit: m/sec)

| Year/ Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Mean | 5.7 | 5.9 | 4.9 | 4.0 | 3.7 | 4.0 | 3.9 | 3.7 | 4.1 | 5.2 | 5.3 | 5.4 |
| Maximum | 32 | 28 | 28 | 20 | 18 | 23 | 32 | 19 | 25 | 31 | 32 | 38 |
| | WSW | SE, SSW | SW | NW, S | NW, W | WSW | S | SE | S | WSW | WSW | W |

Source: Meteorological Station Centre

### (5) Fog

Since Klaipeda City is located at the meeting point of the cold water of the Baltic Sea and the warm water flowing out from the Lagoon, the fog occurs throughout the year.

The average number of foggy days in Klaipeda City is shown in Table III.1.1-4. The occurrence of fog is comparatively low in summer and high in spring.

**Table III.1.1-4 Average Number of Days of Fog in Klaipeda (1961-1990)**

(Unit: day)

| Month | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec | Year |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Foggy Days | 3.4 | 4.0 | 5.9 | 6.0 | 5.7 | 3.6 | 2.4 | 1.9 | 2.7 | 3.4 | 3.5 | 4.4 | 47.0 |

Source : Environmental Impact Assessment Report for the Dredging of the Entrance Channel, 2002

### (6) Freezing

The Curonian Lagoon (the Lagoon) freezes in winter, but most of the Port area remains ice-free. In mild winters and when ice begins to thaw in the springs, ice blocks drift from the Lagoon into the Klaipeda Strait. The Hydrometeorological

Observatory at Melnrage has observed the thickness of ice at the measuring station located at the entrance part of the Klaipeda Straight. Table III.1.1-5 shows average and maximum numbers of days with a thickness of ice more than 10 cm between 1953 and 1991. The average number of days with ice at the Strait is 58 days, while the maximum number of days is 129 days. Though the months of January, February, and March exprience longer days with ice, its thickness is not so large and partially located. As such, ice does not prevent the ship navigation throughout the year.

**Table III.1.1-5 Duration of Freezing Over the Klaipeda Strait (1953-1991)**

(unit : days)

| Month | Nov | Dec | Jan | Feb | Mar | Apr | Year |
|---|---|---|---|---|---|---|---|
| Average | 2 | 7 | 16 | 15 | 14 | 4 | 58 |
| Maximum | 11 | 18 | 28 | 28 | 30 | 14 | 129 |

Source : Klaipedos Valstybinio Juru Uosto Hidrometeorologines Salygos ir ju Itaku Uosto Darbui

## 1.2 Oceanographic Condition

### (1) Wave

#### 1) Deepwater Wave Climate

The deepwater wave climate around the Port has been investigated. Firstly the following statistic data have been collected and analysed.

- wave height distribution estimated from the frequency distribution of the wind in Lithuania, (Marine Research Center)
- wave statistics, Area-5, Baltic Sea (Global Wave Statistics) developed by British Maritime Technology

The above data, though valuable in assessing general trend of waves, are not enough to check the frequency of the wave directions, so that offshore waves have been hindcast by use of the wind data from British Meteorological Office (approximate 40 thousand) at 55.8N and 20.7E between June 1991 and September 2003. The frequency distribution of the height and direction of offshore waves are shown in Table III.1.2-1. The preliminary assessment on the offshore wave characteristics are briefed below.

- the frequency of the waves less than 1.0m in height exceeds 50%
- the wave direction from W-WSW shows high frequency, and high waves often come from the same direction

## Table III.1.2-1 Frequency Distribution of Offshore Wave Height and Direction

**DIRECTION OF HIGHER OF SEA OR SWELL HEIGHT (DEGREES TRUE)**

| LOWER LIMIT | | 346 | 016 | 046 | 076 | 106 | 136 | 166 | 196 | 226 | 256 | 286 | 316 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| UPPER LIMIT | IND. | 015 | 045 | 075 | 105 | 135 | 165 | 195 | 225 | 255 | 285 | 315 | 345 | |
| 【RESULTANT WAVE HEIGHT (%)】 | | | | | | | | | | | | | | TOTAL |
| 0.0 TO 0.2 | · · | 0.0 | 0.1 | 0.1 | 0.2 | 0.2 | 0.4 | 0.7 | 0.4 | 0.1 | 0.2 | 0.2 | 0.3 | 2.8 |
| 0.3 TO 0.4 | · · | 1.1 | 0.3 | 0.2 | 0.3 | 0.5 | 0.7 | 0.8 | 0.6 | 0.5 | 0.6 | 0.3 | 0.6 | 6.2 |
| 0.5 TO 0.6 | · · | 1.4 | 0.5 | 0.6 | 1.7 | 1.2 | 1.0 | 1.0 | 1.3 | 1.0 | 1.7 | 0.9 | 1.3 | 13.4 |
| 0.7 TO 0.8 | · · | 0.5 | 0.2 | 0.6 | 0.9 | 1.2 | 1.0 | 1.6 | 1.1 | 1.0 | 0.8 | 0.9 | 1.3 | 10.8 |
| 0.9 TO 1.0 | · · | 0.3 | 0.2 | 0.1 | 0.5 | 0.4 | 0.7 | 0.6 | 1.0 | 0.7 | 0.3 | 0.6 | 0.4 | 6.0 |
| 1.1 TO 1.2 | · · | 0.7 | 0.3 | 0.4 | 1.1 | 0.7 | 1.5 | 1.7 | 2.0 | 1.3 | 1.1 | 1.2 | 1.2 | 13.2 |
| 1.3 TO 1.4 | · · | 0.5 | 0.1 | 0.0 | 0.3 | 0.4 | 1.1 | 1.3 | 1.4 | 1.1 | 0.8 | 1.0 | 0.7 | 8.8 |
| 1.5 TO 1.6 | · · | 0.6 | 0.2 | · · | · · | 0.2 | 0.7 | 0.8 | 1.7 | 1.6 | 1.3 | 1.1 | 1.2 | 9.5 |
| 1.7 TO 1.8 | · · | 0.3 | 0.0 | · · | · · | 0.1 | 0.3 | 0.7 | 0.8 | 1.1 | 1.2 | 0.5 | 0.7 | 5.8 |
| 1.9 TO 2.0 | · · | 0.1 | · · | · · | · · | 0.1 | 0.1 | 0.2 | 0.2 | 0.5 | 0.4 | 0.2 | 0.1 | 1.9 |
| 2.1 TO 2.2 | · · | 0.1 | 0.1 | · · | · · | 0.1 | 0.3 | 0.3 | 0.2 | 1.4 | 1.3 | 0.7 | 0.1 | 4.6 |
| 2.3 TO 2.4 | · · | 0.0 | · · | · · | · · | 0.1 | 0.1 | 0.1 | 0.4 | 1.8 | 1.6 | 0.6 | 0.2 | 4.8 |
| 2.5 TO 2.6 | · · | · · | · · | · · | · · | · · | · · | · · | 0.6 | 1.9 | 1.4 | 0.3 | 0.0 | 4.2 |
| 2.7 TO 2.8 | · · | · · | · · | · · | · · | · · | · · | · · | 0.2 | 0.7 | 1.2 | 0.1 | 0.1 | 2.3 |
| 2.9 TO 3.0 | · · | · · | · · | · · | · · | · · | · · | · · | 0.0 | 0.3 | 0.2 | · · | · · | 0.5 |
| 3.1 TO 3.2 | · · | · · | · · | · · | · · | · · | · · | · · | 0.2 | 0.4 | 0.4 | 0.1 | 0.1 | 1.2 |
| 3.3 TO 3.4 | · · | · · | · · | · · | · · | · · | · · | · · | 0.1 | 0.6 | 0.3 | 0.1 | · · | 1.1 |
| 3.5 TO 3.6 | · · | · · | · · | · · | · · | · · | · · | 0.0 | 0.0 | 0.7 | 0.4 | 0.2 | · · | 1.4 |
| 3.7 TO 3.8 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.2 | 0.2 | · · | · · | 0.4 |
| 3.9 TO 4.0 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.1 | 0.0 | · · | · · | 0.2 |
| 4.1 TO 4.2 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.1 | 0.1 | · · | · · | 0.2 |
| 4.3 TO 4.4 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.1 | 0.1 | · · | · · | 0.2 |
| 4.5 TO 4.6 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.0 | 0.0 | · · | · · | 0.1 |
| 4.7 TO 4.8 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 4.9 TO 5.0 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 5.1 TO 5.2 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.0 | · · | · · | 0.0 |
| 5.3 TO 5.4 | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.0 | · · | · · | · · | 0.0 |
| 5.5 TO 5.6 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | 0.0 | · · | · · | 0.0 |
| 5.7 TO 5.8 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 5.9 TO 6.0 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 6.1 TO 6.2 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 6.3 TO 6.4 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 6.5 TO 6.6 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| | | | | | | | | | | | | | | |
| 6.9 TO 7.0 | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| 7.1 OR MORE | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · | · · |
| TOTAL | · · | 5.6 | 2.1 | 2.0 | 4.9 | 5.1 | 7.8 | 9.8 | 12.2 | 17.4 | 16.0 | 9.0 | 8.1 | 100.0 |

Source: British Meteorological Office

### 2) Shallow-Water Wave Climate

The shallow-water waves have been measured only for a month in winter of 2001 in Klaipeda Port Entrance Rehabilitation Project. This information is not enough. So, the JICA Study Team has installed one wave recorder in a water depth of 20m off the existing breakwaters of the Port during the study period, and long-term characteristics of waves have been obtained on site. As the wave data collected include a rather high component of long-period waves, the analysis has been made for short-period waves and long-period waves respectively.

a) Short-Period Wave

Based on the obtained data as shown in Table III.1.2-2 and Figure III.1.2-1, the wave characteristics around the port area are summarized as follows.

- The occurence of the waves less than 1.0m in height exceeds 73% and less than 1.5m accounts for 87%, and the waves higher than 3.0m occur several times per month.
- The wave direction from W-WSW shows high frequency, and those from WSW make up 66%.
- The frequency of the wave period shorter than 6.0 seconds constitutes 90%.

The detailed survey result in this study is shown in Appendix E 2.

## Table III.1.2-2 Frequency Distribution of Observed Wave Height and Period

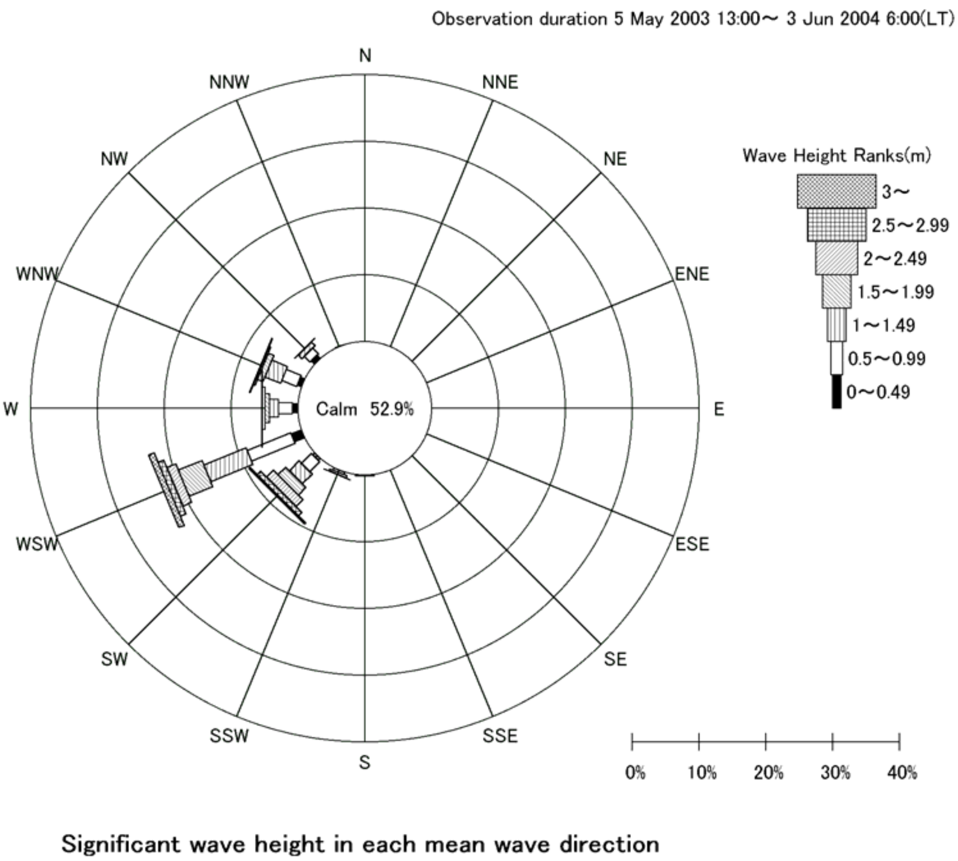
Wave height frequency for each wave period(Significant wave)

KLAIPEDA St1 Date of start: 05May2003 14:00 Date of end: 03Jun2004 06:00

| Height(m) / Period(s) | 0.00- 0.24 | 0.25- 0.49 | 0.50- 0.74 | 0.75- 0.99 | 1.00- 1.24 | 1.25- 1.49 | 1.50- 1.74 | 1.75- 1.99 | 2.00- 2.24 | 2.25- 2.49 | 2.50- 2.74 | 2.75- | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0.0- 0.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 1.0- 1.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 2.0- 2.9 | 10.1 | 6.9 | 0.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 17.1 |
| 3.0- 3.9 | 8.5 | 13.4 | 8.0 | 1.1 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 31 |
| 4.0- 4.9 | 0.9 | 5.2 | 6.5 | 7.9 | 4.2 | 1.4 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 26.1 |
| 5.0- 5.9 | 0.0 | 0.3 | 0.7 | 2.3 | 3.2 | 3.8 | 2.9 | 1.3 | 0.3 | 0.1 | 0 | 0 | 14.8 |
| 6.0- 6.9 | 0.0 | 0.0 | 0.1 | 0.3 | 0.7 | 0.8 | 1.3 | 1.5 | 1.8 | 1 | 0.6 | 0.1 | 8.1 |
| 7.0- 7.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.1 | 0.2 | 0.3 | 0.6 | 1 | 2.1 |
| 8.0- 8.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0.6 | 0.6 |
| 9.0- 9.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0.1 | 0.1 |
| 10.0- 10.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 11.0- 11.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 12.0- 12.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 13.0- 13.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 14.0- 14.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 15.0- 15.9 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| 16.0- | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0 | 0 | 0 | 0 | 0 |
| Total | 19.5 | 25.7 | 15.4 | 11.6 | 8.1 | 6.0 | 4.3 | 2.9 | 2.2 | 1.3 | 1.1 | 1.8 | 100 |

Obtained 3077 Times (%)

Source: JICA Study Team




Source: JICA Study Team

## Figure III.1.2-1 Frequency Distribution of Observed Wave Direction

b) Long-Period Wave

The report of Delft Hydraulic in 1995 and Harris in 1999 mention that there appear the waves with periods of 30 to 300 seconds at the port entrance, and the long-period waves reach 50 cm high. In fact, the ships mooring near the port entrance have ever been influenced by sway and surging motions caused by long-period waves. Since then, a thorough research on long-period waves has not been undertaken yet.

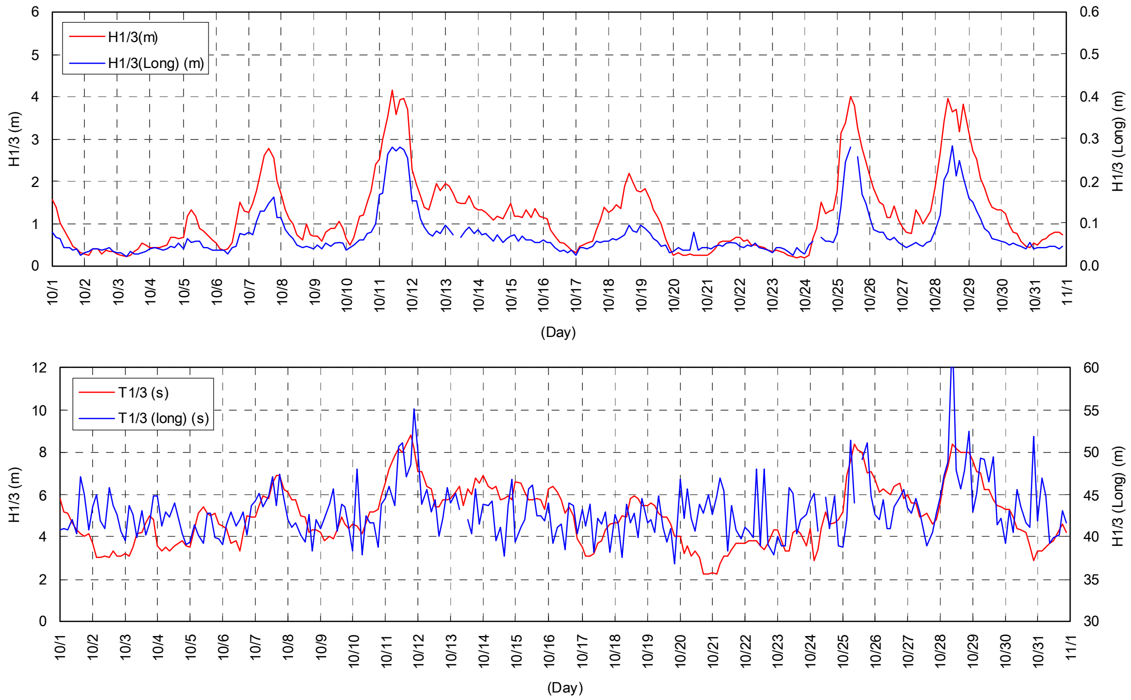
In the JICA Study, the waves have been observed at the depth of -20 m BSL, including the component of long-period waves. Based on the records obtained, the long-period waves have been extracted.

Long-period waves are classified into two categories. One is “bound long-period waves” which are restricted by wave group caused by irregularity of incidental waves. Another is “free long-period waves” which are released from the restriction of wave group by the influence of wave breaking. Generally, the component of long-period waves is not susceptible to decrease than short-period waves, and easily reflects. Thus, it tends to increase wave height in such well-reflecting areas as the inner part of a port.

The percentage of long-period waves components among all incident waves is normally small, but the percentage become larger in shallow area, because certain components of long-period waves reach shallow areas without diminishing its height.

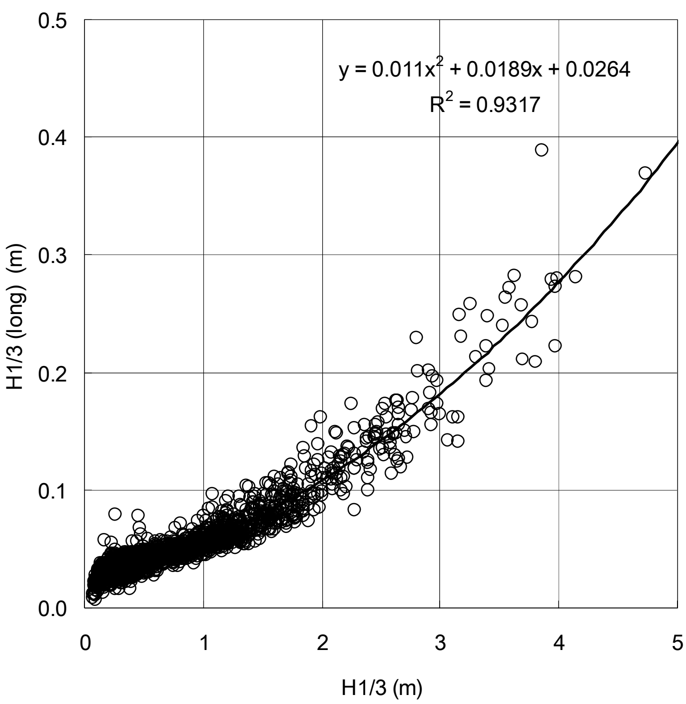
Figure III.1.2-2 shows the change in the significant wave height and period for each of short-period waves ($H_{1/3}$) and long-period waves ($H_{1/3}$ Long) having wave periods over 20 seconds. It seems that such change of $H_{1/3}$ Long is closely similar to that of $H_{1/3}$. Average period of long-period waves is in a range between 40 and 45 seconds.

Figure III.1.2-3 shows the correlation between $H_{1/3}$ and $H_{1/3}$ Long clearly. The ratio of $H_{1/3}$ Long to $H_{1/3}$ is about 5-8%, and it gives larger ratio for higher waves. Based on the observed data at the depth of -20 m BSL and the graph below, it can be said that the ratio of long-period waves is rather large in the shallow area.




Source: JICA Study Team

**Figure III.1.2-2 Change of Wave Height and Period of Both Short and Long Waves**




Source: JICA Study Team

**Figure III.1.2-3 Correlation Between Short and Long Waves**

### (2) Coastal Currents

The coastal currents in the Baltic Sea circulate anti-clockwisely and flow northwards near Klaipeda. The dynamics of water mass in the Baltic Sea is principally generated by the atmospheric processes, which causes annual change in current velocities. The lowest velocity of the currents occur during spring-summer seasons and the highest during autumn-winter seasons. (Lithuanian Energy Institute, 2002) The currents change quickly and form complicated surface and sub-surface flows. The surface water movements are significantly influenced by the river flows. This fresh water enter into the saline water, creating local sub-surface currents.

The fresh water from the Lagoon to the Klaipeda Strait flows in the direction of the north with a speed of less than 0.5 m/sec. During the floods in spring, the fresh water spreads over 9-11 miles from the shore and constitutes the depth of 5-14m. (Lithuanian Energy Institute, 2002)

According to the survey by the JICA Study Team at the offshore area of the breakwaters, the current directions fluctuated, not predominantly directed northward, and its maximum current velocity was about 0.2 m/sec. The observed results are detailed in Appendix E 2.

## 1.3 Hydraulic Condition of Lagoon

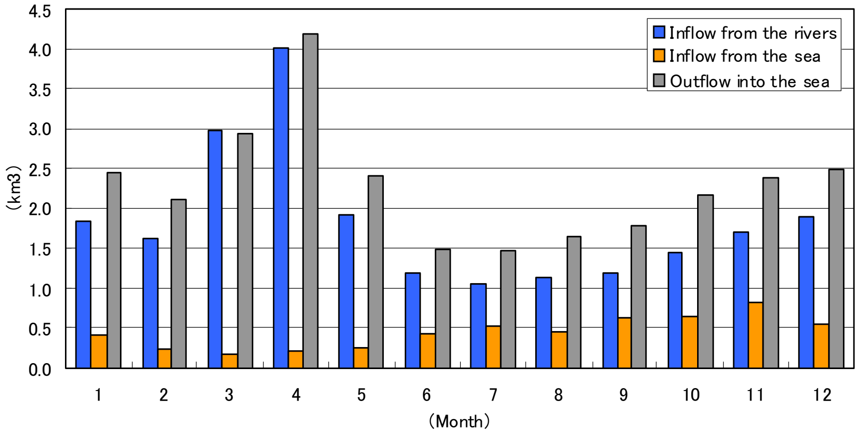
### (1) Water Flows and Water Levels

#### 1) Water Flows into/out of the Lagoon

The water flows in the Lagoon was studied in the EIA report for the dredging (up to -12.5m) of the entrance channel by LEI in 2002 (see Figure III.1.3-1). It shows monthly average changes in water movements between 1958 and 1995. The results of study are sumarized as below;

- The total catchment area of the rivers flowing into the Lagoon is 100,458 km$^2$, out of which 98% of area is covered by the Nemunas basin. The average total inflow from the rivers is 22 km$^3$/year, with a seasonal breakdown of 41.6% in spring, 15.6% in summer, 19.9% in autumn and 22.9% in winter.
- A water exchange takes place through a narrow Klaipeda Strait where 3 types of water mass movements can be observed: 1) two-layer movement when the weather is calm and the difference between the water level in the Lagoon and the sea is negligible, especially in summer, and there exists a flow from the sea to the Lagoon in the deeper layer; 2) water movements from the whole part of the Lagoon to the sea, which is observed during spring floods; 3) water movements from the sea to the Lagoon is observed during the time when the sea water is set-up by strong winds of W, NW, and N.
- Annually about 26.5 km$^3$ of water flows out from the Lagoon to the sea. A 50% portion flows in spring, 15% in summer and the remaining 35% in autumn and winter. According to the data between 1959-1968, the mean annual inflow of the saline water into the Lagoon is 5.1 km$^3$. The saline

water is mostly observed in the northern part of the Lagoon and hardly penetrates 40 km far into the southern part.




Source: Lithuanian Energy Institute

**Figure III.1.3-1 Water Balance between Curonian Lagoon and Baltic Sea**

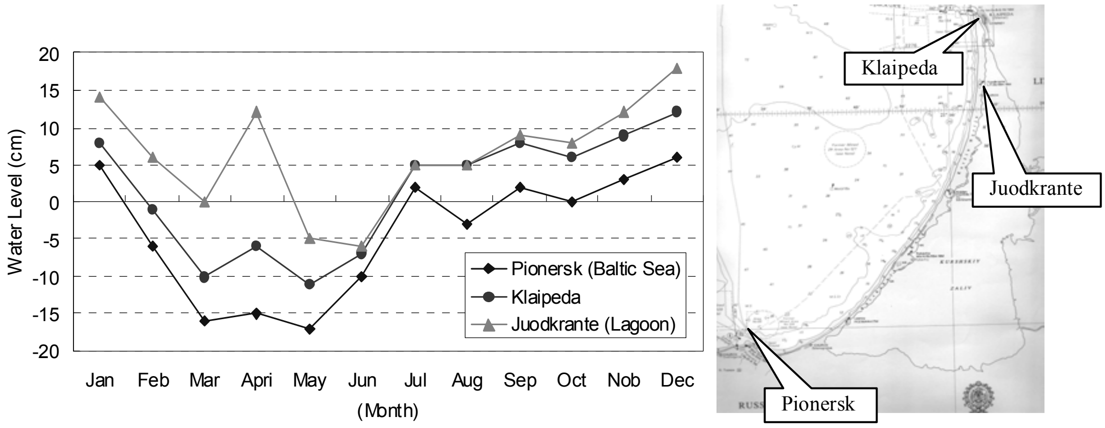
### 2) Water Levels of the Lagoon

The Baltic Sea Level (BSL) is based on the mean water level in St. Petersburg and is used as the standard sea water level by the coastal countries of the Baltic Sea. The water levels inside the Lagoon have been measured by the Energy Institute of Lithuania. The fluctuation of water levels in the Baltic Sea is caused mainly by the wind and its range is small. The tidal variations resulting from the atmospheric pressure are very weak in the Baltic Sea.

Figure III.1.3-2 shows the monthly average of the water levels measured at three points (Pionersk - facing the Baltic Sea, Juodkrante – inside the Lagoon, Klaipeda Port) during the period from 1955 to 1996. According to this data, the water level in the Baltic Sea change seasonally, falling approximately 15cm below BSL in spring and rising approximate 5cm above B.S.L. in winter. In addition, the water level inside the Lagoon is little higher than that of the Baltic Sea.

The relationship between the discharge flows observed at the station 80km upstream of the Nemunas River and the water levels at the above three points were analyzed by the Marine Research Centre. The results of the analysis show the following particular characteristics;

Table III.1.3-1 indicates the probable water levels. It shows a possible fluctuation between –50 cm and +45 cm with a return period of 1 year and between –100 cm and +180 cm with a return period of 100 year.




Source: Lithuanian Energy Institute

**Figure III.1.3-2 Water Level in the Project Area (1955-1996)**

**Table III.1.3-1 Probable Maximal and Minimal Water Levels in Klaipeda Strait**

| Probability (%) | 99 | 50 | 20 | 10 | 5 | 2 | 1 |
|---|---|---|---|---|---|---|---|
| Recurrence, year | 1 | 2 | 5 | 10 | 20 | 50 | 100 |
| Maximal level (cm) | 45 | 85 | 110 | 124 | 143 | 162 | 180 |
| Minimal level (cm) | -50 | -68 | -77 | -83 | -89 | -97 | -103 |

Source: Lithuanian Energy Institute

### (2) Current, Salinity and Turbidity

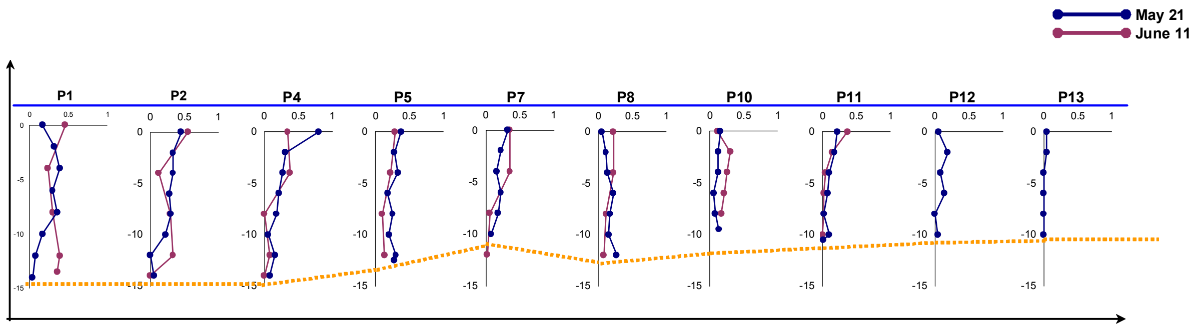
The currents inside the Lagoon are discussed in the Geochemistry of Sediments of the Curonian Lagoon, Institute of Geography, 1998, and are reported as follows;

- Currents in the Lagoon are predetermined by river runoff, wind, and input of saline waters. The bottom relief and configuration of the shoreline are stabilized by the effects of the currents.
- A stable water mass movement induced by the Nemunas basin water discharge into the sea can be observed in the northern part of the Lagoon. Its main flow moves northward through a narrow belt extending from the Ventes Ragas Cape to the Klaipeda Strait, sometimes widening to the central part of the Lagoon.
- In the southern part of the Lagoon, the current regime is mainly governed by wind action. The relief of the shallow depression is predominant at the water depth of 4m to 5.8m. The maximum measured wind speed in the open parts of the Lagoon in the south does not exceed 28 m/sec. Close to the projections of the land during SW and S storms, higher wind speed can be expected (up to 30-40 m/s).
- Periodical fluctuations of water surface are driven by winds through the abrasion-erosion process, disturbing, and sorting of settled sedimentary matter. Wide areas of the shore and bottom (with a depth up to 3 m) are particularly sensitive to the action of water fluctuations, and during long-term unidirectional winds actually all the water column is disturbed. Such mixing

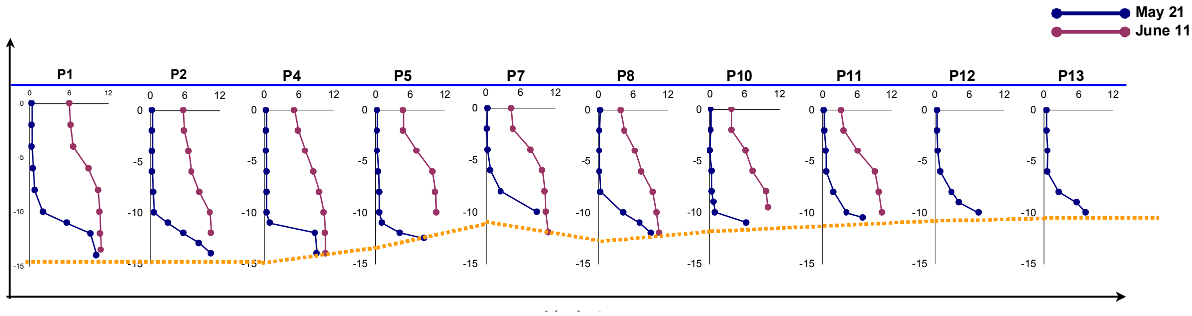
is especially distinct along the whole eastern and southern shore of the Lagoon. It is distinctly reflected in the lithology of sediment thickness.

In the first stage of the field investigation, current, turbidity, and salinity have been measured by the JICA Study Team in the Port area and inner part of the Lagoon, using portable equipment, and current and turbidity using seabed-installed type equipment. Figure III.1.3-3 shows sample of vertical distribution of current, salinity and turbidity measured from port entrance until inner part of port by portable Equipment, and Figure III.1.3-4 and 5, results of current and turbidity measurement by seabed-installed type equipment. The results are summarized as follows.

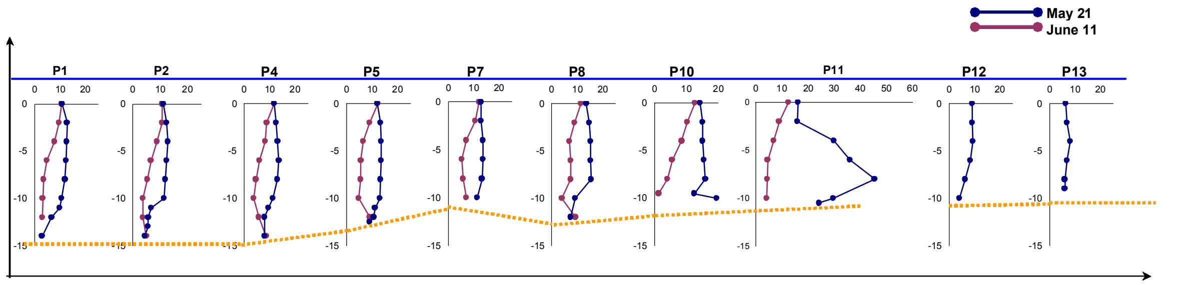
- A stable flow toward the entrance of the Port has been always found in the Klaipeda Strait, which is located on the north of the Lagoon. Its velocity reaches to 0.4-0.5m/sec at several places. A flow toward the Lagoon appears exceptionally after strong winds blow west to northwards. Generally, current speed is fast in the upper layer and decreases proportionally with the depth.
- The current directions inside the Lagoon have not been always stable. Current velocity and direction have been often different between upper and lower layer. This is reasoned that the flow inside the Lagoon depends on the water discharge and the wind condition.
- According to the existing data (ex. Sedimentary Material in the Transitional Aquasystem, Vilnius, 1997), salinity changes everyday. From the measurement results, the characteristics are summarised as follows; 1) Saline water has been located only in the lower layer when it is not so stirred up by the wind. As saline water has been located in the lower layer of the channel as well, it reaches up to the ferry terminal at the inner part of the Port. After the wind blow strongly, high saline water has been measured in the upper layer at the inner part of the Port area. Sometimes it has reached up to 10km deep into the inner part from the entrance of the Port,




(1) Current Distribution




(2) Salinity Distribution




(3) Turbidity Distribution

**Figure III.1.3-3 Sample of Measurements by Portable Equipment**

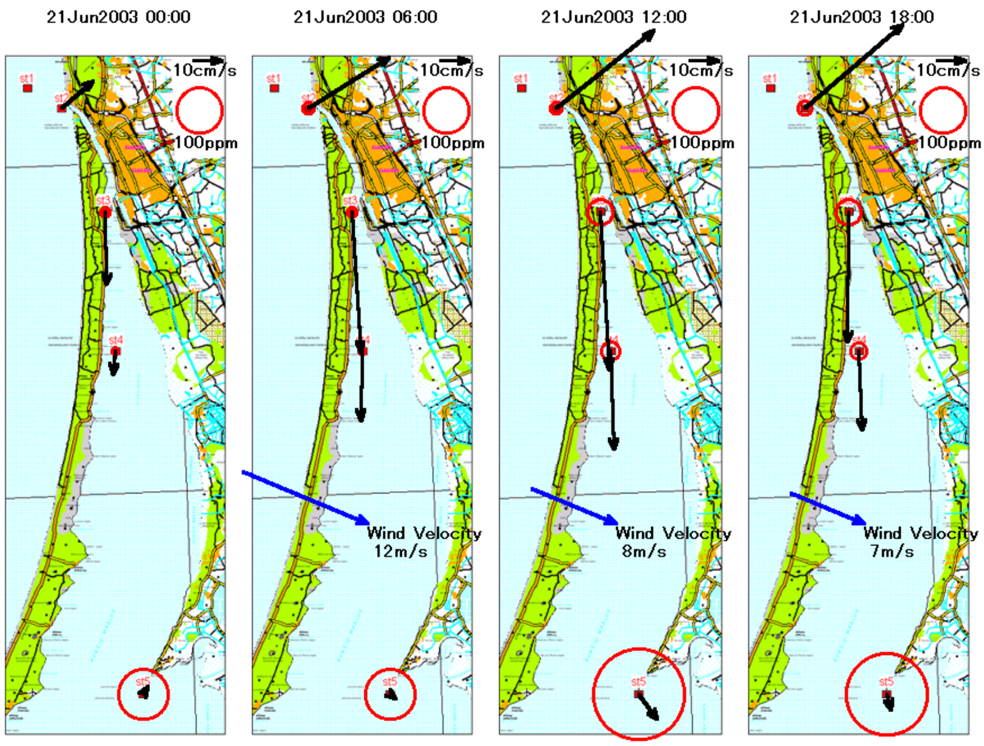



**Figure III.1.3-4 Sample of Measurements by Seabed-Installed Type Equipment (Current, Turbidity and Wind)**

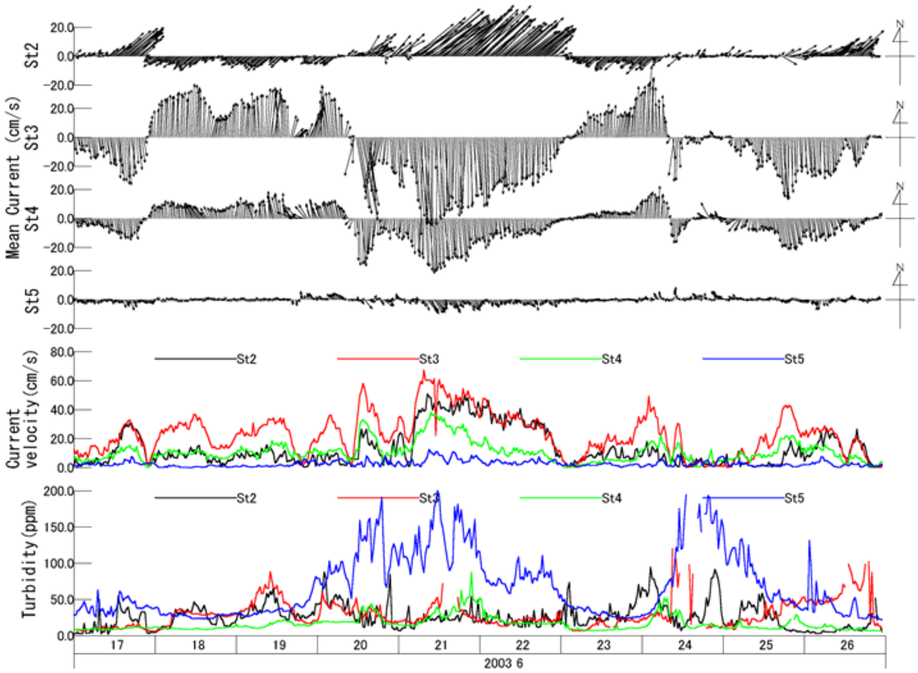



**Figure III.1.3-5 Sample of Measurements by Seabed-Installed Type Equipment**

## 1.4 Topographic and Bathymetric Conditions

### (1) Topography

The Port and Klaipeda City are located in a flat and low-lying land that rises 20-30m gradually to the east of the City, where there are areas of higher ground bisected by the Dane River and Minija River that flow in the north-south direction. To the west of the Port, there exists the Curonian Spit, which is a narrow sandy peninsula consisting of coastal dune and forest. It is about 40m high and was created by the air- and water-borne sand movements along the coast over the centuries.

The water depth of the Lagoon is 3.8m on an average, and becomes deeper towards the western bank, and closer to the Port. The southern half of the Port channel is 8-10m deep, slightly greater in certain areas, including the berths of the International Ferry Terminal. The water depth increases to 12m to the north of “Bega” jetties, and reaches 14m at the Nafta and Klasco terminals. The dredging for these areas were executed in the past few years.

Along the coast, the beach slopes gradually down to the Baltic Sea, and the seabed offshore of Klaipeda reaches a water depth of 15m at 2 kilometres offshore, and 50m at 30km offshore.

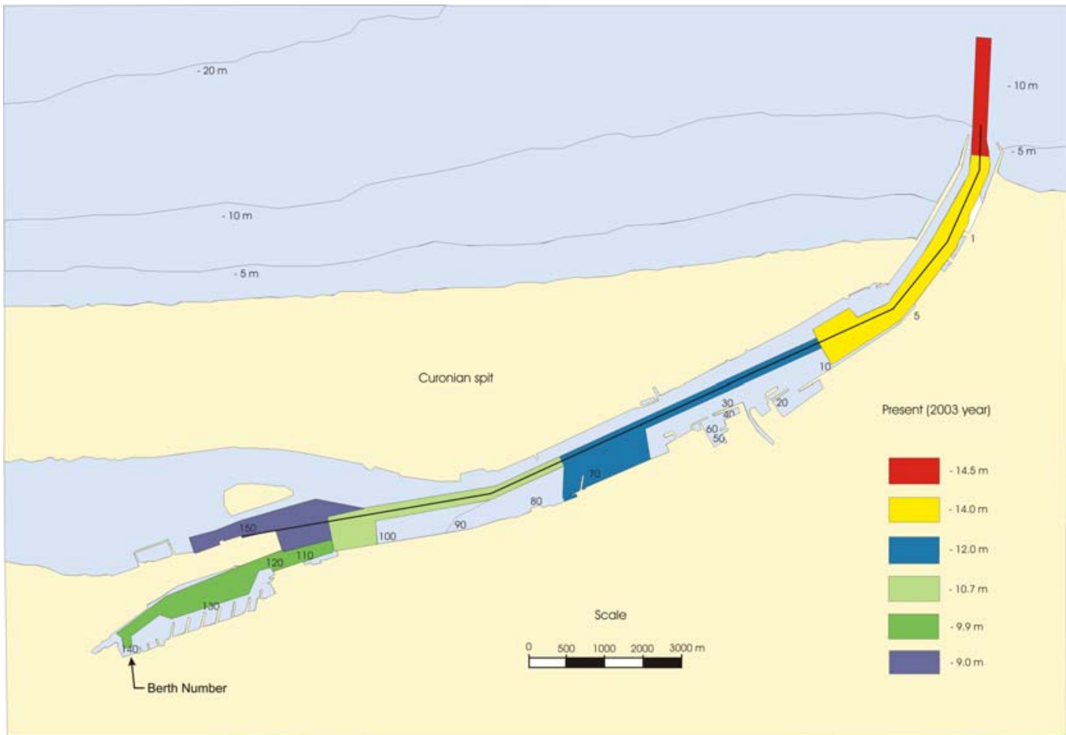
In order to supplement the available topographic data in the port area, topographic survey have been carried out along the beach area of proposed outer port development area and ferry/container terminal area by the JICA Study Team covering the area approximately 0.6 $km^2$.

### (2) Bathymetry

The dredging works in the Port began in the early 1960’s, when the outer channel(sea channel) was dredged to 10-10.5 m below chart datum(BSL), and the inner channel to 9-9.5 m(BSL). The outer channel was deepened to 12-12.5 m in 1982-83, and further deepened to the maximum of -14 m in 1998. The dredging works have been carried out almost every year to maintain the water depth of the channel, and since 1985 around 150,000-200,000 $m^3$/year has been removed. Most of the dredged material were dumped to the sea about 45-50 m deep and 20km southwest of the Port, and small quantity of clean sand from the access fairway was dumped in the sea (25-30m deep) 11km northwest of the Port.

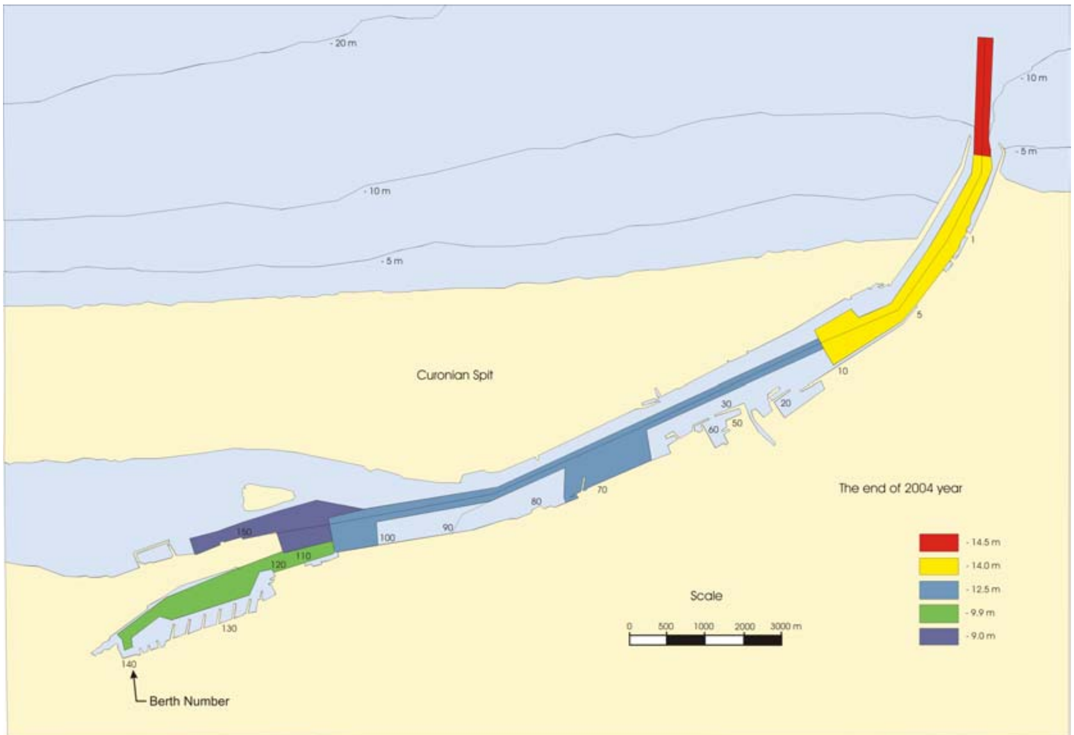
KSSA has a plan to phasewisely deepen and widen the channel from the Quay No.10 to Quay No.115. In the first phase of the dredging from July 2003, approximately 470,000m3 of the soil between Quay No.10 to Quay No.79 was removed in six months. In the second phase, the dredging work will cover the section between the Quay No.80 to Quay No.115, where approximate 1,370,000m3 of the soil will be dredged out in 12 months starting from the date of completion of the first phase. Figure III.1.4-1 and Figure III.1.4-2 show the water depths after the first phase dredging in 2003 and after the second phase dredging respectively.

Bathymetric survey has been coarried out in the proposed outer port development area by the JICA Study Team covering the area more than 4$km^2$.




Source: KSSA

**Figure III.1.4-1 Water Depth of Klaipeda Port after First Phase Dredging**




Source: KSSA

**Figure III.1.4-2 Water Depth of Klaipeda Port after Second Phase Dredging**

### (3) Curonian Sand Spit

According to the Lithuanian books, the history of the Croanian Sand Spit can be briefed as below. Approximately 13,000-15,000 years ago, the last glacier retreated from the present Lithuania, leaving the edge of Littoral Sea (ancestor of present Baltic Sea). The moraine crest, which was protruded above the water in a few places, formed a chain of islands. Approximately 7,000 years ago, there have started an erosion of the slowly lifting edge of the sea – the Semba peninsular (present Kaliningrad area) inducted by the sea waves and the South-western wind took the shore sand to the north. The shore sand was deposited between the islands forming a short and narrow spit called the Curonian Spit around the location of the present Nida. Subsequently, the currents that were induced by the waves carried the sand along the shore from the south to north and extended the spit.

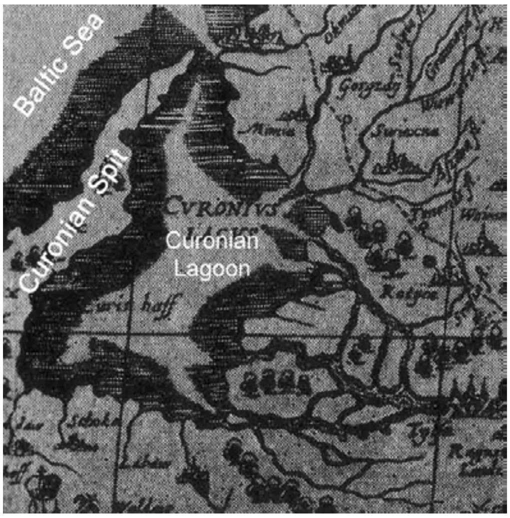



**Figure III.1.4-3 Ancient Curonian Spit and Curonian Lagoon**

The winds carried sand up to the beach and formed dunes on its surface. The development of the Curonian Spit has slowed approximately 4,500-5,000 years ago.

The Spit at this time became a windblown sandy desert. The dunes moved 4-20 m each year and from the 16th to the beginning of the 19th century 14 fishing villages were buried under the sand. The inhabitants had to relocate and Nida moved three times. In the year 1768 a competition was announced in Danzig (Gdansk) to prevent the movement of the dunes and to determine the fate of the Spit. The rector of the University of Wittenberg, Professor Johann Daniel Titzij, suggested reafforestation of the dunes. The reafforestation programme of the Lithuanian Government took part on the Spit from 1862 to 1904. In 1956 the Neringa (the Curonian Sand Spit) forestry was founded and 1,240 ha of forest were created.

Along the coast, the Curonian Spit extends to form a 20-55m wide beach. Behind the beach, dunes extend 4-12m high and 30-150m wide. Generally dunes are protected by twigs which consolidate the sand, plus undergrowth and xerophytes (plants which are adapted to dry condition). In the east, in lowland between high dunes, where the wind blows the sand strongly into the Lagoon, promontories stretch far into the Lagoon. Most of the large dunes are planted with mountain pines. The old dunes of Juodkrante and Nida are planted with natural oak, lime, and elm along with pine woods. The beach along the Lagoon is narrow and sometimes the dunes reach to the water without a beach. During the spring the Eastern coast of the Lagoon is inundated by the Nemunas River which flows into the Lagoon.

The Curonian Spit is an arc-shaped strip of land, 50.8km long in the territory of Lithuania. In the Spit westerly and southerly winds predominate. Every year there are storms and the storm in 1967 uprooted many trees. Since 1960, the Northern part of the Spit has been designated as a nature conservation area. In 1967 the Rules for the care to the Curonian Spit were laid down and the Spit has been designated as a State Forest Park since 1976. Most of the forests are preserved, and any economic activity is forbidden.

Among the total area of the Curonian Lagoon, the part belonging to the Republic of Lithuania is 413km$^2$. Except for the Klaipeda strait, the maximum depth of the Lagoon is only 6m. The water of the Lagoon is warm in July-August, when its surface temperature reaches 23 degrees C.

## 1.5 Geological Condition

### (1) General

In the port area, there lie two types of historic deposits, both of them formed in the Pleistocene and Holocene eras when the Baltic Sea was created. Morainic till was deposited with the ice flows of the Pleistocene, and remains over 40 m-thick belt of loam, containing gravel, pebble and boulders. Above this lies a 5-8 m thick surface layer of younger deposits. It comprises sand, peat and other organic matter.

The recent sediments in the Klaipeda Strait consist of materials from the Lagoon and the sea and spread unevenly, because sedimentation processes are influenced by currents and waves and the activities of man, primarily dredging. These deposits are less than 20 - 30 cm thick in the centre of the channel where water flow is the strongest, and are much thicker in the remaing areas. Alongside the dredged berth-basins and particularly in the enclosed or semi-enclosed harbours, currents slow down in speed, allowing silty materials to settle to a depth over 1 m.

The soil characteristics of sediment near the port entrance tend to be more coarse, sandy. It is judged that its origin would be from the sea, where we can find the deposit more than 1 m thick, after storms.

### (2) Soil Investigations

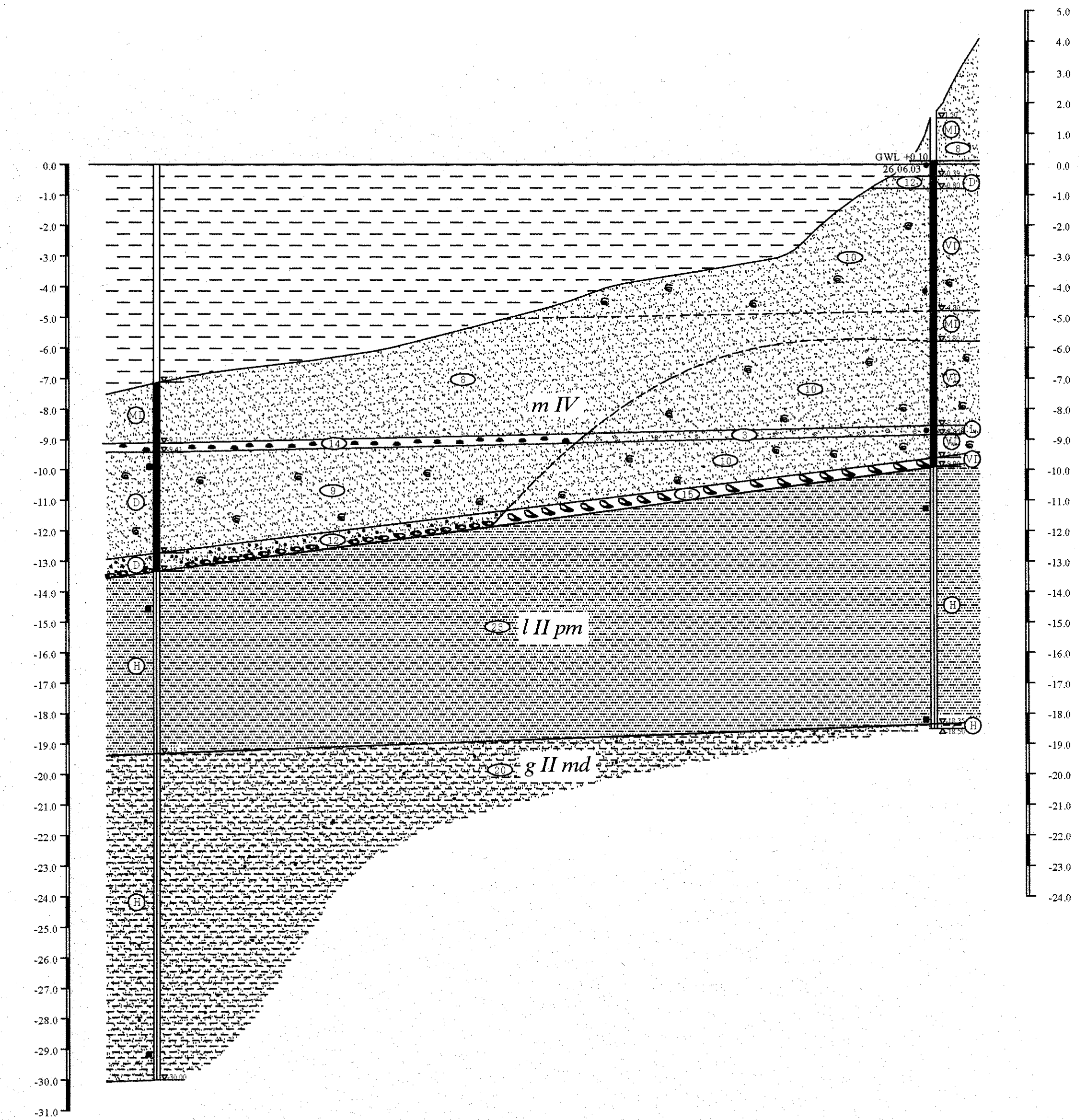
#### 1) Existing Soil Information

Four deep borings were executed in the northern part of Klaipeda Port, close to its entrance during the period of the “Rehabilitation Project (1998)” under the assistance of the World Bank. The boreholes reached more than 20m in depth from the seabed. These borings revealed that the soils in the northern part of Klaipeda Port are represented by a sand layer (down to -13.0 or -14.0m BSL), a silt layer (1.0 - 2.0m thick below the sand layer), and a clay layer (below the silt layer). The clay layer is also called morainic till, which is very hard and sometimes contains sand, gravel, and cobbles.

In addition to the above borings, there are some boreholes in the southern part of Klaipeda Port, but many of them are not deep drilling. Judging from the information from the "Klaipeda Ro/Ro Terminal Modernisation Project (1996)", the soil layers at the southern port area are represented by a silt layer (down to –8.0m BSL), a sand layer (3.0-4.0m thick below the silt layer), and a clay layer (below the sand layer). The silt layer in this area is comparatively soft and often contains organic materials.

**2) Soil Investigation by JICA Study Team**

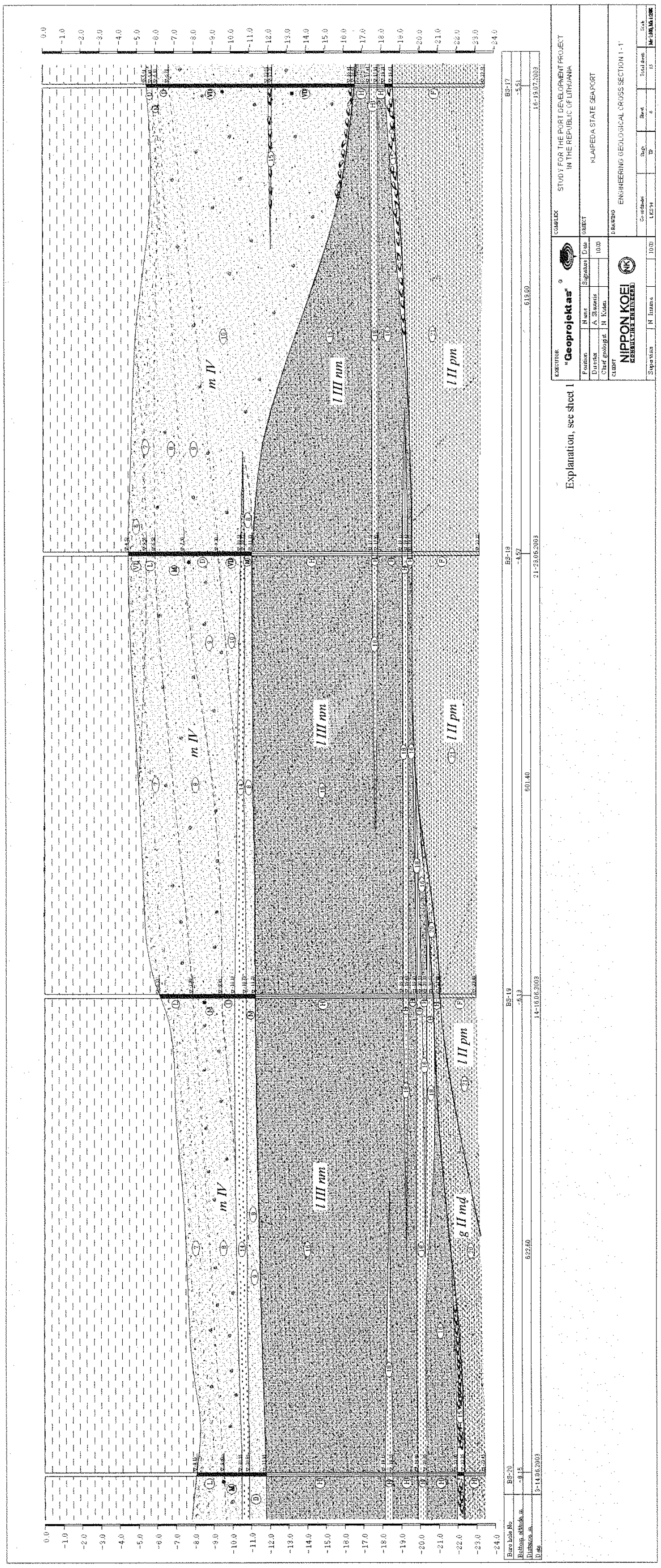
The offshore and onshore borings have been carried out at the southern and northern parts of the Port area in accordance with the BRITISH STANDARD (BS) 5930 "Code of practice for Site Investigations" and BS 1377 requirements. A cross section for the outer port zone is shown in Figure III.1.5-1, and a cross section perpendicular to the shore line in the inner port part is shown in Figure III.1.5-2. More details are included in Appendix E 4 Boring Results.




| Bore hole No | BS-2 | | BL-2 |
|---|---|---|---|
| Bottom altitude, m | -7.11 | | 1.50 |
| Distance, m | | 635.9 | |
| Date | 30.07.2003 | | 26-28.06.2003 |

Source: The JICA Study Team

**Figure III.1.5-1 Geological Profile of Outer Port Zone, Legends**




Source: The JICA Study Team

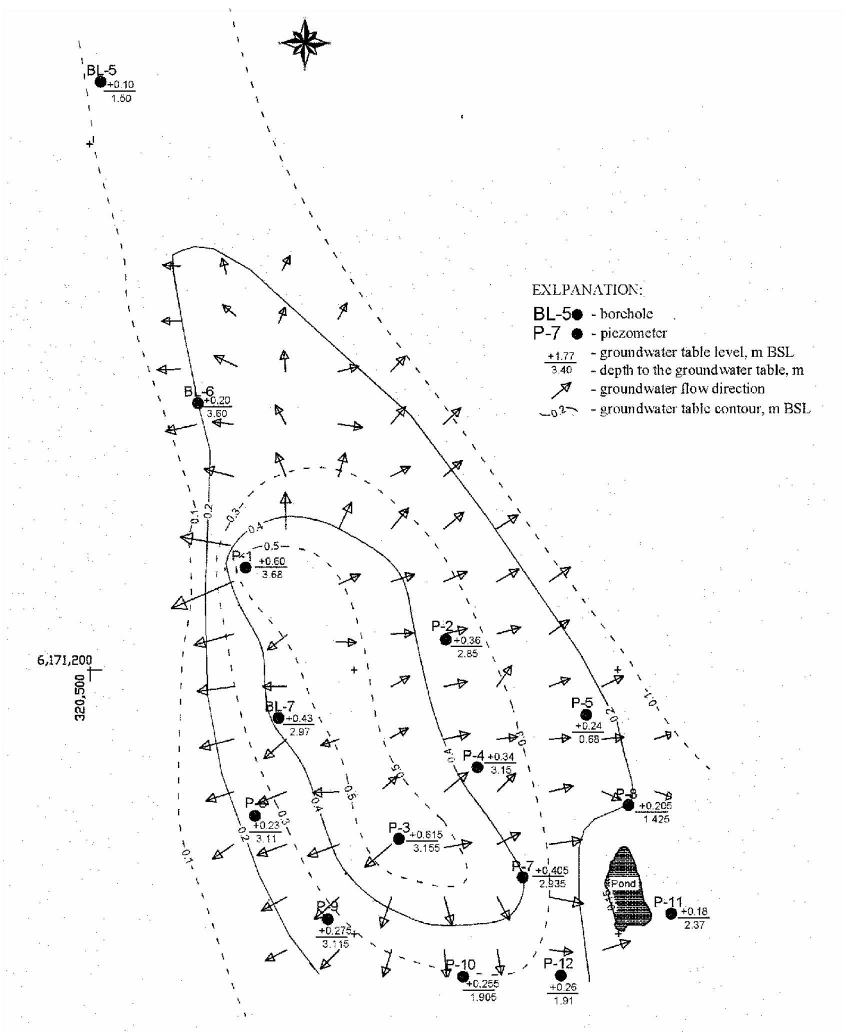
**Figure III.1.5-2 Geological Profile of Inner Port Zone**

Figure III.1.5-1 shows the borders between the sandy layer and silty clay layer. The sandy layer lies down to -9.0 to -13.0m BSL and the silty clay layer underlies this sandy layer with a downward slope of 5%, the same as that of the seabed. Gravels and cobbles appear at the bottom of the sandy layer. The sandy clay layer underlies the above the silty clay layer with the elevation from -18.0 to -19.0m BSL.

Though the geological profile of Figure III.1.5-2 is almost the same as that in Figure III.1.5-1, some mixed layers appear partly at the southern part. The bottom of the sand layer varies in elevation from -12.0 to -16.0m BSL, and the silt layer from -22 to -19m BSL.

### 3) Ground Water Investigation by JICA Study Team

In order to grasp the vertical and horizontal profiles of the ground water around the Klaipeda Canal, from which potable water is pumped up for use of Klaipeda City, 12 shallow boreholes have been drilled and the ground water levels have been measured. The groundwater flows down from the top of a low hill located at the southern part of the Port as shown in Figure III.1.5-3.




Source: The JICA Study Team

**Figure III.1.5-3 Direction of Groundwater Flow**

### (3) Sediment Investigation

#### 1) Existing Sediment Sampling

The sediment inside the Port area was periodically sampled and tested by KSSA in order to monitor the level of pollution at the seabed. The test items include concentrations of oil products, Cu, Pb, Zn, Ni, Cd, Cr and Hg. Details are shown in Appendix E 5. According to "Geography in Lithuania (1996)", the mud at the Malku bay is considerably polluted with heavy metals, and Cu and Zn are especially in high content. The area around the mouth of the Dane River is also contaminated, because it is located in the interface zone between fresh water and saline water, where bilayer water mass circulation develops, and complex geochemical and sedimentation processes take place.

The map of grain size distribution in the whole Klaipeda Port territory can be found in "Klaipedos Uosto Akvatorijos Dugno Nuosedu Litologinis – Geocheminis Rajonavimas (1998)". According to this report, mud is predominant in the depth of 10cm below the seabed from Quay No.5 to Quay No.80, and fine sand appears from Quay No.1 to Quay No.4 and Quay No.81 to Quay No.151 except in the Malku bay (See Appendix E 5).

#### 2) Sediment Analysis by JICA Study Team

The seabed samples have been taken from both inside and outside the Lagoon, and tested in accordance with the DIN (German Standard) and Land 46-2002 standards to analyze their physical and chemical characteristics.

The sediment analysis shows that the fine sand is dominating outside the Lagoon, where heavy metals, oil products and organic matter are low in concentration. In the existing inner port area, there is also a low concentration of polluted materials. Details of sampling and the analysis are shown in Appendix E 5. The seabed profiles especially of muddy (silty) layers have been sounded using an echo-sounder equipped with with two frequencies, 200 kHz and 33 kHz. The silt layers have been found thick in the following areas. This geographical distribution would be very similar to the result by KSSA. Appendix E 3 shows all the results of the monitoring.

- Around the Port entrance
- Around Berth No.2
- Around the mouth of the Dane River
- Around Berth No.69
- Near Mulku bay

## 1.6 Water Quality

The water samplings have been carried out by the JICA Study Team. A total of 15 samples been taken in/around the port area as showen in Figure III.1.6-1 (GP-1 to GP-15). The water samples have been analyzed in the laboratory, covering such test items as 1) water temperature, 2) salinity, 3) dissolved oxygen, 4) oxygen saturation, 5) suspended solids, 6) Biochemical Oxygen Demand, 7) Nitrite, 8) Nitrate, 9) Phosphate, 10) Ammonia, 11) Escherischia coli, 12) Faecal coliforms, and 13) total petroleum hydrocarbons. The results of tests are presented in Appendix E 6. Escherischia Coli and Faecal Coliforms are the parametres to show the magnitude of the influence by human activity.

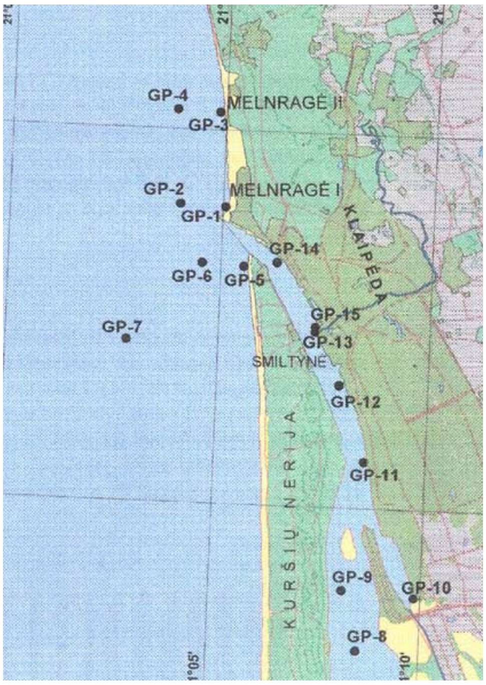
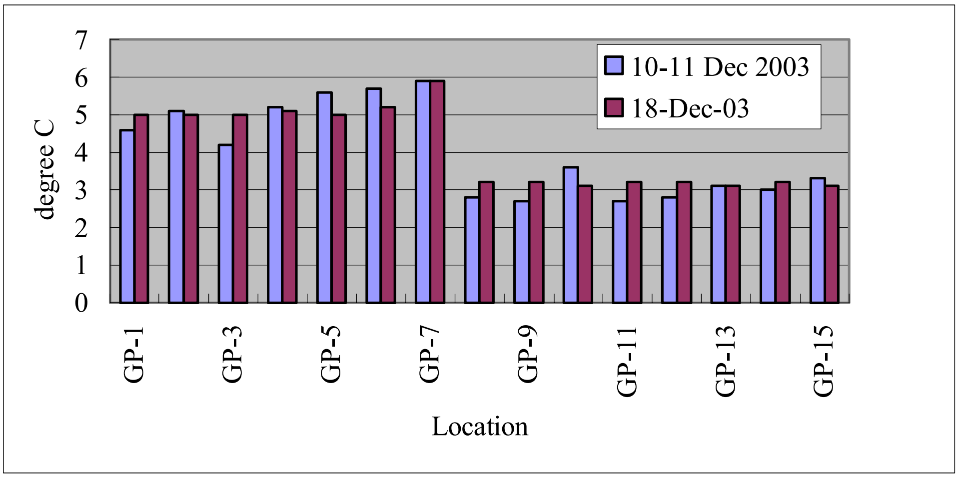



**Figure III.1.6-1 Location Map of Water Sampling**

The analysis shows the following findings.

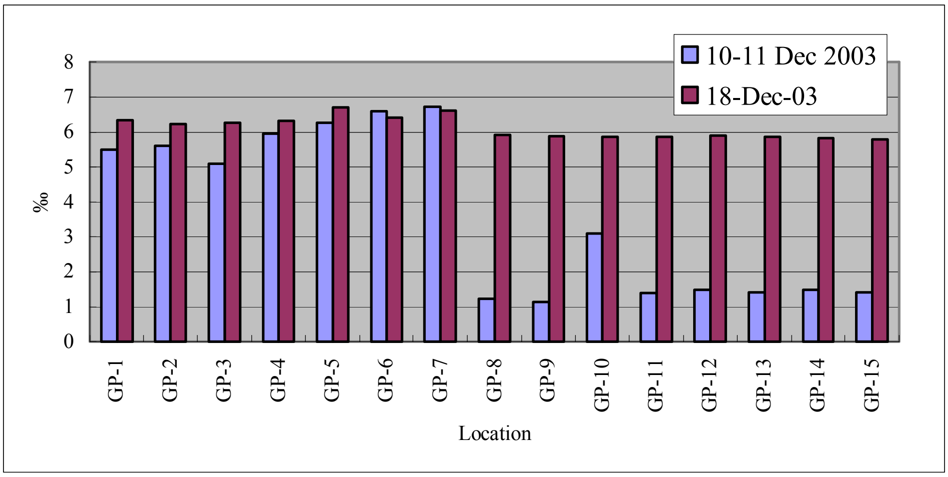
* During the field investigation period, the winds blew from the south on 10 and 11 December 2004, and from the west on 12 December 2004.

- The water temperature was 5 degrees C in the outer port area and it was warmer than that in the inner port by 2 degrees C.
- While the westerly wind blew, the salinity invaded further into the inner part of the Kiaules Nugara Island (GP-8 and GP-9).
- As the concentration of $NO_3$ and the number of Faecal Coliform Bacteria in the outer port area were higher than that in the inner port area. It certified that the inner port area was more influenced by human activities, especially at the mouth of the Dane river (GP-13 and GP-15) and Malku bay (GP-10).



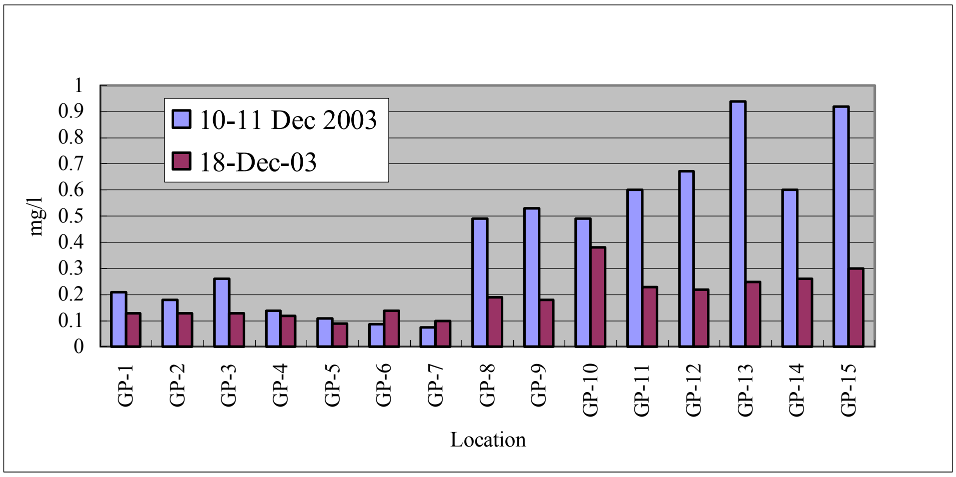

Source: The JICA Study Team

**Figure III.1.6-2 Water Temperature**



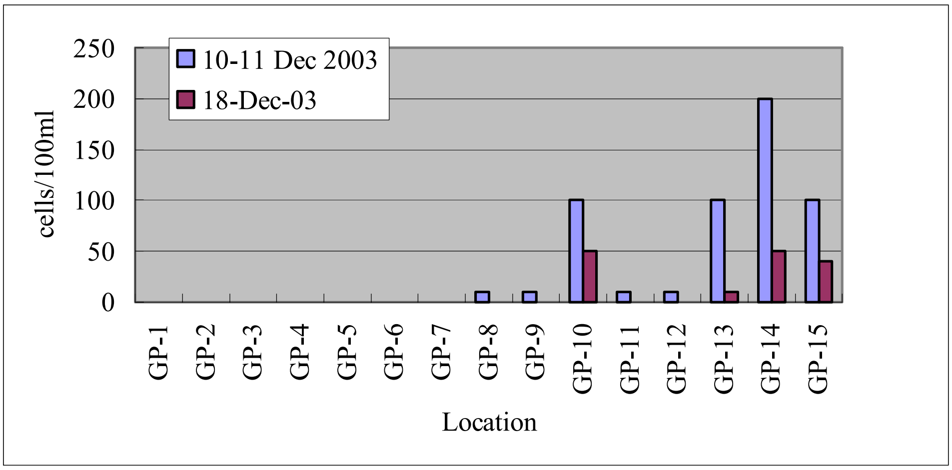

Source: The JICA Study Team

**Figure III.1.6-3 Salinity**




Source: The JICA Study Team

**Figure III.1.6-4 Concentration of $NO_3$**




Source: The JICA Study Team

**Figure III.1.6-5 Number of Faecal Coliform Bacteria**

# CHAPTER 2 COASTAL ENGINEERING

# CHAPTER 2 COASTAL ENGINEERING

## 2.1 Engineering Review of Historical Coastal Records

### 2.1.1 Littoral Drift and Beach Change in Lithuanian Coast

#### (1) General

To know the overall characteristics of littoral drift, it is essential to examine the characteristics of waves in and around the Port area and to trace back the past records of shore line changes. In this study, the following coastal engineering aspects have been analyzed.

- Characteristics of incident waves
- Configuration of the coast line of Lithuania and Kaliningrad
- Shape of beach line around the marine facilities near the Port
- Shape of beach line around the Port

#### (2) Analysis of incident waves

When incident waves approach the shoreline come with a right angle, littoral drift is not created basically. When the approaching angle of waves is less than 90 degrees to the shore line, the littoral drift is generated and its magnitude is suject to the combined factors of waves and directions. According to the historical records of frequency distribution in the deepwater waves as shown in Section 1.2, the prevailing wave direction in the Port area is mainly from W-WSW. Consequently, the northward flowing littoral drift would be predominant in and around the port areas.

#### (3) Analysis of the configulation of coast in the Lithuania and Kaliningrad

Photo III.2.1-1 was developed from a satellite photo in 2002. Through the interpretation of this photo, the littoral drift in the study area can be characterized as follows.

- The shore line inside the Lagoon, most of which are formed with dune, are oriented toward WSW. It is reasoned that this orientation has been set up by the strong winds from the Baltic Sea, so that the prevailing direction of strong winds would be from WSW. As the waves in the Baltic Sea are generated mainly by the wind, it can be concluded that prevailing wave direction is also from W – WSW.
- The shore line in the southern part of the Curonian Spit is oriented to northeast. As the incident waves (W-WSW) approach the shore line obliquely, resulting in the existence of the nortward flowing littoral drift. However, the shore line in the northern part of the Curonian Spit faces the west. So, the incident waves there approach the shore line more frontally. Therefore, the magnitude of littoral drift in the northern part would be less than in the southern part.
- The Curonian Spit, which is the narrowest in the southernmost portion, becomes gradually wider toward the north, and reaching the widest around Nida near the border to Russia. This phenomena can be interpreted that the

northward flowing littoral drift diminish closer to Nida, breaking the net balance toward accumulation at Nida.

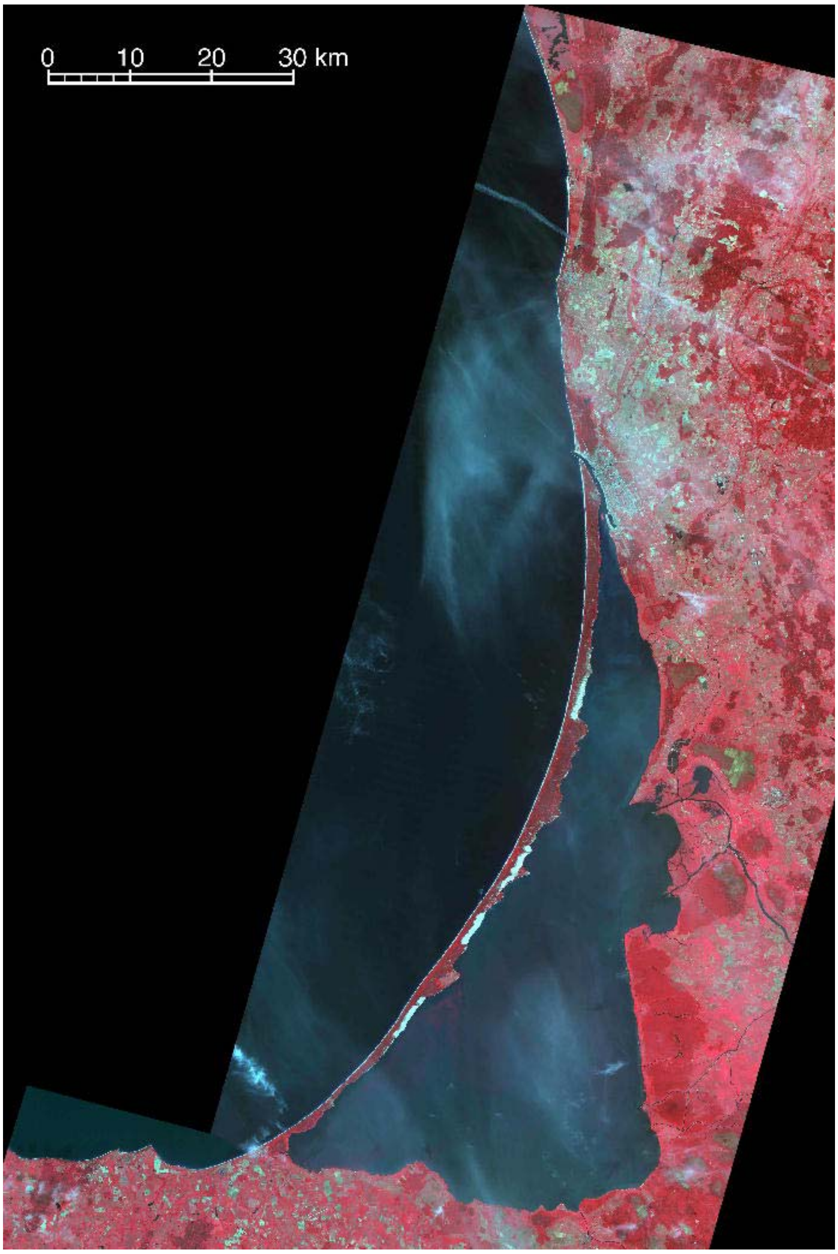



**Photo III.2.1-1 Satellite Photo in/around Lithuania**

### (4) Analysis of the Beach Line around the Marine Facilities near the Port

The change in the shore line frequently occurs by the existence of marine facilities around the Port. To identify these changes induced by local littoral drift, aerial photos have been taken using the helicopter in Palanga and Sventoji. Photo III.2.1-2 and Photo III.2.1-3 show the site condition around Palanga and Sventoji respectively. The jetty at Palanga seems to have caused few change in the shore line, because its structure is of permeable type.

There is a rock-mound jetty at Sventoji, which is about 35km north of Klaipeda Port. To the south of the jetty extends a wide stretch of natural beach. To the north, the shore line shows a gentle curvature, and becomes narrower in the width. Unlike the shore formation noticed at Sventoji, any change in the width of the beach can not be seen in the vicinity of the port entrance of Klaipeda, where the shore line extends, almost perpendicular to the direction of incident waves (W-WSW). This local climate causes less possibility of inducing littoral drift.

**Photo III.2.1-2 Palanga**

**Photo III.2.1-3 Sventoji**

### (5) Analysis of the Beach Line Estimation around the Port area

The historical changes in beach lines around the Port area have been examined and compared. The data analysed include the following.

- Technical report on a long-term shoreline（Zilinskas, 2000）
- Geographical survey data (1953 and 1975)
- Aerial photographs (1991 and 1997)
- Satellite image photograph (2002)
- Shoreline monitoring data (1995 - 1999)

The construction of the breakwater started in 1835, and the present configuration was almost established in 1957. Figure III.2.1-1 shows the changes in shoreline around the breakwaters from 1845 to 1993. The long-term shoreline changes around the breakwater can be examined by overlapping the past topographical maps and the results of shoreline measurements (Zilinskas, 2000).

It is understood that the shore line advanced for 43 years from 1835, when the first breakwater was constructed until 1878, when the both breakwaters were completed. The retreat on the northern side is more remarkable than that on the south. The shoreline on the northern side seems to advance about 1 km wider than in the south. This fact could be interpreted that there is a local south-bound littoral drift.

Nevertheless, it can be further reasoned that the shoreline on the northern side had been advanced remarkably before the construction of the breakwaters. The shoreline on both sides advanced at the beginning of the construction of breakwaters and it can be noticed that a tendency of retreat on the northern shoreline has appeared recently. From these facts, it is suggested the existance of northward littoral drift at least in recent years.

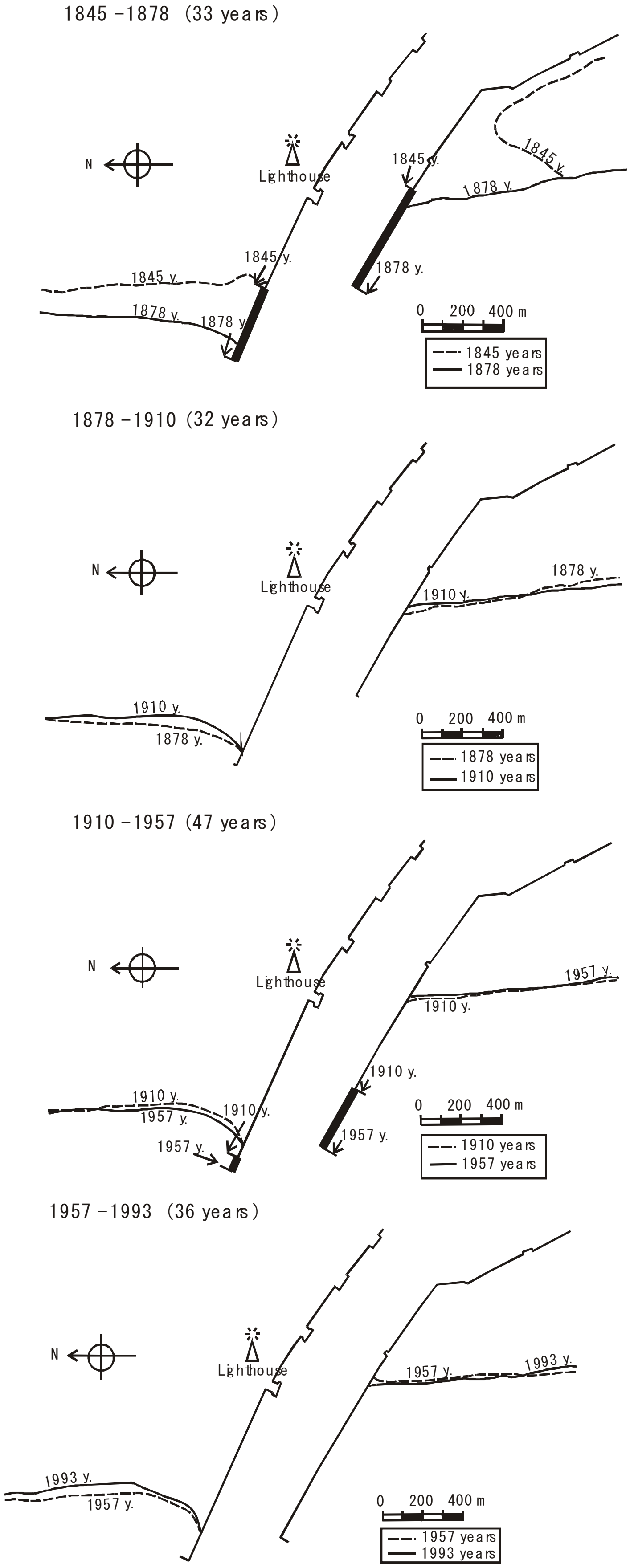



**Figure III.2.1-1 Long-Term Shoreline Change in Last 150 Years (Zilinskas, 2000)**

The dredging for the navigation channel has been executed simultaneously with the extension of the breakwaters. And, the shoreline as well as the water depth around the port entrance has changed remarkably as shown in Figure III.2.1-2. As such, it is considered that the change in bathymetry took place around the breakwaters due to double effects from the construction of breakwater and the dredging work.

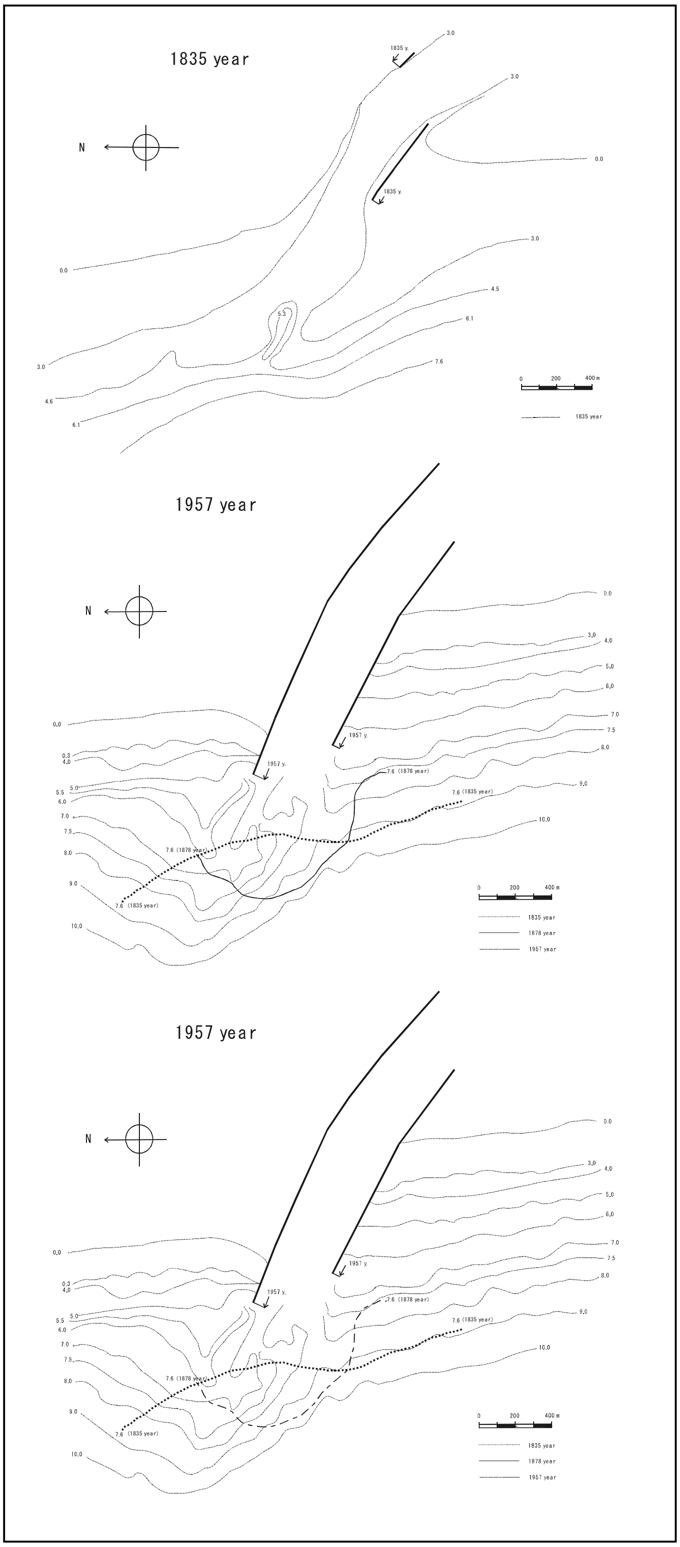
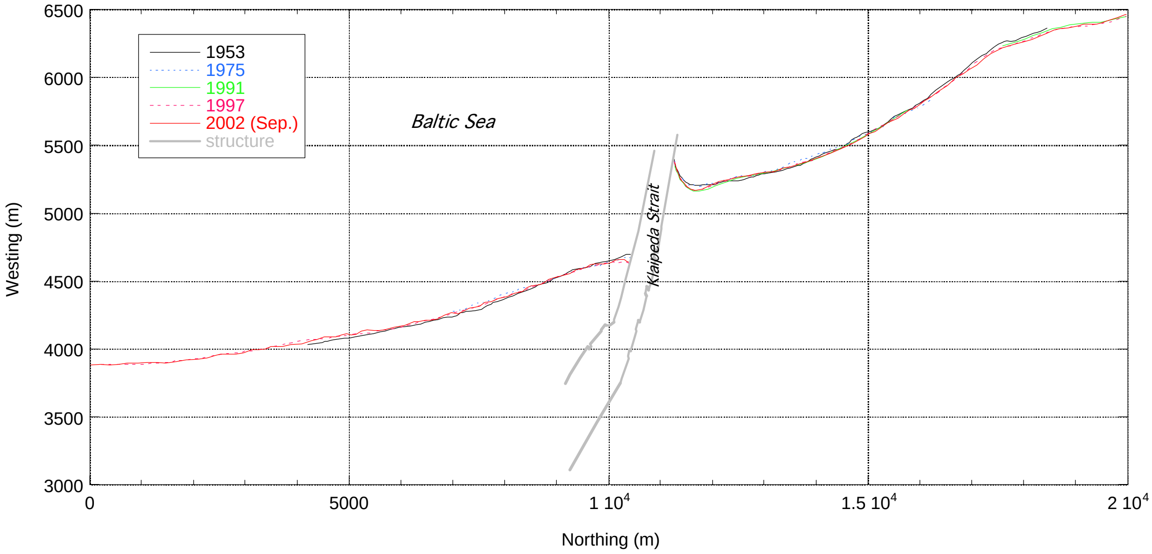



**Figure III.2.1-2 Long-Term Topography Change (Zilinskas, 2000)**

The results of geographical survey executed in 1953 and 1975 and aerial photographs taken in 1991 and 1997 have been examined. These data is useful to analyze the change in shoreline accurately. Figure III.2.1-3 shows the change in shoreline around the port entrance. In this figure, the shoreline position in 1991 is hardly identified in the aerial photograph, thus it is not displayed in this figure. Judging from this figure, the retreat of shorelines has happened for the last 40 years in the vicinity of south breakwater. The amount of the retreat is estimated about 40m at the most remarkable point near the south breakwater. However, the curvature of the shoreline on the northern side of the north breakwater is steeper than before.




Source: Estimate by the JICA Study Team

**Figure III.2.1-3 Shoreline Change in Last 40 Years**

### 2.1.2 Sedimentation in the Port Area

#### (1) Balance of Suspended Load in the Lagoon (Review of Previous Study)

The balance of suspended load in the Lagoon (including port area) are discussed in the study including “THE ONLY LITUANIAN SEAPORT AND ITS ENVIRONMENT, 2003”. The major points described in the above documents are briefed below.

- The total annual amount of suspended load in the Lagoon is about 1,340,000 tons; about 30% from the Nemunas River and 70% from the Lagoon. The 60% for total amount of suspended load from the Nemunas River is lithogenous product, and 40% bioprduct. The suspended load from the Lagoon is mainly bioproduct.
- Most of couse-grain matter transported from the Nemunas River does not reach Klaipeda Port and remains in the Nemunas delta and delta front.
- The total annual amount of suspended load flowing out into the Baltic Sea from the Lagoon is about 550,000 tons. These into the Lagoon from the Baltic Sea is about 33,000 tons.

- It is not cleared how degree of total amount of suspended load settles down on the bottom. The sedimantation rate for suspended load in the Lagoon was assumed as 25% in the previous study. Using this relation, about 400,000 tons of sedimentation occurs in the Lagoon.
- Both of suspended load and sedimentation greatly increase in the spring and summer season.
- In the port area, there exists sediment sand at port entrance to Berth No.5, which was transported from the Baltic Sea. The other part in port area, silt and mud which was transpoted from the Lagoon or produced in port area, are predominant. The thickness of silt and mud is remarkable especially at the deepwater and shelterded area as shown in Figure III.2.1-4. The zone where flocculation of chemicals occurs by mixing with seawater is not clear, since the salinity content at swash area is changeable. The frequency of mixture is comparatively high in the vicinity of Quay No. 5 and No. 30.

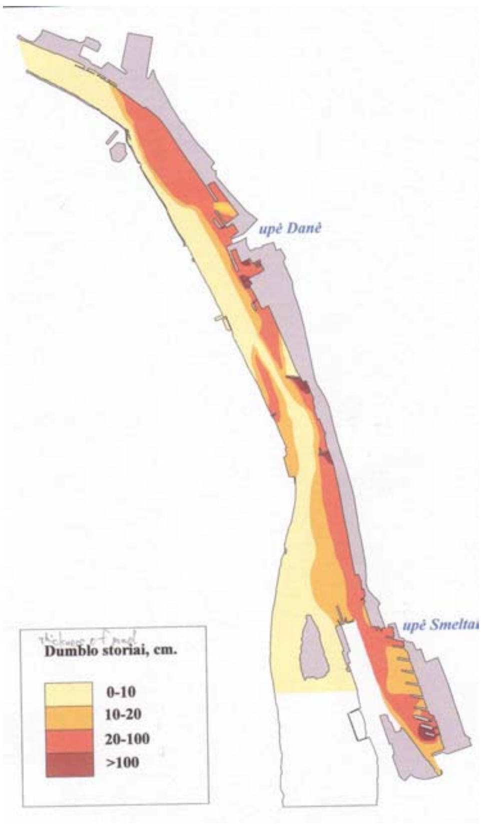



**Figure III.2.1-4 Thickness of Mud Sediments (Galkus, 1999)**

## (2) Sedimentation Analysis based on the Existing Survey Data in Cannel

The bottom sounding in the port area has been performed by KSSA for the capital and maintenance dredging work, constantly. The changes in the seabed profiles along the channel have been examined using the recent dredging and sounding data. The cross-section lines applied for the survey is shown in Figure III.2.1-5, and the changes in the seabed profiles in the typical port zones, namely "Port Entrance and Outer Channel", "KLASCO Area" and "SMELTE Area" are illustrated in Figure III 2.1-6. Historically, the water depths in each port zone were periodically deepened, so that the change in water depths (rate of sedimentation) have been traced back in terms of before dredging and after drdging.

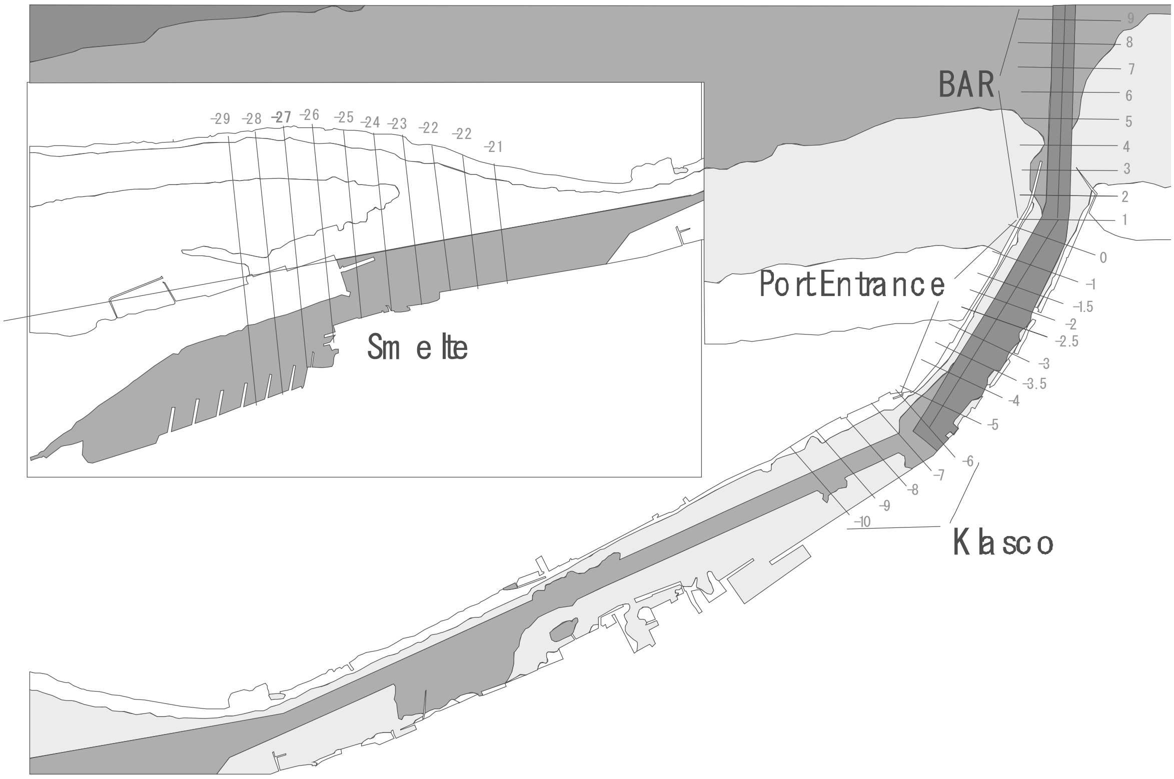


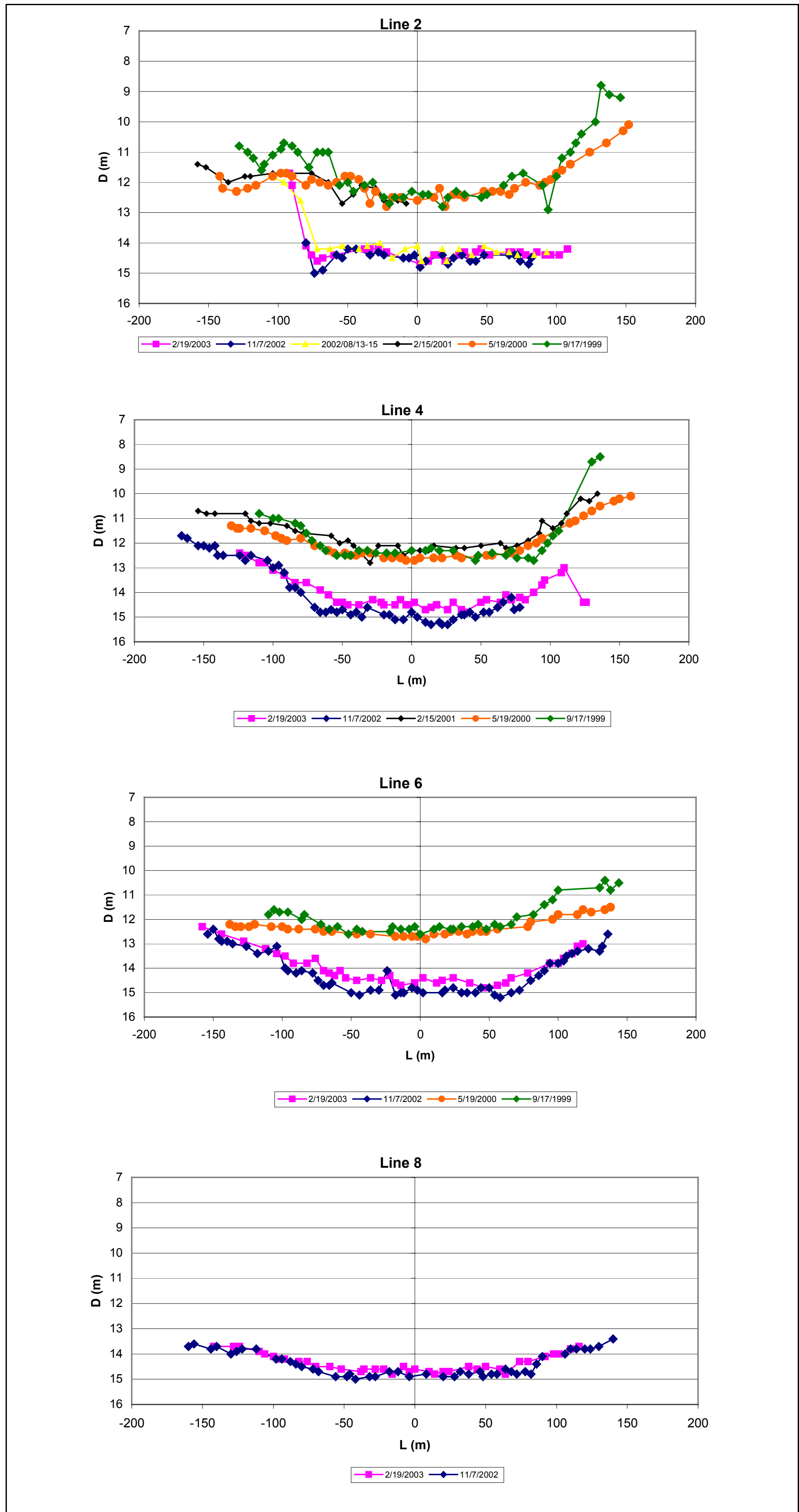

**Figure III.2.1-5 Location of Cross-Section Lines for Profile Change Analysis**

**1) Change at the port entrance and outer cannel before/after the dredging to -14.5 m**

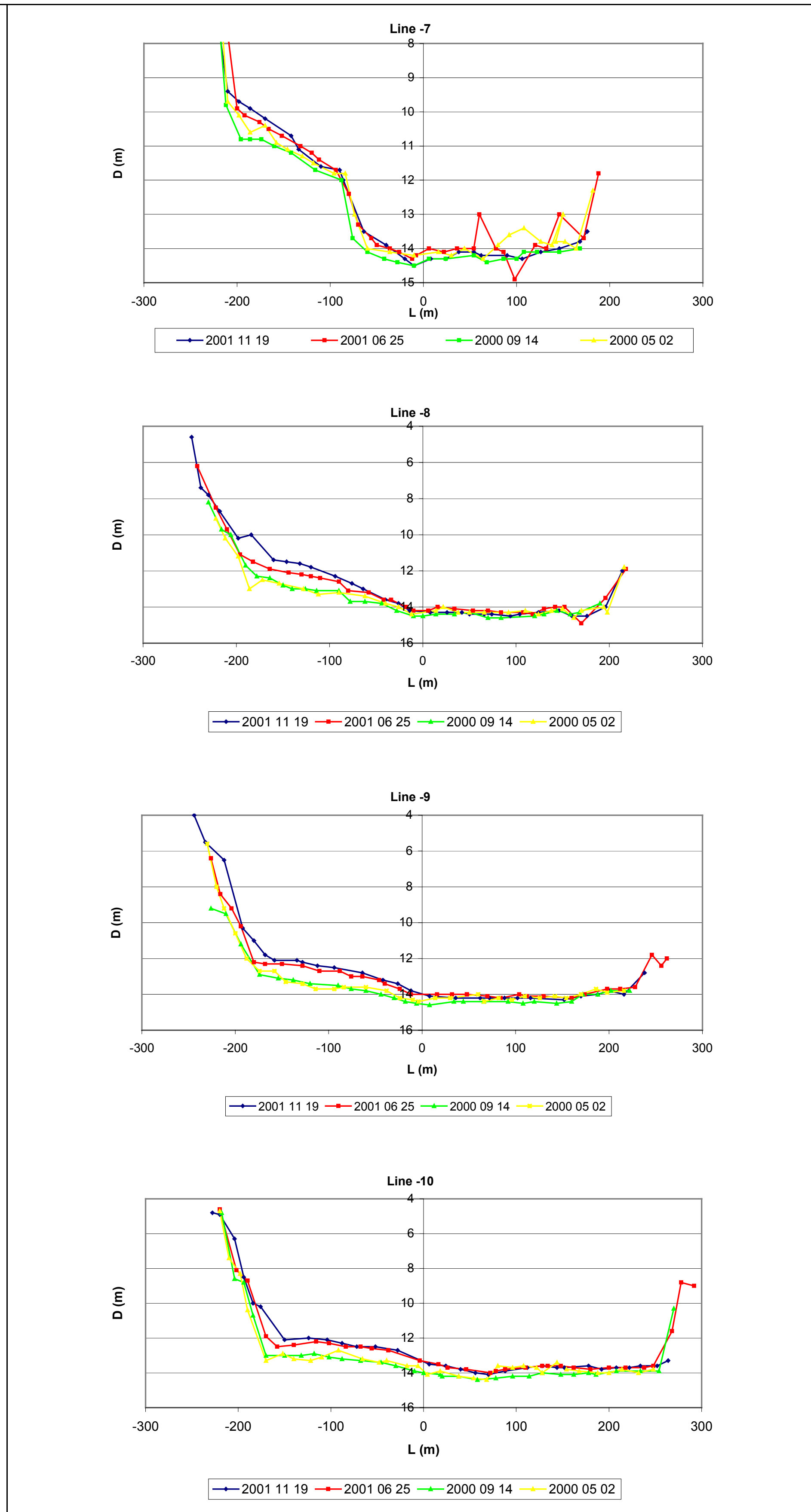
Figure III 2.1-6(1) shows the change of profiles at the port entrance and outer cannel area during eight-month in condition of -12.5m channel from 17 September to 19 May 2000, and during three-month data after -14.5m dredging work from 7 November 2002 to 19 February 2003. After -14.5m dredging work, sedimentation in the channel becomes rather high in the areas extending from Line Nos. 4 to 6 where the previous depth was about -8 to -12m. The sedimentation occurred with a thickness of 50 to 60 cm during the three months in winter. Sedimentation volume for the three months amounts to approximately 50,000m$^3$. The change in profile is hardly seen in Line No.8 where the depth is about -13m, and this tendency of weak sedimentation continues toward offshore.

**2) Change at inner harbor area (KLASCO area, Quay Nos. 5 to 10)**

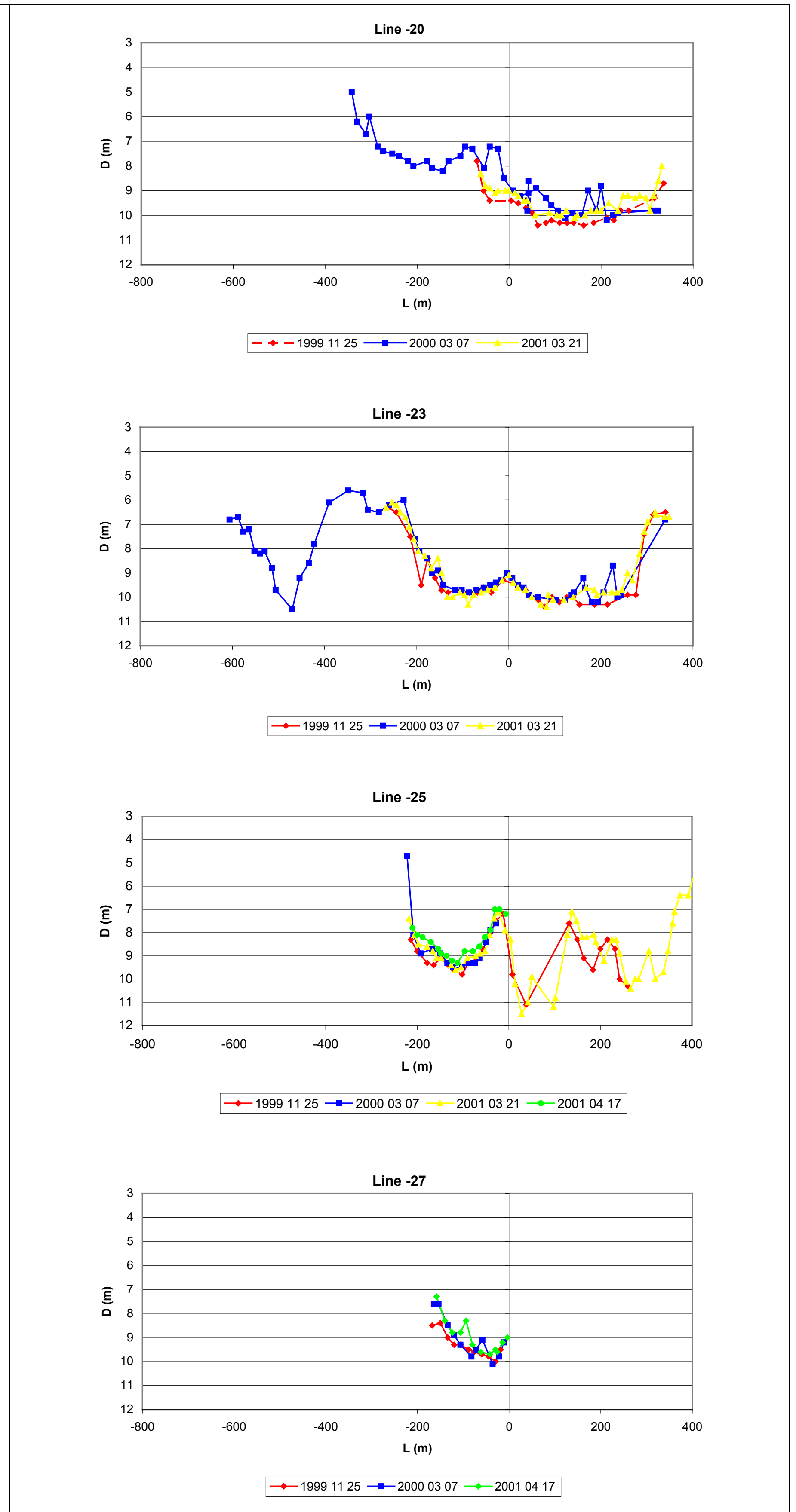
Figure III 2.1-6(2) shows the change of profiles at the KLASCO area (Quay No.5 to 10) during one and half years from 2 May 1999 until 19 November 2001. It is observed that about 1.0 to 1.5m sedimentation occurred on the sand spit side of the channel (left side in Figure). However, sedimentation in the remaining half section of the channel seems small.




*(1) Profile at Port Entrance and Outer Channel*




*(2) Profile at KLASCO Area*




*(3) Profile at SMELTE Area*

Source: Prepared by the JICA Study Team

**Figure III.2.1-6 Profile Change for each Channel Area**

### 3) Change at deep inner harbor area (SMELTE area, Quay Nos. 100 to 150)

Figure III 2.1-6(3) shows the change of profiles at SMELTE area (Quay No.100 to 150) during one and half years from 25 November 1999 until 21 March 2001. About 50 cm of sedimentation exists in the ferry terminal (from Line No20 to 23) and the channel area on south side of island (from Line No. 25 to 27).

In the World Bank project of "Port Entrance Rehabilitation Project", the outer channel has been dredged from -12.5m to -14.5m since 2001. Figure III.2.1-7 shows the change in profiles during three months just after -14.5m dredging work. A remarkable change in profiles can be observed. However, the total volumes of sediment calculated by the difference of profile do not change in total, which means the profile change was caused by the collapse on both sides of channel slope and not caused by the sedimentation from outside channel due to the littoral drift.

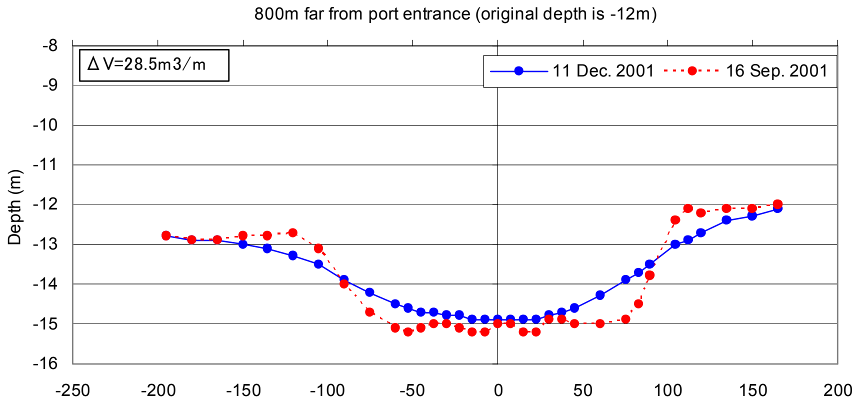



**Figure III.2.1-7 Profile Change After Dredging Work to -14.5m (800m far from the port entrance)**

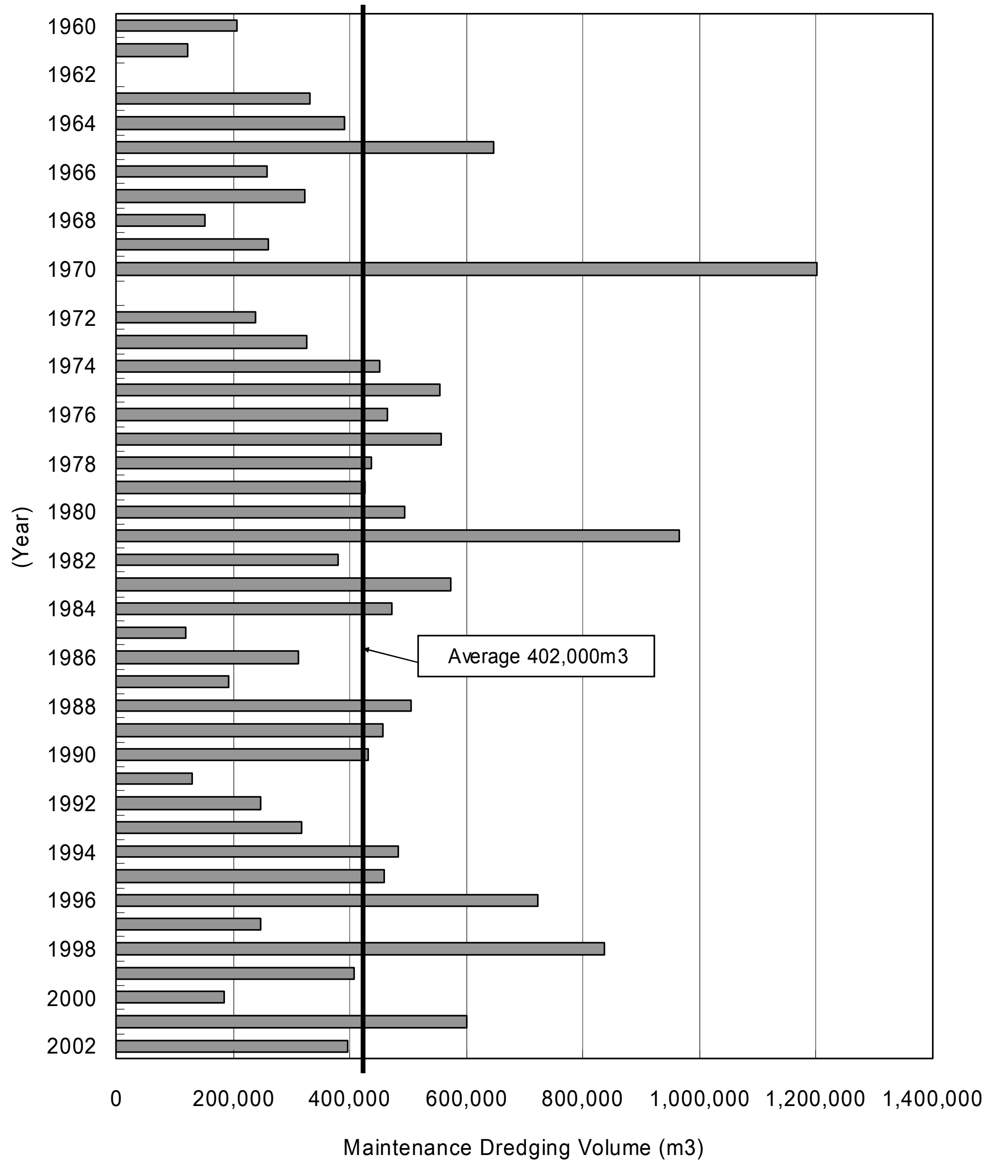
## (3) Sedimentation Analysis from Records of Dredging Volumes in the Port Area

To analyse sedimentation, the records of dredging volumes have been acquired from KSSA. The dredging works executed in the port area can be classified into two types. One is capital dredging for new port areas and another is maintenance dredging for the existing port areas. In estimating sediment volume, the maintenance dredging data is more valuable. Figure III.2.1-8 shows the maintenance dredging volume for each year from 1960 to 2002 in the port. Also, Table III.2.1-1 and Figure III.2.1-9 show the maintenance dredging volume for the period from1994 to 2002 for each area of the port.

As the result, following important points have been identified.

- The annual average of maintenance dredging volume between 1960 and 2002 is estimated at about 400,000$m^3$, while the average dredging volumes only for recent eight years have increased to about 480,000$m^3$per year.
- A large volume of maintenance dredging was executed in the vicinity of the port entrance and BAR (outer channel) areas, which amount to about 110,000$m^3$ and 160,000$m^3$ respectively.

- The annual maintenance volume in the middle part of port area is about 8,000 to 50,000m$^3$.
- About 70,000m$^3$ of maintenance dredging was executed in the vicinity of the international ferry terminal that is located deep inner part of the Port.



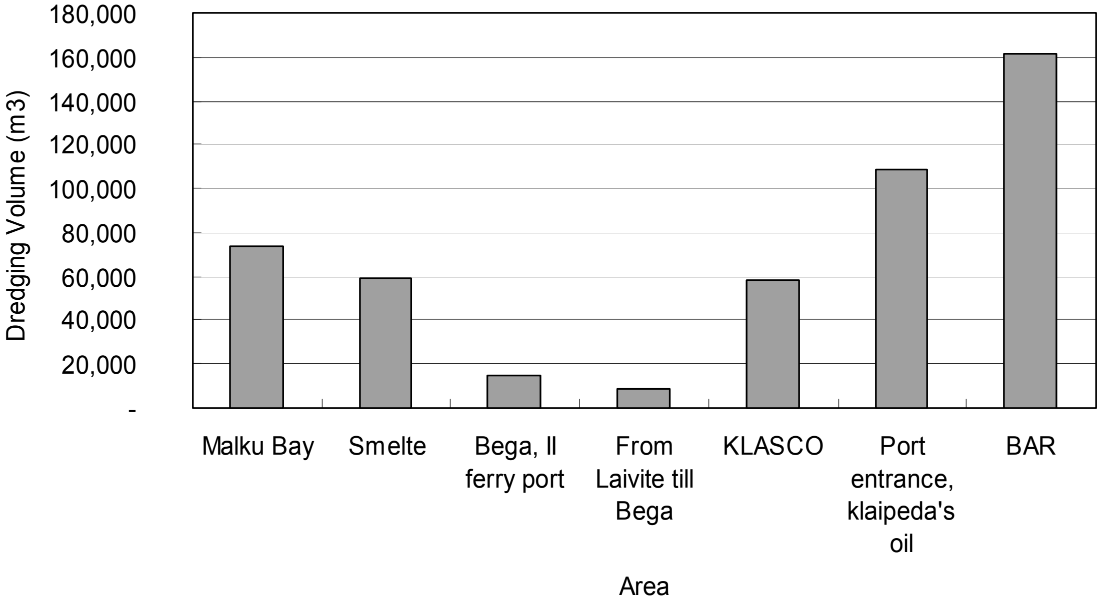

Source: KSSA

**Figure III.2.1-8 Maintenance Dredging Volume (1960 to 2002)**

**Table III.2.1-1 Maintenance Dredging Volume for Each Area (1994 to 2002)**

| Year | Area | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | Malku Bay | Smelte | Bega, II ferry port | From Laivite till Bega | KLASCO | Port entrance, klaipeda's oil | BAR | Total (m3) |
| 1994 | 60,050 | 3,097 | 8,700 | | | 157,623 | 255,471 | 484,941 |
| 1995 | 207,079 | | | | | 9,990 | 243,461 | 460,530 |
| 1996 | | | | | 3,126 | 489,730 | 231,209 | 724,065 |
| 1997 | 25,606 | 30,229 | | | 17,882 | 106,730 | 67,489 | 247,936 |
| 1998 | | 489,575 | | | 134,512 | 13,381 | 200,056 | 837,523 |
| 1999 | 146,550 | | 51,088 | | | | 211,206 | 408,844 |
| 2000 | 120,000 | | | | 33,873 | 30,465 | | 184,338 |
| 2001 | 104,013 | | | 63,636 | 23,604 | 166,566 | 242,270 | 600,089 |
| 2002 | | 4,485 | 69,988 | 14,837 | 307,720 | | | 397,030 |
| Total (m3) | 663,298 | 527,386 | 129,776 | 78,473 | 520,717 | 974,484 | 1,451,162 | 4,345,296 |
| Average (m3) | 73,700 | 58,598 | 14,420 | 8,719 | 57,857 | 108,276 | 161,240 | 482,811 |
| | Without Bar Area | | | | | | | 321,570 |
| | Without Bar and Port Entrance Area | | | | | | | 213,294 |

Source: KSSA




Source: KSSA

**Figure III.2.1-9 Maintenance Dredging Volume for Each Area (1994 to 2002)**

### (4) Summary of Littoral Drift and Sedimentation Analysis

The characteristics of the littoral drift in the outer area (coastal area) and of sedimentation in the port area are summarized as follows.

#### 1) Characteristics of Littoral Drift

- The existence of a predomnant north-bound littoral drift along the Lithuania coast can be well demonstrated through the wave analysis and the interpretation of the historical changes in geography, including the coastline outside the Lagoon, the shape of the beach around Palanga and Sventoji, the long-term change in the shoreline around Klaipeda Port, etc.
- The coastline around Klaipeda Port extends almost perpendicular to the incident wave directions, so the magnitude of longshore currents is not so

strong around the Port. Moreover, the coastline change for the last 50 years seems rather small as evidenced by geographical maps, aerial and satellite photography. From these reasons, it has been concluded that the sediment rate induced by littoral drift is weak around Klaipeda Port.

- There is a possibility that the shoreline tends to retreat on the northern side of port entrance presumably by the influence of sand-mining resulting from the maintenance dredging and the change of local currents caused by the construction of breakwaters.

### 2) Characteristics of Sedimentation in the Port Area

- About 55,000 ton/year of fine materials flow into the port area and about 33,000 ton/year come from the Baltic Sea.
- The process of sedimentation in the inner channel is caused mainly by the convection and settling of suspended load from the Lagoon, and the mixture and re-settling of settled solid by the wind. The process in the outer channel is caused mainly by the drift sand in the Baltic Sea.
- The dredging record in the Port area from 1994 to 2002 gives that the average dredging volume is 0.48 million $m^3$/year (0.15 million $m^3$/year in the outer channel, 0.11 million $m^3$/year in the Port entrance and 0.21 million $m^3$/year in the inner channel).

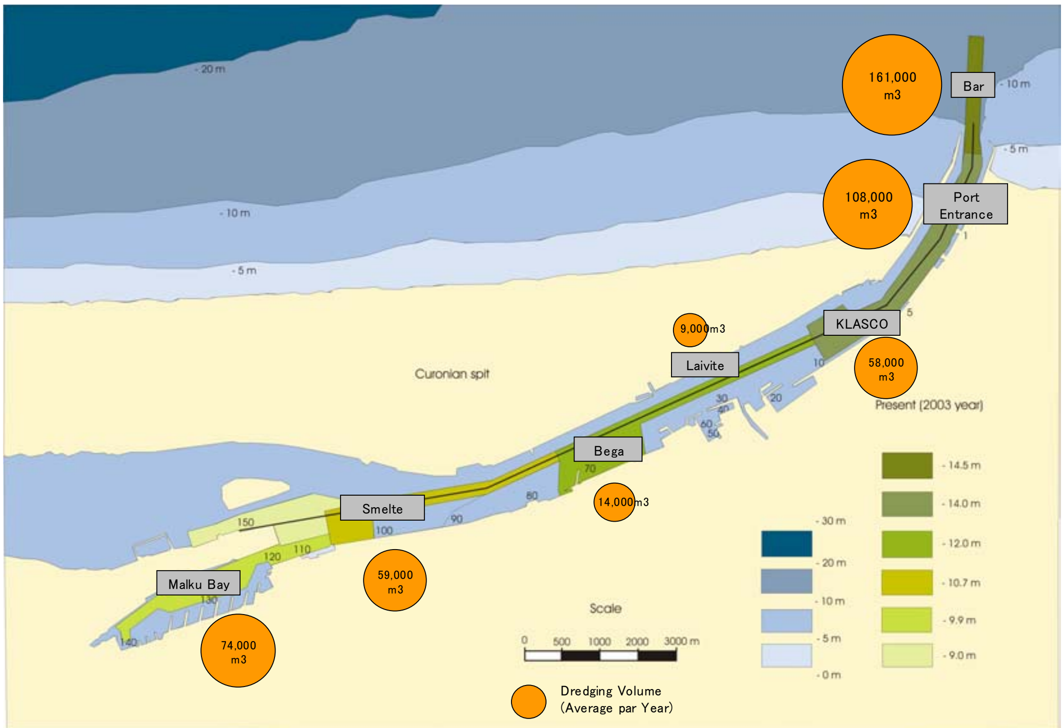



**Figure III.2.1-10 Dredging Volume in the Port Area (Annual Average)**