Marmaray Project: Marine Operations, the Bosphorus Crossing

DLH

AVRASYACONSULT

TAISEI

KUMAGAI

GAMA

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Immersed Tunnel Construction:

- 1 Marine environment of the Bosphorus
- 2 Marine construction activities
- 3 Hydrological survey and modeling
- 4 Model tests for immersion operations

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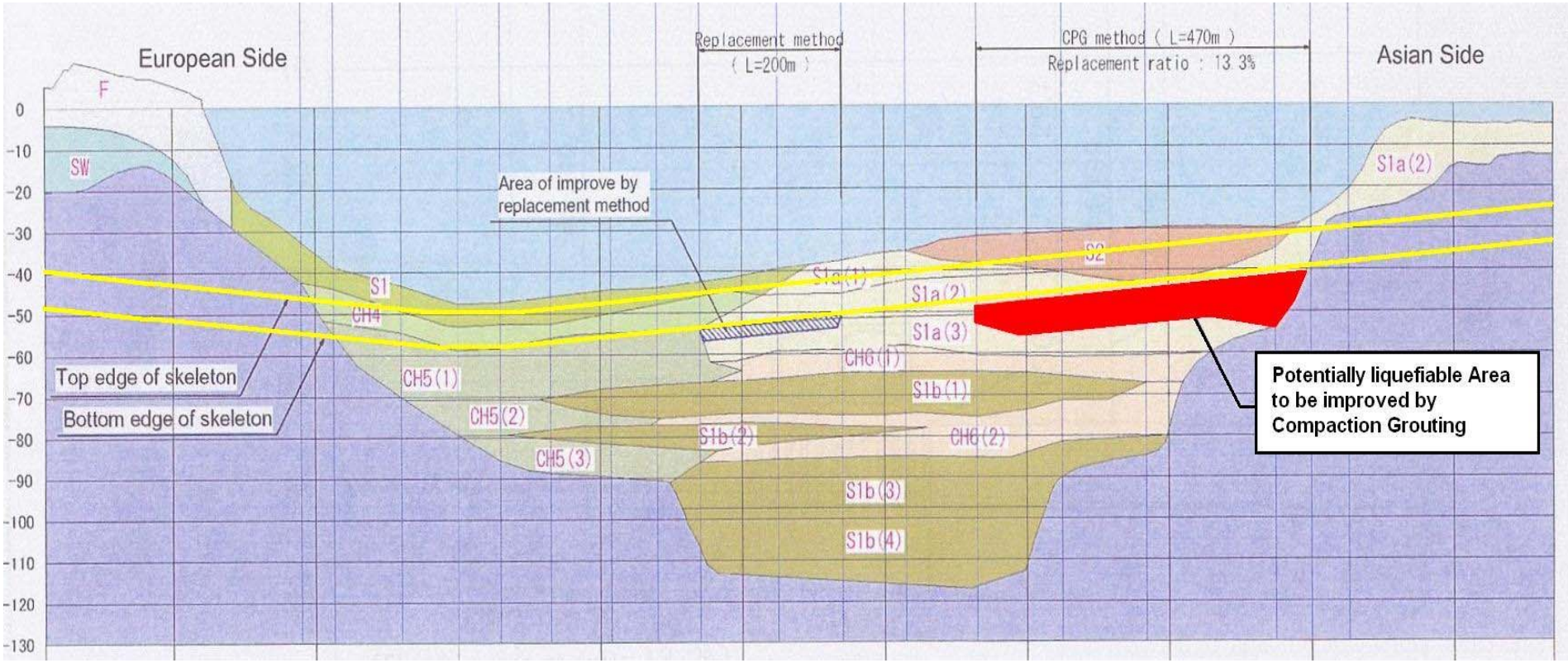
1 Marine Environment of the Bosphorus

- Intensive
- Unpredic
- An ecologi

2 Marine Construction Activities

- 2.1 Ground improvement works
- 2.2 Dredging and backfilling works
- 2.3 Tube immersion operations

2.1 Ground Improvement Works



Treated area: 471 x 20.5 m1 Depth: 4 – 10 m under tunnel

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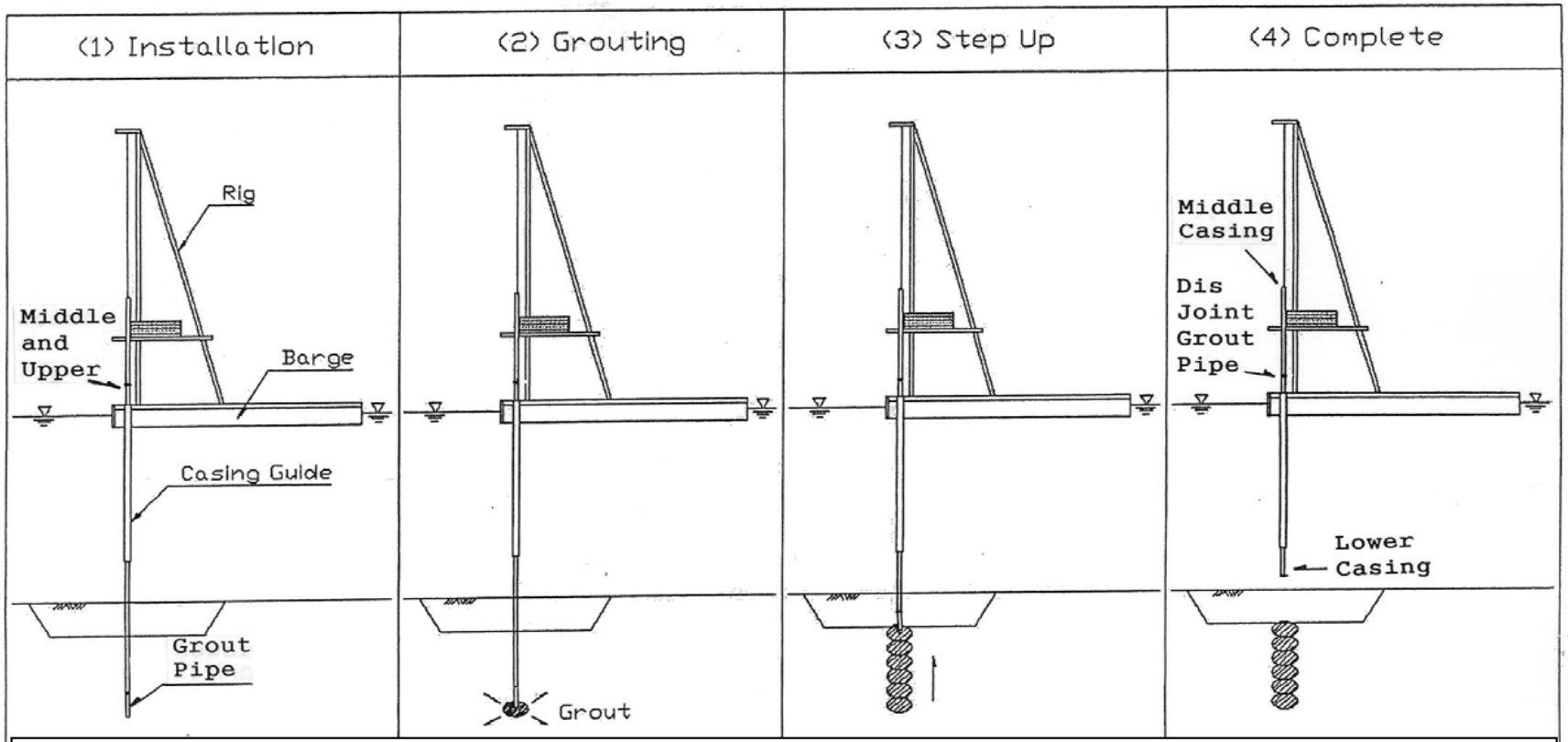
2.1 Ground Improvement Works



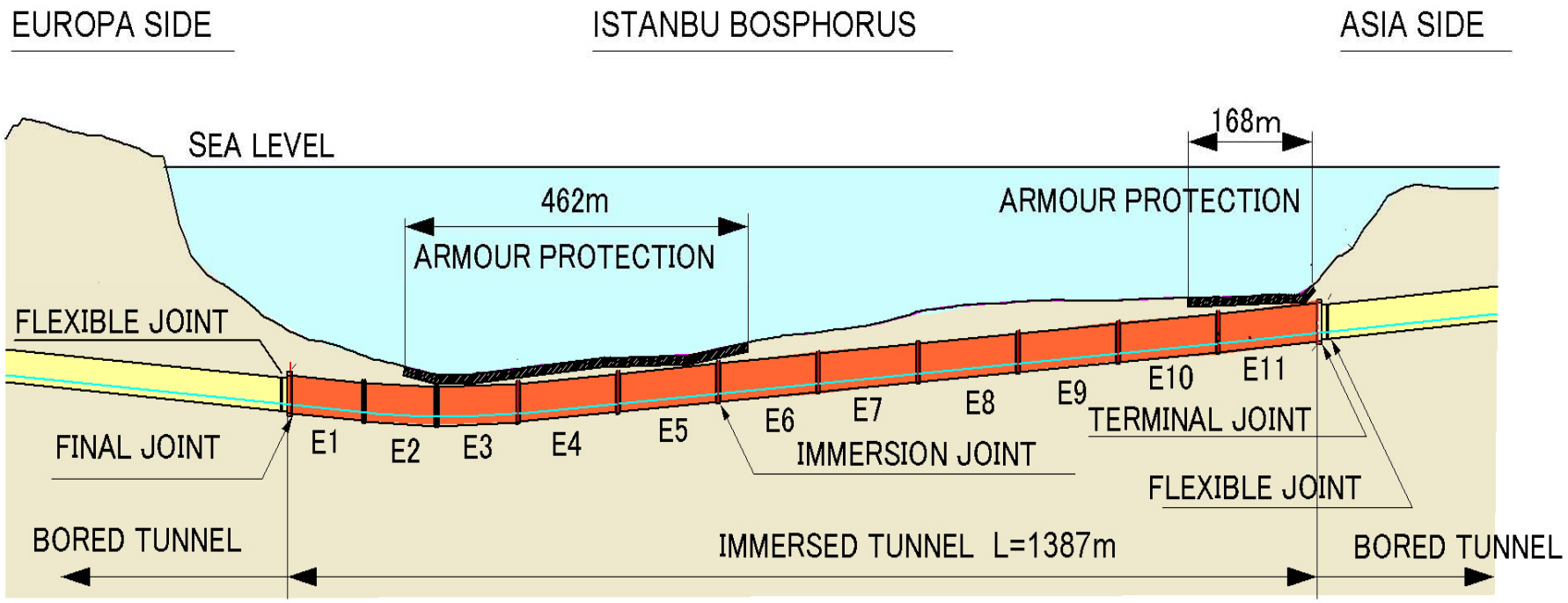
Volume of treated soil: 74.500 m³ **Number of CPG columns: 3.264**

Volume of grout: 11.000 m3 **Replacement ratio: 13.3 %**

2.1 Ground Improvement Works

Compaction Grouting barge *"SAR III"*: 86 x 24 m

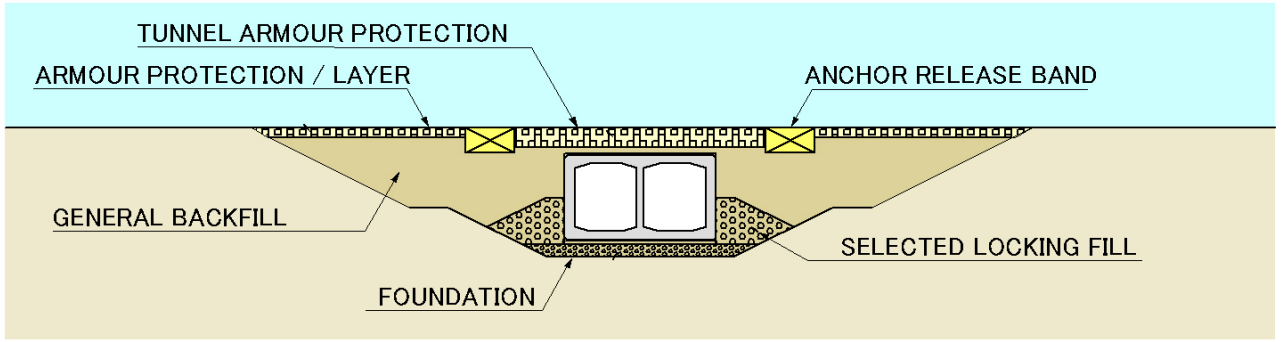
2.2 Dredging and Backfilling Works



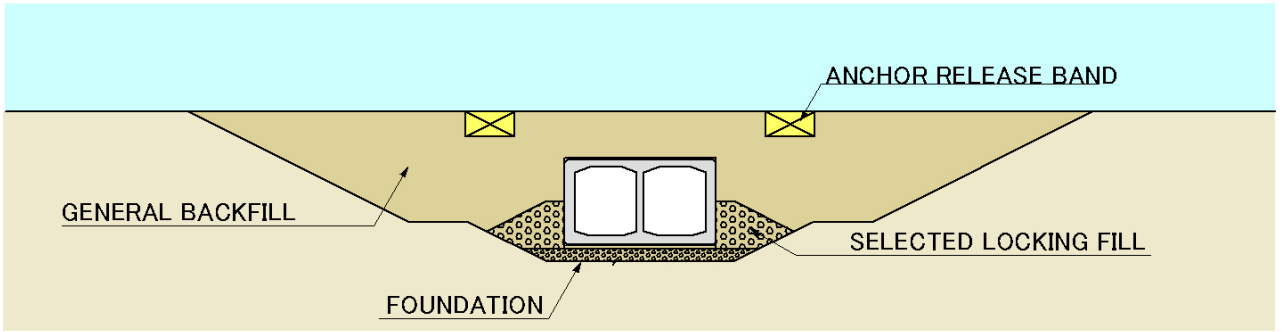
Deepest point: 61 m under Mean Sea Level

2.2 Dredging and Backfilling Works

BACK FILL THICKNESS IS UNDER 4m



BACK FILL THICKNESS IS OVER 4m



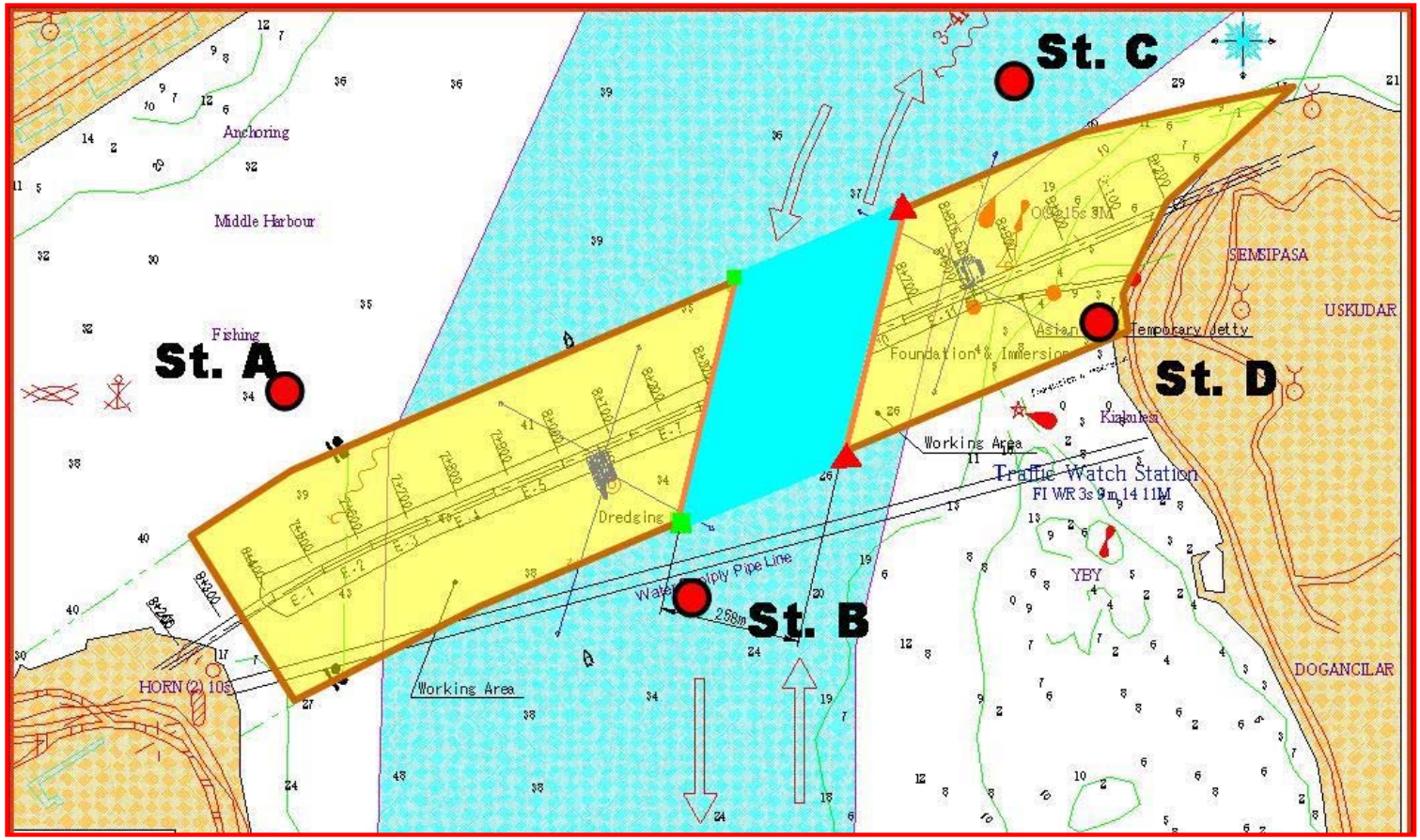
Contaminated soil: 120.000 m3 **Clean soil: 1.000.000 m3**

Stone backfill: 130.000 m3 **Soil backfill: 800.000 m3**

2.2 Dredging and Backfilling Works

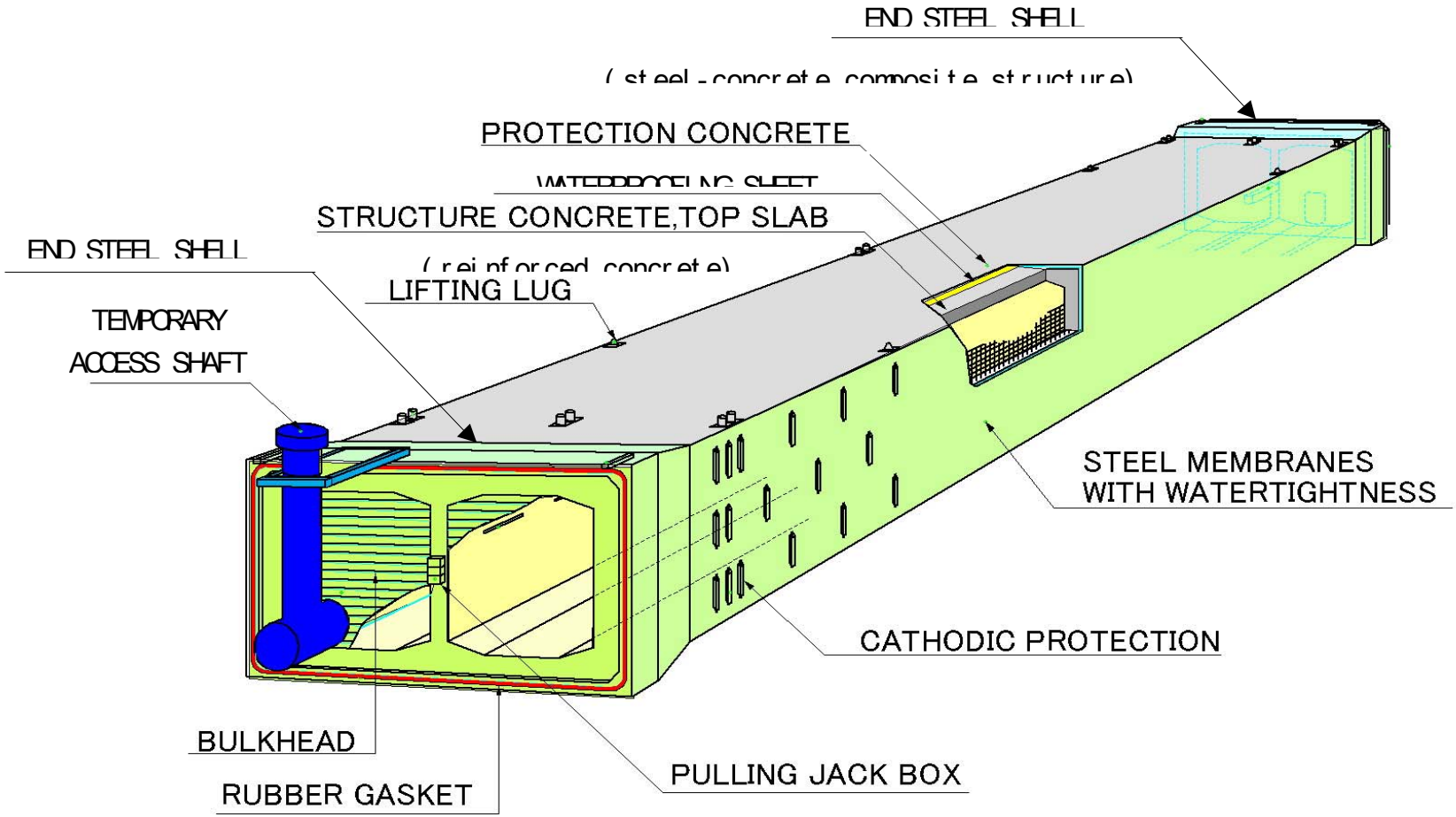
Grab dredger *"Kanyu"*: 4.000 hps **Grab: 27 m3, 3.9 ton**

2.2 Dredging and Backfilling Works



The project's marine operations have a serious impact on navigation

2.3 Tube Immersion Operations



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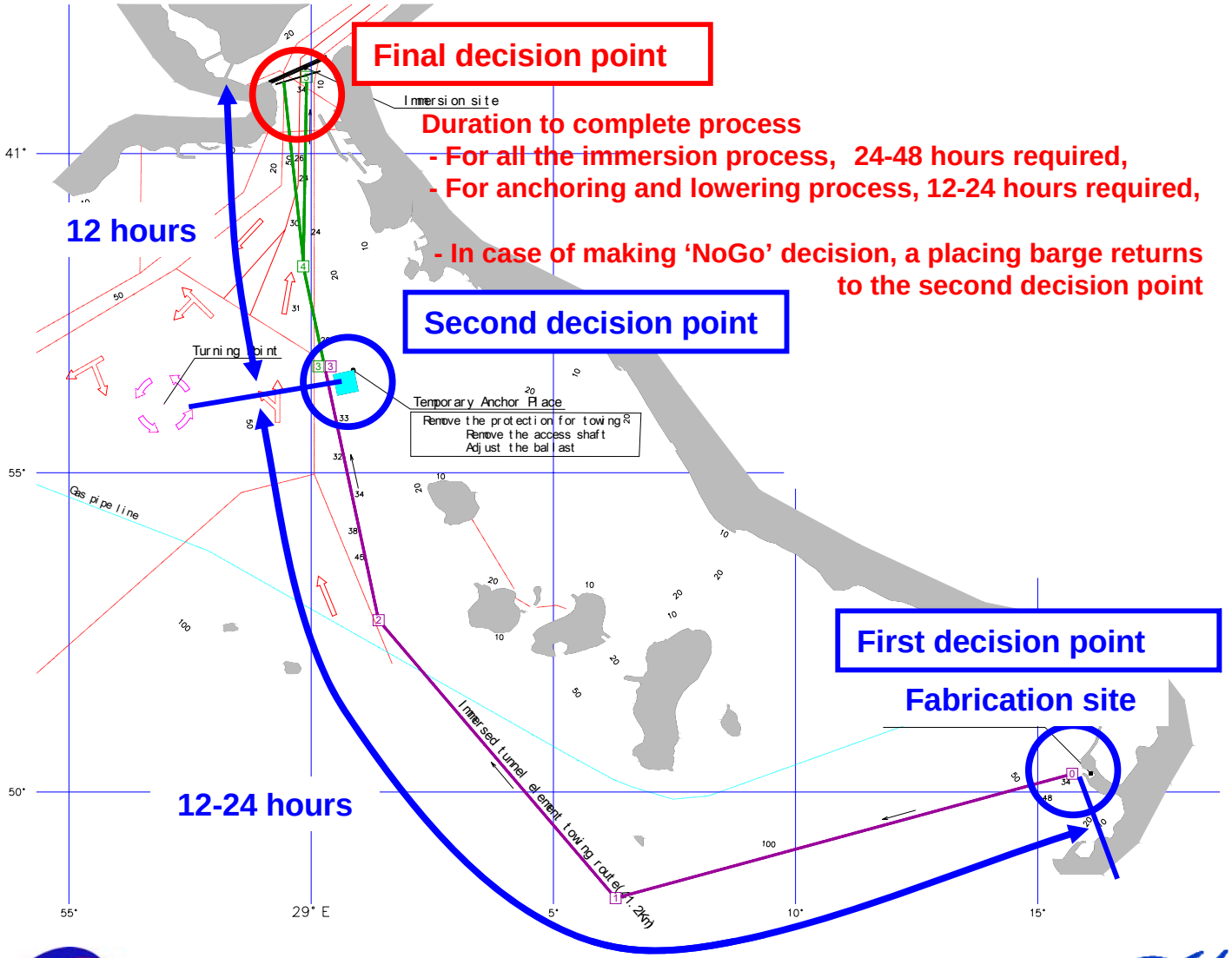

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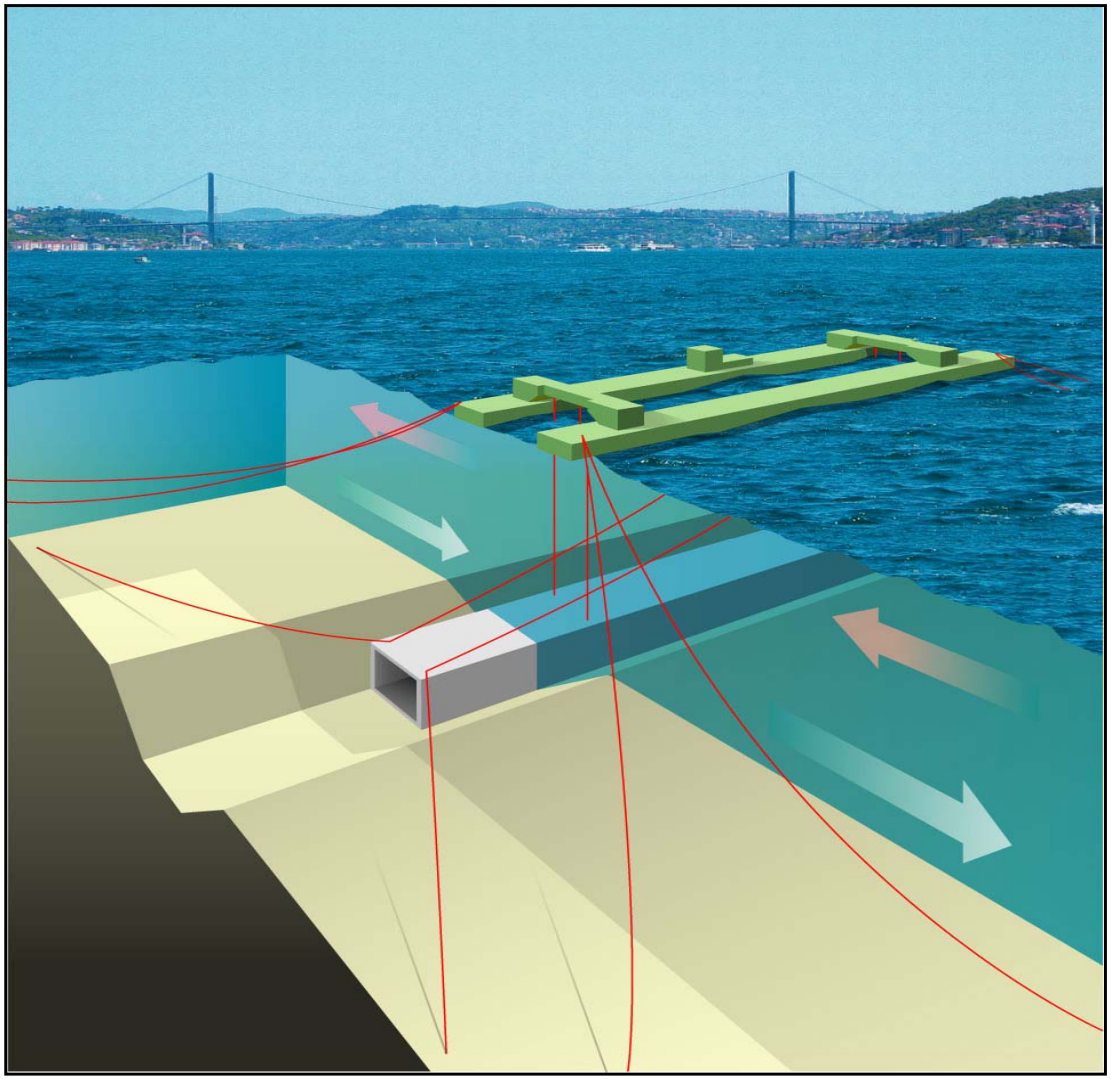
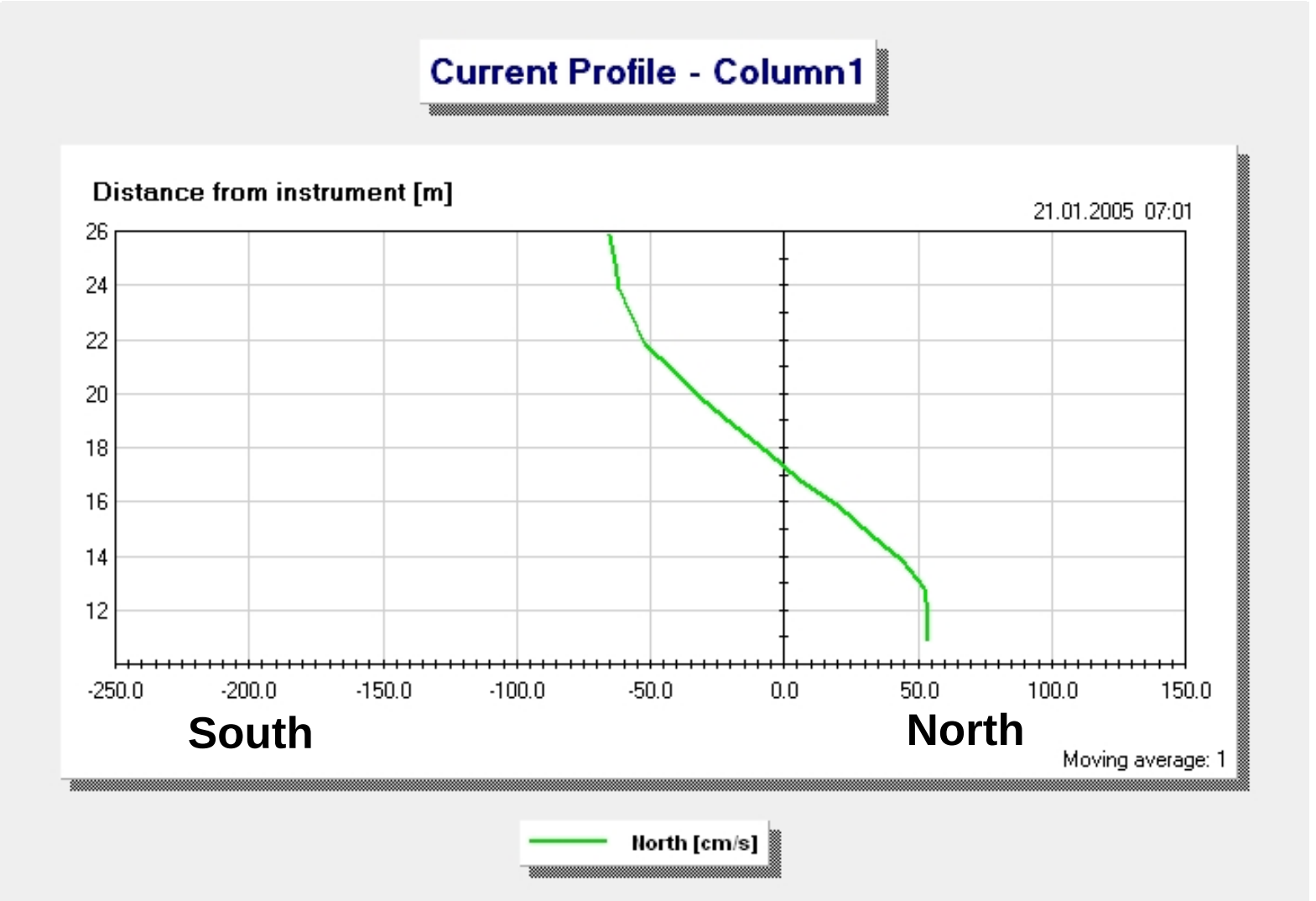


3 Hydrological Survey and Modeling

- Limited knowledge of the Bosphorus' hydrology at tender stage
- Very little tidal movement (10-20 cm)
- Rapid changes in current velocity
- Surface currents up to 3.5 m/s (7 knots) South
- Stratification: bottom current in North direction

3 Hydrological Survey and Modeling



3 Hydrological Survey and Modeling

Employer's Requirement: a comprehensive hydrological monitoring and modeling program

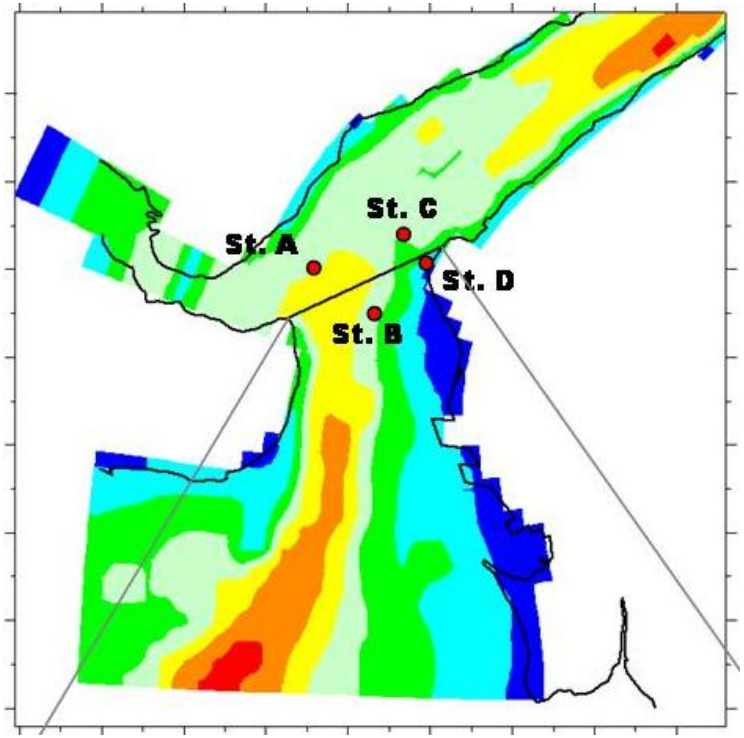
With 2 objectives:

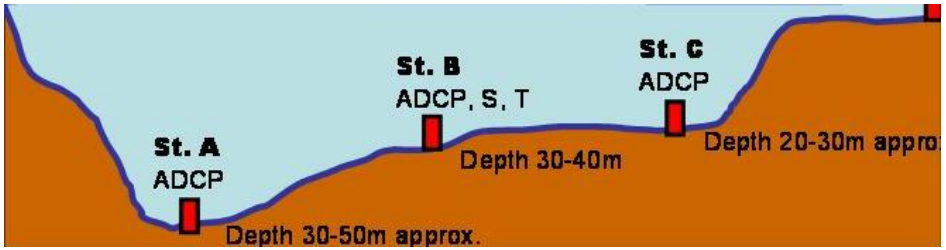
1. **Develop a reliable forecasting model as a tool to avoid risks during the immersion operations**

2. **Establish data that can be used in a risk sharing mechanism for "unforeseen current conditions"**

3 Hydrological Survey and Modeling

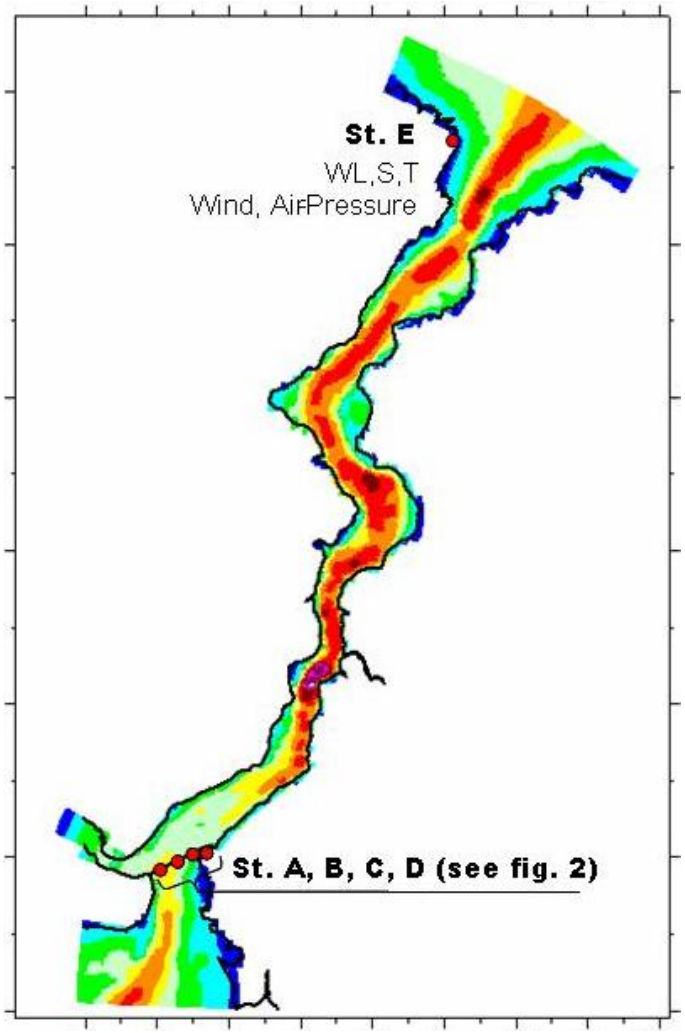
- 3 permanent Acoustic Doppler Current Profilers were placed directly outside the construction area
- Continuous current measurements during the first 10 minutes of every hour
- Wind, air pressure etc.





3 Hydrological Survey and Modeling

- **Modeling of the Bosphorus in a hydrodynamic numerical simulation model (Delft3D-Flow)**
- **Additional current profile measurements in the tunnel alignment**
- **Validation of the models with measured data**



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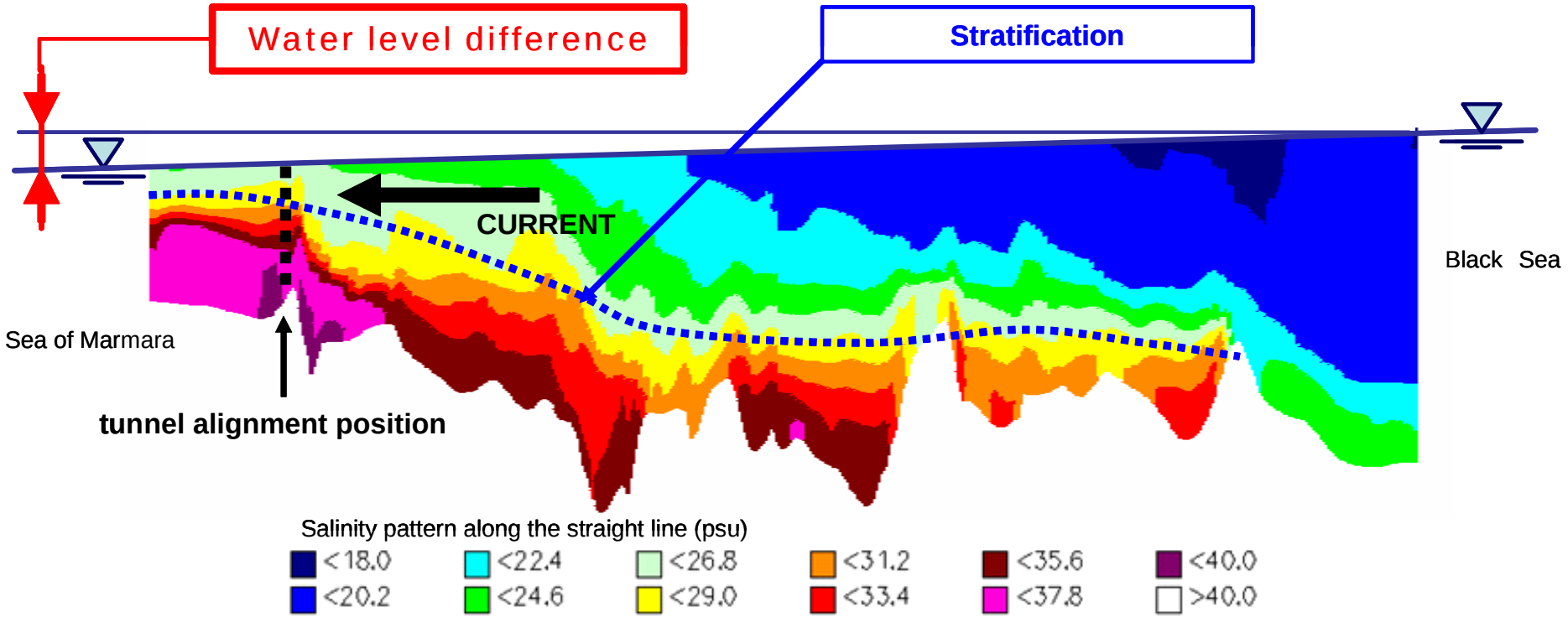
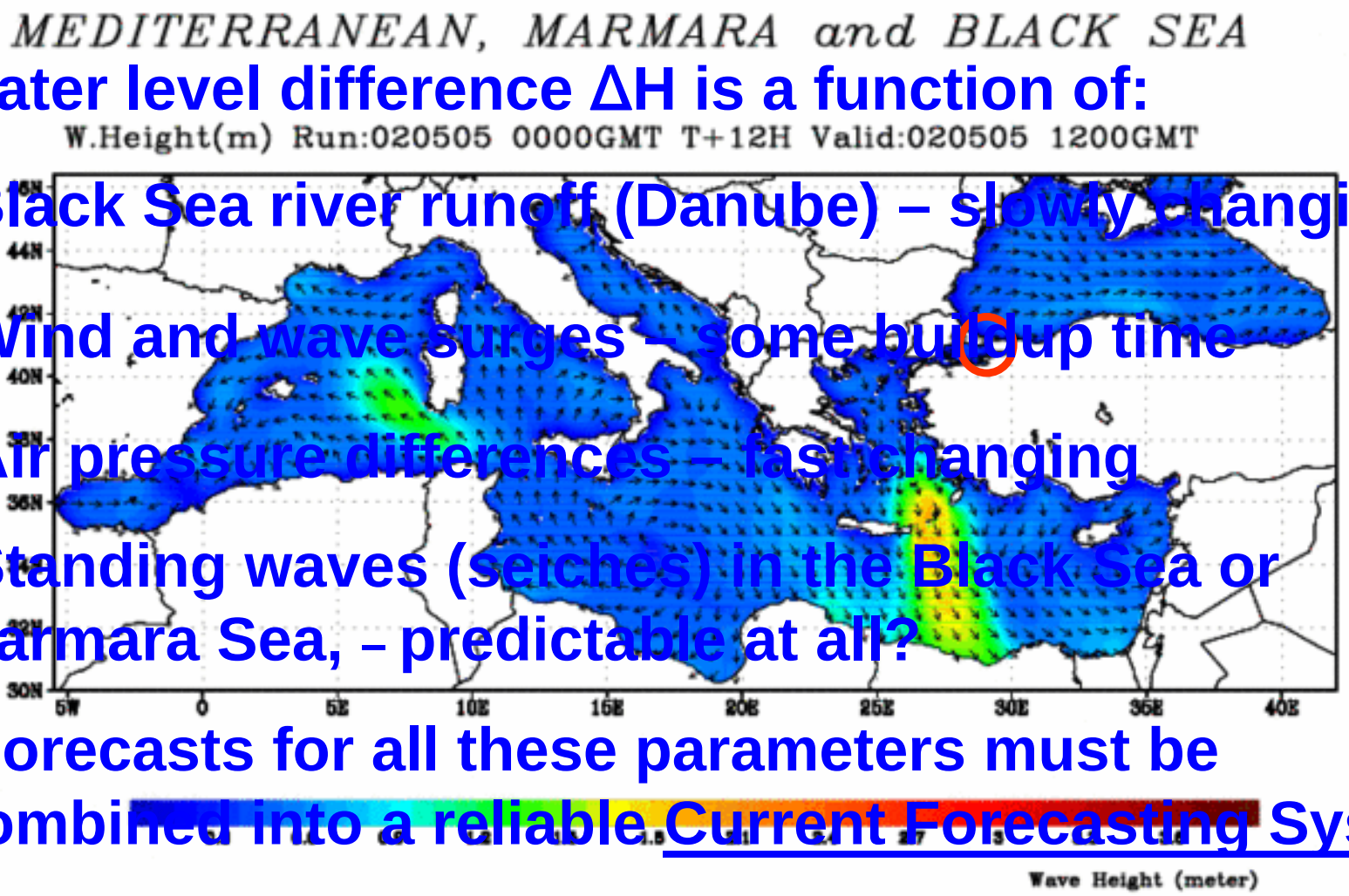
3 Hydrological Survey and Modeling



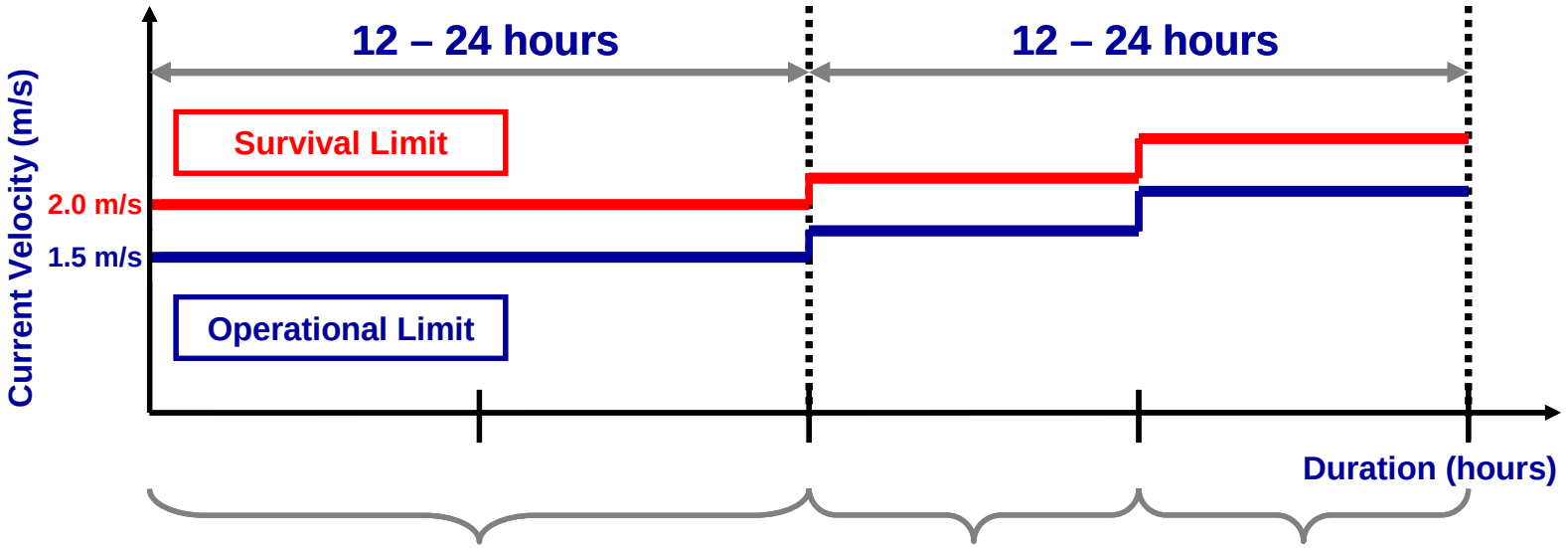
3 Hydrological Survey and Modeling



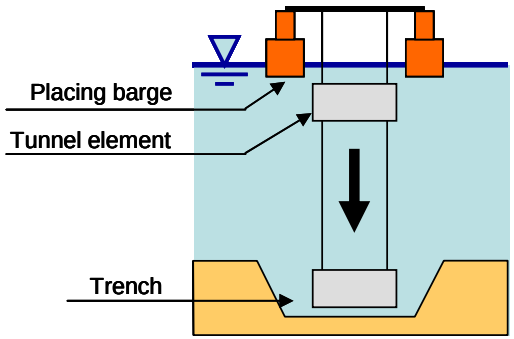
Water level difference ΔH is a function of:

- **Black Sea river runoff (Danube) – slowly changing**
- **Wind and wave surges – some buildup time**
- **Air pressure differences – fast changing**
- **Standing waves (seiches) in the Black Sea or Marmara Sea, – predictable at all?**
- **Forecasts for all these parameters must be combined into a reliable Current Forecasting System**

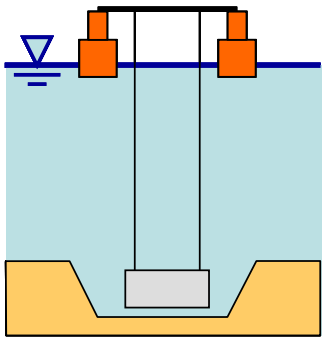
3 Hydrological Survey and Modeling



- Anchoring a placing barge
- Lowering a tunnel element

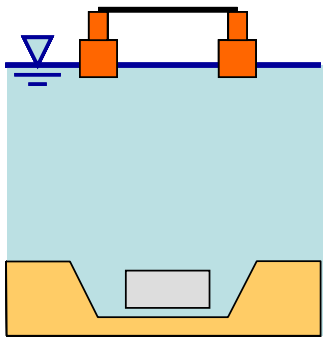


- Aligning a tunnel element
- Connecting tunnel elements



Current force is deceased because a tunnel element in a trench is acted by slow flow.

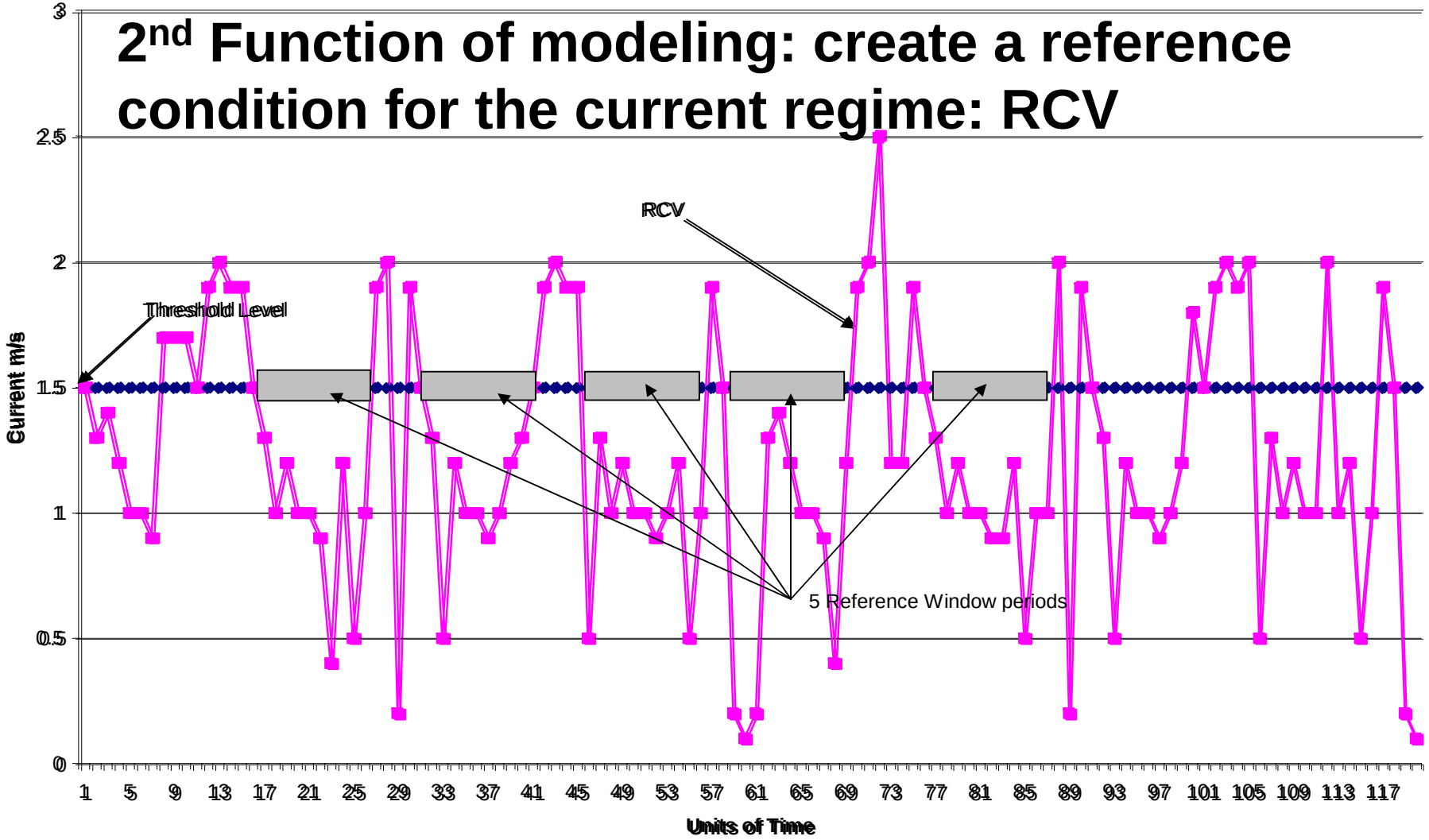
- Detaching a tunnel element
- Releasing anchor lines



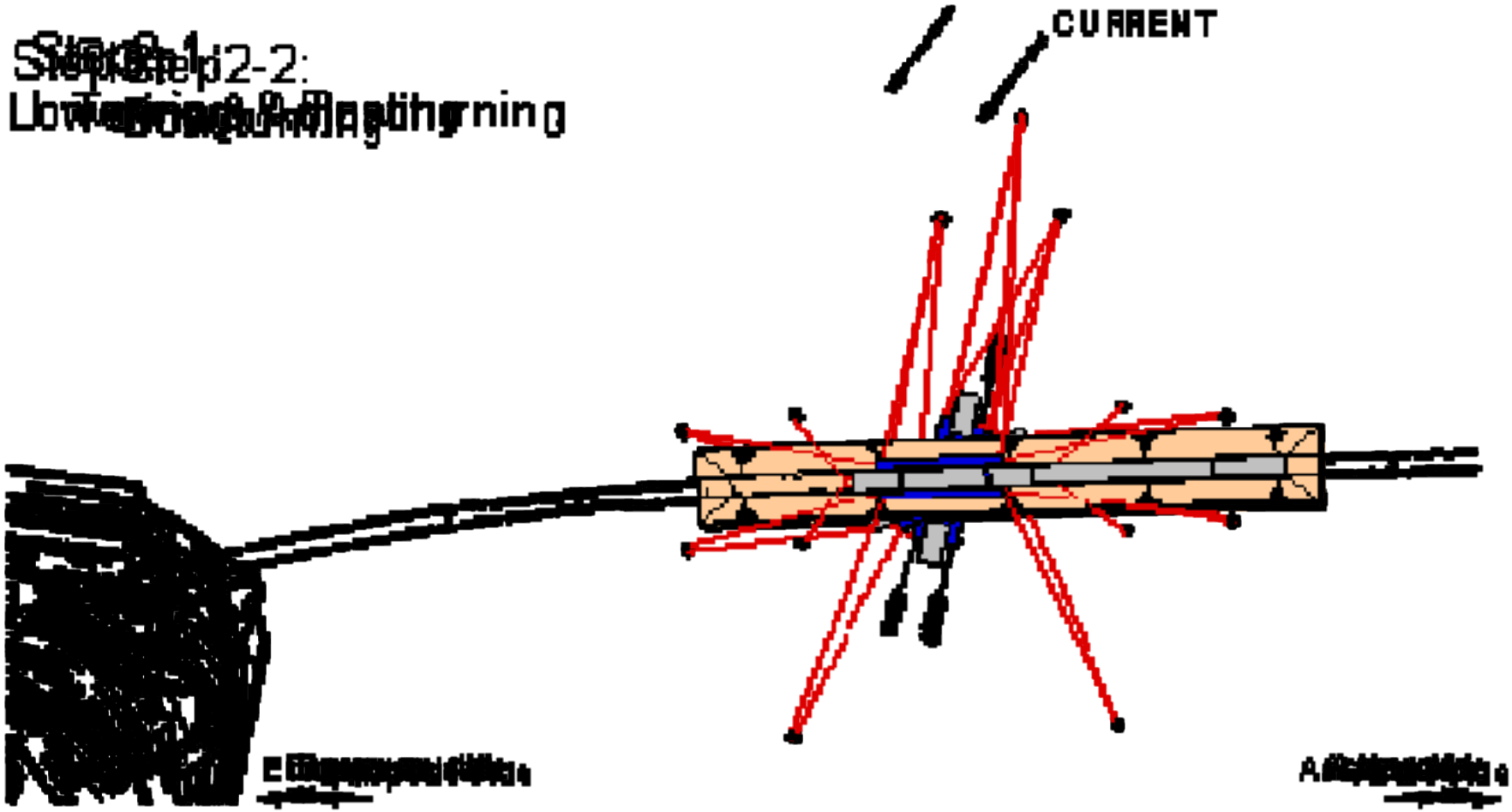
Current force is more deceased because a tunnel element is detached from a placing barge.

3 Hydrological Survey and Modeling

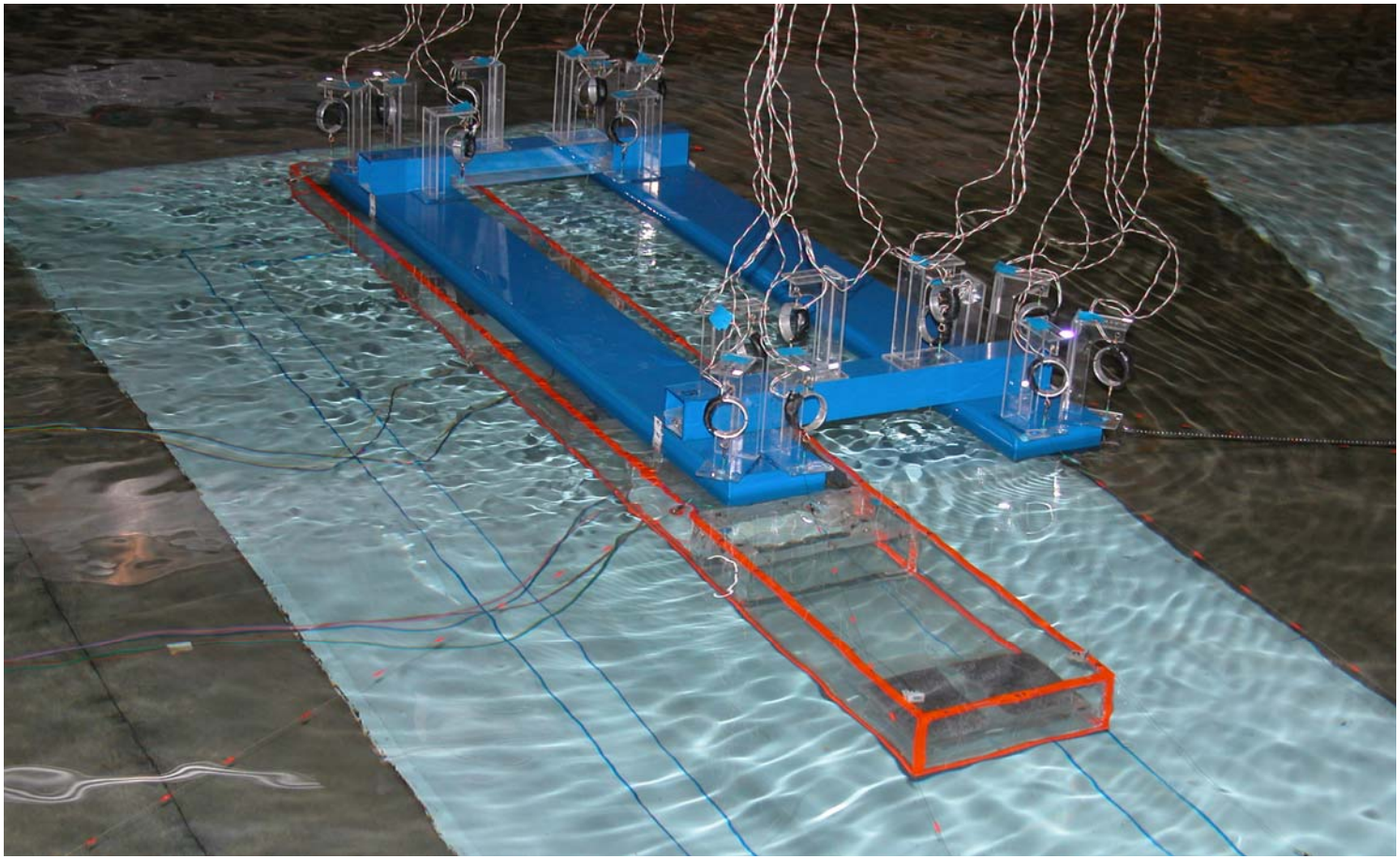
2nd Function of modeling: create a reference condition for the current regime: RCV



4 Model Tests for Immersion Operations



4 Model Tests for Immersion Operations



Scale 1:120	Water depth: 48 m	Flow: 1.0 - 1.5 - 2.0 m/s

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4 Model Tests for Immersion Operations

During immersion:

- **Down force ± 800 ton**
- **Number of holding and adjusting wires: 13**
- **Maximum wire force: ± 140 ton**
- **Adjusting wire force: ± 50 ton**

Thank you for your attention

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