Hydraulic Engineering in The Netherlands: A Visit by the Tufts ASCE Student Chapter

Since over half of their country lies below sea level, the Dutch have developed highly refined facilities for hydraulic research that have practical and vital application worldwide.

Eight civil engineering students at Tufts University in Medford, Massachusetts, participated in the International Concrete Canoe Competition on May 29–30, 1992, that was sponsored by the Delft University of Technology, in Delft, The Netherlands. The participants were members of the Tufts ASCE Student Chapter and included:

- *Six seniors — Eleanor Allen, Patrick Johnston, Genevieve Dyer, Robert Kefalas, Anna Jensen and Normita Villamor;*
- *One junior — Christopher Bell; and,*
- *One sophomore — Joshua Gould.*

The head of the civil engineering program at Tufts, Professor Linfield C. Brown, accompanied the students.

The incentive for this trip came about because Tufts was invited to be the first and only American team to compete in the 16th annual International Concrete Canoe Competition in Delft. This concrete canoe race was part of the celebration of the Delft University of Technology's 150 years of existence. The opportunity to travel to The Netherlands allowed the Tufts students to visit famous hydraulic engineering works, such as one of the Delft Hydraulics Laboratories and the storm surge barrier in the Eastern Scheldt.

The trip lasted eight days. This article, written by the eight student participants in a journal form, recounts their experiences at the canoe competition and at the technical visitations.

May 25, 1992

Today was the start of our week in The Netherlands. All eight of us met in Amsterdam, four coming from the U.S. and four from Belgium after having spent a week traveling together. We spent the day relaxing and enjoying Amsterdam.

May 26

We spent the day touring Amsterdam. The city structure was amazing with all the canals. It was fascinating to think that the Dutch used to do all of their travel through the city by boat. We also got a chance to see some famous sights, the Anne Frank House and the Vincent Van Gogh Museum.

May 27

We woke up early and left Amsterdam for our first tour. We arrived at the Delft Hydraulics Laboratory "de Voorst" in the town of Emmeloord in the North-East Polder at 10:00 a.m. Three students from the technical university at Delft met us there and joined the tour.

When we arrived we were given an introduction to Delft Hydraulics presented by Jitse Wouters, a Senior Project Engineer in Harbors, Coasts and Offshore Technologies. Delft Hydraulics is an independent, non-profit institute that performs consulting in all aspects of water-related problems. The institute was founded in 1927 and now has three research centers: one in Delft, one in Haren and the third, that we were visiting, in de Voorst. The institute has 525 employees and 40 percent of its consulting is done on an international level. Delft Hydraulics specializes in six areas:

- *Hydraulic Engineering:* hydraulics and morphology, sediment transport, estuarine hydraulics, wave dynamics, offshore technology, flood forecasting, hydraulic structures and hydrosurveys.
- *Coastal Zone Development:* oceanography, coastal dynamics, coastal engineering and storm surge protection, coastal zone planning, and marine and coastal pollution.
- *Water Resources Management:* water resources planning, hydrology (surface and groundwater), salt intrusion, river basin development and planning, irrigation, reservoir design and operation, and hydropower.
- *Ecological Studies:* ecological modeling, environmental impact assessment, water quality, soil pollution and groundwater quality, and ecotoxicology.
- *Transportation/Infrastructure:* harbor layout and marine structures, optimization of access channels, inland water transport, river engineering and regulations, navigation and nautical training.
- *Industrial Hydrodynamics:* cooling water recirculation, intakes and outlets, discharge and dispersion of effluents, dredging technology, hydraulic analysis of pipe systems, and testing and research of pipe components and sump pumps.

The de Voorst laboratory facilities cover 125 hectares. There are many different types of physical models in use, the most spectacular being a 230-meter long delta flume. There is also a hall that covers an area of 2.5 hectares that houses many small-scale physical models. The original scale model for the Deltaworks was developed here. Also on site is a multidirectional wave basin.

A video was shown to give us the history behind the grass dikes erected along the coastline in the northern province of Friesland. These dikes were periodically heightened and strengthened as part of a reconstruction program that took place throughout the 1980s. Every 4,000 years there is a storm surge like the one that struck the province of Zeeland in southern Holland in 1953 and that resulted in the loss of almost 2,000 lives and 47,000 homes. Holland must always be prepared for a storm surge since over half of its land lies below sea level.

The Delta Flume

Mr. Freek de Groot gave us a tour of the laboratory's delta flume, the largest flume in the world (see Figure 1). It is hard to imagine a flume 230 meters long, even when you see it. Its dimensions are five meters wide and seven meters deep, with a section 9.5 meters deep. Testing is performed during 25 percent of the year in the areas of coastal, harbor and ocean engineering.

A narrow ridge of natural dunes forms the main sea defence against storm surges in many regions in Holland. Research on dune erosion through the field of coastal engineering has been going on for the past ten years. The delta flume is so large that if a 1:1 scale test were to be performed on dune erosion, 2,000 cubic meters of sand would be required.

Monochromatic and random waves are generated up to a height of two meters. The wave generator is equipped with a unique device to prevent the reflection of waves against the waveboard and also to prevent low frequency resonance waves.

A wide variety of instruments is available to monitor all kinds of hydraulic and geotechnical processes and to transmit about 100 signals into the on-line computer facilities for future data processing. The city does not have the capacity to supply the flume with water. Water for the flume comes from five 85-meter deep wells. There is a treatment plant on site. Two divers are always on hand to make repairs. The walls of the flume contain 300 windows that are installed in a regular pattern so that they can be fitted with measuring equipment.

No testing was being done in the delta flume the day we were there. They had just finished doing testing on grass dikes and, the week after we left, they were going to begin a new series of tests on particle transport. The just finished test was considered to be successful since the grass dike withstood flood conditions for 29 hours. This test was the final part of a three-part program instituted by the Dutch government regarding the safety of dikes. The first part of the study was focused on asphalt dikes and the second part on clay dikes. All three types of dikes are present in The Netherlands.

The first project ever carried out in the delta flume was in the area of harbor engineering. A large-scale model was needed to investigate hydraulic and soil mechanics problems related to the storm surge barrier in the Eastern Scheldt. The delta flume was developed to perform this research. A project with the unprecedented magnitude of the barrier demanded such large-scale testing.

The local depth of 9.5 meters in the flume offers the opportunity to investigate ocean engineering problems such as wave-induced erosion and geotechnical problems in pipeline flotations. In small-scale model testing, the Reynolds numbers are too low to avoid the effects of scale.

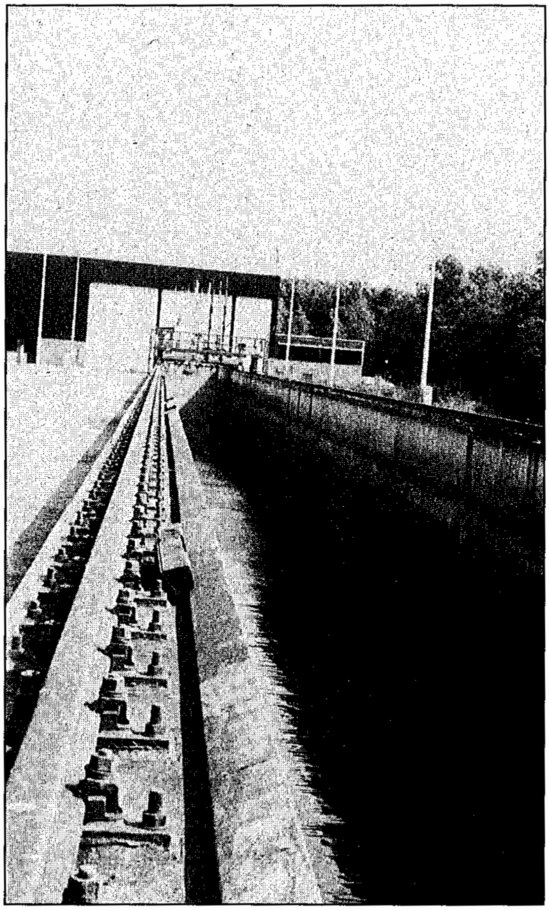

FIGURE 1. One-third of the delta flume at Deflt Hydraulics in de Voorst.

Physical Modeling

Next, we went to the Oosterschelde Hal, a great (2.5 hectares) hall named after the estuary where the storm surge barrier was created. The hall is supplied with water pumped at a rate of three cubic meters per second from a reservoir. There is a constant head, and constant discharge to and from the hall.

In the hall, many small-scale models were in use. There was a model of a river in Bangladesh — the Jamuna — for studying erosion in straight and curved channels. The widths between two restraining barriers where a bridge was to be built were changed and the results analyzed. A flood barrier for the city of Venice was also being tested. This test had begun as a two-dimensional study, but it had become a three-dimensional study designed for a storm surge. The barrier was composed of a series of panels that could have compressed air pumped in behind them in bad weather. They would then rise to fend off the storm.

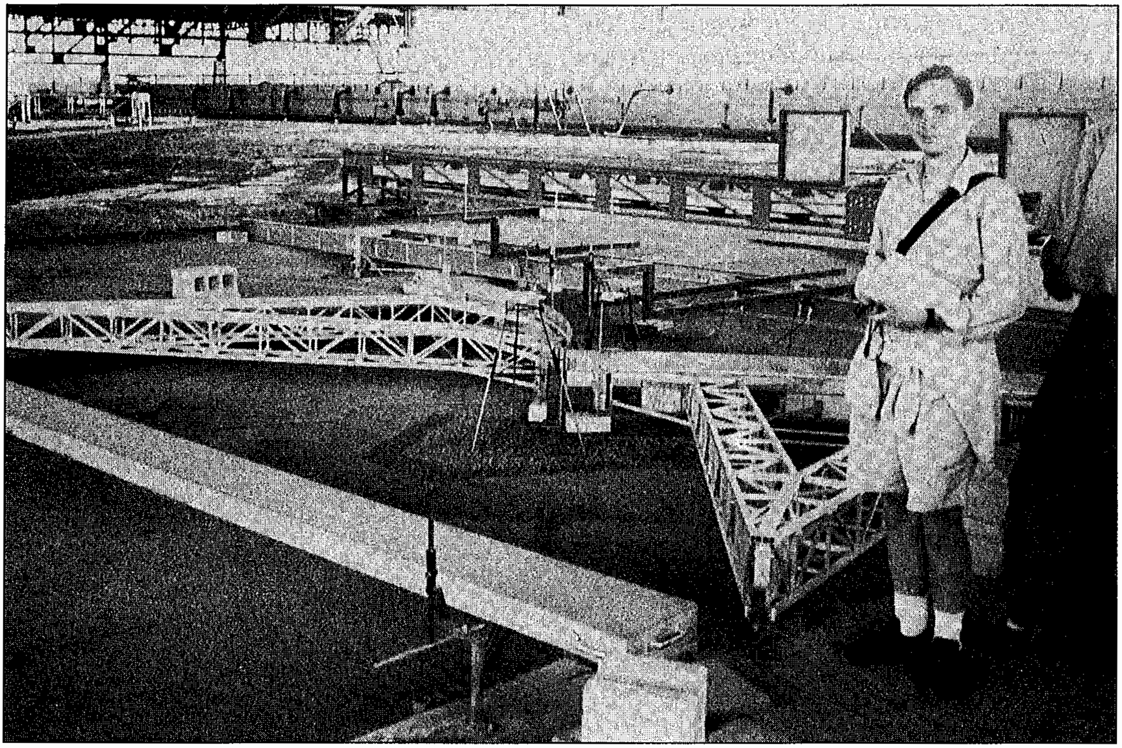

FIGURE 2. Christopher Bell and a scale model of the storm surge barrier for Rotterdam.

The design of a storm surge barrier for the city of Rotterdam was also being tested (see Figure 2). In order not to obstruct the waterway in regular weather, the barrier split in the middle and retreated from the passage. In stormy weather, the two pieces would meet in the middle and the ballasts would fill with water and sink to the bottom. After the storm, the ballasts would drain, and the gates would float to the surface and separate.

An Australian pipeline that rested on the seabed was being tested for the effects of a hurricane. Also present were many flumes from old tests, wave tunnels for studying the orbital motion of waves, piston wave generators, devices for measuring wave velocity through laser refraction, and sand flumes for measuring particle transport and erosion.

Hybrid Modeling

Following the physical modeling section of our tour, we ate lunch with our hosts and then learned about numerical and hybrid modeling techniques. Mr. Gerrit J. Klaasen explained the techniques being used in Delft. Eighty percent of their modeling is mathematical. Most of these models are two-dimensional, with depth averaged. Two different types of flow models are used: fixed and mobile bed. Computational models use differential and difference equations. Difference models can be either square grid or curvilinear.

Mr. Klaasen was studying the Jamuna River in Bangladesh. The Jamuna is the lowest reach of the Brahmaputra River, which forms a barrier between the eastern and western parts of Bangladesh. We had seen a physical model of the river earlier in the day. The Jamuna River is a 15-kilometer wide meandering river that has a scour depth of 30 meters and a flow rate of 1,000 cubic meters per second. Delft Hydraulics was contracted by the government of Bangladesh to build a bridge across the river. At the present time, there are no bridges on the river, and the traffic across it is served by ferries. The problem with building a bridge is that the river is very unstable and changes its course on the average of one kilometer per year. In order to analyze the flow, guide bands were set up to restrain the river. A grid was set up with

FIGURE 3. Part of the Tufts group with Freek de Groot and Gerrit Klaasen at Delft Hydraulics.

boundaries, and a vector field generated (with an average depth). The flow velocities near the structure needed to be analyzed. A scale model was built upstream and velocities of 3.25 meters per second were employed. Maximum erosion depths and the extent of erosion could be determined from the scale model.

Morphological models of the sediment transport were also needed. The river bed was sand, and channel patterns changed very rapidly. Hybrid modeling techniques were needed using mathematical and scale models. A one-dimensional mathematical model was used to study the scour near the bridge. This model, along with scale scour models, were used to measure the scour effects around the piers. The flow field near the bridge was analyzed with a two-dimensional depth-averaged model. After we learned about the numerical models, our tour of Delft Hydraulics at the de Voorst lab was over (see Figure 3). We were grateful to have been granted a look at the amazing facilities.

May 28

Today was a Dutch national holiday, Ascension Day, so the whole country was closed down except for cafés, restaurants, museums and parks. We spent the day at The Hoge Veluwe National Park. This park covers a huge (by Dutch standards) area of land that was formerly owned by the Kroller-Mueller family. The terrain of the park is very flat, like all of Holland, and composed of sand dunes and forested areas. There are numerous bike paths throughout the park, and bikes were available for free on the park premises. In the center of the park is the Kroller-Mueller Museum, which has an extensive collection of impressionist, post-impressionist and modern art. There is also a striking sculpture garden.

May 29

Having driven to Delft the night before, we woke up early and were given a tour of Delft Soil Mechanics and a lecture on soil mechanics by Professor A. Verruit of the Delft University of Technology. Professor Linfield Brown arrived in the early afternoon.

The beginning of the lecture dealt with the recurring problems that the Dutch geotechnical engineers face. Most of the soil in The Netherlands is very soft and groundwater levels can vary between 1.5 meters below or above the soil surface. An important rule that construction

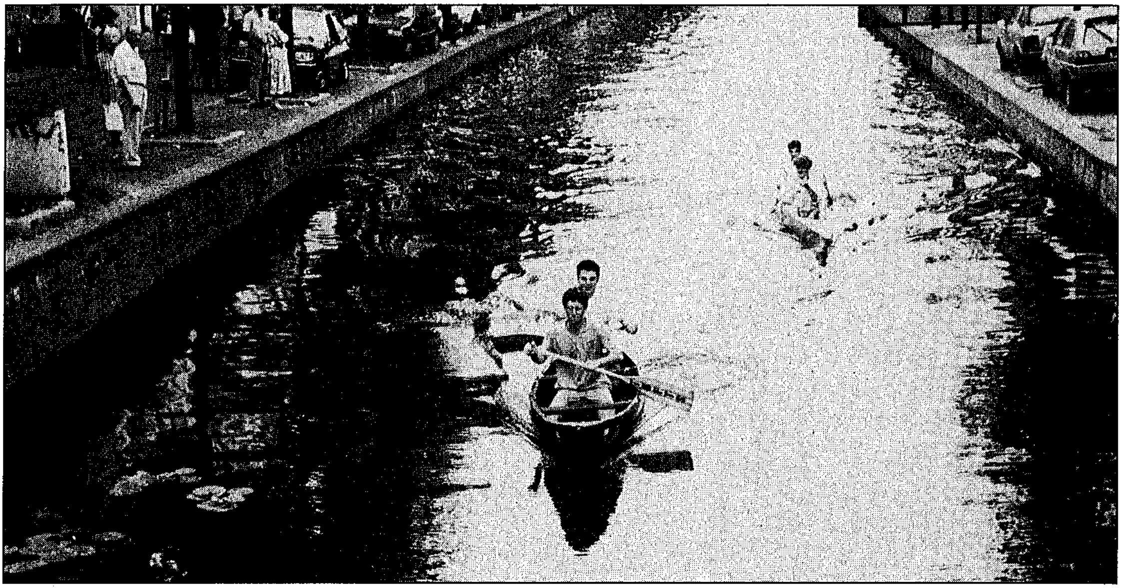

FIGURE 4. The Tufts canoe winning a sprint.

engineers must follow when building a foundation is that water levels near the structure cannot be lowered since the lower levels would weaken the surrounding soil and neighboring buildings could sink and crack.

To ensure that the water level does not change under the surrounding buildings, engineers usually follow a five-step process:

1. Excavate until they reach the water level.
2. Use a dredging machine to excavate to the desired depth.
3. Line the excavation with an impervious membrane.
4. Use a dredger to replace some of the soil on top of the membrane. (Doing so will ensure that the pressure above the membrane is sufficient to overcome the water pressure from below.)
5. Remove the dredger and lower the water level in the soil within the membrane.

After the tour of the soil mechanics labs, we spent some time wandering around the university. The technical university in Delft is one of three technical universities in The Netherlands. There are 15,000 students and eleven different disciplines of engineering are offered at the Delft University of Technology. It is the only university in The Netherlands that provides a program in civil engineering.

The main reason we came to Holland was for the concrete canoe race, which was part of the 150th Anniversary of the Delft University of Technology. The days of the race, May 28–30, were called the "Technical Days." There were displays and booths set up by all the faculties in Delft outlining their work.

Before our group was distracted by jazz bands, ice cream stands, beer sellers, steam engines and racing cars, we managed to see many of the engineering attractions. The water quality students at the university set up a taste test of bottled *versus* tap water, which one member of our group flunked. Harbor engineering students had a "Design Your Own Harbor" exhibit. Structural students offered contests to see who could hold up a concrete block for the longest amount of time, which Rob won. Transportation students had teams playing tug of war with an old-fashioned steam roller.

There were also numerous computer simulations and quizzes, but they were all in Dutch! The most impressive computer display was the fluid mechanics lab, where they had all of their models functioning. Professor Walt Massie, an American professor in Delft in the field of offshore technologies, explained the models. There were many flumes, one showing particle displacement in a meandering river. There was

FIGURE 5. A Tufts crew crossing the finish line.

an irregular wave generator with a small-scale model of a floating harbor entrance, and there were also numerous small flumes demonstrating different types of hydraulic jumps.

The first canoe race we participated in was in the evening after dinner. It began as a tour through the canals in the old center of Delft. The mayor of Delft participated in the tour as well as Pieter Schenk, the "Rector Magnificus" of the Delft University of Technology. After the tour the real racing began with one-on-one sprints (see Figure 4). The course was not very long, about 500 meters, but it was exciting! The canoers passed under several low bridges that were packed with cheering supporters. We did very well, winning most of our heats. Our competition was stiff due to the design of our canoe. Our canoe was a traditional design, like the ones we race in American races. Most of the canoes in Europe are shaped more like a kayak (all are two-person) and go much faster.

May 30

The canoe race was not the only thing happening in Delft this day. It was also "Waterday," the last of the Technical Days. Waterday events included water bike races, dragon boat races (boats from Hong Kong powered by 18 rowers that stroke to the beat of a drum), water games and a concrete sailboat demonstration.

However, the concrete canoe race was definitely *the* race. We were the only team to come from North America, and consequently we received quite a bit of attention. The other teams came from Holland, Germany and Belgium. There were university teams as well as teams from industry. The course was circular, winding through several buoys, and about 1,000 meters long. Each of our four teams got the chance to row in three qualifying rounds (see Figure 5), and one of our women's teams made it to the final. That was our best showing (see Figure 6).

The canoes were judged in several categories including aesthetics, design, weight and racing performance. At the awards ceremony we won two prizes: an Honorable Mention for the appearance of our canoe, and the Management Prize for arranging our trip to Holland.

May 31

We recovered from our hard day of racing and spent the day on the North Sea in Scheveningen. We saw the largest sand castle imaginable being built on commission for the European Community.

June 1

Professor Brown left us for part of the day and met with Pieter Schenk at the university. They spoke about foreign study programs and how,

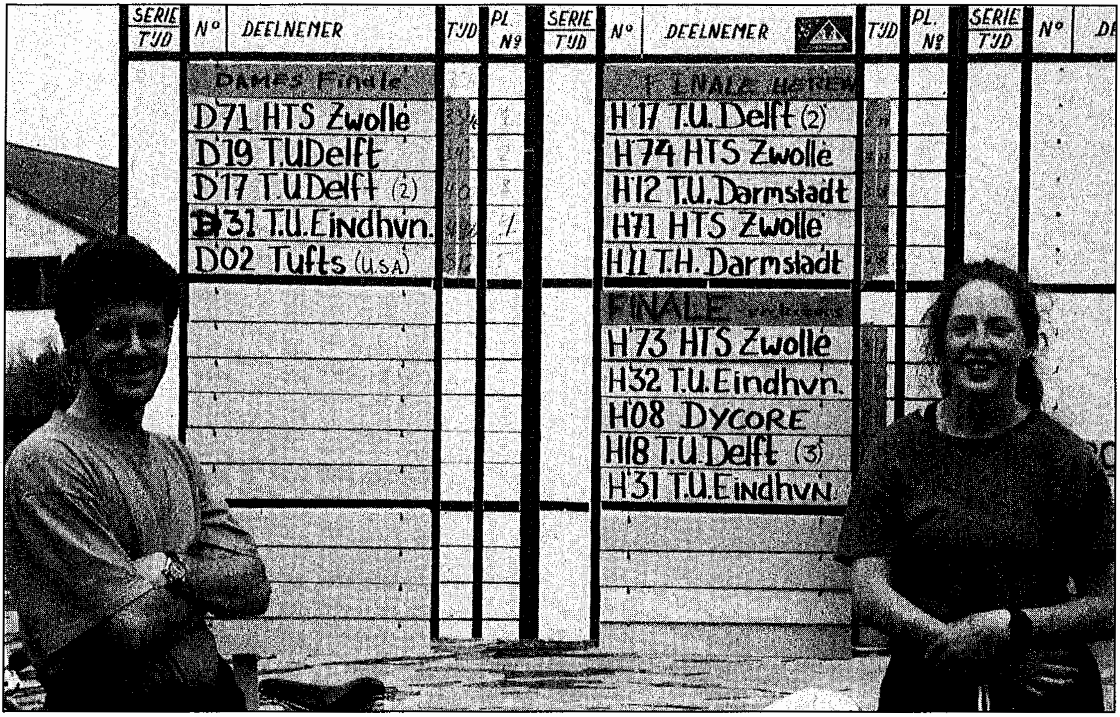

FIGURE 6. Patrick Johnston and Genevieve Dyer with the final standings of the day.

especially in the field of engineering, studying abroad can be a very valuable experience.

We traveled to the province of Zeeland in southern Holland to visit the Delta Expo. The Delta Expo is an exposition of the Delta Project, a project whose goal is to improve the safety of the Southwest Netherlands by considerably shortening and reinforcing the coastline (see Figure 7). On the first of February 1953, the combination of a spring tide and a persistent, violent northwesterly storm destroyed the dikes and flooded the polders, drowning thousands of people. The people of The Netherlands decided that such a catastrophe should never again be allowed to occur. In 1958, the Dutch Parliament passed the Delta Act, and thus the Delta Project was begun.

The Delta Project is one of the largest hydraulic engineering projects in the world. New hydraulic engineering techniques were gradually developed for the construction of eleven dams and barriers of various sizes that were built over a period of thirty years. The only coastal waterways to be left open were the New Waterway and the Western Scheldt, both shipping routes to Rotterdam and Antwerp. The last and most difficult part of the project was the storm surge barrier on the Eastern Scheldt.

History of the Eastern Scheldt Barrier

The mouth of the Eastern Scheldt is the largest of all the Dutch coastal waterways, and consequently the most complex. The original plan was to build a dam across the waterway. In preparation for this task, three islands were constructed: Roggenplaat, Neeltje Jans and Noordland. A pumped sand dam was built between the latter two islands. In the open channels a cableway was constructed to dam the Eastern Scheldt using the traditional dam construction method of gradually dropping rocks into the water. This dam was scheduled for completion in 1978.

Towards the end of the 1960s, protests were voiced about the project. Environmentalists knew of the special varieties of flora and fauna in the estuary and pleaded that the waterway be left open and that, instead, the dikes be built higher. A heated debate flared up between those who wanted the dam, primarily agricultural and water agencies and organizations, and those who were against the dam, mostly

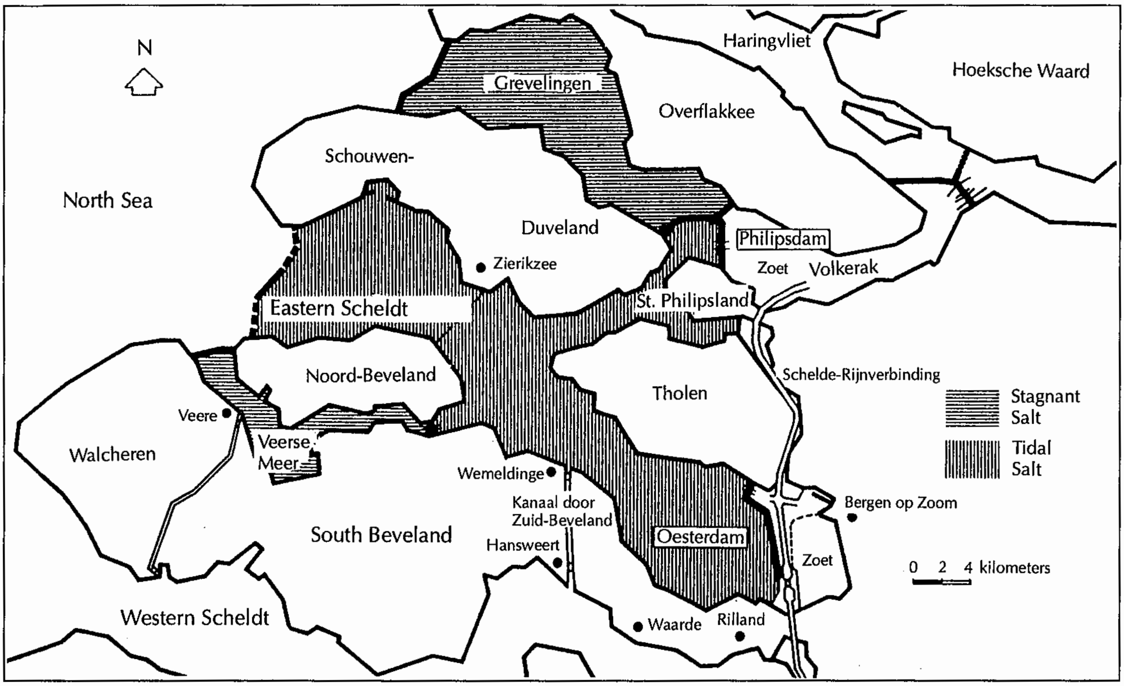

FIGURE 7. The Delta Project.

scientists and fishermen.

A compromise plan was reached in 1976 that consisted of a storm surge barrier that would be open under normal conditions and that could be closed in the case of very high tides (see Figures 8 and 9). The difference between

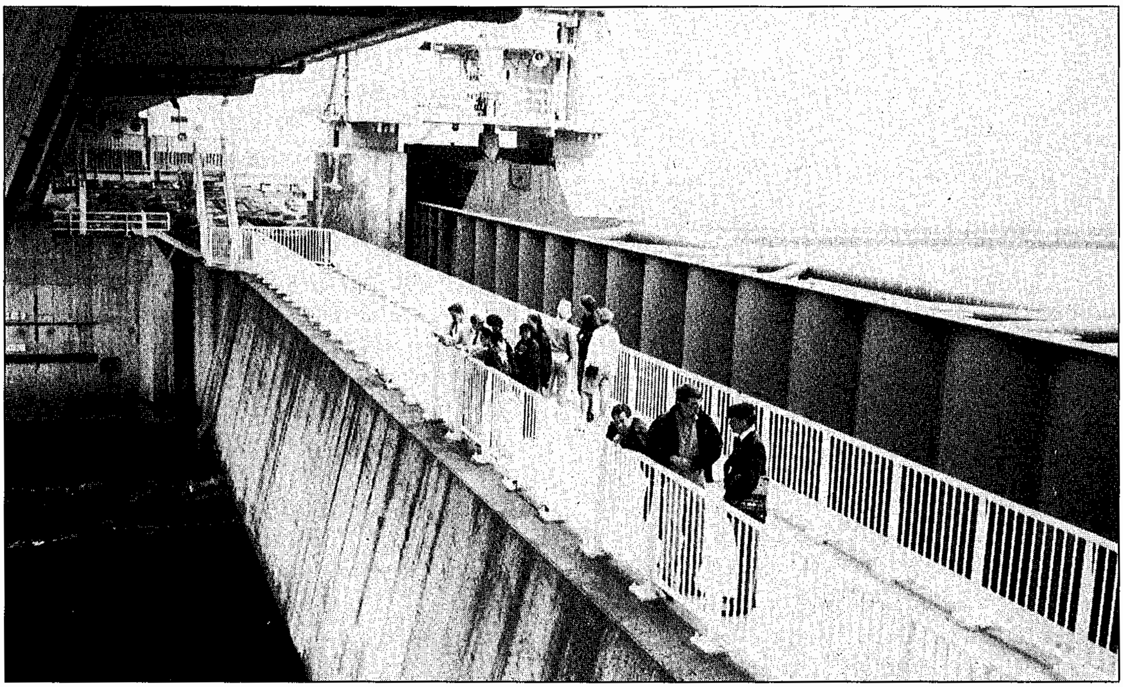

FIGURE 8. Tufts group on the upper beam of the Eastern Scheldt barrier. A steel gate is to the right.

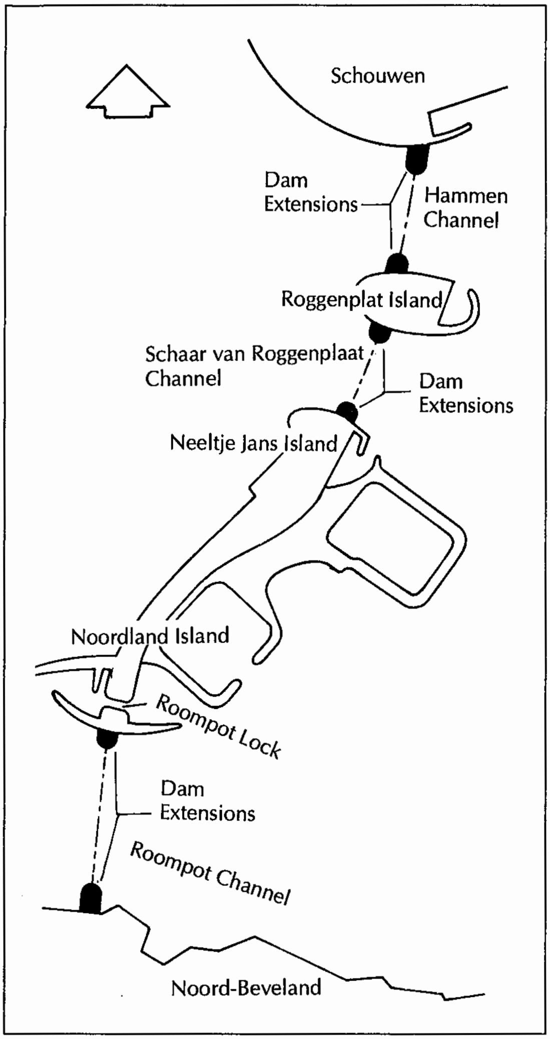

FIGURE 9. The Eastern Scheldt project.

the high and low tides behind the barrier would be maintained at three quarters of the original tidal range at Yerseke, sufficient to preserve the natural environment in the Eastern Scheldt. The opening would cover 14,000 square meters and allow 11 billion cubic meters of water to pass through daily.

Construction Design

The construction of that storm surge barrier required expertise that had yet to be developed. Never before had a project of this sort been attempted. The Dutch public works department, Rijkswaterstaat, commissioned the work. Assisted by consultants in a wide range of specialized areas, the contractors worked in close cooperation with the Rijkswaterstaat. Extensive research was begun to determine the feasibility of building a storm surge barrier that served the interests of the fishermen, flood protection and the environment as much as possible. The completion of the barrier was set for 1986. The barrier was designed to last for 200 years.

The actual construction was viewed as a challenge from all perspectives. Research was being conducted in the newly built delta flume at Delft Hydraulics regarding the hydraulic and soil mechanics problems underneath the foundation structures of the barrier. The barrier was to be constructed of prefabricated concrete and steel components that were to be assembled in three channels in the mouth of the Eastern Scheldt. All of the rocks that had been dropped for the original dam had to be removed. The backbone of the barrier consisted of 65 enormous concrete piers. Between them was a stone sill and a concrete sill beam. The 62 gates for the closure were made of steel. Concrete box girders were placed on top of the piers to form a road deck. Since this barrier was the first project of its kind, special equipment had to be developed for its construction.

Foundation Bed

A new technique was also required in order to prevent the strong current along the barrier from washing away the sand from under the piers. Mattresses filled with graded layers of sand and gravel allowed water to flow through, but trapped the sand.

Construction Site

The entire barrier was to be 3,000 meters long. It was to be built between three tidal channels: Hammen, Schaar van Roggenplaat and Roompot (see Figure 10). The three islands that were constructed under the initial plan served as the dam sections of the storm surge barrier. The island of Neeltje Jans was turned into a construction island from where the operations were conducted. The majority of the prefabricated components were built there — the piers, sill beams and upper beams, and the foundation mattresses.

Bed Improvement

No pile foundations were used to anchor the piers. However, the seabed had to be improved to be able to support the weight of the barrier. First, a cunette was excavated and then replaced by better quality sand (see Figure 11). The deepest parts of the channel were raised and covered with gravel to prevent erosion.

To improve the bearing capacity of the seabed further, and to prevent settlement of the piers, a specially designed compacting unit was used. This rig had four giant vibrating needles that entered the subsoil and that could compact layers of up to 18 meters thick over an area of six by 25 meters.

Foundation Mattresses

After compaction, the seabed had to be dredged and leveled off to the correct depth and covered with prefabricated foundation mattresses measuring 200 by 42 meters and 36 centimeters thick (see Figure 11). The mattresses' function was to absorb the changing water pressure in the subsoil so that it would not weaken, and also to ensure that the fine sand did not wash away.

These mattresses were carried by another specially designed rig and were positioned at a center-to-center distance of 45 meters, leaving a three-meter gap between the mattresses. The space between the mattresses was filled with loose sea gravel and heavy stone. To reinforce the foundation structure, a second smaller mattress measuring 60 by 29 meters and 36 centimeters thick was then placed by the rig on top of the first one. Both mattresses consist of three layers of graded material (sand, fine gravel and coarse gravel) and were specially constructed at Neeltje Jans.

If the foundations were not sufficiently level, a block mattress could be positioned under the pier to smooth out any unevenness. This mattress consisted of concrete blocks 15 to 60 centimeters thick.

In order to protect the joints between the two mattresses from unexpected high currents, a gravel ballast mattress was laid down (see Figure 12). This mattress consisted of a flexible steel woven mat to which rolls of quarry stone packed in wire mesh were attached.

Pier Construction

The piers weighed 18,000 metric tons and were

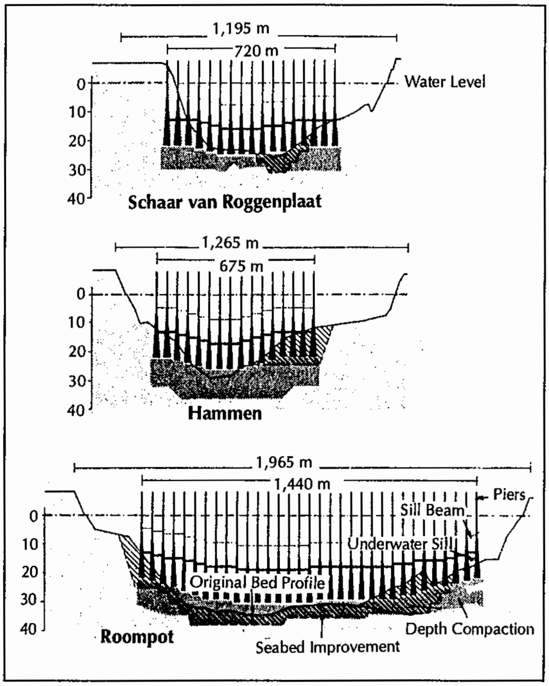

FIGURE 10. Cross sections of the three tidal canals on the Eastern Scheldt.

fabricated of prestressed concrete. Figure 13 illustrates the general pier design. They were constructed in a dock consisting of four different compartments. Each compartment was surrounded by dikes and pumped dry. The base of the dock was 15.2 meters below sea level.

As soon as all of the piers in one compartment were ready, an opening was made in the dike and the compartment was flooded. The flooding allowed boats to come in and transport the newly fabricated piers. The buoyant piers required a hoisting capacity of only 10,000 metric tons. The depth in the compartment was 13 to 17 meters deep, sufficient draft for a large vessel. A special transport vessel, named the "Ostrea," was created for the purpose of transporting the pier. The Ostrea was shaped like the letter "U" and could surround the pier, lift it a few meters, transport it and then lower it for installation (see Figure 14).

Pier construction took almost a year and a half. Every two weeks, work was started on another pier so that at any given time more than 30 piers were under construction, each in a different state of completion. Among the seven stages of construction, were installing the rein-

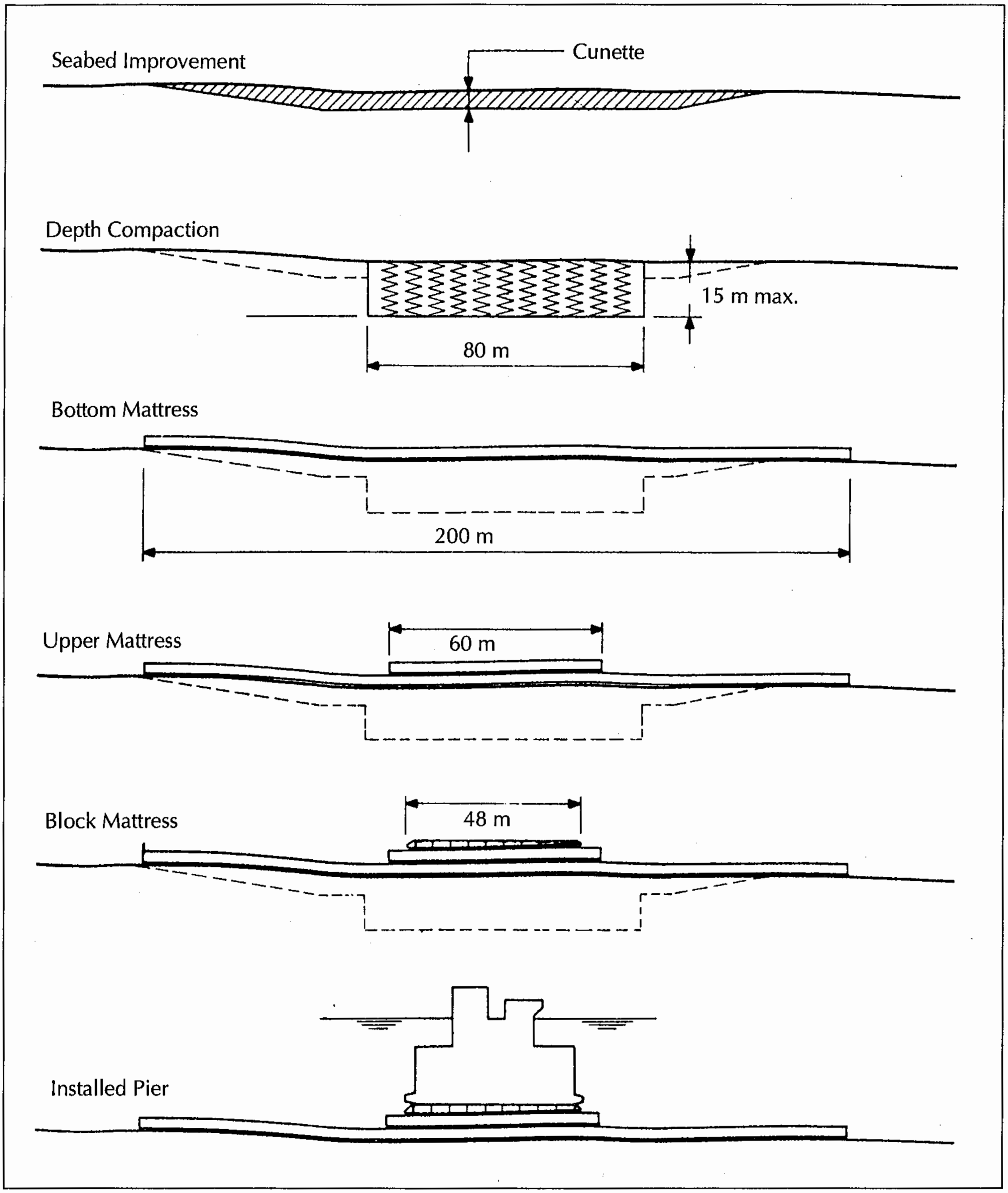

FIGURE 11. Construction of the pier foundations for the Eastern Scheldt barrier.

forcement, prestressing and pouring the concrete. During the construction of the piers, the construction dock was a huge open-air concrete factory. About 4,000 cubic meters of concrete were poured each week. The finished piers varied in height from 30.25 to 38.75 meters depending on the depth of the channel.

After the pier was transported to the site in the channel by the Ostrea, it was met by another vessel, the Macoma. Acting as a mooring pontoon, the Macoma was to keep the Ostrea accurately positioned while the pier was being lowered onto the seabed. The Macoma also cleaned the sand out from between the foundation bed

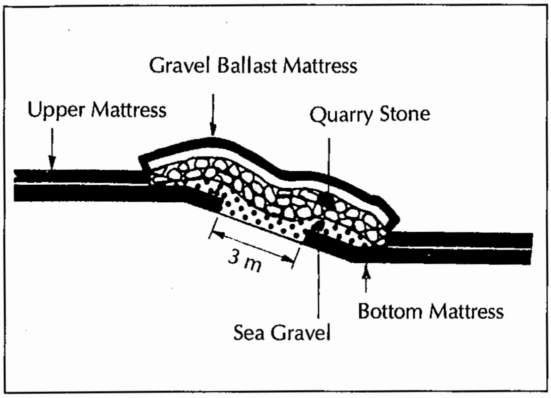

FIGURE 12. Joint between the foundation mattresses.

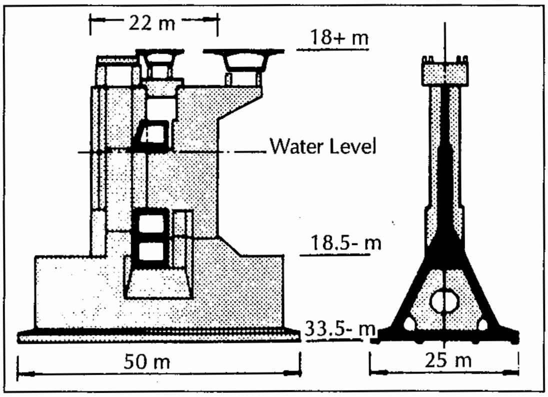

FIGURE 13. General design of the foundation piers.

and the pier. This job was very difficult to accomplish since the currents at the mouth of the Eastern Scheldt are strong.

The cavity between the base of the piers and the foundation was filled with grout to provide uniform bearing conditions over the entire slab area (see Figure 15). Once the pier had been locked into position and pumped dry, grouting was accomplished using a hollow compartment inside the pier. Ballasting was done by pumping a sand and water mixture into the caisson section and then pumping the water out after the sand had settled. The caissons were 90 percent filled with sand.

Sill

After the pier had been put in place, a sill was constructed underwater around the base of the pier. The sill consisted of graded layers of stone. The stones were deposited into position by a specially adapted crane. The smaller stones (weighing one metric ton or less) were dumped

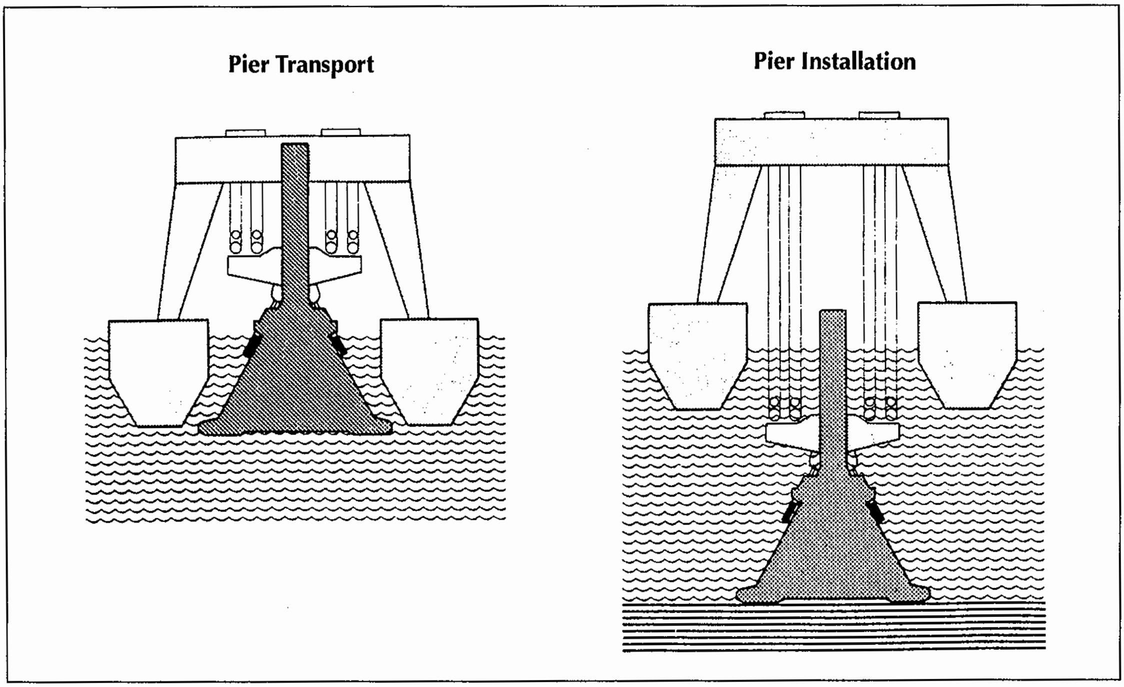

FIGURE 14. Pier transport and installation for the Eastern Scheldt barrier.

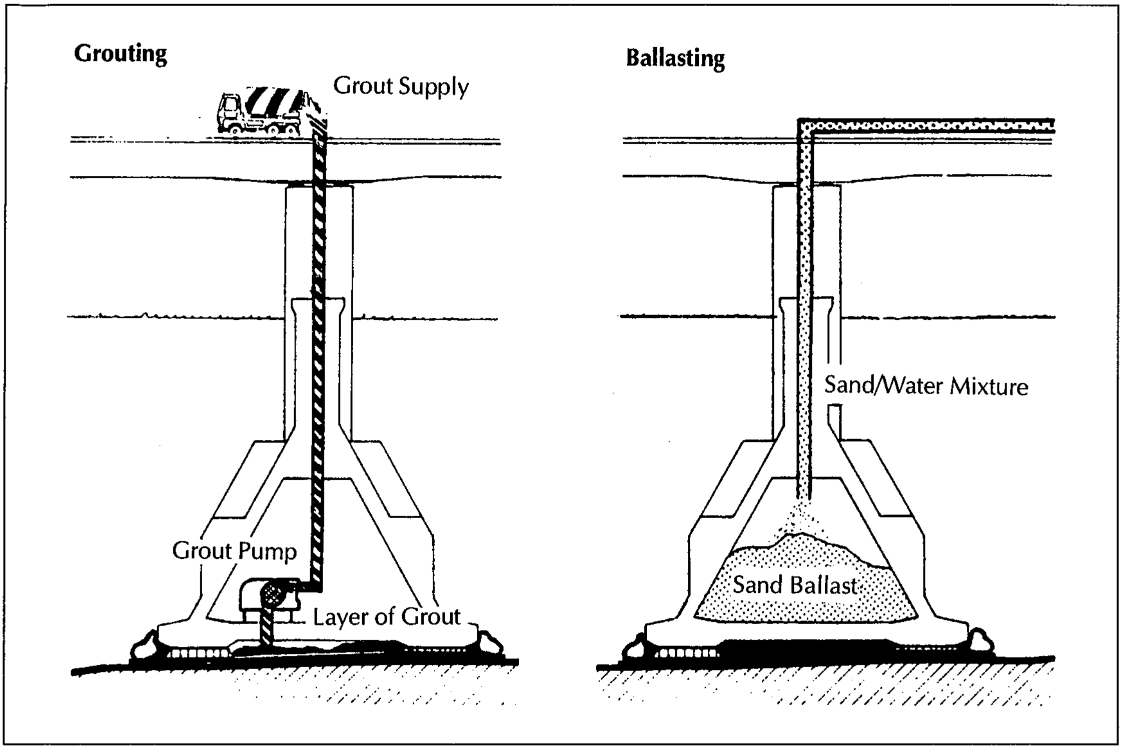

FIGURE 15. Grouting and ballasting a pier.

from vessels equipped with a dynamic positioning system. Over a period of two years, some five million metric tons of stone were dumped.

Pier Superstructure

Once the underwater section of the barrier had been completed, work could begin on the structure above the water (see Figure 16). First, road bridge box girders were placed on top of the piers. Each girder was 45 meters long, made of prestressed concrete and weighed 1,200 metric tons. The gate operating equipment was housed inside the girders. The roadway was then constructed on top of the girders. Capping units increased the height of the piers to accommodate the gate structure. Sill beams were 39 meters long, eight meters wide and eight meters high. Each was hollow (later filled with sand) and weighed 2,500 metric tons. Their purpose was to improve flow through the barrier. The upper beams formed the upper edge of the openings in the barrier that could be closed by the gates. They were hollow beams five by four meters and weighed 1,100 metric tons.

Barrier Operation

An engineer, T. Sep, conducted our tour of the Delta Expo (see Figure 17). We saw a video about the history behind the making of the Deltaworks and Mr. Sep told us quite a bit about the construction process of the barrier. After we had visited the exhibition hall, we went up to the control room. There are two parts to the computerized section of the controls: one to monitor the barrier, and the other to physically close it. Two teams of people work simultaneously at all times: a decision team, and a function team. At the time we were in the control room, they were doing tests on different gates, opening and closing them. It takes approximately one hour to fully close the gates, and they are closed on the average of once per year due to bad weather. Safety was a key factor in the design of the barrier. One gate can fail without having an overwhelming effect on the rest of the system.

On the premises, there is a generator that powers the barrier. On our way into the expo-

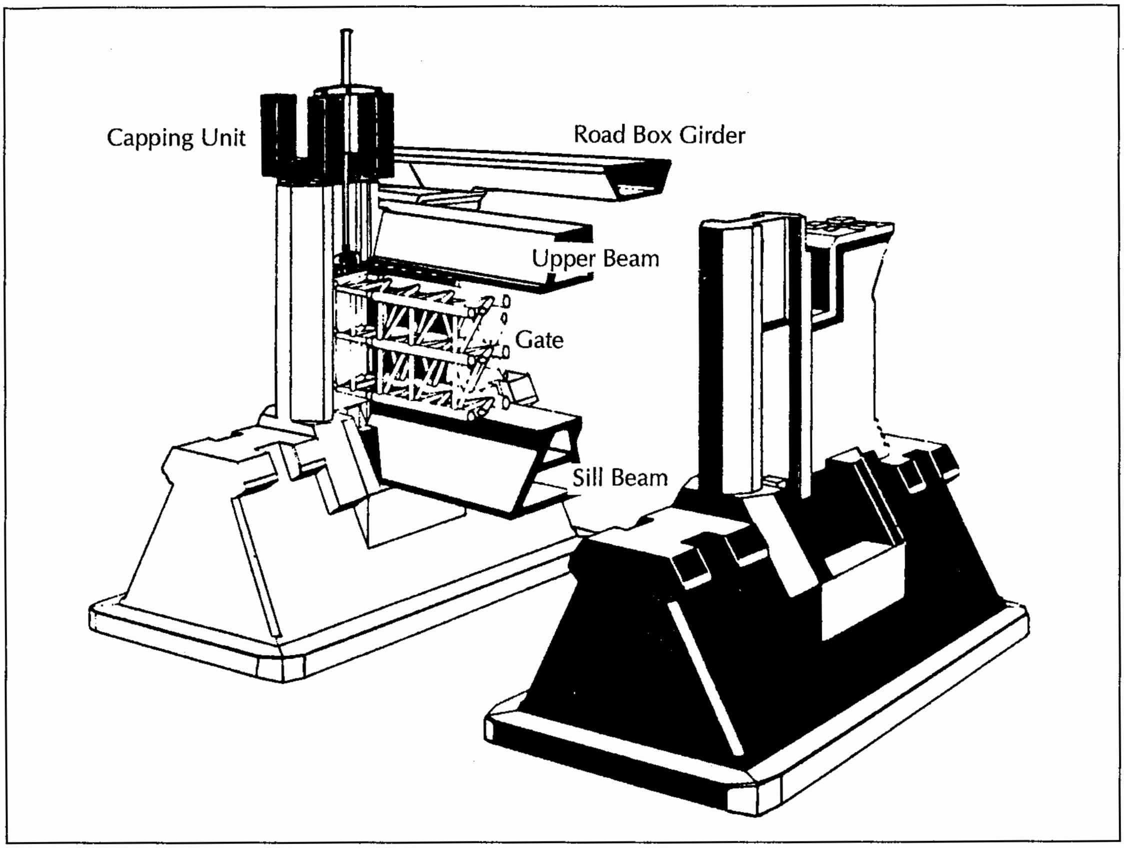

FIGURE 16. Pier superstructure.

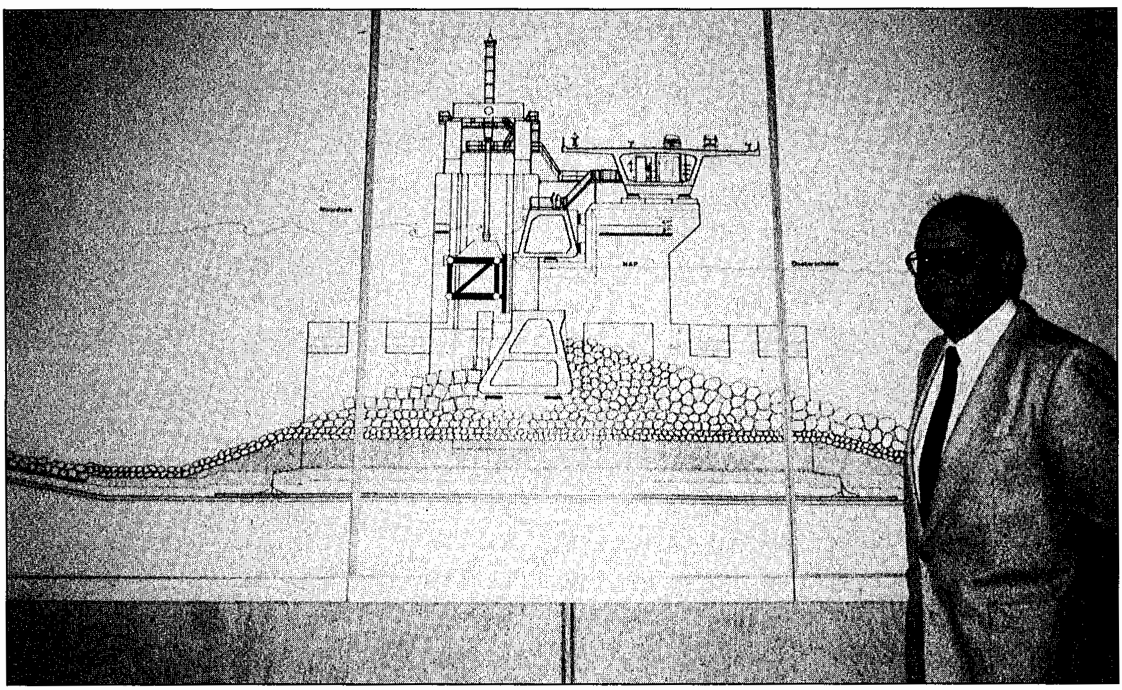

FIGURE 17. Mr. Sep with a diagram of the Eastern Scheldt barrier.

sition center we saw a series of windmills that looked like they had been built to generate power for the barrier. We asked if that was the case, and Mr. Sep told us that it had been a five-year-long experiment that did not work.

After we visited the control room, we walked out onto (and into) the barrier. It was enormous! Then we took a boat ride and enjoyed the scenery along the estuary in the Eastern Scheldt.

June 2

This was the last day of our Tufts trip. Chris, Josh and Professor Brown all flew back to the U.S. The rest of us who had planned to stay in Europe a little longer did something typically Dutch — we went walking in the mud flats in the Wadden Zee in the province of Groningen. When the tide goes out, you can walk on the mudflats to the islands in the Wadden Zee from the mainland. However, since we only had three hours instead of an entire day to spend in Wadden Zee, we just went on a guided tour of the area.

Our week long whirlwind tour of The Netherlands had come to a close. Not only had we had an incredible education on hydraulic engineering in The Netherlands, we had also experienced the Dutch way of life for a week, and enjoyed it immensely. Now all eight of us are going different ways, but our experience in Holland will be with us wherever we are.

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