FHWA Study Tour of Northumberland Strait Crossing Project (NSCP)

INTERNATIONAL
TECHNOLOGY

FHWA's Scanning Program

U.S. Department of Transportation
Federal Highway Administration

July 1996

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Northumberland Strait Crossing Project (NSCP)

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1. EXECUTIVE SUMMARY

1.1 Introduction

President Bill Clinton's Executive Order 12893, *Principles for Federal Infrastructure Investments,* directs agencies to establish programs for developing more effective private investment along with federal funds. In response, the Federal Highway Administration (FHWA) established the *TE-045 Innovative Financing Initiative* to explore potential new financing strategies, drawing on the expertise of State officers and the private sector in attracting more private sector investment in infrastructure projects.

The Northumberland Strait Crossing Project (NSCP) in Canada, between New Brunswick and Prince Edward Island, offered an opportunity to learn firsthand how a private developer is financing, designing, and constructing a major bridge and how the developer plans to operate and maintain it under a long-term agreement with the Government of Canada. Besides the unique contractual and financial arrangements, the Northumberland Strait Crossing Project has addressed significant engineering challenges involved in building a major bridge in a short time in a severe climate. In addition, the crossing is located in an environmentally sensitive area and was the focus of several major environmental investigations. Finally, the social impact of erecting this bridge has been the subject of much discussion and public debate.

To learn more about the project, a three-day scanning review team visited the site in September 1995, under sponsorship of the FHWA Office of International Programs.

The objectives were to observe, investigate, and document detailed program and technical information on the development, construction, and planned operation of the Northumberland Strait Crossing Project. The study focused on three areas:

- Program management and innovative financing.
- Engineering design, construction, and maintenance.
- Environmental management.

The scanning team members consisted of representatives of the Federal Government; the departments of transportation of Florida, Maryland, and Wisconsin; and the private sector.

1.2 Project Background

Northumberland Strait separates Prince Edward Island from the mainland provinces of New Brunswick and Nova Scotia. Under the terms of Prince Edward Island's entry into the Confederation in 1873, the Government of Canada is obligated to provide transportation for people, goods, and services between Prince Edward Island and the mainland. Currently, this obligation is met by two ferry services that cross Northumberland Strait between Prince Edward Island and the mainland.

A fixed link between Prince Edward Island and the mainland has been discussed for many years. In 1985–86 the Canadian Government received three unsolicited proposals from private industry and the financial feasibility of such a crossing appeared realistic. Based on these proposals, the Canadian Government studied the administrative, financial, environmental, and technical impacts of a fixed link. The Government then issued a Stage I Call for Expression of Interest to which 12 Canadian companies responded.

While the environmental, social, and economic impacts of the crossing were examined further, 7 prequalified consortia were invited to submit Stage II proposals. Three proposals met all the administrative, technical, and environmental requirements of the proposal call. An in-depth investigation into the impact of the bridge on the departure of the ice in the spring was then conducted. Environmental challenges were also heard in the courts.

Finally, 3 qualified developers were asked to submit Stage III financial proposals. Because none of these submittals complied fully with the terms of the Stage III proposal call, Public Works Canada initiated discussions with the lowest bidder to decide if the company could submit a plan acceptable to the Canadian Government. Progress was delayed again while the courts decided if the environmental determination had been conducted properly.

On October 7, 1993, an agreement was signed with Strait Crossing Development Inc., to build a bridge between Prince Edward Island and New Brunswick. The bridge is to be privately financed, designed, constructed, and operated for 35 years. The developer will be granted an annual subsidy for bridge operation, along with the right to charge regulated tolls for use of the facility during the ownership period. Ownership of the bridge will revert to the Canadian Government after 35 years.

1.3 Project Administration

A complex arrangement of project administration has been established for bonding, legal, and tax purposes. A chart illustrating the ownership, funding, and agreements for the project is shown in Figure 1. The development company for the project is Strait Crossing Development, Inc. (SCDI), a Canadian consortium that includes Strait Crossing, Inc., Northern Construction Co., Ltd., G.T.M.I. (Canada), Inc., and Ballast Needam Canada, Ltd. SCDI is responsible for raising the necessary funds to develop the project using annual payments from the Canadian Government and revenue from bridge tolls as a basis. SCDI is liable for construction of the bridge according to the approved design, and for its operation and maintenance for 35 years.

The contractor for the crossing is Strait Crossing Joint Venture (SCJV). SCJV is a joint venture of 4 owners of SCDI, and was established as a separate company for bonding and tax purposes. SCJV operates under a construction contract with Strait Crossing Development, Inc.

Under the terms of the project agreement, SCDI is required to retain an independent engineer to review the design and construction and to authorize payments. The independent engineer is Buckland & Taylor, Ltd. The Engineer of Record responsible for design of the bridge is J. Muller International—SLG/Stanley Consultants Joint Venture.

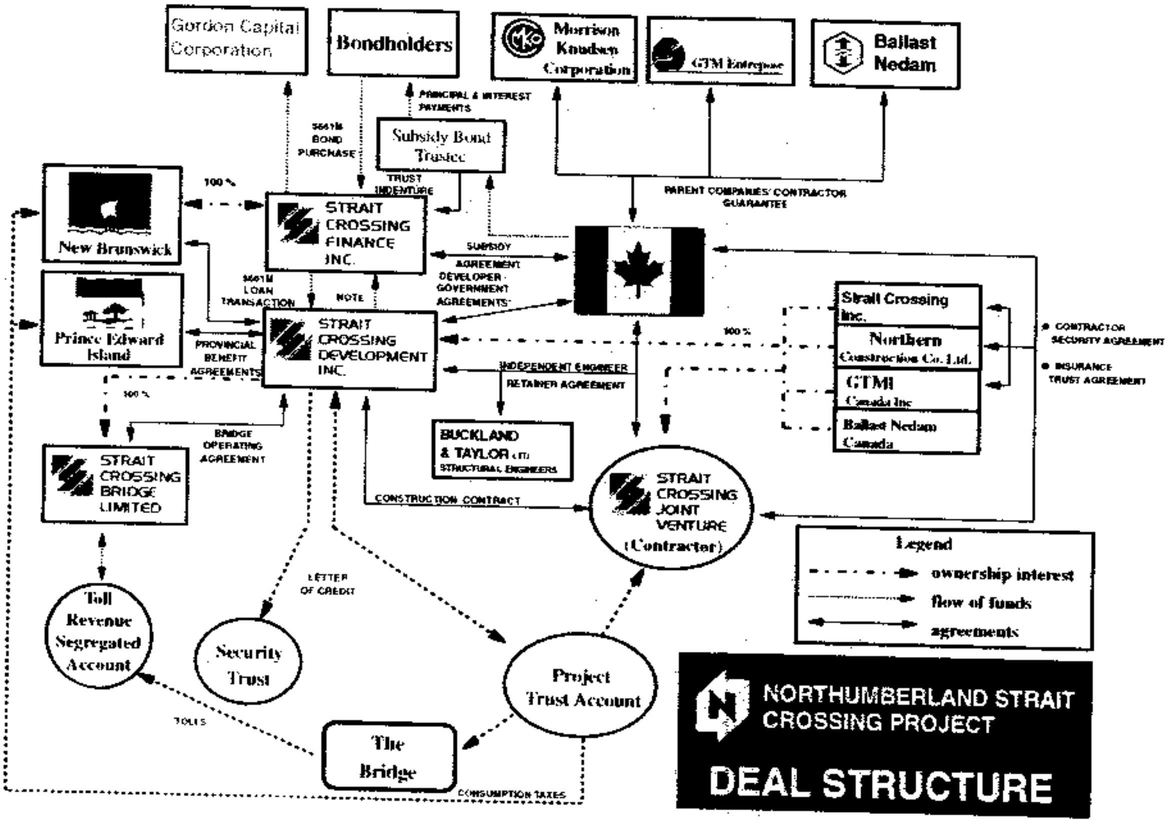

Figure 1: Organizational Framework

When completed, the bridge will be operated and maintained by Strait Crossing Bridge, Ltd., under an operating agreement with Strait Crossing Development, Inc. Strait Crossing Bridge, Ltd. is a wholly owned subsidiary of SCDI.

1.4 Project Finance

The estimated total cost, in 1992, for building the crossing was $C840 million. Capital costs will be borne entirely by the private developer, SCDI, which has two sources of revenue available.

1. Thirty-five annual payments of $C41.9 million adjusted for inflation from 1992 to be made by the Government of Canada. If the bridge is not operational by May 31, 1997, the developer is responsible for funding the existing ferry service until the bridge opens. Annual payments are equal to the estimated costs for the Government to subsidize the ferry service that will be replaced by the bridge.

2. Revenue from bridge tolls. During the first year of operation, the tolls will be comparable to the price of a ferry crossing. In subsequent years, the tolls may be increased, but at a rate no greater than 75 percent of the rate of inflation.

SCDI is required to have the total project cost covered by a combination of principal and interest during construction, with the proceeds placed in a trust account. A separate Canadian Crown Corporation (a public corporation), known as Strait Crossing Finance, Inc., was established by New Brunswick to receive the annual subsidy directly from the Canadian Government, to market the bonds, and to make progress payments to the developer. In this way, the annual payments from the Government go directly to the bond holder rather than through the developer. During construction, release of funds from the trust account to the developer is authorized by the independent engineer.

SCDI is also required to have a $C200 million performance bond, a $C35 million compliance bond, and a $C20 million labor and materials bond. The developer also provided a C$73,000,000 Letter of Credit and the Joint and Several Parent Company Guarantees.

1.5 The Technical Solution

The technical requirements of building a bridge across Northumberland Strait are dictated by six factors:

- The bridge has to be completed by a fixed date or the developer must take over the ferry service.
- Construction season is limited to approximately 8 months a year.
- The bridge must have a service life of 100 years.
- Failure of any one span must not result in the progressive collapse of any other spans.
- The impact of the bridge in delaying the departure of ice from the Strait in the spring must be minimized.
- Environmental effects of construction must be minimized.

The bridge will have 14 approach spans on the New Brunswick side, each about 93 m (305 ft) long; 7 approach spans on the Prince Edward Island side, each about 93 m (305 ft) long; and 45 main spans with a typical length of 250 m (820 ft). Total crossing length is 12.9 km (8.02 mi).

Approach spans on both ends of the crossing are being built using precast concrete, segmental cantilever construction with a launching truss. The substructure and superstructure of the main spans consist of 4 large components: a pier base, a pier shaft with ice shield, a main span girder, and a drop-in span (see Figure 2). They are being manufactured in a precasting plant on Prince Edward Island. A large floating crane moves the components into position. The construction schedule is based on erecting one complete span per week over two construction seasons. The largest of the components will

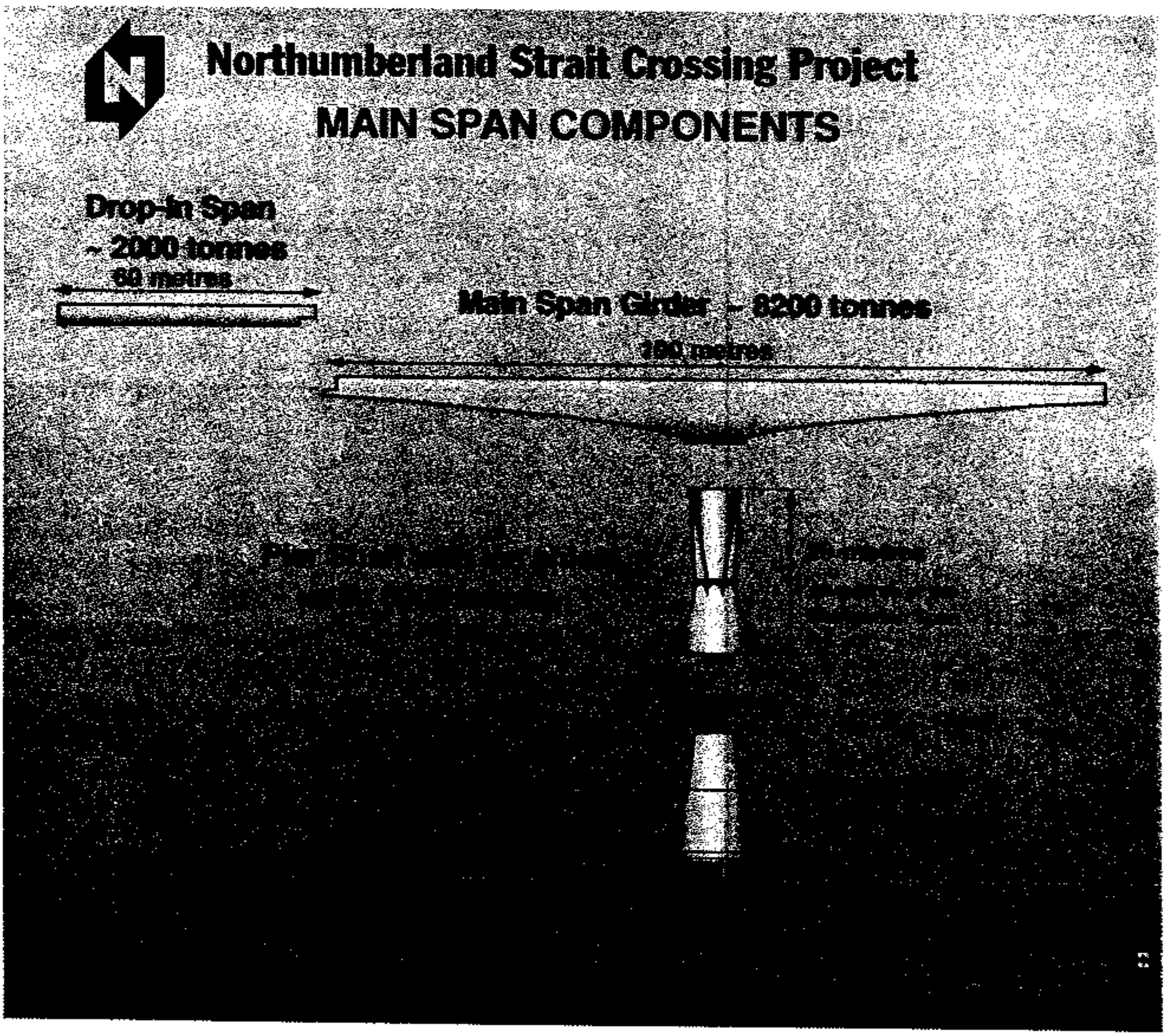

Figure 2: Main Bridge Components

weigh 8,200 tonnes (8,800 tons), and less than one piece per day will be floated from the precasting yard and erected during a 12-hour shift.

A waterproofing membrane and asphalt-wearing surface will protect the upper surface of the structure. Roadway lighting, an emergency telephone system, a closed circuit television system, navigation lights, and changeable message signs also will be installed.

The requirement for a 100-year design life is higher than used for most bridges in the United States and results in a stronger structure. Special attention was paid to using high-performance concrete that will not deteriorate under the harsh weather conditions of the Northumberland Strait. It has a strength of 55 MPa (8,000 psi) and was created by using fly ash, silica fume, and chemical admixtures. With the use of this concrete, a decision was made not to use epoxy-coated reinforcement. Despite the large-scale production of high-performance concrete, quality control procedures are similar to those of any large construction project. For this project, the contractor is responsible for quality assurance and control, and an independent engineer monitors the work.

1.6 Environmental and Social Issues

The impact of a fixed link on the environment, economy, and way of life in the area, have been major considerations since the project was first proposed. Major items of consideration were the following:

- Reduction of fish in the Strait.
- Impact on local fishing industry.
- Loss of ferry workers' jobs.
- Delay of ice departing from the Strait.
- Impact of more visitors to the island.
- Improved transportation for industry.

As part of the project requirements, the developer must produce, receive approval for, and comply with the detailed environmental management plan. The developer will be responsible for implementing the plan throughout the construction period and subsequent 35 years during which the developer will own and operate the bridge. After that time, the responsibility for environmental management and protection will be transferred to the Canadian Government along with ownership of the bridge.

The environmental management plan is based on more than 70 existing baseline environmental studies and related documents produced since 1986. In addition, input was received from the project's review panel, public meetings, and technical expert reviews. As part of the environmental management plan, the developer was required to include environmental protection plans, a program of environmental-effects monitoring, and contingency and emergency response plans.

Ice is a major consideration. The project plan predicts that ice will break up within a general time period of about 2 days in any given year. The final design predicts a 0.4±20 percent a day delay in the 100-year life of the bridge.

Northumberland Strait is one of the richest fishing areas, particularly for lobster, in Atlantic Canada, and the impact of a fixed crossing on the local fishing industry was particularly important. A fisheries compensation fund has been established through which the local fishing industry may be financially compensated for the impact of construction on their businesses.

To compensate the displaced ferry workers, a comprehensive workforce-adjustment strategy is being developed. It includes first choice of employment in operation and maintenance of the bridge, negotiated severance packages, and retraining and relocation assistance where necessary. A regional benefit agreement requires that 70 percent of all materials; 96 percent of all labor except management, professionals, and skilled marine workers; 75 percent of all marine workers; and $C20 million of engineering work be obtained from the Atlantic provinces.

1.7 Observations

The scanning review team made the following observations:

- Initiative for a privately funded fixed link between Prince Edward Island and New Brunswick originated with the private sector.
- After 35 years, the Canadian Government will own the bridge without having provided any initial capital-development funding and at an annual cost to the Government for the first 35 years that will be no more than the estimated annual cost to subsidize the existing ferry service.
- The real cost to bridge users will become less as a result of the limitation on toll increases to 75 percent of inflation.
- Financing was feasible only because the annual guaranteed subsidy payments by the Canadian Government will be independent of the actual project completion date and revenue from tolls. It is appropriate to note that the developer bears the cost and completion risks of the project.
- The selection process for a developer involved three stages to ensure that the quality of the project was considered before price. Only developers whose proposals met the technical requirements of the first two stages were allowed to submit financial bids in the third stage.
- An independent engineer is retained to review the design, ensure conformance with the project requirements, and authorize payments.
- Development and construction have proceeded with a spirit of cooperation and openness between the Canadian Government, the Canadian provinces, and the developer. The key to success is the participation of project champions from the Canadian Government and SCDI.
- To facilitate construction in the shortest time, bridge components are being prefabricated.

- High-performance concrete is being used routinely throughout the project to ensure a durable structure.

- Quality control and quality assurance are the responsibility of the contractor. Because the developer is responsible for maintenance and operation of the bridge and is required to turn the bridge over to the Government after 35 years in a "like new" condition, there is a built-in incentive to ensure quality throughout construction and to implement a high-quality maintenance program.

- Environmental information was made available early in the project to all parties, including the general public.

- The development process from concept to construction has involved extensive open communication with the public, and community involvement continues during construction.

- Development time could have been reduced if the environmental review had been based on the specific bridge design rather than several generic bridges.

1.8 Recommendations

The scanning team developed the recommendations listed below for consideration by all involved in transportation programs. Although these recommendations are based on a very large and unique project, some may also be applicable to smaller projects.

- Innovative financing concepts should be adopted that will be attractive to investors by providing a reasonable and safe financial return.

- An annual subsidy should be made to the developer in lieu of annual maintenance costs.

- Financial risk should be assigned to the private sector.

- Partial reimbursement of proposal-preparation costs should be made to unsuccessful bidders as a way to encourage bidders.

- The number of qualified developers meeting defined project requirements should be reduced before submittal of the financial proposal.

- Prefabricated components will reduce construction time and the impact on local traffic and businesses.

- Greater and more routine use of high-performance concrete will reduce component size, reduce initial cost, improve durability, and provide a longer service life.

- Assignment of quality assurance and quality control to the contractor and built-in incentives and disincentives into the contract will ensure that the benefits and shortcomings accrue to the contractor.

- An independent engineer with financial authority is vital to the success of a project where adequate resources and levels of confidence are present for the independent engineer to perform effectively.

- Public involvement and information exchange throughout the life of the project, including site tours of large projects, should be encouraged.

- Early consideration should be given to environmental impact and management.

In addition, information exchange should continue by inviting key project staff to speak at meetings in the United States. The Federal Highway Administration should continue to monitor the Northumberland Strait Crossing Project for financial and technical results.

2. BACKGROUND

2.1 Purpose of Visit

The Northumberland Strait Crossing Project is a 12.9-km (8.02-mile) long bridge that will link Prince Edward Island and New Brunswick (see Figure 3). The bridge will replace the existing ferry service between the two provinces. The other ferry service, between Prince Edward Island and Nova Scotia, will remain in operation. NSCP provided a unique opportunity to learn firsthand how a private developer is financing, designing, and constructing a major bridge and how the developer plans to operate and maintain it under a 35-year agreement with the Government of Canada.

Besides the unique contractual and financial arrangements, NSCP also has significant engineering challenges. The bridge is located in an environmentally sensitive area, it was the focus of several major environmental investigations, and the social impact has been the subject of much public debate. Consequently, NSCP offered a rare, one-stop visit to a project that addresses many aspects of construction similar to those in the United States.

The general objectives of the tour were to observe, investigate, and document detailed

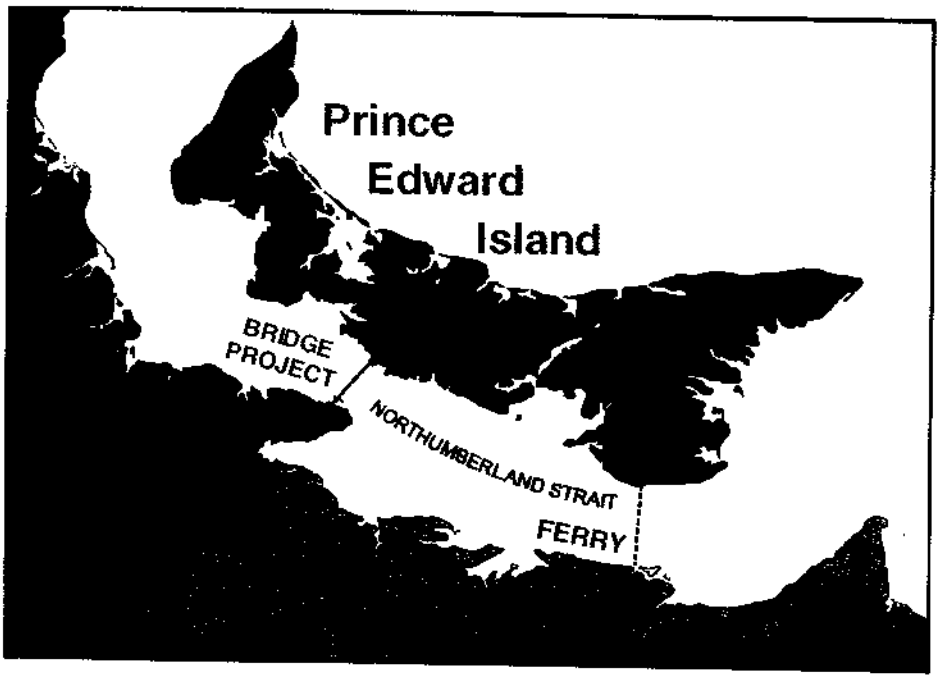

Figure 3: Location Map

program and technical information on the development, construction, and planned operation of the Northumberland Strait Crossing. The study focused on three areas:

- Program management and innovative financing.
- Engineering design, construction, and maintenance.
- Environmental management.

The scanning trip was held over a 3-day period in September 1995. The final agreement for development of the crossing had been in effect for nearly 2 years, and production of precast concrete components was fully under way in plants located in New Brunswick and Prince Edward Island. Foundations for the New Brunswick approach spans were being constructed, superstructure for the Prince Edward Island approach spans was almost complete, and substructure for some of the main spans on Prince Edward Island were in place. Consequently, many phases of the project were observed.

The first day was devoted to site visits at Prince Edward Island, Northumberland Strait, and New Brunswick. On the second and third days, representatives of the Canadian NSCP Team; Strait Crossing Development, Inc., the developer; Concrete Canada; and Buckland & Taylor, Ltd., the independent engineer, gave presentations. Discussions were also held with the various project participants on a wide range of topics.

2.2 Team Members

The NSCP scanning team was composed of the Federal, State, and private sector representatives listed below.

Name	*Representing*	*Organization*
Stanley Gordon (Team Leader)	FHWA	FHWA, Washington, DC
Jim Ahern	ARTBA	Ahern & Associates, Inc.
Louis Colucci	FHWA	FHWA, McLean, VA
Carol D. Cutshall	AASHTO	Wisconsin Department of Transportation
Robert J. Desjardins	AGC	Cianbro Corporation
Gerald L. Eller	FHWA	FHWA, Washington, DC
Hal Kassoff	AASHTO	Maryland State Highway Administration

Susan N. Lane	FHWA	FHWA, McLean, VA
David M. Moskowitz	ACEC	A. G. Lichtenstein and Associates, Inc.
Jerry L. Potter	AASHTO	Florida Department of Transportation
Henry G. Russell	Report Facilitator	Henry G. Russell, Inc.

2.3 Crossing History

The history of the Northumberland Strait Crossing Project began with Prince Edward Island's entry into the Canadian Confederation in 1873. The confederation obligates the Canadian Government to provide continuous and efficient year-round transportation for people, goods, and services between Prince Edward Island and the mainland. Prince Edward Island is separated from the mainland by the Northumberland Strait. The width the Strait varies from 13 km to 55 km (13 km=8.08 mi). It is ice covered for 4 to 5 months of the year.

In 1877, the Canadian Government agreed to provide a subsidy for "steam communication" between the island and the mainland. At that time, ice-breaking ferries were unreliable and could not provide for full transportation needs in all seasons. John Howlan, senator from Prince Edward Island, lobbied for the construction of a tunnel from 1885 to 1890. In 1887, Public Works Canada (PWGSC)* commissioned a tunnel-feasibility study by the British engineering firm of Fox, Hall, and Greathead. The idea was abandoned because of the development of efficient ice-breaking ferries that could be used to provide year-round transportation between the island and the mainland. The first year-round ferry service began in 1917–18.

In the mid-1960s there was a serious attempt to build a causeway between the island at Port Borden and the mainland at Cape Jourimain, and roadways were constructed at each point to connect to the existing highway system. The project was canceled in 1968, when a 15-year regional development plan and improved ferry service were proposed. Since 1968, traffic has increased and ferry costs have risen. Increasing problems with the quality of the ferry service, especially during the peak summer months, are now anticipated.

In 1985–86, the Canadian Government received three unsolicited proposals from private industry for a fixed crossing between Prince Edward Island and the mainland. The proposals included a bridge, a rail tunnel, and a bridge-causeway. Proposals included conditions that the Canadian Government would make available the subsidies that were being granted to the ferry service and that developers could charge tolls to use the

*The name of Public Works Canada has changed during the history of the Strait Crossing. Its current name is Public Works and Government Services Canada. In this report it is referred to as Public Works Canada, or PWGSC.

crossing. These proposals were attractive to the Government because of policies to rely more on the private sector for major development initiatives.

In 1986, the Government authorized studies to determine the feasibility of the projects and to identify private sector interest in developing a fixed crossing. This process involved extensive public consultation and studies of environmental impact, safety in the Strait, impact on farmers, and costs and benefits. These studies concluded that a fixed link was a viable alternative to the ferry service. In May 1987, a Stage I Call for Expression of Interest was issued that described the project as a "Fixed crossing of the Northumberland Strait between Jourimain Island, New Brunswick and Borden Point, Prince Edward Island to be financed, designed, constructed, operated, and maintained by the private sector under a lease-purchase arrangement for a specific period of time (tentatively 35 years)." At that time, it was assumed that the crossing would be in operation by 1993. The project was supposed to have a design life of 100 years and was to consist of either a high-level bridge structure or a tunnel for vehicular traffic. Twelve Canadian companies responded to the Call for Expression of Interest. Seven consortia were selected for Stage II review.

In June 1988, 6 developers submitted six bridge proposals and 1 tunnel proposal to be evaluated in Stage II of the process. The proposals were evaluated by 5 teams for technical, financial, management, environmental, and regional benefits. The teams were staffed by appropriate government agencies, and provincial representatives were included in the environmental and regional benefit teams.

The process of pulling the evaluations together was managed by a coordinating committee chaired by the Public Works Canada Project Manager. In order to participate in Stage II, developers were required to demonstrate that they had financial management, engineering, construction, and operation and maintenance capabilities to successfully execute the project. In addition, they had to demonstrate a commitment to the use of Canadian and regional workers and materials on the project.

Assigned weights in the evaluation for each item wereas follows:

Financial Plan	35%
Design Team	20%
Construction Team	20%
Project Management	15%
Operation and Maintenance	10%

Feedback was provided to the developers on deficiencies in their proposals and they were allowed to make revisions; however, only three proposals were recognized in September 1988 as meeting all the requirements of the proposal call. The other proposals were excluded because they did not meet all the terms of reference, and none of the unsuccessful bidders were reimbursed for their proposals. Cost had not been a factor in selection of the three final developers at that time.

Throughout the development process, there had been constant communication among and involvement of all parties who would be affected by the crossing. In November 1987, the Premier of Prince Edward Island wrote to the Minister of Public Works Canada indicating the Prince Edward Island Government would offer its support to the project provided certain conditions were met. These included the following:

- The Canadian Government would fund the construction of approach roads and transfer them to the Province upon completion.
- Construction of a fixed crossing would replace the Borden-Cape Tormentine ferry only. (A second ferry service operates between the island and Nova Scotia.)
- The Canadian Government would consult with the Provincial Government to ensure that tolls would be fair and reasonable.
- The Canadian Government would develop an assistance program for displaced ferry workers.
- The Canadian Government would conduct studies to offset negative employment and income effects.
- Atlantic regional economic benefits were to be maximized.
- Fishermen whose livelihoods would be adversely affected by activities related to the construction would be compensated.
- A utility corridor would be provided on the fixed link at no cost to the Province.

As project planning gained momentum, the Government of Prince Edward Island held a plebiscite on the issue of a link. Before the vote, the Provincial Government organized many activities to inform the public of the issues and to provide opportunities for participation. Two major interest groups developed on the island and attempted to influence public opinion. "Friends of the Island" showed strong opposition to the project, while "Islanders for a Better Tomorrow" expressed their conviction that the project should proceed for economic reasons. On January 19, 1988, 59 percent of the islanders voted "Yes" to the plebiscite question: "Do you favour the construction of a fixed crossing between Prince Edward Island and New Brunswick?" The Prince Edward Island Government then provided conditional concurrence to the Canadian Government. The New Brunswick Government had already supported the principle of building a fixed link.

In 1989, a Federal Environmental Assessment Review Office (FEARO) panel was appointed to review the environmental and social impacts of the project. Formal public hearings were held and continued into 1990 when the panel recommended the project not proceed primarily because the bridge would cause a delay in break-up of ice in the spring. It was argued that a delay would, in turn, delay the start of the fishing season and reduce local temperatures so that planting of crops would also be delayed. However, the panel's report contained suggestions on how to continue with a project that would be environmentally acceptable.

In November 1990, the Canadian Government responded and announced that it had taken the panel's recommendations into account and that only a bridge that caused a maximum delay of 2 days in ice departure would be selected. A committee of ice experts was assembled by Environment Canada (the Canadian government agency responsible for environmental protection) to review how a bridge would affect the departure of the spring ice in the Strait. In April 1991, the ice committee published a progress report and then conducted public information sessions to demonstrate how the ice would be affected by a variety of bridge features. In December 1991, the committee concluded that a bridge that met the criteria for ice delay established by the FEARO panel could be installed across the Northumberland Strait.

In May 1991, the three previously selected developers were invited to resubmit their proposals to be evaluated against the new environmental requirements and the Government's financial criteria. The Minister of Public Works announced in January 1992 that the three bridge proposals met the environmental requirements, and the developers were then requested to submit their financial and security packages and their bids for federal subsidy. These bids were opened on May 27, 1992. After all three proposals had been evaluated, it was determined that none of the submissions complied fully with the financial and risk terms of the proposal call. On July 17, 1992, Public Works Canada announced that it would initiate discussions with the lowest bidder, Strait Crossing, Inc., to determine if the company could submit a plan that would be acceptable to the Canadian Government. ("Lowest bid" was defined as the one requiring the least annual subsidy.)

On December 16, 1992, a memorandum of understanding was signed between the Government of Canada and the provinces of Prince Edward Island and New Brunswick. This agreement dealt with the resolution of the issues that were previously spelled out by the Premier of Prince Edward Island.

In late 1992, Friends of the Island challenged the Government's adherence to the environment process in Federal Court. They argued that the environmental impact had been assessed based on a generic bridge rather than a specific bridge design. The court agreed and ordered Public Works Canada to do an environmental evaluation based on the specific Strait Crossing, Inc. design. In addition, the judge instructed that appropriate changes be made to the Terms of the Union before termination of the ferry service. The subsequent public review of the environmental evaluation led to the conclusion that the project was environmentally sound. Specifically, the ice committee determined that the ice break-up delay was predicted to be 0.4 days (± 20 percent) over the 100-year life of the bridge. This latest process was again challenged by Friends of the Island, but the court dismissed their application. In June 1993, the Northumberland Strait Crossing Act was signed to provide the annual irrevocable subsidy payment.

On October 7, 1993, legal documents for the project were signed. An official ceremony was held on October 8 to celebrate the signing of the agreement between Strait Crossing Development, Inc. and the

Canadian Government. On October 27, 1993, construction work on the precasting plant began.

The successful developer estimated that approximately $C30 million had been invested in the project up to the signing of the agreement. About $C1.5 million was reimbursed to each of the two unsuccessful bidders as partial compensation for the unanticipated delay caused by the review panel. Additionally, the Government agreed to pay about $C5 million in design costs if negotiations were not successfully completed. While the $C5 million was never paid, an Interim Engineering Agreement permitted the project design to proceed during negotiations.

In summary, the selection process took from May 1987, when the Call for Expression of Interest was issued, until October 1993, when an agreement was signed. By contrast, the time to construct the crossing was reduced during negotiations from an initial estimate of 5 years to 3 years and 8 months. In retrospect, both the developer and Public Works Canada agree that development time could have been reduced if a specific bridge design had been the model used for the environmental evaluation, rather than a generic structure.

2.4 Social and Economic Impacts

Throughout the project development process, there has been an intense and ongoing public consultation process to confirm and refine the impacts that a fixed-link crossing would have on the people and economy of Prince Edward Island. Projected impacts have been both positive and negative.

It should be noted that the primary sources of revenue for Prince Edward Island are fishing, tourism, and potatoes. The fishers (as Canadians refer to fishermen), through their associations, expressed concern over the disruption of their activities and of fishing in general, resulting from a project of this size in the prolific waters of the Strait. They expressed concerns that the bridge piers would create ice jams, affect the ecology of the Strait, and delay the start of the fishing season. They supported a tunnel because it would have no impact on the marine environment.

Because the fixed link was to replace the existing ferry service, ferry workers expressed serious concerns over the abandonment of the service and loss of their jobs. Also, the economies of the two towns closest to the ferry terminals would be affected.

On the other hand, those whose livelihoods depended on tourism very much favored a fixed link as a means of facilitating transportation to and from the island. Trucking industries, construction and engineering associations, and potato farmers would benefit from a fixed link and expressed interest in seeing the idea explored further. As part of the project, the developer was required to commit to regional procurements.

One of the major themes of the project is what Canadians refer to as "being transparent." The Government and developer provide information on every phase of the project to the public. While this may be typical during an environmental review process, it is less common to see ongoing environmental monitoring reports made public. The openness of project staff and availability of information about all phases of the project has helped promote trust and a greater acceptance of the project in general. Ongoing public communication activities have included the following:

- Gift shop and tours of the precasting plant at Borden, Prince Edward Island that are operated by a local business.
- Publication of *Strait Facts*, a newsletter by PWGSC.
- Publication of *Strait Crossing Project Update*, a newsletter by SCDI.
- Establishment of information centers on Prince Edward Island and New Brunswick.
- Sponsorship by SCDI of the Arts Center program in Charlottetown, Prince Edward Island.
- Publishing of labor and procurement forecasts.
- Business- and employment-opportunity meetings.
- Establishment of vendor lists.
- Involvement of key SCDI and PWGSC officials in community activities.

3. ADMINISTRATION, FINANCING, AND CONTRACTING

3.1 Organizational Framework

The organizational framework of NSCP is particularly complex. This was inevitable given the unique nature of the project and the number of parties involved. A chart illustrating the ownership, funding, and agreements for the project is shown in Figure 1.

Public Sector

The Canadian Government department primarily responsible for the NSCP is Public Works and Government Services Agency Canada. PWGSC has led the project from the Government side since the initial submittal of unsolicited proposals in 1985. However, Transport Canada—the equivalent of FHWA—is expected to be the eventual owner of the bridge. Initially, the role of PWGSC was to ensure that a satisfactory agreement could be reached between the developer and the Canadian Government, taking into account the many other entities that would be affected by a fixed link. Since signing of the development agreement, the role of the Canadian Government has changed. Now its primary functions are to monitor the project and to make sure the developer meets general project requirements. To achieve this function, PWGSC established a Northumberland Strait Crossing Project office, staffed with specialists in the fields of engineering, industrial benefits, and environmental compliance. The specific roles and responsibilities of the office are as follows:

1. To represent and secure the Government of Canada's interests as reflected in the agreements related to the design, construction, operation, and eventual transfer of the bridge to the Canadian Government.

2. To provide a focal point for the coordination of information and management issues among the many stakeholders involved with the project.

3. To monitor the effectiveness of the contractual framework, particularly as it relates to the performance of the independent engineer, the financial trusts, and the security of assets. The Government reserves the right to retain independent consultants for second opinions.

4. To monitor and conduct audits of the developer's engineering and construction plans and procedures, environmental management plan, fisheries and ferry workers' commitments, and regional benefits obligations.

5. To generally represent the leadership demonstrated by the Government of Canada in sponsoring the development of a world-class project and a great feat of engineering by the private sector.

The role of the PWGSC project office differs from the traditional role of a State department of transportation in overseeing the construction of a major bridge in the United States. PWGSC does not have any direct authority over the quality of construction and progress payments. Its primary goal is to make sure the developer meets all general project requirements, and that the role is performed with a spirit of cooperation. However, under the development agreement, PWGSC may intervene to resolve any differences through an alternate dispute resolution procedure. If the developer fails to comply, the performance and compliance bonds are at risk.

In addition to PWGSC, numerous other Canadian Government agencies are involved. These include Transport Canada, Environment Canada, Fisheries and Oceans Canada, Atlantic Canada Opportunities Agency, Human Resources Development (Labour), Finance, and Justice. The Provinces of Prince Edward Island, New Brunswick, Nova Scotia, and Newfoundland are also involved. A key to the successful interagency coordination is a committee structure led by an Operations Committee (chaired by the project leader from PWGSC). The Operations Committee meets monthly and monitors the project for the Government through subcommittees dealing with technical, fisheries, environmental, and socioeconomic issues. This committee is not a decision-making group, but ensures that all parties are kept up-to-date by the developer on project status and that compliance with agreements is adequately monitored. The developer's participation and cooperation have been key to the success of this process.

Private Sector

The private sector framework is more complicated than that of the public sector. A number of companies are involved and new companies were formed for a variety of operational, financial, and legal reasons.

The developer of the Northumberland Strait Crossing Project is Strait Crossing Development, Inc. (SCDI). SCDI is a Canadian company formed as a joint venture by Strait Crossing, Inc., Northern Construction Co., Ltd., G.T.M.I. (Canada), Inc., and Ballast Nedam Canada, Ltd. Strait Crossing, Inc. (SCI) is an entirely Canadian-owned corporation and was established in 1988 to participate in the bid for the Northumberland Strait Crossing Project. Northern Construction is a wholly owned Canadian subsidiary of Morrison Knudsen Corp., headquartered in Boise, Idaho. G.T.M.I. (Canada), Inc., is a wholly owned Canadian subsidiary of GTM Entrepose, headquartered in Nanterre, France. Ballast Nedam Canada is owned by Ballast Nedam, headquartered in the Netherlands. Among the four companies, SCI is the apparent organizer and prime mover for the project.

The contractor for the project is Strait Crossing Joint Venture (SCJV). SCJV is owned by the four owners of SCDI and was established as a separate construction company for bonding, legal, and tax purposes. SCJV operates under a construction contract with SCDI and is expected to employ many subcontractors.

Once the bridge is complete, it will be operated and maintained by Strait Crossing Bridge, Ltd., a wholly owned subsidiary of the developer, SCDI. A separate public corporation, Strait Crossing Finance, Inc., was established by the Province of New Brunswick to receive the annual subsidy from the Canadian Government, market the bonds, and oversee progress payments to the developer, following approval by the independent engineer.

The last of the key players in the organizational framework is the independent engineer, Buckland & Taylor, Ltd. The independent engineer operates under a retainer agreement, is paid by the developer out of a trust fund, and reports to the developer, the contractor, and the Canadian Government. The main duties of the independent engineer are to check the design, including a full computational check; confirm that the work is performed to the project requirements; authorize drawdowns from the trust fund; verify that sufficient funds remain in trust for completion; concur with certificates of substantial completion and final completion; and conduct inspections during the operating period. The independent engineer is not responsible for construction quality, but can inform the contractor when construction does not conform with the project requirements. It should be noted that the independent engineer is not the Engineer of Record for the project and functions only in review capacity.

3.2 Financial Plan

The estimated total cost for building the crossing is $C840 million (1992 dollars). The initial capital for this development has been raised by the private sector. Effective May 31, 1997, the Government of Canada will pay the developer $C41.9 million (adjusted for inflation since 1992) every year for 35 years. This amount represents the capital costs to the Canadian Government of replacement ferries and other capital costs, but does not include highway costs, compensation to ferry workers, project administration, and nonavoidable overheads. If the bridge is not completed by May 31, 1997, the developer will assume operation of the ferry until the bridge is completed. Although completion is targeted for May 31, 1997, subsidy payments by the Government are guaranteed on that same date. The net cost of operating the ferry is estimated to be approximately $C100,000 per day, though figures vary by season. This, in essence, represents a penalty against the contractor for late completion.

Before signing the development agreement, the developer was required to establish a trust fund, for an amount which, with accumulated interest, would equal the full cost of building the bridge. Money can only be paid out of the fund with the approval of the independent engineer's certification of work completed. Sufficient money must always remain in the trust to ensure that financing is available to complete the major work items and enough to cover the work-breakdown-schedule line items for non-major work.

The subsidy agreement and payment by the Government of the annual subsidy payments were authorized by the Northumberland Strait Crossing Act (Canada) enacted in June 1993 and put into effect on September 2, 1993. The act provided a parliamentary appropriation for the payment of the subsidy in each of the years that the payments are to be made. It also authorized the Government to waive any rights to offset against payments of the Government's subsidy any indebtedness due to the Government. The subsidy agreement also specifically authorized Strait Crossing Finance, Inc., to assign the right to receive the subsidy.

On the strength of the subsidy agreement, Strait Crossing Finance, Inc. issued $C661 million in inflation-indexed, fully amortizing bonds, from which proceeds were approximately $C640 million. Strait Crossing Finance, Inc.'s rights under the subsidy agreement were assigned by way of security to the bond holders' trustee. Because a separate company is established at no cost and at no risk to New Brunswick, and because federal payments are guaranteed, flow of the annual subsidy goes directly to the bondholders rather than through the developer. Payments on the bridge bonds will be exactly equal to the annual payments of the government subsidy. This means that even if the developer falters, the bondholders are protected. The result was that the bonds received the highest possible rating and lowest interest rates, and the difference in interest rates made the difference in the developer's ability to finance the project.

The bonds are not Government debt nor does the subsidy agreement constitute sovereign debt. Yet, the underwriters obtained discretionary exemptions from the Canadian securities authorities to allow institutional investors to acquire and trade the bonds as though they were Government securities. The target market for the bonds was pension funds looking for a long-term guaranteed rate of return. The tax-exempt status of pension funds in Canada also provided the ability to market the bonds at low cost.

In seeking funding, the developer examined four financial options—equity, traditional debt through toll-revenue bonds, partnership units, and real-rate bonds. The equity and debt approaches represented too high a risk for the capital markets, particularly with respect to the uncertainties of completion and future traffic levels. The use of partnership units was rejected when it became evident that there was a lack of Government support for the special tax treatment that this unique project would have required. Financing was therefore arranged through a real-rate bond, backed by a guaranteed annual payment from the Canadian Government. The key to the financing was the guarantee of a "date certain" for the initiation of 35 annual federal subsidy payments, independent of the actual completion date of the bridge.

In addition to the trust fund, the developer was required to have a 10 percent-funded contingency. This was provided by SCDI posting a clean irrevocable letter of credit in favor of the Government, to remain in place until substantial completion of the crossing.

Extensive additional protection was put in place to address the risks to the Government of committing the annual subsidy on an unconditional basis. A $C200 million performance bond was posted by a consortium of surety companies on behalf of the developer. A $C20 million labor and materials bond and a $C35 million compliance bond were also posted. The security package also includes parent company guarantees, and Government security over assets and insurance; the Government has first mortgage rights on all the developer's assets. After 35 years, ownership of the bridge will revert to the Canadian Government.

The developer will be allowed to charge tolls for use of the bridge. Tolls in the first year must be comparable to those charged by the ferry, based on the 1992 rates, with allowance for inflation. The developer may increase the toll rate in subsequent years; however, the tolls cannot increase by more than 75 percent of the Consumer Price Index (CPI) increase. In the long run, the real costs of tolls will decline because of this 75-percent limitation. Currently, the toll-ferry rate structure is fairly complex. For car and driver, the toll is $C26.50 per round trip; each passenger is extra. Commercial tolls vary by type of vehicle. The average passenger-car toll exceeds $C30 per round trip. The developer plans to simplify the toll structure, which will require Government concurrence that the rates are legitimately comparable with the 1992 levels.

Current ferry traffic amounts to about 1 million crossings per year—June, July, and August being peak travel months. The developer projects a 25-percent increase in traffic resulting from the convenience of the bridge compared to the ferry service. However, these usage levels are not sufficient to provide adequate funding for the project, let alone an adequate rate of return for the private sector. Therefore, the primary source of financing must be considered the Government subsidy. The result will be that the crossing will be financed by the private sector with no additional cost to the Canadian Government.

At completion of the 35-year operating period, the bridge will become the property of the Canadian Government, with virtual elimination of cost to the taxpayer of the subsidy during the 65-year remaining design life of the bridge. Northumberland Strait Crossing is reported to be the first substantial build/operate/transfer project undertaken in Canada to meet an infrastructure requirement.

3.3 Agreement Highlights

A complex array of 39 separate agreements and 400 documents govern every aspect of the project and responsibilities of each of the parties. The main agreements are as follows:

- Development agreement.
- Construction contract.
- Project trust agreement.
- Project security agreement.
- Independent engineer retainer agreement.
- Operating agreement.
- Regional benefit agreement.

The primary agreement is the Development Agreement between the Government of Canada and SCDI to finance, build, and operate the bridge. SCDI is responsible for raising the necessary funds to develop the project and for receiving revenue from the Government subsidy and the bridge tolls. SCDI is also responsible for construction of the bridge according to the approved design and assumes all associated risks. It will operate and maintain the bridge according to the terms of the agreement for a period of 35 years, after which the bridge becomes the property of the Canadian Government.

During construction, the developer assumes the majority of risk for delay in completion and cost overruns. There are no provisions for extra work orders or claims, and time extensions will be granted only for specific delays such as acts of God or the unexpected presence of contaminated materials. Additional compensation will be provided only in the event of acts by enemies of the Crown, an earthquake, nuclear event, Government action, or an environmental injunction. Other items covered by the development agreement include insurance, bonds, ferry cost reimbursement obligation, fisheries compensation obligation, defaults and remedies, warranties and covenants, dispute resolution (arbitrators), audit, and access.

The construction contract between the contractor, SCJV, and the developer, SCDI, mirrors the development agreement. It addresses scope of work and price, cost to complete and drawdowns, and license and charter of certain developer assets, such as the floating crane, Svanen.

The project trust agreement is signed by the developer, the trustee, and the Governments of Canada, New Brunswick and Prince Edward Island. There are two separate trusts—a construction-price trust and a development trust that covers Svanen, which is owned by the developer, not by the contractor.

The various project security agreements include provisions to ensure the financial security of the project and to protect the risk of the Canadian Government. Key factors for security include the trust fund, independent engineer retainer, performance bonds, letter of credit, insurance, and security-over-assets to the Government at closing. Security-over-assets took place at financial closing and continues as assets are acquired and components are fabricated.

The independent engineer retainer agreement defines the duties of the independent engineer. Duties include design review, confirmation that the work is performed to established standards, authorization of drawdowns from the trust funds, concurrence with certificates of substantial and final completion, and inspection during the operating period. The independent engineer reports to the developer, contractor, and the Government, and is paid by the developer from the trust fund.

A regional benefits agreement containing the following highlights was also signed:

Quantitative Covenants

- 70 percent of all materials must be procured from within the Atlantic Provinces region.
- 96 percent of all labor, except management, professionals, and skilled marine workers, must be from the region.
- At least $C20 million of engineering work, after closing, must be from the region.
- 75 percent of all marine workers must be from the region.

Other Covenants

- Right of first refusal to the displaced ferry employees for bridge-operating jobs.
- A human resources plan during the course of construction.
- A labor management plan.
- Technology transfer to local businesses and educational institutions.
- Long-term benefits to Prince Edward Island and the Atlantic region

The developer is required to monitor progress and report on achievements of the above goals.

Naturally, the developer and contractor are expected to comply with all Government regulations and policies, particularly those concerned with the environment, taxation, health, and safety.

3.4 Operation and Maintenance

Upon completion, the Northumberland Strait Crossing will carry two lanes of traffic 24 hours a day. All vehicles permitted to travel on the Trans-Canada highway will be able to use the crossing, and tolls will be collected at the toll plaza on the Prince Edward Island side of the bridge. User facilities including public waiting areas and washrooms will be provided at both ends of the bridge, and emergency telephone call stations will be placed every 500 m (1,640 ft). Access to the bridge will be monitored and electronic signaling systems will allow traffic control as required. The bridge will provide 24-hour roadway lighting, 24-hour video surveillance, shuttle service for pedestrians and cyclists, and 24-hour snow removal. It was anticipated that bridge piers on each side of the navigation channel would be protected from vessel impact by underwater rock-filled islands, but this is under review. A radar reflector system will guide vessel traffic.

Maintenance of the structure for the first 35 years will be the responsibility of the developer. The bridge then will be turned over to the Canadian Government in a "like new" condition. This provision is a major incentive for the developer to achieve quality in construction and implement a high-quality maintenance program. Shortcuts taken during construction to save time and money may result in increased maintenance costs during the first 35 years. The developer is required to prepare a maintenance plan for approval by the independent engineer.

In turn, the independent engineer has responsibilities to review any amendments or alterations to the maintenance require-ments, project requirements, and long-term maintenance plan. The independent engineer is required to perform a comprehensive inspection at least every 6 years and to perform inspections after major or emergency repairs. The independent engineer must also conduct a comprehensive inspection prior to the bridge becoming the responsibility of the Canadian Government. The independent engineer is not responsible for the environmental management, environmental monitoring, environmental protection plans, safety, or labor management.

4. DESIGN, CONSTRUCTION, AND MATERIALS TECHNOLOGY

Northumberland Strait is a relatively shallow, saltwater channel. Water depths average 15 m to 20 m (50 ft to 65 ft) with a maximum depth of 33 m (108 ft). The shoreline at each side of the Strait consists of low banks, 3 m to 5 m (10 ft to 16 ft) high, of exposed weathered bedrock suitable for support of abutments.

The sea floor generally consists of up to 3 m (10 ft) of clay till overburden over bedrock made up of relatively soft layers of sandstone, siltstone, and mudstone. The mudstone, which is discontinuous, has a very low shear strength and was a critical factor in the foundation design.

4.1 Bridge Design

The design solution for crossing the Northumberland Strait with a bridge was dictated by the following factors:

- A design service life of 100 years.
- A maximum ice-out delay of 2 days in any year in a 100-year period.
- Failure or collapse of any one span not leading to progressive failure or collapse of other spans.

In general, the design was based on the Ontario Highway Bridge Design Code (1987) and the draft Canadian Standards Association CAN3-S6, "Design of Highway Bridges." The 100-year-life criterion required a calibration process to determine the target reliability indexes, which relates to the safety of the structure. A higher reliability index means a lower probability that the design condition will be exceeded during the design life of the structure.

A reliability index of 4.0 or greater was a project requirement for those portions of the structure considered to be multi-load paths, such as flexural design of the deck. A reliability index of 4.25 was selected by the developer for those portions of the structure considered to be single-load paths, such as the sliding resistance of the pier bases. Both ultimate-limit states and serviceability-limit states were subjected to probability analysis using the calibration process.

For comparison purposes, the reliability index inherent in the *AASHTO Standard Specifications for Highway Bridges* and the *AASHTO LRFD Bridge Design Specification* is approximately 3.5 for both dead and live traffic loads. Use of a higher reliability index results in higher load factors and/or lower resistance factors. The factors listed below were also included in the design:

- Ice forces of 25 MN (2,800 tons) perpendicular to the bridge and 17.5 MN (2,000 tons) in the longitudinal direction of the bridge.
- A reference wind speed for a 100-year return period of 29.5 m/s (66 mph) with a maximum component transverse to the bridge of 26.4 m/s (59 mph) at 10 m (33 ft) above the water. During construction, a wind speed of 22.5 m/s (50 mph) corresponding to a 10-year return period was considered. In the casting yard, a wind speed of 15 m/s (34 mph) was used.

- A required navigation clearance of 49 m (161 ft) vertically by 200 m (656 ft) horizontally (later reduced to 176 m (577 ft)).

- A utility corridor in the bridge for electrical services, telephone services, and other utilities to the island.

The final structure consists of the west approach spans with foundations in the shallow waters off New Brunswick, the main bridge with foundations in deep water, and the east approach spans in the shallow waters off Prince Edward Island. The total length of the bridge is 12.9 km (8.02 mi). The west approach consists of 14 spans, each with a typical span length of 93 m (305 ft). The main bridge consists of 45 spans, each with a typical span length of 250 m (820 ft). The east approach consists of 7 spans with a typical span length of 93 m (305 ft) each.

Although numerous alternative schemes were considered for the main bridge, the final design was based on a single-cell, post-tensioned concrete box girder with a depth that varies from 14.5 m (47.5 ft) at the piers to 4.5 m (14.8 ft) at mid-span.

The main spans were designed for balanced-cantilever construction and drop-in girders, as shown in Figure 4. The superstructure forms a series of frames consisting of continuous and expansion spans, and each frame consists of a pair of double cantilever main girders fixed to piers. Drop-in girders are provided between the ends of each cantilever, and an expansion joint occurs in every other span. This structural system was selected to meet the progressive collapse criteria.

For the calculation of long-term deflections and prestress losses, the concrete has been modeled using procedures for creep of the American Concrete Institute for shrinkage and the Comité Euro-International du Béton/Fédération Internationale de la Précontrainte. The material properties are being verified with creep and shrinkage tests beginning at 3, 7, 28, and 90 days. In the event that creep and shrinkage values are greater than originally predicted, contingency post-tensioning ducts are being incorporated into the superstructure to allow for additional post tensioning.

The approach spans were designed based on a conventional precast segmental balanced cantilever system, with a launching truss. A single-cell concrete box, with a depth that varies from 5.06 m (16.6 ft) at the piers to 3.0 m (9.8 ft) at midspan, is used. The conventional match casting technique is used in segment production.

4.2 Construction Technique

The construction technique was dictated by four factors:

- The requirement to complete the bridge by a fixed date.

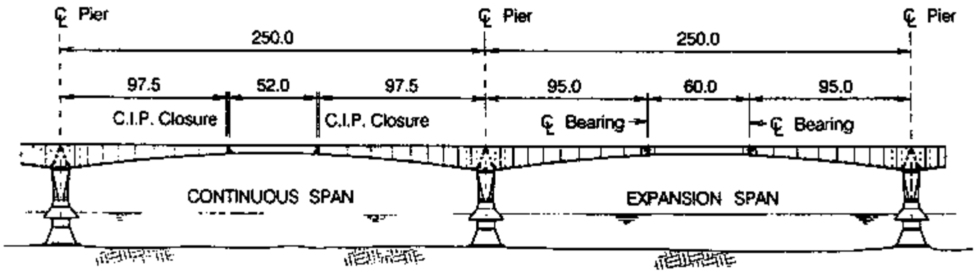

Figure 4: Main Bridge Dimensions

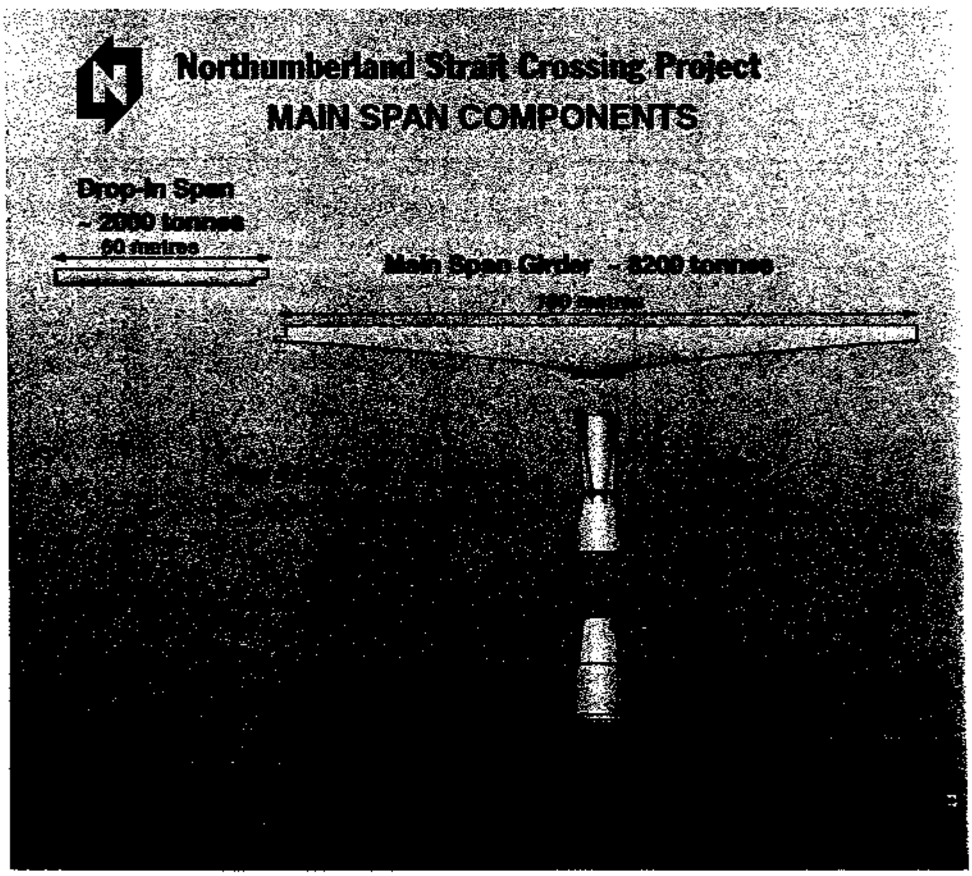

Figure 5: Main Bridge Components

- A construction season limited to approximately 8 months.

- The requirement to minimize the environmental impact.

- The lifting capacity of the floating crane.

On the basis of these factors, the developer decided to prefabricate as much of the bridge as possible on land with the least number of components, and then move the components for the main bridge into position in the Strait using a floating crane. The main bridge is being constructed from four major components and several ancillary pieces. The four major components (Figure 5) are the pier base, pier shaft, main span girder, and drop-in span. The pier base (Figure 6) is placed first, temporarily supported on three concrete hard points, accurately positioned on the bedrock, which is exposed by predredging. Uniform bearing on the bedrock is achieved by filling the space under the footing with tremie concrete, pumped from a barge. The top of the base will extend above mean sea level.

The pier shaft (Figure 7) consists of the shaft itself and the conical ice shield. The ice shield is a critical component because it is in direct contact with seawater in the tidal range and will be exposed to salt-laden spray and ice and to abrasion from the ice. The pier shaft is assembled onto the pier base by lowering the shaft until it rests on hydraulic jacks on top of the base. The position of the top of the pier shaft is adjusted through the jacks. The space left between the outside of the pier base cone and the inside of the shaft cone is then grouted. Vertical post-tensioning is then applied across the joint. Thus no cast-in-place joints are directly exposed to seawater. At the top of the pier shaft, a rectangular transition template that is cast to match the main girder facilitates the positioning and alignment of the main girders.

Each main span girder is prefabricated on land using the balanced-cantilever method of construction. The cantilever segments are cast on a series of fixed beds in the precasting plant, as shown in Figure 8. The process starts with the pier segment, which is always cast at the same location on top of the transition template. From there, the pier segment is moved transversely until it aligns with the first two beds where the first two cantilever segments are cast—one on each end. These segments are then post-tensioned and the formwork extracted from the ends of the cantilever.

Next, the assembly is moved transversely until it aligns with the next set of fixed beds, where another pair of segments is cast. Temporary storage locations are provided between some of the fixed beds. This procedure is continued until the main girder cantilevers, shown in Figure 9, are complete. The main span cantilevers are then moved into the Strait and positioned on top of the transition template and post-tensioned to the pier.

The drop-in girders, shown in Figure 10, are cast in one length. Post-tensioning is provided inside the box, and the drop-in span is used to close the gap between the cantilever tips. It either connects two cantilevers rigidly to create a continuous frame or two frames through an expansion joint. When used within a frame, the gap between each end of the span and the

Figure 6: Pier Base

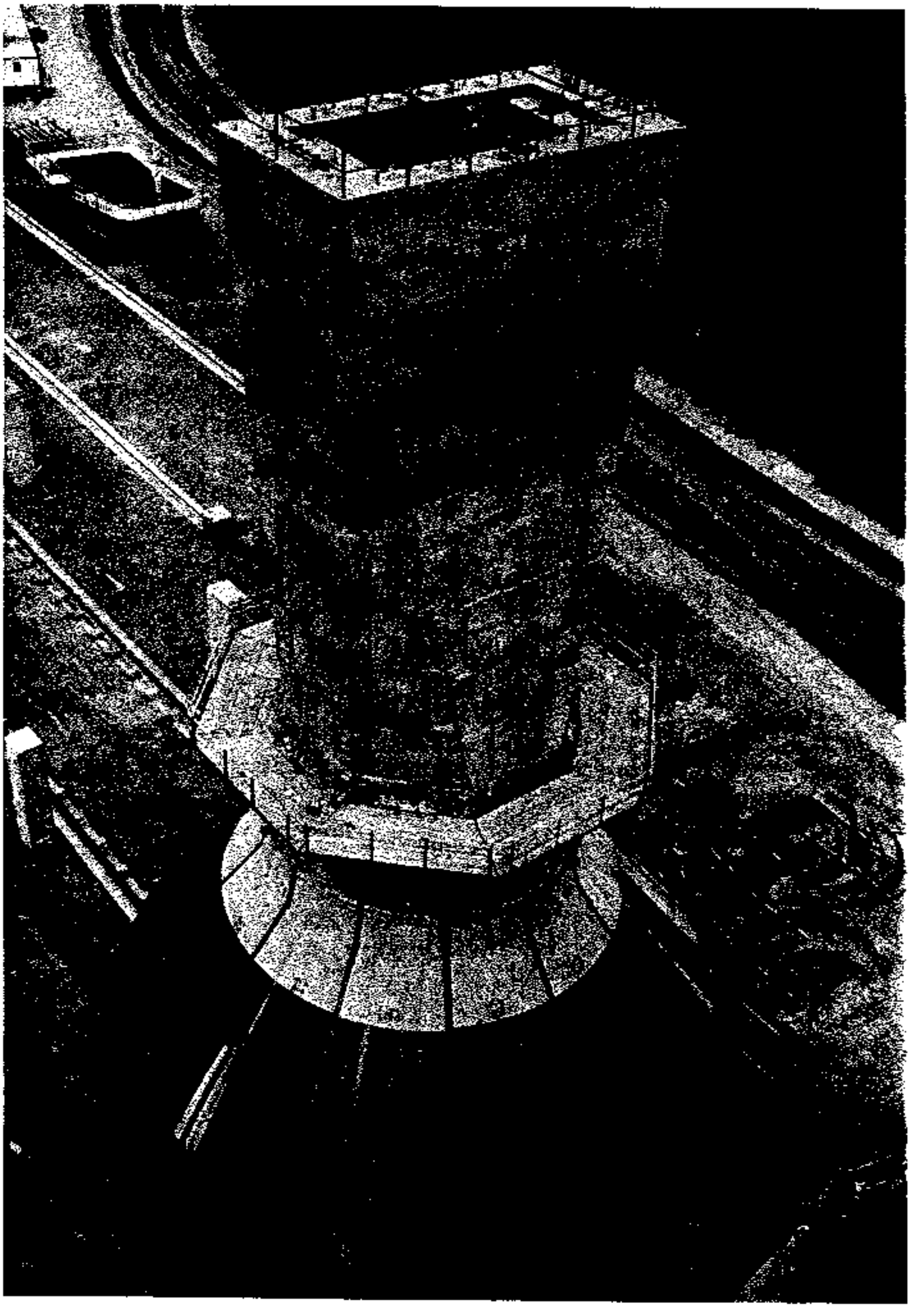

Figure 7: Pier Shaft

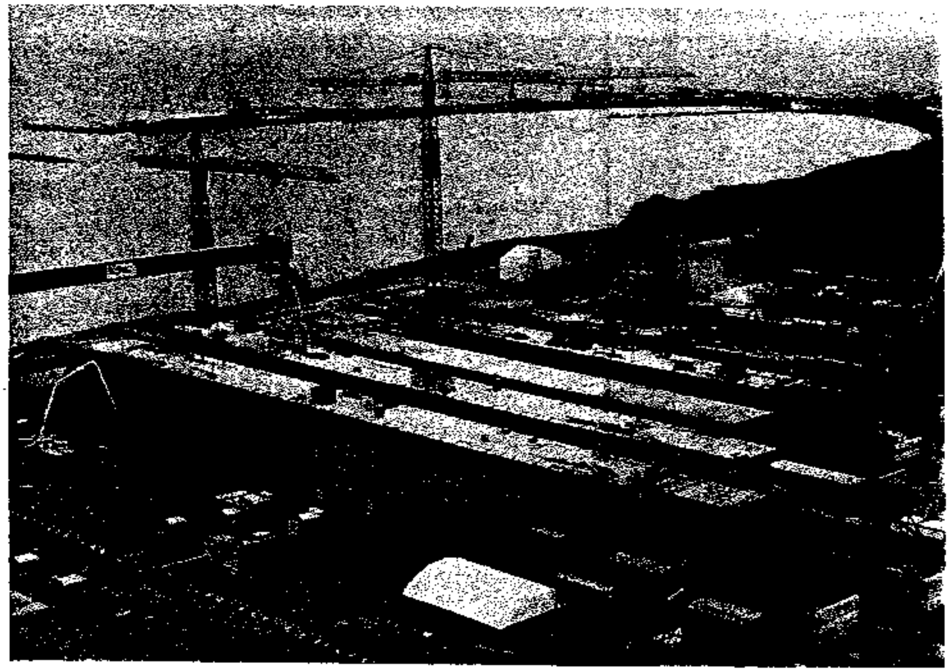

Figure 8: Main Girder Production

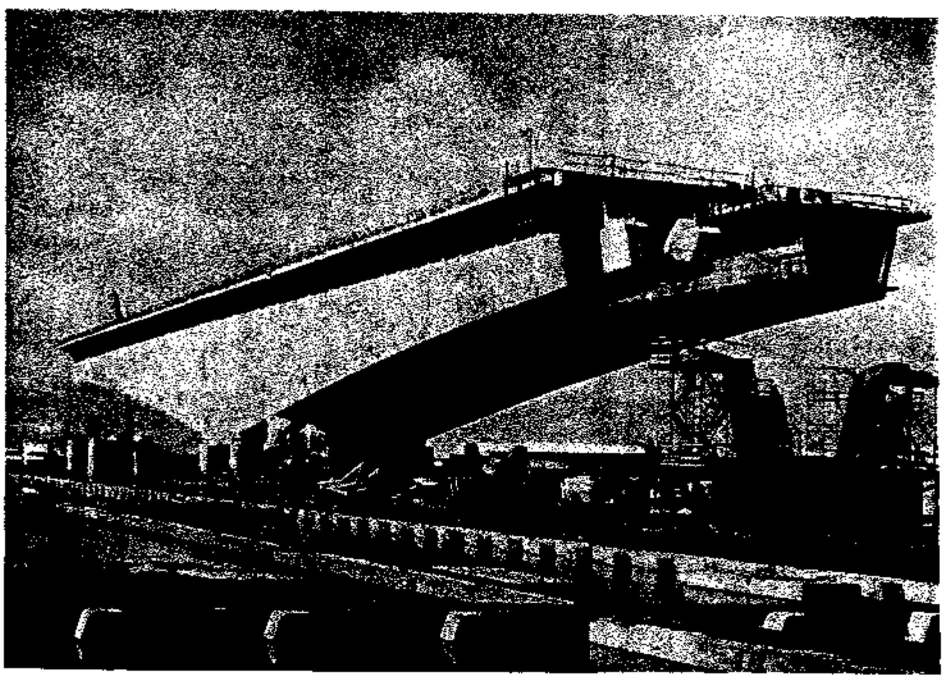

Figure 9: Main Span Girder

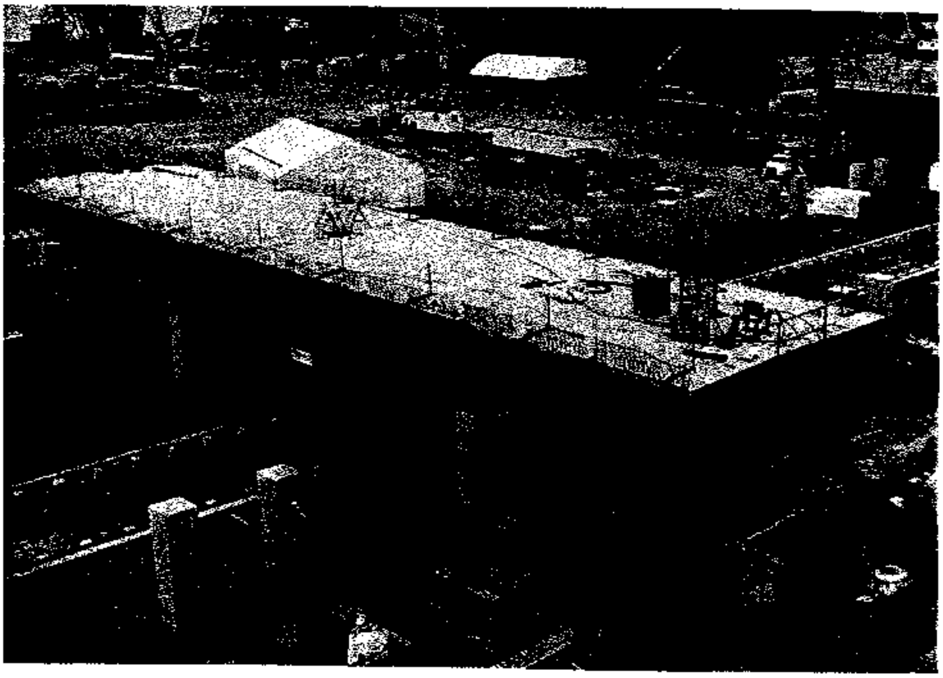

Figure 10: Drop-in Girder

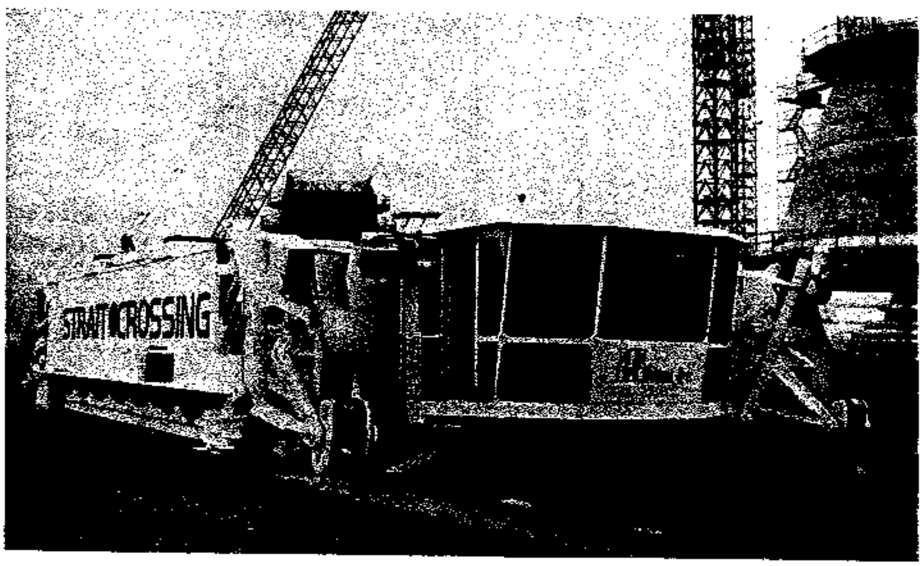

Figure 11: Lifting Device and Sledge

adjacent cantilever contains a jacking device. The drop-in span then acts as a strut when its weight is released onto the cantilevers.

A compressive force is developed in the drop-in span, counteracting the effect of its dead load, which otherwise would induce adverse bending moments in the piers. This horizontal force is subsequently adjusted to offset the long-term effects of creep and shrinkage. The joints between the units are then filled with concrete so that the jacking device can be removed, and post-tensioned tendons are stressed across the gap. When used to connect two frames through an expansion joint, the drop-in span is fitted with hinge segments at each end to turn it into a simply-supported span. This span is always installed after the adjacent frames are completed.

All the main-span components are being fabricated in a Prince Edward Island precasting plant. Within the plant, components are moved utilizing one of two special lifting devices, shown in Figure 11. The largest component weighs approximately 8,200 tonnes (8,800 tons). The precast components will be moved from land into the Strait and into final position using a floating crane, known as Svanen.

Svanen, shown in Figure 12, is a self-propelled C-shaped catamaran, approximately 99 m (325 ft) long, 72 m (236 ft) wide, and 100 m (330 ft) tall. It uses a computer-controlled, eight-point mooring system for positioning itself. Svanen was first used in 1990 for construction of the Store Baelt Bridge in Denmark and has been modified to handle the larger pieces of the NSCP bridge. When positioning bridge members, the two legs of the C straddle a pier location. Final positioning of the bridge components is determined using a global positioning system that is based on satellite information.

The construction schedule is predicated on erecting one complete span per week over two construction seasons. This translates into less than one piece per day to be floated out from the casting yard and erected. It is anticipated that each piece can be moved from the casting yard and erected in a 12-hour shift.

The foundations for the approach spans on both sides are located in shallow water that cannot be accessed by Svanen, so the pier foundations are constructed using more conventional methods. Spread footings are used on the Prince Edward Island approaches; the New Brunswick approaches use piles drilled into the rock. Precast box pier shaft elements are used on top of the cast-in-place ice shield. These are post-tensioned vertically. The superstructure for the approach spans is constructed using the conventional balanced-cantilever method with a launching truss. Components for the approach spans are fabricated in a precasting plant in New Brunswick.

After the structure is complete, a continuous concrete guard rail will be cast in place and a waterproofing membrane and asphalt-wearing surface will be laid to protect the upper surface of the deck. Roadway lighting, emergency telephone system, closed-circuit bridge television system, navigation lights, and changeable message signs will be installed.

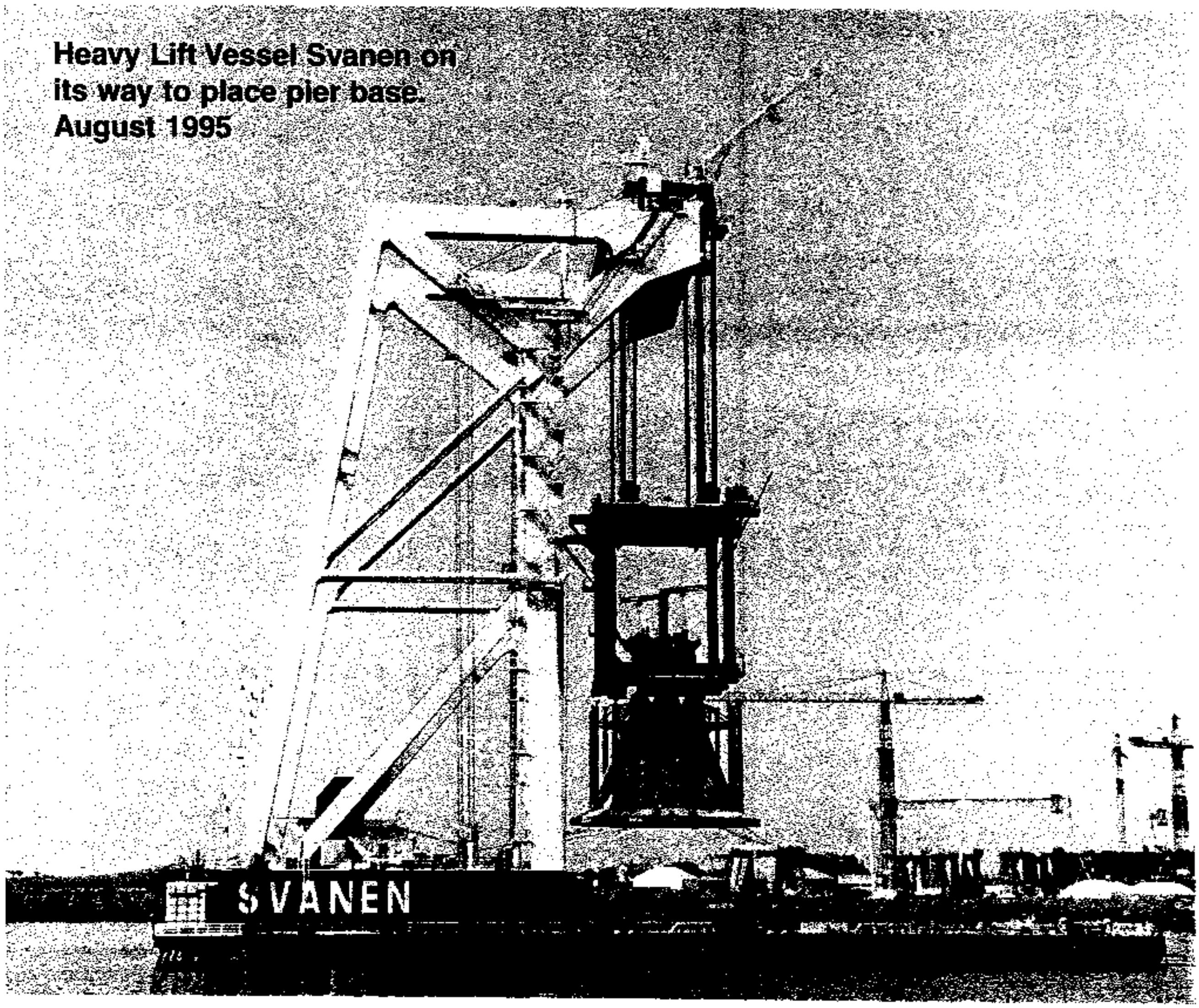

Figure 12: Svanen

4.3 Materials Technology

Originally, epoxy-coated reinforcement and concrete with a specified strength of 45 MPa (6,500 psi) were to be used. Later, the epoxy-coated reinforcement was deleted in favor of additional concrete cover, a more impermeable concrete with a compressive strength of 55 MPa (8,000 psi) and the potential to add cathodic protection. The specified concrete cover is 50 mm (2 in) for the deck and inside superstructure and 75 mm to 100 mm (3 in to 4 in) for the substructure. The concrete cover was selected to ensure that chlorides would not penetrate to the depth of the reinforcement and was based on results of diffusion tests extrapolated for the 100-year life of the structure.

The mix proportions and properties of the concrete are given in Table 1. The concrete mix contains silica fume and fly ash. Cement blended with silica fume is supplied as a single product in Canada. This type of cement is also used in the grout material for corrosion protection of the prestressing steel. Silica fume has the advantage of increasing the early strengths, and fly ash is beneficial in increasing the long-term strengths and reducing the heat of hydration. Both silica fume and fly ash aid in reducing the concrete permeability. Chemical admixtures from a single manufacturer are also used. The goal is to provide a durable concrete to survive the 100-year design life. Based on freeze-thaw tests, the Université de Sherbrooke concluded that an average air content of 5 percent to 5.3 percent would ensure that the concrete would successfully resist 500 freeze-thaw cycles when tested in accordance with ASTM C 666 Procedure A.

Extensive testing and placement trials were conducted before placement of the high-performance concrete. These included about 40,000 m^3 (52,000 yd^3) of concrete used in construction of the precasting plant on Prince Edward Island, which provided a long learning curve for concrete production before producing the major components. During the visit, production of concrete with a compressive strength of 55 MPa (8,000 psi) seemed to be a routine process.

In the initial pier shafts, the ice shield was protected by a 10-mm (3/8-in) thick mild steel sheet. In the more recently produced pier shafts, the steel is omitted and the ice shield is being built with a concrete having a specified compressive strength of 80 MPa (11,600 psi). Mix proportions and properties for the ice shield concrete are given in Table 1. Abrasion tests conducted according to ASTM C 779 Method C showed significantly less depth of wear for 80 MPa (11,600 psi) concrete compared with 70 MPa (10,000 psi) concrete. The concrete ice shield will provide an economical solution and remove any doubts about the surface condition of the concrete under the steel.

Quality assurance and quality control are the responsibility of the contractor on this project. The independent engineer monitors the quality assurance/quality control program, while the Engineer of Record receives all data to verify that the procedures are being followed. The independent engineer has the authority to exclude payments for nonconforming construction in the drawdown from the trust fund.

All concrete is batched on site at either the Prince Edward Island or New Brunswick plant. For quality control, six 100 × 200-mm (4 × 8-in) cylinders are taken for every 100 m^3 (131 yd^3) of concrete. The cylinders are

Table 1: Concrete Mix Proportions and Properties

Concrete Mix	55 MPa	8,000 psi	80 MPa	11,600 psi
Specified Strength				
28 days	50 MPa	7,250 psi	—	—
91 days	60 MPa	8,700 psi	80 MPa	11,600 psi
Quantities	per m^3	per yd^3	per m^3	per yd^3
Cement[(1)]	430 kg	725 lb	520 kg	876 lb
Fly ash (Type F)	45 kg	76 lb	60 kg	101 lb
Sand	705 kg	1,188 lb	570 kg	960 lb
Coarse aggregate (20 mm max)	1,030 kg	1,736 lb	1,100 kg	1,854 lb
Water	145 kg	244 lb	142 kg	239 lb
Air entrainment	AR[(2)]	AR[(2)]	AR[(2)]	AR[(2)]
Water reducer	1.8 l	47 fl oz	1.6 l	41 fl oz
Retarder	—	—	1.0 l	26 fl oz
High-range water reducer	1.2 l	83 fl oz	5.0 l	129 fl oz
Concrete Properties				
Water-cementitious ratio	0.305	0.305	0.245	0.245
Slump	140–220 mm	5.5–8.5 in	140–220 mm	5.5–8.5 in
Unit weight	2.36 Mg/m^3	147 lb/yd^3	2.39 Mg/m^3	149 lb/yd^3
Air content	5–8 %	5–8 %	4.5–5.5 %	4.5–5.5 %
28-day strength[(3)]	59.5 MPa	8,630 psi	—	—
91-day strength[(3)]	64.7 MPa	9,385 psi	81.3 MPa	11,790 psi

(1) Low alkali silica fume cement.
(2) As required.
(3) Average strengths through February 2, 1996.

(4 × 8-in) cylinders are taken for every 100 m^3 (131 yd^3) of concrete. The cylinders are cast in rigid plastic or steel molds and are used for determining compressive strength as follows: one at 24 hours, one at 7 days, two at 28 days, one at 91 days, and one extra.

Acceptance of the concrete is generally based on 28-day strengths. For tests at days one and seven, the cylinders are capped with a high-strength capping compound. For tests at days 28 and 91, end grinding is utilized, and, in some cases, tests are made at 120 days. They are tested in a 1.33 MN (300,000 lb) capacity testing machine. Before the 100 × 200-mm (4 × 8-in) cylinders are used, correlation tests are made with

150 × 300-mm (6 × 12-in) cylinders. Air content is determined for every 100 m^3 (131 yd^3) of concrete.

A concrete compressive strength of 30 MPa (4,350 psi) is required prior to stripping formwork and post-tensioning. In general, the concrete is moist-cured followed by membrane curing compounds. In cold weather, the enclosures of some casting areas are heated.

Despite the large-scale production of high-performance concrete, there do not appear to be any special quality control procedures taken beyond those that would normally be performed on a large construction project. All technicians are certified according to the Canadian Standards Association.

At the time of the visit, a bridge instrumentation program was being developed to monitor performance for the next 20 years. It is anticipated that the program will monitor ice forces, wind loads, traffic loads, corrosion, temperatures, deformations, and vibrations. In addition, ice scour and currents in the Strait will be monitored. The instrumentation is expected to be installed in 1996.

5. ENVIRONMENTAL ISSUES

Environmental assessment began during the feasibility studies authorized by in 1986 and have included preparation of a Generic Initial Environmental Evaluation and project specific Environmental Evaluations. More than 70 baseline environmental studies have examined agriculture, fisheries, biological factors, tides and currents, ice, ice scour, erosion, water quality, heritage resources, social impacts, microclimate effects, and global warming. These studies cost over $C15 million and involved substantial public review. They resulted in specific design criteria such as minimum dredging, maximum fabrication of bridge components on land, minimum concrete placement over water, minimum delay for ice-out, a fisheries compensation plan, and less than 10 percent physical blockage of the Strait. These environmental criteria were incorporated into the project requirements and eventually became part of the development agreement.

5.1 Environmental Management Plan

In addition to the environmental studies by Public Works Canada, the developer was required to prepare an Environmental Management Plan (EMP) for the management of all environmental aspects of the proposed project. The EMP had to be accepted by the Environmental Committee, and the developer had to receive environmental assessment approval for the project from the Provinces of Prince Edward Island and New Brunswick before signing a contract. The Environment Committee included representatives of Federal and provincial regulatory authorities including Public Works Canada, Fisheries and Oceans Canada, Transport Canada (Canadian Coast Guard), Environment Canada, and the New Brunswick, Prince Edward Island, and Nova Scotia Departments of the Environment.

A draft EMP was released for public review in December 1992. Public meetings were then held with an estimated total attendance of more than 3,700 people. The developer also met with about 2,000 people associated with special interest groups. People were able to submit comments via a toll-free telephone number or in writing. The Environmental Committee reviewed the draft EMP concurrently with public review. A revised EMP incorporating as many as possible of the suggestions and input from the public and Environmental Committee was submitted in February 1993.

The Environmental Management Plan is intended to be a dynamic life-of-the-project document that will evolve and be updated to meet the changing needs of the project as it proceeds through the preconstruction, construction, and operational phases. The developer will be responsible for implementing the plan throughout the construction period and the subsequent 35 years that the developer will own and operate the bridge. After that time, responsibility for environmental management and protection will be transferred to the Government.

The major components of the EMP are

- Environment Protection Plans (EPP).
- Contingency and Emergency Response Plans (CERP).
- Environmental Effects Monitoring Programs (EEMP).

The Environmental Protection Plans are descriptions of measures and practices designed to prevent or minimize any adverse effects of the construction or operation of the project on the natural environment.

The Contingency and Emergency Response Plans are measures to be taken in case of an accidental event arising from the construction or operation of the project that could have significant adverse effects on the natural environment.

The Environmental Effects Monitoring Programs involve collection of environmental data over time to detect any changes in the natural environment during the construction and operation of the project. The programs address both marine and terrestrial effects.

Because the EMP was developed before the agreement was signed, the developer adopted a phased approach to development of the EPP. A generic EPP was included as part of the initial EMP, and stage-specific EPPs have been developed as the project proceeds. This is necessary because, before award of the contract, not all design and construction details were available. The generic environmental protection plan identified procedures to mitigate potential impacts on terrain, vegetation, wildlife, freshwater and saltwater habitats and resources, heritage resources, and resource use areas. Standard environmental protection procedures were described for

- Vegetation clearing.
- Grubbing and disposal of related debris.
- Cutting and filling for roads.
- Stream crossings.
- Blasting.
- Infrastructure construction.
- Borrow pits and quarrying.
- Aggregate processing, handling, and storage.
- Infilling.
- Dredging and disposal of dredge spoil.
- Dewatering.
- Drilling on land.
- Drilling in the Strait.
- Solid waste disposal.
- Concrete production.
- Sewage disposal.
- Storage, handling, and disposal of petroleum oils and lubricants.
- Hazardous materials storage, handling, and disposal.
- Equipment movement on land.
- Vessel movement in the Strait.

All NSCP construction workers receive training about environmental issues and the EPP procedures affecting their jobs. The contingency plans address such unplanned events as fuel spills, fires, wildlife encounters, and the discovery of heritage resources.

The EEMP verifies the impact predictions, evaluates the effectiveness of mitigation measures, design of the monitoring programs, and calls for evaluation of results by a multi-disciplinary advisory committee. Factors that are routinely monitored include the following:

- Terrestrial wildlife in nearby wildlife areas or marshes.
- Ocean currents, tides, and sediment modeling.
- Fisheries resources.
- Ice climate and effects of ice scouring.
- Endangered or threatened species.
- Heritage resources.
- Freshwater resources potentially affected by the project.

All data are stored in a computerized geographic information system so that comparisons can be made between existing and preconstruction conditions or between various time periods during construction. The EEMP is updated annually through committee and public input.

The developer received the 1994 Environment Achievement Award from the Canadian Construction Association for the far-reaching and exhaustive management of the project.

5.2 Ice in the Strait

From the beginning of the project, there had been concern regarding the potential impact of the crossing on the ice floe in the Strait. These concerns focused primarily on the concept that a fixed crossing might delay the final clearance of ice from the Strait in the spring, referred to as "ice-out." It was considered that a delay in ice-out could, in turn, delay the start of the fishing season. Similarly, the presence of ice could reduce local temperatures so that the spring planting of crops also could be delayed.

In recognition of public concern, an environmental review was initiated under the Canadian Federal Environmental Assessment and Review Process. A six-member panel was appointed and the review took place from May 1989 to August 1990. The main concern identified in the panel's report was the potential maximum delay in ice-out in the Strait caused by the bridge. Through their consultants, Public Works Canada identified a conservative worst-case scenario of up to a 2-week delay in ice-out. The panel deemed this to be unacceptable and suggested that an acceptable ice-out delay criteria would be a maximum of 2 days in any year over a period of 100 years. The panel added that it would be desirable for any future modeling results to be inde-pendently corroborated against quantitative field observations and that any further analysis on ice climate address the panel's specific concerns on the ice model.

To assess whether a 2-day maximum delay was feasible and to direct the development of assessment tools for compliance, the Government appointed an independent ice committee. The committee was to review the existing ice-jamming model, assess its validity, and recommend improvements. The committee was also asked to assess whether generic bridge designs could meet the specified ice-out delay criteria.

During the course of its work, the ice committee recommended numerous improvements to the previously developed analytical model. In particular, the committee directed the development of a break-up model to address processes affecting ice-out in the Strait, which was calibrated and tested using historical data. A major finding in developing and testing the break-up model was that ice decay and underside melting play significant roles in the date of the ice-out, and these processes would not diminish due to the presence of the bridge. In fact, the underside-melting mechanism would be locally enhanced if the bridge caused ice movement to be slowed against tidal currents, thereby increasing the relative velocity between ice and water.

A series of generic bridge designs as well as the designs submitted by the three bidding finalists were analyzed. In all cases, the analyses indicated that a bridge could be built across the Strait with a very low risk of delaying ice-out by more than 2 days in any year during its 100-year lifetime. Specifically, analysis of the three designs showed delays ranging from one-half day to 1 day in a 100-year return period. The margin achieved in all designs was considered by the committee to be sufficient to cover inherent uncertainties and was typical of design factors used for environmental loads on structures.

The committee also concluded that the bridge will cause some additional ice blockage in the Strait and that, on average, this would be about 5 percent over the course of the winter. However, this small increase would not be sufficient to cause significant delays in ice-out. The report, which concluded that all three bridge designs submitted would meet the 2-day criteria with a comfortable margin, was issued in December 1991.

As a result of litigation in 1993, the project was subsequently delayed, during which time the developer modified the design and increased the span lengths. As a result of these two actions, the ice committee was asked to review the specific design in the context of the delay criteria and to review the potential impact of the bridge on landfast ice and ice scour.

On the basis of the specific design, a 100-year delay of 0.4 days was predicted. This was, however, subject to a scatter of ±20 percent in terms of the number of simulations run. Hence, the delay could be as high as 0.5 days. The ice committee considered the margin achieved by this design over the 2-day criteria to be sufficient to cover inherent uncertainties in the modeling and input data.

Landfast ice exists, as the name implies, because attachment of the ice sheet to the land provides resistance against the forces of winds and currents that would normally move the ice through the Strait. The extent of landfast ice from the shore is dependent on the shape of the shoreline, the presence of shoals and rocks, and the presence of grounded ice. The ice committee found that the approach spans for the bridge are largely contained within the existing boundary of the landfast ice; therefore, the possibility of extending the landfast ice is limited. The first main span after the approach spans has a length of 165 m (525 ft). The committee indicated that there is a slight possibility that the landfast ice could extend across the first main span. If so, this would result in a landfast ice extension on the Prince Edward Island side of 165 m (525 ft) and of 300 m (984 ft) on the New Brunswick side. However, even if these extensions occurred, the overall effect on ice motion and ice delay in the Strait was considered insignificant by the committee.

Ice scour occurs when deep ice contacts the sea floor and is either pushed along by environmental forces or is driven into the sea floor by tidal variations or ice ridge building. The committee determined that ice scour of the sea floor already occurs in the Strait and that it is most common near the landfast ice edge at depths of 8 to 11 m (26 to 36 ft). In deeper water, ice scour is not possible with the thickness of ice usually encountered in the Strait. The ice committee concluded that the bridge is not expected to increase ice scour of the sea floor. In water depths greater than 8 to 11 m, any additional ice ridging and ice rubble buildup could not touch bottom. At the 8 to 11 m water-depths, the sea floor is already scoured, and, in less than 8 m of water, the ice will generally be landfast.

5.3 The Northumberland Strait Fishery

The Northumberland Strait Fishery is one of the most lucrative in Canada. Over the past decade, recorded landings for the entire Strait exceed $C60,000,000 per year, of which $C6,000,000 million is from the project area and fisheries compensation participants. This revenue comes primarily from lobster (74 percent), scallops, and herring, though a few individuals generate income from smelt and other species. For purposes of building the bridge, a construction corridor was established across the Strait, and fishing in this corridor during construction is prohibited. Approximately 220 bona fide operators from communities in Prince Edward Island and New Brunswick fish in the construction corridor and waters immediately adjacent to it.

To compensate the operators for potential losses, a fisheries loss-of-access and interference compensation program was developed, which includes a compensation fund of C$10 million. This program was designed to minimize the negative social and economic effects caused by construction of the crossing. The compensation program, which is in effect only during bridge construction, has two main components—one for lobster compensation and one for other species. Under the lobster compensation program, most eligible operators may bank up to 50 traps for a payment of $C200 per trap. Compensation for other species involves cash payment based on a complex arrangement of factors. In a compensable season, eligible operators are paid $C3,000 for scallops, $C2,000 for herring, and a total of $C1,000 for all remaining species. Annual program costs are expected to be in the vicinity of $C1.7 million for an anticipated total project cost of just over $C5 million.

6. FINDINGS AND RECOMMENDATIONS

6.1 Findings

Based on this scanning tour and review of literature, the team offers the following observations:

- Feasibility of a privately funded fixed link between Prince Edward Island and New Brunswick started with three unsolicited proposals from the private sector.

- After 35 years, the Canadian Government will own the bridge without having provided any initial capital development funding.

- Annual costs to the Canadian Government for the first 35 years will be no more than the estimated annual cost to subsidize the ferry service that will be replaced by the bridge.

- Real cost to bridge users will become less as a result of the limitation on toll increases to 75 percent of inflation.

- Private development is feasible only because of the annual Government subsidy.

- Financing with bonds was feasible because of the guaranteed subsidy payments by the Canadian Government, independent of the project completion date and revenue from tolls.

- The selection process for a developer involved three stages. Stage I involved an Expression of Interest. In Stage II, developers had to show that they could meet the project requirements. Stage III involved submitting a financial package. By this process, quality was considered in Stages I and II before price in Stage III.

- Development and construction have proceeded with a spirit of cooperation and openness between the Canadian Government, the Provinces, and the developer. A strong teamwork spirit in seeking technical solutions appears to exist on the project. The key to success is the participation of project champions from the Canadian Government and SCDI.

- Design of the bridge was driven by the requirements to minimize the impact on ice in the Strait, prevent progressive collapse in the event of failure of one span, and provide a design life of 100 years.

- The construction method of prefabricating the bridge components was driven by the requirements for completion by a specific date, a limited construction season in the Strait, and the requirement to minimize the environmental impact.

- High-performance concrete is being used throughout the project with conventional quality-control procedures. The concrete mix design is determined more by durability requirements than structural strength.

- Quality control and quality assurance are the responsibility of the contractor. However, the developer is responsible for maintenance and operation of the bridge for 35 years and has an incentive to produce quality construction. The developer is required to turn the bridge over to the Government after 35 years in "like new" condition, which will require the implementation of a comprehensive maintenance program.

- The role of the Canadian Government is to monitor the project and to make sure the developer meets the project requirements. The Government has no direct responsibility for quality assurance, quality control, or payments.

- The role of the independent engineer (IE) in reviewing the design, ensuring conformance with the project requirements, and authorizing drawdowns is similar to that of a State DOT resident engineer. (The role of the IE differs from that of a State DOT resident engineer in that the IE does not perform quality assurance—the IE only monitors that it is being done properly and also calculates and withholds the cost to complete.)

- Environmental information was made available early in the project and to all parties, including the general public. This facilitated early establishment of performance standards for the project.

- Extensive public consultation was undertaken during the development process. Specific measures were taken to address the concerns of the islanders, environmentalists, the fishing industry, ferry workers, and farmers. This open communication and community involvement continues during construction.

- All parties agree that the development time could have been reduced if the environmental review had been based on the specific bridge design rather than several generic bridges.

6.2 Recommendations

In evaluating the information gleaned from the scanning review, questions arose regarding the applicability of NSCP development and construction practices in the United States, where there is little use of design/build at present. Many of the findings are applicable to design/build or design/build/operate concepts for bridge and roadway projects and should be considered by FHWA, the States, and other interested parties. Although these recommendations are based on a very large and unique project, some may also be applicable to smaller projects. Particular items that should be considered are the following:

- Adoption of innovative financing concepts that will be attractive to investors by providing a reasonable and safe financial return.

- Use of an annual subsidy to the developer in lieu of annual maintenance costs.

- Assignment of financial risk to the private sector.

- Partial reimbursement of proposal-preparation costs to unsuccessful bidders.

- Reducing the number of qualified developers based on meeting of defined project requirements prior to submittal of the financial proposals.

- Increased use of prefabricated components to reduce construction time and the impact on local traffic and businesses.

- Greater and more routine use of high-performance concrete to reduce component size, reduce initial cost, improve durability, and provide a longer service life.

- Assignment of quality assurance and quality control to the contractor, and built-in incentives and disincentives to ensure that the benefits and shortcomings accrue to the contractor.

- Utilization of an independent engineer with financial authority over those projects where an independent entity is vital to the success of the project and where adequate resources and levels of confidence are present for the independent engineer to perform effectively.

- Greater public involvement and information exchange throughout the life of projects including site tours of large projects.

- Early consideration of the environmental impact and management plans.

- FHWA and members of the scanning team should continue the information exchange by inviting key NSCP and PWGSC staff to professional and technical meetings and by informing other interested parties at meetings such as AASHTO and TRB.

- Federal Highway Administration should continue to monitor Northumberland Strait Crossing Project for financial and technical results.

7. ACKNOWLEDGMENTS

The review team wishes to thank the hosting organizations and their representatives for their gracious hospitality and for sharing their experience and time.

The scanning team acknowledges the cooperation and assistance provided by Public Works and Government Services of Canada, Strait Crossing Development, Inc., and the Provinces of Prince Edward Island, New Brunswick, and Nova Scotia. In particular, the presentations and information provided by Peter Sorensen, Jim A. Feltham, Randy B. Vallis, and Gordon DeWolf of the Northumberland Strait Crossing Project; Paul Giannelia, J. David Pirie, and Kevin M. Pytyck of Strait Crossing Development, Inc.; Gamil Tadros of Strait Crossing, Inc; Pierre-Claude Aitcin of Concrete Canada; and Peter G. Buckland and David E. Boyd of Buckland & Taylor, Ltd. were especially appreciated. The team also acknowledges the valuable special assistance of Douglas Smith for arranging the program and coordinating the visit.

Artwork and photographs were provided by Public Works and Government Services Canada and Strait Crossing Development, Inc. Photographs by Boily Photo, Summerside, Prince Edward Island, are used with permission.

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Special thanks to the Transportation Technology Evaluation Center (TTEC) at Loyola College in Maryland for coordinating the team, providing logistical support, and editing this publication.

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9. ACRONYMS

AASHTO	American Assoviation of State Highway and Transportation Officials
ACEC	American Consulting Engineers Council
AGC	Associated General Contractors of America
ARTBA	American Road and Transportation Builders Association
CERP	Contingency and Emergency Response Plan's
CPI	Consumer Price Index
DOT	Department of Transportation
EEMP	Environmental Effects Monitoring Programs
EMP	Environmental Management Plan
EPP	Environment Protection Plans
FEARO	Federal Environmental Assessment Review Office
FHWA	Federal Highway Administration
NSCP	Northumberland Strait Crossing Project
PWGSC	Public Works and Government Services Canada
SCDI	Strait Crossing Development, Inc.
SCJV	Strait Crossing Joint Venture
TRB	Transportation Research Board

10. PHOTOGRAPHS

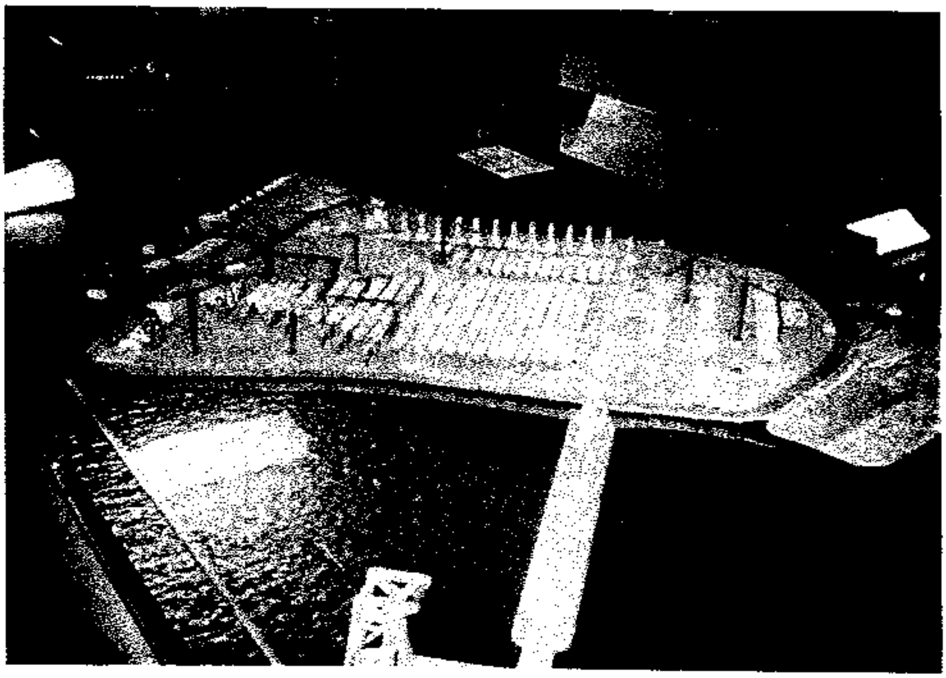

Photo 1: Model of Plant at Borden

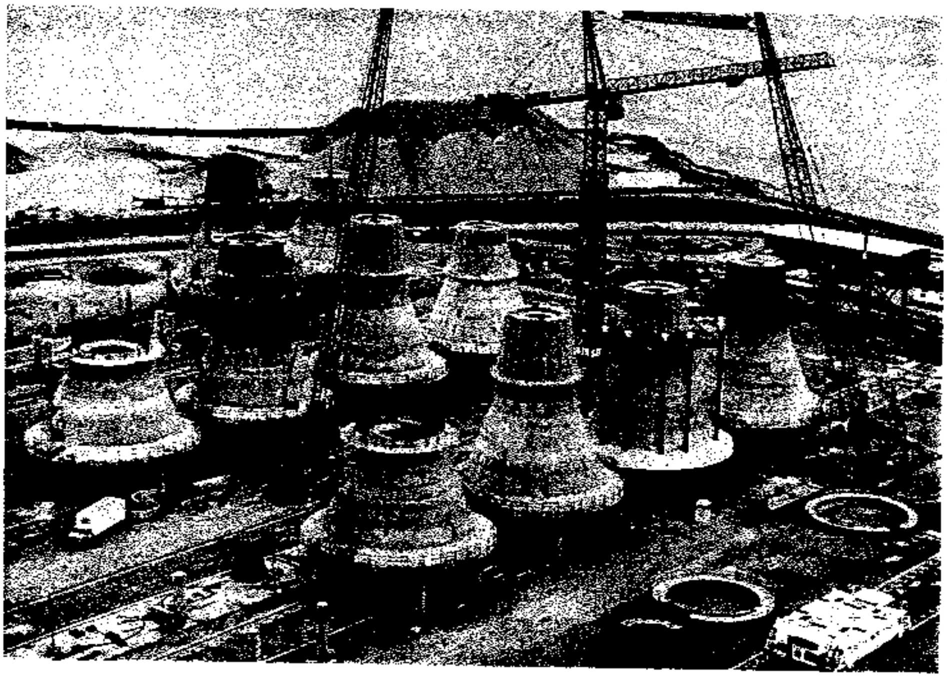
Photo by Boily

Photo 2: Pier Base Production Area

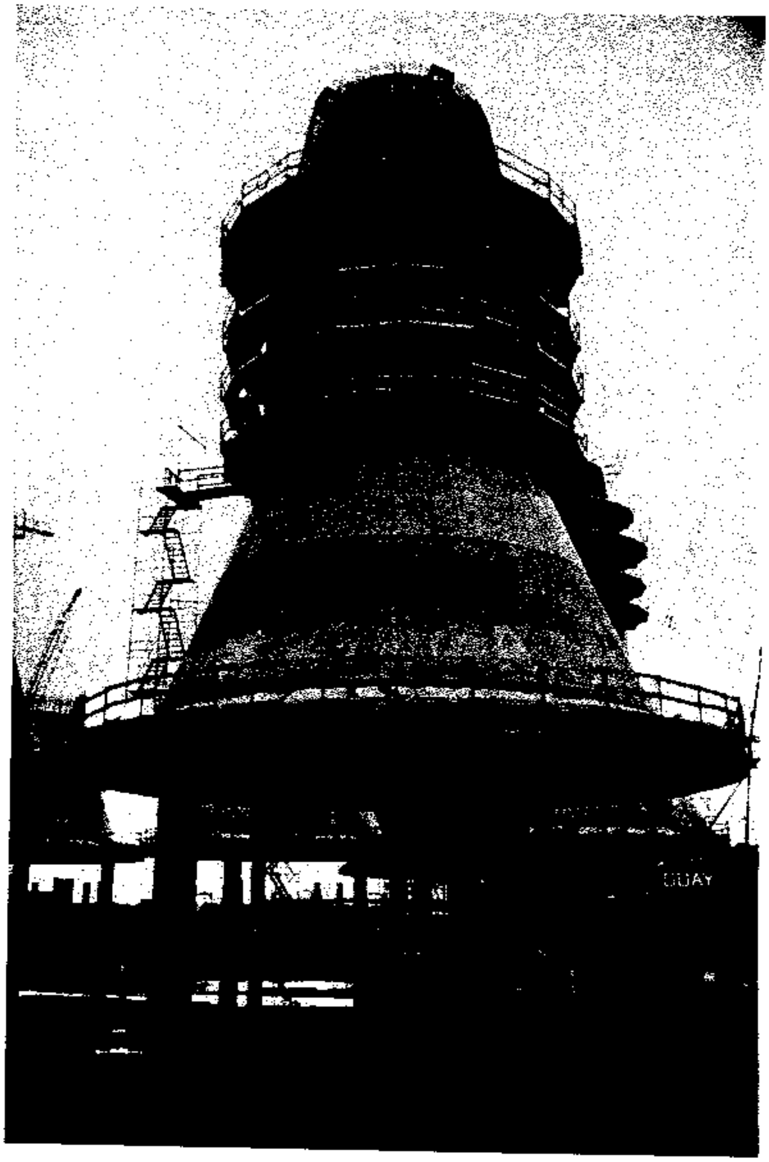

Photo 3: Construction of Pier Base

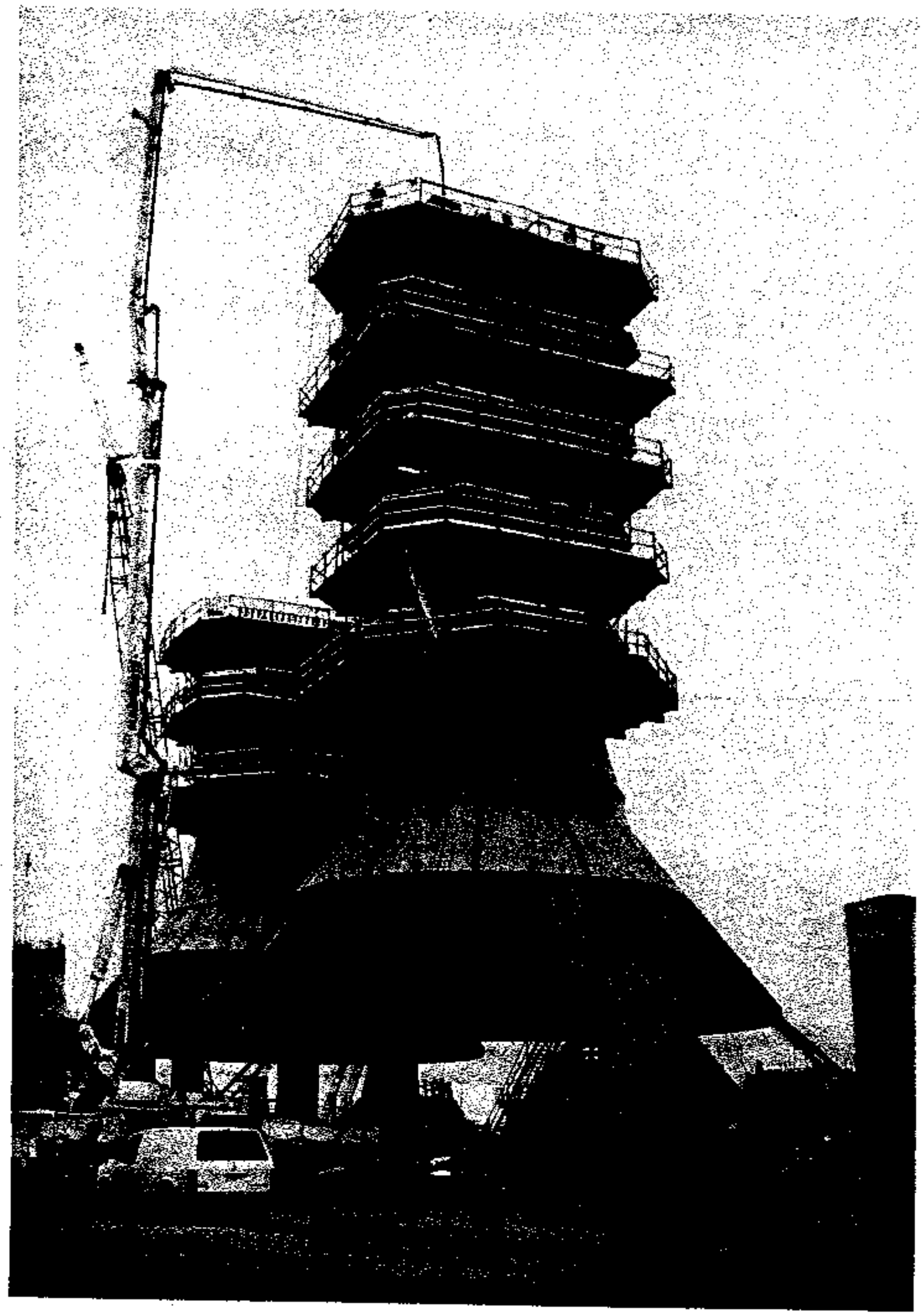

Photo 4: Construction of Pier Shafts

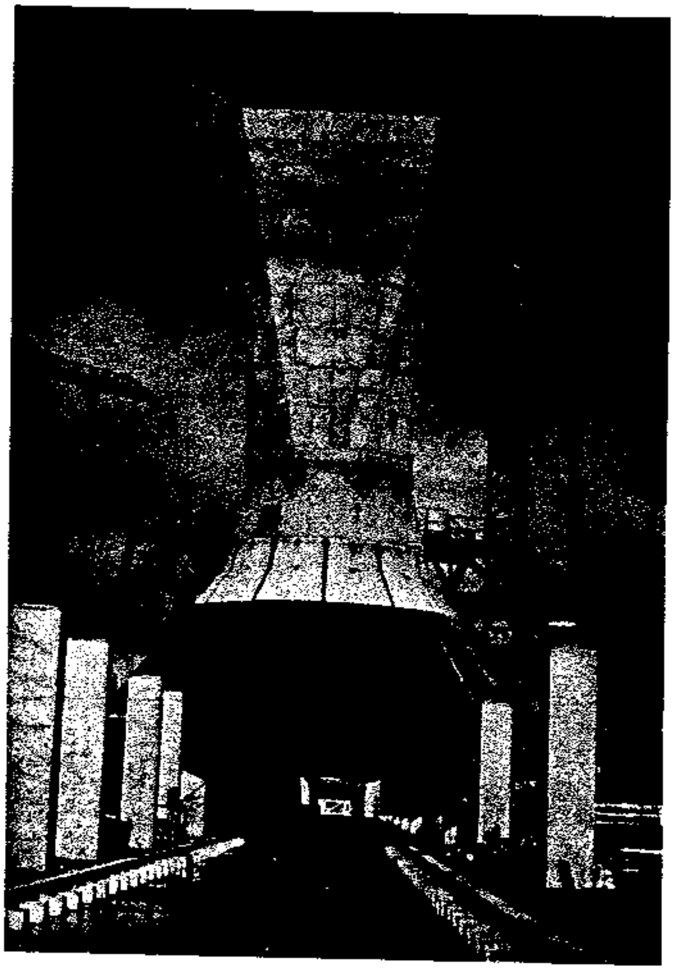

Photo 5: Completed Pier Shaft

Photo 6: Assembly of Reinforcement for Ice Shield

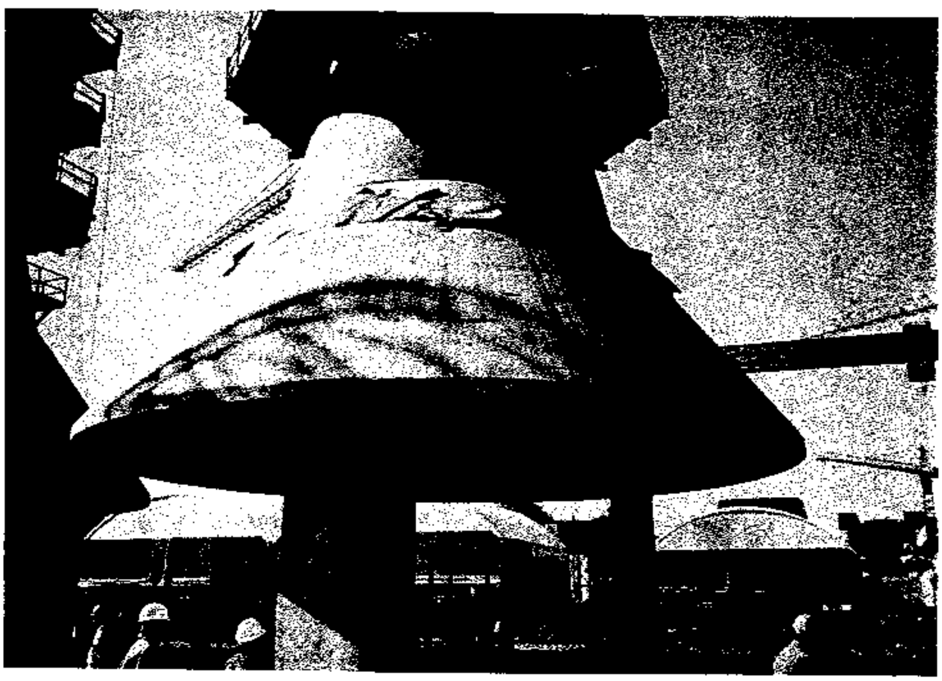

Photo 7: High-Performance Concrete Ice Shield

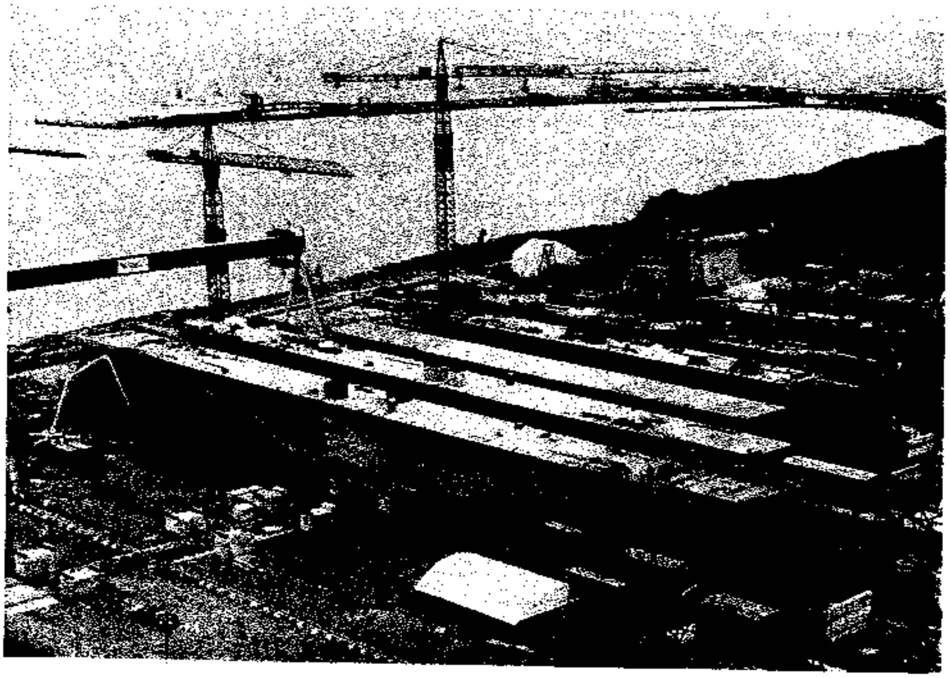

Photo by Boily

Photo 8: Main Girder Production Area

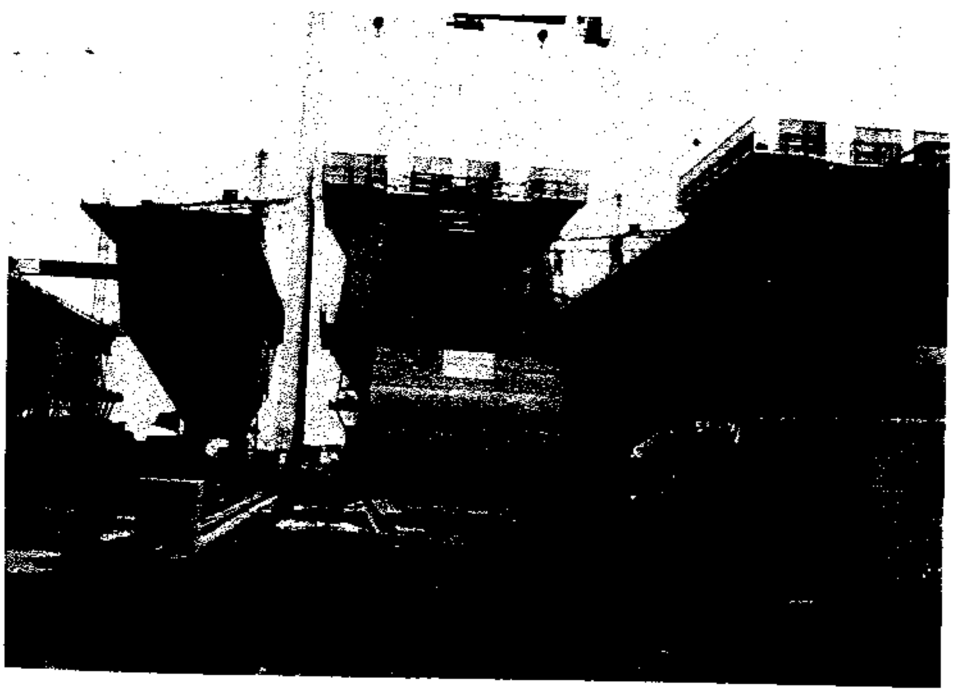

Photo 9: Main Girder Production

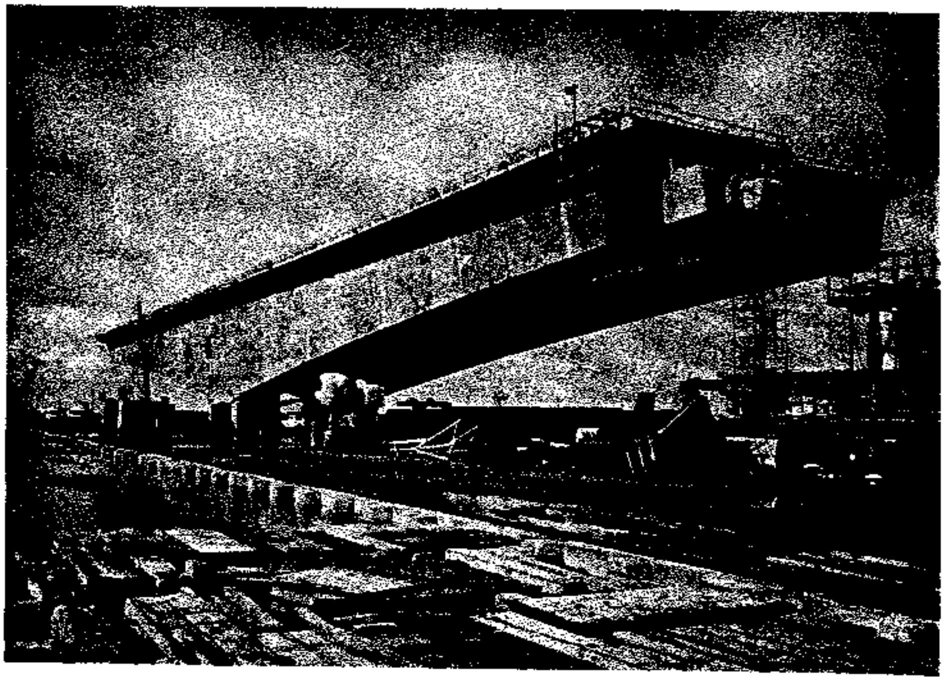

Photo 10: Completed Main Girders

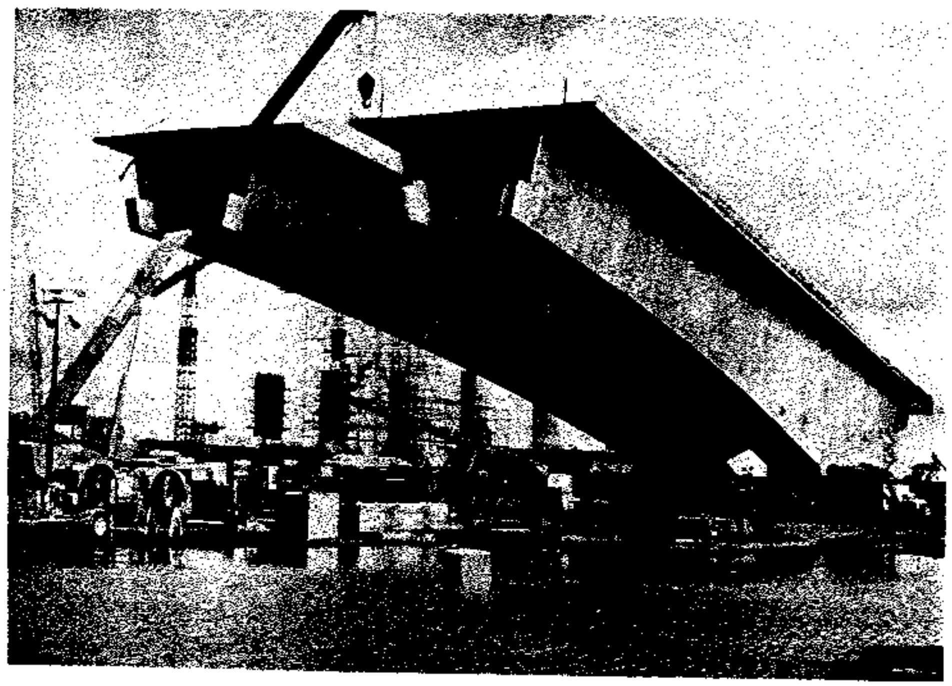

Photo 11: Completed Main Girders

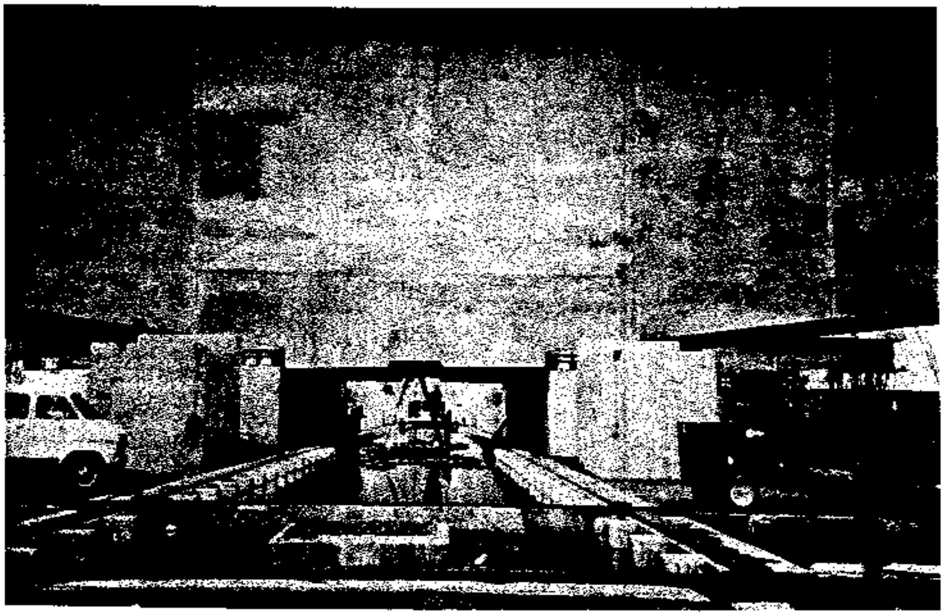

Photo 12: Main Girder Supports Showing Tracks for Moving Girder

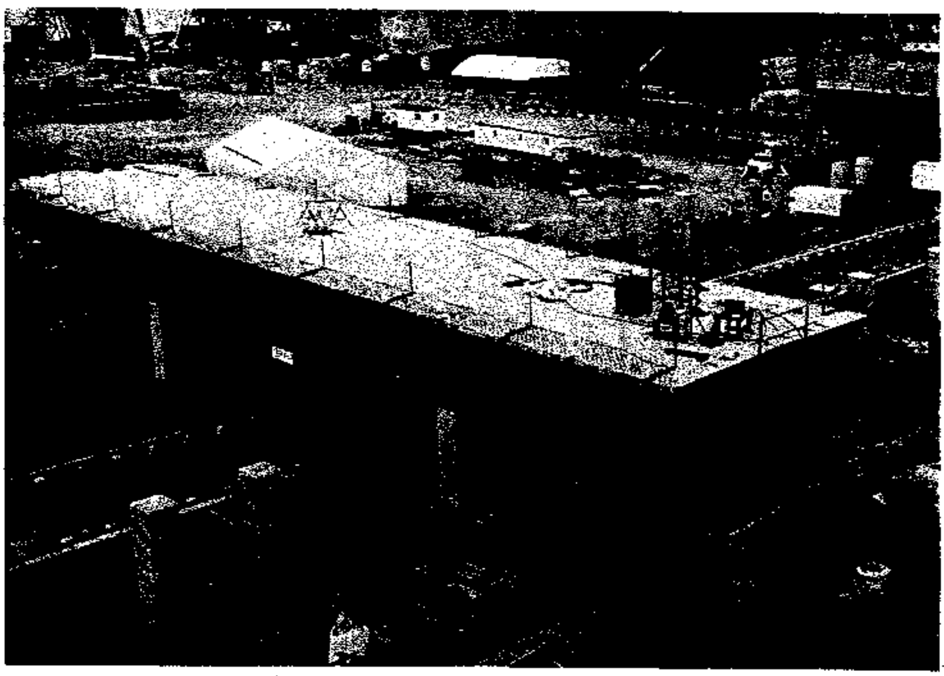

Photo by Boily

Photo 13: Drop-In Girder

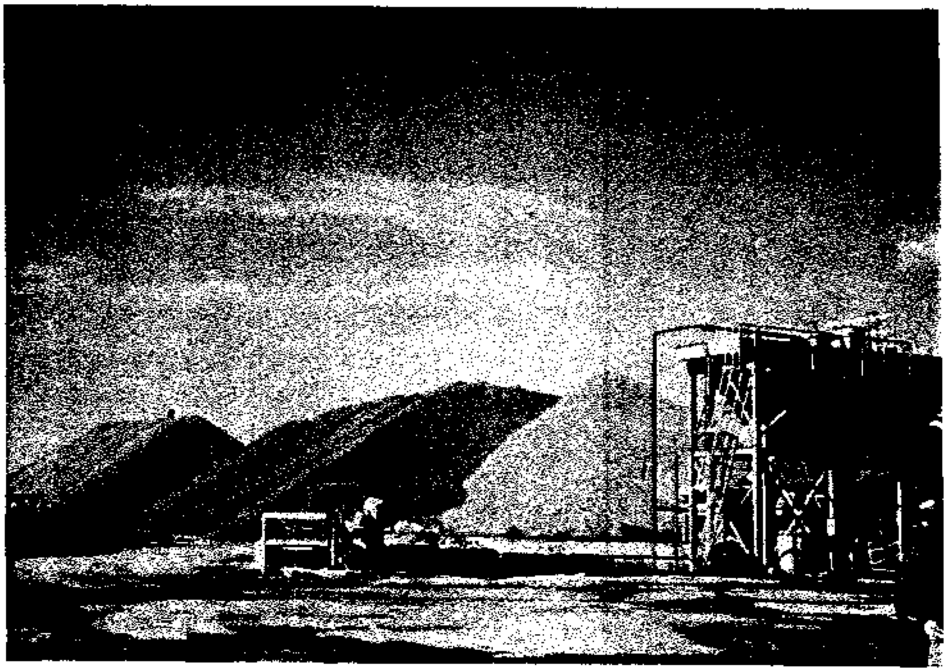

Photo 14: Aggregate Storage

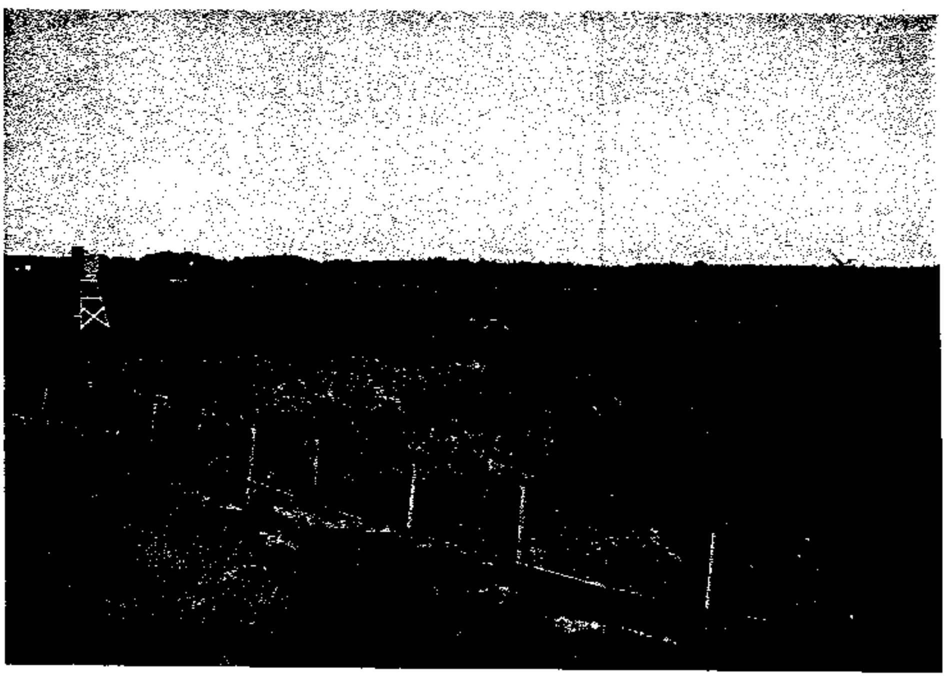

Photo 15: Protecting Wetlands with a Silt Fence

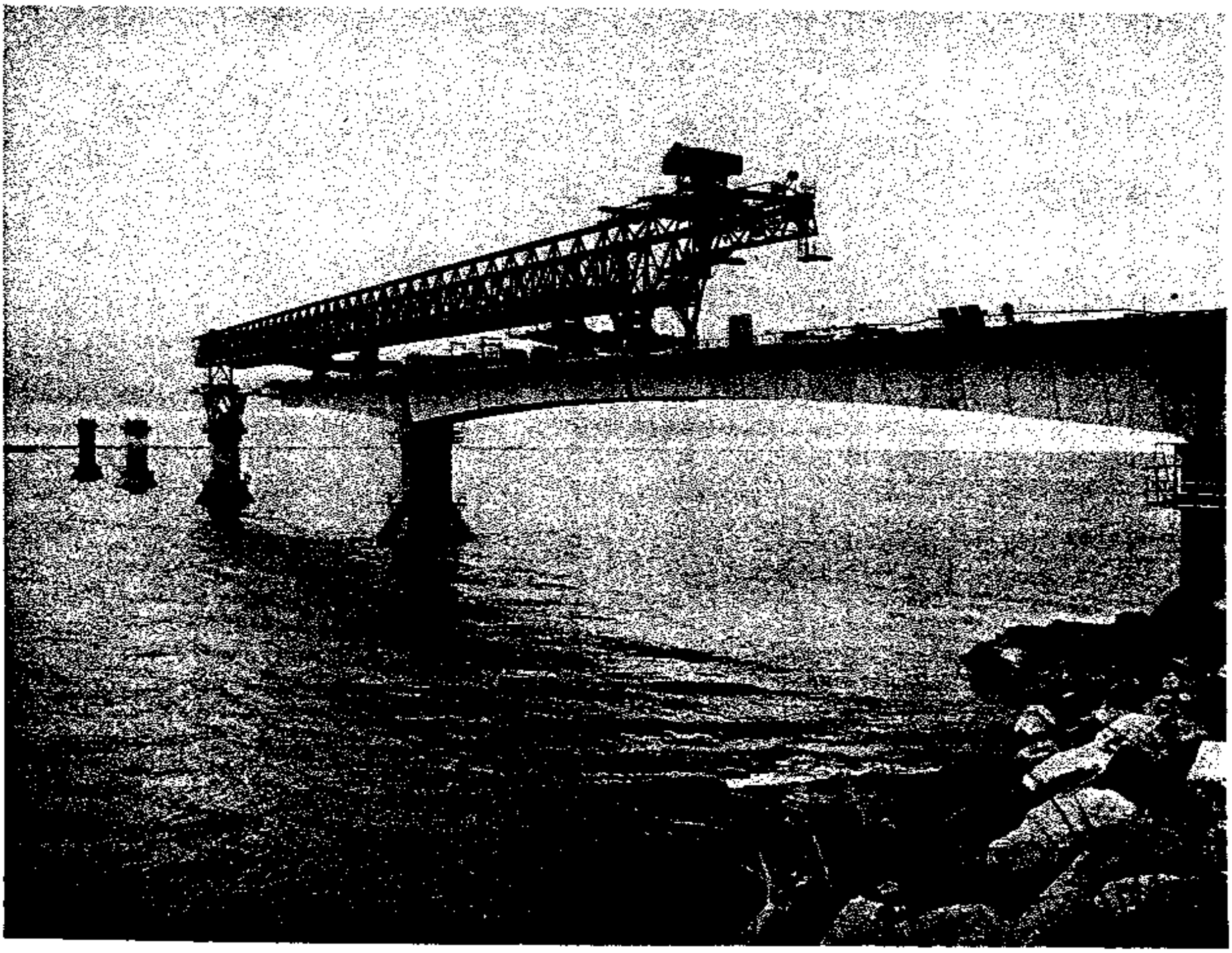

Photo by Boily

Photo 16: Constructing the Prince Edward Island Approach Spans

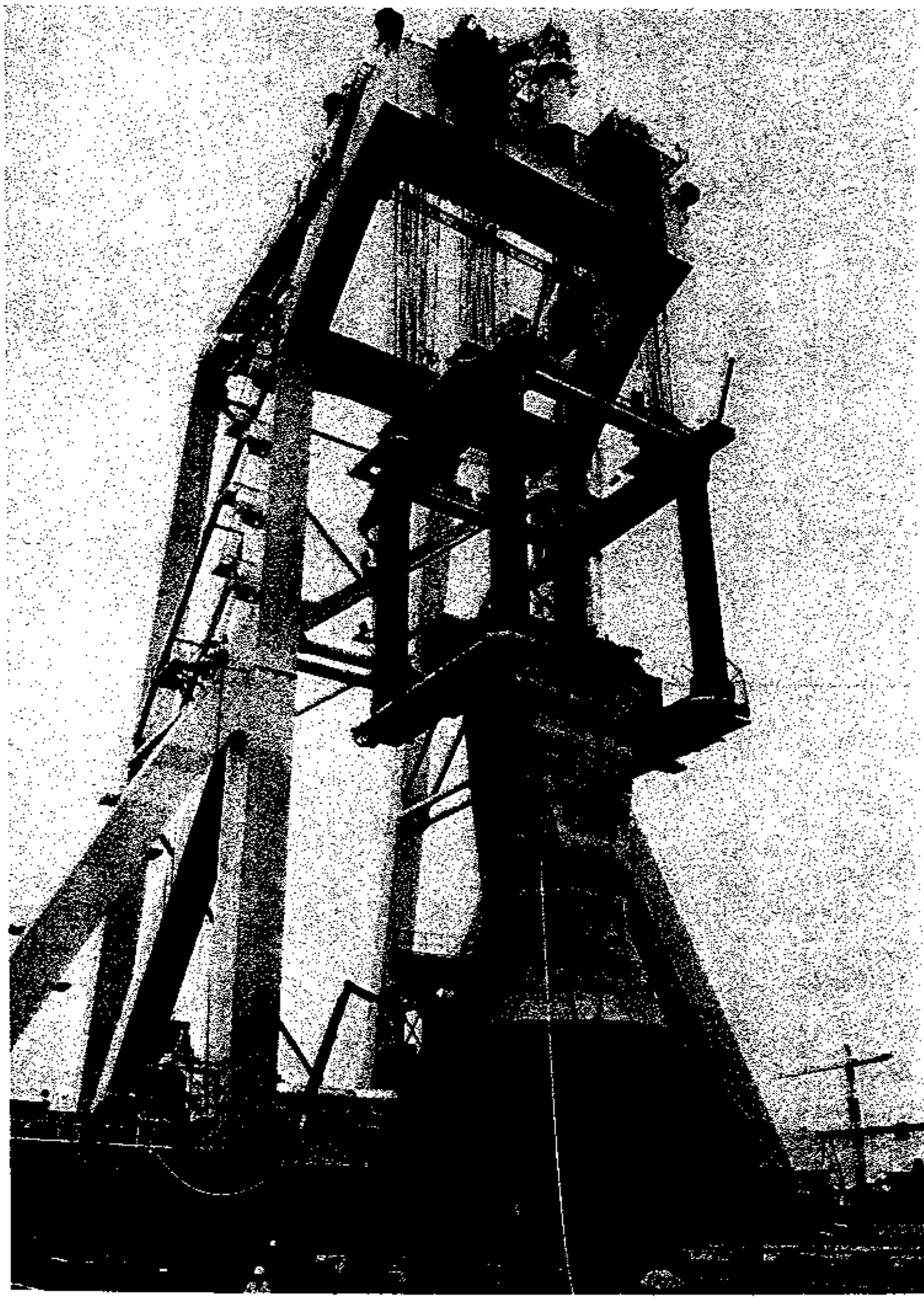

Photo by Boily

Photo 17: Svanen Lifting a Pier Shaft

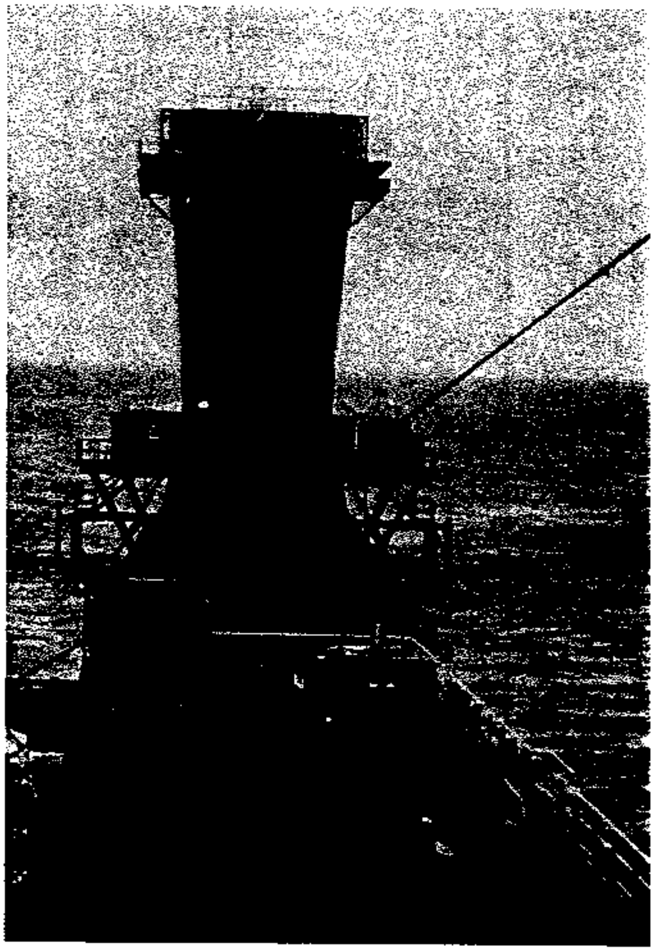

Photo 18: Pier Shaft in the Strait

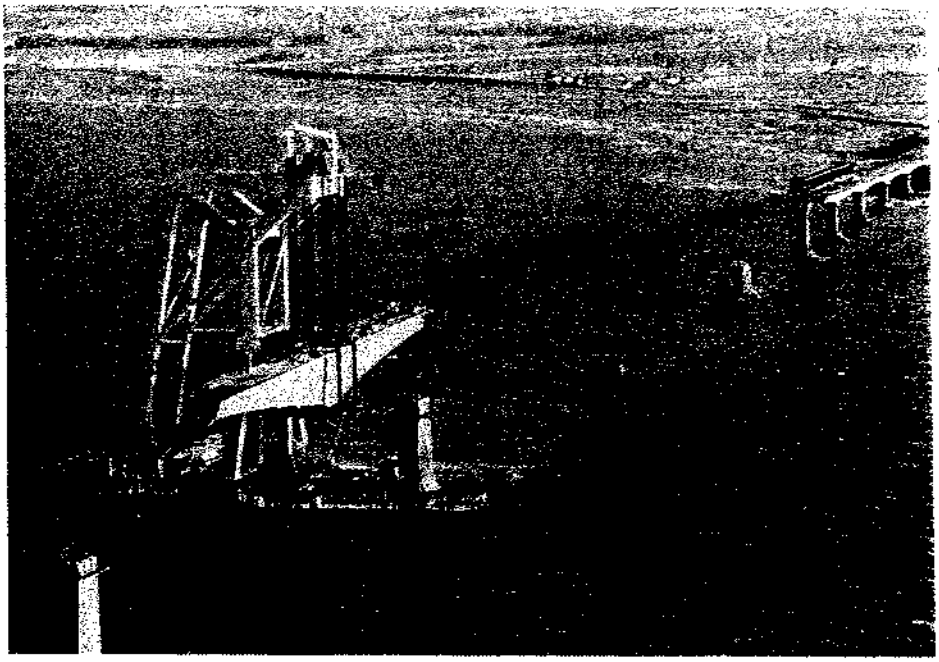

Photo 19: Svanen Placing a Main Span Girder