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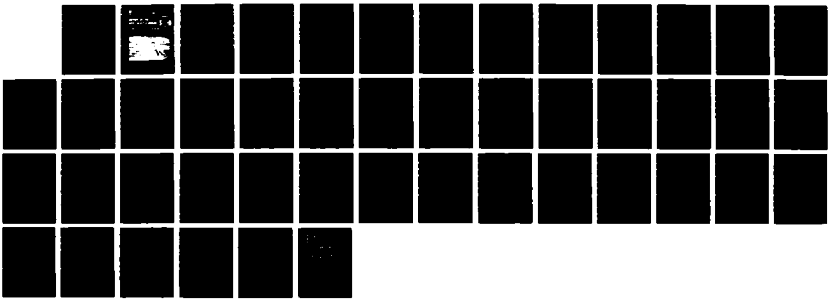

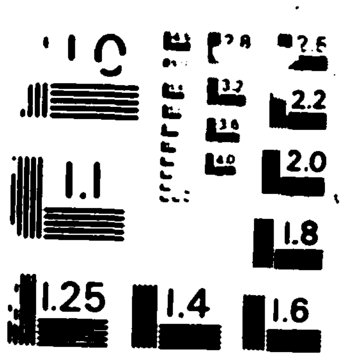
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US Army Corps
of Engineers
Seattle District

HISTORY OF THE WEST SEATTLE BRIDGE

A Unique Alliance in Construction Management

JANUARY 1988

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A history of construction of the West Seattle Bridge project is presented, particularly the cooperative liaison of the Corps of Engineers as construction managers with the City of Seattle. Includes incidents leading to the need for the bridge, funding efforts, design considerations, and lessons learned.

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History of the
West Seattle Bridge

A Unique Alliance in Construction Management

January 1988

FOREWORD

A modern high-level six-lane freeway bridge exists today in Seattle, thanks in part to a unique alliance between the Corps of Engineers and the City of Seattle during construction of the bridge. Commanding a spectacular view of Elliott Bay and the downtown skyline, it provides access between the West Seattle community and major highways. A history of this bridge, including incidents leading to its construction, funding efforts, design considerations, and particularly the Corps of Engineers involvement as the construction managers and lessons that were learned, are presented in this report.

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Chapter 1

FUNDING

OVERVIEW

The Duwamish Waterway in Seattle flows generally south to north, forking at Harbor Island before it empties into the south end of Elliott Bay. Located at the mouth of the Duwamish River, this industrialized shipping channel provides access for vessels as far as 5 miles upstream and is also the site of the Spokane Street crossing, the main arterial linking West Seattle with the rest of the city to the east. Until 1978, twin double-bascule bridges at the Spokane Steet crossing provided eight lanes for vehicle traffic across the waterway and allowed a 150-foot-wide channel for vessels. Today, only one of those twin bridges remains, the other one a victim of a shipping mishap. But the site of the mishap and the remaining riveted-construction bridge now sits in the shadow of a new high-level concrete bridge spanning 141 feet above the waterway and more than 100 feet above the old bridge.

EARLIER STUDIES

The Duwamish Waterway has been the subject of Corps of Engineers studies and improvements dating back to 1919. The most recent Duwamish Waterway study, authorized in 1956, led to the identification of navigational improvements needed for the waterway. These improvements included widening of the channel and, to accommodate the channel improvements and improve traffic flow, replacement of the two low-level vehicular bridges and a single low-level railroad drawbridge nearby. To replace the low-level vehicle bridges, the City of Seattle contracted a design of two four-lane, cable-stayed, high-level bridges. The new bridges were to be aligned just south of the two low-level vehicle bridges.

This design was put out for construction bids in the early 1970's. According to the engineer's estimates, funding available at that time was sufficient to cover construction costs. But high inflation and escalating construction costs created a volatile bidding environment for contractors. Taking into consideration the toll these factors could take on profit margins, especially over the course of multi-year contracts, contractor bids (the lowest being $52.7 million) far exceeded the engineer's estimate of construction cost ($32.7 million) and available funding ceilings. The result was total bid rejection. Corps studies were indefinitely delayed while the bridge project awaited appropriation of additional funding or a more favorable economy for construction. The need for a new bridge was not sufficient to justify the expense, especially with the existing bascules intact and functioning adequately.

The balance between need versus expense tipped drastically in the early morning hours of June 11, 1978. Unable to negotiate the slim opening between the upraised north bascules, the "Antonio Chavez", a 12,000 ton ocean-going freighter of Panamanian registry, fully loaded with gypsum and heading upriver to unload, slammed into the east support pier at 2:53 a.m. The ramming destroyed the pier and caused extensive damage to the superstructure and substructure of the north bascule's east span. Eighty-year old Cpt. Rolf Neslund, piloting the ship during the mishap, was heard to lament just prior to impact, "My God, my wife's going to kill me." Shortly after the incident, which led to the loss of his piloting license, Cpt. Neslund disappeared. Ruth Neslund was convicted in 1987 of killing her husband in a sensational local trial case which alleged she disposed of Cpt. Neslund's body by separating it into small pieces and burning them in her backyard barbeque pit.

The damaged span was never lowered again. In a classic example of recycling, the old bridge was dismantled and taken to the Bethlehem Steel plant in West Seattle where it was melted down and reformed into rebar which was used in the new bridge. The unfortunate luck of Cpt. Neslund and the "Chavez" created a unique opportunity for Seattle to realize a solution to the lingering Spokane Street corridor problems.

SECURING FUNDING

Dedicated in July 1984 the West Seattle Bridge exists as a high-level span today principally due to the influence of Senator Warren G. Magnuson, Chairman of the Senate Appropriations Committee, and the efforts of Jeanette Williams, Chairperson of the City Transportation Committee and the City Council representative from West Seattle to the Seattle City Council. Senator Magnuson was able to secure $110 million in federal funds, without which bridge replacement would not have been possible. Through the efforts of Ms. Williams, additional local funds were secured and commitment to a fixed high-level span was gained from the City Council.

Following the collision between the "Chavez" and the bridge, Seattle Deputy Mayor, Bob Royer, traveled to Washington, D.C. to lobby for federal funds. He met with Senator Magnuson and Secretary of Transportation, Brock Adams, and others to explore the possibilities. Seattle had a strong ally in Senator Magnuson, generally considered to be the most powerful man in the Senate at that time. Just four days after the collision, Senator Magnuson attached an amendment to a pending appropriations bill. Passage of the bill in August of 1978 secured $50 million to be made available in 1979 for the replacement bridge project. The funding was contingent on the damaged bridge being found technically or economically infeasible to repair. Although technically possible to repair the bridge, it was not difficult to make a case for economical infeasibility. The 1920's vintage structure had been deteriorating even prior to the collision and was in need of extensive rehabilitation beyond the estimated $8 million collision repairs. Also, construction of a new bridge was estimated to take only a year longer than the three years needed to repair the old bridge.

Senator Magnuson was also able to approach Secretary Adams (a former Washington State 7th District Representative) about the availability of Department of Transportation unappropriated funds. These funds were "discretionary", controlled by DOT and designed for use in emergency bridge repairs. The incapacitation of the Spokane Street Bridge cut the number of lanes crossing the Duwamish from eight to four. The Spokane Street corridor registered a volume of 70,000 vehicles per day, second highest of any roadway in the state. The accidents per mile in the corridor were three times the statewide average and bridge openings along with train crossings interrupted vehicular traffic flow 7,000 times a year. The situation met the criteria of an emergency, but so did innumerable other similar bridge situations across the country which were competing for the discretionary emergency funds. Senator Magnuson's influence had an impact: Secretary Adams allocated $60 million in unappropriated funds to help finance the replacement bridge project.

With $110 million of committed federal funds, Seattle was assured of a replacement bridge. Estimates for a new mid-level bridge came to $142 million. The mid-level bridge was seen as a compromise between cost and function. Designed to provide a 65-foot navigational clearance above the Duwamish when closed, a mid-level movable span would significantly reduce the number of bridge openings. Also a single mid-level span could service both Harbor Island and through traffic while allowing for widening of the channel by eventual removal of the two low-level bridges. Seattle City Mayor Charles Royer was in favor of this proposal. Besides the $110 million in federal money, the state had allocated $15 million from the Urban Arterial Board and the city had dedicated $17 million from their Forward Thrust Program. Mayor Royer wanted to proceed quickly rather than take the time to raise additional funds for a high-level fixed span with the possible risk of losing federal funds.

Estimates for a high-level bridge were $197 million, which included $25 million for an additional low-level bridge. The low-level bridge would be necessary to provide traffic access to Harbor Island industries, since access from a span providing 140 feet of navigational clearance was infeasible. Both the low- and high-level spans would accommodate channel widening from 150 feet to 250 feet once the existing bridges were removed. West Seattleites lobbied for the procurement of additional funds to build the high-level bridges as they considered it the only feasible permanent solution. Councilwoman Jeanette Williams became the champion of their cause.

For many years prior, the City had always found itself faced with funding replacement bridge construction on its own. The State, King County, and Port of Seattle had all declined financial aid to such projects. Ms. Williams' diligence in lobbying for a high-level bridge was rewarded by obtaining $10 million from King County and a matching $10 million from the Port of Seattle. The City also increased its contribution by $10 million. Funds on hand now totalled $172 million, enough to build the high-level span. Ms. Williams next approached the State House Transportation Committee for a special tax authorization to raise the $25 million to finish the project, including financing for the low-level companion to the high-level bridge. (See Table 1.) The state granted authorization to levee a 2 cent/gallon gasoline tax to raise construction funds.

With all funds procured to finance the high-level bridge, the Seattle City Council voted unanimously to adopt the project. Some opposition was expressed concerning the gasoline tax hike. To help negate the tax issue and begin high-level construction without further opposition, Ms. Williams proposed a phased construction plan. The tax would not be put into effect until the high-level span was complete and subsequent construction on the low-level bridge had begun.

One other incident threatened the realization of the project. Widespread changes in the Carter cabinet saw the removal of Brock Adams from his position as Secretary of Transportation. There was fear that the $60 million unappropriated funds might be withdrawn, effectively cancelling the project. Again, Senator Magnuson's influence and additional Seattle lobbying helped preserve the funding. The new Secretary, Ned Goldschmidt (former Mayor of Portland, Oregon) reaffirmed the dedication of the discretionary funds to the high-level bridge project. The opportunity created by the "Chavez" would be realized in the construction of the long awaited high-level bridge.

Table 1

SOURCES OF WEST SEATTLE FREEWAY
REPLACEMENT BRIDGE PROJECT FUNDS

SOURCE		AMOUNT (IN MILLIONS)
FEDERAL		
Appropriated (by bill amendment)		$ 50
Nonappropriated (DOT discretionary)		60
	SUBTOTAL	$110
NONFEDERAL		
City of Seattle (Forward Thrust Program)		$ 27
State of Washington (Urban Arterial Board)		15
King County		10
Port of Seattle		10
Special Tax Authorization		*25
	SUBTOTAL	$ 87
	GRAND TOTAL	$197

*Available for use when construction on new low-level bridge begins. Not yet levied as of 1 January 1988.

Chapter 2

CORPS OF ENGINEERS INVOLVEMENT

INTRODUCTION

The Corps of Engineers provided costruction management for the City of Seattle's West Seattle Bridge under an arrangement that established unique relationships between federal, state and municipal agencies. Senator Magnuson is generally credited with first proposing the Corps' involvement during deliberations over funding. Following the Senator's proposal, City of Seattle Councilwoman Jeanette Williams led the way in gaining the Corps' assistance. Her enthusiasm and the willingness of the Seattle District Engineer, Col. John Poteat, made the project management venture a reality. Together they were able to gain the support of others needed to authorize the Corps' involvement.

The construction management of the West Seattle Bridge Project would have to be considered a success by any measure. Regulatory requirements were met, opposition from several factions were overcome, and working relationships were developed. The multi-million dollar project was completed under budget, ahead of schedule and without lingering claims or public outcry.

DEVELOPMENT

The first request for the Corps' involvement came from Councilwoman Williams on March 22, 1979. Citing the Corps' experience and expertise in large construction projects, the substantial involvement of federal funds, and the Corps' knowledge of the process for expenditure of federal dollars, Williams sent a letter to Col. Poteat asking if the Corps would be interested in managing the bridge construction. Col. Poteat became very interested in the possibility of having the District manage the project. Not only was this a great opportunity for the professional development of District personnel, the project would fit well with manpower forecasts. The Chief Joseph Dam Resident office would soon be scaling down after the expansion contracts were finished. The residency staff from Chief Joseph could provide the bulk of the manpower required to staff a new resident office for the bridge project, precluding the possible necessity of laying off any District employees. The startup at the bridge would coincide with the scale-down at Chief Joseph Dam. Pointing to this benefit and the fact that the District was involved in improvement studies of the Duwamish Waterway, which were reactivated in October 1978, Col. Poteat requested permission from the Corps' North Pacific Division (NPD) to enter into negotiations with the City of Seattle.

While the request was channeled from the Corps' Seattle District to its Office of the Chief of Engineers (OCE), the District's Office of Council deliberated the requirements governing work by federal agencies for others. The main guideline was ER 1140-2-303, under the authority of Title II Intergovernmental Cooperation Act of 1968. The regulation spelled out certain criteria which would have to be met prior to the District providing any services. Most notable of these criteria were that the services be a regular continuing function of the office which provides them, that such services not require staff additions which would exceed employment ceilings, that the recipient pay for the direct and indirect costs of providing such services and, finally, that the services rendered must be unobtainable in a reasonable and expeditious fashion through ordinary business by the requestor. Most of these criteria would not be difficult to meet. The last criterion, addressing the unavailability of such services from the private sector, would create the most difficulty.

Approval to proceed with negotiations was quickly granted from OCE and NPD. Col. Poteat accepted Ms. Williams' offer to explore the possibilities on March 27, 1979.

Events were moving rapidly to involve the District as construction managers. Lt. Gen. Morris, then Chief of Engineers, received a letter from Senator Magnuson on March 28, 1978, expressing support for the City's request for management services and asking for a favorable response to the request. By the end of March, meetings between members of the City Council, City Engineering Office, and the Seattle District had taken place, discussing the potential role and relationship the District might assume in the construction management of the project. Discussions also covered future meetings which would need to include the State Highway Department and Federal Highway Administration to resolve issues regarding bid documents and contract administration. It was agreed that since the City already had a design firm under contract, and for purposes of legal liability, the Corps' assistance would be limited to construction supervision and inspection. Ms. Williams would seek formal approval for the Corps' involvement from the City Council in the first week of April 1979.

Approval from the Seattle City Council to negotiate an agreement with Seattle District Corps of Engineers came quickly. The actual formal request would not come for a few months. A series of letters, meetings and phone calls during this time established the exact services to be rendered, the legal authority to do so, the concurrence of applicable agencies, and the delineation of authorities and responsibilities.

The primary involvement of the Corps was settled on. The Seattle District was to provide design review and construction management. But problems arose concerning authority. The District maintained that to be most effective, contracting officer authority must be given to the Corps. This was the customary relationship between the Corps and its other customers. The City was finally convinced and agreed to pursue such a relationship. However, the State Department of Transportation (DOT) and the Federal Highway Administration (FHWA), when they were consulted for approval of City-Corps agreements, pointed to regulations requiring the contracting authority to remain with the City, due to the use of federal-aid highway funds. This point of contention was still not resolved when the formal request for Corps involvement was made by the City on 27 July 1979, in a letter signed by Mayor Royer and Councilwoman Williams.

The contracting authority issue continued to be pursued. Office of Counsel at OCE felt the DOT and FHWA requirements were probably more an informal policy than an actual legal requirement. However, due to the unwillingness of DOT or FHWA to concede the point, and in the interest of time and furthering cooperation, the contracting authority formally remained with the city. Instead, under a Memorandum of Agreement, the Corps would be delegated the greatest possible authority short of that customarily exercised by a contracting officer. This arrangement was acceptable to the Corps, City, DOT and FHWA.

Another major issue to be addressed was the choice of using the Corps for construction management over seeking similar services from the private sector. Several firms, as well as the Consulting Engineer Council of Washington, had been quite active in pursuing the work. Maintaining that management services were available from private firms, they wrote letters to the City council discouraging Corps involvement, stating it was not allowed by the city's own regulations. The City pointed to numerous reasons for involving the Corps, including:

- the expertise available in District personnel from Chief Joseph (whose experience included construction of a 2400-foot-long, 285-foot-high bridge),

- involvement of the Seattle District in Duwamish Waterway studies,
- future District involvement with the deepening and widening of the channel,

- ability to ensure the bridge would fully integrate with these future improvements of the channel,

- lack of available assistance from customarily involved state and federal agencies,

- lack of expertise with the City of Seattle Engineering Department,
- tremendous existing involvement of the private consulting industry in other bridge and large structural projects in the area,

- the need to involve the project construction manager as early as possible,

- protection of the large amount of federal and local dollars committed to the project, and

- a degree of authority for the project construction manager greater than would normally be delegated.

While all were legitimate reasons for Corps involvement, it was probably the degree of authority the project construction manager would have that became the leading justification for Corps involvement. Also an agreement to contract certain services from the private sector such as geotechnical, survey and special testing and inspection, helped to appease the consulting community.

During the next few months, efforts were directed at developing a cooperative agreement between the City of Seattle and the Corps of Engineers. Coordination with and approval from agencies such as OCE, DOT, FHWA, City of Seattle, Office of Management and Budget, and the House and Senate Appropriation committees eventually led to an agreement acceptable to all parties. Maj. Gen. Heiberg, Director of Civil Works at the Chief's Office, signed the final authorization for the Seattle District to enter into an agreement with the City of Seattle under the Federal Grant Program pursuant to authority contained in Section 219 of the Flood Control Act of 1965. A cooperative agreement was signed by then Seattle District Engineer Col. Moraski and Mayor Royer in concurrence with the Federal Highway Administration and the Washington Department of Transportation on December 5, 1979. The agreement eventually included seven supplements, some precisely defining City and Corps relationships, but the majority updating payment authorization for Corps services. The final cost of the Corps project construction management came to $7,600,000.

COOPERATIVE AGREEMENT

In accordance with the Cooperative Agreement, all interactions between the Corps and the City were to be administered through the Seattle Engineering Department's Principal Construction Engineer. Further, the agreement spelled out the following:

1. Services to be provided by the City:

a. Furnish multiple sets of construction contract documents for each contract including (full-size and half-size) contract drawings, specifications, and all applicable addenda for use by the Corps and the project contractors.

b. Make available all special forms required by the city or the funding agencies to meet reporting procedures.

c. Provide one copy of all permits obtained by the City and referenced in the construction contract documents.

d. Provide one copy of the signed contract agreement between the city and each selected construction contractor, including unit bid prices, performance bond, and evidence of insurance.

e. Furnish the following data, as available:

(1) Field survey notes of work already performed.

(2) Design criteria and calculations as required.

(3) Plans, profiles, cross sections, quantity calculations, and other documents prepared during the design phase that would facilitate construction administration and inspection.

(4) Base data and location details of existing utilities and facilities within the boundaries of the construction contracts, including underground utilities and service, overhead utilities, grade and alignment of future streets and walks, location and types of street lights, traffic signs, channelization requirements, and other base data pertinent to facilitating construction.

(5) Right-of-way data, boundary lines, and property line locations.

(6) Reports of soil boring data and foundation reports, as applicable.

2. Services to be provided by the Corps:

All engineering services necessary to assist the City in construction management during the construction phase of the bridge replacement project were to be furnished and included the following specific tasks:

a. Attend periodic construction coordination meetings with representatives of the City, the City's design consultant, the Federal Highway Administration, the Washington State Department of Transportation, King County, the Port of Seattle, and others who were to be involved with the design and construction of the project.

b. Provide liaison between the City and the project contractors and between the contractors and the city. Coordination with the design consultant and other Federal, State or local agencies was to be through the City.

c. Perform all construction management services for all construction contracts for the project to include the following:

(1) Attend the preaward (Human Rights) meeting held by the City.

(2) Establish a Resident Office near the construction site.

(3) Staff the Resident Office throughout the lifetime of the project to provide an adequate level of support in all required areas to assure that the provisions of the contract documents were being fulfilled.

(In practice, the residency was jointly staffed by Corps and City engineering department personnel all under the direct supervision of the Corps' Resident Engineer.)

(4) Organize and conduct the preconstruction conferences with the project contracts, including coordination with all affected agencies and public and private utilities. Prepare and distribute minutes of the conferences to the attendees.

(5) Conduct follow-on meetings with contractors as required.

(6) Provide project control survey for each contract.

(7) Provide continuous inspection of all contracts to assure compliance with the contract plans and specifications for each contract.

(8) Provide shop inspection for any items which were manufactured offsite to determine that the items were in full compliance with the contract documents.

(9) Provide continuous material and equipment testing for the project and maintain a complete record file of all tests and results.

(10) Enforce the job safety requirements of the contract. Establish a procedure for accident investigation and reporting requirements.

(11) Maintain a Resident Engineer's Diary in addition to a complete file of inspector logs and field notes.

(12) Monitor and enforce contractors' construction schedules; review monthly updates of construction schedules for all contracts. Coordinate all construction work to eliminate potential delays and to resolve conflicts.

(13) Provide to the contractors interpretations and clarifications of contract plans and specifications with the assistance of the City and the design consultant.

(14) Prepare and recommend for approval by the City the partial and final contractor payment requests, including verifying all payment quantities.

(15) Maintain marked-up sets of as-built drawings in the field offices.

(16) Coordinate and administer contract changes with the contractors and City.

(17) Review and coordinate with the City and design consultant any value Engineering change proposed by the contractors and process as change orders after approval by the City.

(18) Negotiate changes with contractors and prepare change orders and/or Supplemental Agreements for review and approval by the City.

(19) Investigate and resolve, whenever possible, all contractor allegations.

(20) Investigate contractor claims and prepare files for action by the City.

(21) Review and approve shop drawings. Those shop drawings which required engineering design by the contractors, or were otherwise included for review under the design consultant's contract, were to be forwarded to the City for its design consultant's review, comments, and approval. Shop drawings and review comments were to be returned through the city to the Corps for formal transmittal to the contractors.

(22) Assure that preconstruction and progress photographs were provided as necessary to fully document the work.

(23) Provide enforcement of Federal, State, and City requirements for labor relations and Equal Employment Opportunity (EEO), including receipt of contractor payrolls, labor interviews, and verification of posting of minimum wage rates and EEO posters.

(24) Provide enforcement of environmental protection requirements of contract.

(25) Resolve complaints and answer questions from all adjoining property owners regarding the construction contracts.

(26) Perform prefinal and final inspections in coordination with all affected agencies and utilities. Prepare composite punchlists and resolve with the contractors. Perform final check for satisfactory completion of all punchlist items and all construction requirements by the contractors. Make recommendation for final acceptance to the City.

(27) Turn project files over to the City, including record files, shop drawings, certificates, samples, warranties, Resident Engineer's Diary, as-built drawings, inspector logs and field notes.

d. Provide materials testing, project control surveys, and expert prestress concrete or expert steel inspection. These items were permitted to be provided by Architect-Engineer (A-E) contract. General inspection could also be supplemented as required by A-E contract. Selection of the A-E firms was to be in accordance with Corps of Engineers procedures. The goal for minority A-E involvement was established as 20% of the A-E contracts the Corps would award during the construction phase.

e. Provide special services in addition to items mentioned above, as might have been requested by the City. It was noted that such special services could not be specifically identified as of the signing of the Cooperative Agreement, but were to be performed by the Corps upon written request from the City. The exact scope of special services was to be defined by the City in each written request.

Chapter 3

PROJECT CONSTRUCTION MANAGEMENT

INTRODUCTION

The unusual participation of the Corps of Engineers in the management of the City of Seattle's West Seattle Bridge construction project provided some significant insights into the Federal Engineer's work for others. Elements of the Corps were intensively involved before, during and following the four-year construction period as constructibility reviewers, construction managers and claims negotiators.

Although a cooperative agreement existed between the City and the Corps, a clear understanding of the Corps' expected role did not exist. This situation did not create an unmanagable relationship but did require a more intense coordination effort than normal with a client agency. In the absence of clear and formal agreements, as well as a lack of established informal procedures covering a number of areas, it remained for the individuals involved to make the relationship work. Not a quick or simple process -- the task at hand was accomplished. The City and the Corps found a means of working in harmony to accomplish a common goal.

The success of the $150 million project is credited in large part to the teamwork practiced by the several agencies involved and the contractors' application of quality workmanship despite the frequent lack of clarity in broadly expressed contract requirements. The following describes the major operations involved in the bridge construction and the more significant problems experienced regarding technical and administrative matters.

STAFFING

Initial Corps plans for staffing the joint City/Corps construction residency proved to be overly optimistic. The planned staff of 28 was determined without knowledge of the number of contractors to be involved in the four construction contracts to be awarded, the number of shifts to be worked by the project contractors, or the belated demands by the City to avoid reliance on contractor self-inspections and to maximize the construction residency's inspections.

Following the start of construction, the city clarified its intent for the fullest measure of residency inspection in lieu of relying in part on contractor quality control. As a result, the resident staff of construction management personnel was expanded to a 44 full-time member organization as shown in the accompanying diagram (Figure 1). The expansion included a traffic engineering consultant, a 3-member as-built processing team, an additional change order processor, a force account work processor, three additional field engineers, as well as additional non-supervisory inspection personnel. Typical of many large construction management offices, turnover of personnel caused burdens on the undermanned staff. In retaining the top staff complement of 44 full-time members, over twice that number of applicants were hired during the first half of the project period.

Molding a joint City/Corps complement of engineers, technicians and administrative personnel into an effective, teamwork-sensitive work force was not a simple task. Weekly staff meetings, project memorandums and occasional area luncheons were used to remind all staff members that they were a part of a team expected to meet exacting performance requirements. Despite the repetitious supervisory appeals to "pull together" and to endure the unique organizational venture, a small number of Corps and City personnel were unwilling to become effective team members. Other personnel were found to lack expertise or abilities required by their positions. The Corps recognized the resident engineer's authority concerning Corps employees and the City recognized that authority as extending to all residency staff. City liaison personnel were supportive of all requests for staff composition adjustments involving City personnel. Staff members, both Corps and City employees, found ill suited to their duties due to attitude or ability were replaced in the interest of developing as effective a team effort in the residency as possible.

RELATIONSHIPS

While it was recognized from the onset of the Corps' involvement in the management of the bridge construction that a joint Corps/City staff would comprise the construction resident office staff, the Corps did not realize at the beginning that its management of the project construction would be only participatory instead of essentially singular. In the early days of the project period, it was disclosed that the City's *Engineering Department* interpreted the City/Corps Cooperative Agreement as merely providing for the Corps' assistance to the City in the management of the construction. The City saw the Corps' role much in the City's traditional manner of having a job "resident engineer" report to the Engineering Department's Construction Division while administering the contracted work.

Following the onset of the project work, impromptu coordination meetings between the Corps and City clarified the Corps' common approach to large scale construction management and only reluctantly did the City acknowledge the necessity for the resident engineer's freedom in making routine decisions regarding contract interpretation. Daily surveillance of the residency's operation was established by the City, consistent with the provisions of the Cooperative Agreement, by assigning a City liaison engineer to be in residence with, but not as a part of, the construction residency's staff.

This close association actually proved to be quite beneficial, as did the assignment of a City traffic engineer to the resident staff, because of the frequent need to coordinate the project contractors' operations with various departments in the City -- such as the Water Department, Sewer Department, City Light, etc. Both the City's liaison engineer and the traffic engineer aptly coordinated the resolution of the many interfacing problems, principally through their familiarity with the City's organizational composition and procedures, and because of their personal interest in keeping the bridge construction progressing as smoothly as possible.

Unknown to the Corps also at the outset of the project period was the City's intent to review practically all contractor submittals of proposed work methods, equipment, and materials. In order to cope with this burdening aspect of the construction management, the City assigned up to 4 engineers to an on-site office and required at least one Bridge Designer representative to also be in residence with their on-site team. This demanded review took away essentially all of the Corps' planned obligation to routinely evaluate contractor work submittals and required several construction residency coordinators to act as liaison personnel between the project contractors and the City/Designer's review team. At the onset of the project period, the necessity for direct communication between the resident engineer and contractors was emphasized and was accepted by all Owner (City) representations without question.

The rigid requirements typically posed by the City/Designer's review team in their interpretation of broadly expressed contract specifications caused an unusual amount of working meetings between residency personnel, contractor representatives, and the City/Designer reviewers in order to minimize the processing time of submittal reviews. Contractor challenges to non-contract specified requirements were frequent and a number of claims were received due to what both contractors considered to be excessive review times. These claims, however, were not of a major consequence since the project contracts protectively provided for a minimum of 30 days for submittals review.

While the Corps/City/Designer involvement in administrative and field control of the contractors' operations could have been construed as the height of a bureaucratic impediment to progress, it was manageable because of the dedication by all to make the unusual alliance work as timely and as contractually consistent as possible. The project contractors were understandably opposed to the multi-agency evaluation of their planning, from the standpoint of time consumed and because of the sometimes conflicting assessments that developed in their submittals review. The contractors had to be repeatedly prompted to purify their submittals for contract consistency, thoroughness and legibility so that the Owner representative's review would be minimized.

Because of assorted deficiencies in the contractors' staffing, they were not always successful in producing a consistent, thorough, and legible submittal; so they did not always receive prompt acknowledgement of the acceptability of their submittals, but they improved the quality of their first-time proposals as the project period progressed. Had the Corps' Resident Office staff and or the Corps' District Office been solely involved in the review of all contractor submittals, the time of processing acceptable proposals would probably not have been significantly different than that experienced with the city's and Designer's involvement.

AS-BUILTS

The degree of documenting the as-built condition of the project was unusual by Corps standards and was so unplanned that an eventual 3-person expansion of the residency's staff was required to meet the expectations of the City. Understandably, the City was demanding in its requirement for accurately documenting all underground utilities and structures as well as obscured and exposed above-ground work. As a major departure from Corps procedures, however, a listing of payable quantities on each contract drawing was also required. The benefits of such tedious cataloging was seriously questioned since the City's intended presentation of auditable payable quantities would be jeopardized by multiple views of common work areas on one or more drawings. Because of the City's unwavering insistence on the documentation of pay quantities on the drawings, the process was pursued at considerable expense of time to ensure against duplication or overlapping of entries on separate drawings.

QUARTERLY REVIEW

Quarterly reviews of the construction management were routinely provided by two to four representatives of the Federal Highway Administration (through which federal participative funding was provided for the bridge project) and the Washington State Department of Transportation (designated project surveillance agent in behalf of FHWA). Also routinely, the inspection team was accompanied by the City's resident liaison engineer during the typically-provided Resident Engineer's briefing tour and during the team's follow-up examination of the residency's work and documentation procedures. Invariably, the team's inspections were reasonably probing, their inquiries pertinent and encompassing of the project activities, and their exit comments always complimentary and evidencing the fullest confidence in the Corps' practices.

FIGURE 1

WEST SEATTLE FREEWAY BRIDGE RESIDENT OFFICE

R. RUDMAN	Resident Engineer (Supv Civil Engineer)	GM-14
M. Vincent	Asst to Res Engr	CPT, CE
L. Overton	Traffic Engineer	(SED)

ADMINISTRATION BRANCH

H. BAER Chief	Administrative Officer	GS-9
L. Chavarria	Secretary (Typing)	GS-5
L. Barnwell	Contract Payroll Clerk	GS-4
(V)	Clerk-Typist	GS-3

CONSTRUCTION BRANCH

A.R. GOODKIN Chief	Supv Civil Engineer	GM-13
J. DePiazza	Asst to Res Engr	CPT, CE
	FIELD & INSPECTION SECTION	
	CONTRACT NO. 4	
C. Stockwell	Associate Engineer	(SED)
J. Vogel	Civil Engineer	GS-11
G. Duke	Construction Insp	GS-9
	CONTRACT No. 5	
R. Mewa	Assoc Civil Engineer	(SED)
J. Hilario	Construction Rep	GS-11
G. West	Construction Inspector	(SED)
	CONTRACT NO. 6	
J. Dahl	Sr. Civil Engineer	(SED)
D. Messinger	Construction Rep	GS-11
(V)	Construction Insp	GS-9
D. Cain	Construction Insp	GS-9
	CONTRACT NO. 7	
H. Johnson	Sr. Civil Engineer	(SED)
(V)	Construction Rep	GS-11
R. Smith	Construction Insp	GS-7
	FOUNDATIONS SECTION	
A. Rice	Assoc Civil Engineer	(SED)
R. Hohlweg	Civil Engineer Tech	GS-9
(V)	Civil Engineer Tech	GS-9
M. Burnham	Civil Engineer	GS-7 (T)
C. Hamry	Civil Engineer Tech	GS-5 (T)
	MATERIALS SECTION	
R. McDowell	Civil Engineer	GS-12
R. Oedewaldt	Materials Engr Tech	GS-9
(V)	Civil Engr Tech	GS-9
B. Stephens	Civil Engr Tech	GS-4

ENGINEERING BRANCH

D.G. McALISTER Chief	Supv Civil Engineer	GS-13
	TECHNICAL ENGINEERING SECTION	
P. Reh	Supv Civil Engineer	GS-12
L. Gotta	Structural Engineer	GS-11
P. Stoa	Civil Engineer	GS-11
W. Withers	Civil Engineer	GS-11
M. Satter	Civil Engineer Tech	GS-9
T. Gano	File Clerk	GS-3
	MODIFICATIONS, SCHEDULES & PAY SECTION	
S. Hakola	Associate Civil Engineer	(SED)
S. Osborne	Associate Engineer	(SED)
W. Brown	Associate Civ Engr Spec	(SED)
C. Jacobs	Claims Specialist	(SED)
E. Brown	Civil Engineer Tech	GS-9
K. MacCachran	Contract Specialist	GS-7

Chapter 4

CONSTRUCTION

OVERVIEW

Completed in July 1984, the new high-level bridge provides for six lanes of traffic (three each way) in addition to freeway-standard inside and outside shoulder lanes. The new bridge passes over three north-south auto thoroughfares intersecting Spokane Street as well as the East and West Waterways at the upstream end of the industrialized Harbor Island. The West Waterway comprises the shipping channel and is spanned by the high-level portion of the bridge. This span provides for a river crossing 140 feet above water with no obstruction to the passage of ocean-going vessels as was presented by the low-level bascules. The relatively low but elevated main line of the bridge crosses the East Waterway (not passable to ships).

The project included demolition of the ship-damaged bascule bridge, which had carried four lanes of one-way traffic. The undamaged low-level bridge was retained and continues to carry four lanes of traffic (two each way) to and from Harbor Island.

The overall length of the new bridge is approximately 1 1/4 miles with a 590-foot span between main piers adjoining the navigable waterway. The main span and the 375-foot side spans were constructed of concrete by the segmental, cantilevered, cast-in-place process. The remainder of the bridge was conventionally constructed using precast concrete girders integrated with cast-in-place portions.

FOUNDATION WORK

Foundation problems affecting the new bridge project were mitigated by an exploratory program conducted under contract by the City of Seattle before the onset of the new bridge construction. Stability in the sandy areas in and around the land-positioned bridge pier locations was improved during the project construction by soil densification. In this process, the areas in and around the pier locations were consolidated to approximately 40-foot depth by a crane-suspended vibratory "stinger". This involved vibratory probing of the foundation on a grid pattern with 7- to 8-foot spacing between probe locations.

After water-jetting the 1-foot-diameter stinger to the desired depth, a pea gravel stuffing material was pushed by a front-end loader into the "posthole" developed during water-jetting. Vibration was then transmitted through the stuffing material to the surrounding foundation while the stinger was withdrawn slowly in 1-foot increments. The foundation was later checked for compliance with the prescribed degree of consolidation using a standard hydraulically advanced cone probe in accordance with ASTM D1586-67 (1974) "Penetration Test and Split-Barrel Sampling of Soils" and ASTM D3441-75T "Deep, Quasi-Static Cone and Friction Cone Penetration Tests for Soil."

Installation of foundation piles at the pier footing locations followed area soil densification.

Foundation exploration conducted along the entire length of the bridge corridor during the project preconstruction period disclosed no bedrock within 250 feet of ground surface. The necessary support for the massive bridge structure therefore involved foundation pile installation at each of the bridge footing locations. Thirty-six-inch-diameter steel pipe piles of 1-inch to 3/4-inch wall thickness were driven to support the two main bridge pier footings adjoining the waterway and penetrated to a maximum depth of 220 feet. The remaining 31 mainline bridge pier footings and a similar number of ramp footings were founded on octagonal, hollow, prestressed concrete piles, most of which extend unspliced to depths of approximately 120 feet. Some piles extend with splices to approximately 150 feet. The number of piles supporting individual pier footings varies up to a maximum of 64. All foundation piles, both steel and concrete, were designed with load-carrying capacity developed through frictional resistance.

The steel pipe piles were routinely driven with a Delmag D62 hammer having a rate energy of 165,000 foot pounds. Concrete piles were driven by Delmag D46, Kobe K45 and Kobe KC45 hammers, respectively having rate energies of 105,000, 74,400 and 74,400 foot pounds. Partial-depth predrilling was used for driving some of the concrete piles in foundation areas with unusual resistance to pile penetration. Such problem areas were generally confined to the west side of the waterway where clayey soils were in evidence. Some pre-drilling took place on the east side to avoid buried obstructions.

CONCRETE CONSTRUCTION

Approximately 105,000 cubic yards of concrete were used in the bridge construction. With the exception of the precast concrete piles, and the precast girders used on each end of the cast-in-place, cantilevered midsection of the bridge, all concrete in the structure was mixed in two commercial batch plants located within a 2-mile radius of the jobsite. All bridge concrete mixes featured a maximum-sized aggregate of 3/4 inch. For cast-in-place superstructure concrete, a maximum cement content of 7 sacks per cubic yard was used with a maximum water/cement ratio of 0.37. For footings, columns and capbeams, a maximum cement content of 6.5 sacks per cubic yard and a maximum water/cement ratio of 0.42 were used. All concrete was transported to the jobsite in Ready-Mix trucks and was pumped to the placement locations by pump trucks using 4-inch pipelines. The maximum distance pumped at any one time involved approximately 150 feet vertically and 320 feet horizontally. Maximum slump of the pumped concrete with w/c ratio limitation was 3 inches, with this consistency improved to 4 1/2 inches through the use of a workability-enhancing additive.

Type III cement was used in the 1,340 linear feet of cantilevered segmental construction in the main and side span sections of the superstructure in order to minimize concrete strength gain time before prestressing. In general, Type II cement was used in all other bridge structure components. Required concrete strength varied from 4000 psi for footings, 5000 psi for columns and cantilevered superstructure to 7000 psi for precast, prestressed girders and foundation piles.

Reinforcement used in the bridge structure was comprised of bars, coils, and strands. Bar reinforcement notably involved No. 5 bars in the 7-inch bridge span decks outside the cantilevered segmentally constructed section of the superstructure, with No. 11 longitudinals providing support over the piers. Two mats were typically installed in the bridge deck with all top mat reinforcing protected by factory-applied epoxy coating. The epoxy coated feature of the reinforcing steel was furnished at a cost of approximately 25 cents per pound more than uncoated rebar. The four corners of the typical bridge pier column featured, in addition to a more conventional application of vertical and horizontal reinforcing bars, helical 1/2-inch diameter "wires" wound into continuous 18-inch diameter coils on a 2-inch pitch for earthquake reaction. The heaviest bar reinforcement used on the project involved No. 14 bars in the larger pier footings and in critical areas of the superstructure.

The cantilevered segmental construction of the unitized, twin box girder superstructure spanning the Duwamish Waterway was made possible using post-tensioned strand reinforcement. Following approximately a full day of concrete strength gain in the typically placed superstructure segment, (the Type III cement concrete strength exceeded the specified minimum of 2500 psi), post-tensioning of the cast segment was initiated. Longitudinal post-tensioning tendons were comprised of nineteen 7-wire strands of 0.6 inch diameter per strand. Twelve longitudinal tendons were dedicated to the support of each 16 1/2-foot superstructure segment placed. Progressively increased post-tensioning support was provided to any earlier placed segment because the longitudinal tendons dedicated to each of the following segments extended through conduits embedded in the earlier placed segments to anchorages in a matching segment on the other side of the pier. Lengths of post-tensioning tendons therefore gradually increased with the advancing superstructure "teeter-totter" construction until a maximum unspliced length of 582 feet was used. Additional post-tensioning reinforcement was provided for the segments under construction in the form of "vertical" 6-strand tendons spaced at 2-foot centers in the sloped box girder walls and 4-strand transverse tendons spaced at 18-inch centers in the upper slab of the unitized box girders.

During the segmental construction of the portion spanning the waterway, the piers adjacent to the water were constructed to an elevation 2 inches below designed roadway profile (to allow for a later application of a 2-inch thick roadway wearing surface) before the cantilevering of the superstructure was commenced in both directions from each pier. Construction of each of the pier caps initially included a 54-foot-long "pier table" atop the pier's twin columns. This enlarged head of the pier, oriented along the roadway alignment, provided a sufficiently spacious work platform for the mobilization of anchored, cantilevered trussworks which were essential to the segmental construction. These trussworks, commonly known as form travelers, carried the hanging forms for the twin box girders to be built in increments out from the pier.

A form traveler was positioned over the alignment of each box girder section of the superstructure and worked in parrellel with a companion form traveler for the side-by-side box-girder construction. Since the "teeter-totter" sequencing of the superstructure's segmental construction called for a coordinated extension of the work along roadway centerline in both directions from the supporting pier, separate tandem sets of form travelers were positioned atop the pier table in opposing directions. The construction specifications permitted a limited imbalance (one segment) in the alternate placements of segments on opposing sides of the supporting pier. Each segment of superstructure was accordingly placed in a 16 1/2-foot length with the slabs and stem walls of the box girders' configuration placed monolithically. The maximum reinforced concrete load carried by the tandem form travelers was 266 cubic yards.

As the superstructure construction over the waterway closely approached the mid-channel point, the landward end of the superstructure was still 80 feet from contact with the nearest shore pier. Therefore, steel falsework was used adjacent to the shore pier to support a construction platform for the superstructure's end section. The end section consisted of a 77-foot segment and a 3-foot closure segment between the 77-foot section and the superstructure cantilever. Post-tensioning of the end and cantilevered sections followed as soon as the 3-foot tie-in segment of concrete developed a strength of 2,500 psi. After the cantilevered segmental construction was duplicated from the main pier on the other side of the waterway, placement of the final 16-foot closure segment at the mid-channel section of the bridge completed the river span. In order to offset the intolerable movements of the opposing projections of the cantilevered superstructure during the midchannel closure, external post-tensioning was attached to the box girders' upper slab and extra heavy pipe spreaders embedded in the closure section to be placed.

A two-inch concrete wearing surface was placed over the 1,340 lineal feet of segmentally-constructed bridge. This process involved machine strikeoff and plate-vibratory placement of an 8 1/2-sack concrete mix containing 1/2-inch maximum-sized aggregate at a maximum 3/4-inch slump. Other than in the segmentally-constructed portion of the bridge, the 7-inch roadway deck was placed to final profile without an overlay.

Precast girders, used in the support of approximately three fourths of the total length of the bridge's deck, were manufactured at Tacoma and at Woodinville, Washington, 40 and 25 miles respectively, from the bridge construction site. The girders, ranging in lengths up to 154 feet, were all transported by truck and, with the exception of some of the shorter ramp girders, were hoisted into their final position by two cranes.

CONTRACTS

Aside from the award of the bridge demolition contract in December 1980 to remove the damaged bascule and its approaches, the four planned construction contracts for the new high-level bridge were awarded to only two successful low bidders. Three of the construction contracts were won by Kiewit-Grice, a joint venture of Peter Kiewit Sons of Omaha, Nebraska, and

Earnest L. Grice of Federal Way, Washington. The fourth construction contract was awarded to Moseman Construction Company of Redding, California. Each of the construction contracts roughly related to a quarter-mile-long section of the new bridge's length. Information regarding the contracts is summarized in Table 2.

TABLE 2

CONTRACT SUMMARY

BIDDING OPTIONS	AWARD	ORIGINAL CONTRACT AMOUNT	FINAL CONTRACT AMOUNT	NTP	ORIGINAL CONTRACT COMPL DATE	ACTUAL CONTRACT COMPL DATE
a. Contract No. 1 - North Bascule Bridge Demolition.	26 Nov 80 (Sealant Systems)	$ 649,300	$ 713,253.63	8 Dec 80	10 Nov 81	6 Oct 81
b. Contract No. 2 - Mainspan Substructure.	*					
c. Contract No. 3 - Mainspan Superstructure.	*					
d. Contract No. 4 - Mainspan Substructure & Superstructure.	15 Oct 80 (Kiewit-Grice)	23,870,071	24,823,174.20	3 Nov 80	3 Oct 83	13 May 84
e. Contract No. 5 - Harbor Island Structure.	22 Apr 81 (Kiewit-Grice)	13,523,000	14,512,139.87	18 May 81	20 Jul 83	13 May 85
f. Contract NO. 6 - West Interchange.	16 Sep 81 (Kiewit-Grice)	29,099,245	32,779,689.44	26 Oct 81	25 Sep 84	12 Jun 85
g. Contract No. 7 - East Interchange.	16 Sep 81 (Moseman Constr. Co)	23,464,051	27,602,177.99	26 Oct 81	25 Sep 84	29 Oct 85
h. Contract No. 8 - West & East Interchanges.	**					
		$90,605,667				

* Awarded jointly as Contract No. 4

** Awarded separately as Contracts Nos. 6 & 7

Chapter 5

SIGNIFICANT CONSTRUCTION PROBLEMS

CONTRACTOR QUALITY CONTROL

The basic contract specifications used on the West Seattle Bridge construction project were those issued in manual form by the American Public Works Association and by the Washington State Department of Transportation. These broadly expressed requirements were supplemented by general contract requirements and by detailed special provisions compiled by the Bridge Designers. In none of these documents were the terms "Quality Control" or "Quality Assurance" mentioned. A brief section of the contract general requirements specified in part that:

> Inspections, tests, measurements, or other acts or functions performed by or for Owner personnel are recognized as being for the sole purpose of assisting the Engineer to determine with reasonable assurance that the work, materials, rate of progress, and quantities comply with the contract terms. Such acts or functions shall in no manner be construed to relieve the Contractor from determining to his own satisfaction that he is in full compliance with contract requirements at all times nor to relieve him from any of the responsibility for the work assigned to him by the contract. Work and materials not meeting contract requirements shall be made good, and unsuitable work and materials are to be rejected notwithstanding that such work or materials may have been previously inspected or that payment therefore may have been included in a progress estimate.

The remainder of the contract contained no amplifying words relating to correction of defective or deficient work to the satisfaction of the Engineer but did state that work not conforming with the contract requirements would be unauthorized, nonpayable, and was to be promptly "removed".

Early coordination meetings between the Corps of Engineers and the City of Seattle quickly disclosed the City's lack of confidence in a contract-specified contractor quality control program. The City's philosophy of contract construction management was found to be similar to that practiced by the Corps before the late 1960's, where the administering agency's forces would provide near-total inspection of all elements of the contractors' planning and field work.

A brief reference to contract-imposed contractor self-inspection was incorporated as a supplement to the basic job specifications, but the City did not place any measure of reliance on contractor quality control. In expressing its concern about public opinion of quality assurance in the extremely visible bridge construction, the City emphasized its intent of having Owner-representative inspection conveniently noticeable and exacting in practice. To support its demand for Owner (not contractor) inspection, the City readily consented to increasing the construction residency's staff by 43 percent beyond the 28 individuals initially planned by the Corps for the on-site work management.

Despite the City's insistence that the construction residency inspect all aspects of the on-site and off-site construction, frequent coordination meetings between the Corps, the City, and the Bridge Designer were held to reassure the City that effective quality assurance could be gained through a controlled involvement of the contractors' inspection as a separate work examination effort. Concurrently, regularly scheduled weekly meetings with each of the project contractors were used in most part to constantly remind the contractor representatives of the contract-required self inspection of all elements of their work and that of their subs and suppliers.

Despite the oft-expressed reminders, it was found that the prime contractors did not exert an effective on-going appraisal of their subs' work nor did the prime contractors adequately monitor offsite actions by their suppliers, such as in the day-to-day production of job concrete; casting, tensioning and handling of prestressed girders; or in the production of precast concrete foundation piles. Typically, the prime contractors followed a procedure of letting their subs and suppliers be responsible for their respective product quality control. This practice generally produced satisfactory construction but occasionally resulted in avoidable, expensive delays and corrections of unacceptable work. Also typically, the prime contractors, subcontractors and suppliers more than occasionally had to be reminded that work performance based on their experience with other clients was not acceptable where such experience was not compatible with the bridge contract requirements.

In commenting on the overall effectiveness of the imposed contractor quality control and the applied Owner-representative inspections as a measure of product quality assurance, the following points are noteworthy:

1. The City over-estimated the capability of the Corps to inspect all aspects of the contractors' on-site and off-site work, all of the time.

2. The construction residency was only partly successful in convincing the prime contractors that, as required in general contract terms, their self inspection was separate from Owner-representative examinations and would be beneficial from the standpoints of contract compliance, limiting expense and conserving time.

3. The prime contractors, subcontractors and suppliers obviously chose to apply quality control efforts with a considerably larger risk factor involved than was anticipated by the Owner representatives.

4. In the absence of clear contract requirements identifying the contractors' quality control methods and staffing, the contractors were routinely evasive and generally non-committal as to how self inspection would be specifically applied during individual elements of work. Generally, they took a reassuring but noncommittal posture in which it was

stated that the degree of contractor quality control insisted upon by the Engineer would be subject to a claim for extra cost reimbursement.

In the end, no claims were filed for the enforced quality control even though the contractors were pressured into applying certain timely self inspections with available job supervisors or by occasional assignment of additional inspection personnel. In view of the non-specific nature of the contract, the project contractors were not compelled to specifically staff their field operations for self inspection. In one instance, partly as a result of the lack of contractor quality control, a 20-foot long retaining wall section approximately 12-feet high was ordered by the Engineer to be removed twice because of intolerable deviations from prescribed alignment. In this potentially debatable case, the contract was also silent on permissible deviations from prescribed limits of construction. Several other expensive and time-consuming instances of avoidably defective work occurred, all of which were largely due to the contractors' lack of timeliness and thoroughness of inspection.

5. While ackowledging the necessity of and benefits to be derived from Owner-representative quality assurance inspections, the application of a more comprehensive contract requirement for contractor quality control (CQC) would have undoubtedly yielded some improvement in the quality of the bridge construction. Such clarified CQC requirements, however, would have provided the biggest advantages in eliminating significant delays and excessive expenses in the conduct of the work, would have avoided certain claims relating to rejected elements of the work, and would have reduced the costs of Owner-representative construction management.

SOIL DENSIFICATION

Confirming the expectations of the Spec Writer, soil densification was effective in densifiable soils and was not successful in the soils identified as non-densifiable. While such a statement appears to be straightforward, it was not fully understood in the borderline cases of layered soils which should have been densifiable when they were interbedded with soils of questionable consolidation capability. As expressed in the contract, sands and gravels were densifiable, and silts and clays were not. In certain of the pier footing areas in which soil densification efforts were required, it was found that a shallow interbedding of silts with layers of apparently clean sand had a significant effect on the Contractors' ability to consolidate the separated layers of sand.

While the soils consultant advising the City was confident that a reasonable densification effort would yield the expected consolidation of the densifiable layers of sand separated by interbeds of silt, only partial success resulted. By direction, the contractor redensified areas which were test-proved not to meet the consolidation requirements of the specifications. The contractor's renewed and vigorous efforts at redensification disclosed that some of the shallowly interbedded layers of sand and silt would not yield the foundation consolidation expected.

There were early concerns about the possible adverse effect of soil densification on the profile of nearby railroad tracks, streets, and underground utilities. These concerns quickly gave way to confidence. While post-densification density checks clearly showed an improved foundation consolidation, there was insignificant settlement of railroad tracks, streets, or other improvements. Generally speaking, measured settlements did not exceed a range between 1/8 and 1/4 inch.

In the sandier soils being densified, initial concern for disposal of accumulated surface water from water-jetting the vibratory stinger to depth gave way to a realization that the sandy soils would drain off shallowly-diked containment areas. In some cases, the impoundment of water was spread out over a couple thousand square feet and accumulated to 2 to 3 feet in depth. Overnight impoundment, however, usually dissipated most or all of the water in the free draining materials being worked. Draining was much slower, however, in those areas which featured some significant silt component in the foundation materials. In one particular case, the "soupy" effluents from the water-jetting operation had to be removed from the jobsite in water sprinkler trucks. Imperviousness had been created by silty accumulation on the base of the impoundment areas.

PILE DRIVING

One of the major problems encountered in the West Seattle Bridge construction involved the prescribed driving of foundation piles. In addition to differing expressions of the performance requirements in each of the project construction contracts, the specifications were not as clear as they could have been to clearly control the pile-driving responsibilities of the Contractor. A number of contractor claims resulted because of alleged direction to perform the pile-driving according to the Owner's unilateral interpretation of the spec. Generally speaking, one recurrent deficiency in the pile-driving specifications was the lack of a required minimum stroke by the single-acting hammers. In all cases, the contract specifications made reference to a required number of blows per inch or blows per foot which, when coupled with pile penetration to a prescribed depth, was expected to constitute an acceptable driving effort. A concurrent reference to hammer stroke was not included, however. Apparently, it was believed that such reference would not be an issue if a "suitably maintained" hammer was used in the pile-driving.

Additionally, it was found that the pile-driving specifications were deficient in linking blow count (whether expressed in blows per foot or blows per inch) with an established penetration criterion for determining a contractual condition of refusal. In other words, simply specifying a certain bpf or bpi as a measure of refusal was found to be inadequate since momentarily strong resistances were encountered during some of the piles penetration which did not represent or confirm a desired state of refusal. A specified refusal criterion should, therefore, relate blow count and minimum hammer stroke to an increment of penetration as well (such as 12 or more bpi at a minimum 7.5 foot stroke, measured through a minimum pile advance of 6 inches after a total pile penetration has been achieved). During the course of the project work, it was found that certain critics were improperly attempting to equate a specified blows-per-foot criterion with a blows-per-inch standard. In this regard, it is important to note that 144 blows per foot is not the same as 12 blows per inch, for instance.

The appraisal of a "suitably maintained" hammer proved to be quite a problem during the pile-driving. On each of the four construction contracts, the contractors' proposed use of a Kobe KC-45 diesel hammer was touted by the supplier as being much more environmentally acceptable than other similar diesel hammers. The principal difference between the KC-45 and its liquid fuel-injection counterparts was that the KC-45 introduced atomized fuel into the hammer's combustion chamber. According to critics, the atomized fuel logically created preignition conditions and it was vigorously presented by these critics that the pre-ignition frequency could be in milliseconds which were not discernible in the field and yet had a dramatic effect on the ability of the equipment to transfer the energy of a falling hammer to the impacted pile. Because of some considerably erratic pile-driving results with two KC-45 hammers, despite their apparent "suitably maintained" mechanical condition, use of atomized fuel-fired diesel hammers is not recommended in other than the most simple or predictable driving conditions. On one of the four project contracts which featured a relatively fluffy, sandy foundation condition, no problems were encountered in the driving of piles to prescribed depths with a KC-45. In other project areas where silts or clays were strongly evident in the foundation, the quality of pile-driving with the KC-45 was so suspect that the contractor was ordered to remove the hammer from the jobsite.

Agreement was never reached with the Contractor regarding the adequacy of a "suitably maintained" pile-driving hammer in difficult driving conditions presented by "clayey" foundations. Whereas the Engineer, Owner and soils consultant declared three different makes of diesel pile-driving hammers to be mechanically unfit for duty because of their inability to satisfactorily advance a pile and to maintain a prescribed stroke, the contractor strenuously argued that the pile-driving problems were attributable to the rubbery soil conditions and not to the mechanical condition of the hammers. Ultimately, a sizable foundation claim regarding hammer performance was settled without either side conceding to the other's charges of cause for the pile-driving problems. This was done based in part upon a directed change in calibration testing requirements which lead to the establishment of better-defined pile-driving criteria.

While the specifications required the contractor to maintain the alignment of a pile during driving, they also required that he not force the pile to maintain its position and alinement. While the specifications also required that a positioned pile be confined to no more lateral movement than 6 inches during driving to depths in some cases beyond 100 feet, some of the driven piles drifted beyond the specified tolerance. It was properly acknowledged that the contractor could not really control the drift of the pile as it advanced into unknown impediments.

Because of the hollow nature of the concrete piles (with a solid plug at the driving tip), the sweep of a driven pile could have been detected by lowering an inspection light down the pile after the driving had been completed or was well advanced. Unfortunately, no effort was made to measure the sweep of the driven piles. Only after all of the pile-driving had been completed and the piles embedded by footing concrete, were the benefits from such pile-sweep information recognized. Had the information been documented, it is believed that the direction of pile sweep associated with the logged presence of pile cracks could have established some overrunning of tolerable tensile strains in the driven piles.

By contract, any damages sustained by driven piles were chargeable to the contractor. Understandably, an involved contractor presented a claim for all of the corrective work required at the direction of the Engineer pair cracked concrete piles at the direction of the Engineer, arguing that he could not control the cracking despite state of the art handling and driving methods. During the course of driving 1,850 odd piles, some broken or cut-off piles showed that the reinforcement in the piles' manufacture was non-concentric with the axis of the pile. Practically all of the driven piles were cut off to a prescribed stickup elevation prior to embedment with footing concrete, but no attempt was made by the Construction Residency to record the concentricity of observed pile reinforcement exposed in the cut-offs. It was later recognized that such information could have been of considerable importance in the resolution of a long standing debate about the quality of the contractor's/supplier's foundation piles.

Upon encountering unusual driving resistance in clayey soils, some holes were pre-drilled to partial but considerable depths for follow-up pile-driving. However, it was found that such procedure can actually be detrimental in fine-grained soils where intruding water accumulates in the predrilled hole and against which the driven pile eventually works as a piston. In acknowledging this condition, the Designer required that several pier footings be supported by piles without a solid driving tip plug. An immediate improvement in the driving characteristics of the unplugged piles was experienced; however, the Designer was not totally satisfied because of the developed presence of soil on the inside of the pile. In the instances where unplugged piles were driven, the Designer did not specify that the intruded soil be augered out and the interior of the pile cleaned for inspection. Such a procedure could have been applied but at considerable cost.

Because of the considerable amount of pile-driving to be performed closely adjacent to residential and light commercial areas, the contract broadly required that the contractor suppress the noise of construction "to a reasonable degree". This nonspecific requirement caused a considerable administrative problem for the construction management office and for the contractor who was trying to maintain a work schedule. Obviously, the contractor did not come to the project prepared to effectively suppress the noise of pile-driving. In his favor, current City and County ordinances exempted the noise of construction equipment from noise suppression during normal daylight working hours. But because of numerous complaints from the nearby residential community, the contractor was directed to apply effective sound suppression measures, notwithstanding the exemptions provided by the cited ordinances.

Separate searches by the contractor and by the construction management office, however, disclosed that, for the type of massive pile-driving equipment being used, there was no known feasible method of suppressing the pile-driving noise. Studies have been made by CERL in suppressing noise in sound-sensitive areas but their research has been limited to smaller types of piling-driving equipment. The eventual solution of the noise problem at the West Seattle Bridge Project amounted to imposing a 7 p.m. curfew on the pile-driving near the residential community. The contractor submitted a modest claim for alleged additional costs of determining and applying (ineffective) sound-suppression measures.

One notable lesson learned during the attempted suppression of pile-driving noise was that any shield short of a massive containment (such as concrete, heavy slab metal, or heavy timbers) will not arrest the transmission of sound waves. Neoprene-covered lead mesh and shrouds made of thick polyurethane insulation, which were used in attempting to suppress impact noises on two contracts, proved to be completely ineffective. Further attempts by the contractor to house noise-generating impact areas also convincingly demonstrated that the transmission of noise could not be suppressed by thin or light weight containers.

CONCRETE WORK

Control of Concrete Consistency

The Washington State Standard Specifications for Road and Bridge Construction were made a part of the contract documents for the West Seattle Bridge Project. It was found that these specifications were not as explicit as they could have been in fixing the contractor's responsibility for day-to-day control of the consistency of delivered concrete batches. Field disputes resulted, and directives were used to the contractors regarding routine control of the commercially-batched concrete. Because of the routine presence of Residency inspectors taking slump and air tests of delivered concrete, the contractors typically abandoned a delivery-point "self inspection", contending that a ready radio communication between the placing foremen (at elevated locations) and the ground level Residency inspectors at the concrete delivery points should maintain an effective control of the delivered concrete's consistency.

Generally speaking, after the peculiarities of the mix ingredients were well understood, an effective control of the delivered batches was achieved. However, intermittent irregularities in concrete consistency occurred because of fluctuations in absorbed or adsorbed aggregate moisture content, ambient temperature, duration of mix and holding time prior to use, etc. Where the contractors experienced significant extra costs in handling or disposing of marginally workable, unworkable or excessively wet batches of concrete transported to the placement sites, demands for additional compensation were issued because of what they considered to be an overly restrictive "control" by the Residency materials testing inspectors. In all cases, the contractors' requests were denied because of their less than effective control of the delivered concrete. The problem was not a major one but typified those avoidable strained field relations which are caused by non-specific contract language.

Water-Proofing Sealer

Contract specifications called for painting the finished surfaces of the bridge (except the roadway) with a methyl-methacrylate ethyl acrylate copolymer resin at considerable cost. Washington State Department of Transportation frequently uses such sealer on bridges, retaining walls, and other exposed highway concrete structures. Advantageously, during the early phase of the West Seattle Bridge construction project, the proposed water-proofing sealer was applied to a sample area of permanently exposed concrete, and after only 1-year of exposure to temperate weather, was found to be deteriorating. Because of the initial high cost and the potential frequency of maintenance, application of the sealer was deleted from the project contracts.

Finishing Roadway Decks

The project specifications required that roadway surfaces be finished to within a trueness tolerance of 1/8-inch in 10-feet and also in such manner as to assure a "rideable" profile. As permitted by the contract specifications, one contractor proposed to finish the 104-foot-wide bridge deck with a truss-supported machine. It was found that despite the temperate weather for concrete placements and an attempted systematic control of the consistency of the incoming commercially-batched concrete, the actual consistency of the concrete varied to such a detrimental degree that deck finish tolerances were violated over widespread areas. The reassuring contentions of the finishing machine supplier as to its capability in finishing the 104-foot width of the pipeline-transported concrete was extremely optimistic considering the four- and five-man finishing crew that had to work behind the finishing machine.

Under the continuing pressures of localized rejections of roadway surface finish, the contractor elected to reduce the widths of concrete finishing to 52 feet and accomplished the task much more closely to the specified surface finish. Extensive corrective grinding and regrooving of the finished pavement was required later in order to achieve the 1/8-inch in 10-feet tolerance and the "rideable" roadway profile. The contractor conceded during the placement phase that there should be an individual in the placement crew with the sole responsibility of checking the finished concrete while the concrete was still in a plastic state.

Consistent with Corps of Engineers Quality Control/Quality Assurance procedures (which were not written into the West Seattle Bridge project specifications), a critical appraisal of the first prototype segments of finished roadway deck should have been conducted in order to advise the contractor as early as practicable as to the acceptability or unacceptability of his concrete finish. Additionally, in retrospect, a sample area of finished roadway deck should have been established as soon as the deck finishing program was initiated to ensure agreement on the nature of an acceptable deck striation. Extensive, expensive and time-consuming grinding and regrooving was also necessary to correct belatedly identified areas of unacceptable striation in the field roadway sections.

Bridge Deck Thickness

Well after the start of bridge deck construction, it was discovered that the deck slab was being constructed up to 2-inches deeper than required. This occured in approximately half of a quarter-mile length of bridge deck where the contract required a 7-inch thick slab. When the discrepancy was identified to the contractor, he reacted with surprise that anyone would complain about getting a "stronger" deck at no additional cost. The Bridge Designer, on the other hand, logically voiced his dissatisfaction with the over-thick deck slab construction from the standpoint of excessive and undesirable dead load. Additionally, it was noted that where the contract prescribed 2 1/2-inches of cover over the top mat of reinforcing steel in the deck, the actual cover ranged in some cases between 4 and 4 1/2-inches. Corrective grinding of the over-thick deck sections was applied but not to total correction. The Designer eventually and reluctantly accepted most of the over-thick decks in their as-built condition. This experience is another example of the benefits of an early appraisal on the condition of a prototype for repetitious construction.

An analysis did not reveal any clear-cut reason for the over-thick condition of the bridge decks even though the contractor's surveying party chief and the Corps' counterpart party chief were extensively questioned about the procedures used in establishing controls for the roadway deck thickness. It was concluded, however, that unanticipated settlement occurred in the contractor's falsework supporting positioned girders, and the surveying crews then inadvertently or deliberately set controls to maintain the designed profile to specified elevation of the roadway deck. This would explain an over-thick constructed deck, but the magnitude is surprising since the steel framework supporting installation of the bridge-deck girders were founded in all cases on the concrete footings of the piers.

Elevated Benchmarks

During the latter phase of construction of the West Seattle Bridge, an elevated benchmark set at the roadway level approximately 100 feet above ground level indicated a settlement of the structure of approximately 1 1/2 inches over a 1-year period. At the onset of bridge construction, the wisdom of assuming the constancy of an elevated benchmark was recognized. In other words, once a benchmark is transferred from the ground level to an elevated location which will be affected by later settlement-generating construction, the benchmark must be assumed to remain constant in elevation in order to not adversely affect a coordinated control of superstructure construction based on the elevated datum.

Because of the significance of potential problems due to errors in survey control, checking of the contractor's surveying work at ground and elevated locations was done routinely. Due to the variable-elevation nature of the elevated benchmarks, coordinated use of more than one such datum had to be kept in mind.

Chapter 6

CHANGE ORDERS AND CLAIMS

GENERAL

Claims management is difficult and controversial enough within the standard context of Corps contracts. The unique involvement of both the City of Seattle and the Corps of Engineers on this project could have led to disastrous results, particularly in the area of claims. The success in this ares is a testimony to the cooperative and reasonable attitudes of all involved. The contractors, Corps, and the City worked out a system which produced settlements considered equitable by all. The experience and expertise of the resident engineer was instrumental in gaining such success. This history presents no statistics on specific claim settlements, dollar amounts, time extensions, or length of time to reach a resolution. Success is based on two significant criteria. First, no contractor claim proceeded to any form of adjudication. All claims were settled between the idividual contractors, the Corps and the City. Secondly, all claims were effectively resolved within the timeframe of construction. This allowed for a distinct end to the project rather than a drawn out nondefinitive conclusion.

ORGANIZATION

Contractor claims were submitted to the resident engineer for consideration. The disposition of these claims was greatly expedited through the preparation of summary documents by key members of the Resident staff which included the Resident Engineer, the Chief of Construction Branch and the Chief of Engineering Branch. These summary documents briefly cited the pertinent claim details, relevant contractual provisions and, most importantly, the recommendation of the Resident Engineer as to whether or not the claim should be denied or recognized in part or in whole. On more technical claims, the Resident Engineer would solicit the opinions of those at the District office or elsewhere in the Corps of Engineers with expertise in the area in question prior to preparing the summary document.

These summary documents were reviewed on an "as completed" basis with the City of Seattle project managers in a round table manner. As mutual understandings developed between the Corps of Engineers and the City of Seattle on the interpretation of the broad APWA language and the hierarchy of the multi-volume contract documents, the frequency of internal disputes dwindled. These discussions were invaluable in establishing defensible positions on claims deemed nonmeritorious as well as in establishing a mutually agreeable justification for recognizing those claims deemed to be meritorious in part or whole. After agreement was reached between the City and the Resident Engineer, the decision was rendered to the contractor through the Resident Engineer.

The lack of monetary authority for the Resident Engineer created no significant problem. Whereas over 400 change orders averaging approximately $15,000 per change were issued during the project period, a prompt review of prepared change orders by the City was provided and processing of the changes proceeded without undue delay.

As the contract periods came to a close, the construction contractors individually pursued previously denied claims at forums jointly chaired by both Corps and City representatives. The City contracts did not rigorously define the appeal process or provide for an independent review process prior to a contractor undertaking a formal action through the courts on a claim previously denied by the engineer. However, the process of adjudicating claims at the Resident Engineer level proved effective except for several monetarily significant and hotly disputed claims. To negotiate these more difficult claims, similar forums were conducted for the contractor to present his arguments at a level analogous to the Chief of a District Construction Division within the Corps of Engineers circles.

HIGHLIGHTS OF CLAIMS SETTLEMENT

On a few occasions relating to contractor-proposed construction methods, the city overruled the experience-supported decisions of the Resident Engineer and generated some avoidable claims from the contractors when the City's demands were imposed. The City and Designer adopted very stern interpretations of the contract language where expressions such as "to the satisfaction of the Engineer", "as specified by the Engineer", or "as approved" were applicable. The City and the Designer were adamant in their contractual philosophy that the Engineer (Owner) had virtually unrestrained rights to specify, without additional Owner cost, construction details which were not expressed in the contract documents. While avoidable claims were submitted because of the occasionally extraordinary demands of the Owner representatives, the claims are not considered to be of a major consequence.

The number and variety of claim issues on the West Seattle Freeway Bridge Project were typical of large, complex construction projects. Claim issues relating to differing site conditions, maintenance of local traffic detours, Engineer's interpretations of the contract felt to be overly stringent, and constructive acceleration constituted the bulk of the more significant monetary claims. The general methodology used by the Resident Office to process contractors' claims flowed from the daily routine of meetings with the contractors, serial letters from the contractors, and use of a two part inquiry form. This form had been previously developed by Kiewit-Standard (a joint venture) and effectively employed at the Chief Joseph Dam project. The form was initiated by the contractor, detailing his inquiry on the top half of the form with room at the bottom for the Resident office response. The form was a carbonless multiple copy format to allow document tracking and a hard copy for both the Resident office and the contractor. The Resident Engineer's policy of using serial letters to confirm actions which had been discussed and agreed upon was particularly effective in reducing misunderstandings and miscommunications with contractors and helped resolve many issues before they reached the claim status.

Many manhours of effort were expended in maintaining a composite index of claims and related correspondence. Future projects would do well to take advantage of computer systems to assist in the management of the claims process in this regard. The procedure of systematically entering the Engineer's and the Contractor's serial letter number, subject and contract number into a retrievable file by key word or other identifier would materially reduce the amount of effort in determining the last and next administrative action. With no computer assistance available, logs of correspondence were kept by hand. The tedious process of researching and securing all correspondence related to a specific issue or claim was often the single most time consuming element of the resolution process. The benefits of increased accuracy, completeness of research, and decreased manpower made possible by a computerized system on a project of this size would be extremely great.

While some early reluctance was voiced by certain City liaison engineers regarding reimbursement for costs resulting from disruptive change orders, in-house coordination meetings confirmed the legal consistency of such contractor charges even though the project documents were silent on the subject of extended costs.

Although there was an early-project opinion by members of the City's Engineering Department that the Corps was traditionally too lenient with contractors on thier demands for extra work reimbursement, the Residency's analysis of direct and extended costs of extra work and delays reassured critics as to the reasonableness of the Corps' procedures. The methodical, reasonable approach followed in claims analysis by the Residency's claims analyst was eventually accepted with confidence by the city.

The development and use of cyclically formatted, time scaled precedence network summaries and detailed diagrams by the construction contractors were extremely useful. These summaries and diagrams aided in the management of construction, determination of before-the-fact time extensions and resolution of claims. One of the contractors employed a unique and functional method of using the diagrams. Time-now lines drawn vertically through the diagram from the horizontally depicted feature-of-work to the appropriate completion percentage readily depicted scheduling problems to both contractor and government personnel alike. Computer printouts and non-time scaled theoretical progress charts were required in the formulation of bidding documents and contracts. These printouts and charts were not nearly as effective as the computer-assisted, critical path scheduling techniques utilized by the contractors. The requirements for printouts and non-time scaled theoretical progress charts should be dropped in favor of the critical path scheduling method.

The process for resolving time extension claims was particularly difficult to develop. The Chief's office representative at the NAS School and the Seattle District were unable to agree on an interpretation of the contract standard clause related to time extensions. The disparity in interpretations was so great the Resident Office was instructed to disregard all construction progress reports when evaluating claims for additional time. This was not acceptable to the City's project managers. They opted for the more traditional approach where float time and its effects are considered on claims for time extension, and they instructed the Resident

Office to approach such claims in this manner. The City further recognized that float could be used to offset the amount of delay but that the contractor was entitled to consideration of additional reimbursement for the extended time (within the project period) that the contractor had to remain on the jobsite as a result of delays caused by changes.

The successes of the claim processing system flow from the collective experiences of a large number of people, and, in particular, those of the Resident Engineer. His consistently applied policy of defining contractual relationships and roles helped all parties grow into these roles and relationships as they continued to be defined. This and similar policies directed toward defining contractor obligations, duties and limitations helped establish and develop the process used for claims resolution. This evolution of the claims resolution process provided a working environment where all parties involved could maintain their individual contractual identities in a manner which was assertive of their own rights and yet protective of the rights of others. It was this process, developed with the cooperative assistance of all contractual individuals that provided the means for an agreeable, timely, and therefore successful resolution of all change orders and claims which, in turn, contributed to the ultimate successful conclusion of the project.

Chapter 7

LESSONS LEARNED

The involvement of the Corps on the City of Seattle owned West Seattle Bridge Project was the result of a unique chain of events culminating in a hybrid application of project management in the Corps' work for others. This led to a number of insights and realizations specific to this one project. These bits of wisdom have been discussed in the various sections of this history and may prove valid for some future researchers' specific area of interest.

One major lesson does stand out as applicable to any such future relationship which may be entered into by the Corps: the Corps should be delegated contracting officer authority. This one major point would have significantly reduced or eliminated the major contentions involving the City/Corps relationship. In spite of this, the venture can only be considered a huge success.

This one instance of the Corps' work for others is a true model of the satisfaction such work can bring. Because of the public popularity of the project, its distinct visibility, its quality construction provided on time and well below the City's forecasted cost, feelings of professional pride and a sense of meaningful, well-appreciated accomplishment are held by all of those who participated in this grand undertaking.

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