DOCUMENTATION OF THE DESIGN AND CONSTRUCTION OF THE NEW TACOMA NARROWS BRIDGE

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Planning and Capital Program Management

Research Report

DOCUMENTATION OF THE DESIGN AND CONSTRUCTION OF THE NEW TACOMA NARROWS BRIDGE

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DISCLAIMER

No part of the research that is proposed in this report is going to be funded from bridge tolls unless it was a normal part of the design, construction, or operation of the Tacoma Narrows Bridge.

INTRODUCTION

The newest Tacoma Narrows Bridge will be the largest suspension bridge built in the United States in 40 years. It will also be the first project completed under Washington State's Public-Private Initiatives Act. This study outlines the documentation plan for the design and construction of the new Tacoma Narrows Bridge. The plan includes research task orders associated with the design and construction of the bridge relative to: public relations/educational opportunities, written documentation, and potential research.

BACKGROUND

The design and construction of the first Tacoma Narrows Bridge in the late 1930's, was described as a feat of engineering excellence and as a triumph of man over nature. The bridge was built to connect Washington's Olympic Peninsula to the rest of the state with hopes that the region would experience prosperity and development. The slender bridge design was considered to be state-of-art. Existing construction videos from the project show that there were hundreds of workers on the bridge at that time and tours of the construction site for lay-people were common. Press coverage of the project was largely positive, with the exception of editorials written by those opposed to tolls on the bridge. The Tacoma Narrows Bridge was completed in June of 1940 and collapsed in approximately 40 mph winds in November of that same year.

Much of the building material from that bridge (particularly the steel) was salvaged to contribute to the war effort in the early 1940s, though parts of the bridge deck remain at the bottom of the Narrows (the area has been included on the National Historic Register). Forensic investigations into the cause of the collapse were undertaken in the early 1940's for both insurance and research purposes. Over $4 million was recovered from the insurance company after legal battles, but perhaps even more valuable were the research findings regarding suspension bridge behavior in wind. It was found that the bridge's slenderness had contributed to its failure. Efforts to rebuild the bridge (with a more robust design) were not seriously considered until the late 1940's following World War II.

The design and construction of the second Tacoma Narrows Bridge (which was sometimes called "Sturdy Gertie," though the nickname never did become that well-known), was documented primarily in terms of wind-resistance. Much of the historical literature in WSDOT's library in Olympia contains information about how the design of the second bridge differs from that of the first and how much more wind-resistant the newer bridge is. Video footage taken during construction of the second Tacoma Narrows Bridge shows that, again, a large number of workers were employed on the project. There were no historical documents found that show opposition to tolls on the second Tacoma Narrows Bridge. The new bridge was opened in October of 1950, and with higher usage than anticipated, tolls was discontinued earlier than expected.

Construction of the most recent Tacoma Narrows Bridge may start soon. The project has been a highly controversial one, with strong opposition to tolling in particular including negative media coverage. The newest bridge will parallel the existing bridge and will be built with concrete towers, as opposed to steel.

PROCEDURE

Developing a plan for the documentation of the newest Tacoma Narrows Bridge Project involved several steps. First, it was necessary to develop a study scope, then to review historical documents to better understand how the design and construction of the first two bridges were documented, and to interview those familiar with the new bridge's design and construction to gain a better understanding of its unique qualities.

This effort began with a meeting in March of 2000 with Rhonda Brooks of WSDOT's Public Private Initiatives Program as well as Tom Horkan, United Infrastructure of Washington's (UIW) Project Manager for the Tacoma Narrows Bridge project and Jim Metcalf, the Manager of Public Involvement and Project Development for the project for UIW. During that meeting, the project was broadly defined.

The next phase of this study included a literature search in the libraries of the University of Washington, the WSDOT Library in Olympia and materials at UIW's Tacoma office. A visit to the Gig Harbor Peninsula Historical Society and Museum was made to view the collection of Tacoma Narrows Bridge materials located there. This information was presented to Rhonda Brooks at a meeting in June 2000 in Olympia. She then suggested a list of personnel involved with the project to contact for interviews.

Interviewees included Linea Laird, State Maintenance Engineer for WSDOT (based in Tacoma), Russ McCarty, Manager of Toll Systems for UIW, Manuel Rondon, Project Manager from Tacoma Narrows Constructors, Scott Steingraber and Steve Wuthrich, Design and Construction Managers for Tacoma Narrows Constructors and Tim Moore, a Structural Engineer for WSDOT. Interviewees were asked a variety of questions about the unique qualities of this project from the perspective of their specialization, the challenges associated with the project and the types of documentation they would most like to see for this project. Contact was also made with several professors at the University of Washington as to the types of research desirable with respect to the design and construction of the new bridge.

A web site for this project was also developed (it can be viewed at http://students.washington.edu/mmcfly/narrows.html). Information available on the web site included the scope and goals of this project, a brief history of Tacoma Narrows Bridges, and links to other relevant sites. All interviewees were referred to the web site prior to the interview in order to better understand this study.

A meeting was held in Olympia in August with Rhonda Brooks and John Heinley, Research Program Manager for WSDOT's Economic Partnerships Office. At that meeting, a list of possible candidates for the expert panel was developed.

In September, a visit was made to the current Tacoma Narrows Bridge to gain insight into the actual dimension of this construction project and to view, firsthand, the conditions that designers and builders face.

Three documentation plans have been developed since that meeting. The first is a public-relations/educational plan to document the design and construction of the bridge. The second is a research plan, and the third is a general documentation plan to record the design and construction as a part of history.

RESULTS

Findings from the literature review and interview responses were compiled and are included as appendices to this document. Appendix A of this document contains a listing of historical materials that are relevant to this project. Appendix B is a summary table that organizes the questions and responses from interviews. Appendix C is a listing of individuals for the expert panel that assisted in the development of the research program.

ANALYSIS

Included in this report (Appendix D) are three separate documentation strategies: a public relations/education plan, a documentation plan and a research plan.

The first details a plan to document the bridge's design and construction using public relations and educational tools, a construction observation site and a hands-on bridge-building activity for K-12 students. The goal of this plan is to educate the public about the project during construction, and to promote interest in engineering and construction-related fields among students.

The second plan is intended to document the design and construction as a historical event with news coverage of the project as well as the production of books and a documentary film. Again, the newest Tacoma Narrows Bridge will be the largest suspension bridge to be built in the United States in 40 years, and the relative fame (or infamy) of previous efforts at bridging the Narrows have caused the public to take a strong interest.

The third plan is an outline for possible research projects pertaining to bridge design and construction and to identify funding sources for those projects. Because large suspension bridges are rarely constructed in the United States, this project provides a unique opportunity to improve suspension bridge design and construction methods through the examination of current practices.

SUMMARY

People have differing reasons for being interested in the newest Tacoma Narrows Bridge Project. A great many of them have seen the fascinating footage of Galloping Gertie as she took her final ride. Some are interested in bridge design and construction practices (note the recent success of PBS's "Building Big" series), and some are just interested in avoiding a toll every morning during their commute. But whatever the interest, everyone should have access to information about the project.

"A signature project," that's what Manuel Rondon, Tacoma Narrows Constructor's Project Manager called the newest Tacoma Narrows Bridge Project. The world is watching as this project moves forward. In this information age, the public should be able to access the highest quality information available, and rapidly. That is why it is so important to plan for a variety of documentation strategies that will be accessible to all.

APPENDIX A: RELEVANT DOCUMENTS

WSDOT

The following materials are located at the WSDOT Bridge Office in Lacey, Washington (Tim Moore):

Washington State Department of Transportation. Final Report on Design and Construction of the Tacoma Narrows Bridge. 1940.

Washington State Department of Transportation. Final Report on Construction of the Substructure of the Tacoma Narrows Bridge. 1940.

Washington State Department of Transportation. Final Report on the Design of the Superstructure of the Tacoma Narrows Bridge. 1940.

Washington State Department of Transportation. Final Report on Surveying, Tacoma Narrows Bridge. 1940.

Washington State Department of Transportation. Tacoma Narrows Bridge Pier Investigation. 1946.

Washington State Department of Transportation. Hydraulic Jack Tests. 1950.

Washington State Department of Transportation. Tower Repair Due to Fire During Construction of the Tacoma Narrows Bridge. 1950.

Washington State Department of Transportation. Final Report on the Reconstruction of the Tacoma Narrows Bridge. 1950.

Washington State Department of Transportation. Seismic Vulnerability Study: Tacoma Narrows Bridge. 1990's.

Washington State Department of Transportation. Condition Survey: Tacoma Narrows Bridge. 1986.

The following videos are available at the WSDOT Library in Olympia, WA:

Washington State Department of Transportation. "Tacoma Narrows Bridge Construction Videos." 1940 and 1950.

Video. "Bridging the Future." Modern.

The WSDOT library also has a variety of newspaper clippings, toll booklets from the Tacoma Narrows Bridges completed in 1940 and 1950, and Washington Toll Bridge Authority fliers.

United Infrastructure of Washington

The following materials are located at United Infrastructure of Washington's Tacoma office:

Washington Toll Bridge Authority. The Redesign of the Tacoma Narrows Bridge. Late-1940's.

Board of Engineers: O. Ammann, T. von Karman, and G. Woodruff. The Failure of the Tacoma Narrows Bridge. 1941

C.E. Andrew. Final Report on the Tacoma Narrows Bridge. 1952.

University of Washington Engineering Library

Joe Gotchy. Bridging the Narrows. 1980's.

Farquharson, F. B. Bulletins: Engineering Experimental Station, University of Washington--Investigations Prior to October, 1941. 1941.

Gig Harbor Peninsula Historical Museum

Gig Harbor Peninsula Historical Society and Museum. A History of the Tacoma Narrows Bridge. Display. August-October, 2000.

"Gertie Gallops Again." Documentary film. 1980's.

APPENDIX B: INTERVIEW QUESTIONS/RESPONSES

(1) Linea Laird—WSDOT

(2) Russ McCarty—UIW

(3) Manuel Rondon, Scott Steingraber, Steve Wuthrich—TNC

(4) Tim Moore—WSDOT

<table>
<tr><th rowspan="3">Questions</th><th colspan="4">Response Groupings</th></tr>
<tr><th rowspan="2">Public Involvement</th><th rowspan="2">Project Development</th><th colspan="2">Detail/Technical</th></tr>
<tr><th>Design</th><th>Construction</th></tr>
<tr><td>What do you think is unique about the newest Tacoma Narrows Bridge?</td><td>(1) -Highly scrutinized (by opponents)
-Lots of public involvement was required

(2) –Efficiency (or lack thereof) of Pierce Transit (70% of riders transfer)

(3) -"Signature project" (everyone has been following Tacoma Narrows Bridges since the collapse)
-Largest suspension. bridge built in US in last 40 years.</td><td>(1) -Suspension bridge
-design/build
-public/ private

(3) -Lump sum pricing
-Team (TNC) includes different contractors
-Contractors "teaming" with WSDOT

(4) –design/build
-developer financed
-Suspension bridge</td><td>(1) Foundations in deep water w/currents

(2) -No national standards exist for tolling (using California's Title 21 standards)

(3) -Proximity of new bridge
-Upgrade of existing bridge (changing wind response, internal cable evaluation

(4) -Capability for 2nd deck
-New deck type for WSDOT (orthotropic)
-Micro-silica concrete (not used that often)</td><td>(1) Caissons not often used (rather dual shaft)

(3) - Proximity of new bridge

(4) -Caisson tower foundation construction methods
-Micro-silica concrete (not used that often)</td></tr>
<tr><td>What type of research is currently being done that should/could apply to the newest TNB project?</td><td>(2) -Use of electronic tolling devices for other purposes (drive throughs)</td><td>No responses</td><td>(2) -Vehicle profiling

(3) -Wind factor effects in side-by-sides suspension bridges
-Scour analysis (2 large piers close together)

(4) -Seismic retrofit of suspension bridges
-Suspension cable corrosion
-Caisson scour with 2 caissons (HEC 18 Program at Colorado State University being used—unsuccessfully
-Fatigue on welds (Lehigh University)</td><td>(3) -Control tension cable spinning

(4) -Concrete permeability (corrosion of reinforcing steel in contact with seawater)
-performance of asphalt deck overlay (specialty asphalt, dissimilar to underlying steel)</td></tr>
</table>

<table>
<tr><th rowspan="3">Questions</th><th colspan="4">Response Groupings</th></tr>
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<tr><th>Design</th><th>Construction</th></tr>
<tr><td>What types of research opportunities (in your field) do you feel should be available on this project?</td><td>(2) -Effects of tolling on "discretionary" trips
-Effects of a toll bridge on transit use</td><td>(1) -Comparison of this project to Carquinas (time-frame, cost, design build vs. bid build)</td><td>(1) -Epoxy coat rebar? (perm. of concrete at bottom of foundations)

(3) -Wind effects on side-by-side suspension bridges
-Use of concrete towers
-Wind response in current bridge when deck grates are removed.

(4) -Aerodynamics of suspension bridges
-Orthotropic deck plate and asphalt deck overlay</td><td>(1) -Wet cure time of concrete prior to exposure to saltwater
-Effects of pumping concrete great distances

(3) -Caissons: turning, sinking too fast, interaction of two at close proximity (scouring vortices)
-Permeability of fly ash concrete
-Feasibility of long-range concrete pumping
-Effects of long-range concrete pumping on air content

(4) -Suspension cable corrosion (attributed to construction methods)
-Live load deflection ratios >L/300 (will they cause out-of-plane stresses in floor members, floor beams or truss connections?)
-Caisson scour (physical model testing)</td></tr>
<tr><td>How would you like to see the construction documented?</td><td>(1) -Coffee table book (i.e. Bechtel: Building a Century)

(3) -Coffee table book
-Viewing Deck

(4) –Viewing deck (possible location on north side of bridge on Gig Harbor side of Narrows)</td><td>No Responses</td><td>(3) -Technical book (helpful to next bridge builders—include both successes and failures</td><td>(1) –Diary (what went well as well as what went NOT so well)

(2) -Camera that takes photos at regular intervals (not digital or web—real film)

(4) –Interesting semi-technical book (i.e. Bridging the Narrows by Joe Gotchy)
-Keep good inspector records
-Footage of Construction</td></tr>
</table>

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<tr><th rowspan="3">Questions</th><th colspan="4">Response Groupings</th></tr>
<tr><th rowspan="2">Public Involvement</th><th rowspan="2">Project Development</th><th colspan="2">Detail/Technical</th></tr>
<tr><th>Design</th><th>Construction</th></tr>
<tr><td>What are some problems that may be encountered during construction?</td><td>(1) –Traffic

(3) –Too many "visitors" to the site
-Working within right-of-way</td><td>(1) -Meeting minority goals (among workers)

(4) –High costs associated with construction methods.</td><td>(3) –Unknown subsurface soil conditions

(4) –Rehab of existing bridge (poor confinement, splices at critical locations) Some conditions may be difficult to remedy</td><td>(1) –Traffic congestion

(3) –Caisson construction (turning while sinking, cutting too fast or slow)
-Interaction with current bridge
-Re-agitation of concrete to maintain air content
-Amount of material/equipment used in cable spinning may be difficult to fit in such a small area.

(4) –Lots of welding involved (effects on cost, fatigue stress, labor, etc.)
-Special asphalt being used (not used by paving companies in this area)
-Corrosion on cables of existing bridge (how much is not known)
-Possible hazardous materials involved in rehab of existing bridge (lead-based paints, etc.)</td></tr>
<tr><td>What measures are being taken to mitigate the impacts of construction on the environment?</td><td>(2) –Public cooperation in using electronic tolling will reduce emissions (from waiting in line at toll facilities)</td><td>(1) -Spill protection plan
-Pollution control plan</td><td>(2) –None are necessary where toll facilities are concerned (see EIS)

(3) –See EIS</td><td>(1) –Noise, lights kept to minimum
-Typical measures (i.e. silt fences, straw bales, rock-lined ditches, cleaning pads for truck tires, etc.)
-See EIS

(3) –See EIS

(4) –Dredged material will be evaluated for hazardous substances and a site for dumping will be determined based on that evaluation.</td></tr>
</table>

Questions	Response Groupings			
	Public Involvement	Project Development	Detail/Technical	
			Design	Construction
How is the partnership between UIW and WSDOT working?	No Responses	(4) –Price may be higher than "normal" (due to risk associated)	(1) –Seems like UIW wants more info. at times. They were only given WSDOT's standards and design manuals for the project and have had to come up with a design with less input from the state than usual. (3) –Strong partnership -"Task-force" environment (4) –Cooperative	(4) –WSDOT's role in construction will be very limited.

APPENDIX C: INVITED RESEARCH PANEL

NAME	AGENCY
Steve Kramer	UW (Geotechnical Engineer)
John Stanton	UW (Structural Engineer)
David McLean	WSU (Structural Engineer)
Rafik Itani	WSU (Structural Engineer)
Tim Moore	WSDOT (Bridge Office)
Marty Pietz/Doug Brodine	WSDOT (Research)
Chris Keegan	WSDOT (Olympic Region Operations)
Nabil Dbaibo	WSDOT (Geotechnical Lab)
Toby Rickman	WSDOT (Traffic)
Manual Rondon	Tacoma Narrows Constructors
Tom Horkan	United Infrastructure

RESEARCH PANEL ATTENDEES Dec 8, 2000

NAME	AGENCY
Steve Kramer	UW (Geotechnical Engineer)
John Stanton	UW (Structural Engineer)
David McLean	WSU (Structural Engineer)
Linea Laird	WSDOT (Tacoma Office)
Tim Moore	WSDOT (Bridge Office)
Jerry Ellis	WSDOT (Economic Partnerships Office)
Chris Keegan	WSDOT (Olympic Region Operations)
Nabil Dbaibo	WSDOT (Geotechnical Lab)
Toby Rickman	WSDOT (Traffic Engineer)
John Nesbit	WSDOT (Transportation Engineer)
Tom Horkan	United Infrastructure
Joe Mahoney	UW (Construction/Transportation Engineer)
Scott Rutherford	UW (Transportation Engineer)

APPENDIX D: DOCUMENTATION PLANS PUBLIC RELATIONS/EDUCATION

PROBLEM STATEMENT

The purpose of this project is to allow the Washington State Department of Transportation (WSDOT) to document the design and construction of the newest Tacoma Narrows Bridge in a manner that will relay valuable information to the public and will provide educational opportunities for students.

BACKGROUND

The newest Tacoma Narrows Bridge will be the largest suspension bridge built in the United States in the last 40 years. It will also be Washington State's first project completed under its Public-Private Initiatives Act. The use of new technology in the documentation effort will set this bridge apart from its predecessors and will ensure that the story of its landmark construction will be preserved as an important part of Washington's history.

OBJECTIVES

The objectives of this project are as follows:

1) to encourage public involvement by developing a Tacoma Narrows Bridge web site with live web camera access

2) to plan the construction of an observation site (including location, size, parking, accessibility, available technology and staffing) from which viewers can watch construction of the bridge take place

3) to make educational materials available for students (grades K-12 as well as college-level)

BENEFITS

The Internet is a technology that has revolutionized the way the public receives information and the way students learn—both in and out of the classroom. Providing access to information about the design and construction of the newest Tacoma Narrows Bridge over the Internet is key to the success of the project from a public relations and education standpoint.

Documentation via live web cams during construction will satisfy the curiosity of many local citizens about the project and will help to alleviate traffic congestion and attempted site visitations. A construction observation site would also allow the public to watch the bridge being built without trying to enter the project site. In addition an observation site would act as a learning tool by featuring interpretive talks (regarding the construction process as well as the history of bridges across the Tacoma Narrows) led by observation site staff and on-site access to the project web site.

This project will provide educators with interesting and applicable teaching materials that will stimulate interest in engineering and construction-related fields among students. And the use of technology like the Internet in the documentation effort is a valuable learning tool in itself.

PRODUCTS

The products of this project will be:

1) a project web site including variations for K-12 and college-level students

2) a construction observation site

3) instructions for conducting local bridge-building competitions with K-12 students

WORK PLAN

Task 1—Review project purpose

Meet with project personnel to gain perspective on how the project should proceed.

Task 2—Web development

a) **Live coverage**--Develop a web site for the project. The web site will include live streaming video coverage of the construction. Video cameras will be set up at two locations (one on each side of the narrows) facing construction. When tower construction begins, two additional cameras will be set up closer to the construction (possibly on the existing bridge). Using the streaming video coverage, web site users will also be able to view the entire building of the bridge (from day-1 until "present") as a high-speed video clip.

b) **Historical information--**The web site will also include a link with historical information about the Tacoma Narrows Bridges. The historical portion should include information about the conception and construction of Galloping Gertie, it's collapse and the reconstruction of the bridge in 1950.

c) **Construction timeline**--A detailed construction timeline will be included on the TNB web site. The timeline will include all milestones in the bridge construction process. Tentative dates for those processes that have not already begun will be included. From the timeline, the user will be able to link to descriptions of each process and its purpose in terms that can be easily understood by an average adult (i.e. www.bigdig.com). Processes that will be included in this section include sinking of the caissons and cable spinning. Other processes that may be included are anchorage construction, tower construction, deck placement and paving. Photos of the equipment and materials used in each process will also be included.

d) **Virtual tour**--Also available on the web site will be a virtual tour of the bridge. A user will be able to view a computer-animated drive across the finished bridge. In addition, a schematic drawing of the finished bridge will be available with links from each segment of the drawing to a close-up picture of the part and a description of its purpose. (As an example: http://www.discovery.com/stories/technology/buildings/bridges.html)

e) **Toll information**--Because tolls have been the main focus of the bridge's opponents, true information about tolls must be included on the web site. The figures and information included in the newsletter distributed by United Infrastructure Washington (May, 2000) should be included. These include the expected toll schedule (with both upside and downside cases included), current tolls from other toll bridges in the United States and elsewhere, and a graph representing the vehicle toll rate on the TNB over the next 40 years adjusted for inflation. A discussion of present vs. future worth will also be included on this page. Finally, the tolls from the first two TNBs (in 1940 and in 1950) converted to year-2000 dollars must be included to represent how much less (relatively) toll-payers will be paying in tolls for each trip across this bridge.

f) **Environmental information**--A limited amount of environmental information will be included on the TNB web site. Environmental issues that will be included are those that have been targeted by the media recently (i.e. ESA, HAZMat, noise) and measures that are being taken to mitigate the impacts of construction in each of those areas.

Other information that must be included in the environmental part of the web site are those areas that will be positively impacted by the construction of the newest TNB. For instance, there will be a reduction in air pollution as the flow of traffic improves (due to an increase in the number of lanes crossing the Narrows). Improvements have also been planned for the retention and treatment of storm water run-off from the bridge.

g) **Additional features**--Other features that will be added to the web site include recent news articles and updates on changes in the construction schedule, maps of the affected area, and traffic revisions in the area. Also included will be contact information for the offices (PR people) of the construction team and WSDOT.

Task 3—Educational web variations

The TNB web site will be reproduced (with some changes) to act as a learning aid for K-12 students. Simplified variations on the history of the TNB, the construction processes, and the environment will be used on this web site. Also available will be plans to build a replica of the new TNB and ways to test the model. Users should also have the capability to email questions to an engineer about bridges, bridge design and bridge construction and receive responses within a few days (the emails can be distributed to volunteer experts by whomever maintains the web site). Interesting questions and responses will be posted on a list of FAQs.

The TNB web site will also have a link to an engineer's web site. This site will provide engineering students with a more in-depth discussion of the bridge design and some of the construction processes being used. This page will also give engineering students the opportunity to email bridge engineers with questions (questions will be distributed to experts, again, by whomever maintains the site). In addition, users will have the ability to distribute load data for use in college design classes. Those leading the documentation effort will also assess the possibility of assistance from college-level student interns on this project.

Task 4—Facilitate a bridge building contest

Another educational project that will be developed is a bridge building contest for students. The rules and judging criteria will be developed and distributed to allow school districts to hold competitions without involving outside agencies.

Task 5—Construction of an observation site

To enable members of the public to view the construction of the bridge without the danger of visiting the construction site, an observation deck will be constructed somewhere along the shoreline. A worker at the observation deck should be available for several hours each day to describe the construction processes that are taking place and to discuss the history of the TNBs. Also available at the observation site will be binoculars for better viewing the construction and monitors to access the bridge web site.

BUDGET

Task	Estimated Cost	Type/Duration of Cost
1) Review	$3,000	Startup/One-time
2.1) Cameras	$100,000	Startup/One-time
2.2) Web Site	$100,000 + $20K/yr	Startup/Ongoing
3) Educational Web Site	$50,000 + $10K/yr	Startup/Ongoing
4) Bridge Building Contest	$25,000	Startup/One-time
5.1) Construction Observation Site	$200,000 - $400,000	Startup/One-time
5.2) Site Access	$100,000 - $300,000	Startup/One-time

PROJECT DOCUMENTATION

PROBLEM STATEMENT

The purpose of this project is to allow the Washington State Department of Transportation (WSDOT) to document the design and construction of the new Tacoma Narrows Bridge. The documentation will be in the form of a children's book, a "coffee table" book and a technical book as well as a documentary film.

BACKGROUND

The newest Tacoma Narrows Bridge will be the largest suspension bridge built in the United States in the last 40 years. It will also be Washington State's first project completed under the state's Public-Private Initiatives Act. The bridge will make history in many ways and the documentation of its design and construction will ensure that the story of this monumental effort is preserved.

OBJECTIVES

The objective of the project is to document the design and construction of the bridge from both a technical and a public interest standpoint.

BENEFITS

The Tacoma Narrows Bridge has both state and international implications for the future finance, design and construction of suspension bridges and therefore needs to be carefully documented. Technical information that is recorded regarding the design and construction of this bridge will aid bridge designers and builders in providing safe and efficient bridges in the future. Photo and video documentation of this project will allow residents of the State of Washington to take pride in the achievements of its industry. Documentation aimed at children will encourage interest in engineering and construction fields—which are integral to Washington's economy, now and in the future. The documentation of the design and construction of this bridge will serve as a reminder of this great accomplishment and is sure to become a vital part of Washington State's history.

PRODUCTS

The products of this project will be:

1) a children's book describing the history of Tacoma Narrows Bridges as well as the construction of the newest bridge

2) a coffee table book including both historical photos and pictures of the construction of the new bridge as well as supporting text

3) a video documentary focusing on the construction of the new TNB but also including a limited amount of historical information

4) a technical book detailing the design and construction of the bridge.

WORK PLAN

Task 1—Review project purpose

Meet with project personnel as well as the project staff to gain perspective on how this project should proceed.

Task 2—News coverage

Local news stations will cover the construction of the new bridge. Included in the news coverage will be information about traffic revisions and construction scheduling. Local news stations that participate will also be allowed to have a film crew on-site during specified days and times to film the construction and to conduct brief interviews with workers and managers in order to inform the public of the progress that is taking place.

Task 3—Produce a documentary video

A video documentary will be produced after construction is finished to tell the story of the newest bridge. The documentary will include footage of all phases of the construction, from ground breaking to grand opening, but will focus on the most interesting and unusual aspects of this bridge's construction—particularly the sinking of the caissons and the spinning of the cables.

The design and construction managers as well as some of the workers will be interviewed during and after construction to provide insight into the more interesting and challenging aspects of the project. Footage from those interviews will be included in the documentary.

Because a great deal of public interest in the project is a result of the collapse of the first Tacoma Narrows Bridge 60 years ago, a brief history of the previous two bridges must be included. Footage from the construction of the first two Tacoma Narrows Bridges will also allow viewers to compare construction practices and technologies that have been developed in the last 60 years.

Task 4—Produce a coffee table book

Throughout the design and construction of the bridge, information and pictures will be gathered and will finally be compiled into a coffee table book. As the history of Tacoma Narrows Bridges is so well known, a brief history and some historical photos will be included, but the book will primarily focus on the construction of the newest bridge and will include mainly photos with supplemental text. Interesting quotes from interviews with design and construction managers as well as workers will also be included.

Task 5—Develop a children's book

A book for grade school aged children will also be produced. The book will include a history of Tacoma Narrows Bridges, an explanation for the collapse of the first bridge, and a discussion of why it is important to build another bridge (all in terms that are easily understood by children).

Task 6—Produce a technical book

A technical book will also be produced. This book will aid future bridge engineers in the design of suspension bridges under similar conditions. The book will include information about innovative construction processes that were applied and their results as well as interesting research projects that were carried out during design and construction. Interviews with managers and workers will also be included in the technical book, as will technical drawings of the bridge.

BUDGET

Task	Estimated Cost	Type/Duration of Cost
1) Review	$3,000	Startup/One-time
2) News Coverage	$10,000/yr	Ongoing/Annual
3) Documentary Video	$175,000	Startup/One-time
4) Coffee Table Book	$40,000	Startup/One-time
5) Children's Book	$25,000	Startup/One-time
6) Technical Book	$30,000	Startup/One-time

RESEARCH

PROBLEM STATEMENT

The purpose of this project is to promote learning regarding suspension bridge design and construction by developing research opportunities in those fields.

BACKGROUND

The newest Tacoma Narrows Bridge will be the largest suspension bridge built in the United States in the last 40 years. Because suspension bridges are not often built, it is important to take this opportunity to assess design and construction techniques and to evaluate the finished product with expectations for improvement in future methods.

OBJECTIVES

The objectives of the project are to provide relevant research opportunities in the fields of structural engineering, construction engineering and management, transportation and planning and environmental engineering and water resources.

BENEFITS

The Tacoma Narrows Bridge has international implications for the future design and construction of suspension bridges and should be carefully studied. This effort will provide the scientific community with opportunities to research suspension bridge design and construction in order to produce safer, more efficient bridges in the future.

PRODUCTS

The products of this project will be research on important aspects of the bridge design and construction.

RESEARCH COST ESTIMATES

Task	Estimated Cost	Type/Duration of Cost
Structures		
1) Scour	See Project 1) in Geotech	
2) Deck pavement interaction	$250K + $30K/yr for 10 yr	Startup/Ongoing
3) Bridge Motion	$400K + $50K/yr for 2 yr	Startup/Ongoing
4) Crack Detection	$50K	Startup/Normal Maint.
Geotechnical		
1) Scour	$300K + $50K/yr for 4 yr	Startup/Ongoing
2) Slope Stability	Materials Lab Funding	Startup/Ongoing
3) Seismic	Materials Lab Funding	Startup/Ongoing
Operations		
1) Painting Model	$150K	Startup/One Time
2) Local Traffic Patterns	$ 300K	Startup/One Time
3) Regional Diversion	$75K to $200K	Startup/One Time
4) Land Use Impacts	$500K over 20 years	Startup/Ongoing
5) Environmental	$350K	Startup/One Time
6) Travel Information	$200K	Startup/One Time

RESEARCH FUNDING SOURCES

Structures Projects

Project 1: Scour	See Geotechnical Project 1
Project 2: Steel/Asphalt Interaction	National Science Foundation
Project 3: Wind/Earthquake Effects	Federal Highway Administration
Project 4: Crack Detection	WSDOT Structures Office

Geotechnical Projects

Project 1: Scour	United Infrastructure of Washington WSDOT National Science Foundation Federal Highway Administration
Project 2: Slope Stability	WSDOT Geotechnical Section
Project 3: Seismic Considerations	WSDOT Bridge and Geotechnical Sections

Operations Projects

Project 1: Painting Model	Federal Highway Administration National Cooperative Highway Research Program
Project 2: Local Traffic Patterns	Puget Sound Regional Council
Project 3: Regional Diversion	National Cooperative Highway Research Program Puget Sound Regional Council Congressional Earmark
Project 4: Land Use Impacts	Lincoln Land Institute National Cooperative Highway Research Program Congressional Earmark
Project 5: Environmental Impacts	Environmental Protection Agency Washington State Department of Ecology
Project 6: Travel Information	USDOT ITS Office National Cooperative Highway Research Program

Tacoma Narrows Bridge
Research Opportunities Panel Meeting
December 8, 2000

Breakout Discussion for Structural Research

1) Scour

Description

Existing scour models have predicted that the construction of caissons for the new bridge will have implications as far as scour is concerned. This study would evaluate the impacts of the caissons constructed for the new bridge—both during and after construction.

Outcome

Evaluation of caisson construction methods used and possible scour model.

Cost & Time

See estimate for Project #1 under the Geotechnical section.

2) Steel deck/Asphalt concrete pavement interaction

Description

An orthotropic deck was chosen in the design for its light weight. The bridge deck will be fully continuous with joints at either end. The asphalt and steel have different thermal properties, so it is important to monitor the differential movements between the steel orthotropic deck and asphalt concrete pavements and how temperature affects those movements.

Outcome

Model linking temperature recordings to differential movements between orthotropic steel deck and asphalt concrete pavement.

Cost & Time

An initial setup cost of $250,000 plus $30,000/yr for at least 10 years.

3) Bridge motion due to wind and earthquake loading

Description

The current Tacoma Narrows Bridge was constructed with grates along the deck that allow wind to pass through without producing motion. In designs for the retrofit of that bridge, the grates have been removed, and wind tunnel testing of that design has shown that accelerations may be outside of the acceptable range. While the design will be modified to produce more acceptable results, data can be collected on the current bridge and on the new bridge to monitor the effectiveness of assumptions that were made in design. Also, because the two bridges are being built close together, their interaction with one another under wind loading should also be monitored. With instrumentation in place to monitor motion under wind loading, motion in an earthquake might also be measured.

Outcome

Data describing side-by-side suspension bridge behavior under wind and earthquake loading.

Cost & Time

Setup cost of $400,000 plus $50,000/year for two years.

4) Crack Detection

Description

Crack detection paint may be useful to monitor critical points in the orthotropic deck and at connections where cracking is most likely to occur. These locations might include suspender cable connections and on the stiffening truss. The paint makes cracks visible before they could otherwise be seen by the naked eye.

Outcome

Possible improvement in preventative maintenance techniques.

Cost & Time

Application costs of $50,000 plus regular maintenance monitoring of painted areas.

Breakout Discussion for Geotechnical Research

1) Scour

Description

The piers for the new bridge and the existing bridge have not been analyzed as to the potential for scour due to current flow interactions. There is potential for scour based on historical records. Soundings taken in 1940 (first bridge) and 1946 (before construction the current bridge) indicated scour that necessitated placement of riprap near the existing piers. Current flows are very high at both existing Piers 4 and 5 (the main channel piers). The needed work is to monitor scour during construction and long term follow up. The activity can be divided into three broad categories. These are:

- Caisson touchdown (construction)
- Scour due to the proximity of caissons
- Numerical modeling of caisson sinking

Outcomes

The major outcome is knowledge of scour in the vicinity of the piers. Further, new instrumentation might result from this effort. The basic data to be collected includes:

- Scour detection including its location relative to the new and existing piers
- Results that form an excellent case study of scour prediction versus measured (This includes how the scour develops with time)
- The possibly of obtaining "real-time" profiles of foundation soil elevations
- Verification of numerical modeling of caisson installation

Cost and Time

The study duration would be approximately five years. The duration is largely due to the needed long term monitoring. Various interim work products could be produced. Funding could come from several sources for the three focus areas:

- Caisson touchdown—UIW and WSDOT
- Scour due to the proximity of caissons—NSF and FHWA
- Numerical modeling of caisson sinking—NSF and FHWA

An approximate estimate for the total funding is $300,000 for setup and $50,000/year for four years.

2) Slope Stability

Description

Slope stability is primarily a concern in the vicinity of the east abutment. Fortunately, the consensus is that there is little slope stability risk associated with the new anchors and road approaches. However, it is recommended that the anchor blocks be monitored for movements during construction.

Outcome

The gaining of documented information associated with anchor block movements.

Cost and Time

It was agreed that the WSDOT Geotechnical Section should undertake these measurements.

3) Seismic Considerations

Description

A "free field" seismic sensing instrument should be installed and monitored in the vicinity of the new bridge. Additionally, specific monitoring of the new caissons via tilt meters should be done for the purpose of checking lateral stiffness during seismic events and soil-structure interaction.

Outcome

The documentation of information associated with caisson lateral stiffness and soil-structure interaction.

Cost and Time

The study should run for the full duration of bridge construction. The WSDOT Bridge and Geotechnical Sections should undertake the work.

Breakout Discussion for Operations Research

1) Painting Model

Description

In about three years the WSDOT will have a need for research to be done on what constitutes an adequate level of paint maintenance for the new Tacoma Narrows Bridge. This project would include a literature search to uncover information about maintenance standards for bridge painting and the development of a model to minimize long-range bridge paint maintenance.

Outcome

Painting standards and paint model to minimize costs.

Cost & Time

Two years and $150,000 one-time cost.

2) Local Traffic Patterns

Description

This project would research issues such as: operation of ramp meters, diversion of traffic through neighborhoods and the general orientation of traffic. This study will collect before and after traffic data to document the changes in patterns.

Outcomes

Documentation of local traffic pattern changes, operation of ramp meters and neighborhood impacts.

Cost & Time

Three years and $300,000 one-time cost.

4) **Regional Diversion and Tolling**

Description

This project explores the effect tolling the bridge has on regional travel. The project could be done with traffic counts alone but would be more effective if a survey was done at the same time as the surveys done by the ferry system and/or the Puget Sound Regional

Council. Either way information can be gained about regional travel diversions to help provide planning data and an understanding of the impacts from the bridge.

Outcomes

Documentation of regional changes in traffic patterns.

Cost & Time

Three years and $75,000 one-time cost using traffic counts.
Three years and $200,000 one-time cost if done as a survey in conjunction with Washington State Ferries and/or the Puget Sound Regional Council.

4) Land Use Impacts

Description

New transportation links are thought to have an effect on the development of the land being served by the new facility. This is a rare opportunity to measure that effect. The study would collect Land Use data over a twenty-year period to document the impacts on land use of the new bridge.

Outcomes

The project will help assess the validity of assumptions of how transportation projects affect land use.

Cost & Time

Twenty years with expenditures of $100,000 in Years 1, 5, 10, 15, 20.

5) Environmental Issues

Description

The runoff from the new bridge will be treated before being released. The project is intended to monitor the effectiveness of that treatment and experiment with ways that may be more effective and/or cheaper to implement. Several treatment options might be tried in the field to gain insight.

Outcomes

This project could result in waste treatment facilities that are less expensive and/or more effective.

Cost & Time

Three years and a $350,000 one-time cost.

6) Travel Information Market

Description

Travelers currently have access to a wide variety of travel information. The purpose of this project is to assess what information is the most cost-effective for agencies and travelers.

Outcome

An assessment of the cost-effectiveness of travel information.

Cost & Time

Two years and a $200,000 one-time cost.