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Title: Analysis of Best Management Practices in the Columbia River Channel Improvement Project (CRCIP)

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The Columbia River Channel Improvement Project (CRCIP) was constructed along 166.6 km (103.5 miles) of Columbia River (from River Mile 3 to 106.5), which was from Interstate 5 Bridge (between Portland and Vancouver) to the river mouth, before emptying into the Pacific Ocean. It deepened the river by 0.9 m (3-feet), from 12.2 m to 13.1 m (40-foot to 43-foot) depth, in order to provide enough depth for the need of current transportation. The project obtained approval from US Congress after presenting the Benefit-Cost Ratio (BCR) of 1.66. In addition, it also anticipated continued sedimentation, enabling full capacity loads in cargo transportation, as well as providing a positive balance of environmental benefits.

Significant discrepancies in terms of volume, cost and duration in the CRCIP were found after the project completion in fall 2010. With such lingering open-ended questions, this research seeks to clarify these questions by looking into the activities during the project implementation.

Data were collected from the U.S. Army Corps of Engineers (USACE) Feasibility Study and Environmental Impact Statement (FSEIS) in 2003 as well as Final Report Adaptive

Environmental Management (AEM) in 2011. The data were then contrasted with those from opposing parties, such as Northwest Environmental Advocates (NWEA), declaration of Ernie Niemi (an economist), and related news. Data analysis was made by evaluating the methods applied in the dredging work (bathymetric survey), cost breakdown, benefit-cost analysis, as well as time schedule. Post-implementation data/information obtained from the USACE Portland District Office were used as additional input in discussing different viewpoints in the scope of research.

Result showed additional dredging volume of about 32%, which was caused by the extra work of maintenance dredging. This compared to a 7% difference in calculation due to different methods between the dredging of material and its disposal. The difference in the project cost was referred to the point-in-time estimate between year of project initiation and year of its completion. The benefit-cost ratio was verified, despite different opinions from opposing parties about the factors to be included in the project's benefits and costs. Extended project duration was analyzed by assessing the availability of funding for every year of implementation. Most of the funding came from US Congress, thus the amount of its annual disbursement significantly affected the progress of project implementation.

It is recommended to conduct continuing research of the CRCIP with regards to environmental issues. The maintenance phase, which will end this year, could provide some information about the extent of environmental benefits as claimed by the project.

Analysis of Best Management Practices in the Columbia River Channel Improvement Project (CRCIP)

by

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I understand that my thesis will become part of the permanent collection of Oregon State University libraries. My signature below authorizes release of my thesis to any reader upon request.

Denni Ridwan, Author

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GLOSSARY AND ACRONIMS

Name	Definition
AEM	Adaptive Environmental Management
BCR	Benefit-Cost Ratio
CRCIP	Columbia River Channel Improvement Project
CRM	Columbia River Mile
DMMS	Dredged Material Management Study
DQA	Data Quality Act
DSEIS	Draft Supplemental Environmental Impact Statement
DWS	Deep Water Ocean Disposal Site
EA	Environmental Assessment
FSEIS	Feasibility Study and Environmental Impact Statement
FY	Fiscal Year
GIS	Geographic Information System
GPS	Global Positioning System
MCR	Mouth of the Columbia River
NED	National Economic Development
NEPA	National Environmental Policy Act
NJS	North Jetty Site
NMFS	National Marine Fisheries Service
NOAA	National Oceanic and Atmospheric Administration
NWEA	Northwest Environmental Advocates
O&M	Operation and Maintenance
PNWA	Pacific Northwest Association
ROD	Record of Decision
SEI	Sustainable Ecosystems Institute
SONAR	Sound Navigation and Ranging
SWS	Shallow Water Site
USACE	U.S Army Corps of Engineers
USEPA	U.S Environmental Protection Agency
USFWS	U.S Fish and Wildlife Service

Analysis of Best Management Practices in the
Columbia River Channel Improvement Project (CRCIP)

1 Introduction

The Columbia River is the dominant river of the Pacific Northwest in the USA. The river is utilized for various purposes such as recreation, agriculture, fisheries, hydropower, and transportation. In order to make the best use of it, many construction activities are already implemented. One of the big works completed in the river was the dredging work of 166.6 km (103.5 mile)-length from the mouth, fulfilling the need of current ship transportation. The dredging work was aimed to deepen the river along its transportation line, considering the increase in size of the newest generation of manufactured ships. In addition, it was also intended for channel maintenance, which was periodically carried out to keep sedimentation levels at a tolerable thickness at the river bed.

The dredging work, which was officially known as the Columbia River Channel Improvement Project (CRCIP), took five years (2005-2010) to implement. It deepened the channel from 12.2 m to 13.1 m (40-foot to 43-foot) depth. The outcome was additional loads in cargo transportation, i.e. carrying the loads to maximum capacity. The U.S. Army Corps of Engineers (The Corps), as the federal government agency for project implementation, had calculated considerable reduction in cost of transporting goods through the channel which generated the Benefit-Cost Ratio (BCR) of 1.66. For this reason, the project was technically feasible to be implemented.

Initiated in 1989, a massive dredging effort to deepen 166 km (103 miles) of the Columbia River had an objective of securing Oregon's connection to the rest of the world. At 13.1 m (43-feet), the channel, otherwise too shallow to compete with deep-water ports, could become host to today's larger vessels and more efficiently send

Northwest wheat and steel to markets around the globe. Port officials from Portland to Longview had long said that deepening the Columbia River is a matter of survival for upriver ports struggling to compete against bigger, more accessible ports in Seattle, Tacoma and Vancouver, B.C. (Wojahn, 2010).

For more than 100 years, the lower Columbia River navigation channel had been dredged to insure safe passage of cargo ships. The previously existing channel, however, was not deep enough to handle the new generation of larger, deep-draft vessels when they were fully loaded (PNWA, n.d). As these larger ships entered the trade in greater numbers, the channel depth limitation threatened the region's ability to gain efficient access to world markets. This, in turn, impacted regional growers and producers who relied on the channel and the larger vessels to reach world markets at competitive costs.

The Corps identified $18.8 million in annual transportation savings to the nation from channel deepening. For every $1.00 invested, the nation would receive an economic benefit of $1.66 in return (USACE, n.d). There were also significant additional regional economic benefits. Furthermore, the project provided a positive balance of environmental benefits to the region and nation by avoiding environmental impacts where possible, mitigating for unavoidable impacts, and including ecosystem restoration measures that would leave the river better than it was before the project (USACE, n.d).

Despite significant regional economic enhancement brought about by the channel deepening, environmentalist groups raised their concern of potential harm to salmon habitat and contamination of estuaries. Such lingering controversy continued through project completion in 2010. Anticipating these matters, monitoring of environmental impact is now underway, scheduled for three years from the time of completion.

Apart from the environmental issue (which was excluded from the investigation of this research), the project management during its implementation also raised some question marks. Facts showed that total dredging volume increased by 32% of its initial estimate, and there was also significant inaccuracy between the projected and actual volumes along most of the reaches. The overall project costs also increased apparently in agreement with increased dredging volumes. In addition, the project duration, which was initially scheduled for two years, took five years to be completed. With opposition from various parties concerning these matters, it becomes an interesting subject to focus on this research. Based on this viewpoint, this research aims to evaluate the elements of volume, cost and duration of the project in order to provide analysis of best management practices. Best management practices are defined as the most effective ways in achieving the objective of additional 0.9 m (three-foot) channel deepening, by preventing or minimizing adverse impacts to environmental resources resulting from dredging activities, as well as making the optimum use of the available funding and given time frame. Questions about the factors causing discrepancies between projected and actual volume, cost, and duration of the project are addressed and there is a determination whether best management practices have been applied. Lukens (2000) in the document of National Coastal Program Dredging Policies provided the following guidelines for best management practices in the states of Oregon and Washington:

"Some local plans do outline preferred dredging techniques and methodologies, but there are none found in the DLCD Statewide Planning Goals." (Oregon)

"The preference for dredging equipment, as a matter of policy, is specified on the basis of individual project reviews, but in a few instances is more formalized, such as is contained in the Grays Harbor Crab Mitigation Memorandum of Agreement. In this case, a clam shell dredge (instead of a hopper dredge) has been used more to dredge portions of the navigation channel in Grays Harbor where there is a higher crab abundance. The mortality of adult Dungeness crabs caused by entrainment in a hopper dredge is over 90%, versus less than 10% for that of a clamshell dredge." (Washington)

Background of this project will be presented in the next chapter, providing clear description of the project initiative as well as its chronology. Research is conducted through data collection, i.e. presenting comparison of elaborative data between the projected and actual volume, cost, and duration of the project; followed by data analysis to look into the causes of the discrepancies. Results of bathymetric surveys are presented to compare the results with the actual dredging volume, conducting the analysis at each dredging bar, approximately 4.8 km (3-mile) long reaches. Analysis of benefit-cost ratios is employed to find comparison of its projected and actual value and by looking into reduction of average transportation cost when carrying the commodities at maximum capacity. Furthermore, this research will also investigate factors causing discrepancy between projected and actual time schedule.

Discussion of the project implementation includes controversial issues raised by various groups/parties, and verification to clarify acceptability of the output. It also looks into the project efficiency by evaluating two economics factors: Pareto Improvement (whether there is still room for it) and Externalities (both positive and negative ones).

Conclusions are expected to provide the summary of the objectives of project implementation in applying best management practices as well as the extent to which it was successful. This report provides recommendations for future research related to dredging in the Columbia River.

2 Background

2.1 Initial Plan

The dredging work in the Columbia River, officially known as The Columbia River Channel Improvement Project (CRCIP), started in 2005 and was completed in 2010. It served multi-purposes from enabling full capacity loads in cargo transportation, anticipating continued sedimentation, to providing positive balance of environmental benefits (USACE, n.d).

Figure 2.1 Detailed map showing scope of the Columbia River Channel Improvement Project (CRCIP) (USACE, 2003)

The project was implemented along 166.6 km (103.5 miles) of the river, from Interstate 5 Bridge (between Portland in state of Oregon and Vancouver in state of Washington) to the river mouth, before emptying into the Pacific Ocean. By deepening the river 0.9 m (3.0 feet) from 12.2 m to 13.1 m (40-foot to 43-foot) depth, it overcame the problem of shallow water depth which had become a long-time barrier to the ports on the lower Columbia River.

Well-known as one of the world's most important trade routes for grain, the Columbia River has its shipping channel deepened periodically. In fact, this matter is a historical problem of the river. The first dredging work took place in the 19th century, when the channel was deepened to 6.1 m (20 feet)-depth from its initial 3.0-4.6 m (10-15 feet) depth. The work, done in 1878, was seen as a big achievement then, considering that additional 1.5 m (5 feet)-depth was enabling the vessels at the time to fully operate in terms of goods transportation. Subsequent dredging followed during certain periods, in accordance with the need of providing more depth in the transportation lanes of the river as new generations of ships were produced in larger sizes. The latest and most massive change of channel size prior to the CRCIP was initiated in 1962, when the state legislature agreed to a plan of deepening it to 12.2 m (40 feet), as well as doubling its width to 182.9 m (600 feet). With its completion in 1976, it had been in operation for thirteen years until the new initiative for channel deepening emerged in 1989 in anticipation of the significant rise of overseas trade in the late 1980s (Center for Columbia River History, n.d).

In 1989, six ports on the Columbia River (Portland and St. Helens in Oregon; Vancouver, Woodland, Kalama, and Longview in Washington) made requests to the state legislatures to direct the Corps as the government implementing agency to conduct a feasibility study for deepening the channel to 13.1 m (43 feet) depth (USACE, n.d). It was expected to enable the ships to carry larger cargo loads by making the river 0.9 m (three feet) deeper from Portland to its mouth. Subsequently, it became a collaborative effort between the Corps and the six lower Columbia River ports in order to improve navigation by deepening the navigation channel for accommodating the fleet of international bulk cargo and container ships. In addition, it also aimed to improve the condition of the Columbia River estuary through the completion of environmental restoration projects.

2.2 Reconnaissance and Feasibility Study

The Corps initiated the work in 1989 with a reconnaissance study which included envisioning habitat restoration projects. The study took one year and it was a favorable one, as there was a federal interest in pursuing further investigations. In subsequent events, a feasibility study was started in 1994 aiming at evaluating options for improving navigation in the river (USACE, n.d). .

Authorized by a resolution of the U.S. House of Representatives, Committee on Public Works and Transportation (adopted August 3, 1989), the feasibility study was co-sponsored by the Corps and seven lower Columbia River ports that originally requested the initial study: Astoria, St. Helens, and Portland in Oregon and Longview, Kalama, Woodland, and Vancouver in Washington. The Corps entered an agreement with them to partner and share the cost of the feasibility study and any resulting construction. The Port of Portland served as the overall coordinator for the sponsoring ports (USACE, n.d).

The feasibility study was intended to improve the deep-draft transport of goods on the authorized navigation channel as well as to provide ecosystem restoration for fish and wildlife habitats. The need for navigation improvements was driven by the steady growth in waterborne commerce and the use of larger, more efficient vessels to transport bulk commodities. With the increased use of deep-draft vessels, limitations posed by the existing channel dimensions occurred with greater frequency. By improving navigation, there was an opportunity to realize greater benefits resulting from reduction of transportation costs by allowing deep-draft vessels to carry more tonnage and reducing vessel delays (USACE, n.d).

The purpose of the feasibility study was to identify potential actions, determine the best course of action to take (if any), determine how much that action would cost and associated national economic benefits, and identify potential environmental impacts and restoration actions. The Corps also completed a Dredged Material Management Study (DMMS) to evaluate the most efficient way to maintain the existing 12.2 m (40-foot) navigation channel. This provided the study team a baseline condition for evaluation purposes. The feasibility study evaluated various alternatives for improving navigation in the Columbia River. The alternatives studied included dredging the river bottom to various depths, updating river level forecasting systems, upgrading existing port facilities or developing a regional port, and taking no action. At the completion of the study, the Corps concluded that deepening the channel to a depth of 13.1 m (43 feet) provided the greatest benefit of the options studied (USACE, n.d).

The DMMS was completed in 1998, the feasibility study was completed in August 1999 and the project was authorized by the Congress in December 1999. The project, as authorized, serves multiple purposes, including navigational improvements and environmental restoration (USACE, n.d).

2.3 Environmental Concern

The impact of the project on the environment has become the biggest issue throughout the project phase. This report does not include the environmental viewpoint in the study, nevertheless a little background information is provided here for getting a thorough description of project implementation.

Deepening the Columbia River federal navigation channel required full compliance with various environmental laws, which include the Clean Water Act, Endangered Species Act, and National Environmental Policy Act (NEPA). To comply with NEPA, the Corps conducted an environmental review of the project and published comprehensive environmental impact statements for both the feasibility study and the DMMS. For their part, the National Marine Fisheries Service (NMFS) issued a No Jeopardy Biological Opinion in December 1999 on the expected impacts to salmonids, while the U.S. Fish and Wildlife Service (USFWS) completed its No Jeopardy Biological Opinion on the potential impacts to birds, wildlife, and plant species in December 1999. NMFS later withdrew their document in August 2000, citing the availability of new information (USACE, n.d).

Following this withdrawal, in February 2001, the Sustainable Ecosystems Institute (SEI) was retained to help resolve scientific concerns raised in connection with the CRCIP. The Corps, NMFS, and USFWS jointly agreed to use SEI's experience to help resolve fishery issues surrounding the project. The SEI process included formal and informal review of scientific materials by SEI staff and an independent panel of seven scientific experts. This process included five workshops which were open to the public from March 2001 to August 2001 to review the science underlying the proposed CRCIP. It also included ad hoc meetings between panelists and project managers and agency scientists, as well as a questionnaire completed by all the panelists. Based on its comprehensive discussion of all relevant issues (numeric and conceptual modeling, fisheries, sediment and water quality, and monitoring and adaptive management), the panel determined that the knowledge base was adequate to resolve environmental concerns through re-consultation process. The panel addressed only issues relevant to conservation of threatened and endangered salmonids (USACE, n.d).

The Corps worked closely with NMFS and USFWS to address the new information as well as to resolve concerns included in the original biological opinions. Updated opinions were released in May 2002. The services determined that the project could proceed without jeopardizing listed species. Additionally, the states of Oregon and Washington needed to certify the project's compliance with the Clean Water Act, and state water quality standards and coastal zone management rules (USACE, n.d).

On January 28, 2003 the Corps issued its Final Supplemental Report. A notice was published in the Federal Register on January 31, 2003. The final report reflected comments and information received by the Corps since the publishing of the draft supplemental report in summer 2002. Since the receipt of water quality approvals and concurrences to the Corps' coastal zone management consistency determinations in June 2003, the Corps had modified the project to address conditions handed down by the states of Oregon and Washington. As a result of those conditions, the Corps would not proceed with construction of the Miller-Pillar or Lois-Mott ecosystem restorations features, or the embayment portion of the Martin Island mitigation site. Instead, the Corps would place some dredged material in the ocean (USACE, n.d).

2.4 Discrepancies between Projected and Actual Implementation

The Columbia River Channel Improvement Project started in 2005 and was implemented by Great Lakes Dredge & Dock Co., the Corps' contractor. The dredge was to pump silt onto nearby Sandy Island on the Oregon side of the Columbia. Dredging maintained the ship channel at its authorized depth of 13.1 m (43 feet) (Anonymous, n.d).

Volumes were reported for each dredging bar made up of approximately 4.8 km (3-mile) reaches. Adaptive management could be triggered if actual construction volumes exceeded projected volumes. In addition, the adaptive component of the proposed Adaptive Environmental Management (AEM) Plan might be initiated if the volumes of dredged materials exceeded the capacity for disposal. Volumes and disposal of

Operation and Maintenance (O&M) dredging were also tracked in relation to the project. These three aspects of project construction contributed to decision-making concerning the adaptive management (Bartell et al, 2011).

Upon the completion of the CRCIP in fall 2010, facts showed significant discrepancies in terms of dredging volume, cost and duration of the project. Wojahn (2010) reported in *The Oregonian* (April 24, 2010) that the cost of the project, estimated at $134 million in 2003 to calculate its cost-benefit, had grown by 33 percent, with 11.9 million m^3 (15.6 million yd^3) of sediment removed from the river. It was also stated that from the outset, the ratio of estimated cost to estimated economic benefit -- the key decision point on whether the Corps should do a project -- was close to not making financial sense. Under the Corps' policy, project estimates used to calculate cost-benefits and to win congressional approval were based on budgets and timelines reflecting ideal conditions. In reality, the Corps' projects typically took years longer to complete, driving up costs. In this case, time to complete the project was extended to five years from the initial two-year plan.

In relation to these matters, opposition to the project came from Northwest Environmental Advocates (NWEA), a Portland-based non-profit organization, which submitted Data Quality Act Challenge to Final Supplemental Integrated Feasibility Report and Environmental Impact Statement for The Columbia River Federal Navigation Channel Improvement Project in March 2006. Nina Bell, Executive Director of Northwest Environmental Advocates, stated that the Corps' evaluation of costs and benefits in the Feasibility Study and Environmental Impact Statement (FSEIS) document were seriously and significantly flawed. Furthermore, she pointed out that there was no basis for the Corps to assert or assume that the channel deepening project would be constructed within the two-year period (in fact, the project was completed within five years). In addition, the Corps failed to take into consideration the erosion and deterioration of the jetties at the mouth of the Columbia River, an essential part of the navigation channel, a problem the Corps' own engineers had concluded would cost from $140 to $250 million just to rehabilitate 20 percent of their length (NWEA, 2006).

2.5 Research Objectives

Questions of the project management are to be addressed in this project, limited in scope to discussions about the volume, cost, and duration. More specifically this project will:

1. Investigate the implementation of dredging work, which was done in four phases at each bar station, with regards to the level of accuracy of bathymetric survey data (obtained during feasibility study in 1994-1995), factors causing the dredging volume discrepancies, as well as related concerns of environmental impacts from opposite parties.

2. Analyze the projected cost and benefit of the project, by looking towards the descriptions and commodities included in the calculation of cost and benefit. The Benefit-Cost Ratio (BCR) can be verified after ascertaining that no item is excluded from the calculation. It also needs to clarify the factors which possibly generated negative externalities, thus increasing total cost and reducing total benefit, for maintaining the accuracy of BCR. Furthermore, the actual cost and benefit upon the project completion is compared to the projected ones in order to provide comparison between point-in-time estimates and actual cost of the project.

3. Scrutinize the extended duration of the project. In this case, the discussion focuses on factors which contributed to the project taking longer than planned and verifies whether these delays are acceptable.

3 Literature Review

3.1 Bathymetric Survey

A bathymetric survey is a survey that measures water depth and determines the shape of the seabed. It is conducted by installing a transducer (mounted to a boat) to receive sound pulse transmission from the water surface. The transducer also records the transmission signal of its bounce from the bottom of the water body (USGS, n.d).

To filter and record the pulse travel time, an echo-sounder is attached to the transducer. When the pulse occurs, the reading location is recorded by a Global Positioning System (GPS) unit (El-Rabbany, 2006). The readings are taken many times to obtain a high level of accuracy and then corrections are made to the output by referring to the fluctuations that occur in the elevation of water surface. Mapping of the individual points of under-water bottom is done in a Geographic Information Systems (GIS) (USEPA, n.d).

A bathymetric survey is carried out by sending an acoustic signal to the seabed. The depth can be measured from its travel time (from the water surface). The value of depth is converted from measurement of sound velocity at different spots of the seabed. (NOAA, n.d). To ensure sufficient accuracy, calibration of the transducer is done twice a day. This way the accuracy of water depth measurement can be expected to be to within ± 0.1 m (0.3 ft). The survey is conducted in a grid pattern and the required resolution determines the line spacing (Simons and Snellen, n.d).

Simons and Snellen (n.d) in their discussion of acoustic seafloor mapping as the output of bathymetric survey, highlighted three different methods of the mapping. The oldest concept is single-beam echo sounder which has been in use since the 1920s. It measures the depth vertically below the ship. Through this method, one point of water depth measurement is obtained from each transmitted signal. The second concept is the side scan sonar which is capable of providing acoustic images of the seafloor from echoes at different angles of incidence. It has been in use since the 1960s. The newest concept of acoustic seafloor mapping is the multi-beam sonar which is the most widely applied nowadays. Using this method, it is possible to perform a large number (typically 200) point measurements along a wide strip of seafloor terrain perpendicular to the ship's track. Furthermore, the water depth and seafloor reflectivity can be measured simultaneously. The multi-beam sonar has been in use since the late 1970s, with continuous significant development in its technology and performance. It is currently considered the most sophisticated technology in the area of seafloor mapping.

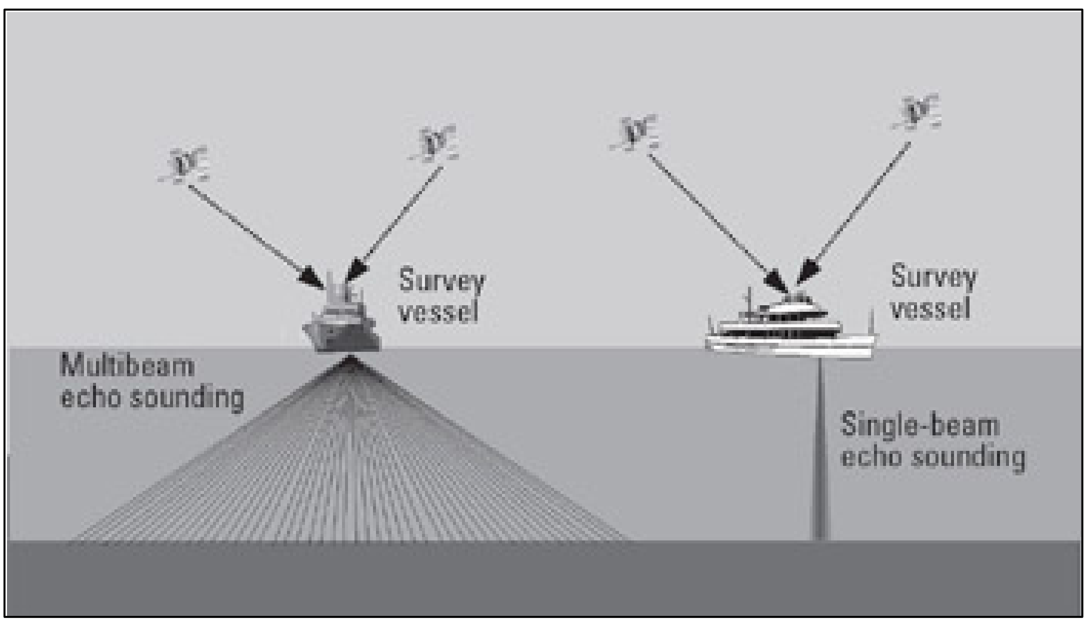


Figure 3.1 Multi-beam and single-beam echo sounding (El-Rabbany, 2006)

The side-scan sonar and multi-beam sonar are two methods applied by The National Oceanic and Atmospheric Administration (NOAA) in conducting bathymetric surveys. SONAR (sound navigation and ranging) finds and identifies objects in the water by making use of sound waves. The water depth is then determined.

Side-scan sonar is a specialized system for detecting objects on the seafloor. Most side-scan systems cannot provide depth information. Like other sonars, a side-scan transmits sound energy and analyzes the return signal (echo) that has bounced off the seafloor or other objects. Side-scan sonar typically consists of three basic components: towfish (a data-acquiring instrument), transmission cable, and topside processing unit (NOAA, n.d).

In a side-scan system, the transmitted energy is formed into the shape of a fan that sweeps the seafloor from directly under the towfish to either side, typically to a distance of 100 meters. The strength of the return echo is continuously recorded, creating a "picture" of the ocean bottom. For example, objects that protrude from the bottom create a light area (strong return) and shadows from these objects are dark areas (little or no return), or vice versa, depending on operator preference (NOAA, n.d). Side-scan sonar is typically used in conjunction with a single beam or multi-beam sonar system to meet full bottom coverage specifications for hydrographic surveys. NOAA field units use various models of side-scan sonar in both hull-mounted and towed configurations (NOAA, n.d).

For a number of reasons, bathymetric surveys are also used to characterize contaminated sediment sites. The surveys record the sediment surface prior to remediation to assist in the remediation process. Surveys taken over time assist project managers in determining the transience of bottom sediments. This information can determine whether the contaminated sediment is stable or is susceptible to re-suspension. Surveys can also check on the efficiency of dredging operations (USEPA, n.d).

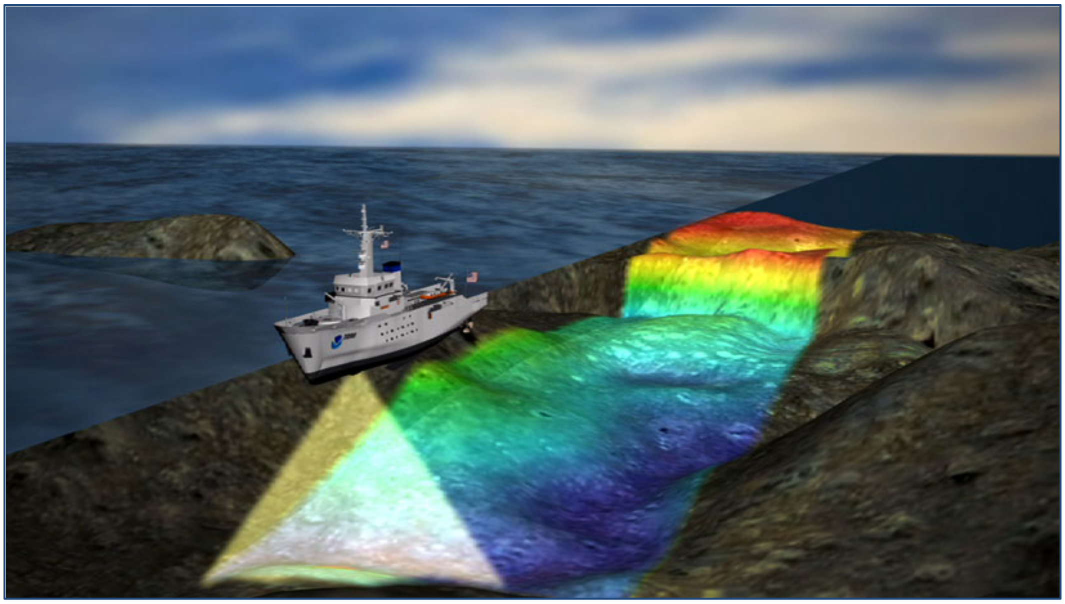


Figure 3.2 Visualization of how multi-beam bathymetry is collected (source: NOAA)

Levec and Skinner (2004) explained that boat speed during data collection must be considered for two reasons. First, transom-mounted transducers may cut out at faster speeds due to greater turbulence around the transducer. By reducing boat speed, loss of depth signals will be minimized. Second, the sound waves are generally pulsed at intervals of around one to two seconds which results in a time lag between pulses. This time lag affects the accuracy of input data for the position and depth of the targeted spot on the seafloor. This error is in addition to any error present in the calculation of the position. Slower speeds obviously reduce this error but also reduce the area that can be covered in the course of a day. Although consideration must be given to tradeoffs between operational efficiency and accuracy, an average speed of no greater than 15 km/h (9.3 mph) is recommended. Exceptions would be when traveling close to shore. Speed should be reduced for safety reasons as well as adhering to a 'no wake' principal. Speed should also be reduced when making turns at the end of a transect. This will help to reduce cavitation and improper sounder operation.

3.2 Tonnage (Carrying Capacity) of Shipping

Tonnage (carrying capacity) of shipping is calculated in deadweight (dwt), i.e. a measure of how much weight a ship is carrying or can safely carry. Gilmer (1975) defined the tonnage as the sum of the weights of cargo, fuel, fresh water, ballast water, provisions, passengers, and crew. The 'deadweight' term is often used to specify maximum permissible deadweight of a ship, i.e. when its plimsoll line (the line where the hull of a ship meets the surface of the water) is at the point of submersion.

Pearn (2000) used the formula expressed by Thames shipbuilders in 1678 to derive the cargo deadweight as 3/5 of ship's displacement (the weight of the water that a ship displaces when it is floating). The following expression was used to define the displacement:

Displacement = Length x Breadth x Draught x Block Coefficient / 35

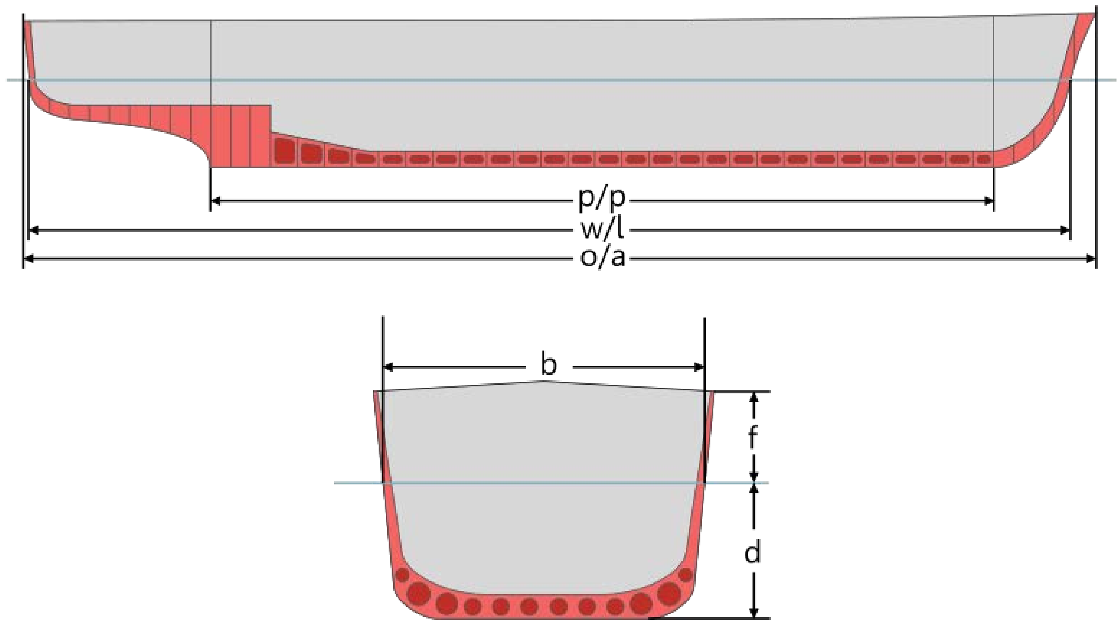
where:

Draught was estimated to be ½ Breadth

Block Coefficient was averaged to be 0.62

35 was used being the number of cubic-feet per ton of sea water

Using the above formula, we can obtain the amount of increase in tonnage for every one-meter (or one-foot) increase of the channel depth, by adding one meter (or one foot) to the vertical distance of the draft (original usage is "draught" from English in the United Kingdom) and redoing the calculation. The measurements of the draft and other ship dimensions are shown in Figure 3.3.



- **p/p** = length between perpendiculars
- **w/l** = length at waterline (plimsoll line)
- **o/a** = length overall
- **b** = beam
- **f** = freeboard
- **d** = draft

Figure 3.3 Measurements of ship dimensions (source: Wikipedia)

3.3 Externalities

An externality is a cost or benefit that is experienced by someone who is not a party to the transaction that produced it. Externalities arise whenever the actions of one party make another party worse off (negative externalities) or better off (positive externalities), yet the first party neither bears the costs nor receives the benefits of doing so (Gruber, 2010).

An externality can only exist when the welfare of some agent, or group of agents, depends on an activity under the control of another agent. Under these circumstances, an externality arises when the effect of one economic agent on another is not taken into account by normal market behavior (Zilberman, 1999).

Simpson (2007) stated in his paper that externality theory is used to claim that markets fail. It is claimed that because of the existence of externalities, the market will provide too much or too little of a particular good, and that the government must step in and use taxes, subsidies, restrictions on the provision of the good, or take over the production of the good in order to remedy the situation. However, these conclusions do not hold if one performs a comprehensive analysis of externality theory.

An externality is a cost or benefit imposed on people other than those who purchase or sell a good or service. The recipient of the externality is neither compensated for the cost imposed on him or her, nor does he or she pay for the benefit bestowed upon him or her. These costs and benefits are labeled “externalities” because the people who experience them are outside of or external to the transaction to buy and sell the good or service (Simpson, 2007).

Zilberman (1999) explained that externalities are a type of market failure. When an externality exists, the prices in a market do not reflect the true marginal costs and/or marginal benefits associated with the goods and services traded in the market. A competitive economy will not achieve a Pareto optimum (i.e. a situation when no part can be improved without making some other parts worse) in the presence of externalities because individuals acting in their own self-interest will not have the correct incentives to maximize profit (total surplus). Figure 3.4 shows the cost increase (from MPC to MSC) as an effect of externalities.

Because competitive markets are inefficient when externalities are present, governments often take policy action in an attempt to correct, or internalize, externalities. Externalities may be related to production activities, consumption activities, or both. Production externalities occur when the production activities of one individual imposes costs or benefits on other individuals that are not transmitted accurately through a market (Zilberman, 1999).

Because a competitive economy will not achieve a Pareto Optimum in the presence of externalities, combating externalities is a legitimate arena for government policy. The policy goal is to move the economy to a socially optimal point such as point B in Figure 3.4, where MSB (i.e. Demand) equals MSC.

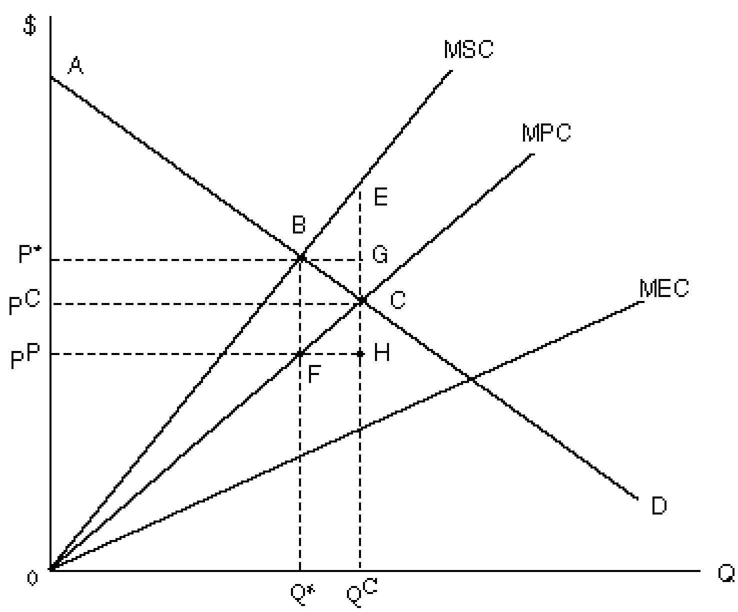


Figure 3.4 Production Externalities and the Failure of Competitive Markets (Zilberman, 1999)

where:

MPC = marginal private cost (this is the inverse of the private supply curve)

MEC = marginal externality cost (suffered by people damaged by pollution)

MSC = marginal social cost (vertical sum of MPC and MEC)

MSB = marginal social benefit (demand curve A-D)

Social optimum at B (where MSB=MSC)

Social Benefits = ABQ*O.

Social Costs = OBQ*.

Social Welfare = ABO.

Free market outcome at C

Social Benefits = ACQ^cO.

Social Costs = OCQ^c + OEC = OEQ^c.

Social Welfare = ABO - BEC.

Deadweight Loss = BEC.

3.4 Benefit-Cost Ratio (BCR)

The Benefit-Cost Ratio (BCR) is the ratio of the equivalent worth of benefits to the equivalent worth of costs (Sullivan et al, 2012). It is a parameter used to determined feasibility of a project. The project is feasible when BCR $\geq$ 1 (Sullivan et al, 2012). Such an indicator has been used in decision making in a variety of fields: water-supply projects, transport, land usage, health, education, research, etc.

Prest and Turvey (1965) defined the project's analysis of costs and benefits as a way of setting out the factors which need to be taken into account in making certain economic choices. Most of the choices to which it has been applied involve investment projects and decisions --- whether or not a particular project is worthwhile, which is the best of several alternative projects, or when to undertake a particular project. Cost-benefit analysis can also be applied to proposed changes in laws or regulations, to new pricing schemes and the like.

Although this method is very popular in practice, there are a few disadvantages that must be considered before basing a decision on the results of the cost-benefit analysis (Plowman, 2011):

1. Potential Inaccuracies in Identifying and Quantifying Costs and Benefits

   A cost-benefit analysis requires that all costs and benefits be identified and appropriately quantified. Unfortunately, human error often results in cost-benefit analysis errors such as accidentally omitting certain costs and benefits due to the inability to forecast indirect causal relationships. Additionally, the ambiguity and uncertainty involved in quantifying and assigning a monetary value to intangible items leads to an inaccurate cost-benefit analysis. These two tendencies lead to inaccurate analyses, which can lead to increased risk and inefficient decision making.

2. Increased Subjectivity for Intangible Costs and Benefits

   Another disadvantage of the cost-benefit analysis is the amount of subjectivity involved when identifying, quantifying, and estimating different costs and benefits. Since some costs and benefits are non-monetary in nature, such as increases in customer and employee satisfaction, they often require one to subjectively assign a monetary value for purposes of weighing the total costs compared to overall financial benefits of a particular endeavor. This estimation and forecasting is often based on past experiences and expectations, which can often be biased. These subjective measures further result in an inaccurate and misleading cost-benefit analysis.

3. Inaccurate Calculations of Present Value Resulting in Misleading Analyses

   Since this evaluation method estimates the costs and benefits for a project over a period of time, it is necessary to calculate the present value. This equalizes all present and future costs and benefits by evaluating all items in terms of present-day values, which eliminates the need to account for inflation or speculative financial gains. Unfortunately, this poses a significant disadvantage because, even if one can accurately calculate the present value, there is no guarantee that the discount rate used in the calculation is realistic.

4. A Cost-Benefit Analysis Might Turn into a Project Budget

   Another disadvantage seen when utilizing a cost-benefit analysis is the possibility that the evaluative mechanism turns in to a proposed budget. When a project manager puts together a cost-benefit analysis and presents it to a leadership team, the leadership team might view the expected costs as actual rather than estimated, which may lead to misappropriating costs and setting unrealistic goals when approving and implementing a project budget. This can put a project manager in an unfavorable situation when he or she attempts to control costs in order to maintain the expected profit margin.

Jonkman et al (2004) investigated the cost-benefit analysis methods in the decision-making on flood damage mitigation in the Netherlands. The application of cost-benefit analysis in flood management, as defined by Jonkman et al (2004), is a comparison between the costs of measures for increasing the safety against flooding (e.g. dike strengthening of flood plain lowering) and the decrease in expected flood damage. Different types of costs have to be included: costs of investment (fixed and variable) and the costs of maintenance and management. The investment costs in flood defense can include the construction costs of dikes and the maintenance costs. Also the decrease of agricultural production and other limitations of economic growth of certain areas utilized for dike construction should be considered. The benefits include the costs of damage reduction which are often subdivided in direct costs (repair of buildings and interior damage), costs of business interruption of companies in the flooded area, and indirect costs outside the flooded area (mainly due to business interruption). It has to be noted that companies outside the flooded area may also benefit from a flood due to the temporary situation during flood recovery, known as transition effects. In addition, the potential economic growth due to improved flood defense should be taken into account.

Yohe and Tol (2002) employed the cost-benefit analysis in an illustrative application by constructing a hypothetical example around historical flows in the Nile River. The output was then used as a reference to offer a more realistic application to the Rhine Delta in the Netherlands. In the illustrative example, three different adaptation options were explored in terms of their cost-benefit analysis which might alter either the flow of the Nile River or the indicated thresholds of significant impact towards the annual river flow:

<u>Option A:</u> Construction of a series of protection levies
Cost: Large initial investment; modest on-going expense; modest environmental impact; modest amenity cost; downstream flooding possible.
Benefit: Reduction in the frequency of flooding in the study location.

<u>Option B:</u> Building a dam upstream
Cost: Largest initial investment; large on-going expense; large environmental impact.
Benefit: Reduction in the frequency of flooding in the study location and downstream; modest amenity gain; additional power capacity; recreational benefit; increased tourism.

<u>Option C:</u> Periodically dredging the river

Cost: Largest on-going expense distributed unevenly over time; modest environmental impact possible; downstream flooding possible.

Benefit: Reduction in the frequency of flooding in the study location.

In another case study, Griganulas et al (n.d) discussed the BCR analysis of the proposed deepening of the Delaware Bay and River main federal channel. The proposed project would involve initial dredging of some 19.9 million m^3 (26 million yd^3) of sediment and 16.8 million m^3 (22 million yd^3) of rock over a 7-year period. It would deepen 165.0 km (102.5 mi) of the main federal channel in the Delaware Bay and River from 12.2 m (40 ft) to 13.7 m (45 ft) mean low water and also straighten 12 bends in the river to facilitate the movement of larger vessels than currently serve Delaware River facilities. Quantification of benefit and cost was made from the scope of State Economic Development (SED), a narrower scope of National Economic Development (NED). In sum, the SED accounting stance was conceptually similar to the familiar NED standard used to assess benefits and costs to the nation as a whole. The benefits included the state share of transportation cost savings, share of profits accruing to Delaware residents, and environmental benefits (after mitigation) to Delaware attributable to the project. Project costs were made up of the share of project costs paid by Delaware residents as federal taxpayers, environmental costs to Delaware (after mitigation) because of the project, and costs to the state of Delaware as a nonfederal cosponsor of the project.

Regarding enumeration of costs and benefits in water resources project, the cost of environmental externalities is one significant factor which could fail the project when it is underestimated in BCR analysis. Freudenburg et al (2009) analyzed the impact of Hurricane Katrina with regards to underestimation of environmental externalities in the project of Mississippi River-Gulf Outlet, a transportation canal excavated in 1963. The outlet construction project, as the author claimed, destroyed 8,000 – 27,000 ha (20,000 – 65,000 acres) of wetlands that in the past had protected New Orleans from hurricanes. Such environmental damage contributed to the high-rise of water elevation, creating deadly flooding when the strong wind at approximate speed of 200 km/h (125 mph) came. Another evidence of environmental externalities was given by Day Jr. et al (2007), who concluded that the destruction caused by Hurricanes Katrina and Rita was exacerbated by deterioration of Mississippi Deltaic Plain as a result of river embankment projects which isolated the river from the plain. Such hydrological alteration proved to significantly contribute to the high cost of related water projects in Louisiana, mainly in the city of New Orleans, such as constructions of canals and levees. Responding to this fact, Day Jr. et al (2007) suggested restoration efforts on the Mississippi Delta aiming to re-establish dynamic interactions between river and coast at various temporal and special scales, with emphasis on reconnecting the river to the deltaic plain. Referring to a previous study conducted by Turner and Boyer (1996), the proposed Mississippi Delta restoration could gain more favor if there is an economy of scale in the project. A study is necessitated for this objective.

Wilson (2002) reported the outcome of a workshop about analysis of risks and benefits of dredged material management. Placement of dredged materials containing toxic/contaminating substances has negative impacts on the environment, either underwater or upland (on land). In another study, Grigalunas et al (2000) reported considerable economic costs as a result of fishery losses due to dredged sediment disposal, ranging from about $460 thousand to $3.4 million between the lowest- and highest-cost sites in and around Providence Harbor, Rhode Island. For this reason, the risks (costs) and benefits of possible alternatives are necessary to evaluate. In his workshop report, Wilson (2002) stated the US Army Corps of Engineer as the US Government’s implementing agency responsible for assuring the navigability of waters in the United States may need improvement in its methods and practices for risk/cost/benefit characterization. The workshop released some recommendations: 1) develop appropriate tools for risk and benefit analysis, 2) increase the Corps' knowledge of stakeholders (the public and others) and their values, both local and national, 3) continue to upgrade project managers' skills (including cultivating relations with stakeholders), 4) evaluate methodologic needs and identify ways to fill them, particularly risk-cost tradeoff for internal planning, communications plans, methods, tools, and food safety standards for noncommercial fish and shellfish, 5) evaluate utility to the Corps of adjusting requirements (job) of senior management positions in navigation dredging and long-term forward planning for foreseeable materials management problems, 6) develop plans for working with USDA and EPA over the long term to reduce sediment inputs to navigable streams, 7) consider reviewing the appropriateness of judging value of navigation dredging projects only by a differential in direct-use benefits, and 8) build communication and public participation efforts into all projects that deal with contaminated sediments, matching the level of effort to the issues involved.

4 Method

4.1 Data Collection

The data needed for this research were collected from various sources. Most of them were available online from the USACE website, Columbia River Channel Coalition, online newspapers, and related documents. Some additional data were obtained from correspondence with the USACE Portland District Office. In addition, some were modified and presented in the form of tables and figures for practical analysis. All compiled data were used as input for verification of issues within the scope of this research. The collected input data were elaborated separately in terms of the project's volume, cost and duration, as indicated below.

4.1.1 Projected and Actual Dredging Volume

Bartell et al (2011) in the Final Report of Adaptive Environmental Management for the Columbia River Channel Improvement Project, presented the breakdown of dredging volume at each bar station. Table 4.1 shows the difference between projected and actual new work volume at each dredging bar (approximately 4.8 km or three-mile reaches). The report is in fulfillment of Monitoring Action over annual dredging volumes and their disposal associated with construction and operation of the 13.1 m (43-foot) navigation channel. Figure 4.1 presents the same data, but in the form of a topographic map. It highlights the extent of accuracy of calculated volumes at each dredging bar. As shown, in some bar stations, there are significant differences in which the actual volumes of dredging exceed projected volumes by 200%.

Table 4.1 Comparisons of Projected and Actual CRCIP Construction Volumes through 2010 (Bartell et al, 2011)

No.	Bar Name	Bar Stations by River Mile	D/S River Mile	Projected Volume Above 48 ft (yd^3)	Projected Volume Above 45 ft (yd^3)	Projected New Work (48-45ft) Volume (yd^3)	Actual New Work (48-45ft) Volume (yd^3)
1	2	3	4	5	6	7	8
1	Lower Desdemona	04+20+00	04+00+00	317,100	222,412	94,688	3,894
			05+00+00	550,640	353,916	196,724	
2	Upper Desdemona	06+22+00	06+00+00	66,193	0	66,193	22,704
			07+00+00	1,039	0	1,039	
			08+00+00	61,140	8,742	52,398	
			09+00+00	71,593	8,742	62,851	
3	Flavel Bar	10+00+00	10+00+00	379,028	49,732	329,296	337,154
			11+00+00	833,973	298,900	535,074	241,059
			12+00+00	360,900	121,292	239,608	38,373
			13+00+00	138,168	72,425	65,743	64,007
4	Upper Sands	13+30+00	14+00+00	226,017	54,585	171,432	102,699
			15+00+00	323,787	51,945	271,842	202,911
			16+00+00	354,274	47,557	306,717	152,940
			17+00+00	108,631	0	108,631	
5	Tongue Point Crossing	17+28+00	18+00+00	188,889	14,775	174,113	165,325
			19+00+00	169,841	6,976	162,864	207,932
			20+00+00	140,502	13,283	127,219	284,167
6	Miller Sands	21+20+00	21+00+00	220,662	48,572	172,090	233,323
			22+00+00	536,271	397,564	138,706	241,015
			23+00+00	16,212	2	16,210	116,866
			24+00+00	168,189	37,335	130,854	315,619
7	Piller Rock	25+10+00	25+00+00	384,769	112,426	272,344	194,323
			26+00+00	171,408	44,197	127,211	55,796
			27+00+00	56,322	6,553	49,769	744,839
8	Brookfield Welch	28+40+00	28+00+00	193,261	28,356	164,905	191,091
			29+00+00	224,225	64,782	159,443	
			30+00+00	89,561	23,615	65,947	
			31+00+00	40,513	26,657	13,855	

Table 4.1 Comparisons of Projected and Actual CRCIP Construction Volumes through 2010 (Bartell et al, 2011). (Continued).

1	2	3	4	5	6	7	8
9	Skamokawa Bar	32+30+00	32+00+00	167,896	31,955	135,941	243,063
			33+00+00	651,852	455,132	196,720	
			34+00+00	90,709	9,367	81,342	325,439
			35+00+00	358,874	37,059	321,816	
10	Puget Island	36+31+00	36+00+00	17,288	354	16,934	
			37+00+00	162,466	17,838	144,628	610,292
			38+00+00	374,599	54,709	319,889	
			39+00+00	46,331	4,940	41,391	
11	Wauna–Driscoll	40+40+00	40+00+00	164,427	26,349	138,077	258,062
			41+00+00	226,584	40,230	186,354	
			42+00+00	323,422	84,593	238,829	330,034
			43+00+00	375,149	77,874	297,275	
12	Westport Bar	44+27+00	44+00+00	251,076	32,800	218,276	927,116
			45+00+00	458,268	67,950	390,318	
			46+00+00	285,678	26,341	259,337	
			47+00+00	338,946	60,526	278,420	
13	Eureka Bar	48+10+00	48+00+00	200,332	41,415	158,918	
			49+00+00	73,575	4,751	68,824	
			50+00+00	1,812	0	1,812	
			51+00+00	0	0	0	
14	Gull Island	51+45+00	52+00+00	0	0	0	
			53+00+00	0	0	0	
			54+00+00	19,107	485	18,623	174,379
15	Stella Fisher	55+30+00	55+00+00	9,824	0	9,824	
			56+00+00	181,756	34,201	147,554	683,050
			57+00+00	31,463	0	31,463	
			58+00+00	543,065	137,229	405,836	996,392
16	Walker Island	59+22+00	59+00+00	95,243	15,759	79,484	
			60+00+00	82,387	3,116	79,270	146,009
			61+00+00	20,432	296	20,136	
			62+00+00	32,466	1,679	30,787	

Table 4.1 Comparisons of Projected and Actual CRCIP Construction Volumes through 2010 (Bartell et al, 2011). (Continued).

1	2	3	4	5	6	7	8
17	Slaughters Bar	63+10+00	63+00+00	195,190	15,000	180,190	1,015,926
			64+00+00	304,956	30,000	274,956	
			65+00+00	338,641	67,058	271,583	2,374,461
			66+00+00	561,173	107,960	453,213	
18	Lower Dobelbower	67+06+00	67+00+00	192,962	54,691	138,271	310,697
			68+00+00	3,116	16	3,100	188,968
			69+00+00	46,386	16	46,370	
19	Upper Dobelbower	69+50+00	70+00+00	194,244	34,134	160,110	273,024
			71+00+00	12,900	0	12,900	
			72+00+00	14,371	0	14,371	128,261
20	Kalama Bar	72+40+00	73+00+00	115,482	0	115,482	
			74+00+00	78,329	5,381	72,948	143,777
			75+00+00	135,429	16,591	118,838	204,861
21	Lower Martin Bar	76+25+00	76+00+00	406,832	125,671	281,161	260,042
			77+00+00	169,712	14,880	154,833	159,112
			78+00+00	5,860	39	5,821	343,337
			79+00+00	281,891	68,988	212,903	
22	Upper Martin Bar	80+16+50	80+00+00	168,158	18,927	149,231	296,815
			81+00+00	68,884	22,936	45,948	142,936
			82+00+00	226,583	12,745	213,838	296,898
23	St. Helens	83+44+00	83+00+00	113,920	8,610	105,311	186,561
			84+00+00	60,424	7,337	53,087	124,405
			85+00+00	97,614	3,681	93,933	98,635
			86+00+00	268,809	69,223	199,386	152,966
24	Warrior Rock	87+15+00	87+00+00	161,482	45,127	116,355	462,416
			88+00+00	157,476	21,660	135,816	411,942
			89+00+00	117,165	14,924	102,241	
25	Henrici Bar	90+20+00	90+00+00	481,852	100,142	381,709	306,720
			91+00+00	232,015	51,233	180,781	279,964
			92+00+00	86,909	7,234	79,675	199,040

Table 4.1 Comparisons of Projected and Actual CRCIP Construction Volumes through 2010 (Bartell et al, 2011). (Continued).

1	2	3	4	5	6	7	8
26	Willow Bar	93+50+00	93+00+00	261,237	67,579	193,659	278,513
			94+00+00	156,838	45,286	111,552	136,003
			95+00+00	78,237	6,356	71,881	355,623
			96+00+00	191,681	31,588	160,093	
27	Morgan Bar	97+40+00	97+00+00	167,351	31,430	135,922	
			98+00+00	50,416	3,821	46,595	56,013
			99+00+00	9,172	0	9,172	
			100+00+00	0	0	0	
28	Lower Vancouver	101+18+00	101+00+00	87,054	10,311	76,744	
			102+00+00	84	0	84	406,064
			103+00+00	87,909	1,810	86,099	
			104+00+00	393,116	0	393,116	
29	Vancouver Turning Basin	104+31+25	105+00+00	287,713	69,220	218,493	1,163,547
			105+31+07			0	
			TOTAL =	**19,047,502**	**4,573,889**	**14,473,613**	**19,088,483**

Figure 4.1 Comparison of Actual to Projected CRCIP Construction Volumes through 2010

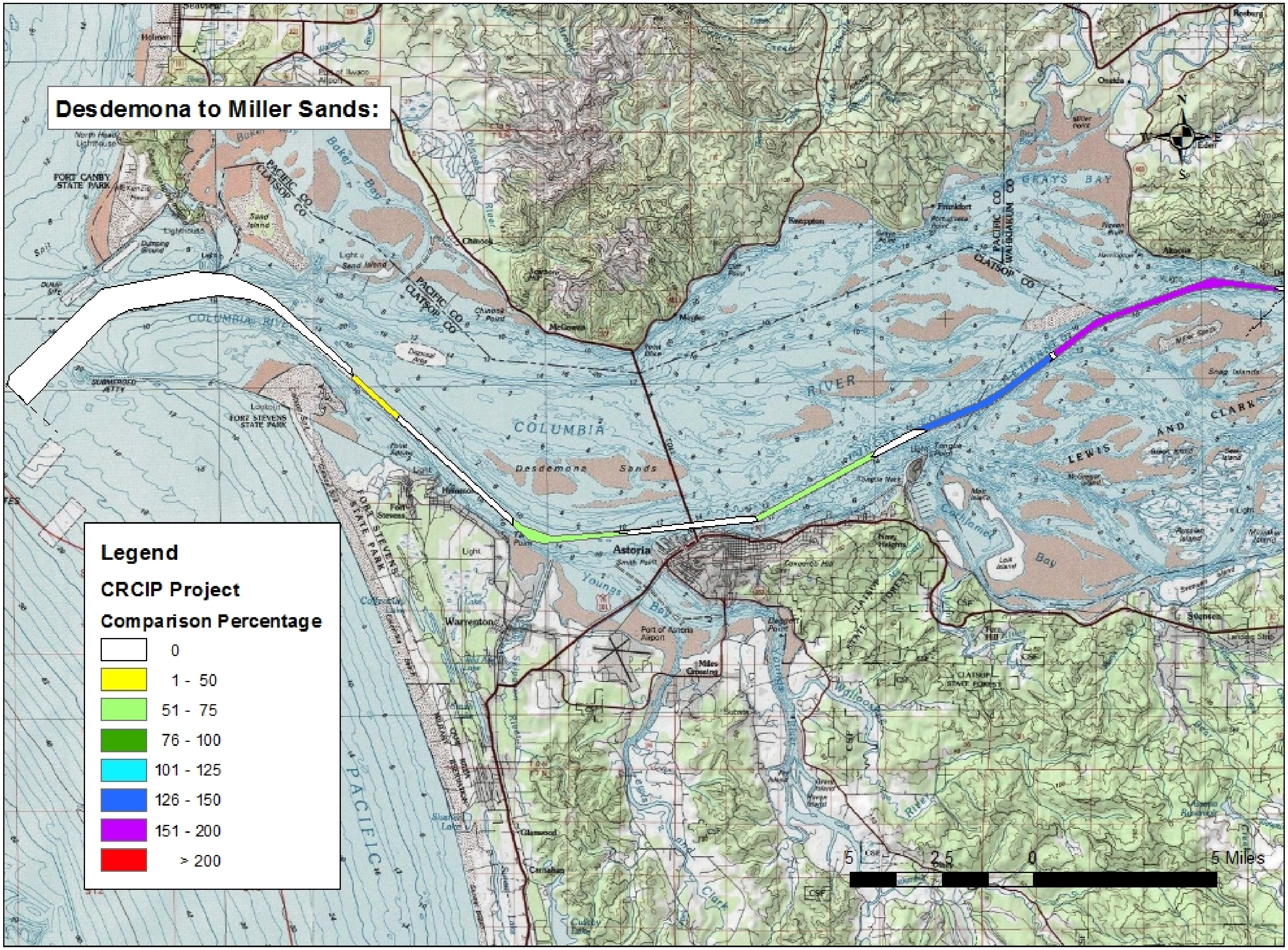


Figure 4.1 Comparison of Actual to Projected CRCIP Construction Volumes through 2010. (Continued).

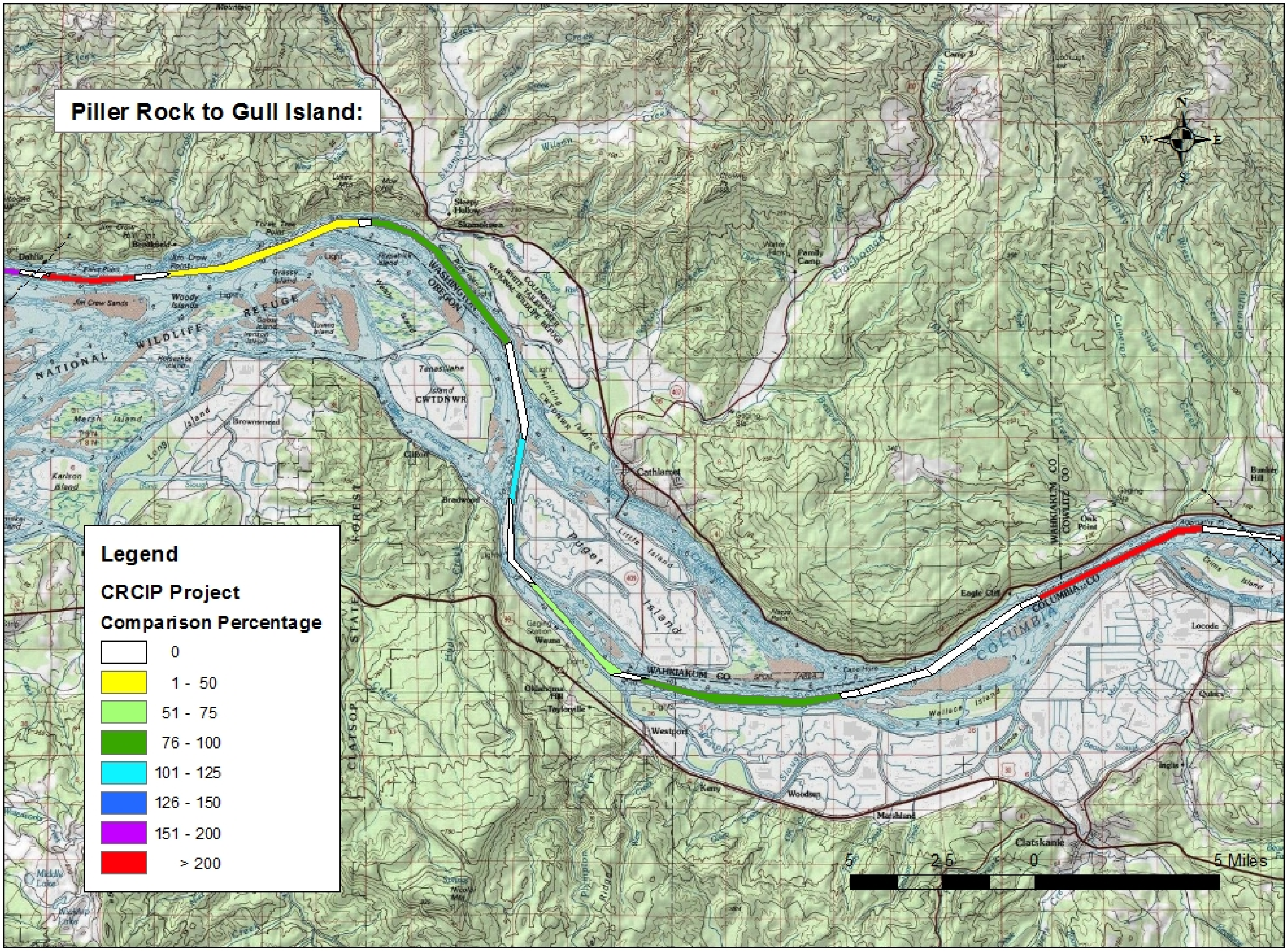


Figure 4.1 Comparison of Actual to Projected CRCIP Construction Volumes through 2010. (Continued).

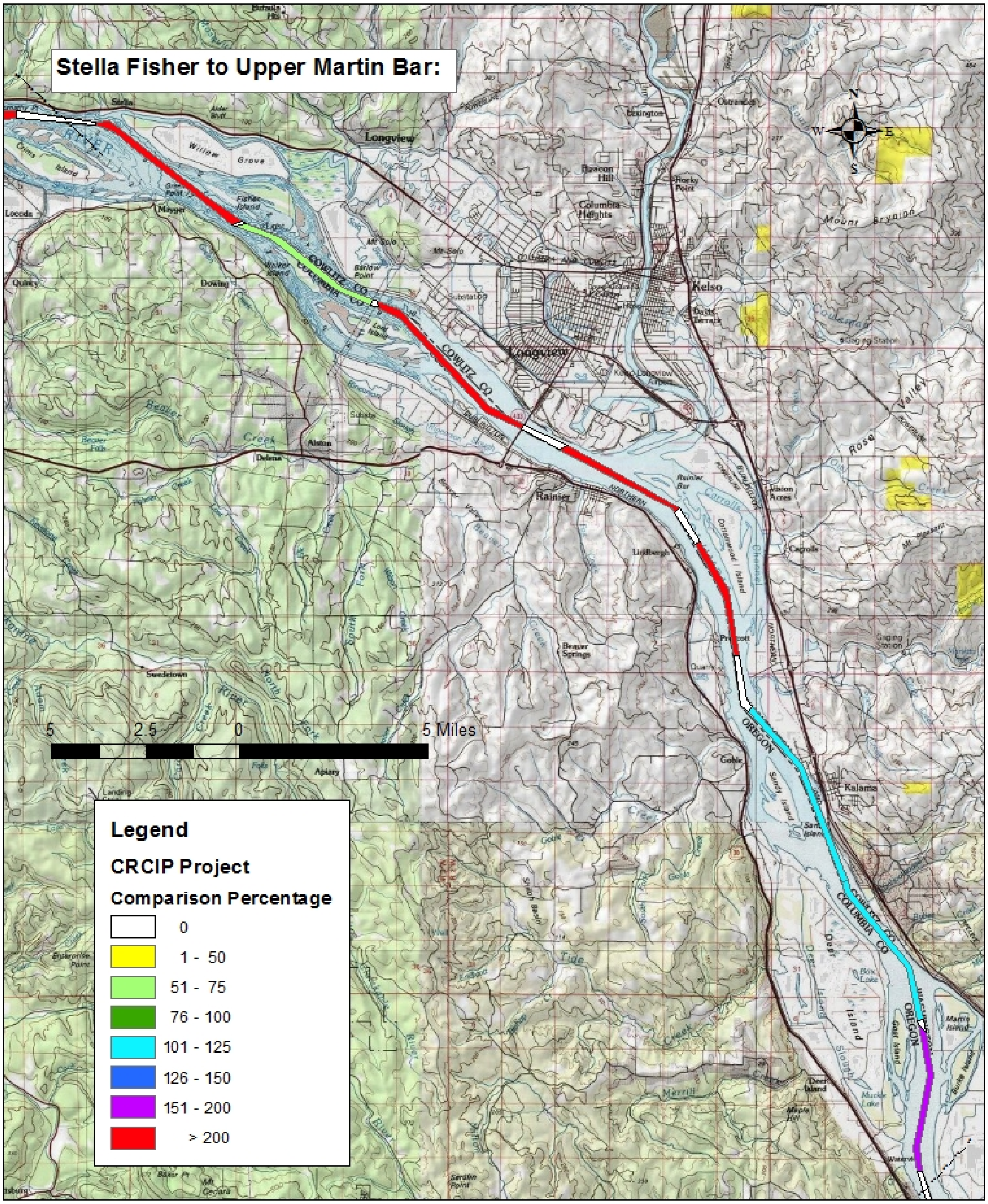
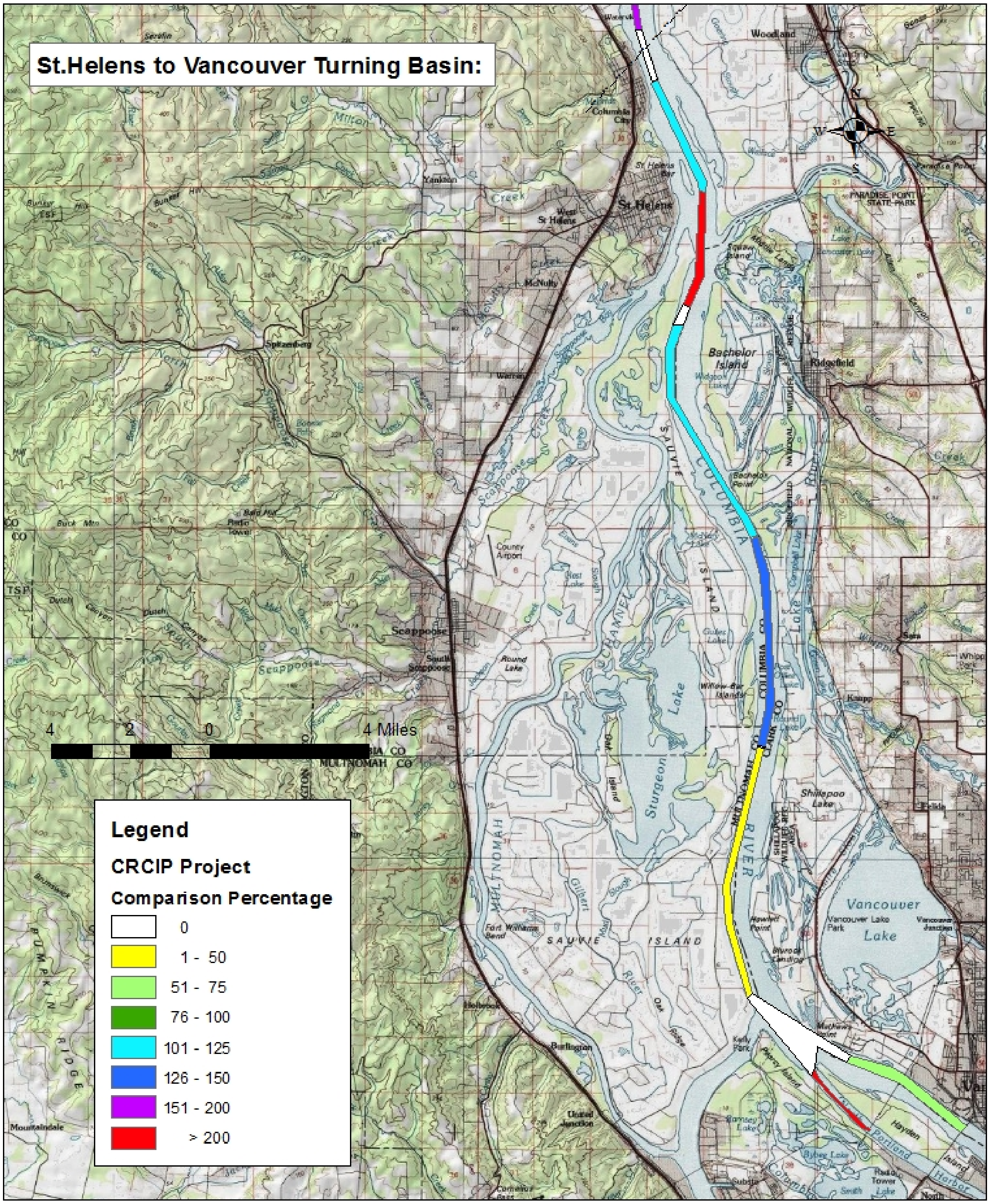


Figure 4.1 Comparison of Actual to Projected CRCIP Construction Volumes through 2010. (Continued).



4.1.2 Projected and Actual Total Cost

The projected total cost of the project is given in Table 4.2, which refers to Exhibit L of Final Supplemental Integrated Feasibility Report and Environmental Impact Statement (USACE, 2003).

Table 4.2 Projected Total Cost Summary of Columbia River Channel Improvement Project (USACE, 2003)

No.	Feature Description	Cost ($)
1	Columbia River Channels and Canals	56,756,000
2	Willamette River Channels and Canals	17,998,000
3	Environmental Restoration	18,030,000
4	Lands and Damages (Disposal and Mitigation)	16,574,000
5	Lands and Damages (Environmental Restoration)	2,500,000
6	Columbia River Engineering and Design	2,097,000
7	Columbia River during Construction	319,000
8	Columbia River Monitoring and Evaluation (GNF)	9,259,000
9	Columbia River Monitoring and Evaluation (Envir. Restoration)	700,000
10	Water Resources Engineering and Design	392,000
11	Water Resources Engineering during Construction	1,080,000
12	Columbia River Construction Management	7,479,000
13	Water Resources Construction Management	506,000
	Total Cost	**133,689,000**

Wojahn (2010) in *The Oregonian* (April 24, 2010) reported that actual total cost of the project was $178.4 million. The amount has been confirmed with the USACE Portland District Office, with the cost breakdown given in Table 4.3. Such discrepancy between projected and actual cost will be discussed further in this report.

Table 4.3 Actual Total Cost Summary of Columbia River Channel Improvement Project (USACE Portland District Office, 2012)

No.	Feature Description	Cost ($)
1	Navigation cost, including dredging and monitoring	160,812,215
2	Mitigation	8,672,785
3	Ecosystem Restoration	8,939,000
	Total Cost	**178,424,000**

4.1.3 Projected and Actual Project Duration

The project was initially scheduled for two-year construction and three years of maintenance dredging to a maximum depth of 13.1 m (43 feet) (USACE, 2003). According to Exhibit M of Final Supplemental Integrated Feasibility Report and Environmental Impact Statement (USACE, 2003), there would be a brief period of capacity utilization adjustment as container carriers began to make use of the additional capacity created by the new channel depth in 2007. By 2008, it was expected that the operators would have fully adjusted to the new channel depth. Fact showed, as reported by Columbia River Channel Coalition (2012), the 166.6 km (103.5-mile) project was completed in November 2010; meaning that that there was three-year extension from initial schedule of completion in 2007.

4.2 Data Analysis

4.2.1 Measurement of Channel Depth

Bathymetric surveys using side scan sonar and bathymetric systems were conducted to continuously map the seafloor in the vicinity of the proposed deep water site. Through this method, accurate depth data were collected (USACE, 2003). Dredging volumes estimated from bathymetric surveys were taken during 1994 and 1995. The design, measuring the dredging volumes at every bar station, included quantities for over-depth and over-width (USACE, 2003).

Acoustic seafloor mapping survey provided baseline physical information for the deep water site. Furthermore, the Corps conducted a bank-to-bank bathymetric survey of the estuary prior to construction, as well as performed annual bathymetric surveys in and adjacent to the navigation channel. Those surveys provided an update of overall estuary sedimentation and monitored the predicted channel response to the 0.9 m (three-foot) deepening of the channel (USACE, 2003).

4.2.2 Analysis of Benefit – Cost Ratio (BCR)

Average annualized benefit upon the completion of this project was expected from additional loads of commodities as well as the containers (carried to the full capacity by the ships). As reported by USACE (2003), the amount of annual benefit is given in Table 4.4 below.

Table 4.4 Average Annualized Transportation Benefits, 43-foot Channel Improvement (USACE, 2003)

Commodity	Average Annualized Benefit ($)
Corn	3,842,000
Wheat	2,054,000
Barley	185,000
Soybeans	976,000
Containers	11,748,000
Total	**18,806,000**

With respect to water resources projects, the discount rate is applied for the purpose of converting total implementation cost to average annual costs. Discount rate is defined as the interest rate used in discounted cash flow analysis to determine the present value of future cash flows (www.investopedia.com).

USACE (2003) reported that in the CRCIP, the implementation costs included all costs associated with the potential projects, such as development costs, real estate costs, monitoring costs, and operation and maintenance costs. The discount rate for the CRCIP was 5.875%, as set by the Federal Reserve Bank for Fiscal Year 2003. All costs were amortized at the discount rate over the 50-year project life to develop equivalent average annual costs.

The CRCIP also set interest during construction and included it as part of the total average annualized cost. This way it determined the economic cost of the potential projects and various components. Table 4.5 below shows the cost breakdown of the total average annualized cost.

Table 4.5 Average Annualized Cost, 43-foot Channel Improvement (USACE, 2003)

First Costs Item:	**Total Cost ($)**
Construction	97,618,000
Land Acquisition	17,436,000
Berthing Areas	843,000
Interest During Construction	2,728,000
Total First Cost (rounded)	**118,625,000**
Annualized Costs:	
First Costs (5 7/8%, 50 years)	7,395,000
O&M Dredging	3,334,000
Mitigation Site Management/Monitoring	250,000
Real Estate required throughout O&M	35,000
Total Average Annualized Cost	**11,014,000**

The Benefit-Cost Ratio (BCR) as the annualized return on investment at initiation of the project was calculated from comparison of average annualized transportation benefit with average annualized cost, as shown in Table 4.6.

Table 4.6 Benefit-Cost Ratio, at project initiation (USACE, 2003)

Total Average Annualized Benefit	$ 18,806,000
Total Average Annualized Cost	$ 11,014,000
Net Benefits	$ 7,792,000
Benefit-Cost Ratio (BCR)	**1.71**

At the time of project completion (in fall 2010), in response to conditions on state approvals, total average annualized cost slightly rose to $ 11.3 million (from an initial estimate of $ 11.0 million). Consequently, the BCR slightly dropped to 1.66 (USACE, n.d).

4.2.3 Time Schedule

Through contact with the Corps' Portland District Office some information was obtained regarding the schedule of project implementation. The project was implemented by referring to the most efficient method of building a project, on which the required construction cost estimates were based. This matter became a base of setting the initial two-year construction estimate (and cost) which reflected the policy.

During its progress, actual construction was dependent on the funding priorities of the US Congress, which allocated funding over a five-year period. The funding for the CRCIP came from various sources: federal appropriations, the states of Oregon and Washington, as well as local sponsoring ports including Portland and St. Helens in Oregon, and Kalama, Longview, Vancouver in Woodland in Washington (PNWA, n.d).

USACE (n.d) reported that the cost of the authorized project - both deepening the navigation channel and the environmental restoration component - was $136 million. The Federal government covered about 65 percent of the cost, with the states of Oregon and Washington each contributing about $27 million for the Columbia portion of the project. Actual construction took place between spring 2005 and fall 2010. The work was done in four phases with a January 2006 mid-point.

5 Discussion

Upon its completion in fall 2010 controversy over the CRCIP feasibility kept lingering. Various groups raised their concern over the environmental impact the project could cause, despite the fact that the Record of Decision (ROD) had been signed before the project initiation. As this report excludes environmental issues of the project, the discussion below elaborates some compiled opinions from the parties opposing the project in terms of its volume, cost, and duration (time schedule), accompanied by clarification of each issue.

Figure 5. 1 Completion work of The Columbia River Channel Improvement Project (CRCIP), picture taken in April 2010 (source: *The Oregonian*)

5.1 Outlook towards Emerging Issues

5.1.1 Complaint from Northwest Environmental Advocates (NWEA)

Northwest Environmental Advocates (NWEA), a non-profit organization based in Portland, Oregon, submitted a complaint on March 15, 2006 before the U.S Department of Defense on the Corps' dredging work. The complaint was pursuant to The Data

Quality Act (DQA) of 2000, submitted as Data Quality Act Challenge to Final Supplemental Integrated Feasibility Report and Environmental Impact Statement for The Columbia River Federal Navigation Channel Improvement Project.

NWEA (2006) also raised concerns about the factual inaccuracies of portions of the FSEIS, which it claimed to be illegally disseminated, including aspects of the economic evaluation in its lawsuit against the Corps concerning whether this document violated the National Environmental Policy Act (NEPA).

In addition to the environmental aspect, NWEA (2006) in its complaint also mentioned its concerns about factual inaccuracies with regards to economic evaluation over the scope of project work by submitting a declaration from an economist, Ernie Niemi of EcoNorthwest, presenting his analysis that the Corps' calculations and projections of economic benefit of the channel deepening project were grossly exaggerated.

Furthermore, NWEA (2006) pointed out that in the FSEIS the Corps based its cost estimate of $151 million for the channel deepening project, $95 million of which was to be Federal-funded, on a two-year construction period. In response to a comment regarding this time frame, the Corps had explained that "from a least cost perspective, minimizing the construction costs reduces the overall cost of the project." NWEA claimed that there was no basis for the Corps to assert or assume that the project was to be constructed within a two-year period for two fundamental reasons as follows:

1. The Corps had not yet received and was not likely to receive the full allocations from the Congress that were necessary for the agency to complete construction of the project within the two-year time frame, upon which all the estimated and predicted costs were based. According to published news reports, to maintain its

two-year time frame upon which all of its cost estimates were based the Corps required $15 million for FY 2005, $40 million for FY 2006, and $40 million for FY 2007 (NWEA, 2006; Columbia River Channel Coalition, n.d).

Facts revealed that the Corps only received $9 million, rather than $15 million, for FY 2005, and only $15 million, rather than $40, for FY 2006 (NWEA, 2006; Columbia River Channel Coalition, n.d). Likewise, the President's FY 2007 budget only included $15 million (NWEA, 2006; Columbia River Channel Coalition, n.d). Therefore, there was no basis for believing that the optimistic schedule of appropriations upon which the Corps had based its entire cost projections was accurate, clear, complete, or unbiased. Likewise, there was no reason for believing that the resultant cost projections in the FSEIS themselves were accurate, clear, complete, or unbiased (NWEA, 2006).

2. The Corps had been forced to radically scale back its initial contract for the project because it grossly underestimated the costs of the project. The Corps had combined portions of the Channel Deepening Project with operation and maintenance dredging of the Columbia River Navigation Channel and the Mouth of the Columbia River (MCR) for a solicitation issued on February 10, 2005. The lowest total bid received by the Corps in response to this February solicitation, and opened on April 12, was 69% higher than the government estimate. Even so, the lowest bidder for the three dredging projects was 17.95% over the government estimate (NWEA, 2006).

For these two reasons, NWEA (2006) in its complaint concluded:

- The economic analysis, both costs and benefits, upon which the information disseminated in the FSEIS was based, had failed to ensure and maximize the quality, objectivity, utility, and integrity of information disseminated by the agency as mandated by the DQA, its implementing regulations and relevant guidance. The cost estimates were based on a wholly unrealistic "optimistic" scenario that construction was to be completed within two years, contrary to every indication of how long construction was to actually take.

- In choosing to use a wholly unrealistic completion time frame, and choosing to not provide alternative time frames that would present a range of more realistic cost estimates, the Corps violated the DQA by presenting unrealistically low cost estimates that it was unlikely to achieve. These low cost estimates, in turn, affected the net benefits projected for the Channel Deepening Project.

- A gross underestimate of sediment volume would have a significant impact on the costs associated with the project. With lack of appropriations sufficient to maintain a two-year construction period, the Corps' seriously flawed cost estimates for certain phases of the project, and the flawed projections of both costs and benefits in the FSEIS demonstrated that the Corps' predictions of dredging and disposal costs in the FSEIS failed to meet the required quality of information disseminated to the public by Federal agencies.

5.1.2 Declaration by Economist Ernie Niemi

Ernie Niemi, an economist and vice president of ECONorthwest, submitted a declaration to explain technical economic concepts employed in the Corps' analysis of the economic costs and benefits of the channel deepening project, as well as to explain economic concepts and evidence that must be incorporated into the Corps' analysis if it was to provide a full and accurate picture of the project costs and benefits (NWEA, 2006).

In his review of the FSEIS, Niemi showed his viewpoints of incorrectness in the key assumptions and calculations made by the Corps regarding the projects' economic cost and benefit. Further, Niemi explained that his conclusion was supported by information available to, but ignored by, the Corps during the FSEIS preparation (NWEA, 2006).

Following is the summary of his declaration (NWEA, 2006):

1. <u>The Corps significantly disregarded cost of environmental externalities</u>

   The cost of environmental externalities was not included by the Corps in its cost calculation of the project. The total amount of disregarded cost was significant enough that it would most probably drive the BCR below 1.0, from projected 1.71. Such correction of the BCR value means that the project was not feasible.

   The Corps in the FSEIS (USACE, 2003) concluded that there were no environmental consequences of the project relative to 20.2 ha (50 acres) of riparian forest, 69.6 ha (172 acres) of agricultural lands and 6.5 ha (16 acres) of wetlands (p. 4-15). It also concluded that there would be no significant economic effects from the project's impacts that increase salinity, cause short-term increase in turbidity and sediment suspension, disturb additional bottom habitat, affect benthic habitat, affect 20.2 ha riparian (50 acres) at seven upland (sediment) disposal sites, affect 9.7 ha (24 acres) of wetlands at three disposal sites, impact general wildlife on 116.1 ha (287 acres) at five new disposal sites, mitigate for 104.0 ha (257 acres) agricultural, 2.0 ha (5 acres) riparian, and 9.7 ha (24 acres) wetland losses, change forested land/open space to disposal site use, change agricultural land to disposal site uses at five locations, and have minor additional impacts on aesthetics, air quality, noise, and the commercial fishery (FSEIS, pp. 4-16 to 4-18). Moreover, it concluded that there would be no environmental consequence with significant economic effects from dredging and removing millions of cubic yards of dredge material from the river system. To reach these conclusions the Corps either discounted or ignored altogether considerable evidence indicating that the project would generate negative environmental externalities.

With regards to the fact he put forward in his declaration (Attachment A – Declaration of Ernie Niemi, November 19, 2004: NWEA, 2006), Niemi concluded:

- Erosion problems at and near the MCR were significant. They had been made worse by past deepening and maintenance of the channel and there was a recognized risk, which was unable to be dismissed properly, that the project would make them even worse.

- Researchers from the Corps had concluded that some of the problems could be mitigated by strategically placing 3.1 million m^3 (4 million yd^3) of dredged material per year at or near the jetties.

- Repairing only the critical areas of the jetties would cost up to $14.1 million.

- A pilot study found that one alternative, placing dredged material on Benson Beach, would cost $5 per cubic yard more than dumping it in the deep ocean, which the Corps currently plans to do, if the project were implemented.

- Hence, at least one of the potential strategies for responding to erosion problems attributable in some part to channel-deepening, including what was proposed as part of the project, could cost $20 million per year.

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Niemi also stated that the Corps' analysis in the FSEIS (USACE, 2003) of the project costs and benefits did not account for any economic relationship between the project and the MCR. This, despite the fact that the economic benefits, if any, of a deepened channel upriver from the MCR could not be reaped if the jetties should fail or the MCR should become clogged. Thus, expenditures on the project and the expenditures necessary to keep the jetties and the MCR functioning fit together, each imposed externalities on the other. To provide a full accounting of the project costs and benefits, the Corps' analysis of the project had to be expanded to incorporate these externalities explicitly.

Accounting fully for environmental externalities could substantially alter the Corps' calculation of the project's BCR. Indeed, incorporating just the externalities associated the project's impacts on erosion at and near the MCR could reduce the ratio to less than 1.0. The Corps then calculated the benefit-to-cost ratio is 1.66, reflecting the Corps' estimate that the project would yield annual benefits of $18.8 million, incurred annual costs of $11.3 million, and generated net annual benefits of $7.5 million. These numbers, however, excluded any costs associated with the project's impacts on erosion at and near the MCR, and excluded any consideration of what might be necessary to keep the MCR open to ships so they could access a deepened channel upriver of the MCR. To incorporate the erosion-related externalities into its analysis, the Corps should account for known erosion-related damages, erosion-related risks, and the costs to mitigate the erosion-related damages and risks, which stem from the project.

If, after taking these steps, the Corps determined that the additional annual costs to the project exceeded $7.5 million, the project's benefit-to-cost ratio would fall below 1.0. Because the expenditures associated with each of these missing costs were so high, including any one of them in the cost-benefit analysis had the potential to alter the project benefit-to-cost ratio dramatically.

2. <u>The calculated total benefit was overstated</u>

The Corps' estimate of the project's benefits rested on its projections of the amount of cargo that would be shipped through the Columbia River ports. After the release of the FSEIS (USACE, 2003), events at the Port of Portland showed a reduction in shipments of containerized cargo, far below the Corps' expectations and markedly reduced the likelihood that future shipments would meet the Corps' projections. Facts showed that at the Port of Grays Harbor (to the north) the likelihood that future shipments of soybeans through ports on the Columbia River would meet the Corps' projections was unlikely to take place.

The FSEIS (USACE, 2003) stated that the project would generate economic benefits solely by reducing the costs of shipping cargo through the Columbia River ports. The Corps concluded, however, that the amount of cargo shipped was not dependent on the project. The analysis did not assume that, if the channel was deepened, shippers would be more disposed to use Columbia River ports. In other words, with or without the project, the Corps assumed that the same ships would carry the same cargo, but, with the project they would do so at a lower vessel-operating cost.

The Corps estimated that the project would generate benefits of $18.8 million per year (USACE, 2003). Of this amount, it attributed $11.7 million, or about two-thirds of the total, to its predictions of shipments of containerized cargo. It attributed an additional $1.0 million to its predictions of shipments of soybeans.

Regarding containerized cargo, shortly after the FSEIS was released, however, two of three shipping lines that carried containerized cargo announced that they no longer would call at the Port of Portland. Their withdrawal reduced the amount of containerized cargo flowing through the Port of Portland for the foreseeable future by two-thirds, relative to the amount the Corps assumed in its analysis. This reduction, in turn, reduced the project's total annual benefits from $18.8 million to $11.0 million. When this amount was compared with even the Corps' incomplete estimate of the project's annual costs, $11.7 million, the project's benefit-to-cost ratio fell from 1.66, as reported in the FSEIS, to 0.97.

Regarding soybeans, the Corps overlooked the development of a competing port facility nearby at the Port of Grays Harbor. This facility, which began service in 2004, focused on the export of soybeans, represented a significant competitor for ports on the lower Columbia River. It was sufficiently closer to the markets of the Pacific Rim that a ship stopping at Grays Harbor rather than at a port on the lower Columbia River would save two-day's travel time. It had not been in operation long enough to determine the extent to which this advantage would enable it to siphon soybean cargo away from the ports on the lower Columbia River. Whatever it siphoned off, however, would reduce the project's benefits beyond the reductions associated with the loss of containerized cargo. If it were to siphon all of the soybean cargo, and the loss of containerized cargo were as described in the preceding paragraph, then, all else equal, the project's annual benefits would decline from $11.0 million to $10.0 million, and the benefit-to-cost ratio would fall further, from 0.97 to 0.88.

Niemi contrasted his analysis with the Corps' FSEIS (USACE, 2003), which stated that these reductions in cargo shipments were independent of the project itself: implementing the project would not cause more containers or soybeans to flow through the Columbia River ports.

3. Significant Inconsistencies of the Corps' Economic Analysis as Result of Its Failure to Consider All Relevant Factors and Evidence

Niemi stated that the Corps had generated several serious inconsistencies in its analysis as a result of overlooking important factors and evidence related to the economic assessment of the project. He raised his concerns towards the Corps' treatment of the project's interactions with foreign entities and with ports elsewhere in the U.S, for which the Corps assumed that with the project or without the project the same vessels would carry the same cargo. If this assumption was true, then the only direct economic consequence of the project would be a reduction in the operating costs of the vessels calling at the Columbia River ports. There would be no increase in cargo shipped from or to these ports and no shift in the composition of cargo.

At that time, all vessels calling at these ports were owned by foreign companies, a pattern unlikely to change in the foreseeable future. Foreign ownership of the vessels raised the possibility that the project's direct benefits - the reductions in the vessels' operating costs - would accrue to foreign entities rather than to U.S. entities. Benefits accruing to foreign entities would lie outside the focus of the National Economic Development (NED) account, which set the guidelines governing the Corps' analysis, and focused solely on the costs and benefits to the U.S. economy, exclusive of impacts on foreign entities and economies.

Furthermore, Niemi claimed that the Corps' analysis left open the possibility that the cost savings would remain with foreign vessel owners. In an extensive critique of the DSEIS, it pointed out the importance of knowing what share of the transportation-cost savings would be enjoyed by U.S. entities, rather than remaining with foreign vessel owners or, alternatively, being passed to the foreign purchasers of the products being shipped from the U.S. The FSEIS, however, offered no quantitative estimate of the savings enjoyed by U.S. entities. It held to such inconsistent positions:

- The Corps stated that the project's benefits would manifest themselves as lower operating costs for vessels owned by foreign entities, but it then treated the accrual of benefits to foreign entities as benefits within the NED account, even though the NED account explicitly focused solely on the national output of goods and services in the U.S.

- The Corps stated that shippers would see lower shipping costs, but it then assumed, contrary to economic principles, that shippers would not respond by increasing the amount shipped.

- The Corps stated that the project would annually generate benefits of $18.8 million in the form of reductions in shipping costs, but it then assumed that benefits of this magnitude would have no impact: the same cargo would be shipped on the same vessels, with or without the project.

- The Corps stated that the project would reduce the costs of shipping cargo through the ports on the lower Columbia River, but it then assumed the reduced costs would have no impacts on the amount of cargo shipped through other U.S. ports.

5.1.3 Various Sources

As reported by Brent Wojahn in *The Oregonian* (April 24, 2010), the following issues were related to the CRCIP implementation:

1. The cost of the project, estimated at $134 million in 2003 to calculate its cost-benefit, had grown by 33 percent and taken years longer to complete than expected.
2. Under Corps' policy, project estimates used to calculate cost-benefits and to win congressional approval were based on budgets and timelines reflecting ideal conditions. In reality, Corps' projects typically take years longer to complete, driving up costs.
3. In 2003, the Corps staff asked Congress for $148.8 million for two-years of construction starting in 2005. But by 2005, when construction started, the price tag rose to $151 million and the economic cost-benefit fell to $1.66.

5.2 Follow Up of the Issues and Current Activity in the Project Site

Discussion of the project's flaws raised by NWEA was appreciable. Concerns for the environment, together with the case of extended project durationhad consequences of increasing the cost from the initial estimate. Further elaboration of BCR analysis was brought by Ernie Niemi, an economist hired by NWEA, who scrutinized the cost and benefit of the project.

The NWEA brought the case to the Ninth Circuit Court of Appeals (citation 460 F.3d 1125, docket number: 05-35806), argued and submitted on March 7, 2006; filed August on 23, 2006. In connection to its previously-submitted complaint before the U.S. Department of Defense, in its appeal to the Ninth Circuit the NWEA stated:

"A central concern of this appeal is the potential for various Corps projects to exacerbate coastal erosion. Historically, the Columbia River has drawn sand from inland areas and deposited it in the estuary, which in turn provided sediment to 100 miles of shoreline from Tillamook Head, Oregon to Point Grenville, Washington. This area is known as the Columbia River littoral cell. Over the past 120 years, various natural and human activities have reduced the amount of sand deposited in and throughout the littoral cell, contributing to erosion of the Oregon and Washington coasts."

NWEA, as the plaintiff, argued that the Corps failed, in the FSEIS, to take the requisite "hard look" at the direct, indirect, and cumulative impacts of the project under NEPA. Specifically, NWEA contended that the Corps:

a. failed to adequately analyze the cumulative impact of both the channel deepening project and the MCR Project on coastal erosion by the disposal of large quantities of sediment at the deep water site;
b. failed to adequately assess the project's direct impact on toxic pollutant mobilization and salinity;
c. failed to adequately assess the project's cumulative effects in light of past and future projects; and
d. failed to adequately consider the project's costs and benefits.

This case eventually resulted in rejection by the Ninth Circuit towards all of NWEA's arguments and held that the FSEIS complied with NEPA. The court first addressed the plaintiff's coastal erosion argument and held the Corps took the requisite "hard look" at the project's cumulative effects on coastal erosion. Particular weight was placed on the fact that the Corps had considered the environmental effect of deepwater disposal of both the MCR Project and channel deepening dredged material in the 1999 FSEIS, and had structured a plan to minimize deepwater disposal with the problem of erosion in mind. The court also found the Corps had assessed various potential mechanisms for sediment loss due to channel deepening, and had concluded that these would have "no appreciable impact" on sediment loss from the littoral cell.

With regard to plaintiff's other arguments, the court found the Corps had taken a "hard look" at the project's direct and cumulative effects. According to the court, the Corps had performed a number of studies addressing the project's direct effect on toxic pollutant mobilization and salinity. With specific regard to toxins, the court found the Corps tested for toxins both within and outside the navigation channel, and found that the project was "not expected to make an incremental contribution to sediment quality degradation."

Moreover, the court found that the Corps had not addressed impacts in isolation, but had examined the project's cumulative effects on salinity and sediment transport in conjunction with the MCR Project and other projects in the area. With regard to effects on estuary salinity, the court found that the Corps had analyzed the impact of both channel deepening and the MCR Project on estuary salinity, and had concluded "that the channel deepening project will have virtually no effect" on that parameter. Similarly, the court found that the Corps had appropriately analyzed the project's "negligible" cumulative impact on sediment transport in light of MCR Jetties, and upstream dams. The court also found the Corps had adequately addressed foreseeable future cumulative impacts of the project in conjunction with ongoing operation of the MCR Project since there was no plan to change the MCR Project at the time.

Finally, the Ninth Circuit rejected plaintiffs challenge to the Corps' alleged failure to correctly analyze the project costs and benefits. Here, plaintiff contended that the Corps' refusal to consider the additive effects of related dredging and disposal "caused the agency to ignore substantial project costs and ways of avoiding those costs." However, since the court had already decided that the Corps had taken a "hard look" at the substantive issues, it found that plaintiff's attempt to "refashion substantive criticisms of the Corps' considerations of cumulative impacts into arguments about faulty cost analysis" was unavailing.

Apart from the case settlement in court, as the project is now already completed and currently in three-year maintenance phase, a number of milestone pre- and post-construction are highlighted below in order to draw a clear picture of different viewpoints between the Corps and opposing parties:

5.2.1 Project Duration

Corps' sources explained that the USACE policy required that construction cost estimates be based on the most efficient method of building a project. The two-year construction estimate (and cost) reflected that policy. However, actual construction was dependent on the funding priorities of the US Congress. The federal funds which were appropriated for the project were distributed for separate fiscal years (FY), i.e. $4.5 million for FY2001; $2 million for FY2003; $3.5 million for FY2004; $9 million for FY2005; $15 million for FY2006; $30 million for FY2007; $14.76 million for FY2008; and $34.5 million for FY2009 (Appropriations Request Form, Oregon House Delegation Fiscal Year 2010). The 2009 federal American Recovery and Reinvestment Act (ARRA) Stimulus Package included the final $26.6 million needed for rock removal in the Columbia River navigation channel – which finally completed this vitally important project in November 2010 (Association of Pacific Ports, n.d).

5.2.2 Sedimentation and Erosion

With regards to Ernie Niemi's declaration, the Corps did not account for the project's potential impacts on sedimentation and erosion at and near the MCR as externality. This issue was seen as outside the project scope, and recent development reveals that the Corps is now looking to fix the jetties that shield the channel at the MCR. The work, if implemented, will become a project bigger than the CRCIP with approximate cost of $400 million to $500 million (Rivera, 2010).

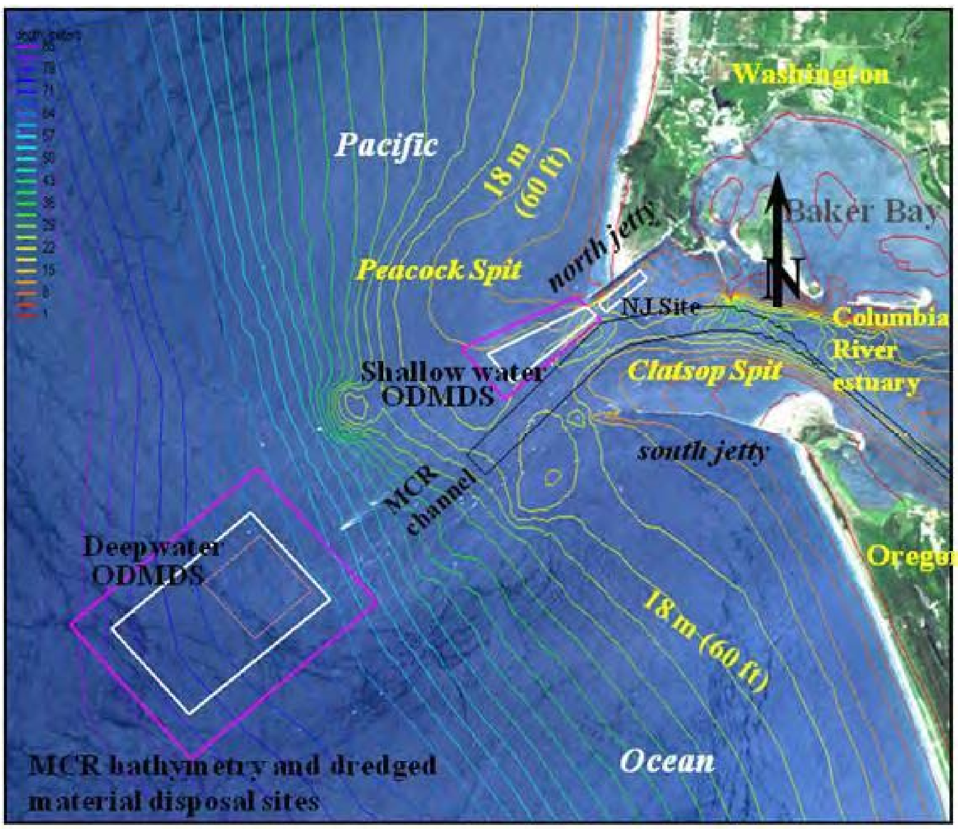

Figure 5.2 Existing Dredged Material Disposal Sites at the Mouth of Columbia River (MCR) (USACE, 2009)

In April 2012, the Corps prepared a Draft Environmental Assessment for Proposed Nearshore Disposal Locations at the Mouth of the Columbia River Federal Navigation

Project for public review under applicable laws and regulations, including the National Environmental Policy Act, and Clean Water Act. This draft EA disclosed the range of alternatives considered and the environmental consequences associated with the Corps' proposed use of three near-shore dredged material disposal sites for the MCR federal navigation project. The use of these sites would improve the following aspects of the overall operation and maintenance of the MCR federal navigation project:

- Provide additional long-term dredged material disposal options for the MCR dredged material disposal site network;
- Increase efficiency of dredging operations by using sites closer to the federal navigation channel;
- Protect the existing jetties that are a part of the MCR navigation system;
- Beneficially use dredged material by keeping it in the Columbia River littoral cell.

This draft Environmental Assessment (EA) evaluated the environmental effects for incorporating additional near-shore disposal sites for the beneficial use of dredged material at the Mouth of Columbia River Federal Navigation Project (MCR project). Every year, from 2.3 to 3.8 million m^3 (3 to 5 million yd^3) of sand is dredged by the Corps from the MCR entrance channel to keep the Columbia River deep-draft federal navigation channel open. Currently, the sediment dredged spoils are disposed of at three existing sites. Two of these sites are within the near-shore littoral area – the Shallow Water Site (SWS) and the North Jetty Site (NJS). The third site is a Deep Water Ocean Disposal Site (DWS) that is used when the other two sites are at capacity or when the weather is too treacherous to use them. Over the past five years, approximately one-third of the sand dredged at the MCR has been taken to the DWS. This removes a large portion of this clean (uncontaminated) resource from the Columbia River littoral cell, where it would help sustain the jetties, beaches, and marine habitats in the MCR area.

The purpose of the proposed action was to add additional, long-term dredged material disposal sites to the existing network of disposal sites for the MCR operations and maintenance project. Additional disposal sites were needed to supplement sediment within a naturally erosive environment, obtain needed information on near-shore processes, and divert a sand resource that is otherwise "lost" if it goes to deep-water disposal rather than to beneficial use in the littoral zone. The addition of near-shore disposal sites also would give the Corps' flexibility for disposal options.

The existing SWS is the current disposal site utilized as a feeder of sediment back into the littoral system. Strategic placement of sediment in this disposal site has improved the movement of sediment into Peacock Spit (to the north of the North Jetty). However, the littoral cell is still experiencing depletion of sediment. Due to the variability of each dredging season, definitive actions cannot be predefined; sediment must be distributed among disposal sites in order to not overload one disposal zone. Although they are dispersive sites, disposal at the SWS and NJS has been limited because of bathymetric restrictions (i.e. potential for dredged material mounding). Therefore, the Corps is seeking to use other near-shore sites to aid in returning sand to the littoral cell and, in the process, reducing the need to place dredged material in the DWS.

5.2.3 Dredging Volume

USACE (2003) in The Supplemental Feasibility Report/Environmental Impact Statement (FS/EIS) estimated 11.46 million m^3 (14.99 million yd^3) of dredging for construction of the 13.1 m (43-foot) channel. This calculation was based on the quantity of material between 13.7 m (45 feet) and 14.6 m (48 feet). The projected quantity dredged, as noted in the Adaptive Environmental Management (AEM) report was 11.06 million m^3 (14.47

million yd^3) (Bartell et al, 2011). Therefore, the quantity dredged between 13.7 m (45 feet) and 14.6 m (48 feet) was 4.5% less than the estimated quantity.

To understand the discrepancy, there was another aspect to consider. During new construction, it was necessary to remove any maintenance material that might exist (because it was literally 'on top of' the new work material). Further, when USACE did maintenance dredging to an authorized depth, an additional amount of 'advanced maintenance' material was also removed. In the Columbia River, the normal amount of advanced maintenance was 1.5 m (5 feet). Therefore, dredging to a total depth of 13.7 m (45 feet), i.e. 12.2 m (40 feet) authorized channel + 1.5 m (5 feet) of advanced maintenance could be considered 'maintenance dredging' and be paid for with normal maintenance funding. That was why the CRCIP report only considered the quantity (and cost) of removing material between 13.7 m (45 feet) and 14.6 m (48 feet) (i.e. the removal of maintenance material, including advanced maintenance material was not considered a project cost for the channel deepening project). However, USACE maintenance dredging funds during the years of construction were limited. When it came time to actually deepen the channel some concessions were needed in order to move forward. The agreed upon solution was as follows: the project paid for the removal of maintenance material only if there was no intention or need to do maintenance dredging in that location, for instance, if the channel was already at 12.8 m (42 feet). The maintenance program paid for the removal of maintenance material to 13.7 m (45 feet) if there was a need to perform maintenance dredging in that location, i.e. if the channel depth was less than 12.2 m (40 feet). This location specific funding arrangement increased the quantities paid for by the Corps as project implementing agency to the total cited in the report.

Bartell et al (2011) discussed discrepancies between the projected and actual volume of new work by comparing the estimated volume of material between 13.7-14.6 m (45-48 feet) at the amount of 11.06 m^3 (14.47 million yd^3) and additional volume removed above 13.7 m (45 feet) if there would have been no O&M of the 12.2 m (40 feet) channel in the area at the time of deepening and the quantity removed below 14.6 m (48 feet) in rock removal areas which were deepened to 15.5 m (51 feet). The volumes calculated in this depth range, in addition to initial estimated volume, reached a total amount of 14.60 million m^3 (19.09 million yd^3). As shown in Table 4.1, we find approximately 32% additional dredging volume in the actual work due to above-mentioned additional work.

Furthermore, by referring to Table 4.1 and Figure 4.1 (a map of every bar of dredging work), we can see significant variation between the actual dredging and the originally forecasted volumes. As explained by Bartell et al (2011), this case was due to the dynamic moving of the dredging material sand waves between shoals. The quantities varied greatly by year and with changing flow rates in the river. Such unpredictable movement in the seabed made it unlikely to make an accurate match between the acceptance areas chosen for deepening and the limits of the Columbia River Mile (CRM)/shoals used for the initial construction estimate. For this reason, interpretation of the output given in Table 4.1 was taken as a bottom line number rather than shoal-by-shoal comparisons.

It is important to understand that two independent methods were used to quantify the construction material removed and the disposed materials. The materials removed were calculated by bathymetric surveys of in-place quantity removed, while the volumes disposed were calculated by measurements of what was hauled. The dredging quantity would not exactly match the disposal quantity because of the two separate volume measurement methods, however both quantities were correct (Bartell et al, 2011).

Wojahn (2010) in *The Oregonian* (April 24, 2010) reported discrepancy in calculation of the total volume of removed material, i.e. between 11.06 million m^3 (14.47 million yd^3) of estimated quantity and 11.92 million m^3 (15.59 million yd^3) of actual work. The Corps had confirmed this matter, indicating such 7% discrepancy was tolerable due to unpredictable movement in the seabed as discussed above. The breakdown of dredged material placement and material removal from USACE Portland District Office is presented in Table 5.1 below.

Table 5.1 Dredged material placement and material removed from the channel (in yd^3) compared to the 2003 projected volume (USACE Portland District Office, 2012)

Total Upland	7,806,366
Deep Water Disposal Site (DWS)	2,170,532
In-water (flow lane)	5,490,079
Rehandled (subtracted)	2,279,575
Subtotal	13,187,402
Estimate to Complete	2,400,000
Total	**15,587,402**
Estimated Quantity	**14,470,000**
Percent higher than estimated	**7%**

5.2.4 Project Cost and Verification of BCR

Clarification was obtained from the USACE concerning the cost change of the project, saying that even though the total quantity of material increased, the total cost of the project had not increased. There had been a difference in price and the difference in price was mainly attributed to the timing of construction. Strictly speaking, the $134 M estimate in 2003 (without contingency) was the same as an estimate of $184.7M (with contingency) in 2010. The point in time estimates in Table 5.2 below clarify such discrepancies. They indicate how the same cost estimate was adjusted (to its real value) in the present day or in a particular year. The actual cost of the project (projected to be $178M) was less than the estimate when the price was adjusted to 2010.

Table 5.2 Comparison of point in time project costs estimates in different years (USACE Portland District Office, 2012)

Year	1999	2002	2003	2010	Actual
CRCIP Point in Time Estimate (in US Dollars)	151,638,000	132,787,000	134,042,000	184,739,000	178,424,000

The present day-cost estimate is the real value of dollars expected to expense. As presented in the table, the actual price is about 3.5% lower than the projected price in year 2010 (with contingency). This matter also clarifies the issue raised by Wojahn (2010) in *The Oregonian* (April 24, 2010) regarding the project cost discrepancy.

6 Conclusions and Recommendations

The evaluation of inconsistency between projected and actual dredging volume, project cost, and time schedule of the Columbia River Channel Improvement Project (CRCIP) clarifies various controversies that emerged concerning these three elements of the project. Despite limited sources of information available, discussion in previous chapters reveals the facts of project activity during its implementation.

The Best Management Practices of the CRCIP were applied in the dredging work by referring to the guidelines for best management practices in the states of Oregon and Washington as stated in the document of National Coastal Program Dredging Policies. The Corps as the implementing agency faced funding limitation for the project's annual disbursement. This matter caused the increase in nominal value of the project cost and the extended project duration. Thus, it is concluded that best management practices in the scope of the project cost and duration were applied optimally utilizing the limited funding available.

In terms of discrepancy of dredging volume, we can look into this case in two different ways of comparing the projected and actual one. One way is by comparing the projected volume with total actual volume of dredging, which included the maintenance dredging volume. With additional maintenance dredging at average of 1.5 m (5-feet) depth, there was approximately 32% additional volume reported by the time of project completion. We can also note the significant variation of sedimentation by year (at the river bed), which made such a difference in volume. Another way is by calculating the total placement of dredged material removed from the channel. Here we find approximately 7% additional volume. Such difference was caused by the different methods applied in calculation of removed material (bathymetric survey) and calculation of material disposal (total hauled volume).

As the project cost was reported to increase in close agreement with increasing volume, at first it was understandable to assume the cost increase was simply caused by increasing volumes. This project reveals a different fact. While the volume increased due to some cases as mentioned above, the cost increase was principally caused by the difference between point-in-time calculation. In fact, the actual cost decreased slightly (about 3.5% lower) when it was compared to point-in-time cost in year 2010, when the project was completed.

More concern from the economic viewpoint was put into the Benefit-Cost Ratio (BCR). Discussion about the many factors affecting the BCR value was presented in the previous chapter. The project at its completion came out with BCR of 1.66, which justified its implementation. Concerning BCR validity, this project elaborates on the complaint from Northwest Environmental Advocates (NWEA), accompanied by declaration from Ernie Niemi, an economist. They provided much insight as to whether the project could result in significant benefit, as an expression of their concerns towards funding for its implementation. Despite the court's denial to their appeal, which on the other hand gave the Corps much favor for this project, it is interesting to consider the possibility of accommodating their concerns. In fact, the externalities put forward by Niemi in his declaration, i.e. erosion and sedimentation at the MCR, is now given much attention by the government by considering a massive plan of jetty construction which is currently in assessment phase (USACE, 2012).

This research also provides clarification regarding extended time schedule of the project. Initially projected to complete in 2007, the project took three-years longer. The initial time schedule was set with regards to the basis of a project's most efficient method. Throughout the implementation, the schedule needed to adjust to the US Congress' funding priorities, which allocated the funding over a five-year period.

This project was limited in scope. The CRCIP was a massive project, thus different areas of research could be explored and studies made of the best management practices. The one which has been much highlighted in the news is the environmental impact of the project. Although the Corps has submitted all required reports pursuant to its responsibility of preventing any negative externalities, it is worth monitoring the maintenance phase which is ongoing.

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