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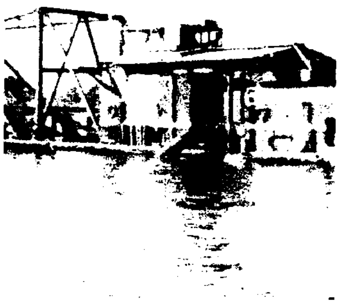

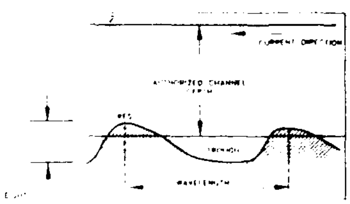

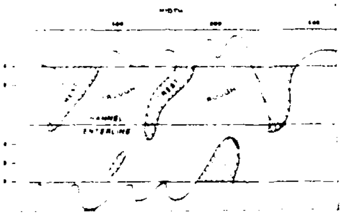

HYDRAULICS LABORATORY

IMPROVEMENT OF OPERATIONS AND MAINTENANCE TECHNIQUES RESEARCH PROGRAM

MISCELLANEOUS PAPER HL-90-4

EVALUATION OF AN EXPERIMENTAL JET FLUIDIZER FOR REMOVAL OF SAND WAVES IN THE COLUMBIA RIVER

Report 2

1988 EXERCISE

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by

Mitchell A. Granat, Michael P. Alexander

Hydraulics Laboratory

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
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13. ABSTRACT *(Maximum 200 words)*

Western Pacific Dredging Company designed and built an experimental jet fluidizer for the removal of sand waves in the Columbia River navigation channel in 1987 (under contract to the US Army Corps of Engineers). The performance of this jet fluidizer is being evaluated and reported on in a series of reports. Report 1 of this series presents design details and results of the first dredging exercise that took place September-October 1987. Although the fluidizer proved successful at removing the specified sand wave volumes, recommendations were made for improving the fluidizer efficiency and reducing the unit cost per cubic yard of material removed. Report 2 describes the modifications that were made to the fluidizer dredge and evaluates the field performance for the second dredging exercise that took place September-October 1988.

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PREFACE

The 1988 fluidizer dredging exercise for the removal of sand waves in the Columbia River was evaluated for the US Army Engineer District, Portland, by personnel of the Hydraulics Laboratory (HL), US Army Engineer Waterways Experiment Station (WES), Vicksburg, MS. The fluidizer dredge is owned and operated by Western Pacific Dredging Company (WPD), a division of Riedel International, headquartered in Portland, OR. The dredging work began on 26 September and ended on 28 October 1988. Analysis of the field test results and preparation of this report were performed during the period November 1988 to April 1991. Publication of these results was sponsored by the Headquarters, US Army Corps of Engineers (HQUSACE), under the Improvement of Operations and Maintenance Techniques (IOMT) research program, Work Unit No. 32386, "Mitigating Sand Waves in Navigation Channels." Field data were collected by Portland District, WES Coastal Engineering Research Center (CERC), and HL personnel.

The report was written by Messrs. Mitchell A. Granat and Michael P. Alexander, Estuarine Engineering Branch, Estuaries Division, HL, under the general supervision of Messrs. Frank A. Herrmann, Chief, HL; Richard A. Sager, Assistant Chief, HL; William H. McAnally, Chief, Estuaries Division; and William D. Martin, Chief, Estuarine Engineering Branch. Mr. Granat was Chief, Estuarine Engineering Branch, during final report preparation and publication. Assistance with field data reduction was provided by Portland District personnel. Mr. Robert F. Athow, Estuaries Division, was IOMT Program Manager, and Messrs. Jim Gottesman and Jim Crews were former and present HQUSACE Technical Monitors. Technical review of this report was provided by Mr. Glynn Banks, Estuarine Engineering Branch, and Messrs. Jeff Lillycrop and Doug Levin, CERC.

Commander and Director of WES during preparation of this report was COL Larry B. Fulton, EN. Technical Director was Dr. Robert W. Whalin.

CONTENTS

CONVERSION FACTORS, NON-SI TO SI (METRIC) UNITS OF MEASUREMENT

Non-SI units of measurement used in this report can be converted to SI (metric) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres

EVALUATION OF AN EXPERIMENTAL JET FLUIDIZER FOR REMOVAL OF SAND WAVES IN THE COLUMBIA RIVER

1988 EXERCISE

PART I: INTRODUCTION

Background

1. Large-scale sand wave formations in the Columbia River are a continual navigation maintenance problem for the US Army Engineer District, Portland. Conventional pipeline and hopper dredges are used to mitigate sand wave formations and restore navigable depths along the Columbia River. The shape of these bedforms results in inefficient conventional dredging techniques and has spurred interest in developing innovative dredging techniques that attempt to "level" the protruding crest portion of the sand wave (Figure 1)* into the adjacent trough sections. The Western Pacific Dredging Company (WPD) jet fluidizer is one such device for leveling sand waves. The fluidizer was constructed and initially tested in 1987. The 1987 fluidizer exercise evaluation indicated that the fluidizer could level the sand waves and restore navigable depths, but modifications to operating procedure and design were needed to make the fluidizer economically competitive with conventional dredging. The jet fluidizer, as designed and constructed by WPD, is shown in Figure 2. The problems associated with sand waves in the Columbia along with the 1987 fluidizer exercise evaluation can be found in Martin, Banks, and Alexander (1990),** and a summary of innovative sand wave dredging techniques can be found in Alexander (1990).†

2. The fluidizer exercise took place along four Columbia River sand-wave-prone channel reaches between river miles 80 and 100 (Figure 3). In an upriver direction, these locally named reaches included St. Helens Bar,

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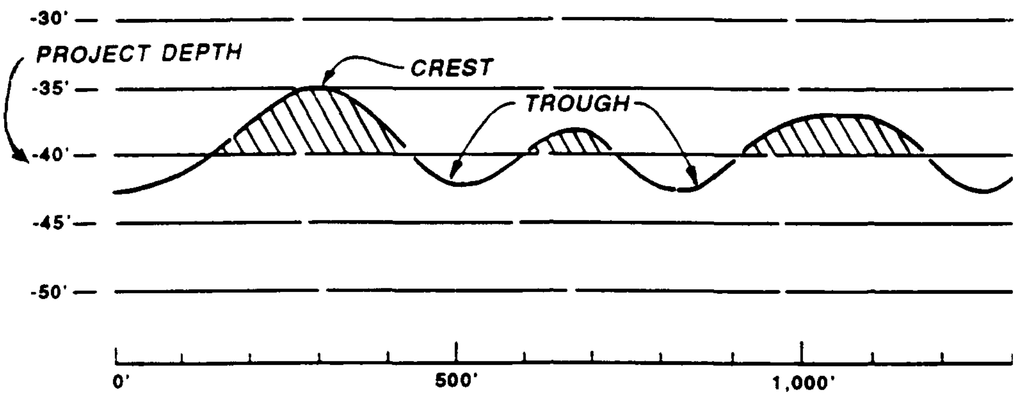
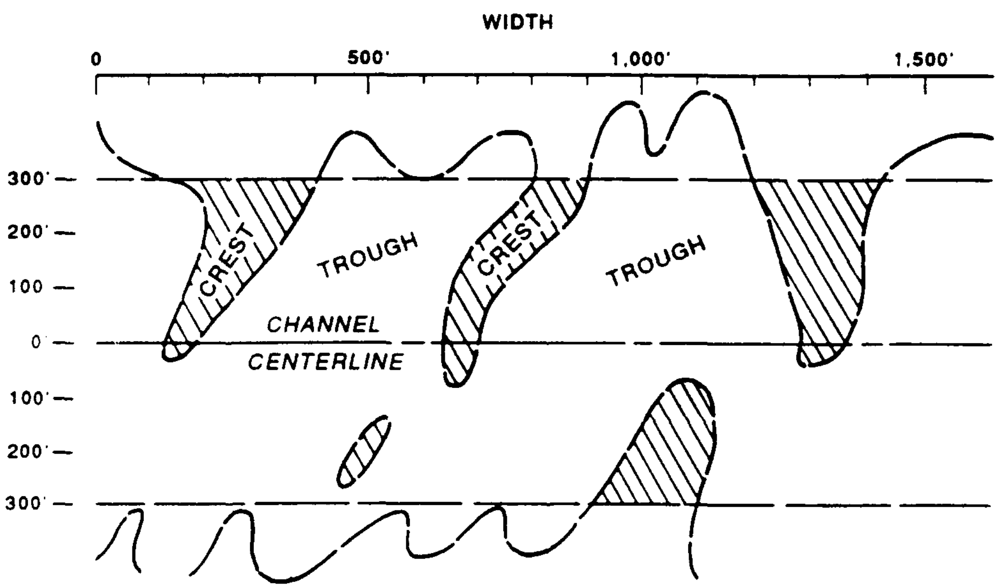
* A table of factors for converting non-SI units of measurement to SI (metric) units is found on page 3.

** W. D. Martin, G. E. Banks, and M. P. Alexander. 1990 (Jul). "Evaluation of an Experimental Jet Fluidizer for Removal of Sand Waves in the Columbia River, Report 1, 1987 Exercise," Miscellaneous Paper HL-90-4, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

† M. P. Alexander. 1990. (Sep). "Sand Waves, Report 2, Engineering Considerations and Dredging Techniques," Technical Report HL-90-17, US Army Engineer Waterways Experiment Station, Vicksburg, MS.



a. Side view



b. Plan view

Figure 1. Typical Columbia River project sand wave dimensions

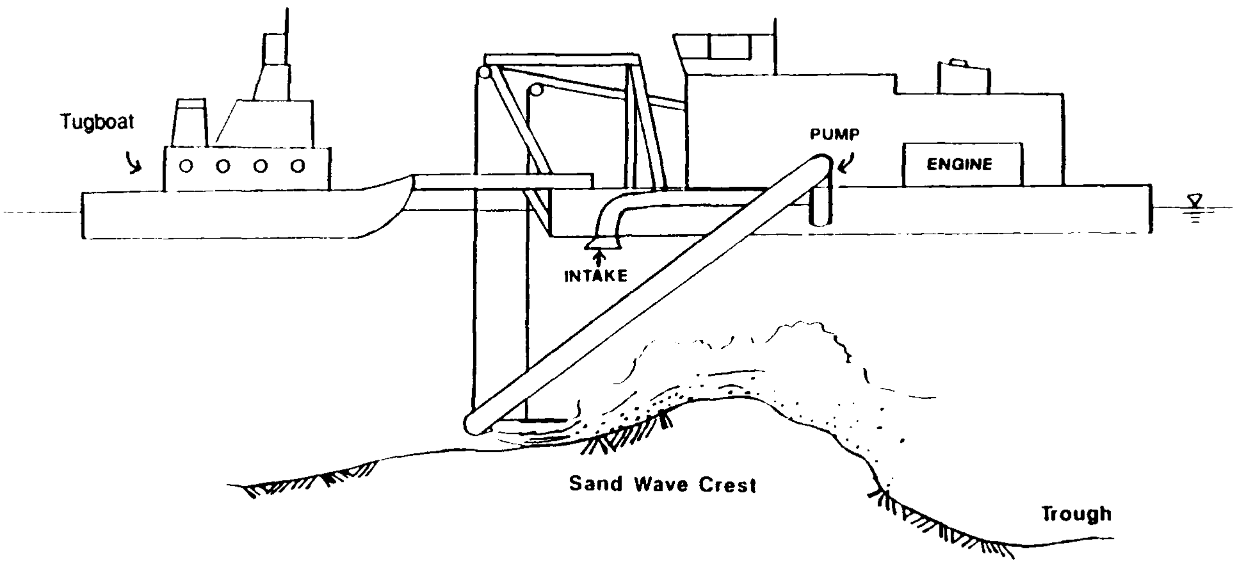


Figure 2. Western Pacific Dredging Company jet fluidizer

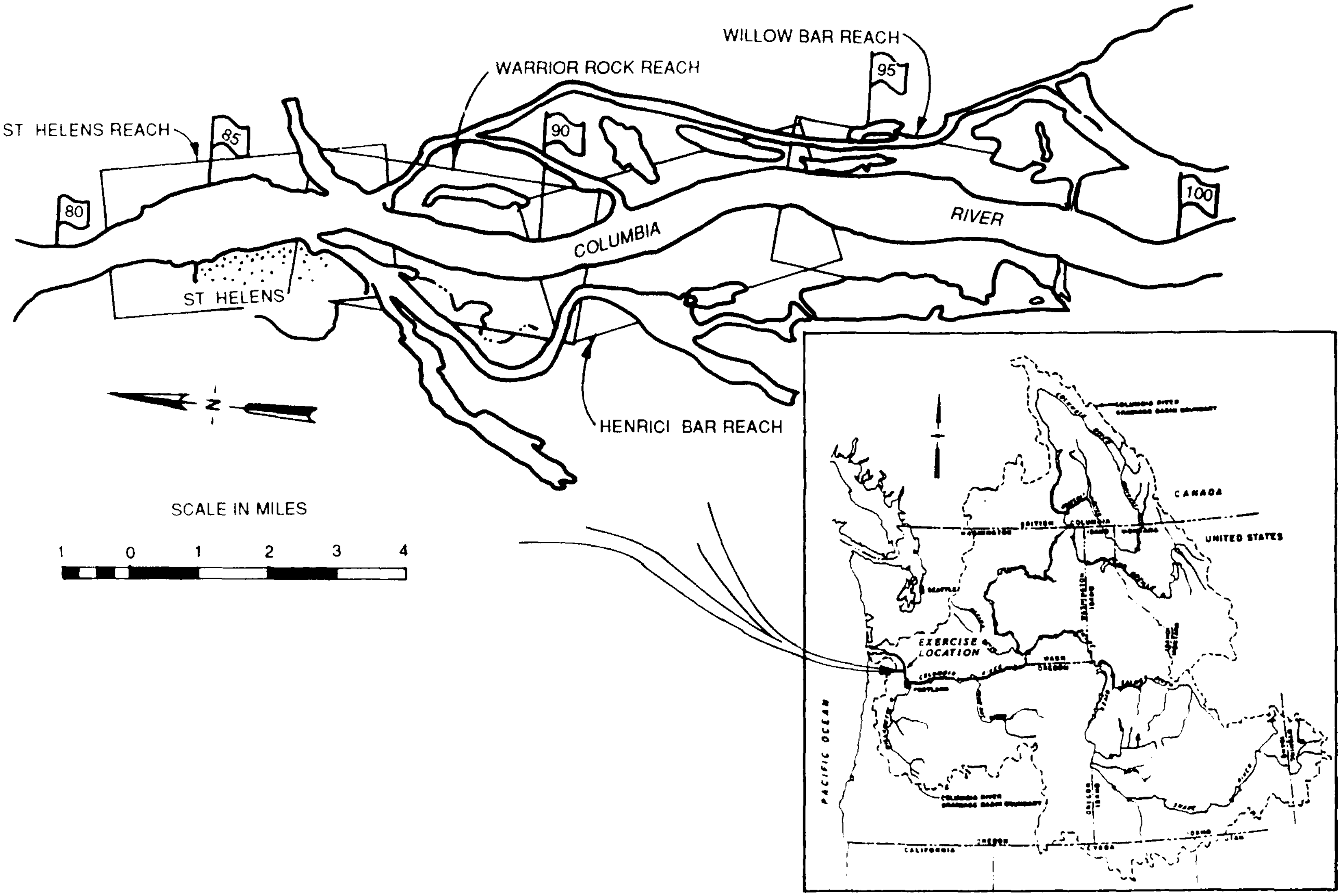


Figure 3. Columbia River vicinity map and dredged river reaches

Warrior Rock, Henrici Bar, and Willow Bar. Predredge and postdredge surveys over these areas were conducted aboard the Portland District survey vessel *NORMAN BRAY* using a Ross multitransducer sweep survey system. Predredge surveys were used to identify problem sand waves for production testing. During and after the exercise, postdredge surveys and volume computations were completed with the Ross system.

Testing Arrangement

3. The exercise was sponsored by the Portland District through a US Army Engineer Waterways Experiment Station (WES), Hydraulics Laboratory (HL), contract with WPD. Since the fluidizer was experimental and required a performance evaluation, the contract was research and development oriented. To facilitate data collection, general attendant vessel support, and fluidizer maneuverability, fluidizer operations were specified to take place during daylight hours only. The contract called for 25 days of daylight operation and allowed for 5 days of data monitoring on board the fluidizer and in the working areas. The 5-day data monitoring effort took place 3-7 October.

Objective

4. The objective of this report is to describe the modifications made to the WPD jet fluidizer and to evaluate its field performance during the 1988 dredging exercise. This performance includes ambient hydrodynamic influence, production, and technique feasibility in relation to conventional sand wave mitigation.

PART II: FLUIDIZER MODIFICATIONS

Hood and Jet Nozzle Angle

5. The hood and jet nozzle arrangement (Figure 4) was originally designed to act with eductor-type transport capability.* The hood and jet nozzles were directed horizontally, or 0 deg, during the 1987 exercise. The 1988 trials began with the hood at 0 deg, and the jet nozzles angled 10 deg downward where a portion of the jetting action was directed into the bed. Two separate sand waves from the St. Helens Bar area were selected for testing with the angled jet position during the monitoring period. Based on the predredging and postdredging surveys, volume computations, operation time estimates, and comparisons with results from the 1987 exercise, it was concluded that the waves were not as efficiently degraded with the 10-deg setting. The angle of the jet nozzles was returned to the horizontal setting for the remainder of the production dredging exercise.

6. The effects of the hood on stimulating any eductor-type transport are still unclear, although indications are that the effects are insignificant. The hood was hinged from the boom and controlled with a separate cable and winch system (Figure 4). This arrangement was awkward and caused the hood to contact and "plow" into the sand wave crest before fluidizing action moved the material. On one occasion this situation caused cable connections to break. Operations were halted to reattach the hood winch line. The difficulty in evaluating eductor transport is due in part to the increment of material removed and the lateral angle of the sand waves, as discussed in the next section.

Positioning and Operation

7. The fluidizer was operated with the jet flow in a downstream direction to take advantage of ambient currents. After making a single pass over a sand wave, repositioning was required. This involved moving the fluidizer upstream to the same starting position to progressively degrade the sand wave. Sand waves generally slope laterally downward toward the channel thalweg. It

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* Martin et al., op. cit.

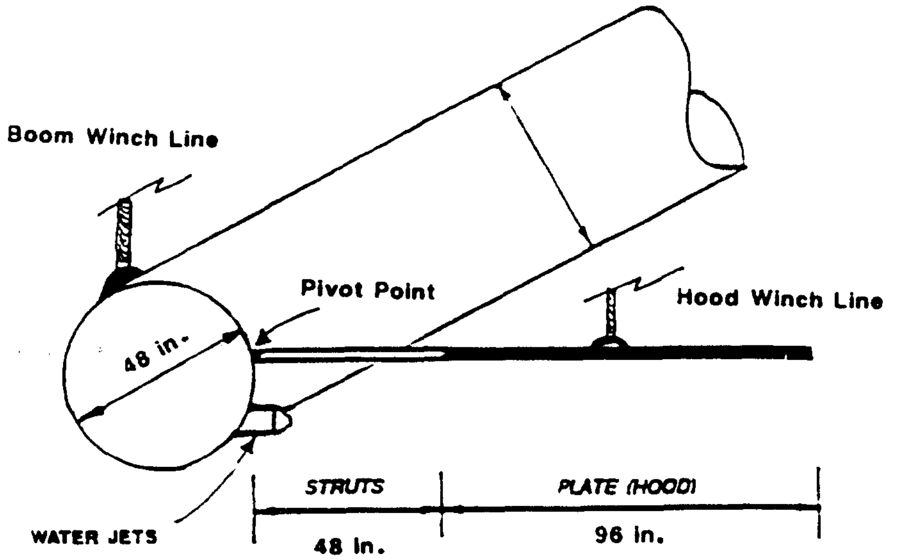

Figure 4. Fluidizer boom and hood arrangement

was not possible for the floating fluidizer vessel with its fixed horizontal boom to position evenly over the laterally sloping material. The fixed boom caused the fluidizer to twist off line when one corner of the boom was in contact with the bed and the other was not. The problem was more severe during initial passes; after several passes the fluidizing action began to level the crest in a lateral as well as vertical direction, increasing production and making operation more manageable (Figure 5). The test attempted to fluidize and remove approximately 0.5 ft of the sand wave height per pass. The fluidizer encountered problems with material buildup in front of the boom when attempts were made to remove more than 1 ft of material. These problems were basically the same as described in Report 1,* limiting the increment of material to be removed to less than 1 ft of improved operation. Dredge controllability (accurate positioning and maintaining a desired dredging cut) was once again a primary problem.

Increasing Fluidizer Flow Capacity

8. To date, the design flow capacity for the fluidizer has not been achieved in the prototype. In an effort to improve pumping efficiency during the 1988 exercise, the nozzle exit diameters were reduced from 4 to 3 in., which increased the pressure head on the pump and allowed a more efficient

* Martin et al., op. cit.

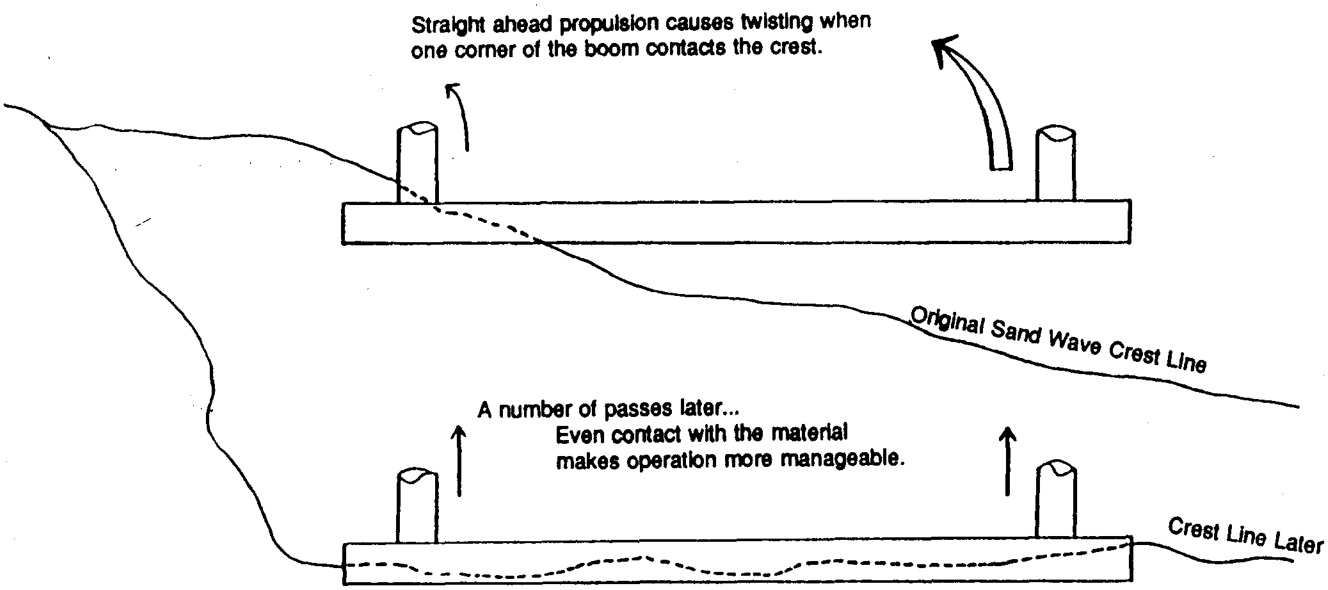

Figure 5. Rear view of fluidizer boom as lateral and vertical sand wave degradation takes place

engine pump shaft speed. This modification also increased the jets' exit velocities.

9. The transport capacity (jet velocities and momentum) measured during the previous (1987) dredging exercise was too low to provide cost-effective production rates. Accurate measurements were not available for the original and modified prototype velocities, head, and pressure; therefore, the fluidizer evaluation was based on overall production between the two exercises as described in Parts IV and V of this report.

Operation in Conjunction with Favorable Ambient Flow

10. The fluidizer was designed to operate with assistance from an ambient velocity of up to 8 fps. Velocities on this order are generally associated with spring runoff or other high flow events. The field exercise was conducted from the end of September to the end of October 1988, resulting in a seasonal time frame that limited ambient current assistance. This situation was similar to that for the 1987 exercise. To further compound the exercise problem of seasonal low flows, the Columbia River basin experienced drought conditions during 1988. Sediment loads and sand wave development (crest heights) were less than normal. Part III describes in detail the influences

of ambient conditions and addresses production in terms of timing such an operation to coincide with optimum ambient currents.

PART III: AMBIENT HYDRODYNAMICS

11. Freshwater discharge along the Columbia River basin during the September–October 1988 time frame was low, and channel shoaling associated with sand wave encroachment on the navigation depth was below anticipated levels. These conditions provided a challenging test site for the fluidizer. The level of production attained is dependent on ambient flow assistance, and the original design specifications included the "ability to work in constantly changing flow velocities, ranging from 2 to 8 fps." Flow conditions during the exercise resulted in velocities of 0 to 3 fps. At times, tidally influenced flow reversals actually hindered dredging efforts.

12. The tidal cycle flood velocities from downstream are usually insufficient to overcome the dominant ebb direction river discharge at the exercise location. The flood tidal influence retards river velocities as river stage rises in response to the tidal influence. Although surface and bottom flow velocity direction had not been previously known to reverse at the exercise location,* during the monitoring period, river velocities reversed at times due to the flood tidal cycle.

River Stage

13. Figure 6 illustrates the water level time-history recorded at the St. Helens Gaging Station 2–8 October 1988. Daylight working hours (0600–1800 hr) are shaded for each day of operations. This figure demonstrates a mixed tide semidiurnal inequality in the water surface elevations typical for this reach of the Columbia River during autumn. The time duration of falling water levels was longer than the time duration of rising water levels. Figure 7 illustrates the water-surface elevations for 1–28 October 1988. For this period, the average duration of the falling levels (ebb portion of the tidal cycle) was 7.6 hr while the average duration of the rising levels (flood portion of the tidal cycle) was 4.7 hr. Figure 8 illustrates hourly observed water levels during the 3–6 October monitoring period. This figure illustrates the typical lunar (tidal) influence on the water levels. High and low

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* Personal Communication, Karl Eriksen, 1988, US Army Engineer District, Portland, Portland, OR.

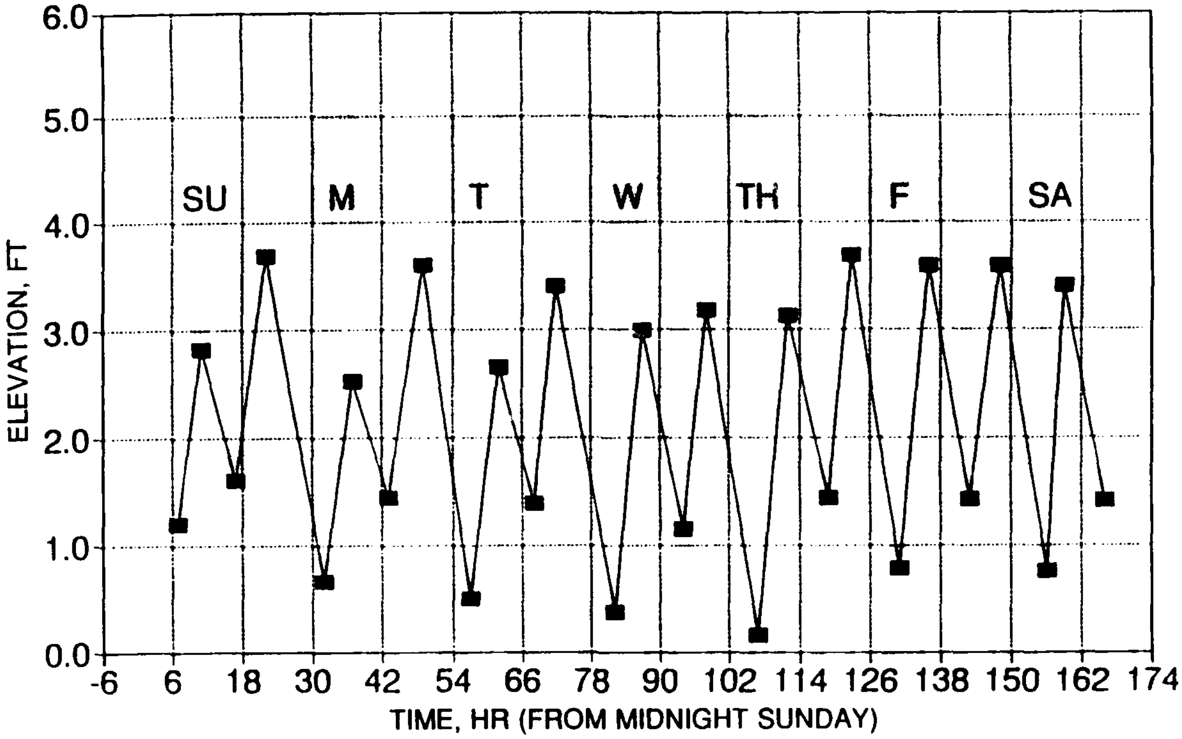


Figure 6. St. Helens water-surface elevations, 2-8 October 1988

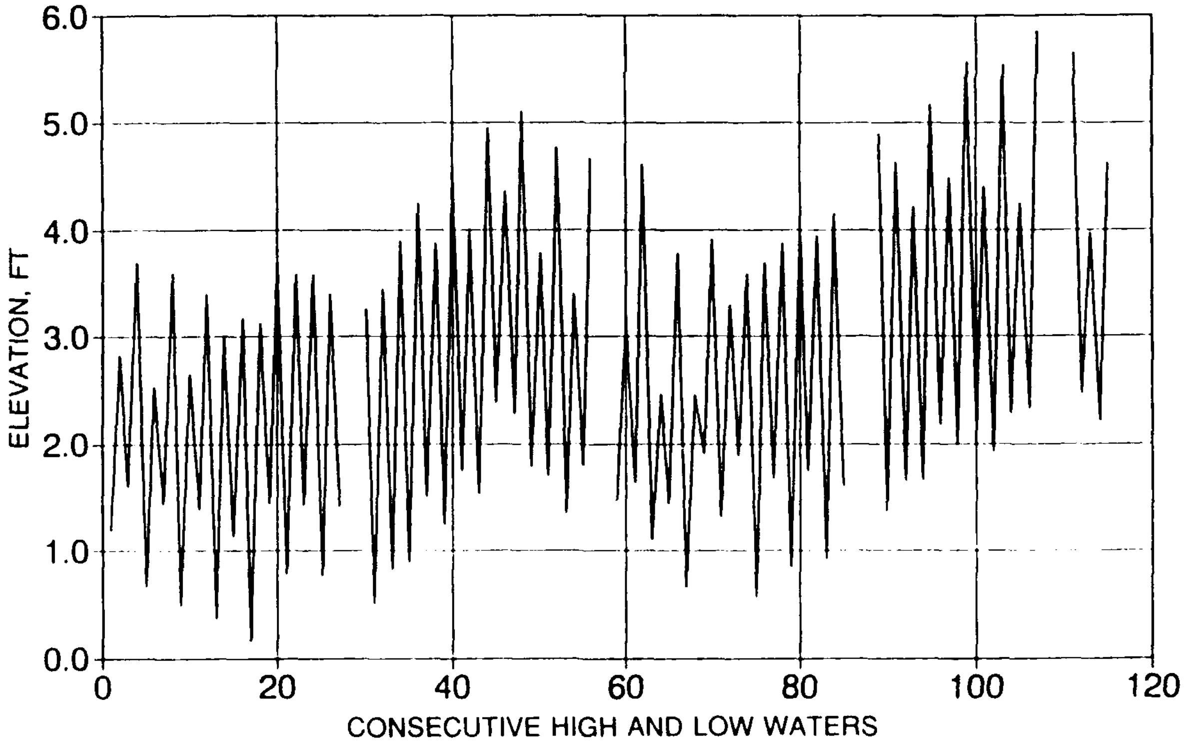


Figure 7. St. Helens water-surface elevations, 2-29 October 1988

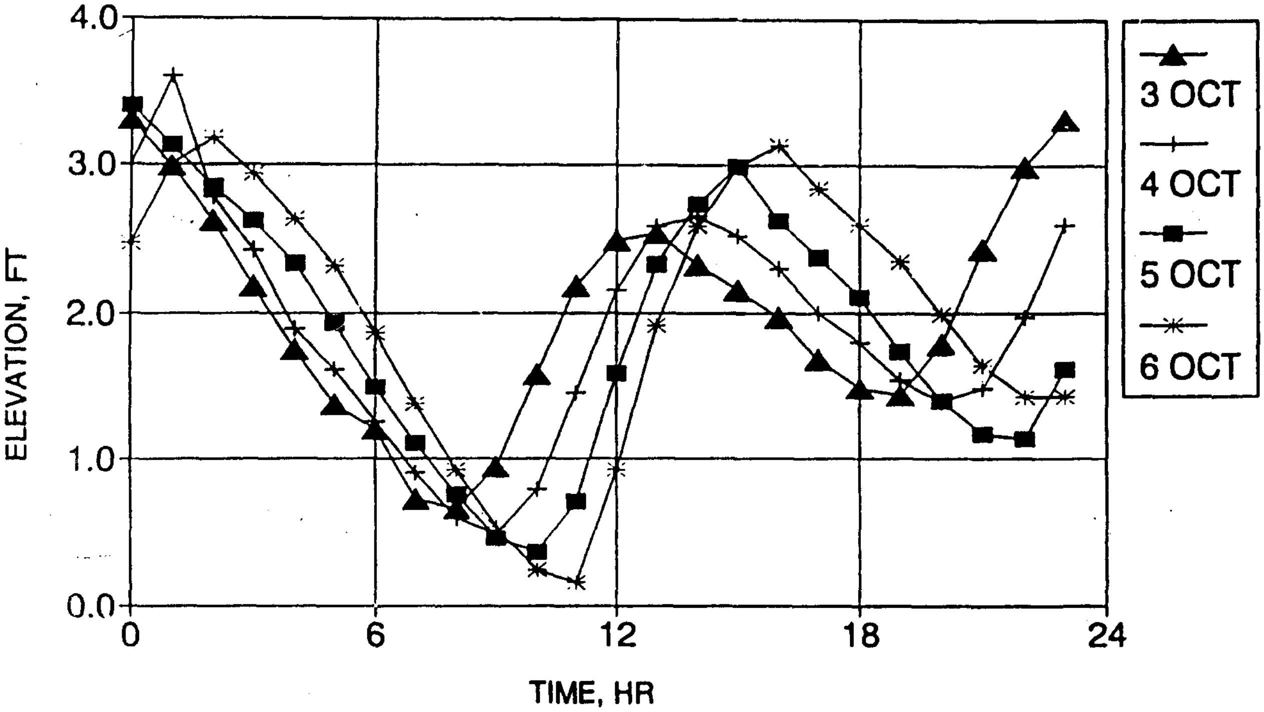


Figure 8. St. Helens hourly water-surface elevations, 3-6 October 1988

waters for successive days occur about 0.84 hr later each day. Notice also the increased tidal range during the daylight hours from 3 to 6 October (progressing towards a spring tide).

Flow Measurements

14. Ambient current measurements were made during fluidizer operation from the Corps of Engineers survey vessel *BABY BIDDLE*. Surface, middepth, and bottom velocities were recorded with a Gurly model 665 cup-type current meter. The meter was raised and lowered through the water column for measurements with an over-the-side winching arrangement (Figure 9). The *BABY BIDDLE* was anchored approximately 100 ft away from the toe of the channel toward the Oregon side of the river over the crest of the sand wave being dredged. Current direction was obtained with a remote-reading compass mounted directly above the current meter as shown in Figure 9.

15. In addition to the measurements made from the *BABY BIDDLE*, a self-contained ENDECO 174 ducted impeller current meter was operated from a moored location on the Washington side of the river, approximately 1,000 ft from the

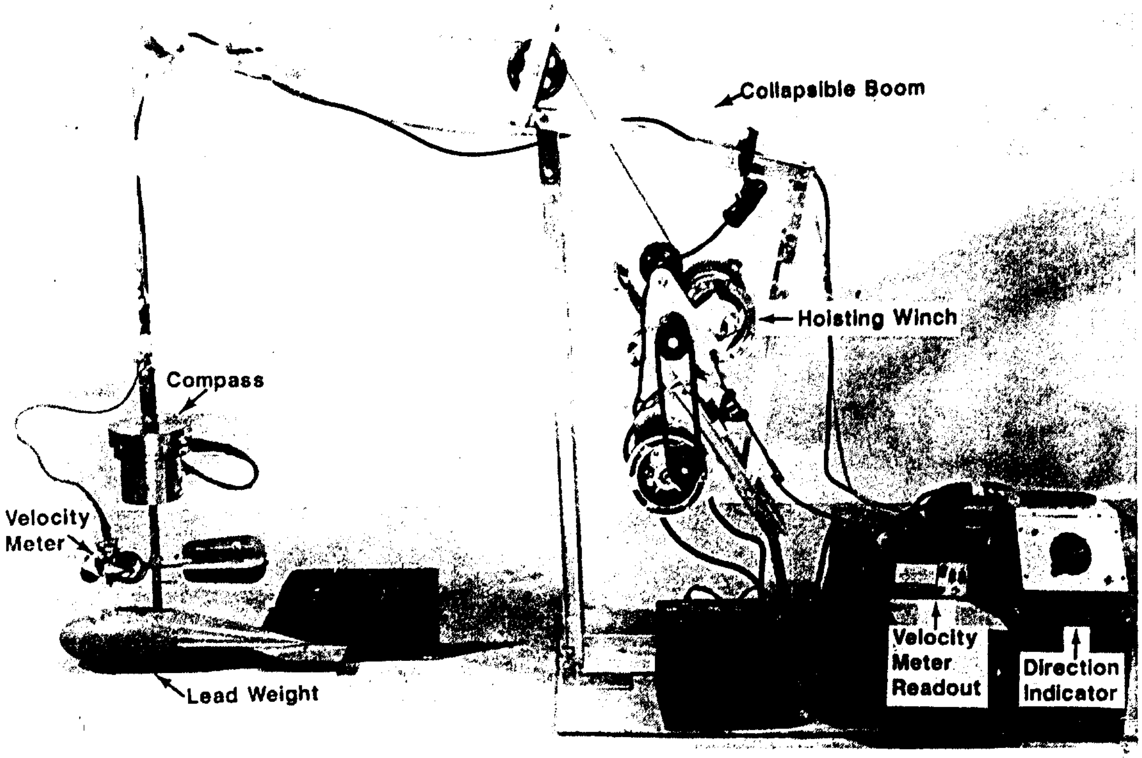
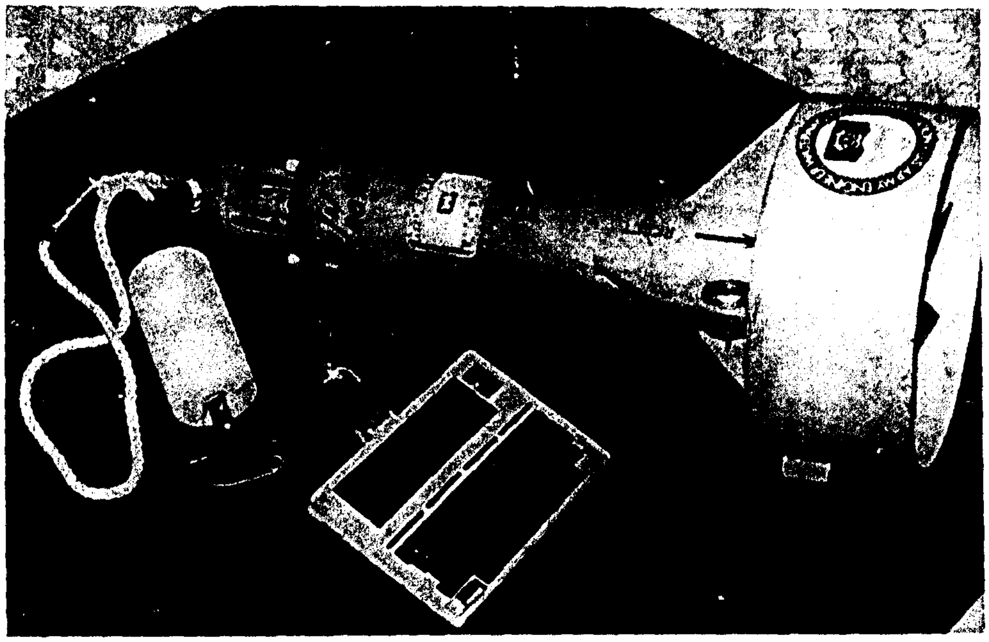


Figure 9. Over-the-side sampling apparatus

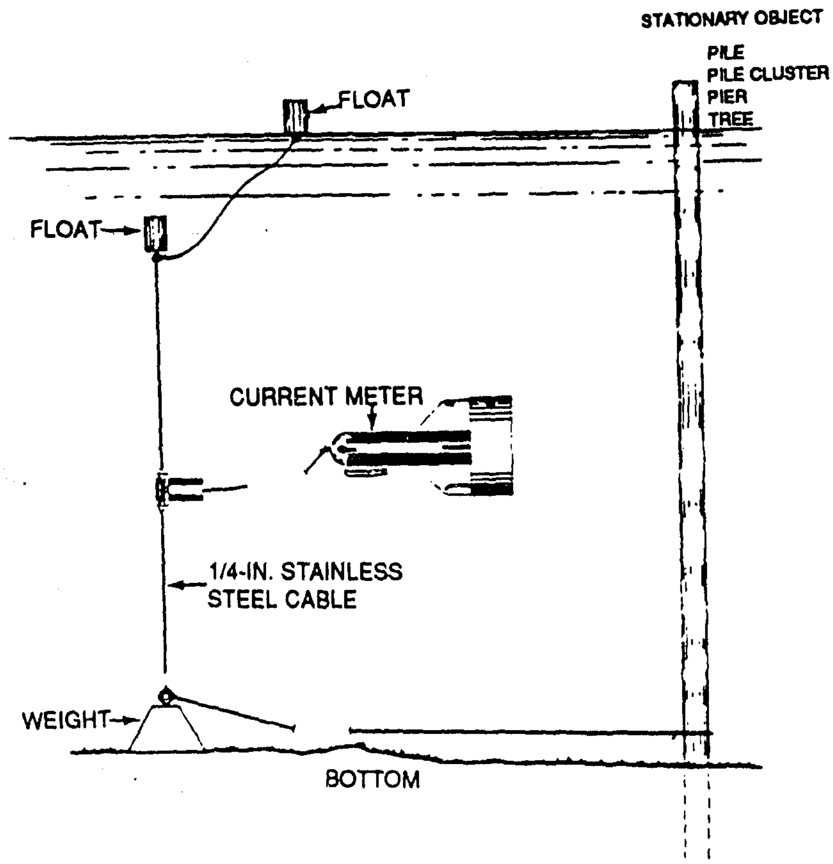
navigation channel. It was deployed in about 30 ft of water using a buoy and line anchored on the river bottom. The current meter was suspended horizontally from the buoy line using a tether (Figure 10). Data were collected approximately 3 ft above the bottom.

Ambient Velocities

16. Figure 11 illustrates the observed velocity/river stage versus time relationship for fluidizer operations on 5 and 6 October 1988. Rising river stage was dominant during most of each working day, and resulting velocities fell from more than 2.0 fps to less than 0.5 fps. Surface, middepth, and bottom velocities around 0.5 fps in the flood (upstream) direction were observed between 1200 and 1400 hr on 5 October (between low water and high water). Flood velocities also started around 1200 hr on 6 October and are thought to have persisted until around 1500 hr. The near-bottom velocities recorded with the fixed current meter provided a comparable record although these velocities were considerably lower (Figure 12). The velocity plots (Figures 11 and 12) reflect the tidal inequality described in paragraph 13;

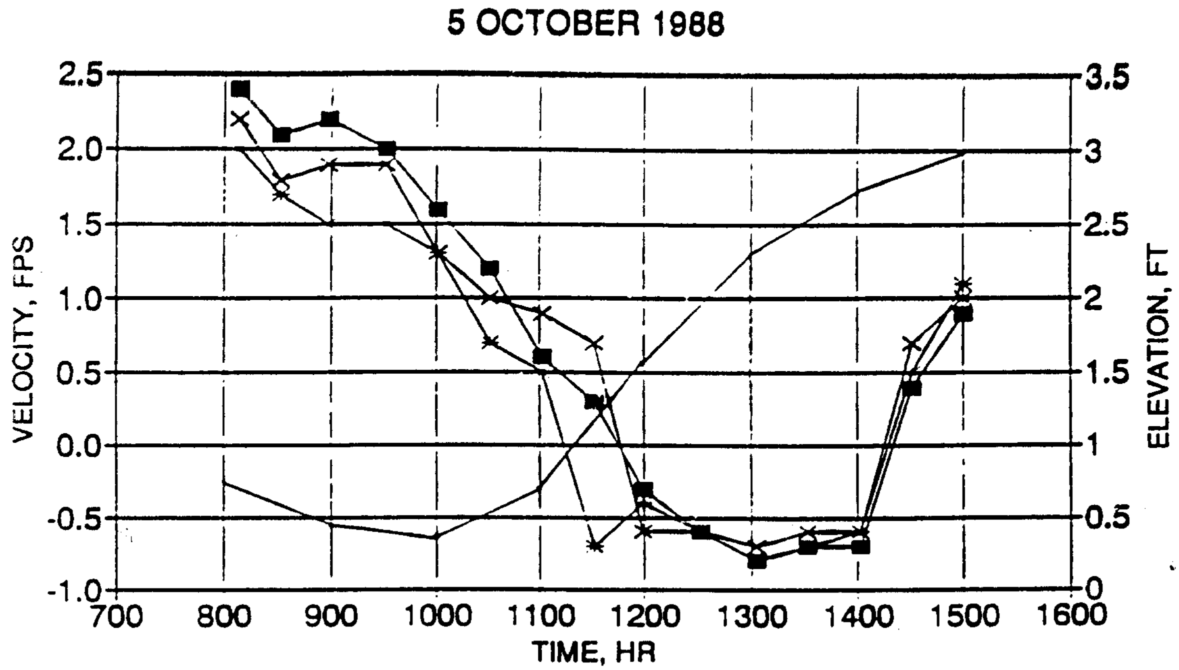


a. ENDECO 174 meter



b. Model 174 tethering arrangement

Figure 10. Moored velocity meter apparatus



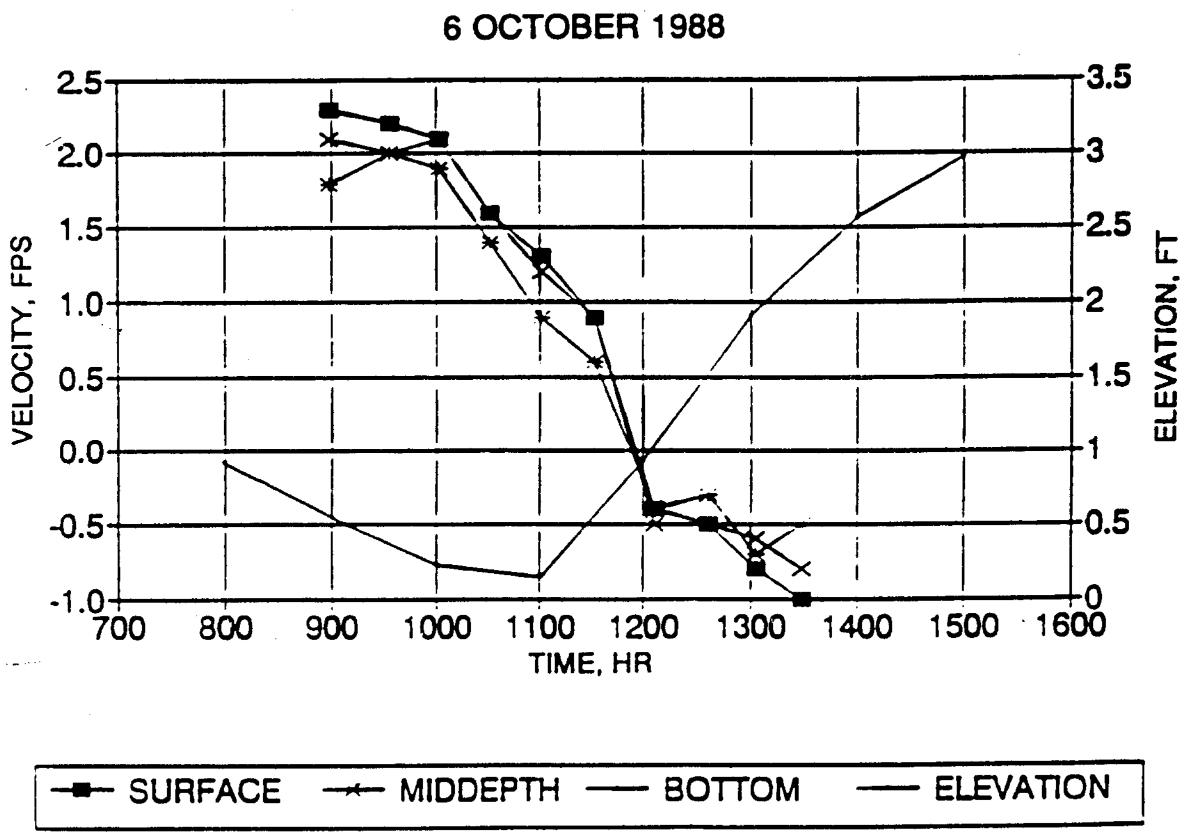


Figure 11. St. Helens hourly velocity and water-level observations, 5 and 6 October 1988

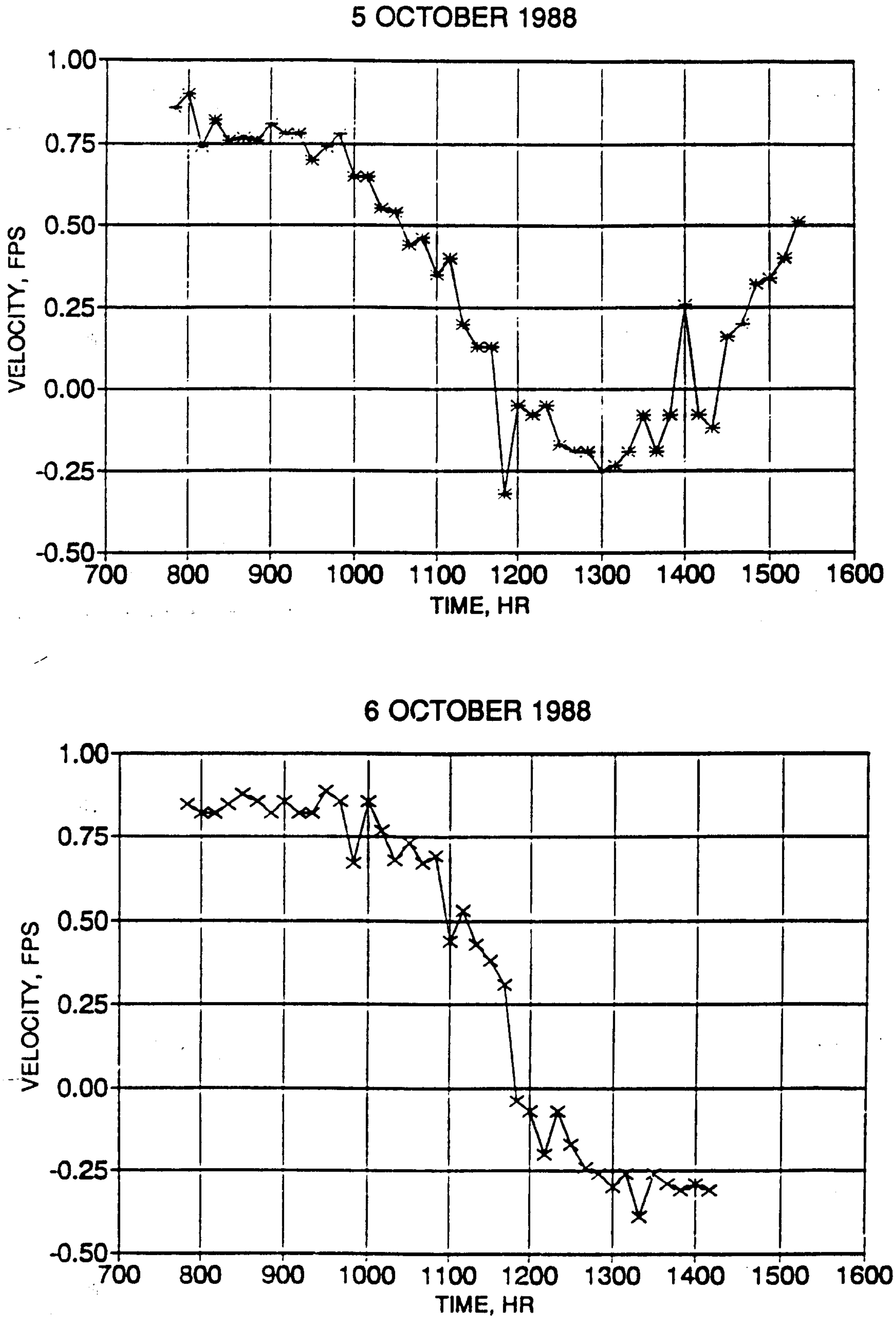


Figure 12. Moored near-bottom velocity observations, 5 and 6 October 1988

ebb current velocity durations and magnitudes are much greater than flood current velocity durations and magnitudes.

17. In this reach of the Columbia River, the degree and type of hydrodynamic response to the tidal influence depend upon the volume of freshwater discharge and the tidal range and associated velocity magnitudes. Optimum dredging conditions for the sand wave fluidizer are when ambient currents are the strongest and help transport the resuspended material from the crest of the sand wave. As such, ideal conditions would occur during higher river discharge periods, for example, during late spring when the freshwater discharge is falling, but still high.

18. For the dredging procedures followed in this exercise, optimum ebb cycle dredging periods are when the tidal range from high water to low water is the greatest so that tidal velocity influence would be additive to the freshwater discharge velocity. Optimum flood cycle dredging conditions are when the tidal range from low water to high water and associated flood tidal velocity are minimal. As illustrated in Figure 6, the optimum dredging time for the data monitoring period (3-7 October) would have been between midnight and 0700 hr (i.e., from high high-water to low low-water periods) rather than during the daylight working hours. Contract constraints, however, required dredging operations to occur only during the daylight hours for this field exercise. As illustrated in the next section, this requirement resulted in reduced ambient velocities and associated reduced dredging production rates. Planning future contract efforts to coincide with favorable ambient velocity conditions could have a significant impact on production.

Fluidizer Sand Wave Degradation

19. Figure 13 illustrates the general location of the two St. Helens Bar sand waves (Sites A and B) selected for dredging during the 5-day monitoring period. Operational procedures and techniques were developed and improved during this monitoring period. The navigation equipment and maneuvering skill were also improved during this period. A detailed analysis of the degradation of these two sand waves provides an excellent illustration of the importance of optimum ambient velocity conditions and indicates how ambient forces influence this dredging technique.

20. Figure 14 illustrates the predredge and postdredge survey

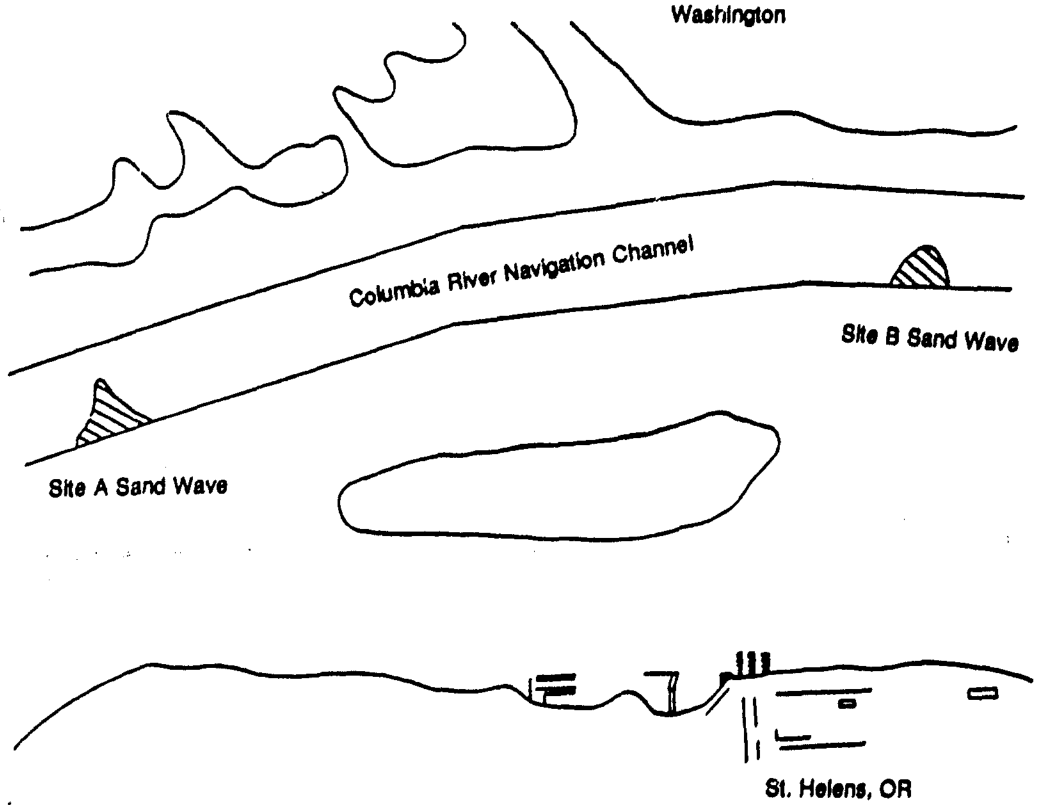
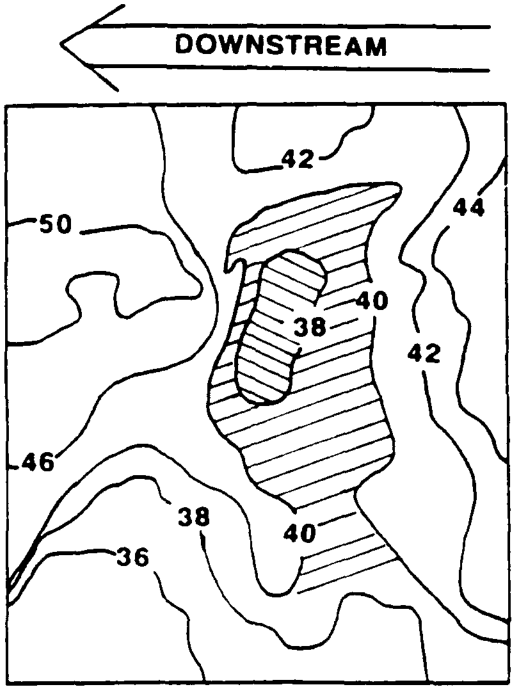
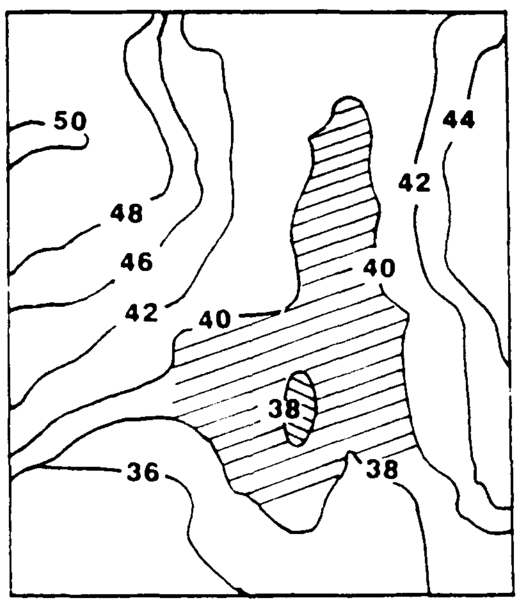


Figure 13. St. Helens Reach sediment sampling locations

conditions for the Site A sand wave. Approximately 12 hr of dredging time was spent working on this wave during the 3-5 October period. As shown, the width and crest of the wave were reduced with the eroded material deposited in the downstream trough. Figure 15 similarly illustrates the predredge and post-dredge survey conditions for the Site B sand wave. Approximately 6 hr of dredging time was spent working on this wave on 6 October between 1100 and 1700 hr. As with the Site A wave, the Site B sand wave was also noticeably reduced in width; however, this sand wave was actually displaced in the upriver direction. The predredge and postdredge surveys were checked for possible navigation errors, but none were identified. Although the fluidizer worked in the downstream direction, this sand wave actually migrated in the upstream direction. The jetting action of the fluidizer resuspended surface material from the sand wave crest, but this material appeared to be transported back over the fluidizer in the upstream direction by the flood currents.

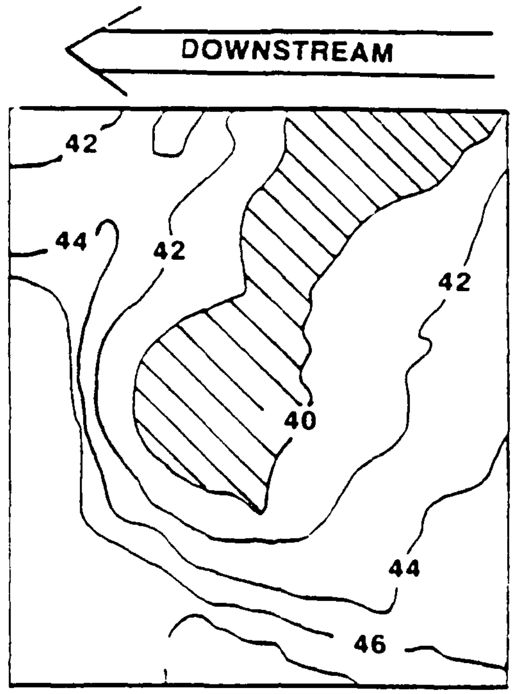


a. Predredge survey

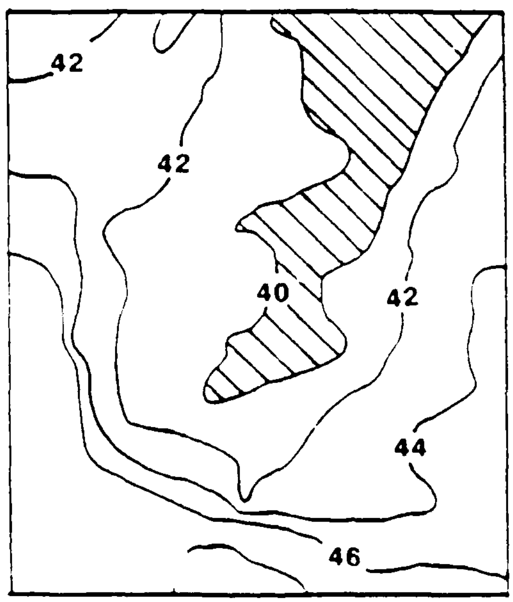


b. Postdredge survey

Figure 14. St. Helens sand wave, Site A, predredge and postdredge bottom contours



a. Predredge contours, ft



b. Postdredge contours, ft

Figure 15. St. Helens sand wave, Site B, predredge and postdredge bottom contours

Sediment Grain-Size Distribution

21. Sediment sampling was carried out to investigate sediment responses to the fluidizer dredging action. Predredge and postdredge bed surface sediment samples were collected from St. Helens sand waves at Sites A and B. Bed sampling was performed aboard the Portland District vessel *CATHLAMET BAY* using a grab sampler. The vessel was equipped with a Del Norte positioning system for navigation. Sampling locations were selected from predredge surveys. Four sampling lines were identified for the wave at Site A and two were selected for the wave at Site B. Three grab sample locations, corresponding to the upstream face, the downstream face, and the sand wave crest, were identified for each line. The coordinates of the actual sampling locations were also recorded for later plotting.

22. Twelve predredge samples were collected from Site A on 3 October and corresponding postdredge samples were collected on 6 October. Six predredge samples were collected from Site B on 5 October and corresponding postdredge samples were collected on 7 October. Postdredge surveys were not completed until after the sampling period. Grain-size analyses were performed by the Portland District following standard laboratory procedures.

23. Sediment grain-size variations were identified along each of the sand waves. The most consistent trend indicated that coarser grain sizes were located toward the Oregon side of the channel for each wave. The grain-size distribution appeared to get finer toward the center of the channel along each sand wave. This general trend existed for both the predredge and postdredge samples. Other grain-size characteristics also varied along and across each sand wave, but a consistent trend was not apparent.

24. Several other factors, in addition to natural sediment variations along and across the sand waves, complicated sediment grain-size distribution interpretations. For example, due to sampling difficulties, predredge and postdredge samples were not taken at the same locations. Also, due to the upstream migration of the wave at Site B, a fact not known until all sampling was completed, postdredge samples were all collected on the downstream face of the wave.

25. Specific grain-size distribution changes between predredge and postdredge conditions could not be made because of the natural grain-size distribution variation over the sand wave, the different sampling locations,

and the limited number of samples. A more detailed and better controlled sampling program is recommended for future investigations.

PART IV: PRODUCTION EVALUATION

Factors Included in Production Calculation

26. Contractor's reports provided actual production (fluidizer dredging) time and downtime for each day's operations. Downtime included the amount of time used for maneuvering the dredge to the proper cut line, waiting for passing vessel traffic to clear the dredge site, minor repairs, and navigation equipment failures. Downtime did not include travel time to and from anchorage prior to each day's operations or travel time from one sand wave work site to another. A daily listing of dredging hours spent at each sand wave is documented in Granat (1990).* A summary of production time and downtime by reach is provided as follows:

Production Time, hr	Downtime, hr	Total Time, hr
	St. Helen's Reach	
12.8	29.9	42.7
	Warrior Rock Reach	
1.3	0.8	2.1
	Henrici Bar Reach	
3.8	1.9	5.7
	Willow Bar Reach	
31.5	23.6	55.1
49.4	56.2	105.6

The above values show that actual fluidizing dredging constitutes approximately 50 percent of the operational time. Although the above tabulation incorporates the bulk of the exercise operating time, some work site records

* M. A. Granat. 1989 (12 Jul), "Evaluation of an Experimental Jet Fluidizer for Removal of Sand Waves in the Columbia River, Report 2, Interim Report, October 1988 Field Exercise," Memorandum, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

were not included because of the excess downtime associated with data collection.

Production Calculation

27. Agitation dredging techniques use below-project-depth areas as disposal sites. Shoal material is transferred to deep areas where it does not impede navigation. The WPD fluidizer effected this concept by transferring, or leveling, above-project-depth sand wave crest material into adjacent below-project-depth trough sections (Figure 1). Production calculation for an agitation dredging technique must be based on a constant bottom datum. Otherwise, accurate production would not be realized because a significant portion of the "relocated" material may still remain within the postdredging survey prism, only below project depth. Dredged volumes for the fluidizer exercise were related to Columbia River Datum (CRD) and indicate the sum of material removed above selected datum increments. Since sand wave shoaling was abnormally low during 1988 and because the exercise was experimental, fluidizer dredging was continued below the project depth of -40 ft CRD. The tabulation below presents the total volume of sand wave material displaced and/or removed

Volume (cubic yards) Removed Above:

-41 ft	-42 ft	-43 ft	-44 ft
	St. Helens Reach		
8,800	14,100 (5,300)	16,400 (2,300)	18,800 (2,400)
	Warrior Rock Reach		
1,500	1,800 (300)	1,800 (-0-)	1,900 (100)
	Henrici Bar Reach		
2,700	5,400 (2,700)	7,100 (1,700)	7,300 (200)
	Willow Bar Reach		
16,700	29,900 (13,200)	40,100 (10,200)	44,000 (3,900)

from each work area. Beginning with the second (−42 ft CRD) increment, the value in parentheses represents the volume removed between that datum increment and the previous datum increment. For example, the 5,300 cu yd at the −42 ft CRD depth, St. Helens Reach, indicates the volume of crest material removed between −41 and −42 ft CRD. These volumes are associated with the working times presented in the previous paragraph and are based on four 1-ft removal depths, beginning with −41 ft CRD. Essentially, no sand wave crest degradation was effected below −41 ft CRD for the Warrior Rock Reach work sites. This is indicated by the relatively small volume (0 to 300 cu yd) of material degraded below −41 ft CRD. Such small volumes of material may be within the survey and volume calculation error band. Generally flat bottom conditions were achieved as fluidizer operation filled adjacent trough "disposal areas." Since it cannot move material any considerable distance (especially without significant ambient current assistance), the fluidizer was less efficient as flat bottom conditions were approached. Flat bottom conditions were reached at the Henrici Bar Reach below the −43 ft CRD depth. The St. Helens and Willow Bar areas show a significant increase in displaced material down to the −43 ft CRD depth. Below the −43 ft CRD depth, material displacement minimizes and fluidizing approached flat bottom conditions at these sites as well. Detailed volume computations for each sand wave dredged are documented in Granat (1989).*

28. Hourly production for the exercise was based on the total time and associated volume displaced at each general dredging location (river reach). The overall (time-weighted average) exercise production rate was approximately 685 cu yd removed per hour of operating time.

Reach	Production, cu yd/hr	Total Operating Time, hr
St. Helens	450	42.1
Warrior Rock	900	2.1
Henrici Bar	1200	5.7
Willow Bar	800	55.1
Exercise Average	685	

* Granat, op. cit.

Technique Feasibility

29. Using the jet fluidizing technique instead of conventional pipeline or hopper dredges for sand wave mitigation is an economic decision. Although the contract for the 1988 exercise was research and development oriented, a cost estimate for typical operations was prorated based on actual production times. The cost for the 25 days of daily (Monday-Friday) daylight operation was $311,562. Fluidizer mobilization cost was $28,940 and demobilization cost was $16,755. The total contract cost was $357,257. Work days were approximately 10 hr, resulting in operational costs of about $1,246 per hour, excluding mobilization and demobilization costs. Using the same 105 hr of operation and associated volume removed results in a cost of $1.82 per cubic yard removed. Including mobilization and demobilization costs, this figure increases to $2.45 per cubic yard removed.

PART V: CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Advantages

30. The fluidizer dredging technique possesses several advantages over conventional pipeline and hopper dredging practices. The principal advantage is that no pipeline transport and material disposal are involved. Sand wave material is leveled in-place with an agitation dredging technique, eliminating the need for upland, open water, or other dredged material disposal sites. Other advantages include the capability to easily move for passing vessel traffic, travel between job sites, and quickly mobilize because the fluidizer is self-propelled and operates without spuds or anchors.

Limitations

31. The primary obstacles in efficient fluidizer dredge production in this exercise were the controllability of the dredge and the magnitudes of ambient currents. As ambient velocities increase, dredge production would also increase, if maneuverability of the dredge were not negatively affected. Improved controllability of the WPD dredge or some other more easily controlled fluidizer dredge would likely result in increased production.

Production

32. During the 1988 exercise, the WPD jet fluidizer averaged a 685-cu-yd/hr production rate. Based on this production rate and excluding operational time associated with data collection, the average cost per cubic yard of material moved was $2.45. Conventional dredging typically costs $1.00 to $1.15 per cubic yard for sand wave mitigation along these reaches of the Columbia.* Although the production rate and associated costs are significantly improved over the 1987 exercise, which resulted in an overall $3.75 per cubic yard removed, the fluidizer was not demonstrated to be competitive with conventional dredging along this region of the Columbia for flow speeds less than 4 fps. However, the fluidizer is a new type of dredger, and mobilization/demobilization costs and operating costs are expected to decrease with future, more typical contracting arrangements.

* Martin et al., op. cit.

Recommendations

33. The capabilities of the WPD jet fluidizer were evaluated, initially during the 1987 exercise and more thoroughly during the 1988 exercise. Two general recommendations are presented for future use of the fluidizer dredge:

- a. Plan fluidizer dredging activity to coincide with optimum ambient velocities as described in Part III of this report. Recommendations following the 1987 exercise included operation in conjunction with more favorable ambient flows. Ambient hydrodynamics more conducive to fluidized material transport are expected to significantly improve performance and reduce unit costs. The fluidizer was designed to operate with two to three times the magnitude of flow velocity encountered during the exercise.
- b. Consider using the fluidizer in a more fine-grained material application. Such an application might not be considered sand wave mitigation; but the fluidizer is expected to be both capable and competitive in a silt, clay, or fluid mud dredging environment.