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EVALUATION OF THE DIVER-OPERATED DREDGE AND BOTTOM-COVERING MATERIALS FOR CONTROL OF *HYDRILLA* IN THE POTOMAC RIVER

by

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A diver-operated dredge and two types of bottom-covering materials were evaluated in the Potomac River to determine their applicability as a technique to manage the monoecious biotype of *Hydrilla verticillata*. The results showed that it would take 58 hr for two divers to remove 1 acre of hydrilla, including 90 percent of the tubers, using a dredge capable of pumping 800 to 1,100 gal/min. Estimated cost is $17,500/acre. In addition to the dredge being extremely time-consuming, rapid reinfestation of the dredged plots occurred from remaining tubers and from fragments drifting in from adjacent areas. Therefore, the dredge is not recommended as a control measure except in areas that prevent the use of other techniques such as around rocks or piers or after use of more conventional techniques to ensure maximum control.

Two types of bottom-covering materials, Dartek and Texel, were placed in boat lanes and boat slips. The time expended to prepare and install Dartek and Texel in a 9,000-sq-ft

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(30 ft by 300 ft) boat lane was 6.6 and 1.1 hr, respectively. Sections of Dartek must be taped together to obtain the desired dimensions, increasing preparation time of this material, while taping is not necessary for Texel. Estimated cost per acre is $11,745 for Dartek and $10,875 for Texel. For boat slips (16 ft by 30 ft), the average rate of installation (95-percent confidence interval) for Dartek (not including taping) and Texel was 9 to 13 min and 11 to 12 min, respectively. Hydrilla grew through the slits and seams of Dartek, resulting in plant height measurements similar to the control 20 days after installation. Furthermore, during low tide, boat propellers would come in contact with the Dartek and dislodge the material from the anchoring system. Sediment settled on the Texel and prevented benthic gases from escaping, causing the material to "balloon" and interfere with boat navigation. Consequently, both materials were removed from the boat lanes and slips 1 month following installation.

Preface

This report was prepared for the US Army Engineer District, Baltimore (NAB), for use in the development of a State Design Memorandum and an Environmental Impact Statement regarding the management of monoecious *Hydrilla verticillata* (L.f.) Royle in the Potomac River and its tributaries. Funds were provided by the NAB under appropriation number 96X4902, Revolving Fund, through the Aquatic Plant Control Research Program (APCRP) at the US Army Engineer Waterways Experiment Station (WES), Vicksburg, Miss. Mr. E. Carl Brown of the Office, Chief of Engineers, was APCRP Technical Monitor.

The study was completed by the Aquatic Habitat Group (AHG), Environmental Resources Division (ERD), Environmental Laboratory (EL), WES. The report was prepared by Mr. K. Jack Killgore, AHG. Mr. Glenn Earhart and Mr. Bill Malette, NAB, and Messrs. Russell Theriot and Kenneth Conley, WES, contributed to the conduct of this study. Mr. Terry McNabb, Aquatics Unlimited, designed and operated the diver-operated dredge. Special field assistance was provided by Mr. Hank Snyder and Ms. Jeri Hall of the US Department of the Interior, National Park Service. Technical review of the report was provided by Dr. Barry Payne and Ms. Katherine Long, WES. This report was edited by Ms. Jamie W. Leach of the WES Information Products Division.

The work was conducted under the general supervision of Dr. John Harrison, Chief, EL; Dr. Conrad J. Kirby, Jr., Chief, ERD; and Dr. Thomas D. Wright, Chief, AHG. Mr. J. Lewis Decell was Program Manager of the APCRP at WES.

Commander and Director of WES is COL Dwayne G. Lee, CE. Dr. Robert W. Whalin is Technical Director.

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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
acres	4,046.873	square metres
feet	0.3048	metres
gallons	3.785412	cubic decimetres
inches	2.54	centimetres
miles (US statute)	1.609347	kilometres
pounds (mass) per square foot	4.882428	kilograms per square metre
square feet	0.09290304	square metres

EVALUATION OF THE DIVER-OPERATED DREDGE AND BOTTOM-COVERING MATERIALS FOR CONTROL OF HYDRILLA IN THE POTOMAC RIVER

Background and Purpose

1. The monoecious biotype of *Hydrilla verticillata* (L.f.) Royle became established in the Potomac River in 1981 and covered 3,600 acres* by 1985 (Rybicki et al. 1986). The exponential increase in hydrilla abundance and the paucity of information pertaining to the control of monoecious hydrilla in a riverine tidal basin necessitated the reevaluation of existing treatment techniques that would contribute to the development of an overall management strategy in the Potomac River. The diver-operated dredge (hereinafter referred to as the dredge) and bottom-covering materials (BCM) were considered to have potential for controlling hydrilla in localized areas since both techniques are capable of influencing the asexual reproductive ability of hydrilla. A demonstration project was conducted in the summer of 1985 to evaluate the applicability and efficacy of these two methods in an effort to minimize impacts of hydrilla on the various water uses in the Potomac River.

Objectives

2. The objectives of the dredge evaluation were to determine the time required to dredge a given surface area of hydrilla, and to determine the rate of regrowth in dredged areas. The objectives for evaluation of the BCM were to determine the installation time required for a given surface area of hydrilla, and to determine the reduction in plant height and tuber density within a growing season.

Materials and Methods

Study site

3. The dredge and BCM demonstration projects were conducted at Belle Haven Marina and Old Towne Yacht Basin, respectively, in the Potomac River

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

near Washington, D. C. Semi-diurnal tides occurred in the study area with mean levels ranging from 0.7 to 1.4 ft (Environmental Laboratory 1985). Depending on the tide, the average water depth at Belle Haven Marina ranged from 3.5 to 4.5 ft and 1.0 to 3.0 ft at Old Towne Yacht Basin. The sediment was composed of silt underlain by clay. Hydrilla was the dominant submersed macrophyte at both sites with coontail (*Ceratophyllum demersum*), water stargrass (*Heteranthera dubia*), and Eurasian watermilfoil (*Myriophyllum spicatum*) occurring infrequently.

Dredge

4. Eight treatment plots and one control plot, each measuring 1,800 sq ft (60 ft by 30 ft) were marked with buoys in areas around Belle Haven Marina. The dredge was positioned adjacent to the plot being harvested. The onboard equipment was based on a pontoon barge and consisted of two gasoline-driven pumps and an air compressor to deliver air to the divers. Two 4-in.-diam hoses (one hose per pump) were extended from the barge to the bottom of the plot by divers (one diver/hose). Water was pumped through a Venturi manifold creating a suction of 800 to 1,100 gal/min in each hose. The divers removed the standing crop and 2 to 4 in. of hydrosoil to ensure removal of tubers. The spoils were directed through the hoses to a wire mesh spoils collection basket on the barge. Spoils were then loaded into a portable debris box.

5. To assess rate of removal, the time required for the two divers to remove all the vegetative structure in the plot was recorded. To determine diver efficiency in removing the vegetation and the rate of regrowth in each plot, divers collected six random samples of vegetation and hydrosoil (2 to 4 in.) within a 1-sq-ft quadrant before, immediately after, and 2 months subsequent to dredging. Each sample was sieved, plants weighed, and tubers counted. In addition, water samples were collected at regular distances from two treatment plots during high and low tide to measure turbidity values during dredging operations.

Bottom-covering materials

6. Two types of BCM, Dartek and Texel, were evaluated at Old Towne Yacht Basin. Dartek is a black-pigmented nylon film with a smooth, glossy surface slitted to allow gas to escape. Dartek is available in rolls measuring 16 ft by 100 ft; sections are taped together to obtain the final desired dimensions. Dartek's primary means of controlling aquatic plants is by eliminating the

plants' exposure to photosynthetic light. Texel is a tan, needle-punched, polyester fabric with a specific gravity greater than water. It comes in a variety of dimensions; however, two 30- by 150-ft rolls were used in this study. Texel controls aquatic plants by creating a chemically reduced environment. For a more detailed description of Dartek and Texel, see Environmental Laboratory (1985).

7. Dartek and Texel were placed in two boat lanes (each 30 ft by 300 ft) and 20 boat slips (each 16 ft by 30 ft) at Old Towne Yacht Basin during June 1985. A control boat lane and 10 control boat slips were also established to monitor the unregulated growth of hydrilla. Six rolls of 16-ft by 100-ft Dartek were taped together in order to obtain the boat lane dimension. Four divers then placed the Dartek in a boat lane and anchored it to the substrate. Texel was unrolled off a barge into the boat lane and anchored by six divers. Thirty boat slips were randomly subdivided into 10 Dartek, 10 Texel, and 10 control slips. Both materials were cut into 16- by 30-ft sections, and two divers placed and anchored the material in the boat slips. The anchoring system for boat lanes and slips consisted of tying the edges of the material to piers and placing rebar and blocks on top at various locations. The time spent to install the BCM in boat lanes and boat slips was recorded to determine rate of installation. Plant height and tuber density were measured before, immediately after, and 58 days following installation to determine efficacy of the materials. Fathometer readings were taken across three transects in each boat lane and slip, and plant height was interpreted from the graphs at 10 randomly selected points. Replicate tuber samples (5/boat slip, 30/boat lane) were collected with a petite Ponar. Each grab sample was sieved and the tubers counted.

Results

Dredge

8. The mean time required for two divers to remove all vegetative structure from each plot was 2.4 hr/1,800 sq ft (58 hr/acre) with a 95-percent confidence interval of 1.9 to 2.9 hr/1,800 sq ft (Table 1). The estimated cost to remove 1 acre of hydrilla is $17,513 (Table 2). This cost reflects only the activities associated with actual dredging operations using four certified divers. Diving time was not significantly influenced by predredge biomass

($R = 0.09$, $p < 0.47$) or predredge tuber density ($R^2 = 0.06$, $p < 0.57$). The time required to excavate 2 to 4 in. of the substrate to ensure removal of the tubers was the most time-consuming task of the dredging operation. The time spent on mobilization and equipment malfunctions was minimal.

9. Changes in hydrilla biomass and tuber density before and after dredging are shown in Table 1. Virtually 100 percent of the biomass was removed by the divers whereas an average of 91 percent of the tubers were excavated. However, by the end of the study (63-71 days after dredging), substantial increases in both biomass and tuber density were noted. The tubers missed by the divers (due to poor visibility caused by resuspension of bottom sediment during dredging) could have contributed to the regrowth. Higher predredging tuber density in the plots was significantly related to higher biomass ($R^2 = 0.43$, $p < 0.07$) and tuber density ($R^2 = 0.70$, $p < 0.01$) 2 months after dredging. These relationships indicate that biomass regrowth could have occurred from tubers, which in turn generates even more tubers by the end of the growing season. Another reason biomass increased after dredging could be attributed to colonizing fragments produced from heavy boat traffic. Plots 3, 5, 6, 7, and 8 were situated in areas subject to high boat traffic. Even though virtually all of the biomass was removed in these plots, they were rapidly reinfested by hydrilla fragments created by boats and drifting in from adjacent areas. As a result, the biomass of the dredged plots located in high use areas approached or exceeded the biomass of the control plot approximately 2 months after dredging. Conversely, plot 4, and to a lesser extent, plots 1 and 2, were located in hydrilla beds isolated from drifting fragments and only small increases in biomass were measured.

10. Localized turbidity increased as a result of dredging operations. During periods of no wind, turbidity increased from 5 Nephelometric Turbidity Units (NTUs) to 75 NTUs approximately 50 ft from the dredge. A turbidity plume would form, move towards the main channel, and dissipate. During windy periods (5-10 mph), turbidity increased from an ambient level of 30-35 NTUs to 110-115 NTUs and immediately drifted in the direction of the wind and eventually dissipated.

Bottom-covering materials

11. Installation of Dartek in a 9,000-sq-ft boat lane took 6.6 hr. Installation activities included taping, placement by divers, and anchoring the material to the substrate by divers. In contrast, only 1.1 hr was

expended to prepare and place Texel in a 9,000-sq-ft boat lane because taping was not necessary and the material was loaded off a barge rather than using divers to place the material. A total of eight people, including six divers, were required for the BCM operation. Assuming these times remain constant, it would take 32 and 5.3 hr to install 43,500 sq ft (1 acre) of Dartek and Texel, respectively. The cost of installation is similar between the two types of BCM because Texel is more expensive ($0.15/sq ft) than Dartek ($0.10/sq ft). Estimated costs per acre are $11,745 for Dartek and $10,875 for Texel.

12. The average rate (95-percent confidence interval) of Dartek (not including taping) and Texel installation in 16-ft by 30-ft boat slips was 9.0 to 13.2 min and 10.7 to 12.5 min, respectively. Although preparation time will vary, an additional 5 to 15 min per slip was required to cut the sections to the desired dimensions and carry them to the treatment location.

13. Changes in plant height and tuber density over time are shown in Figure 1. The materials were removed in both boat lanes and slips approximately 30 days after installation because they were interfering with boat navigation. Therefore, the data collected on day 80 indicate the amount of unregulated vegetative growth between 30 and 80 days after placement. Although the materials were removed 1 month after installation, the reduction of light levels during this period was apparently adequate to inhibit tuber production. The mean tuber density in the control boat lane was 5 tubers/sq ft 80 days after placement and only 1 tuber/sq ft in the Texel and Dartek boat lanes. Texel was more effective than Dartek in reducing plant height 20 days after placement. However, because the materials were removed, plant height measurements in both BCM lanes were similar to the control lane 80 days after placement. The use of these materials in shallow boat lanes for long-term control is not feasible unless a more effective anchoring system is used. Texel proved to be impermeable to benthic gases, causing the materials to "balloon" after installation, while hydrilla grew through the slits and seams of the Dartek. Empirical evaluation of the boat slips was abandoned after the materials were removed. However, by the end of the study, hydrilla was topped out in all treatment and control slips.

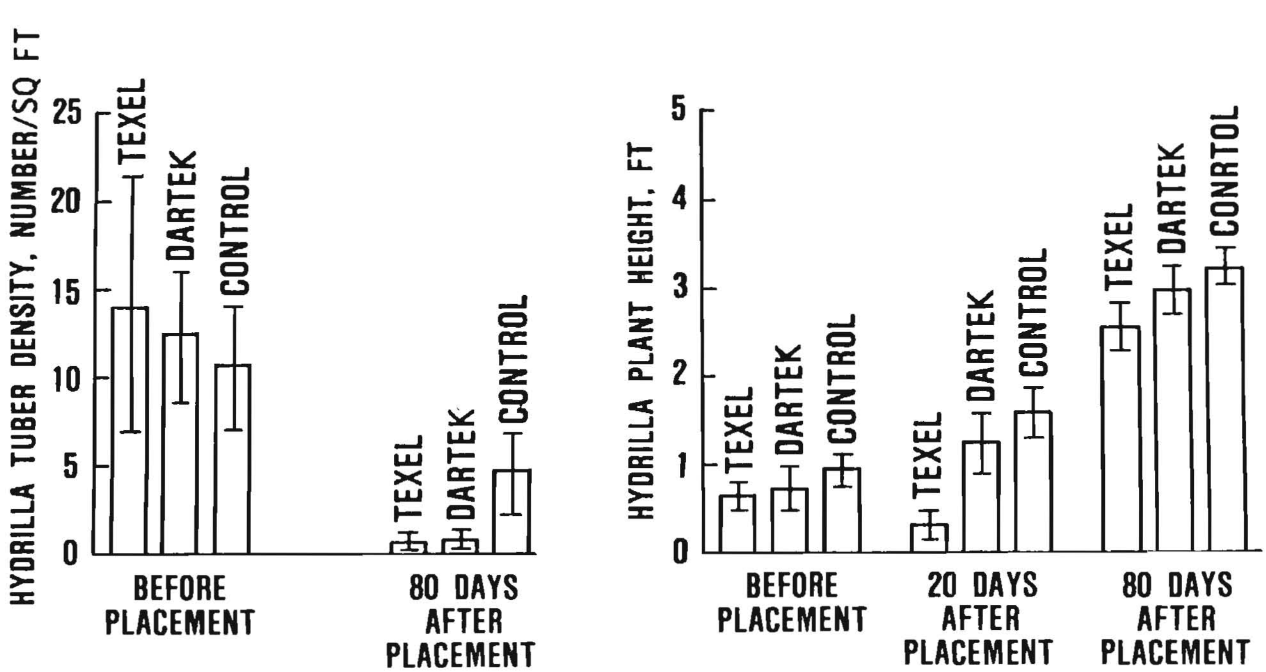

Figure 1. Average changes in hydrilla tuber density and plant height before and after installation of BCM in boat lanes. Bars indicate the 95-percent confidence interval. Both materials were removed 30 days after installation

Discussion

14. The dredge can provide virtually complete removal of hydrilla shoot biomass and 90-percent removal of tubers, but use of the dredge is time-consuming. For example, it would take approximately 60 diving hours to remove 1 acre of hydrilla in the Potomac River using the dredge described herein. Using a dredge with similar operating capabilities, Killgore (1982) estimated it would take 67 to 217 diving hours (two divers) to remove 1 acre of *Myriophyllum spicatum* depending on plant density. Conversely, mechanical harvesters have removal rates ranging from 0.7 acre/day (Bryant 1974, Newroth 1979) to 4.4 acres/day (Johnson and Bagwell 1979). Rate of harvest for the dredge is dependent on species composition, visibility, type of substrate, diver dedication, and engineering performances such as pumping rates. Even if site-specific conditions with respect to these variables were such to provide optimum rates of harvest, time expenditure would still limit the dredge's applicability to small, high-use areas where maximum removal is desired or in areas inaccessible to other conventional techniques.

15. The capability of the divers to remove the entire plant, including most tubers, should provide long-term control and offset the high initial cost of removal. Killgore (1982) reported minimum regrowth of *M. spicatum* 1 year after dredging. However, Collet et al. (1981) found macrophytes growing in dredged plots 4 months after dredging, and the plants had completely reestablished in the shallower sites at approximately equivalent plant biomass as the control plot within 12 months. Rapid regrowth in dredged plots was also found in this study, although total reinfestation occurred only 2 months after dredging. Because of hydrilla's ability to colonize available substrates with viable fragments capable of growing 0.5 to 1 cm per day (Environmental Laboratory 1985), short-term control can only be obtained if dredged areas are isolated from fragments or from repetitive treatments during the growing season. Long-term control also may not be feasible with a dredging operation. Although the dredge provides one of the most effective means of removing tubers, 10 percent were missed by the divers. The remaining tubers allow hydrilla to overwinter and withstand periods of desiccation (Environmental Laboratory 1985); therefore, hydrilla can recolonize an area devoid of standing vegetation the following year via tubers.

16. Both types of BCM failed to control hydrilla. Their ineffectiveness can be primarily attributed to the characteristics of a marina located in a fluctuating tidal basin. During the tidal cycle, water levels would change 2 to 3 ft every day and deposit suspended solids on the Texel, preventing sediment gases from escaping. Consequently, the Texel would balloon, lose its contact with the substrate, and interfere with boat navigation. Furthermore, during low tide boat propellers would come in contact with the Dartek and dislodge the material from the anchoring system. As a result, both materials were removed from Old Towne Yacht Basin approximately 1 month after they were installed. These materials have been shown to be effective in controlling submersed aquatic plants in certain types of environment (Perkins 1984, Wright 1984, Environmental Laboratory 1985), but given the conditions of a marina located in a tidal basin, their applicability is limited. Other types of fabrics and membranes have been used as a bottom-covering device to control submersed aquatic vegetation but are not drastically different than Dartek or Texel and may also be of limited use in the Potomac River environment. For additional information on other types of BCM, see Environmental Laboratory (1985) or Wright (1984).

Conclusions and Recommendations

17. The diver-operated dredge is time-consuming and costly, with an estimated harvesting rate of 58 hr/acre at a cost of $17,513. Furthermore, dredged areas are rapidly reinfested by hydrilla. Therefore, the dredge is not recommended as a control measure except in areas that prevent the use of other techniques (mechanical harvesting) such as around rocks or piers or as a follow-up to other conventional techniques.

18. This study showed that hydrilla can rapidly colonize an area devoid of aboveground vegetation. Within 2 months after dredging, hydrilla had reestablished itself at levels equal to nondredged areas either with fragments drifting in from adjacent areas or from new plants regenerated from the tubers that were missed by the divers.

19. Dartek is not recommended for use as a hydrilla control technique in marinas. Installation is time-consuming primarily due to taping requirements, and mechanical dislodgement by boats is common.

20. Texel is more appropriate than Dartek as a bottom-covering barrier because of its ease of installation and longer effective life. However, excessive sedimentation on top of the Texel will prevent sediment gases from escaping and will cause the material to balloon. Therefore, Texel should not be placed in areas subject to high sediment deposition and should be securely anchored to the substrate.

21. The cost associated with installing either type of BCM is greater than 10,000 per acre.

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Table 1

Divers' Down Time and Biomass and Tuber Density of Hydrilla in Eight Plots Harvested by a Diver-Operated Dredge and One Unharvested Plot, Belle Haven Marina*

Plot	Divers' Down Time hr	Hydrilla Biomass, lb/sq ft			Hydrilla Tuber Density, number/sq ft		
		Before Dredging	Immediately After Dredging	63-71 Days After Dredging	Before Dredging	Immediately After Dredging	63-71 Days After Dredging
1	1.55	1.49 ± 1.47	0 ± 0	1.47 ± 1.10	6.60 ± 2.62	0 ± 0	2.17 ± 2.34
2	1.97	1.12 ± 0.65	0 ± 0	0.89 ± 0.54	2.00 ± 1.46	0.50 ± 1.28	1.17 ± 0.79
3	2.90	0.30 ± 0.20	0 ± 0	2.19 ± 1.05	3.20 ± 2.03	0.40 ± 0.93	2.00 ± 2.10
4	3.10	0.55 ± 0.52	0.06 ± 0.04	0.80 ± 0.78	1.83 ± 1.39	1.00 ± 2.57	1.33 ± 2.06
5	3.50	0.85 ± 0.36	0 ± 0	2.49 ± 1.40	13.3 ± 7.90	0 ± 0	3.33 ± 4.68
6	2.30	0.37 ± 0.47	0.01 ± 0.02	1.11 ± 0.87	1.33 ± 2.06	0 ± 0	0.67 ± 1.08
7	2.10	0.49 ± 0.45	0.01 ± 0.02	2.86 ± 0.64	6.50 ± 6.40	0.33 ± 0.54	2.50 ± 1.45
8	1.80	0.26 ± 0.13	0.02 ± 0.01	3.14 ± 1.15	7.00 ± 3.20	0.33 ± 0.54	3.67 ± 4.02
1 - 8	-	0.70 ± 0.20	0.01 ± 0.007	1.87 ± 0.35	5.10 ± 1.49	0.47 ± 0.33	2.10 ± 0.73
Unharvested (control)		0.20 ± 0.26	-	2.11 ± 0.82	1.80 ± 1.68	-	3.67 ± 1.83

* 95% confidence interval. Six 1-sq-ft quadrats were sampled by divers in each plot to determine biomass and tuber density.

Table 2

Cost Summary for Installation of Dartek and Texel in Old Towne Yacht Basin and Removal of Aquatic Vegetation at Belle Haven Marina Using Diver Dredge*

Activity	Material Equipment Cost		Labor			Divers			Miscellaneous Supplies	Total Cost	Unit Cost	Cost per Acre
	Unit Price	Total Price	Man-Hours	Unit Price	Total Price	Man-Hours	Unit Price	Total Price				
Dartek	$0.10/ft^2	$900/9,000 ft^2	17.7**	$31/hr	$548.7	13.2	$37/hr	$488.4	$479	$2,416.1	$0.27/ft^2	$11,745
Texel	$0.15/ft^2	$1,350/9,000 ft^2	4.4	$31/hr	$136.4	6.6	$37/hr	$244.2	$491	$2,221.6	$0.25/ft^2	$10,875
Diver dredge	$125/hr	$2,387.5/19.1 hr	--	--	--	76.4†	$25/hr	$1,910	$1,500	$5,797.5	$0.40/ft^2	$17,513

* Costs based only on installation and dredging activities.
** Total man-hours includes 13.3 hr for taping sections of Dartek together.
† Diver hours includes two divers and two stand-by divers. Stand-by divers also off-loaded dredged material to disposal area.