1/20/93
under review

CEWES-HE-P

MEMORANDUM FOR RECORD

SUBJECT: Mobile Bay Channel, Advanced Maintenance Testing

Summary

1. Mobile Bay and River Channel dredging has been little affected by historical channel geometry changes, and is therefore a suitable location for advanced maintenance dredging procedures. Advanced maintenance could reduce dredging frequency and costs while maintaining controlling depth. As a first phase of implementation, three possible advanced maintenance test sections and configurations are proposed.

Introduction

2. This memorandum is a results from the meeting at the US Army Engineers District, Mobile (CESAM), Mobile Area Office held 17 Dec 1992. That meeting was originally initiated by Pat Langan, CESAM-OP-O. Representatives from CESAM and the Waterways Experiment Station (CEWES) Hydraulics Laboratory discussed problems with the Mobile River and Bay Channel maintenance and a set of possible measures put forth in a Dredging Operations Technical Support (DOTS) program memorandum. Of those previously identified measures, advanced maintenance (AM) options appear to have the best potential for alleviating maintenance problems. It was the consensus of those present at the meeting that CEWES should examine AM in more detail and, if found to be economically feasible, field tests should be planned.

3. This memorandum outlines an analysis of the suitability of AM procedures for reducing dredging frequency and costs for Mobile Bay Channel, and proposes full scale field tests as a first step in the development of a permanent AM plan. In the sections that follow: the problem and bay setting are described; the history of channel development and maintenance dredging are presented leading to a evaluation of AM effects on dredging requirements; alternate

configurations are described, discussed, and a possible test plan recommended; and a monitoring plan is recommended.

Problem Description

4. The Mobile Bay Channel project has recently been deepened to 45 ft deep and 2 ft of AM was applied over the entire channel area. The present channel is dredged to 47-ft-depth by a nominal 400-ft-width and extends from stations 85+00 to 1577+50 relative to the highway 90 bridge. The project has been authorized for 55 ft deep by 550 ft wide for future expansion.

5. Since the 1988-1989 deepening of the Mobile Bay Channel from 40 ft to 45 ft, some operational problems have been experienced with channel maintenance. The problem is not necessarily the drastic increase in the total shoaling or maintenance dredging volumes, but rather is related to the long dredging cycle times caused by the new requirement for disposal of maintenance material seaward of the estuary entrance. Dredging cycles have been as long as 6 months. Furthermore, it is imperative that the controlling channel depth be maintained at 45 ft to accommodate frequent visits by world-class colliers. Long dredging-cycle times and low allowable accumulation thicknesses of material in the channel combine to make the dredging times not much different from the required dredging interval. While it is too early to determine whether shoaling distributions have changed by the deepening, shoaling is not uniform and shoals have intruded above 45 ft depth quickly and required rapid dredging responses. Dredging is now required over shorter channel reaches than before the deepening to maintain controlling depth. Recourse has been made to time-contract hopper dredges. Mobilization costs are high and advanced planning of dredging requirements is difficult.

6. The required channel maintenance since the deepening has been about 5-6 million cubic yards (M cu yds) per year (Dyess, personal communication). However, the exact amount dredged can not be estimated with certainty because of the method of dredging and dredge contracting. A short term increase in dredging volumes would be expected due to the disturbance of channel and channel side-slopes during dragging operations. Dragging was used during the deepening to bring the center of the channel and channel side slopes to grade.

None of the additional 2 ft of allowable overdepth was excavated during construction.

Circulation and Sedimentation in the Bay

7. Mobile Bay is a large shallow estuary with a significant freshwater and sediment inflows from fluvial drainage. Figure 1 shows the layout of the bay and the bay channel. The area of tidal influence is 409 sq mi while the bay proper has an area of about 380 sq mi. The average bay width is 13.8 mi and average depth is 9.6 ft. The long-term average annual inflow is 79.3 thousand cubic feet per second (kcfs) and monthly averages range from 179 to 29 kcfs. Tide range is 1.3 ft at the entrance and 1.4 ft at mid- and upper-bay areas. The tidal prism is 585 M cu yds (1.58e10 cu ft).

8. Mobile Bay adjoins Mississippi Sound and the Gulf of Mexico at two wide entrances (2.5 and 3.2 mi respectively). The drainage basin for the bay is about 40,000 sq mi. The bay is composed of an small saltwater zone near the entrance, and a mixing zone covering the remainder of the bay area. The bay is moderately to highly stratified depending on the level of freshwater inflow.

9. With respect to coastal sedimentation, the bay, with its relatively low tidal flows, can be classified as wave dominated. Wave energy in the Gulf of Mexico supplies sediment to the seaward end from where it can be transported headward by tidal currents. Because of the size of the bay, internally generated waves are also important to sedimentation. From the bay entrance, tidal currents decrease toward the central portion of the bay and then increase again (as ebb tidal currents) toward the bayhead delta. Thus, the middle bay is the locus above which the sediments are expected to coarsen and have more riverine character. At the seaward end of the bay, sediments coarsen and have more marine or coastal character.
The middle bay is expected to contain the greatest fraction of fine-grained sediments in the system. A bayhead delta has formed over geologic time filling the northern portion of the bay mainly by fluvial sediments. Thus, the bay as filling toward its middle from the landward end with riverine sediments and from the seaward end with marine sediments.

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History of Dredging and Channel Maintenance in Mobile Bay

10. The period 1871 through 1913 saw drastic channel expansion in Mobile Bay. The natural 12.7-ft bay channel was deepened, widened, and lengthened in stages to the dimensions of 27 ft by 200 ft by 177,000 ft. Total new-work dredging was 63 M cu yds while the total maintenance dredging was only 6.2 M cu yds for the period. This period of construction brought the bay channel to its full length, a critical point with respect to maintenance requirements (Berger, personal communication). Following this period maintenance dredging became much more substantial.

11. Annual maintenance dredging volumes for the Mobile River and Bay Channel were compiled for the period 1915 through 1987 to help predict the possible effects of AM on shoaling. Data were obtained from annual reports by the Chief of Engineers, and are shown in Figure 2. There were four channel configurations and two initial configuration phases in the period of record. However, the initial 30 ft by 220 ft phase was short and was combined with the 30 ft by 300 ft configuration. Mean values for the channel configurations were calculated over periods starting the second year after major new-work dredging (to allow equilibration). The results were as follows:

Channel		Year		Mean Dredging Volume,
Depth	Width	Start	End	M cu yds per yr
27'	200'	1915	1920	3.68
30'	300'	1928	1931	7.07
32'	300'	1935	1955	4.05
36'	400'	1959	1964	4.10
40'	400'	1967	1987	3.68

Annual variations are large and standard deviation of all annual values is 2.64 M cu yds per year. Because variability is so high, differences between mean values in the table above are not statistically significant. The mean value of all data is 4.00 million cu yds per year. In addition to individual annual values, a smooth trend fit to the data is shown in Figure 2. That trend line shows no relationship with channel configuration. Any number of other trend lines could be fit to the data, but there is much scatter in the data and no trend associated with channel geometry can be discerned visually.

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A linear least-squares regression fit to the data shows a negative slope with time, bisecting the trend line shown in Figure 2.

12. As evidenced by the above table and the data in Figure 2, there has been no clear relation between required maintenance dredging and channel configuration. The conclusion of the analysis of historic dredging volumes is that channel geometry has had only a second-order (small) effect on dredging requirements of the channel.

13. The historic maintenance dredging data show that factors other than channel dimensions dominate the year-to-year variations and probably the long-term trend. For instance, following the flood of 1927 heavy channel maintenance was required for several years resulting in a spike in the annual dredging volumes. Other short term fluctuations may be due to fluctuations in river inflow, coastal wave energy, as well as dredging operational considerations. The long-term decreasing trend may be due to decreased sediment yield from the Mobile River and/or decrease in the bay volume. It seems unlikely that the dominant factors contributing to short- and long-term variations in shoaling could be identified with sufficient accuracy to allow quantification of secondary effects, such as channel geometry.

14. From experience in other estuaries and an understanding of estuarine features, channel dimension generally do effect shoaling and maintenance dredging volumes, sometimes in unexpected ways. Thus, while historic data indicate Mobile Bay and River Channel is suitable for AM, it is prudent to develop a plan slowly while monitoring the response of the system over time. While the annual variability in dredging volumes is likely to continue and obscure the response, monitoring information other than total volumes could be used to gage AM field test results, as will be described in a latter section.

Advanced Maintenance Concepts

15. Advanced maintenance can be used to reduce dredging frequency and costs while maintaining controlling depth and/or width. Advanced maintenance can be applied by channel deepening and/or widening, in a uniform or varied amount along a channel. The first step in the application of AM is a prediction of

the shoaling response of the channel. In most cases, this is best done by an analysis of the shoaling history of the channel as it was developed as done in the last section. For AM to be successfully applied, the increase in shoaling volume associated with the expansion of the channel prism must be more than offset by the economy gained by reduced dredging frequency.

Advanced Maintenance Requirements

16. Advanced maintenance creates storage volume for channel shoaling and thereby reduced the time interval between required dredging. As indicated in the earlier section, annual shoaling volumes can be expected to average about 4 M cu yds per year but will vary considerably from year to year. To accommodate shoaling in most years, 6.6 M cu yds (the annual mean plus standard deviation) is suggested as an appropriate planning volume. The channel currently has 2 ft of AM, and since the controlling depth is 45 ft, this amounts to 4.6 M cu yds of sediment storage. However, shoaling along the channel is not uniform along its length. The first maintenance dredging covered 119,000 ft channel length and the second dredging covered about 38,000 ft channel length. On average (so far) about 78,500 ft channel length actually shoals. The present storage volume over this portion of the channel is only 2.3 M cu yds, indicating that insufficient storage volume is available to allow annual dredging cycles. It is anticipated that additional AM on the order of 4 M cu yds may eventually be economical.

Selection Factors for Advanced Maintenance Configuration

17. The AM configurations which were considered included over-depth, over-width, and wing-cut. Wing-cut AM is over-width dredging which is not carried to the full channel depth. Several factors were used to rate the three configurations and are defined next. Lateral shoaling storage is the efficiency of AM to store sediment which enter and deposit from lateral sediment sources. Longitudinal shoaling storage is the efficiency to store deposited sediments transported to the site in the channel. Efficiency here refers to the fraction of AM used by a deposit at it reaches the controlling depth. Channel sediment capture is here related to the decrease in local shear stresses attributable to AM section enlargement (ignoring transport

gradient effects). Storage per unit section area is the AM area divided by the area of cross section enlargement attributable to AM construction. This is inversely related to another factor-construction cost (excavation per unit storage).

18. The following are relative ratings ascribed to the three AM configurations for Mobile Bay Channel:

	Configuration		
	Over-depth	Over-width	Wing-cut
Lateral Shoaling Storage	low	high	high
Longitudinal Shoaling Storage	high	medium	low
Channel Sediment Capture	low	medium	medium
Storage per Unit Section Area	high	low	medium
Construction Costs	low	high	medium

Where sediment encroaches on a channel laterally, over-width and wing-cut have be successful at intercepting and storing sediment at other sites. Over-depth dredging is less effective in this case but most effective if the shoaling results from sediment carried by the channel and uniformly distributed across the channel. Channel shoaling is never perfectly uniform across channels, but tends to concentrate near the toes of the side slopes where shear stresses and vessel disturbances are less severe. Sediments depositing on channel side slopes indicate a lateral sediment source, flows crosswise to the channel, or a combination of both.

19. Sediment capture is related to storage and to section area, but also includes the the ability of the channel with AM to convey sediment longitudinally in the channel. One factor which can not be easily quantified is the effect of ship disturbances. In channels frequently traversed by vessels with draft approaching the controlling depth for the channel, ship disturbances have a considerable effect on resident sediments near the center of channels. Commonly, sediments are slightly finer and fine-grained sediments more well-settled in the flanks of the channel compared to the area where ships tend to navigate. This being the case, a narrow channel will have a greater fraction of the channel disturbed by shipping and is most likely to transport sediments longitudinally. Wider channels give more undisturbed

storage area for sediments to deposit. For channels of equal cross section area, a deeper channel will have larger shear stress and transport a greater sediment load.

20. Over-depth dredging produces the greatest AM storage per unit cross section excavated (1:1) compared to over-width or wing-cut dredging. The initial construction costs for over-width AM are higher because of the necessity to remove side slope material.

Recommended Advanced Maintenance Tests

21. A recommended test plan was developed to serve as a starting point for further discussions, refinement, and evaluation by CESAM. Given the possible total AM which may be required, the tests were scaled to represent a significant fraction of the anticipated AM. Three test sections are recommended to test the shoaling response of the channel, test the utility of various configurations, and begin to develop a plan for dredging frequency for various channel reaches. The strategy used was to create needed AM storage in appropriate areas while trapping the maximum amount of sediment in the middle bay area. All proposed cuts are within the authorized 55 ft by 550 ft channel prism. Channel side slopes were maintained at 1 vertical on 5 horizontal. The tests are described in the following paragraphs.

22. Stations 240+00 to 285+00. This reach contains a bend (station 265+00) where the channel width is 500 ft. Shoaling occurs on both sides of the channel, centered at the point of the bend. Depths are shallow outside of the channel. For this 4500 ft reach, partial over-depth dredging to 52 ft depth is recommended over the central part of the channel inside 25 ft from each existing channel toe. Thus the AM would vary from 350 to a maximum of 450 ft in width and represent a 319,456 cu yd cut. Figure 3 shows a typical section in this reach and the proposed AM.

23. Partial over-depth AM is recommended for this reach because of its location. In the upper bay, the channel is relatively confined, ebb flows dominate, and sediments are relatively coarse. Partial over-depth will not affect the channel side slopes which still appear to be adjusting to the

channel deepening. By not disturbing channel side slopes, the question of side slope adjustment effects on shoaling will be minimized and analysis of test results will be simplified. Furthermore, maintaining a compact cross section where ebb currents are strong and sediments are most likely to be disturbed by passing vessels will foster transport of sediment further down bay where dredging transport distances are shorter.

24. Stations 717+00 to 782+00. This reach is adjacent to the Gilliard Island disposal site near the Theodore Ship Channel. AM dredging is recommended to 52 ft depth. This would extend the entire channel width, and involve removal of material on channel side slopes. Figure 4 shows a typical section and the proposed over-depth AM. The proposed AM is shown in Figure 4 for an typical section, and would effectively increase channel width by 50 ft over existing conditions. The estimated volume of this cut is 784,051 cu yds.

25. Station 870+00 to 925+00. This reach contains a bend and maximum width of 505 ft. A wing-cut on the western channel slope, and partial over-depth are recommended. The partial over-depth AM is to 52 ft depth, and over the 5500-ft channel reach amounts to an estimated 383,056 cu yds. The proposed wing-cut consists of two cuts. First a cut at 30 ft depth from the existing channel prism 165 ft to the west. The end point corresponds to the edge of the 55 ft by 550 ft authorized channel prism. The second cut is 100 ft wide starting 25 ft from the outside edge of the first, and is 5 ft deep. The proposed wing-cut is estimated to be 612,251 cu yds.

26. Figures 5 and 6 show typical sections in this reach, and the proposed AM. The wing-cut is a partial over-width AM intended to intercept sediment material from moving laterally into the channel. Before-dredging cross sections from this reach indicate that such lateral sediment movements have occurred. The two-cut configuration will provide a sill to better retain sediments. Increasing cross sections in the mid-bay is least likely to increase dredging requirements.

Advanced Maintenance Monitoring

27. It is envisioned that establishment of a permanent AM system may require

several dredging seasons and special monitoring is recommended during this process. The size, configuration, and distribution of AM storage must be tailored to the optimal dredging frequency for various individual reaches. As shown in the historical dredging analysis, required total dredging volumes vary widely year to year. Thus, in order to assess AM and estimate AM needs, shoaling by reach as well as total shoaling should be monitored. This will require more frequent comprehensive surveying than otherwise necessary. Condition and before-dredging surveys should be carried out over the entire channel length about quarterly. This will allow total shoaling volumes and volumes by reach to be computed at least several times per year.

28. Analysis of monitoring results will not be straight forward. If the shoaling in a test reach increases, it will not be immediately apparent whether this has resulted from an increase in total shoaling material supplied to the channel, an increase in the total sediment capture, or an increase in the local sediment capture of the channel. If local sediment capture increases, then adjacent reaches may experience a decrease in shoaling. Eight combinations of test reach, adjacent reaches, and total shoaling increases or decreases are possible. Statistical tests of whether the test sections have increased or decreased total shoaling and increased local sediment capture will require at least two years of monitoring data. Historic data from since the deepening should be analyzed in the same manner to provide a baseline.

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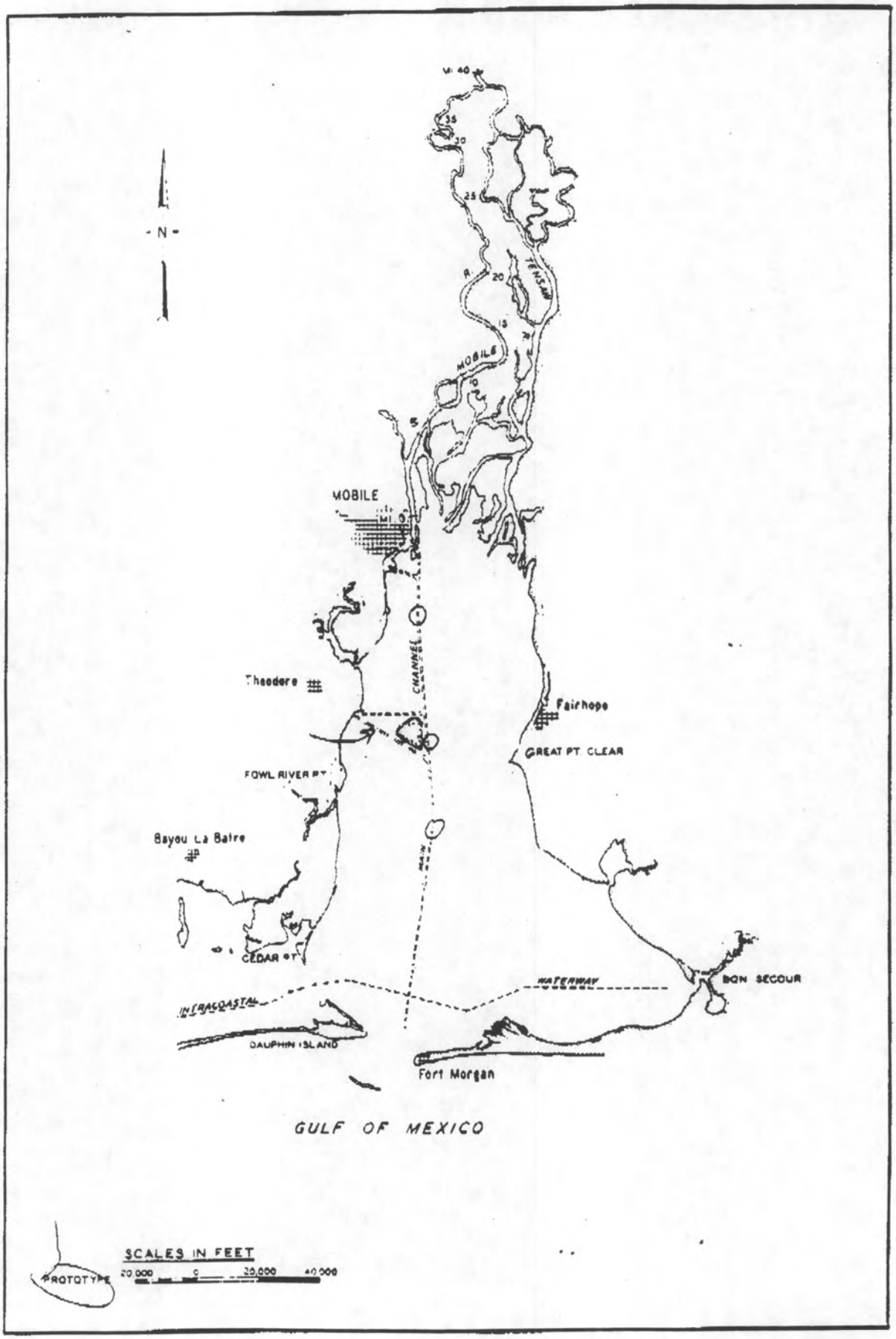

Figure 1. Mobile Bay with navigation channel

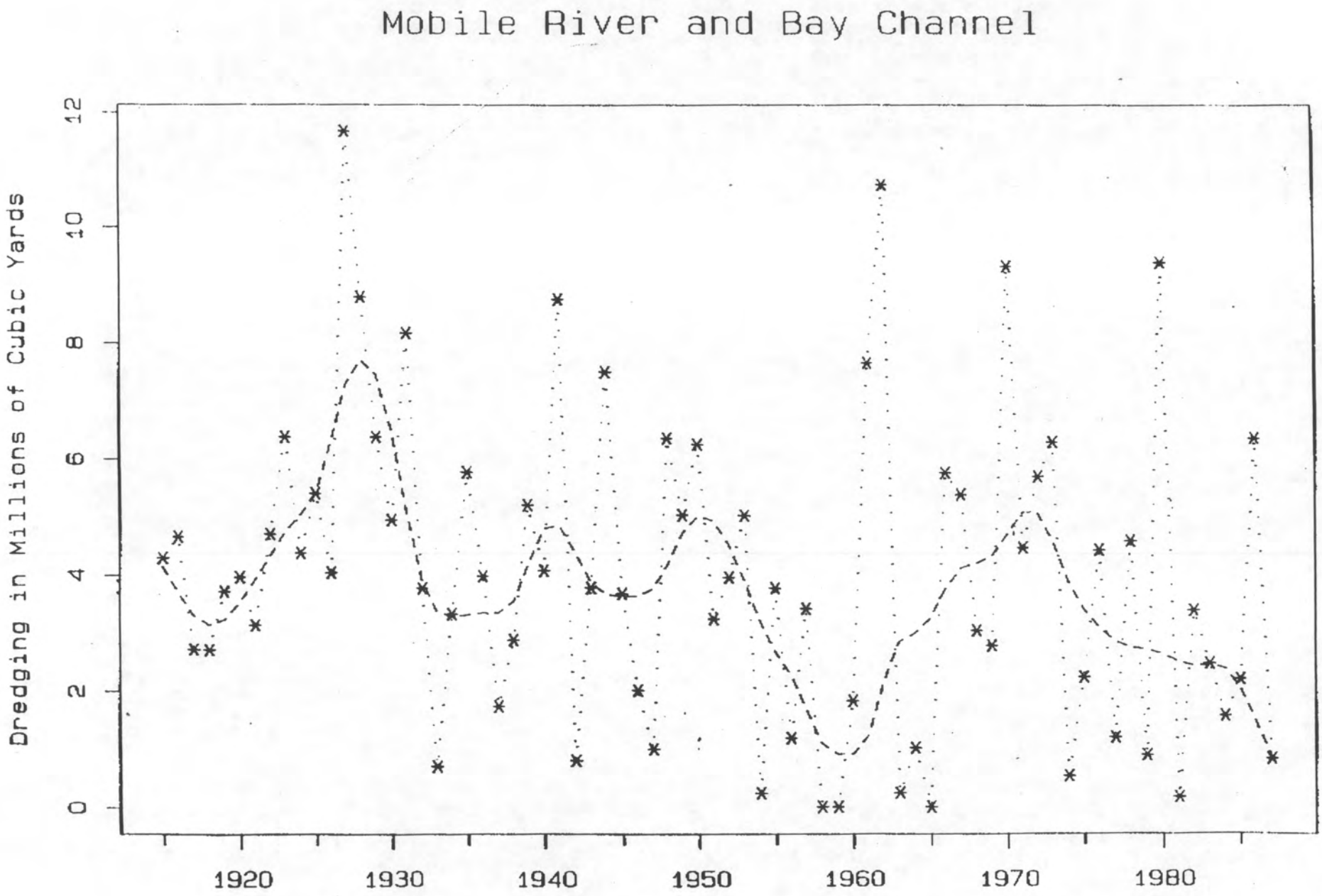

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Figure 2. Annual dredging volumes and trend line

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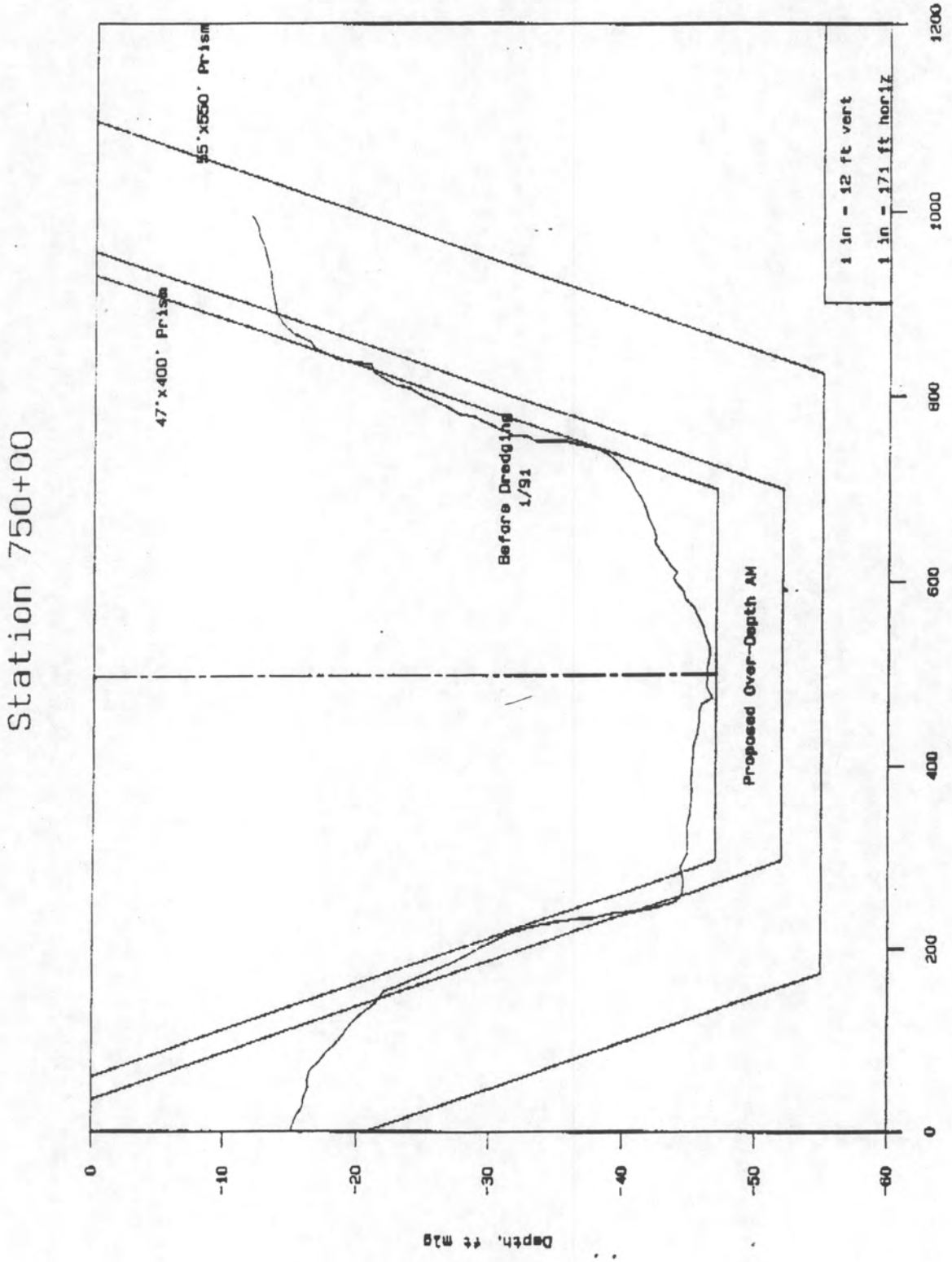

Figure 4. Typical section of the proposed test reach

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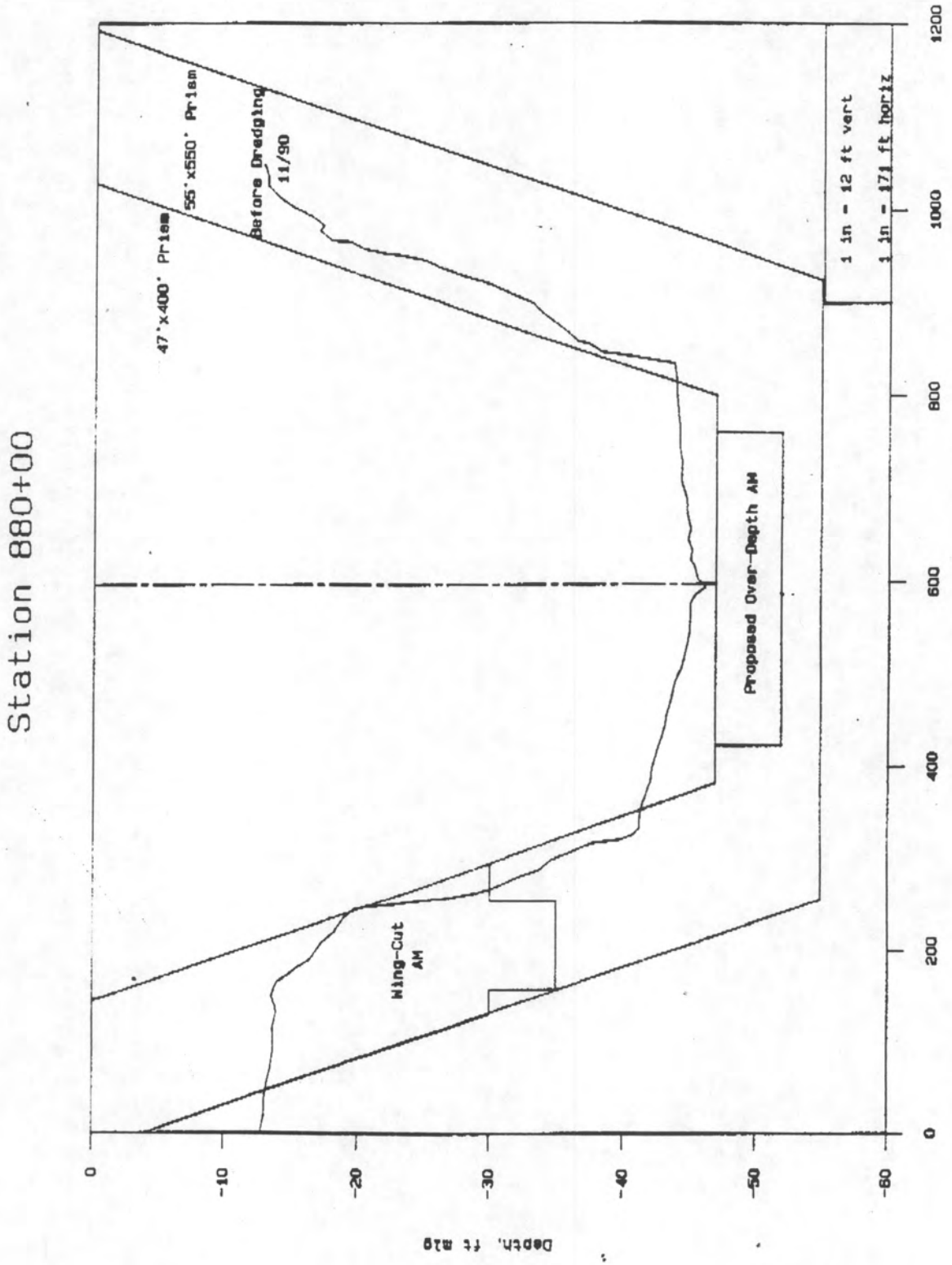

Figure 5. Typical section of the proposed test reach between stations 870+00 and 895+00

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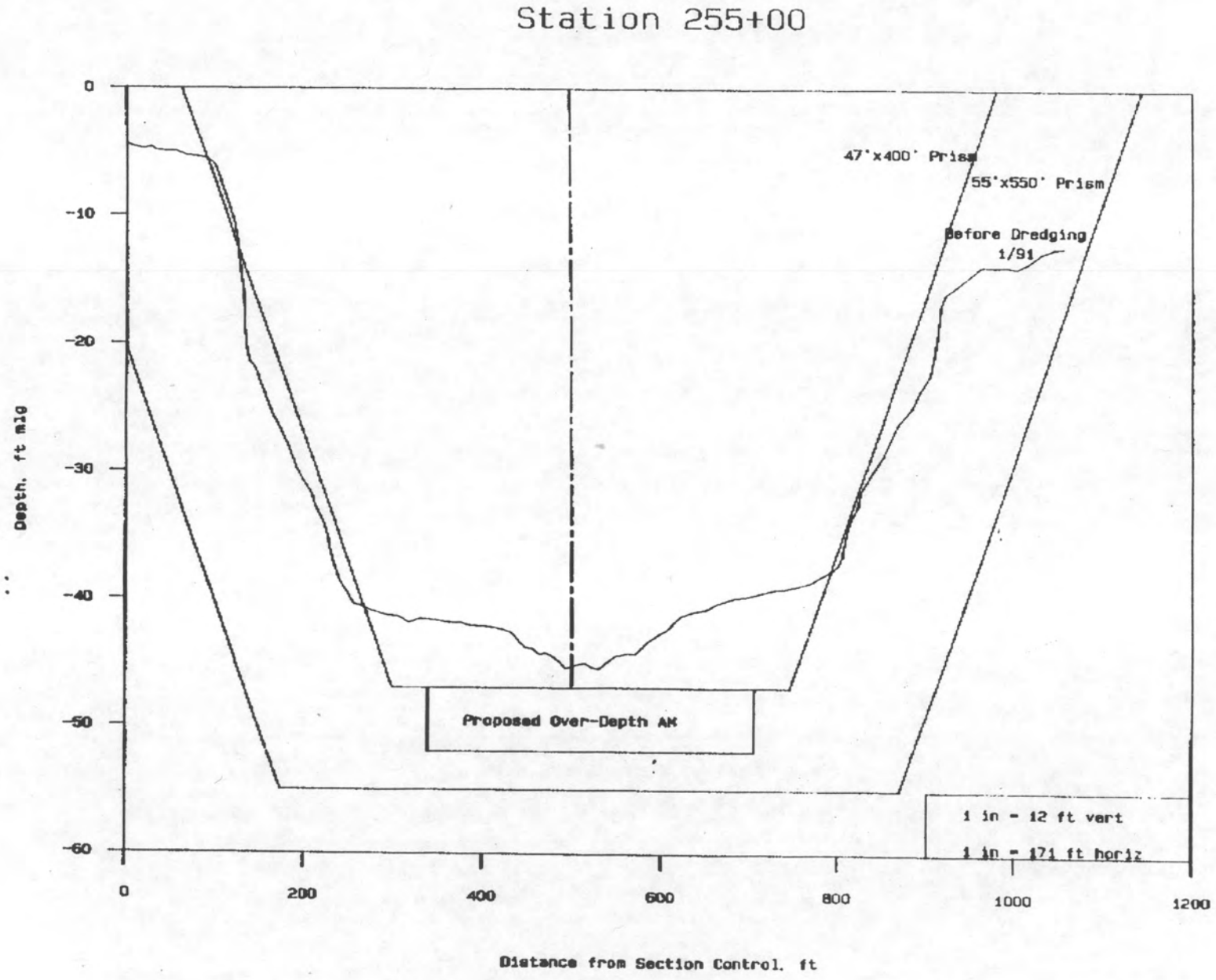

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Figure 3. Typical section of the proposed test reach between stations 240+00 and 295+00

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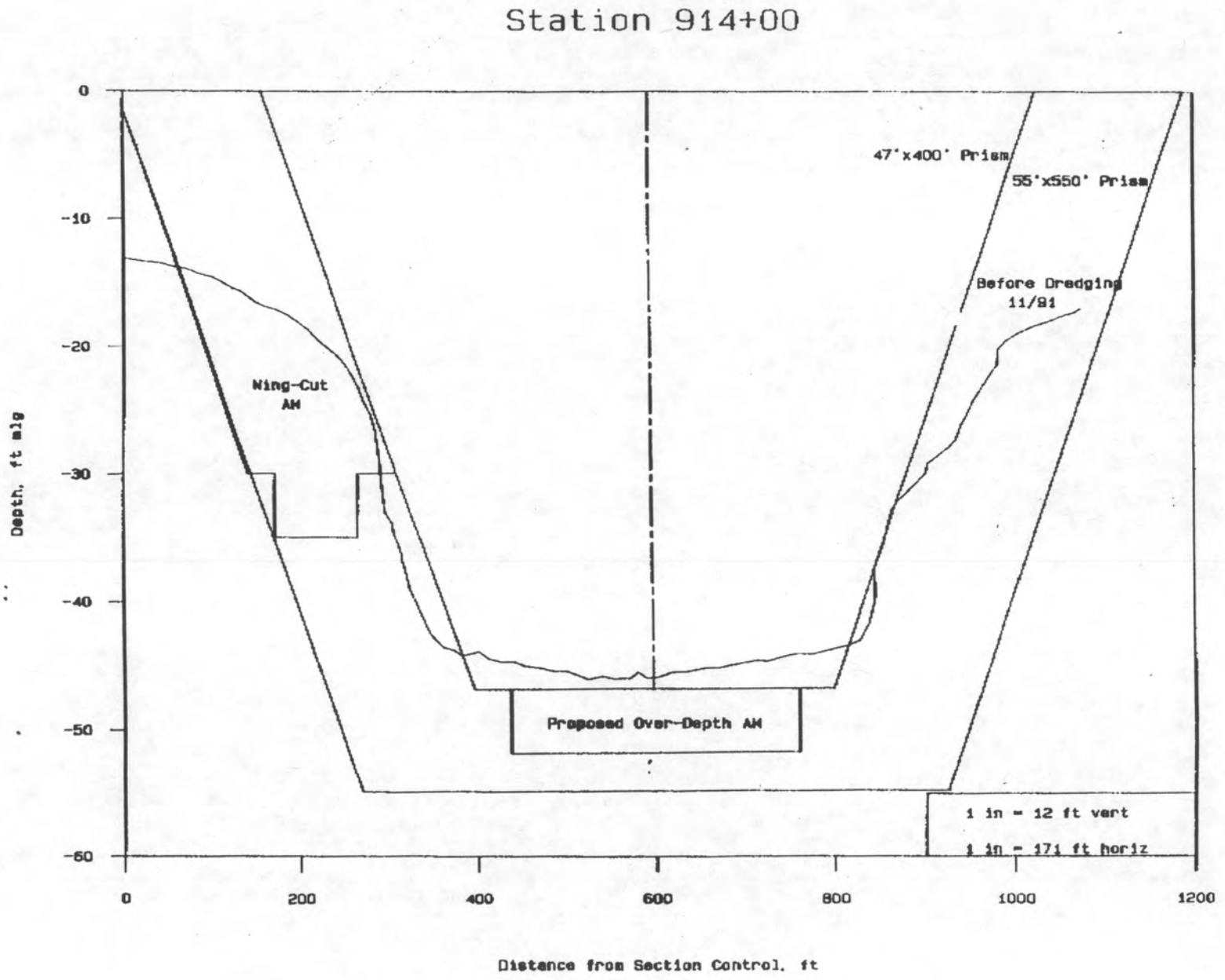

Figure 6. Typical section of the proposed test reach

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