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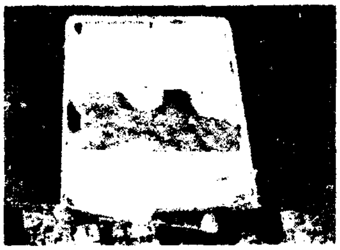

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CRANEY ISLAND DISPOSAL AREA: UPDATED PROJECTIONS FOR FILLING RATES THROUGH 1989

by

Tamsen S. Dozier, Michael R. Palermo, John J. Ingram

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13. ABSTRACT *(Maximum 200 words)*

The Craney Island disposal area is a 2,500-acre confined dredged material disposal facility located near Norfolk, VA. In 1981, the Craney Island Management Plan (CIMP) was developed to extend the useful life of the site for disposal of maintenance material from the project area. The CIMP called for subdivision of the site into three subcontainments and use of alternating filling and dewatering cycles. Management of the site in general accordance with the CIMP was implemented in 1984.

This report documents site operations and monitoring data for the Craney Island disposal area from October 1984 to October 1989. Updated projections of filling rates are also presented.

Based on the monitoring data collected to date and projections of future fill rates, the site will reach full capacity in FY99 if the present intensity of management is continued. Because of the larger area and lower average elevation of the center cell, it is recommended that the future filling schedule be revised so that more material is placed in this subcontainment, and less in the north cell which has the highest elevation and smallest area.

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Contents

Preface

This report describes site operations and monitoring data for the Craney Island disposal area near Norfolk, VA. The work was conducted by the U.S. Army Engineer District, Norfolk, and the Environmental Laboratory (EL) of the U.S. Army Engineer Waterways Experiment Station (WES). Funding for WES was provided by the Norfolk District under Intra-Army Order for Reimbursable Services No. CA-89-3029, 2 August 89. The Norfolk District Project Manager for the study was Mr. Tom Szelest.

This report was prepared by Mrs. Tamsen S. Dozier, Water Resources Engineering Group (WREG), Environmental Engineering Division (EED), Dr. Michael R. Palermo, Research Projects Group, EED, and Dr. John J. Ingram, Chief, WREG, EED. Field monitoring activities and laboratory analyses described in the report were conducted by the Norfolk District. Technical review of this report was provided by Dr. Paul R. Schroeder and Mr. E. A. Dardeau, Jr., WREG, and Mr. Szelest.

The study was conducted under the general supervision of Dr. Raymond L. Montgomery, Chief, EED, and Dr. John Harrison, Director, EL.

At the time of publication of this report, Director of WES was Dr. Robert W. Whalin. Commander and Deputy Director was COL Leonard G. Hassel, EN.

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Conversion Factors, Non-SI To SI 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
cubic yards	0.7645549	cubic metres

1 Introduction

Background

The Craney Island Management Plan (CIMP) was developed in 1981 and included measures designed to maximize the useful life of the Craney Island disposal facility near Norfolk, VA. This site (Figure 1) receives dredged material from the Hampton Roads area. The management actions outlined in the CIMP included subdividing the site into three subcontainments (or cells) using cross dikes, and employing alternate filling and dewatering cycles. During a 1-year filling period, ponded water would be maintained to ensure acceptable effluent water quality. During a 2-year dewatering period, surface water would be removed, ponding would be prevented, and surface trenching systems would be constructed to promote drainage and desiccation (Palermo, Shields, and Hayes 1981).

The site has been managed in general accordance with the CIMP since October 1984. However, the alternation of active filling between the subcontainments on a strictly annual basis and timely completion of surface trenching systems has proven difficult (Palermo and Schaefer 1990).

Filling Rate Projections

Palermo and Schaefer (1990) evaluated the storage capacity of the site by estimating future filling rates using a mathematical model that considers both consolidation and desiccation of the dredged material. For the model simulations, actual amounts of dredged material placed in the subcontainments from 1984 to 1987 were available, and a projected annual maintenance requirement of 5 million cu yd[1] was assumed beginning in 1988. The results from these simulations indicated the site should have sufficient capacity to accommodate dredging requirements through FY99.

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[1] A table of factors for converting non-SI units of measurement to SI units is presented on page v.

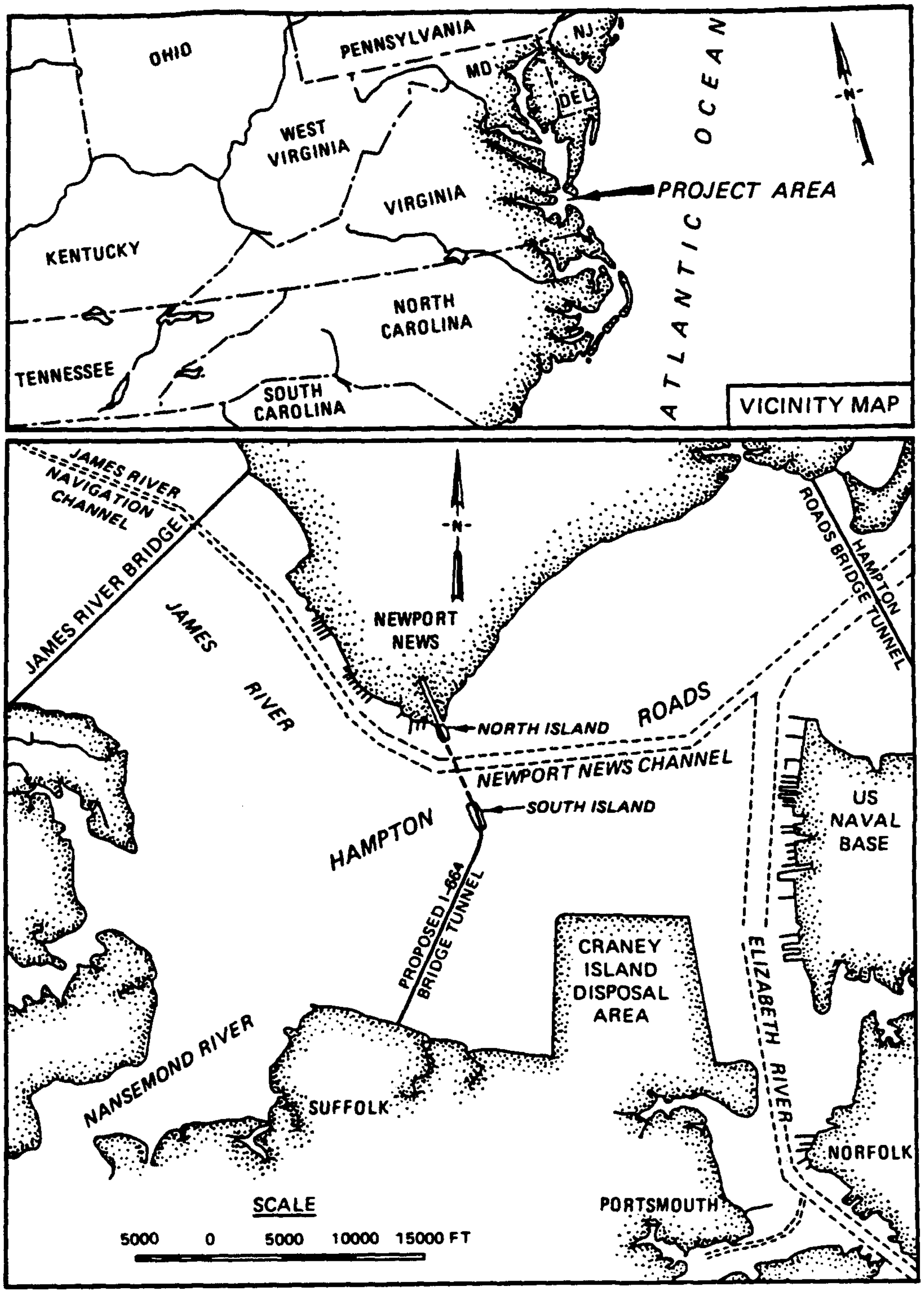

Figure 1. Craney Island disposal area and vicinity (after Poindexter-Rollings 1989)

This represented a gain of 3 years over a projected life of 12 years (beginning in FY85) with no management.

Objectives

The objective of this study is to update the previous projections of filling rates using actual volumes of dredged material placed in the subcontainments during the FY88 and FY89 filling cycles instead of the assumed volume of 5 million cu yd per year. This report describes the mathematical model used to make these projections and presents the results of the model simulations. Using these results, the remaining life of the site is estimated, and recommendations on altering of future filling schedules are made to extend the site life.

2 Modeling Approach

Mathematical Model

The mathematical model used for the storage capacity evaluations by Palermo and Schaefer (1990) and in the current study originated from the Primary Consolidation and Desiccation of Dredged Fill (PCDDF) model developed by Cargill (1985). The numerical solution used in the PCDDF model was modified to improve its numerical stability and convergence to the solution. This version was modified for use on personal computers and included in the Automated Dredging and Disposal Alternatives Management Systems (ADDAMS) (Schroeder and Palermo 1990). The modified version is referred to as the CONS (consolidation) module of ADDAMS and was also used by Poindexter-Rollings (1989) for evaluations of expansion alternatives for the Craney Island site.

The PCDDF model uses finite strain consolidation theory which is applicable for predicting consolidation in thick deposits of fine-grained dredged material. An explicit finite-difference scheme is employed to calculate material settlement based on the sediment compressibility and permeability characteristics as described by the input data. The data consist of coefficients to equations which describe the void ratio-effective stress and the void ratio-permeability relationships of the soil. Poindexter-Rollings (1989) describes these equations and the laboratory tests used to obtain the required relationships.

The desiccation process of a normally consolidating dredged material layer will result in the formation of a surface crust. Additional consolidation then results because of the surcharge created by the drop in the water table during crust formation. Surface drying may be significant between disposal operations; therefore, desiccation settlement is incorporated in the model computations (Poindexter-Rollings 1989).

In addition to consolidation and desiccation parameters, precipitation and evaporation rates are also required by the model. Except as noted, all input parameters used in the model simulations in this study were the same as those used by Palermo and Schaefer (1990). A description of these input parameters is presented in that report and summarized below.

Dredged Material Properties

Using the results from a series of consolidation tests on dredged material samples taken from the site, a relationship of void ratio versus effective stress was developed by Palermo and Schaefer (1990). A relationship for void ratio versus permeability was similarly determined. For input to the model, coefficients to fitted curves of the following form were determined:

$$e = A\sigma^B + C$$

(for the void ratio-effective stress relationship)

and

$$e = Dk^E + F$$

(for the void ratio-permeability curve)

where:

e = void ratio

σ = effective stress, psf

k = permeability, ft/day

A, B, C, D, E, and F are coefficients

The consolidation parameters for the dredged material and compressible foundation are shown in Table 1. Also shown are consolidation parameters for the incompressible foundation assumed to underlie the compressible foundation.

The desiccation parameters used in the model were varied by Palermo and Schaefer (1990) for several simulations for calibration of the predicted filling rates to field data. The values which produced good calibration results and which were used in the projection simulations are given in Table 2. Average monthly precipitation and evaporation rates for Norfolk, VA, were used and are presented in Table 3.

Dredged material lift thicknesses for each disposal operation were determined from the dredging volumes and surface areas available in the subcontainment in which the material was placed. In the north cell, 658 acres are available for dredged material placement; 720 acres are available in the center cell; and the effective area of the south subcontainment is 702 acres. In calculating the initial lift thickness from dredged volumes, an in-channel void ratio of 5.93 and a zero effective stress (that which occurs immediately following the sedimentation process and at the beginning of consolidation) void ratio of 10.5 were used which are representative of the maintenance material from the site (Palermo and Schaefer 1990).

Table 1
Consolidation Parameters for Model Simulations

Dredged Material and Compressible Foundation	
Specific gravity of the soil solids	2.75
Initial void ratio (before consolidation)	10.5
Coefficients of the void ratio-effective stress equation	
($e = A\sigma^B + C$; where p is expressed in pounds per square foot): $A = 11.43$ $B = -0.09009$ $C = -3.0$	
Coefficients of the void ratio-permeability equation	
($e + Dk^E + F$; where k is expressed in feet per day): $D = 14.92$ $E = 0.08065$ $F = -4.0$	
Incompressible Foundation	
Void ratio at the boundary with the compressible layer	0.65
Permeability at the boundary with the compressible layer, ft/day	3×10^{-4}
Drainage path length, ft	6.06

Table 2
Desiccation Parameters for Model Simulations

Void ratio at the end of desiccation	3.2
Void ratio at the saturation limit	6.5
Maximum crust thickness, ft	1.0
Maximum evaporation efficiency, percent	100.0
Surface drainage efficiency, percent	75.0
Saturation at the end of desiccation, percent	75.0
Time to desiccation after filling, days	30.0

Table 3
Norfolk, VA, Climatic Data, Average Monthly Values

Month	Pan Evaporation ft	Precipitation ft	Month	Pan Evaporation ft	Precipitation ft
January	0.00	0.28	July	0.67	0.48
February	0.00	0.28	August	0.51	0.49
March	0.00	0.29	September	0.34	0.35
April	0.39	0.23	October	0.26	0.26
May	0.57	0.28	November	0.00	0.25
June	0.57	0.30	December	0.00	0.26
Total	3.31	3.75			

Filling - Dewatering Cycles

Following completion of the cross-dikes in 1984, disposal operations have generally alternated between the subcontainments. Table 4 shows the subcontainment designated for disposal each fiscal year and how placement of volumes from individual contracts has actually occurred through FY89. During filling cycles, water was allowed to pond in the subcontainments so that suspended solids could settle effectively yielding return water of adequate quantity. During the drying cycles, weirs were opened in the subcontainments, and water was allowed to drain to prevent ponding. In addition, surface trenches were constructed to rapidly drain precipitation from the site to promote more efficient natural drying. However, because of difficulties with mobility of the trenching equipment in the soft mud bottoms and frequent breakdowns, trenching over the entire surface area of any subcontainment has not yet been accomplished (Palermo and Schaefer 1990).

Table 4
Craney Island Disposal History - FY85 to FY89

FY	Designated Cell	Dates of Actual Disposal	Amount, cu yd	Cell In Which Material Was Actually Disposed
85	North	01-Oct-84 to 14-Dec-84 16-Sep-84 to 28-Nov-84 23-Oct-84 to 24-Nov-84 03-Feb-85 to 02-Apr-85 02-Feb-85 to 07-Mar-85 07-Mar-85 to 01-May-85 16-May-85 to 22-May 85 22-May-85 to 24-May-85 31-Jul-85 to 11-Aug-85	876,171 775,448 121,457 600,095 183,546 610,386 77,150 45,140 251,987	North North North Center North North North North North
Total Volume Disposed in North Cell in FY85 = 2,941,545 cu yd Total Volume Disposed in Center Cell in FY85 = 600,095 cu yd				
86	Center	07-Jan-86 to 19-Mar-86 02-Feb-86 to 22-Mar-86 22-May-86 to 22-Jun-86 01-Jun-86 to 22-Jun-86 15-Jul-86 to 14-Aug-86 15-Jul-86 to 30-Aug-86	997,142 150,431 1,618,841 185,365 192,055 529,325	Center South Center Center Center Center
Total Volume Disposed in Center Cell in FY86 = 3,522,728 cu yd Total Volume Disposed in South Cell in FY86 = 150,431 cu yd				
87	South	09-Jun-87 to 01-Aug-87 20-Jul-87 to 08-Aug-86 08-May-87 to 23-Aug-87	978,250 153,474 1,681,024	South South *South and Center*[1]
Total Volume Disposed in South Cell in FY87 = 2,812,748 cu yd[1]				
88	North	01-Oct-87 to 18-Jul-88 07-Aug-88 to 15-Sep-88 01-May-88 to 20-Jul-88 05-Jul-88 to 30-Sep-88 01-Dec-87 to 30-Mar-88 01-Nov-87 to 17-Nov-87 01-May-88 to 03-Dec-88	3,412,714 624,764 616,387 540,586 1,770,000 280,615 1,590,267	North North North North North North North
Total Volume Disposed in North Cell in FY88 = 8,835,333				
89	Center	19-Apr-89 to 25-May-89 15-Apr-89 to 30-Jun-89 16-Aug-89 to 31-Oct-89	1,353,460 103,610 916,834	Center Center Center
Total Volume Disposed in Center Cell in FY89 = 2,373,904				

[1] Exact volume deposited in Center Cell or South Cell for FY87 is unknown.

3 Storage Capacity Evaluations

Updated Filling Simulations: Comparison to Field Data

In conducting the updated filling projections, one model simulation was made for each subcontainment, representing the fill-dewater cycles during the life of that particular cell. A subcontainment was considered to be filled when the surface elevation following desiccation for a fill cycle remained above +30 ft mean low water (mlw) (Craney Island Datum).

The filling simulations made by Palermo and Schaefer (1990) used actual volumes and times from disposal operations made for the period FY85 through FY87. For projections of future filling rates, a dredging fill time of 5 months and an annual dredging volume of 5 million cu yd were assumed beginning in 1988. Assuming future dredging volumes are not significantly greater or less than these projected amounts, the results from that study predicted the site would be filled to elevation +30 ft during FY2000.

Updated simulations for the north and center cells were made based on actual dredging volumes and times of disposal for FY85 through FY89. As shown in Table 4, all of the material deposited at the site in FY88 went into the north cell. With the exception of a small amount placed at the beginning of the fiscal year in the north cell, all of the material dredged during FY89 was deposited in the center subcontainment. The amount of material placed in the north cell during the FY88 fill cycle was 8,835,333 cu yd—over 75 percent more than the previously projected 5,000,000 cu yd. The volume of material that was dredged and placed in the center cell during the following year was 2,373,904 cu yd—less than half of the previously projected amount.

Figure 2 compares the results of the updated filling simulation to average surface elevations for the north subcontainments as determined by survey for the period October 1984 through October 1989. (The average surface elevations were determined from the annual aerial surveys and are presented in Table 5.) The model simulations predicted higher elevations

Table 5
Average Surface Elevations (ft) from Aerial Surveys

Date	North Cell	Center Cell	South Cell
Sep 1984	19.1	16.9	19.1
Sep 1985	19.9	16.4	20.2
Oct 1986	19.9	19.7	20.0
Sep 1987	20.0	19.4	21.9
Oct 1988	25.8	19.5	21.1
Aug 1989	24.7	21.8	21.2

for the north subcontainment in 1988 and 1989 than shown by the field data. One possible reason for this discrepancy is the uncertainty in the parameters used to determine initial lift thicknesses from dredged volumes. Any discrepancies between laboratory-determined values for the in-channel void ratio of the material and zero effective stress void ratio and values that are actually representative of the average field condition of the material could result in a significant difference in the calculated and the observed lift thicknesses. However, the model is accurately representing the rate of fill and rate of settling of the material. The model predicted a difference of 1.1 ft between the October 1988 average elevation (near the end of the filling period) and the August 1989 elevation. This is the same as the difference between the actual average surface elevations for these two dates as determined by the aerial surveys.

The predictions for the center cell elevations for 1988 and 1989 were slightly less than field data values as is shown in Figure 3. The actual increase in the average surface elevation of the cell between the October 1988 and August 1989 surveys (due to the disposal of over 2 million cu yd of material) was approximately 2 ft. This is just slightly greater than the model-predicted increase of over 1.5 ft. However, it appears that the model is overpredicting the amount of settling for this cell. No material was placed in the center cell between October 1986 and October 1988, yet very little settling seems to have occurred. This lack of consolidation is possibly due to the difficulties in obtaining efficient dewatering of the subcontainments.

No material was placed in the south subcontainment during the FY89 and FY90 filling cycles, and Figure 4 compares the field data with the original projection made by Palermo and Schaefer (1990) for that cell. The projected elevations correlate well with the field data for this cell. The model appears to have accurately predicted the amount of settling that occurred in FY88; however, it appears to have slightly overpredicted the settlement occurring in FY89.

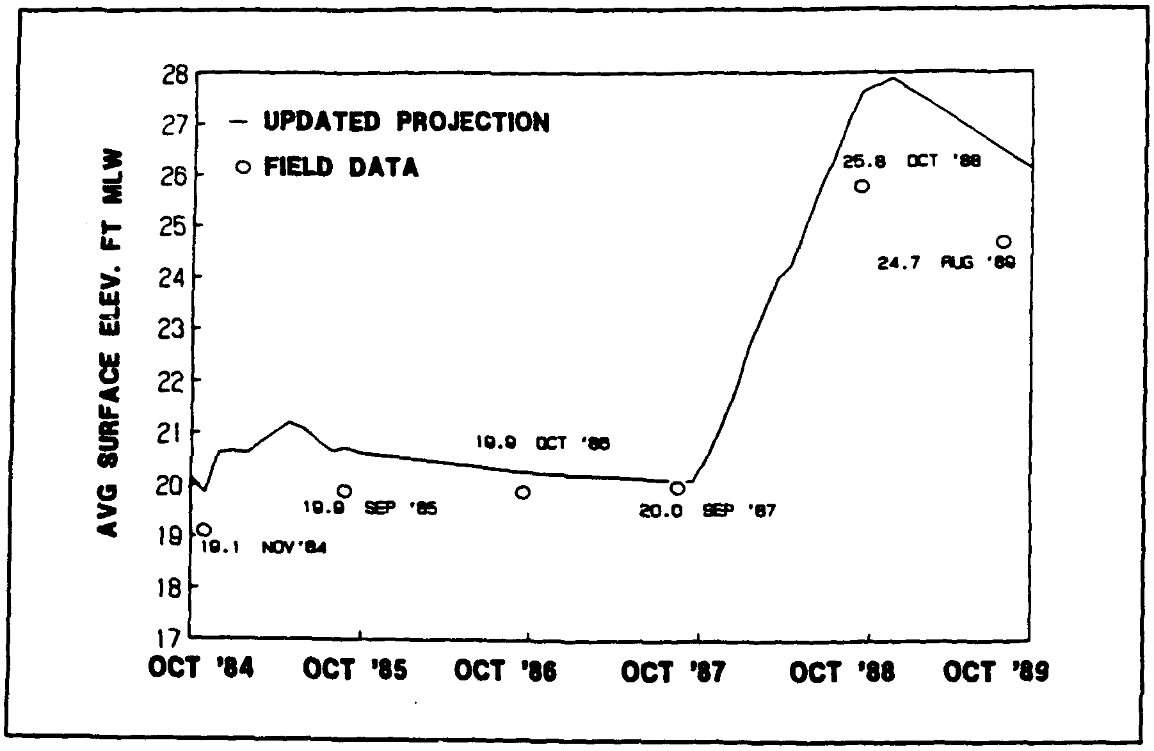

Figure 2. Filling simulations for the north subcontainment from 1984 to 1989 (based on actual dredged volumes)

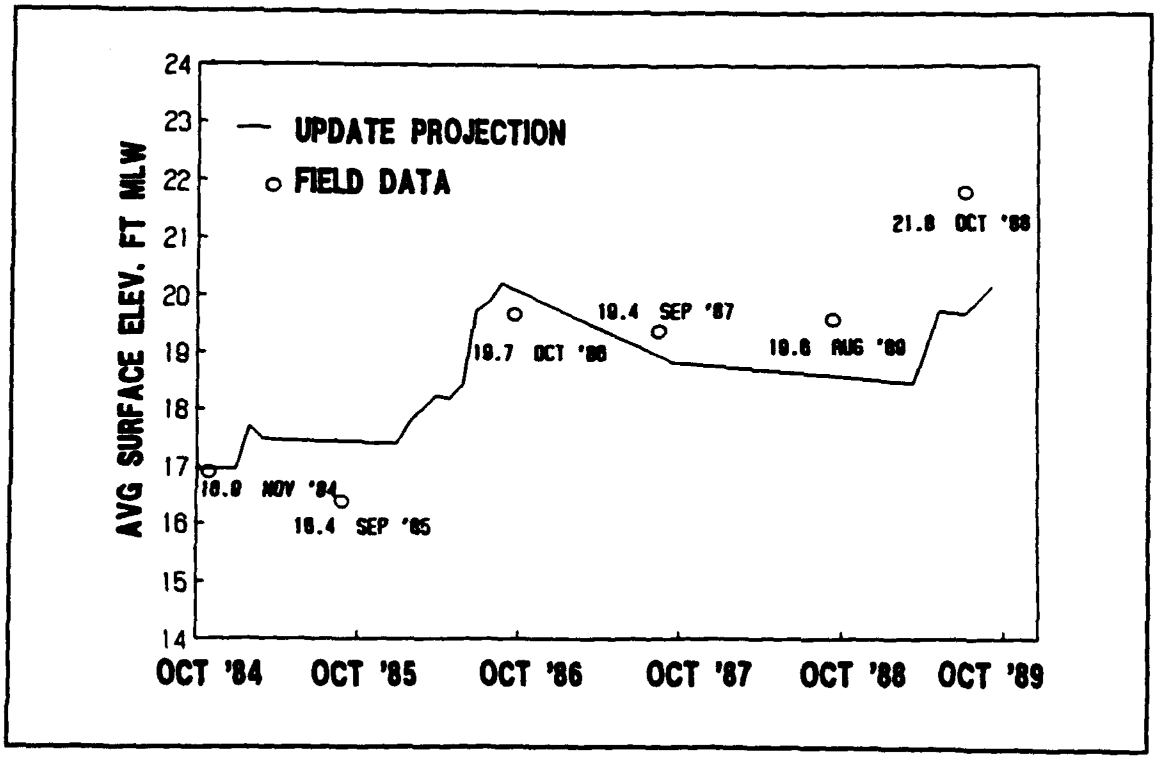

Figure 3. Filling simulations for the center subcontainment from 1984 to 1989 (based on actual dredged volumes)

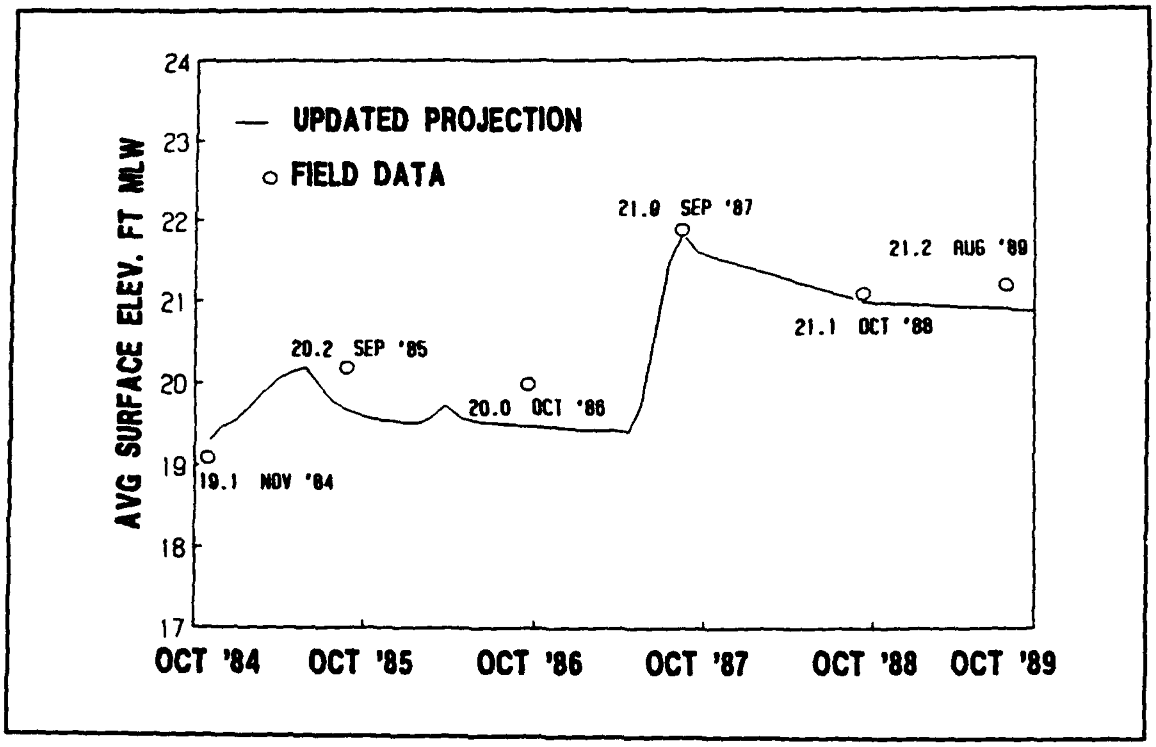

Figure 4. Filling simulations for the south subcontainment from 1984 to 1989 (based on actual dredged volumes)

Updated Filling Simulations: Future Predictions

Model simulations were made for projections of future fill rates, assuming that the cell rotation schedule would remain unchanged. Figures 5 and 6 show the results from the updated filling simulations for the north and center cell from October 1984 to the time at which the fill elevation reaches an elevation limit of +30 ft. Figure 7 reproduces the results from the simulation of future filling rates for the south cell made by Palermo and Schaefer (1990). As can be seen in Figure 5, based on the projected annual dredging volume of 5 million cu yd, the north cell will reach an elevation of +30 ft at the end of the FY94 filling cycle. Based on these projections, the center cell will not reach its full capacity until the FY2001 filling cycle due to its larger effective area and lower starting elevation in 1984. The prediction for the south cell made by Palermo and Schaefer (1990) of reaching capacity at the end of the FY96 filling cycle remains the same. Naturally, these projections for the center and south cells are not applicable if material must be diverted from the north cell once it has reached its capacity.

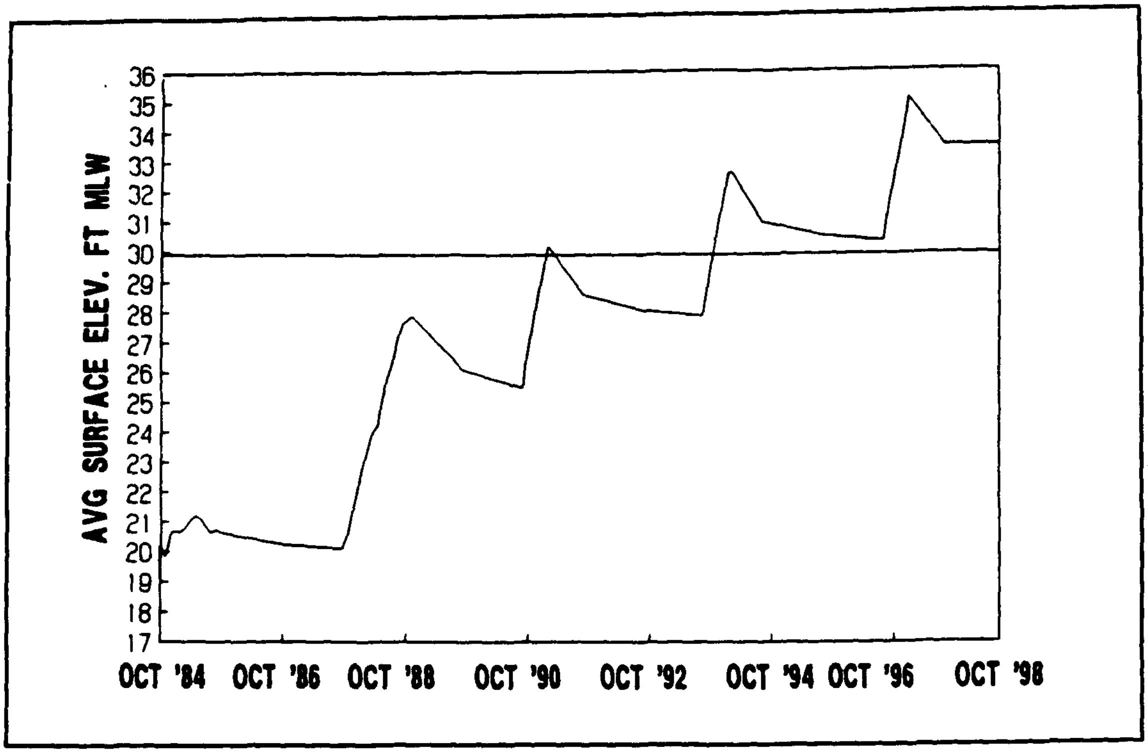

Figure 5. Filling simulations for the north cell from 1984 to +30 ft elevation using the original filling schedule

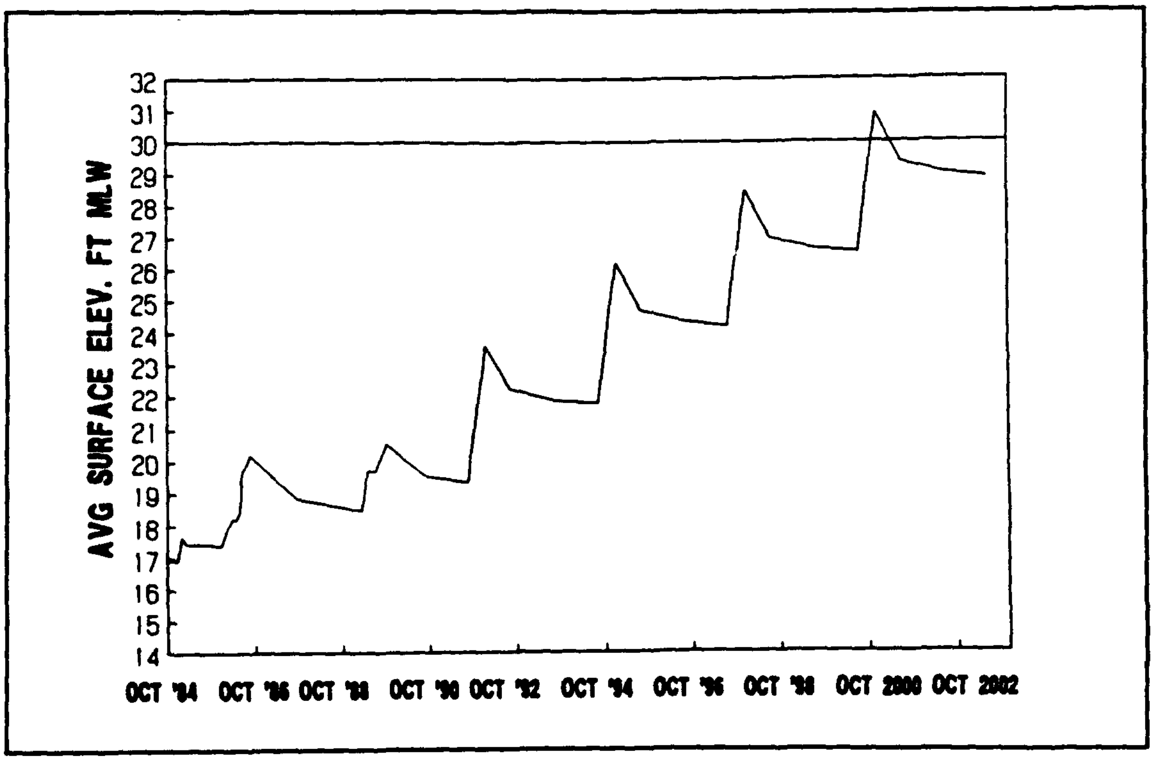

Figure 6. Filling simulations for the center cell from 1984 to +30 ft elevation using the original filling schedule

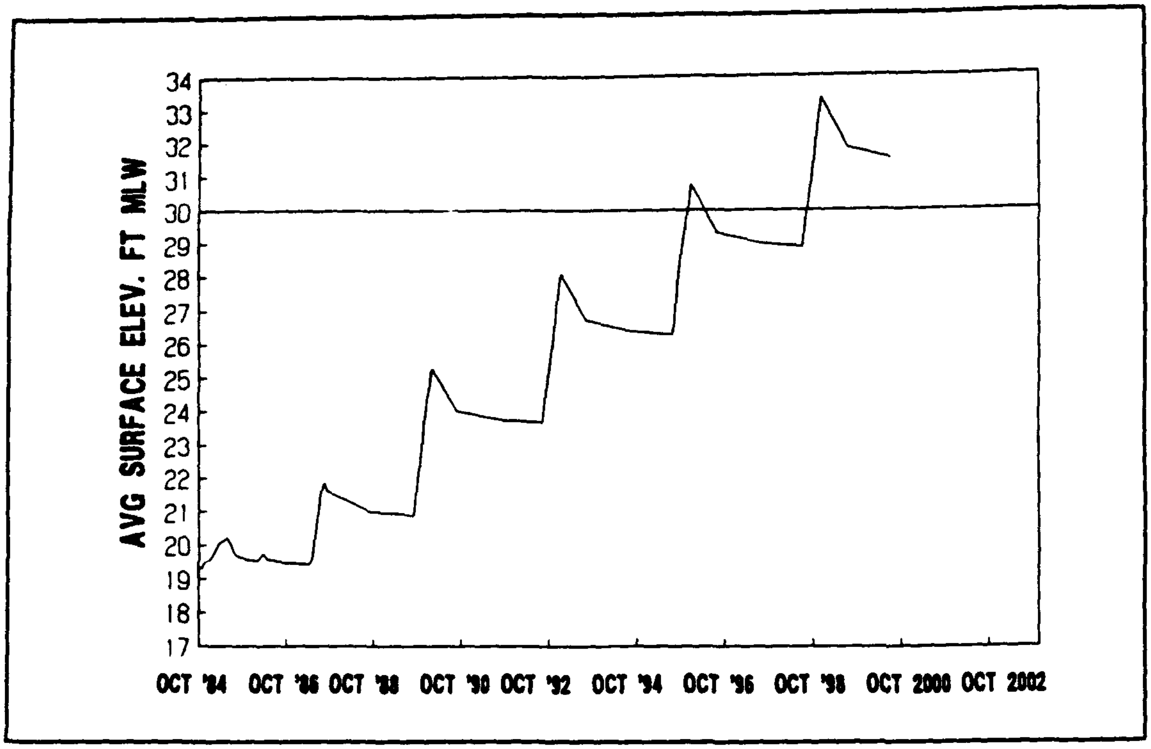

Figure 7. Filling simulations for the south cell from 1984 to +30 ft elevation using the original filling schedule

Updated Filling Simulations: Revised Schedule

Because of the large volume of material deposited in the north cell in FY88, and because it is the smallest of the three subcontainments in area, less usage of it is recommended than that of the other three in the future. A revised filling schedule which makes use of the lower average elevation and larger area of the center cell is presented as follows:

April 1991 to April 1992 — Center
April 1992 to April 1993 — South
April 1993 to April 1994 — Center
April 1994 to April 1995 — North
April 1995 to April 1996 — South
April 1996 to April 1997 — Center

The original North-Center-South cycle is resumed in April 1997.

Palermo and Schaefer (1990) recommended scheduling the "changeover" of pumping to the next cell in the spring rather than the present October changeover, which is now done to correspond with the fiscal year. This change would provide a better opportunity to perform dewatering operations immediately after changeover. Norfolk District is now considering performing this changeover in April.

A series of simulations for projected future filling rates was conducted using an April changeover and the revised schedule as recommended. Figures 8-10 present the results from these simulations. Based on these revised projections, the north cell would reach its capacity a few months into the FY97 fill cycle (which is now assumed to begin in April 1997). The elevation of the center cell would reach an elevation of +30 ft late in the FY98 fill cycle. The south subcontainment will just reach its capacity at the end of the FY95 fill cycle, but will recover enough for a partial fill in FY99. Some diversion of pumping from the designated cell to one of the other subcontainments will be required during these final 3 years to make best use of those with greater capacities remaining.

If future dredging volumes are not significantly greater than the projected volume of 5 million cu yd, and if the efficiency of the dewatering operation can be improved, the divided site should have sufficient capacity to accommodate disposal requirements through FY99, based on this revised schedule. This is 1 year less than the projections made by Palermo and Schaefer (1990) as a result of the increased volume of material placed in the north cell in FY88 and the apparent difficulties in obtaining efficient dewatering in the center and south cells.

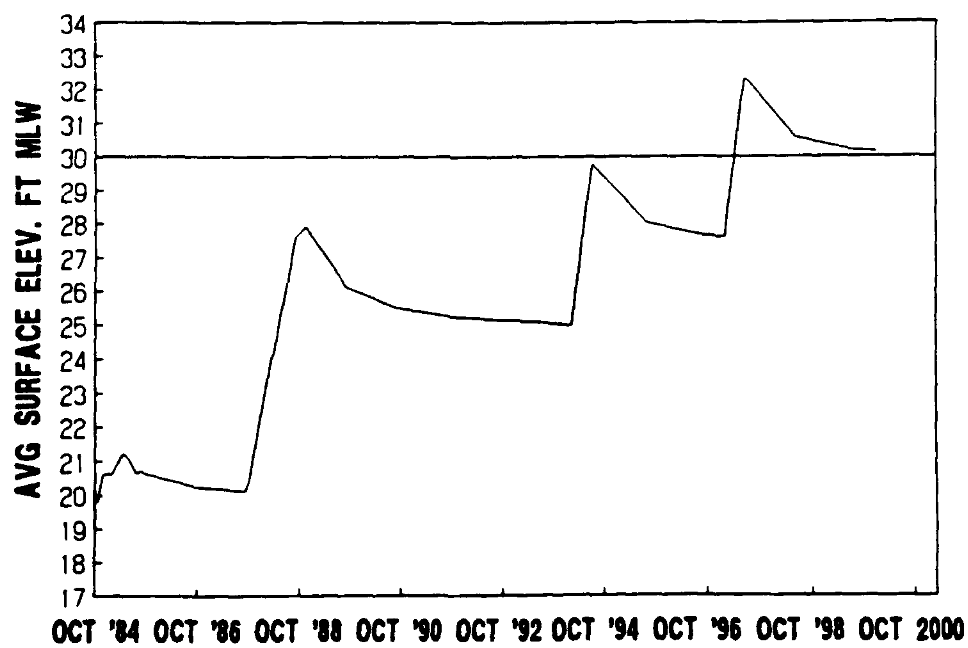

Figure 8. Filling simulations for the north cell from 1984 to +30 ft elevation using a revised filling schedule

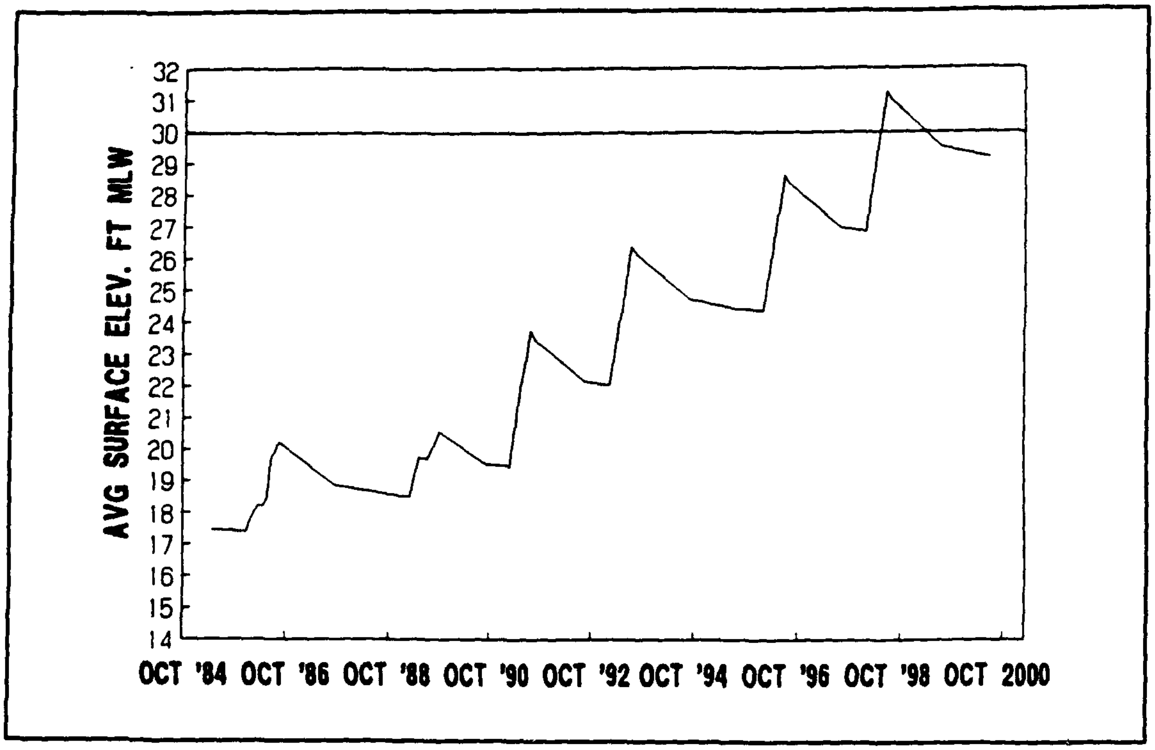

Figure 9. Filling simulations for the center cell from 1984 to +30 ft elevation using a revised filling schedule

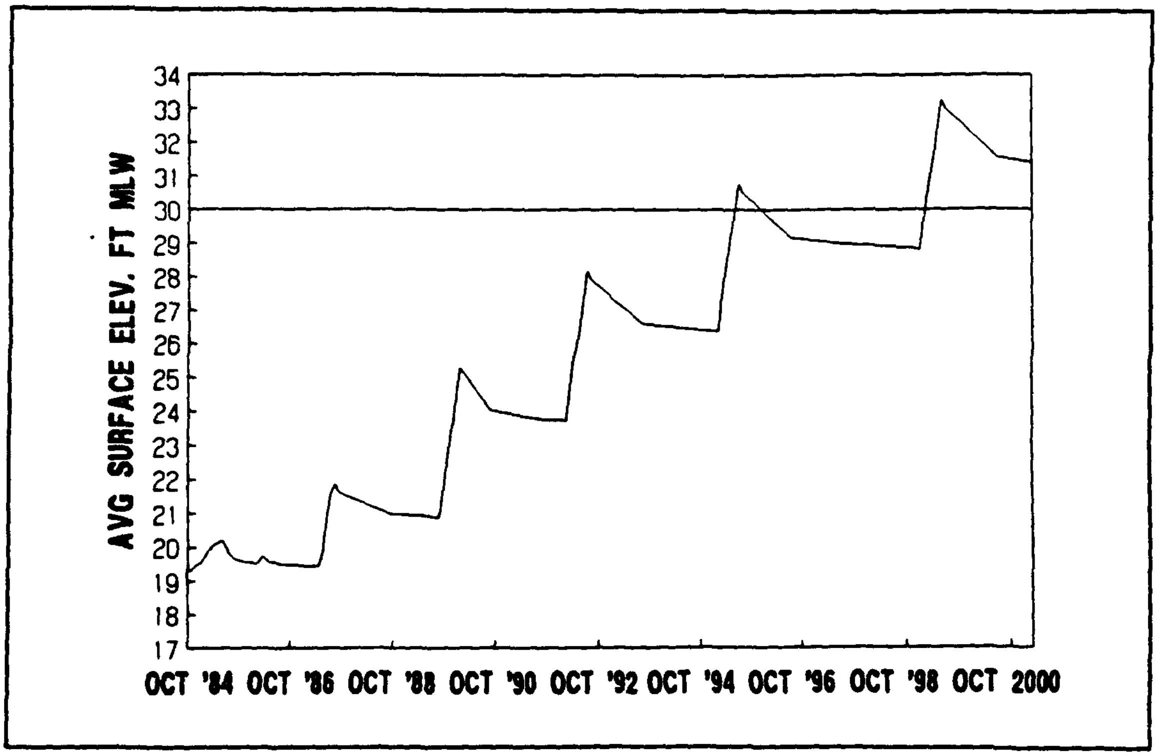

Figure 10. Filling simulations for the south cell from 1984 to +30 ft elevation using a revised filling schedule

4 Conclusions and Recommendations

Conclusions

During the FY88 and FY89 filling cycles, the alternation of disposal between the subcontainments has been performed in accordance with the CIMP, and significant consolidation of the material immediately following "changeover" was observed in the north and south cells.

In general, the model appears to be overpredicting the rate of consolidation, especially in the second drying year. During these periods (FY86 for the north cell, FY87 for the center, and FY88 for the south cell), aerial survey data showed no change in elevation.

The updated model simulations based on the original North-Center-South filling/dewatering cycles showed that the north cell will reach an elevation of +30 ft at the end of the FY91 filling cycle. This is one cycle sooner than originally predicted because of the large volume of material placed in the subcontainment in FY88. The life of the center cell was extended to FY2001 as a result of the small volume of material it received in FY89; however, in reality, it would fill sooner than this because of the necessity of diverting disposal material to it from the north cell.

Model simulations were performed based on a revised filling schedule which places more material in the center cell and less in the north. These model simulations predict that the site will reach full capacity in FY99, 1 year sooner than the projections made by Palermo and Schaefer (1990). This difference in predictions is partially a result of the increased volume of material placed in the north cell in FY87 and the apparent difficulties in obtaining efficient dewatering in the center and south cells.

Recommendations

Because of the larger area and lower average elevation of the center cell, revising the future filling schedule so that more material is placed in this subcontainment, and less in the north cell, which has the highest elevation and smallest area, is recommended. The following schedule is suggested:

April 1991 to April 1992 — Center
April 1992 to April 1993 — South
April 1993 to April 1994 — Center
April 1994 to April 1995 — North
April 1995 to April 1996 — South
April 1996 to April 1997 — Center

The original North-Center-South cycle is resumed in April 1997.

The recommendations made by Palermo and Schaefer (1990) related to dewatering operations remain in effect if the site is to continue to be used in the future for disposal of all material from the Hampton Roads area.

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