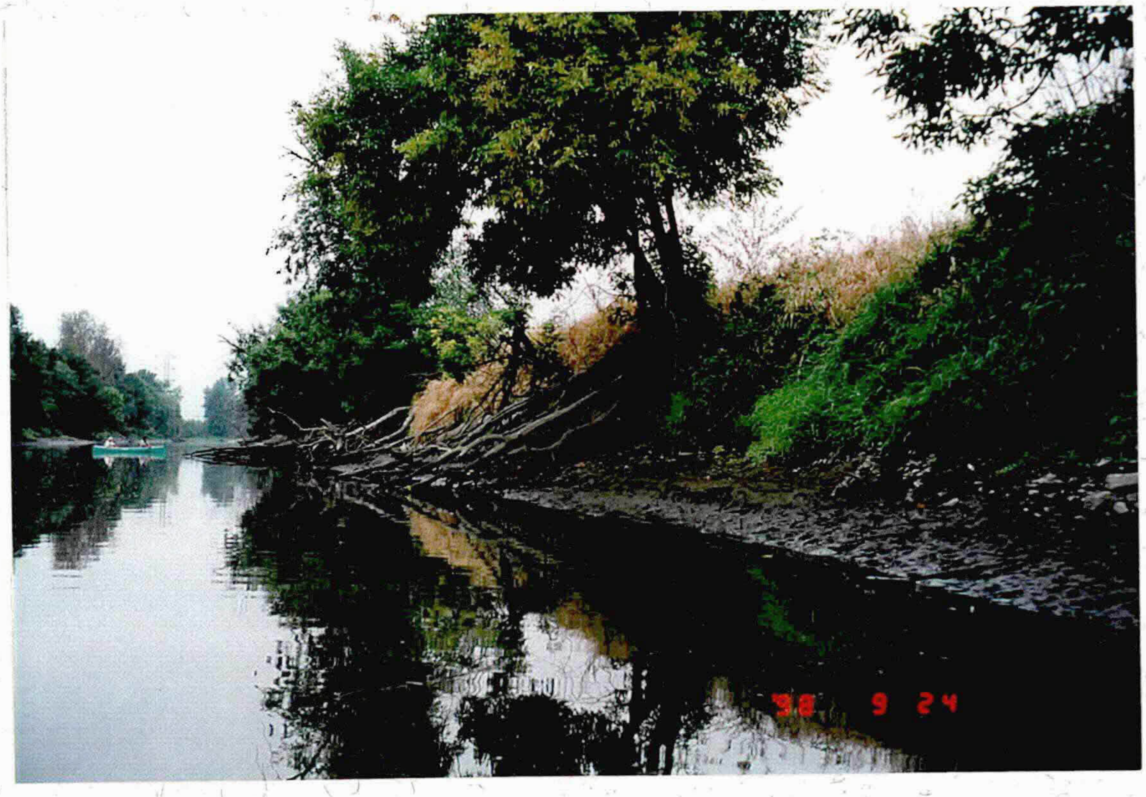
METRO REGIONAL ENVIRONMENTAL MANAGEMENT

PRELIMINARY DIKE STABILIZATION STUDY
ST. JOHNS LANDFILL
PORTLAND, OREGON



JUNE 1999

Cornforth Consultants Inc.

TECHNICAL MEMORANDUM

Technical Memorandum to:

Metro
Regional Environmental Management
Engineering and Analysis Division
600 NE Grand Avenue
Portland, Oregon 97232-2736

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ST. JOHNS LANDFILL
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June 1999

By

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1. INTRODUCTION

1.1. General

In accordance with Metro's authorization, we have completed a preliminary evaluation of methods to stabilize the dike around the perimeter of St. Johns Landfill, in Portland, Oregon. This technical memorandum discusses conceptual dike stabilization options, and presents a recommended repair method.

For this preliminary phase of the project, Cornforth Consultants evaluated dike stabilization concepts and conceptual costs. We were assisted by Fishman Environmental Services (permitting issues, fish and wildlife habitat); Ogden Beeman & Associates, Inc. (slough hydraulics analyses); and Mr. George Kral (vegetation). Each of the team members are based in Portland, Oregon.

1.2. Scope of Work

The scope of work for this study included the following tasks:

- Review Cornforth's files from previous site investigations.
- Perform a reconnaissance of the perimeter dike.
- Perform an analysis of the slough hydraulics to evaluate: (i) channel flow velocities at key locations around the landfill perimeter; and (ii) the impact on flow velocities caused by removing the existing dam on the North Slough.
- Evaluate conceptual dike stabilization methods which would minimize impacts on water quality and wildlife habitat, and would provide enhanced ecological functions within the Smith and Bybee Lakes/Columbia Slough Management Area.
- Determine the likely permits required for the project.
- Review the existing vegetation around the site, and evaluate ways to establish native vegetation on the repaired dike.
- Prepare a report summarizing the conceptual stabilization techniques, analyses and conclusions.

1.3. Background/Previous Investigations

A site plan for the landfill is shown on Figure 1. In July 1997, Metro retained Cornforth Consultants to perform a geotechnical reconnaissance of the perimeter dike to assess: (i) general erosion-related problems; and (ii) a failed section of the dike located at the northwest end of Subarea 1 (near the confluence of the Columbia Slough and North Slough). The results of this earlier investigation were summarized in a report to Metro titled "Geotechnical Evaluation, St. Johns Landfill Perimeter Levee," dated July 24, 1997.

During the July 1997 study, the dike showed signs of erosion and minor slumping that are commonly observed along the shorelines of other sloughs and rivers in the region. We frequently observed erosion at the toe of the perimeter dike, especially below the average high tide waterline. Many of the trees along the shoreline had been undercut by this erosion, and some had fallen into the slough. In isolated areas we observed shallow slope failures (or "slumps") on the face of the dike, which were probably caused by oversteepening at the toe of the slope. One of the slumps was located along the southwest end of the landfill. Metro treated this slump in the Fall of 1997 by constructing a sand-filled buttress (or a "sand bench") at the toe of the slope. A second sand bench was constructed a short distance to the east to test whether adjacent benches could reduce scour of the bank between them. A third sand bench was constructed along the shoreline in the Blind Slough area to improve fish and wildlife habitat.

Subarea 1 Dike Failure. The dike failure in Subarea 1 occurred in early 1996 after a period of torrential rainfall and flooding. The failure occurred as a flow slide, which carried trees and loose soil into the Columbia Slough. The failed section was approximately 45 feet in length and 20 feet in height. In the July 24, 1997 report, we presented a conceptual option for reconstructing the slope and buttressing it with rockfill materials. In the Fall of 1997, Metro repaired the dike by excavating the loose debris and infilling the slide area with rockfill.

1.4. Concurrent Waste Cutoff Study

Previous subsurface investigations at the landfill have revealed the presence of a refuse layer within the dike embankment, along a segment adjacent to the North Slough. In March 1998, our firm identified the lateral extent of this refuse layer with a series of borings performed through the dike. The western and eastern limits of the refuse layer are two of the key locations around the landfill perimeter where the slough hydraulics were evaluated in this study. These areas are discussed further in Chapter 3 of this report.

Concurrent with this dike stabilization study, Metro authorized our firm to evaluate methods to construct an impermeable barrier (or waste cutoff) through the refuse layer. The results of our waste cutoff study are submitted in a separate report titled "Waste Cutoff Study, St. Johns Landfill," dated June 1999.

2. SHORELINE RECONNAISSANCE

2.1. General

On September 24, 1998, members of the project team and representatives from Metro toured the perimeter of the landfill from a canoe. The areas observed included the shoreline along the Columbia Slough and North Slough. The purpose of this boat reconnaissance was to observe the condition of the dike at a time when water levels are normally low. A second reconnaissance was performed on December 12, 1998 by walking along the Columbia Slough, North Slough and Blind Slough shoreline. Photographs taken during these reconnaissances are on file in our office.

2.2. Erosion Assessment

General. In general, the perimeter dike continues to show signs of erosion and slumping. The erosion is a result of the soft, silty embankment soils being scoured by currents, tidal fluctuations and wave action. During the boat tour we observed that the most extensive erosion has occurred at the toe of the dike, below the average high tide waterline. The eroded portion of the slope is quite steep, ranging from near-vertical to approximately 1.5 horizontal to 1 vertical. The eroded toe condition is essentially continuous along the northern and southern sides of the landfill, and also occurs along much of the western side.

Vegetation. Many of the trees and bushes along the shoreline have been undermined by erosion, which has also exposed the root systems. Several of the trees have been severely undercut and are either leaning or have fallen into the slough (see report cover photo). Based on a recent visit to the site at the end of February 1999, it appeared that several trees had fallen into the sloughs since our previous visit in December 1998. In general, we observed that there is very little vegetation growing below the average high tide waterline on the slope (which is roughly elevation 12 feet, City of Portland Datum).

A review of old photographs of the site dating back to the 1950s indicates that there is presently much less vegetation growing along the slough shorelines than had existed previously. There are a number of factors that could contribute to this loss of vegetation, such as animal predation, pollution issues, or human activities (i.e. previous landfill operations, etc.). However, based on our observations over the past several years, shoreline erosion appears to be a significant factor in the loss of vegetation along the slough corridors.

Opposite Shoreline. We observed extensive erosion along the shoreline on the opposite sides of the Columbia Slough and North Slough (i.e. across the waterways from the landfill). The conditions are very similar, including many fallen trees and localized slope failures.

Previously Repaired Areas. The Subarea 1 dike segment repaired with rockfill in 1997 appeared to be in good condition. We did not observe any new signs of scour or slope instability in the treated area. Similarly, we did not observe any significant erosion of the sand benches at the southwest end of the landfill and in the Blind Slough area.

2.3. Overall Stability of Dike

Erosion around St. Johns Landfill has removed the support for the perimeter dike, thereby causing numerous slumps and a few larger slope failures. During our reconnaissance we noted the locations of the most significant slope failures. These areas of concern are discussed in greater detail in Chapter 3 of this report.

The occurrence of minor slumps and slope failures around the landfill perimeter signifies that the overall stability of the dike is marginal at present. Therefore, as the erosion slowly advances, we anticipate that the frequency and magnitude of the slope failures would increase accordingly. If any changes are made that increase the or velocity of flow through the slough channels, the frequency of slope failures would probably increase also due to an increased rate of scour.

3. SLOUGH HYDRAULICS EVALUATION

3.1. Hydraulic Model

The slough hydraulics evaluation was performed by Ogden Beeman & Associates using the existing Portland State University QUALW2 model for the Columbia Slough System. The model provided estimates of maximum flow velocities at key locations around the landfill perimeter. These estimates are maximum projected values based on actual flow data collected from the Columbia Slough over the past nine years. Dr. Scott Wells of Portland State University assisted Ogden Beeman with the coordination of input and output data for the model.

As requested by Metro, the hydraulic analyses were performed for two conditions: (i) existing conditions, and (ii) an open lakes condition, which assumes that the existing dam on the North Slough has been removed. This second condition was modeled to evaluate a possible future scenario, where the dam has been removed and water is free to flow between the North Slough and Smith and Bybee Lakes.

3.2. Channel Sections Analyzed

The maximum flow velocities were calculated for 12 separate slough channel sections around the landfill perimeter using the QUALW2 model. The locations of the sections are shown on Figure 1. These key areas were selected to include: (i) segments of the dike exhibiting more significant erosion or slope failures; (ii) areas likely to have higher flow velocity due to channel geometry (i.e., a tighter cross-sectional area or a constricted bend in the channel); or (iii) areas previously repaired with rockfill or a sand bench. Sections located at the western and eastern limits of the refuse layer in the north perimeter dike were also evaluated to check the scour potential in these areas. Brief descriptions for each of the twelve sections are presented below.

<u>Section 1</u>. Significant erosion occurring at the outfall end of a pipe that extends out into the slough from a sedimentation basin. Observed erosion and minor slumping along the toe of the slope. The eroded/failed toe appears to be working its way upslope and may eventually encroach upon the perimeter gas collection trench (located about 18 feet further upslope).

Section 2. Area located approximately 100 feet west of the bridge, and across the Columbia Slough from a combined sewer outfall. Observed extensive erosion and minor slumping along the toe of the slope, with a 3- to 4-foot vertical face below the average high waterline. The area is moderately vegetated.

Section 3. A failed section of the dike measuring approximately 50 feet in width. The slope failure has removed the outer face of the dike, and left behind an erosional bowl. The headscarp (or uphill edge) of this slide area is located along the outer edge of the gravel road on top of the dike. Based on posted utility signs, it appears that a gas pipeline is buried beneath the outer edge of the road; therefore, the slope failure could be close to undermining the pipeline.

Section 4. Location of the westernmost of two sand benches constructed in 1996 at the southwest end of the landfill.

Section 5. A tall, very steep, and heavily undermined segment of the dike located at the southwest end of the landfill. Observed the outer face of the dike actively slumping in February 1999, and also observed the trace of a headscarp crack near the crest of the slope. The headscarp crack could signify the development of a larger, or more deep-seated, failure within the slope. The eroded face of the slope is encroaching upon the perimeter road. The area is heavily vegetated, with some trees leaning into the slough.

Section 6. A tall, steep, and heavily undermined segment of the dike located within a constricted bend of the Columbia Slough channel. Observed localized slumping along the toe, and a trace of a headscarp crack in the crest of the slope. The area is heavily vegetated, with some large trees leaning into the slough.

Section 7. A constricted bend in the Columbia Slough channel. Observed extensive erosion along the toe of the slope, with a 3- to 4-foot vertical face below the high tide waterline. The area is heavily vegetated. There were no ground cracks or other signs of slope movement.

Section 8. Failed section of dike that was repaired with rockfill materials in 1996.

Section 9. Entrance to the North Slough. Moderate erosion along the toe, and lightly vegetated slope.

Section 10. Western end of the refuse layer within the dike along the North Slough. Observed extensive erosion along the toe, with a near-vertical face below the average high tide waterline. The slope is lightly vegetated.

Section 11. Eastern end of the refuse layer within the dike along the North Slough. Relatively tall and steep slope, with minor slumping and heavy erosion at the toe. The slope is moderately vegetated.

Section 12. Section very near the dam on the North Slough which, in turn, is at the entrance to Smith and Bybee Lakes. The section was analyzed to evaluate the change in maximum flow velocity through this area if the dam was removed.

3.3. Results of Hydraulic Analyses

Existing Conditions – Dam Left In-Place. The maximum calculated flow velocities for each of the 12 sections are summarized in Table 1 below. It should be noted that the highest calculated velocities occur at the locations where dike failures occurred previously (Sections 4 and 8). This relationship indicates that there is a correlation between the occurrence of dike stability problems and slough flow velocity (i.e., higher velocity results in more scour and, therefore, greater impact to stability).

Dam Removed. The maximum calculated flow velocities for the 12 sections with the dam removed are also summarized in Table 1 below.

Table 1
Maximum Calculated Flow Velocities

Section	Existing Conditions Maximum Velocity (feet/second)	Dam Removed Maximum Velocity (feet/second)
1	3.68	2.89
2	3.81	3.10
3	3.66	3.04
4	3.82	3.22
5	3.04	2.82
6	2.89	3.21
7	3.61	4.54
8	3.90	7.22
9	1.88	4.00
10	1.18	4.84
11	1.35	5.94
12	1.37	7.53

N. Slough

Differences Between Analyses. A comparison between the two analyses suggests that the removal of the dam on the North Slough would have a significant impact on the flow velocities around the landfill. Removing the dam would result in large increases along the northern and northwest sides, and a slight decrease along the southern and southwest sides. The increase in maximum velocity along the North Slough would be particularly dramatic (see Sections 8 through 12), which would likely result in significant increases of the rate of scour.

Scour Potential. During our previous investigations of the site (discussed in Chapter 1), we determined that most of the soil along the perimeter dike consists of slightly clayey, fine sandy silt, to silty fine sand. Overall, soils consisting of fine sand and cohesionless silt have the highest susceptibility to scour[1]. Studies by Hjulstrom in 1935 found that for silt and fine

[1]Graf, W. H., 1984, Hydraulics and Sediment Transport, p. 88.

sand-sized soil particles, the probable channel flow velocity for incipient erosion is approximately 1½ ft./sec.[1] As indicated above, removing the dam would increase the maximum velocity along the North Slough from just over 1 ft./sec. to more than 4 ft./sec. Therefore, removing the dam would probably cause a significant increase in the rate of scour along the North Slough unless other steps were taken to reduce the flow velocity. This high rate of scour would continue until the channel enlarged sufficiently to convey the increased flow.

[1]Graf, p. 88.

4. PRIORITY REPAIR AREAS

4.1. General

Erosion around the toe of the perimeter dike of the landfill has been quite extensive. Therefore, the effort and cost to reconstruct the toe and provide erosion control measures around the entire site would be very high. In our opinion, the perimeter dike could be repaired following a staged approach. We recommend repairing the higher priority areas initially, and then observing conditions in less critical areas and treating problems as they occur or as budgeting allows. The priority areas would include dike sections that: (i) are actively failing; (ii) are in close proximity to refuse, pipelines, access roads, or other landfill facilities; (iii) have a higher scour potential (i.e., are subjected to higher channel flow velocities); or (iv) have little existing vegetation to help support the slope.

As mentioned previously, the removal of the dam on the North Slough would affect the slough flow velocity (and rate of scour) around the site, especially along the North Slough. For this reason, the priority repair areas would be different for the existing condition versus the dam-removed condition. Our recommended priority repair areas for both conditions are discussed below.

4.2. Waste Cutoff Issues

As part of the concurrent waste cutoff study, we determined that the most practical methods for constructing an impermeable barrier would include excavating a trench along the levee alignment, and then backfilling the trench with a low-permeable material (soil, soil-bentonite slurry, cement-bentonite slurry, etc.). We performed a slope stability evaluation which indicated that the trench excavation and backfill work could temporarily destabilize the dike. Therefore, to mitigate the impact of the waste cutoff construction, we recommend that the dike stabilization work be performed first. On this basis, the stabilization of the dike segment between Sections 10 and 11 on Figure 1 would become a higher priority, regardless of whether the dam is left in-place or removed.

4.3. Priority Areas – Existing Condition (Dam Left In-Place)

Assuming the North Slough dam would not be removed, our recommended priority areas include Section 3, Section 5, and the dike segment between Sections 10 and 11. Reasons for this priority ranking are presented below.

Section 3 is critical because the slope failure has already progressed to the edge of the perimeter access road, and is very close to exposing a gas pipeline. The situation at Section 5 is critical because the slope is actively sliding and the failure appears to be relatively deep-seated. If left untreated, there is a possibility that this segment of the dike could fail catastrophically, which could drop a significant quantity of soil into the Columbia Slough. Furthermore, a large failure at Section 5 would probably impact the perimeter road. As discussed in Section 4.2, stabilization of the segment between Sections 10 and 11 is critical in order to construct a waste cutoff barrier.

The medium priority areas include Sections 1, 2, 6, 7 and another small section of eroded shoreline located a short distance east of Section 11 (discussed below). We recommend that Section 6 be watched very closely, because the dike is tall and very steep in this area. We observed a trace of a headscarp crack at the crest of the slope at Section 6, which suggests that a fairly deep-seated slope failure may be forming.

Approximately 1,000 feet east of Section 11 is a very small (less than about 30 feet in width) section of failed shoreline. At this location, the landfill dike consists of an engineered embankment that was constructed over a natural berm of native soils. The failed section of shoreline has extended through the berm of native soil and progressed to near the toe of the overlying engineered dike. We did not observe any signs of slope instability in the engineered dike; therefore, the situation does not appear to be critical at present. However, it is likely that the failure will grow in size over time. Due to the present small size of the failure and its proximity to the priority repair area between Sections 10 and 11, it would be simple and economical to repair it at the same time. Therefore, we recommend that Metro consider repairing the area along the with the higher priority areas.

4.4. Priority Areas – Dam Removed

As discussed in Chapter 3, removing the dam would probably cause an increase in the rate of scour along the North Slough shoreline due to an increase in flow velocity. On this basis, it would be necessary to treat the entire length of landfill dike through the North Slough to prevent scour-related slope failures (approximately 4,600 feet of shoreline). A conceptual treatment method for repairing the dike and protecting it from additional scour is presented in Chapter 5.

The increased rate of scour would likely affect the natural dike along the northern shoreline of the North Slough also. This scour would gradually remove vegetation and habitat from a small portion of the Smith and Bybee Lakes wildlife management area. If this loss was considered unacceptable, it would become necessary to treat the northern shoreline to prevent scour there also (approximately 4,600 feet). If needed, the conceptual treatment method discussed in Chapter 5 could be applied to the northern shoreline of the North Slough also.

Aside from the North Slough area, the other priority treatment areas would remain the same as the existing condition where the dam remains in-place. We recommend that Sections 3 and 5 be stabilized for the same reasons discussed above, and the medium priority areas be watched closely.

Flow Velocity Reduction Alternatives. As an alternative to treating the entire North Slough shoreline to prevent scour, the scour potential could be minimized by implementing other methods to offset the increase in flow velocity caused by the dam removal. Some alternatives include: dredging or widening the channel; installing wing wall structures into the channel; constructing weirs across the slough; creating new breaches between the North Slough and adjacent lakes; or replacing the existing dam with a new structure capable of regulating flows during seasonal flood periods. An evaluation of flow velocity reduction methods is beyond the scope of this study. However, as requested by Metro, our design team is preparing a separate proposal to provide this service.

5. CONCEPTUAL DIKE REPAIR METHODS

5.1. General

The primary goals of the dike repair method would be to: (1) stabilize the slope and provide erosion protection; (2) avoid or minimize impacts to water quality, wetlands, fish and wildlife habitat; and (3) provide enhanced ecological functions and values within the Smith and Bybee Lakes/Columbia Slough Management Area. Our recommended repair method incorporates these goals. Since the primary function of the dike is to prevent refuse from entering the slough, we have assumed that the overriding criteria in the design is to provide for the long-term structural stability of the dike.

5.2. Conceptual Repair Methods

Traditional Methods. We considered several traditional shoreline stabilization methods for the dike, including methods commonly used by the U. S. Army Corps of Engineers. Some of these methods include:

- reconstructing the slope with rockfill and armoring it with riprap;
- constructing gabions (wire baskets infilled with rock pieces) along the shoreline;
- sheet pile bulkheads or other types of retaining walls; and
- armoring the slope with Reno mats (concrete blocks interconnected by a cable) or similar commercially available products.

These traditional methods are very useful for stabilizing the shoreline and preventing erosion. However, the major drawbacks to these methods are that they would likely produce an adverse impact on the existing fish and wildlife resources, and they would not meet the goals of the Smith and Bybee Lakes Wildlife Management Plan. Furthermore, they are generally not considered aesthetically pleasing.

In addition to the drawbacks listed above, gabions and sheet pile walls would not be practical at this site because: (i) the soft sediments along the shoreline could not safely support the load from a gabion structure; and (ii) sheet piles would have to be driven to a great depth through the soft sediments (to develop the support needed to withstand the lateral earth pressures from the dike).

Biotechnical Methods. Due to the importance of preserving fish and wildlife habitat, biotechnical techniques have been developed in recent years which incorporate vegetation into a slope stabilization repair. Biotechnical methods typically involve planting willows, grasses and other vegetation on a slope face which has been reinforced with logs, coconut fiber mats or some other biodegradable product. This vegetation serves several purposes: (i) it improves the appearance of the slope; (ii) it provides wildlife habitat; and (iii) the root systems help reinforce the slope and reduce erosion. The vegetation could be particularly useful on repaired dike sections around St. Johns Landfill, because leachate discharge through the dike would receive some biochemical treatment by the root systems and associated micro-organisms. This biochemical treatment would help maintain water quality around the site.

The limitations and potential drawbacks of biotechnical methods are: (i) it could take a few growing seasons for the plants to become well-established; (ii) inundation from seasonal and tidal fluctuations in the slough would prevent vegetation from becoming established on the lower portion of the dike; (iii) the plants are subject to predation; and (iv) the slope would lose internal support as the logs or fiber reinforcement mats deteriorate. Therefore, additional scour or slope stability problems may result if the vegetation does not survive for some reason or when the reinforcement decays.

Combined Methods. The traditional and biotechnical methods can be combined to create a stabilization technique that takes advantage of the strengths of both methods. For example, a traditional riprap slope could be constructed up to a selected elevation on the dike face to protect against heavy currents and wave action, and the upper portion of the slope could be completed with a biotechnical method to improve aesthetics and provide habitat.

This combined method approach has been used recently by the Port of Portland on slope failures at Terminals T5 and T6 along the Willamette River. Members of our design team and representatives from Metro toured these facilities on April 2, 1999. The Port successfully repaired the failed slopes by placing rockfill overlain by riprap up to a selected flood stage level, and then completing the upper part of the slope with lifts of compacted sand reinforced by plastic geogrids. (This process of reinforcing a soil slope with a geogrid is commonly referred to as "mechanically stabilized earth," or MSE.) The geogrid reinforcement has an openwork pattern; therefore, vegetation can grow through it. The upper part of the slope was then covered by a thin layer of topsoil, and was later planted with bushes and trees, and hydroseeded with native grasses. It is our understanding that permitting for the Port of Portland's work took four to six months.

5.3. Recommended Dike Repair Method

General. Based on the foregoing, we recommend stabilizing the priority sections of the dike at St. Johns Landfill using a combined method consisting of: (a) rockfill armored with riprap on the lower portion; and (b) a vegetated MSE slope on the upper portion. In our opinion, this method would provide the erosion protection and long-term stability required for the dike, while providing superior aesthetics, water quality and habitat values over a traditional method.

Transition Elevation – Riprap to Vegetated MSE. A key factor in the slope repair design would be to determine a suitable elevation to transition between riprap to the vegetated MSE. As discussed previously, vegetation does not appear to survive along the shoreline below about elevation 12 feet (approximation based on visual estimates). Therefore, elevation 12 feet may be the lowest practical limit for the MSE section. Information from the hydraulic analyses suggests that a transition near elevation 12 feet to elevation 15 feet would provide for riprap protection during the maximum flow velocity events discussed in Chapter 3. However, it is common for slough stage levels to exceed elevation 12 by several feet during winter floods and spring snow-melt periods. Therefore, until the plants become well established, there could be a risk of losing soil and vegetation from the MSE slope during these high water periods. Metro would need to evaluate this risk versus the desire to maximize the vegetated surface area on the dike.

For the purposes of this report, we have assumed that the riprap/MSE transition would occur at elevation 12 feet. In the next phase of this project, we intend to coordinate with Metro on taking actual survey measurements of the vegetation growth elevation at various locations around the landfill dike. Measuring this elevation would help to define a suitable transition elevation from riprap to MSE.

Recommended Repair Method. Metro performed cross-section surveys in January and February 1999 for several of the 12 sections analyzed in the hydraulic evaluation. Included among the surveyed sections were Sections 3, 5 and 10, which are representative of the priority treatment areas discussed in Chapter 4. Our recommended method for reconstructing the dike at each of these high priority cross-sections is shown on Figure 2. More specific details for the procedure are given below:

1. While slough stage levels are low in late summer, use a crane with a clam shell or dragline to excavate all water-softened debris, fallen trees and roots from the treatment areas. At the toe of the slope, excavate an 8-foot bench to support the rock materials. The contractor would be required to use great caution when excavating debris at Section 3 to avoid disturbing or damaging the gas pipeline.

2. Place and tamp a 1-foot layer of crushed rock against the base of the bench and the slope immediately above it (Fig. 2) to provide a filter layer which would prevent internal erosion. The filter material should consist of clean, well-graded, 1½-inch minus crushed rock.

3. Complete the lower portion of the slope by placing an intermediate rockfill layer on top of the gravel filter layer, and then armoring the outer face of the slope with a 2-foot layer of riprap. Recommended slope: 1.75H:1V. Tamp the rockfill and riprap materials firmly into place with the clam shell bucket. The rockfill should be well-graded from 4 inches to the U. S. No. 4 sieve. The riprap should be well graded between 12 inches and 3 inches.

   We should note that the filter, rockfill and riprap sizes have been carefully selected to: (i) prevent internal erosion of the dike soils through the rock particles; (ii) provide for stability of the dike; and (iii) prevent scour from the water in the slough channel. Each of these materials plays a critical role in the design; therefore, they should not be altered. However, isolated boulders, logs, or wooden crib structures could be placed on the surface of the riprap slope to further improve aesthetics and habitat qualities.

4. At the transition elevation (shown at elevation 12 feet on Fig. 2), place a non-woven geotextile to separate the lower rockfill portion from the upper MSE portion of the reconstructed slope.

5. Construct the MSE slope by wrapping geogrids and tufted erosion control mats over 2-foot layers of compacted soil as shown on Figure 3. At the outer face of the slope, include a 1-foot layer of topsoil inside of the geogrid and tufted erosion control mat to provide a growing medium for plants. The purpose of the tufted erosion control mat would be to help prevent the topsoil from eroding until the vegetation becomes established. Repeat the process, and continue the slope upward at 1.75H:1V.

   In MSE applications the compacted soil typically consists of clean, free-draining sand to prevent pore water pressure buildup in the slope. However, the free-draining soil could allow drought conditions to develop during the summer months, which would make it difficult for the vegetation to survive. Therefore, during the final design phase of the project, we will evaluate the feasibility of different soil/geogrid combinations which may allow the use of a siltier soil in the MSE slope.

6. Plant native bushes and trees as appropriate for the season, and then seed the MSE slope with native grasses. If necessary, return to the site during the other seasons to install additional native plants. In addition to the vegetation on the MSE slope, the riprap could be joint-planted with willows to help improve the look and habitat of the riprap portion of the dike. An idealized cross-section of the vegetated slope is shown on Figure 4. Specific species of suitable vegetation are discussed below.

5.4. Vegetation

Mr. George Kral (vegetation specialist) has had significant prior experience planting native vegetation at St. Johns Landfill and the Columbia Slough area. Based on this prior experience, our preliminary recommendations for vegetation on the dike treatment area would include the following plant species:

Zone 1: Elevation 12 feet to 17 feet

Total plants per 10 feet of treated dike:	Trees (7-foot centers)	2
	Willow (2-foot centers)	25
	Shrubs (4-foot centers)	6.3

Species	Common Name	Plant Category
Fraxinus latifolia	Oregon ash	Tree
Salix piperi	Piper's willow	Willow
Salix sitchensis	Sitka willow	Willow
Salix rigida	Heart-leaved willow	Willow
Cornus stolonifera	Red-twig dogwood	Shrub
Spiraea douglasii	Douglas' spiraea	Shrub

Zone 2: Elevation 17^{+} feet

Total plants per 10 feet of treated dike:	Trees (7-foot centers)	2
	Shrubs (2.5-foot centers)	16

Species	Common Name	Plant Category
Fraxinus latifolia	Oregon ash	Tree
Rosa nutkana	Nutka rose	Shrub
Rosa pisocarpa	Swamp rose	Shrub
Symphoriocarpus alba	Snowberry	Shrub
Cornus stolonifera	Red-twig dogwood	Shrub
Sambucus racemosa	Red elderberry	Shrub
Oemleria cerasiformis	Indian plum	Shrub

Grass Seed (in order of application from bottom to top of MSE slope)

Application rate: 0.8 pounds per 10 feet of treated dike

Species	Common Name
Bidens cernua	Nodding beggar tick
Eleocharis palustris	Common spike rush
Carex aperta	Columbia sedge
Leersia oryzoides	Rice cutgrass
Alopecurus geniculatus	Water foxtail
Hordeum brachyantherum	Meadow barley
Elymus glaucus	Blue wildrye
Bromus sitchensis	Sitka brome (California brome)

5.5. Permitting

The proposed dike stabilization project will require permits from local, state and federal authorities, as discussed below.

Local Land Use Review. The City of Portland's land use review for the proposed dike stabilization project is expected to be reviewed against the Smith and Bybee Lakes Natural Resources Management Plan. We anticipate that the project will be found to be consistent with Minor Exception h (page 68) of the Plan.

The stabilization project may also be reviewed under the City of Portland compliance mechanism with Metro Title 3: Water Quality, Flood Management and Fish and Wildlife Conservation. This City of Portland mechanism is not yet in place; however, it could be in effect when the project documents are submitted. The proposed stabilization project may not be subject to the flood management performance standards of Title 3, as described in Title 3 Section 4A3b. The water quality performance standards of Title 3 would probably be met by the recommended repair method. However, it is unclear at this point how the Water Quality Resource Areas buffer requirements will be applied to the St. Johns Landfill.

Oregon Removal/Fill Law. An application will need to be submitted to the Oregon Division of State Lands (ODSL) for a removal/fill permit. The ODSL will determine whether the project needs an individual permit, or is to be covered under an existing General Authorization, such as the one for erosion control projects. We believe that the dike stabilization project would not be covered by the General Authorization because of the extent of fill required. An individual permit through ODSL would require at least two to three months following submission of a complete application. We believe that ODSL generally prefers shoreline designs that utilize biotechnical techniques in order to preserve habitat values; therefore, we do not expect any mitigation requirements.

Clean Water Act Sections 401 and 404: Rivers and Harbors Act Section 10. An application will need to be submitted to the U. S. Army Corps of Engineers (USACE) for authorization to place fill material in waters of the United States and to place structures in navigable waters. The USACE determines if the project would require an individual permit, or whether it can be authorized under Nationwide Permit 13, Bank Stabilization. Water quality certification under CWA Section 401 would be reviewed by the Oregon Department of Environmental Quality (ODEQ). No mitigation requirement is anticipated for this project; however, we anticipate that the USACE and possibly ODEQ would require any design to incorporate plantings for fish and wildlife habitat. The project will require consultation with the National Marine Fisheries Service (NMFS) in regard to Endangered Species Act listed fish in the lower Willamette River. We feel that it would be preferable to conduct this consultation under the informal, rather than formal procedure. We anticipate that the NMFS would prefer to see maximum use of vegetation associated with the project design.

6. CONCEPTUAL COSTS

6.1. Conceptual Costs

The conceptual costs presented below are based on quantity calculations derived from limited survey data. The conceptual costs include the contractor's mobilization, profit and overhead. The conceptual costs do not include engineering design, permitting, administrative or quality control costs. Actual construction bids would depend on many factors such as environmental and permitting restrictions, level of competition between contractors, time of year, etc. Values shown are in 1999 dollars.

Estimated Unit Rates. The estimated unit rates for the rockfill/riprap portion and the MSE portion of the dike (with vegetation) are presented below.

- Rockfill/Riprap: $18 to $21 per square foot of slope face
- MSE with vegetation: $14 to $17 per square foot of slope face

Conceptual Cost – Existing Conditions (Dam Left In-Place). With the dam remaining in-place, the estimated costs to treat the three priority areas are:

- Section 3: $27,000 to $32,000
- Section 5: $60,000 to $75,000
- Sections 10 to 11: $560,000 to $690,000

Conceptual Cost – Dam Removed. Removing the dam would not affect the cost of treating Sections 3 and 5; therefore, the conceptual costs for these areas would be as indicated above.

- Section 3: $27,000 to $32,000
- Section 5: $60,000 to $75,000

As discussed in Chapter 4, Metro has requested that we submit a proposal to evaluate various options for reducing flow velocity in the North Slough. Cost estimates for velocity reduction methods would be presented in a separate study.

For the purposes of this study, we have evaluated conceptual costs for one viable shoreline stabilization option. Our conceptual cost estimate for treating the entire 9,200 feet of the North Slough shoreline (i.e. both the southern side and, if considered necessary, the northern side) is presented below. Treating the northern shoreline of the North Slough would also require the construction of an access road for equipment, at an estimated cost of $500,000.

- St. Johns Landfill Side of North Slough: $2,500,000 to $3,000,000
- North Shoreline of North Slough (with access road) $3,000,000 to $3,500,000

Shoreline Repair Total: $5,500,000 to $6,500,000

CORNFORTH CONSULTANTS, INC.

By__________
Michael R. Meyer, P.E.
Associate Engineer

REGISTERED PROFESSIONAL ENGINEER 15,644
OREGON SEPT. 17, 1991
MICHAEL R. MEYER

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OREGON AUG. 22, 1975
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Karl Krcma, P.E.
Vice President

REGISTERED PROFESSIONAL ENGINEER 13,269
OREGON JULY 17, 1986
KARL KRCMA

Limitations in the Use and Interpretation of This Geotechnical Report

Our professional services were performed, our findings obtained, and our recommendations prepared in accordance with generally accepted engineering principles and practices. This warranty is in lieu of all other warranties, either expressed or implied.

The geotechnical report was prepared for the use of the Owner in the design of the subject facility and should be made available to potential contractors and/or the Contractor for information on factual data only. This report should not be used for contractual purposes as a warranty of interpreted subsurface conditions such as those indicated by the interpretive boring and test pit logs, cross-sections, or discussion of subsurface conditions contained herein.

The analyses, conclusions and recommendations contained in the report are based on site conditions as they presently exist and assume that the exploratory borings, test pits, and/or probes are representative of the subsurface conditions of the site. If, during construction, subsurface conditions are found which are significantly different from those observed in the exploratory borings and test pits, or assumed to exist in the excavations, we should be advised at once so that we can review these conditions and reconsider our recommendations where necessary. If there is a substantial lapse of time between the submission of this report and the start of work at the site, or if conditions have changed due to natural causes or construction operations at or adjacent to the site, this report should be reviewed to determine the applicability of the conclusions and recommendations considering the changed conditions and time lapse.

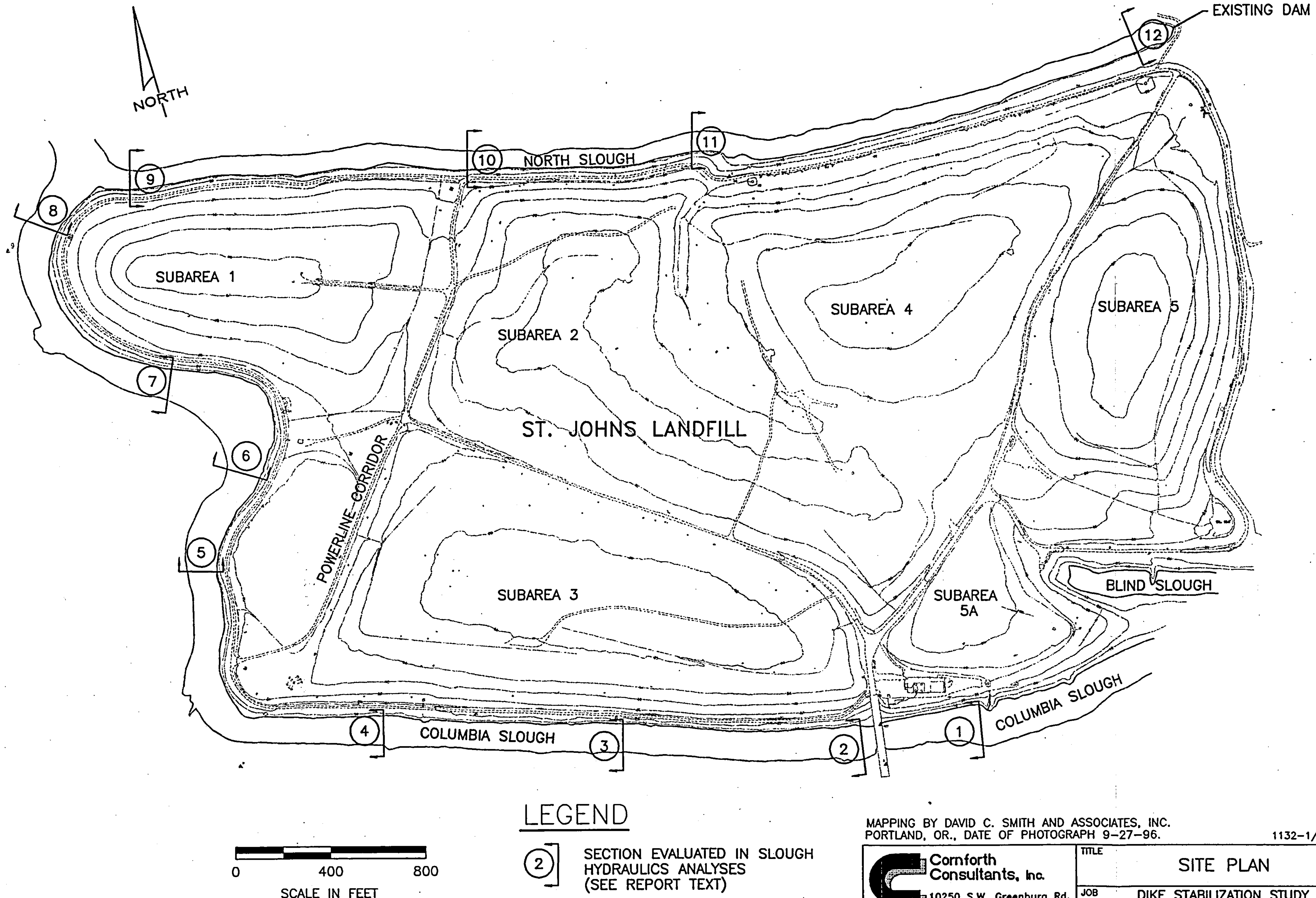
The Summary Boring Logs are our opinion of the subsurface conditions revealed by periodic sampling of the ground as the borings progressed. The soil descriptions and interfaces between strata are interpretive and actual changes may be gradual.

The boring logs and related information depict subsurface conditions only at these specific locations and at the particular time designated on the logs. Soil conditions at other locations may differ from conditions occurring at these boring locations. Also, the passage of time may result in a change in the soil conditions at these boring locations.

Groundwater levels often vary seasonally. Groundwater levels reported on the boring logs or in the body of the report are factual data only for the dates shown.

Unanticipated soil conditions are commonly encountered on construction sites and cannot be fully anticipated by merely taking soil samples, borings or test pits. Such unexpected conditions frequently require that additional expenditures be made to attain a properly constructed project. It is recommended that the Owner consider providing a contingency fund to accommodate such potential extra costs.

This firm cannot be responsible for any deviation from the intent of this report including, but not restricted to, any changes to the scheduled time of construction, the nature of the project or the specific construction methods or means indicated in this report; nor can our firm be responsible for any construction activity on sites other than the specific site referred to in this report.



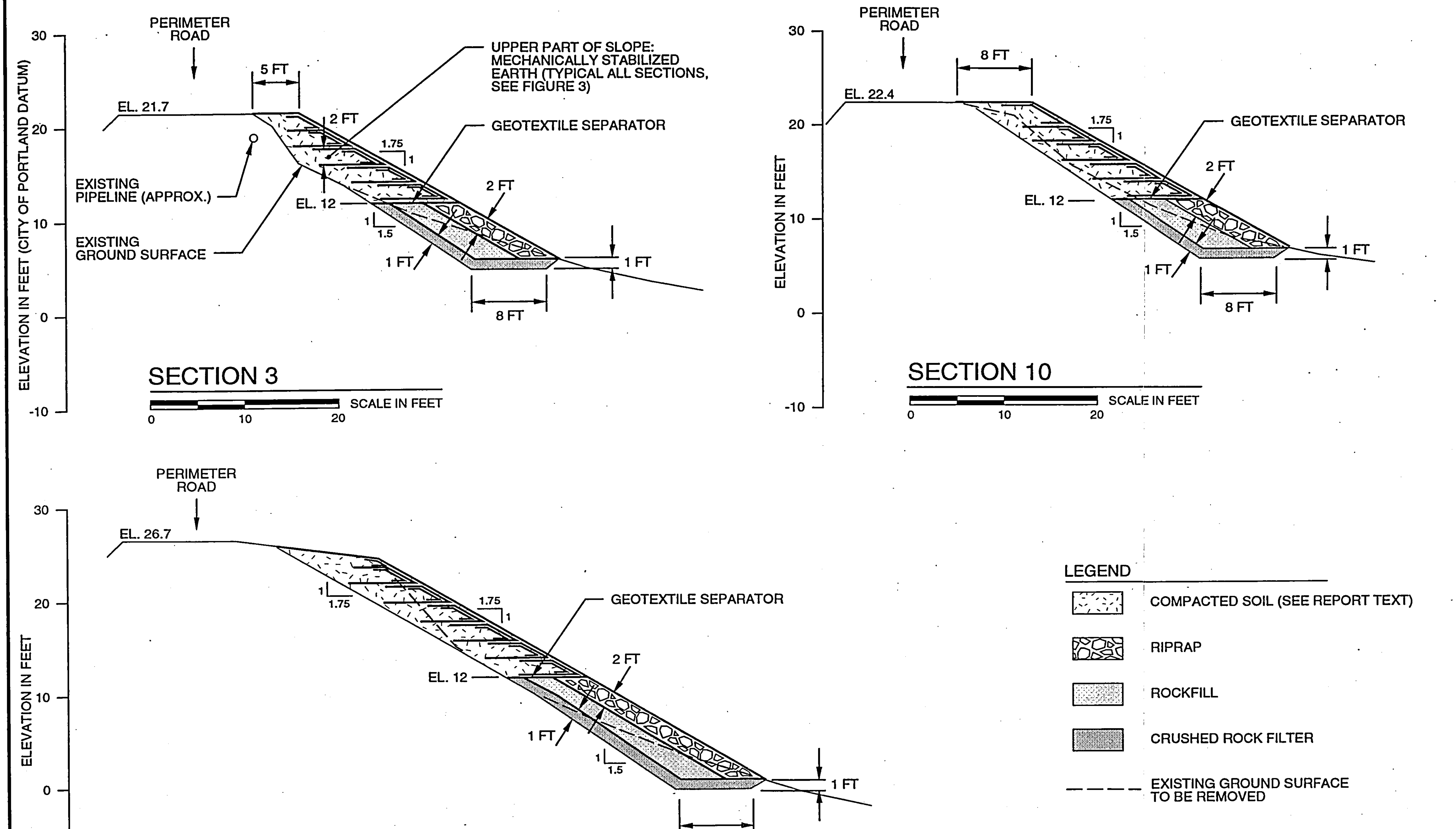
LEGEND

(2) SECTION EVALUATED IN SLOUGH HYDRAULICS ANALYSES (SEE REPORT TEXT)

MAPPING BY DAVID C. SMITH AND ASSOCIATES, INC.
PORTLAND, OR., DATE OF PHOTOGRAPH 9-27-96.

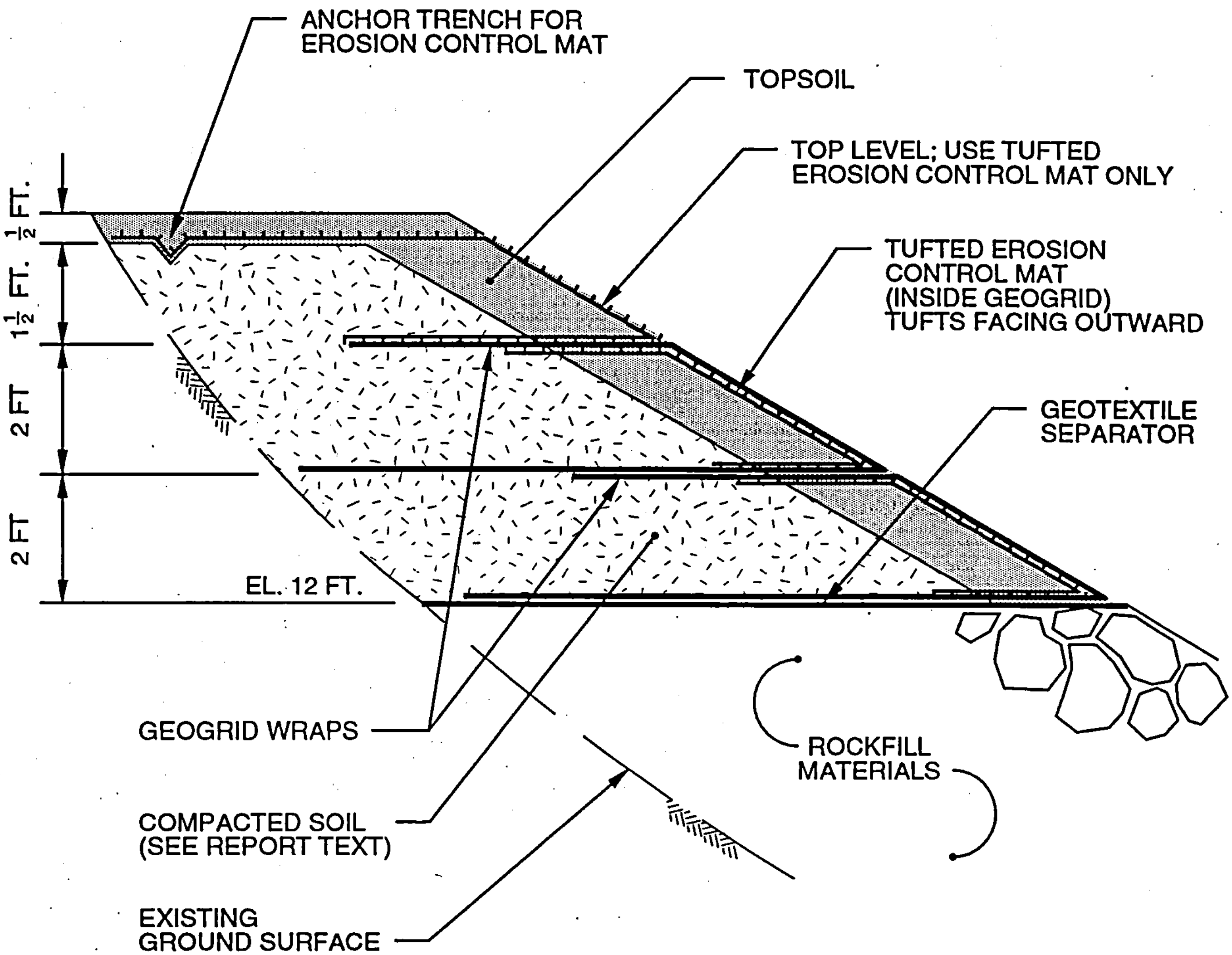
1132-1/SITEPLN2/1:400/MPL

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE: SITE PLAN	DATE: JUN 1999 / JOB NO. 1132-1
	JOB: DIKE STABILIZATION STUDY ST. JOHNS LANDFILL	FIG. 1



M1132-01\FIGURE02

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE CROSS SECTIONS – CONCEPTUAL TREATMENT METHOD	DATE JUN 1999
		JOB NO. 1132-1
	JOB DIKE STABILIZATION STUDY ST. JOHNS LANDFILL	FIG. 2

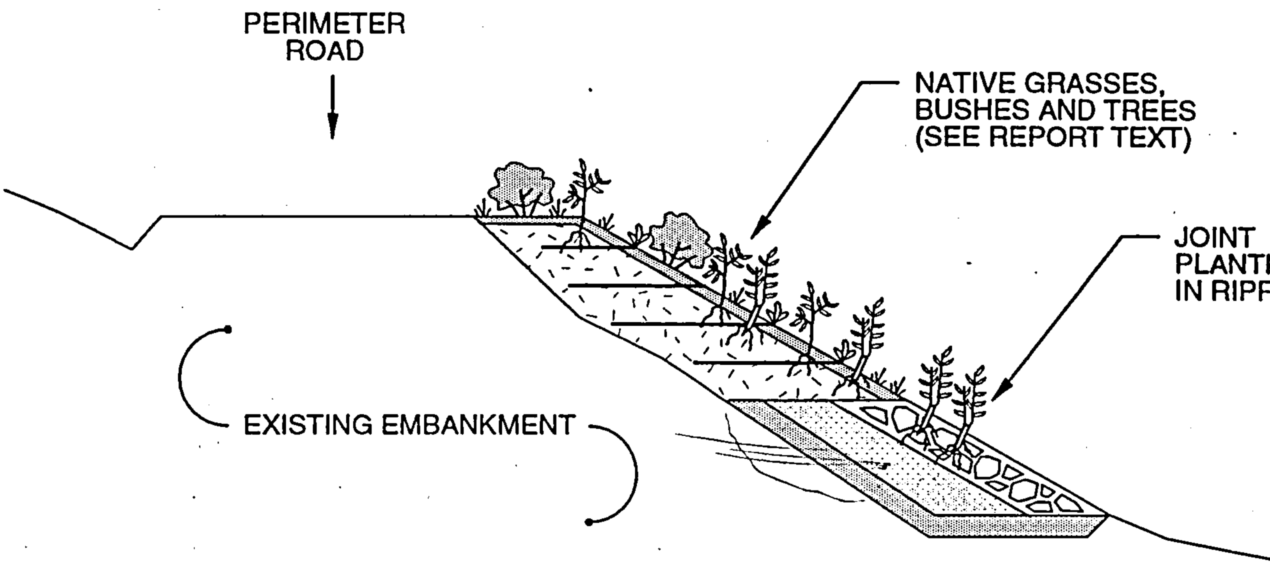


NOT TO SCALE

NOTE: FOLLOWING CONSTRUCTION – PLANT NATIVE TREES AND BUSHES AND HYDROSEED GROUND SURFACE (SEE FIGURE 4)

M1132-01\FIGURE03 LJW

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE LAYOUT FOR MECHANICALLY STABILIZED EARTH	DATE JUN 1999
		JOB NO. 1132-1
	JOB DIKE STABILIZATION STUDY ST. JOHNS LANDFILL	FIG. 3



M1132-01\FIGURE04 LJW

Cornforth Consultants, Inc. 10250 S.W. Greenburg Rd. Portland, OR 97223	TITLE IDEALIZED CROSS SECTION AFTER PLANTING	DATE JUN 1999
		JOB NO. 1132-1
	JOB DIKE STABILIZATION STUDY ST. JOHNS LANDFILL	FIG. 4