Montlake Landfill
Information Summary

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The Montlake Landfill Work Group

By Members Of

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Washington State Department of Health
University of Washington

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Executive Summary

In response to community concerns regarding east campus development and the former site of the Montlake landfill, the University formed a multi-agency work group to investigate the environmental and public health concerns related to this site. The University of Washington's Environmental Health and Safety Department (EH&S) facilitated this work group, which examined in depth all available information relevant to the landfill operations.

Questions

The following questions, raised primarily by the Laurelhurst community, became the focus of the investigation:

A. Is the weight of the landfill moving peat and garbage into Union Bay?
B. Is the leachate from the landfill contributing to the Eurasian water milfoil problem?
C. Is the leachate from the landfill degrading Union Bay's water quality?
D. How would an earthquake affect the Montlake landfill?
E. Is gas escaping from the landfill?
F. Was the landfill closed according to regulations in effect at the time?
G. Has the landfill caused the depth of Union Bay to change?

Findings

The findings of the effort include:

1. Beginning in 1959, dikes were placed around and within the landfill to stop lateral movement into Union Bay. Since that time, no evidence has been found to suggest the weight of the landfill has caused any significant lateral movement of peat or garbage into the bay.

2. Once milfoil is established, as in Union Bay, nutrients added to the bay from urban storm water runoff and landfill leachate do not influence the colonization or growth rate of milfoil.

3. The water quality data obtained to date, shown in Table 4, when compared to State Water Quality Standards (WAC 173-201A), show high levels of lead, silver, pH and fecal coliform. There is no evidence at this time to link these occurrences to the landfill leachate.

4. During a major earthquake, liquefaction may occur within the boundary of the landfill. Structures built on the landfill on pilings, reaching below the peat layer, should not be affected.

5. Methane gas is escaping from the landfill area, but in such small quantities that it does not pose a health concern or combustion hazard.

6. The landfill was closed according to the guidance available at the time.

7. The depth changes occurring in Union Bay can be attributed to the measured rate of natural sedimentation in this area.

Recommendations

After reviewing these results, the following recommendations were made by the work group:

1. Long-Term Testing or Monitoring

    a. Aerial photos of the Montlake landfill should continue to be taken biennially by Facilities Services to monitor University property abutting the Union Bay shoreline. Stereo-pair aerial photos should be taken twice to measure land settlement at 5-year increments, in 2003 and 2008, and then their need should be reevaluated. The aerial photos should be analyzed by the Center of Urban Horticulture, and any unusual or significant observation should be reported to the Director of the Environmental Health and Safety Department.

    b. The University should participate, with appropriate agencies, such as the Seattle-King County Department of Public Health and the Washington State Department of Ecology, in the development of a plan to determine any future impacts of the landfill on surface water quality in Union Bay.

    c. A plan should be developed and implemented by Facilities Services and the Environmental Health and Safety Department, with input from Capital Projects, to assure that a long-term monitoring program is in place for tracking both settlement points and methane, with methane mitigation being part of standard procedures at the site. Such requirements should be incorporated into the Facilities Design Information (FDI) Manual, East Campus Plan, and appropriate planning documents.

2. Clean-Up Activities

    a. Since federal, state and local agencies have assessed the site and found that it presents no apparent environmental or public health hazard requiring additional closure activities, and based on the data obtained to date, there is no evidence to suggest that it is necessary to make any physical changes or undertake clean-up activities at the Montlake landfill site at this time.

3. Policies and Guidelines for Future Use of the Site

    a. Engineering Services, the Environmental Health and Safety Department, and the Capital Projects Office should develop and implement an operational policy and management plan regarding grades at the landfill site that recognizes the dynamics of the landfill, and its maintenance requirements. This should be incorporated into the FDI Manual and appropriate planning documents.

    b. The Capital Projects Office and Engineering Services, with input from the Center for Urban Horticulture and the Environmental Health and Safety Department, should develop and implement guidelines for construction on the Montlake landfill site. This should be incorporated into the FDI Manual.

4. Other Recommendations

   a. The University, upon invitation from the Washington State Department of Ecology (Ecology), should participate in Ecology's planning activities regarding sediment quality in Union and Portage Bays.

   b. The University Real Estate Office, Center of Urban Horticulture, and Facilities Services should monitor implementation of the Ravenna Creek Daylighting Project and assure that the landfill site is adequately protected.

   c. The University Relations Office and the Environmental Health and Safety Department should be added to the mailing list for information regarding city and county activities, regarding the regional waste water service plan and storm water issues.

   d. In conjunction with state-wide storm water management planning, the University Engineering Services should participate in the development of a storm water management plan for developed portions on the landfill site.

   e. A committee should be formed by the Executive Vice President of the University to provide administrative oversight of future landfill activities, track on-going development, and respond to public requests for information regarding the landfill. The committee should include a representative from the following University departments or units: Capital Projects, Center for Urban Horticulture, Intercollegiate Athletics, Engineering Services, Environmental Health and Safety, Facilities Services, Recreational Sports Programs, and Transportation Services. Furthermore, the Attorney General's office should designate an ex-officio member to serve the committee. Because of the added value in working with regulatory agencies on this project, the following agencies should be requested to send ad-hoc members: Seattle-King County Department of Public Health, Seattle Public Utilities, Washington State Department of Ecology, and Washington State Department of Health.

   f. Annual training should be provided for the Environmental Health and Safety Department, Facilities Services, and the Capital Projects Office regarding landfill evolvement.

   g. The University should continue to gather baseline data on the depth of Union Bay extending at least 500 feet into the Bay from the University's shoreline.

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I. Introduction

As a result of concerns expressed by some members of the Laurelhurst community in Seattle[31], the University of Washington's Environmental Health and Safety Department assembled a multi-agency work group to examine the Montlake Municipal Landfill's current public health and environmental impacts on the community shoreline and Lake Washington's Union Bay. This work group was comprised of personnel having knowledge of this landfill or other landfills of similar age.

Concerns

The neighbors posed the following questions for the University's consideration:

A. Is the weight of the landfill cover moving peat and garbage into Union Bay?
B. Is the leachate from the landfill contributing to the Eurasian water milfoil problem?
C. Is the leachate from the landfill degrading Union Bay's water quality?
D. How would an earthquake affect the Montlake landfill?
E. Is gas escaping from the landfill?
F. Was the landfill closed according to regulations in effect at the time?
G. Has the landfill caused the depth of Union Bay to change?

Process

The work group met for the first time on August 12, 1997, to help EH&S obtain a broad perspective of the landfill's history, closure, and applicable regulations and to determine what, if any, further actions were necessary. During this meeting, EH&S discovered that each department representative had information concerning the landfill. It was concluded that all of the studies completed to date would be reviewed, and a report would be produced that could address the neighbors' specific concerns. The members of the work group reviewed existing data in-depth, interviewed individuals who had knowledge of the operation of the site, and met to review and discuss the findings until work group members were satisfied that what could be found and known regarding the site had been adequately explored. The findings were compiled in one summary document. This report is the result of that effort.

II. The Union Bay Area

Historical Perspective

Over the past 130 years, Lake Washington has been changed from a "wild" lake in a wilderness setting to a regulated lake surrounded by a growing metropolis. Prior to 1911, the east campus of the University of Washington was submerged. The Union Bay shoreline bordered directly adjacent to Husky Stadium, covering the present site of the Intramural Activities Building and paralleling Montlake Boulevard on the west. To the north, it extended across N.E. 45th into the present site of University Village and roughly paralleled Union Bay Place N.E., N.E. 41st and Surber Drive on the east. The University owns most of this area up to N.E. 45th to the North and to the inner harbor line to the East. Figures 1 and 2 are Kroll maps showing the University's present property boundaries.

The construction of the Lake Washington Ship Canal was the most important human factor to impact the lake and its shore lands.[1] Upon completion of the canal and the Hiram M. Chittenden locks at Ballard in 1916, the surface of Lake Washington was lowered 2.7 meters, at high water, and drainage of Lake Washington was changed to its present westerly direction. Lake water now passes through Union Bay, past the Montlake Bridge and into Portage Bay. Fresh water discharges through the lake system from the Sammamish and Cedar Rivers to the Locks in excess of 33.98 m^3/s during high water.[2] In winter months, Lake Washington's water level is drained down a maximum of .61 meters in order to facilitate clean up and dock repairs along the Ship Canal and shoreline. As a result of lowering the surface of Lake Washington, much of Union Bay became a large cattail marsh.[3] Union Bay marsh was partially filled with the dredged material taken from the approaches and extensions of the Lake Washington canal.[4] Figure 3 shows the current shoreline of Union Bay.

Physical Description

Union Bay has a surface area of approximately 985,000 m^2 and a volume of about 1.4×10^6 m^3. A geological study from the Washington State Highway Commission reported that Union Bay was a shallow embayment with water depths ranging uniformly from 1.5 to 3.0 meters, except in the navigation channel, which has been dredged to a depth of approximately 9.1 meters. The study stated that the bay lies in a glacially carved depression in which considerable amounts of peat and soft inorganic sediments have been deposited.[5] The Union Bay area was the site of the deepest peat deposit in Washington State.

In 1984, cross sections of the Montlake landfill revealed garbage and debris up to 12.2 meters in depth underlain by a peat layer of approximately 6.1 to 12.2 meters in depth. Soft to medium clay and silt up to 30.5 meters in depth were found below the peat with compact clay, sand and gravel below the soft clay.[6] Figure 4 shows a diagram of the layers of fill, peat and clay found near Montlake Boulevard. The water table lays within .6 meters or less of the surface over a large percentage of the landfill. In 1980, an impact statement indicated that almost all of the garbage and debris within the site were saturated with water due to the high water table.[5,7]

The peat extends into much of the Bay. In 1956 and 1959, Professor Richard Meese took some core samples from the bottom of Union Bay to determine the composition of the Bay's sediments. His results complimented the findings of Dr. Rigg from Peat Resources of Washington.[7] They both concluded that Union Bay sediment was made up almost entirely of all-organic matter consisting of:

- Floating mats of fibrous plant life, varying in depth to a meter.
- Heavily saturated fibrous raw peat consisting of plant remains.
- Saturated mixture of sedimentary and fibrous peat.

III. Landfill Operations

Beginning in 1926, the City of Seattle negotiated the use of University property, the northeast corner of the former inlet, located at the intersection of N.E. 45th and Mary Gates Memorial Way, as a municipal garbage and debris landfill. The original fill site extended south to the present "Fire Arts" building on Mary Gates Memorial Drive. Over a period of forty years, landfill activities expanded from this initial location, west to Montlake Boulevard and further south to Husky Stadium. Figure 5 shows the progression of the filling operation.

The Montlake landfill was used both as a fire dump and as a general landfill operation during its existence. It received 40 to 60 percent of Seattle's garbage and biodegradable and non-biodegradable debris during its operation. Although the city operated the landfill, the collection of garbage from Seattle households was contracted by the city to a private firm. The site was open to the public and industries from about 1949 until November 30, 1964. The open dumpsite extended from the north pedestrian bridge to the present driving range.[3]

In 1954, the public expressed opposition to open burning, and later "modern" sanitary landfill methods were initiated. This change in landfill policy and practices, coupled with an expanding amount of garbage and debris from Seattle's growing population, quickly increased the rate of marsh reclamation by the landfill. By late 1956, the western portion of the interior perimeter-loop channel had been covered over by garbage and debris, as shown in Figure 5. The first Montlake parking lot was completed in 1958.[3] By 1959, a major portion of the University's family housing, which had been constructed over the oldest portion of the fill area in 1946 was removed to construct a golf driving range and softball fields over the former fill areas in the northeastern portion of the Union Bay/Montlake property.[3]

Primary Operation

The primary operation involved a contractor to the city, Seattle Disposal, who collected and processed the garbage and debris from individual homes. By the late 1950s, approximately 110 truckloads of garbage and debris were trucked into the site each day, five days per week, in enclosed 18 m^3 compactor trucks. Although the City of Seattle did not keep records of the type of garbage hauled to Montlake landfill, Table 1 is a general breakdown of municipal solid waste developed in 1958. After 1954, the contractor also hauled in approximately 8230 m^3 of soil per month. The soil was used to completely cover the municipal solid waste at the end of each day.

Secondary Operation

The secondary operation was the public portion of the landfill. This portion was open to individuals and industries to transport and discard their own wastes. The wastes discarded in the public portion of the landfill contained some non-biodegradable matter, but was mainly comprised of paper, lumber, and yard trimmings.[6] Approximately 2,500 private vehicles dumped waste at this site on a single Sunday afternoon during good weather.[8] Figures 8 through 11 are pictures taken between 1950 and 1960 of the garbage and debris landfilled.

Other Waste

The open dumpsite was utilized mostly by local households. However, a 1987 report from Ecology and Environmental, Inc. (EE) to the Environmental Protection Agency (EPA) indicated that the Seattle Gas Company hauled three types of wastes to the landfill.[9] One of the waste types, a black acid concentrate, caused problems at the landfill because of its offensive odor and liquid state. A letter dated 1955 from the Campus Sanitary Engineer to the City of Seattle requested that the city stop accepting this waste. The other two waste types were described as wet, yellow, clay-like material and sawdust material. The report further identified these wastes as: 1) a wet clay-like material that was a product of a process that scrubbed hydrogen sulfide from the gas; and 2) a sawdust containing iron oxide that was used in the same process. The report could not identify the black acid concentrate. The volume of these substances landfilled is unknown. The report concluded that the health risk to the local population from these wastes was "minimal." EE found no evidence that required further testing or monitoring at the site. EE recommended EPA not pursue further work at the Montlake landfill under the federal clean-up programs, CERCLA/SARA Superfund. [9]

Early in 1961, construction of the I-5 freeway began and the State Highway Department designated the Montlake landfill as the main dumping site of the demolition debris, i.e., lumber, rubble, excavated soil and broken concrete. During 1961 and 1962, 9.5×10^5 m^3 of soil and an unrecorded, but extremely large, volume of debris from the freeway project had been dumped at the site. In 1962, the City of Seattle closed the Interbay disposal site south of Salmon Bay. The closure of the Interbay site left Union Bay the only city dump north of the main business district. Both events greatly affected the amount of debris material placed in the Montlake landfill. The volume of garbage and debris nearly doubled.[10]

During the early 1960s, several meetings were held between the city, the U.S. Army Corps of Engineers and the State Pollution Control Commission to discuss the placement of fill in open water. The resultant decision was to place only non-biodegradable matter in open water. Recommended materials were logs, stumps, lumber, rubble and soil. Garbage and household rubbish were not to be placed in open water.[10]

Landfill Closure

Garbage and debris filling was discontinued when the City of Seattle began to close the landfill in 1965.[3] The University became actively involved in the closure process in 1969. Cover filling, grading, and seeding operations continued until a clean soil cover or cap of at least .61 meters was spread over the entire landfill area. In 1971, rubble and soil fill from the Health Sciences expansion was spread across the site, and final grading and seeding were undertaken.[6] Closure of the landfill was completed in 1971.

Subsidence Rates

In general, a landfill subsides approximately 15 percent over a 30 years period.[18] During the first year after closure, 20 to 40 of the projected settlement occurred, depending upon the amount of compaction. After the first year, subsidence rates ranged from zero to greater than one meter, but were less than .3 meters per year in most areas.[11]

IV. Landfill Design

Until the early 1950s, garbage and debris brought to the landfill were burned or spread over manmade and natural depressions in the drained marsh. Beginning in the 1950s, garbage and debris were covered nightly with a layer of soil and compacted with large soil moving equipment. It was discovered in 1959 that the weight of the debris and compaction techniques had moved underlying peat into Union Bay. Working closely with officials from the City of Seattle Engineering

Department, Professor Walter Dunn studied the characteristics and behavior of the peat. Professor Dunn was a professor in the UW Department of General Engineering.

Dikes

As a result of several studies, Professor Dunn concluded that sinking dikes through the peat to the clay layer could stop the peat from moving laterally. In 1959, the University and City of Seattle began using dikes to stabilize the landfill, prevent lateral movement of any peat or garbage, and provide clean drainage canals and stable roadways.[10, 29] Over a period of ten years, dikes were applied to form "cells" or compartments throughout the landfill, essentially encircling and crisscrossing the entire site. Specifically, dikes were placed on the northern and western limits of the landfill, following roughly the course of the former canals. Dikes were also placed along two sides of the large, central portion of the marsh, and along the southern most boundary of the central area of marsh. Several of the dikes are shown on Figure 6.[3] The "timber mat diking" was built in layers. The first layer consisted of a layer of timber mats from 4.6 to 12 meters thick and more than 45.7 meters in width. Soil was then spread over these mats in adequate depth and weight to drive the mat into the underlying peat, well below lake level.[3,12,10] At the time, this technique was considered a state-of-the-art remedy for retaining the garbage. Figure 7 shows a cross-section of a dike and identifies the components used for construction.

This diking method allowed for rapid expansion of the fill area.[3] As waterways or roadways were constructed, more dikes were laid in the same direction as the waterway and roadway. Drainage waterways were excavated in the soil portion of the dikes. The soil provided clean banks for the waterways and served as a filter to prevent the percolation of pollutants from the garbage into the water of the canal and lake.

Methane

During the 1960s, large French drains were built underground to provide for storm water drainage and to act as a methane gas collection system. Waste lumber was used to construct these drains, which were about 6 meters wide, 3 meters deep, and up to 60 meters long. The drains extended underground from the filled areas to the outer swamp. The upper end of the underground drains terminated in a large underground culvert. Above the culvert several 1.5 meters diameter gas burners were installed. One such burner was in continuous operation for three years.[13]

V. Potential Effects of Landfill

Concerns voiced by the Laurelhurst community have centered around the potential effects of the Montlake landfill on its immediate environment and public health. The following is an examination of the issues listed in the introduction.

A. Is the weight of the landfill moving peat and garbage into Union Bay?

Between 1959 and 1969, dikes were placed around and within the landfill to stop the lateral movement of the underlying peat into Union Bay. Since that time, no evidence has been found to suggest the weight of the landfill has caused any significant lateral movement of peat or garbage into the bay.

There is evidence to show that peat had been displaced into Union Bay during the filling operations that occurred between 1926 and 1959. In 1959, University consultants collected data on the horizontal movement of peat caused by loading the swamp with waste materials. The consultants placed grooved plastic casings down through the peat to the sand bottom reaching depths of 15.5 to 16 meters. A slope indicator was placed in the casings. Readings were taken from the slope indicator and plotted over time.[8] This test verified that continual lateral displacement took place in underlying peat strata as loading proceeded. Displaced peat was observed at several locations, one of which was located at the NE corner of the Conibear Shell House. There, corner pilings had been pushed approximately 0.46 meters east from the corner of the building.[12]

Dikes

From 1959 to 1969, the City of Seattle stabilized the underlying peat by sinking dikes to the clay layer.[10] These dikes were designed to prohibit the movement of peat and garbage into Union Bay. A recent study performed by the UW Center for Urban Horticulture (CUH) measured the changes of the non-seasonal islands and the shoreline along the landfill, using aerial photographs from the 1930s to 1996. The study demonstrated that the dikes, making up the shoreline, have not moved since they were constructed. Data from this study are provided in Table 7. The dikes should remain stable for many more years since they are comprised of soil, concrete debris and treated wooden poles. The poles will resist biodegradation since they are treated and completely submerged in water, an anaerobic environment. The dikes that make up the cells of the landfill should also be stable since they are made of the same materials. Photos of the timber dikes are provided as Figures 22 and 23. Since the pilings under the Conibear Shell House provided the first evidence of the landfill's lateral movement, the fact that the pilings have not visibly moved horizontally since they were repaired in 1979 provides circumstantial evidence that the diking system is effective.

Seasonal Islands

If peat is not moving laterally from the landfill, then what is causing seasonal "peat islands" in Union Bay? Peat islands, better known as mats of vegetation, are known to occur in lakes other than Lake Washington. Dr. Eugene B. Welch, limnologist and professor in the University's Department of Civil Engineering, suggests that methane production from bacterial decomposition of the peat and vegetation that underlies Union Bay gives the uncompacted, low-density peaty material buoyancy. The Eurasian milfoil's pervasive root system will create large mats of buoyant vegetation and peat. Changes in the lake's water level and temperature in the winter months will affect the visibility and buoyancy of these mats. Therefore, the "peat islands" appear and disappear seasonally.[18]

Jennifer Parsons from Ecology indicated that vegetation mats are not uncommon in lake systems. She stated that, "Sometimes there are naturally occurring mats of floating, decomposing vegetation in highly productive systems. These mats sometimes appear to be buoyant from the gases that naturally build beneath them from the decomposition of organic matter in the sediments." Floating mats of "duckweed" and other plant life were recorded in a book depicting Union Bay called *Life of a City Marsh* by Harry W. Higman and Earl J. Larrison, written in 1951.

Correspondence dated December 29, 1970 from the Army Corps of Engineers to Mrs. E. Corr, of Surber Drive, suggested that the appearance of the "peat islands" could have been caused by many factors other than displacement including the low lake level during the fall and winter months.[14] Other factors, such as water circulation patterns, may also influence the appearance of these mats. However, these factors have not been studied.

Non-Seasonal Islands

Several islands parallel the shoreline in Union Bay. These islands are primarily composed of compacted peat and vegetation and are visible year-round. A recent study of the non-seasonal islands has shown that almost all of the offshore islands have been receding. The Center for Urban Horticulture (CUH) measured the changes of fourteen islands using aerial photographs of Union Bay from the 1930s to 1996. Of the original fourteen islands, four have disappeared, four have fragmented into separate smaller islands, five have become smaller, and only one remained the constant size. Overall island area has decreased from 36,540 meters squared in 1966 to 22,932 in 1996, a reduction of 37%. It is not known if the islands are decomposing, and therefore subsiding, or are losing peat to Union Bay. The data obtained by the CUH are presented in Table 7.

B. Is the landfill contributing to the Eurasian Water Milfoil (milfoil) problem?

Milfoil is abundant throughout King County in shallow bays with soft organic sediment bottoms. Once established, as in Union Bay, nutrients added to the bay from storm water runoff and landfill leachate do not affect the colonization or growth rate of milfoil.

Myriophyllum spicatum (Eurasian Water Milfoil) is a perennial plant that was accidentally introduced into Lake Washington in 1974. Milfoil is found in clear, shallow waters with rich, organic sediments. Since Union Bay has these characteristics, it is easy to comprehend why plant populations flourish. The average depth of water in more than eighty percent of the bay is less than 3 meters. Sufficient light for plant growth reaches approximately 2.4 meters. Peat is the primary bottom sediment type.

Union Bay now has approximately fifty acres of well-established milfoil.[15] Milfoil is a nuisance to swimmers and boaters and it inhibits the growth of some native aquatic plants, but it is not unique to Union Bay. Milfoil has become a problem in the shallow waters throughout the integrated lake system, Lake Sammamish, Lake Union and Lake Washington, and is found in shallow areas of many other local lakes. Metro has tried to control the growth of milfoil in Union Bay by harvesting the plants. A substantial harvesting project occurred in 1987 that was somewhat effective in removing milfoil, but the results were only temporary.[16] Harvesting did not remove the root system and it left fragments in the water. Milfoil reproduces or spreads primarily through the root system and by fragmentation.[17]

Milfoil is a rooted plant and obtains most of its nutrients from the sediments on the lake bottom. Nutrients introduced into the bay from urban surface water runoff, leachate and other non-point pollutants will have little to no affect on the colonization and growth rate of milfoil.[18]

Non-Point Pollutants

In accordance with standards set by the Washington State University (WSU), the University of Washington uses fertilizer on many of its playing fields and urban gardens for a variety of reasons. If used in excessive quantities, the nutrients found in fertilizer, such as nitrates, can increase the nutrient load of surface water. This can aid the growth of non-rooted plants and algae. Table 2 identifies the University of Washington departments applying the fertilizer, quantity of nitrogen per 100 m^2, number of times per year applied, total area fertilized and total quantity of nitrogen applied to the landfill area.

WSU Department of Crop and Soil Sciences recommends that fertilizer be applied at rates of 1.95 to 2.45 kg/100 m^2/year. Based on WSU and the fertilizer manufacturer's recommendations, the University is using an appropriate amount of fertilizer per square foot. The fertilizer is being delivered at a rate that can be taken up by the target plants or tied up in the soil structure.[19, 18]

C. Is the leachate from the landfill degrading Union Bay's water quality?

Ecology concluded that the water quality data obtained from samples taken in Union Bay, shown in Table 4, when compared to State Water Quality Standards (WAC 173-201A), exceed standards for lead, silver, pH and fecal coliform. Ecology has found no evidence at this time to link these occurrences to the landfill leachate.

Municipal solid waste landfills generate leachate from processes of decomposition and water percolation through the waste. Most of the water entering the Montlake landfill is through ground water and infiltration of rain and surface water runoff.[20] The mass of garbage and debris stored in a municipal solid waste landfill represents a finite source of pollutants.[21] Most of the water-soluble pollutants leach out of the landfill through successive volumes of water, their concentrations diminishing over time. Other materials remain in the landfill for many reasons, including but not limited to adsorption, water solubility, and particle size.[20]

Leachate Chemistry

In the initial stages of decomposition, larger quantities of organic materials dissolve in the percolating water, resulting in high organic concentrations in leachate as measured by chemical oxygen demand (COD) and biological oxygen demand (BOD) values. Leachate COD is primarily composed of fatty acids, humic and fulvic acids, as well as proteins and carbohydrates. These organic components are subject to biological degradation by the anaerobic bacteria present in the landfill. As the landfill ages, the COD and BOD values diminish exponentially. Due to the age of the Montlake landfill, the COD and BOD values should be low, although the COD and BOD values will be higher than unaffected ground water.

Ammonia is the most reduced inorganic form of nitrogen in water and includes dissolved or aqueous ammonia and the ammonium ion. As landfill leachate ages, the ratio of ammonia nitrogen to organic nitrogen increases. However, much of the ammonia nitrogen is taken up by the anaerobic microbes as a nutrient. Leachates are typically deficient in phosphate. The main sources of phosphate for leachate are decomposition of organics as well as ash-soil-rock components of the municipal garbage and debris. Like ammonia nitrogen, phosphate is taken up by microbes. Additionally, the movement of phosphate through the garbage and debris is impeded by adsorption and precipitation. For these reasons, ammonia nitrogen and phosphate typically remain within the landfill.[21]

Early stages of decomposition reduce leachate pH levels to between 5.5 and 6.5, resulting in a chemically aggressive leachate that can dissolve inorganic materials from the wastes. Thus, the leachate has a high specific conductance, a high dissolved inorganic content. When a landfill reaches later stages of decomposition, generally after ten or more years, the pH returns to neutral, and the specific conductance is reduced due to the rise in pH.[20] In old leachate, generated from extensively leached garbage and debris, the conductivity is mainly attributed to sodium, potassium, and bicarbonate ions.[22] In most cases, concentrations of metals such as lead and cadmium in landfill leachate are low. Concentrations are initially high, but quickly diminish to non-detectable levels.[21] Therefore, the leachate should have a neutral pH, low conductivity, and low to non-detectable levels of metals.

Relevant Reports

The following facts were taken from reports that reported water and sediment quality data pertaining to the Montlake landfill and Union Bay.

Storm Drainage and Gas Burning at Seattle's Union Bay Refuse Disposal Site Report

During the late 1950s, water samples were taken by an unknown source in Union Bay and adjacent Lake Washington areas. The report stated that sample results indicated pollutants from the landfill were not reaching the lake. The report also stated that great quantities of peat and growing vegetation undoubtedly provided a "buffer between the garbage and debris fill and the lake."[23] However, the data used to make this conclusion were not available for review.

Union Bay Reclamation - Progress Report

In 1962, the UW supported systematic sampling and testing of the marsh waters. Testing was also performed at various points in Union Bay, and the adjacent ship canal. This work was conducted under the direction of Robert O. Sylvester, UW Professor of Sanitary Engineering in the Civil Engineering Department. It was concluded that the greatest quantity of pollutants entering Union Bay was via the municipal storm drain. The report stated that small amounts of pollutants were attributed to the landfill.[10]

Center for Urban Horticulture at Union Bay Physical Site Study

Surface water samples, taken in 1980 from ten different locations within the landfill, exhibited slightly elevated specific conductance, normal to moderately elevated total suspended solids, elevated pH, and elevated total coliform and chemical oxygen demand (COD) when compared to State ground water standards. Analysis also showed some elevated metal concentrations. However, there was no detection of these elevated characteristics in the surface waters from Union Bay. The report concluded that the dikes along the perimeter of the Montlake fill appeared to be an effective barrier and filter to the passage of the ground water through the site.[6] Analytical results concerning the surface water and ground water samples are provided in Table 3. Analytical results of the samples taken in Union Bay are provided in Table 4.[11]

Metro Water Quality Study of Union Bay

A three-year study performed by Metro in the early 1980s included water samples taken from various locations in Lake Washington, including four locations in Union Bay. The study found that data from one sampling station near the University were somewhat atypical. The conductivity, chlorophyll a, total phosphorus, and suspended solids were all slightly higher than the rest of Union Bay. Although slightly elevated, the water quality in that area was still quite good.[24] Data are provided in Table 4.

Table 4 also provides water quality values obtained from a sample station east of Union Bay during the same time period for comparison. The sampling station east of Union Bay is thought to represent open lake water quality values. Since the water in Lake Washington flows east to west, water east of Union Bay should not be affected by pollutant sources from Union Bay's shoreline.[24]

Abandoned Landfill Study in the City of Seattle

Twelve abandoned landfills in the City of Seattle, including the Montlake landfill, were assessed in 1984 by the Seattle-King County Department of Public Health. The primary objective was to determine if any public health problems existed at the twelve sites. Surface water samples, taken at various locations above the landfill, showed slightly high specific conductance, high metals, alkalinity, total coliform and COD when compared to drinking water standards, as shown in Table 3.

The report also concluded that ground water samples exhibited particularly high concentrations of some metals, COD and total coliform when compared to drinking water standards. However, water samples taken from Union Bay did not exhibit the characteristics observed in the landfill. The report concluded that further study would be necessary to fully characterize the landfill.[6]

University Regulator Combined Sewer Overflow Control Predesign Project Report

A report developed by a consultant in 1987 was provided to Metro for the purpose of identifying the best outfall for storm drains which, at the time, had been combined with the sewer. This report is the most extensive environmental assessment found concerning Union Bay. In addition to reporting the water and sediment quality values, the report provided the general circulation pattern of Union Bay.

Union Bay receives large quantities of storm water runoff from its drainage area. Almost 40 percent of the total runoff from Webster Point to the Fremont Bridge drains into Union Bay. The water quality data obtained, when compared to State Water Quality Standards (WAC 173-201A), shows that lead, silver, pH and fecal coliform were exceeded, although these occurrences are consistent with that expected from urban storm water runoff. The sediment quality data, when compared to Ecology's freshwater sediment guidelines, also show that some parameters were exceeded. However, bioassays were not performed using collected sediment samples from Union Bay. Under the State sediment management standards, bioassays can override individual chemical exceedances. Water quality data are presented in Table 4 and sediment values are presented in Table 5. Maps identifying the sampling locations are presented in Figures 15 and 16, respectively.

The report indicated that the general circulation of the water in Union Bay varies from summer to winter. In the summer months, when dense stands of milfoil are present, a general gradient is apparent whereby phosphorus concentrations in the inner bay are higher than in the outer bay and Ship Canal. During the winter, when the macrophytes are absent, the entire bay appears to be completely mixed. Phosphorus concentrations in the inner bay and outer bay were the same.[25]

University of Washington and Sediment Quality Surveys

On September 18, 1997, Professor Edmondson's research group, from the University's Department of Zoology, ran some tests off the shore of the landfill at 0.5, 1, and 2.5 meters in depth. Their results are in Table 4. Data provided by Metro from a sampling station east of Union Bay, a control station, are also provided in Table 4.

On August 6, 1997, Rob Harrison, Associate Professor in Forest Resources, took sediment samples from ten different locations in Union Bay. The samples were analyzed for sixteen different metals using an inductively coupled plasma spectrophotometer. The results indicated that toxic metals such as chromium, copper, lead, zinc and mercury were either not detectable or the value was less than Ecology's freshwater sediment guidelines. In some samples, arsenic, nickel, silver, and cadmium exceeded the freshwater sediment guidelines. Results are presented in Table 5.

On December 8, 1997, the University Environmental Health and Safety Department (EH&S) took samples from the three largest perennial ponds on the landfill. These ponds are marked on Figure 14. Two samples were taken from each pond, at the surface and one foot in depth. The samples were analyzed for pH, conductivity, ammonia nitrogen, fecal coliform, COD and BOD. The south pond was the only pond to exhibit a high level for any characteristics when compared to Ecology's guidelines for surface water and the only high level was for fecal coliform, which is attributed to the fecal matter from the large goose population. The results are presented in Table 3.

Affect on Union Bay Fish

Several residents wondered whether water quality was adversely impacting fish fingerlings. Kurt Fresh, from the Washington State Department of Wildlife, stated that there are no records of salmon or smelt fish kills occurring in Union Bay. South of Mercer Island, low dissolved oxygen levels and high lake temperatures have killed smelt fingerlings on several occasions during 1997.

D. How would an earthquake effect the Montlake landfill?

During a major earthquake, landfill areas may be prone to liquefaction. Thus in a major earthquake, liquefaction may occur within the boundary of the Montlake landfill. Structures built on the landfill on pilings, reaching below the peat layer, should not be effected.

Liquefaction is one of the major causes of ground or geotechnical failure during earthquakes. Liquefaction is the term used to describe when a solid, in this case soil, begins to act as a fluid. The "shear strength" of the soil depends upon the friction between the soil particles. When soil is saturated with water, the shear strength of the soil is reduced, increasing the likelihood of liquefaction. Liquefaction of the soil may result in differential settlement and can cause distress in structures founded on spread footings, but is not likely to affect structures founded on pilings.

A paper written by H. Bolton Seed measured the shear strength, or frictional force, of the soils underlying the Union Bay area. This paper, published in the *Bulletin of the Seismological Society of America*, February 1970, measured the shear strength of the peat layer to be on average 269 Kg/m^2 between 0 to 4 meters. This value when compared to the shear strength of water, which is 0 Kg/m^2, and solid clay, which is 3322 Kg/m^2, indicates that during a major earthquake, the Union Bay area may be prone to liquefaction.

While some authorities have expressed concern that portions of the landfill could undergo liquefaction during a major earthquake, Steven Kramer, Ph.D., University of Washington Civil Engineering Professor and recognized expert regarding liquefaction, stated that refuse materials typically placed in landfills, due to their fibrous, elongated, and often organic nature, are not susceptible to liquefaction.[30] They have neither the contractive volume change tendencies nor the cohesionless behavior that are found in inorganic silts, sands, and gravels that are known to be susceptible to liquefaction. Thus, the issue of liquefaction will only influence a landfill if the landfill is resting on liquefiable soils.

Although Dr. Kramer had not reviewed subsurface conditions beneath the Montlake landfill in detail, he understood that it rests primarily on deposits of Union Bay peat. With this understanding, Dr. Kramer stated the following:

> "Peat is not susceptible to liquefaction... Peat is extremely soft and weak in its virgin state, such as the state of the peat that was tested by H. Bolton Seed back in the late 1960's. The peat that underlies the Montlake landfill, however, has been consolidated under the weight of the landfill due to confining pressures that are undoubtedly many times greater than those of the virgin peat tested by Seed. As a result, the shear strength of the peat under the landfill is undoubtedly many times greater than the values referred to in Seed's report. There is some potential for strong ground shaking that could cause instability of the slopes at the margins of the landfill, but I would expect that potential movements would be localized and limited to displacements of less than a few feet."

If liquefaction were to occur during a major earthquake, the larger structures on the landfill should not be affected since they are all founded on pilings extending down to the underlying firm clay layer. Figure 12 shows the areas of the landfill that could be prone to liquefaction during a major earthquake.

In addition to liquefaction, another implication of a major local earthquake may be land either raising or subsiding. While this phenomenon would not likely have a direct affect on the landfill, it could cause the depth of Union Bay to change. If the land were raised, the Bay could become shallower, while if it subsided, it could become deeper.

Since 1926, western Washington has experienced eight moderate to major earthquakes:

- 1932 magnitude 5.2
- 1939 magnitude 6.2
- 1946 magnitude 6.3
- 1949 magnitude 7.1
- 1965 magnitude 6.5
- 1995 magnitude 5.1
- 1996 magnitude 5.5
- 1997 magnitude 5.0.

No evidence could be found that liquefaction occurred within the boundary of the landfill as a result of these recorded earthquakes.

E. Is gas escaping from the landfill?

Methane gas is escaping from the landfill area, but in such small quantities that it does not pose a health concern or combustion hazard.

Aerobic decomposition of the biodegradable garbage occurred on initial placement of the garbage and debris, while oxygen was still available. Once the oxygen was used up, the anaerobic microbes began to decompose the garbage and debris. Anaerobic decomposition's primary by-products are methane, carbon dioxide, water, organic acids, nitrogen, ammonia, ferrous and manganous salts, and hydrogen sulfide.[20] Tests performed in 1980 showed that biological decomposition of the garbage and debris was in an anaerobic stage.[11] Methane gas production slows after approximately 15 years of anaerobic decomposition.[21]

While the Montlake landfill still generates methane as decomposition continues to occur, the quantity of methane released is now so minor that flares are no longer used nor needed to burn off any excess gas on the sites. Even though the methane collection system is still in place, most of the flares were extinguished in the late 1970s. In 1997, the University measured the concentration of methane generated in the landfill area, using a method similar to that used by the Seattle-King County Department of Public Health during their study of abandoned landfills in 1984. The concentrations of methane measured during both studies are presented in Table 6. A corresponding map of the sample locations is provided in Figure 13.

The results of the studies are as expected. While methane is still released, concentrations of methane measured in 1997 are below the lowest combustion limit and significantly below the levels measured in 1984. Such small quantities do not pose a combustion or public health hazard. However, since decomposition of the vast layer of underlying peat also produces methane gas, methane will continue to be produced even when the garbage is depleted. Due to the potential for methane to "pool" under and around impermeable layers, such as asphalt or concrete, long-term measurements are generally done around such landfill areas, even after long-term closure. For example, methane monitoring recently done at the old Genessee Landfill and at the Interbay Landfill sites have shown continued methane production. Based on this fact, long-term use of such sites incorporate methane mitigation measures.

F. Was the landfill closed according to regulations in effect at the time?

The landfill was closed according to the guidance available at the time.

As previously stated, the City of Seattle began closing the landfill in 1965. The University took over the closure of the landfill in 1969, under the guidance of Seattle's Engineering Department, to expedite the process. The University capped the landfill with soil provided from a variety of sources including the Health Science complex excavation and the I-5 project. The entire landfill area was capped with approximately .61 meters of soil. As subsidence occurred in the parking areas, the University regraded and filled the areas. This process thickened the cap in some areas, as the garbage and peat decomposed and subsided.

The State of Washington did not have closure requirements for landfills until 1972. The steps taken to close the Montlake landfill met existing guidelines and technology.

G. Has the landfill caused the depth of Union Bay to change?

As part of a natural and gradual process, all lakes decrease in depth over time. The rate of change is related to the lake's sedimentation rate. The changes occurring in Union Bay can be attributed to the measured rate of sedimentation in this area.

In 1959, the City of Seattle placed dikes along the perimeter of the landfill to stop the slow migration of peat into the bay. Based on aerial photos, the dikes continue to hold the peat and decaying debris in place. If the dikes have stopped the movement of peat, what could be causing the depth of Union Bay to decrease? In order to respond to this question, the natural life cycle of a lake must be addressed. The Environmental Protection Agency (EPA) published a guidance manual entitled *Lake and Reservoir Restoration,* Second Edition, which provides information on the natural life cycle of lakes. This manual states the natural geologic process for lakes of moderate depth is to gradually fill and become wetlands. Lakes are extremely efficient sediment traps. Filling in with silt is part of a lake's natural aging pattern, but poor land management practices can speed up the process significantly. Suspended sediment particles, carried by rivers and steams, settle out once they reach the lake environment.[26]

Large inputs of silt and incomplete decomposition of macrophytes, such as algae, milfoil, and other weeds, can make lakes become shallow rapidly. Silt comes from soil erosion in the lake's watershed, which is delivered by rivers, streams or storm drains.[27] Historically in Lake Washington, there have been three sedimentation rates since the early 1900s.

150 grams/m^2/year	Before 1889	(Natural rate)
1800 grams/m^2/year	1890-1902	(Twelve times the natural rate)
644 grams/m^2/year	1916-1983	(Four times the natural rate)

Since 1916, the sedimentation rate has averaged 644 g/m^2/year, or about four times the natural rate. Diverting the Cedar River into Lake Washington in 1916 provided the water necessary to operate the ship canal locks. However, it also increased the volume of sediment entering the lake, contributing an estimated 5 x 10^7 kg/year of external organic and inorganic material.[27] This additional source has accelerated the sedimentation rate in the Madison Park area, near Union Bay, even though the sediment source is some 7 kilometers south.

This suggests that for the relevant time period, one square meter of lake-bottom would gain 644 grams of sediment on average during a period of one year. From 1926 to date, that one square meter would gain approximately 46 kilograms of sediment. This rate could be higher since Union Bay receives large quantities of storm water runoff from its drainage area and has a well-established population of milfoil.[18]

The most recent increase in the sedimentation rate occurred in the early 1960's when the lake was enriched with treated sewage effluents. Increased nutrients like phosphorus and nitrogen, increased biological production of those plants that absorb nutrients from lake water. This, in turn, increased the sedimentation rate. It was noted that there were distinctive increases in the sedimentation rates following seasonal events such as diatom blooms and high runoff periods. Treated sewage is no longer discharged in the lake. The sedimentation rate in Lake Washington has not been measured since 1974.[28]

Bathymetry maps measuring the depth of Union Bay were obtained from the Army Corp of Engineers and the National Oceanic and Atmospheric Administration. These maps are provided as Figures 19, 20 and 21. Depth measurements of Union Bay were taken in 1910, 1978 and 1985. These maps show small to no changes in the depth of Union Bay during this time period, with an average of $\pm$ 0.3 meters.

While the impacts of the lateral movement prior to 1959 on the depth of Union Bay cannot be measured, the rate of natural sedimentation has been measured. Based on this measured rate, the natural history of lakes and what is found in other parts of Lake Washington, the small changes in the depth of Union Bay can be entirely attributed to seasonal variation of the lake level, natural sedimentation, and dredging activities.

VI. Summary of Impacts

The University has a broad range of scientifically grounded data that, when placed together like pieces of a puzzle, form a picture of the landfill and the Union Bay area. Based on the data presented herein, the following conclusions are reasonable:

A. *Weight of Landfill:* Peat was extruded from under the fill prior to the placement of the dike system. The perimeter dikes were engineered to stop the peat from moving laterally. Aerial photographs show the perimeter dike has remained stable over the years. The Union Bay area is experiencing a net decrease, not increase, of dry land.

B. *Milfoil:* Milfoil is currently well established in the shallow areas of Union Bay. The plant colonized in many areas of Lake Washington once it was introduced in the early 1970s. The colonization and growth rate is not affected by nutrient inflow through non-point pollution such as urban storm water runoff or landfill leachate.

C. *Leachate:* All landfills produce leachate early in their history. However, pollutants that could affect Union Bay should have already leached from the Montlake landfill. The data indicate that the quality of water and sediments in Union Bay are similar to that found in areas receiving a large quantity of urban storm water.

D. *Earthquakes:* The landfill area, as well as the entire Union Bay area, is prone to liquefaction during a major earthquake. Large buildings founded on pilings will not be affected by liquefaction.

E. *Gas:* Methane gas is still escaping from the landfill and peat bogs, but the rate has decreased and present quantities are not sufficient to support combustion or become a public health hazard.

F. *Closure:* The landfill was closed according to the guidelines of the time.

G. *Bay Depth:* Changes in the depth of Union Bay could be contributed to natural sedimentation and dredging activities.

VII. Future Use of the Montlake Landfill

The University is currently in the process of developing the 10-Year Recommended Plan for the University of Washington East Campus. The East Campus is defined by Montlake Boulevard on the west, the Lake Washington Ship Canal on the south, N.E. 45th Street on the north and Union Bay on the east. This area includes the Montlake landfill and surrounding areas. While fiscal realities will ultimately determine what or when such plans my be implemented, the recommendation for the future of the East Campus is to continue the current uses: recreational sports activities, intercollegiate athletics, parking, wetlands, and some accessory uses in the northeast corner. The overall plan's organizational concept seeks to establish a more well defined "village" by improving the landscaping to reflect the individual uses as well as improve the pedestrian and vehicular circulation. A new bridge to the main campus located north of the Intramural Activities (IMA) building is recommended to improve the connections to the main campus. More specific project information follows.

Proposed Projects

Proposed projects for improving the recreational sports facilities include:

- Construction of an addition to the northwest corner of the IMA building.
- New tennis courts near the playing fields along Clark Road.
- Artificial turf and lights for the field immediately north of the IMA building.
- Increasing the capacity of the driving range.

Intercollegiate Athletics' proposed projects include:

- An indoor practice facility north of the IMA building, adjacent to Montlake Boulevard.
- Interior renovations to the Hec Edmundson Pavilion.
- Renovation of the Conibear Shell House.
- New stadiums for the recently completed soccer and baseball fields.
- Expanding the track and field area east of Husky Stadium.

No overall increases in the parking areas are recommended at this time. The plan does not recommend any new buildings in the East Campus grasslands or wetlands areas. Minimal improvements could include the addition of a trailhead, limited trail improvements, and the reclamation of parking area E5 to a naturalized condition.

The Center for Urban Horticulture (CUH) is planning an addition of 929 m^2 within the next ten years. The plan also recommends consolidating the Environmental Health & Safety temporary buildings into a permanent building located on Corporation Yard 1 and the consolidation of the maintenance facilities for intercollegiate athletics and recreational sports in Corporation Yard 2. No further development is anticipated to Laurel Village, family housing owned by the University of Washington.

Other Goals

The Union Bay Planning Committee published a report called the Management Plan for the Union Bay Shoreline and Natural Areas Owned by the University of Washington.[32] This report details the following goals for the Union Bay shoreline and natural areas:

- Maintain and restore the biodiversity and ecosystem function.
- Increase wildlife habitat.
- Increase research and teaching.
- Increase the area's service to the public.

In meeting these goals, the CUH would like to complete the several projects, which have been approved by the Union Bay Natural Area Advisory Committee. These projects include:

- Develop all-weather gravel paths.
- Restore and plant the E5 parking lot.
- Develop a new path on Douglas Road when E5 is abandoned for parking.
- Construct blinds and observatory platforms.
- Construct a limited boardwalk in the southeast riparian area just south of the CUH.
- Post interpretive signage.
- Remove invasive plant species.
- Plant native plant species.
- Light Wahkiakum Lane.

Ravenna Creek Daylighting Project

One of the most significant projects proposed is the daylighting of Ravenna Creek. While not a University of Washington project, this project will impact University property, and most specifically the landfill site. When this occurs, the route carved for the Creek could compromise the integrity of the cap covering the landfill and potentially breach the protection provided between surface and ground water and leachate. Engineering efforts to protect the site and assure impermeable separation between the landfill and Ravenna Creek will be essential to plan during design and construction.

Construction Caveats

In December of 1993, the University produced a report entitled, "East Campus Task Force Report." The purpose of this report was to review the known soil conditions in the East Campus area and to make recommendation to guide future construction activities in the area. The primary design guidelines contained in this report recommend that new facilities be either pile supported or be lightweight structures.

VIII. Implications and Recommendations for the Future

While no significant public health or environmental impacts were discovered associated with the current activities on the Montlake landfill, the work group developed recommendations regarding the Montlake landfill area. These recommendations take into consideration the long-term plans for the East Campus and the fact that a landfill site presents certain unique challenges for use and/or development.

A. Long-Term Testing or Monitoring

1. Aerial photos of the Montlake landfill should continue to be taken biennially by Facilities Services to monitor University property abutting the Union Bay shoreline. Stereo-pair aerial photos should be taken twice to measure land settlement at 5-year increments, in 2003 and 2008, and then their need should be reevaluated. The aerial photos should be analyzed by the Center of Urban Horticulture, and any unusual or significant observation should be reported to the Director of the Environmental Health and Safety Department.

2. The University should participate, with appropriate agencies, such as the Seattle-King County Department of Public Health and the Washington State Department of Ecology, in the development of a plan to determine any future impacts of the landfill on surface water quality in Union Bay.

3. A plan should be developed and implemented by Facilities Services and the Environmental Health and Safety Department, with input from Capital Projects, to assure that a long-term monitoring program is in place for tracking both settlement points and methane, with methane mitigation being part of standard procedures at the site. Such requirements should be incorporated into the Facilities Design Information (FDI) Manual, East Campus Plan, and appropriate planning documents.

B. Clean-Up Activities

1. Since federal, state and local agencies have assessed the site and found that it presents no apparent environmental or public health hazard requiring additional closure actions, and based on the data obtained to date, there is no evidence to suggest that it is necessary to make any physical changes or undertake clean-up activities at the Montlake landfill site at this time.

C. Policies and Guidelines for Future Use of the Site

1. Engineering Services, the Environmental Health and Safety Department, and the Capital Projects Office should develop and implement an operational policy and management plan regarding grades at the landfill site that recognizes the dynamics of the landfill, and its maintenance requirements. This should be incorporated into the FDI Manual, and appropriate planning documents.

2. The Capital Projects Office and Engineering Services, with input from the Center for Urban Horticulture and the Environmental Health and Safety Department, should develop and implement guidelines for construction on the Montlake landfill site. This should be incorporated into the FDI Manual.

D. Other Recommendations

1. The University, upon invitation from the Washington State Department of Ecology (Ecology), should participate in Ecology's planning activities regarding sediment quality in Union and Portage Bays.

2. The University Real Estate Office, Center of Urban Horticulture, and Facilities Services should monitor implementation of the Ravenna Creek Daylighting Project and assure that the landfill site is adequately protected.

3. The University Relations Office and the Environmental Health and Safety Department should be added to the mailing list for information regarding city and county activities, regarding the regional waste water service plan and storm water issues.

4. In conjunction with statewide storm water management planning, the University Engineering Services should participate in the development of a storm water management plan for developed portions on the landfill site.

5. A committee should be formed by the Executive Vice President of the University to provide administrative oversight of future landfill activities, track on-going development, and respond to public requests for information regarding the landfill. The committee should include a representative from the following University departments or units: Capital Projects, Center for Urban Horticulture, Intercollegiate Athletics, Engineering Services, Environmental Health and Safety, Facilities Services, Recreational Sports Programs, and Transportation Services. Furthermore, the Attorney General's office should designate an ex-officio member to serve the committee. Because of the added value in working with regulatory agencies on this project, the following agencies should be requested to send ad-hoc members: Seattle-King County Department of Public Health, Seattle Public Utilities, Washington State Department of Ecology, and Washington State Department of Health.

6. Annual training should be provided for the Environmental Health and Safety Department, Facilities Services, and the Capital Projects Office regarding landfill evolvement.

7. The University should continue to gather baseline data on the depth of Union Bay extending at least 500 feet into the Bay from the University's shoreline.

Glossary

aerobic: Relating to a process that occurs in the presence of, or requiring, oxygen.

anaerobic: Relating to a process that occurs with little of no oxygen present.

biochemical Oxygen demand (BOD): A Measure of the amount of oxygen removed from aquatic environments by aerobic micro-organisms for their metabolic requirements. Measurement of BOD is used to determine the level of organic pollutant of a stream or lake. The greater the BOD, the greater the degree of water pollution.

biodegradable: Able to decompose by natural biological processes, such as by being digested by bacteria of fungi.

chemical oxygen demand (COD): A chemical measure of the amount of organic substances in water or wastewater. A strong oxidizing agent together with acid and heat are used to oxidize all carbon compounds in a water sample. The actual measurement involves a determination of the amount of oxidizing agent (typically potassium dichromate) that is reduced during the reaction.

fecal coliform bacterial: A group of bacteria normally present in large numbers in the intestinal tracts of humans and other warm-blooded animals. Specifically, the group includes all of the rod-shaped bacteria that are non-sporeforming, Gram-Negative, lactose-fermenting in 24 hours at 44°C, and which can grow with or without oxygen. The presence of this type of bacteria in water, beverages, or food is usually taken to indicate that the material is contaminated with fecal matter.

embayment: An indentation in the shoreline forming an open bay.

landfill: A disposal site which disposes of solid wastes on land. Wastes are deposited and compacted. At specific intervals, a layer of soil covers the waste and the process of deposit and compaction is repeated.

macrophyte: A member of the macroscopic plant life, especially of a body of water.

microbes: Microscopic living organisms, including bacteria, protozoa, and fungi.

non-point source (NPS) **pollution**: Pollution discharged over a wide land area, not from one specific location. Non-point source pollution occurs when rainwater, snowmelt, or irrigation washes off plowed fields, city streets, or suburban backyards. As this runoff moves across the land surface, it picks up soil particles and pollutants such as nutrients and pesticides. Some of the polluted runoff infiltrates into the soil to contaminate (and recharge) the groundwater below. The rest of the runoff deposits the soil and pollutants in rivers, lakes, wetlands, and coastal waters.

peat: Any mass of semi-carbonized vegetable tissue formed by partial decomposition of various plants, especially mosses of the genus Sphagnum. Peat varies in consistency from turf to slime. As it decomposes its color deepens, old peat being dark brown or black, and keeping little of the plant texture.

percolating waters: Underground waters whose course and boundaries are incapable of determination. Waters which pass through the ground beneath the earth's surface without a definite channel. It is presumed that ground waters percolate.

pH (hydrogen concentation): A convenient method of expressing the acidity or basicity of a solution in terms of the logarithm of the reciprocal (or negative logarithm) of the hydrogen ion concentration. The pH scale runs from 0 to 14; a pH value of 7.0 indicates a neutral solution. Values above 7.0 pH indicated basicity (basic solution); those below 7.0 indicate acidity (acid solution). Water usually has a pH between 6.5 and 8.5.

phosphates: General term used to describe phosphorus containing derivatives of phosphoric acid (H_3PO_4). The chemical containing the phosphate group (PO_4, PO_3) can be either organic or inorganic and either particulate or dissolved. Phosphates constitute an important plant nutrient.

specific conductance: A measure of the ability of water to conduct an electrical current. Specific conductance is related to the type and concentration of ions in solution and can be used for approximating the total dissolved solids (TDS) content of water by testing its capacity to carry an electrical current. Specific conductance is used in groundwater monitoring as an indication of the presence of ions of chemical substance that may have been released by a leaking landfill or other waste storage or disposal facility.

subsidence: A sinking of an area of earth's crust.

water table: The level of groundwater, the upper surface of the Zone of Saturation for underground water. It is an irregular surface with a slope or shape determined by the quantity of ground water and the permeability of the earth material. In general, it is highest beneath hills and mountains and lowest beneath valleys.

Conversion Chart

Standard International Units (SIU)	British Units
1 meter	3.3 feet
1 cubic meter (m^3)	264 gallons
1 kilogram	2.2 pounds

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Fresh, Kurt and Fisher, Larry (10/97)
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Woodhouse, Philip (10/97, 3/98)
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[23] Dunn, Walter, Assistant Professor, Storm Drainage and Gas Burning at Seattle's Union Bay Refuse Disposal Site, Department of General Engineering, University of Washington, February 16, 1960.

[24] Metro, Water Quality in Nearshore Lake Washington, 1985.

[25] Metro, University Regulator Combine Sewer Overflow Control Predesign Project, March 1987.

[26] EPA, Lake and Reservoir Restoration Guidance Manual - Second Edition, 1990 (440/4–90–006).

[27] Crecelius, E.A., Limnol. Oceanographer 20, Arsenic Geochemical Cycle in Lake Washington, (1975) 441.

[28] Nevissi, A., and Schell, W. R., Sedimentation in Lakes and Reservoirs, Guidebook on Nuclear Techniques in Hydrology, 1983, p 163.

[29] Correspondence from Frederick Mann, University Architect, to Ray Morse, City Engineer, regarding Union Bay Marsh Lands-Soil Study and Reclamation Procedures dated September 29, 1959.

[30] Correspondence from Judy Foss to Karen VanDusen, EH&S Director, regarding the Montlake landfill dated June 29, 1998.

[31] Correspondence from Ralph L. Swanson to Dr. Richard McCormick, University President, regarding the Montlake landfill dated January 2, 1997.

[32] The Union Bay Planning Committee, Management Plan for the Union Bay Shoreline and Natural Areas Owned by the University of Washington, November 20, 1995.

FIGURES 1 – 23

Figure 1

Kroll Map Showing University's Property Boundaries

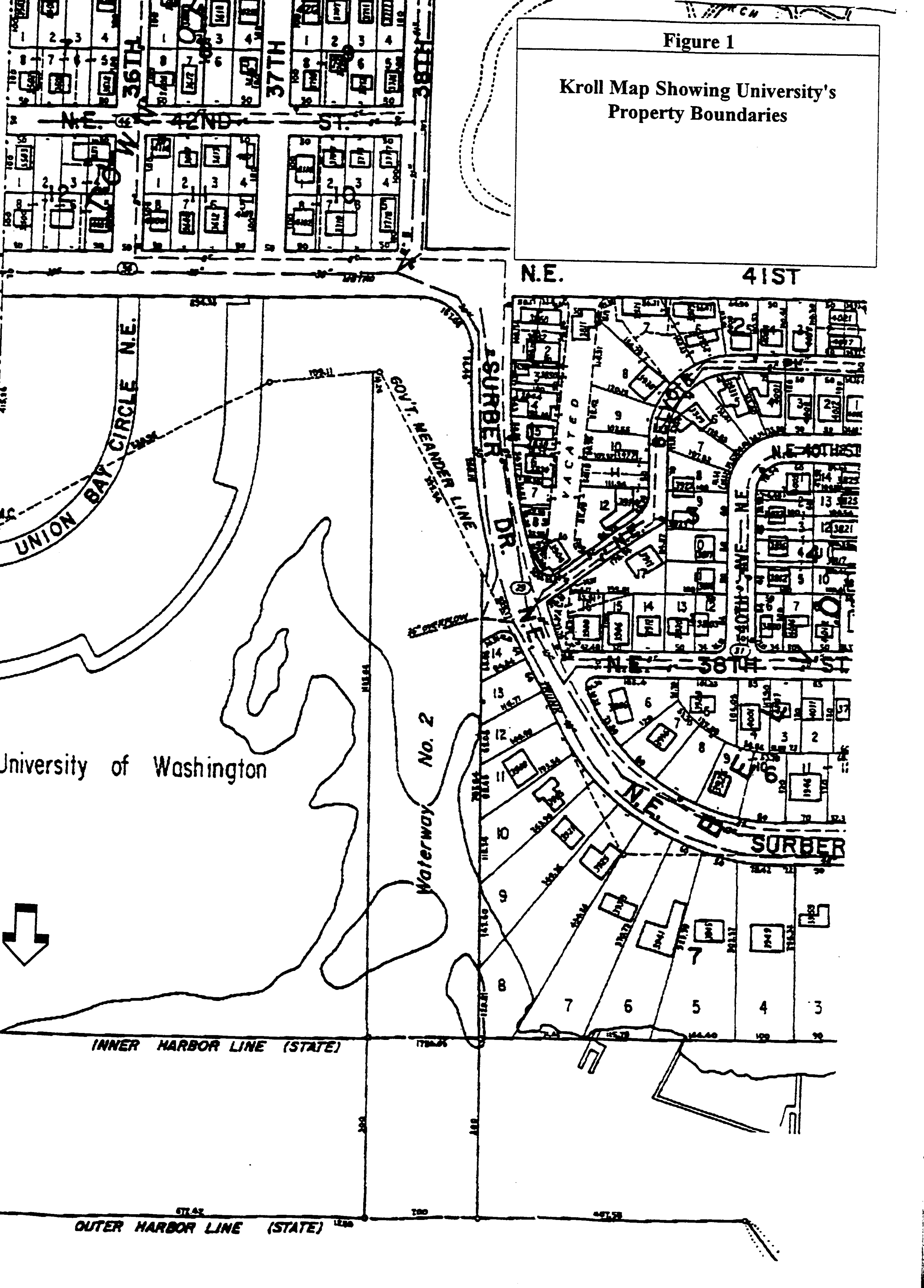


Figure 2

Kroll Map Showing University's Property Boundaries

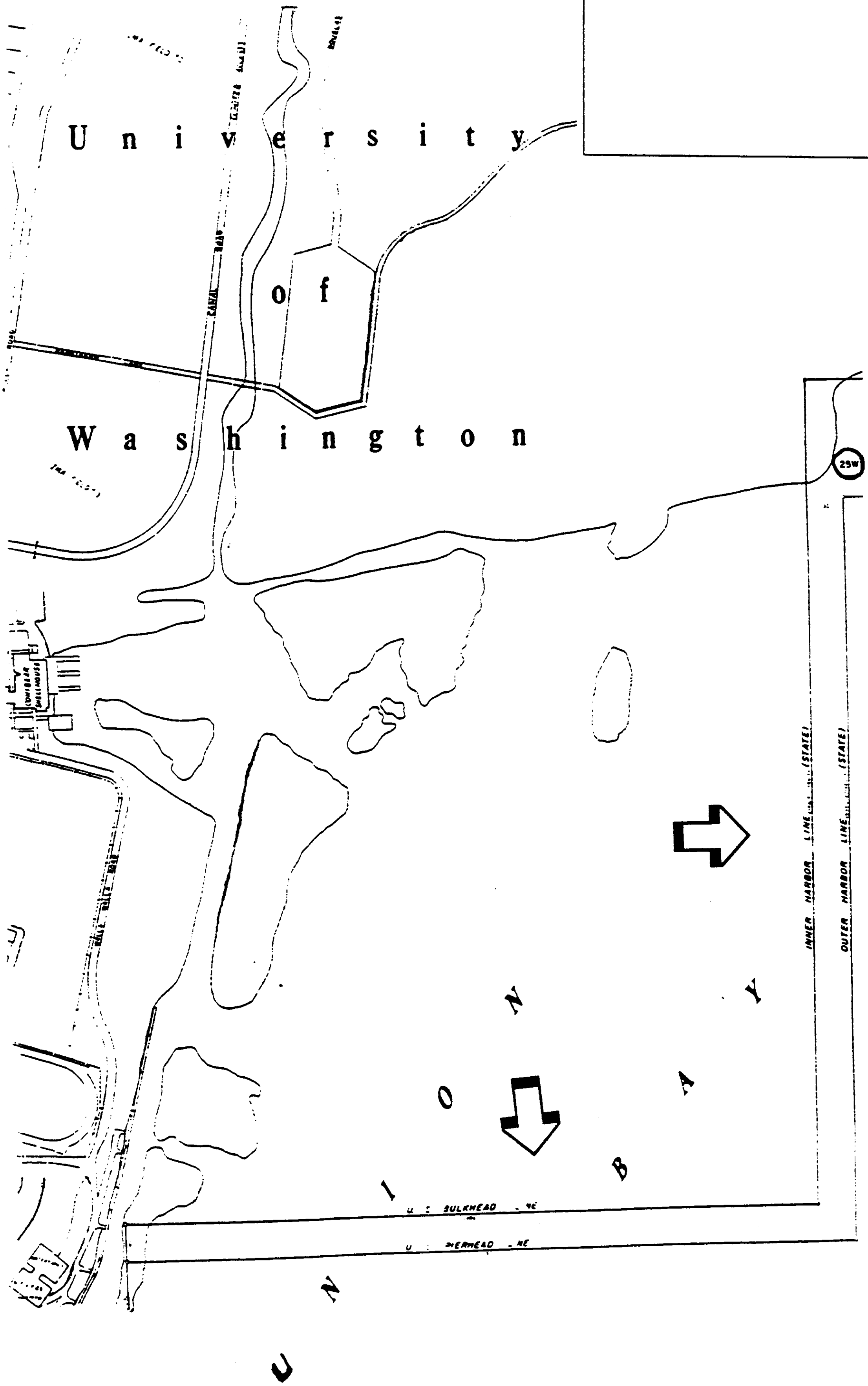


Figure 3

horeline of Union Bay & Montlake Landfill Boundaries Seattle, Washington

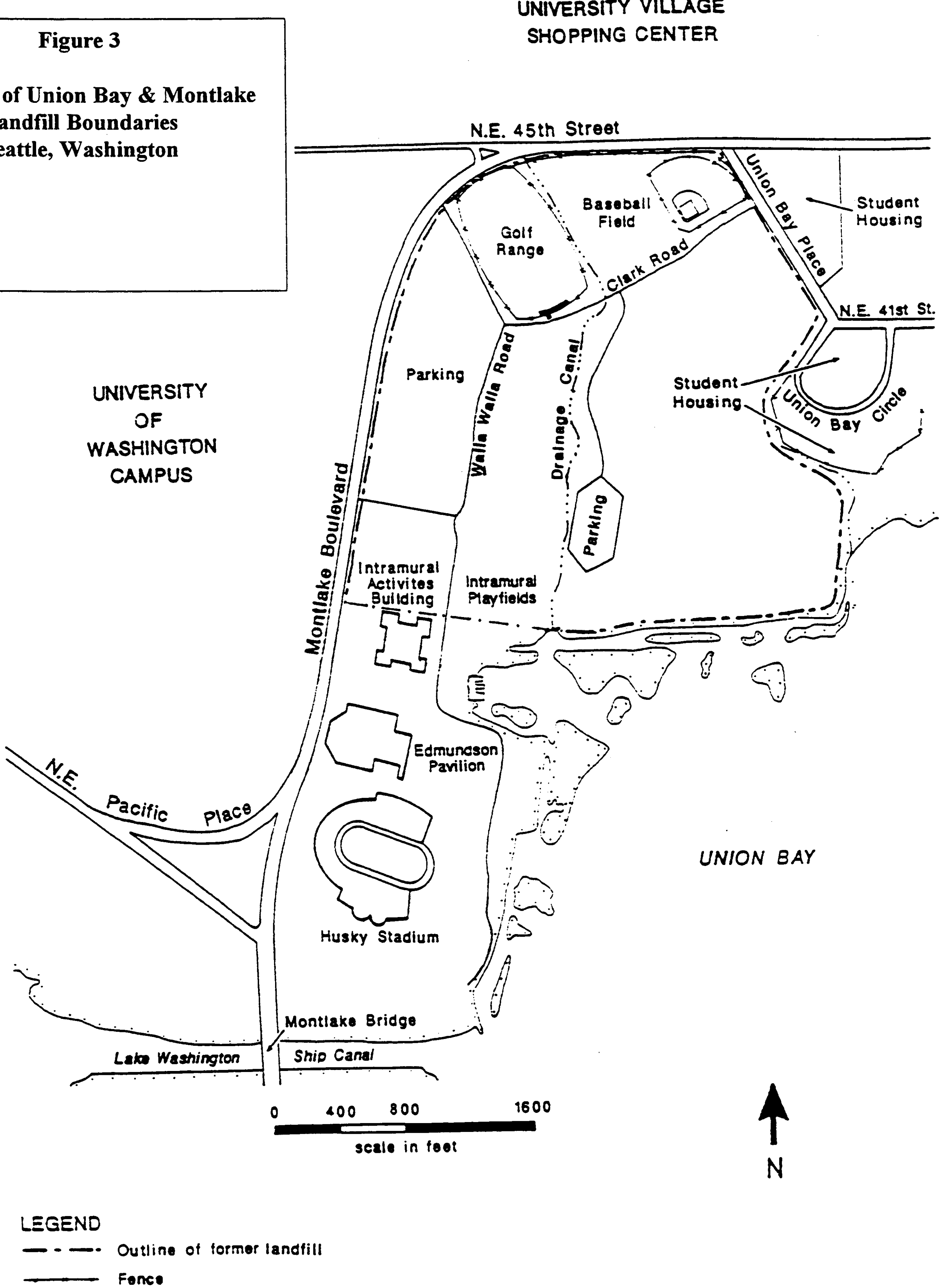


Figure 4

Layers of Fill, Peat and Clay Found Near Montlake Boulevard

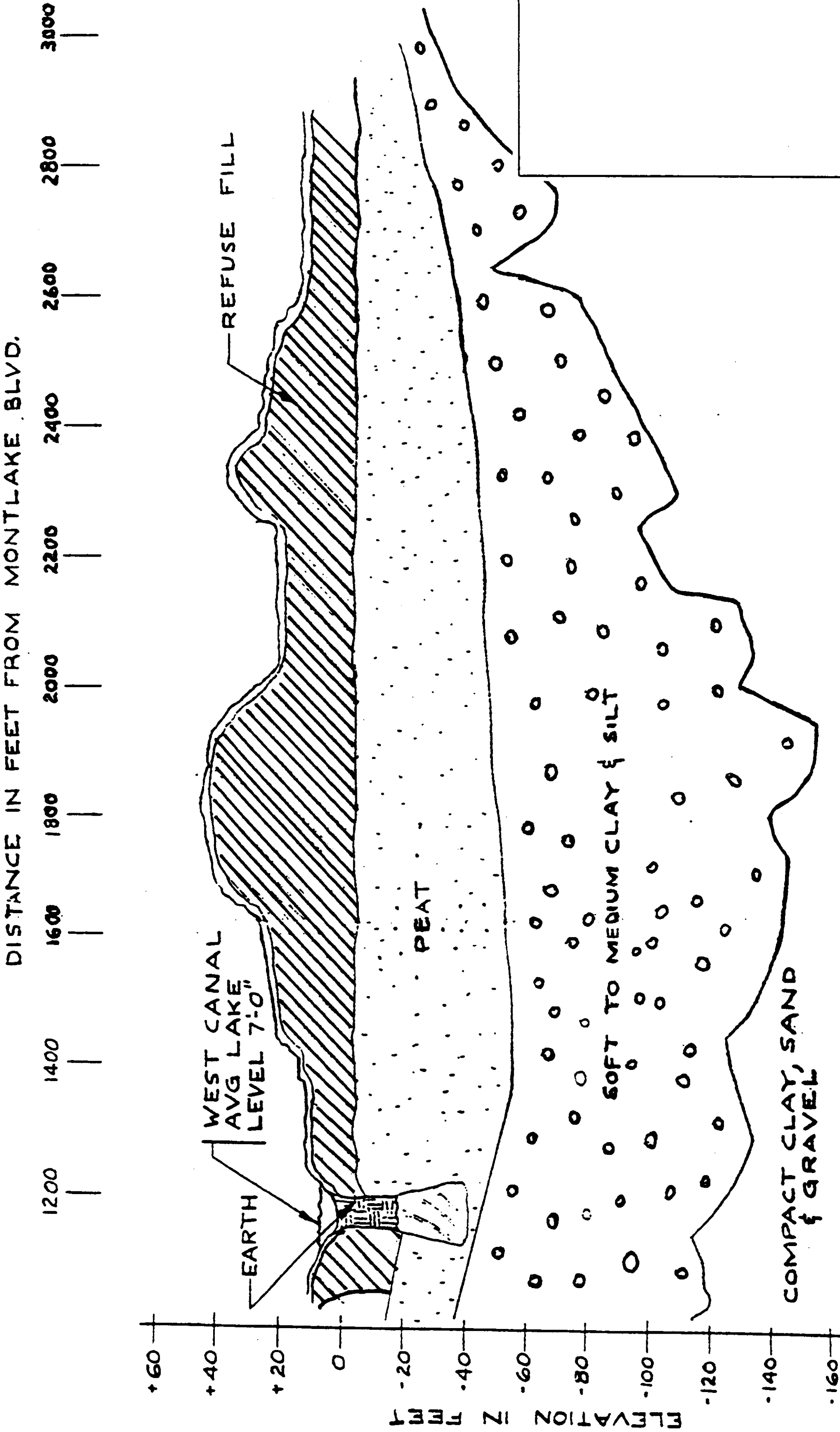


Figure 5

Progression of the Filling Operation 1926-1974

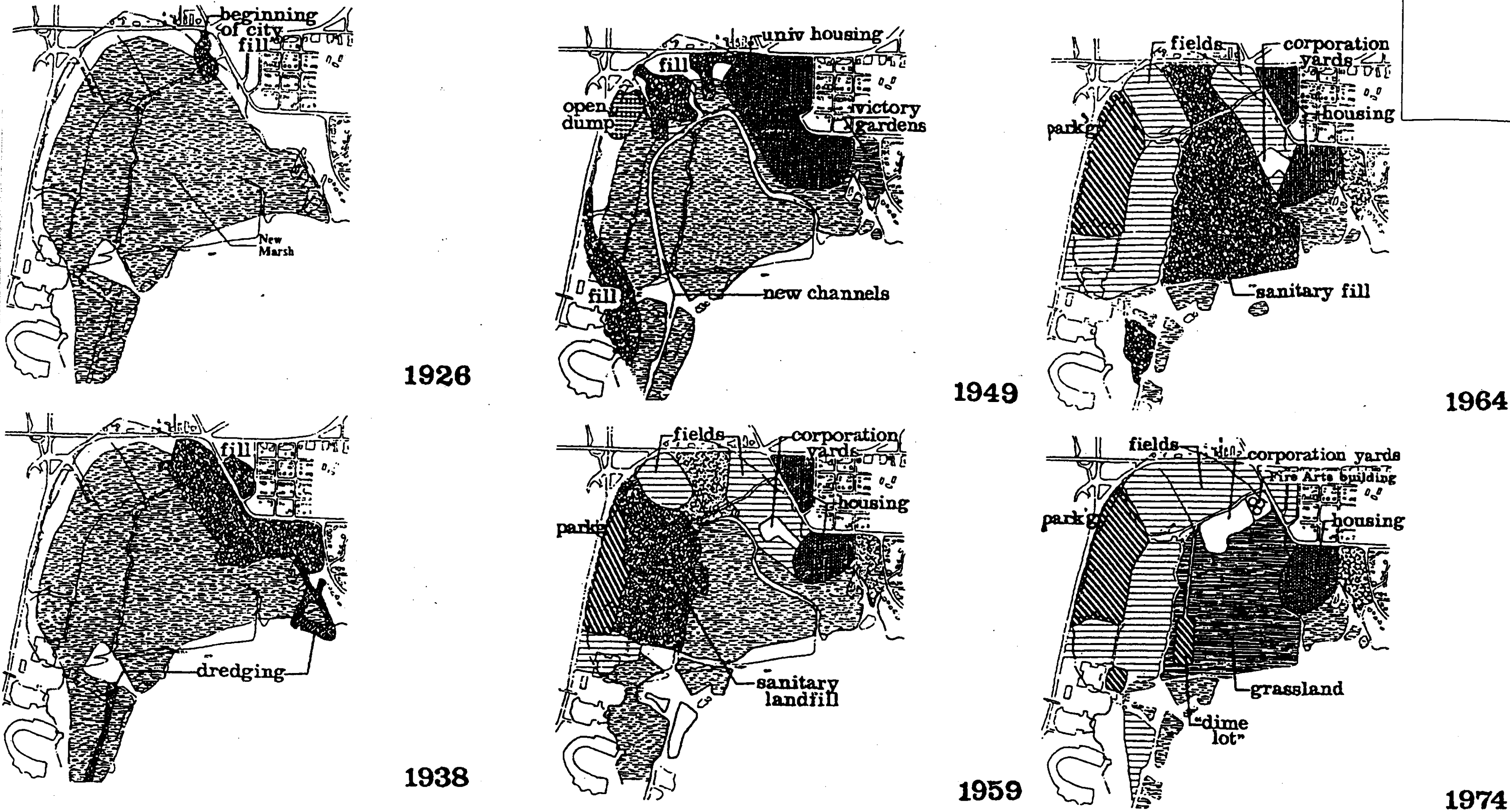
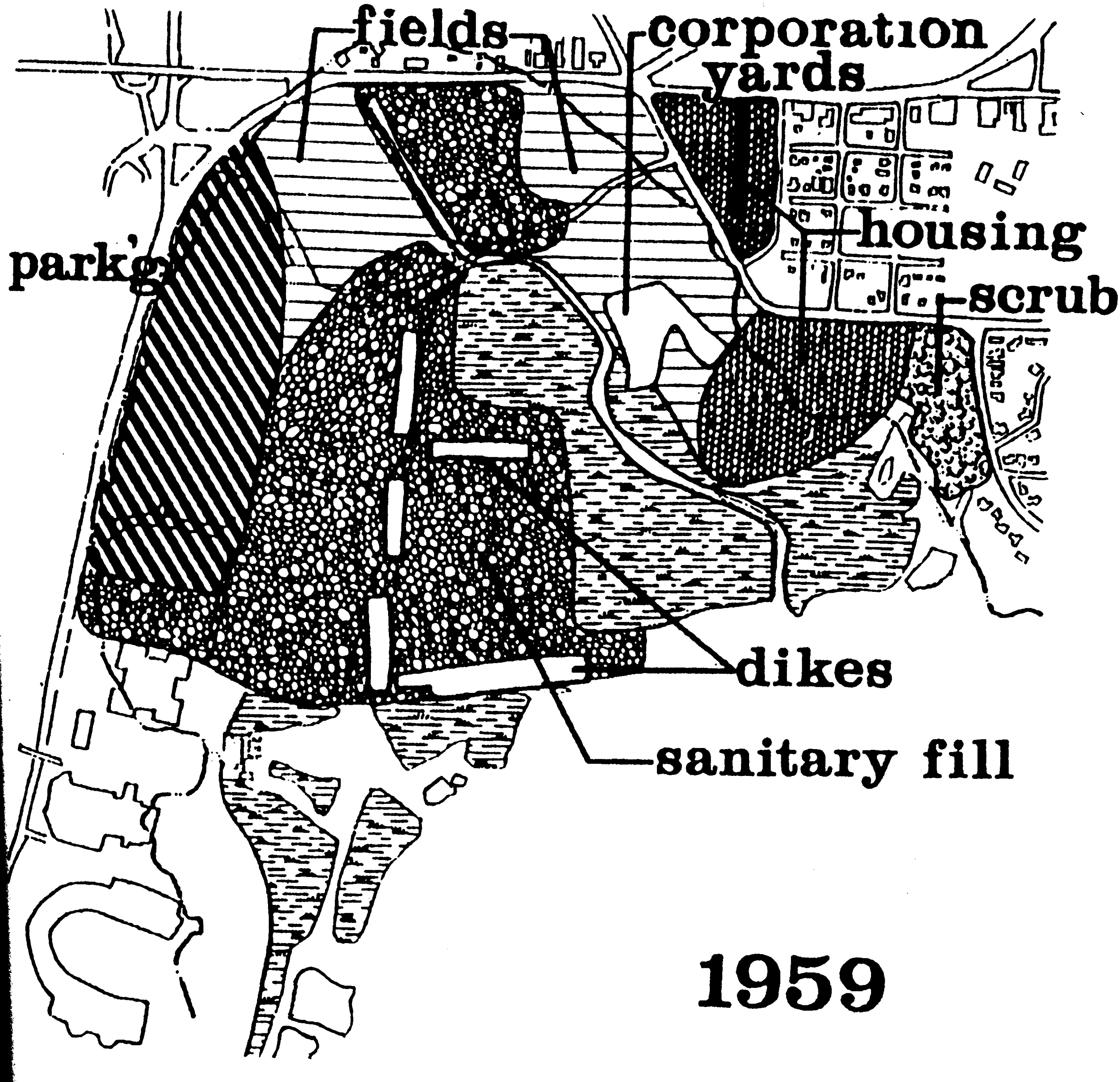
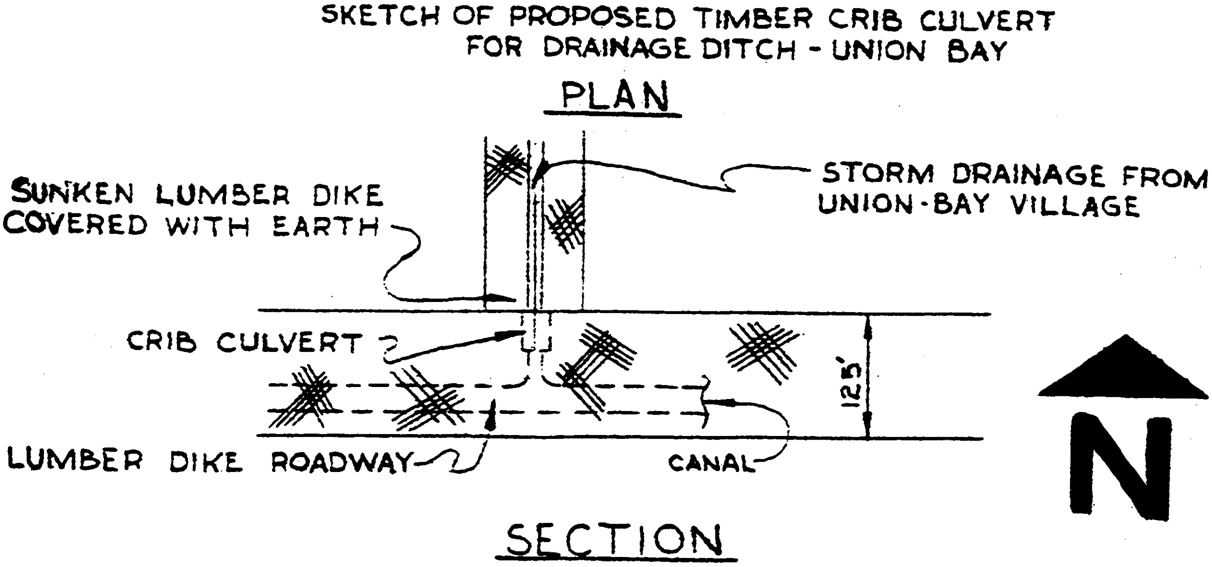
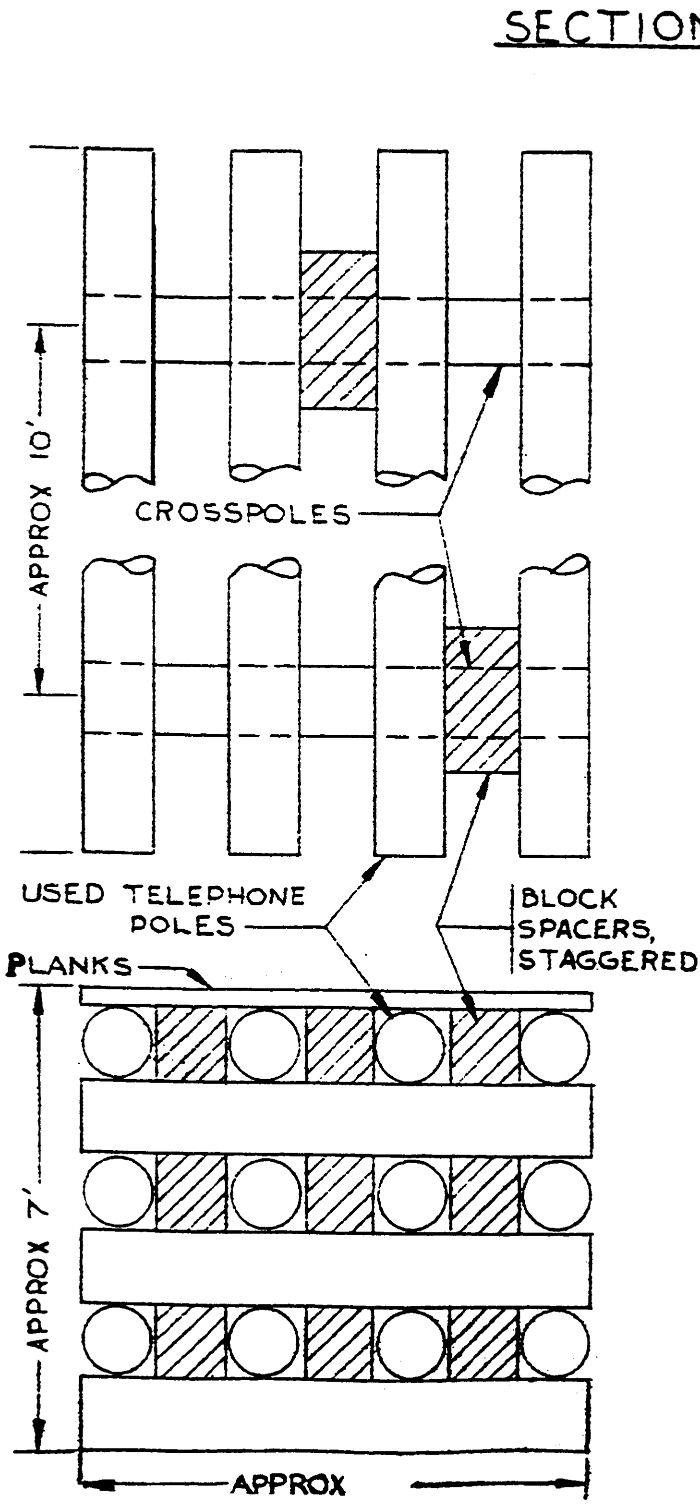


Figure 6
Map Showing Several Dike Locations







PLACE CULVERT ON LUMBER DIKE ABOUT ONE FOOT BELOW WATER LEVEL.
PLACE PLANKS OR TIMBER OVER TOP AND SIDES OF CULVERT
USE WASTE LUMBER AND RUBBLE FOR APPROACHES.

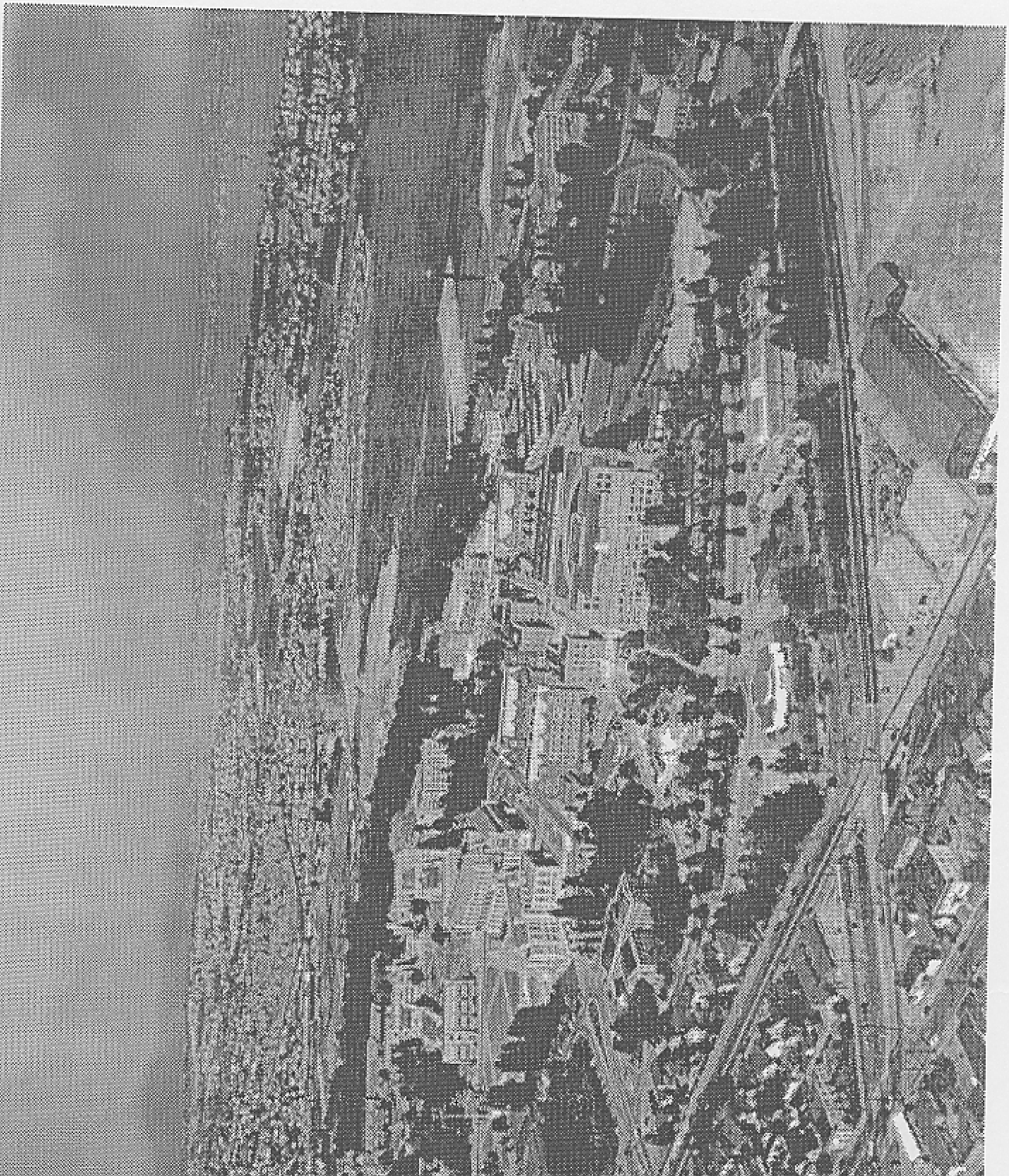
MATERIALS

12 USED TELEPHONE POLES, 25'-3
12 PIECES PHONE POLE, 7'-10'.
18 BLOCK SPACERS, SQUARE OR ROUND APPROX. SIZE OF TELEPHONE POLES ABOUT 24" LONG.
CABLE AND FASTENERS AND/OR PLANK AND SPIKES.
USED PLANKS OR BOARDS.

Figure 7

Timber Mat Cross-section, 1959

Source
Office of the University Architect
University of Washington
B&G Office Building
Seattle, Washington



igure 8: Picture of Montlake Landfill dating from 1951.
Picture courtesy of Special Collections Division of the University of Washington Libraries

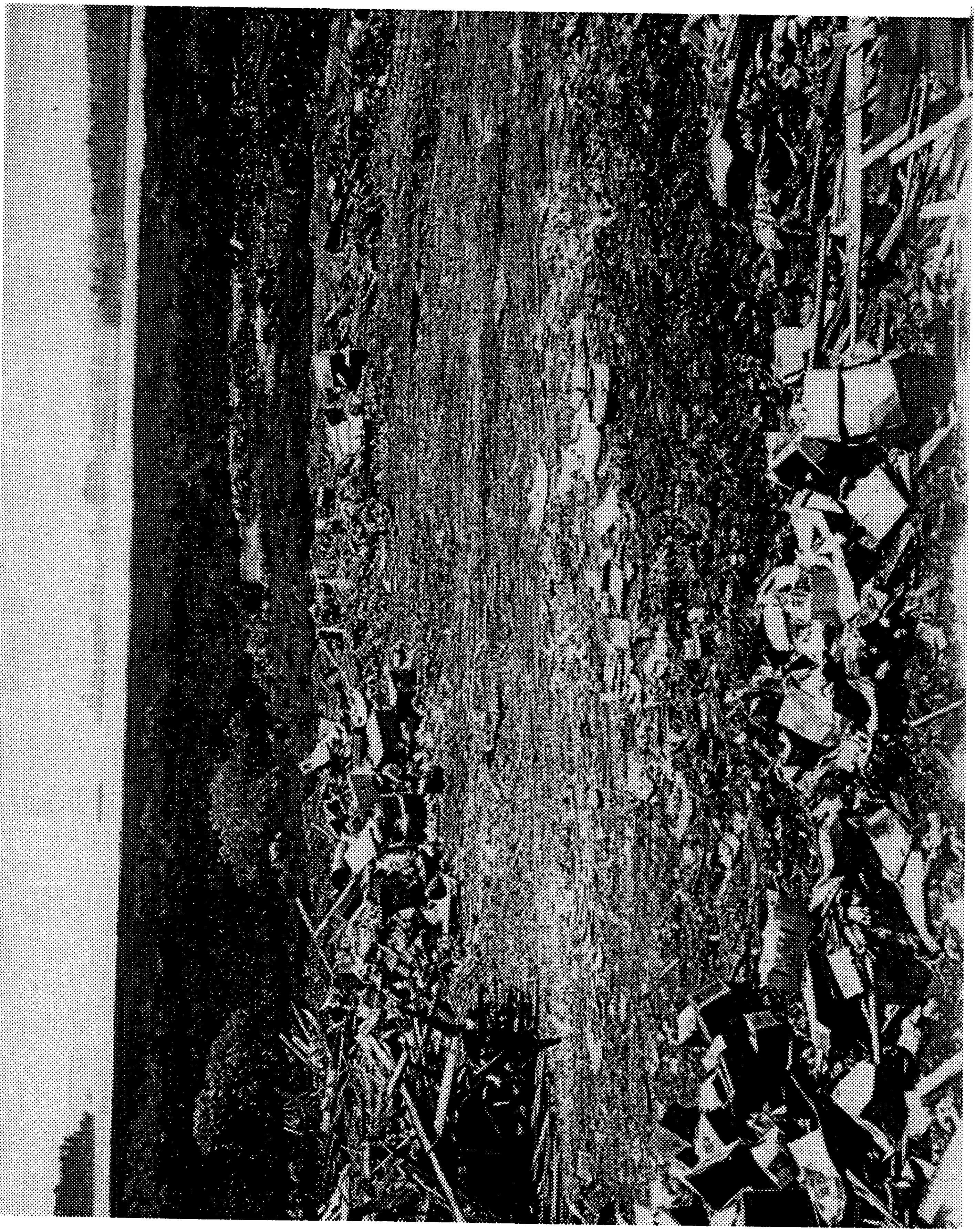


Figure 9: Picture of Montlake Landfill dating from February 15, 1960.
Picture courtesy of Special Collections Division of University of Washington Libraries

Figure 10: Picture of Montlake Landfill dating from June 19, 1959.
Picture courtesy of Special Collections Division of University of Washington Libraries

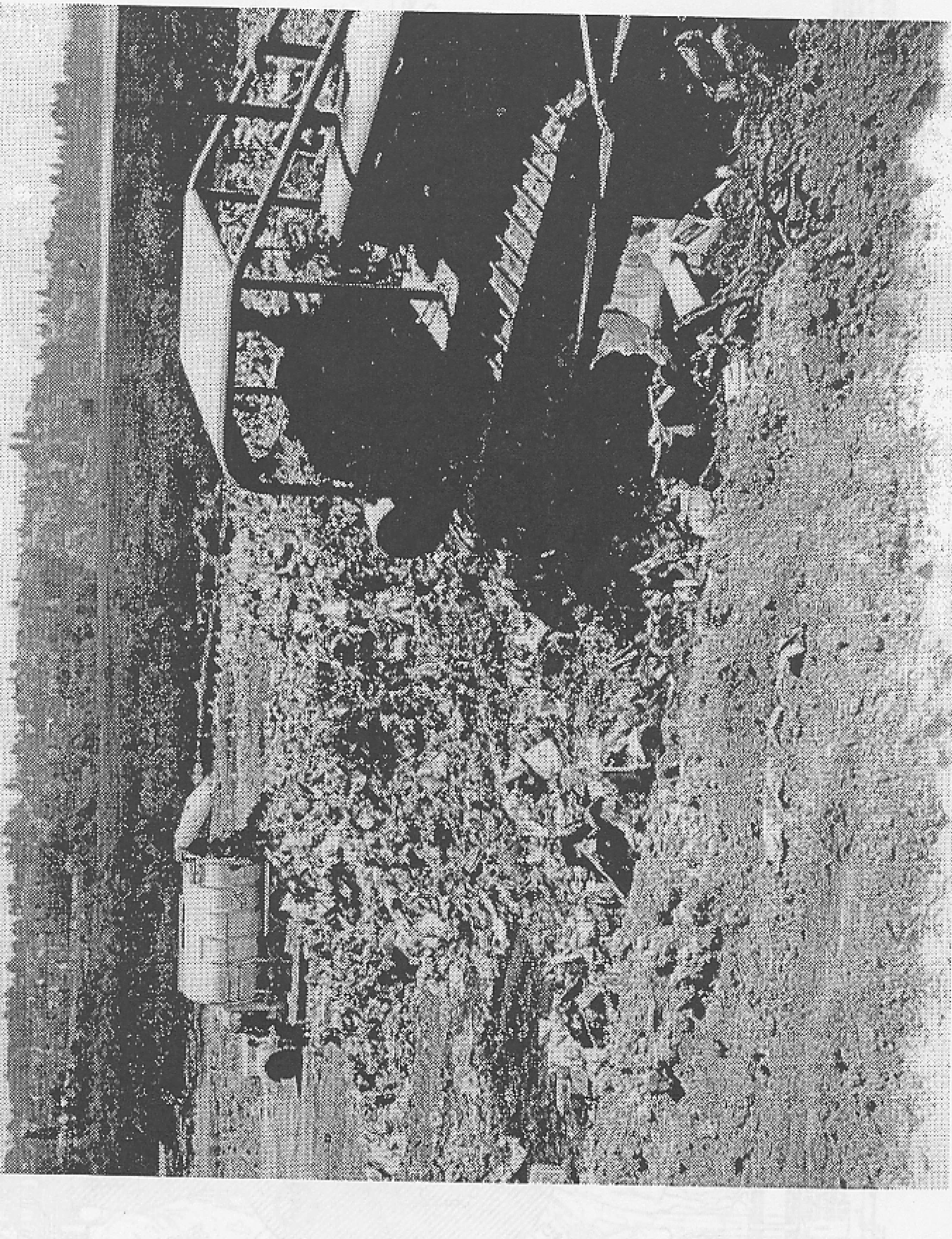


Figure 11: Picture of Montlake Landfill dating from June 19, 1959.
Picture courtesy of Special Collections Division of University of Washington Libraries

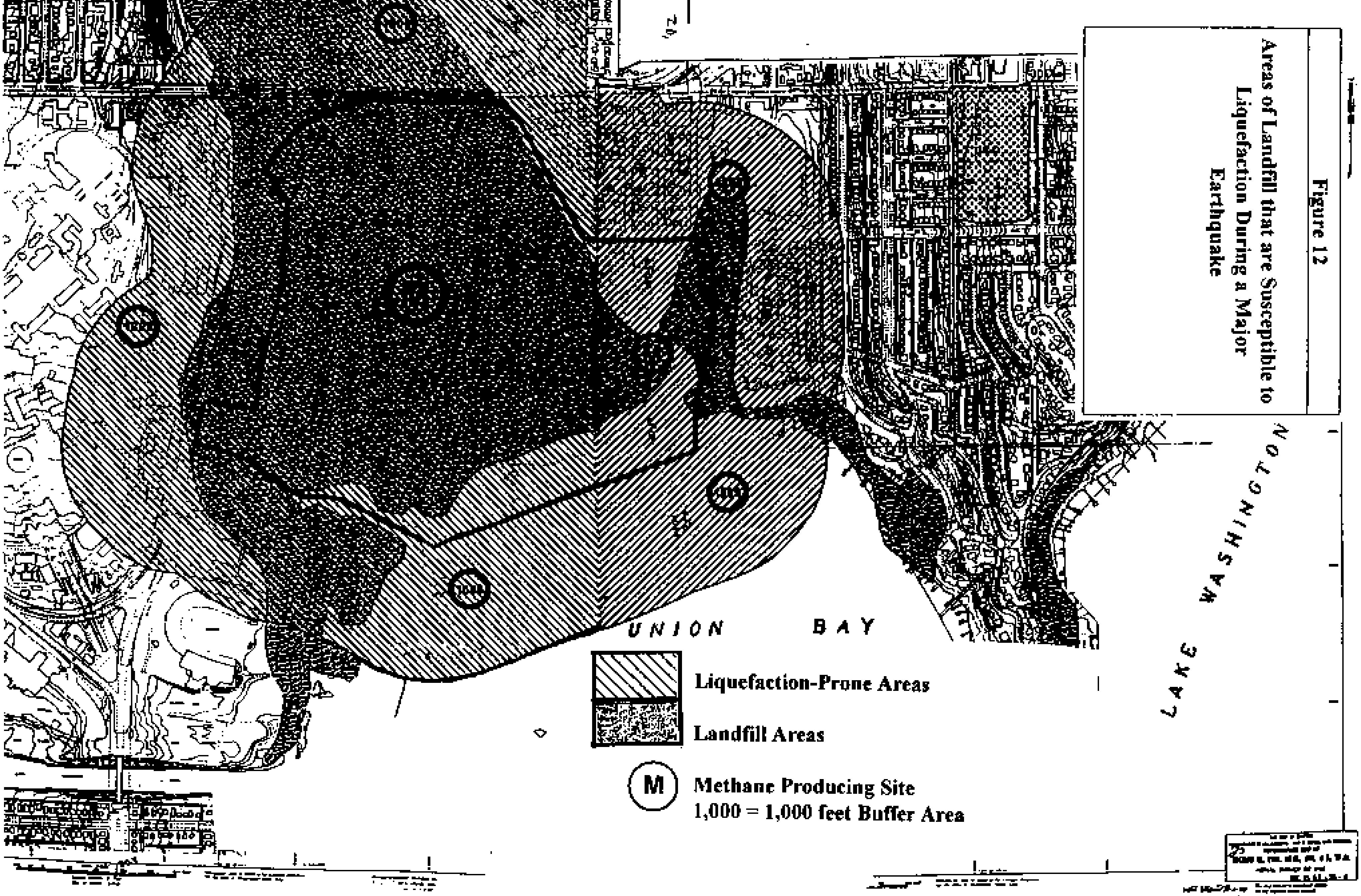
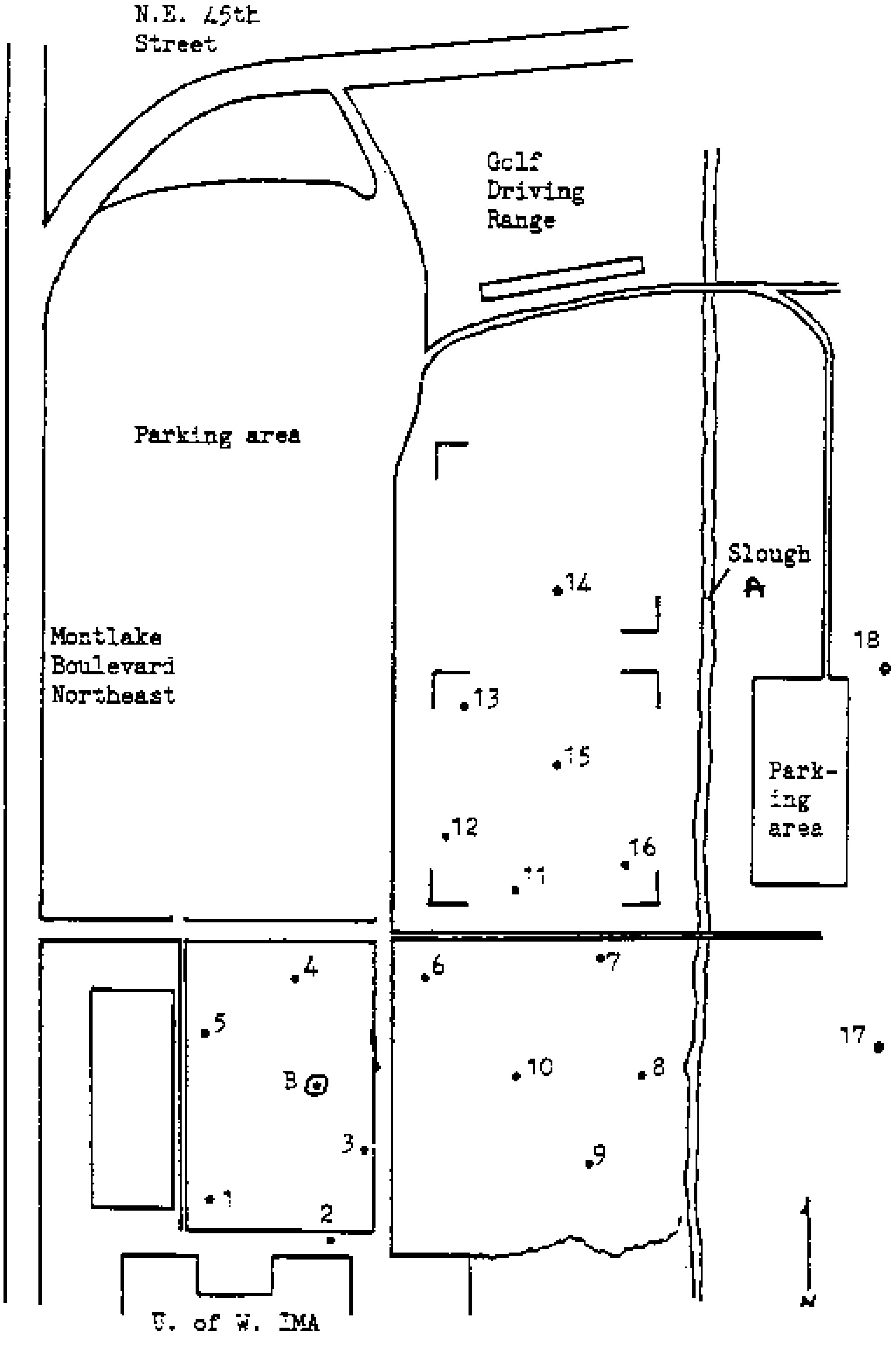


Figure 12
Areas of Landfill that are Susceptible to Liquefaction During a Major Earthquake



& B Surface water sample locations
18 Methane sample locations

Data presented in Table 6

Figure 13

Map of Methane Sampling Locations of Montlake Abandoned Landfill

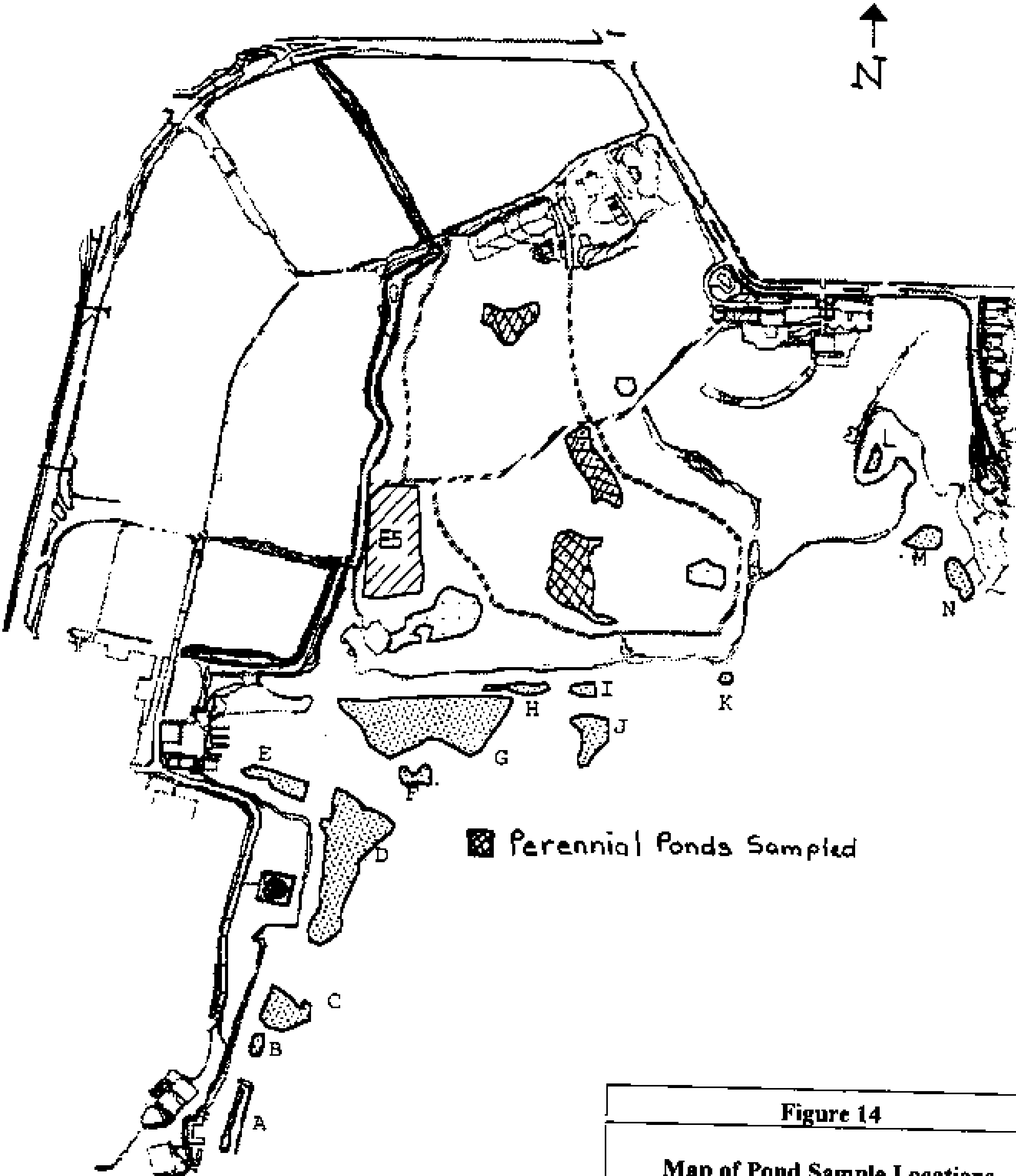


Figure 14

Map of Pond Sample Locations 1997

Data presented in Table 7

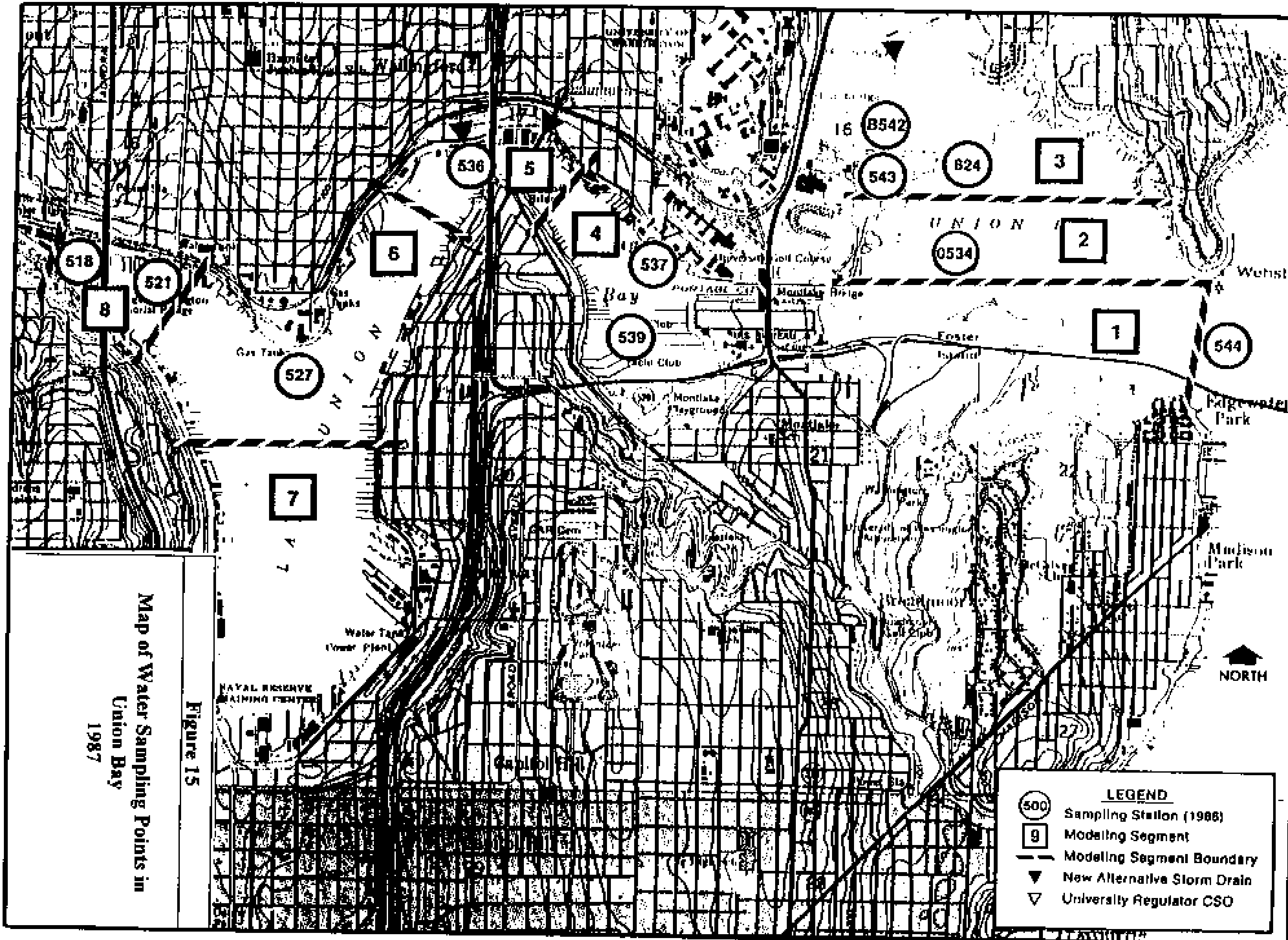


Figure 15
Map of Water Sampling Points in Union Bay
1987

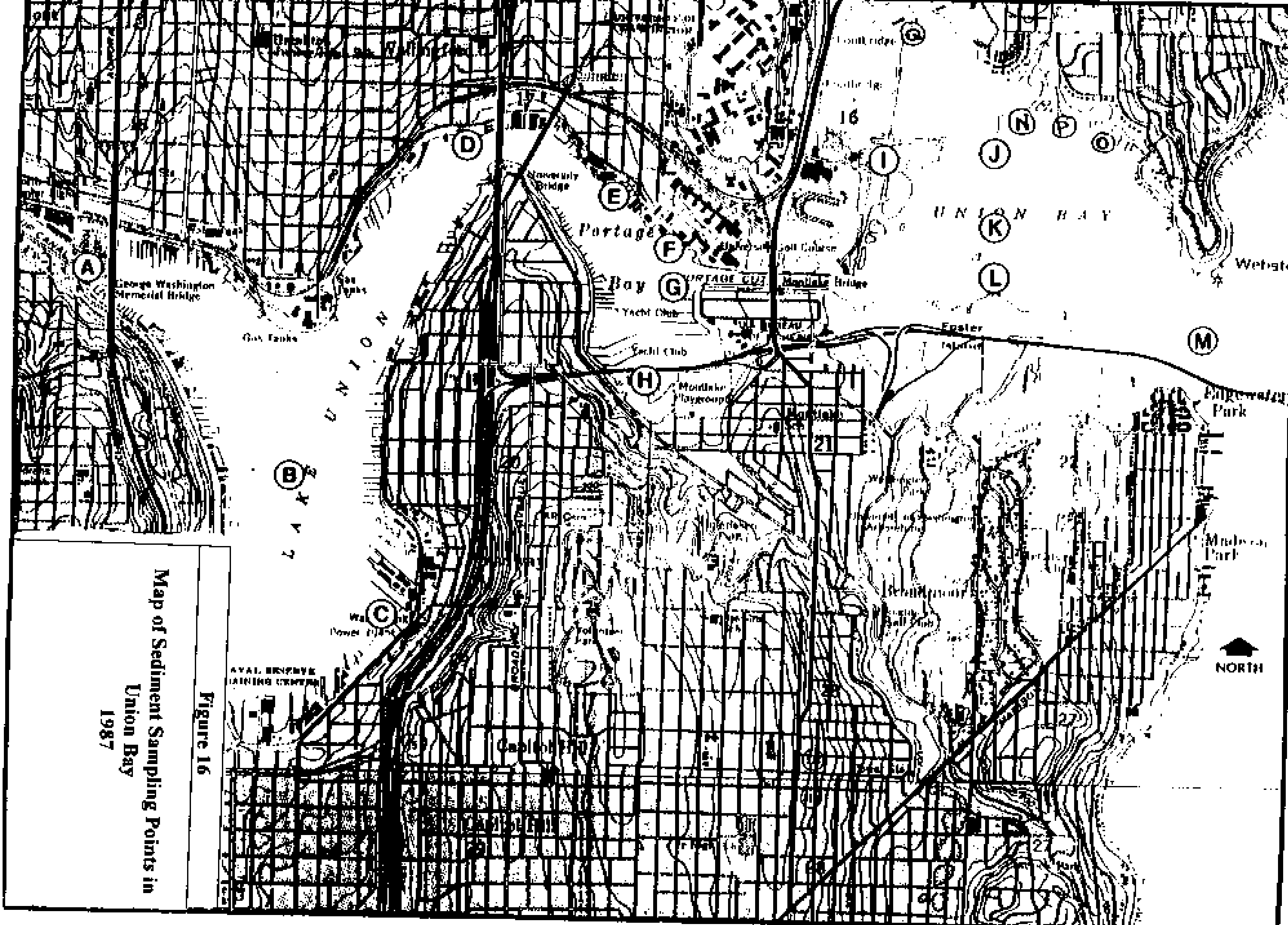
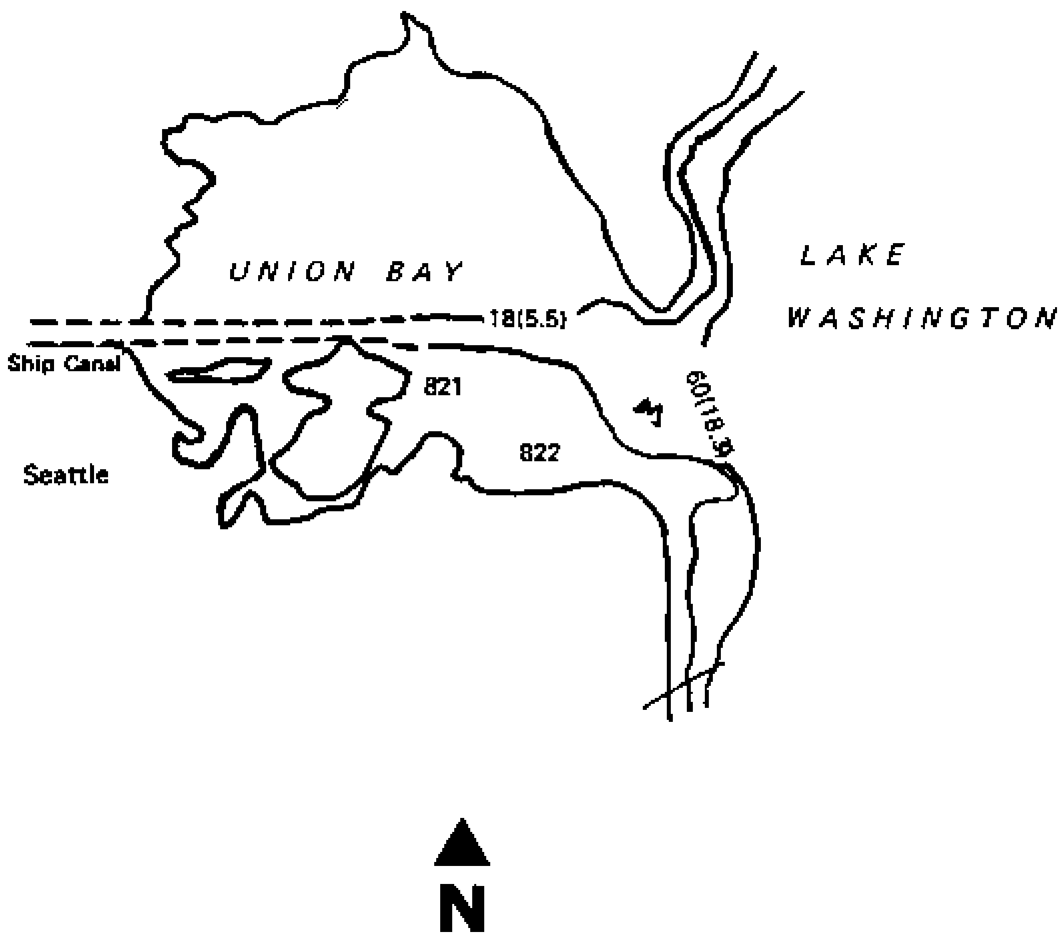


Figure 16
Map of Sediment Sampling Points in Union Bay
1987

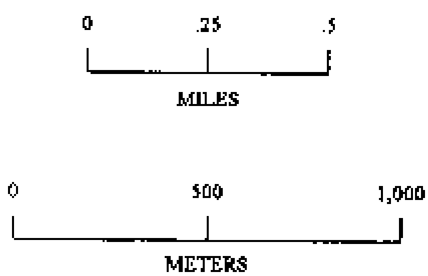
Figure 17

Map of Water Sampling Points in Union Bay 1980's



LEGEND

821	Sampling station
60(18.3)	Depth in feet (meters)
M	Madison Park sampling station



LEGEND

- Observation well
- 2.85 Elevation of surficial aquifer
- Contour elevation

NOTES

1. Elevations relative to Seattle city datum.
2. Elevations for 10/8/80. Represents approximate lowest point of surficial aquifer.
3. Dashed line where elevation inferred.

GROUND WATER ELEVATION

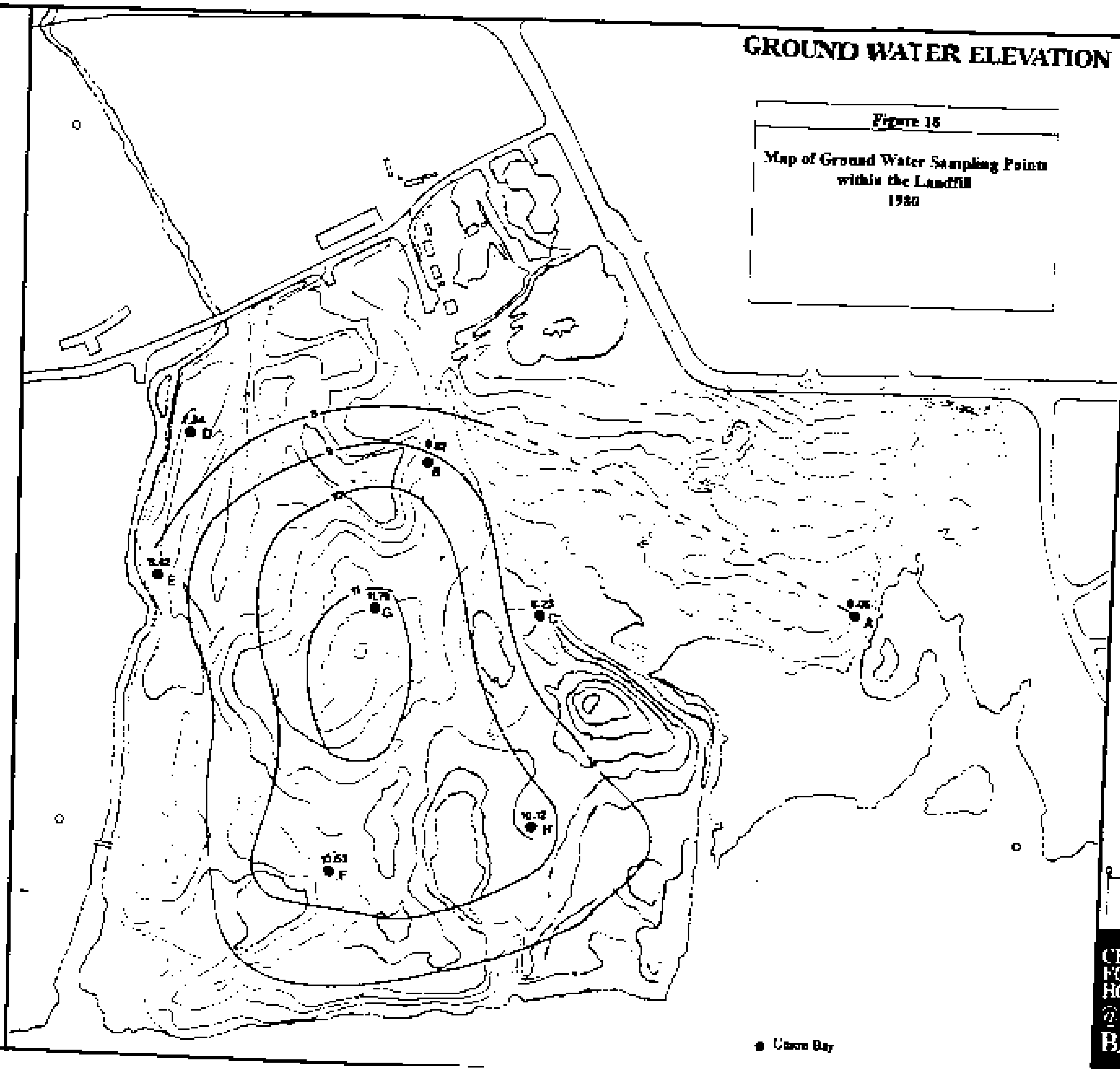


Figure 15

Map of Ground Water Sampling Points within the Landfill 1980

JONES & JONES

Osbom & Roy, Planners, inc.

CENTER FOR URBAN HORTICULTURE @ UNION BAY

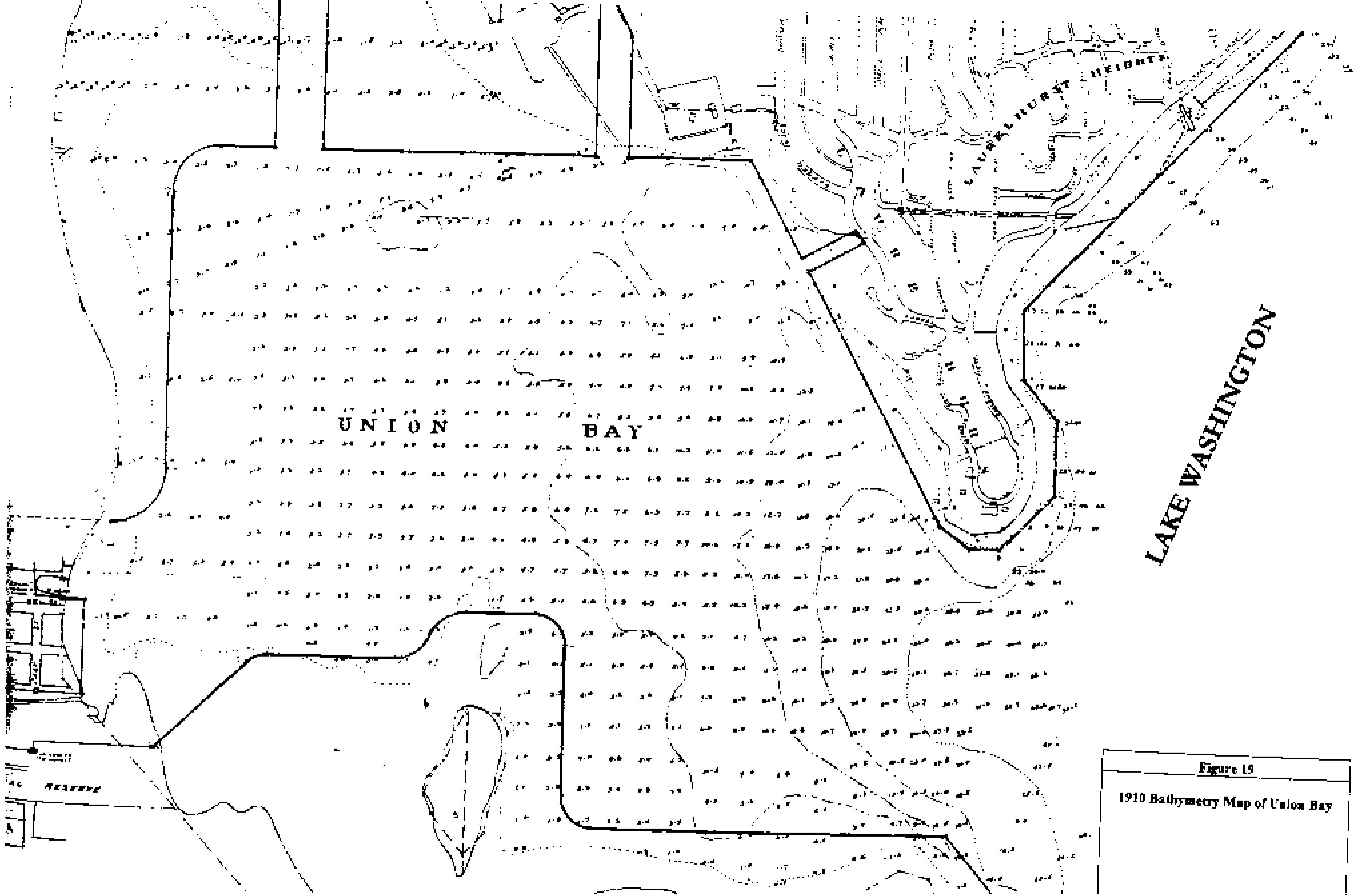


Figure 15

1910 Bathymetry Map of Union Bay

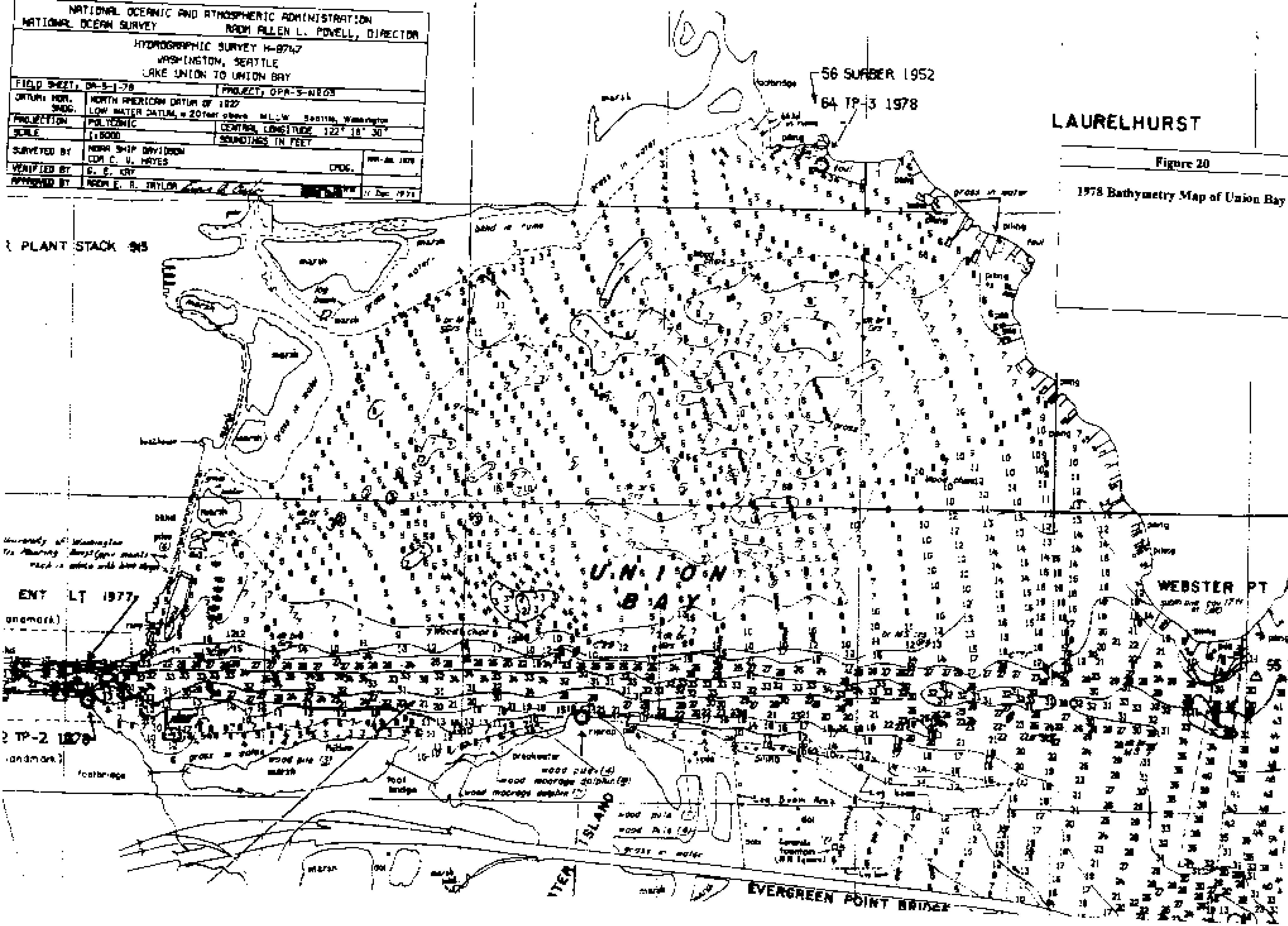


Figure 20

1978 Bathymetry Map of Union Bay

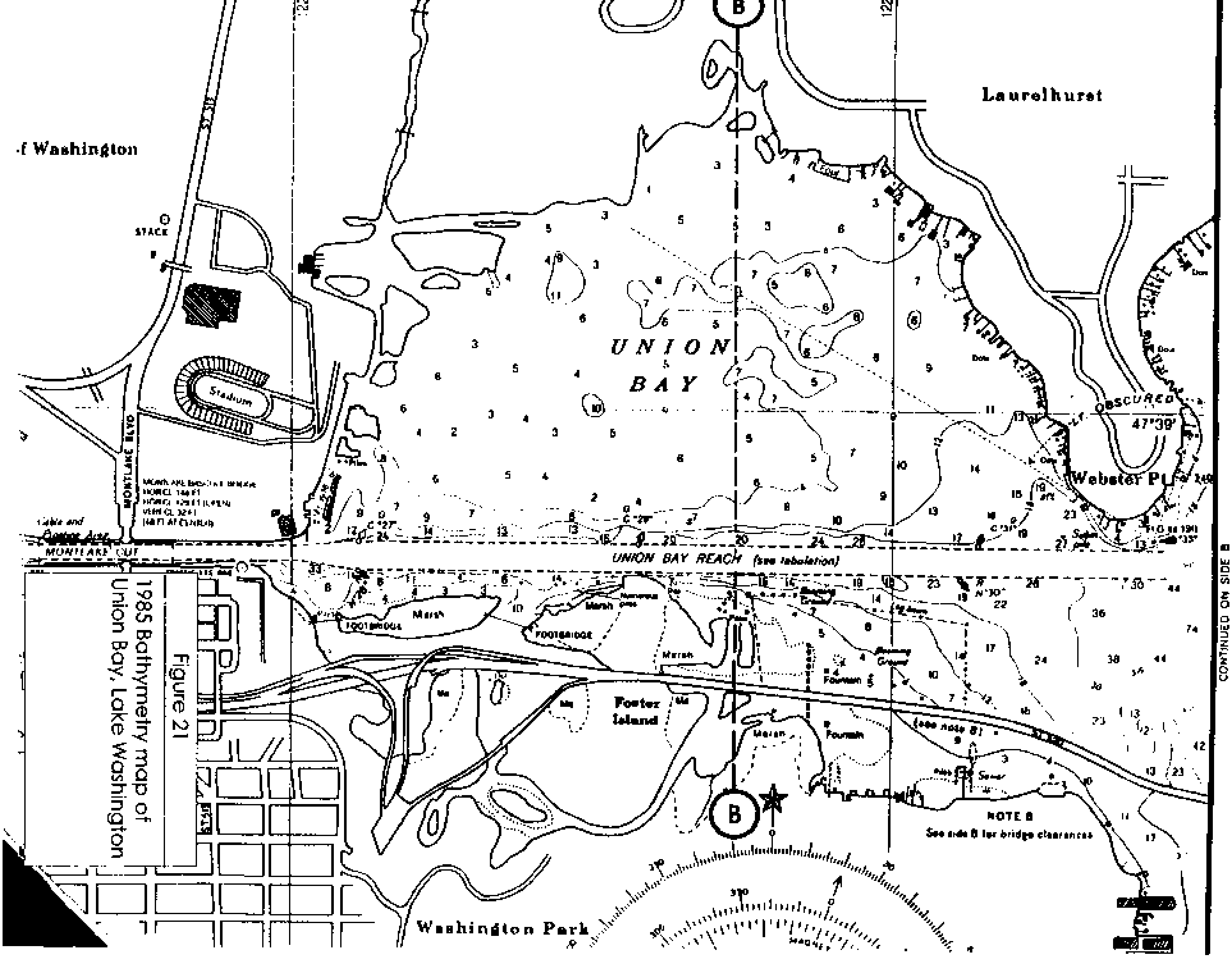


Figure 21
1985 Bathymetry map of Union Bay, Lake Washington

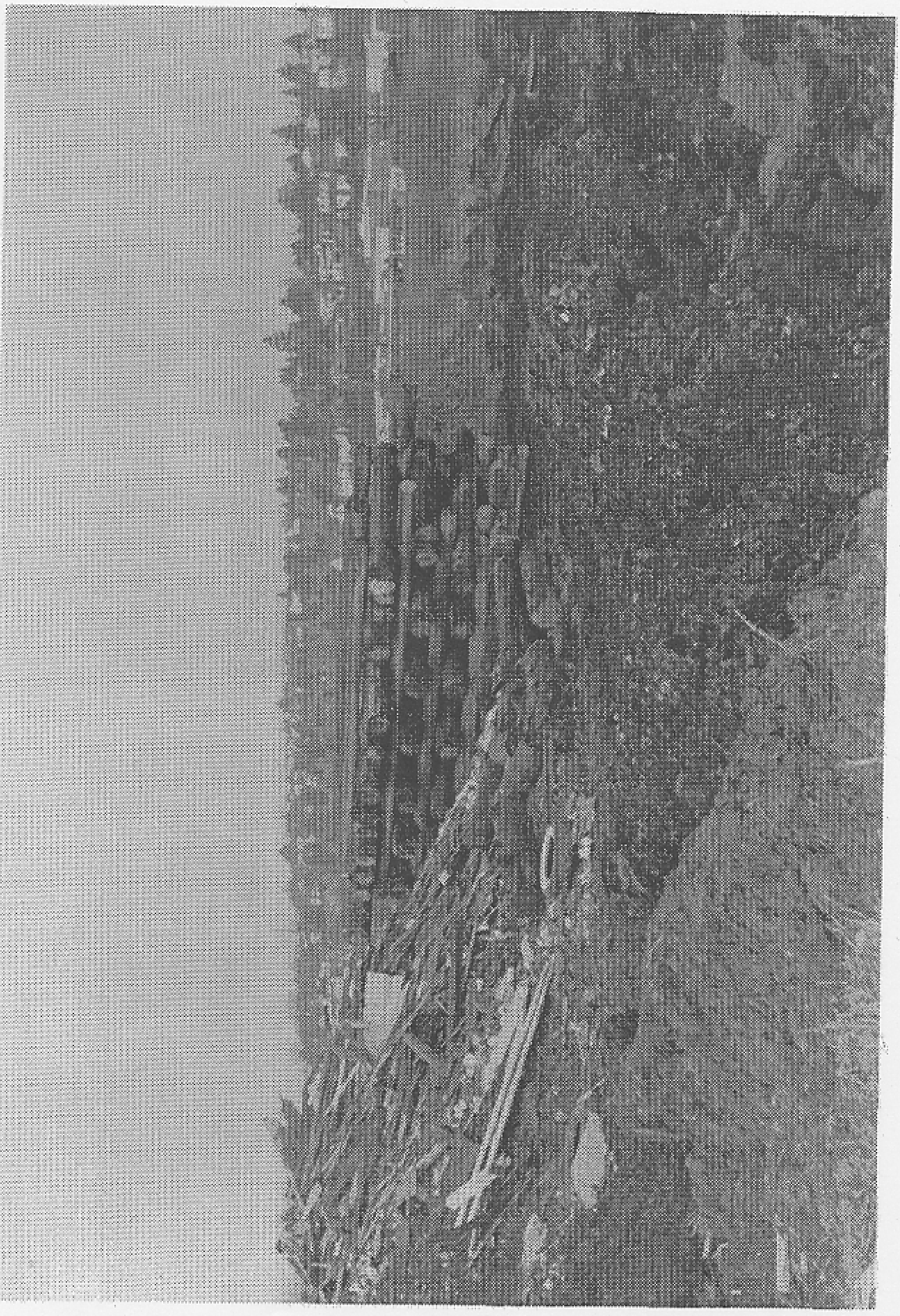


Figure 22: Picture of timber dikes in Montlake landfill January 1960

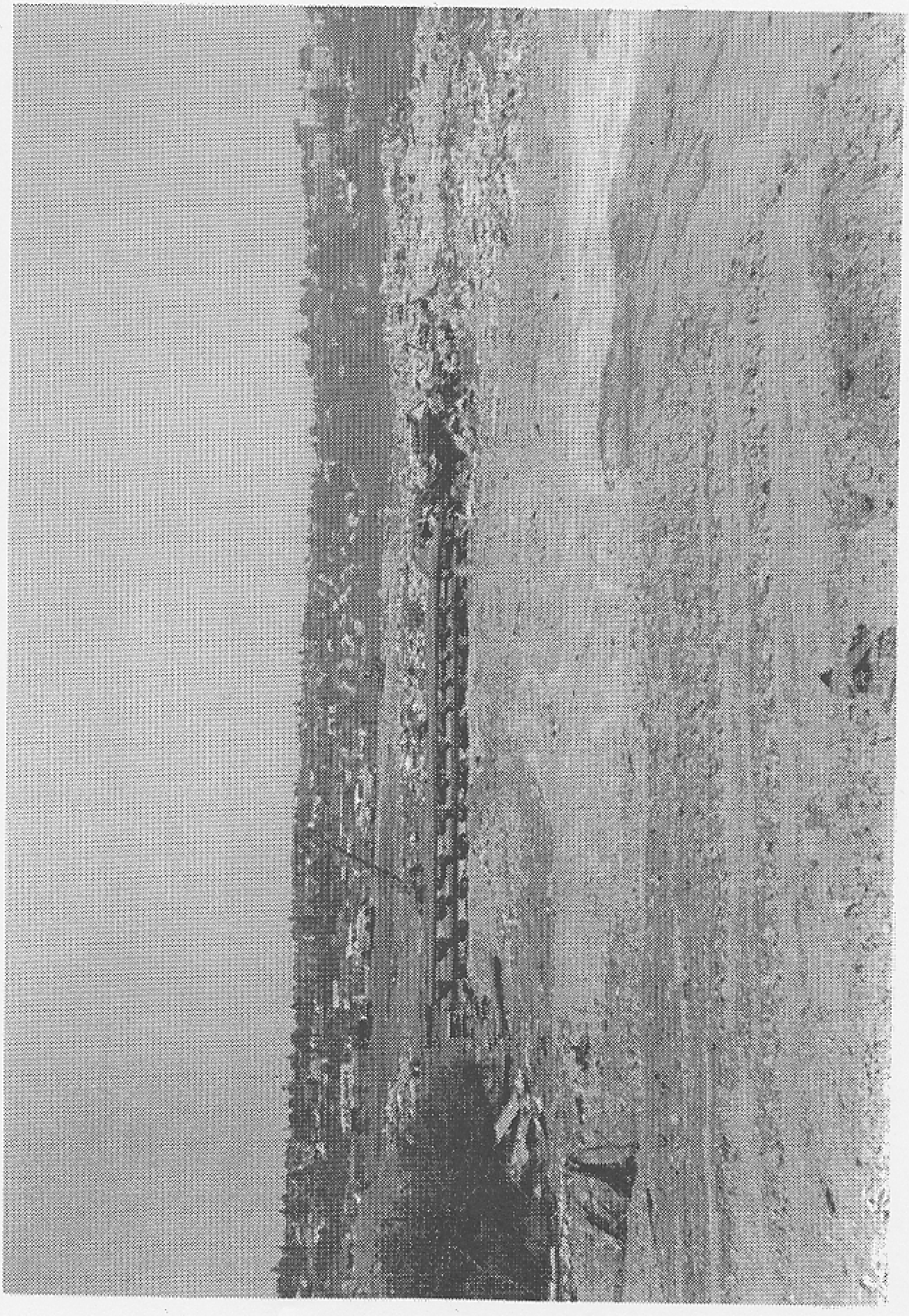


Figure 23: Picture of timber dikes in Montlake Landfill July 1961

TABLES 1 - 7

Table 1
Classification of Refuse Materials*

Type	Description
Garbage	Waste from the preparation, cooking and serving of food. Market refuse, waste from the handling, storage and sale of produce.
Refuse • Combustible Rubbish	Paper, cartons, boxes, barrels, wood, trees, branches, yard waste, wood furniture, and bedding.
• Non-combustible Rubbish	Metals, tin cans, metal furniture, dirt, glass, crockery and other mineral refuse.
• Ashes	Residue from fires used for cooking and for heating buildings.
• Street Refuse	Street sweepings, dirt, leaves, catch basin dirt and contents of litter receptacles.
• Dead Animals	Small animals such as cats, dogs, etc. from streets, sidewalks, alleys and vacant lots, etc..
• Industrial Refuse	Solid waste resulting from industrial processes and manufacturing operations, such as food processing waste, boiler house cinders, lumber scraps and shavings, metal scraps and shavings, etc.. from factories, power plants, etc..

*Source: Refuse Collection Practice, 2nd ed., 1958 American Public Works Association.

Table 2
Fertilization Rate of University Fields*

Department	Area Fertilized (100m² x)	Nitrogen Applied (Kg/100m²)	Application Frequency/Year	Total Quantity of Nitrogen Applied per year (Kg/Year)	Kilograms of Nitrogen per 100m²/year
Intercollegiate Athletics	140	0.245	8	274	1.96
Intermural Athletics	251	0.122	8	245	0.98
Driving Range	279	0.651	3	545	1.95
Center for Urban Horticulture	93	0.490	3	137	1.47

Prepared by University of Washington Environmental Health and Safety Department.

* Source: Brian Harman, Capital Projects

Table 3
Montlake Landfill Water Quality Data

Test	University slew 1984 [1]	University slew 1987 [2]	Landfill groundwater mean 1980 [3]	Ponds mean 1980	Pond 1984 [1]	Playfield standing water 1984 [1]	North pond mean 1997 [4]	South pond mean 1997 [4]	Southeast pond mean 1997 [4]	State water quality standards*
Dissolved Oxygen (mg/l)	6.50	7.7			6.10	2.90				
pH	5.80	6.7	6.98	7.20	6.80	6.50	6.60	7.30	6.60	6.5-8.5
Alkalinity ($CaCO_3$/l)		48								20,000
Conductivity µs/cm	200.00	120	1319.00	271.00			197.00	169.00	164.00	
Total Phosphates (mg/l)		0.15	1.72	1.13						
Nitrate (mg/l as Nitrogen)			0.32	0.17						10
Ammonia Nitrogen (mg/l)							ND	ND	ND	
COD (mg/l)			973.00	135.00			120.00	122.00	80.90	
BOD (mg/l)							12.70	33.60	6.60	
Fecal Coliform (FCU/100 ml)		2400					47.50	530.00	10.00	50
Arsenic (µg/l)		<0.001								190
Cadmium (µg/l)		<0.0001								.46
Copper (µg/l)		0.002								4.5
Chromium (µg/l)		<0.0005								74
Lead (µg/l)		<0.001								.76
Nickel (µg/l)		0.005								63
Silver (µg/l)		<0.0003								.54
Zinc (µg/l)		<0.01								42

Prepared by University of Washington Environmental Health and Safety Department December 16, 1997.

Units Key	
mg/l is miligrams per liter	ml is mililiter
µg/l is micrograms per liter	cm is centimeter
CFU is Colony Forming Units	$CaCO_3$/l is calcium carbonate per liter
COD is Chemical Oxigen Demand	µs is microsiemans (measured in mhos) which is the reciprocal of resistvity (measured in ohms)
BOD is Biological Oxigen Demand	ND is not detected

* Source: Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington., November 25, 1992.
ND - Not detected
[1] Sample locations recorded on Figure 13
[2] Sample locations recorded on Figure 15
[3] Sample locations recorded on Figure 18
[4] Sample locations recorded on Figure 14

Table 4
Union Bay Water Quality Data

Test (*see units key*)	1980 Union Bay[2]	1980's Union Bay[1]	1980's Madison Park[1]	1987 Union Bay nearshore[3]	1987 Union Bay open water[3]	1987 Webster Point[3]	1987 UW Crewhouse[3]	1997 Union Bay	1997 Madison Park	State Water Quality Standards*
Disolved Oxygen (mg/l)		10.2 to 12.8	9 to 12	9	10.2	9.1	8.6	9.4	7.8	6.5-8.5
pH	7.4	7.9	7.5	7	7.6	7.3	6.8	7.4	7.6	
Alkalinity ($CaCO_3$/l)		40	31.9 - 36.5	38	40	40	42			
Conductivity µs/cm	146	105	96-100	90	99	90	110	97.1	105	
Total Phosphates (mg/l)	0.96			0.013	0.025	0.020			0.023	
$NO_3 + NO_2$ (mg/l as Nitrogen)	0.04			0.134	0.131	0.153				
Ammonia Nitrogen (mg/l)				0.005	0.005	0.041			0.013	
COD (mg/l)										
BOD (mg/l)										
Fecal Coliform (CFU/100 ml)				33	22	4	2400			50
Arsenic (µg/l)				<0.001	<0.001		<0.001			190
Cadmium (µg/l)				<0.0001	<0.0001		<0.0001			.46
Copper (µg/l)				0.002	0.001		0.001			4.5
Chromium (µg/l)				<0.0005	<0.0005		<0.0005			74
Lead (µg/l)				0.013	<0.001	<0.001	<0.001			.76
Nickel (µg/l)				0.001	0.001		0.001			63
Silver (µg/l)				<0.0003	<0.0003		<0.0003			.54
Zinc (µg/l)				0.011	0.029		0.017			42

Prepared by University of Washington Environmental Health and Safety Department December 16, 1997

Units Key	
mg/l is miligrams per liter	ml is mililiter
µg/l is micrograms per liter	cm is centimeter
CFU is colony forming units	$CaCO_3$/l is calcium carbonate per liter
COD is Chemical Oxigen Demand	
BOD is Biological Oxigen Demand	
µs is microsiemans (measured in mhos) which is the reciprocal of resistivity (measured in ohms)	

*Source: Chapter 173-201A WAC Water Quality Standards for Surface Waters of the State of Washington., November 25, 1992

[1] Sample locations recorded on Figure 17

[2] Sample locations recorded on Figure 18

[3] Sample locations recorded on Figure 15

Table 5
Sediment Sampling Results
(in mg/kg)

Site	Total Oil & Grease	Hydrocarbon Oil & Grease	Total Phosphorus	Total Organic Carbon	Total Solids (in %)	Total Volatile Solids (in %)
I	2150.0	1340.0	1560.0	18.0	10.0	4.6
J	1842.9	1842.9	357.1	35.0	7.0	6.0
K	1697.0	1121.2	545.5	23.7	6.6	4.0
L	1307.7	369.2	392.3	16.0	13.0	4.7
M	1418.2	1418.2	663.6	12.0	12.0	3.8

Metal	Sediment Samples Taken by Metro[1]					Sediment Samples Taken by Dr. Harrison[2]				Sediment Quality Values[3]
	I	J	K	L	M	N	O	P	Q	
Silver	3.0	5.7	4.5	2.3	3.1	ND	ND	ND	ND	4.5
Aluminum	12400.0	28.9	7318.2	9000.0	15435.6	ND	ND	ND	ND	ND
Arsenic	23.0	14.3	10.6	4.6	12.2	ND	ND	ND	ND	4.0
Cadmium	3.0	2.9	3.0	1.5	2.6	5.0	3.0	16.0	7.0	7.6
Chromium	103.0	15.7	28.8	22.3	50.1	65.7	22.0	87.0	43.5	280.0
Copper	60.0	21.4	48.5	21.5	62.3	18.0	22.5	155.0	28.5	840.0
Iron	24400.0	10528.6	9757.6	11538.5	18178.0	ND	ND	ND	ND	ND
Mercury	ND	ND	ND	ND	ND	0.13	0.18	0.35	0.15	0.56
Manganese	262.0	311.4	272.7	286.9	451.2	ND	ND	ND	ND	1800.0
Nickel	50.0	42.9	60.6	30.8	52.3	41.3	13.0	51.0	32.5	46.0
Lead	160.0	42.9	75.8	38.5	152.7	30.0	65.5	747.0	204.0	260.0
Tin	10.0	28.6	15.2	7.7	13.3	ND	ND	ND	ND	ND
Zinc	305.0	51.4	100.0	52.3	144.2	81.6	45.5	848.0	194.0	520.0

Prepared by University of Washington Environmental Health and Safety Department February 3, 1998.

[1] University Regulator Combined Sewer Overflow Control Predesign Project, Metro, March 1987.
[2] See Interviews under References #33.
[3] Creation & Analysis of Fresh Water Sediment Quality Values in Washington State - July 1997 Publication No. 97-323a.

Table 6
Montlake Landfill Methane Sampling*

Site	% Methane in air (1984)	% Methane in air (1997)
1	40	Trace
2	Trace	Trace
3	28	Trace
4	38	Trace
5	15	Trace
6	11	Trace
7	16	Trace
8	7	Trace
9	9	Trace
10	14	2
11	10	Trace
12	10	Trace
13	Trace	Trace
14	2.4	Trace
15	Trace	Trace
16	Trace	Trace
17	8	Trace
18	Trace	Trace

*Prepared by the University of Washington Environmental Health and Safety Department.

Methane was sampled in 1997 via a Bacharach Model Sentinel 4, Serial UCC543 calibrated to methane on 1/9/97. The 1997 methane levels are reported as a % Methane, though measured in % of the Lower Explosive Limit (LEL). 1984 methane levels were reported as % methane in air using a different model Bacharach Gas Meter capable of measuring directly the % methane in air.

Sampling locations presented in Figure 13.

Table 7
Measurement of Non-Seasonal Islands[1]

Island**	Year					
	1966	1972	1986	1992	1993	1996
A	1250	1000	210/210	270/210	210/60/170	50/80/50
B	800	730	420	310	310	310
C	2500	2720	2090	2050	1940	1520
D	9930	8830	1520/7110	1250/5960	1360/6640	1250/6170/20
E	2200	2200	2090	2200	2090	110/20
F	480	260	20	20		*
G	11390	11230	12020	10190	10930	9570
H	1050	940	520	50/310	420	6/6/310
I	390	380	60	*	*	*
J	2610	210	*	*	*	*
K	60	*	*	*	*	*
L	480	380	380	340	280	360
M	2350	1250	1250	940	1050	990
N	NA	1050	1110	940	940	1110

* No land showing above water level surface.
** See Figure 14 of this report for placement of islands.

[1] Source: University of Washington Union Bay Landfill Fertilizer Usage, Fred Hoyt, Center for Urban orticulture, 1997 (Report).